NASA
Technical Memorandum 80608

Documentation of the Fourth Order Band Model

Eugenia Kalnay-Rivas
David Hoitsma

(NASA-TM-80608) DOCUMENTATION OF THE FOURTH ORDER BAND MODEL (NASA) 117 p HC A06/MF A01 CSCL 04B
N80-17638
Unclas
G3/47 12902

DECEMBER 1979

National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Documentation of the
Fourth Order Band Model

Eugenia Kalnay-Rivas

David Hoitsma
Sigma Data Services Corp.

November 1979

Modeling and Simulation Facility
Laboratory for Atmospheric Sciences
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

TABLE OF CONTENTS

Preface

We have decided to compile a preliminary documentation of the new GLAS Fourth Order General Circulation Model. The present documentation has not been subjected to a careful editing process; we hope that its possible usefulness will compensate for some of its defects. The model dynamics (COMP0, COMP1 and COMP2) is still undergoing minor improvements, especially in the time differencing scheme which we hope will improve its efficiency. The "physics" routine (COMP3) has not been documented because it is being thoroughly revised. The present version of COMP3, similar to the one used in the GLAS/GISS models (see the documentation by Tsang and Karn), with modifications introduced by Y. Sud (1979) is included in the code. Criticisms and suggestions for improvement will be reatly appreciated, since a final documentation will be prepared in 1980.

We are very grateful to all the people that have helped us generously. In particular, Dr. N. Rushfield had a major impact in the process of making the model operational. W. Connelly, D. Edelmann, D. Han, S. Breining, P. Anolick and M. Almeida were very helpful in the development of the model. The documentation was expertly and cheerfully typed by S. Mathis; D. Edelmann and D. Rosen have also cooperated in its compilation. We want to express our special gratitude toward Dr. Y. Sud, who offered us generously both his advice and his time in the development of the "physics" routine, and most especially to Dr. M. Halem without whose many useful suggestions, constant encouragement, and long patience, this work would not have been finished.

Eugenia Kalnay-Rivas

November 1979

I. Introduction

The band fourth order model is a GCM which uses quadratically conservative, fourth order horizontal space differences on an unstaggered grid and second order vertical space differences with a Matsuno (forward-backward) or a smooth leapfrog time scheme to solve the primitive equations of motion.

This program numerically solves these equations one latitude band at a time which greatly reduces the amount of computer core storage needed to run the program. It also uses the same variable names, order of computations, I/O, post-processing as the standard second order GCM. Appropriate modifications have been made for the fourth order differences and leapfrog scheme. (See the 1978 Goddard Modeling and Simulation Research Review for an overview of the fourth order band model.)

The main feature of this model is that fourth order approximations are used for all the horizontal derivatives. The derivative $\frac{\partial q}{\partial x}$ is approximated by

$$\frac{4}{3}\left(\frac{q(x+\Delta x)-q(x-\Delta x)}{2\Delta x}\right)-\frac{1}{3}\left(\frac{q(x+2\Delta x)-q(x-2\Delta x)}{4\Delta x}\right)$$

and the derivative $\frac{\partial}{\partial x}(qT)$ by

$$\frac{4}{3}\left[\frac{(T(x)+T(x+\Delta x))(q(x)+q(x+\Delta x))-(T(x)+T(x-\Delta x))(q(x)+q(x-\Delta x))}{4\Delta x}\right]$$

$$-\frac{1}{3}\left[\frac{(T(x)+T(x+2\Delta x))(q(x)+q(x+2\Delta x))-(T(x)+T(x-2\Delta x))(q(x)+q(x-2\Delta x))}{8\Delta x}\right]$$

The second approximation is derived by averaging the flux qT to yield a conservative form of the dynamic equations. Note that if T is equal to 1 the second equation reduces to the first.

The primary variables are the horizontal components of the wind velocity, $\mathbb{V}=(u,v)$, the temperature, T, the specific humidity, q, and the shifted surface pressure, π, ($\pi=P_s-P_{top}$, $P_{top}=10$ mb).

The secondary variables are the geopotential, ϕ, the vertical wind velocity, $\dot{\sigma}$, and the pressure, p.

The following pages give the differential equations of motion for the GCM model with the initial and boundary conditions. This is followed by the equations with the corresponding fourth order approximations which use the same notation as the current second order model. A complete description of the primitive equations with the σ coordinate system is found in the Arakawa UCLA notes (1976).

II. Primitive Equations of Motion

1.&2. Horizontal momentum equations

$$\mathbb{V}\frac{d\pi}{dt}+\pi\frac{d\mathbb{V}}{dt} = \frac{\partial\,\pi\mathbb{V}}{\partial t} + \nabla\cdot(\pi\mathbb{V}\mathbb{V}) + \frac{\partial}{\partial\sigma}(\pi\dot{\sigma}\mathbb{V})$$

$$= -\pi\nabla\phi - \pi\sigma\frac{RT}{p}\nabla\pi-(f+u\frac{\tan\phi}{a})\,\mathbb{k}\times\pi\mathbb{V} + \pi\mathbb{F}$$

3. Continuity equation

$$(3.1)\quad \frac{\partial\pi}{\partial t} + \nabla\cdot(\pi\mathbb{V}) + \frac{\partial}{\partial\sigma}(\pi\dot{\sigma}) = 0\ , \quad \text{or}$$

$$(3.2)\quad \frac{\partial\pi}{\partial t} = -\int_0^1\nabla\cdot(\pi\mathbb{V})\,d\sigma = -\nabla\cdot\int_0^1\pi\mathbb{V}\,d\sigma$$

4. Equation of state

$$\alpha = \frac{RT}{p}$$

5. First law of thermodynamics

$$\frac{\partial\,\pi T}{\partial t} + \nabla\cdot(\pi\mathbb{V}T) + \frac{\partial}{\partial\sigma}(\pi\dot{\sigma}T) = \frac{\pi\omega\alpha}{C_p} + \frac{\pi Q}{C_p} \qquad (\omega=\frac{dp}{dt})$$

From $\theta = T/p^k$, $p=p_T+\sigma\pi$, $\omega=\dot{\sigma}\pi+\dot{\pi}\sigma$, $\dot{\pi}=\frac{\partial\pi}{\partial t}+\mathbb{V}\cdot\nabla\pi$, $k=R/C_p$ we get

$$\frac{\partial\,\pi\dot{\sigma}T}{\partial\sigma} = p^k\,\frac{\partial\,\pi\dot{\sigma}\theta}{\partial\sigma} + \pi\frac{\dot{\sigma}\alpha\pi}{C_p}$$

Replacing in 5,

$$\frac{\partial\,\pi T}{\partial t} + \nabla(\pi\mathbb{V}T) + p^k\,\frac{\partial\,\pi\dot{\sigma}\theta}{\partial\sigma} = \frac{\pi\sigma kT}{p}(\frac{\partial\pi}{\partial t} + \mathbb{V}\cdot\nabla\pi) + \frac{\pi Q}{C_p}$$

6. Humidity equation

$$\frac{\partial\,\pi q}{\partial t} + \nabla\cdot(\pi\mathbb{V}q) = 0$$

7. Hydrostatic equation

$$\frac{\partial\phi}{\partial p^k} = -C_p\theta \qquad (\text{from } \frac{\partial p}{\partial\phi} = -\rho = -\frac{1}{\alpha})$$

Of the variables $\pi, u, v, T, q, \phi, \alpha, \dot{\sigma}$ we update the 5 primary variables π, u, v, T, and q using equations 1,2,3.2,5 and 6. From equations 3.1, 4, and 7 we can obtain ϕ, α, and $\dot{\sigma}$ which are our secondary variables. Note that $p=\sigma\pi+p_{top}$.

Sea level pressure (used only in the smoothing routine SMSHAP)

Hydrostatic eq. $\Rightarrow \frac{\partial p}{\partial \phi} = -p = -\frac{1}{\alpha} = -\frac{p}{RT} \therefore \log\left(\frac{SLP}{p}\right) = -\int_{\phi_s}^{0} \frac{d\phi}{RT}$

$\therefore \; SLP = p(\sigma=1)\ \exp\left(\frac{\phi_s}{R\overline{T}}\right)$

DERIVATION OF THE EQUATIONS AT THE POLES

Consider the continuity equation

$$\frac{\partial \pi}{\partial t} + \nabla.(\pi\mathbb{V}) + \frac{\partial \pi\dot{\sigma}}{\partial \sigma} = 0$$

coupled with a conservation equation $\frac{dT}{dt}$=S which can be expanded into

$$\frac{\partial \pi T}{\partial t} + \nabla.(\pi\mathbb{V}T) + \frac{\partial \pi\dot{\sigma}T}{\partial \sigma} = \pi S$$

If we integrate this equation over a polar cap of radius $\Delta\phi$

$$\int_0^{2\pi}\int_{\frac{\pi}{2}}^{\frac{\pi}{2}-\Delta\phi} \frac{\partial \pi T}{\partial t}\ a^2\cos\phi d\phi d\lambda = -\int_0^{2\pi}\int_{\frac{\pi}{2}}^{\frac{\pi}{2}-\Delta\phi} \nabla.(\pi\mathbb{V}T)a^2\cos\phi d\phi d\lambda$$

$$-\int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} \frac{\partial \pi\dot{\sigma}T}{\partial \sigma}\ a^2\cos\phi d\phi d\lambda - \int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} \pi S a^2\cos\phi d\phi d\lambda$$

and we assume the value of $\frac{\partial \pi T}{\partial t}$ to be approximately constant over the polar cap

$$\int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} \frac{\partial \pi T}{\partial t}\ a^2\cos\phi d\phi d\lambda \simeq \left(\frac{\partial \pi T}{\partial t}\right)\int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} a^2\cos\phi d\phi d\lambda$$

$$= 2\pi a^2(1-\cos\Delta\phi)\ \left(\frac{\partial \pi T}{\partial t}\right)_{NP}$$

The first term in the rhs is, using Gauss' theorem

$$-\int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} \nabla.(\pi\mathbb{V}T)a^2\cos\phi d\phi d\lambda = -\int_0^{2\pi} \pi vT\ a\ \sin\Delta\phi d\lambda$$

This can be approximated as

$$-\frac{2\pi}{IM}\sum_{i=1}^{IM}\pi_i v_i T_i \ a \sin\Delta\phi$$

The third term on the rhs is

$$\int_0^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi}\frac{\partial\pi\dot{\sigma}T}{\partial\sigma}\ a^2\cos\phi\, d\phi\, d\lambda \simeq 2\pi a^2(1-\cos\Delta\phi)\left(\frac{\partial\pi\dot{\sigma}T}{\partial\sigma}\right)_{NP}$$

and similarly with the source term.

From these equations we obtain

$$\boxed{\left(\frac{\partial\pi T}{\partial t}\right)_{Pole} = -(-1)^m\frac{\cot\Delta\phi/2}{aIM}\sum_{i=1}^{IM}(\pi_i v_i T_i)_{\frac{\pi}{2}-\Delta\phi} - \left(\frac{\partial\pi\dot{\sigma}T}{\partial\sigma}\right)_{Pole} + S}$$

since $\frac{2\pi a}{IM}\sin\Delta\phi / 2\pi a^2(1-\cos\Delta\phi) = \frac{2\sin\Delta\phi/2\cos\Delta\phi/2}{IMa\ 2\sin^2\frac{\Delta\phi}{2}} = \frac{\cot\frac{\Delta\phi}{2}}{aIM}$

This formulation is used in the continuity, momentum temperature and moisture equations. Note that the first term changes sign in the South Pole (m=1). In the momentum equations we make use of the transformation

$$U_i = -\sin\lambda u_i - (-1)^m\cos\lambda v_i$$

$$V_i = (-1)^m\cos\lambda u_i - \sin\lambda v_i$$

where m=1 for the South Pole and m=2 for the North Pole. U_i, V_i are the "cartesian" velocities at longitude λ_i, and u_i, v_i the corresponding spherical velocities.

The pressure gradient terms are computed making use of Green's Theorem: $\iint\frac{\partial Q}{\partial x}dxdy = \oint Qdy; \iint\frac{\partial P}{\partial g}dxdy = -\oint Pdx$

For example

$$\int_{0}^{2\pi}\int_{\pi/2}^{\pi/2-\Delta\phi} \frac{\partial \phi}{\partial x}\, a^{2}\cos\phi\, d\phi\, d\lambda \;=\; -\Phi \;\phi a\Delta\phi(-\cos\lambda d\lambda)$$

$$\phi = \frac{\pi}{2} - \Delta\phi$$

$$\approx + \frac{a\Delta\phi 2\pi}{IM} \sum_{i=1}^{IM} \phi_{i}\cos\lambda_{i}$$

In the U-momentum equation we have then the following pressure terms

$$\left(\frac{\partial \pi U}{\partial t}\right)_{P} = - \frac{\Delta\phi}{a(1-\cos\phi)IM} \sum_{i=1}^{IM} \left(\phi_{i} + \left(\frac{\sigma RT}{\rho}\right)_{P} \pi_{i}\right)\cos\lambda_{i}$$

and similarly for πV .

In the model we have approximated $\Delta\phi \simeq 2\sin\frac{\Delta\phi}{2}$

Then $$\frac{\Delta\phi}{a(1-\cos\phi)IM} \simeq \frac{1}{a \sin\frac{\Delta\phi}{2}\, IM}$$

Based on this formulation we construct the fourth order scheme at the Poles by taking $\frac{4}{3}$ of the differences evaluated at $\Delta\phi$ from the Poles (as expanded here), minus $\frac{1}{3}$ of the differences at $2\Delta\phi$ from the Poles.

This formulation is not conservative at the Poles. However we have found that this has had no noticeable effect in the conservation of mass or energy in the model. In our shallow water experiments we studied a set of equations that were quadratically conservative, but inconsistent at the Pole, and another scheme analagous to the GFDL scheme, which is both quadratically conservative and consistent at the Poles, but suffers from a serious truncation error near the Poles in the pressure gradient term. The scheme that we chose gave better results than the other two (Kalnay-Rivas, 1976).

Computation of the horizontal pressure gradient as suggested by N. A. Phillips

(1) Let $\theta = \bar{\theta} + \theta'$, $\bar{\theta} = 280°K/1000^k$ i.e. constant

(2) $\phi = \bar{\phi} + \phi'$, $k = R/Cp = .286$

$$\frac{\partial\bar{\phi}}{\partial p^k} = -Cp\bar{\theta} \quad \therefore \quad \bar{\phi} = \phi_0 - Cp\bar{\theta}p^k \quad \text{with } \phi_0 = Cp\bar{\theta}1000^k$$

(3) $T = \bar{T}(p) + T'$, $\bar{T}(p) = \bar{\theta}p^k$

Thus our new dependent variables are

$$\phi' = \phi + Cp\bar{\theta}\,(p^k - 1000^k)$$

$$T' = T - \bar{\theta}p^k$$

In this way $\pi(\nabla\phi + \frac{\sigma RT}{p}\nabla\pi)$, the pressure gradient in the momentum equations gets transformed into

$$(4) \quad \pi(\nabla_\sigma\bar{\phi} + \nabla_\sigma\phi' + \sigma R\bar{\theta}\frac{p^k}{p}\nabla\pi + \frac{\sigma RT'}{p}\nabla\pi)$$

$$= \pi(\nabla_\sigma\phi' + \frac{\sigma RT'}{p}\nabla\pi) + \pi(\nabla_\sigma\bar{\phi} + \sigma R\bar{\theta}\frac{p^k}{p}\nabla\pi)$$

But the second parenthesis is zero:

$$\nabla\bar{\phi} + \sigma R\bar{\theta}\,\frac{p^k}{p}\,\nabla\pi = -Cp\bar{\theta}\nabla p^k + R\bar{\theta}\frac{p^k}{p}\nabla p = 0$$

In regions of steep orography, the second parenthesis in (4) is much larger than the first. When the horizontal pressure gradient terms are computed in their original form, the near cancellation of the two terms introduces large truncation errors. The procedure suggested by Phillips greatly reduces this truncation error. We have chosen a simpler definition of ϕ_o than the one suggested by Phillips.

III. Finite Difference Variables and Grid

The notation used in fourth band model is the same as the standard GLAS(GISS) second order GCM except that we use a non-staggered horizontal grid. A complete description of the variables can be found in the TSANG-KARN documentation of the GISS 9 level model.

Let u_{ijk}, v_{ijk}, T_{ijk}, q_{ijk}, π_{ij} be the

finite difference approximations to the primary variables u,v,T,q, and π at the mesh point $(i\Delta\lambda, j\Delta\phi, (k-\frac{1}{2})\Delta\sigma)$. Also the scaled variables $\pi u, \pi v$, ...are approximated by πu_{ijk}, πv_{ijk}, ...

The finite difference equations also use the following geometric arrays:

$$DXP(j) = m_j = a \cos\phi_j \Delta\lambda, \quad DYU(j) = n_j = a\Delta\phi_j \ ,$$

We use a factor of 12 in DXYP to make our scaled fourth order differences simpler.

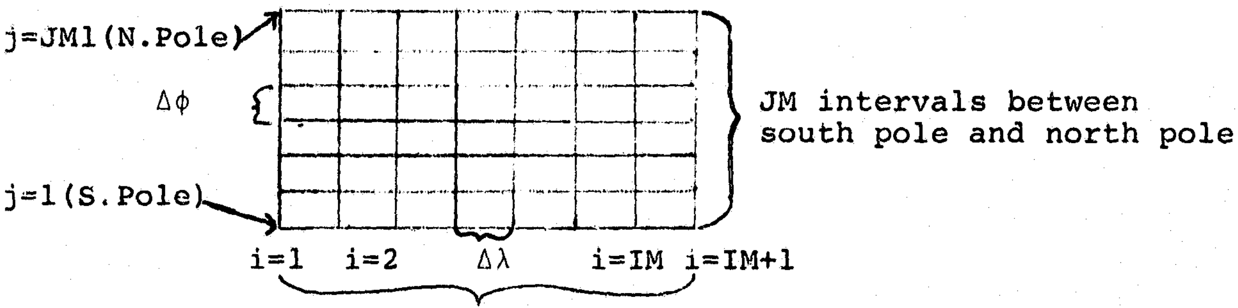
$$DXYP(j) = 12.m_j \cdot n_j \ , \ \Pi_{ij} = DXYP(j) \cdot \pi_{ij} \ , \ U^*_{ijk} = n_j \pi_{ij} U_{ijk}$$

$$\dot{S}_{ijk} = \Pi_{ij} \cdot \dot{\sigma}_{ijk} \ , \quad ADLDP = 12.a*\Delta\lambda\Delta\phi \ , \ V^*_{ijk} = m_j \pi_{jj} V_{ijk}$$

$$F_{ijk} = DXYP(j) f_j + ADLDP \cdot SIN\phi_j \ U_{i\ell j}$$

Horizontal Grid

The fourth order band model uses an unstaggered grid in the horizontal direction.



IM intervals in the longitudinal direction and periodic, i=IM+1 is identical to i=1.

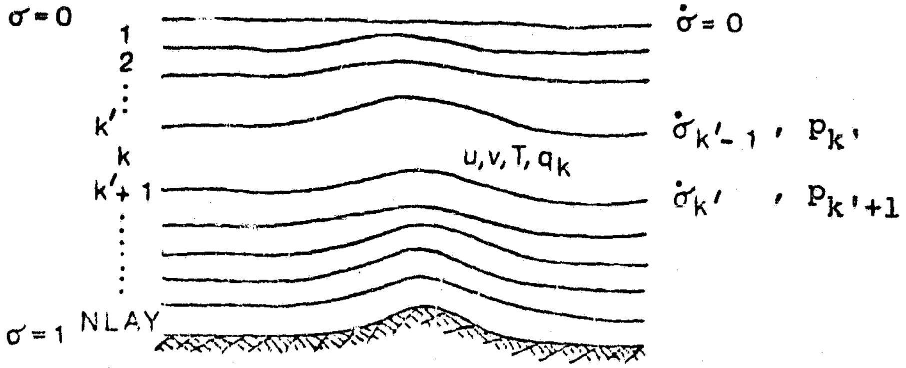
$\Delta\lambda$ = DLON = $\frac{2\pi}{IM}$ $\Delta\phi$ = DLAT = $\frac{\pi}{JM}$

$\lambda_i = (i-1)\Delta\lambda-\pi = (i-1)5°-180°$ $\phi_j = (j-1)\Delta\phi - \frac{\pi}{2} = (j-1)4°-90°$

JSP = 1 JNP = JM1 = JM+1

Vertical Grid

The vertical grid is staggered; the values of all the variables u,v,T,q,π, ... except $\dot\sigma$ are computed at the center of each layer. The values of $\dot\sigma$ are computed at the edges of the layers.



In the case of uniform vertical resolution and NLAY=9 vertical layers,

$$\sigma_k = \text{SIG(K)} = \frac{k-1}{9}(0,1/9,...1)$$

$$\sigma_{k'} = \text{SIGE(K)} = \frac{2k-1}{18} = (\frac{1}{18},...,\frac{17}{18})$$

and $\Delta\sigma = 1/9$.

$\dot\sigma_{ijk}$ and its scaled version $\dot S_{ijk}$ are defined at the eight interior edges, i.e. for σ'_k with k=1 to 8 since $\dot\sigma(0)=\dot\sigma(1)=0$ from the boundary conditions. The pressure $p_{k'}=\pi\sigma_{k'}+p_{TOP}$ is defined at the same level as $\dot\sigma_{k'-1}$.

Note for level k we need $\dot S_{ijk}$ and $\dot S_{ijk-1}$ to form the second order vertical differences:

$$\dot S_{ijk}\ (V_{ijk}+V_{ijk+1}) - \dot S_{ijk-1}(V_{ijk}+V_{ijk-1}) \ .$$

III-2 Periodic Filtering of Short Waves

An integral part of the numerical scheme is the periodic application (every ISMTH steps, generally 2 hours) of a 16th order Shapiro filter. This has the effect of removing waves shorter than $4\Delta x$, which are not resolved in the model, while waves longer than $4\Delta x$, which are accurately computed by the difference scheme, are not affected by the filter (Kalnay-Rivas and Hoitsma, 1979).

The filter is applied to an array q_j in the following way:
Let $d_+ (q_j) = q_{j+1} - q_j$, $d_- (q_j) = q_j - q_{j-1}$

Then a Shapiro filter of order 2N is given by

$$\bar{q}_j = q_j - (-1)^N (d_+ d_-)^N q_j$$

The response of the filter applied to a wave of the form $q_j = Q \exp(i\frac{2\pi}{L}\Delta x j)$ is

$$\bar{q}_j = (1 - \sin^{2N} \frac{\pi\Delta x}{L})\, q_j$$

The 2-dimensional filter is applied as a product of 1-dimensional filters (first in longitude, then in latitude). In latitude we filter the fields on great circles formed by meridians of longitude λ and $\lambda+\pi$, where $0 \leq \lambda < \pi$. We are presently filtering only potential temperature and sea level pressure. These fields were chosen because they are not very affected by orography. Winds are not currently filtered, because the adjustment between mass and velocity fields does not allow the development of short waves in the winds alone. However, in the tropics, where the adjustment of winds to the mass field is minimal, the winds are somewhat noisy, and we may opt to filter them too.

IV. Boundary Conditions

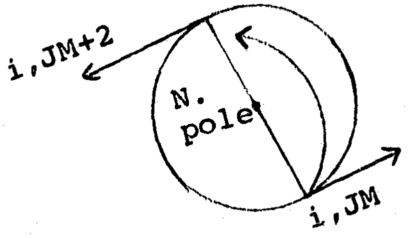
Periodicity in the Zonal (East-West) direction

$\Pi_{IM+mj} = \Pi_{mj}$ $\quad m=1,2,3,\ldots, \quad j=2,\ldots,JM$

$Q_{IM+mjk}=Q_{mjk}$ $\quad m=1,2,3,\ldots, \quad j=2,\ldots,JM, \quad k=1,\ldots,NLAY$

for $Q=u,v,T,q,\phi,\dot{\sigma},\pi u,\pi v,\ldots$

Boundary conditions at the north and south poles. Define the array INDEX as follows:



$$INDEX(i) = i + \frac{IM}{2} \qquad i=1,2,\ldots,\frac{IM}{2}$$

$$INDEX(i+\frac{IM}{2}) = i \qquad i=\frac{IM}{2}+1,\ldots,IM$$

i.e., INDEX: $\frac{IM}{2}+1, \frac{IM}{2}+2,\ldots,IM,1,2,\ldots,\frac{IM}{2}$

Then we can define

$\pi_{iJM+2} = \pi_{INDEX(i)JM}$ for the points needed "beyond" the North Pole,

and $\pi_{i0} = \pi_{INDEX(i)2}$ for the points "beyond" the South Pole

and similarly for T,q,ϕ.

For the horizontal velocity $V=(u,v)$ we have

$$V_{iJM+2k} = -V_{iJMk}$$

$$V_{i0k} = -V_{i2k}$$

V. Finite Difference Equations

THE ZONAL (U) MOMENTUM EQUATION

$$\frac{\partial \pi u}{\partial t} = -\frac{1}{a\cos\phi}\left[\frac{\partial(\pi u\cdot u)}{\partial\lambda} + \frac{\partial(\pi v\cos\phi\cdot u)}{\partial\phi}\right] - \frac{\partial(\pi\dot{\sigma}u)}{\partial\sigma}$$

$$-\frac{\pi}{a\cos\phi}\left[\frac{\partial\phi}{\partial\lambda} + \frac{\sigma RT}{p}\frac{\partial\pi}{\partial\lambda}\right] + \left(f + \frac{u\tan\phi}{a}\right)\pi v + \pi F_x$$

$$\frac{\partial \Pi U_{ijk}}{\partial t} = \overset{\text{COMP1: HA:}}{\Big\{} 4.*[(\overbrace{U^*_{ijk} + U^*_{i-1jk}}^{PU1_{i-1/2j}})(U_{ijk}+U_{i-1jk}) - (\overbrace{U^*_{ijk}+U^*_{i+1jk}}^{PU1_{i+1/2}})(U_{ijk}+U_{i+1jk})]$$

$$-.5[(\overbrace{U^*_{ijk}+U^*_{i-2jk}}^{PU2_{i-1}})(U_{ijk}+U_{i-2jk}) - (\overbrace{U^*_{ijk}+U^*_{i+2jk}}^{PU2_{i+1}})(U_{ijk}+U_{i+2jk})$$

$$+4*[(\overbrace{V^*_{ijk}+V^*_{ij-1k}}^{PV1})(U_{ijk}+U_{ij-1k}) - (V^*_{ijk}+V^*_{ij+1k})(U_{ijk}+U_{ij+1k})]$$

$$-.5*[(V^*_{ijk}+V^*_{ij-2k})(U_{ijk}+U_{ij-2k}) - (\overbrace{V^*_{ijk}+V^*_{ij+2k}}^{PV2})(U_{ijk}+U_{ij+2k})$$

VA:

$$+.5*[\dot{S}_{ijk-1}(U_{ijk}+U_{ijk-1}) - \dot{S}_{ijk}(U_{ijk}+U_{ijk+1})]/\Delta\sigma_k \Big\}$$

COMP2: PG:

$$+(\pi_{ij}*n_j*\{8*[\phi'_{i-1jk}-\phi'_{i+1jk}+\frac{\sigma_k RT'_{ijk}}{p_k}(\pi_{i-1j}-\pi_{i+1j})] +$$

$$[\phi'_{i+2jk}-\phi'_{i-2jk}+\frac{\sigma_k RT'_{ijk}}{p_k}(\pi_{i+2j}-\pi_{i-2j})]\Big\}$$

$$\overset{\text{C:}}{+}\ F_{ijk}*\pi_{ij}*V_{ijk}) + \overset{\text{COMP3}}{(\Pi F_x)}$$

Note: COMP1, COMP2, COMP3 are the names of the three subroutines where the different terms are computed. HA: Horizontal advection terms. VA: Vertical advection terms. PG: Pressure gradient terms. C: Coriolis term.

Also note that PV2 is set equal to zero for j=0 and j=JM, i.e., there is no transport of mass across the poles.

THE MERIDIONAL (V) MOMENTUM EQUATION

$$\frac{\partial \pi V}{\partial t} = - \frac{1}{a\cos\phi} [\frac{\partial (\pi u \cdot v)}{\partial \lambda} + \frac{\partial (\pi v \cos\phi V}{\partial \phi}] - \frac{\partial \pi \dot{\sigma} V}{\partial \sigma}$$

$$- \frac{\pi}{a}[\frac{\partial \phi}{\partial \phi} + \frac{\sigma RT}{p} \frac{\partial \pi}{\partial \phi}] - (f+\frac{u\tan\phi}{a}) \pi u + \pi F_y$$

COMP1: HA:

$$\frac{\partial \Pi V_{ijk}}{\partial t} = \{ 4.*[(U^*_{ijk}+U^*_{i-1jk}) (V_{ijk}+V_{i-1jk}) - (U^*_{ijk}+U^*_{i+1jk}) (V_{ijk}+V_{i+1jk})$$

$$-.5[(U^*_{ijk}+U^*_{i-2jk})*(V_{ijk}+V_{i-2jk}) - (U^*_{ijk}+U^*_{i+2jk}) (V_{ijk}+V_{i+2jk})$$

$$+4.*[(V^*_{ijk}+V^*_{ij-1k}) (V_{ijk}+V_{ij-1k}) - (V^*_{ijk}+V^*_{ij+1k}) (V_{ijk}+V_{ij+1k})$$

$$-.5*[(V^*_{ijk}+V^*_{ij+2k}) (V_{ijk}+V_{ij-2k}) - (V^*_{ijk}+V^*_{ij+2k}) (V_{ijk}+V_{ij+2k})$$

VA:

$$+.5*[\dot{S}_{ijk-1} (V_{ijk}+V_{ijk-1}) - \dot{S}_{ijk} (V_{ijk}+V_{ijk+1})]/\Delta\sigma_k \}$$

COMP2: P:

$$+(\pi_{ij}*m_j*\{8.*[\phi'_{ij-1k}-\phi'_{ij+1k}+ \frac{\sigma_k RT'_{ijk}}{p_k} (\pi_{ij-1}-\pi_{ij+1})]$$

$$+ [\phi'_{ij+2k}-\phi'_{ij-2k}+ \frac{\sigma_k RT'_{ijk}}{p_k} (\pi_{ij+2}=\pi_{ij-2})]\}$$

C: COMP3:

$$-F_{ijk}*\pi_{ij}*U_{ijk})+(\Pi F_y)$$

THE THERMODYNAMIC ENERGY EQUATION

$$\frac{\partial \pi T}{\partial t} = -\frac{1}{a\cos\phi}\left[\frac{\partial \pi U T}{\partial \lambda} + \frac{\partial \pi V\cos\phi \cdot T}{\partial \phi}\right] - p^{k}\,\frac{\partial \pi \dot{\sigma} T/p^{k}}{\partial \sigma}$$

$$+ \frac{\pi\sigma K T}{p}\left(\frac{\partial \pi}{\partial t} + \frac{U}{a\cos\phi}\,\frac{\partial \pi}{\partial \lambda} + \frac{V}{a}\,\frac{\partial \pi}{\partial \phi}\right) + \frac{\pi Q}{C_p}$$

COMP1: HA:

$$\frac{\partial \Pi T_{ijk}}{\partial t} = \{4*[(U^*_{ijk}+U^*_{i-1jk})(T_{ijk}+T_{i-1jk})-(U^*_{ijk}+U^*_{i+1jk})(T_{ijk}+T_{i+1jk})$$

$$-.5*[(U^*_{ijk}+U^*_{i-2jk})(T_{ijk}+T_{i-2jk}) - (U^*_{ijk}+U^*_{i+2jk})(T_{ijk}+T_{i+2jk})$$

$$+4*\ [(V^*_{ijk}+V^*_{ij-1k})(T_{ijk}+T_{ij-1k}) - (V^*_{ijk}+V^*_{ij+1k})(T_{ijk}+T_{ij+1k})$$

$$-.5*[(V^*_{ijk}+V^*_{ij-2k})\ (T_{ijk}+T_{ij+2k}) - (V^*_{ijk}+V^*_{ij+2k})(T_{ijk}+T_{ij+2k})]$$

VA:

$$+.5p^{k}_{ijk}[\dot{S}_{ijk-1}\left(\frac{T_{ijk}}{p^{k}_{ijk}} + \frac{T_{ijk-1}}{p^{k}_{ijk-1}}\right) - \dot{S}_{ijk}\left(\frac{T_{ijk}}{p^{k}_{ijk}} + \frac{T_{ijk+1}}{p^{k}_{ijk+1}}\right)]/\Delta\sigma_{k}\ \}$$

COMP2:

$$(+\ \frac{\sigma_k K T_{ijk}}{p_{ijk}}\ [\pi_{ij}\,\frac{\partial \pi}{\partial t} + U^*_{ijk}\{8.*[\pi_{i+1j}-\pi_{i-1j}]+\pi_{i-2j}-\pi_{i+2j}\ \}$$

$$+ V^*_{ijk}\{8.*[\pi_{ij+1}-\pi_{ij-1}]+\pi_{ij-2}-\pi_{ij+2}\}])$$

COMP3:

$$+\left(\frac{\pi Q_{ijk}}{Cp}\right)$$

THE MOISTURE EQUATION

$$\frac{\partial \pi q}{\partial t} = - \frac{1}{a\cos\phi} [\frac{\partial \pi U \cdot q}{\partial \lambda} + \frac{\partial \pi V\cos\phi \cdot q}{\partial \phi}] - \frac{\partial \pi \dot{\sigma} q}{\pi \sigma} + \pi (E-C)$$

COMP1: HA

$$\frac{\partial \Pi q_{ijk}}{\partial t} = \{ 4.*[(U^*_{ijk}+U^*_{i-1jk})(q_{ijk}+q_{i-1jk})-(U^*_{ijk}+U^*_{i+1jk})(q_{ijk}+q_{i+1jk})]$$

$$-.5*[(U^*_{ijk}+U^*_{i+2jk})(q_{ijk}+q_{i-2jk})-(U^*_{ijk}+U^*_{i+2jk})(q_{ijk}+q_{i+2jk})]$$

$$+4.*[(V^*_{ijk}+V^*_{ij-1k})(q_{ijk}+q_{ij-1k})-(V^*_{ijk}+V^*_{ij+1k})(q_{ijk}+q_{ij+1k})]$$

$$-.5*[(V^*_{ijk}+V^*_{ij-2k})\ (q_{ijk}+q_{ij-2k})-(V^*_{ijk}+V^*_{ij+2k})(q_{ijk}+q_{ij+2k})]$$

$$+.5*[\dot{S}_{ijk-1}(q_{ijk}+q_{ijk-1})-\dot{S}_{ijk}(q_{ijk}+q_{ijk+1})]/\Delta\sigma_k\}$$

COMP3:

$$+\Pi(E_{ijk}-C_{ijk})$$

Note: The current transport scheme for the moisture field is being modified.

THE PRESSURE-TENDENCY EQUATION

$$\frac{\partial \pi}{\partial t} = - \sum_{\ell=1}^{L} \frac{(\Delta\sigma)_\ell}{a\cos\phi} \left[\frac{\partial \pi u}{\partial \lambda} + \frac{\partial \pi v\cos\phi}{\partial \phi}\right]$$

COMP1:

$$\mathrm{CONV}_{i\ell j} = \Delta\sigma_\ell \{8.*(U^*_{i-1j\ell} - U^*_{i+1j\ell}) + U^*_{i+2j\ell} - U^*_{i-2j\ell}$$

$$+ 8.*(V^*_{ij-1\ell} - V^*_{ij+1\ell}) + V^*_{ij+2\ell} - V^*_{ij-2\ell}\}$$

COMP1:

$$\frac{\partial \Pi_{ij}}{\partial t} = \left(\sum_{\ell=1}^{L} \mathrm{CONV}_{i\ell j} \right)$$

THE VERTICAL VELOCITY EQUATION

$$\frac{\partial \pi}{\partial t} = - \frac{1}{a\cos\phi} \left[\frac{\partial \pi U}{\partial \lambda} + \frac{\partial \pi V\cos\phi}{\partial \phi}\right] - \frac{\partial}{\partial \sigma} (\pi\dot{\sigma})$$

Thus

$$\Delta\sigma_k \frac{\partial \Pi}{\partial t} = \mathrm{CONV}_{ikj} - \Delta\dot{S}_{ijk}$$

giving:

COMP1:

$$\dot{S}_{ijk} = \{\dot{S}_{ijk-1} + \mathrm{CONV}_{ikj} - \Delta\sigma_k \frac{\partial \Pi}{\partial T}\}$$

VI. The Forecast Equations at the Poles

The fourth order band model uses a spherical cap at the poles, and the finite difference approximations to the equations of motion must be derived for this spherical region. Stereographic projection is used to give us a well-defined velocity vector at the poles.

From trigonometry, (Fig. VIa) if the vector (U,V) in X-Y coordinates is represented by (U',V') in X'-Y' coordinates where the prime coordinate axes are rotated by an angle λ then,

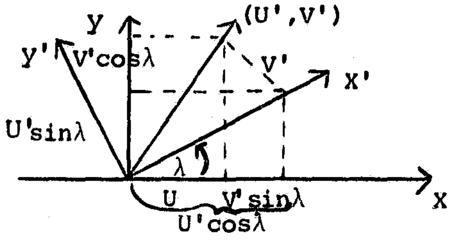


Fig. VIa

$$(1) \qquad U = U'\cos\lambda - V'\sin\lambda$$

$$(2) \qquad V = U'\sin\lambda - V'\cos\lambda$$

We want to interpret "polar stereographic" velocities (U_{NP},V_{NP}) also as "spherical" velocities $(U,V)_\lambda$, as we approach the North Pole along a meridian of longitude λ.

From Fig. VIb, which shows a unit vector in both coordinate systems, we see that, at the North Pole, spherical coordinates are rotated by an angle $(\frac{\pi}{2}+\lambda)$ with respect to the polar stereographic coordinates. Therefore,

$$U_{NP} = U\cos(\lambda+\tfrac{\pi}{2}) - V\sin(\lambda+\tfrac{\pi}{2})$$

$$V_{NP} = U\sin(\lambda+\tfrac{\pi}{2}) + V\cos(\lambda+\tfrac{\pi}{2})$$

or

$$(3) \qquad \boxed{\begin{aligned} U_{NP} &= -U\sin\lambda - V\cos\lambda \\ V_{NP} &= U\cos\lambda - V\sin\lambda \end{aligned}}$$

Similarly, for the South Pole:

$$(4) \qquad \boxed{\begin{aligned} U_{SP} &= -U\sin\lambda + V\cos\lambda \\ V_{SP} &= -U\cos\lambda - V\sin\lambda \end{aligned}}$$

also,

$$(5) \qquad \boxed{\begin{aligned} U &= -U_{NP}\sin\lambda + V_{NP}\cos\lambda \\ V &= -U_{NP}\cos\lambda - V_{NP}\sin\lambda \end{aligned}}$$

$$(6) \qquad \boxed{\begin{aligned} U &= -U_{SP}\sin\lambda - V_{SP}\cos\lambda \\ V &= U_{SP}\cos\lambda - V_{SP}\sin\lambda \end{aligned}}$$

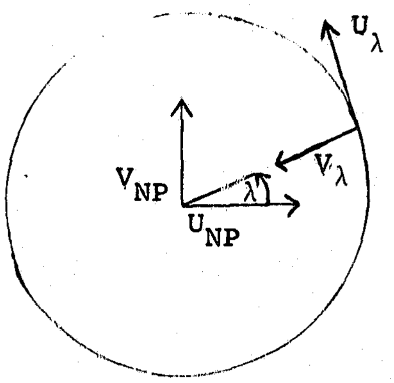


Fig. VIb

The initial values for U_{NPk} , V_{NPk} , U_{SPk} , V_{SPk} are obtained from equations 3 and 4 by averaging in the zonal direction on the line of latitude j=45 for the north pole and j=2 for the south pole. In the forecast stereographic velocities are advected and transformed back into spherical velocities after each time step by equations 5 and 6.

In the following equation we will denote the polar velocities by $VP_{k,m}$, $VP_{k,m}$ and the temperature and other variables in a similar way, $TP_{k,m}$, $\pi P_{k,m}$, ... where m=1 for the south pole and m=2 for the north pole. The following constants are used,

$COEF1=(-1)^m$ COEF2=-COEF1 RADIM=$3 \cdot a \cdot IM$

CON1=4COT(.5$\Delta\phi$)/RADIM

CON2=-COT($\Delta\phi$)/RADIM

CON3=4DT/(RADIM*SIN(.5$\Delta\phi$)

CON4=DT/(RADIM*SIN($\Delta\phi$))

$$JPOL(K,M)=\begin{pmatrix} 2 & JM \\ 3 & JM-1 \end{pmatrix}$$

r=JPOL(1,m)=first interior value of j (2 for the S. Pole, JM for the N. Pole)

s=JPOL(2,m)=second interior value of j(3 for the S. Pole, JM-1 for the N. Pole).

ZONAL (U) MOMENTUM EQUATION (POLES)

COMP1:

$$\frac{\partial \pi UP_{k,m}}{\partial t} = \{COEF1*[CON1*\sum_{i=1}^{IM} -\pi_{ir}V_{irk}(U_{irk}Sin\lambda_i+COEF1*V_{irk}COS\lambda_i)$$

$$+CON2*\sum_{i=1}^{IM} -\pi_{is}V_{isk}(U_{isk}Sin\lambda_i+COEF1*V_{isk}COS\lambda_i)]$$

$$+.5[\dot{S}P_{k-1}(UP_k+UP_{k-1})-\dot{S}P_k(UP_k+UP_{k+1})]/\Delta\sigma_k\}$$

COMP2:

$$+\ \pi P_m\cdot[-\frac{CON3}{DT}*\sum_{i=1}^{IM}(\phi'_{irk}+\frac{\sigma_k RTP'_k}{pP_k}\ \pi_{ir})COS\lambda_i$$

$$+\frac{CON4}{DT}*\sum_{i=1}^{IM}(\phi'_{isk}+\frac{\sigma_k RTP'_k}{pP_k}\ \pi_{is})COS\lambda_i]$$

COMP3:

$$+\ f_m\pi P_m\cdot VP_{k,m})\ +\ (\pi P_m\cdot FP_{k,m}$$

MERIDIONAL (V) MOMENTUM EQUATION (POLES)

COMP1:

$$\frac{\partial \pi VP_{k,m}}{\partial t} = \{COEF1*[CON1*\sum_{i=1}^{IM} -\pi_{ir}V_{irk}(COEF2*U_{irk}*COS\lambda_i+V_{irk}Sin\lambda_i)$$

$$+CON2*\sum_{i=1}^{IM} -\pi_{is}V_{isk}(COEF2*U_{isk}*COS\lambda_i+V_{isk}Sin\lambda_i)]$$

$$+.5[\dot{S}P_{k-1}(VP_k+VP_{k-1})-\dot{S}P_k(VP_k+VP_{k+1})]/\Delta\sigma_k\}$$

COMP2:

$$+\pi P_m\cdot[-\frac{CON3}{DT}*\sum_{i=1}^{IM}(\phi'_{irk}+\frac{\sigma_k RTP_k}{pP_k}\pi_{ir})Sin\lambda_i$$

$$+\frac{CON4}{DT}*\sum_{i=1}^{IM}(\phi'_{isk}+\frac{\sigma_k RTP_k}{pP_k}\pi_{is})Sin\lambda_i]$$

COMP3:

$$-\ f_m\pi P_m\cdot UP_{k,m}\ +\ (\pi P_m\cdot SP_{k,m})$$

THE THERMODYNAMICS ENERGY EQUATION (POLES)

COMP1:

$$\frac{\partial \pi TP_{k,m}}{\partial t} = \{\mathrm{COEF1}*(\mathrm{CON1}*\sum_{i=1}^{IM} \pi_{ir}V_{irk}T_{irk}+\mathrm{CON2}*\sum_{i=1}^{IM} \pi_{is}V_{isk}T_{isk})$$

$$+.5pP^{k}_{k,m}*[\dot{S}P_{k-1,m}(\frac{TP_{k,m}}{pP^{k}_{k,m}}+\frac{TP_{k-1,m}}{pP^{k}_{k-1,m}})$$

$$-\dot{S}P_{k,m}(\frac{TP_{k,m}}{pP^{k}_{k,m}}+\frac{TP_{k+1,m}}{pP^{k}_{k+1,m}})]/\Delta\sigma_{k}\}$$

COMP2:

$$+(\frac{\pi P_{m}\sigma_{k}KTP_{k,m}}{pP_{k,m}}\{\frac{\partial \pi P_{m}}{\partial t}+\mathrm{CON5}*\sum_{i=1}^{IM}[(\mathrm{COEF1}*UP_{k,m}\mathrm{COS}\lambda_{i}+VP_{k,m}\mathrm{SIN}\lambda_{i})*(8\pi_{ir}-\pi_{is})]\})$$

COMP3:

$$+(\frac{\pi P_{m}}{Cp}QP_{k})$$

THE MOISTURE BALANCE EQUATION (POLES)

COMP1:

$$\frac{\partial \pi qP_{k,m}}{\partial t} = \{\mathrm{COEF1}*(\mathrm{CON1}*\sum_{i=1}^{IM} \pi_{ir}V_{irk}q_{irk}+\mathrm{CON2}*\sum_{i=1}^{IM} \pi_{is}V_{isk}q_{isk})$$

$$+.5[\dot{S}P_{k-1,m}(qP_{k,m}+qP_{k-1,m})-\dot{S}P_{k,m}(qP_{k,m}+qP_{k+1,m})]/\Delta\sigma_{k}\}$$

COMP3:

$$+(\pi P_{m}*EP_{k})$$

THE PRESSURE TENDENCY EQUATION (POLES)

$$CONVPL_{k,m}=COEF1*(CON1*\sum_{i=1}^{IM}\pi_{ir}V_{irk}+CON2*\sum_{i=1}^{IM}\pi_{is}V_{isk})\Delta\sigma_k$$

$$\frac{\partial \pi P_m}{\partial t} = \sum_{k=1}^{NLAY} CONVPL_{k,m}$$

THE VERTICAL VELOCITY EQUATION (POLES)

$$\dot{S}P_{k,m} = \dot{S}P_{k-1,m} + CONVPL_k - \Delta\sigma_k \frac{\partial \pi P_m}{\partial t}$$

VII. Diagnostic Equations ($\phi,\dot{\sigma},p$)

Once the updated values of πU, πV, πT, πq are found we unscale:

$$U^{n+1}_{ijk} = \pi U^{n+1}_{ijk}/\pi^{n+1}_{ij} \qquad \text{for all } i,j,k.$$

Similarly for V,T,q. We also filter the fields near the poles to prevent linear instability (see subroutine AVRX). $\dot{\sigma}$ is obtained from $\dot{S}$ by unscaling also.

We determine from π^{n+1}_{ij} and σ_k, p^{n+1}_{ijk}

$$p^{n+1}_{ijk} = \sigma_k \pi^{n+1}_{ij} + p_{TOP} \qquad p_{TOP}=\text{constant.}$$

ϕ_S is the surface geopotential (a function only of latitude and longitude)

For the Phillips geopotential we define $(p)^k$ at the center of the layer in the following way:

$$(p)^k_{ijk} = \frac{p^{k+1}_{ijk+1'} - p^{k+1}_{ijk'}}{(k+1)(p_{ijk'+1} - p_{ijk'})} \qquad \left(p^k = \frac{1}{k+1}\frac{\partial p^{k+1}}{\partial p}\right)$$

$$k=1,2,\ldots,NLAY$$

where

$$p^{k+1}_{ijk'} = (SIGE(k)*\pi_{ij} + p_{TOP})^{k+1} \qquad (SIGE(k)=\sigma'_k),\text{ i.e.}$$

p^{k+1} is obtained by exponentiation and $(p)^k$ by differences.

The following equations represent the geopotential calculations used in the old fourth order model.

Let

$$C_{ijk} = \frac{\pi_{ij}\sigma_k R\Delta\sigma_k}{P_{ijk}} - \frac{C_p}{2}\left[\sigma_{k'}\left(\frac{p^k_{ijk+1}}{p^k_{ijk}} - 1\right) + \sigma_{k'-1}\left(1-\frac{p^k_{ijk-1}}{p^k_{ijk}}\right)\right]$$

for $k=1,\ldots,NLAY$

with

$$p^k_{ij0} = p^k_{ij1} \text{ and } p^k_{ijNLAY+1} = p^k_{ijNLAY}$$

An optimized version of C_{ijk} is:

$$C_{ijk} = \frac{\pi_{ij}\sigma_k R\Delta\sigma_k}{P_{ijk}} - \frac{.5Cp}{p^k_{ijk}}\left\{\Delta\sigma_{k'}(p^k_{ijk+1}-p^k_{ijk}) + \sigma'_{k-1}(p^k_{ijk+1}-p^k_{ijk-1})\right\}$$

Rather than compute ϕ and then subtract $\bar{\phi}$ we do everything at once:

$$(1) \quad \phi'_{ijNLAY} = \phi'_S - CPTH*(PSKAPA - p^k_{ijNLAY}) + \sum_{\ell=1}^{NLAY} C_{ij\ell}T_{ij\ell}$$

$$(2) \quad \phi'_{ij\ell} = \phi'_{ij\ell+1} + \frac{Cp}{2}*(p^k_{ij\ell+1}-p^k_{ijk}) \quad ((\frac{T_{ijk}}{p^k_{ijk}} + \frac{T_{ijk+1}}{p^k_{ijk+1}}) - 2\bar{\theta})$$

where

$CPTH = C_p \cdot \bar{\theta}$ $\qquad$ $PSKAPA = 1000^k = p^k_s$.

VIII. The Time Differencing Scheme

The fourth order band model has the option of using the Matsuno time scheme or the smooth leapfrog scheme (see MWR-Vol 100 (487-490) R. Asselin).

Let Q^n represent a typical variable that is to be updated to time n+1, and let $D(Q^n)$ represent the nonlinear space differences. The Matsuno (Euler-backward) scheme is as follows:

$$\tilde{Q} = Q^n + \Delta t D(Q^n)$$
$$Q^{n+1} = Q^n + \Delta t D(\tilde{Q})$$

The standard leapfrog scheme is given by

(1) $$\frac{Q^{n+1} - Q^{n-1}}{2\Delta t} = D(Q^n)$$

For the smooth leapfrog scheme we replace Q^{n-1} by $\bar{Q}^{n-1}$

(2) $$Q^{n+1} = \bar{Q}^{n-1} + 2\Delta t D(Q^n)$$

with

(3) $$\bar{Q}^n = (1-\nu)Q^n + .5\nu(\bar{Q}^{n-1} + Q^{n+1})$$

Equation (3) represents a simple time filter except $\bar{Q}^{n-1}$ is used instead of Q^{n-1} in order to save core storage. The above equations (2) and (3) represent the order in which the smooth leapfrog scheme is evaluated. For n=1 we define $\bar{Q}^0 = Q^0$ then we update in equation (2) followed by the filtering in equation (3) which is needed for the next time step.

The smoothing step introduces dissipation with respect to time, controlled explicitly by the parameter ν, as compared to the implicit dissipation in the Matsuno scheme. The amplification factor can be found in the paper by Asselin.

A further modification must be made to the smooth leapfrog scheme when source terms are included. Essentially the idea is that we must include the source term effect over two steps rather than one. If we do not do this, then the source effects (COMP3) are included only in every other step which will introduce large discretization errors. (For details see the attached report, Appendix B.)

If the source terms are called every NCOMP3 steps, then for step n=NCOMP3

$$Q_*^n = \bar{Q}^{n-2} + 2\Delta t D(Q^{n-1})$$

$$\bar{Q}_*^{n-1} = (1-\nu) \quad Q^{n-1} + .5\nu(\bar{Q}^{n-2} + Q^n)$$

Then compute the source terms S^n and include in both steps n and n-1,

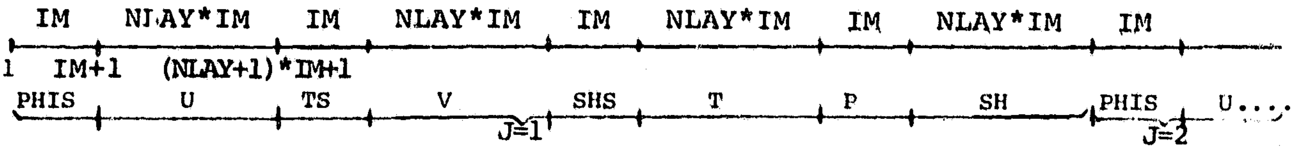
$$Q^n = Q_*^n + \mathrm{NCOMP3} \cdot \Delta t S^n$$

$$\bar{Q}^{n-1} = \bar{Q}_*^{n-1} + \mathrm{NCOMP3} \cdot \Delta t S^n$$

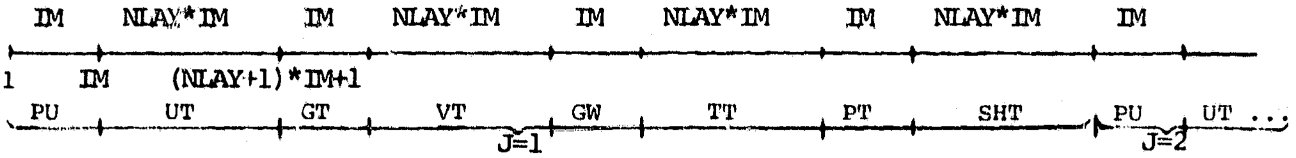
The actual code is complicated by the fact that we actually use scaled and unscaled variables, but the generalization is straightforward.

IX. Documentation of the Code (Preliminary)

The band fourth model uses special equivalences and nonstandard dimensions in order to have the variables P,U,V,T,SH stored in contiguous locations for each line of latitude. Thus, we desire to have the variables stored as follows.



The scaled variables PT, UT, VT, TT, SHT are to be stored as follows:



The above storage designation is accomplished by dimensioning PHIS(4*(NLAY+1)*IM,JNP) instead of PHIS(IM,JNP) (for a fine grid we have PHIS(2880,46), for ultrafine we have PHIS(4800,72)). Then we equivalence NLAY*IM locations of the first line of latitude of U with PHIS(IM+1,1) to PHIS((NLAY+1)*IM,1) (the first IM locations of PHIS are used for the quantity PHIS itself).

Similarly, we equivalence TS(1,1) to TS(IM,1) with PHIS((NLAY+1)*IM+1,1) to PHIS((NLAY+2)*IM,1) and so forth. (See the enclosed computer codes for the exact values in the fine and ultrafine versions.)

In order to have the successive lines of latitude arranged properly in storage we dimension our variables to achieve this purpose. Thus, we have U(IM,4*(NLAY+1),1) instead of U(IM,NLAY,JM), similarly for V,T,SH,UT,VT,TT, and SHT. For P we have P(4*(NLAY+1)*IM,1) instead of P(IM,JNP) and similarly for TS, SHS,GT,GW, and PT. Note that the variables U,UT,... are only computed at IM*NLAY*JNP points, the special dimensions are needed to properly align the variables in storage. It is important to recall that we are using two properties of the FORTRAN Compiler:

First, by equivalencing two elements of two different arrays we implicitly equivalence the other elements of the arrays. Second, that last array dimension can be left as 1 as long as it is dimensioned properly in the calling routine or it is equivalenced to a properly dimensioned array. Note we could have dimensioned U as U(IM,4*(NLAY+1),JNP) we would use the same amount of storage. It is crucial to have the IM*(NLAY+1) dimension because it would cause the computations on U for the successive lines of latitude to be shifted IM*(NLAY+1) locations where the next line of latitude of U are stored. For clarity and simplicity in programming we use the standard equivalence of U,V,T,SH with Q(I,L,N,J) with U equivalent to Q(I,L,1,J) and so forth. Since we want P,U,V,T, and SH in contiguous storage locations and the equivalence of Q with U,V,T, and SH, then we must dimension Q as Q(IM,NLAY+1,4,1) instead of Q(IM,NLAY,4,1). We fill in the extra locations by including PHIS,TS,SH, and P.

COMP0 Description

This subroutine contains the time schemes and controls the calling sequences of the routines COMP1, COMP2, COMP3, and the polar filtering routine AVRX.

The logic of this subroutine involves three considerations. First, it permits one to choose either the Matsuno or the smooth leapfrog time scheme. Second, the latter scheme involves the use of storage arrays PSM and QSM. Third, the unscaling, smoothing of the updated variables QT and the call of subroutine COMP3 occur at the value JS2=J-2 when J is the value of the current line of latitude which is being computed. The routine COMP1 and COMP2 require the values of U,V,... at JS2 in order to compute the updated values at J because fourth order differences are used in the meridional (J) direction. Only after the COMP1 and COMP2 are called for value J can we unscale, smooth, and finish processing the variables at JS2.

The code for the poles is identical in format with the code for the other J values except the variables are scaled by the pressure PPOL only.

The main program contains two calls to COMP0 which cannot be treated independently because of the calling sequence: COMP0(Q,QT), COMP0 (QT,Q). If the first call is a leapfrog step (LF), the second one must be also LF. If the first call is Matsuno predictor (MP), the second one must be Matsuno corrector (MC). This is represented symbolically by LF→LF, or MP→MC. The second call can be followed by either MP or LF. Each of these combinations requires different transfers.

Description of the Time Step Sequence Parameters

NSTEP:	Counts the time steps. Starts and restarts both begin with NSTEP=0.
NSEQ:	The number of steps (combined matsuno and leapfrog) in each (repeated) sequence of time steps.
MLF(I):	MLF(I)=0 or 1 according to whether the Ith step in the sequence is Leapfrog or Matsuno, respectively. First step is always Matsuno (MLF(1)=1).
ISMTH, NSM1:	Smoothing routine (SMSHAP) is called MOD(NSTEP-NSM1, ISMTH); if ISMTH=0, there is no smoothing.
NCOMP3, NCM1:	Physics routine (COMP3) is called MOD (NSTEP-NCM1, NCOMP3).

Sample Runs

Matsuno only:

NSEQ=1, MLF(1)=1, MATSUN=1, DT=750., NSM1=0, NCM1=0
BCINO3=4, ISMTH=8

Leapfrog only:

NSEQ=1, MLF(1)=1, MATSUN=0, DT=600., NSM1=0, NCM1=0
NCOMP3=5, ISMTH=10

1 Matsuno, 4 Leap-Frog:

NSEQ=5, MLF=(1,0,0,0,0), MATSUN=not needed, NSM1=0,
NCM1=0, DT=600., NCOMP3=5, ISMTH=10

COMP1 Description

The COMP1 subroutine contains the horizontal and vertical advection differences. The DO loops over I are arranged to make use of the periodicity of the variables in the zonal (I) direction. For example, suppose we are to compute D(I)=Q(I+1)-Q(I) for I=1,...,IM. Then the corresponding code is

```
           I=IM
           DO 10 IP1=1,IM
           D(I)=Q(IP1)-Q(I)
           I=IP1
        10 CONTINUE
```

Where we used the periodicity Q(IM+1)=Q(1).

In the meridional (J) direction we compute our difference approximations in stages in order to make maximum use of each line of latitude of a typical variable when it is in core. The fourth order difference approximation to $\frac{\partial Q}{\partial \phi}(i\ell j\Delta\phi)=D(i,\ell,j)$

$$\frac{4}{3}\left(\frac{Q_{i\ell j+1}-Q_{i\ell j-1}}{2\Delta\phi}\right) - \frac{1}{3}\left(\frac{Q_{i\ell j+2}-Q_{i\ell j-2}}{4\Delta\phi}\right) \tag{1}$$

Thus we see that $Q_{i\ell j}$ will be needed in the difference approximations to $\frac{\partial Q}{\partial \phi}$ for j-2, j-1, j+1, and j+2. The corresponding code is

```
              DO 20    I = 1,IM
              QFLUX1=   4*(Q(I,L,JP1)+Q(I,L,J))
              QFLUX2=-.5*(Q(I,L,JP2)+Q(I,L,J))
         D(I,L,JP2)=  D(I,L,JP2)-QFLUX2
         D(I,L,JP1)=  D(I,L,JP1)-QFLUX1
         D(I,L,J)   =  D(I,L,J)+QFLUX1+QFLUX2
      20 CONTINUE
```

For simplicity the array D is inititalized to zero and Q is scaled so that (1) contains no divisions.

At the poles (j=1 or J=JNP=46) we use the values given in section IV on boundary conditions. We have special code for these cases denoted J=2 or J=JM corrections.

COMP2 Description

This routine contains the Coriolis force term, the geopotential calculation (which should be made into a separate subroutine), and the pressure gradient and energy term calculations.

The geopotential PHI is dimensioned PHI(72,9,5) since we only need at most five storage locations for any computation. We use modular arithmetic (MOD5) to compute the indices JMOD, JP1MOD, JP2MOD which correspond to the standard index values of J,J+1, and J+2. Thus PHI(I,L,6) is stored in PHI (I,L,1), and we avoid shifting array values by using the JMOD index as a pointer.

For the south pole calculation we need geopotential values at J=2 and 3, thus, for J=1 we compute PHI for J=1,2, and 3. For successive values of J we need only compute PHI at JP2 which is needed in the pressure gradient calcualtion at J. Therefore, the calculation of PHI and the associated array PK are coded for calculation at JP2. Except for the first J value we are only computing the geopotential at one latitude value for each pressure gradient calculation.

X: Flow Charts

COMPO (Q,QT)

```
                    JS1=1
                    JS2=1

                    ((MAIN LOOP))
                    DO 10 J=1,JM

                    ((COMPUTE ALL J-PARAMETERS))

    IF(JP2>JM)                                          GO TO 25

    IF(J>1)                                             GO TO 18

                    JP2=JP2MOD=2
                    ((SAVE QTPOL(M) IN QSMPOL(M),M=1,2))

18                  ((SAVE QJ(JP2) IN QSM(JP2MOD)))

    IF(JP2>2)                                           GO TO 25
                    ((INCREMENT JP2,JP2MOD))            GO TO 18

25                  CALL COMP1(Q,QT,J)
                    CALL COMP2(Q,QT,J)

                    ((ELIMINATE NEGATIVE HUMIDITIES)

    IF(PT∉(400,1100.))                                  STOP

    IF(J<3)                                             GO TO 200

    IF(J=3)                                             GO TO 70

29                  ((UNSCALE QT(JS2)))
                    CALL AVRX(QT,JS2)

                    ((LEAP FROG, MATSUNO AS RELATED TO THE
                    SEQUENCE OF 2 CALLS TO COMPO:
                    1st CALL ⇒ LF ⇒ LF or MP ⇒ MC,
                    2nd CALL ⇒ LF ⇒ LF or LF ⇒ MP or MC ⇒ MP)

    IF(LF→LF)                                           GO TO 45

    IF(LF→MP.OR.MC→MP)                                  GO TO 58

                    ((STATUS: MP→MC OR MC→LF))
                    ((P(I,JS2)←PSM(I,JS2MOD),Q←QSM))

    IF(MC→LF)                                           GO TO 63

                    (STATUS: MP→MC))
```

(contin.)

COMP[illegible] (Q,QT)

```
58                 ((P(I,JS2)←PT(I,JS2),Q←QT*DXYP*PT))     GO TO 64

45                 ((P(I,JS2)← *P(I,JS2)+α*(PSM+PT),
                   Q←β*DXYP*P*Q+α*(QSM+QT*DXYP*PT)))

63                 CONTINUE
                   ((SOURCE TERM CORRECTION FOR LEAP FROG))

    IF(NOT COMP3 CALL)                                     GO TO 67

                   ((Q←Q-QT*DXYP*PT))

64  IF(NOT COMP3 CALL)                                     GO TO 67

    IF(MATSUNO PREDICTOR STEP)                             GO TO 67

                   CALL COMP3(QT,JS2)
                   ((COMPLETE SOURCE TERM CORRECTION,
                   Q←Q+QT*DXYP*PT))

67  IF(J<JM)                                               GO TO 200

                   ((INCREMENT JS2,JS2MOD))

    IF(JS2≤JM)                                             GO TO 29

70                 ((POLES))

200                JS2=JS1
                   JS1=J

10                 CONTINUE

                   ((END OF J LOOP))

                   RETURN
```

COMP1 (Q,QT,J)

```
                   ((COMPUTE JP2-JS2MOD))

    IF(J>2)                                                GO TO 2150

                   JS1=JS2-JS1MOD=JS2MOD=1
```

(contin.)

COMP1 (Q,QT,J)

```
2150  IF (J=JM)                                                   GO TO 2158
                        ((COMPUTE $PV_1,PV_2 = V^*_j + V^*_{j+2}$))
      ──────────────────────────●──────────────────────────
      IF(J=1)                                                     GO TO 2225

2158                    ((COMPUTE $PU_1, PU_2 = U^*_i + U^*_{i+2}$))

                        ((COMPUTE HORIZ.ADVEC.-IN LONG. DIREC.))
      IF (J = JM)                                                 GO TO 2237

2225                    ((COMPUTE HORIZ.ADV.-IN LAT. DIREC.))
      IF (J>1)                                                    GO TO 2290
                        ((J=2 CORREC. TO HORIZ. ADVEC & CONV.))
                        ((CONV. CALC. FOR CONT. EQ.))
2290  IF (J<JM)                                                   GO TO 2405

2237                    ((J=JM CORREC. TO HORIZ. ADVEC. & CONV.))
      ──────────────────────────●──────────────────────────
2405                    ((CONV + CONV * DSIG(L)))
      IF (L≤NLAY)                                                 GO TO 2150

      IF (J=1)                                                    GO TO 2600
                        ((COMPUTE SIGDOT,PT))
                        ((COMPUTE VERTICAL ADVEC.))

      IF (J<JM)                                                   RETURN

2600                    ((POLES,  M=1 or 2))
                        ((HORIZ. ADVEC.))
                        ((CONT. E.Q.))
                        ((SIGDOT PL, PTPOL))
                        ((VERT. ADVEC.))
                                                                  RETURN

                        END OF COMP1
```

```
Alternative code from ────●──── to ────●────

                        ----●----
      IF(J.EQ.1)                                                  GO TO 2222
                        ((COMPUTE $PU_1$, $PU_2$))
                        ((COMPUTE HA(I)         ))
                                                                  GO TO 2235

2222                    ((J=2 CORREC        ))

2235  IF  (J<JM)                                                  GO TO 2225
                        ((J=JM CORREC))
                                                                  GO TO 2405

2225                    ((HORIZ ADVEC(J)         ))
                        ((CONV.CALC.FORCONT.EQ.))

2405                    ((CONV CONV*DSIG(L)))
                        ----●----
```

COMP2 (Q,QT,J)

```
                          ((COMPUTE JP2=...   ))

     IF(J>1)                                          GO TO 3001
                          ((JP2=JP2MOD=JPKP2=1))       :3005

3001                      ((CORIOLIS          ))

     IF(J≥JM)                                         GO TO 3032

                          ((FIRST MAIN LOOP IN L))

3005                      ((DO 3030 LX=1,NLAY ))
                          ((COMPUTE ENERGY TERM IN
                            THERMODYNAMIC EQN ))
                          ((L=NLAY+1-LX       ))
     IF(L<NLAY)                                       GO TO 3055

3007                      ((COMPUTE PK(I,LL,JPKP2)FORLL=1,NLAY))
                          ((COMPUTE PHI'(I,NLAY,JP2MOD))   :3065

3055                      ((COMPUTE PHI' AT JP2MOD FOR L<NLAY))

3065 IF(JP2=1 or JP2=JNP)                             GO TO 3030
                          ((COMPUTE W(JP2MOD)))

3030                      ((INCREMENT LX     ))
                          ((IF J=1 GO TO 3005 AND COMPUTE PHI(2),W(2)))


                         (( 2nd MAIN LOOP IN L))

3032                     ((DO 3031 LX=1, NLAY))
      IF(J=1)                                           GO TO 3111 ( POLES)

      IF (J > 2)                                        GO TO 3085
                         ((J=2:  VT,TT CORREC.))

3085                     (((P) FOR U EQ.))
      IF (J=2orJM)                                      GO TO 3135
                         (((P) FOR V EQ.))


3135  IF (J < JM)                                       GO TO 3031
                         (( CORREC. TO (P) J=JM))
3111                     ((POLES))

3031                     ((CONTINUE))
                         ((RETURN))
                           END
```

A FOURTH-ORDER FORECASTING MODEL*

(E. Kalnay-Rivas, D. Hoitsma, and P. Anolick)

The GISS fourth-order model (Kalnay-Rivas, et al., 1977), which is a fourth-order, energy-conserving GCM on an unstaggered grid, had shown promising capabilities. It produced forecasts that showed an improvement over the second-order GISS forecasts with the same fine grid (4° x 5°) resolution, but that were somewhat inferior to the "ultrafine" forecasts. However, the first version of the model required excessive amounts of computer memory and time for execution.

The model has been reprogrammed into the "fourth-order band model." The new program solves the primitive equations one latitude band at a time. The arrays are stored in an interlaced way, with all arrays being updated at the same latitude stored contiguously, and similarly for all arrays used in the computation of the time derivatives. This design of the program makes effective use of the virtual memory capability of the Modeling and Simulation Facility's IBM 370/165 or Amdahl computers. The virtual memory facility permits the execution of programs whose core size is larger than the one available, by placing the excess on disk and reading in those pages of information needed in the current calculations. The band fourth-order data structure and computations were constructed to optimize this virtual I/O process; a possible improvement may be to interlace also the arrays being updated with those used to compute the time derivatives. The use of the virtual memory facility avoids the explicit I/O used in the current Kern model, and yields a simpler program. (The band structure was suggested by G. Russell.)

The band fourth-order model computations have been optimized so that each time step is computed in the Amdahl in half the time required by the old model. The array structure has also been designed to reduce the amount of overall storage and high-speed memory by a factor of two (see Table 1).

Table 1. Comparison of Fourth-Order Model Computing Requirements.

	Original 4th-Order Model	Band 4th-Order Model
Core (bytes)	3500K	1500K
CPU time per step (COMP1, COMP2)	34 sec	17 sec

---

*Reprint from Atmospheric and Oceanographic Research Review-1978, GLAS, NASA Technical Memorandum 80253.

The model has been programmed so that it can use both the Matsuno and the leapfrog time schemes, the latter with the Robert time smoother. If Q^n and $D(Q^n)$ denote the fields at time $n\Delta t$ and the corresponding time derivative computed from the space differences, the smoothed leapfrog scheme is

$$Q^{n+1} = \bar{Q}^{n-1} + 2\Delta t\ D(Q^n)$$

$$\overline{Q^n} = Q^n + .5\nu(Q^{n-1} + Q^{n+1} - 2Q^n)$$

with $\bar{Q}^o = Q^o$. The use of a smoothing coefficient requires a slightly smaller time step. For example, with $\nu = .1$, the model is marginally stable with $\Delta t = 288$ sec., compared to $\Delta t = 300$ sec. for the Matsuno and leapfrog schemes.

The smoothed leapfrog scheme is further modified to include the subgrid "physics" terms, and scaling and spatial smoothing procedures. Since the "physics" is called every few time steps, unless the leapfrog scheme is restarted after every call to the "physics," only one of the two consecutive fields will be affected. The restarting procedure is time-consuming, so it has been replaced by the following algorithm

$$Q^{n-1} = Q^{n-1} - Q^n$$

$$\tilde{Q}^n = Q^n + S^n$$

$$Q^{n-1} = Q^{n-1} + \tilde{Q}^n$$

where S^n corresponds to the "physics" terms. This procedure, which ensures that the physics is applied to two consecutive time steps, has been tested with good results.

The model can be extended into an "ultrafine" version in a straightforward way.

Preliminary Results. The first numerical integrations performed with the new band fourth-order model show dramatic improvements over forecasts made with the GLAS model with the same resolution ("fine grid" or 4° latitude by 5° longitude). The quality of the forecasts is now comparable with those produced with the "ultrafine" (2.5° latitude by 3° longitude) version of the model. Results from a 3-day numerical integration are presented in Figure 1. During an extended 8-day integration of the new fourth-order model, the atmospheric systems remained remarkably smooth, exhibiting a realistic behavior both with respect to position and intensities.

References

Kalnay-Rivas, E., A. Bayliss, and J. Storch, 1977: The fourth-order GISS model of the global atmosphere. Contributions to Atmos. Phys., 20, pp. 299-311.

The 4th Order GISS Model of the Global Atmosphere*

E. Kálnay-Rivas 1) and 2), A. Bayliss*) 2) and J. Storch 2)

1) Massachusetts Intitute of Technology Dept. of Meteorology, Cambridge, MA 02139, USA
2) Goddard Institute for Space Studies NASA, New York, NY 10025, USA
*) Present affiliation: ICASE, NASA Langley Research Center Hampton, Virginia 23665, U.S.A.

Abstract: The new GISS 4th order model of the global atmosphere is described. It is based on 4th order quadratically conserving differences with the periodic application of a 16th order filter on the sea level pressure and potential temperature equations, a combination which is approximately enstrophy conserving. Several short range forecasts indicate a significant improvement over 2nd order forecasts with the same resolution (∼ 400 km). However the 4th order forecasts are somewhat inferior to 2nd order forecasts with double resolution. This is probably due to the presence of short waves in the range between 1000 km and 2000 km, which are computed more accurately by the 2nd order high resolution model. An operation count of the schemes indicates that with similar code optimization, the 4th order model will require approximately the same amount of computer time as the 2nd order model with the same resolution.

It is estimated that the 4th order model with a grid size of 200 km provides enough accuracy to make horizontal truncation errors negligible over a period of a week for all synoptic scales (waves longer than 1000 km).

1. Introduction

It is generally accepted that the use of 4th order finite differences is more efficient in reducing space truncation errors than the use of higher resolution on a 2nd order model (KREISS and OLIGER, 1972). Linear analyses and shallow water type of experiments give *an upper limit* of the improvement that can be expected from the reduction of errors in the horizontal differences. For example, Table 1 corresponds to a linear wave equation with phase speed $c = 11 \text{ ms}^{-1}$, typical of atmospheric motions. It provides a measure of the "computational predictability period" after which the errors introduced by horizontal truncation alone become very serious. The table suggests that for waves longer than 2000 km a 4th order ∼ 400 km grid model is preferable to a 2nd order ∼ 200 grid model. Waves shorter than 2000 km are forecast more accurately by a 2nd order ∼ 200 km grid model. In order to insure that horizontal truncation errors are small in the 1–3 week period of atmospheric predictability for all synoptic scale waves it is necessary to use either 4th order differences with a grid resolution of the order of 200 km or 2nd order differences with a grid of the order of 100 km. Numerical experiments with simple nonlinear models (WILLIAMSON and BROWNING, 1973, KALNAY-RIVAS 1976a, from now on I) also indicate dramatic reduction of errors by the use of 4th order differences.

All these studies indicate that a considerable improvement in forecasting skill is to be expected from the use of 4th order differences *if a substantial portion of the forecasting errors is due to horizontal truncation errors.* In actual numerical forecasts there are several are several other important sources of errors: vertical truncation errors, errors in the initial conditions, and poor "physics" (i.e. parameterization of physical processes like radiation, dissipation, subgrid transports, cumulus convection, boundary layers, etc.)

---

* (Paper presented during the DMG-AMS Meeting, Hamburg 1976; see Preface to Issue 1 – 2/1977)

Beiträge zur Physik der Atmosphäre, 50. Band, 1977, Seite 299–311

■ Table 1. Elapsed time T after which a wave of wavelength L moving with a phase speed $c = 11\ ms^{-1}$ lags by more than 100 km due to space truncation errors.

	Δx = 400 km	Δx = 200 km
2nd order differences	L = 2000 km, T = 0,4 days L = 4000 km, T = 1.6 days	L = 2000 km, T = 1.6 days L = 4000 km, T = 6,4 days
4th order differences	L = 2000 km, T = 1.5 days L = 4000 km, T = 21 days	L = 2000 km, T = 21 days L = 4000 km, T = 328 days

At the Goddard Institute for Space Studies (GISS), New York, we have developed a 4th order general circulation model (GCM) with the expectation that it will yield more accurate short range forecasts, and probably more realistic climate simulations, but with the improvement limited by the other sources of errors. The model is described in Section 2. The results of several experimental short range forecasts are discussed in Section 3. A sample 36-hour forecast is presented and compared with forecasts by the standard 2nd order GISS model, which has the same resolution as the 4th order model, and by the "ultrafine" 2nd order GISS model, which has twice the horizontal resolution. Section 4 contains the conclusions and a discussion of future work.

2. Description of the model

The 4th order GISS global atmospheric model is a primitive equation model using longitude (λ), latitude (φ) and sigma (σ) coordinates. The basic equations and the parameterizations of physical processes are the same as those of the standard 2nd order GISS global model (Somerville et al, 1974). The finite difference scheme is quite different and is described in the following subsections.

2.1. Finite-difference scheme

The horizontal grid is uniform (constant Δλ and Δφ) and non-staggered. There are two ways to define such a grid, depending on whether variables are defined at the poles, as done by WILLIAMSON and BROWNING (1973), or half a grid size away from the poles (HOLLOWAY et al, 1973). We chose the former method because in the absence of smoothing near the poles it allows a time step twice as large as the latter. The singularity that sherical coordinates have at the poles is explicitly avoided by the use of a polar cell where "stereographic" velocities are used.

In the vertical direction we use a staggered grid with $\dot{\sigma}$, the vertical velocity, defined at the boundaries of each layer, and all other variables in the center of the layer. The vertical grid can be non uniform although experiments have been made so far with constant Δσ. Experiments reported in I indicated that no significant improvement in accuracy was obtained when a 4th order staggered conservative scheme was used in the vertical direction. Therefore the model has 2nd order vertical differences. The computation of the geopotential Φ is performed as indicated by ARAKAWA (1972), with a modification suggested by PHILLIPS (1974).

a) Forecast equation away from the poles

Several systems of horizontal difference werl tested as reported in I. The scheme chosen for the basis of these experiments consists of the simplest possible quadratically conservative 4th order differences.

We define the finite difference horizontal divergence operator at the vertical level k as

$$D_k(g) = \frac{1}{a\cos\phi}\left[\frac{4}{3}\delta_\lambda\left(\overline{\Pi u}^{\lambda}\,\overline{g}^{\lambda}\right) - \frac{1}{3}\delta_{2\lambda}\left(\overline{\Pi u}^{2\lambda}\,\overline{g}^{2\lambda}\right) + \frac{4}{3}\delta_\phi\left(\overline{\Pi v\cos\phi}^{\phi}\,\overline{g}^{\phi}\right) - \frac{1}{3}\delta_{2\lambda}\left(\overline{\Pi v\cos\phi}^{2\phi}\,\overline{g}^{2\phi}\right)\right]_k \tag{2.1}$$

and the finite difference gradient operator as

$$\nabla g = \frac{\mathbf{i}}{a\cos\phi}\left[\frac{4}{3}\delta_\lambda\overline{g}^{\lambda} - \frac{1}{3}\delta_{2\lambda}\overline{g}^{2\lambda}\right] + \frac{\mathbf{j}}{a}\left[\frac{4}{3}\delta_\phi\overline{g}^{\phi} - \frac{1}{3}\delta_{2\phi}\overline{g}^{2\phi}\right] \tag{2.2}$$

Here $\Pi = p_S - p_T$ is the difference between the pressure at the surface and the constant pressure at the top of the model, a is the radius of the earth, $\mathbf{v} = u\mathbf{i} + v\mathbf{j}$ is the horizontal velocity vector in spherical coordinates, and we use the finite difference notation

$$\begin{aligned}\delta_{n\lambda}g &= [g(\lambda + n\Delta\lambda/2, \phi, \sigma, t) - g(\lambda - n\Delta\lambda/2, \phi, \sigma, t)]/(n\Delta\lambda),\\ \overline{g}^{n\lambda} &= [g(\lambda + n\Delta\lambda/2, \phi, \sigma, t) + g(\lambda - n\Delta\lambda/2, \phi, \sigma, t)]/2,\end{aligned} \tag{2.3}$$

and similar formulas for the other independent variables. With this notation, the continuity equation away from the poles is

$$\frac{\partial\Pi}{\partial t} = -D_k(1) - \Pi\delta_\sigma\dot{\sigma}_k \tag{2.4a}$$

or, if we integrate it in the vertical and make use of the boundary condition

$\dot{\sigma} = 0$ at $\sigma = 0, 1$,

$$\frac{\partial\Pi}{\partial t} = -\sum_{k=1}^{K} D_k(1)\,\Delta\sigma_k \tag{2.4b}$$

where K is the number of vertical layers. Equation (2.4b) is the forecast equation for Π. The momentum equation is

$$\left(\frac{\partial\Pi\mathbf{v}}{\partial t}\right)_k = -D_k(\mathbf{v}) - \Pi\delta_\sigma\left(\dot{\sigma}\,\overline{\mathbf{v}}^{\sigma}\right)_k + \left(f + \frac{u_k\tan\phi}{a}\right)\mathbf{k}\times(\Pi\mathbf{v})_k - \Pi\left[\nabla\Phi' + \frac{\sigma RT'}{p}\nabla\Pi\right]_k + \mathbf{F}_k. \tag{2.5}$$

The first law of thermodynamics is

$$\left(\frac{\partial\Pi T}{\partial t}\right)_k = -D_k(T) - \left\{p^{\kappa}\,\Pi\delta_\sigma\left[\dot{\sigma}\,\overline{(T/p^{\kappa})}^{\sigma}\right]\right\}_k + \left\{\frac{\Pi\sigma\kappa T}{p}\left[\frac{\partial\Pi}{\partial t} + \mathbf{v}.\nabla\Pi\right]\right\}_k + \frac{\Pi}{C_p}Q. \tag{2.6}$$

Here T is absolute temperature, **F** is the frictional force, $\kappa = R/C_p$, Q is the diabatic heating per unit mass, p is the pressure and p^κ is computed as indicated in Subsection 2.1c. The moisture equation for the water vapor mixing ratio q is

$$\left(\frac{\partial \Pi q}{\partial t}\right)_k = -D_k(q) - \Pi\,\delta_\sigma(\dot\sigma q^\sigma)_k + \Pi(E - C). \qquad (2.7)$$

E and C are the rates of evaporation and condensation.

In the momentum equation (2.5) we follow a device suggested by PHILLIPS (1974) to alleviate the difficulties of the computation of the pressure gradient in σ-coordinates in the vicinity of orography. We define $T' = T - \bar T(p)$, $\Phi' = \Phi - \bar\Phi(p)$, where $\bar T = \bar\theta p^\kappa$, $\bar\theta = 280\ \mathrm{K}/(1000\ \mathrm{mb})^\kappa$, $\bar\Phi = \Phi_0 - C_p\bar\theta p^\kappa$ and $\Phi_0 = [(1000\ \mathrm{mb})^\kappa - p_T^\kappa]$. We have simplified PHILLIPS' expression for Φ_0 since its precise value is not important. With this procedure, in the pressure gradient term there is an exact cancellation of the terms $\nabla\Phi + \frac{\sigma R T}{p}\nabla\Pi$, and this implies a significant reduction of truncation errors in regions with steep orography.

b) Forecast equations at the Poles

We have followed the method used by WILLIAMSON and BROWNING (1973) and define a polar cap of radius $a\Delta\varphi$ on which we use "stereographic" (or rather "cartesian") velocity components defined by the transformation

$$\begin{aligned} U_{\pm p} &= -u\sin\lambda \pm v\cos\lambda \\ V_{\pm p} &= \pm u\cos\lambda - v\sin\lambda \end{aligned} \qquad (2.8)$$

with inverse

$$\begin{aligned} u &= -U_{\pm p}\sin\lambda \pm V_{\pm p}\cos\lambda \\ v &= \pm U_{\pm p}\cos\lambda - V_{\pm p}\sin\lambda \end{aligned} \qquad (2.9)$$

where the top and bottom signs correspond to the north and south poles respectively. The positive x-axis of the cartesian coordinates coincides with the meridian of longitude $\lambda = 0$. The difference in signs at the south pole is due to the choice of a right handed system of coordinates with the vertical unit vector pointing outwards. Formulas (2.8) and (2.9) are used to define "spherical" or "cartesian" velocity components wherever they are required in the finite difference equations.

The finite difference horizontal divergence operator at the poles is defined by an average aver all longitudes λ_i:

$$D_{\pm p,k}(g) = \pm\sum_{i=3}^{I+2}\left\{\frac{4}{3}A_1(\Pi v g)_{\lambda_i,\pm(\frac{\pi}{2}-\Delta\phi)} - \frac{1}{3}A_2(\Pi v g)_{\lambda_i,\pm(\frac{\pi}{2}-2\Delta\phi)}\right\}_k \qquad (2.10)$$

where $\lambda_i = (i-3)\,\Delta\lambda$, $\Delta\lambda = 2\pi/I$, and $A_n = \Delta\lambda\, a\sin(n\Delta\phi)/[2\pi a^2(1-\cos(n\Delta\phi))]$. The finite difference gradient operator at the poles is also defined by an average over all longitudes:

$$\nabla_{\pm p} g = \frac{2}{I a\Delta\phi}\sum_{i=3}^{I+2}\left\{\frac{4}{3}g_{\lambda_i,\pm(\frac{\pi}{2}-\Delta\phi)} - \frac{1}{6}g_{\lambda_i,\pm(\frac{\pi}{2}-2\Delta\phi)}\right\}\cdot\{\cos\lambda_i\,\mathbf{i} \pm \sin\lambda_i\,\mathbf{j}\} \qquad (2.11)$$

Then the continuity equation at the poles is

$$\frac{\partial \Pi_{\pm P}}{\partial t} = \mp \sum_{k=1}^{K}{}' D_{\pm P,k}(1)\,\Delta\sigma_k, \tag{2.12}$$

the momentum equation is

$$\left(\frac{\partial \Pi \mathbf{V}}{\partial t}\right)_k = \mp D_{\pm P,k}(\mathbf{V}) - \Pi_{\pm P}\,\delta_\sigma\left(\dot{\sigma}_{\pm P}\,\overline{\mathbf{V}}^{\sigma}_{\pm P}\right)_k + f_{\pm P}\,\mathbf{k}\times(\Pi\mathbf{V})_{\pm P,k}$$

$$- \Pi_{\pm P}\left[\nabla_{\pm P}\,\Phi' + \frac{\sigma R T'}{p}\,\nabla_{\pm P}\,\Pi\right]_k + \mathbb{F}_{\pm P,k} \tag{2.13}$$

where $\mathbf{V}_{\pm P} = U_{\pm P}\,\mathbf{i} + V_{\pm P}\,\mathbf{j}$. The thermodynamic equation is

$$\left(\frac{\partial \Pi T}{\partial t}\right)_{\pm P,k} = \mp D_{\pm P,k}(T) - \left\{p^{\kappa}_{\pm P}\,\Pi_{\pm P}\,\delta_\sigma\left[\dot{\sigma}_{\pm P}\,\overline{\left(T_{\pm P}/p^{\kappa}_{\pm P}\right)}^{\sigma}\right]\right\}_k \tag{2.14}$$

$$+ \left\{\frac{\Pi_{\pm P}\,\sigma\,\kappa\,T_{\pm P}}{p_{\pm P}}\left[\frac{\partial \Pi_{\pm P}}{\partial t} + \mathbf{V}_{\pm P}\cdot\nabla_{\pm P}\,\Pi\right]\right\}_k + \frac{\Pi_{\pm P}}{C_p}\,Q_{\pm P}$$

and the moisture equation is similar.

c) Diagnostic equations

In σ-coordinates, the pressure is defined by $p = \sigma\Pi + p_T$. Following a suggestion by PHILLIPS (1974) we define at the center of a layer $p_k^\kappa = 1/(\kappa + 1)\,\delta_\sigma p_k^{\kappa+1}/\delta_\sigma p_k$, instead of $p_k^\kappa = (\overline{p}_k^\sigma)^\kappa$ as in ARAKAWA (1972). This formula was derived under the assumption that the potential temperature varies in a σ-layer much less than either the temperature of the pressure. PHILLIPS indicated that a more accurate relationship between temperature and geopotential can be expected from this formula.

The geopotential Φ is determined following ARAKAWA (1972): If Φ_S is the surface geopotential, then the geopotential at the center of the lowest layer is

$$\Phi_K = \Phi_S + \sum_{k=1}^{K}{}' C_k T_k \tag{2.15}$$

and at other levels

$$\Phi_k = \Phi_{k+1} + C_p\,\Delta\sigma_{k+\frac{1}{2}}\,\delta_\sigma\left(p^\kappa_{k+\frac{1}{2}}\right)\left(\overline{\frac{T_{k+1/2}}{p^\kappa_{k+1/2}}}^{\sigma}\right) \tag{2.16}$$

The coefficients C_k are determined from

$$C_k = \frac{\Pi\,\sigma_k\,R\,\Delta\sigma_k}{p_k} - \frac{C_p}{p_k^\kappa}\,\overline{\left(\sigma\,\Delta\sigma\,\delta_\sigma\,p^\kappa\right)_k}^{\sigma} \tag{2.17}$$

The vertical velocity in σ-coordinate is determined from (2.4a) and (2.4b), and the boundary condition $\dot{\sigma} = 0$ at $\sigma = 0, 1$:

$$\delta_\sigma\,\dot{\sigma}_k = \frac{1}{\Pi}\left\{\sum_{k=1}^{K}{}' D_k(1)\,\Delta\sigma_k - D_k(1)\right\} \tag{2.18}$$

d) Boundary conditions

In the east-west direction we use periodicity: $g(\lambda + 2\pi, \phi) = g(\lambda, \phi)$ for all variables. When the value of a variable is needed "beyond" the poles, we define it by continuation along the same meridian:

$$\mathbf{v}\left(\lambda, \pm\left(\frac{\pi}{2} + \Delta\phi\right)\right) = -\mathbf{v}\left(\pi + \lambda \pm \left(\frac{\pi}{2} - \Delta\phi\right)\right) ; g\left(\lambda, \pm\left(\frac{\pi}{2} + \Delta\phi\right)\right) = g\left(\pi + \lambda, \pm\left(\frac{\pi}{2} - \Delta\sigma\right)\right),$$

where g represents all variables other than the two horizontal velocity components. In the vertical the top and bottom are material surfaces through which there is no flux ($\dot{\sigma} = 0$ at $\sigma = 0, 1$) except for subgrid boundary layer fluxes of momentum and heat included in F and Q.

2.2. Filtering near the poles and high order filtering

The CFL computational stability condition requires a very small time step unless linearly unstable short waves are filtered out near the poles. For this purpose several alternative procedures have been tried but so far the method found to give most satisfactory results is the fourier filtering of the prognostic variables u, v, T and *the indirect smoothing of* H *through the filtering of the sea level pressure (SLP) field.*

The fourier filtering is performed polewards of 66° latitude. The amplitudes of the fourier components of zonal wavenumber n are multiplied by a transfer function which is 1 for $n \leq N$ and decreases linearly to zero between $n = N$ and $n = N + 5$. The number of retained modes is defined by $N(\phi)$ = integer part of $(90 \cos\phi)$. We have tried filtering the stereographic velocities U, V instead of u, v but no improvement was obtained.

Since both the surface geopotential and the surface pressure fields contain large amplitude short wave components due to the presence of orography, an artifical smoothing of these fields represents a distortion of the real geometry of the boundary. On the other hand, the SLP is an instrinsically smooth field, and its high wavenumber components more closely represent *atmospheric* waves. Therefore in our model *the SLP is filtered near the poles and* H *is recovered by solving the transcendental equation used to relate them.*

It was found that the 4th order model forecasts were less smooth than those of the 2nd order GISS model, especially in regions with steep orography. Based on the same considerations we have introduced a periodic application of a high (16th) order filter (SHAPIRO, 1970) on the SLP and potential temperature fields, which are not very affected by orography.

The filter is of the form $\tilde{g} = \{1 - (F_\phi^2)^8\}\{1 - (F_\lambda^2)^8\}\, g$, where $F_\lambda^2(g_{ij}) = (g_{i+1j} - 2g_{ij} + g_{i-1j})/4$ and has a response $F_\lambda^2\,[\exp(ik\lambda)] = -\sin^2(k\Delta\lambda/2)\exp(ik\lambda)$. This filter eliminates waves shorter than $4\Delta\lambda$ and even after hundreds of applications has negligible damping effect on waves longer than $4\Delta\lambda$.

In the meridional direction there are three simple alternative forms for F_ϕ^2:

$$F_{\phi I}^2(g_{ij}) = (g_{ij+1} - 2g_{ij} + g_{ij-1})/4$$

$$F_{\phi II}^2(g_{ij}) = [(g_{ij+1} - g_{ij})\cos\phi_{j+1/2} - (g_{ij} - g_{ij-1})\cos\phi_{j-1/2}]/(4\cos\phi_j)$$

and

$$F_{\phi III}^2(g_{ij}) = [F_{\phi I}^2(g_{ij}\cos\phi_j)]/\cos\phi_j$$

FRANCIS (1975) used $F_{\phi II}^2$, which is the only one that conserves the area weighted average of g. However, we have found that the three meridional filters produced virtually identical results. This could be expected because the waves affected by the filter are too short to be strongly influenced by the convergence of the meridians. Since $F^2_{\phi I}$ and $F^2_{\phi III}$ can be programmed as efficiently as F^2_λ we find them preferable. In the model we use $F^2_{\phi I}$, with g continued "beyond" the poles as indicated in Subsection 2.1d. At the poles $\bar{g}_{\pm P}$ is defined as the average over all longitudes λ_i of the filtered values $\bar{g}_{i,\pm P}$. At the present we are applying the high order filter to the SLP and potential temperature fields once every two hours.

2.3. Enstrophy constraint

BAYLISS and ISAACSON (1975) have developed a simple method to make any finite difference scheme conservative with respect to any quantity. The method has been tested in our model by forcing conservation of enstrophy on the dry adiabatic version of the model, although in such a model it is potential enstrophy that is conserved. The procedure is the following: Let the vectors U and V represent the values of the velocity components discretized over the grid and let the functional G(U, V) denote the consistent 4th order approximation of the mean square vorticity. At each time step a correction U', V' is added to the predicted values $\bar{U}, \bar{V}$ such that $G(\bar{U} + U', \bar{V} + V') = G(U_0, V_0)$ where U_0, V_0 denote the velocities at time $t = 0$. Since this equation cannot be solved explicitly, it is linearized about the predicted values $\bar{U}, \bar{V}$:

$$\left(\frac{\partial G}{\partial U}\right)_{\bar{U},\bar{V}} \cdot U' + \left(\frac{\partial G}{\partial V}\right)_{\bar{U},\bar{V}} \cdot V' = G(U_0, V_0) - G(\bar{U}, \bar{V}) \tag{2.19}$$

If we assume

$$(U', V') = \alpha \left(\frac{\partial G}{\partial U}, \frac{\partial G}{\partial V}\right)_{\bar{U},\bar{V}} \tag{2.20}$$

then α can be determined from (2.19):

$$\alpha = \frac{G(U_0, V_0) - G(\bar{U}, \bar{V})}{\left|\frac{\partial G}{\partial U}\right|^2 + \left|\frac{\partial G}{\partial V}\right|^2} \tag{2.21}$$

It may be easily shown that the choice (2.20) minimizes $\| U' \| + \| V' \|$, the norm of the correction vector. It has been found that this procedure improves the forecasting skill of the model. However, when it is used in combination with the periodic application of the high order filter the improvement is marginal. Therefore this option is not included in the standard version of our model.

2.4. Summary of the properties of the model

The finite differences of the model have the following properties:

a) Horizontal differences are performed on a nonstaggered grid and have 4th order truncation errors.
b) Vertical differences are performed on a staggered grid and have 2nd order truncation errors.
c) The differences are conservative in the sense that in the absence of diabatic and dissipation, mass and energy are conserved except for marginal terms at the poles. Non-conservative differences similar to those used by WILLIAMSON and BROWNING (1973), *starting from real data*, proved to be nonlinearly unstable after less than one day of integration.
d) Unlike the "box method", the horizontal differences remain 4th order near the poles (KALNAY-RIVAS, 1976b)

e) The model contains *no horizontal diffusion* expect for the possible use of a dissipative time scheme and for the periodic application of the high order filter. It has been shown in I that the combination of a 4th order quadratically conservative scheme with the *periodic* application of a high order filter *replaces successfully the use of an enstrophy-conserving scheme.* This is because waves shorter than four times the grid size are the ones subject to aliasing and to large truncation errors, and they are removed by the filter *before they attain finite amplitude.* Waves longer than four times the grid size are accurately computed by the 4th order scheme and are not affected by the filter.

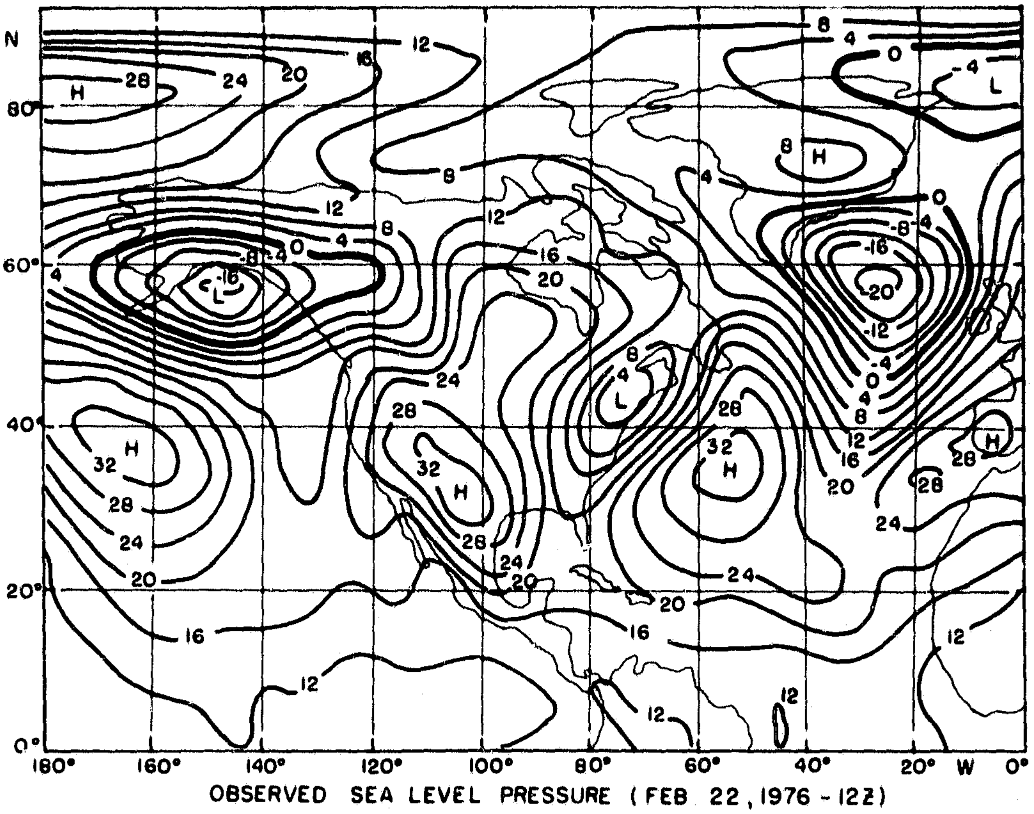
3. Numerical forecasts

3.1. Analytical initial conditions

The model was tested using 3 dimensional extensions of both the nontrivial steady state solution and the Rossby-Haurwitz wave initial conditions used in I. The forecasts remained smooth during the several days of interation. Errors in the steady state case were an order of magnitude larger than in I because of the use of single precision arithmetic on the IBM/360-95 computer. However, it was found necessary to use double precision for the longitudinally averaged pressure gradient at the poles in order to avoid excessive local error growth.

3.1. Forecasts with real initial data

As mentioned before, the parameterization of physical processes included in the terms **F**, Q, C and E of Equations (2.5) - (2.7) has been adapted from the standard 2nd order GISS model (SOMERVILLE et al, 1974). The only change that has been introduced is the reduction by a factor of 2 of the surface drag coefficient. This was found to be necessary in order to avoid an excessive damping of the pressure systems after one or two day forecasts. We believe that the fact that in the staggered grid the surface winds are obtained by a horizontal average reduces the relative effect of friction in the standard model.
At the present time (November 1976), we have performed 5 experimental short range forecasts. Since they have been made with slightly different versions of the 4th order model, we don't yet have a reliable measure of the model's forecasting skill. The initial data so far has been available in the staggered grid used by the standard model so that winds have been linearly interpolated to the nonstaggered grid. This is a source of error which may have adversely affected the 4th order forecasts.
We have performed a single 4-day forecast which indicated that the model remains very stable and that synoptic systems show no tendency to become unrealistically weak.
All the numerical 4th order forecasts show a significant improvement over the 2nd order forecasts performed with the same resolution. This improvement appears as a better estimation of the changes in position and intensity of several pressure systems. This in an encouraging result, especially in view of the study made by BAUMHEFNER and DOWNEY (1976) which indicates that the standard 2nd order GISS model forecasts compare favorably with those made by the NMC and NCAR models with similar resolution.
On the other hand, and contrary to our expectations, the forecasts made with the 2nd order GISS model with double horizontal resolution were found to be either similar or superior to the 4th order forecasts. This is more true in the sea level pressure than in the 500 mb forecasts. We consider that there are several possible reasons for this result. One is the extra errors introduced in the 4th order model initial



• Figure 1. Observed 36 hr. sea level pressure at 0000 GMT, 22 February 1976

data by the averaging of the winds. A second reason (and probably the most important one) is the existence of waves with significant amplitudes and wavelengths between 1000 and 2000 km. These short waves are better detected in the initial data and more accurately forecast by the 2nd order model with double resolution. The nonlinear interaction of these short waves with longer synoptic waves which according to linear theory are better forecasted by the 4th order model is clearly very important. A third important reason is the fact that errors introduced by the parameterization of subgrid processes become less important as the grid size is reduced.

We present an example of a 36 hour forecast of the sea level pressure corresponding to February 22, 1976, 12Z. Figure 1 is the verification sea level pressure map. Figure 2 is the forecast computed with the standard 2nd order GISS model, which has a resolution $\Delta\lambda = 5°$, $\Delta\phi = 4°$, $\Delta\sigma = 1/9$. Figure 3 is the 4th order forecast computed with the same resolution, and Figure 4 is the forecast obtained using the "ultrafine" 2nd order GISS model which has a resolution $\Delta\lambda = 2.5°$, $\Delta\phi = 2°$, $\Delta\sigma = 1/9$.

The most striking improvement showed by the 4th order forecast is in the position and intensity of the low in the eastern portion of North America. In fact, this low and the high over the Atlantic Ocean have been forecasted better by the 4th order model than by the 2nd order model with double resolution. On the other hand the developing cold high in central Canada and the intense low pressure center south of Greenland have been predicted better by the double resolution 2nd order model. As usual in this

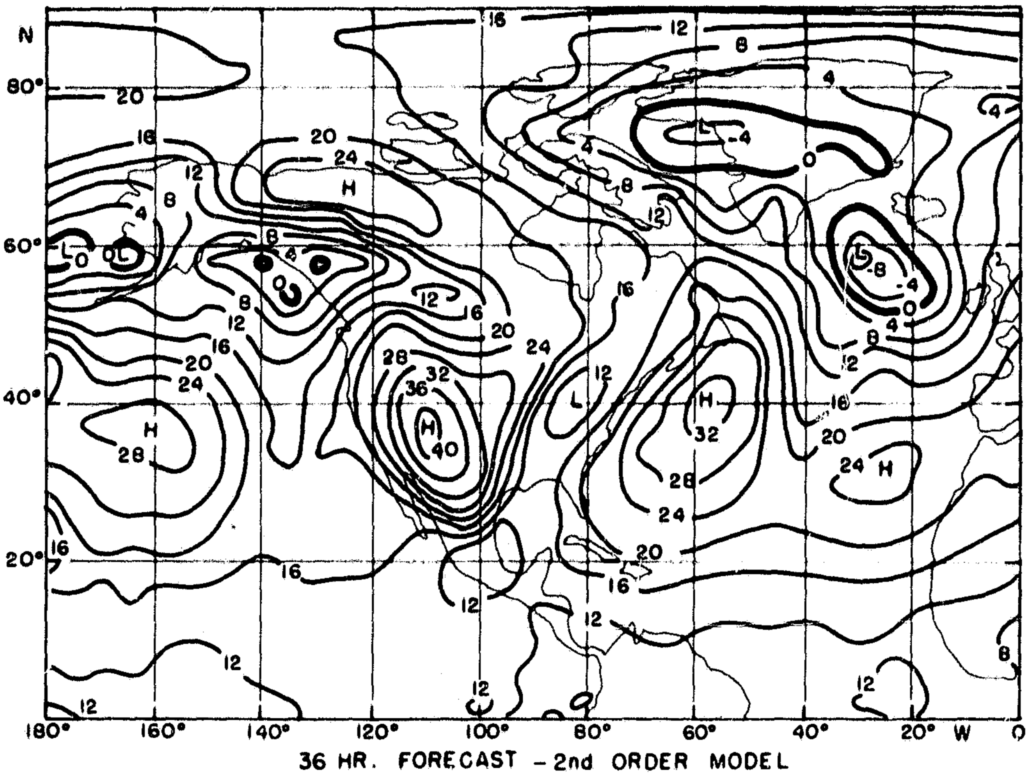
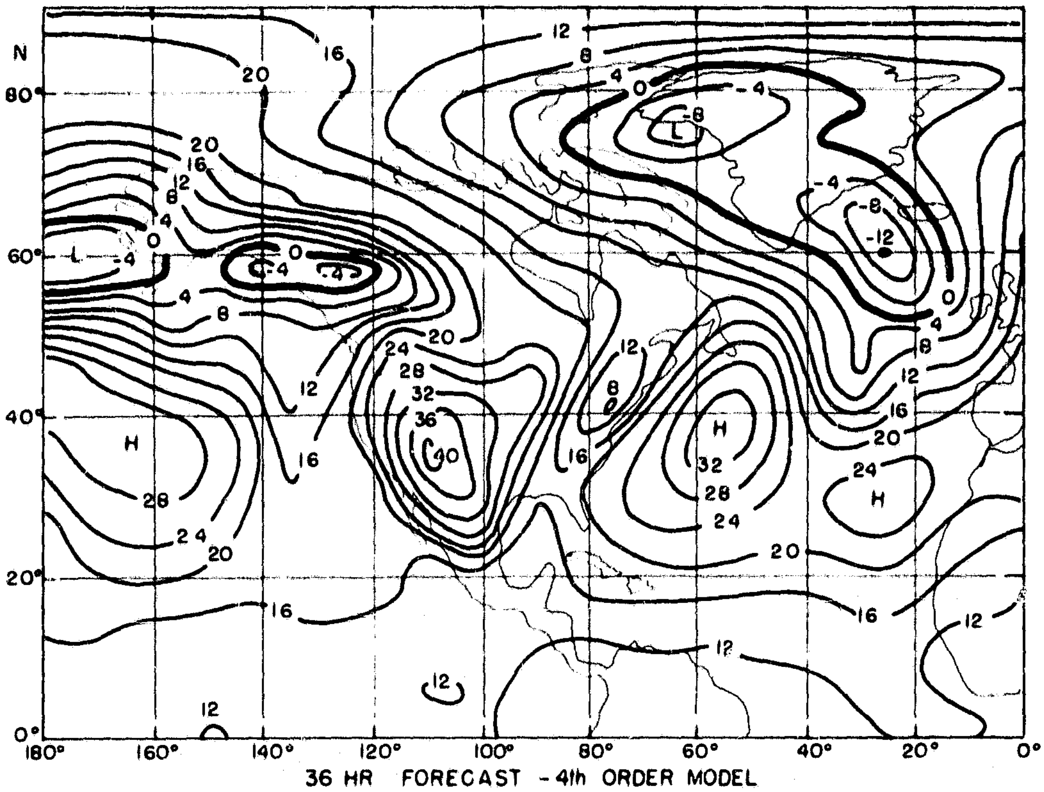


Figure 2. 36 hr. forecast using the standard 2nd order GISS model

type of comparison, the three forecasts share several important deficiencies. For example the intensity of the high over southwest USA has been overpredicted by the three models, probably because of difficulties introduced by the orography. The low south of Alaska has been erroneously split by the three models. This splitting, which is slightly less pronounced in the 4th order forecast, may be due to both errors in the initial data and orographic and coastal problems.

4. Summary and conclusions

We have described the characteristics of the 4th order GISS model of the global atmosphere. It is based on a quadratically conservative scheme with the periodic application of a 16th order filter on the sea level pressure and potential temperature fields. As shown in I this combination is approximately enstrophy-conserving. An operation count of the numerical schemes indicates that with similar code optimization the 4th order model will require approximately the same amount of computer time as the 2nd order enstrophy-conserving GISS model with the same resolution. We also plan to introduce a simplified semi-implicit scheme, and to study the possibility of using the combination of a nonstaggered vertical grid with the Kreiss 4th order method described in I.

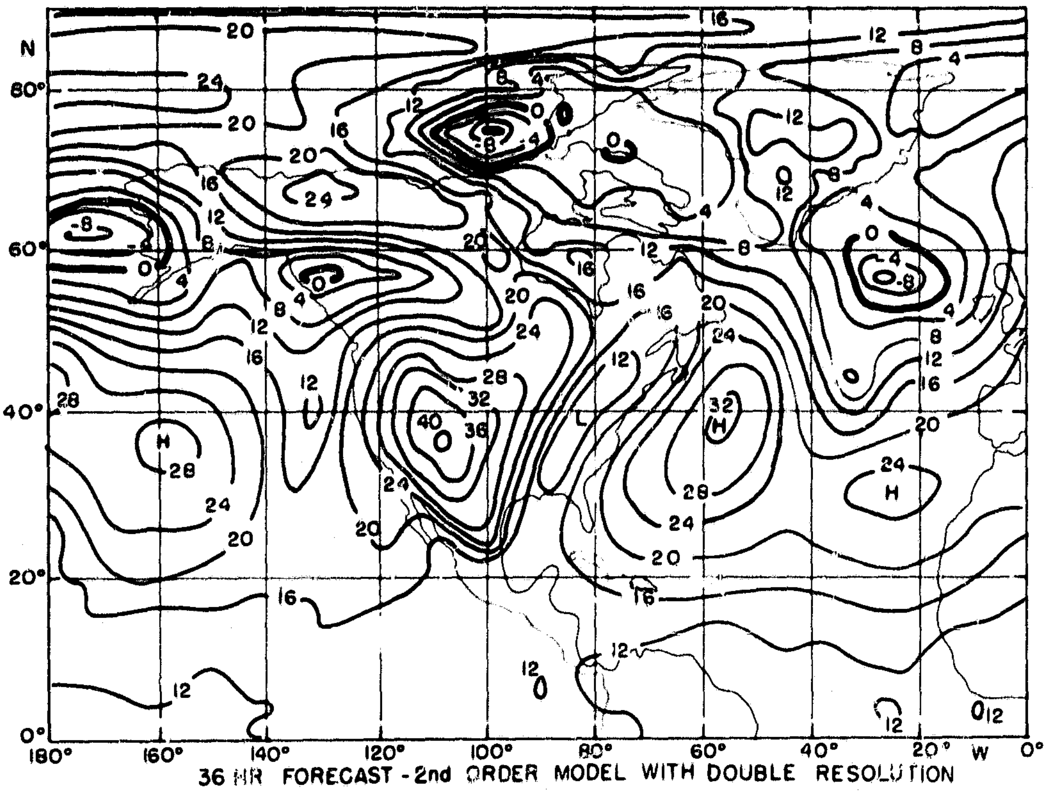


- **Figure 3.** 36 hr. forecast using the 4th order GISS model with the same resolution as in Figure 2

The results of several short range forecasts indicate a significant improvement over the 2nd order forecast with the same resolution. This improvement is shown in the estimations of changes in position and intensity of several pressure systems. We plan to study the impact that the greater accuracy of 4th order differences has on the forecasting skill of variables of more practical importance, such as temperature and precipitation.

It has been found that the 4th order forecasts are somewhat inferior to the forecasts made with a 2nd order model with double horizontal resolution. We consider that one of the most important reasons for this result are the presence of waves in the range between 1000 km and 2000 km which are computed more accurately by the high resolution 2nd order model than by the 4th order model. Another important reason is that errors introduced by the parameterization of subgrid processes become smaller as the size is reduced.

It is estimated that the 4th order model with a grid size of 200 km provides enough accuracy to make horizontal truncation errors negligible over a period of a week for all synoptic scales (waves longer than 1000 km).



● **Figure 4.** 36 hr. using the "ultrafine" 2nd order GISS model with double horizontal resolution

Acknowledgements

We are grateful to Drs. M. Halem, W. Quirk and Prof's. J. Charney and P. Stone for their continuous support and encouragement. Prof. E. Isaacson provided generous advice and Prof. Dr. Randall made useful comments on the manuscript. Prof. F. Sanders comments on the numerical forecasts are also gratefully acknowledged.

References

ARAKAWA, A. 1972: Design of the UCLA GCM. Techn. Rept. No. 7, Dept. of Meteorology, UCLA.

BAUMHEFNER, D., and P. DOWNEY, 1976: Forecast intercomparisons between large-scale numerical weather prediction models. Annalen der Meteorologie, 11. Simulation of large scale atmospheric processes (extended abstracts) 205–208.

BAYLISS, A. and E. ISAACSON, 1975: How to make your algorithm conservative. Notices of the Am. Math. Soc., August 1975.

FRANCIS, P.E., 1975: The use of a multipoint filter as a dissipative mechanism in a numerical model of the general circulation of the atmosphere, Q.J. Roy. Meteor. Soc., 101, 567–582.

HOLLOWAY, J. L., M. Spelman and S. Manabe, 1973: Latitude-longitude grid suitable for numerical time integration of a global atmospheric model. Mon. Wea. Rev., **101**, 69–78.

KALNAY-RIVAS, E. 1976a: Numerical experiments with 4th order conservative finite differences. Annalen der Meteorologie, **11**. Simulation of large scale atmospheric processes (extended abstracts). Addendum.

KALNAY-RIVAS, E., 1976b: High latitude truncation errors of box-type primitive equation models. Mon. Wea. Rev., **104**, 1066–1069.

KREISS, H.-O., and J. OLIGER, 1972: Comparison of accurate methods for the integration of hyperbolic equation. Tellus, **24**, 199–215.

PHILLIPS, N. A., 1974: Application of Arakawa's Energy-Conserving Layer Model to Operational Numerical Weather Prediction. NMC Office Note 104.

SHAPIRO, R., 1970: Smoothing, filtering and boundary effects. Rev. Geophys. and Space Phys., **8**, 359–387.

SOMERVILLE, R., P. H. STONE, M. HALEM, J. E. HANSEN, J.S. HOGAN, L. M. DRUYAN, G. RUSSELL, A. A. LACIS, W. J. QUIRK and J. TENENBAUM, 1974: The GISS model of the global atmosphere. J. of Atmos. Sci., **31**, 84–117.

WILLIAMSON, D. L. and G. L. BROWNING, 1973: Comparison of grids and difference approximations for numerical weather prediction over a sphere. J. Applied Met., **12**, 264–274.

THE EFFECT OF ACCURACY, CONSERVATION AND FILTERING ON NUMERICAL WEATHER FORECASTING

Eugenia Kalnay-Rivas

Department of Meteorology, Massachusetts Institute of Technology
and NASA/Goddard Space Flight Center

and

David Hoitsma(*)

Sigma Data Corporation, c/o NASA/Goddard Space Flight Center

1. INTRODUCTION

The design of a numerical model for atmospheric simulation is not a straight-forward procedure. Both in the areas of mathematical and numerical analysis, and in the parameterization of physical processes not explicitly resolved, the modeler faces several difficult choices between equally reasonable methods, and sometimes between similarly unsatisfactory methods.

In this paper we discuss the considerations leading to the numerical design of the GLAS Fourth-Order Global Atmospheric Model. This model, which was briefly described in Kalnay-Rivas et al., [1977], has been restructured, and several minor changes were introduced. *The computation time and memory requirements for the 4th order model are now similar to those of the present second order GLAS model with the same 4° latitude, 5° longitude and 9 vertical-level resolution [Sommerville et al., 1974]. However, the fourth-order model forecast skill is significantly better than that of the current GLAS model, and after 3 days it is comparable or better than that obtained with the 2.5° by 3° version of the GLAS model.*

A discussion of several of the basic characteristics of the model design is contained in section 2. For each of them we present some of the possible alternatives, their advantages and disadvantages, and the reason for our choice. In section 3, we discuss the effect on numerical forecasts of changes in the accuracy, resolution and conservation properties of the models.(1) Section 4 contains some final remarks.

2. DISCUSSION OF THE DESIGN OF THE MODEL

Different numerical analysts and atmospheric modelers often take different approaches in the design of a numerical model for weather prediction. Sometimes they even have different basic philosophies. For example Arakawa [1966, 1972], has been a pioneer in the development and use of numerical schemes that reproduce as closely as possible the conservation properties of the continous equations of fluid dynamics that determine the motion of the atmosphere. On the other extreme, Kreiss and Oliger [1972, 1973] have advocated the use of more accurate schemes even when they don't formally satisfy any conservation properties.

The current GLAS model is based on Arakawa's [1972] second order scheme using a staggered grid B. The scheme is energy conserving and approximately enstrophy conserving for non-divergent flow. In this section we isolate the areas in which the Fourth-Order model is different from the GLAS model, discuss some of the alternatives, and the justification of our choice.

2.1 Accuracy

There is a consensus among modelers that for finite difference models with second-order accuracy, horizontal resolution of about 400 km, and about 10 vertical levels, horizontal truncation errors are the most important source of errors. The truncation errors can be reduced by any of the following methods:

a. Increased horizontal resolution, retaining second-order differences. Advantages: If the horizontal grid size is reduced by a factor of 2, truncation errors are reduced by a factor of 4. A comparison of the effect of truncation errors on the computational phase speed and group velocity of a linear wave is presented in Fig. 1. Another advantage is that increasing

---

(1) As of this writing, several of the numerical experiments are not complete.

(*) Present affiliation: Department of Mathematics, Wesleyan University of Connecticut

the resolution allows smaller but possibly important scales to be explicitly included in the model.
Disadvantages: The reduction of error is slow, and the computation time is increased by a factor of 8.

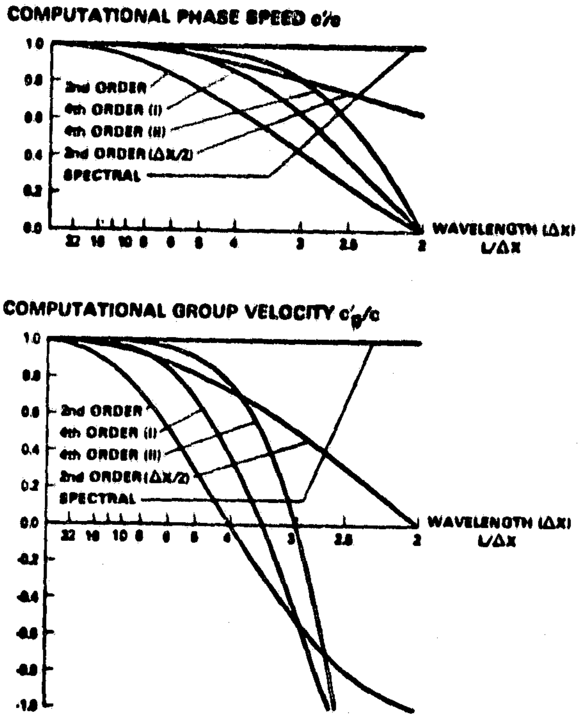


Fig. 1 Computational phase speed and group velocity fot a linear wave of constant phase speed c, for different numerical schemes as a function of wavelength L.

b. Fourth order schemes of the first kind. We include in this group the common 5-point explicit fourth order schemes [Kreiss and Oliger, 1972].
Advantages: Phase speed errors are much smaller, especially for long waves (Fig. 1). Waves longer than 5Δx have smaller errors in their phase speed with fourth order differences than with second order differences with twice the resolution. If we consider the computational group velocity, the crossover occurs at about 7Δx. The computational time is only increased by a factor between 2 and 3.
Disadvantages: Waves in the range of 2Δx to 4Δx are still grossly misrepresented.

c. Fourth order schemes of the second kind. In this group we include linear finite elements, cubic splines and the "compact" or Pade type 3-point 4th order differences introduced by Kreiss [Orszag & Israeli, 1972], all of which have the same fourth order accuracy.
Advantages: These fourth-order differences are considerably more accurate than the fourth-order differences of the first kind (Fig. 1). The crossover with double-resolution second-order differences in the phase speed error occurs at 3Δx, and in the group velocity error at about 4Δx.
Disadvantages: In the simplest case, Kreiss' fourth order differences require the solution of tri-diagonal matrices. Finite element schemes require the solution of at least block tri-diagonal matrices. Even though there are efficient methods to perform these inversions, they are still computationally expensive. The extra accuracy can be compensated with 4th order differences of the first kind by increasing the resolution, which has other advantages, as we mentioned earlier. These schemes, as well as in higher order finite difference schemes, waves in the range of 2Δx to 4Δx are still grossly misrepresented.

d. Spectral schemes.
Advantages: *If the basis of the spectral expansion are the eigenfunctions of the wave equation,* spectral schemes have no phase speed errors. Because of this they require less resolution than finite difference schemes.
Disadvantages: Because of the large number of computations required for the nonlinear terms, spectral schemes are competitive with finite difference schemes only in combination with the use of less resolution and semi-implicit time schemes.

Our choice: We chose to use fourth order finite differences of the first kind because they are computationally efficient and have small truncation errors except in the range of waves with wavelengths between 2Δx and 4Δx.

2.2 Type of Grid

Both staggered and unstaggered grids have been widely used by atmospheric modelers.

a. Unstaggered grid: The advantage of this grid is its simplicity. Higher order schemes are easily developed with this grid. Its disadvantage is that all centered differences have to be computed over a distance of 2Δx.

b. Staggered grids: Several staggered grid configurations are possible as reviewed by Arakawa [1972]. The one he called scheme C, which is the most commonly used, has the pressure defined at the center of a grid cell, and the velocity components u and v defined at their corresponding normal walls. This grid has the advantage that the pressure gradient and velocity divergence terms are computed over a distance of only 1Δx, so that *inertia gravity waves are computed with double resolution.* Therefore, as pointed out by Arakawa, geostrophic adjustment is best represented in this grid. On the other hand, advection terms are computed with no more accuracy than in the unstaggered grid, and in the Coriolis' acceleration term, it is necessary to take horizontal averages of the velocities. The higher resolution of inertia gravity waves *reduces the maximum time step for explicit time schemes by a factor of two.* Full fourth order schemes can be developed with staggered schemes but they are very involved [Kalnay-Rivas, 1976]. To date, modelers using staggered grids have introduced fourth order differences *only* in the advection terms.

Our choice: During extended range forecasts, second order errors in the non-advective terms may become important. For this reason we chose to use an unstaggered grid that allows the use of a simple, full fourth-order scheme.

2.3 Conservation Properties and the Use of Horizontal Diffusion

With respect to conservation properties, there are basically 3 types of finite difference schemes for the primitive equations:
a) Nonconservative schemes, the simplest of which is the one based on the advective form of the equations; b) quadratically or energy conserving schemes; and c) enstrophy conserving schemes. Advective and quadratically conservative schemes can be easily developed using staggered or unstaggered grids [Lilly, 1965; Bryan, 1966]. Enstrophy conserving schemes for the primitive equations have been developed on a grid C by Grammeltvedt [1969] and Arakawa and Mintz [1974]. Sadourny [1965a, b] constructed a potential enstrophy conserving scheme on grid C, and Arakawa [1978] has recently developed a potential enstrophy and energy conserving scheme also on grid C.

Nonconservative schemes require a procedure to damp waves shorter than $4\Delta x$, which otherwise grow spuriously causing catastrophic nonlinear instability [Phillips, 1959]. This has usually been done by means of linear or nonlinear horizontal diffusion, or by using dissipative numerical schemes such as the Lax-Wendroff, or schemes that contain explicit horizontal averaging.

Quadratically conservative schemes avoid the unbounded growth of the solutions associated with catastrophic nonlinear instability. However, as Arakawa [1972] and Sadourny [1975a, b] have pointed out, in the course of long integrations, there is still a spurious build up of energy in the shortest waves, which appears as an *unbounded growth of the total enstrophy.* In the absence of horizontal diffusion, this type of *slow nonlinear instability* will completely distort the solution. Enstrophy conserving schemes, on the other hand, impose a stronger constraint on the growth of the smallest scales present in the model. For this reason, the UCLA and the GLAS models, which use enstrophy conserving schemes, *do not need to include horizontal diffusion.*

It should be emphasized that conservation of enstrophy does not necessarily imply a more accurate or realistic simulation. In the real atmosphere, the constraint of quasi-geostrophic motion implies that very little of the energy generated in the baroclinically unstable scales can reach the smallest scales and be eventually dissipated [Charney, 1972]. In a numerical model, *the finite resolution imposes an artificial "wall" at the short end of the spectrum,* inducing an excessive accumulation of energy in the shortest waves. This problem is worst in nonconservative schemes, but it appears even in alias-free, energy- and enstrophy-conserving spectral models. This justifies using some parameterization of the unresolved subgrid eddies to withdraw energy from the smallest resolved scales.

For this purpose, Leith [1972] suggested the use of nonlinear horizontal diffusion in which the eddy diffusion coefficient is proportional to the local gradient of vorticity. This formulation is consistent with the transfer of energy to subgrid scales in two-dimensional turbulence. In another widely used formulation, suggested by Smagorinsky [1963] and based on a three-dimensional turbulent cascade theory, the diffusion coefficient is proportional to the deformation tensor. These formulations are better than the use of linear diffusion, but they both share the following problems: a) the diffusion coefficient is computed inaccurately for the shortest waves, and, more importantly, b) when the diffusion coefficient is large enough to avoid the spurious growth of the smallest scales, it produces excessive damping of the larger scales [Merilees, 1975; Williamson, 1978]. Furthermore, at the short end of the spectrum (scales of the order of 100 km), neither quasi-geostrophic nor 3-dimensional isotropic turbulence theories are really justified. Williamson [1978] generalized a higher order diffusion of the form $\nabla^2\kappa\nabla^2$, suggested by Kreiss and Oliger [1972], still using the deformation type of diffusion coefficient. This formulation has the advantage that, because it is more scale dependent, there is less damping of the longer waves.

In our model, we have taken an approach closer to Fourier filtering the shortest waves, as suggested by Phillips [1959]. Our "subgrid parameterization" is based on the following argument: The 4th order scheme is adequate accurate for waves longer than $4\Delta x$, but grossly inaccurate for waves between $2\Delta x$ and $3\Delta x$. Since the shortest waves *cannot provide any useful information in a finite difference scheme,* we filter them out of the system while their amplitude is still small. Even though they are filtered out, the shortest waves still play an important role in the model: they act as a buffer or "sponge layer" in the spectrum domain, allowing energy to trickle down from longer waves and avoiding the accumulation of energy that would otherwise occur at the short wave cutoff.

The elimination of the short waves is performed in the model with the periodic use of a 16th order Shapiro [1970] filter, first introduced in GCMs by Francis [1975]. Figure 2 indicates the response of Shapiro filters of order 4, 8 and 16. It can be observed that in the case of a 16th order filter waves longer than 4 are scarcely affected at all even after 128 applications, which in our model correspond to a 10 day integration. Waves shorter than 4 are virtually eliminated. Lower order filters introduce too much decay at long scales.

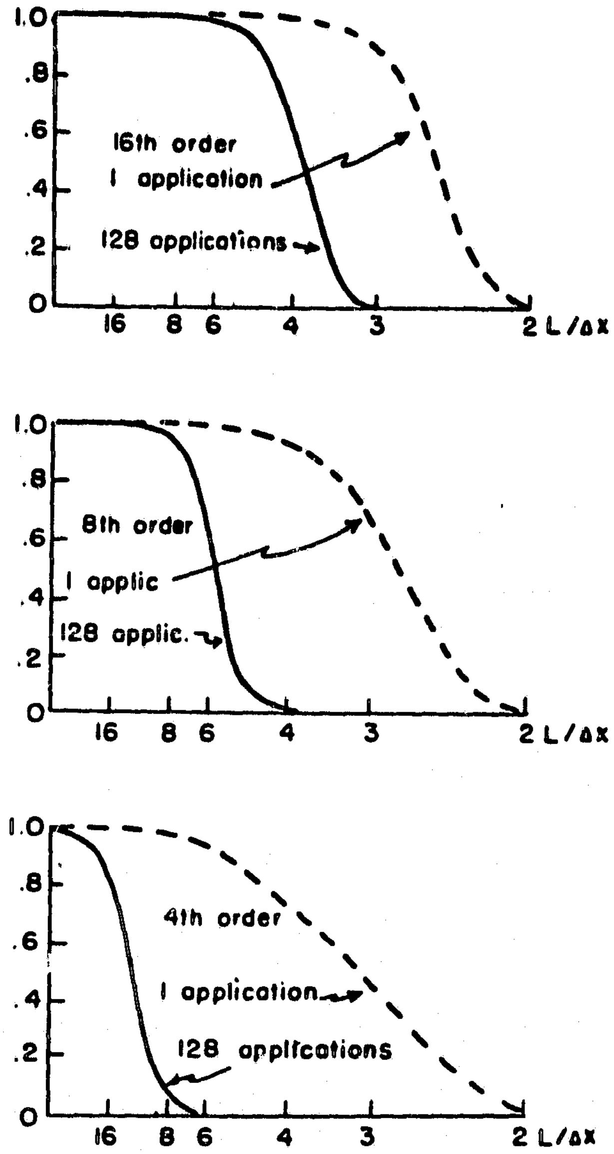


Fig. 2 Response of Shapiro filters after 1 and after 128 applications.

In order to explore the effect of filtering short waves we performed a series of 20 day forecasts with a simple shallow water equation model [Kalnay-Rivas, 1976], using different combinations of schemes, smoothing operators and frequency of application as indicated on Table 1.

A1: 4th order, non-conservative, no smoothing.
A2: " , " ,linear diffusion,$\nu = 10^{5}\,m^{2}/s$
A3: " , " ,16th order filter/4 hrs.
A4: " , " , " /time step.

B1: " , quadrat. conserv., no smoothing.
B2: " , " ,16th order filter/4 hrs.
B3: " , " , 8th " " "
B4: " , " , 4th " " "

C: 2nd order, " , no smoothing

TABLE 1: Characteristics of the different runs in Fig. 3.

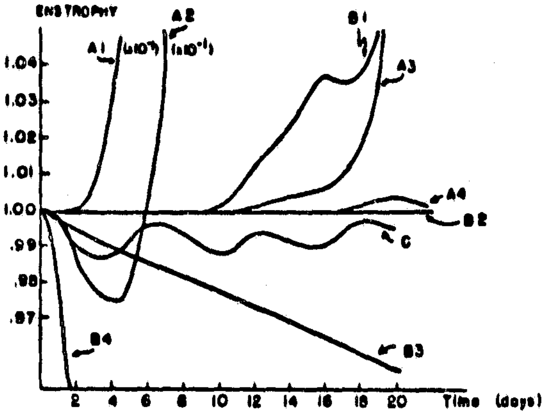


Fig. 3 Variations of total enstrophy during numerical integrations as indicated in Table 1. The scale corresponding to experiments A1 and A2 is multiplied by 10^{-1}.

We found that all stable runs conserved total energy with a high degree of accuracy. Fig. 3 shows the variation in time of the total potential enstrophy, which is conserved exactly in the continuous equations. The results indicate that when the 16th order filter is applied every time step (10 minutes) even a formally nonconservative scheme conserves both total energy and total potential enstrophy during a long integration (Run A4). The quadratically conservative scheme controls better the amount of energy going into the smallest scales, so that in Run B2 it was enough to apply the filter every 4 hours to conserve potential enstrophy within 0.05%, even though such conservation is not formally guaranteed in the scheme.

It may be questioned whether the application of a high order filter eliminates small scale features like frontal zones or the effects of orographic or cumulus convection forcing on small scales. Fig. 4 indicates that this is true for lower order filters. However a 16th order filter eliminates only those components which are not resolved anyway, and still allows for the formation of sharp gradient zones and strong local maxima.

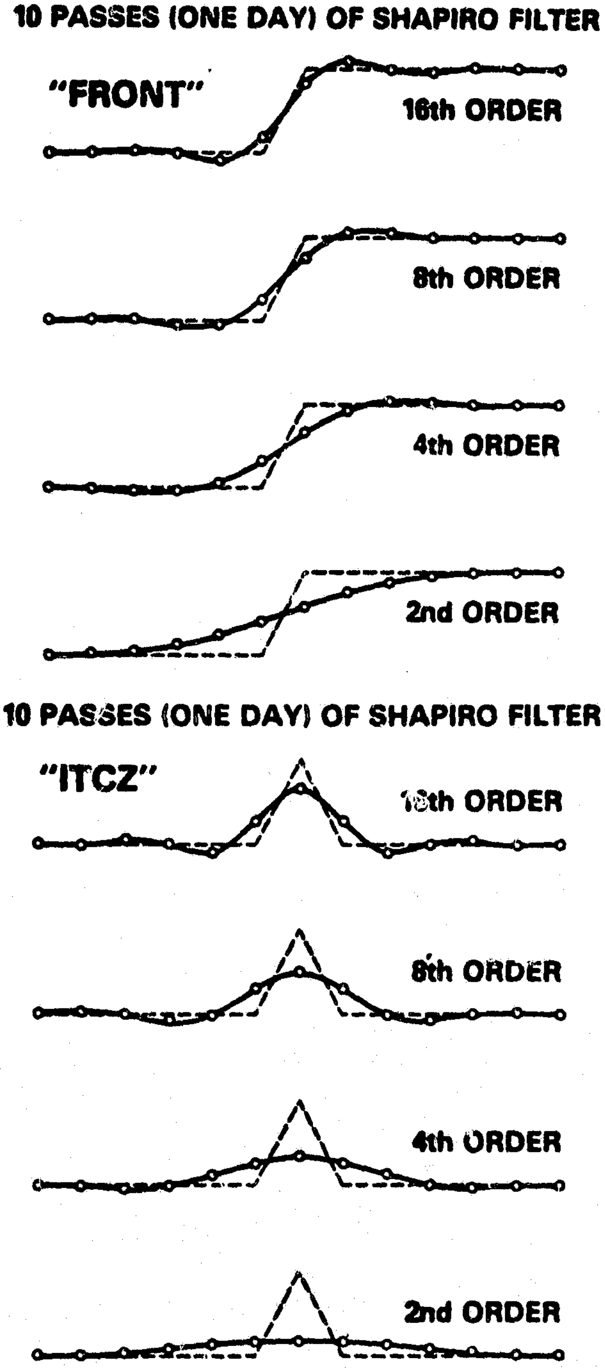


Fig. 4 Effect of 10 applications of a 16th order Shapiro filter on a) a step function b) a spike.

Our choice: We chose to use a quadratically (energy) conserving scheme because it is only slightly less efficient than an advective scheme and it requires the application of a high-order filter only every few hours to avoid the effect of slow nonlinear instability associated with a spurious growth of enstrophy. We apply the filter to the *sea level pressure and potential temperature fields* in order to compensate for the effect of topography.(3)

3. EXPERIMENTAL FORECASTS: PRELIMINARY RESULTS

We plan to perform an extensive series of forecasts to study the effect of using different schemes and varying resolution on the quality of actual weather forecasts. In this section we present some preliminary results.

We tested the Fourth Order model by making 3-day forecasts from several initial conditions. In every case the model performed much better than the GLAS model with the same 4° by 5° resolution. After 3 days the forecasts were comparable to the 2.5° by 3° version of the GLAS model in the sea level pressure maps, and had slightly less phase errors in the 500 mb maps.

Fig. 5a shows the verification sea level pressure map corresponding to a 3-day forecast with February 19, 1976, 0Z (a case that has been studied in detail by Atlas et al., 1979). Fig. 5b is the 3-day forecast with the Fourth Order 4° by 5° model verifying on the same date. The excessive gradients, especially at high latitudes are due to a faulty computation of the ground temperature by the radiation routine used in that run. Figs. 5c and 5d are the forecasts generated by the GLAS models with 4° by 5° and 2.5° by 3° resolution respectively. Fig. 6 displays the corresponding 500 mb maps.

In Fig. 7a, we present the verification sea level pressure map corresponding to a 3-day forecast with February 1, 1976, 0Z initial conditions. The results of six different 3-day forecasts are shown in Figs. 7b to 7g. The forecast in Fig. 7b was computed with the new full Fourth-Order model, using the same resolution and parameterization of physical processes (except for the long-wave radiation routine) as in the 4° by 5° GLAS model (Fig. 7c). In Fig. 7d, the model was the same as in 7b, but full Second-Order accuracy was used. If we compare these three made with the same resolution, we see that the fourth order model did considerably better, especially in forecasting the development and motion of the cyclone southwest of Greenland. The two second-order forecasts are close to each other.

---

(3) The idea of filtering these fields is due to Dr. A. Bayliss.

Fig. 7 shows the forecast made with the 2.5° by 3° GLAS model starting from the NASA initial conditions with assimilation of satellite data [Atlas et al., 1979]. All other forecasts were made from NMC's Global Analysis initial conditions. The cyclogenesis forecast was poorer than with the fourth order model, but over continental North America the forecast was better. This may be due to the higher resolution or, possibly, improved initial conditions. Fig. 7f presents the forecast made with NMC's 6-layer, 380 km resolution, which has resolution comparable to our 4° by 5° grid. For these initial conditions, NMC's forecast was better than the GLAS second order forecast, although it shared some of its errors (such as a spurious anticyclogenesis over the Great Lakes).

Fig. 7g shows a forecast made with a slightly different version of the fourth order model. The differences were as follows: In the 7g forecast we used a Matsuno time step, a surface drag that was .75 of that of the standard model, the Shapiro was applied every two hours, and a slightly different scheme for the vertical advection of moisture was used. In the 7b forecast we used a combined Matsuno-leap-frog scheme, the surface drag was the same as in the standard model and the filter was applied every hour. The two forecasts are quite similar, but from other experiments it seems that the positions of the oceanic lows west of Spain and south of Alaska were somewhat affected by the change in frequency of the Shapiro filter.

4. FINAL REMARKS

Although these are preliminary results, the new Fourth-Order model seems to have very good forecasting skill. Similar excellent results with fourth order schemes were reported by Campana [1978, 1979], and by Williamson (1978). Campana found that most of the improvement over the second order model was obtained just by introducing fourth order accuracy on the horizontal averages performed on the Shuman-Hovermale model. Campana also obtained that for 2-day forecasts, fourth order differences were important in the advection terms but not in the pressure and continuity terms. We made shallow water equation experiments that showed some deterioration of the solution after about 8 days when only the advection terms were written with fourth order accuracy. Since baroclinic models are much more unstable than the SWE, Campana's results may not hold during extended forecasts. We are performing experiments to study this possibility in our model. We are also repeating some of the forecasts using a vector invariant form of the momentum equations. The NMC 6-layer PE model used in Fig. 7f is based on such a formulation, and we want to determine if it affects the solution.

We are performing integrations with a 2.5° by 3° version of the Fourth-Order model. From linear theory, this should make horizontal truncation errors negligible for most synoptic scales for periods of a week or longer. Still, narrow atmospheric features like those due to sharp orographic forcing on the ITCZ will remain poorly resolved.

We have found the fourth order model to be extremely sensitive to the parameterization of physical processes. For example, it became unstable through excessive cooling near the surface, apparently due to a flaw in the radiation routine. None of the second order models was sensitive to this problem.

In this paper we have discussed the use of formally nonconservative schemes coupled with periodic filtering of the shortest waves as an alternative to the use of conservative schemes. It is clear from the experimental results that formal enstrophy conservation has had no beneficial impact on the quality of the forecast (Figs. 7c and 7d). Conservation of potential enstrophy [Arakawa, 1978] might have a more positive effect.

We think that the use of nonconservative schemes with high order periodic filtering is also justified in climate simulations as long as the rates of energy or enstrophy loss due to filtering remain much smaller than the observed rates of generation and dissipation.

Acknowledgements: Dr. A. Bayliss' contribution was crucial in the development of the model. The authors have benefitted from stimulating discussions with Profs. M. Cane, E. Isaacson and D. Randall. The authors are grateful to Dr. M. Halem for his patience, encouragement and many useful suggestions. Dr. N. Rushfield and Mr. W. Connelly were extremely helpful in the development of the program. Dr. M. Wu provided us with her accurate radiation routine.

Fig. 5	Sea level pressure maps corresponding to 3-day forecasts with February 19, 1976, OZ initial conditions.
Fig. 6	Same as Fig. 5 but 500 mb geopotential heights.
Fig. 7	Same as Fig. 5 but for February 1, 1976, OZ initial conditions.

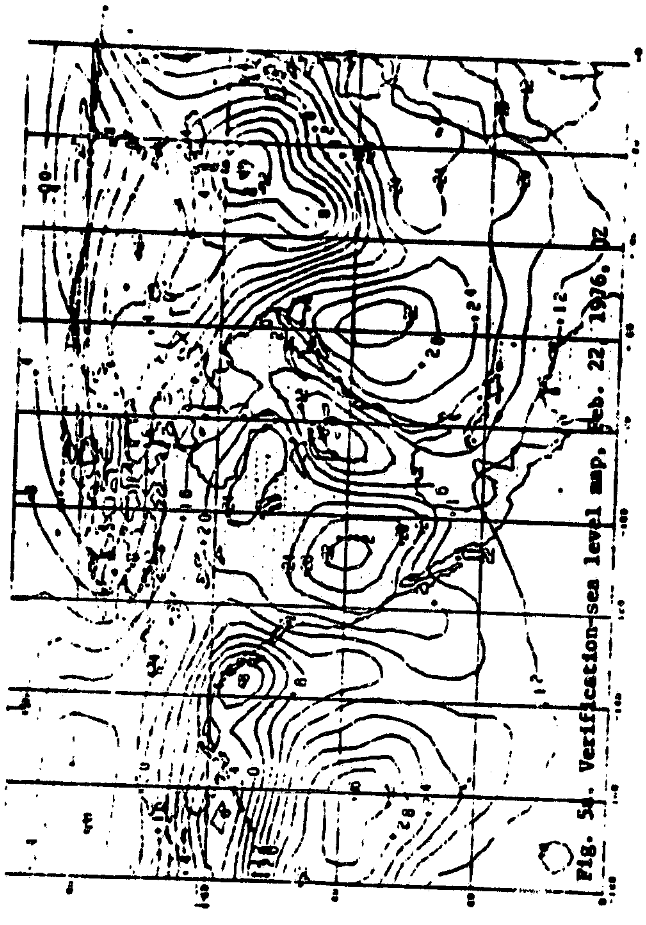


Fig. 5a. Verification-sea level map, Feb. 22 1976, 0Z

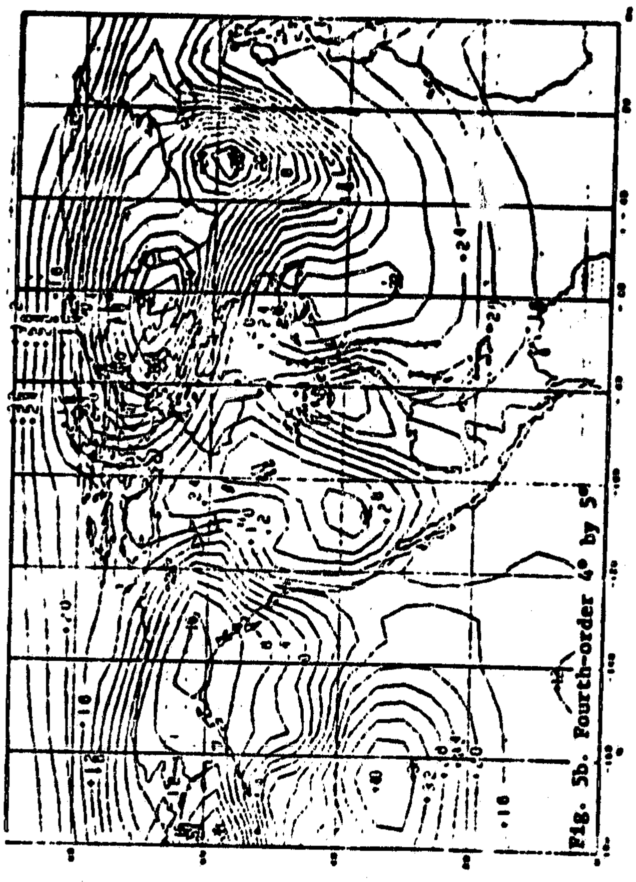


Fig. 5b. Fourth-order 4° by 5°

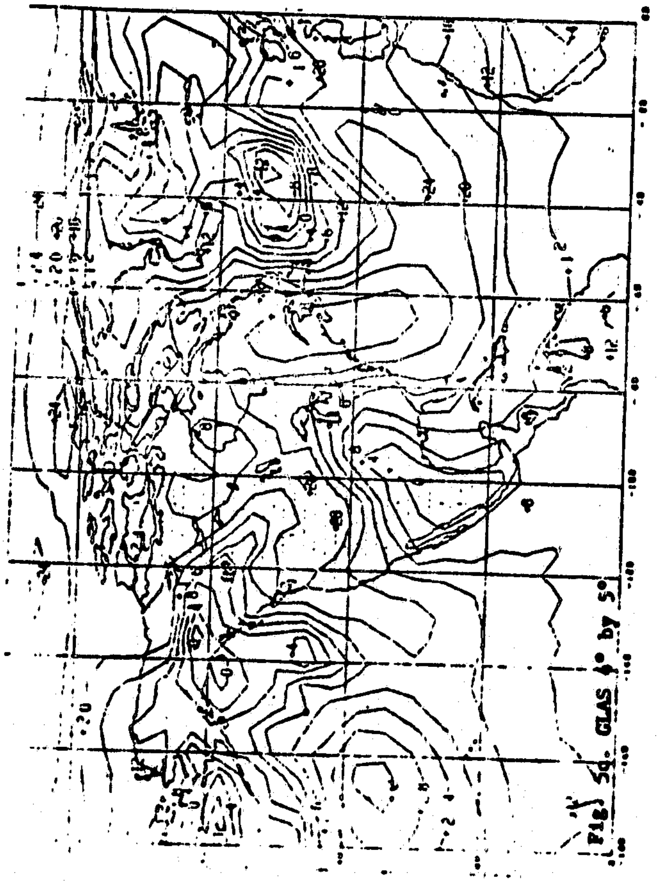


Fig. 5c. GLAS 4° by 5°

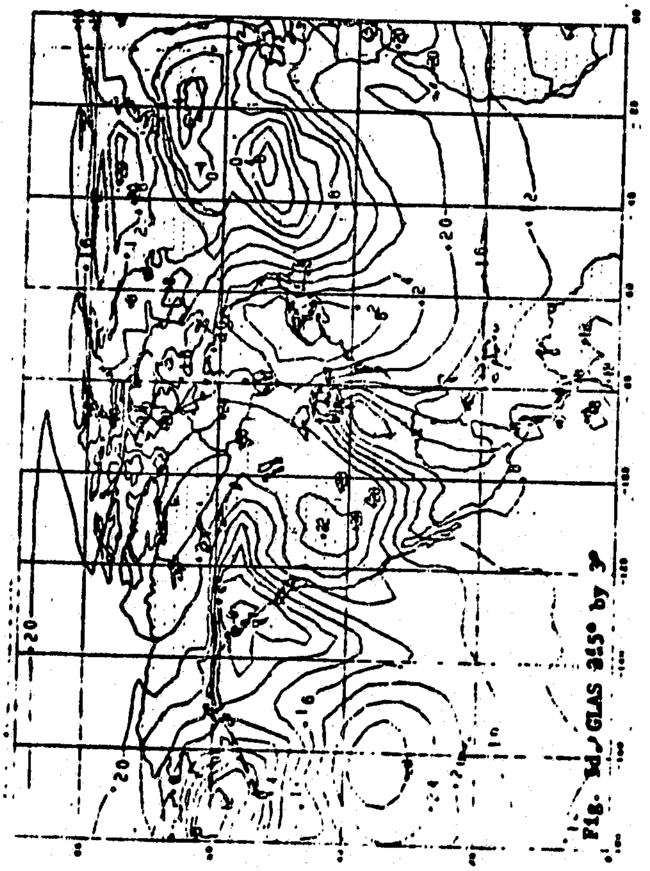


Fig. 5d. GLAS 2.5° by 3°

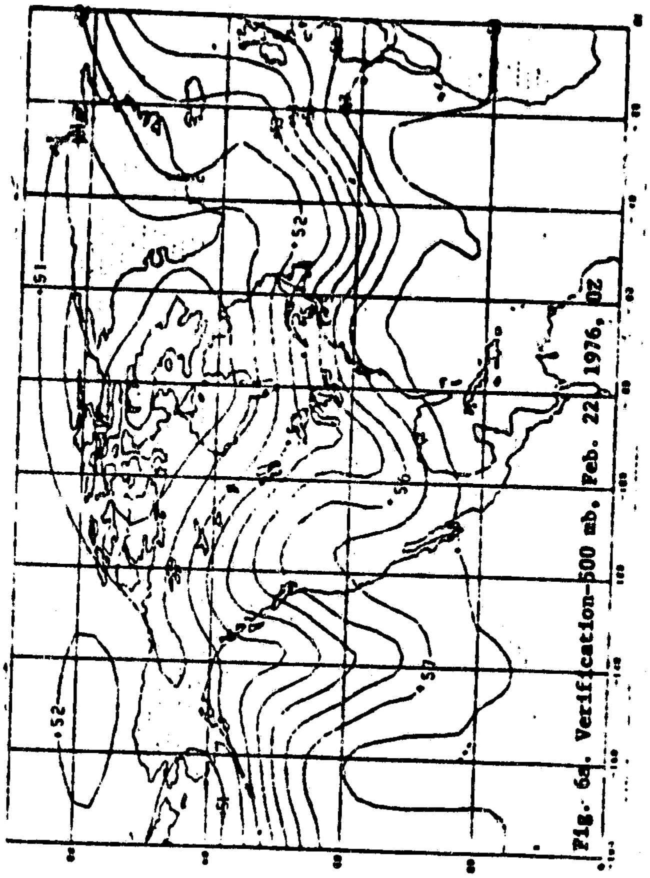


Fig. 6a. Verification-500 mb. Feb. 22, 1976, 0Z

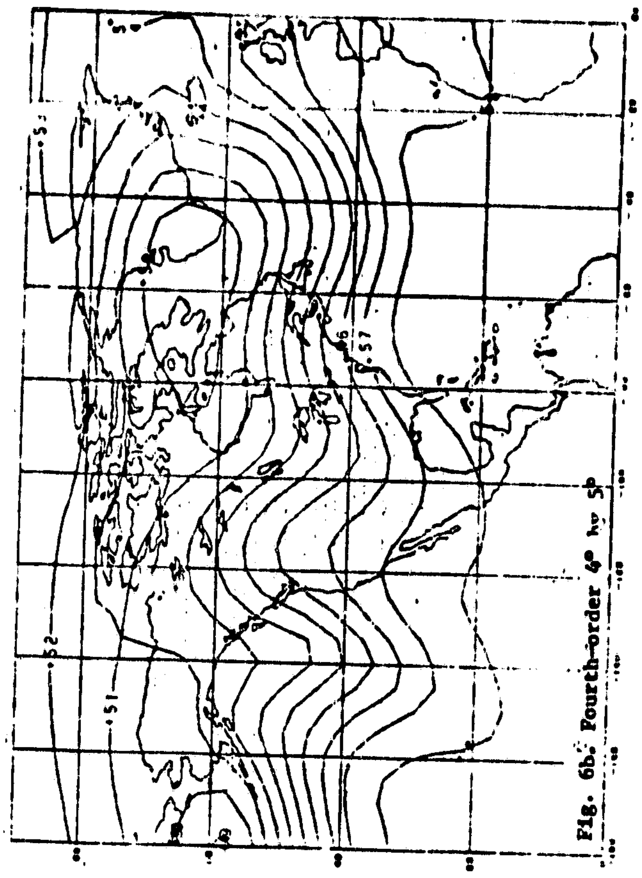


Fig. 6b. Fourth-order 4° by 5°

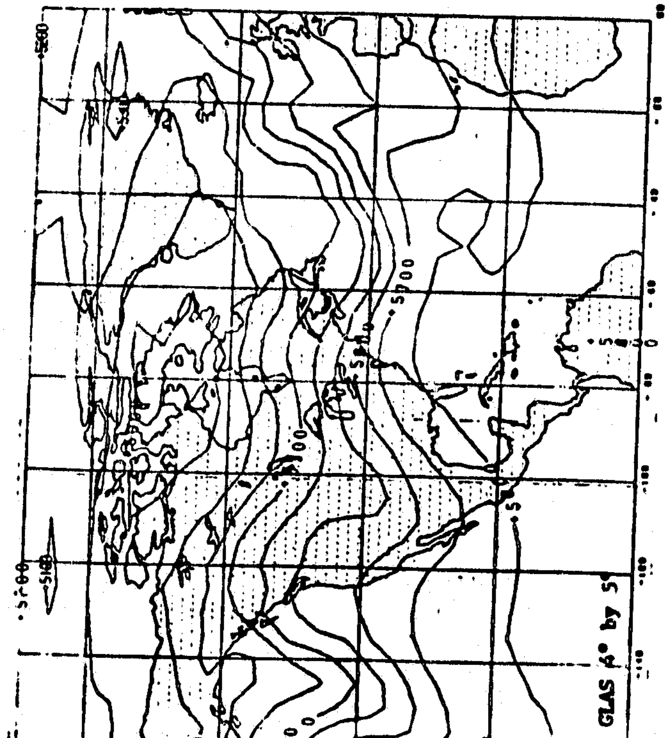


Fig. 6c. GLAS 4° by 5°

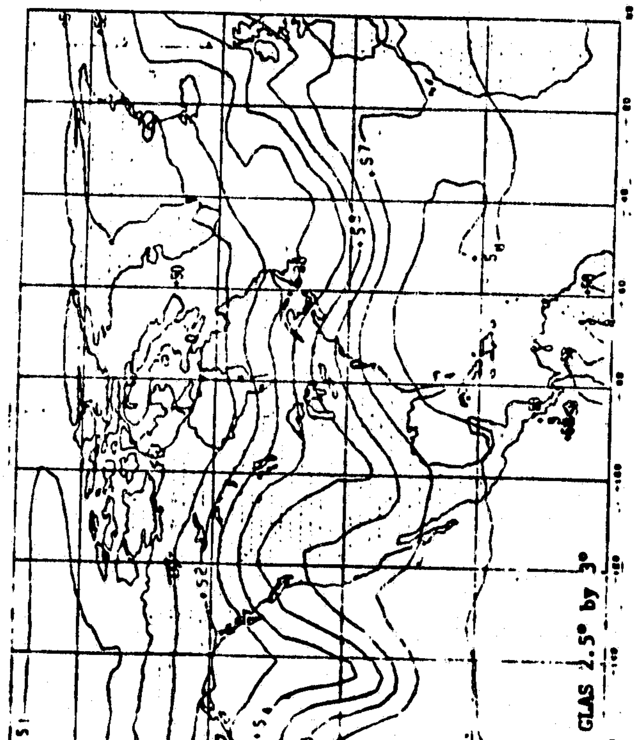


Fig. 6d. GLAS 2.5° by 3°

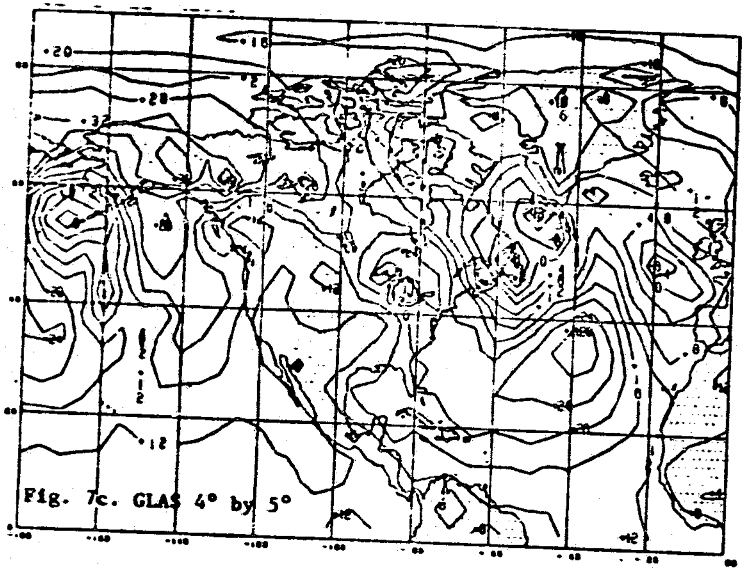


Fig. 7c. GLAS 4° by 5°

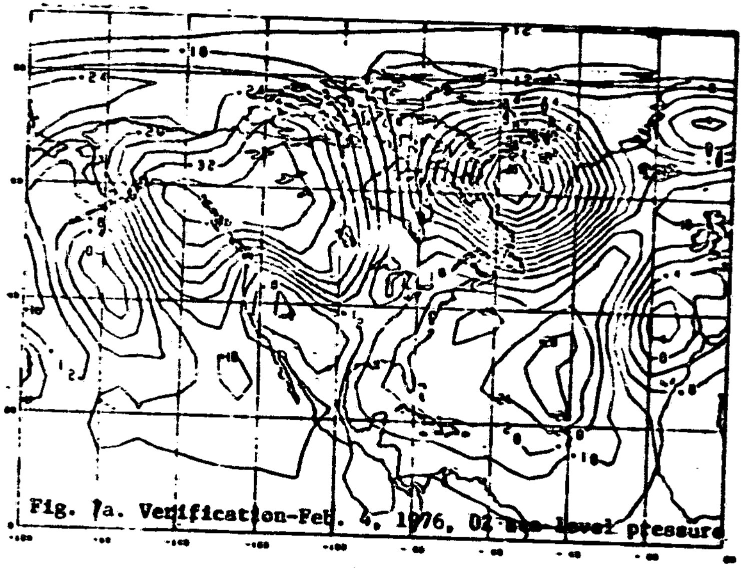


Fig. 7a. Verification-Feb. 4, 1976, 0Z sea-level pressure

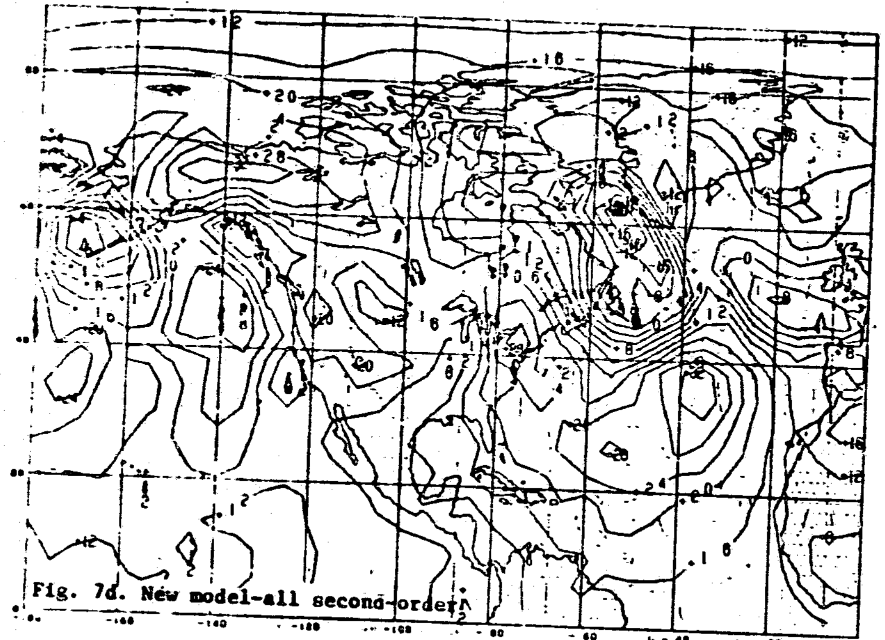


Fig. 7d. New model-all second-order

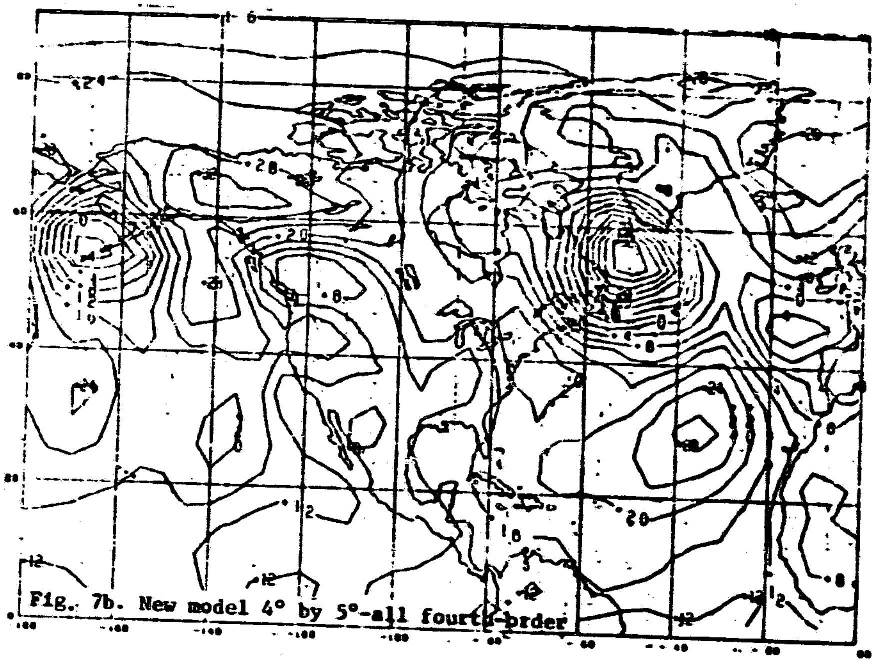


Fig. 7b. New model 4° by 5°-all fourth-order

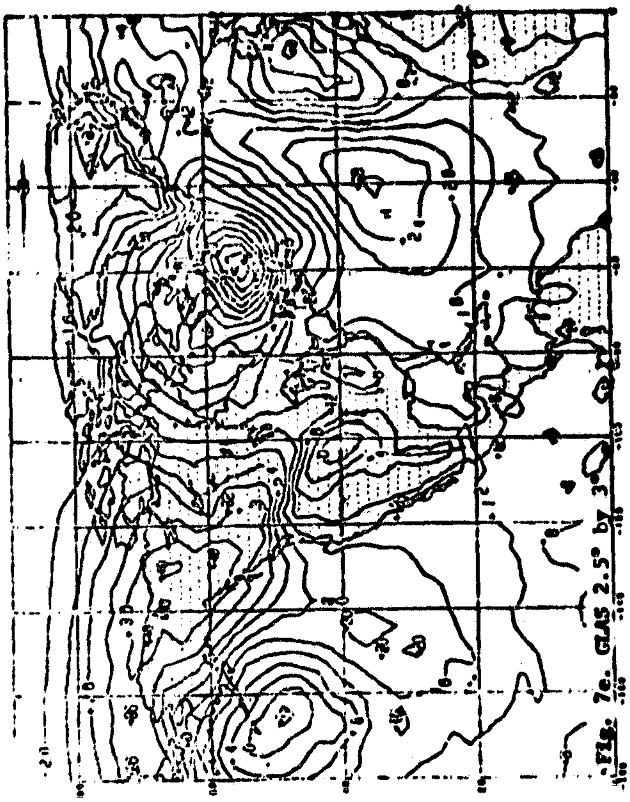


Fig. 7e. GLAS 2.5° by 3°

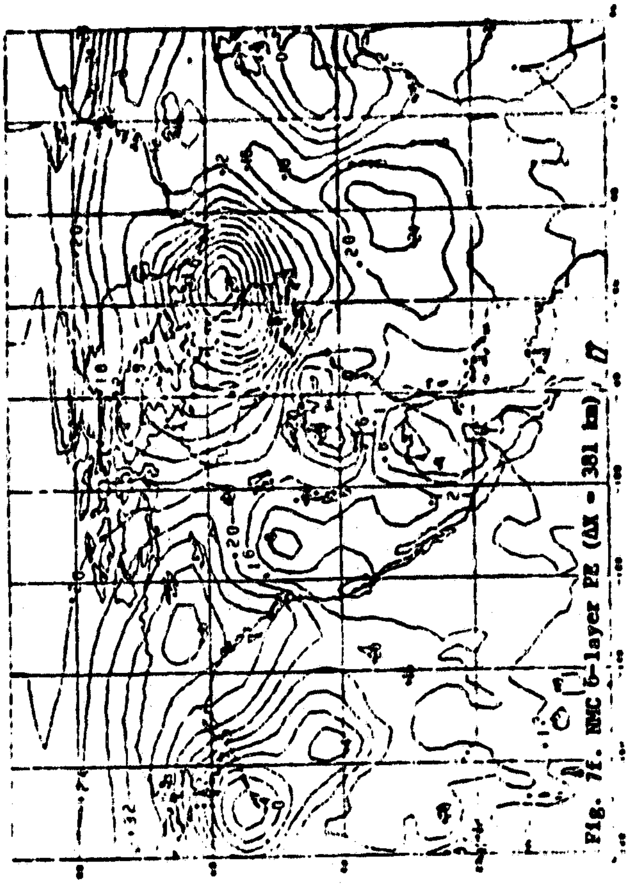


Fig. 7f. NMC 6-layer PE (ΔX = 381 km)

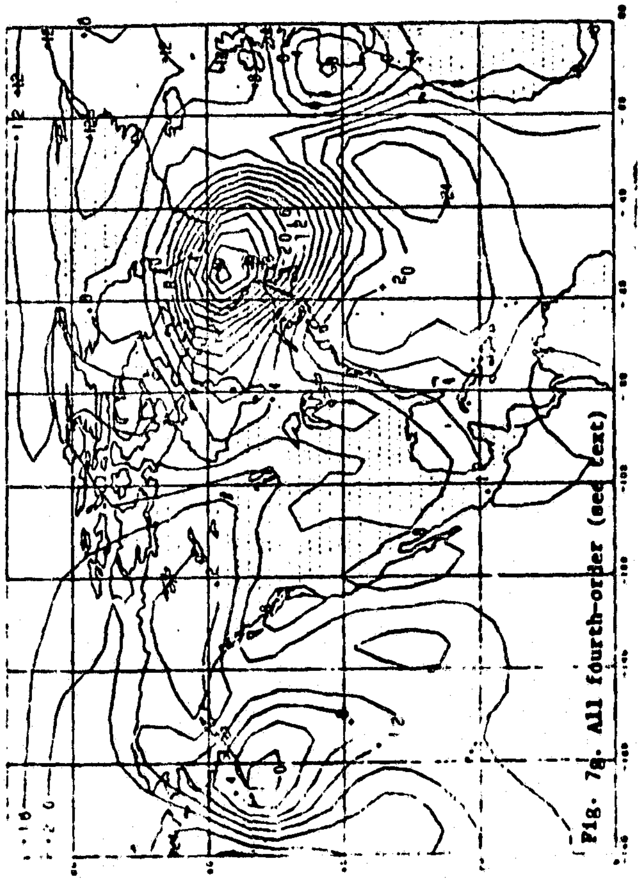


Fig. 7g. All fourth-order (see text)

REFERENCES

Arakawa, A., 1966: Computational design for long term numerical integration of the equation of fluid motion: Two dimensional incompressible fluid. Part I. J. Compu. Phys., 1, 119-143.

Arakawa, A., 1972: Design of the UCLA GCM, Report No. 7, Dept. of Meteorology, UCLA.

Arakawa, A. and Y. Mintz, 1974: The UCLA atmospheric GCM. Workshop Notes, Dept. of Meteorology, UCLA.

Atlas, R., M. Halem and M. Ghil, 1979: Subjective evaluation of the combined influence of satellite temperature sounding data and increased model resolution on numerical weather forecasting. To be presented at the 4th Conference on Numerical Weather Prediction, Silver Spring, MD, October.

Campana, K., 1978: Real data experiments with a fourth-order version of the operational seven-layer model. NMC Office Note 188.

Campana, K, 1979: Higher order finite difference experiments with a semi-implicit model at NMC. J. Atmos. Sci., 107, 363-376.

Charney, J. G., 1971: Geostrophic turbulence, *J. Atmos. Sci.*, *28*, 1087-1095.

Francis, P. E., 1975: The use of a multipoint filter as a dissipative mechanism in a numerical model of the general circulation of the atmosphere. *Q. J. Roy. Met. Soc.*, *101*, 567-582.

Grammeltvedt, A., 1969: A survey of finite difference schemes for the primitive equations for a barotropic fluid. *Mon. Wea. Rev.*, *97*, 384-404.

Kalnay-Rivas, E., 1976: Numerical experiments with fourth-order conservative finite differences. *Annalen der Meteorologie*, *11*. Simulation of large scale atmospheric processes (extended abstracts). Addendum.

Kalnay-Rivas, E., A. Bayliss and J. Storch, 1977: The 4th order GISS model of the global atmosphere. *Cont. to Atmos. Phys.*, *50*, 306-311.

Kreiss, H.-O. and J. Oliger, 1972: Comparison of accurate methods for the integration of hyperbolic equations. *Tellus*, *24*, 199-215.

Kreiss, H.-O. and J. Oliger, 1973: Methods for the approximate solution of time dependent problems. *GARP Pub. Series No. 10*, WMO.

Leith, C. E., 1972: Internal turbulence and vertical momentum transfer. *Parameterization of Sub-grid Processes*, *GARP Pub. Series No. 8*, 40-51.

Lilly, D. K., 1965: On the computational stability of numerical solutions of time-dependent nonlinear geophysical fluid dynamic problems. *Mon. Wea. Rev.*, *93*, 11-26.

Merilees, P. E., 1975: The effect of grid resolution on the instability of a simple baroclinic flow. *Mon. Wea. Rev.*, *103*, 101-104.

Orszag, S. A. and M. Israeli, 1974: Numerical simulation of viscous incompressible flow. *Ann. Rev. of Fluid Mech.*, *6*, 281-318.

Phillips, N. A., 1959: An example of nonlinear computational instability. *The Atmosphere and Sea in Motion*, Rockefeller Inst. Press, New York, 501-504.

Shapiro, R., 1970: Smoothing, filtering and boundary effects. *Rev. Geophys. and Space Phys.*, *8*, 359-387.

Smagorinsky, J., 1963: General circulation experiments with the primitive equations. *Mon. Wea. Rev.*, *91*, 99-164.

Williamson, D. L., 1978: The relative importance of resolution, accuracy and diffusion in short-range forecasts with the NCAR global circulation model. *Mon. Wea. Rev.*, *106*, 69-88.

```
SIZE=0K
USRDDS
EXEC     *,'SIZE=1000K'

LEVEL 19.6-APR 71                      OS/360 FORTRAN H AT GISS                           DATE 12/12/79-0782.83

     COMPILER OPTIONS -   NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                          SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  ISN 0002             COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,TMBAR,ALPHA,BETA,IMD2P1,   B4M00010
                     $    ADLDP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,         B4M00020
                     $    IMD2,RADIM,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),        B4M00030
                     $    JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),         B4M00040
                     $    PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),             B4M00050
                     $    CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                       B4M00060
  ISN 0003             EQUIVALENCE (QPOL(1,1,1),POLES(1)),(QTPOL(1,1,1),POLES(73)),    B4M00070
                     $    (UPOL(1,1),POLES(1)),(VPOL(1,1),POLES(10)),(TPOL(1,1),        B4M00080
                     $    POLES(19)),(SHPOL(1,1),POLES(28)),(UTPOL(1,1),POLES(73)),     B4M00090
                     $    (VTPOL(1,1),POLES(82)),(TTPOL(1,1),POLES(91)),(SHTPOL(1,1),   B4M00100
                     $    POLES(100)),(PPOL(1),POLES(145)),(PTPOL(1),POLES(147))        B4M00110
  ISN 0004             DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),  B4M00120
                     $    SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                          B4M00130
  ISN 0005             DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),        B4M00140
                     $    SHTPOL(36,1),QTPOL(9,4,2),QT(72,10,4,1)                       B4M00150
  ISN 0006             COMMON/SMITH/QSM(72,9,4,5),PSM(72,5),QSMPOL(9,4,2),PSMPOL(2)   B4M00160
  ISN 0007             COMMON/SMOTH/DATA(150),CATA(150),SLP(72,46)                    B4M00170
  ISN 0008             COMMON/RMWRT/C3WRT,NOC3,SHSMOO,FAST,TMP,SWAFTA,ADPCLD          B4M00180
  ISN 0009             COMMON/SDOT48/SDOT(72,46,8),OMEGA(72,46,5),MNMXTS,RADT(72,46,10) B4M00190
                     + ,COMG                                                           B4M00200
             C                                                                         B4M00210
  ISN 0010             INTEGER*2 RADT,OMEGA                                            B4M00220
  ISN 0011             INTEGER*2 ISDOT(72,46,8)                                        B4M00230
             C                                                                         B4M00240
  ISN 0012             EQUIVALENCE (SDOT(1,1,5),ISDOT(1,1,1))                          B4M00250
             C                                                                         B4M00260
  ISN 0013             LOGICAL C3WRT,NOC3,SHSMOO,FAST,SWAFTA,ADPCLD,COMG               B4M00270
  ISN 0014             INTEGER*2 ALBEDO                                                B4M00280
  ISN 0015             REAL*4 KAPA,LAT                                                 B4M00290
             C         REAL*8 SINLON,COSLON,SUM                                        B4M00300
  ISN 0016             COMMON /CNTRL/                                                  B4M00310
                     *  JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,     B4M00320
                     *  J1,JM,KM,TAUT,IROT,WROT,JTEST,ITEST,                           B4M00330
                     *  NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                        B4M00340
                     *  DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP, B4M00350
                     *  NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUO,DTMULT,               B4M00360
                     *  PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLW,PSF,WRCH,RSDIST,SIND,COSD,   B4M00370
                     *  RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                        B4M00380
                     *  XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                B4M00390
                     *  JIPS(11),JMPS(11),JIUS(11),JMUS(11),KSES(11),KNBS(11),         B4M00400
                     *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46), B4M00410
                     *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                   B4M00420
  ISN 0017             DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),        B4M00430
                     *P(2880,1),TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)    B4M00440
  ISN 0018             COMMON/WORK/ WORKX(72,9,46)                                     B4M00450
  ISN 0019             COMMON/WORK2/PU(2880,46)                                        B4M00460
  ISN 0020             DIMENSION UT(72,40,1),VT(72,40,1),TT(72,40,1),SHT(72,40,1),    B4M00470
                     *PT(2880,1)                                                       B4M00480
  ISN 0021             EQUIVALENCE                                                     B4M00490
                     $    (Q(1,1,1,1),U(1,1,1),PHIS(73,1)),(TS(1,1),PHIS(721,1)),      B4M00500
                     $    (V(1,1,1),PHIS(793,1)),(SHS(1,1),PHIS(1441,1)),              B4M00510
                     $    (T(1,1,1),PHIS(1513,1)),(P(1,1),PHIS(2161,1)),               B4M00520
                     $    (SH(1,1,1),PHIS(2233,1)),(QT(1,1,1,1),UT(1,1,1),PU(73,1)),   B4M00530
                     $    (GT(1,1),PU(721,1)),(VT(1,1,1),PU(793,1)),                   B4M00540
                     $    (GW(1,1),PU(1441,1)),(TT(1,1,1),PU(1513,1)),                 B4M00550
                     $    (PT(1,1),PU(2161,1)),(SHT(1,1,1),PU(2233,1)),(C(1),JSP)      B4M00560
  ISN 0022             COMMON/SMOO/ISMTH,NPC                                           B4M00570
  ISN 0023             COMMON/TPG/TOPOG(72,46)                                         B4M00580
  ISN 0024             COMMON /DBUG/ISWTCH                                             B4M00590
  ISN 0025             COMMON/S/JMIN,JMAX,JSUM,SMTH(37,17)                             B4M00600
  ISN 0026             COMMON/MLFS/NSEQ,MLF(10),MATSNX,MSM1,NCM1                       B4M00610
  ISN 0027             REAL*8 ADATE,ATIME,WCODE,BLANK/'        '/,ONTAPE/'ON TAPE.'/   B4M00620
  ISN 0028             LOGICAL EVENT                                                   B4M00630
  ISN 0029             NAMELIST/OUPUTZ/JSP,JNP,IM,NLAY,PTOP,ISTART,J1,JM,KM,TAUT,IROT, B4M00640
                     *  WROT,NR,JSB,JNB,DLAT,DLON,JTEST,ITEST,DT,NCYCLE,NCOMP3,NHOGAN, B4M00650
                     *  TAUP,TAUI,TAUE,TAUO,DTMULT,PSL,ED,FMU,CDX,NFLW,PSF,SIG,DSIG,   B4M00660
                     * ISMTH,MATSUN,ISWTCH                                              B4M00670
  ISN 0030             INTFX(XTAU)=INT(XTAU*XINT+.5)                                   B4M00680
```

```
ISN 0031            EVENT(XTAU)=MOD(ITAU,INTFX(XTAU)).LT.IDTHR                       B4M00690
ISN 0032            CALL SUPUND                                                      B4M00700
ISN 0033            CALL DATE(ADATE)                                                 B4M00710
ISN 0034            CALL TIME(ATIME)                                                 B4M00720
ISN 0035            CALL CLOCKS(ITM)                                                 B4M00730
ISN 0036            NDS=1                                                            B4M00740
ISN 0037            ITIME=ITM                                                        B4M00750
ISN 0038            LNTM=ITM                                                         B4M00760
ISN 0039            CALL INPUT                                                       B4M00770
ISN 0040            CALL INPUT4                                                      B4M00780
ISN 0041            DTSAVE = DT                                                      B4M00790
ISN 0042            DTS2=2.*DT                                                       B4M00800
              C     NPC=0  FOR PREDICTOR STEP                                        B4M00810
              C     NPC=1  FOR CORRECTOR STEP                                        B4M00820
ISN 0043            TAUO=TAUI+12.                                                    B4M00830
ISN 0044            DTHR=DT/3600.                                                    B4M00840
ISN 0045            IDTHR=INTFX(DTHR)                                                B4M00850
ISN 0046            I24=INTFX(24.)                                                   B4M00860
ISN 0047            NSTP=.5+TAU/DTHR                                                 B4M00870
ISN 0048            NSTEPC=.5+(TAU-TAUI)/DTHR                                        B4M00880
ISN 0049            WRITE(3,26)NSTEPC                                                B4M00890
ISN 0050         26 FORMAT(//30X,'FIRST NSTEP=',I5//)                                B4M00900
ISN 0051            NSTEP=0                                                          B4M00910
ISN 0052            IF(NSEQ.EQ.1)MLF(2)=MATSUN                                       B4M00920
ISN 0054            MATSNX=MLF(1)                                                    B4M00930
ISN 0055            ITAU=NSTP*IDTHR                                                  B4M00940
ISN 0056            TAU = FLOAT(ITAU)/XINT                                           B4M00950
ISN 0057            IDAY=ITAU/I24                                                    B4M00960
ISN 0058            TOFDAY=FLOAT(ITAU-IDAY*I24)/XINT                                 B4M00970
ISN 0059            CALL DAILY0                                                      B4M00980
ISN 0060            IF(IALTER.GT.0) CALL ALTER                                       B4M00990
ISN 0062            WRITE (3,OUPUTZ)                                                 B4M01000
ISN 0063            TAUST=TAU                                                        B4M01010
ISN 0064            TAPNUM=XLABEL(20)                                                B4M01020
ISN 0065            WRITE (3,901) TAPNUM,TAUST,TAU,TAUT,XLABEL                       B4M01030
ISN 0066            WCODE=BLANK                                                      B4M01040
ISN 0067            WRITE(3,24)                                                      B4M01050
ISN 0068         24 FORMAT(////50X,'NEW FOURTH ORDER'//)                             B4M01060
ISN 0069            IF(ISTART.LE.4) GO TO 45                                         B4M01070
              C**** MAIN LOOP                                                        B4M01080
ISN 0071         40 WCODE=BLANK                                                      B4M01090
ISN 0072            IF(IALTER.GT.0) CALL ALTER2                                      B4M01100
ISN 0074         45 CONTINUE                                                         B4M01110
ISN 0075            NSTEPT=NSTEP+NSTEPC                                              B4M01120
ISN 0076            COMG = .FALSE.                                                   B4M01130
ISN 0077            IF(.NOT.EVENT(TAUT)) GO TO 50                                    B4M01140
ISN 0079            COMG = .TRUE.                                                    B4M01150
              C                                                                      B4M01160
              C     REPLACE DT WITH MATSUNS TIME-STEP SIZE SINCE                     B4M01170
              C     ANY RESTART NEEDS TO BEGIN WITH A MATSUNC STEP                   B4M01180
              C                                                                      B4M01190
ISN 0080            TEMP = DT                                                        B4M01200
ISN 0081            DT = DTSAVE                                                      B4M01210
              C                                                                      B4M01220
ISN 0082            CALL CLOCKS(NTM)                                                 B4M01230
ISN 0083            WCODE=ONTAPE                                                     B4M01240
ISN 0084            CALL TWRITE                                                      B4M01250
              C  INITIALIZE PRECIPITATION ARRAY.                                     B4M01260
ISN 0085            ITAU1 = TAU + 0.01                                               B4M01270
ISN 0086            IF (MOD(ITAU1, 12) .NE. 0) GO TO 47                              B4M01280
ISN 0088            DO 46 J = 1, JNP                                                 B4M01290
ISN 0089            DO 46 I = 1, IM                                                  B4M01300
ISN 0090            SDOT(I, J, 3) = 0.                                               B4M01310
ISN 0091            SDOT(I, J, 4) = 0.                                               B4M01320
ISN 0092         46 CONTINUE                                                         B4M01330
ISN 0093         47 CONTINUE                                                         B4M01340
              C                                                                      B4M01350
              C     REPLACE DT WITH CURRENT STEP-SIZE                                B4M01360
              C                                                                      B4M01370
ISN 0094            DT = TEMP                                                        B4M01380
              C                                                                      B4M01390
ISN 0095         50 CALL CLOCKS(NTM)                                                 B4M01400
ISN 0096            TOTM=FLOAT(ITM-NTM)/100.                                         B4M01410
ISN 0097            STM=FLOAT(LNTM-NTM)/100.                                         B4M01420
ISN 0098            LNTM=NTM                                                         B4M01430
ISN 0099            WRITE(3,902)NSTEPT,IDAY,TOFDAY,JDATE,JMONTH,STM,TOTM,TAU         B4M01440
                  1   ,XLABEL(20),WCODE                                              B4M01450
ISN 0100            CALL SSWTCH(4,ISS4)                                              B4M01460
ISN 0101            IF (ISS4.EQ.1) WRITE (15,906)TAU,IDAY,TOFDAY,TAUST,TAUE          B4M01470
ISN 0103            IF (ISS4.EQ.1) CALL SSOFF                                        B4M01480
ISN 0105            CALL SSWTCH (6,KSS6)                                             B4M01490
ISN 0106            IF(KSS6.EQ.1)WRITE(3,27)NSTEP                                    B4M01500
ISN 0108         27 FORMAT(//30X,'LAST  NSTEP=',I5//)                                B4M01510
ISN 0109            IF(KSS6.EQ.1)GOTO 87                                             B4M01520
ISN 0111            IF(TAU+.01 .GT. TAUE)GOTO 88                                     B4M01530
ISN 0113            IF(NSTEPT.NE.0)GO TO 86                                          B4M01540
ISN 0115            DO 60 J=1,JNP                                                    B4M01550
ISN 0116         60 CALL COMP3(U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,J)        B4M01560
```

```
ISN 0117          86 ITAU=ITAU + IDTHR                                                 B4M01570
ISN 0118             NPC=0                                                             B4M01580
ISN 0119             TAU=FLOAT(ITAU)/XINT                                              B4M01590
               C * * *                                                                 B4M01600
ISN 0120             IDAY=ITAU/I24                                                     B4M01610
ISN 0121             TOFDAY=FLOAT(ITAU-IDAY*I24)/XINT                                  B4M01620
ISN 0122             NSTEP=NSTEP+1                                                     B4M01630
ISN 0123             IF(NSEQ.GT.1)GO TO 12                                             B4M01640
ISN 0125             MATSUN=MATSNX                                                     B4M01650
ISN 0126             MATSNX=MLF(2)                                                     B4M01660
ISN 0127             GO TO 11                                                          B4M01670
ISN 0128          12 NTH=MOD(NSTEP-1,NSEQ)+1                                           B4M01680
ISN 0129             NEXT=MOD(NSTEP,NSEQ)+1                                            B4M01690
ISN 0130             MATSUN=MLF(NTH)                                                   B4M01700
ISN 0131             MATSNX=MLF(NEXT)                                                  B4M01710
ISN 0132          11 CONTINUE                                                          B4M01720
ISN 0133             DT=DTSAVE                                                         B4M01730
ISN 0134             IF(MATSUN.EQ.0)DT=DTS2                                            B4M01740
ISN 0136             CALL COMPO(U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,UT,VT,TT,  B4M01750
                    $     SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL)              B4M01760
ISN 0137             IF(ISMTH.EQ.0)GO TO 14                                            B4M01770
ISN 0139             IF(NDS.EQ.0)GO TO 14                                              B4M01780
ISN 0141             NSM=MOD(NSTEP-NSM1,ISMTH)                                         B4M01790
ISN 0142             IF(MATSUN.EQ.1)GO TO 14                                           B4M01800
ISN 0144             IF(NSM.GT.1)GO TO 14                                              B4M01810
ISN 0146             CALL SMSHAP(TT,PT,QT,TTPOL,PTPOL,QTPOL,P,Q,PPOL,QPOL)             B4M01820
ISN 0147          14 CONTINUE                                                          B4M01830
ISN 0148             NDS=1                                                             B4M01840
               C *** IF(MATSUNO.OR FIRST LEAP FROG STEP)                               B4M01850
ISN 0149             NPC=1                                                             B4M01860
ISN 0150             IF((MATSUN.EQ.1).OR.(NSTEP.EQ.1))GO TO 84                         B4M01870
ISN 0152             NSTEP=NSTEP+1                                                     B4M01880
ISN 0153             IF(NSEQ.GT.1)GO TO 15                                             B4M01890
ISN 0155             MATSUN=MATSNX                                                     B4M01900
ISN 0156             MATSNX=MLF(2)                                                     B4M01910
ISN 0157             GO TO 18                                                          B4M01920
ISN 0158          15 NTH=MOD(NSTEP-1,NSEQ)+1                                           B4M01930
ISN 0159             NEXT=MOD(NSTEP,NSEQ)+1                                            B4M01940
ISN 0160             MATSUN=MLF(NTH)                                                   B4M01950
ISN 0161             MATSNX=MLF(NEXT)                                                  B4M01960
ISN 0162          18 CONTINUE                                                          B4M01970
ISN 0163             ITAU=ITAU + IDTHR                                                 B4M01980
ISN 0164             TAU=FLOAT(ITAU)/XINT                                              B4M01990
ISN 0165             IDAY=ITAU/I24                                                     B4M02000
ISN 0166             TOFDAY=FLOAT(ITAU-IDAY*I24)/XINT                                  B4M02010
ISN 0167        84   CALL COMPO(UT,VT,TT,SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,     B4M02020
                    $     QTPOL,U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL)           B4M02030
ISN 0168             IF(ISMTH.EQ.0)GO TO 17                                            B4M02040
ISN 0170             NSM=MOD(NSTEP-NSM1,ISMTH)                                         B4M02050
ISN 0171             IF(NSM.GT.1)GO TO 17                                              B4M02060
ISN 0173             IF(MATSUN*NSM.EQ.1)GO TO 17                                       B4M02070
ISN 0175             CALL SMSHAP(T,P,Q,TPOL,PPOL,QPOL,PT,QT,PTPOL,QTPOL)               B4M02080
ISN 0176          17 CONTINUE                                                          B4M02090
ISN 0177             IF(MATSUN.EQ.1)NDS=0                                              B4M02100
ISN 0179             IF(EVENT(24.)) CALL DAILY                                         B4M02110
ISN 0181             GOTO 40                                                           B4M02120
               C**** END OF MAIN LOOP                                                  B4M02130
ISN 0182          87 WRITE(3,905)                                                      B4M02140
ISN 0183             WRITE (15,905)                                                    B4M02150
ISN 0184          88 CONTINUE                                                          B4M02160
ISN 0185             WRITE (3,904) IDAY,TOFDAY                                         B4M02170
ISN 0186             STOP                                                              B4M02180
ISN 0187        901  FORMAT('0TAPE ',A4,'  TAUS',2F10.3,F8.3,5X,20A4,/,                B4M02190
                    1  '     WCODE=',2A4)                                              B4M02200
ISN 0188         902 FORMAT(5X,'STEP'I4,5X,'SIMU TIME IS DAY' I4,7X,'HOUR'F7.3,I5,1X2A4,B4M02210
                   12F7.2,6X,'TAU=',F9.3,' TAPE='A4,' WCODE=',2A4)                     B4M02220
ISN 0189         904 FORMAT ('0PROGRAM HAS TERMINATED AT DAY',I4,' HOUR',F7.3)         B4M02230
ISN 0190         905 FORMAT(' SENSE SWITCH 6 ON')                                      B4M02240
ISN 0191         906 FORMAT(' SS4 ON. TAU='F8.2,2X'DAY'I4,2X'HOUR'F6.2/                B4M02250
                    *  ' RUN START'F8.2,2X'WILL END'F6.2)                              B4M02260
ISN 0192             END                                                               B4M02270

                                          /      MAIN /      SIZE OF PROGRAM 00116C HEXADECIMAL BYTES

NAME TAG TYPE ADD.    |= ***    % NAME TAG TYPE ADD.    |= ***    % NAME TAG TYPE ADD.    |= ***    % NAME TAG TYPE ADD.    |= ***    %
      C       CE  R*4  000000            F       C  R*4    N.R.              I SF          I*4  000388              J SFA         I*4  00038C
      P SFA   CE  R*4  002F10            Q SFA  CE  R*4  000E70              R         C  R*4    N.R.              T SFA  CE  R*4  0024F0
      U SFA   CE  R*4  000E70            V SFA  CE  R*4  0019B0              W         C  R*4    N.R.             CP         C  R*4    N.R.
     DT SF     C  R*4  00006C           ED       C  R*4  00012C             GT        CE  R*4  000840             GW        CE  R*4  001680
     IN  F     C  I*4  000008           JM       C  I*4  000030             JA         C  I*4  00002C             KN         C  I*4  000034
     NR        C  I*4  00004C           PI       C  R*4    N.R.             PK         C  R*4    N.R.             PT SFA  CE  R*4  0021C0
     PU       CE  R*4  000000           QT SFA  CE  R*4  000120             SH SFA  CE  R*4  003030             TS        CE  R*4  001890
     TT SFA   CE  R*4  0017A0           UT SFA  CE  R*4  00012C             VT SFA  CE  R*4  000C60            CDX         C  R*4  000144
    DXP        C  R*4    N.R.          DXU       C  R*4    N.R.            DYP         C  R*4    N.R.            DYU         C  R*4    N.R.
    FIN        C  R*4    N.R.          FMU       C  R*4  000124            INC         C  I*4    N.R.            ITN SFA        I*4  0003C0
    I24 SFA       I*4  0003C4          JNB       C  I*4  0000BC            JNP  F      C  I*4  000004            JP1         C  I*4    N.R.
    JP2        C  I*4    N.R.          JSB       C  I*4  0000AC            JSP        CE  I*4  000000            LAT         C  R*4    N.R.
    MLF SF     C  I*4  000004          NSM S        I*4  0003C8            NDS S          I*4  0003CC            NPC S       C  I*4  000004
```

```
   NTH SF       I*4   0003D0        NTM SFA       I*4   0003D4          PSF         C  R*4   00012C         PSL         C  R*4   00011C
   PSM        C R*4     N.R.        QSM         C R*4     N.R.          RAD         C  R*4     N.R.         SHS        CE  R*4   002300
   S4T SFA CE   R*4   0022E0        SIG         C R*4   00037C          SLP         C  R*4     N.R.         STM SF         R*4   000308
   SUM        C R*4     N.R.        TAU SF      C R*4   0000CC          TMP         C  R*4     N.R.        BETA         C  R*4     N.R.
  CATA        C R*4     N.R.       COMG S       C L*4   0389A4         CON1         C  R*4     N.R.        CON2         C  R*4     N.R.
  CON3        C R*4     N.R.       CON4         C R*4     N.R.         CONS         C  R*4     N.R.        COSD         C  R*4     N.R.
  COSL        C R*4     N.R.       CPD2         C R*4     N.R.         CPTH         C  R*4     N.R.        DATA         C  R*4     N.R.
  DATE SF    XF R*4   000000       DIFF         C R*4     N.R.         DLAT         C  R*4   000084        DLON         C  R*4   000088
  DSIG        C R*4   0003C0       DTHR SFA       R*4   0003DC         DTS2 SF         R*4   0003E0        DXYP         C  R*4     N.R.
  FAST        C L*4   00000C       GRAV         C R*4     N.R.         IDAY SFA    C   I*4   0000CC        IND2         C  I*4     N.R.
  INCS        C I*4     N.R.       IROT         C I*4   00003C         ISS4 SFA        I*4   0003E4        ITAU SFA     C  I*4   0000C4
  JAYS        C I*4     N.R.       JDAY         C I*4     N.R.         JEND         C  I*4     N.R.        JMAX         C  I*4     N.R.
  JMIN        C I*4     N.R.       JMPS         C I*4     N.R.         JMS1         C  I*4     N.R.        JMS2         C  I*4     N.R.
  JMUS        C I*4     N.R.       JPOL         C I*4     N.R.         JSUM         C  I*4     N.R.        JIP5         C  I*4     N.R.
  JIUS        C I*4     N.R.       KAPA         C R*4     N.R.         KNBS         C  I*4     N.R.        KSBS         C  I*4     N.R.
  KSS6 SFA      I*4   0003E8       LNTM SFA       I*4   0003EC         MRCH         C  I*4     N.R.        MROT         C  I*4   000040
  NCM1        C I*4     N.R.       NEXT SF        I*4   0003FC         NFLW         C  I*4   000128        NLAY         C  I*4   00000C
  NOC3        C L*4   000004       NSEQ  FA     C I*4   00000C         NSM1  FA     C  I*4   000030        NSTP SF         I*4   0003F4
  PHIS       CE R*4   000050       PPOL SFA CE    R*4   000654         PTOP         C  R*4   000010        QPOL SFA CE     R*4   000414
  RADT        C I*2     N.R.       RGAS         C R*4     N.R.         SOCT S      CE  R*4   000000        SIGE         C  R*4     N.R.
  SINC        C R*4     N.R.       SINL         C R*4     N.R.         SMTH         C  R*4     N.R.        TAUE  F      C  R*4   000100
  TAUI  F     C R*4   0000FC       TAUO S       C R*4   000104         TAUP         C  R*4   0000F8        TAJT  FA     C  R*4   000038
  TEMP SF       R*4   0003F8       TIME SF     XF R*4   00000C         TOTM SF         R*4   0003FC        TPOL SFA CE     R*4   00045C
  UPOL SFA CE   R*4   000414       VPOL SFA CE    R*4   00043E         XINT  FA     C  R*4   0000C8       ADATE SFA        R*8   000420
 ADLDP        C R*4     N.R.      ALPHA         C R*4     N.R.        ALTER SF     XF  R*4   000000       ATIME SFA        R*8   000428
 BLANK  F       R*8   000430      COMPO SF     XF R*4   00000C        COMP3 SF     XF  R*4   000000       C3WRT         C  L*4   000000
 DAILY SF    XF R*4   00[illegible]0      DSIGO         C R*4     N.R.        DUMMY         C  R*4     N.R.       EVENT S   ASF   L*4   000000
 IDTHR SF       I*4   000400      INDEX         C I*4     N.R.        INPUT SF     XF  I*4   000000       INTFX S  AASF   I*4   000000
 ISDOT       CE I*2   00CF00      ISMTH  FA     C I*4   00000C        ITAU1 S  A       I*4   000404       ITEST         C  I*4   000048
 ITIME S        I*4   000408      JDATE  F      C I*4   0000DE        JNEXT         C  I*4     N.R.       JNPM1         C  I*4     N.R.
 JPMOD        C I*4     N.R.      JSPP1         C I*4     N.R.        JTEST         C  I*4   000044       JYEAR         C  I*4     N.R.
 MODPK        C I*4     N.R.      NSTEP SFA     C I*4   0000E8        OMEGA         C  I*2     N.R.       POLES        CE  R*4   000414
 PSIGN        C R*4     N.R.      PTPOL SFA CE    R*4   00065C        QTPOL SFA CE     R*4   000534       RADIM         C  R*4     N.R.
 RHMAX        C R*4     N.R.      SDPOL         C R*4     N.R.        SHPOL SFA CE     R*4   000480       SSOFF SF     XF  R*4   000000
 TAUST SF       R*4   00040C      THBAR         C R*4     N.R.        TOPOG         C  R*4     N.R.       TTPOL SFA CE     R*4   00057C
 UTPOL SFA CE   R*4   000534      VTPOL SFA CE    R*4   00055E        WCODE SF         R*8   000438       WORKX         C  R*4     N.R.
ADPCLD        C L*4   000018     ALBEDO         C I*2     N.R.       ALTER2 SF     XF  R*4   000000      CLOCKS SF     XF  R*4   000000
CONVPL        C R*4     N.R.     COSLON         C R*4     N.R.       DAILYO SF     XF  R*4   000000      DTMULT         C  R*4   000108
DTSAVE SF       R*4   000410     DUMMYA         C R*4     N.R.       DUMMYC         C  R*4     N.R.      FWRNL#  F     XF  R*4   000000
IALTER        C I*4   000190     IBCOM#  F     XF R*4   00000C       IND2P1         C  I*4     N.R.      INPUT4 SF     XF  I*4   000000
ISTART        C I*4   000014     ISWTCH         C I*4   00000C       JMONTH  F      C  I*4   0000DC      MATSNX SF      C  I*4   00002C
MATSUN SF     C I*4   000058     MNMXTS         C I*4     N.R.       NCOMP3         C  I*4   0000F0      NCYCLE         C  I*4   0000EC
NHOGAN        C I*4   0000F4     NLAYM1         C I*4     N.R.       NLAYP1         C  I*4     N.R.      NSTART         C  I*4     N.R.
NSTEPC SF       I*4   000414     NSTEPT SF        I*4   00041E       ONTAPE  F         R*8   000440      OUPUTZ  F               000001
PHISPL        C R*4     N.R.     PITPOL           R*4     N.R.       PSKAPA         C  R*4     N.R.      PSMPOL         C  R*4     N.R.
QSMPOL        C R*4     N.R.     RSDIST         C R*4     N.R.       SHSMOO         C  L*4   000008      SHTPOL SFA CE     R*4   0005A0
SINLON        C R*4     N.R.     SMAFTA         C L*4   000014       SMSHAP SF     XF  R*4   000000      SSWTCH SF     XF  R*4   000000
SUPUND SF    XF R*4   000000     TAPNUM SF        R*4   00041C       TOFDAY SF      C  R*4   000004      TWRITE SF     XF  R*4   000000
XLABEL  F     C R*4   000320

                                       *****  COMMON INFORMATION   *****

    NAME OF CCMMON BLOCK * F;U#.ZE OF ELOCKCOMMON      005E24 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      CON1    R*4      N.R.           CON2    R*4      N.R.           CON3    R*4      N.R.           CON4    R*4      N.R.
      CONS    R*4      N.R.          THBAR    R*4      N.R.          ALPHA    R*4      N.R.           BETA    R*4      N.R.
    IND2P1    I*4      N.R.          ADLCP    R*4      N.R.           JMS2    I*4      N.R.           JMS1    I*4      N.R.
      CPTH    R*4      N.R.         PSKAPA    R*4      N.R.              R    R*4      N.R.            RAD    R*4      N.R.
        CP    R*4      N.R.            INC    I*4      N.R.         NSTART    I*4      N.R.           CPD2    R*4      N.R.
      IND2    I*4      N.R.          RADIM    R*4      N.R.           JEND    I*4      N.R.            JP1    I*4      N.R.
       JP2    I*4      N.R.         MATSUN    I*4    000068          JNEXT    I*4      N.R.          MODPK    I*4      N.R.
      JPOL    I*4      N.R.          JPMCD    I*4      N.R.         SINLON    R*4      N.R.         COSLON    R*4      N.R.
     INDEX    I*4      N.R.          PSIGN    R*4      N.R.          POLES    R*4    000414              #    R*4      N.R.
        PK    R*4      N.R.           DIFF    R*4      N.R.         CONVPL    R*4      N.R.          SDPOL    R*4      N.R.
    PHISPL    R*4      N.R.            SUM    R*4      N.R.

  EQUIVALENCED VARIABLES WITHIN THIS CCMMEN GRCUP
   VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
      QPOL    000414                QTPOL    000534                UPOL    000414                VPOL    000438
      TPOL    00045C                SHPCL    000480               UTPOL    000534               VTPOL    000558
     TTPCL    00057C               SHTPOL    0005AC                PPOL    000654               P7POL    00065C


    NAME OF CCMMON BLCCK *  =M..ZE OF ELOCKCOMMON      000148 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      QSM     R*4      N.R.            PSM    R*4      N.R.         QSMPOL    R*4      N.R.         PSMPOL    R*4      N.R.

    NAME OF CCMMON BLOCK *  =M6.ZE OF ELOCKCOMMON      003E70 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      DATA    R*4      N.R.           CATA    R*4      N.R.            SLP    R*4      N.R.
```

```
  NAME OF COMMON BLOCK *  }HWR.E OF BLOCKCOMMON     00001C HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   C3WRT    L*4   000000          NOC3     L*4   000004         SHSMOO    L*4   000008           FAST    L*4   00000C
     TMP    R*4     N.R.        SHAFTA     L*4   000014         ADPCLD    L*4   000018

  NAME OF COMMON BLOCK * S*OT'9E OF BLOCKCOMMON     0385A8 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    SDOT    R*4   000000         OMEGA     I*2     N.R.         MNMXTS    I*4     N.R.           RADT    I*2     N.R.
    COMG    L*4   0389A4

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE            VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
   ISDOT    00CF00

  NAME OF COMMON BLOCK *  ¬NTR#E OF BLOCKCOMMON     083C30 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
     JSP    I*4   000000           JNP     I*4   000004             IM    I*4   000008           NLAY    I*4   00000C
    PTOP    R*4   000010        ISTART     I*4   000014          JSPP1    I*4     N.R.          JNPM1    I*4     N.R.
     FIM    R*4     N.R.        NLAYM1     I*4     N.R.         NLAYP1    I*4     N.R.             J1    I*4   00002C
      JM    I*4   000030            KM     I*4   000034           TAUT    R*4   000038           IROT    I*4   00003C
    MROT    I*4   000040         JTEST     I*4   000044          ITEST    I*4   000048             NR    I*4   00004C
    JAYS    I*4     N.R.          INCS     I*4     N.R.            JSB    I*4   0000AC            JNB    I*4   0000B0
    DLAT    R*4   0000B4          DLON     R*4   0000B8             DT    R*4   0000BC            TAU    R*4   0000C0
    ITAU    I*4   0000C4          XINT     R*4   0000C8           IDAY    I*4   0000CC           JDAY    I*4     N.R.
  TOFDAY    R*4   0000D4         JDATE     I*4   0000D8         JMONTH    I*4   0000DC          JYEAR    I*4     N.R.
   NSTEP    I*4   0000E8        NCYCLE     I*4   0000EC         NCOMP3    I*4   0000F0         NMOGAN    I*4   0000F4
    TAUP    R*4   0000F8          TAUI     R*4   0000FC           TAUE    R*4   000100           TAUO    R*4   000104
  DTMULT    R*4   000108            PI     R*4     N.R.           GRAV    R*4     N.R.           RGAS    R*4     N.R.
    KAPA    R*4     N.R.           PSL     R*4   00011C             ED    R*4   000120            FMU    R*4   000124
    NFLW    I*4   000128           PSF     R*4   00012C           MRCH    I*4     N.R.         RSDIST    R*4     N.R.
    SIND    R*4     N.R.          COSD     R*4     N.R.          RHMAX    R*4     N.R.            CDX    R*4   000144
  DUMMYC    R*4     N.R.        IALTER     I*4   000198         DUMMYA    R*4     N.R.         XLABEL    R*4   000320
     SIG    R*4   000370          DSIG     R*4   0003C0           SIGE    R*4     N.R.          DSIGO    R*4     N.R.
    J1PS    I*4     N.R.          JMPS     I*4     N.R.           J1US    I*4     N.R.           JMUS    I*4     N.R.
    KSBS    I*4     N.R.          KNBS     I*4     N.R.            LAT    R*4     N.R.            DXU    R*4     N.R.
     DXP    R*4     N.R.           DYU     R*4     N.R.            DYP    R*4     N.R.           DXYP    R*4     N.R.
       F    R*4     N.R.          SINL     R*4     N.R.           COSL    R*4     N.R.          DUMMY    R*4     N.R.
    PHIS    R*4   000050        ALBEDG     I*2     N.R.

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE            VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
       Q    000E70                   U    000E70                  TS    001890                   V    001980
     SHS    0023D0                   T    0024F0                   P    002F10                  SH    003030
       C    000000

  NAME OF COMMON BLOCK *  *W6R#E OF BLOCKCOMMON     01D1C0 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   WORKX    R*4     N.R.

  NAME OF COMMON BLOCK *  =O#S#E OF BLOCKCOMMON     081C00 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      PU    R*4   000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE            VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
      QT    000120                  UT    000120                  GT    000840                  VT    000C60
      GW    001680                  TT    0017A0                  PT    0021C0                 SHT    0022E0

  NAME OF COMMON BLOCK *  *S6¬*E OF BLOCKCOMMON     000008 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   ISMTH    I*4   000000           NPC     I*4   000004

  NAME OF COMMON BLOCK *  * T¬?E OF BLOCKCOMMON     0033C0 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   TOPOG    R*4     N.R.

  NAME OF COMMON BLOCK *  *DS_7E OF BLOCKCOMMON     000004 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  ISWTCH    I*4   000000

  NAME OF COMMON BLOCK *  * SI.E OF BLOCKCOMMON     0005E0 HEXADECIMAL BYTES
```

```
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    JMIN     I*4      N.R.            JMAX     I*4      N.R.            JSUM     I*4      N.R.            SMTH     R*4      N.R.

  NAME OF COMMON BLOCK *  *M3|.E OF BLOCKCOMMON     000C38 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    NSEQ     I*4    000000            MLF      I*4    000004            MATSNX   I*4    00002C            NSM1     I*4    000030
```

```
   LABEL   ADDR                LABEL   ADDR                LABEL   ADDR                LABEL   ADDR
      40   000A44                 45   000A62                 46   000B7A                 47   000B82
      50   000B9A                 60   000D66                 86   000D86                 12   000E4A
      11   000E8A                 14   000F0A                 15   000F6E                 18   000FAE
      84   001032                 17   00108E                 87   0010F2                 88   00111C

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=55,SIZE=100K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      191  PROGRAM SIZE=      4460

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                             852K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                                  OS/360 FORTRAN H AT GISS                              DATE 12/12/79-0783.03

         COMPILER OPTIONS -   NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                              SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
   ISN 0002                 SUBROUTINE DAILY                                                      B4M02280
                      C**** FINE NINE LAYER GLOBAL CDE BLOCK FOR VM MODEL, FEBRUARY 1976          B4M02290
   ISN 0003                 INTEGER*2 ALBEDO                                                      B4M02300
   ISN 0004                 REAL*4 KAPA,LAT                                                       B4M02310
                      C     REAL*8 SINLON,COSLON,SUM                                              B4M02320
   ISN 0005                 COMMON/FOURTH/CON1,CON2,CON3,CON4,CONS,THBAR,ALPHA,BETA,IMD2P1,       B4M02330
                           $   ADLDP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP, INC,NSTART,CPD2,             B4M02340
                           $   IMD2,RADIM,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),             B4M02350
                           $   JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),              B4M02360
                           $   PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),                  B4M02370
                           $   CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                            B4M02380
   ISN 0006                 EQUIVALENCE (QPOL(1,1,1),POLES(1)),(QTPOL(1,1,1),POLES(73)),          B4M02390
                           $   (UPOL(1,1),POLES(1)),(VPOL(1,1),POLES(10)),(TPOL(1,1),             B4M02400
                           $   POLES(19)),(SHPOL(1,1),POLES(28)),(UTPOL(1,1),POLES(73)),          B4M02410
                           $   (VTPOL(1,1),POLES(82)),(TTPOL(1,1),POLES(91)),(SHTPOL(1,1),        B4M02420
                           $   POLES(100)),(PPOL(1),POLES(145)),(PTPOL(1),POLES(147))             B4M02430
   ISN 0007                 DIMENSION PPOL(2),PITPCL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),         B4M02440
                           $   SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                               B4M02450
   ISN 0008                 DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),               B4M02460
                           $   SHTPOL(36,1),QTPOL(9,4,2),QT(72,10,4,1)                            B4M02470
   ISN 0009                 COMMON /CNTRL/                                                        B4M02480
                           *  JSP,JNP,IM,NLAY,PTOP,ISTART,JSFP1,JNPM1,FIM,NLAYM1,NLAYP1,          B4M02490
                           *  J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                                B4M02500
                           *  NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                             B4M02510
                           *  DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,      B4M02520
                           *  NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUO,DTMULT,                    B4M02530
                           *  PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLW,PSF,MRCH,RSDIST,SIND,COSD,        B4M02540
                           *  RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                             B4M02550
                           *  XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                     B4M02560
                           *  J1PS(11),JMPS(11),J1US(11),JMUS(11),KSES(11),KNBS(11),              B4M02570
                           *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),      B4M02580
                           *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                        B4M02590
   ISN 0010                 DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),               B4M02600
                           *P(2880,1),TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)         B4M02610
   ISN 0011                 EQUIVALENCE (U(1,1,1),PHIS(73,1)),(TS(1,1),PHIS(721,1)),              B4M02620
                           $   (V(1,1,1),PHIS(793,1)),(SHS(1,1),PHIS(1441,1)),                    B4M02630
                           $   (T(1,1,1),PHIS(1513,1)),(P(1,1),PHIS(2161,1)),                     B4M02640
                           $   (SH(1,1,1),PHIS(2233,1)),(GT(1,1),PU(721,1)),(GW(1,1),             B4M02650
                           $    PU(1441,1)),(C(1),JSP)                                            B4M02660
   ISN 0012                 COMMON /WORK2/PU(2880,46)                                             B4M02670
   ISN 0013                 INTEGER AMONTH,DAYSPM,DAYSPY                                          B4M02680
   ISN 0014                 DIMENSION AMONTH(2,12),DAYSPM(12)                                     B4M02690
   ISN 0015                 DATA AMONTH/'JANU','ARY ','FEBR','UARY','MARC','H   ','APRI',         B4M02700
                           $   'L   ','MAY ','    ','JUNE','    ','JULY','    ','AUGU',           B4M02710
                           $   'ST  ','SEPT','EMBR','OCTO','BER ','NOVE','MBER','DECE',           B4M02720
                           $   'MBER'/                                                            B4M02730
   ISN 0016                 DATA DAYSPM/31,28,31,30,31,30,31,31,30,31,30,31/                      B4M02740
   ISN 0017                 DATA IDAY0/302/,DAYSPY/365/                                           B4M02750
   ISN 0018                 DATA SOLS,APHEL,ECCN/173.,183.,.0178/                                 B4M02760
   ISN 0019                 IFIRST=0                                                              B4M02770
                      C**** CALCULATE GLOBAL MEAN SURFACE PRESSURE                                B4M02780
                      C * * *                                                                     B4M02790
   ISN 0020               5 SAREA=0.                                                              B4M02800
   ISN 0021                 SMASS=0.                                                              B4M02810
   ISN 0022                 INC=1                                                                 B4M02820
   ISN 0023                 FINC=INC                                                              B4M02830
   ISN 0024                 DO 20 J=2,JM                                                          B4M02840
   ISN 0025                 SPRESS=0.                                                             B4M02850
   ISN 0026                 DO 10 I=INC,IM,INC                                                    B4M02860
   ISN 0027              10 SPRESS=SPRESS+P(I,J)                                                  B4M02870
   ISN 0028                 SAREA=SAREA+DXYP(J)*FIM                                               B4M02880
   ISN 0029              20 SMASS=SMASS+SPRESS*DXYP(J)                                            B4M02890
   ISN 0030                 DAP = 4. * PI * SIN(.5*DLAT) ** 2                                     B4M02900
```

```
ISN 0031            SAREA = SAREA + 2. * DAP                                        B4M02910
ISN 0032            SMASS = SMASS + DAP * (PPOL(1) + PPOL(2))                       B4M02920
ISN 0033            PBAR=SMASS/SAREA+PTOP                                           B4M02930
ISN 0034            IF(IFIRST.NE.1) GO TO 30                                        B4M02940
ISN 0036            PSF=PBAR                                                        B4M02950
ISN 0037            GO TO 50                                                        B4M02960
ISN 0038         30 DELTAP=PSF-PBAR                                                 B4M02970
ISN 0039            DO 40 I=1,IM                                                    B4M02980
ISN 0040            DO 40 J=1,JNP                                                   B4M02990
ISN 0041         40 P(I,J)=P(I,J)+DELTAP                                            B4M03000
ISN 0042            WRITE (3,901) DELTAP                                            B4M03010
               C**** CALCULATE CALENDAR                                             B4M03020
ISN 0043         50 JYEAR=1+(IDAY+IDAY0-1)/DAYSPY                                   B4M03030
ISN 0044            JDAY=IDAY+IDAY0-DAYSPY*(JYEAR-1)                                B4M03040
ISN 0045            J=0                                                             B4M03050
ISN 0046            DO 60 MONTH=1,12                                                B4M03060
ISN 0047            J=J+DAYSPM(MONTH)                                               B4M03070
ISN 0048            IF(JDAY.LE.J) GO TO 70                                          B4M03080
ISN 0050         60 CONTINUE                                                        B4M03090
ISN 0051            WRITE (3,902) JDAY                                              B4M03100
ISN 0052         70 JDATE=JDAY-(J-DAYSPM(MONTH))                                    B4M03110
ISN 0053            JMONTH(1)=AMONTH(1,MONTH)                                       B4M03120
ISN 0054            JMONTH(2)=AMONTH(2,MONTH)                                       B4M03130
               C**** CALCULATE ORBIT POSITION                                       B4M03140
ISN 0055            FDAY=JDAY                                                       B4M03150
ISN 0056            SEASON=(FDAY-SOLS)/DAYSPY                                       B4M03160
ISN 0057            DIST=(FDAY-APHEL)/DAYSPY                                        B4M03170
ISN 0058            DECMAX=PI*(23.5/180.)                                           B4M03180
ISN 0059            DEC=DECMAX*COS(2.*PI*SEASON)                                    B4M03190
ISN 0060            RSDIST=(1.+ECCN*COS(2.*PI*DIST))**2                             B4M03200
ISN 0061            SIND=SIN(DEC)                                                   B4M03210
ISN 0062            COSD=COS(DEC)                                                   B4M03220
ISN 0063            CALL NEWDAY(JDAY)                                               B4M03230
ISN 0064            RETURN                                                          B4M03240
ISN 0065            ENTRY DAILY0                                                    B4M03250
ISN 0066            IF(ISTART.LE.4) GO TO 50                                        B4M03260
ISN 0068            IFIRST=1                                                        B4M03270
ISN 0069            GO TO 5                                                         B4M03280
ISN 0070        901 FORMAT (' PRESSURE ADDED IN GMP IS',F10.6)                      B4M03290
ISN 0071        902 FORMAT ('0JDAY=',I4)                                            B4M03300
ISN 0072            END                                                             B4M03310

                                                 /   DAILY /      SIZE OF PROGRAM 00067C HEXADECIMAL BYTES

NAME TAG TYPE ADD.   |* ***    % NAME TAG TYPE ADD.   |* ***    % NAME TAG TYPE ADD.   |* ***    % NAME TAG TYPE ADD.   |* ***    %
      C      CE   R*4   000005           F       C   R*4    N.R.           I SF        I*4  000120            J SF        I*4  000124
      P SF   CE   R*4   002F10           Q           R*4    N.R.           R       C   R*4    N.R.            T      CE   R*4  0024F0
      U      CE   R*4   000E70           V      CE   R*4  00198C           W       C   R*4    N.R.           CP       C   R*4    N.R.
     DT       C   R*4     N.R.          ED       C   R*4    N.R.          GT      CE   R*4  000840           GW      CE   R*4  001680
     IM  F    C   I*4   000008          JM  F    C   I*4  00003C          J1       C   I*4    N.R.           KM       C   I*4    N.R.
     NR       C   I*4     N.R.          PI  FA   C   R*4  00010C          PK       C   R*4    N.R.           PU      CE   R*4  000000
     QT           R*4     N.R.          SH      CE   R*4  00303C          TS      CE   R*4  001890          CDX       C   R*4    N.R.
    DAP SF        R*4   000128         DEC SFA       R*4  00012C         DXP       C   R*4    N.R.          DXU       C   R*4    N.R.
    DYP       C   R*4     N.R.         DYU       C   R*4    N.R.         FIM F     C   R*4  000020          FMU       C   R*4    N.R.
    INC SF    C   I*4   000044         JNB       C   I*4    N.R.         JNP F     C   I*4  000004          JP1       C   I*4    N.R.
    JP2       C   I*4     N.R.         JSB       C   I*4    N.R.         JSP      CE   I*4  000090          LAT       C   R*4    N.R.
    PSF SF    C   R*4   00012C         PSL       C   R*4    N.R.         RAD       C   R*4    N.R.          SHS      CE   R*4  0023D0
    SIG       C   R*4     N.R.         SUM       C   R*4    N.R.         TAU       C   R*4    N.R.         BETA       C   R*4    N.R.
   CON1       C   R*4     N.R.        CON2       C   R*4    N.R.        CON3       C   R*4    N.R.         CON4       C   R*4    N.R.
   CON5       C   R*4     N.R.        COSD S     C   R*4  00013C        COSL       C   R*4    N.R.         CPD2       C   R*4    N.R.
   CPTH       C   R*4     N.R.        DIFF       C   R*4    N.R.        DIST SFA       R*4  000130         DLAT  FA   C   R*4  000084
   DLON       C   R*4     N.R.        DSIG       C   R*4    N.R.        DXYP F     C   R*4  000950         ECCN  F        R*4  000134
   FDAY SF        R*4   000138        FINC S         R*4  00013C        GRAV       C   R*4    N.R.         IDAY  F    C   I*4  0000CC
   IMD2       C   I*4     N.R.        INCS       C   I*4    N.R.        IROT       C   I*4    N.R.         ITAU       C   I*4    N.R.
   JAYS       C   I*4     N.R.        JDAY SFA   C   I*4  0000D0        JEND       C   I*4    N.R.         JMPS       C   I*4    N.R.
   JMS1       C   I*4     N.R.        JMS2       C   I*4    N.R.        JMUS       C   I*4    N.R.         JPOL       C   I*4    N.R.
   J1PS       C   I*4     N.R.        J1US       C   I*4    N.R.        KAPA       C   R*4    N.R.         KNBS       C   I*4    N.R.
   KSBS       C   I*4     N.R.        MRCH       C   I*4    N.R.        MROT       C   I*4    N.R.         NFLW       C   I*4    N.R.
   NLAY       C   I*4     N.R.        PBAR SF        R*4  00014C        PHIS      CE   R*4  000050         PPOL  F   CE   R*4  000654
   PTOP  F    C   R*4   000010        QPOL      CE   R*4  000414        RGAS       C   R*4    N.R.         SIGE       C   R*4    N.R.
   SIND S     C   R*4   000138        SINL       C   R*4    N.R.        SOLS  F        R*4  000144         TAUE       C   R*4    N.R.
   TAUI       C   R*4     N.R.        TAUQ       C   R*4    N.R.        TAUP       C   R*4    N.R.         TAUT       C   R*4    N.R.
   TPOL      CE   R*4   00045C        UPOL      CE   R*4  000414        VPOL      CE   R*4  000438         XINT       C   R*4    N.R.
  ADLOP       C   R*4     N.R.       ALPHA       C   R*4    N.R.       APHEL  F        R*4  000148        DAILY           R*4  00014C
  DSIGO       C   R*4     N.R.       DUMMY       C   R*4    N.R.       IDAY0  F        I*4  000150        INDEX       C   I*4    N.R.
  ITEST       C   I*4     N.R.       JDATE S     C   I*4  0000D8       JNEXT       C   I*4    N.R.        JNPM1       C   I*4    N.R.
  JPMOD       C   I*4     N.R.       JSPP1       C   I*4    N.R.       JTEST       C   I*4    N.R.        JYEAR SF    C   I*4  0000E4
  MODPK       C   I*4     N.R.       MONTH SF        I*4  000154       NSTEP       C   I*4    N.R.        POLES      CE   R*4  000414
  PSIGN       C   R*4     N.R.       PTPOL      CE   R*4  00065C       QTPOL      CE   R*4  000534        RADIM       C   R*4    N.R.
  RHMAX       C   R*4     N.R.       SAREA SF        R*4  000158       SDPOL       C   R*4    N.R.        SHPOL      CE   R*4  000480
  SMASS SF        R*4   00015C       THBAR       C   R*4    N.R.       TTPOL      CE   R*4  00057C        UTPOL      CE   R*4  000534
  VTPOL      CE   R*4   000558         COS      XF   R*4  000000         SIN      XF   R*4  000000       ALBEDO       C   I*2    N.R.
 AMONTH   F       I*4   00017C      CONVPL       C   R*4    N.R.      COSLON       C   R*4    N.R.       DAILY0           R*4  000160
 DAYSPM   F       I*4   0001DC      DAYSPY  F        I*4  000164      DECMAX SF        R*4  000168       DELTAP SF        R*4  00016C
 DTMULT       C   R*4     N.R.      DUMMYA       C   R*4    N.R.      DUMMYC       C   R*4    N.R.       IALTER       C   I*4    N.R.
 IBCOM#   F  XF   R*4   000000      IFIRST S         I*4  00017C      IND2PI       C   I*4    N.R.       ISTART       C   I*4  000014
 JMONTH S     C   I*4   0000DC      MATSUN       C   I*4    N.R.      NCOMP3       C   I*4    N.R.       NCYCLE       C   I*4    N.R.
 NEWDAY SF   XF   I*4   000000      NHOGAN       C   I*4    N.R.      NLAYM1       C   I*4    N.R.       NLAYP1       C   I*4    N.R.
```

```
NSTART       C  I*4    N.R.      PHISPL         C  R*4    N.R.      PITPOL         R*4    N.R.      PSKAPA     C  R*4    N.R.
RSDIST S     C  R*4  000134      SEASON SFA        R*4  000174      SHTPOL     CE  R*4  0005A0      SINLON     C  R*4    N.R.
SPRESS SF       R*4  000178      TOFDAY         C  R*4    N.R.      XLABEL     C   R*4    N.R.
                                  *****  COMMON INFORMATION   *****

   NAME OF COMMON BLOCK * F;U#.ZE OF BLOCKCOMMON      005E24 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
     CON1     R*4     N.R.           CON2     R*4     N.R.           CON3     R*4     N.R.           CON4     R*4     N.R.
     CONS     R*4     N.R.          THBAR     R*4     N.R.          ALPHA     R*4     N.R.           BETA     R*4     N.R.
   IND2PI     I*4     N.R.          ADLDP     R*4     N.R.           JMS2     I*4     N.R.           JMS1     I*4     N.R.
     CPTH     R*4     N.R.         PSKAPA     R*4     N.R.              R     R*4     N.R.            RAD     R*4     N.R.
       CP     R*4     N.R.            INC     I*4   000044         NSTART     I*4     N.R.           CPD2     R*4     N.R.
     IND2     I*4     N.R.          RADIN     R*4     N.R.           JEND     I*4     N.R.            JP1     I*4     N.R.
      JP2     I*4     N.R.         KATSUN     I*4     N.R.          JNEXT     I*4     N.R.          MODPK     I*4     N.R.
     JPOL     I*4     N.R.          JPMOD     I*4     N.R.         SINLON     R*4     N.R.         COSLON     R*4     N.R.
    INDEX     I*4     N.R.          PSIGN     R*4     N.R.          POLES     R*4   000414              B     R*4     N.R.
       PK     R*4     N.R.           DIFF     R*4     N.R.         CONVPL     R*4     N.R.          SOPOL     R*4     N.R.
   PHISPL     R*4     N.R.            SUM     R*4     N.R.
EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
     QPOL   000414                 QTPCL   000534                  UPOL   000414                  VPOL   000438
     TPOL   00045C                 SHPOL   00048C                 UTPOL   000534                 VTPOL   000558
    TTPOL   00057C                SHTPCL   0005A0                  PPOL   000654                 PTPOL   00065C

   NAME OF COMMON BLOCK *  -NTR#E OF BLOCKCOMMON      083C30 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      JSP     I*4   000005            JNP     I*4   000004             IM     I*4   000008           NLAY     I*4     N.R.
     PTOP     R*4   000010         ISTART     I*4   000014         JSPP1      I*4     N.R.          JNPM1     I*4     N.R.
      FIM     R*4   000020         NLAYM1     I*4     N.R.         NLAYP1     I*4     N.R.             J1     I*4     N.R.
       JM     I*4   000030             KM     I*4     N.R.           TAUT     R*4     N.R.           IROT     I*4     N.R.
     MROT     I*4     N.R.          JTEST     I*4     N.R.          ITEST     I*4     N.R.             NR     I*4     N.R.
     JAYS     I*4     N.R.           INCS     I*4     N.R.            JSB     I*4     N.R.            JNB     I*4     N.R.
     DLAT     R*4   000084           DLCN     R*4     N.R.             DT     R*4     N.R.            TAU     R*4     N.R.
     ITAU     I*4     N.R.           XINT     R*4     N.R.           IDAY     I*4   0000CC           JDAY     I*4   0000D0
   TOFDAY     R*4     N.R.          JDATE     I*4   000008         JMONTH     I*4   0000DC          JYEAR     I*4   0000E4
    NSTEP     I*4     N.R.         NCYCLE     I*4     N.R.         NCOMP3     I*4     N.R.         NHOGAN     I*4     N.R.
     TAUP     R*4     N.R.           TAUI     R*4     N.R.           TAUE     R*4     N.R.           TAUO     R*4     N.R.
   DTMULT     R*4     N.R.             PI     R*4   00010C           GRAV     R*4     N.R.           RGAS     R*4     N.R.
     KAPA     R*4     N.R.            PSL     R*4     N.R.             ED     R*4     N.R.            FMU     R*4     N.R.
     NFLW     I*4     N.R.            PSF     R*4   00012C           MRCH     I*4     N.R.         RSDIST     R*4   000134
     SIND     R*4   000138           COSD     R*4   00013C          RHMAX     R*4     N.R.            CDX     R*4     N.R.
   DUMMYC     R*4     N.R.         IALTER     I*4     N.R.         DUMMYA     R*4     N.R.         XLABEL     R*4     N.R.
      SIG     R*4     N.R.           DSIG     R*4     N.R.           SIGE     R*4     N.R.          DSIGO     R*4     N.R.
     J1PS     I*4     N.R.           JMFS     I*4     N.R.           J1US     I*4     N.R.           JMUS     I*4     N.R.
     KSBS     I*4     N.R.           KNBS     I*4     N.R.            LAT     R*4     N.R.            DXU     R*4     N.R.
      DXP     R*4     N.R.            DYU     R*4     N.R.            DYP     R*4     N.R.           DXYP     R*4   000950
        F     R*4     N.R.           SINL     R*4     N.R.           COSL     R*4     N.R.          DUMMY     R*4     N.R.
     PHIS     R*4   000D50         ALBEDO     I*2     N.R.
EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
        U   000E70                    TS   00189C                     V   001980                   SHS   002300
        T   0024F0                     P   002F10                    SH   003030                     C   000000

   NAME OF COMMON BLOCK *  =O#S#E OF BLOCKCOMMON      081E00 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
       PU     R*4   000000
EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
```

```
     LABEL   ADDR                  LABEL   ADDR                  LABEL   ADDR                  LABEL   ADDR
         5  000298                    10  0002F4                    20  000314                    30  000384
        40  0003FE                    50  000430                    60  00049A                    70  0004C4

*OPTIONS IN EFFECT*        NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*        SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*      SOURCE STATEMENTS =       71   PROGRAM SIZE=       1660

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                              868K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                              OS/360 FORTRAN H AT GISS                                  DATE 12/12/79-0783.04

        COMPILER OPTIONS -   NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  ISN 0002                SUBROUTINE INPUT                                                   B4M03320
  ISN 0003                LOGICAL FLAGS                                                      B4M03330
  ISN 0004                COMMON/LID/FLAGS(5)                                                B4M03340
  ISN 0005                COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,TPBAR,ALPHA,BETA,IND2P1,    B4M03350
                         $   ADLDP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,           B4M03360
                         $   IND2,RADIN,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),          B4M03370
                         $   JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),           B4M03380
                         $   PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),               B4M03390
                         $   CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                         B4M03400
  ISN 0006                EQUIVALENCE (QPOL(1,1,1),POLES(1)),(QTPOL(1,1,1),POLES(73)),       B4M03410
                         $   (UPOL(1,1),POLES(1)),(VPOL(1,1),POLES(10)),(TPOL(1,1),          B4M03420
                         $   POLES(19)),(SHPOL(1,1),POLES(28)),(UTPOL(1,1),POLES(73)),       B4M03430
                         $   (VTPOL(1,1),POLES(82)),(TTPOL(1,1),POLES(91)),(SHTPOL(1,1),     B4M03440
                         $   POLES(100)),(PPOL(1),POLES(145)),(PTPOL(1),POLES(147))          B4M03450
  ISN 0007                DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),      B4M03460
                         $   SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                            B4M03470
  ISN 0008                DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),            B4M03480
                         $   SHTPOL(36,1),QTPOL(9,4,2),QT(72,10,4,1)                         B4M03490
  ISN 0009                INTEGER*2 ALBEDO                                                   B4M03500
  ISN 0010                REAL*4 KAPA,LAT                                                    B4M03510
                    C     REAL*8 SINLON,COSLON,SUM                                           B4M03520
  ISN 0011                REAL*8 ALONG,TWOPI                                                 B4M03530
  ISN 0012                COMMON/INSMSH/F5D6,F17,F98                                         B4M03540
  ISN 0013                COMMON/WORK2/PU(2880,46)                                           B4M03550
  ISN 0014                COMMON/SMITH/QSM(72,9,4,5),PSM(72,5),QSMPOL(9,4,2),PSMPOL(2)       B4M03560
                    C                                                                        B4M03570
  ISN 0015                COMMON/SDOT48/SDOT(72,46,8),OMEGA(72,46,5),MNMXTS,RADT(72,46,10)   B4M03580
                         + ,COMG                                                             B4M03590
  ISN 0016                LOGICAL COMG                                                       B4M03600
                    C                                                                        B4M03610
  ISN 0017                INTEGER*2 RADT,OMEGA                                               B4M03620
  ISN 0018                INTEGER*2 ISDOT(72,46,8)                                           B4M03630
                    C                                                                        B4M03640
  ISN 0019                EQUIVALENCE (SDOT(1,1,5),ISDOT(1,1,1))                             B4M03650
                    C                                                                        B4M03660
  ISN 0020                COMMON /CNTRL/                                                     B4M03670
                         *   JSP,JNP,IM,NLAY,PTOP,ISTART,JSFP1,JNPM1,FIM,NLAYM1,NLAYP1,      B4M03680
                         *   J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                            B4M03690
                         *   NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                         B4M03700
                         *   DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,  B4M03710
                         *   NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUO,DTMULT,                B4M03720
                         *   PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLB,PSF,ARCH,RSDIST,SIND,COSD,    B4M03730
                         *   RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                         B4M03740
                         *   XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                 B4M03750
                         *   J1PS(11),JMPS(11),J1US(11),JMUS(11),KSES(11),KNBS(11),          B4M03760
                         *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),   B4M03770
                         *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                     B4M03780
  ISN 0021                DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),            B4M03790
                         *P(2880,1),    TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)  B4M03800
  ISN 0022                DIMENSION UT(72,40,1),VT(72,40,1),TT(72,40,1),SHT(72,40,1),        B4M03810
                         *PT(2880,1)                                                         B4M03820
  ISN 0023                COMMON/S/JMIN,JMAX,JSUM,SMTH(37,17)                                B4M03830
  ISN 0024                COMMON/MLFS/NSEQ,MLF(10),MATSNX,NSM1,NCM1                          B4M03840
  ISN 0025                EQUIVALENCE                                                        B4M03850
                         $   (Q(1,1,1,1),U(1,1,1),PHIS(73,1)),(TS(1,1),PHIS(721,1)),         B4M03860
                         $   (V(1,1,1),PHIS(793,1)),(SHS(1,1),PHIS(1441,1)),                 B4M03870
                         $   (T(1,1,1),PHIS(1513,1)),(P(1,1),PHIS(2161,1)),                  B4M03880
                         $   (SH(1,1,1),PHIS(2233,1)),(QT(1,1,1,1),UT(1,1,1),PU(73,1)),      B4M03890
                         $   (GT(1,1),PU(721,1)),(VT(1,1,1),PU(793,1)),                      B4M03900
                         $   (GW(1,1),PU(1441,1)),(TT(1,1,1),PU(1513,1)),                    B4M03910
                         $   (PT(1,1),PU(2161,1)),(SHT(1,1,1),PU(2233,1)),(C(1),JSP)         B4M03920
  ISN 0026                DIMENSION C1(300)                                                  B4M03930
  ISN 0027                DIMENSION INCP(46),INCU(46)                                        B4M03940
  ISN 0028                REAL*8 RECORD,ANDEND,DPI                                           B4M03950
  ISN 0029                DIMENSION RECORD(10)                                               B4M03960
```

```
.SN C030           CATA ANDEND/' &END    '/                                            B4M03970
ISN 0031           COMMON/RMWRT/ C3WRT,NCC3,SHSMOO,FAST,TMP,SMAFTA,ADPCLD              B4M03980
ISN 0032           COMMON /DBUG/ISWTCH                                                 B4M03990
ISN 0033           COMMON /LIC35/ITC,GSW                                               B4M04000
ISN 0034           COMMON/SMOO/ISMTH,NPC                                               B4M04010
ISN 0035           COMMON/TPG/TOPOG(72,46)                                             B4M04020
ISN 0036           LOGICAL   C3WRT,NOC3,SHSMOO,FAST,SMAFTA,ADPCLD                      B4M04030
ISN 0037           NAMELIST/INPUTZ/ ISTART,IM,NLAY,NR,JAYS,INCS,PAWZE,IALTER,DSIG,     B4M04040
                 *  DT,NCOMP3,NHOGAN,DTMULT,TAUP,TAUI,TAUE,TAUO,                      B4M04050
                 *  TAUT,MROT,J1,JM,KM,JTEST,ITEST,                                   B4M04060
                 *  PTOP,PSL,ED,FMU,COX,NFLW,PSF,RHMAX,                               B4M04070
                 * XINT,C3WRT,NOC3,SHSMOO,FAST,SMAFTA,ALPHA,ISMTH,MATSUN,ISWTCH       B4M04080
                 1 ,NSEQ,MLF,NSM1,NCM1,ITC,GSW                                        B4M04090
ISN 0038            DATA DISK/'DISK'/                                                  B4M04100
ISN 0039            FAC=60.                                                            B4M04110
ISN 0040            ALPHA = .05                                                        B4M04120
ISN 0041            ISMTH = 6                                                          B4M04130
ISN 0042            MATSUN = 0                                                         B4M04140
               C * * MATSUNO   : NSEQ=1,MLF(1)=1,MATSUN=1                              B4M04150
ISN 0043            NSEQ=1                                                             B4M04160
ISN 0044            NSM1=1                                                             B4M04170
ISN 0045            NCM1=1                                                             B4M04180
ISN 0046            MLF(1)=1                                                           B4M04190
               C * * LEAP FROG: NSEQ=1,MLF(1)=1,MATSUN=0                               B4M04200
               C * * NSM1 IS STEP IN SEQ. WHERE SMSHAF MAY BE CALLED                   B4M04210
               C * * NCM1 IS STEP IN SEQ. WHERE CCMP3  MAY BE CALLED                   B4M04220
               C * * ISMTH  MUST BE MULTIPLE OF NSEQ                                   B4M04230
               C * * NCOMP3 MUST BE MULTIPLE OF NSEQ                                   B4M04240
               C * *                                                                   B4M04250
               C * * NSM1   .NE.  NSEQ OR NSEQ-1                                       B4M04260
               C * * NCM1   .NE.  NSEQ                                                 B4M04270
               C * *                                                                   B4M04280
ISN 0047            IU = 1                                                             B4M04290
ISN 0048            DPI=3.141592654                                                    B4M04300
ISN 0049            PI = DPI                                                           B4M04310
ISN 0050            J1=1                                                               B4M04320
ISN 0051            JM=45                                                              B4M04330
ISN 0052            IM=72                                                              B4M04340
ISN 0053            NLAY=9                                                             B4M04350
ISN 0054            KM=4*NLAY+5                                                        B4M04360
ISN 0055            KMM4=KM-4                                                          B4M04370
ISN 0056            IM4=IM*4                                                           B4M04380
ISN 0057            IMP1 = IM + 1                                                      B4M04390
ISN 0058            IM2 = 2 * IM                                                       B4M04400
ISN 0059            IM2P1 = IM2 + 1                                                    B4M04410
ISN 0050            IM3 = 3 * IM                                                       B4M04420
ISN 0061            IM3P1 =  IM3 + 1                                                   B4M04430
ISN 0062            C3WRT = .FALSE.                                                    B4M04440
ISN C063            NOC3 = .FALSE.                                                     B4M04450
ISN 0064            SHSMOO = .TRUE.                                                    B4M04460
ISN C065            FAST = .FALSE.                                                     B4M04470
ISN C066            TMP = 12.                                                          B4M04480
ISN 0057            SMAFTA = .FALSE.                                                   B4M04490
ISN 0068            JSP=1                                                              B4M04500
ISN 0069            JNP=46                                                             B4M04510
ISN 0070            PTOP=10.                                                           B4M04520
ISN 0071            ISTART=7                                                           B4M04530
ISN 0072            JTEST=33                                                           B4M04540
ISN 0073            ITEST=16                                                           B4M04550
ISN 0074            GRAV=9.81                                                          B4M04560
ISN 0075            RGAS=287.                                                          B4M04570
ISN 0076            KAPA=.286                                                          B4M04580
ISN 0077            PSL=1000.                                                          B4M04590
ISN 0078            ED=0.5                                                             B4M04600
ISN 0079            FMU=0.00067                                                        B4M04610
ISN 0080            NFLW=5                                                             B4M04620
ISN 0081            COX=1.                                                             B4M04630
ISN 0082            XINT=600.                                                          B4M04640
ISN 0083            DT=60.                                                             B4M04650
ISN 0084            NCOMP3=6                                                           B4M04660
ISN 0085            NCYCLE=1000000                                                     B4M04670
ISN 0086            DTMULT=1.                                                          B4M04680
ISN 0087            NHOGAN=4                                                           B4M04690
ISN 0088            RHMAX=1.                                                           B4M04700
ISN 0089            TAUP=-1.                                                           B4M04710
ISN 0090            TAUI=-1.                                                           B4M04720
ISN 0091            TAUE=24000.                                                        B4M04730
ISN 0092            TAUO=24000.                                                        B4M04740
ISN 0093            TAUT=4.0                                                           B4M04750
ISN 0094            IROT=0                                                             B4M04760
ISN 0095            MROT=49                                                            B4M04770
ISN 0096            PAWZE=1.                                                           B4M04780
ISN 0097            RAD=6375000.                                                       B4M04790
ISN C098            SDAY=86400.                                                        B4M04800
ISN 0099            ROTPER=24.                                                         B4M04810
ISN 0100            IALTER=0                                                           B4M04820
ISN 0101            NR=1                                                               B4M04830
               C**** BEGIN TITLE PAGE                                                  B4M04840
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
ISN 0102            WRITE (6,901) IVER                                            B4M04850
ISN 0103            READ (5,902) XLABEL                                           B4M04860
ISN 0104            WRITE (3,903) XLABEL                                          B4M04870
              C**** COPY INPUTZ NAMELIST ONTO CORE TAPE AND TITLE PAGE            B4M04880
ISN 0105         20 READ (5,904) RECORD                                           B4M04890
ISN 0106            WRITE (11,904) RECORD                                         B4M04900
ISN 0107            WRITE (3,905) RECORD                                          B4M04910
ISN 0108            IF(RECORD(1).NE.ANDEND) GO TO 20                              B4M04920
ISN 0110            REWIND 11                                                     B4M04930
ISN 0111            READ (11,INPUTZ)                                              B4M04940
ISN 0112            IF(ISTART.EQ.7) WRITE (3,938) ISTART                          B4M04950
ISN 0114            IF(ISTART.EQ.7.AND.PAWZE.NE.0.) WRITE (15,938) ISTART         B4M04960
              C**** READ IN VARIABLE ALBEDO                                       B4M04970
ISN 0116            READ (40)((ALBEDO(I,J),J=J1,JNP),I=1,IM)                      B4M04980
              C**** READ IN SURFACE GEOPOTENTIAL                                  B4M04990
ISN 0117            READ (17)((PHIS(I,J),J=J1,JNP),I=1,IM)                        B4M05000
ISN 0118            READ (46)((TOPOG(I,J),J=J1,JNP),I=1,IM)                       B4M05010
ISN 0119            WRITE(6,1900)(J,(PHIS(I,J),I=1,IM),J=1,JNP)                   B4M05020
ISN 0120       1900 FORMAT(1X,46(' J=',I3,' PHIS(I,J)='/9(1X,8E13.6/)/))          B4M05030
ISN 0121            WRITE(6,1941)(J,(ALBEDO(I,J),I=1,IM),J=1,JNP)                 B4M05040
ISN 0122       1941 FORMAT(1X,46(' J=',I3,' ALBEDO(I,J)='/2(1X,36I3/)/))          B4M05050
ISN 0123            MNMXTS = TAUT + XINT + .01                                    B4M05060
ISN 0124            IF(PAWZE.EQ.1.) PAUSE ' MOUNT TAPES'                          B4M05070
ISN 0126            CALL SSWTCH (5,KSSW5)                                         B4M05080
ISN 0127            IF(KSSW5.EQ.1) ISTART=8                                       B4M05090
ISN 0129            KTR=8                                                         B4M05100
              C                                                                 * B4M05110
              C * * * ON INITIAL START ENDFILE MODEL OUTPUT TAPE                * B4M05120
              C                                                                 * B4M05130
ISN 0130            IF(ISTART.GE.5.AND.ISTART.LE.7) ENDFILE MTR                   B4M05140
ISN 0132            GO TO (30,120,120,40,110,110,40,90,90),ISTART                 B4M05150
ISN 0133         30 STOP                                                          B4M05160
              C**** SET DEPENDENT QUANTITIES                                      B4M05170
ISN 0134         40 DLON=2.*DPI/IM                                                B4M05180
ISN 0135            DLAT=DPI/JM                                                   B4M05190
ISN 0136            FIM=IM                                                        B4M05200
ISN 0137            KM=4*NLAY+5                                                   B4M05210
ISN 0138            KMM4=KM-4                                                     B4M05220
ISN 0139            IM4=IM*4                                                      B4M05230
ISN 0140            JSPP1=JSP+1                                                   B4M05240
ISN 0141            JNPM1=JNP-1                                                   B4M05250
ISN 0142            JNPP1 = JNP + 1                                               B4M05260
ISN 0143            JMP1D2 = (JM + 1) / 2                                         B4M05270
ISN 0144            JSB=1                                                         B4M05280
ISN 0145            JSBP1 = JSB + 1                                               B4M05290
ISN 0146            JNB=JM                                                        B4M05300
ISN 0147            JNBM1=JNB-1                                                   B4M05310
ISN 0148            NLAYM1=NLAY-1                                                 B4M05320
ISN 0149            NLAYP1=NLAY+1                                                 B4M05330
              C *---IF(DSIG(1).NE.0.) GO TO 60                                    B4M05340
ISN 0150            DO 50 L=1,NLAY                                                B4M05350
ISN 0151         50 DSIG(L)=1./NLAY                                               B4M05360
ISN 0152         60 SIGE(1)=0.                                                    B4M05370
ISN 0153            DO 70 L=1,NLAY                                                B4M05380
ISN 0154            SIGE(L+1)=SIGE(L)+DSIG(L)                                     B4M05390
ISN 0155         70 SIG(L)=.5*(SIGE(L)+SIGE(L+1))                                 B4M05400
ISN 0156            DO 80 L=1,NLAYM1                                              B4M05410
ISN 0157         80 DSIGO(L)=SIG(L+1)-SIG(L)                                      B4M05420
ISN 0158            IF(ISTART.EQ.4) GO TO 120                                     B4M05430
ISN 0160            IF(ISTART.EQ.7) GO TO 110                                     B4M05440
              C**** MACHINE CHECK RESTART, ISTART = 8 OR 9                        B4M05450
ISN 0162         90 IF(KSSW5.NE.1) GO TO 100                                      B4M05460
ISN 0164            WRITE (15,906)                                                B4M05470
ISN 0165            READ (15,907) TAUP                                            B4M05480
ISN 0166        100 TAUP=TAUP-AMOD(TAUP,TAUT)                                     B4M05490
ISN 0167            WRITE (3,908) TAUP                                            B4M05500
ISN 0168            GO TO 120                                                     B4M05510
              C**** INITIAL CONDITIONS FROM UNIT 12, ISTART= 5, 6, OR 7           B4M05520
ISN 0169        110 KTR=12                                                        B4M05530
ISN 0170            IROT=1                                                        B4M05540
ISN 0171            TAU=TAUI                                                      B4M05550
ISN 0172            IF(TAUP.LT.0.) TAUP=TAUI                                      B4M05560
ISN 0174            TAPNUM=DISK                                                   B4M05570
ISN 0175            IF(PAWZE.EQ.0.) GO TO 120                                     B4M05580
ISN 0177            WRITE (15,909)                                                B4M05590
ISN 0178            READ (15,902) TAPNUM                                          B4M05600
ISN 0179            WRITE (3,910) TAPNUM                                          B4M05610
              C     READ TAPE ON UNIT KTR                                         B4M05620
              C                                                                   B4M05630
ISN 0180        120 READ(KTR,ERR=800,END=130)TAUX,C1,((PI(I,J),J=1,JNP),I=1,IM),  B4M05640
                 $    ((TS(I,J),J=1,JNP),I=1,IM),((SHS(I,J),J=1,JNP),I=1,IM),     B4M05650
                 $    ((GT(I,J),J=1,JNP),I=1,IM),((GW(I,J),J=1,JNP),I=1,IM)       B4M05660
ISN 0181            CALL RDTAPE(KTR)                                              B4M05670
ISN 0182            IF (ISTART.LE.4) GO TO 120                                    B4M05680
ISN 0184            IF (TAUX.LT.TAUP-.01) GO TO 120                               B4M05690
ISN 0186            IF (TAUX.LE.TAUP+.01) GO TO 140                               B4M05700
ISN 0188      121   CONTINUE                                                      B4M05710
ISN 0189            WRITE (6,912) TAUP                                            B4M05720
```

```
ISN 0190          CALL EXIT                                                       B4M05730
           C                                                                      B4M05740
ISN 0191      130 IF(ISTART.GE.5)GOTO 830                                         B4M05750
ISN 0193          BACKSPACE KTR                                                   B4M05760
ISN 0194          TAUI=TAUX                                                       B4M05770
ISN 0195      140 TAU=TAUI                                                        B4M05780
ISN 0196          TAUP=TAUX                                                       B4M05790
ISN 0197          DO 145 J=J1.JM                                                  B4M05800
ISN 0198      145 BACKSPACE KTR                                                   B4M05810
ISN 0199          BACKSPACE KTR                                                   B4M05820
ISN 0200          IROT=IROT-1                                                     B4M05830
ISN 0201          IF(ISTART.EQ.4.OR.ISTART.EQ.7) GC TO 160                        B4M05840
           C**** COPY C ARRAY FROM C1 ARRAY                                       B4M05850
ISN 0203          C1(6)=C(6)                                                      B4M05860
ISN 0204          DO 150 K=1.300                                                  B4M05870
ISN 0205      150 C(K)=C1(K)                                                      B4M05880
ISN 0206          IF(ISTART.EQ.2.OR.ISTART.EQ.5) GC TO 160                        B4M05890
ISN 0208          REWIND 11                                                       B4M05900
ISN 0209          READ (11.INPUTZ)                                                B4M05910
ISN 0210      160 IF(KTR.EQ.8) C(16)=C1(16)                                       B4M05920
ISN 0212          IF(KTR.EQ.8) XLABEL(20)=C1(220)                                 B4M05930
ISN 0214          IF(KTR.EQ.12) XLABEL(20)=TAPNUM                                 B4M05940
           C**** CALCULATE DISTANCE PROJECTION ARRAYS                             B4M05950
ISN 0216      190 FJEQ=.5*(JSP+JNP)                                               B4M05960
ISN 0217          DO 200 J=1.JNP                                                  B4M05970
ISN 0218      200 LAT(J)=DLAT*(J-FJEQ)                                            B4M05980
ISN 0219          DO 210 J=1.JNP                                                  B4M05990
ISN 0220          SINL(J)=SIN(LAT(J))                                             B4M06000
ISN 0221      210 COSL(J)=COS(LAT(J))                                             B4M06010
ISN 0222          DO 220 J=1.JM                                                   B4M06020
ISN 0223      220 DXP(J)=RAD*DLON*COSL(J)                                         B4M06030
ISN 0224          DO 230 J=2.JM                                                   B4M06040
ISN 0225          DYU(J) = RAD * DLAT                                             B4M06050
           C      DYU(J)=RAD*(LAT(J)-LAT(J-1))                                    B4M06060
ISN 0226      230                           CONTINUE                              B4M06070
ISN 0227          JMP1D2 = (JM + 1)/2                                             B4M06080
ISN 0228          JNPP1 = JNP + 1                                                 B4M06090
ISN 0229          DO 240 J = 2.JMP1D2                                             B4M06100
ISN 0230          DXYP(J) = 12. * DXP(J) * DYU(J)                                 B4M06110
ISN 0231      240 DXYP(JNPP1-J) = DXYP(J)                                         B4M06120
ISN 0232          DXYP(1) = 0.                                                    B4M06130
ISN 0233          DXYP(JNP) = 0.                                                  B4M06140
ISN 0234          WRITE(3.2200)(DXYP(J).J=1.JNP)                                  B4M06150
ISN 0235     2200 FORMAT(1X.' DXYP='/(1X.8E16.8))                                 B4M06160
ISN 0236          RETURN                                                          B4M06170
           C                                                             *        B4M06180
           C * * * AUG 23 1977 ADDITIONS HERE TILL RETURN                *        B4M06190
           C                                                             *        B4M06200
ISN 0237                                    ENTRY INPUT4                          B4M06210
ISN 0238          INC = 1                                                         B4M06220
ISN 0239          BETA = 1. - 2. * ALPHA                                          B4M06230
ISN 0240          F5D6 = 5. / 6.                                                  B4M06240
ISN 0241          F17 = 17. / 18.                                                 B4M06250
ISN 0242          F98 = .325 / 981.                                               B4M06260
ISN 0243          R = RGAS                                                        B4M06270
ISN 0244          RADIM = 3 * RAD * IM                                            B4M06280
ISN 0245          CON1 = 4. * COTAN(.5*DLAT) / RADIM                              B4M06290
ISN 0246          CON2 = -COTAN(DLAT) / RADIM                                     B4M06300
ISN 0247          CON5 = 1. / (RADIM * DLAT)                                      B4M06310
ISN 0248          INC = 1                                                         B4M06320
ISN 0249          JPOL(1.1) = 2                                                   B4M06330
ISN 0250          JPOL(2.1) = 3                                                   B4M06340
ISN 0251          JPOL(1.2) = JM                                                  B4M06350
ISN 0252          JPOL(2.2) = JM - 1                                              B4M06360
ISN 0253          JPMOD(1.1) = 2                                                  B4M06370
ISN 0254          JPMOD(2.1) = 3                                                  B4M06380
ISN 0255          JPMOD(1.2) = MOD(JM-1.5) + 1                                    B4M06390
ISN 0256          JPMOD(2.2) = MOD(JM-2.5) + 1                                    B4M06400
ISN 0257          MODPK(1.1) = 2                                                  B4M06410
ISN 0258          MODPK(2.1) = 3                                                  B4M06420
ISN 0259          MCDPK(1.2) = MOD(JM-1.3) + 1                                    B4M06430
ISN 0260          MODPK(2.2) = MOD(JM-2.3) + 1                                    B4M06440
ISN 0261          JNP=JM+1                                                        B4M06450
ISN 0262          JEND(1) = 1                                                     B4M06460
ISN 0263          JEND(2) = JNP                                                   B4M06470
ISN 0264          JNEXT(1) = 2                                                    B4M06480
ISN 0265          JNEXT(2) = JM                                                   B4M06490
ISN 0266          ADLDP = 12. * RAD * DLAT * DLON                                 B4M06500
ISN 0267          IMD2=IM/2                                                       B4M06510
ISN 0268          IMD2P1 = IMD2 + 1                                               B4M06520
ISN 0269          JMS1 = JM - 1                                                   B4M06530
ISN 0270          JMS2 = JM - 2                                                   B4M06540
ISN 0271          JSMT=6                                                          B4M06550
ISN 0272          JMIN = 2 + JSMT                                                 B4M06560
ISN 0273          JMAX = JM - JSMT                                                B4M06570
ISN 0274          JSUM = JMAX + JMIN                                              B4M06580
ISN 0275          TWOJM = 2. * JM                                                 B4M06590
ISN 0276          JLIM = JMIN - 1                                                 B4M06600
```

```
ISN 0277          DO 301 J = 1.JLIM                                                    B4MD6610
ISN 0278          JDH = J + 1                                                          B4MD6620
            C     IF(J.GE.JMIN)                 JDH= JMAX + . - JMIN                   B4MD6630
ISN 0279          IMAX=INT(FAC*COSL(JDH))                                              B4MD6640
ISN 0280          IMAXM1 = IMAX - 1                                                    B4MD6650
ISN 0281          IMAXP3=IMAX+4                                                        B4MD6660
            C                                                                          B4MD6670
ISN 0282             DO 310 I = 1.IMD2                                                 B4MD6680
ISN 0283          SMTH(I.J) = 1.                                                       B4MD6690
ISN 0284          IF((I.GE.IMAX).AND.(I.LE.IMAXP3))SMTH(I.J)=1.-FLOAT(I-IMAXM1)/6.     B4MD6700
ISN 0286          IF(I.GT.IMAXP3)               SMTH(I.J) = C.                         B4MD6710
ISN 0288     310                                CONTINUE                               B4MD6720
ISN 0289     301                                CONTINUE                               B4MD6730
ISN 0290          P1KAPA = KAPA + 1                                                    B4MD6740
ISN 0291             DO 320 L = 1.NLAY                                                 B4MD6750
ISN 0292          DIFF(L) = P1KAPA * DSIG(L)                                           B4MD6760
ISN 0293     320                                CONTINUE                               B4MD6770
ISN 0294          PSKAPA = EXPBYK(1000.)                                               B4MD6780
ISN 0295          THBAR = 280. / PSKAPA                                                B4MD6790
ISN 0296          CP = RGAS / KAPA                                                     B4MD6800
ISN 0297          CPD2=.5 * CP                                                         B4MD6810
ISN 0298          CPTH = CP * THBAR                                                    B4MD6820
ISN 0299          WRITE(6.9778)PSKAPA.THBAR.RGAS.KAPA.CP.CFTH                          B4MD6830
ISN 0300     9778 FORMAT(1X.' PSKAPA.THBAR.RGAS.KAFA.CP.CPTH(IN INPUT)='/1X.6E15.8)    B4MD6840
ISN 0301          PHISPL(1) = PHIS(1.1)                                                B4MD6850
ISN 0302          PHISPL(2) = PHIS(1.JNP)                                              B4MD6860
ISN 0303          IMD2 = IM / 2                                                        B4MD6870
ISN 0304          TWOPI=2.*PI                                                          B4MD6880
ISN 0305          TWOPI = 6.283185307175587                                            B4MD6890
ISN 0306          DO 1000 I = 1.IMD2                                                   B4MD6900
ISN 0307          ALONG = FLOAT(I-1) * TWOPI / FLOAT(IM)                               B4MD6910
            C                                                                        * B4MD6920
            C * * * ALONG =  FLOAT(I-1) * TWCPI / FLCAT(IM) - PI                     * B4MD6930
            C                                                                        * B4MD6940
ISN 0308          SINLON(I) = -DSIN(ALONG)                                             B4MD6950
ISN 0309          COSLON(I) = -DCOS(ALONG)                                             B4MD6960
ISN 0310          SINLON(IMD2+I) = -SINLON(I)                                          B4MD6970
ISN 0311          COSLON(IMD2+I) = -COSLCN(I)                                          B4MD6980
ISN 0312          INDEX(I) = I + IMD2                                                  B4MD6990
ISN 0313          INDEX(IMD2+I) = I                                                    B4MD7000
ISN 0314    1000                                CONTINUE                               B4MD7010
ISN 0315          OHM2=2.*TWOPI/SDAY                                                   B4MD7020
ISN 0316          DO 1010 J=1.JM                                                       B4MD7030
ISN 0317          F(J)=OHM2*SINL(J)                                                    B4MD7040
ISN 0318    1010                                CONTINUE                               B4MD7050
ISN 0319          F(JNP)=OHM2                                                          B4MD7060
ISN 0320          PSIGN(1) = -1.                                                       B4MD7070
ISN 0321          PSIGN(2) = -1.                                                       B4MD7080
ISN 0322          PSIGN(3) = 1.                                                        B4MD7090
ISN 0323          PSIGN(4) = 1.                                                        B4MD7100
            C                                                                        * B4MD7110
            C * * * INITIAL VELOCITIES GIVEN ON A STAGGEREC GRID.                    * B4MD7120
            C * * * INTERPOLATION TO UNSTAGGERED GRID IS USED.                       * B4MD7130
            C * * * MAKE USE OF EQUIVALENCING AND CVERLAPPING THE U ARRAY.           * B4MD7140
            C                                                                        * B4MD7150
ISN 0324          DO 1015 M=1.2                                                        B4MD7160
ISN 0325          DO 1018 N=3.4                                                        B4MD7170
ISN 0326          NM2=N-2                                                              B4MD7180
ISN 0327          DO 1018 L=1.NLAY                                                     B4MD7190
ISN 0328          DO 1018 I=1.IM                                                       B4MD7200
ISN 0329          IF(ISTART.EQ.7)GO TO 1017                                            B4MD7210
ISN 0331          Q(I.L.NM2.JEND(M))=QT(I.L.NM2.JEND(M))                               B4MD7220
ISN 0332     1017 Q(I.L.N.JEND(M))=QT(I.L.N.JEND(M))                                   B4MD7230
ISN 0333     1018 CONTINUE                                                             B4MD7240
ISN 0334          DO 1015 I=1.IM                                                       B4MD7250
ISN 0335          P(I.JEND(M))=PT(I.JEND(M))                                           B4MD7260
ISN 0336    1015  CONTINUE                                                             B4MD7270
ISN 0337          DO 1020 J = 2.JM                                                     B4MD7280
ISN 0338          JP1 = J + 1                                                          B4MD7290
ISN 0339          DO 1025 N = 1.2                                                      B4MD7300
ISN 0340          NP2 = N + 2                                                          B4MD7310
ISN 0341          DO 1025 L = 1.NLAY                                                   B4MD7320
ISN 0342          IS1 = IM                                                             B4MD7330
ISN 0343          DO 1025 I = 1.IM                                                     B4MD7340
ISN 0344          Q(I.L.NP2.J) = QT(I.L.NP2.J)                                         B4MD7350
ISN 0345          IF(ISTART.NE.7)GO TO 1026                                            B4MD7360
ISN 0347          Q(I.L.N.J) = .25 * (QT(IS1.L.N.J) + QT(I.L.N.J) +                    B4MD7370
                 $   QT(IS1.L.N.JP1) + QT(I.L.N.JP1))                                  B4MD7380
ISN 0348          IS1 = I                                                              B4MD7390
ISN 0349          GO TO 1025                                                           B4MD7400
ISN 0350     1026 Q(I.L.N.J)=QT(I.L.N.J)                                               B4MD7410
ISN 0351     1025                               CONTINUE                               B4MD7420
ISN 0352          DO 1030 I = 1.IM                                                     B4MD7430
ISN 0353          P(I.J) = PT(I.J)                                                     B4MD7440
ISN 0354     1030                               CONTINUE                               B4MD7450
            C                                                                        * B4MD7460
            C * * * SCALE UT                                                         * B4MD7470
            C                                                                        * B4MD7480
```

```
      DO 1020 N = 1.4
      DO 1020 L = 1.NLAY
      DO 1020 I = 1.IM
      QT(I.L.N.J) = DXYP(J) * P(I.J) * Q(I.L.N.J)
 1020                               CONTINUE
C                                                                      *
C * * * COMPUTATION OF STEREOGRAPHIC POLAR VELOCITIES: UPOL(L.M).      *
C * * * VPOL(L.M). WHERE M=1 CORRESPONDS TO SOUTH POLE                 *
C                                                                      *
      DO 1040 M = 1.2
      COEF1 = (-1) ** M
      DO 1040 L = 1.NLAY
      IF(ISTART.NE.7) GO TO 1052
      S1 = 0.
      S2 = 0.
      DO 1050 I = 1.IM
      S1 = S1 - U(I.L.JNEXT(M)) * SINLON(I) - COEF1 * V(I.L.JNEXT(M))
     $        * COSLON(I)
      S2 =S2+COEF1*U(I.L.JNEXT(M))*COSLON(I)-V(I.L.JNEXT(M))*SINLON(I)
 1050                              CONTINUE
      UPOL(L.M) = S1 / FLOAT(IM)
      VPOL(L.M) = S2 / FLOAT(IM)
      GO TO 1053
 1052 UPOL(L.M) = -U(1.L.JEND(M))*SINLON(1) -
     1                            COEF1*V(1.L.JEND(M))*COSLON(1)
      VPOL(L.M) = -U(1.L.JEND(M))*COSLON(1) +
     1                            COEF1*V(1.L.JEND(M))*SINLON(1)
 1053 CONTINUE
      TPOL(L.M) = T(1.L.JEND(M))
      SHPOL(L.M) = SH(1.L.JEND(M))
      PPOL(M) = P(1.JEND(M))
      WRITE(6.1968)M.L.PPOL(M).(QPOL(L.N1.M).N1=1.4)
 1968 FORMAT(1X.' PPOL.QPOL= FOR M='.I2.' L='.I3.5E13.6)
      PTPOL(M)=PPOL(M)
      DO 1045 N = 1.4
 1045 QTPOL(L.N.M) = QPOL(L.N.M) * PTPOL(M)
C * * * THE QT(I.L.JEND(M)) COMPUTATION BELOW AGREES                   *
C * * * WITH THE PROCEDURE USED IN COMP0                               *
      DO 1040 I=1.IM
      IF(ISTART.NE.7) GO TO 1054
      U(I.L.JEND(M))=-UPOL(L.M)*SINLON(I)+COEF1*VPOL(L.M)*COSLON(I)
      V(I.L.JEND(M))=-COEF1*UPOL(L.M)*COSLON(I)-VPOL(L.M)*SINLON(I)
 1054 CONTINUE
         DO 1040 N = 1.4
      QT(I.L.N.JEND(M)) = Q(I.L.N.JEND(M)) * PTPOL(M)
 1040                              CONTINUE
                                   RETURN
C**** ERROR ENCOUNTERED READING TAU.C RECORD ON UNIT KTR
  800 WRITE (3.911)
      CALL EXIT
C**** ERROR ENCOUNTERED READING LATITUDE RECORD ON UNIT KTR
  810 WRITE (3.916) J
      CALL EXIT
C**** END-OF-FILE ENCOUNTERED READING LATITUDE RECORD ON UNIT KTR
  820 WRITE (3.917) J
      CALL EXIT
C**** LATER PICKUP TAPE NEEDED
  830 WRITE (3.913) TAUP
      CALL EXIT
      STOP
  901 FORMAT (//40X.'GISS N LAYER WEATHER MODEL'//100X 'VERSION' I4//)
  902 FORMAT (20A4)
  903 FORMAT (25X.20A4)
  904 FORMAT (10A8)
  905 FORMAT (35X.10A8)
  906 FORMAT (' ENTER THE RESTART VALUE OF TAU AS AN 8 CHARACTER NUMBER
     * E.G. 4026.2 AS 04026.20')
  907 FORMAT (F8.2)
  908 FORMAT ('/MACHINE CHECK RESTART. TAUP='.F9.2/)
  909 FORMAT (' ENTER THE NUMBER OF THE NEW OUTPUT TAPE AS A FOUR DIGIT
     *NUMBER.')
  910 FORMAT (//' THE NUMBER OF THE NEW TAPE IS '.A4//)
  911 FORMAT ('0ERROR ENCOUNTERED READING TAU.C RECORD ON UNIT KTR.')
  912 FORMAT ('0EARLIER PICKUP TAPE NEEDED.  TAUP ='.F10.2)
  913 FORMAT ('0LATER PICKUP TAPE NEEDED.  TAUP ='.F10.2)
  914 FORMAT (' I.C. READ FROM UNIT'.I3.'  TAU ='.F9.2.3X.20A4.3X.
     *  'IROT= '.Z2)
  915 FORMAT ('0'.I2.' REGION SPLIT GRID LIMITS    JIP'.11I5/31X.'JNP'.
     *   11I5/31X.'JIU'.11I5/31X.'JMU'.11I5/31X.'INC'.11I5/31X.'KSB'.
     *   11I5/31X.'KNB'.11I5/)
  916 FORMAT ('0ERROR ENCOUNTERED READING LATITUDE RECORD ON UNIT KTR.
     *J BEING READ WAS'.I4)
  917 FORMAT ('0END-OF-FILE ENCOUNTERED READING LATITUDE RECORD ON UNIT
     *KTR.  J BEING READ WAS'.I4)
  938 FORMAT (' ISTART ='.I2.' THE DECK IS SET UP AS AN INITIAL START'
     *./.' IF IT SHOULD BE A RESTART DO JOB NO. AND INSERT AN ISTART=3 C
     *ARD BEFORE &END AND RELOAD.  THANK YOU')
      END
```

```
                                        /    INPUT /     SIZE OF PROGRAM 003100 HEXADECIMAL BYTES

NAME TAG TYPE ADD.  |* ***      % NAME TAG TYPE ADD.  |* ***      % NAME TAG TYPE ADD.  |* ***      % NAME TAG TYPE ADD.  |* ***      %
      C SF  CE  R*4  000000         F S   C   R*4  000A08         I SFA     I*4  00066C         J SFA     I*4  000670
      K SF      I*4  000674         L SF      I*4  000678         M SF      I*4  00067C         N SF      I*4  000680
      P SF  CE  R*4  002F10         Q SF  CE  R*4  00CE70         R S   C   R*4  000038         T F   CE  R*4  0024F0
      U SF  CE  R*4  000E70         V SF  CE  R*4  0019B0         W     C   R*4    N.R.        CP SF  C   R*4  000040
     C1 SF      R*4  000748        DT S   C   R*4  000080        ED S   C   R*4  000120        GT S   CE  R*4  000840
     GW S   CE  R*4  001680        IM SFA C   I*4  000008        IU S       I*4  000684        JM SFA C   I*4  000030
     J1 SF  C   I*4  00002C        KM SF  C   I*4  000034        NR S   C   I*4  00004C        N1 F       I*4  000688
     P1 SF  C   R*4  00010C        PK     C   R*4    N.R.        PT SF  CE  R*4  0021C0        PU     CE  R*4  000000
     QT SF  CE  R*4  000120        SH F   CE  R*4  003030        S1 SF      R*4  00068C        S2 SF      R*4  000690
     TS S   CE  R*4  001890        TT     CE  R*4  0017A0        UT     CE  R*4  000120        VT     CE  R*4  000C60
    CDX S   C   R*4  000144       DPI SF      R*8  000728       DXP SF  C   R*4  000728       DXU     C   R*4    N.R.
    DYP     C   R*4    N.R.       DYU SF  C   R*4  0007E0       FAC SFA     R*4  000694       FIN S   C   R*4  000020
    FMU S   C   R*4  000124       F17 S   C   R*4  000004       F98 S   C   R*4  000008       GSW     C   R*4  000004
    IN2 SF      I*4  000698       IM3 SF      I*4  000690       IM4 S       I*4  0006A0       INC S   C   I*4  000044
    IS1 SF      I*4  0006A4       ITC     C   I*4  000C00       JDM SFA     I*4  0006A8       JNB SF  C   I*4  000080
    JNP SF  C   I*4  000004       JP1 SF  C   I*4  000060       JP2     C   I*4    N.R.       JSB SF  C   I*4  0000AC
    JSP SF  CE  I*4  000000       KIR SFA     I*4  0006AC       LAT SFA C   R*4  0005D8       MLF S   C   I*4  000004
    NM2 SF      I*4  000680       NPC     C   I*4    N.R.       NP2 SF      I*4  0006D4       PSF     C   R*4  00012C
    PSL S   C   R*4  00011C       PSM     C   R*4    N.R.       QSM     C   R*4    N.R.       RAD SF  C   R*4  00003C
    SHS S   CE  R*4  0023D0       SHT     CE  R*4  0022E0       SIG SF  C   R*4  000370       SUM     C   R*4    N.R.
    TAU S   C   R*4  0000C0       TMP S   C   R*4  000010      BETA S   C   R*4  00001C      CONG     C   L*4  0389A4
   CON1 S   C   R*4  000000      CON2 S   C   R*4  000004      CON3     C   R*4    N.R.      CON4     C   R*4    N.R.
   CON5 S   C   R*4  000010      COSD     C   R*4    N.R.      COSL SFA C   R*4  000B78      CPD2 S   C   R*4  00004C
   CPTH SF  C   R*4  000030      DIFF S   C   R*4  005764      DISK F       R*4  000688      DLAT SFA C   R*4  000084
   DLON SF  C   R*4  000088      DSIG SF  C   R*4  0003C0      DXYP SF  C   R*4  000950      EXIT SF  XF  R*4  000000
   FAST S   C   L*4  00000C      FJEQ SF      R*4  000680      FSD6 S   C   R*4  000000      GRAV S   C   R*4  000110
   IDAY     C   I*4    N.R.      IMAX SF      I*4  0006C0      IND2 SF  C   I*4  000050      INP1 S       I*4  0006C4
   INCP         I*4    N.R.      INCS     C   I*4  000080      INCU         I*4    N.R.      IRUT SF  C   I*4  00003C
   ITAU     C   I*4    N.R.      IVER F       I*4  0006C8      JAYS     C   I*4  000050      JDAY     C   I*4    N.R.
   JEND SF  C   I*4  000058      JLIM SF      I*4  0006C0      JMAX SF  C   I*4  000004      JMIN SF  C   I*4  000000
   JMPS     C   I*4    N.R.      JMS1 S   C   I*4  00002C      JMS2 S   C   I*4  000028      JMUS     C   I*4    N.R.
   JPOL S   C   I*4  000064      JSMT SF      I*4  0006D0      JSUM S   C   I*4  000008      J1PS     C   I*4    N.R.
   J1US     C   I*4    N.R.      KAPA SF  C   R*4  000118      KMM4 S       I*4  0006D4      KNBS     C   I*4    N.R.
   KSBS     C   I*4    N.R.      MRCH     C   I*4    N.R.      MROT S   C   I*4  000040      NCM1 S   C   I*4  000034
   NFLW S   C   I*4  000128      NLAY SF  C   I*4  000030      NOC3 S   C   L*4  000004      NSEQ S   C   I*4  000000
   NSM1 S   C   I*4  000030      OHM2 SF      R*4  0006D8      PHIS SF  CE  R*4  000D50      PPOL SF  CE  R*4  000654
   PTOP S   C   R*4  000010      QPOL F   CE  R*4  000414      RADT     C   I*2    N.R.      RGAS SF  C   R*4  000114
   SDAY SF      R*4  0006DC      SDOT     CE  R*4  000000      SIGE SF  C   R*4  000410      SIND     C   R*4    N.R.
   SINL SF  C   R*4  000AC0      SMTH S   C   R*4  000000      TAUE S   C   R*4  000100      TAUI SF  C   R*4  0000FC
   TAUO S   C   R*4  000104      TAUP SFA C   R*4  0000F8      TAUT SFA C   R*4  000038      TAUX SF      R*4  0006E0
   TPOL S   CE  R*4  00045C      UPOL SF  CE  R*4  000414      VPOL SF  CE  R*4  000438      XINT SF  C   R*4  0000C8
  ADLDP S   C   R*4  000024     ALONG SFA     R*8  000730     ALPHA SF  C   R*4  000018     COEF1 SF      R*4  0006E4
  C3WRT S   C   L*4  000000     DSIGO S   C   R*4  000464     DUMMY     C   R*4    N.R.     FLAGS     C   L*4  000000
  IM2P1 S       I*4  0006E8     IM3P1 S       I*4  0006E0     INDEX S   C   I*4  0002E4     INPUT         I*4  0006F0
  ISDOT     CE  I*2  00CF00     ISMTH S   C   I*4  000000     ITEST S   C   I*4  000048     JDATE     C   I*4    N.R.
  JNBM1 S       I*4  0006F4     JNEXT SF  C   I*4  000060     JNPM1 S   C   I*4  00001C     JNPP1 SF      I*4  0006F8
  JPMOD S   C   I*4  000094     JSBP1 S       I*4  0006FC     JSPP1 S   C   I*4  000018     JTEST S   C   I*4  000044
  JYEAR     C   I*4    N.R.     KSSW5 SFA     I*4  000700     MODPK S   C   I*4  000074     NSTEP     C   I*4    N.R.
  OMEGA     C   I*2    N.R.     PAWZE S       R*4  000704     POLES     CE  R*4  000414     PSIGN S   C   R*4  000404
  PTPOL SF  CE  R*4  00065C     QTPOL S   CE  R*4  000534     RADIN SF  C   R*4  000054     RMMAX S   C   R*4  000140
  SDPOL     C   R*4    N.R.     SHPOL S   CE  R*4  000480     THBAR SF  C   R*4  000014     TOPOG S   C   R*4  000000
  TTPOL     CE  R*4  00057C     TWOJM S       R*4  000708    TWOPI( SF      R*8  000738     UTPOL     CE  R*4  000534
  VTPOL     CE  R*4  000558    FIXPI#     XF  I*4  000000      DCOS     XF  R*8  000000      DSIN     XF  R*8  000000
  COTAN     XF  R*4  000000       COS     XF  R*4  000000       SIN     XF  R*4  000000    ADPCLD     C   L*4  000018
 ALBEDO SF  C   I*2  082350    ANDEND         R*8  000740    CONVPL     C   R*4    N.R.    COSLON SF  C   R*4  0001C4
 DTMULT S   C   R*4  000108    DUMMYA     C   R*4    N.R.    DUMMYC     C   R*4    N.R.    EXPBYK F   XF  R*4  000000
 FRDNL# F   XF  I*4  000000    IALTER S   C   I*4  000190    IBCOM# F   XF  I*4  000000    IMAXM1 SFA     I*4  00070C
 INAXP3 S       I*4  000710    IMD2P1 S   C   I*4  000020    INPUTZ F            FS7AF7    INPUT4         I*4  000714
 ISTART SF  C   I*4  000014    ISWTCH     C   I*4  000000    JMONTH     C   I*4    N.R.    JMP1D2 SF      I*4  000718
 MATSNX     C   I*4    N.R.    MATSUN S   C   I*4  000068    MNMXTS S   C   I*4  0286E0    NCOMP3 S   C   I*4  0000F0
 NCYCLE S   C   I*4  0000EC    NHOGAN S   C   I*4  0000F4    NLAYM1 SF  C   I*4  000024    NLAYP1 S   C   I*4  000028
 NSTART     C   I*4    N.R.    PHISPL S   C   R*4  0057F4    PITPOL         R*4    N.R.    PSKAPA SF  C   R*4  000034
 PSMPOL     C   R*4    N.R.    PIKAPA SF      R*4  000710    QSMPOL     C   R*4    N.R.    ROTAPE SF  XF  R*4  000000
 RECORD SF      R*8  0008F8    ROTPER S       R*4  000720    RSDIST     C   R*4    N.R.    SMSMOO S   C   L*4  000008
 SHTPOL     CE  R*4  0005A0    SINLON SF  C   R*4  0000A4    SHAFTA S   C   L*4  000014    SSWTCH SF  XF  R*4  000000
 TAPNJM SF      R*4  000724    TUFDAY     C   R*4    N.R.    XLABEL SF  C   R*4  000320

                               *****   COMMON INFORMATION   *****

   NAME OF COMMON BLOCK *  * 3I_E OF BLCCKCOMMON      000014 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
    FLAGS    L*4    000000

   NAME OF COMMON BLOCK * F;U#.ZE OF BLOCKCOMMON      005E24 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      CON1   R*4    000000           CON2   R*4    000004           CON3   R*4      N.R.           CON4   R*4      N.R.
      CON5   R*4    000010          THBAR   R*4    000014          ALPHA   R*4    000018           BETA   R*4    00001C
    IMD2P1   I*4    000020          ADLDP   R*4    000024           JMS2   I*4    000028           JMS1   I*4    00002C
      CPTH   R*4    000030         PSKAPA   R*4    000034              R   R*4    000038            RAD   R*4    00003C
        CP   R*4    000040            INC   I*4    000044         NSTART   I*4      N.R.           CPD2   R*4    00004C
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      IND2     I*4    000050          RADIN    R*4    000054          JEND     I*4    000058           JP1     I*4    000060
       JP2     I*4      N.R.         MATSUN    I*4    000068         JNEXT     I*4    00006C         MODPK     I*4    000074
      JPOL     I*4    000084          JPMOD    I*4    000094        SINLON     R*4    0000A4        COSLON     R*4    0001C4
     INDEX     I*4    0002E4          PSIGN    R*4    000404         POLES     R*4    000414             W     R*4      N.R.
        PK     R*4      N.R.           DIFF    R*4    005764        CONVPL     R*4      N.R.         SDPOL     R*4      N.R.
    PHISPL     R*4    0057F4            SUM    R*4      N.R.

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
      QPOL   000414                 QTPOL   000534                  UPOL   000414                  VPOL   000438
      TPOL   00045C                 SHPOL   000480                 UTPOL   000534                 VTPOL   000558
     TTPOL   00057C                SHTPOL   0005A0                  PPOL   000654                 PTPOL   00065C


  NAME OF COMMON BLOCK * ()S6.ZE OF BLOCKCOMMON      00000C HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      F5D6     R*4    000000            F17    R*4    000004           F98     R*4    000008

  NAME OF COMMON BLOCK *  =O#S#E OF BLOCKCOMMON      081600 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
        PU     R*4    000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
        QT   000120                    UT   000120                    GT   000840                    VT   000C60
        GW   001680                    TT   0017A0                    PT   0021C0                   SHT   0022E0


  NAME OF COMMON BLOCK *  =M..ZE OF BLOCKCOMMON      00D148 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
       QSM     R*4      N.R.            PSM    R*4      N.R.        QSMPOL     R*4      N.R.        PSMPOL     R*4      N.R.

  NAME OF COMMON BLOCK * S*OT*9E OF BLOCKCOMMON      0385AE HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      SDOT     R*4    000000          OMEGA    I*2      N.R.        MNMXTS     I*4    0286E0          RADT     I*2      N.R.
      CONG     L*4    0389A4

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
     ISDOT   00CF00

  NAME OF COMMON BLOCK *  ¬NTR#E OF BLOCKCOMMON      083C30 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
       JSP     I*4    000000            JNP    I*4    000004            IM     I*4    000008          NLAY     I*4    00000C
      PTOP     R*4    000010         ISTART    I*4    000014         JSPP1     I*4    000018         JNPM1     I*4    00001C
       FIM     R*4    000020         NLAYM1    I*4    000024        NLAYP1     I*4    000028            J1     I*4    00002C
        JM     I*4    000030             KM    I*4    000034          TAUT     R*4    000038          IRQT     I*4    00003C
      MROT     I*4    000040          JTEST    I*4    000044         ITEST     I*4    000048            NR     I*4    00004C
      JAYS     I*4    000050           INCS    I*4    000080           JSB     I*4    0000AC           JNB     I*4    0000B0
      DLAT     R*4    000084           DLON    R*4    000088            DT     R*4    0000BC           TAU     R*4    0000C0
      ITAU     I*4      N.R.           XINT    R*4    0000C8          IDAY     I*4      N.R.          JDAY     I*4      N.R.
    TOFDAY     R*4      N.R.          JDATE    I*4      N.R.        JMONTH     I*4      N.R.         JYEAR     I*4      N.R.
     NSTEP     I*4      N.R.         NCYCLE    I*4    0000EC        NCOMP3     I*4    0000F0        NMOGAN     I*4    0000F4
      TAUP     R*4    0000F8           TAUI    R*4    0000FC          TAUE     R*4    000100          TAUO     R*4    000104
    DTMULT     R*4    000108             PI    R*4    00010C          GRAV     R*4    000110          RGAS     R*4    000114
      KAPA     R*4    000118            PSL    R*4    00011C            ED     R*4    000120           FMU     R*4    000124
      NFLW     I*4    000128            PSS    R*4    00012C          MRCH     I*4      N.R.        RSDIST     R*4      N.R.
      SIND     R*4      N.R.           COSS    R*4      N.R.         RHMAX     R*4    000140           CDX     R*4    000144
    DUMMYC     R*4      N.R.         IALTER    I*4    000190        DUMMYA     R*4      N.R.        XLABEL     R*4    000320
       SIG     R*4    000370           DSIG    R*4    0003C0          SIGE     R*4    000410         DSIGG     R*4    000464
      J1PS     I*4      N.R.           JMPS    I*4      N.R.          J1US     I*4      N.R.          JMUS     I*4      N.R.
      KSBS     I*4      N.R.           KNBS    I*4      N.R.           LAT     R*4    000588           DXU     R*4      N.R.
       DXP     R*4    000728            DYU    R*4    0007E0           DYP     R*4      N.R.          DXYP     R*4    000950
         F     R*4    000A08           SINL    R*4    000AC0          COSL     R*4    000878         DUMMY     R*4      N.R.
      PHIS     R*4    000D50         ALBEDO    I*2    082350

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
         Q   000E70                     U   000E7C                    TS   001890                     V   001980
       SHS   0023D0                     T   0024F0                     P   002F10                    SH   003030
         C   000000

  NAME OF COMMON BLOCK *  * SI.E OF BLOCKCOMMON      0005E0 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      JMIN     I*4    000000           JMAX    I*4    000004          JSUN     I*4    000008          SNTH     R*4    00000C
```

```
  NAME OF COMMON BLOCK *  *N3I.E OF BLOCKCOMMON      000C38 HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   NSEG    I*4    000030
   NCMI    I*4    000034            MLF     I*4    000004         MATSNX     I*4      N.R.          NSMI     I*4    000030

  NAME OF COMMON BLOCK *  IMWR.E OF BLOCKCCMMON      000C1C HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  C3WRT    L*4    000000            NOC3    L*4    000004         SHSMOD     L*4    000008          FAST     L*4    00000C
   TMP     R*4    000010          SMAFTA    L*4    000014         ADPCLD     L*4    000018

  NAME OF COMMON BLOCK *  *DS_?E OF BLOCKCOMMON      000C04 HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
 ISWTCH    I*4    000000

  NAME OF COMMON BLOCK *  ¬IT#'E OF BLOCKCOMMON      000C08 HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    ITC    I*4    000000            GSW     R*4    000004

  NAME OF COMMON BLOCK *  *S6¬"E OF BLCCKCOMMON      000C08 HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  ISMTH    I*4    000000            NPC     I*4     N.R.

  NAME OF COMMON BLOCK *  * T¬?E OF BLCCKCOMMON      0033C0 HEXADECIMAL BYTES
VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
```

```
   LABEL   ADDR              LABEL   ADDR              LAEEL   ADDR              LABEL   ADDR
      20  001430                30  001840                40  00184E                50  0019C8
      60  0019D0                70  0019F6                80  001A22                90  001A4A
     100  001A88               110  001ACC               120  001B54               121  001D62
     130  001D8C               140  001DAC               145  001DCA               150  001E24
     160  001E6C               190  001EAC               200  001EFA               210  001F6E
     220  001FBE               230  001FF6               240  00204E               310  0023D2
     301  0023DE               320  002440              1000  0025FA              1010  002644
    1017  00276A              1018  002776              1015  0027F0              1026  002960
    1025  002968              1030  0029F6              1020  002A70              1050  002C6E
    1052  002C98              1053  002CE2              1045  002E18              1054  002F16
    1040  002F30               800  002FE0               810  003000 NR            820  003028 NR
     830  003050

*OPTIONS IN EFFECT*       NAME=  MAIN.OPT=02.LINECNT=55.SIZE=1000K.

*OPTIONS IN EFFECT*       SOURCE.EBCDIC.NOLIST.NODECK.LOAD.MAP.NOEDIT.ID.NOXREF

*STATISTICS*      SOURCE STATEMENTS =      421   PROGRAM SIZE=      12544

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                       772K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                               OS/360 FORTRAN H AT GISS                          DATE 12/12/79-0783.20

       COMPILER OPTIONS -     NAME=  MAIN.OPT=02.LINECNT=55.SIZE=1000K.
                              SOURCE.EBCDIC.NOLIST.NODECK.LOAD.MAP.NOEDIT.ID.NOXREF
  ISN 0002             SUBROUTINE TWRITE                                                      B4M08370
                 C**** FINE NINE LAYER GLOBAL CDE BLOCK FOR VM MODEL, FEBRUARY 1976           B4M08380
  ISN 0003             INTEGER*2 ALBEDO                                                       B4M08390
  ISN 0004             REAL*4 KAPA.LAT                                                        B4M08400
                 C     REAL*8 SINLON.COSLON.SUM                                               B4M08410
  ISN 0005             COMMON /CNTRL/                                                         B4M08420
                     *   JSP.JNP.IM.NLAY.PTOP.ISTART.JSPP1.JNPM1.FIM.NLAYM1.NLAYP1.           B4M08430
                     *   J1.JM.KM.TAUT.IRGT.MROT.JTEST.ITEST.                                 B4M08440
                     *   NR.JAYS(12).INCS(11).JSB.JNB.CLAT.DLON.                              B4M08450
                     *   DT.TAU.ITAU.XINT.IDAY.JDAY.TOFDAY.JDATE.JMONTH(2).JYEAR.NSTEP.       B4M08460
                     *   NCYCLE.NCOMP3.NHOGAN.TAUP.TAUI.TAUE.TALO.DTMULT.                     B4M08470
                     *   PI.GRAV.RGAS.KAPA.PSL.ED.FMU.NFLW.PSF.MRCH.RSDIST.SIND.COSD.         B4M08480
                     *   RHMAX.CDX.DUMMYC(18).IALTER.DUMMYA(99).                              B4M08490
                     *   XLABEL(20).SIG(20).DSIG(20).SIGE(21).DSIGO(19).                      B4M08500
                     *   J1PS(11).JMPS(11).J1US(11).JMUS(11).KSES(11).KNBS(11).               B4M08510
                     *LAT(46).DXU(46).DXP(46).DYU(46).CYP(46).DXYP(46).F(46).SINL(46).        B4M08520
                     *COSL(46).DUMMY(72).PHIS(2880.46).ALBEDO(72.46)                          B4M08530
  ISN 0006             DIMENSION U(72.40.1).V(72.40.1).T(72.40.1).SH(72.40.1).                B4M08540
                     *P(2880.1).    TS(2880.1).SHS(2880.1).GT(2880.1).GW(2880.1).C(300)       B4M08550
  ISN 0007             COMMON/WORK2/PU(2880.46)                                               B4M08560
                 C                                                                            B4M08570
  ISN 0008             COMMON/SDOT48/SDOT(72.46.8).OMEGA(72.46.9).MNMXTS.RADT(72.46.10)       B4M08580
                     +  .COMG                                                                 B4M08590
  ISN 0009             LOGICAL COMG                                                           B4M08600
                 C                                                                            B4M08610
  ISN 0010             INTEGER*2 RADT.OMEGA                                                   B4M08620
  ISN 0011             INTEGER*2 ISDOT(72.46.8)                                               B4M08630
                 C                                                                            B4M08640
  ISN 0012             EQUIVALENCE (SDOT(1.1.5).(SDOT(1.1.1))                                 B4M08650
                 C                                                                            B4M08660
  ISN 0013             DIMENSION SDFIL(72.12).RADFIL(72.10).OMFIL(72.9)                       B4M08670
                 C                                                                            B4M08680
  ISN 0014             EQUIVALENCE                                                            B4M08690
                     $    (U(1.1.1).PHIS(73.1)).(TS(1.1).PHIS(721.1)).                        B4M08700
                     $    (V(1.1.1).PHIS(793.1)).(SHS(1.1).PHIS(1441.1)).                     B4M08710
                     $    (T(1.1.1).PHIS(1513.1)).(P(1.1).PHIS(2161.1)).                      B4M08720
                     $    (SH(1.1.1).PHIS(2233.1)).                                           B4M08730
                     $    (GT(1.1).PU(721.1)).(GW(1.1).PU(1441.1)).(C(1).JSP)                 B4M08740
  ISN 0015             COMMON/SMOO/ISMTH.NPC                                                  B4M08750
  ISN 0016             EQUIVALENCE(C(100).MACHIN)                                             B4M08760
  ISN 0017             MACHIN = 165                                                           B4M08770
  ISN 0018             IMP1 = IM + 1                                                          B4M08780
  ISN 0019             IM2 = 2 * IM                                                           B4M08790
  ISN 0020             IM2P1 = IM2 + 1                                                        B4M08800
  ISN 0021             IM3 = 3 * IM                                                           B4M08810
  ISN 0022             IM3P1 = IM3 + 1                                                        B4M08820
  ISN 0023             KMM4=KM-4                                                              B4M08830
  ISN 0024             IM4=IM*4                                                               B4M08840
  ISN 0025             TAUR = INT(TAU + .5)                                                   B4M08850
  ISN 0026             BACKSPACE 8                                                            B4M08860
                 C                                                                            B4M08870
                 C                                                                            B4M08880
  ISN 0027          70 WRITE (8.END=80.ERR=90)TAUR.C.((P(I.J).J=1.JNP).I=1.IM).               B4M08890
                     $    ((TS(I.J).J=1.JNP).I=1.IM).((SHS(I.J).J=1.JNP).I=1.IM).             B4M08900
                     $    ((GT(I.J).J=1.JNP).I=1.IM).((GW(I.J).J=1.JNP).I=1.IM)               B4M08910
```

```
ISN 0028           DO 75 J = 1,JNP                                                  B4M08920
              CCCC  IF (AMOD((TAU+.0001).TAUT) .LT. .0010) GC TO 76      CCCCCCC    B4M08930
ISN 0029           DO 73 L=1,4                                                      B4M08940
ISN 0030           DO 73 I=1,IM                                                     B4M08950
ISN 0031        73 SDFIL(I,L) = SDOT(I,J,L)                                         B4M08960
ISN 0032           DO 77 I=1,IM                                                     B4M08970
ISN 0033           DO 76 L=1,8                                                      B4M08980
ISN 0034           OMFIL(I,L) = OMEGA(I,J,L)                                        B4M08990
ISN 0035           RADFIL(I,L) = RADT(I,J,L)                                        B4M09000
ISN 0036        76 SDFIL(I,L+4) = ISDOT(I,J,L)                                      B4M09010
ISN 0037           OMFIL(I,9) = OMEGA(I,J,9)                                        B4M09020
ISN 0038           RADFIL(I,9) = RADT(I,J,9)                                        B4M09030
ISN 0039           RADFIL(I,10) = RADT(I,J,10)                                      B4M09040
ISN 0040        77 CONTINUE                                                         B4M09050
ISN 0041           WRITE (8,END=80,ERR=90) ((U(I,K,J),I=1,IM),K=1,9),((V(I,K,J),   B4M09060
                $     I=1,IM),K=1,9),((T(I,K,J),I=1,IM),K=1,9),((SH(I,K,J),        B4M09070
                $     I=1,IM),K=1,9),SDFIL,RADFIL,OMFIL                             B4M09080
ISN 0042        75 CONTINUE                                                         B4M09090
ISN 0043           IROT=IROT+1                                                      B4M09100
ISN 0044           ENDFILE 8                                                        B4M09110
ISN 0045           IF(IROT.LE.MROT) RETURN                                          B4M09120
              C**** BEGIN A NEW OUTPUT TAPE                                         B4M09130
ISN 0047        80 IROT=0                                                           B4M09140
ISN 0048           REWIND 3                                                         B4M09150
ISN 0049           WRITE (15,901)                                                   B4M09160
ISN 0050           READ (15,902) TAPNUM                                             B4M09170
ISN 0051           WRITE (3,903) TAPNUM,TAUST,TAU,TAUT,XLABEL                       B4M09180
ISN 0052           TAUST=TAU                                                        B4M09190
ISN 0053           XLABEL(20)=TAPNUM                                                B4M09200
ISN 0054           GO TO 70                                                         B4M09210
              C**** ERROR OCCURRED WRITING OUTPUT TAPE                              B4M09220
ISN 0055        90 WRITE (15,904)                                                   B4M09230
ISN 0056           WRITE (3,904)                                                    B4M09240
ISN 0057           GO TO 80                                                         B4M09250
ISN 0058       901 FORMAT (' MOUNT A NEW OUTPUT TAPE (RING IN) AND ENTER THE TAPE NUMB4M09260
                  *BER AS A FOUR DIGIT NUMBER.')                                    B4M09270
ISN 0059       902 FORMAT (A4)                                                      B4M09280
ISN 0060       903 FORMAT ('0TAPE ',A4,'    TAUS',2F10.3,F8.3,5X,20A4/)            B4M09290
ISN 0061       904 FORMAT (' ERROR OCCURRED WRITING OUTPUT TAPE. WRITE A NOTE ON SETJB4M09300
                  *P TICKET.IF PROGRAM JUST STARTED.CLEAN TAPE DRIVE OR USE ANOTHER'/B4M09310
                  $    1X, 'DRIVE AND RESUBMIT THE JOB .')                          B4M09320
ISN 0062           END                                                              B4M09330

                                               /  TWRITE /     SIZE OF PROGRAM 002CD8 HEXADECIMAL BYTES

NAME TAG TYPE ADD.    |* ***    % NAME TAG TYPE ADD.    |* ***    % NAME TAG TYPE ADD.    |* ***    % NAME TAG TYPE ADD.    |* ***    %
      C  F  CE  R*4  000000            F        C  R*4     N.R.            I SF          I*4  0001E8            J SF          I*4  0001FC
      K  F      I*4  0001F0            L SF        I*4  0001F4             P  F   CE  R*4  002F10             T  F   CE  R*4  0024F0
      U  F  CE  R*4  00CE70            V  F   CE  R*4  00198C             DT       C  R*4     N.R.            ED       C  R*4     N.R.
     GT  F  CE  R*4  000840           GW  F   CE  R*4  00168C             IM  F    C  I*4  000008             JM       C  I*4     N.R.
     J1     C   I*4     N.R.          KM  F    C  I*4  000034             NR       C  I*4     N.R.            PI       C  R*4     N.R.
     PU     CE  R*4  000000           SH  F   CE  R*4  00303C             TS  F   CE  R*4  001890            CDX       C  R*4     N.R.
    DXP     C   R*4     N.R.         DXU       C  R*4     N.R.           DYP       C  R*4     N.R.           DYU       C  R*4     N.R.
    FIM     C   R*4     N.R.         FMU       C  R*4     N.R.           IM2 SF       I*4  0001F8            IM3 SF       I*4  0001FC
    IM4 S       I*4  000200          JNB       C  I*4     N.R.           JNP  F    C  I*4  000004            JSB       C  I*4     N.R.
    JSP     CE  I*4  0000C0          LAT       C  R*4     N.R.           NPC       C  I*4     N.R.           PSF       C  R*4     N.R.
    PSL     C   R*4     N.R.         SHS  F   CE  R*4  0023DC            SIG       C  R*4     N.R.           TAU FA    C  R*4  0000C0
   COMG     C   L*4  0389A4         COSD       C  R*4     N.R.          COSL       C  R*4     N.R.          DLAT       C  R*4     N.R.
   DLON     C   R*4     N.R.        DSIG       C  R*4     N.R.          DXYP       C  R*4     N.R.          GRAV       C  R*4     N.R.
   IDAY     C   I*4     N.R.        IMP1 S        I*4  000204           INCS       C  I*4     N.R.          IROT SF    C  I*4  00003C
   ITAU     C   I*4     N.R.        JAYS       C  I*4     N.R.          JDAY       C  I*4     N.R.          JMPS       C  I*4     N.R.
   JMUS     C   I*4     N.R.        J1PS       C  I*4     N.R.          J1US       C  I*4     N.R.          KAPA       C  R*4     N.R.
   KMM4 S       I*4  000208         KNBS       C  I*4     N.R.          KSBS       C  I*4     N.R.          MRCH       C  I*4     N.R.
   MROT     C   I*4  000040         NFLW       C  I*4     N.R.          NLAY       C  I*4     N.R.          PHIS         CE  R*4  000D50
   PTOP     C   R*4     N.R.        RADT  F    C  I*2  0286E4           RGAS       C  R*4     N.R.          SDOT  F   CE  R*4  00C000
   SIGE     C   R*4     N.R.        SIND       C  R*4     N.R.          SINL       C  R*4     N.R.          TAUE       C  R*4     N.R.
   TAUI     C   R*4     N.R.        TAUO       C  R*4     N.R.          TAUP       C  R*4     N.R.          TAUR SF       R*4  00020C
   TAUT  F  C   R*4  000038         XINT       C  R*4     N.R.          DSIGO      C  R*4     N.R.         DUMMY       C  R*4     N.R.
  IM2P1 S       I*4  000210        IM3P1 S        I*4  000214          ISDOT  F   CE  I*2  00CF00         ISMTH       C  I*4     N.R.
  ITEST     C   I*4     N.R.       JDATE       C  I*4     N.R.         JNPM1       C  I*4     N.R.         JSPP1       C  I*4     N.R.
  JTEST     C   I*4     N.R.       JYEAR       C  I*4     N.R.         NSTEP       C  I*4     N.R.         OMEGA  F   C  I*2  019E00
  OMFIL SF      R*4  000224        RHMAX       C  R*4     N.R.         SDFIL SF       R*4  000C44         TAUST SF       R*4  000218
 ALBEDO     C   I*2     N.R.      DTMULT       C  R*4     N.R.        DUMMYA       C  R*4     N.R.        DUMMYC       C  R*4     N.R.
 IALTER     C   I*4     N.R.      IBCOM#  F   XF  R*4  00000C         ISTART       C  I*4     N.R.        JMONTH       C  I*4     N.R.
 MACHIN S   CE  I*4  00018C       MNMXTS       C  I*4     N.R.        NCOMP3       C  I*4     N.R.        NCYCLE       C  I*4     N.R.
 NHOGAN     C   I*4     N.R.      NLAYM1       C  I*4     N.R.        NLAYP1       C  I*4     N.R.        RADFIL SF       R*4  0019C4
 RSDIST     C   R*4     N.R.      TAPNUM SF       R*4  00021C         TOFDAY       C  R*4     N.R.        TWRITE          R*4  000220
 XLABEL SF  C   R*4  000320

                                           *****  COMMON INFORMATION   *****

            NAME OF COMMON BLOCK *  ¬NTR#E OF BLOCKCOMMON      083C30 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      JSP  I*4    000000            JNP  I*4    000004             IM  I*4    000008            NLAY  I*4    N.R.
     PTOP  R*4    N.R.           ISTART  I*4    N.R.            JSPP1  I*4    N.R.           JNPM1  I*4    N.R.
      FIM  R*4    N.R.           NLAYM1  I*4    N.R.           NLAYP1  I*4    N.R.              J1  I*4    N.R.
```

```
      JM     I*4      N.R.            KM     I*4    000034          TAUT     R*4    000038          IROT     I*4    00003C
    MROT     I*4    000040         JTEST     I*4      N.R.         ITEST     I*4      N.R.            NR     I*4      N.R.
    JAYS     I*4      N.R.          INCS     I*4      N.R.           JSB     I*4      N.R.           JNB     I*4      N.R.
    DLAT     R*4      N.R.          DLCN     R*4      N.R.            DT     R*4      N.R.           TAU     R*4    0000C0
    ITAU     I*8      N.R.          XINT     R*4      N.R.          IDAY     I*4      N.R.          JDAY     I*4      N.R.
  TOFDAY     R*4      N.R.         JDATE     I*4      N.R.        JMONTH     I*4      N.R.         JYEAR     I*4      N.R.
   NSTEP     I*4      N.R.        NCYCLE     I*4      N.R.        NCOMP3     I*4      N.R.        NMOGAN     I*4      N.R.
    TAUP     R*4      N.R.          TAUI     R*4      N.R.          TAUE     R*4      N.R.          TAUO     R*4      N.R.
  DTMULT     R*4      N.R.            PI     R*4      N.R.          GRAV     R*4      N.R.          RGAS     R*4      N.R.
    KAPA     F*4      N.R.           PSL     R*4      N.R.            ED     R*4      N.R.           FMU     R*4      N.R.
    NFLW     I*4      N.R.           PSF     R*4      N.R.          MRCH     I*4      N.R.        RSDIST     R*4      N.R.
    SIND     R*4      N.R.          COSD     R*4      N.R.         RHMAX     R*4      N.R.           CDX     R*4      N.R.
  DUMMYC     R*4      N.R.        IALTER     I*4      N.R.        DUMMYA     R*4      N.R.        XLABEL     R*4    000320
     SIG     R*4      N.R.          DSIG     R*4      N.R.          SIGE     R*4      N.R.         DSIGO     R*4      N.R.
    J1PS     I*4      N.R.          JMPS     I*4      N.R.          J1US     I*4      N.R.          JMUS     I*4      N.R.
    KSBS     I*4      N.R.          KNBS     I*4      N.R.           LAT     R*4      N.R.           DXU     R*4      N.R.
     DXP     R*4      N.R.           DYU     R*4      N.R.           DYP     R*4      N.R.          DXYP     R*4      N.R.
       F     R*4      N.R.          SINL     R*4      N.R.          COSL     R*4      N.R.         DUMMY     R*4      N.R.
    PHIS     R*4    000D50        ALBEDO     I*2      N.R.

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE CFFSETE            VARIABLE OFFSETE             VARIABLE OFFSETE             VARIABLE OFFSETE
        U   000E70                  TS   001890                   V   001980                 SMS   002300
        T   0024F0                   P   002F10                  SH   003030                   C   000009
  MACHIN    00018C

  NAME OF CCMMON BLOCK *  =O#S#E GF ELOCKCOMMON     081600 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
     PU    R*4   000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE CFFSETE            VARIABLE OFFSETE             VARIABLE OFFSETE             VARIABLE OFFSETE
      GT    000840                  GW   00168C

  NAME OF CCMMON BLOCK * S*OT'9E OF BLOCKCOMMON     0385AE HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    SDOT    R*4   000300          OMEGA    I*2   019E09          MNMXTS    I*4     N.R.            RADT    I*2   0286E4
    COMG    L*4   0389A4

EQUIVALENCED VARIABLES WITHIN THIS CCMMON GROUP
  VARIABLE CFFSETE            VARIABLE OFFSETE             VARIABLE OFFSETE             VARIABLE OFFSETE
   ISDCT    00CF00

  NAME OF CCMMON BLOCK *  *S6¬"E OF ELOCKCOMMON     000008 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
```

```
    LABEL   ADDR                LABEL   ADDR                LABEL   ADDR                LABEL   ADDR
       70  002680                  73  002856                  76  00293A                  77  002A22
       75  0028A0                  80  0028EC                  90  002C88

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =       61   PROGRAM SIZE =     11480

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                          864K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                         OS/360 FORTRAN H AT GISS                              DATE 12/12/79-0763.23

       COMPILER OPTIONS -    NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  ISN 0002                 SUBROUTINE COMPO(J,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,       B4M09340
                          $   UT,VT,TT,SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL)          B4M09350
  ISN 0003                 COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,TFBAR,ALPHA,BETA,IMD2P1,     B4M09360
                          $   ADLOP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,             B4M09370
                          $   IMD2,RADIM,JEND(2),JP1,JP2,MAISUN,JNEXT(2),MODPK(2,2),            B4M09380
                          $   JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),             B4M09390
                          $   PSIGN(4),POLES(148),*(72,9,5),PK(72,9,3),D,FF(9),                 B4M09400
                          $   CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                           B4M09410
  ISN 0004                 DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),       B4M09420
                          $   SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                              B4M09430
  ISN 0005                 DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),             B4M09440
                          $   SHTPOL(36,1),QTPOL(9,4,2),QT(72,10,4,1)                           B4M09450
  ISN 0006                 COMMON/SMITH/QSM(72,9,4,5),PSM(72,5),QSMPOL(9,4,2),PSMPOL(2)        B4M09460
  ISN 0007                 INTEGER*2 ALBEDO                                                    B4M09470
  ISN 0008                 REAL*4 KAPA,LAT                                                     B4M09480
                   C       REAL*8 SINLON,COSLON,SUM                                            B4M09490
  ISN 0009                 COMMON /CNTRL/                                                      B4M09500
                          *  JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,        B4M09510
                          *  J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                              B4M09520
                          *  NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                           B4M09530
                          *  DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,    B4M09540
                          *  NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUO,DTMULT,                  B4M09550
                          *  PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLM,PSF,PRCH,RSDIST,SIND,COSD,      B4M09560
                          *  RHMAX,COX,DUMMYC(18),IALTER,DUMMYA(99),                           B4M09570
                          *  XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                   B4M09580
                          *  JIPS(11),JMPS(11),JIUS(11),JMUS(11),KSES(11),KNBS(11),            B4M09590
                          *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),    B4M09600
                          *COSL(46),DUMMY(2),PHIS(2880,46),ALBEDO(72,46)                       B4M09610
  ISN 0010                 DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),             B4M09620
                          *P(2880,1),    TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)   B4M09630
  ISN 0011                 EQUIVALENCE (TS(1,1),PHIS(721,1)),(SHS(1,1),PHIS(1441,1)),          B4M09640
                          $    (GT(1,1),PU(721,1)),(GW(1,1),PU(1441,1)),(C(1),JSP)             B4M09650
  ISN 0012                 COMMON /DBUG/ISWTCH                                                 B4M09660
                   C                                                                           B4M09670
  ISN 0013                 COMMON/SDOT48/SDOT(72,46,8),OMEGA(72,46,5),MNMXTS,RADT(72,46,10)    B4M09680
                          +  ,COMG                                                             B4M09690
  ISN 0014                 LOGICAL COMG                                                        B4M09700
                   C                                                                           B4M09710
  ISN 0015                 INTEGER*2 RADT,OMEGA                                                B4M09720
  ISN 0016                 INTEGER*2 ISDOT(72,46,8)                                            B4M09730
                   C                                                                           B4M09740
  ISN 0017                 EQUIVALENCE (SDOT(1,1,5),ISDOT(1,1,1))                              B4M09750
                   C                                                                           B4M09760
  ISN 0018                 COMMON/SMOO/ISMTH,NPC                                               B4M09770
  ISN 0019                 COMMON/MLFS/NSEG,MLF(10),MATSNX,NSM1,NCM1                           B4M09780
  ISN 0020                 COMMON/TPG/TOPOG(72,46)                                             B4M09790
  ISN 0021                 COMMON/WORK/ FD(648,46)                                             B4M09800
  ISN 0022                 COMMON/WORK2/PU(2880,46)                                            B4M09810
  ISN 0023                 DIMENSION UT(72,40,1),VT(72,40,1),TT(72,40,1),SHT(72,40,1),         B4M09820
                          *PT(2880,1)                                                          B4M09830
                   C                                                                           B4M09840
                   C                                                                         * B4M09850
                   C * * *            M A I N   L O O P                                      * B4M09860
                   C                                                                         * B4M09870
  ISN 0024                 CON3 = 4. * DT / (RADIM * SIN(.5 * DLAT))                           B4M09880
  ISN 0025                 CON4 = DT / (RADIM * SIN(DLAT))                                     B4M09890
  ISN 0026                 JS2 = 1                                                             B4M09900
  ISN 0027                 JS1 = 1                                                             B4M09910
  ISN 0028                 K=2                                                                 B4M09920
  ISN 0029                 DO 10 JJ = 1,JM                                                     B4M09930
  ISN 0030                 J = JJ                                                              B4M09940
  ISN 0031                 JP1 = J + 1                                                         B4M09950
  ISN 0032                 JP2 = J + 2                                                         B4M09960
  ISN 0033                 JP2MOD = MOD(JP2 - 1,5) + 1                                         B4M09970
  ISN 0034                 JP1MOD = MOD(JP1 - 1,5) + 1                                         B4M09980
```

```
ISN 0035          JMOD = MOD(J - 1,5) + 1                                                        B4M09990
ISN 0036          JS1MOD = MOD(JS1 - 1,5) + 1                                                    B4M10000
ISN 0037          JS2MOD = MOD(JS2 - 1,5) + 1                                                    B4M10010
ISN 0038          IF (JP2 .GT. JM)                GO TO 25                                       B4M10020
ISN 0040          IF (J .GT. 1)                   GO TO 18                                       B4M10030
ISN 0042          JP2 = 2                                                                        B4M10040
ISN 0043          JP2MOD = 2                                                                     B4M10050
            C                                                                                  * B4M10060
            C * * * SAVE QTPOL IN QSMPOL                                                       * B4M10070
            C                                                                                  * B4M10080
ISN 0044          DO 15 M = 1,2                                                                  B4M10090
ISN 0045          PSMPOL(M) = PTPOL(M)                                                           B4M10100
ISN 0046          DO 15 N = 1,4                                                                  B4M10110
ISN 0047          DO 15 L = 1,NLAY                                                               B4M10120
ISN 0048          QSMPOL(L,N,M) = QTPOL(L,N,M)                                                   B4M10130
ISN 0049       15                                 CONTINUE                                       B4M10140
            C                                                                                    B4M10150
            C                                                                                  * B4M10160
            C * * * SAVE QT(JP2) IN QSM(JP2MOD)                                                  B4M10170
            C                                                                                  * B4M10180
ISN 0050       18 DO 22 I = INC,IM,INC                                                           B4M10190
ISN 0051          PSM(I,JP2MOD) = PT(I,JP2)                                                      B4M10200
ISN 0052       22                                 CONTINUE                                       B4M10210
ISN 0053          DO 20 N = 1,4                                                                  B4M10220
ISN 0054          DO 20 L = 1,NLAY                                                               B4M10230
ISN 0055          DO 20 I = INC,IM,INC                                                           B4M10240
ISN 0056          QSM(I,L,N,JP2MOD) = QT(I,L,N,JP2)                                              B4M10250
ISN 0057       20                                 CONTINUE                                       B4M10260
ISN 0058          IF (JP2 .GT. 2)                 GO TO 25                                       B4M10270
ISN 0060          JP2 = JP2 + 1                                                                  B4M10280
ISN 0061          JP2MOD = JP2MOD + 1                                                            B4M10290
ISN 0062                                          GO TO 18                                       B4M10300
ISN 0063       25 CALL COMP1(U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,UT,VT,TT,               B4M10310
                 $   SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL,J)                           B4M10320
ISN 0064          CALL COMP2(U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,UT,VT,TT,               B4M10330
                 $   SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL,J)                           B4M10340
ISN 0065          IF(J.NE.1.AND.J.NE.JNP)GO TO 210                                               B4M10350
ISN 0067          M=1                                                                            B4M10360
ISN 0068          IF(J.EQ.JNP)M=2                                                                B4M10370
ISN 0070          DO 204 L=2,NLAY                                                                B4M10380
ISN 0071          LM1=L-1                                                                        B4M10390
ISN 0072          IF(SHTPOL(LM1,M).GE.0.)GO TO 204                                               B4M10400
ISN 0074          SHTPOL(L,M)=SHTPOL(L,M)+SHTPOL(LM1,M)*DSIG(LM1)/DSIG(L)                        B4M10410
ISN 0075          SHTPOL(LM1,M)=0.                                                               B4M10420
ISN 0076      204 CONTINUE                                                                       B4M10430
ISN 0077          IF(SHTPOL(NLAY,M).LT.0.)SHTPOL(NLAY,M)=0.                                      B4M10440
ISN 0079          GO TO 212                                                                      B4M10450
ISN 0080      210 DO 202 L=2,NLAY                                                                B4M10460
ISN 0081          DO 202 I=1,IM                                                                  B4M10470
ISN 0082          LM1=L-1                                                                        B4M10480
ISN 0083          IF(SHT(I,LM1,J).GE.0.)GO TO 202                                                B4M10490
ISN 0085          SHT(I,L,J)=SHT(I,L,J)+SHT(I,LM1,J)*DSIG(LM1)/DSIG(L)                           B4M10500
ISN 0086          SHT(I,LM1,J)=0.                                                                B4M10510
ISN 0087      202 CONTINUE                                                                       B4M10520
ISN 0088          DO 203 I=1,IM                                                                  B4M10530
ISN 0089          IF(SHT(I,NLAY,J).LT.0.)SHT(I,NLAY,J)=0.                                        B4M10540
ISN 0091      203 CONTINUE                                                                       B4M10550
ISN 0092      212 CONTINUE                                                                       B4M10560
ISN 0093          DO 27 I = INC,IM,INC                                                           B4M10570
ISN 0094          PST = PT(I,J) + PTOP                                                           B4M10580
ISN 0095          IF((PST.GE.400.).AND.(PST.LE.1100.)) GO TO 27                                  B4M10590
ISN 0097          WRITE(3,301)I,J,PT(I,J),P(I,J)                                                 B4M10600
ISN 0098          WRITE(3,302)(U(I-INC,L,JP1),L=1,NLAY)                                          B4M10610
ISN 0099          WRITE(3,302)(U(I,L,JP1),L=1,NLAY)                                              B4M10620
ISN 0100          WRITE(3,302)(U(I-INC,L,J),L=1,NLAY)                                            B4M10630
ISN 0101          WRITE(3,302)(U(I,L,J),L=1,NLAY)                                                B4M10640
ISN 0102          WRITE(3,302)(V(I-INC,L,JP1),L=1,NLAY)                                          B4M10650
ISN 0103          WRITE(3,302)(V(I,L,JP1),L=1,NLAY)                                              B4M10660
ISN 0104          WRITE(3,302)(V(I-INC,L,J),L=1,NLAY)                                            B4M10670
ISN 0105          WRITE(3,302)(V(I,L,J),L=1,NLAY)                                                B4M10680
ISN 0106          WRITE(3,302)(T(I,L,J),L=1,NLAY)                                                B4M10690
ISN 0107          WRITE(3,302)(SH(I,L,J),L=1,NLAY)                                               B4M10700
ISN 0108          STOP                                                                           B4M10710
ISN 0109       27                                 CONTINUE                                       B4M10720
ISN 0110          IF (J .LT. 3)                   GO TO 200                                      B4M10730
ISN 0112          IF (J .EQ. 3)                   GO TO 70                                       B4M10740
            C                                                                                  * B4M10750
            C * * * UNSCALE                                                                    * B4M10760
            C                                                                                  * B4M10770
ISN 0114       29 DO 60 N = 1,4                                                                  B4M10780
ISN 0115          DO 60 L = 1,NLAY                                                               B4M10790
ISN 0116          DO 60 I = INC,IM,INC                                                           B4M10800
ISN 0117          QT(I,L,N,JS2) = QT(I,L,N,JS2) / (DXYP(JS2) * PT(I,JS2))                        B4M10810
ISN 0118       60                                 CONTINUE                                       B4M10820
ISN 0119             CALL AVRX(UT,VT,TT,SHT,PT,QT,JS2)                                           B4M10830
            C                                                                                  * B4M10840
            C * * * NO TIME SMOOTHING FOR MATSUNO STEP                                         * B4M10850
            C                                                                                  * B4M10860
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
                C *** IF(LEAP.AND.NEXT STEP IS LEAP)                                     B4M10870
ISN 0120              IF(MATSUN+MATSNX.EQ.0)GO TC 45                                     B4M10880
                C *** IF(NEXT CALL IS TO MATS PRED.)                                     B4M10890
ISN 0122              IF((NPC.EQ.1).AND.(MATSNX.EQ.1))GO TO 58                           B4M10900
ISN 0124              DO 28 I = INC.IM.INC                                               B4M10910
ISN 0125              P(I.JS2) = PSM(I.JS2MOD)                                           B4M10920
ISN 0126           28                               CONTINUE                             B4M10930
ISN 0127              DO 30 N = 1.4                                                      B4M10940
ISN 0128              DO 30 L = 1.NLAY                                                   B4M10950
ISN 0129              DO 30 I = INC.IM.INC                                               B4M10960
ISN 0130              Q(I.L.N.JS2) = QSM(I.L.N.JS2MOD)                                   B4M10970
ISN 0131           30                               CONTINUE                             B4M10980
ISN 0132              IF(NPC.EQ.1)GO TO 63                                               B4M10990
ISN 0134                                            GO TC 67                             B4M11000
ISN 0135           58 DO 61 I=INC.IM.INC                                                 B4M11010
ISN 0136              P(I.JS2) = PT(I.JS2)                                               B4M11020
ISN 0137         61                                 CONTINUE                             B4M11030
ISN 0138              DO 62 N=1.4                                                        B4M11040
ISN 0139              DO 62 L=1.NLAY                                                     B4M11050
ISN 0140              DO 62 I=INC.IM.INC                                                 B4M11060
ISN 0141              Q(I.L.N.JS2) = QT(I.L.N.JS2) * (DXYP(JS2) * PT(I.JS2))             B4M11070
ISN 0142         62                                 CONTINUE                             B4M11080
ISN 0143                                            GO TC 64                             B4M11090
                C                                                                      * B4M11100
                C * * * SMOOTH Q(JS2) FOR SMOOTH LEAPFROG TIME SCHEME                   * B4M11110
                C * * * ALPHA = .5 * NU     BETA = 1 - 2. * ALPHA                      * B4M11120
                C                                                                      * B4M11130
ISN 0144           45 DO 48 I = INC.IM.INC                                               B4M11140
ISN 0145              P(I.JS2) = BETA * P(I.JS2) + ALPHA * (PSM(I.JS2MOD) + PT(I.JS2))   B4M11150
ISN 0146           48                               CONTINUE                             B4M11160
ISN 0147              DO 50 N = 1.4                                                      B4M11170
ISN 0148              DO 50 L = 1.NLAY                                                   B4M11180
ISN 0149              DO 50 I = INC.IM.INC                                               B4M11190
ISN 0150              Q(I.L.N.JS2) = BETA * DXYP(JS2) * P(I.JS2) * Q(I.L.N.JS2)          B4M11200
                     $ +ALPHA*(QSM(I.L.N.JS2MOD)+QT(I.L.N.JS2)*DXYP(JS2)*PT(I.JS2))      B4M11210
ISN 0151           50                               CONTINUE                             B4M11220
                C                                                                      * B4M11230
ISN 0152           63 CONTINUE                                                           B4M11240
                C * * * SOURCE TERM CORRECTION DUE TO LEAPFROG TIME SCHEME             * B4M11250
                C                                                                      * B4M11260
                C *** 12/12/77                                                           B4M11270
ISN 0153              IF(MOD(NSTEP-NCM1.NCOMP3).NE.0)GC TO 67                            B4M11280
ISN 0155              DO 57 N = 1.4                                                      B4M11290
ISN 0156              DO 57 L = 1.NLAY                                                   B4M11300
ISN 0157              DO 57 I = INC.IM.INC                                               B4M11310
ISN 0158              Q(I.L.N.JS2) = Q(I.L.N.JS2) - QT(I.L.N.JS2) *                      B4M11320
                     1DXYP(JS2)*PT(I.JS2)                                                B4M11330
ISN 0159           57                               CONTINUE                             B4M11340
ISN 0160           64 IF(MOD(NSTEP-NCM1.NCOMP3).NE.0)GC TO 67                            B4M11350
                C     IF(MATSUNO PRED. STEP)                                             B4M11360
ISN 0162              IF((MATSUN.EQ.1).AND.(NPC.EQ.0))GO TO 67                           B4M11370
ISN 0164              CALL COMP3(UT.VT.TT.SHT.PT.QT.UTPOL.VTPOL.TTPOL.SHTPOL.PTPOL.      B4M11380
                     $    QTPOL.JS2)                                                     B4M11390
                C *** IF(MATSUNO.OR NOT COMP3 STEP)                                      B4M11400
ISN 0165              IF((MATSNX.NE.0).OR.(MOD(NSTEP-NCM1.NCOMP3).NE.0))GO TO 67         B4M11410
ISN 0167              DO 65 N=1.4                                                        B4M11420
ISN 0168              DO 65 L=1.NLAY                                                     B4M11430
ISN 0169              DO 65 I=INC.IM.INC                                                 B4M11440
ISN 0170              Q(I.L.N.JS2) = Q(I.L.N.JS2) + DXYP(JS2) * PT(I.JS2) *              B4M11450
                     $    QT(I.L.N.JS2)                                                  B4M11460
ISN 0171        65    CONTINUE                                                           B4M11470
ISN 0172        67    IF (J .LT. JM)                GO TC 200                            B4M11480
ISN 0174              JS2 = JS2 + 1                                                      B4M11490
ISN 0175              JS2MOD = MOD(JS2-1.5) + 1                                          B4M11500
ISN 0176              IF (JS2 .LE. JM)              GO TO 29                             B4M11510
                C                                                                      * B4M11520
                C * * * POLES                                                          * B4M11530
                C                                                                      * B4M11540
ISN 0178           70 M = 1                                                              B4M11550
ISN 0179              IF (J .EQ. JM)                M = 2                                B4M11560
ISN 0181              COEF1 = (-1.) ** M                                                 B4M11570
                C *** IF(LEAP.AND.NEXT STEP IS LEAP)                                     B4M11580
ISN 0182              IF(MATSUN+MATSNX.EQ.0)GO TC 85                                     B4M11590
                C *** IF((MATS PRED.OR.(MATS CORR. AND NEXT STEP IS LEAP))               B4M11600
ISN 0184              IF((MATSUN.EQ.1).AND.(NPC*MATSNX.EQ.0))GC TO 78                    B4M11610
ISN 0186              PPOL(M) = PTPOL(M)                                                 B4M11620
ISN 0187                 DO 75 N = 1.4                                                   B4M11630
ISN 0188                 DO 75 L = 1.NLAY                                                B4M11640
ISN 0189              QPOL(L.N.M) = QTPOL(L.N.M)                                         B4M11650
ISN 0190           75                               CONTINUE                             B4M11660
ISN 0191                                            GO TC 94                             B4M11670
ISN 0192           78 PPOL(M) = PSMPOL(M)                                                B4M11680
ISN 0193              DO 80 N = 1.4                                                      B4M11690
ISN 0194              DO 80 L = 1.NLAY                                                   B4M11700
ISN 0195              QPOL(L.N.M) = QSMPOL(L.N.M)                                        B4M11710
ISN 0196           80                               CONTINUE                             B4M11720
ISN 0197              IF(NPC.EQ.1)GO TO 93                                               B4M11730
ISN 0199                                            GO TC 94                             B4M11740
```

```
ISN 0200        85 PPOL(M) = BETA * PPOL(M) + ALPHA * (PSMPOL(M) + PTPOL(M))                   B4M11750
ISN 0201           DO 87 N = 1,4                                                                B4M11760
ISN 0202           DO 87 L = 1,NLAY                                                             B4M11770
ISN 0203           QPOL(L,N,M)=BETA*PPOL(M)*QPOL(L,A,M)+ALPHA                                   B4M11780
                 $    * (QSMPOL(L,N,M) + QTPOL(L,N,M))                                          B4M11790
ISN 0204        87                            CONTINUE                                          B4M11800
              C                                                                              *  B4M11810
              C * * * SOURCE TERM CORRECTION DUE TO LEAPFROG TIME SCHEME                     *  B4M11820
              C                                                                              *  B4M11830
              C *** 12/12/77                                                                    B4M11840
ISN 0205        93 CONTINUE                                                                     B4M11850
ISN 0206           IF(MOD(NSTEP-NCM1,NCOMP3).NE.0)GC TO 94                                      B4M11860
ISN 0208           DO 92 N = 1,4                                                                B4M11870
ISN 0209           DO 92 L = 1,NLAY                                                             B4M11880
ISN 0210           QPOL(L,N,M) = QPOL(L,A,M) - QTPOL(L,N,M)                                     B4M11890
ISN 0211        92                            CONTINUE                                          B4M11900
              C                                                                              *  B4M11910
              C * * * UNSCALE                                                                *  B4M11920
              C                                                                              *  B4M11930
ISN 0212        94                            CONTINUE                                          B4M11940
ISN 0213           DO 96 N = 1,4                                                                B4M11950
ISN 0214           DO 96 L = 1,NLAY                                                             B4M11960
ISN 0215           QTPOL(L,N,M) = QTPOL(L,N,M) / PTPOL(M)                                       B4M11970
ISN 0216        96                            CONTINUE                                          B4M11980
ISN 0217           IF(MOD(NSTEP-NCM1,NCOMP3).NE.0)GC TO 98                                      B4M11990
              C    IF(MATSUNO PRED. STEP)                                                       B4M12000
ISN 0219           IF((MATSUN.EQ.1).AND.(NPC.EQ.0))GO TO 98                                     B4M12010
ISN 0221           CALL COMP3(UT,VT,TT,SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,                B4M12020
                 $    QTPOL,JS2)                                                                B4M12030
ISN 0222           IF(MATSNX.NE.0)GO TO 98                                                      B4M12040
ISN 0224           DO 105 N = 1,4                                                               B4M12050
ISN 0225           DO 105 L = 1,NLAY                                                            B4M12060
ISN 0226           QPOL(L,N,M) = QPOL(L,N,M) + PTPOL(M) * QTPOL(L,N,M)                          B4M12070
ISN 0227       105                            CONTINUE                                          B4M12080
              C                                                                              *  B4M12090
              C * * * COPY QTPOL INTO  QT                                                    *  B4M12100
              C                                                                              *  B4M12110
ISN 0228        98 DO 100 I = INC,IM,INC                                                        B4M12120
ISN 0229           PT(I,JEND(M)) = PTPOL(M)                                                     B4M12130
ISN 0230       100                            CONTINUE                                          B4M12140
ISN 0231           DO 110 N = 3,4                                                               B4M12150
ISN 0232           DO 110 L = 1,NLAY                                                            B4M12160
ISN 0233           DO 110 I = INC,IM,INC                                                        B4M12170
ISN 0234           QT(I,L,N,JEND(M)) = QTPOL(L,N,M)                                             B4M12180
ISN 0235       110                            CONTINUE                                          B4M12190
ISN 0236           DO 120 L = 1,NLAY                                                            B4M12200
ISN 0237           DO 120 I = INC,IM,INC                                                        B4M12210
ISN 0238           UT(I,L,JEND(M))=-UTPOL(L,M)*SINLON(I)+COEF1*VTPOL(L,M)*COSLON(I)             B4M12220
ISN 0239           VT(I,L,JEND(M))=-COEF1*UTPOL(L,M)*COSLON(I)-VTPOL(L,M)*SINLON(I)             B4M12230
ISN 0240       120                            CONTINUE                                          B4M12240
ISN 0241       200 JS2 = JS1                                                                    B4M12250
ISN 0242           JS1 = J                                                                      B4M12260
ISN 0243        10                            CONTINUE                                          B4M12270
ISN 0244       301 FORMAT( '0    PRESSURE DIAGNOSTIC.  I,J,PT,P=',2I4,2E15.5)                   B4M12280
ISN 0245       302 FORMAT(5X,9E14.4)                                                            B4M12290
ISN 0246                                      RETURN                                            B4M12300
ISN 0247                                      END                                               B4M12310

                                           /   COMPC /     SIZE OF PROGRAM 002B70 HEXADECIMAL BYTES

NAME TAG TYPE ADD.            NAME TAG TYPE ADD.            NAME TAG TYPE ADD.            NAME TAG TYPE ADD.
    C        CE  R*4 000000       F         C  R*4   N.R.       I SF         I*4 0001CC       J SFA        I*4 000100
    K S          I*4 0001D4       L SF         I*4 0001DE       M SF         I*4 0001DC       N SF         I*4 0001E0
    P SFA  XR    R*4 000000       Q SFA  XR    R*4 00000C       R         C  R*4   N.R.       T SFA  XR    R*4 000000
    U SFA  XR    R*4 000000       V SFA  XR    R*4 00000C       W         C  R*4   N.R.      CP         C  R*4   N.R.
   DT  F      C  R*4 00008C      ED         C  R*4   N.R.      FD         C  R*4   N.R.      GT        CE  R*4 000840
   GM        CE  R*4 001680      IM  F      C  I*4 00000E      JJ SF         I*4 0001E4      JM  F      C  I*4 000030
   J1         C  I*4   N.R.      KM         C  I*4   N.R.      NR         C  I*4   N.R.      PI         C  R*4   N.R.
   PK         C  R*4   N.R.      PT SFA  XR    R*4 00000C      PU        CE  R*4 000000      QT SFA  XR    R*4 000000
   SH SFA  XR    R*4 000000      TS        CE  R*4 00189C      TT SFA  XR    R*4 000000      UT SFA  XR    R*4 000000
   VT SFA  XR    R*4 000000     CDX         C  R*4   N.R.     DXP         C  R*4   N.R.     DXU         C  R*4   N.R.
  DYP         C  R*4   N.R.     DYU         C  R*4   N.R.     FIM         C  R*4   N.R.     FMU         C  R*4   N.R.
  INC  F      C  I*4 000044     JNB         C  I*4   N.R.     JNP         C  I*4 000004     JP1 SFA     C  I*4 000060
  JP2 SFA     C  I*4 000064     JSB         C  I*4   N.R.     JSP        CE  I*4 000000     JS1 SFA        I*4 0001E8
  JS2 SFA        I*4 0001EC     LAT         C  R*4   N.R.     LM1 SF         I*4 0001F0     MLF         C  I*4   N.R.
  NPC         C  I*4 000004     PSF         C  R*4   N.R.     PSL         C  R*4   N.R.     PSM SF      C  R*4 00CA80
  PST S          R*4 0001F4     QSM SF      C  R*4 00000C     RAD         C  R*4   N.R.     SMS        CE  R*4 002300
  SHT SFA  XR    R*4 000000     SIG         C  R*4   N.R.     SUM         C  R*4   N.R.     TAU         C  R*4   N.R.
 AVRX SF   XF    R*4 000000    BETA  F      C  R*4 00001C    COMG         C  L*4 0389A4    CON1         C  R*4   N.R.
 CON2         C  R*4   N.R.    CON3 S       C  R*4 00000E    CON4 S       C  R*4 000[illegible]C    CONS         C  R*4   N.R.
 COSD         C  R*4   N.R.    COSL         C  R*4   N.R.    CPD2         C  R*4   N.R.    CPTM         C  R*4   N.R.
 DIFF         C  R*4   N.R.    DLAT  FA     C  R*4 0000B4    DLON         C  R*4   N.R.    DSIG  F      C  R*4 0003C0
 DXYP  F      C  R*4 000950    GRAV         C  R*4   N.R.    IDAY         C  I*4   N.R.    IND2         C  I*4   N.R.
 INCS         C  I*4   N.R.    IROT         C  I*4   N.R.    ITAU         C  I*4   N.R.    JAYS         C  I*4   N.R.
 JDAY         C  I*4   N.R.    JEND  F      C  I*4 00005E    JMOD S          I*4 0001F8    JMPS         C  I*4   N.R.
 JMS1         C  I*4   N.R.    JMS2         C  I*4   N.R.    JMUS         C  I*4   N.R.    JPOL         C  I*4   N.R.
 JIPS         C  I*4   N.R.    JIUS         C  I*4   N.R.    KAPA         C  R*4   N.R.    KNBS         C  I*4   N.R.
 KSBS         C  I*4   N.R.    MRCH         C  I*4   N.R.    NROT         C  I*4   N.R.    NCM1    A    C  I*4 000034
```

```
   NFLW     C   I*4    N.R.         NLAY F   C   I*4  00000C         NSEQ     C   I*4    N.R.         NSM1     C   I*4    N.R.
   PHIS     CE  R*4  000D50         PPOL SFA XR  R*4  00000C         PTOP F   C   R*4  000010         QPOL SFA XR  R*4  000000
   RADT     C   I*2    N.R.         RGAS     C   R*4    N.R.         SDOT     CE  R*4  000030         SIGE     C   R*4    N.R.
   SIND     C   R*4    N.R.         SINL     C   R*4    N.R.         TAUE     C   R*4    N.R.         TAUI     C   R*4    N.R.
   TAUD     C   R*4    N.R.         TAUP     C   R*4    N.R.         TAUT     C   R*4    N.R.         TPOL SFA XR  R*4  000000
   UPOL SFA XR  R*4  000000         VPOL SFA XR  R*4  00000C         XINT     C   R*4    N.R.        ADLDP     C   R*4    N.R.
  ALPHA F   C   R*4  000018        COEF1 SF      R*4  0001FC        COMP0         R*4  000230        COMP1 SF  XF  R*4  000000
  COMP2 SF  XF  R*4  000000        COMP3 SF  XF  R*4  00000C        DSIGO     C   R*4    N.R.        DUMMY     C   R*4    N.R.
  INDEX     C   I*4    N.R.        ISDOT     CE  I*2  00CF0C        ISMTH     C   I*4    N.R.        ITEST     C   I*4    N.R.
  JDATE     C   I*4    N.R.        JNEXT     C   I*4    N.R.        JNPM1     C   I*4    N.R.        JPMOD     C   I*4    N.R.
  JSPP1     C   I*4    N.R.        JTEST     C   I*4    N.R.        JYEAR     C   I*4    N.R.        MODPK     C   I*4    N.R.
  NSTEP   A C   I*4  0000E8        OMEGA     C   I*2    N.R.        POLES     C   R*4    N.R.        PSIGN     C   R*4    N.R.
  PTPOL SFA XR  R*4  000000        QTPOL SFA XR  R*4  00000C        RADIM F   C   R*4  000054        RHMAX     C   R*4    N.R.
  SDPOL     C   R*4    N.R.        SHPOL SFA XR  R*4  00000C        THBAR     C   R*4    N.R.        TOPOG     C   R*4    N.R.
  TTPOL SFA XR  R*4  000000        UTPOL SFA XR  R*4  00000C        VTPOL SFA XR  R*4  000000       FRXPI#     XF  R*4  000000
    SIN     XF  R*4  000000       ALBEDO     C   I*2    N.R.       CONVPL     C   R*4    N.R.       COSLON F   C   R*4  0001C4
 DTMULT     C   R*4    N.R.       DUMMYA     C   R*4    N.R.       DUMMYC     C   R*4    N.R.       IALTER     C   I*4    N.R.
 IBCOM# F   XF  I*4  000000       IMD2P1     C   I*4    N.R.       ISTART     C   I*4    N.R.       ISWTCH     C   I*4    N.R.
 JMONTH     C   I*4    N.R.       JP1MOD S       I*4  000204       JP2MOD SF      I*4  000208       JS1MOD S       I*4  00020C
 JS2MOD SF      I*4  000210       MATSNX     C   I*4  00002C       MATSUN     C   I*4  000068       MNMXTS     C   I*4    N.R.
 NCOMP3   A C   I*4  0000F0       NCYCLE     C   I*4    N.R.       NHOGAN     C   I*4    N.R.       NLAYM1     C   I*4    N.R.
 NLAYP1     C   I*4    N.R.       NSTART     C   I*4    N.R.       PHISPL     C   R*4    N.R.       PITPOL         R*4    N.R.
 PSKAPA     C   R*4    N.R.       PSMPOL SF  C   R*4  00D14C       QSMPOL SF  C   R*4  000020       RSDIST     C   R*4    N.R.
 SHTPOL SFA XR  R*4  000000       SINLON F   C   R*4  0000A4       TOFDAY     C   R*4    N.R.       XLABEL     C   R*4    N.R.

                                          *****   COMMON INFORMATION   *****

   NAME OF COMMON BLOCK * F;U#.ZE OF BLOCKCOMMON     005E24 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
      CON1  R*4      N.R.             CON2  R*4      N.R.             CON3  R*4    000008             CON4  R*4    00000C
      CON5  R*4      N.R.            THBAR  R*4      N.R.            ALPHA  R*4    000018             BETA  R*4    00001C
    IMD2P1  I*4      N.R.            ADLDP  R*4      N.R.             JMS2  I*4      N.R.             JMS1  I*4      N.R.
      CPTH  R*4      N.R.           PSKAPA  R*4      N.R.                R  R*4      N.R.              RAD  R*4      N.R.
        CP  R*4      N.R.              INC  I*4    000044           NSTART  I*4      N.R.             CPD2  R*4      N.R.
      IMD2  I*4      N.R.            RADIM  R*4    000054             JEND  I*4    000058              JP1  I*4    000060
       JP2  I*4    000064           MATSUN  I*4    000068            JNEXT  I*4      N.R.            MODPK  I*4      N.R.
      JPOL  I*4      N.R.            JPMOD  I*4      N.R.           SINLON  R*4    0000A4           COSLON  R*4    0001C4
     INDEX  I*4      N.R.            PSIGN  R*4      N.R.            POLES  R*4      N.R.                W  R*4      N.R.
        PK  R*4      N.R.             DIFF  R*4      N.R.           CONVPL  R*4      N.R.            SDPOL  R*4      N.R.
    PHISPL  R*4      N.R.              SUM  R*4      N.R.

   NAME OF COMMON BLOCK *  =M..ZE OF BLOCKCOMMON     00D148 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
       QSM  R*4    000000              PSM  R*4    00CA80           QSMPOL  R*4    000020           PSMPOL  R*4    00D140

   NAME OF COMMON BLOCK *  -NTR#E OF BLOCKCOMMON     083C30 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
       JSP  I*4    000000              JNP  I*4    000004               IM  I*4    000008             NLAY  I*4    00000C
      PTOP  R*4    000010           ISTART  I*4      N.R.            JSPP1  I*4      N.R.            JNPM1  I*4      N.R.
       FIM  R*4      N.R.           NLAYM1  I*4      N.R.           NLAYP1  I*4      N.R.               J1  I*4      N.R.
        JM  I*4    000030               KM  I*4      N.R.             TAUT  R*4      N.R.             IROT  I*4      N.R.
      MROT  I*4      N.R.            JTEST  I*4      N.R.            ITEST  I*4      N.R.               NR  I*4      N.R.
      JAYS  I*4      N.R.             INCS  I*4      N.R.              JSB  I*4      N.R.              JNB  I*4      N.R.
      DLAT  R*4    000084             DLON  R*4      N.R.               DT  R*4    0000BC              TAU  R*4      N.R.
      ITAU  I*4      N.R.             XINT  R*4      N.R.             IDAY  I*4      N.R.             JDAY  I*4      N.R.
    TOFDAY  R*4      N.R.            JDATE  I*4      N.R.           JMONTH  I*4      N.R.            JYEAR  I*4      N.R.
     NSTEP  I*4    0000E8           NCYCLE  I*4      N.R.           NCOMP3  I*4    0000F0           NHOGAN  I*4      N.R.
      TAUP  R*4      N.R.             TAUI  R*4      N.R.             TAUE  R*4      N.R.             TAUD  R*4      N.R.
    DTMULT  R*4      N.R.               PI  R*4      N.R.             GRAV  R*4      N.R.             RGAS  R*4      N.R.
      KAPA  R*4      N.R.              PSL  R*4      N.R.               ED  R*4      N.R.              FMU  R*4      N.R.
      NFLW  I*4      N.R.              PSF  R*4      N.R.             MRCH  I*4      N.R.           RSDIST  R*4      N.R.
      SIND  R*4      N.R.             COSD  R*4      N.R.            RHMAX  R*4      N.R.              CDX  R*4      N.R.
    DUMMYC  R*4      N.R.           IALTER  I*4      N.R.           DUMMYA  R*4      N.R.           XLABEL  R*4      N.R.
       SIG  R*4      N.R.             DSIG  R*4    0003C0             SIGE  R*4      N.R.            DSIGO  R*4      N.R.
      J1PS  I*4      N.R.             JMPS  I*4      N.R.             J1US  I*4      N.R.             JMUS  I*4      N.R.
      KSBS  I*4      N.R.             KNBS  I*4      N.R.              LAT  R*4      N.R.              DXU  R*4      N.R.
       DXP  R*4      N.R.              DYU  R*4      N.R.              DYP  R*4      N.R.             DXYP  R*4    000950
         F  R*4      N.R.             SINL  R*4      N.R.             COSL  R*4      N.R.            DUMMY  R*4      N.R.
      PHIS  R*4    000D50           ALBEDO  I*2      N.R.
 EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
   VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE
         TS  001890                     SHS  0023DC                       C  000000

   NAME OF COMMON BLOCK *  *DS_7E OF BLOCKCOMMON     000C04 HEXADECIMAL BYTES

 VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
    ISWTCH  I*4      N.R.
```

```
   NAME OF CCMMON BLOCK * S*OT*9E OF BLOCKCOMMON      038SAE HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    SDOT     R*4   000003          OMEGA    I*2     N.R.          MNMXTS    I*4     N.R.          RADT     I*2     N.R.
    COMG     L*4   0389A4

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
   ISDCT     00CF00

   NAME CF CCMMCN BLOCK *  *S6-"E OF BLOCKCOMMON      000C0E HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   ISMTH     I*4     N.R.          NPC      I*4   000004

   NAME OF CCMMON BLOCK *  *M3|.E OF BLOCKCOMMON      000C38 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    NSEQ     I*4     N.R.          MLF      I*4     N.R.          MATSNX    I*4   00002C          NSM1     I*4     N.R.
    NCM1     I*4   000034

   NAME CF CCMMON BLOCK *  * T-7E OF BLOCKCOMMON      0033C0 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   TOPOG     R*4     N.R.

   NAME CF CCMMON BLOCK *  *W6R*E OF BLOCKCOMMON      010ICO HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      FD     R*4     N.R.

   NAME CF CCMMON BLOCK *  =O*S*E OF BLOCKCOMMON      081C00 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.FE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      PU     R*4   000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
```

```
 LABEL   ADDR              LABEL   ADDR              LABEL   ADDR              LABEL   ADDR
   15  000B1E                18  000B66                22  000BDE                20  000CC6
   25  000D4A               204  000E2A               210  000E84               202  000F5C
  203  000FCA               212  000FD4                27  00152E                29  00156A
   60  001648                28  001750                30  001834                58  0018A4
   61  0018FA                62  0019EE                45  001A3E                48  001AC2
   50  001C12                63  001C6E                57  001D5E                64  001DB2
   65  001F2E                67  001F72                70  001FB4                75  002098
   78  002004                80  002142                85  00218E                87  002244
   93  002278                92  0022F0                94  002324                96  0023A2
  105  002482                98  0024E6               100  00254C               110  00263E
  120  00278C               200  0027CC                10  0027E4

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      246  PROGRAM SIZE=      11120

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                          780K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                              OS/360 FORTRAN H AT GISS                                DATE 12/12/79-0783.48

        COMPILER OPTIONS -   NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
   ISN 0002                 SUBROUTINE COMP1(U,V,T,SH,P,C,UPCL,VPCL,TPCL,SHPOL,PPCL,QPOL,          B4M12320
                           $   UT,VT,TT,SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL,J)          B4M12330
   ISN 0003                 COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,TPBAR,ALPHA,BETA,IMD2P1,       B4M12340
                           $   ADLDP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,              B4M12350
                           $   IMD2,RADIM,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),             B4M12360
                           $   JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),              B4M12370
                           $   PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),                  B4M12380
                           $   CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                            B4M12390
   ISN 0004                 DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),         B4M12400
                           $   SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                               B4M12410
   ISN 0005                 DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),               B4M12420
                           $   SHTPOL(36,1),QTPOL(9,4,2),CT(72,10,4,1)                            B4M12430
   ISN 0006                 COMMON/SMITH/QSM(72,9,4,5),PSM(72,5),QSMPOL(9,4,2),PSMPOL(2)          B4M12440
   ISN 0007                 INTEGER*2 ALBEDO                                                      B4M12450
   ISN 0008                 REAL*4 KAPA,LAT                                                       B4M12460
                  C         REAL*8 SINLCN,COSLON,SUM                                              B4M12470
   ISN 0009                 COMMON /CNTRL/                                                        B4M12480
                           *   JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,         B4M12490
                           *   J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                               B4M12500
                           *   NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                            B4M12510
                           *   DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,     B4M12520
                           *   NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TALO,DTMULT,                   B4M12530
                           *   PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NPL,PSF,MRCH,RSDIST,SIND,COSD,        B4M12540
                           *   RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                            B4M12550
                           *   XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                    B4M12560
                           *   JIPS(11),JMPS(11),JIUS(11),JMUS(11),KSBS(11),KNBS(11),             B4M12570
                           *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),CXYP(46),F(46),SINL(46),      B4M12580
                           *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                        B4M12590
   ISN 0010                 DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),               B4M12600
                           *P(2880,1),    TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)     B4M12610
   ISN 0011                 EQUIVALENCE (TS(1,1),PHIS(721,1)),(SHS(1,1),PHIS(1441,1)),            B4M12620
                           $   (GT(1,1),PU(721,1)),(GW(1,1),PU(1441,1)),(C(1),JSP)                B4M12630
   ISN 0012                 COMMON/COMP12/PITPOL                                                  B4M12640
   ISN 0013                 COMMON/WORK/ CONV(72,9,46)                                            B4M12650
   ISN 0014                 COMMON/WORK2/PU(2880,46)                                              B4M12660
   ISN 0015                 DIMENSION UT(72,40,1),VT(72,40,1),TT(72,40,1),SHT(72,40,1),           B4M12670
                           *PT(2880,1),SD(72,9,1),PIT(648,1),PV(72,2)                             B4M12680
   ISN 0016                 EQUIVALENCE (SD(1,1,1),CONV(1,1,1)),(          CONV(1,9,1),           B4M12690
                           *   PIT(1,1))                                                          B4M12700
   ISN 0017                 COMMON /DBUG/ISWTCH                                                   B4M12710
                  C                                                                               B4M12720
   ISN 0018                 COMMON/SDOT48/SDOT(72,46,8),OMEGA(72,46,5),MNMXTS,RADT(72,46,10)      B4M12730
                           + ,COMG                                                                B4M12740
   ISN 0019                 LOGICAL COMG                                                          B4M12750
                  C                                                                               B4M12760
   ISN 0020                 INTEGER*2 RADT,OMEGA                                                  B4M12770
   ISN 0021                 INTEGER*2 ISDOT(72,46,8)                                              B4M12780
                  C                                                                               B4M12790
   ISN 0022                 EQUIVALENCE (SDOT(1,1,5),ISDOT(1,1,1))                                B4M12800
                  C                                                                               B4M12810
   ISN 0023                 COMMON/SMOO/ISMTH,NPC                                                 B4M12820
   ISN 0024                 QSAT(TM,PR) = .622 * EXP(21.65604 - 5417.983 / TM) / PR               B4M12830
   ISN 0025                 DATA J2/2/                                                            B4M12840
   ISN 0026                 JMS2 = JM - 2                                                         B4M12850
   ISN 0027                 F1CO = 4. * DT                                                        B4M12860
   ISN 0028                 F2CO = -.5 * DT                                                       B4M12870
```

```
ISN 0029          L = 1                                                            B4M12880
ISN 0030          JP2 = J + 2                                                      B4M12890
ISN 0031          JP1 = J + 1                                                      B4M12900
ISN 0032          JS1 = J - 1                                                      B4M12910
ISN 0033          JS2 = J - 2                                                      B4M12920
ISN 0034          JP2MOD = MOD(JP2-1,5) + 1                                        B4M12930
ISN 0035          JP1MOD = MOD(JP1-1,5) + 1                                        B4M12940
ISN 0036          JMOD = MOD(J-1,5) + 1                                            B4M12950
ISN 0037          JS1MOD = MOD(JS1-1,5) + 1                                        B4M12960
ISN 0038          JS2MOD = MOD(JS2-1,5) + 1                                        B4M12970
ISN 0039          IF (J .GT. 2)                 GO TO 2150                         B4M12980
ISN 0041          JS1 = 1                                                          B4M12990
ISN 0042          JS2 = 1                                                          B4M13000
ISN 0043          JS1MOD = 1                                                       B4M13010
ISN 0044          JS2MOD = 1                                                       B4M13020
            C                                                                    * B4M13030
            C * * * BEGIN OF LAYER LOOP                                          * B4M13040
            C * * * CALC OF PV                                                   * B4M13050
            C                                                                    * B4M13060
ISN 0045     2150 IF (J .EQ. JM)                GO TO 2158                         B4M13070
ISN 0047          DO 2154 I = INC,IM,INC                                           B4M13080
ISN 0048          PV(I,1) = DXP(J) * P(I,J) * V(I,L,J) + DXP(JP1) * P(I,JP1)       B4M13090
                 $    * V(I,L,JP1)                                                 B4M13100
ISN 0049          PV(I,J2) = DXP(J) * P(I,J) * V(I,L,J) + DXP(JP2) * P(I,JP2)      B4M13110
                 $    * V(I,L,JP2)                                                 B4M13120
ISN 0050     2154                               CONTINUE                           B4M13130
            C                                                                    * B4M13140
            C * * * PU CALCULATION (OMIT FOR J=1 , SOUTH POLE)                   * B4M13150
            C                                                                    * B4M13160
ISN 0051          IF (J .EQ. 1)                 GO TO 2225                         B4M13170
ISN 0053     2158 IS1 = IM - 1                                                     B4M13180
ISN 0054          I = IM                                                           B4M13190
ISN 0055          PUIS1 = DYU(J) * P(IS1,J) * U(IS1,L,J)                           B4M13200
ISN 0056          PUI = DYU(J) * P(I,J) * U(I,L,J)                                 B4M13210
ISN 0057          DO 2160 IP1 = INC,IM,INC                                         B4M13220
ISN 0058          PUIP1 = DYU(J) * P(IP1,J) * U(IP1,L,J)                           B4M13230
ISN 0059          PU(IS1,1) = PUIS1 + PUI                                          B4M13240
ISN 0060          PU(IS1,2) = PUIS1 + PUIP1                                        B4M13250
ISN 0061          PUIS1 = PUI                                                      B4M13260
ISN 0062          PUI = PUIP1                                                      B4M13270
ISN 0063          IS1 = I                                                          B4M13280
ISN 0064          I = IP1                                                          B4M13290
ISN 0065     2160                               CONTINUE                           B4M13300
            C                                                                    * B4M13310
            C * * * HORIZONTAL ADVECTION OF MOMENTUM, TEMPERATURE, MOISTURE       * B4M13320
            C * * * COMPUTE FLUXES FIRST IN THE LONGITUDINAL (I) DIRECTION        * B4M13330
            C                                                                    * B4M13340
ISN 0066          IS1 = IM - 1                                                     B4M13350
ISN 0067          I = IM                                                           B4M13360
ISN 0068          DO 2220 IP1 = INC,IM,INC                                         B4M13370
ISN 0069          FLUX1 = F1CO * PU(IS1,1)                                         B4M13380
ISN 0070          FLUX2 = F2CO * PU(IS1,2)                                         B4M13390
ISN 0071          DO 2223 N = 1,4                                                  B4M13400
ISN 0072          QFLUX1 = FLUX1 * (Q(IS1,L,N,J) + Q(I,L,N,J))                     B4M13410
ISN 0073          QFLUX2 = FLUX2 * (Q(IS1,L,N,J) + Q(IP1,L,N,J))                   B4M13420
ISN 0074          IF(N.NE.4)GO TO 100                                              B4M13430
ISN 0076          IF(Q(IS1,L,4,J).GT.0.)GO TO 110                                  B4M13440
ISN 0078          IF(QFLUX1.GT.0.)QFLUX1=0.                                        B4M13450
ISN 0080          IF(QFLUX2.GT.0.)QFLUX2=0.                                        B4M13460
ISN 0082      110 IF((Q(I,L,N,J).LE.0.).AND.(QFLUX1.LT.0.))QFLUX1=0.               B4M13470
ISN 0084          IF((Q(IP1,L,N,J).LE.0.).AND.(QFLUX2.LT.0.))QFLUX2=0.             B4M13480
ISN 0086      100 CONTINUE                                                         B4M13490
ISN 0087          QT(IP1,L,N,J) = QT(IP1,L,N,J) + QFLUX2                           B4M13500
ISN 0088          QT(I,L,N,J) = QT(I,L,N,J) + QFLUX1                               B4M13510
ISN 0089          QT(IS1,L,N,J) = QT(IS1,L,N,J) - QFLUX1 - QFLUX2                  B4M13520
ISN 0090     2223                               CONTINUE                           B4M13530
ISN 0091          IS1 = I                                                          B4M13540
ISN 0092          I = IP1                                                          B4M13550
ISN 0093     2220                               CONTINUE                           B4M13560
ISN 0094          IF (J .EQ. JM)                GO TO 2237                         B4M13570
            C                                                                    * B4M13580
            C * * * NOW DO FLUX CALCULATION IN THE LATITUDINAL (J) DIRECTION      * B4M13590
            C                                                                    * B4M13600
ISN 0096     2225 DO 2230 I = INC,IM,INC                                           B4M13610
ISN 0097          FLUX1 = F1CO * PV(I,1)                                           B4M13620
ISN 0098          FLUX2 = F2CO * PV(I,J2)                                          B4M13630
ISN 0099          DO 2230 N = 1,4                                                  B4M13640
ISN 0100          QFLUX1 = FLUX1 * (Q(I,L,N,J) + Q(I,L,N,JP1))                     B4M13650
ISN 0101          QFLUX2 = FLUX2 * (Q(I,L,N,J) + Q(I,L,N,JP2))                     B4M13660
ISN 0102          IF(N.NE.4)GO TO 120                                              B4M13670
ISN 0104          IF(Q(I,L,N,J).GT.0.)GO TO 115                                    B4M13680
ISN 0106          IF(QFLUX1.GT.0.)QFLUX1=0.                                        B4M13690
ISN 0108          IF(QFLUX2.GT.0.)QFLUX2=0.                                        B4M13700
ISN 0110      115 IF((Q(I,L,N,JP1).LE.0.).AND.(QFLUX1.LT.0.))QFLUX1=0.             B4M13710
ISN 0112          IF((Q(I,L,N,JP2).LE.0.).AND.(QFLUX2.LT.0.))QFLUX2=0.             B4M13720
ISN 0114      120 CONTINUE                                                         B4M13730
ISN 0115          QT(I,L,N,JP2) = QT(I,L,N,JP2) + QFLUX2                           B4M13740
ISN 0116          QT(I,L,N,JP1) = QT(I,L,N,JP1) + QFLUX1                           B4M13750
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
ISN 0117            QT(I.L.N.J) = QT(I.L.N.J) - QFLUX1 - QFLUX2                            B4M13760
ISN 0118      2230                              CONTINUE                                   B4M13770
            C                                                                           *  B4M13780
            C * * * FOLLOWING IS CORRECTION FOR CASE J=2                                *  B4M13790
            C * * * P(I.0) = P(INDEX(I).2)                                              *  B4M13800
            C * * * V(I.L.0) = -V(INDEX(I).L.2)  ETC.                                   *  B4M13810
            C * * * PV(I.2) FOR J=0 IS EQUAL TO: -CONV(I.L.2) . . SEE ABOVE             *  B4M13820
            C                                                                           *  B4M13830
ISN 0119            IF(J .GT. 1)                GO TO 2290                                 B4M13840
ISN 0121            DO 2240 I = INC.IM.INC                                                 B4M13850
ISN 0122            CONV(I.L.2)=0.                                                         B4M13860
ISN 0123      2240                              CONTINUE                                   B4M13870
            C                                                                           *  B4M13880
            C * * * CONTINUITY EQUATION                                                 *  B4M13890
            C * * * DUE TO 1 LINE OF LATITUDE AT A TIME THE DEFINITION OF PV.           *  B4M13900
            C * * * AND 4TH ORDER FORM OF CONV. WE COMPUTE IT AS FOLLOWS:               *  B4M13910
            C                                                                           *  B4M13920
ISN 0124      2290 IS2 = IM - 1                                                            B4M13930
ISN 0125           IS1 = IM                                                                B4M13940
ISN 0126           DO 2400 I    = INC.IM.INC                                               B4M13950
ISN 0127           CONV(I.L.JP2) = - PV(I.J2)                                              B4M13960
ISN 0128           CONV(I.L.JP1) = CONV(I.L.JP1) + 8. * PV(I.1)                            B4M13970
ISN 0129           CONV(I.L.J) = CONV(I.L.J) - 8. * PV(I.1) + PV(I.J2)                     B4M13980
                  $   + 8. * (PU(IS1.1) - PU(I.1)) + (PU(I.2) - PU(IS2.2))                 B4M13990
ISN 0130           IS2 = IS1                                                               B4M14000
ISN 0131           IS1 = I                                                                 B4M14010
ISN 0132      2400                              CONTINUE                                   B4M14020
            C                                                                           *  B4M14030
            C * * * FOLLOWING IS CORRECTION FOR J=JM.                                   *  B4M14040
            C * * * U(I.L.JM2) = -U(INDEX(I).L.JM). ETC.                                *  B4M14050
            C                                                                           *  B4M14060
ISN 0133           IF (J .LT. JM)               GO TO 2405                                 B4M14070
ISN 0135      2237 IS2 = IM - 3                                                            B4M14080
ISN 0136           IS1 = IM - 2                                                            B4M14090
ISN 0137           I = IM - 1                                                              B4M14100
ISN 0138           IP1 = IM                                                                B4M14110
ISN 0139           DO 2250 IP2 = INC.IM.INC                                                B4M14120
ISN 0140           PV1JM = DXP(JM) * P(I.JM) * V(I.L.JM)                                   B4M14130
ISN 0141           PV2JM=0.                                                                B4M14140
ISN 0142           CONV(I.L.JM) = CONV(I.L.JM) - 8. * PV1JM                                B4M14150
                  $    + PV2JM + DYU(JM) * (8. * (P(IS1.JM) * U(IS1.L.JM)                  B4M14160
                  $    - P(IP1.JM) * U(IP1.L.JM)) + (P(IP2.JM) * U(IP2.L.JM)               B4M14170
                  $    - P(IS2.JM) * U(IS2.L.JM)))                                         B4M14180
            C                                                                           *  B4M14190
            C * * * CALCULATION OF THE REMAINDER OF QT(I.L.N.JM)                        *  B4M14200
            C                                                                           *  B4M14210
ISN 0143           FLUX1 = F1CO * PV1JM                                                    B4M14220
ISN 0144           FLUX2 = F2CO * PV2JM                                                    B4M14230
ISN 0145           DO 2255 N = 1.4                                                         B4M14240
ISN 0146           QFLUX1 = FLUX1 * (Q(I.L.N.JM) + Q(I.L.N.JNP))                           B4M14250
ISN 0147           QFLUX2 = FLUX2 * (Q(I.L.N.JM) + FSIGN(N) * Q(INDEX(I).L.N.JM))          B4M14260
ISN 0148           IF(N.NE.4)GO TO 126                                                     B4M14270
ISN 0150           IF(Q(I.L.N.JM).GT.0.)GO TO 126                                          B4M14280
ISN 0152           IF(QFLUX1.GT.0.)QFLUX1=0.                                               B4M14290
ISN 0154           IF(QFLUX2.GT.0.)QFLUX2=0.                                               B4M14300
ISN 0156       126 IF((Q(I.L.N.JNP).LE.0.).AND.(QFLUX1.LT.0.))QFLUX1=0.                    B4M14310
ISN 0158           IF((PSIGN(N)*Q(INDEX(I).L.N.JM).LE.0.).AND.                             B4M14320
                  1(QFLUX2.LT.0.))QFLUX2=0.                                                B4M14330
ISN 0160           QT(I.L.N.JM)=QT(I.L.N.JM)-QFLUX1-QFLUX2                                 B4M14340
ISN 0161      2255                              CONTINUE                                   B4M14350
ISN 0162           IS2 = IS1                                                               B4M14360
ISN 0163           IS1 = I                                                                 B4M14370
ISN 0164           I = IP1                                                                 B4M14380
ISN 0165           IP1 = IP2                                                               B4M14390
ISN 0166      2250                              CONTINUE                                   B4M14400
            C                                                                           *  B4M14410
            C * * * NOTE: MULTIPLY BY DSIG(L) FOR LAT J ONLY.                           *  B4M14420
            C                                                                           *  B4M14430
ISN 0167      2405 DO 2410 I = INC.IM.INC                                                  B4M14440
ISN 0168           CONV(I.L.J) = CONV(I.L.J) * DSIG(L)                                     B4M14450
ISN 0169      2410                              CONTINUE                                   B4M14460
ISN 0170           L = L + 1                                                               B4M14470
ISN 0171           IF (L .LE. NLAY)             GO TO 2150                                 B4M14480
            C                                                                           *  B4M14490
            C * * *         END OF LAYER LOOP                                           *  B4M14500
            C                                                                           *  B4M14510
            C * * * COMPUTATION OF SIGMA DOT AND NEW SURFACE PRESSURE                   *  B4M14520
            C * * * SKIP THIS COMPUTATION IF (J .EQ. 1) (SOUTH POLE)                    *  B4M14530
            C * * * PIT(I.J) IS EQUIVALENCED TO CONV(I.9.J)                             *  B4M14540
            C                                                                           *  B4M14550
ISN 0173           IF (J .EQ. 1)                GO TO 2600                                 B4M14560
ISN 0175           DO 2440 I = INC.IM.INC                                                  B4M14570
            C * * PIT(I.J) = CONV(I.9.J)                                                   B4M14580
ISN 0176           DO 2420 L = 1.NLAYM1                                                    B4M14590
ISN 0177           PIT(I.J) = PIT(I.J) + CONV(I.L.J)                                       B4M14600
ISN 0178      2420                              CONTINUE                                   B4M14610
ISN 0179           SD(I.1.J) = CONV(I.1.J) - DSIG(1) * PIT(I.J)                            B4M14620
ISN 0180           IF(COMG) OMEGA(I.J.1) = SD(I.1.J)/DXYP(J)*1.E6                          B4M14630
```

```
ISN 0182          IF (NLAY .EQ. 2)                GO TC 2440                            B4M14640
ISN 0184          DO 2430 L = 2.NLAYM1                                                  B4M14650
ISN 0185          SD(I.L.J) = SD(I.L-1.J) + CONV(I.L.J) - DSIG(L) * PIT(I.J)            B4M14660
ISN 0186          IF(CONG) OMEGA(I.J.L) = SD(I.L.J)/DXYP(J)*1.E6                        B4M14670
ISN 0188     2430                                 CONTINUE                              B4M14680
ISN 0189     2440                                 CONTINUE                              B4M14690
ISN 0190          DO 2450 I = INC.IM.INC                                                B4M14700
ISN 0191          DELPT = DT * PIT(I.J) / DXYP(J)                                       B4M14710
ISN 0192          II=I-1                                                                B4M14720
ISN 0193          IF(I.EQ.1)II=1                                                        B4M14730
ISN 0195          PT(I.J) = PT(I.J) + DT * PIT(I.J) / DXYP(J)                           B4M14740
ISN 0196     2450                                 CONTINUE                              B4M14750
ISN 0197          IF(.NOT.CONG)   GO TO 2456                                            B4M14760
ISN 0199          DO 2455 L = 1.NLAY                                                    B4M14770
ISN 0200          DO 2455 I = 1.IM                                                      B4M14780
ISN 0201     2455 OMEGA(I.J.L) = OMEGA(I.J.L) + SIG(L)*PIT(I.J)/DXYP(J)                 B4M14790
ISN 0202     2456 CONTINUE                                                              B4M14800
            C                                                                         * B4M14810
            C * * * VERTICAL ADDVECTION OF MOMENTUM AND TEMPERATURE                      B4M14820
            C                                                                         * B4M14830
ISN 0203          DO 2490 L = 1.NLAYM1                                                  B4M14840
ISN 0204          LP1 = L + 1                                                           B4M14850
            C                                                                         * B4M14860
            C                                                                           B4M14870
            C     FIRST DO MOMENTUM                                                     B4M14880
            C                                                                           B4M14890
ISN 0205          DO 2470 N=1.2                                                         B4M14900
            C                                                                           B4M14910
ISN 0206          DO 2470 I=INC.IM.INC                                                  B4M14920
            C                                                                           B4M14930
ISN 0207          SFLUX = F2CO*SD(I.L.J)*(Q(I.L.N.J) + Q(I.LP1.N.J))                    B4M14940
            C                                                                           B4M14950
ISN 0208          QT(I.LP1.N.J) = QT(I.LP1.N.J) - SFLUX / DSIG(LP1)                     B4M14960
ISN 0209          QT(I.L.N.J) = QT(I.L.N.J) + SFLUX / DSIG(L)                           B4M14970
ISN 0210     2470                                 CONTINUE                              B4M14980
            C                                                                         * B4M14990
            C * * * VERTICAL ADVECTION CF TEMPERATURE                                 * B4M15000
            C * * * TRYING GISS CODE FOR PK CALC. INSTEAD OF 4TH ORDER CODE           * B4M15010
            C                                                                         * B4M15020
ISN 0211          DO 2480 I =INC.IM.INC                                                 B4M15030
ISN 0212          PL1 = SIG(L) * P(I.J) + PTOP                                          B4M15040
ISN 0213          PL2 = SIG(LP1) * P(I.J) + PTOP                                        B4M15050
ISN 0214          PK1 = EXPBYK(PL1)                                                     B4M15060
ISN 0215          PK2 = EXPBYK(PL2)                                                     B4M15070
ISN 0216          TFLUX = F2CO * SD(I.L.J) * (T(I.L.J) / PK1 + T(I.LP1.J) / PK2)        B4M15080
ISN 0217          TT(I.LP1.J) = TT(I.LP1.J) - PK2 * TFLUX / DSIG(LP1)                   B4M15090
ISN 0218          TT(I.L.J) = TT(I.L.J) + PK1 * TFLUX / DSIG(L)                         B4M15100
ISN 0219     2480                                 CONTINUE                              B4M15110
ISN 0220     2490                                 CONTINUE                              B4M15120
ISN 0221          IF (J .LT. JM)                  RETURN                                B4M15130
            C                                                                         * B4M15140
            C                                                                         * B4M15150
            C * * * CALCULATIONS AT THE POLES                                         * B4M15160
            C                                                                         * B4M15170
            C                                                                         * B4M15180
            C * * * WHEN (J=1) OR (J=JM) WE DO THE CALCULATIONS AT THE POLES.         * B4M15190
            C * * * MOMENTUM. TEMPERATURE. SPECIFIC HUMIDITY AT SOUTH POLE            * B4M15200
            C * * * (M = 1)  AND NORTH POLE (M = 2)                                   * B4M15210
            C * * * JPOL(K.M) = (2.3.JM.JM-1)                                         * B4M15220
            C * * * CON1 = DXP(2) / (3 PI * A * A * SIN(DLAT / 2) ** 2)               * B4M15230
            C * * * CON2 = -DXP(3) / (12 PI * A * A * SIN(LAT) ** 2)                  * B4M15240
            C * * * (K = 1) CORRESPONDS TO THE LATITUDE LINE NEAREST TO THE POLE.     * B4M15250
            C                                                                         * B4M15260
ISN 0223     2600 M = 1                                                                 B4M15270
ISN 0224          IF (J .EQ. JM)                  M = 2                                 B4M15280
ISN 0226          PITPOL(M) = 0.                                                        B4M15290
ISN 0227          COEF1 = (-1.) ** M                                                    B4M15300
ISN 0228          COEF2 = -COEF1                                                        B4M15310
ISN 0229          DO 2500 L = 1.NLAY                                                    B4M15320
ISN 0230          DO 2505 N = 1.5                                                       B4M15330
ISN 0231          DO 2505 K = 1.2                                                       B4M15340
ISN 0232          SUM(K.N) = 0.                                                         B4M15350
ISN 0233     2505                                 CONTINUE                              B4M15360
            C                                                                         * B4M15370
            C * * * HORIZ. ADVEC. OF MOMENTUM. TEMPERATURE. SPECIFIC HUMIDITY         * B4M15380
            C * * * AT THE NORTH AND SOUTH POLES.                                     * B4M15390
            C * * * 4/4/78 -PIV TO BE CHANGED TO PIV FOR: -PIE<LONG<PIE               * B4M15400
            C                                                                         * B4M15410
ISN 0234          DO 2510 I = INC.IM.INC                                                B4M15420
ISN 0235          DO 2510 K = 1.2                                                       B4M15430
ISN 0236          JKP = 1                                                               B4M15440
ISN 0237          IF (M.EQ.2) JKP = JNP                                                 B4M15450
ISN 0239          JK = JPOL(K.M)                                                        B4M15460
ISN 0240          PIV = P(I.JK) * V(I.L.JK)                                             B4M15470
ISN 0241          SUM(K.1) = SUM(K.1) - PIV * (U(I.L.JK) * SINLON(I)                    B4M15480
                 $    + COEF1 * V(I.L.JK) * COSLON(I))                                  B4M15490
ISN 0242          SUM(K.2) = SUM(K.2) - PIV * (COEF2 * U(I.L.JK) * COSLON(I)            B4M15500
                 $    + V(I.L.JK) * SINLON(I))                                          B4M15510
```

```
ISN 0243             SUM(K,3) = SUM(K,3) + PIV * T(I,L,JK)                                    B4M15520
ISN 0244             SUM(K,4) = SUM(K,4) + PIV * SH(I,L,JK)                                   B4M15530
               C     DO 2515 N = 3,4                                                          B4M15540
               C2515                                    CONTINUE                              B4M15550
ISN 0245             SUM(K,5) = SUM(K,5) + PIV                                                B4M15560
ISN 0246        2510                                    CONTINUE                              B4M15570
ISN 0247             DO 2520 N = 1,4                                                          B4M15580
ISN 0248             QTPOL(L,N,M) = QTPOL(L,N,M) + COEF1 * DT * (CON1 * SUM(1,N)              B4M15590
                    $    + CON2 * SUM(2,N))                                                   B4M15600
ISN 0249        2520                                    CONTINUE                              B4M15610
               C                                                                           *  B4M15620
               C * * * CONTINUITY EQUATION  AT THE POLES.                                  *  B4M15630
               C                                                                           *  B4M15640
ISN 0250             CONVPL(L) = COEF1 * (CON1 * SUM(1,5) + CON2 * SUM(2,5))*DSIG(L)          B4M15650
ISN 0251             PITPOL(M) = PITPOL(M) + CONVPL(L)                                        B4M15560
ISN 0252        2500                                    CONTINUE                              B4M15670
               C                                                                           *  B4M15680
               C * * * COMPUTATION OF SIGMA DOT AND NEW SURFACE PRESSURE AT POLES.         *  B4M15690
               C                                                                           *  B4M15700
ISN 0253             SDPOL(1,M) = CONVPL(1) - DSIG(1) * PITPOL(M)                             B4M15710
ISN 0254             IF(COMG) OMEGA(1,JKP,1) = SDPOL(1,M)*1.E6                                B4M15720
ISN 0256             IF (NLAY .EQ. 2)                   GO TO 2538                            B4M15730
ISN 0258             DO 2530 L = 2,NLAYM1                                                     B4M15740
ISN 0259             SDPOL(L,M) = SDPOL(L-1,M) + CONVPL(L) - DSIG(L) * PITPOL(M)              B4M15750
ISN 0260             IF(COMG) OMEGA(1,JKP,L) = SDPOL(L,M)*1.E6                                B4M15760
ISN 0262        2530                                    CONTINUE                              B4M15770
ISN 0263        2538 PTPOL(M) = PTPOL(M) + DT * PITPOL(M)                                     B4M15780
ISN 0264             IF(.NOT.COMG) GO TO 2537                                                 B4M15790
ISN 0266             DO 2539 L = 1,NLAY                                                       B4M15800
ISN 0267        2539 OMEGA(1,JKP,L) = OMEGA(1,JKP,L) + SIG(L) * PITPOL(M)                     B4M15810
ISN 0268        2537 CONTINUE                                                                 B4M15820
               C                                                                           *  B4M15830
               C * * * VERTICAL ADVECTION OF MOMENTUM AND TEMPERATURE AT POLES                B4M15840
               C * * * FIRST DO MOMENTUM                                                      B4M15850
               C                                                                           *  B4M15860
ISN 0269             DO 2540 L = 1,NLAYM1                                                     B4M15870
ISN 0270             LP1 = L + 1                                                              B4M15880
ISN 0271             DO 2550 N=1,2                                                            B4M15890
               C                                                                              B4M15900
ISN 0272             SFLUX = F2CO*SDPOL(L,M)*(QPOL(L,N,M) + QPOL(LP1,N,M))                    B4M15910
               C                                                                              B4M15920
               C                                                                              B4M15930
ISN 0273             QTPOL(LP1,N,M) = QTPOL(LP1,N,M) - SFLUX / DSIG(LP1)                      B4M15940
ISN 0274             QTPOL(L,N,M) = QTPOL(L,N,M) + SFLUX /DSIG(L)                             B4M15950
ISN 0275        2550                                    CONTINUE                              B4M15960
               C                                                                           *  B4M15970
               C * * * VERTICAL ADVECTION OF TEMPERATURE AT THE POLES.                     *  B4M15980
               C                                                                           *  B4M15990
ISN 0276             PL1 = SIG(L) *PPOL(M) + PTOP                                             B4M16000
ISN 0277             PL2 = SIG(LP1) * PPOL(M) + PTOP                                          B4M16010
ISN 0278             PK1 = EXPBYK(PL1)                                                        B4M16020
ISN 0279             PK2 = EXPBYK(PL2)                                                        B4M16030
ISN 0280             TFLUX = F2CO * SDPOL(L,M) * (TPOL(L,M) / PK1 + TPOL(LP1,M) / PK2)        B4M16040
               C                                                                              B4M16050
ISN 0281             TTPOL(LP1,M) = TTPOL(LP1,M) - PK2 * TFLUX / DSIG(LP1)                    B4M16060
ISN 0282             TTPOL(L,M) = TTPOL(L,M) + PK1 * TFLUX / DSIG(L)                          B4M16070
ISN 0283        2540                                    CONTINUE                              B4M16030
ISN 0284                                                RETURN                                B4M15090
ISN 0285                                                END                                   B4M16100

                                                     /    COMP1 /     SIZE OF PROGRAM 002802 HEXADECIMAL BYTES

NAME TAG TYPE ADD.   |= ***    % NAME TAG TYPE ADD.   |= ***    % NAME TAG TYPE ADD.   |= ***    % NAME TAG TYPE ADD.   |= ***    %
       C      CE  R*4  000000            F       C  R*4    N.R.            I SF        I*4  0000F8            J  FA      I*4  0000FC
       K SF       I*4  000100            L SF       I*4  000104            M SF        I*4  000108            N SF       I*4  00010C
       P  F   XR  R*4  000000            Q  F   XR  R*4  00000C            R        C  R*4    N.R.            T  F   XR  R*4  000000
       U  F   XR  R*4  000000            V  F   XR  R*4  00000C            W        C  R*4    N.R.           CP        C  R*4    N.R.
      DT  F    C  R*4  0000BC           ED       C  R*4    N.R.           GT       CE  R*4  000840           GW       CE  R*4  001680
      IM  F    C  I*4  000008           I1  S       I*4  00011C           JK SF        I*4  000114           JM  F     C  I*4  000030
      J1       C  I*4    N.R.           J2  F       I*4  00011E           KM        C  I*4    N.R.           NR        C  I*4    N.R.
      PI       C  R*4    N.R.           PK       C  R*4    N.R.           PT SF    XR  R*4  000000           PU SF    CE  R*4  000000
      PV SF       R*4  0001A8           QT SF   XR  R*4  00000C           SD SF    CE  R*4  000000           SH  F    XR  R*4  000000
      TS      CE  R*4  001890           TT SF   XR  R*4  00000C           UT       XR  R*4  000000           VT       XR  R*4  000000
     CDX       C  R*4    N.R.          DXP  F    C  R*4  00072E          DXU        C  R*4    N.R.          DYP        C  R*4    N.R.
     DYU  F    C  R*4  0007E0          FIM       C  R*4    N.R.          FMU        C  R*4    N.R.          INC  F     C  I*4  000044
     IP1 SF       I*4  00011C          IP2 SF       I*4  00012C          IS1 SF        I*4  000124          IS2 SF        I*4  000128
     JKP SF       I*4  00012C          JNB       C  I*4    N.R.          JNP  F     C  I*4  000004          JP1 SFA    C  I*4  000060
     JP2 SFA   C  I*4  000064          JSB       C  I*4    N.R.          JSP       CE  I*4  000000          JS1 SFA       I*4  000130
     JS2 SFA      I*4  000134          LAT       C  R*4    N.R.          LP1 SF        I*4  000138          NPC        C  I*4    N.R.
     PIT SF   CE  R*4  000900          PIV SF       R*4  00013C          PK1 SF        R*4  000140          PK2 SF        R*4  000144
     PL1 SFA      R*4  000148          PL2 SFA      R*4  00014C          PSF        C  R*4    N.R.          PSL        C  R*4    N.R.
     PSM       C  R*4    N.R.          PUI SF       R*4  00015C          QSM        C  R*4    N.R.          RAD        C  R*4    N.R.
     SHS      CE  R*4  002300          SHT      XR  R*4  00000C          SIG  F     C  R*4  000370          SUM SF     C  R*4  0057FC
     TAU       C  R*4    N.R.         BETA       C  R*4    N.R.         COMG        C  L*4  0389A4         CONV SF    CE  R*4  000000
    CON1  F    C  R*4  000000         CON2  F    C  R*4  000004         CON3        C  R*4    N.R.         CON4        C  R*4    N.R.
    CON5       C  R*4    N.R.         COSD       C  R*4    N.R.         COSL        C  R*4    N.R.         CPD2        C  R*4    N.R.
    CPTH       C  R*4    N.R.         DIFF       C  R*4    N.R.         DLAT        C  R*4    N.R.         DLON        C  R*4    N.R.
    DSIG  F    C  R*4  0003C0         DXYP  F    C  R*4  00095C         F1CO SF        R*4  000154         F2CO SF        R*4  000158
```

```
  GRAV          C   R*4      N.R.       IDAY         C   I*4      N.R.        IMD2         C   I*4      N.R.        INCS         C   I*4      N.R.
  IROT          C   I*4      N.R.       ITAU         C   I*4      N.R.        JAYS         C   I*4      N.R.        JDAY         C   I*4      N.R.
  JEND          C   I*4      N.R.       JMOD  S          I*4    00015C        JMPS         C   I*4      N.R.        JMS1         C   I*4      N.R.
  JMS2  S       C   I*4    000028       JMUS         C   I*4      N.R.        JPOL   F     C   I*4    000084        J1PS         C   I*4      N.R.
  J1US          C   I*4      N.R.       KAPA         C   R*4      N.R.        KNBS         C   I*4      N.R.        KSBS         C   I*4      N.R.
  MRCH          C   I*4      N.R.       MROT         C   I*4      N.R.        NFLW         C   I*4      N.R.        NLAY   F     C   I*4    00000C
  PHIS         CE   R*4    000D50       PPOL   F    XR   R*4    00000C        PTOP   F     C   R*4    000010        QPOL   F    XR   R*4    000000
  QSAT  S     ASF   R*4    000000       RADT         C   I*2      N.R.        RGAS         C   R*4      N.R.        SDOT        CE   R*4    000000
  SIGE          C   R*4      N.R.       SIND         C   R*4      N.R.        SINL         C   R*4      N.R.        TAUE         C   R*4      N.R.
  TAUI          C   R*4      N.R.       TAUO         C   R*4      N.R.        TAUP         C   R*4      N.R.        TAUT         C   R*4      N.R.
  TPOL   F     XR   R*4    000000       UPOL        XR   R*4    00000C        VPOL        XR   R*4    000000        XINT         C   R*4      N.R.
 ADLDP          C   R*4      N.R.      ALPHA         C   R*4      N.R.       COEF1  SF         R*4    000160       COEF2  SF         R*4    000164
 COMP1              R*4    000168      DELPT  S          R*4    00016C       DSIGO         C   R*4      N.R.       DUMMY         C   R*4      N.R.
 FLUX1  SF          R*4    000170      FLUX2  SF         R*4    000174       INDEX  F      C   I*4    0002E4       ISDOT        CE   I*2    00CF00
 ISMTH          C   I*4      N.R.      ITEST         C   I*4      N.R.       JDATE         C   I*4      N.R.       JNEXT         C   I*4      N.R.
 JNPM1          C   I*4      N.R.      JPMOD         C   I*4      N.R.       JSPP1         C   I*4      N.R.       JTEST         C   I*4      N.R.
 JYEAR          C   I*4      N.R.      MODPK         C   I*4      N.R.       NSTEP         C   I*4      N.R.       OMEGA  SF     C   I*2    019E00
 POLES          C   R*4      N.R.      PSIGN  F      C   R*4    000404       PTPOL  SF    XR   R*4    000000       PUIP1  SF         R*4    000178
 PUIS1  SF          R*4    00017C      PV1JM  SF         R*4    00018C       PV2JM  SF         R*4    000184       QTPOL  SF    XR   R*4    000000
 RADIM          C   R*4      N.R.      RHMAX         C   R*4      N.R.       SDPOL  SF     C   R*4    0057AC       SFLUX  SF         R*4    000188
 SHPOL         XF   R*4    000000      TFLUX  SF         R*4    00018C       THBAR         C   R*4      N.R.       TTPOL  SF    XR   R*4    000000
 UTPOL         XR   R*4    000000      VTPOL        XR   R*4    00000C      FRXPI#        XF   R*4    000000      ALBEDO         C   I*2      N.R.
CONVPL  SF      C   R*4    005788     COSLON  F      C   R*4    0001C4      DTMULT         C   R*4      N.R.      DUMMYA         C   R*4      N.R.
DUMMYC          C   R*4      N.R.     EXPBYK  F     XF   R*4    00000C      IALTER         C   I*4      N.R.      IMD2P1         C   I*4      N.R.
ISTART          C   I*4      N.R.     ISWTCH         C   I*4      N.R.      JMONTH         C   I*4      N.R.      JP1MOD  S          I*4    000190
JP2MOD  S           I*4    000194     JS1MOD  S          I*4    00019E      JS2MOD  S          I*4    00019C      M[illegible]SUN         C   I*4      N.R.
MNMXTS          C   I*4      N.R.     NCOMP3         C   I*4      N.R.      NCYCLE         C   I*4      N.R.      NMOGAN         C   I*4      N.R.
NLAYM1   F      C   I*4    000024     NLAYP1         C   I*4      N.R.      NSTART         C   I*4      N.R.      PHISPL         C   R*4      N.R.
PITPOL  SF      C   R*4    000000     PSKAPA         C   R*4      N.R.      PSMPOL         C   R*4      N.R.      QFLUX1  SF         R*4    0001A0
QFLUX2  SF          R*4    0001A4     QSMPOL         C   R*4      N.R.      RSDIST         C   R*4      N.R.      SHTPOL        XR   R*4    000000
SINLON   F      C   R*4    0000A4     TOFDAY         C   R*4      N.R.      XLABEL         C   R*4      N.R.

                                          *****   COMMON INFORMATION   *****

    NAME OF CCMMON BLOCK * F:U#.ZE OF BLOCKCOMMON       005E24 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
       CON1     R*4    000000           CON2     R*4    000004           CON3     R*4      N.R.           CON4     R*4      N.R.
       CON5     R*4      N.R.          THBAR     R*4      N.R.          ALPHA     R*4      N.R.           BETA     R*4      N.R.
     IMD2P1     I*4      N.R.          ADLDP     R*4      N.R.           JMS2     I*4    000028           JMS1     I*4      N.R.
       CPTH     R*4      N.R.         PSKAPA     R*4      N.R.              R     R*4      N.R.            RAD     R*4      N.R.
         CP     R*4      N.R.            INC     I*4    000044         NSTART     I*4      N.R.           CPD2     R*4      N.R.
       IMD2     I*4      N.R.          RADIM     R*4      N.R.           JEND     I*4      N.R.            JP1     I*4    000060
        JP2     I*4    000064         MATSLN     I*4      N.R.          JNEXT     I*4      N.R.          MODPK     I*4      N.R.
       JPOL     I*4    000084          JPMOD     I*4      N.R.         SINLON     R*4    0000A4         COSLON     R*4    0001C4
      INDEX     I*4    0002E4          PSIGN     R*4    000404          POLES     R*4      N.R.              W     R*4      N.R.
         PK     R*4      N.R.           DIFF     R*4      N.R.         CONVPL     R*4    005788          SDPOL     R*4    0057AC
     PHISPL     R*4      N.R.            SUM     R*4    0057FC

    NAME OF COMMON BLOCK *  =M..ZE OF BLOCKCOMMON       00D14E HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
        QSM     R*4      N.R.            PSM     R*4      N.R.         QSMPOL     R*4      N.R.         PSMPOL     R*4      N.R.

    NAME OF COMMON BLOCK *  ¬NTR#E OF BLOCKCOMMON       083C30 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
        JSP     I*4    000000            JNP     I*4    000004             IM     I*4    000008           NLAY     I*4    00000C
       PTOP     R*4    000010         ISTART     I*4      N.R.          JSPP1     I*4      N.R.          JNPM1     I*4      N.R.
        FIM     R*4      N.R.         NLAYM1     I*4    000024         NLAYP1     I*4      N.R.             J1     I*4      N.R.
         JM     I*4    000030             KM     I*4      N.R.           TAUT     R*4      N.R.           IROT     I*4      N.R.
       MROT     I*4      N.R.          JTEST     I*4      N.R.          ITEST     I*4      N.R.             NR     I*4      N.R.
       JAYS     I*4      N.R.           INCS     I*4      N.R.            JSB     I*4      N.R.            JNB     I*4      N.R.
       DLAT     R*4      N.R.           DLON     R*4      N.R.             DT     R*4    00008C            TAU     R*4      N.R.
       ITAU     I*4      N.R.           XINT     R*4      N.R.           IDAY     I*4      N.R.           JDAY     I*4      N.R.
     TOFDAY     R*4      N.R.          JDATE     I*4      N.R.         JMONTH     I*4      N.R.          JYEAR     I*4      N.R.
      NSTEP     I*4      N.R.         NCYCLE     I*4      N.R.         NCOMP3     I*4      N.R.         NMOGAN     I*4      N.R.
       TAUP     R*4      N.R.           TAUI     R*4      N.R.           TAUE     R*4      N.R.           TAUO     R*4      N.R.
     DTMULT     R*4      N.R.             PI     R*4      N.R.           GRAV     R*4      N.R.           RGAS     R*4      N.R.
       KAPA     R*4      N.R.            PSL     R*4      N.R.             ED     R*4      N.R.            FMU     R*4      N.R.
       NFLW     I*4      N.R.            PSF     R*4      N.R.           MRCH     I*4      N.R.         RSDIST     R*4      N.R.
       SIND     R*4      N.R.           COSD     R*4      N.R.          RHMAX     R*4      N.R.            CDX     R*4      N.R.
     DUMMYC     R*4      N.R.         IALTER     I*4      N.R.         DUMMYA     R*4      N.R.         XLABEL     R*4      N.R.
        SIG     R*4    000370           DSIG     R*4    0003C0           SIGE     R*4      N.R.          DSIGO     R*4      N.R.
       J1PS     I*4      N.R.           JMPS     I*4      N.R.           J1US     I*4      N.R.           JMUS     I*4      N.R.
       KSBS     I*4      N.R.           KNBS     I*4      N.R.            LAT     R*4      N.R.            DXU     R*4      N.R.
        DXP     R*4    000728            DYU     R*4    0007E0            DYP     R*4      N.R.           DXYP     R*4    000950
          F     R*4      N.R.           SINL     R*4      N.R.           COSL     R*4      N.R.          DUMMY     R*4      N.R.
       PHIS     R*4    000D50         ALBEDC     I*2      N.R.

EQUIVALENCED VARIABLES WITHIN THIS CCMMCN GROUP
   VARIABLE OFFSETE               VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE
         TS    001890                   SHS    002300                      C    000000
```

```
   NAME OF COMMON BLOCK * C:M79*E OF ELOCKCOMMON      000C08 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  PITPOL     R*4    000000

   NAME OF COMMON BLOCK *  *W6R*E OF ELOCKCOMMON      010IC0 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    CONV     R*4    000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
      SD     000000                  PIT    000900

   NAME OF COMMON BLOCK *  =O#S*E OF ELOCKCOMMON      081600 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
      PU     R*4    000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
      GT     000840                  G*     0016EC

   NAME OF COMMON BLOCK *  *DS_?E OF BLOCKCOMMON      000C04 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  ISWTCH     I*4     N.R.

   NAME OF COMMON BLOCK * S*OT'9E OF ELOCKCOMMON      038SAE HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    SDOT     R*4    000000         OMEGA     I*2    019E00         MNMXTS    I*4     N.R.          RADT     I*2     N.R.
    COMG     L*4    0389A4

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE               VARIABLE OFFSETE
   ISDOT     00CF00

   NAME OF COMMON BLOCK *  *S6-"E OF ELOCKCOMMON      000C08 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
```

```
     LABEL   ADDR                LABEL   ADDR                LABEL   ADDR                LABEL   ADDR
      2150  0009B2                2154  000AD4                2158  000B04                2160  000C28
       110  000D7A                 100  000DF6                2223  000E32                2220  000E4C
      2225  000E7C                 115  000FC4                 120  001034                2230  001084
      2240  001120                2290  001138                2400  00123E                2237  001276
       126  0014AC                2255  001550                2250  001588                2405  0015A0
      2410  001628                2420  00173E                2430  0018A6                2440  0018CC
      2450  00199A                2455  001A58                2456  001B0E                2470  001C4E
      2480  001D92                2490  001D86                2600  001DE6                2505  001E82
      2510  002006                2520  0020A2                2500  002120                2530  00226A
      2538  002284                2539  0022FC                2537  002376                2550  00243E
      2540  002508

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*      SOURCE STATEMENTS =      284   PROGRAM SIZE=      10242

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                             788K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                              OS/360 FORTRAN H AT GISS                                      DATE 12/12/79-0783.61

         COMPILER OPTIONS -   NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                              SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
   ISN 0002               SUBROUTINE COMP2(U,V,T,SH,P,Q,UPOL,VPOL,TPOL,SHPOL,PPOL,QPOL,               B4M16110
                        $    UT,VT,TT,SHT,PT,QT,UTPOL,VTPOL,TTPOL,SHTPOL,PTPOL,QTPOL,J)               B4M16120
   ISN 0003               COMMON/FOURTH/CON1,CON2,CON3,CON4,CONS,THBAR,ALPHA,BETA,IMD2P1,             B4M16130
                        $    ADLOP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,                    B4M16140
                        $    IMD2,RADIM,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),                   B4M16150
                        $    JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),                    B4M16160
                        $    PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),                        B4M16170
                        $    CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,2)                                  B4M16180
   ISN 0004               DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),               B4M16190
                        $    SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                                     B4M16200
   ISN 0005               DIMENSION PTPOL(2),UTPOL(36,1),VTPOL(36,1),TTPOL(36,1),                     B4M16210
                        $    SHTPOL(36,1),QTPOL(9,4,2),QT(72,10,4,1)                                  B4M16220
   ISN 0006               COMMON/SMITH/QSM(72,9,4,5),PSM(72,5),QSMPOL(9,4,2),PSMPOL(2)                B4M16230
   ISN 0007               INTEGER*2 ALBEDO                                                            B4M16240
   ISN 0008               REAL*4 KAPA,LAT                                                             B4M16250
                   C      REAL*8 SINLON,COSLON,SUM                                                    B4M16260
   ISN 0009               REAL*8 PL1,PL2,PK1,PK2                                                      B4M16270
   ISN 0010               DIMENSION DD(73),EE(73)                                                     B4M16280
   ISN 0011               COMMON /CNTRL/                                                              B4M16290
                        *    JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,               B4M16300
                        *    J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                                     B4M16310
                        *    NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                                  B4M16320
                        *    DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,           B4M16330
                        *    NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUO,DTMULT,                         B4M16340
                        *    PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLW,PSF,ARCH,RSDIST,SIND,COSD,             B4M16350
                        *    RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                                  B4M16360
                        *    XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                          B4M16370
                        *    J1PS(11),JMPS(11),J1US(11),JMUS(11),KSES(11),KNBS(11),                   B4M16380
                        *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),             B4M16390
                        *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                               B4M16400
   ISN 0012               DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),                     B4M16410
                        *P(2880,1),    TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)            B4M16420
   ISN 0013               EQUIVALENCE (TS(1,1),PHIS(721,1)),(SHS(1,1),PHIS(1441,1)),                  B4M16430
                        $    (GT(1,1),PU(721,1)),(GW(1,1),PU(1441,1)),(C(1),JSP)                      B4M16440
   ISN 0014               COMMON/WORK/ CONV(72,9,46)                                                  B4M16450
   ISN 0015               COMMON/WORK2/PU(2880,46)                                                    B4M16460
   ISN 0016               DIMENSION UT(72,40,1),VT(72,40,1),TT(72,40,1),SHT(72,40,1),                 B4M16470
                        *PT(2880,1),PHI(72,9,5),PIT(648,1)                                            B4M16480
   ISN 0017               EQUIVALENCE                                                                 B4M16490
                        $    (PIT(1,1),CONV(1,9,1))                                                   B4M16500
   ISN 0018               COMMON /DBUG/ISWTCH                                                         B4M16510
                   C                                                                                  B4M16520
   ISN 0019               COMMON/SDOT48/SDOT(72,46,8),OMEGA(72,46,5),MNMXTS,RADT(72,46,10)            B4M16530
                        + ,COMG                                                                       B4M16540
   ISN 0020               LOGICAL COMG                                                                B4M16550
                   C                                                                                  B4M16560
   ISN 0021               INTEGER*2 RADT,OMEGA                                                        B4M16570
   ISN 0022               INTEGER*2 ISDOT(72,46,8)                                                    B4M16580
                   C                                                                                  B4M16590
   ISN 0023               EQUIVALENCE (SDOT(1,1,5),ISDOT(1,1,1))                                      B4M16600
                   C                                                                                  B4M16610
   ISN 0024               COMMON/SMOO/ISMTH,HPC                                                       B4M16620
   ISN 0025               COMMON/COMP12/PITPOL                                                        B4M16630
   ISN 0026               TTHBAR = 2.*THBAR                                                           B4M16640
   ISN 0027               JP2 = J + 2                                                                 B4M16650
   ISN 0028               JP1 = J + 1                                                                 B4M16660
```

```
ISN 0029          JS1 = J - 1                                                        B4M16670
ISN 0030          JS2 = J - 2                                                        B4M16680
ISN 0031          JP2MOD = MOD(JP2-1,5) + 1                                          B4M16690
ISN 0032          JP1MOD = MOD(JP1-1,5) + 1                                          B4M16700
ISN 0033          JMOD = MOD(J-1,5) + 1                                              B4M16710
ISN 0034          JS1MOD = MOD(JS1-1,5) + 1                                          B4M16720
ISN 0035          JS2MOD = MOD(JS2-1,5) + 1                                          B4M16730
            C * * *                                                                  B4M16740
ISN 0036          JPKP2 = MOD(JP2-1,3)  + 1                                          B4M16750
ISN 0037          JPKP1 = MOD(JP1-1,3)   + 1                                         B4M16760
ISN 0038          JPK = MOD(J-1,3) + 1                                               B4M16770
ISN 0039          DTKAPA = DT * KAPA                                                 B4M16780
ISN 0040          IF(J.GT.1)                       GO TO 3001                        B4M16790
ISN 0042          JP2 = 1                                                            B4M16800
ISN 0043          JP2MOD = 1                                                         B4M16810
ISN 0044          JPKP2 = 1                                                          B4M16820
ISN 0045                                           GO TO 3005                        B4M16830
            C                                                                      * B4M16840
            C * * * CORIOLIS FORCE FOR 4TH ORDER DOES NOT FOLLOW GISS              * B4M16850
            C * * * METHOD OF COMPUTATION                                          * B4M16860
            C * * * ADLDP = (12 * RAD * DLAT * DLON = 12. * DYU(J) * DLON)         * B4M16870
            C                                                                      * B4M16880
            C                                                                        B4M16890
ISN 0046     3001 DO 3000 L = 1,NLAY                                                 B4M16900
ISN 0047          DO 3000 I = INC,IM,INC                                             B4M16910
ISN 0048          FX = DT * (F(J) * DXYP(J) + ADLDF * SINL(J) * U(I,L,J))            B4M16920
ISN 0049          UT(I,L,J) = UT(I,L,J) + FX * P(I,J) * V(I,L,J)                     B4M16930
ISN 0050          VT(I,L,J) = VT(I,L,J) - FX * P(I,J) * U(I,L,J)                     B4M16940
ISN 0051     3000                                  CONTINUE                          B4M16950
            C                                                                      * B4M16960
            C * * *              M A I N    L O O P                                * B4M16970
            C                                                                      * B4M16980
ISN 0052          IF(J.GT.JM) GO TO 3032                                             B4M16990
            C                                                                        B4M17000
ISN 0054     3005    DO 3030 LX = 1,NLAY                                             B4M17010
ISN 0055          L = NLAYP1 - LX                                                    B4M17020
ISN 0056          LP1 = L + 1                                                        B4M17030
            C                                                                        B4M17040
ISN 0057          IF(J.EQ.1.OR.J.EQ.JNP) GO TO 3141                                  B4M17050
            C                                                                        B4M17060
            C     COMPUTATION OF THE ENERGY TERM FOR THE THERMODYNAMIC               B4M17070
            C     EQUATION FOR J=2,3,....,JM-1,JM                                    B4M17080
            C                                                                        B4M17090
            C     SET UP CYCLIC I-INDICES                                            B4M17100
            C                                                                        B4M17110
ISN 0059          IS2 = IM - 3                                                       B4M17120
ISN 0060          IS1 = IM - 2                                                       B4M17130
ISN 0061          I = IM - 1                                                         B4M17140
ISN 0062          IP1 = IM                                                           B4M17150
            C                                                                        B4M17160
            C     SET UP J-INDICES                                                   B4M17170
            C                                                                        B4M17180
ISN 0063          NDXJP2 = JP2                                                       B4M17190
ISN 0064          IF(J.EQ.JM) NDXJP2 = JM                                            B4M17200
            C                                                                        B4M17210
ISN 0066          NDXJS2 = JS2                                                       B4M17220
ISN 0067          IF(J.EQ.2) NDXJS2 = 2                                              B4M17230
            C                                                                        B4M17240
            C     PERFORM CALCULATIONS                                               B4M17250
            C                                                                        B4M17260
ISN 0069          DO 3140 IP2 = INC,IM,INC                                           B4M17270
            C                                                                        B4M17280
ISN 0070          SKT = DTKAPA*SIG(L)*T(I,L,J)/(PTCP+SIG(L)*P(I,J))                  B4M17290
ISN 0071          PIV = DXP(J)*V(I,L,J)                                              B4M17300
            C                                                                        B4M17310
            C     SET UP PROPER I-INDEX AND PRESSURE TERMS                           B4M17320
            C                                                                        B4M17330
ISN 0072          NDXI = I                                                           B4M17340
ISN 0073          IF(J.EQ.JM) NDXI = INDEX(I)                                        B4M17350
ISN 0075          G1 = P(NDXI,NDXJP2)                                                B4M17360
            C                                                                        B4M17370
ISN 0076          NDXI = I                                                           B4M17380
ISN 0077          IF(J.EQ.2) NDXI = INDEX(I)                                         B4M17390
ISN 0079          G2 = P(NDXI,NDXJS2)                                                B4M17400
            C                                                                        B4M17410
ISN 0080          TT(I,L,J) = TT(I,L,J) + SKT*P(I,J)*(PIT(I,J) + DYU(J) *            B4M17420
                 1      U(I,L,J)*(8.*(P(IP1,J)-P(IS1,J)) - P(IP2,J) +                B4M17430
                 1      P(IS2,J)) + PIV*(8.*(P(I,JP1)-P(I,JS1)) - G1 + G2))          B4M17440
            C                                                                        B4M17450
            C     RESET CYCLIC INDICES                                               B4M17460
            C                                                                        B4M17470
ISN 0081          IS2 = IS1                                                          B4M17480
ISN 0082          IS1 = I                                                            B4M17490
ISN 0083          I = IP1                                                            B4M17500
ISN 0084          IP1 = IP2                                                          B4M17510
            C                                                                        B4M17520
ISN 0085    3140  CONTINUE                                                           B4M17530
            C                                                                        B4M17540
```

```
ISN 0086      3141  CONTINUE                                                           B4M17550
              C                                                                         B4M17560
ISN 0087            IF(J.EQ.JM) GO TO 3030                                              B4M17570
              C                                                                         B4M17580
              C                                                                       * B4M17590
              C * * * COMPUTE PK AT LATITUDE JP2 (USING GISS METHOD)                  * B4M17600
              C                                                                       * B4M17610
ISN 0089            IF(L.LT.NLAY)                   GO TO 3055                          B4M17620
              C                                                                         B4M17630
ISN 0091       3007    DO 3010 I = 1,IM                                                 B4M17640
ISN 0092            PL1 = SIGE(1) * P(I,JP2) + PTOP                                     B4M17650
ISN 0093            PK1 = PL1 * EXPBYK(PL1)                                             B4M17660
ISN 0094            LL = 1                                                              B4M17670
ISN 0095               DO 3010 LLP1 = 2,NLAYP1                                          B4M17680
ISN 0096            PL2 = SIGE(LLP1) * P(I,JP2) + PTOP                                  B4M17690
ISN 0097            PK2 = PL2 * EXPBYK(PL2)                                             B4M17700
ISN 0098            PK(I,LL,JPKP2) = (PK2 - PK1) / (DIFF(LL) * P(I,JP2))                B4M17710
ISN 0099            PK1 = PK2                                                           B4M17720
ISN 0100            LL = LLP1                                                           B4M17730
ISN 0101       3010                                 CONTINUE                            B4M17740
              C                                                                       * B4M17750
              C * * * COMPUTATION OF PHI (GEOPOTENTIAL) AT JP2 FOR L=NLAY.            * B4M17760
              C * * * PSKAPA=1000*K, SIGE(1)=0.                                       * B4M17770
              C * * * HERE PHI IS NORMALIZED,I.E.,EQUALS (STANDARD PHI)-PHIBAR.       * B4M17780
              C                                                                       * B4M17790
ISN 0102            IF (L .LT. NLAY)                GO TO 3055                          B4M17800
ISN 0104            DO 3050 I = INC,IM,INC                                              B4M17810
ISN 0105            PHI(I,L,JP2MOD) = PHIS(I,JP2) + CPTH*(PK(I,L,JPKP2) - PSKAPA)       B4M17820
              C                                                                         B4M17830
ISN 0106            LLM1 = 1                                                            B4M17840
ISN 0107            DO 3050 LL = 1,NLAY                                                 B4M17850
ISN 0108            LLP1 = LL + 1                                                       B4M17860
ISN 0109            IF(LL.EQ.NLAY)  LLP1 = LL                                           B4M17870
              C                                                                         B4M17880
ISN 0111            DUM1 = DSIG(LL)*(PK(I,LLP1,JPKP2) - PK(I,LL,JPKP2))                 B4M17890
              C                                                                         B4M17900
ISN 0112            DUM2 = SIGE(LL)*(PK(I,LLP1,JPKP2) - PK(I,LLM1,JPKP2))               B4M17910
              C                                                                         B4M17920
ISN 0113            WL = SIG(LL) * P(I,JP2)                                             B4M17930
ISN 0114            DUM3 = WL * R * DSIG(LL) / (WL + PTOP)                              B4M17940
ISN 0115            LLM1 = LL                                                           B4M17950
              C                                                                         B4M17960
ISN 0116            PHI(I,L,JP2MOD) = PHI(I,L,JP2MOD)+(DUM3-(PO2*                       B4M17970
                  1  (DUM1+DUM2)/PK(I,LL,JPKP2))*T(I,LL,JP2)                            B4M17980
ISN 0117       3050                                 CONTINUE                            B4M17990
ISN 0118                                            GO TO 3065                          B4M18000
              C                                                                       * B4M18010
              C * * * COMPUTATION OF PHI AT JP2                                       * B4M18020
              C                                                                       * B4M18030
ISN 0119       3055 DO 3060 I = INC,IM,INC                                              B4M18040
ISN 0120            PHI(I,L,JP2MOD) = PHI(I,LP1,JP2MOD) + CPO2 * (PK(I,LP1,JPKP2) -     B4M18050
                  $   PK(I,L,JPKP2))                                                    B4M18060
                  $   * (   (T(I,L,JP2)/PK(I,L,JPKP2)+T(I,LP1,JP2) /                    B4M18070
                  $ PK(I,LP1,JPKP2)) - THBAR)                                           B4M18080
ISN 0121       3060                                 CONTINUE                            B4M18090
              C                                                                       * B4M18100
              C * * * FOR PHI(I,L,0) USE INDEX(I)                                     * B4M18110
              C * * * COMPUTE W(I,L,JP2MOD) FOR PRESSURE GRADIENT TERM AND SKT.       * B4M18120
              C * * * PIV FOR ENERGY TERM IN THERMODYNAMICS EQ.                       * B4M18130
              C                                                                       * B4M18140
ISN 0122      3065  IF(JP2.EQ.1.OR.JP2.EQ.JNP) GO TO 3030                               B4M18150
ISN 0124            DO 3070 I = INC,IM,INC                                              B4M18160
ISN 0125            TBAR = THBAR * PK(I,L,JPKP2)                                        B4M18170
ISN 0126            TPRIME = T(I,L,JP2) - TBAR                                          B4M18180
ISN 0127            PRESUR = PTOP + SIG(L) * P(I,JP2)                                   B4M18190
ISN 0128            W(I,L,JP2MOD) = SIG(L) * R * TPRIME / PRESUR                        B4M18200
ISN 0129       3070                                 CONTINUE                            B4M18210
ISN 0130                                            GO TO 3030                          B4M18220
              C                                                                       * B4M18230
              C * * * IF (J=1) RETURN AND COMPUTE PHI(I,L,2),W(I,L,2),.....            * B4M18240
              C * * * FOR SOUTH POLE CALCULATIONS                                     * B4M18250
              C                                                                       * B4M18260
ISN 0131       3030                                 CONTINUE                            B4M18270
ISN 0132            IF(J.GE.JM)                     GO TO 3032                          B4M18280
ISN 0134       3074 IF(JP2.GE.3)                    GO TO 3032                          B4M18290
ISN 0136            JP2 = JP2 + 1                                                       B4M18300
ISN 0137            JP2MOD = JP2MOD + 1                                                 B4M18310
ISN 0138            JPKP2 = JPKP2 + 1                                                   B4M18320
ISN 0139                                            GO TO 3005                          B4M18330
              C                                                                       * B4M18340
              C     PRESSURE GRADIENT (V EQUATION) FOR J=2                              B4M18350
              C                                                                       * B4M18360
ISN 0140       3032 DO 3031 LX = 1,NLAY                                                 B4M18370
ISN 0141            L = NLAYP1 - LX                                                     B4M18380
ISN 0142            IF(J.EQ.1) GO TO 3111                                               B4M18390
ISN 0144       3080 IF (J .GT. 2)                   GO TO 3085                          B4M18400
              C                                                                         B4M18410
ISN 0146            DO 3083 I=INC,IM,INC                                                B4M18420
```

```
                C                                                                        B4M18430
ISN 0147              PIV = DXP(J) * V(I,L,J)                                            B4M18440
ISN 0148              F1 = PHI(INDEX(I),L,J)                                             B4M18450
ISN 0149              G1 = P(INDEX(I),J)                                                 B4M18460
ISN 0150              F2 = PHI(I,L,1)                                                    B4M18470
ISN 0151              G2 = P(I,1)                                                        B4M18480
ISN 0152              W1 = W(I,L,J)                                                      B4M18490
ISN 0153              VT(I,L,J) = VT(I,L,J) + DT * DXP(J) * P(I,J) * (8.                 B4M18500
                     $   * (F2 - PHI(I,L,JP1MOD) + W1 * (G2 - P(I,JP1)))                 B4M18510
                     $   +(PHI(I,L,JP2MOD) - F1 + W1 * (P(I,JP2) - G1)))                 B4M18520
ISN 0154         3083                           CONTINUE                                 B4M18530
                C                                                                     *  B4M18540
                C * * * COMPUTATION OF THE PRESSURE GRADIENT FOR ZONAL (U)            *  B4M18550
                C * * * MOMENTUM EQ.                                                  *  B4M18560
                C                                                                     *  B4M18570
ISN 0155         3085 IS2 = IM - 3                                                       B4M18580
ISN 0156              IS1 = IM - 2                                                       B4M18590
ISN 0157              I = IM - 1                                                         B4M18600
ISN 0158              IP1 = IM                                                           B4M18610
ISN 0159              DO 3090 IP2 = INC, IM, INC                                         B4M18620
ISN 0160              W1 = W(I,L,JMOD)                                                   B4M18630
                C * * * NEXT TWO LINES HAVE ADDED ()'S                                    B4M18640
ISN 0161              UT(I,L,J) = UT(I,L,J) + DT * DYU(J) * P(I,J) * (8.                 B4M18650
                     $   * (PHI(IS1,L,JMOD) - PHI(IP1,L,JMOD) + W1 * (P(IS1,J)           B4M18660
                     $   -P(IP1,J)))+(PHI(IP2,L,JMOD)-PHI(IS2,L,JMOD)+W1                 B4M18670
                     $   *(P(IP2,J)-P(IS2,J))))                                          B4M18680
ISN 0162              IS2 = IS1                                                          B4M18690
ISN 0163              IS1 = I                                                            B4M18700
ISN 0164              I = IP1                                                            B4M18710
ISN 0165              IP1 = IP2                                                          B4M18720
ISN 0166         3090                           CONTINUE                                 B4M18730
ISN 0167              IF (J .EQ. 2.OR.J .EQ. JM)   GO TO 3135                            B4M18740
                C                                                                     *  B4M18750
                C * * * COMPUTATION OF THE PRESSURE GRADIENT FOR                      *  B4M18760
                C * * * MERIDONAL (V) MOMENTUM EQ.                                    *  B4M18770
                C                                                                     *  B4M18780
ISN 0169              DO 3100 I = INC,IM,INC                                             B4M18790
ISN 0170              W1 = W(I,L,JMOD)                                                   B4M18800
ISN 0171              VT(I,L,J) = VT(I,L,J) + DT * DXP(J) * P(I,J) * (8.                 B4M18810
                     $   * (PHI(I,L,JS1MOD) - PHI(I,L,JP1MOD) + W1 * (P(I,JS1)           B4M18820
                     $   - P(I,JP1))) +(PHI(I,L,JP2MOD) - PHI(I,L,JS2MOD) + W1           B4M18830
                     $   * (P(I,JP2) - P(I,JS2))))                                       B4M18840
ISN 0172         3100                           CONTINUE                                 B4M18850
                C                                                                     *  B4M18860
ISN 0173         3135 IF(J.LT.JM)               GO TO 3031                               B4M18870
                C                                                                     *  B4M18880
                C     PRESSURE GRADIENT FOR J=JM                                         B4M18890
                C                                                                        B4M18900
ISN 0175              DO 3150 I=INC,IM,INC                                               B4M18910
                C                                                                        B4M18920
ISN 0176              G1 = P(I,JM)                                                       B4M18930
ISN 0177              G2 = P(I,JNP)                                                      B4M18940
ISN 0178              G3 = P(INDEX(I),JM)                                                B4M18950
ISN 0179              W1 = W(I,L,JMOD)                                                   B4M18960
ISN 0180              VT(I,L,JM) = VT(I,L,JM) + DT * DXP(JM) *  G1 * (8.                 B4M18970
                     $   * (PHI(I,L,JS1MOD) - PHI(I,L,JP1MOD) + W1 * (P(I,JS1)           B4M18980
                     $   - G2)) +(PHI(INDEX(I),L,JMOD) - PHI(I,L,JS2MOD) + W1            B4M18990
                     $   * (G3 - P(I,JS2))))                                             B4M19000
ISN 0181         3150                           CONTINUE                                 B4M19010
                C                                                                     *  B4M19020
                C * * * CALCULATIONS AT THE POLES                                     *  B4M19030
                C                                                                     *  B4M19040
                C * * * MOMENTUM AND TEMPERATURE AT SOUTH POLE (M = 1) AND AT          *  B4M19050
                C * * * NORTH POLE (M = 2).                                           *  B4M19060
                C * * * (K = 1) CORRESPONDS TO THE LATITUDE LINE NEAREST THE POLE     *  B4M19070
                C * * * JPMOD(K,M)=(2,3,MOD(JM-1,5)+1,MOD((JM-1)-1,5)+1               *  B4M19080
                C * * *  CON3 = 4.*DT/(3.*RAD*IM*SIN(.5*DLAT))                        *  B4M19090
                C * * *  CON4 = DT/(3.*RAD*IM*SIN(DLAT))                              *  B4M19100
                C * * *  CON5 = 1./(3.*RAD*IM*DLAT)                                   *  B4M19110
                C                                                                     *  B4M19120
ISN 0182         3111 M = 1                                                              B4M19130
ISN 0183              IF (J .EQ. JM)                 M = 2                               B4M19140
ISN 0185              JKP = 1                                                            B4M19150
ISN 0186              IF(M.EQ.2) JKP = JNP                                               B4M19160
ISN 0188              JP2 =1                                                             B4M19170
ISN 0189              JP2MOD = 1                                                         B4M19180
ISN 0190              JFKP2 = 1                                                          B4M19190
                C                                                                     *  B4M19200
                C * * * CORIOLIS TERM AT THE POLES                                    *  B4M19210
                C                                                                     *  B4M19220
ISN 0191              F1 = F(JEND(M)) * PPOL(M)                                          B4M19230
ISN 0192              UTPOL(L,M) = UTPOL(L,M) + DT * F1 * VPOL(L,M)                      B4M19240
ISN 0193              VTPOL(L,M) = VTPOL(L,M) - DT * F1 * UPOL(L,M)                      B4M19250
ISN 0194              COEF1 = (-1) ** M                                                  B4M19260
ISN 0195              DO 3200 N = 1,3                                                    B4M19270
ISN 0196              DO 3200 K = 1,2                                                    B4M19280
ISN 0197              SUM(K,N) = 0.                                                      B4M19290
ISN 0198         3200                           CONTINUE                                 B4M19300
```

```
              C                                                                        *   B4M19310
              C * * * 7/31/78 USING PHILLIPS GEOPOTENTIAL AT POLES **                  *   B4M19320
              C * * * PRESSURE GRADIENT AND ENERGY CONVERSION TERMS FOR                *   B4M19330
              C * * * MOMENTUM,TEMPERATURE EQUATIONS                                   *   B4M19340
              C * * * JPMOD(K,M) = (2,3,MOD(JM-1,5)+1),MOD((JM-1)-1,5)+1               *   B4M19350
              C * * * MODJPK(K,M) = (2,3,MOD(JM-1,3)+1,MOD(JM-2,3)+1                   *   B4M19360
              C                                                                        *   B4M19370
ISN 0199              PRPOL = SIG(L) * PPOL(M) + PTOP                                      B4M19380
ISN 0200              SKTPOL = SIG(L) * KAPA * TPOL(L,M) / PRPOL                           B4M19390
ISN 0201              WPOL = W(1,L,JP2MOD)                                                 B4M19400
              C                                                                            B4M19410
              C       COMPUTE SUMMATION FOR TEMPERATURE EQUATION                           B4M19420
              C                                                                            B4M19430
ISN 0202              DO 3211 I=1,IM                                                       B4M19440
ISN 0203      3211    SUM(1,3) = SUM(1,3) + (COEF1*UPOL(L,M)*COSLON(I)                     B4M19450
                    1   + VPOL(L,M)*SINLON(I))*(8.*P(I,JPOL(1,M))-P(I,JPOL(2,M)))          B4M19460
              C                                                                            B4M19470
              C       MODIFY TEMPERATURE AT POLES                                          B4M19480
              C                                                                            B4M19490
ISN 0204              TTPOL(L,M) = TTPOL(L,M) + DT*SKTPOL*PPOL(M)*                         B4M19500
                    1     (PITPOL(M) + CON5*SUM(1,3))                                      B4M19510
              C                                                                            B4M19520
ISN 0205              DO 3210 I=1,IM                                                       B4M19530
ISN 0206              DO 3220 K = 1,2                                                      B4M19540
ISN 0207              JK = JPOL(K,M)                                                       B4M19550
ISN 0208              JKMOD = JPMOD(K,M)                                                   B4M19560
ISN 0209              MOD3J = MODPK(K,M)                                                   B4M19570
ISN 0210              TERM = PHI(I,L,JKMOD) + WPOL*P(I,JK)                                 B4M19580
ISN 0211              SUM(K,1) = SUM(K,1) + COSLON(I) * TERM                               B4M19590
ISN 0212              SUM(K,2) = SUM(K,2) + SINLON(I) * TERM                               B4M19600
ISN 0213       3220                              CONTINUE                                  B4M19610
ISN 0214       3210                              CONTINUE                                  B4M19620
ISN 0215                 DO 3222 K = 1,2                                                   B4M19630
ISN 0216              SUM(K,2) = COEF1 * SUM(K,2)                                          B4M19640
ISN 0217       3222                              CONTINUE                                  B4M19650
ISN 0218              DO 3225 N = 1,2                                                      B4M19660
              C       CHANGED SIGN BELOW TO -                                              B4M19670
ISN 0219              QTPOL(L,N,M)=QTPOL(L,N,M)-PPOL(M)*(-CON3*SUM(1,N)+                   B4M19680
                    $    CON4 * SUM(2,N))                                                  B4M19690
ISN 0220       3225                              CONTINUE                                  B4M19700
              C                                                                            B4M19710
ISN 0221              OMEGA(1,JKP,L) = OMEGA(1,JKP,L)+SIG(L)*(PITPOL(M)+CON5*SUM(1,3))     B4M19720
ISN 0222      3031                               CONTINUE                                  B4M19730
ISN 0223                                         RETURN                                    B4M19740
ISN 0224                                         END                                       B4M19750

                                      /   COMP2 /     SIZE OF PROGRAM 005398 HEXADECIMAL BYTES

NAME TAG TYPE ADD.    |= ***   % NAME TAG TYPE ADD.    |= ***   % NAME TAG TYPE ADD.    |= ***   % NAME TAG TYPE ADD.    |= ***   %
       C      CE  R*4  000000           F  F   C  R*4  000A08           I SF      I*4  0000DC           J  FA     I*4  0000E0
       K SF       I*4  0000E4           L SF      I*4  0000E8           M SF      I*4  0000EC           N SF      I*4  0000F0
       P  F   XR  R*4  000000           Q      XR R*4  000000           R  F   C  R*4  000038           T  F   XR R*4  000000
       U  F   XR  R*4  000000           V  F   XR R*4  000000           W SF   C  R*4  000664          CP      C  R*4    N.R.
      DD          R*4    N.R.          DT  F   C  R*4  0000B0          ED      C  R*4    N.R.          EE         R*4    N.R.
      FX SF       R*4  0000F4          F1 SF      R*4  0000F8          F2 SF      R*4  0000FC          GT      CE R*4  000840
      GW      CE  R*4  001680          G1 SF      R*4  000100          G2 SF      R*4  000104          G3 SF      R*4  000108
      IM  F   C   I*4  000008          JK SF      I*4  00010C          JM  F   C  I*4  000030          J1      C  I*4    N.R.
      KM      C   I*4    N.R.          LL SF      I*4  000110          LX SF      I*4  000114          NR      C  I*4    N.R.
      PI      C   R*4    N.R.          PK SF   C  R*4  003904          PT      XR R*4  000000          PU      CE R*4  000000
      QT      XR  R*4  000000          SH      XR R*4  000000          TS      CE R*4  001890          TT SF   XR R*4  000000
      UT SF   XR  R*4  000000          VT SF   XR R*4  000000          WL SF      R*4  000118          W1 SF      R*4  00011C
     CDX      C   R*4    N.R.         DXP  F   C  R*4  000728         DXU      C  R*4    N.R.         DYP      C  R*4    N.R.
     DYU  F   C   R*4  0007E0         FIM      C  R*4    N.R.         FMU      C  R*4    N.R.         INC  F   C  I*4  000044
     IP1 SF       I*4  000120         IP2 SF      I*4  000124         IS1 SF      I*4  000128         IS2 SF      I*4  00012C
     JKP SF       I*4  000130         JNB      C  I*4    N.R.         JNP  F   C  I*4  000004         JPK S       I*4  000134
     JP1 SFA  C   I*4  000060         JP2 SFA  C  I*4  000064         JSB      C  I*4    N.R.         JSP      CE I*4  000000
     JS1 SFA      I*4  000138         JS2 SFA     I*4  00013C         LAT      C  R*4    N.R.         LP1 SF      I*4  000140
     NPC      C   I*4    N.R.         PHI SF      R*4  0001E0         PIT  F   CE R*4  000900         PIV SF      R*4  000144
     PK1 SF       R*8  0001C0         PK2 SF      R*8  0001C8         PL1 SFA     R*8  0001D0         PL2 SFA     R*8  0001D8
     PSF      C   R*4    N.R.         PSL      C  R*4    N.R.         PSM      C  R*4    N.R.         QSM      C  R*4    N.R.
     RAD      C   R*4    N.R.         SHS      CE R*4  0023D0         SHT      XR R*4  000000         SIG  F   C  R*4  000370
     SKT SF       R*4  000148         SUM SF   C  R*4  0057FC         TAU      C  R*4    N.R.        BETA      C  R*4    N.R.
    COMG      C   L*4  0389A4        CONV      CE R*4  000000        CON1      C  R*4    N.R.        CON2      C  R*4    N.R.
    CON3  F   C   R*4  000008        CON4  F   C  R*4  00000C        CON5  F   C  R*4  000010        COSD      C  R*4    N.R.
    COSL      C   R*4    N.R.        CPD2  F   C  R*4  00004C        CPTH  F   C  R*4  000030        DIFF  F   C  R*4  005764
    DLAT      C   R*4    N.R.        DLON      C  R*4    N.R.        DSIG  F   C  R*4  0003C0        DUM1 SF      R*4  00014C
    DUM2 SF       R*4  000150        DUM3 SF      R*4  000154        DXYP  F   C  R*4  000950        GRAV      C  R*4    N.R.
    IDAY      C   I*4    N.R.        IMO2      C  I*4    N.R.        INCS      C  I*4    N.R.        IROT      C  I*4    N.R.
    ITAU      C   I*4    N.R.        JAYS      C  I*4    N.R.        JDAY      C  I*4    N.R.        JEND  F   C  I*4  000058
    JMOD SF       I*4  000158        JMPS      C  I*4    N.R.        JMS1      C  I*4    N.R.        JMS2      C  I*4    N.R.
    JMUS      C   I*4    N.R.        JPOL  F   C  I*4  000084        J1PS      C  I*4    N.R.        J1US      C  I*4    N.R.
    KAPA  F   C   R*4  000118        KNBS      C  I*4    N.R.        KSBS      C  I*4    N.R.        LLM1 SF      I*4  00015C
    LLP1 SF       I*4  000160        MRCH      C  I*4    N.R.        MROT      C  I*4    N.R.        NDXI SF      I*4  000164
    NFLW      C   I*4    N.R.        NLAS  F   C  I*4  00000C        PHIS  F   CE R*4  000D50        PPOL  F   XR R*4  000000
    PTOP  F   C   R*4  000010        GPOL      XR R*4  000000        RADT      C  I*2    N.R.        RGAS      C  R*4    N.R.
    SDOT      CE  R*4  000000        SIGE  F   C  R*4  000410        SIND      C  R*4    N.R.        SINL  F   C  R*4  000AC0
    TAUE      C   R*4    N.R.        TAUI      C  R*4    N.R.        TAUO      C  R*4    N.R.        TAUP      C  R*4    N.R.
    TAUT      C   R*4    N.R.        TBAR SF      R*4  000168        TERM SF      R*4  00016C        TPOL  F   XR R*4  000000
```

```
   UPOL   F  XR  R*4  000030        VPOL  F  XR  R*4  00000C        WPOL  SF     R*4  000170        XINT         C  R*4     N.R.
  ADLDP   F   C  R*4  000024       ALPHA      C  R*4     N.R.      COEF1  SF     R*4  000174       COMP2            R*4  000178
  DSIGO       C  R*4     N.R.      DUMMY      C  R*4     N.R.      INDEX   F  C  I*4  0002E4       ISDOT        CE I*2  00CF00
  ISMTH       C  I*4     N.R.      ITEST      C  I*4     N.R.      JDATE      C  I*4     N.R.      JKMOD  SF       I*4  00017C
  JNEXT       C  I*4     N.R.      JNPM1      C  I*4     N.R.      JPKP1  S      I*4  000180       JPKP2  SF       I*4  000184
  JPMOD   F   C  I*4  000094       JSPP1      C  I*4     N.R.      JTEST      C  I*4     N.R.      JYEAR        C  I*4     N.R.
  MODPK   F   C  I*4  000074       MOD3J  S      I*4  00018E       NSTEP      C  I*4     N.R.      OMEGA  SF    C  I*2  019E00
  POLES       C  R*4     N.R.      PRPOL  SF     R*4  00018C       PSIGN      C  R*4     N.R.      PTPOL        XR R*4  000000
  QTPOL  SF  XR  R*4  000000       RADIM      C  R*4     N.R.      RHMAX      C  R*4     N.R.      SOPOL        C  R*4     N.R.
  SHPOL      XR  R*4  000000       THBAR  F   C  R*4  000014       TTPOL  SF XR  R*4  000000       UTPOL  SF    XR R*4  000000
  VTPOL  SF  XR  R*4  000000      FIXPI#     XF  I*4  000000      ALBEDO      C  I*2     N.R.      CONVPL       C  R*4     N.R.
 COSLON   F   C  R*4  0001C4      DTKAPA  SF     R*4  00019C      DTMULT      C  R*4     N.R.      DUMMYA       C  R*4     N.R.
 DUMMYC       C  R*4     N.R.     EXPAYK  F  XF  R*4  00000C      IALTER      C  I*4     N.R.      IMD2P1       C  I*4     N.R.
 ISTART       C  I*4     N.R.     ISWTCH      C  I*4     N.R.      JMONTH      C  I*4     N.R.      JP1MOD SF       I*4  000194
 JP2MOD  SF      I*4  000198      JS1MOD  SF     I*4  00019C      JS2MOD  SF     I*4  0001A0      MATSUN       C  I*4     N.R.
 MNMXTS       C  I*4     N.R.     NCOMP3      C  I*4     N.R.      NCYCLE      C  I*4     N.R.      NDXJP2 SF       I*4  0001A4
 NDXJS2  SF      I*4  0001A8      NHOGAN      C  I*4     N.R.      NLAYM1      C  I*4     N.R.      NLAYP1  F    C  I*4  000028
 NSTART       C  I*4     N.R.     PHISPL      C  R*4     N.R.      PITPOL  F   C  R*4  000000      PRESUR SF       R*4  0001AC
 PSKAPA   F   C  R*4  000034      PSMPOL      C  R*4     N.R.      QSMPOL      C  R*4     N.R.      RSDIST       C  R*4     N.R.
 SHTPOL      XR  R*4  000000      SINLON  F   C  R*4  0000A4      SKTPOL  SF     R*4  000180      TOFDAY       C  R*4     N.R.
 TPRIME  SF      R*4  000184      TTHBAR  SF     R*4  00018E      XLABEL      C  R*4     N.R.

                                   *****  COMMON INFORMATION  *****

   NAME OF COMMON BLOCK * F:U#.ZE OF BLOCKCOMMON       005E24 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
      CON1     R*4     N.R.            CON2     R*4     N.R.            CON3     R*4   000008            CON4     R*4   00000C
      CON5     R*4   000010           THBAR     R*4   000014           ALPHA     R*4     N.R.            BETA     R*4     N.R.
    IMD2P1     I*4     N.R.           ADLDP     R*4   000024            JMS2     I*4     N.R.            JMS1     I*4     N.R.
      CPTH     R*4   000030          PSKAPA     R*4   000034               R     R*4   000038             RAD     R*4     N.R.
        CP     R*4     N.R.             INC     I*4   000044          NSTART     I*4     N.R.            CPD2     R*4   00004C
      IMD2     I*4     N.R.           RADIM     R*4     N.R.            JEND     I*4   000058             JP1     I*4   000060
       JP2     I*4   000064          MATSUN     I*4     N.R.           JNEXT     I*4     N.R.           MODPK     I*4   000074
      JPOL     I*4   000084           JPMOD     I*4   000094          SINLON     R*4   0000A4          COSLON     R*4   000::4
     INDEX     I*4   0002E4           PSIGN     R*4     N.R.           POLES     R*4     N.R.               W     R*4   000664
        PK     R*4   003904            DIFF     R*4   005764          CONVPL     R*4     N.R.           SOPOL     R*4     N.R.
    PHISPL     R*4     N.R.             SUM     R*4   0057FC

   NAME OF COMMON BLOCK *  =M..ZE OF BLOCKCOMMON       000148 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
       QSM     R*4     N.R.             PSM     R*4     N.R.          QSMPOL     R*4     N.R.          PSMPOL     R*4     N.R.

   NAME OF COMMON BLOCK *  ¬NTR#E OF BLOCKCOMMON       083C30 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
       JSP     I*4   000000             JNP     I*4   000004              IM     I*4   000008            NLAY     I*4   00000C
      PTOP     R*4   000010          ISTART     I*4     N.R.           JSPP1     I*4     N.R.           JNPM1     I*4     N.R.
       FIM     R*4     N.R.          NLAYM1     I*4     N.R.          NLAYP1     I*4   000028              J1     I*4     N.R.
        JM     I*4   000030              KM     I*4     N.R.            TAUT     R*4     N.R.            IROT     I*4     N.R.
      MROT     I*4     N.R.           JTEST     I*4     N.R.           ITEST     I*4     N.R.              NR     I*4     N.R.
      JAYS     I*4     N.R.            INCS     I*4     N.R.             JSB     I*4     N.R.             JNB     I*4     N.R.
      DLAT     R*4     N.R.            DLON     R*4     N.R.              DT     R*4   0000BC             TAU     R*4     N.R.
      ITAU     I*4     N.R.            XINT     R*4     N.R.            IDAY     I*4     N.R.            JDAY     I*4     N.R.
    TOFDAY     R*4     N.R.           JDATE     I*4     N.R.          JMONTH     I*4     N.R.           JYEAR     I*4     N.R.
     NSTEP     I*4     N.R.          NCYCLE     I*4     N.R.          NCOMP3     I*4     N.R.          NHOGAN     I*4     N.R.
      TAUP     R*4     N.R.            TAUI     R*4     N.R.            TAUE     R*4     N.R.            TAUO     R*4     N.R.
    DTMULT     R*4     N.R.              PI     R*4     N.R.            GRAV     R*4     N.R.            RGAS     R*4     N.R.
      KAPA     R*4   000118             PSL     R*4     N.R.              ED     R*4     N.R.             FMU     R*4     N.R.
      NFLW     I*4     N.R.             PSF     R*4     N.R.            MRCH     I*4     N.R.          RSDIST     R*4     N.R.
      SIND     R*4     N.R.            COSD     R*4     N.R.           RHMAX     R*4     N.R.             CDX     R*4     N.R.
    DUMMYC     R*4     N.R.          IALTER     I*4     N.R.          DUMMYA     R*4     N.R.          XLABEL     R*4     N.R.
       SIG     R*4   000370            DSIG     R*4   0003C0            SIGE     R*4   000410           DSIGO     R*4     N.R.
      J1PS     I*4     N.R.            JMPS     I*4     N.R.            J1US     I*4     N.R.            JMUS     I*4     N.R.
      KSBS     I*4     N.R.            KNES     I*4     N.R.             LAT     R*4     N.R.             DXU     R*4     N.R.
       DXP     R*4   000728             DYU     R*4   0007E0             DYP     R*4     N.R.            DXYP     R*4   000950
         F     R*4   000A08            SINL     R*4   000AC0            COSL     R*4     N.R.           DUMMY     R*4     N.R.
      PHIS     R*4   000050          ALBEDO     I*2     N.R.
  EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
    VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE
        TS     001890                  SHS     002300                    C     000000

   NAME OF COMMON BLOCK *  *W6R#E OF BLOCKCOMMON       01D1C0 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE     VAR. NAME TYPE REL. ADDR.HE
     CONV     R*4    000000

  EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
    VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE                VARIABLE OFFSETE
       PIT     000900
```

```
  NAME OF COMMON BLOCK *  =O#S#E OF BLOCKCOMMON     081 60C HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
     PU     R*4   000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
     GT     000B40                   G*     00168C

  NAME OF COMMON BLOCK *  *DS_?E OF BLOCKCOMMON     000C04 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
  ISWTCH     I*4      N.R.

  NAME OF COMMON BLOCK * S*OT'9E OF BLOCKCOMMON     038CA8 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
    SDOT     R*A   000000          OMEGA    I*2   019E00         MNMXTS     I*4      N.R.           RADT     I*2      N.R.
    CONG     L*4   0389A4

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE              VARIABLE OFFSETE
   ISDOT    00CF00

  NAME OF COMMON BLOCK *  *S6-*E OF BLOCKCOMMON     000C08 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
   ISMTH     I*6      N.R.             NPC     I*4      N.R.

  NAME OF COMMON BLOCK * C:M79#E OF BLOCKCOMMON     000C0E HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
```

```
 LABEL   ADDR              LABEL   ADDR             LABEL   ADDR              LABEL   ADDR
 3001   0039E8              3000   003ABE            3005   003AFA             3140   003E18
 3141   003E34              3007   003E58            3010   003F68             3050   004132
 3055   004176              3060   004258            3065   00427A             3070   00435A
 3030   00437E              3074   0043AE            3032   0043E2             3089   004552
 3083   0046CC              3085   0046F0            3090   004856             3100   0049F4
 3135   004A16              3150   004B76            3111   004B98             3200   004CDA
 3211   004DC6              3220   004F0A            3210   004F2E             3222   004F6C
 3225   004FE6              3031   005098

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      223  PROGRAM SIZE=     21400

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******

LEVEL 19.6-APR 71                                                             808K BYTES OF CORE NOT USED

                                                      OS/360 FORTRAN H AT GISS

      COMPILER OPTIONS -    NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,                                       DATE 12/12/79-0783
  ISN 0002                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
                      SUBROUTINE AVRX(U,V,T,SH,P,Q,J)
               C****  FINE NINE LAYER GLOBAL CDE BLOCK FOR VN MODEL, FEBRUARY 1976           B4M19760
  ISN 0003            INTEGER*2 ALBEDO                                                        B4M19770
  ISN 0004            REAL*4 KAPA,LAT                                                         B4M19780
               C                                                                              B4M19790
                      REAL*8 SINLON,COSLON,SUM                                                B4M19800
  ISN 0005            COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,THBAR,ALPHA,BETA,IND2PI,         B4M19810
                     $   ADLDP,JMS2,JMS1,CPTM,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,                B4M19820
                     $   IND2,RADIN,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),               B4M19830
                     $   JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),                B4M19840
                     $   PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),                    B4M19850
                     $   CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                              B4M19860
  ISN 0006            COMMON /CNTRL/                                                          B4M19870
                     *   JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,           B4M19880
                     *   J1,JM,KM,TAUT,IRCT,MROT,JTEST,ITEST,                                 B4M19890
                     *   NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                              B4M19900
                     *   DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,       B4M19910
                     *   NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TALO,DTMUL,                      B4M19920
                     *   PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLW,PSF,MRCH,RSDIST,SIND,COSD,         B4M19930
                     *   RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                              B4M19940
                     *   XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                      B4M19950
                     *   JIPS(11),JMPS(11),JIUS(11),JMUS(11),KSES(11),KNBS(11),               B4M19960
                     *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),        B4M19970
  ISN 0007           *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                          B4M19980
                      DIMENSION U(72,40,1),V(72,40,1),T(72,40,1),SH(72,40,1),                 B4M19990
  ISN 0008           *P(2880,1),TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)           B4M20000
                      EQUIVALENCE (TS(1,1),PHIS(721,1)),(SHS(1,1),PHIS(1441,1)),              B4M20010
                     $   (GT(1,1),PU(721,1)),(GW(1,1),PU(1441,1)),(C(1),JSP)                  B4M20020
  ISN 0009            DIMENSION PPOL(2),PITPOL(2),UPOL(36,1),VPOL(36,1),TPOL(36,1),           B4M20030
                     $   SHPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)                                 B4M20040
  ISN 0010            EQUIVALENCE (QPOL(1,1,1),POLES(1)),                                     B4M20050
                     $   (UPOL(1,1),POLES(1)),(VPOL(1,1),POLES(10)),(TPOL(1,1),               B4M20060
                     $   POLES(19)),(SHPOL(1,1),POLES(28)),                                   B4M20070
                     $   (PPOL(1),POLES(145))                                                 B4M20080
  ISN 0011            COMMON/INSMSH/F5D6,F17,F98                                              B4M20090
  ISN 0012            COMMON /DBUG/ISWTCH                                                     B4M20100
  ISN 0013            COMMON/SMOO/ISMTH,NPC                                                   B4M20110
  ISN 0014            COMMON/S/JMIN,JMAX,JSUM,SMTH(37,17)                                     B4M20120
  ISN 0015            COMPLEX TRAN(37)                                                        B4M20130
  ISN 0016            EQUIVALENCE(TRAN(1),DATA(1))                                            B4M20140
  ISN 0017            COMMON/WORK2/PU(2880,46)                                                B4M20150
  ISN 0018            COMMON/SMOTH/DATA(150),CATA(150),SLP(72,46)                             B4M20160
  ISN 0019            SLEXP(PHI,T10) = EXP(PHI / (T10 + F98 * PHI ) / 287.)                   B4M20170
  ISN 0020            T10(PP,T8,T9) = (T8 * ALOG((F17 * PP + PTOP) / (PP + PTOP))             B4M20180
                     $   + T9 * ALOG((PP + PTOP) / (F5D6 * PP + PTOP)))                       B4M20190
                     $   / ALOG((F17 * PP + PTOP) / (F5D6 * PP + PTOP))                       B4M20200
  ISN 0021            MISS = 1                                                                B4M20210
  ISN 0022            IF (MISS.EQ.1)                    GO TO 50                              B4M20220
  ISN 0024            INC = 1                                                                 B4M20230
  ISN 0025            DRAT=DYU(J)/DXP(J)                                                      B4M20240
  ISN 0026            IF(DRAT.LT.1.) GO TO 40                                                 B4M20250
  ISN 0028            ALP=.125*(DRAT-1.)                                                      B4M20260
  ISN 0029            NN=DRAT                                                                 B4M20270
  ISN 0030            FNN=NN                                                                  B4M20280
  ISN 0031            ALPH=ALP/FNN                                                            B4M20290
  ISN 0032            DO 30 N=1,4                                                             B4M20300
  ISN 0033            DO 30 L = 1,NLAY                                                        B4M20310
  ISN 0034            IMINC=IM-INC                                                            B4M20320
  ISN 0035            I=IM                                                                    B4M20330
  ISN 0036            DO 10 IPINC=INC,IM,INC                                                  B4M20340
```

```
ISN 0037          DUMMY(I)=Q(I,L,N,J)+ALPH*(Q(IPINC,L,N,J)+Q(IMINC,L,N,J)-                B4M20350
                 $    Q(I,L,N,J)-Q(I,L,N,J))                                                B4M20360
ISN 0038          IMINC=I                                                                   B4M20370
ISN 0039       10 I=IPINC                                                                   B4M20380
ISN 0040          DO 20 I=INC,IM,INC                                                        B4M20390
ISN 0041       20 Q(I,L,N,J)=DUMMY(I)                                                       B4M20400
ISN 0042       30 CONTINUE                                                                  B4M20410
ISN 0043          IMINC = IM - INC                                                          B4M20420
ISN 0044          I = IM                                                                    B4M20430
ISN 0045             DO 35 IPINC = INC,IM,INC                                               B4M20440
ISN 0046          DUMMY(I)=P(I,J)+ALPH*(P(IPINC,J)+P(IMINC,J)-P(I,J)-P(I,J))               B4M20450
ISN 0047          IMINC = I                                                                 B4M20460
ISN 0048       35 I = IPINC                                                                 B4M20470
ISN 0049             DO 40 I = INC,IM,INC                                                   B4M20480
ISN 0050          P(I,J) = DUMMY(I)                                                         B4M20490
ISN 0051       40 CONTINUE                                                                  B4M20500
ISN 0052                                          GO TO 60                                  B4M20510
             C                                                                            * B4M20520
             C * * * FOURIER SMOOTHING NEAR POLES                                         * B4M20530
             C12/12 VERSION 3 SMSHAP ON P AND T.                                          * B4M20540
ISN 0053       50 IF(((J.GT.JMIN).AND.(J.LT.JMAX)).OR. J.EQ.1 .OR. J.EQ.JNP) RETURN         B4M20550
ISN 0055          JSUB = J - 1                                                              B4M20560
ISN 0056          IF(J.GE.JMAX)                   JSUB=JSUM - J - 1                         B4M20570
ISN 0058             DO 650 N = 1,4                                                         B4M20580
             C    N = (2**NN) / 2                                                           B4M20590
ISN 0059             DO 650 L = 1,NLAY                                                      B4M20600
ISN 0060             DO 650 I = 1,IM                                                        B4M20610
ISN 0061          DATA(I) = Q(I,L,N,J)                                                      B4M20620
ISN 0062      650                                 CONTINUE                                  B4M20630
ISN 0063                                          CALL FOURT2(DATA,IM,1,-1,0)               B4M20640
ISN 0064             DO 670 I = 1,IMD2P1                                                    B4M20650
ISN 0065          TRAN(I) = SMTH(I,JSUB) * TRAN(I)                                          B4M20660
ISN 0066      670                                 CONTINUE                                  B4M20670
ISN 0067                                          CALL FOURT2(TRAN,IM,1,+1,-1)              B4M20680
ISN 0068             DO 680 I = 1,IM                                                        B4M20690
ISN 0069          Q(I,L,N,J) = DATA(I) / FLOAT(IM)                                          B4M20700
ISN 0070      680                                 CONTINUE                                  B4M20710
ISN 0071      650                                 CONTINUE                                  B4M20720
             C    IF(J.EQ.JM)                     CALL SMSHAP                               B4M20730
ISN 0072       60                                 CONTINUE                                  B4M20740
ISN 0073             DO 100 I = 1,IM                                                        B4M20750
ISN 0074          SLP(I,J) = P(I,J)                                                         B4M20760
ISN 0075      100                                 CONTINUE                                  B4M20770
             C                                                                            * B4M20780
             C * * * TRANSFORM TO SEA LEVEL PRESSURE                                      * B4M20790
             C                                                                            * B4M20800
ISN 0076             DO 110 I = 1,IM                                                        B4M20810
ISN 0077          TSURF = T10(SLP(I,J),T(I,NLAYM1,J),T(I,NLAY,J))                           B4M20820
ISN 0078          SLP(I,J) = (SLP(I,J) + PTOP) * SLEXP(PHIS(I,J),TSURF)                     B4M20830
ISN 0079      110                                 CONTINUE                                  B4M20840
ISN 0080          IF(IM.GT.0)GO TO 781                                                      B4M20850
ISN 0082          DO 760 I=1,IM                                                             B4M20860
ISN 0083          DATA(I)=SLP(I,J)                                                          B4M20870
ISN 0084      760 CONTINUE                                                                  B4M20880
ISN 0085          CALL FOURT2(DATA,IM,1,-1,0)                                               B4M20890
ISN 0086          DO 770 I=1,IMD2P1                                                         B4M20900
ISN 0087          TRAN(I)=SMTH(I,JSUB)*TRAN(I)                                              B4M20910
ISN 0088      770 CONTINUE                                                                  B4M20920
ISN 0089          CALL FOURT2(TRAN,IM,1,1,-1)                                               B4M20930
ISN 0090          DO 780 I=1,IM                                                             B4M20940
ISN 0091          SLP(I,J)=DATA(I)/FLOAT(IM)                                                B4M20950
ISN 0092      780 CONTINUE                                                                  B4M20960
ISN 0093      781 CONTINUE                                                                  B4M20970
             C                                                                            * B4M20980
             C * * * SMOOTHING ALONG LONGITUDE (SEE SMSHAP)                               * B4M20990
             C                                                                            * B4M21000
ISN 0094          NSM = 8                                                                   B4M21010
ISN 0095          IF(J.LT.8.OR.J.GT.JM-6)         NSM = 4                                   B4M21020
ISN 0097          IF(J.LT.6.OR.J.GT.JM-4)         NSM = 2                                   B4M21030
ISN 0099          IF(J.LT.4.OR.J.GT.JM-2)         NSM = 1                                   B4M21040
ISN 0101          SGN = (-1) ** NSM                                                         B4M21050
ISN 0102          CX = 4.** NSM                                                             B4M21060
ISN 0103             DO 130 I = 1,IM                                                        B4M21070
ISN 0104          DATA(I) = SLP(I,J)                                                        B4M21080
ISN 0105      130                                 CONTINUE                                  B4M21090
ISN 0106             DO 140 N = 1,NSM                                                       B4M21100
ISN 0107          I = IM                                                                    B4M21110
ISN 0108             DO 145 IP = 1,IM                                                       B4M21120
ISN 0109          CATA(I) = DATA(IP) - DATA(I)                                              B4M21130
ISN 0110          I = IP                                                                    B4M21140
ISN 0111      145                                 CONTINUE                                  B4M21150
ISN 0112          IS = IM                                                                   B4M21160
ISN 0113             DO 150 I = 1,IM                                                        B4M21170
ISN 0114          DATA(I) = CATA(I) - CATA(IS)                                              B4M21180
ISN 0115          IS = I                                                                    B4M21190
ISN 0116      150                                 CONTINUE                                  B4M21200
ISN 0117      140                                 CONTINUE                                  B4M21210
ISN 0118             DO 160 I = 1,IM                                                        B4M21220
```

```
ISN 0119           SLP(I.J) = SLP(I.J) - SGN * CATA(I) / CX                       B4M21230
ISN 0120       160                            CONTINUE                            B4M21240
             C                                                                 *  B4M21250
             C * * * TRANSFORM BACK TO SURFACE PRESSURE                        *  B4M21260
             C                                                                 *  B4M21270
ISN 0121           MAXIT = 50                                                     B4M21280
ISN 0122              DO 200  I = 1.IM                                            B4M21290
ISN 0123           PSFC = SLP(I.J) - PTOP                                         B4M21300
ISN 0124           PHISX = PHIS(I.J)                                              B4M21310
ISN 0125              DO 210 NITX = 1.MAXIT                                       B4M21320
ISN 0126           P1 = PSFC                                                      B4M21330
ISN 0127           TSURF = T10(PSFC.T(I.NLAYM1.J).T(I.NLAY.J))                    B4M21340
ISN 0128           PSFC = SLP(I.J) / SLEXP(PHISX.TSURF) - PTOP                    B4M21350
ISN 0129           IF(ABS(PSFC-P1)/1000..LE.1.E-5)GO TO 230                       B4M21360
ISN 0131       210                            CONTINUE                            B4M21370
ISN 0132           PRINT 220.MAXIT.I.J                                            B4M21380
ISN 0133       220 FORMAT(1X.'MORE THAN:'.I5.'ITERATIONS FOF J='.I5.' I='.I5)     B4M21390
ISN 0134       230 P(I.J) = PSFC                                                  B4M21400
ISN 0135       200                            CONTINUE                            B4M21410
ISN 0136           RETURN                                                         B4M21420
ISN 0137           END                                                            B4M21430

                                               /     AVRX /     SIZE OF PROGRAM 00191A HEXADECIMAL BYTES

NAME TAG TYPE ADD.  |* ***    % NAME TAG TYPE ADD.  |* ***    % NAME TAG TYPE ADD.  |* ***    % NAME TAG TYPE ADD.  |* ***    %
      C       CE  R*4  000000          F        C  R*4    N.R.          I SFA        I*4  000198          J SFA        I*4  00019C
      L SF        I*4  0001A0          N SF        I*4  0001A4          P SF   XR    R*4  000000          Q SF   XR    R*4  000000
      R        C  R*4    N.R.          T   FA  XR  R*4  00000C          U      XR    R*4  000000          V      XR    R*4  000000
      W        C  R*4    N.R.         CP        C  R*4    N.R.         CX SF         R*4  0001A8         DT       C    R*4    N.R.
     ED        C  R*4    N.R.         GT       CE  R*4  00084C         GW      CE    R*4  001680         IM SFA   C    I*4  000008
     IP SF        I*4  0001AC         IS SF        I*4  0001BC         JM       C    I*4  000030         J1       C    I*4    N.R.
     KM        C  I*4    N.R.         NM SF        I*4  000184         NR       C    I*4    N.R.         PI       C    R*4    N.R.
     PK        C  R*4    N.R.         PU       CE  R*4  00000C         P1 S A        R*4  000188         SH      XR    R*4  000000
     TS       CE  R*4  001890        ALP SF        R*4  0001BC        CDX       C    R*4    N.R.        DXP  F   C    R*4  000720
    DXU        C  R*4    N.R.        DYP        C  R*4    N.R.        DYU  F    C    R*4  0007EC        FIN      C    R*4    N.R.
    FMU        C  R*4    N.R.        FNM SF        R*4  0001CC        F17  FA   C    R*4  000004        F98  FA  C    R*4  000008
    INC SF     C  I*4  000044        JNB        C  I*4    N.R.        JNP       C    I*4  000004        JP1      C    I*4    N.R.
    JP2        C  I*4    N.R.        JSB        C  I*4    N.R.        JSP      CE    I*4  000000        LAT      C    R*4    N.R.
    NPC        C  I*4    N.R.        NSM SF        I*4  0001C4        PSF       C    R*4    N.R.        PSL      C    R*4    N.R.
    RAD        C  R*4    N.R.        SGN SF        R*4  0001CE        SHS      CE    R*4  002300        SIG      C    R*4    N.R.
    SLA SFA    C  R*4  0004B0        SUM        C  R*4    N.R.        TAU       C    R*4    N.R.        T10 S  ASF    R*4  000000
   ALPH SF        R*4  0001CC       AVRX           R*4  0001D0       BETA.      C    R*4    N.R.       CATA SF   C    R*4  000258
   CON1        C  R*4    N.R.       CON2        C  R*4    N.R.       CON3       C    R*4    N.R.       CON4      C    R*4    N.R.
   CONS        C  R*4    N.R.       COSD        C  R*4    N.R.       COSL       C    R*4    N.R.       CPD2      C    R*4    N.R.
   CPTH        C  R*4    N.R.       DATA SFA   CE  R*4  00000C       DIFF       C    R*4    N.R.       DLAT      C    R*4    N.R.
   DLON        C  R*4    N.R.       DRAT SF        R*4  0001D4       DSIG       C    R*4    N.R.       DXYP      C    R*4    N.R.
   F5D6   FA   C  R*4  000000       GRAV        C  R*4    N.R.       IDAY       C    I*4    N.R.       IMD2      C    I*4    N.R.
   INCS        C  I*4    N.R.       IROT        C  I*4    N.R.       ITAU       C    I*4    N.R.       JAYS      C    I*4    N.R.
   JDAY        C  I*4    N.R.       JEND        C  I*4    N.R.       JMAX       C    I*4  000004       JMIN      C    I*4  000000
   JMPS        C  I*4    N.R.       JMS1        C  I*4    N.R.       JMS2       C    I*4    N.R.       JMUS      C    I*4    N.R.
   JPOL        C  I*4    N.R.       JSUB SF        I*4  0001DE       JSUM  F    C    I*4  000008       J1PS      C    I*4    N.R.
   J1US        C  I*4    N.R.       KAPA        C  R*4    N.R.       KNBS       C    I*4    N.R.       KSBS      C    I*4    N.R.
   MISS S         I*4  0001DC       MRCH        C  I*4    N.R.       MROT       C    I*4    N.R.       NFLW      C    I*4    N.R.
   NITX SF        I*4  0001E0       NLAY   FA   C  I*4  00000C       PHIS  FA  CE    R*4  003D50       PPOL     CE    R*4  006654
   PSFC SFA       R*4  0001E4       PTOP   FA   C  R*4  00001C       QPOL      CE    R*4  000414       RGAS      C    R*4    N.R.
   SIGE        C  R*4    N.R.       SIND        C  R*4    N.R.       SINL       C    R*4    N.R.       SMTH  F   C    R*4  00000C
   TAUE        C  R*4    N.R.       TAUI        C  R*4    N.R.       TAUO       C    R*4    N.R.       TAUP      C    R*4    N.R.
   TAUT        C  R*4    N.R.       TPOL       CE  R*4  00045C       TRAN SFA  CE    C*8  000000       UPOL     CE    R*4  000414
   VPOL       CE  R*4  000438       XINT        C  R*4    N.R.      ADLDP       C    R*4    N.R.      ALPHA      C    R*4    N.R.
  DSIGO        C  R*4    N.R.      DUMMY SF     C  R*4  000C30      IMINC SF         I*4  0001E8      INDEX      C    I*4    N.R.
  IPINC SF        I*4  0001EC      ISMTH        C  I*4    N.R.      ITEST       C    I*4    N.R.      JDATE      C    I*4    N.R.
  JNEXT        C  I*4    N.R.      JNPM1        C  I*4    N.R.      JPMOD       C    I*4    N.R.      JSPP1      C    I*4    N.R.
  JTEST        C  I*4    N.R.      JYEAR        C  I*4    N.R.      MAXIT SF         I*4  0001F0      MODPK      C    I*4    N.R.
  NSTEP        C  I*4    N.R.      PHISX SFA       R*4  0001F4      POLES      CE    R*4  000414      PSIGN      C    R*4    N.R.
  RADIM        C  R*4    N.R.      RHMAX        C  R*4    N.R.      SDPOL       C    R*4    N.R.      SMPOL     CE    R*4  00048C
  SLEXP S    ASF  R*4  000000      THBAR        C  R*4    N.R.      TSURF SFA        R*4  0001F8     FRXPI#     XF    R*4  000000
 FIXPI#       XF  I*4  000000        EXP       XF  R*4  00000C       ALOG      XF    R*4  000000      CMPY#     XF    C*8  000000
 ALBEDO        C  I*2    N.R.     CONVPL        C  R*4    N.R.     COSLON       C    R*4    N.R.     DTMULT      C    R*4    N.R.
 DUMMYA        C  R*4    N.R.     DUMMYC        C  R*4    N.R.     FOURT2 SF   XF    R*4  000000     IALTER      C    I*4    N.R.
 IBCOM#       XF  I*4  000000     IMD2P1   F    C  I*4  00002C     ISTART       C    I*4    N.R.     ISWTCH      C    I*4    N.R.
 JMONTH        C  I*4    N.R.     MATSUN        C  I*4    N.R.     NCOMP3       C    I*4    N.R.     NCYCLE      C    I*4    N.R.
 NMOGAN        C  I*4    N.R.     NLAYM1   FA   C  I*4  000024     NLAYP1       C    I*4    N.R.     NSTART      C    I*4    N.R.
 PHISPL        C  R*4    N.R.     PITPOL          R*4    N.R.     PSKAPA       C    R*4    N.R.     RSDIST      C    R*4    N.R.
 SINLON        C  R*4    N.R.     TOFDAY        C  R*4    N.R.     XLABEL       C    R*4    N.R.

                                   *****  COMMON INFORMATION   *****

      NAME OF COMMON BLOCK * F;U#.ZE OF BLOCKCOMMON      005E24 HEXADECIMAL BYTES

  VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE   VAR. NAME TYPE REL. ADDR.HE
       CON1  R*4       N.R.           CON2  R*4       N.R.           CON3  R*4       N.R.           CON4  R*4       N.R.
       CONS  R*4       N.R.          THBAR  R*4       N.R.          ALPHA  R*4       N.R.           BETA  R*4       N.R.
     IMD2P1  I*4     000020          ADLDP  R*4       N.R.           JMS2  I*4       N.R.           JMS1  I*4       N.R.
       CPTH  R*4       N.R.         PSKAPA  R*4       N.R.              R  R*4       N.R.            RAD  R*4       N.R.
         CF  R*4       N.R.            INC  I*4     000044         NSTART  I*4       N.R.           CPD2  R*4       N.R.
       IMD2  I*4       N.R.          RADIM  R*4       N.R.           JEND  I*4       N.R.            JP1  I*4       N.R.
        JP2  I*4       N.R.         MATSUN  I*4       N.R.          JNEXT  I*4       N.R.          MODPK  I*4       N.R.
```

```
     JPOL      I*4      N.R.            JPMCD      I*4      N.R.             SINLUN      R*4      N.R.            CUSLUN      R*4      N.R.
    INDEX      I*4      N.R.            PSIGN      R*4      N.R.              POLES      R*4    000414                 W      R*4      N.R.
       PK      R*4      N.R.             DIFF      R*4      N.R.             CONVPL      R*4      N.R.             SDPOL      R*4      N.R.
   PHISPL      R*4      N.R.              SUM      R*4      N.R.

EQUIVALENCED VARIABLES WITHIN THIS CCMMON GROUP
  VARIABLE OFFSETE                   VARIABLE OFFSETE                    VARIABLE OFFSETE                    VARIABLE OFFSETE
     OPOL    000414                       JPOL    000414                       VPOL    000438                       TPOL    00045C
    SHPOL    000480                       PPOL    000654

   NAME OF CCMMON BLOCK *  ¬NTR*E OF BLOCKCOMMON      083C30 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
      JSF    I*4    000000             JNP    I*4    000004              IM    I*4    000008            NLAY    I*4    00000C
     PTOP    R*4    000010          ISTART    I*4      N.R.          JSPP1    I*4      N.R.           JNPM1    I*4      N.R.
      FIM    R*4      N.R.          NLAYM1    I*4    000024          NLAYP1    I*4      N.R.              J1    I*4      N.R.
       JM    I*4    000030              KM    I*4      N.R.           TAUT    R*4      N.R.            IROT    I*4      N.R.
     MROT    I*4      N.R.           JTEST    I*4      N.R.          ITEST    I*4      N.R.              NR    I*4      N.R.
     JAYS    I*4      N.R.            INCS    I*4      N.R.            JSB    I*4      N.R.             JNB    I*4      N.R.
     DLAT    R*4      N.R.            DLON    R*4      N.R.             DT    R*4      N.R.             TAU    R*4      N.R.
     ITAU    I*4      N.R.            XINT    R*4      N.R.           IDAY    I*4      N.R.            JDAY    I*4      N.R.
   TOFDAY    R*4      N.R.           JDATE    I*4      N.R.         JMONTH    I*4      N.R.           JYEAR    I*4      N.R.
    NSTEP    I*4      N.R.          NCYCLE    I*4      N.R.         NCOMP3    I*4      N.R.          NMOGAN    I*4      N.R.
     TAUP    R*4      N.R.            TAUI    R*4      N.R.           TAUE    R*4      N.R.            TAUO    R*4      N.R.
   DTMULT    R*4      N.R.              PI    R*4      N.R.           GRAV    R*4      N.R.            RGAS    R*4      N.R.
     KAPA    R*4      N.R.             PSL    R*4      N.R.             SD    R*4      N.R.             FMU    R*4      N.R.
     NFLW    I*4      N.R.             PSF    R*4      N.R.           MRCH    I*4      N.R.          RSDIST    R*4      N.R.
     SIND    R*4      N.R.            COSD    R*4      N.R.          QHMAX    R*4      N.R.             CDX    R*4      N.R.
   DUMMYC    R*4      N.R.          IALTER    I*4      N.R.         DUMMYA    R*4      N.R.          XLABEL    R*4      N.R.
      SIG    R*4      N.R.            DSIG    R*4      N.R.           SIGE    R*4      N.R.           DSIGO    R*4      N.R.
     J1PS    I*4      N.R.            JMPS    I*4      N.R.           J1US    I*4      N.R.            JMUS    I*4      N.R.
     KSBS    I*4      N.R.            KNBS    I*4      N.R.            LAT    R*4      N.R.             DXU    R*4      N.R.
      DXP    R*4    000728             DYU    R*4    0007E0            DYP    R*4      N.R.            DXYP    R*4      N.R.
        F    R*4      N.R.            SINL    R*4      N.R.           COSL    R*4      N.R.           DUMMY    R*4    000C30
     PHIS    R*4    000050          ALBEDO    I*2      N.R.

EQUIVALENCED VARIABLES WITHIN THIS CCMMON GROUP
  VARIABLE OFFSETE                   VARIABLE OFFSETE                    VARIABLE OFFSETE                    VARIABLE OFFSETE
       TS    001890                        SHS    0023DC                          C    000000

   NAME OF CCMMON BLOCK * I)S6.ZE OF BLOCKCOMMON      000C0C HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
     F5D6    R*4    000000             F17    R*4    000004            F98    R*4    000008

   NAME OF CCMMON BLOCK *  *DS_?E OF BLOCKCOMMON      000C04 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
   ISWTCH    I*4      N.R.

   NAME OF CCMMON BLOCK *  *S6¬*E OF BLOCKCOMMON      000C08 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
    ISMTH    I*4      N.R.             NPC    I*4      N.R.

   NAME OF CCMMON BLOCK *  * SI.E OF BLOCKCOMMON      000SEC HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
     JMIN    I*4    000000            JMAX    I*4    000004           JSUM    I*4    000008            SMTH    R*4    00000C

   NAME OF CCMMON BLOCK *  =O*S*E OF BLOCKCOMMON      081C00 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
       PU    R*4    000000

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE                   VARIABLE OFFSETE                    VARIABLE OFFSETE                    VARIABLE OFFSETE
       GT    000840                         GW    0016EC

   NAME OF CCMMON BLOCK *  =M6.ZE OF BLOCKCOMMON      003E70 HEXADECIMAL BYTES

VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE    VAR. NAME TYPE REL. ADDR.HE
     DATA    R*4    000000            CATA    R*4    000258            SLP    R*4    000480

EQUIVALENCED VARIABLES WITHIN THIS COMMON GROUP
  VARIABLE OFFSETE                   VARIABLE OFFSETE                    VARIABLE OFFSETE                    VARIABLE OFFSETE
```

```
   LABEL   ADDR              LABEL   ADDR              LABEL   ADDR              LABEL   ADDR
     10   000464                20   0004E6                30   0004C6                35   00056E
     40   0005AE                50   0005CA               660   0006F0               670   000778
    680   0007F4               650   0007FA                60   000822               100   00088A
    110   0009F6               760   000A38               770   000AE6               780   000B64
    781   000B6A               130   000C6C               145   000CA6               150   000CC6
    140   000CCC               160   000D14               210   000ECA               230   000EFC
    200   000F08

*OPTIONS IN EFFECT*       NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,

*OPTIONS IN EFFECT*       SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

*STATISTICS*     SOURCE STATEMENTS =      136   PROGRAM SIZE=      4122

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                        848K BYTES OF CORE NOT USED

 LEVEL 19.6-APR 71                              OS/360 FORTRAN H AT GISS                                  DATE 12/12/79-0783.96

        COMPILER OPTIONS -    NAME=  MAIN,OPT=02,LINECNT=55,SIZE=1000K,
                              SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
  ISN 0002             SUBROUTINE SMSHAP(T,P,Q,TPOL,PPOL,QPOL,PT,QT,PTPOL,QTPOL)          B4M21440
  ISN 0003             COMMON/WORK/POT(72,46,9)                                           B4M21450
  ISN 0004             COMMON/FOURTH/CON1,CON2,CON3,CON4,CON5,THBAR,ALPHA,BETA,IMD2P1,    B4M21460
                     $    ADLOP,JMS2,JMS1,CPTH,PSKAPA,R,RAD,CP,INC,NSTART,CPD2,           B4M21470
                     $    IMD2,RADIN,JEND(2),JP1,JP2,MATSUN,JNEXT(2),MODPK(2,2),          B4M21480
                     $    JPOL(2,2),JPMOD(2,2),SINLON(72),COSLON(72),INDEX(72),           B4M21490
                     $    PSIGN(4),POLES(148),W(72,9,5),PK(72,9,3),DIFF(9),               B4M21500
                     $    CONVPL(9),SDPOL(9,2),PHISPL(2),SUM(2,5)                         B4M21510
  ISN 0005             DIMENSION PPOL(2),PITPOL(2),TPOL(36,1),QPOL(9,4,2),Q(72,10,4,1)    B4M21520
  ISN 0006             DIMENSION PTPOL(2),QTPOL(9,4,2),CT(72,10,4,1)                      B4M21530
  ISN 0007             INTEGER*2 ALBEDO                                                   B4M21540
  ISN 0008             REAL*4 KAPA,LAT                                                    B4M21550
               C       REAL*8 SINLON,COSLON,SUM                                           B4M21560
  ISN 0009             DIMENSION T(72,40,1),PT(2880,1),                                   B4M21570
                      *P(2880,1),TS(2880,1),SHS(2880,1),GT(2880,1),GW(2880,1),C(300)      B4M21580
  ISN 0010             COMMON/WORK2/PU(2880,46)                                           B4M21590
  ISN 0011             EQUIVALENCE                                                        B4M21600
                      1(TS(1,1),PHIS(721,1)),(SHS(1,1),PHIS(1441,1))                      B4M21610
                      2,(GT(1,1),PU(721,1)),(GW(1,1),PU(1441,1)),(C(1),JSP)               B4M21620
  ISN 0012             COMMON /CNTRL/                                                     B4M21630
                     *  JSP,JNP,IM,NLAY,PTOP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,        B4M21640
                     *  J1,JM,KM,TAUT,IROT,MROT,JTEST,ITEST,                              B4M21650
                     *  NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,                           B4M21660
                     *  DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,    B4M21670
                     *  NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TALO,DTMULT,                  B4M21680
                     *  PI,GRAV,RGAS,KAPA,PSL,ED,FMU,NFLW,PSF,ARCH,RSDIST,SIND,COSD,      B4M21690
                     *  RHMAX,CDX,DUMMYC(18),IALTER,DUMMYA(99),                           B4M21700
                     *  XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGO(19),                   B4M21710
                     *  J1PS(11),JMPS(11),J1US(11),JMUS(11),KSES(11),KNBS(11),            B4M21720
                      *LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),DXYP(46),F(46),SINL(46),   B4M21730
                      *COSL(46),DUMMY(72),PHIS(2880,46),ALBEDO(72,46)                     B4M21740
  ISN 0013             COMMON/SMOTH/DATA(150),CATA(150),SLP(72,46)                        B4M21750
  ISN 0014             COMMON/INSMSH/F5D6,F17,F98                                         B4M21760
  ISN 0015             COMMON /DBUG/ISWTCH                                                B4M21770
  ISN 0016             COMMON/SMOO/ISMTH,NPC                                              B4M21780
  ISN 0017             COMMON/MLFS/NSEQ,MLF(10),MATSNX,NSM1,NCM1                          B4M21790
  ISN 0018             DATA J2/2/                                                         B4M21800
               C                                                                        * B4M21810
               C * * * DEFINITION OF SURFACE TEMPERATURE AND                            * B4M21820
               C * * * SEA LEVEL PRESSURE FUNCTIONS                                     * B4M21830
               C                                                                        * B4M21840
  ISN 0019             SLEXP(PHI,T10) = EXP(PHI / (T10 + F98 * PHI ) / 287.)              B4M21850
  ISN 0020             T10(PP,T8,T9) = (T8 * ALOG((F17 * PP + PTOP) / (PP + PTOP))        B4M21860
                     $    + T9 * ALOG((PP + PTOP) / (F5D6 * PP + PTOP)))                  B4M21870
                     $    / ALOG((F17 * PP + PTOP) / (F5D6 * PP + PTOP))                  B4M21880
               C                                                                        * B4M21890
               C * * * FIRST J LOOP                                                     * B4M21900
               C * * * GET SURFACE PRESSURE AND TEMPERATURE INCLUDING POLES              * B4M21910
               C                                                                        * B4M21920
  ISN 0021             IF(NSTEP.LE.NSM1)RETURN                                            B4M21930
  ISN 0023             WRITE(3,999) TAU                                                   B4M21940
  ISN 0024             M=1                                                                B4M21950
  ISN 0025             DO 200 J = 1,JNP                                                   B4M21960
  ISN 0026             IF (J.NE.1 .AND. J.NE.JNP)  GO TO 120                              B4M21970
  ISN 0028             DO 130 L = 1,NLAY                                                  B4M21980
               C                                                                          B4M21990
  ISN 0029             POT(1,J,L) = TPOL(L,M)                                             B4M22000
  ISN 0030        130                         CONTINUE                                    B4M22010
  ISN 0031             SLP(1,J) = PPOL(M)                                                 B4M22020
  ISN 0032              M=2                                                               B4M22030
```

```
ISN 0033                                     GO TO 140                                        B4M22040
ISN 0034          120 DO 110 L = 1.NLAY                                                       B4M22050
ISN 0035              DO 110 I = 1.IM                                                         B4M22060
ISN 0036              POT(I.J.L) = T(I.L.J)                                                   B4M22070
ISN 0037          110                        CONTINUE                                         B4M22080
ISN 0038              DO 100 I = 1.IM                                                         B4M22090
ISN 0039              SLP(I.J) = P(I.J)                                                       B4M22100
ISN 0040          100                        CONTINUE                                         B4M22110
                C                                                                          *  B4M22120
                C * * * TRANSFORM TO SEA LEVEL PRESSURE AND POTENTIAL TEMPERATURE          *  B4M22130
                C                                                                          *  B4M22140
ISN 0041          140 DO 210 I = 1.IM                                                         B4M22150
ISN 0042              TSURF = T10(SLP(I.J).POT(I.J.8).POT(I.J.5))                             B4M22160
ISN 0043              DO 220 L = 1.NLAY                                                       B4M22170
ISN 0044              PKAPA = EXPBYK(SLP(I.J) * SIG(L) + PTOP)                                B4M22180
ISN 0045              POT(I.J.L) = POT(I.J.L) / PKAPA                                         B4M22190
ISN 0046          220                        CONTINUE                                         B4M22200
ISN 0047              PHISX = PHIS(I.J)                                                       B4M22210
ISN 0048              SLP(I.J) = (SLP(I.J) + PTOP) * SLEXP(PHISX.TSURF)                       B4M22220
ISN 0049              IF (J .EQ. 1.OR.J .EQ. JNP) GO TO 230                                   B4M22230
ISN 0051          210                        CONTINUE                                         B4M22240
ISN 0052                                     GO TO 200                                        B4M22250
ISN 0053          230 DO 240 I = 2.IM                                                         B4M22260
ISN 0054              DO 250 L = 1.NLAY                                                       B4M22270
ISN 0055              POT(I.J.L) = POT(1.J.L)                                                 B4M22280
ISN 0056          250                        CONTINUE                                         B4M22290
ISN 0057              SLP(I.J) = SLP(1.J)                                                     B4M22300
ISN 0058          240                        CONTINUE                                         B4M22310
ISN 0059          200                        CONTINUE                                         B4M22320
ISN 0060              NF = -1                                                                 B4M22330
                C                                                                          *  B4M22340
                C * * * SMOOTHING ALONG LONGITUDE                                          *  B4M22350
                C * * *                                                                    *  B4M22360
                C * * *                                                                    *  B4M22370
                C * * *                                                                    *  B4M22380
                C * * * 16TH ORDER AT ALL J VALUES.                                        *  B4M22390
                C                                                                          *  B4M22400
ISN 0061         1000 NF = NF + 1                                                             B4M22410
ISN 0062              DO 1010 J = 2.JM                                                        B4M22420
ISN 0063              NSM = 2                                                                 B4M22430
                C     IF (J.LT.8 .OR. J.GT.JM-6)    NSM = 4                                   B4M22440
                C     IF (J.LT.6 .OR. J.GT.JM-4)    NSM = 2                                   B4M22450
                C     IF (J.LT.4 .OR. J.GT.JM-2)    NSM = 1                                   B4M22460
                C     SGN = (-1) ** NSM                                                       B4M22470
ISN 0064              CX = 4. ** NSM                                                          B4M22480
ISN 0065              IF (NF .GT. 0)                 GO TO 1024                               B4M22490
ISN 0067              DO 1020 I = 1.IM                                                        B4M22500
ISN 0068              DATA(I) = SLP(I.J)                                                      B4M22510
ISN 0069         1020                        CONTINUE                                         B4M22520
ISN 0070                                     GO TO 1028                                       B4M22530
ISN 0071         1024 DO 1026 I = 1.IM                                                        B4M22540
ISN 0072              DATA(I) = POT(I.J.NF)                                                   B4M22550
ISN 0073         1026                        CONTINUE                                         B4M22560
ISN 0074         1028 DO 1030 N = 1.NSM                                                       B4M22570
ISN 0075              I = IM                                                                  B4M22580
ISN 0076              DO 1035 IP = 1.IM                                                       B4M22590
ISN 0077              CATA(I) = DATA(IP) - DATA(I)                                            B4M22600
ISN 0078              I = IP                                                                  B4M22610
ISN 0079         1035                        CONTINUE                                         B4M22620
ISN 0080              IS = IM                                                                 B4M22630
ISN 0081              DO 1040 I = 1.IM                                                        B4M22640
ISN 0082              DATA(I) = CATA(I) - CATA(IS)                                            B4M22650
ISN 0083              IS = I                                                                  B4M22660
ISN 0084         1040                        CONTINUE                                         B4M22670
ISN 0085         1030                        CONTINUE                                         B4M22680
ISN 0086              IF (NF .GT. 0)                 GO TO 1054                               B4M22690
ISN 0088              DO 1050 I = 1.IM                                                        B4M22700
ISN 0089              SLP(I.J) = SLP(I.J) -          DATA(I) / CX                             B4M22710
ISN 0090         1050                        CONTINUE                                         B4M22720
ISN 0091                                     GO TO 1010                                       B4M22730
ISN 0092         1054 DO 1056 I = 1.IM                                                        B4M22740
ISN 0093              POT(I.J.NF) = POT(I.J.NF) -          DATA(I) / CX                       B4M22750
ISN 0094         1056                        CONTINUE                                         B4M22760
ISN 0095         1010                        CONTINUE                                         B4M22770
                C                                                                          *  B4M22780
                C * * * SMOOTHING ALONG LATITUDE                                           *  B4M22790
                C * * * ALSO USE PERIODICITY ALONG COMPLETE MERIDIAN (J=1.2*JM)             *  B4M22800
                C                                                                          *  B4M22810
ISN 0096              CY=4.**NSM                                                              B4M22820
ISN 0097              IMD2 = IM / 2                                                           B4M22830
ISN 0098              JMT2 = JM * 2                                                           B4M22840
ISN 0099              DO 1110 I = 1.IMD2                                                      B4M22850
ISN 0100              IF (NF .GT. 0)                 GO TO 1124                               B4M22860
ISN 0102              DO 1120 J = 1.JM                                                        B4M22870
ISN 0103              DATA(J) = SLP(I.J)                                                      B4M22880
ISN 0104              DATA(J+JM) = SLP(I+IMD2.JM-J+2)                                         B4M22890
ISN 0105         1120                        CONTINUE                                         B4M22900
ISN 0106                                     GO TO 1128                                       B4M22910
```

```
                C                                                                    *  B4M22920
                C * * * SHOULD PUT (-1) FOR WIND SMOOTHING IN 1126                   *  B4M22930
                C                                                                    *  B4M22940
ISN 0107          1124 DO 1126 J = 1,JM                                                 B4M22950
ISN 0108               DATA(J) = POT(I,J,NF)                                            B4M22960
ISN 0109               DATA(J+JM) = POT(I+IMD2,JM-J+2,NF)                               B4M22970
ISN 0110          1126                               CONTINUE                           B4M22980
ISN 0111          1128 DO 1130 N=1,NSM                                                  B4M22990
ISN 0112               J = JMT2                                                         B4M23000
ISN 0113               DO 1135 JP = 1,JMT2                                              B4M23010
ISN 0114               CATA(J) = DATA(JP) - DATA(J)                                     B4M23020
ISN 0115               J = JP                                                           B4M23030
ISN 0116          1135                               CONTINUE                           B4M23040
ISN 0117               JS = JMT2                                                        B4M23050
ISN 0118               DO 1140 J = 1,JMT2                                               B4M23060
ISN 0119               DATA(J) = CATA(J) - CATA(JS)                                     B4M23070
ISN 0120               JS = J                                                           B4M23080
ISN 0121          1140                               CONTINUE                           B4M23090
ISN 0122          1130                               CONTINUE                           B4M23100
ISN 0123               IF (NF .GT. 0)                GO TO 1154                         B4M23110
ISN 0125               DO 1150 J = 1,JM                                                 B4M23120
ISN 0126               SLP(I,J) = SLP(I,J) - DATA(J) / CY                               B4M23130
ISN 0127               SLP(I+IMD2,JM-J+2) = SLP(I+IMD2,JM-J+2) - DATA(J+JM) / CY        B4M23140
ISN 0128          1150                               CONTINUE                           B4M23150
ISN 0129                                             GO TO 1110                         B4M23160
ISN 0130          1154 DO 1170 J = 1,JM                                                 B4M23170
ISN 0131               POT(I,J,NF) = POT(I,J,NF) - DATA(J) / CY                         B4M23180
ISN 0132               POT(I+IMD2,JM-J+2,NF)=POT(I+IMD2,JM-J+2,NF) - DATA(J+JM) / CY    B4M23190
ISN 0133          1170                               CONTINUE                           B4M23200
ISN 0134          1110                               CONTINUE                           B4M23210
ISN 0135               IF (NF .GT. 0)                GO TO 1164                         B4M23220
ISN 0137               S1 = 0.                                                          B4M23230
ISN 0138               S2 = 0.                                                          B4M23240
ISN 0139               DO 1160 I = 1,IM                                                 B4M23250
ISN 0140               S1 = S1 + SLP(I,1)                                               B4M23260
ISN 0141               S2 = S2 + SLP(I,JNP)                                             B4M23270
ISN 0142          1160                               CONTINUE                           B4M23280
ISN 0143               S1 = S1 / IM                                                     B4M23290
ISN 0144               S2 = S2 / IM                                                     B4M23300
ISN 0145               DO 1165 I = 1,IM                                                 B4M23310
ISN 0146               SLP(I,1) = S1                                                    B4M23320
ISN 0147               SLP(I,JNP) = S2                                                  B4M23330
ISN 0148          1165                               CONTINUE                           B4M23340
ISN 0149                                             GO TO 1180                         B4M23350
ISN 0150          1164 S1 = 0.                                                          B4M23360
ISN 0151               S2 = 0.                                                          B4M23370
ISN 0152               DO 1173 I = 1,IM                                                 B4M23380
ISN 0153               S1 = S1 + POT(I,1,NF)                                            B4M23390
ISN 0154               S2 = S2 + POT(I,JNP,NF)                                          B4M23400
ISN 0155          1173                               CONTINUE                           B4M23410
ISN 0156               S1 = S1 / IM                                                     B4M23420
ISN 0157               S2 = S2 / IM                                                     B4M23430
ISN 0158               DO 1175 I = 1,IM                                                 B4M23440
ISN 0159               POT(I,1,NF) = S1                                                 B4M23450
ISN 0160               POT(I,JNP,NF) = S2                                               B4M23460
ISN 0161          1175                               CONTINUE                           B4M23470
ISN 0162          1180                               CONTINUE                           B4M23480
ISN 0163               IF (NF .LT. NLAY)             GO TO 1000                         B4M23490
                C                                                                       B4M23500
                C                                                                       B4M23510
                C                                                                    *  B4M23520
                C * * * SECOND MAIN J-LOOP                                           *  B4M23530
                C * * * TRANSFORM BACK TO SURFACE PRESSURE                           *  B4M23540
                C                                                                    *  B4M23550
ISN 0165               MAXIT = 50                                                       B4M23560
ISN 0166               DO 2000 J = 1,JNP                                                B4M23570
ISN 0167               DO 1320 I = 1,IM                                                 B4M23580
ISN 0168               PHISX = PHIS(I,J)                                                B4M23590
ISN 0169               PSFC = SLP(I,J) - PTOP                                           B4M23600
ISN 0170               DO 1330 NITX = 1,MAXIT                                           B4M23610
ISN 0171               P1 = PSFC                                                        B4M23620
ISN 0172               T8 = POT(I,J,8) * EXPBYK(PSFC * SIG(8) + PTOP)                   B4M23630
ISN 0173               T9 = POT(I,J,9) * EXPBYK(PSFC * SIG(9) + PTOP)                   B4M23640
ISN 0174               TSURF = T10(PSFC,T8,T9)                                          B4M23650
ISN 0175               PSFC = SLP(I,J) / SLEXP(PHISX,TSURF) - PTOP                      B4M23660
ISN 0176               IF (ABS(PSFC-P1)/1000. .LE. 1.E-5)  GO TO 1340                   B4M23670
ISN 0178          1330                               CONTINUE                           B4M23680
ISN 0179               PRINT 1335,MAXIT                                                 B4M23690
ISN 0180          1335 FORMAT(1X,' MORE THAN',I5,' ITERATIONS.')                        B4M23700
ISN 0181               PRINT 7990,J                                                     B4M23710
ISN 0182               PRINT 7991,I                                                     B4M23720
ISN 0183          7990 FORMAT(1X,' J = ',I5)                                            B4M23730
ISN 0184          7991 FORMAT(1X,' I = ',I5)                                            B4M23740
ISN 0185          1340 SLP(I,J) = PSFC                                                  B4M23750
ISN 0186               IF (J.EQ.1 .OR. J.EQ.JNP)     GO TO 1350                         B4M23760
ISN 0188          1320                               CONTINUE                           B4M23770
ISN 0189                                             GO TO 1310                         B4M23780
ISN 0190          1350 DO 1360 I = 2,IM                                                 B4M23790
```

```
ISN 0191           SLP(I,J) = SLP(1,J)                                                  B4M23800
ISN 0192      1360                                    CONTINUE                          B4M23810
ISN 0193      1310                                    CONTINUE                          B4M23820
            C                                                                         * B4M23830
            C * * * TRANSFORM BACK TO TEMPERATURE                                     * B4M23840
            C                                                                         * B4M23850
ISN 0194           DO 1400 L = 1,NLAY                                                   B4M23860
ISN 0195           DO 1420 I = 1,IM                                                     B4M23870
ISN 0196           PKAPA = EXPBYK(SLP(I,J) * SIG(L) + PTOP)                             B4M23880
ISN 0197           POT(I,J,L) = POT(I,J,L) * PKAPA                                      B4M23890
ISN 0198           IF (J.EQ.1 .OR. J.EQ.JNP)   GO TO 1430                               B4M23900
ISN 0200      1420                                    CONTINUE                          B4M23910
ISN 0201                                              GO TO 1400                        B4M23920
ISN 0202      1430 DO 1440 I = 2,IM                                                     B4M23930
ISN 0203           POT(I,J,L) = POT(1,J,L)                                              B4M23940
ISN 0204      1440                                    CONTINUE                          B4M23950
ISN 0205      1400                                    CONTINUE                          B4M23960
            C                                                                         * B4M23970
            C * * * RETURN SMOOTHED VALUES                                            * B4M23980
            C                                                                         * B4M23990
ISN 0206           DO 1520 L = 1,NLAY                                                   B4M24000
ISN 0207           DO 1520 I = 1,IM                                                     B4M24010
ISN 0208           T(I,L,J) = POT(I,J,L)                                                B4M24020
ISN 0209      1520                                    CONTINUE                          B4M24030
ISN 0210      1525 DO 1530 I = 1,IM                                                     B4M24040
ISN 0211           P(I,J) = SLP(I,J)                                                    B4M24050
ISN 0212      1530                                    CONTINUE                          B4M24060
ISN 0213      2000                                    CONTINUE                          B4M24070
ISN 0214           DO 1550 L = 1,NLAY                                                   B4M24080
ISN 0215           TPOL(L,1) = POT(1,1,L)                                               B4M24090
ISN 0216           TPOL(L,J2) = POT(1,JNP,L)                                            B4M24100
ISN 0217      1550                                    CONTINUE                          B4M24110
ISN 0218           PPOL(1) = SLP(1,1)                                                   B4M24120
ISN 0219           PPOL(2) = SLP(1,JNP)                                                 B4M24130
            C ***  12/14 RUN1 HERE TILL RETURN                                          B4M24140
ISN 0220           IF(KATSNX.EQ.0)RETURN                                                B4M24150
ISN 0222           DO 500 J=2,JM                                                        B4M24160
ISN 0223           DO 500 N=1,4                                                         B4M24170
ISN 0224           DO 500 K=1,NLAY                                                      B4M24180
ISN 0225           DO 500 I=1,IM                                                        B4M24190
ISN 0226           QT(I,K,N,J)=P(I,J)*DXYP(J)*Q(I,K,N,J)                                B4M24200
ISN 0227       500 CONTINUE                                                             B4M24210
ISN 0228           DO 501 J=2,JM                                                        B4M24220
ISN 0229           DO 501 I=1,IM                                                        B4M24230
ISN 0230           PT(I,J)=P(I,J)                                                       B4M24240
ISN 0231       501 CONTINUE                                                             B4M24250
ISN 0232           DO 502 L=1,NLAY                                                      B4M24260
ISN 0233           DO 502 N=1,4                                                         B4M24270
ISN 0234           DO 502 M=1,2                                                         B4M24280
ISN 0235           QTPOL(L,N,M)=PPOL(M)*QPOL(L,N,M)                                     B4M24290
ISN 0236       502 CONTINUE                                                             B4M24300
ISN 0237           PTPOL(1)=PPOL(1)                                                     B4M24310
ISN 0238           PTPOL(2)=PPOL(2)                                                     B4M24320
ISN 0239       999 FORMAT(1X,' NEW SMOOTHER ENTERED.   TAU=',F12.3)                     B4M24330
ISN 0240                                              RETURN                            B4M24340
ISN 0241                                              END                               B4M24350
```