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(NASA-TM-82326) DO INITIAL CONDITIONS MATTER? A COMPARISON OF MODEL CLIMATOLOGIES GENERATED FROM DIFFERENT INITIAL STATES (City Coll. of the City Univ. of New York.) 29 p HC A03/MF A01 CSCL 04B G3/47
N81-21702
Unclas 41902

Do Initial Conditions Matter? A Comparison of Model Climatologies Generated from Different Initial States[1]

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April 1981

APR 1981 RECEIVED NASA STI FACILITY ACCESS DEPT.

Introduction

The GISS coarse-mesh ($8^{\circ} \times 10^{\circ}$) 7-layer global climate model (Hansen et al., 1980) was used to compute 15 months of meteorological history in two perpetual January experiments on a water planet (without continents) with a zonally symmetric climatological January sea-surface (SST) temperature field (Spar, 1981).

In the first of the two water planet experiments (001) the initial atmospheric state was a set of zonal mean values of specific humidity, temperature, and wind at each latitude and on each sigma-level surface derived from the January output of an earlier 5-year climate simulation (Christidis and Spar, 1981), but with a constant surface pressure of 1010 mb. In the second experiment (000) the model was initialized with globally uniform mean values of specific humidity and temperature on each sigma-level surface, constant surface pressure (1010 mb), and zero wind everywhere. The latter run (000) will be referred to as a "spin-up" experiment.

The evolution of the two water planet climatologies has been described by Spar, Cohen and Wu (Spar, 1981). This report presents a further comparison of the mean January climatic states generated by the two water planet experiments, and a further assessment of the influence of different initial conditions on the model-generated climatologies. For the purpose of this comparison, the first two months of each 15 January run were discarded, and 13-month averages were computed from months 3 through 15.

[1]Grant NGR 33-016-086, NASA Goddard Space Flight Center. This research was carried out at the Goddard Institute for Space Studies (GISS).

Meridional Cross-sections

Mean meridional cross-sections of the temperature distributions (in ^{o}C) generated by runs 001 and 000, shown in Figures 1(a) and 1(b), respectively, indicate no apparent differences between the two climatologies. Indeed, the difference between the two temperature cross-section, illustrated in Figure 2 in units of $0.1^{o}C$, shows temperature differences close to zero and generally less than $1^{o}C$ everywhere except in the polar regions. (The larger mean differences in the polar regions are associated with large sample variances, and are not statistically significant.)

Mean meridional cross-sections of the zonal wind components (in units of 0.1 ms^{-1}), generated by runs 001 and 000, and shown in Figures 3(a) and 3(b) respectively, also appear on inspection to be virtually identical. However, the cross-section of differences between 001 and 000 (in units of 0.01 ms^{-1}) shown in Figure 4 does reveal that the differences, while generally small, do reach values close to 6 ms^{-1} in the high equatorial stratosphere. As shown in Figure 5, these large differences appear in a region where the standard deviations of the sample (for run 001) are less than 3 ms^{-1}, and they are found to be statistically significant. Thus, there is some indication that, at least over the 15 year period from which the 13-year mean was computed, the effect of initial conditions may be of some minor importance in the climate calculation. (The appearance of stronger, high stratospheric easterlies (see dotted curve denoting negative zonal winds) over the equator in run 001 (Fig. 3a) compared with run 000 (Fig. 3b) is the principal effect of the different initial conditions on the mean zonal flow, and is due to the fact that run 001 was initialized with excessively strong equatorial stratospheric easterlies (- 19 ms^{-1} at 32 mb) which persisted for several months of the 15-January run before decaying.)

**SPAR.WU.COHEN:RUN#1

TEMPERATURE (DEGREES CENTIGRADE) AVERAGE OF LAST 13 MONTHS

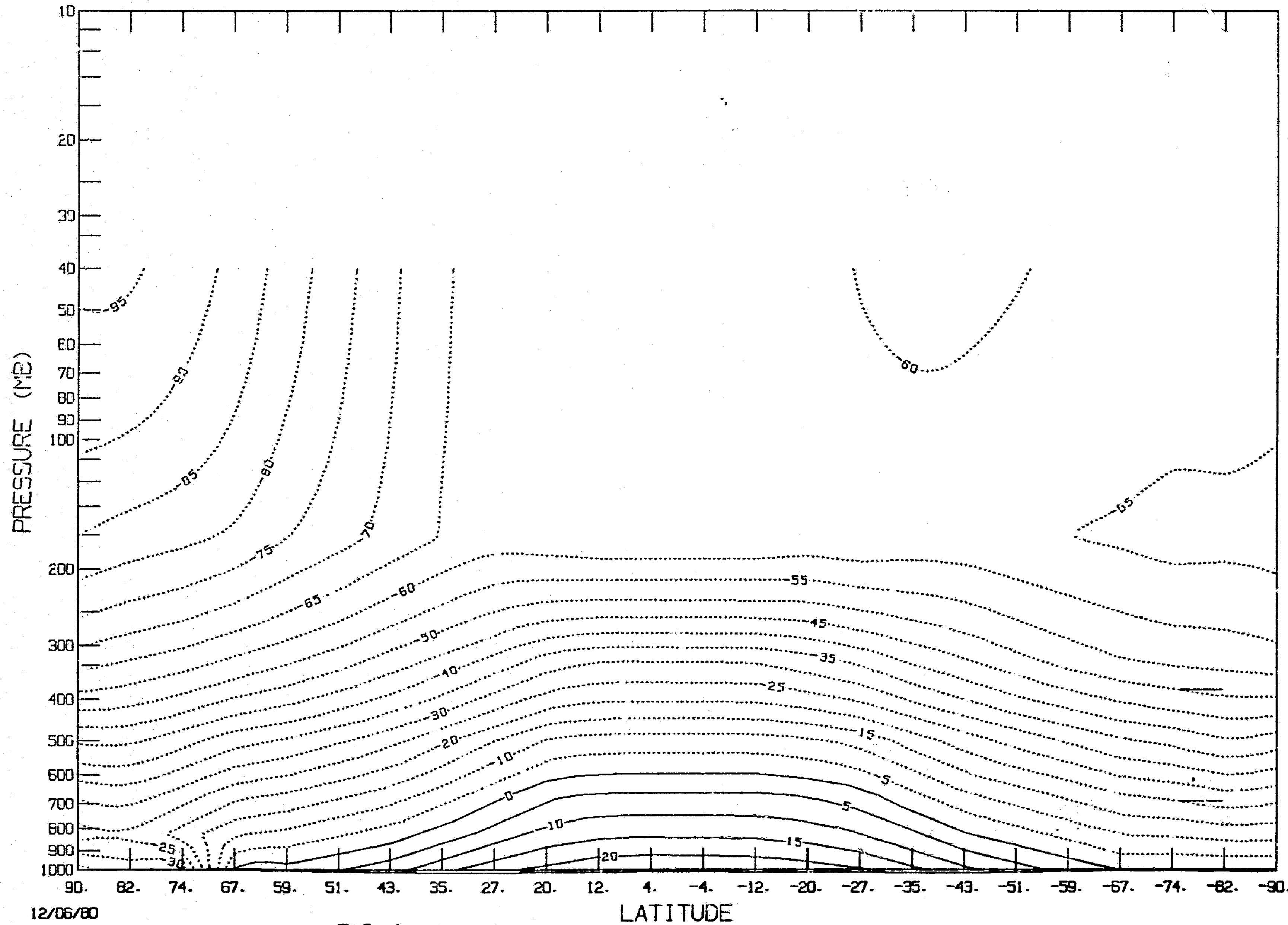


FIG. 1a

THIS IS THE OOGRUN (WATER SPHERE) WITH MEAN GLOBAL TEMP . SPEC..HUMIDITY........SPAR.COHEN.WU:RUN#0

TEMPERATURE (DEGREES CENTIGRADE) AVERAGE OF **LAST 13 MONTHS**

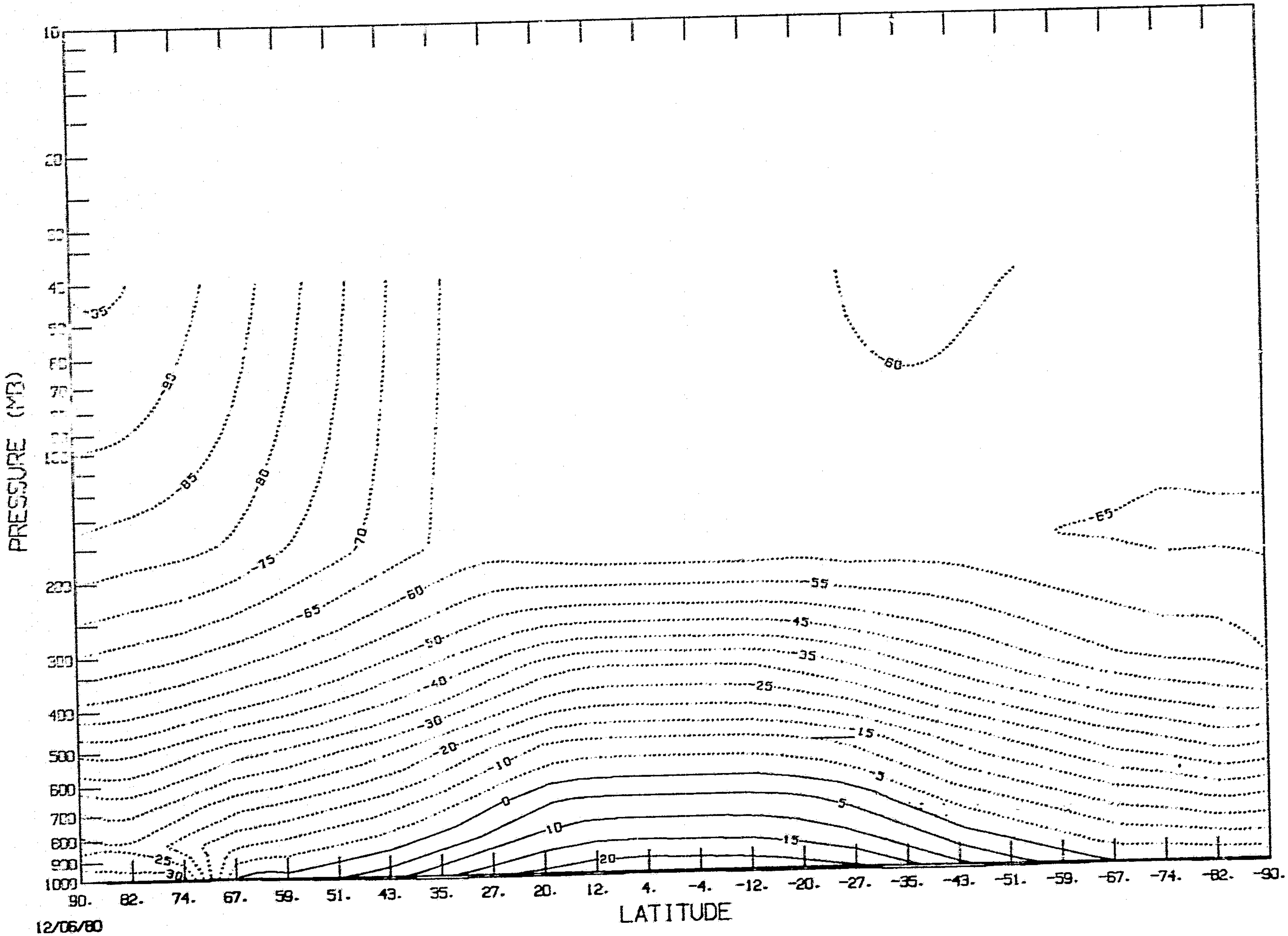


FIG. 1b

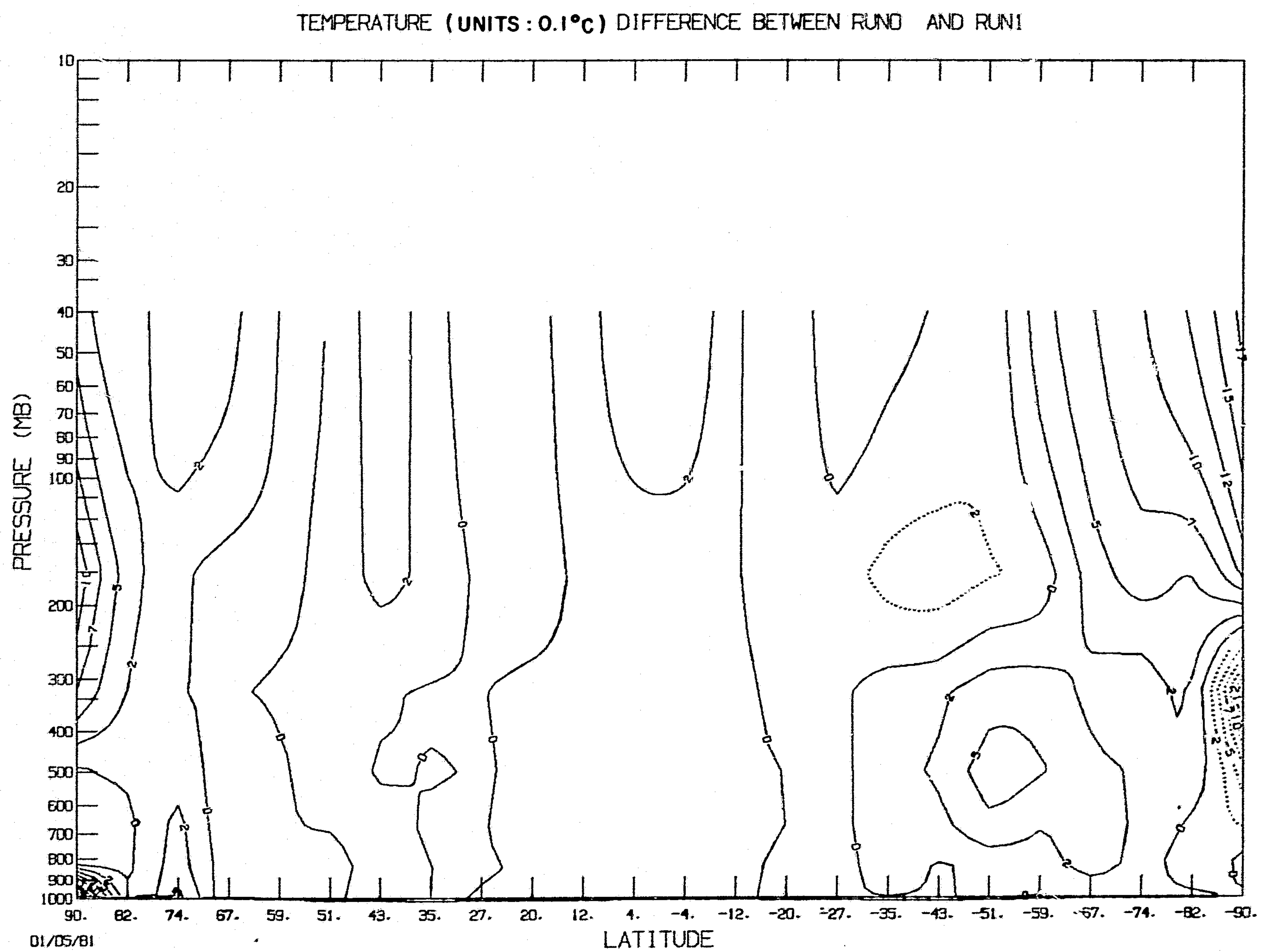

TEMPERATURE (UNITS: 0.1°C) DIFFERENCE BETWEEN RUN0 AND RUN1
PRESSURE (MB)
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
LATITUDE
90. 82. 74. 67. 59. 51. 43. 35. 27. 20. 12. 4. -4. -12. -20. -27. -35. -43. -51. -59. -67. -74. -82. -90.
0
2
-2
5
7
10
12
15
17
01/05/81

FIG. 2

**SPAR.WU.COHEN:RUN#1

ZONAL WIND (TENTHS OF M/SEC) RUN1 AVERAGE OF LAST 13 MONTHS

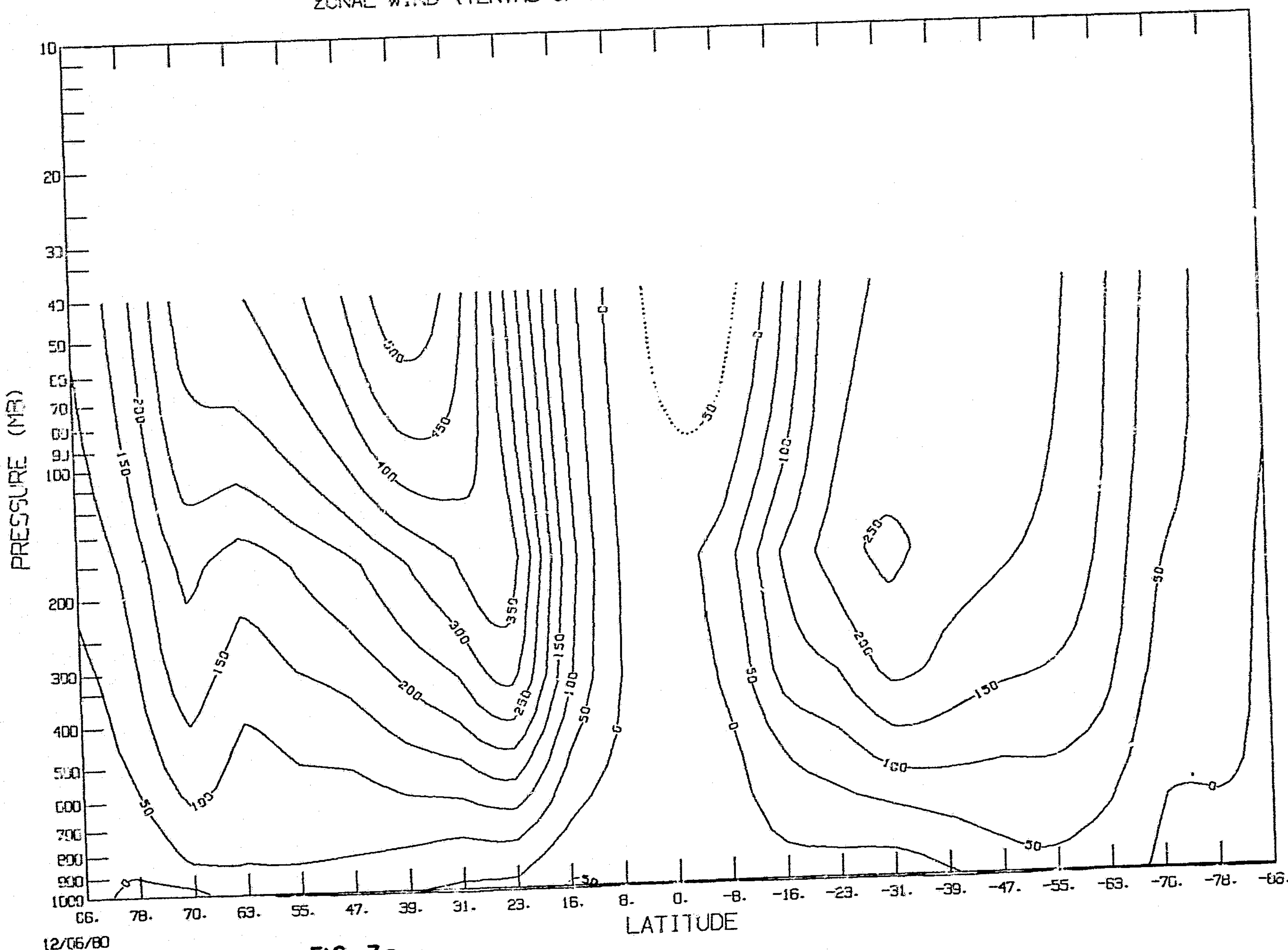


FIG. 3a

THIS IS THE OODRUN (WATER SPHERE) WITH MEAN GLOBAL TEMP . SPEC..HUMIDITY........SPAR.COHEN.WU:RUN#0

ZONAL WIND (TENTHS OF M/SEC) RUNO AVERAGE OF LAST 13 MONTHS

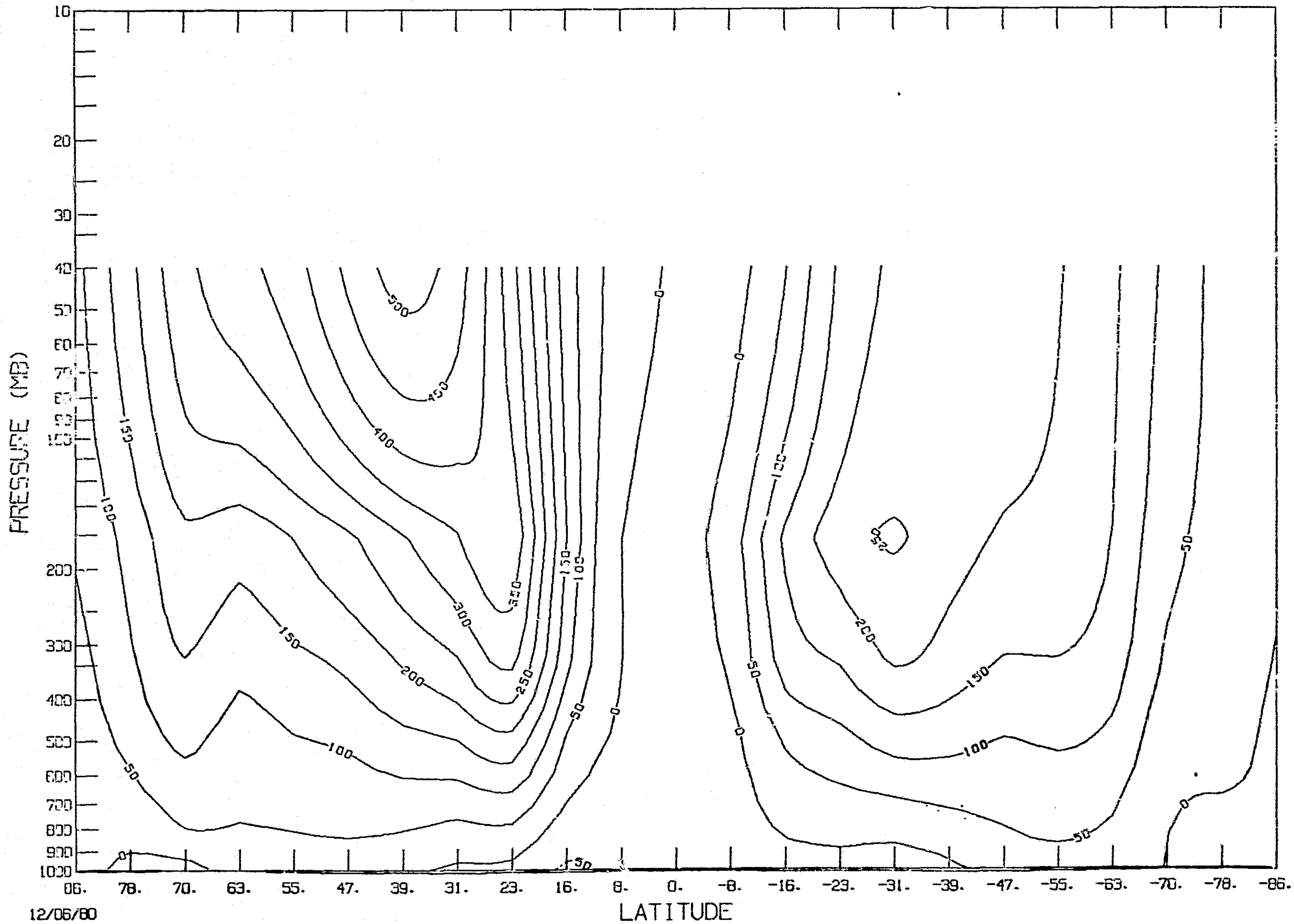


FIG. 3b

ZONAL WIND **(UNITS: 0.01 M/SEC)** DIFFERENCE BETWEEN RUN0 **AND** RUN1

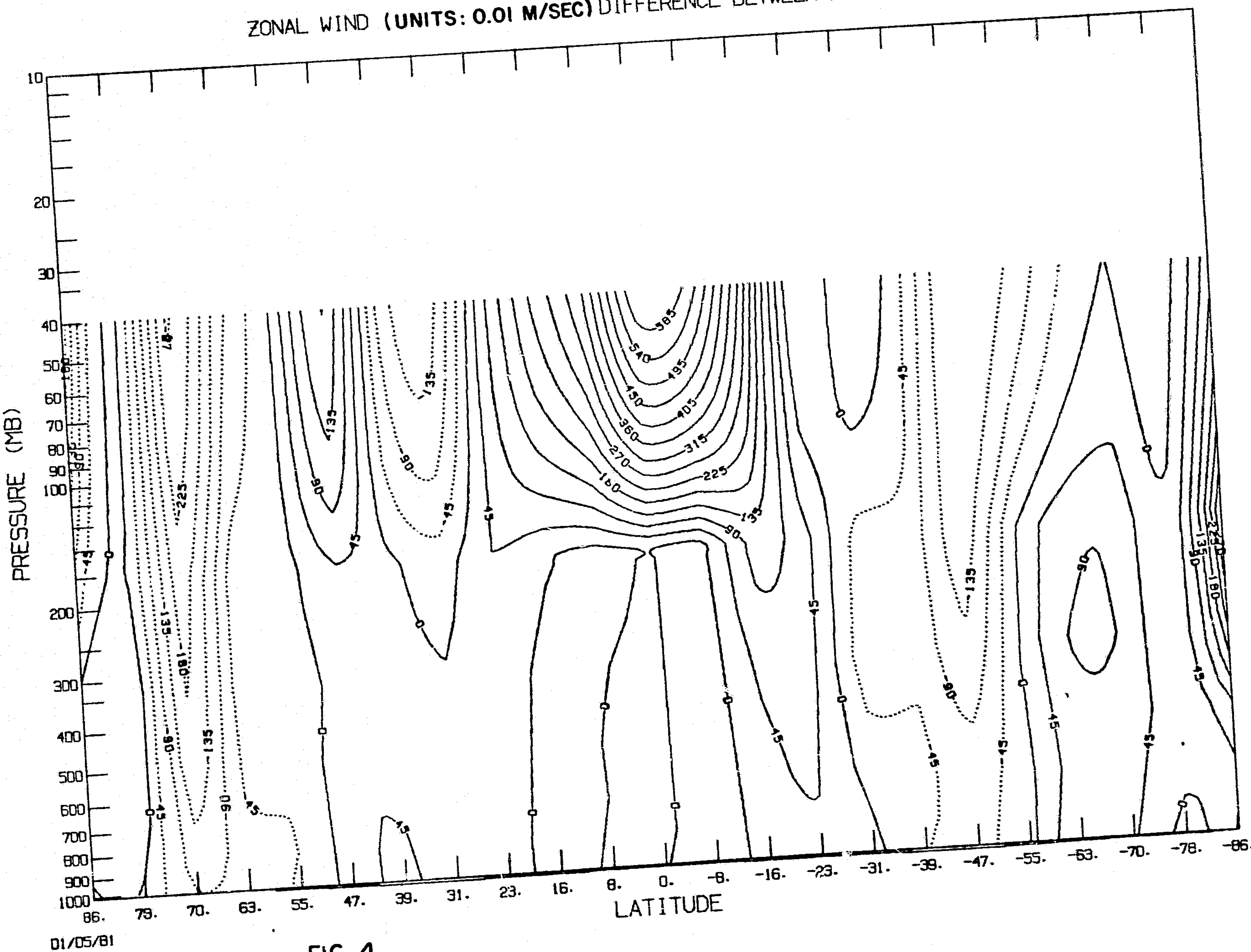
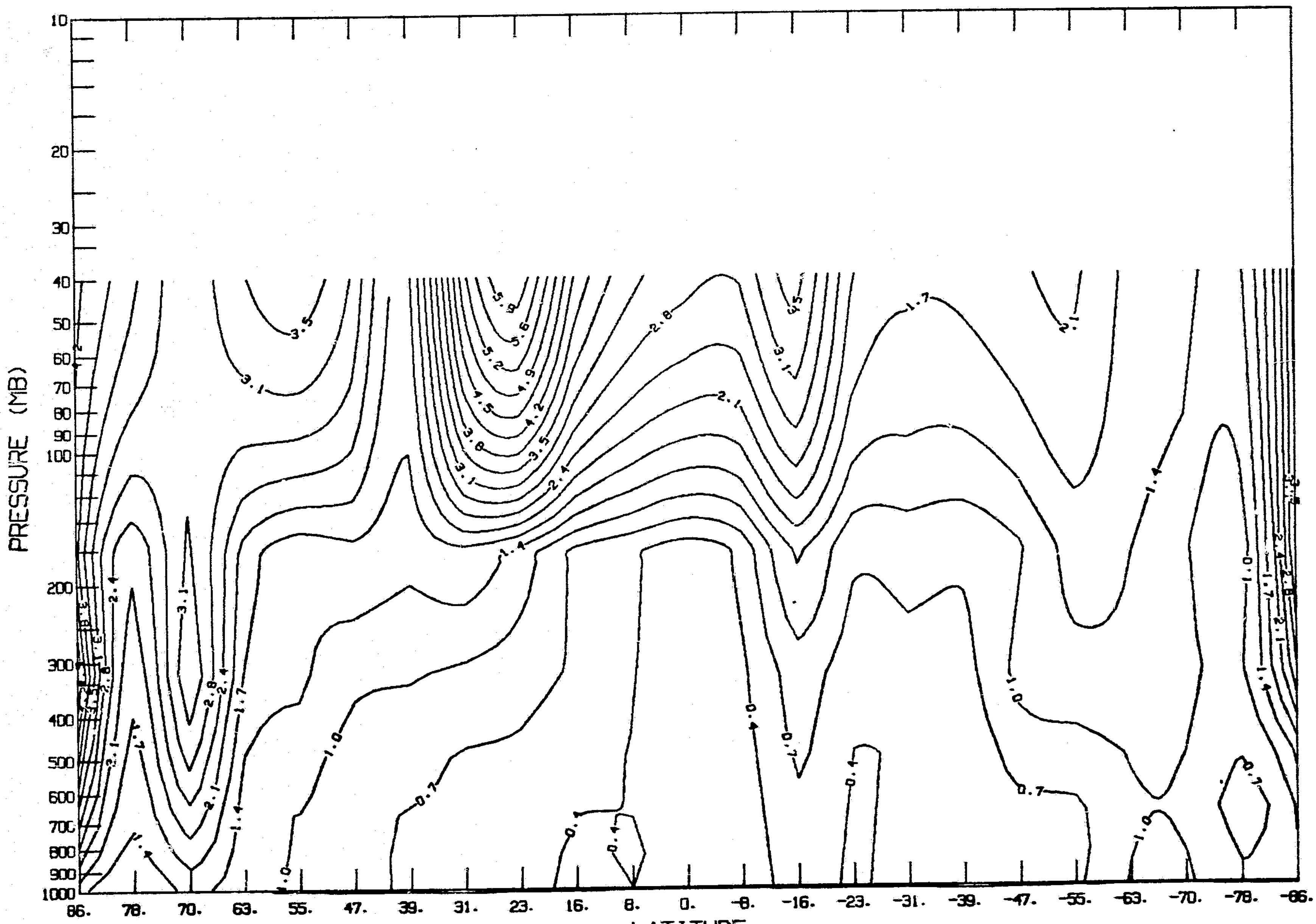


FIG. 4

ZONAL WIND (M/SEC) OF RUN1 STANDARD DEVIATIONS



01/22/81

FIG. 5

The zonally averaged meridional wind components for run 001 and 000 are displayed (in units of 0.1 ms^{-1}) in the mean meridional cross-sections shown in Figures 6(a) and 6(b), respectively. Solid curves are drawn for positive (southerly) components and dotted curves for negative (northerly) components. The convergence of the low-level trade winds toward an ICZ at 4° N, with divergence aloft, clearly defines virtually identical Hadley circulations in the two cross-sections. The differences between the two meridional circulations (Fig. 7) are seen to be small, random, and confined generally to the surface layer.

The vertical velocities (units: 10^{-5} ms^{-1}) associated with the divergence of the meridional velocity are shown in Figures 8(a) and 8(b) for runs 001 and 000, respectively, with solid curves indicating upward motions and dotted curves showing subsidence. Again, the Hadley circulation, centered at 4° N, appears to be nearly identical in the two simulations, and the difference cross-section (Fig. 9) does indeed show that the maximum differences are an order of magnitude smaller than the maximum vertical velocities themselves.

Difference maps

It is reasonable to expect that on a zonally symmetric water planet the model-generated climate would be independent of longitude, if the model were run for a sufficiently long time. As noted by Spar (1981), this is almost the case even for a short (15 month) run of the GISS climate model. Furthermore, it was found that mean meridional profiles of surface pressures (as well as other variables) are nearly identical for runs 001 and 000, when averaged over the last 13 Januaries. However, on the 13-month mean maps we do find some residual zonal structures (see Figs. 7 and 16 in Spar, 1981), which are reflected in the mean difference maps for the two runs (Figs. 10, a-g).

V WIND (TENTHS OF M/SEC) RUN1 AVERAGE OF LAST 13 MONTHS

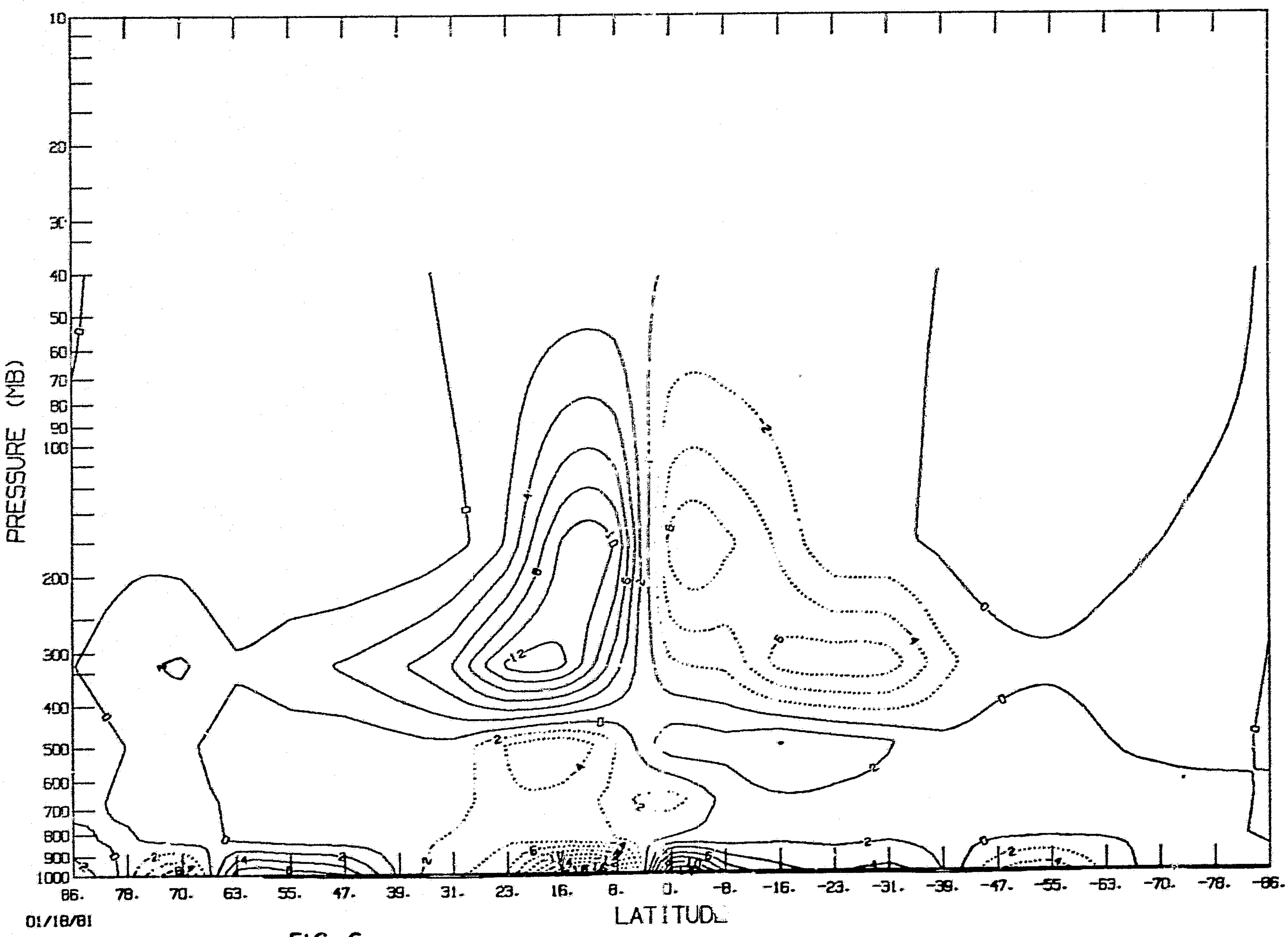


FIG. 6a

V WIND (TENTHS OF M/SEC) RUN0 AVERAGE OF LAST 13 MONTHS

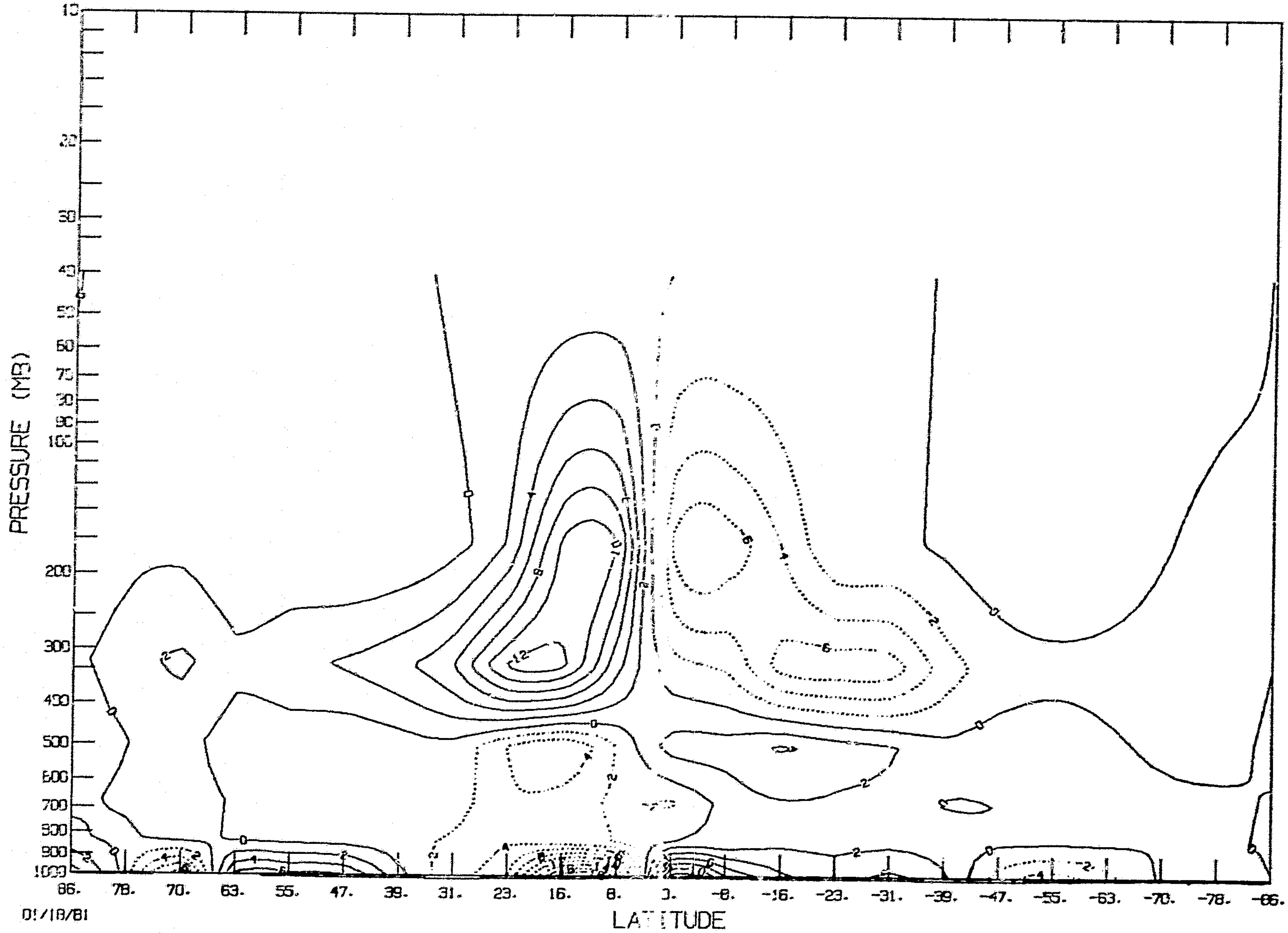


FIG. 6b

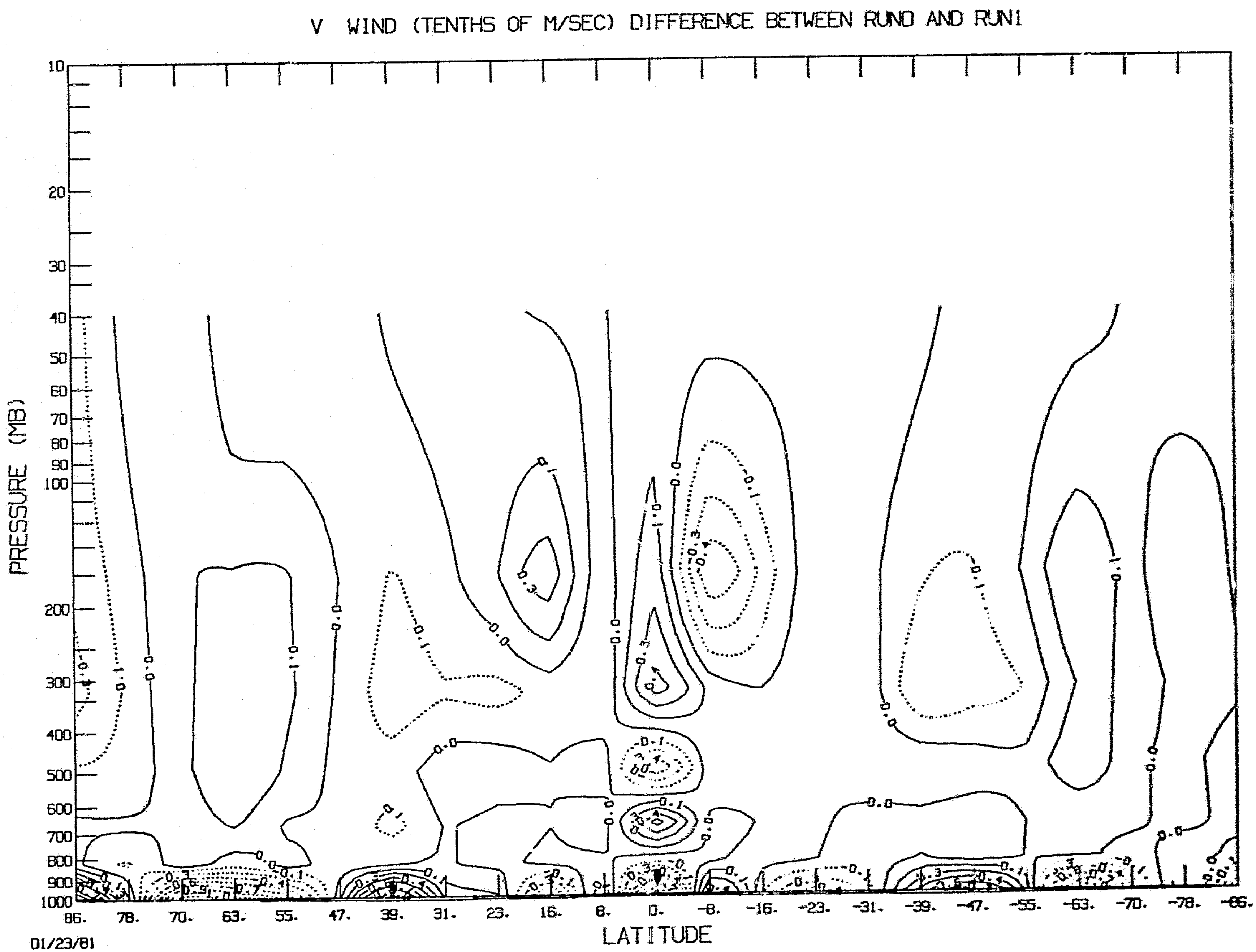

V WIND (TENTHS OF M/SEC) DIFFERENCE BETWEEN RUN0 AND RUN1
PRESSURE (MB)
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
86. 78. 70. 63. 55. 47. 39. 31. 23. 16. 8. 0. -8. -16. -23. -31. -39. -47. -55. -63. -70. -78. -86.
LATITUDE
01/23/81

FIG. 7

VERTICAL VELOCITY(10**-5 M/SEC) AVERAGE OF 13 MONTHS RUN1

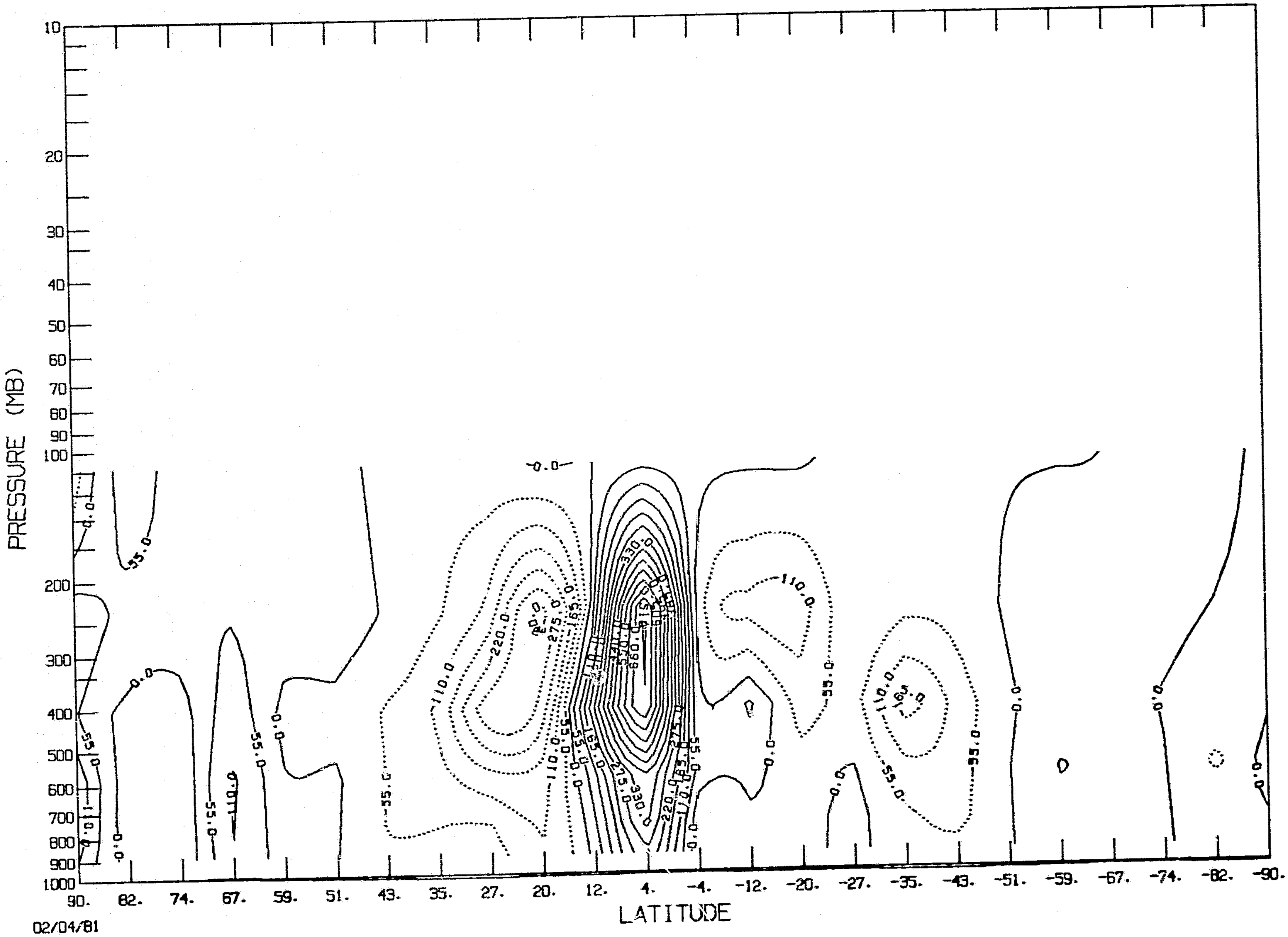


FIG. 8a

VERTICAL VELOCITY(10**-5 M/SEC) AVERAGE OF 13 MONTHS RUND

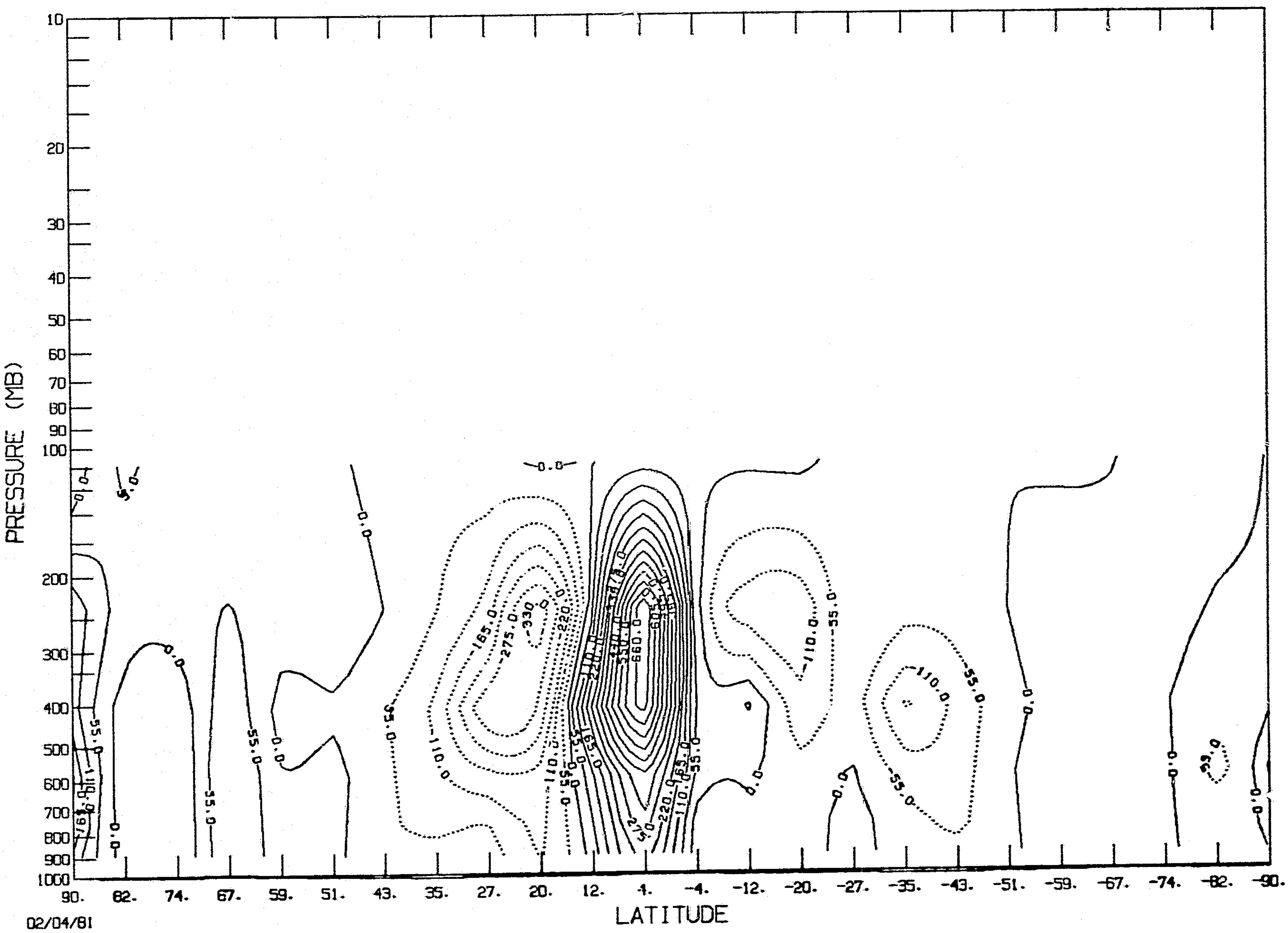


FIG. 8b

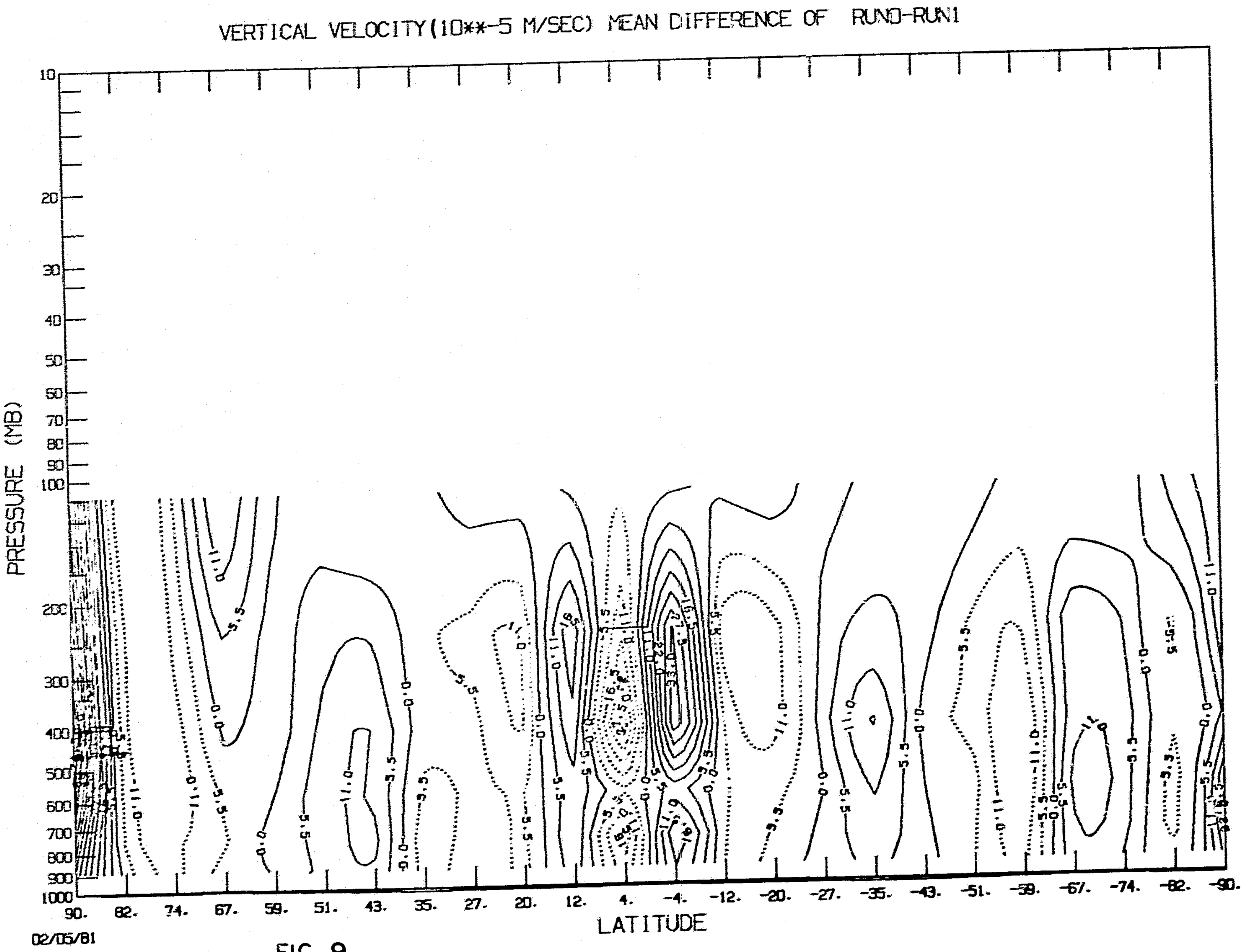
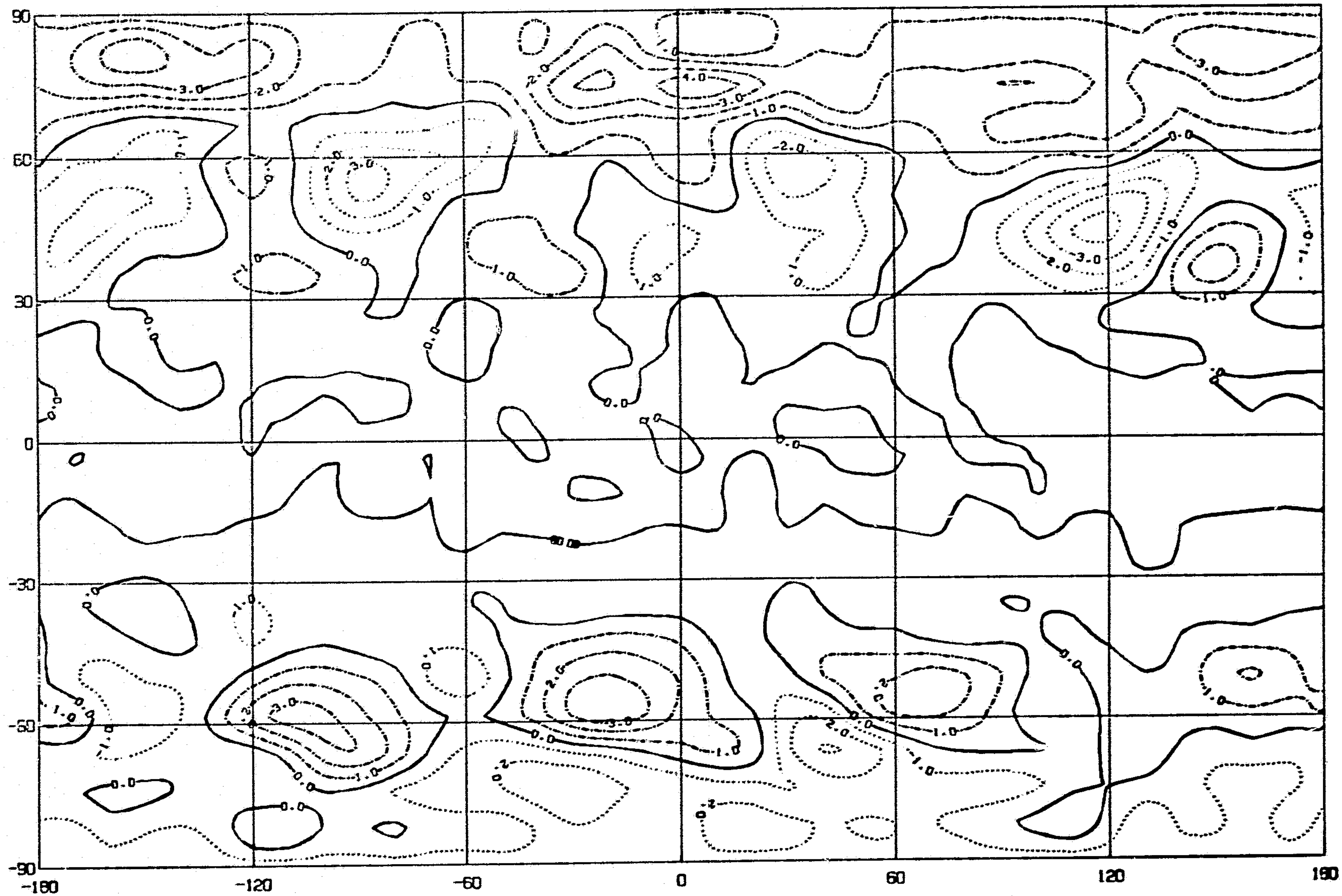

VERTICAL VELOCITY(10**-5 M/SEC) MEAN DIFFERENCE OF RUN0-RUN1
PRESSURE (MB)
LATITUDE
02/05/81

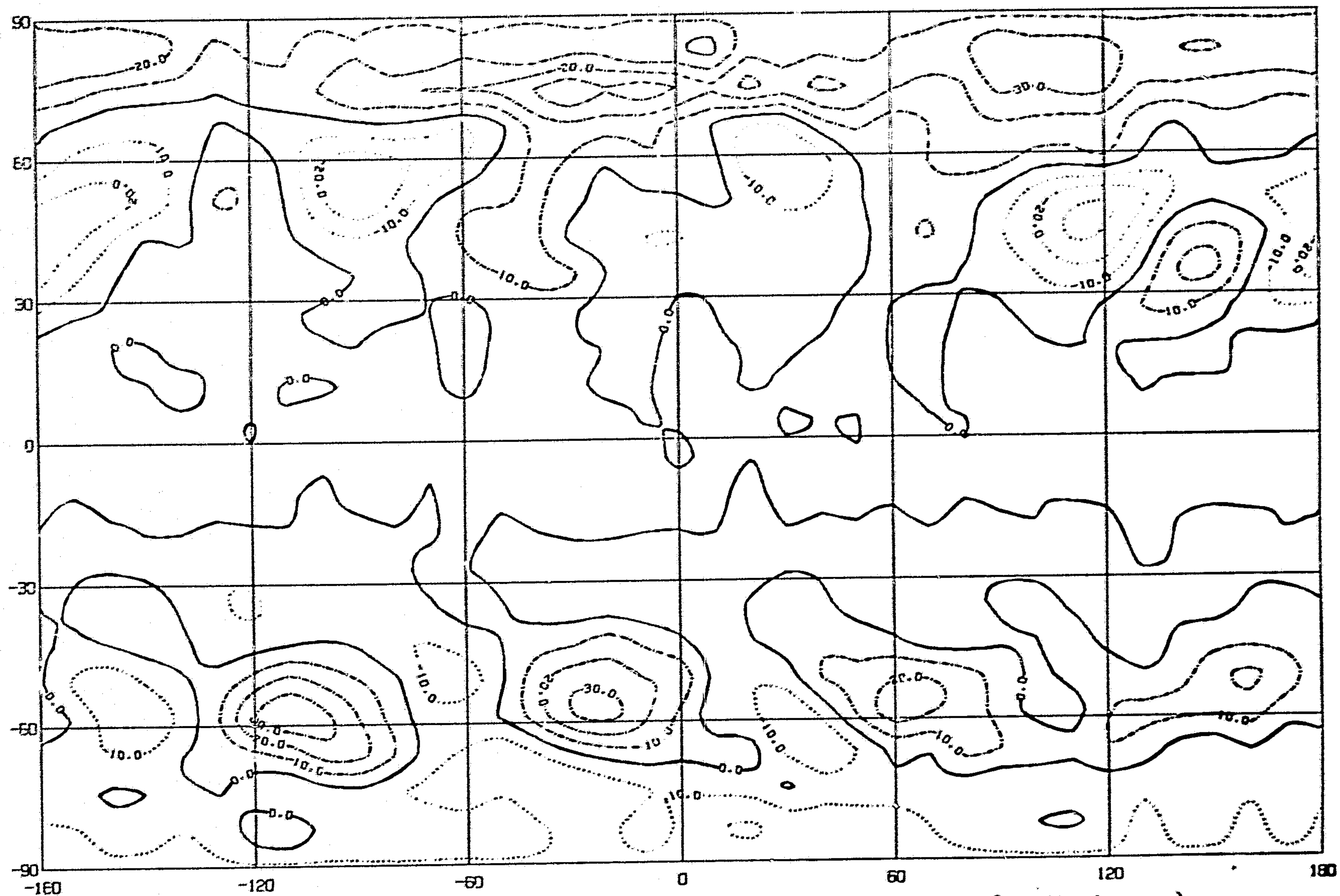
FIG. 9



Sea level pressure in (millibars)

The mean Difference for RUN000-RUN001

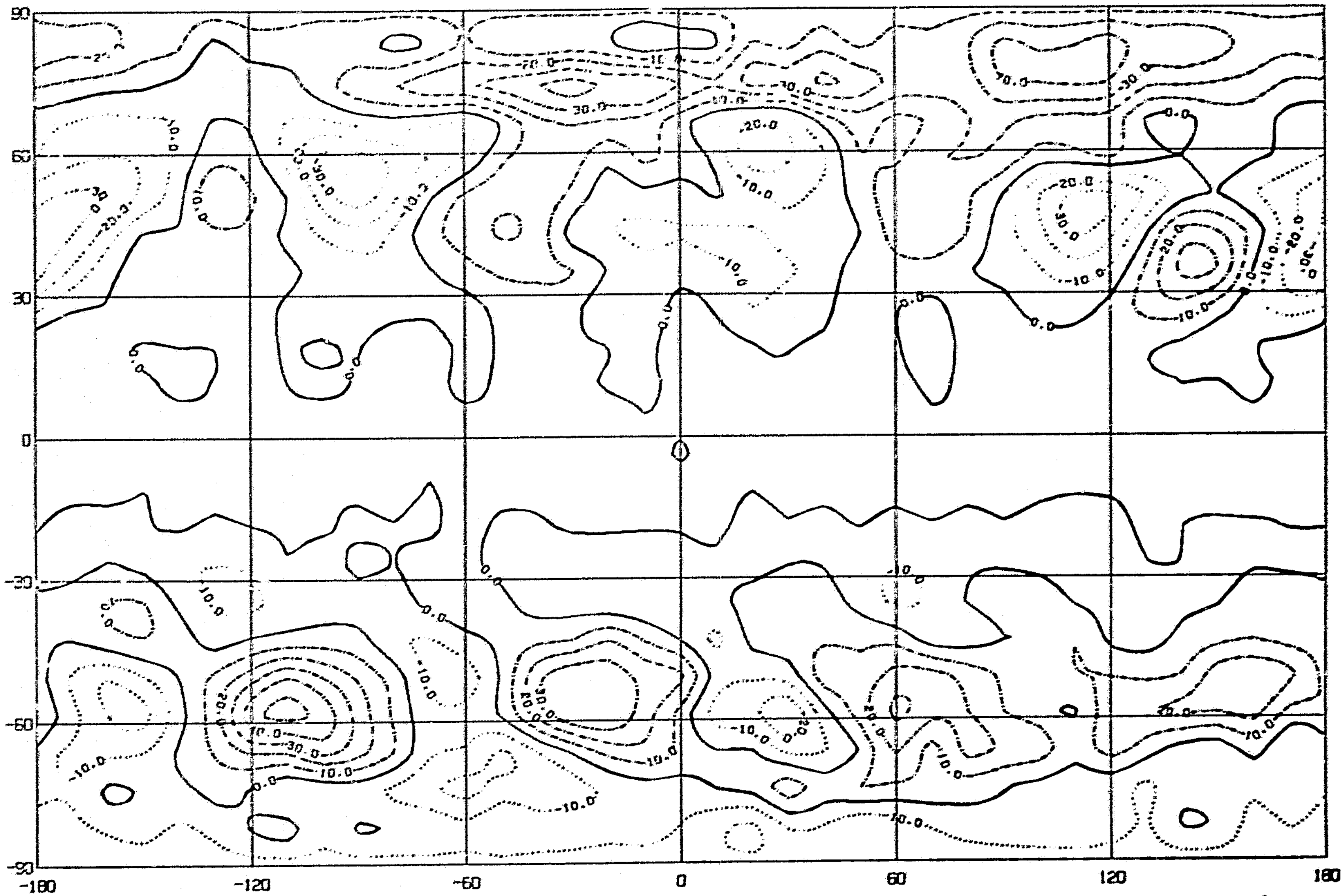
FIG. 10a



700 Millibar Geopotential Height in (Meters)

The mean Difference for RUN000-RUN001

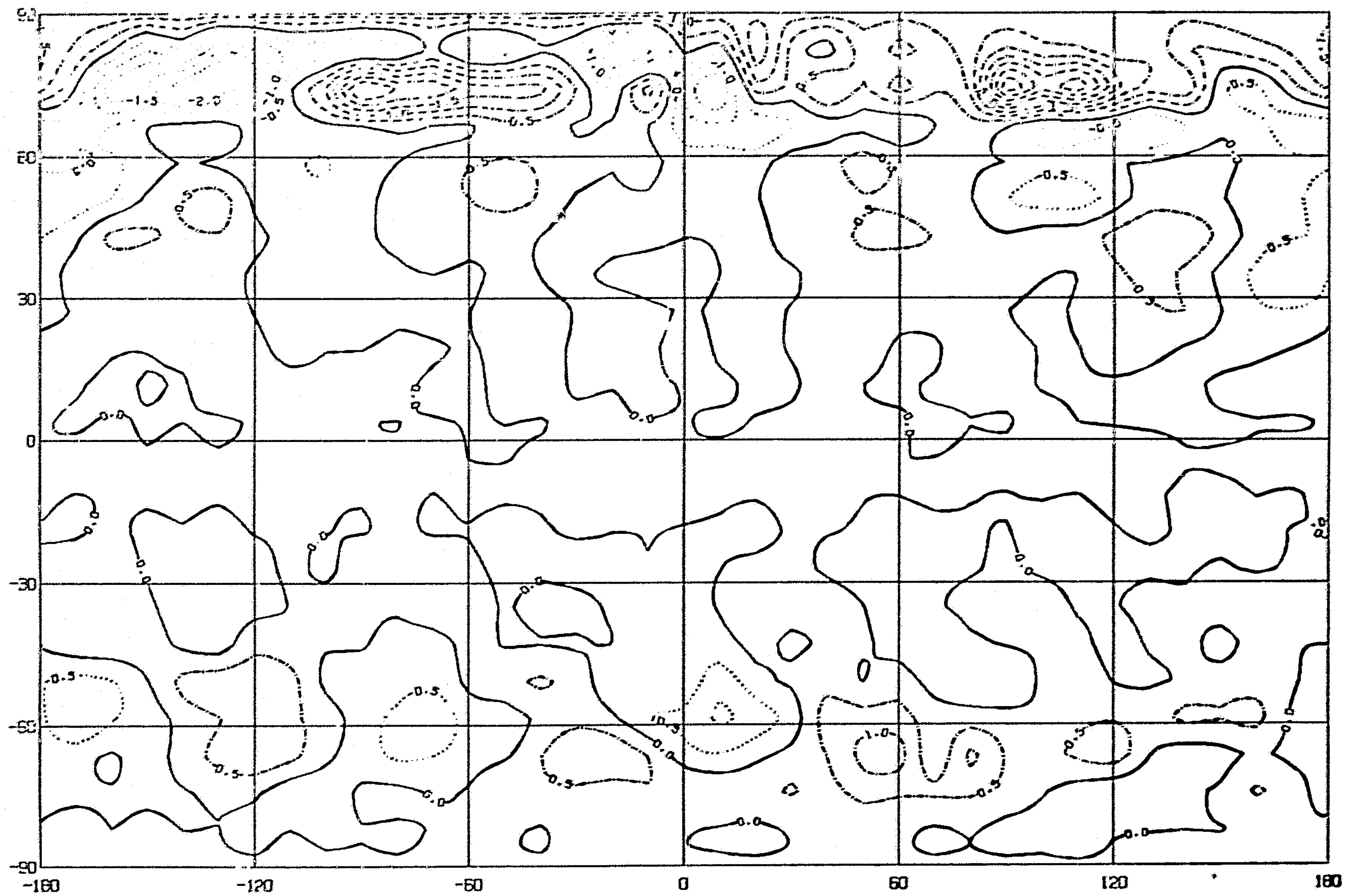
FIG. 10b



500 Millibar Geopotential Height (in Meters)

The mean Difference for RUN000-RUN001

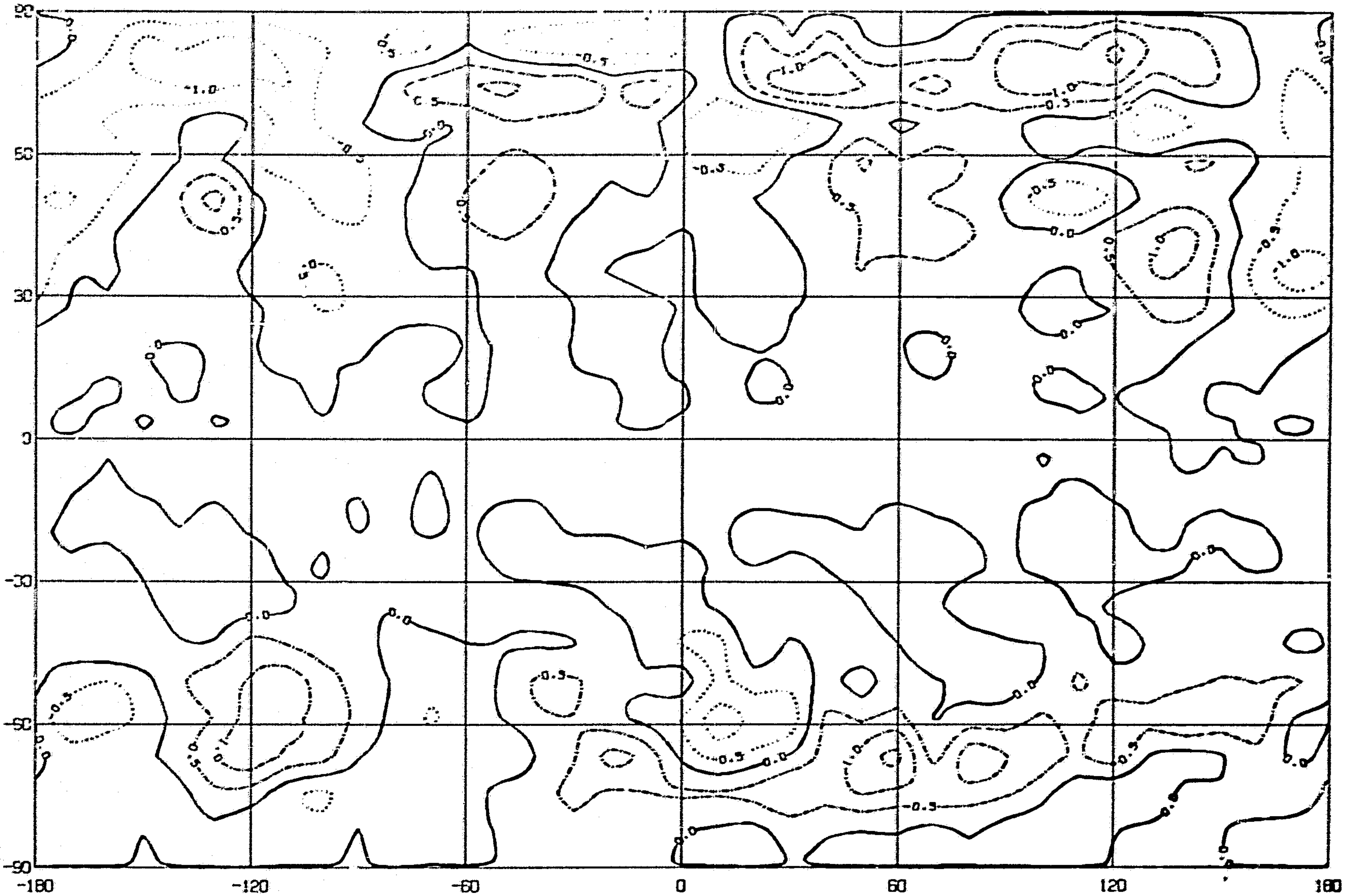
FIG. 10c



Mean Thickness Temperature from 1000mb to 850mb in Kelvin

The mean Difference for RUN000-RUN001

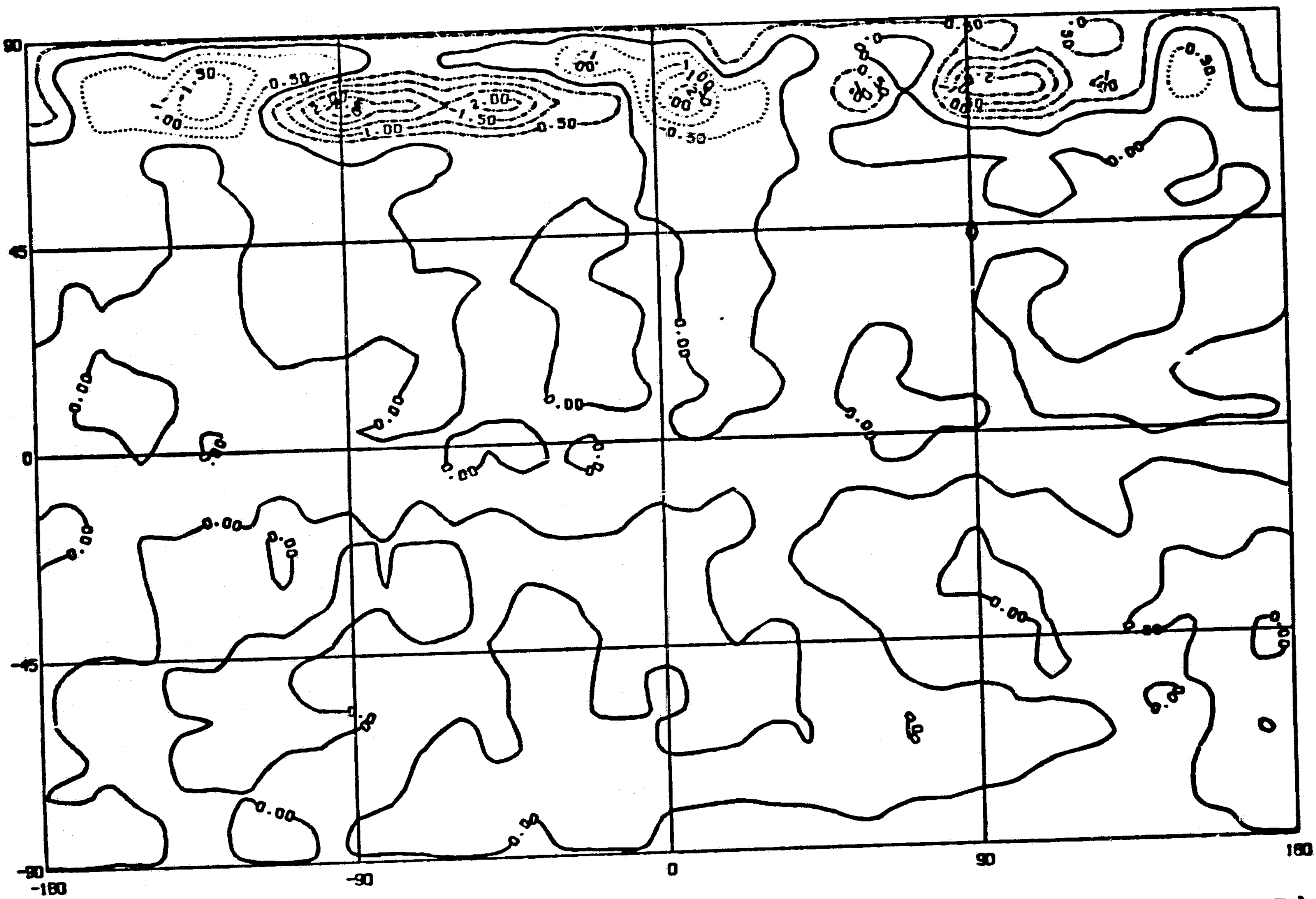
FIG. 10d



Mean Thickness Temperature from 850mb to 700mb degrees (K)

The mean Difference for RUN000-RUN001

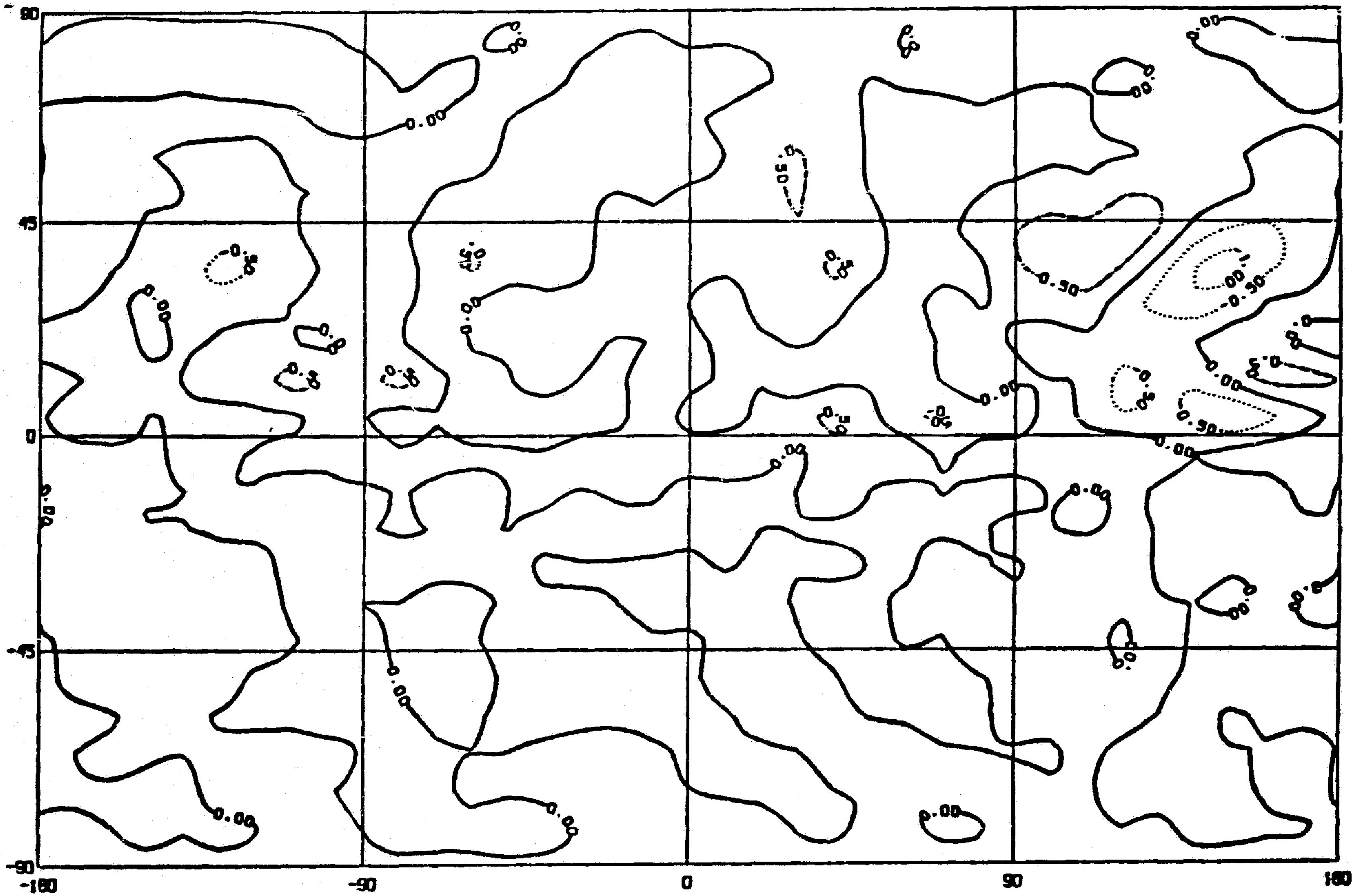
FIG. 10e



MEAN SURFACE AIR TEMPERATURE (IN DEGREES CENTIGRADE)

The mean Difference for RUN000-RUN001

FIG. 10f



PRECIPITATION IN (MM/DAY)

The mean Difference for RUN000-RUN001 FIG. 10g

The differences of the fields represented in Figs. 10, a-g (sea level pressure, 700 and 500 mb geopotential height, layer mean temperatures, surface air temperature, and precipitation rate) are all close to zero in the tropics. Outside the tropics, in those places where the differences between 001 and 000 means are of appreciable magnitude, it is found that maps of standard deviations of these quantities (not reproduced), computed from the 13 individual monthly maps, show values generally of the same magnitude as the differences between the means. Student's-t tests indicate no statistical significance, in general, for the differences between means.

Spherical harmonics

Spherical harmonic analysis was employed for the purpose of objective comparison of maps of the mean horizontal synoptic fields generated by the climate model (Christidis and Spar, 1981). Amplitudes (A) and phase angles (b) are shown in Tables 1-3 for the ten leading spherical harmonics of degree n and order m for runs 001 and 000 for three fields: sea-level pressure (SLP), mean temperature of the layer 850-1000 mb (T 8-10), and 500 mb geopotential height (Z 500). (The longitudinal wave number is represented by m, while n-m denotes the number of nodal parallels of the harmonic function on the globe. The zonal harmonics, for which m = 0, represent the zonally symmetric components of the field.)

The most obvious result of the harmonic analysis is the confirmation of the expectation of zonal symmetry for the water planet experiments. Only zonal harmonics are found among the ten leading harmonics for both runs. Any longitudinal structure may be viewed as computational "noise".

Table 1. Amplitudes (A) and phase angles (b) of first ten spherical harmonics of the sea-level pressure (SLP) fields (in mb) generated by runs 001 and 000.

001			000 ("spin up")		
n,m	A(mb)	b(°)	n,m	A(mb)	b(°)
4,0	9.6	180	4,0	9.0	180
2,0	7.1	180	2,0	6.8	180
8,0	3.6	0	8,0	3.4	0
6,0	3.4	0	6,0	3.4	0
3,0	3.0	180	1,0	2.9	180
1,0	3.0	180	3,0	2.4	180
10,0	1.1	0	5,0	2.0	0
11,0	1.1	0	10,0	1.2	0
18,0	0.9	180	18,0	1.1	180
5,0	0.7	0	7,0	1.0	0

Table 2. Same as Table 1, but for temperature of the layer from 850 to 1000 mb (T 8-10, in K)

001			000 ("spin-up")		
n,m	A(k)	b(°)	n,m	A(k)	b(°)
2,0	35.7	180	2,0	35.6	180
1,0	6.0	180	1,0	6.0	180
7,0	4.1	180	7,0	4.0	180
5,0	3.6	180	5,0	3.5	180
8,0	3.0	180	3,0	3.0	180
3,0	3.0	180	8,0	3.0	180
4,0	2.3	180	4,0	2.2	180
15,0	2.3	0	15,0	2.2	0
17,0	2.0	0	17,0	1.9	0
14,0	1.9	0	14,0	1.8	0

Table 3 Same as Table 1, but for 500 mb geopotential height (Z 500, in m).

001			000 ("spin-up")		
n,m	A(m)	b(^{o})	n,m	A(m)	b(^{o})
2,0	791	180	2,0	786	180
1,0	129	180	1,0	132	180
4,0	82	180	4,0	78	180
7,0	45	180	7.0	37	180
3,0	39	180	3,0	36	180
8,0	31	180	8,0	31	180
6,0	29	0	6,0	27	0
15,0	21	0	15,0	20	0
5,0	15	180	10,0	14	0
10,0	13	0	9,0	13	180

That the two runs generated very similar large-scale structures is apparent from a comparison of the leading harmonics listed in Tables 1-3. For SLP (Table 1) the first 4 harmonics are nearly the same for the two runs, and 5 of the 6 remaining harmonics appear in both runs with the same phases and, with the exception of 5, 0, nearly the same amplitudes. All 10 harmonics listed for T 8-10 in Table 2 are virtually identical for the two runs, while for Z 500 (Table 3) the same is true for 9 of the first 10 terms.

Summary

Extreme and unrealistic initial conditions may decay slowly enough to leave residual effects in a 15 month climate simulation with the GISS climate model. However, the effects of initial conditions are generally small. A climate simulation started from a state of rest and horizontal uniformity yielded virtually the same mean atmospheric state as one initialized with a field of motion and meridional gradients, when carried out on a water planet. Longer runs of the model would probably reduce the differences below detectable levels. Apparently, initial conditions are relatively unimportant in climate simulations.

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