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FOREWORD

This report is submitted to the Aerospace Environment Division, Space Science Laboratory, Science and Engineering Directorate, NASA Marshall Space Flight Center, Alabama, in partial fulfillment of requirements under Contract Number NAS8-31173. SAI wishes to acknowledge the technical guidance provided by Dr. George Fichtl, Technical Monitor for NASA/MSFC Aerospace Environment Division, during the course of this study.

ABSTRACT

A relationship between the atmospheric general circulation and geophysical hydrodynamic experiments was sought by attempting to find a relationship between wave number and temperature gradient at mid-latitudes at 500 mb. To this end data were gathered from four winter seasons and analyzed. The statistical analysis failed to provide convincing support for the hypotheses of a direct relationship between wave number and temperature gradient, although an indication that the transient waves may be so related was noted. Future studies should start by examining this possible relationship and should also concentrate on more detailed analyses of specific phenomena found in both geophysical systems.

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I. INTRODUCTION

Geophysical fluid dynamics experiments, often known as dishpan experiments, have contributed significantly to our understanding of the basic physics of the atmospheric general circulation. The analogous relationship between the dishpan experiments and the atmosphere have been noted by Fultz, Riehl and others The present study is an investigation into the question whether the basic wave structure observed in the atmosphere is directly influenced by the meridional temperature gradient as it is in the dishpan experiments.

To perform this study, data at 500mb was examined. This data consisted of temperatures at 30N and 60N and of pressure heights at 45N for four winter seasons. The data was taken from the NWP map series and was processed for use on the UNIVAC 1108.

Several statistical analyses were performed on the data. Since our primary interest was in the wave-number relationship to the temperature gradient, the pressure height data was converted to counts of zero crossings after the daily mean height was removed and again after the seasonal mean was removed. Also, the number of extrema were recorded for each day in the data series. Histograms were prepared for all variables and the central moments found. The central moments were again computed for the wave-number variables for each set of data associated with a given range of observed temperature gradient. Finally, a correlation matrix was computed. These analyses were performed for several time lags between the wave-number variables and the temperature gradient and all results have been collected in Appendix A.

The results of the study failed to provide any convincing evidence that the basic long wave structure was related to the temperature gradient. However, there is an indication that the transient waves may be related to this gradient. Further, it is suggested that isolated phenomena such as vacillation, Appendix B, could provide a useful and profitable extension of this work.

II. DATA

In this study an attempt was made to draw parallels between hemispheric flow in the atmosphere and flow fields observed in geophysical fluid dynamics experiements. To perform this study, hemispheric weather charts were obtained for the northern hemisphere winter months (Dec., Jan., Feb., Mar.) from the National Climatic Center. These hemispheric charts were obtained for the years 1968 through 1975 and for December 1958 and January 1959. Also available were hemispheric charts for September through December 1966 and January through June 1967. The data were available for all levels from 850 mb to 10 mb for the 1968-1975 data. The 1958-1959 data were available from 850 mb to 100 mb and the September 1966-June 1967 data were available at 700, 500 and 300 mb. The hemispheric data for this project were received in the form of microfilm. These data were converted to hard copy rolls by the NASA/MSFC Computation Laboratory.

It was decided that for this project only 500 mb fields would be analyzed. Seven tasks were then defined to reduce this data to a form suitable for analysis.

<u>Task 1.</u> From many rolls, each containing about 10 meteorological map series for a given month, the appropriate map series' (500 mb) were found, cut from the rolls and organized into books.

<u>Task 2.</u> Each map was color coded to simplify the reading of the data and to help assure accuracy and consistency in reading the data.

<u>Task 3.</u> Data from each map was read and tabulated.

<u>Task 4.</u> The tabulated data was checked by reading randomly selected maps from each time period and comparing the results. Errors could be examined to determine their nature and to determine whether similar errors may be prevalent throughout the entire set.

Task 5. Each data set was completed by filling missing data.

Task 6. The data was put on computer cards and the data was to be checked with systematic computer examination of the data.

Task 7. Data was transferred to tape for analysis.

Tasks 1, 2, and 3 were the most time consumming. Task 4, besides giving quality assurance, was used also in the training of Engineering Aides to perform the first three tasks. The 500 mb data was taken from the 500 mb NWP-Unit map series. When this chart was missing or regions of a map unreadable then the 500 mb NWS-maps were used to fill the data, when they were available. Task 5, the systematic computer examination of the data for Task 6, and Task 7 were performed by computer programs developed for these tasks.

Three techniques were developed for checking data accuracy. The first technique was that of Task 4. This check consisted of the comparison of independently analyzed maps. This technique was useful as a teaching aid for training Engineering Aides to read charts consistently but was considered to be too time consumming and was discontinued when obvious systematic errors were eliminated. The second technique was somewhat similar to the first in that visual inspection of the data was required. The second technique was to use the computer to plot all daily values of the parameter recorded and then to visually inspect these graphs to find anomalous values. This technique made it possible to easily spot key punch errors and large errors at a point but it was still difficult to identify some reading errors, such as misreading a pressure height contour over a significant longitudnal extent.

Consequently, a computer program named GFD/CHK was developed. This program was to check the data for four types of error

1. Values exceeding expected limits of the data
2. Interpolation errors leading to two consecutive extrema
3. Interpolation errors transposing regions of high pressure (temperature) into regions of low pressure (temperature)
4. Interpolation errors yielding significant changes in height (temperature) over several consecutive data points

This program was debugged and test cases run. Unfortunately time limits prevented the complete evaluation of the program. As a result much of the data remains unchecked for these types of errors. Thus, all errors have been assumed to be random errors and it has been assumed that they will not significantly effect the analysis performed.

A second program was developed to replace GFD/CHK. This program was named GFD/TAPE. The purpose of this program was to simply fill missing data by linear interpolation, in either time or space as required, and to place the card image data on a tape file.

Next a program GFD/SMOOTH was developed. This program took the data for each winter season and performed various running averages of the data. Three day, five day, seven day, eleven day and twenty-one day running averages were computed. A program GFD/SORT was developed to sort the data records for preliminary analysis.

When the data processing was completed only the data for four winter seasons were available for analysis. These data were for the winters of 1970-1971, 1971-1972, 1972-1973 and 1973-1974. The data consists of pressure heights at 500 mb for 45 N latitude and temperatures at 500 mb for 30 N and 60 N latitudes.

III. ANALYSIS

3.1 PRELIMINARY ANALYSIS

It has been observed in geophysical fluid dynamics experiments that the steady wave regime yields wave numbers which depend upon the temperature gradient across the annulus. Thus, a simple hypothesis was proposed:

> The wave number structure in the atmosphere at midlatitudes is directly dependent upon the temperature gradient across the midlatitude.

The atmospheric wave number was counted from the wave structure of the pressure heights at 45N. The temperature gradient was measured between 30N and 60N.

The mean temperature gradient G

$$G = \frac{1}{A} \int_0^{2\pi} \int_{\phi_1}^{\phi_2} \frac{\partial T}{\partial \phi} \; a \; d\phi \; d\lambda$$

was simplified to

$$G = \frac{1}{N} \sum_{i-1}^{N} (\Delta_\phi T)_i$$

where N is the total number of data points.

Here

$$\Delta_\phi T = T(\phi_2, \lambda_i) - T(\phi_1, \lambda_i)$$

A second parameter was also considered for analysis. This was a shear parameter S.

$$S \equiv \frac{1}{A} \int_{0}^{2\pi} \int_{\phi}^{\phi_2} \frac{\partial u}{\partial z} \; a^2 \cos\phi \; d\phi \; d\lambda$$

This was simplified by several assumptions. First, it was assumed that

$$\frac{\partial u}{\partial z} = \frac{F(\phi,\lambda)}{a\partial\phi}$$

and that

$$\frac{\partial F}{a\partial\phi} = \frac{\Delta_\phi F}{a\Delta\phi}$$

where

$$\Delta_\phi F = F(\phi_2,\lambda) - F(\phi_1,\lambda)$$

and

$$\Delta\phi = \phi_2 - \phi_1$$

Then

$$S = \frac{a}{A} \, \frac{\sin\phi_2 - \sin\phi_1}{\phi_2 - \phi_1} \int_{0}^{2\pi} \Delta_\phi F \; d\lambda$$

Finally, this last integral is removed by

$$S = \frac{a}{A} \frac{(\sin\phi_2 - \sin\phi_1)}{(\phi_2 - \phi_1)} \sum_{i=1}^{N} F_i \Delta\lambda_i$$

Now, the area A is given by

$$A = 2\pi a^2 (\phi_2 - \phi_1) \cos\phi_0$$

where $\phi_0 = (\phi_2 + \phi_1)/2$; and, the wind velocity is approximated by its geostrophic value

$$F = -\frac{g}{f_0} \Delta_\phi \ln T$$

With these values substituted

$$S = \frac{g(\sin\phi_2 - \sin\phi_1)}{N\, a\, f_0\, (\phi_2 - \phi_1)^2 \cos\phi_0} \sum_{i=1}^{N} (\Delta_\phi \ln T)_i$$

where

$$(\Delta\lambda)_i = \frac{2\pi}{N}$$

since $\Delta_\phi \ln T$ is evaluated at equal longitudinal intervals.

These two parameters, G and S, were evaluated using data for December 1970. The results are shown in Table III-1 and III-2. In these tables n is the observed wave number and $\hat{n}$ is the 5-day running mean wave number. The apparent correlation between G and S comes from the following derived relationship

Table III-1. Relationship Between Wave Number and Temperature Gradient for December 1970 (See Text).

	n	$\hat{n}$	$\frac{1}{n}\Sigma\|\Delta T\|$	$\dot{S}$	G/S
1	5		16.92	1.91×10^{-3}	8.859(3)
2	6		17.28	1.95	8.862
3	6	5	19.42	2.19	8.868
4	7	5	20.36	2.30	8.852
5	6	5	20.33	2.30	8.839
6	5	4	21.14	2.39	8.845
7	5	5	19.92	2.25	8.853
8	7	5	17.75	2.00	8.825
9	7	5	19.06	2.16	8.824
10	7	5	19.03	2.16	8.810
11	7	4	18.86	2.14	8.813
12	7	5	19.28	2.19	8.803
13	7	4	18.61	2.11	8.820
14	6	5	19.64	2.23	8.807
15	6	6	20.19	2.29	8.817
16	7	4	19.74	2.24	8.812
17	7	5	19.31	2.19	8.817
18	6	4	19.28	2.19	8.804
19	6	4	19.53	2.21	8.837
20	6	4	19.78	2.25	8.791
21	5	4	19.14	2.18	8.780
22	6	4	20.42	2.33	8.764
23	5	5	20.75	2.36	8.792
24	6	5	19.25	2.19	8.790
25	5	4	19.61	2.23	8.79[illegible]
26	5	4	20.83	2.37	8.789
27	5	5	20.00	2.28	8.772
28	5	5	20.03	2.29	8.747
29	6	5	20.31	2.32	8.754
30	6		22.25	2.54	8.760
31	6		22.56	2.57	8.778

Table III-2. Statistics of Relationship Between Wave Number and Temperature Gradient G.

Variable	Mean	Std dev	Correlation with G
n	6	0.77	-0.229
$\hat{n}$	4.63	0.56	+0.012
$n-\hat{n}$	1.41	0.93	-0.514

$$\ln T = \ln \frac{T(\phi_2)}{T(\phi_1)}$$

but

$$T(\phi_2) = T(\phi_1) - \Delta_\phi T;$$

thus,

$$\Delta \ln T = \ln\left(\frac{1}{1+\frac{\Delta_\phi T}{T(\phi_2)}}\right) \sim \ln\left(1 - \frac{\Delta_\phi T}{T(\phi_2)}\right) \sim \underline{\frac{\Delta_\phi T}{T(\phi_2)}}$$

Consequently, if $T(\phi_2)$ does not vary significantly around the latitude ϕ_2, then the two parameters, G and S, would differ only by a constant factor. For Table III-1, this constant would be $(8.8106 \pm 0.0348) \times 10^3$ corresponding to a mean temperature $\bar{T}(\phi_2) = 248K$.

Table III-2 further summarizes the relationship between the wave number and the temperature gradient found from the data of Table III-1. There is a significant difference in the wave number between the observed daily value and the 5-day running mean. Supposedly, the 5-day running mean removes transient perturbations leaving only the stable wave structure. The mean difference in wave number between the two is 1.41 and this difference correlated with the temperature gradient G with a correlation coefficient of -.514. However, the range of G for this wave number difference is small, both extrema in the data set not being included in the one for the 5-day running average, yielding a standard deviation of only 0.74. This correlation should be performed over a larger sample to determine whether or not this correlation has any significance. The "vacillation" between waves number 4 and 5 observed in the 5-day running mean apparently has little relationship to the temperature gradient. Also the "vacillation" in the daily wave number appears to have less relationship to the temperature gradient than does the difference between the steady wave number and the transient wave number.

3.2 INITIAL STATISTICAL ANALYSIS

Following this simple analysis a computer program was developed to perform the preliminary statistical analysis on the entire data set. This program included the following operations:

- Remove daily mean from data
- Remove semipermanent features from the data
- Count the number of zeros for each day, Z_j
- Count the number of extrema for each day, P_j
- Compute the ratio $R_j = Z_j/P_j$
- Compute the variances σ_Z^2, σ_P^2, σ_R^2

The results of this analysis were to be retained on a data file for future use.

The computer analysis was performed on both the pressure and the temperature gradient data and for the daily values as well as the running means. Defining a variable ϕ to be either pressure height or temperature gradient, the mean of ϕ was calculated for each day

$$\bar{\Phi}_j = \frac{1}{N}\sum_{i=1}^{N}\phi_{i,j}$$

where the j-index indicated that the variable is still a function of the day number. The original field was reduced to obtain

$$\psi_{ij} = \phi_{ij} - \bar{\Phi}_j$$

The ψ-field was then analyzed to determine the number of zero crossings $Z_j(\psi)$ and the number of extrema $P_j(\psi)$.

	Z (ψ)	P (ψ)	R (ψ)	Z (ζ)	P (ζ)	R (ζ)
r = 0						
1970 – 71	7.1	12.6	0.58	8.8	13.6	0.67
1971 – 72	7.9	12.8	0.63	9.2	13.4	0.70
1972 – 73	7.6	12.8	0.61	9.0	13.4	0.69
1973 – 74	6.9	12.5	0.57	8.8	13.7	0.66
1970 – 71	6.5	13.8	0.49	7.7	14.4	0.55
1972 – 72	5.6	12.6	0.45	8.0	13.8	0.60
1972 – 73	6.3	13.1	0.49	7.8	14.2	0.56
1973 – 74	6.3	13.0	0.50	7.9	14.5	0.56
r = 3						
	6.3	10.5	0.62	7.7	11.7	0.68
	7.0	10.4	0.69	8.0	11.3	0.72
	6.5	10.4	0.64	8.0	11.4	0.72
	5.9	10.0	0.61	7.4	11.7	0.65
	5.8	12.2	0.49	7.0	12.9	0.56
	4.9	10.9	0.48	7.1	12.6	0.57
	5.4	11.3	0.49	6.7	13.2	0.53
	4.9	11.1	0.46	6.8	12.8	0.55
r = 5						
	6.1	9.7	0.64	7.4	11.4	0.67
	6.8	9.8	0.70	7.7	10.9	0.72
	6.2	9.9	0.64	7.4	10.4	0.73
	5.7	9.5	0.61	7.0	11.3	0.64
	5.2	11.5	0.48	6.4	12.2	0.55
	4.6	10.3	0.47	6.8	12.3	0.58
	5.0	11.0	0.47	6.3	13.0	0.52
	4.5	10.5	0.47	6.3	12.8	0.50
r = 7						
	5.8	9.1	0.65	7.1	11.5	0.63
	6.7	9.4	0.73	7.4	10.7	0.70
	6.2	9.4	0.68	7.3	10.4	0.72
	5.4	9.1	0.61	6.8	11.0	0.65
	5.1	11.0	0.48	6.1	12.1	0.53
	4.6	10.0	0.48	6.5	11.9	0.57
	4.6	10.6	0.46	6.3	13.1	0.50
	4.3	9.9	0.48	6.1	13.1	0.47
r = 11						
	5.5	8.7	0.65	6.5	11.5	0.58
	6.4	8.7	0.74	7.1	10.5	0.70
	5.9	9.2	0.67	7.0	10.0	0.72
	5.1	8.9	0.58	6.6	10.6	0.64
	4.8	10.8	0.46	6.0	12.4	0.50
	4.6	9.4	0.52	6.5	12.4	0.56
	4.3	9.5	0.49	6.0	13.1	0.48
	4.3	9.7	0.49	6.1	13.5	0.46
r = 15						
	5.2	8.0	0.69	6.3	11.1	0.58
	6.2	8.5	0.74	7.2	10.6	0.71
	5.5	8.9	0.65	6.9	9.9	0.71
	4.8	8.8	0.57	6.8	10.3	0.68
	4.5	10.6	0.45	5.8	12.7	0.46
	4.6	9.0	0.54	6.4	12.9	0.52
	4.3	9.8	0.47	6.4	13.7	0.48
	4.3	9.0	0.53	5.9	14.0	0.43

Table III-3. Summary of computer analysis of pressure height p and temperature gradient ΔT data for four winter seasons and for different r-day running averages of the data. Z is the number of zero crossings, P is the number of extrema and R is the ratio of Z to P.

	$Z(\dot\psi)$	$P(\dot\psi)$	$R(\dot\psi)$	$Z(\dot\zeta)$	$P(\dot\zeta)$	$R(\dot\zeta)$
r = 21						
	5.0	7.3	0.70	6.2	11.1	0.57
	6.0	8.4	0.72	7.2	10.6	0.72
	5.5	8.3	0.70	7.8	9.8	0.72
	4.8	7.9	0.62	7.1	10.0	0.73-
	4.3	10.3	0.46	5.5	13.4	0.72
	4.2	8.8	0.51	6.3	13.5	0.46
	4.2	9.2	0.48	6.4	14.1	0.48
	4.21	8.2	0.59	6.0	14.2	0.43
r = 27						
	5.0	7.5	0.70	6.1	11.2	0.56
	5.7	8.6	0.67	7.1	10.7	0.69
	5.5	7.9	0.75	6.8	9.9	0.71
	4.5	8.1	0.59	7.3	9.8	0.77
	4.4	10.2	0.46	5.6	14.2	0.42
	4.2	8.4	0.53	6.4	14.1	0.47
	4.3	9.2	0.48	6.6	14.1	0.48
	4.5	7.9	0.63	6.3	14.7	0.43
r = 35						
	4.8	7.1	0.70	5.9	11.2	0.54
	5.3	8.8	0.62	7.2	11.1	0.67
	5.6	7.8	0.75	7.0	9.7	0.74
	4.6	7.8	0.60	7.0	9.8	0.75
	4.3	9.6	0.47	5.3	14.6	0.39
	4.0	8.4	0.50	7.7	15.6	0.51
	4.3	8.2	0.54	6.7	16.5	0.46
	4.5	7.2	0.69	6.7	16.2	0.42
r = 49						
	4.5	6.8	0.69	5.8	11.7	0.62
	5.0	8.8	0.59	8.4	10.5	0.81
	5.7	7.5	0.79	6.7	10.8	0.64
	4.0	7.1	0.59	6.8	10.6	0.70
	4.3	10.0	0.46	7.0	15.7	0.46
	4.1	8.4	0.50	7.3	16.8	0.45
	4.2	7.9	0.56	7.3	16.7	0.45
	4.4	7.0	0.68	7.3	17.6	0.43
r = 63						
	4.0	6.7	0.61	6.9	14.0	0.51
	5.6	8.3	0.68	8.4	12.4	0.71
	5.2	6.9	0.78	7.6	12.1	0.64
	4.0	6.3	0.64	7.1	11.9	0.62
	3.8	9.6	0.43	9.9	19.6	0.51
	4.0	8.4	0.50	9.0	17.5	0.52
	4.1	7.2	0.58	9.3	18.6	0.49
	4.1	6.7	0.67	11.5	20.9	0.56

SAI 37[illegible]

Table III-3 (continued). Summary of computer analysis of pressure height p and temperature gradient ΔT data for four winter seasons and for different r-day running averages of the data. Z is the number of zero corssings, P the number of extrema and R is the ratio of Z to P.

Also the ratio

$$R_j(\psi) = \frac{\bar{Z}_j(\psi)}{P_j(\psi)}$$

was computed as were the standard deviations for all quantities

$$\sigma_Z, \ \sigma_P, \ \sigma_R$$

Next, the mean field was computed by averaging ψ_{ij} over all days of each winter season

$$\left[\psi_i\right] = \frac{1}{M} \sum_{j=1}^{M} \psi_{ij}$$

Then the ψ-field was reduced to obtain

$$\zeta_{ij} = \psi_{ij} - \left[\psi_i\right]$$

The resulting ζ-field was analyzed to obtain $Z(\zeta)$, $P(\zeta)$, and $R(\zeta)$ as well as the standard deviations of each quantity.

Each variable was available for four winter seasons encompassing December through March. Table III-3 summarizes the mean values of Z, P and $\bar{R}$ for these four years. It appears that one could interpret $\bar{Z}(\psi)$ as giving the basic long wave structure and $P(\psi) - Z(\psi)$ as giving an indication of the mean number of transient waves observed. From this point of view the quantity $Z(\zeta) - Z(\psi)$ should give an indication of the variability in position of the semi-permanent centers of action.

3.3 FINAL STATISTICAL ANALYSIS

The data, having been processed into five fields $(\Delta T, Z(\psi), P(\psi), Z(\zeta), P(\zeta))$, was next analyzed to determine the statistical structure of the data. This analysis consisted of the following:

1) A histogram of the entire data sample was prepared.
2) The central moments were computed for each data sample analyzed.
3) The wave number data was divided as a function of the temperature difference interval and the central moments were computed for each interval. This analysis was performed for each wave-number variable $(Z(\psi), P(\psi), Z(\zeta)$ and $P(\zeta))$ and for each data sample analyzed.
4) A correlation matrix was prepared for the five variables for each data sample.

Several data samples were analyzed, as time lags of the wave-number variables with respect to the temperature gradients were considered. These time lags, in days, included:

$$\Delta t = 0, \pm 1, \pm 2, \pm 4, \pm 8, \pm 16, \pm 32 \text{ [days]}.$$

The histogram shown in Table III-4, and reproduced in Appendix A, is divided into class intervals which are numbered sequentially from 1 through 20. These intervals represent for temperature difference:

$$11.5 + k \leq \Delta T < 12.5 + k \qquad [^{\circ}K]$$

where k is the class interval; the wave-number variables are given by:

$$k - 1 \leq Z/2,\ P/2 < k,$$

the division by two reduces these variable from zero-crossings and extrema counts to wave-number. From the Table III-4 it is found that $\Delta T < 23.5^{\circ}K$ and that the wave-number data is always less than wave-number 12.

The central moments for the entire data set are

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HISTOGRAM DISTRIBUTION

	1	2	3	4	5
1	4	0	0	0	0
2	3	0	0	0	0
3	35	46	0	11	0
4	45	161	0	79	0
5	95	181	13	152	0
6	113	87	95	163	49
7	115	8	173	71	165
8	52	1	132	6	153
9	15	0	63	2	95
10	7	0	7	0	21
11	0	0	1	0	0
12	0	0	0	0	1
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

Table III-4 Histogram of geophysical variables. Column 1 is the temperature gradient between 30N and 60N which the class intervals k are given as $11.5 + k \leq \Delta T < 12.5 + k$. Columns 2 through 5 are Z (ψ), P (ψ), Z (ζ), P (ζ), respectively; all have been divided by two to represent them as wave-number and the class intervals are $k - 1 \leq Z/2, P/2 < k$.

CENTRAL MOMENTS

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8927+01	2.6358+00	-7.8772-01	2.1621+01
7.3926+00	3.5401+00	8.7367-01	3.3587+01
1.2669+01	4.5932+00	1.8806+00	5.7323+01
8.9504+00	4.5182+00	3.7473-01	5.7636+01
1.3496+01	4.3409+00	2.8916+00	5.3230+01

Table III-5 Central moments of all variables. The rows are ΔT, Z (ψ), P (ψ), Z (ζ), and P (ζ) from the first to the fifth.

presented in Table III-5. From these data one notices that all variables have large standard deviations; temperature difference is negativily skewed whereas the wave-number variables are positively skewed; and all variables have large kurtosis. Note that the standard deviation is <u>not</u> the standard deviation of the mean which would require an additional division by the square-root of the number of data points, with 484 data points this is 22. Thus, the mean should be relatively stable. Note also that the wave-number variables have <u>not</u> been divided by 2; thus, the average zero crossings $Z(\psi)$ of 7.3926 yields an average wave number of 3.6963.

Table III-6 contains four separate tables showing the central moments for each of the wave-number variables within a given temperature difference class. That is, these data have been separated and analyzed with respect to the observed temperature gradient. As before the class intervals for temperature difference, given in the first column refers to ΔT

$$11.5 + k \leq \Delta T < 12.5 + k \quad [^\circ K]$$

The second column gives the number of data falling into each class.

Table III-7 gives the correlation matrix for the five variables. The 10 x 10 matrix is laid out as shown below

$$\begin{array}{l} \\ \Delta T(t + \delta t) \\ Z(\psi,\ t + \delta t) \\ P(\psi,\ t + \delta t) \\ Z(\zeta,\ t + \delta t) \\ P(\zeta,\ t + \delta t) \\ \Delta T(t) \\ Z(\psi,\ t) \\ P(\psi,\ t) \\ Z(\zeta,\ t) \\ P(\zeta,\ t) \end{array}
\begin{array}{c} \Delta T(t + \delta t) \quad Z(\psi,\ t + \delta t), \ldots \quad \Delta T(t) \ldots \\ \left(\begin{array}{c:c} \mathrm{I} & \mathrm{II} \\ \hdashline \mathrm{IV} & \mathrm{III} \end{array}\right) \end{array}$$

NMAX = 484 LP = 1

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

Z(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	6.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4998+00
3	35.	6.9143+00	1.8108+00	1.2768-01	2.2305+00
4	45.	7.1556+00	2.0435+00	9.1444-01	4.5155+00
5	95.	7.7684+00	1.9852+00	-2.8845-01	2.4513+00
6	113.	7.0973+00	1.7648+00	3.1577-01	2.5552+00
7	115.	7.4435+00	1.8566+00	1.8698-01	2.6281+00
8	52.	7.6538+00	1.9103+00	-1.7868-01	2.4679+00
9	15.	7.6000+00	1.5853+00	-3.0486-01	2.5474+00
10	7.	7.7143+00	1.6660+00	-1.2106+00	4.0383+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2829+01	2.0155+00	1.1220-02	3.1333+00
4	45.	1.2489+01	2.1564+00	1.4151-01	2.0438+00
5	95.	1.2358+01	2.0309+00	3.3026-01	2.8584+00
6	113.	1.2637+01	2.2304+00	2.8821-01	3.2254+00
7	115.	1.2730+01	1.9970+00	1.8395-01	2.3859+00
8	52.	1.3346+01	2.4090+00	5.2910-02	2.2139+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3418-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Z(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1615+00
4	45.	8.2667+00	2.0913+00	-3.4731-02	2.1879+00
5	95.	9.3895+00	2.2304+00	7.5141-02	2.9415+00
6	113.	9.0796+00	2.2428+00	1.0763-01	3.3589+00
7	115.	8.9739+00	1.9625+00	-2.1207-01	2.4280+00
8	52.	8.9615+00	2.0188+00	-1.7198-01	2.3420+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4998+00
3	35.	1.3771+01	1.7742+00	-2.0687-02	2.8421+00
4	45.	1.3422+01	2.2557+00	3.9600-01	2.4954+00
5	95.	1.3305+01	2.0265+00	4.9199-01	2.7218+00
6	113.	1.3699+01	2.0988+00	7.3127-02	2.1582+00
7	115.	1.3409+01	1.9015+00	-4.8891-02	2.4788+00
8	52.	1.3538+01	1.9460+00	4.7434-01	2.2546+00
9	15.	1.4800+01	3.1665+00	2.3383-01	2.9840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Table III-6 Central moments for given temperature distribution. These four tables refer, respectively, to Z (ψ), P (ψ), Z (ζ), and P (ζ). The first column is the temperature difference class intervals k and $k + 11.5 \leq \Delta T < k + 12.5^{0}K$. The second column is the number of cases following into each category.

NMAX = 484 LP = 1

CORRELATION MATRIX

.1000+01	.6101-01	.1454+00	.7311-02	.4342-01	.1000+01	.6101-01	.1454+00	.7311-02	.4342-01
.6101-01	.1000+01	.1357+00	.4047+00	.3994-01	.6101-01	.1000+01	.1357+00	.4047+00	.3994-01
.1454+00	.1357+00	.1000+01	.2123+00	.3643+00	.1454+00	.1357+00	.1000+01	.2123+00	.3643+00
.7311-02	.4047+00	.2123+00	.1000+01	.9139-01	.7311-02	.4047+00	.2123+00	.1000+01	.9139-01
.4342-01	.3994-01	.3643+00	.9139-01	.1000+01	.4342-01	.3994-01	.3643+00	.9139-01	.1000+01
.1000+01	.6101-01	.1454+00	.7311-02	.4342-01	.1000+01	.6101-01	.1454+00	.7311-02	.4342-01
.6101-01	.1000+01	.1357+00	.4047+00	.3994-01	.6101-01	.1000+01	.1357+00	.4047+00	.3994-01
.1454+00	.1357+00	.1000+01	.2123+00	.3643+00	.1454+00	.1357+00	.1000+01	.2123+00	.3643+00
.7311-02	.4047+00	.2123+00	.1000+01	.9139-01	.7311-02	.4047+00	.2123+00	.1000+01	.9139-01
.4342-01	.3994-01	.3643+00	.9139-01	.1000+01	.4342-01	.3994-01	.3643+00	.9139-01	.1000+01

Table III-7 Correlation Matrix. See Text.

where δt is the lag time. Quadrants I and III give the auto- and cross-correlations at given times; quandrants II and IV give auto- and cross correlations at the lagged times. Since $\delta t=0$ for the results in Table III-4 all quandrants represent identical 5 x 5 matrices.

The results obtained from this study do not confirm the simple hypothesis stated in the beginning of this section. It would have been surprising to have found otherwise as early works of Bolin and Smagorinsky had demonstrated the relationship of the semipermanent centers of action to orography and to baroclinic zones at land-sea boundaries. Figure III-1 shows the cross-correlation of the temperature gradient with the wave-number variables. None of the correlations exceeds r=0.2. The fields with the seasonal mean removed have smaller correlation than those with only the daily mean height removed. This is perhaps an indication that the oscillation in position of the long waves is less correlated with the temperature gradient than the number of waves.

The results of the preliminary study which showed some indication that the number of transient wave might have a better correlation than the number of long waves was not pursued. The subsequent results shown in Figure III-1, however, may give a further indication of this result. This is seen in the fact that the number of extrema present correlates better with the temperature gradient than does the number of zero crossings. This is predicated on the idea that the basic long waves are more likely to result in pressure height differences leading to zero crossings than the transient waves. This result could be easily tested by removing the 5-day running means from the data and performing the analysis once again.

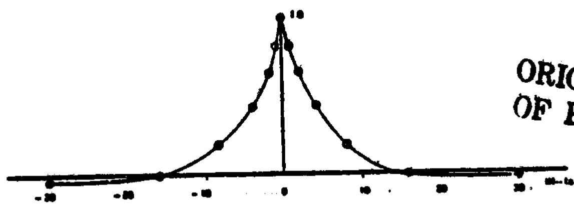

Figure III-1a Auto-correlation ΔT

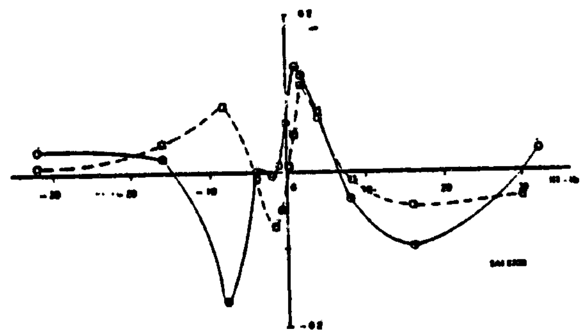

Figure III-1b Cross-correlations ⊙ $Z(\psi)$ ⊡ $Z(\zeta)$

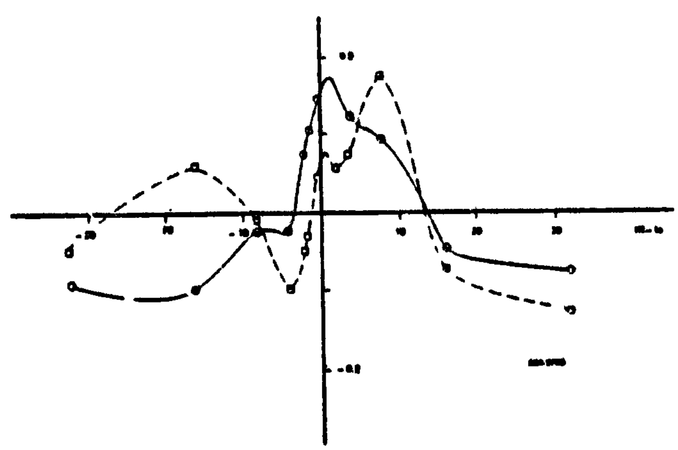

Figure III-1c Cross-correlations ⊙ $P(\psi)$ ⊡ $P(\zeta)$

Figure III-1 Auto-correlation and cross-correlations of wave-number variables with the temperature gradient (ordinate) as functions of time lag (abscissa) in days.

This analysis was carried out for each lag time. Tables similar to Tables III-4 through III-7 have been constructed for each lag time analyzed. These tables are to be found in Appendix A.

IV. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the original simple hypothesis that wave-number is directly related to the meridional temperature gradient is not supported by the results presented in Section III. There are several reasons why such a relationship, at best would be difficult to establish. First, it is not clear that the thermal Rossby number of geophysical fluid dynamic (GFD) experiments is directly correlated with the meridional temperature gradient of the atmosphere. Second, the ground state of the GFD experiments is a zonal baroclinic fluid flow and that of the atmosphere is an orographically perturbed baroclinic flow. Third, besides the orographic perturbation present in the ground state, a longitudinal temperature gradient at land-sea interfaces serves to further perturb the atmospheric flow. Fourth, it is not clear whether or not a temperature gradient wave structure relationship in the atmosphere is a hemispheric relationship rather than a local relationship.

Many of the uncertainties in setting forth hypotheses relating GFD experiments and atmospheric circulation certainly arise because of the complexity of atmospheric circulation. But equally responsible is the lack of data from GFD experiments approaching atmospheric ciruclations. First, the atmosphere in all probability cannot be equated to a steady wave regime vacillating between two wave-numbers. It is probably related to the unsteady regimes of the GFD experiments. This itself does not rule out a simple wave-number - temperature gradient hypothesis since the mean wave-number of the unsteady regime may very well be related to the imposed temperature gradient. The author knows of no data which will either support or deny this supposition.

Second the relationship between wave-number and temperature gradient has been established in a GFD experiment with imposed orographic boundary conditions. This would appear to be a simple experiment requiring only that previous experiments to be repeated with barriers imposed at the lower boundary. Such an experiment in the steady three wave regime with two barriers would appear to offer intriguing possibilities. To the author's knowledge no such data exists.

It is recommended that future efforts in relating GFD experiments to the atmospheric circulation be directed toward more specific physical relationships. For instance, it is not clear that vacillation in GFD experiments corresponds to supposed wave-number transitions or wave amplification phenomena in the atmosphere. However, a study of the atmospheric phenomena should prove profitable whether pursued on the synoptic/analytic or on the theoretical level. It is anticipated that such a study on the synoptical/analytic level would not be global in scale but would be a more detailed three-dimensional study of the isolated sector where the changes are found. Results from current GFD studies could then be directly compared although simple relationships should not be anticipated.

A second path would be to modify the GFD experiments themselves. This would require the analysis of such experiments as the unsteady wave regimes and wave regimes modified by barriers.

APPENDIX A. DATA ANALYSIS SUMMARY

The analyses presented in this section consists of all analyses conducted during this study and have been discussed in Section III of this report. There are three types of tables collected in this summary for each of the time lags analyzed. In addition, the first table found is the histogram of all data, repeated from Table III-4.

The central for a given temperature distribution are those obtained for each wave-number variable, N ( ), Z ( ), N ( ), Z ( ) dividing the data into discrete sets associated with given temperature gradients. The first column in these tables is the temperature gradient class interval k

$$11.5 + k \leq \Delta T < 12.5 + k.$$

The second column gives the number of the data points found in each category. The central moments then refer to those data found in that particular category.

The central moments of all data are given for each time lag because the data set is reduced in number with each increasing value of the time lag. The five rows give the central moments for ΔT, N (ψ), Z (ψ), N (ζ), and Z (ζ) respectively.

The correlation matrices relate the auto-correlations and cross-correlations found between the variables. The matrix elements may be identified from the organization shown below.

$$\begin{array}{l}
\\
\Delta T(t+\delta t) \\
Z(\psi,\ t+\delta t) \\
P(\psi,\ t+\delta t) \\
Z(\zeta,\ t+\delta t) \\
P(\zeta,\ t+\delta t) \\
\Delta T(t) \\
Z(\psi,\ t) \\
P(\psi,\ t) \\
Z(\zeta,\ t) \\
P(\zeta,\ t)
\end{array}
\begin{array}{c}
\Delta T(t+\delta t)\quad Z(\psi,\ t+\delta t),\ .\ .\ .\ \Delta T(t)\ .\ .\ . \\
\left(\begin{array}{c:c}
\mathrm{I} & \mathrm{II} \\
\hdashline
\mathrm{IV} & \mathrm{III}
\end{array}\right)
\end{array}$$

NMAX = 484 LP = 1

HISTOGRAM DISTRIBUTION

	1	2	3	4	5
1	4	0	0	0	0
2	3	0	0	0	0
3	35	46	0	11	0
4	45	161	0	79	0
5	95	181	13	152	0
6	113	87	95	163	49
7	115	8	173	71	165
8	52	1	132	6	153
9	15	0	63	2	95
10	7	0	7	0	21
11	0	0	1	0	0
12	0	0	0	0	1
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

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NMAX = 484 LP = 1

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.8108+00	1.2768-01	2.2305+00
4	45.	7.1556+00	2.0435+00	9.1444-01	4.5155+00
5	95.	7.7684+00	1.9852+00	-2.9945-01	2.4513+00
6	113.	7.0973+00	1.7848+00	3.1577-01	2.5552+00
7	115.	7.4435+00	1.8565+00	1.8899-01	2.6281+00
8	52.	7.6538+00	1.9103+00	-1.7869-01	2.4679+00
9	15.	7.6000+00	1.6853+00	-3.0486-01	2.5474+00
10	7.	7.7143+00	1.6660+00	-1.2106+00	4.0363+00
11	0.	0.0000	0.0000	0.00C0	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2829+01	2.0155+00	1.1220-02	3.1333+00
4	45.	1.2489+01	2.1564+00	1.4151-01	2.0438+00
5	95.	1.2358+01	2.0309+00	3.0026-01	2.8584+00
6	113.	1.2637+01	2.2304+00	2.6821-01	3.2254+00
7	115.	1.2730+01	1.9970+00	1.6395-01	2.3859+00
8	52.	1.3346+01	2.4090+00	5.2910-02	2.2139+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1615+00
4	45.	8.2667+00	2.0913+00	-3.4731-02	2.1679+00
5	95.	9.3895+00	2.2304+00	7.5141-02	2.9415+00
6	113.	9.0796+00	2.2428+00	1.0783-01	3.3589+00
7	115.	8.9739+00	1.9825+00	-2.1207-01	2.4280+00
8	52.	8.9615+00	2.0188+00	-1.7190-01	2.3420+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	7.	7.7143+00	1.8880+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	35.	1.3771+01	1.7742+00	-2.0867-02	2.8421+00
4	45.	1.3422+01	2.2557+00	3.9800-01	2.4954+00
5	95.	1.3305+01	2.0265+00	4.9199-01	2.7218+00
6	113.	1.3699+01	2.0986+00	7.3127-02	2.1582+00
7	115.	1.3409+01	1.9015+00	-4.8891-02	2.4768+00
8	52.	1.3538+01	1.9460+00	4.7434-01	2.2546+00
9	15.	1.4800+01	3.1665+00	2.3383-01	2.8840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4989+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to Z (ψ), P (ψ), Z (ζ), and P (ζ). The first column is the temperature difference class intervals k and $k + 11.5 < \Delta T < k + 12.5^\circ K$. The second column is the number of cases following into each category.

NMAX = 484 LP = 1

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, (ψ)., P (ψ), Z¨(ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8927+01	2.6358+00	-7.8772-01	2.1621+01
7.3926+00	3.5401+00	8.7367-01	3.3587+01
1.2669+01	4.5932+00	1.8808+00	5.7323+01
8.9504+00	4.5182+00	3.7473-01	5.7636+01
1.3496+04	4.3409+00	2.8916+00	5.3230+01

CORRELATION MATRIX

.1000+01	.6101-01	.1454+00	.7311-02	.4342-01	.1000+01	.6101-01	.1454+00	.7311-02	.4342-01
.6101-01	.1000+01	.1357+00	.4047+00	.3994-01	.6101-01	.1000+01	.1357+00	.4047+00	.3994-01
.1454+00	.1357+00	.1000+01	.2123+00	.3643+00	.1454+00	.1357+00	.1000+01	.2123+00	.3643+00
.7311-02	.4047+00	.2123+00	.1000+01	.9139-01	.7311-02	.4047+00	.2123+00	.1000+01	.9139-01
.4342-01	.3994-01	.3643+00	.9139-01	.1000+01	.4342-01	.3994-01	.3643+00	.9139-01	.1000+01
.1000+01	.6101-01	.1454+00	.7311-02	.4342-01	.1000+01	.6101-01	.1454+00	.7311-02	.4342-01
.6101-01	.1000+01	.1357+00	.4047+00	.3994-01	.6101-01	.1000+01	.1357+00	.4047+00	.3994-01
.1454+00	.1357+00	.1000+01	.2123+00	.3643+00	.1454+00	.1357+00	.1000+01	.2123+00	.3643+00
.7311-02	.4047+00	.2123+00	.1000+01	.9139-01	.7311-02	.4047+00	.2123+00	.1000+01	.9139-01
.4342-01	.3994-01	.3643+00	.9139-01	.1000+01	.4342-01	.3994-01	.3643+00	.9139-01	.1000+01

NMAX = 480 LP = 2

LAG = 1

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.8106+00	1.2768-01	2.2305+00
4	44.	7.1818+00	2.0590+00	6.7092-01	4.4319+00
5	93.	7.7634+00	1.9880+00	-2.6592-01	2.3982+00
6	113.	7.0973+00	1.7648+00	3.1577-01	2.5552+00
7	115.	7.4435+00	1.8506+00	1.6599-01	2.6281+00
8	52.	7.6538+00	1.9193+00	-1.7688-01	2.4679+00
9	14.	7.7143+00	1.6660+00	-4.6910-01	2.7647+00
10	7.	7.7143+00	1.6660+00	-1.2108+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2629+01	2.0155+00	1.1220-02	3.1333+00
4	44.	1.2545+01	2.1475+00	1.0287-01	2.0692+00
5	93.	1.2387+01	2.0375+00	2.7749-01	2.9460+00
6	113.	1.2637+01	2.2304+00	2.6821-01	3.2254+00
7	115.	1.2733+01	1.9970+00	1.6296-01	2.3859+00
8	52.	1.3346+01	2.4090+00	5.2910-02	2.2139+00
9	14.	1.4003+01	1.5119+00	-9.9216-01	4.3747+00
10	7.	1.2283+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	9.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1619+00
4	44.	8.2727+00	2.1145+00	-4.2913-02	2.1413+00
5	93.	9.3763+00	2.2524+00	9.1587-02	2.8907+00
6	113.	9.0796+00	2.2426+00	1.0763-01	3.3589+00
7	115.	8.9739+00	1.9629+00	-2.1207-01	2.4280+00
8	52.	8.9615+00	2.0188+00	-1.7736-01	2.3420+00
9	14.	8.4286+00	2.2902+00	4.3108-01	1.7510+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.0180-01	1.4999+00
3	35.	1.3771+01	1.7748+00	-2.0667-02	2.9421+00
4	44.	1.3455+01	2.2709+00	3.6182-01	2.4594+00
5	93.	1.3355+01	2.0148+00	4.8849-01	2.7178+00
6	113.	1.3693+01	2.0986+00	7.3167-02	2.1582+00
7	115.	1.3409+01	1.9315+00	-4.6891-02	2.4786+00
8	52.	1.3533+01	1.9460+00	4.7434-01	2.2546+00
9	14.	1.5143+01	2.9966+00	2.4443-01	3.3255+00
10	7.	1.2003+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\xi)$, and $P(\xi)$. The first column is the temperature difference class intervals k and $k + 11.5 < \Delta T < k + 12.5°K$. The second column is the number of cases following into each category.

NMAX = 450 LP = 2

LAO = 1

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, (ψ), $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$ from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8928+01	2.6278+00	-8.4005-01	2.1602+01
7.3958+00	3.5600+00	8.5633-01	3.3839+01
1.2683+01	4.5997+00	1.7848+00	5.7483+01
8.9500+00	4.5475+00	3.8225-01	5.8108+01
1.3517+01	4.3164+00	2.8383+00	5.2783+01

CORRELATION MATRIX

.1000+01	.6302-01	.1435+00	.8917-02	.4580-01	.8250+00	.1134-01	.1114+00	-.4721-01	-.3064-01
.6302-01	.1000+01	.1350+00	.4036+00	.3818-01	.1394+00	.4450+00	.8756-01	.3039+00	.2781-01
.1435+00	.1350+00	.1000+01	.2134+00	.3621+00	.1654+00	.9630-01	.3002+00	.5734-01	.1911+00
.8917-02	.4036+00	.2134+00	.1000+01	.9235-01	.4715-01	.3244+00	.1049+00	.4438+00	.5045-01
.4580-01	.3818-01	.3621+00	.9235-01	.1000+01	.7565-01	.2768-01	.1836+00	.6516-01	.2911+00
.8250+00	.1394+00	.1654+00	.4715-01	.7565-01	.1000+01	.6400-01	.1540+00	.9059-02	.4750-01
.1134-01	.4450+00	.9630-01	.3244+00	.2768-01	.6400-01	.1000+01	.1315+00	.4054+00	.3645-01
.1114+00	.8756-01	.3002+00	.1049+00	.1836+00	.1540+00	.1315+00	.1000+01	.2154+00	.3817+00
-.4721-01	.3039+00	.5734-01	.4438+00	.6516-01	.9059-02	.4054+00	.2154+00	.1000+01	.8087-01
-.3064-01	.2781-01	.1911+00	.5045-01	.2911+00	.4750-01	.3645-01	.3817+00	.8087-01	.1000+01

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OF POOR QUALITY

NMAX = 480   LP = 3

LAG # = 1

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	34.	6.9412+00	1.0302+00	8.8858-02	2.1914+00
4	45.	7.1556+00	2.0435+00	9.1444-01	4.5159+00
5	93.	7.7419+00	1.9724+00	-2.7787-01	2.4348+00
6	113.	7.0973+00	1.7648+00	3.1577-01	2.5552+00
7	114.	7.4737+00	1.8363+00	2.0348-01	2.6464+00
8	52.	7.6530+00	1.9103+00	-1.7868-01	2.4679+00
9	15.	7.6000+00	1.8653+00	-3.0488-01	2.5474+00
10	7.	7.7143+00	1.6660+00	-1.2108+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	34.	1.2558+01	2.0309+00	6.1821-02	3.1247+00
4	45.	1.2489+01	2.1584+00	1.4151-01	2.0438+00
5	93.	1.2280+01	1.9804+00	3.1574-01	3.0239+00
6	113.	1.2637+01	2.2304+00	2.6821-01	3.2254+00
7	114.	1.2737+01	2.0046+00	1.5434-01	2.3885+00
8	52.	1.3348+01	2.4090+00	5.2910-02	2.2139+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3418-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	34.	8.6471+00	1.8811+00	1.9248-01	2.1697+00
4	45.	8.2667+00	2.0913+00	-3.4731-02	2.1679+00
5	93.	9.4194+00	2.2448+00	4.0491-02	2.8219+00
6	113.	9.0796+00	2.2426+00	1.0763-01	3.3589+00
7	114.	9.0000+00	1.9512+00	-2.2673-01	2.4706+00
8	52.	8.9615+00	2.0189+00	-1.7190-01	2.3420+00
9	15.	8.4000+00	2.2151+00	4.6285-01	1.8913+00
10	7.	7.7143+00	1.6680+00	2.7238-01	1.4831+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	34.	1.3765+01	1.7987+00	-9.2150-03	2.7634+00
4	45.	1.3422+01	2.2557+00	3.9800-01	2.4954+00
5	93.	1.3269+01	2.0274+00	5.3017-01	2.7778+00
6	113.	1.3699+01	2.0988+00	7.3127-02	2.1562+00
7	114.	1.3421+01	1.9052+00	-6.4942-02	2.4795+00
8	52.	1.3538+01	1.9460+00	4.7434-01	2.2548+00
9	15.	1.4830+01	3.1665+00	2.3383-01	2.9840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\xi)$, and $P(\xi)$. The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k - 12.5^{\circ}$K. The second column is the number of cases following into each category.

NMAX = 480   LP = 3

LAG = - 1

CENTRAL MOMENTS   Central moments of all variables. The rows are ΔT, (ψ), P (ψ), Z (ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8935+01	2.6374+00	-8.2350-01	2.1741+01
7.3358+00	3.5266+00	8.9532-01	3.3475+01
1 2654+01	4.5804+00	1.9477+00	5.7393+01
8 9583+00	4.5316+00	3.2486-01	5.7940+01
1.3492+01	4.3583+00	2.9444+00	5.3830+01

CORRELATION MATRIX

.1000+01	.8400-01	.1540+00	.9059-02	.4750-01	.8250+00	.1394+00	.1654+00	.4719-01	.7565-01
.8400-01	.1000+01	.1315+00	.4054+00	.3645-01	.1134-01	.4450+00	.8630-01	.3244+00	.2768-01
.1540+00	.1315+00	.1000+01	.2154+00	.3617+00	.1114+00	.8756-01	.3002+00	.1049+00	.1836+00
.9059-02	.4054+00	.2154+00	.1000+01	.9087-01	-.4721-01	.3039+00	.5734-01	.4438+00	.6516-01
.4750-01	.3645-01	.3617+00	.9087-01	.1000+01	-.3064-01	.2781-01	.1911+00	.5045-01	.2911+00
.8250+00	.1134 01	.1114+00	-.4721-01	-.3064-01	.1000+01	.6302-01	.1439+00	.8917-02	.4580-01
.1394+00	.4450+00	.8756 01	.3039+00	.2781-01	.6302-01	.1000+01	.1350+00	.4036+00	.3818-01
.1654+00	.8630 01	.3002+00	.5734-01	.1911+00	.1435+00	.1350+00	.1000+01	.2134+00	.3621+00
.4715 01	.3244+00	.1049+00	.4438+00	.5045-01	.8917-02	.4036+00	.2134+00	.1000+01	.8235-01
.7565-01	.2768 01	.1836+00	.6516-01	.2911+00	.4580-01	.3818-01	.3621+00	.8235-01	.1000+01

NMAX = 478   LP = 2 -

LAG = 2

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

Z(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.9106+00	1.2768-01	2.2305+00
4	43.	7.8093+00	2.0749+00	6.4458-01	4.3500+00
5	92.	[illegible] 7609+00	1.9968+00	-2.8358-01	2.3717+00
6	118.	7.0714+00	1.7511+00	3.2005-01	2.6103+00
7	114.	7.4385+00	1.8639+00	1.9422-01	2.6113+00
8	52.	7.6538+00	1.9103+00	-1.7468-01	2.4679+00
9	14.	7.7143+00	1.6960+00	-4.8910-01	2.7647+00
10	7.	7.7143+00	1.6860+00	-1.2106+00	4.0383+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2629+01	2.0155+00	1.1220-02	3.1333+00
4	43.	1.2512+01	2.1607+00	1.4322-01	2.0685+00
5	92.	1.2391+01	2.0481+00	2.7226-01	2.8152+00
6	112.	1.2643+01	2.2395+00	2.5990-01	3.1988+00
7	114.	1.2737+01	2.2046+00	1.5434-01	2.3685+00
8	52.	1.3349+01	2.4290+00	5.2910-02	2.2139+00
9	14.	1.4003+01	1.9118+00	-9.9816-01	4.3747+00
10	7.	1.2289+01	1.2778+00	-[illegible].3418-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Z(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6957+00	1.9481+00	1.3940-01	2.1619+00
4	43.	8.2791+00	2.1389+00	-5.1301-02	2.0949+00
5	92	9.3696+00	2.2637+00	9.9981-02	2.8654+00
6	112.	9.0714+00	2.2529+00	1.1773-01	3.3407+00
7	114.	9.0000+00	1.9512+00	-2.2873-01	2.4726+00
8	52.	8.9615+00	2.3188+00	-1.7192-01	2.3422+00
9	14.	8.4285+00	2.2902+00	4.3108-01	1.7510+00
10	7.	7.7143+00	1.6660+00	2.7239-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1020+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	35.	1.3771+01	1.7742+00	-2.2687-02	2.8421+00
4	43.	1.3535+01	2.2345+00	3.8567-01	2.4913+00
5	92.	1.3370+01	2.0201+00	4.7087-01	2.6985+00
6	118.	1.3714+01	2.1022+00	5.0499-02	2.1587+00
7	114.	1.3421+01	1.9092+00	-6.4942-02	2.4797+00
8	52.	1.3931+01	1.7460+00	4.7434-01	2.2546+00
9	14.	1.5143+01	2.9966+00	2.4443-01	3.3279+00
10	4.	1.2000+01	1.2897+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to Z(ψ), P(ψ), Z(ζ) and P(ζ). The first column is the temperature difference class intervals k and k + 11.5 ≤ ΔT ≤ k + 12.5°K. The second column is the number of cases following into each category

NMAX = 478 LP = 2

LAG = 2

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, (ψ), P (ψ), Z (ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8930+01	2.6398+00	-8.5716-01	2.1767+01
7.3908+00	3.5700+00	8.8559-01	3.4036+01
1.2685+01	4.6318+00	1.7756+00	5.7947+01
8.9538+00	4.5609+00	3.8459-01	5.8424+01
1.3534+01	4.3119+00	2.7563+00	5.2677+01

CORRELATION MATRIX

.1000+01	.6141-01	.1455+00	.1074-01	.4318-01	.6556+00	-.3640-02	.7133-01	-.7217-01	-.4920-01
.6141-01	.1000+01	.1377+00	.4043+00	.3895-01	.1228+00	.2417+00	.9401-01	.2064+00	-.2474-02
.1455+00	.1377+00	.1000+01	.2144+00	.3648+00	.1637+00	.1519-01	.2152+00	.2309-01	.8918-01
.1074-01	.4043+00	.2144+00	.1000+01	.9083-01	.1122+00	.1605+00	.9028-01	.3103+00	.7370-01
.4318-01	.3895-01	.3648+00	.9083-01	.1000+01	.5841-01	.1813-01	.1270+00	.8254-01	.1965+00
.6556+00	.1228+00	.1637+00	.1122+00	.5841-01	.1000+01	.6332-01	.1558+00	.5352-02	.4653-01
-.3640-02	.2417+00	.1519-01	.1606+00	.1813-01	.6332-01	.1000+01	.1252+00	.4019+00	.3226-01
.7133-01	.9401-01	.2152+00	.9028-01	.1270+00	.1558+00	.1252+00	.1000+01	.2113+00	.3601+00
-.7217-01	.2064+00	.2309-01	.3103+00	.8254-01	.5352-02	.4019+00	.2113+00	.1000+01	.8628-01
-.4920-01	-.2474-02	.8918-01	.7370-01	.1965+00	.4693-01	.3226-01	.3601+00	.8628-01	.1000+01

ORIGINAL PAGE IS OF POOR QUALITY

NMAX = 478   LP = 3

LAG = - 2

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.8603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4998+00
3	34.	6.9412+00	1.8302+00	6.8858-02	2.1914+00
4	44.	7.1818+00	2.0580+00	8.7992-01	4.4319+00
5	92.	7.7391+00	1.8829+00	-2.7222-01	2.4074+00
6	111.	7.0811+00	1.7560+00	3.1560-01	2.5961+00
7	114.	7.4737+00	1.8383+00	2.0342-01	2.8484+00
8	52.	7.6538+00	1.9103+00	-1.7888-01	2.4679+00
9	15.	7.6000+00	1.6653+00	-3.0488-01	2.5474+00
10	7.	7.7143+00	1.6660+00	-1.2108+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	34.	1.2588+01	2.0309+00	6.1821-02	3.1247+00
4	44.	1.2500+01	2.1794+00	1.2314-01	2.0003+00
5	92.	1.2261+01	1.9829+00	3.3915-01	3.0478+00
6	111.	1.2631+01	2.2135+00	2.7184-01	3.3218+00
7	114.	1.2737+01	2.0046+00	1.5434-01	2.3885+00
8	52.	1.3346+01	2.4090+00	5.2810-02	2.2139+00
9	15.	1.3967+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	34.	8.6471+00	1.8811+00	1.9248-01	2.1697+00
4	44.	8.3182+00	2.0865+00	-8.0711-02	2.2309+00
5	92.	9.4348+00	2.8521+00	2.2683-02	2.9131+00
6	111.	9.0631+00	2.2432+00	1.1277-01	3.3920+00
7	114.	9.0000+00	1.9512+00	-2.2673-01	2.4706+00
8	52.	8.9815+00	2.0188+00	-1.7190-01	2.3480+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	34.	1.3765+01	1.7997+00	-9.2150-03	2.7634+00
4	44.	1.3455+01	2.2709+00	3.6182-01	2.4594+00
5	92.	1.3261+01	2.0370+00	5.3981-01	2.7839+00
6	111.	1.3578+01	2.1080+00	9.5300-02	2.1578+00
7	114.	1.3421+01	1.9052+00	-6.4942-02	2.4795+00
8	52.	1.3538+01	1.9460+00	4.7434-01	2.2948+00
9	15.	1.4800+01	3.1885+00	2.3383-01	2.9840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and k + 12.5 < ΔT < k + 12.5°K. The second column is the number of cases following into each category.

[illegible] = [illegible]   LP = 3

LAG = - 2

CENTRAL MOMENTS   Central moments of all variables. The rows are [illegible], [illegible], [illegible], [illegible], and [illegible] from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

CORRELATION MATRIX.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.1228+00	.1537+00	.1122+00	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.2117+00	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NMAX = 488 LP = 2

LAG = 4

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.6108+00	1.2768-01	2.2305+00
4	43.	7.2093+00	2.0749+00	8.4452-01	4.3500+00
5	90.	7.7556+00	1.9862+00	-2.9013-01	2.3989+00
6	109.	7.0459+00	1.7473+00	3.4259-01	2.6500+00
7	111.	7.4595+00	1.8589+00	2.2374-01	2.5946+00
8	52.	7.6538+00	1.9103+00	-1.7868-01	2.4679+00
9	14.	7.7143+00	1.6660+00	-4.6910-01	2.7847+00
10	7.	7.7143+00	1.6660+00	-1.2106+00	4.0383+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	RTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2629+01	2.0155+00	1.1220-02	3.1333+00
4	43.	1.2512+01	2.1607+00	1.4322-01	2.0685+00
5	90.	1.2356+01	2.0565+00	3.1422-01	2.8429+00
6	109.	1.2697+01	2.2402+00	2.2429-01	3.2217+00
7	111.	1.2685+01	1.9818+00	1.6305-01	2.4268+00
8	52.	1.3346+01	2.4090+00	5.2910-02	2.2139+00
9	14.	1.4000+01	1.5119+00	-9.9216-01	4.3747+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1615+00
4	43.	8.2791+00	2.1385+00	-5.1301-02	2.0948+00
5	90.	9.3778+00	2.2439+00	1.1366-01	2.9446+00
6	109.	9.0826+00	2.2792+00	1.0373-01	3.2845+00
7	111.	9.0090+00	1.9705+00	-2.3862-01	2.4417+00
8	52.	8.9615+00	2.0188+00	-1.7190-01	2.3420+00
9	14.	8.4286+00	2.2902+00	4.3106-01	1.7510+00
10	7.	7.7143+00	1.6660+00	2.7236-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	35.	1.3771+01	1.7742+00	-2.0667-02	2.8421+00
4	43.	1.3535+01	2.2345+00	3.6667-01	2.4913+00
5	90.	1.3400+01	2.0320+00	4.3481-01	2.6829+00
6	109.	1.3701+01	2.1111+00	4.8884-03	2.1647+00
7	111.	1.3405+01	1.9096+00	-6.0376-02	2.4881+00
8	52.	1.3538+01	1.9460+00	4.7434-01	2.2546+00
9	14.	1.5143+01	2.9866+00	2.4443-01	3.3255+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4988+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k + 12.5°K$. The second column is the number of cases following into each category.

NMAX = 468   LP = 2

LAG = 4

CENTRAL MOMENTS   Central moments of all variables. The rows are ΔT, $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$ from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8925+01	2.6781+00	-8.4195-01	2.2112+01
7.3889+00	3.5667+00	8.3814-01	3.4127+01
1.2679+01	4.6238+00	1.7994+00	5.8224+01
8.9573+00	4.5879+00	3.4041-01	5.9059+01
1.3547+01	4.3418+00	2.6429+00	5.3281+01

CORRELATION MATRIX

.1000+01	.6359-01	.1442+00	.1160-01	.4161-01	.4285+00	.1312-02	-.2576-01	-.1853-02	-.9932-01
.6359-01	.1000+01	.1464+00	.4024+00	.3825-01	.7661-01	.5513-01	.8733-02	-.4571-01	-.3730-01
.1442+00	.1464+00	.1000+01	.2188+00	.3701+00	.1221+00	.3043-01	.5133-01	-.3744-01	-.4837-02
.1160-01	.4024+00	.2188+00	.1000+01	.8950-01	.6808-01	.9428-02	.4414-01	-.1723-01	.3882-01
.4161-01	.3825-01	.3701+00	.8950-01	.1000+01	.7910-01	.1060+00	.7688-01	.7638-01	.1670+00
.4285+00	.7661-01	.1221+00	.6808-01	.7910-01	.1000+01	.5770-01	.1535+00	.2883-03	.4663-01
.1312-02	.5513-01	.3043-01	.9428-02	.1060+00	.5770-01	.1000+01	.1193+00	.3964+00	.3983-01
-.2576-01	.8733-02	.5133-01	.4414-01	.7688-01	.1535+00	.1193+00	.1000+01	.2105+00	.3656+00
-.1853-02	-.4571-01	-.3744-01	-.1723-01	.7638-01	.2883-03	.3964+00	.2105+00	.1000+01	.8864-01
-.9932-01	-.3730-01	-.4837-02	.3882-01	.1670+00	.4663-01	.3983-01	.3656+00	.8864-01	.1000+01

NMAX = 468 LP = 3

LAG = - 4

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4998+00
3	34.	6.9412+00	1.8302+00	8.6858-02	2.1914+00
4	42.	7.2381+00	2.0909+00	8.0818-01	4.2701+00
5	91.	7.6923+00	1.9425+00	-3.3838-01	2.3523+00
6	108.	7.0920+00	1.7719+00	2.9914-01	2.5826+00
7	113.	7.4330+00	1.7942+00	1.4493-01	2.5813+00
8	51.	7.6078+00	1.9002+00	-1.4936-01	2.5067+00
9	15.	7.6000+00	1.6653+00	-3.0486-01	2.5474+00
10	7.	7.7143+00	1.6680+00	-1.2106+00	4.0383+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	34.	1.2588+01	2.0309+00	6.1821-02	3.1247+00
4	42.	1.2524+01	2.1848+00	1.2540-01	2.0229+00
5	91.	1.2242+01	1.9853+00	3.6310-01	3.0727+00
6	108.	1.2630+01	2.2385+00	2.8976-01	3.2629+00
7	113.	1.2743+01	2.0123+00	1.4486-01	2.3515+00
8	51.	1.3294+01	2.4034+00	9.2899-02	2.2545+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	34.	8.6471+00	1.9611+00	1.9248-01	2.1697+00
4	42.	8.3810+00	2.1039+00	-1.4007-01	2.2369+00
5	91.	9.4066+00	2.2482+00	4.4325-02	2.9481+00
6	108.	9.0556+00	2.2883+00	1.2168-01	3.3354+00
7	113.	8.9912+00	1.9575+00	-2.1414-01	2.4557+00
8	51.	8.9412+00	2.0332+00	-1.4414-01	2.3134+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	7.	7.7143+00	1.6680+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	34.	1.3765+01	1.7997+00	-9.2150-03	2.7634+00
4	42.	1.3476+01	2.3119+00	3.3680-01	2.3817+00
5	91.	1.3275+01	2.0438+00	5.2234-01	2.7409+00
6	108.	1.3611+01	2.0986+00	1.5356-01	2.2206+00
7	113.	1.3416+01	1.9128+00	-5.6939-02	2.4813+00
8	51.	1.3509+01	1.9529+00	4.4176-01	2.2308+00
9	15.	1.4800+01	3.1665+00	2.3303-01	2.9840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k + 12.5°K$. The second column is the number of cases following into each category.

NMAX = 468   LP = 3

LAG = - 4

CENTRAL MOMENTS: Central moments of all variables. The rows are ΔT, Z(ψ), P (ψ), Z¯(ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8946+01	2.6702+00	-8.9349-01	2.2223+01
7.3803+09	3.4707+00	6.2155-01	3.2200+01
1.2645+01	4.6007+00	2.0214+00	5.8157+01
8.9573+00	4.5537+00	3.3603-01	5.8717+01
1.3479+01	4.3948+00	3.0841+00	5.4780+01

CORRELATION MATRIX

.1000+01	.5770-01	.1535+00	.2883-03	.4563-01	.4285+00	.7681-01	.1221+00	.6808-01	.7910-01
.5770-01	.1000+01	.1193+00	.3964+00	.3983-01	.1312-02	.5513-01	.3043-01	.9428-02	.1060+00
.1535+00	.1193+00	.1000+01	.2105+00	.3656+00	-.2576-01	.8733-02	.5133-01	.4414-01	.7688-01
.2883-03	.3964+00	.2105+00	.1000+01	.8864-01	-.1853-02	-.4571-01	-.3744-01	-.1723-01	.7638-01
.4663-01	.3983-01	.3656+00	.8864-01	.1000+01	-.9932-01	-.3730-01	-.4837-02	.3882-01	.1670+00
.4285+00	.1312-02	-.2576-01	-.1853-02	-.9932-01	.1000+01	.6359-01	.1442+00	.1160-01	.4161-01
.7661-01	.5513-01	.8733-02	-.4571-01	-.3730-01	.6359-01	.1000+01	.1464+00	.4024+00	.3825-01
.1221+00	.3043-01	.5133-01	-.3744-01	-.4837-02	.1442+00	.1464+00	.1000+01	.2188+00	.3701+00
.6808-01	.9428-02	.4414-01	-.1723-01	.3882-01	.1160-01	.4024+00	.2188+00	.1000+01	.8950-01
.7910-01	.1060+00	.7688-01	.7638-01	.1670+00	.4161-01	.3825-01	.3701+00	.8950-01	.1000+01

ORIGINAL PAGE IS
OF POOR QUALITY

NMAX = 452 LP = 8

LAG = 8

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

Z(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.8106+00	1.2768-01	2.2305+00
4	42.	7.1429+00	2.0537+00	9.2697-01	4.6728+00
5	86.	7.7674+00	2.0097+00	-3.1599-01	2.4191+00
6	103.	7.0291+00	1.7915+00	3.6819-01	2.6025+00
7	107.	7.4579+00	1.8560+00	2.1704-01	2.8126+00
8	51.	7.6471+00	1.9264+00	-1.6668-01	2.4211+00
9	14.	7.7143+00	1.6660+00	-4.6910-01	2.7647+00
10	7.	7.7143+00	1.6660+00	-1.2106+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2629+01	2.0155+00	1.1220-02	3.1333+00
4	42.	1.2571+01	2.1508+00	1.0315-01	2.0988+00
5	86.	1.2372+01	2.1023+00	2.8443-01	2.7148+00
6	103.	1.2796+01	2.2528+00	1.5252-01	3.2354+00
7	107.	1.2692+01	2.0112+00	1.5033-01	2.3694+00
8	51.	1.3373+01	2.4250+00	2.3582-02	2.1945+00
9	14.	1.4000+01	1.5119+00	-9.9216-01	4.3747+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Z(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1615+00
4	42.	8.2301+00	2.1471+00	-6.8925-03	2.0981+00
5	86.	9.3953+00	2.2839+00	9.4367-02	2.8750+00
6	103.	9.1456+00	2.2914+00	7.2948-02	3.3010+00
7	107.	8.9720+00	1.9597+00	-2.5884-01	2.4649+00
8	51.	8.9020+00	1.9927+00	-1.6204-01	2.3848+00
9	14.	8.4286+00	2.2902+00	4.3106-01	1.7510+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.81[illegible]	1.4999+00
3	35.	1.3771+01	1.7742+00	-2.066[illegible]	2.8421+00
4	42.	1.3571+01	2.2482+00	3.2738-01	2.4608+00
5	86.	1.3465+01	2.0329+00	4.2001-01	2.6255+00
6	103.	1.3903+01	2.0739+00	-5.9718-02	2.2176+00
7	107.	1.3383+01	1.9221+00	-4.6623-02	2.4779+00
8	51.	1.3490+01	1.9339+00	5.2722-01	2.3544+00
9	14.	1.5143+01	2.9936+00	2.4443-01	3.3299+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to Z (ψ), P (ψ), Z (ζ), and P (ζ). The first column is the temperature difference class intervals k and k + 11.5 ≤ ΔT < k + 12.5°K. The second column is the number of cases following into each category.

NMAX = 452 LP = 2

LAG = 8

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, Z(ψ), P (ψ), Z (ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8924+01	2.7297+00	-8.7367-01	2.2775+01
7.3805+00	3.6163+00	9.7589-01	3.5007+01
1.2717+01	4.7074+00	1.5087+00	5.9552+01
8.9513+00	4.6259+00	3.6143-01	6.0226+01
1.3584+01	4.3403+00	2.5496+00	5.3441+01

CORRELATION MATRIX

.1000+01	.6697-01	.1417+00	.5294-02	.3268-01	.1743+00	-.1620-01	-.2640-01	.8157-01	-.1210-01
.6697-01	.1000+01	.1527+00	.4037+00	.4219-01	-.3521-01	.3992-01	.3112-01	.3182-01	.1864-01
.1417+00	.1527+00	.1000+01	.2199+00	.3655+00	.9376-01	-.5346-01	.1168-01	-.2878-01	.8298-02
.5294-02	.4037+00	.2199+00	.1000+01	.7843-01	-.1035-01	.4600-01	.1764-01	-.9691-01	.3340-01
.3268-01	.4218-01	.3655+00	.7843-01	.1000+01	.1746+00	.9574-01	.5097-01	.2132-01	.5528-01
.1743+00	-.3521-01	.9376-01	-.1035-01	.1746+00	.1000+01	.3737-01	.1520+00	-.6784-02	.4794-01
-.1620-01	.3992-01	-.5346-01	.4600-01	.9574-01	.3737-01	.1000+01	.1067+00	.3891+00	.3511-01
-.2640-01	.3112-01	.1168-01	.1764-01	.5097-01	.1520+00	.1067+00	.1000+01	.2066+00	.3643+00
.8157-01	.3182-01	-.2878-01	-.9691-01	.2132-01	-.6784-02	.3891+00	.2066+00	.1000+01	.8278-01
-.1210-01	.1864-01	.8296-02	.3340-01	.5528-01	.4794-01	.3511-01	.3643+00	.8278-01	.1000+01

NMAX = 452 LP = 3

LAG = - 8

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	28.	7.3103+00	1.5988+00	2.9522-01	2.2242+00
4	41.	7.1707+00	2.0707+00	8.8206-01	4.5798+00
5	88.	7.6512+00	1.9579+00	-3.1545-01	2.3332+00
6	105.	7.1238+00	1.7872+00	2.5398-01	2.5228+00
7	111.	7.4234+00	1.8088+00	1.6040-01	2.5480+00
8	51.	7.8078+00	1.9002+00	-1.4838-01	2.5067+00
9	15.	7.8000+00	1.8853+00	-3.0488-01	2.5474+00
10	7.	7.7143+00	1.6860+00	-1.2108+00	4.0383+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8858+00	7.0710-01	1.5001+00
3	29.	1.2590+01	2.0528+00	3.8448-02	3.2872+00
4	41.	1.2488+01	2.1989+00	1.6775-01	2.0239+00
5	88.	1.2256+01	1.9953+00	3.7447-01	3.1251+00
6	105.	1.2705+01	2.2251+00	2.2835-01	3.3448+00
7	111.	1.2757+01	2.0278+00	1.2497-01	2.3171+00
8	51.	1.3284+01	2.4034+00	9.2899-02	2.2545+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.8330+00	0.0000	1.5000+00
3	29.	8.8968+00	1.8633+00	2.2812-02	2.1290+00
4	41.	8.2927+00	2.0511+00	-1.5964-01	2.2616+00
5	86.	9.3488+00	2.2298+00	1.1463-02	2.8874+00
6	105.	9.0288+00	2.2947+00	1.5417-01	3.2807+00
7	111.	9.0090+00	1.9705+00	-2.3862-01	2.4417+00
8	51.	8.9412+00	2.0332+00	-1.4414-01	2.3134+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	29.	1.3793+01	1.8454+00	-5.7321-02	2.8006+00
4	41.	1.3463+01	2.3384+00	3.4850-01	2.3383+00
5	86.	1.3302+01	2.0407+00	5.4018-01	2.7700+00
6	105.	1.3600+01	2.1094+00	1.8170-01	2.2224+00
7	111.	1.3405+01	1.9283+00	-4.0704-02	2.4248+00
8	51.	1.3569+01	1.8529+00	4.4178-01	2.2306+00
9	15.	1.4800+01	3.1665+00	2.3333-01	2.9840+00
10	7.	1.2500+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k + 12.5$°K. The second column is the number of cases following into each category.

NMAX = 452 LP = 3

LAG = - 8

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, Z(ψ), P (φ), Z (ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8968+01	2.6498+00	-9.7129-01	2.2308+01
7.3382+00	3.4255+00	7.0286-01	3.1782+01
1.2677+01	4.6302+00	1.9143+00	5.9148+01
8.9513+00	4.5551+00	1.3970-01	5.8626+01
1.3478+01	4.4530+00	3.2237+00	5.6082+01

CORRELATION MATRIX

.1000+01	.3737-01	.1520+00	-.6784-02	.4794-01	.1743+00	-.3521-01	.9378-01	-.1035-01	.1748+00
.3737-01	.1000+01	.1067+00	.3891+00	.3511-01	-.1620-01	.3992-01	-.5348-01	.4600-01	.9574-01
.1520+00	.1067+00	.1000+01	.2066+00	.3643+00	-.2640-01	.3112-01	.1168-01	.1764-01	.5097-01
-.6784-02	.3891+00	.2066+00	.1000+01	.8278-01	.8157-01	.3182-01	-.2878-01	-.9691-01	.2132-01
.4794-01	.3511-01	.3643+00	.8273-01	.1000+01	-.1210-01	.1864-01	.8298-02	.3340-01	.5528-01
.1743+00	-.1620-01	-.2640-01	.8157-01	-.1210-01	.1000+01	.6697-01	.1417+00	.5294-02	.3268-01
-.3521-01	.3932-01	.3112-01	.3182-01	.1864-01	.6697-01	.1000+01	.1527+00	.4037+00	.4218-01
.9376-01	-.5346-01	.1168-01	-.2878-01	.8296-02	.1417+00	.1527+00	.1000+01	.2199+00	.3655+00
-.1035-01	.4600-01	.1764-01	-.9691-01	.3340-01	.5294-02	.4037+00	.2199+00	.1000+01	.7843-01
.1746+00	.9574-01	.5097-01	.2132-01	.5528-01	.3268 01	.4218-01	.3655+00	.7843-01	.1000+01

ORIGINAL PAGE IS OF POOR QUALITY

NMAX = 480 LP = 8

LAG = 18

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	35.	6.9143+00	1.8108+00	1.2789-01	2.8305+00
4	42.	7.1429+00	2.0537+00	9.2097-01	4.6728+00
5	81.	7.7284+00	2.0307+00	-2.9221-01	2.3990+00
6	86.	7.0465+00	1.8230+00	3.4567-01	2.9612+00
7	100.	7.3800+00	1.8481+00	2.7111-01	2.7891+00
8	49.	7.7551+00	1.8793+00	-1.9719-01	2.9174+00
9	13.	8.0000+00	1.3987+00	0.0000	2.1686+00
10	7.	7.7143+00	1.6880+00	-1.2105+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	35.	1.2629+01	2.0155+00	1.1220-02	3.1333+00
4	42.	1.2571+01	2.1508+00	1.0315-01	2.0966+00
5	81.	1.2370+01	2.1571+00	2.7691-01	2.5973+00
6	86.	1.2884+01	2.3547+00	7.9228-02	3.1131+00
7	100.	1.2720+01	2.0302+00	1.5348-01	2.3548+00
8	49.	1.3369+01	2.4646+00	8.0686-03	2.1386+00
9	13.	1.4000+01	1.5689+00	-9.5605-01	4.0825+00
10	7.	1.2286+01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	35.	8.6857+00	1.8481+00	1.3940-01	2.1615+00
4	42.	8.2381+00	2.1471+00	-8.8925-03	2.0981+00
5	81.	9.3580+00	2.3270+00	1.2754-01	2.8175+00
6	86.	9.2791+00	2.3608+00	4.6710-02	3.1485+00
7	100.	8.9600+00	1.9896+00	-2.7997-01	2.4181+00
8	49.	9.0612+00	1.8561+00	-1.2823-02	2.1427+00
9	13.	8.6154+00	2.2715+00	3.2248-01	1.7012+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\xi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	35.	1.3771+01	1.7742+00	-2.0867-02	2.8421+00
4	42.	1.3571+01	2.2462+00	3.2738-01	2.4606+00
5	81.	1.3481+01	2.0555+00	3.9753-01	2.8157+00
6	86.	1.3930+01	2.0561+00	-1.2289-01	2.2976+00
7	100.	1.3387+01	1.8264+00	-1.3747-01	2.5167+00
8	49.	1.3551+01	1.9490+00	4.6074-01	2.2987+00
9	13.	1.5539+01	2.7348+00	4.2083-01	3.8307+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\xi)$, and $P(\xi)$. The first column is the temperature difference class intervals k and k + 11.5 < ΔT < k + 12.5°K. The second column is the number of cases following into each category.

NMAX = 420 LP = 2

LAG =16

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, Z(9), P (9), Z (5), and P (5) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.6992+01	2.6790+00	-9.3921-01	2.3983+01
7.3257+00	3.5131+00	1.0946+00	3.5707+01
1.2739+01	4.6233+00	1.4294+00	8.2775+01
8.5910+00	4.6754+00	5.3592 01	6.0649+01
1.3500+01	4.2564+00	2.4520+00	5.3110+01

CORRELATION MATRIX

.1000+01	.6578 01	.1435+00	.2525 01	.4560 01	-.1934 01	.2017-01	-.1033+00	.3913-01	.5594-01
.6578-01	.1000+01	.1622+00	.4035+00	.4561 01	-.5595-01	.1501-01	.1359-01	-.5590-01	.1221-01
.1435+00	.1622+00	.1000+01	.2350+00	.3530+00	-.4185 01	.1211+00	.2903-01	-.5111-01	.2914-01
.2525 01	.4035+00	.2350+00	.1000+01	.8573 01	-.4380 01	.6152 01	-.9684-01	.1417-01	.1431-01
.4560 01	.4561 01	.3530+00	.8573 01	.1000+01	-.7451-01	.1216+00	.2009 01	.9815-01	-.5248-01
-.1934 01	-.5595 01	-.4185 01	-.4380 01	-.7451-01	.1000+01	.6335-01	.1721+00	-.6504-02	.5522-01
.2017 01	.1501 01	.1211+00	.6152 01	.1216+00	.6335 01	.1000+01	.1042+00	.3854+00	.4229 02
-.1033+00	.1359 01	.2903 01	-.9684 01	.2009 01	.1721+00	.1042+00	.1000+01	.2178+00	.3702+00
.3913 01	-.5590-01	-.5111 01	.1417 01	.9815 01	-.6504 02	.3854+00	.2178+00	.1000+01	.7739 01
.5594 01	.1221-01	.2914-01	.1431-01	-.5248-01	.5522-01	.4229 02	.3702+00	.7739-01	.1000+01

ORIGINAL PAGE IS OF POOR QUALITY

NMAX = 480   LP = 3

LAG = -16

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	24.	7.2500+00	1.8137+00	3.0488-01	2.2716+00
4	32.	6.8750+00	1.6536+00	3.3893-02	2.4502+00
5	76.	7.6053+00	1.9740+00	-2.5420-01	2.2084+00
6	101.	7.0891+00	1.7816+00	2.7938-01	2.5482+00
7	109.	7.4312+00	1.8192+00	1.5181-01	2.5288+00
8	49.	7.6327-00	1.8240+00	-1.7672-01	2.4806+00
9	15.	7.6000-00	1.6853+00	-3.0486-01	2.5474+00
10	7.	7.7143-00	1.6060+00	-1.2108+00	4.0363+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	24.	1.2417+01	1.9130+00	-4.2589-01	2.4233+00
4	32.	1.2375+01	2.2044+00	1.8486-01	2.0713+00
5	76.	1.2316+01	2.0014+00	3.1056-01	3.1969+00
6	101.	1.2713+01	2.2618+00	2.1431-01	3.2529+00
7	109.	1.2734+01	2.0393+00	1.5452-01	2.3109+00
8	49.	1.3347-01	2.4374+00	3.3784-02	2.2092+00
9	15.	1.3867-01	1.5434+00	-7.5558-01	3.6409+00
10	7.	1.2286-01	1.2778+00	-1.3416-01	2.3898+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	24.	8.9167+00	1.8238+00	-4.1399-02	2.1790+00
4	32.	9.1875+00	1.8947+00	-1.8758-01	2.0717+00
5	76.	9.2632+00	2.2674+00	1.0625-01	3.0298+00
6	101.	8.9703+00	2.2623+00	1.1892-01	3.3577+00
7	109.	8.9541+00	1.9460+00	-2.3429-01	2.4805+00
8	49.	8.9388+00	2.0644+00	-1.4066-01	2.2626+00
9	15.	8.4000+00	2.2151+00	4.8289-01	1.8913+00
10	7.	7.7143+00	1.6660+00	2.7238-01	1.4931+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8180-01	1.4999+00
3	24.	1.4000+01	1.9149+00	-2.8485-01	2.8761+00
4	32.	1.3062+01	2.1789+00	5.7278-01	2.7039+00
5	76	1.3237+01	2.0253+00	5.8841-01	2.7800+00
6	101.	1.3584+01	2.1307+00	1.7533-01	2.2049+00
7	109.	1.3394+01	1.9443+00	-2.4133-02	2.3881+00
8	49.	1.3469+01	1.9283+00	5.5033-01	2.4363+00
9	15.	1.4800+01	3.1665+00	2.3383-01	2.9840+00
10	7.	1.2000+01	1.0690+00	0.0000	3.4999+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and $k + 11.5 < \Delta T < k + 12.5°K$. The second column is the number of cases following into each category.

NMAX = 420 LP = 3

LAG = -16

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$ from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.9075+01	2.6073+00	-1.2728+00	2.2931+01
7.3619+00	3.3452+00	2.2541-01	2.7361+01
1.2676+01	4.6856+00	1.6905+00	6.3078+01
8.9048+00	4.4765+00	3.2753-01	5.7681+01
1.3429+01	4.4544+00	3.4799+00	5.6644+01

CORRELATION MATRIX

.1000+01	.6395-01	.1724+00	-.6504-02	.5562-01	-.1934-01	-.9286-01	-.4486-01	-.4384-01	-.7451-01
.6395-01	.1000+01	.1042+00	.3854+00	.4229-02	.2017-01	.1601-01	.1211+00	.8362-01	.1218+00
.1724+00	.1042+00	.1000+01	.2178+00	.3702+00	-.1033+00	.1300-01	.2903-01	-.9084-01	.2004-01
-.6504-02	.3854+00	.2178+00	.1000+01	.7739-01	.3913-01	-.5599-01	-.5111-01	.1417-01	.9815-01
.5562-01	.4229-02	.3702+00	.7739-01	.1000+01	.5994-01	.1221-01	.2914-01	.1431-01	-.5248-01
-.1934-01	.2017-01	-.1033+00	.3913-01	.5994-01	.1000+01	.8578-01	.1435+00	.2655-01	.4569-01
-.9266-01	.1601-01	.1300-01	-.5599-01	.1221-01	.8578-01	.1000+01	.1622+00	.4038+00	.4661-01
-.4486-01	.1211+00	.2903-01	-.5111-01	.2914-01	.1435+00	.1622+00	.1000+01	.2369+00	.3630+00
-.4384-01	.8362-01	-.9084-01	.1417-01	.1431-01	.2655-01	.4038+00	.2369+00	.1000+01	.8578-01
-.7451-01	.1216+00	.2004-01	.9815-01	-.5248-01	.4569-01	.4661-01	.3630+00	.8579-01	.1000+01

NMAX = 356 LP = 2

LAG = 24

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

Z(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4998+00
3	32.	6.7500+00	1.7139+00	9.3105-02	2.3599+00
4	38.	7.1579+00	2.0330+00	1.0832+00	5.0903+00
5	71.	7.6310+00	2.0823+00	-3.7020-01	2.4295+00
6	70.	7.0000+00	1.7485+00	1.2829-01	2.3081+00
7	80.	7.4250+00	1.9024+00	2.5176-01	2.7862+00
8	41.	7.9024+00	1.9730+00	-3.5981-01	2.4692+00
9	11.	8.0000+00	1.2060+00	8.6982-08	2.7499+00
10	6.	7.6667+00	1.7951+00	-1.0501+00	3.3781+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ψ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	32.	1.2562+01	2.0757+00	6.9593-02	3.0391+00
4	38.	1.2421+01	2.1598+00	2.0179-01	2.1285+00
5	71.	1.2338+01	2.2262+00	2.7826-01	2.5006+00
6	70.	1.3057+01	2.3597+00	1.4045-01	3.0819+00
7	80.	1.2850+01	2.0439+00	6.2441-02	2.4272+00
8	41.	1.3122+01	2.3394+00	-9.8539-03	2.1428+00
9	11.	1.4000+01	1.7056+00	-6.7946-01	3.4371+00
10	6.	1.2000+01	1.1547+00	0.0000	2.9998+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Z(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	32.	8.5000+00	1.8028+00	2.5602-01	2.8781+00
4	38.	8.1053+00	2.1000+00	3.1358-02	2.1070+00
5	71.	9.2676+00	2.4028+00	1.9549-01	2.7622+00
6	70.	9.2000+00	2.2776+00	-4.4008-02	2.7998+00
7	80.	8.8250+00	2.0235+00	-3.6855-01	2.4167+00
8	41.	9.0244+00	1.0278+00	-3.6049-02	2.1883+00
9	11.	9.0909+00	2.1513+00	1.0142-01	1.7165+00
10	6.	8.0000+00	1.6330+00	0.0000	1.5000+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

P(ζ)

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2657+01	2.4944+00	3.8180-01	1.4999+00
3	32.	1.3750+01	1.7854+00	-1.6474-02	2.9239+00
4	38.	1.3632+01	2.2875+00	2.5871-01	2.4354+00
5	71.	1.3606+01	2.0880+00	3.2565-01	2.5537+00
6	70.	1.4086+01	2.0684+00	-1.0312-01	2.3019+00
7	80.	1.3500+01	1.7464+00	-2.8159-01	2.4040+00
8	41.	1.3561+01	1.9006+00	6.2004-01	2.4931+00
9	11.	1.5273+01	2.8633+00	6.5446-01	3.9093+00
10	6.	1.1667+01	7.4536-01	-1.7889+00	4.1971+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Central moments for given temperature distribution. These four tables refer, respectively, to Z(ψ), P(ψ), Z(ζ), and P(ζ). The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k + 12.5$°K. The second column is the number of cases following into each category.

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NMAX = 350 LP = 8

LAG =32

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$ from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.8829+01	2.9892+00	-8.9931-01	2.5688+01
7.4101+00	3.6857+00	7.2778-01	3.7541+01
1.2725+01	4.9467+00	1.4712+00	6.3241+01
8.9157+00	4.6333+00	4.1352-01	5.7841+01
1.3669+01	4.2609+00	2.4082+00	5.4529+01

CORRELATION MATRIX

.1000+01	.1030+00	.1501+00	.6321-01	.4229-01	-.1117+00	.2779-01	-.9315-01	.8954-02	-.1794+00
.1030+00	.1000+01	.1501+00	.4135+00	.1871-01	.2644-01	.6457-01	.2751-01	.7386-01	.8767-02
.1501+00	.1501+00	.1000+01	.2369+00	.3852+00	-.7679-01	.1358-01	.5340-01	-.3290-02	.5545-02
.6321-01	.4135+00	.2369+00	.1060+01	.8866-01	-.3038-01	.3941-01	.6699-01	.6356-01	-.6907-02
.4229-01	.1871-01	.3852+00	.8866-01	.1000+01	-.1282+00	-.6063-01	-.7960-01	.4414-01	.2677-01
-.1117+00	.2644-01	-.7679-01	-.3038-01	-.1282+00	.1000+01	.6288-01	.2244+00	.5570-03	.9679-01
.2779-01	.6457-01	.1358-01	.3941-01	-.6063-01	.6288-01	.1000+01	.1272+00	.4162+00	-.1293-01
-.9315-01	.2751-01	.5340-01	.6699-01	-.7960-01	.2244+00	.1272+00	.1000+01	.2042+00	.3728+00
.8954-02	.7386-01	-.3290-02	.6356-01	.4414-01	.5570-03	.4162+00	.2042+00	.1000+01	.6892-01
-.1794+00	.8767-02	.5545-02	-.6907-02	.2677-01	.9679-01	-.1293-01	.3728+00	.6892-01	.1000+01

NMAX = 356 LP = 3

LAG = -32

CENTRAL MOMENTS FOR GIVEN TEMPERATURE DISTRIBUTION

$Z(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	7.5000+00	8.6603-01	-1.1547+00	2.3333+00
2	3.	7.3333+00	9.4281-01	-7.0710-01	1.4999+00
3	23.	7.3043+00	1.6268+00	2.3000-01	2.2425+00
4	26.	6.7692+00	1.7608+00	1.8408-01	2.3375+00
5	59.	7.3898+00	1.9917+00	-8.1947-02	2.2821+00
6	89.	6.9438+00	1.7509+00	3.3720-01	2.8049+00
7	90.	7.3333+00	1.8135+00	2.5832-01	2.7063+00
8	41.	7.5122+00	1.9846+00	-1.1472-01	2.4988+00
9	15.	7.6000+00	1.6853+00	-3.0486-01	2.5474+00
10	6.	7.6667+00	1.7951+00	-1.0501+00	3.3781+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\psi)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.0000+01	1.4142+00	0.0000	2.0000+00
2	3.	1.1333+01	1.8856+00	7.0710-01	1.5001+00
3	23.	1.2522+01	1.8852+00	-5.3987-01	2.6661+00
4	26.	1.2000+01	2.1485+00	3.7238-01	2.2533+00
5	59.	1.2136+01	1.9086+00	9.8578-02	3.0073+00
6	89.	1.2652+01	2.2591+00	3.6584-01	3.3995+00
7	90.	1.2756+01	2.0893+00	1.2271-01	2.2516+00
8	41.	1.3610+01	2.3465+00	1.1087-01	2.0436+00
9	15.	1.3867+01	1.5434+00	-7.5558-01	3.6409+00
10	6.	1.2333+01	1.3744+00	-2.2827-01	2.1075+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$Z(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	9.0000+00	1.7321+00	-1.1547+00	2.3333+00
2	3.	8.0000+00	1.6330+00	0.0000	1.5000+00
3	23.	9.0435+00	1.7564+00	-6.8256-02	2.3007+00
4	26.	8.3846+00	1.7558+00	-4.2386-02	1.8837+00
5	59.	8.9831+00	2.1509+00	-9.9415-02	2.6268+00
6	89.	8.8315+00	2.2795+00	1.8522-01	3.3813+00
7	90.	8.9556+00	1.9374+00	-1.9397-01	2.3088+00
8	41.	8.9268+00	2.1229+00	-1.4893-01	2.2118+00
9	15.	8.4000+00	2.2151+00	4.8285-01	1.8913+00
10	6.	8.0000+00	1.6330+00	0.0000	1.5000+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

$P(\zeta)$

		AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1	4.	1.1000+01	1.0000+00	0.0000	1.0000+00
2	3.	1.2667+01	2.4944+00	3.8190-01	1.4999+00
3	23.	1.3913+01	1.9091+00	-2.1320-01	2.9338+00
4	26.	1.2692+01	1.9169+00	8.3514-01	3.5996+00
5	59.	1.2881+01	1.8511+00	8.1514-01	3.4569+00
6	89.	1.3438+01	2.0769+00	1.5835-01	2.2299+00
7	90.	1.3333+01	1.9551+00	6.3438-02	2.4413+00
8	41.	1.3463+01	2.0254+00	5.5505-01	2.3188+00
9	15.	1.4800+01	3.1665+00	2.3383-01	2.9940+00
10	6.	1.2000+01	1.1547+00	0.0000	2.9998+00
11	0.	0.0000	0.0000	0.0000	0.0000
12	0.	0.0000	0.0000	0.0000	0.0000

Table III-6 Central moments for given temperature distribution. These four tables refer, respectively, to $Z(\psi)$, $P(\psi)$, $Z(\zeta)$, and $P(\zeta)$. The first column is the temperature difference class intervals k and $k + 11.5 \le \Delta T < k + 12.5°K$. The second column is the number of cases following into each category.

NMAX = 358 LP = 3

LAG = -32

CENTRAL MOMENTS Central moments of all variables. The rows are ΔT, Z(ψ), P (ψ), Z (ζ), and P (ζ) from the first to the fifth.

AVERAGE	STD. DEV.	SKEWNESS	KURTOSIS
1.9070+01	2.7535+00	-1.5440+00	2.5618+01
7.2416+00	3.3461+00	7.0134-01	2.8585+01
1.2652+01	4.7214+00	1.9983+00	6.1411+01
8.8427+00	4.3236+00	6.6702-02	5.1141+01
1.3298+01	4.3720+00	4.1862+00	5.8490+01

CORRELATION MATRIX

.1000+01	.6288-01	.2244+00	.5570-03	.9679-01	-.1117+00	.2644-01	-.7879-01	-.3038-01	-.1282+00
.6288-01	.1000+01	.1272+00	.4162+00	-.1293-01	.2779-01	.6457-01	.1358-01	.3941-01	-.6063-01
.2244+00	.1272+00	.1000+01	.2042+00	.3728+00	-.9315-01	.2751-01	.5340-01	.6699-01	-.7960-01
.5570-03	.4162+00	.2042+00	.1000+01	.6832-01	.8954-02	.7386-01	-.3290-02	.6358-01	.4419-01
.9579-01	-.1293-01	.3728+00	.5892-01	.1000+01	-.1794+00	.8767-02	.5545-02	-.6907-02	.2677-01
-.1117+00	.2779-01	-.9315-01	.8954-02	-.1794+00	.1000+01	.1030+00	.1501+00	.6321-01	.4229-01
.2644-01	.6457-01	.2751-01	.7386-01	.8767-02	.1030+00	.1000+01	.1501+00	.4135+00	.1871-01
-.7679-01	.1358-01	.5340-01	-.3290-02	.5545-02	.1501+00	.1501+00	.1000+01	.2369+00	.3852+00
-.3038-01	.3941-01	.6699-01	.6356-01	-.6907-02	.6321-01	.4135+00	.2369+00	.1000+01	.9866-01
-.1282+00	-.6063-01	-.7960-01	.4414-01	.2677-01	.4229-01	.1871-01	.3852+00	.9866-01	.1000+01

APPENDIX B. VACILLATING CIRCULATIONS

The Basic States

Simulations relating to large scale atmospheric motions have been performed experimentally, as opposed to numerically, using a rotating vessel containing a fluid which is differentially heated. The typical vessel is either an annulus or an open dishpan, which does not have the central core. These simulations yield both axisymmetric and irregular flow regimes which are illustrated in Figure A-1. A steady wave regime can also be established in an annulus. Fultz et al (1959) and Lorenz (1967) seem to imply that the steady wave regime is limited to the annulus; but Hide (1970) claims this is erroneous.

The particular flow regime which is established in the annular fluid depends upon two parameters: the rate of rotation of the system and the temperature differential maintained between the outer wall and the inner core. These parameters can be conveniently represented by two nondimensional numbers which characterize the flow: The Taylor number

$$Ta = \frac{4\Omega^2 \Delta r^4}{\nu^2} ,$$

where Ω is the rotation rate, Δr is a characteristic length and ν is the viscosity of the fluid; and the thermal Rossby number

$$Ro_T = \frac{gd\varepsilon\Delta T}{\Omega^2 \Delta R^2} ,$$

where g is the acceleration of gravity, d is the depth of the fluid, ΔR is the width of the annular gap, ΔT is the temperature differential measured externally and ε is the coefficient of volume expansion.

Using these two parameters, the flow regimes can be graphically represented as shown in Figure A-2a. Figure A-2b illustrates a result from an experiment (Fowlis and Hide, 1965) to determine the boundaries of each regime. This last figure should not be considered to be universal for the transition points between the different flow regimes as these values also depend on the Prandtl number.

The basic flow regimes can also be classified as shown in Figure A-3. In this classification, the regular regime is subdivided into regular waves and vacillation. Vacillation is a form of regular flow where certain characteristics of the flow vary either periodically or quasi-periodically. And, as shown in Figure A-3, vacillation may take any of three basic forms.

Wave Form Vacillation

Wave form vacillation, or tilted trough vacillation, was originally observed by Hide (1953) as a wavering in the shape of the flow pattern. A complete cycle of this type of vacillation is shown in Figure A-4 where one sees that the troughs tilt first one way and then the other. In this type of vacillation, one finds a regular change of wave shape and wave progression.

This form of vacillation is observed to take place in the transition from the steady wave regime to the irregular flow regime. Lorenz (1963) has hypothesized that this form of vacillation arises from the instability of the steady wave regime to small perturbations in the region of transition; and, further, he hypothesized that at higher rotation rates the vacillating flow is unstable to small pertubations giving rise to the irregular flow. Pfeffer and Chiang (1967) from the data of Fultz et al (1959) noted that "the rate of conversion of kinetic energy between the eddies and the mean zonal flow ... undergoes substantial fluctuations on magnitude, and apparently also in sign, during this (vacillation) cycle." This led Pfeffer and Chiang to term this phenomenon kinetic energy vacillation.

It seems not unreasonable to view the axisymmetric regime as a baroclinic fluid which under increased rotation becomes unstable to only the most unstable mode of oscillation. This should follow from the linear theories of baroclinic instability. Further increases in rotation will lead to the instability of other modes of oscillation accompanied by nonlinear interaction between the waves. Viewed in this manner, wave form vacillation is seen as the first manifestation of this nonlinear interaction - taking place between the principle mode and the zonal current.

The principle consequence of wave form vacillation for the atmospheric circulation appears to lie in the fact that this phenomenon shows the capacity of a fluid motion to sustain a strictly periodic fluctuation. Thus, this phenomenon lends some credence to the observations of quasi-periodic fluctuations in the atmosphere, such as the index cycle.

Wave-Number Vacillation

Fultz has been ascribed to have first noted wave-number vacillation in a dishpan experiment in the transition region between two adjacent steady wave regimes (see Pfeffer and Chiang, 1965). Figure A-5b shows a wave pattern giving evidence of both wave dispersion and wave drift. According to Pfeffer and Fowlis (1968), the wave dispersion arises with the simultaneous presence of adjacent wave numbers between which nonlinear interations are not immediately evident. Figure A-5a illustrates such a simultaneous presence of two waves and should be compared with Figure A-5b.

In an experiment, which differs significantly from those discussed to this point, Snyder and Youtz (1969) produced wave number transitions in a periodic manner by sinusoidally varying the imposed temperature difference across the annulus. Again, such transitions occur only near a wave-number transition point on the Ro_T-Ta diagram. Figure A-6 shows various "steady states" which resulted from this experiment. Snyder and Yontz described the transition from a three wave pattern, A-6a, to two wave patterns as occurring in any of three ways: (1) A-6a disappears entirely giving way to a circular jet which in turn is transformed by the appearance of the two lobe pattern A-6b; (2) one lobe becomes detached and drifts downstream until it coalesces with the next lobe resulting in pattern A-6c; pattern A-6 may become confused, with the jet disappearing entirely, and with pattern 6d or 6e ultimately resulting. The return to the three wave pattern involves similar but not identical sequences.

The applicability of these results to transitions between dominant wave numbers in the atmosphere is uncertain. The asymmetric patterns such as described as wave dispersion are remeniscent of upper level patterns found in the atmosphere - perhaps indicating the presence of more than one dominant wave number - but more likely related to the asymmetric land-sea distribution. Again, the experiment of Synder and Yontz appears to simulate some aspects of seasonal changes in the atmosphere but the experiment resulted in the conclusion that the seasonal cycle was too fast or the temperature gradients too weak to give rise to such wave-number transitions.

Amplitude Vacillation

Amplitude vacillation was apparently first described by Pfeffer and Chiang (1967). Figure A-7 shows typical cycles of this phenomenon. It is noted that the wave pattern can disappear entirely giving way to axisymmetric flow. Thus, amplitude vacillation is similar to the description of the index cycle, except that it is a nearly periodic cycle whereas the index cycle is not.

Amplitude vacillation occurs near the transition between axisymmetric and regular flow (Ketchum, 1972). It may be obtained by increasing the temperature gradient after a steady wave pattern has beer established or, as seen from Figure A-8, the rotation rate can be decreased at a constant temperature difference obtaining increasingly stronger amplitude vacillation. It has been suggested that "amplitude vacillation takes place well within the steady wave regime and that it is most pronounced at lower Taylor numbers, higher thermal Rossby numbers, and higher Prandtl numbers" (Pfeffer and Chiang, 1969).

Pfeffer et al (1974) have discussed some of the synoptic features and transport properties of a fluid circulation undergoing amplitude vacillation. Their study pointed out that tilted trough and amplitude vacillation not only differ in that no tilt of the trough was observed in the latter but also in the energy cycles responsible for the phenomena. Tilted trough vacillation appears to result from conversions of eddy kinetic energy to zonal kinetic energy ($K_E \rightarrow K_Z$); whereas, amplitude vacillation depends on conversion between available potential and kinetic energy, ($A_Z \rightarrow K_Z$) and ($A_E \rightarrow K_E$). Consequently, amplitude vacillation has been viewed as a more strictly baroclinic process.

The physical processes leading to amplitude vacillation imply a strictly baroclinic process. The applied temperature gradient produces available potential energy which is manifest as an interior temperature differential that increases during the axisymmetric flow regime. As the internal temperature gradient increases, the thermal wind grows and perturbations begin to grow rapidly until the wave regime is established. The internal temperature gradient is significally reduced by the eddy transport of heat and the wave regime weakens. At this point the cycle begins anew.

Related Atmospheric Studies

The most prominantly mentioned quasi-periodic flow property observed in the atmosphere is the so-called index cycle. In an index cycle the upper air circulation is supposed to oscillate between periods of strong zonal flow and periods of eddy dominated flow. The period of the cycle ranges between 3 to 8 weeks (Willett and Sanders, 1959). Figures A-9 shows a record of the zonal index between November 1936 and May 1938 as given by Namias and Clapp (1951). However, when Julian (1966) subjected such records to statistical analysis he had to conclude that "... if a phenomenon so distinct as to be named 'the index cycle' has an existence apart from the shifts or displacements of the easterlies covering a very broad range of frequency characteristic of 'normal' atmospheric variability, the coherence statistic, ..., should confirm that existence. The data do not give evidence for such a confirmation."

Yeh, Dao and Li (1959) noted a sudden shift in the dominant planetary wave number from three to four between the winter and summer Northern Hemispheric circulations and from four to three in going from summer to winter. They proposed to explain this by the weakening of the temperature gradient during the summer leading to the transition in circulation. This corresponds to the observed transition found in dishpan experiments; but, as noted before, Synder and Yontz (1969) conducting an experiment with a sinusoidal variation of the temperature gradient concluded that the atmospheric seasonal variation was not great enough to lead to such a transition in wave number. Also, Yeh, Dao, and Li concluded that this effect should be more evident in the Southern Hemisphere; however, in the Southern Hemisphere Webster and Curtin have concluded from observations of balloons drifting near the 200 mb level that the dominant wave number undergoes transition but that wave number three dominates from December to February and also from June to August, March to May possesses a strong four wave pattern and September to November has a three or four wave pattern. Consequently, it appears that wave number transitions are probably not simply a response to increased temperature differentials between equator and pole.

Webster and Keller (1974) have observed from Southern Hemisphere balloon data an 18 - 24 day variation in the circulation. One possible explanation considered for this variation was that the circulation was responding to an amplitude vacillation; however, Webster and Keller (1975) found that barotropic processes play too important a role for this to be the case. Consequently, one has to look to other explanations for this quasi-periodic variation.

Pfeffer and Chiang (1967) have cited a study by Winston and Krueger (1961) of a cycle of available potential energy observed between late December 1958 and early January 1959 as an example of amplitude vacillation. Figure A-10 taken from Winston and Krueger illustrate the strengthening of the four wave pattern between December 26 and January 10. However, interestingly, the period from early January 1959 to late January 1959 has been noted by Palmen and Newton (1969) as a period of transition from a dominant four wave pattern to a dominant five wave pattern in a description remeniscent of Synder and Yontz's (1969) description of wave-number transitions in an annulus.

Thus, while one believes that vacillation phenomena, as observed in geophysical experiments, should have a counterpart in the atmospheric circulation, no clear example is readily available.

Theoretical Studies Relative to Vacillation

There have been several theoretical studies which are directly applicable to the phenomenon of vacillation. Lorenz (1962, 1963) using a simple mathematical model has investigated the mechanics of vacillation. He found that the occurrence of vacillation (wave-form vacillation) was due to the instability of the steady Rossby flow. Considering Pfeffer and Chiang's (1967) description of this process as "kinetic energy vacillation" and its relationship to barotropic processes, this form of vacillation may be a magnifestion of the barotropic instability of Rossby wave motion described by Lorenz (1972) and further discussed by Hoskin and Hollingsworth (1973). This connection between vacillation and barotropic Rossby wave instability does not appear to have been made previously. Figure A-11 from Lorenz's (1972) paper shows the distortion of the Rossby wave due to barotropic instability which has some of the appearance of tilted trough vacillation.

Meriles (1972) applied Lorenz's simple mathematical model to the study of amplitude vacillation. He was able to obtain solutions which bear a "remarkable resemblence" to amplitude vacillation, as shown in Figure A-12. However, the results did not reveal the cause of the vacillation.

Pedlosky (1970, 1971, 1972) in a series of papers has put forth a theory of finite amplitude baroclinic waves which has most completely described the occurrence of amplitude vacillation. Using a two layer quasi-geostropic model similar to that of Phillips (1954), Pedlosky (1970) analytically solved the system of model equations under certain simplifying assumptions. When sufficient dissipation was included in the model, the perturbation wave reached a steady, finite wave amplitude; but when no dissipation was included the amplitudes of the baroclinic wave and of the mean flow were found to oscillate. The amplitude oscillation was also found to be present for small values of dissipation. Following on this result, Pedlosky (1971) attempted to develop a theory to connect the steady and the oscillating regimes. In so doing he discovered that if the dissipation is small enough the amplitude oscillation may approach a limit cycle and, thus, be independent of the initial conditions. Pedosky (1972) later explored the limit cycles of the unstable baroclinic waves further. Smith (1974) noted that the deliberate neglection of a side wall boundary condition introduced a spurious kinetic energy source which could have been responsible for the limit cycle solution; and, hence, he called into question the relevance of Pedosky's study. However, further study has convinced Smith (1975) that Pedlosky's results were indeed correct.

Application to Study

Vacillation has been observed in geophysical experiments, has been noted in numerical circulation models, and has received the attention of several theoretical studies. However, there appears to be no well documented synoptic cases. The advantage of geophysical fluid experiments, other than the obvious ability to unify our concept of fluid responses to rotating systems, is to isolate specific processes, such as baroclinic instability and vacillation, from the complexities of the irregular flow. If one assumes the general circulation to be an irregular flow regime, then vacillation may yield an insight into some of the processes active during the amplification and weakening of atmospheric waves or during wave-number transitions in the atmosphere. Possible synoptic cases of vacillation should, however, be sought and subjected to study.

On the theoretical side, it would appear feasible to at least formulate the barotropic Rossby wave instability problem in terms of the annulus experiment. Then one could determine the form the resulting unstable waves would take in this coordinate system to compare with the cases of vacillation

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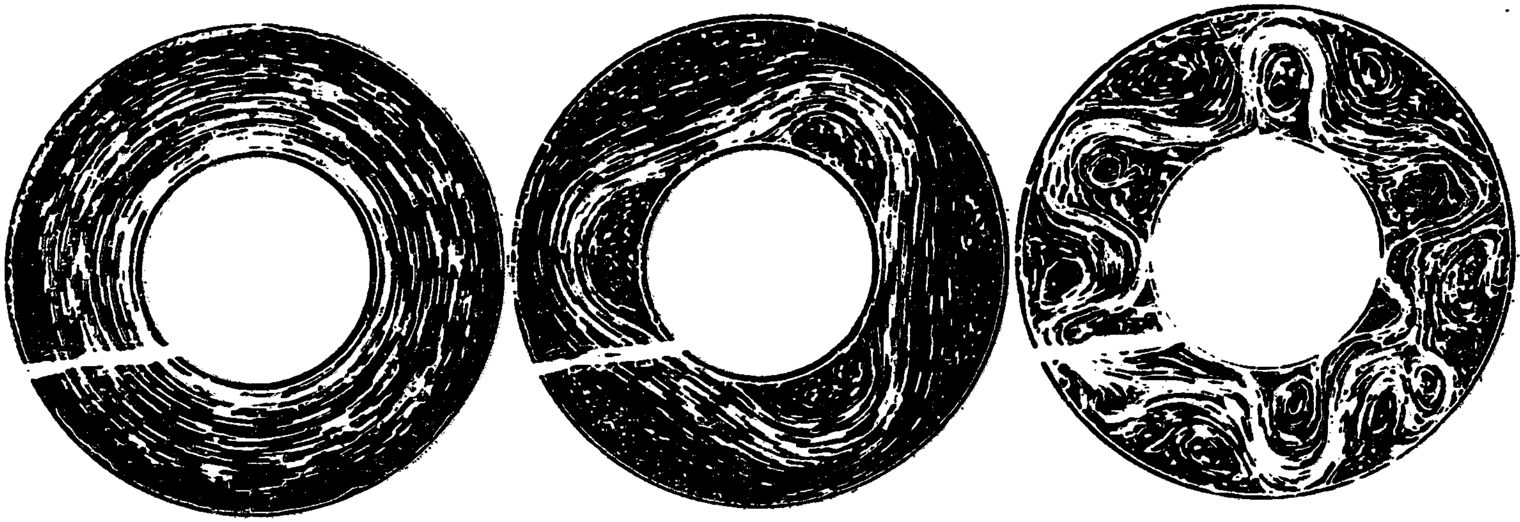

(I) symmetric (Ω = 0·341 rad s^{-1})

(II) steady waves (Ω = 1·19 rad s^{-1})

(III) irregular (Ω = 5·02 rad s^{-1})

Figure B-1. Annular Flow Regimes (Hide, 1969)

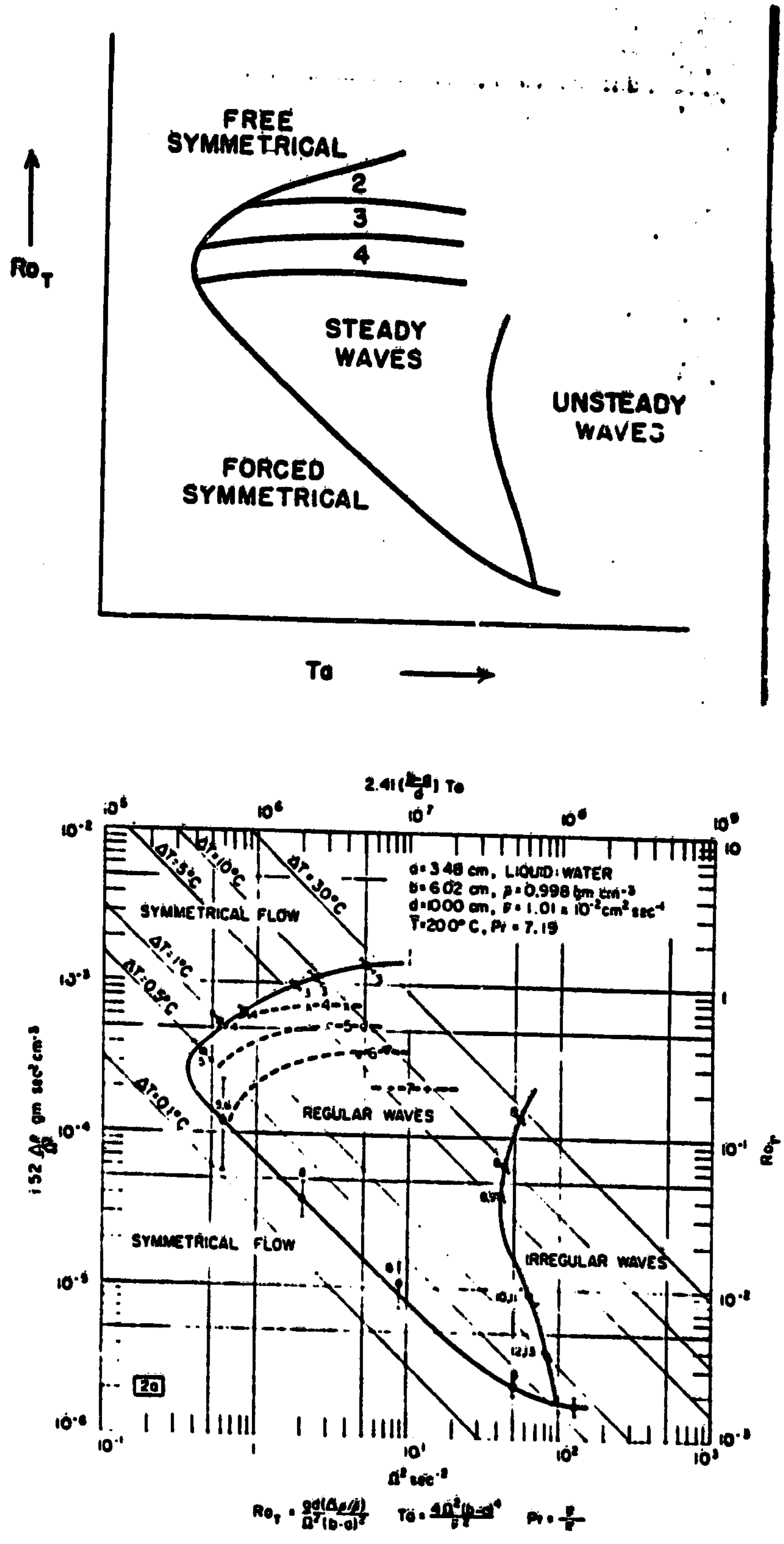

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Figure B-2. Flow regime dependence on Taylor number Ta and thermal Rossby number Ro_T: (a) general (Pfeffer and Chiang, 1969), b. experimentally determined (Fowlis and Hide, 1965)

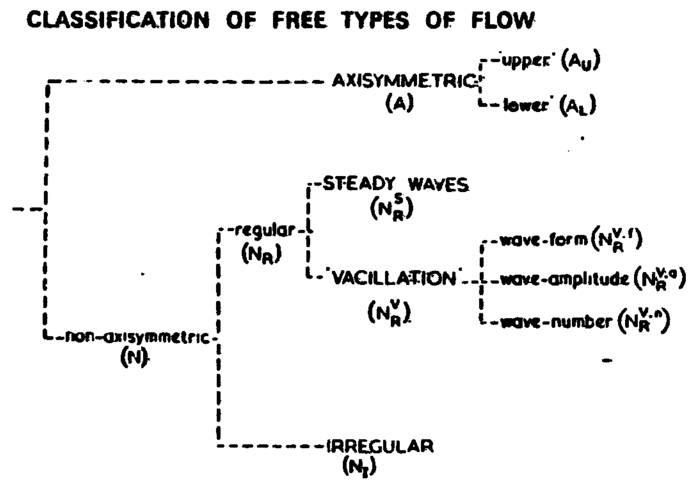

Figure B-3. Classification of flow regimes in an annulus (Hide, 1969)

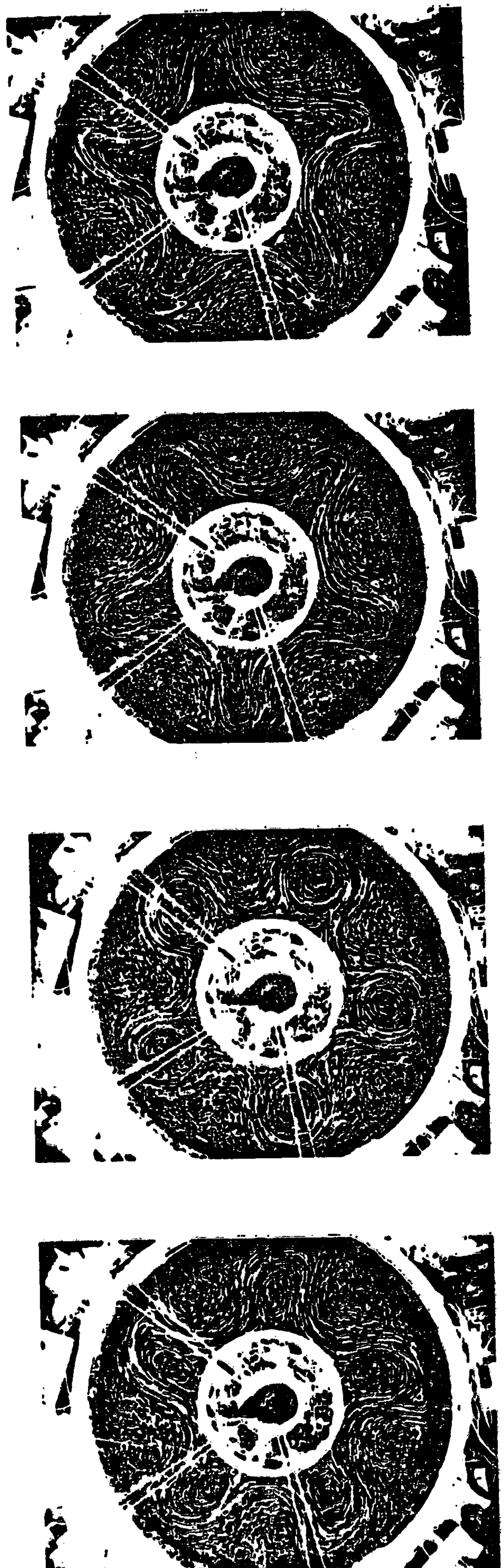

Figure B-4. Example of wave-form or tilted-trough vacillation (Lorenz, 1967)

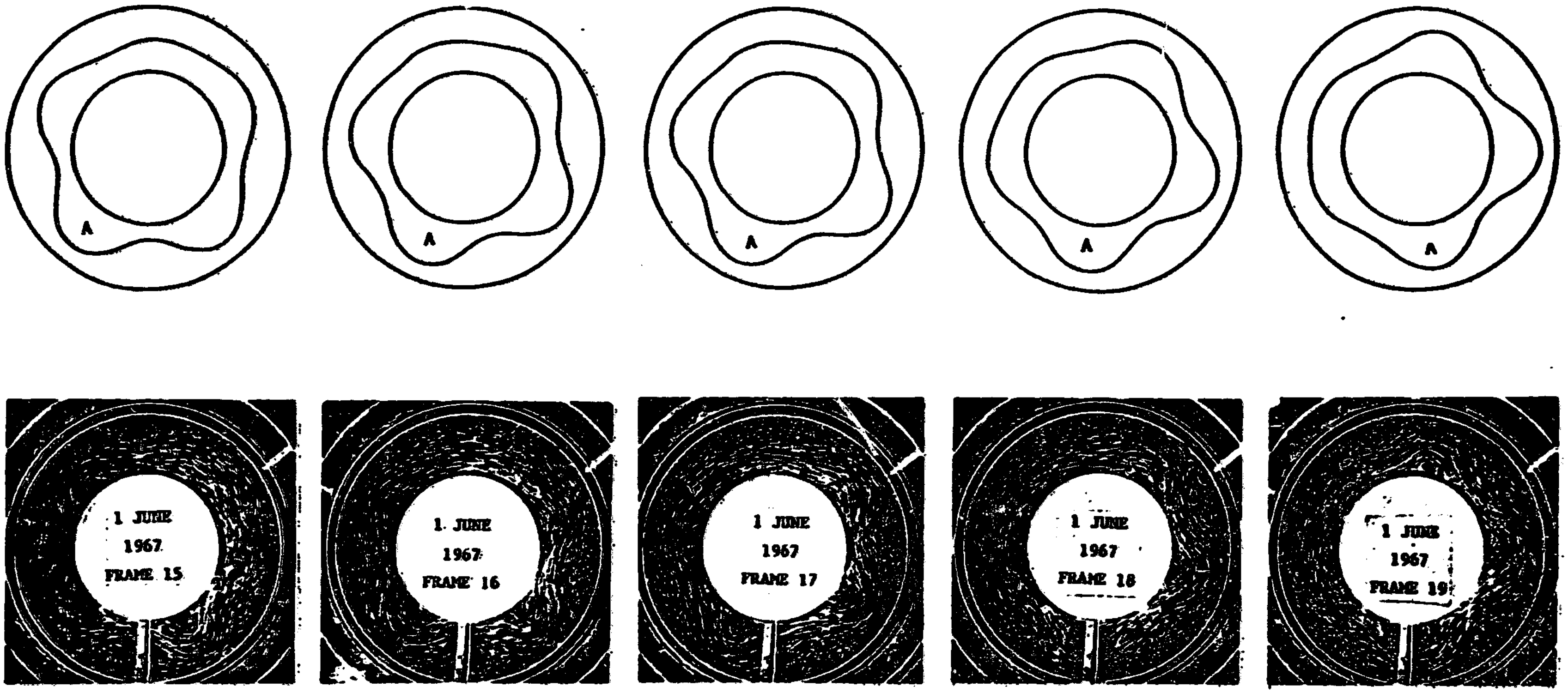

Figure B-5. Example of wave-number vacillation: (a) Computer generated using adjacent wave numbers (b) Observed phenomenon (Pfeffer and Fowlis, 1968)

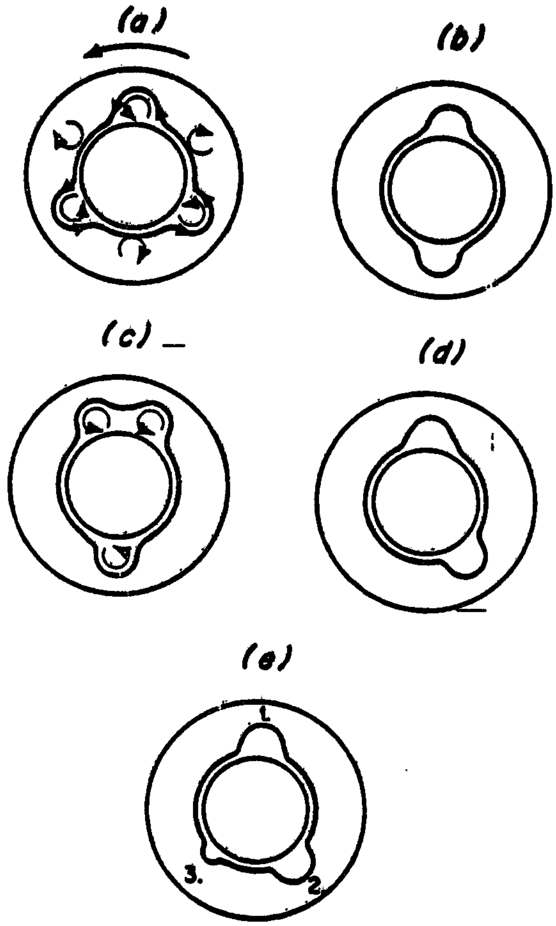

Figure B-6. Steady wave regimes for a sinusoidally varying temperature gradient experiment (Synder and Yontz, 1969)

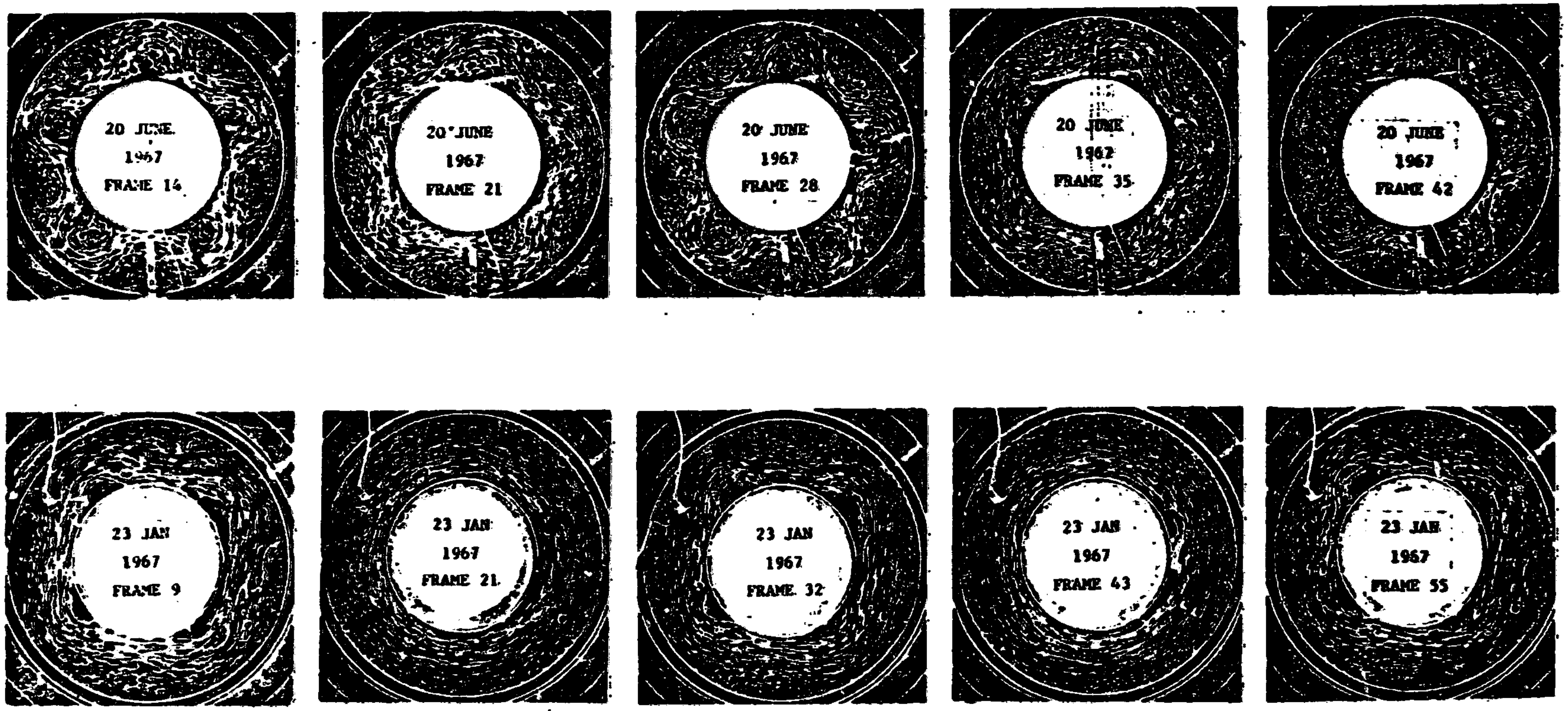

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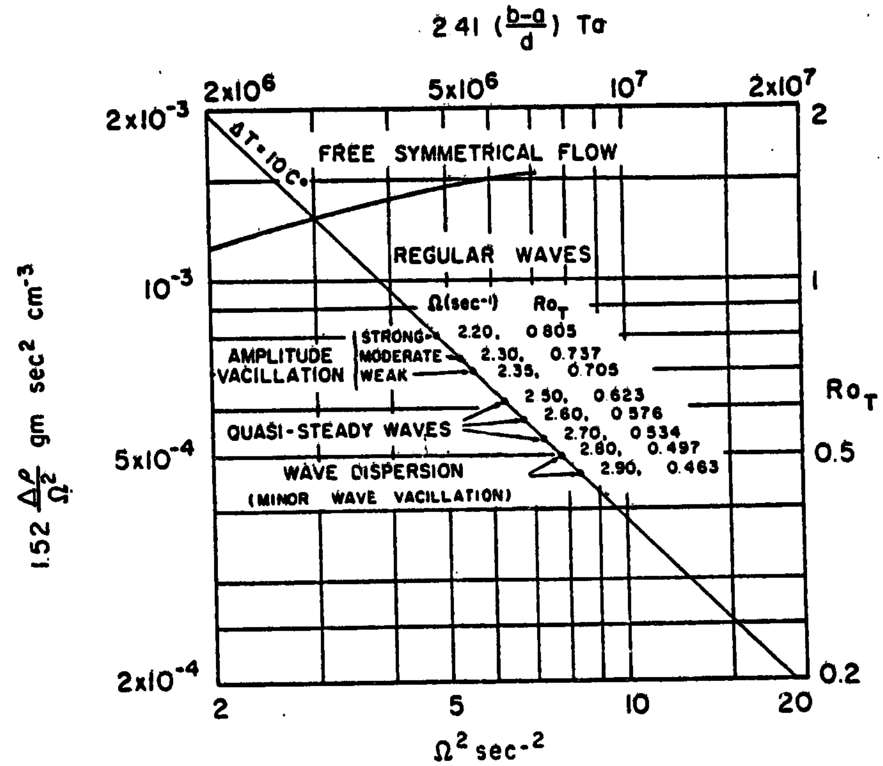
Figure B-7. Examples of amplitude vacillation: (a) five-wave; (b) four-wave (Pfeffer and Fowlis, 1968)



$$Ro_T = \frac{gd(\Delta\rho/\bar{\rho})}{\Omega^2(b-a)^2}, \quad Ta = \frac{4\Omega^2(b-a)^4}{\nu^2}, \quad Pr = \frac{\nu}{\kappa}$$

Figure B-8. The establishment of amplitude vacillation by decreasing the rotation rate (Fowlis and Pfeffer, 1969)

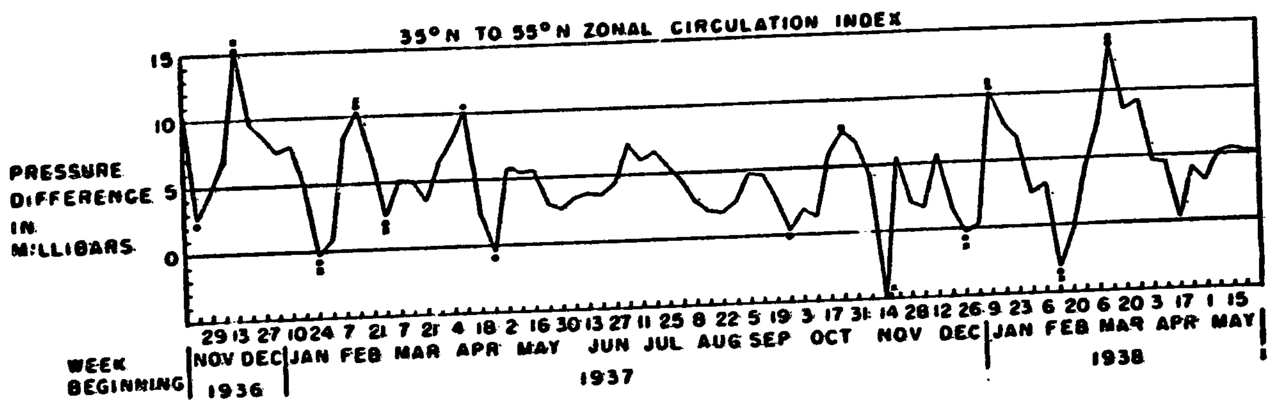


Figure B-9. Index cycle (Namias and Chapp, 1951)

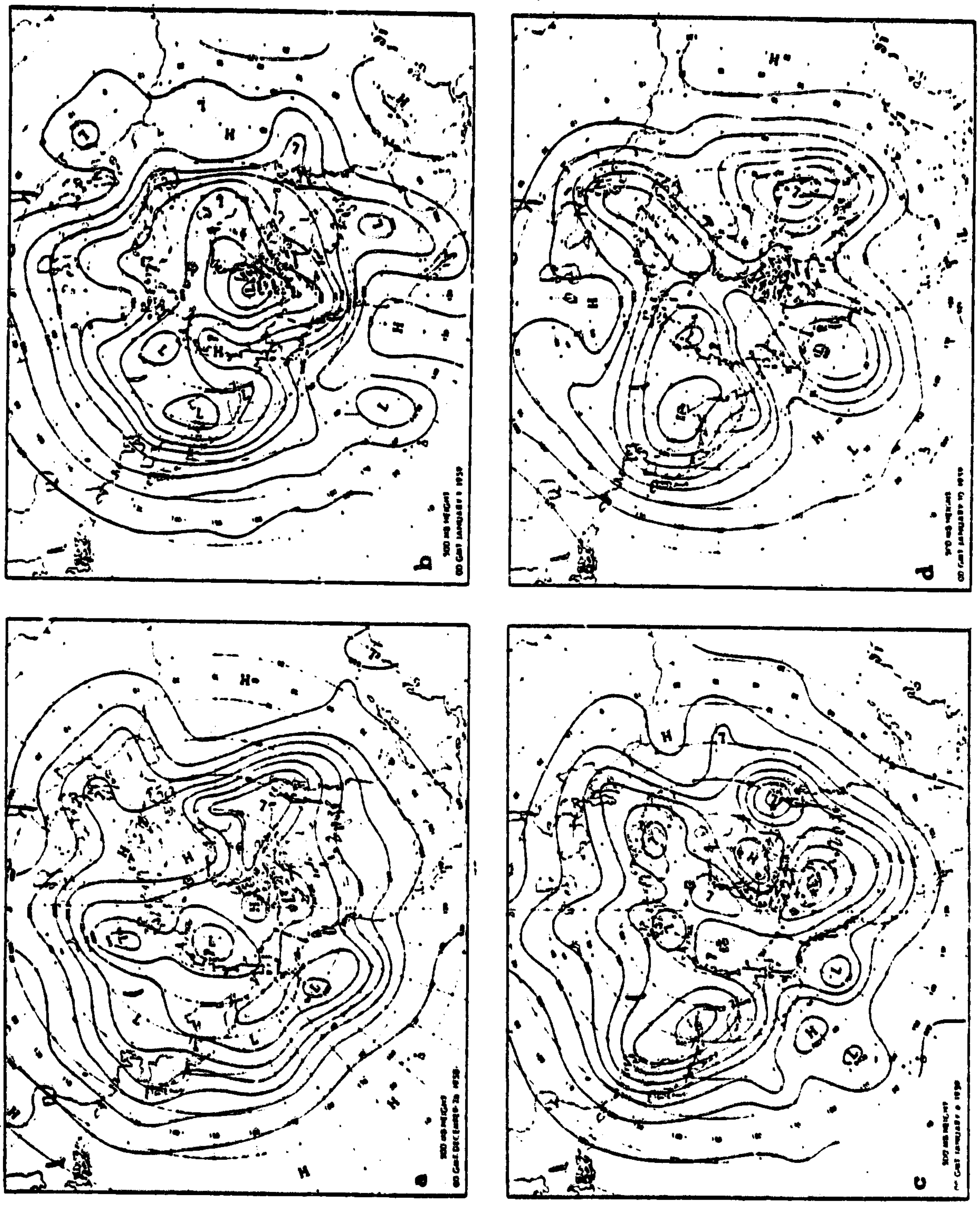


Figure B-10. Synoptic example of amplitude vacillation (Winston and Krueger, 1961)

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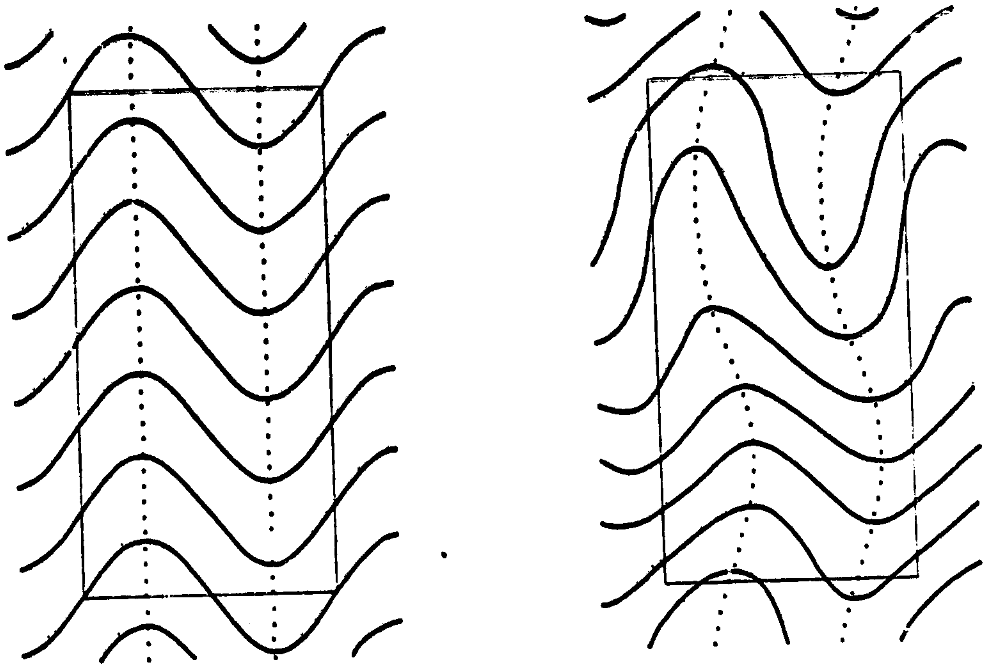

Figure A-11. Steady Rossby waves (a) undergoing barotropic instability (b) (Lorenz, 1972)

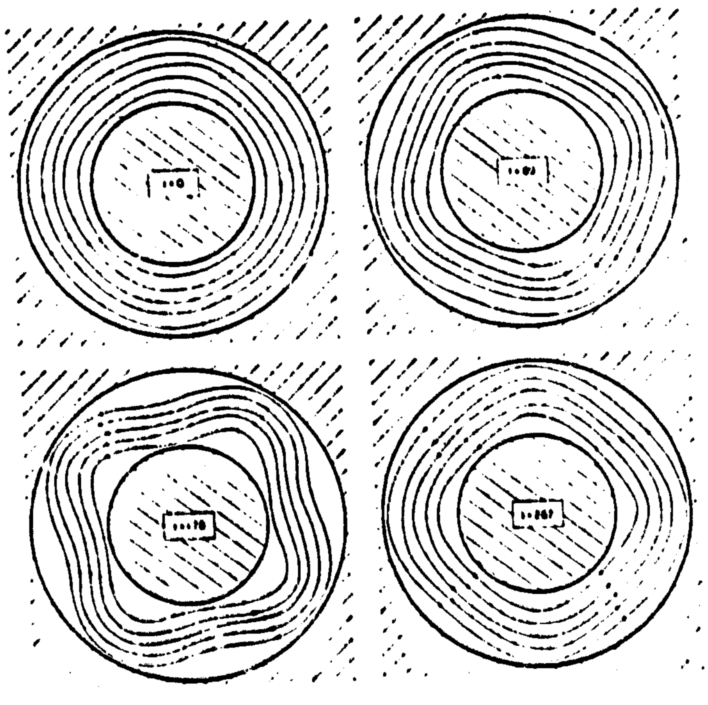

Figure A-12. Computer modeled amplitude vacillation (Merilees, 1972). Compare with Figure A-7