U. S. DEPARTMENT OF COMMERCE
Charles Sawyer, Secretary
U.S. WEATHER BUREAU
F. W. Reichelderfer, Chief

RESEARCH PAPER NO. 12

NOTES ON INTERDIURNAL PRESSURE AND TEMPERATURE CHANGES IN THE UPPER AIR

by

R. C. Gentry

LIBRARY
JUN 25 1951
WEATHER BUREAU

QC
852
.U55
no.12

LIBRARY
APR 06 2007
National Oceanic &
Atmospheric Administration
U.S. Dept. of Commerce

Washington
May 1946

077258

National Oceanic and Atmospheric Administration
Weather Bureau Research Papers

ERRATA NOTICE

One or more conditions of the original document may affect the quality of the image, such as:

Discolored pages
Faded or light ink
Binding intrudes into the text

This has been co-operative project between the NOAA Central Library and the Climate Database Modernization Program, National Climate Data Center (NCDC). To view the original document contact the NOAA Central Library in Silver Spring, MD at (301) 713-2607 x 124 or Library.Reference@noaa.gov.

HOV Services
Imaging Contractor
12200 Kiln Court
Beltsville, MD 20704-1387
January 22, 2008

NOTES ON INTERDIURNAL PRESSURE AND TEMPERATURE CHANGES IN THE UPPER AIR

by
R. C. Gentry

INTRODUCTION

This report deals mainly with analyses made in an effort to find empirical relationships of use to forecasters. Although the type of analysis employed in this study is not the most complete than can be made of the existing data, it is comparatively simple. Any useful relationships discovered could probably be used by the forecasters in the limited time they have for making forecasts. Other methods of analysis might give more complete and accurate results but would not be as practical for use by the forecaster because of the time element.

Many relationships were studied. Little time was spent studying individual cases, but most of the general relationships discussed in this paper could be made subjects of complete investigations in which individual cases might be studied and analyzed. Relationships studied may be divided into four general groups:

1. Static relationships between pressures at different constant levels.
2. Relation of temperature changes at 13 kilometers to advection.
3. Comparison of changes in potential temperature at 13 kilometers with changes in temperature and pressure at other levels.
4. Compensation between stratosphere and troposphere.
5. Relationships concerning the 3-kilometer charts.

---

[1] This paper was originally prepared in January 1944.

STATIC RELATIONSHIPS BETWEEN PRESSURES AT DIFFERENT CONSTANT LEVELS

If the hypsometric equation is differentiated logarithmically,

$$\frac{\partial p_o}{\partial t} = \frac{p_o}{p_1} \frac{\partial p_1}{\partial t} - \frac{g}{R} z p_o \sum_{k=1}^{n} \frac{1}{T_k^2} \frac{\partial T_k}{\partial t} \tag{1}$$

where p is pressure, t is time, and T is temperature.

When the mean virtual temperature of a layer remains constant, this equation reduces to

$$\frac{\partial p_o}{\partial t} = \frac{p_o}{p_1} \frac{\partial p_1}{\partial t} \tag{2}$$

or if finite changes are used, to

$$\Delta p_o \cong \frac{p_o}{p_1} \Delta p_1 \tag{3}$$

Thus, the pressure change at the bottom of an air column is $\frac{p_o}{p_1}$ times larger than the pressure change at the top of the column (when the mean virtual temperature in the column is constant). The ratio remains so nearly constant that it may be used as such in any rough computations.

Mean values for this ratio were computed for several pairs of constant levels from data for Point Barrow, Sault Ste. Marie, Washington, and Miami. Data used were taken from observation records for each station three times a month for eleven months (every month except August). Thus, the ratios were computed from 132 sets of data taken for all seasons and from stations of widely different latitudes. The values obtained were averaged, and the percentage by which the most extreme cases differed from the averages were computed. Mean values of the factors and the percentage of extreme variations for certain selected levels were as follows:

Level	Value	Largest percentage variation from the mean
$\frac{p_3}{p_6}$	.69	4%
$\frac{p_3}{p_{10}}$	.67	4%
$\frac{p_6}{p_{13}}$	.57	4%
$\frac{p_{10}}{p_{16}}$	.63	5%
$\frac{p_{13}}{p_{16}}$	.62	5%

From these values, obtained by use of original data, the following values were computed:

Level	Value	Level	Value
$\frac{p_0}{p_3}$	1.45	$\frac{p_3}{p_6}$	.69
$\frac{p_0}{p_6}$	2.17	$\frac{p_3}{p_{10}}$	1.49
$\frac{p_0}{p_{10}}$	3.8	$\frac{p_3}{p_{13}}$	2.63
$\frac{p_0}{p_{13}}$	5.9	$\frac{p_3}{p_{16}}$	4.17
$\frac{p_0}{p_{16}}$	10.0		6.67

The subscript refers to the height of the level in kilometers, e.g., p_6 is the pressure at 6 kilometers.

When the pressure change at one level is multiplied by one of the factors, the product is the pressure change that would result at the other level if there were no change in mean virtual temperature within the column. Therefore, when the observed pressure change at the latter level differs from the pressure change computed by use of the product, there has obviously been a change in temperature between the two levels. The amount of change in the mean virtual temperature can be computed approximately. If the observed pressure change at the lower level is subtracted from the pressure change computed by use of the factor and the pressure change at the upper level, the difference should be multiplied by the following amounts to arrive at the approximate number of degrees change in the mean virtual temperature of the column:

Level	Change in T_{mv}
0--3 km.	1°
3--6	1°
6--10	$1\frac{1}{2}^{\circ}$
10--13	3°
13--16	$4\frac{1}{2}^{\circ}$

The analyst can use the relations given above to check the data transmitted for the constant level charts. For the temperature change computed in the above manner must agree approximately with the observed temperature changes or there is some error in the reported pressures; e.g., if the 24-hour pressure change for Washington at 3 kilometers is +4 mb., and at 6 kilometers is +8 mb., the change in mean virtual temperature between 3 and 6 kilometers must be approximately 8°C. This is true because 8 x 1.49 $\left(\Delta p_6 \times \frac{p_3}{p_6}\right)$ equals 11.9; 11.9 - 4 = 7.9; 7.9 x 1° (difference multiplied by change in T_{mv} of the layer from 3--6 km.) gives approximately 8°. If absolute accuracy is required, this method should not be used because it uses several approximations.

The forecaster is often interested in whether the column of air over a station on one day is colder or warmer than the column that was over the station on the previous day. This information can also be obtained approximately and rapidly by use of the factors as illustrated.

RELATION OF TEMPERATURE CHANGES AT 13 KILOMETERS TO ADVECTION

Many forecasters attempt to predict temperature changes in the free atmosphere by considering the effect of advection alone. A check was made of this method with the 13-km. potential temperature charts by constructing trajectories, and checking, to see if the temperature change indicated by advection actually resulted.

Since it is quite easy to find examples that indicate that advection is of great importance, and others that indicate that advection is of little importance, the particular cases used for this test were selected as nearly as possible at random. Cases were chosen from several different types of maps, and they were selected without reference to succeeding maps, i.e., the situations were chosen before the results were observed. The only real limitation on the examples selected was that the point of origin had to be so located that its 12-hour trajectory would end in the

United States. However, a high percentage of comparatively simple isobaric patterns were selected because of the greater ease in constructing trajectories.

The 12-hourly potential temperature charts show the 13-km. isobars (drawn for every 3 mb.) and isolines of potential temperature (drawn for every 5°). In constructing the trajectories an approximate gradient wind was used. (It was not the true gradient wind because the radius of curvature of the isobars was used instead of the radius of curvature of the trajectory.) The trajectory was constructed along the isobars (whether straight or curved), and for the first 6 hours, 3/4 weight was given to the vector computed from the map of the beginning of the period and 1/4 weight to the vector computed from the map for the end of the period. For the second 6 hours this procedure was reversed. After the trajectory was constructed, the two maps were compared to see if the results were reasonable. In many cases both maps indicated approximately the same results. There were, however, some cases where the trajectories differed widely. In these cases there was probably considerable error in the trajectory as finally constructed. This method of constructing the trajectories was used after trying several others, including the one described by Petterssen[2]. Most methods tried gave unreasonable results when the trajectory was based on the high wind speeds often encountered at 13 km.

Thirty-four trajectories were computed. In 20 the computed change had the same sign as the actual temperature change; in eleven, they differed in sign; and in three, the observed change was zero. Thus, in 65 percent of the cases the observed change (excluding the three cases of zero change) and the change computed by advection alone were of the same sign. However, the average error of the computed changes was 7.6°. The average observed change was only 5.1°. Thus, a forecast of no change would have given less average error than the forecasts based on advection alone.

There were several possible errors in the trajectories. The isobars may have been based on poor data or may have been drawn poorly, so that an incorrect gradient wind may have been used. The curvature of the isobars, rather than the curvature of the trajectory, was used in computing the gradient wind. Winds at the 13-km. level are quite strong, so that even a small percentage of error in the gradient wind could result in a large error in terms of miles. Although the winds at this level probably average somewhat less than 100 miles per hour, it is not unusual for winds of 200 miles per hour to be indicated by the pressure gradient. Also, it was not unusual for the gradient wind to differ from the geostrophic wind by as much as 50 miles per hour. When the pattern of the isobars was changing rapidly, it was quite difficult to determine the trajectory. However, in spite of these and other possible errors, the trajectories were probably more accurate than those that anyone could forecast, because the maps for both beginning and end of the period were used, whereas a

person making a forecast would have only the map at the beginning of the period plus, possibly, a prognostic chart which ordinarily would not be exactly like the map at the end of the period. The forecaster would also encounter all of the other difficulties of constructing a trajectory.

While the number of cases studied is not enough to be used as a basis for definite conclusions, the study convinced the writer that the potential temperature changes at 13 kilometers cannot be forecasted even approximately by advection alone (if by advection one means that the temperature at one point can be moved ahead with the speed and direction of the wind, and that it will be observed at the thus computed point on the next map).

In the twenty cases mentioned above, where the signs of the computed and observed changes were the same, the absolute value of the computed change was too large 75 percent of the time. One explanation that may be given for this concerns vertical motion.

If θ (potential temperature) is differentiated with respect to time, and the resulting equation is solved for the local change, we have:

$$\frac{\partial\theta}{\partial t} \quad \frac{d\theta}{dt} - V \cdot \text{grad}\,\theta - W\frac{\partial\theta}{\partial z} \tag{4}$$

is the change in potential temperature with time at some point in the free atmosphere, e.g., at 13 kilometers over Washington. This change can be observed. $\frac{\partial\theta}{\partial t}$ is the total change in potential temperature of a particle of air as it moves through space. $(V \text{ grad } \theta)$ is the product of the horizontal component of the wind velocity and the gradient of potential temperature. This is the quantity that was computed in the above experiment. is the product of the vertical component

of the wind velocity and the rate of change of potential temperature with height. This term was ignored in the above experiment.

If it is assumed that all changes in temperature are results of adiabatic processes, then

(5)

In that case

$$\frac{\partial \theta}{\partial t} = -\mathbf{V} \cdot \text{grad}\, \theta - W \frac{\partial \theta}{\partial z} \qquad (6)$$

is referred to in the above experiment as the observed change, and grad as the computed or forecasted change. The results would indicate that the second term on the right (the vertical motion term) is very important in accounting for changes of potential temperature in the free atmosphere.

From equation (2) it follows that when the absolute value of the computed change is larger than that of the observed change, the two terms on the right side of the equation must have different signs. Since the forecasted change was usually too large, we may conclude that the sign of ( ) usually differed from that of $(\mathbf{V} \cdot \text{grad}\, \theta)$. This would indicate that the vertical component of the air velocity is usually positive when the isentropic surfaces are inclined upward in the direction of the horizontal component of the wind, and is usually negative when the isentropic surfaces are inclined downward in the direction of the horizontal component of the wind.

For purposes of comparison, another series of forecasts was made by a different method. Only two things were considered: (1) the isolines of potential temperature were moved along in the direction of the wind and with a speed equal to the average movement of surface pressure systems; (2) it was arbitrarily assumed that horizontal divergence at 13 kilometers would result in subsidence, and horizontal convergence at 13 kilometers would result in ascending currents. No charts were used other than the 13-km. potential temperature charts, and no effort was made to extrapolate isolines by referring to previous movements. Horizontal convergence and divergence at the 13-km. level were estimated qualitatively after looking at the isobars by a method outlined by J. Bjerknes [1] which is based on the tendency equation. For further discussion of the method used, see Petterssen [2] . No attempt was made to visualize the isobaric pattern of the succeeding chart. Forecasts made in this fashion were not expected to be good, and they were not. They were, however, much better than those made by consideration of advection alone. Eighty-four forecasts were made, and the sign of the forecasted change was right 80 percent of the time. The average error was 5.2°, and the average observed change was 7.2°. These forecasts then, were better than the forecasts of no change, whereas the "advective" forecasts were not as good as those of no change. Both types of fore-

casts were made from the same series of maps, December 1941 and January 1942, but the same days were not necessarily used.

From this work it appears inadvisable, then, to try to forecast for one level without considering the other levels. Instead of considering convergence and divergence for the 13-km. level only, all levels should be considered, so that it may be possible to arrive at a more accurate measurement of the vertical motion resulting from horizontal divergence. While there is no doubt that advection is important, poor forecasts of 13-km. changes will result when it is used alone. The isolines of potential temperature usually move with the wind, but not with the speed of the wind. Configurations in the isolines of potential temperature tend to move at about the same speed and usually in conjunction with the surface pressure systems. To emphasize the fact that other things besides advection need to be considered, there are times when the isolines move against the wind, and other times when the isolines move into a region with, apparently, no component of the wind to move them there.

COMPARISON OF CHANGES IN POTENTIAL TEMPERATURE AT 13 KILOMETERS WITH CHANGES IN TEMPERATURE AND PRESSURE AT OTHER LEVELS

In using the 13-km. potential temperature chart it is assumed that changes in potential temperature at that level are quasi-representative of density changes in the stratosphere. Thus, if changes in the stratosphere are significant, the chart should be a valuable tool for forecasting tropospheric pressure changes. Relationships of several variables to the potential temperature change were computed. Potential temperature changes were compared with (1) weight changes of the column from 10--16 kilometers, (temperature changes at 3 kilometers, (3) pressure changes at 3 kilometers, and (4) pressure changes at the earth's surface.

To check, in part, the assumption that changes in potential temperature at 13 kilometers are representative of the density changes in the stratosphere, the former were compared with the weight changes of the column from 10--16 kilometers. "Weight" is here used to mean the difference in pressure between the 10-and 16-km. levels and was used rather than mean density because of the greater convenience in gathering data. A scatter diagram (Fig. 1) of the two quantities was plotted. Most of the values were grouped along a line on which 2° change in potential temperature corresponds to a 1-millibar change in weight of the opposite sign. Data included in this diagram were taken from the months of September, October, November, December, and January, for stations distributed between Fairbanks and Miami.

Using data taken from the months of October through March, two more scatter diagrams were plotted, in which changes in potential temperature were plotted against changes in temperature (cf. Fig. 2) and pressure (cf. Fig. 3) at 3 kilometers. The data were taken from the records of eleven well-spaced stations in the first case and from twelve stations in the second case.

Dots in these diagrams were not as well grouped as the dots in Fig. 1. However, by inspection, regression lines could be drawn through the center. These lines indicated that potential temperature varies inversely as 1.8 T_3 and 1.5 p_3. The correlations of the variables were not high enough for this principle to be used in forecasting unless considerable judgment was exercised in the use of it.

The data for the scatter diagram of potential temperature change at 13 kilometers, and the surface pressure changes (cf. Fig. 4), were taken from the same series as those of the 3-km. temperature changes. The points are widely and irregularly scattered on this diagram.

Where the surface pressure change was as much as 8 millibars in 24 hours, the potential temperature change was of opposite sign to the surface pressure change about 70 percent of the time. However, in a small percentage of cases the change in density below 10 kilometers entirely accounted for this large surface pressure change, and, in addition, overbalanced a large change in density of the opposite sign in the stratosphere. There was a slightly larger percentage of cases in which the change in density in all layers below 10 kilometers called for a surface pressure change of the opposite sign to that of the large change that occurred, indicating that the stratospheric effect was all-important in these particular cases.

In studying the above examples we became interested in which layers contribute most to the surface pressure changes. The average weight change was computed for each of the following layers: surface--3 km., 3--6 km., 6--10 km., and above 10 km. The weight changes for 12-hour periods were compiled for every other day for all available raob stations in the United States and Alaska for December 1941. The results were as follows:

Layer	Average 12-hr. weight change in millibars
0--3 km.	2.5
3--6	1.9
6--10	0.6
above 10	3.1

This indicated that slightly more than half of the change took place above 6 kilometers. For the series studied, the layer between 6 and 10 kilometers had, on the average, very small changes. This agrees with the idea of a layer of quasi-constant density near 8 kilometers. Although the average change in this layer was small there were occasionally cases of comparatively large changes.

These results agree well with previous studies made by Haurwitz [3] of soundings at Boston, and by Penner [4] of soundings at Sault Ste. Marie. Haurwitz analyzed 25 pairs of soundings with surface pressure variations greater than or equal to 10 millibars. He used a method developed by Rossby [5], Ertel and Szan-zsi Li [6] for determining the advective changes of mass within each layer. He found the greatest advective changes to be in the layers near the earth and near the tropopause. There was a minimum near 7 kilometers.and above 12 kilometers.

Penner considered the weight changes in the layers 0--4 km., 4--8 km., 8--12 km., and above 13 km. He found the greatest changes in the 0--4 km. layer and the least in the 4--8 km. layer.

Compensation Between Stratosphere and Troposphere

To aid in studying the relative effects of changes of air masses in the stratosphere and troposphere, compensation charts were constructed. The compensation chart was designed to show the percentage of the effect of air mass changes above 10 kilometers that is compensated by air mass changes between 3 and 10 kilometers. Multiplying by , the 10-km. pressure change is reduced to what the change should be at 3 kilometers if there were no change in the mean temperature between 3 and 10 kilometers. If this reduced pressure change is called "R", then

$$\frac{R - \Delta p_3}{R} = \text{percent of compensation} \qquad (7)$$

077258

Isolines are drawn for the various percentage values, and the chart is divided into three areas: (A) where the percentage is more than 100, i.e., where the effect on p_3 of changes in the mass of air above 10 kilometers is more than compensated by changes in temperature between 3 and 10 kilometers; (B) where the percentage is between 0 and 100, i.e., where the effect on p_3 by changes in the mass of air above 10 kilometers is partially compensated by changes in temperature between 3 and 10 kilometers; and (C) where the percentage is less than zero, i.e., where the effect on p_3 of changes in the mass of air above 10 kilometers and of temperature changes between 3 and 10 kilometers are of the same sign.

In choosing the 10-km. level for getting the "reduced" pressure change, it was assumed that the level would be in the troposphere, but only a short distance below the tropopause, so that changes in pressure at 10 kilometers would be representative of density changes in the stratosphere. If the tropopause were high, the chart would probably not be as useful. As a partial check on this assumption and also on the assumption that the changes in potential temperature are representative of density changes in the stratosphere, the Verification Section computed some correlations. Data for the correlations were taken from the maps of October 1941 through March 1942. The data were taken six times each month, so for each station there were 36 sets of data. The correlations are as follows:

Station	r_1 $(\Delta\theta, \Delta p_{10})$	r_2 $(\Delta\theta, HT)$	r_3 $(\Delta p_{10}\ HT)$	HT
Bismarck	-.67	-.32	.18	10.6
Miami	-.07	-.04	.21	15.8
Washington	-.77	-.03	.07	11.8
Portland	-.73	-.08	.19	10.4
Fairbanks	.77	-.46	.49	8.7
Buffalo	-.82	-.51	.50	10.5
St. Louis	-.90	-.14	.04	11.6
Spokane	-.83	-.22	.31	10.6
Oakland	-.69	-.08	-.03	11.8
Denver	-.53	-.21	.06	11.2

HT is the average height of the tropopause in kilometers, is the change in potential temperature, and is the change in pressure at 10 kilometers.

The correlations of potential temperature changes with 10-km. pressure changes are reasonably high negative values for all stations except Miami. Miami is the only station whose tropopause height averaged above 13 kilometers for the series. This may account for the low correlation, and it may be that, due to the smaller changes at Miami, instrumental errors were a large factor in the lack of correlation. The negative correlations between potential temperature and HT were never large, but the lower the average height of the tropopause, the higher was the correlation (Portland was the major exception to this statement).

The compensation charts indicate that changes of mass in the stratosphere are usually greater than the changes in that portion of the troposphere between 3 and 10 kilometers. There are many exceptions to this, however. Of the three areas previously mentioned, area C (where the stratosphere and the portion of the troposphere between 3 and 10 kilometers work in conjunction) occupies only 5 percent of the charts, on the average. This area rarely has any large 3-kilometer pressure changes in it. It seems that usually when changes of mass in the stratosphere and in the middle and upper portions of the troposphere are of the same sign, nothing very important is taking place. Area B (where changes of mass in the stratosphere are partially compensated by the changes in the troposphere) covers 74 percent of the charts, on the average. Area A (where changes of mass in the stratosphere are completely compensated by changes in the troposphere) covers 21 percent of the charts, on the average. A number of the changes that take place in this area are large. In spite of the fact that the area covers only an average of about 1/5 of the charts, it is very important.

With 3-kilometer 24-hour changes larger than 8 millibars, the percentage of compensation averages about 50; it may be almost any value, but the preponderance of percentages is between 30 and 70. Almost any percentage of compensation may accompany 24-hour surface changes greater than 10 millibars. This would be expected from the figures previously given concerning the importance of the weight changes below 3 kilometers. These changes would not affect the percentage computed for the compensation charts, since the latter concern the layers from 3--10 kilometers and above 10 kilometers.

RELATIONSHIPS CONCERNING 3-KILOMETER CHARTS

Several relationships concerning the changes in temperature and pressure at 3 kilometers, with each other and with other quantities, were computed. The ones with the changes in potential temperature have already been mentioned.

In the Special Forecast Section much use is made of the evident fact that the temperature and pressure at 3 kilometers tend to change with the same sign and same magnitude under certain situations. To find to what extent this relation holds, data were tabulated for all United States and Alaskan raob stations six times a month for the months of October 1941 through April 1942. The following algebraic differences were tabulated: $\Delta p_3 - \Delta T_3$; $\Delta T_{mv} - \Delta T_3$; $\Delta p - \Delta T_{mv}$, where ΔT_{mv} is the change in the mean virtual temperature between the surface and 3 kilometers. For example, if at a certain time the 12- and 24-hour changes of p, T, and T_{mv} at Washington were:

	12-hour change	24-hour change
Δp_3	+6	+12
ΔT_3	+5	+ 6
ΔT_{mv}	+7	+ 8

the differences tabulated would be as follows:

	12-hour change	24-hour change
$\Delta p_3 - \Delta T_3$	+1	+6
$\Delta T_{mv} - \Delta T_3$	+2	+2
$\Delta p_3 - \Delta T_{mv}$	-1	+4

The percentage of cases where the absolute values of the algebraic differences fell within various numerical limits are as follows:

	12-hour changes			24-hour changes		
	0--2km	3--5km	5km	0--2km	3--5km	5km
$\Delta p_3 - \Delta T_3$	58%	31%	11%	48%	32%	20%
$\Delta T_{mv} - \Delta T_3$	72	26	2	70	25	5
$\Delta p_3 - \Delta T_{mv}$	56	33	11	49	31	20

It is interesting to note that the pressure changes at 3 kilometers agree with the temperature changes at 3 kilometers, and with the mean virtual temperature changes between the surface and 3 kilometers almost equally well.

The fact that the 12-hour changes give better results than the 24-hour changes can probably be explained in two ways. (a) The 12-hour changes are usually smaller than the 24-hour changes so there would naturally be less difference between them. (b) The 12-hour changes are partly diurnal changes, which, at 3 kilometers, are usually of about the same magnitude and sign for both pressure and temperature.

From the above results it should be clear that the relationship between the pressure and temperature changes at 3 kilometers is rigid enough that it can be quite useful to the forecaster, but it is not rigid enough that it can be used blindly. There are numerous exceptions to the use of this relationship especially when the changes are large. When the 12-hour changes are observed on the west side of a trough or a ridge, they are more likely to be of opposite sign than when they are in the center of a trough or ridge or to the east of it. This is believed to be more nearly true when the isobars at 3 kilometers resemble a sine wave. The following are the results of tabulations made from all definite ridges and troughs found on the 3-km. maps in the eastern portion of the United States for December 1941 and January 1942. The percentages refer to the proportion of cases in which the pressure and temperature changes were of the same sign.

	Ridge			Trough		
	West	Center	East	West	Center	East
Dec. 1941	58%	69%	79%	67%	80%	77%
Jan. 1942	70%	86%	86%	61%	84%	80%

In both months the percentage was somewhat higher for the central and eastern portions of both the ridges and troughs than for the western portion.

On the compensation charts in Areas A and C the mean virtual temperature change in the layer between 3 and 10 kilometers must of necessity be opposite in sign to the 3-km. pressure change; and in Area B the mean virtual temperature change should be the same in sign as the 3-km. pressure change. Temperature changes at 3 kilometers were compared with the pressure changes at the same level to see if the temperature changes at 3 kilometers were representative of the temperature changes in the entire layer between 3 and 10 kilometers. Results are compiled in the following table. The percentages refer to the proportion of cases in which the temperature and pressure changes were of the same sign. If the 3-km. temperature changes were representative of the mean temperature change between 3 and 10 kilometers at all times, the percentages would be 100% for the Area B, and 0% for Areas A and C.

	Area A	Area B	Area C
Dec. 1941	23%	82%	59%
Jan. 1942	32	84	57

The high percentages reported in Area C are not particularly disturbing since, as previously noted, the changes in Area C are relatively small, and the fact that a change is of the wrong sign does not necessarily mean that there was much difference in the actual magnitude of the changes. The percentages in Area A indicate that significant changes frequently occur in which the 3-km. temperature change is not representative of the change in the 3--10-km. layer.

The results reported in this paper are based on preliminary analyses. In many cases the types of analyses are experimental and subject to revision after more data have been examined and the preliminary results studied in greater detail. Several of the relationships reported are based on a limited series of data, and the results will probably be modified after more data have been studied.

CONCLUSIONS

1. Static analyses of pressure data can be used to make a simple check on constant level data, and also to determine the changes in mean virtual temperature between the different levels.

2. Attempts to forecast changes in potential temperature at 13 kilometers by advection alone were unsuccessful. The average error was greater than it would have been if "no change" had been forecast each time. The isolines of potential temperature usually move in the same direction as the wind, but with less speed.

3. a. There is a high negative correlation between the changes in potential temperature at 13 kilometers and the weight changes in the layer between 10 and 16 kilometers.

   b. There is a high negative correlation between the changes in potential temperature at 13 kilometers and changes in pressure at 10 kilometers.

   c. There are smaller negative correlations between the changes in potential temperature at 13 kilometers, and the changes in temperature and pressure at 3 kilometers.

   d. There is very little correlation between the change in potential temperature at 13 kilometers and the change in pressure at the surface during the same time period.

4. If the atmosphere is divided into four layers, 0--3 kilometers; 3--6 kilometers; 6--10 kilometers; and 10 kilometers to the top; the layer above 10 kilometers contributes most to the surface pressure changes, but the layer next to the earth's surface contributes almost as much.

5. If the weather map were divided into two areas, (1) where the stratosphere dominates the 3-km. pressure changes, and (2) where the troposphere dominates the 3-km. pressure changes, the first area would cover about 74% of the average map.

6. a. In the majority of cases the pressure and temperature changes at 3 kilometers and the mean virtual temperature changes between the surface and 3 kilometers agree quite well in sign and value when pressure is measured in millibars and temperature in °C).

   b. In 78% of the cases studied the temperature changes at 3 kilometers were of the same sign as the temperature changes in the layer between 3 and 10 kilometers.

BIBLIOGRAPHY

1. Bjerknes, J., Theorie der Aussertropischen Zyklonenbildung, Meteorologische Zeitschrift, vol. 54, 1937, pp. 462-466.

2. Petterssen, Sverre, Weather Analysis and Forecasting, McGraw-Hill Book Co., New York, 1940.

3. Haurwitz, B. and Haurwitz, E., Pressure and Temperature Variations in the Free Atmosphere over Boston, Harvard Meteorological Studies, No. 3, Harvard University Press, 1939.

4. Penner, C. M., "The Effects of Tropospheric and Stratospheric Advection on Pressure and Temperature Variations", Canadian Journal of Research, A, vol. 19, pp. 1-20, 1941.

5. Rossby, C. G., "Zustandsanderungen in atmospharischen Luftsaulen", Beitrage zur Physik der freien Atmosphare, vol. 13, p. 163, 1927.

6. Ertel, H. and Sjan-zsi Li, "Der Advektionsmechanismus der atmospharischen Druckschwankungen", Zeitschrift fur Physik, vol. 94, p. 661, 1933.

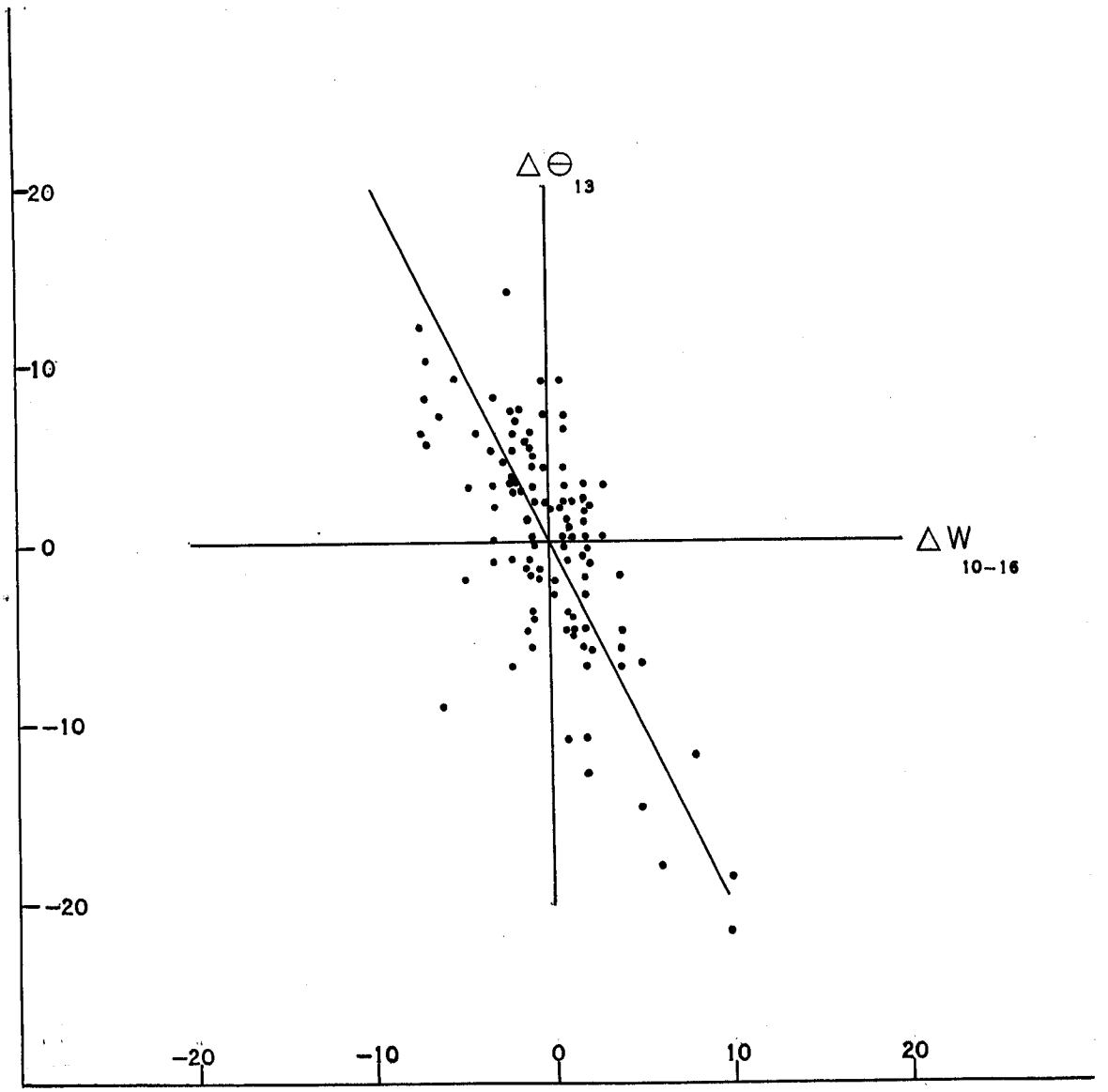

Fig. 1.--Changes in weight (mb.) between 10-16 km., plotted against changes in potential temperature (deg. A.) at 13 km.

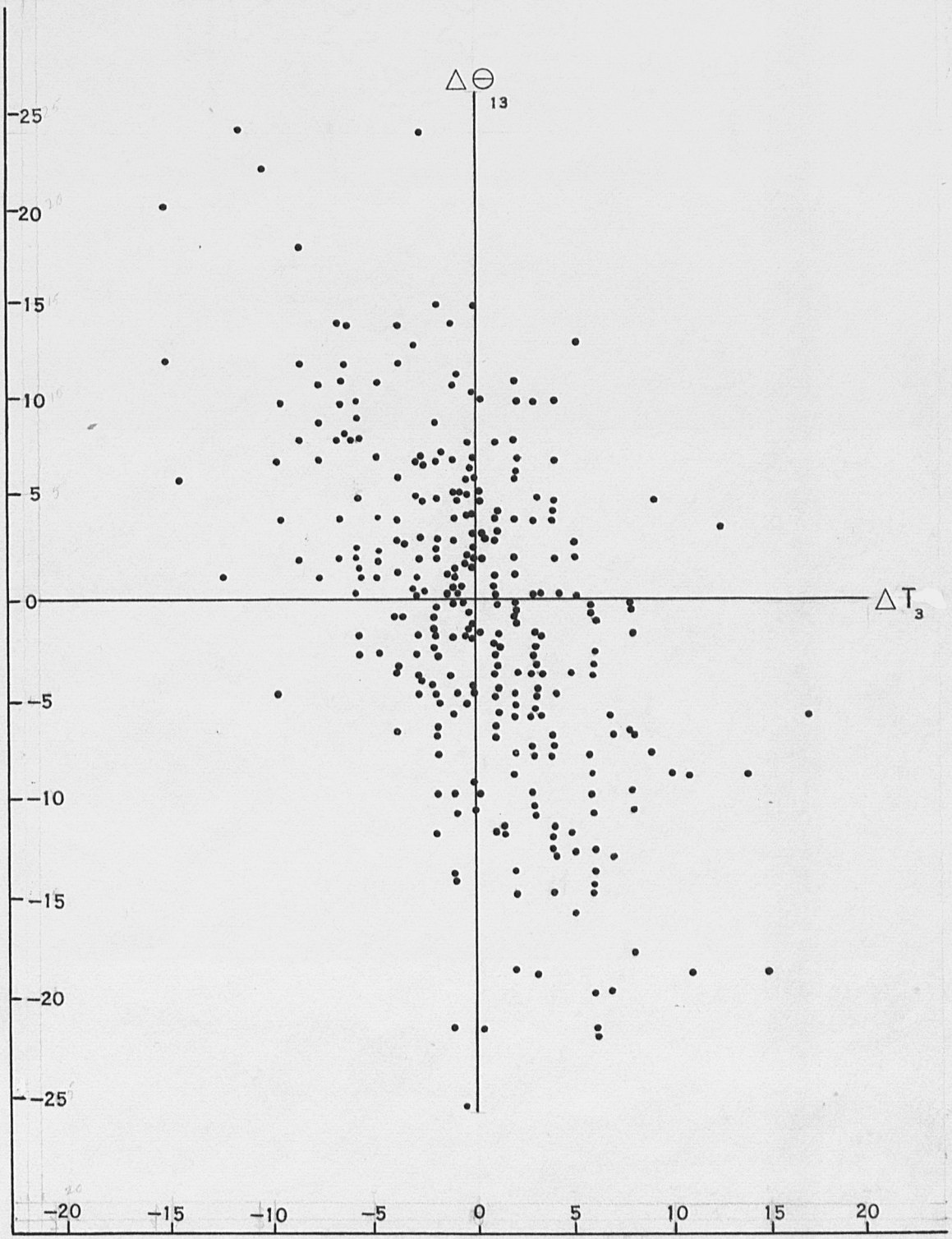

Fig. 2.--Changes in temperature (deg. A.) at 3 km., plotted against changes in potential temperature (deg. A.) at 13 km.

Fig #2

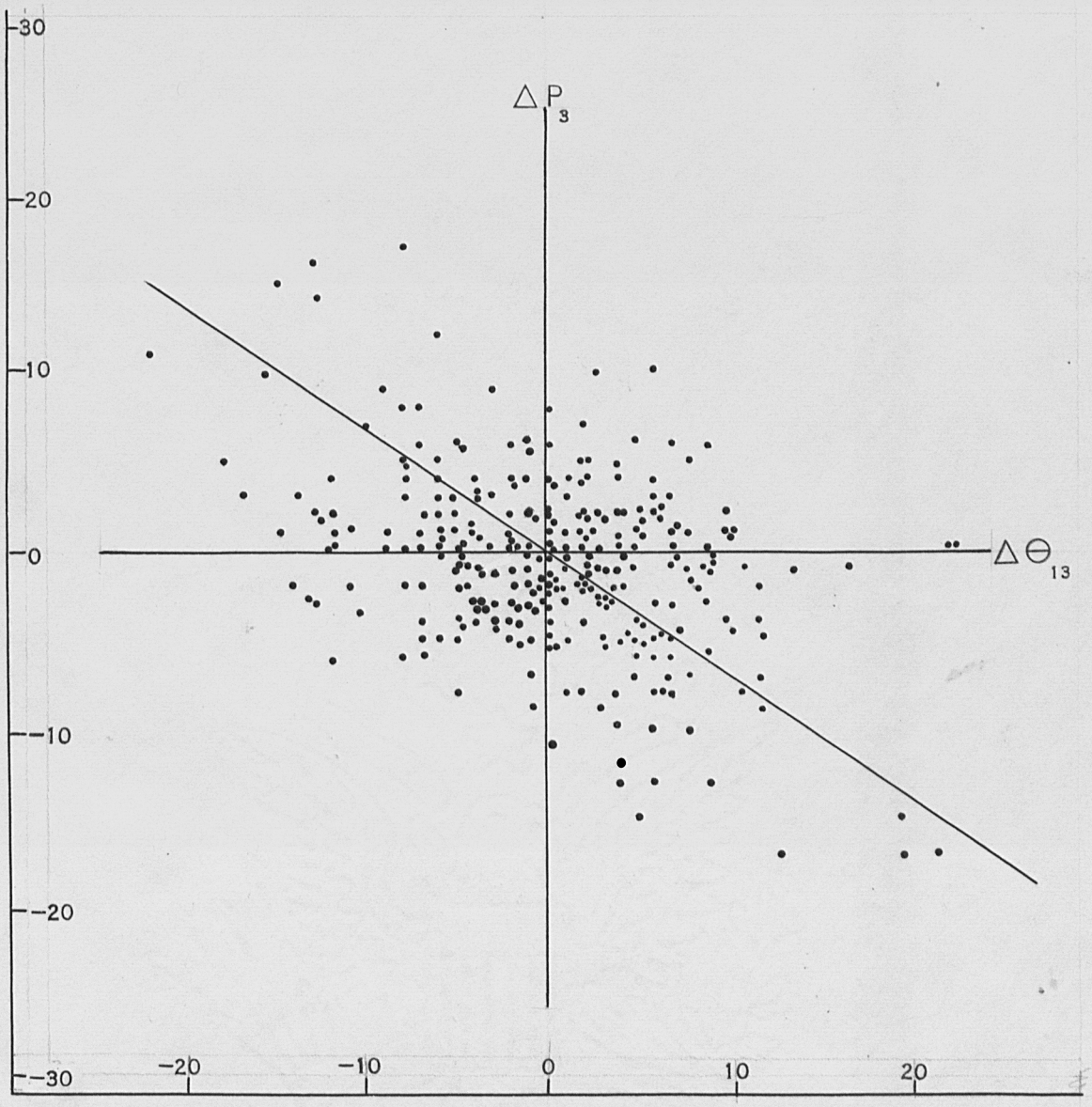

Fig. 3.--Changes in potential temperature (deg. A.) at 13 km., plotted against changes in pressure (mb.) at 3 km.

Fig 3

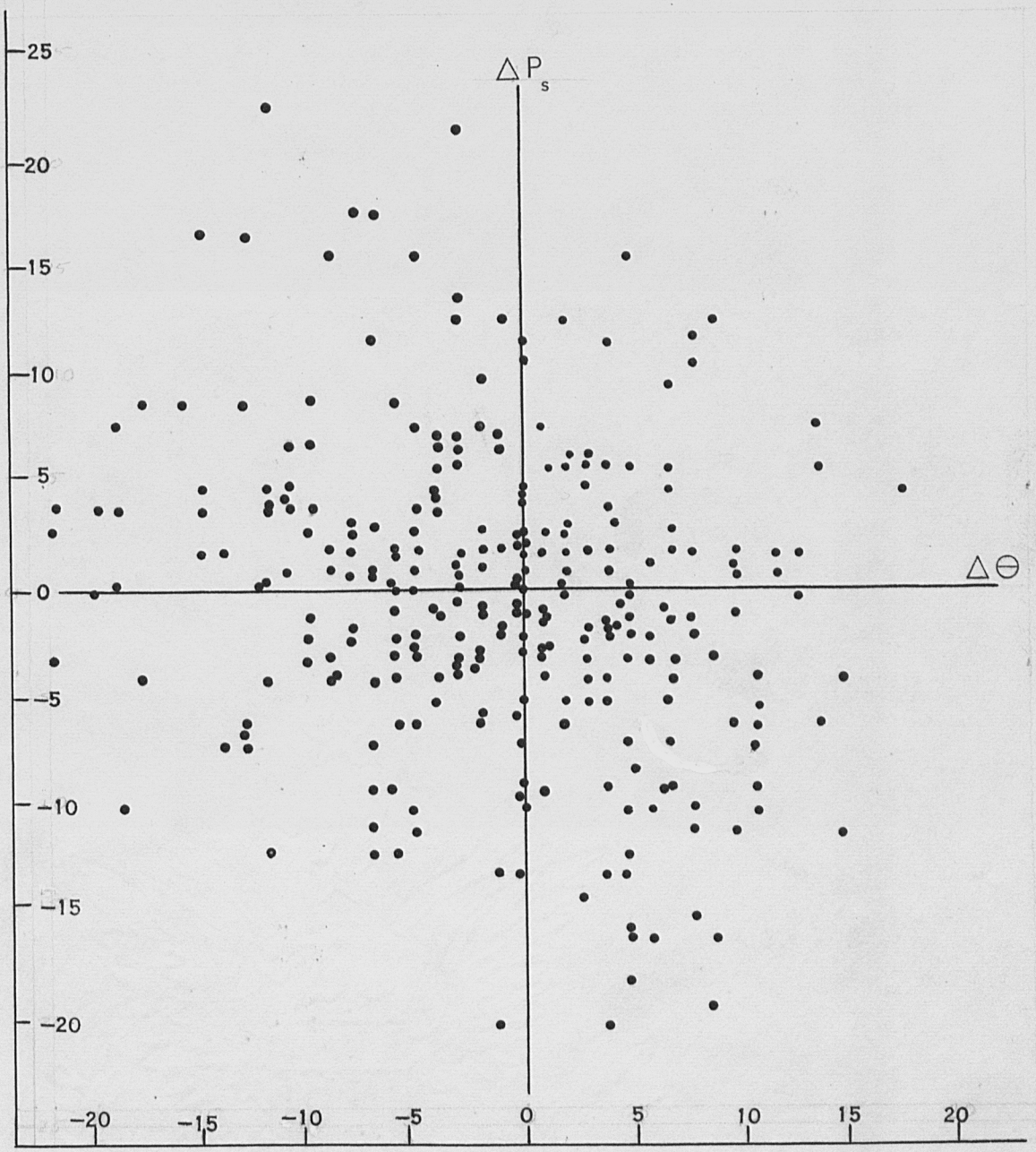

Fig. 4.--Changes in potential temperature (deg. A.) at 13 km., plotted against changes in pressure (mb.) at the surface.