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A COLLECTION OF REPORTS ON EXTENDED FORECASTING RESEARCH

FORECAST RESEARCH DIVISION

WASHINGTON
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CONTENTS

ERRATA

Research Paper FR-03

Page 3

Change "2^1 for two letters" to "2^2 for two letters"
"2^2 for three letters" to "2^3 for three letters"
"2^3 for four letters" to "2^4 for four letters"

In the last line change the expression

$$2^{m+2} (M + 2) \quad \text{to} \quad 2^{(m-2)} (M + 2)$$

Page 7 Table III

Change the observed number under sequence length 3 from 90 to 93.

Research Paper FR-04

Page 2

Delete the last sentence: "Fronts are shown for the middle day of the five-day mean."

Page 3 Table 1

Insert $<$ in "Daily Lows
(mbs $<$ mean)"

Insert $>$ in "Daily Highs
(mbs $>$ mean)

Page 5

The last line should read, "the paths of the mean centers. Figures 1 to 10 bring out these features."

In Figures 1 to 10 insert the legend.

● position of High
O position of Low
The figure above the circle is the day of the forecast period, e.g. 3 is the 3rd day.
The figure below the circle is the central pressure of the High or Low given in mbs., the hundreds and thousands figures omitted.

Research Paper FR-10

Page 6 Table 7 under "Source"

Change "'Errors'" to "'Error'"

Page 9

The fifth line from the top should read, "the two months, $\overline{S}$ and $\overline{A}$, σ_s and σ_a are . . .,"

A PROJECT TO TEST THE POTENTIAL USEFULNESS OF PRESSURE PATTERNS FOR FORECASTING

Horace W. Norton
Glenn W. Brier
Roger A. Allen

One of the objectives of the five-day forecasting project has been to evaluate individual steps of the forecasting procedure with a view to elimination of ineffective tools, the development and more effective use of tools which prove valuable, and the indication of directions in which research might be profitable. Two fundamental steps in the five-day procedure are (1) the construction of prognostic five-day mean pressure charts, and (2) the interpretation of the prognostic charts in terms of temperature and precipitation anomalies. This report describes an experiment which was designed to test the second step of the forecast procedure by estimating the average success that can be achieved by meteorologists in forecasting five-day temperature and precipitation anomalies having given a perfect forecast of the mean pressure pattern (i.e. having given the observed pressure patterns). The estimate of accuracy of interpretation will indicate the upper limit of forecasting achievement so far as it is limited at present by ability to interpret mean pressure patterns in terms of temperature and precipitation anomalies. If this limit is high, the forecasting of pressures would be indicated as the chief problem of research. On the other hand, if this limit is low, the interpretation of pressure patterns will be indicated to be a subject worth more investigation. Further investigation might reveal additional significant relationships between pressure patterns and weather that would be of value to the forecasters. On the other hand, further investigation might disclose only that a relatively small amount of the variation in surface weather can be accounted for by the pressure pattern and that the forecasters are already utilizing the bulk of the information contained in the pressure pattern. This experiment is not competent to indicate more than whether errors in current forecasts tend to occur before or after the completion of the prognostic pressure patterns.

Other specific objectives of the experiment were to obtain an estimate of the mean square error of various anomaly forecasts, and to obtain estimates of differences between seasons, between forecasters, and so on.

Procedure

Each of three meteorologist individually prepared temperature and precipitation anomaly maps for the United States corresponding to observed five-day mean sea level and three kilometer pressure maps for each of six past situations, three in summer and three in winter. Five day periods were chosen for which mean maps had not been previously constructed. The selection of situations was made without regard to synoptic considerations and no information was left on any of the working charts that would give a clue to the date of the charts. The forecaster was given the name of the month so he could take account of climatological considerations in making his "forecast." The experiment was divided into two sections. In Part A, the forecaster was given the following observed charts upon which to base his anomaly "forecasts":

(1) The five-day mean sea level analyzed map for North America for the period concerned,

(2) The five-day mean three kilometer map for the same area,

(3) A map of the mean virtual temperature of the layer between sea level and three kilometers, and

(4) The sea level and three kilometer zonal indices based upon the above maps.

After the forecasters completed the anomaly charts using the information contained in Part A, they were given additional information (Part B) and made another set of anomalies. The additional information contained in Part B was that obtained from data that occurred at least forty-eight hours prior to the five-day period concerned. This included the following:

(1) Daily surface and three kilometer synoptic charts for seven consecutive days preceding the forecast period, the time of the last chart being forty-eight hours before the beginning of the five-day period concerned.

(2) The daily isentropic chart and twenty-four hour mean surface temperature departure chart corresponding to the last daily surface chart.

(3) Five-day mean pressure maps (sea level and three kilometer) and temperature and precipitation anomaly maps for the periods centered seven days and eleven days prior to the five-day period concerned.

(4) Virtual temperature maps, pressure change maps, three kilometer and sea level indices and profiles based upon the above charts.

The maps and charts presented in Parts A and B and a sample "forecast" are illustrated by the accompanying diagrams.

Verification of the Anomaly Forecasts

The anomaly charts prepared by the forecasters were verified and scored in the same manner as the routine current forecasts. The exact procedures have been described elsewhere.(1) The final scores are summarized in Table 1 on the next page. The analysis of variance of these forecast scores is given in Table 2 and a discussion of the results of the analysis of variance follows.

Results of Analysis of Variance

Proceeding upward in Table 2 from the most complex interactions, no variance seems significant until we come to SFE, and this may be discounted because its test variance appears to be somewhat subnormal.

The next apparently significant variance is that for FD. If it is accepted as significant, it means that the effect of the "additional data" was appreciably different for different forecasters--that the forecasters were not equal in their ability to use the "additional data."

The next apparently significant variance is that for ET. There can be no doubt as to its significance, and it means that, at different times in the same season, scores for the two elements (temperature and precipitation) stood in different relations to each other, sometimes one relatively high, sometimes the other.

No other variance appears significant, but F is tested against FD which, it must be remembered, is of somewhat doubtful significance. If it be thought that the variance for FD is large only as a result of random sampling, then F should be tested against the interactions

(1) See H. C. Willett, "Report of the Five-Day Forecasting Procedure, . . . ," Massachusetts Institute of Technology, Papers in Physical Oceanography and Meteorology, Volume IX, No. 1, 1941, p. 60. The procedure described therein has been modified in the following manner: Instead of giving varying weights to errors of various magnitudes, current procedure is to give unit weight to all zero errors and zero weight to all other errors.

TABLE 1

Verification scores obtained on experimental forecasts.

Weather Element	Forecaster	Amount of Data	WINTER Feb. Per-cent	WINTER Dec. A Per-cent	WINTER Dec. B Per-cent	SUMMER Aug. A Per-cent	SUMMER Aug. B Per-cent	SUMMER June Per-cent
Temperature	A	Part A *	47	47	54	40	18	30
		Part B **	60	19	57	41	22	35
	B	A	58	24	63	45	26	37
		B	58	14	62	45	27	33
	C	A	62	42	57	42	27	25
		B	76	31	71	42	37	58
Precipitation	A	A	7	12	65	-3	16	16
		B	1	9	56	23	-4	12
	B	A	22	14	71	22	14	6
		B	14	14	75	22	3	23
	C	A	4	25	80	38	28	1
		B	29	13	75	38	32	52

* Part A - Incomplete

** Part B - Complete

TABLE 2

Analysis of Variance of Verification Scores.

Source	Symbol	Degrees of Freedom	Sum of Squares	Mean Squares
Season (Winter, Summer)	S	1	3807.73	3807.73
Forecaster (A, B, C)	F	2	1970.87	985.44
Element (Temperature and Precipitation)	E	1	5107.24	5107.24
Time within season	T	4	12,724.29	3181.07
Amount of Data (Parts A & B)	D	1	126.93	126.93
Interactions	SF	2	57.13	28.56
	SE	1	6.97	6.97
	FE	2	240.80	120.40
	FT	8	360.74	45.09
	ET	4	4980.72	1245.18
	SD	1	239.08	239.08
	FD	2	532.57	266.28
	ED	1	0.64	0.64
	TD	4	985.06	246.26
	SFE	2	316.73	158.36
	FET	8	232.67	29.08
	SFD	2	63.75	31.88
	SED	1	3.92	3.92
	FED	2	20.32	10.16
	FTD	8	1021.65	125.21
	ETD	4	451.94	112.98
	SFED	2	13.27	6.64
	FETD	8	521.07	65.13
		10	534.34	53.43
TOTAL		71	33,786.09	475.86

Note: The variance ratios and associated probabilities are omitted from this table. A more complete discussion showing in greater detail the use of analysis of variance in testing the significance of various factors is reserved for a later paper.

of FD with the various other elements. When this is done, F is undoubtedly significant.

This clearly demonstrates a difference among the three forecasters, though it is not clear whether that difference is in general ability or in ability to make use of the "additional data" in revising a forecast based on the minimum of data. The following table shows mean scores for each forecaster with the minimum data and with the additional data and averages.

	Forecaster			
	A	B	C	Average
Minimum data (Part A)	29.1	33.4	35.9	32.8
Additional data (Part B)	27.7	32.5	46.2	35.5
Average	28.4	33.0	41.0	34.1

It may be remarked that a difference between temperature and precipitation should have been expected, and the failure of this difference to appear significant is probably purely a result of the small scale of the experiment, the amount of data collected being simply too small to demonstrate convincingly that there is a difference of ability to forecast these two elements.

We come now to the comparison of the results of this experiment to to the results of past experience. Taking, for past experience, the winter seasons of 1940-41, 1941-42, and 1942-43, and the summer seasons for 1941 and 1942, the following table of mean scores may be formed.

	Temperature		Precipitation	
	Experiment	Past Performance	Experiment	Past Performance
Winter (Dec-Jan-Feb)	50.1	22.7	32.8	11.6
Summer (June-July-Aug)	35.0	17.5	18.8	5.6

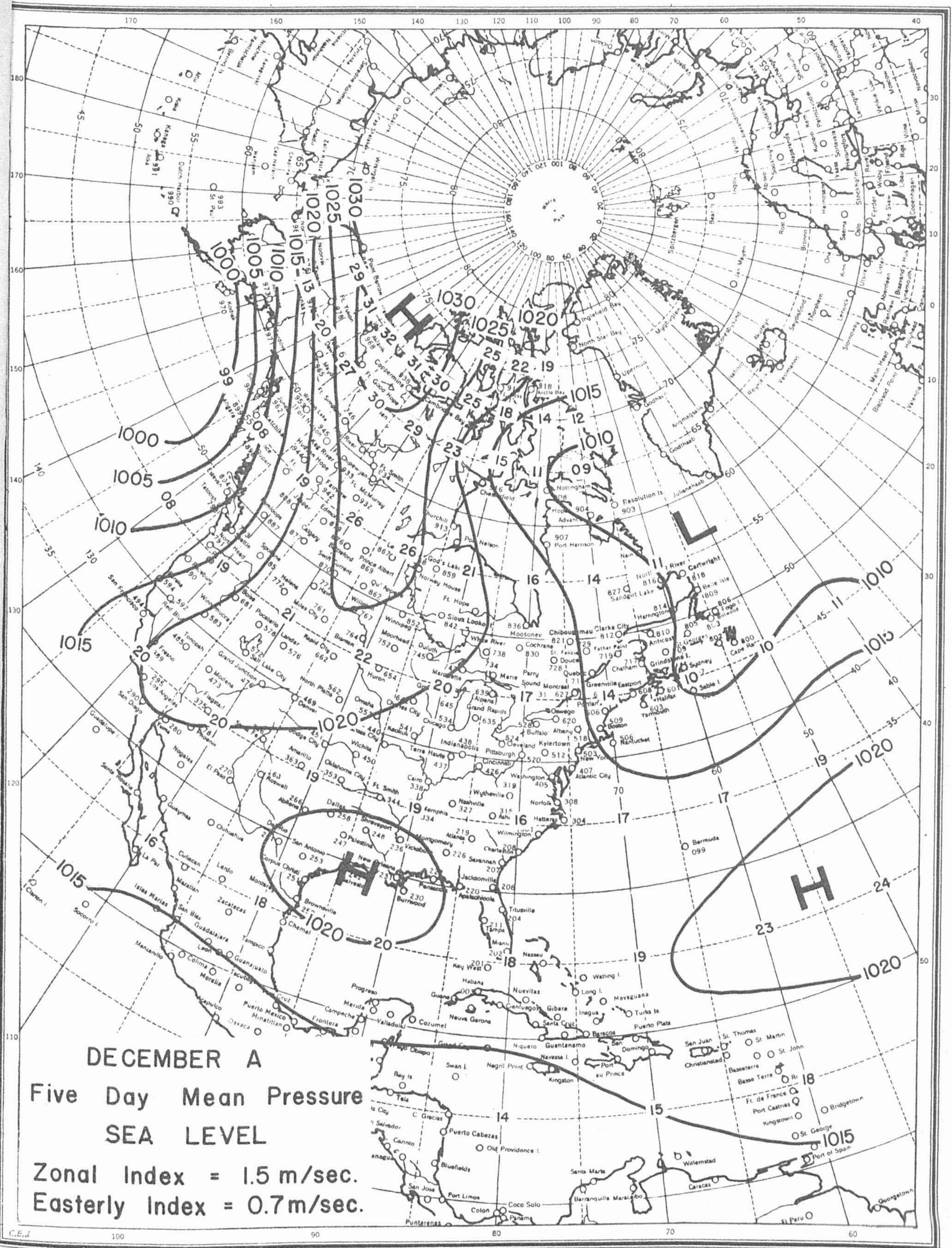
In the figures given for past performance, forecasters "B" and "C" are about equally represented. However, forecaster "A" made a relatively small contribution to both the summer and winter figures. Since both this experiment and past performance are agreed in ranking these three forecasters in the order "C", "B", and "A", the figures for past performance are probably somewhat too high relative to the figures resulting from this experiment. Even so, it is obvious (as of course it should be) that the elements can be better "forecast" when the pressures are known than when the pressures themselves must be forecast.

Taking the figures at their face value, it is clear that a large proportion (of the order of one-half) of errors in forecasts are made subsequent to the completion of the prognostic pressure maps. The scores resulting from this experiment are so low as to suggest that efforts to improve the interpretation of prognostic pressure patterns would have the same opportunity of success, in terms of immediate improvement of forecasts, as would efforts to improve the prognostic pressure patterns. In fact, it has been suggested that there should be more hope of immediate progress in interpretation of pressure patterns because the problem is more specific and well-defined than the general and fundamental problem of improving the prognosis of pressure patterns.

This general conclusion is of interest, and if it is correct, it is of considerable importance. It may be disputed on several grounds. One is that pressure patterns supplied to the forecasters were based on average values plotted at the corners of ten-degree "squares," which they regard as insufficient, and, partly as a consequence, no doubt, that the analyses were unsatisfactory. The limitation to ten-degree "squares" came from resorting to past data, some of it so old that the maps which were then in use were themselves limited to ten-degree "squares." It was necessary to put all maps used in the experiment on this basis so as to give no clue to the date of any sequence. This objection, and the objection to the analyses, can be easily overcome in a new experiment, of somewhat different design. In particular, an experiment can be arranged to test also the contention that ten-degree "squares" are inadequate.

Another objection is to the interpretation of the results. It has been maintained, quite rightly, that so long as the class limits used in verification are so badly estimated as at present, it is impossible (except with the aid of chance) to get a score of 100, and hence the scores achieved are much nearer to perfection than they appear. Though this objection is admittedly valid in a qualitative sense, quantitatively it is weak. The upper limit of scores which can be reached by skill alone is almost certainly higher than 80, in which case the conclusion drawn above need not be altered. Even if it were as low as 60, the conclusion would be invalidated only in regard to winter temperatures.

Other objections were made. For example, one forecaster was of the opinion that in the "complete" data, the mean isentropic chart would have been helpful. However, though some of these objections are obviously correct in form, it is strongly doubted whether they materially weaken the conclusion that the subject of interpretation of pressure patterns requires further investigation. This does not guarantee that progress in forecasting the anomalies will be made. It might very well turn out that the maximum that can be accomplished from interpreting pressure patterns is already attained by the forecasters, and that further accomplishment in forecasting ability will come only as a result of other lines of attack.



DECEMBER A

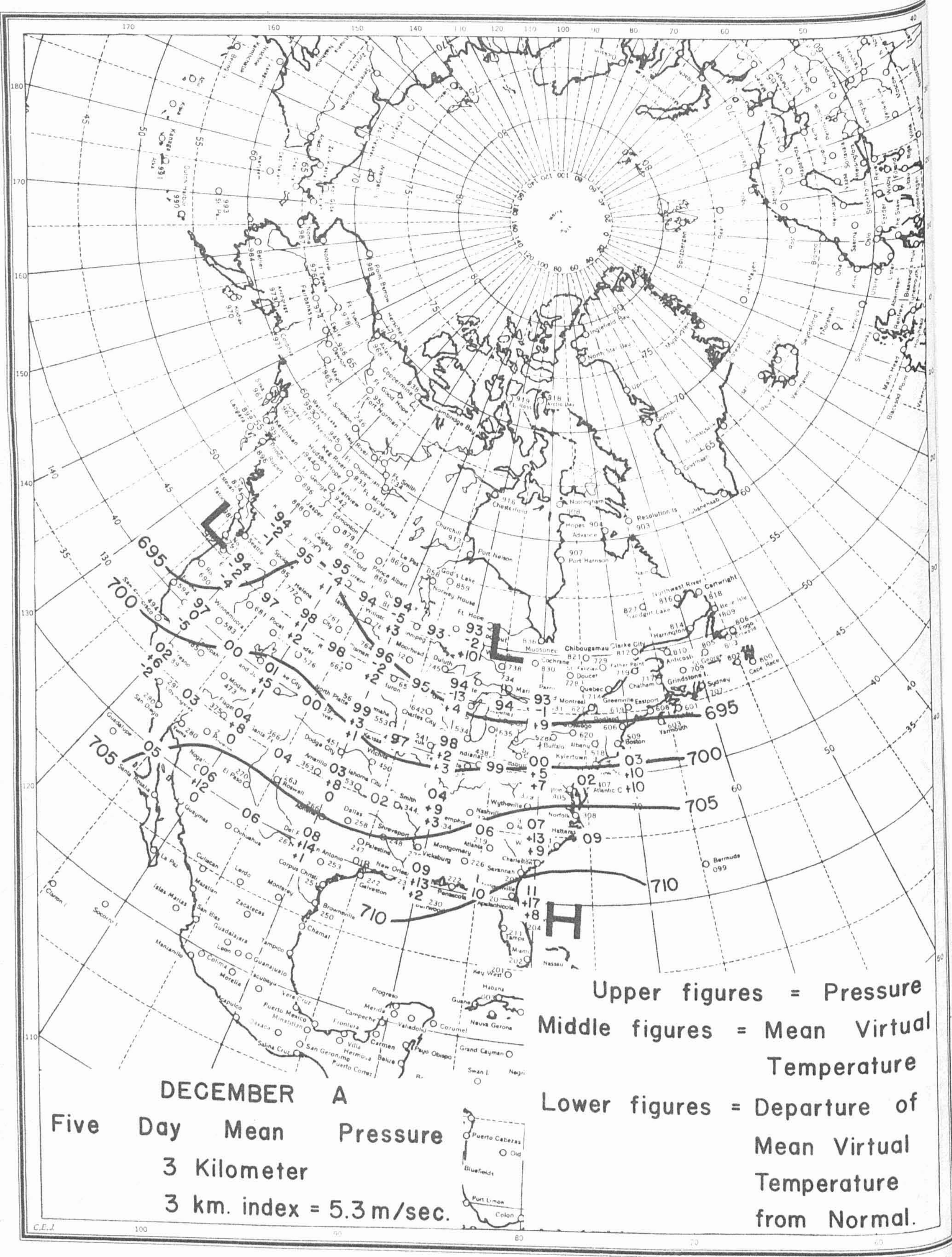
Five Day Mean Pressure

SEA LEVEL

Zonal Index = 1.5 m/sec.

Easterly Index = 0.7 m/sec.

C.E.J.



DECEMBER A

Five Day Mean Pressure

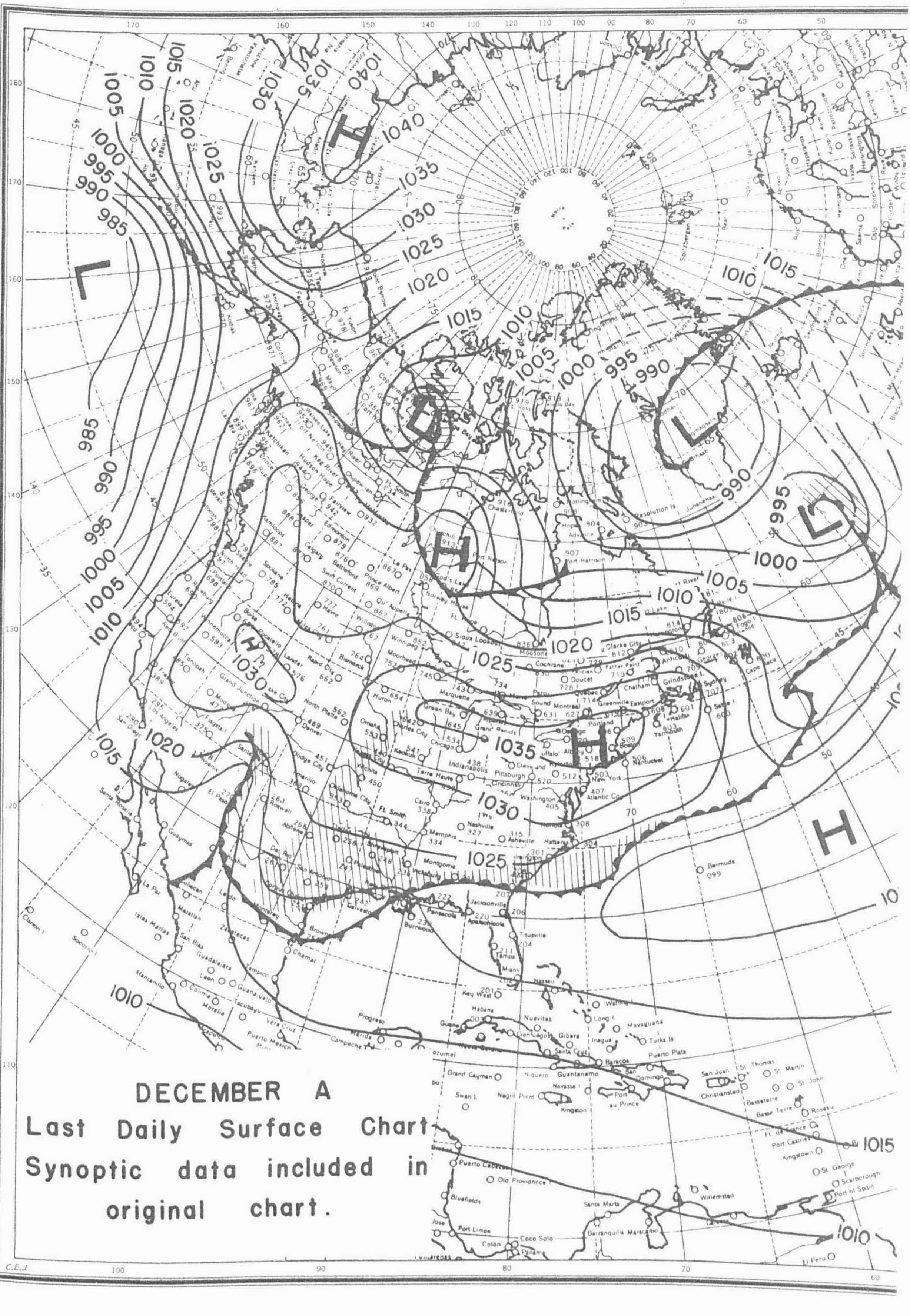
3 Kilometer

3 km. index = 5.3 m/sec.

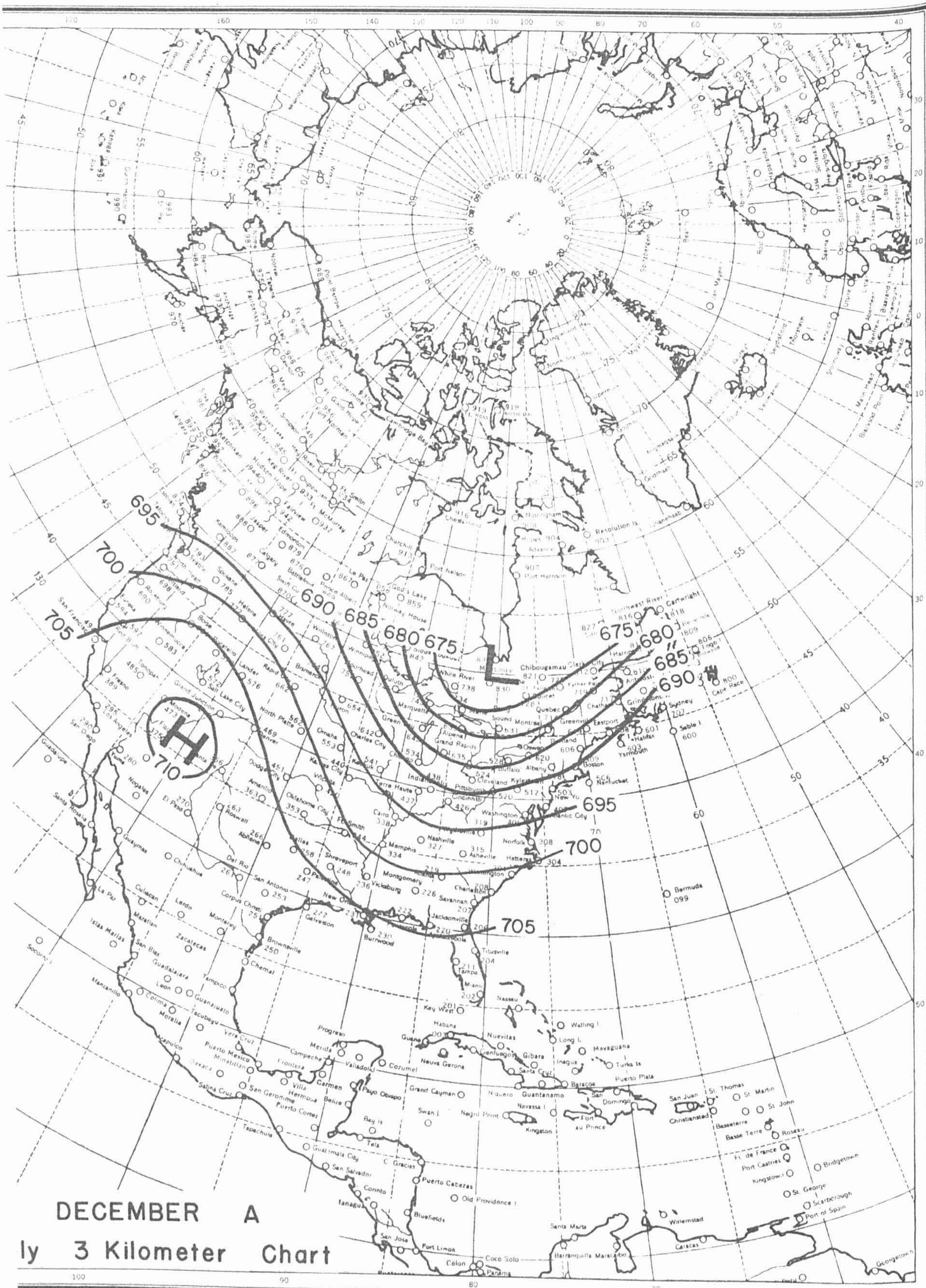
Upper figures = Pressure

Middle figures = Mean Virtual Temperature

Lower figures = Departure of Mean Virtual Temperature from Normal.

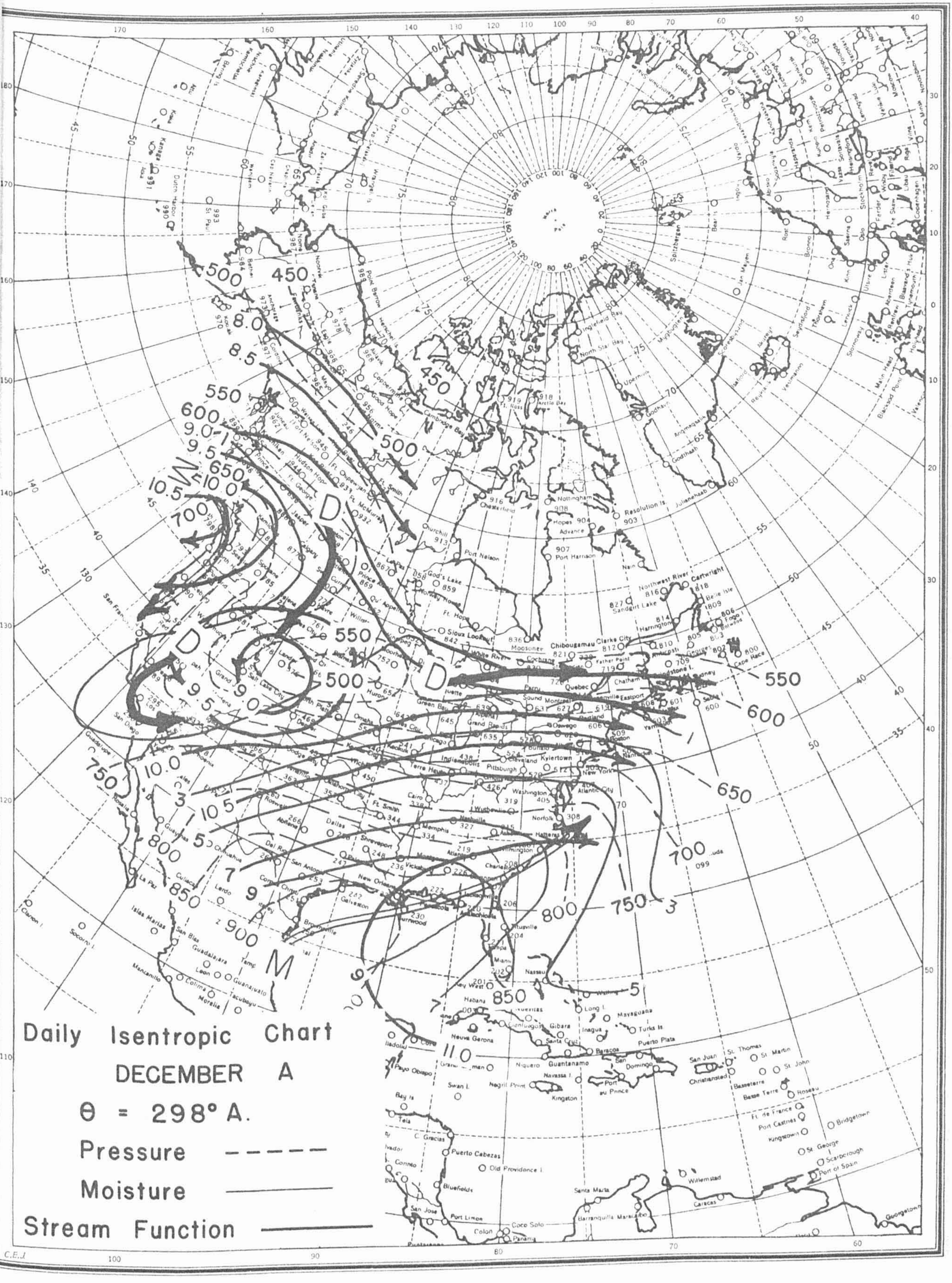


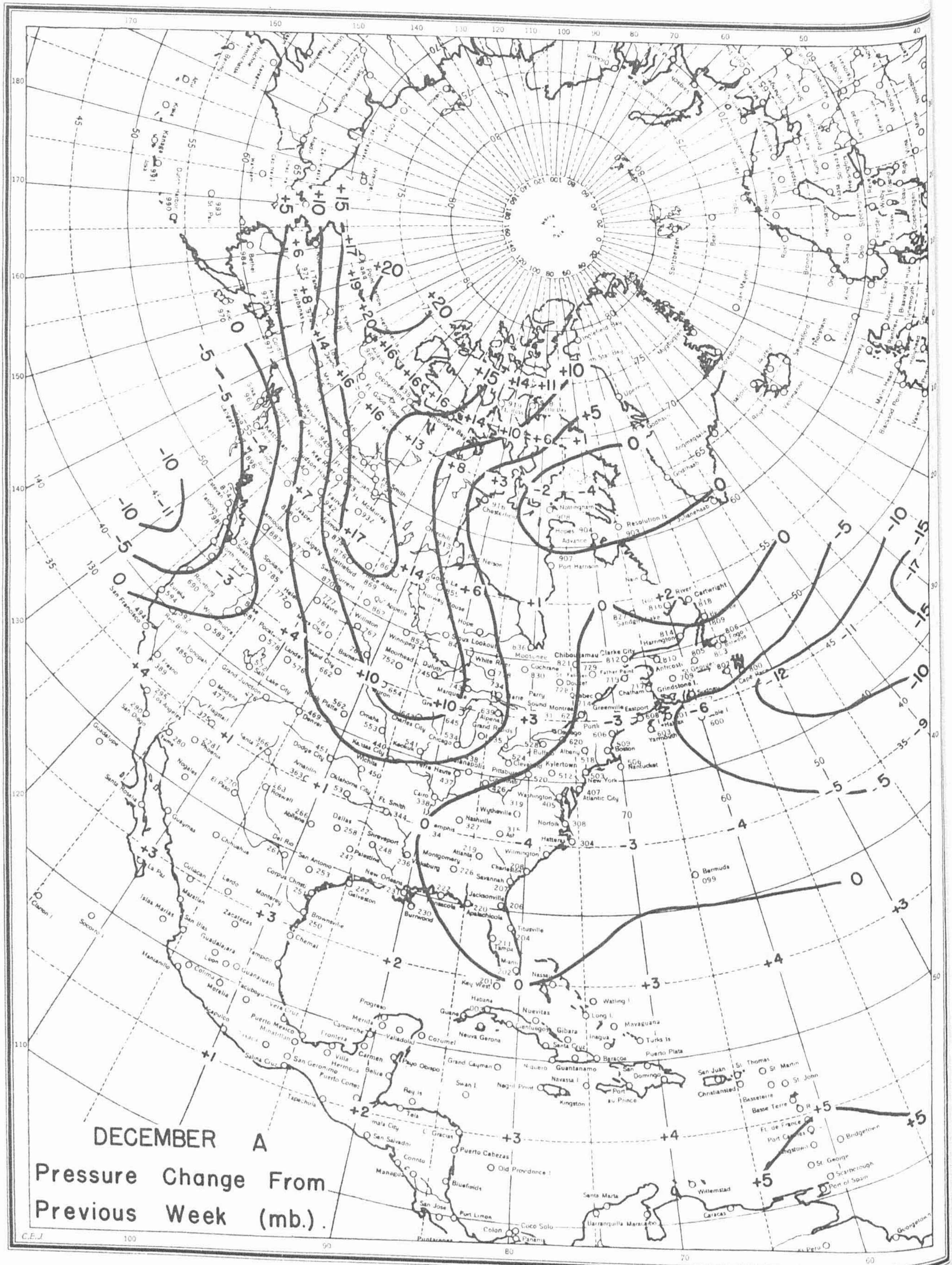
DECEMBER A
Last Daily Surface Chart
Synoptic data included in original chart.



DECEMBER A

ly 3 Kilometer Chart

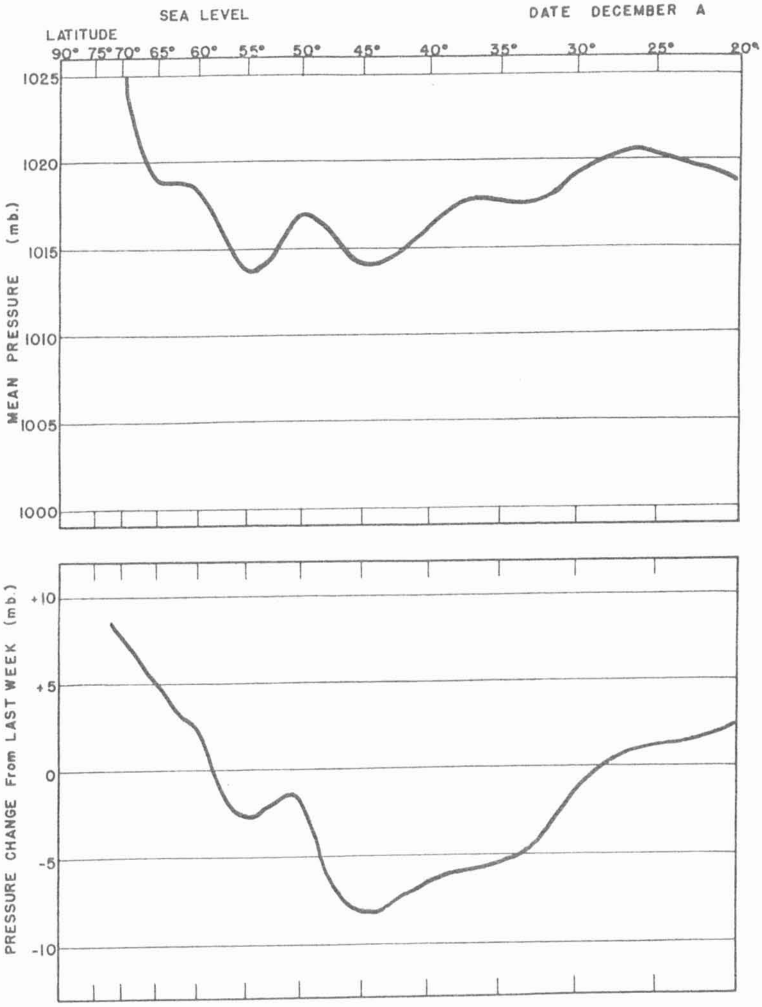

Daily Isentropic Chart
DECEMBER A
θ = 298° A.
Pressure
Moisture
Stream Function
C.E.J.

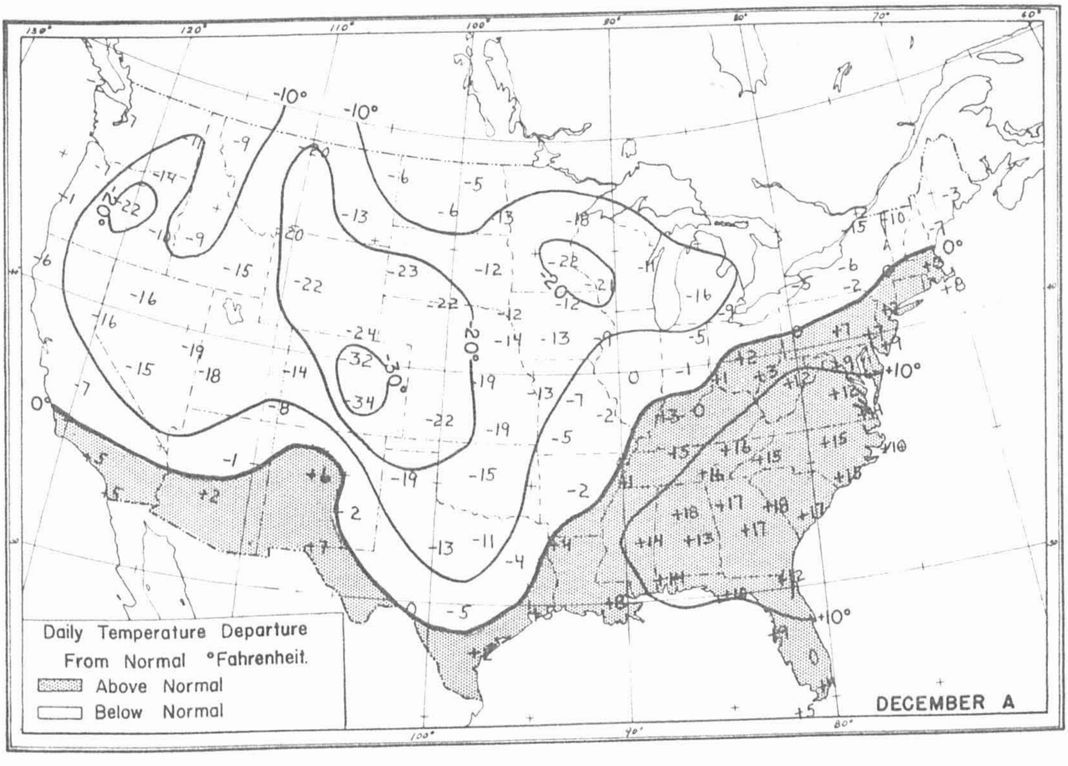


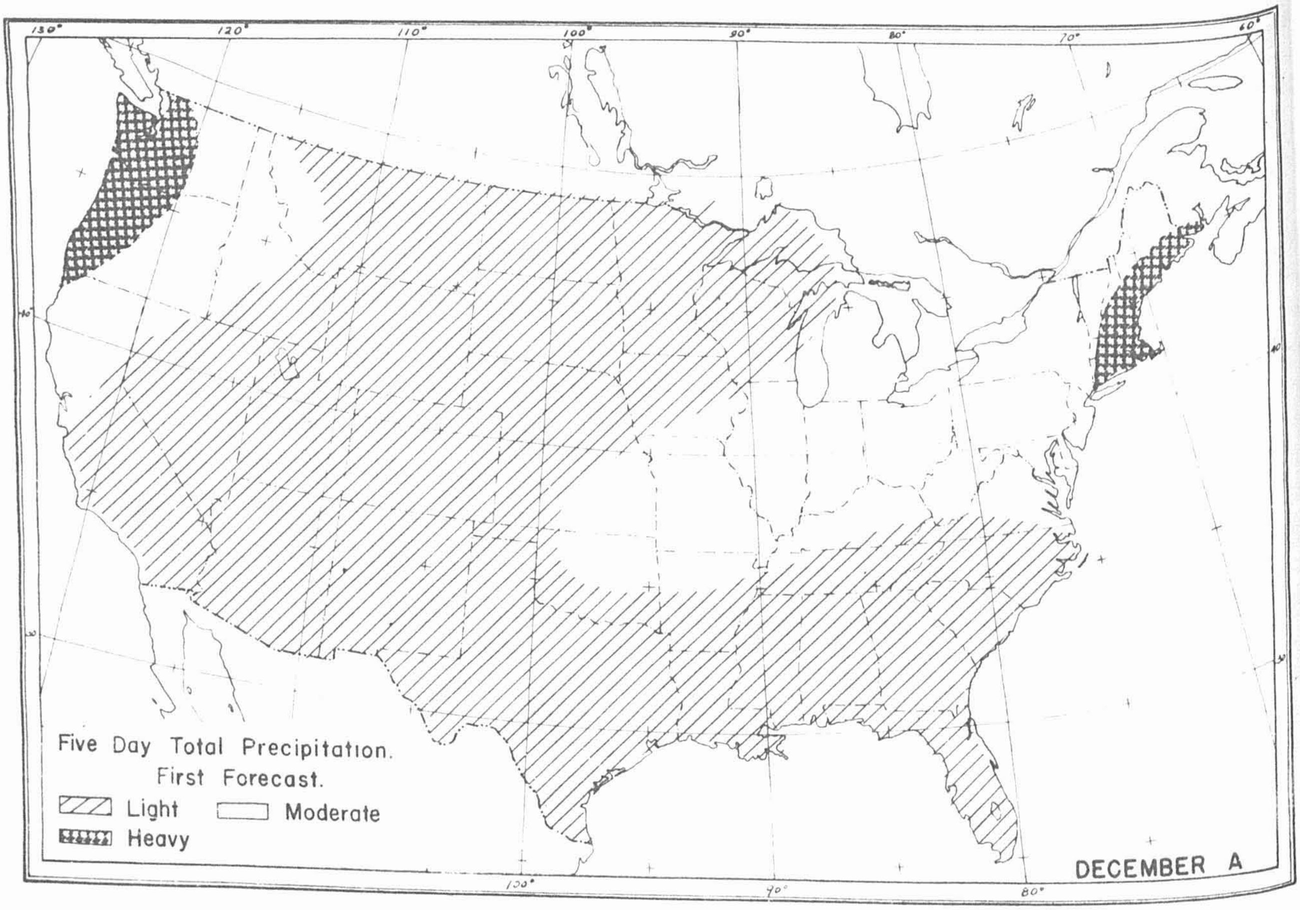
DECEMBER A

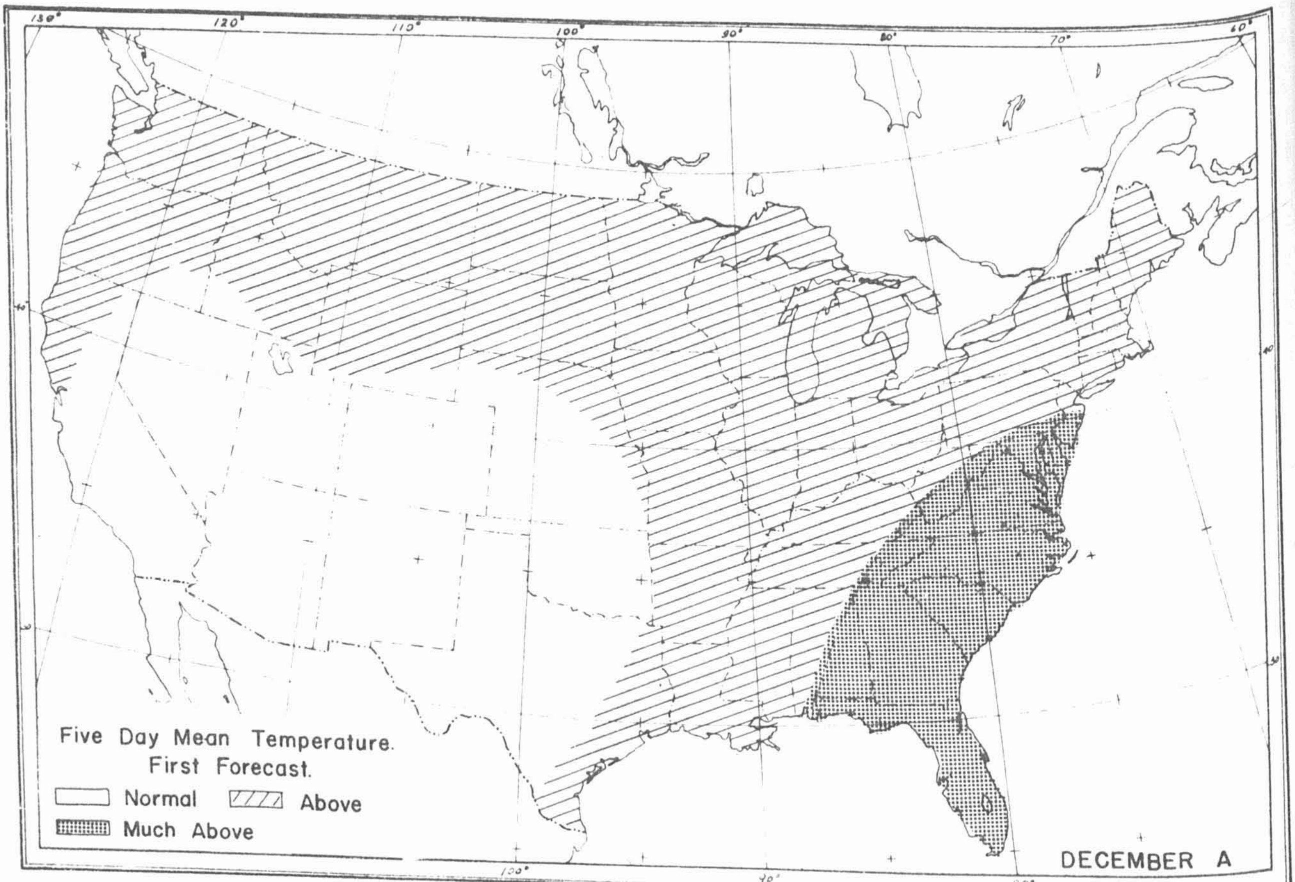
Pressure Change From Previous Week (mb.).

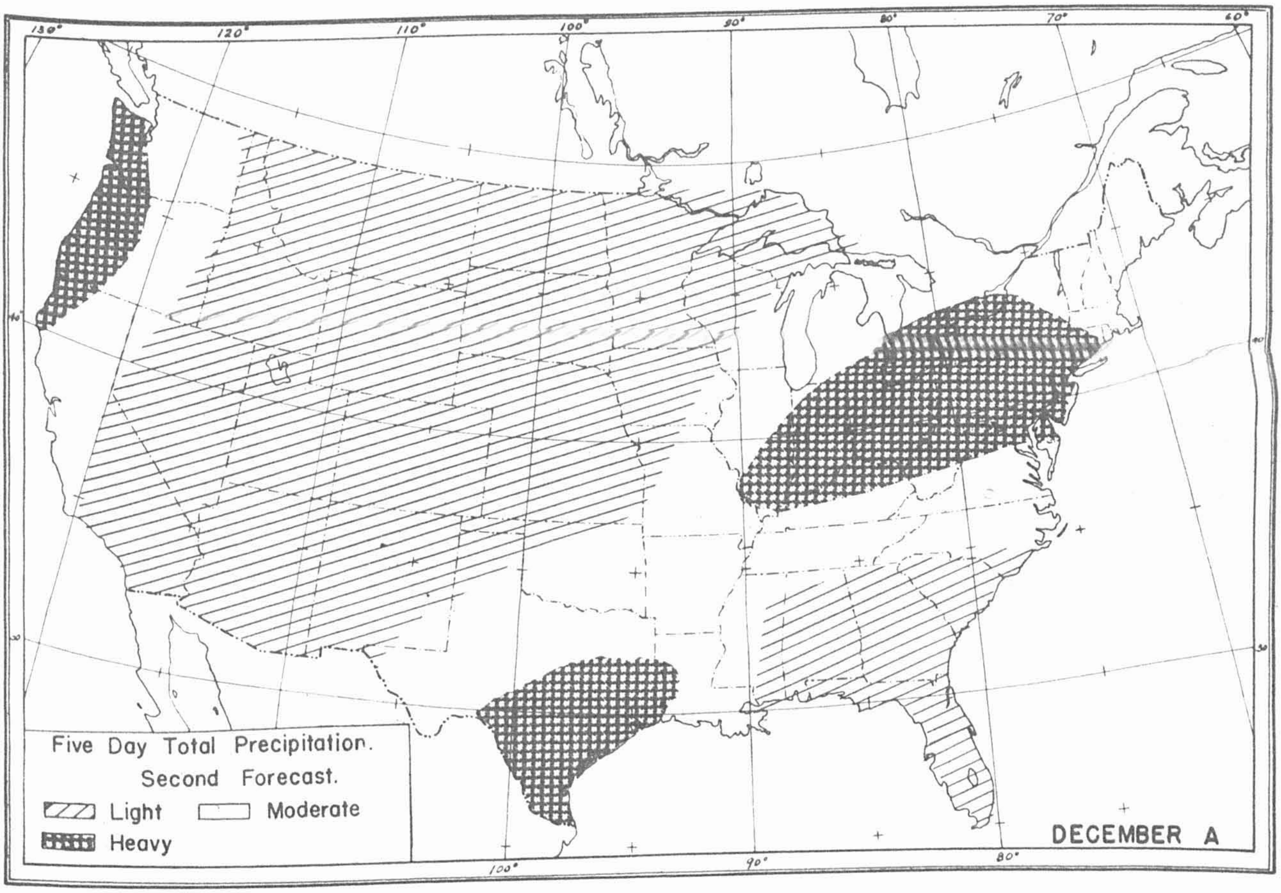
PRESSURE PROFILE

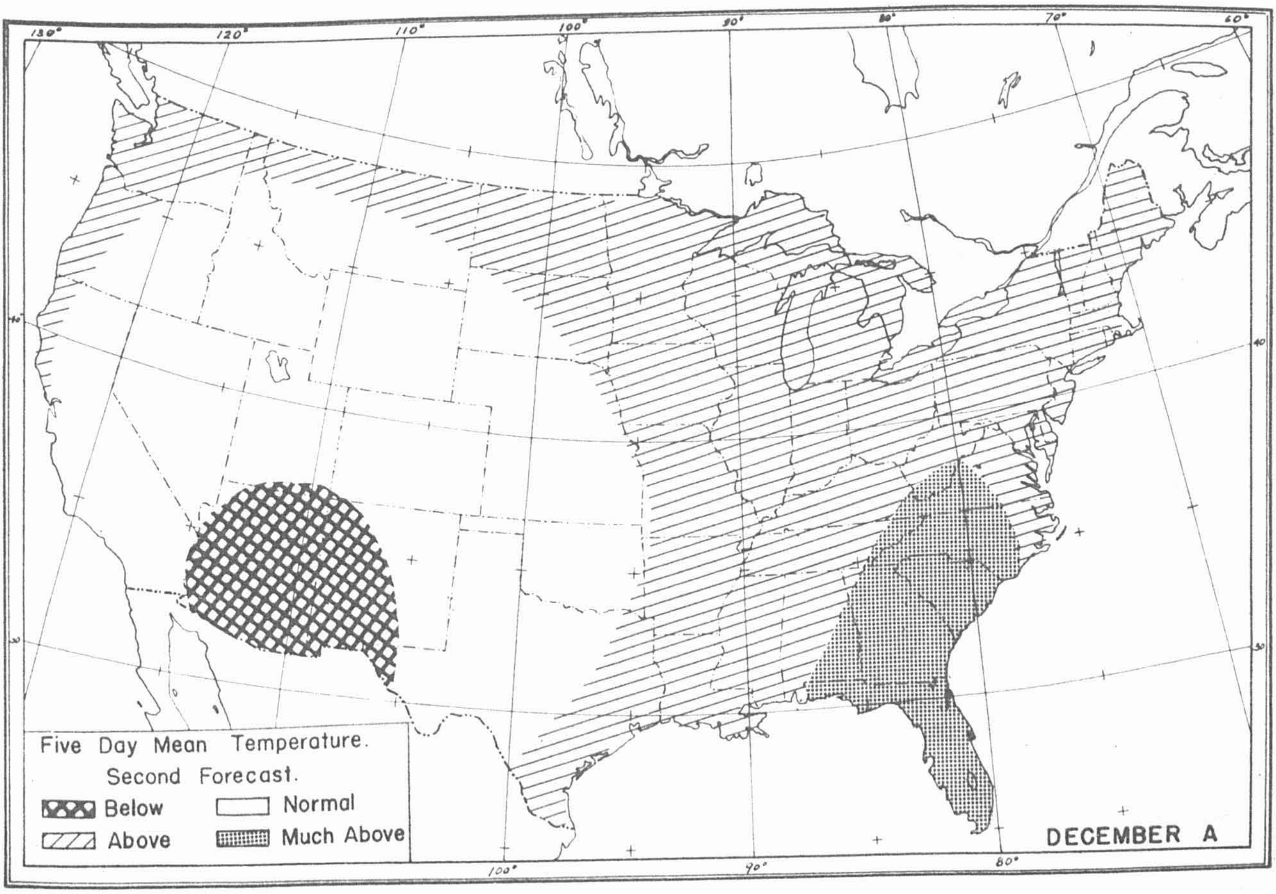


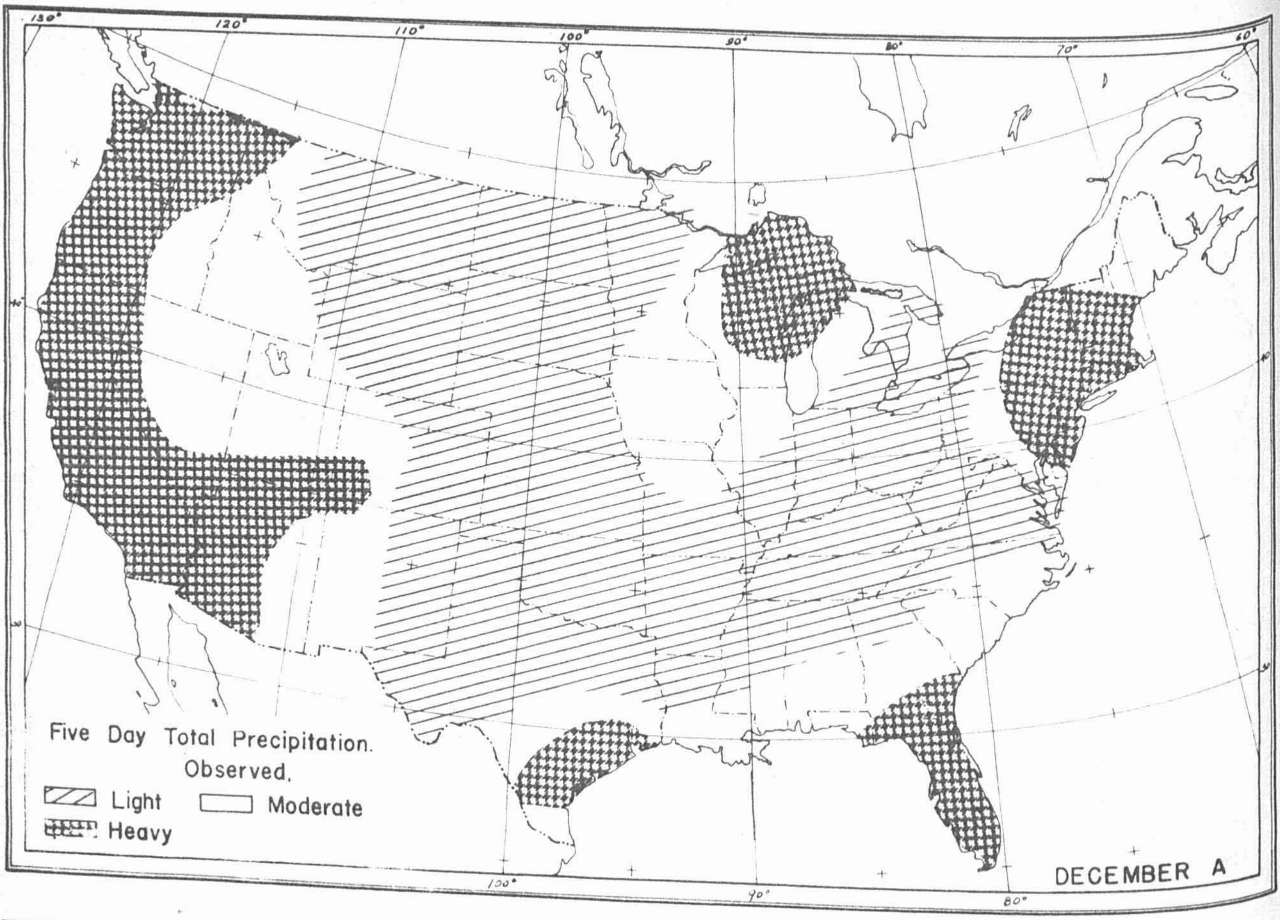



Five Day Total Precipitation.
First Forecast.
Light
Moderate
Heavy
DECEMBER A

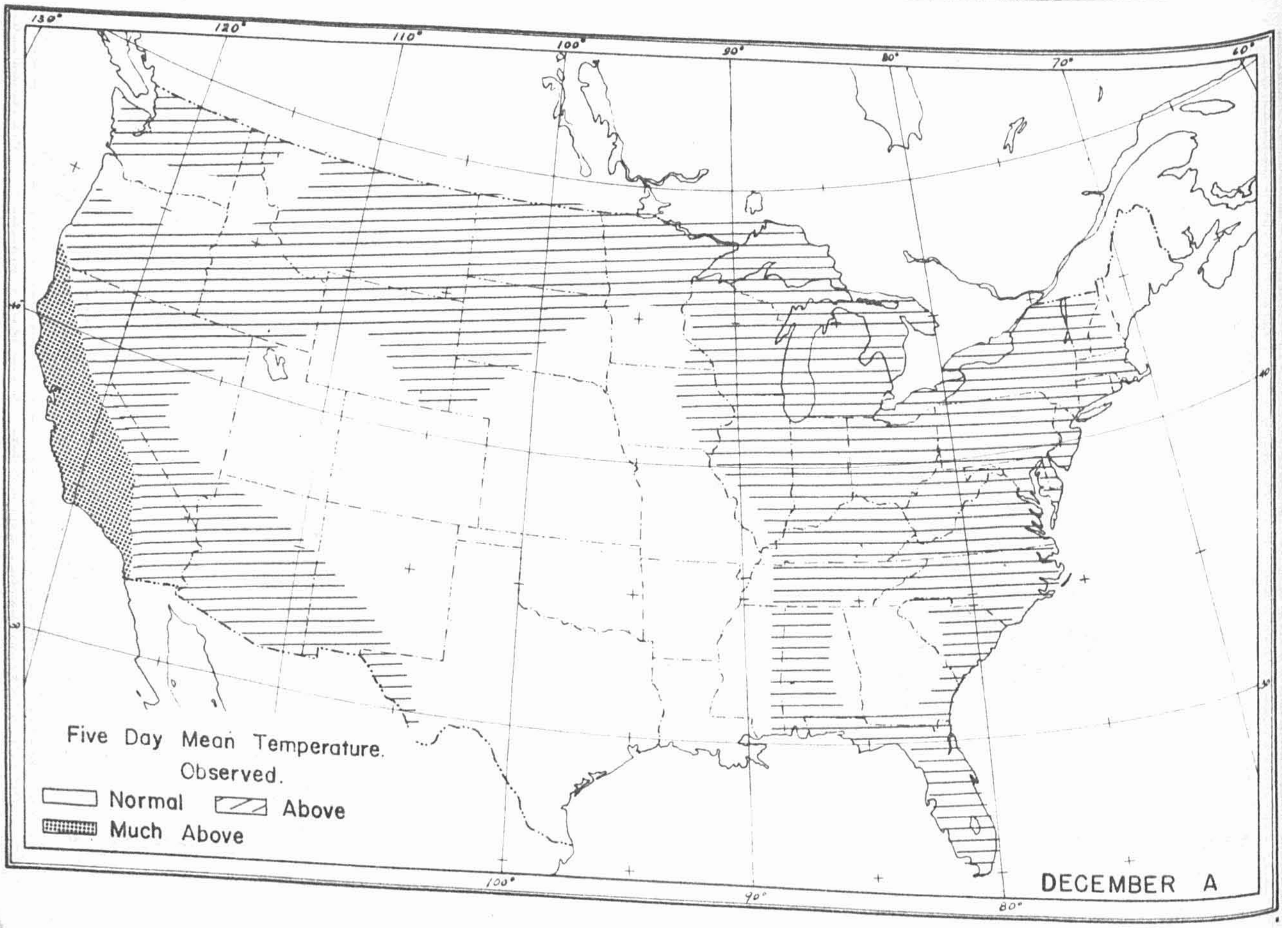

Five Day Mean Temperature.
First Forecast.
Normal
Above
Much Above
DECEMBER A


Five Day Total Precipitation.
Second Forecast.
Light
Moderate
Heavy
DECEMBER A


Five Day Mean Temperature.
Second Forecast.
Below
Normal
Above
Much Above
DECEMBER A



Five Day Total Precipitation.
Observed.
Light
Moderate
Heavy
DECEMBER A



Five Day Mean Temperature.
Observed.
Normal
Above
Much Above
DECEMBER A