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OFFICE NOTE 160

Data and Analysis Errors on 9 January 1977

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This is an unreviewed manuscript, primarily intended for informal exchange of information among NMC staff members.

1. Introduction

Forecasts from 00Z 9 January 1977 formed one of the six cases used in the May 1977 tests to select the most promising successor to the 6-level PE model. This case was selected because of strong east coast cyclogenesis, locked-in error in the eastern United States, and cross-contour flow at 300 mb in the PE over the western United States. A retrospective look at the initial data and model performance for this case uncovered four analysis problems which very likely occur in other cases:

(1) Much too high water temperatures off the New England coast in the data that NMC gets from NESS.

(2) Probable underestimate of an important vorticity center at 500 mb in northwest Canada in the Flattery analysis.

(3) Incorrect Flattery wind analyses in the initial trough over the Rockies.

(4) Too cold low-level thickness temperatures in the Flattery analysis in the northwestern Pacific.

These errors are documented here in order to focus attention on improving these aspects of our analysis system. They are discussed individually after a general review of the synoptic situation and general model performance in this case. They lead to several recommendations.

I. NMC's use of satellite-derived sea surface temperatures for model input be replaced as soon as possible by climatology. A RAND-derived global 1° x 1° tape of monthly climatology and ice cover has been obtained from NCAR with this possibility in mind. This change should be made before late fall. The basis for this recommendation is given in section 3.

II. Ship surface air temperatures be raised to full status in NMC's temperature and height analyses (they are now ignored in the Flattery height analyses, being used only in the special quasi-independent "temperature" analyses for the operational cycle). This recommendation is based on section 6 below.

III. The accuracy of the NMC routine analysis methods be examined even more aggressively and regularly than has been possible in the past. This recommendation is justified by the errors uncovered by only a partial look at the synoptic case described herein.

2. The synoptic situation and some model results

Fig. 1 shows the initial, 24-hr, and 48-hr charts at 500 mbs taken from the Flattery global analyses. The development is most easily described as a simple (?) amalgamation over Pennsylvania of a southeastward moving vorticity center from the vicinity of Great Slave Lake with a northeastward moving vorticity center from the western United States.

Fig. 2 shows the 48-hr 500-mb height errors of the LFM, the PE, the HFM (high resolution version of the PE or "hemispheric fine mesh") and the NGM ("nested grid model") over the United States. The HFM and the NGM had horizontal grid resolutions of about 165 and 205 km, respectively, over the central United States, compared to the 330 and 165 km resolution of the PE and LFM. The vertical structure of the HFM is identical with the "6-level" PE and LFM, while the NGM had 9 levels. The NGM had no heating except release of latent heat, and no evaporation or sensible heat flux from either ground or ocean.

Fig. 3 shows the Flattery analyzed initial and 48-hr 1000-mb charts, together with the observed and predicted postions of the New England low[1,2] center.

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[1] The real low split temporarily at 36 hours; a new center formed near Hatteras and rapidly superseded the original center then located over the Appalachians. None of the regular models seem to have predicted this detail. A run with the MFM ("movable fine mesh") of 100 km resolution did predict a split low. However, the new low in the MFM was too far southeast and did not supersede the original low. Since the area of the MFM at $t = 0$ did not include the two major 500-mb vorticity maxima in the west, and its 48-hr 500-mb locked in error was at least as large as that of the PE on Fig. 2, this run on the MFM has been disregarded.

[2] The 9L model is the 2 degree 9-level hemispheric version of J. Stackpole's latitude-longitude model. This model had considerable smoothing during its integration in order to obtain forecasts to 84 hours without "polar instability." This smoothing unfortunately produced too much effect even at 48 hours and this model therefore is not discussed further.

3. Water temperature in the Atlantic

One paradox is the better performance of the HFM in the Eastern United States vis-a-vis the NGM at 1000 mb as compared to 500 mb. Some light is shed on this by Fig. 4. This figure shows the result at 1000 mb of adding sea-surface heat flux and evaporation to the NGM, processes which were absent in the NGM test computations shown in Figs. 2 and 3. (The PE and HFM have oceanic heat flux. Instead of evaporation, however, relative humidities over the ocean in those models are not allowed to dip below 30 percent.) The 1000 mb NGM forecast is now very similar to that of the HFM, which, according to Fig. 3, was the best of all model test predictions at 1000 mb. The NGM precipitation forecast was also improved to be similar to that of the HFM, with 36-48 hr amounts of 2 inches over Rhode Island compared to observed amounts of 2-3 inches in southeastern Maine.

The addition of oceanic heating to the NGM resulted in a slight increase of the 500-mb height error, i.e., the heating seemed too intense. This suggested a look at the sea temperatures used in the calculations. These were the same as those used in all other models, being taken from a data set updated by NESS and archived by NMC on the ADP file. Water temperatures from ships or climatology are not used by NESS in preparing this data--only satellite measured radiances from the appropriate channels. Fig. 5 is a map of the 10, 15, 20, and 25°C isotherms from this data set, together with plotted values of ship water temperatures measured at 00, 06, or 12Z on Jan. 9, and the 10°C and 20°C climatological January isotherms. There is an extremely warm error off the United States and Canadian coast in the NESS SST data set, as much as 16°C. A glance at the initial and 48-hr 1000-mb flow pattern (Fig. 3) shows that this area has very cold air flowing over it initially from the northwest; this air then moves to the southwest and then back to the northwest over New England in advance of the developing low along the coast. This trajectory is ideal for responding to the abnormal warm ocean temperature.

Tests have not been made with either corrected ocean temperatures in the NGM or with the ocean heating removed in the PE. It is obvious however that the NESS temperatures will grossly corrupt the computation of heat flux.

Fig. 5 also contains the climatological 10 and 20 degree isotherms. They are much closer to the ship values than are the NESS temperatures. Recommendation I follows from this fact, and the following two points:

a. Although satellite SST may show in principle deviations from climatology, these deviations (if correct) will either be of a horizontal scale too small to affect NMC models (such as 50-100 km meanders of the Gulf Stream) or, when of a large scale, of too small amplitude (1-2°) to seriously modify operational runs at NMC.

b. SST could be a control on acceptability of ship air temperature reports (section 6). SST errors of the type shown here would result in discarding of good ship air temperatures.

4. Vorticity analysis in western Canada

Fig. 6 shows the LFM initial 500 mb analysis. The vorticity center in western Canada has an inner isoline of 22×10^{-5} $\sec^{-1}$. This is 4×10^{-5} $\sec^{-1}$ larger than the $18 \times 10^{-5} \sec^{-1}$ isoline given by the Flattery analysis (Fig. 1). Fig. 7 shows the 24-hr forecasts from the HFM, NGM (both from the initial data of Fig. 1) and the LFM. The observed North Dakota vorticity center in the 24-hr Flattery analysis (Fig. 1) is very similar to this LFM prediction, with an equal-sized 20×10^{-5} $\sec^{-1}$ contour analyzed only about 100 km southeast of the LFM forecast. The HFM and NGM produced almost identical 24-hr predictions of this center, which differ from the more accurate LFM prediction by the same amount that the Flattery initial analysis differed from the LFM analysis. The conclusion seems inescapable that part of the 48-hr 500-mb + 180 meter height error in Ontario produced by the HFM and NGM (Fig. 2) has already been made at 24 hours and, in fact, at $t = 0$ in the Flattery analysis of the Canadian vorticity center. This also explains at least part of the reason why the LFM positive error of + 60 meters on Fig. 2 is better than the + 180 meter error of the HFM--since these models have identical horizontal and vertical structure this difference is not too easily explained otherwise.

5. Flattery analyses in the western United States

Fig. 8 shows the "1+40" LFM analysis at 500 mb together with the data. There is an intense frontal zone extending from 60N to 30N near longitude 115W. The initial Flattery analysis (Fig. 1) places a vorticity maximum of 16 x 10^{-5} sec^{-1} by Salt Lake in the cold air east of the frontal zone (note that this is again several units weaker than the LFM analysis on Fig. 6). The 24-hr 500-mb vorticity predictions of the HFM and NGM in the Texas area (Fig. 7) err in that the Flattery 24-hr analysis had a 22 x $10^{-5}sec^{-1}$ vorticity center on the southern border of Oklahoma. The LFM 24-hr vorticity forecast on Fig. 7 is no better; although it has a more realistic maximum value, the center is already too far south and will contribute to the very large negative 48-hr height error shown on Fig. 2 (worse even than the PE).

A preliminary doubt about the Flattery analysis on Fig. 1 was raised by the fact that the analysis 12 hours earlier had the center (16 x 10^{-5} sec^{-1} isoline) located less than 200 km to the northwest of its location on Fig. 1. Continuity would certainly suggest that one of these is incorrect.

Fig. 9 is a cross-section (based only on observations) along 40°N, extending from San Francisco (493) to Denver (469). This representation brings out in a conclusive manner the concentration of horizontal shear ($\partial v/\partial x$) and vertical shear ($\partial v/\partial z$) in the sloping frontal zone. (The section is not quite typical in that usually the jet maximum is at the main tropopause level (250 mb, say) above where the frontal zone intersects the 500 mb surface. Stations further south do reach their maximum wind speed around the 200-mb level.)

The Flattery analysis for this section is shown in Fig. 10. It is of course much smoother than the data shown in Fig. 9, and the region of maximum $\partial v/\partial x$ is shifted eastward in the middle troposphere from the correct location just west of station 572. The sloping frontal zone is completely smoothed out. It of course cannot be said that an analysis capturing the detail of Fig. 9 is necessary for the current 6 (or 7) layer NMC models. However, the common occurrence of "locked-in" error from troughs similar to this one, and the inability of the HFM or LFM to consistently and significantly improve on the PE in this respect, suggests that improvements in vertical resolution may be necessary in the models and, by implication, in the analyses.

An indication of how the 500-mb vorticity pattern in the western states should look, instead of the broad patterns shown on Fig. 1 (Flattery) and Fig. 8 (LFM), is obtained by computing $\partial v/\partial x$ between stations 486 and 572 on Fig. 9. When this added to f, the resulting absolute vorticity is

20×10^{-5} sec^{-1}. In other words, the spread out vorticity maximum on Figs. 1 and 8 should be concentrated into a narrow north-south ribbon in the frontal zone along 115W. Immediately outside this zone the vorticity would be smaller than is now analyzed. If captured in an analysis scheme of fine vertical and horizontal resolutions, such a change could produce a considerably different forecast in a model of fine resolution.

A large scale error in the Flattery wind analysis shows up when the velocity components of Fig. 9 are subtracted from those of Fig. 10. This difference [-v(Flattery)] - [-v(obs)] is shown in Fig. 11. An overall positive bias of perhaps 3-5 m sec^{-1} is shown, indicating an excessive southward component in the Flattery analysis.[1] This, by advecting properties too rapidly southward, could explain part of the tendency in the PE, HFM, and NGM to end up 48 hours later with too much cyclonic vorticity in the southeastern United States (Fig. 2).

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[1] The Flattery height data (not shown) gives geostrophic winds equal to those on Fig. 10 to within ± 1 m sec^{-1}.

6. Oceanic air temperatures

The northwestern Pacific contained a deep low (Fig. 12) with secondary vortices sweeping around it. In the course of checking out the sea surface heating and evaporation code for the NGM, maps of $(T_{water} - T_{air})$ derived from the Flattery heights and the SST file showed several abnormally large positive values here. In this case the SST data agreed moderately well with the reported ship water temperature and SST climatology. Therefore we looked for suspiciously low air temperatures.

Fig. 13 is a map of T*--the surface temperature field obtained in the Flattery analysis, with observed ship temperatures for comparison. The two cold centers are unrealistically cold. The eastern one is cold compared to the nearby ship temperatures of 8, 9, 11, 6 and 8 degrees. The western one is located in a region of no ship reports, but the analyzed temperature is unbelievably low.

Fig. 14 is a map of an artificial surface temperature obtained by extrapolating dry adiabatically downward from 922 mb $[\ln 922 = \frac{1}{2} \ln(1000{+}850)]$ to sea level, with T at 922 being derived hydrostatically from the Flattery height fields at 1000 and 850 mb. The dry adiabatic extrapolation was used to produce the warmest reasonable surface temperature. The same unnaturally cold centers are present, however.

The analysis programs involving ship air temperatures at NMC are such that

a. The global forecast-analysis final cycle never examines ship air temperature data.

b. The global forecast-analysis operational process does not use ship air temperature in analyzing the 12 mandatory height fields. These temperatures are used in analyzing T* and mandatory level T fields.

T* is used as input for the operational model as the main ingredient of its 50 mb thick boundary layer temperature. (The operational Flattery analysis is used throughout this note.) The mandatory level T fields provide lapse rate values to interpolate from mandatory layer thickness temperatures to sigma layer temperatures.

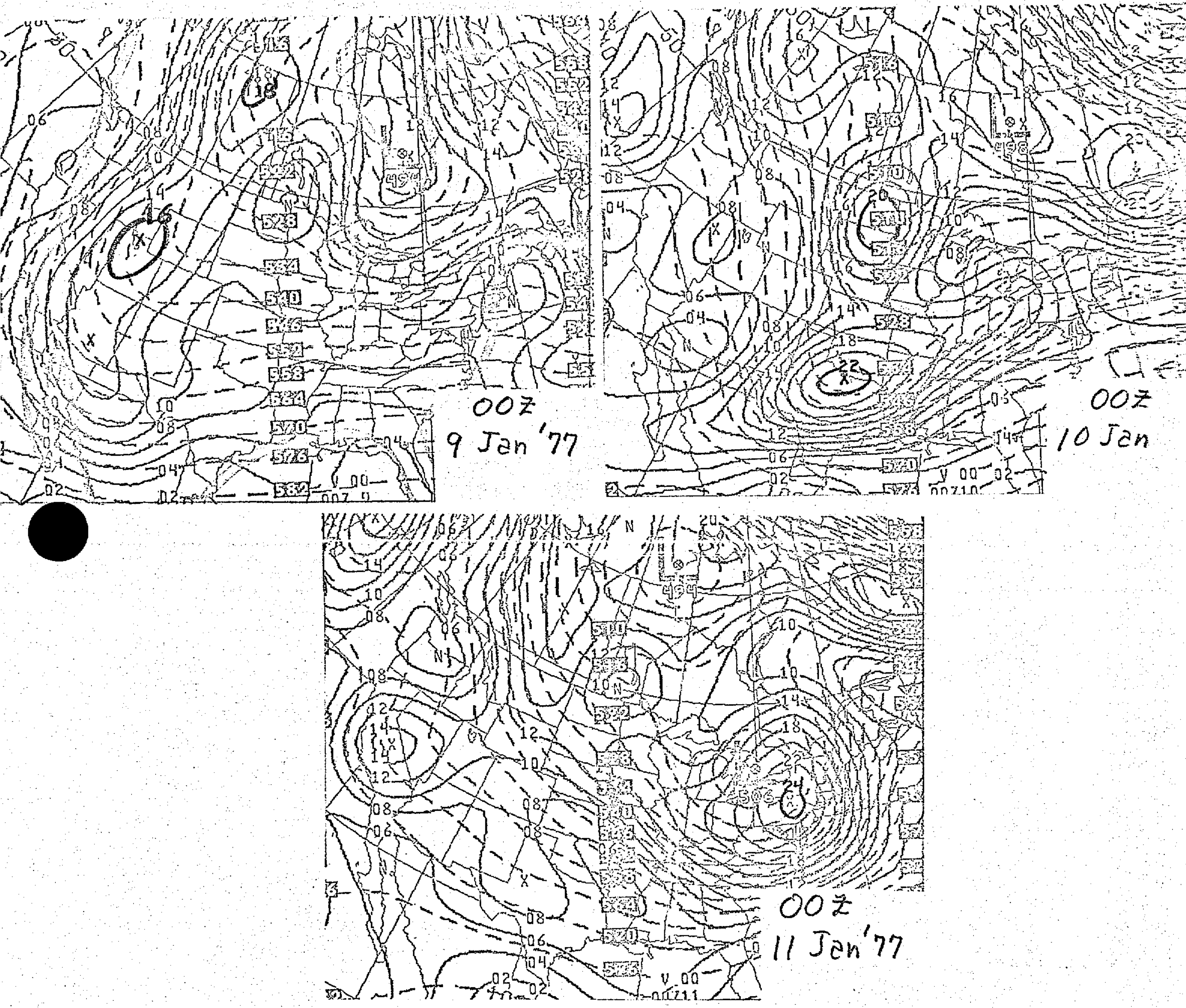
The similarity of the cold errors on Fig. 13 and Fig. 14, and the fact that the analysis of the height fields used in Fig. 14 did not use current ship air temperatures, show that the misinformation about T* and the 1000-850 thickness field most likely came from the analyzed height fields. It is then likely--although this would require further checking--that the first guess was too cold. This is believable since the global forecast-analysis model is never influenced by the fact that ships observe air temperature. The reasonableness with respect to temperature of the first guess provided in this region then depends very much on the accuracy with which the surface heat and moisture fluxes are modeled (as well as the overall dynamic accuracy of the global model).

The suggested steps to correct this are two:

(a) Use ship air temperatures in the height analyses.

(b) Do this in the final as well as the operational analyses.

The use of climatological water temperatures as a control on the ship air temperature may be desirable.



00Z
9 Jan '77

00Z
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Fig. 1 Flattery 500-mb analyses.
—— Abs vorticity $\times 10^5$ sec. – – – height contours

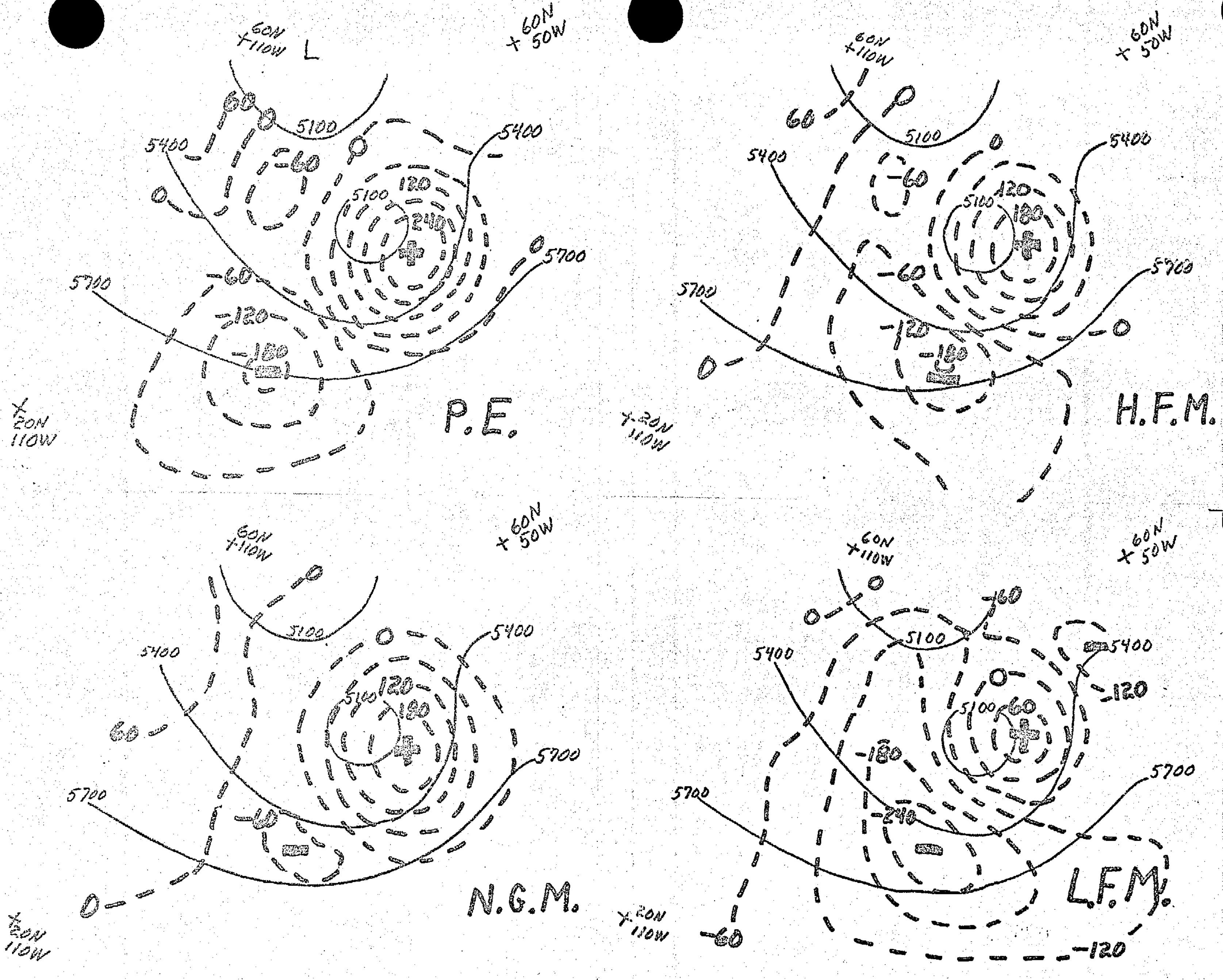
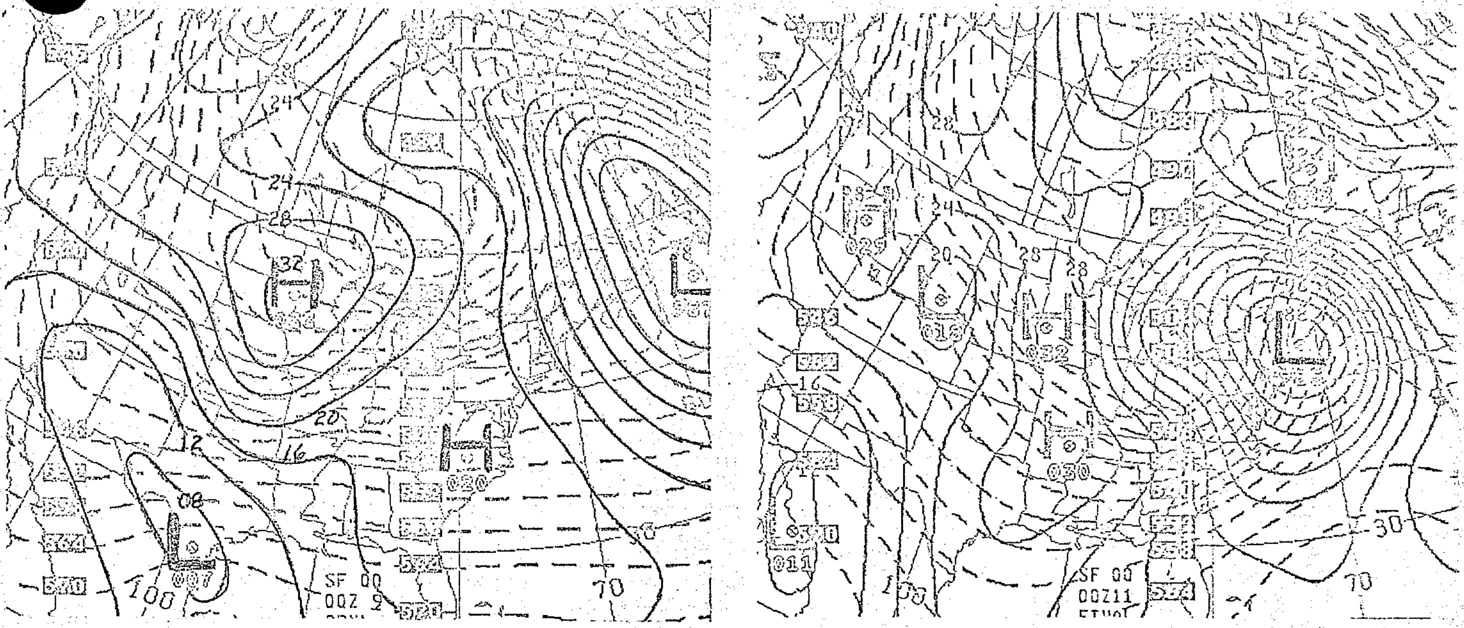
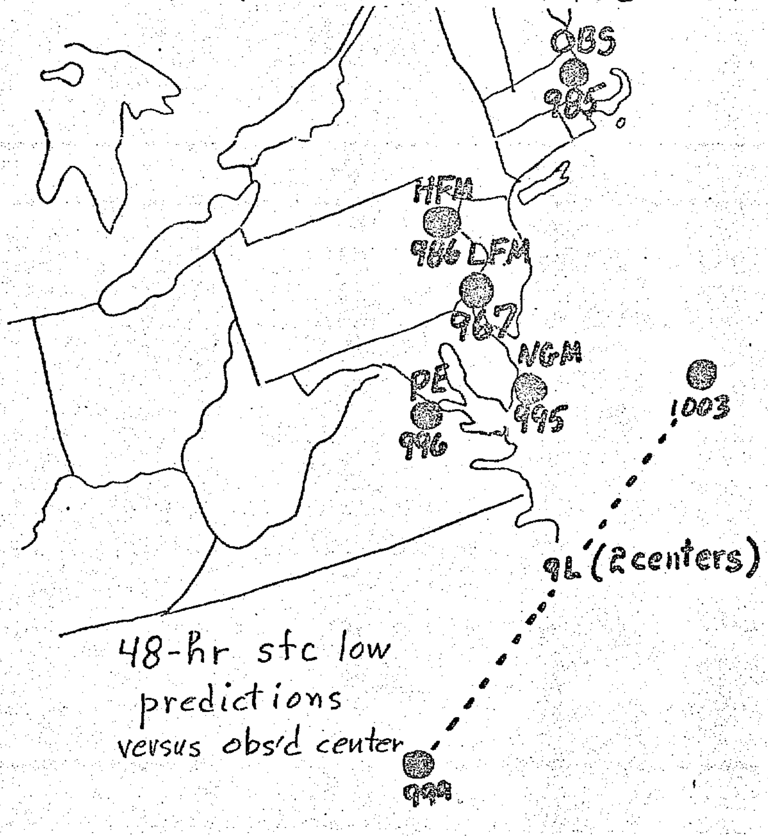


Fig. 2. 48-hr 500 mb height errors (meters) in dashed isolines. Thin solid curves are verifying contours for orientation.



Obs'd 00z 9 Jan '77 Obs'd 00z 11 Jan '77



48-hr sfc low predictions versus obs'd center

FIG. 3 Observed initial and 48-hr sfc charts; observed and predicted low centers and central pressure.

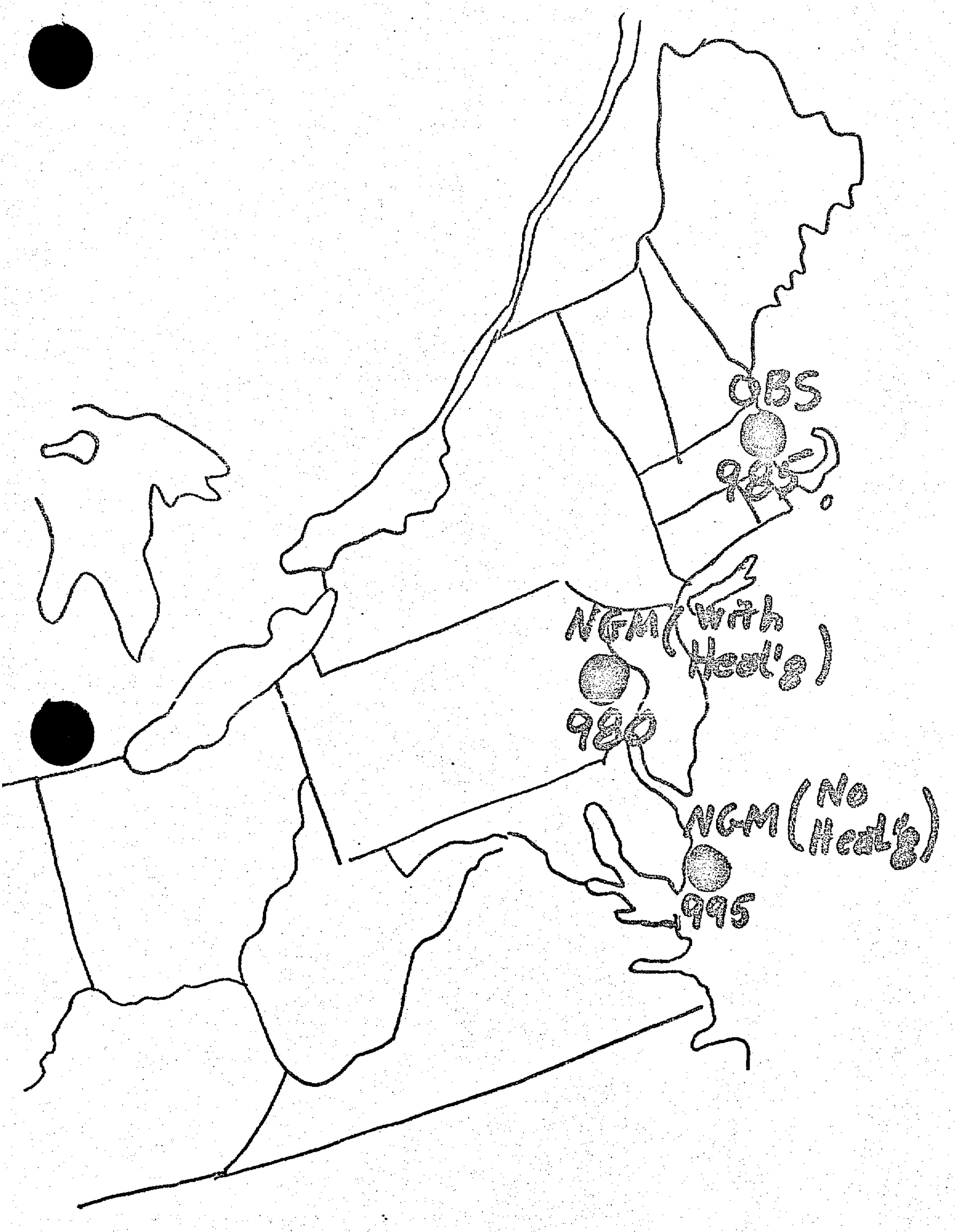


Fig. 4. 48-hr sfc. low predictions from the NGM, with and without oceanic heat flux and evaporation.

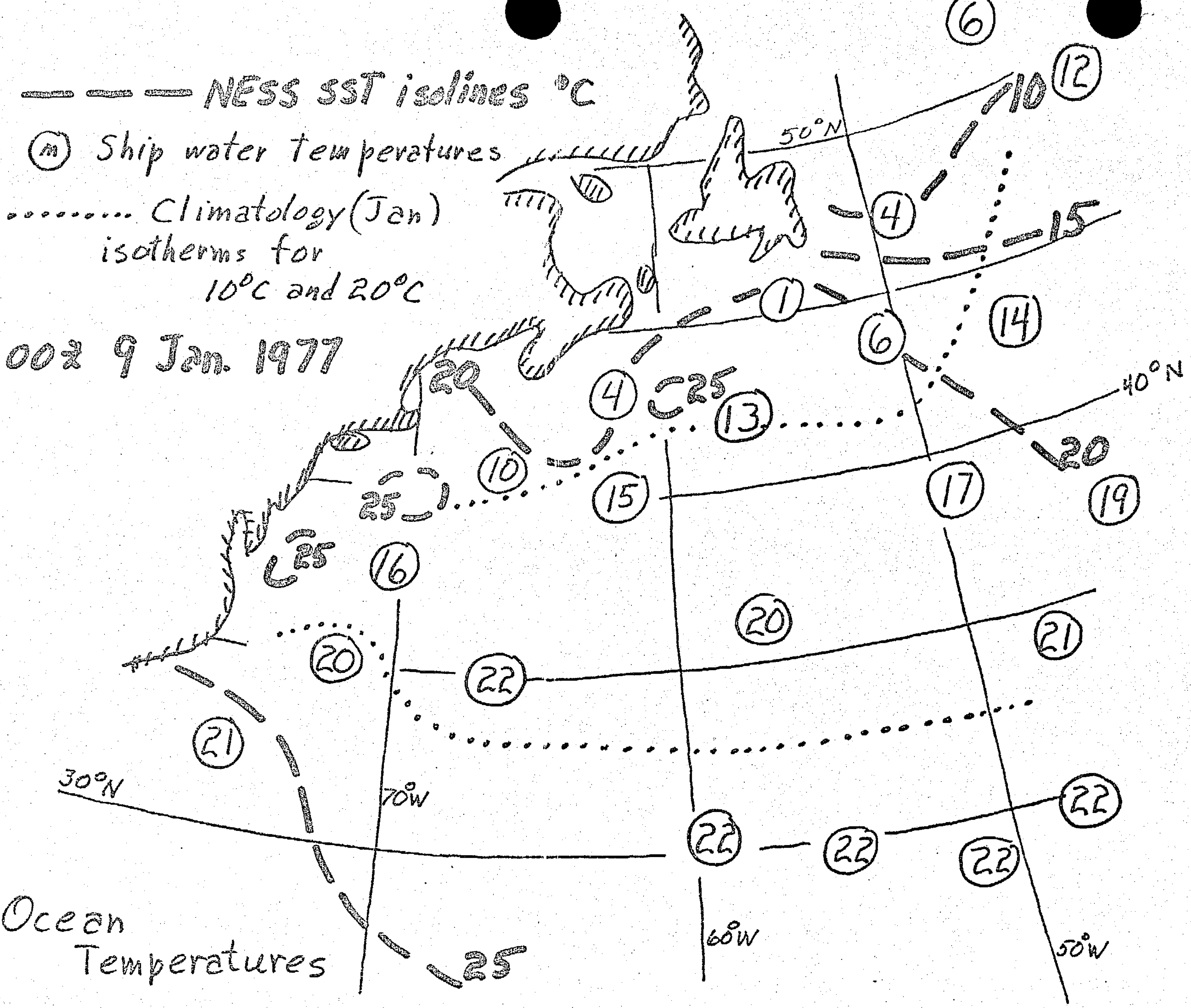


Fig. 5. Ocean Temperatures

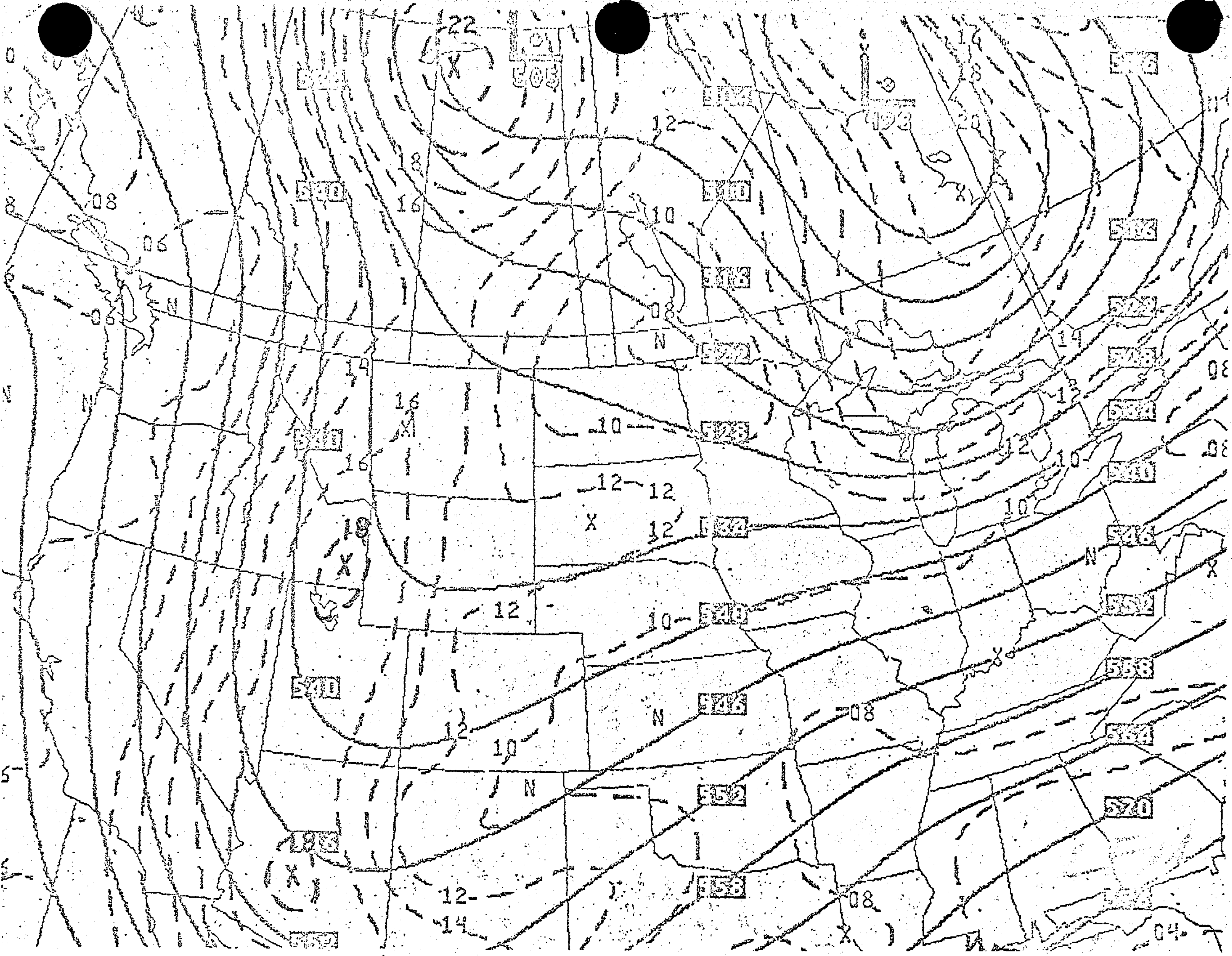


FIG. 6 LFM 500 mb analysis 00Z 9 Jan 1977

- - - - Abs. vorticity x 10^5 sec ——— Height in meters/10.

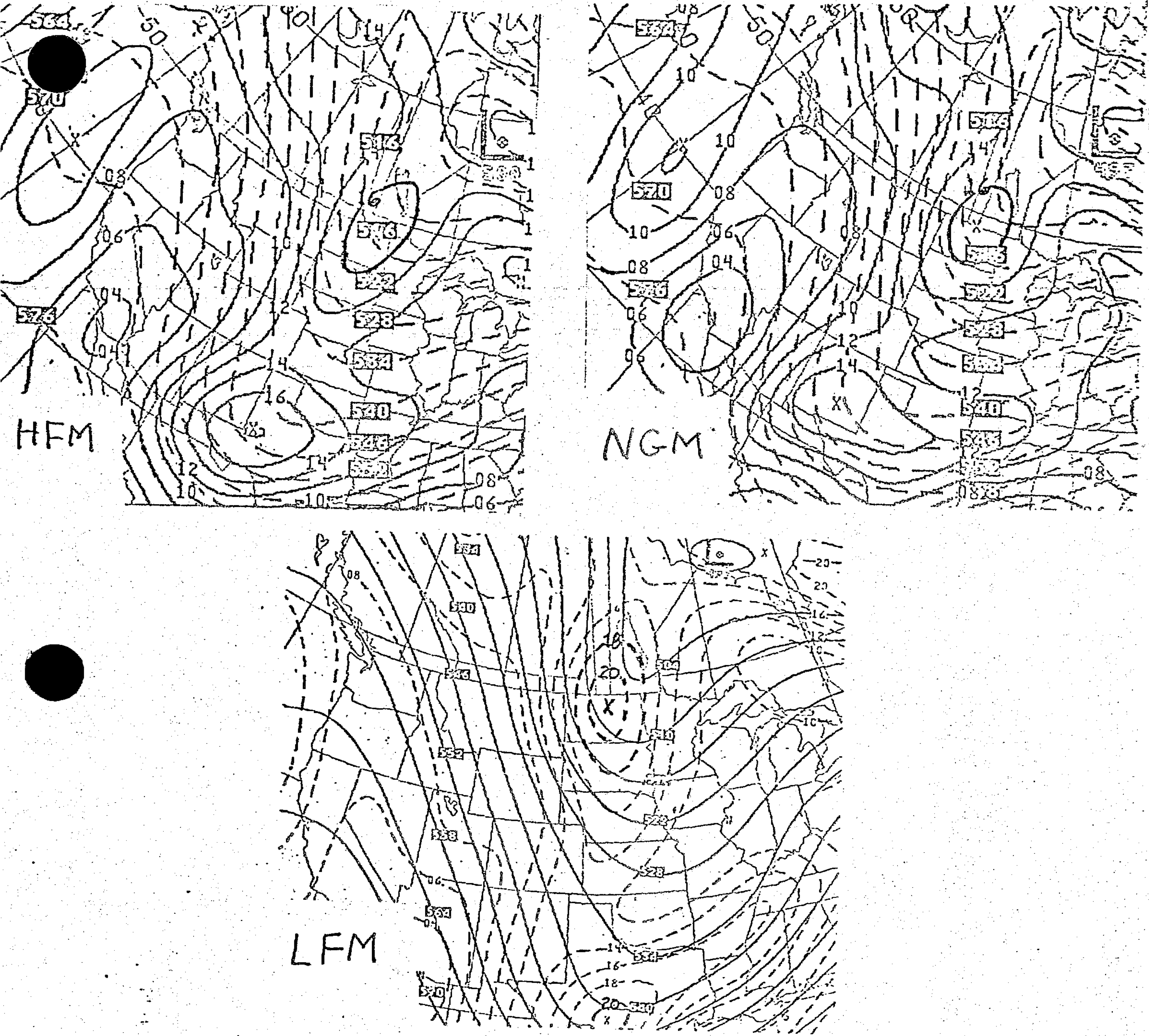


FIG. 7 24-hr fcst 500 mb charts valid 00Z 10 Jan 1977
Abs. Vort x10^5sec is solid on HFM, NGM; dashed on LFM
Heights are dashed on HFM, NGM; solid on LFM

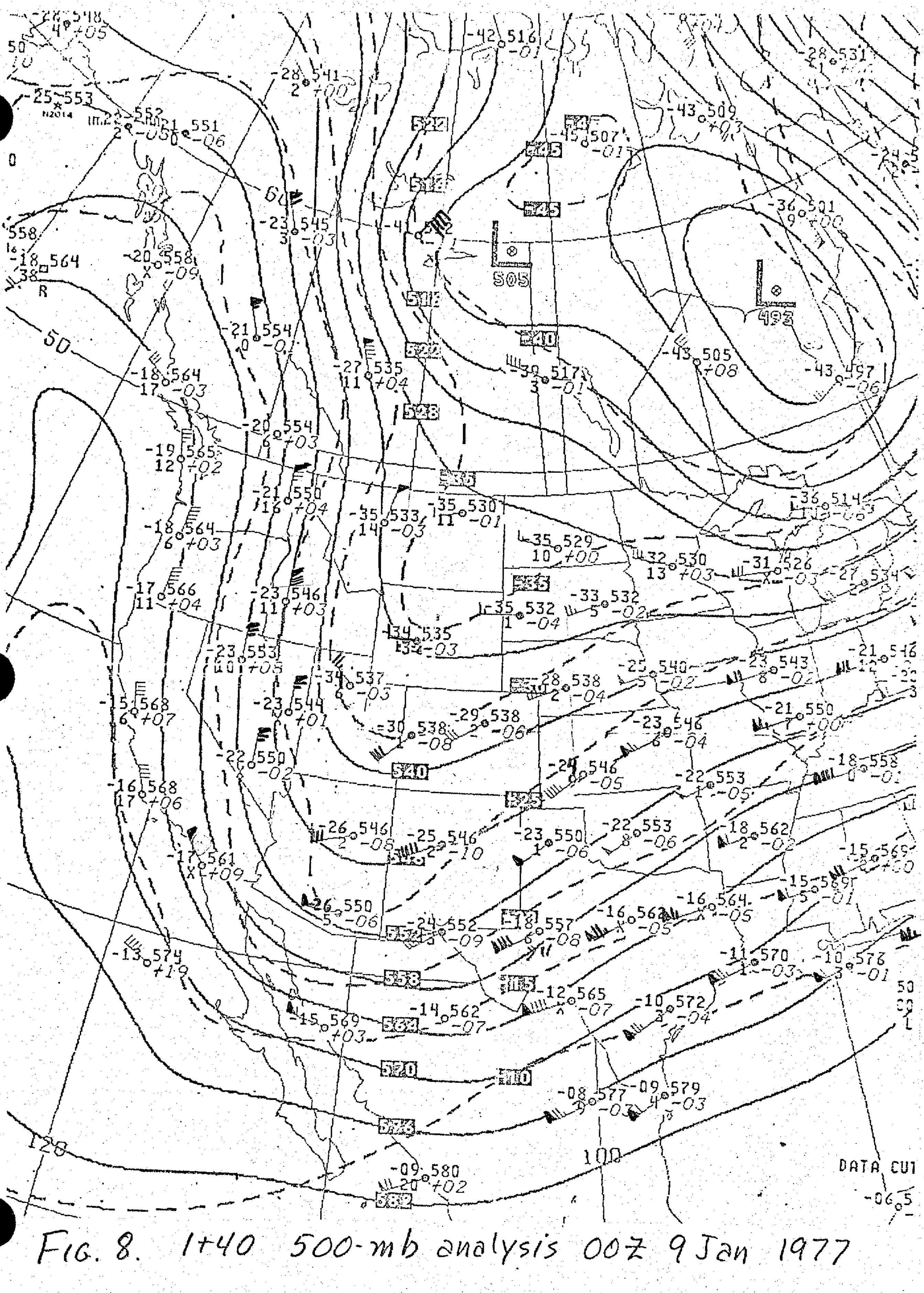


Fig. 8. 1+40 500-mb analysis 00Z 9 Jan 1977

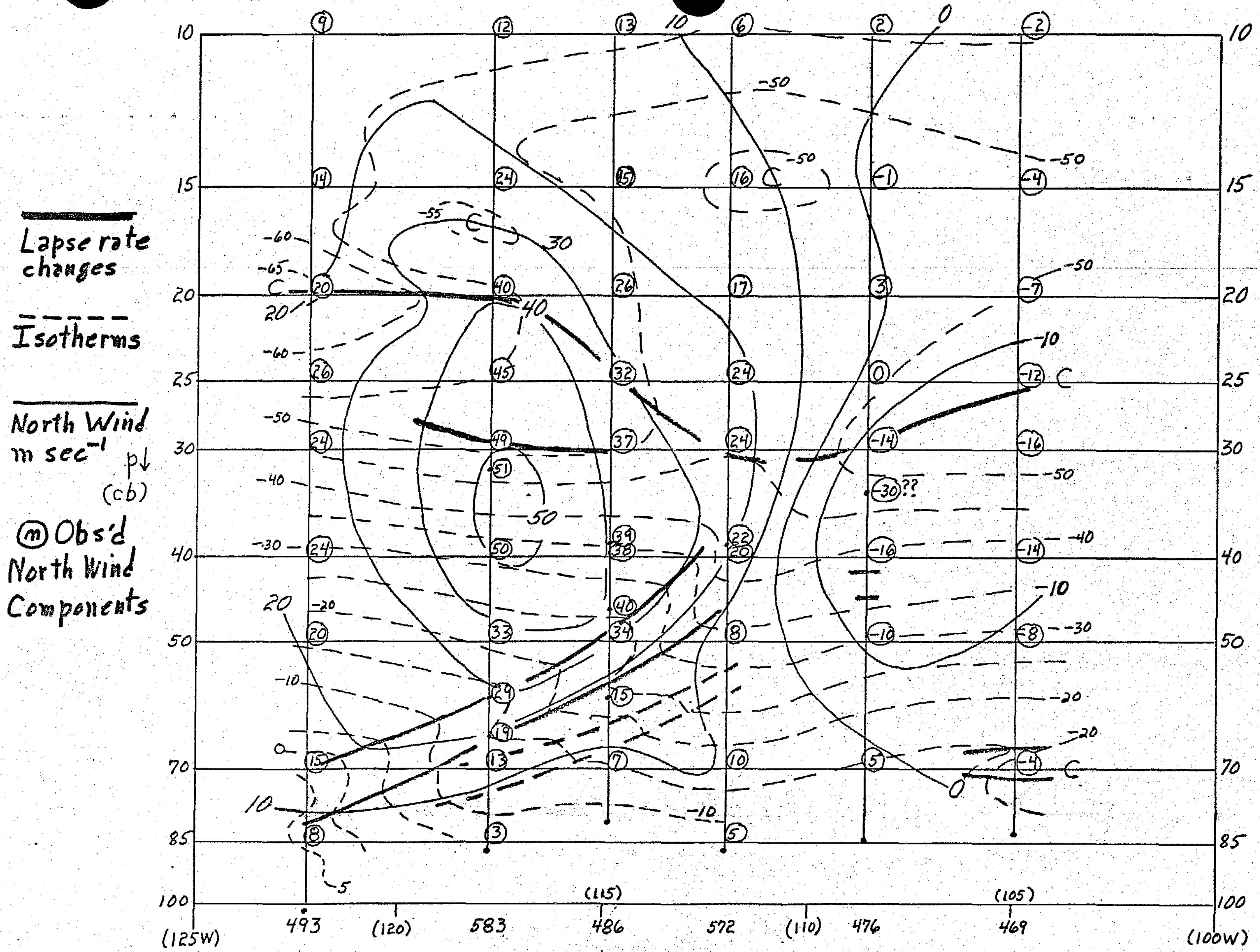


FIG. 9 Cross-section at 40°N 00Z 9 Jan 1977

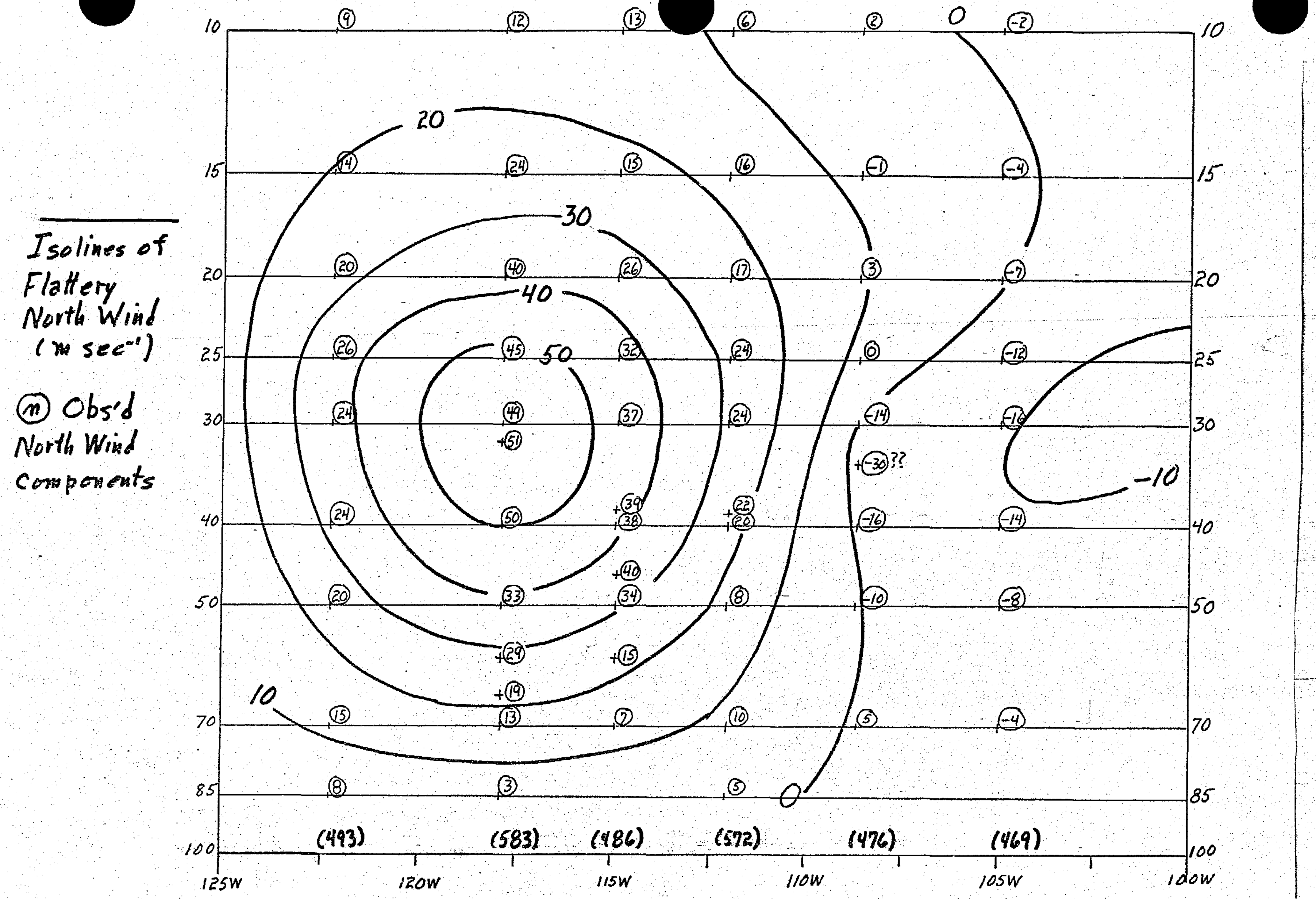


Fig. 10 Cross-section of Flattery wind analysis (component from North in m sec⁻¹) 00z 9 Jan 1977

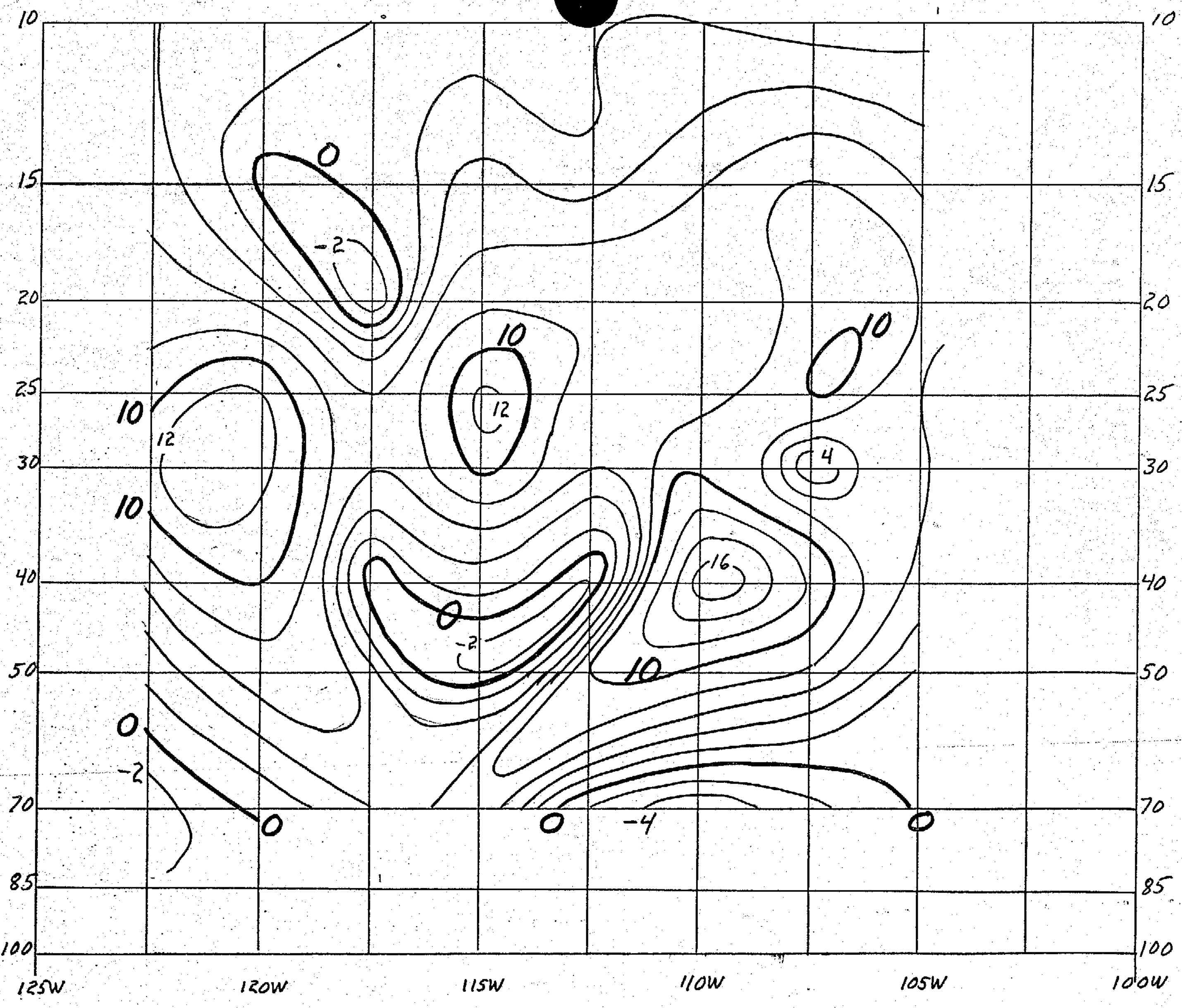


FIG. 11. North wind components (Flattery—Observed), m sec^{-1}

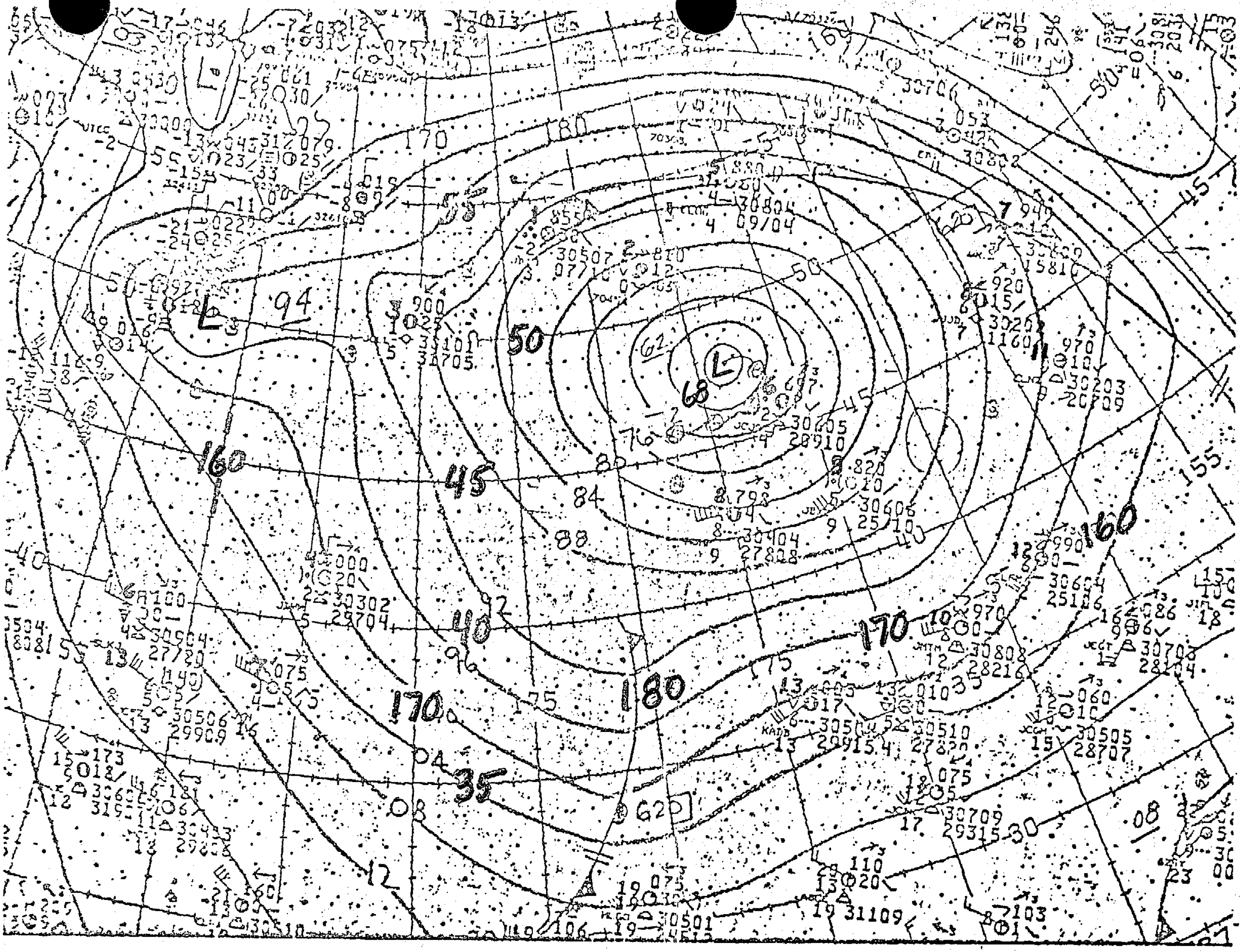


Fig. 12. Pacific surface analysis, 00Z 9 Jan 1977.

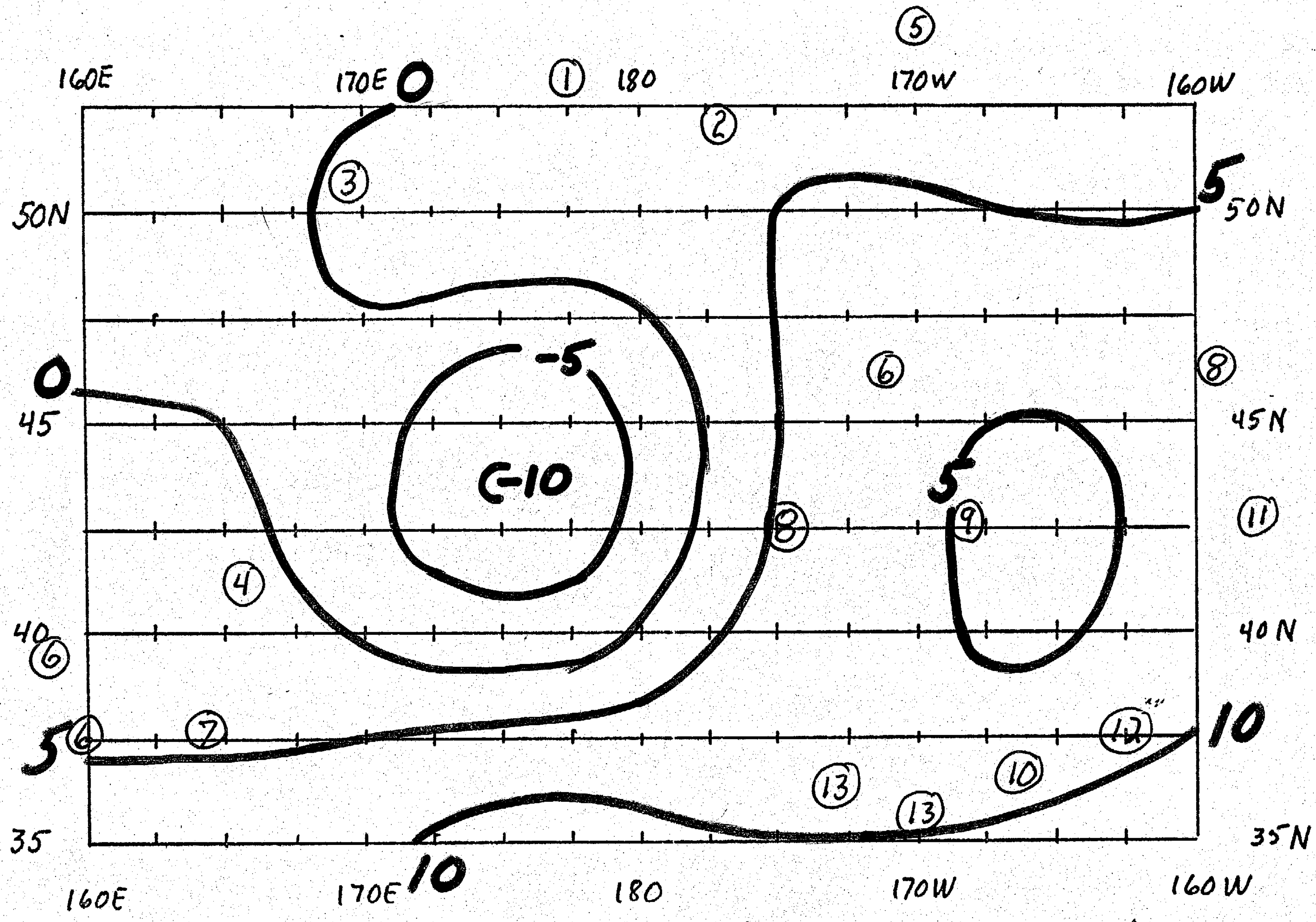


Fig. 13. T* isolines and observed ship air temperatures (encircled). 00Z 9 Jan. 1977

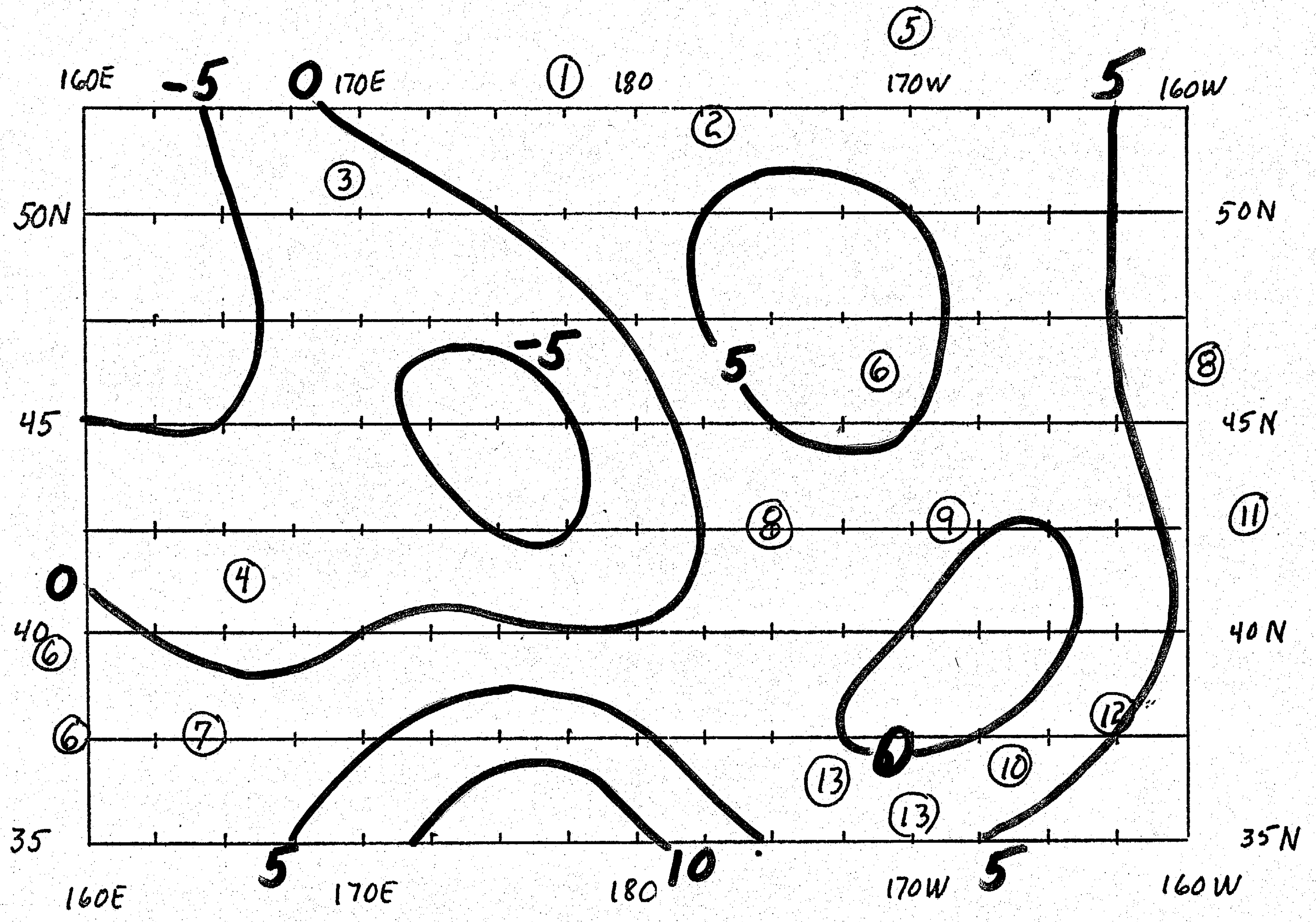


Fig. 14. Artificial surface air temperature isolines