U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
NATIONAL METEOROLOGICAL CENTER

OFFICE NOTE 174

An Investigation of Data and Analysis Error on February 21, 1977

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MARCH 1978

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I. Introduction

Last year a test was conducted at the National Meteorological Center (NMC) to choose a successor to the then operational 6-layer Hemispheric Primitive Equation Prediction Model (Shuman and Hovermale, 1968)--hereafter referred to as the 6L PE. Three different models were contenders for the role of successor: a model similar to the 6L PE but with half the grid size (HFM), a nested grid model (NGM), and a 9-layer hemispheric version of the NMC 2.5^{o} Global Model (NLH) (Stackpole, Vanderman, and Shuman, 1974).

As part of this test, 84-hour forecasts were made with each of these three models on six test cases and their performance compared to that of the 6L PE. In one of the six test cases in which the 6L PE performed poorly, all three contending models performed poorly as well. Further consideration of this case led the finger of suspicion to be pointed at the initial analysis as a major factor in the uniformly poor forecasts. This investigation was initiated to study the initial analysis of this case in some detail.

The next section presents the evidence that first aroused suspicions of the quality of the initial analysis in this case. The results of an investigation of the data and analysis errors involved is described in the third section. A summary of the results concludes this document.

II. The Evidence

The initial time for this case was 1200 GMT 21 February 1977. The major deficiency of the forecasts is most evident in the 48-hour 500-mb forecast height fields made by the HFM, NGM, and NLH. These are shown in Figures 1, 2, and 3, respectively, and the verifying analysis in Figure 4. In each forecast, there is a trough in the continental United States near 100°W. This position is approximately correct. However, the depth of the system is badly underdone by all three models, for none predicted the 5340m closed low that verifies in that area. At the surface (not shown), the models predicted the central pressure of the low center to be 7 to 20 mb too high and located at thickness values 60 to 120m too warm. Thus, all three contending models badly underforecast this important winter storm.

The 24-hour 500-mb predicted height fields made by the HFM, NGM, and NLH are shown in Figures 5, 6, and 7, respectively, along with the verifying analysis in Figure 8. At this time, the trough of interest verifies near 110°W, 40°N. Inspection of Figures 5-8 reveals that the three models forecast this trough to be 100m too shallow. Furthermore, the 500-1000 mb thicknesses (not shown) were too warm by 60-100m. This magnitude of error at such an early stage of the forecast, coupled with the fact that this trough was initially located in the data-sparse region off the west coast of the United States, led to suspicion of the quality of the initial analysis. The remainder of this document is concerned with the results of an investigation into the accuracy of that analysis.

III. The Investigation

a. The Quality of the Analysis

The storm described in the previous section originated in an area bounded by 125°W, 150°W, 20°N, and 50°N. Therefore, attention will be directed to this area in our consideration of the analysis.

The first step in the investigation was to obtain as detailed a 3-dimensional picture of the analysis in this area as possible by considering horizontal maps, vertical cross-sections, and continuity in time. Figures 9 and 10 present the 500-mb height and isotach and the 300-mb height and temperature maps, respectively.

At 500 mb, there is a complex trough-ridge-trough pattern just off the northwest coast of the United States. Just south of this feature, the jet drops to about 33°N with a maximum value of 90 kts. Also note that the 50 kt isotach dips south of 40°N. At 300 mb, the height field depicts a simpler trough structure than was the case at 500 mb. However, the temperature field has a bag of cold air, below -50°C, in the trough. This feature of the temperature field lies directly above the small 500-mb ridge just mentioned.

A vertical cross-section of the first guess to the analysis from 50^{o}N, 140^{o}W to 20^{o}N, 130^{o}W and the same cross-section from the analysis itself are shown in Figures 11 and 12. The most obvious changes to the first guess were made in the area between the arrows. Here, the analysis is warmer than the first guess below 400 mb and colder above. As a result, the 1000-500 mb thickness values were raised in the area in question. However, it was mentioned in the previous section that this trough was predicted to have thickness values too high by 24 hours. One would therefore suspect that this alteration in the first guess was at least overdone and perhaps in the wrong direction.

Two comparisons were made to further assess the accuracy of the analysis in the area of interest. First, the satellite IR movie loops were inspected. These seemed to indicate the existence of a simple single trough structure rather than the more complicated one depicted by the analyzed 500-mb height field. Second, the 500-mb jet in the analysis 12 hours earlier had a 110 kt maximum, and the radiosonde reports 12 hours later indicated a 110 kt jet maximum had entered the west coast of the United States at that time. This suggested that the analyzed wind speeds were too low in the jet maximum in the base of the trough. Given the lack of 500-mb data there, this feature of the analysis is probably a reflection of a first guess with wind speeds too light.

b. A Problem with the Cloud-Tracked Wind Data

In order to determine whether or not some of the analysis deficiencies mentioned above were caused by the data, the analysis was rerun twice. In the first rerun, all the Vertical Temperature Profile Radiometer (VTPR) reports were withheld from the analysis. In the second rerun, all the cloud-tracked wind reports were withheld. Vertical cross-sections of these analyses for the same path as before are shown in Figures 13 and 14, respectively.

Withholding all the VTPR reports made little difference to the analysis. This can be seen by noting the similarity between Figures 13 and 12. (It should be mentioned that the nearest swath of VTPR reports was to the west of this cross-section. Nevertheless, withholding the VTPR reports made only slight differences even there.) However, when the cloud-tracked wind reports were withheld, the analysis was much more similar to the first guess (Figure 11) than to the analysis using all the data (Figure 12). Thus, it is apparent that much of the alteration to the first guess in the area between the arrows was due to the cloud-tracked wind reports. Since these changes appeared to degrade the analysis in this region, it seemed prudent to consider these reports in some detail.

The previous subjective examination suggested that one source of problems is in the middle levels. Examination of the cloud-tracked wind reports available to the analysis revealed that there were indeed a small number at 500 mb in the small ridge mentioned previously. There, enhanced cumulus elements with tops at approximately 500 mb and bases near the ocean surface, were used to produce the wind reports. At the time the original analysis was performed, cloud tracked winds were routinely assigned the height of the cloud tops. Since it is likely that these clouds were being advected by winds at a level lower than their tops, these reports were probably assigned an erroneously high height.

In this area, the first guess indicated that the wind speed was increasing with height. Assuming this was the case in the atmosphere as well, the effect of assigning these reports erroneously high heights would have been to provide 500 mb wind reports with speeds too low. The global spectral analysis system would respond to such reports by reducing the horizontal height gradient. Because of the location of these heights in the prevailing synoptic pattern, the net effect would have been to raise the heights in the vicinity of the reports and, consequently, create a spurious ridge. Furthermore, the wind speed would have been reduced, the 1000 mb to 500 mb thickness would have been too large and the 500 mb to 200 mb thickness too small. Since the temperatures provided by the global spectral analysis are derived from thicknesses, the temperatures above the offending reports would be too low. These symptoms fit many of the suspicious characteristics of this analysis noted above.

c. <u>A Solution to the Problem</u>

At the suggestion of Mike Young, Chief of the Satellite Winds Section of NESS, these reports were assigned a pressure of 700 mb (this was done within the analysis itself) and the analysis was rerun. The cross-section from this analysis is shown in Figure 15. It is for the same path as the previous ones.

Comparison of this cross-section with those from the first guess (Figure 11) and the original analysis (Figure 12) reveals that the area between the arrows is now closer to the first guess than originally. At 500 mb (Figure 16) the small ridge embedded in the broad trough is now smaller than in the original analysis (Figure 9), and the winds are slightly stronger north of the jet (the 70 kt isotach is now north of 40°N between 130°W and 140°W). At 300 mb (Figure 17) the bag of temperature below -50°C in this area is elimianted. At the surface (not shown) the 1000-500 mb thickness values in the low pressure trough are now smaller by from 30m to 60m. All of these changes, although small, are at least subjectively in the right direction.

An HFM forecast was integrated from this analysis and the results compared to the original HFM forecast. The differences between the two forecasts were negligible. Although this was disappointing, it was probably unrealistic to expect such small changes in a very limited region of the initial analysis to make significant changes in an ensuing forecast.

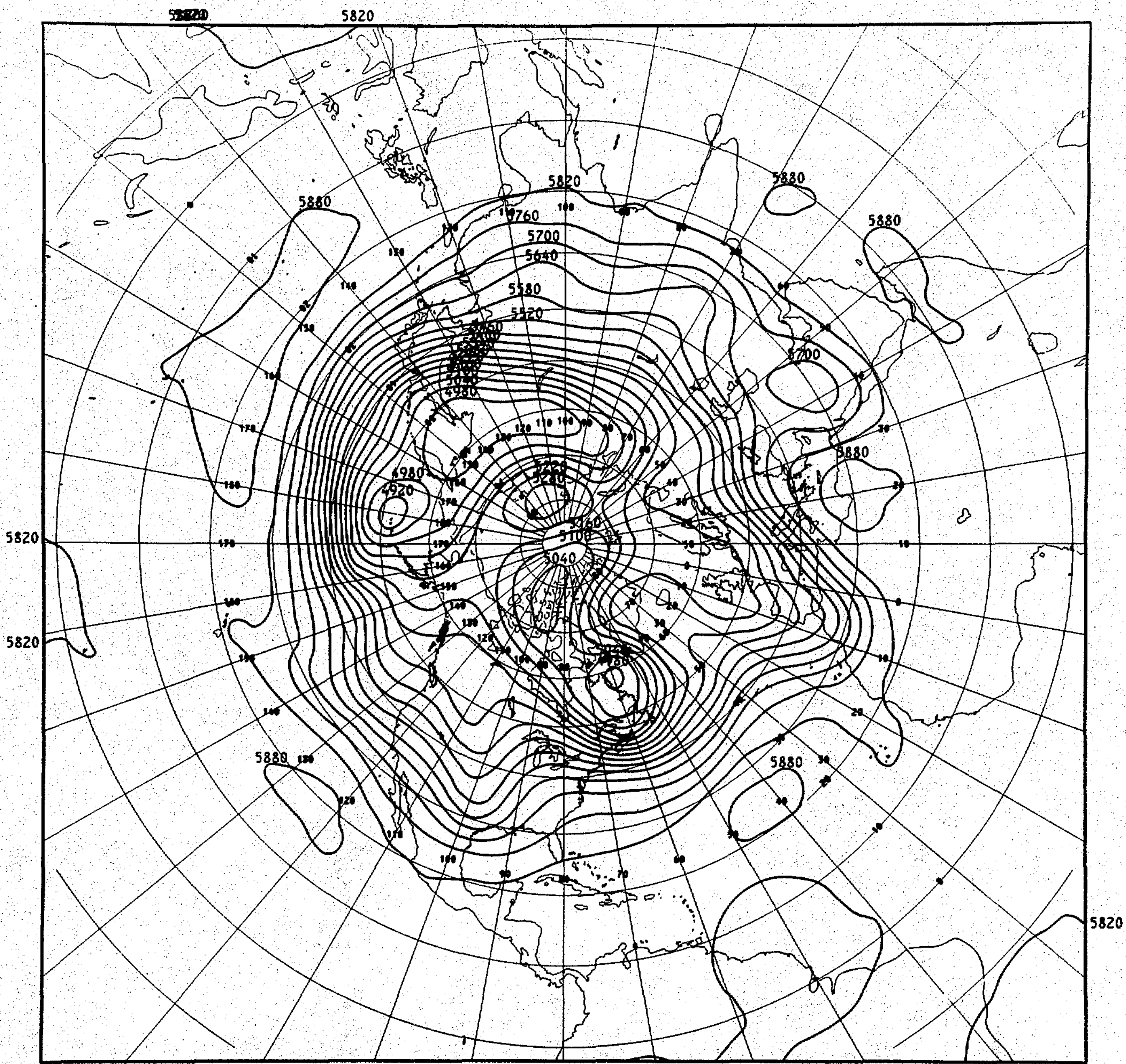
IV. The Verdict

Forecasts made by several different models from the global spectral analysis valid 1200 GMT 21 February 1977 contained significant errors. The large magnitude of the errors rather early in all forecasts suggested that problems existed in the initial analysis.

The results of this study lead us to conclude that there were several serious problems in the initial analysis. A meteorologically significant weather system just off the west coast of the United States was depicted to be too complex and the wind speeds in the accompanying jet too light.

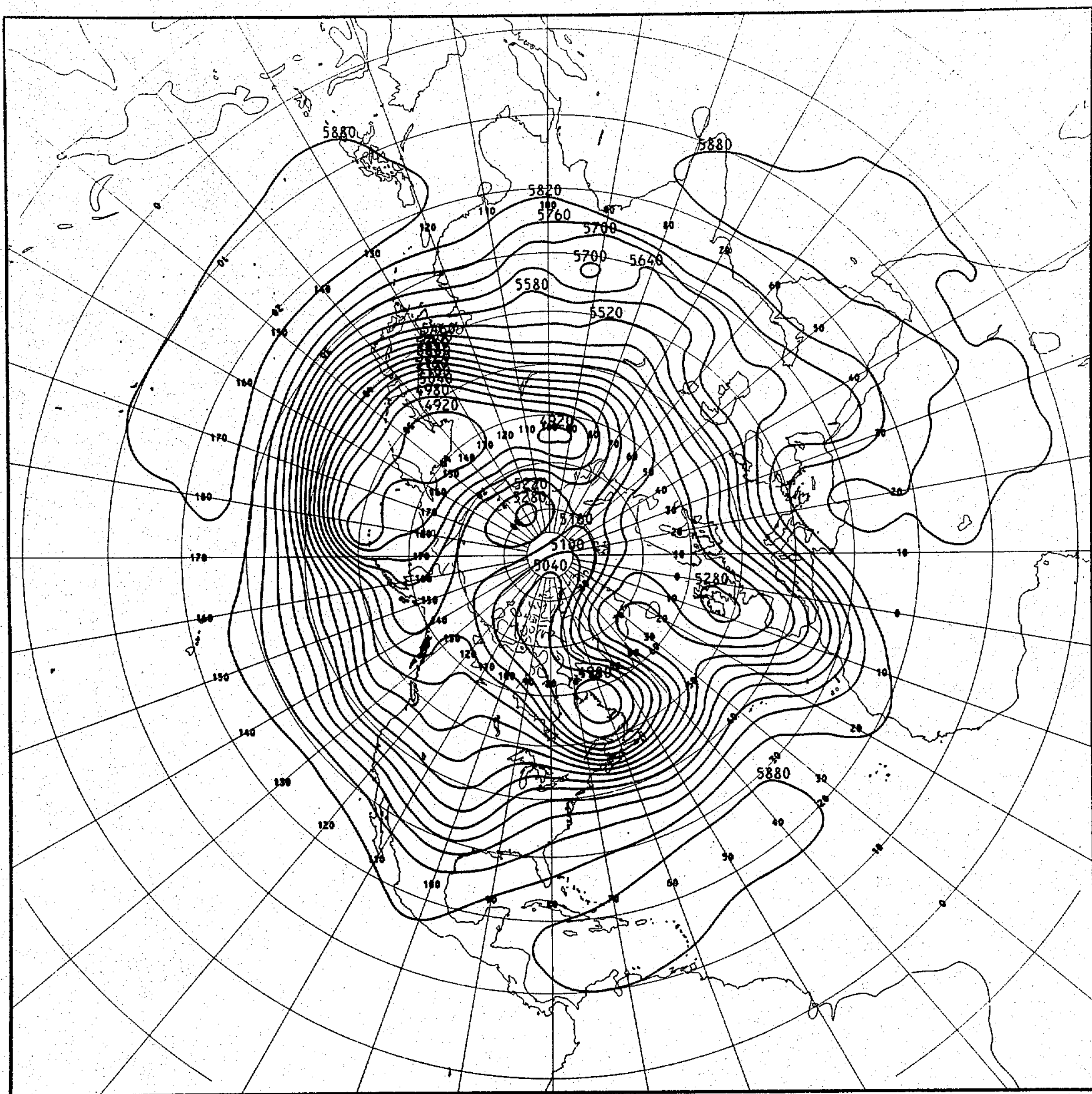
A problem in assigning the altitude to the cloud tracked wind reports was revealed. The problem occurred when enhanced cumulus elements were used to produce the reports. When the previous decision to assign such reports the altitude of the cloud tops was replaced by one to assign them the altitude of the middle of the clouds, beneficial changes occurred in the analysis. This alteration is now part of the operational procedures used by the NESS Satellite Winds Section.

Although the analysis made using the alteration was somewhat less complex, the weather system was still too weak and there was little change in the ensuing forecast. The most likely culprits for this result are a poor first guess, insufficient data, and the inability of the Global Spectral Analysis Method to adequately depict narrow jet maxima and sharp changes in horizontal gradients.



500.00 MB HGT FOR 048 HRS AFTER 12Z 21 FEB 77 WMC/NMC WASHINGTON.
HFM CASE 6

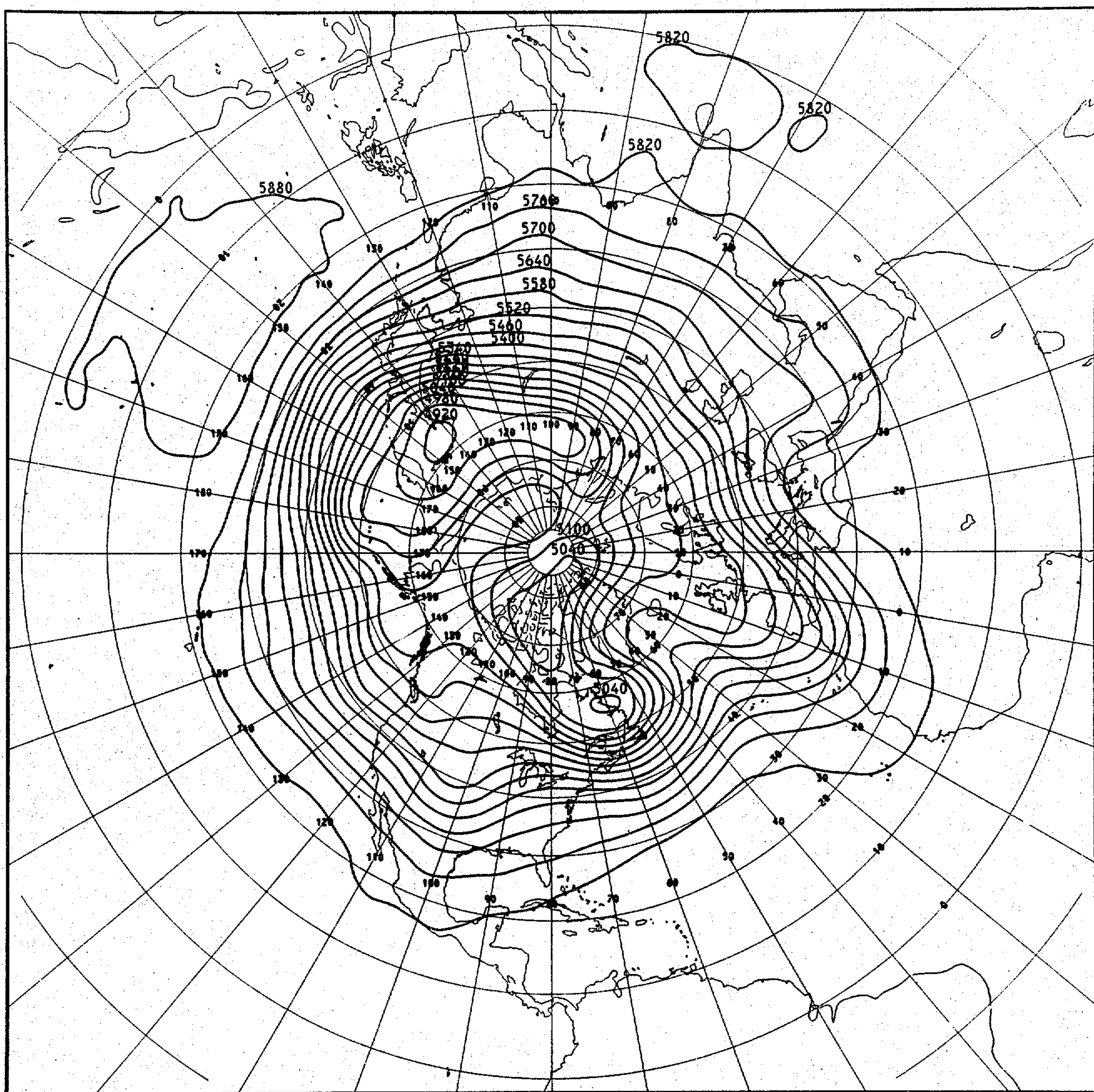
Figure 1



500.00 MB HGT FOR 048 HRS AFTER 12Z 21 FEB 77 WMC/NMC WASHINGTON.

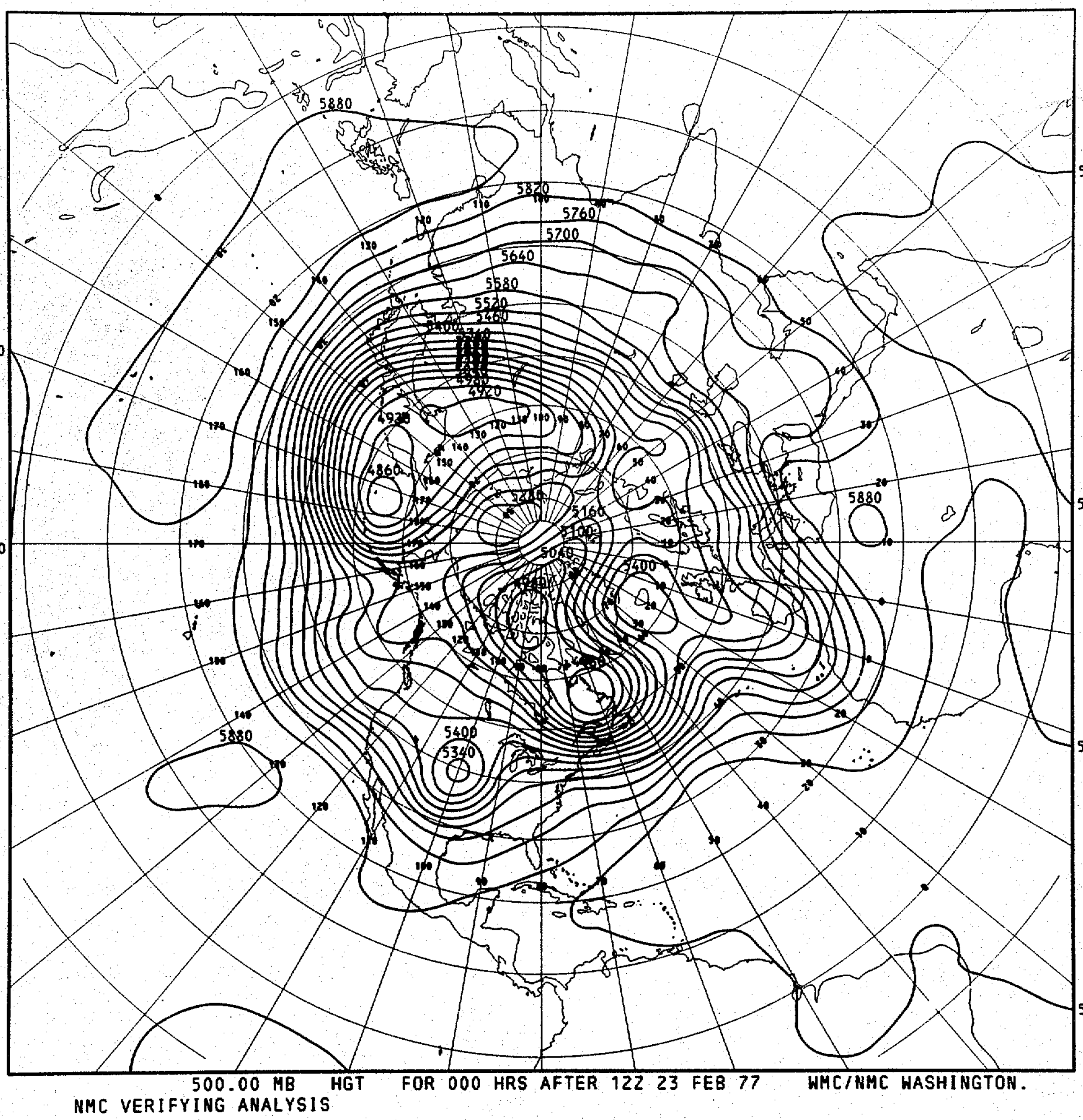
NGM CASE 6

Figure 2



500.00 MB HGT FOR 048 HRS AFTER 12Z 21 FEB 77 WMC/NMC WASHINGTON.
NLH CASE 6

Figure 3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4860
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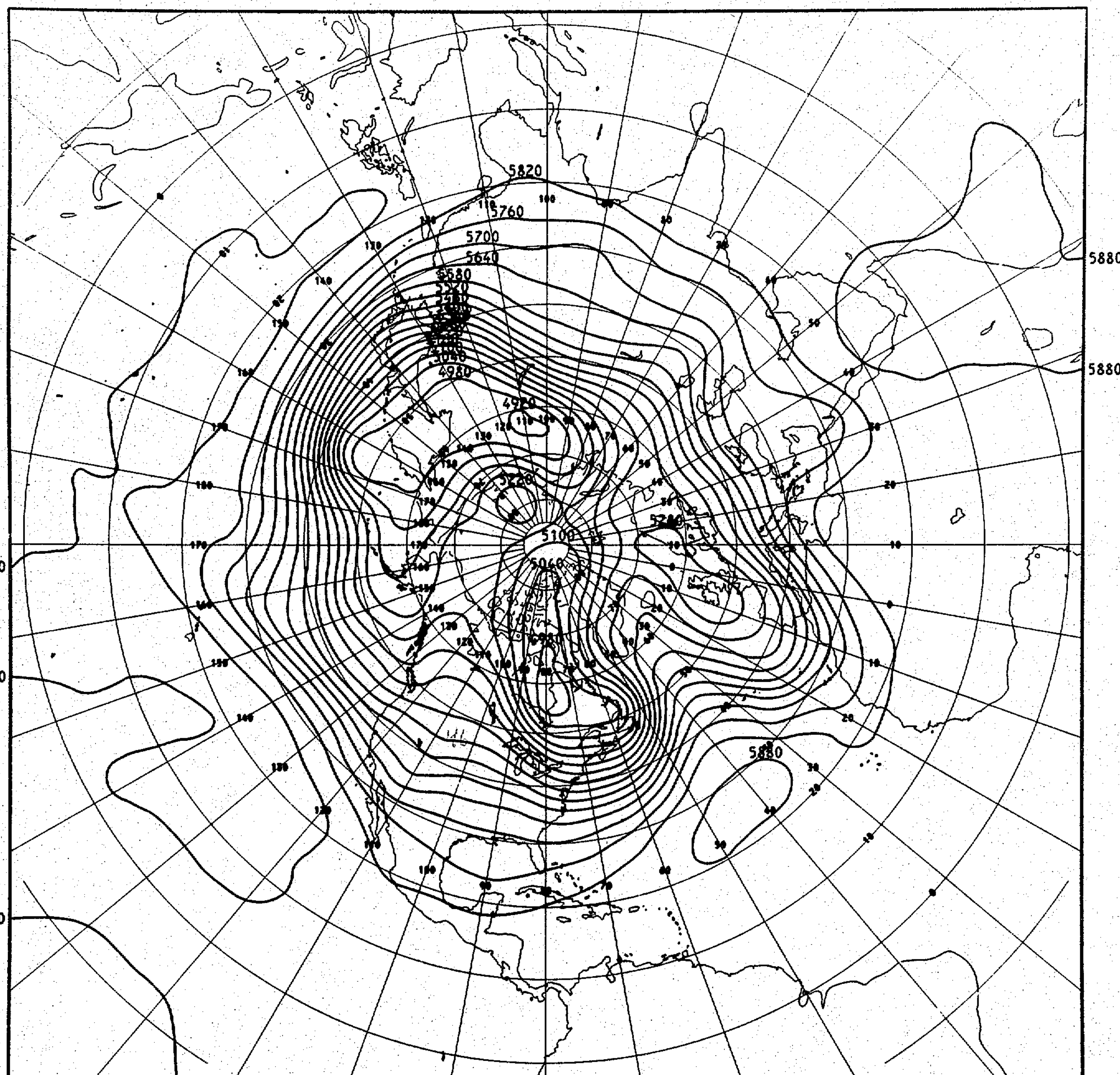
5400
5340
500.00 MB HGT FOR 000 HRS AFTER 12Z 23 FEB 77 WMC/NMC WASHINGTON.
NMC VERIFYING ANALYSIS

Figure 4



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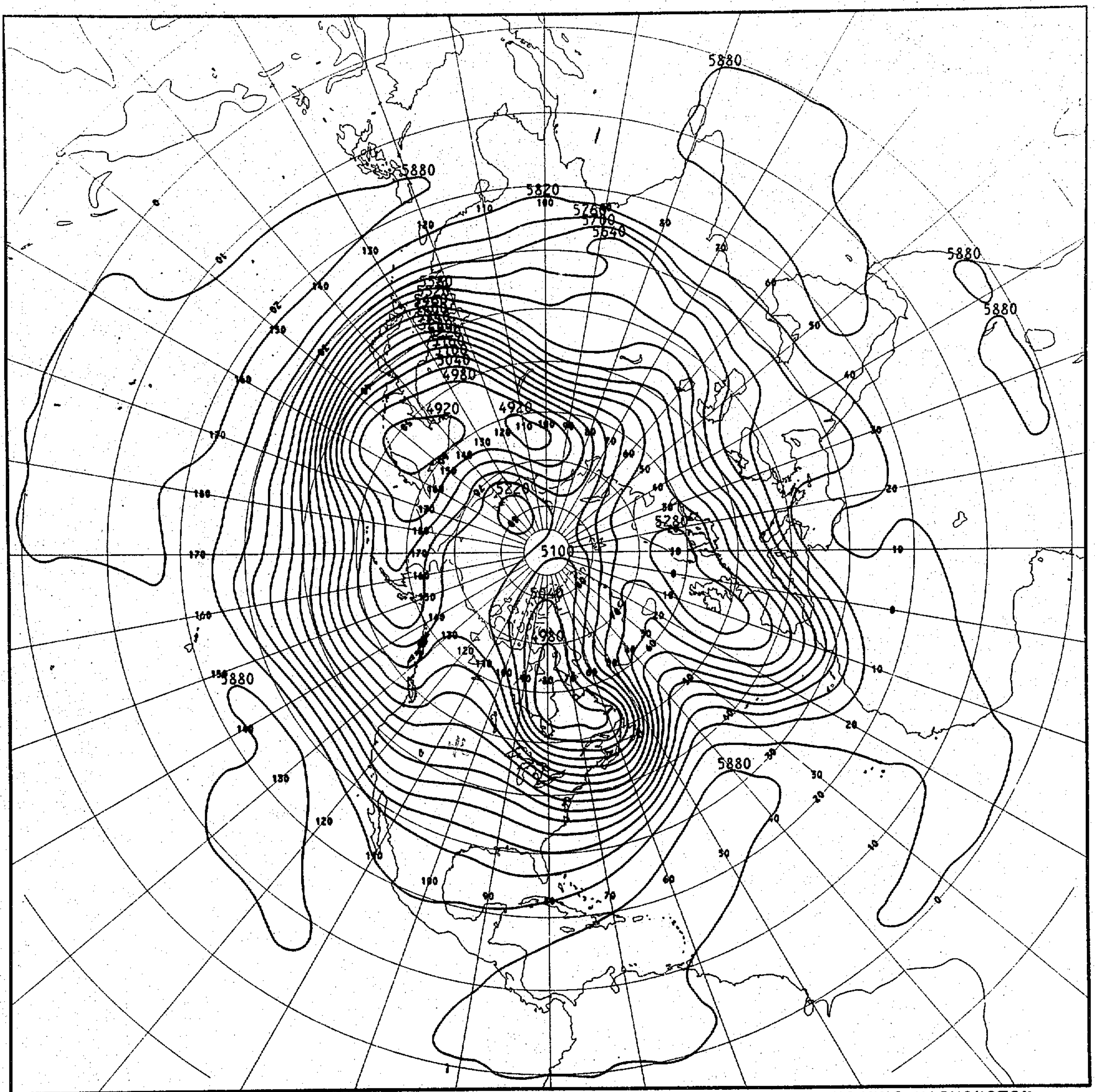
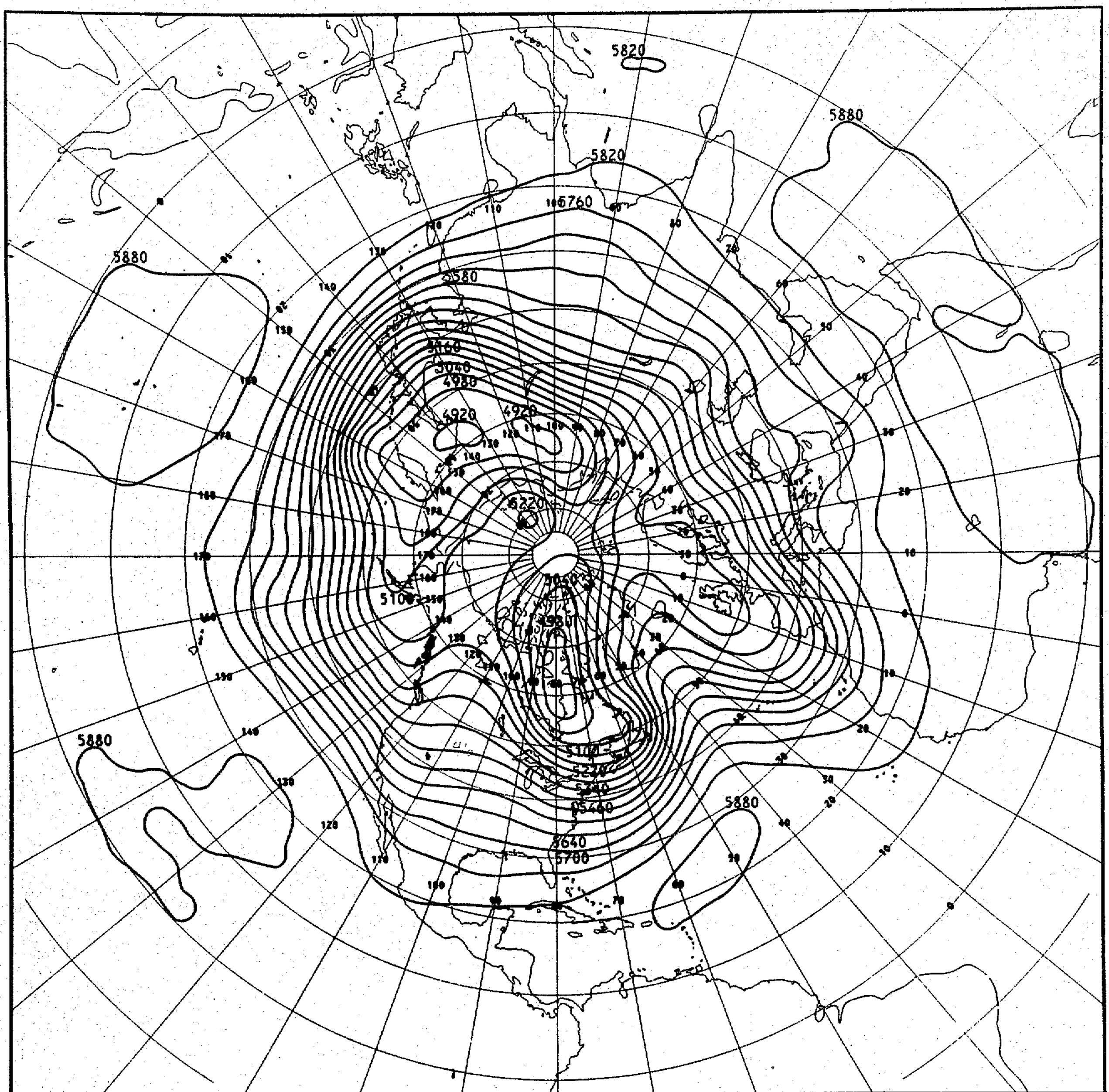
HFM CASE 6

Figure 5



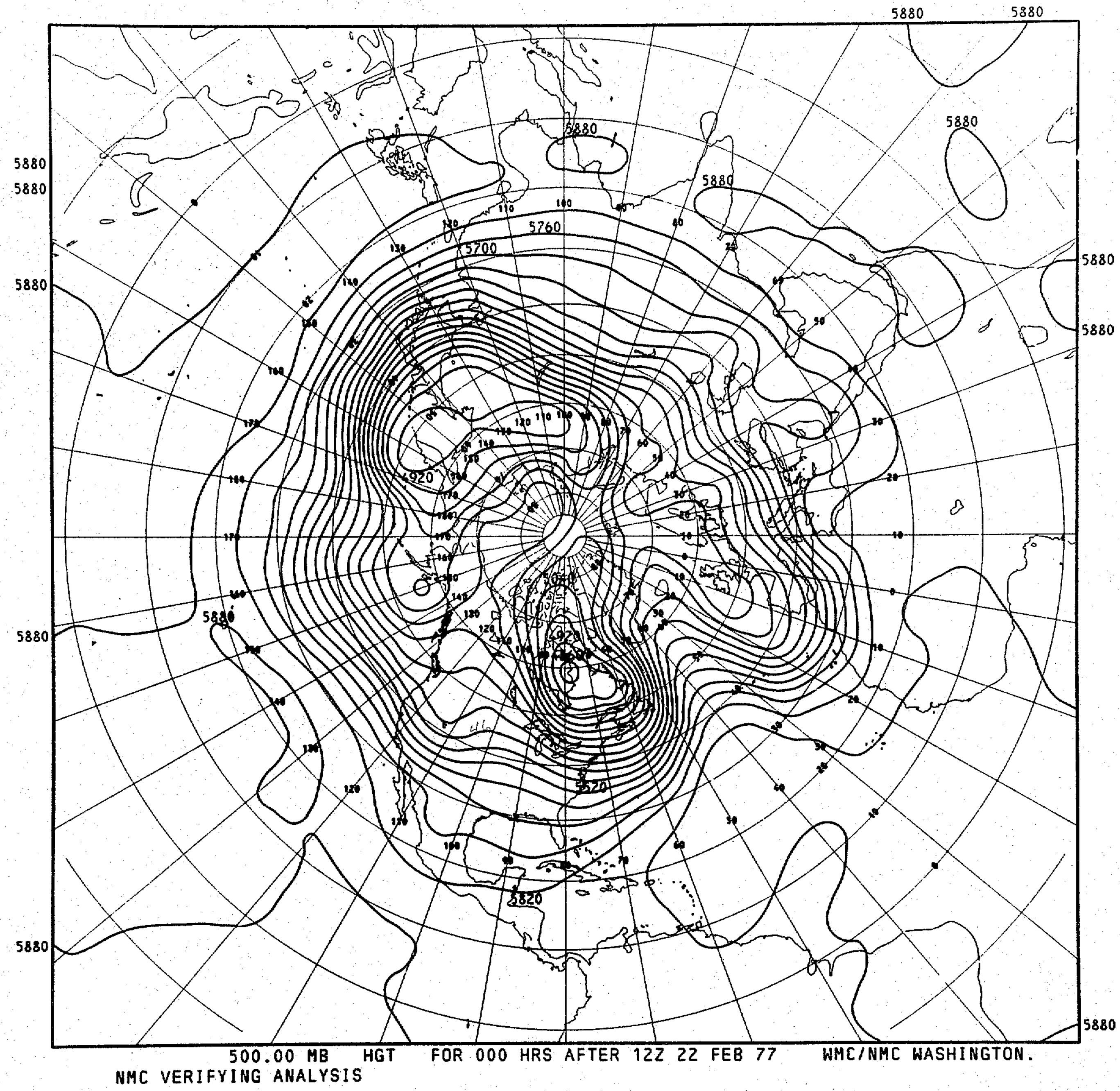
500.00 MB HGT FOR 024 HRS AFTER 12Z 21 FEB 77 WMC/NMC WASHINGTON.
NGM CASE 6

Figure 6



500.00 MB HGT FOR 024 HRS AFTER 12Z 21 FEB 77 WMC/NMC WASHINGTON.
NLH CASE 6

Figure 7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5760
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5520
5820
500.00 MB HGT FOR 000 HRS AFTER 12Z 22 FEB 77 WMC/NMC WASHINGTON.
NMC VERIFYING ANALYSIS

Figure 8

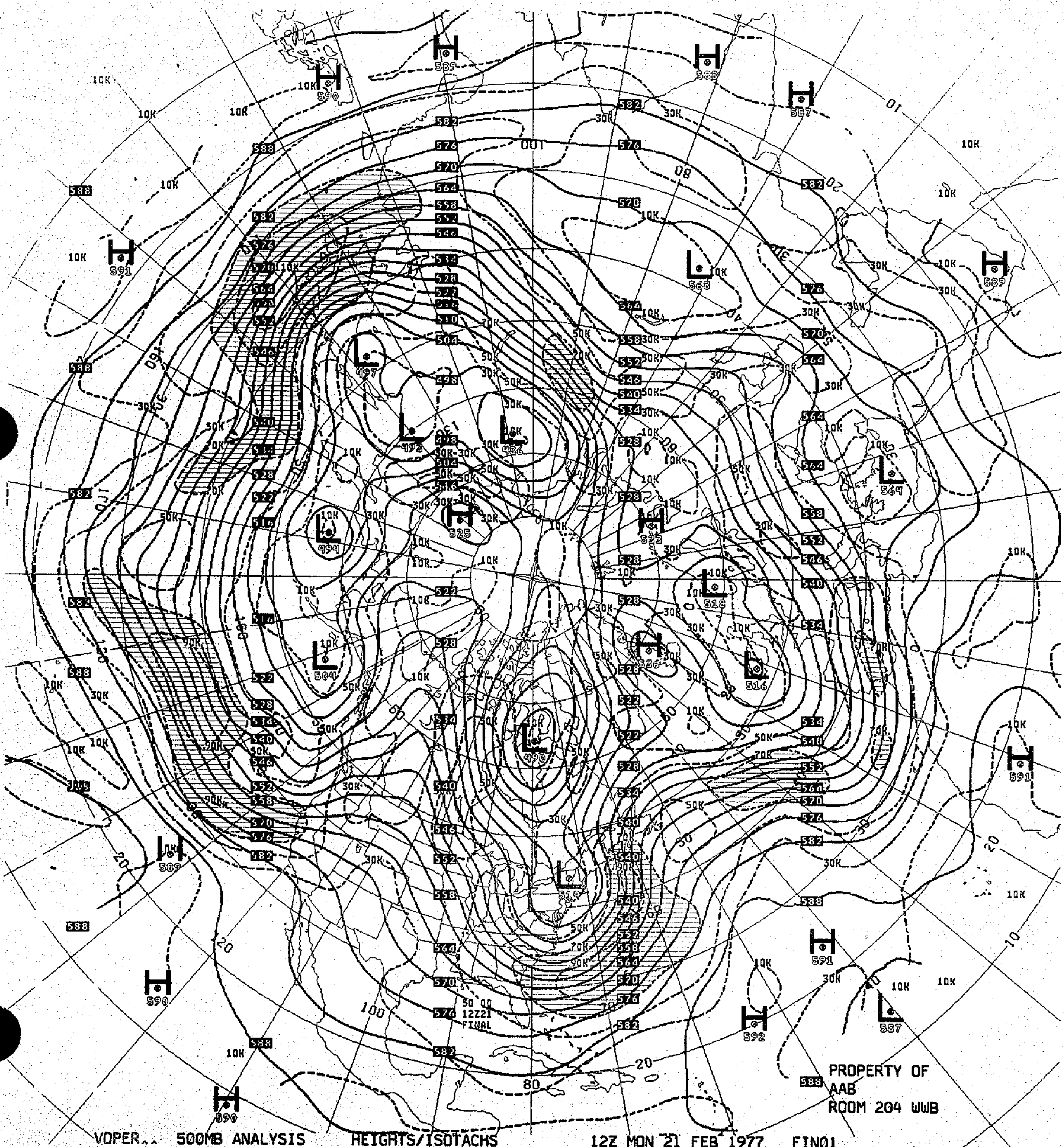

PROPERTY OF
AAB
ROOM 204 WWB
VOPER.. 500MB ANALYSIS HEIGHTS/ISOTACHS 12Z MON 21 FEB 1977 FIN01

Figure 9

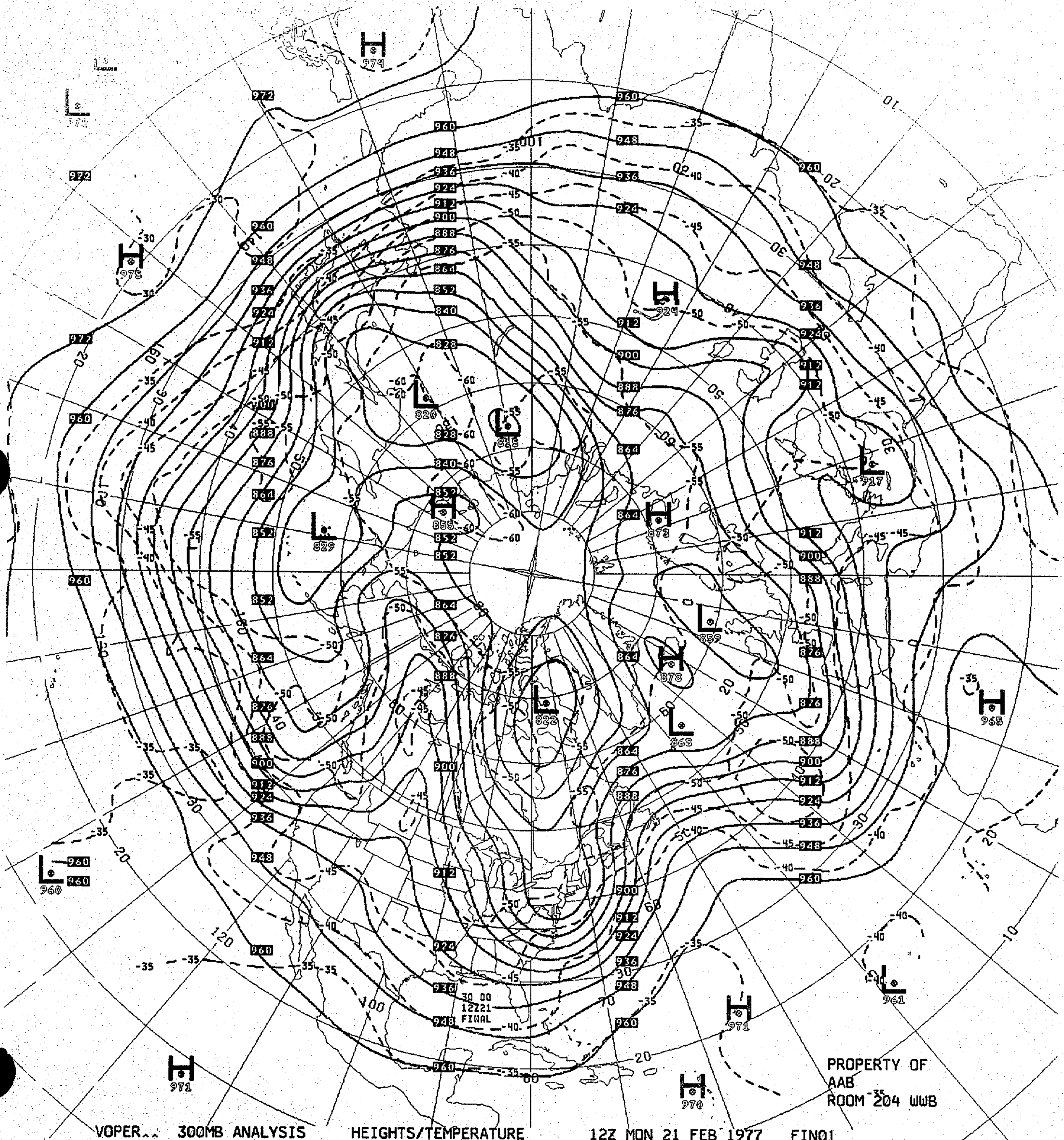
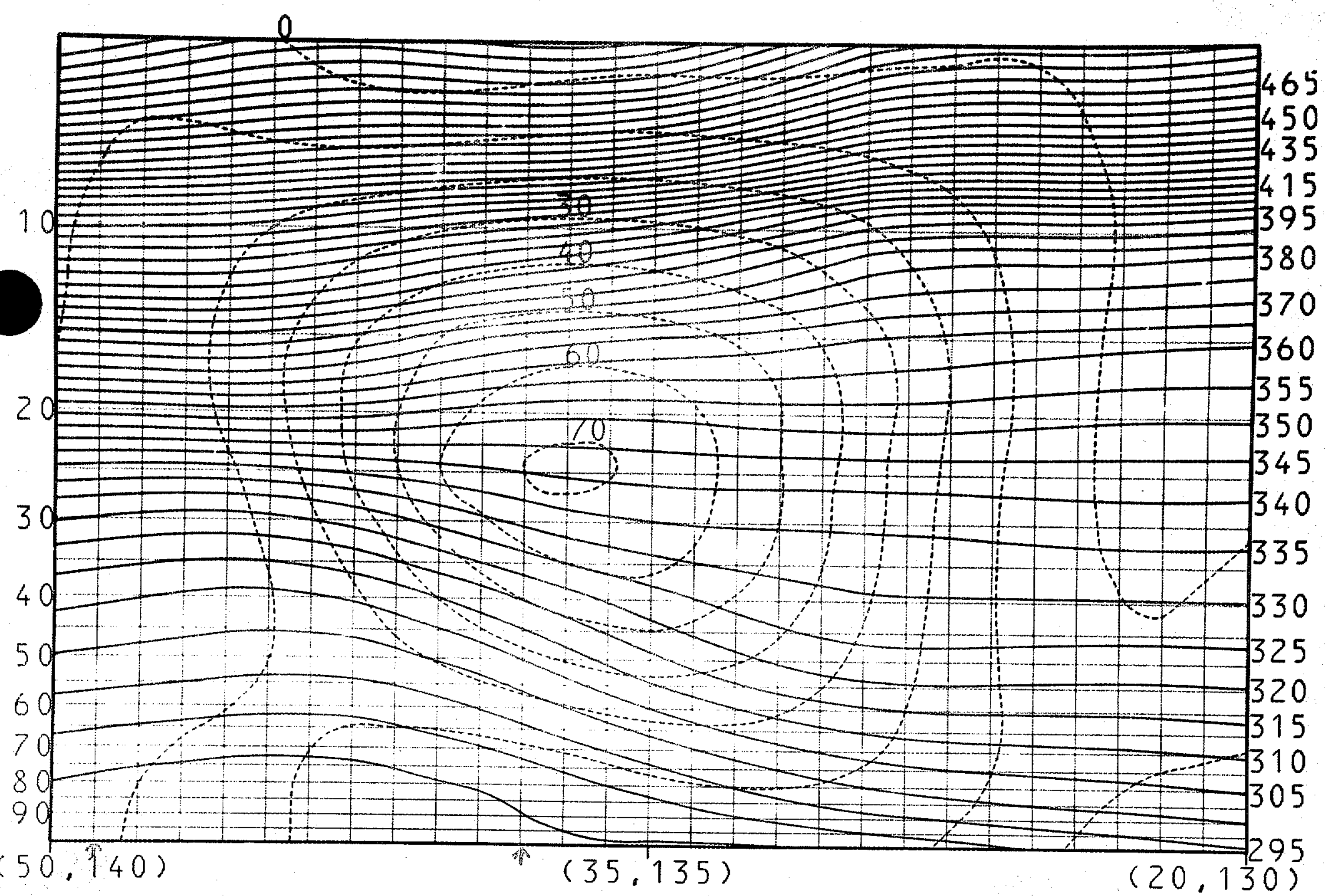

VOPER.. 300MB ANALYSIS HEIGHTS/TEMPERATURE 12Z MON 21 FEB 1977 FIN01
PROPERTY OF
AAB
ROOM 204 WWB
30 00
12Z21
FINAL

Figure 10

50 DEG N, 140 DEG W TO 20 DEG N, 130 DEG W

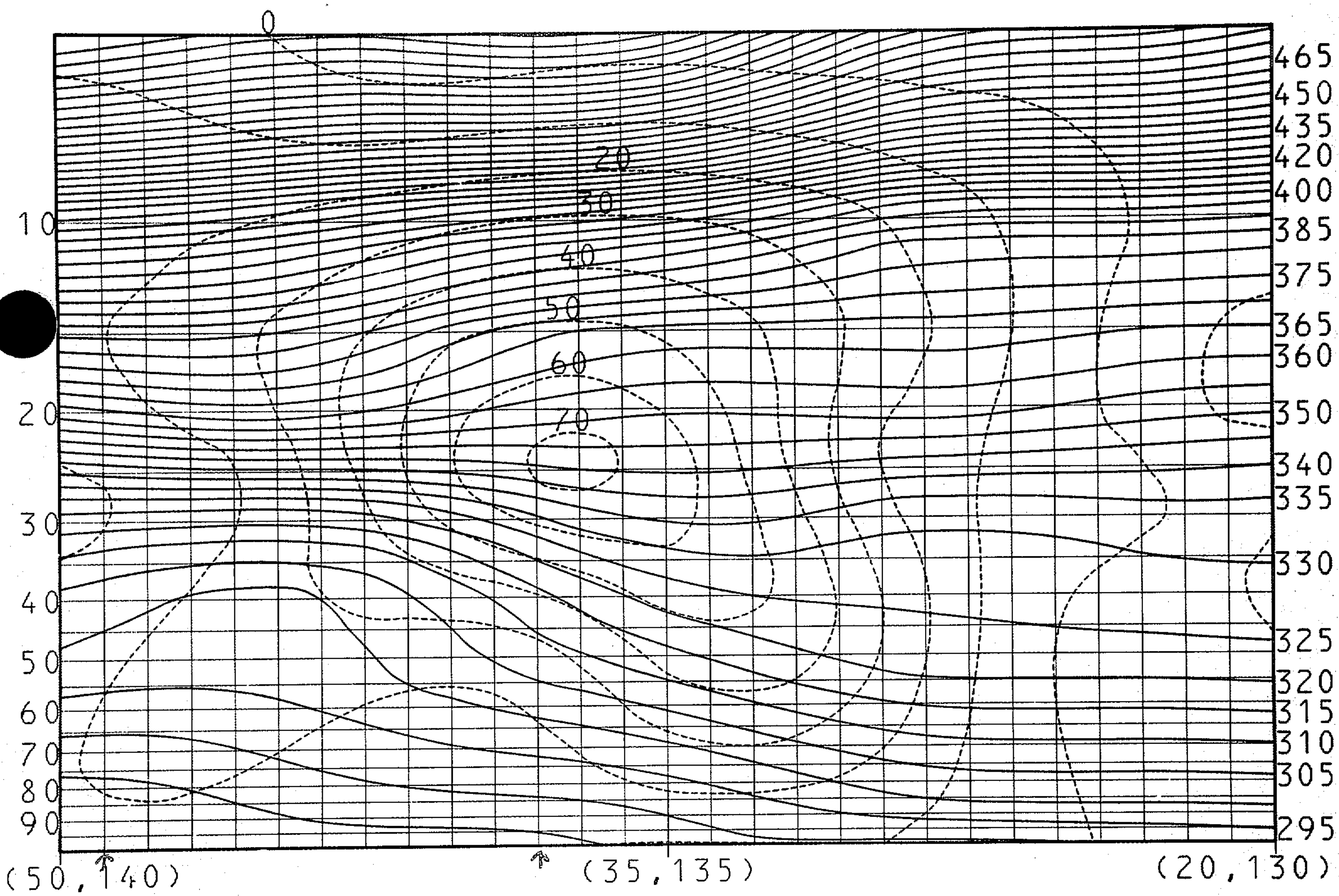


ISENTROPES SOLID
ISOTACHS DASHED

12Z FEB 21, 1977 FIRST GUESS

Figure 11

50 DEG N, 140 DEG W TO 20 DEG N, 130 DEG W



ISENTROPES SOLID
ISOTACHS DASHED

12Z FEB 21, 1977 ORIGINAL ANALYSIS

Figure 12

50 DEG N, 140 DEG W TO 20 DEG N, 130 DEG W

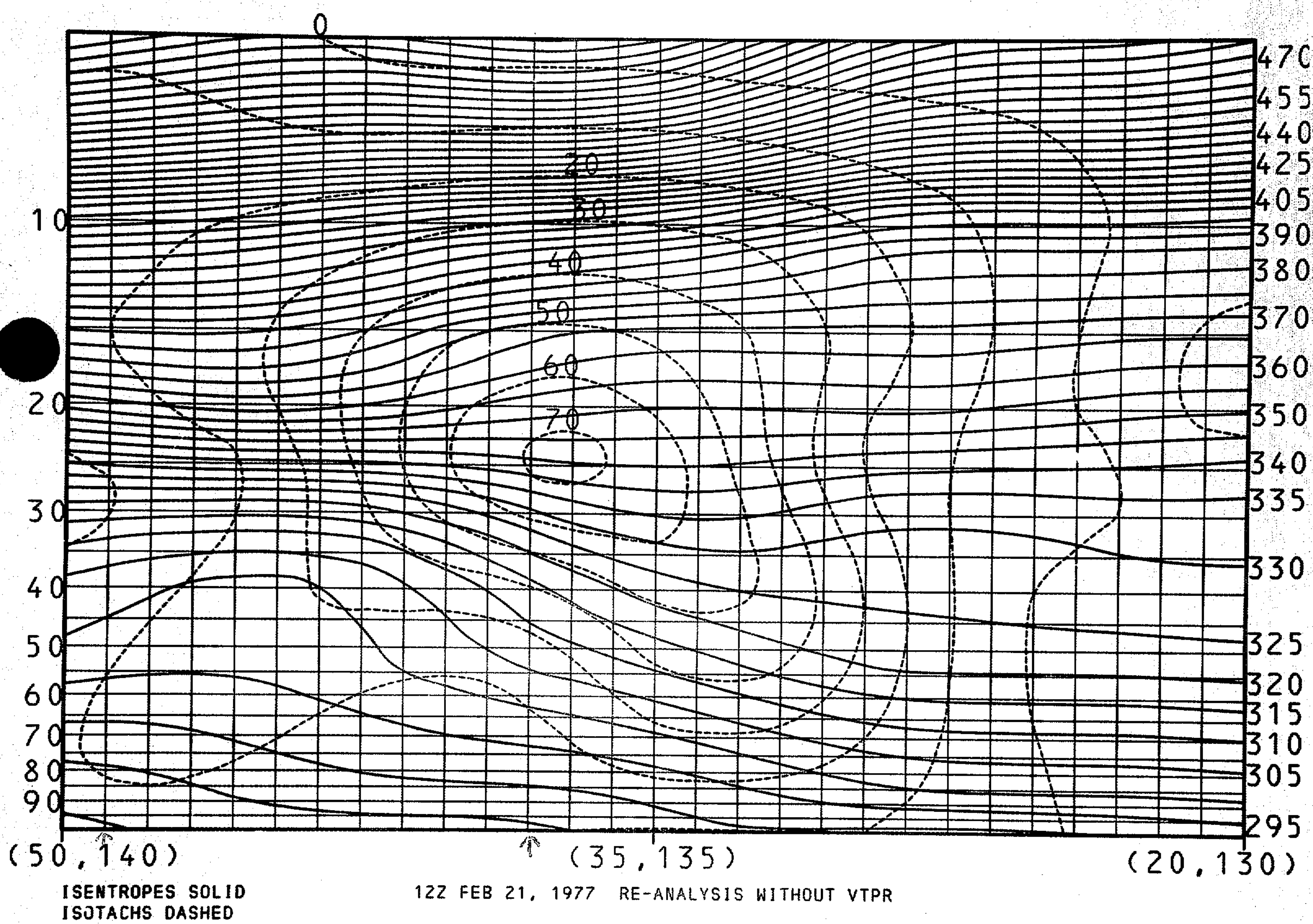
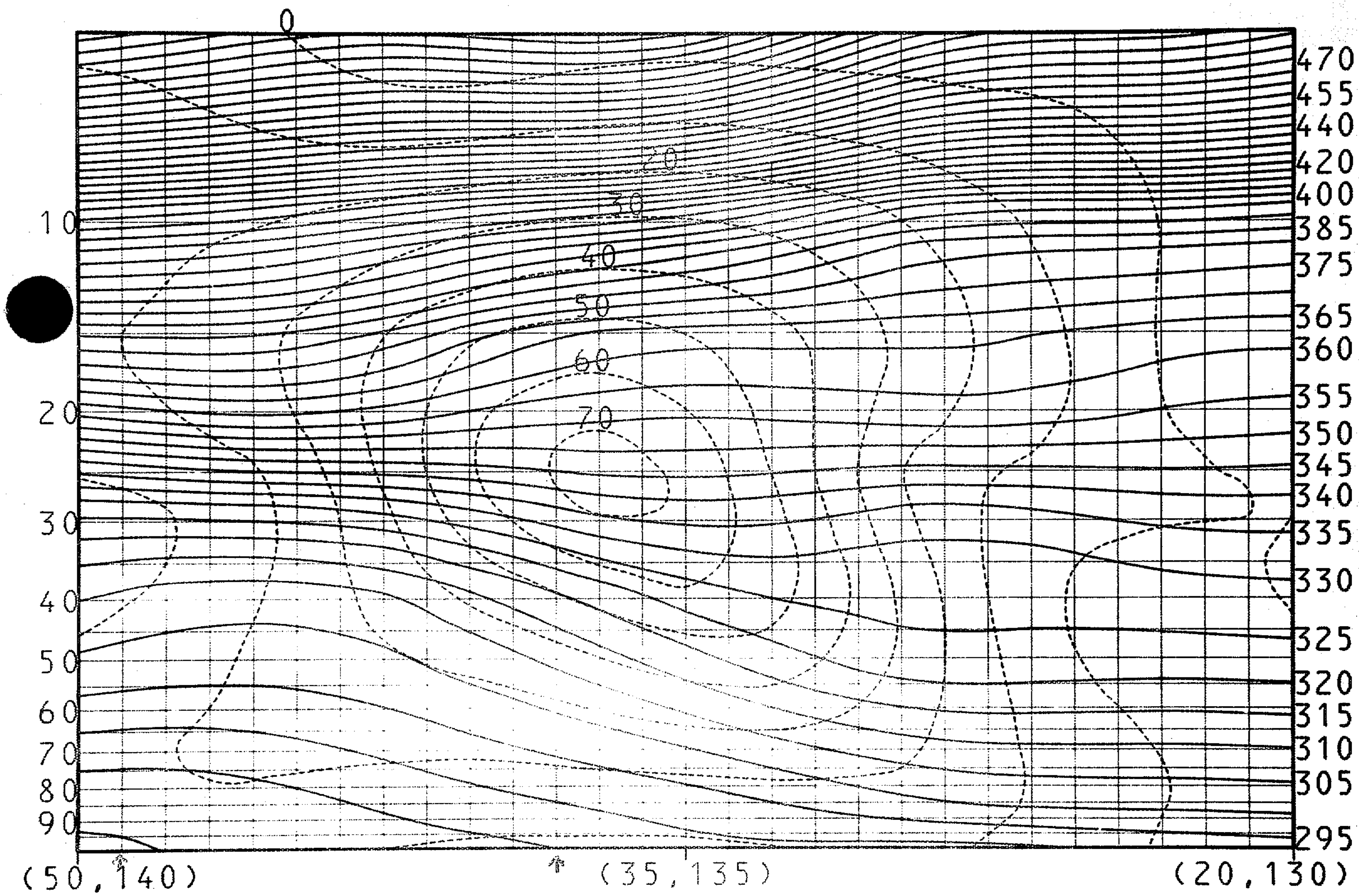


Figure 13

50 DEG N, 140 DEG W TO 20 DEG N, 130 DEG W

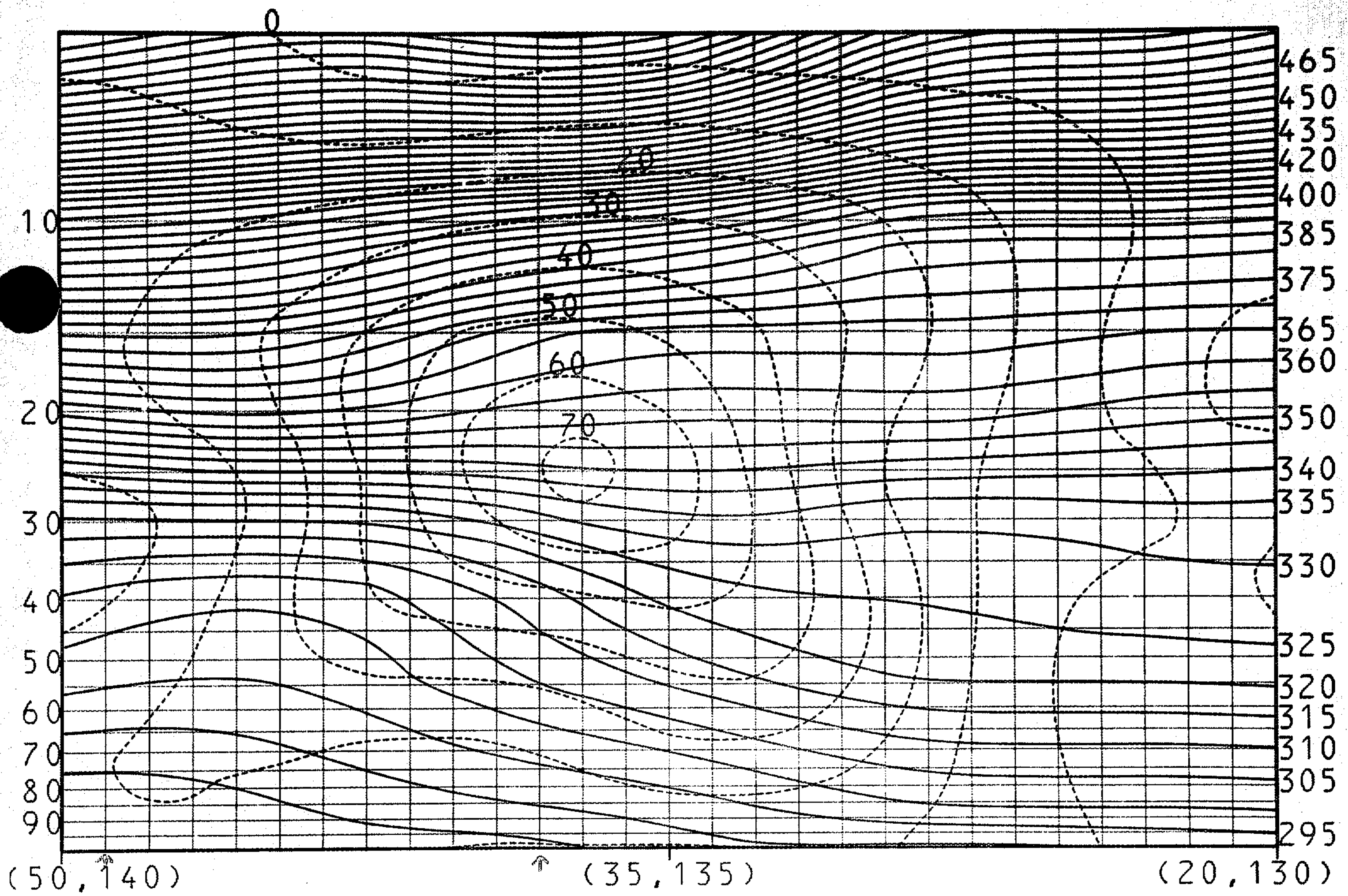


ISENTROPES SOLID
ISOTACHS DASHED

12Z FEB 21, 1977 RE-ANALYSIS WITHOUT SATELLITE WINDS

Figure 14

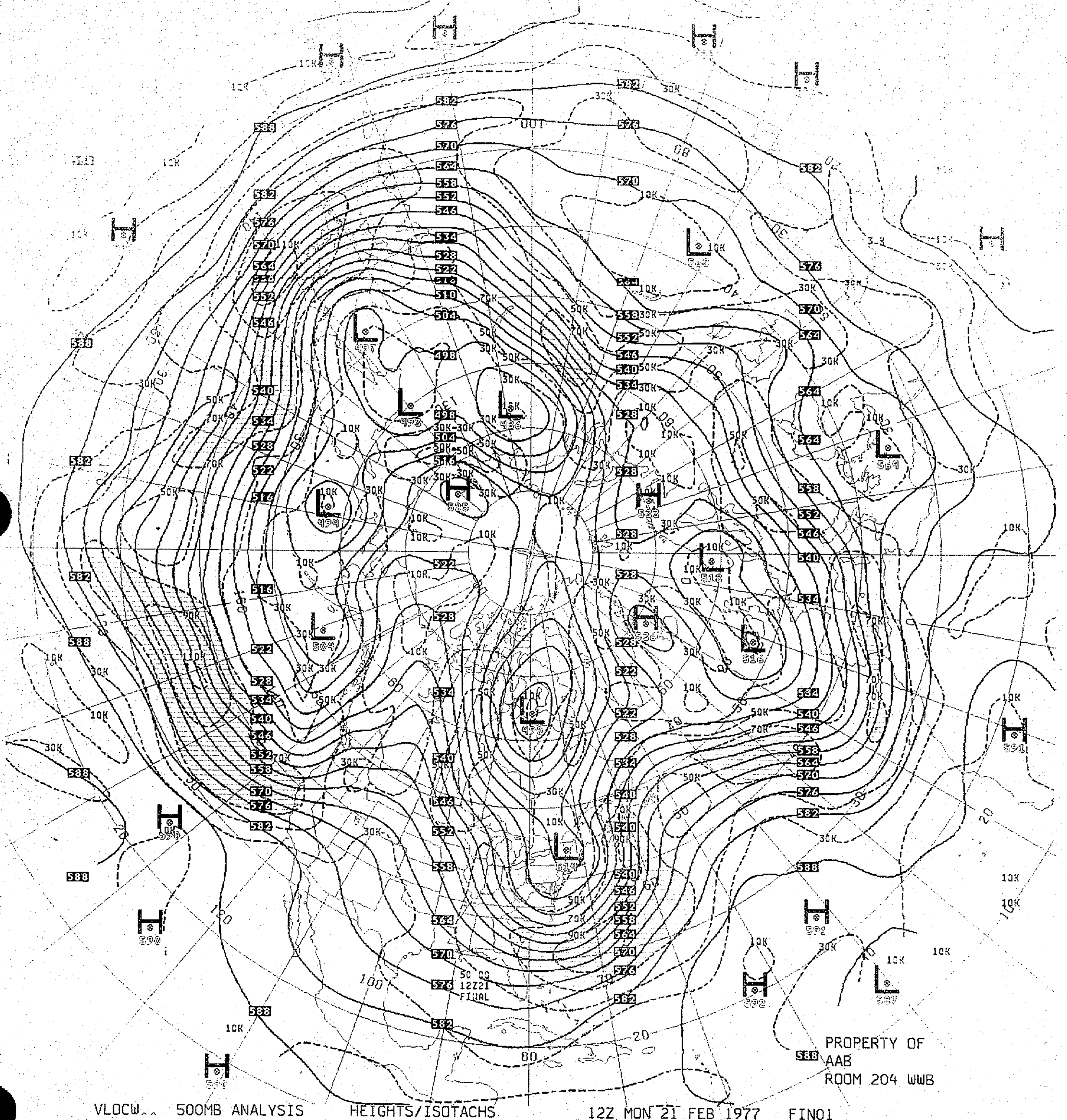
50 DEG N, 140 DEG W TO 20 DEG N, 130 DEG W



ISENTROPES SOLID
ISOTACHS DASHED

12Z FEB 21, 1977 RE-ANALYSIS WITH LOWERED SATELLITE WINDS

Figure 15


50 CQ
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PROPERTY OF
AAB
ROOM 204 WWB
VLOCW.. 500MB ANALYSIS HEIGHTS/ISOTACHS 12Z MON 21 FEB 1977 FIN01

Figure 16

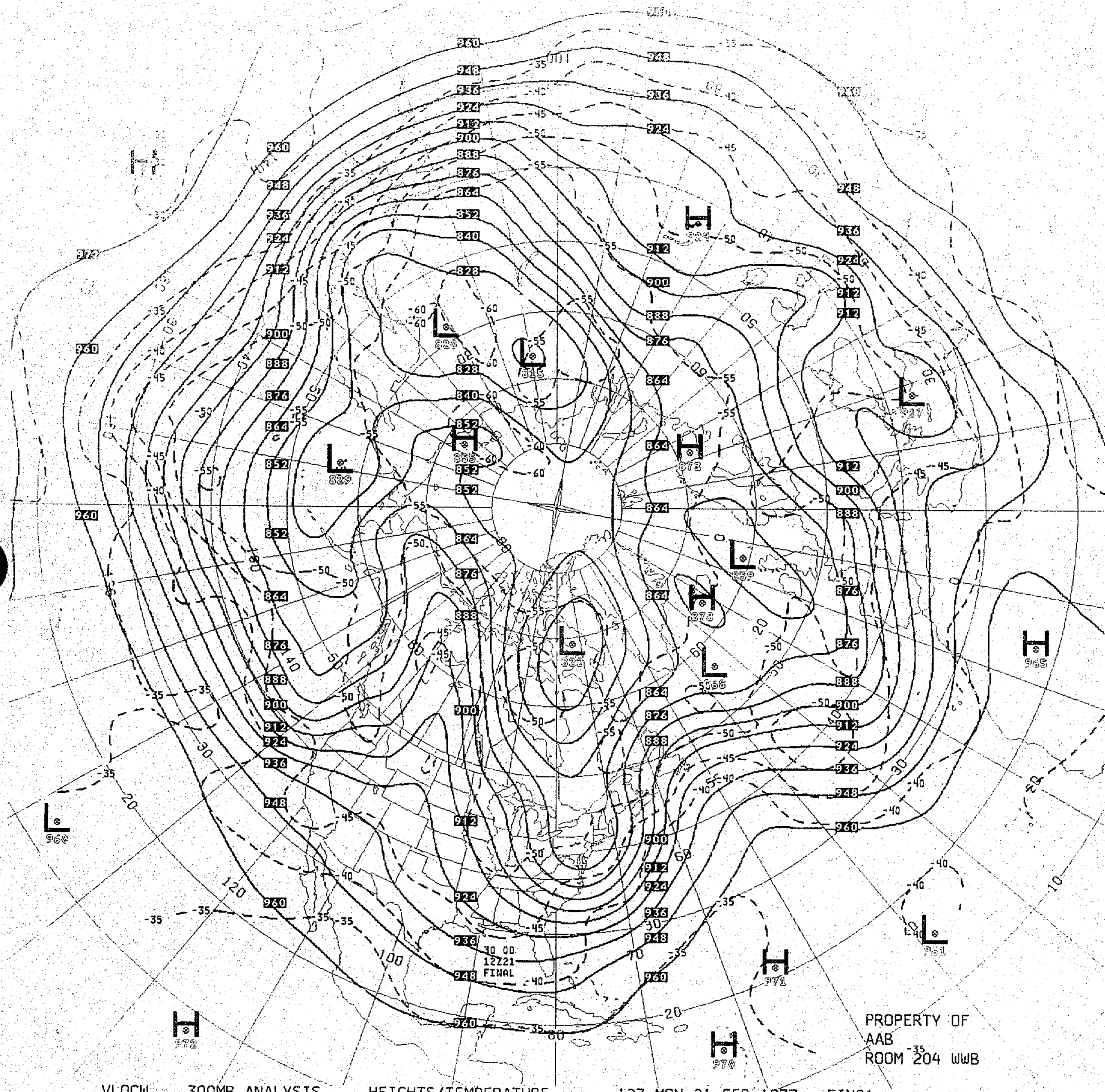
VLOCW.. 300MB ANALYSIS HEIGHTS/TEMPERATURE 12Z MON 21 FEB 1977 FINO1
PROPERTY OF
AAB
ROOM 204 WWB
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Figure 17