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Large-scale sea surface temperature anomalies in the NW Atlantic from February to July in relation to monthly mean surface pressure

by

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Abstract

The large-scale monthly mean sea surface temperature (SST) anomalies in the NW Atlantic from February to July are analyzed for the years 1963 to 1966 (inclusive) in relation to monthly mean surface pressure. The most pronounced anomalies are usually found in N. American coastal waters from Georges Bank to Grand Banks and the Gulf Stream proper.

Once the pronounced anomalies are created during late autumn and early winter, they persist usually until summer, but change somewhat in intensity. Most anomalies and their fluctuations during the winter and spring can be explained by advection caused by surface winds.

1. Introduction

The importance and application of sea surface temperature (SST) anomalies to numerous fisheries, climatological and other problems has been ventilated in numerous publications during the past fifty years. A thoroughly systematic study of these anomalies has, however, been hampered by the lack of systematic synoptic SST analyses. Twice daily synoptic numerical hemispheric SST analyses are now available at Fleet Numerical Weather Facility (FNWF), Monterey, starting mid 1962 (Carstensen and Wolff 1966). A brief analysis is made below of the large-scale monthly mean SST anomalies in the NW Atlantic from February to July for the years 1963 to 1966 (inclusive). An attempt is made to explain these anomalies with the "zusatswinde" in the sense of Rodewald (1960).

According to Ekman's (1905) theory, the direction of wind current at the surface is 45° to the right in the northern hemisphere and the current speed decreases with depth while the deflection becomes larger until, at a "depth of frictional influence", the direction of the current is opposite to that at the surface. Although Ekman's theory has been useful in many theoretical studies, it has not been verified in detail in the field. It cannot be applied to practical situations because the conditions under which the problem was solved do not exist in nature (Belinsky and Glagoleva 1960). A number of reliable investigations indicate that the wind current in offshore areas in middle latitudes is deflected less than 20° to the right of the surface wind (Bowden, 1953 - 18°; Gaul, 1960 - 15°; Lisitzin, 1938 - 12°; Stommel, 1954 - 20°). In the latitudes of the ICNAF area the surface wind is 15-20° to the left of the geostrophic wind (Carstensen, personal communication). The latter is in the direction of the isobars on the mean surface pressure charts and so we take advection due to the surface wind-driven current as being approximately parallel to those isobars.

2. Data

The synoptic hemispheric sea surface temperature analysis at FNWF is made with a 125 x 125 grid (mesh size of about 100 nautical miles). The climatology is saved, however, in a standard FNWF 63 x 63 grid (mesh size about 200 nautical miles). The present computations were made with this standard FNWF 63 x 63 grid, thus only large-scale features can be studied in this scale. It should be pointed out here that small-scale synoptic analyses ("zoom" analyses) are also done for the N. Atlantic by FNWF: see examples in Figures 1 and 2. These analyses have not been saved in numerical form for climatological studies.

The accuracy of hemispheric SST analyses is principally determined by data density in sparse areas (see Figure 3) and by grid size in areas with sharp gradients (see Figure 4). Data are generally sparse along the East Greenland coast and in the Davis Strait. For this reason not much mention is made of these areas in the analyses which follow below.

The long term (20 years) monthly mean SST has been obtained from the unpublished work of Mrs. M. Robinson, Scripps Institution of Oceanography, and Miss E. Schroeder, Woods Hole Oceanographic Institution, and put into the FNWF grid. The monthly mean anomalies have been computed by subtraction and plotted on a Calcomp plotter. Only whole degree C isopleths and maximum-minimum values are indicated on the enclosed example charts. Exact values at gridpoints are available at FNWF. Monthly mean surface pressure charts are computed from 6-hourly numerical surface analyses at FNWF. These charts were used to estimate prevailing winds, at times using sequences of synoptic analyses as aids. Only a selection of pertinent charts are reproduced here. In case of wide interest in these charts, it is assumed that arrangements will be made at the present

ICNAF meeting to obtain and distribute them through proper channels.

3. Descriptive analyses of monthly mean anomalies in relation to surface winds

3.1 February

1963: A positive SST anomaly over Grand Banks (max +2.7°C) is apparently caused by warm advection from the Gulf Stream as a result of the "zusatswinde" of the monthly mean low centered over the Labrador Coast.

A negative SST anomaly in the southeastern part of the Labrador Sea and south of Greenland is caused by advection of cold water along the west coast of Greenland, driven by winds around the same low.

1964: The positive anomaly over the continental slope off Newfoundland and south of the Gulf of St. Lawrence is probably caused by relatively strong SW winds which intensify the Gulf Stream flow. However, the mean SST of this month is relatively unreliable due to missing SST analyses during 10 days in the first part of the month.

1965: The negative anomaly over Grand Banks, the continental slope south of Newfoundland and off the Gulf of St. Lawrence (min -4.3°C) is apparently caused and/or maintained by NW winds over the area driving cold water from the Gulf of St. Lawrence and from the Labrador Current towards the southeast.

1966: A negative anomaly over the continental slope from Georges Bank (min -3.5°C) to the southeast tip of Grand Banks (min -4.3°C) is caused and maintained by N and NW winds as in February 1965.

3.2 March

1963: A positive anomaly occurs over the southern slopes of Grand Banks (max +4.8°C) and in American coastal waters to C. Hatteras (max +3.8°C). The northern portion of this anomaly is apparently caused by an increased flow of Gulf Stream water at the surface as a result of relatively strong winds blowing approximately along the Gulf Stream axis and belonging to the circulation of the monthly mean low centered at 57°N, 30°W.

A negative anomaly in the Labrador Sea persists and is maintained by the same winds as in February.

1964: The positive anomaly found in February on the continental slope and south of Newfoundland has changed to a negative anomaly (min -3.1°C), apparently caused by NNW winds associated with the prolonged monthly mean low centered at 58°N, 36°W. However, the February 1964 mean SST analysis was unreliable due to missing analyses on the climatological tape.

1965: A negative anomaly over the southern slopes of Grand Banks and over the continental slope south to Georges Bank (min -3.5°C) persists from February 1965 and is maintained by the same winds as in February. This is the second month in this analysis series when a number of days of SST analyses are missing in the middle of the month.

1966: A negative anomaly on the continental slope from Georges Bank (min -3.7°C) to the southeastern slope of Grand Banks (min -3.1°C) persists from the previous month. Winds over the area are relatively weak and the anomaly can only be explained on the basis of persistence.

3.3 April

1963: The positive anomaly over the southern slopes of Grand Banks and in N. American coastal waters persists (max +3.5°C). Apparently it is caused by winds oriented in the west-east direction, which are due to the prolonged monthly mean low centered northeast of Newfoundland and which intensify the Gulf Stream flow at the surface.

1964: The negative anomaly south of Grand Banks persists from the previous month, March 1964, (min $-3.3^{\circ}C$), and is maintained by NNW winds along the Labrador coast and the north coast of Newfoundland.

1965: The negative anomaly over the southern slopes of Grand Banks and over the continental slope south to Georges Bank persists (min $-3.6^{\circ}C$) and is caused and maintained by the same winds as in February and March 1965.

1966: The negative anomaly over the continental slope from Georges Bank to the southern slope of Grand Banks persists but has decreased in intensity (min -2.4° and $-2.1^{\circ}C$ respectively). The anomaly can be explained mainly on the basis of persistence. Only slight advection of cold water from the Gulf of St. Lawrence and the Labrador Current is possible with the mean winds prevailing in this month.

The positive anomaly in the Irminger Sea and south of Greenland can be explained by increased advection of warm North Atlantic Drift water into the Irminger Gyral by the winds belonging to the low centered at $51^{\circ}N$, $25^{\circ}W$.

3.4 May

The Icelandic low is relatively weak in this month. The heating of the sea surface by heat exchange is also intensifying in May. Thus, most anomalies change relatively rapidly in this month and are mainly explainable by persistence. New pronounced anomalies occur in May over the Gulf Stream proper. These are caused in April/May by the changing "push" of the circulation around the Bermuda-Azores high.

1963: A positive anomaly persists over the southern slope of Grand Banks (max $+3.2^{\circ}C$) and on the N. American continental slope south to Georges Bank, but has decreased in intensity. This anomaly is explainable only on the basis of persistence. A negative anomaly occurs over the Gulf Stream proper (min $-5.1^{o}C$).

1964: The negative anomaly south of Grand Banks found in April has decreased considerably. The Icelandic low is in its "normal" position and the month can be characterized as a close to "average" month.

1965: The negative anomaly south of Grand Banks and over the continental slope of N. America has decreased from the previous month (min $-2.1^{o}C$). A positive anomaly exists over the Gulf Stream proper (max $+3.9^{o}C$). Winds are weak over the NW Atlantic.

1966: The negative anomaly on the continental slope from Grand Banks to Georges Bank persists but has weakened considerably. There is a negative anomaly over the Gulf Stream proper (min $-3.3^{o}C$).

3.5 June

1963: The positive anomaly from previous months over the continental slope from Georges Bank to Grand Banks still persists but has decreased considerably (max $+1.7^{o}C$). The negative anomaly over the Gulf Stream proper still persists but has decreased in intensity considerably (min $-1.9^{o}C$).

1964: There is a weak negative anomaly on the slopes of Grand Banks (min $-1.5^{o}C$) and a positive anomaly over the Gulf Stream proper (max $+2.0^{o}C$).

1965: The sea surface temperature data for this month are missing.

1966: A weak negative anomaly persists over the continental slope and south of Grand Banks (min $-1.6^{o}C$).

3.6 July

1963: A slight positive anomaly in the NW Atlantic, reaching the southern part of the Labrador and Irminger Seas is explainable by advection caused by prevailing winds.

1964: A small part of the negative anomaly of the previous month remains over Georges Bank only (min -1.2°C). The rest of the area off the N. American coast, including the Gulf Stream proper, has a positive anomaly. A negative anomaly in the Labrador and Irminger Seas can be explained by advection due to winds belonging to the low centered over Greenland.

1965: The sea surface temperature data for this month are missing.

1966: The weak negative anomaly from the previous month is barely recognizable and is located now over part of the Gulf Stream. A negative anomaly in the southern part of the Labrador Sea is apparently caused by prevailing winds pushing cold Labrador Current water into this area.

4. Discussion

4.1 The SST anomaly patterns vary over the N. Atlantic, both negative and positive anomaly areas are present in any given month. Greatest anomalies (by magnitude) occur in N. American coastal waters, and over the banks, continental slope and Gulf Stream area in the NW Atlantic.

4.2 SST anomalies in the N. Atlantic area are brought about by the interaction of a number of factors. Winds have both a thermal effect and a dynamic effect which tend to reinforce each other. Thus, a northerly wind generally drives more cold water from high latitudes southward, but it also reduces the SST by bringing about a loss of sensible and latent heat from the sea to the air: a southerly wind has the opposite thermal and dynamic effects. This combination of the advective effect and the thermal effect brought about by the atmospheric pressure distribution can be recognized as one of the principal causes of our SST anomalies during winter and early spring.

4.3 The SST anomalies are most pronounced in February and March and decrease in intensity towards July.

4.4 Only the winter of 1963 had positive anomalies on the N. American continental shelf and slope in the NW Atlantic. The winters of 1964, 1965 and 1966 had negative anomalies; winter 1965 being the coldest (see Figure 20).

4.5 The winter anomalies are formed in late fall and early winter and tend to persist through late winter and spring. Of 18 intermensal changes studied only one changed from positive to negative anomaly in the N. American continental shelf/slope area (February-March 1964). This change is also questionable, as the monthly mean SST for February 1964 was computed from incomplete records.

4.6 The corresponding monthly mean surface pressure patterns also show considerable persistence from month to month. The change of these patterns occurs mostly during a change of season (in general in May and November).

4.7 The persistency of the anomalies promises a useful tool for long-range prediction.

4.8 The present available data can enable studies to be made of the influence of these anomalies on (i) spawning time/place displacement (ii) survival of larvae (iii) occurrence and availability of fish to fisheries, e.g. if the survival of haddock larvae is dependent on temperature as well as drift, it can be assumed that only 1963 gave a successful year-class of this species on Georges Bank and Grand Banks as this is the only year with a positive anomaly over the months February-July.

5. References

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List of Figures

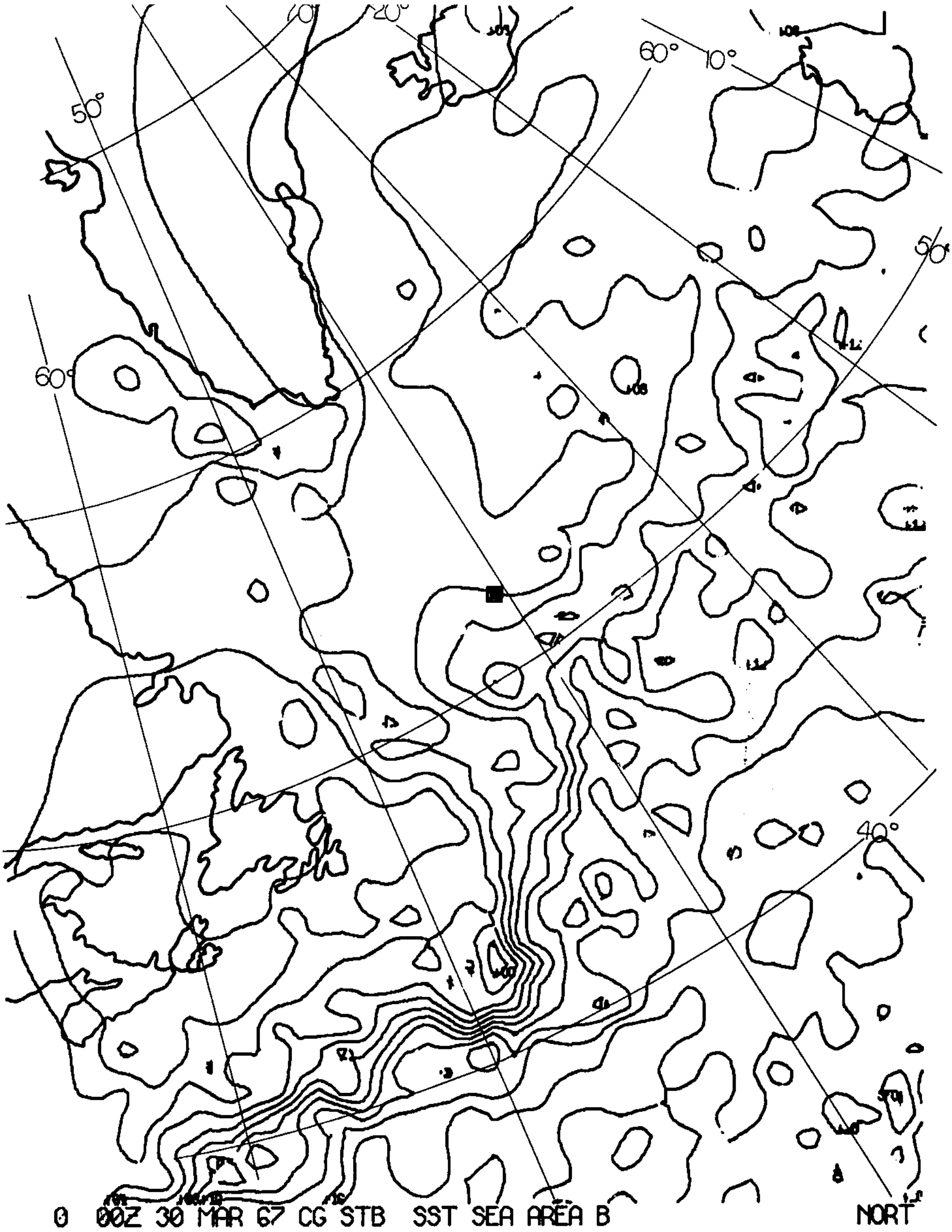


FIGURE 1.

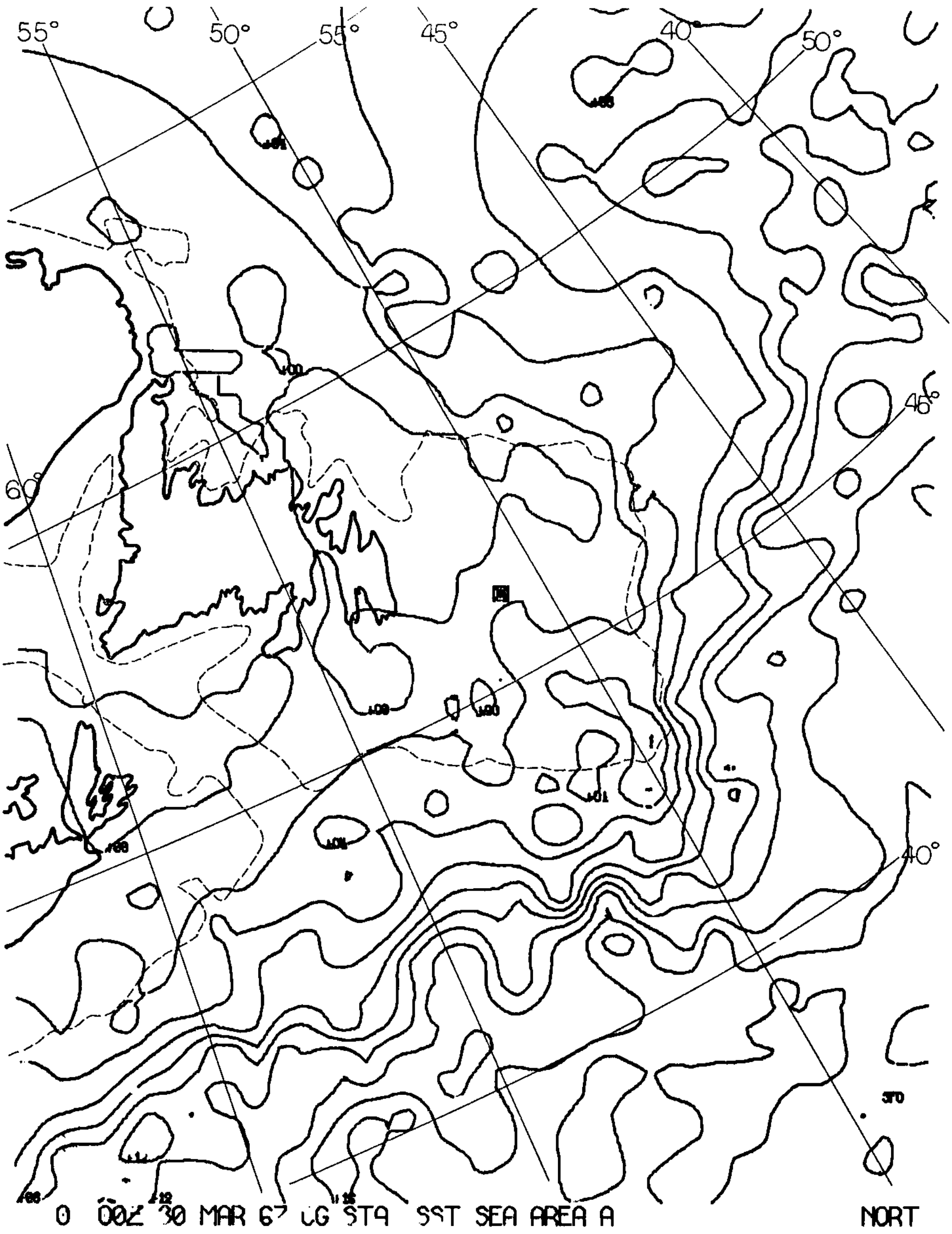


FIGURE 2.

C 1

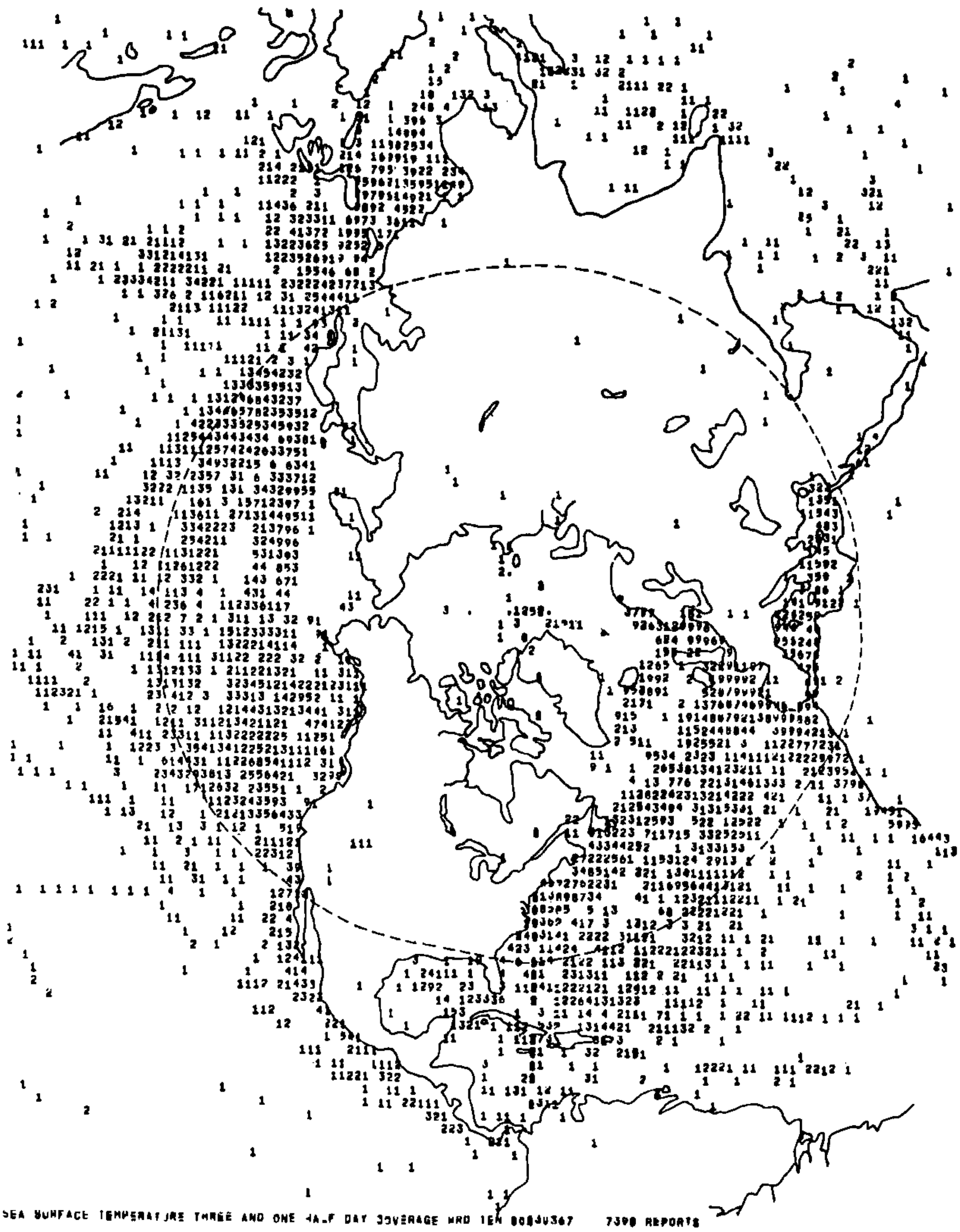


FIGURE 3 DENSITY OF SYNOPTIC SEA SURFACE TEMPERATURE REPORTS DURING THREE AND A HALF DAYS, PERIOD ENDING ON 00Z 13 MARCH 1967. THE NUMBERS ON THE CHART INDICATE THE NUMBER OF REPORTS UNDER THE AREA OF THE FIGURE. 9 MEANS 9 OR MORE REPORTS.

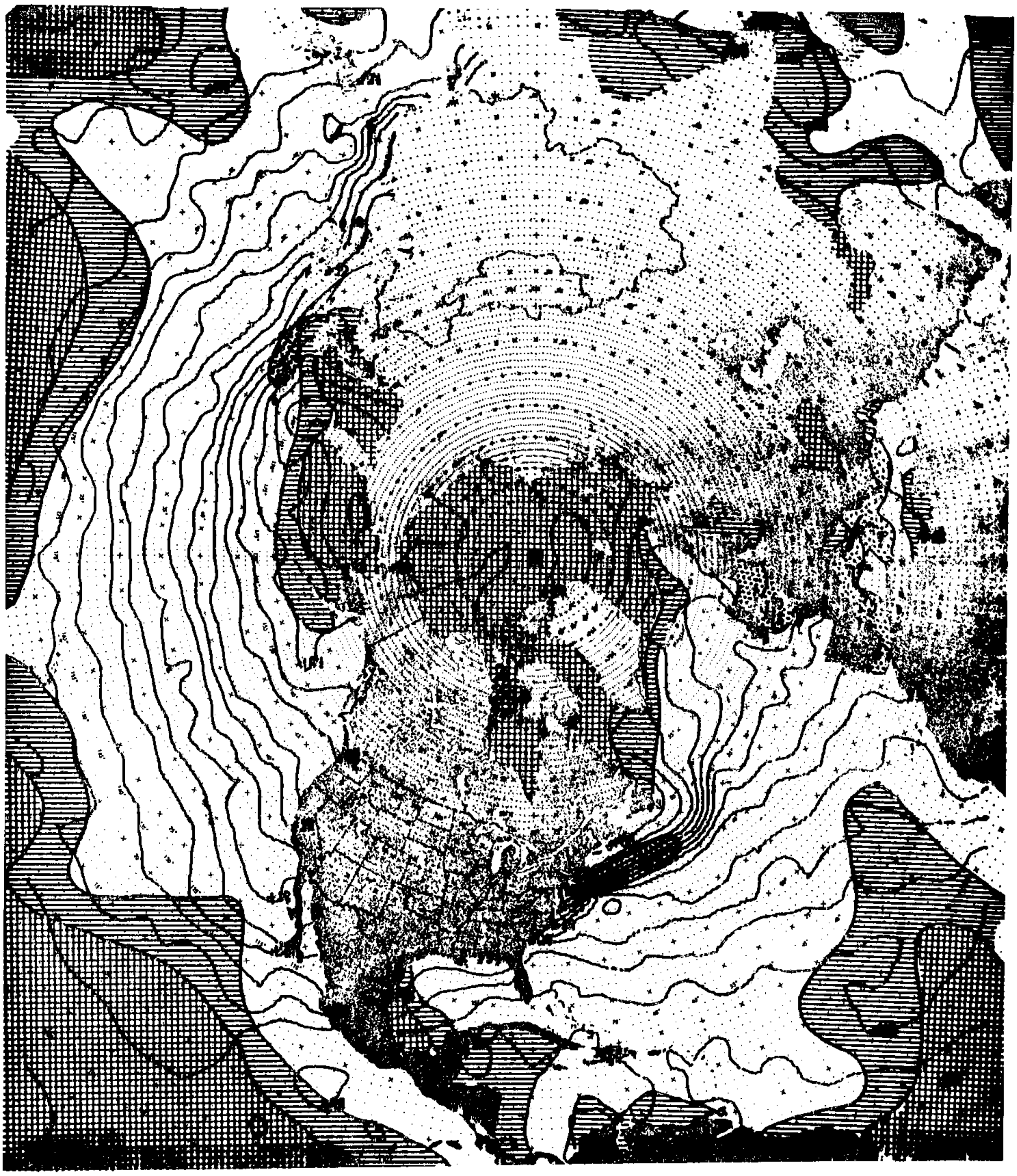
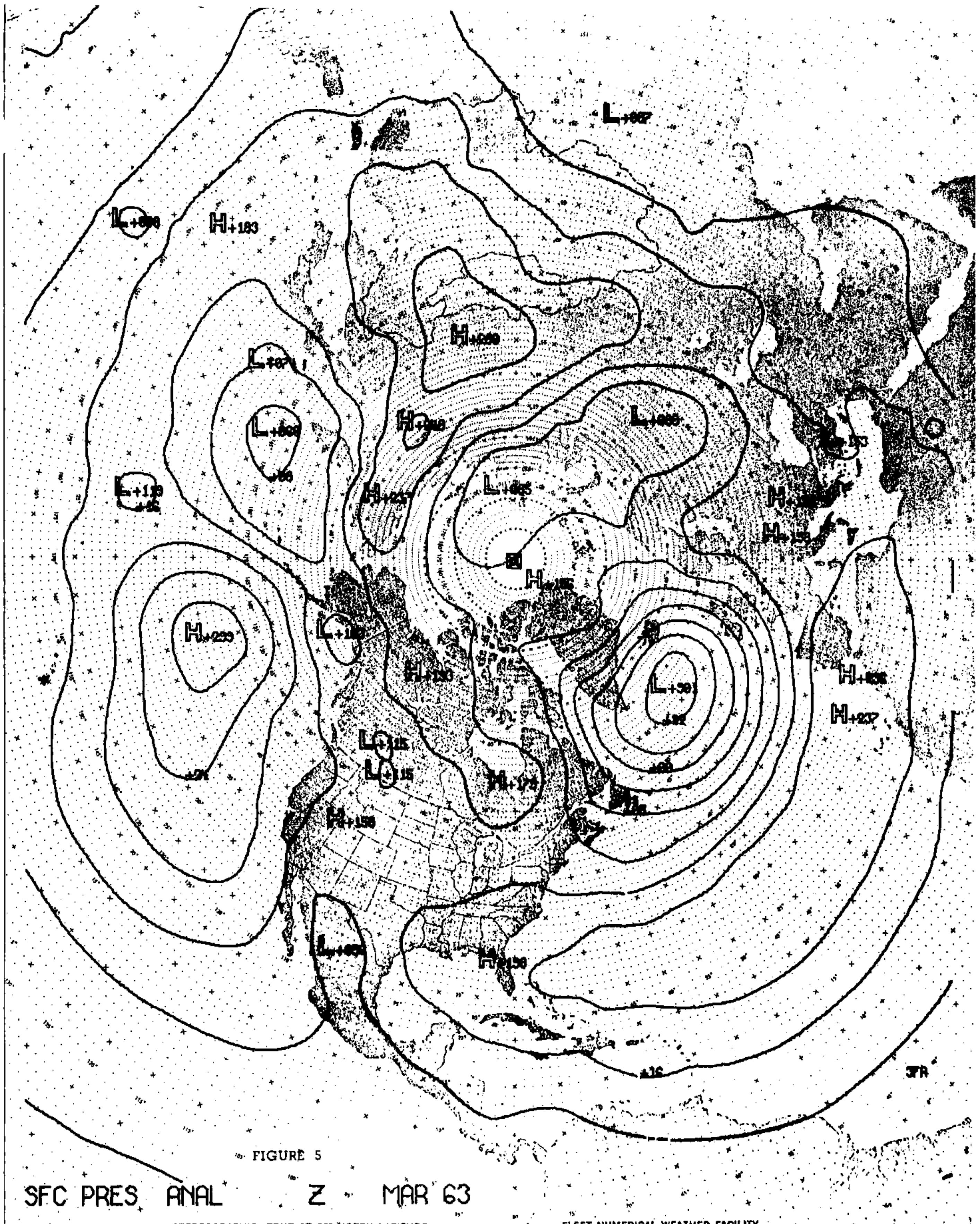


FIGURE 4 HEMISPHERIC SST ANALYSIS ON 00Z 13 MARCH 1967.

The areas where grid size is limiting the accuracy are dotted; areas where the accuracy is decreased by low data density are hatched and in cross-hatched areas the analysis is unreliable due to lack of synoptic data.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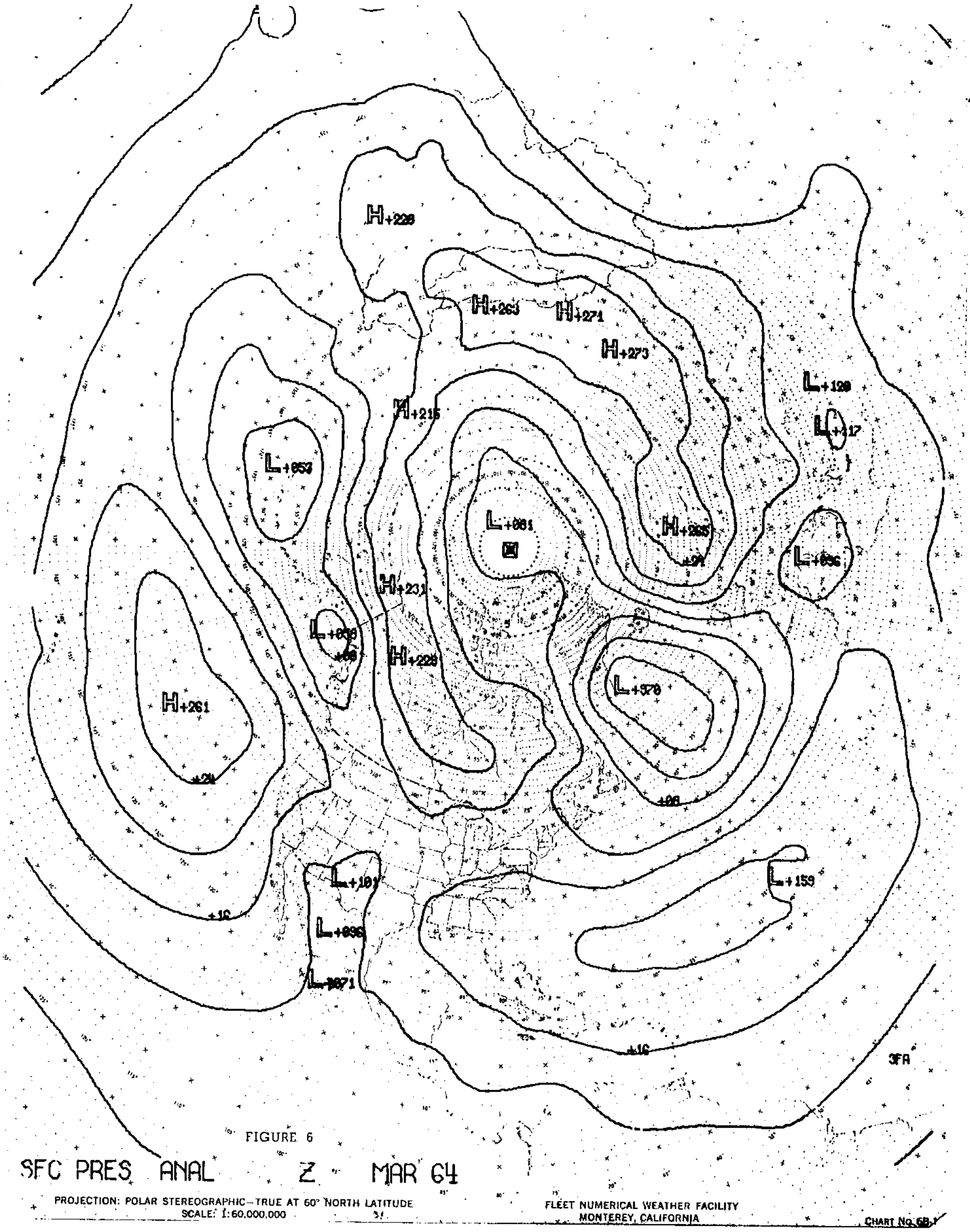
FLEET NUMERICAL WEATHER FACILITY
MONTEREY, CALIFORNIA

FIGURE 5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H+263
H+271
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L+117
H+215
L+057
L+081
H+265
L+096
H+231
L+039
H+228
H+261
L+970
L+101
L+096
L+071
L+159
3FA
SFC PRES ANAL Z MAR 64
PROJECTION: POLAR STEREOGRAPHIC—TRUE AT 60° NORTH LATITUDE
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MONTEREY, CALIFORNIA
CHART No. 6B

FIGURE 6

C 5

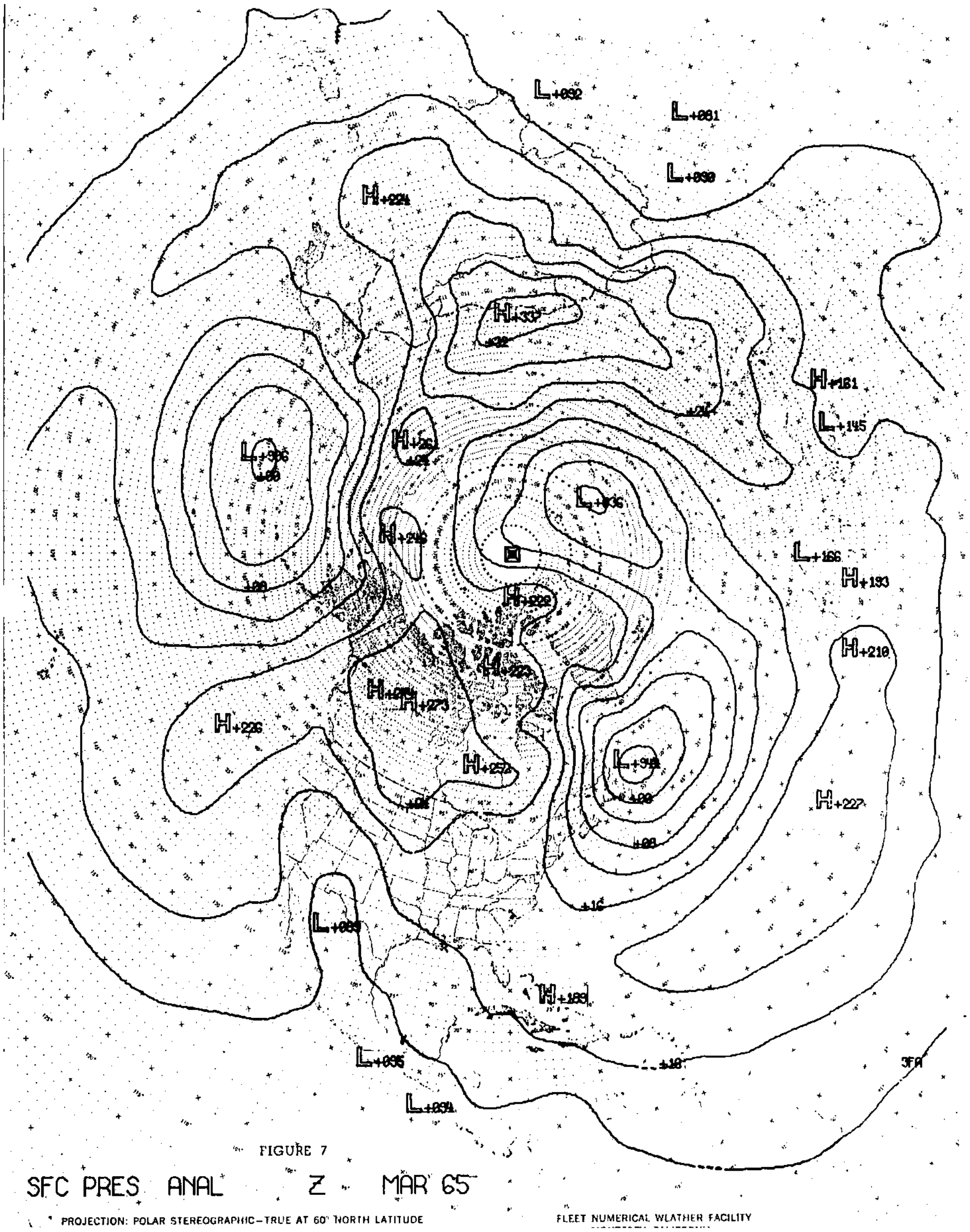
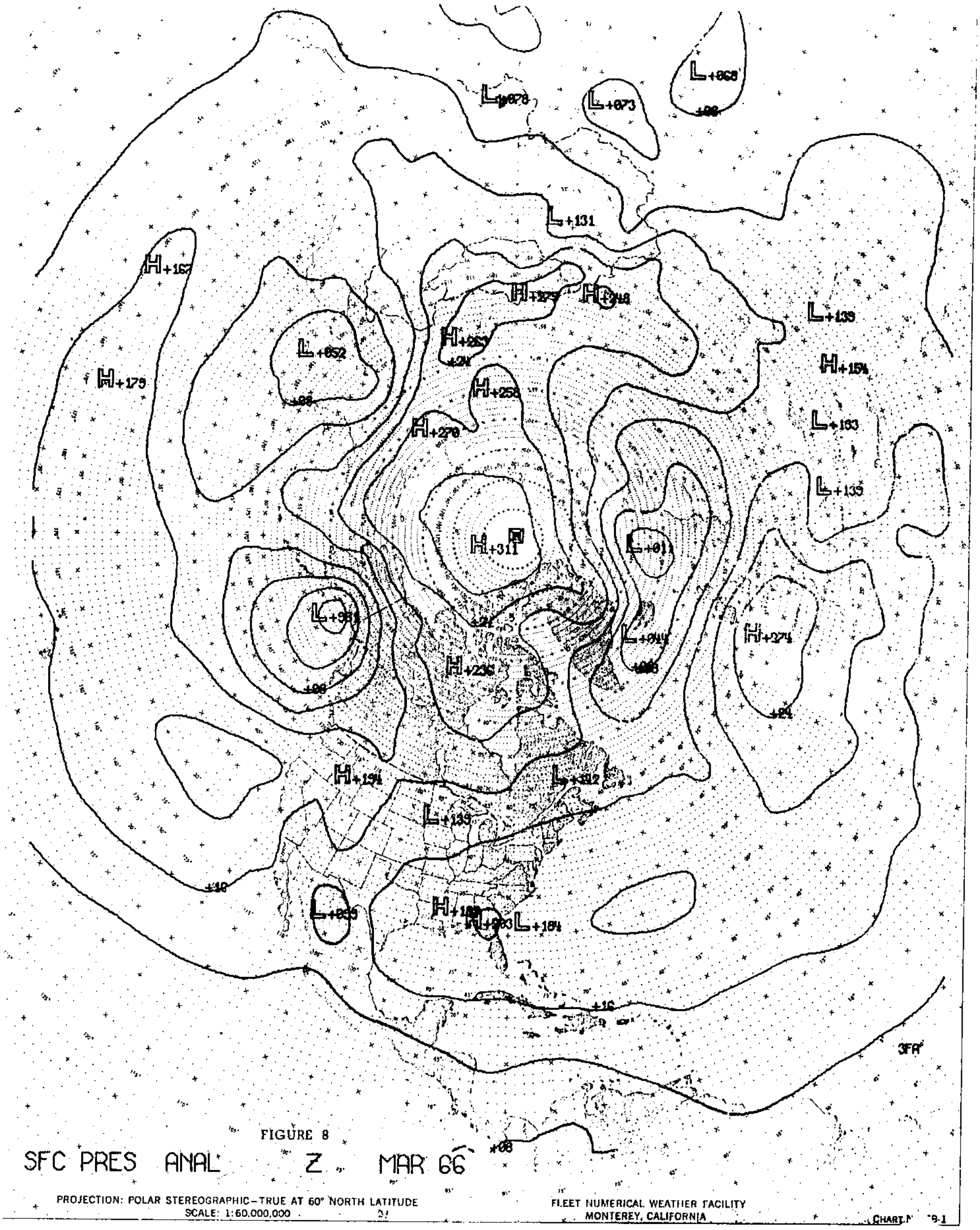

SFC PRES ANAL Z MAR 65
PROJECTION: POLAR STEREOGRAPHIC—TRUE AT 60° NORTH LATITUDE
FLEET NUMERICAL WEATHER FACILITY

FIGURE 7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PROJECTION: POLAR STEREOGRAPHIC–TRUE AT 60° NORTH LATITUDE
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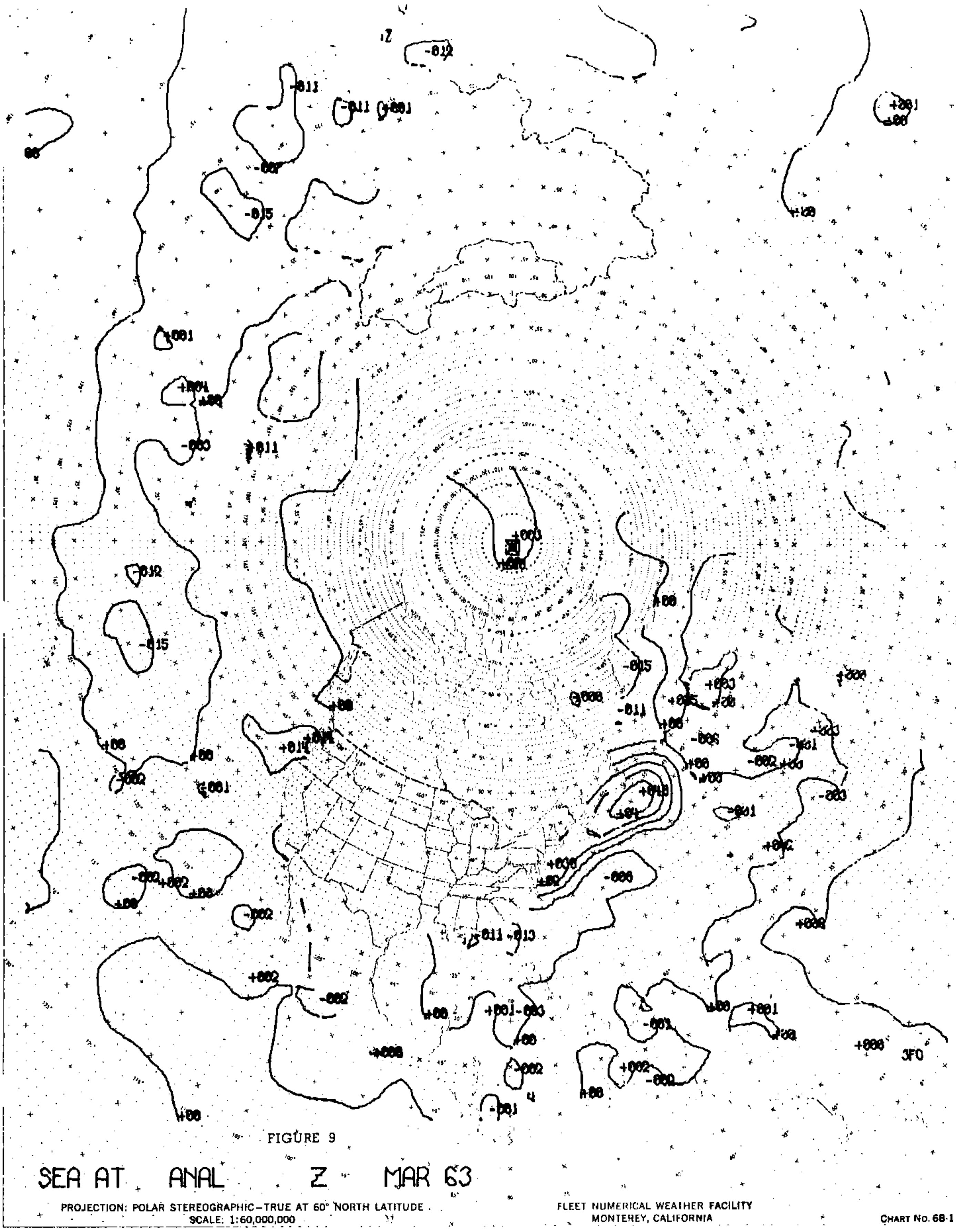
FLEET NUMERICAL WEATHER FACILITY
MONTEREY, CALIFORNIA

FIGURE 8


SEA AT ANAL Z MAR 63
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MONTEREY, CALIFORNIA
CHART No. 68-1

FIGURE 9

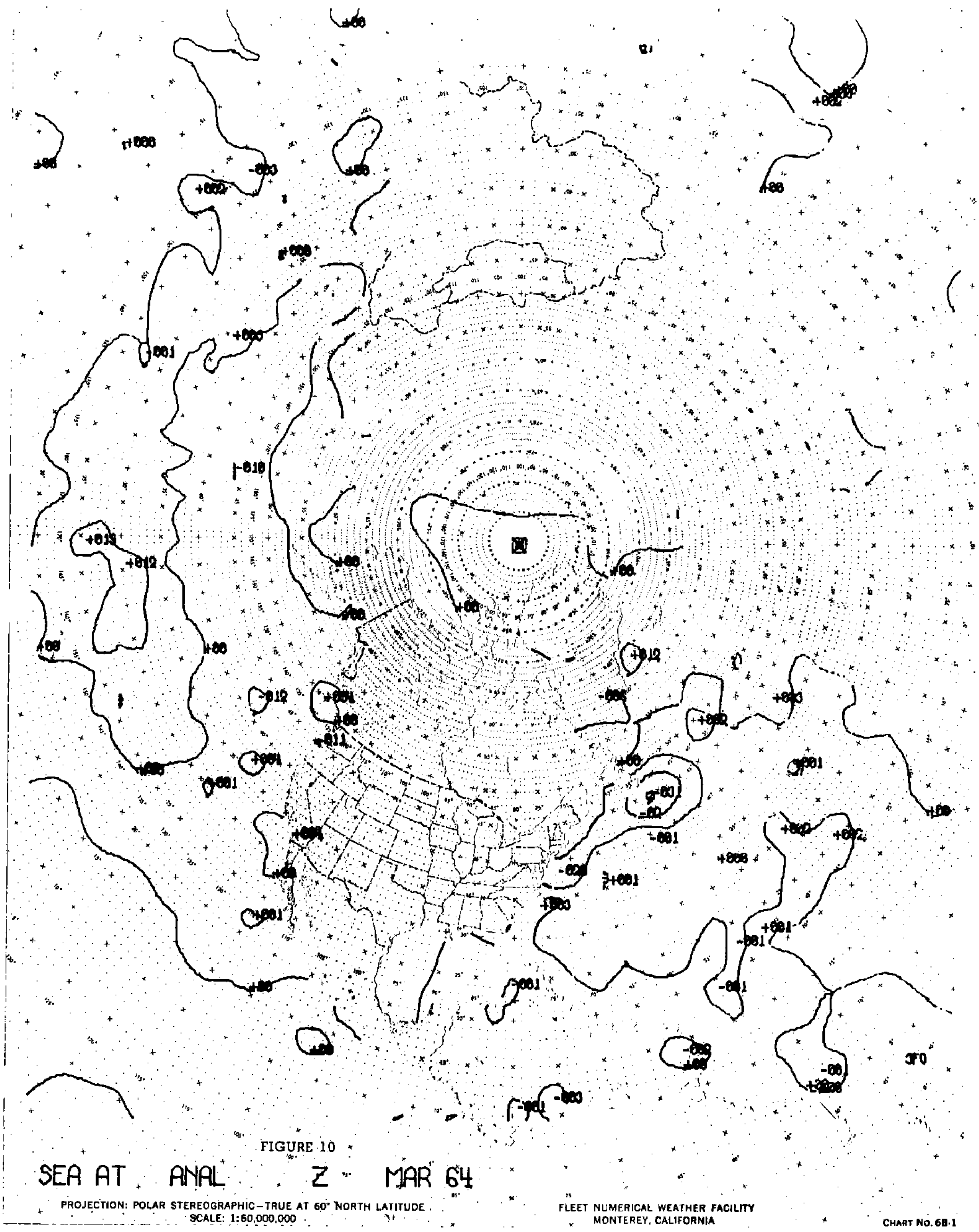
SEA AT ANAL Z MAR 64
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FIGURE 10

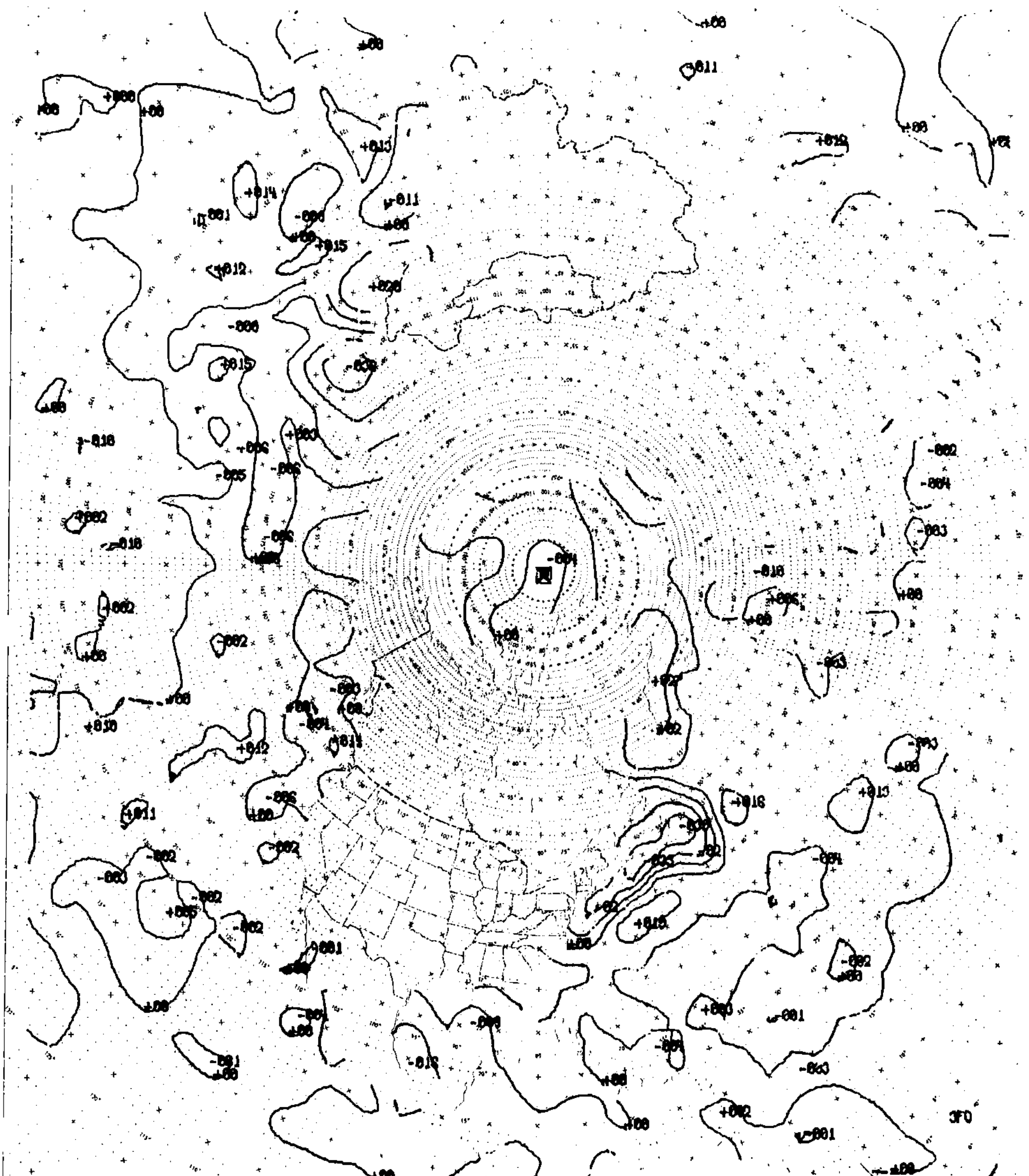

FIGURE 11

SEA AT ANAL Z MAR 65

PROJECTION: POLAR STEREOGRAPHIC—TRUE AT 60° NORTH LATITUDE
SCALE: 1:60,000,000

FLEET NUMERICAL WEATHER FACILITY
MONTEREY, CALIFORNIA

CHART No. 68-1

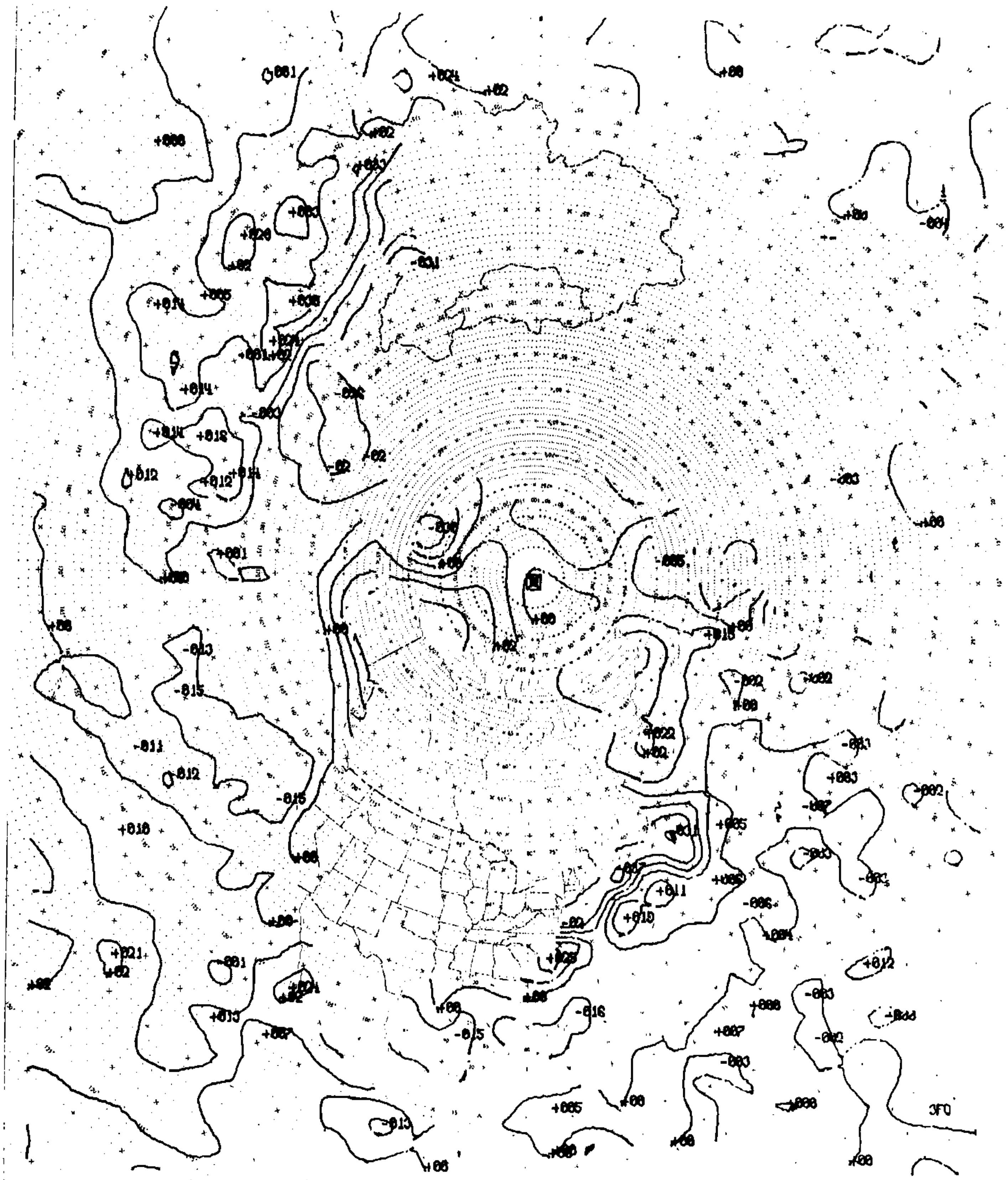

FIGURE 12

SEA AT ANAL Z MAR 66

PROJECTION: POLAR STEREOGRAPHIC - TRUE AT 60 NORTH LATITUDE
SCALE: 1:60,000,000

FLEET NUMERICAL WEATHER FACILITY
MONTEREY, CALIFORNIA

CHART NO. 6B 1

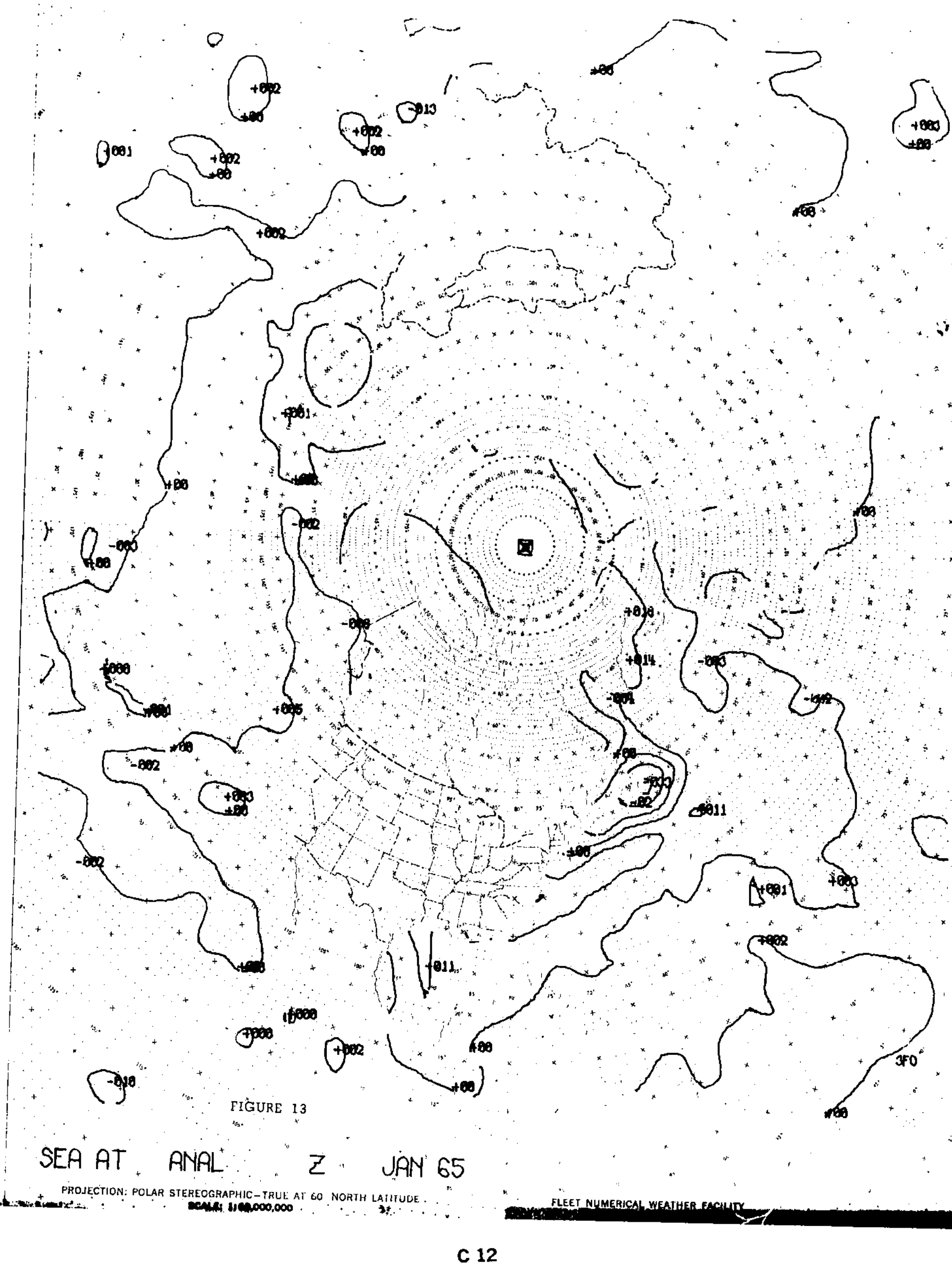
SEA AT ANAL Z JAN 65
PROJECTION: POLAR STEREOGRAPHIC–TRUE AT 60 NORTH LATITUDE
FLEET NUMERICAL WEATHER FACILITY

FIGURE 13

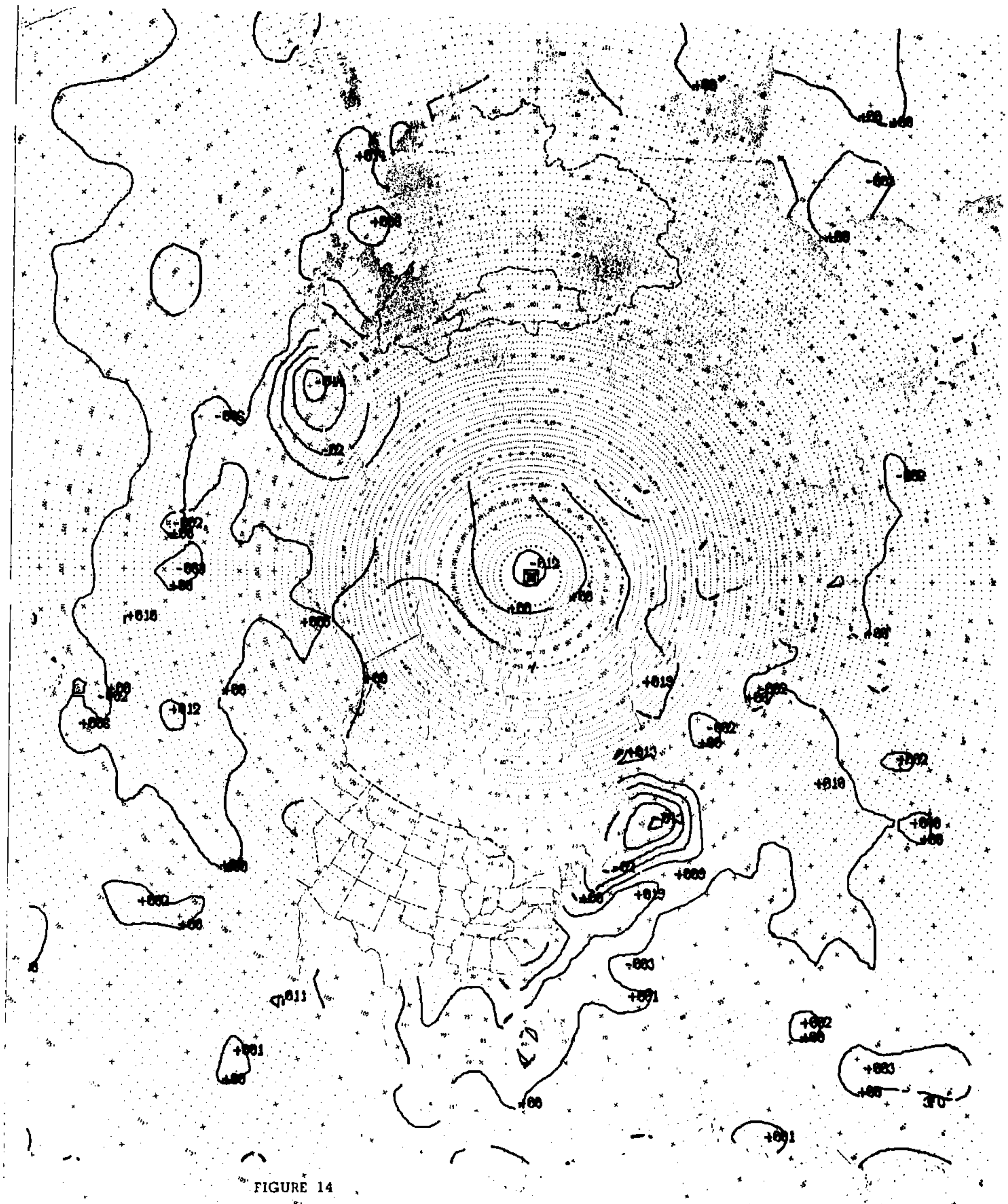

FIGURE 14

SEA AT ANAL Z FEB 65

PROJECTION: POLAR STEREOGRAPHIC–TRUE AT 60° NORTH LATITUDE
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MONTEREY, CALIF[illegible]

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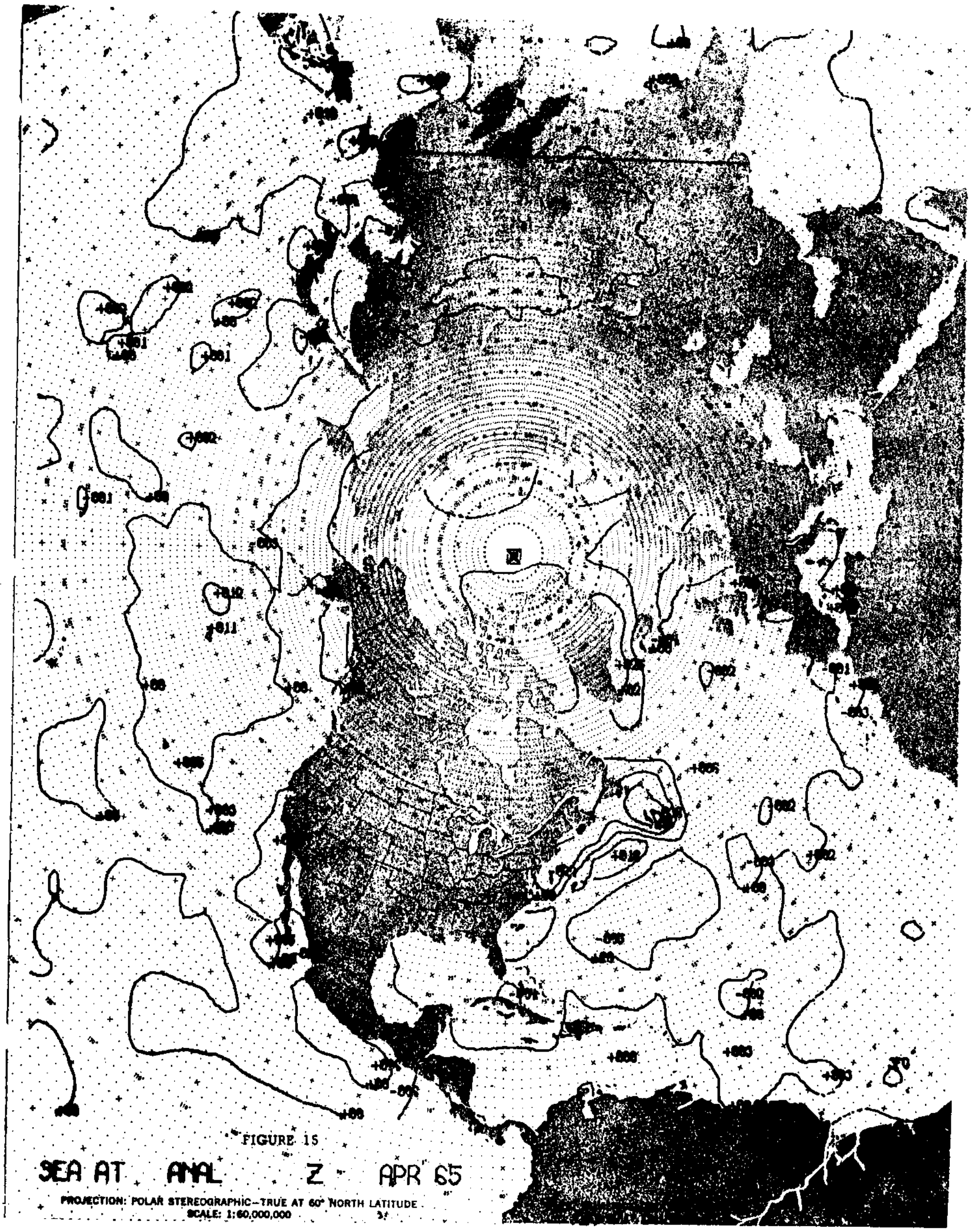

FIGURE 15

SEA AT ANAL Z APR 65

PROJECTION: POLAR STEREOGRAPHIC—TRUE AT 60° NORTH LATITUDE
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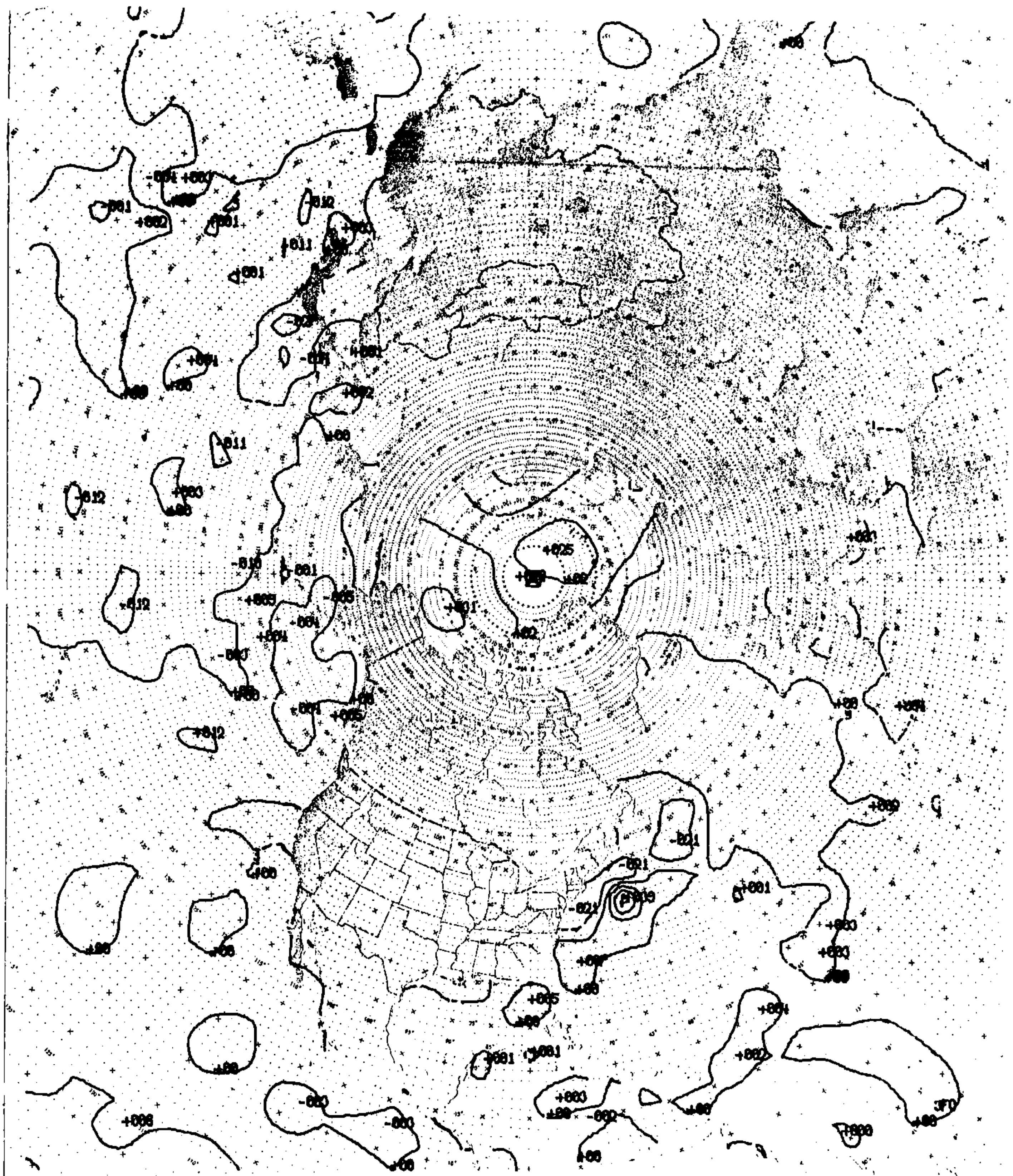

FIGURE 16

SEA AT ANAL Z MAY 65

PROJECTION: POLAR STEREOGRAPHIC—TRUE AT 60° NORTH LATITUDE
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FLEET NUMERICAL WEATHER FACILITY
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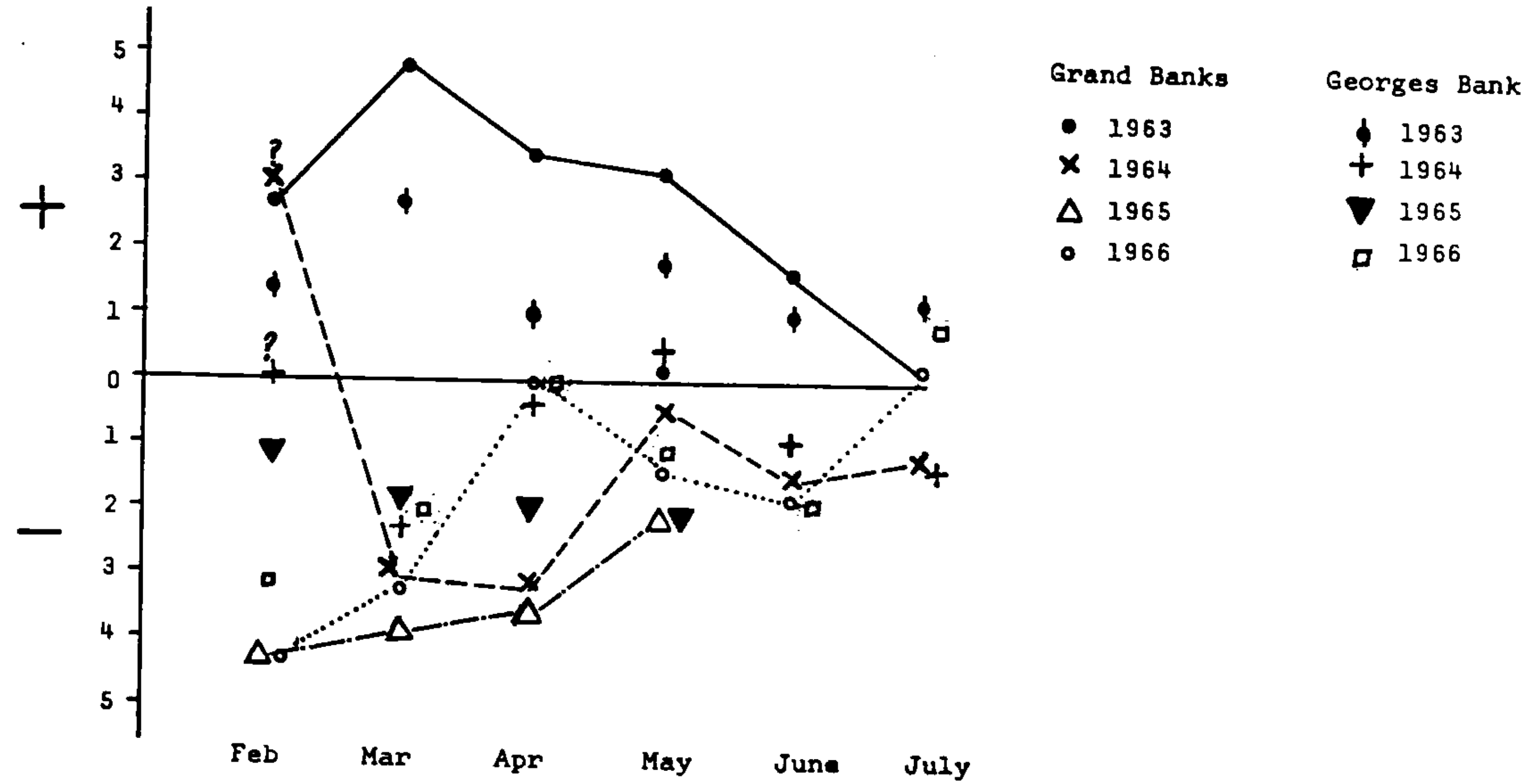

Figure 17 Maximum and minimum anomalies of sea surface temperature in Grand Banks, Georges Bank and N. American continental shelf area from February to July 1963 to 1966

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