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SYNOPTIC ANALYSIS OF THE SOUTHERN HEMISPHERE STRATOSPHERE

by Alvin J. Miller and Frederick G. Finger

ESSA, Weather Bureau, National Meteorological Center

Hillcrest Heights, Md.

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SUMMARY

Rawinsonde data from 84 stations in the Southern Hemisphere are combined with constant-level balloon information to construct weekly hemispheric analyses for the 30-mb level for the month of June, 1967. Rocket information from Chamical, Argentina; Natal, Brazil and Ascension Island are employed to infer the circulation at higher levels.

During the period of study, the lower stratosphere of the Southern Hemisphere was dominated by a polar low with a subtropical ridge present at about 20°S. The lateral extent of the westerlies increased with height with the result that westerly winds existed in the tropical region at upper levels.

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INTRODUCTION

With the establishment of the Experimental Inter-American Meteorological Rocket Network (EXAMETNET) in 1965 (Bettle et al., ref. 1), a significant first step was taken to provide information which would increase our knowledge of the middle and upper stratospheric structure and behavior in the Southern Hemisphere. This would also allow comparisons to be made with the relatively well charted Northern Hemisphere in order to determine similarities and differences. Additionally, possible interactions between the two hemispheres could be investigated.

Heretofore, stratospheric constant-pressure analyses for the Southern Hemisphere have been necessarily limited to the Antarctic region because of the general paucity of data elsewhere. However, on 13 March 1967 a constant level balloon was launched from Christchurch, New Zealand for flight at 23 mb. as part of the Global Horizontal Sounding Technique (GHOST) balloon project (Lally, ref. 2). The balloon remained aloft until 6 July 1967 and provided valuable information over the relatively data-free areas of the South Atlantic and Indian Oceans. It was felt that stratospheric data from the flight combined with a number of high-level rawinsonde reports from 84 stations in the Southern Hemisphere, could be utilized to construct analyses at least on a weekly basis for the 30-mb. level (≈23 km.). The month of June, 1967 was selected for this analysis attempt primarily because of the availability of data. It is at this time, at least by Northern Hemisphere standards, that the polar vortex is most stable.

Our experience with Northern Hemisphere analysis suggested that the available upper-level rocket data from the EXAMETNET stations at Chamical, Argentina (30°S, 66°W); Natal, Brazil (6°S, 35°W), as well as that from the Ascension Island station (8°S, 14°W) might be effectively superposed upon these constant-pressure analyses of rawinsonde data to infer the circulation patterns at higher stratospheric levels. The circulation features could then be compared with the daily Northern Hemisphere 30-mb objective series (Finger et al., ref. 3) and also the 5-, 2- and 0.4-mb analyses (Finger *et al.*, ref. 4) of the North American region being carried out on a research basis.

30-MB ANALYSES

Figure 1 presents the daily positions of the GHOST balloon in its flight from Christchurch, New Zealand to South America, its retreat past South Africa and the balloon's ultimate cyclonic recurvature to the southeast of South Africa. Also shown are the locations of the rawinsonde stations employed in the analyses. The additional information gained from the constant-level balloon flight over the essentially data-free areas of the South Atlantic and Indian Oceans is evident.

The basic rawinsonde data used for the analyses, consisted of several days of reports, centered on the Wednesday of each particular week. Data from the 20-mb level as well as from the constant-level balloon were used in conjunction with the 30-mb data as an aid in analysis. Contours for 30 mb were constructed taking into account all available information and assuming quasi-geostrophic equilibrium. In areas where no clear indication of the isotherm orientation existed, the colder temperatures were located in the troughs and the warmer temperatures in the ridges. This general configuration is obvious in Northern Hemisphere analyses at these levels during the early winter period (Staff, Upper Air Branch, ref. 5). However, because this method is climatologically biased, slightly less credence must be given to the configuration of the isotherm pattern compared to that of the height field. Unfortunately, no satellite radiation measurements capable of yielding stratospheric temperatures were available for this period.

Figures 2-5 present the 30-mb Southern Hemisphere analyses for the period June 4 to June 30, 1967. Clearly evident is the existence of the subtropical ridge line that separates the mid- and high-latitude westerlies from the tropical easterlies. Analysis of monthly mean zonal wind data at 30-mb from Ascension Island (not shown here) indicates that the general trend of the quasi-biennial oscillation during this period is toward increasing tropical easterlies (Reed, ref. 6; Quiroz and Miller, ref. 7).

An inspection of the Southern Hemisphere charts reveals a pronounced intensification of the polar low with time, accompanied by a general decrease of temperatures at all but the tropical latitudes. Although the polar cyclone center varies somewhat in location during the period, it can certainly be classified as circumpolar by Northern Hemisphere standards (Staff, Upper Air Branch, ref. 5).

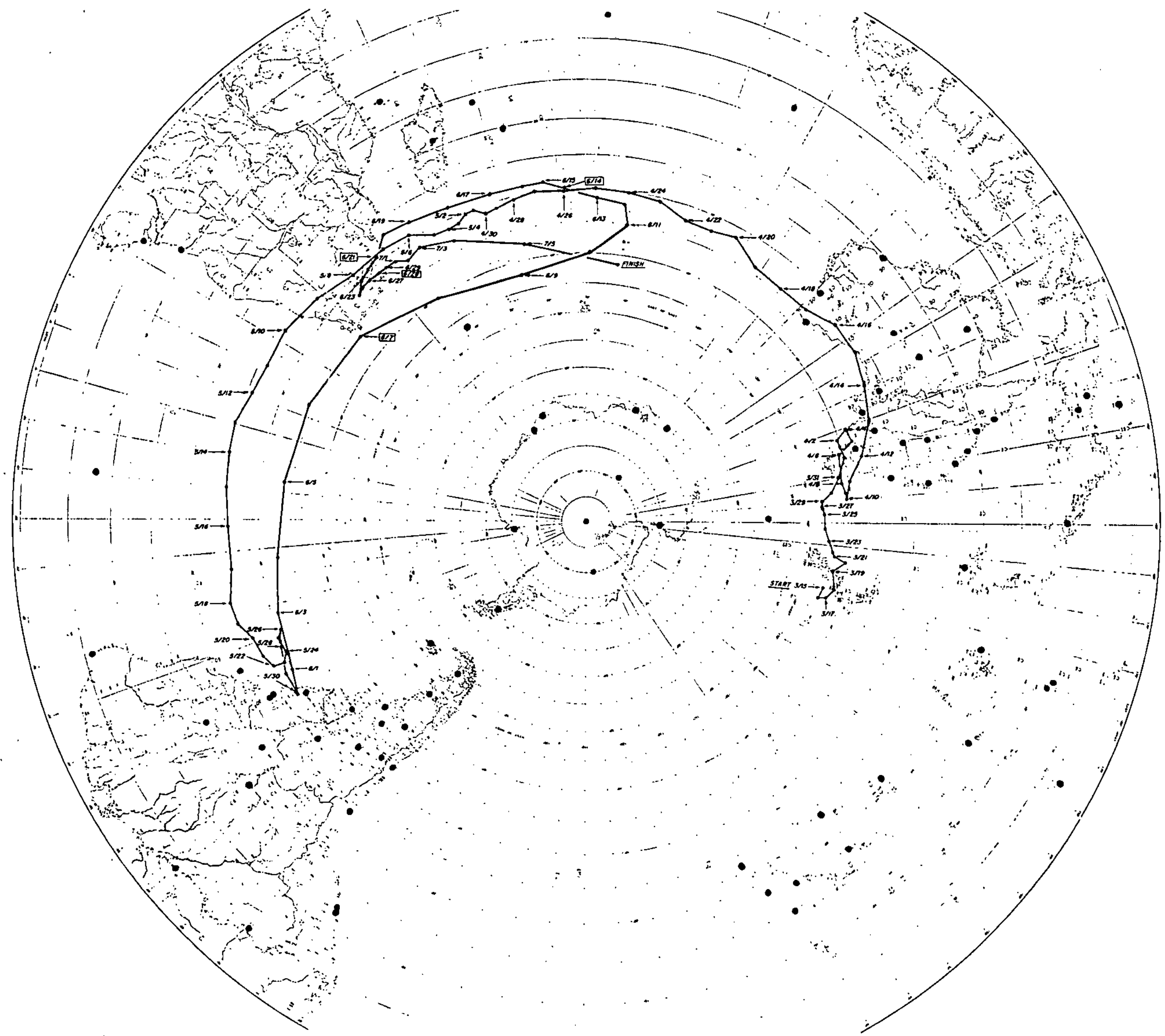

Figure 1. Daily positions of GHOST balloon from 3/15/67-7/6/67. Stations employed in this study are denoted by filled circles ( ).

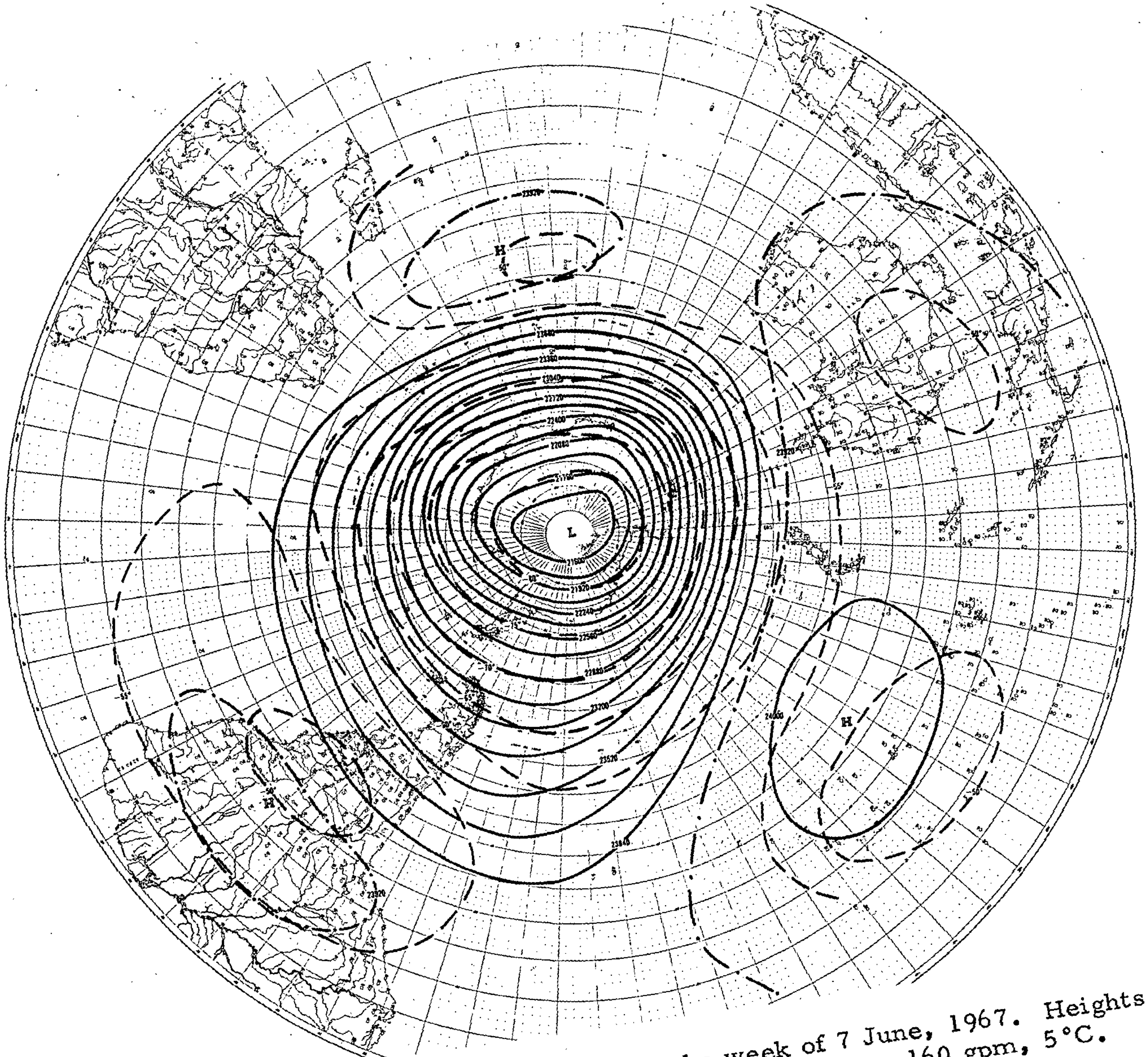

Figure 2. Southern Hemisphere 30-mb analysis for the week of 7 June, 1967. Heights in geopotential meters, temperatures in degrees Celsius. Contour intervals: 160 gpm, 5°C.

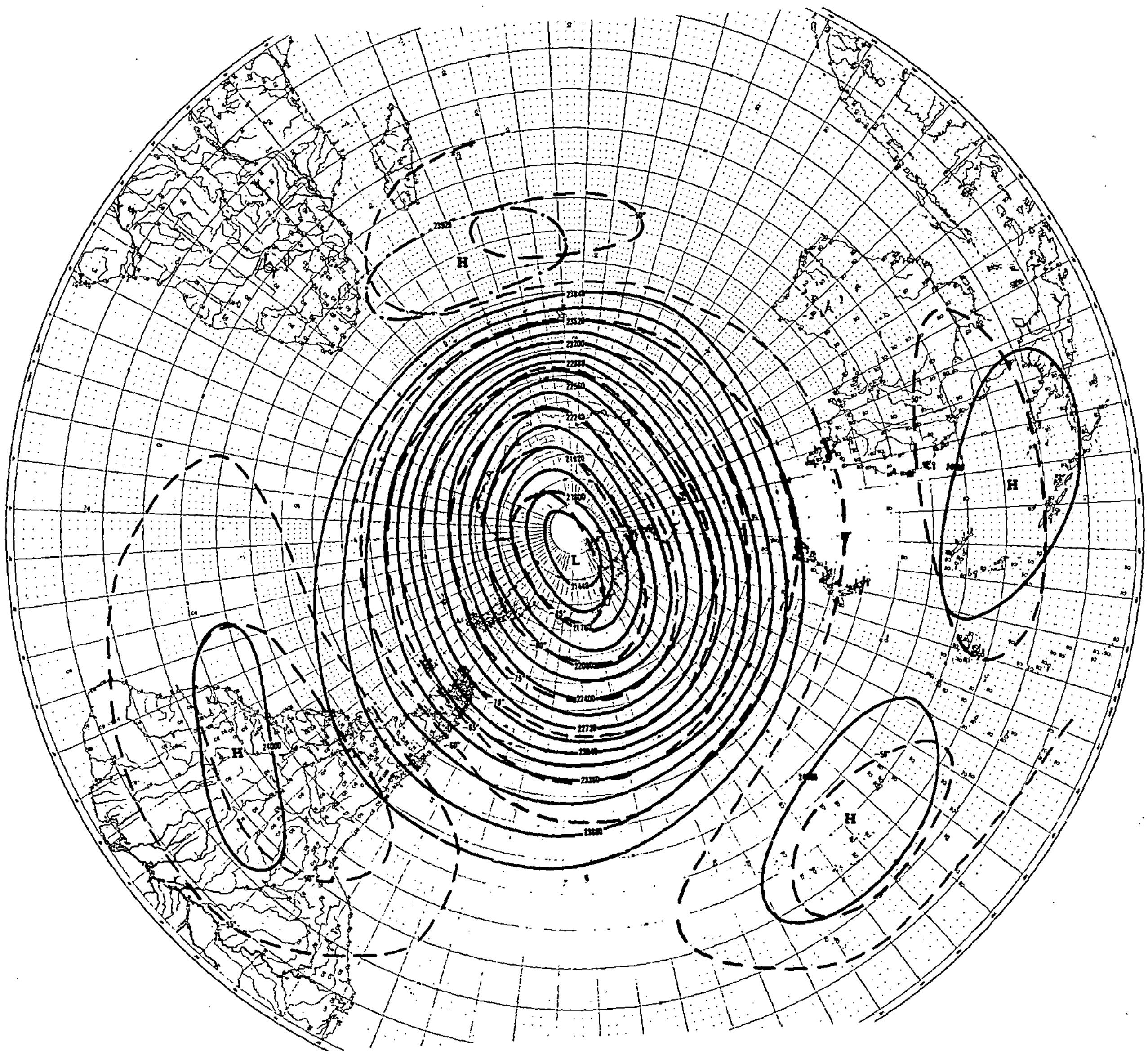

Figure 3. Same as Figure 2 for the week of 14 June, 1967.

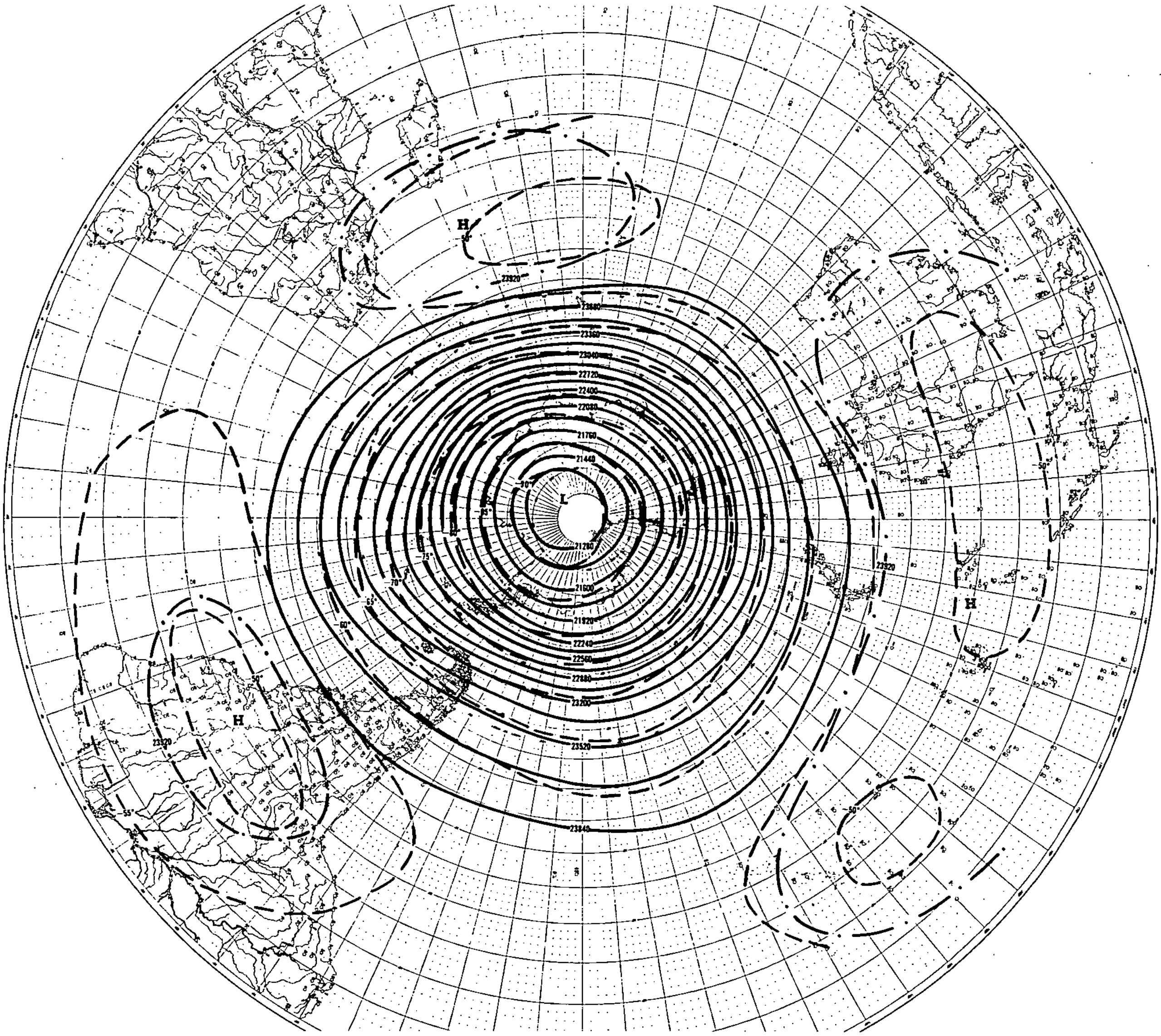

Figure 4. Same as Figure 2 for the week of 21 June, 1967.

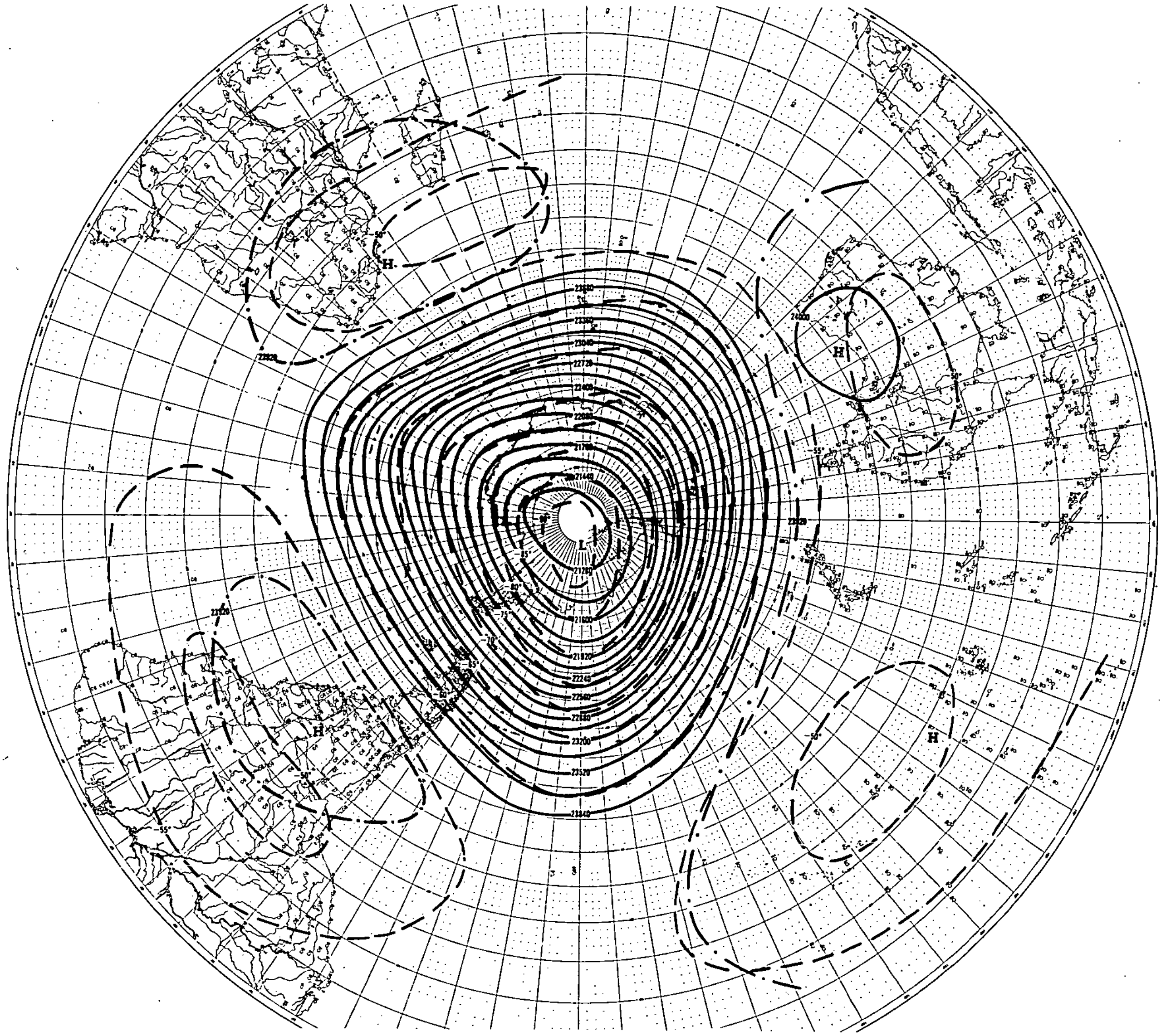

Figure 5. Same as Figure 2 for the week of 28 June, 1967.

COMPARISON OF HEMISPHERIC CIRCULATIONS

Illustrated in Figs. 6-9 are the Northern Hemisphere objectively analyzed 30-mb charts for the Wednesday of each week of June 1967. As this period is the Northern Hemisphere summer, the circulation is dominated by a nearly circumpolar anticyclone, with easterly winds extending southward to the lower latitudes. The data in the tropics are rather sparse and the hortizontal temperature gradients are so small that meaningful analyses could not be drawn for the lower latitudes. The reports that are available, however, support the continued decrease of temperature with decreasing latitude. This is consistent with the observation that, in the broad sense, the tropics must be dominated by relatively low pressure.

To facilitate a comparison between circulation patterns of the two hemispheres for the same season, the Northern Hemisphere objectively analyzed 30-mb charts for 7, 14, 21, and 28 December 1964 are presented in Figures 10-13. This particular period was chosen because the relative phase of the tropical quasi-biennial oscillation was approximately the same as that during June 1967.

Obviously, the most prominant features, such as the polar cyclone and the low latitude ridge exist in both hemispheres during the early winter period. As noted by Godson (ref. 8), Arctic temperatures and heights are not as low as in the Antarctic. Quite pronounced in the Northern Hemisphere is the influence of the well-known Aleutian anticyclone, which results in the rather eccentric pattern about the North Pole. Kennedy and Nordberg have pointed out (ref. 9) that this anticyclone is considerably more intense than its Southern Hemisphere counterpart.

It should be stated that the bipolar pattern observed on the 21st of the month is a transient feature and not representative of the normal circulation for this period. In fact, the secondary high over the North Atlantic diminished in strength during the following days and was not evident on the 28th.

INCORPORATION OF METEOROLOGICAL ROCKET DATA

Presented in Figures 14-15 are time sections of the meteorological rocket observations taken at Ascension Island; Chamical, Argentina; and Natal, Brazil for June 1967. The more numerous soundings at Ascension indicate a rather dramatic fluctuation in wind direction, which occurs throughout the entire stratosphere for the first half of the month, with the easterlies underlying the higher level westerlies.

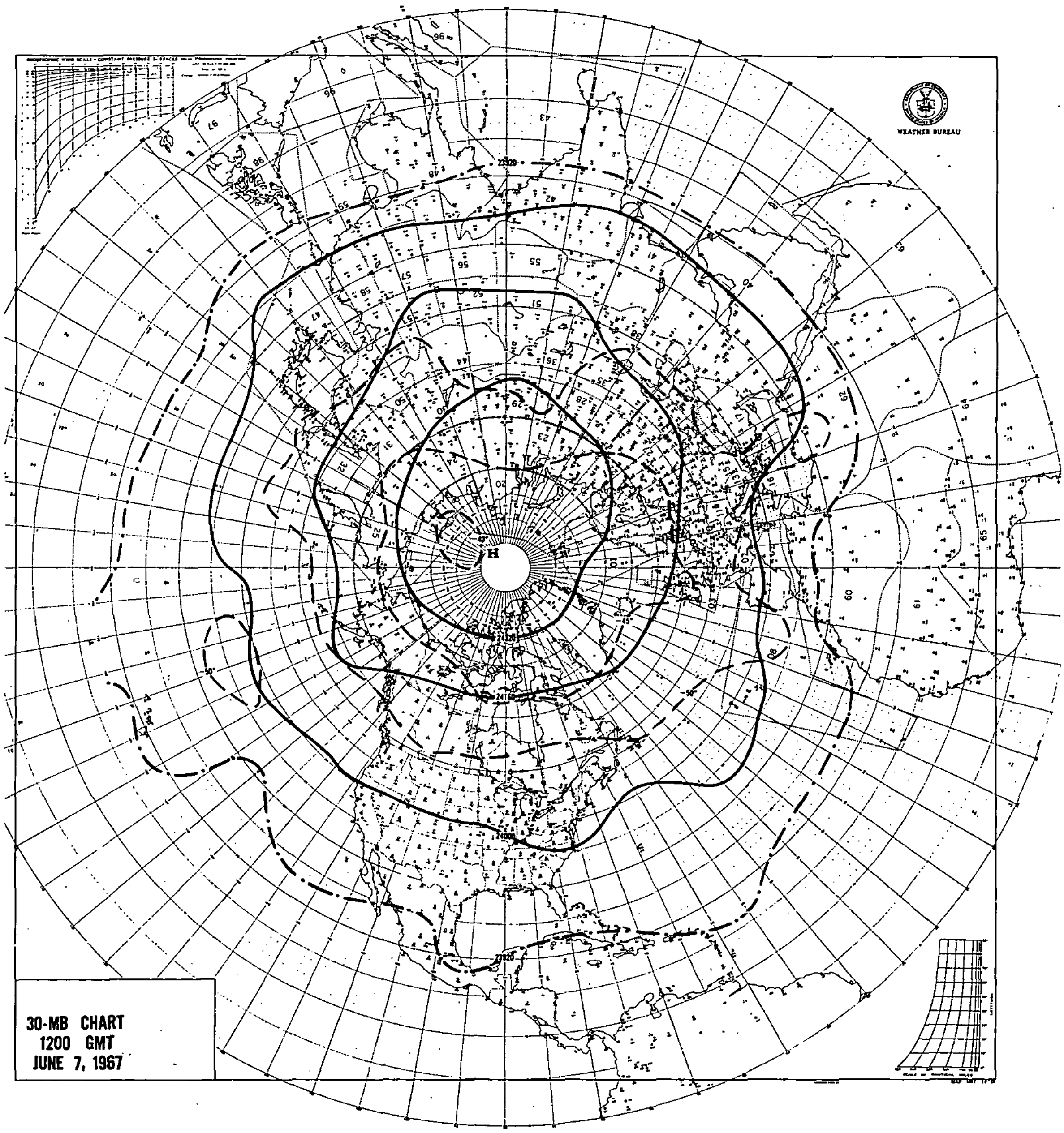

Figure 6. Northern Hemisphere 30-mb analysis for 7 June, 1967. Heights in geopotential meters, temperatures in degrees Celsius. Contour intervals: 160 gpm, 5°C.

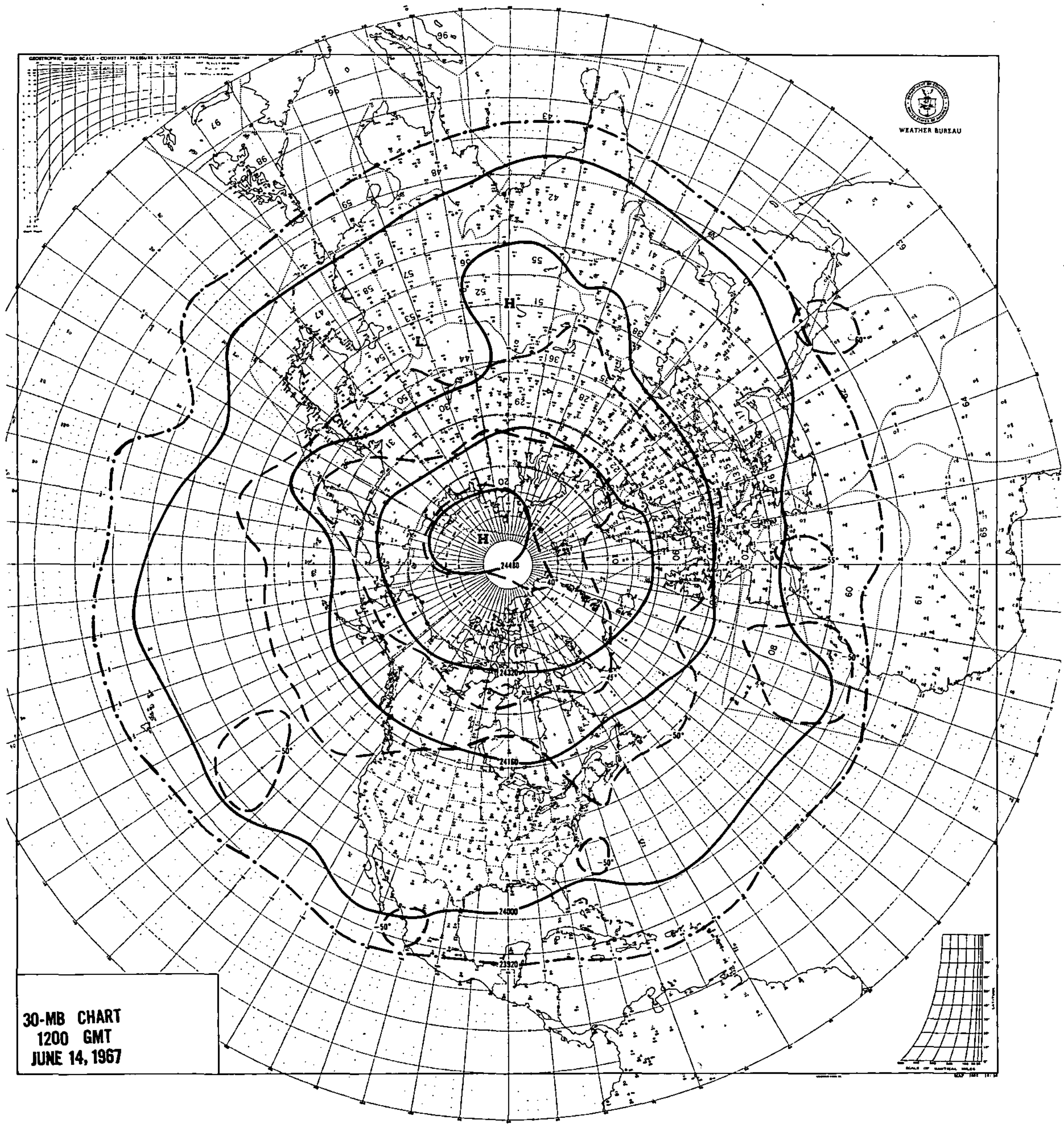

Figure 7. Same as Figure 6 for 14 June, 1967.

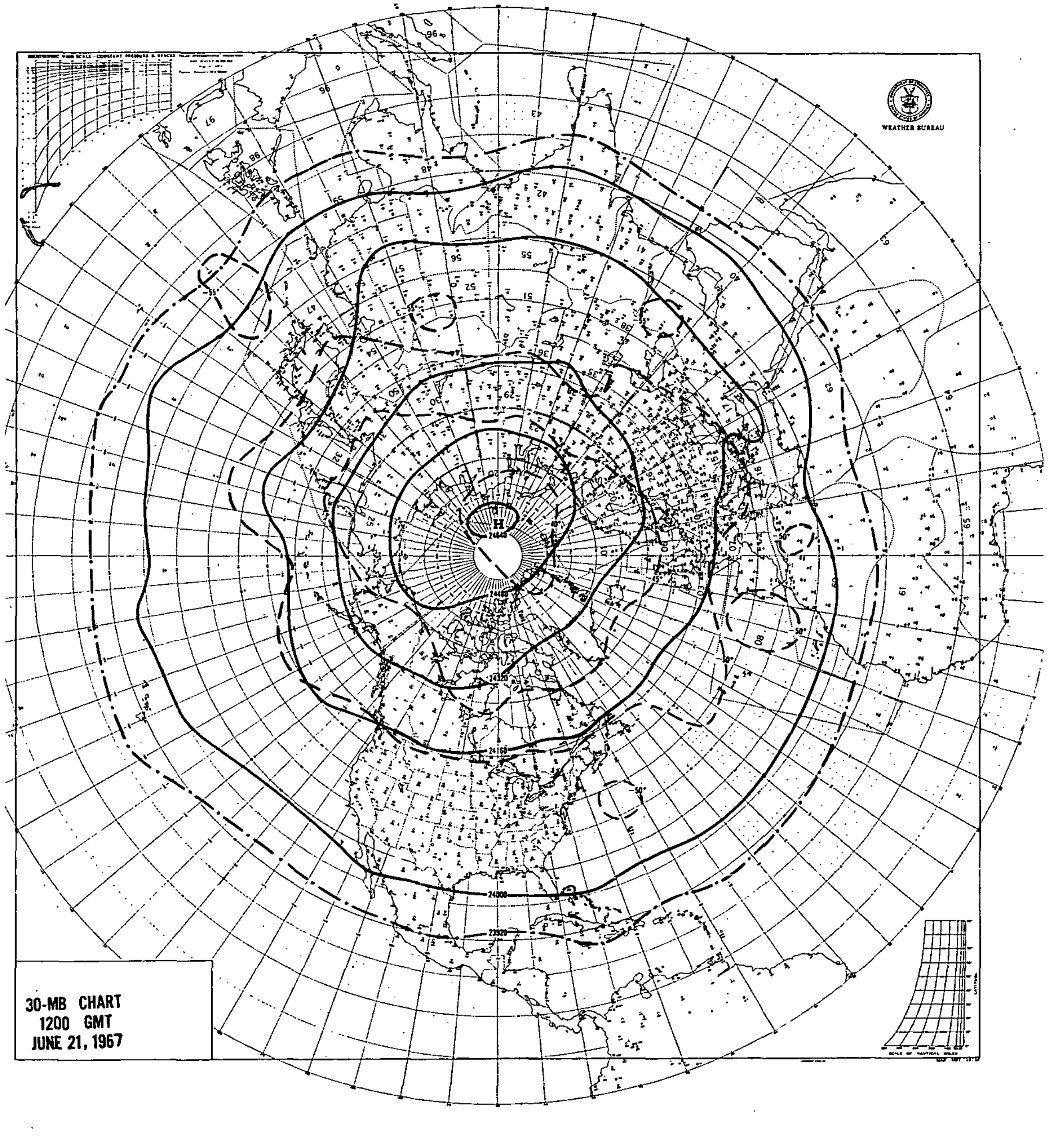

Figure 8. Same as Figure 6 for 21 June, 1967.

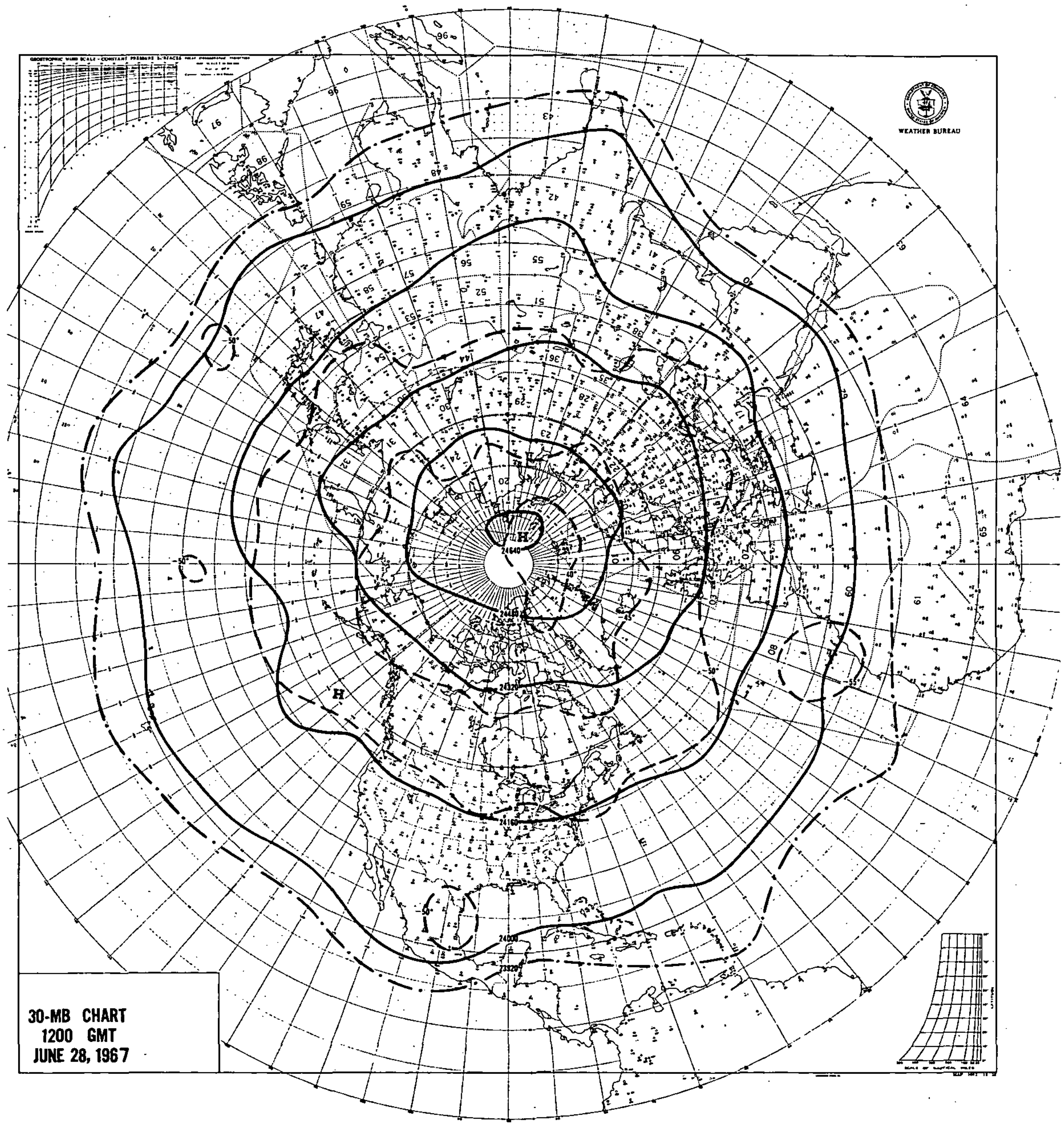

Figure 9. Same as Figure 6 for 28 June, 1967.

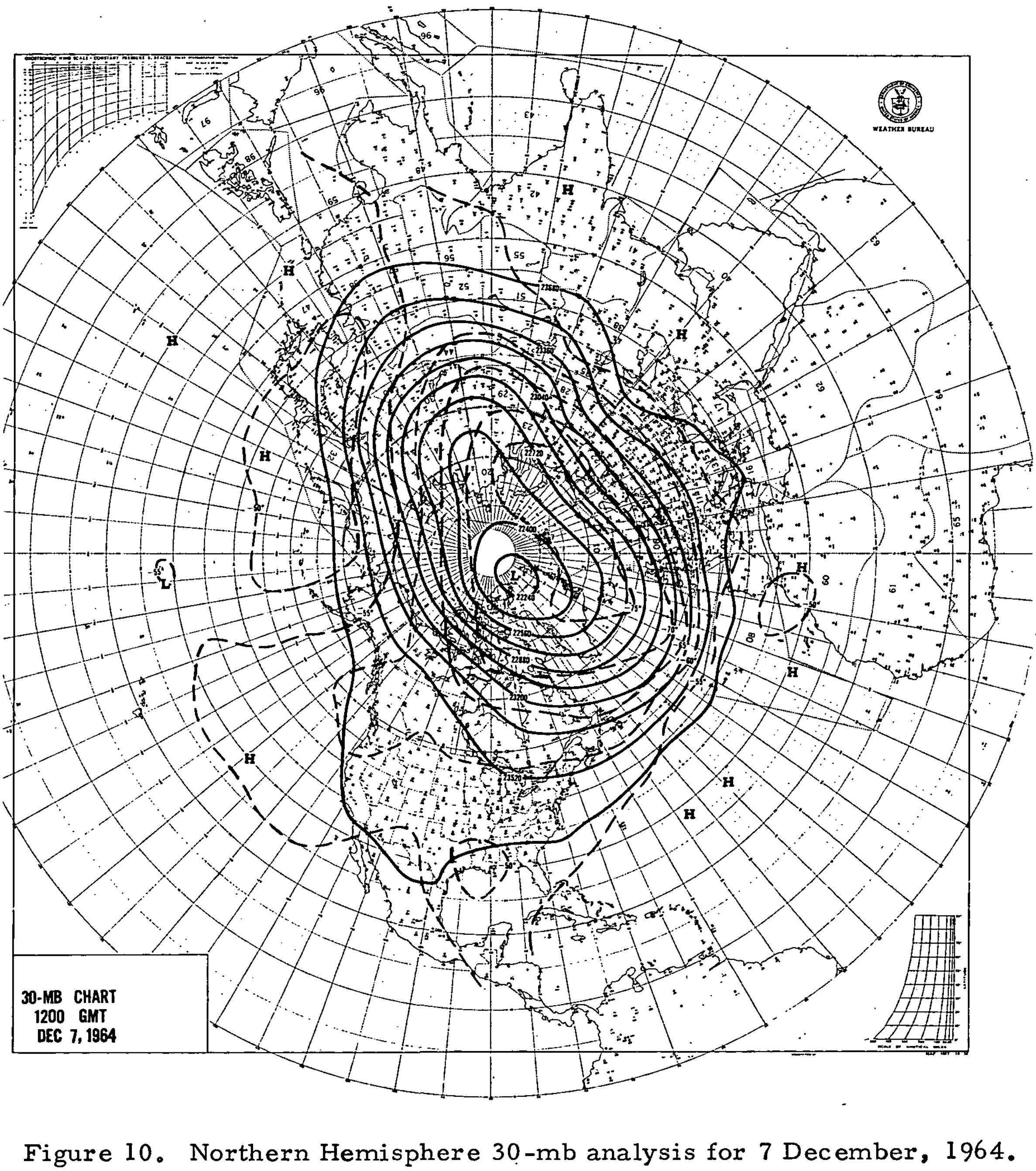

Figure 10. Northern Hemisphere 30-mb analysis for 7 December, 1964. Heights in geopotential meters, temperatures in degrees Celsius. Contour intervals: 160 gpm, 5 °C.

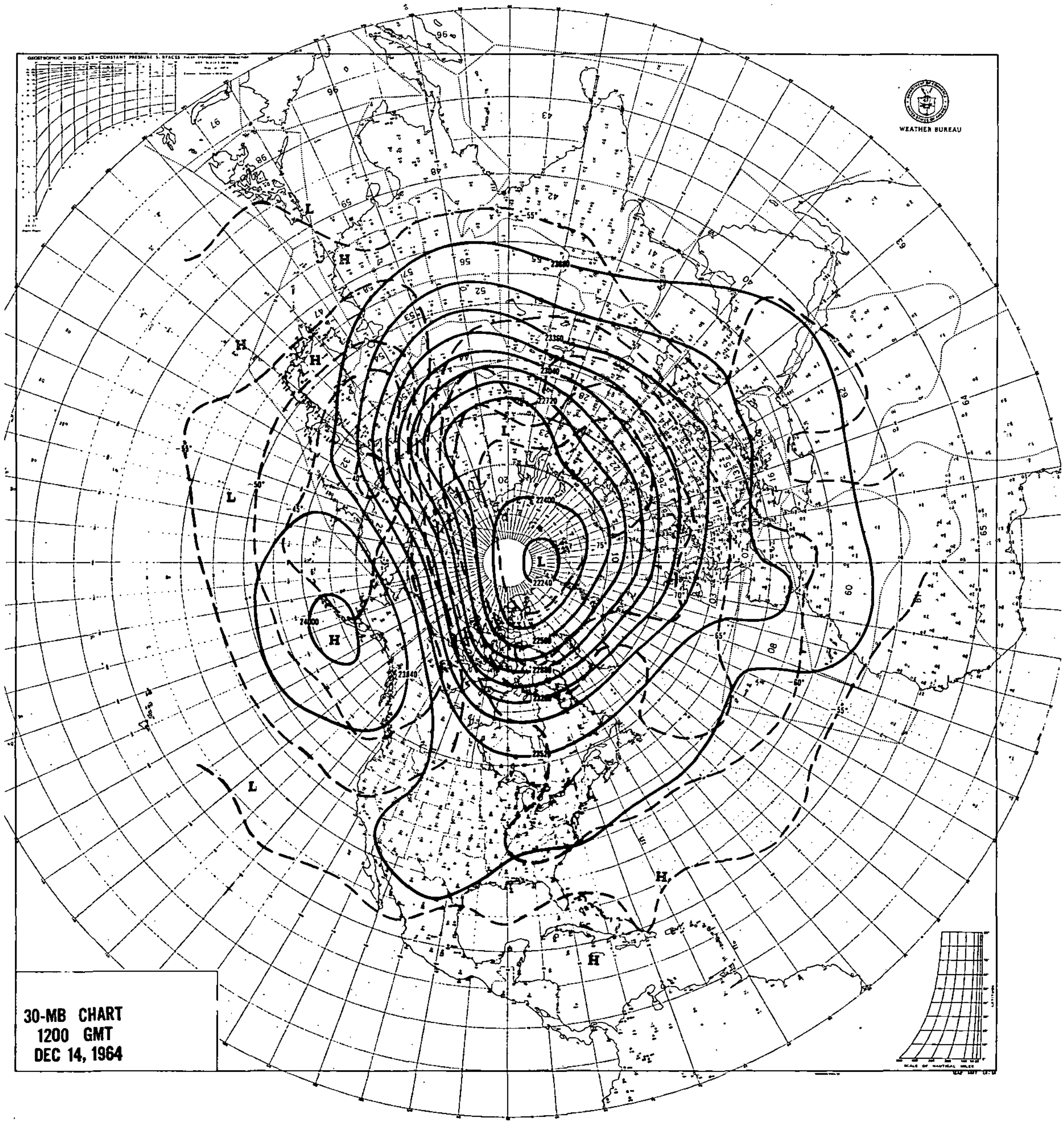

Figure 11. Same as Figure 10 for 14 December, 1964.

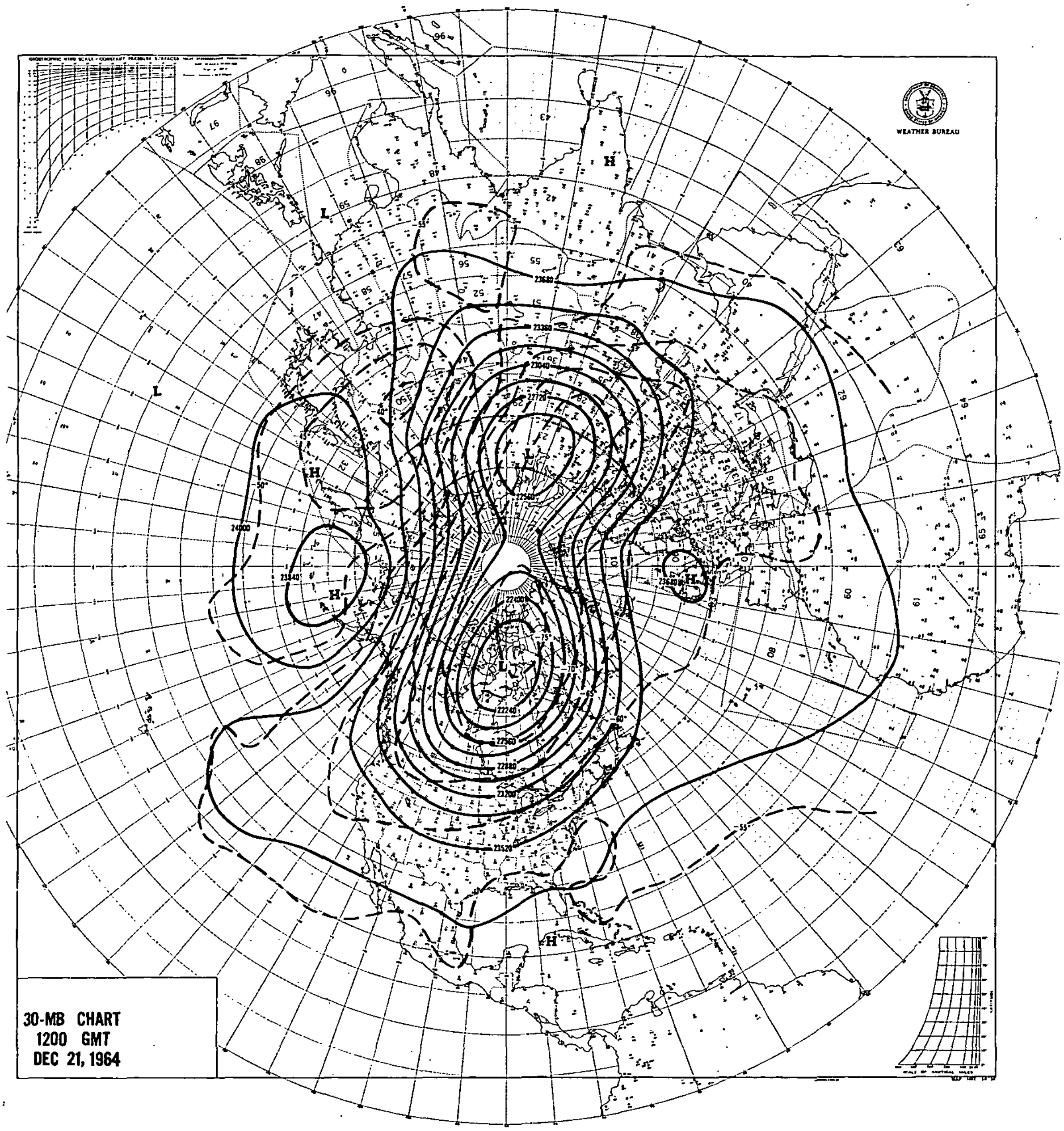

Figure 12. Same as Figure 10 for 21 December, 1964.

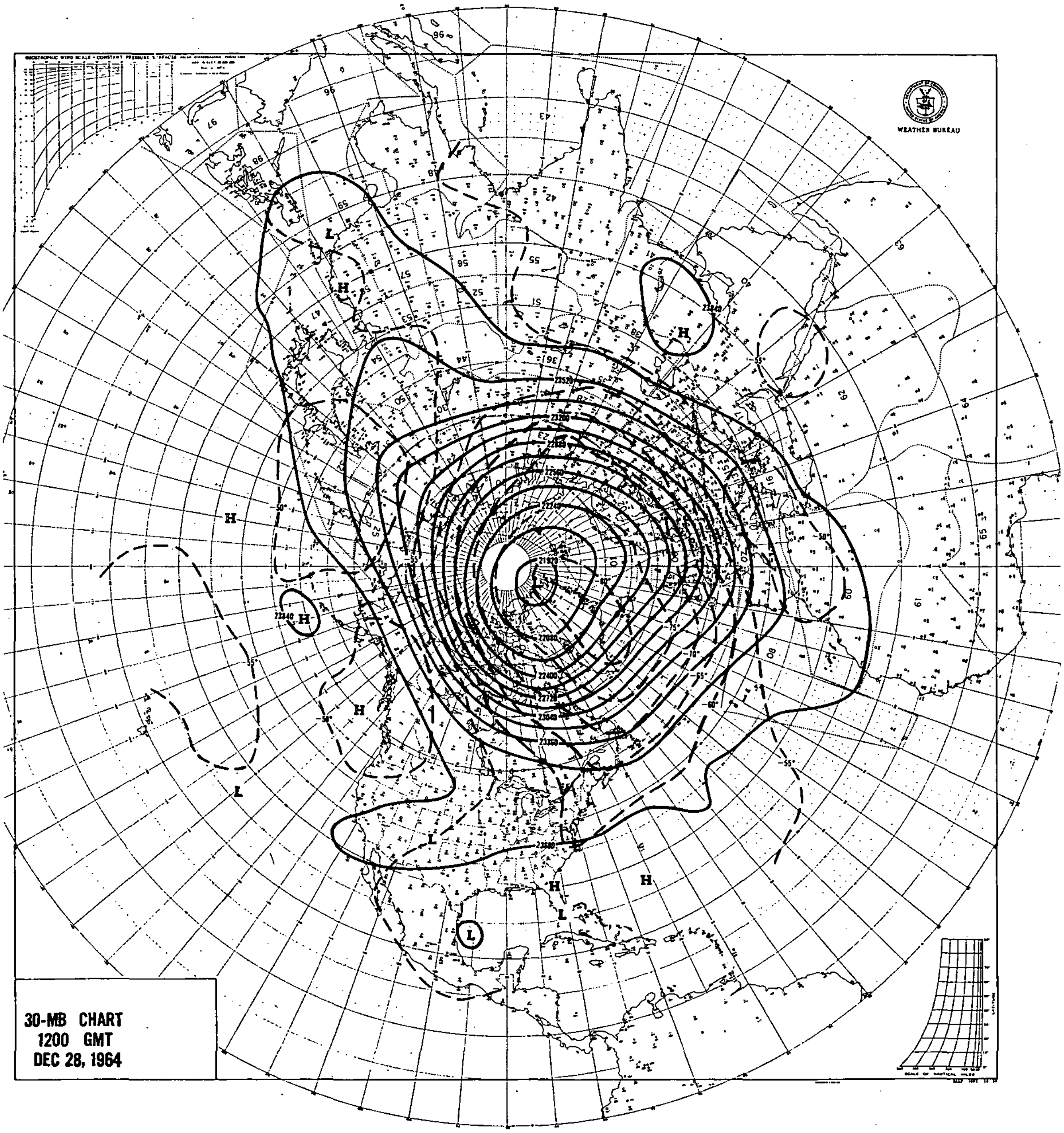

Figure 13. Same as Figure 10 for 28 December, 1964.

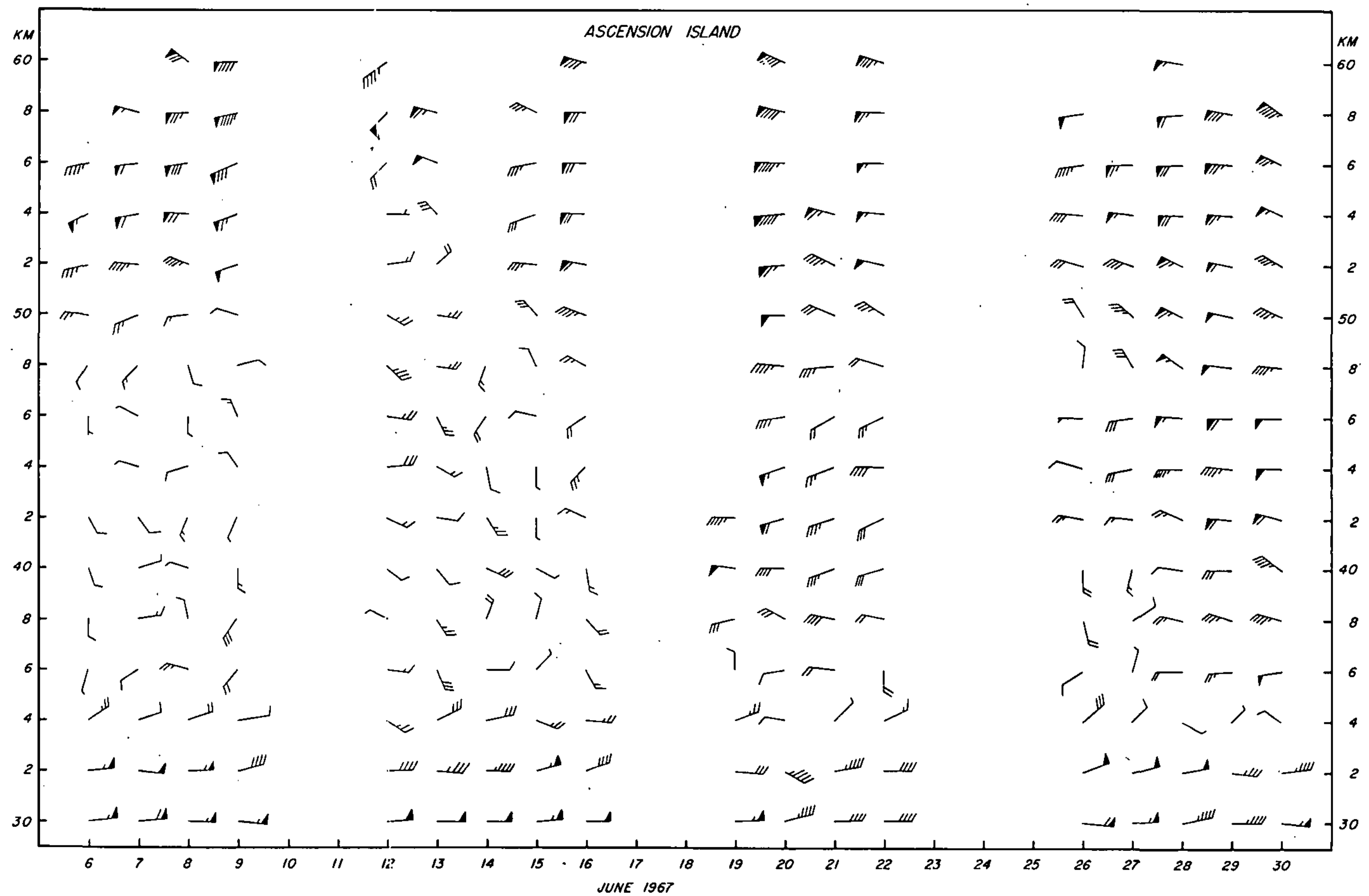

Figure 14. Time section of observed rocketsonde winds (knots) for Ascension Island; June 1967. A full barb represents 10 knots, a pennant, 50 knots.

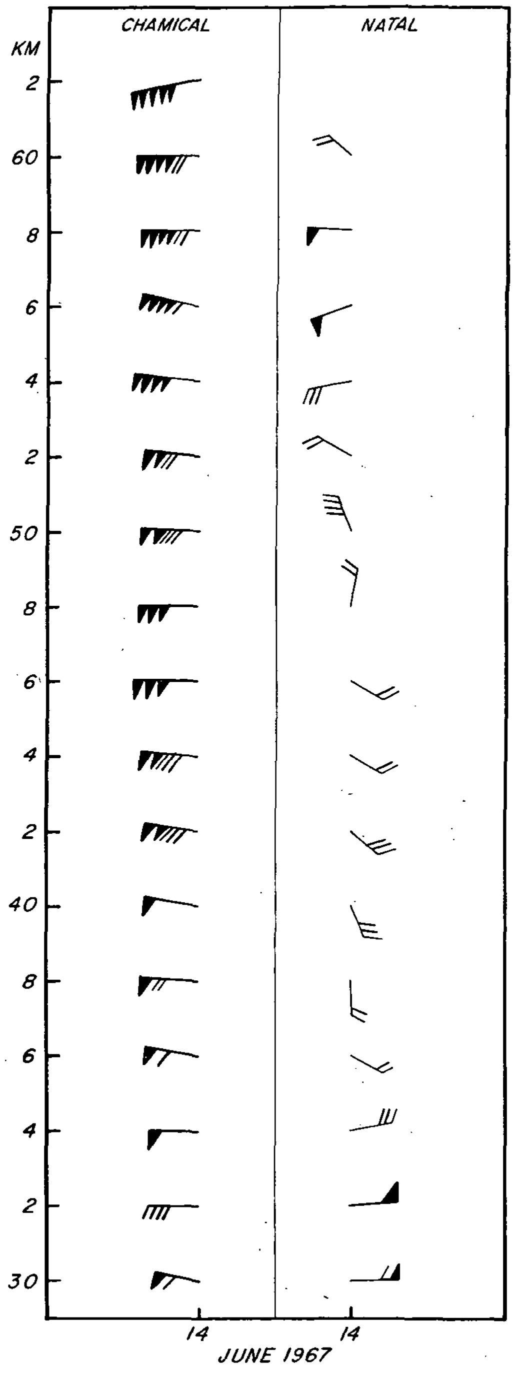

Figure 15. Observed rocketsonde winds (knots) for Chamical, Argentina and Natal, Brazil; 14 June, 1967. A full barb represents 10 knots; a pennant, 50 knots.

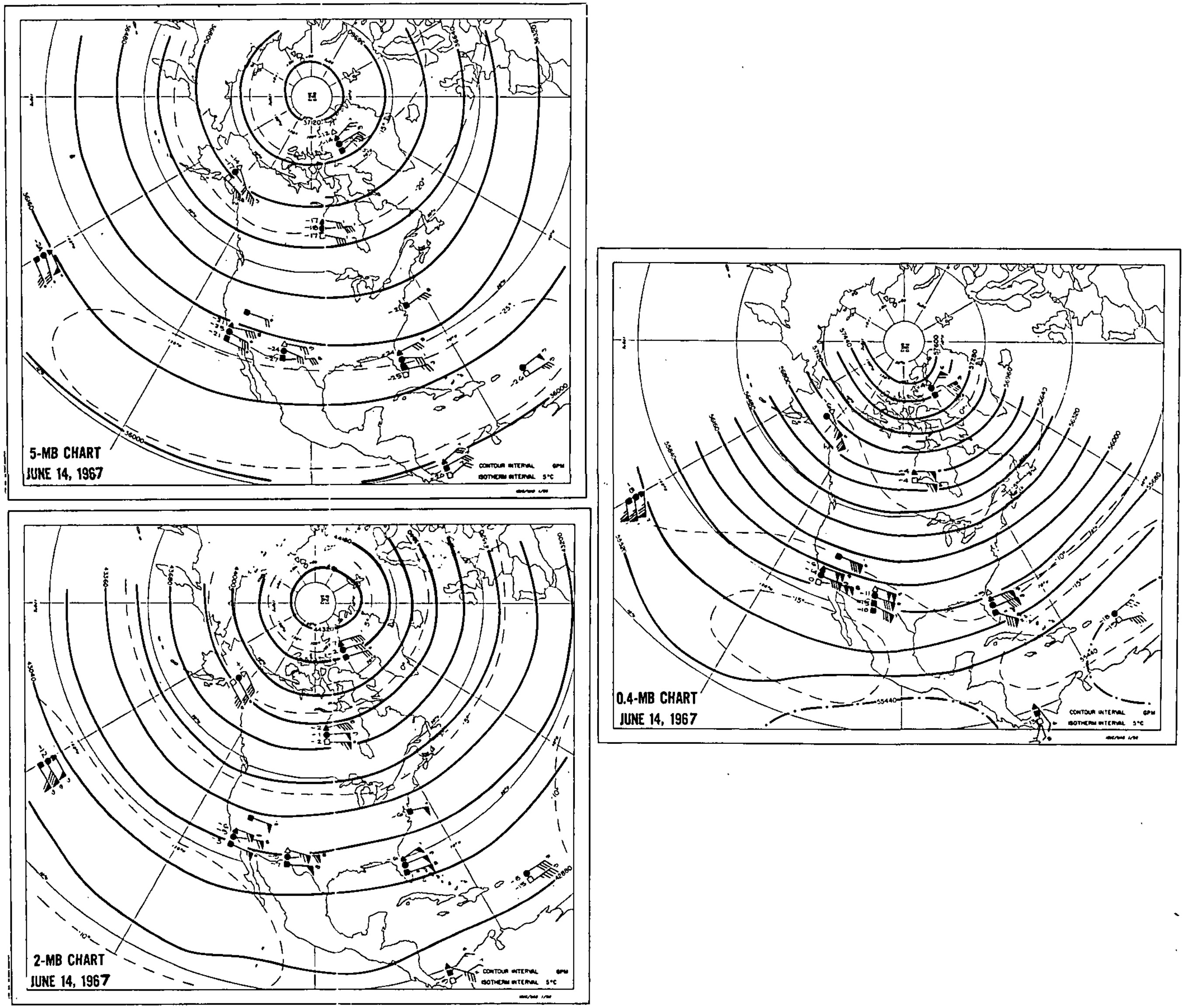

Figure 16. Northern Hemisphere 5-, 2- and 0.4-mb analyses for 14 June, 1967. Heights in geopotential meters, temperatures in degrees Celsius. Wind vector units: knots. Contour intervals: 160 gpm, 5°C.

If we focus our attention on the 14th of the month, the increasing westerlies with height at Chamical along with the transition of easterlies to westerlies with height at Natal and Ascension Island suggest that the polar low has expanded laterally with height. Figure 16 illustrates the Northern Hemisphere 5-, 2- and 0.4-mb analyses for 14 June constructed by the method of Finger et al. (ref. 4). While certain analysis problems exist during the summer period because of the diurnal oscillation (Staff, Upper Air Branch, ref. 10) both the wind and temperature data support the existence of low-latitude cellular structure at the higher levels. This, then, serves as the transition zone between the summertime easterlies of the Northern Hemisphere and the wintertime westerlies of the Southern Hemisphere. The varying height of the easterly to westerly wind transition zone demonstrated above, within this context, can be explained as the result of latitudinal shifts with time of these tropical cells.

Worth mentioning at this point are the Southern Hemisphere stratospheric analyses of Finger and Woolf (ref. 11) based on data from the NASA Mobile Launch Expedition aboard the USNS Croatan for early autumn 1965. Despite the fact that their data were limited longitudinally to 70°-90°W, they were able to ascertain that at that time low pressure dominated the polar region at all levels, while a pronounced subtropical ridge existed at 35 km and appeared to tilt equatorward with height. The ridge line was located north of 10°S at about 53 km. The Northern Hemisphere stratosphere, however, had not yet completed its changeover to summertime easterlies.

FINAL REMARKS

While there are insufficient data to extend formally the hemispheric analyses up to and across the equator at stratospheric levels above 25 km, it appears that the global circulation at these heights can be described in at least a qualitative manner.

During the month of June 1967, the stratosphere at the 30-mb level was dominated by the usual Northern Hemisphere polar anticyclone and a Southern Hemisphere polar cyclone. One identifiable coupling system for the two wind regimes was a subtropical ridge centered near 20°S. This latter feature, combined with the summertime easterly circulation, accounted for easterly winds on both sides of the equator at a time when the quasi-biennial wind oscillation was in an easterly phase.

The analyses point to a change in the tropical regimes with increasing height, at least identifiable over the tropical Americas. At about 50 km the westerlies of the Southern Hemisphere, which had expanded laterally with increasing height, appeared to extend to at least the equator and possibly into the Northern Hemisphere. The coupling mechanism here is a relative Northern Hemisphere trough which separates the Northern Hemisphere easterlies from the Southern Hemisphere westerlies.

This description of the global circulation between 23 and 55 km for June, 1967 is, of necessity, sketchy at present. We look forward, however, to the time when sufficient data will become available at all levels so that we may distinguish the details and physical mechanisms of this circulation and enhance our knowledge of the atmosphere in toto.

ACKNOWLEDGMENTS

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