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30-MB SYNOPTIC ANALYSES FOR THE 1969 SOUTHERN HEMISPHERE WINTER DERIVED WITH THE AID OF NIMBUS III (SIRS) DATA

by A. J. Miller, F. G. Finger, and M. E. Gelman

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National Meteorological Center

Hillcrest Heights, Md.

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SUMMARY

Employing both Nimbus III (SIRS) retrieval data (heights and temperatures derived from the measured radiances) and conventional rawinsonde data, we have constructed 30-mb synoptic analyses for selected periods during the Southern Hemisphere winter of 1969. The analyses indicate several warming pulses penetrating southward to the higher middle latitudes throughout the winter season. These warmings could not be classified as strong by Northern Hemisphere standards and were not accompanied by major circulation changes. The 30-mb maps, as well as time-section type diagrams of the radiance values,indicate that during the warming period the entire synoptic pattern rotated eastward around the polar axis at a rate of about 15° longitude per day. Analyses for the final spring warming period of late October through mid-November show that the warm air center which was initially near Australia slowly progressed toward the pole, with the reversal of the temperature gradient (warm air at the pole) completed by the end of the period. The reversal in the height field, lagged the temperature reversal by about three weeks so that the change to easterly circulation at 30 mb did not occur until early December.

Attention is also drawn to the effects of the equatorial quasi-biennial oscillation on the wintertime height field.

CONTENTS

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INTRODUCTION

Unlike the Northern Hemisphere where the number of daily stratospheric reports has allowed detailed analyses of circulation patterns for some time, the data coverage in the Southern Hemisphere has been far less satisfactory. This is especially pertinent in the case of the mid-winter and spring-time stratospheric warmings when comparisons between the two hemispheres would be extremely interesting.

While stratospheric analyses for the Southern Hemisphere winter have been attempted (e.g. Phillpot, 1969; Godson, 1963) these efforts have been limited because of the general paucity of data. With the advent of the Global Horizontal Sounding Technique (GHOST) balloon project (Lally, 1967; Miller, 1969) and the launching of the first satellite radiometer systems for sounding the stratosphere (e.g. Warnecke, 1967; Shen et al., 1968; Julian, 1967), the possibilities for reliable analyses improved, but the situation was not yet completely satisfactory.

The launching of the Nimbus III Satellite Infra Red Spectrometer (SIRS) multi-channel radiometer satellite in April 1969, however, coupled with the height and temperature retrieval scheme of Smith and Woolf (1970) has resulted in a great increase in upper air data to as high as 10 mb. Thus, an excellent opportunity, is now afforded for combining both SIRS retrieval data and conventional rawinsonde data in regular synoptic analyses.

The basic objective of this paper is to describe the circulation at the 30-mb level during the Southern Hemisphere winter of 1969. For this, charts for selected dates during the period from June through November 15 are presented. It is felt that the increased confidence in the analyses due to the vastly increased amount of data caused by the SIRS retrievals allows meaningful comparison with circulation patterns of the Northern Hemisphere.

DATA AND ANALYSIS TECHNIQUE

Since the Nimbus III (SIRS) data played such an important role in the analyses used here, a brief description of the system should be given. The experiment measures the outgoing earth radiance in 7 select channels of the 15 carbon dioxide band and one channel of the water vapor window. The actual radiance received by the satellite in any particular channel is a function of the temperature structure of the atmosphere and the vertical weighting function of that channel. Depicted in Figure 1 are the weighting functions of the 8 SIRS channels (e.g. Wark and Fleming, 1966). Note that the weighting functions of channels 7 and 8 have their maximum values in the stratosphere; hence, the radiances received in these channels are essentially a function of the temperature structure of the stratosphere.

The so-called retrieval method developed by Smith and Woolf (1970) involves the regression of the heights and temperatures at specific pressure levels as measured by conventional rawinsondes against the radiances measured in the various channels. Thus, given a sufficient data base, heights and temperatures can be retrieved from the measured radiances. As can be seen from Figure 1, the weighting function of channel 7 peaks in the lower stratosphere while that for channel 8 is very much broader with height. We would expect, then, that the measured radiances in channel 7 would effectively be a function of the temperature of the lower stratosphere while those in channel 8 would be a function of the gross temperature structure of the entire stratosphere. After careful consideration of the derived regression data, we found that 30 mb was the highest standard pressure level for which consistently reliable Southern Hemisphere retrievals could be obtained with the present basic data sample. Hence this study was restricted to analysis at that pressure surface.

As a general indication of the amount of satellite and rawinsonde data available for this study, Figure 2 presents a chart of the stations from which rawinsonde data were received during this period and a typical set of satellite tracks during the course of a given day. Data are derived for points located every few degrees of latitude along each track. It should be emphasized, that since the satellite precesses at a rate of about 5.4° longitude per day, and the tracks are about 27° longitude apart, the above pattern is repeated every five days.

Zonal averages of the channel 8 radiance values at 40°S and 60°S were computed (Fig. 3) in order to provide an index of the temperature field in the middle and upper stratosphere during the period of analysis (June 14 to November 30). The average radiances for 40°S indicate a general increase with time, on

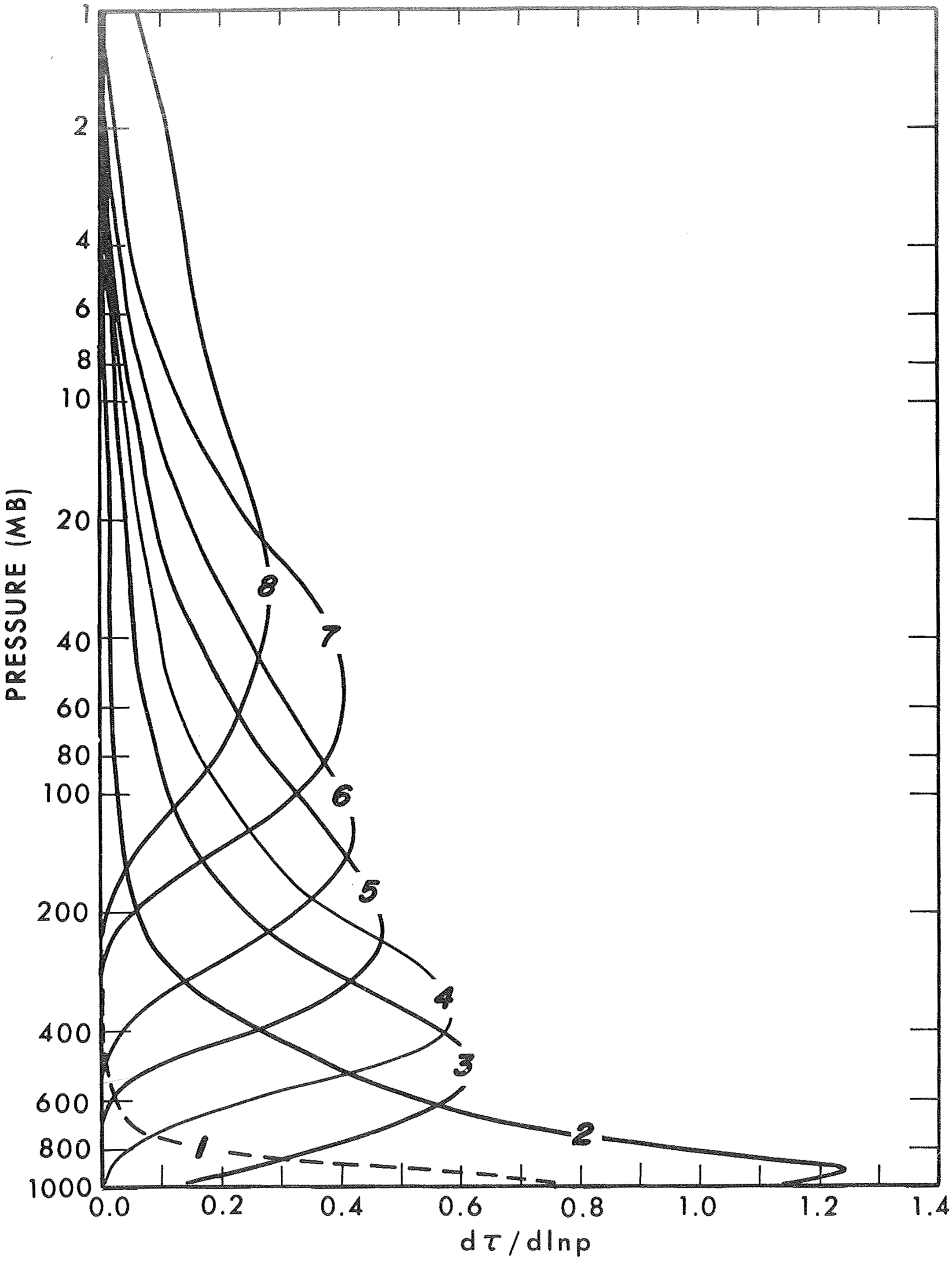

Figure 1. Weighting function ($d\tau/d \ln p$) as a function of height for the NIMBUS III (SIRS) channels: 1 (899-cm^{-1}), 2 (750-cm^{-1}), 3 (714-cm^{-1}), 4 (706-cm^{-1}), 5 (699-cm^{-1}), 6 (692-cm^{-1}), 7 (677-cm^{-1}), 8 (699-cm^{-1}).

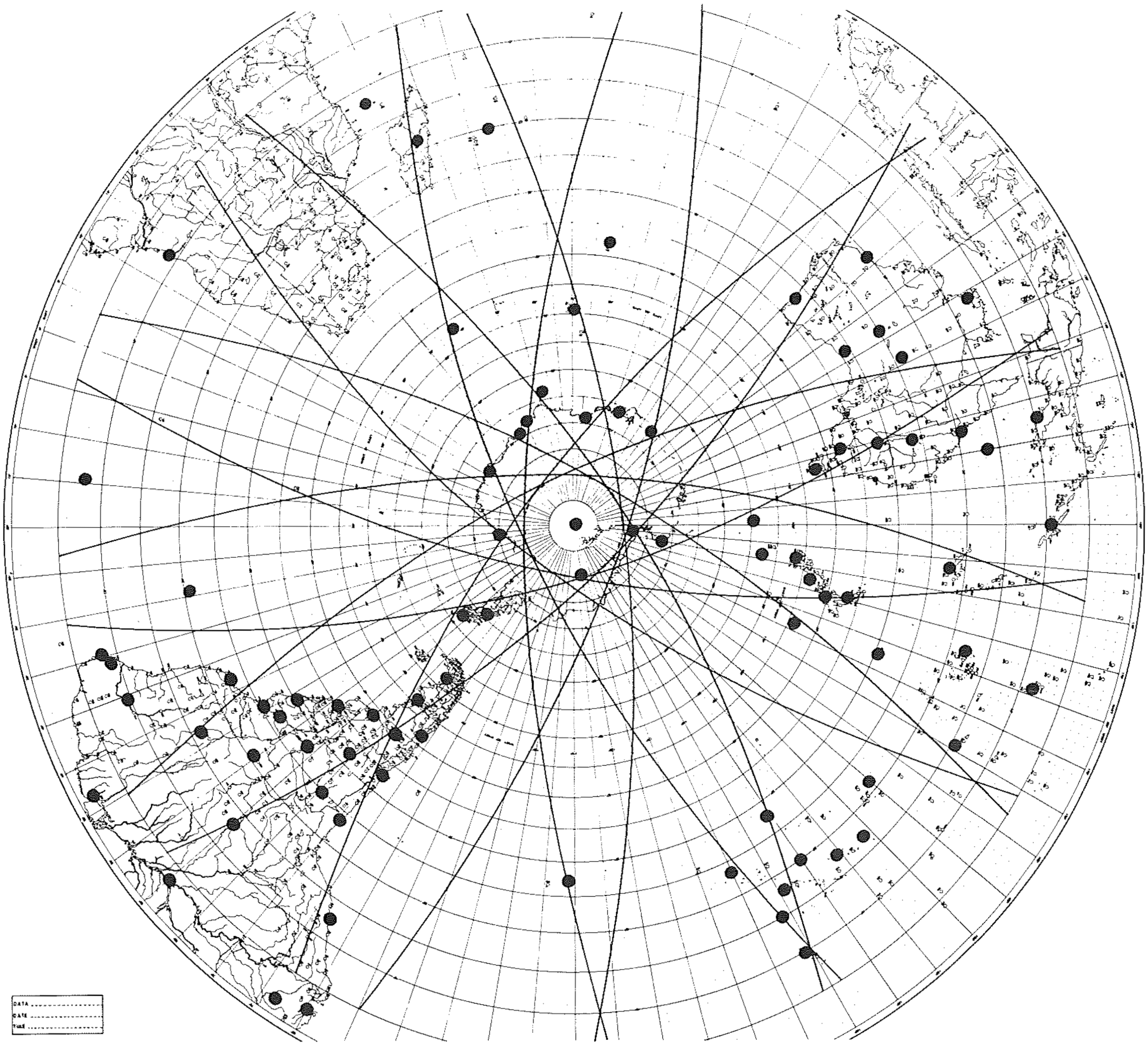

Figure 2. Chart of typical Nimbus III paths during a 24 hour period (solid lines) and rawinsonde stations from which data were received (filled circles).

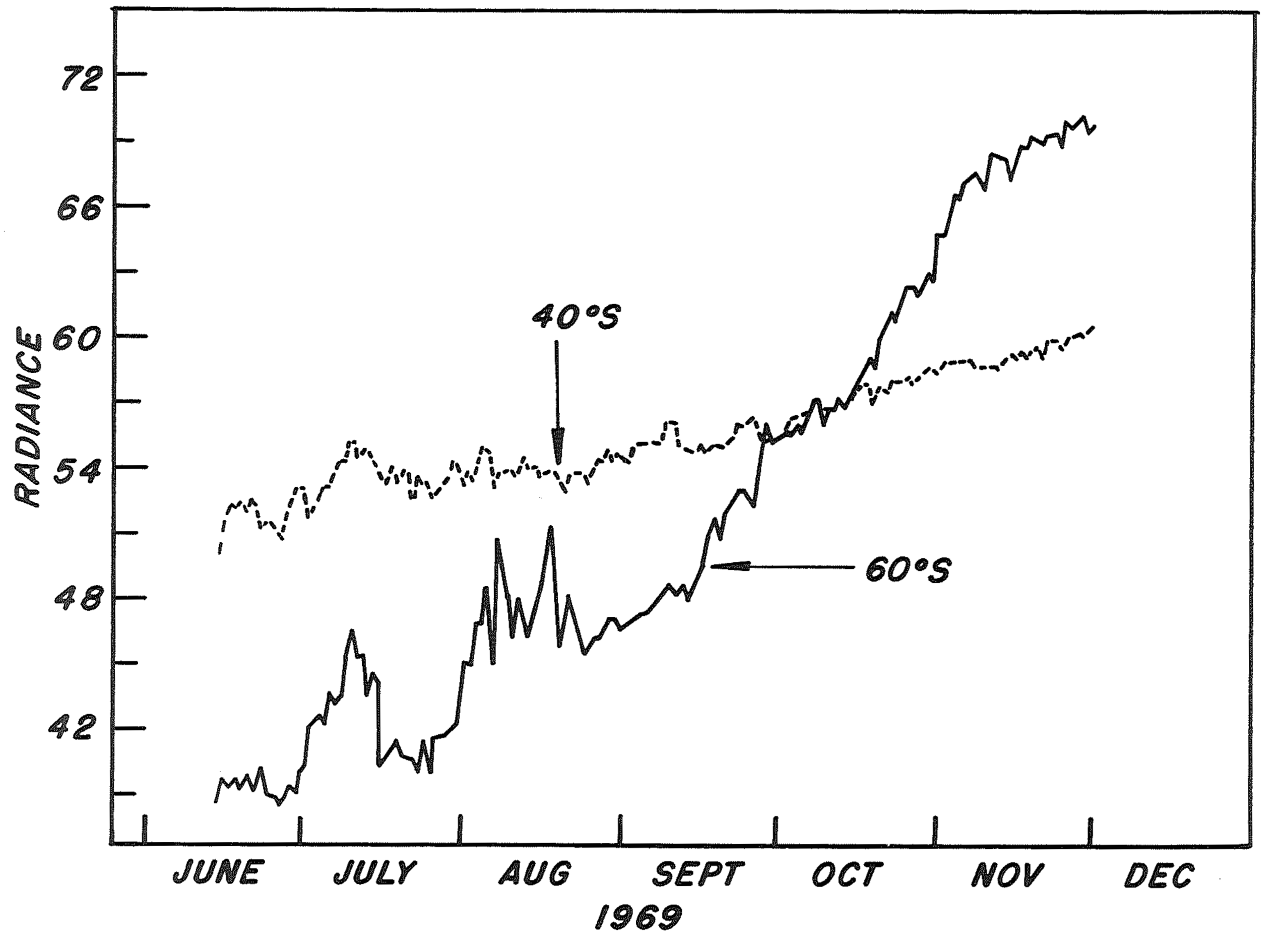

Figure 3. Zonal mean radiance values at 40°S (dashed curve) and 60°S (solid curve) for period 14 June-30 November, 1969. Units: erg-cm^{-2}-sec^{-1}-sterad^{-1}(cm^{-1})$^{-1}$.

which are superimposed several small perturbations. On the other hand, the curve for 60°S shows several major peaks, centered on July 10, August 7 and August 17. Thus, there appear to be three periods of relative warming at 60°S. It is interesting to note that the radiances in late August do not return to their original low level of July, but continue to increase until the final spring transition.

The analyses presented in this paper were selected to represent various types of circulation patterns analyzed during the course of the 1969 winter season. These patterns were associated with a non-warming situation (June 18), the first major peak shown in the zonal analyzed radiances (July 9), the second warming period (August 7-27) and, finally, the spring transition (October 29-November 19).

All analyses were based on Nimbus data obtained for the entire day and rawinsonde data obtained several days before and after the actual analysis date. In all cases, the analyses were first constructed using only the satellite data, and then modified to conform to any available rawinsonde data. Any revisions were then rechecked against the original satellite data. This system resulted in what we considered to be the best possible analysis and also enabled us to arrive at the qualitative estimate of the compatibility between the two data systems. In general, the agreement in temperature at 30-mb was within 2°C. The satellite-derived height data enabled a definition of the gross features in high latitudes quite well, and were extremely useful in areas where radiosonde data are extremely sparse. However, at lower latitudes where very weak gradients predominated, some difficulty was experienced in utilizing both types of data together. As an example, 30-mb retrieval heights in the mid-latitude high pressure areas, appeared to be lower by up to three hundred meters, than those reported by the radiosondes. The reasons for these discrepancies are not clear at this time and an investigation is in progress that will hopefully resolve the problem. Thus the rawinsonde data, especially the wind reports, though sparse, were indispensible for the definition of the circulation features at low latitudes.

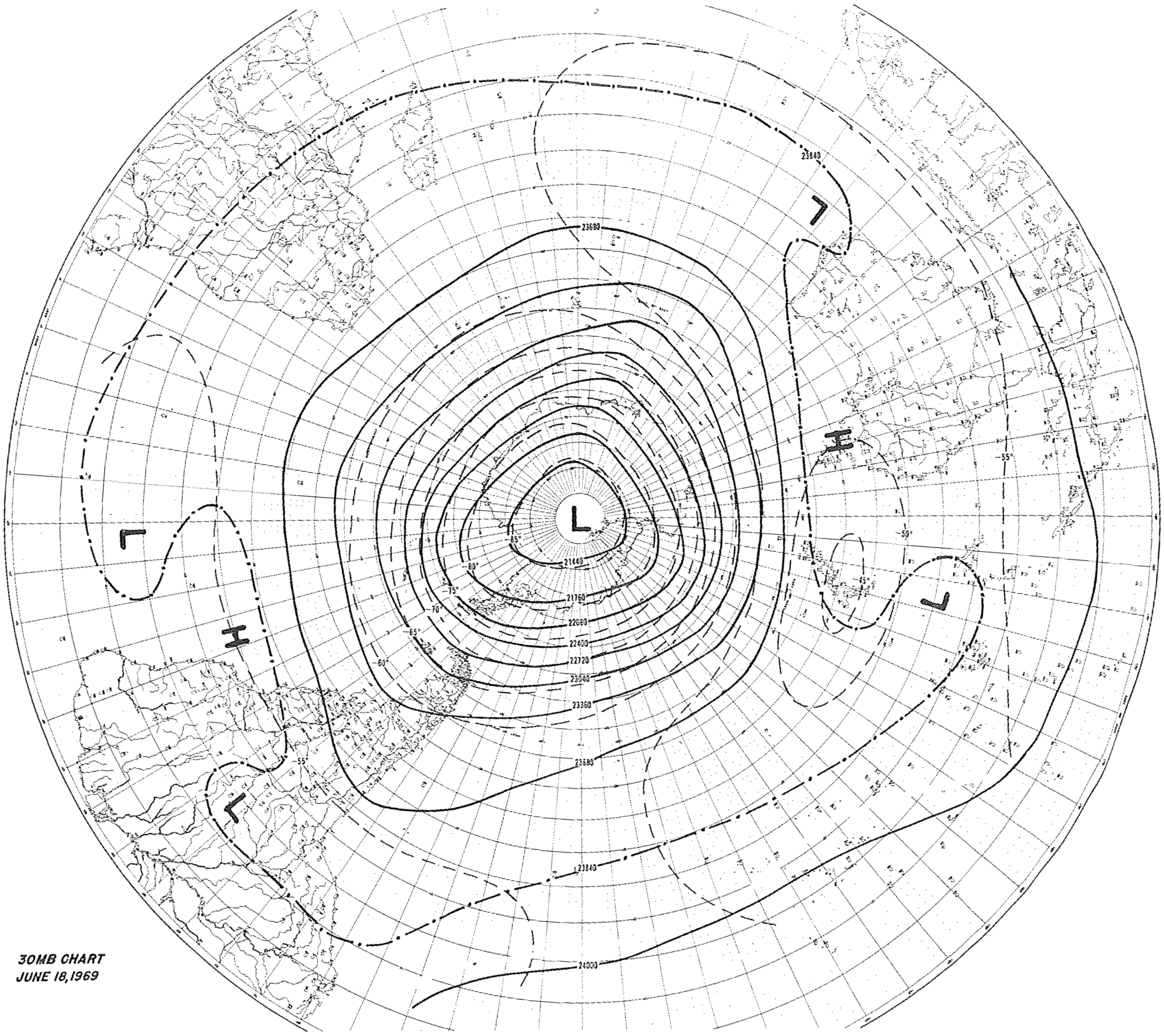

Figure 4. 30-mb analysis for 18 June, 1969. Units: geopotential meters and degrees Celsius.

RESULTS

The early winter chart (Fig. 4), as expected, is dominated by the polar cyclone and the associated westerly winds extend northward to the middle latitudes. A comparison of this pattern to that of June 1967 (Miller and Finger, 1969) reveals the expected similarity with respect to the polar cyclones. A considerable difference between the two years, however, was noted at lower latitudes. In 1967 all available radiosonde data clearly indicated easterly winds equatorward from a seemingly continuous ridge line located near 20°S.

The low latitude circulation as depicted by the June 1969 chart (Fig. 4), however, appears more complex, especially in light of the tropical trough line located equatorward of the subtropical ridges. Unfortunately, the problems encountered with the generally weak pressure gradients in the tropics coupled with the general sparseness of regular rawinsonde reports did not allow the resolution needed for the proper delineation of such systems. Even so, the many reported westerly winds, extending to the equator and around the Hemisphere leave no doubt that a ridge-trough effect as shown by the chart did indeed exist.

The low latitude differences between June 1967 and June 1969 may be explained in terms of the phases of the so-called quasi-biennial oscillation (QBO). For example, in June 1967 the general trend of the oscillation was toward increasing tropical easterlies, while in June 1969 westerlies were predominant. Schematic diagrams of these two situations are seen in figures 5a and 5b. These show a simplified picture of what was observed during June 1967 and June 1969 respectively. While the synoptic systems are represented by only the zonal wind component, it is understood that in actuality these idealized systems may have been a series of low or high pressure systems in a roughly zonal pattern around the hemisphere.

In June 1967 during the easterly phase of the QBO (Fig. 5a) easterly winds at 30 mb were seen over the entire Northern Hemisphere and extending to the tropics of the Southern Hemisphere. The easterlies on both sides of the equator required (if some sort of geostrophic balance is assumed) a relative trough located in the equatorial region. During the westerly phase of the QBO, as occurred in June 1969 (Fig. 5b) the light westerly winds in the tropics of both hemispheres required a relative ridge on the equator. A trough in the subtropics of the Northern Hemisphere served as a transition area to the dominant summer easterlies and a ridge in the Southern Hemisphere subtropics led to the winter westerlies.

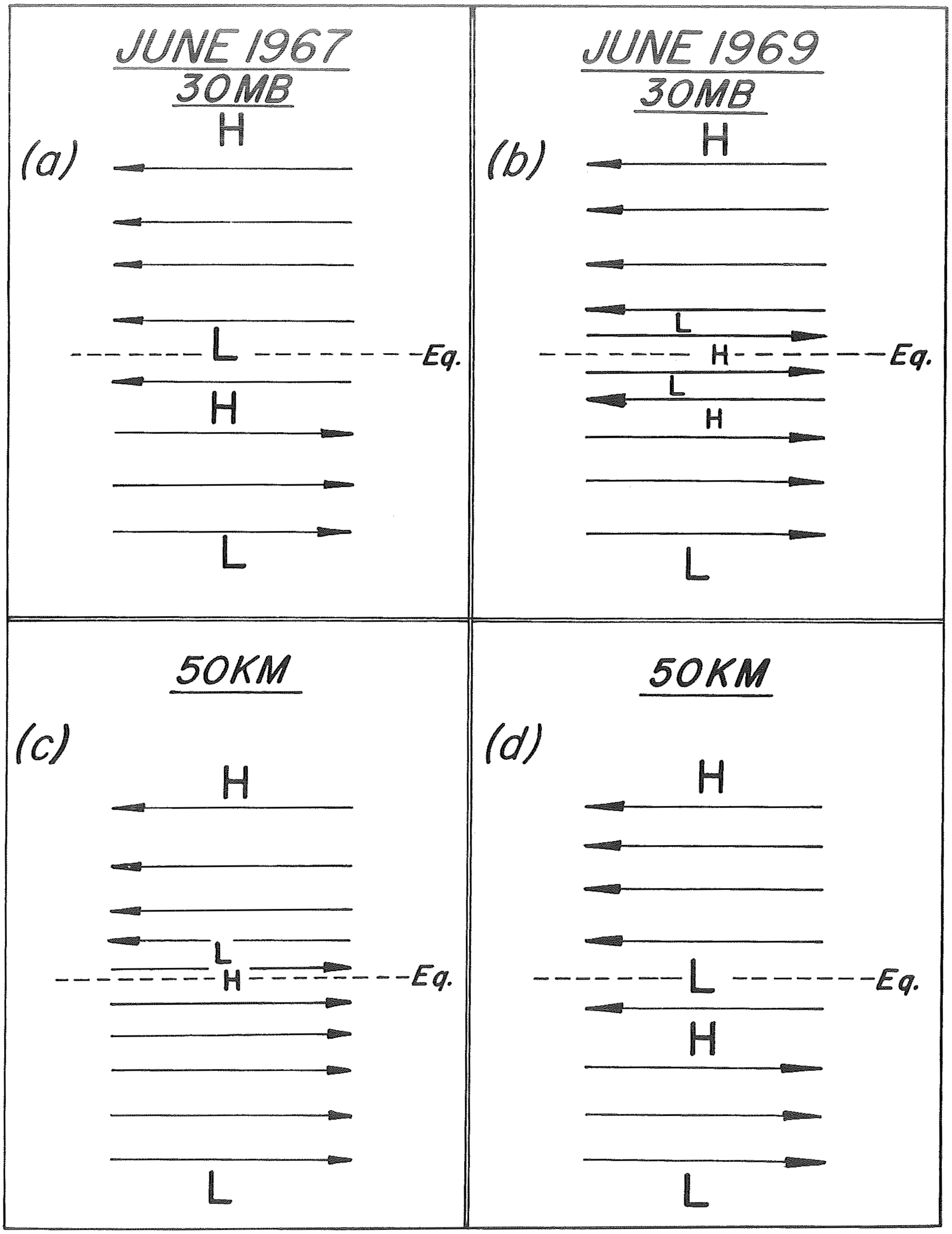

Figure 5. Schematic diagram of general synoptic pattern at 30 mb (a,b) and 50 km (c,d) for June 1967 (left side) and June 1969 (right side). North Pole is at top and South Pole is at the bottom in all diagrams.

In order to evaluate the upward extent of the tropical wind regimes during June 1969, rocketsonde data from Ascension Island (8°S, 14°W) and Fort Sherman, Canal Zone (9°N, 80°W), were inspected (Figure 6). These reports indicated generally easterlies at Fort Sherman and that the westerlies at Ascension changed to easterlies above about 35 km. This is in general agreement with the dominance of the semi-annual cycle in the tropics at these higher altitudes (Reed, 1966; Quiroz and Miller, 1967). The rocketsonde winds at Mar Chiquita, Argentina (37°45'S, 57°25'W) for June 18 (shown in Figure 6), however, indicated an increase of westerly winds with height. As the Northern Hemisphere upper stratosphere was dominated by easterly winds during this period (Northern Hemisphere summer) the data suggested that the subtropical low pressure regions at 30 mb seen schematically in Fig. 5b in both hemispheres diminished with height. The Southern Hemisphere mid-latitude ridge Fig. 5d then, served in the middle and upper stratosphere as the transition zone between the polar westerlies and tropical easterlies. Fig. 5c shows the situation at 50 km as observed in June 1967 when very strong westerly winds were dominant in the tropics (Miller and Finger, 1969)

The first major peak in the channel 8 radiance index at 60°S appeared in early July (Fig. 3), although the actual increase in values is seen to have begun in late June. The July 9 analysis (Fig. 7) showed maximum temperatures of about -50°C centered at 40°-50°S. Examination of other maps analyzed during this period, however, revealed that the temperature changes at 30 mb could hardly be classified in the warming category, at least when considering the much more pronounced changes that take place in the Northern Hemisphere. Nevertheless, some changes did take place; the most obvious being a poleward extension of normally warm air usually located in lower-middle latitudes. The largest changes occurred at about 80°E, or between South Africa and Australia.

The rather abrupt changes in the zonal radiance index during August were dominated by the two peaks, one on the 7th and the other on the 17th. These double peaks suggest two distinct pulses of the warm air very similar to what has been observed in the Northern Hemisphere (e.g. Quiroz, 1969). We will concentrate on the second warming period by presenting analyses for August 13, 17, 20, and 27 in Figures 8-11 respectively.

On August 13th the warmest air with central temperatures higher than -50°C was located between Southern Africa and Antarctica. By the 17th two warm centers were apparent; one between South America and South Africa, the second to the southwest of Australia. Both areas it should be noted, are void of rawinsonde coverage and thus the satellite data are the sole source of information on the existence of these warm regions. The rather rapid changes in the thermal pattern, and the intensification of the associated anticyclones resulted in an elongation of the polar vortex. Figure 10, (August 20) indicates a slow eastward movement of the anticyclones. In this particular

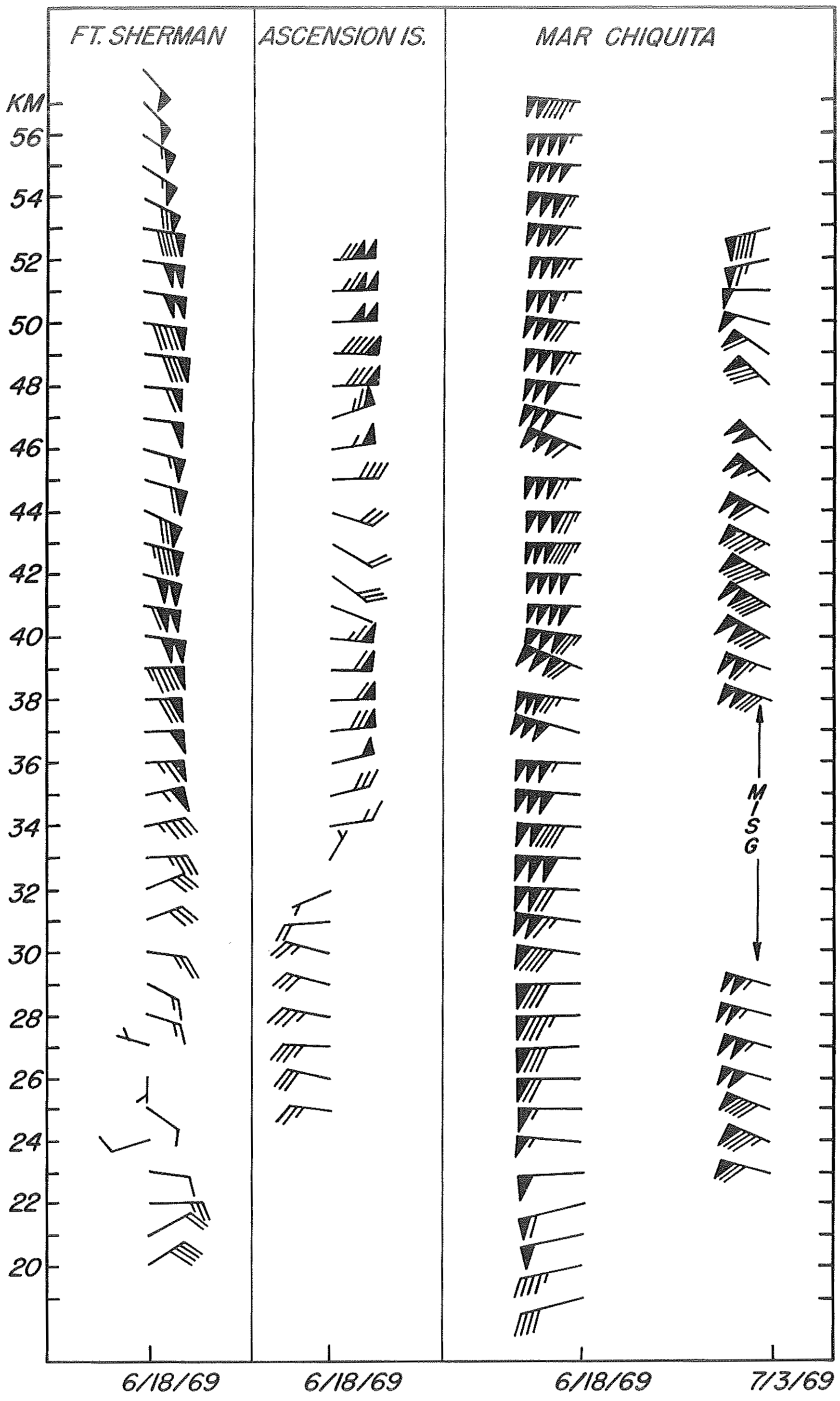

Figure 6. Meteorological rocketsonde winds from Fort Sherman, Canal Zone and Ascension Island for June 1969 and Mar Chiquita, Argentina for 18 June and 3 July, 1969. Units: knots.

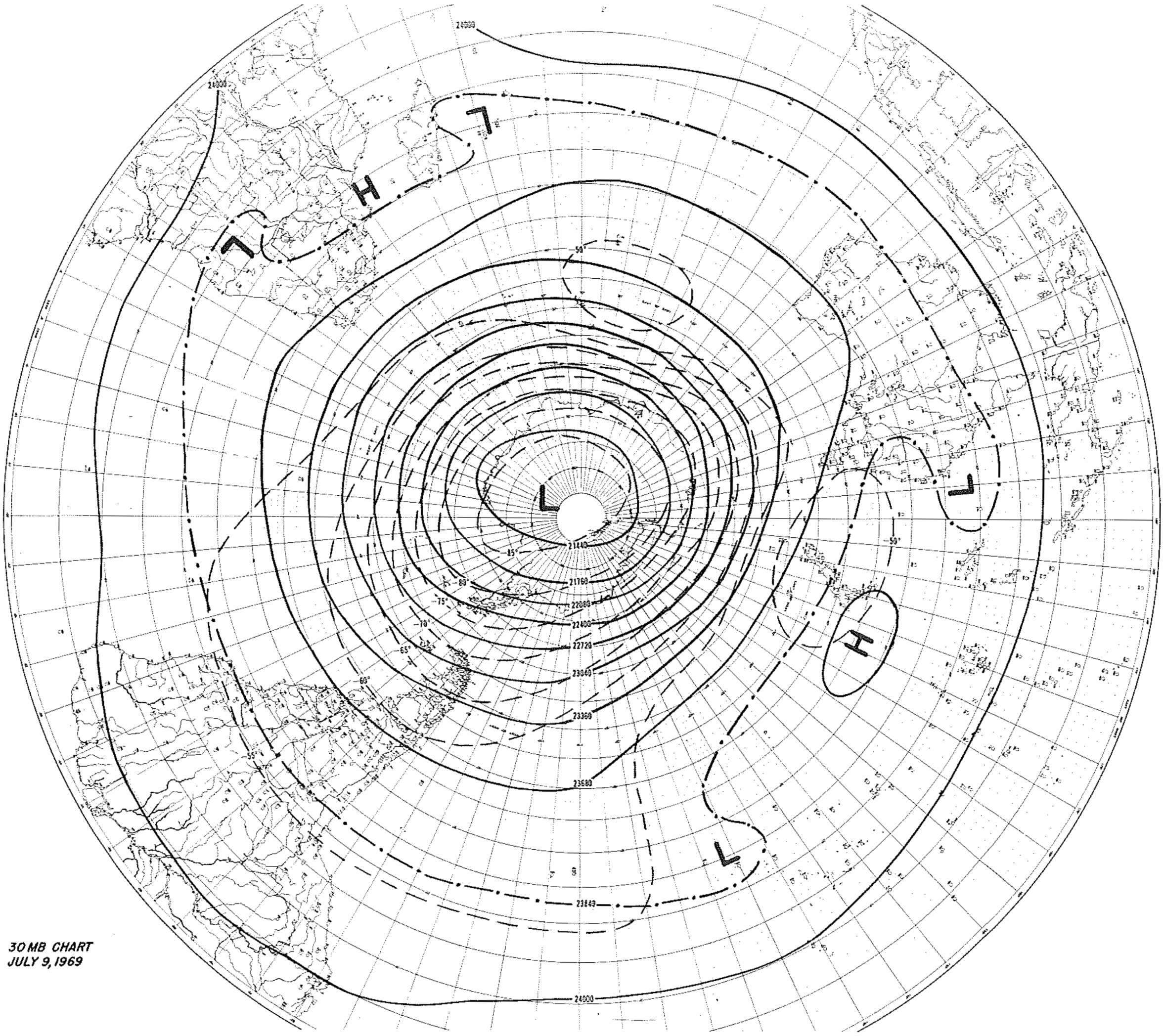

Figure 7. 30-mb analysis for 9 July, 1969. Units: geopotential meters and degrees Celsius.

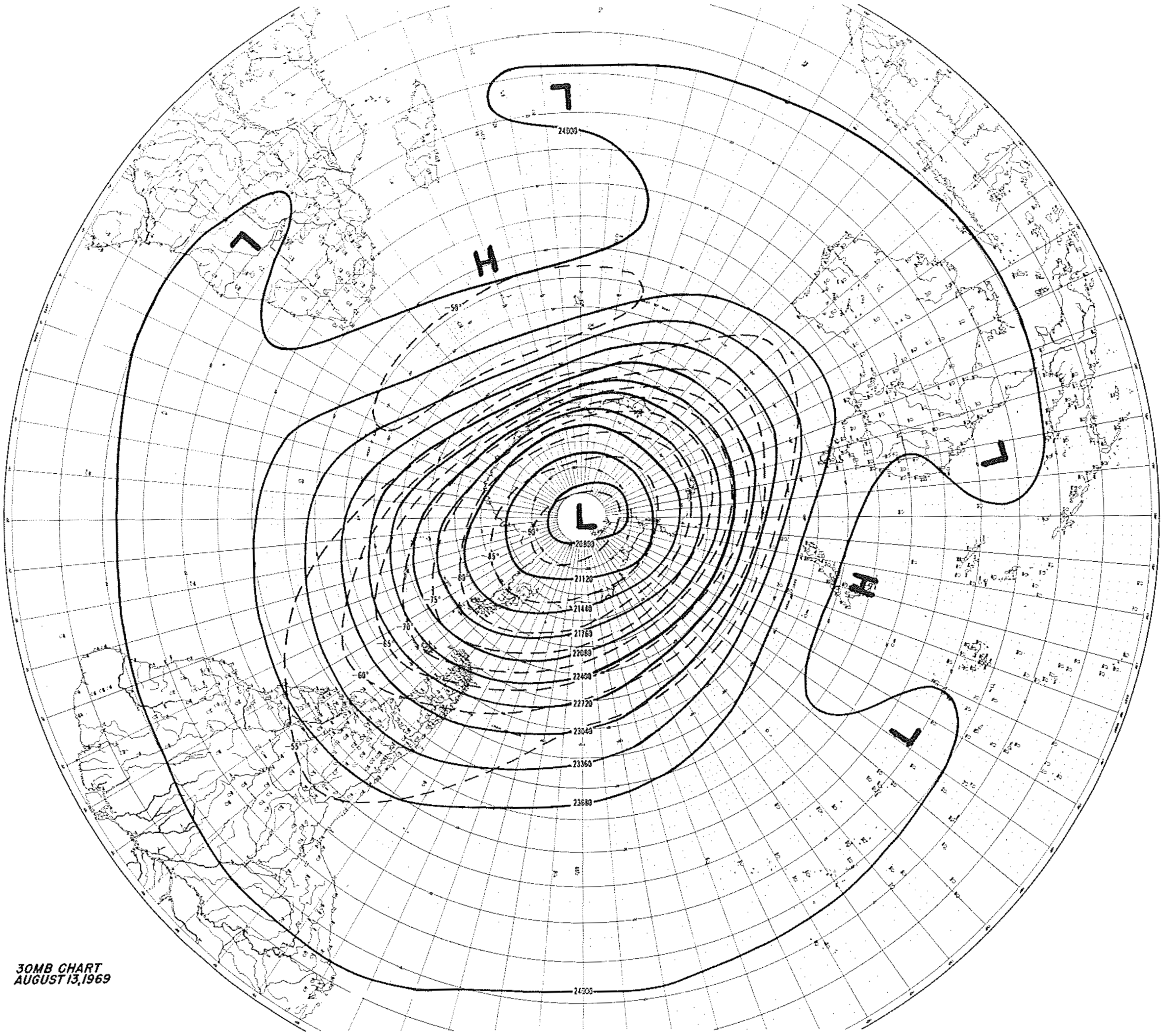

Figure 8. 30-mb analysis for 13 August, 1969. Units: geopotential meters and degrees Celsius.

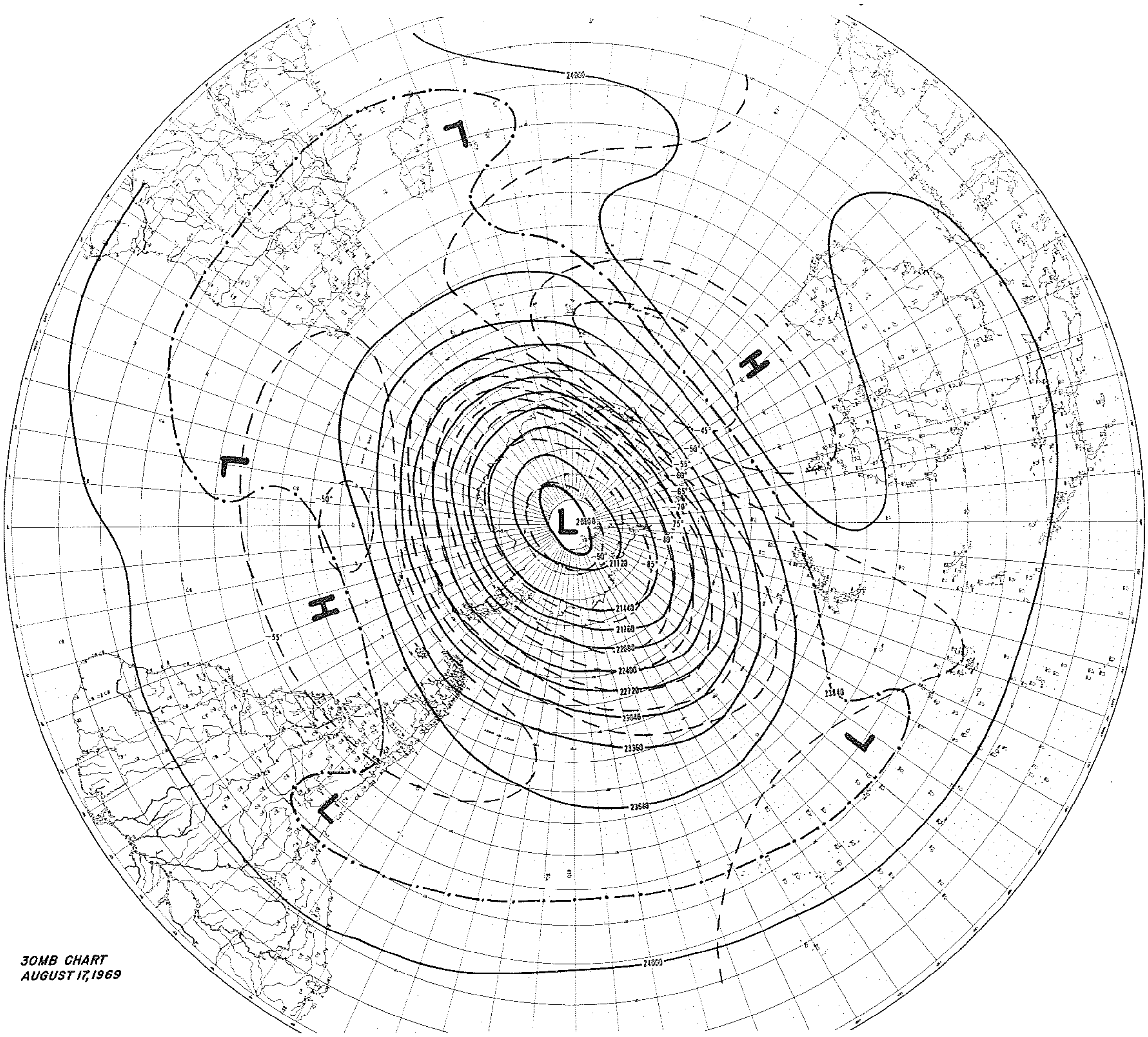

Figure 9. 30-mb analysis for 17 August, 1969. Units: geopotential meters and degrees Celsius.

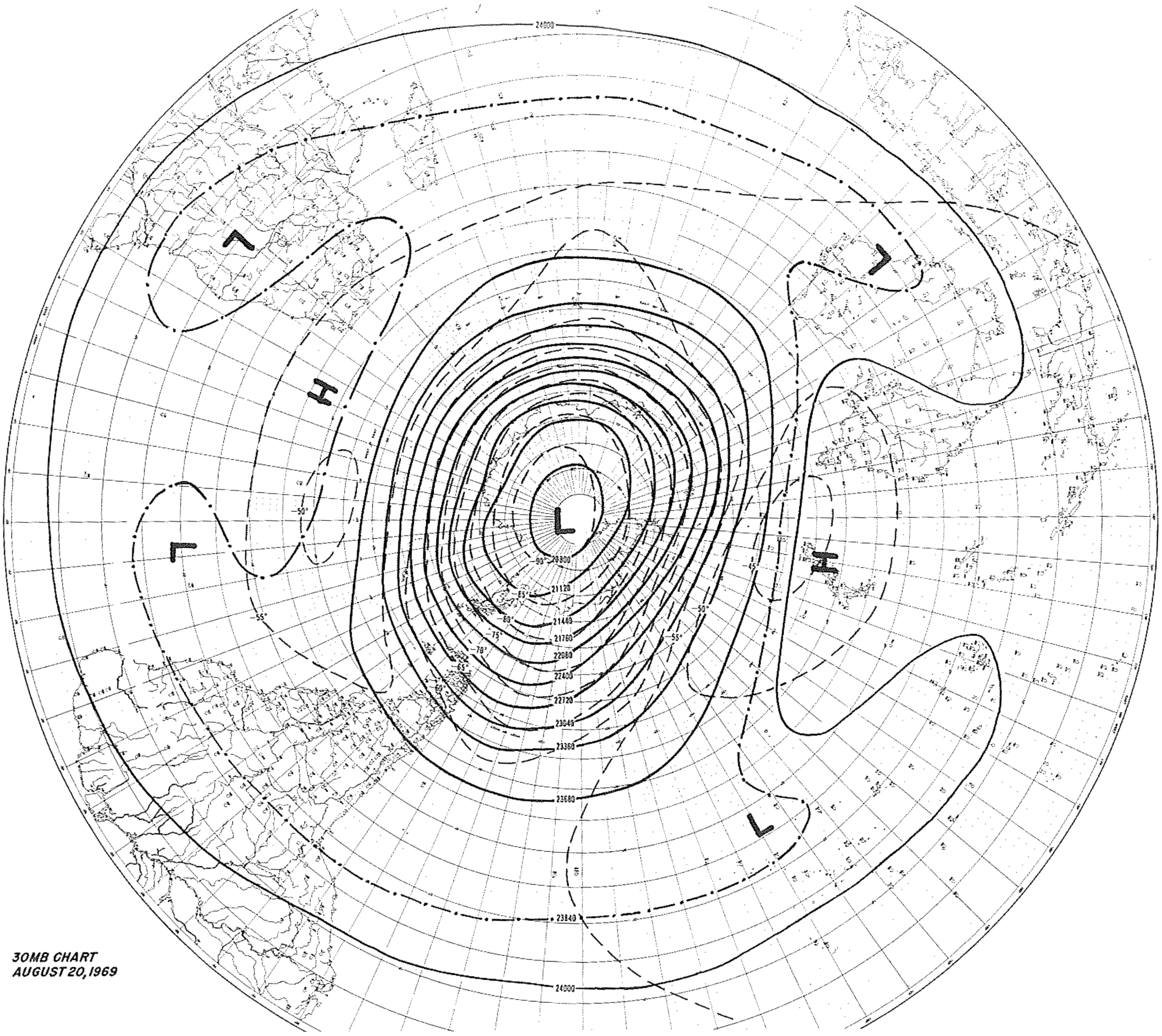

Figure 10. 30-mb analysis for 20 August, 1969. Units: geo-potential meters and degrees Celsius.

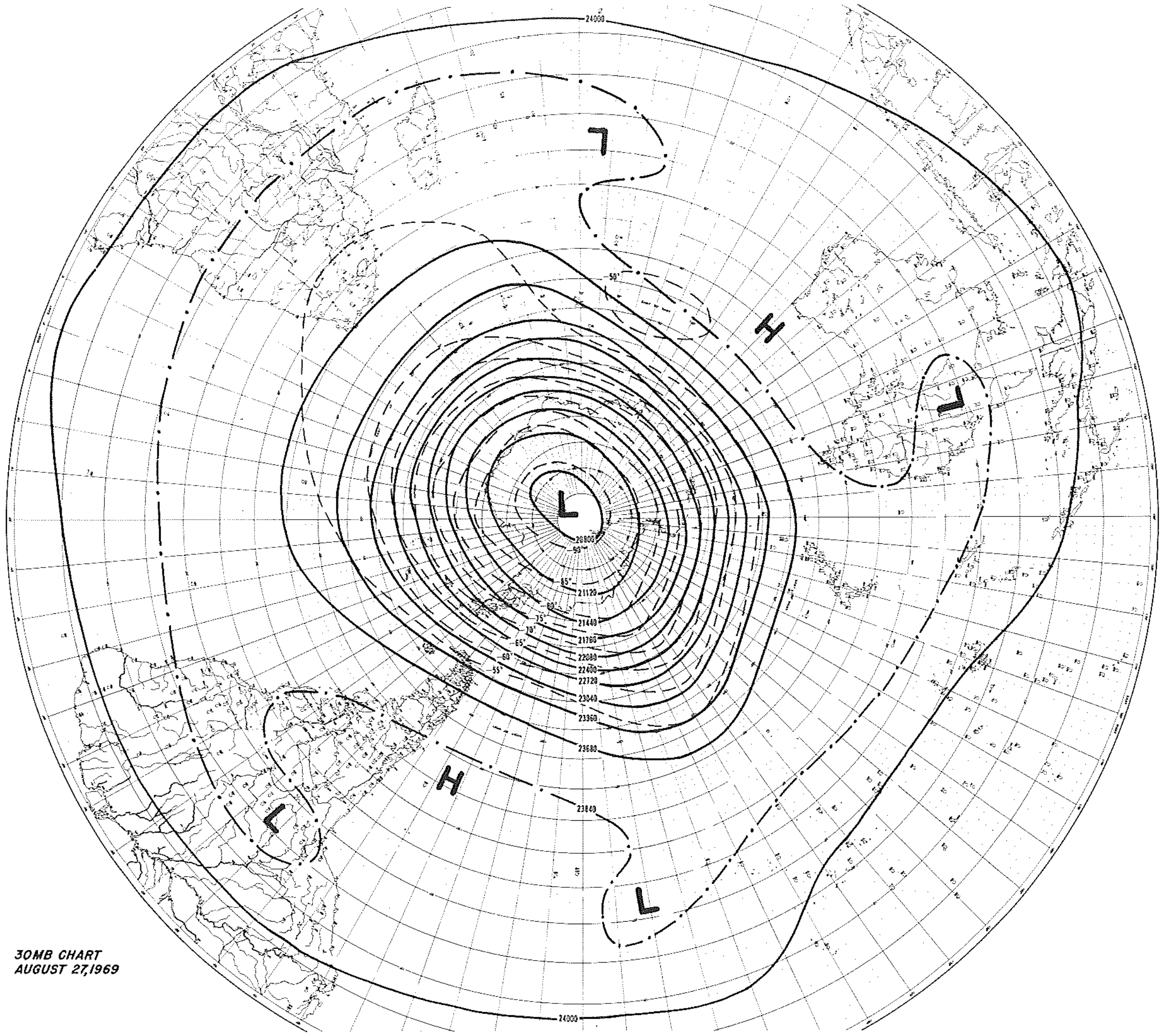

Figure 11. 30-mb analysis for 27 August, 1969. Units: geopotential meters and degrees Celsius.

case, data from New Zealand was available to aid in the delineation of the warm air center, but once again no rawinsonde data were available in the South Atlantic. By the 27th (Figure 11) the warming appeared to have run its course.

The seemingly continuous movement of the warm air centers and anticyclonic regions was a rather intriguing feature of these analyses. To investigate this further, longitude versus time cross-sections were drawn at 60°S for channels 7 and 8 for the entire period under study. The results are shown in Figure 12.

The general slope of the radiance pattern for channel 7 suggested that the temperature field was consistently moved from west to east with a speed of about 15 degrees longitude per day starting in early July and continuing until about late October. Fritz (1970) has referred to this eastward movement of radiance values and has shown that this feature occurred early in the 1969 winter period. It is worthy of note also that Phillpot (1969) in his discussion of the Spring transition of 1967 showed similar movement of 30 mb geopotential heights around the pole at 65°S. Channel 8 radiances do not show the steady slope as consistently as channel 7 although it is predominant during certain periods; the reason for this different behavior is not clear but it may be due to the relatively broad weighting function of channel 8 (Fig. 1).

The information from channels 7 and 8 suggests that during the course of the various warming episodes temperature changes at 30-mb and below could not account for all of the large radiative changes observed. This points to the possibility that changes in temperature and circulation at higher levels may have been much more pronounced.

In support of this hypothesis, the time section of observed stratospheric temperatures at Mirny, Antarctica (66°33'S,93°01'E) (Figure 13) indicates that the largest temperature changes took place above the 30-mb level. This, in turn, is in general agreement with observations in the Northern Hemisphere. Interestingly, although several pulses of warm air appear to exist at the highest levels, the winds remain generally from the west indicating that at least up to these levels the ridge has remained off the pole.

The final springtime warming and circulation change at 30 mb began in the last half of October 1969, with warm air generally moving poleward from the Indian Ocean-South Pacific area. Various stages are shown in Figs. 14-16. By the end of October the cold polar air mass had modified considerably (from about -90°C to -65°C) and had moved from that area toward South America. Relatively rapid intensification of the warm center took place in early November (Fig. 15) as the cold air continued to modify.

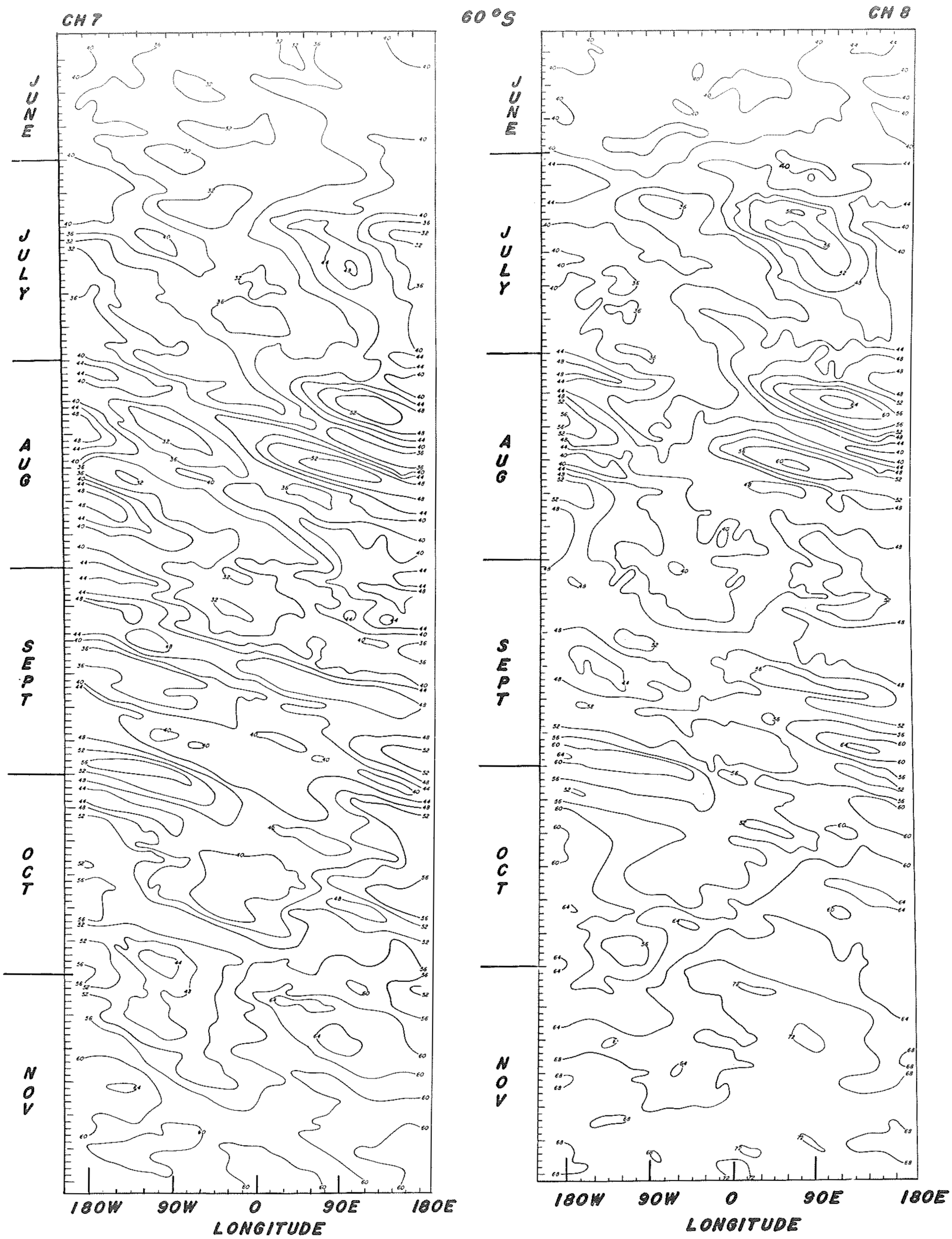

Figure 12. Longitude versus time cross-sections of channel 7 (left section) and channel 8 (right section) radiances at 60°S for the period 14 June - 30 November, 1969. Units: erg-cm^{-2}-sec^{-1}-sterad^{-1}-(cm^{-1})$^{-1}$.

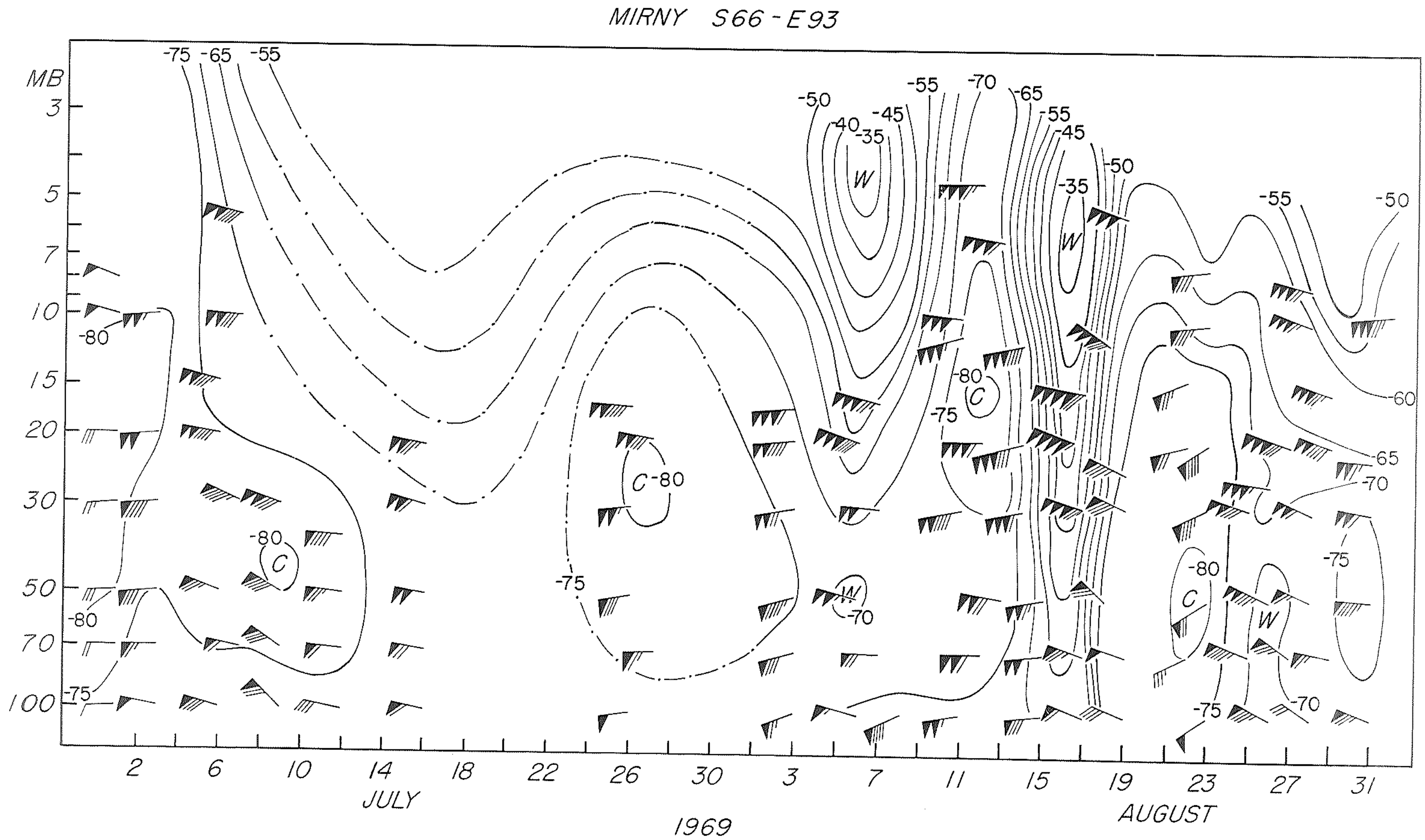

Figure 13. Time-height section of radiosonde observations taken at Mirny, Antarctica (66°33'S, 93°01'E). Temperature units: °C. The broken portion of the analysis(---) reflects a period where data were sparse and resulted in a decreased confidence level in the analysis. Wind units: knots.

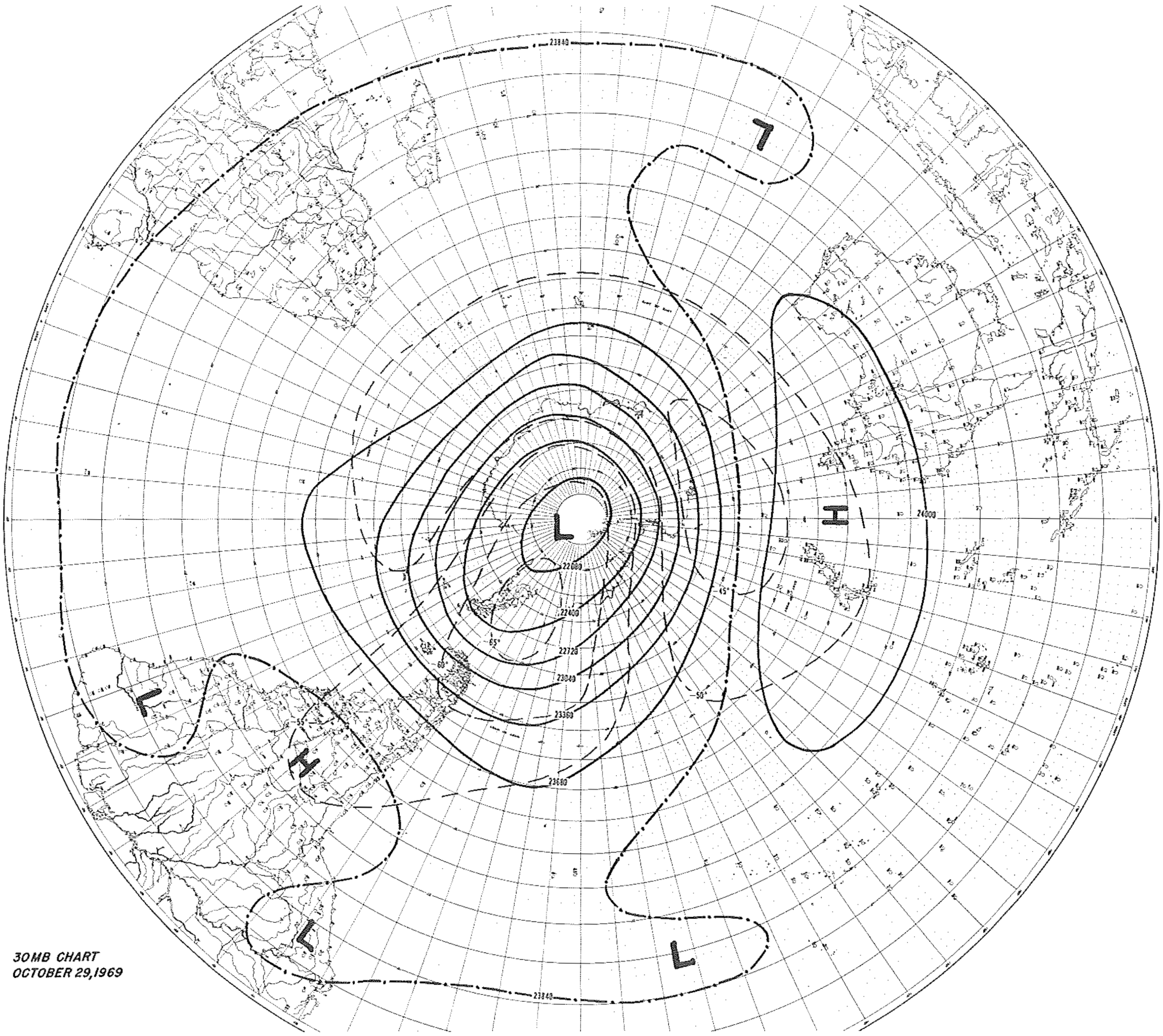

Figure 14. 30-mb analysis for 29 October, 1969. Units: geo-potential meters and degrees Celsius.

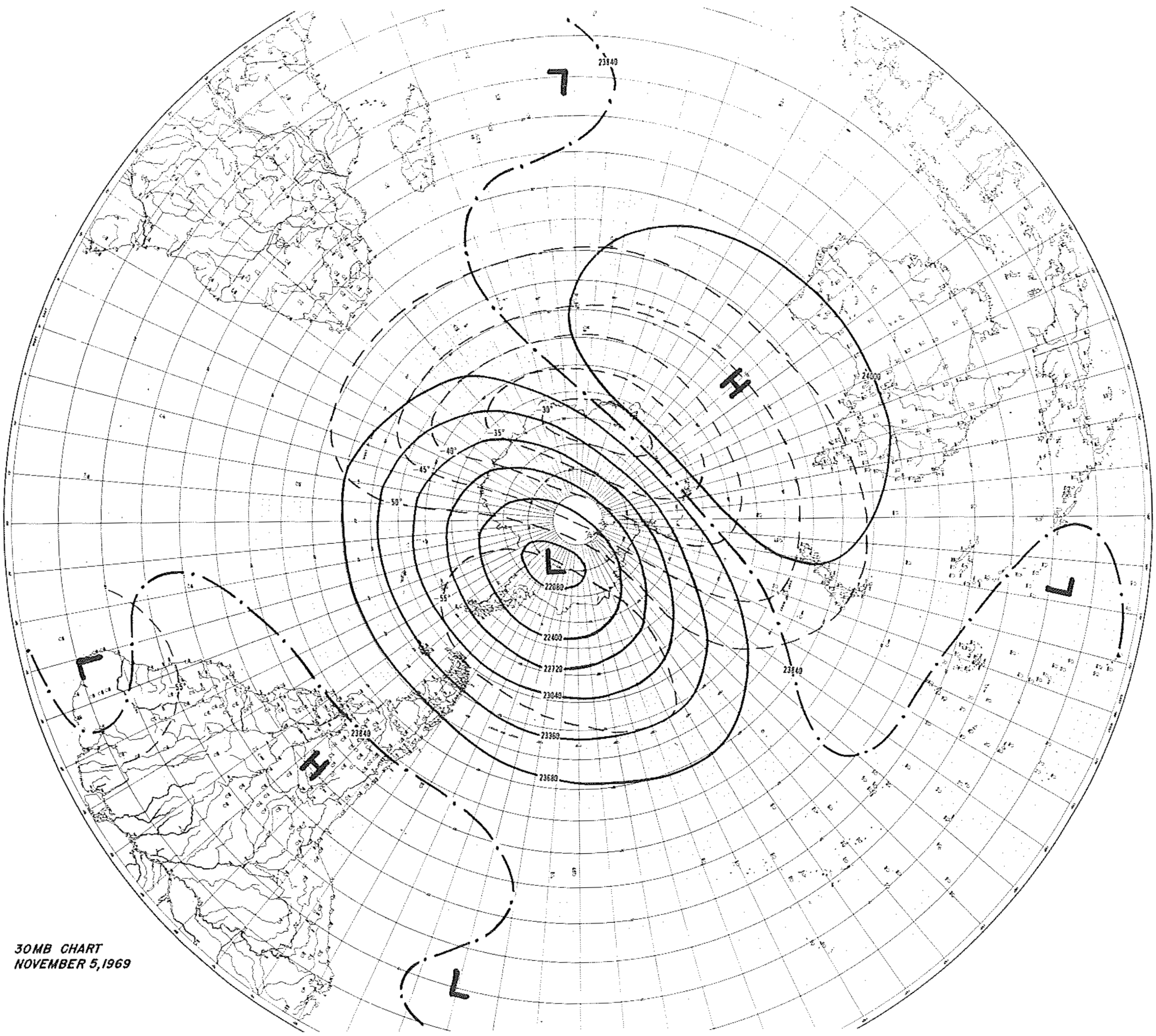

Figure 15. 30-mb analysis for 5 November, 1969. Units: geo-potential meters and degrees Celsius.

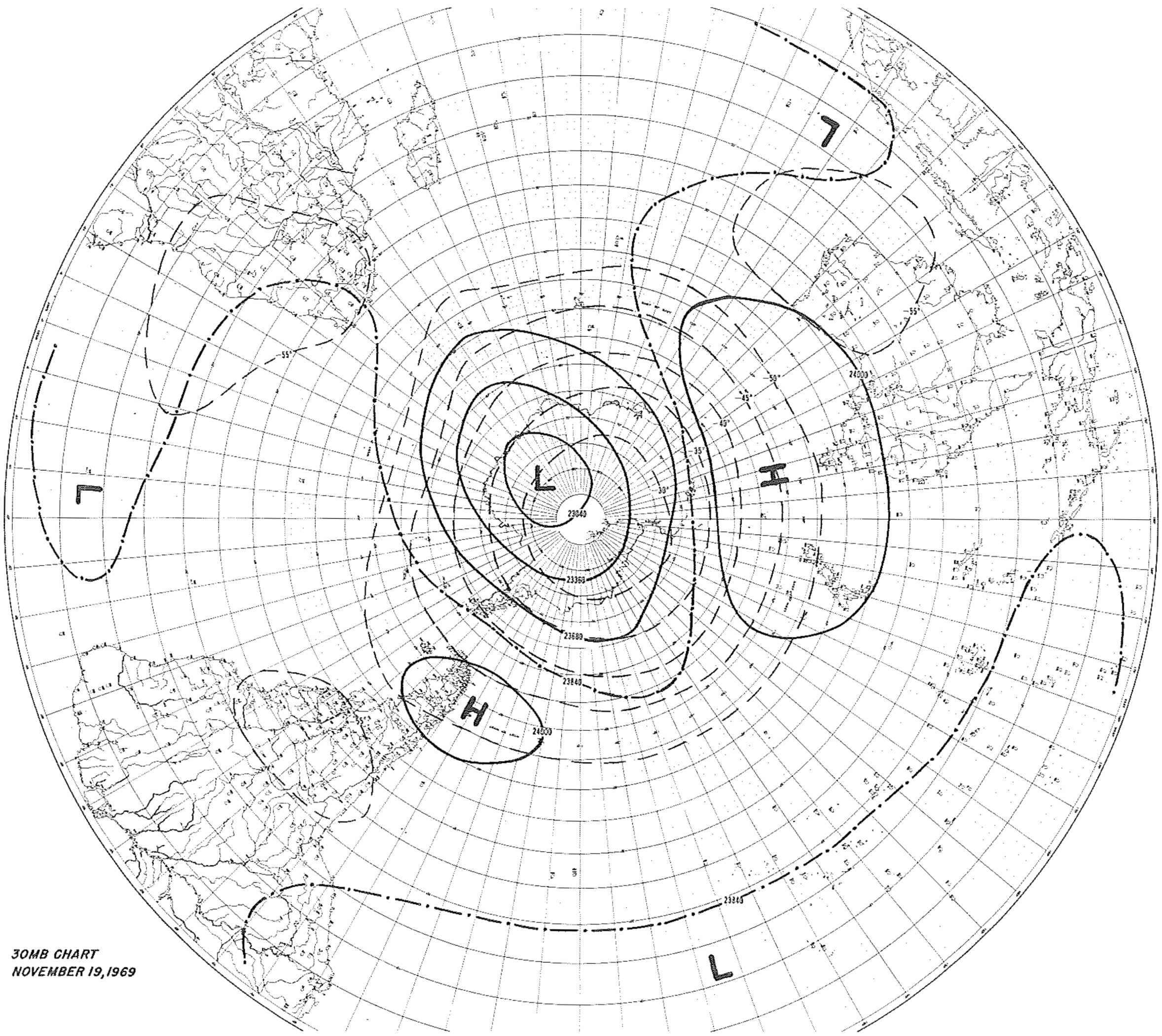

Figure 16. 30-mb analysis for 19 November, 1969. Units: geopotential meters and degrees Celsius.

Definitive changes in both the height and temperature fields are obvious when comparing the chart for November 19, 1969 (Fig. 16) with earlier analyses (Figs. 14 and 15). At that time the temperature reversal had been fully completed and temperatures near the pole had risen to higher than -30°C. It is rather remarkable that the circulation at higher latitudes remained westerly even after the temperature reversal had been completed. In fact the change to an easterly circulation was not completed until early December. It is perhaps worthy of note that the height field in the Northern Hemisphere appears to respond more rapidly to the springtime reversal (i.e. the establishment of anticyclonic easterlies is more coincident with the reversal of the temperature field).

FINAL REMARKS

There is no doubt that satellite data from SIRS can be an extremely valuable supplement for use in stratospheric analyses. The many additional observational points provided by the SIRS retrievals for the data-sparse Southern Hemisphere, indeed, makes analysis readily attainable instead of just possible. However, since the satellite data used for our analyses were obtained from a yet experimental system, the results must obviously be reviewed with a certain amount of caution. In this regard, we are currently engaged in an evaluation of the retrieval data for the Northern Hemisphere stratosphere where independent analyses are available.

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. In addition to the comparison of high latitude events, the interesting patterns occurring in trough zones may be more precisely defined. For example, the question of what the circulation patterns at low latitudes look like during different stages of the quasi-biennial, annual and semi-annual cycles may be approached with more confidence. It appears to be just a matter of time before we have a complete definition of such patterns.

The analyses clearly revealed several periods when the relatively warm mid-latitude ridge zone extended poleward in what may be termed as "minor warming events." None of these instances, however, matched the more intense warming events that have been observed in the Northern Hemisphere.

Experience in the Northern Hemisphere has shown that it is not uncommon for pronounced warmings to occur at mid- and upper-stratospheric levels and yet be only faintly discernible at the 30 or even 10 mb level. In view of our results, it would be extremely interesting to be able to determine if a similar course of events occurs in the Southern Hemisphere and that the warmings noted above were slight manifestations of major circulation changes at the upper levels. We look forward to the time when such data will be available so that we can investigate this possibility for the Southern Hemisphere stratosphere.

ACKNOWLEDGMENTS

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