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# INFERENCES OF STRATOSPHERIC AND MESOSPHERIC CIRCULATION SYSTEMS FROM ROCKET EXPERIMENTS

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# INFERENCES OF STRATOSPHERIC AND MESOSPHERIC CIRCULATION SYSTEMS FROM ROCKET EXPERIMENTS

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## ABSTRACT

INFERENCES OF STRATOSPHERIC AND MESOSPHERIC CIRCULATION SYSTEMS FROM ROCKET EXPERIMENTS

by


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Recently performed rocket grenade experiments at Wallops Island and Churchill and MRN data are interpreted to show the existence and movement of conventional circulation systems throughout the upper stratosphere and mesosphere. Evidence of moving pressure systems exists up to an altitude of 70 km where the nature of the circulation changes abruptly. Also, the pattern of the pressure systems in the stratosphere (below 50 km) seems to be different from the pattern inferred at higher altitudes (50 - 70 km). Author


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## Introduction

Since the early rocket grenade experiments more than ten years ago and the successful firings during the IGY period, the experiments have been continued by NASA at Wallops Island. Thus a large number of soundings is available giving already a climatological survey on the gross features of the winds and the thermal structure in the upper stratosphere and in the mesosphere (1) (2). Experiments have also been performed by Australia, Japan, Sweden, Italy, and France and the United States program will be extended to include simultaneous launchings at Churchill, Wallops Island, and Ascension Island. The number of rocket stations reporting data above the normal Meteorological Rocket Network (MRN) levels is gradually increasing promising an improving global data coverage for the levels between 50 and 90 kilometers during the forthcoming International Geophysical Year (IQSY). In this report, interesting features are derived from the first simultaneous rocket grenade experiments performed at Churchill, Manitoba, and Wallops Island, Virginia, and from simultaneous Meteorological rockets launched at the various MRN sites over North America. While the earlier sporadic experiments enabled a study of climatological gross features of the mesospheric circulation, these simultaneous observations have encouraged us to investigate the dynamic structure of the mesosphere on a smaller scale by means of synoptic presentation of flow patterns for selected days over the North American continent. At the higher altitudes, the acoustic temperature and wind measurements were supplemented by other sounding techniques such as wind measurements by means of sodium vapor release.

## The Vertical Change in Stratospheric and Mesospheric Wind Structure

Considering the seasonal variations of stratospheric and mesospheric winds as measured at Wallops Island over a period of 3 years, one finds a remarkable change in the behavior of mesospheric winds around the height of 70 km. Below this level, the wind follows a consistent and predictable seasonal pattern while above 70 km the wind structure becomes very irregular and does not show the well-known regular features observed at levels below (5).

This fact is apparent in figure 1, where all rocket grenade winds for the years 1960 through 1963 are presented in polar diagrams for the lower, middle, and upper mesosphere. The winds in the 45 - 55 km layer show the same general features as in the stratosphere: strong and relatively steady westerly winds with maximum deviations of $\pm 25°$ about an average direction of 265° and light but equally steady easterly winds in summer. During the transitions between winter and summer seasons, there is a large variability in wind strength and direction; however, this variability is still part of a consistent seasonal pattern which has been the subject of several previous analyses (6). In the middle mesosphere (60-70 km) one finds qualitatively the same behavior, although variations in the wind directions are somewhat larger. In the upper mesosphere (80 - 90 km), however, the picture changes completely. The winds both in winter and summer are blowing from all directions and in highly variable strengths. The same characteristics are shown by the results of recent sodium vapor release experiments at Wallops Island (7). In figure 2 wind direction profiles from five experiments reaching below 70 km are reproduced, and the drastic change in wind structure between 70 and 80 km is apparent.

From these rocket observations with both the grenade and sodium release methods, one may conclude that above a transition layer between 70 and 80 km the dynamic behavior of the mesosphere becomes so complex that synoptic representations of the flow patterns on a day to day basis will be meaningless. The motions above this layer appear to be highly "disorganized" from the standpoint of conventional synoptic meteorology. Therefore, such an abrupt change in the wind structure may very well be found in the increasing importance of tidal motions and possibly in the fact that the atmospheric structure as a whole undergoes certain important changes at the 80 km level.

Nevertheless, up to this level the mesospheric motions are still organized in the usual meteorological sense, and synoptic presentations are quite justified and well representative of the stream patterns over periods of several days.

## Inferred Mesospheric Synoptic Circulation Systems up to 70 Kilometers

Several investigators have already extended presentation of synoptic weather maps up to the 0.5 or 0.4 mb level (about 55 km) by using Meteorological Rocket Network data (8), (9), (10), (11). In this paper, an attempt is made to construct synoptic maps up to the 0.05 mb level

(68 km) for a few special days by making use of recent grenade and MRN data.

Data from the first simultaneous rocket grenade soundings at Churchill and Wallops Island, in early December, 1962,* were analyzed in addition to Meteorological Rocket Network data also available for that time period. Variation of flow and pressure patterns for various upper stratospheric and mesospheric levels over the American continent were investigated by constructing synoptic maps for 4 December and 6 December, 1962. In these maps, the pressure fields at constant heights are presented. Using the geostrophic approximation, the isobars were spaced such that each pressure field is in accordance with the observed winds. The pressure values of the isobars were determined by the observed pressures over the discrete points of observation.

The circulation in the lower stratosphere (100 mb or 16 km) around 5 December, 1962, was characterized by the displacement of the cold polar vortex to Siberia, the entire North American continent being under a rather uniform westerly stratospheric flow with a slowly developing trough moving gradually eastward over the United States (figures 3) (12). The middle stratosphere (30 mb or 23 km) (figure 4) shows a quite different stream pattern over the entire western hemisphere (13) with a weak but, nevertheless, unusual quasi-stationary

*Data performed by W. Smith and J. Theon, NASA, Goddard Space Flight Center, Greenbelt, Maryland, will be published.

anticyclone over Canada and a zonally oriented trough over the United States along 40 deg. latitude. In the upper stratosphere (10 mb or 30 km) the same contour pattern appears with greater intensity: the easterly wind at the southern flank of the Canadian anticyclone exceeds 25 m/sec (50 knots), whereas a stratospheric jet stream with winds up to 50 m/sec (100 knots) is located over the Gulf coast (figure 5B). There are no significant changes of the circulation pattern at 30 km within the period of December 4-6, 1962, as indicated by Figures 5A-5C. The North American high pressure systems represent an eastwardly displaced Aleutian anticyclone that governed the Northern hemispheric circulation throughout November (14) and is still apparent at the 5 mb surface, which was constructed for 5 December, 1962, (figure 6). The 40 km pressure maps (figure 7) show the pronounced trough over the Great Lakes area moving slowly southward, whereas the existence of the Canadian anticyclone is not necessarily indicated at this level. Its center may well have shifted to the Pacific region, Alaska and Canada being in the regime of the polar vortex. The anticyclone can still be observed ten kilometers higher (figure 8), and here there is a definite indication that its center has shifted northward, causing a nearly northerly wind over Churchill on 4 December and a southwesterly wind over Alaska. Although the stream pattern remains essentially the same at 60 km (figure 9), there is a distinct further shift in the position of the center of the anticyclone. It is apparently displaced to the Arctic, as indicated by the southeasterly wind over Alaska. The pronounced trough, which has persisted at all altitude levels from

23 km up, is still located over southern Canada; and there is some indication that its vertical axis is slightly inclined to the north, such that at 60 km the trough has taken the position of the ridge in the stratosphere (20 to 35 kilometers).

At 68 km (figure 10) data are very sparse and are mainly based on grenade soundings at Churchill and Wallops Island. There is evidence that the zonally oriented trough over North America still exists, as indicated by strong winds from the west south-west over the United States and very light northwesterly wind inside the trough over Churchill on 4 December, 1962. In general, it is interesting to note the alternation between low and high pressure systems on a vertical scale between the 30 and 60 km levels as shown in figures 5-10. This seems to confirm the theoretical expectation of such alternations previously expressed by Paetzold (15).

Differences in the flow and pressure patterns between 4 December and 6 December were found to be insignificant at 40, 50, and 60 km. This is not surprising because the patterns in the stratosphere also remained nearly unchanged. At 68 km, however, a significant change seems to have taken place between 4 December and 6 December over Churchill and 1 December and 6 December over Wallops Island. There is a 90 degree rotation of the wind vectors at both stations, but at Churchill this rotation is clockwise, while at Wallops Island it is counter clockwise. This may be interpreted as a southwestward motion of the low pressure system (figures 10A, 10B).

Of course, the sparsity of data permits only a very crude analysis even in this case, which could be considered well documented by rocket sounding standards. Nevertheless, this case shows that significant non-uniformities exist in the slopes of the constant pressure surfaces which are generally inclined downward toward the winter pole. If in the past such uniformity was assumed, it was only because the available data were not sufficient to observe any detail. It is to be expected that systematic rocket observations of the mesosphere extended over the hemisphere and spaced over distances in the order of 1000 km will reveal up to about 70 km circulation systems of similar variability and variety as observed at lower altitudes.

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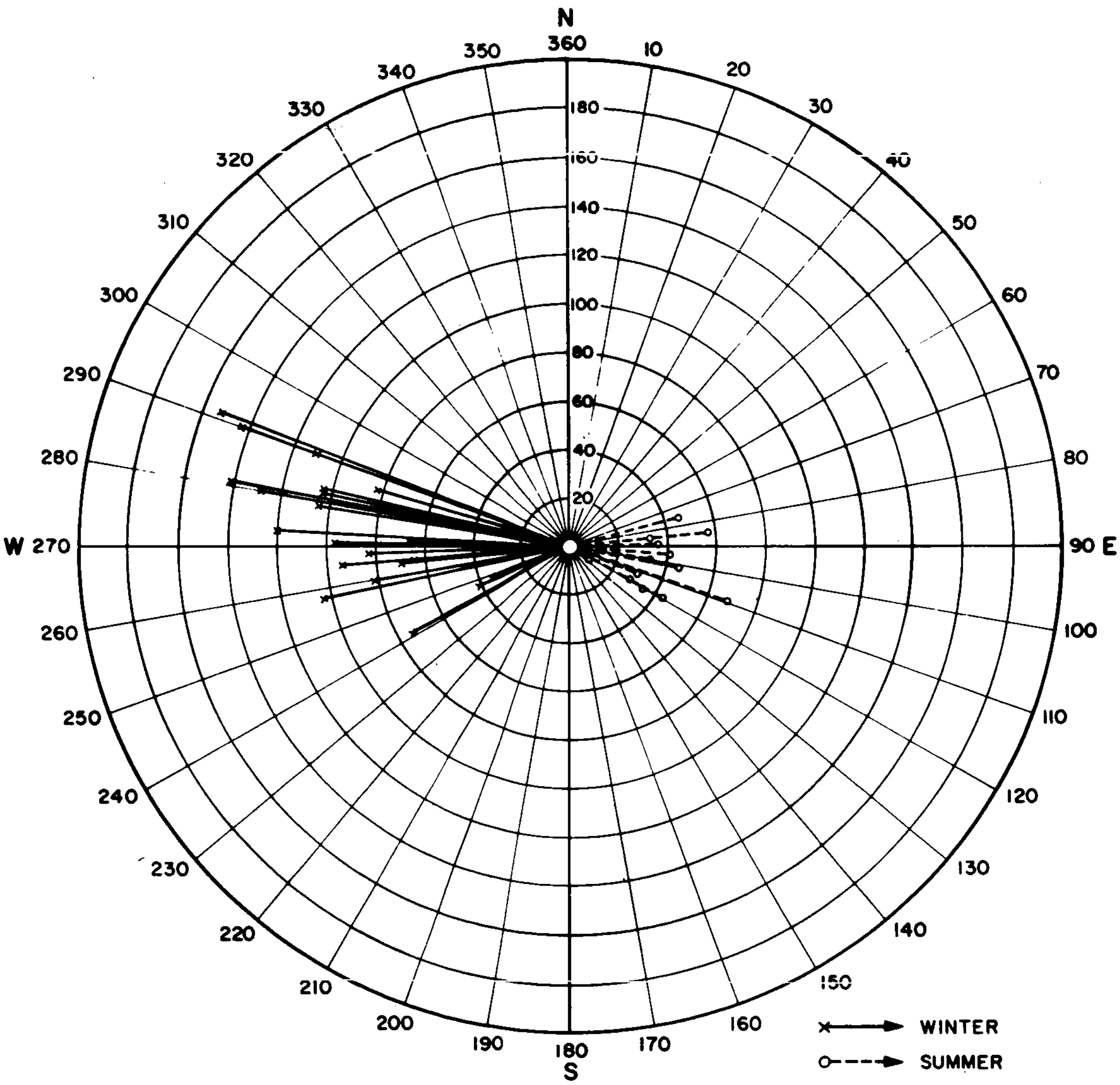


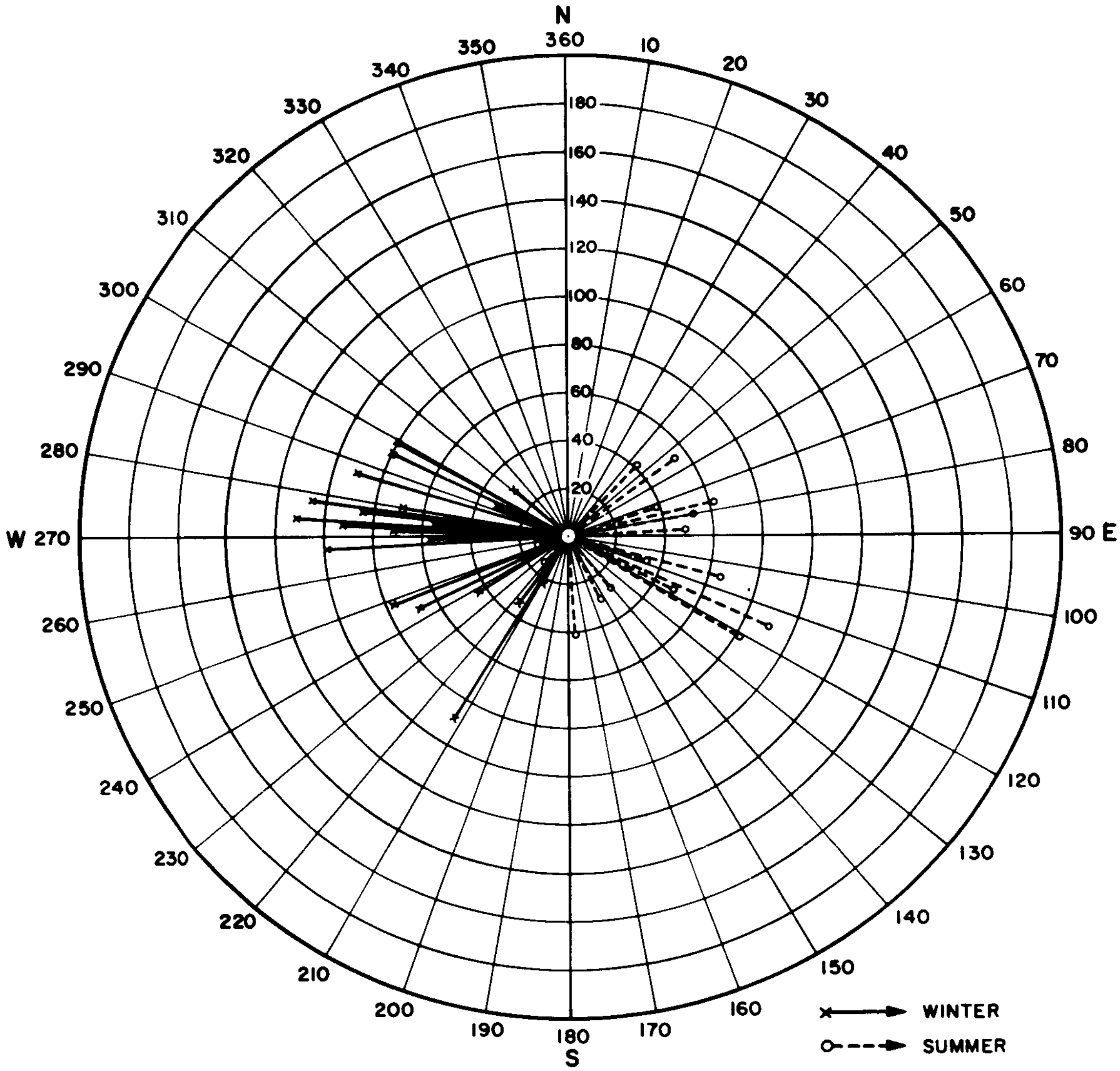

ROCKET GRENADE WINDS (m/sec)

**45 - 55 KM**

WALLOPS ISLAND, VA.

1960-63

Figure 1A



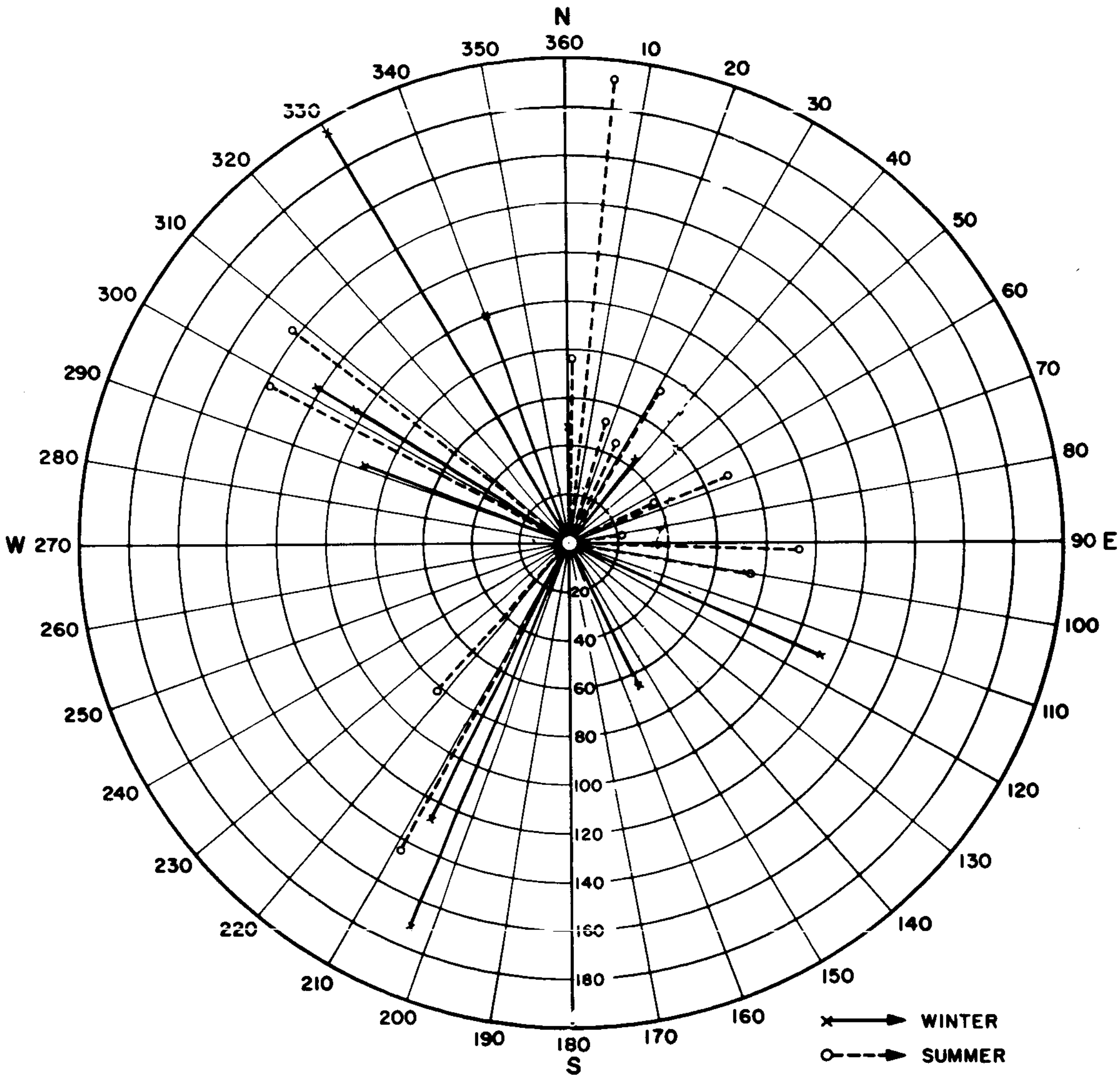

ROCKET GRENADE WINDS (m/sec)

60 - 70 KM

WALLOPS ISLAND, VA.

1960-63

Figure 1B




ROCKET GRENADE WINDS (m/sec)

80-90 KM

WALLOPS ISLAND, VA.

1960-63

Figure 1C

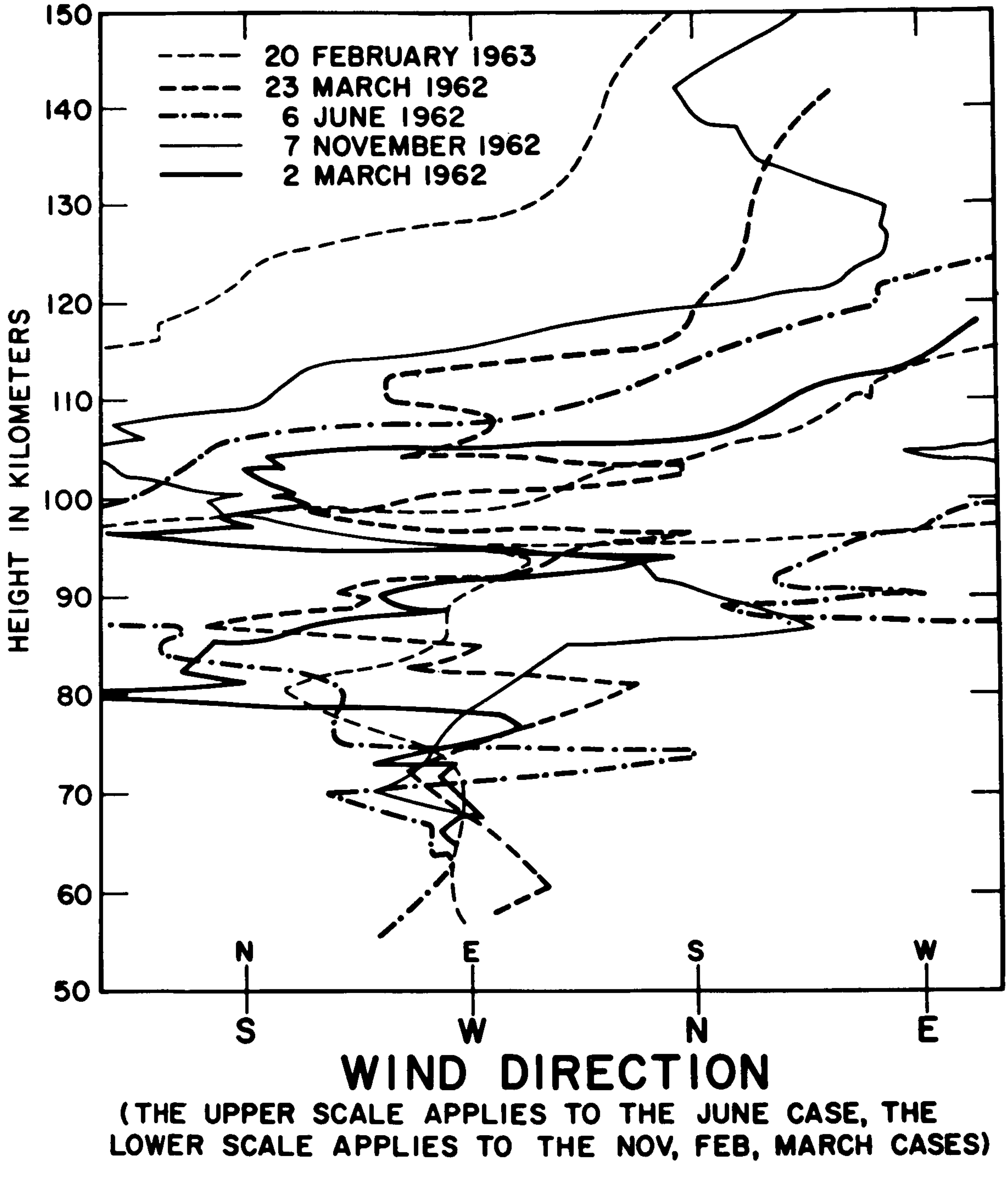
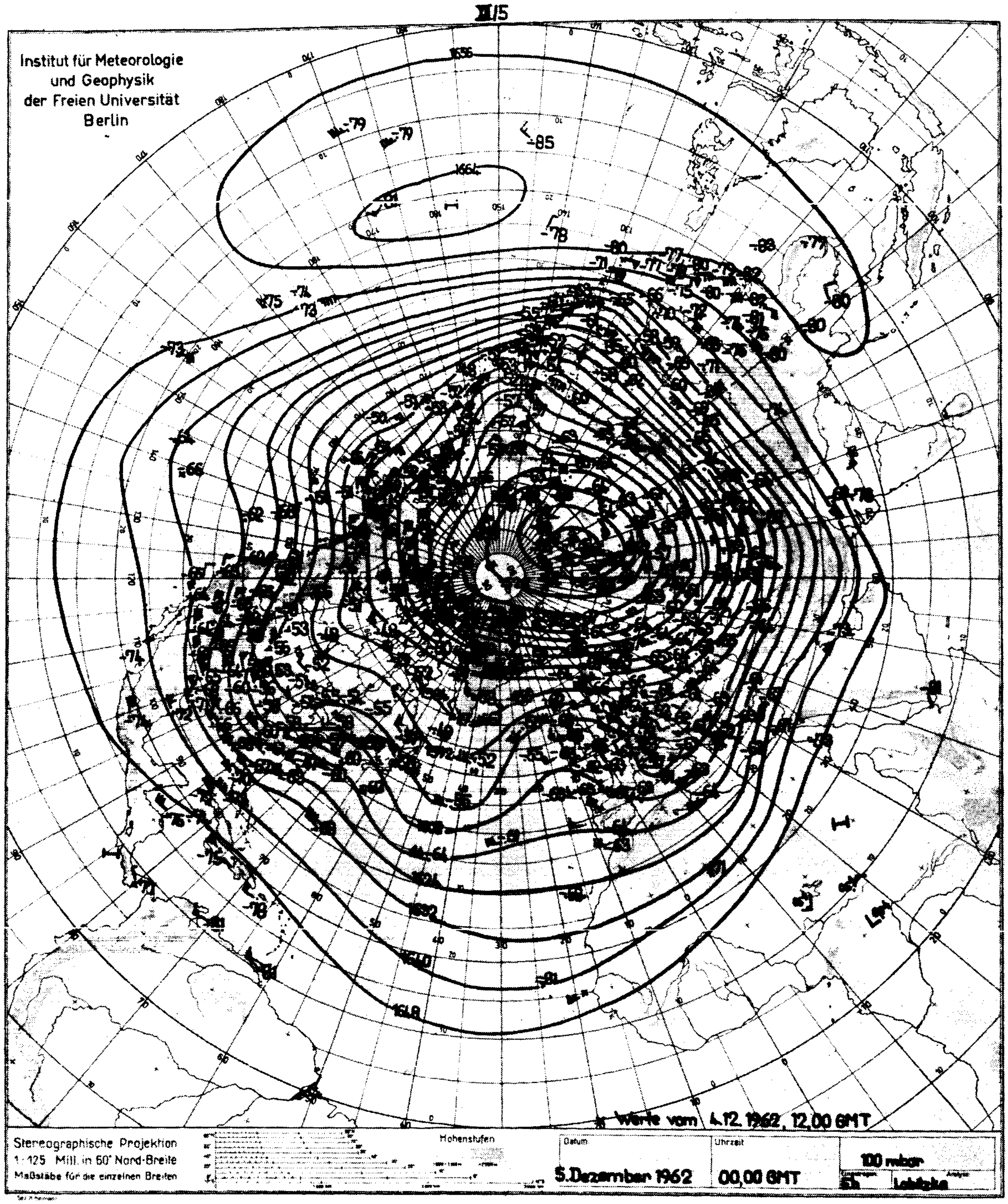
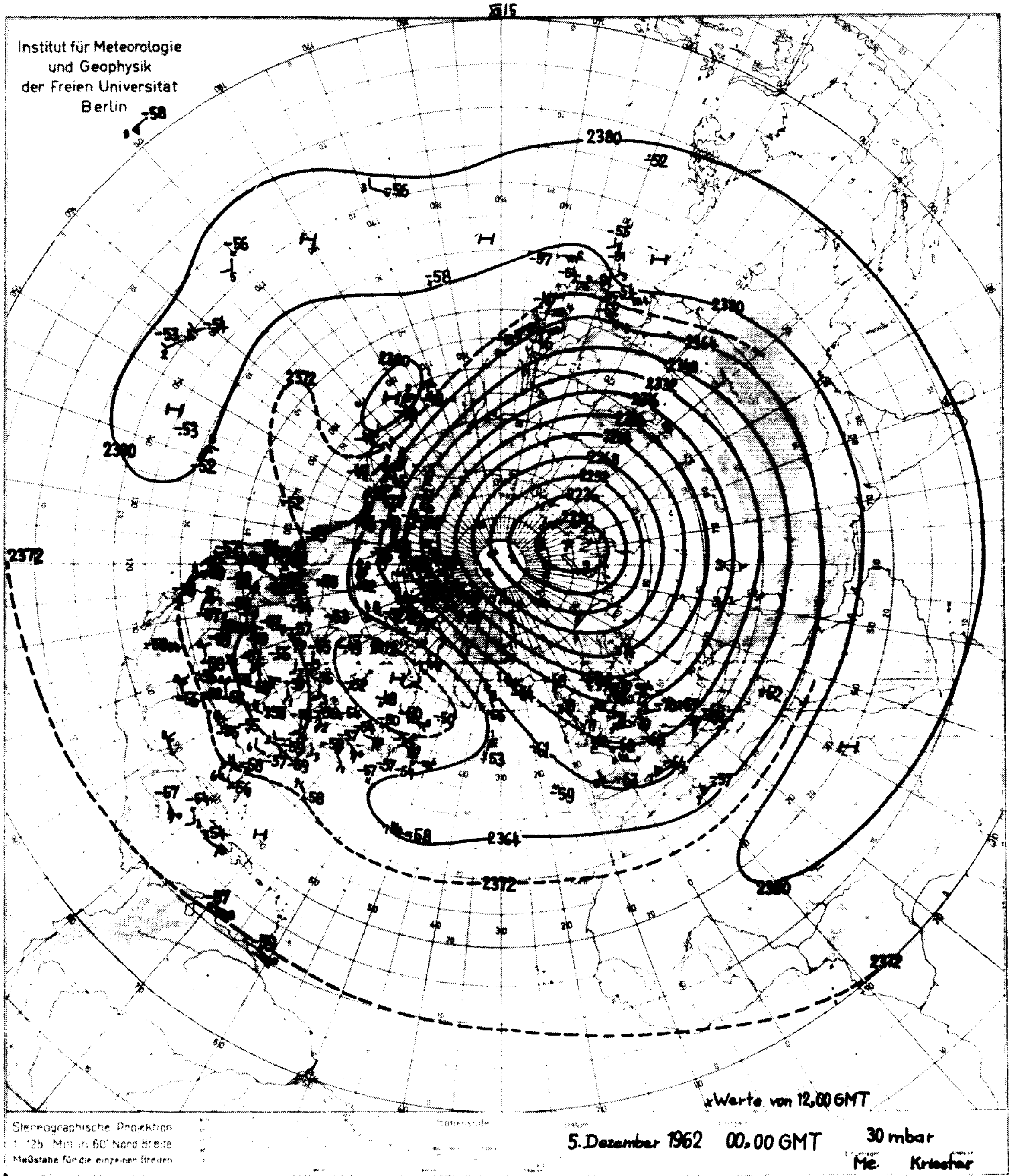

20 FEBRUARY 1963
23 MARCH 1962
6 JUNE 1962
7 NOVEMBER 1962
2 MARCH 1962
HEIGHT IN KILOMETERS
150
140
130
120
110
100
90
80
70
60
50
N
E
S
W
S
W
N
E
WIND DIRECTION
(THE UPPER SCALE APPLIES TO THE JUNE CASE, THE LOWER SCALE APPLIES TO THE NOV, FEB, MARCH CASES)

Figure 2



III/5
Institut für Meteorologie
und Geophysik
der Freien Universität
Berlin
Werte vom 4.12.1962, 12.00 GMT
Stereographische Projektion
1:125 Mill. in 60° Nord-Breite
Maßstäbe für die einzelnen Breiten
Höhenstufen
Datum
5.Dezember 1962
Uhrzeit
00.00 GMT
100 mbar


Figure 3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und Geophysik
der Freien Universität
Berlin
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2372
2364
xWerte von 12,00 GMT
Stereographische Projektion
5. Dezember 1962
00,00 GMT
30 mbar

Figure 4

XII/4

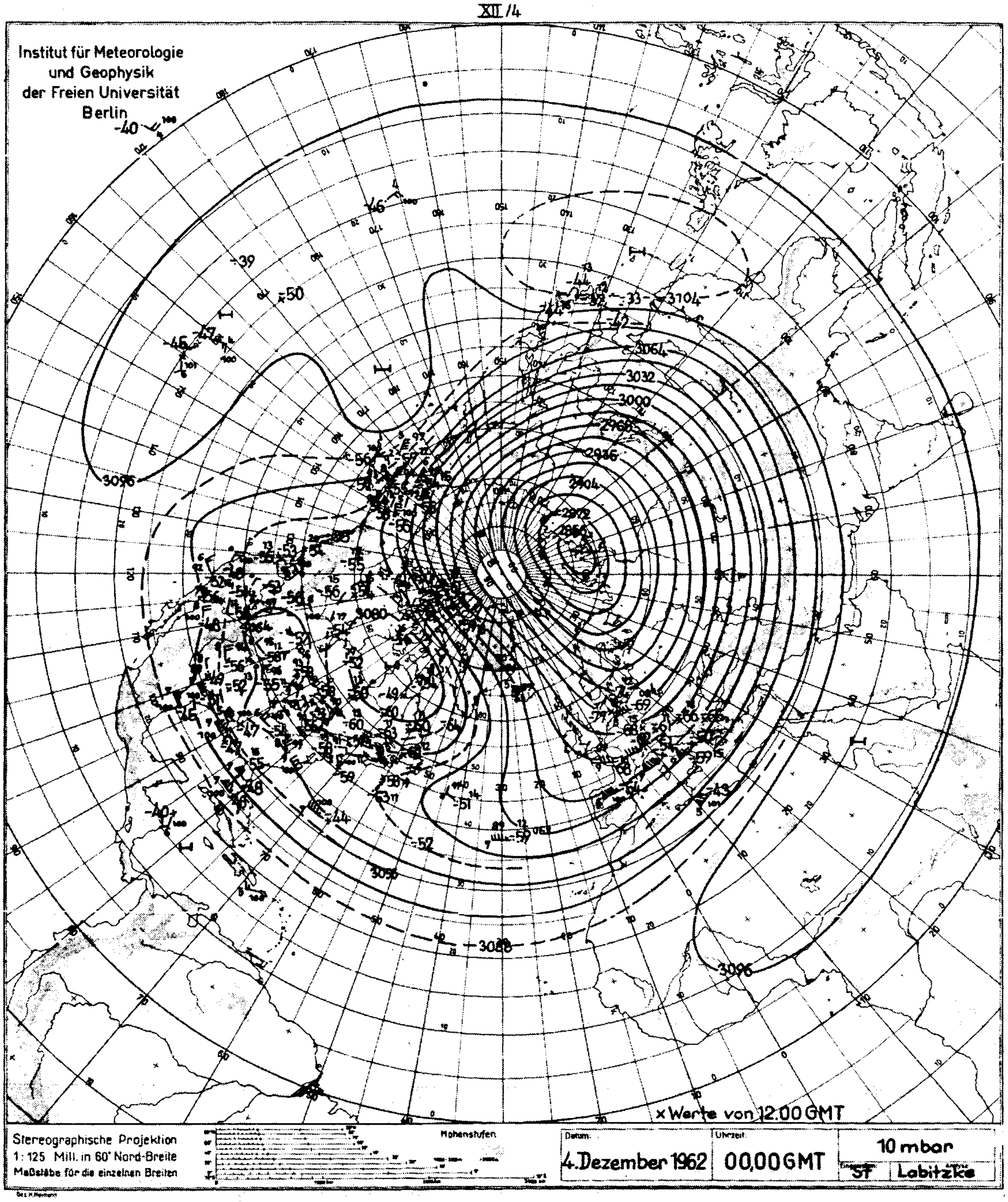
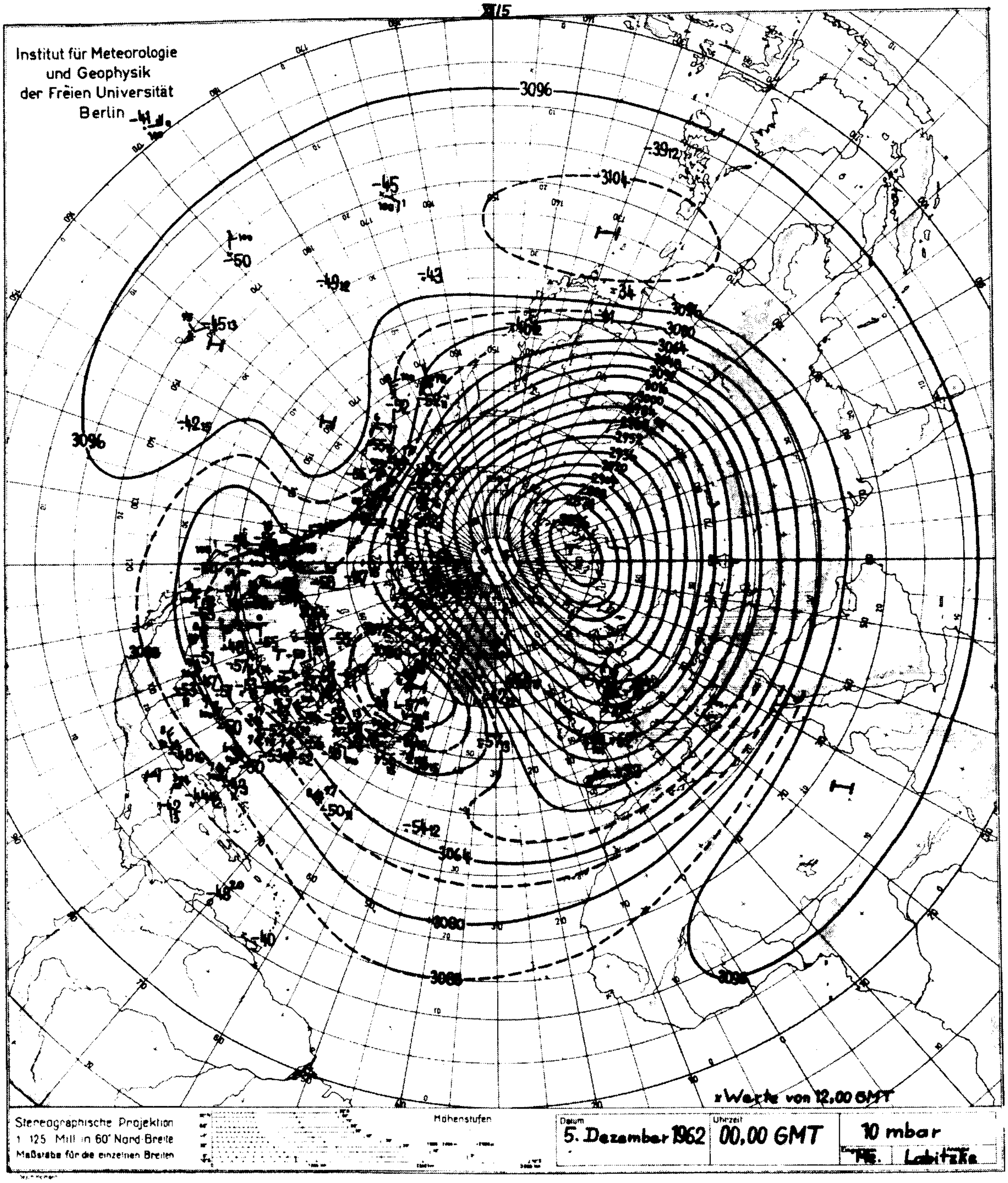



Figure 5A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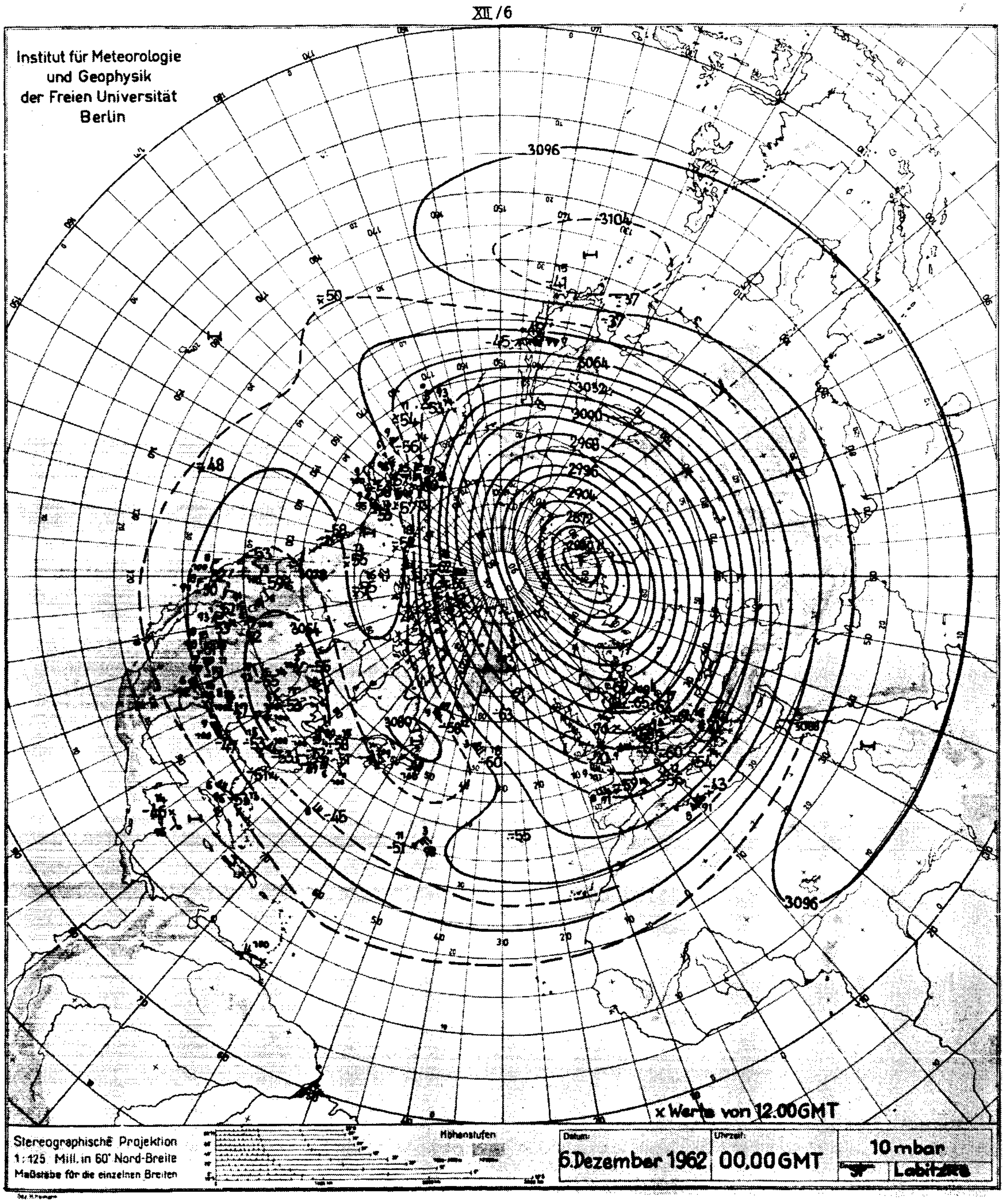
und Geophysik
der Freien Universität
Berlin
Stereographische Projektion
1 : 125 Mill in 60° Nord-Breite
Maßstäbe für die einzelnen Breiten
Höhenstufen
x Werte von 12,00 GMT
Datum
5. Dezember 1962
Uhrzeit
00,00 GMT
10 mbar
Labitzke

Figure 5B


XII/6
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und Geophysik
der Freien Universität
Berlin
3096
3104
3064
3052
3000
2968
2936
2904
2872
3080
x Werte von 12.00GMT
Stereographische Projektion
1:125 Mill. in 60° Nord-Breite
Maßstäbe für die einzelnen Breiten
Höhenstufen
6.Dezember 1962
00.00GMT
10 mbar
Labitzke

Figure 5C

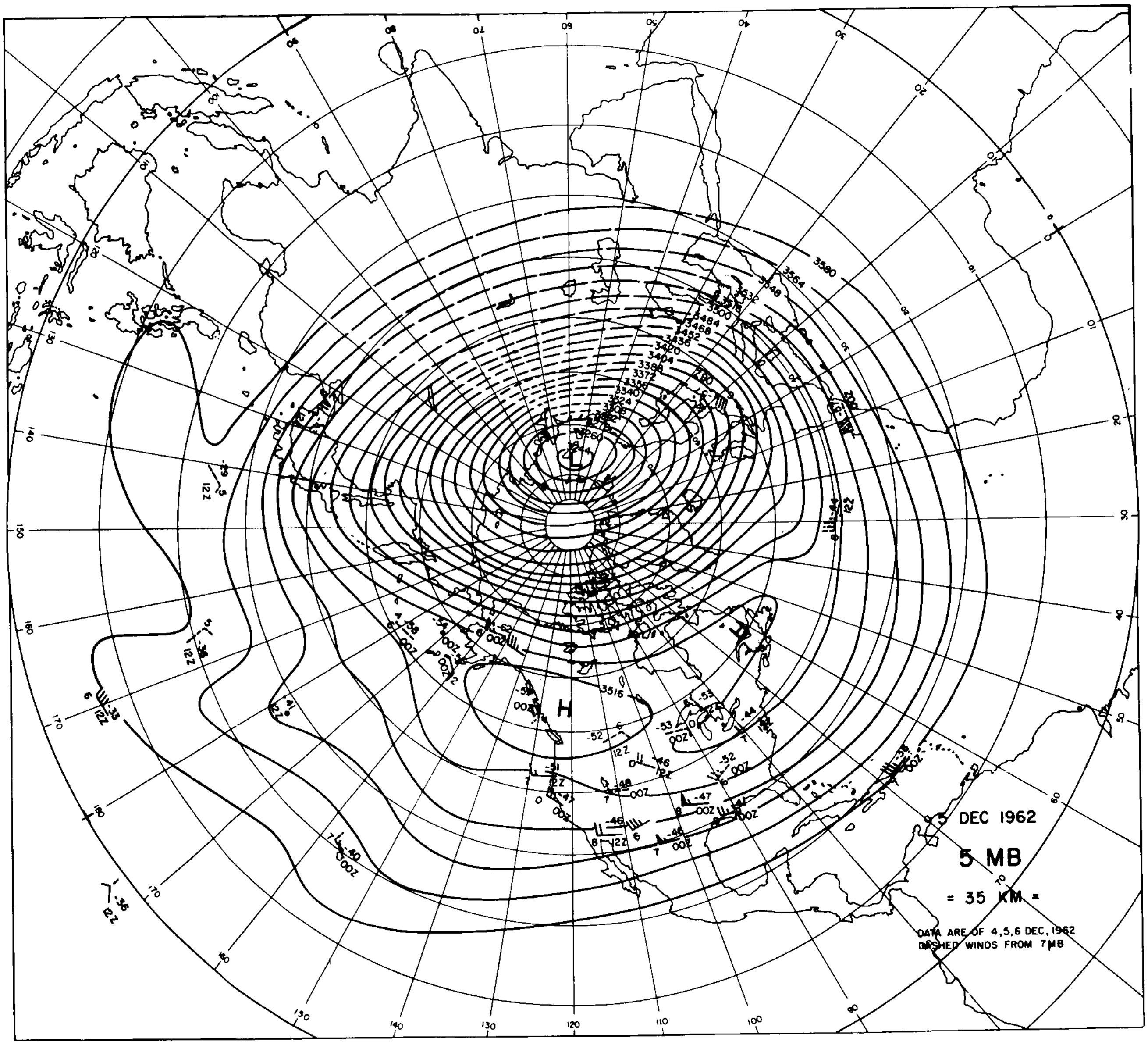
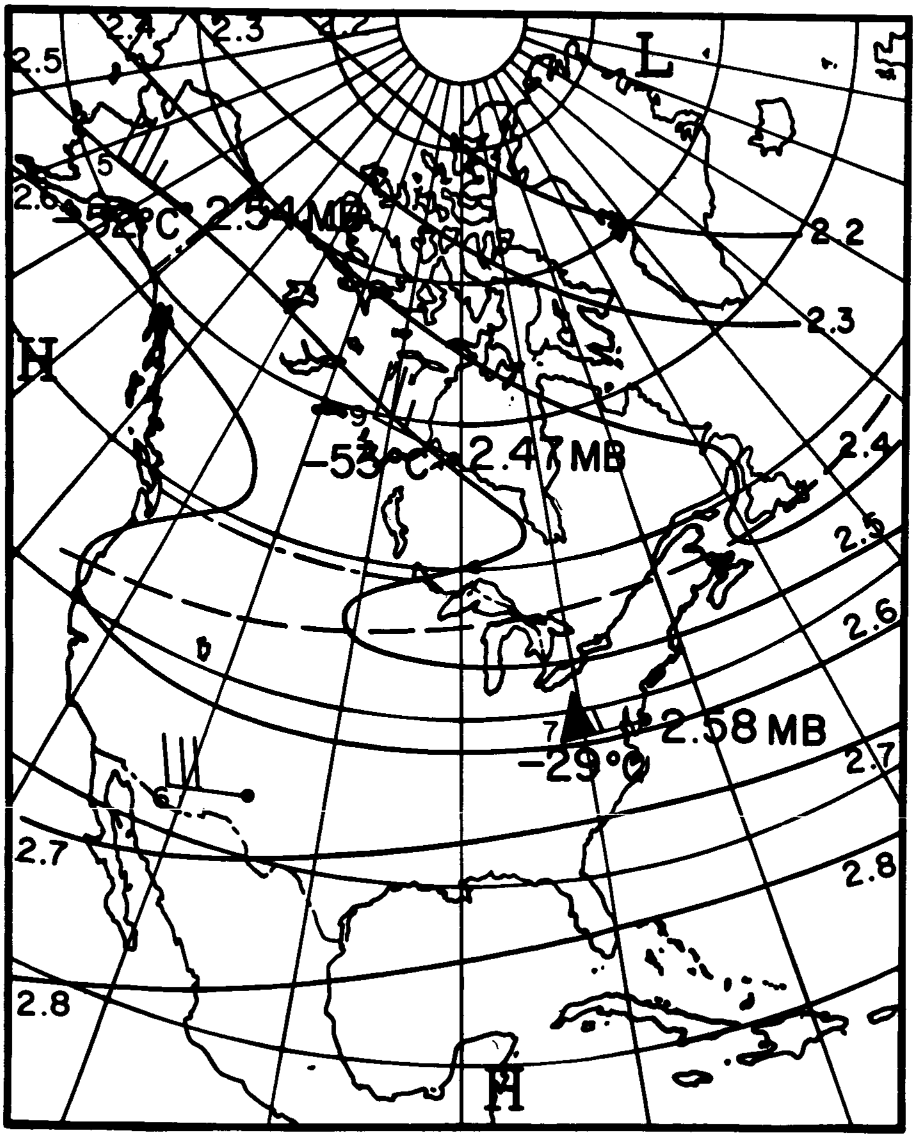

5 DEC 1962
5 MB
= 35 KM =
DATA ARE OF 4,5,6 DEC, 1962
DASHED WINDS FROM 7MB

Figure 6




**40 km**

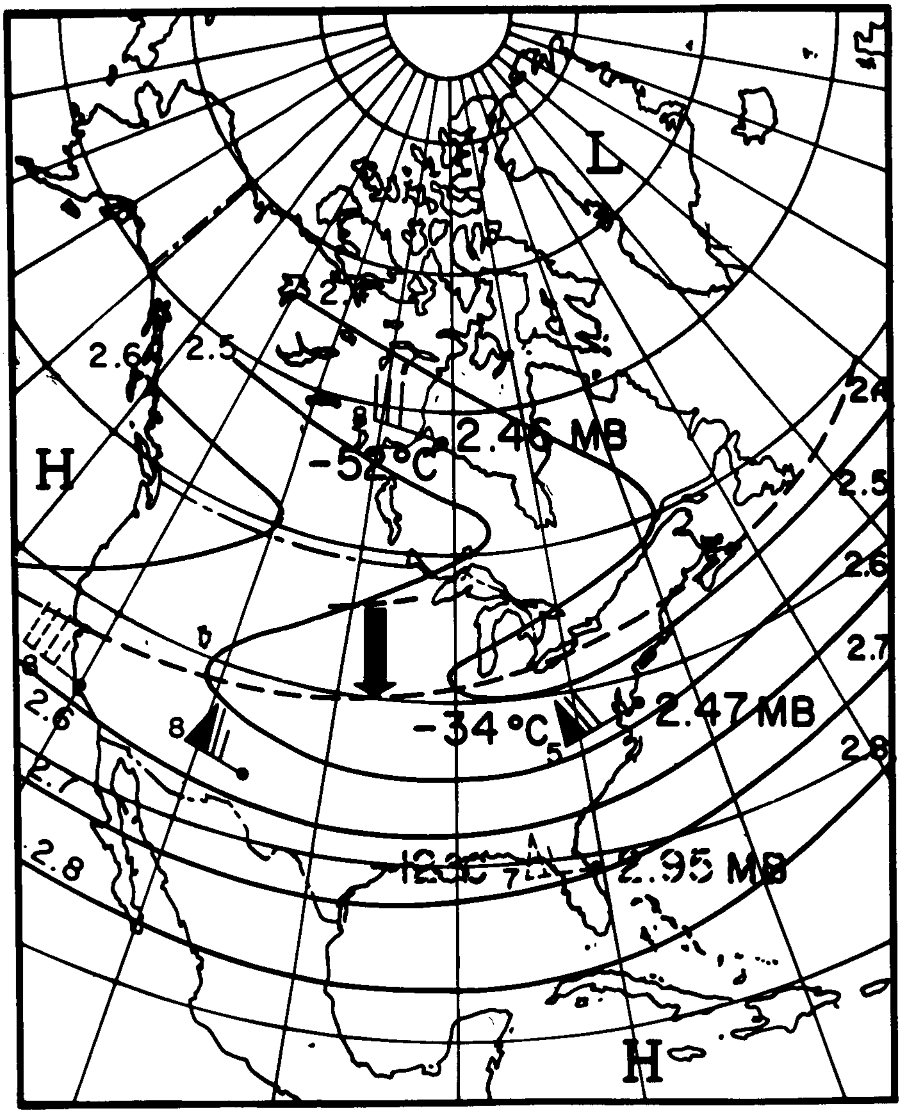
**DEC 4, 1962**

**LEGEND**

**WINDS IN m/sec**

**DATA AT WALLOPS ISLAND DEC. 1, 1962**

Figure 7A




40 km

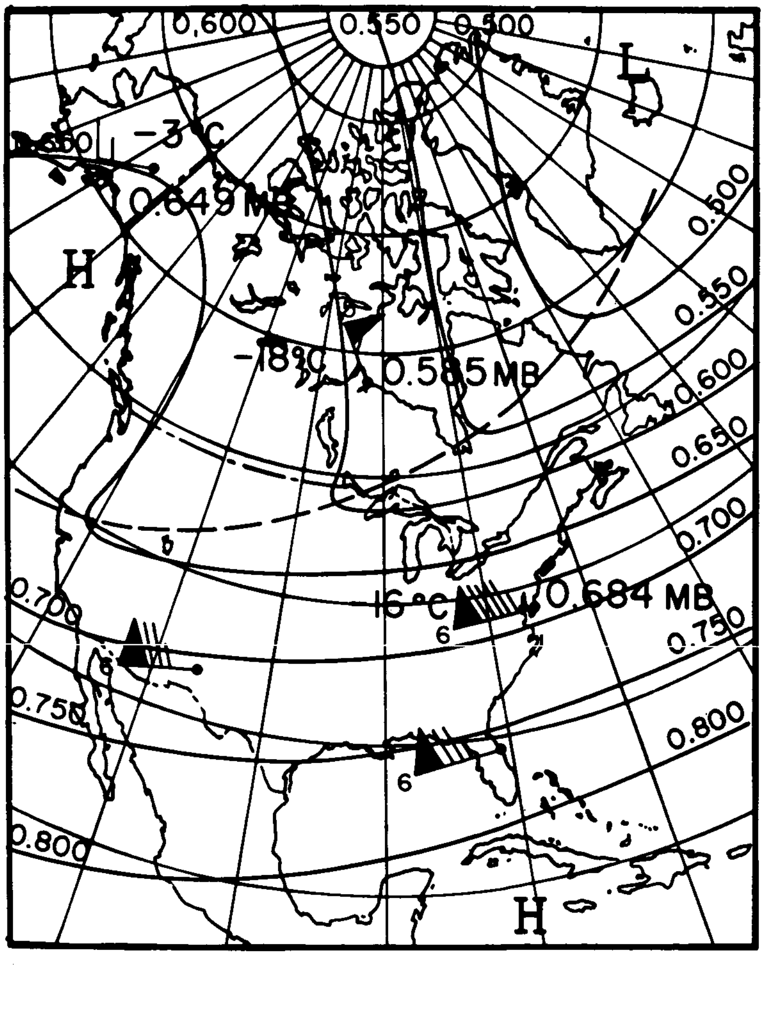
DEC 6, 1962

LEGEND

WINDS IN m/sec

△__ DATA FOR DEC. 7 '62

Figure 7B



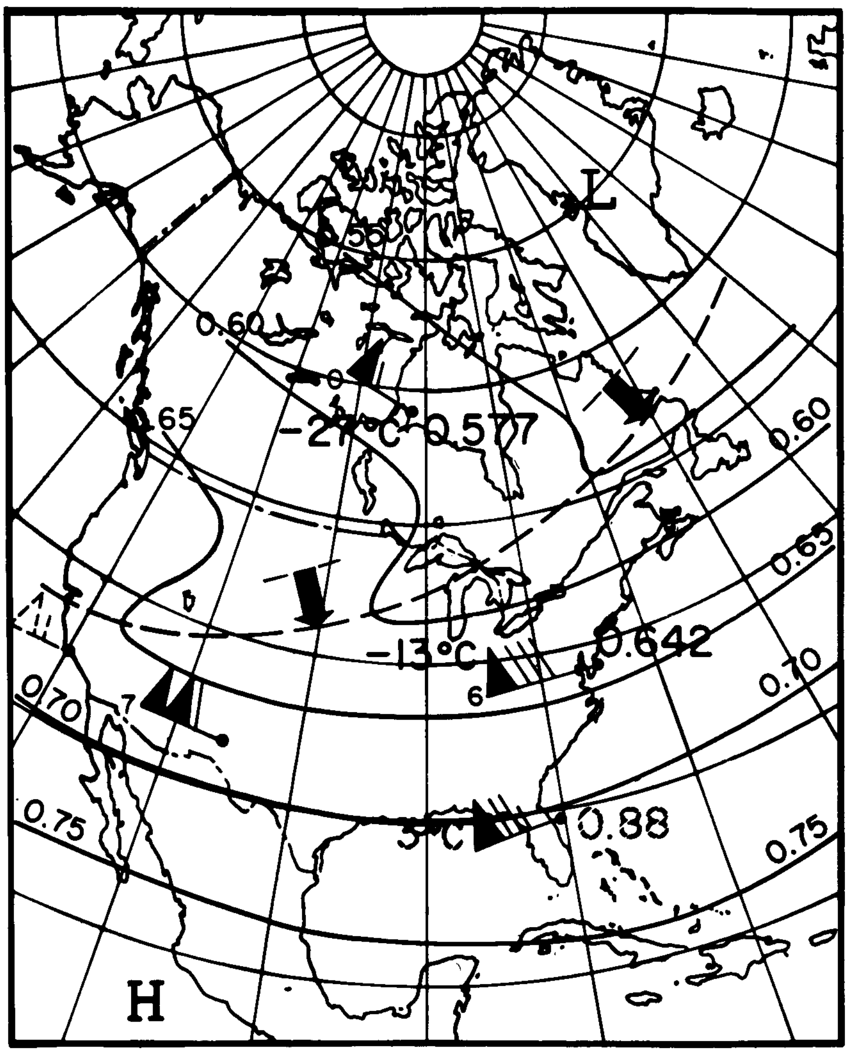

**50 km**
**DEC 4, 1962**

**LEGEND**

**WINDS IN m/sec**

**DATA AT WALLOPS ISLAND DEC. 1, 1962**

Figure 8A




50 km

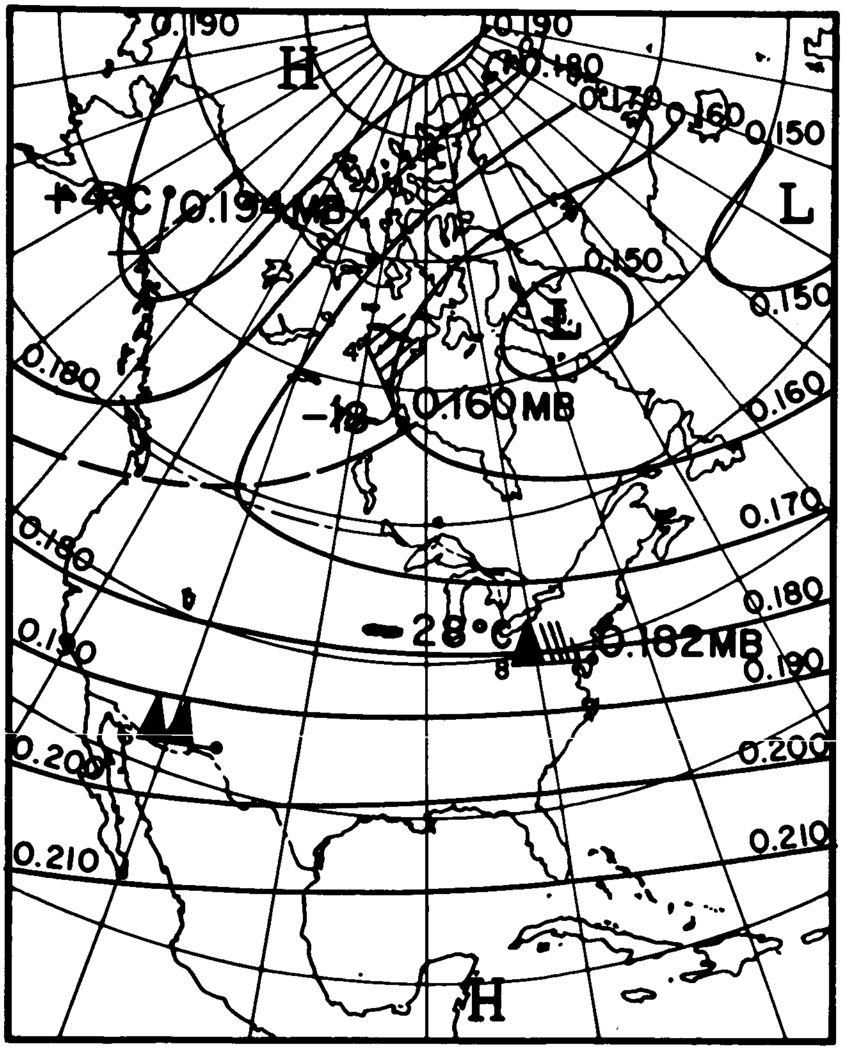
DEC 6, 1962

LEGEND

WINDS IN m/sec

DATA FOR DEC. 7 '62

Figure 8B




**60 km**

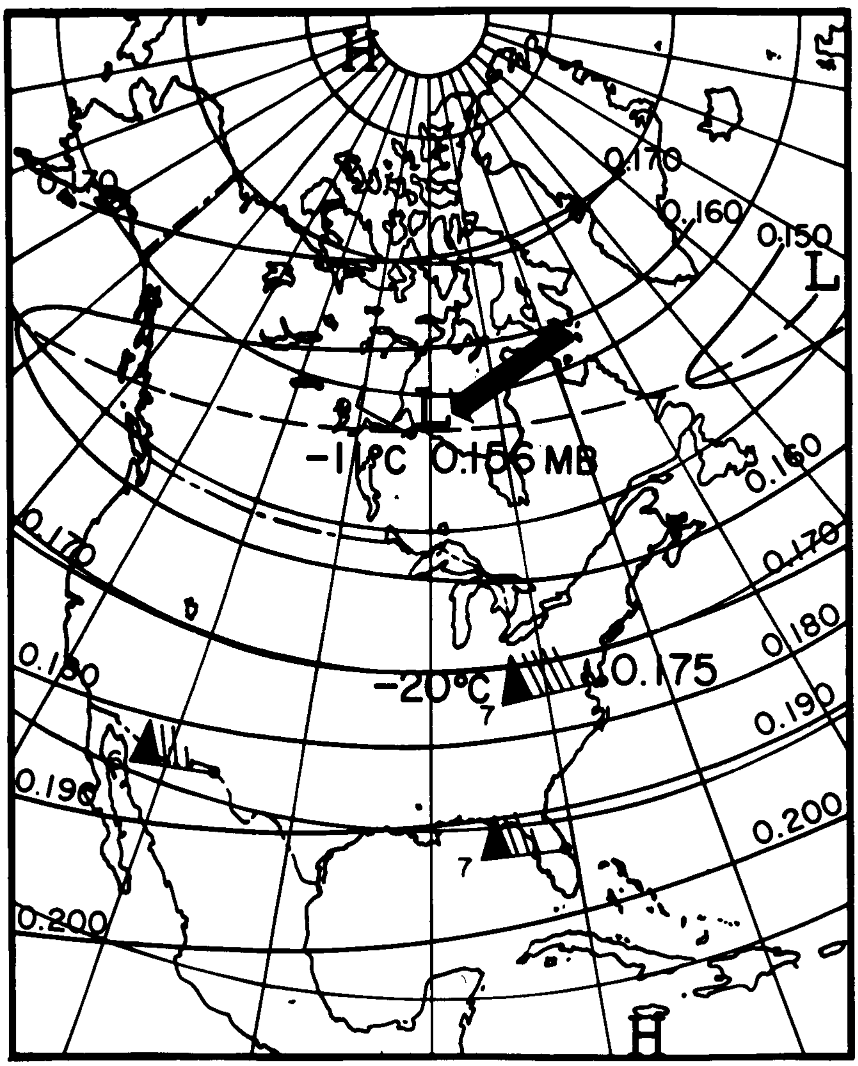
**DEC 4, 1962**

**LEGEND**

**WINDS IN m/sec**

**DATA AT WALLOPS ISLAND DEC. 1, 1962**

Figure 9A



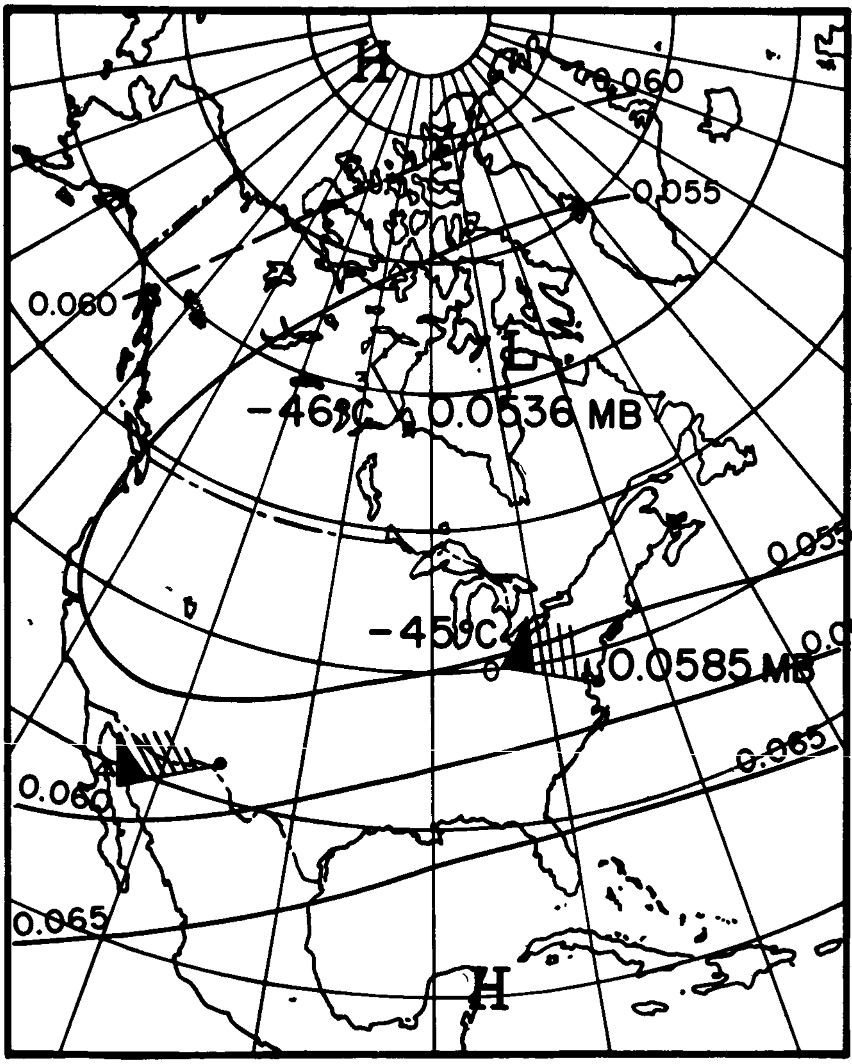

60 km

DEC 6, 1962

LEGEND

WINDS IN m/sec

Figure 9B




# 68 km

DEC 4, 1962

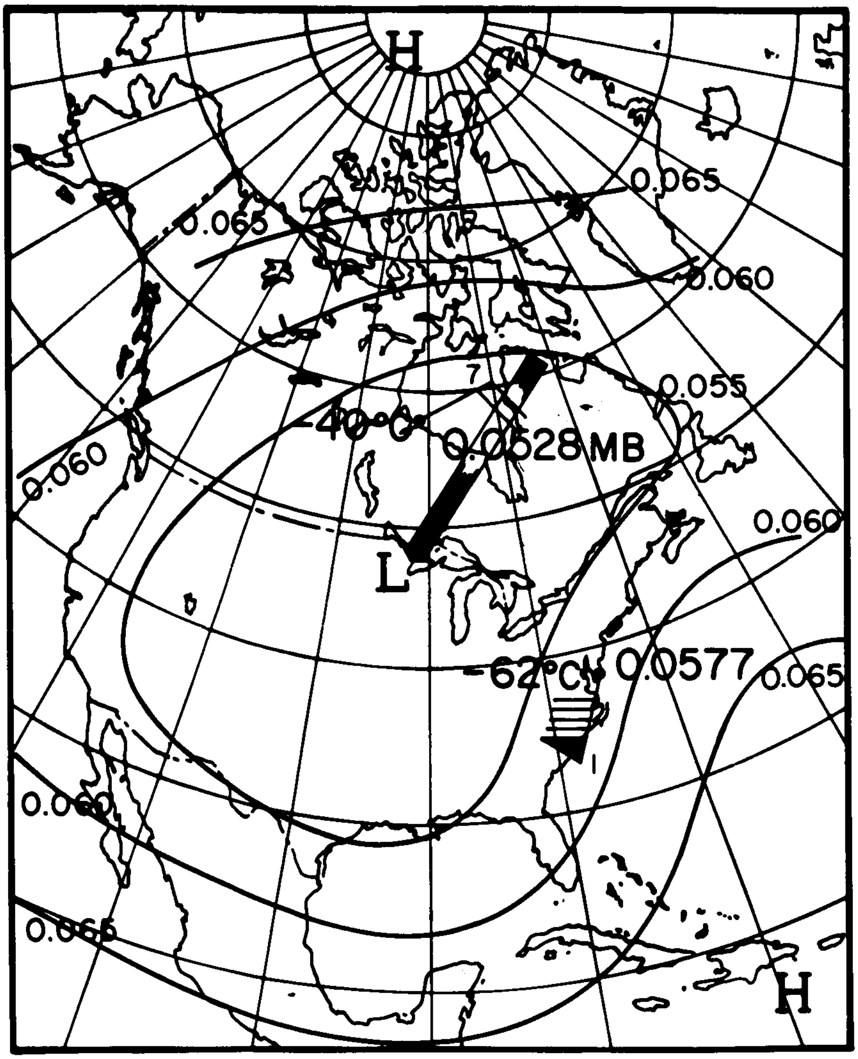
LEGEND

WINDS IN m/sec

WHITE SANDS, N.M.
WIND FROM 66km

WALLOPS ISLAND
DATA FOR DEC.1, 1962

Figure 10A




68 km

DEC 6, 1962

LEGEND

WINDS IN m/sec

Figure 10B