AD-A119 321 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 4/2

A SYNOPTIC/STATISTICAL ANALYSIS OF SUMMER SEASON CIRCULATION PA--ETC(U)

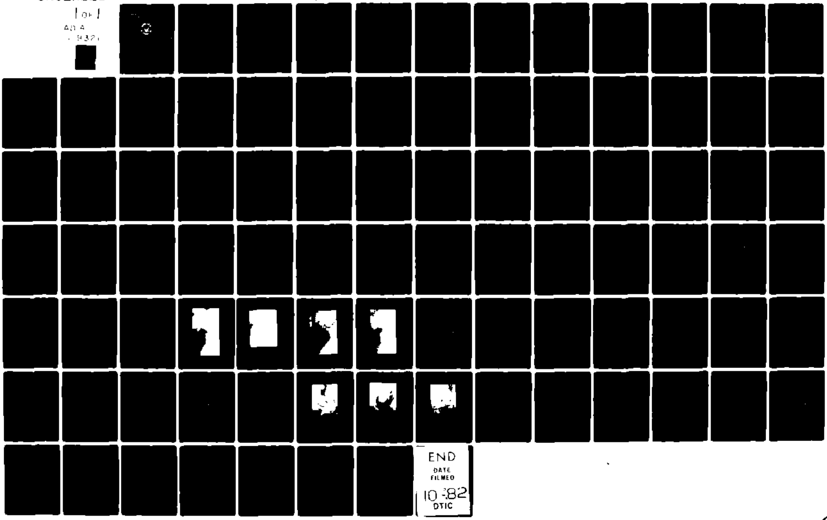
JUN 82 R L FAUQUET

UNCLASSIFIED NL

1 OF 1

AD A

119321



NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A SYNOPTIC/STATISTICAL ANALYSIS OF SUMMER SEASON CIRCULATION PATTERNS OVER EASTERN ANTARCTICA DURING MOIST AIR INTRUSIONS

by

Ronald L. Fauquet

June 1982

Thesis Advisor: R. J. Renard

Approved for public release; distribution unlimited

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A119321
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) A Synoptic/Statistical Analysis of Summer Season Circulation Patterns over Eastern Antarctica During Moist Air Intrusions	5. TYPE OF REPORT & PERIOD COVERED Master's Thesis June 1982
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ronald L. Fauquet	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940	12. REPORT DATE June, 1982
	13. NUMBER OF PAGES 88
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Antarctica, Antarctic 400 mb Analysis Model, Compositing, Antarctic 400 mb climatology, aircraft enroute wind forecast aid, upper-air analysis model, 400 mb height anomaly.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

U.S. Navy weather forecasters in Antarctica provide forecast services for aviation and field operations of the U.S. Antarctic Research Programs. Due to very limited conventional data, meteorological satellite imagery becomes a primary resource for circulation diagnosis. However, qualitative interpretation techniques, as used in Antarctica, fail to provide definitive information on the intensity of synoptic features. A compositing technique was used in the study to identify a 400 mb geopotential height anomaly pattern

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) common to a satellite-observed cloud signature indicating moist air intrusions onto the continent. Two test cases, one dependent and one independent, are explored to determine the usefulness of the height anomaly pattern as an operational analysis aid over the data sparse regions of eastern Antarctica. Finally, the model 400 mb analysis is compared qualitatively to the National Meteorological Center and Fleet Numerical Oceanography Center 500 mb analyses for the same times. The model developed on the study shows some promise of improving the operational Naval Support Force Antarctica circulation analyses in data poor areas.

Approved for public release; distribution unlimited

A
Synoptic/Statistical
Analysis of Summer Season Circulation
Patterns over Eastern Antarctica During Moist Air Intrusions

by

Ronald L. Fauquet
Lieutenant Commander, United States Navy
B.S., U.C.L.A., 1970

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN METEOROLOGY AND OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
June 1982

Author: Ronald L. Fauquet

Approved by: ______________ Thesis Advisor

______________ Second Reader

______________ Chairman, Department of Meteorology

______________ Dean of Science and Engineering

ABSTRACT

U.S. Navy weather forecasters in Antarctica provide forecast services for aviation and field operations of the U.S. Antarctic Research Programs. Due to very limited conventional data, meteorological satellite imagery becomes a primary resource for circulation diagnosis. However, qualitative interpretation techniques, as used in Antarctica, fail to provide definitive information on the intensity of synoptic features.

A compositing technique was used in the study to identify a 400 mb geopotential height anomally pattern common to a satellite-observed cloud signature indicating moist air intrusions onto the continent. Two test cases, one dependent and one independent, are explored to determine the usefulness of the height anomaly pattern as an operational analysis aid over the data sparse regions of eastern Antarctica. Finally, the model 400 mb analysis is compared qualitatively to the National Meteorological Center and Fleet Numerical Oceanography Center 500 mb analyses for the same times.

The model developed in the study shows some promise of improving the operational Naval Support Force Antarctica circulation analyses in data poor areas.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENT

The author wishes to express his heartfelt thanks to the many people who assisted him in this endeavor. To my wife, Pat, and family for their patience and understanding during the long hours involved in this project, I say thank you. To Professor Robert J. Renard, without whose encouragement and guidance this project would have died as an idea, thank you.

Special thanks are extended to Mr. Dennis Mar and Ms. Kristina Butler at the NPS computer center for their patience and assistance during my learning how to manage, manipulate and edit large data files.

Appreciation is also extended to Mr. B. Wallace at the Naval Oceanography Command Detachment, Asheville, N.C. for furnishing upper-air observations used in this project, and to Mr. M. McDermet for his assistance on the technical details, and also to Dr. C. Wash for his comments and suggestions on the text.

I. INTRODUCTION

The use of NAVY long range heavy transport aircraft by Naval Support Force Antarctica (NSFA) in support of the United States Antarctic Research Program (USARP) research field parties, and in the annual resupply of permanent U.S. stations, requires a large number of flight hours each year (approximately 7000) over Antarctica. Most of the time, continental weather is benign both enroute and at destination. However, when an oceanic cyclone moves toward the coast and its circulation system enters the continent, rapid deterioration of weather conditions can occur. The surface conditions at field camps can become hazardous in minutes. Enroute flight level winds (400 mb), which are normally light due to the proximity of the polar vortex, can become very strong. If there are unforecast adverse flight winds, fuel considerations can lead to mission aborts, and a waste of limited flight hours. Under extreme conditions, unscheduled refuelling at Amundsen-Scott (South Pole) station may be required. This is highly undesirable because every gallon used that was not preprogrammed to be used for refuelling must be replaced before the winter-over period. Extra fuel flights to South Pole station put a strain on already over committed flight hours and crews.

A quantitative model describing the 400 mb geopotential height structure of maritime cyclone circulation systems, and their attendent cloud signatures moving onto the Antarctic continent would be a major step in improving the synoptic analysis and forecasting at the aircraft flight level. A better understanding of the 400 mb height structure would improve the enroute flight level wind forecast, as well as the surface wind forecast because 400 mb is a good approximation of the steering flow for surface cyclones.

Operationally, a better 400 mb analysis would reduce the frequency of underforecast flight winds, thereby improving the cargo transport efficiency of the NSFA LC-130 aircraft, and also improve the forecast timing of deteriorating surface weather conditions, thus reducing the loss of "in the field" time by research parties. Thus, the purpose of this project is,

1. to establish if the extensive and organized weather satellite-observed cloud shields over eastern Antarctica in spring and summer are associated with a common geopotential height pattern at one or more constant pressure levels, and further
2. to quantify the modelled height pattern in order to assist operational forecasters in their analysis of the atmospheric circulation at the LC-130 aircraft flight level, generally near 400 mb.

II. BACKGROUND

A. GEOGRAPHY AND CLIMATOLOGY

Of the 14.2 million square kilometers (5.5 million square miles) in Antarctica, over 95% is snow and ice covered. This continental area equals 1.5 times that of the U.S. The geography of Antarctica is one of dull monotony interspersed with narrow regions of wild extremes. Over half of the continent lies at elevations greater than 2000m, and 25% above 3000m (Fig. 1). The high plateau of East Antarctica, with slopes less than 1/1000, is a featureless ice cap varying from 1000m to more than 3000m thick. Within 100 km of the coastline, a steep escarpment, with slopes as large as 1/7, reaches down to the sea. Steep glacial valleys are especially prevalent along the coast east of 90° E.

The climatology of the plateau region is distinct from that of the coastal regions. In general, the plateau is characterized by clear skies, cold temperatures and light winds. This prevailing condition is interrupted by short periods of strong winds, obscured skies and near zero visibility when the circulation system of a near-continent maritime cyclone moves onto the plateau.

The coastal regions have a much higher incidence of cloudiness, snowfall and warmer temperatures. Winds at the coast are katabatic in nature, being the result of gravity controlled flow moving down the steep coastal slopes. These prevailing conditions are frequently interrupted by the approach of maritime cyclones. The World Survey of Climatology, Vol. 14, (Schwerdtfeger, 1970) has an excellent detailed account of Antarctic climatology.

B. OPERATIONAL CONSIDERATIONS

Upper-air observing stations used in this project are listed in Table I and their locations are shown in Fig. 1. Vostok and Amundsen-Scott (South Pole) are the only plateau stations continuously manned.

NSFA acts as the logistics support force for the USARP, which includes weather observing, reporting and forecasting services for the science and supply efforts. NSFA maintains a full time weather office manned by Navy personnel. Poor conventional data coverage makes most subjective analysis and forecast techniques ineffective. Weather forecasters for NSFA have resorted to polar orbiting meteorological satellites (metsat) almost exclusively for information on the current state of the atmosphere in and around Antarctica. The hazards to life due to the severe weather in Antarctica add to the importance of reliable, accurate and timely weather forecasts. The sparsity of routine weather observations and useful numerical guidance compound the problems facing an operational forecaster.

1. Meteorlogical Satellite Uses

Mid-tropospheric wind directions are related to the streaking, banding and curvature of high clouds in the metsat imagery. However, determination of mid-tropospheric wind speed, and of surface wind speed and direction can be quantitatively estimated only from cloud movement in successive metsat pictures. This is effectively done in low and mid-latitudes from sequences of consecutive geostationary metsat images. The main USARP base at McMurdo Station at 78° S is so near the pole that all orbits of a polar orbiting metsat can be received as it passes over the near polar region. Resolution problems caused by the limb-of-the-earth, make geostationary metsats of little use in high latitudes. Therefore, stations in the polar regions must rely on polar orbiting metsats. Image time loops are not possible utilizing polar orbiting metsats because any position on the continent is only covered by three sequential satellite passes twice each day. Only the satellite orbit passing nearly over the point can provide accurate information on cloud location. The other two passes will be near the edge of the picture where cloud element resolution and gridding are poor. Perspective errors, which are caused by the earth's curvature and which increase away from the satellite subpoint track, and gridding errors combine to make tracking of individual cloud elements too imprecise for making mid-tropospheric wind speed or near-surface wind speed and direction estimates from polar orbiting metsats. These wind parameters are of critical importance to the NSFA heavy transport aircraft (LC 130) and field party research operations.

While polar orbiting metsats are of little use in tracking cloud elements, they do provide excellent qualitative information on synoptic-scale features. Some cloud mass signatures do correspond to synoptically significant surface features such as cyclones, trough lines, ridgelines, etc., and to upper-air features like closed circulations, jet stream axes, ridge axes, etc. Until recently, interpretation of synoptic features from cloud signatures has been the primary interest of satellite meteorologists. Volumes have been written on metsat cloud pattern interpretation tc reclaim parameters of operational interest from the metsat images (Fett et al, 1979 and Weldon, 1975). Thus, visual and infrared metsat imagery provide the working basis for NSFA forecasters to support aviation and research operations in Antarctica.

C. SYNOPTIC ANALYSIS

Mid-latitude forecasters rely heavily on synoptic observations or numerical guidance to determine the intensity of surface and upper-air features. Antarctic forecasters do not have numerical guidance routinely available to them due to the large data volumes necessary to digitally transmit fields or charts, and the historically poor facsimile transmission conditions to the continent. In addition, until very recently, numerical guidance for the high southern latitudes was not usable (Trenberth, 1979). The observational network is at best sparse, and communications difficulties lower the available data at any synoptic time. Thus, the intensity of synoptic features in the high southern latitudes remain virtual estimates. Presentations by Guymer and LeMarshall (1980) of sea-level pressure analysis in the Southern Hemisphere during the lifetime of several hundred drifting bouys, released for the First GARP Global Experiment (FGGE) in 1979-80, showed that analyses prior to the bouy deployments tended to overestimate the central pressure of maritime cyclones by 40 to 50 mb.

1. Cyclone Models Based on Cloud Patterns

Several non-quantitative methods of describing various states in the cyclone life cycle from metsat imagery exist. Sherr and Rogers (1965) and Widger et al (1967) determined that mid-latitude cyclones are initiated in four basic ways observable from metsat imagery:

1. bulges in a pre-existing frontal band without an approaching vorticity maximum aloft,

2. a frontal band bulge with a vorticity maximum aloft,

3. a vorticity maximum aloft with no apparent frontal zone,

4. from a narrow cloud band in the northern and northeastern sectors of an upper level cut off low in the Northern Hemisphere.

Chang and Sherr (1969) then extended the cloud pattern models from the cyclogenesis initiation categories through the development, maturation and dissipation stages of the cyclone life cycle. Research continued to refine the cloud pattern classification techniques, and to relate specific synoptic features to associated cloud patterns. By the mid 1970's, pressure from operational forecasters and numerical modellers caused an attempt to be made to develop a system, similar to the Dvorak technique, to correlate extratropical cyclone development and surface winds. Junker and Haller (1980) noted that this effort to relate surface wind speeds to cloud patterns in extratropical cyclones failed. However, this work motivated them to propose a model relating cyclone cloud patterns to the lowest observed sea-level pressure; thus inferring a synoptic scale horizontal wind speed profile by specifying the geostrophic pressure gradient. This model showed some promise in improving the pressure gradients in oceanic cyclones, but is restricted to the winter northeast Pacific Ocean region.

Nagle and Hayden (1971) developed a model statistically relating cloud vortices and cyclonic relative vorticity. This approach separates the 500 mb geopotential height field into long- and short-wave components. The short-wave component (perturbation) is shown to be related to the 500 mb relative vorticity field, and several cloud patterns were correlated to relative vorticity field patterns. Modification of the perturbation field then can be made based on specific cloud signatures. The total 500 mb height field is then formed by recombining the short- and long-wave fields.

In the early 1970's, operational forecasters and researchers in Australia began a program to infer quantitatively, from metsat imagery, parameters which could be used as inputs to their numerical models. The vast data void areas of the Southern Oceans made optimal use of metsat data imperative if any improvements in forecasting were to be made.

Martin (1968) developed a cyclone classification technique and empirically related representative profiles of temperature, wind and moisture for each stage of cyclone development. These "pseudo-soundings" appeared to be statistically significant in improving the World Meteorological Center Melbourne Southern Hemisphere analyses of the surface and upper air. Zillman and Price (1972) tested the pseudo-temperature profiles and NIMBUS III SIRS profiles against an independent sample of radiosonde data. It was found that with well defined cloud patterns, the pseudo soundings could be used as a supplementary analysis aid. Next, they extended the method to provide a representative thickness pattern and thermal structure in the model cyclone. The thickness pattern concept was to be the basis for the input of derived metsat imagery values into an operational numerical model. It has since become known as the Australian bogus method.

Troup and Streten (1972) and Streten and Kellas (1972), in addition to those researchers already mentioned, were deeply involved in the development of the Australian bogus model. The culmination of the Australian effort to develop formal procedures to quantify the thermal and dynamic structure of Southern Ocean mid-latitude oceanic cyclones was published by Guymer (1978).

The Australian bogus model uses satellite imagery interpretation by highly skilled analysts, to produce manual analyses of the MSL pressure pattern and the 1000-500 mb thickness pattern. Cloud signatures are thus used to bogus the first-guess fields for the next forecast run. The analysis procedure is based on recognizing a basic cloud signature, quantifying the concomitant vertical shear, and thus estimating the 1000-500 mb thickness anomaly. There are several disadvantages in this procedure. First, there is the requirement for highly skilled and experienced analysts who are familiar with the cloud patterns and cyclone development patterns, thus making the approach quite subjective.

Military forecasters with NSFA have a three-year tour of duty, making their Southern Hemisphere experience level fairly low, and the Australian approach would be difficult for NSFA to use. Second, the procedure assumes that either the 1000 mb or the 500 mb constant pressure surface can be sufficiently well defined to give meaning to the layer thickness anomaly as a meteorological parameter. This is by no means an easy feat over the data void oceanic regions, or even over the Antarctic continent. Third, the model assumes that the long term climatological means for sea level and the 500 mb surface are known, and that a reasonably accurate anomaly value can thus be formed. Despite these disadvantages, the Australian bogus model was a landmark development to Southern Hemisphere analysts and forecasters. It also provided a starting point and focus for this project.

Efforts have been made to reduce the subjectivity of the Australian model by incorporation of vertical temperature profile retrievals (VTPR) (Kelley 1978) into the thickness pattern procedure. The satellite interpretation procedure outlined above then is used as a quality control method for the VTPR data, before it is used in an objective analysis routine to initialize the next forecast cycle.

As developed, the Australian technique applies only to the mid-latitude oceanic cyclones of the Southern Hemisphere. One of the objectives of this project is to determine if the technique is also meaningful in the high southern latitudes.

The basic qualitative satellite interpretation techniques to delineate synoptic-scale features are critical to Antarctic weather forecasting. No quantitative models yet exist for situations where oceanic cyclonic circulation systems, usually in the mature or decaying states, move onto the continent. The Junker and Haller model (1980) is limited to the eastern part of the North Pacific Ocean, and insufficient observational data exists to determine if it could be successfully applied to the Antarctic. The Nagle and Hayden mode (1971) assumes that the long wave component of the forecast 500 mb field is accurate; a poor assumption over the data void Southern Ocean. Extension of the Australian model to Antarctica is impractical because of the continental topography. The height of the continent makes 500 mb the lowest standard level common to the entire continent. In some areas of eastern Antarctica, the 500 mb surface is within a few thousand feet of the ice covered surface. Thus the Australian work correlating MSL pressure patterns and 1000-500 mb thickness anomalies to cloud signatures is not of value over the continent. A simple change of levels, i.e., to use the 500-200 mb layer thickness values, is impractical because the observation density is too low to provide an accurate analysis of either the 500 mb or the 200 mb surfaces. Without an accurate analysis of either level, a thickness anomaly pattern is of little value.

III. DATA SOURCE AND PROCESSING OF DATA

A. OBSERVATIONAL DATA

The primary observational data sources are the upper air observations furnished by the Naval Oceanography Command Detachment, Asheville, N.C. from the archives of the colocated National Climatic Center (NCC), and the plotted observations from the 400 mb charts subjectively analyzed by NSFA meteorologists. Initial data checks of the NCC archived data revealed a data count lower than that expected considering scheduled radiosonde observations. Specifically, a comparison of NCC archived 400 mb observations with the plotted 400 mb NSFA charts shows that the NCC data archives are missing about 30% of the observations available to NSFA. The NCC data files were manually edited to add to the NSFA data.

The data disparity between the NCC archives and NSFA charts is most probably due to the low reliability of long distance high frequency radio communications. The observations from Antarctic stations are transmitted to other continental stations via an Antarctic communications net. Weather message delivery on this net may involve relay by one or more other Antarctic stations. Thus, poor transmitting conditions can be overcome by multiple relays. However, each station independently enters its weather observations into the Global Telecommunications System (GTS) of the World Weather Watch via regional collection centers in New Zealand, Australia, Argentina, or South Africa, or through their own national weather communications network. This method has no transmission redundancy to overcome poor long range communications conditions, and probably accounts for the data disparity.

B. REMOTE SENSING OBSERVATIONS

Heights of the 400 mb surface recovered from the vertical temperature profile retrieval (VTPR) system for NIMBUS VI were obtained from FNOC for the period September through December 1976. A representative sample of the 1976 retrievals are plotted in Fig. 2. They were found to be both unusable as height values or as indicators of the height gradient field. Retrievals of the VTPR soundings from TIROS N by FNOC, after December 1978, did not include the 400 mb surface, and could not be analyzed. However, the 500 mb retrievals by NMC in Test Case I (Section IV, D) did show a major improvement in the utility of VTPR as compared to those from NIMBUS VI.

The inaccuracies of VTPR soundings as data sources can possibly be attributed to the lack of a reasonably accurate surface temperature analysis from which the vertical profiles are calculated. The strong surface inversions which prevail over the snow and ice covered continent, strong gradients at the sea-ice edge and again at the steep coastal escarpment, and the lack of reporting stations combine to make accurate surface temperature analyses nearly impossible. The errors associated with imperfectly known weighting functions in the radiative transfer equation and the smoothing of the profile due to the volumetric nature of the temperature sounding technique also contribute to the VTPR inaccuracies. The 400 mb heights obtained from VTPR soundings were not used in this project.

C. CLIMATOLOGICAL DATA

The 400 mb climatological height, $\bar{z}$, is of primary importance to the computation of the 400 mb height anomaly, z', used in the compositing technique, as it was used to reduce each observed height, z_{ob}, by

$$z' = z_{ob} - \bar{z} \tag{1}$$

Because the 400 mb height climatology was not directly computed by Taljaard et al (1969), it was linearly interpolated from the climatological 500 mb and 300 mb (or 200 mb) levels plotted on a Skew T-Log P diagram. When the derived climatological heights were subtracted from the observations (z_{ob}) in January and February 1978, positive anomalies appeared over the entire continent. Several factors appeared to have interacted to cause the climatological heights to be too low. These factors are discussed below.

The use of linear interpolation tends to yield lower heights when approximating the logarithmic decrease of pressure with height. For the months of January and October, Taljaard et al (1969) provides climatological heights for the 500 mb and 300 mb levels. Interpolation for the 400 mb surface between these levels is considered to be reasonably accurate. However, for February, November and December, the climatological source computed only the 500 mb and 200 mb heights. A linear interpolation between these two surfaces could yield large errors. To assess the error, a linear interpolation for 400 mb, using the 500 mb and 200 mb height was made for January and October. The height difference between the 500-200 mb interpolation and the 500-300 mb interpolation for January was assumed to be applicable to the other summer months of December and February. The difference was applied to the station 400 mb climatology in order to adjust for interpolation biases. November is considered to be a transition month from the late winter month of October to the summer month of December. As a result, the interpolation biases for October and January were averaged before being applied to each station's climatological 400 mb heights in November. The interpolation adjustment factors ranged from as much as 8 dkm in October to 2 dkm in January.

Trenberth (1979) found that there has been an increasing height trend at Amundsen-Scott (South Pole) station since

1958, amounting to a total increase of 232 m at the 500 mb level. Because of this trend, Trenberth recomputed a 500 mb climatology for the Southern Hemisphere based on the period May 1972-January 1978. His computations show that 500 mb heights throughout much of the hemisphere are higher than those of Taljaard et al (1169). Trenberth then computed zonal mean height differences for each month of the year between his and Taljaard's climatology. Table II shows the difference between the two zonally averaged climatologies over the latitudes of interest. Because of the fact that eastern Antarctic stations are the only stations in that latitude zone, the zonally averaged trends are assumed to be representative of the trends at each station. The height difference between the two climatologies was used to adjust the individual station 400 mb height monthly climatology. The monthly zonal trend was applied to all stations within 2.5° latitude of the zone, e.g., the 70° S trend adjustment was applied to stations between 67.5° S and 72.5° S.

The use of the 500 mb height trend adjustment at 400 mb is considered to be justified and conservative in approach. When the interpolated 400 mb monthly height climatology, adjusted for trends, was used for the same dates in January-February 1978 that were tested earlier, negative anomalies appeared in the polar vortex and other closed cyclonic circulations, as would be expected.

IV. MODEL DESCRIPTION

A. BACKGROUND

It is well established that mid-latitude developing baroclinic waves in the middle/high troposphere are associated with a synoptic-scale warm ridge aloft downstream from the cyclonic vorticity center. This ridge is characterized by an extensive reasonably smooth appearing cloud shield predominately composed of cirrus overriding multi-layered warm frontal type clouds. As the cyclone progresses through its life cycle, the upper air trough-ridge system also develops, forming a closed low aloft as the surface low becomes cold core.

The work done by several Australian researchers in developing their bogus model demonstrates that there is little difference between Northern and Southern Hemisphere mid-latitude cyclone development. Nothing has been published on the cyclone life cycle after it encounters the Antarctic continent. Mechoso (1980) shows in a linearized shallow hydrostatic model that baroclinic waves migrating from middle latitudes can interact with the topography of Antarctica (and the resulting horizontal thermal gradients along the steep coastal regions) to generate jetlike westerlies over the coastal slopes. He concludes that the region around

Antarctica is not a region which damps out all baroclinic wave activity. Instead, it is baroclinically active, and is a local source of cyclogenesis. Test Case II (Section E) is an example of such cyclogenesis. Lysakov (1978) has shown that mean air motion is directed off the eastern plateau. This accounts for prevailing subsidence and clear skies. The cloudiness associated with coastal circulation centers penetrates the continent quite routinely during the summer months, indicating convergence, and moisture and thermal advection onto the continent. However, only once or twice each summer season do identifiable cyclonic circulations centers move onto the high plateau of eastern Antarctica.

B. COMPOSITING PROCEDURE

Visual and infrared strip photographs from the NOAA 5 and TIROS N metsats were manually processed to identify a cloud mass signature representing moist warm-air advection penetrating the east Antarctic plateau. Only the austral summer months of October through February were considered for the years 1976-77, 1977-78 and 1979-80. The cloud mass was required to extend at least 300 n mi (560 km) into the continent, exist for at least 12 hours, and be associated with an identifiable cyclonic circulation center off shore.

The requirements on extent and time were designed to restrict the sample to vigorous moisture advection associated with sustained meridional flow, that is strong enough to generate significant clouds along the steep coastal regions and over the plateau. The remaining requirement was instituted to reject from consideration unorganized and irregular cloud masses which remain as transitory features on the plateau after the cessation of meridional moisture advection.

Lack of a sufficiently dense network of conventional upper-air observations in Antarctica necessitated the use of a compositing technique to obtain an adequate amount of data to describe the large scale circulation in the vicinity of cloud intrusions into east Antarctica. A rectangular compositing grid was placed over the cloud signature. The grid, moving with the cloud mass, was fixed to an identifiable cloud feature and oriented such that the longitudinal axis of the grid was due south. A three degree (180 n mi, 336 km) square mesh was used along with a total compositing grid rectangle 2700km by 2400km. This size was chosen as representative of synoptic scale systems and the associated horizontal scale for numerical models.

As an objective identification of the cloud signature, a compositing point was chosen such that the moving grid would be placed consistently in the same relative position with respect to the cloud mass. Specifically, a compositing point was chosen which is considered to be reproducible for any cloud mass, and which is objectively determinable from the satellite imagery brightness, contrast or some other objective measure. The point chosen was at the most poleward extent of the continuous high cloud mass associated with a cyclonic circulation off shore. This point is assumed to coincide with the middle/high troposphere ridgeline, and to lie near the ridge axis for both broad and sharp ridges. Sharp ridges which from striations in the high clouds appear to be strongly tilted relative to the meridian ($\geq$ about 60° upstream) were assumed not to be nearly meridional, and were rejected from the compositing base. This type of compositing point was chosen because it is easily reproduced and can be found objectively by the strong contrast at the poleward side of the cloud edge.

The reproduction of the metsat pictures in Figs. 6 a-d and Figs. 13 a-c, tends to reduce the grey shade contrast. Thus, it may appear that the location of the compositing point is unclear or arbitrary. NSFA metsat interpreters have much higher quality imagery with which to work. In addition, they are quite accustomed to working with the subtle grey shading of clouds over ice, and the detection of the most poleward edge of the continuous cloud mass would be relatively simple.

Satellite imagery coverage, being asynoptic in nature, required that the compositing points chosen be linearly interpolated to the nearest synoptic time (Fig. 4). Due to operational and research constraints, Antarctic upper-air observing stations may take their soundings up to two hours off synoptic time. These observations were treated as though they were taken at synoptic time.

All continental upper air observations coinciding with the compositing point times determined by the metsat imagery were tested to determine if they were located in the compositing grid; if so, their grid box coordinates were determined. Any observation falling within each three-degree compositing box was treated equally and assigned to the center of the box. The adjusted 400 mb climatological height for the appropriate month was subtracted from the observed 400 mb height to form a height anomaly. The anomaly values in each grid box were then averaged. Use of the height anomalies adjusts observed height values for monthly and seasonal trends. Thus, occurrences from all spring and summer months were combined. The composited average 400 mb height anomaly, from the 15 months considered, and the individual anomalies were used to compute the standard deviation of each compositing box. The average 400 mb anomaly for each compositing grid box was then recomputed with the constraint that all height anomaly values beyond two standard deviations from the original average were rejected. This final statistical processing was performed to remove any highly anomalous height observations. The adjusted height anomaly field composited from the 15 month period considered is shown in Fig. 5; its analysis readily allows interpolation to any point in the grid.

C. MODEL CHARACTERISTICS

The cloud signature to which the model was applied is illustrated schematically in Fig. 3. It is the hypothesis of this study that the particular cloud signature will correspond to a warm mid-tropospheric moist-air ridge ahead of the upper-air trough associated with the surface cyclonic circulation. Positive height anomalies will occur along the ridge in the compositing grid, with lower positive and/or negative anomalies on either side of it.

While the anomaly pattern in Fig. 5 generally agrees with the expected pattern, it is not as uniform nor simplistic as proposed. There are exceptions to the assumed meridionally oriented ridgeline. The trough, exemplified by negative height anomalies downstream of the ridge is readily apparent. The upstream trough associated with the off-shore circulation appears only as a decreasing trend in the height anomalies in the northwest corner of the grid. The positive height anomaly, corresponding to the ridgeline, is oriented southwest-northeast and is quite strong. From the location of the positive anomaly, the compositing point, as chosen, was located 300 n mi (500 km) downstream of the ridgeline, rather than on or near it as was assumed. The upstream tilt to the ridge is indicative of an intensifying system. In 19 of the 40 cases compiled, the cloud mass compositing point actually moved west; in addition, the tendency for the cloud mass to remain over the continent for periods of days seems to imply a typical synoptic blocking situation. Over half of the occurences lasted for more than three days, with the longest cloud signature being maintained for six days. The upstream tilt, long duration and westward migration of the cloud signature lends credence to the theory that this cloud pattern only enters the continental region under conditions of sustained strong meridional flow aloft.

The height anomaly pattern in Fig. 5 still appears to be biased to positive values. From the Australian model and experience, the zero anomaly contour should separate a large negative region in the southeast portion of the grid from the positive region in the northwest. Despite much effort to adjust the published climatology, it appears that there is still a +6 to +12 dkm bias in the composited field because the +12 contour divides the negative region in the upper left from the more positive region in the lower right of the grid.

D. TEST CASE I -- 1200 GMT 8 JANUARY 1980 (DEPENDENT CASE)

This date was chosen because of a major synoptic analysis change that occurred at 0000 GMT 9 January 1980, when the report for Vostok station (89606) was received for the first time in several days. Metsat imagery at 1200 GMT 8 January revealed a cloud mass of the type being studied, and the successful application of the model should reveal a closed center ridge on the continent. Figs. 6 a-d are representative of the imagery used from 7 to 9 January 1980. The point CP denotes the compositing point chosen. Although the required circulation center near the coast is not evident in Fig. 6b, a large oceanic cyclone is present just off the east edge of the picture. The compositing point chosen for 1200 GMT 8 January was chosen at 76.0° S 119.0° E, and is shown in Fig. 6b.

The adjusted 400 mb climatological heights for the stations used in this project are plotted and analyzed in Fig. 7. This analysis used the 500 mb climatology from Trenberth (1980) as an aid in providing vertical consistency, and the 500 mb and 300 mb winds from Taljaard et al (1969) as guides in establishing cols and gradients. It is suspected that the very broad trough over the continent from 0° E to 60° E has more structure than shown, but without observational data no attempt was made to depict it. The compositing grid was then positioned over the compositing point on the climatological analysis (as in Fig. 7), and the mean height value for each grid box was interpolated from the analysis. These grid values were then added to the model anomaly grid values from Fig. 5 to form the estimated (i.e., modelled) 400 mb height field (Fig. 8a) for 1200 GMT 8

January 1980. Hopefully, the model January height field is representative of the observed 400 mb height field associated with the cloud signature under study.

Fig. 8b is a 400 mb contour analysis for 1200 GMT utilizing the model height field (Fig. 8a) as modified by radiosonde observations, aircraft reports, and using the previous NSFA analysis for history. The observational data required some adjustment of the model heights, but the model still forced a closed center high with a southwest-northeast ridge between 90° E and 120° E, and a trough along 140° E into the analysis.

Objective 500 mb and sea-level analyses for 1200 GMT 8 January are presented in Figs. 10 and 11. Figs.9a and 9b are the NSFA operational analyses for 400 mb and sea-level at 1200 GMT 8 January. It is to be noted that station 89606 (Vostok) did not report at this time, and as a result, no intelligent analysis could be made over much of eastern Antarctica from 90° E to 180. Aircraft reports along 170° E were not well represented in the analysis. In the absence of reliable radiosonde observations, the 400 mb heights computed from aircraft reports apparently were less important to the analyst than maintaining continuity. Also. Vostok, Davis, and D'Urville stations (89606, 89611, 95502) had failed to report over the previous 36 hours.

An extensive ridge, such as the one in the model (Fig. 8b), would yield an enroute wind forecast for any aircraft flight to the plateau significantly different than a forecast from the NSFA analysis. The modified model trough along 140° E, could be expected to intensify and dig back toward 120° E through a diffluent trough mechanism. This trough also lends upper-air support to the NSFA analyzed sea-level frontal system arcing toward 150° E along the coast (Fig. 9b). With the suspected intensification of the trough aloft, surface frontal regeneration or cyclogenesis can be expected. The increasing heights downstream of the trough shown in Fig. 8a, better fits the aircraft winds and heights reported along 170° E.

When compared with the NSFA analysis for the same time, the model 400 mb field shows a major difference in location, orientation and intensity of synoptic features. Moreover, the differences imply possible radical forecast changes for aircraft and surface operations. But, is this analysis model accurate and reliable? Figs. 9c and d are the NSFA analyses of the 400 mb and surface pressure for 0000 GMT 9 January 1980. Vostok station has reported, and because of that report, a 690 dkm closed center high and east-west oriented ridge is analyzed over the plateau, nearly in the same position and of the same intensity as that depicted by the model analysis 12 hours earlier.

Although there is no trough near 140° E in Fig. 9c, a 976 mb occluded low is analyzed at the surface near 150° E with no upper air support to account for the intensification. It is expected that some form of upper-air support was required for the surface intensification. Apparently, the NSFA analysis was deficient for that feature.

The FNOC 500 mb analysis for 1200 GMT 8 January (Fig. 10a) carries the same major features as the model analysis. An east-west oriented ridge ahead of a deep low (4985 m) near 60° S 110° E is reflected in the model analysis (Fig. 8b). The model trough along 140° E is not analyzed, but the FNOC 0000 GMT 9 January 500 mb chart (not shown) analyzes a weak shortwave trough from 58° S 145° E to 65° S 130° E. Fig. 11, the NMC 1200 GMT 8 January analysis for 500 mb, carries an open trough (5160m) near 60° S 100° E, accompanied by a meridional ridge into Antarctica along 140° E, and a separate cut off high center (5160m) near 75° S 70° E. The NMC analysis of circulation features differs appreciably from FNOC in magnitude and orientation. Height retrievals from TIROS N provides a dense network of 500 mb heights that appear to be of much greater value to the NMC analysis than the retrievals from NIMBUS VI mentioned earlier. Either of the analyses from the numerical centers would be a major input to analysis at NSFA. Unfortunately, as of this writing, communications difficulties preclude routine receipt of either of the analyses in an operationally meaningful timeframe.

This case was one of the 40 cases used in the compositing of the 400 mb anomaly field. The model analysis reflects the analyses by FNOC and NMC better than the NSFA analysis, and since the numerical centers had better conventional data coverage during the previous 36 hours, than NSFA, the model would improve the NSFA analysis. Where observational data are available to adjust the values of some of the model height contours, as in this case, the geostrophic wind gradients are quite reasonable being 30 kt (15 m/s) at points A and B in Fig. 8b. Thus, the model appears to be a promising analysis aid for eastern Antarctica, and by revealing features which may be missed due to missing observations, it appears to be a useful forecasting aid as well.

E. TEST CASE II -- 1200 GMT 18 FEBRUARY 1979 (INDEPENDENT CASE)

This case was chosen because of the rapid development of a maritime cyclone along coastal Antarctica, the strong almost classical cloud shield development and its movement westward into the continent. None of the austral summer months in 1978-79 were used in developing the composited anomaly field so that an independent test of the model could be made. The use of February was mandated by the lack of a

U.S. polar orbiting metsat until December 1978, and missing NSFA 400 mb analyses for December 1978 and January 1979. The use of the February time frame is less instructive because the redeployment of USARP personnel to New Zealand and the refuelling of Amundsen-Scott and Siple Stations for the winter-over period take operational priority. Consequently, the NSFA analysis in areas not involved in these activities does not get the attention and care common during the height of the operation season.

Adjusted February climatological 400 mb height values for Antarctic stations are plotted and analyzed in Fig. 12, with the compositing grid oriented as shown. Figs. 13 a-c are the TIROS N metsat imagery for the time frames under study. The point CP denotes the compositing point in the image. Note that in infrared imagery the ice covered continent appears white, with low clouds being dark, and with higher (colder) clouds shading towards white. High clouds cannot be detected over the continent from infrared imagery unless there are low clouds under them. A compositing point for 1200 GMT 1800 February 1979 at 81.7° S 64° E was chosen by interpolation from the asynoptic metsat imagery times. The same procedure was used to produce a model mean 400 mb height field (Fig. 14a) as was described in the dependent Test Case I. In this case there is little difficulty in determining that there is a cyclonic circulation center near the coast. (Refer to Figs. 13 b and c.)

In the absence of observational data to modify the model analysis (Fig. 14a), the model was applied directly to produce Fig. 14b. This analysis differs considerably from the NSFA analysis (Fig. 15a). The model analysis carries a closed low center (672 dkm), L1, near 66° S 35° E, a general troughing from a low center (654 dkm) near 82° S 115° E northward over much of eastern Antarctica, and a strong ridge (690 dkm) from 77° S 60° E northeastward to the coast near 70° S 0°. In general, the model analysis appears too busy, with numerous weak low centers. No smoothing of the model field was performed because it is felt that the forecaster in the field should have all possible information from which to choose the data he desires to use in his analysis. The low center near 65° S 60° E is reflected in the cyclonically curved low clouds visible in the metsat imagery, and in the history of a strong occluded low there 24 hours previously. The presence of a cold core low aloft over a dissipating low pressure surface center is probable. The general troughing over the continent between 90° E and 120° E is reflected by the clear skies (white) east of the cloud edge. Of interest is how the southwest-northeast oriented positive height anomaly field interacts with the climatological field to produce a trough in the northeast portion of the height anomaly grid.

The NSFA 400 mb 1200 GMT 18 February 1979 analysis (Fig. 15a) carries a single open low center near 72° S 60° E with troughs extending to the northwest and northeast. Little structure is evident in the analysis. The FNOC 500 mb analysis for the same time (Fig. 16a) shows a closed low (5002 m) near 60° S 30° E, a closed low (5002 m) near 70° S 90° E with general troughing across the pole and a 5130 m high center near 76° S 45° E with a ridge extending northeastward. By 0000 GMT 19 February 1979 (Fig. 16b) this ridge cuts off to a closed center, with new ridging building into the continent from the northwest. The trough along 90° E also intensifies. The NMC 1200 GMT 18 February 500 mb analysis (Fig. 17a) is quite different from either the FNOC or model analysis. It resembles the NSFA analysis with the addition of a closed low center along 90° E. By 0000 GMT 19 February, the NMC analysis (not shown) has changed little, except for increased troughing over all of eastern Antarctica. The 0000 GMT 19 February 400 mb NSFA analysis (Fig. 15b) has changed appreciably as the addition of several observations revealed a broad trough (poorly analyzed) oriented along 90° E. The trough apparently has unanalyzed low centers near 80° S and 70° S on 90° E. The trough formerly near 68° S 70° E, has either been dropped or moved 900 n mi east in 12 hours. A new closed center (660 dkm) has appeared near 69° S 40° E. All other features have been advected from the previous analysis.

A comparison of the model analysis and the 0000 GMT 19 February NSFA analysis reveals at least a semblance of continuity. The model low, L1, and trough along 90° E supports the NSFA low near 69° S 40° E, and trough in the same location respectively. The model trough in the westerlies along 85° E supports the NSFA trough along 100° E (300 n mi in 12 hours). In this case, the model analysis is quite similar to the FNOC analysis in the location of major synoptic features. However, the ridging orientation is different, and this difference could lead to a different enroute wind forecast for any flight into eastern Antarctica. The orientation difference is resolved by 0000 GMT 19 February. The NMC analysis does not resemble the model analysis except for the trough along 90° E. When the model height field is used without the benefit of modifications by observational data, as in this case, the model induces very strong gradients. In Fig. 15b, geostrophic wind values of 50 kt (25 m/s), 100 kt (50 m/s) and 50 kt (25 m/s) were computed for points A, B and C respectively. These values are higher than commonly thought to exist in the near-pole regions. Mechoso (1980), in simulations of the zonal and meridional winds over Antarctica, shows maximum wind speeds on the order of 40 kt (20 m/s). Flight level winds reported by Navy aircraft at 24,000 ft (400 mb) over western Antarctica were up to 80 kts in a sharp ridge during November 1978.

This case is not as clearly verified against the NSFA analysis as Case I. However, the model does verify well with the FNOC analysis and does identify at least two synoptic features missing from the NSFA 1200 GMT 18 February 1979 analysis which appeared suddenly on the next analysis. The missed features are synoptically significant. The model analysis does appear to provide a valuable aid in analysis where observational data are missing completely.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

A height anomaly model is critically dependent on the climatological values, z, used to form the height anomaly, z'. Fig. 5 reflects the inaccuracies involved in the interpolation of the 400 mb station climatology from published values. The +6 to +12 dkm bias discussed earlier reasonably could be expected to result in the quantitative values in the ridges (troughs) being too positive (not negative). The geostrophic winds calculated for Test Case I appeared to be reasonable, while for Test Case II the model gradients imposed very strong geostrophic winds over the continent. Winds of 50-100 kt (25-50 m/s) are not common in Antarctica, but they do occur. Smoothing of the model analysis field by the operational forecaster would help to portray wind speeds that are more indicative of the conditions at the time. Thus, local effects and seasonal tendencies could be added by the operational forecaster.

Comparison of the NMC, FNOC and NSFA analyses for cases I and II demonstrates that there is considerable variability among the analysis centers in defining the circulation in the high southern latitudes. The inclusion of useful VTPR soundings from the NOAA 6 (TIROS N) series of metsats into the NMC analysis seemed to bring the analyses from the numerical centers into agreement after December 1978. The model analysis for both cases delineated significant 400 mb height pattern features based solely on metsat imagery cloud signatures. The features were operationally significant, and were not depicted by the NSFA analysts. Also, the model analysis was qualitatively equal to the numerical center analyses presented. Until the numerical center analyses become operationally available to NSFA, this model appears to provide a viable analysis aid to the operational analyst/forecaster in Antarctica.

B. RECOMMENDATIONS

The following recommendations are made regarding future studies in this area:

1. Determine if the broad range of cloud signatures considered in this study can be stratified by month, or categorized into subgroups with common height pattern anomalies that are substantially different.

2. Investigate the current model anomaly patterns for usefulness in west Antarctica where the bulk of USARP research operations take place. A major problem in this area is the lack of any upper-air reporting stations. Instead, numerous aircraft wind reports will need to be correlated with metsat imagery.

3. Attempt to automate the scheme developed here by using the strong brightness contrast at the cloud edge as a method of establishing the compositing point around which the model height field can be built.

APPENDIX A

TABLES AND FIGURES

Table I

Antarctic Radiosonde Observing Stations

Station Number	Name	Lat(°S)	Long.	Elev.(m)
89001	Sanae (Norway)	70.3	2.4W	52
89009	Amundsen-Scott (USA)	90.0	0	2800
89512	Novolazarevskaya(USSR)	70.8	11.8E	87
89532	Syowa Base (Japan)	69.0	39.6E	15
89542	Molodezhnaya (USSR)	67.7	45.9E	42
89571	Davis (Aust.)	68.6	78.0E	12
89592	Mirny (USSR)	66.6	93.0E	35
89606	Vostok (USSR)	78.5	106.9E	3488
89611	Wilkes (Aust.)	66.3	110.5E	12
89664	McMurdo Station (USA)	77.9	166.7E	24
94986	Mawson (Aust.)	67.6	62.9E	8
95502	Dumont d'Urville (Fr)	66.7	140.0E	41

Table II

The Climatological Zonal Mean 500 mb Geopotential Heights (in dkm) Derived from Trenberth (1979) Minus Taljaard et al (1969) Values

	Latitude ° S					
Month	60	65	70	75	80	85
Oct	0	1.7	2.8	2.3	2.3	2.5
Nov	1.4	1.9	3.0	3.7	3.8	4.1
Dec	3.2	4.5	5.1	5.7	6.6	7.7
Jan	1.0	2.2	3.8	5.9	7.1	7.9
Feb	-1.9	-2.2	-2.5	-2.0	-1.0	0

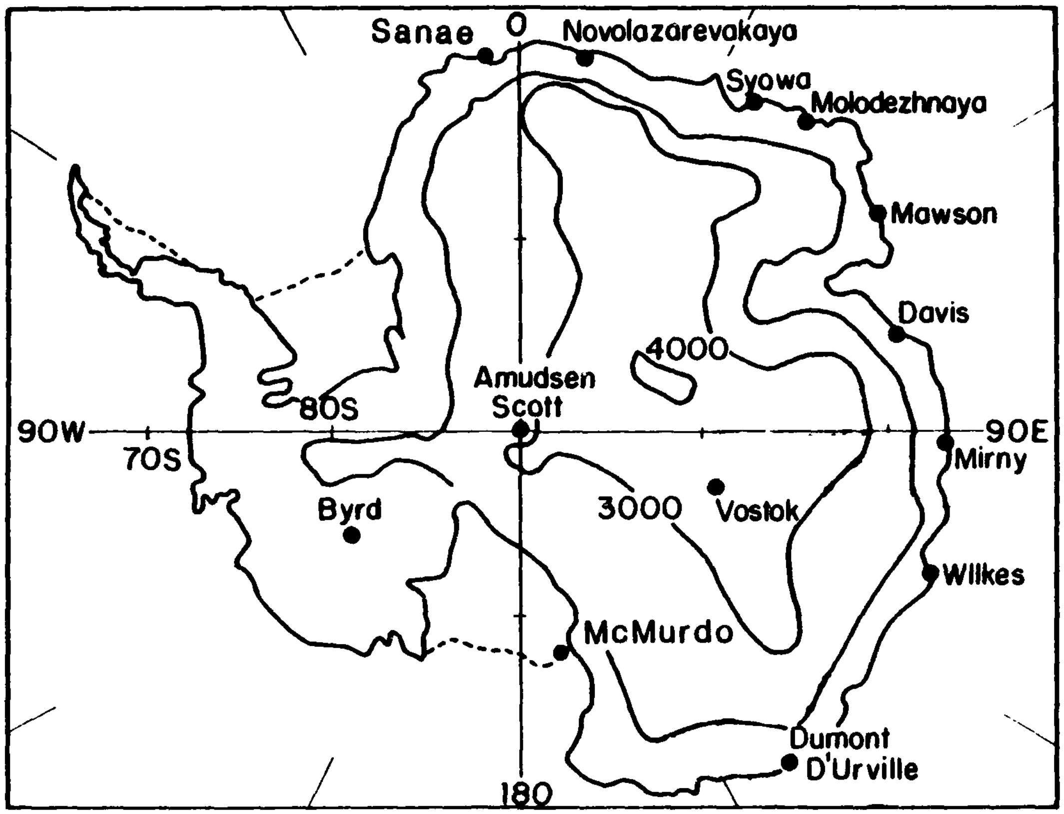


Figure 1. The Antarctic Continent. Table I lists radiosonde stations. Contours are in meters. (after Parish, 1982).

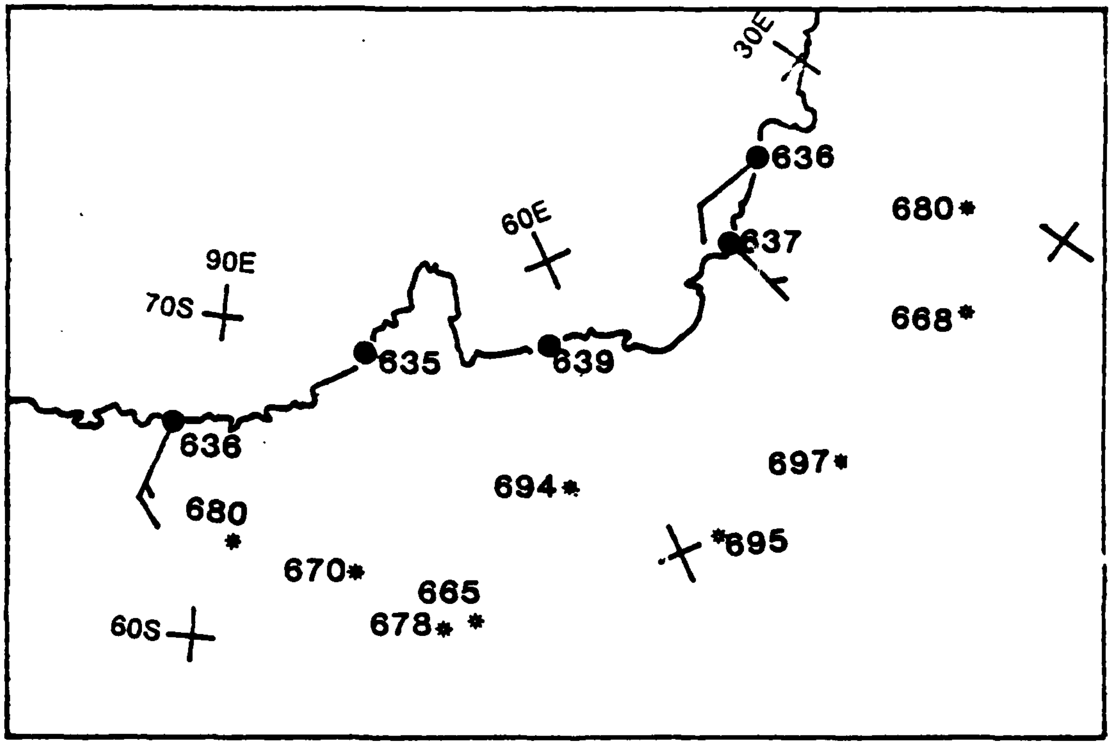


Figure 2. A Sample VTPR 400 mb Height Retrieval from NIMBUS VI and Radiosonde Observations, 1 October 1976. (*) VTPR Retrievals, (●) Radiosonde Observations.

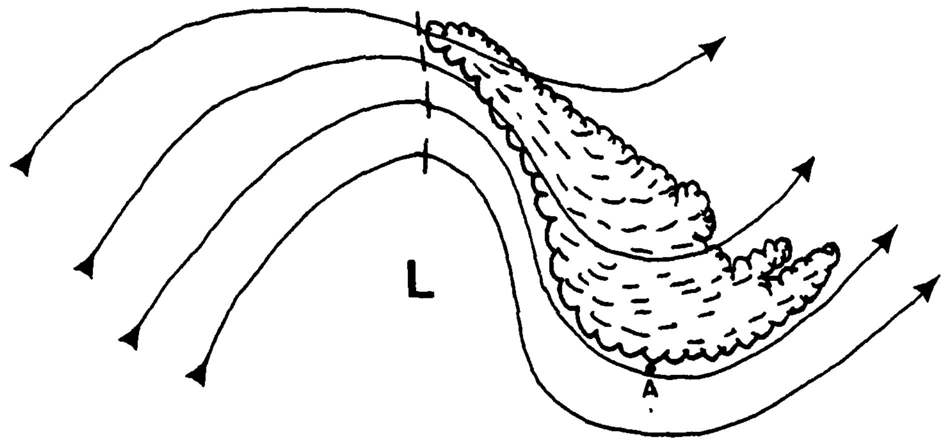


Figure 3. Schematic Representation of a Cloud Shield Relative to a Middle/High Tropospheric Synoptic Scale Wave. Compositing Point, A, is located at the Most Poleward Extent of Cloud.

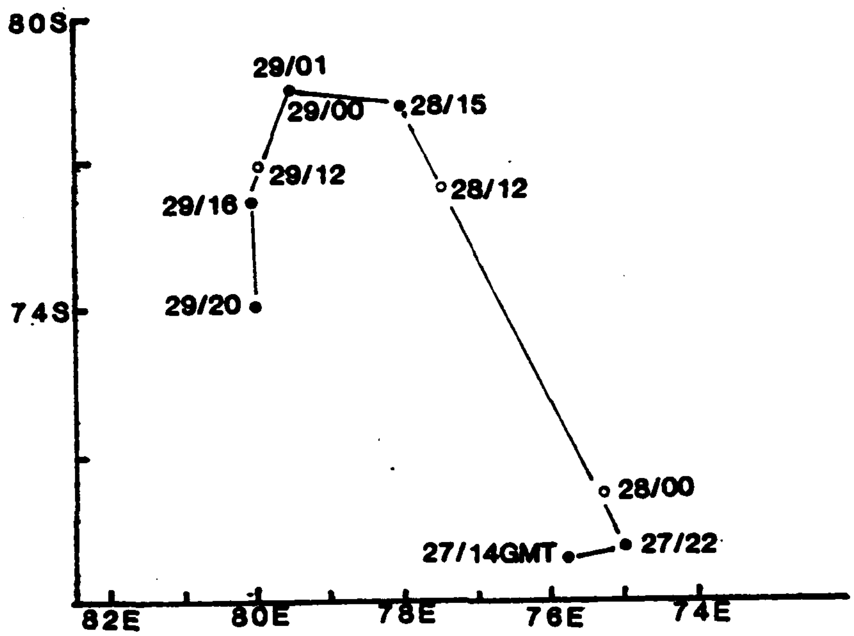


Figure 4a. Compositing Point Track 27-29 November 1976. Linear Interpolation was used to Determine the Compositing Point Location at each Synoptic Time.

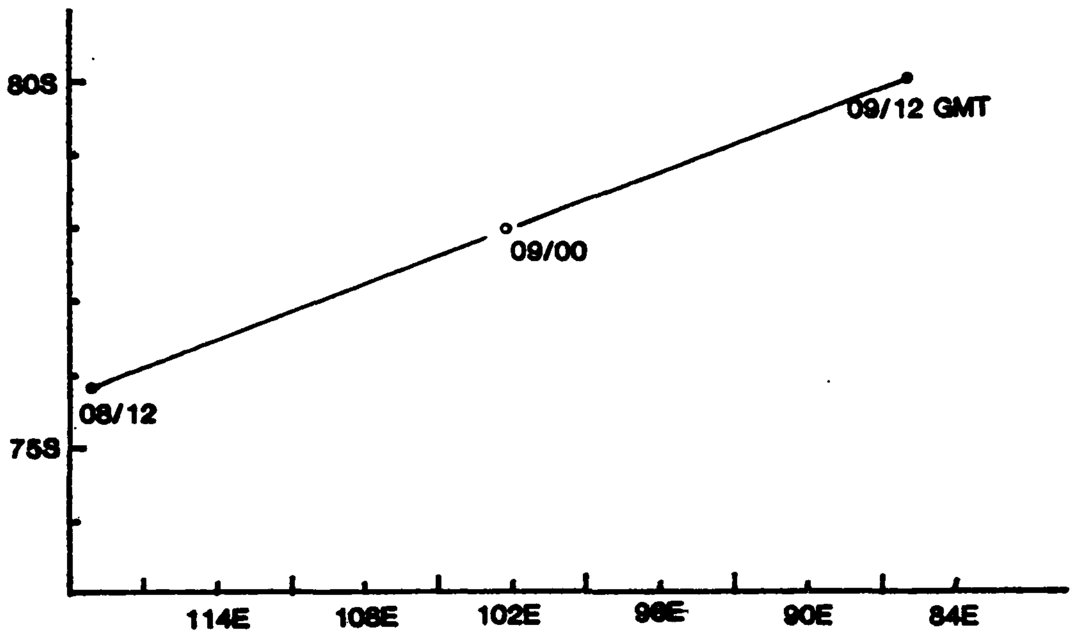


Figure 4b. Compositing Point Track 8-9 January 1980. Linear Interpolation was used to Determine the Compositing Point Location at each Synoptic Time.

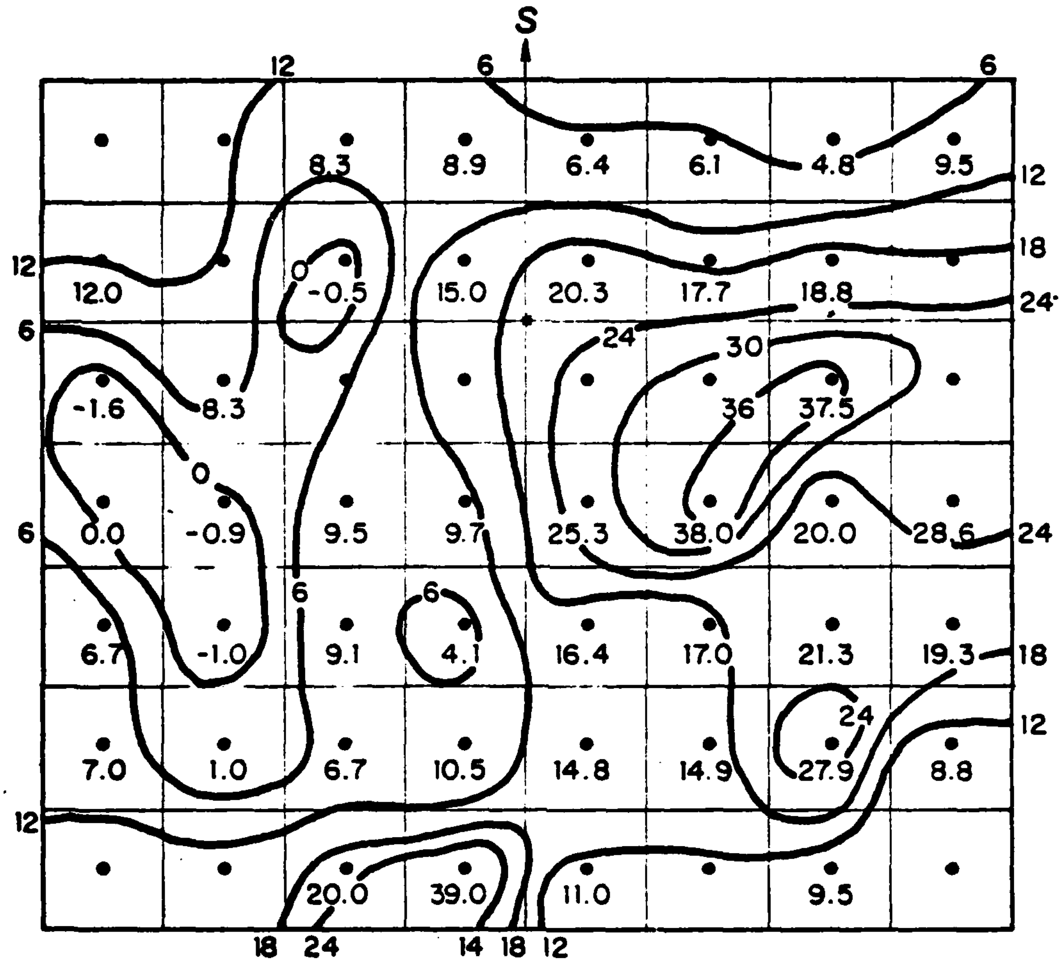


Figure 5. Statistically Adjusted 400 mb Composite Height Anomaly Field. (*) indicates the grid position of the compositing point. (Contour Interval: 6 dkm).

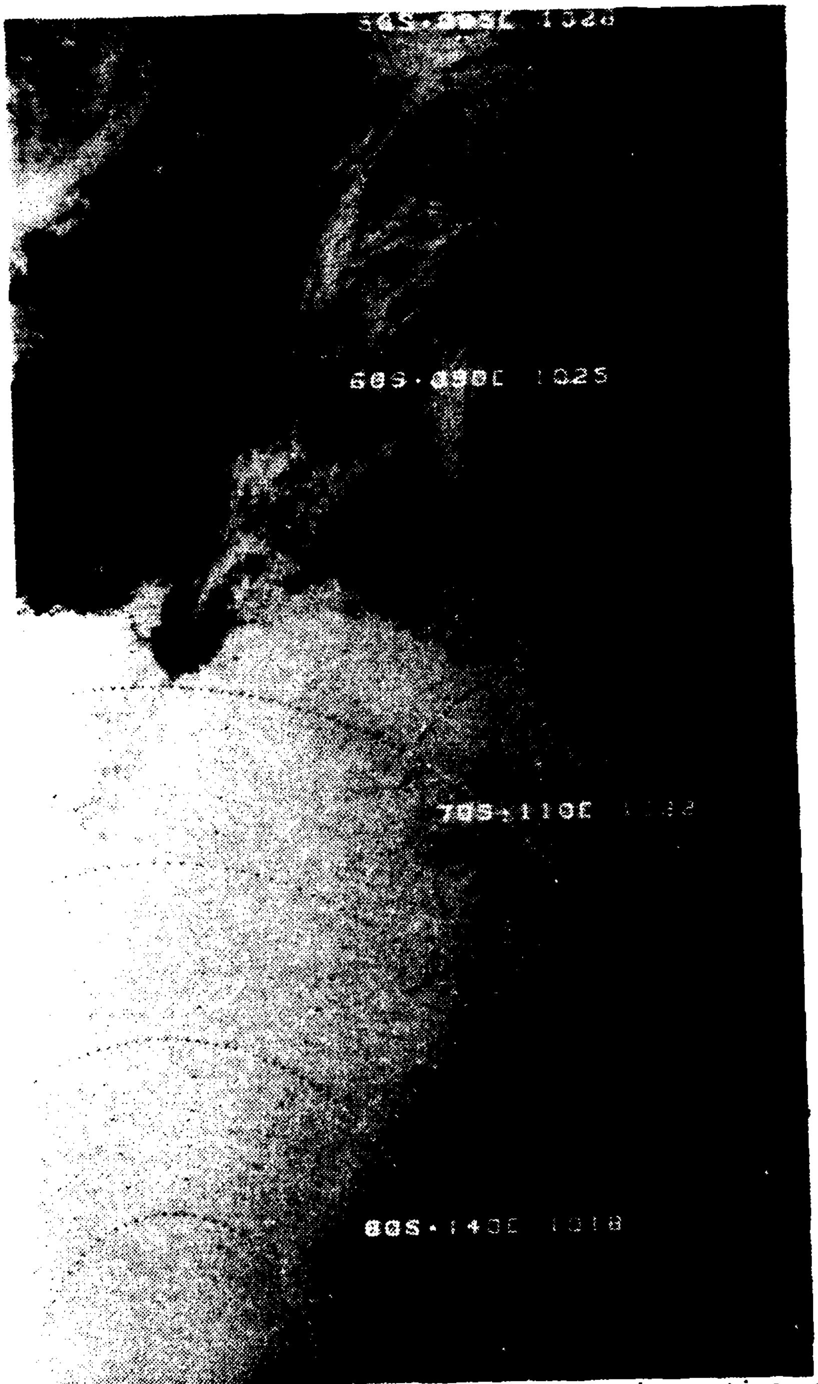


Figure 6a. NOAA 5 Satellite Imagery of Eastern Antarctica at 1016 GMT 7 January 1980. CP denotes the Compositing Point Chosen in all Satellite Imagery.

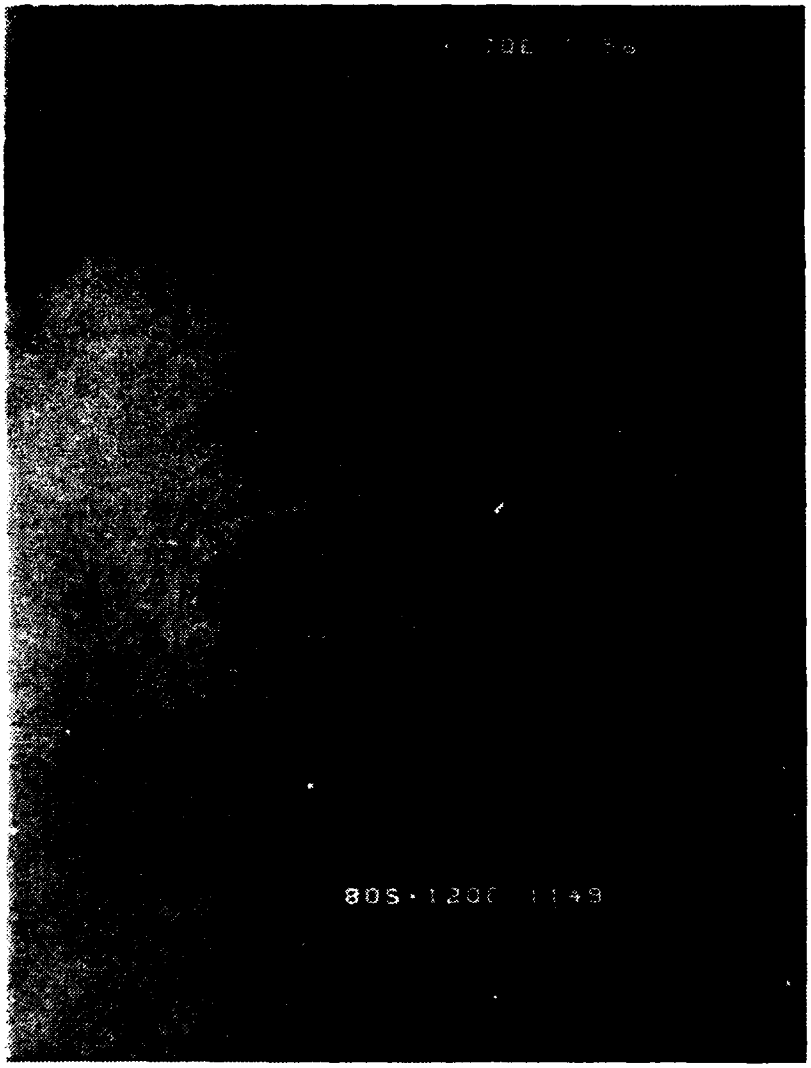


Figure 6b. NOAA 5 Satellite Imagery of Eastern Antarctica at 1147 GMT 8 January 1980.

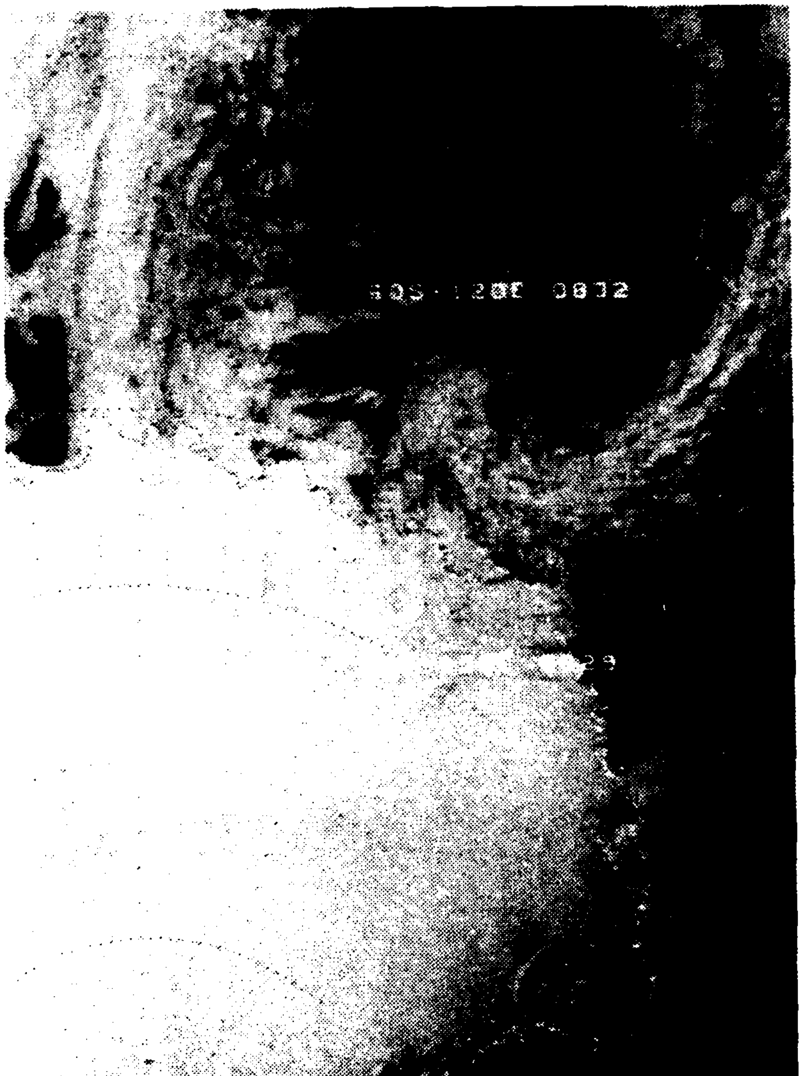


Figure 6c. NOAA 5 Satellite Imagery of Eastern Antarctica at 0823 GMT 8 January 1980.

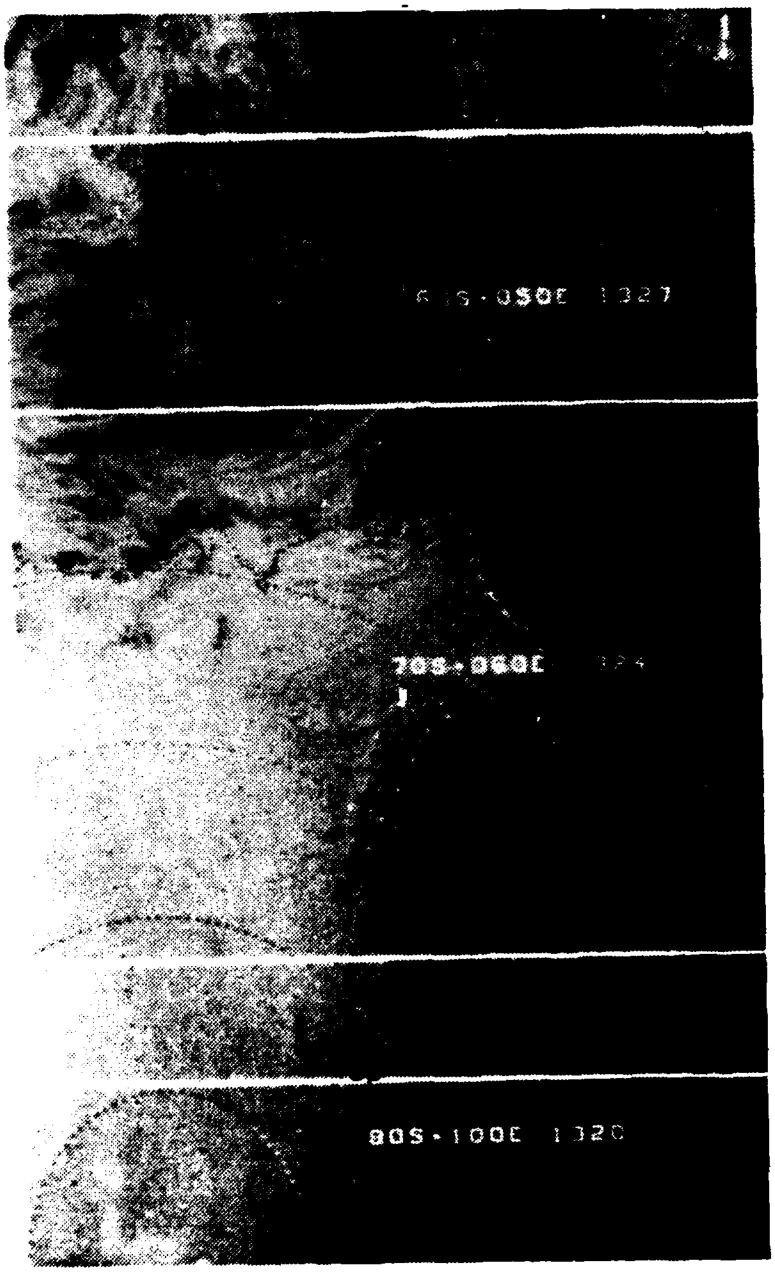


Figure 6d. NOAA 5 Satellite Imagery of Eastern Antarctica at 1318 GMT 9 January 1980.

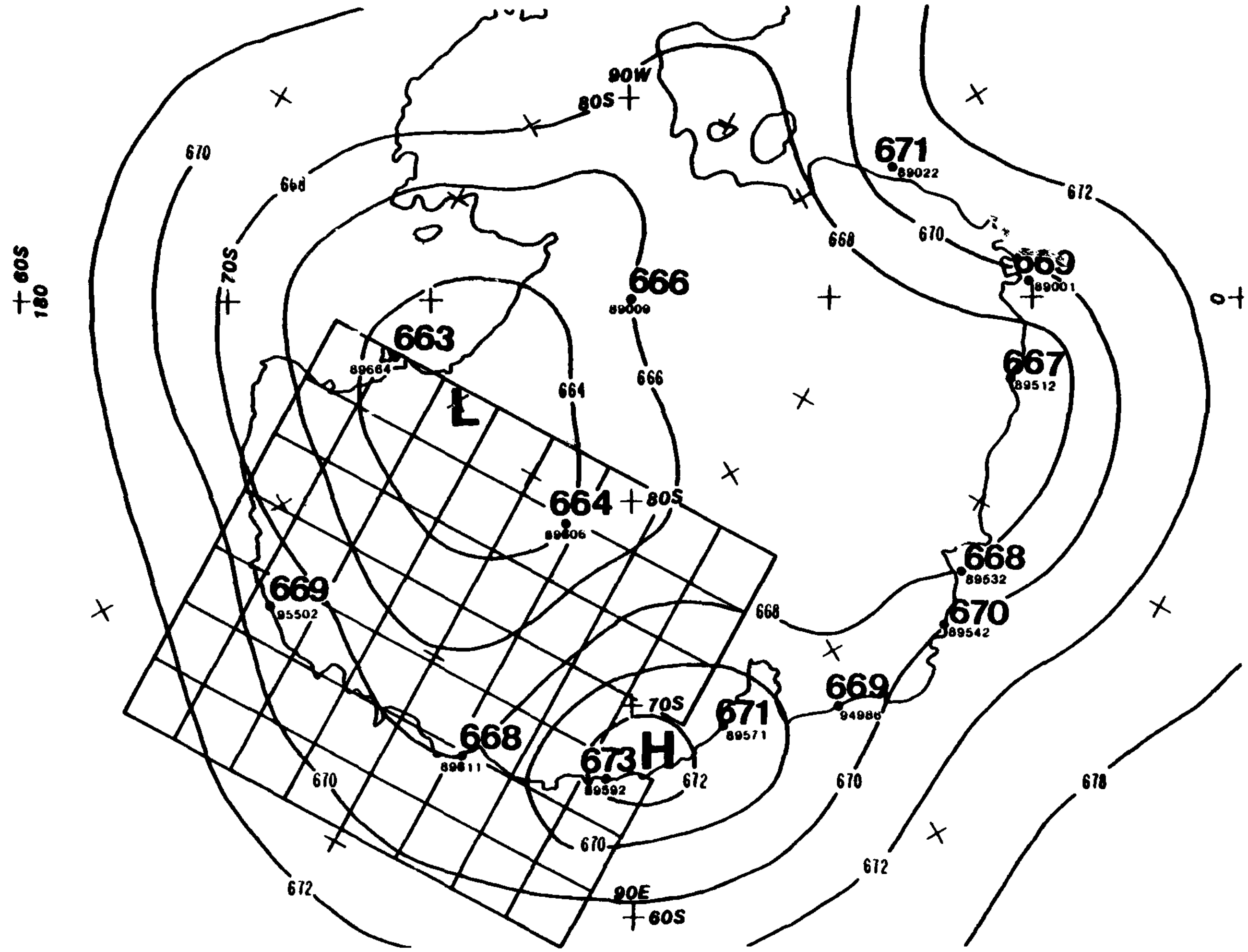


Figure 7. 400 mb Climatological Heights for January with the Compositing Grid Oriented for Test Case I (Contour Interval: 2 dkm).

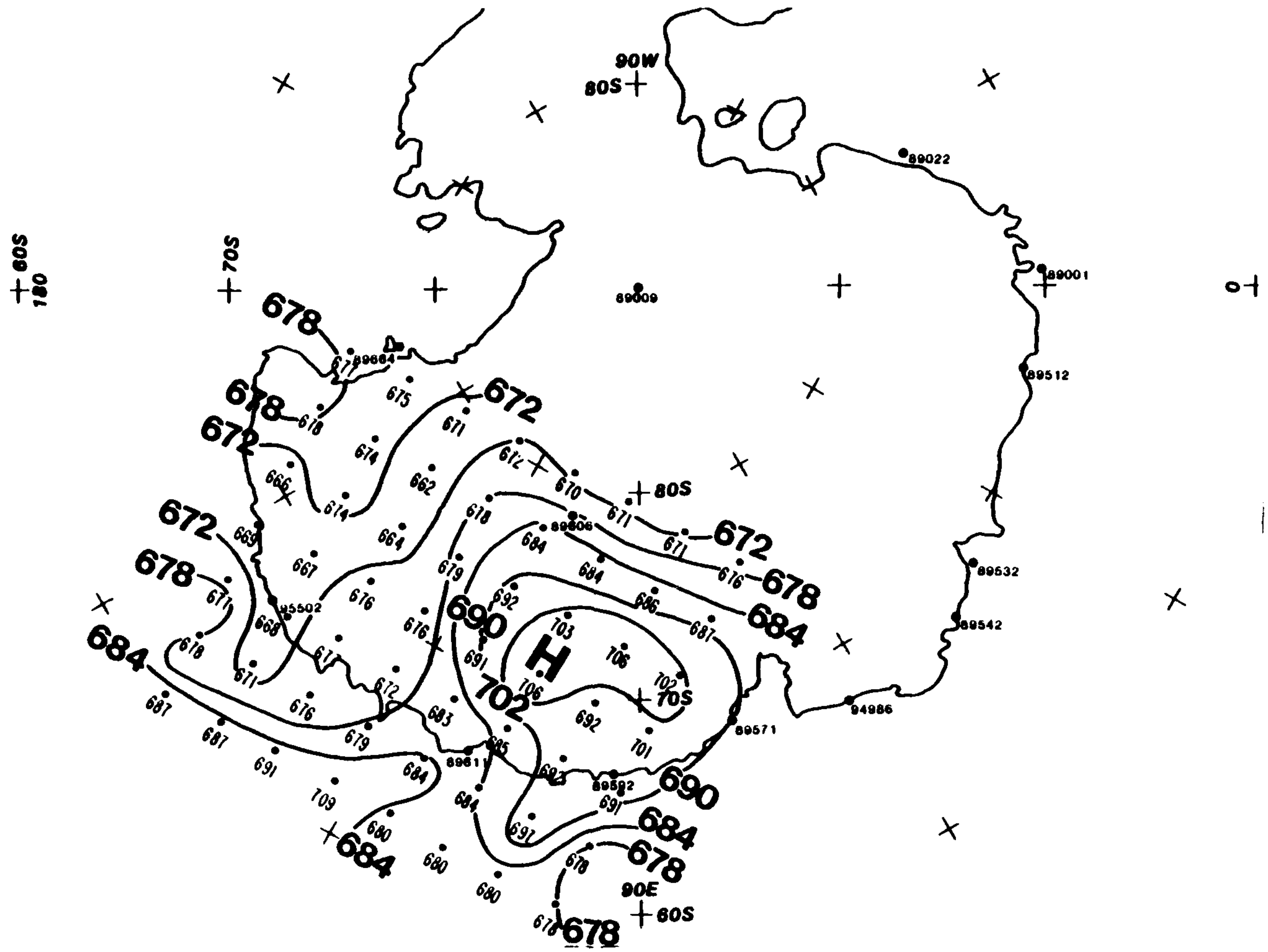


Figure 8a. Model 400 mb Height Field for 1200 GMT 8 January 1980. (Contour Interval: 12 dkm).

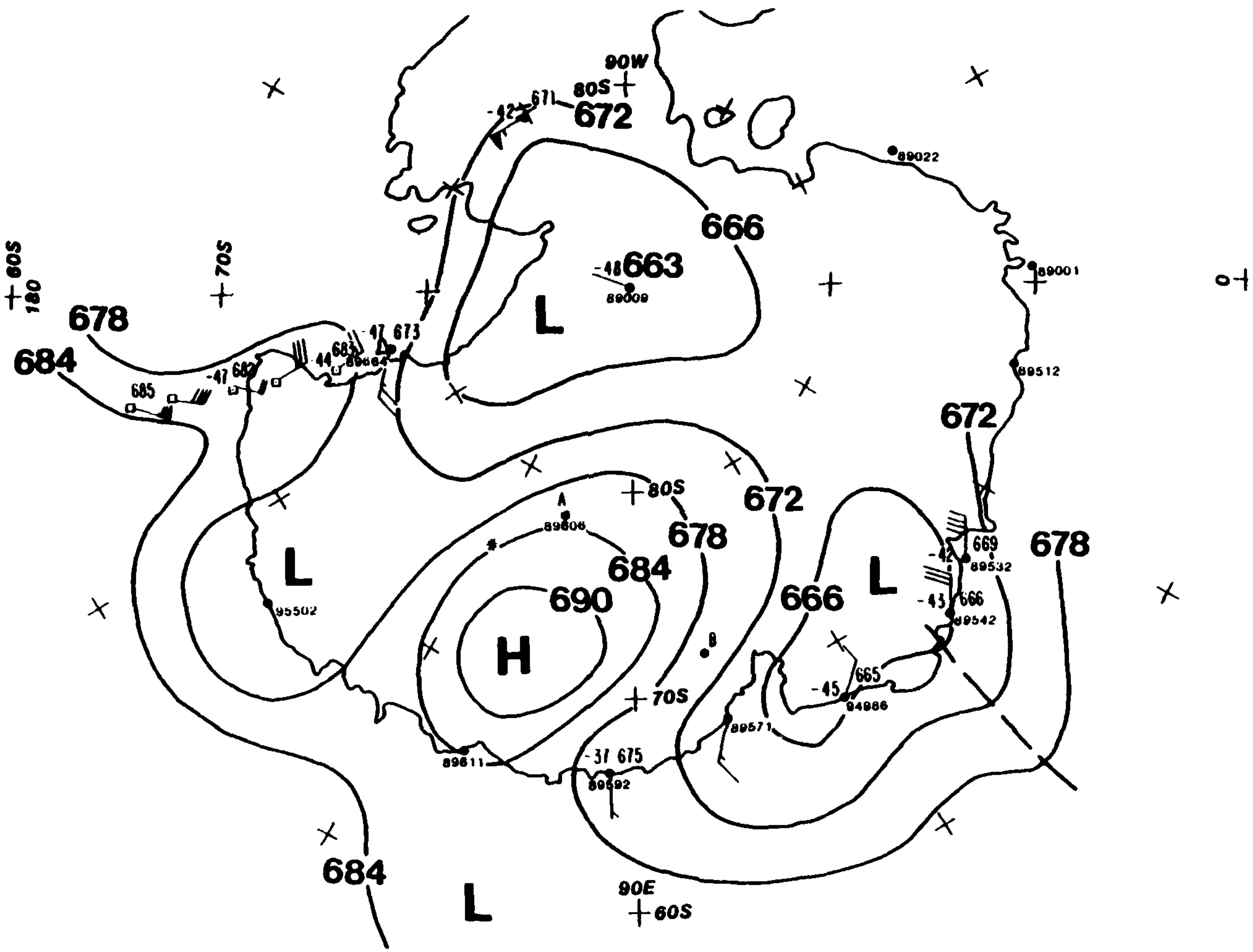


Figure 8b. Model 400 mb Analysis over Eastern Antarctica for 1200 GMT 8 January 1980. Model Field has been Modified by Observational Data. (Contour Interval: 6 dkm).

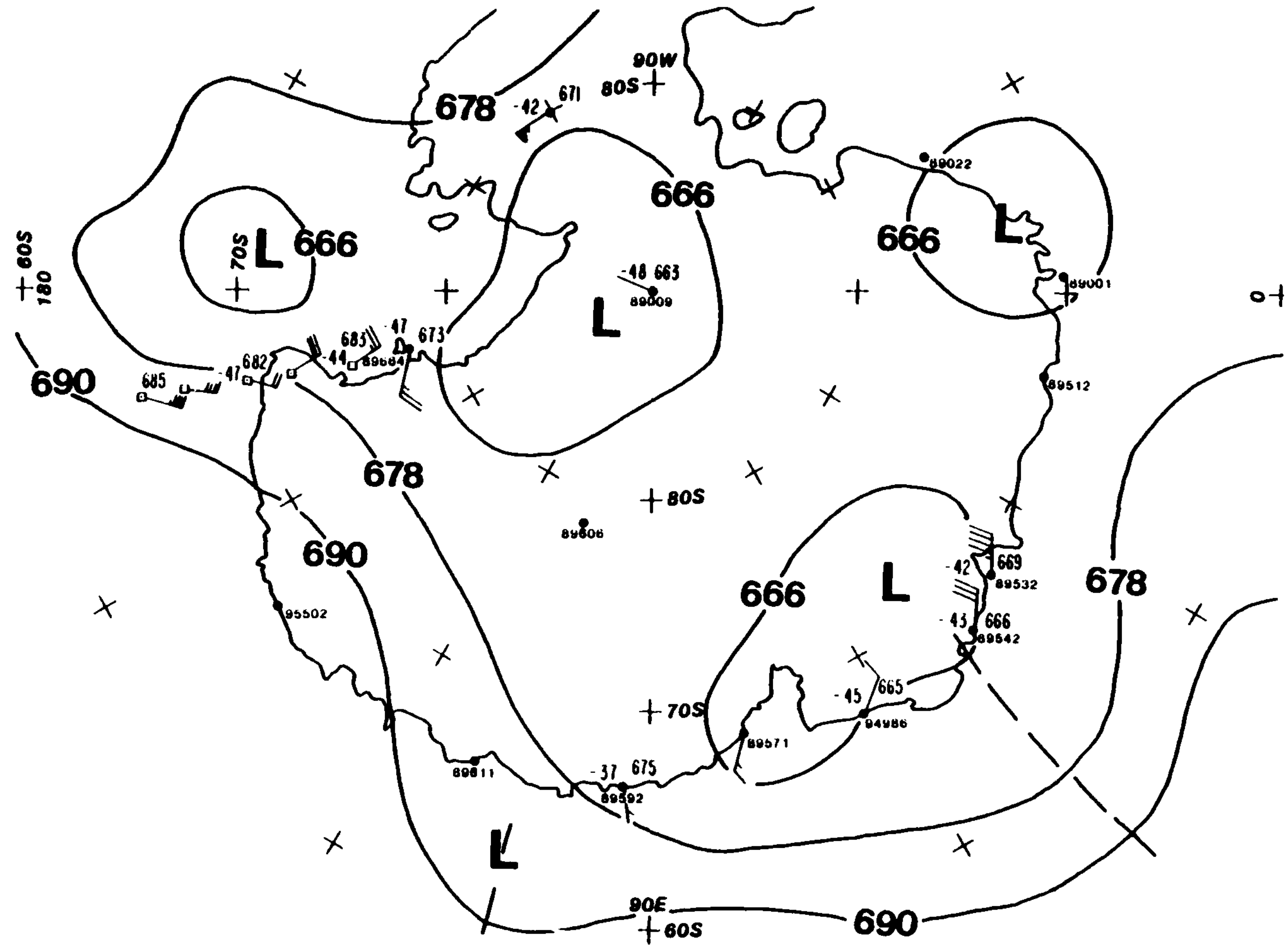


Figure 9a. NSFA 400 mb Analysis for 1200 GMT 8 January 1980.

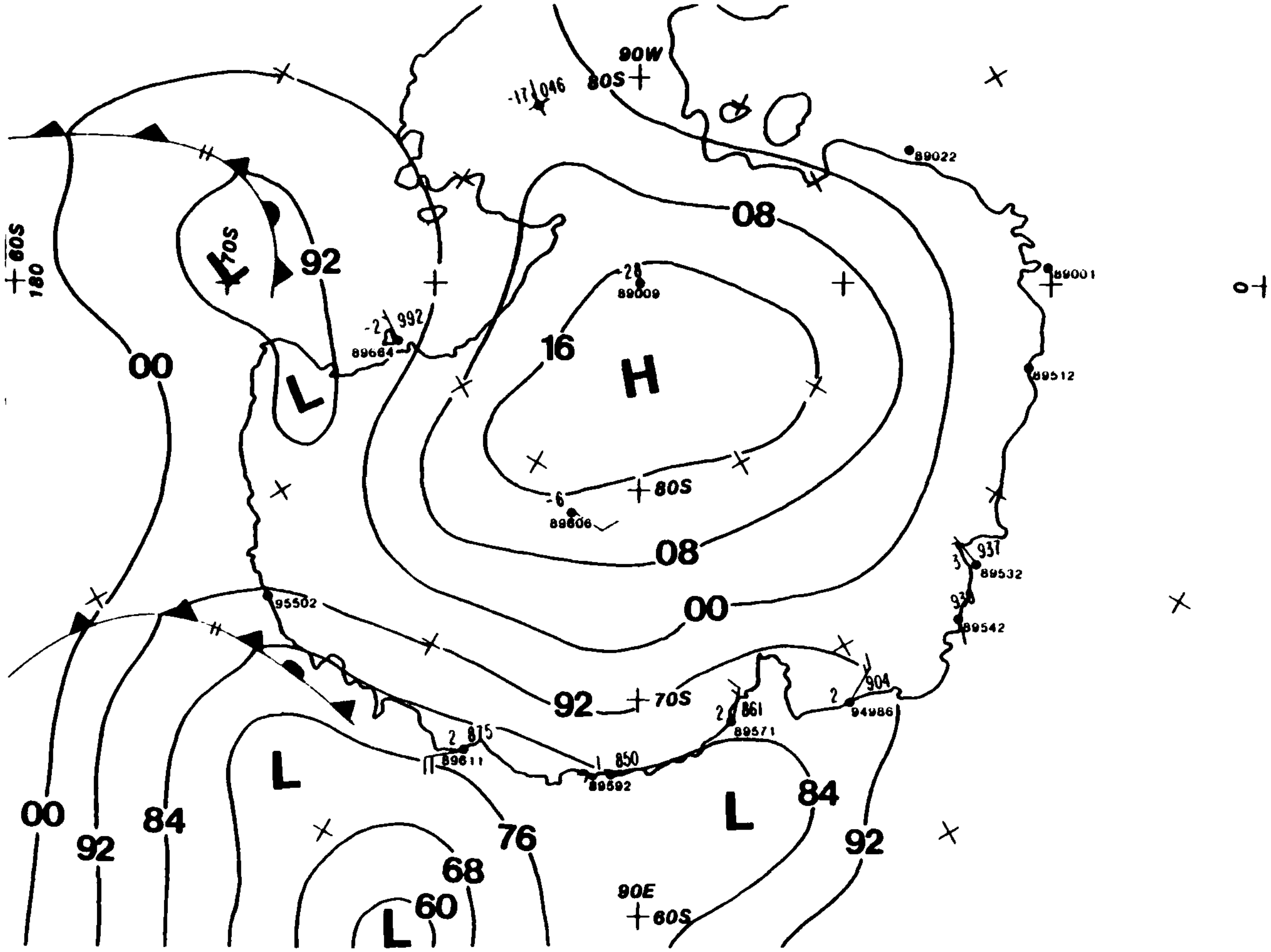


Figure 9b. NSFA Sea-Level Analysis for 1200 GMT 8 January 1980.

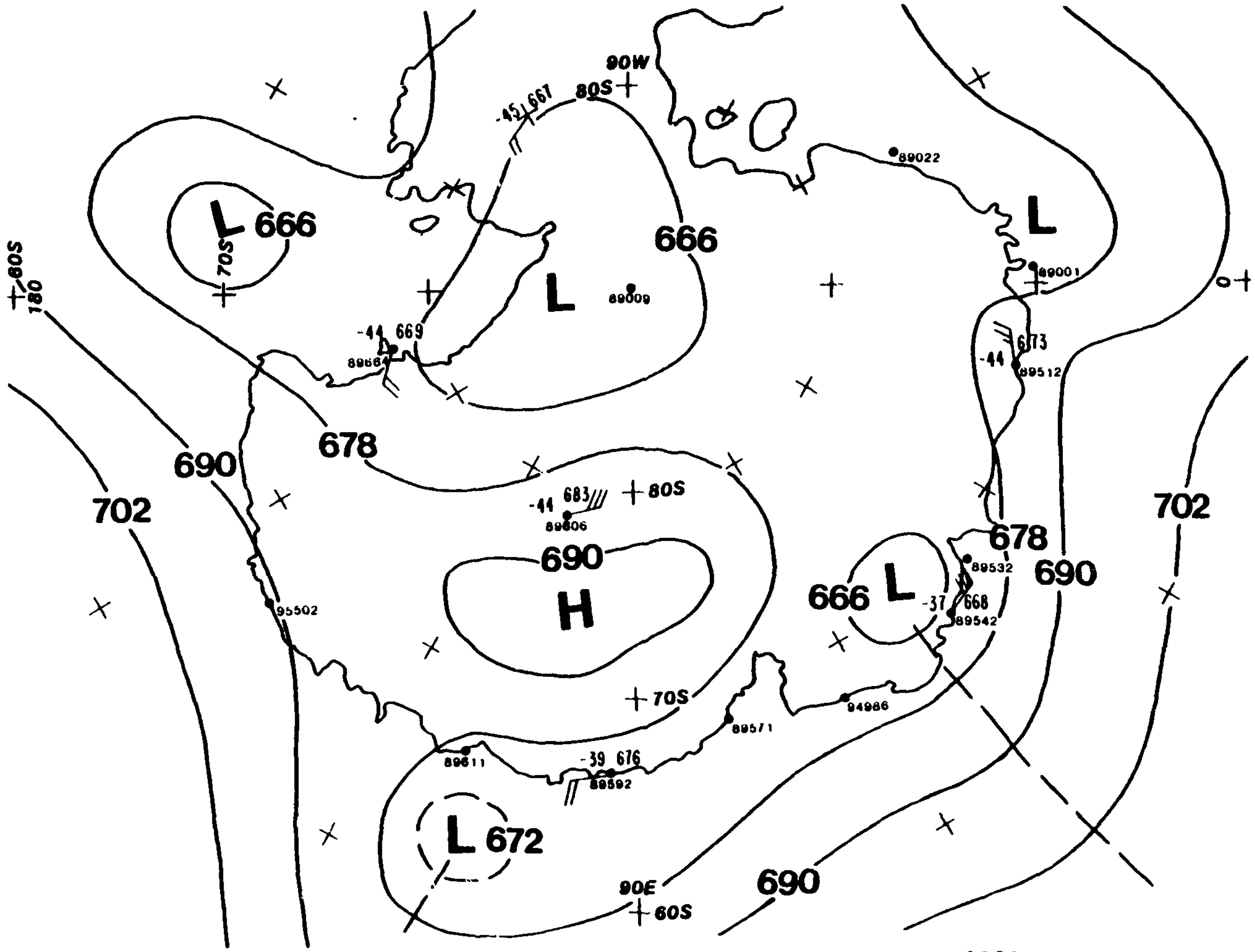


Figure 9c. NSFA 400 mb Analysis for 0000 GMT 9 January 1980.

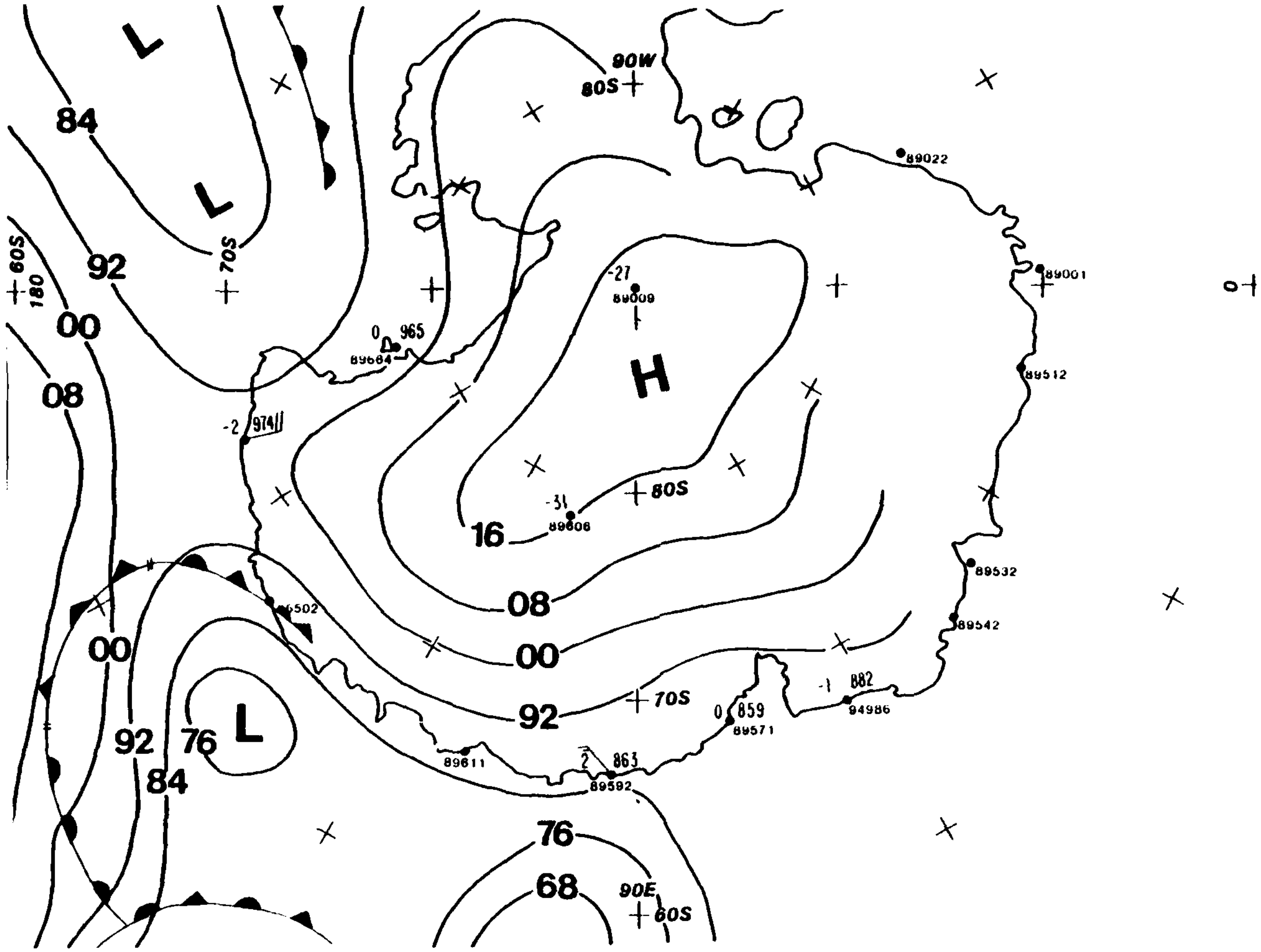


Figure 9d. NSFA Sea-Level Analysis for 0000 GMT 9 January 1980.

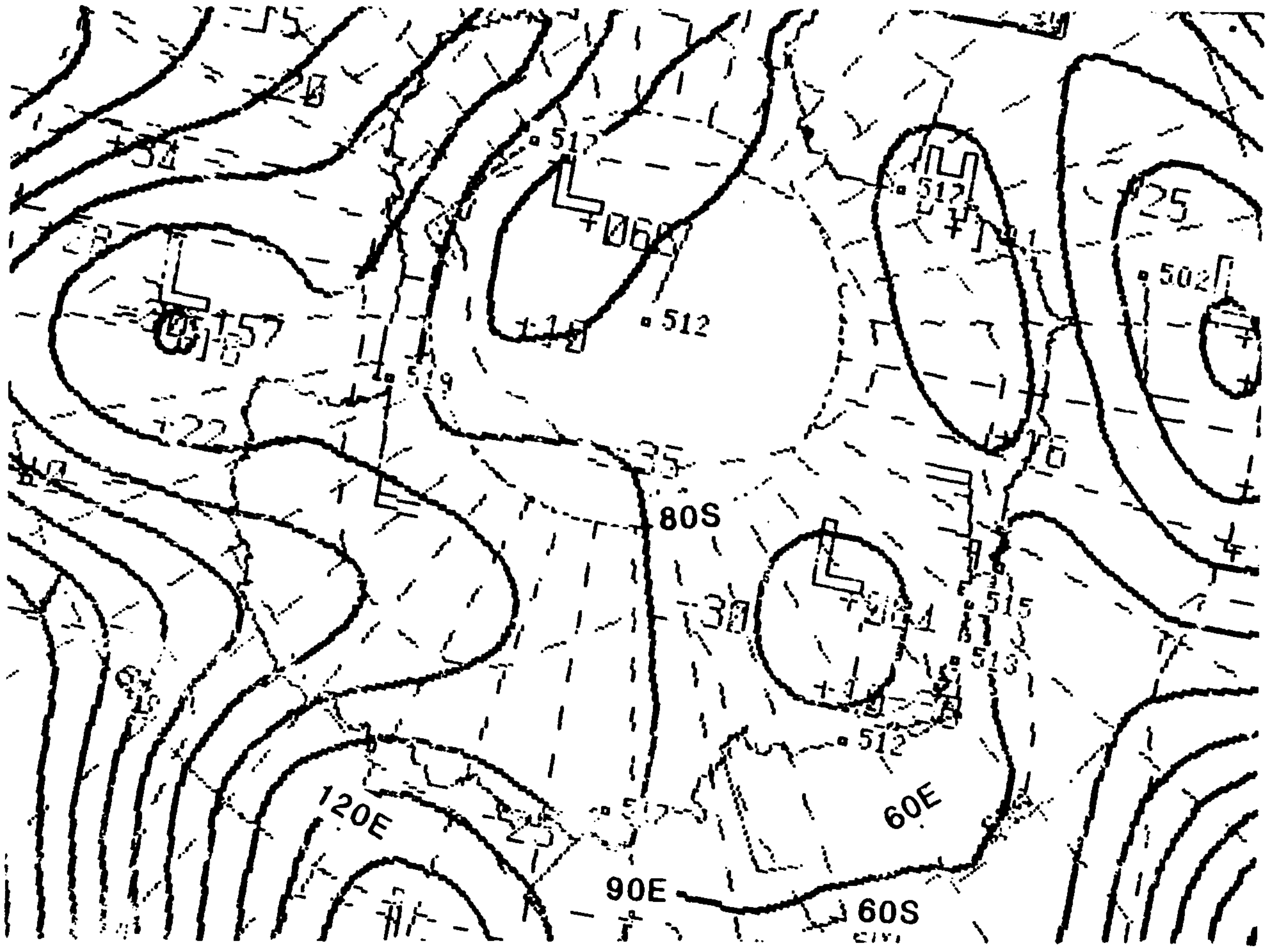


Figure 10a. FNOC 500 mb Analysis for 1200 GMT 8 January 1980.

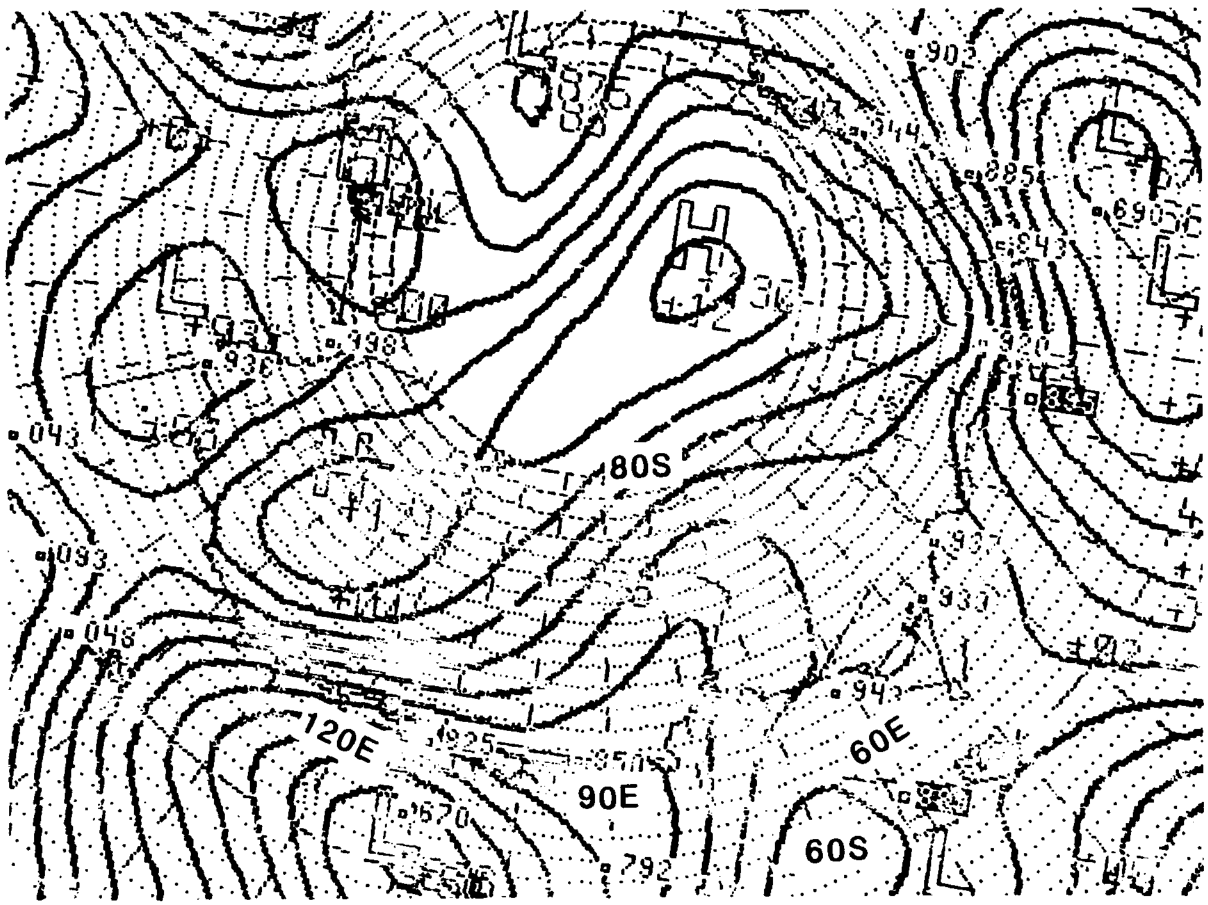


Figure 10b. FNOC Sea-Level Analysis for 1200 GMT 8 January 1980.

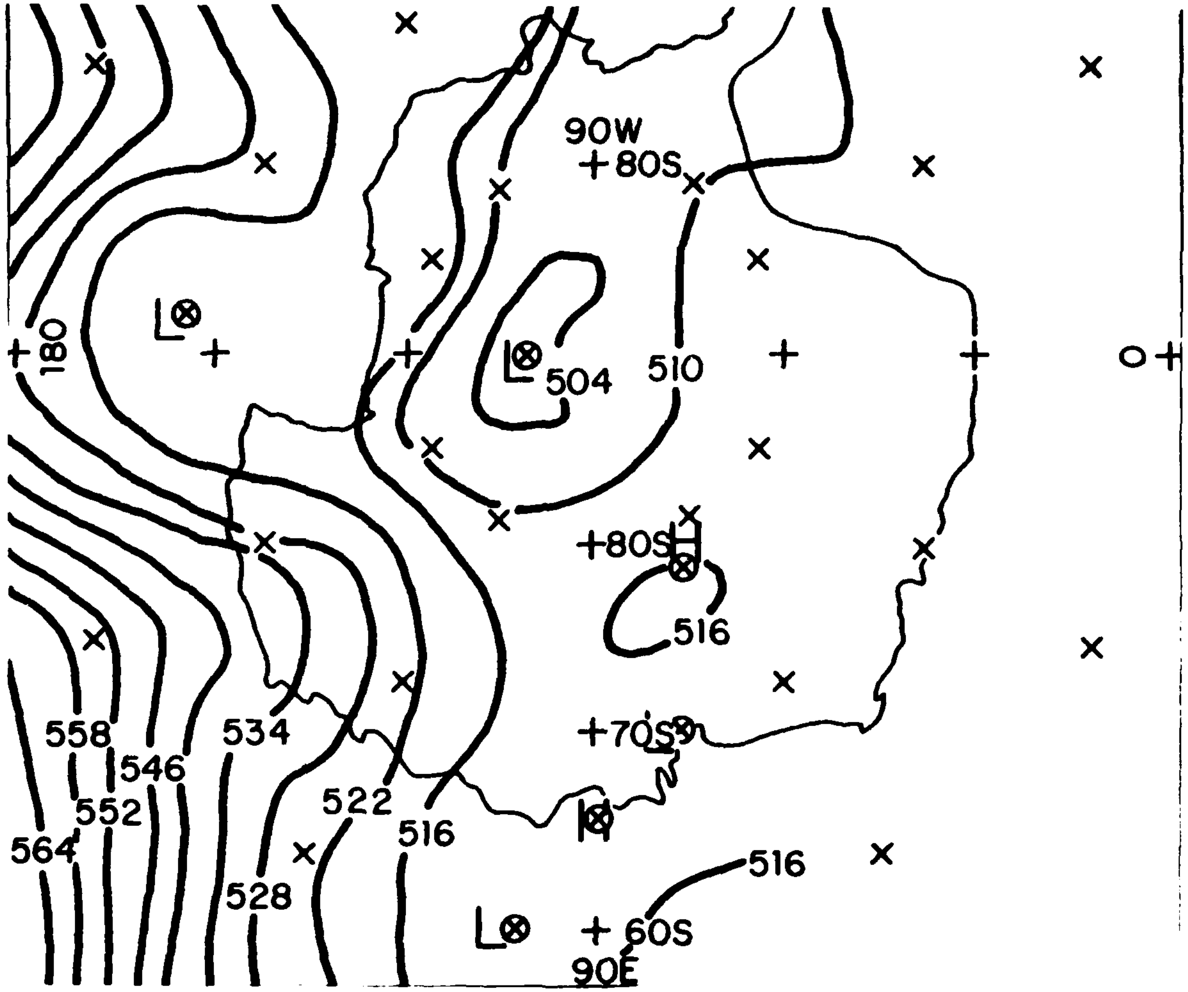


Figure 11a. NMC 500 mb Analysis for 1200 GMT 8 January 1980.

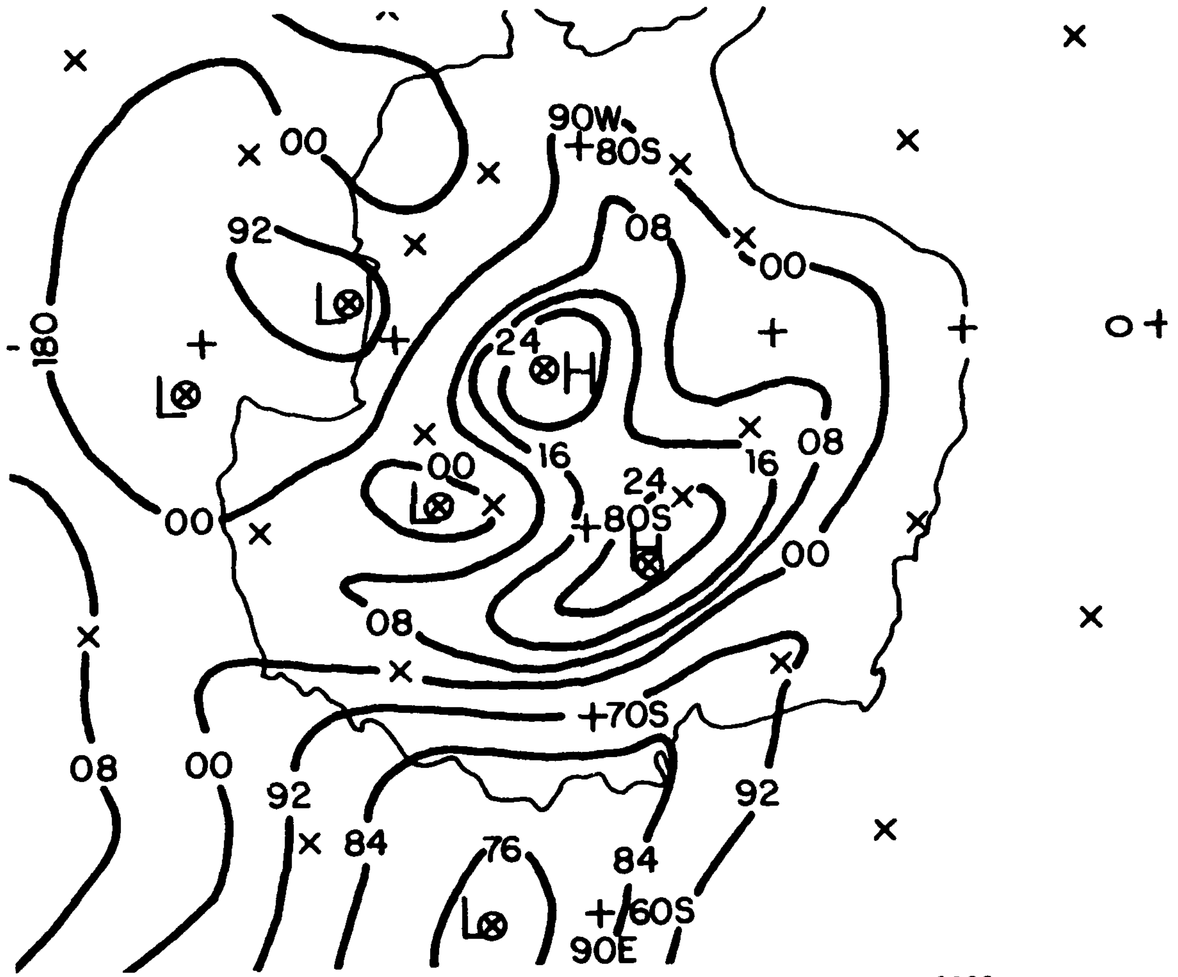


Figure 11b. NMC Sea-Level Analysis for 1200 GMT 8 January 1980.

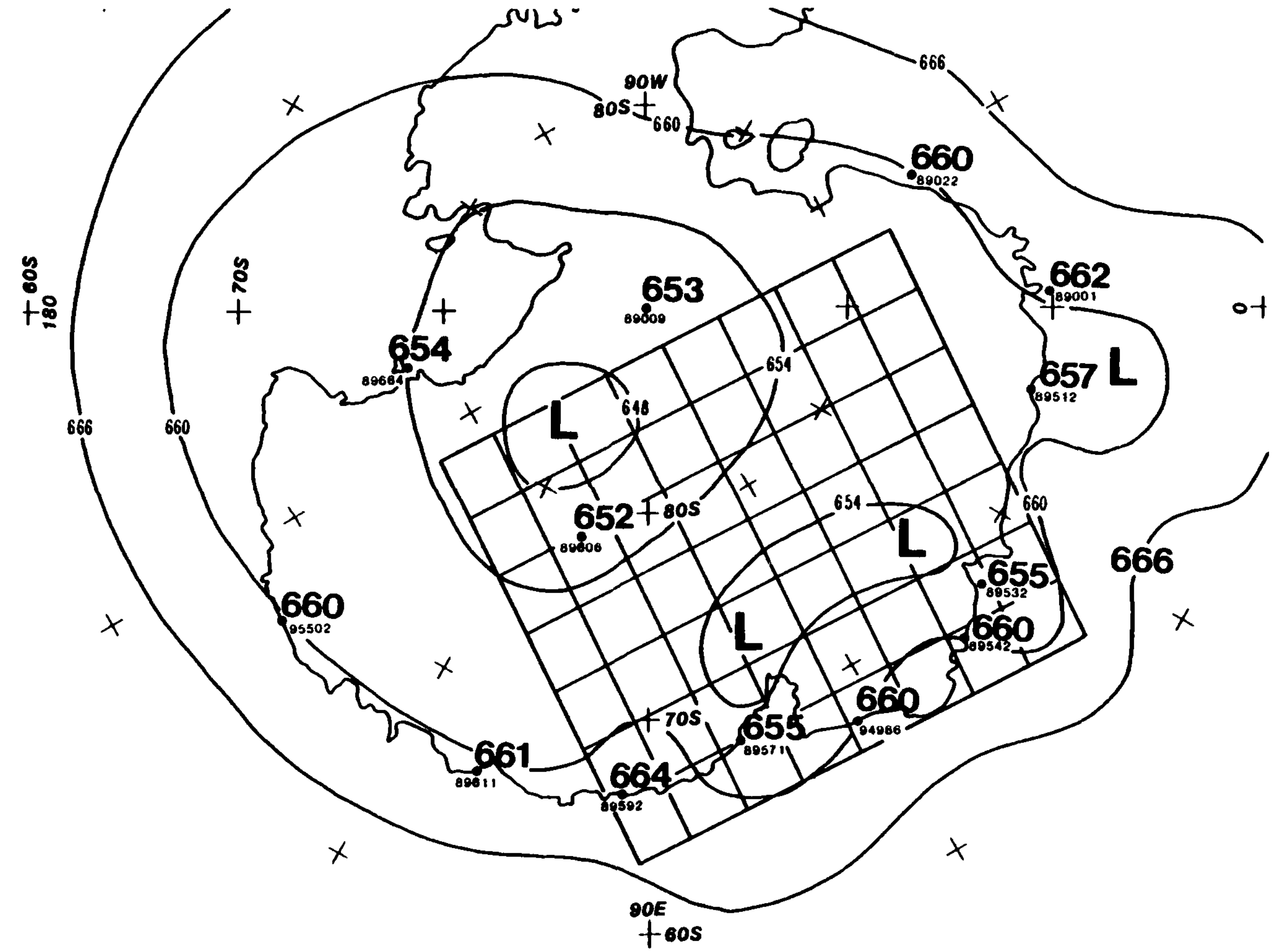


Figure 12. 400 mb Climatological Heights for February, with Compositing Grid Oriented for Test Case II. (Contour Interval: 6 dkm).

80S·120E 160

Figure 13a. TIROS N Satellite Imagery of Eastern Antarctica at 1601 GMT 16 February 1979.

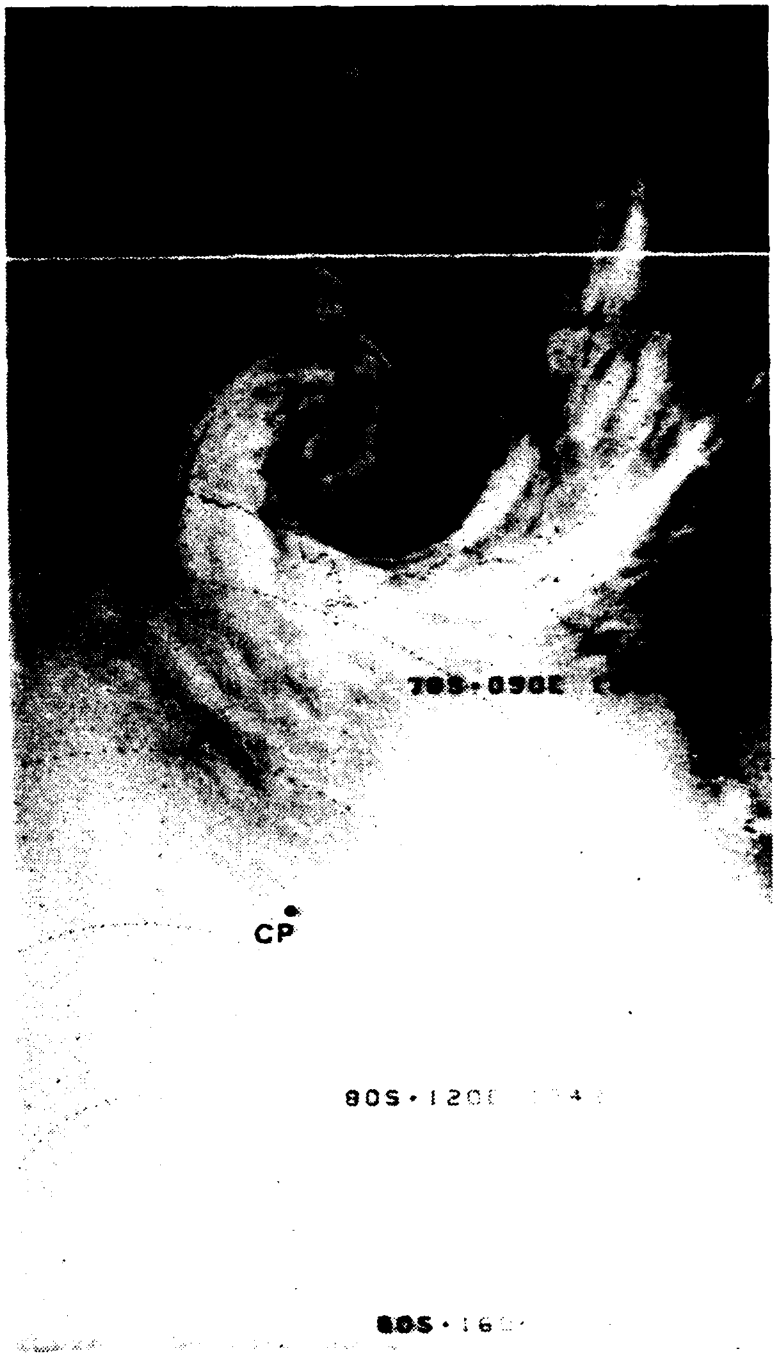


Figure 13b. TIROS N Satellite Imagery of Eastern Antarctica at 1539 GMT 17 February 1979.

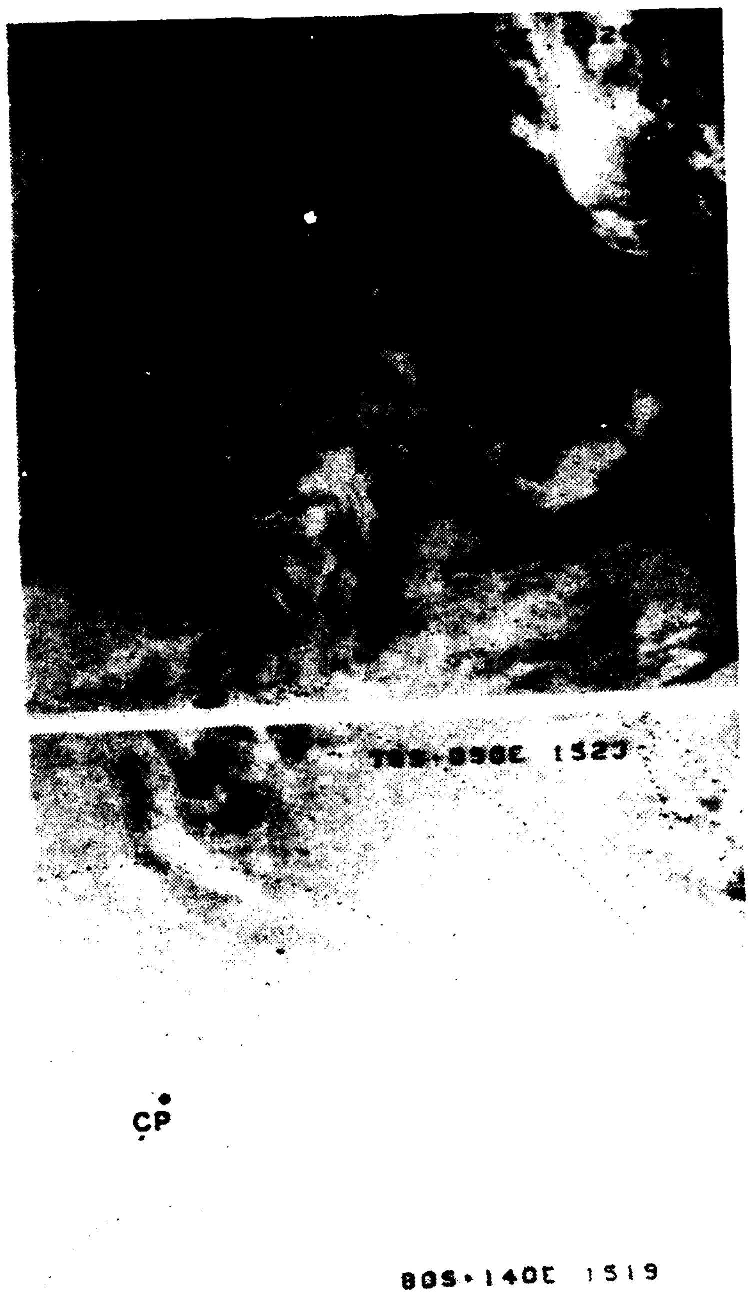


Figure 13c. TIROS N Satellite Imagery of Eastern Antarctica at 1517 GMT 18 February 1979.

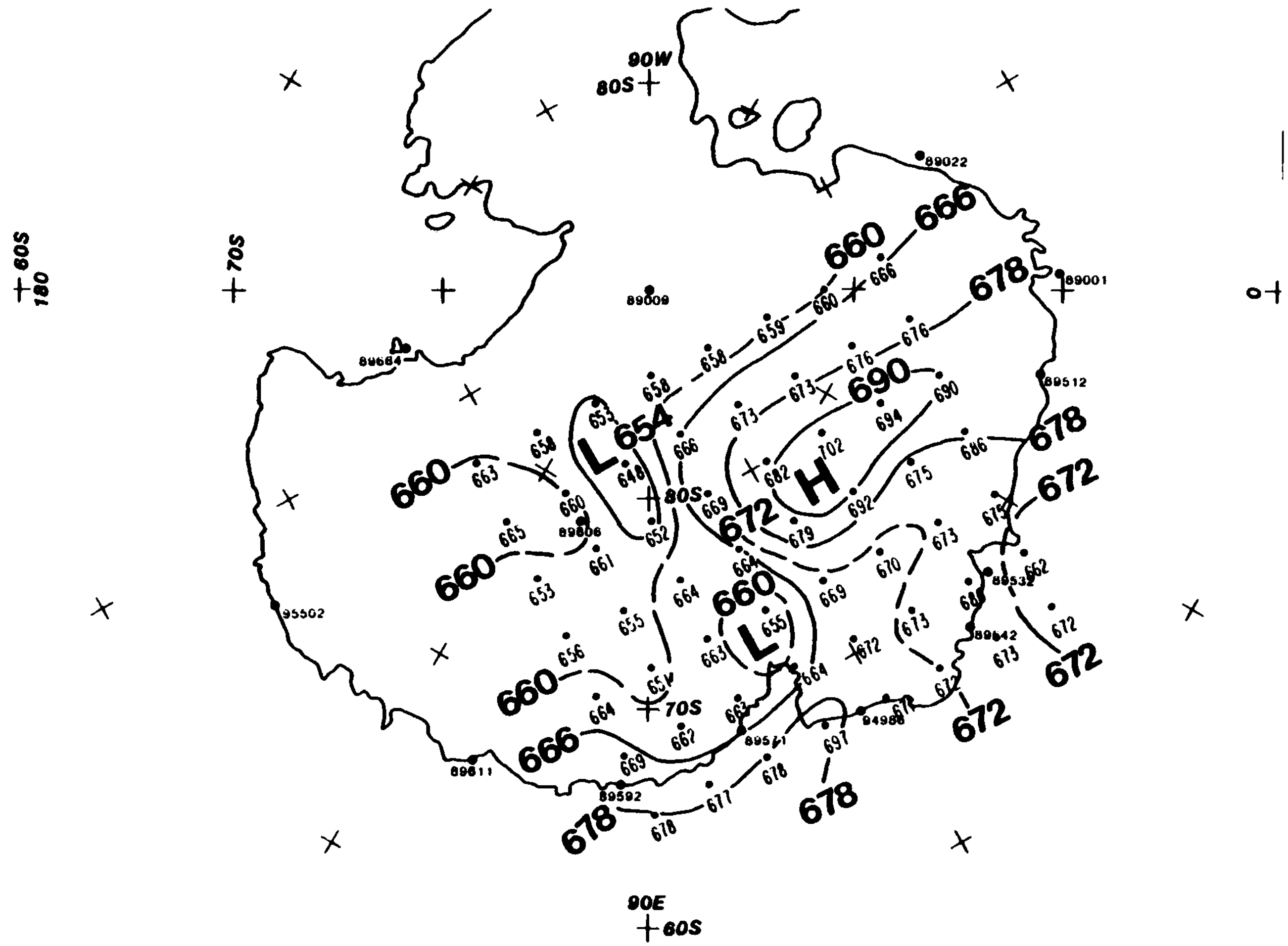


Figure 14a. Model 400 mb Height Field for 1200 GMT 18 February 1979. (Contour Interval: 12 dkm).

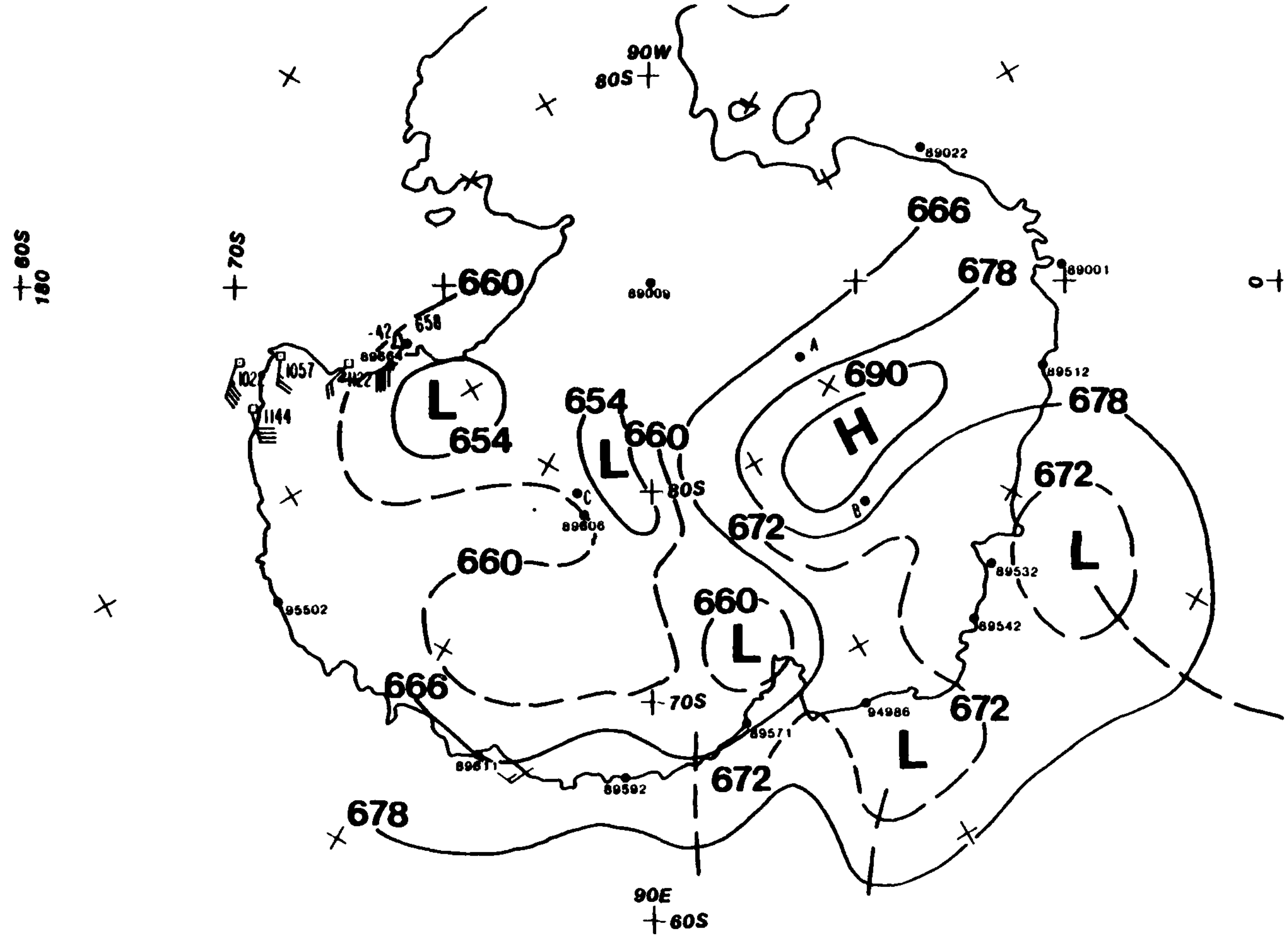


Figure 14b. Model 400 mb Analysis for Eastern Antarctica for 1200 GMT 18 February 1979. Analysis Area has been extended to include available observational data. (Contour Interval: 6 dkm).

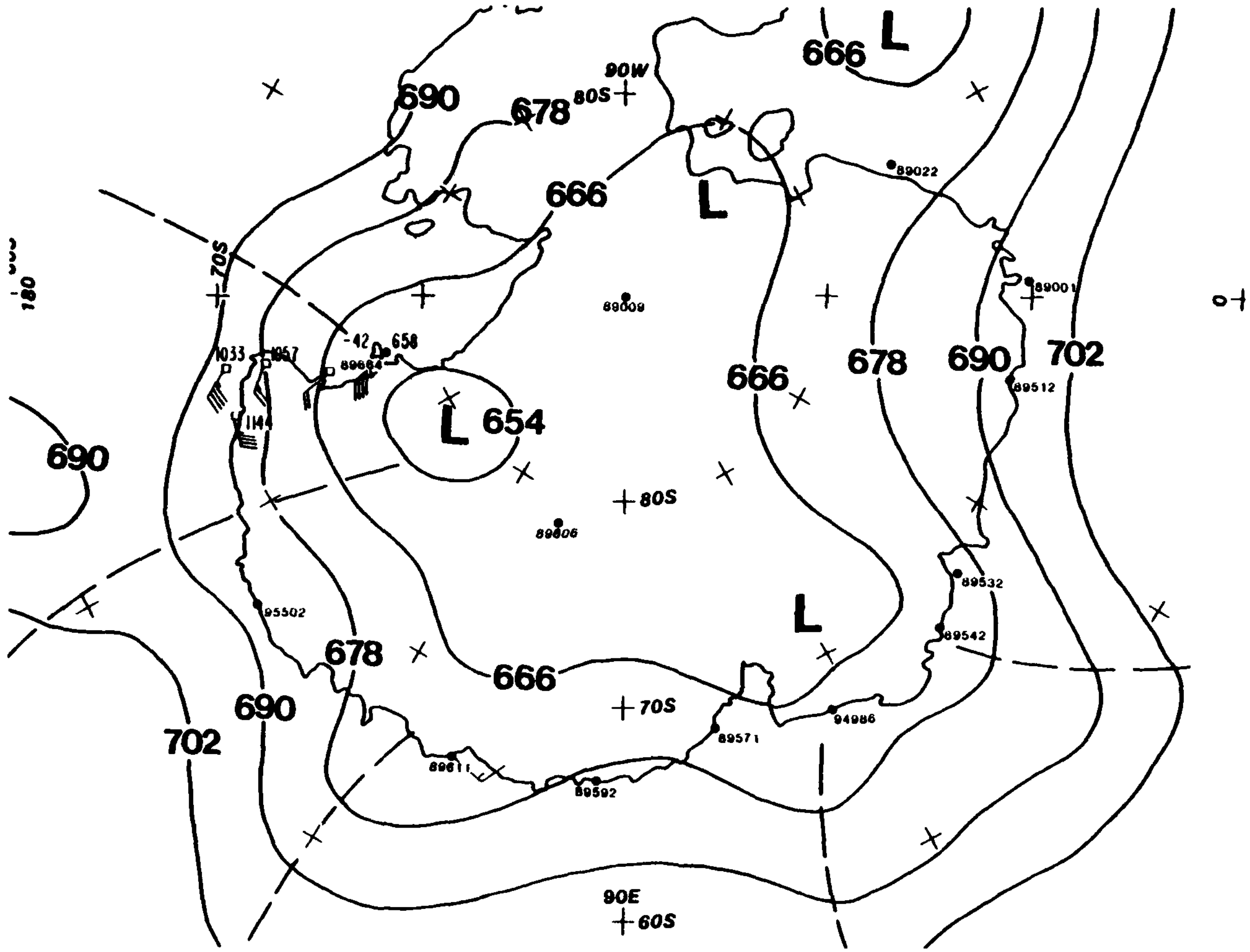


Figure 15a. NSFA 400 mb Analysis for 1200 GMT 18 February 1979.

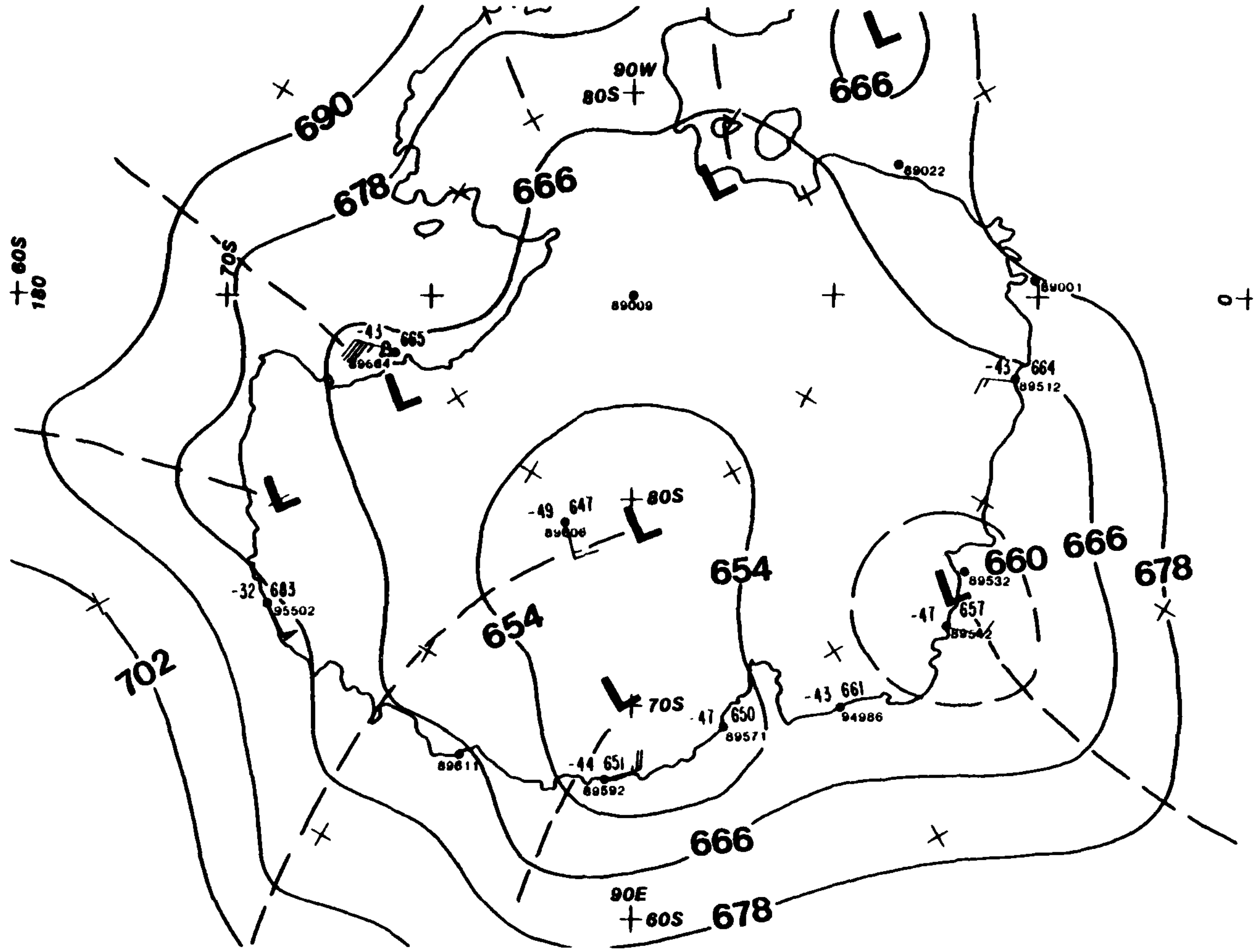


Figure 15b. NSFA 400 mb Analysis for 0000 GMT 19 February 1979.

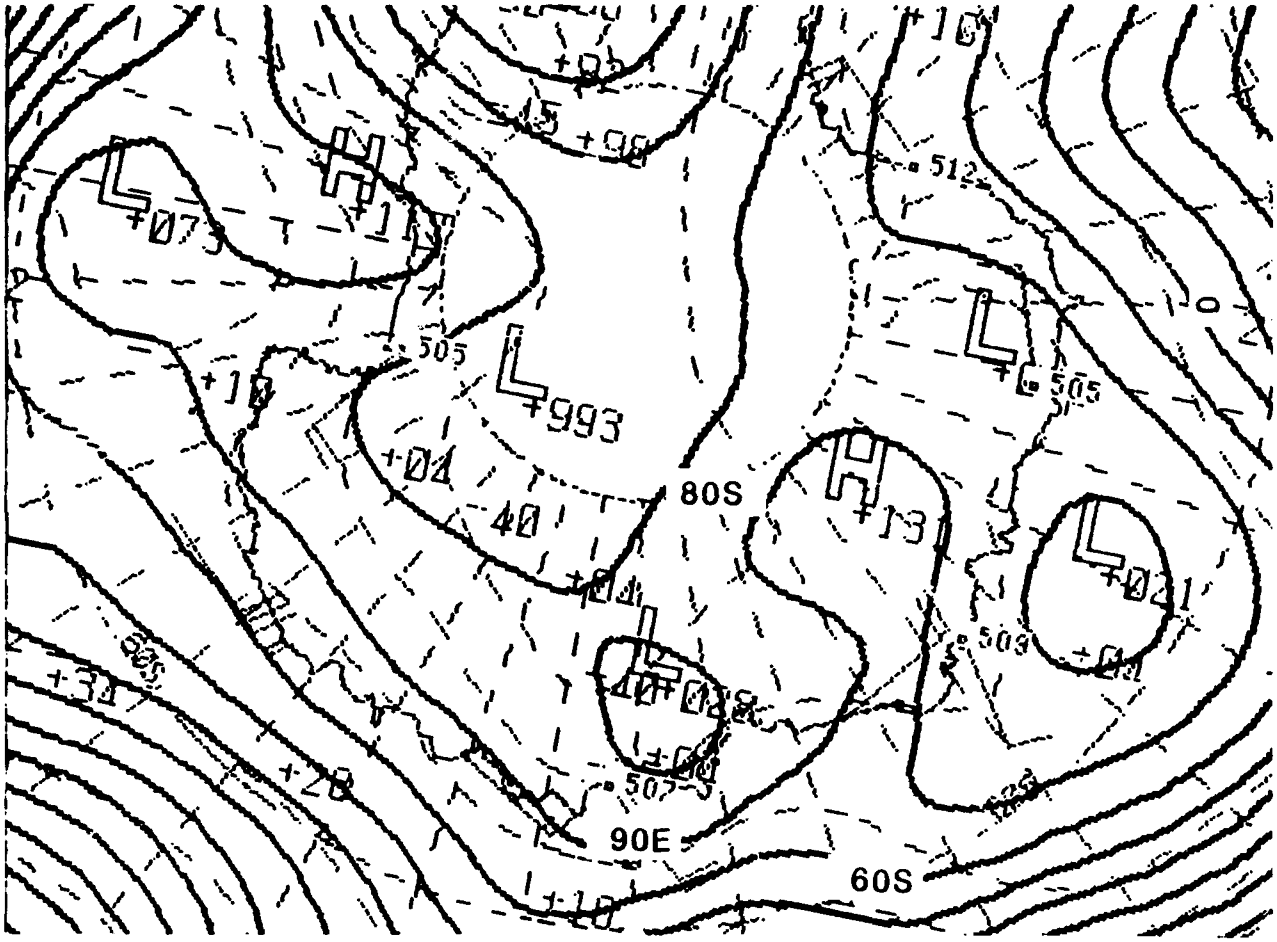


Figure 16a. FNOC 500 mb Analysis for 1200 GMT 18 February 1979.

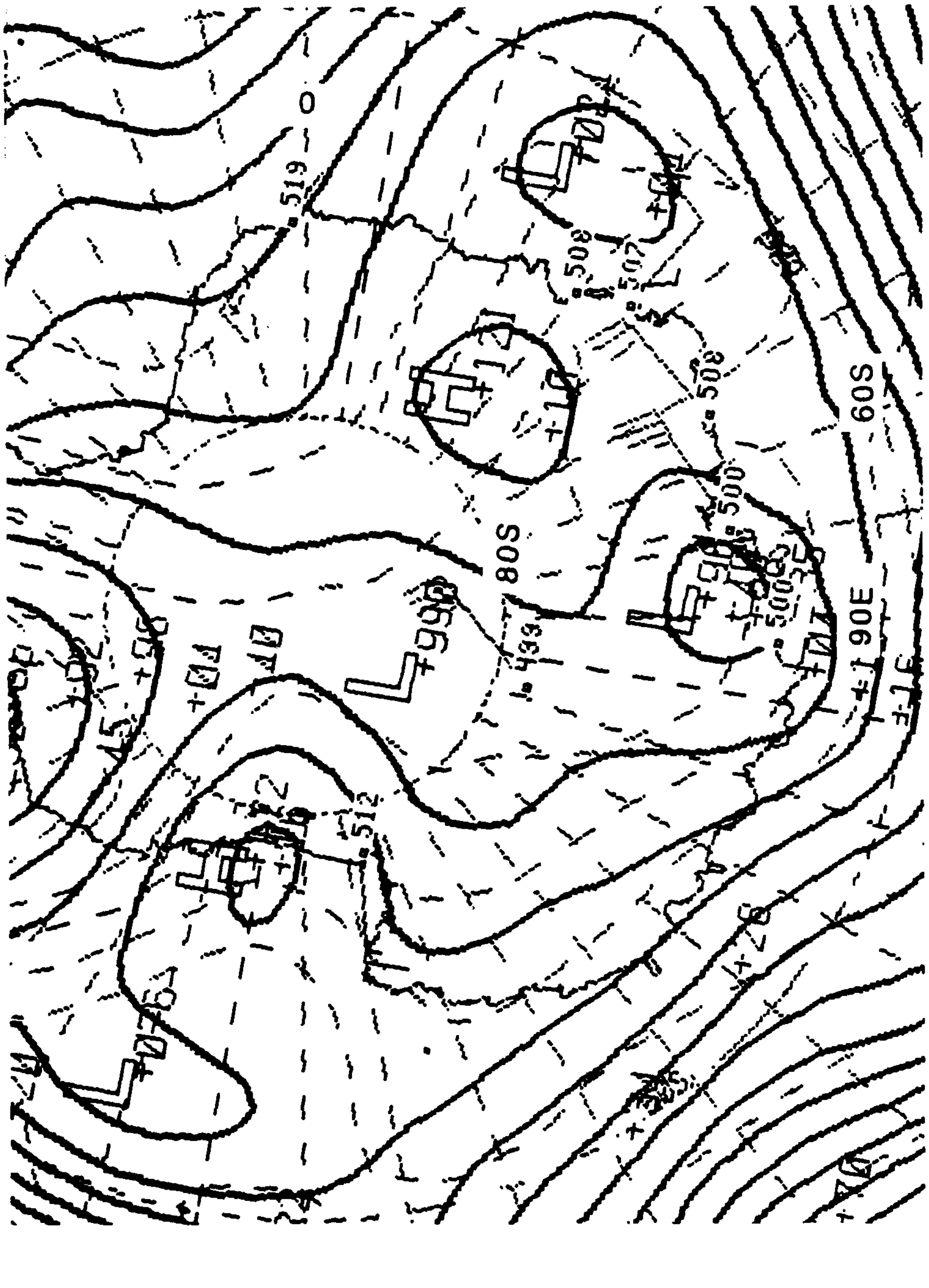


Figure 16b. FNOC 500 mb Analysis for 0000 GMT 19 February 1979.

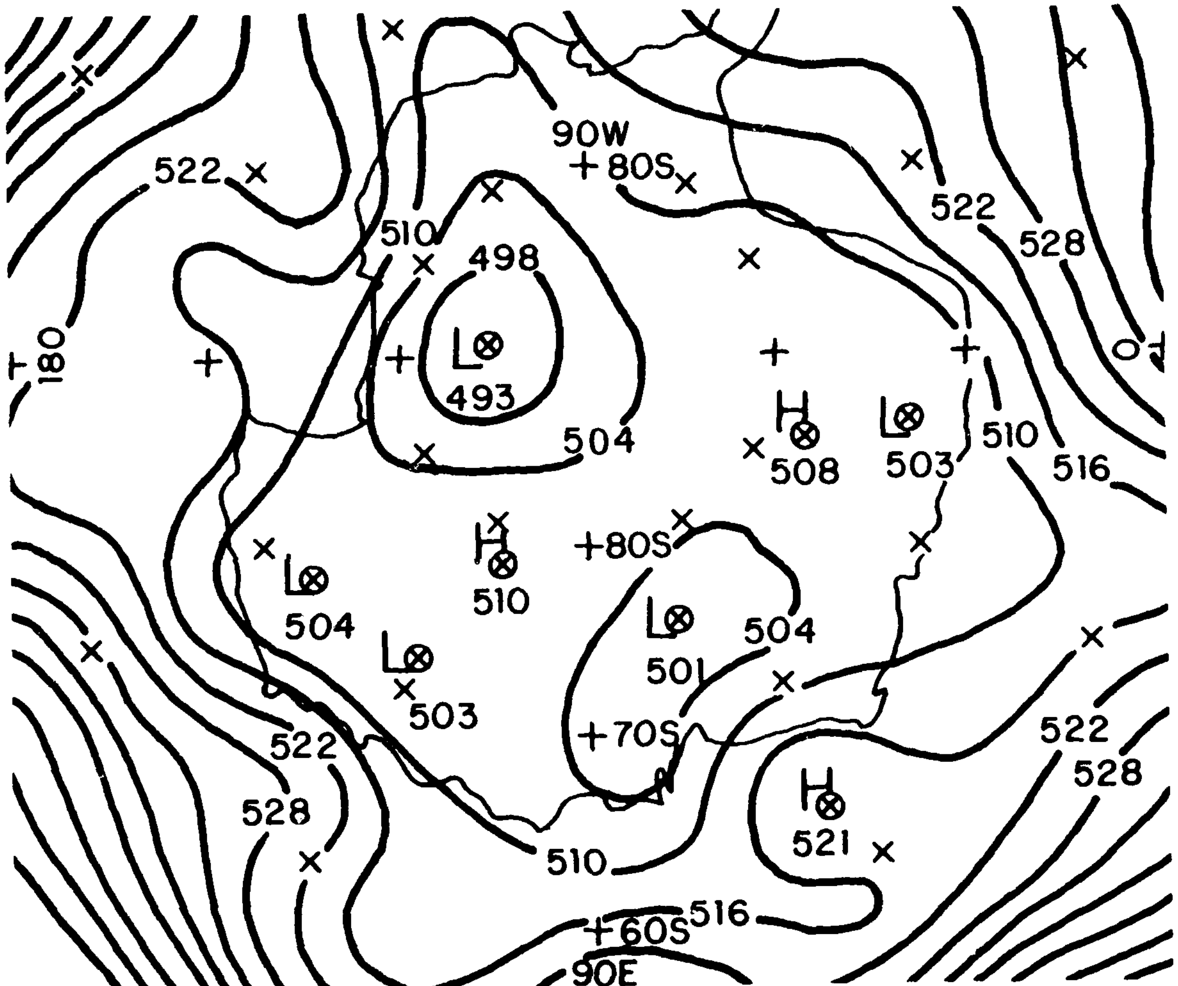


Figure 17. NMC 500 mb Analysis for 1200 GMT 18 February 1979.

LIST OF REFERENCES

Chang, D. T., and P. E. Sherr, 1969: Cloud Pattern Models for Extratropical Cyclogenesis. Final Rept., Contract No. E-203-68, Dept. of Commerce, ESSA, Washington, D.C.

Fett, R. W., P. E. LaViolette, M. Nestor, J. W. Nicholson, and K. Rabe, 1979: Navy Tactical Applications Guide, Vol II. NAVENVPREDRSCHFAC Tech. Rept. 77-04.

Guymer, L. B. and J. F. LeMarshall, 1980: Impact of FGGE Bouy Data on Southern Hemisphere Analysis. Aust. Met. Mag., 28, 19-42.

Guymer, L. B., 1978: Operational Application of Satellite Imagery to Synoptic Analysis in the Southern Hemisphere. Bur. of Meteor. Tech. Rept. 29, Dept. of Science, Melbourne, Australia, 82pp.

Junker, N. W. and D. J. Haller, 1980: Estimation of Surface Pressures from Satellite Cloud Patterns. Mariners Wea. Log. 24, 83-87.

Kelly, G. A. M., 1978: Interpretation of Satellite Cloud Mosaics for Southern Hemisphere Analysis and Reference Level Specification. Mon. Wea. Rev.,106, 870-889.

Lysakov, E. P., 1978: Possible Mechanisms of Meridional Atmosphere Circulation over Antarctica. Ant. Jour. of the U.S., XIII, 181-183.

Martin, D. W., 1968: Satellite Studies of Cyclonic Development over the Southern Ocean. Intl. Ant. Met. Res. Cen. Tech. Rept., 9, 64pp.

Mechoso, C. R., 1980: The Atmospheric Circulation Around Antarctica: Linear Stability and Finite Amplitude Interactions with Migrating Cyclones. Jour. Atm. Sci., 37, 1224-1248.

Nagle, R. E. and C. M. Hayden, 1971: The Use of Satellite Observed Cloud Patterns in Northern Hemisphere 500 mb Numerical Analysis. NOAA Tech. Rept., NESS 55, U.S. Dept. of Commerce, Washington, D.C, 24 pp.

Parish, T. R., 1982: Surface Airflow over East Antarctica, Mon. Wea. Rev., 110, 84-90.

Schwerdtfeger, W., 1970: World Survey of Climatology (S. Orvig, ed), Vol. XIV, Elsevier Pub. Co. Amsterdam, Netherlands, 383 pp.

Sherr, P. E. and C. W. Rogers, 1965: The Identification and Interpretation of Cloud Vortices Using TIROS and Infrared Observation. Final Rept., U.S. Weather Bureau Contract No. CWB-10812, ARACON Geophysics Co.

Streten, N. A. and W. R. Kellas, 1973: Aspects of Cloud Pattern Signatures of Depressions in Maturity and Decay. Jour. App. Meteor., 12, 23-27.

Taljaard, J. J., 1967: The Behavior of 1000-500 mb Thickness Anomalies in the Southern Hemisphere. Notos, 16, 3-20.

Taljaard, J. J., H. van Loon, H. L. Crutcher, and R. L. Jeanne, 1969: Climate of the Upper Air, Part 1 Southern Hemisphere. Navair 50-1C-55, U.S. Navy, Washington, D. C.

Trenberth, K. E., 1979: Interannual Variability of the 500 mb Zonal Mean Flow in the Southern Hemisphere. Mon. Wea. Rev., 107, 1515-1524.

Troup, A. J. and N. A. Streten, 1972: Satellite Observed Southern Hemisphere Cloud Vortices in Relation to Conventional Observations. Jour. Appl. Meteor., 11, 909-917.

Van Loon, H., J. J. Taljaard, T. Sasamori, J. London, D. V. Hoyt, K. Labitzke, and C. W. Newton, 1972: Meteorology of the Southern Hemisphere (C. W. Newton, ed). Amer. Met. Soc. Monograph, Boston, Mass, 263 pp.

Weldon, R. B., 1975: NWS Satellite Training Note Part I and II. Unpublished Report.

Widger, W. K., Jr., C. W. Rogers, and P. E. Sherr, 1967: Applications of Satellite Observations of Extratropical Cloud Vortices. Proc. of the Tech. Exchg. Conf., AWS TR 1967, USAF, Air Wea. Serv.

Zillman, J. W. and P. G. Price, 1972: On the Thermal Structure of Mature Southern Ocean Cyclones. Aust. Met. Mag., 20, 34-48.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, CA 93940	2
3.	Professor C. N. K. Mooers, Code 68 Naval Postgraduate School Monterey, CA 93940	1
4.	Professor R. J. Renard, Code 63 Naval Postgraduate School Monterey, CA 93940	10
5.	Professor C. H. Wash, Code 63WY Naval Postgraduate School Monterey, CA 93940	1
6.	Professor R. G. Paquette, Code 68Pa Naval Postgraduate School Monterey, CA 93940	1
7.	Director Naval Oceanography Division Naval Observatory 34th and Massachusetts Ave. NW Washington, D. C. 20390	1
8.	Commander Naval Oceanography Command NSTL Station Bay St. Louis, MS 39522	1
9.	Commanding Officer Naval Oceanographic Office NSTL Station Bay St. Louis, MS 39522	1

10. Commanding Officer 1
Fleet Numerical Oceanography Center
Monterey, CA 93940

11. Commanding Officer 1
Naval Ocean Research and Development Activity
NSTL Station
Bay St. Louis, MS 39522

12. Commanding Officer 1
Naval Environmental Prediction Research Facility
Monterey, CA 93940

13. Chairman, Oceanography Department 1
U.S. Naval Academy
Anapolis, MD 21402

14. Chief of Naval Research 1
800 N. Quincy Street
Arlington, VA 22217

15. Office of Naval Research (Code 480) 1
Naval Oceanography Research and Development
Activity
NSTL Station
Bay St. Louis, MS 39522

16. LCDR R. L. Fauquet 3
7662 Fallswood Way
Lorton, VA 22079

17. Dr. David Bromwich 1
Institute of Polar Studies
Ohio State University
125 S. Oval Mall
Columbia, Ohio 43210

18. Dr. Austin W. Hogan 1
Atmospheric Sciences Research Center
Earth Science Bldg., Rm. 324
State University of New York at Albany
1400 Washington Avenue
Albany, N.Y. 12222

19. Dr. T. R. Parish 1
Dept. of Atmospheric Science
University of Wyoming
Box 3038 University Station
Laramie, WY 82070

20. Dr. Allen M. Peterson 1
Center for Radar Astronomy
Durand Bldg., Rm. 227
Stanford University
Stanford, CA 94305

21. Dr. G. Wendler 1
Geophysical Institute
University of Alaska
College, AK 99701

22. Dr. Ben Fogle 2
Program Manager
Office of Polar Programs
National Science Foundation
Washington, D. C. 20550

23. Dr. Werner Schwerdtfeger 1
Dept. of Meteorology
University of Wisconsin
Madison, WI 53706

24. Dr. A. Poggi 1
Centre, National de la Recherche Scientifique
Laboratorie de Glaciologie
2, rue Tres-Cloitres
38301 Grenoble, France

25. Library 1
Cold Regions Research and Engr. Lab
U.S. Army
Hanover, NH 03755

26. Polar Research Lab 1
Attn. John Anderson
123 Santa Barbara St.
Santa Barbara, CA 93101

27. Science Applications Inc. 2
2999 Monterey-Salinas Hwy.
Monterey, CA 93940

28. Commanding Officer 1
Naval Support Force Antarctica
FPO San Francisco, CA 96601

29. Officer in Charge 1
Met. Div., Code 30
Naval Support Force Antarctica
FPO San Francisco, CA 96601

30.	Commanding Officer Naval Polar Oceanography Center Navy Department 4301 Suitland Road Washington, D.C. 20390	1
31.	LCDR K. M. Scarbro Naval Polar Oceanography Center Navy Department 4301 Suitland Road Washington, D.C. 20390	1

ATE

MED

-8