A Selected Climatology of the Southern Hemisphere: Computer Methods and Data Availability

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FOREWORD

Four volumes of a Southern Hemisphere Climatological Atlas which include selected maps and cross-sections have been published. Volumes I and IV are available from the National Climatic Center (NCC); Volumes II and III are also available from NCC or may be obtained from NCAR.

In this write-up we discuss computer methods and announce the availability of a tape with magnetic grid point information for a more complete set of basic and derived data than that presented in the atlas. We also describe a set of microfilm having approximately 10,000 frames of basic charts, seasonal changes, cross sections, grid point values, etc. We finally announce the availability of a computer produced motion picture concerning the climatology of the Southern Hemisphere.

ACKNOWLEDGMENTS

Special thanks are due Dennis Joseph of NCAR who wrote the raob statistics program, helped with the computer microfilming, and worked on other aspects of the computer programming. Dori Bundy contributed a large amount of effort toward the production of the computer microfilm.

Robert Quayle at the National Climatic Center has been very helpful in getting the grid point data to NCAR, and in helping with the drafting of charts for publication. He also helped resolve analysis problems when a given machine-calculated intermediate-month southern hemisphere map did not closely match the corresponding northern hemisphere hand-analyzed map in some region along the equator.

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INTRODUCTION

The basic analyses and selected derived products have been published in four volumes of an atlas covering selected climatic conditions in the southern hemisphere. Volume I (Taljaard, et al., 1969) gives mean monthly isopleth charts of sea-level pressure and of height, temperature and dew point at selected upper levels together with smoothed grid-point values produced by computer analysis from these charts. Volume II (Van Loon, et al., 1971) deals with geostrophic zonal and meridional wind components, Volume III (Jenne, et al., 1971) with isogons and isotachs of the geostrophic wind, and Volume IV (Crutcher, et al., 1971) with selected meridional cross sections of temperature, dew point and isobaric height.

The Analysis Procedures

In the analysis of the data, procedures were first used to insure time and space continuity of surface temperature and sea level pressure over the ocean areas. Grid point data were read from the U. S. Navy Marine Climatic Atlas series for selected latitudes in order to construct curves as shown in Figure 1. Data for Orcadas provided guidance in drawing the curves showing the annual march of temperature at the other grid points. After the curves were drawn, points were read from them to use in drawing the monthly maps. In Volume I of the southern hemisphere atlas, we describe the procedures used to maintain vertical consistency in the analyses. The seven levels are the surface, 850, 700, 500, 300, 200 and 100 mb.

The basic analyses were for the seven levels for the four seasonal months of January, April, July, and October. For the other eight months analyses were only made at sea level, 500 mb, and 200 mb. Later on, the other 100 mb height maps were also hand-drawn. The computer derivation of the remaining intermediate month grids and of the various derived grids such as geostrophic winds will be discussed.

We will describe the computer methods used in processing the observed data and the grid point values from the Southern Hemisphere Climatology Project. We will discuss the total set of long-term mean monthly analyses plus derived data and their format on magnetic tape. We will also indicate
the availability of computer-prepared microfilm maps of the analyses and
of many derived microfilm charts, such as cross-sections and harmonic
analyses. Motion pictures presenting these and other data will also be
described.

The references include a number of publications such as the AMS

PROCESSING THE OBSERVED DATA

PROCESSING THE UPPER AIR DATA

We now describe the processing of the major part of the upper air
data that was used. The National Climatic Center (NCC), Asheville, North
Carolina, provided the National Center for Atmospheric Research (NCAR),
Boulder, Colorado, with magnetic tapes containing the world monthly mean
rawinsonde (raob) data from "climat temp" reports as published in "Monthly
Climatic Data of the World." Available data for southern hemisphere sta-
tions for 1965 and 1966 were specially punched at NCC to include data
through October 1966. These 1,855 more recent reports brought the total
number of available monthly reports to 52,868. Of these, 11,261 were for
stations south of 5°N latitude.

Since data for several stations were still completely missing from
the record, we obtained tapes with daily raob data (39,288 raobs) from
the U.S. Air Force Air Weather Service, Data Processing Division. Stations
included were Ascension Island; Belem, Brazil; Sao Paulo, Brazil; Fernando
Noronha, Brazil; Porto Alegre, Brazil; and Salinas, Ecuador.

In Volume I of the atlas we have described the other sources of
data. For example, the wind data often had to be obtained elsewhere
because it was not included in most of the earlier climate reports.

CHECKING THE RAWINSONDE DATA

The monthly mean raob data contained the usual errors of computation,
transcription, and communication which may be expected in such large sets
of data that have not been quality checked. We now describe the checks that were made.

The monthly mean raob reports were first put into a packed binary format to make further processing easier and more efficient. During this process the original punched cards were checked for certain errors which could be detected just by checking for proper format.

Library data then were added to the monthly reports. These included location data and the station elevation which was necessary for a hydrostatic check that included the surface level. Most of this information came from a library tape obtained from the Air Force; the tape data were largely based on station data published by the World Meteorological Organization (WMO). Station data for some current southern hemisphere stations and for all discontinued stations were missing on this tape. These were obtained from other sources. In the atlas, we present a station locator chart and an associated station listing. The elevation data were checked for those stations that reported surface pressure and temperature data. To do this we calculated an elevation for each station by integrating downward from the first reported mandatory level (assuming that the temperature change is linear in ln P).

After initial computer checks were made on the data, it was apparent that the errors were too numerous to be corrected manually. Thus the program was designed so that the computer could both identify the errors and modify the mean year-month soundings. The program was normally able to identify temperature errors over 2-4°C and height errors over 21-35 m.

We now describe the major features of the hydrostatic checking program. For each layer in a radiosonde observation (raob), we calculated a mean virtual temperature from the height data and a mean virtual temperature from the temperature and humidity data. If these temperatures agreed to within 2°C, the whole sounding passed the hydrostatic check without corrections. If not, the program first searched for a single bad interior level with a bad temperature or height, but not both. In this case the temperature or the height was set to be the average of the values computed
by working up from below and down from above. These corrections have a very high accuracy. To make other necessary corrections, the program built up or down from the good levels in the sounding.

In building up from a good to a bad level, the program decided whether the temperature or height or both needed correction at the bad level. To do this it first checked the temperature. If it was within 2°C of the normal temperature, it was accepted. The normal temperature was defined by an original statistics run that included only the data that passed a hydrostatic check. Also, the reported temperature was accepted if it was within 2.5°C of a temperature built up from the lower level temperature and the normal lapse rate. If the temperature was bad, it was replaced with either the built-up temperature just discussed or with a temperature calculated from the two heights and the lower temperature. The latter was used if it was within 2.9°C of the built-up temperature. Then an expected height value was calculated from the two temperatures and the lower height. The reported height was accepted if it was within 21 m of this value in the lower levels, 25 m above 150 mb, or 35 m for the top level. If several interior standard levels were missing in a sounding, the program did not use a straight-line temperature assumption to calculate the expected heights; instead, it used the normal thickness, as adjusted by the deviation from the normal temperatures.

The checks going downward from a good level were made in the same way except for the surface level. Here the station elevation was considered to be known, so the pressure was checked for consistency within 3 mb.

About 6,000 of the 53,000 reports had at least one correction or the recalculation of a missing value. About 600 reports did not have any levels that checked hydrostatically. Time was not available to salvage good data in these reports. The 6,000 corrected reports were printed to enable a person to monitor the corrections made. The printed corrections for southern hemisphere reports were scanned. Although the modifications looked very good, in general, a few control cards were cut to force the program to correct some reports in a different way.
Often more trouble occurred in the hydrostatic check of the height at the top level than for the other heights. For this reason the throw-out limit at the top was set fairly wide at 35 m. Some of these top-level problems were caused by the proximity of the tropopause, some were normal errors, and some likely were caused by only a few of the month's balloons reaching the top level.

All of the reports were next put through a wind checking program. It identified and printed cases of questionable wind shear. These were inspected manually, and necessary corrections were made.

Similar programs were used to check the daily raob data, but time was not available to program for all peculiar cases nor could manual effort be used to salvage data that did not pass the checks. Enough data did pass the check to allow the calculation of monthly mean data for nearly all available year-months.

**CALCULATION OF RAWINSONDE STATISTICS**

All of the checked monthly mean data for each station and month were then summarized to produce long-term monthly mean data. The mean values were calculated in the normal way. Standard deviations were calculated according to the formula:

\[
SD = \sqrt{\frac{\sum_{1}^{n} (x - \bar{x})^2}{n - 1}}
\]

or for ease of calculation:

\[
SD = \sqrt{\frac{\sum_{1}^{n} x^2 - nx^2}{n - 1}}
\]

where \(x\) is an individual value
\n\(\bar{x}\) is the mean of \(n\) values.
In this formula, the denominator is \( n - 1 \) instead of \( n \) in order to give an estimate of the standard deviation in the total population. See Crutcher and Meserve (1970) or textbooks on statistics for a discussion of the statistical properties for these distributions.

**PROBLEMS WITH HUMIDITY DATA**

An interesting data problem appeared when the summarized dew-point temperature for Belem, Brazil, seemed too low for several months. For example, in August at 850 mb the dew point was about 0°C instead of the more likely value of 13°C. When the original daily data for August 1944 and August 1945 were inspected, we found, for example, that only 20 of the 58 raobs had actual relative humidity data reported at 850 mb. The humidity elements on the other balloons apparently did not work; and the data on the punched cards were set to the "statistical value" of 20 percent relative humidity. An inspection of continuity indicated that on most days the actual humidity was between 70 and 100 percent. Belem mean monthly rainfall for the months May through September is 10.2, 6.7, 5.9, 4.4, and 3.5 inches. Thus one would not expect the dew points in July and August to be much lower than in June and September, but they were lower when the statistical humidity values were used in the statistics.

To obtain the best estimate of the dew-point temperatures at Belem and at other South American stations where we had daily data, we made the calculations using all of the statistical humidity values and using none of them. Both of the resulting average values were available to the analyst drawing the chart. A further discussion of the dew-point temperature analysis problem is contained in Volume I of the atlas.
PROCESSING THE GRID POINT DATA

THE READING OF GRID POINT DATA

The NCC staff at Asheville read grid point values of pressure, height, temperature, and dew point for each 5° intersection of latitude and longitude on the analyzed charts. Temperatures and dew points were read to the nearest tenth of a degree, sea-level pressures to the nearest 0.5 mb, and heights to the nearest geopotential dekameter. The values were punched on cards, which were put onto magnetic tape and sent to NCAR for further processing.

QUALITY CHECKS ON GRID POINT VALUES

NCAR prepared computer programs which organized the data into more convenient hemispheric grids (72 x 19 points). The computer checked the mechanical accuracy of the grid point values. These checks were made by curve fitting techniques and by visual inspection of contoured maps. The latter were made directly on microfilm by the computer from the grid point values (see Figure 4, discussed later after Figures 2 and 3). To make microfilm maps the computer uses a cathode ray tube device with its light beam under computer control. Where the computer-made map showed a sudden kink in the contours, an error could be found in the grid point values.

Some corrections were made for errors as small as 10 m in height when it appeared that the grid point smoothing procedure might not completely get rid of the problem.

SURFACE GRID MAP CORRECTIONS MADE DUE TO GRID SCALE

On the surface maps of temperature and dew point some relatively small-scale features were drawn in to indicate changes with elevation on mountains. These were then reflected in the grid point values. Thus certain grid points had values appropriate to mountain peaks in New Guinea, or the Andes, etc. These grid values have been altered so that they are more
appropriate to the relatively coarse grid used (5° latitude and longitude).

**COMPUTER SMOOTHING OF THE GRIDS**

Even in the best hand analyses, there are small unwanted wavelengths that are introduced by the way the contours are drawn or traced. In addition, the reading of the grid point values introduces some noise. Therefore, a smoothing method had to be applied to insure a set of grid values which could be used to obtain a variety of derived parameters, such as geostrophic winds.

The smoothing method that was applied to the grids was based on a 25-point two-dimensional filter (Bleck, 1965). At each point in the grid, a new smoothed value is obtained by multiplying this value by the weight from Figure 2a, by multiplying the surrounding 24 unsmoothed values by the corresponding weights from Figure 2a, and then summing the results. Note from Figure 2b, which shows the spectral response of this filter, that waves having a wavelength of less than 2.5 grid distances are almost entirely eliminated, and those over 5.0 grid distances are almost entirely preserved.

The application of the smoothing filter is more complicated than implied above. On a latitude-longitude grid, the meridians converge to the pole so that proper polar area smoothing cannot be obtained by just applying the filters to this grid. For the polar region, the grid was transformed to the southern hemisphere equivalent of the United States National Meteorological Center (NMC) octagonal grid, which is a uniformly spaced grid on a polar stereographic chart. The polar data were smoothed on this grid (which has a grid spacing of about 380 km) and then transformed back to the latitude-longitude grid.

The computer smoothing of a complete map was done as follows: To obtain a reasonably smooth polar area before the grid transformation, a 9-point smoother (Figure 3) was applied in the east-west direction at all points from 75°S through 85°S. It was also applied at the equator and at 5°S. Then a 16-point interpolation scheme was used to obtain an NMC
octagonal grid. The 25-point filter was applied to the interior points of this grid. Then the 16-point interpolation scheme was used for obtaining values from the smoothed NMC grid for the latitude-longitude grid in the region from 60°S to the pole.

The 25-point filter was then applied to all points in the latitude-longitude grid from 5°S through 85°S. In order to apply the smoother at 5°S, data points at 5°N were created by extrapolation based on the gradient from 5°S to the equator. For the height and surface pressure grids, northern hemisphere grid analyses were available to permit smoothing across the equator. This allowed us to make revised smoothed values at the equator and 5°S. We also smoothed the temperature and dew point grids at all levels above the surface. For these, we did not revise the equatorial smoothed values by using northern hemisphere data.

In the microfilm data, which is available for purchase through NCC, we have included prints showing all of the changes made by the smoothing of the grids. Generally, the smoothing process only changed the surface pressures by 0.0-0.5 mb with some peak changes of 1.5-2.0 mb. The changes in the upper air grid point data are generally 0-8 gpm with some peak changes of about 25 gpm. The temperature changes were usually 0.0-0.5°C with peak changes of 2 or 3°C, and peak dew point changes of about 4°C.

Figures 4 and 5 show contours of unsmoothed and smoothed versions of a height grid.

In the atlases the smoothed grid point data are printed on the same page as the map; the surface temperature and surface dew point data have not been smoothed.
Hand analyses of pressure-heights were made of all of the selected levels for the four seasonal months: January, April, July and October. Analyses were first drawn at only the surface, 500 and 200 mb levels for the other eight months. Later, we made hand analyses of the eight 100 mb maps. In this section we describe the computer methods used to complete the set of height analyses. The methods use grid points from the various hand drawn maps as input; the station data were not used.

The analysis grids for the intermediate months were calculated by using a method of dividing up the observed thicknesses based on how they are known to be divided up in the four midseason months. Thus the assumption for the 850 and 700 mb levels was that the thickness between a pressure-height surface near sea level (calculated from the sea-level pressures) and the 500 mb heights could be divided up by a weighted average of the way that it was observed to be divided up in the associated two midseason months. Note that this does not put any restrictions on the mean layer temperatures in the intermediate months, but is, for example, satisfied when the lapse rate changes in a linear way. Values for 300 mb were calculated in the same way, only they were based on the 500-200 mb thicknesses. As these intermediate month grids were calculated from smooth grids, we found that it was neither necessary nor desirable to smooth them.

The eight intermediate-month 100 mb maps, though hand-drawn, were not built up from 200 mb by making 200-100 mb thickness analyses. Instead, the drawing of a number of annual height curves permitted control of time continuity over the oceanic areas. In these annual curves the grid point values for the four seasonal months act as fixed control points.

ACCURACY OF THE COMPUTED HEIGHT GRIDS

The method of calculation was applied to observed data from southern
hemispheric stations for which at least five years of data were available. Table 1 is a listing of the "error" frequency for these calculations. The errors include problems in the station data as well as in the assumptions used; many of the "errors" at 850 and 700 mb were found to be due to the problem of finding a sea-level pressure for the station data that was completely compatible with the upper air data. Note that at the 300 mb level the errors are small even though the data are less reliable and the tropopause variations can introduce some errors.

In addition, computed intermediate month grid values were compared with values from hand analyses that did not involve the elaborate vertical build-up procedures that were used for the main set of hand analyses. Such an analysis for February at 700 mb and another one for August at 300 mb were compared with the calculated grids. In areas where data was available, differences were 0 to 15 m. Over the ocean areas, where data are sparse, differences went up to 80 m, and the computer product was better.

One can note from the available microfilm time continuity plots (see example in Figure 6) and in the cross sections of height D-values that the values from the calculated heights fit in smoothly with the values from the hand-drawn heights.

**COMPUTER CALCULATION OF SELECTED LEVEL VIRTUAL TEMPERATURES AND TROPOPAUSE DATA FROM HEIGHT GRIDS**

For the following reasons, a method was developed to calculate an approximate virtual temperature profile from the surface pressure and the six pressure-height analyses for each month:

1. To provide first-guess temperature data for the hand-drawn temperature analyses. These have helped to insure consistency between the height and temperature analyses over the ocean areas.
2. To provide some approximate information about the height and temperature of the tropopause.

First, a mean virtual temperature was calculated for each of the six layers between sea level and 100 mb. Each mean temperature was assigned to
Table 1. Frequency of "errors" when the method of calculating heights was applied to station data.

<table>
<thead>
<tr>
<th>Error in Meters</th>
<th>0-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-25</th>
<th>25-40</th>
<th>40-60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level: 850 mb</td>
<td>355</td>
<td>141</td>
<td>65</td>
<td>40</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Level: 700 mb</td>
<td>426</td>
<td>133</td>
<td>30</td>
<td>17</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Level: 300 mb</td>
<td>422</td>
<td>125</td>
<td>40</td>
<td>19</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Empirical corrections involved in the calculation of 100 mb temperatures from heights.

<table>
<thead>
<tr>
<th>Latitude:</th>
<th>Eq.</th>
<th>5S</th>
<th>10S</th>
<th>15S</th>
<th>20S</th>
<th>25S</th>
<th>30S</th>
<th>35S</th>
<th>40S</th>
<th>45S</th>
<th>50S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correction:</td>
<td>6.0°C</td>
<td>6.0</td>
<td>6.1</td>
<td>6.0</td>
<td>5.9</td>
<td>5.4</td>
<td>4.4</td>
<td>3.2</td>
<td>2.2</td>
<td>1.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>
the midpoint of the layer as defined by the average logarithm of the pressures. From these values, initial virtual temperatures at the standard levels of 850-200 mb were calculated by assuming a straight-line temperature change (in space that is linear in ln(pressure) and temperature) between layer mean temperatures. A sea-level temperature was calculated from a straight line (in ln P) to sea level that passed through the mean temperatures at 592 mb and at about 925 mb. A temperature at 100 mb was similarly computed by straight-line extrapolation of the mean temperatures at 245 mb and 141 mb to 100 mb. For the latitudes, equator through 50°S, an empirical correction (shown in Table 2) was added to the 100 mb temperatures thus calculated. Poleward of 25°S, an additional 1-3°C of accuracy could have been obtained by also making a seasonal correction, but time did not permit this. If the calculated 100 mb temperature as corrected was less than -83°C, it was set to -83°C.

Tropopause Calculation and Temperature Adjustment

One of the three main decisions that the program made in computing the tropopause from the computed temperatures was that there was no tropopause below the height of 100 mb. This decision was made when the upper portion of the temperature sounding was not significantly more stable than the lower part. Thus there was no tropopause below the 100 mb height if the following quantity was greater than -11:

\[
\left( \frac{T_{925mb} - T_{387}}{\ln(925/387)} + \frac{T_{141} - T_{100}}{\ln(141/100)} \right)
\]

In this case, the tropopause was assigned to 99 mb and given the 100 mb temperature. The peculiar pressure levels in the above expression are associated with the midpoints of layers as defined by the average of the logarithms of pressure.

In the other two cases, the height and temperature of the tropopause were derived by solving for the intersection of two straight lines in temperature-ln(P) space. One of these lines was defined by the temperatures
at 925 and 387 mb. The other straight line was defined by temperatures at 245 and 141 mb if $T_{141} - T_{245}$ was greater than -1.5. Otherwise, the other straight line was given by temperatures at 141 and 100 mb.

If the pressure of the calculated tropopause was more than 141 mb, two adjustments were made to the temperatures already calculated. One was that the tropopause temperature was increased slightly since the tropopause in a mean sounding normally would not have an abrupt change in lapse rate. Also, the temperature for the mandatory level nearest to the tropopause was recalculated from the appropriate one of the two straight lines. (It was originally computed from a straight line between the mean temperatures.) This normally lowers the previously calculated temperature 1° to 4°C.

QUALITY OF CALCULATED VIRTUAL TEMPERATURE AND TROPOPAUSE DATA

The calculated virtual temperatures are good at 500 mb. They are slightly worse at 700 and 300 mb. At 850 mb and especially at sea level, they suffer mostly from problems caused by inversions in the lapse of temperature, by error magnification in the extrapolation to sea level, and by small problems introduced by differing lengths of record between the surface and the upper air data. An example of the problems associated with surface inversions is that the Antarctic surface inversion near 700 mb causes the calculated 500 mb temperature to be 2 or 3°C too low in the winter months.

Following are the changes in layer thicknesses that will produce a change in layer mean temperature of 1°C:

<table>
<thead>
<tr>
<th>Layer (mb)</th>
<th>ΔH (m)</th>
<th>Layer (mb)</th>
<th>ΔH (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000/850</td>
<td>4.8</td>
<td>500/300</td>
<td>15.0</td>
</tr>
<tr>
<td>850/700</td>
<td>5.7</td>
<td>300/200</td>
<td>11.9</td>
</tr>
<tr>
<td>700/500</td>
<td>9.8</td>
<td>200/100</td>
<td>20.3</td>
</tr>
</tbody>
</table>

As the calculated tropopause levels are based on only a limited amount of thermal data derived from the heights, and on empirical tempera-
ture corrections at 100 mb, they can be used only as a guide. The values under about 200 mb should be quite good; those closer to 100 mb are likely to be progressively worse. The values are probably within about 30 mb of the best value with space and time consistency even better than this. We also should note that there are problems in the tropopause statistics from raob stations, because it is often difficult to assign a single clear-cut tropopause level to a sounding.

CALCULATION OF TEMPERATURE AND DEW POINT ANALYSES FOR INTERMEDIATE MONTHS

We have described the calculation of the virtual temperatures that were used as a first guess for some of the manual temperature analyses. Now we will describe how the temperature and dew point analyses for the intermediate eight months were computer derived for 850 and 700 mb by using a method similar to that used for the calculation of the intermediate month height analyses. For example, to calculate an 850 mb February temperature at a grid point, the program first found the ratio of the January temperature change from surface to 850 mb to the change from surface to 500 mb. It then multiplied this ratio by 2/3 and a similar April ratio by 1/3 to compute a February ratio. From this ratio and the February surface and 500 mb hand-analyzed temperatures (both smoothed in the horizontal—not in time), the desired 850 mb temperature was calculated. In the procedure used, 100, 200, or 300 degrees was first added to the temperatures at 850, 700, or 500 mb, respectively, to avoid problems with large changes in the ratios caused by small deviations from near-isothermal lapse rates. Dew-point temperatures were calculated in the same way by using the hand-analyzed dew point fields as the input grids. The microfilm temperature continuity plots (Figure 17 is an example) show that the calculated temperatures are reasonable. The differences between station data and grid point data are nearly the same for the computed grids and the hand-analyzed grids.

A different method had to be used to calculate the temperatures for the intermediate months at 300, 200, and 100 mb because no manual analyses of temperature were made above 500 mb for these eight months. To derive
these temperatures, we first took our complete set of height grids as analyzed or derived, and time smoothed them, using the 9 point filter (shown in Figure 3) on each grid point. We used the resulting set of heights to calculate virtual temperatures as previously described. These virtual temperatures at 300, 200, and 100 mb for the intermediate months were used together with the hand-analyzed grids for January, April, July and October. Then each of the three levels was time smoothed using the 11-point filter shown in Figure 7 which is a "heavier" filter than the usual 9-point one that we used. To do the smoothing, at each grid point (and for each level) we took the 12 temperature values for the year and applied the 11-point filter centered at each intermediate month, putting the smoothed data into another array. Then the same filter was applied again using the original data for the four seasonal months and using the results of the first smoothing pass for the other months. The filter was applied a third time in the same way. The seasonal months were not altered. The high level temperatures for intermediate months published in NOTOS (Jenne et al., 1968) show more variability than is desirable because the heights were not time smoothed and the 11-point filter was not used. All temperature data (type 3) on microfilm and tape reflect the new results, but the calculated virtual temperatures and the tropopause data on film and tape are not based on the time smoothed heights.

When the upper air temperature charts were drawn for the four seasonal months, the calculated virtual temperatures were available to use as a guide. When the other eight months of 500 mb temperatures were analyzed, the calculated temperatures were not yet available. Also, some adjustments in the height analyses were made after the original temperatures were calculated. In order to help see if changes should be made in the temperature analyses, computer printouts were made of the original calculated virtual temperatures minus the latest calculated temperatures, and of calculated minus hand-drawn temperatures. An inspection of these prints showed that a few additional changes could be made in the hand-drawn temperatures. Time was not available to make such changes, but most changes would be small with the largest around 1 or 2°C. The calculated virtual
temperatures (defined as type code 10) minus the associated temperatures based on hand-drawn data (type code 3) are included in the set of microfilm data. These indicate that the calculated intermediate month type 3 temperatures are of nearly comparable quality to the hand-analyzed grids. The microfilm temperature cross sections and the time continuity plots also support this conclusion.

After the dew point charts were available, grids of temperature minus dew point were printed. Where these showed dew point temperatures warmer than the temperature, adjustments were made in the dew points. We have already discussed how some very small-scale features were removed from the surface temperature and dew point grids.

**CALCULATION OF SURFACE PRESSURE AND PRECIPITABLE WATER**

To calculate a surface pressure, we first derived a mean elevation for the 5° lat-long square centered on each grid point. We calculated the mean elevation from a tape received from the Scripps Institute of Oceanography, La Jolla, California, which has the elevation for 1° squares. If the mean surface elevation was zero at a grid point, the surface pressure was set equal to the sea level pressure. If the elevation was at or under 150 meters, the surface pressure was calculated by integrating the hydrostatic equation between sea level and the surface. To do this, we used the given sea level pressure, and assumed isothermal temperatures equal to the mean surface virtual temperature.

For elevations above 150 m, the surface pressure was calculated by working down from above. We identified several levels to use in calculating the surface pressure and the precipitable water: surface, 900 meters above the surface, first mandatory level that was more than 900 m above the surface, next mandatory level, succeeding mandatory levels, and tropopause.

The mandatory levels that might be between the 900 m level and the tropopause are the 850, 700, 500, 300 and 200 mb levels. The two levels above the 900 m level were used to define a temperature lapse rate with
height, which was used to extrapolate the temperature curve down to the 900 m level. If this temperature was more than 15°C warmer than the surface temperature, the surface temperature was warmed up so that the difference was 15°C. Surface inversions of over 15°C were not permitted in these calculations because such intense inversions normally apply to a very shallow layer. A dew point temperature for the 900 m level was also calculated by downward extrapolation. The dew point temperatures for the levels above 500 mb and for the tropopause were calculated by assuming the same temperature-dew point spread as at 500 mb.

Guess pressures for the 900 m and surface levels were calculated by integrating downward from the third level. The guess pressures were then used to calculate virtual temperatures at each of the three levels, and then new pressures for 900 m and the surface were calculated assuming a linear temperature change (in ln P).

The program was somewhat more general than this to account for the possibility of very high elevations combined with a low tropopause. If the tropopause were the only level above the 900 m level, the lapse rate used to integrate down from the tropopause was the rate between the tropopause and the mandatory level under it. If the tropopause were below the 900 m above ground level, then the two mandatory levels above and below would be used. This latter case rarely if ever happens in the southern hemisphere.

The downward extrapolation was actually made for all of the grid points. Thus the results could be compared with the sea level pressures for the 808 ocean grid points, and with the isothermal calculations for the other 113 points less than 150 m in elevation. The absolute errors in surface pressure are shown in Table 3. The smallness of these errors is another indication of the vertical consistency of the analyses, and of the fact that the calculated intermediate month analyses at 850 and 700 mb are also reliable. To consider possible problems concerning the assumed structure of the temperature near the ground, note that a 5°C error in the mean temperature of the 900-meter-thick surface layer causes an error in calculated surface pressure of about 2.5 mb.
Table 3. The sea level column shows the average absolute difference between the analyzed sea level pressure and the pressure calculated downward using the 850 and 700 mb levels (for 808 grid points). The other column shows the absolute difference between pressures calculated by upward and downward extrapolation for other elevations under 150 meters (113 grid points).

<table>
<thead>
<tr>
<th>Month</th>
<th>Sea Level</th>
<th>&lt; 150 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.76 mb</td>
<td>1.00 mb</td>
</tr>
<tr>
<td>2</td>
<td>.79</td>
<td>.93</td>
</tr>
<tr>
<td>3</td>
<td>.74</td>
<td>1.15</td>
</tr>
<tr>
<td>4</td>
<td>.80</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>.75</td>
<td>1.24</td>
</tr>
<tr>
<td>6</td>
<td>.74</td>
<td>1.36</td>
</tr>
<tr>
<td>7</td>
<td>.74</td>
<td>1.08</td>
</tr>
<tr>
<td>8</td>
<td>.72</td>
<td>1.56</td>
</tr>
<tr>
<td>9</td>
<td>.72</td>
<td>1.29</td>
</tr>
<tr>
<td>10</td>
<td>.96</td>
<td>1.28</td>
</tr>
<tr>
<td>11</td>
<td>.84</td>
<td>.92</td>
</tr>
<tr>
<td>12</td>
<td>.76</td>
<td>.98</td>
</tr>
</tbody>
</table>
The levels from the surface, 900 m, etc. through the tropopause (all with a dew point temperature as noted above) were used to calculate the precipitable water. First a vapor pressure in millibars at each level was calculated by:

\[
\text{Vapor pressure (mb)} = \frac{(A \times \text{DP})}{(B + \text{DP})}
\]

where \( A = 7.5 \)

\( B = 237.3 \)

\( \text{DP} = \text{Dew Point temperature in degrees C (not K)}. \)

This approximation for vapor pressure doesn't differ by more than .008 mb (from the preferred but more complicated formula) in the temperature range -40 to +30°C.

Then the mixing ratio was calculated by:

\[
\text{Mratio} = 0.622 \times \frac{\text{Vapor}}{\text{Pressure-Vapor}}
\]

Note that a mixing ratio of 12 grams of water per kilogram of dry air is .012. The precipitable water was calculated for a layer by:

\[
\text{PW} = \text{Avemix} \times \text{Deltapress}/(1. + \text{Avemix})
\]

where \( \text{PW} = \) precipitable water in millibars

\( \text{Avemix} = \) average mixing ratio for the pressure layer;

made by averaging the mixing ratio at either end.

\( \text{Deltapress} = \) the layer thickness in millibars: pressure at the bottom minus the pressure at the top.

The fairly large steps in the integration overestimate the moisture by about 2 percent. This helps to compensate for the underestimate caused by the calculation from monthly means rather than from daily values. Errors in the assumed dew points above 500 mb give errors of less than .1 mb in the total amount of precipitable water that is calculated. It is, however, important to use at least the 500 to 300 mb layer because there may be a considerable amount of moisture at 500 mb. One millibar of precipitable water means that one millibar of the total surface pressure is due to water...
vapor in the atmosphere. One millibar due to water vapor is approximately equal to one centimeter of precipitable water.

COMPUTATION AND REPRESENTATIVENESS OF THE GEOSTROPHIC WINDS

We have described how the grid point data were checked for mechanical errors, how the grids were computer smoothed, and how the missing grids for intermediate months were computed. We will now describe the computation of geostrophic winds from the smoothed grids.

First, the pressure (or pressure-height) gradient was calculated at each point in the grid. To do this a cubic curve was fit by the least squares method to the five north-south points, and another curve was fit to the five east-west points centered on the point in question. Then derivatives valid at the center data point were calculated from these cubic curves. A cosine-of-latitude factor was brought into the east-west derivative so that the units of all derivatives would be millibars (or meters) per distance of five degrees of latitude. Component winds were then calculated from the relations, for a constant height level:

\[
ug = -\frac{1}{\rho f} \frac{\partial p}{\partial y}
\]

\[
v_g = \frac{1}{\rho f} \frac{\partial p}{\partial x}
\]

for a constant pressure level:

\[
ug = -\frac{g}{f} \frac{\partial h}{\partial y}
\]

\[
v_g = \frac{g}{f} \frac{\partial h}{\partial x}
\]

where:

\[
f = 2\Omega \sin(\text{latitude}) \quad (\text{latitude is negative in southern hemisphere})
\]

\[
\Omega = 7.292116 \times 10^{-5} \text{ radians/sec}
\]
\[ \rho \text{ (at surface)} \approx 1.225 \times 10^{-3} \text{ gm/cm}^3 \]
\[ g = 980.665 \text{ cm/sec}^2 \]
\[ u = \text{zonal component of the wind} \]
\[ v = \text{meridional component of the wind} \]

**Special Procedures in the Calculation of Geostrophic Winds**

Near the equator, the geostrophic wind becomes a poor approximation to the real wind. This must be the case because even in the long-term mean there is often a pressure gradient across the equator in spite of the fact that the Coriolis force goes to zero there. A more or less zonal air flow which does not reverse direction at the equator often is associated with such an average pressure gradient. Thus, there is a region near the equator where other terms in the equations of motion have a dominating effect. This normally will cause the calculated geostrophic winds to be much too strong near the equator.

In low latitudes a small error in the pressure gradient will cause a large error in the geostrophic wind. For example, from Table 4 it is seen that an error in a height gradient of 10 m in 5° of latitude would produce a geostrophic wind error of 4.68 m/sec at the 15th parallel, but only 1.40 m/sec at the 60th parallel. The small errors in the analysis of pressure near the equator likely are biased toward indicating gradients that are too strong.

To obtain a better approximation to the real winds at 5° and 10° latitude, the wind there was calculated by arbitrarily using a Coriolis parameter valid at 15°. The component winds at the equator are set equal to .6 (sum of calculated winds at 5°S and 5°N) - .1 (sum of winds at 10°S and 10°N), subject to the restriction that they may not differ from the average of the 5°S and 5°N winds by over 1.5 m/sec.

**Time Smoothing of the Calculated Winds**

The grid point values were read only to the nearest dekameter. Errors in the analyses and in the tracing of lines are likely to be of at least
Table 4. Geostrophic wind speeds at various latitudes for a pressure height gradient of 10 meters per 5 degrees of latitude. For our wind calculations at 5 and 10 degrees latitude, we used the Coriolis value for 15 degrees; thus, large wind errors due to small gradient errors are avoided.

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Speed (mps)</th>
<th>Latitude</th>
<th>Speed (mps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>13.89</td>
<td>40</td>
<td>1.88</td>
</tr>
<tr>
<td>10</td>
<td>6.97</td>
<td>50</td>
<td>1.58</td>
</tr>
<tr>
<td>15</td>
<td>4.68</td>
<td>60</td>
<td>1.40</td>
</tr>
<tr>
<td>20</td>
<td>3.54</td>
<td>70</td>
<td>1.29</td>
</tr>
<tr>
<td>25</td>
<td>2.86</td>
<td>80</td>
<td>1.23</td>
</tr>
<tr>
<td>30</td>
<td>2.42</td>
<td>90</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Table 5. Magnitude of the curvature term (m/sec) in Eq. (1). If the real wind curves as much as the latitude circle, the curvature effect will cause the real west wind to be slower than the geostrophic wind by this amount. (A real east wind then will be greater than the geostrophic wind by this amount.)

<table>
<thead>
<tr>
<th>$u$ wind</th>
<th>latitude</th>
<th>10°</th>
<th>20°</th>
<th>30°</th>
<th>40°</th>
<th>50°</th>
<th>60°</th>
<th>70°</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 m/sec</td>
<td></td>
<td>0.11</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.17</td>
<td>0.22</td>
<td>0.31 m/sec</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>0.44</td>
<td>0.46</td>
<td>0.50</td>
<td>0.56</td>
<td>0.67</td>
<td>0.86</td>
<td>1.26</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>0.98</td>
<td>1.03</td>
<td>1.12</td>
<td>1.26</td>
<td>1.51</td>
<td>1.94</td>
<td>2.83</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>1.75</td>
<td>1.83</td>
<td>1.99</td>
<td>2.25</td>
<td>2.68</td>
<td>3.44</td>
<td>5.03</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>2.73</td>
<td>2.86</td>
<td>3.11</td>
<td>3.51</td>
<td>4.19</td>
<td>5.38</td>
<td>7.87</td>
</tr>
</tbody>
</table>
this magnitude. Where these errors are random, the smoothing of the grids should almost eliminate the errors, but any remaining height errors cause problems in the derived winds.

After viewing microfilm plots showing the time continuity of the calculated u-winds (see Figure 19, for example), we decided that the winds could be improved by smoothing these winds in time. Thus for the grids of u and v winds the 9 point filter in Figure 3 was applied to the 12 monthly values at each grid point location. Then a special horizontal smoothing pass (with no pole area transformation) was applied to these grids. These winds were then blended with the northern hemisphere winds as shown above. The resulting time smoothed geostrophic winds are presented in the tape and microfilm set of data unless otherwise noted. In the atlas and in the NOTOS articles (Taljaard et al., 1968, van Loon et al., 1968, Jenne et al., 1968), the winds used were not time smoothed.

The Wind at the Pole

In the grid there are 72 south pole points (one for each 5° of longitude). All 72 south pole data points are the same except in the grids of component winds; in this case the velocity vector is rotated with longitude to define a wind having the same direction sense as other winds at each longitude. These pole winds can then be used in meridional wind cross sections that extend to the pole.

Differences between Geostrophic and Reported Winds

All differences between the geostrophic and reported winds should not be resolved in favor of the reported winds. The period of record of the height data available was normally much longer than that of the wind data; also, differences in the period of record from station to station can cause differences between the geostrophic and reported winds. There are also instances in which the wind observations are strongly biased against the strong wind cases. For example, the geostrophic wind and the observed wind were in good agreement over Marion Island at and below 500 millibars in February, but at 200 millibars the geostrophic wind was considerably higher than the recorded wind. Daily ascents at Marion Island were checked for February and other months in 1958. The normal pattern
was that all but two or three ascents per month reached the 500 mb level, but fewer than half of the ascents reported winds at the 200 mb surface. The data also showed that when strong winds existed at 500 millibars, it was unlikely that winds would be observed at 200 millibars. Kerguelen Island, which is in the same belt of strong winds and strong thermal gradient from 500 to 200 millibars, is able to observe winds at all levels even when high winds exist. Figure 8 is a plot of the observed resultant winds at Kerguelen Island and Marion Island compared with a plot of the resultant geostrophic winds for a grid point near Marion Island.

The calculated v-winds must be used with some caution since the error may mask the real v-wind which is often small. We have noticed, however, that at least with the time smoothed winds, the v-winds appear reasonable and are consistent in the vertical.

Note also that the discrepancy between the sea-level geostrophic wind and observed wind at the surface must be large, particularly on land.

Theoretical Reasons for Systematic Differences Between Geostrophic and Real Winds

Figure 9 shows a comparison between observed zonal winds and geostrophic zonal winds interpolated from the grids for the station locations. These data were taken from the microfilm set where grid data and station data are compared. There would be more scatter in the points if the difference for each month were plotted rather than the average difference of the four mid-season months.

Some of the reasons for the scatter of the points in Figure 9 already have been considered. Now attention is turned to the systematic difference between observed and geostrophic winds (which now is assumed to approximate the difference between real and geostrophic winds). From Figure 9 it appears that in subtropical latitudes this difference is about 2 m/sec at 500 mb and about 2.5 m/sec at 200 mb.

Some of this systematic difference may be explained by evaluating two of the terms in the expression for the real average west wind minus
the geostrophic west wind, \([\tilde{u}] - [\tilde{u}_g]\). See Lorenz (1967) for the development of this expression from the equation of motion for the meridional component. The expression stems from the meridional equation because the difference between real and geostrophic west winds is one of the factors that produce daily accelerations in the north-south direction. In spherical coordinates, the equation averaged with respect to time and longitude is:

\[
[\tilde{u}] - [\tilde{u}_g] = - \frac{[u^2]}{f a} \tan \phi - \frac{1}{fa \cos \phi} \frac{\partial}{\partial \phi} (\cos \phi [v^2]) \\
- \frac{1}{f} \frac{\partial}{\partial p} [\tilde{v}_w] + \frac{1}{f} [\tilde{F}_\phi] \tag{1}
\]

The last (fourth) term in Eq. (1) presumably has only a minor effect in the free atmosphere away from the equator. The third term on the right-hand side is presumably small and in any case it disappears in the vertical average if \([\tilde{v}_w]\) vanishes at the upper and lower boundaries. Therefore, attention is confined to the first two terms on the right-hand side of Eq. (1).

In the free atmosphere where frictional forces are negligible, a wind equal to the geostrophic wind would have no horizontal acceleration and would therefore follow a great circle trajectory. On the average, however, wind trajectories in the zone of westerlies are curved at least as greatly as the latitude circles. The first term on the right of Eq. (1) shows the effect of an amount of curvature equal to that of the latitude circles. A west wind that curves like this will be slower than the geostrophic wind. An east wind with this curvature will increase in strength relative to the geostrophic wind. Table 5 shows the magnitude of this term as a function of latitude and wind speed.

In Volume III of the atlas we presented an evaluation of the average annual effect of the first two terms on the right of Eq. (1). The curvature term has annual values of about -1.4 m/sec in the subtropical jet at 200 mb, 30S. Its annual average is about -1.6 m/sec in the lower stratosphere between 50 and 60S. A hint of the effects of the second term on the
right has been obtained from its evaluation in the northern hemisphere and from 500 mb daily southern hemisphere IGY data. This term will be negative equatorward of about 50°S and positive toward the pole. The present information suggests that all but about 1 m/sec of the systematic difference between geostrophic and observed winds noted in Figure 9 can be explained by evaluating the first two terms on the right of Eq. (1). However, enough problems remain in the question of geostrophic balance to make additional studies desirable.

AVAILABLE DATA

A SELECTED CLIMATOLOGY OF THE SOUTHERN HEMISPHERE ON MICROFILM

The data presented in this microfilm climatology of the southern hemisphere primarily are based on the grid point values from charts published in the four volumes of the atlas by Taljaard, van Loon, Jenne, and Crutcher (1969, 1971). Except for the eight intermediate month 100 mb height analyses, which were made at the NCC, the analyses that were not previously published in the atlas were all derived from the basic maps by using computer methods which have been described in this note.

This set of 7 reels of microfilm has been generated under computer control directly onto 35 mm microfilm. By this means we are able to supplement the information available in the atlases at a relatively low cost.

All computer contouring has been done by linear interpolation between data points at each 5° of latitude and longitude, and between the 7 levels of data from sea level to 100 mb in the cross sections. Thus one cannot expect to find the tropopause at its proper position on the cross sections. Also, the contouring of phase charts is poorly handled when, for example, the phase is changing from month 1 to month 12, or where there should be nodal points on the chart. In some cases there is a phase reversal between grid points. This implies that the amplitude and the percent of variance will approach zero between the grid points, but the machine
procedure will simply draw for the grid point values using linear interpolation.

The linear interpolation can produce a contour that is somewhat more ragged than one that a person would draw through the same grid point values. For the hemispheric maps, the contouring is done on a 5° latitude-longitude grid; the two end points of each contour line segment are transformed to the projection used. For more information on machine contouring, see Washington, et al. (1968).

Grid point values are included for such fields as sea level pressure, 850 mb temperature and dew point even when they are under the Antarctic ice cap. The grid point arrays were made complete for computational simplicity, but values under the ice cap should not be considered as being meaningful. In the temperature cross sections, the values given at the bottom level should be mentally applied at the real surface height, and intervening data between sea level and the surface should be thrown out.

We have previously described the computation of the "geostrophic wind" and noted that near the equator it will often be quite different from the real wind.

The reader must also recognize that although we think that the analyses are good, they are not perfect. One must especially take this fact into account when interpreting some of the derived products which are sensitive to small changes in the analyses. Note that this microfilm set includes a number of plots and prints to help the viewer assess the quality of the analyses.

To help the viewer identify the contour lines on the hemispheric charts, we have printed one strip of grid points with the charts which starts at the equator at 0°W and goes over the pole. Month number 13 is used for maps of annual means.

Copies of this microfilm may be ordered on either negative or positive roll film or on microfiche by writing to the Director, National Climatic Center, NOAA, EDS, Asheville, North Carolina 28801. When information
from this microfilm set is used for publication, one of the volumes of the atlas should also be referenced if the information is based on the climatological analyses.
Inventory of Reel 1

R1.1 Print of the station library list (6 frames)

R1.2 Geography for both hemispheres. This gives average elevation data by 5° lat-lon squares centered about each grid point. Data is given for the elevation (or depth) of the solid crust (not ice), and for the elevation (including ice) above sea level. (4 maps) (4 prints)

Contour hemispheric maps

R1.3 Sea level pressure and constant pressure height contours (see item R6.9 for printed grids). (84 maps)

R1.4 Hand-drawn temperatures and dew point temperatures. The values for intermediate months at 850 and 700 mb are calculated from hand-drawn temperatures (item R6.10 has grids). (143 maps)

R1.5 Temperature minus dew point temperatures (item R6.11 has grids). Figure 10 is an example. (48 maps)

R1.6 Showalter Stability Index calculated from the mean 850 mb temperature and dew point and the 500 mb temperature (item R6.12 has grids). (12 maps)

R1.7 u, v, and total geostrophic wind. Time smoothed (item R7.1 has grids of u and v wind; item R6.18 has direction/speed print). Figure 11 is an example. (273 maps)

R1.8 Virtual temperature, tropopause pressure, and tropopause temperature calculated from the heights (item R6.17 has grids). (108 maps)

R1.9 Annual mean maps, not included in the film above: 7 height maps, 2 tropopause maps, and 4 temperature-dew point spread maps (item R6.13 has grids). (13 maps)

Mass of air and of water vapor

In this section we present the calculated surface pressure, the pressure of the dry air and of the water vapor. From these values we derive mass, mass divergence, and net meridional motion due to the mass divergence. The calculation of the surface pressure data has been described.

R1.10 Print of total calculated surface pressure, surface pressure from the dry air, and pressure from the water vapor. The latter is numerically very close to the
precipitable water in centimeters. Months 1-13. (39 grids)

Rl.11 Zonal means of mass of total air, dry air and water vapor in metric tons. These values were calculated from the surface pressure values from Rl.10 applied to a 5° latitude and longitude area about each grid point. The area of these belts was calculated from an ellipsoidal earth with an equatorial radius of 6,378,388 m and a polar radius of 6,356,912 m. Means of the total hemispheric mass by months are also presented. (2 frames)

Rl.12 A print of month-to-month changes in the mass of total air and of dry air for 5° latitude strips. (1 frame)

Rl.13 Contoured mass divergence maps made from the data in Rl.12. (2 plots)

Rl.14 Contoured maps of average zonal v-component wind by latitude and month as implied by month-to-month mass changes. The values given are appropriate if all of the net motion is through a layer 100 mb thick. (2 plots)

Area weighted average data

Rl.15 Average data for the areas Equator to 25°S, 25°S to Pole and the whole southern hemisphere. Averages are presented for each month and an annual mean for sea level pressure, height, temperature, dew point temperature, surface pressure, pressure from dry air, and pressure from water vapor. (5 frames)

RMS daily changes for the IGY period

Root Mean Square daily changes of sea level pressure and 500 mb height were calculated from the IGY daily grid point data for the period July 1957 through December 1958 with the additional month of June 1957 at sea level. This parameter has been calculated because it is not as sensitive as the standard deviation to changes in longer period means. The daily grid point values of sea level pressure and 500 mb heights were read to the nearest millibar and dekameter respectively.

The RMS daily change for individual year-months was first calculated at each grid point. The data for the same months were averaged when possible and the resulting 12 data points were time smoothed.

Rl.16 "Long-term" mean monthly maps of RMS daily changes at sea level and 500 mb. Based on the time smoothed data from Rl.19 below, which is then space smoothed. This is the best
approximation to long term mean monthly values that could be made from the 18 months of available data. Ignore the data at the equator through 10°S. For months 1-13 (item R6.14 has grids).

Rl.17 Time harmonic analyses of the monthly RMS change grids above (item R6.15 has grids). See the discussion of reel 2 for an explanation of these plots.

Rl.18 RMS daily changes for the individual year-months in the IGY period. Values are zero (missing) equatorward of 15°S. These grids have not been smoothed.

Rl.19 Plots at selected latitude-longitude points that show the time variation of the RMS daily changes. The dashed line shows the annual march of the daily changes after the same months were averaged where possible and then the resulting 12 data points were time smoothed with the 11-point filter in Figure 7. Figure 12 is an example.

Standard deviation of daily IGY values

The standard deviation of the daily values was first calculated for individual year-months of the 18-month IGY period. The methods used to calculate "long-term" mean monthly data from the year-monthly values were the same as those described for the RMS daily changes.

Rl.20 "Long-term" mean monthly standard deviation of daily values of sea level pressure and 500 mb height. From time and space smoothed data with dummy values at the equator through 10°S. Months 1-13 (item R6.16 has grids).

Rl.21 Year-monthly maps of standard deviations of daily values for the IGY period.

Rl.22 Plots at selected latitude-longitude points that show the time variation of the standard deviations. It includes a dashed line for the time smoothed values.

Anomalies (local value minus zonal mean)

Rl.23 Height and pressure anomalies (91 maps), temperature and dew point anomalies (143 maps) and annual mean u-wind anomalies (7 maps) (item R7.3 has grids).

Thermal winds

Rl.24 Thermal winds (u, v, and total) for the layers 1000 to 500 millibars (level code 1005), 1000-700 mb, 700-500 mb,
Inventory of Reel 2

Contoured maps of harmonic analyses

At each grid point, these grids give the harmonic analysis of the twelve monthly mean values taken from the grid point analysis data. The harmonic analysis data is given only for the first two harmonics. In addition, a grid of the remaining percent variance in harmonics 3-6 is given. Another grid shows the composite single wave "remaining amplitude" that would explain the remaining variance. This grid has been defined so that one can quickly determine whether there is much actual variation associated with a high remaining variance. Thus the eight grids given for the harmonic analyses of each map are:

a. First harmonic, amplitude. An amplitude of twelve means that the first harmonic sine wave ranges from +12 to -12 about the mean.

b. First harmonic, phase. This is given in months. Thus a value of 1.0 says that the first harmonic sine wave has its maximum on the first day of January. (We have assumed that the mean value for each month is valid on the middle day of the month.)

c. First harmonic, percent of variance. This shows the amount of the variance in the yearly march of the 12 values that is explained by the first harmonic.

d. Second harmonic, amplitude.

e. Second harmonic, phase. A phase of 5.5 means that the second harmonic reaches its first maximum on May 15 and its second maximum on November 15.

f. Second harmonic, percent variance.

g. Composite amplitude for waves 3-6. This is the amplitude of a single wave that would explain the remaining variance.

h. Remaining percent variance in waves 3-6.

These harmonic analyses are given on microfilm for the following fields:

R2.1 Harmonics of six levels of heights (850-100) and the
sea level pressure (item R2.21 has grids). (56 maps)

R2.2 Harmonics of all hand-drawn and derived type 3 temperatures (surface to 100 mb) with intermediate month temperatures at 850 and 700 mb, calculated from the hand-drawn temperatures. Dew point temperatures at surface, 850, and 500 mb (item R2.22 has grids). (88 maps)

R2.3 Harmonics of all u-component geostrophic winds (time smoothed) for sea level through 100 mb (item R2.23 has grids). (56 maps)

R2.4 Harmonics of the thickness fields (1000-500 mb), (500-300 mb), (300-200 mb), and (200-100 mb) (item R2.24 has grids). (40 maps)

R2.5 Harmonics of all calculated virtual temperatures (sea level to 100 mb), calculated tropopause pressure and temperature (item R5.12 has grids). (72 maps)

See R1.17 for harmonics of daily RMS changes based on the IGY data.

Annual Range

The annual range is calculated at each grid point by finding the difference between the month with the highest value and the month with the lowest.

R2.6 Annual range of heights and sea level pressure (item R4.8 has grids). (7 maps)

R2.7 Annual range of temperature (item R4.9 has grids). At 100 mb it is probably more accurate to use the first harmonic amplitude than this range data. (7 maps)

Contours of seasonal changes and change anomalies

Seasonal changes of selected parameters and the anomalies (versus the zonal mean) of these changes. We give changes for Jan to Jul, Feb to Aug, Jan to Apr, Apr to Jul, Jul to Oct, and Oct to Jan, along with anomalies for each.

R2.8 Seasonal sea level pressure change and anomalies (item R4.10 has grids). (12 maps)

R2.9 Seasonal height changes and height change anomalies (item R4.11 has grids). (72 maps)
R2.10 Seasonal hand temperature changes and temperature change anomalies (item R4.12 has grids). (78 maps)

R2.11 Seasonal geostrophic u-wind changes and change anomalies (item R4.13 has grids). (84 maps)

R2.12 Seasonal thickness changes and change anomalies (item R4.14 has grids). (60 maps)

Wave numbers from mean climatology

This represents only the standing waves of height and temperature since all of the daily fluctuations are of course missing in the long-term means. The waves were computed from the 72 data points around each latitude circle (taken in the order 0°E, 5°E, ..., 355°E). Printed data are given for the first 6 waves and plots are shown for the first 4 waves. The phase of the waves is given as the longitude east of Greenwich where the wave first reaches a maximum.

R2.13 Film print of wave number data for the first 6 waves of height and temperature. The variance remaining in waves 7-36 is also given in the print along with the remaining amplitude which is defined as the single wave amplitude that would explain the remaining variance. For months 1-13. (91 frames)

R2.14 Height and temperature wave numbers. Month versus latitude plots of amplitude, phase, and percent variance for each level (waves 1-4). See Figure 13 for a sample plot. (168 plots)

R2.15 Height and temperature wave numbers. Pressure versus latitude plots. These plots show how the amplitude, phase, and variance of waves 1-4 vary with pressure and latitude. For months 1-13. (312 plots)

R2.16 Print of correlation coefficients across the pole for heights and temperature. Correlations are made of the data along each latitude circle. Thus the pairs of data points going into the correlation at 30°S would be (30°S, 0°W and 30°S, 180°W), (30°S, 5°W and 30°S, 175°E), etc. If, for example, the data at the latitude is a perfect wave one, then the correlation is minus 1. Some correlations are also given for more than one latitude circle. For this case, the data values were weighted according to area. (17 frames)

Wave number data from daily IGY 500 mb maps

Printed values and plots give information for waves 1-6 from daily
500 mb maps. The print also shows the variance (and equivalent amplitude) remaining in waves 7-36. The plots include a dashed line giving a mean value which is computed in the same way that daily values were grouped and time smoothed for the standard deviation data. Average phase angles are computed by vector summation of daily unit vectors. These were then normalized to unit vectors, and the x and y of each was smoothed in time. The smoothed values were then changed back into angles for plotting at the mid-month position on the plots.

The phase is always given as the east longitude where the first maximum of the wave is encountered as one moves east from the Greenwich meridian. The phase speed is given as the wave motion toward the east in the units of degrees of latitude per day. Multiply these numbers by 1.3 to obtain the wave speed in meters per second. The wave speed is computed by taking the smaller of the forward and backward movements, each within one wavelength per day. Thus any motion over one-half wavelength per day will not be computed properly. At 60°S this means that a real speed for wave 6 of over 15° lat/day (19.5 m/sec) will not be computed correctly. Van Loon (1967) found that 15% of the low pressure centers between 50°S and 60°S move at speeds faster than this. The problem is further complicated because something as tangible as a low pressure center is really the result of a group of waves which may individually have motions quite different from the storm motion.

R2.17 Print of daily wave number values for waves 1-6 during the IGY (latitudes 20, 30, 40, 50, 60, 70°S). (79 frames)

R2.18 Plots of the daily wave number data with a dashed mean value curve. Graphs of amplitude, percent variance, phase, and phase speed are shown together on each plot. Plots are given for six wave numbers and six latitudes. (36 plots)

R2.19 Print showing harmonics through the year of each 12 grouped and smoothed monthly mean values of various wave number properties. For example, one print shows the 12 monthly values of wave 2 amplitude at 40°S. This is identified by WV240 where the first 1 is a code for amplitude (2 = percent variance, 3 = phase, 4 = phase speed as shown by the dashed lines on the plots above), WV2 is for wave 2, 40 is 40°S. The phase angles
in the print are in time relative to Jan 15. At the right, Plmo and P2mo give the phases for the first two waves in months (1.5 is 15 Jan). One can tell by looking at the 12 monthly values in this print, or by looking at the dashed lines in the plots above whether the time harmonics of the wave number phase angles will make any sense. If for example some phases of wave 1 are 350 to 360 degrees and others are 1 to 10 degrees, the phase harmonics will be nonsense. (16 frames)

R2.20 Print showing the frequency of daily IGY 500 mb wave speeds in various speed categories. The print gives the data for 6 latitudes (20°S to 70°S), waves 1-6 and for 3 categories. The first category is winter: Jul, Aug 57 and Jun, Jul, Aug 58. The second is summer: Dec 57 and Jan, Feb, Dec 58. The third is for one full year, Jul 57 through Jun 58. (18 frames)

Selected grid prints of harmonic analyses

R2.21 Grid print, harmonic analyses of height. (56 grids)

R2.22 Grid print, harmonic analyses of temperature (type 3) and dew point. (88 grids)

R2.23 Grid print, harmonic analyses of u-component geostrophic winds. (56 grids)

R2.24 Grid print, harmonic analyses of thickness. (40 grids)

Inventory of Reel 3

U-geostrophic wind cross sections

R3.1 U-component geostrophic wind cross sections each 10° of longitude and a zonal mean cross section that is coded as 500°W. For months 1-13. The "geostrophic wind" at 5°S and 10°S is based on the gradient and a Coriolis parameter valid at 15°S. The wind at the equator is blend of the winds at 5° and 10° north and south. Figures 14, 15, and 16 are examples. (481 plots)

Temperature and dew point spread cross sections

R3.2 Temperature (heavy lines) and temperature-dew point spread (dashed lines) cross sections each 10° of longitude plus zonal averages. For months 1-13. The printed grid values are the temperatures. The high and low values are given for the temperature-dew point
spread. Remember that the bottom level temperatures are valid at the actual surface elevation. For the intermediate eight months, the temperatures for 850, 700, 300, 200, and 100 mb were calculated as described elsewhere.

D-values cross sections

R3.3 D-value cross section at each 10° of longitude with a zonal mean cross section coded as 500°W. For months 1-12. The sea level pressure maps were converted to 1000 mb maps using a conversion of 1 mb to 8.2 m. The standard atmosphere height values that were used are 111 m, 1457, 3012, 5574, 9164, 11784, and 16180 m for the levels 1000, 850, 700, 500, 300, 200, and 100 mb, respectively.

Potential temperature cross sections

R3.4 Potential temperature cross sections at 10°W, 40°W, 70°W ... 340°W and a zonal mean. For months 1-13. These were calculated from the temperature grids. The surface temperature and the calculated surface pressure were used in the calculation of the surface potential temperature (level 1001). The formula is

\[ \theta = T \left( \frac{1000}{P} \right)^{\frac{R}{cp}}. \]

The theoretical (and preferred) value of the constant \( \frac{R}{cp} \) is 2/7 or 0.285714. The value that we used was 0.285909. Various adiabatic charts such as the Skew-T, Tephigram, and Stüve use the older value of 0.288. For an example of the differences that this constant can make, assume a temperature of -70°C at 100 mb. The potential temperature is 392.2 if the constant is 2/7, 392.4 for the value we used, and 394.3 when the constant is 0.288. The difference decreases closer to the ground, so that at 500 mb it is only 0.5 degrees.

Inventory of reel 4

Annual march plots at grid points

R4.1 Annual march of heights plotted for selected grid points. Each plot shows curves for the 7 levels. The values are plotted on a relative scale with the actual values printed below the chart. Figures 6 and 31 are examples.

R4.2 Annual march of temperature plotted for selected grid points. Figure 17 is an example.
R4.3 Annual march of geostrophic u-winds for selected grid points. Solid lines are values before the winds were time smoothed. Dashed lines show the time smoothed values. The dashed values are slightly different from the final time smoothed grids (used in R4.4) because another horizontal smoothing pass was applied to the time smoothed grids. Figure 19 is an example. (244 plots)

R4.4 Annual march of time smoothed geostrophic u-winds for selected grid points. Figure 18 is an example. (244 plots)

R4.5 Selected annual march plots from other atlases. Data for these plots were obtained from two published international atlases and from two unpublished domestic atlases. Figures 20 through 22 show examples of these plots in the South Pacific Ocean along with a plot from our data set (Fig. 19) at the same location. Note that some of the values are in knots. There are wide differences between the values in the four figures and even differences in the overall shape of the annual curve. (29 frames)

Plots of grid data versus longitude

R4.6 Plots of heights versus longitude at each 10° of latitude. The plots are from grid point data for the 7 levels. Selected grid point data are plotted below the plot. Figure 23 is an example. (96 plots)

R4.7 Plots of temperature versus longitude. (104 plots)

Grid prints

R4.8 Annual range of heights and sea level pressure. (7 grids)

R4.9 Annual range of temperature. At 100 mb it is likely more accurate to use the first harmonic amplitude than this range data. (7 grids)

R4.10 Seasonal sea level pressure change and change anomalies. (12 grids)

R4.11 Seasonal height changes and change anomalies. (72 grids)

R4.12 Seasonal temperature change and change anomalies. (78 grids)

R4.13 Seasonal geostrophic u-wind change and change anomalies. (84 grids)

R4.14 Seasonal thickness change and change anomalies. (60 grids)
Inventory of Reel 5

Station data

R5.1 Plots of mean monthly data in annual march form for stations south of $5^\circ$N. There may be up to 5 plots for each station: height, temperature, dew point, u-winds, and v-winds. The long-term mean data are printed under the plots along with the standard deviation of the year-monthly means. The numbers of years of data that went into each mean are printed on the plotted curve: the number of years at the 1000 mb level is zero because the data there are calculated. Whenever the annual height range exceeds 800 m the range is reduced to 800 m and the curve is plotted as a dashed line. Figures 24, 25 and 26 are examples.

R5.2 Print of station mean data and harmonics for selected stations. Long-term mean monthly data is given for as many levels as available. The number of years of data available for January and the total number of year-months of data are also given. The annual average; the amplitude, phase (in months: $1.5 = 15$ Jan), and percentage of variance in the annual and semi-annual wave; and the amplitude and variance remaining are also printed.

R5.3 Selected plots of year-month station data. Figure 27 is an example showing temperature at Pretoria. It shows the effect on the mean data of switching from a night to a day sounding time. From Figures 28 and 29 we can quickly see that the long term mean would be different with shorter periods of record.

Grid point data compared to station data

R5.4 Print of station mean data by months followed by differences between the station data and data from the grids interpolated for the station location. The difference is grid minus station value; thus it may be added to the observed data to obtain the grid value. The next line contains similar differences after the station data has been smoothed in time. Where the station data are missing for a month, the value of the grid data replaces the difference print. The number of years of January data (NJ) are also printed along with the total number of year-months (NT) of data that went into the means. The values 4Dif and 4Abs are the arithmetic and absolute averages for Jan, Apr, Jul, and Oct. The terms 8Dif and 8Abs apply to the other eight months.
R5.5 Plots of contoured u and v wind maps from the grid point values with observed values in tenths of m/sec printed at station locations. For the area 25°S to 25°N. (168 maps)

Grid smoothing effects

R5.6 Mountain value corrections in surface temperatures. These corrections were made so that the grid point values would better represent the temperature over a 5° lat-lon square rather than a mountain top temperature at a grid point. (3 frames)

R5.7 Smoothed minus unsmoothed heights and sea level pressure. Shows the changes that the smoother made in the grids. (60 frames)

R5.8 Smoothed minus unsmoothed temperatures. (52 frames)

R5.9 Re-smoothed 100 mb height grids minus unsmoothed grids to show the harmful effects that excessive smoothing could have. (8 grids/16 frames)

Miscellaneous

R5.10 Maps of the unsmoothed height grids. (60 maps)

R5.11 Virtual temperatures calculated from the height grids minus "hand analyzed" (type 3) temperature. At the bottom level we are comparing calculated sea level virtual temperature (and with no thin inversion layer) to surface temperature so the differences may be large due to both elevation and inversion effects. (84 maps/84 grids)

R5.12 Grid prints of the harmonic analysis of calculated virtual temperature and tropopause data. (72 grids)

Inventory of reel 6

Zonal and sector means

R6.1 Print of zonal means and of selected means for the sectors 210°W-330°W (30°E-150°E) and 120°W-150°W. for each latitude, the print shows the 12 monthly values (and the annual average) of a parameter along with harmonic analyses of these values. The latter includes the amplitude, the phase (in months for maximum value: Jan 1 is 1.0), and the percentage of variance in the first two harmonics. It also has the
"amplitude remaining" (AMPR) which we have defined to be the amplitude of a single wave which would explain the variance remaining (VARR) in waves 3-6. The zonal means (Jenne, et al., 1968) published in NOTOS are somewhat different in that the winds were not as yet time smoothed, and the calculated intermediate month temperatures were not as reliable as these.

R6.2 Plots of zonal and sector means of heights, temperature, and geostrophic winds. The plots are in annual march form (Figure 30 is an example) and are made for each 5° of latitude.

R6.3 Shows various zonal mean (and sector mean) cross sections including monthly and average yearly values and cross sections of the harmonic analysis data.

More data from daily IGY 500 mb grids

The mean monthly data given in items R6.4-R6.7 was calculated from the 18 months of daily IGY values using the time smoothing procedure described for the calculation of monthly values of RMS daily changes.

The daily geostrophic winds were calculated from grid point data that were on a diamond latitude-longitude grid with points at each 5° of latitude and 10° of longitude read to the nearest 10 m of geopotential height. Additional height data were interpolated with a cubic interpolation function to complete the grid for each 5° of latitude and longitude from 15°S to the south pole. Geostrophic winds valid between the height grid points were then calculated from the height differences taken over 5° of latitude or longitude. Finally, cubic interpolation was used to obtain u and v winds valid at the original 5° grid point locations from 15°S through 85°S. Linear extrapolation was used to obtain u winds at 15°S.

R6.4 "Long-term" mean monthly geostrophic momentum flux (uv) (13 maps/at 500 mb from daily maps. Units m²/sec². 13 grids)

R6.5 "Long-term" mean monthly average absolute geostrophic v-component winds from daily 500 mb maps. (13 maps/13 grids)

R6.6 "Long-term" mean monthly standard deviation of daily geostrophic u-winds from daily 500 mb maps. (13 maps/13 grids)

R6.7 "Long-term" mean monthly standard deviation of daily geostrophic v-winds from daily 500 mb maps. (13 maps/13 grids)
Thickness and thickness anomalies

R6.8 Thickness and thickness anomalies for each month for the thicknesses 1000-500, 500-300, 500-200, 300-200, and 200-100 mb (item R7.4 has grids). (120 maps)

Grid prints

R6.9 Sea-level pressure and heights. (84 grids)
R6.10 Temperature and dew points. (143 grids)
R6.11 Temperature minus dew point. (48 grids)
R6.12 Showalter Stability Index. (12 grids)
R6.13 Annual mean prints not above. (13 grids)
R6.14 RMS daily changes by months. (26 grids)
R6.15 Harmonic analyses of RMS daily changes. (16 grids)
R6.16 Standard deviation of daily changes by months. (26 grids)
R6.17 Virtual temperature, tropopause data. (108 grids)
R6.18 Wind direction/speed print. (91 grids/273 frames)

Inventory of reel 7

We have previously described the calculation of the geostrophic winds and noted that near the equator they ought to be used with caution.

R7.1 Print of u, v geostrophic winds (time smoothed). (182 grids)
R7.2 Print of thermal winds calculated by taking differences between the time smoothed geostrophic winds. (216 grids)
R7.3 Print of height, temperature, and dew point anomalies. The units for the surface pressure anomalies should read mb x 10. (241 grids)
R7.4 Print of thickness and thickness anomalies. (120 grids)
R7.5 Print of u, v geostrophic wind before time smoothing. (168 grids)
R7.6 Print of geostrophic wind direction/speed before time smoothing. 84 grids. (252 frames)
Data Availability and Format on Magnetic Tape

We will now discuss the content and format of a magnetic tape that has grid-point data for the basic southern hemisphere analyses and for many derived quantities such as geostrophic winds and surface pressure. The grid used has points each 5° of latitude and longitude. We will describe both the binary floating point format of the grid-point data and the BCD format that is available for purchase from the Director, National Climatic Center, NOAA, EDS, Federal Building, Asheville, North Carolina, 28801. When information from this tape is used for publication, one of the volumes of the atlas should be referenced, except that NOTOS should be referenced for data based on the daily analyses.

To give a better fit to observed winds, the geostrophic winds at 5°S and 10°S are calculated using a Coriolis parameter valid at 15°S. The winds at the equator are set equal to .6 (winds at 5°N + 5°S) - .1 (10°N + 10°S), subject to the restriction that they do not differ from the average of the 5°N and 5°S winds by over 1.5 m/sec. These winds can still be poor approximations to the real winds.

Grid-point values under the antarctic ice cap are not meaningful, but are included to provide reasonable continuity in the grids. Also please refer to the section on problems remaining in the grids for further comments on analysis problems.

A similar data tape is available for the northern hemisphere based on Crutcher and Meserve (1970). These data are described in a note (Crutcher and Jenne, 1969). The winds given at the equator are the same on both tapes. The unsmoothed hand-analyzed height grids are the same at the equator; but since the northern heights have been time smoothed, there are some differences in the processed grids. The match between respective hand-drawn temperature (and dew point) grids for the two hemispheres should be very close at the equator. The differences may be somewhat larger when the southern hemisphere grid was derived by computer methods.
<table>
<thead>
<tr>
<th>Item</th>
<th>Types</th>
<th>#grids</th>
<th>nform</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>6,1</td>
<td>91</td>
<td>85, or 84</td>
<td>Sea level pressure plus height grids for levels 850, 700, 500, 300, 200, 100 mb. The grids were horizontally smoothed. Some intermediate month grids were not 'hand' analyzed but were computer derived. (The number of grids is 7 grids/month times 13 months.)</td>
</tr>
<tr>
<td>2</td>
<td>3,4</td>
<td>143</td>
<td>85, 84</td>
<td>Temperature and dew point. Temperature for surface through 100 mb; dew point, surface through 500 mb. Surface is not smoothed. Levels above surface were horizontally smoothed. A number of the intermediate month grids were not hand analyzed but were computer derived; the methods are described elsewhere. (11*13 grids)</td>
</tr>
<tr>
<td>3</td>
<td>16,17,18</td>
<td>273</td>
<td>85, 84</td>
<td>Geostrophic U, V, total winds (m/sec) derived from grids in item 1 above. These winds were then time smoothed and then horizontally smoothed with a simplified smoothing program that had no polar area grid transformation. U and V wind components are positive if they are from the west and south, respectively. The special calculation of the winds at the equator, 5S, 10S, and the pole is described elsewhere. (21*13 grids)</td>
</tr>
<tr>
<td>4</td>
<td>50,51,52</td>
<td>39</td>
<td>85, 84</td>
<td>Surface pressure, pressure from dry air, pressure from water vapor. Calculated from grids in items 1, 2, 13 and from the tropopause pressure and temperature in item 12.</td>
</tr>
<tr>
<td>5</td>
<td>53,54</td>
<td>26</td>
<td>85,84</td>
<td>Mean monthly standard deviation of daily values of sea-level pressure and 500 mb height. Based on 18 months of data from the IGY period. Grids for the same months were averaged when available, and then the 12 grids were time smoothed followed by a horizontal smoothing pass. Disregard data at the equator through 10S.</td>
</tr>
<tr>
<td>6</td>
<td>55,56</td>
<td>26</td>
<td>85, 84</td>
<td>Mean monthly RMS of daily changes of sea-level pressure and 500 mb height during</td>
</tr>
<tr>
<td>Item</td>
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<td>uform</td>
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<tr>
<td>7</td>
<td>57</td>
<td>13</td>
<td>85, 84</td>
<td>during the IGY period. Shows the 24-hour changes. The data were grouped and smoothed as in item 5. Disregard data at the equator through 10S.</td>
</tr>
<tr>
<td>8</td>
<td>58</td>
<td>13</td>
<td>85, 84</td>
<td>Mean monthly 500 mb geostrophic momentum flux (uv). Based on 18 months of daily IGY 500 mb data. The data were grouped and smoothed as in item 5 except that no final horizontal smoothing was applied after time smoothing. Disregard the data at the equator through 10S and at the pole.</td>
</tr>
<tr>
<td>9</td>
<td>59</td>
<td>13</td>
<td>85, 84</td>
<td>Mean monthly average absolute geostrophic v-component winds from daily 500 mb maps. See discussion in item 7.</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>13</td>
<td>85, 84</td>
<td>Mean monthly standard deviation of geostrophic u-winds from daily 500 mb maps. See discussion in item 7.</td>
</tr>
<tr>
<td>11</td>
<td>91</td>
<td>12</td>
<td>85, 84</td>
<td>Showalter stability index calculated from the mean monthly values in item 2. This was computed by lifting the 850 mb air parcels dry adiabatically until saturated, and then moist adiabatically. The index is the ambient 500 mb temperature minus the parcel temperature.</td>
</tr>
<tr>
<td>12</td>
<td>10,11,12, 108</td>
<td>85, 84</td>
<td>Calculated virtual temperature at sea level through 100 mb and tropopause pressure and temperature from the pressure and height grids in item 1. (9*12 grids)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>97,98</td>
<td>4</td>
<td>85, 84</td>
<td>Geography. Type 97 is elevation of the earth's crust. Thus it gives the depth of the oceans and the base of the icecaps. Code 98 gives the normal elevation data, thus 0 over water and the elevation of ice or earth over land. All values represent an average value for a 5° latitude-longitude square centered about each grid point. If the month code is 1, the data is for the northern hemisphere; 2 is for the southern hemisphere.</td>
</tr>
<tr>
<td>14</td>
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<td>60</td>
<td>75</td>
<td>Sea-level pressure and height grids.</td>
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<tr>
<td></td>
<td>3,4</td>
<td>76</td>
<td>75</td>
<td>Same as item 1 only before smoothing. The other 24 grids plus the annual means in item 1 were derived by computer methods.</td>
</tr>
</tbody>
</table>

Temperature and dew point temperature grids. Same as item 2 only before smoothing. The surface grids include some "mountain" corrections where the original temperature (and dew point) represented a mountain peak temperature rather than the surface temperature at an average elevation. The surface grids are identical to the corresponding grids in item 2. This contains only the hand analyzed maps; these were not drawn for all months at all levels.

**Total grids** 910

**Tape Format in Floating Point Binary**

The above analyses are available for use at NCAR in a binary format. They can be read on the CDC 6600, 7600 with the following Fortran read statement:

```
Read tape Jtape, nform, ntype, level, month,
   ((Y(I,J),I=1,72),J=1,19)
```

where:

- nform = 85 or 84 for the processed and derived grids.  
  = 75 for all of the original hand-analyzed grids after mechanical and mountain corrections were made, but before smoothing. These grids are on the tape after all of the other grids.

- ntype = code giving type of data:
  6  Sea-level pressure (mbs)
  1  Heights (m)
  3  Temperature (degrees C)
  4  Dew point temperature (degrees C)
  16 Geostrophic U wind (m/sec)
  17 Geostrophic V wind (m/sec)
  18 Geostrophic total wind (m/sec)
  50 Surface pressure (mbs)
  51 Portion of surface pressure due to dry air (mbs)
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>Portion of surface pressure due to water vapor (mbs)</td>
</tr>
<tr>
<td>53</td>
<td>Mean monthly standard deviation of daily sea-level pressure values (mbs)</td>
</tr>
<tr>
<td>54</td>
<td>Mean monthly standard deviation of daily height values (dKm)</td>
</tr>
<tr>
<td>55</td>
<td>Mean monthly RMS of daily sea-level pressure changes (mbs)</td>
</tr>
<tr>
<td>56</td>
<td>Mean monthly RMS of daily height changes (dKm)</td>
</tr>
<tr>
<td>57</td>
<td>Mean monthly geostrophic momentum flux (m²/sec²)</td>
</tr>
<tr>
<td>58</td>
<td>Mean monthly average absolute geostrophic V wind (m/sec)</td>
</tr>
<tr>
<td>59</td>
<td>Mean monthly standard deviation of geostrophic U wind (m/sec).</td>
</tr>
<tr>
<td>60</td>
<td>Mean monthly standard deviation of geostrophic V wind (m/sec)</td>
</tr>
<tr>
<td>91</td>
<td>Showalter stability index from monthly means</td>
</tr>
<tr>
<td>10</td>
<td>Virtual temperature calculated from height grids</td>
</tr>
<tr>
<td>11</td>
<td>Tropopause pressure calculated from height grids</td>
</tr>
<tr>
<td>12</td>
<td>Tropopause temperature calculated from height grids</td>
</tr>
<tr>
<td>97</td>
<td>Elevation (depth) of the earth's crust (not ice) (m)</td>
</tr>
<tr>
<td>98</td>
<td>Normal elevation data of ice or land (the ocean is zero) (m)</td>
</tr>
</tbody>
</table>

**level** = the level of the data in millibars. Numbers as follows are used for levels where the pressure is not constant: the number 1013 is used for sea level, 1001 is used for surface, 1002 is used for depth data (type 97), and 5 is used for the tropopause.

**month** = 1 through 13, where 13 is an annual mean value.

I = 1,72 is 0°W, 5°W, ..., 355°W

J = 1,19 is 0°S, 5°S, ..., 90°S
There is an end of file at the end of the data.

All 72 south pole data points are identical, except in the case of the winds for which the velocity vector is rotated with the longitude to define a wind having the same direction sense as other winds at that longitude.

**Tape Format in BCD**

The same grid point information may be purchased in BCD form on magnetic tape by writing to the Director, National Climatic Center, Asheville, North Carolina 28801.

In this format, the data for one longitude from equator to pole has been encoded into one logical record in BCD as follows:

Encode \((130,910,Nbuf)\) nhem, nform, ntype, level, month, Ilon, (Ival(I),I=1,19), nine

910 Format \((I1,I2,I4,I2,I3,19I6,I2)\)

In this statement 130 characters are encoded into an array called NBUF according to the format statement where:

- nhem = 2 for southern hemisphere
  = 1 for northern hemisphere

- nform, ntype, level, month: refer to the writeup of the binary format.

- Ilon = 0 through 355 for 0°W, 5°W, ..., 355°W

- Ival = the 19 values from equator to pole, each 5°. All values have been multiplied by 10, so the units are now tenths of millibars, tenths of degrees, tenths of meters/second, etc.

- nine = the constant 99 is coded here to provide the user with some check on his tape read and formatting program.

These logical records with 130 characters each are blocked in groups of 18 on the tape, so that there are four physical records for each grid map.

There is an end of file at the end of the data.
A few data values on the tape are provided for program checkout:

<table>
<thead>
<tr>
<th>Grid number</th>
<th>form</th>
<th>type</th>
<th>level</th>
<th>month</th>
<th>OS OW</th>
<th>70S 245W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
<td>6</td>
<td>1013</td>
<td>1</td>
<td>1010.6</td>
<td>991.6 mb</td>
</tr>
<tr>
<td>9</td>
<td>84</td>
<td>1</td>
<td>850</td>
<td>2</td>
<td>1498.1</td>
<td>1199.5 m</td>
</tr>
<tr>
<td>98</td>
<td>85</td>
<td>3</td>
<td>500</td>
<td>1</td>
<td>-5.8</td>
<td>-32.3 °C</td>
</tr>
<tr>
<td>268</td>
<td>85</td>
<td>16</td>
<td>300</td>
<td>2</td>
<td>-2.6</td>
<td>8.2 m/sec</td>
</tr>
<tr>
<td>517</td>
<td>85</td>
<td>50</td>
<td>1001</td>
<td>4</td>
<td>1010.7</td>
<td>707.3 mb</td>
</tr>
<tr>
<td>771</td>
<td>85</td>
<td>97</td>
<td>1002</td>
<td>2</td>
<td>-4626.0</td>
<td>540.8 m</td>
</tr>
<tr>
<td>910</td>
<td>75</td>
<td>4</td>
<td>500</td>
<td>12</td>
<td>-14.8</td>
<td>-40.4 °C</td>
</tr>
</tbody>
</table>

Problems Remaining in the Grids

In the set of microfilm data we provide a number of plots (see Figure 17) for selected grid points that show the time continuity of data for the seven pressure levels. Figure 6 shows the point of worst height continuity. Other graphical data and comparisons between grid data and station data are also included to help the reader assess the quality of the analyses. In this section we will comment on some of the problems in the analyses.

The winds for Recife, Brazil, on the November 200 mb chart, were originally plotted from the NW instead of from the correct SW. Thus the trough was drawn on the west side of Recife instead of the east side. This has been corrected on the published maps, but not in the grid-point values on tape. Table 6 shows the problems caused by a mistake in a program that made some of the summarized wind statistics wrong for the few stations that had fewer than 5 reports in a month. The original and the corrected values are shown in the table.

At Port Stanley, Falkland Islands, the heights for the 850 through 200 mb levels increase about 30 to 40 m from June to July, decrease to the lowest value in August and then increase again. (See Figure 25 from the microfilm data.) This "July hump" is a real feature for several individual years at Port Stanley and at other stations in the vicinity. However, judging from the lack of such a hump in the longer term surface
Table 6. Errata in Volume I of the atlas: Plotted winds and corrected winds.

An error in a computer program affected some of the winds for Ascension Island, Fernando Noronha, and Recife that were plotted in Volume I of the atlas. This table shows the old and new winds where corrections were necessary. At Ascension only minor changes were made in the January 300 and 200 mb winds. These did not affect the analyses. Some of the April winds at Fernando Noronha were changed. The winds at Recife were affected for most months, and in a few cases some minor changes in the analyses would be desirable in this region: the high pressure areas over South America and Africa could be merged on the February and March 500 mb height maps. Some changes should also be made in the April 300 and 100 mb height charts, and in the July 100 mb chart.

The grid point data on the tape and in the microfilm set do not incorporate these desirable changes in the analyses. The station data presented in the microfilm set is made from the corrected data.

<table>
<thead>
<tr>
<th>Month</th>
<th>Level</th>
<th>Old Wind  m/sec</th>
<th>New Wind  m/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>264/ 6</td>
<td>349/ 2</td>
</tr>
<tr>
<td>1</td>
<td>200</td>
<td>280/11</td>
<td>310/ 8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Level</th>
<th>Old Wind  m/sec</th>
<th>New Wind  m/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>500</td>
<td>231/ 6</td>
<td>89/ 4</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>243/ 8</td>
<td>0/ 0</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>251/15</td>
<td>294/ 3</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>243/19</td>
<td>0/ 0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month</th>
<th>Level</th>
<th>Old Wind  m/sec</th>
<th>New Wind  m/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>500</td>
<td>204/ 1</td>
<td>79/ 4</td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>253/18</td>
<td>275/ 9</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>258/ 8</td>
<td>290/ 3</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>161/ 2</td>
<td>91/ 5</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>263/12</td>
<td>275/ 9</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>259/ 8</td>
<td>297/ 3</td>
</tr>
<tr>
<td>7</td>
<td>850</td>
<td>163/ 7</td>
<td>135/ 8</td>
</tr>
<tr>
<td>7</td>
<td>700</td>
<td>210/ 3</td>
<td>107/ 3</td>
</tr>
<tr>
<td>7</td>
<td>500</td>
<td>150/ 2</td>
<td>91/ 5</td>
</tr>
<tr>
<td>7</td>
<td>300</td>
<td>262/ 9</td>
<td>315/ 3</td>
</tr>
<tr>
<td>7</td>
<td>200</td>
<td>260/17</td>
<td>291/ 9</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>252/10</td>
<td>310/ 2</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>268/10</td>
<td>289/ 6</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>240/ 5</td>
<td>0/ 0</td>
</tr>
<tr>
<td>9</td>
<td>500</td>
<td>136/ 3</td>
<td>96/ 6</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
<td>256/ 6</td>
<td>288/ 2</td>
</tr>
<tr>
<td>10</td>
<td>850</td>
<td>223/ 9</td>
<td>112/ 6</td>
</tr>
<tr>
<td>10</td>
<td>700</td>
<td>234/ 9</td>
<td>92/ 4</td>
</tr>
<tr>
<td>10</td>
<td>500</td>
<td>237/10</td>
<td>94/ 3</td>
</tr>
<tr>
<td>10</td>
<td>300</td>
<td>255/14</td>
<td>300/ 4</td>
</tr>
<tr>
<td>10</td>
<td>200</td>
<td>253/16</td>
<td>278/ 7</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
<td>245/11</td>
<td>291/ 1</td>
</tr>
<tr>
<td>11</td>
<td>500</td>
<td>242/ 6</td>
<td>66/ 2</td>
</tr>
<tr>
<td>11</td>
<td>200</td>
<td>235/11</td>
<td>230/ 7</td>
</tr>
<tr>
<td>11</td>
<td>100</td>
<td>240/ 8</td>
<td>235/ 3</td>
</tr>
</tbody>
</table>

61900 Ascension Island 7°58'S 14°24'W 82899 Recife Continued 82400 Fernando Noronha 3°51'S 32°25'W

<table>
<thead>
<tr>
<th>Month</th>
<th>Level</th>
<th>Old Wind  m/sec</th>
<th>New Wind  m/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>850</td>
<td>223/ 9</td>
<td>105/ 6</td>
</tr>
<tr>
<td>4</td>
<td>700</td>
<td>227/ 8</td>
<td>90/ 6</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>235/ 8</td>
<td>81/ 5</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>245/ 8</td>
<td>60/ 5</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>252/12</td>
<td>341/ 2</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>239/10</td>
<td>83/ 2</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>204/ 1</td>
<td>79/ 4</td>
</tr>
<tr>
<td>5</td>
<td>200</td>
<td>253/18</td>
<td>275/ 9</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>258/ 8</td>
<td>290/ 3</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>161/ 2</td>
<td>91/ 5</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
<td>263/12</td>
<td>275/ 9</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>259/ 8</td>
<td>297/ 3</td>
</tr>
<tr>
<td>7</td>
<td>850</td>
<td>163/ 7</td>
<td>135/ 8</td>
</tr>
<tr>
<td>7</td>
<td>700</td>
<td>210/ 3</td>
<td>107/ 3</td>
</tr>
<tr>
<td>7</td>
<td>500</td>
<td>150/ 2</td>
<td>91/ 5</td>
</tr>
<tr>
<td>7</td>
<td>300</td>
<td>262/ 9</td>
<td>315/ 3</td>
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<td>100</td>
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<td>310/ 2</td>
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<td>8</td>
<td>200</td>
<td>268/10</td>
<td>289/ 6</td>
</tr>
<tr>
<td>8</td>
<td>100</td>
<td>240/ 5</td>
<td>0/ 0</td>
</tr>
<tr>
<td>9</td>
<td>500</td>
<td>136/ 3</td>
<td>96/ 6</td>
</tr>
<tr>
<td>9</td>
<td>100</td>
<td>256/ 6</td>
<td>288/ 2</td>
</tr>
<tr>
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<td>850</td>
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</tr>
<tr>
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<td>700</td>
<td>234/ 9</td>
<td>92/ 4</td>
</tr>
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<td>500</td>
<td>237/10</td>
<td>94/ 3</td>
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<td>300</td>
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</tr>
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<td>100</td>
<td>245/11</td>
<td>291/ 1</td>
</tr>
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<td>500</td>
<td>242/ 6</td>
<td>66/ 2</td>
</tr>
<tr>
<td>11</td>
<td>200</td>
<td>235/11</td>
<td>230/ 7</td>
</tr>
<tr>
<td>11</td>
<td>100</td>
<td>240/ 8</td>
<td>235/ 3</td>
</tr>
</tbody>
</table>

82899 Recife 8°09'S 34°55'W
pressure data, and from some previous upper air data for Stanley not in our nine-year sample, the hump should at least be smaller for a longer record. Our grid data reflects this July hump (see Figure 31).

On the April 100 mb chart, the ridge line should be moved slightly to the south so that the east wind at Cocos Island is accounted for.

Near 20°S 120°W there are errors of up to 80 m in the 200 mb analyses for June through September. Various other more minor problems can be noted in the microfilm continuity plots that have been mentioned.

The analyses do not fully account for radiation correction problems which can be as high as about 60 m for daytime soundings at 100 mb according to McInturff and Finger (1968). However, we sometimes made even larger corrections than this to the mean data. For example from the microfilm data in R5.4 one may see that we drew for the 500 mb heights at Tahiti, but at the 300, 200, and 100 mb levels our analyses are respectively about 20 m, 35 m, and 125 m less than the reported data.

At the upper levels we have analyzed for Christmas Island (2°N 157°W) heights about 30 to 50 m higher than the reported values. Although the Christmas Island data from the Line Islands Experiment agrees with the older statistics, one cannot plausibly analyze for values this low unless the other stations are all too high.

In the set of microfilm data, the dew point data given for Sao Paulo, Brazil is calculated without using any of the "statistical humidities" that replace the very dry or the missing values. Table 7 shows the cases in which the drier value using the statistical values has been plotted in the atlas. The best value to use for the dew point is probably between the values listed. As explained in the introduction to Volume 1 of the atlas, the analyst had both values available when he was making the analysis.
Table 7. A listing of cases for which the drier dew point value has been plotted in the atlas for Sao Paulo (23°30'S 46°37'W). The best dew point temperature is probably between the two values listed.

<table>
<thead>
<tr>
<th>Month</th>
<th>level (mb)</th>
<th>plotted dew point (°C) with statistical humidities</th>
<th>dew point (°C)-no statistical humidities</th>
<th>analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>700</td>
<td>.9</td>
<td>2.4</td>
<td>-.7</td>
</tr>
<tr>
<td>1</td>
<td>500</td>
<td>-20.6</td>
<td>-14.5</td>
<td>-20.1</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>-18.4</td>
<td>-14.3</td>
<td>-19.1</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>-21.1</td>
<td>-15.1</td>
<td>-20.9</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>-24.6</td>
<td>-16.6</td>
<td>-21.9</td>
</tr>
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<td>5</td>
<td>500</td>
<td>-27.0</td>
<td>-18.7</td>
<td>-25.9</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>-28.5</td>
<td>-21.6</td>
<td>-24.9</td>
</tr>
<tr>
<td>9</td>
<td>500</td>
<td>-26.2</td>
<td>-18.2</td>
<td>-26.5</td>
</tr>
<tr>
<td>10</td>
<td>500</td>
<td>-24.7</td>
<td>-18.9</td>
<td>-25.0</td>
</tr>
<tr>
<td>11</td>
<td>500</td>
<td>-24.2</td>
<td>-16.6</td>
<td>-24.2</td>
</tr>
<tr>
<td>12</td>
<td>500</td>
<td>-21.3</td>
<td>-15.1</td>
<td>-21.6</td>
</tr>
</tbody>
</table>
Motion Pictures that Present Climatological Data and Daily Data

Several black and white 16 mm motion pictures are available at cost (from about $20.00 to $50.00 each) which may be used as aids in the study of climatology and meteorology. These were produced by using a computer with a cathode ray tube. Some sequences show the smooth changes of mean monthly climatology, and others show daily changes. The parameters include temperature, pressure, winds and moisture. Following is a description of several movies.

Film J-1:

A selected climatology of the southern hemisphere. (29 minutes at 16 frames/second).

This motion picture is primarily based on the mean monthly grid data which has been discussed in this note. Heights and temperatures were time smoothed before the movies were made. The grids were time smoothed with the 9-point filter in Figure 3 and then horizontally smoothed. Most of the movie sequences from the mean monthly grids have 20 frames per month, where the frames between the months are derived by linear interpolation. The time convention used is such that month 1.5 is mid-January, etc. The frame with a month of 1.5 is thus the map given in the microfilm set for January, except that the movie uses time smoothed data. This film is described in detail in van Loon and Jenne (1970).

Running times and contents of the film

Each yearly sequence from the long-term mean climatology is repeated several times; the number of repetitions (runs) is shown in the following list. Total running time at 16 frames/second is 29 minutes. (NCAR 1969)

1. Southern hemisphere, mean monthly temperature (20 frames/month).
   a. Surface temperature 5 runs 1 min 15 sec
   b. Temperatures for 850, 700, 500, 300, 200, 100 mb 3 runs 4 min 30 sec
2. Southern hemisphere, mean monthly sea-level pressure and pressure heights (20 frames/month).
   a. Sea-level pressure 5 runs 1 min 15 sec
   b. Heights for 850, 700, 500, 300, 200, 100 mb 3 runs 4 min 30 sec

3. Northern hemisphere, mean monthly sea-level pressure and pressure heights (20 frames/month).
   a. Sea-level pressure 5 runs 1 min 15 sec
   b. Heights for 500, 100 mb 3 runs 1 min 30 sec

   a. 500, 200, 100 mb 2 runs 1 min 30 sec

5. Southern hemisphere, cross sections of zonally averaged geostrophic u-wind (20 frames/month).
   a. Equator-to-pole cross section 3 runs 45 sec

6. Southern hemisphere, cross sections of zonally averaged potential temperature (20 frames/month). The 300 K line is dashed.
   a. Equator-to-pole cross section 3 runs 45 sec

7. Southern hemisphere, mean monthly temperature minus dew point temperature (20 frames/month).
   a. Surface, 850, 700, 500 mb 3 runs 3 min

8. Southern hemisphere, monthly means of rms daily changes (20 frames/month).
   a. Sea-level pressure changes 3 runs 45 sec
   b. Height changes at 500 mb 3 runs 45 sec

9. Southern hemisphere, daily maps from the International Geophysical year (1 July 1957 = 31 July 1958). No interpolation is made between days. A slow-speed version is available in another film.
   a. 500 mb height (4 frames/day) 395 days 1 min 39 sec
The analyses are from NMC. No interpolation is made between
12-hr periods. A slow-speed version is available in another
film.

a. 500 mb height (4 frames/day) 395 days 1 min 39 sec

Film J-2:

Southern Hemisphere Daily Weather Maps
This black and white film is based on daily IGY grid point analyses
from NOTOS, Volumes 8 and 9. It repeats the fast-speed sequence of daily
500 mb height maps that is found in the film of southern hemisphere clima-
tology. It also includes slow-speed sequences of sea-level pressure and
500 mb height maps, so that many details of the movement of pressure systems
can be seen. The film jumps from one daily map to the next, and individual
pressure systems often show for only a few seconds. Total running time
at 16 frames/sec is 13 minutes.

Contents of the film

1. Daily sea-level pressure maps for 1 July 1957 - 30 July 1958
   (395 days); 14 frames/day, contour interval 5 mb, running
time 5 min 45 sec.

2. Daily 500 mb maps for the same period; 14 frames/day, 5 min
   45 sec.

3. The same 500 mb maps at a faster speed; 4 frames/day, 1 min
   39 sec.

Film J-3:

Northern Hemisphere daily weather maps
This film is much like Film J-2 only for the northern hemisphere.
It is based on twice-daily grids from the National Meteorological Center
(NCAR 1970)
Film J-4:

Daily 500 mb heights and long period fluctuations - northern hemisphere
Periods longer than about 15 days are shown for 1 July 1966 - 30
June 1971. Twice daily maps with linear interpolation for a smooth
sequence are given for 1 August 1969 - 30 July 1970. Time: 13 min at
24 frames/sec. (NCAR 1972)

Film J-5:

A selected climatology of the northern stratosphere - 100 to 10 mb
This is a black and white, silent film. Time: 12 min at 24 frames/
sec. (NCAR 1972)

Film J-6:

Long period fluctuations in 500 mb heights
This gives data for 1 July 1969 to 30 June 1971 (periods longer than
15 days), 1 July 1967 to 30 June 1971 (periods longer than 30 days), 1 July
1963 to 30 June 1971 (periods longer than 30 days), 1 July 1963 to 30
June 1971 (longer than 60 days). Black and white silent. Time: 11 min
at 24 frames/sec. See other details in this text. (NCAR 1973)

To obtain information on costs for these films write to:

Mr. Roy L. Jenne
National Center for Atmospheric Research
P.O. Box 1470
Boulder, Colorado 80302
A collaborative effort produced a series of atlases on the climate of the Southern Hemisphere. Numerous other publications were based on the analyses. A monograph on the meteorology of the Southern Hemisphere has been published by the American Meteorological Society.

In this note we have described the computer methods used in the preparation of the atlases and in the preparation of an augmented set of data. We have indicated what is available on microfilm, on tape, and in a motion picture film.
Figure 1 Dashed lines show the annual march of temperatures from the U.S. Navy Marine Atlas for different latitudes at 40°W. Data for the station Orcadas is plotted as a dotted line. The solid lines show an estimate of the annual march of temperatures at each latitude.
Where:

- \( W_1 = .275020 \)
- \( W_2 = .175338 \)
- \( W_3 = -.004785 \)
- \( W_4 = .085365 \)
- \( W_5 = -.026692 \)
- \( W_6 = -.021289 \)

FIGURE 2a Values of weighting coefficients for the 25-point, 2-dimensional smoothing filter. After Bleck (1965).

FIGURE 2b Ratio of initial amplitude to final amplitude after filtering, related to the wavelength (in grid distances) of information in the data. In order to obtain the ratio for waves that are not oriented along the x or y axis, the wavelength must be resolved into its x and y components. This graph is for the 25-point filter in Figure 2a. After Bleck (1965).
FIGURE 3  Ratio of initial amplitude to final amplitude after filtering, related to the wavelength (in grid units) of information in the data. The weighting coefficients are for 9 data points in one direction where W1 is the weight for the center point. After Bleck (1967).
FIGURE 4  Unsmoothed 500-mb height field for July.
Contour interval 40 geopotential meters.

FIGURE 5  Smoothed 500-mb height field for July.
Contour interval 40 geopotential meters.
Figure 6 The worst case of height continuity that is in the atlas data.
Figure 7  Ratio of initial amplitude to final amplitude after filtering, related to the wavelength (in grid units) of information in the data. The weighting coefficients are for 11 data points in one direction where W1 is the weight for the center point. After Bleck (1967).
FIGURE 8 A comparison of observed resultant winds at two islands with the resultant geostrophic wind in the same region.
Figure 9. Each point represents the average difference between the observed west wind and the geostrophic west wind at a station for the four months: Jan, Apr, Jul and Oct. A minus sign means that the geostrophic wind is greater than the observed wind. The period of record of the observed wind available to us was usually shorter than that of the height data. The geostrophic wind was interpolated from the atlas data for the station location. Equatorward of 15°, the geostrophic winds were calculated using a Coriolis parameter valid at 15°.
Figure 10  Temperature minus dew point temperature. High values show the location of dry descending air.
Figure 11  Geostrophic wind speed
Figure 12  Root mean square of the daily changes of sea level pressure (mbs) and 500 mb heights (dekameters: value + 10). The smoothed curve shows a time averaged annual curve.
Figure 13 Month vs. latitude plot of the amplitude of wave 1 of the heights around each latitude circle at 500 mb.
Figure 14  Zonal mean geostrophic west wind
Figure 15  Zonal mean geostrophic west wind
Figure 16 Geostrophic west wind
Figure 17  Temperature continuity with time. Note that the calculated temperature data for the intermediate eight months at 850, 700, 300, 200, 100 mb fits in well with the other analyzed data.
Figure 18 Time continuity of geostrophic west wind. Note the dominant half-yearly variation in the wind.
Figure 19  Time continuity of geostrophic west wind. Dashed lines show data after time smoothing. These winds were calculated from the heights in Taljaard, et al., 1969.
Figure 20 West wind (knots) from an unpublished atlas. See R4.5 on page 39. Compare with Figure 19.
Figure 21 West wind (m/sec) from a published atlas. See R4.5 on page 39. Compare with Figure 19.
Figure 22  West wind (knots) from a published atlas. See R4.5 on page 39. Compare with Figure 19.
Figure 23 Height curves vs. longitude for latitude 50°S in July. For the levels 1000 through 100 mb.
Figure 24 West wind vs. month at Cocos Island. 850 through 100 mbs.
This plot shows the variation with time of pressure-height data at Port Stanley. The pressure level for each curve is given near the July and month 13 (Jan) values. The yearly average is given near the left side of the chart. The numbers of year-months of data going into each mean value are given on the curves. The numbers are zero on the 1000-mb curve because those data were derived by downward extrapolation of the data above. The table gives the actual mean values and the standard deviation of the year-month data.
Figure 26 Observed mean temperature data at Singapore.
Figure 27 Observed 850 mb temperature data at Pretoria for each year-month. It shows the effect of changing from a night to a daytime sounding time.
Figure 28  Observed 200 mb temperature for many year-months at Darwin.
Figure 29  Observed 200 mb temperature for many year-months at Tahiti.
Figure 30  Zonal mean geostrophic west wind at 55° South. Note the dominant half yearly variation in the data.
Figure 31 This plot shows the variation with time of the heights from our analyses at a grid point near Port Stanley. The grid point values are printed below the chart. Sea level pressure is converted to 1000 mb height by assuming a change of 8.2 m for each millibar. Compare with Figure 25.
REFERENCES AND BIBLIOGRAPHY


___, 1967: Personal communication.


___, ___, and ___, 1971a: Wavenumber frequency spectra of the meridional transport of sensible heat in the mid-troposphere of the Southern Hemisphere. PAGEOPH 86, 159-170.

Lorenz, E. N., 1967: The nature and theory of the general circulation of

McInturff, R. M. and F. G. Finger, 1968: The compatibility of radiosonde
data at stratospheric levels over the Northern Hemisphere. ESSA Tech
Memo WBTM-DATAC 2, ESSA Weather Bureau, Silver Spring, Maryland.

Meinardus, W., 1940: Die interdiurne Veränderlichkeit der Temperatur und
57, 165-176 and 219-233.

Monthly Climatic Data for the World. National Climatic Center and World
Data Center-A, Asheville, N.C.


Taljaard, J. J., R. L. Jenne, H. van Loon, and H. L. Crutcher, 1968: Sea-
sonal range, anomalies and other aspects of sea-level pressure, isobaric
height, temperature and dew point at selected levels in the Southern
Hemisphere. Notos 17, 63-140. (Published in 1970.)

—, H. van Loon, H. L. Crutcher, and R. L. Jenne, 1969: Climate of
the Upper Air: Southern Hemisphere. Vol. I, Temperatures, dew points,
and heights at selected pressure levels. NAVAIR 50-1C-55, Chief Naval

van Loon, H., 1966: On the annual temperature range over the southern

—, 1967: The half-yearly oscillations in middle and high southern lati-

—, and R. L. Jenne, 1969: The half-yearly oscillations in the tropics

AMS Symp. on Tropical Meteor., University of Hawaii, Honolulu, Hawaii,
L IV-1 to L IV-3.

—, and —, 1970b: On the half-yearly oscillations in the tropics.
Tellus 22, 391-398.

—, and —, 1970c: Supplementary text to a film on the climatology
of the Southern Hemisphere. LAS and FAL, National Center for Atmospheric

—, and —, 1970d: The annual wave in the temperature of the low
stratosphere. J. Atmos. Sci. 27, 701-705.

—, and —, 1972: The zonal harmonic standing waves in the Southern

____, R. L. Jenne, J. J. Taljaard, and H. L. Crutcher, 1968: An outline of the yearly and half-yearly components in the zonal mean temperature and wind between the surface and 100 mb in the Southern Hemisphere. Notos 17, 53-62. (Published in 1970.)


U. S. Navy, 1957-65: Marine Climatic Atlas of the World, Volumes III (Indian Ocean), IV (South Atlantic Ocean), V (South Pacific Ocean), and VII (Antarctic), Washington, D.C.


