CLIMATE OF THE UPPER AIR: SOUTHERN HEMISPHERE

VOLUME II
ZONAL GEOSTROPHIC WINDS

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3 National Climatic Center
Foreword

This volume is the second in a series depicting the upper air climatology of the Southern Hemisphere. Volume I presented mean monthly isopleth charts of sea-level pressure and of height, temperature, and dew point at selected upper levels, as well as smoothed grid-point values produced from these charts by computer analysis. Volume II depicts the zonal geostrophic wind components in the Southern Hemisphere. Harmonic analyses of the wind components in time portray some of the characteristics of the annual wind regimes. Volume III will deal with isogons and isochas of the geostrophic wind; Volume IV will present selected meridional cross sections of temperature, dew point, and isobaric height, and derived statistics.

Production of these four volumes results from a merger of efforts at the National Center for Atmospheric Research (NCAR) and the National Climatic Center (NCC). Additional funds came from the Department of Defense. The volumes contain support material for investigations of the Southern Hemisphere atmospheric circulation that are being conducted at NCAR. All data presented here have been recorded on magnetic tape; the tapes and computer products derived from them are archived at NCC and NCAR.

Acknowledgments

Since 1948, various nations have contributed climatological information to Monthly Climatic Data for the World (U.S. Dept. of Commerce). The ready availability of these data greatly facilitated preparation of the present volume.

The authors wish especially to acknowledge the sustained and competent help of Dennis Joseph (NCAR) and Robert Quayle (NCC). Many other staff members of NCC aided in preparation of this work, in particular, Benjamin Davis, Warren Hatch, and J. M. Menerve (analyst); Robert Courtney (drafting); and Wanda Ross (preparation of grid-point values).
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INTRODUCTION

The zonal geostrophic winds presented in this volume were computed from the isobaric heights given in Volume I (Taljaard et al., 1969). A detailed description of the treatment of the data and of the methods employed in the analysis of the isobaric heights is presented in Volume I. Four other comprehensive accounts of the wind in the Southern Hemisphere have been published: Brooks et al., 1950; Haustie and Stephenson, 1960; Dubenstov and Davidova, 1964; and Guterman, 1967. A comparison of these works with the present Atlas revealed significant differences, possibly resulting from the longer period of data used in compiling this Atlas. In addition, we have been able to describe Southern Hemisphere winds in somewhat greater detail in this Atlas than was previously possible.

The increase in Southern Hemisphere data promises to be phenomenal, and without doubt the present Atlas will be supplanted in turn. However, until more data have accrued from new observational techniques using satellites and constant-density balloons, this Atlas can serve as a basis for general conclusions about the average wind field below the 100-mb level in the Southern Hemisphere.

GEOSTROPHIC WINDS

COMPUTATION OF GEOSTROPHIC WINDS

Volume I described computer methods used in checking climatological grid-point data for numerical errors and in smoothing the grids. To compute geostrophic winds from the smoothed grids, we first calculated the pressure (or pressure height) gradient at each point in the grid. Employing the least squares method, we computed cubic curves from the five north-south points centered on the point in question. From these cubic curves we then calculated derivatives valid at the center data point.

We computed the component winds from the following relations:

\[ u = \frac{\partial p}{\partial y} \]

\[ v = \frac{\partial p}{\partial x} \]

where

\[ f = 2 \Omega \sin \lambda \]

\[ \Omega = 7,392,116 \times 10^{-5} \text{ rad/ sec} \]

\[ \rho = (\text{at surface}) = 1,223 \times 10^{-5} \text{ g/cm}^3 \]

\[ g = 980,665 \text{ cm/sec}^2 \]

\[ u \] is the zonal component of the wind

The grid-point data printed next to the maps are the computed values. Occasional smoothing was necessary in the analyses of these computed values on the maps and cross sections; as a result, grid points and isopleths may not always be in perfect agreement.

REPRESENTATIVENESS OF GEOSTROPHIC WINDS

At low latitudes the geostrophic wind becomes a poor approximation of the real wind, and a small error in the pressure gradient can cause a large error in the geostrophic wind. For example, Table I shows that an error in the pressure-height gradient of 10 m per 5° of latitude would produce an error of 4.7 m/sec at 15° latitude, but only 1.4 m/sec at 60° latitude. To obtain a better approximation to the real wind at 10° latitude, the wind was calculated by arbitrarily using a coriolis parameter for 15°.

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<th>Latitude (°)</th>
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Geostrophic winds were computed from grid points read to the nearest 10 m. Errors in the analyses and in the tracing of lines are likely to be of this magnitude. Where these errors are random, the smoothing of the grids should almost eliminate them. Spot checks comparing observed winds with geostrophic winds indicated that the errors are comparable in magnitude to, but usually smaller than, those listed in the table. Errors in the zonal means are probably much smaller than errors at point locations. Analyses of harmonic data showing the amplitude and phase of the first two harmonics in time and the percentage of the total variance accounted for by these were also compared with a similar analysis of observed winds. Even at low latitudes the phases were in agreement, but there the amplitudes were exaggerated in the calculated values, and more noise (shown by more variance in the higher harmonics) appeared in these values. For these reasons the geostrophic winds are not indicated between the Equator and 10°S in the figures. Even at 15° and 20°S the computed amplitudes may be too high. Winds are not indicated in the region from 85°S to the South Pole, which is a singular point.

Differences between geostrophic and observed winds should not necessarily be judged in favor of the latter. The period for which heights were available was usually much longer than that for winds, though differences from station to station in the length of the records of the heights will occasionally make the geostrophic wind representation less representative. Furthermore, there are instances when the mean speed of the observed wind is too low because the daily observations are systematically biased against strong winds. For example, the geostrophic wind and the observed wind were in good agreement in February over Marion Island at and below 500 m, but at 200 m the geostrophic wind was considerably stronger than the recorded wind. Daily ascents at Marion Island were checked for February and other months in 1958. Normally, all but two or three ascents per month reached the 500-m level, but fewer than half of the ascents reported winds at 200 m. The data also showed that when the wind was strong at 500 m, winds at 200 m were not likely to be observed. Kerguelen Island, which is in the same belt of strong winds and strong thermal gradient from 500 to 200 m, is able to observe winds at all levels even when high winds exist. Figure I shows the observed resultant winds at Kerguelen and Marion Islands compared with resultant geostrophic winds for a point near Marion Island. (The Introduction to Volume III contains additional information about the relationship between real winds and calculated geostrophic winds.)

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

![FIGURE 1 A comparison of observed resultant winds at two islands with the resultant geostrophic wind in the same region.](image)
TERRAIN IN THE CROSS SECTIONS

Terrain profiles in meridional sections refer to the height scale (kilometers) on the left side of the sections. Terrain profiles for Antarctica on the zonally averaged sections represent average terrain elevations for the hemisphere based on a 5° x 5° latitude-longitude grid.

CHARACTERISTICS OF SEASONAL WIND VARIATIONS

In addition to the description of the zonal wind components in meridional sections and on polar stereographic maps, several diagrams illustrate the seasonal variations of the zonal geostrophic wind. It is not the purpose of this discussion to provide an exhaustive description and explanation of the wind distribution and its variations with season, but because most users of this Atlas may be unfamiliar with the circulation in the Southern Hemisphere, we shall point out certain characteristics of the annual march of the zonal wind.

The change in zonally averaged geostrophic winds from January (summer) to July (winter) is shown in the center of Figure 19. A marked weakening from winter to summer of the subtropical jet and of the westerlies in the lower stratosphere in subpolar latitudes and a strengthening in summer of the zonal component in the troposphere between 40 and 55°S are evident (van Loon, 1966). Note also the substantial weakening of the tropical easterlies at the surface in summer.

The annual march and the first two harmonic components of the zonal geostrophic wind at every fifth parallel at sea level, and at 500 and 200 mb, are presented in Figures 34, 35, and 36. These diagrams show that the circulation in the southern half of the atmosphere has substantial half-yearly components. In high latitudes the half-yearly component of the zonal wind reaches its maxima in March-April and September-October and increases in amplitude from sea level to 200 mb. Note, however, that it accounts for a larger proportion of the annual march of the wind speed in the lower half of the troposphere than in the upper half or in the lower stratosphere. North of about 50°S the phase changes so that the maxima occur in June and December at approximately 35 - 45°S. Although the amplitude here is small, so is that of the first harmonic, and the half-yearly component in this belt thus explains a substantial part of the variance.

The half-yearly oscillations are therefore important in the tropospheric circulation of middle and high southern latitudes. Their nature and distribution have been described by Schwertfeger (e.g., 1963) and van Loon (1967).

Another large half-yearly oscillation of the zonal wind is found in low latitudes. It is hardly visible at sea level and at 500 mb, but is conspicuous at the 200 - mb level, where it reaches its largest amplitude at 10 - 15°S. Its share of the annual march is highest at the lowest latitude shown in the profile. This oscillation reaches maxima in May and November; the phase change from the June-December oscillation in middle latitudes to the May-November oscillation in the tropics is a gradual one. The low-latitude oscillation has been described by van Loon and Jenne (1969, 1970).

REFERENCES


FIGURE 2 Map of sea-level mean geostrophic zonal wind (u) component and associated grid point values (mps, positive from the west) JANUARY
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The diagram shows the distribution of the zonal wind component at 500 millibars, with values ranging from 2.5 m/s to 27.5 m/s, indicated by contour lines on a spherical projection. The map covers a range of longitudes from 0° to 180°, with specific values marked at various locations, indicating the direction and magnitude of the wind direction.
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FIGURE 13 Map of 200 mb mean geostrophic zonal wind (u) component and associated grid point values (mps, positive from the west) OCTOBER

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Note: The grid point values are in mps and positive from the west.
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FIGURE 34  

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(b) Latitude versus amplitude (in meters per second) of the first and second harmonics of sea-level zonal geostrophic wind. Numbers appearing next to the dots along the smooth amplitude curve indicate percent of variance of the zonal wind accounted for by the respective harmonic. Broken curves with circular data points indicate the date of occurrence of the peak for the first harmonic and first peak for the second harmonic with reference to the month scale in the center of the diagram. The second maximum of the second harmonic will occur six months after the first maximum.
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   b. Latitude versus amplitude (in meters per second) of the first and second harmonics of the 500 mb zonal geostrophic wind. Numbers appearing next to the dots along the smooth amplitude curve indicate percent of variance of the zonal wind accounted for by the respective harmonic. Broken curves with circular data points indicate the date of occurrence of the peak for the first harmonic and first peak for the second harmonic with reference to the month scale in the center of the diagram. The second maximum of the second harmonic will occur six months after the first maximum.
FIGURE 36 a. Annual march of zonally averaged zonal geostrophic wind at 200 mb.
b. Latitude versus amplitude (in meters per second) of the first and second harmonics of the 200 mb zonal geostrophic wind. Numbers appearing next to the dots along the smooth amplitude curve indicate percent of variance of the zonal wind accounted for by the respective harmonic. Broken curves with circular data points indicate the date of occurrence of the peak for the first harmonic and first peak for the second harmonic with reference to the month scale in the center of the diagram. The second maximum of the second harmonic will occur six months after the first maximum.
FIGURE 37 Zonal cross sections of January and July mean geostrophic meridional wind (v) components (mps, positive from the south) for the Southern Hemisphere for 50° SOUTH LATITUDE.