A Tidal Experiment in the Equatorial Stratosphere over Ascension Island

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1. Introduction

A program designed to determine the nature and extent of atmospheric tides in the 30–60 km region is being conducted by the U. S. Army Atmospheric Sciences Laboratory at White Sands Missile Range, N. M., and has been in progress since early in 1964. The approach has mainly involved the use of small meteorological rockets as are used in the Meteorological Rocket Network (MRN). These rockets have the capability of directly measuring winds and temperatures over the altitude range being investigated.

Four rocketsonde experiments have been conducted at White Sands Missile Range which have provided information on tides (Beyers and Miers, 1965; Miers, 1965; Beyers *et al.*, 1966). These experiments consisted of series of soundings spaced 2–4 hr apart and continued over periods of 24–48 hr. From such experiments it has been concluded that there exists (near the stratopause over White Sands) a large atmospheric tidal oscillation during all seasons of the year. The oscillation has a dominant diurnal mode whose amplitude of around 10 m sec^{-1} diminishes to the sensor noise level near 40 km. The meridional component v displays more uniformity between seasons in both phase and amplitude, and its amplitudes are roughly double those of the zonal u components. Similarly, there is a dominant diurnal temperature oscillation which consistently displays maximum temperature values near the stratopause at approximately 1200–1400 hours local time, with minimum values some 12 hr later. The mean temperature amplitudes increase from near 2C at 40 km to 8C at 60 km.

Another approach has been taken by Reed *et al.* (1966a,b), who have examined routinely published wind observations for several MRN stations and determined the diurnal behavior through a grouping of the observations at a particular station according to hour of day. Despite the fact that most MRN soundings are made during daylight hours, by using data over several years they have been successful in establishing the characteristics of the meridional components at various stations for the summer season. The results of the detailed experiment of White Sands during the summer season and the more general wind analyses by Reed *et al.* are in good agreement.

2. The experiment

Recently, the results of another detailed series of meteorological rocket soundings have become available. The latest series was conducted in April 1966 by the U. S. Air Force at Ascension Island, near 8S, 15W. The series included 24 Arcasonde soundings over a 2-day period, and the schedule consisted of 8 sets of 3 soundings, with each sounding within a set taken 1 hr apart and each set separated by 4 hr. The 4-hr interruptions in the schedule were necessitated by operations considerations.

The Arcasonde system is one of the standard meteorological rocket systems and a principal contributor to the Meteorological Rocket Network. It includes a radarreflective parachute which supports a temperature instrument equipped with a bead thermistor. Wind determinations were calculated from position vs. time data from AN/FPS-16 precision instrumentation radars as they track the descending parachutes. Radar data were recorded at a rate of 10 points sec^{-1} and then subjected to a smoothing and filtering technique (Eddy *et al.*, 1965; Kays and Olsen, 1966) by use of a high-speed computer. There will be differences between the published data (IRIG-MWG, 1966) and the data presented here. These differences will mostly concern the detailed features of each wind sounding and occur because the smoothing and filtering process used here was not incorporated in the more general processing used for the MRN publication. The general features will be the same in both cases. The wind components are considered accurate to within 3 m sec^{-1}.

Temperatures from the bead thermistors were telemetered continuously by the instrument suspended on the parachute and recorded on standard GMD ground receivers and recorders. The temperatures are considered accurate to within 2C at 50 km.

3. Results

Figs. 1 and 2 are time sections of the zonal u and meridional v wind components, respectively, which were observed during the series. Each of the data points represents a 4-km average from the observed profile, and levels were chosen at 36, 40, 44, 48, 52 and 56 km. The results of a harmonic analysis for the diurnal mode are included along with the actual points. For the harmonic analysis, the sets of three soundings were averaged and the mean assigned to the mid-time of each set. Thus, data points were available every 6 hr and, consequently, only the diurnal component of the motion was examined.

In contrast to results obtained at White Sands, the data in Figs. 1 and 2 do not display a consistent, well defined diurnal oscillation in either the u or v component. Notice that there is an apparent lack of continuity in the phase with altitude and considerable variation between the two days. A further examination of the phase and amplitude continuity of the v component is made in Fig. 3. Also for comparison, the results obtained in the more general analysis for Ascension Island by Reed *et al.* (1966b) are included. There is a general

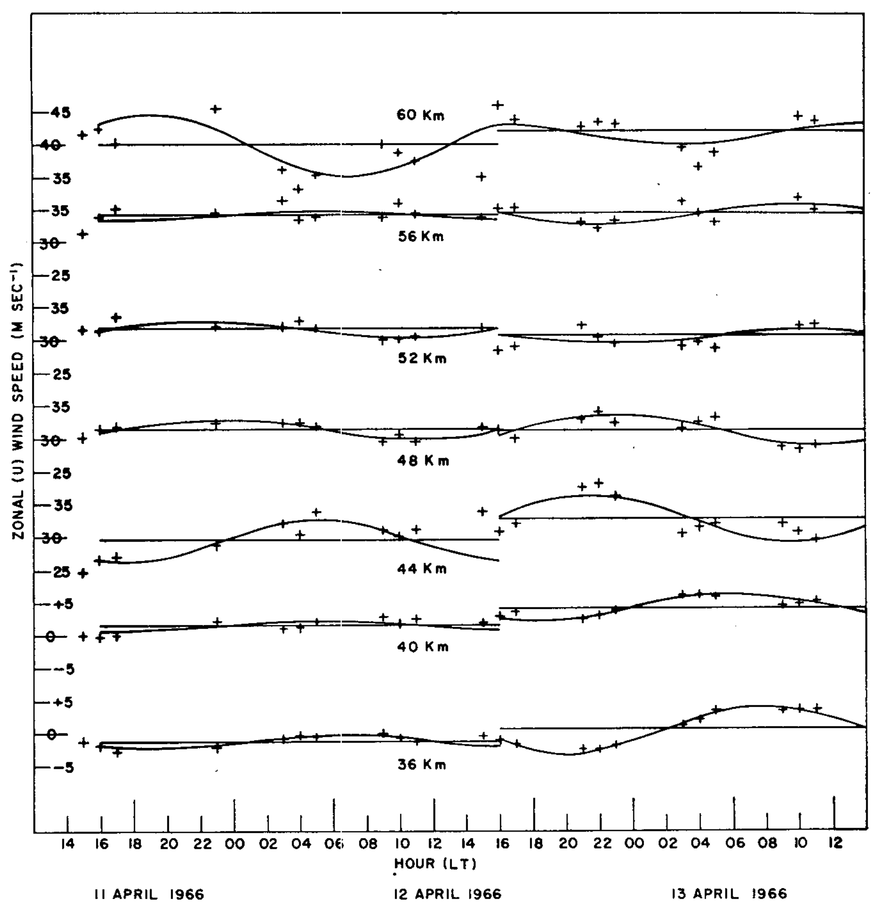

FIG. 1. Time section of the zonal wind u for various altitudes over Ascension Island 11–13 April 1966. Crosses indicate actual data points and the smooth lines are harmonic analyses of these points for two 24-hr periods (1400 LST 11 April to 1600 LST 12 April, day one, and 1600 LST 12 April to 1400 LST 13 April, day two).

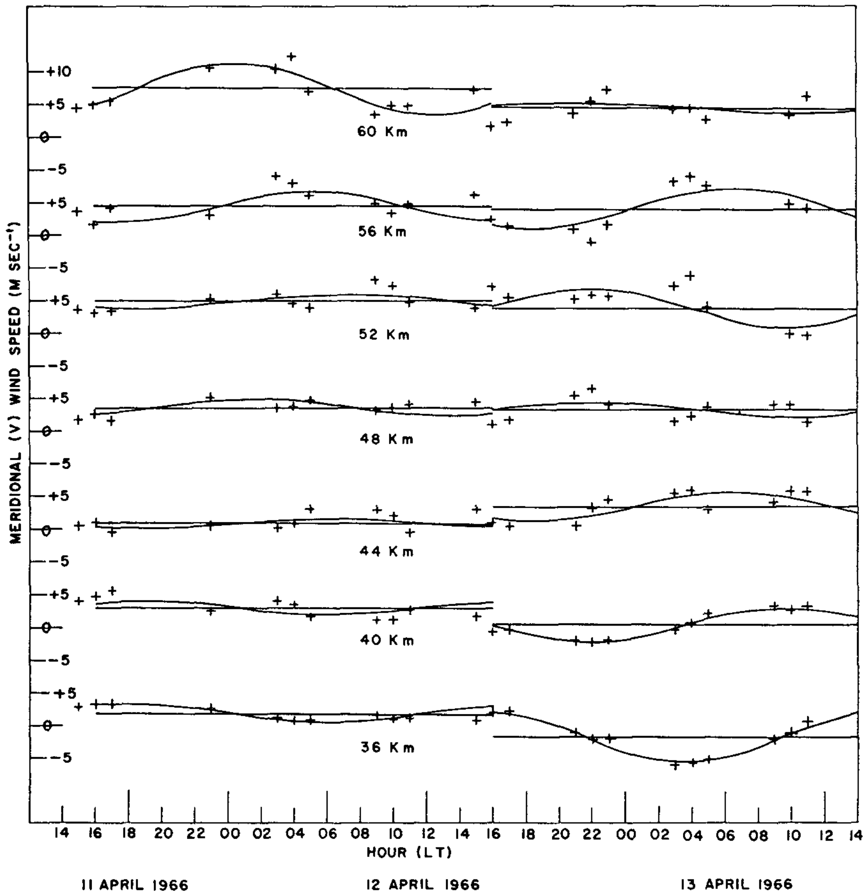

Fig. 2. Time section of the meridional wind component v for various altitudes over Ascension Island 11–13 April 1966. Crosses indicate actual data points and the smooth lines are harmonic analyses of these points for two 24-hr periods (1400 LST 11 April to 1600 LST 12 April, day one, and 1600 LST 12 April to 1400 LST 13 April, day two).

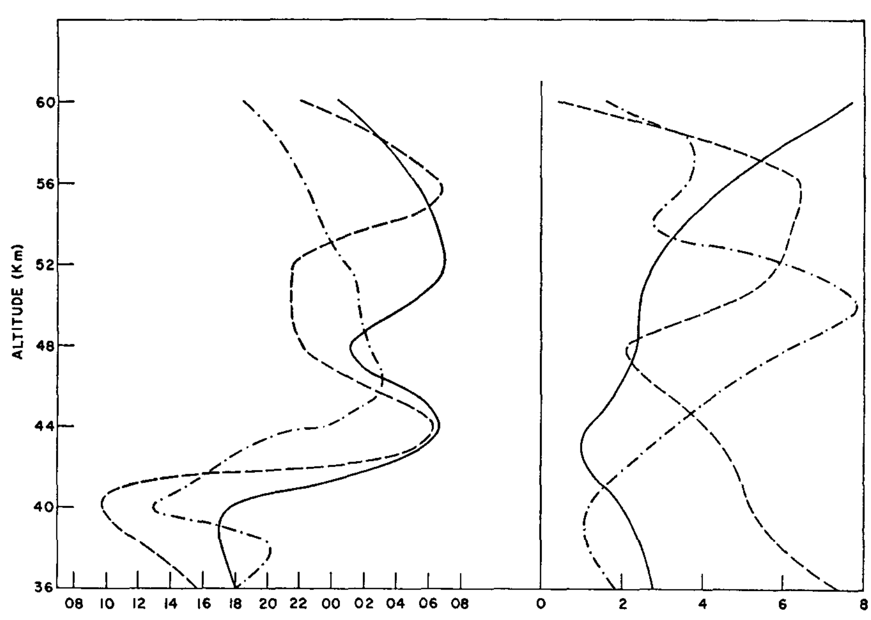

Fig. 3. Phase (left) and amplitude (right) of the meridional wind component of day one (solid line) and day two (dashed line) compared with the analysis of Reed *et al.* (1966), shown by dotted line.

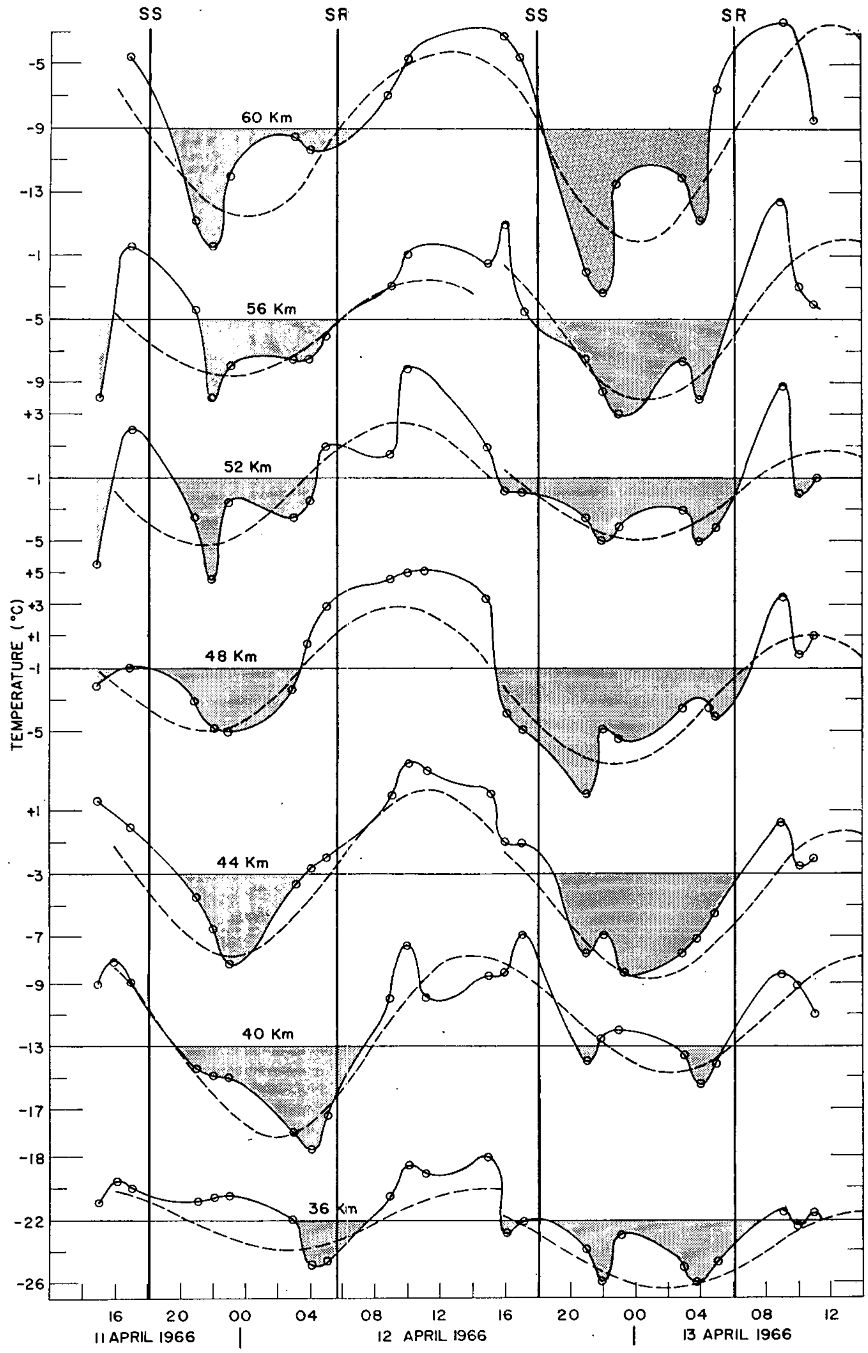

FIG. 4. Time section of temperature variation for various altitudes over Ascension Island 11–13 April 1966. Circles joined by a smooth solid line are actual data points. Stipled areas indicate departures from a mean temperature (4-km average) in the colder direction. Dashed lines are harmonic analyses of actual data points for day one and day two. Sunrise and sunset lines are also shown.

similarity in the phase vs. altitude between the results of Reed *et al.*, and the April series, but the amplitude comparisons are poor. Due to the considerable variations between the two days of the series, it is concluded that the diurnal variation may have been masked or distorted by some other short-term disturbance during the period of the April series, or that the tidal motion may be inherently more complex at the equatorial station.

In contrast to the wind results, the temperature displayed a striking diurnal oscillation as shown in Fig. 4. This is the most complete set of temperature soundings for tidal analysis thus far available at any station. In this figure, the 4-km averaging was again used, and the

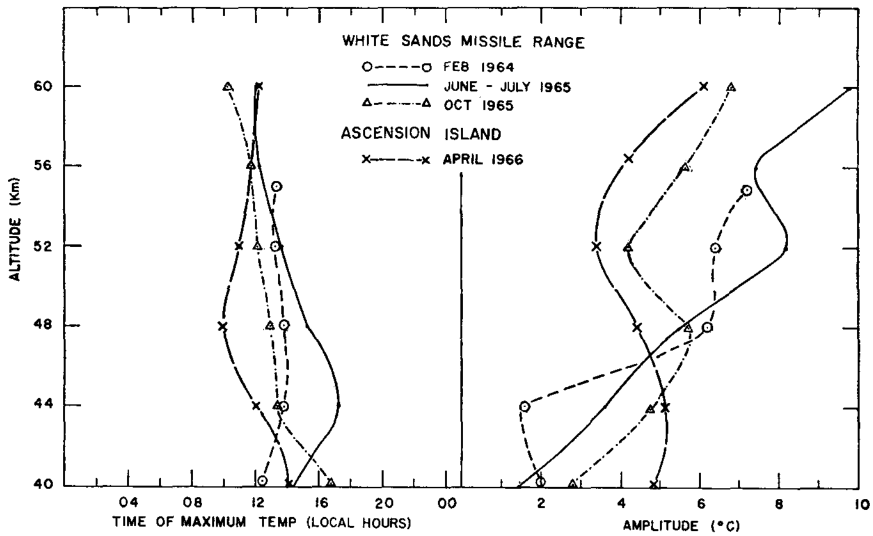

FIG. 5. Phase (left) and amplitude (right) of the diurnal temperature variation over Ascension Island compared to three previous White Sands determinations.

harmonic analysis results are included with the actual data points. The results are quite similar to the temperature oscillations observed at White Sands. These observed temperature oscillations as well as the White Sands data are in definite disagreement with the assumptions of Finger and Woolf (1967) in which they imposed the condition of maximum and minimum temperatures in the stratopause region, near sunset and sunrise, respectively, on their data. Notice that sunrise and sunset lines have been included in the figure. The phase and amplitude of the diurnal temperature variation for this series are presented in Fig. 5 and compared to the earlier White Sands data.

For this series the time of maximum ranges from near 1400 at 36 km, to 1000 at 48 km, and to near 1200 at 60 km. The amplitudes form an S shape with minimum of 2.3 and 3.3C at 26 and 52 km, respectively, and maximum of 5C and 6C at 44 and 60 km, respectively. Thus, the diurnal range from the harmonic analysis reaches 12C. Comparing this series to the White Sands results, the phase is in good agreement except at the 48-km level where it leads the nearest White Sands point by about 3 hr. The amplitudes of this series are slightly smaller throughout the 48–60 km layer but larger at 40 and 44 km.

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