Adv. Space Res. Vol.2, No.10, pp.125-128, 1983
Printed in Great Britain.
0273-1177/83/100125-04$03.00/0

WIND STRUCTURE AND SMALL-SCALE WIND VARIABILITY IN THE STRATOSPHERE AND MESOSPHERE DURING THE NOVEMBER 1980 ENERGY BUDGET CAMPAIGN

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ABSTRACT

Between November 6 and December 1, 1980, a series of rocket observations obtained from two sites in northern Scandanavia as part of the Energy Budget Campaign indicated that significant vertical and temporal changes in the wind structure were present and were noted to coincide with different geomagnetic conditions, i.e., quiet and enhanced. This series of observations represents for the first time the largest amount of data ever gathered at high latitudes over such a short interval of time. It is observed that prior to November 16, the meridional wind component above 60 kilometers was found to be positive (southerly) while the magnitude of the zonal wind component increased with altitude. After November 16 the meridional component became negative (northerly) and the magnitude of the zonal wind component was noted to decrease with altitude. Time-sections of the perturbations of the zonal wind show the presence of vertically propagating waves which suggest gravity wave activity. These waves increase in wavelength from 3-4 kilometers near 40 kilometers to over 12 kilometers near 80 kilometers. The observational techniques employed at Andoya, Norway, and ESRANGE in Sweden, consisted of chaff foil, chemical trails, inflatable spheres, and parachutes.

INTRODUCTION

The wind structure and small-scale wind variability found in the high-latitude stratosphere and mesosphere over ESRANGE (Kiruna, Sweden) during the Energy Budget Campaign of November 1980 is described. This campaign was designed to examine the little understood processes which may affect the energetics of the mesosphere and thermosphere [1]. Numerous measurements of atmospheric temperature, density, and wind were obtained between 20 and 85-90 km. Radar-tracked meteorological rocket payloads [2] provided the majority of the wind data. Other wind measurements were obtained using foil chaff [3], rigid spheres [4], and chemical trails [5]. Because of the many diverse experiments in the campaign and the unique experimental conditions imposed, large gaps (in time) occur between observations. In spite of the nature of discrete measurements, it is possible to determine the wind structure and small-scale wind variability. Four special observational periods were established based on the level of geomagnetic activity. The dates of the observational periods were November 10, 16, 27, and December 1.

DISCUSSION

During each of the four observational periods the mean pattern was found to be different, as exhibited in Figure 1. Each of the mean profiles was derived from four rocketsonde observations. Quiet polar night conditions occurred on November 10 and was a necessary part of the experimental criteria in order to establish background information. The mean meridional wind, Figure 1a, was predominantly from the south at speeds less than 30 meters per second (mps). Below 37 km a slight northerly componented was observed. The zonal wind was westerly and increased with altitude. At altitudes above 60 km the speed decreased and became easterly above 68 km. On November 16, during slightly enhanced geomagnetic conditions, the meridional wind above 55 km reached twice the magnitude observed on November 10, Figure 1b, while below 55 km the northerly wind was more dominant. Similarly, the zonal wind increased in speed, peaking near 65 km and became easterly above 77 km. On November 27 and December 1, when auroral and other geomagnetic conditions were strongest, the meridional component was northerly and the zonal speed decreased and did not indicate the presence of any easterly winds. Whether the changes observed in these mean conditions

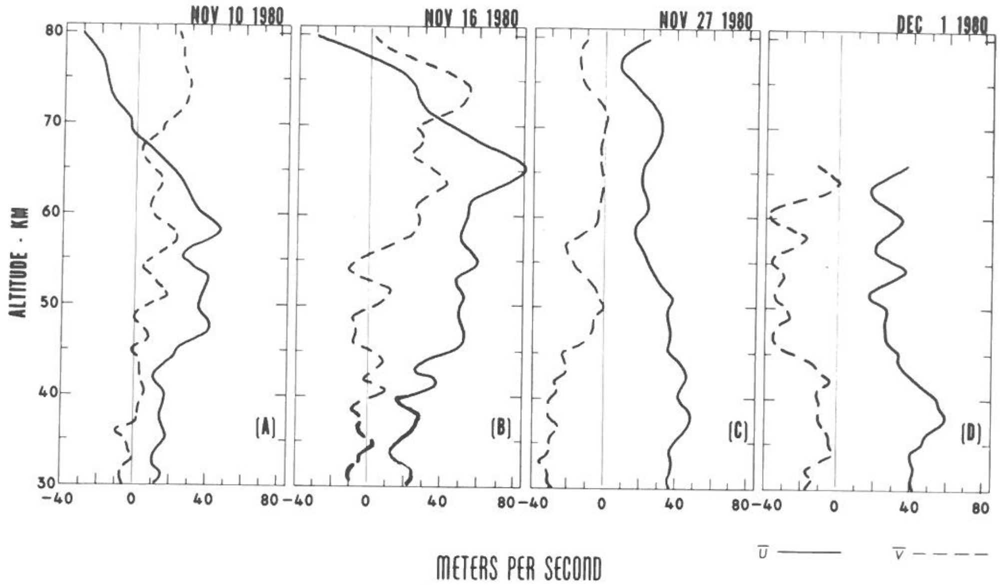

Fig. 1. Profiles of mean zonal and meridional winds vs altitude observed during four geomagnetic observational periods: a) quiet, November 10, 1980; b) slightly enhanced, November 16, 1980; c) and d) very active, November 27, 1980 and December 1, 1980, respectively. Mean data were derived from the meteorological soundings obtained during each period.

are associated with changing polar night conditions, with changing hemispheric circulation patterns, or with some other physical phenomenon remains to be determined.

The inflatable sphere profiles best characterize the vertical structure of the wind. Figure 2 presents profiles from the slightly enhanced and from the active geomagnetic periods. The general character of these profiles indicates oscillations, in some cases, reaching peak-to-peak changes in speed of 35-40 mps within a few hours. The vertical wavelengths of the oscillations are small near 30-40 km altitude (~1-2 km), increases near 50 km (~3-4 km), and are largest above 65-70 km (>12 km). It is possible that short wavelength oscillations (~1-4 km) are present above 65 km, however, the speed at which the sphere falls through the atmosphere limits our capability to resolve oscillations of that size. Suffice to say, the profiles of Figure 2 indicate that the high-latitude wind may be rather turbulent.

Examining the observations of Figure 2 further, a number of interesting characteristics immediately becomes apparent. An orderly change of the meridional wind with changes in time occurred between 50 to 62 km on November 16, Figure 2a. The observation at 0512UT reveals a northerly peak wind of 30 mps near 55 km but at 0823UT the wind at the same altitude has become southerly at about 10 mps. The zonal wind profiles, Figure 2b, indicate that the vertical oscillations have a rather long persistence, especially below 45 km. These oscillations are in all the measurements, but the in-phase persistence seen in Figure 2b is the most coherent. One further characteristic is the rather disorganized behavior noted on November 27, Figures 2c and 2d. This apparent anomalous structure may be a result of the relatively long time difference between the observations, a highly turbulent state in the atmosphere, or a readjustment of the circulation. These few profiles, shown in Figure 2, are representative of all the measurements obtained during the Energy Budget Campaign, and confirm that the winds are not constant in space nor time.

The general incoherence observed among many of the wind profiles suggest the presence of propagating waves. The observed wavelengths are similar to those found with internal gravity waves. However, the fact that discrete observations only are available preclude conclusive judgment concerning the continuity of the waves in time and space. Nevertheless, oscillations with periods in the range of 10-200 minutes are usually manifest in gravity waves; the observations shown in Figure 2 were obtained within this same time scale. One important aspect not clear from Figure 2 is the direction in which the waves propagate.

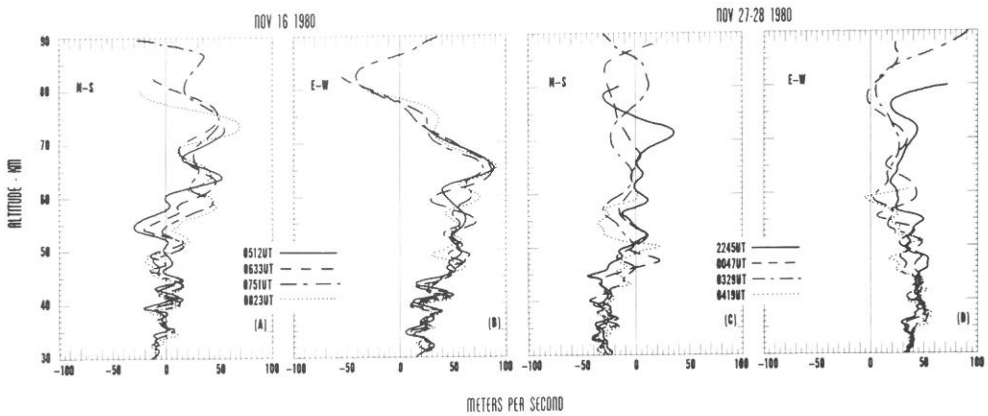

Fig. 2. Wind measurements observed on a geomagnetically quiet (slightly enhanced) night, November 16, 1980, a) meridional wind observations, b) zonal wind observations; and on a geomagnetically active night, November 27-28, 1980, c) meridional and d) zonal.

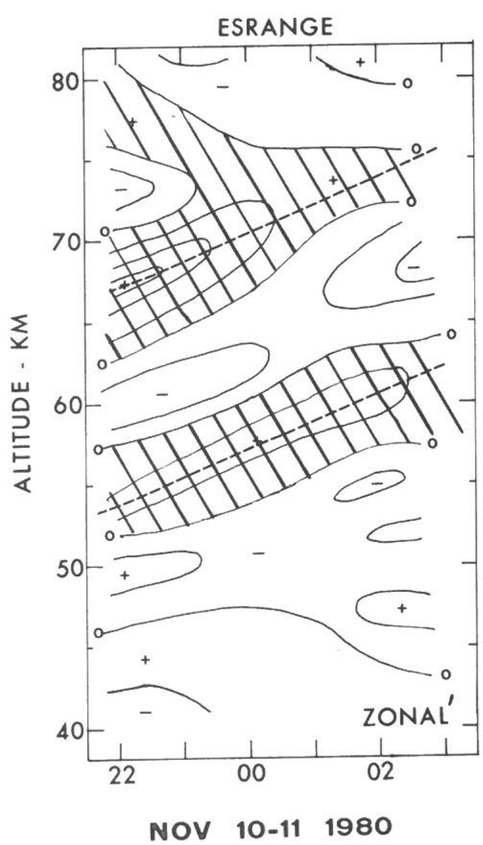

Fig. 3. Perturbation velocities of the zonal wind obtained on a geomagnetically quiet night.

Time sections of the perturbation velocities show wavelengths consistent with the observations as mentioned earlier. The phase propagation was found to be downward, upward, and, at times is moving down and up on the same vertical section. The propagation rates varied from 0.7 km per hour to 2 km per hour. Generally, the direction of phase propagation is downward, but on the night of November 10 the propagation was decidedly upward as shown in Figure 3. The importance of the direction of propagation is obvious, but only rarely is upward propagation observed. Considerably more measurements over short time periods are desirable if this downward direction is to be confirmed.

CONCLUSIONS

It must be concluded that the wintertime, high-latitude wind structure is highly complex. Observations show it to be variable in time and space, to contain considerable structure, and to be inconsistent in many ways. The observed wind suggests that vertically propagating gravity waves may contribute substantially to the patterns observed. Their source was not determined in preparing this paper, and indeed, it may be necessary to obtain many measurements much closer in time than were obtained during the Energy Budget Campaign to conclusively determine the influence of gravity waves on the type of measurements shown here.

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