4.1A TECHNIQUES FOR STUDYING GRAVITY WAVES AND TURBULENCE: HORIZONTAL, VERTICAL AND TEMPORAL RESOLUTION NEEDED

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One of the most important atmospheric measurements that is needed is a measure of the gravity-wave spectrum. Theoretical modeling of the breakdown of gravity waves and the resulting generation of turbulence has shown that this mechanism is crucial in understanding the general circulation of the middle atmosphere (LINDZEN, 1981; HOLTON, 1982; MATSUNO, 1982). In these models a knowledge of the gravity-wave periods and horizontal phase velocities is necessary. To date a thorough observational study to help delineate the gravity-wave parameters has not been done although a measure of the gravity-wave upward energy flux has been made by VINCENT and REID (1983). A detailed analysis of the sources of gravity waves is also lacking.

According to the dispersion relationship for gravity waves (HINES, 1960), the periods of these waves, including the tidal oscillations, range from minutes to hours. Corresponding horizontal wavelengths range from 10^2m to 10^7m and vertical wavelengths range from 10^2 to 10^5m. Thus there is a wide band of frequencies and wavelengths that are associated with gravity-wave motions. Since the background atmosphere acts as a filter for upward propagating gravity waves, the spectrum observed at mesospheric heights should be different than that at tropospheric heights.

The large temporal and spatial scales of tidal oscillations require continuous data collection (at least over 48 hours) and a global network of stations.* Coordinated observational periods have been made amongst meteor radar, partial reflection drifts, and MST radar groups. A workshop discussing the results of one such global campaign will be held in Hamburg at the IUGG meeting, August 1983.

Shorter period oscillations will require temporal resolution on the order of minutes or less. This time resolution is already available on many MST or ST radars (BALSLEY and GAGE, 1980). An indication of the spatial resolution required for observations can be obtained from vertical velocity data taken simultaneously by 3 ST radars a few km apart during the ALPEX experiment in southern France in 1982. Figure 1 displays vertical velocity power spectra, coherence, and cross-phase (phase of the cross-spectrum) for two sites which were separated by 4.6 km. The curves at short periods are averaged over 18 consecutive 4-hour periods and over 5 adjacent 750-meter range gates in the troposphere and 3 range gates in the stratosphere. The curves between 3 and 24 hour periods were obtained from 3 24-hour data sets averaged over the same range gates. For the short-period sections of the coherence curves, the 99% confidence level for zero coherence is at a value of 0.22 for the troposphere and 0.29 for the stratosphere.

Note that the power drops off dramatically in the troposphere below the Brunt-Vaisala period (T_B). A lesser drop-off in power is seen in the stratosphere. The coherence between the two sites for periods less that T_B is small and increases rapidly with increasing period. For periods greater than 3 hours the coherence is greater than 0.7 and the cross phase between the sites is zero. The coherence is still relatively high for periods between 3 H and 1 H and a gradual increase in the cross phase is seen in the stratosphere. The cross

*The time resolution only needs to be on the order of one hour or less unless one is studying the interaction with shorter period gravity waves.

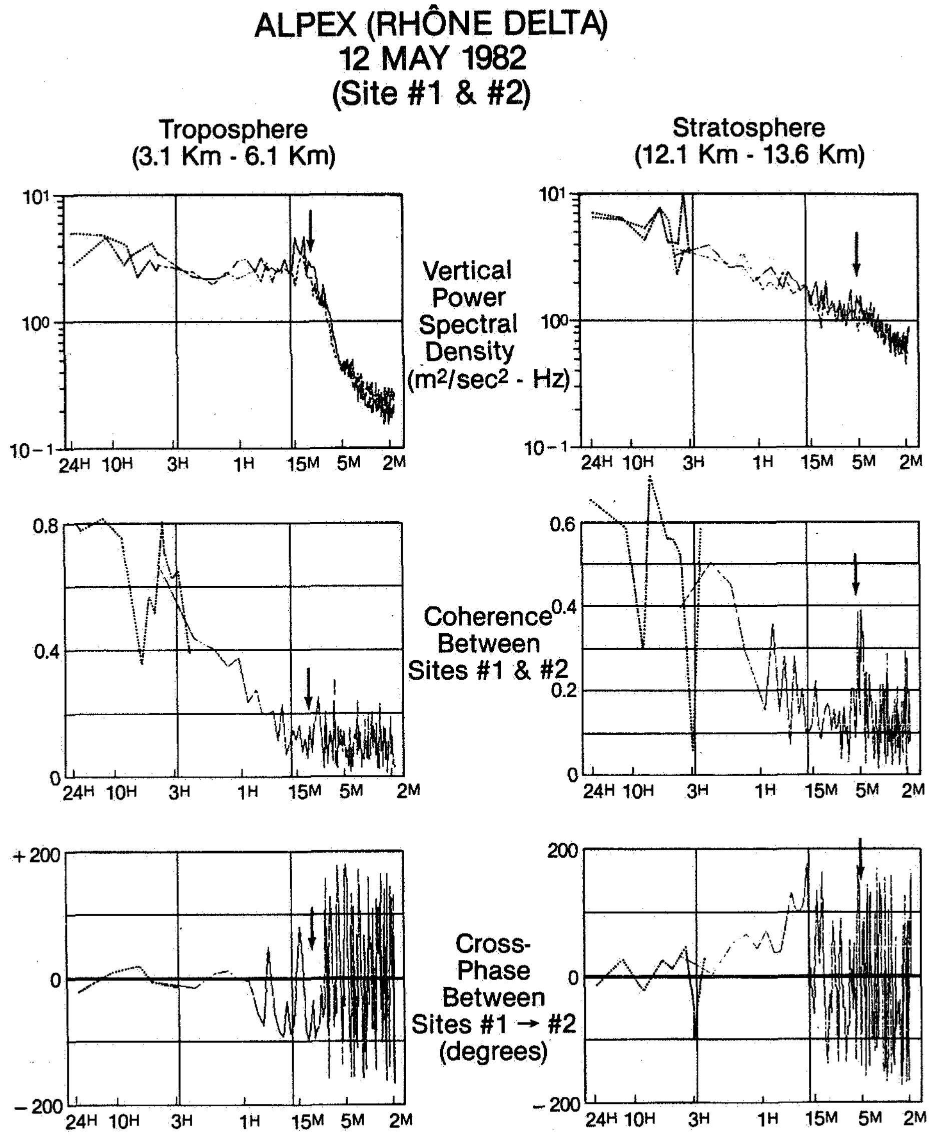

Figure 1.

phase is approximately 50° for waves with periods of 2 H which corresponds to a horizontal wavelength component of 35 km and a phase speed of 4.5 m/s.

From this type of analysis we can obtain a measure of the horizontal spacing required to measure horizontal wavelengths. Below T_B the horizontal resolution needed is less than 5 km. For wave periods between 3 H and 1 H the 5 km spacing appears to be adequate. Periods greater than 3 H in the stratosphere will require a horizontal resolution greater than 5 km. It is difficult to obtain an upper limit on the required horizontal spacing since it will depend on the periods of wave motion that one wishes to determine.

The vertical resolution needed is also dependent on the periods of interest. Two km resolution over several heights has been adequate to resolve vertical wavelengths greater than 10 km (CARTER and BALSLEY, 1982). However, oscillations near the Brunt-Vaisala frequency appear to be coherent over 1-2 height ranges. This has been seen in the Alpex data which has a vertical resolution of 750 m and the Urbana data which has a vertical resolution of 3 km. These oscillations do not appear to be propagating waves.

In addition GIBBS and BOWHILL (1983) has shown that within the Urbana 3-km spacing, several smaller scale features of the scatterers exist. He was able to obtain finer vertical resolution by using a parbolic fit of the amplitude of the Doppler frequency. Thus it is possible to use signal processing techniques to enhance the vertical resolution.

In summary, the MST radar has the temporal resolution required to determine gravity-wave oscillations. Of course the amount of temporal averaging that is required to obtain a significant measurement of the wind will vary depending on the signal-to-noise ratio. However, 4-minute averaged data have been routinely available at Poker Flat, which is probably sufficient for gravity wave motions. With the radar operating at full power, one minute data are available. The required vertical and horizontal resolution will depend on which particular part of the gravity-wave spectrum one wishes to analyze. It appears that 5-km horizontal spacing is adequate to resolve the horizontal structure of 3 H - 1 H oscillations.

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