1.4A METEOROLOGICAL AND DYNAMICAL REQUIREMENTS FOR MST RADAR NETWORKS: WAVES

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Studies of wave motions using the MST radar have concentrated on single station time series analyses of gravity waves and tides (for examples see CARTER and BALSLEY, 1982; BALSLEY and CARTER, 1982; ROTTGER, 1980). Since these radars can collect high time resolution data they have the potential to become a significant tool for mesoscale research. In addition, these radars can be operated almost continuously unattended and, consequently, data sets are available for analyzing longer period wave motions such as tides and planetary scale waves. Although we still have much to learn from single station data, the possibilities of new knowledge from a network of radars is exciting.

The scales of wave motions in the atmosphere cover a broad range (see GELLER, 1979 for a review). Consequently the choice of a radar network will depend to a large extent on the types of wave motions that are to be studied. There are many outstanding research problems that would benefit from observations from a MST radar network. In particular, there is a strong need for measurements of gravity wave parameters and equatorial wave motions. Some of the current problems in wave dynamics are discussed below.

Studies of large scale waves have been accomplished through balloon soundings as well as satellite data on a global scale. Supplementary data have been provided by ground-based experiments from single stations and rocket experiments. These techniques have been useful in studying the evolution of stratospheric warmings, the quasi-biennial oscillation, and the semiannual oscillation (HIROTA, 1980; LABITZKE, 1982; HOLTON and TAN, 1982; SMITH 1983). It is important to obtain global coverage when studying large-scale waves. In terms of a radar network this would mean locating two or three stations around a latitude circle at several latitudes. The temporal resolution need only be on the order of hours. Since satellites determine the wind field from a temperature measurement through geostrophy, one of the main contributions that can be made by MST radars is an independent estimate of the winds for these large-scale waves.

Measurements of tidal oscillations also require global observations. Several cooperative observational campaigns have been made amongst meteor radar, partial reflection, and MST radars. From these cooperative observation programs as well as single station data, it has been seen that discrepancies still exist between the latest theories (FORBES, 1982 a,b) and observations in the mesosphere. Most of the tidal information we have is from the upper mesosphere and stratosphere. Tropospheric tides have small amplitudes and therefore require accurate measurements and long data sets to isolate the tidal harmonics. Since the MST radar can operate unattended for long periods, it could provide valuable information about tropospheric tides. Traditionally both theory and observations have dealt with the migrating tides (functions of local time) although recently there has been some theoretical studies of nonmigrating diurnal tides (functions of longitude and local time) by KATO et al. (1982). Kato considered diurnal tides forced by localized heat sources near the equator. These sources generated tidal perturbations having short vertical wavelengths (10 km) in addition to the longer wavelengths associated with classical tides. This may have important implications for observations of tides over a limited height region. The phase variation with height may only determine the smaller wave-length and obscure the longer one. The relative importance of the migrating and and nonmigrating tides needs exploring.

Day-to-day variations in tides have been observed and are not well understood. According to KATO et al. (1982), the amplitudes and phases of the non-migrating tides vary with time. This may explain some of the variability. Another mechanism to explain tidal variability has been suggested by WALTERSCHEID (1981). In this mechanism, the tidal variability is produced by the interaction of long-period gravity waves with the globally forced tide. To verify this mechanism, simultaneous observations of the tidal structure and gravity wave horizontal and vertical phase speeds are needed. In fact, a determination of the climatology of gravity waves is probably one of the most important measurements needed. The breaking of upward propagating gravity waves and tides and the subsequent generation of turbulence plays an important role in balancing the momentum budget of the mesosphere (LINDZEN, 1981; HOLTON, 1982; MATSUNO, 1982). The partial-reflection experiment in Adelaide, Australia has been used to determine the vertical flux of horizontal momentum during May 1981 (VINCENT and REID, 1983). Vincent and Reid found a mean upward flux of westward momentum which was equivalent to a -20 m/s/day acceleration. There was also significant variations in the flux on the order of hours. This type of measurement is extremely useful and would be desirable at other locations. Since Vincent and Reid's results suggest that most of the momentum is associated with periods less than one hour, the high temporal resolution of the MST would lend itself nicely to this type of measurement. Ideally a gravity wave climatology would also include measurements of periods, wavelengths, and associated phase velocities. The spatial and temporal requirements for obtaining this climatology is discussed by Avery and Carter, p. 247, this volume.

Another important dynamical region in which an MST radar network would be valuable is the equatorial region. There have been very few measurements of short-period waves in this dynamically active region. Satellite and rocket data have shown a semiannual oscillation in the middle atmosphere (HIROTA, 1980). The interaction between midlatitude Rossby waves and Kelvin waves is believed to be the source for driving the semiannual oscillation in the stratosphere and observations support this theory. Recent theoretical modeling by DUNKERTON (1982) suggests that high frequency gravity waves and Kelvin waves are responsible for the mesospheric semiannual oscillation. The large-scale Kelvin waves can be observed in satellite data but the gravity waves will require much higher time resolution data.

Inertial instabilities in the tropical mesosphere should occur due to cross-equatorial shear resulting from the solstice circulation pattern. This has been studied by DUNKERTON (1981) using a simple model. Dunkerton showed that the solstice diabatic circulation produces a much larger cross-equatorial shear than what has been observed. The magnitude of the instability is determined by the magnitude of the eddy diffusion. One of the main questions is whether this is controlled by high frequency gravity waves or whether the inertial waves are self-stabilizing. An MST radar network would be ideally suited to address this problem.

There has been an increased awareness of the potential of a network of ST radars in the use of operational forecasting. While caution must be exercised in using a research instrument for operational applications (BALSLEY and GAGE, 1982), it appears that a national network would be of great value for the commercial aviation industry in providing instantaneous upper level wind measurements (CARLSON and SUNDARARAMAN, 1982). In addition, mesoscale research would be enhanced by observations from an ST network. The evolution of fronts and associated mesoscale phenomena could be more easily tracked. A network of NOAA's Environmental Research Laboratory Profilers is being planned along the Rocky Mountain front range to be used for this type of research and will probably be a test site for the viability of using ST radars in operational forecasting.

In summary, MST (or ST) radar networks would provide valuable information regarding the wave dynamics of the atmosphere. The high temporal resolution that can be obtained with these radars is essential in order to determine gravity-wave fluctuations. A network is needed to measure the corresponding horizontal wavelengths and phase velocities. Of great scientific interest is the role of the equatorial region in driving circulation patterns. Very few observations are available in the tropics, yet several theories of equatorial instabilities and oscillations have been developed. The MST radar can play a significant role in testing these theories. Finally, operational applications using ST radar networks could also provide information for tropospheric mesoscale research.

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