 D13-47 4 P.

2.1.2 NEED FOR A SUBTROPICAL WIND PROFILING SYSTEM

J. Rottger[1], M. F. Larsen[2], H. M. Ierkic[1], and T. Hagfors[3]

[1]Arecibo Observatory, Arecibo, Puerto Rico
[2]Clemson University, Clemson, South Carolina
[3]NAIC, Ithaca, New York

INTRODUCTION

The purpose of this paper is to point out the need for, and the benefit that can be derived from, a national wind profiling facility located in the subtropics. At present no such facility exists. There are several advantages associated with a low-latitude location. The first is that wave motions and large-scale circulations unique to the tropics can be studied. The second is that the relatively steady mean flows in the subtropical belt may provide a "cleaner" environment for studies of waves common at all latitudes. Examples will be given below. We suggest the Arecibo Observatory as an ideal site for a wind profiling facility since the land and much of the computing, technical, and scientific support is already available.

LARGE-SCALE WAVES

The Arecibo Observatory in Puerto Rico is located at 18°N and has a subtropical climate. Large-scale disturbances affecting the island are typically associated with waves in the easterlies. The ITCZ (Intertropical Convergence Zone) is usually considerably south of Arecibo but does reach that far north on occasion. Hurricanes and tropical storms sometimes track across or very near the island.

An example of the research topics that a wind profiler system at Arecibo could be used to investigate is the observation of quasi-inertial waves. SATO and WOODMAN (1982) obtained radar data in the upper troposphere and lower stratosphere over a period of 48 hours. Their analysis indicated a long period wave in the lower stratosphere with amplitude of several m/s. Further analysis of the same data set by MAEKAWA et al. (1984) has shown that the intrinsic wave period is very near the inertial period, although the earth-fixed period is nearly twice as long. The wave behavior is particularly evident between 14 and 20 km altitude. A graduate student at Cornell (C. R. Cornish) is just finishing his analysis of a 6-day data set obtained in May 1982. Again there were wind perturbations with a period very near the inertial period for the latitude of Arecibo. The preliminary results indicate that the waves are generated near the height of the subtropical jet and propagate upward into the lower stratosphere. The wave is dissipated significantly by the time it reaches an altitude of 20 km due to its short vertical wavelength of the order of 1 km. Amplitudes of 3-5 m/s are significant in the lower stratosphere, and the dissipation of the waves implies that there is a redistribution of energy and momentum so as to decrease the subtropical jet maximum. The wind profiler array, together with radiosonde data from the region, would provide information about the intermittency of the waves, the dependence of wave amplitude on the wind speed maximum or local shear, and the effect of wave dissipation on the flow at higher altitudes.

The observations of CADET and TEITELBAUM (1979) and BARAT (1983) indicate that quasi-inertial waves are strongly affected by the mean flow when the wind speeds increase. The steady easterly flows in the subtropical regions provide a good "laboratory" for studying the interaction of waves and the background medium under conditions that are less complicated than those typically found at midlatitudes.

EFFECTS OF TROPICAL CONVECTION AND LOCAL HEATING

Other topics of interest would include the dynamics of locally generated tides as first observed by WALLACE and HARTRANFT (1969) and WALLACE and TADD (1974). They noted that the tidal motions in the lower stratosphere in the Caribbean were not migrating tides but appeared to be generated by local surface heating. To our knowledge, still very little is known about such an effect. Data could also be provided to support land/sea breeze studies and modeling. Land/sea breezes have been reviewed extensively by ATKINSON (1981) who points out the connection between this type of circulation and the development of local convection.

A great deal was learned about the dynamics of waves in the easterlies in the GATE experiment (NCAR, 1977). However, further observations can still be useful for the purpose of better defining the interaction between large and small scales and for improving our understanding of the effect of the environment on clouds. Also, measurements of vertical velocity fields within developing clouds can be used to improve parameterizations of the effects of clouds on their environment (ANTHES, 1983). Vertical velocity measurements will not be possible once heavy precipitation develops since even the echoes at the relatively long wavelength of 6 m will then be dominated by the precipitation. Cloud studies will be particularly effective if they are carried out with the VHF radar in conjunction with other instrumentation to determine temperature and moisture fields. On a longer time scale, a climatology of the vertical velocity can be developed in order to improve our understanding of the dynamics responsible for the vertical velocity fields in the subtropics.

Dr. Joanne Simpson of GLAS (Goddard Laboratory for Atmospheric Sciences) has indicated (private communication, 1984) that observations of the horizontal winds and vertical velocity fields prior to the development of cumulus over the island would be valuable input to and for comparison with a numerical cloud model that Dr. Simpson has developed at GLAS. Dr. Bruce Albrecht of the Pennsylvania State University has pointed out (private communication, 1984) that our understanding of how convection develops could be improved significantly if the Penn State portable 0.5-cm radar was brought to Puerto Rico for the purpose of observing clouds and the dynamic environment in which they develop in conjunction with the profiler measurements. The wind profiler data could be used to study land/sea breezes and for comparisons with models such as the one developed by Dr. Roger Pielke of Colorado State University.

TURBULENT PROCESSES

Recently, there has been considerable controversy about the underlying dynamics responsible for mesoscale kinetic energy spectra. There appears to be agreement about the spectral slope of the energy spectrum of the horizontal wind (BALSLEY and CARTER, 1982; LARSEN et al., 1982; NASTROM and GAGE, 1983; LILLY and PETERSEN, 1983). A number of observations have shown the slope to follow a $k^{-5/3}$ power law from some undetermined small-wavelength or low-frequency limit out to scales as large as 500-1000 km and periods out to 12 hours. There is little doubt that the motions are not three-dimensional at such large scales, at least not in the sense required for a Kolmogoroff inertial subrange. The competing interpretations argue that the observations indicate either a two-dimensional turbulent process (GAGE, 1979; LILLY, 1983) or that it is a manifestation of a universal spectrum of gravity waves similar to what is observed in the oceans (VANZANDT, 1982).

Analysis by LARSEN et al. (1985) of several of the 3 to 8 hour time series of velocity obtained earlier at Arecibo has shown an instance of a strong spectral peak near the Brunt-Vaisala period during a period of active convection. The spectrum a few hours later shows an enhancement of the energy at lower frequencies. This example is far from conclusive, but it is suggestive of a two-dimensional turbulent process in which energy cascades from smaller to larger scales. More extensive observations during and following periods of convection are needed to determine whether the effect is repeatable. It is possible that the enhancement of low frequency power is associated with an unrelated process. Simultaneous frequency and vertical wave number spectra of the horizontal and vertical velocities would also help to resolve the problem of the interpretation of mesoscale kinetic energy spectra since the predictions of the universal gravity-wave spectrum theory, in particular, could then be tested.

In addition, the VHF array can provide information about the frequency of occurrence and spatial distribution of turbulent layers in the lower stratosphere. The theoretical analysis of WOODMAN and RASTOGI (1984), based on earlier Arecibo 430-MHz observations, has already shown that vertical transport by turbulence is a much more important process than had been thought earlier. The crucial parameters determining the magnitude of the transport are the frequency of occurrence and distribution of widths of the layers, information that the radar can provide. Also, the relationship between the layers and waves in the medium is still an open question, although it appears that the layers occur at certain phases of the long-period, near-inertial waves seen in the lower stratosphere. Dr. P. K. Rastogi of Case Western Reserve University is interested in obtaining more statistics on the intermittency, width, and height of occurrence of turbulent layers in the lower stratosphere in order to refine a model of turbulent transport due to such layers.

VERTICAL MOMENTUM FLUXES

At present there is great interest in upward momentum fluxes due to gravity waves (VINCENT and REID, 1983) since it is believed that gravity waves breaking in the mesosphere account for the momentum sources needed to explain the general circulation of that region (LINDZEN, 1983; LINDZEN and FORBES, 1983). The wind profiling array at Arecibo could be used to study both the momentum fluxes out of the troposphere and their variation with height in the mesosphere. The antenna array will probably not be sensitive enough to detect turbulent scatter from the mesosphere directly, but it should be possible to use it as a meteor radar (S. K. Avery, private communication). Whenever detection of turbulence in the mesosphere is required, the 430-MHz facility may be applied.

METEOR RADAR

In addition to studying the momentum fluxes in the mesosphere, an important research topic, it is also important to obtain a better climatology of the mesospheric circulation above Arecibo. The data could be used to calculate momentum fluxes and accelerations of the mean flow due to gravity waves (S. K. Avery, private communication, 1984) and to study tidal characteristics at those altitudes.

CONCLUSION

The research topics described above are only representative, but they indicate the unique characteristics of the subtropical region as a site for a wind profiling system.

REFERENCES

Anthes, R. A. (1983), Numerical models, in The National STORM Program: Scientific and Technological Bases and Major Objectives, edited by R. A. Anthes, UCAR, Boulder, Colorado.

Atkinson, B. W. (1981), Meso-scale Atmospheric Circulations, Academic Press, New York, 495 pp.

Balsley, B. B., and D. A. Carter (1982), The spectrum of atmospheric velocity fluctuations at 8 km and 86 km, Geophys. Res. Lett., 9, 465-468.

Barat, J. (1983), The fine structure of the stratospheric flow revealed by differential sounding, J. Atmos. Sci., 40, 2451-2466.

Cadet, D., and H. Teitelbaum (1979), Observational evidence of internal inertia-gravity waves in the tropical stratosphere, J. Atmos. Sci., 36, 892-907.

Gage, K. S. (1979), Evidence for a $k^{-5/3}$ law inertial range in mesoscale turbulence, J. Atmos. Sci. 36, 1950-1954.

Larsen, M. F., M. C. Kelley, and K. S. Gage (1982), Turbulence spectra in the upper troposphere and lower stratosphere at periods between 2 hours and 40 days, J. Atmos. Sci., 39, 1035-1041.

Larsen, M. F., R. F. Woodman, T. Sato, and M. K. Davis (1985), Power spectra of vertical velocities in the troposphere and lower stratosphere observed at Arecibo, Puerto Rico, submitted to J. Atmos. Sci..

Lilly, D. K. (1983), Stratified turbulence and the mesoscale variability of the atmosphere, J. Atmos. Sci., 40, 749-761.

Lilly, D. K., and E. L. Petersen (1983), Aircraft measurements of atmospheric kinetic energy spectra, Tellus, 35A, 379-382.

Lindzen, R. S. (1983), Turbulence and stress owing to gravity wave and tidal breakdown, J. Geophys. Res., 86, 9707-9714.

Lindzen, R. S., and J. Forbes (1983), Turbulence originating from convectively stable internal waves, J. Geophys. Res., 88, 6549-6553.

Maekawa, Y., S. Fukao, T. Sato, S. Kato, and R. F. Woodman (1984), Internal inertia-gravity waves in the tropical lower stratosphere observed by the Arecibo radar, submitted to J. Atmos. Sci..

Nastrom, G. D., and K. S. Gage (1983), A first look at wavenumber spectra from GASP data, Tellus, 35A, 383-388.

NCAR (1977), Report of the U. S. Gate Central Program Workshop, 25 July-12 August, NCAR, Boulder, Colorado.

Sato, T., and R. F. Woodman (1982), Fine altitude resolution radar observations of upper tropospheric and lower stratospheric winds and waves, J. Atmos. Sci., 39, 2539-2545.

VanZandt, T. E. (1982), A universal spectrum of buoyancy waves in the atmosphere, Geophys. Res. Lett., 9, 575-578.

Vincent, R. A., and I. M. Reid (1983), HF Doppler measurements of mesospheric gravity wave momentum fluxes, J. Atmos. Sci., 40, 1321-1333.

Wallace, J. M., and F. R. Hartranft (1969), Diurnal variations, surface to 30 kilometers, Mon. Wea. Rev., 97, 446-455.

Wallace, J. M., and R. F. Tadd (1974), Some further results concerning the vertical structure of atmospheric tidal motions within the lowest 30 kilometers, Mon. Wea. Rev., 102, 795-803.

Woodman, R. F., and P. K. Rastogi (1984), Evaluation of effective eddy diffusive coefficients using radar observations of turbulence in the stratosphere, Geophys. Res. Lett., 11, 243-246.