Investigating Mountain Waves in MTM Image Data at Cerro Pachon, Chile

Neal R. Criddle  
*Utah State University*

Michael J. Taylor  
*Utah State University*

P. D. Pautet  
*Utah State University*

Y. Zhao  
*Utah State University*

G. Swenson  
*University of Illinois at Urbana-Champaign*

S. Franke  
*University of Illinois at Urbana-Champaign*

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Authors
Neal R. Criddle, Michael J. Taylor, P. D. Pautet, Y. Zhao, G. Swenson, S. Franke, and A. Liu

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Gravity waves are important drivers of chemical species mixing, energy and momentum transfer into the ML (30 ~ 100 km region). As part of a collaborative program involving institutions from several states, Utah State University has operated a Mesospheric Temperature Mapper (MTM) at the new Andes-Lidar Observatory (ALO) on Cerro Pachon (39.2°S, 70.7°W) Since August 2009. A primary goal of this program is to quantify the impact of mountain waves on the ML region. The Andes region is an excellent natural laboratory for investigating large-scale gravity influences on the ML region, especially the study of mountain waves, created by strong winds blowing in from the Pacific Ocean. Large amplitude mountain waves have been measured in the stratosphere on many occasions, however, their penetration into the mesosphere has only recently been recorded (Smith et al., 2009), as shown in the all sky OH image to the left.

In this study we have used MTM image data in coordination with all sky imager, meteor wind radar and other wind measurements to investigate the properties of several mountain wave events observed over Cerro Pachon.

Results

Phase Velocities
Figure 6 is a histogram of horizontal phase speed for small-scale gravity wave events measured by the MTM over a one year period (Aug. 2009 – 2010). The plot is characterized by a strong peak with horizontal phase speeds between 20 m/s and 50 m/s which is typical of short-period wave measurements from other sites. However, at Cerro Pachon, we also see a small cluster of low phase speeds corresponding to mountain wave events.

Mountain Wave Motions
Figure 7 superimposes zonal phase velocities as a function of time for several identified mountain wave events. These events appeared more frequently during the hours 22:00 ~ 1:00 UT. The average of all velocities is 0.47 m/s westward.

Wind Profiles
Figure 4 shows how mountain waves are formed by strong winds flowing over a prominent ridge. These waves are characterized by near zero phase speeds (stationary) and align parallel to the mountain range that forms them. Once formed, mountain waves can propagate upwards until they are filtered out.

Figure 5 models zonal wind speeds as a function of altitude for mountain wave events in 1982. When the wind component parallel to the wave vector is equal to the observed phase speed of the wave, the frequency of the wave is Doppler shifted to zero and the wave dissipates at that altitude (Taylor et al., 1998). The models predict that for winter months, winds allow for the propagation of mountain waves into the ML region. This is because we treat mountain waves as stationary with respect to the ground and locally North-South oriented, so they would not propagate upward through layers with zonal horizontal wind speed.

Mesoatheric Temperature Mapper (USU)
The MTM is a sensitive CCD imager used to image two mesospheric airflow emissions over ALO. Sequential measurements of the OH (787 km) and the O (94 km) emissions are taken every 6 minutes. These data are used to investigate mesospheric temperatures and gravity wave structures.

Scanning Radar (JHU)
Scanning radar measurements are taken twice daily at 08:00 and 20:00 from Santo Domingo (33.67°N, 71.76°W), ~400 km to the south. Measurements of horizontal winds are made at frequent, but arbitrary altitudes up to ~72 km. Data are made available online by the University of Wyoming.

Summary

Low velocity waves over the Andes have been observed in the ML region in MTM and all sky image data during June and July 2010. Models suggest that during these winter months the background wind field allows mountain waves to reach altitudes of 80 ~ 100 km. Analysis of the MTM data show signatures characteristic of mountain waves with near zero average phase speeds and wave front orientations aligned with the Andes range. Data from other sources shows that wind fields needed to generate mountain waves peak in intensity during the winter months, and that on nights when waves were observed in the all sky emissions the corresponding lower altitude winds had large eastward velocities permitting propagation into the mesopause region.

Future work: Identify and study more stationary events using the full ALO instrument suite (and other available data) to quantify mountain wave propagation and dissipation effects in the MLT.