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

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Investigating Mountain Waves in MTM image data at Cerro Pachon, Chile

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Introduction

Gravity waves are important drivers of chemical species mixing, energy and momentum transfer into the MLT [~80 – 100 km] region. As part of a collaborative program involving instruments from several institutions Utah State University has operated a Mesospheric Temperature Mapper (MTM) at the new Andes-Lidar Observatory (ALO) on Cerro Pachon (30.2°S, 70.7°W) since August 2009. A primary goal of this program is to quantify the impact of mountain waves on the MLT region. The Andes region is an excellent natural laboratory for investigating the gravity wave influences on the MLT 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 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.

Mountain Waves

Figure 4 shows how mountain waves are formed by strong winds blowing 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 the middle and lower stratosphere over Cerro Pachon (5200 ft). 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 onward winds allow for the propagation of mountain waves into the MLT 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 zero zonal horizontal wind speed.

Winds

Figure 9 plots ridge-top winds from the SOAR observatory at Cerro Pachon for 2010. These strong mountain winds blowing in from the Pacific Ocean are responsible for the generation of mountain waves. The red envelope plots maximum wind magnitude and direction for the winter months when mountain waves can penetrate into the MLT region. Wind speeds up to 30 m/s (~70 mph) were recorded during June and July.

Propagation

Figure 10 shows radiosonde winds profile taken at 12 hour intervals (June 8, 2010 to July 2, 2010) indicating strong upward zonal winds (maximum ~80 m/s at ~12 km altitude) on the nights when mountain waves were observed. The red dots show wind profiles when stationary waves were observed in the OH emission and blue dots when they were detected in both OH and O emissions. When mountain waves were observed on sequential nights radiosonde profiles showed strong westward flow. These conditions favor the propagation of mountain waves into the mesopause region.

Results

Phase Velocities

Figure 6 is a histogram of zonal, horizontal phase velocity 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 an additional 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 velocity is 0.47 m/s westward.

Winds

Figure 11 shows ceilometer data showing zonal wind contour maps during extended periods (4 nights) in June and July 2010 when mountain waves were detected in the image data. Red and blue boxes at nominal OH and O₃ altitudes mark the occurrence of mountain waves as seen in the MTM and all sky data, respectively. Contour plots indicate that mountain waves in the OH airglow layer occurred mainly during times with Eastward (positive) winds. The consistency of winds at and directly below the OH layer suggests that zero wind contour does in fact act as a switch, ‘turning off’ mountain waves. The appearance of stationary waves in the O₃ layer always occurred in conjunction with mountain waves appearing in the OH layer, however at O₃ altitudes the winds appeared to be westward.

Summary

Low velocity waves over the Andes have been observed in the MTM 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 airglow emissions the corresponding lower altitude winds had large eastward velocities permitting propagation into the mesopause region.

Mountain radar data show that at MLT altitudes background winds act to filter out mountain waves, and that mountain wave effects can be seen at altitudes above where the waves are expected to propagate.

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.

References