First Year Investigation of Gravity Waves and Temperature Variability over the Andes

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Overview

- Instrumentation
- USU Mesospheric Temperature Mapper
- Andes Lidar Observatory, Cerro Pachon, Chile
- Example OH Intensity and Temperature Data
- Seasonal Result
- Seasonal Comparisons
- Summary
Multi-Instrument Measurements of the MLT Region

University of Illinois
- Na Lidar: for winds and temperature in the Mesosphere and Lower Thermosphere (MLT) region (80-100 km)
- All Sky Imager: for MLT gravity wave structure
- Multi Channel Photometer: Long-period Gravity Waves in different emissions
- Meteor Wind Radar: background wind measurements in MLT region

The Aerospace Corporation
- Aerospace Infrared Camera: small scale waves and wave breaking

Utah State University
- Mesospheric Temperature Mapper: Intensity and temperature maps of gravity waves and mesospheric temperature variability in OH and O2 emissions.


Andes Program (2009-to date): Same instrument suite employed to investigate mesospheric dynamics over Andes Mountains and effects of orography.
Mesospheric Temperature Mapper

- Sensitive bare CCD Imager developed to measure mesospheric temperature variability using airglow emissions.

- Field of view ~90°, (180 x 180 km at 90 km altitude).

- Sequential observations (60 sec. exposure) of:
  - NIR OH (6, 2) Band ~ 87 km
  - O₂(0,1) A Band ~ 94 km
  - Background (~857.5 nm)

- Cycle time: ~ 3 min per OH/O₂ temperature determination. (Precision~2K)
Example of MTM Measurements

- From Maui-MALT Program

Nocturnal Temp Variability

Gravity Wave Images

Seasonal Temperature Measurements
Andes LIDAR Observatory (ALO)

- 30.2°S, 70.7°W
- Cerro Pachon Telescopes
- Camera installed August 2009
- 14 months of data to date
- Data analysis focusing on OH temperatures and waves detection
Example OH and O$_2$ Zenith Data

ALO, Chile

UT Day 263 2009  (LT Sep 19 - 20 $\delta$t = -4 hrs)

- P12A
- 866A
- BG
- ActDark
- P14A
- 868A

Intensity (counts)

UT Time
Example OH Analysis

ALO, Chile
UT Day 263 2009  (LT Sep 19 - 20 $\delta$t = -3 hrs)

Band Intensity (counts)

UT Time (hr)

OH Band Int $\bar{v} = 96719.16 \pm 970.93$
Std.dev. = 9413.56

OH Temp Stab $\bar{v} = 195.5 \pm 0.54$
Std.dev. = 5.2

ALO, Chile
UT Day 263 2009  (LT Sep 19 - 20 $\delta$t = -4 hrs)

Temperature (K)

UT Time (hr)
Example of Short-period Wave Measurements

OH Temperature and Band intensity in phase

Period ~50 min
Example of Large Amplitude OH Temperature Perturbation

Jan 12-13, 2010

\[ \Delta T \sim 40 \text{K (peak to trough)} \]

Phase shift: Temperature leading intensity by \(~2\text{hrs}\)
Seasonal OH Temperature and Intensity Results

OH Rotational Temperature

255 Nights of data

OH Intensity
TIMED-SABER Comparisons

Average difference between SABER and ALO < 1K

Cerro Pachon, Chile, Sep.25, 2009

Satellite Passover
Seasonal Comparison with El Leoncito

OH (6,2) Band at ~87 km.

Site separation ~220 km

Courtesy J. Sheer
Seasonal Comparison of Maui-MALT and Cerro Pachon

Maui MALT 2003
Mean = 200.4 ± 6.9 K

Cerro Pachon 2009-2010
Mean = 202.9 ± 9.4 K

More variability

Spring
Autumn
Summer
Investigating AO and SAO Signatures
Maui-MALT (2202-2004)

\[ fit = A + B \cos\left(\frac{2\pi x}{182} + \phi_1\right) \]
\[ + C \cos\left(\frac{2\pi x}{365} + \phi_2\right) \]

Mean: 196.7 K
SAO: 3.6 K  AO: 3.3 K

Zhao et al., JASTP, 2007
Seasonal Variability at Cerro Pachon

- August 2009 to August 2010

Mean: 204.0 K  
SAO: 3.6 K  
AO: 6.9 K  
QAO: 5.3 K?

Period = 85 ± 2 days
Amplitude: 3.6 ± 0.3 K

Mean: 204.0 K  
SAO: 3.6 K  
AO: 6.9 K  
QAO: 5.3 K?
Early Results

- AO signature (6.9 K), ~2 times amplitude of Maui
- SAO similar signature (3.6K) at both sites
- Persistent ~85-day oscillation in T and I (Amplitude 5.3 K) (QAO?) (similar variability observed at El Leoncito, Argentina, 220 km away)
- Coordinated analysis on prominent events continuing
Summary

• 255 Nights of OH temperature data acquired to date exhibit unexpected short-term oscillations that persist during the seasons.

• Similar variability appears to be present in OH spectrometer data from El Leoncito, Argentina.

• Nocturnal variations are highly variable and at times can exhibit large amplitudes, exceeding 40 K during the course of a night observations. Other nights show evidence for large amplitude gravity waves in intensity and temperature data with periods of ~1-2 hours.

• MTM image data also reveal a wealth of short-period (< 1 hour) gravity waves as well as an abundance of ripple instability structures indicating that the mesosphere over the Andes mountain region is very dynamic.
Future Work

- Compare MTM data with Na Lidar temperature measurements and El Leoncito, Argentina.
- Compare with SABER temperatures from the TIMED satellite as we conducted during the Maui-MALT program.
- Comparative study of OH and O2 temperature data to investigate phase relationships of wave events and to study wave growth and/or dissipation.
- Ongoing seasonal measurements will be used to build a clearer understanding of the temperature variability and its intra-annual variability.
- Mountain Waves
Thank You

- Mike Taylor
- Utah State University
- PASI/NSF

QUESTIONS??