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Satellite and Ground-Based Measurements of Mesospheric Temperature Variability Over Cerro Pachon, Chile (30.3° S)

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The Andes region is an excellent natural laboratory for investigating gravity wave influences on the upper mesosphere and lower thermosphere (MLT) dynamics. The instrument suite that comprised the very successful MALT-M program was relocated to the new Andes Lidar Observatory (ALO) located high in the Andes mountains (2,520 m) near the Cerro Pachon astronomical telescopes, Chile (30.3°S, 70.7°W). As part of this instrument set the Utah State University (USU) CEDAR Mesospheric Temperature Mapper (MTM) has operated continuously since August 2009 measuring the near infrared OH (6,2) band and temperature perturbations to obtain in-depth seasonal measurements of MLT dynamics over the Andes. This poster presents results of an ongoing analysis of nightly OH (6,2) band intensity and rotational temperatures and their seasonal variability (40 months of data to date). These are compared with SABER temperature measurements as well as results from the Maui-MALT program, Maui, HI (19.5°N, 155.6°W).

**Introduction**

The Andes region is an excellent natural laboratory for investigating gravity wave influences on the upper mesosphere and lower thermosphere (MLT) dynamics. The instrument suite that comprised the very successful MALT-M program was relocated to the new Andes Lidar Observatory (ALO) located high in the Andes mountains (2,520 m) near the Cerro Pachon astronomical telescopes, Chile (30.3°S, 70.7°W). As part of this instrument set the Utah State University (USU) CEDAR Mesospheric Temperature Mapper (MTM) has operated continuously since August 2009 measuring the near infrared OH (6,2) band and temperature perturbations to obtain in-depth seasonal measurements of MLT dynamics over the Andes.

This poster presents results of an ongoing analysis of nightly OH (6,2) band intensity and rotational temperatures and their seasonal variability (40 months of data to date). These are compared with SABER temperature measurements as well as results from the Maui-MALT program, Maui, HI (19.5°N, 155.6°W).

**Instrumentation**

The USU CEDAR MTM is a high performance CCD imaging system designed to provide accurate measurements of mesospheric temperature variability and velocities. It is a small, multi-channel radiometer using infrared observations of the OH (6,2) band airglow emissions at a nominal altitude of ~87 km.

- **Field of view:** ~90° (180 x 180 km)
- **Spectral coverage:** (750-850 nm)
- **Spatial resolution:** 6.4 km
- **Temporal resolution:** ~1 minute
- **Temperature precision:** ~2 K

The NASA SABER instrument onboard the TIMED spacecraft (launched December 2001) is a multi-channel radiometer used to globally measure infrared emissions from the MLT layers. SABER uses 10 channels to measure emissions from eight atmospheric gas species. The sensor observes the emission bands at a tangent point on the horizon using a motion-compensated scanning mirror. These time scans provide vertical profile measurements of temperature of the atmosphere between 15-180 km in altitude. SABER has a horizontal field of view ~400x300 km at the Earth tangent height and a vertical temperature resolution of ~2 K. Temperature measurements are derived from CO_2 channel radiances in the stratosphere and mesosphere (Remsberg, et al., 2008). SABER takes a scan approximately every ~60 seconds, providing ~1500 scans a day. In this study, the latest SABER version 2.0 temperatures are used.

**OH Temperature Analysis**

The MTM takes sequential 30 second exposures using narrow-band (~1.2 nm) filters centered on the P(2) and P(4) lines for the OH (6,2) band. In addition, a background measurement and a dark image are also recorded resulting in a cadence time of ~2 minutes. Data are recorded nightly except during the full moon period (~2.5 nights/month). To date we have obtained nearly 4 years of observations, comprising ~750 nights of high quality data.

The data are analyzed using software developed at USU to determine the band intensity and rotational temperatures variability during each night. OH rotational temperatures are computed using the well-established “ratio method” (Mewaldt, et al., 1984). Comparisons of the MTM OH temperatures with those established “ratio method” (Meriwether, et al. 1984). Comparisons of the MTM OH temperatures with those obtained by other well-calibrated instruments (Na temperature lidars, SABER instrument aboard TIMED satellite, and FTIR spectrometers) indicate that our absolute temperatures referenced to the 87 km lidar temperatures are accurate to ±5 K (Peterson et al., 2000).

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**SABER Measurements**

As TIMED-orbit SABER makes temperature profile measurements within a 10° x 10° field of view (see map to left) centered on ALO (red dot) from August 2009 to September 2013 are plotted below (~1000 measurements). The temperature profile is height weighted with a Gaussian profile (FWHM ~9 km) at the nominal peak OH emission layer of 87 km. Each of the SABER temperature measurements is compared to the closest in time MTM temperature measurement (averaged over ~10 min) of the seasonal temperatures ranging from ~150-230 K and the plots show good agreement throughout this period. However, the mean temperature measurements from SABER are consistently lower than those measured at ALO (and Maui) as shown in the table below.

<table>
<thead>
<tr>
<th>Day</th>
<th>MTM</th>
<th>ALO</th>
<th>SABER</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1</td>
<td>197.3 K</td>
<td>202.2 K</td>
<td>191.7 K</td>
<td>6.5 K</td>
</tr>
<tr>
<td>July 1</td>
<td>197.0 K</td>
<td>202.2 K</td>
<td>191.7 K</td>
<td>6.5 K</td>
</tr>
<tr>
<td>Sept 1</td>
<td>197.3 K</td>
<td>202.2 K</td>
<td>191.7 K</td>
<td>6.5 K</td>
</tr>
<tr>
<td>Nov 1</td>
<td>197.0 K</td>
<td>202.2 K</td>
<td>191.7 K</td>
<td>6.5 K</td>
</tr>
</tbody>
</table>

**Example Nocturnal Variability**

The above figures show data obtained UT day 258, 2012 illustrating the quality of the temperature measurements and the typical variability observed at ALO. Plot (a) shows the raw intensity data for the OH measurements (red and magenta) during the course of the night. The black line shows the background sky emission while the black line shows the camera dark current. Plot (b) shows the derived zenith (5x5 km field of view) OH (6,2) rotational temperature (blue) and two superimposed coincident SABER overpass temperature measurements (green stars) at 6:30 UT. The horizontal line represents the mean nocturnal temperature of 188.8 ± 7.1 K displaying the geophysical variability.

**Comparing Seasonal Variability at Maui and ALO**

MTM nightly averaged OH temperature measurements from August 12, 2009 until June 5, 2013. Days are counted from January 1, 2009, where years are separated by black vertical lines. The blue circles are the nocturnal mean temperature and the error bars represent the standard deviation in temperature each night. A 15 day running average (red line) and the mean temperature of 198 K (black) are shown.

ALO MTM nightly mean OH temperature (blue) folded into one year. As above, the error bars represent the night-to-night standard deviation and the red line is a 15 day running average. Similar data is shown from three folded years of data from the MAULT campaign (teal).

**Summary and Future Work**

Nocturnal temperature variations at ALO are highly variable and at times can exhibit large amplitudes, exceeding 20 K. Many nights show evidence for smaller amplitude (several K) gravity waves with well-defined periods ranging from tens of minutes to a few hours. SABER temperature comparisons demonstrate the long-term stability of ongoing MTM observations at ALO. The comparison with Maui data show a consistent ~5 K offset (SABER cooler) at both sites, and a larger spread in temperatures at ALO. This may be due to enhanced wave activity over the Andes (as suggested by gravity wave variance measurements, currently under investigation).

Harmonic analysis applied to the 40 months OH intensity and temperature data shows clear signature of an annual (AO) and semi-annual (SAO) oscillations, with similar amplitude to those observed at Maui. However, the ALO data reveal an unexpected 90 day oscillation. This result is under further investigation.

**Ongoing future work: Comparison of MTM data with OH spectrometer temperature data from nearby (200 km) El Leoncito, Argentina (courtesy J. Sheer) extending our study with SABER.**

For the first two years of operation at ALO the MTM also measured O_3 temperatures. Phase differences between the O_3 and OH temperatures were used to determine net emissions are being measured to investigate gravity wave growth and dissipation over the Andes Mountains. Study of regional differences in gravity wave forcing in the MLT region using MTM data from a mid-latitude oceanic site and high-latitude sites in Antarctica.