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

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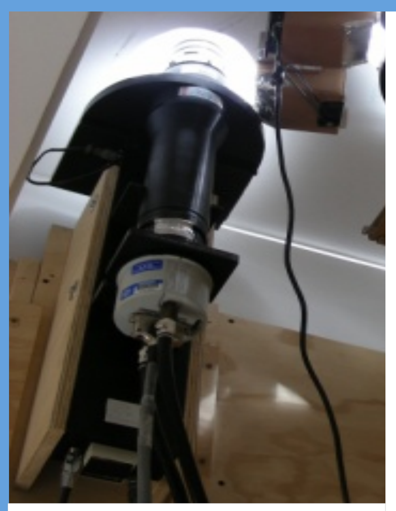
Introduction

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 Maui-MALT 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.

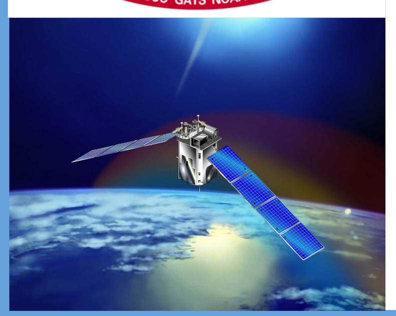
This poster presents results of an ongoing analysis of nightly OH (6,2) band intensity and rotational temperatures and their seasonal variability (40 months of data to date). These are compared with SABER temperature measurements as well as results from the Maui-MALT program, Maui, HI (19.5° N, 155.6°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

Instrumentation



The USU CEDAR MTM is a high performance CCD imaging system designed to provide accurate measurements of mesospheric temperature variability and gravity wave intensity and rotational temperature perturbations using observations of the OH (6,2) band airglow emissions at a nominal altitude of ~87 km.

- Field of view: ~90° (180 x 180 km)
- Sequential observations (30 sec. exp.) of:
  - NIR OH (6, 2) Band ~87 km
  - Background (~857.5 nm)
- Cycle time: ~2 min per OH emission
- Temperature precision: ~2 K

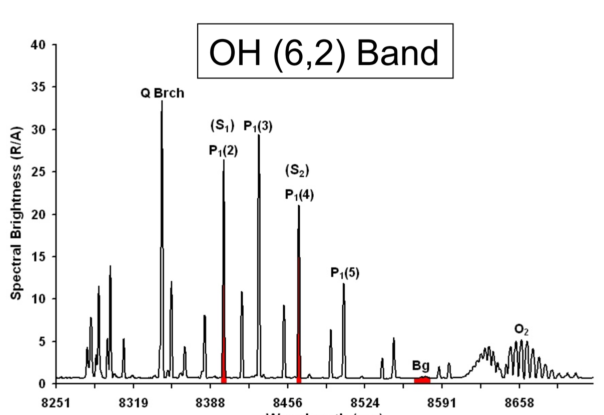


The NASA SABER instrument onboard the TIMED spacecraft (launched December 2001) is a multichannel radiometer used to globally measure infrared emissions from the MLT regions. SABER uses 10 channels to measure emissions from eight atmospheric gas species. The sensor observes the emission bands at a tangent point on the horizon using a motion-controlled scanning mirror. These limb scans provide vertical profile measurements of temperature of the atmosphere between 10-180 km in altitude. SABER has a horizontal field of view ~40x300 km at the OH tangent height and a vertical temperature resolution of ~2 km. 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 $P_1(2)$, and $P_1(4)$ 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 (~25 nights/month). To date we have obtained nearly 4 years of observations, comprising ~750 nights of high quality data.

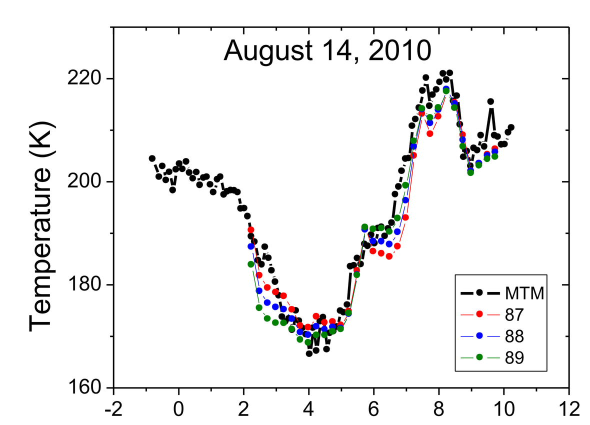
The data are analyzed using software developed at USU to determine the band intensity and rotational temperatures variability during each night. OH rotational temperatures are computed using the well-established "ratio method" [Meriwether, et al. 1984]. Comparisons of the MTM OH temperatures with those 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 [Pendleton et al., 2000].



Keck data, courtesy T. Slanger, SRI

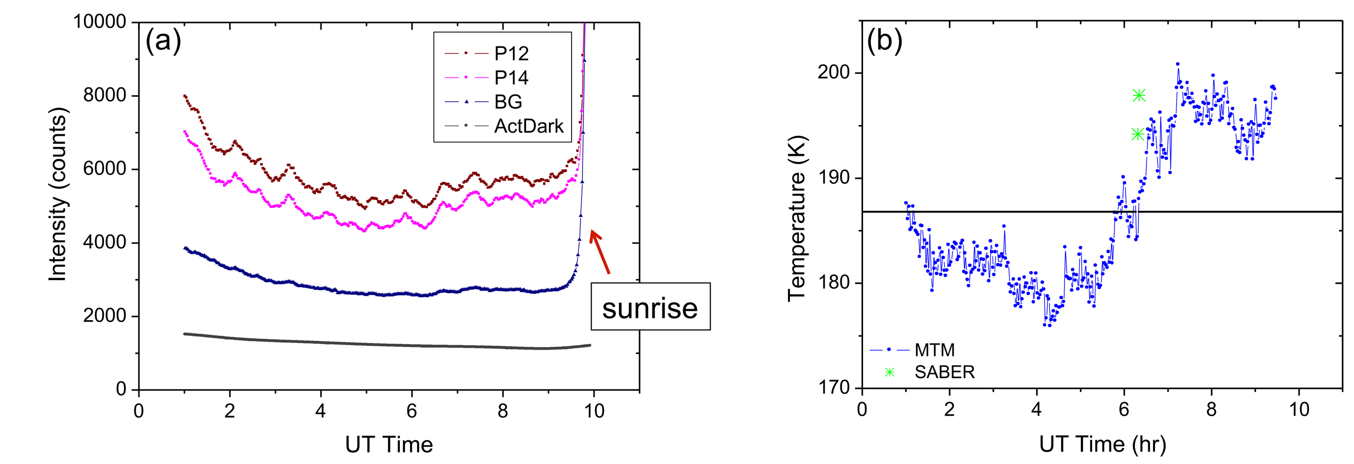
$$T_{OH} = \frac{228.45\,K}{\ln[(2.600)(S_{1c}/S_{2c})]}$$

•OH transition parameters from Goldman et al., 1998.
•Relative band intensity from ($S_{1c}+S_{2c}$) and T using simplified LTE calculation.



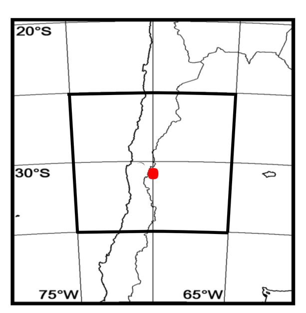
Graph comparing Gaussian height weighted (~8 km) MTM OH temperature measurements with coincident University of Illinois Na wind-temperature lidar observations from ALO. Note high quality of the agreement using these two different techniques. [Courtesy G Swenson, A. Liu, and Y. Zhao]

Example Nocturnal Variability

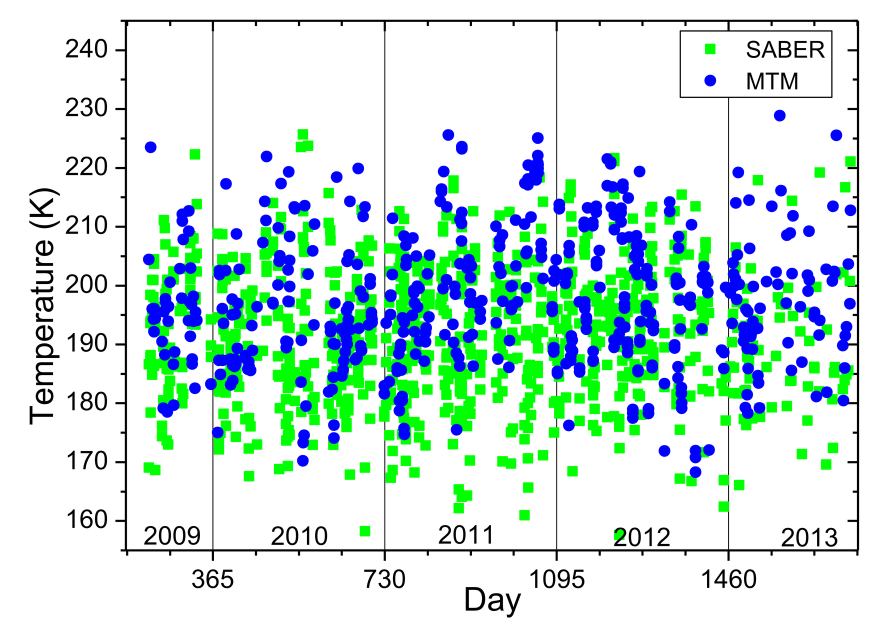


The above figures show data obtained UT day 258, 2012 illustrating the quality of the temperature measurements and the typical variability observed at ALO. Plot (a) shows the raw intensity data for the OH measurements (red and magenta) during the course of the night. Note the clear wave activity. The dark blue curve shows the background sky emissions 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 186.8 ± 7.1 K displaying the geophysical variability.

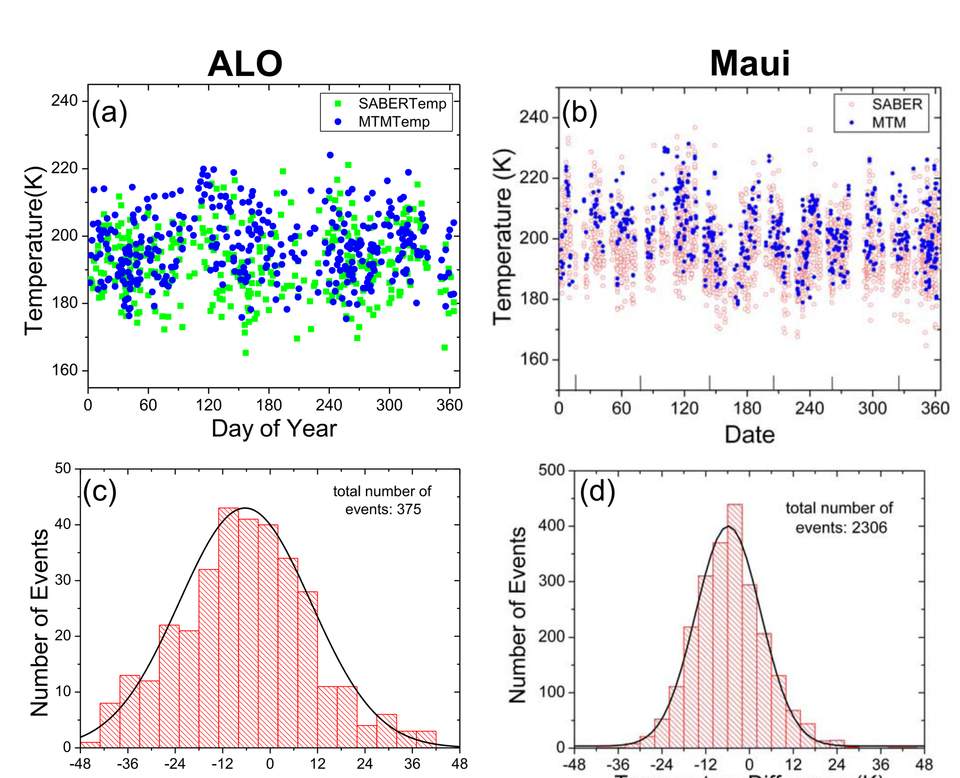
SABER Measurements



As TIMED orbits earth SABER makes temperature profile measurements. All coincidence measurements within a 10°x10° 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 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). The seasonal temperatures ranged from ~160-230 K and the plot shows 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.



	ALO	Maui
MTM	197.3 K	202.2 K
SABER	191.7 K	197.0 K
Difference	5.6 ± 0.6 K	5.2 ± 0.2 K
σ	16.9 K	8.9 K



Time series plots for only the closest overpass SABER Temperatures (green) and the MTM OH Temperatures (blue) (a) for 2009-2013 at ALO are compared with overpass data for 2003 at Maui (b) showing SABER (red circles) and MTM (blue) temperatures (Note: Maui comparison used a 10°x20° box). The histogram plots (c) and (d) with fitted Gaussian curves show the distribution of the differences in the MTM and SABER measurements. Both indicate SABER temperatures are ~5 K lower than MTM temperatures.

References

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Meriwether, J.W., 1984. Ground based measurements of mesospheric temperatures by optical means. MAP Handbook 13, 1-18.
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Remsberg, E. E., et al. (2008), Assessment of the quality of the Version 1.07 temperature-versus-pressure profiles of the middle atmosphere from TIMED/ SABER, J. Geophys. Res., 113, D17101
Zhao, Y., Taylor, M.J., Liu, H.-L., Roble, R.G., 2007. Seasonal oscillations in mesospheric temperatures at low-latitudes. JASTP 69, 2367-2378.

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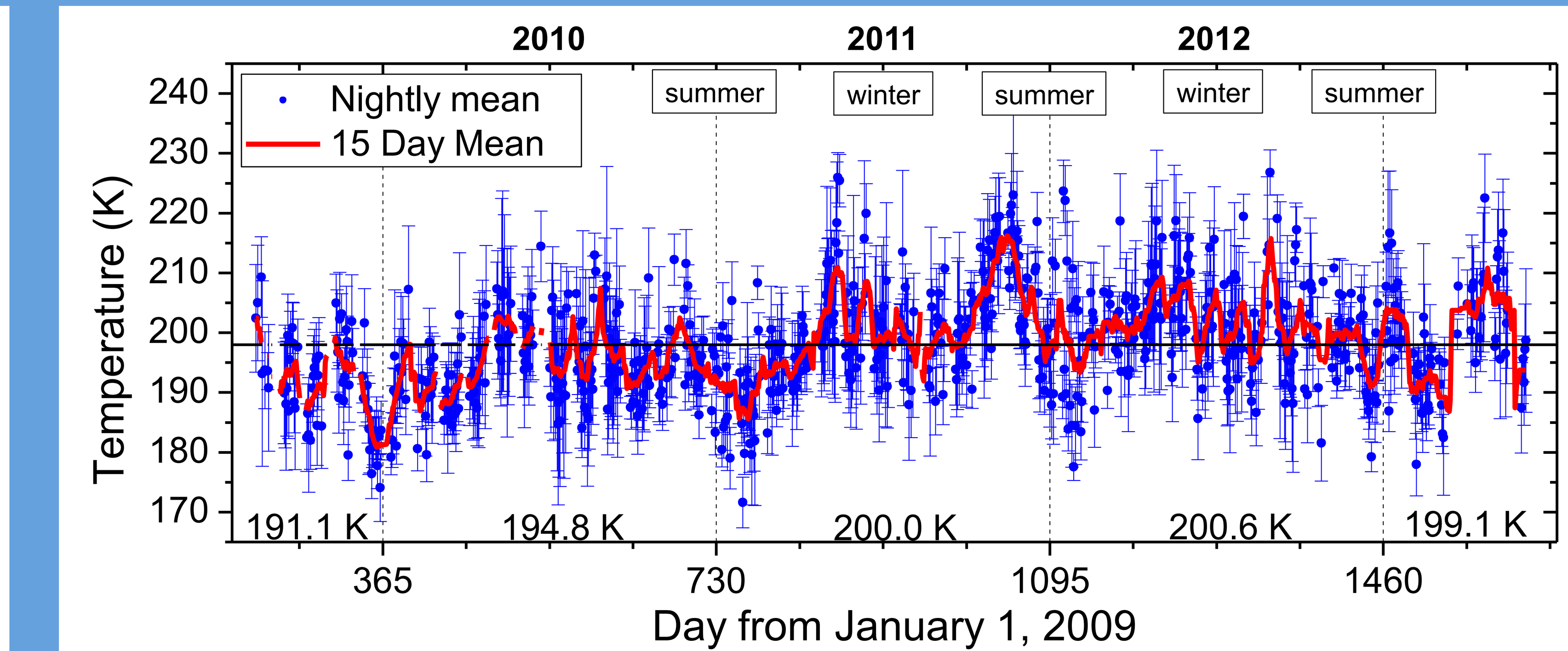
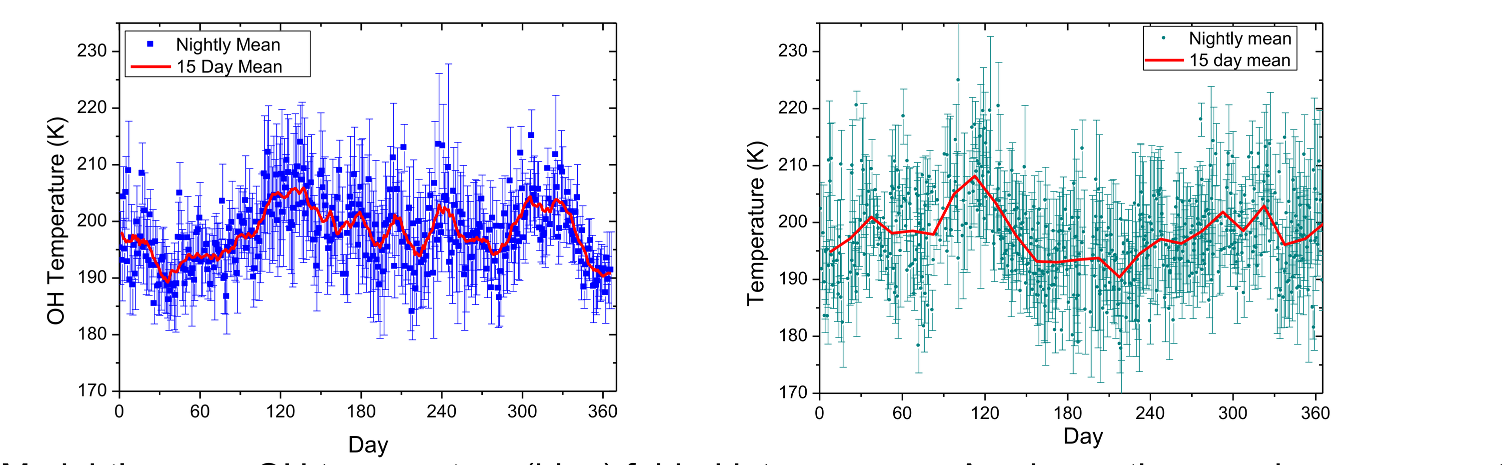
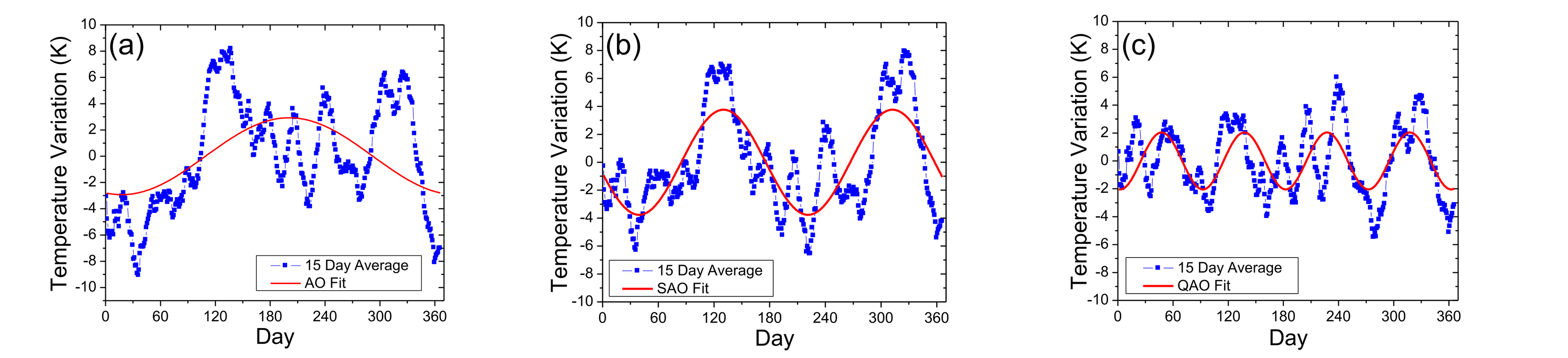
Comparing Seasonal Variability at Maui and ALO



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 nightly standard deviation and the red line is a 15 day running average. Similar data is shown from three folded years of data from the Maui-MALT campaign (teal).



15 day running-average OH temperature data from ALO (2009-2012) fit to (a) an annual, (b) a semi-annual, and (c) an unusual ~90 day (quarter-annual) oscillation. ALO temperature amplitudes are compared to Maui results, which used the below fit, are shown in the table (courtesy Y. Zhao).

$$fit = A + B\cos(2\pi x/182 + \varphi_1) + C\cos(2\pi x/365 + \varphi_2)$$

	ALO	Maui
AO	2.9 K	3.8 K
SAO	3.8 K	2.4 K
QAO	2.0 K	--

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 minute 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_2 temperatures. Phase differences between the O_2 and OH temperature waves in these two 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 an mid-latitude oceanic site and high-latitude sites in Antarctica.