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Mesospheric Temperature Variability and Seasonal Characteristics Over the Andes

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Introduction

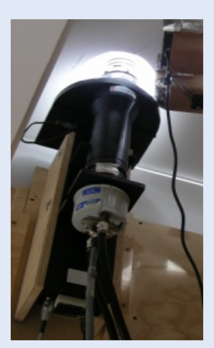
The Andes region is an excellent natural laboratory for investigating gravity wave influences on the Upper Mesospheric and Lower Thermospheric (MLT) dynamics. The instrument suite that comprised the very successful Maui-MALT program was relocated to the new Andes Lidar Observatory (ALO) located high 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 the O_2(0,1) Atmospheric band intensity 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 (20 months of data to date). These are compared with our results from the Maui-MALT program, Maui, HI (19.5° N, 155.6° W).

Instrumentation

The USU CEDAR Mesospheric Temperature Mapper (MTM) is a high performance CCD imaging system designed to provide accurate measurements of mesospheric temperature variability at two altitudes and gravity wave intensity and rotational temperature perturbations using precise observations of the OH (6,2) band and O_2 (0,1) airglow emissions at nominal altitudes of ~87 and ~94 km.

- Field of view: ~90°, (180 x 180 km).
- Sequential observations (60 sec. exp.) of :
  - NIR OH (6, 2) Band ~87 km
  - O_2 (0,1) A Band ~94 km
  - Background (~857.5 nm)
- Cycle time: ~3 min per OH/O_2 emission
- Temperature precision: ~2 K

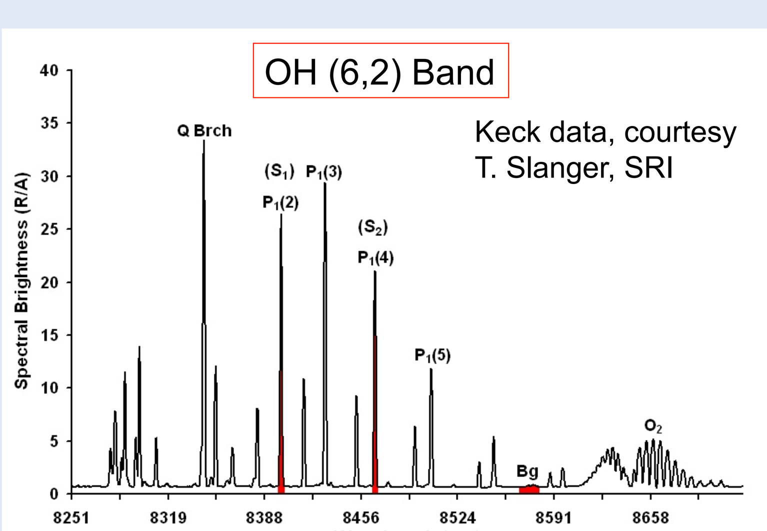


USU CCD Camera System in ALO at Cerro Pachon.

OH Temperature Analysis

The MTM took sequential 60 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 followed by similar observations of the O_2 (0,1) emission. In addition, a background measurement and a dark image were also recorded resulting in a cadence time of ~6 minutes. Data were recorded nightly except during the full moon period (~25 nights/month). To date we have obtained nearly 2 years of observations, comprising ~450 nights of high quality data.

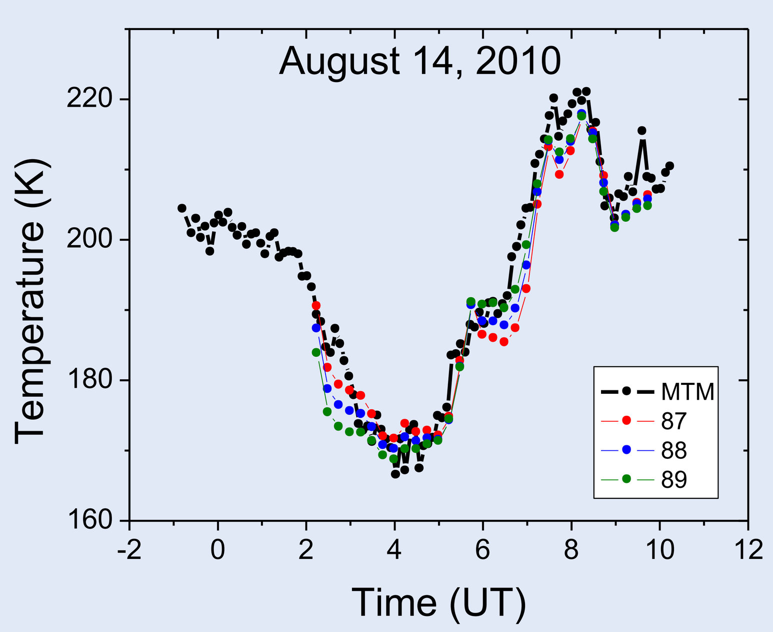
For this study we have focused our analysis on the OH emission. The data were analyzed using software developed at USU to determine the band intensity and rotational temperatures variability during each night. OH rotational temperatures were computed using the well-established "ratio method" (Meriwether, et al. 1984). Comparisons of the MTM OH temperatures with those obtained by other well calibrated instruments (Na temperature lidars, 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).



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

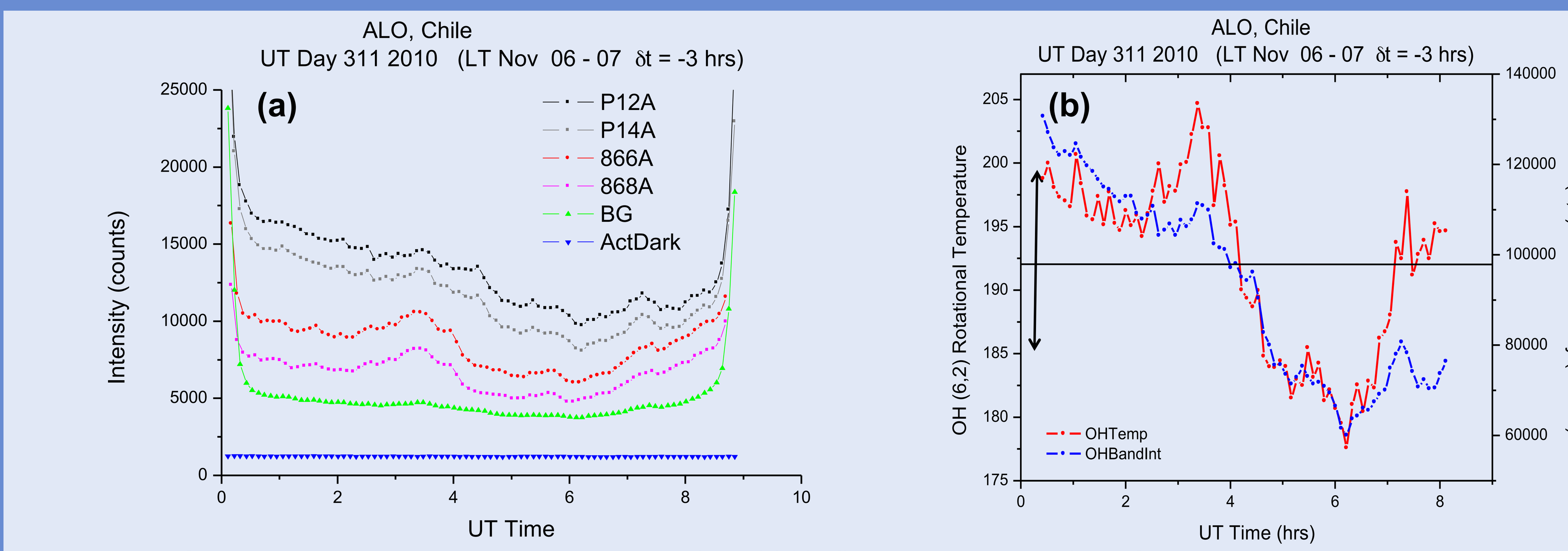
•OH transition parameters from Goldman et al., 1998.

•Relative band intensity from (S_{1c}+S_{2c}) and T using simplified LTE calculation.

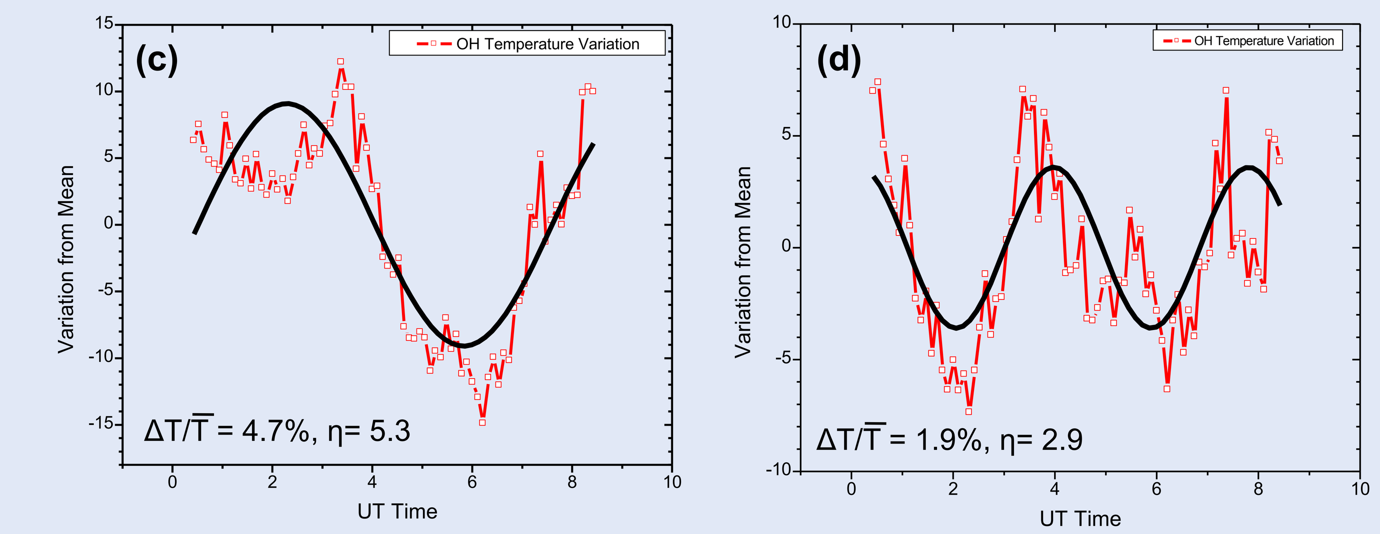


Graph comparing Gaussian height weighted (~8 km) MTM OH temperature measurements with coincident University of Illinois Na wind-temperature lidar observations from ALO. Note high quality of the agreement using these two different techniques. (Courtesy G Swensen, A. Liu, and Y. Zhao)

Example Nocturnal Variability and Quasi-Periodic Wave Analysis



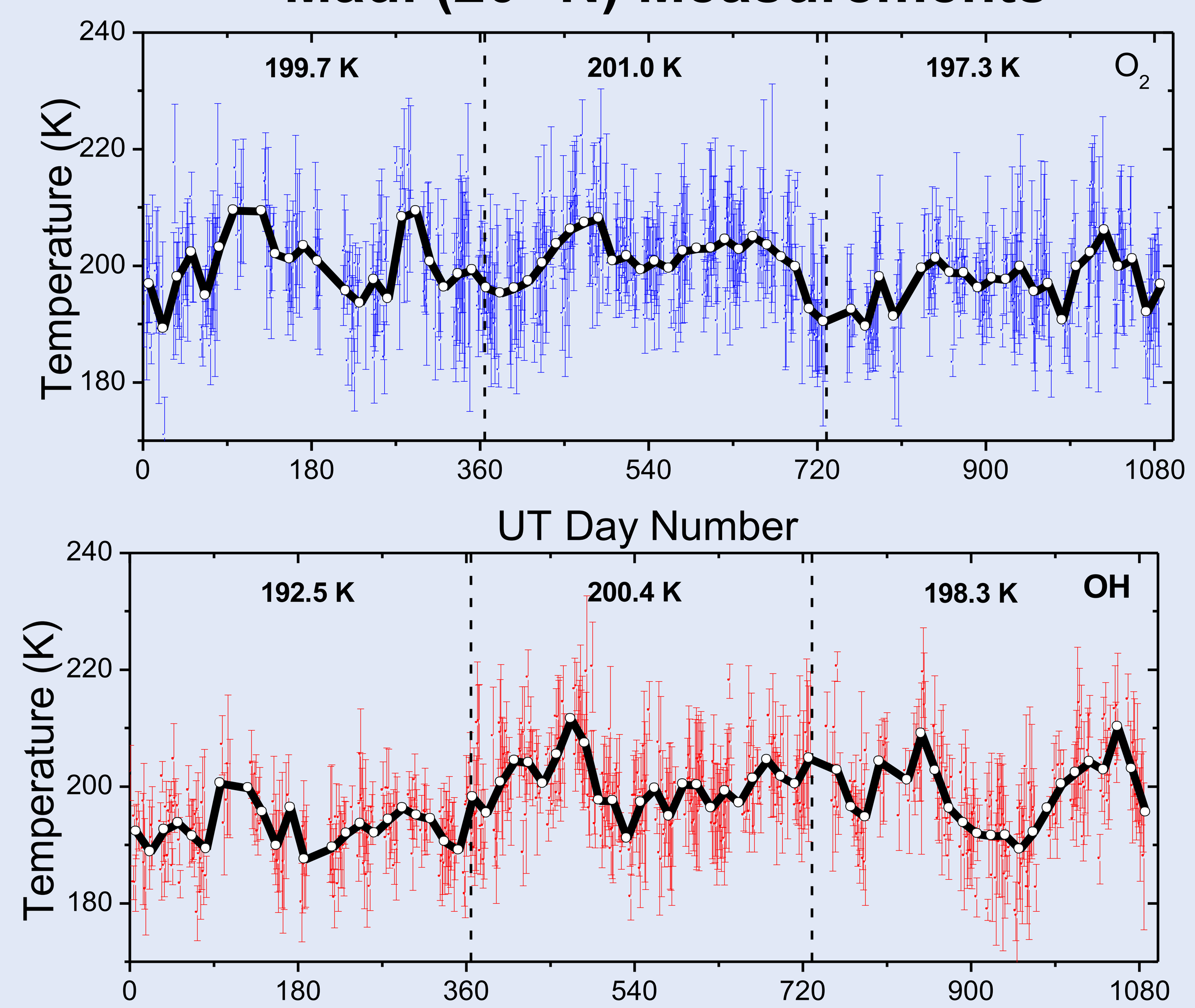
The above figures show data obtained November 6-7, 2010 illustrating the quality of the temperature measurements and the typical variability observed at Cerro Pachon. Plot (a) shows the raw intensity data for the OH and O_2 measurements during the course of the night (typically 8 hours in duration). The steep slopes at the beginning and end of the plot show sunset and sunset. The OH and O_2 show significance wave like variability throughout the course of the night. The green curve shows the background sky emissions while the blue curve shows the camera dark current. Plot (b) shows the superposition of the derived OH (6,2) band intensity and rotational temperature. During the night the intensity decreases significantly probably due to large scale wave which is more easily seen in the temperature data. The temperature variation during the night is ~27K and appears typical at this site. The black horizontal line represents the mean nocturnal temperature of 192.1 K, while the vertical arrow represents the standard deviation (±7.1K) of the geophysical variability.



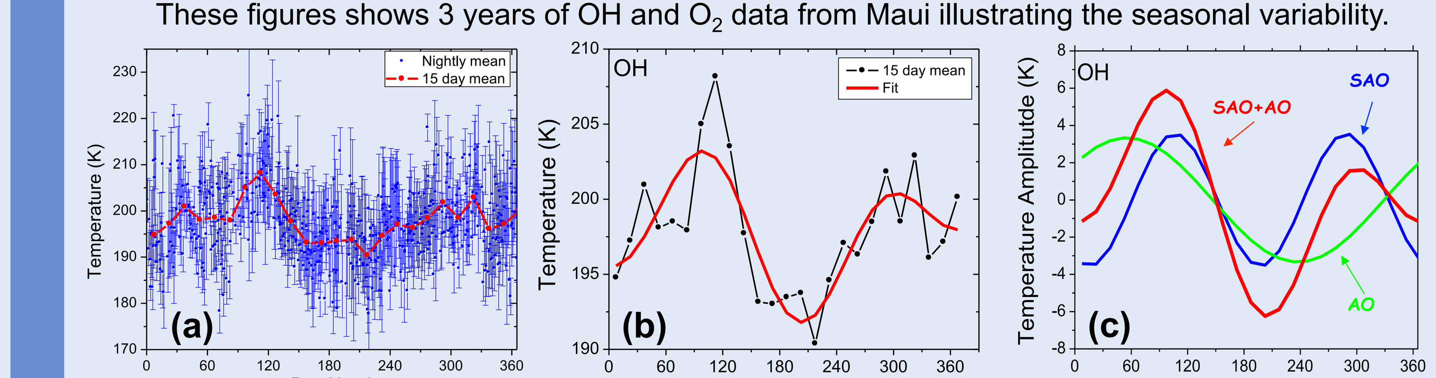
Plots (c) and (d) show a simple harmonic analysis applied to the temperature data to investigate the dominate wave periodicities and their amplitudes. In (c) the black curve shows the best fit to these data indicating a well defined wave period of ~7.1 hrs and an amplitude of ~9.1K. Plot (d) shows the resultant variation (red curve) when the large-scale 7 hr wave is removed from the data. A second significant oscillation is apparent (black curve) with period 3.8 hrs and amplitude of 3.6 K.

Comparing Seasonal Variability at Maui and ALO

Maui (20° N) Measurements



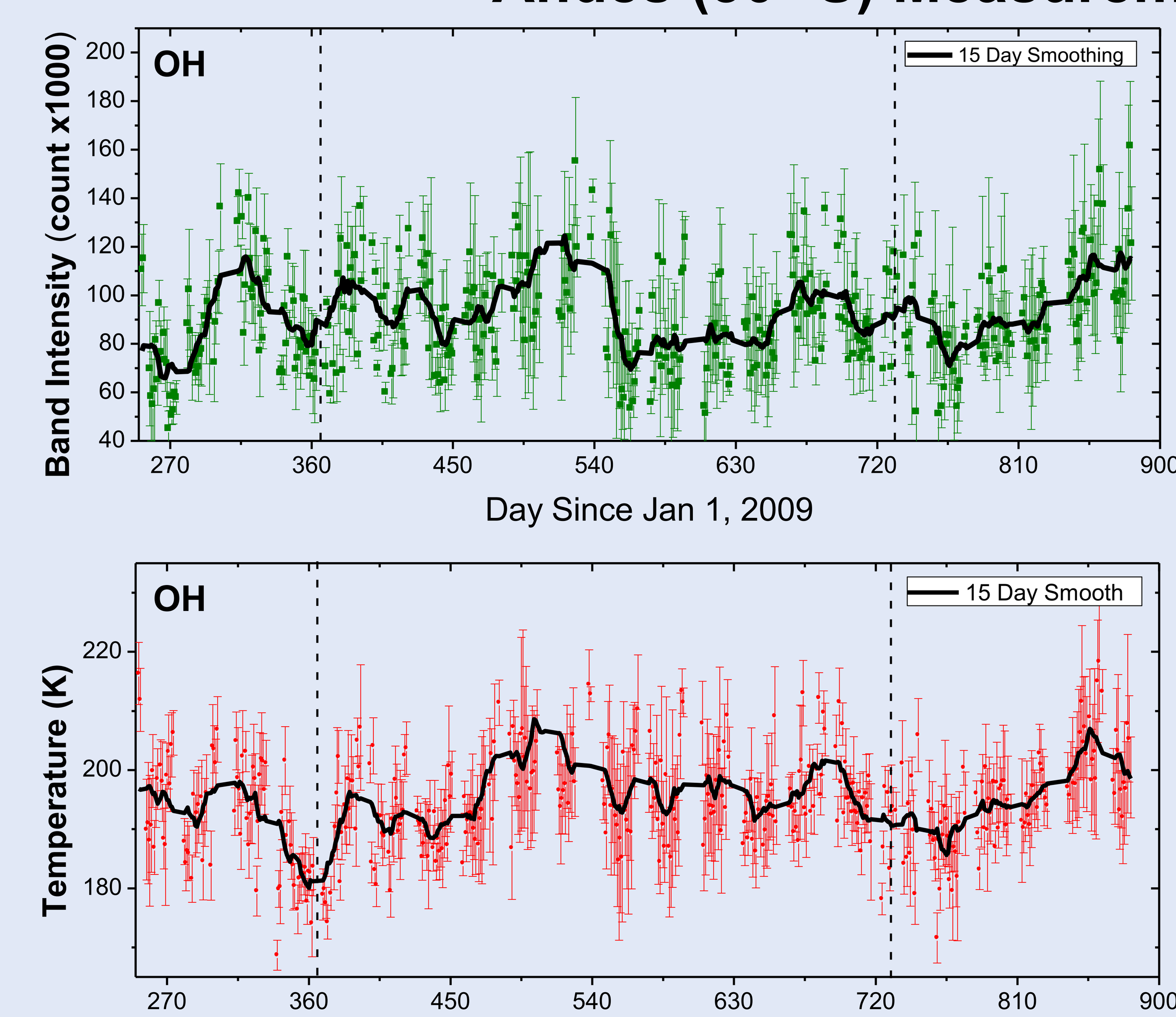
These figures shows 3 years of OH and O_2 data from Maui illustrating the seasonal variability.



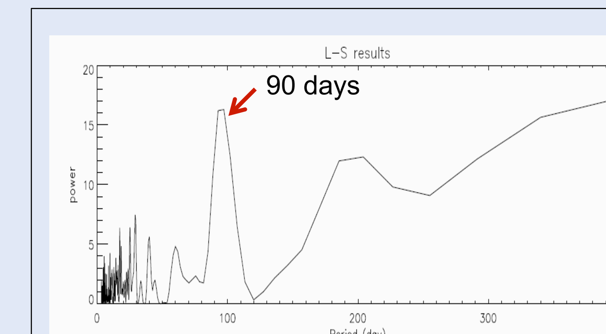
$$fit = A + B\cos(2\pi x/182 + \varphi_1) + C\cos(2\pi x/365 + \varphi_2)$$

Plot (a) shows the OH data folded into one year showing the annual (AO) and semiannual oscillations (SAO). This is more clearly shown in (b) which shows a 15 day average to the data (black curve) and superposed AO and SAO using the above equation. Plot (c) shows the individual AO (3.3 K) and SAO (3.6K) components (Zhao et. al., 2007). A similar analysis is currently underway using the more limited ALO data.

Andes (30° S) Measurements



These plots shows 20 months (450 nights) of mean MTM OH Band Intensity and temperature data from ALO. The error bar show the standard deviation of the nocturnal temperature variability as described above. The black curve shows the 15 day smoothing to the data and as well as a AO and SAO, there is evidence of a ~90 day oscillation during the first year of measurements.



This plot is the Lomb-Scargle periodogram showing the dominant periodicities in the data. Note the strong peak at 90 days. The SAO and AO are not yet well defined due to the limited length of the dataset (Analysis courtesy Y. Zhao).

Summary and Future Work

- ❖Nocturnal variations at Cerro Pachon 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 well-defined periods of a few to several hours (The image data also show periods of less than 1 hr).
- ❖A initial sinusoidal wave analysis applied to the OH intensity and temperature data has been used to study the wave amplitudes and periodicities in the data.
- ❖The 20 months of mesospheric OH temperature data acquired to date exhibit AO and SAO signatures and unexpected short-term oscillations (~90 day) that is currently under investigation at USU. Comparison with data from nearby El Leoncito, Argentina is in progress (Courtesy J. Sheer).

- ❖Investigation of long-and short period gravity waves using MTM and collaborative Na lidar and meteor radar winds to investigate intrinsic wave characteristics, propagation and momentum fluxes.
- ❖Perform a detailed comparison with SABER temperatures from the TIMED satellite as we conducted during the Maui-MALT program.
- ❖Comparative study of OH and O_2 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.

References

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