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Satellite measurements of mesospheric gravity wave temperature variances over the Andes

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I. Introduction

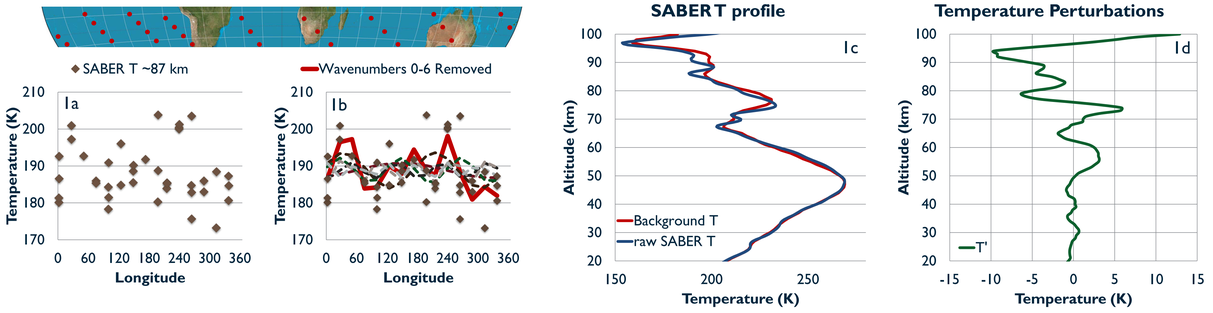
Utah State University's Mesospheric Temperature Mapper (MTM) has operated continuously at the Andes Lidar Observatory on Cerro Pachon, Chile (30.3° S, 70.7° S) since August 2009. Its purpose is to quantify gravity wave (GW) activity as observed in OH rotational temperature measurements in the mesosphere at an altitude of ~87 km with a particular interest in investigating short period GWs and their seasonal variability. 5.5 years data to date.

The SABER instrument aboard the TIMED satellite provides complimentary data to measure temperature variances and GW potential energy (PE) to quantify the small-scale GWs propagating up into the mesosphere, and lower thermosphere (MLT) region over the Andes.

II. Methods

SABER temperature profiles for 13 years (2002-2015) were used to extract wave induced fluctuations. The background and mean trends were removed by using a least-square fit to subtract the estimated amplitudes of 0-6 zonal wavenumbers from all the daily instantaneous profiles in the latitude bin (Figure 1a, 1b) [see Liu et al., 2014; John and Kumar, 2012; Preusse et al., 2002]. Ascending and descending modes were analyzed separately to account for diurnal tides. The removal of the large-scale waves and mean background from the raw profiles (Figure 1c) revealed the fluctuations due to GWs(Figure 1d) allowing further investigation using the temperature variance and GW PE.

Figure 1- Extraction of temperature perturbations caused by GWs from SABER



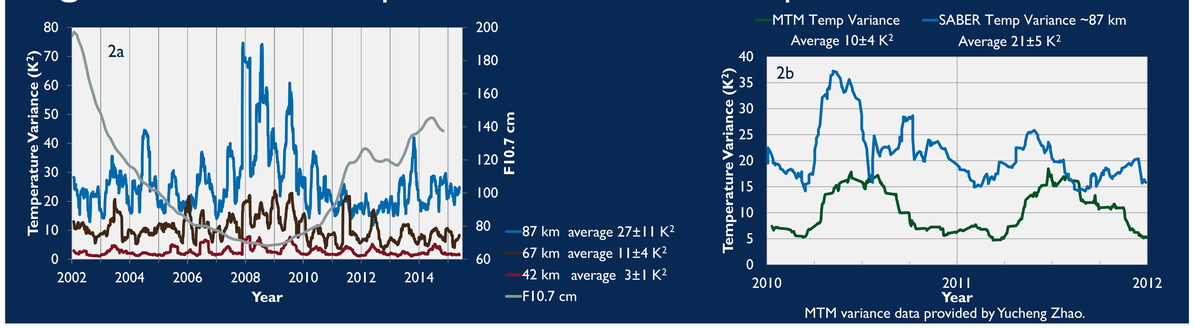
III. Results

Temperature variances for all profiles within a 5°x10° box centered on Cerro Pachon are plotted in Figure 2a. At the altitudes centered on 42 km and 67 km (with a 10 km width) an annual trend is prominent with maxima during each winter season. The enhanced wave activity may be due to mountain waves. At a higher altitude of 87 km the variance is increased (due to wave amplitude growth) and along with the annual winter maxima, it displays more variability. Importantly, all levels show major enhancements (factor of ~2) in temperature variance and PE during 2008 and 2009. The origin of this increase requires further investigation. Its interesting to note that this peak happened during solar minimum (Figure 2a).

Comparing the SABER measured temperature variance with the MTM measured temperature variance (Figure 2b) for 2 years (2010-11) shows the same basic annual Structure. The SABER mesospheric data also show smaller enhancements during other times of the year which vary from year to year. This may be due to differences in the observable wave spectrum based on each methods. Also, note MTM data are limited to only clear, moonless nights with at least 4 hours of data.

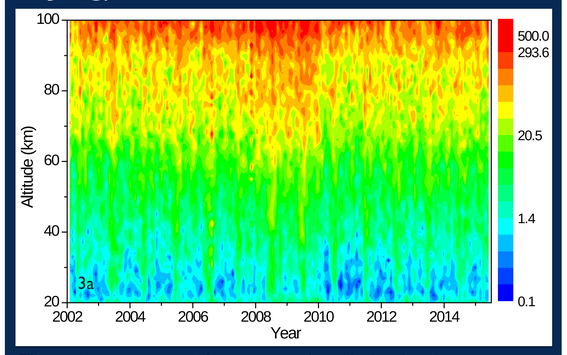
Figure 3a shows the monthly mean GW PE plotted for 13 years. Figure 3b shows these data averaged into a single year. PE depends on the temperature perturbation and quantifies the annual wave variability in the Andes region. While there is significant variability in PE from year to year each year exhibits the same annual behavior firmly establishing the seasonal variability.

Figure 2 – SABER Temperature Variance and comparison with MTM



MTM variance data provided by Yucheng Zhao.

Figure 3 – Potential Energy (J/kg) over the Andes, 2002-2015

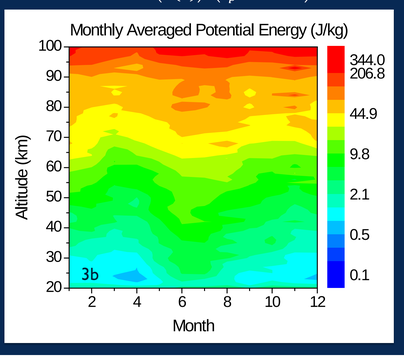


The gravity wave potential energy was also calculated using

$$PE(z) = \frac{1}{2}\left(\frac{g}{N(z)}\right)^2\left(\frac{T'(z)}{\overline{T}(z)}\right)^2$$

where

$$N^2(z) = \left(\frac{g}{\overline{T}(z)}\right)\left(\frac{g}{c_p} + \frac{\partial \overline{T}(z)}{\partial z}\right)$$



IV. Conclusions

These coordinated temperature variances and GW PE observations reveal increased wave activity over the Andes during the winter months. Our results are consistent with prior ground-based airglow measurements by Reisin and Scheer [2004] from nearby El Leoncito, Argentina. The utilization of SABER measurements provides strong additional evidence of the winter time maximum. This technique has high potential for investigating gravity wave effects with other ground-based temperature measurements around the world starting with Maui and Bear Lake Observatory, UT.

Liu, X., et al. (2014), Gravity wave variations in the polar stratosphere and mesosphere from SOFIE/AIM temperature observations, *Journal of Geophysical Research: Atmospheres* 119.12: 7368-7381.
John, S.R., and Kumar, K.K. (2012), TIMED/SABER observations of global gravity wave climatology and their interannual variability from stratosphere to mesosphere lower thermosphere, *Climate dynamics*, *39*(6), 1489-1505
Reisin, E. R., & Scheer, J. (2004), Gravity wave activity in the mesopause region from airglow measurements at El Leoncito. *Journal of Atmospheric and Solar-Terrestrial Physics*, *66*(6), 655-661.
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F10.7 cm data retrieved from http://spaceweather.com/

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