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Catching Mesospheric Gravity Waves Over Bear Lake, Utah

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Introduction

The Utah State Mesospheric Temperature Mapper (MTM) is a high resolution CCD imager capable of remote sensing faint optical emissions from the night sky to determine mesospheric temperature and its variability at an altitude of ~87 km (or 50 miles). The MTM was operated at the Bear Lake Observatory (BLO) for a two year period (Jan 2012 – Dec 2013) to investigate the seasonal characteristics of temperature variability at mid-latitudes.

This study was to be done from March 2013 – April 2014 but due to issues with the data in late 2013 it was changed to January 2013 - December 2013. But when looking at the variance plot for 2013 it was noticed that because of the issues in the second half of 2013 a good understanding of the variance could not be obtained. Thus the project was changed again to look at January 2013 – December 2013. Then the reduced variance would be compared to a similar camera operation USU has in Chile to determine if we see similar strong winter-summer variance. The original goal of this study was to calculate the nightly temperature variance from OH and O_2. Unfortunately the nothing conclusive came from the O_2 temperatures.

Figure 1. MTM at BLO.

Background/ Theory

The MTM system was designed at USU to provide accurate mesospheric temperature and intensity measurements on gravity wave perturbations using precise observations of the OH (6,2) band airglow layer which originates in the mesosphere at an altitude of ~87 km and has a thickness of ~8-10 km [Baker and Staire, 1988].

The MTM utilizes a high performance 1024 x 1024 pixel, bare Charged Coupled Device (CCD) array. Similar but less sensitive devices are used in common digital cameras. The MTM camera uses a wide-angle (90^0) telecentric lens to image selected emission lines in the OH band from which the temperature of the upper atmosphere can be determined.

Gravity waves are oscillations of air parcels by the lifting force of buoyancy and the restoring force of gravity. Gravity waves are caused by a variety of sources, including strong winds blowing over large mountain ranges and strong weather disturbances such as thunderstorms. Gravity waves generated in the troposphere can propagate energy and momentum into the upper atmosphere where they break and deposit their energy, like waves on a beach. Tides are global-scale oscillations in the atmosphere. They are similar to ocean tides and can last anywhere from an hour to a couple of days. The strength of a tide increases with height [Chapman, Lindzen] this means that in the lower atmosphere tides do not as many visible effects as they do in the upper atmosphere.

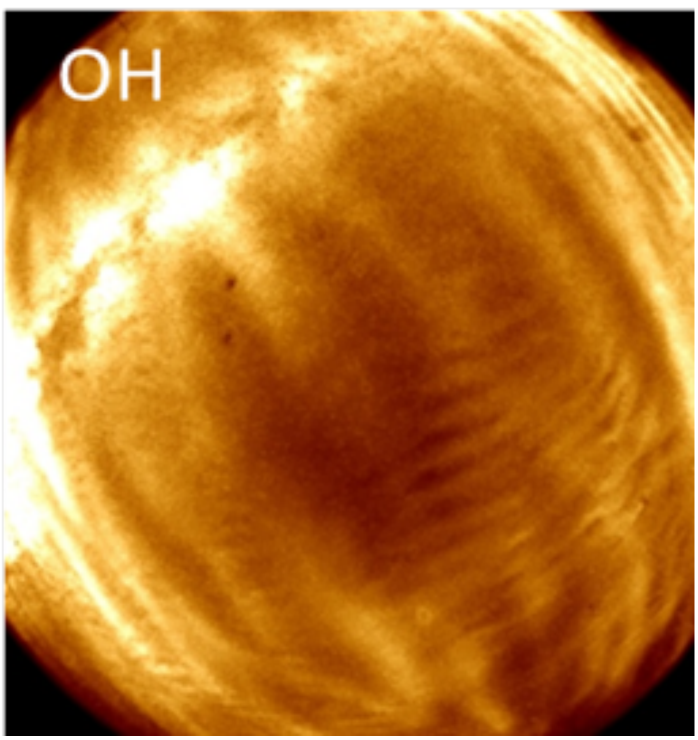
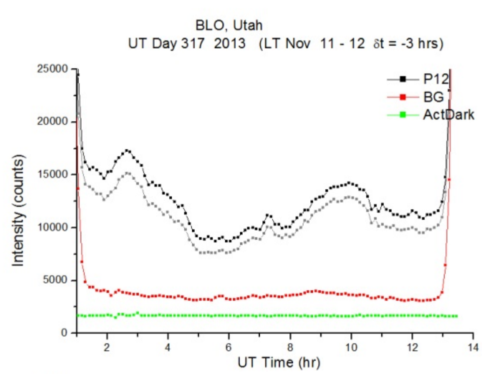


Figure 2. False color all sky image (180º) showing extensive gravity waves over Bear Lake Observatory. Note the Milky Way in the top left.

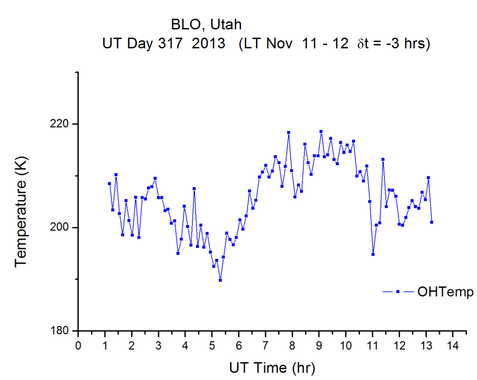
Procedure

The MTM takes pictures of the night sky with filters that look at the emissions from certain molecules in the atmosphere. In this study we are specifically looking at the emissions from OH. The images look something similar to the image in Figure 2. Stars were removed from the images before any analysis was done.

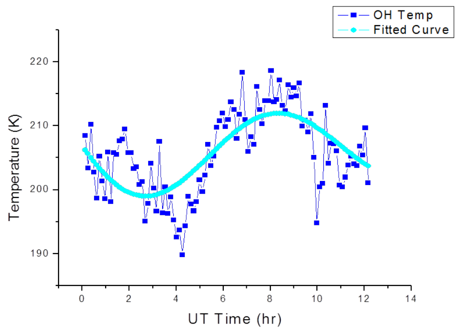
The figures below depict the process of obtainin the temperature variance for day 317. The images that were taken for day317 are processed in IDL to obtain the temperature and a plot of the two emission bands from the hydroxyl (OH) atom and the background (Figure 3a). Then taking the ratio of the P_12 and P_14 emission bands we get the temperature for that night (Figure 3b). The temperature is inversely proportional to the ratio of P_12 and P_14. Removing the tides (large scale waves we see in the cyan curve of Figure 3c) from that night so we can just look at the smaller scale waves, Figure 3c. Subtracting the blue temperature curve from the cyan curve in Figure 3c the residual temperatures for that night (Figure 3d) are obtained. Then taking the average of these residual temperatures and squaring it gives us the temperature variance for that night. This process was repeated for the rest of the data.



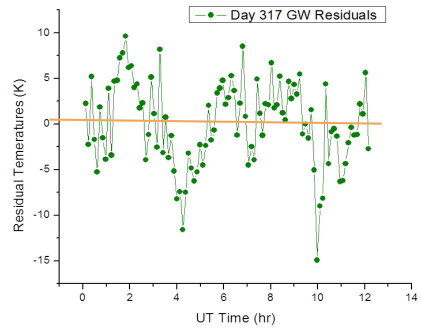
(a)



(b)



(c)



(d)

Figure 3. The process of finding the temperature variance for one night in November 2012. (a) Plot of emissions from P_12 and P_14 bands of OH. (b)Temperature derived from taking the average of the P_12 and P_14 emissions. (c) The cyan curve is the subtraction of larger tides from the temperature data. (d) The temperature residuals of the night obtained by subtracting the blue and cyan curve in (b), notice how the residual temperatures oscillate about 0.

Results

The figures below are of the temperature variances near Bear Lake, Utah (42° N) over a two year period (2012-2013) that were reduced in this study. Notice in 2013 (Figure 6) that the variance is much higher than it was expected to be and that we do not see any strong winter-summer differences because in the summer and most of the winter months the filter wheel on the camera had stopped working. The much higher variance in 2013 compared to 2012 could be a result of the radar that was in use during 2013, interfering with any measurements being taken. In figure 4 we can see that winter-summer difference clearly, which compares well with the data collected from another site in Chile.

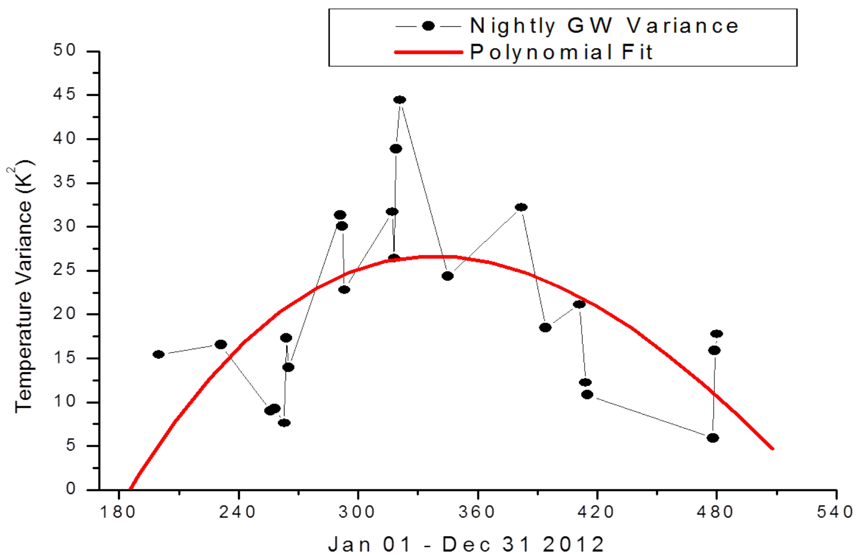


Figure 4. Plot of summer-winter-summer variance in 2012.

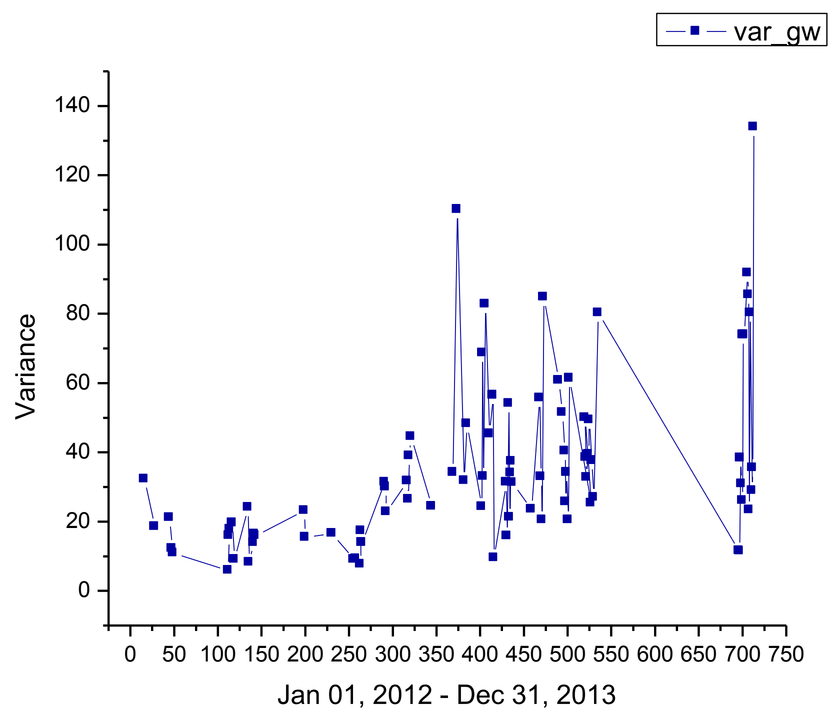


Figure 5. Plot of the variance from Jan 2012 – Dec 2013.

There is a similar camera operation in Andes Mountains, Chile (~30° S) where we have collected temperature variance since 2009. Notice in Figure 6 that there are strong winter-summer variances over these four years. When compared to Figure 5 we cannot see that winter-summer differences in the variance at Bear Lake are remotely similar to the ones in Chile. But if we look at Figure 4, which is a plot of the temperature variance for summer-winter-summer in 2012, we can see that there is a higher variance in the winter than in the summer.

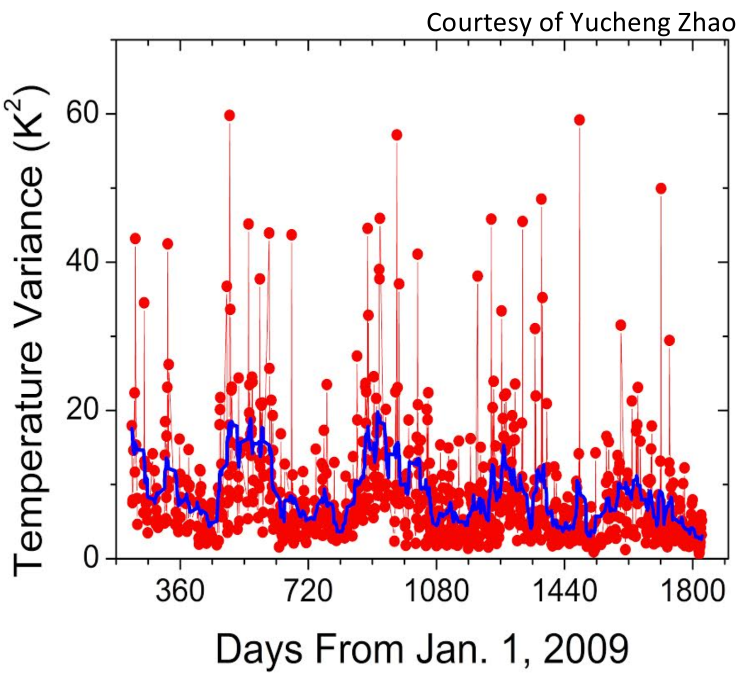


Figure 6. Plot of temperature variances over a 4 year period (2009-2013).

Conclusion

Two years of temperature data from BLO, 2012 and 2013 were reduced for this study. Due to interference from a nearby radar in 2013 the usable data set was reduced to 23 days for this study. The results, although limited, clearly indicate a significantly stronger gravity wave variance during the winter months at BLO which compares well with similar measurements from

Chile where strong summer-winter differences are evident. Further comparison with more detailed data from BLO will enable us to investigate differences in the wave variances which will help us to understand differences in the regional wave sources at geophysically different sites.

References

Baker, D.J., and A.T. Staire Jr., Rocket measurements of the altitude distributions of the hydroxyl airglow, *Phys. Scr.*, 37, 611, 1988.

Chapman, Sydney, and Richard S. Lindzen. *Atmospheric tides: thermal and gravitational*. Vol. 15. Springer Science & Business Media, 1970.