

Utah State University

DigitalCommons@USU

---

Posters

Green Beam (Rayleigh-Scatter LIDAR)

---

12-3-2012

## First Temperature Observations with the USU Very Large Rayleigh Lidar: An Examination of Mesopause Temperatures

Leda Sox

*Utah State University*

Vincent B. Wickwar

*Utah State University*

Joshua P. Herron

*Utah State University*

Marcus J. Bingham

*Utah State University*

Lance W. Petersen

*University of Utah*

Matthew T. Emerick

*Utah State University*

Follow this and additional works at: [https://digitalcommons.usu.edu/atmlidar\\_post](https://digitalcommons.usu.edu/atmlidar_post)



Part of the [Atmospheric Sciences Commons](#), [Climate Commons](#), and the [Physics Commons](#)

---

### Recommended Citation

Sox, L., Wickwar, V., Herron, J., Bingham, M., Petersen, L., & Emerick, M. T. (2012, December 3). First Temperature Observations with the USU Very Large Rayleigh Lidar: An Examination of Mesopause Temperatures. Presented at the American Geophysical Union Fall Meeting.

This Poster is brought to you for free and open access by the Green Beam (Rayleigh-Scatter LIDAR) at DigitalCommons@USU. It has been accepted for inclusion in Posters by an authorized administrator of DigitalCommons@USU. For more information, please contact [digitalcommons@usu.edu](mailto:digitalcommons@usu.edu).



# First Temperature Observations with the USU Very Large Rayleigh Lidar: An Examination of Mesopause Temperatures



Leda Sox<sup>1</sup>, Vincent B. Wickwar<sup>1</sup>, Joshua P. Herron<sup>2</sup>, Marcus J. Bingham<sup>1</sup>, Lance W. Petersen<sup>3</sup>, Matthew T. Emerick<sup>1</sup>  
(<sup>1</sup>Physics and CASS, <sup>2</sup>Space Dynamics Lab, Utah State University, Logan, UT; <sup>3</sup>University of Utah, Salt Lake City, Utah)



## Introduction

As the impetus for extended observational measurements throughout the middle atmosphere has increased<sup>1</sup>, the limits of previous instrumentation need to be pushed. The Rayleigh lidar group at the Atmospheric Lidar Observatory (ALO) at Utah State University has pushed such limits on existing Rayleigh scatter lidar technology and, through major upgrades to the previous lidar system, has been able to gather temperature measurements in the upper mesosphere and lower thermosphere from approximately 70-109 km. A data campaign with the new system was conducted around the annual temperature minimum, centered on late June 2012, in this region. The temperatures from this campaign show a considerable night-to-night variation as well as evidence of wave activity on several nights.

## Background

The Rayleigh lidar group at the ALO on the campus of Utah State has been conducting mesospheric research since 1993. The original Rayleigh lidar system that operated at ALO, primarily consisting of one 24 W Nd:YAG laser pulsed at a wavelength of 532 nm; one 44 cm diameter telescope; and one photomultiplier tube (PMT) detection channel. This Rayleigh lidar system was capable of obtaining temperature measurements throughout the mesosphere from 45-90 km, which are common altitude limits for most Rayleigh lidar systems.

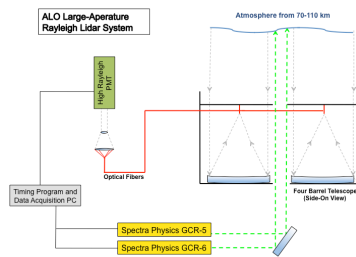


Figure 1. Block diagram of the new large-aperture Rayleigh lidar system at ALO, as of Summer 2012.

As the necessity for extended observations throughout the middle atmosphere has grown, the we have undertaken many upgrades of the original lidar to extend its measurement limits. Our group conducted the first data campaign with the new, large-aperture Rayleigh lidar system operating with two lasers for a combined 42 W, a four-mirror telescope with 4.9 m<sup>2</sup> receiving area, and one PMT detector (Fig. 1), in the summer of 2012.

## Data Campaign and Analysis Methods

Once operational, the large-aperture Rayleigh lidar was used to conduct a month long data campaign centered around the annual temperature minimum in the mesopause region 80-100 km. Twenty nights of data were collected between mid-June to mid-July.

The traditional Rayleigh lidar temperature algorithm<sup>2</sup> used by the ALO Rayleigh group<sup>1</sup> was used to reduce the lidar signal into nightly-averaged temperature profiles. This algorithm uses the lidar signal equation to find the relative density profiles and then assumes hydrostatic equilibrium and the ideal gas law to derive an integral to find temperatures,

$$T(h) = T(h_{\max}) \frac{n(h_{\max})}{n(h)} + \frac{1}{k} \int_h^{h_{\max}} \frac{n(h')}{n(h)} m(h') g(h') dh'$$

This temperature algorithm allows us to take relative densities, given by the lidar signal, and reduce them to get absolute temperature profiles in the upper mesosphere and lower thermosphere.

The algorithm requires an initial temperature at a maximum height,  $h_{\max}$ . In the past, the initial temperature, or seed temperature, was taken from the Colorado State Na lidar climatology. Due to the increased upper altitude limit of the new large-aperture Rayleigh lidar, all of the initial temperatures for this study were taken from the MSIS90 Atmospheric Model<sup>3</sup>.

## Temperature Observations

Nightly-averaged temperature profiles were measured for some twenty nights during the month long summer data campaign. The altitude covered by these temperature profiles ranged, on average from 70-105 km.

On a night with particularly good observing conditions, June 16, 2012, the temperature algorithm was pushed to 109 km. The profile from this night (Fig 2.), is the best example of the current capabilities of the large-aperture Rayleigh lidar.

In Figure 2, additional temperature profiles with seed temperatures of  $\pm 20$  K (red curves) are plotted concurrently with the temperature profile using the MSIS90 model seed temperature. This illustrates how the choice of seed temperature has a diminishing effect as the temperature integration is brought down in altitude.

A great deal of variability in the structure of the temperature profiles was seen from night-to-night. The group of four consecutive nights from June 21<sup>st</sup> to June 24<sup>th</sup> exhibits this variability (Fig. 3). Between June 21<sup>st</sup> and June 22<sup>nd</sup>, a large-amplitude wave-like structure formed which seems to dissipate over the night of June 23<sup>rd</sup> and is completely gone by the night of the June 24<sup>th</sup>.

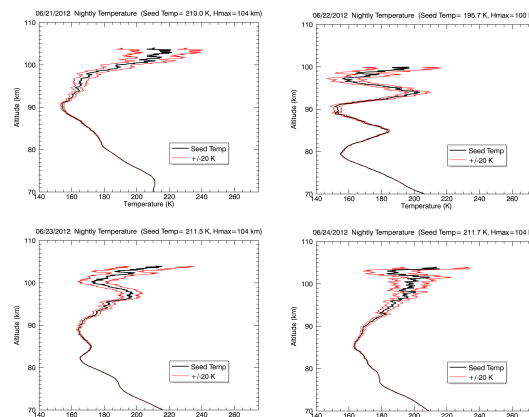


Figure 3. Nightly-averaged temperature profiles for the consecutive nights between June 21-24, 2012. The night-to-night variability of the temperature profile structure in this atmospheric region can be clearly seen throughout these four nights.

## Wave Activity

On several nights during the Summer 2012 campaign, wave-like signatures were seen in the nightly averaged temperatures.

To examine these wave structures further, hourly averages of the temperatures for the night of June 26, 2012 were plotted with 50 K offsets (Fig. 4). In this plot, one can see evidence of waves with a downward phase progression. The dominant wave appears to be monochromatic with a wavelength of 11 km and a phase speed of -1 km/hr, giving an approximate 12-hr period. Other waves are also present.

With further analysis, the horizontal wavelengths and phase velocities can also be found using the densities or temperatures measured with this Rayleigh lidar system<sup>4</sup>.

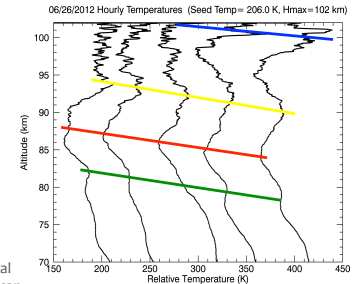


Figure 4. On the night of June 26, 2012, evidence of wave structures were found in the hourly averaged temperature profiles. Colored lines suggest a dominant monochromatic wave.

## Conclusions and Future Work

First observations were made with the new, large-aperture Rayleigh lidar at Utah State during the middle of the 2012 summer. The upper altitude limit for Rayleigh-scatter lidar measurements has been extended to 109 km. Good results have also been obtained above 100 km with only a 1-hour integration. Observations on 20 nights have shown that temperatures in the region, consisting of the upper mesosphere and lower thermosphere, to be highly variable. The minimum temperature can occur at 80 km or at 90 km. This variability may well arise from waves. For instance, one long night showed a wave with  $\lambda = 11$ , speed  $-1$  km/hr, and  $\tau = 12$  hrs. A much shorter night appeared to show much stronger waves.

Our Rayleigh group will continue with its plans for further upgrades to the system by adding more detection channels in the coming months. The new detection channels will allow for measurements to be made with the system over a larger altitude range, which will extend down to 15 km, and will allow for the detection of Rayleigh, Mie and Raman scatter. These additions, along with fine tuning of the completed Rayleigh-Mie-Raman (RMR) lidar will give an overall temperature and density measurement range of 15-120 km.

## References

- <sup>1</sup>CEDAR: The New Dimension, NSF CEDAR Strategic Plan, (2011).
- <sup>2</sup>Herron, J.P., Mesospheric Temperature Climatology Above Utah State University, (2004).
- <sup>3</sup>MSIS90 Atmospheric Model, [http://omniweb.gsfc.nasa.gov/vitmo/msis\\_vitmo.html](http://omniweb.gsfc.nasa.gov/vitmo/msis_vitmo.html).
- <sup>4</sup>Kafle, D.N., Rayleigh-Lidar Observations of Mesospheric Gravity Wave Activity Above Logan, Utah, (2009).

## Acknowledgements

I would like with thank the Rocky Mountain NASA Space Grant Consortium, the Space Dynamics Lab IR&D program, the USU Physics Department, the USU Center for Women and Gender and Utah State University for their support of this project.