6-22-2016

Simultaneous, Collocated Rayleigh And Sodium Lidar Temperature Comparison

Leda Sox  
*Utah State University*

Vincent B. Wickwar  
*Utah State University*

Tao Yuan  
*Utah State University*

Neal Criddle  
*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, and the Physics Commons

**Recommended Citation**
[https://digitalcommons.usu.edu/atmlidar_post/28](https://digitalcommons.usu.edu/atmlidar_post/28)

This Article 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.
Simultaneous, collocated Rayleigh and sodium lidar temperature comparison

Leda Sox1,2, Vincent B. Wickwar1,2, Tao Yuan3, and Neal R. Criddle1,2
1Department of Physics and 2Center for Atmospheric and Space Sciences, Utah State University, Logan, Utah

Abstract

There are relatively few instruments that have the capabilities to make near continuous measurements of the mesosphere-lower thermosphere (MLT) region. Rayleigh-scatter (RS) and sodium lidar, particularly sodium (Na) lidar, have been the two dominant ground-based techniques for acquiring mesosphere and MLT vertical temperature profiles, respectively, for more than two decades. With these measurements, the dynamics and long-term temperature trends of the MLT region can be studied. For the first time, we will present simultaneous, night-time averaged temperatures acquired from the same observational site, on the campus of Utah State University (USU), using these two lidar techniques. This comparison is also unique in that this will be the first time that the Rayleigh and Na lidar profiles will cover the same altitude range (80-110 km). This altitude overlap has been achieved through upgrades to the existing USU Rayleigh lidar, which elevated its observational range from 45-90 km to 70-115 km, making it one of two Rayleigh lidars in the world that can extend into the thermosphere, and by the relocation of the Colorado State Na lidar to the USU campus. The comparison of the two sets of temperature measurements is important because the two lidar techniques derive temperature profiles using different observational and analysis methods, each of which are based on different sets of physical processes. Furthermore, previous climatological comparisons between Rayleigh and Na lidar in the 80-90 km range, have suggested that significant temperature differences can occur. This comparison aims to elucidate the climatological differences by comparing the agreement between the lidar techniques with respect to altitude and season.

1. Motivation

Lidar systems remain the most advantageous method for acquiring temperature measurements in terms of vertical and temporal resolution. Two of the most widely used lidar techniques for the study of MLT are RS lidar and Na resonance lidar. However, the two techniques have yet to be compared with one another using simultaneous, collocated measurements, which cover the same altitude range. Using the Na lidar and newly upgraded high power, large aperture RS lidar located at the same USU observatory, this work aims to make this temperature comparison for the first time.

2. Lidar system descriptions and 2014-2015 observations

The Na lidar was moved from Colorado State University to the USU campus and began operations there in 2011 [Auerger et al., 2015]. The RS lidar was recently upgraded by a factor of 66 in order to extend its observational range from 45-90 km to 70-115 km and the new system began operations in 2014 [Sox et al., 2016]. The two lidar’s system parameters are given in Table 1. Between 2014 and 2015, there were 19 nights when the two lidars made simultaneous measurements throughout the night for at least four hours. Though these observations are sparse, they span one full annual cycle, covering all four seasons. A subset of the temperatures derived from the lidar measurements are given in Fig. 1.

3. Results

The plots in Fig. 1 illustrate the differences between the two lidars’ temperatures with respect to altitude and time of year:

- The best agreement between the two temperature curves occurs from 85 to 95 km
- RS temperatures are colder than Na temperatures below 90 km
- RS temperatures are warmer than Na temperatures from 95 km and above
- RS temperatures show stronger vertical wave structure

The worst agreement between the two temperature curves, at all altitudes, occurs in late fall-early winter

The agreement, at all altitudes, occurs near equinoxes

3.1 Seasonal comparison

Fig. 2 gives temperatures from the two lidars with respect to day of year for five altitudes. The differences between the two sets of temperature averages are also given for each of the five altitudes. From these plots, we find that:

- At 85 and 90 km, RS temperatures are, on average, 1.5 K colder than Na temperatures
- At 95 km and above RS temperatures are warmer, on average, by about 1.3 K

The agreement between the two lidars’ temperatures of lower altitudes

The worst agreement between the two sets of temperatures occurs during the equinoxes

These results are corroborated by those seen in Fig. 1, and the other 10 profiles in general, we observe that the RS lidar’s temperatures are slightly colder than the Na temperatures below 85 km and much warmer above about 95 km. On a seasonal basis, the best agreement occurs during the equinoxes.

4. Discussion

Here, we have shown that RS lidar temperatures are colder than simultaneous Na lidar temperatures between 85 and 90 km. Observations were compared by Argoll and Sica [2007] and Leblanc et al. [1998]. Two data sets from different sites which were at roughly the same latitude, but several hundred kilometers apart in longitude. They also covered a smaller overlapping altitude range, reaching most 95 km (see Fig. 5). However, the RS lidar temperatures were 7 K from 80-95 km and 2.6 K from 80-88 km in Leblanc et al. [1998]. While our data show the Rayleigh temperatures being colder at these altitudes, our difference is not as large as having an average of only about 1.5 K.

At 95 km and above, our data shows that the RS temperatures are on average increasingly warmer as one goes up in altitude, reaching an average maximum temperature difference of about 16 K at 105 km. This result, which was only possible due to the new large-aperture, high power USU RS lidar, cannot be compared with the previous studies. Their overlapping measurements do not extend this high. The comparison between the three studies is summarized in Fig. 5.

5. Conclusions and Future Work

For the first time, we present a comparison between simultaneous, collocated RS and Na lidar temperatures. In general, we found that the best agreement occurs between 85 and 90 km, the worst agreement above 95 km.

These results can be refined with simultaneous RS and Na lidar measurements. The differences in temperature and detected wave activity need to be further investigated in order to discover if they suggest changes to our current understanding of atmospheric structure, composition and chemistry.

References

Figures 1-5. All Figure captions are inside the figures. All Figures are referred to in the text. The authors are responsible for the quality of the figures. The figures should be placed in the manuscript where they are mentioned.