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Rayleigh Lidar Temperature Studies in the Upper Mesosphere and Lower Thermosphere
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Introduction
Rayleigh lidar technology opened the middle atmosphere (from 30–90 km) to ground-based observations. The upgraded system at the Atmospheric Lidar Observatory (ALO) on the campus of Utah State University (117.4°W, 111.8°N) has shown that these ground-based observations can be extended to 109 km, with the goal of reaching 120 km. The resulting study of short and long-term temperature trends, using Rayleigh lidar, contributes immensely to the overall understanding of the properties and dominant physical processes in the middle atmosphere (Middle and Upper Atmosphere and Mesosphere-Lower Thermosphere (MLT) region). Temperature variations on short time scales, from minutes to days, give insight into the effects of waves (gravity waves, tides, planetary waves), while climatological studies of temperatures can help in the study of global change throughout the atmosphere.

Summer Rayleigh Lidar Data Campaigns
During the summer 2012 data campaign, observations were made over a month-long period (June 13–July 12). Data from eighteen nights gave good temperature profiles in the MLT region from 75 km up to a maximum of 109 km. Temperatures were reduced using the Charnin-Hauchecorne method, which was modified to use temperatures instead of pressures as the initial condition at the top altitude. The initial temperatures were taken from the MSISe00 model for each hour. Why the observed temperature profiles approach the MSISe00 curve at the highest altitudes in the top altitude. The initial temperatures were taken from the MSISe00 model for each method, which was modified.

Figure 1 shows a simplified diagram of the upgraded ALO Rayleigh lidar system. The major improvements to the system include the use of two, pulse NeYAG lasers with a combined power output of 42 W and the use of four parabolic mirrors as one receiving telescope with an overall aperture area of 4.9 m².

Rayleigh Lidar MLT Temperatures
As expected, temperatures in this region during this period are quite low compared to the temperatures during other seasonal periods. Ignoring obvious wave structures, there is an underlying average of approximately 163 K near 87 km (Fig. 2), which could indicate the mesopause. However, four individual nights, exhibiting what appear to be wave-like variations, clearly show temperatures only slightly greater than 150 K between 79 and 84 km (Fig. 3a). Another set of four nights shows minima of about 140 K between approximately 94 and 100 km. This illustrates the fact that, from night-to-night the mesopause is not clearly present and can only be found through averages over large amounts of data, such as the MSISe00 model makes into account.

System Improvements
Over the course of the past year, major improvements to the system have been completed with the help of additional electrical and mechanical engineering support. The timing of the Rayleigh lidar system is now run with an A1m2168 micro controller and accompanying software. New sockets, which control the voltage to the photomultiplier tube (PMT) stage and the gating of that voltage, are also being developed.

For a single temperature profile the altitude resolution has increased. For the night of May 15, 2013, 6 hours’ worth of data give temperatures up to an altitude of 109 km, as high as the highest night from 2012. The shortest integration time for this night, while reaching 107 km in altitude, was 30 minutes. Each curve shows a 30 minute data integration shifted successively by 200 K.

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Upcoming Work
The fully upgraded ALO Rayleigh lidar is in a prime location to make comparisons with many different instruments also located at ALO and USU including: the Na Lidar, Airglow imagers and temperature mapper, a meteor wind radar and an emulsions, as well as satellite-based instruments. With whole groups of different, but complimentary, instruments conducting data campaigns together, we will be able to gather the most complete observations of the whole middle atmosphere.