Upgraded ALO Rayleigh Lidar System and Its Improved Gravity Wave Measurements

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We have recently made the first measurements with the new, very large Rayleigh-scatter lidar system at the Atmospheric Lidar Observatory (ALO) at Utah State University in Logan, Utah. The new system is an upgraded version of the original Rayleigh lidar that operated at ALO from 1993 to 2004. With the new system the observational altitude upper limit has increased and the resolutions in the reduced data have become finer. These improvements to the data will have significant impacts on the study of atmospheric gravity waves and other middle atmosphere phenomena.

### System Background

The much larger ALO Rayleigh-scatter lidar combines two Nd:YAG lasers to achieve a total laser power output of 42 W at 532 nm. The lasers are pulsed at 50 Hz and frequency-doubled from a wavelength of 1064 nm to operate at 532 nm. This wavelength was chosen to take advantage of the UV absorption in the ALO lidar cross section. Photons emitted from the laser are backscattered in the middle atmosphere and collected by four 1.25 m diameter parabolic mirrors, equivalent to one 2.5 m diameter mirror. These mirrors focus the returned photons into optical fibers that, in combination with detector optics, transfer the photons to a photomultiplier tube (PMT). From there, a multi-channel scalar (MCS) unit and its software package count the photoelectrons and record them to a PC.

The original Rayleigh lidar at ALO operated with only one laser and a single small receiving mirror. Through the addition of multiple larger mirrors and a second laser, the new system is substantially more sensitive in its raw data collection. This increased sensitivity enables data to be acquired at greater altitudes and analyzed with better resolutions and precision. These first observations with this system were recently acquired, on June 13, 2012. The first temperature profiles are shown in the next column to illustrate this improved capability. Future studies of atmospheric gravity waves and other middle atmosphere phenomena will benefit from these improvements.

### Raw Data Comparison

The increased sensitivity of the new system is evident in the raw data, seen as the average number of photoelectrons counted in two minutes. In Figure 3 (a) and (b), the photoelectrons are represented as “count” and are plotted versus altitude. As can be seen in the figure, the new, large Rayleigh lidar detects, so far approximately 30 times more photoelectrons than the original configuration at an altitude of 60 km, which means that the new system is able to acquire data at higher altitudes than the previous model. At approximately 90 km, the new system is able to gather significant data in two minutes whereas the old system has no perceivable count rate at this altitude.

### First Temperature Results

The original ALO Rayleigh lidar operated from 1993 to 2004, developing an extensive data set spanning 11 years. From that an 11-year temperature climatology was developed. The new system has begun to add to this data set. As predicted, the system is probing higher into the atmosphere, making it, so far, to nearly 105 km, whereas the old system’s upper limit for temperature data was 90 km. After more optimization of the system, this upper limit should increase even further.

### Improved Atmospheric Gravity Wave Studies

Another important study that will benefit from the increased sensitivity of the new, very large Rayleigh system is that of atmospheric gravity waves (AGWs). Like the temperature climatology, AGW studies were carried out with data taken using the original Rayleigh lidar, having first been explored by Kafle (2009).

### Additional Future Work

Along with continuing optimization of the lidar’s various systems, there will be further upgrades as well. As can be seen in Figure 2, three more PMT detection channels (the pale PMTs) will be added to the system. One of these channels will be for continuing Rayleigh scatter measurements down to approximately 40 km (the original lidar’s lower limit), another channel will measure both Rayleigh and Mar scatter from 15-65 km and the final channel will measure Rayleigh scatter from 15-45 km (Table 2). The rate at which this will occur and the examination of scientific problems with this unique system will depend on significant future funding.

### Conclusion

Presented above are first observations from the new ALO very large Rayleigh lidar consisting of four collecting mirrors and two lasers, whose signals have been combined into one PMT detection channel. Having proved the feasibility and functionality of such a system to reach significantly higher altitudes, we will now proceed with additional detector channels that will be used to gather data from a larger altitude range than was previously possible by any other remote sensing systems. Additionally temporal and spatial resolution of the new system will allow for unprecedented measurements of phenomena throughout the middle atmosphere.

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