Observations with the Most Sensitive Rayleigh-Scatter Lidar

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Introduction

An atmospheric lidar (Light Detection And Ranging) system uses lasers to probe the atmosphere to gather information about particle densities, temperatures, wind velocities and various other properties of the atmosphere. The Rayleigh-scatter lidar system at the Atmospheric Lidar Observatory (ALO) is an example of an Atmospheric lidar system. Examples of basic observations made by atmospheric lidars, in general, can be seen in the figures below.

The ALO Rayleigh lidar transmits a 532 nm wavelength beam, the “Green Beam”, from a pulsed frequency-doubled Nd:YAG laser, vertically into the sky from the ALO site on the Utah State campus. Once in the atmosphere, the incident laser pulses scatter off atmospheric constituents and those that scatter back (at nearly a 180° angle) are then collected by a receiving telescope. From the mirrors, the scattered photons are then focused onto the photocathode of a photomultiplier tube (PMT), which, along with a multi-channel scaler, acts as the system’s detection channel. From there the returned photons are now digital signal pulses that an be recorded onto a PC.

What Has Been Measured with the ALO Rayleigh Lidar?

Mesospheric temperatures:
About 11 years worth of temperature data was gathered by the Rayleigh lidar team. This extensive data set can be added to and used to study temperature trends throughout the mesosphere where few instruments can measure.

Atmospheric Gravity Waves (AGWs):
AGWs are oscillations in the atmosphere that occur when an air parcel is lifted up by a buoyant force and restored by gravity. They cause ripples in clouds and control much of the dynamics of the middle atmosphere.

Atmospheric Lidar Systems Background

Lidar systems are analogous to Radar systems in that they both use electromagnetic radiation to induce different types of scattering off of particles. There are many different types of lidar systems that have applications from coastline mapping to detecting speeds of oncoming vehicles.

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Upgrades to the ALO Rayleigh Lidar System

The ALO Rayleigh lidar is currently being redesigned to greatly increase the sensitivity and altitude range from which data can be collected. The new lidar will have to take into account various forms of scattering and thus will have the more appropriate name- Rayleigh-Mie-Raman scatter lidar.

The first major upgrades to the system where made to increase the output power and the backscattered photon collection area. To do so, the group set up two Spectra Physics GCR series lasers in parallel to operate as one outgoing laser beam and constructed a large four-mirror telescope that has a combined receiving area of 4.9 m².

Having multiple detection channels and greatly increasing the system’s detection channels. From there, the photelectrons are then collected by a receiving mirror. Through a series of receiving optics, the returned photons are then directed onto the photocathode of a photomultiplier tube (PMT), which, along with a multi-channel scaler, acts as the system’s detection channel. From there the returned photons are now digital signal pulses that an be recorded onto a PC.

Effects on What We Measure

The resulting power of the two lasers in parallel will be about 42 W. Taking this, the augmented receiving area and the use of four detection channels as opposed to one will greatly improve the observable altitude range of the system. Previously, the Rayleigh lidar measured from 45-90 km, which encompasses most of the mesosphere. The new system will measure from approximately 16-122 km and will span the stratosphere, mesosphere and into the lower thermosphere.

RMR Lidar Altitude Ranges

<table>
<thead>
<tr>
<th>Original System</th>
<th>High Rayleigh</th>
<th>Mid Rayleigh</th>
<th>Low Rayleigh-Mie</th>
<th>Raman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Limit</td>
<td>40 km</td>
<td>65 km</td>
<td>40 km</td>
<td>15 km</td>
</tr>
<tr>
<td>Upper Limit</td>
<td>90 km</td>
<td>115 km</td>
<td>90 km</td>
<td>65 km</td>
</tr>
</tbody>
</table>

With the new RMR lidar system, researchers will be able to make similar observations with finer altitude resolutions. The altitude resolution in this plot to the left is 3 km and were integrated over an hour’s worth of photon collecting and the entire 45-90 km range of the system. The RMR system will be able to reduce these integration limits to roughly about 37.5 m and 1 hour, or 3 km and 1 minute over the entire 16-120 km altitude range. This means that one can adjust either the time resolution or the spatial resolution to be much finer. The spatial and temporal resolutions can also be adjusted simultaneously to achieve greater sensitivity, however these resolutions will in turn be somewhat larger than 37.5 m and 1 minute.