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The World's Most Sensitive Rayleigh-Scatter Lidar

Leda Sox
Utah State University

V. B. Wickwar
Utah State University

J P. Herron
Utah State University

Marcus J. Bingham
Utah State University

Lance W. Peterson
Utah State University

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Leda Sox[1], Vincent B. Wickwar[1], Joshua P. Herron[2], Marcus J. Bingham[1], Lance W. Petersen[1]
([1]Physics and CASS; [2]Space Dynamics Lab; Utah State University Logan, UT)

Introduction

A lidar (**LI**ght **D**etection **A**nd **R**anging) system uses lasers to probe the atmosphere. It makes use of Rayleigh scattering of light from atmospheric molecules to detect relative particle densities, absolute temperatures, and periodic phenomena such as gravity waves. The Rayleigh-scatter lidar system at Utah State University employs a pulsed Nd:YAG laser, frequency doubled to 532 nm, to measure such atmospheric properties, formerly only in the mesosphere. It is currently being upgraded to make it the most sensitive of its kind and to provide continuous coverage from the stratosphere to the lower thermosphere, 15-110 km.

ALO Background

Rayleigh lidar uses the time of flight of backscattered light pulses off of atmospheric particles to measure the altitude of the particles and the particle density in a given column of the atmosphere. Particle density data can then be reduced, assuming hydrostatic equilibrium and the ideal gas law, to determine temperature profiles.

Starting in 1993, the original Rayleigh lidar located at USU's Atmospheric Lidar Observatory (ALO) was comprised of a Spectra Physics 24-W GCR-6 Nd:YAG laser as a transmitter and a 44-cm Newtonian telescope as a receiver. Between 1996 and 2004 the GCR-6 was replaced with an 18-W GCR-5.

The original lidar had a Power-Aperture Product (PAP), a figure of merit to describe the sensitivity of a Rayleigh-scatter lidar, of 2.7 Wm^2 and was comparable to, but smaller than other Rayleigh lidars of its time.

Upgrades to the System

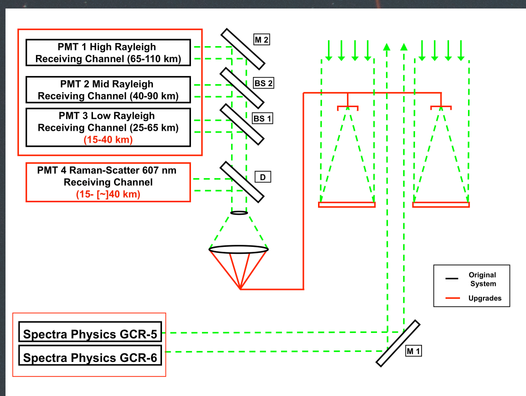

Fig. 1. Block Diagram of the ALO Rayleigh Lidar system

The system's transmitter has more than doubled in power by running two lasers in parallel, a Spectra Physics GCR-6 and GCR-5 (Fig. 1). The receiving area is more than 33 times greater with a 4-mirror telescope, each mirror being 1.25 m in diameter. The PAP, or sensitivity, is more than 70 times greater (Table 1).

In order to stretch the system's altitude range lower, we have to take into account both the Rayleigh and Mie scattering that the 532-nm beam undergoes from 15-25 km. To separate the Rayleigh and Mie a fourth detector channel will be added for Raman scatter from N_2.

Table 1. PAP Figure of Merits for Original and Improved Systems

System Setup	Laser Power	Receiving Aperture Area	Power-Aperture Product
With GCR-5 and 44-cm dia. Newtonian Telescope	18 W	0.15 m^2	2.7 Wm^2
With GCR-6 and 44-cm dia. Newtonian Telescope	24 W	0.15 m^2	3.7 Wm^2
With GCR-6 and GCR-5 and 4-mirror Telescope	42 W	4.91 m^2	206 Wm^2

Improvements in the Data

Larger altitude range: By increasing the PAP and by adding three more PMT detector channels, the system will be able to take data from more than twice the altitude range, from the lower stratosphere to the lower thermosphere, 15-110 km (Fig. 2).

Shorter temporal resolution: The more sensitive system will also allow us to integrate data over shorter time periods, which will enable us to observe rapidly changing phenomena such as short-period gravity waves.

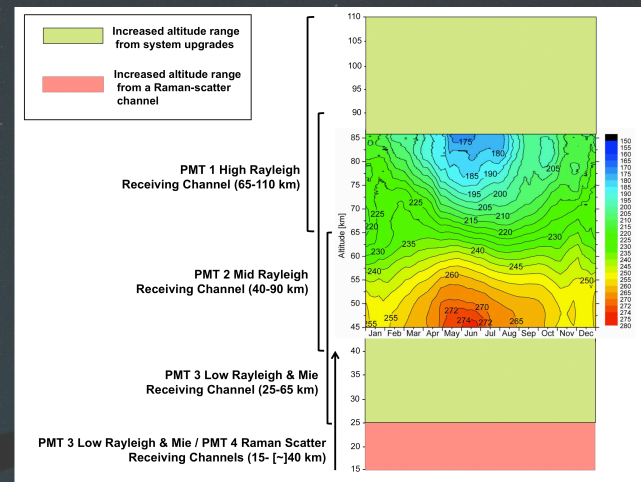

Fig. 2. Increased altitude range in the Rayleigh lidar's temperature profiles [Adapted from Herron (2007)]

Finer altitude resolution: The improved system will also let us change the altitude resolution from 3.0 km to 37.5 m. This will give a better picture of small-scale atmospheric phenomena such as noctilucent clouds (NLCs) and anomalous thin layers.

Future Research

These improvements to the system will allow us to investigate densities in the lower thermosphere; better high-altitude temperatures for examining the summer-winter mesopause transition and the conditions under which NLCs occur; gravity, tidal and planetary waves; coupling between atmospheric regions; and comparisons with other mesospheric instruments at USU and Bear Lake Observatory such as the Na lidar, OH temperature mapper, and meteor wind radar; and with satellite-borne instruments.

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