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SEASONAL TEMPERATURES FROM THE UPPER MESOSPHERE TO THE LOWER THERMOSPHERE OBTAINED WITH THE LARGE, ALO-USU, RAYLEIGH LIDAR

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Abstract: Observations have been made with the large, Rayleigh-scatter lidar at the Atmospheric Lidar Observatory at Utah State University (ALO-USU) 41.74°N, 111.81°W from summer 2014 to winter 2015. During this first operational year, the lidar acquired nearly 100 nights of observations between 70 and 115 km altitude, i.e., from the upper mesosphere, through the mesopause, and into the lower thermosphere. This was possible because of the large 4.9 m2 collecting area of the mirrors and the 42 W of 532 nm emission at 30 Hz. These two factors produce a figure of merit, the power-aperture-product, of 206 Wm⁴, making this one of the two most sensitive Rayleigh lidars in the world. The all-night data have been reduced to obtain relative densities and absolute temperatures. The temperatures are divided into three-month seasons, which are used to determine variations in altitude and in time. They clearly show significant and complex patterns. Additionally, they are compared to the original ALO-USU temperature climatology, which extends from 45 to 90 km, from 11 years of data from the original lidar and they are compared to the temperatures from the NRL-MSISE00 empirical model.

RESULTS

The large Rayleigh lidar at ALO-USU has extended observations from 90 km into the lower thermosphere at 115 km. (Close to our 120 km goal.)

Individual nights show waves with long vertical wavelengths (10–20 km) growing in amplitude from 10 to 20 – 30 K with increasing altitude.

Big temperature spikes occur, but are unexplained.

A 1st temperature min. occurs at 80–85 km in spring, summer, & fall.

• Grows from 178 K (summer mesopause) to rel. min. of 200 K (fall).

• In contrast, MSIS only has a minimum in this region in summer.

A 2nd temperature min. appears at 100 – 110 km in fall, winter, & spring.

• Grows from 190 K (winter mesopause) to 200 K in fall & spring.

• In contrast, MSIS has this minimum ~ 10 km lower & 10 K colder.

From 80 – 105 km the fall profile is “almost” constant at ~200 K.

• MSIS has positive slope above ~100 km in fall, winter, & spring.

• MSIS has negative slope below ~95 km in fall, winter, & spring.

Below 90 km, compare these new observations to ALO-USU climatology.

• Summer, fall & (spring) show remarkably good agreement.

• Winter has significant differences. (Because of the small number of nights, this may arise from geophysical variability.)

• Good agreement between the two at 90 km supports agreement of Rayleigh and Na temperatures.

• The new results are good since they start at least 20 km higher.

• Climatological results are based on Na temps. from CU [4].

• In fall and spring, temperatures are less than MSIS below 85 km.

BACKGROUND

Rayleigh-Scatter Lidar Temperature Retrieval

• Elastic scattering from N₂, O₂, Ar, and O.

• Obtain a backscatter profile.

• Convert that profile to a relative density profile.

• From that profile derive an absolute temperature profile [1]. Use:

  o Ideal gas law
  o Hydrostatic equilibrium
  o Top temperature

New, Large, Rayleigh-Scatter Lidar at ALO-USU

• System (65 times greater sensitivity than the original)

  o ~42 W of laser power at 532 nm and pulsed at 30 Hz.
  o Almost 5 m² mirror area (four 1.25 m diameter mirrors).

• Observations for this study:

  o 98 nights, 4 – 10 hrs/night.
  o 70 to ~115 km in the zenith

Figure 1. ALO-USU Rayleigh lidar telescope cage system. The telescope cage (cyan) is supported by the a 2-m-long mount (magenta). Two vertical laser beams (green) from the lab below go through the center of the cage. An example of the backscattered light (green) is seen focused by one of the mirrors (red) onto an optical fiber (orange) that takes the signal to the lab below and the detector system.

NEW HIGH-ALTITUDE DATA — 70 TO 115 KM

Data from 4 seasons, each having 9–48 nights of data:

• Averaged over 4–10 hrs/night.

• Smoothed over 3 km in altitude.

Temperatures derived with usual Rayleigh assumptions and composition correction [1,2]:

• Error from composition ± 2 K at highest altitudes.

• Maximum altitude is where signal-to-noise drops below 16.

Minimum alt. is just above where PMT signal becomes nonlinear.

Initial temperatures are from the NRL-MSIS00 (MSIS) model [3]

• Its “error” might affect the top 10 – 20 km.

Uncertainties are derived from Poisson statistics. For a given night:

• ± 1 K at 70 km

• ± 2 –12 K at top altitude

REFERENCES


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