Results from the Middle Atmosphere with the Rayleigh-Scatter Lidar at USU’s Atmospheric Lidar Observatory

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Results from the Middle Atmosphere with the Rayleigh-Scatter Lidar at USU’s Atmospheric Lidar Observatory

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Atmospheric Regions

Atmospheric regions are characterized by their temperature gradient, dT/dz, a illustrates in Figure 1. Starting from the ground, there is the

- Troposphere—negative gradient
- Stratosphere—positive gradient
- Mesosphere—negative gradient
- Thermosphere—positive gradient

The region 30–80 km (20–50 miles) was known as the gnosphere for a long time because of the difficulty of making measurements:

- Balloons and planes only go to 30 km (20 miles)
- Optical emissions occur above 80 km (50 miles)
- Radio techniques have a gap from 30 to 80 km
- Rockets work, but are expensive
- Satellites work, but do not provide a time history.

The development of the laser opened up research in this region. Since 1993 USU has been operating a Rayleigh-scatter lidar. More recently, ALO has been working on providing the densities in the middle atmosphere from 10 to 110 km. Most of the ALO observations are in the mesosphere.

Lidar

Lidar (Light Detection and Ranging) is analogous to radar, except that it uses visible, or near-visible, light instead of radio waves. Figure 2 shows the lidar starting with a laser (Light Amplification by Stimulated Emission of Radiation), which is analogous to a transmitter. The ALO laser is a frequency-doubled, solid-state, Nd:YAG laser emitting 18 W in the green, Figure 3.

These profiles provide the molecular number density for 30–100 km. At lower altitudes and, occasionally, near 83 km, these profiles are contaminated by scattering from aerosols. Absolute temperatures are then derived from these relative density profiles.

We will now show the lifetime density and temperature climatologies, the full, detailed temperature climatology is shown in Figure 8. The basic average is over 31 days and 3 km. To emphasize the major features, additional smoothing has been carried out over 14 days and 1.5 km. In addition to the features described above, a significant spring-fall asymmetry appears along with significant warming near spring and fall equinox at high altitudes.

Density Climatology

The relative densities are made absolute by normalizing to the MSISE00 empirical model at 45–48 km. The multiyear, annual mean density (D0) is found by averaging the 12 multiyear, monthly mean densities (Dmn), Figure 4. It decreases by 10% by 100 km, reaching what would be a good vacuum in the laboratory. To show monthly variations, (Dmn–D0)/D0, the fractional difference relative to the multiyear average, is plotted vs altitude in Figure 5. The overall climatology is shown in Figure 6. The major annual variability, almost ±20%, occurs near 70 km with a summer maximum and winter minimum. Another minimum occurs at 90–95 km in summer.

Global Change

In addition to providing the density and temperature climatologies, the extensive ALO dataset provides information related to global change. This shows up in temperature trends and in the detection of notoccluent clouds (NLCs). While the build up of greenhouse gases, of which CO2 is the most important, is expected to lead to tropospheric heating, model calculations indicate that it should lead to mesospheric cooling. The concept is that energy carried by upward infrared radiation from these gases will be lost to space, thereby acting like a refrigerator. (This leaves out other possible effects such as changes in the atmospheric circulation and the impact of tropospheric and stratospheric changes.) A small linear temperature trend has been sought in the ALO data. It has to be separated from comparable and larger variations arising from the sum and differences in the solar cycle. The results are shown by the solid red line in Figure 8. The dashed lines show the 95% confidence limits.

In addition to increases in greenhouse gases, there is a significant increase in methane CH4. Through a combination of dissociation by solar radiation (photolysis), oxidation, and chemical reactions, this leads to an increase in water vapor in the upper mesosphere.

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