12-2004

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Rayleigh-Lidar Observations of Mesospheric Mid-latitude Density Climatology above Utah State University

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Abstract. Data from Rayleigh lidars have been used extensively to derive temperatures in the mesospheric region of the atmosphere. However, these data have not been used extensively in a similar way to derive neutral densities. We report on one such mid-latitude, density climatology between 45 and ~90 km, based on nearly 600 good nights of observations carried out since 1993 at the Atmospheric Lidar Observatory (ALO) at Utah State University (41.7°N 111.8°W). They produce relative density profiles that are then normalized at 45 km to an empirical model, in this case the MSISe00 model. Despite this normalization, significant differences are found between the observations and the model starting as low as 50 km. For instance, the lower mesosphere is denser than the model in summer and less dense in winter. In contrast, the upper mesosphere is denser near the equinoxes and less dense at other times. Differences between the climatology and the model reach ±11%. The normalized observations show a large seasonal variation, with the summer densities in the 65-75 km region being approximately 55% greater than the winter densities. At both lower and higher altitudes, the seasonal variation is less.

INTRODUCTION

The absolute neutral densities in the middle atmosphere, especially between the stratosphere and the lower thermosphere, are important for a number of reasons. These include:

- The reference for minor constituents whose concentrations are given as so many parts per million or per billion.
- The concentrations available for chemical reactions giving rise to heating or airglow emissions.
- The mass that rockets, the Shuttles, or future hypersonic airliners will pass through.
- The mass used for aero breaking of orbital transfer vehicles.

Yet the neutral densities are not well known. Below 30 km and above ~170 km, measurements are regularly made by balloons, satellite-borne accelerometers, measuring satellite drag, or are derived from incoherent scatter radar. Between 30 and ~170 km, however, measurements are more difficult to make. Most of the observational information has been brought together into empirical models like NRL-MSISE00.

CONCLUSIONS

A mesospheric density climatology has been derived from 10 years of ALO Rayleigh-scatter lidar data. Here, it is normalized to MSISe00 absolute densities at 45 km. In general the following points can be made:

- The averaged 41-night density climatology shows differences from MSISe00 of up to 55% in the upper mesosphere.
- The summer densities in the upper mesosphere of the 41-night climatology are 53% larger than the winter densities.
- In particular, there is considerable annual variability in the 41-night climatology: 19% depletions in winter and 24% enhancements in summer within the middle region compared to the annual MSISe00 value.
- There is a 25% depletion in the climatology at ~90 km during the summer months. The depletion is 7 km lower than MSISe00.
- Also of note is the sudden density enhancement between 70 and 80 km in late fall.

While the MSISe00 model is a good approximation to the real geophysical structure of the mesosphere, this comparison shows that at least at mid latitudes there are significant differences with observations. In particular, the density structures (depletion and enhancements) occur at a significantly lower altitude than in the model. Most occur earlier, but the winter depletion starts later. A fall/winter enhancement occurs between 70 and 80 km that is not in the model. In the future, the densities could be examined further by normalizing the ALO relative densities to other purported sources of absolute density.

ACKNOWLEDGEMENTS

We gratefully thank Joshua Herron for his work with the raw data and the many people (mostly undergraduates) who made the observations. The MSISe00 model is supported by the Naval Research Laboratory. This project was in part supported by NSF grant ATM-0123414.

REFERENCES