4-2009

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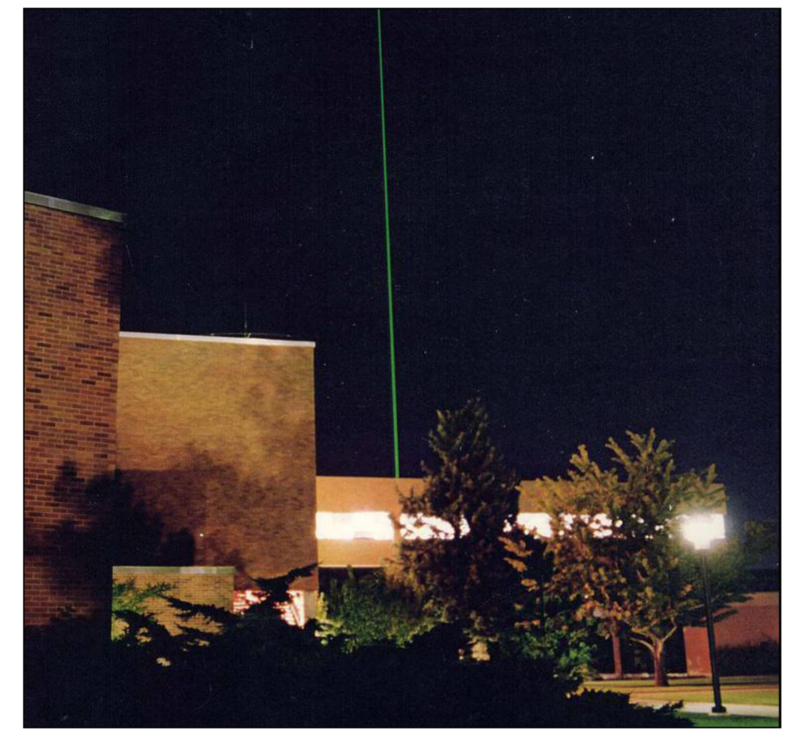
Abstract

Atmospheric structures have been observed in the Rayleigh lidar data acquired between 1993 and 2004 at Utah State University (USU). The observations pertain to the density and temperature in the mesosphere between 45 and 90 km altitude. The structures referred to arise from monochromatic Atmospheric Gravity Waves (AGWs). Previous analysis of these data have searched for and found a spectrum with a peak in the vertical wavelength 12–16 km. It has been suggested by other researchers using other types of data that there may be another peak in the spectrum at shorter wavelengths. For this study the lidar data were re-analyzed to search for such waves. To do this, the altitude resolution was reduced from 3 km to 600 m. This enabled the shortest wavelength AGW that can be examined to be reduced from 6 km to ~1.2 km, thereby significantly extending the spectrum investigated. Two additional peaks in the spectrum were found at 1.25–1.75 and 3.0–4.0 km.



LIDAR

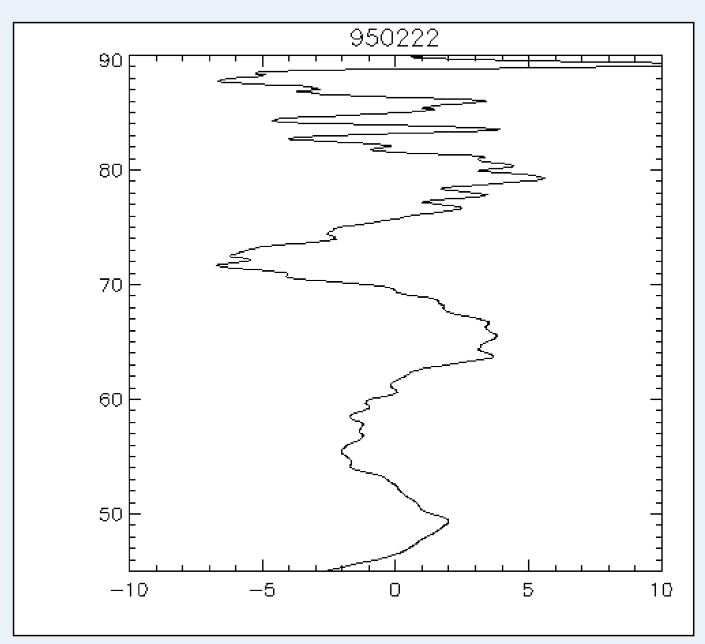
Light Detection and Ranging of Atmospheric Gravity Waves

Theory & Methods

The individual density profiles containing observed mesospheric data are processed into profiles of relative density, showing density perturbations versus altitude. Periodic structures were identified and measured. Three general categories of wavelengths are demarcated, namely longer, medium, and shorter wavelengths. The shorter wavelength waves were measured in the 50–60 and 60–70 km ranges to determine if there was an apparent altitude dependence on the wavelength of small-scale waves. The measured wavelength frequency counts were binned versus wavelength to determine if a dominant wavelength existed within each subspectrum. The distribution of the long wavelengths is compared to previous studies of the same data as a check of data processing methods. The results of the binning process showed a small dominant range of wavelengths in each of the three ranges.

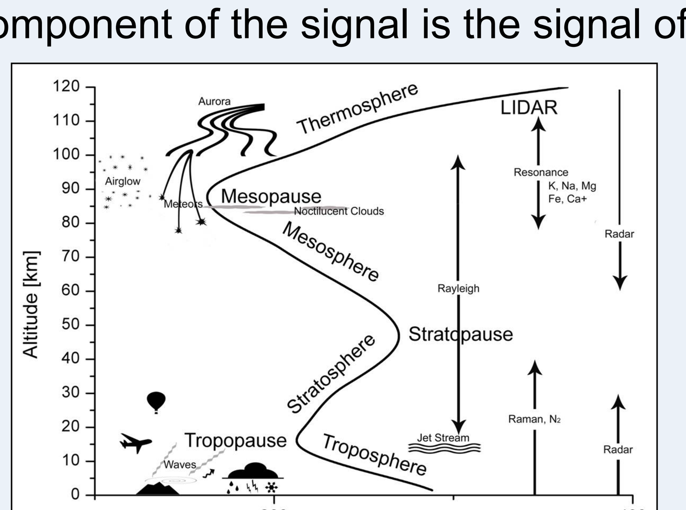
Introduction

Rayleigh-scatter lidar data from the Atmospheric Lidar Observatory (ALO) at USU's Center for Atmospheric and Space Sciences at 41.74º N, 111.81º W, 1.47 km above sea level are used to study dynamic properties of the mesosphere (45 to 90 km). This region is a difficult part of earth's atmosphere to observe as it is above the aircraft accessible stratosphere and below airglow emissions and radar backscatter. In situ rocket observations are occasionally made, but they are expensive. ALO's lidar is a 532-nm laser that scatters light off particles at a vertical resolution of 37.5 meters and a temporal resolution of 2 minutes during 4-10 hour nights of observation. Photons returned through a 44-cm Newtonian telescope are mechanically chopped, optically filtered, detected with a gated PMT and converted to a digital signal. Background light levels and thermionic noise are measured at 120–150 km and subtracted from the signal. The remaining component of the signal is the signal of interest.

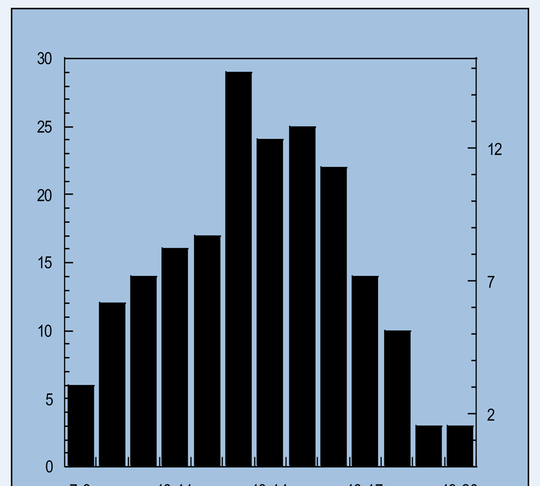


Fluctuations of wavelength are plotted with altitude on the vertical axis and percent relative density fluctuation on the horizontal axis.

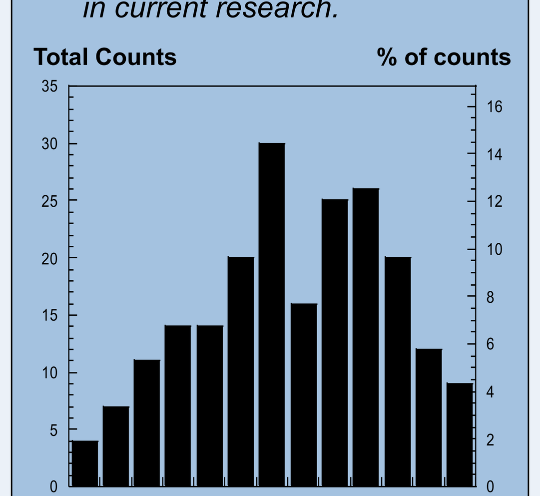
Relative density fluctuations are described in terms of vertical wavelength, period, amplitude, and vertical phase speed. One-hour and all-night integrations of density fluctuations display wave behavior measured and characterized by theoretical models of perturbation theory and thermodynamics. The methods of data reduction smooth noise and render monochromatic wave structures more clearly. The AGWs have vertical wavelengths previously measured with lidars in the 6–19 km range with a dominant peak at 12–16 km, and shorter wavelengths suggested by other research to have peaks in the distribution at specific wavelengths.



Data Analysis & Preliminary Results



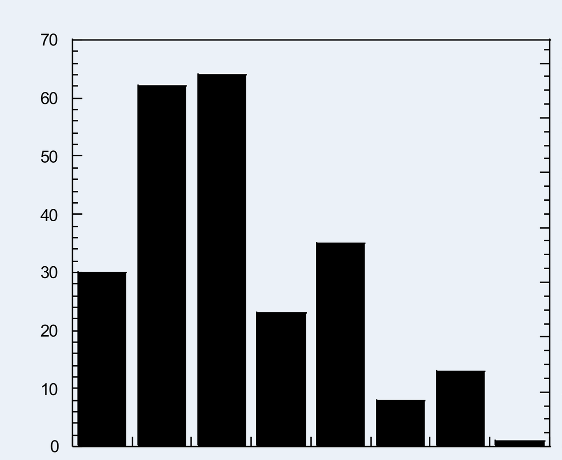
Large scale AGWs observed in current research.



Large scale AGW wavelengths observed in Kafle and Wickwar research using the same data.

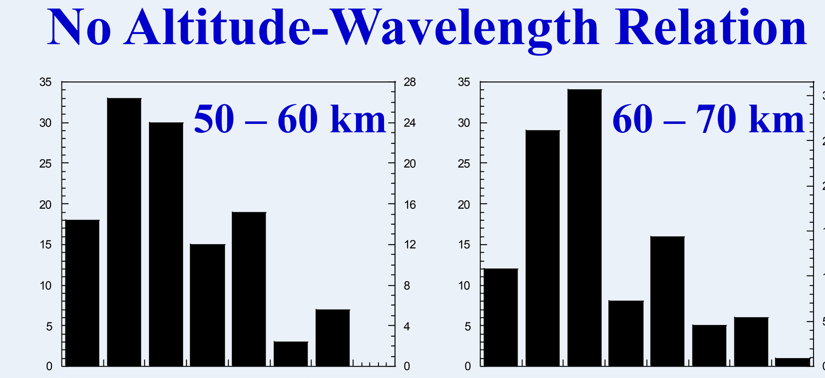
Wavelength determination by visual method correlates to results of work in progress by Kafle & Wickwar suggesting a dominant wavelength of 12 to 15 km within the distribution.

Small-scale structure

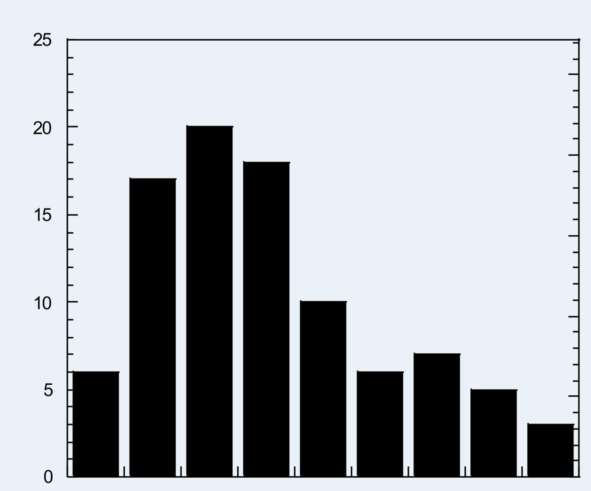


Small scale AGWs observed suggest that a preferred wavelength in the 1.25 to 1.75 km range may exist. Integrations in the data reduction techniques theoretically allow wavelengths above 1.2 km, and there are many structures of such magnitude observed.

No Altitude-Wavelength Relation



With regard to small scale AGWs, there appears to be strong altitude-wavelength relation. The prevalent wavelengths observed were very similar in counts and count percentages throughout large regions of the mesosphere, as the distribution of the peak is not shifted.



Preliminary data suggests that there may be another prevalent wavelength around 3-4 km. Further research will allow the specification of which wavelengths nature prefers.

Continued Research

To confirm that the measurement methods used in this study adequately correspond to the theoretical construct, a wider variety of integrations on specific observing dates should be employed. Wave mechanics may confirm visual determinations. A larger sample of nights will be used (on the order of 800 nights, as opposed to this sample of 100). Hourly integrations will show phase shifts to properly determine wave speed and energy. Ultimately we seek to understand the mechanisms behind the observational data and reasons we observe dominant wavelengths within the atmospheric gravity wave spectrum.