Investigation of vertical wavenumber and frequency and spectra of gravity wave motions using vertical wind measurements at Boulder.

Anthony Lima[1], Cao Chen[1], Dr. Xinzhao Chu[1]

[1]*University of Colorado at Boulder, 216 UCB CIRES, Boulder, CO 80309 Email: Anthony.Lima@colorado.edu*

Abstract

Vertical wind measurements made with the Sodium Lidar in Boulder, Colorado were used to evaluate the frequency and vertical wavenumber spectra in the mesosphere and lower thermosphere (MLT) region. The spectral characteristics measured in this region can be used to gather insights into the mechanisms for wave damping and dissipation in the upper atmosphere. The observed spectral shape of the vertical wind perturbations can be used to test whether the diffusive filtering plays a crucial role in gravity wave propagation. Measurements can either validate the existing theory or call for a new theory to explain the dissipation of gravity waves.

Background

Despite the numerous theoretical and observational studies that aim to advance our understanding of gravity waves (GWs), there is still considerable disagreement about the dominant wave saturation and dissipation processes. Consequently, gravity wave effects have been poorly parameterized in existing global circulation models. Currently, several proposed mechanisms that dominate gravity wave saturation and dissipation processes include:

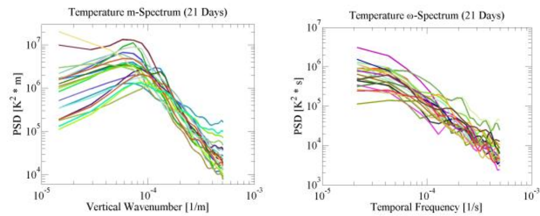
- shear and convective instabilities (LIT)
- non-linear effects of wave-wave interaction (SCT)
- scale-dependent diffusion (DDT)
- diffusion filtering theory (DFT)

Gardner (1996) compared the different theories and compiled a table of predictions on the spectra of the horizontal and vertical winds. Some of the theories are founded on the assumption that the vertical wind and temporal motions (m, ω) are separable. In this study, we make high resolution measurements of the vertical wind (w) and temperature (T) in the mesosphere and lower thermosphere which are used to calculate the vertical (m) and temporal (ω) spectra.

This study aims to assess the accuracy of various GW saturation and dissipation theories by comparing them to lidar data.

Numerical Methods

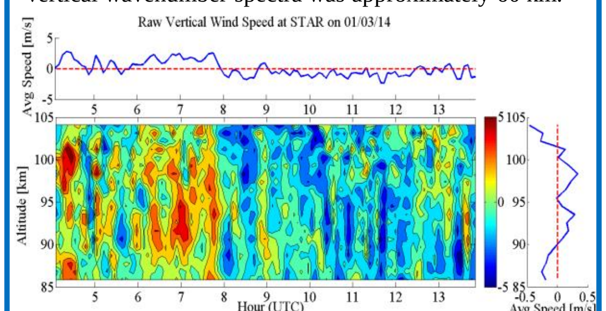
- Remove outliers and bad data
- Remove means by time and altitude
- Detrend data by time and altitude
- For each altitude bin and time bin, pre-whiten and post-color using 2nd order AR model
- Calculate periodogram to find PSD
- Average PSD over all altitudes and times



- Average spectra over all 21 days and fit power-law model →

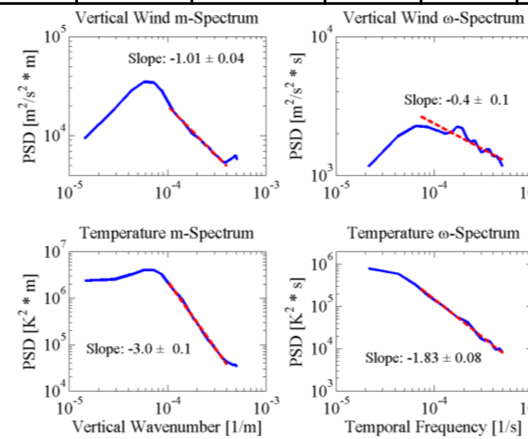
Data

233 hours of observations over 21 nights from August, 2013 to January 2014 from the Student Training and Atmospheric Research (STAR) Sodium Doppler Lidar North of Boulder, CO. Each night has 11 hours of consecutive data on average. The shortest night of data is approximately 7 hours long and subsequently the longest resolvable wave period in the frequency spectra was 14 hours. Data was used around the Sodium Layer peak: 85 to 105 km. The longest resolvable wavelength in the vertical wavenumber spectra was approximately 60 km.



Observed Spectra

Data Set	Spectrum	Spectral Index	LIT (p = 2)	DFT (p = 2)	SCT
Temperature	m	-3.0 ± 0.1	-3	-3	-3
	ω	-1.83 ± 0.08	-p	-p	-2
Vertical Wind	m	-1.01 ± 0.04	-3	5-2p	1
	ω	-0.4 ± 0.1	N/A	0	0



Conclusions and Future Work

The results found in this study agree strongly with the findings in Gardner et. al. 1998 which used Na Lidar data from the Starfire Optical Range.

- Temperature (m, ω) spectra agree with established theory.
- Vertical Wind (m, ω) spectra are significantly shallower than the temperature and horizontal wind. Suggesting that the spectra are not separable.

We would like to compare our results with a larger and more modern group of GW saturation theories. We want to do further investigation into the vertical wind ω-spectrum discrepancy. It has been suggested that Doppler shifts and/or critical layer effects could cause the shallower spectrum. Finally, the study would greatly benefit from simultaneous measurements of horizontal wind speeds which we are currently working on measuring.