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Winter Climatology of Short-Period Mesospheric Gravity Waves Over Alaska

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Introduction

Momentum deposition by short-period (<1 h) gravity waves is known to play a major role in the global circulation in the mesospheric (MLT) region (~80-100 km). Observations of these waves over the Arctic region, however, are few and their impact on the Arctic MLT region is of high interest, but has yet to be determined.

The Mesospheric Airglow Imaging and Dynamics (MAID) project was initiated in January 2011 to investigate short-period gravity wave dynamics over central Alaska.

Maid is a collaborative project between Utah Valley University (UVU) (Principle Investigator K. Nielsen), Utah State University (USU), and the University of Alaska, Fairbanks (UAF). The project combines a multi-wavelength airglow imager with a co-located Poker Flat Research Range (PFRR), with additional campaign data from the Poker Flat Incoherent Scatter Radar (PFISR) and the National Inst. of Information and Communications Technology (NICT) MP radar.

The main goals of this program are:
- Establish a long-term climatology of short-period gravity waves observed in the Arctic MLT region.
- Determine dominant source regions and potential sources of the observed waves.
- Investigate the impact of large-scale waves (tidal and planetary wave motions) on the short-period wave field.
- Perform quantitative comparison between Arctic and Antarctic winter-time wave dynamics.

In this poster, we focus on quantifying the climatology of short-period gravity waves during two winter seasons (2011-2012) over central Alaska.

Observations and Data Analysis

Measurements of short-period quasi-monochromatic gravity wave events were made from PFRR, Alaska (65°N, 147°W) using a Keoko flety all-sky, multi-wavelength CID imaging system. The imager remotely senses several faint airglow emissions primarily in the MLT region.

Figure 1 shows an example of an event in the OH emission (~87 km altitude) exhibiting extensive band structure.

Raw images were calibrated using the star field. The stars were removed and the image was then transformed to uniformly spaced geographic coordinates, through a process commonly known as unbarping, and was rotated onto a 500 x 500 km geographic grid as shown in figure 1a. Using images obtained sequentially in time, an unambiguous 3-D spectral analysis (Coble et al., 1995; Gardner et al., 1998) was performed on a selected region of interest to determine the horizontal wave parameters as shown in figure 1c.

Figure 2: Unwarped images of an isolated peak (c) shown in the observed event. The reported westward wave propagation is consistent with previous results at 75°N. The relative locations of these high-latitude sites are indicated in figure 6.

Comparisons with other High Latitude Measurements

In this section we compare our results from PFRR (65°N) with other recent and ongoing high-latitude measurements of short-period gravity waves in the Arctic at: Resolute Bay (74°N) (Suzuki et al., 2009), Svalbard (78°N) (Dyrdal et al., 2012), and ALOMAR (69°N) in Antarctica at Rothera (Nielsen, 2007). The relative locations of these high-latitude sites are indicated in figure 6.

Comparison of observed wave parameters at PFRR and four other high-latitude sites, illustrating the similarity of the wave characteristics. These distributions are also similar to short-period events measured at mid and low latitudes, indicating their global nature.

Alaska 2011-2012 Results

The MAID imager runs continuously during the winter months to gain maximum data. Our observations since January 2011 have yielded 1249 hours of data with 699 hours of clear sky and 279 hours of good wave events.

Figure 3 summarizes the results of the image analysis in a standard form of histogram plots of the observed horizontal, vertical and zonal wave speed, and period. The data are plotted for the two winter seasons (January to March) to remove the observed short-period wave events. The horizontal wavelengths range from 15-47 km, horizontal phase speeds range from 10 to 70 m/s yielding short observed wave periods typically 10-15 mins. These results are in good agreement with recent and other ongoing measurements at high latitudes as discussed below.

Figure 4a-c plots the observed horizontal wave parameters separately for January, February, and March (red 2011 and blue 2012). The plots show significant variability in wave directionality from month to month during the two winter seasons, and the observed variations in directionality are not consistent from year to year. Some of this variability might be due to the relatively low number of events per month (~18). However, the summary plot in figure 4d clearly shows dominant eastward wave propagation (70%) with preference to the northeast and southeast, and only limited westward propagation (30%).

Figure 5 plots the measured phase velocities of the individual events for each month for the two winter seasons. During 2011, the number of events (red) with high phase speeds (typically >50 m/s) grew from January to March, with a preference for northeasterward propagation in January, which evolved to strong northeast and southeastward preference for February and March. In contrast, the wave events in 2012 (blue) exhibited relatively low phase speeds (~20-40 m/s) in January which increased significantly in February but with no clear preferential propagation directions throughout the winter.

Figure 6d summarizes the phase velocities for the two years and clearly shows that 2011 was a more ‘‘active’’ year with high velocity wave propagation to the northeast and southeast, while 2012 the velocities were generally lower and isotropic in their propagation.

Comparisons of observed wave parameters at PFRR and four other high-latitude sites, illustrating the similarity of the wave characteristics. These distributions are also similar to short-period events measured at mid and low latitudes, indicating their global nature.

Summary so far...

- Our determination of strong eastward propagation during the winter is most intriguing as it differs strongly from previous results to date.
- The reported eastward wave propagation is attributed to critical layer filtering of the upward propagating gravity waves by the background wind field.
- Importantly, the PFRR eastward propagating waves exhibited relatively low phase speeds suggesting they were not restricted by the critical layer filtering.
- Project work: Further investigation of these high speed events, their potential sources, and collaborative measurements with PFISR to study their penetration into the lower thermosphere.

Acknowledgments

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References


