Winter Climatology of Short-Period Polar Mesospheric Gravity Waves Observed Over Poker Flat Research Range, Alaska (65 N, 147 W)

Michael R. Negale, Utah State University
Kim Nielsen, Utah Valley University
Mike J. Taylor, Utah State University
Dominique Pautet, Utah State University
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Michael R. Negale¹, K. Nielsen², M. J. Taylor¹, P. D. Pautet¹
¹Center for Atmospheric and Space Sciences, Utah State University, ²Department of Physics, Utah Valley University

Introduction
Momentum deposition by short-period (<1 h) gravity waves is known to play a major role in the global circulation in the mesosphere and lower thermosphere (MLT) region (~80-100 km), e.g. Fritts and Alexander, 2003). Observations of these waves over the Arctic region 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.

The main goals of this project are to:
- 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 (tides and planetary waves) on the short-period wave field.
- Perform quantitative comparison between Arctic and Antarctic winter-time 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 were made from Poker Flat Research Range (PFRR, Alaska (65° N, 147° W)) using a Koo Koo sky all-sky, multi-wavelength CCD imager system. The imager remotely senses several faint airglow emissions in the MLT region. Figure 1a shows an example of an event in the OH emission (~87 km altitude) exhibiting extensive band structure. The background star field was used to calibrate raw images. After calibration, the stars were removed and the imaged was transformed to uniformly spaced geographic coordinates (commonly known as unwrapping), and mapped onto a 500 x 500 km geographic grid as shown in Figure 1b. Images obtained sequentially in time were used in the unambiguous 3D spectral analysis (Coble et al., 1998; Gardner et al., 1996), which give the horizontal wave parameters as shown in Figure 1c.

Critical Level Filtering
To investigate the eastward wave motion at PFRR we consider the effects of critical level filtering. Critical level filtering occurs when the intrinsic wave speed is less than or equal to the background wind in the direction of the wave. Most gravity waves are assumed to be tropospheric in origin and propagate up into the MLT region. If the intrinsic phase speed of the wave matches, or is less than, the wind speed in the direction of the wave, the wave will not be able to propagate up into the MLT region (Taylor et al., 1993). There were on-going anomalies in the needlepoint measurements made during the PFRR wind observations at PFRR, however these were from the Horizontal Wind Model 2007 (HWMO7) and NASA’s Modern Era Retrospective Analysis for Research and Applications (MERRA) were used as shown in Figure 8. Figure 9 plots blocking diagrams using MERRA (orange) and HWMO7 (pink) monthly averaged winds for 2011 and 2012 as well as observed phase speeds for individual events (blue dots). Figure 9 shows the summary blocking diagram for 2011 and 2012 combined. Most of the observed phase speeds were well outside the blocking regions, indicating the observed wave events were not affected by critical level filtering.

Figure 3 summarizes the results of the image analysis in standard histogram plots of the modal horizontal phase speed, wavelength, and periods. The data are plotted for the two winter seasons combined together yielding 117 short-period wave events. Horizontal wavelengths range from 15-47 km, phase speeds range from 10 to >70 m/s with periods of 10-15 mins.

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., 2008), Svalbard (78° N) (Dyrlund et al., 2012), and ALOMAR (63° N). The relative locations of these high-latitude sites are indicated in Figure 5. Figure 6 illustrates the similarity of the wave characteristics, which are also similar to short-period events measured at mid- and low-latitudes, indicating their global nature. Figure 7 shows the comparisons of the observed wave directionality of the five high-latitude sites. The reported measurements at the comparison sites are all dominated by westward motion. In stark contrast, PFRR shows clear eastward propagation.

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 westward wave propagation is attributed to critical level filtering of the upward propagating gravity waves by the background wind field.
- Importantly, the PFRR eastward propagating waves exhibited relatively high phase speeds suggesting they were not restricted by the critical level filtering.
- Future work: Further investigation of these high speed events, their potential sources, and collaborative measurements with the Poker Flat Incoherent Scatter Radar to study their penetration into the lower thermosphere.

Figure 2: Daily averaged wave speed for mid-latitude sites for each month in 2011 and 2012.

PFRR 2011-2012 Results

Poker Flat Research Range

Figure 5: Comparison of observed wave parameters at PFRR and four other high-latitude sites.

Figure 6: Comparison of observed wave parameters at PFRR and four other high-latitude sites.

Figure 7: (a) Resolute Bay, (b) Svalbard, (c) ALOMAR, (d) PFRR

Comparisons

Figure 8: Observed phase speeds for individual events (blue dots), blocking diagrams using MERRA (red) and HWMO7 (pink) for each month in 2011 and 2012.

Figure 9: Observed phase speeds for individual events (blue dots), blocking diagrams using MERRA (red) and HWMO7 (pink) for each month in 2011 and 2012.

Critical Level Filtering

Figure 10: Raw OH image containing wave structures.

Figure 11: Unwrapped image with region of interest.

Figure 12: Observed phase speeds for individual events (blue dots), blocking diagrams using MERRA (red) and HWMO7 (pink) for each month in 2011 and 2012.

Figure 13: Observed phase speeds for individual events (blue dots), blocking diagrams using MERRA (red) and HWMO7 (pink) for each month in 2011 and 2012.

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References

Figure 14: Regional HARD map of 1985, 1986, 2012.

Figure 15: Regional HARD map of 1985, 1986, 2012.

Figure 16: Regional HARD map of 1985, 1986, 2012.

Figure 17: Regional HARD map of 1985, 1986, 2012.

Figure 18: Regional HARD map of 1985, 1986, 2012.

Figure 19: Regional HARD map of 1985, 1986, 2012.

Figure 20: Regional HARD map of 1985, 1986, 2012.

Figure 21: Regional HARD map of 1985, 1986, 2012.