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

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Introduction

Momentum deposition by short-period (<1 hr) 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.

MAID is a collaborative project between Utah Valley University (UVU) (Principle Investigator Kim Nielsen), Utah State University (USU), and the University of Alaska, Fairbanks (UAF).

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 Keo Sentry all-sky, multi-wavelength CCD imaging 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 image was transformed to uniformly spaced geographic coordinates (commonly known as unwarping), 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 3-D spectral analysis (*Coble et al.*, 1998; *Gardner et al.*, 1996), which give the horizontal wave parameters as shown in Figure 1c.

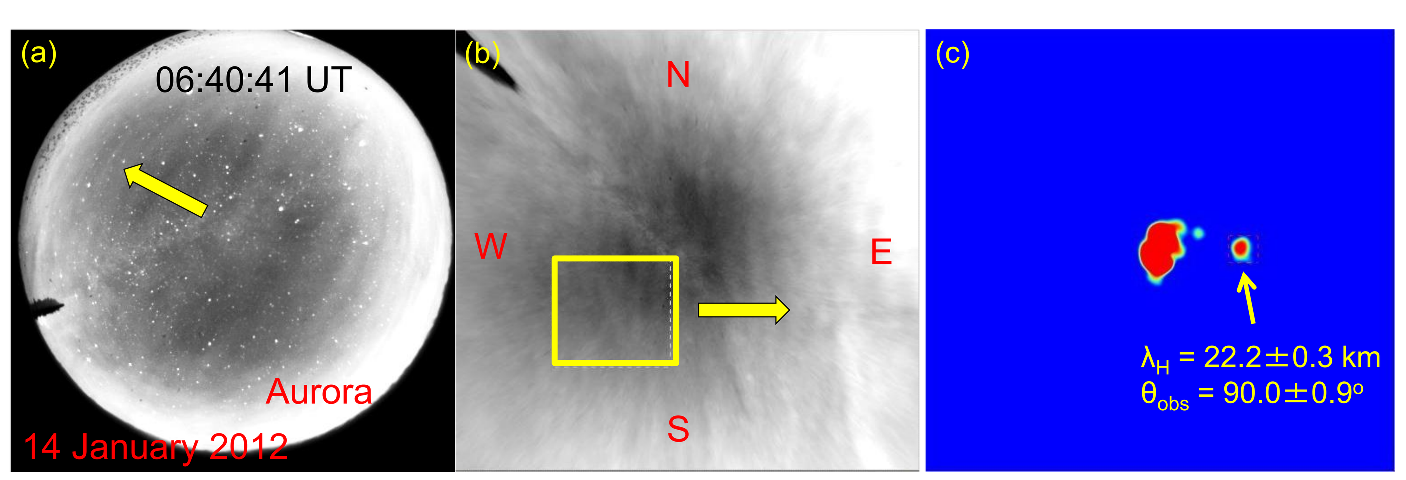

Figure 1: (a) Raw OH image containing wave structure. (b) Unwarped rotated image with region of interest. (c) Unambiguous spectrum technique showing isolated peak corresponding to the observed wave event.

Optical measurements of gravity waves in the Arctic MLT region are difficult to obtain due to limited observing conditions and the frequent presence of aurora which overpower the fainter airglow wave structures as seen in Figure 1a. The MAID imager runs continuously during the winter months, and have yielded 1249 hours of data with 609 hours of clear sky and 279 hours of good wave events. Figure 2 summarizes the monthly distributions of our observations for 2011 and 2012.

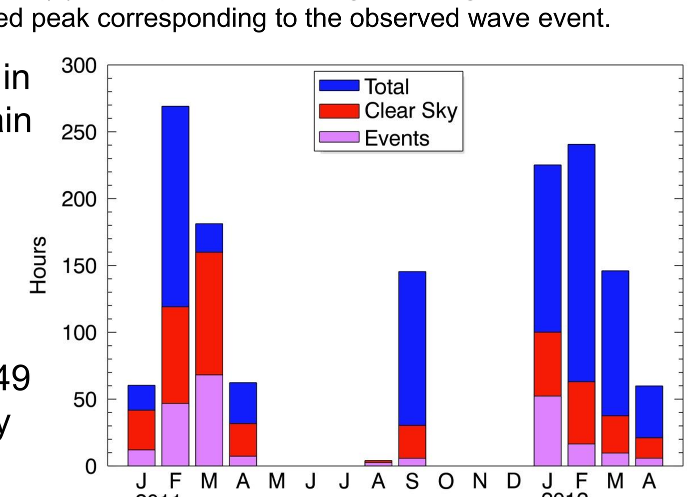

Figure 2: Monthly sampling distribution for 2011 and 2012. Blue bars correspond to total observation time, red bars to total clear observation times, and pink bars to total event hours.

PFRR 2011-2012 Results

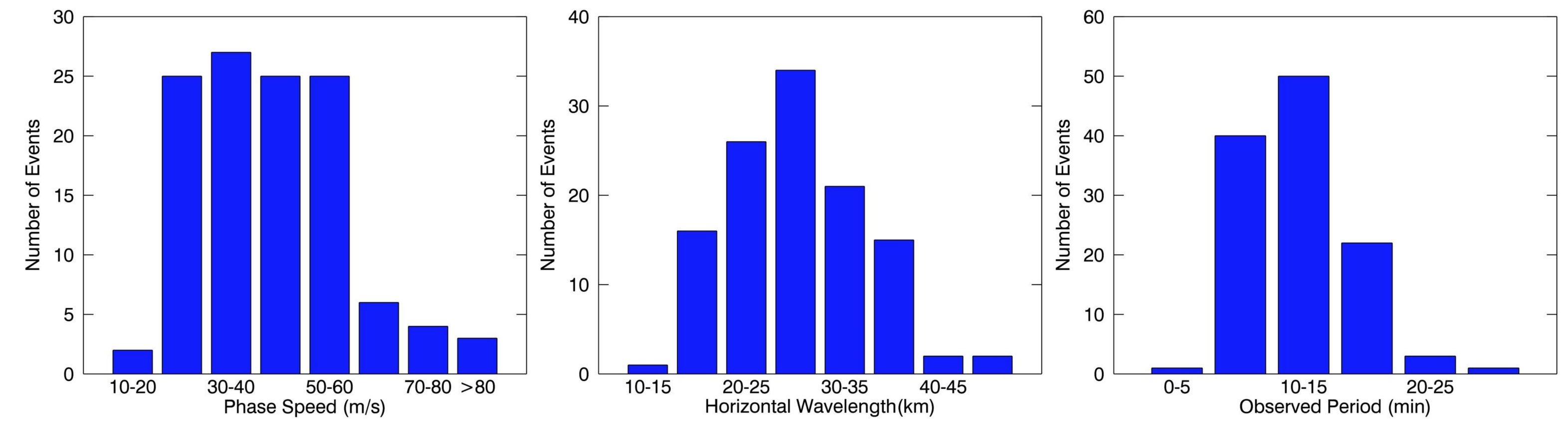

Figure 3: Histogram plots showing combined 2011 and 2012 winter-time distributions of the observed wave parameters.

Figure 3 summarizes the results of the image analysis in standard histogram plots of the observed horizontal phase speeds, wavelengths, 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.

Figure 4 plots the observed direction of motion of the 117 wave events separately for January (a), February (b), and March (c) (blue 2011 and red 2012). The plots show significant variability from month to month, which are not consistent from year to year. Some of this variability might be due to relatively low number of events per month (~18). However, the summary plot in Figure 4d clearly shows dominant eastward wave propagation (70%) and limited westward propagation (30%).

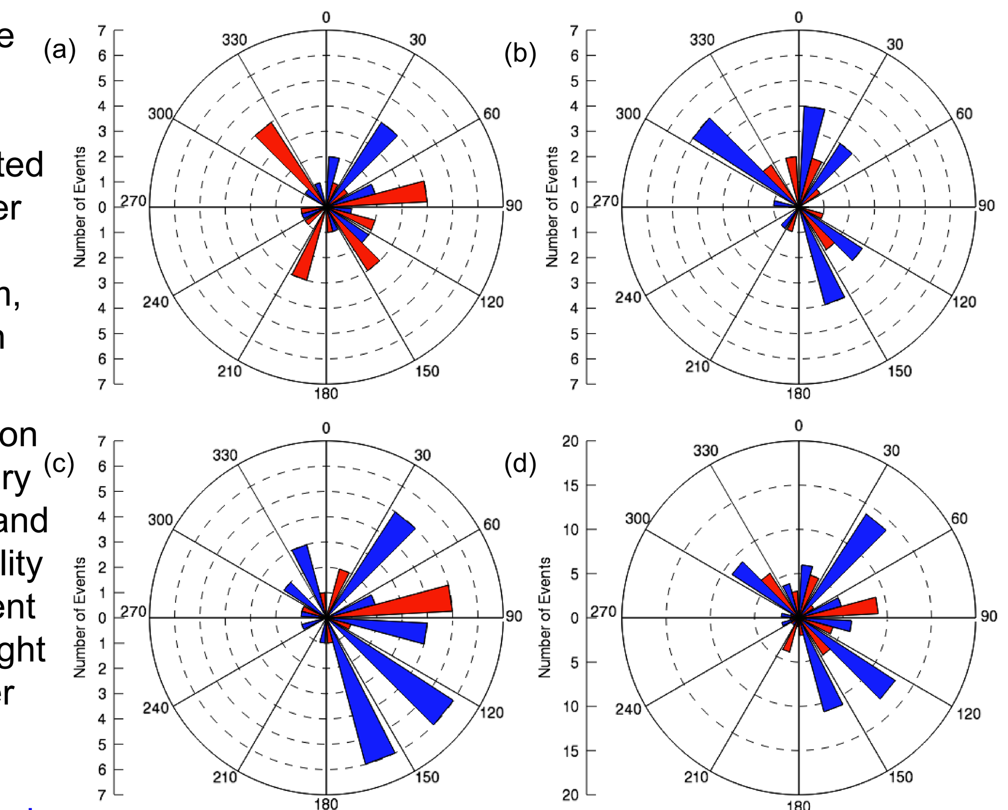

Figure 4: Polar plots summarizing the number of wave events vs. direction of propagation.

Comparisons

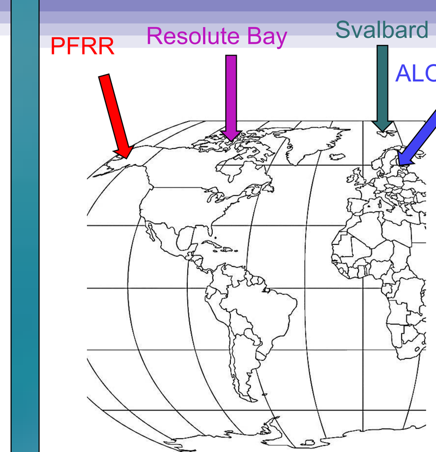

Figure 5: Comparison sites.

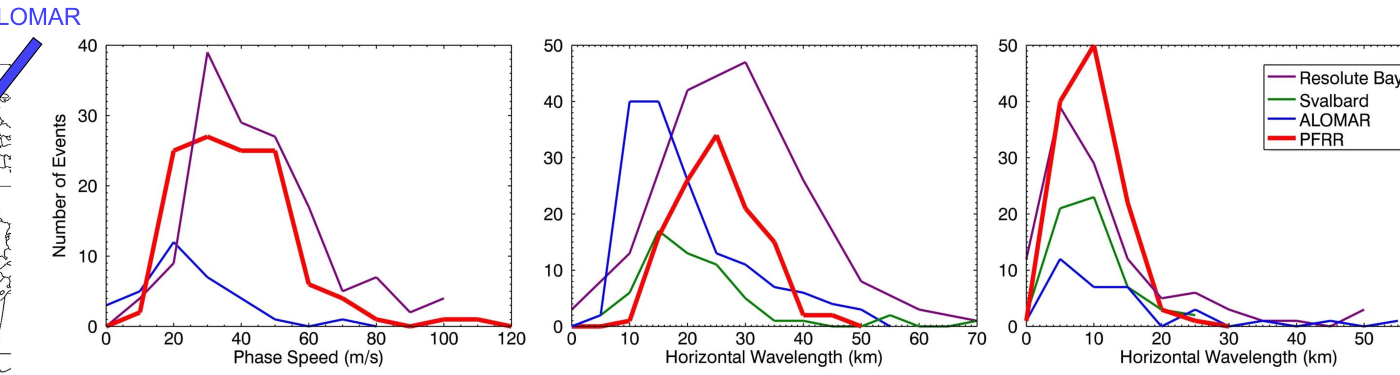

Figure 6: Comparison of observed wave parameters at PFRR and four other high-latitude sites.

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) (*Dyrland et al.*, 2012), and ALOMAR (69° 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.

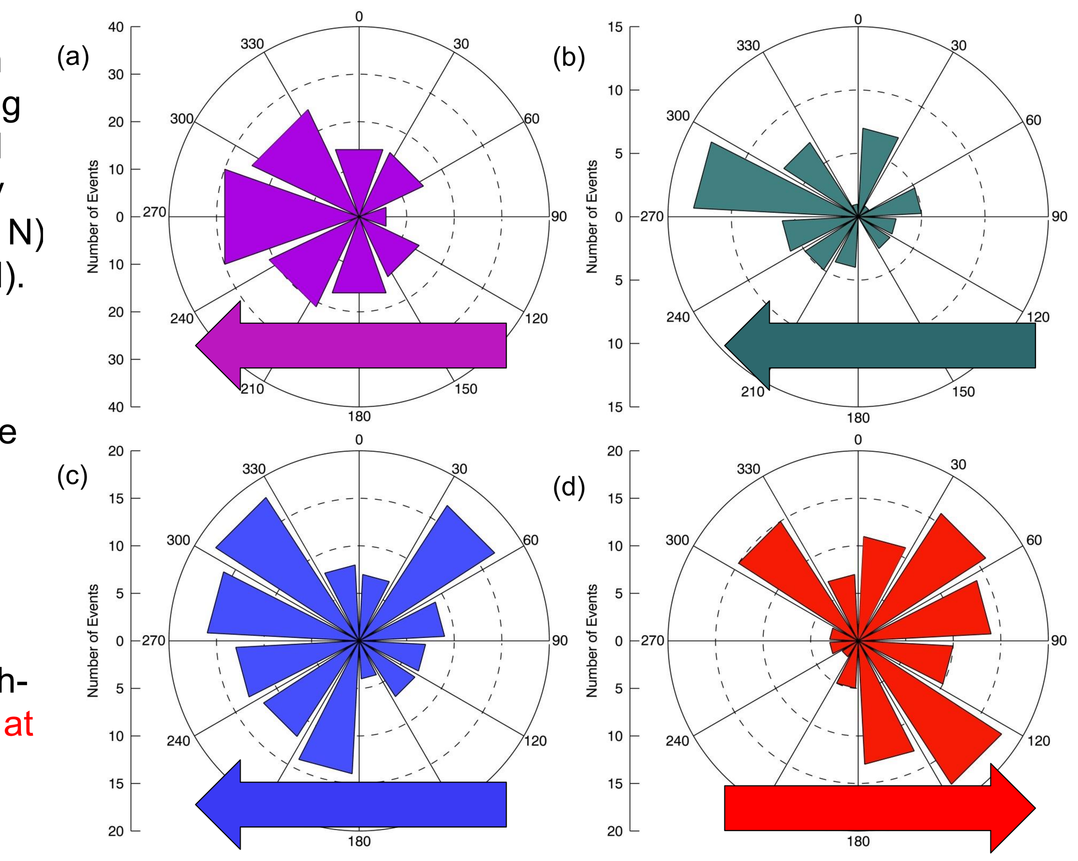

Figure 7: (a) Resolute Bay, (b) Svalbard, (c) ALOMAR, (d) PFRR

Critical Level Filtering

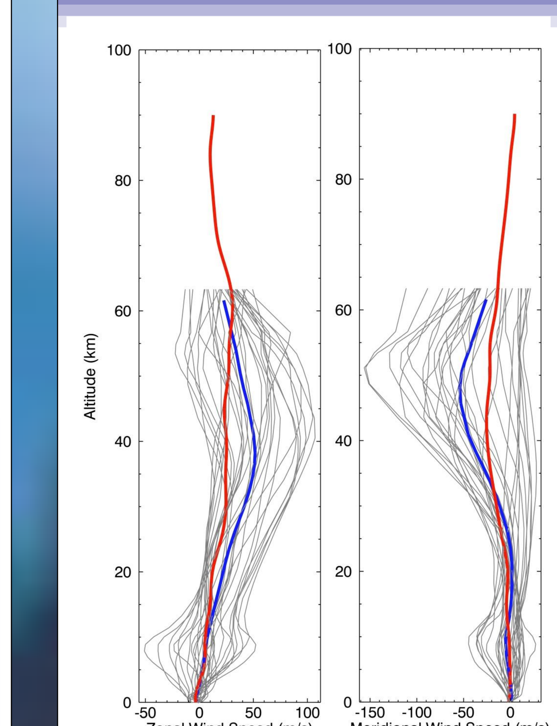

Figure 8: Daily averaged MERRA (gray), monthly averaged MERRA (blue), and monthly averaged HWM07 zonal and meridional winds.

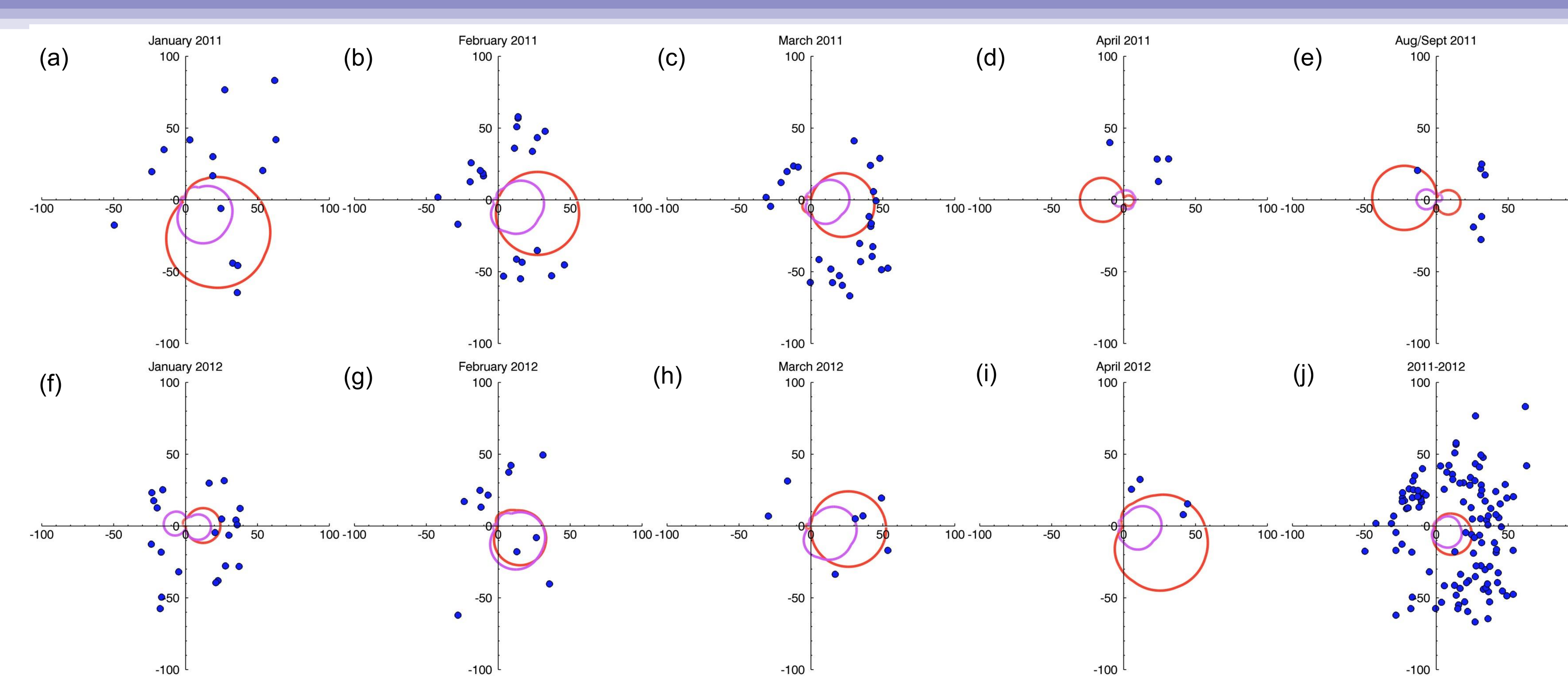

Figure 9: Observed phase speeds for individual events (blue dots), blocking diagrams using MERRA (red) and HWM07 (pink) for each month in 2011 and 2012.

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 no wind measurements made during the observation periods at PFRR, therefore winds from the Horizontal Wind Model 2007 (HWM07) 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 HWM07 (pink) monthly averaged winds for 2011 and 2012 as well as observed phase speeds for individual events (blue dots). Figure 9j, 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.

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.

Acknowledgments

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