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Observing Gravity Wave Coupling and Day-to-Day Variability Over the Polar Vortex During the 2018-2019 Winter Season

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I. Introduction

Gravity Waves (GW) are highly influential drivers of Earth's atmosphere. Caused by air particle displacements, they perturb background winds, temperatures, and densities both horizontally and vertically. They propagate upward to the thermosphere/ ionosphere. As GWs propagate upward, they can break and create body forces that give rise to secondary GWs (Vadas et al., 2003). Their activity can be affected by global events such as Sudden Stratospheric Warmings (SSW). This work focuses on the localized effects of GW coupling within the northern hemispheric polar vortex during an SSW during the 2018-2019 winter. This is done analyzing a coupling case study, a seasonal study of GW variance in the stratosphere and Medium Scale Travelling Atmospheric/Ionospheric Disturbance (MSTID/MSTAD) index in the thermosphere, then seasonal daily averaged background winds for GW propagation conditions over the region of Alaska.

II. Data and Instruments

Stratosphere (30-60km): Atmospheric Infrared Sounder (AIRS; Hoffman et al., 2013)
Thermosphere (120km/250-350km): Scanning Doppler Imager (SDI) - All sky imaging Fabry-Perot Spectrometer at Poker Flat, Alaska (147W, 65N) and Toolik Lake, Alaska (149.6W,68.6N).
Ionosphere (400km): SuperDARN – ground-based radar observing MSTID activity in ionosphere

Coordinate Ranges: Europe: 55-85N, 0-50E / Alaska: 55-85N, 130-180W / NE Russia: 55-85N, 130-180E / Global: 55-85N, 180W-180E

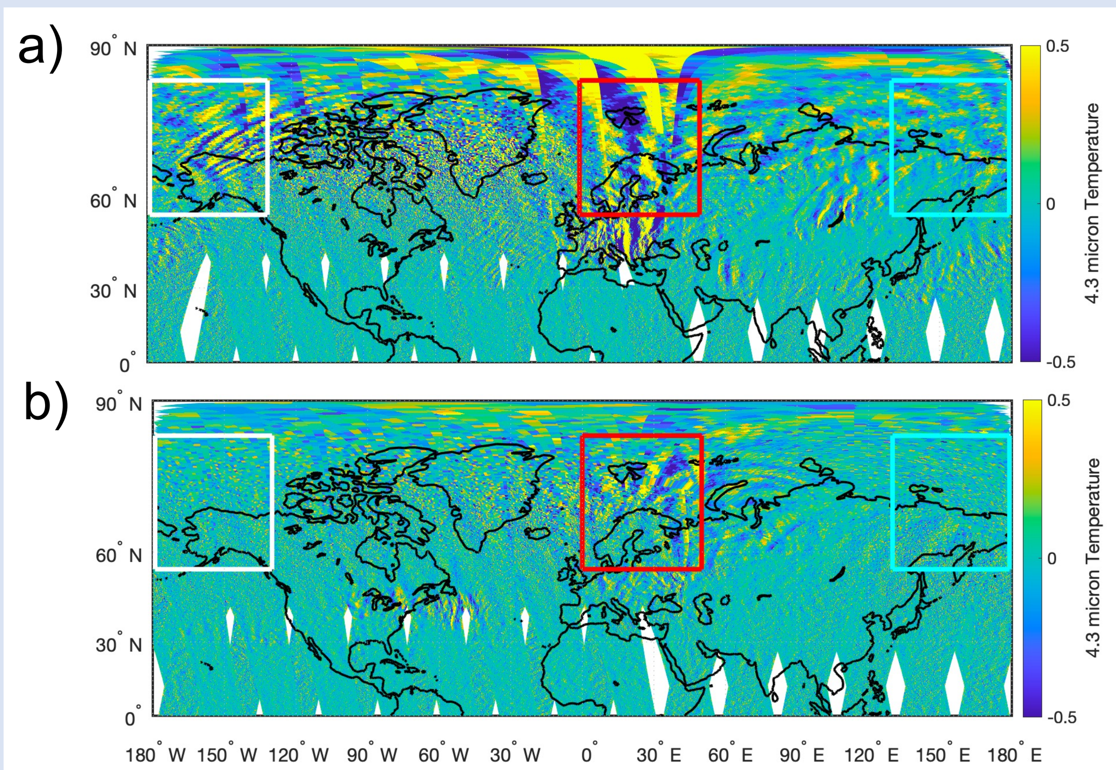

Figure 1. Global Temperature perturbation data on (a) December 23rd, 2018, and (b) January 5th, 2019, with boxes outlining 3 coordinate regions (Alaska – White, Europe – Red, NE Russia – Blue)

III. Case Study

December 24th, 2018, and January 6th, 2019, are two days that stick out as high and low variant days, respectfully. Figures 2 and 3 show wave activity in the stratosphere and thermosphere.

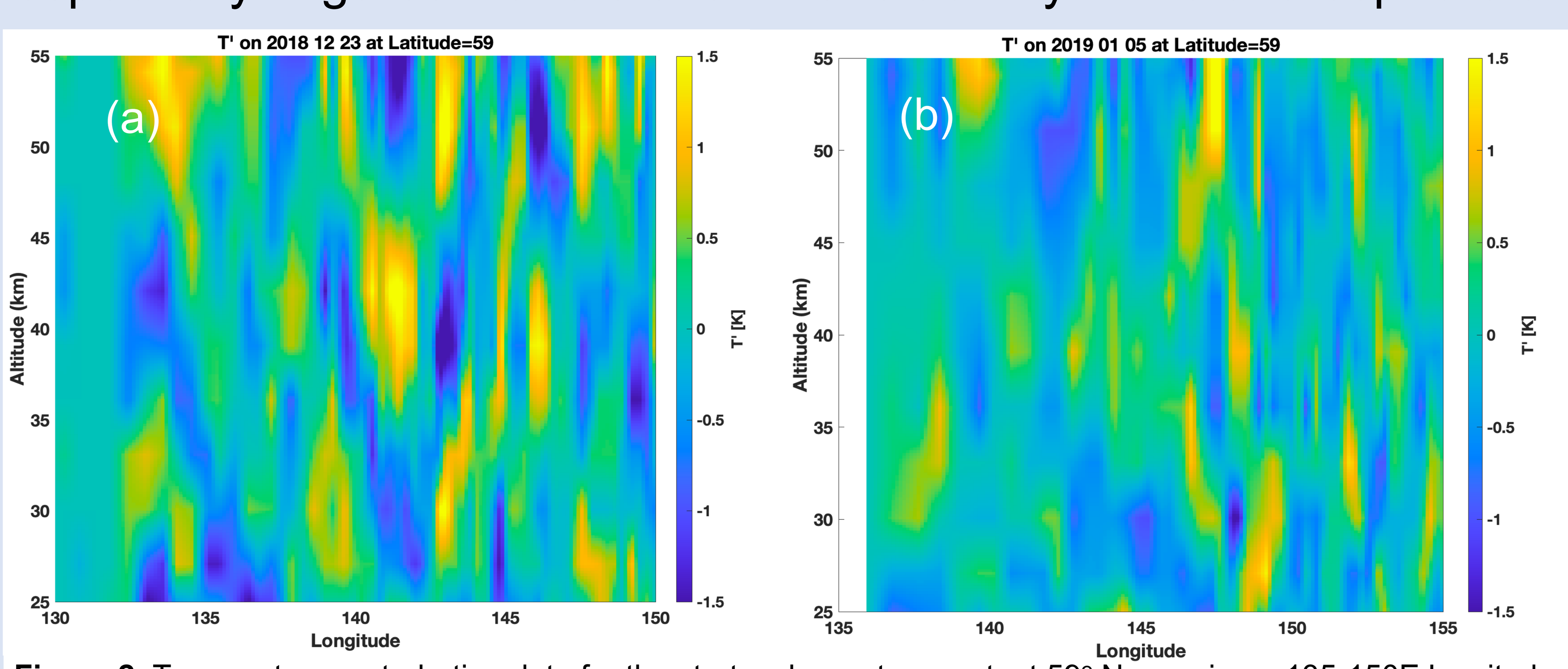

Figure 2. Temperature perturbation data for the stratosphere at a constant 59° N covering a 135-150E longitude range and 25-55km altitude for (a) December 23rd, 2018, and (b) January 5th, 2019.

Stratospheric Waves:

Max Amplitude of Waves:
High Variance Night: 1.7 K
Low Variance Night: 1.2 K
Mean Variance:
High Variance Night: 0.3 K^2
Low Variance Night: 0.15 K^2

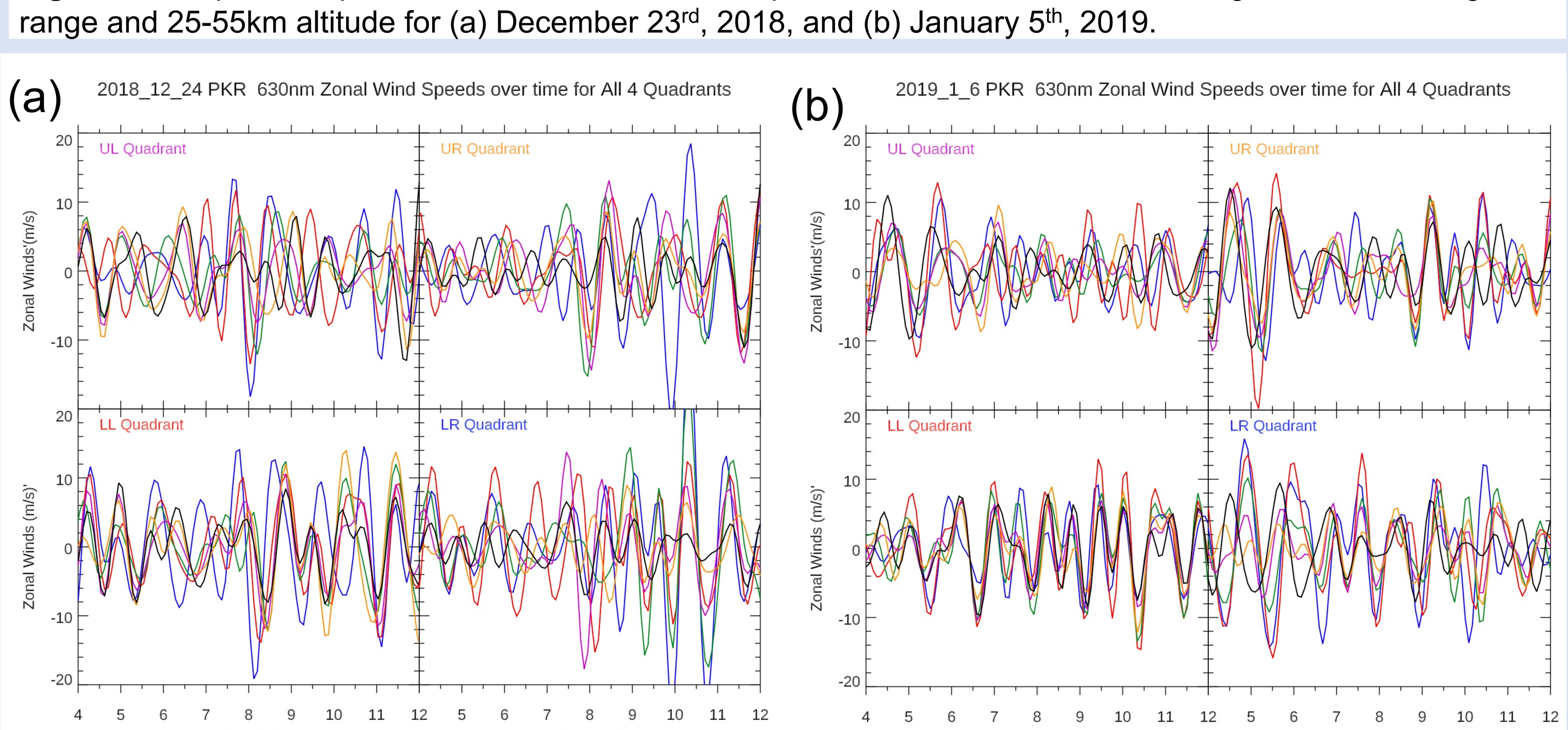

Figure 3. Nightly 630.0nm thermospheric wind speeds for (a) December 24, 2018 and (b) January 6th, 2019. 105 SDI directions are split up into their respective FOV quadrants, Upper Left/Right (UL/UR) or Lower Left/Right

Thermospheric Waves:

- By separating data into nearby directions, can analyze average wave amplitudes
- Calculated by taking absolute value, then computing mean

Average Amplitude of Waves:
High Variance Night: 5.7 m/s
Low Variance Night: 4.2 m/s

IV. Stratosphere & Thermosphere/Ionosphere Seasonal Analysis

- Figure 4 shows seasonal temperature variances from AIRS averaged over each coordinate range from box II
- Local peaks during December over Alaska are typically one day after a local peak over NE Russia

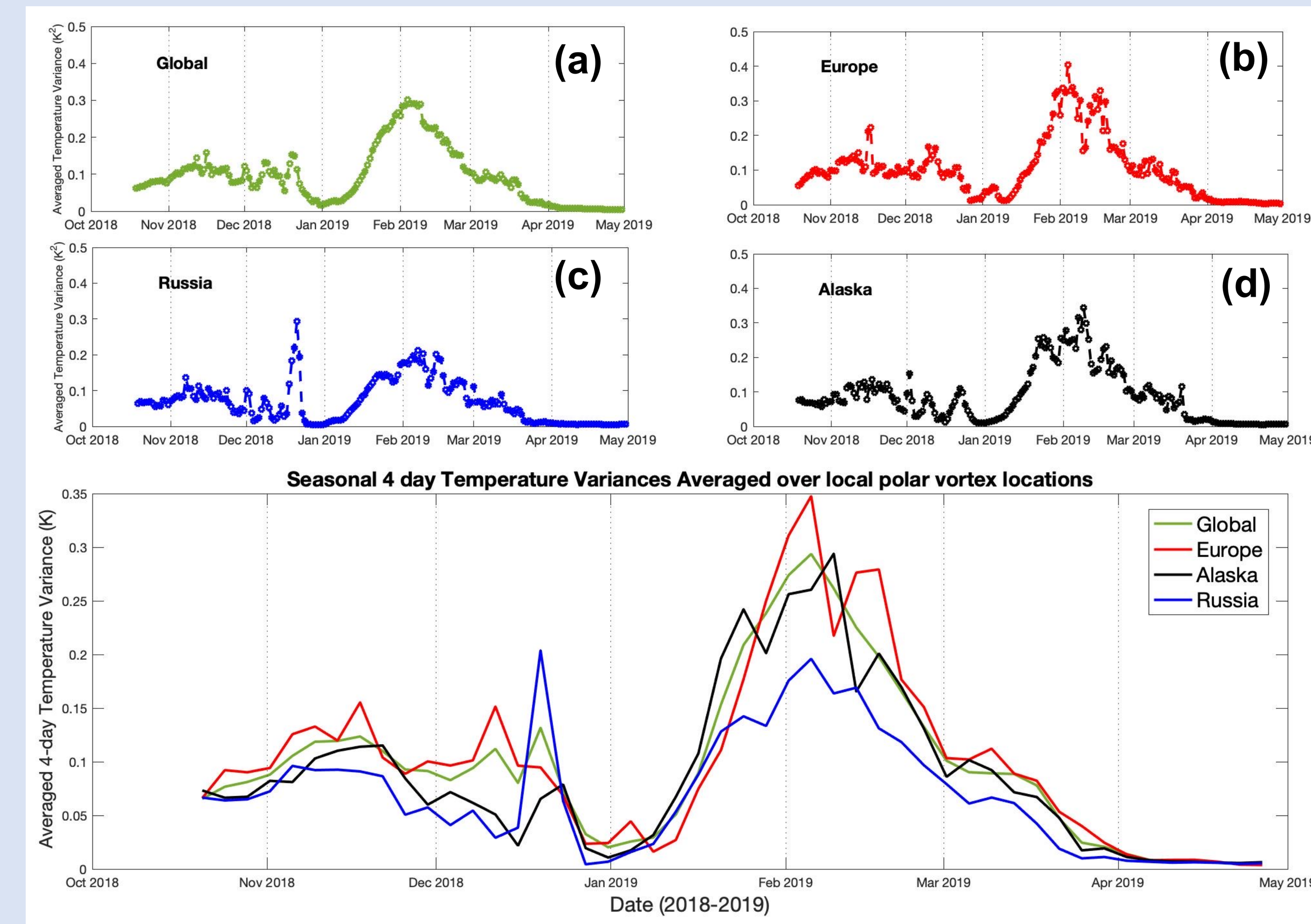

Figure 4. Averaged 4-micron temperature perturbation variances for 2018-2019 winter season, over 4 different regions, (a) Global Polar Vortex, (b) Europe, (c) NE Russia, and (d) Alaska.

- Figure 5 shows (a) MSTID and (b) MSTAD index for 2018-2019
- Thermosphere peak in activity in late December, but not in ionosphere
- SSW recovery in both instruments in mid-January

- Figure 6 shows planetary wave amplitude gradients
- Close correlation between MSTAD index and planetary wave amplitude gradient in both zonal (blue) and meridional (red) winds

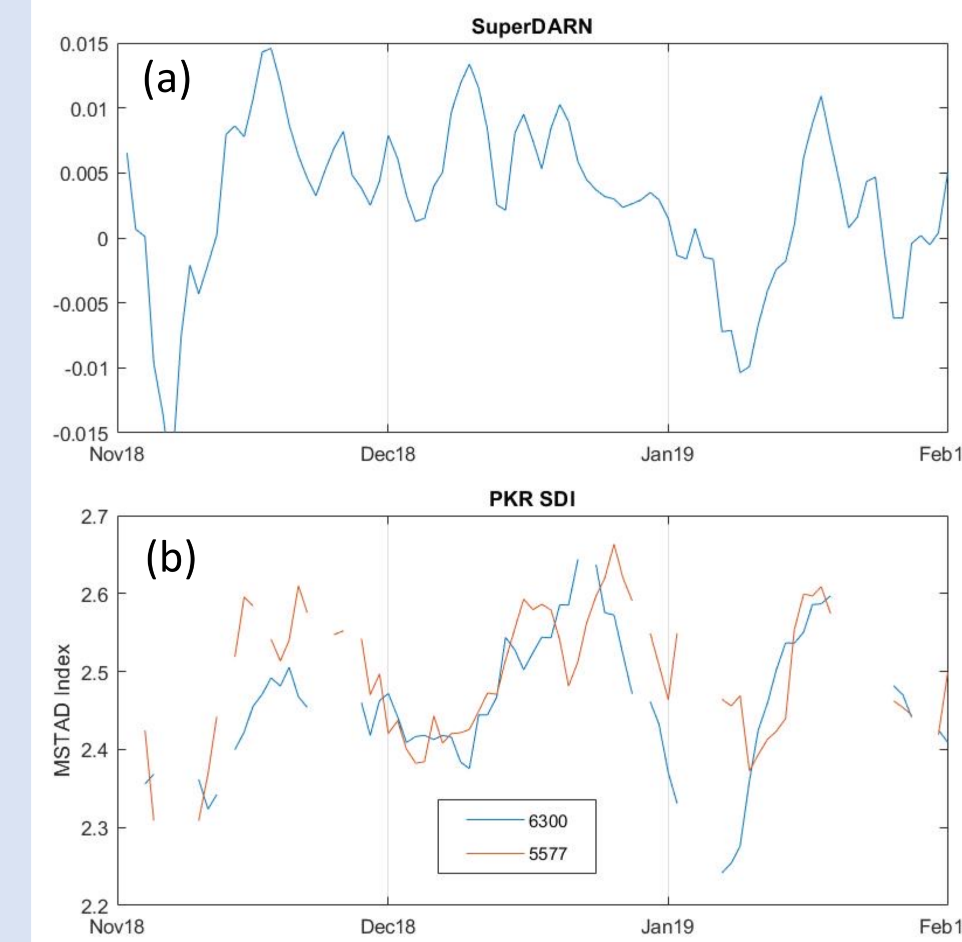

Figure 5. 4-day averaged thermospheric/ionospheric (a) MSTID and (b) MSTAD indices calculated for the 2018-2019 season. In panel (b), blue line is 630nm and orange is 557.7nm

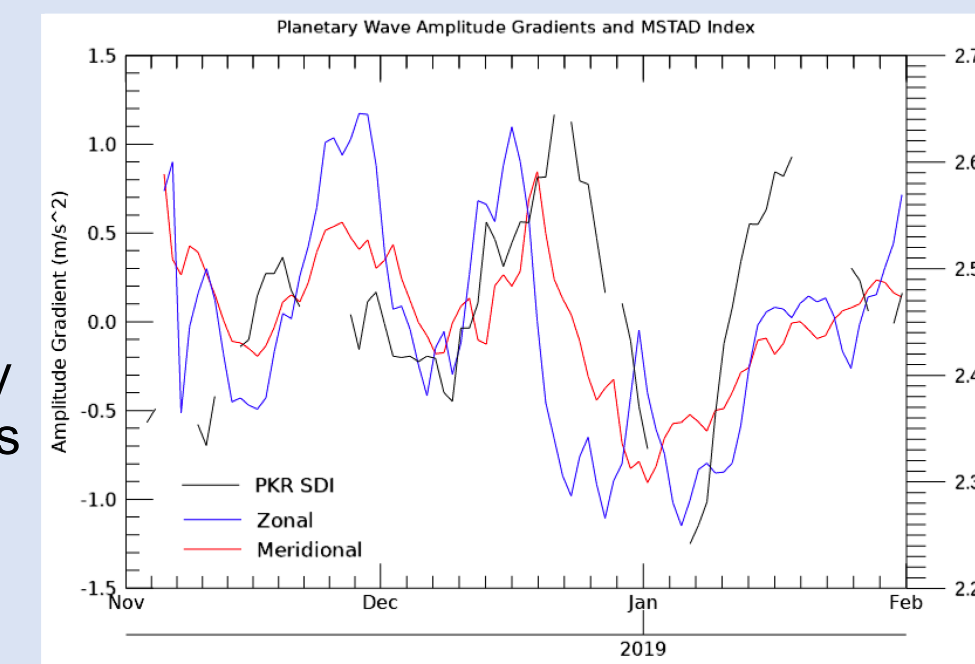

Figure 6. Planetary Wave Amplitude Gradients for Zonal (Blue) and Meridional (Red) Winds and MSTAD index (Black) over 2018-2019.

V. Background Wind Analysis

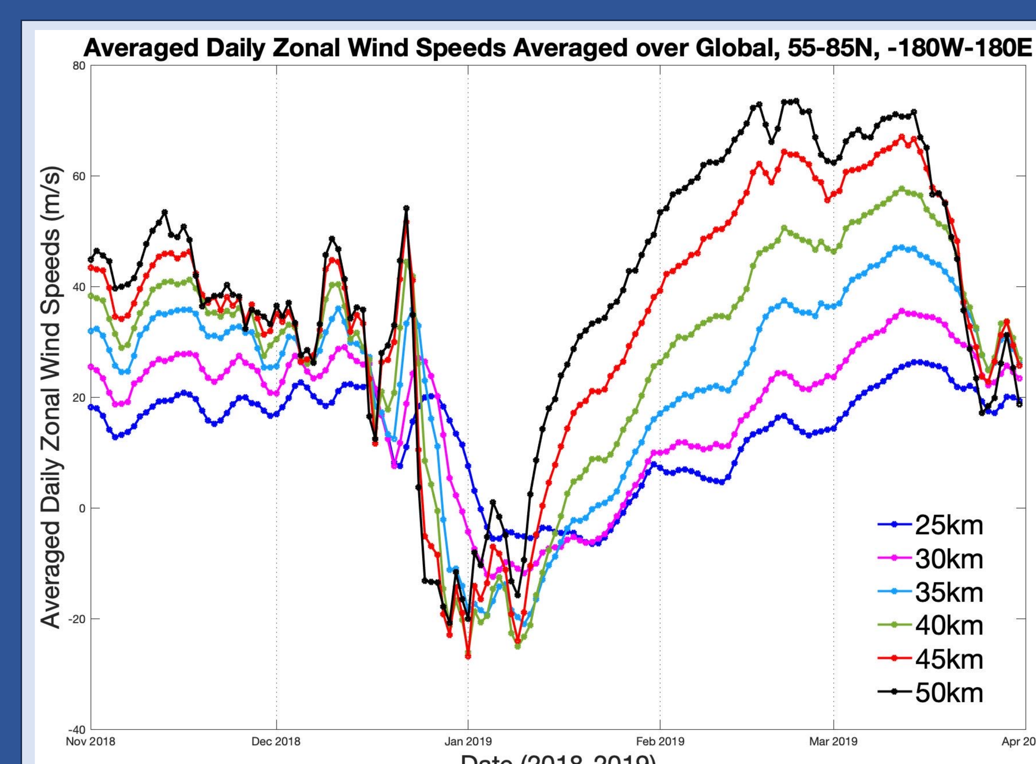

Figure 7. Average global polar vortex background zonal wind speeds for varying heights over 2018-2019 winter.

- Background winds reanalyzed by MERRA-2 to provide zonal wind speeds from 25-50km
- Figure 7 shows the averaged zonal wind speeds at 3UT over polar vortex region for each day in the winter season, at different altitudes
- Drop in wind speeds at the end of December 2018 until the middle of January 2019, due to SSW
- Local peak in zonal wind speeds between December 22nd-24th 2018

VI. Conclusion

- Within the polar vortex, although general trends are consistent, there are localized effects from global phenomena, such as localized disruptions to the vortex.
- NE Russia affects stratospheric GW variance over Alaska after local peak GW activity; this is supported by the strong seasonal zonal winds provided by MERRA-2.
- There is a correlation between planetary wave amplitude gradients and MSTAD index over Alaska region

VII. Acknowledgements and References

We'd like to thank Lars Hoffman for providing AIRS data.

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Hoffmann, L., Xue, X., and Alexander, M. J. (2013), A global view of stratospheric gravity wave hotspots located with Atmospheric Infrared Sounder observations, *J. Geophys. Res. Atmos.*, 118, 416– 434, doi:10.1029/2012JD018658.