Ionosphere Coupling From Lower Drivers During the 2018-2019 Winter

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I. Introduction

- Processes in the lower atmosphere have a large influence on upper atmospheric dynamics
- Gravity waves (GWs) generate in the lower atmosphere, propagate upward, break, and then cause higher order GWs (Vadas 2003)
- Sudden Stratospheric Warmings disrupt the polar vortex, affecting GW upward propagation
- This work seeks to investigate local effects lower drivers in the stratosphere have on the upper ionosphere in the 2018-2019 winter; during which, there was a Sudden Stratospheric Warming

II. Data and Instruments

- Stratosphere (30-60km): Atmospheric Infrared Sounder (AIRS; Hoffman et al., 2013)
- Ionosphere (220-350km): SuperDARN PGR/KOD – ground-based radar (54N,123W and 57 N,152 W, respectively) and Poker Flat Incoherent Scatter Radar (PFISR; 65N, 147.5W)
- Coordinate Ranges: Alaska: 55-85N, 130-180W / Europe: 55-85N, 0-50E / NE Russia: 55-85N, 130-180E / Global: 55-85N, 180W-180E

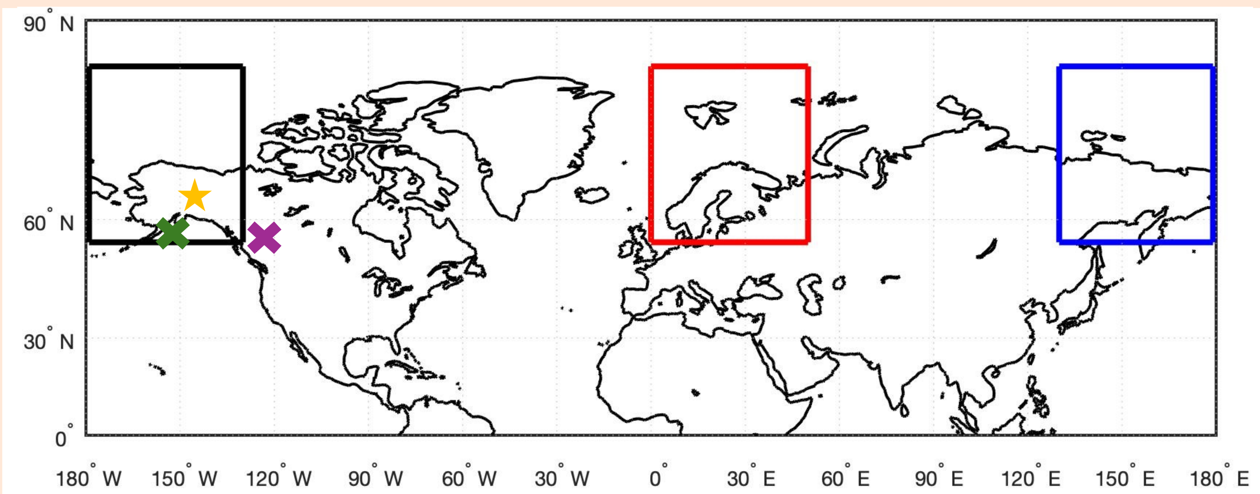

Figure 1. Northern hemisphere showing 3 stratospheric coordinate regions (Alaska – Black, Europe – Red, NE Russia – Blue), PFISR (yellow star), SuperDARN PGR (Purple X), and Kodiak (Green X).

III. Characterizing Day-to-Day Activity

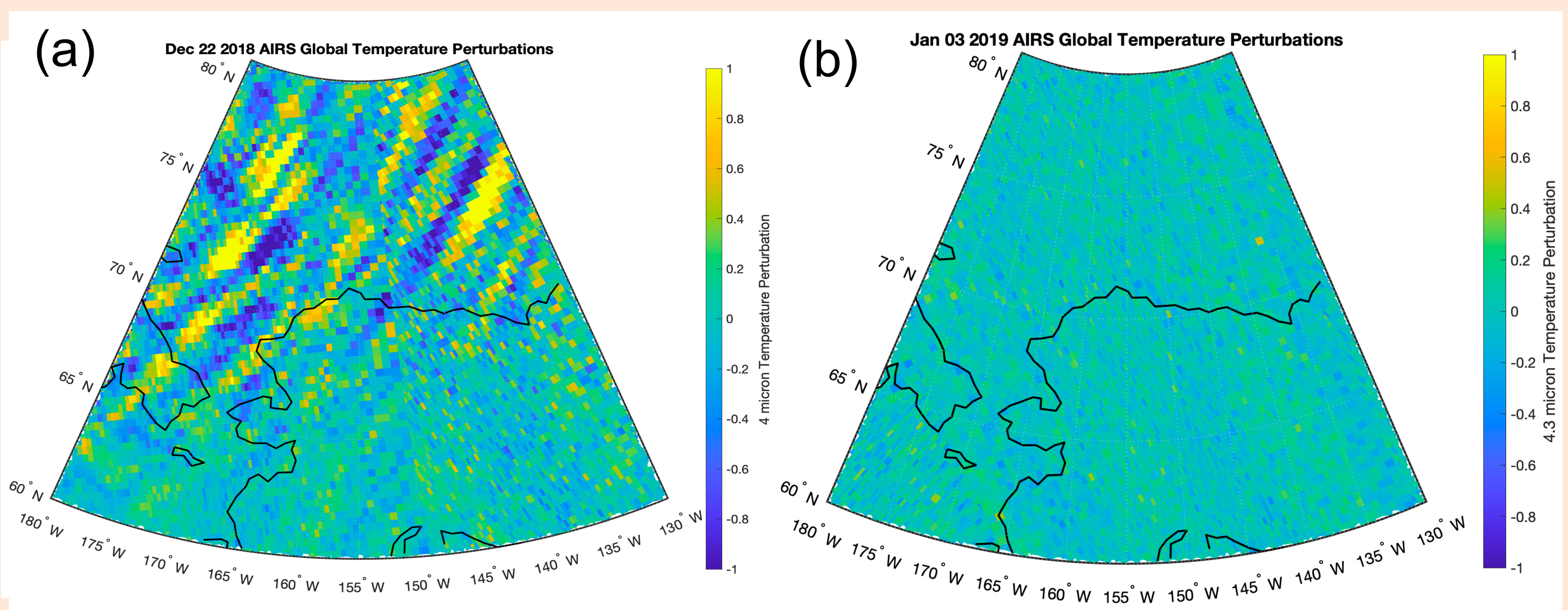

Figure 2. Stratospheric GW temperature perturbations over Alaska observed by AIRS in 4.3-micron channel for (a) December 22, 2018, and (b) January 3rd, 2019.

Stratospheric Waves:

- Shown in Figure 2, Dec 22 2018 has GWs present with horizontal wavelengths of up to 260km, vs no wave activity on Jan 3rd 2019
- Average T variance over Alaska on Dec 22nd= 0.107 K^2
- Average T Variance over Alaska on Jan 3rd = 0.014K^2

Ionospheric Waves:

- Figure 3 shows electron density perturbations the day after the stratospheric activity in Figure 2
- Densities were background subtracted (<40km, 2 hrs), lowpass filtered (>25km, 25m), and normalized
- Average MSTID amplitude on Dec 23 = 0.076 m^{-3}
- Average MSTID amplitude on Jan 4 = 0.030m^{-3}

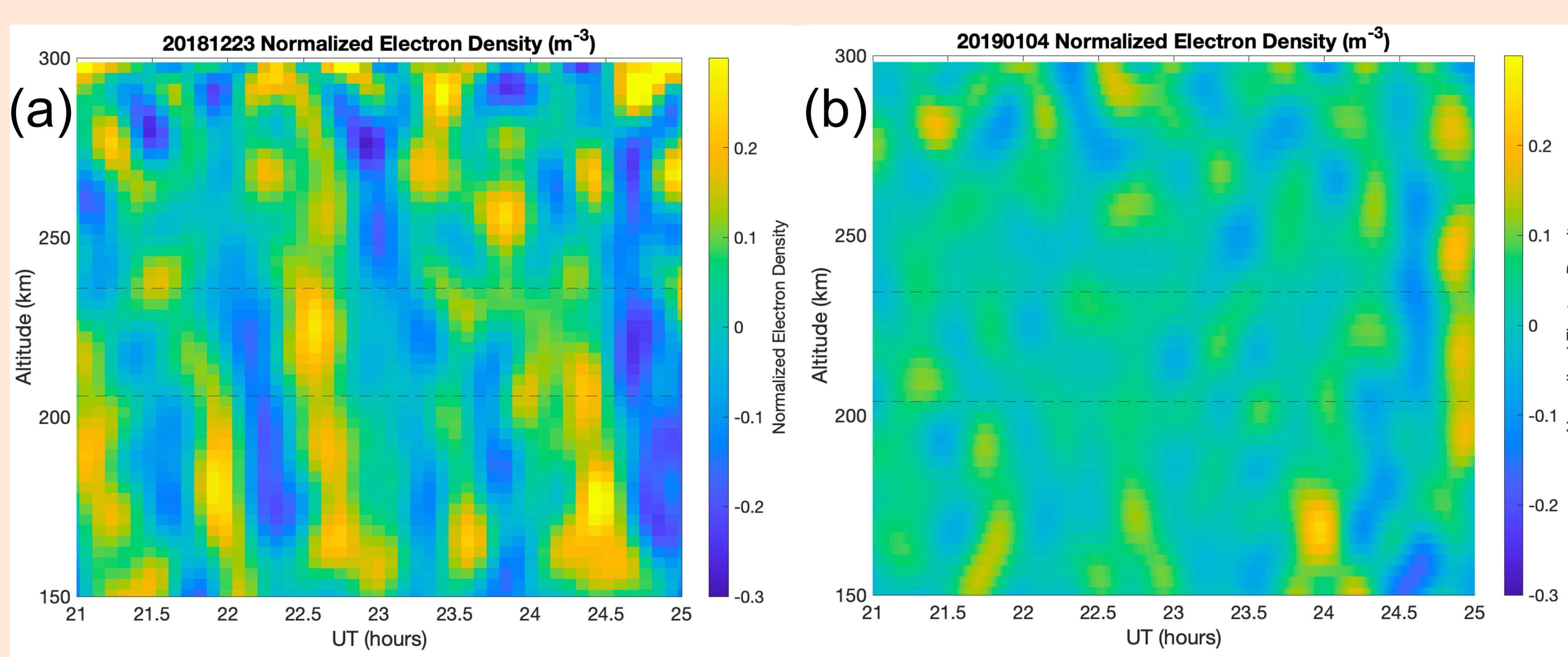

Figure 3. Ionospheric electron density perturbations for (a) December 23, 2018 and (b) January 4th, 2019

IV. Stratosphere/Ionosphere Seasonal Wave Activity

- Figure 4 shows day-to-day stratosphere temperature variances averaged over each regional range
- Peak shown in December before SSW, then much larger peak in February
- Local differences are observed in each unique region

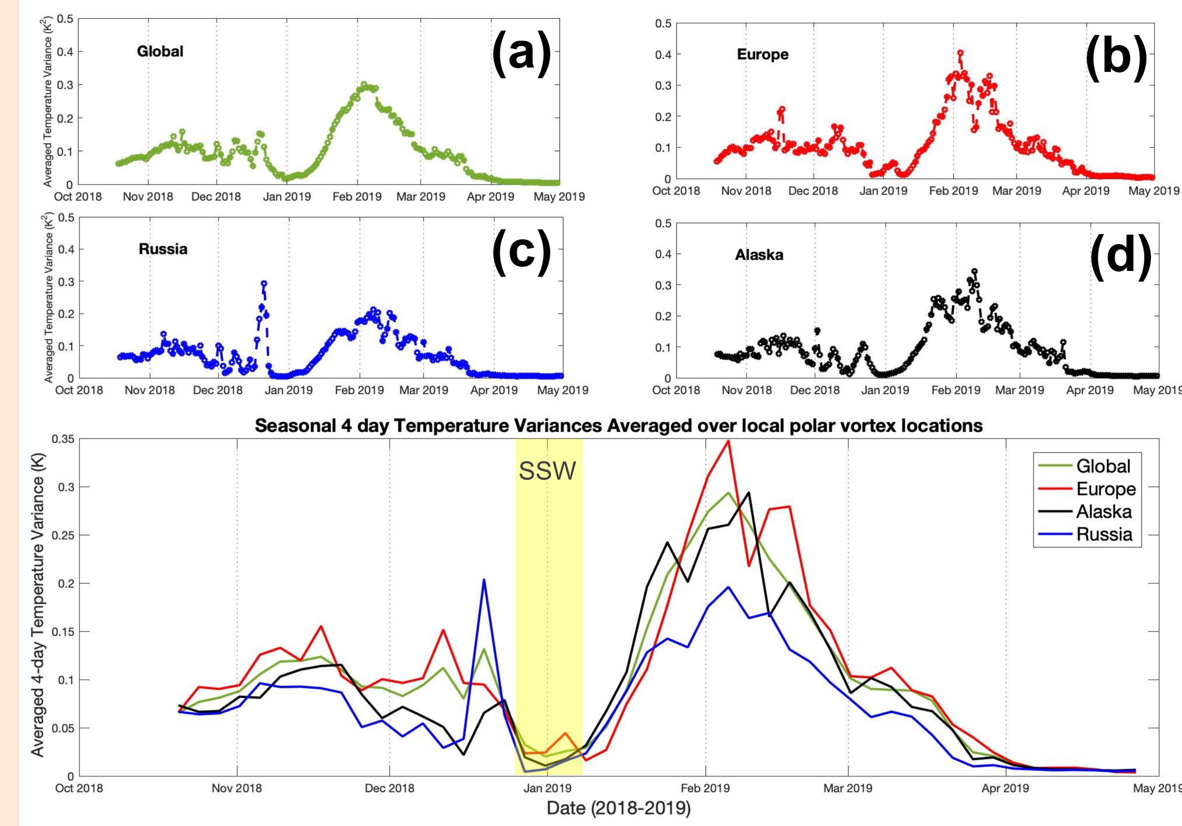

Figure 4. Averaged 4-micron temperature perturbation variances for 2018-2019 winter season, over 4 different regions, (a) Global Polar Vortex, (b) Europe, (c) NE Russia, and (d) Alaska.

- Figure 5 shows ionospheric (a) ISR daily averaged MSTID amplitudes and (b) Kodiak radar MSTID index
- Both show recover after SSW, but Kodiak MSTID index in Fig 5b does not decrease during SSW

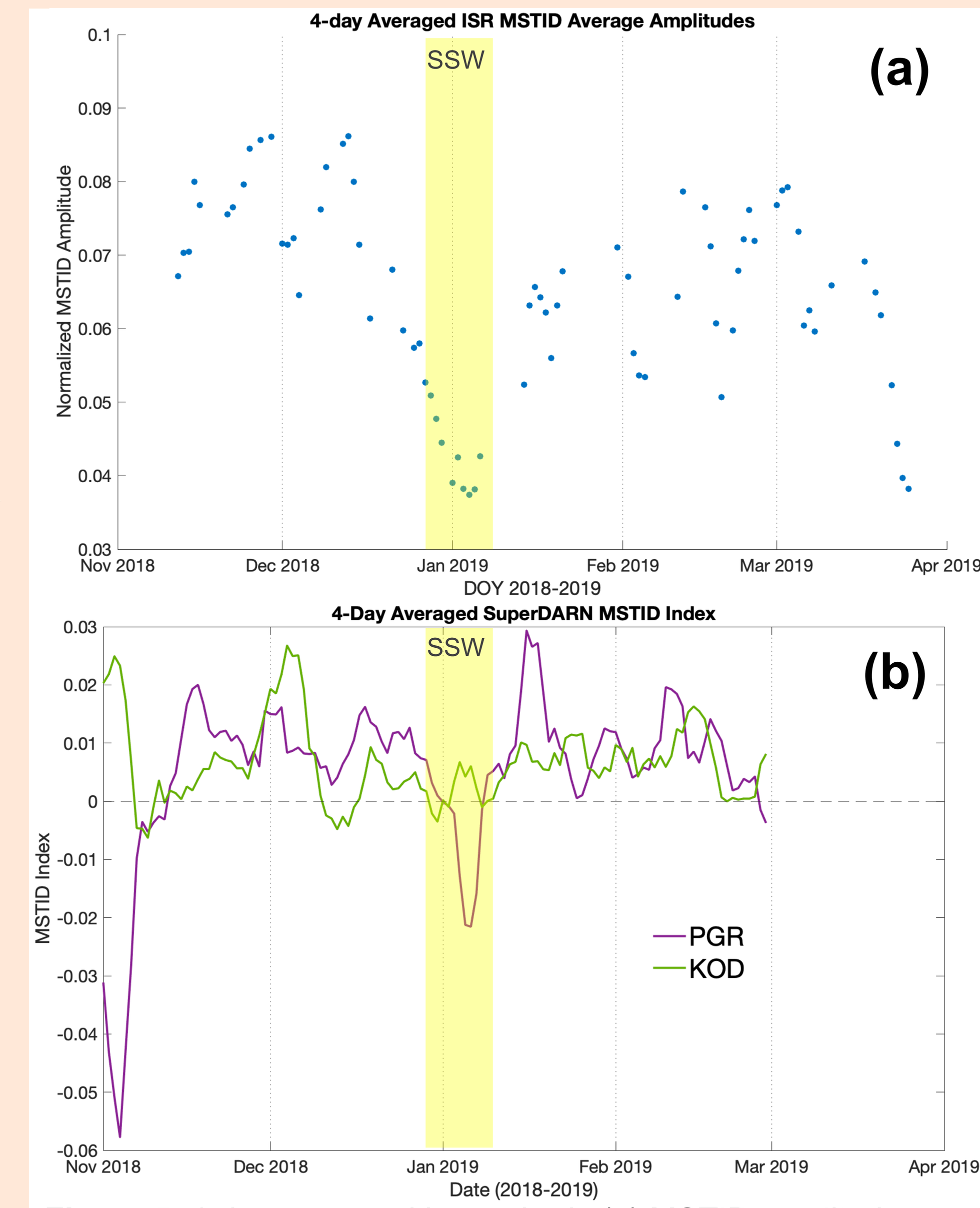

Figure 5. 4-day averaged ionospheric (a) MSTID amplitude from PFISR, (b) MSTID index from nearby SuperDARN radars

V. Investigating Lower Drivers

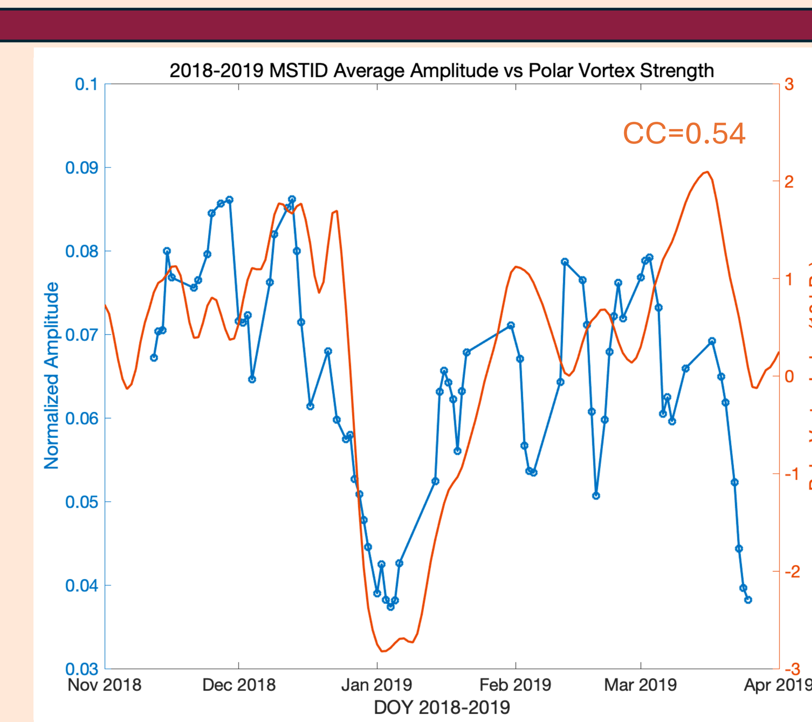

Figure 6. MSTID Amplitudes vs NAM Index, used to represent Polar Vortex strength.

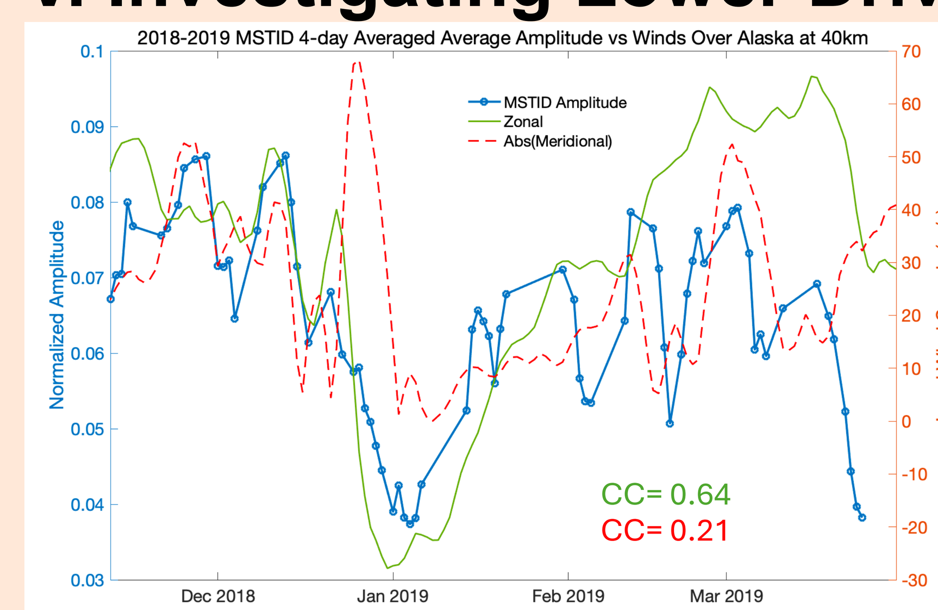

Figure 7. MSTID Amplitudes vs Local Wind speeds (Zonal and magnitude of Meridional) over Alaska (55-75N, 180-130W).

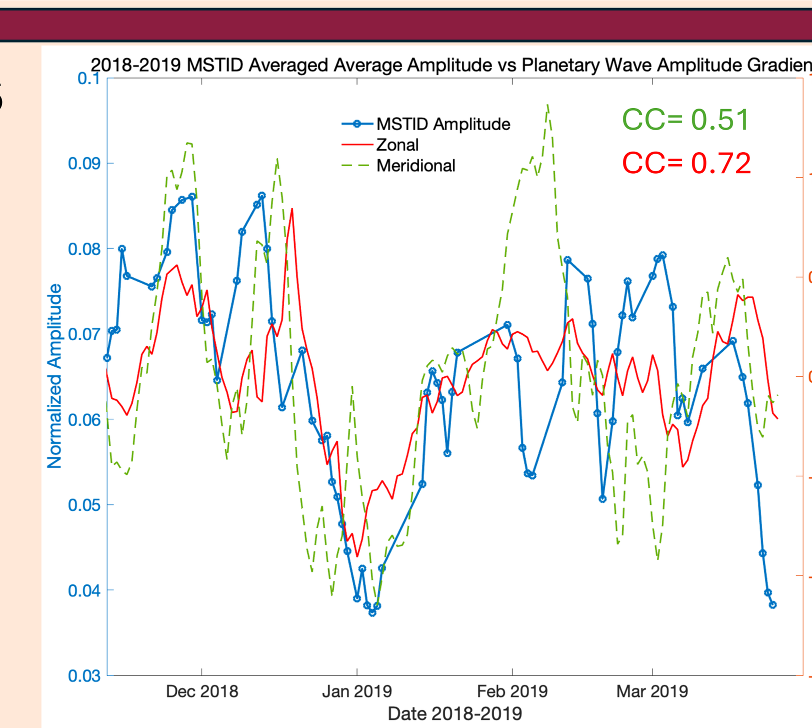

Figure 8. MSTID Amplitudes vs Planetary Wave Amplitude Gradients.

VI. Model Validation

- Fig 9 shows HIAMCM model – increase in thermospheric GW activity before SSW, then decrease in thermospheric GW activity during SSW
- Peak in GWs in mid-February

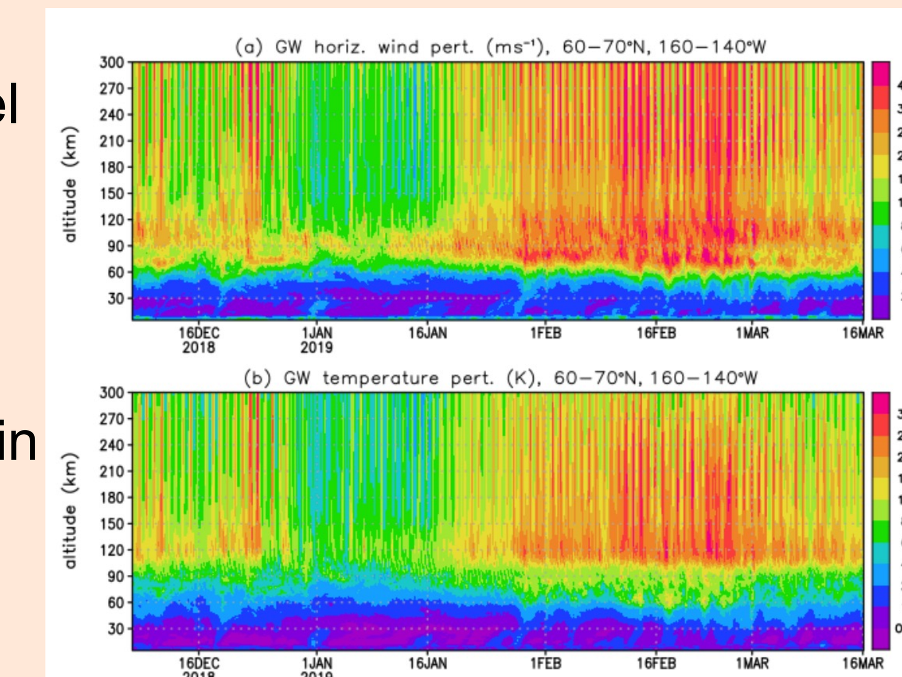

Figure 9. Model results showing 2018-2019 GW (a) wind perturbations and (b) temperature perturbations

VII. Conclusion

- Stratospheric, thermospheric, ionospheric wave activity were all linked with SSW onset in late Dec to early Jan
- Ionospheric MSTID amplitude peaks generally follow modelled thermosphere GW activity peaks
- Polar vortex strength and local zonal wind speeds appear to drive long term trends in ionospheric activity
- Shorter period peaks in MSTID amplitudes appear to be driven by changes in planetary wave amplitudes, and linked to regional stratospheric winds over Alaska

VI. Acknowledgements & References

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