Thermospheric Gravity Wave Characterization over Alaska

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I. Overview

Gravity Waves (GWs) drive the energy and momentum budget of the atmosphere; they are typically generated in the lower atmosphere and propagate upwards. Upon breaking, they deposit their energy and momentum, create localized body forces, and generate higher order GWs (Vadas et al., 2003). GWs are largely driven by internal atmospheric processes, such as the polar vortex (Frissell et al., 2016). While individual measurements of GWs are plentiful in the ionosphere, observations are sparser in the thermosphere. Furthermore, temporally varying observations of thermospheric GWs are limited. We present a case study analysis of a high latitude GW observation using red line scanning doppler imager (~250 km) wind data in concurrence with the Global Ionosphere Thermosphere Model (GITM). GITM and SME index indicate this wave did not originate from geomagnetic forcing. The wave was found to have a phase speed of 320 m/s and horizontal wavelength of ~1150 km.

II. Instrumentation

Toolik Lake (TLK) Scanning Doppler Imager (SDI)

- Nighttime meridional and zonal wind measurements in 630nm (~250 km) and 557.7nm (~120 km). Located at 68.6N, 149.3W.

Global Ionosphere Thermosphere Model (GITM)

- Altitude based model providing neutral zonal, meridional, and vertical wind output that considers high latitude electrodynamic sources of waves such as auroral electrojet. It is run for 23-24 December 2018.

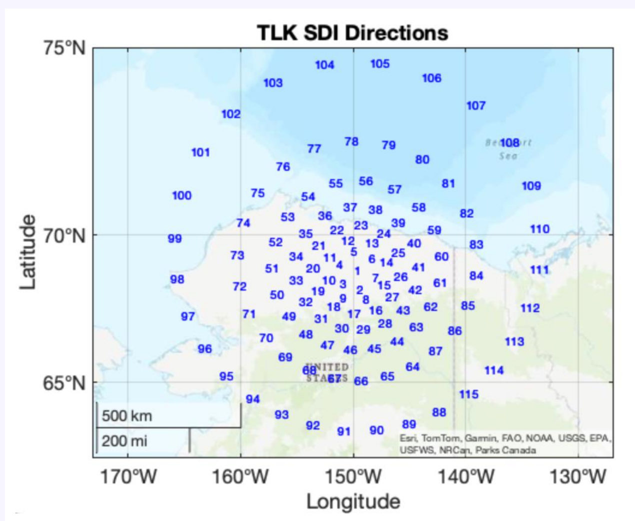


Figure 1. All viewing directions for TLK SDI.

III. Observational Thermospheric Gravity Wave

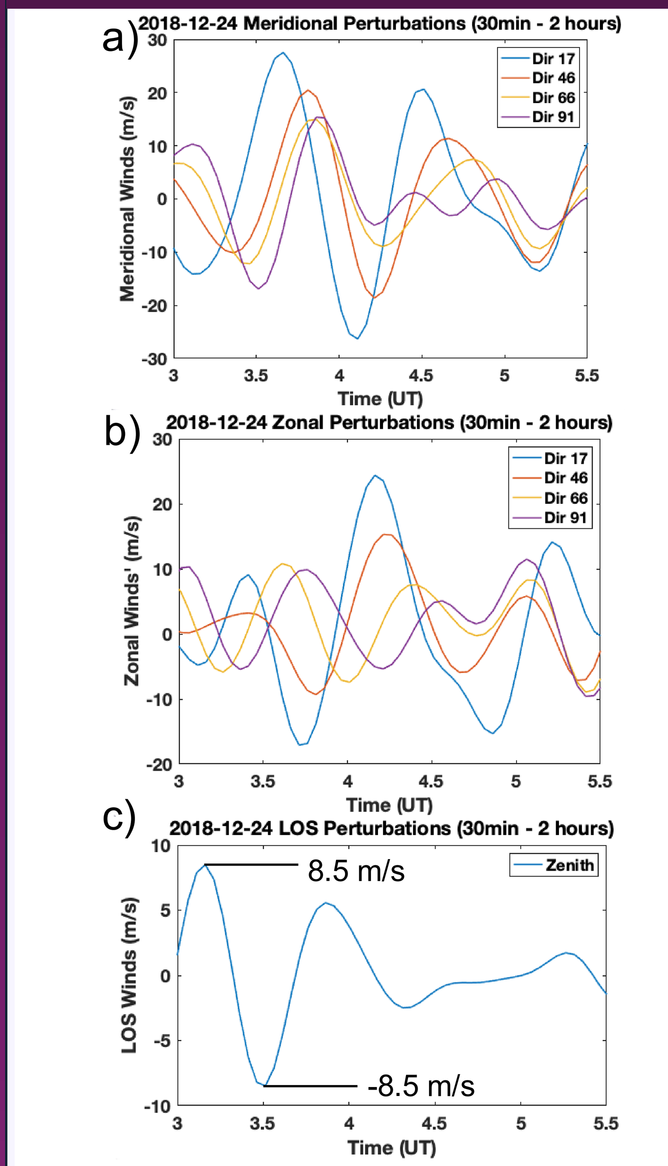


Figure 2. a) Meridional, b) zonal, and c) LOS wind perturbations for 4 select viewing directions

- From LOS Zenith direction, w'≈8.5 m/s. Vertical flux of horizontal momentum $=\overline{v'w'}$=(27 m/s* 8.5 m/s) = **229.5 m^2/s^2**

- SDI winds are background (>2 hours) subtracted and low pass filtered for noise (>30 minutes) to obtain perturbations
- Primarily southward propagating wave observed in SDI field of view
- Averaged wavelet reveals wave with a period of **~60 minutes** from 3-5.5 UT in 4 meridional example look directions
- By estimating distance between looking directions at 250 km, and calculating temporal lag between these directions, average phase speed was calculated to be c_h**= 320 m/s**, and horizontal wavelength was calculated to be **~1150 km.**

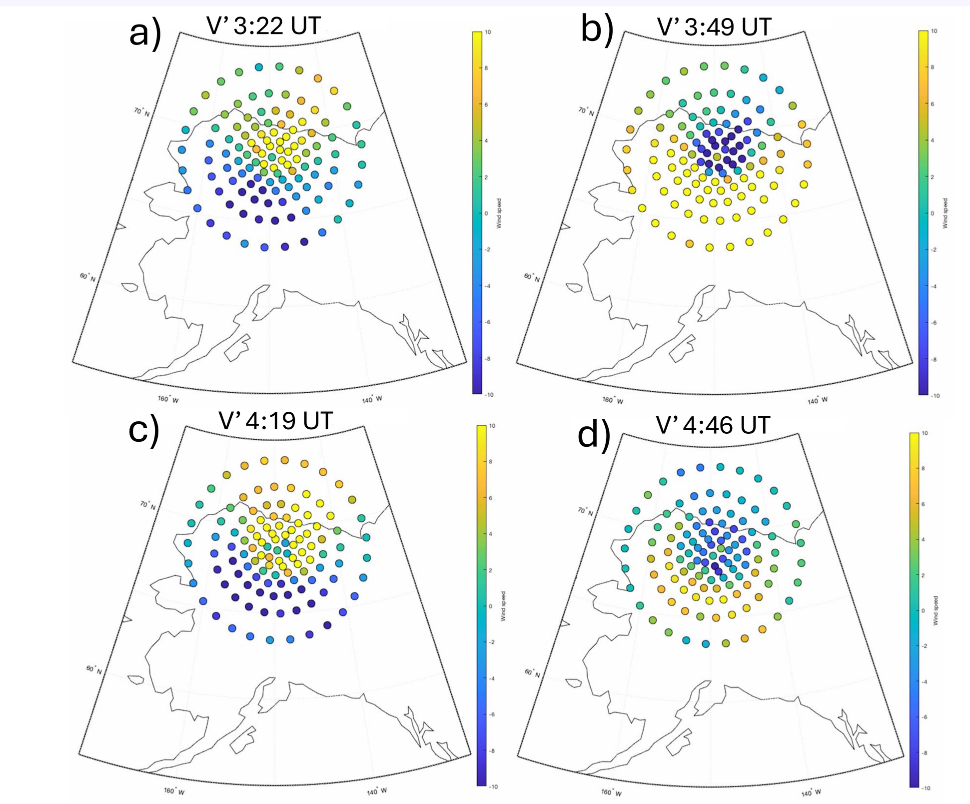
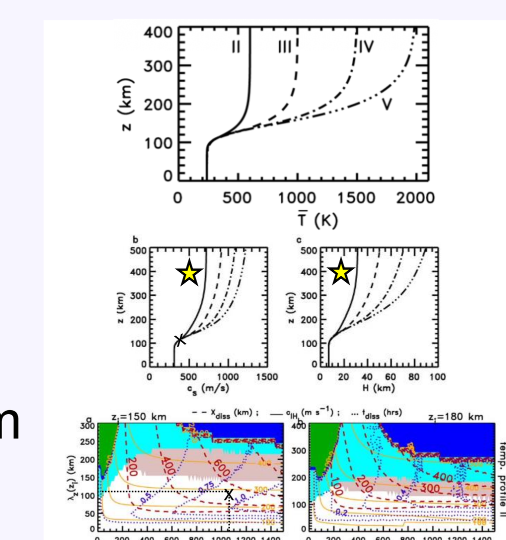


Figure 3. 630 nm meridional wind perturbations for entire SDI FOV for 4 select times.

- $\overline{T}$=550 K (solid line). With this wave's c_h = 320 m/s, the wave likely generated above 120 km
- The wave likely dissipated at ~500 km as indicated by the X in Fig. 5a from Vadas (2007)



Figures 1, 2, and 5a/b from Vadas, 2007.

IV. GITM Results

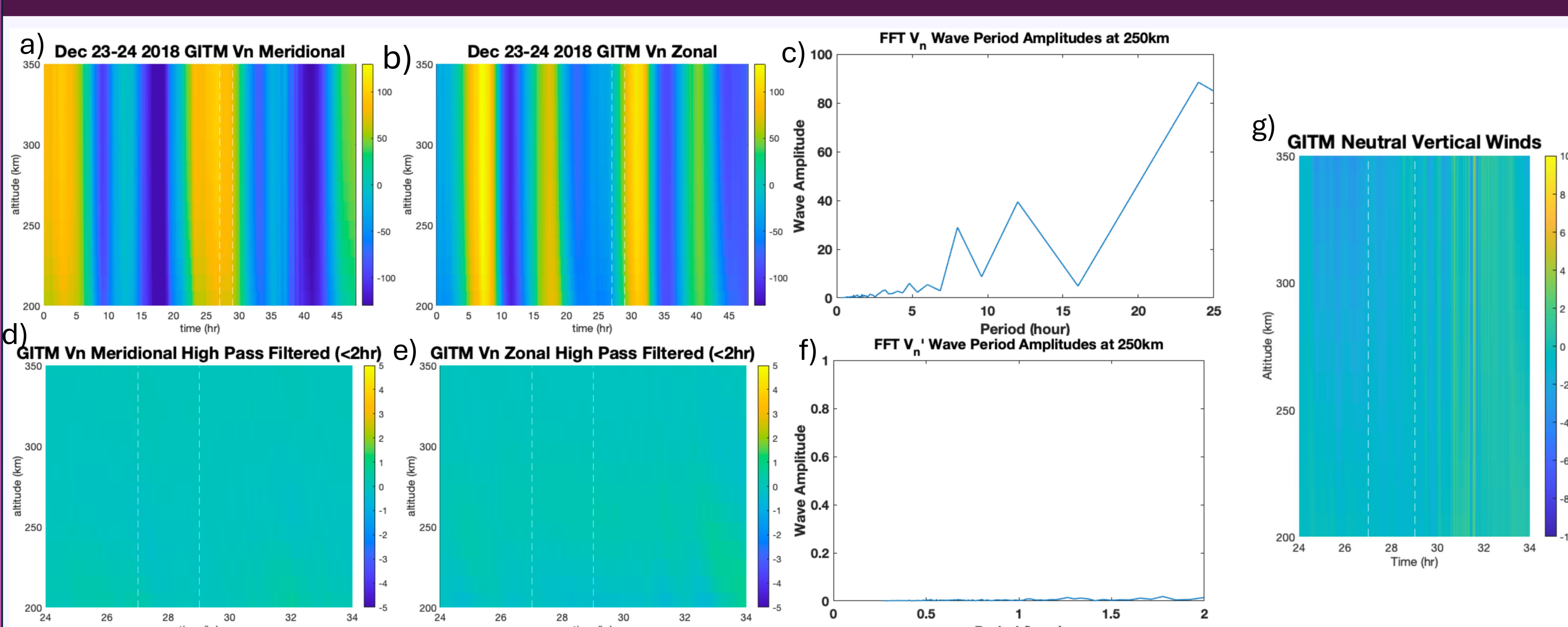


Figure 4. GITM a) meridional and b) zonal total neutral winds, with panel c showing FFT periods. High Pass filtered neutral winds for d) meridional and e) zonal directions with FFT in panel f). Panel g shows neutral vertical winds

- 24-,12-, and 8-hour periods present in raw GITM neutral winds
- After a 90-min high pass filter, no significant wave activity is present in the red layer (200-350 km)
- Since this GITM run only took solar/geomagnetic influences into account, the lack of perturbations present at these scales indicate the thermospheric wave observed likely propagated from the lower atmosphere, which aligns with low SME index during this time

V. Potential Sources

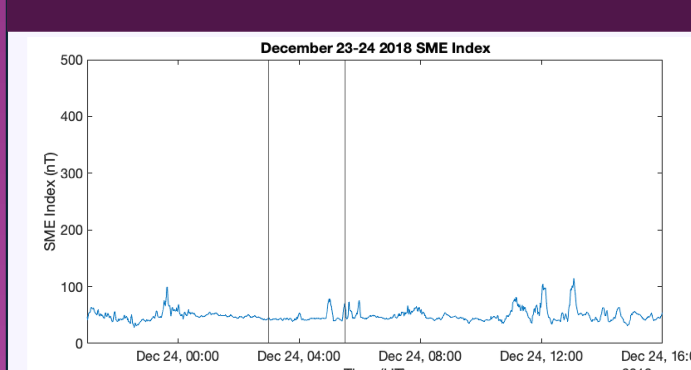
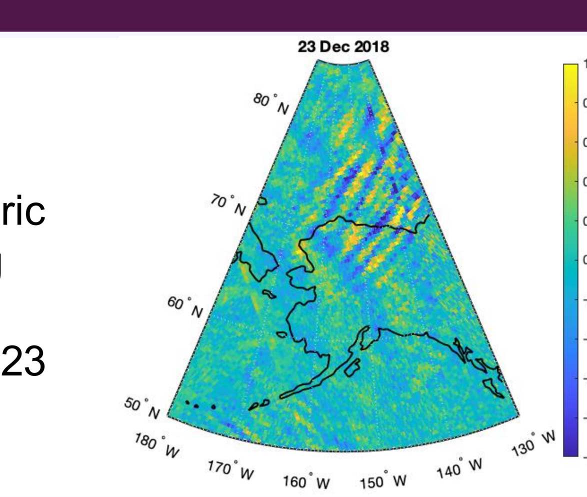


Figure 5. SME index from 21UT on 23 Dec 2018 - 16 UT on 24 Dec 2018

- SuperMAG Electrojet (SME) index shows low geomagnetic activity during this time (3-6UT)
- Strong stratospheric GW activity is seen over Alaska the day before, 23 December 2018

Figure 6. AIRS stratospheric T' showing GW over Alaska on 23 Dec 2018.



VI. Conclusions

- On 24 December 2018, observed a southward propagating thermospheric GW with a period of 60 minutes, phase speed of 320 m/s, and a horizontal wavelength of ~1150 km
- From Vadas (2007) thermospheric wave estimates, this wave likely was generated at ~120 km, and dissipated at ~550 km due to viscous dissipation
- GITM neutral winds from the same time show almost no wave activity, indicating the wave wasn't generated from geomagnetic sources, and was likely generated from the lower altitudes in the atmosphere

VII. Acknowledgements & References

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Vadas, S. L. (2007). Horizontal and vertical propagation and dissipation of gravity waves in the thermosphere from lower atmospheric and thermospheric sources. J. Geophys. Res., 112, A06305, doi:10.1029/2006JA011845.

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