GPS-RO remote sensing for stratospheric dynamics

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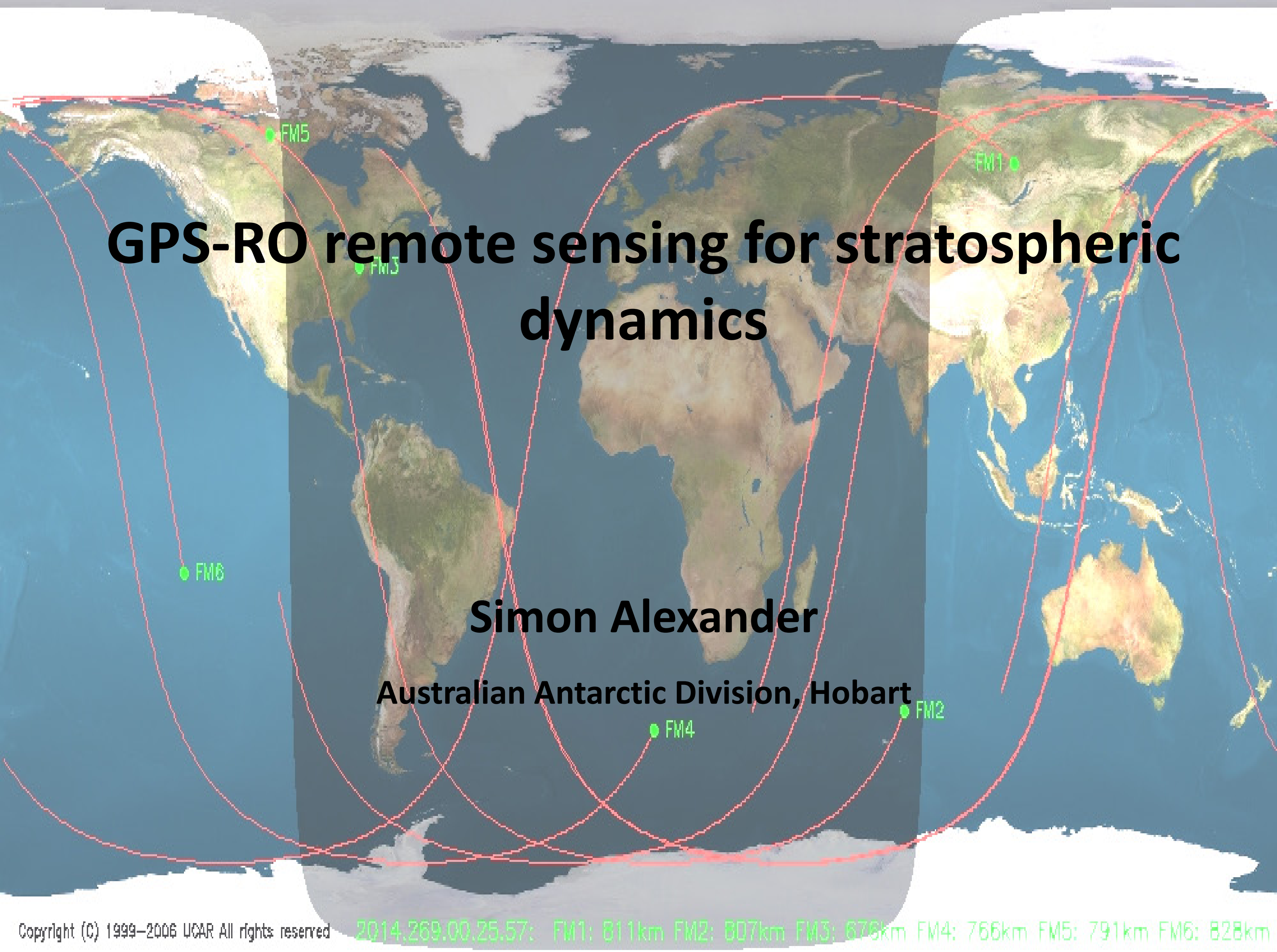
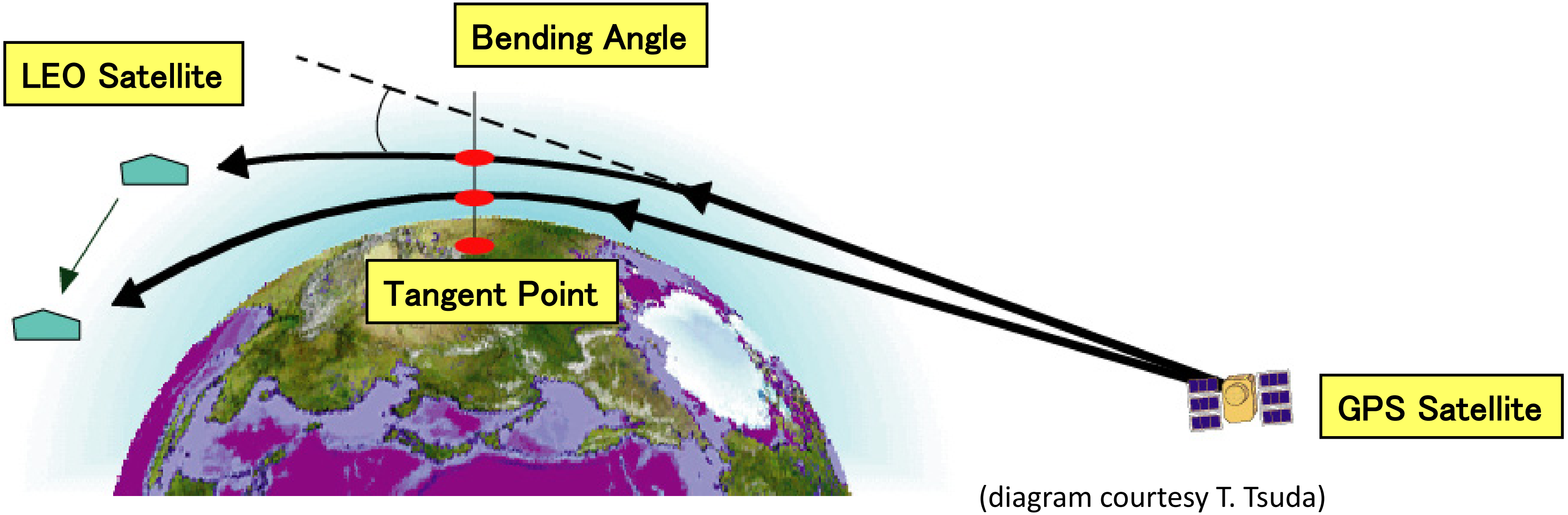


GPS Temperature Profiling

- Low-earth orbiting (LEO) satellites at ~700km observe GPS satellites at ~20,000km rising and setting
  - Radio waves bent by the atmosphere
  - Refractive index obtained by time variations of bending angle
- Refractivity profile at tangent point is inverted to obtain:
  - Humidity (troposphere)
  - Temperature (upper troposphere and stratosphere, up to 40km)



(diagram courtesy T. Tsuda)

Why use GPS-RO in the stratosphere?

- Accurate, stable observations of temperature (10 - ~35km)
- Global coverage – especially useful in the Southern Hemisphere where there is a lack of weather balloons (radiosondes)
- GPS-RO particularly useful for studying small-scale (<~ 1000km) oscillations in temperature: gravity waves. (these waves are unresolved in climate models, yet needed to correctly represent the middle atmosphere)

GPS Temperature Profiles

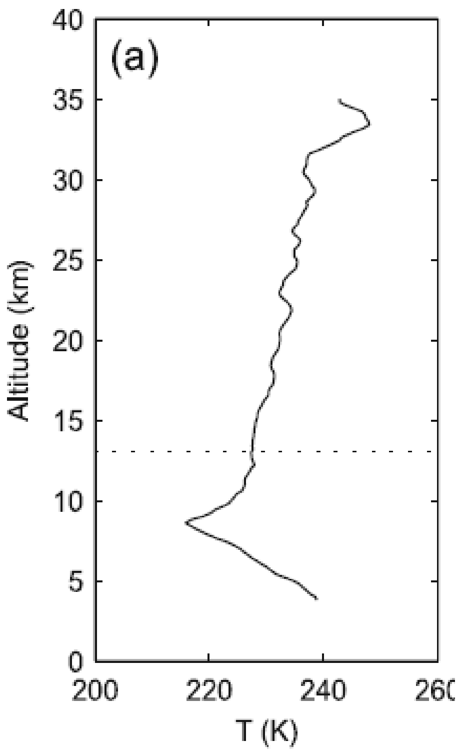
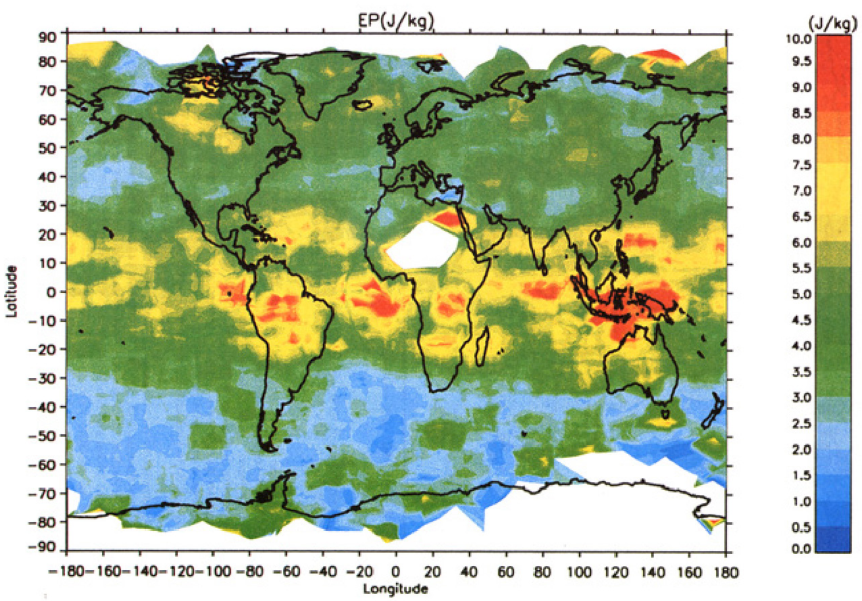


Figure 1. (a) Temperature profile, (b) temperature perturbations, (c) Brunt-Väisälä frequency squared, and (d) potential energy for the profile obtained by CHAMP on 01 February 2004 16:03 UTC at 80°S, 54°E.

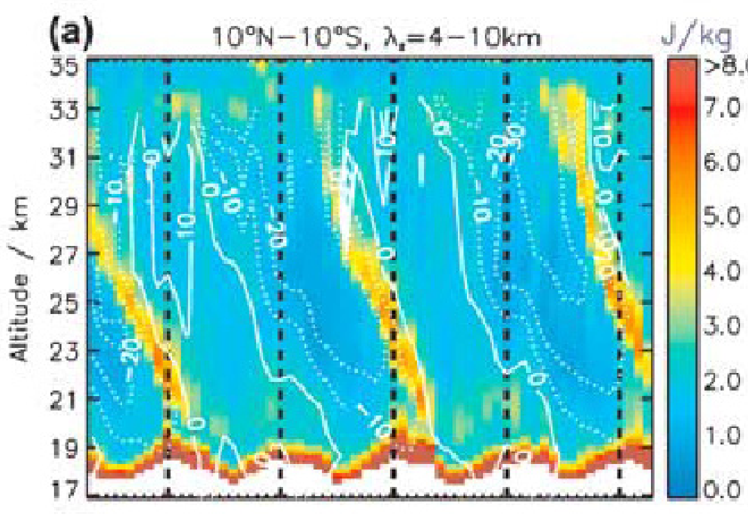
(Baumgaertner & McDonald, JGR, 2007)

GPS-RO: Setting the scene… (1/2)

- GPS/MET in the mid-90s provided the first global picture of gravity-wave activity using GPS-RO
- CHAMP provided a multi-year dataset for wave analyses
- GPS Radio Occultations are more likely to capture gravity waves with slow vertical group velocities and with short vertical wavelengths (contrast with e.g. MLS)



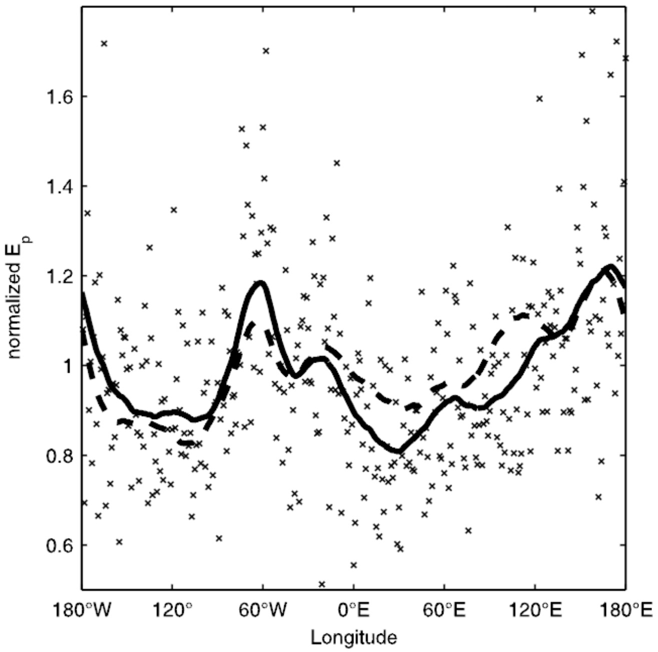
Tsuda et al., 2000



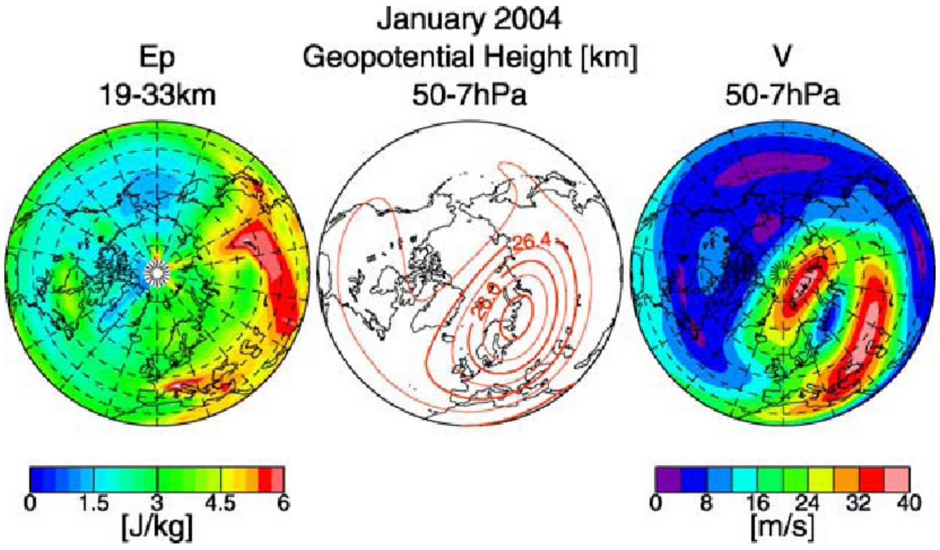
de la Torre et al., 2006

GPS-RO: Setting the scene… (2/2)

- Polar observations using CHAMP showed large orographic gravity wave activity above the Peninsula and Trans-Antarctic Mountains as well as the relationship between large gravity-wave activity and strong winds



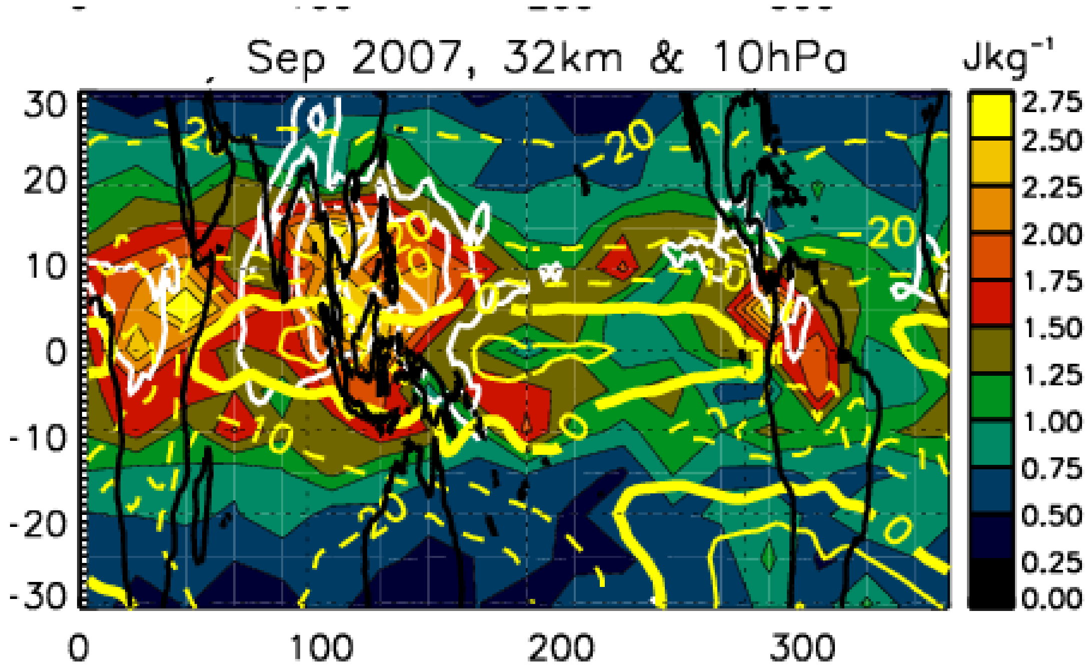
Baumgaertner & McDonald, 2007



Hei et al., 2008

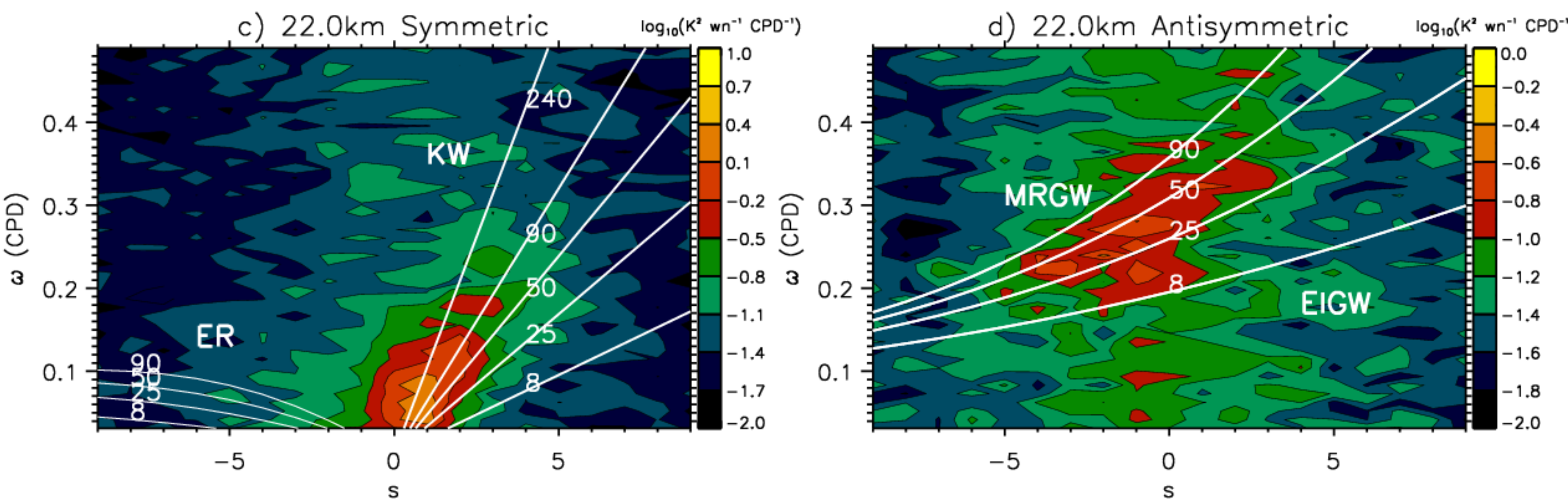
Tropical gravity waves

- COSMIC GPS-RO results for September 2007
- Winds were westward below 32km
- Large potential energy is visible directly above deep convective activity.
  - Slow $c_x > 0$ waves are encountering their critical level (group velocities also decrease close to critical levels, increasing the chance of wave observation.)



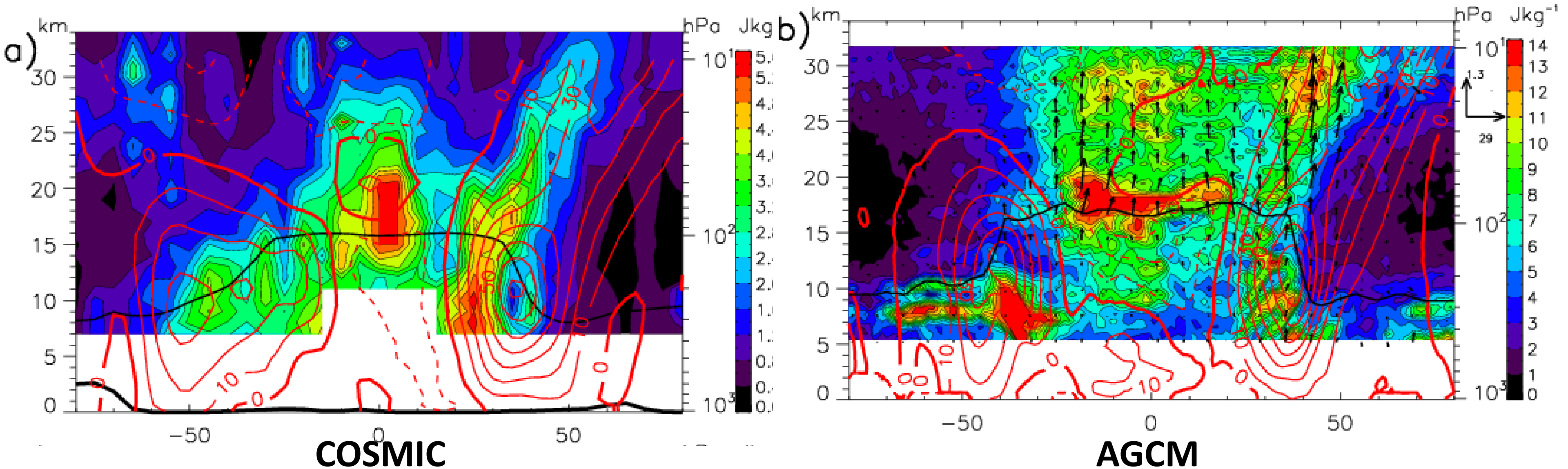
Equatorially-trapped waves

- Investigate with COSMIC data:
  - ‘slow’ Kelvin waves with $8 < h_e < 90$ m, corresponding to λ_z less than ~8 km ($h_e = 90$ m corresponds to $c_x = 30$ ms^{-1})
  - MRGWs with $8 < h_e < 90$ m.
  - While we can theoretically observe n=1 ER and n=0 EIGW, the resultant wave structures appear noisy and / or show little height consistency (there isn’t much power in these bands)



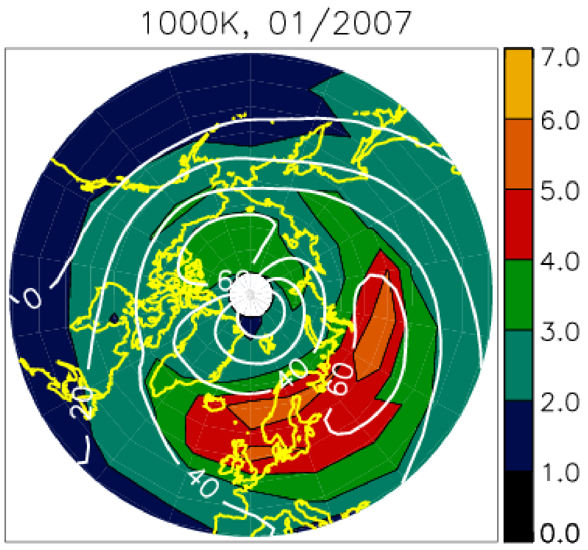
Extra-tropical gravity waves

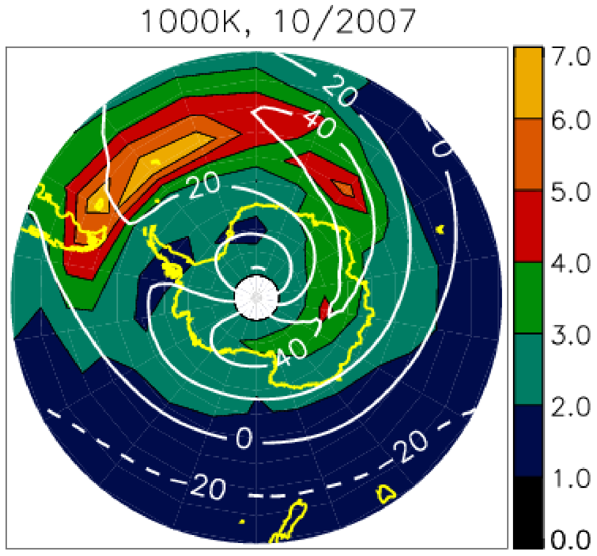
- COSMIC E_p (LHS) for 12-18 Dec 2006 at 140E
- AGCM E_p (RHS) for 1-7 Jan (similar wind conditions): vectors show meridional and vertical energy fluxes due to λ_z < 7km
- Large PE along the equatorward side of observed and modeled jet from mid-troposphere up to polar night jet



Gravity waves in the polar regions

- COSMIC resolves more intermittent orographic waves than CHAMP due to the larger amount of occultation events
- Evidence of gravity-wave Doppler shifting and orographic-wave activity in monthly averages

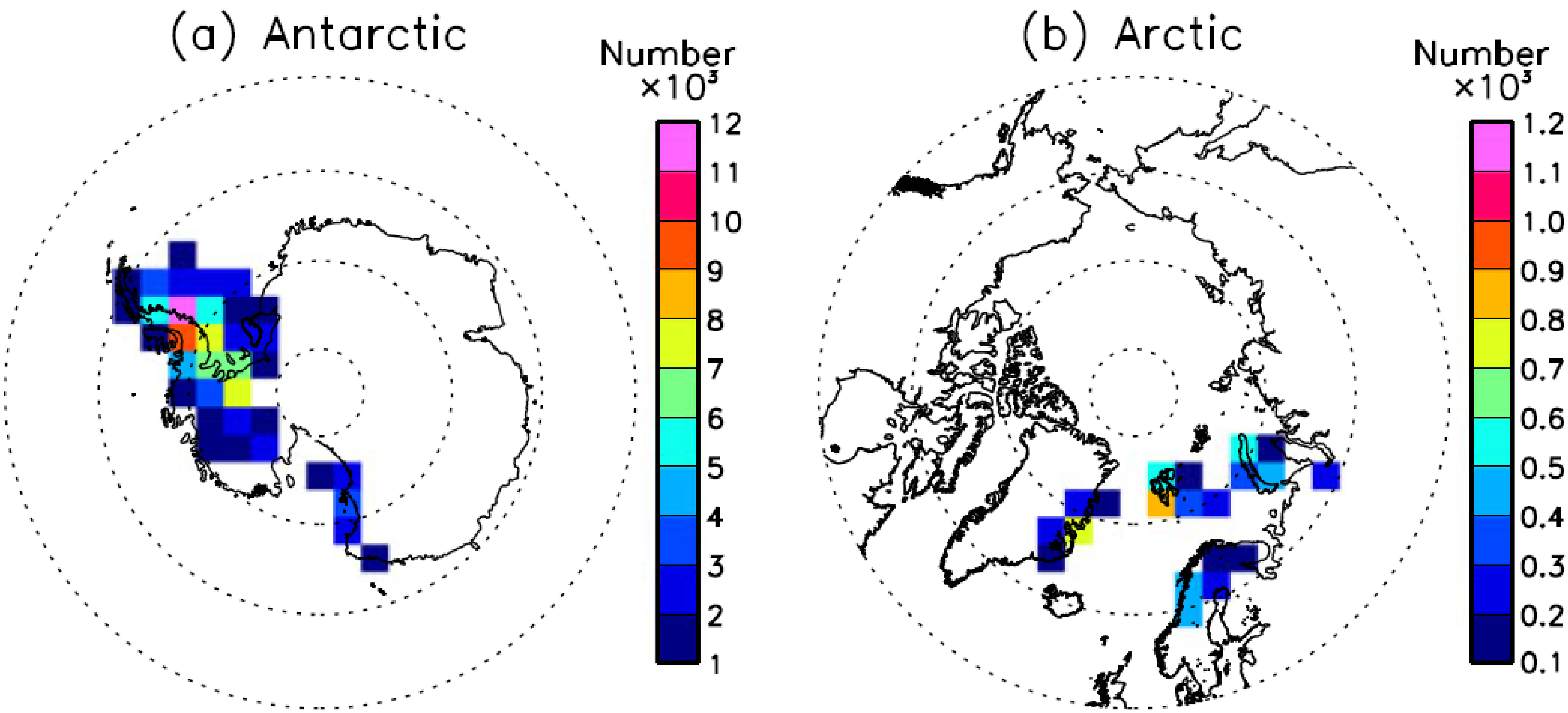




Orographic-gravity wave activity and Polar Stratospheric Clouds (PSCs)

- Question: Given that with COSMIC we can observe relatively short (< 1 week) variations in orographic-gravity wave activity above the Antarctic Peninsula, are these observable waves likely responsible for initiating the production of any PSCs?
- **Answer: YES!**

Ice PSC clouds generated by gravity waves

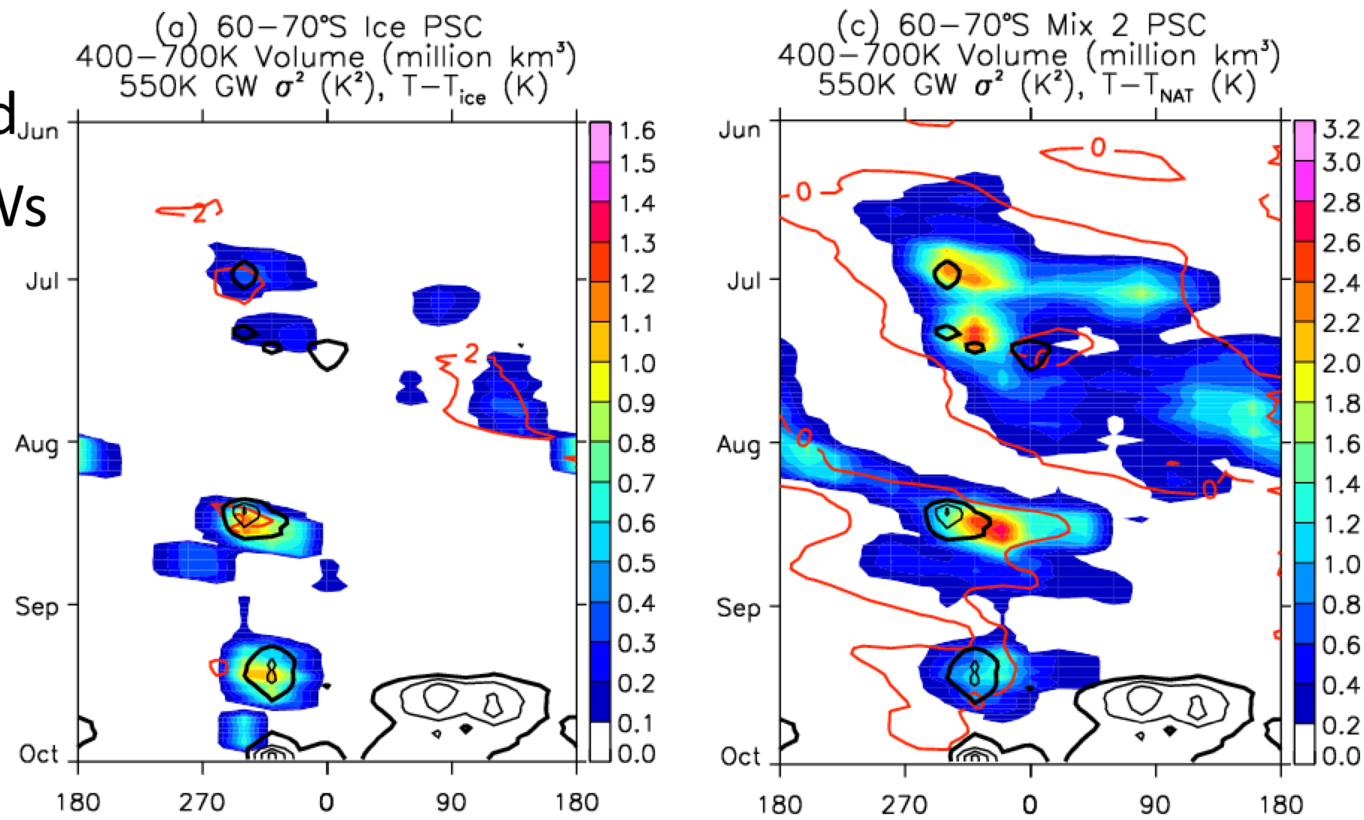


Orographic-gravity wave activity and Polar Stratospheric Clouds (PSCs)

- Large H_2O ice volumes above Peninsula when have large orographic gravity wave σ^2
- Increased NAT volumes for considerable distances downstream
- OGWs needed

in addition to PWs

to explain PSCs



Summary

- GPS-RO, and especially COSMIC, provide sufficient profiles of stratospheric temperature distributed around the world to investigate the structure of small-scale waves and their interactions with the atmosphere
- We expect that follow-up missions, such as COSMIC-2, will enable us to monitor shorter time-scale and smaller spatial-scale disturbances in the stratosphere.

References

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