Propagation of small-scale gravity waves of lower atmospheric origin into the thermosphere during sudden stratospheric warmings

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Sudden Stratospheric Warming

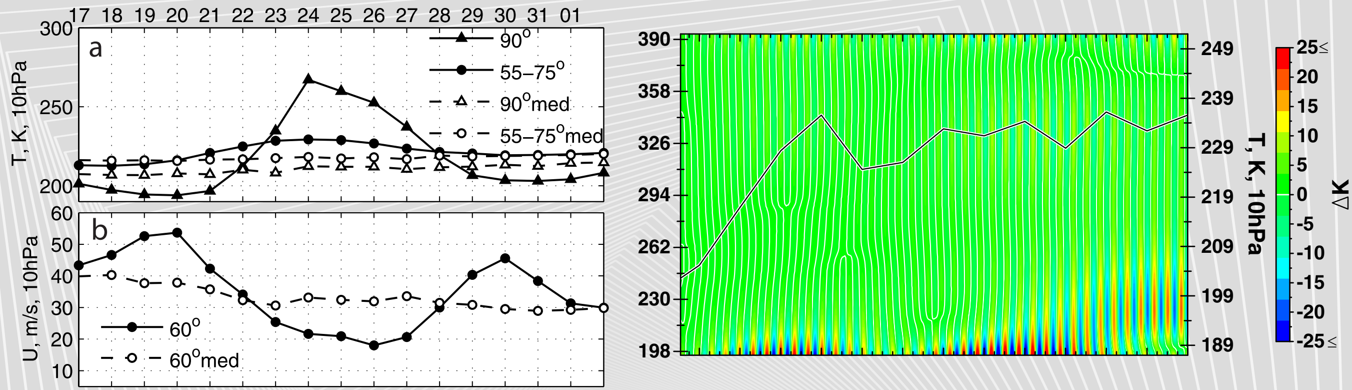

Figure 1: *Left: NCEP $\bar{T}$ and $\bar{u}$ ~ 30 km in Jan 2008 (Goncharenko and Zhang, 2008, Figure 1). Right: T_i residual oscillations during Jan 2010 SSW (Goncharenko et al., 2013, Figure 10).*

- Ionospheric effects (***Goncharenko and Zhang*, 2008; *Goncharenko et al.*, 2010; *Pancheva and Mukhtarov*, 2011)**
- Primary cause: PW amplification & breaking
- Wave signatures in the upper atmosphere during SSW (***Goncharenko et al.*, 2013)**

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Introduction - Science Question

Motivation/Science Question

How do gravity waves influence the thermosphere during sudden stratospheric warmings?

Gravity Waves

- Small-scale internal waves generated in the lower atmosphere.
- Unresolved & thus parameterized in GCMs.
- GW signatures observed in the thermosphere (***Djuth et al.***, **2004**)
- Propagation into the thermosphere ($>$ 105 km) and resulting ...
  - dynamical effects (***Yiğit et al.***, **2009**; ***Vadas and Liu***, **2009**; ***Yiğit et al.***, **2012**)
  - solar cycle variations (***Fritts and Vadas***, **2008**; ***Yiğit and Medvedev***, **2010**)
  - heating/cooling (***Yiğit and Medvedev***, **2009**)
- Significant variations of GW-induced effects in the thermosphere are expected during transient events occurring in the lower atmosphere.

The Extended Spectral Nonlinear Gravity Wave Parameterization

- Subgrid-scale GWs in GCMs (***Yiğit et al.*, 2008**)
- Neither intermittancy factors nor fudge factors are used!
- Input : Initial gravity wave activity at a given source level
- Output: GW induced dynamical and thermal effects
- Further developments of the work by ***Medvedev and Klaassen* (1995)**
- Accounts for the dissipation of GWs of lower atmospheric origin in the thermosphere: Nonlinear diffusion β_{non}, ion drag β_{ion}, radiative damping β_{new}, molecular viscosity and thermal conduction β_{mol}, eddy viscosity β_{eddy}.
- Applications:
  Earth: (***Yiğit et al.*, 2009; *Yiğit and Medvedev*, 2009, 2010; *Yiğit et al.*, 2012; *Yiğit and Medvedev*, 2012**)
  Mars: (***Medvedev et al.*, 2011a,b; *Medvedev and Yiğit*, 2012**)
  Venus: ***(Nakagawa et al., 2013)***

The Extended GW Parameterization

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Parameterization of the effects of vertically propagating gravity waves for thermosphere general circulation models: Sensitivity study

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[1] A parameterization of gravity wave (GW) drag, suitable for implementation into general circulation models (GCMs) extending into the thermosphere is presented.

⋮

Gravity waves during SSW

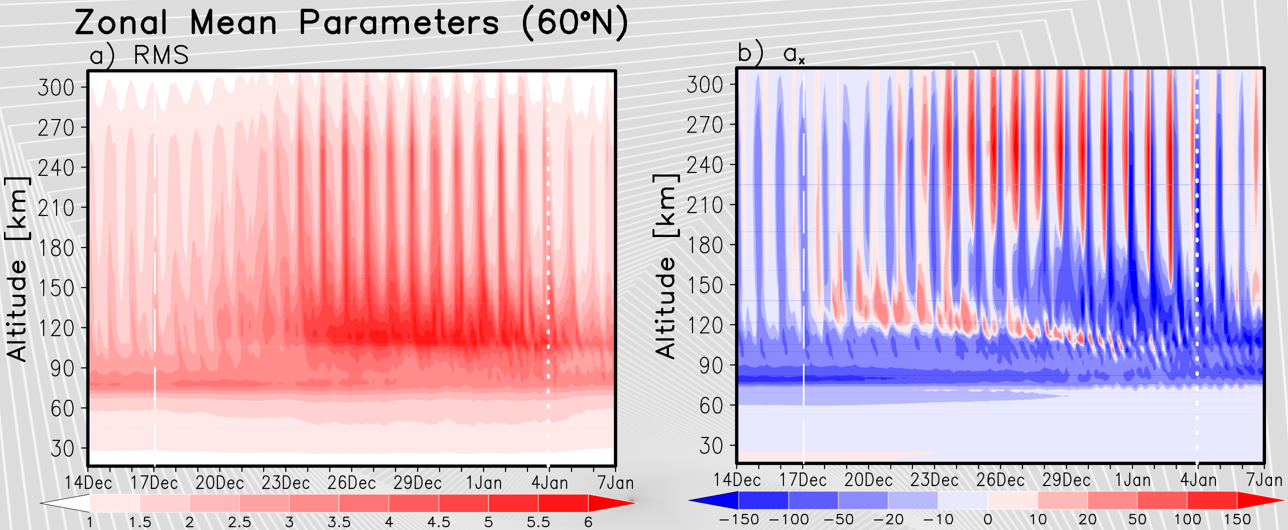

Figure 2: *Zonal mean a) RMS; b) zonal GW drag (Yiğit and Medvedev, 2012, Figure 2).*

GW activity

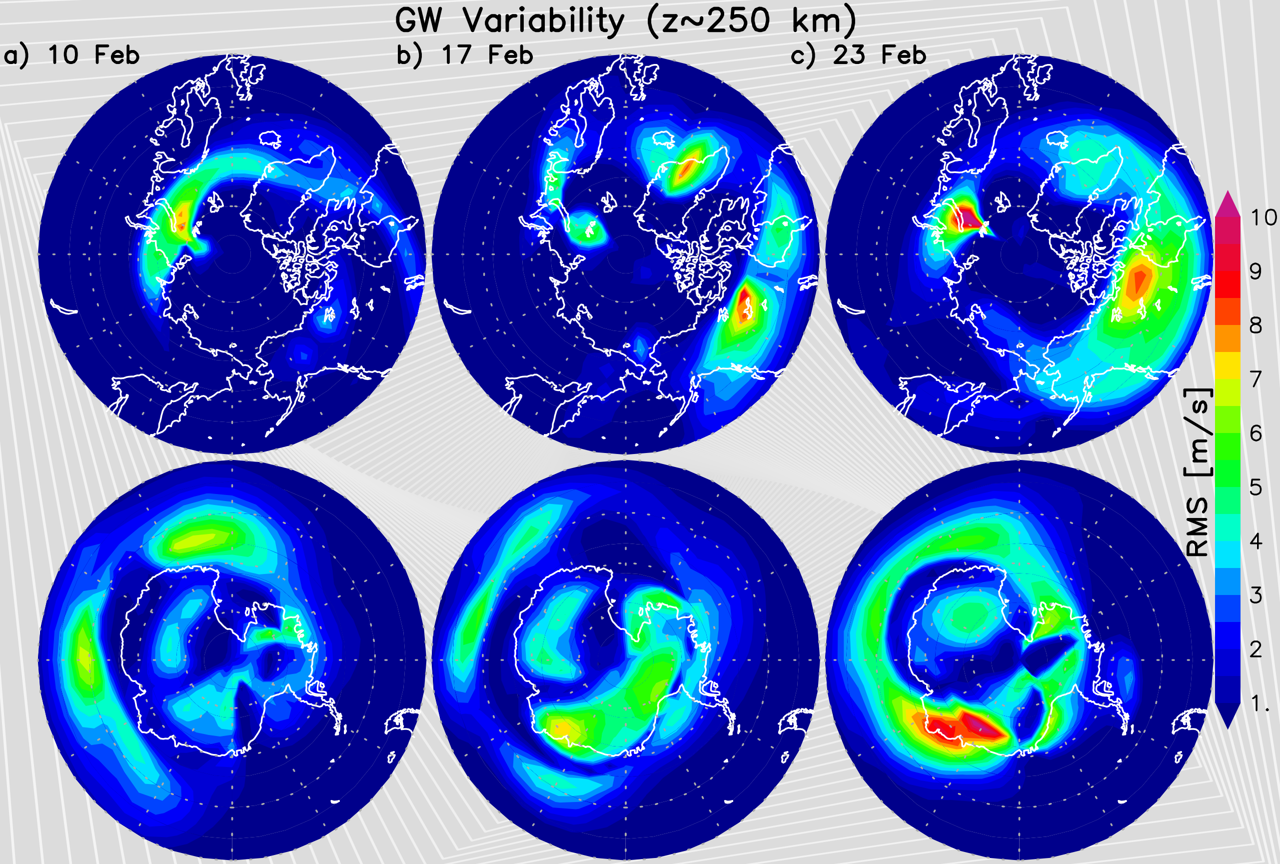

Figure 3: *GW activity variability at 250 km. [Yiğit et al., 2013, GRL, submitted]*

GW drag

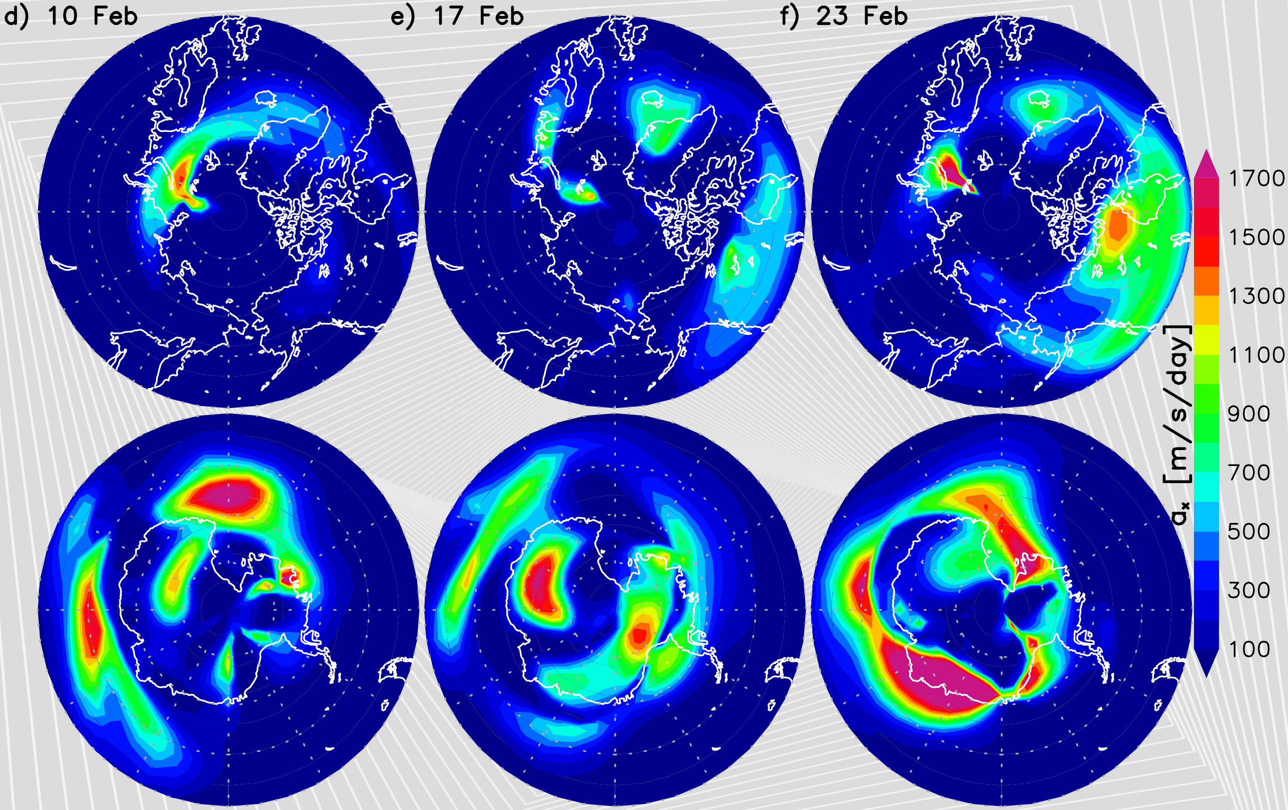

Figure 4: *GW drag variability at 250 km. [Yiğit et al., 2013, GRL, submitted]*

Effects on Thermospheric Variability

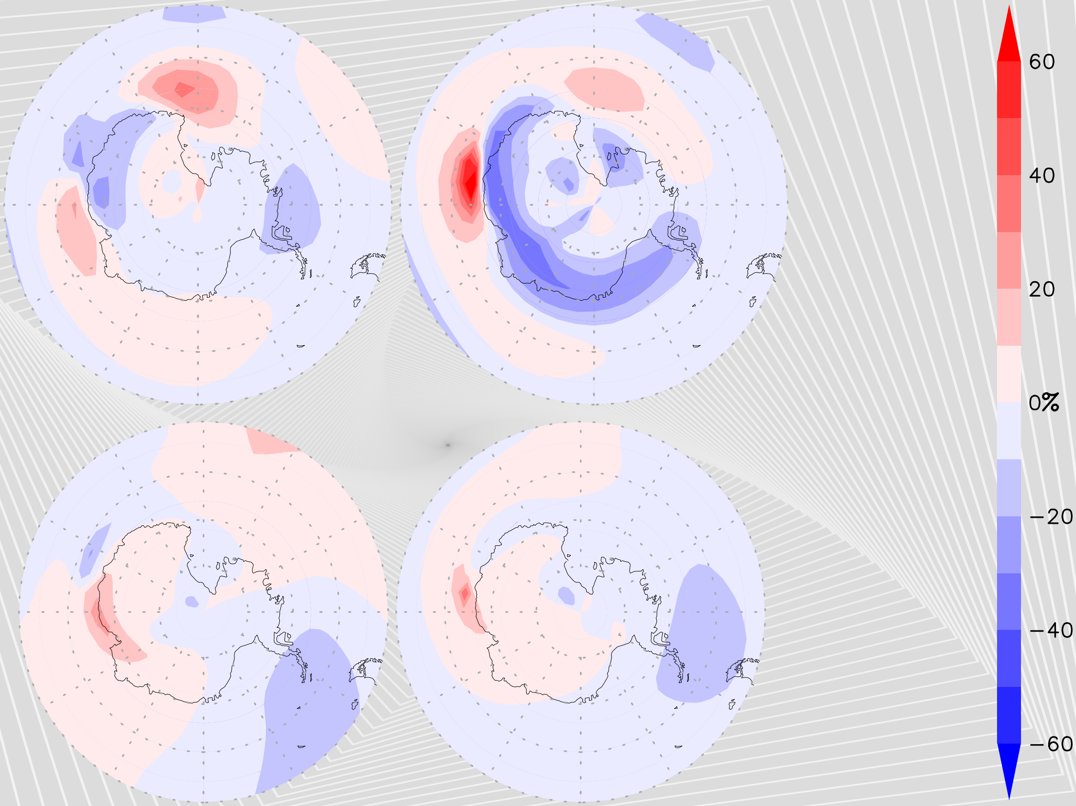

Figure 5: *Zonal wind variability change at 250 km in the SH [Yiğit et al., 2013, GRL, submitted].*

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Summary and Conclusion

Significant variations of GW activity/effects during SSW

During SSWs,

- GW penetration into the thermosphere above the turbopause
- Mean GW activity/effects in the thermosphere increase
- GW temporal variability increase
- GWs produce effects in the Southern (summer) Hemisphere in the thermosphere
- GWs influence thermospheric wind variability dramatically

SSW-induced GW variations are an appreaciable source of thermospheric variability

COSPAR: C2.2 Wave-coupling Session

2–10 August 2014

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Wave Coupling Processes in the Whole Atmosphere

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Description

This symposium focuses on troposphere to ionosphere multi-scale wave coupling. New measurements, modeling and theoretical results, and analysis techniques are encouraged, including electrodynamical and chemical studies. In particular, studies in the following areas are most welcome:

1. Global structure, variability, and sources of gravity waves, planetary waves, and tides.
2. Secondary wave generation, propagation, and their effects on the neutral and ionized atmosphere.
3. Neutral atmosphere-ionosphere coupling processes.
4. Ionosphere-thermosphere-mesosphere response to lower and middle atmosphere variability.

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