Evidence of tropospheric 90-day oscillations in the thermosphere

F. Gasperini¹, M. E. Hagan², and Y. Zhao²

[¹] Advanced Study Program, National Center for Atmospheric Research
[²] Department of Physics, Utah State University

OUTLINE

- Background
- Satellite Observations and Modeling
- Evidence of 90-day Oscillations in the Thermosphere
- Link to Tropospheric Convection
- Summary
Sources of Thermospheric Variability

Energy and momentum are transferred from one point to another within the atmosphere-ionosphere system through the generation and propagation of waves. In the ionosphere, wind perturbations associated with the waves can redistribute ionospheric plasma, either through the electric fields generated via the dynamo mechanism, or directly by moving plasma along magnetic field lines. Adapted from Figure 8.10, Solar and Space Physics Decadal Survey, National Academy of Sciences, 2012.

**Wave Coupling in the Atmosphere-Ionosphere System**

- Aurorally-generated waves
- Secondary waves
- Wave dissipation & mean flow acceleration
- Wave-wave interactions
- Equatorial wave-dynamo
- Plasma flow
- Tidal dissipation
- GW seeding
- GW, Tides
- Kelvin waves
- GW, Tides
- Modulation
- Turbulence and mixing
- Planetary wave-Tide Modulation
- GW
- O$_3$
- H$_2$O
- Tides

**Dissipation of Upward Propagating Waves**

**Sources from BELOW**

Solar and Space Physics Decadal Survey, National Academy of Sciences, 2012 (Jeff Forbes).

CEDAR Workshop - 28 June 2018
DE3 tide

i.e. Diurnal Eastward propagating wavenumber 3 tide

- Excited in the tropical troposphere by latent heat release in deep convective clouds
- Significant source of variability in the ionosphere and thermosphere
- Large contributor to the ionospheric 4-cell (or wave-4) structure
3. OBJECTIVE

**A. Data**

- **TIMED-SABER CHAMP GOCE**
  - Jul 00 – Sept 10
  - near-circular 450-300 km with \( i = 87° \) (slowly precessing)
  - Global
  - Cross-track (east-west) winds from accelerometer data

**LIFETIME**

- Mar 09 – Nov 13
- near-circular 260 km dawn-dusk with \( i = 96.7° \) (sun-synchronous)
- Global
- Cross-track (east-west) winds from accelerometer data

**CHAMP**

- Jul 00 – Sept 10
- near-circular 450-300 km with \( i = 87° \) (slowly precessing)
- Global
- Cross-track (east-west) winds from accelerometer data
Global time-dependent model developed by NCAR.

F10.7 and Kp indices used to represent solar radiative and high-latitude forcing.

Grid: 2.5°x2.5°, 30-500 km, 1-min time step.

Lower boundary set with MERRA reanalysis data that provides realistic wave forcing.

The focus here is on zonal winds during 2009-2010.

Infrared radiation emitted from Earth and its atmosphere to space.

Measured by radiometers onboard NOAA’s polar orbiting satellites.

Serves as proxy for tropospheric convection, because convective cloud tops are cold and thus emit little long-wave radiation.
Evidence of 90-day oscillations in the thermosphere

The 90-day oscillation does not appear to be connected to solar or geomagnetic forcing.
Vertical structure

TIME-GCM - Zonal Mean Wind

TIME-GCM - DE3 Zonal Wind

85-95 day filtered

a.  
b.  
a'.  
b'.
Link to Tropospheric Convection

- OLR (blue) and TIME-GCM mean wind at 400 km
- Time (days since 1 January 2009)
- Wind (m/s)

- TIME-GCM mean winds at 400 km
- Wind (m/s)
- Time (days since 1 January 2009)

- OLR (blue) and TIME-GMC mean wind at 400 km (red)
- OLR (blue), CHAMP (solid orange) and GOCE mean wind (dashed orange)

- Smoothed OLR

- Periodogram
- Period (days)

- Correlation coefficients: r=0.71, r=0.59, r=0.63
Summary

- CHAMP and GOCE cross-track winds reveal the existence of significant 90-day variations in the thermospheric mean winds (±20 m/s) and DE3 (±3 m/s) during 2009-2010.

- MERRA/TIME-GCM demonstrates that this oscillation is coherent with height and is not propagating from below.

- OLR reveals that the same 90-day oscillation is present in tropospheric convection and that it correlates with observed (r=0.59-0.63) and modeled (r=0.71) thermospheric winds.

- Similar (but localized) 90-day oscillations are also present in mesospheric temperatures [Y. Zhao].

- Our results suggest that tides and gravity waves are modulated by tropospheric convection at a period of 90 days and transfer this periodicity to the mean circulation of the thermosphere via dissipation and energy/momentum deposition.
Outstanding Questions

Q1: How frequent, prevalent, and persistent are correlations between 30-100 day variations in the troposphere, mesosphere, and thermosphere in the past 15 years?

Q2: How well does WACCM-X 2.0 capture the observed intra-seasonal variability from the mesosphere up to the thermosphere?

Q3: What plausible roles do large-scale upward propagating waves play in dynamically coupling tropical tropospheric intra-seasonal variability into the thermosphere?
ACKNOWLEDGEMENTS

This work was primarily supported by NASA subaward 75900816 to Utah State University under the USPI Program for the GOCE mission.

Questions?
federico@ucar.edu

A special thanks to Dr. Yucheng Zhao for valuable conversations about 90-day oscillations in mesospheric temperatures during 2009.