

## WACCM-X Nature Run

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1: NCAR/HAO; 2: NCAR/CGD; 3: NCAR/ACOM; 4: NCAR/MMM



# Outline

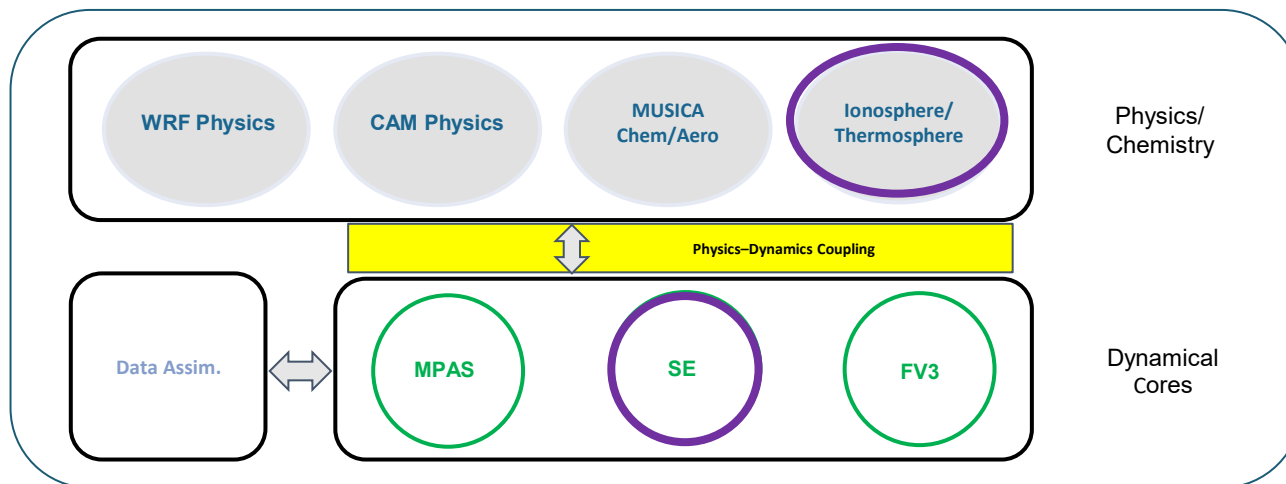
- High-resolution WACCM-X Model and full year Whole Atmosphere Nature Run.
  - Branch runs:
    - Hunga-Tonga impact simulation
    - Storm time simulation with GAMERA driving
- Assessment of climatology and weather
  - Gravity wave distribution and scale dependence
  - Tides and tidal variability (DW1)
  - Semi-annual Oscillation
- Dynamics and composition: thermospheric O/N<sub>2</sub> and MLT NO
- Ionospheric TIDs.
- Storm time responses.
- Potential applications.



# SIMA/WACCM-X With High Resolution Capability

- NCAR System for Integrated Modeling of the Atmosphere (SIMA)-Geospace.
- Neutral dynamics and physics
  - WACCM-X Species Dependent Spectral Element (SE) Dynamical core.
  - Cubed sphere grid (no polar singularity)
  - Molecular viscosity/diffusion in horizontal and vertical direction.
- Regridding between physics mesh and geomagnetic grid.
  - Interactive ionospheric dynamo, transport, and energetics.
- High resolution configuration:
  - ~25km horizontal, 0.1 scale height vertical resolutions.

## SIMA Geospace

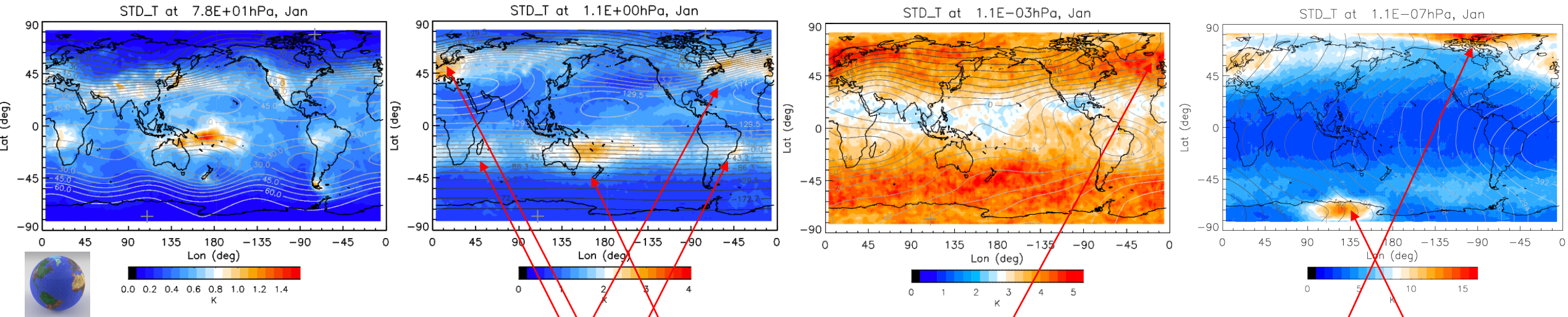


# Nature Run

- Simulation over one model year (F10.7=120, geomagnetically quiet).
- **Monthly output**: Key quantities for composition, energetics, dynamics, and electrodynamics from the troposphere to the thermosphere and ionosphere (142 fields, 14TB)
- **Daily output**: Tidal components of winds and temperature (18 fields, 7TB).
- **6-hourly output**: Key quantities for composition, energetics, dynamics, and electrodynamics from the troposphere to the thermosphere and ionosphere (27 fields, 36TB).
- **5-min output**: 2D ionospheric quantities (TEC, electric potential, Petersen and Hall conductances, 0.7TB)
- Restart files every 10 days (1<sup>st</sup>, 11<sup>th</sup>, 21<sup>st</sup> of each month) can be used for branch runs (27 TB).
- ~15 Million Core Hours on NCAR Cheyenne Supercomputer with SIMA NCAR Strategic Capability (NSC) allocation.

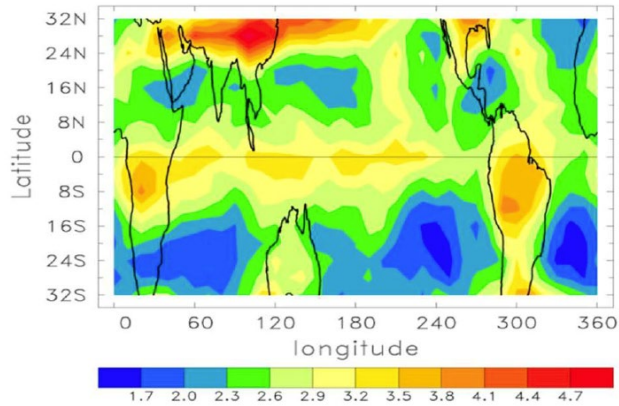


# Gravity Wave Distribution: Longitude-Latitude-Height

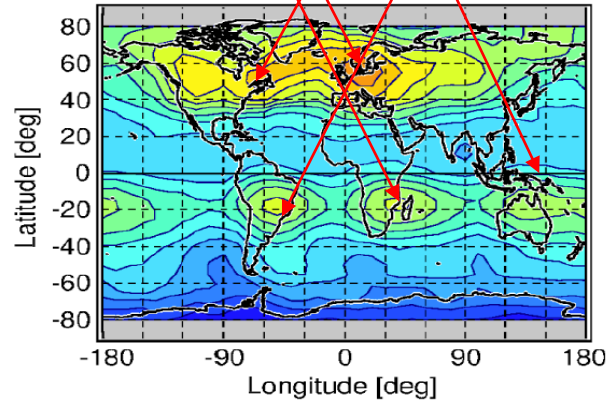


**(a) SABER: January**

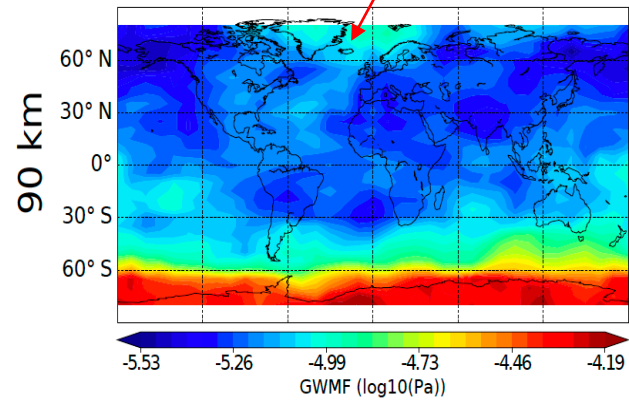
a) 18-20 km residual variance



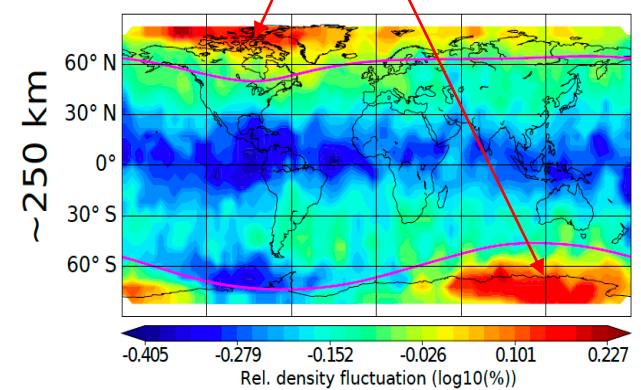
Randel et al., 2021



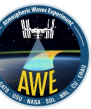
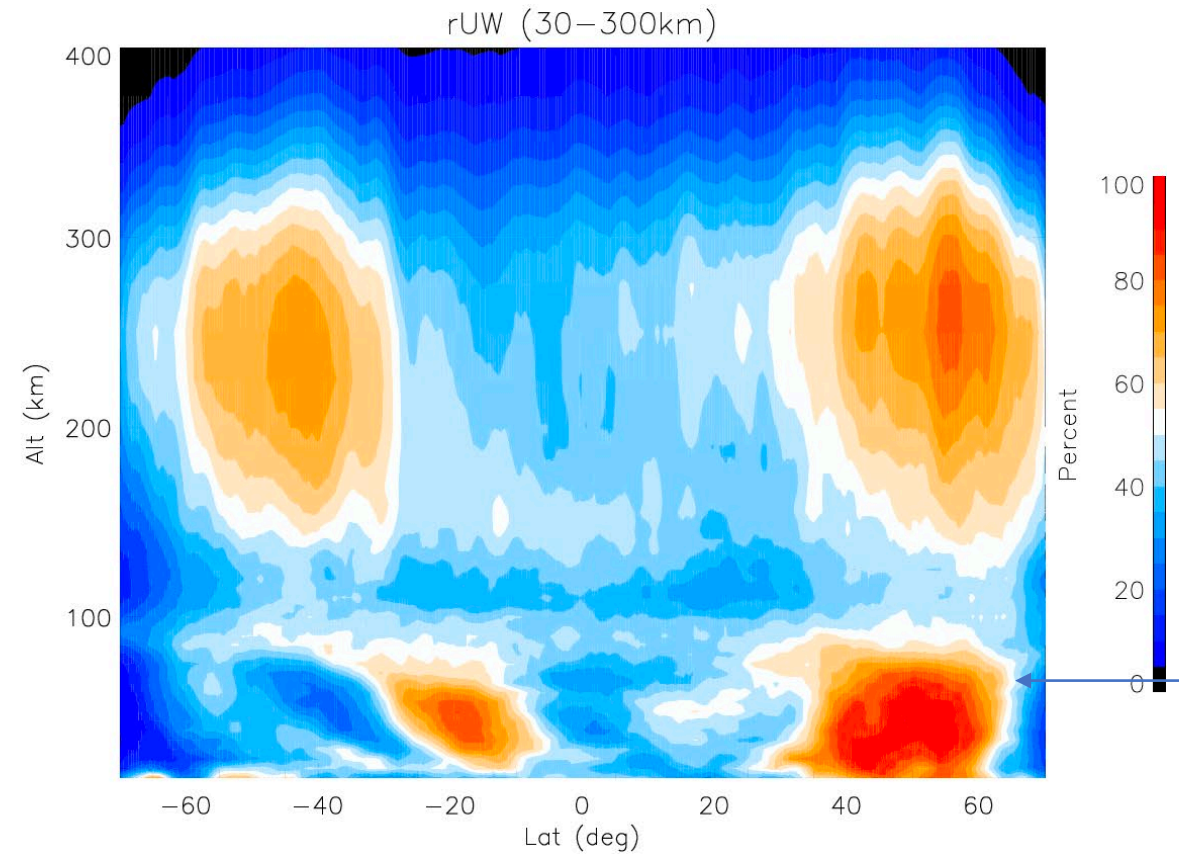
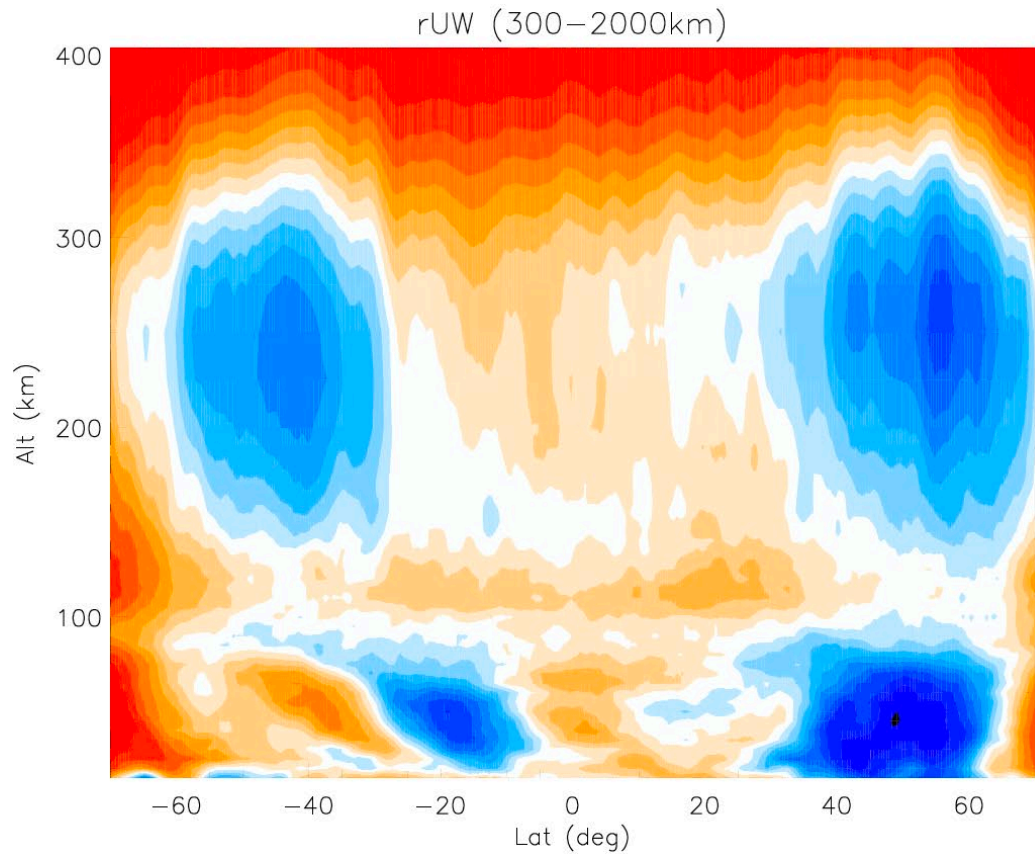
Ern et al. 2011



Trinh et al. 2018

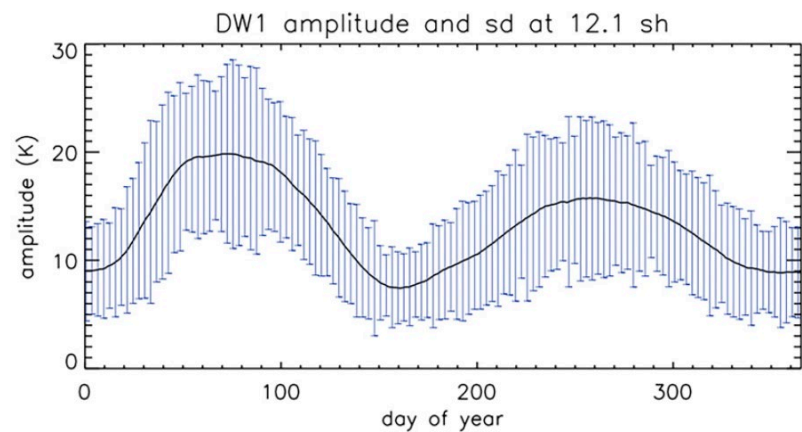
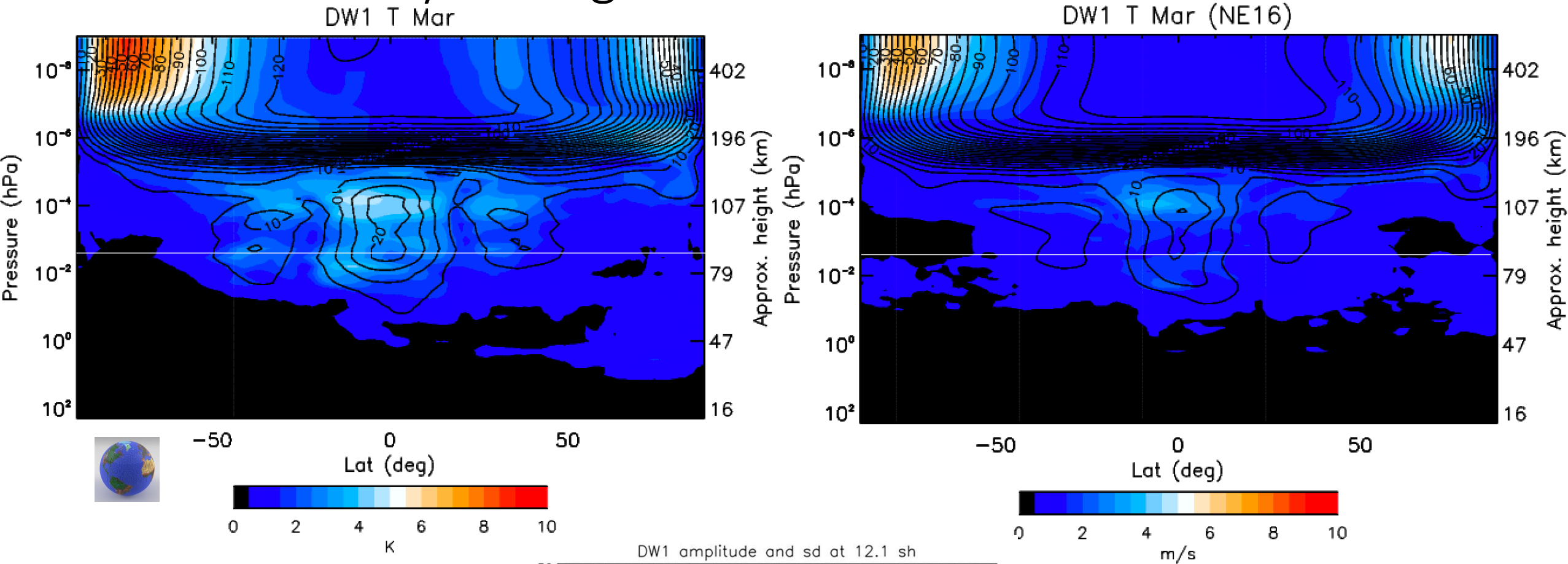


# Scale Dependence of Gravity Wave Momentum Flux



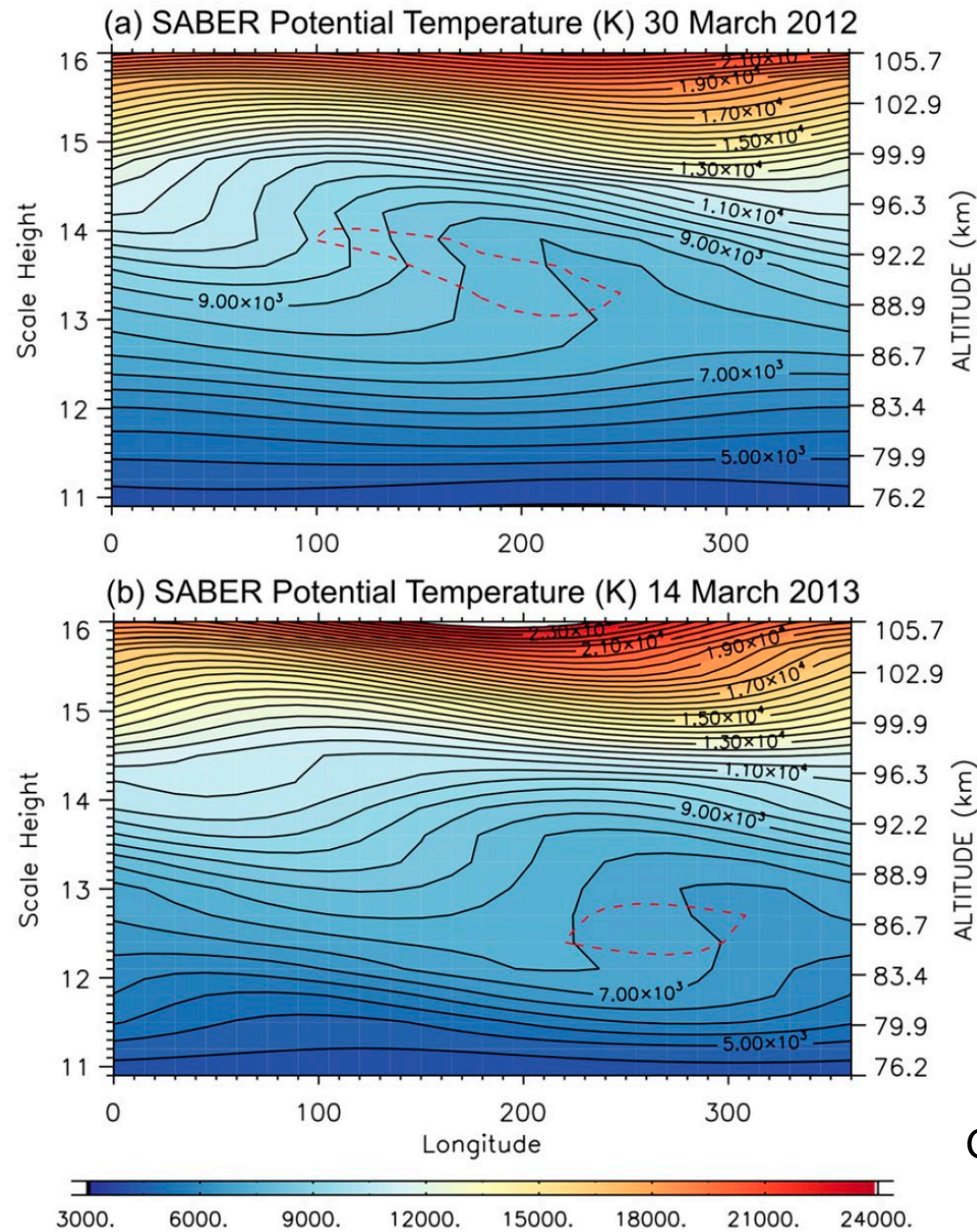
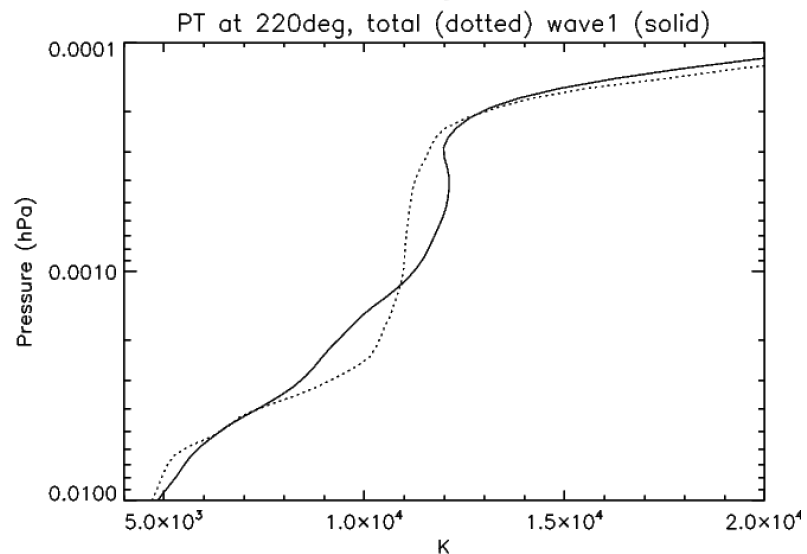
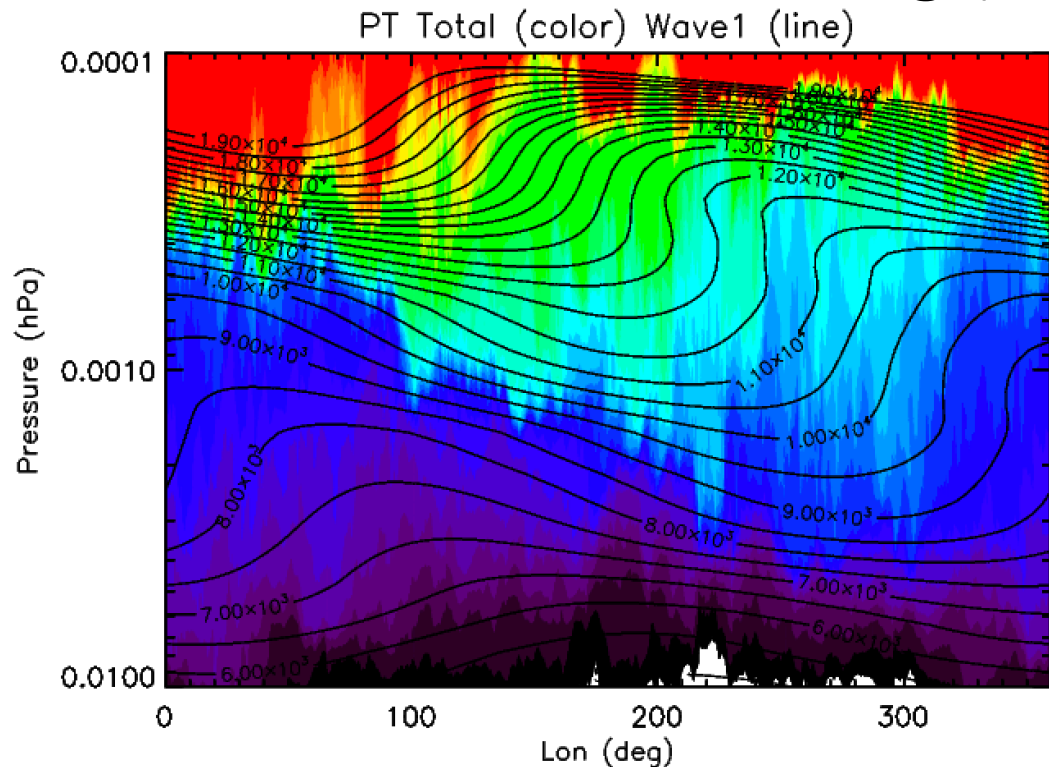


# DW1 Monthly Average and Variability



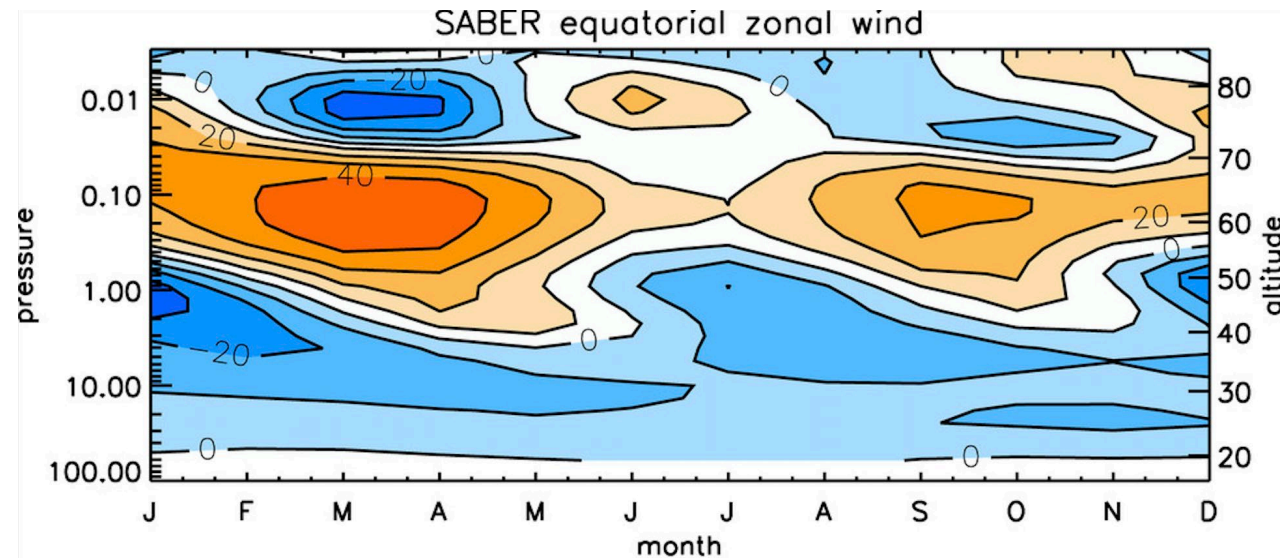
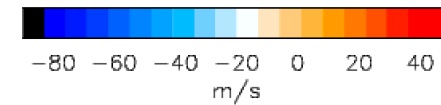
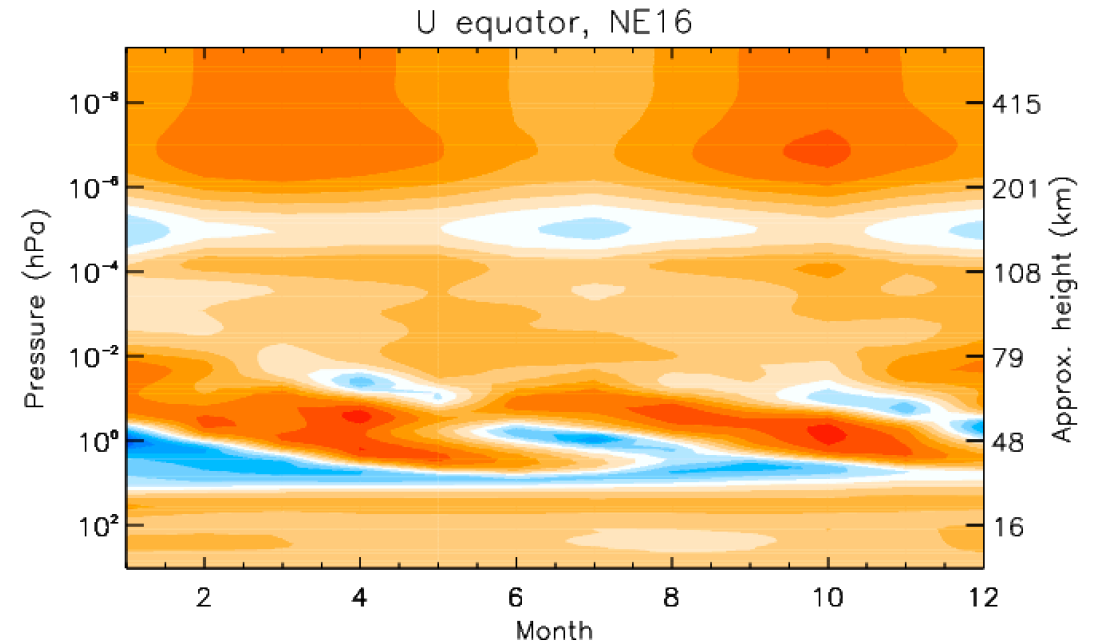
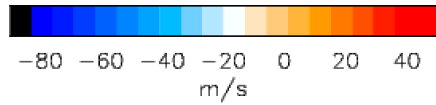
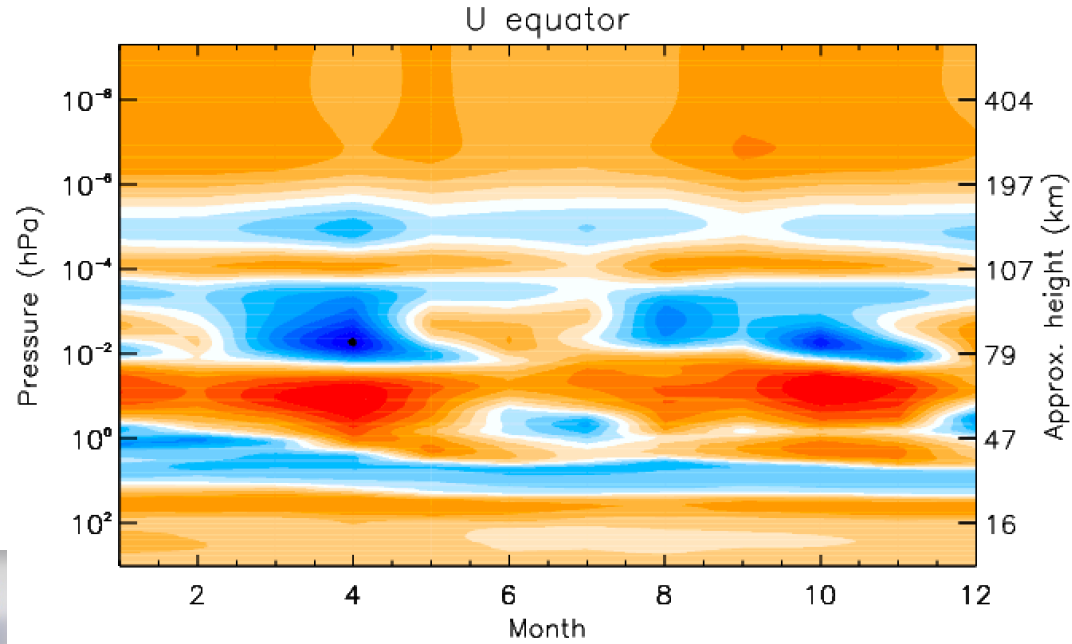
Garcia, 2023

# Diurnal Tidal Wave Breaking (March)





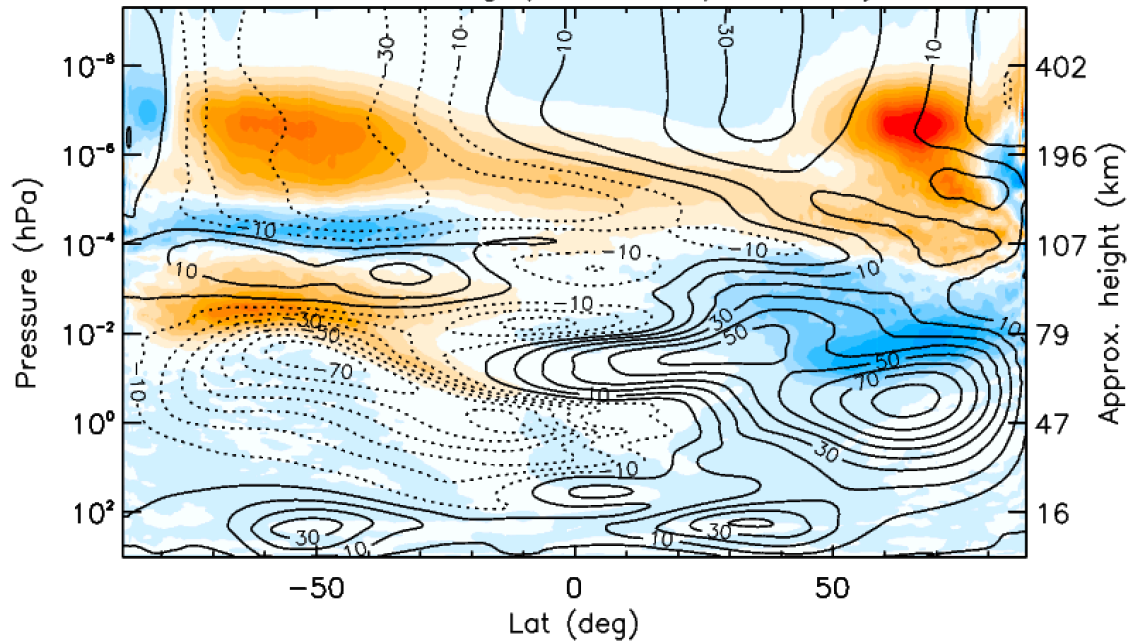
# Equatorial Dynamics: Semi-Annual Oscillation



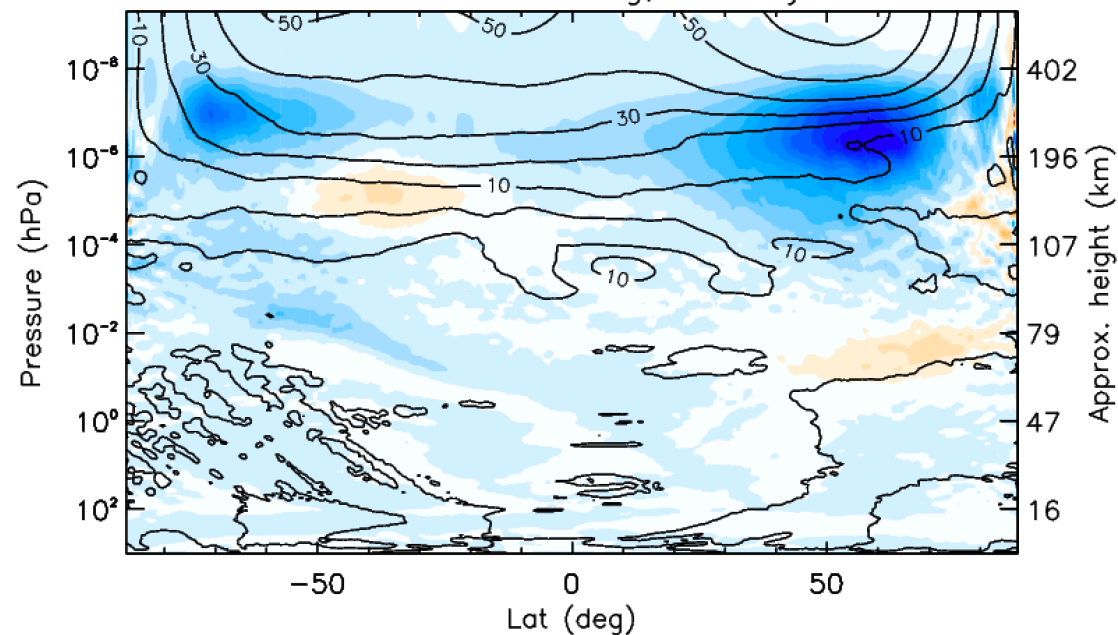
Smith et al., 2017

# Impact on Wind and Circulation

Zonal forcing (<2000km), January

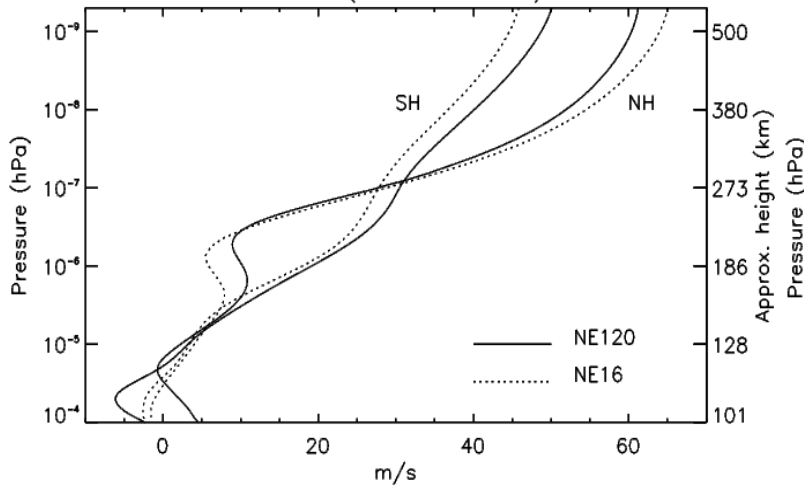


Meridional forcing, January

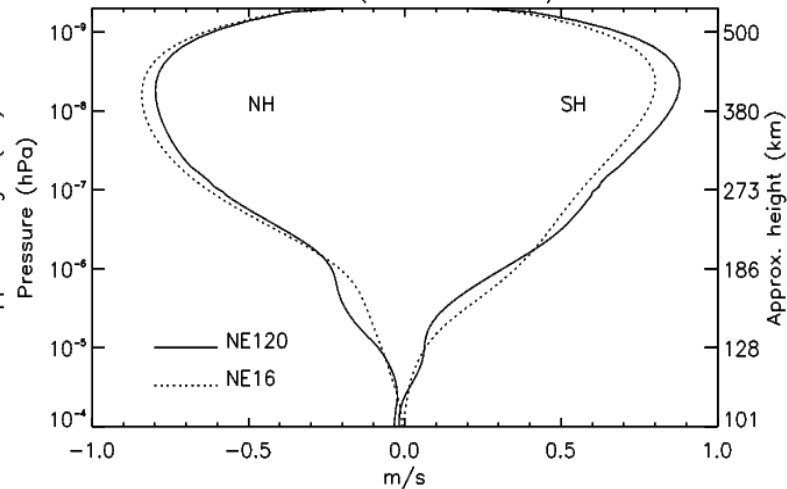


Liu et al., 2024

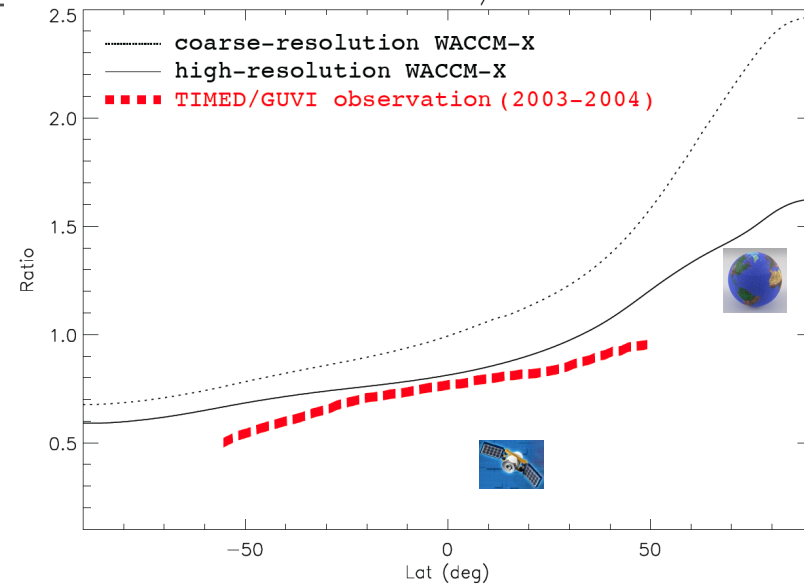
Mean V (Lat 57.5–63.5)



Mean W (Lat 57.5–63.5)



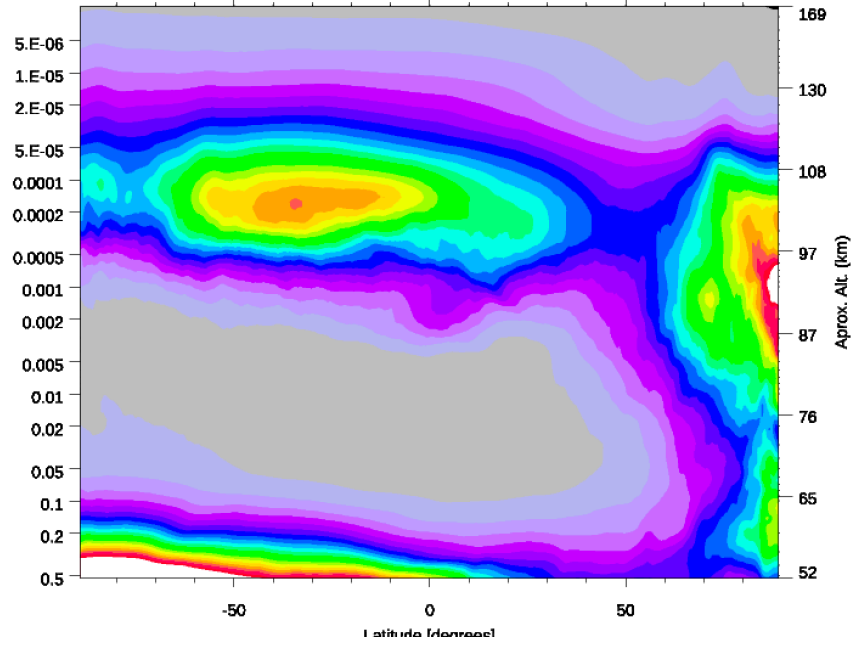
Zonal mean O/N<sub>2</sub> Jan



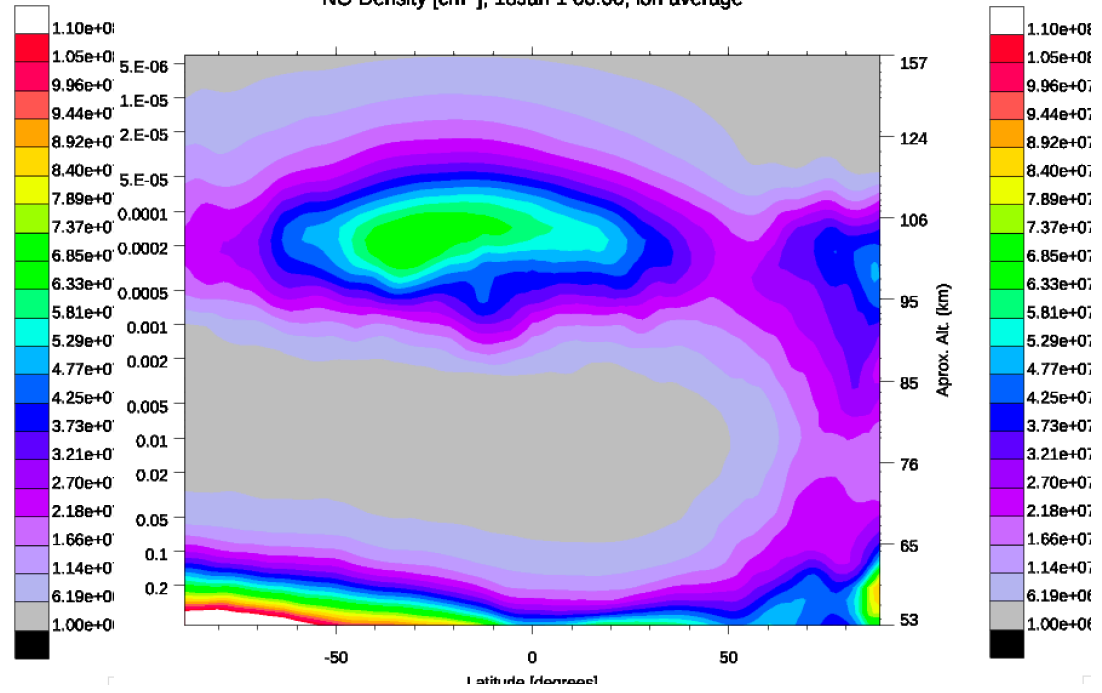


# NO in MLT

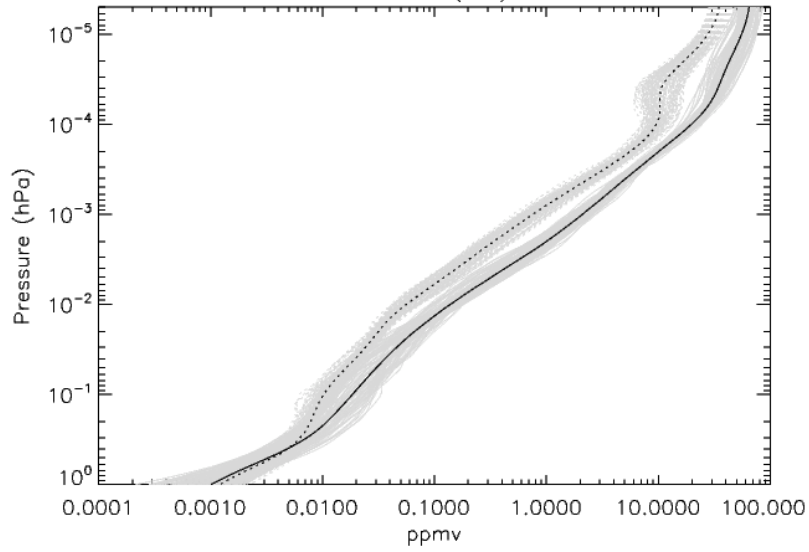
NO Density [cm<sup>-3</sup>], 18Jan 1 00:00, lon average



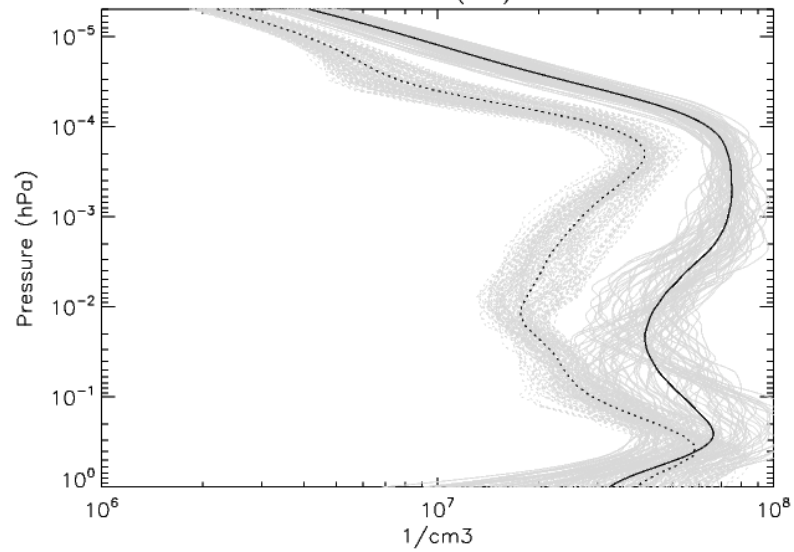
NO Density [cm<sup>-3</sup>], 18Jan 1 00:00, lon average



Zonal mean vmr(NO) 75N Jan

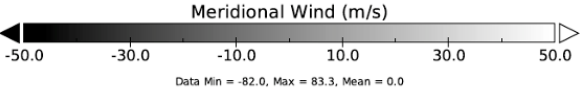
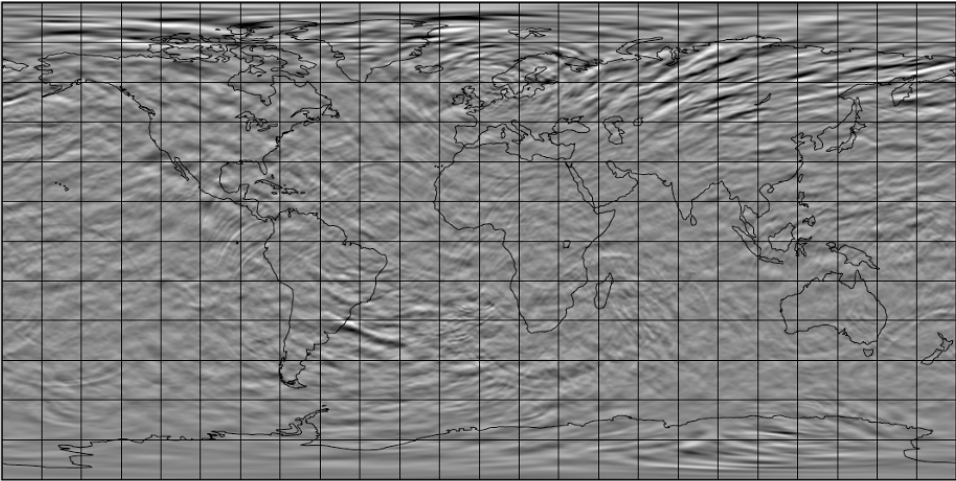


Zonal mean vmr(NO) 75N Jan



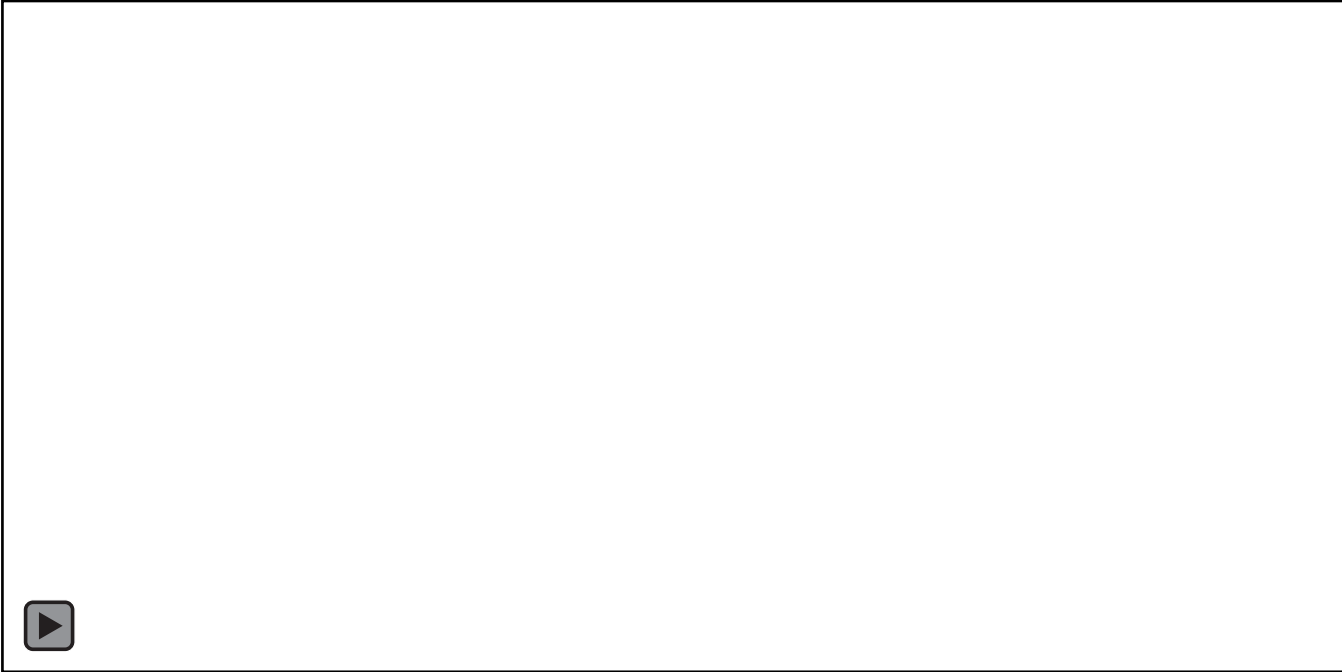
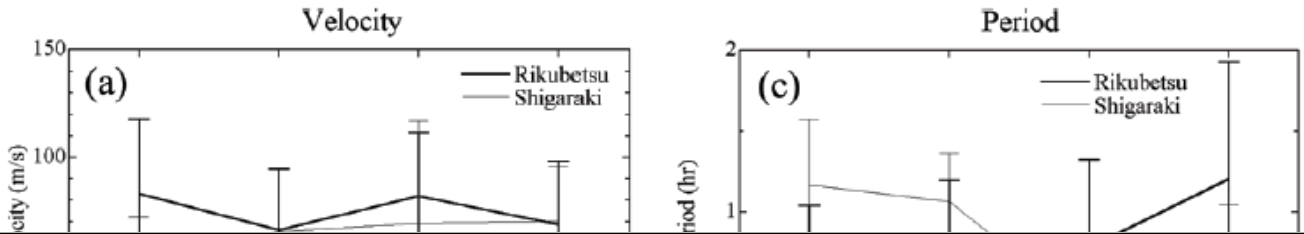
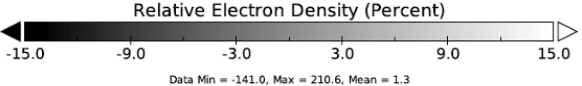
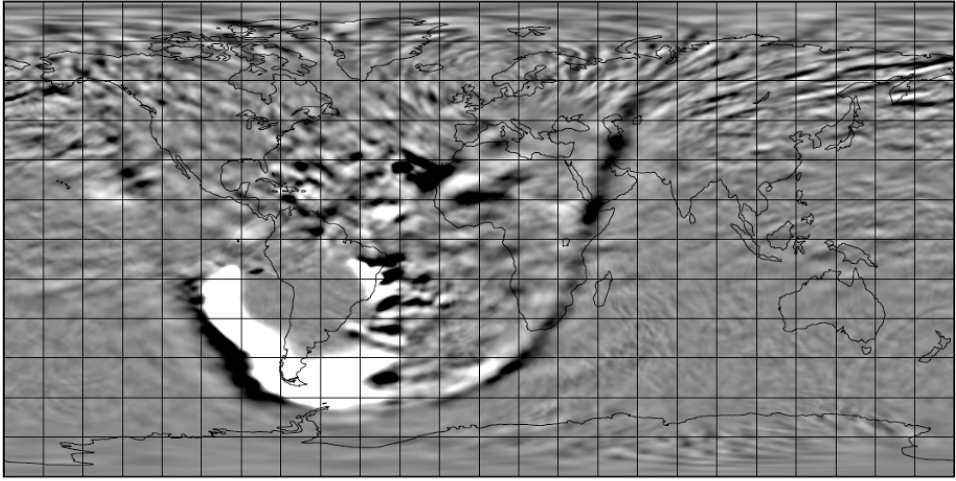
# Gravity Wave driven TAD/TID

Meridional Wind



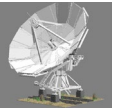
< 2 Hours

Relative Electron Density



Shiokawa et al., 2003

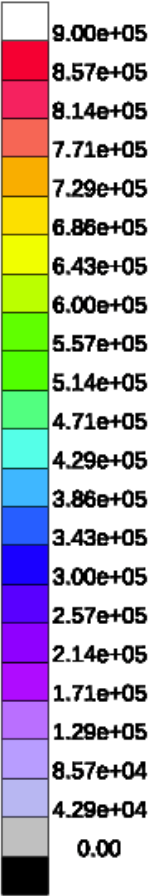
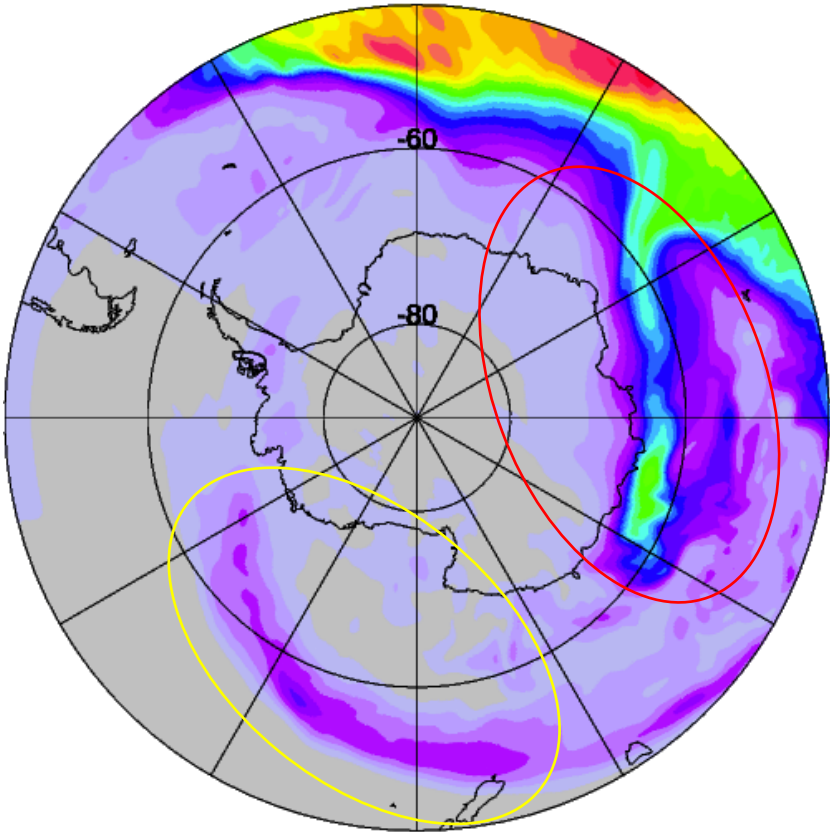
Statistics of Nighttime MSTIDs at Midlatitudes



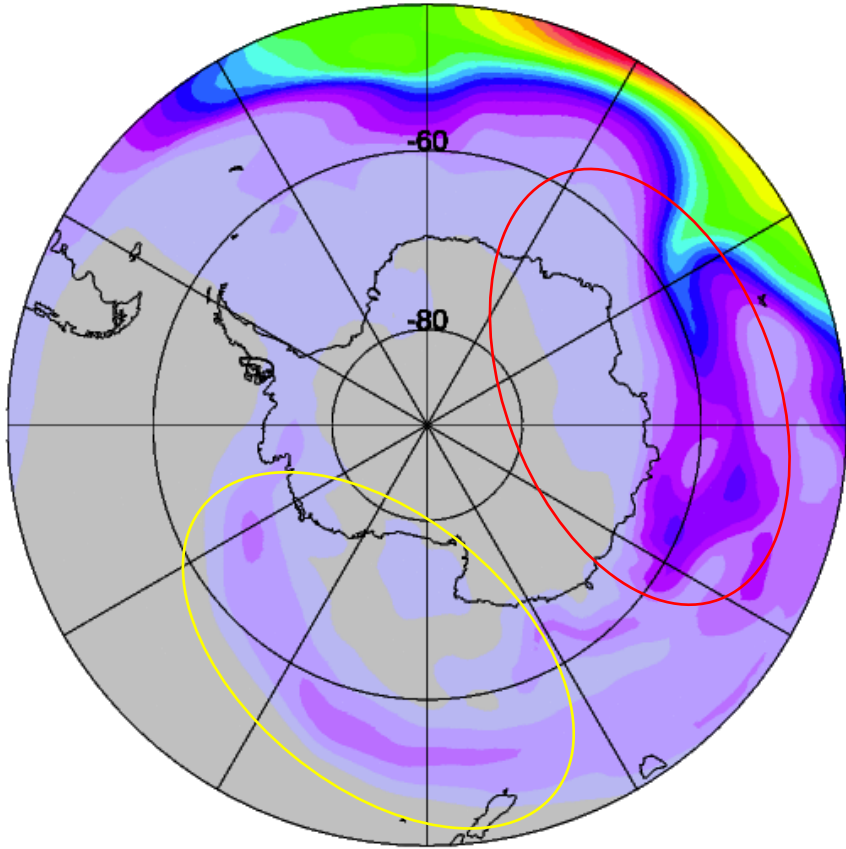


# Storm Time Response: Electron Density:

EDens [cm<sup>-3</sup>], ca. 3.9391303e-08 hPa, 24Aug2005 10:30

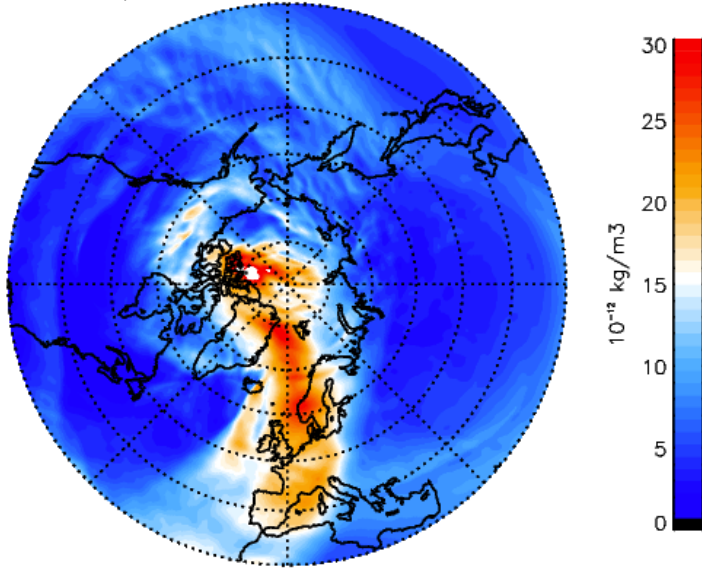


EDens [cm<sup>-3</sup>], ca. 3.6503215e-08 hPa, 24Aug2005 10:30

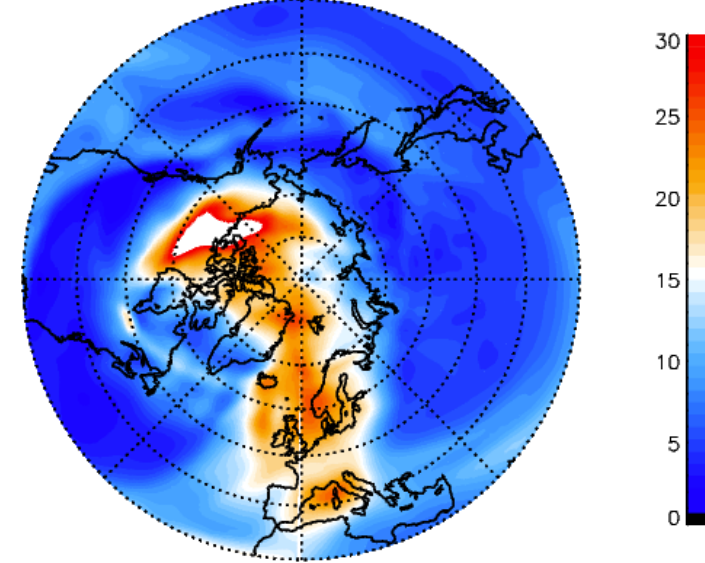


# Neutral Density: UT1132

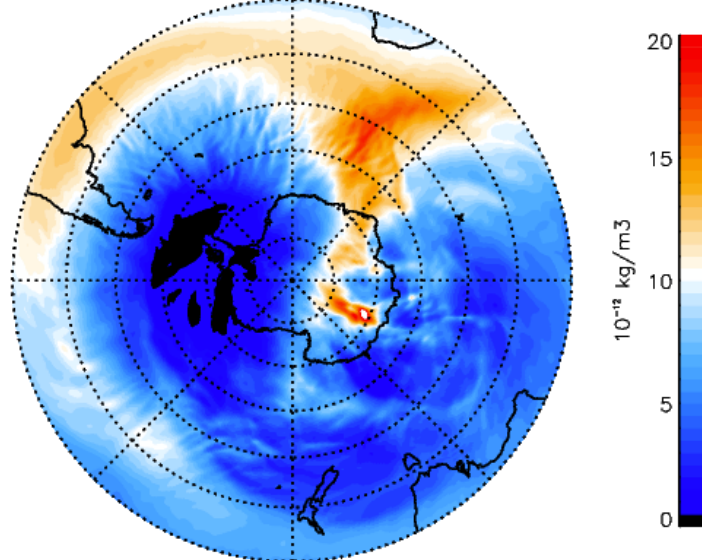
Density 400km 8/24/2005 UT 11:32



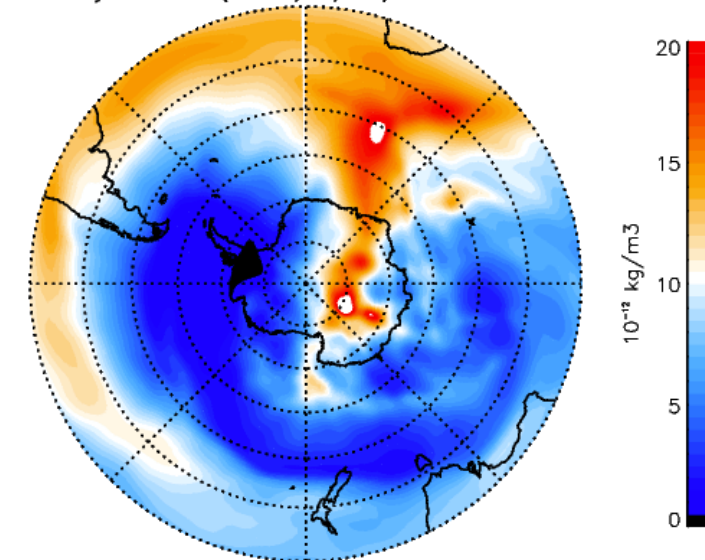
Density 400km (NE30)8/24/2005 UT 11:32



Density 400km 8/24/2005 UT 11:32



Density 400km (NE30) 8/24/2005 UT 11:32



# Potential Applications

- Explore dynamics-chemistry-electrodynamics coupling.
- Interpret observations and test hypothesis.
- Forward modeling for mission planning.
- Use for OSSE and data assimilation.
- Developing parameterizations schemes.
- ...
- Caveats
- Data serving: Globus, but currently have issues after transition in November