Ionospheric Variability Due to Lower Atmosphere Driving

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Motivation

- Ionospheric day-to-day variability ~= Near Space Weather.
- Lower atmosphere contribution ~= Geomagnetic disturbances contribution (e.g. Rishbeth and Mendillo, 2001; Rishbeth, 2006). Though pathways not clear.
- Day-to-day variability from TIME-GCM/ECMWF study was much weaker than observed.

Methodology

- NCAR Whole Atmosphere Community Climate Model with thermosphere extension (WACCM-X): 20-year climate simulation under perpetual 2000 conditions (geomagnetically quiet, and with nudged QBO).
- SD-WACCM-X with troposphere/stratosphere constrained by MERRA reanalysis (Jan-Feb 2006).
- TIME-GCM with stratosphere/mesosphere constrained by WACCM-X/MERRA simulations results.

Numerical Model: WACCM-X

- Whole Atmosphere Community Climate Model extending from earth surface to the upper thermosphere.
- Self-consistently resolve the dynamical, physical and chemical processes (ionospheric electrodynamics under development).
- Now released as one of the atmosphere components of NCAR CESM (CESM1.0.4).
- Can be run either as a climate model or with lower/middle atmosphere nudging (specified dynamics).

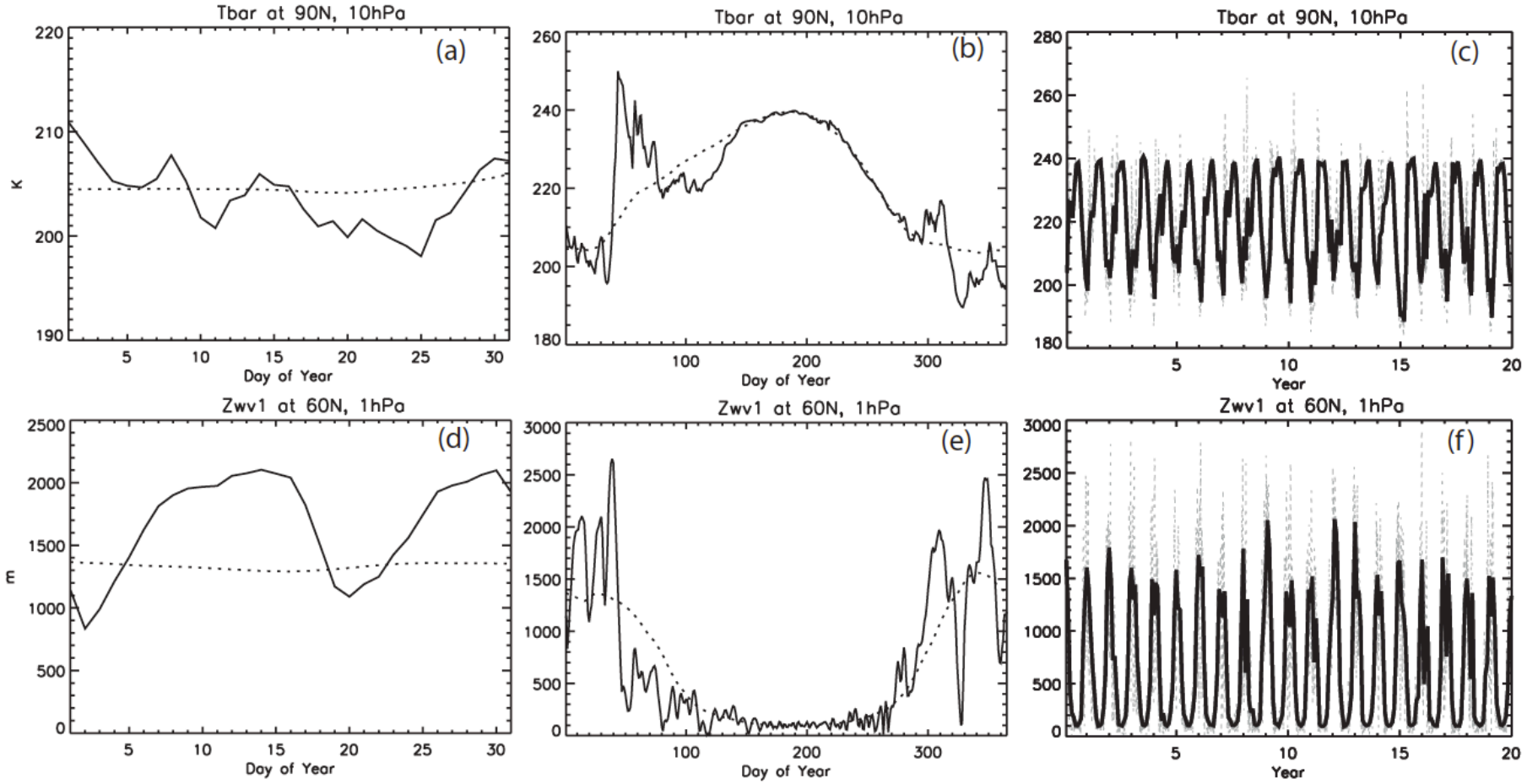
Numerical Model: NCAR TIME-GCM

- NCAR TIME-GCM: Thermosphere-ionosphere-mesosphere-electrodynamics general circulation model:
  - Simulates the circulation, thermal, and compositional structures and electrodynamics from the upper stratosphere to the exosphere (30-500km) (Roble, 2000).
  - Tidal waves from the lower atmosphere specified by Global Scale Wave Model (GSWM, Hagan, 1996).
  - Lower boundary can be specified by re-analysis output (NCEP or ECMWF) or idealized planetary waves.

  OR

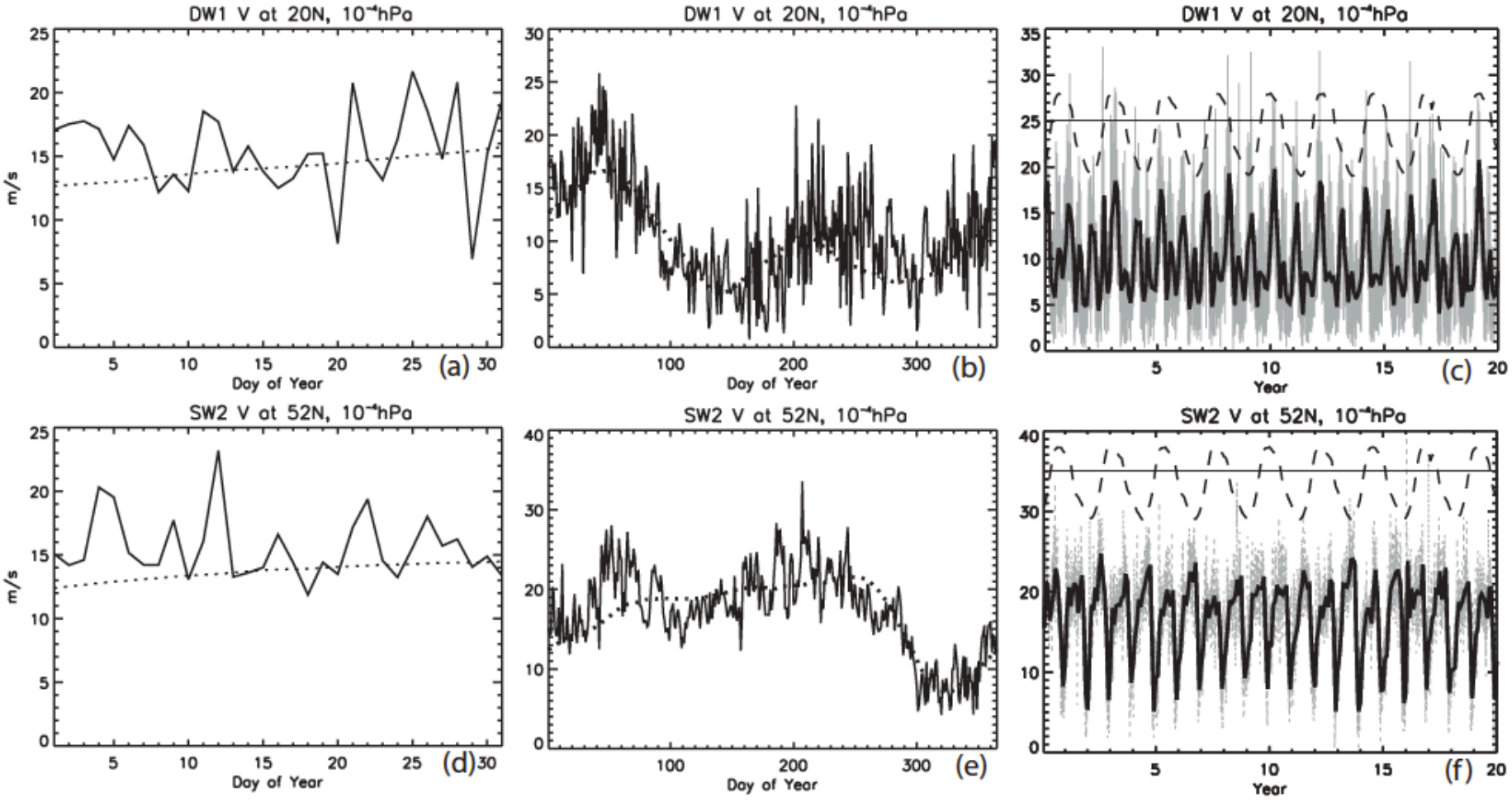
  - "Nudging" by meteorological fields (Liu et al., 2013).

Variability at Stratopause/Stratosphere: NH

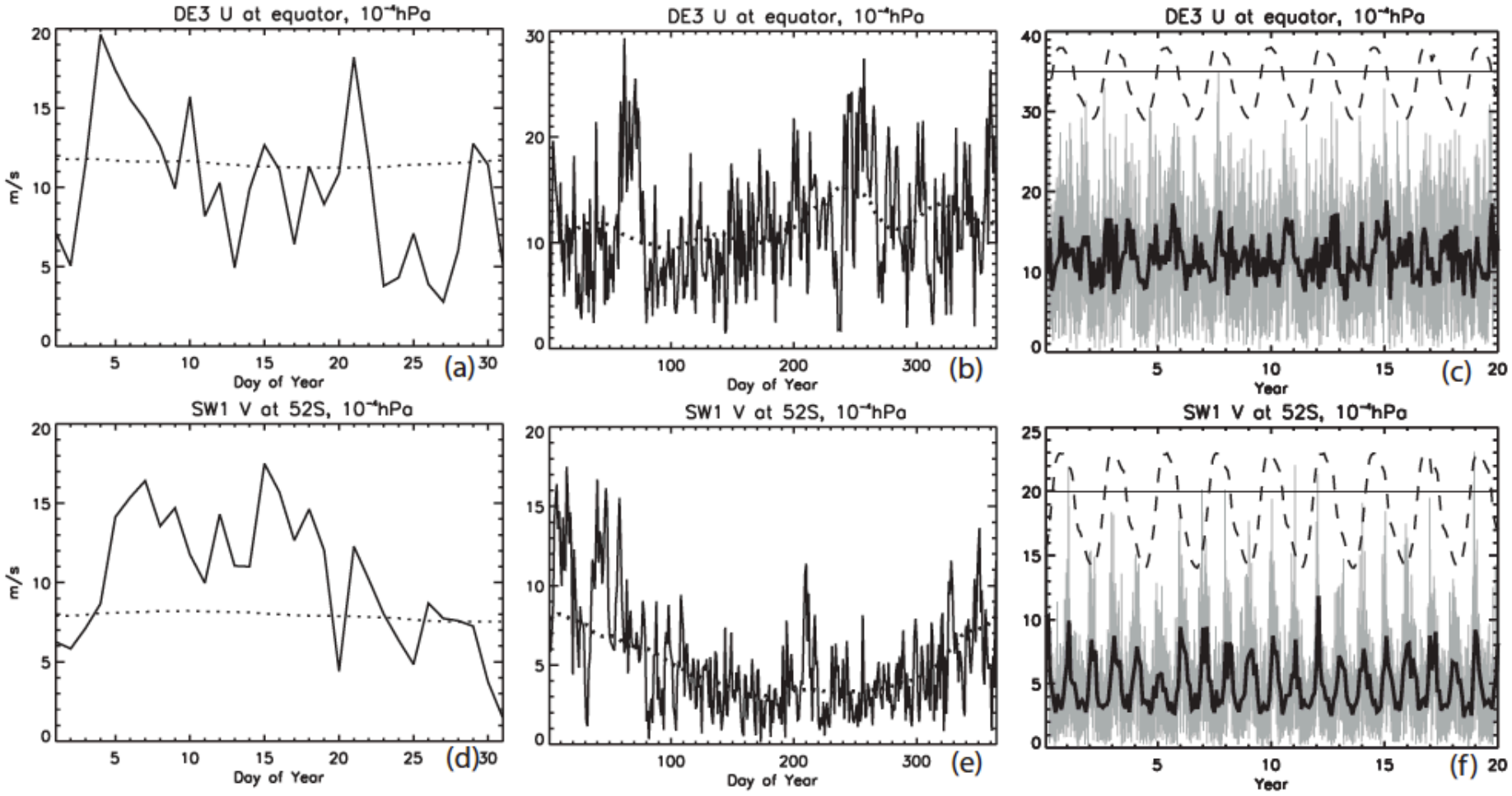


Liu, 2013

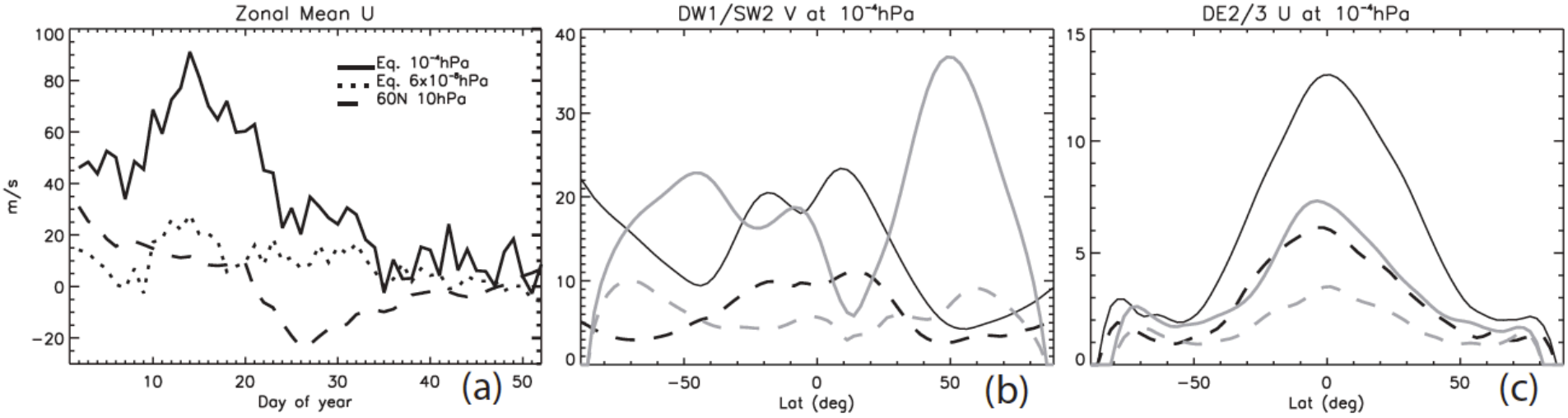
Variability of Migrating Tides



Variability of Non-migrating Tides

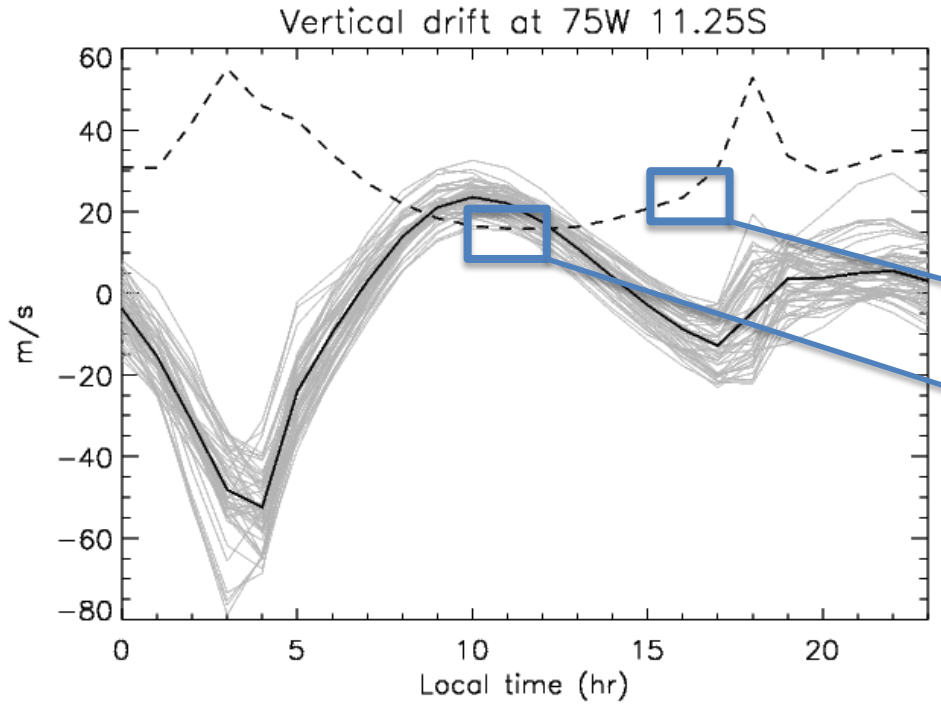


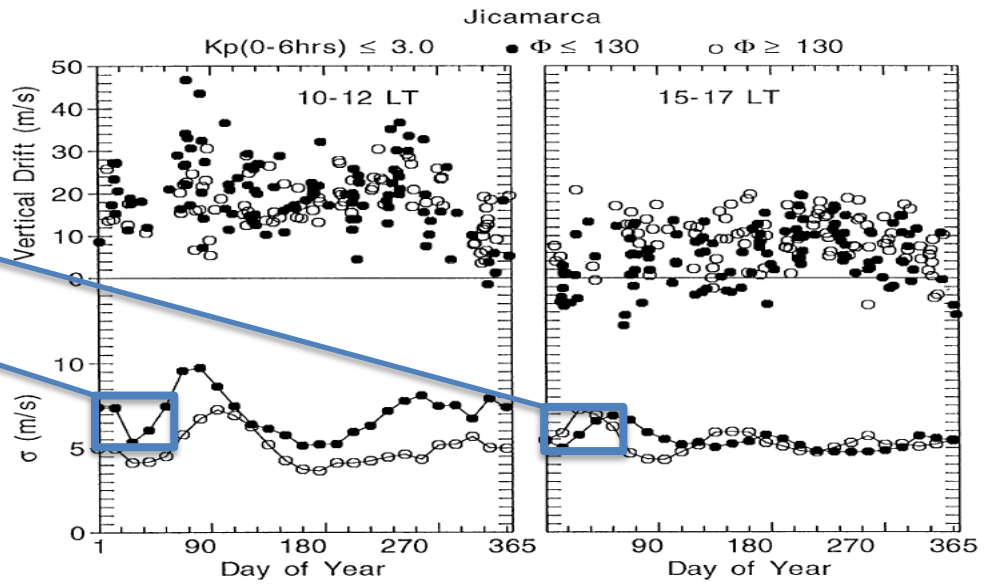
TIME-GCM/WACCM-X/MERRA: Mean State and Tidal Variability



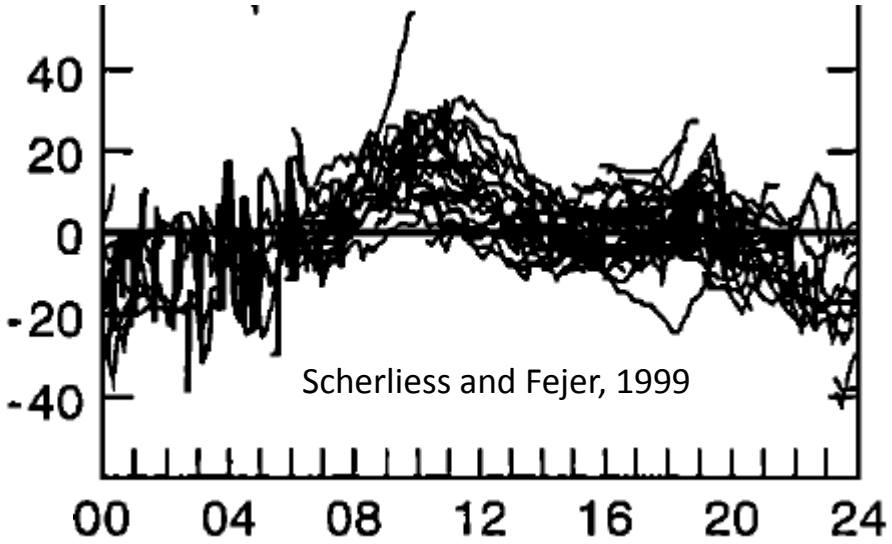
Liu, Yudin and Roble (2013)

Variability of Vertical Drifts

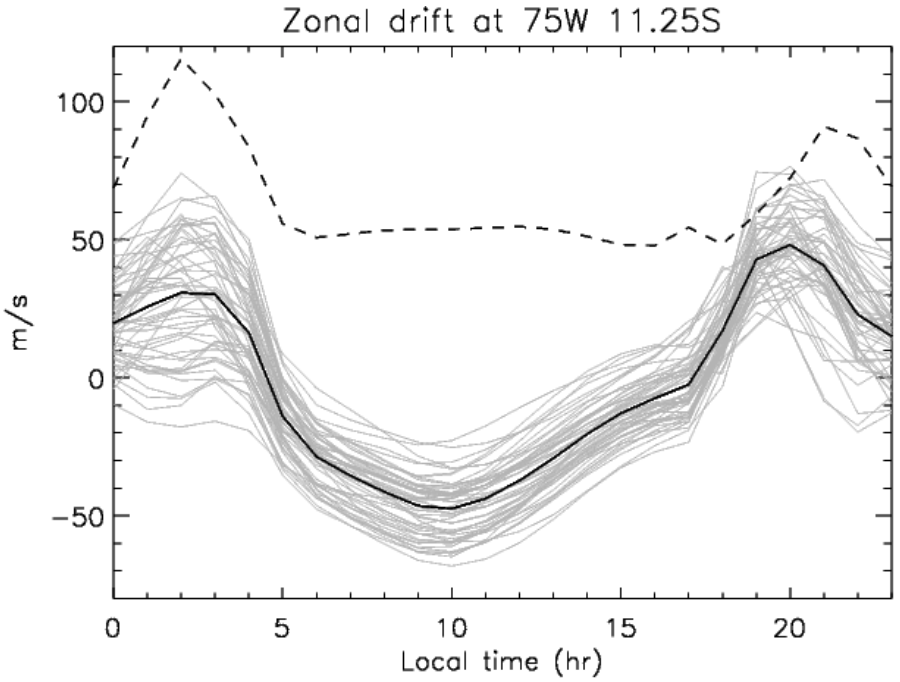


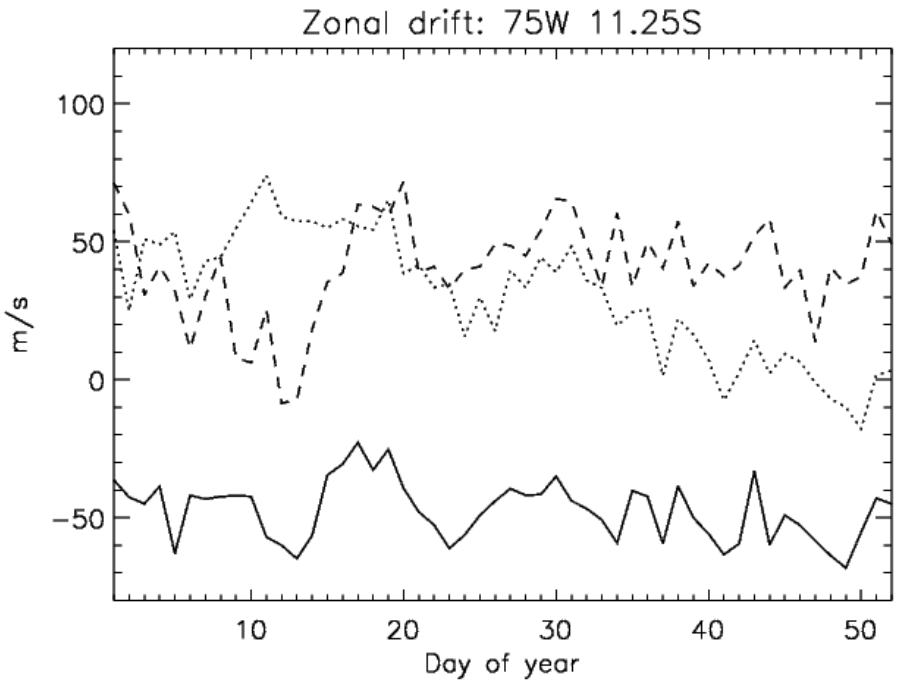


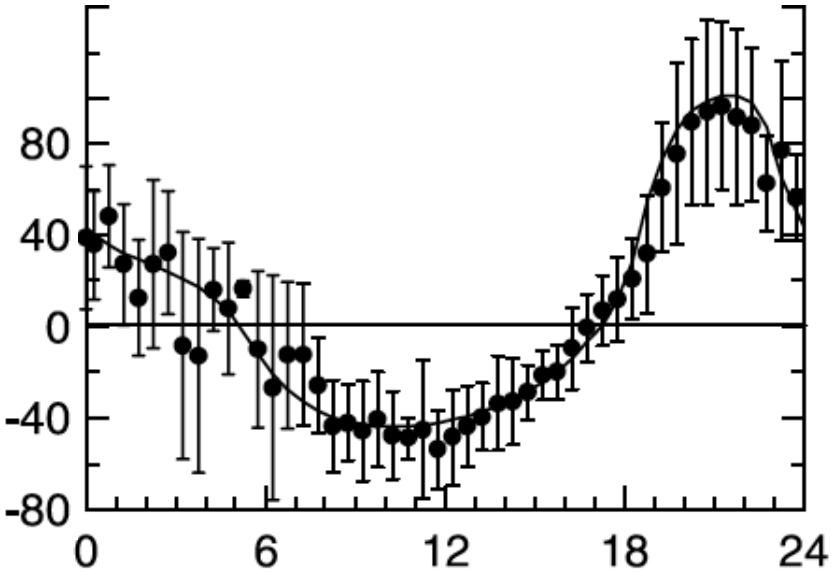
Fejer and Scherliess, 2001

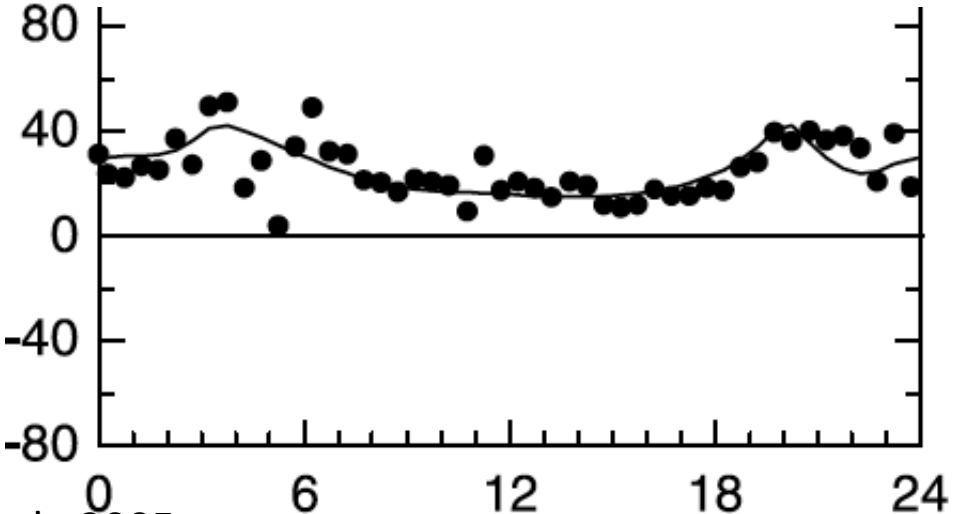


Variability of Zonal Drift



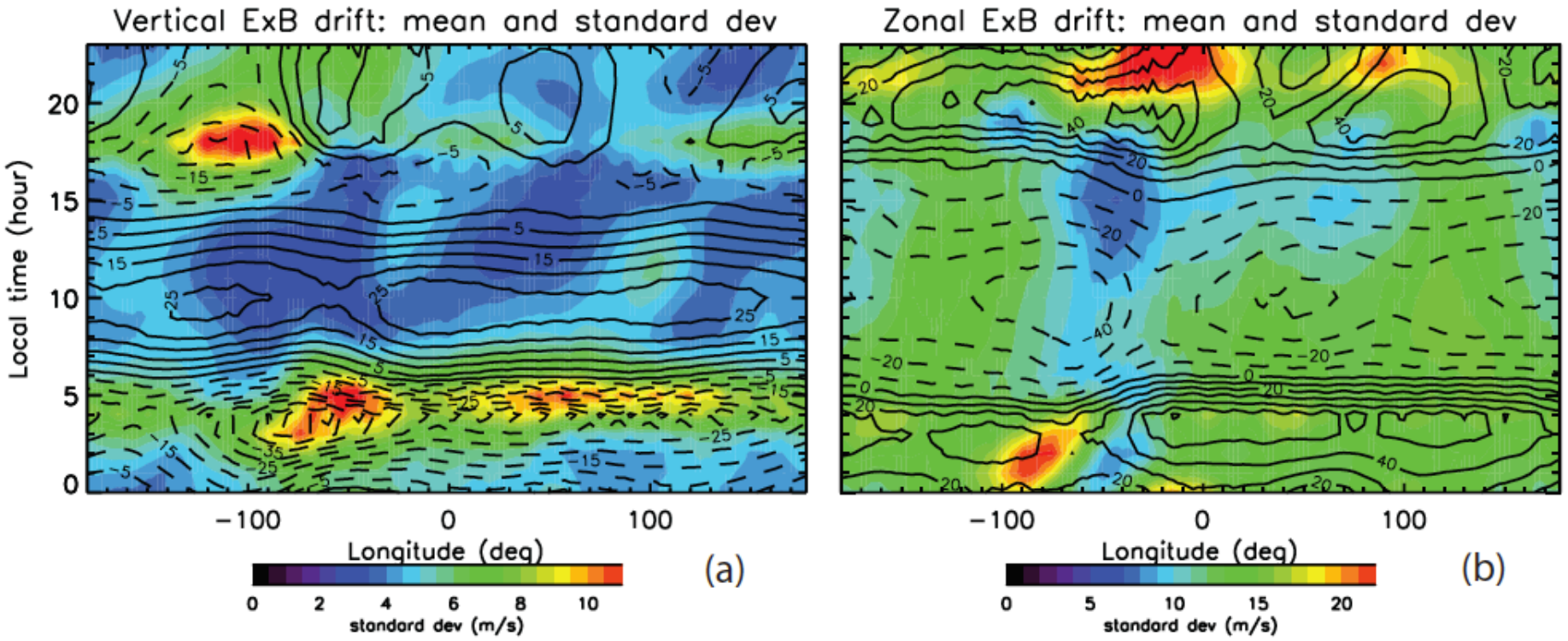




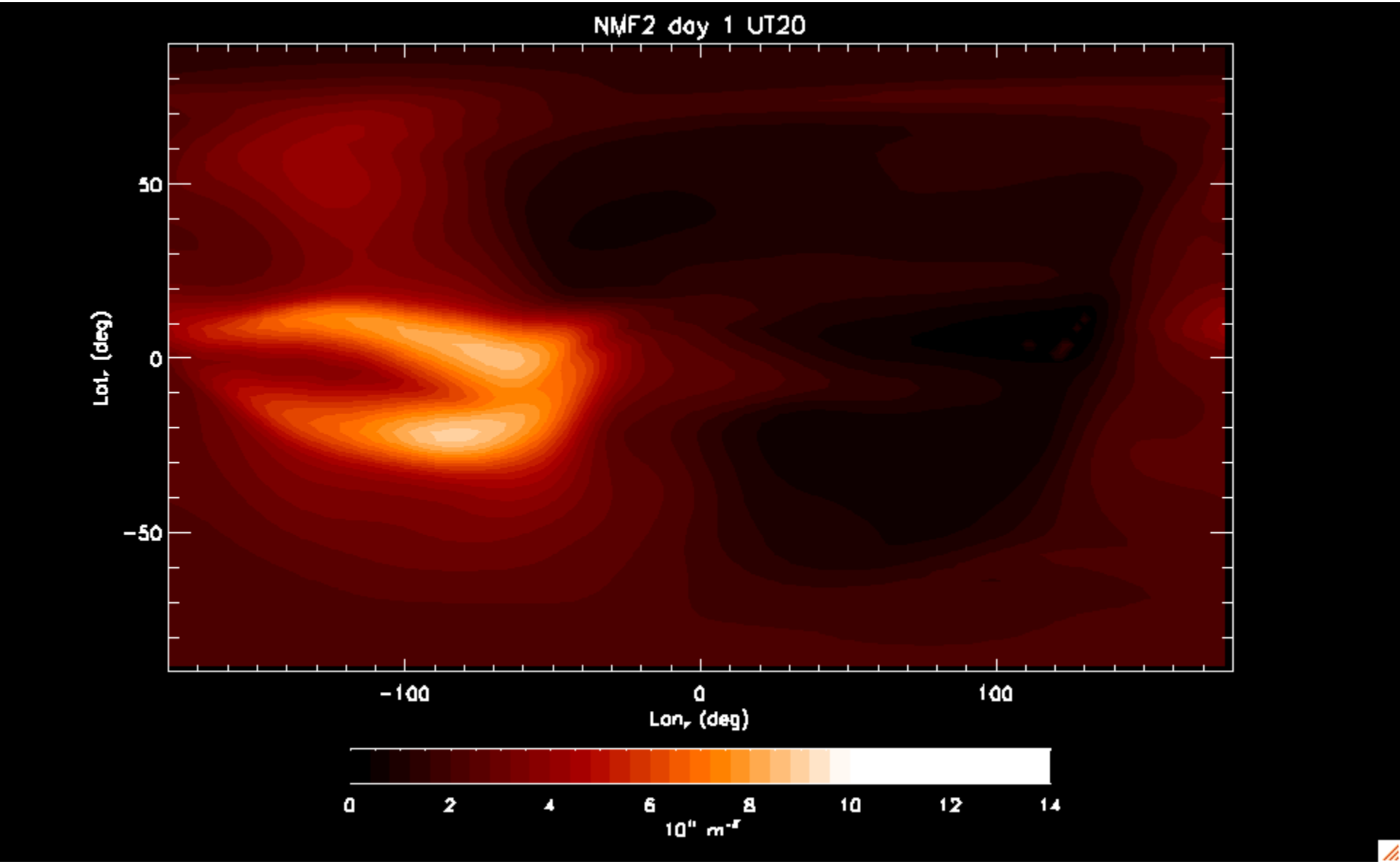


Fejer et al., 2005

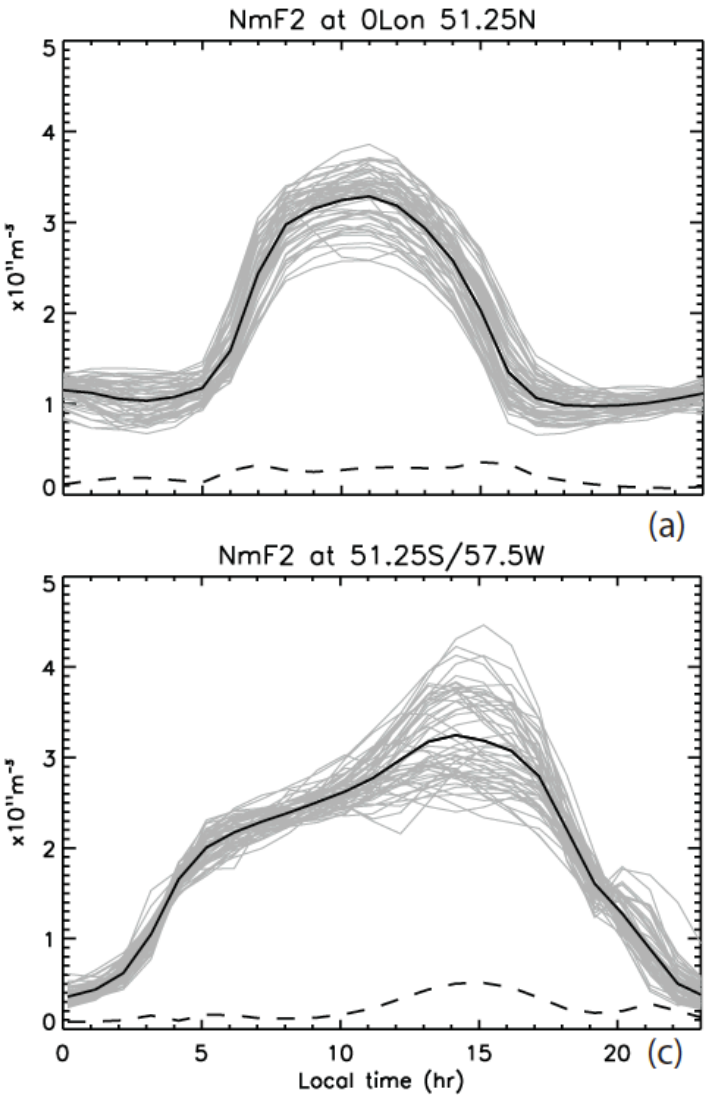
Longitude/Local Time Structures

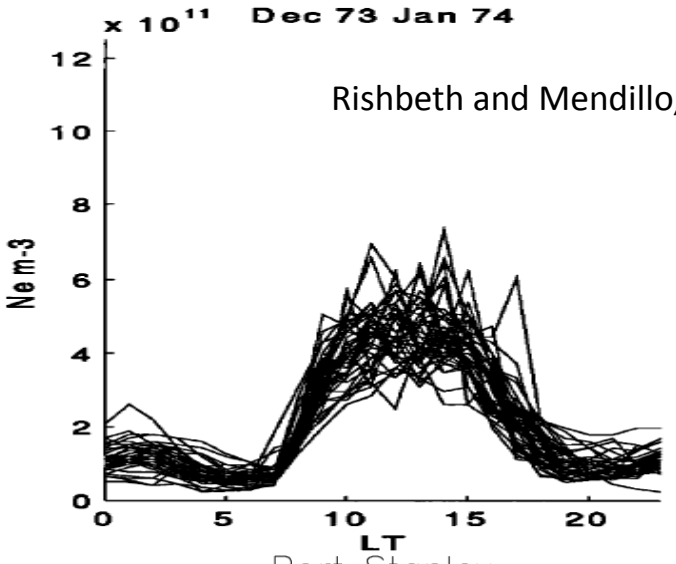


Short-term Variability: Ionosphere

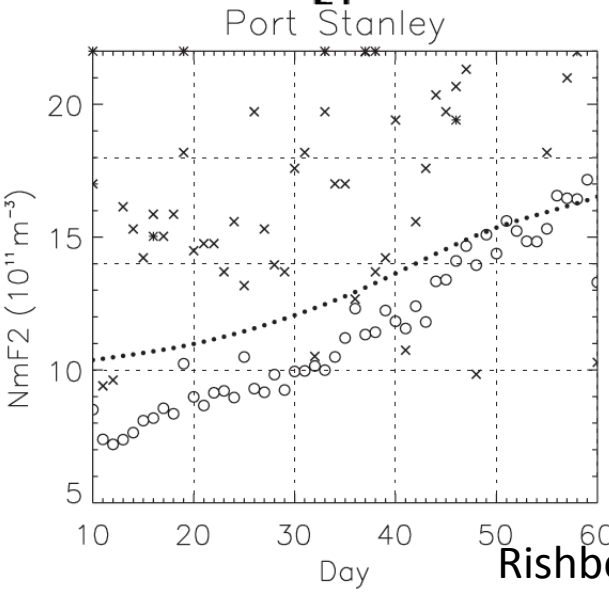


Variability of NmF2



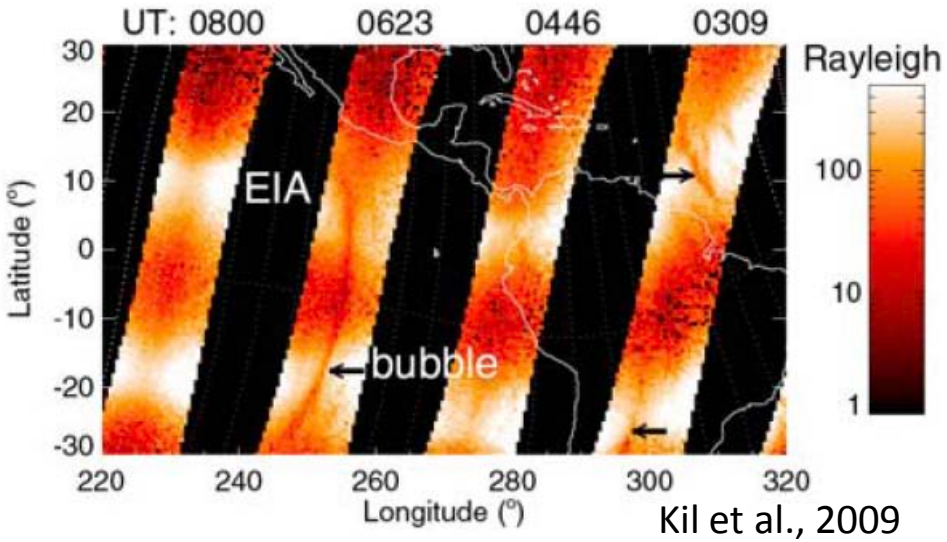


Rishbeth and Mendillo, 2001

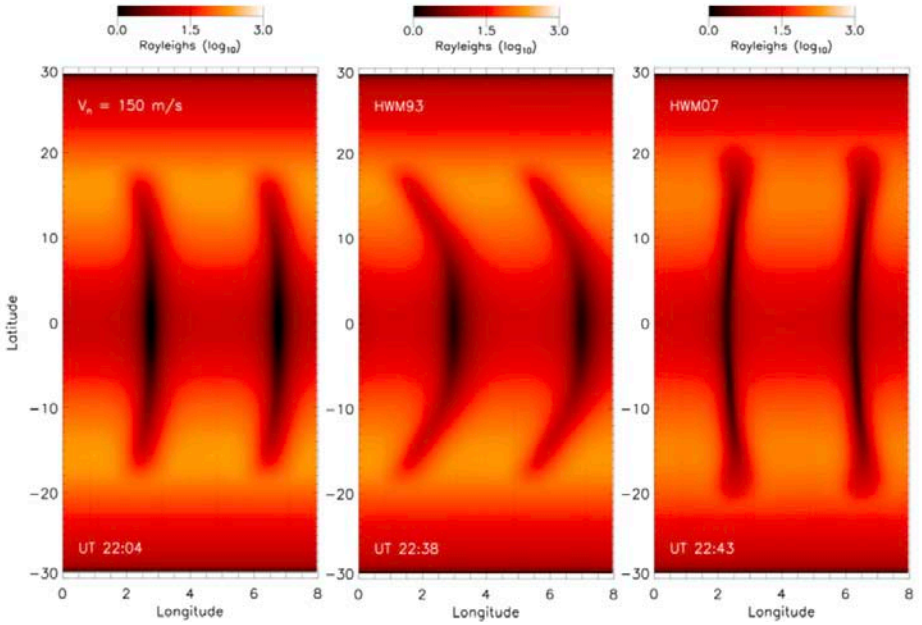


Rishbeth, 2006

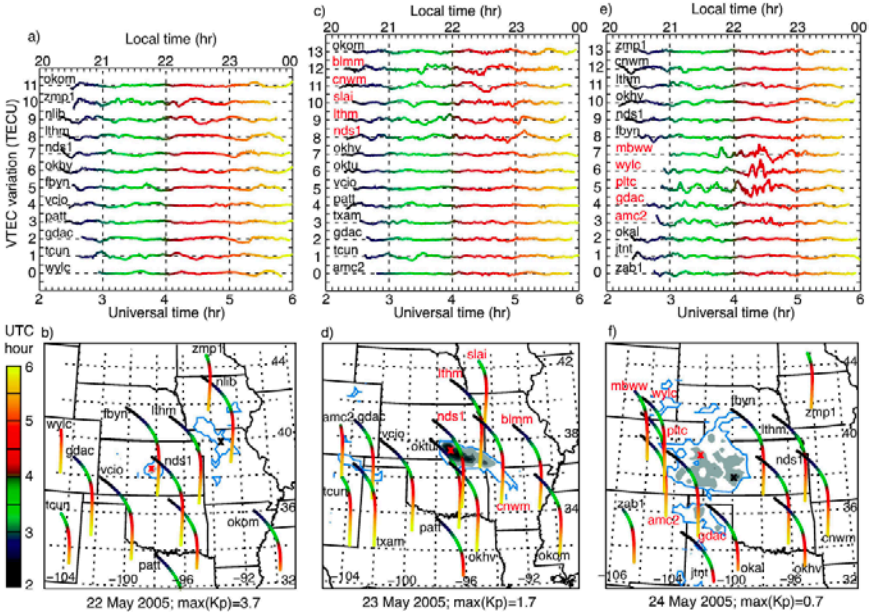
Missing Scales: Ionosphere Irregularities



Kil et al., 2009

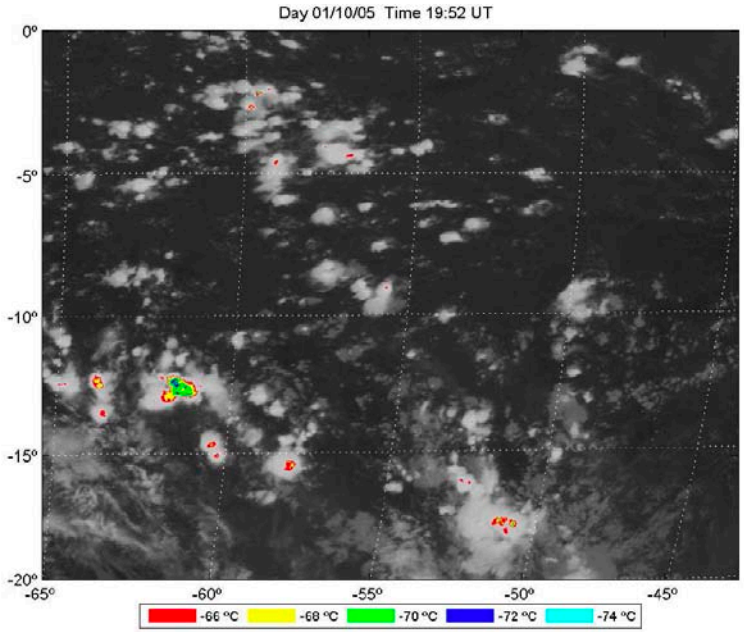


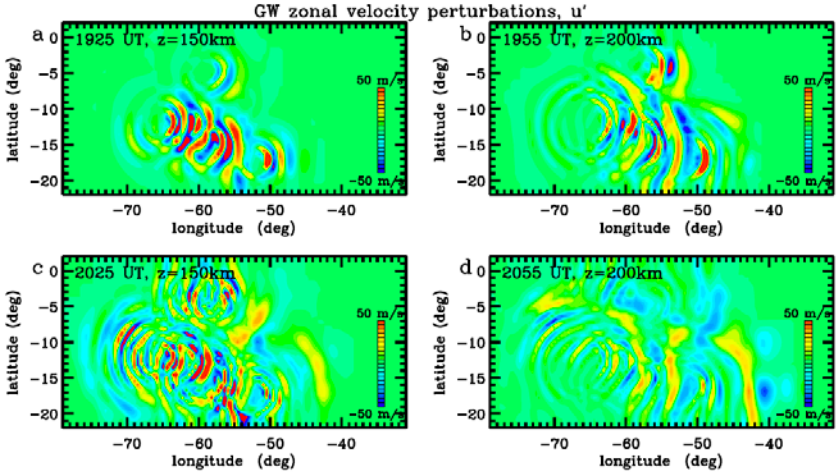
Huba et al, 2009



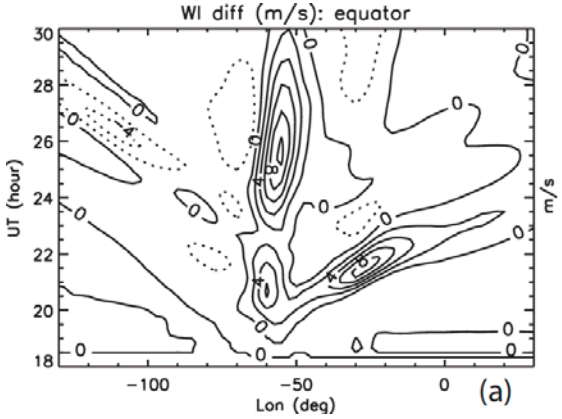
Lay et al, 2013

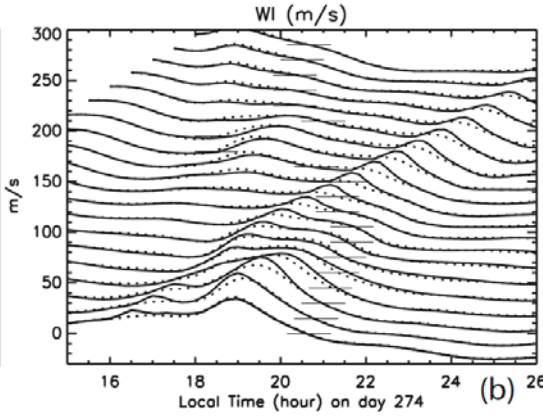
Missing Forces: GW Effects in the Ionosphere

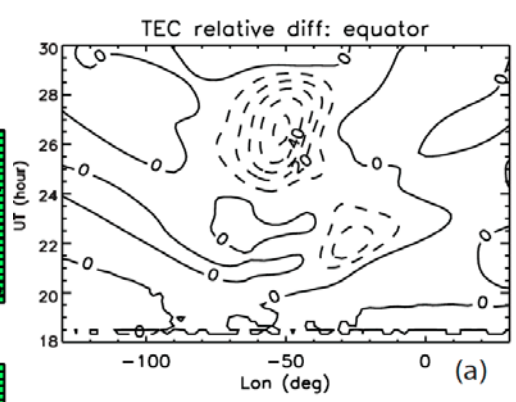


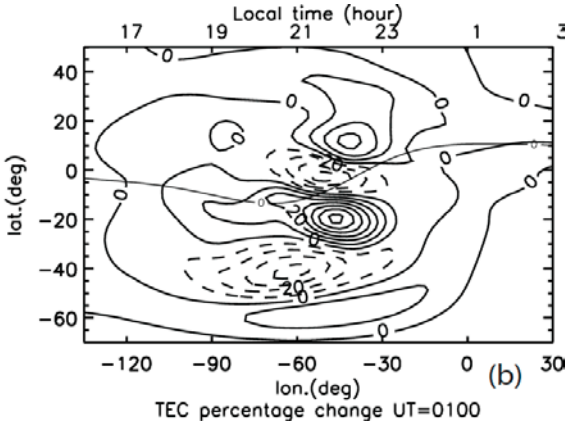


Vadas and Liu, 2013









Liu and Vadas, 2013.

Summary and Conclusion

- Large-scale waves in the upper atmosphere display large day-to-day variability from WACCM-X simulations. Compared with the stratospheric planetary waves:
  - They have a much shorter time scale.
  - They do not show clear seasonal variation.
- TIME-GCM/WACCM-X/MERRA simulation is able to produce ionospheric day-to-day variability comparable with observations.
- Ionospheric day-to-day variability can be caused by day-to-day variability of tides and mean wind in the thermosphere.
- Studying ionosphere irregularities requires high resolution simulations.