Coupling between the lower and upper atmosphere as simulated by the Whole Atmosphere Model (WAM)

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Integrated Dynamics in the Earth's Atmosphere (IDEA) project

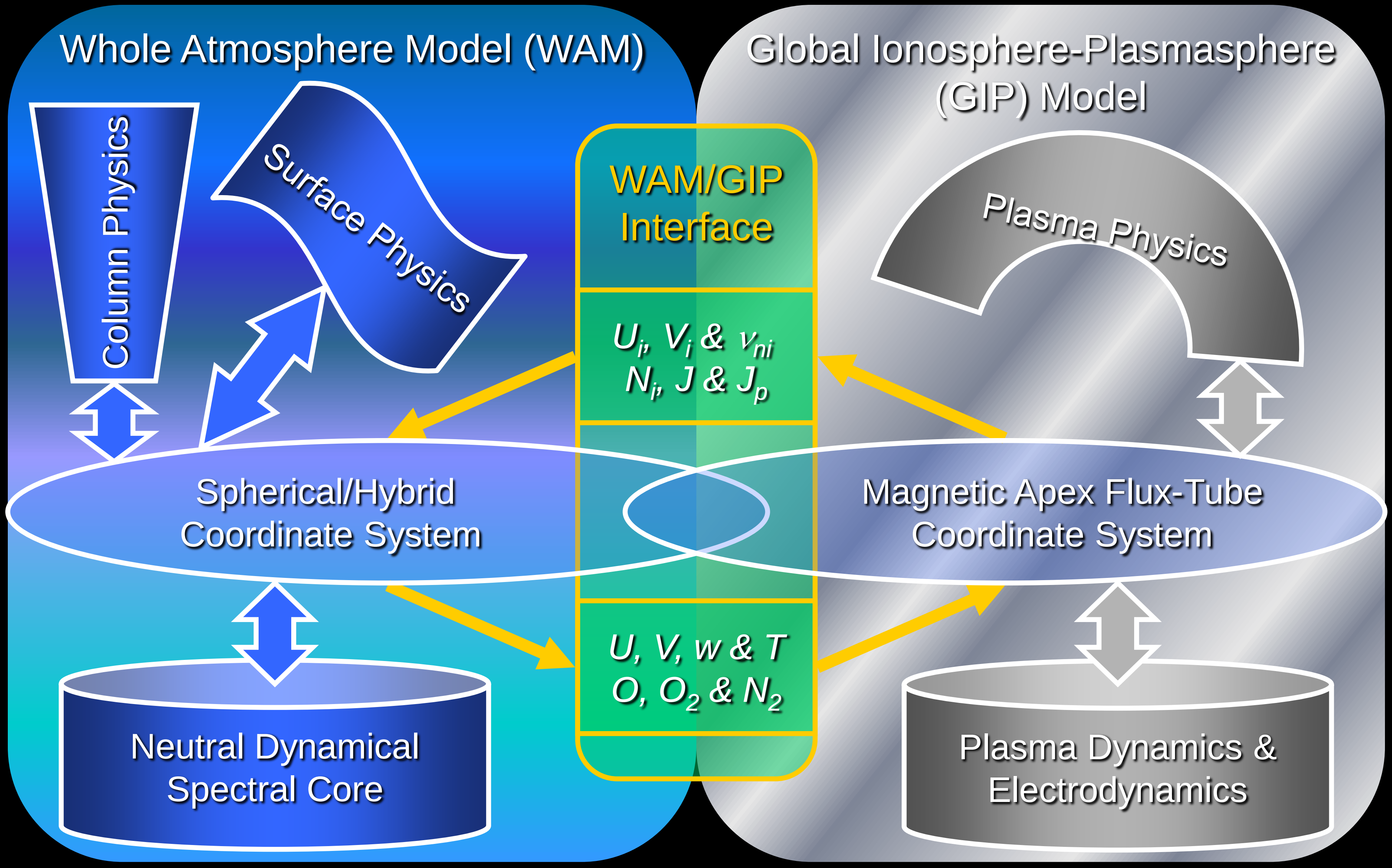
Collaborators

- NCEP Environmental Modeling Center (EMC)
- Naval Research Laboratory (NRL)
- National Center for Atmospheric Research (NCAR)
- Others

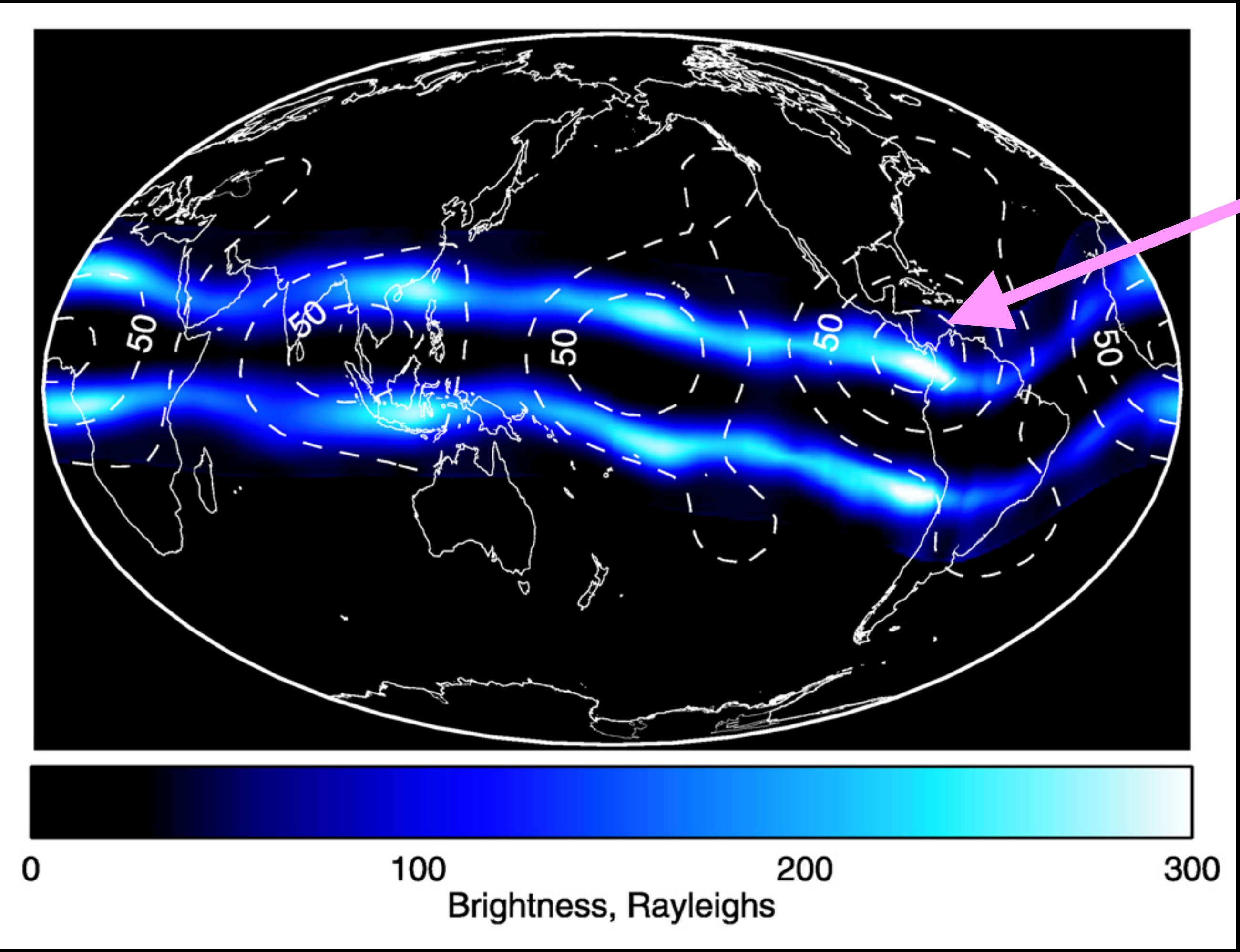
Sponsored by

- NASA LWS and Heliophysics Theory programs
- AFOSR Multidisciplinary University Research Initiative (MURI) program

Coupled IDEA model



Motivation: Tidal signatures in nightside Equatorial Ionospheric Anomaly (EIA)



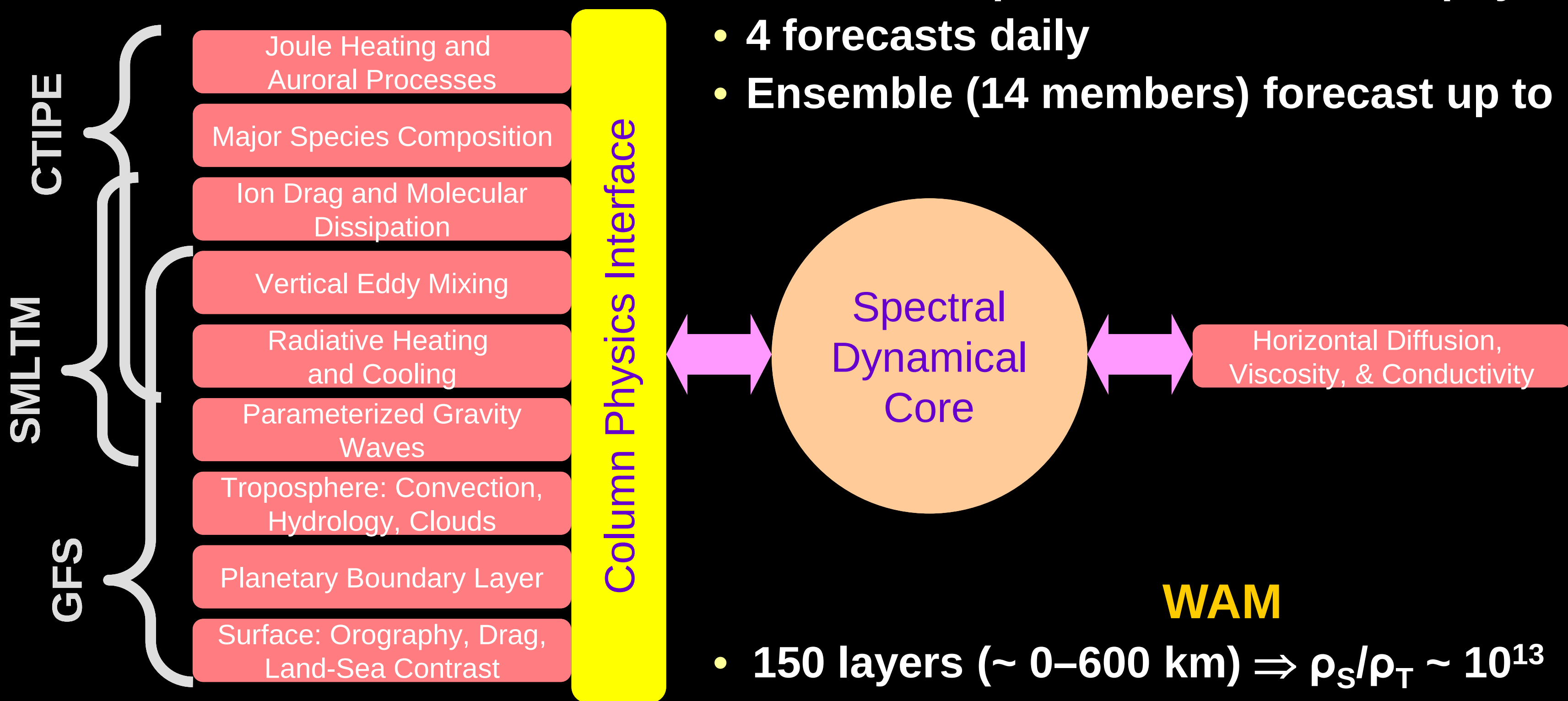
The four peaks in diurnal temperature amplitude result from superposition of the migrating (to the west) tide (DW1) and nonmigrating eastward mode with zonal wavenumber 3 (DE3).

IMAGE composite of 135.6-nm O airglow (350–400 km) in March–April 2002 for 20:00 LT and amplitude of modeled diurnal temperature oscillation @ 115 km (Immel et al., 2006).

WAM = Extended GFS + Physics

Operational Global Forecast System (GFS)

- T382L64 (~ 0.3°×0.3°, ~ 0–62 km)
- Hydrology, surface exchange processes, ozone transport, radiation, cloud physics, etc.
- 4 forecasts daily
- Ensemble (14 members) forecast up to 16 days



WAM

- 150 layers (~ 0–600 km) ⇒ $\rho_S/\rho_T \sim 10^{13}$
- Numerical stability issues
- Timing: T62L150 ~ 8 min/day on 32 P6 nodes
- Column + horizontal-surface physics
- Variable composition ⇒ thermodynamics

Composition effects on thermodynamics

Traditional approximation | **Consistent approach**

$$\frac{d c_p T}{dt} - \frac{1}{\rho}\frac{dp}{dt} = Q$$

Traditional approximation:

$$c_p \frac{dT}{dt} - RT\frac{dp}{pdt} = Q$$

$$\frac{dT}{dt} - \kappa T\frac{dp}{pdt} = \frac{Q}{c_p}$$

Consistent approach:

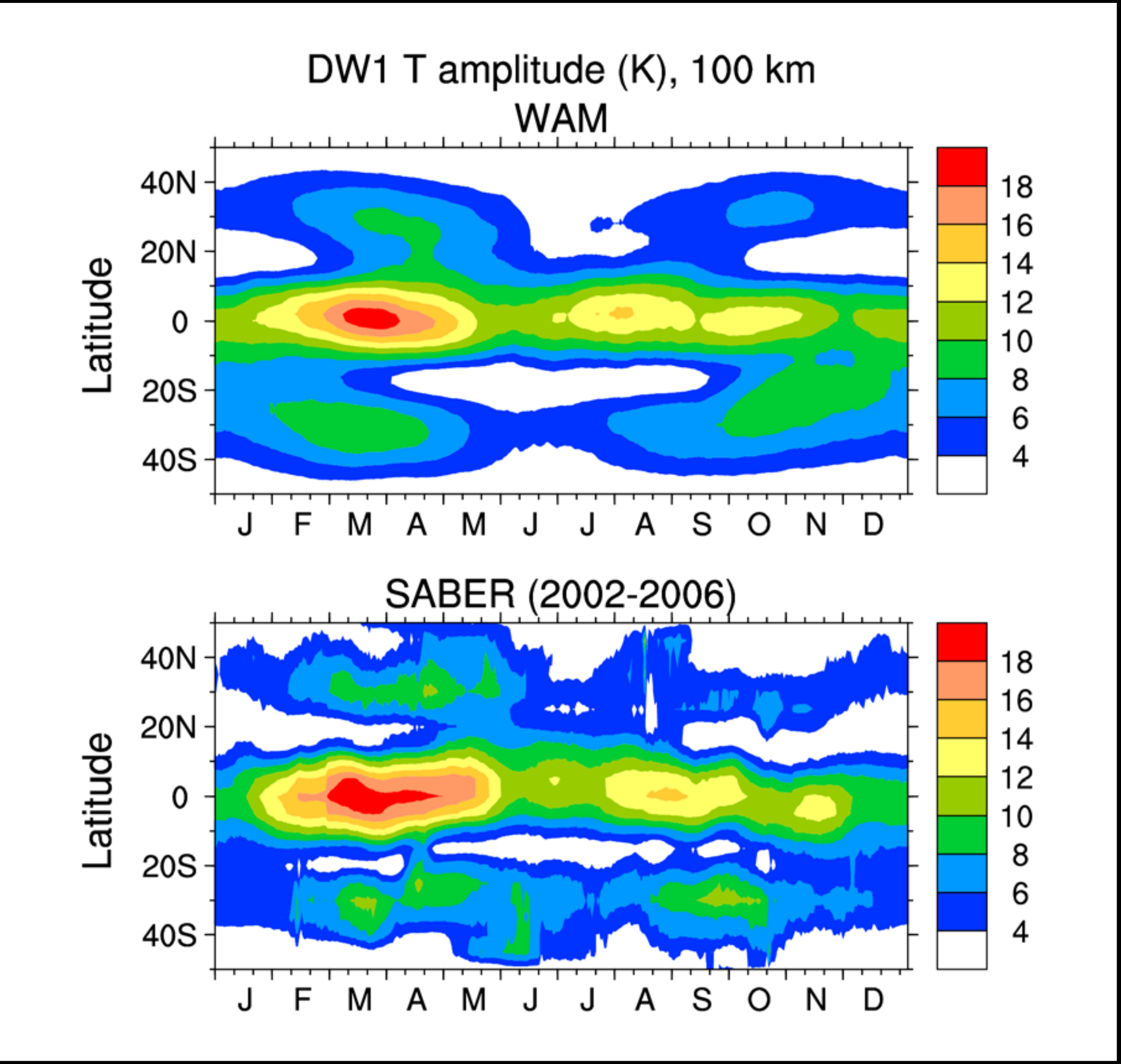
$$\frac{dh}{dt} - \kappa h\frac{dp}{pdt} = Q$$

$$h = c_p T$$

$$\kappa = R/c_p$$

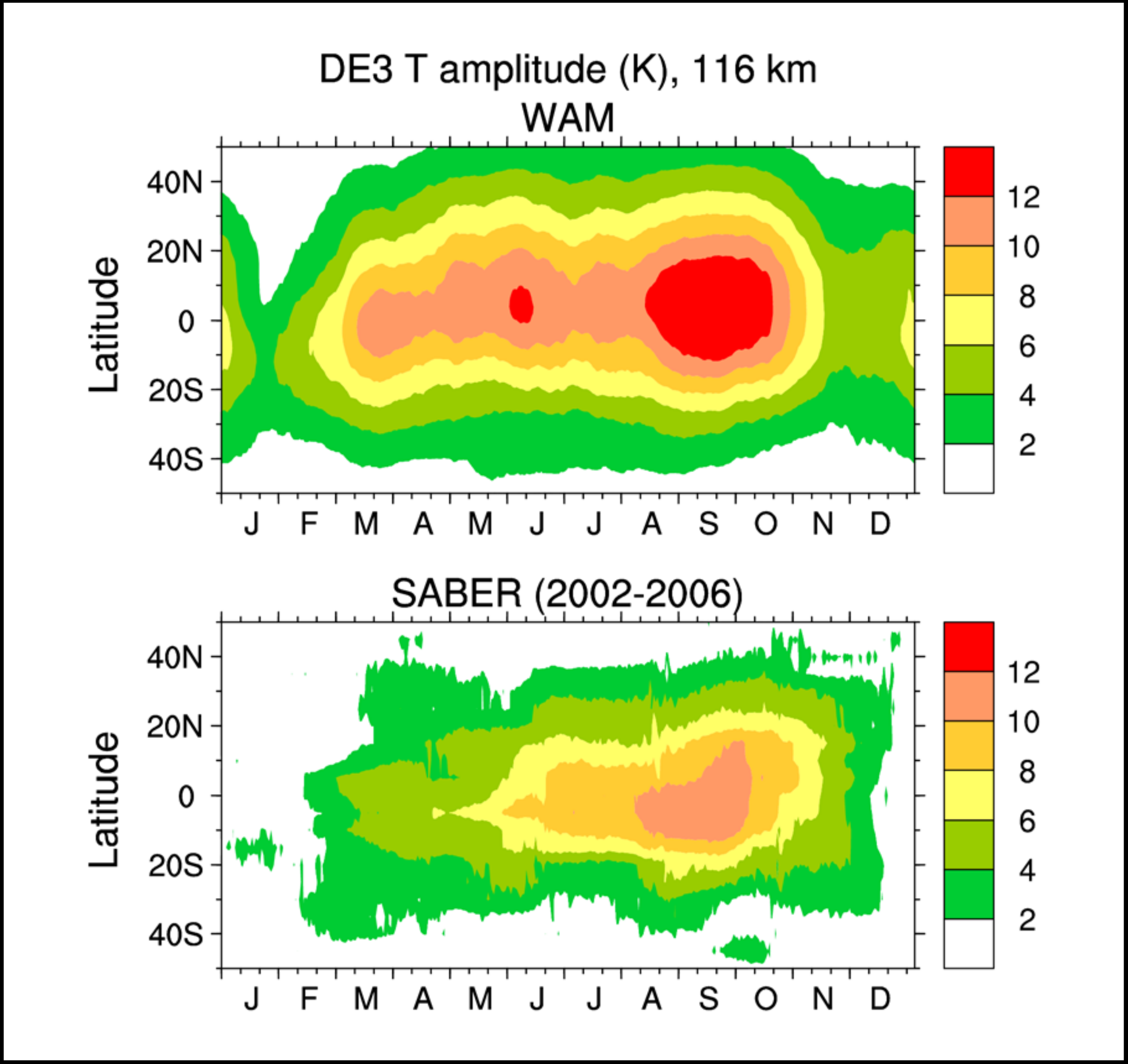
Richmond & Matsushita (JGR, 1975), Fuller-Rowell & Rees (JAS, 1980), Akmaev and Juang (QJRMS, 2008)

Validation: DW1 tide @ 100 km



Example: DW1 migrating tidal temperature amplitude compared to TIMED/SABER data analysis (Forbes et al., 2008) @ 100 km.

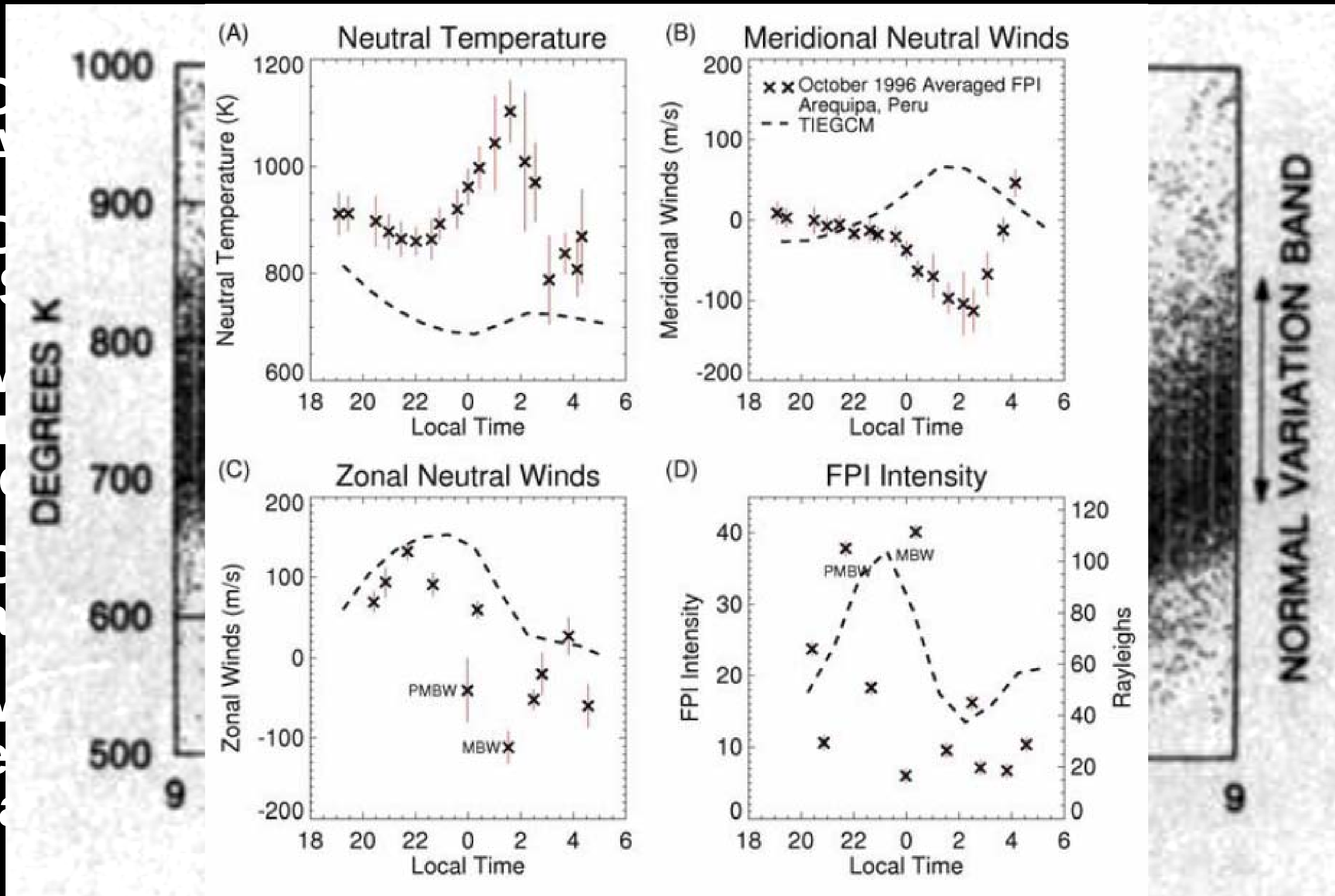
Validation: DE3 tide in the E-layer



Example: DE3 nonmigrating tidal temperature amplitude compared to TIMED/SABER data analysis (Forbes et al., 2008) in the E-layer dynamo region.

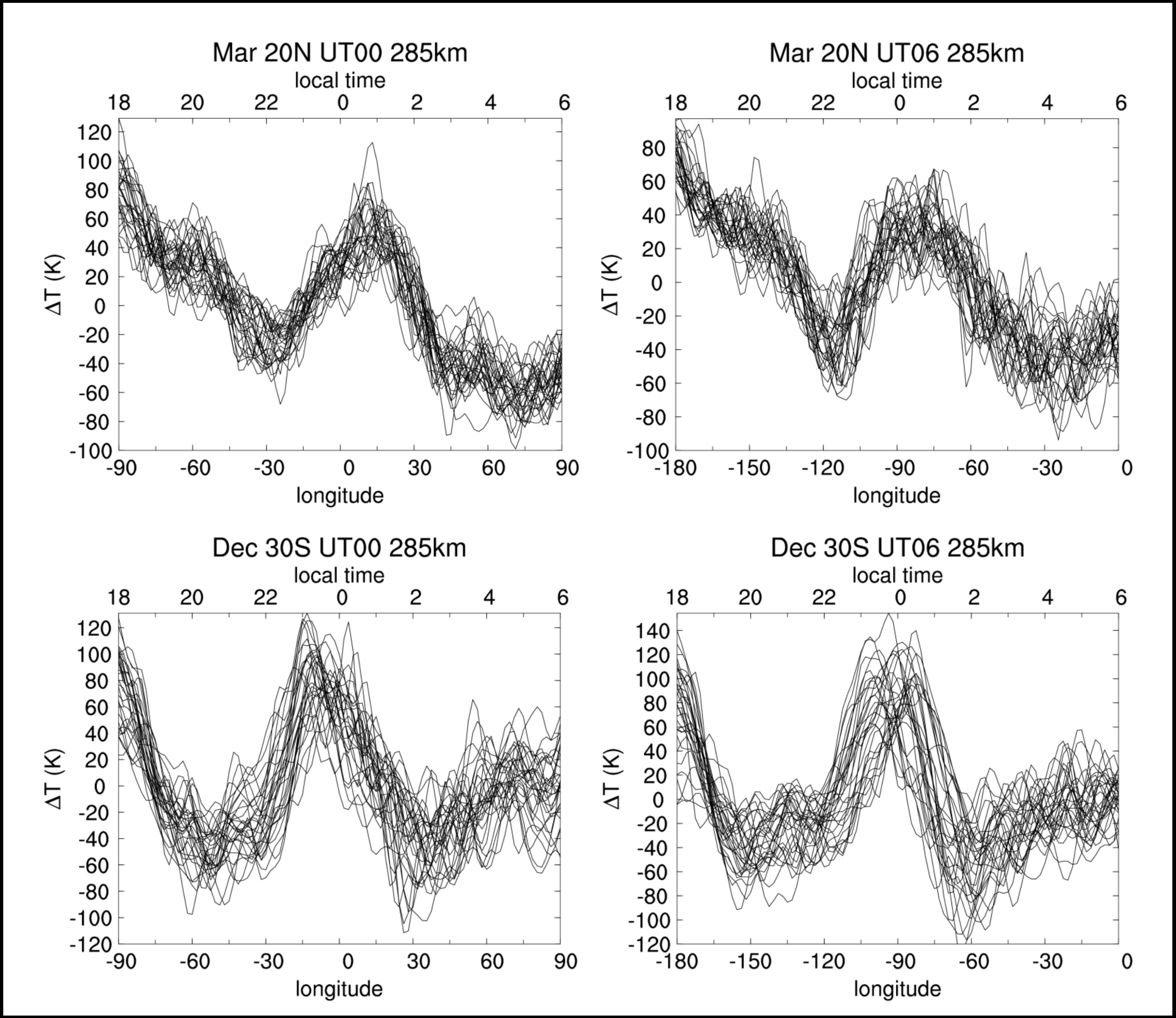
Other tides (e.g., SW2) and variables (winds) validated as well (Akmaev et al., GRL, 2008; Fuller-Rowell et al., GRL, 2008).

Midnight temperature maximum (MTM)

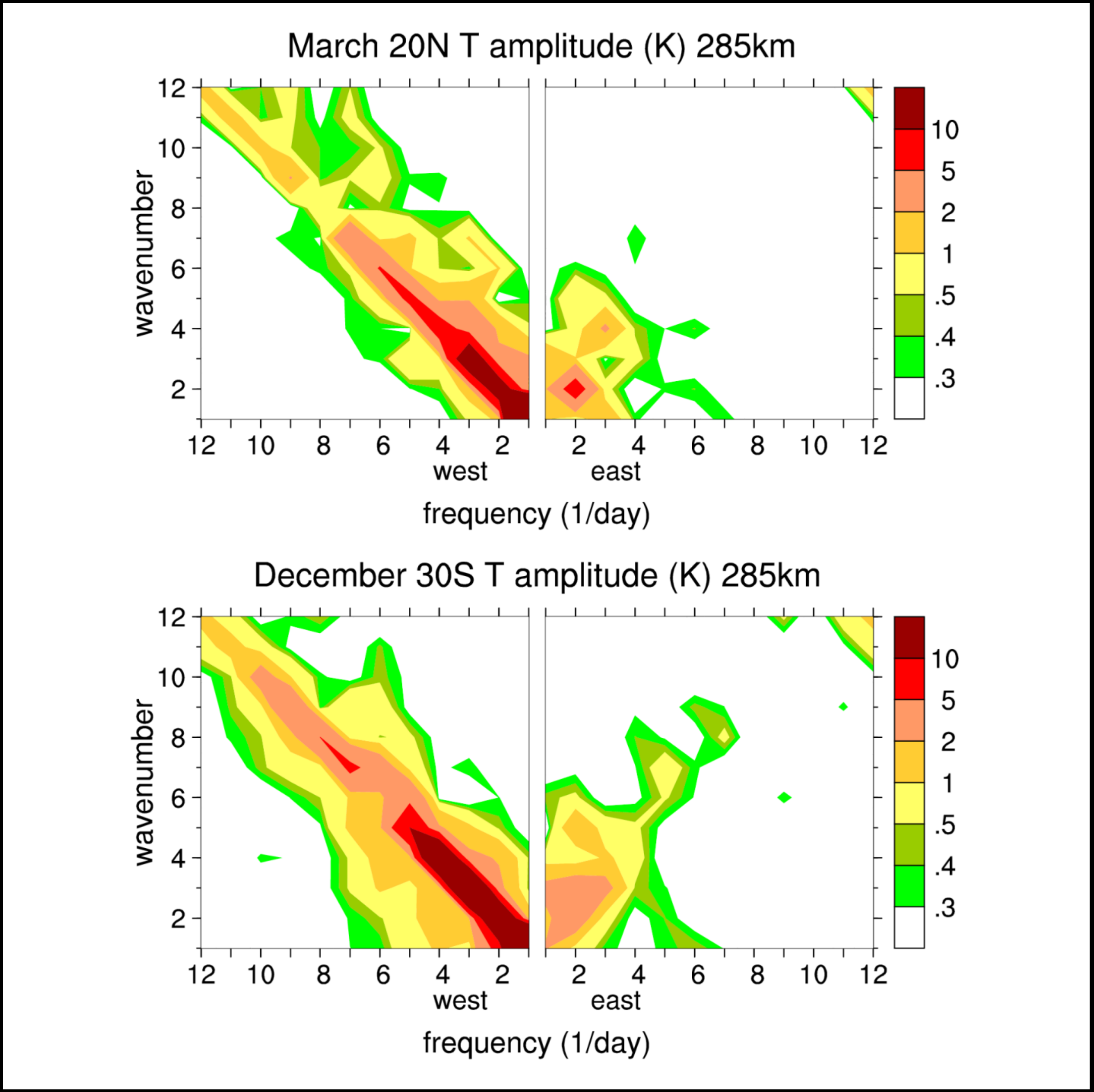


FPI observations @16°S compared to TIEGCM simulations (Colerico et al., 2006)

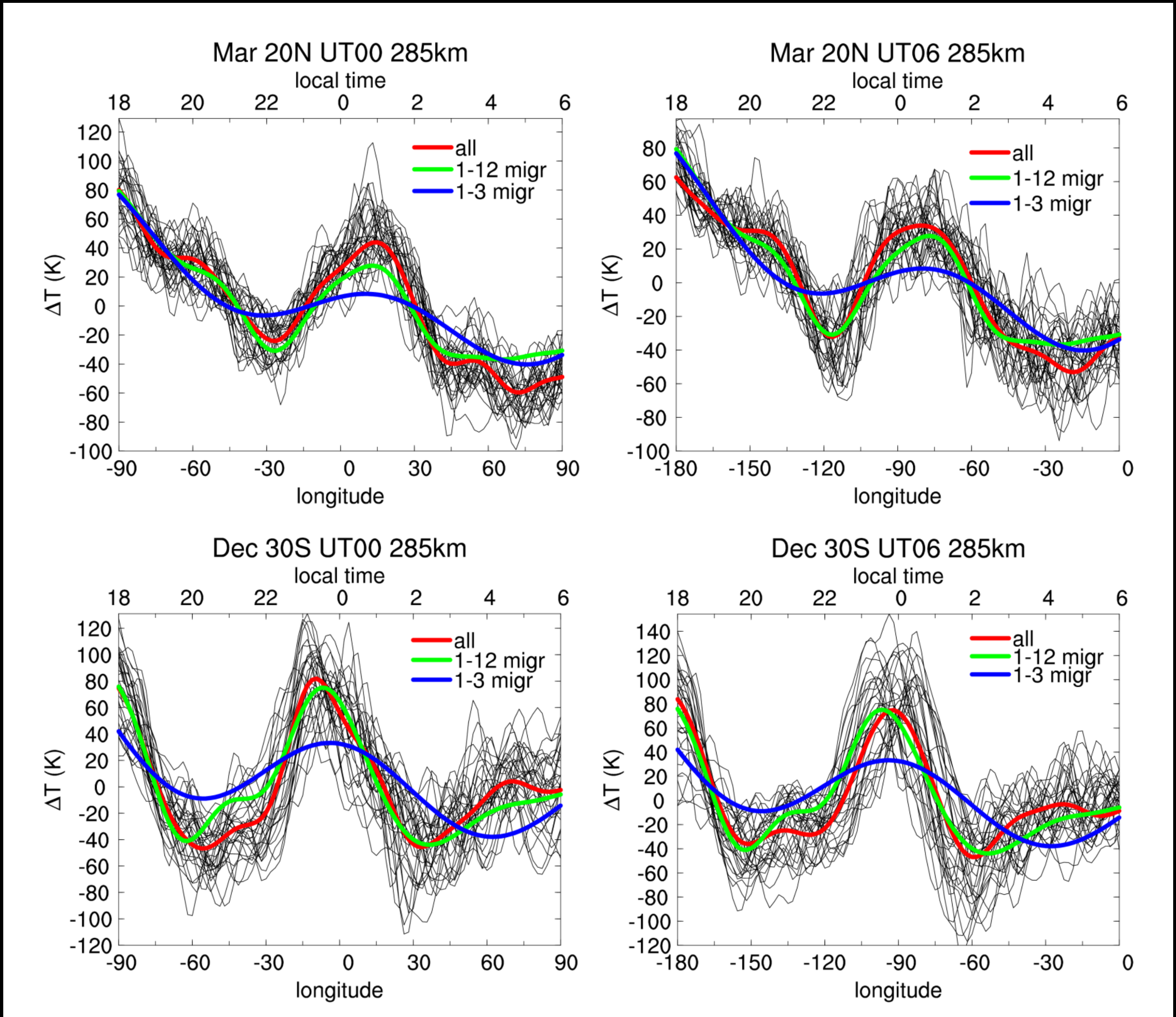
MTM in WAM: Variability



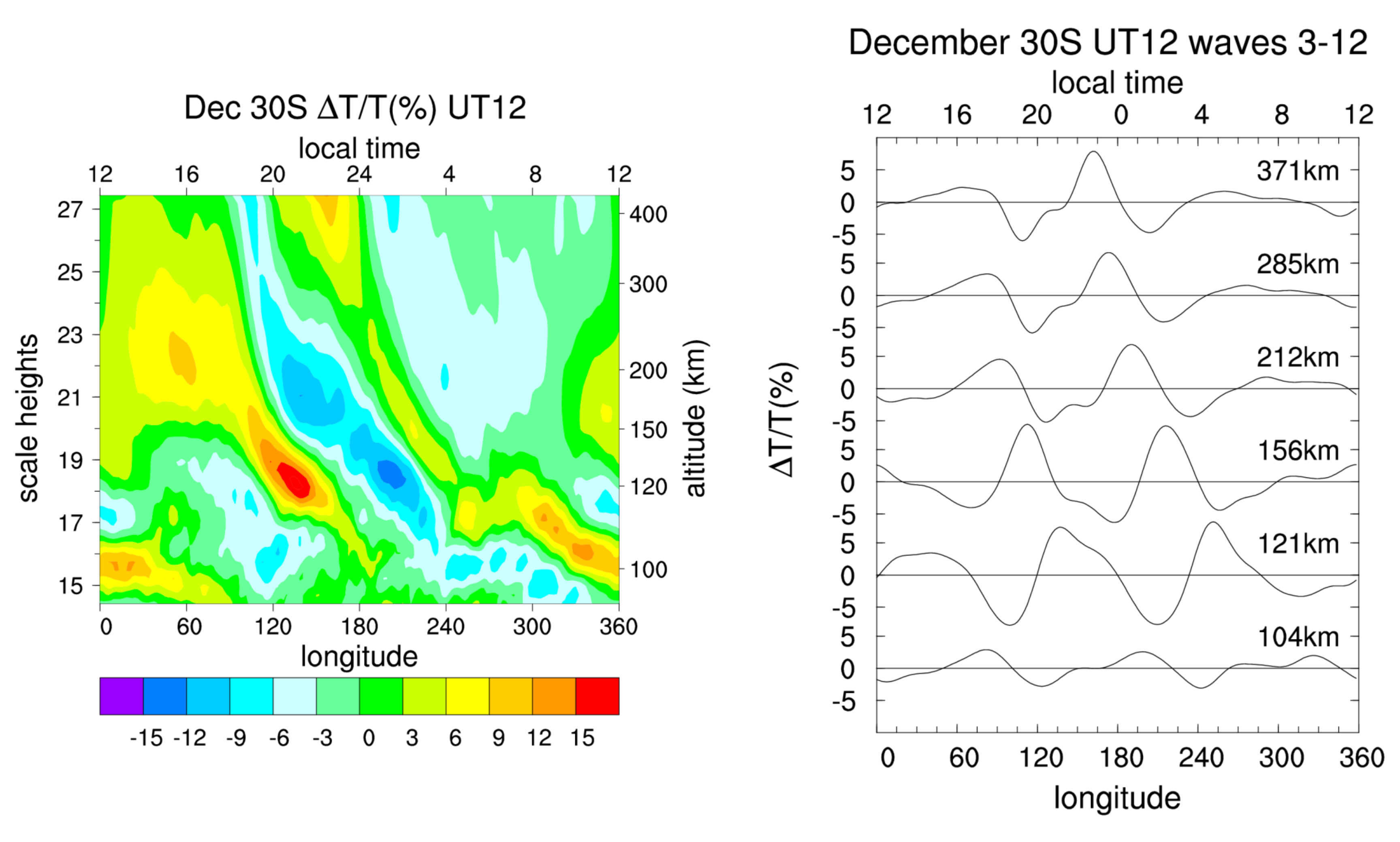
MTM in WAM: Spectrum



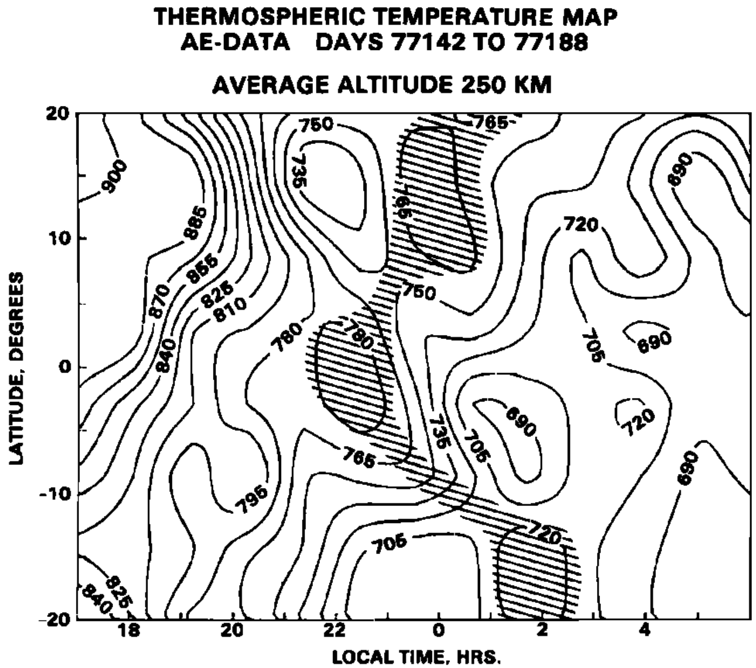
MTM in WAM: Spectral contributions



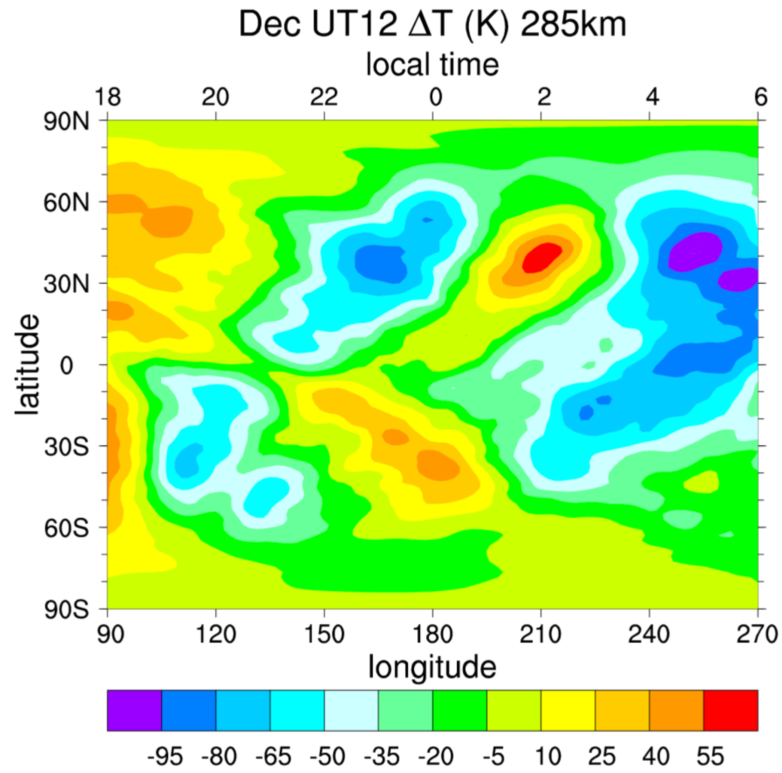
MTM in WAM: Connection to lower thermosphere



MTM in WAM: Seasonal and latitudinal variability



AE-E data, May–July 1977 (Herrero and Spencer, 1979)



Summary

- WAM has been validated on satellite observations of tides propagating from below to the thermosphere, including the non-migrating waves implicated in the observed global morphology of the ionosphere.

- WAM is the first comprehensive model to realistically reproduce the thermospheric MTM, including its variability. The MTM appears to extend into mid-latitudes in agreement with recent observations.

- Preliminary analysis indicates that the MTM is primarily produced by the terdiurnal and higher-order waves propagating upward from below and possibly interacting with the primary tidal harmonics and dissipative processes in the thermosphere.