Towards Bridging the Gap Between Terrestrial and Space Weather

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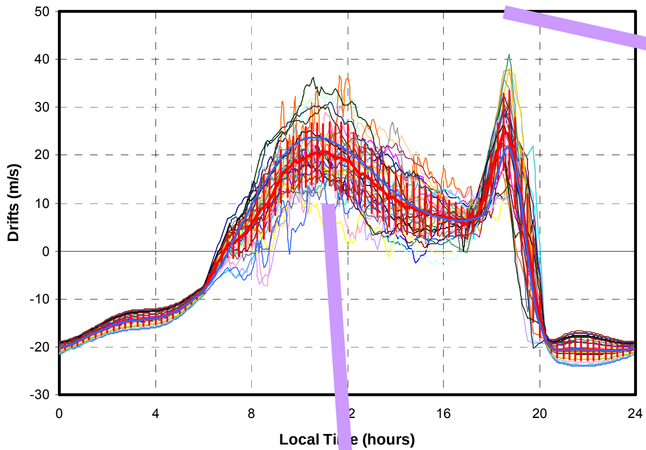
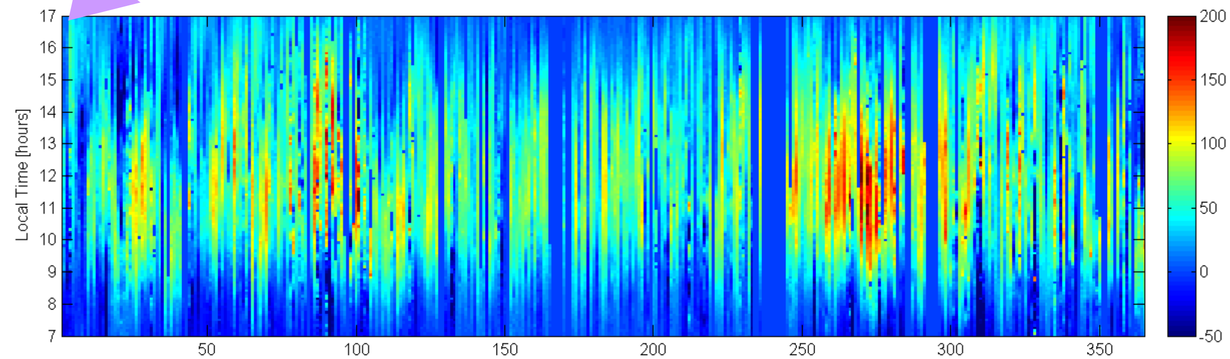
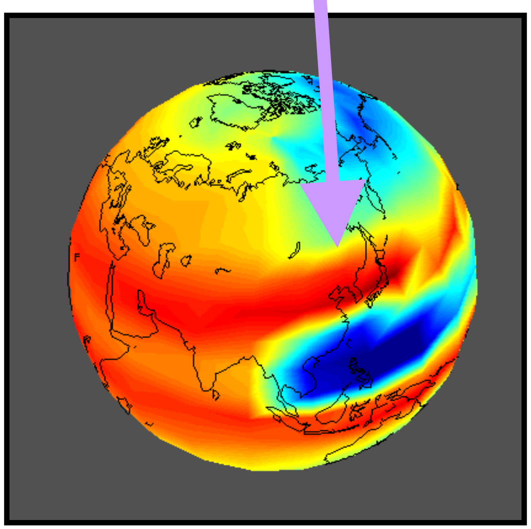
Motivation: Planetary wave periodicities in dayside ionosphere



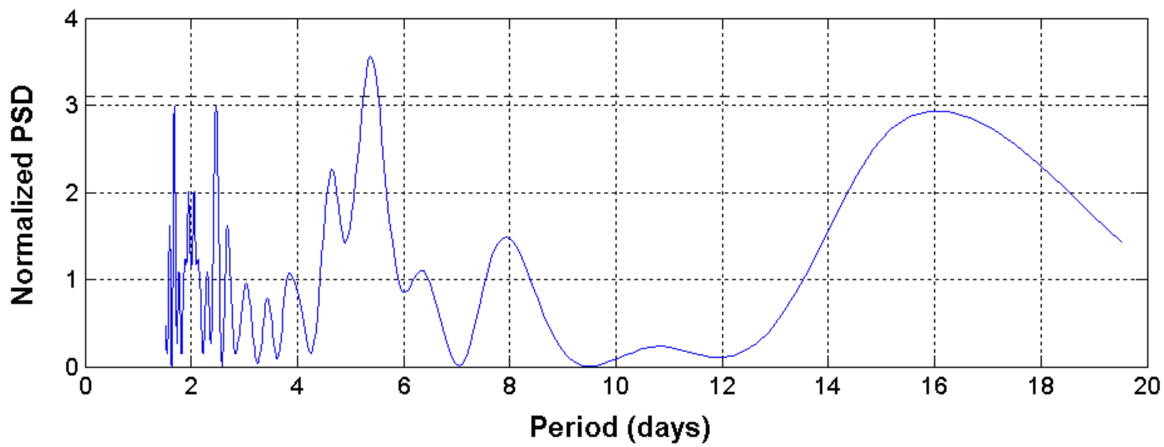
Dayside electrodynamics during 2001



Electrodynamics drives plasma transport



Possible PW signatures



Courtesy D. Anderson & A. Anghel (2006)

Motivation: Tidal signatures in nightside Equatorial Ionospheric Anomaly

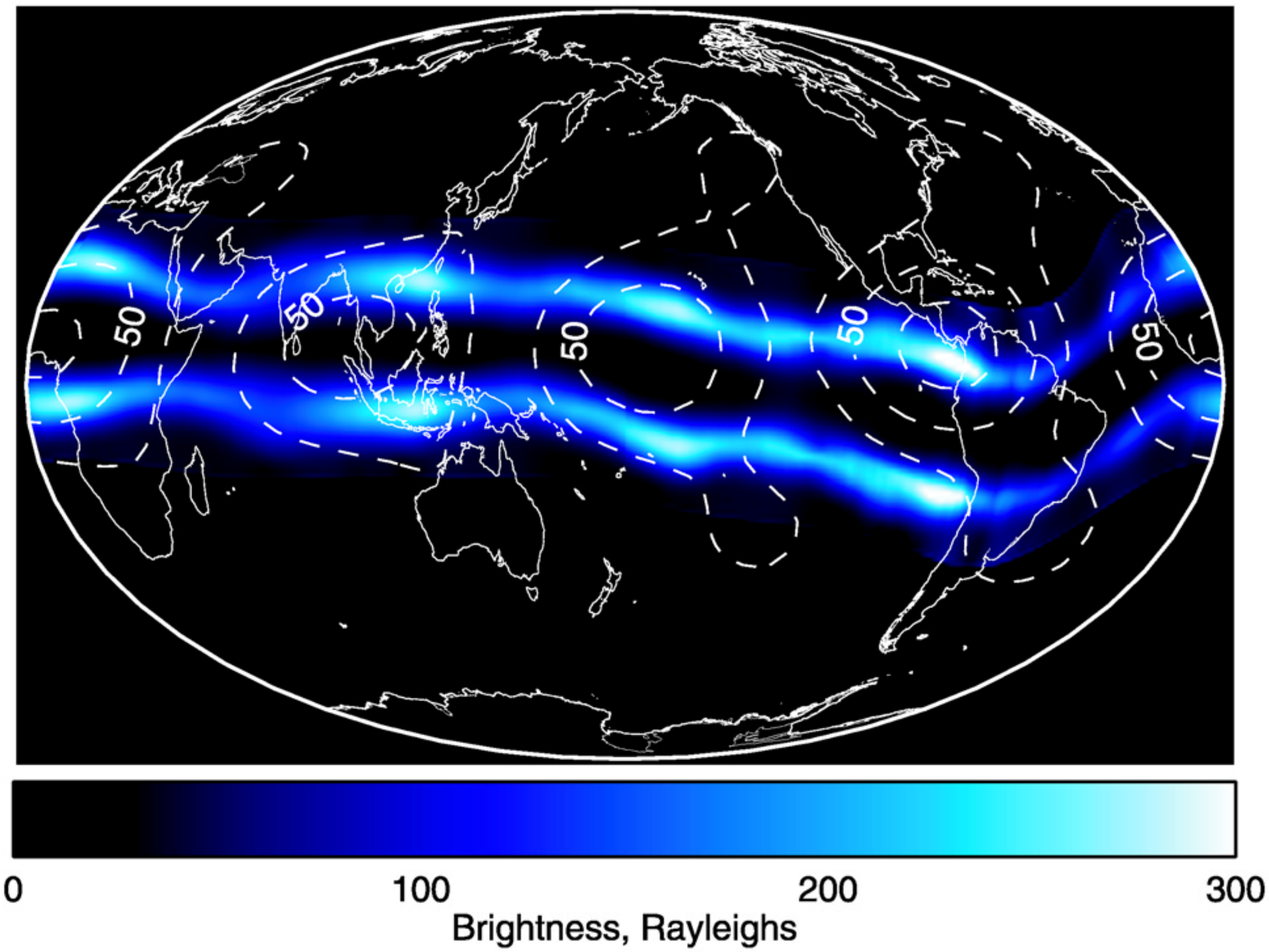
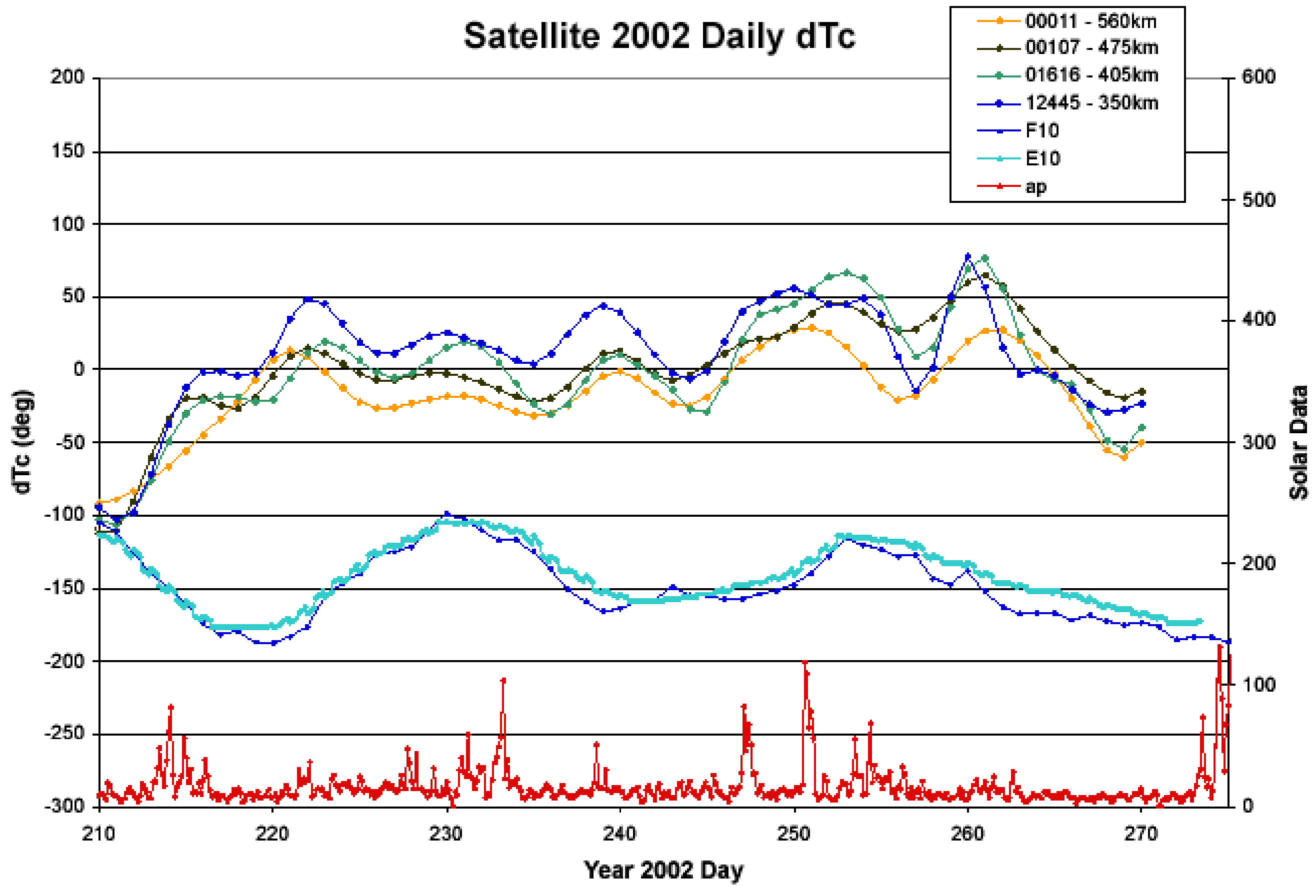


IMAGE composite of 135.6-nm O airglow (350-400 km) for March-April 2002 and magnitude of tidal temperature oscillations at 115 km (Immel et al., 2006).

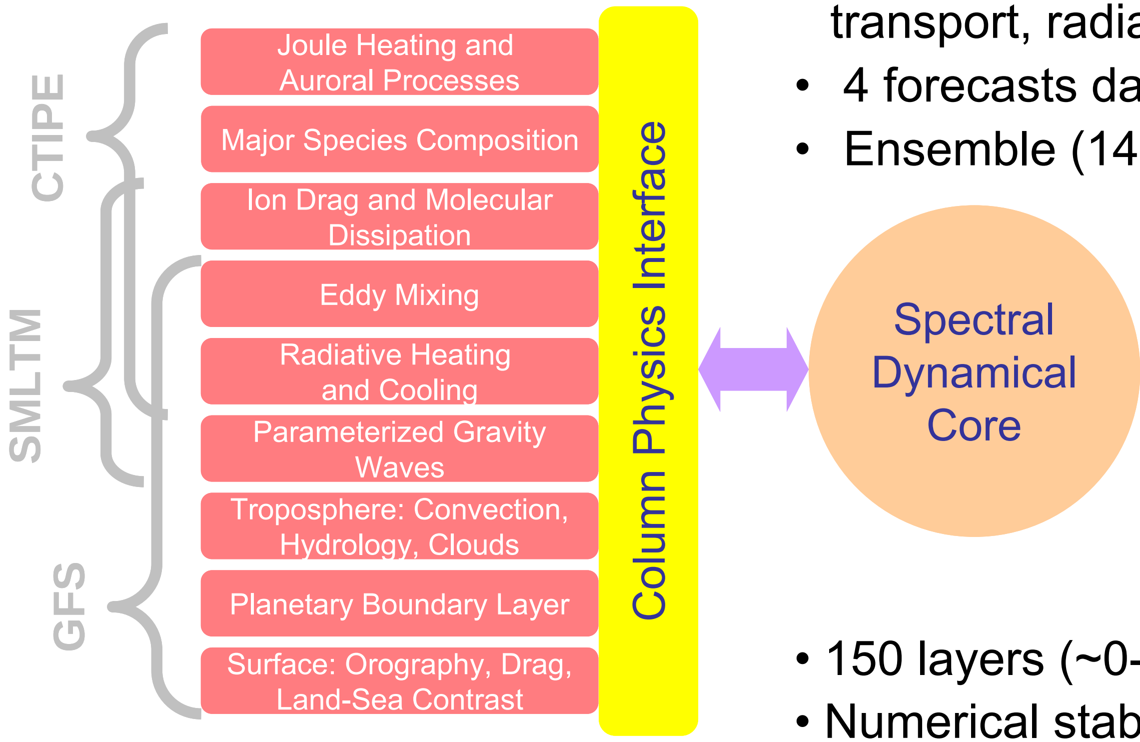
Motivation: thermospheric density



Temperature correction (dTc) to empirical J70 model from 4 satellite orbits in 2002 compared to solar and geomagnetic indices. Significant spectral peaks near 11, 14, and 19 days are a likely manifestation of PW effects.
(Courtesy B. Bowman, 2006).

IDEA = WAM + GIP

Whole Atmosphere Model = Extended GFS + Physics



<u>Operational Global Forecast System</u>

- T382L64 (~.3°×.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

<u>WAM</u>

- 150 layers (~0-600 km) ⇒ $\rho_{sfc}/\rho_{top} \sim 10^{13}$
- Numerical stability issues
- Variable composition ⇒ thermodynamics
- Column physics (some exceptions)
- Timing: ~13 min/day on 21 nodes @ T62L150

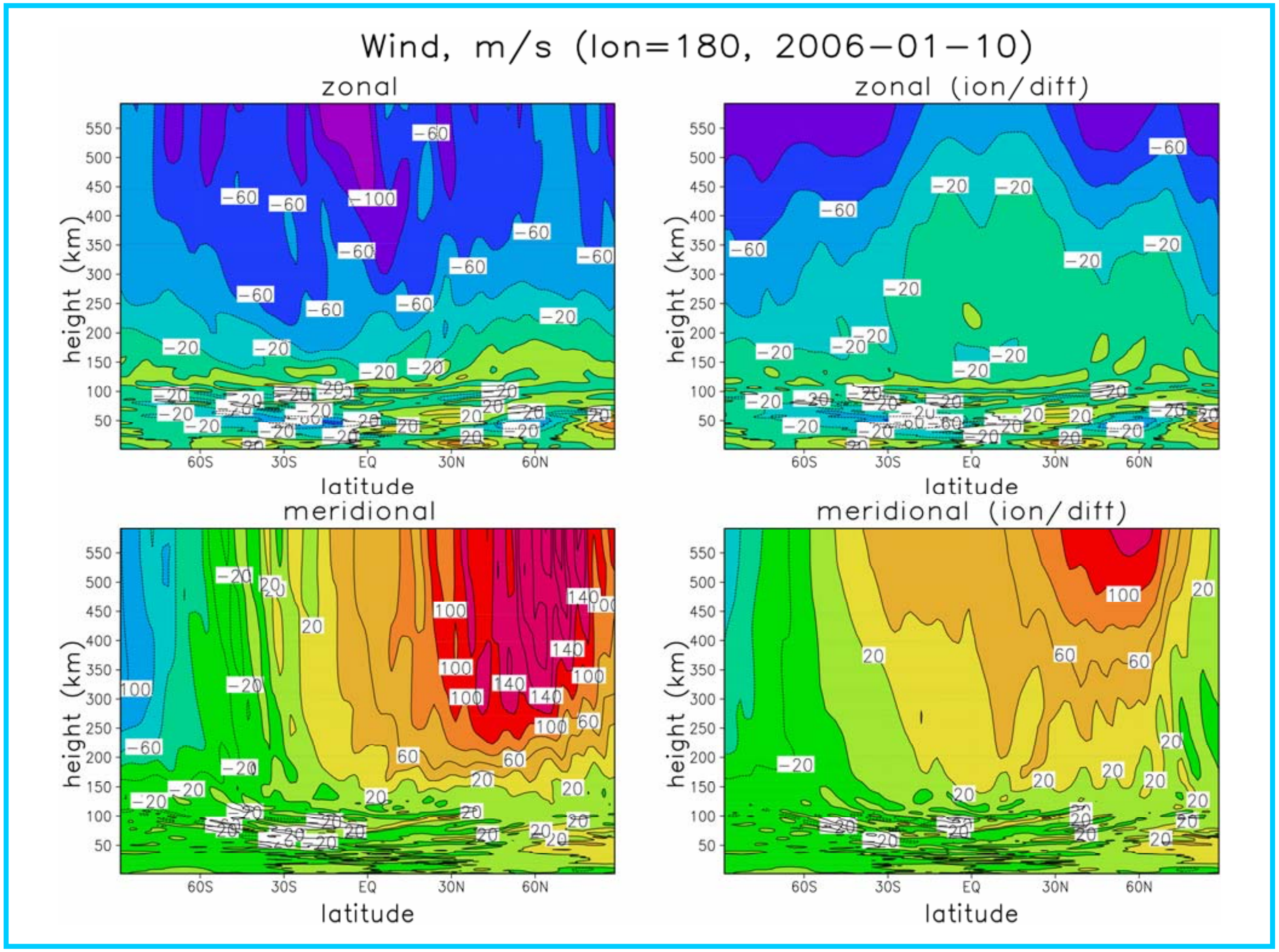
Effect of variable composition on thermodynamics

Traditional	New
$$C_P \frac{dT}{dt} - \frac{RT}{p}\frac{dp}{dt} = Q$$	$$\frac{dC_P T}{dt} - \frac{RT}{p}\frac{dp}{dt} = Q$$
$$T_v = T\left[1 + (R_v / R_d - 1)q\right]$$	$$\frac{dh}{dt} - \frac{Rh}{C_P p}\frac{dp}{dt} = Q$$

$$\frac{dT_v}{dt} - \frac{RT_v}{C_P p}\frac{dp}{dt} - (R_v / R_d - 1)T\frac{dq}{dt} = \frac{Q}{C_P}$$

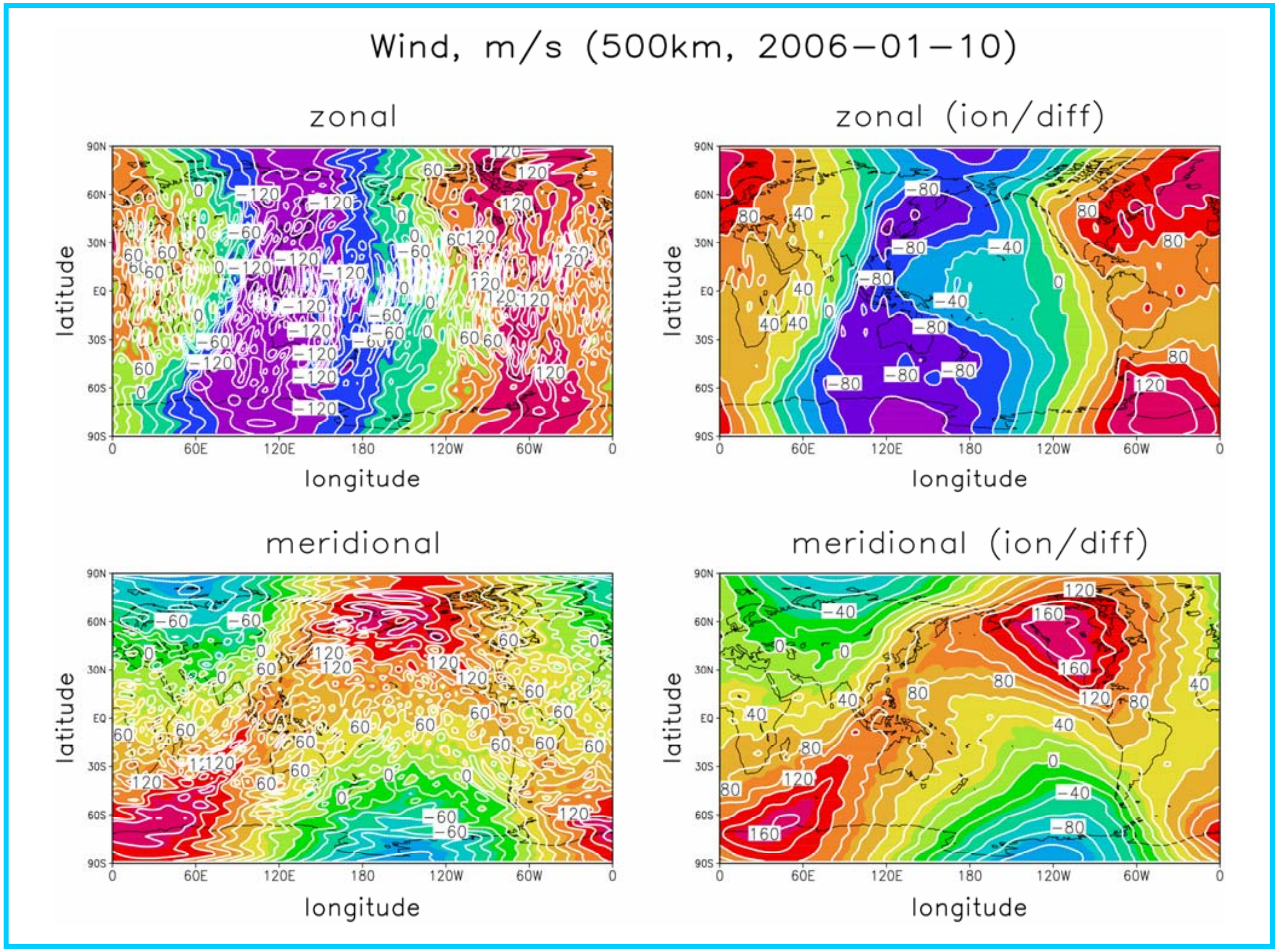
New enthalpy based thermodynamics is implemented (H. Juang) and is planned to be incorporated into a unified operational version of GFS.

WAM: Effect of ion drag & horizontal diffusion



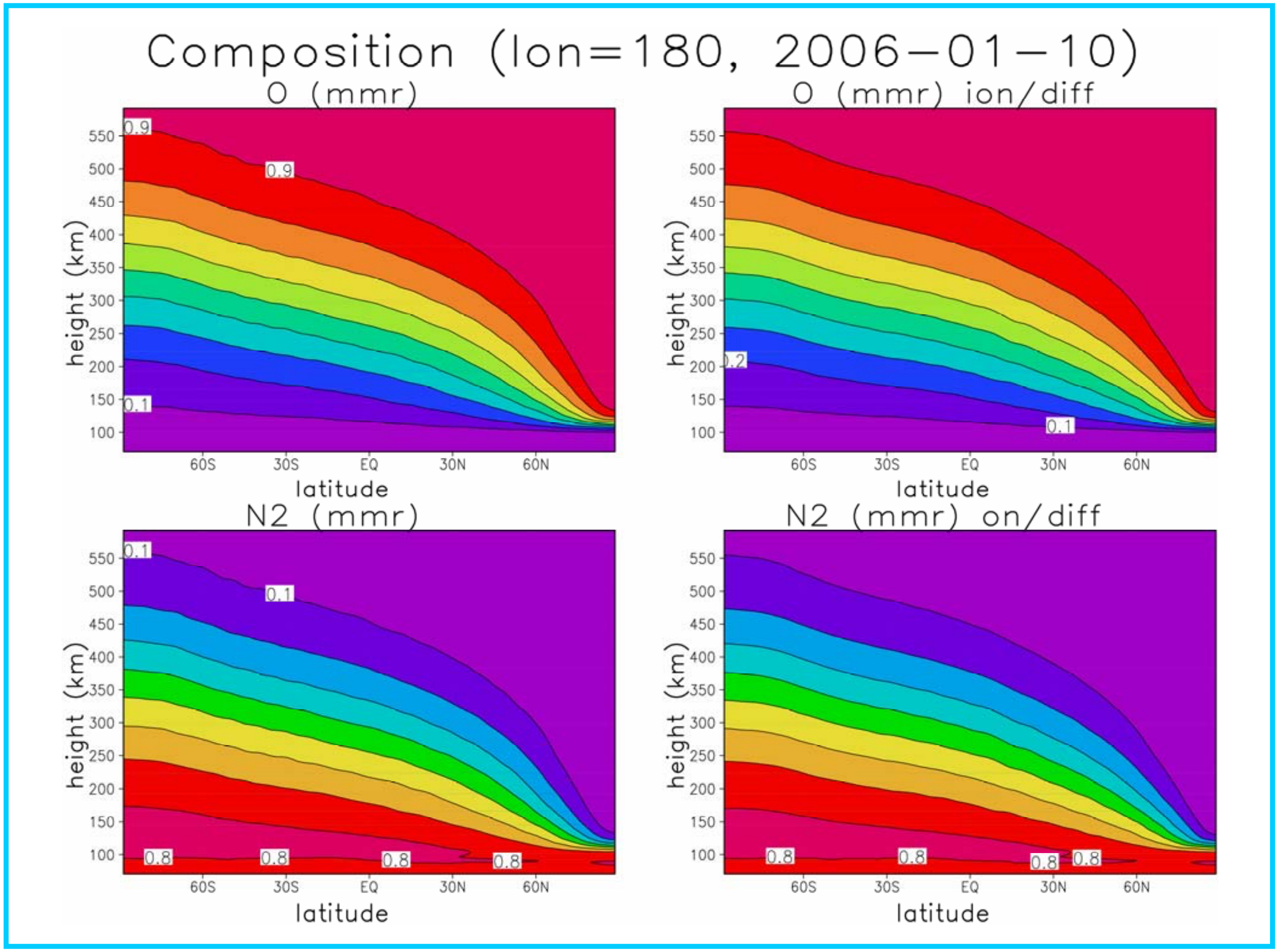
10-day test simulations for Jan. 10, 2006. Height vs. latitude @ 0 UT, longitude = 180º (noon LT).

WAM: Effect of ion drag & horizontal diffusion



10-day test simulations for Jan. 10, 2006.
Latitude vs. longitude @ ~500 km, 0 UT.

WAM: Thermospheric composition

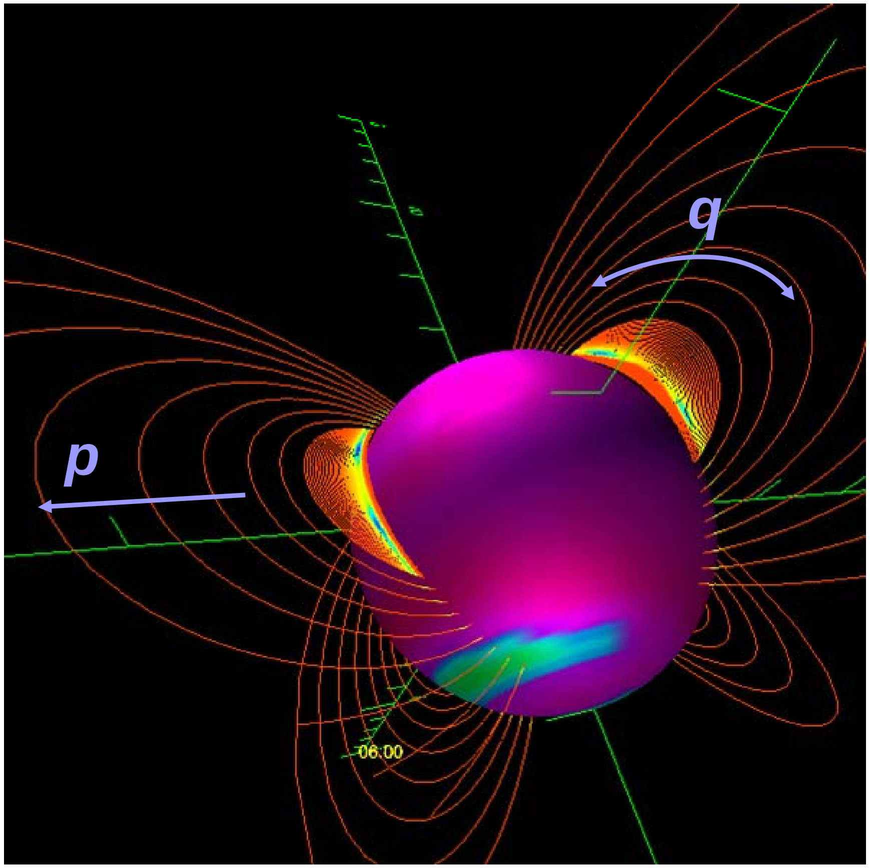


10-day test simulations for Jan. 10, 2006. Height vs. latitude @ 0 UT, longitude = 180º (noon LT).

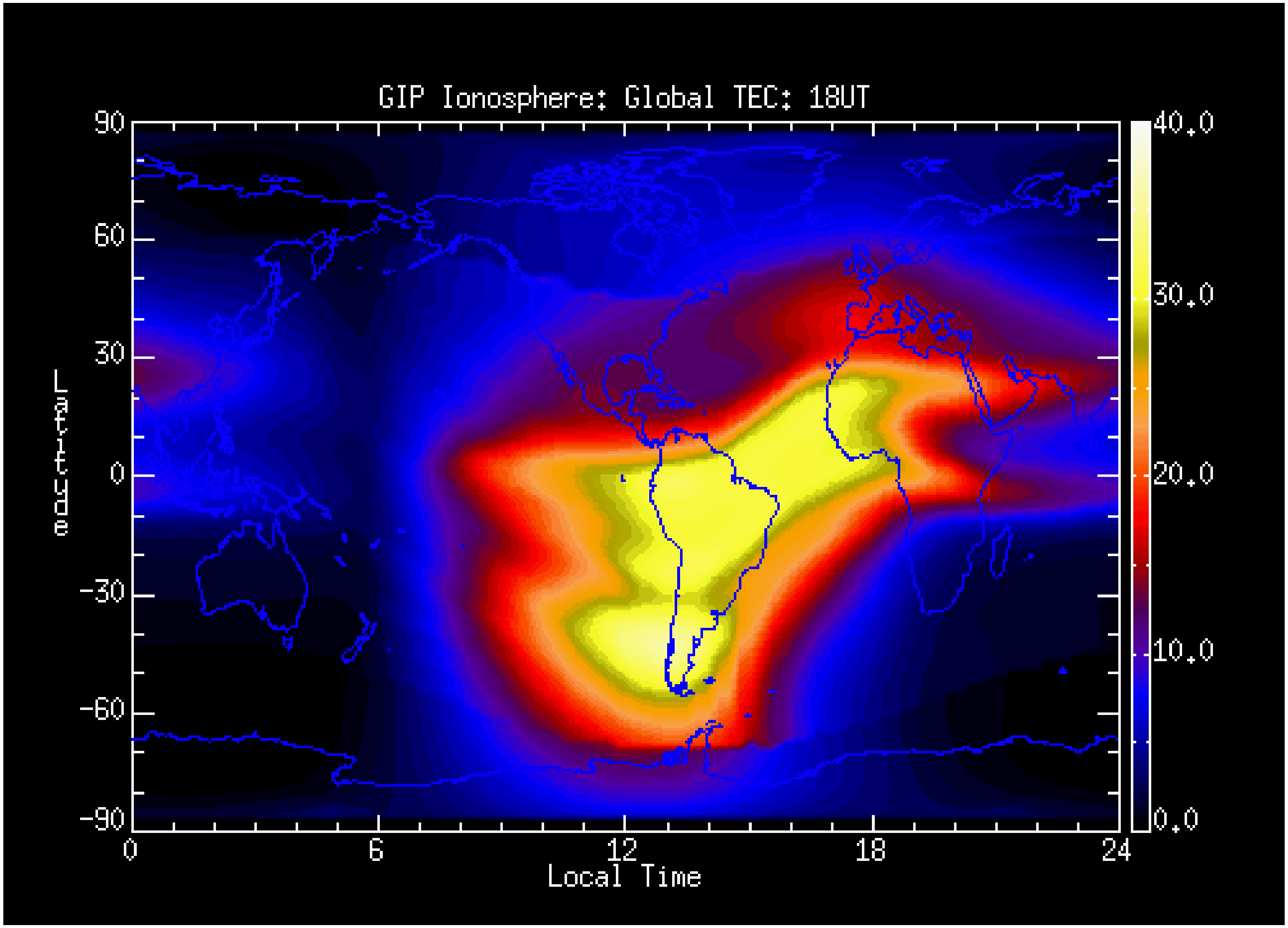
Global Ionosphere Plasmasphere (GIP)

- Altitude Range: ~90-19000 km
- Lagrangian fluid equations solved along magnetic coordinates:
  - Ion Continuity for O^+, H^+, He^+, N_2^+, O_2^+, and NO^+
  - Ion Momentum
  - Electron/Ion Energy
- Geomagnetic field: APEX coordinate based on IGRF
- Data exchange with WAM:
  - In: neutral density, composition, temperature, and wind vector
  - Out: frictional momentum tendency and Joule heating rate
- Has been coupled with a number of thermospheric models

Millward et al. (2005)



GIP TEC @ 1800 UT



Summary and future work

- Observed variability in ionospheric & thermospheric parameters clearly demonstrates influence of lower-atmospheric planetary-scale waves $\Rightarrow$ a need for seamless whole-atmosphere models coupled with ionosphere-plasmasphere.

- GFS code is extended to ~600 km with a new formulation for compositionally dependent thermodynamics & dynamics $\Rightarrow$ WAM is stably running under MPI.

- Principal upper-atmospheric physical processes are incorporated, including “non-column” dissipative processes.

- Substantial effort is being devoted to efficient coupling of WAM with GIP in a parallel environment.

- Initially the IDEA project aims to study and understand the effects of upward coupling between the lower & upper atmosphere and ionosphere. The model clearly will be applicable in other areas including possible downward coupling, global change in the whole Earth system environment. Conventional weather forecasts may also be improved by removing artificial boundaries in existing NWP models or more realistic specifications of the upper atmosphere for satellite soundings and data assimilation.