

Thermosphere and Ionosphere Extension of the Whole Atmosphere Community Climate Model (WACCM-X)

WACCM-X Development Team:

Han-Li Liu¹, Benjamin T. Foster¹, Rolando R. Garcia², Maura E. Hagan¹,
Douglas E. Kinnison², **Joseph M. McInerney**¹, Daniel R. Marsh², Astrid
Maute¹, Liying Qian¹, Arthur D. Richmond¹, Jadwiga H. Richter³, Raymond G.
Roble¹, Fabrizio Sassi³, Anne K. Smith, Stanley C. Solomon¹

1. High Altitude Observatory

2. Atmospheric Chemistry Division

3. Climate and Global Dynamics Division

Earth and Sun Systems Laboratory

National Center for Atmospheric Research



NCAR



Outline

- Thermosphere/ionosphere extension of the NCAR Whole Atmosphere Community Climate Model (WACCM): Model structure and components
- Model results:
 - Compositional structures
 - Temperature and winds
 - Seasonal variability
 - Tides and Short-term variability
- Summary and future studies

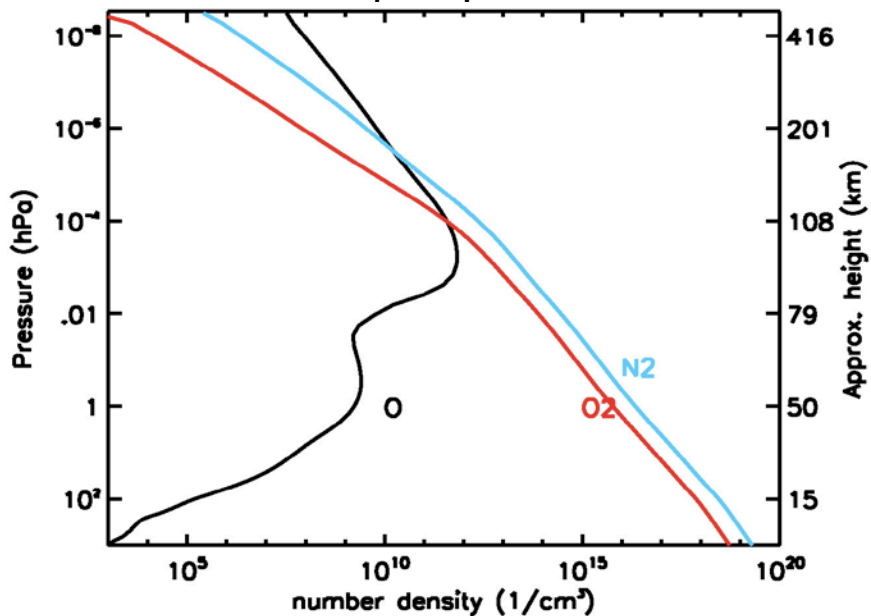
WACCM-X Model Components

Model Framework	Chemistry	Physics	Physics	Resolution
<p>Extension of the NCAR Community Atmosphere Model V.3 (CAM3)</p> <p>Finite Volume Dynamical Core</p> <p>Current version based on WACCM3.5.48</p> <p>CCSM-Compliant: WACCM-X a build time option.</p> <p>Green: Thermosphere extension. Red: Ionosphere extension.</p>	<p>MOZART+ Ion Chemistry (52 neutral+5 ions+electron)</p> <p>Fully-interactive with dynamics.</p>	<p>Long wave/short wave/EUV</p> <p>IR cooling (LTE/non-LTE)</p> <p>Major/minor species diffusion</p> <p>Molecular viscosity and thermal diff.</p> <p>Species dependent Cp, R, m.</p> <p>Parameterized electric field at high, mid, low latitudes. IGRF geomagnetic field.</p> <p>Auroral processes, ion drag and Joule heating</p> <p>Parameterized GW (including thermosphere)</p>	<p>Ambipolar diffusion</p> <p>Ion/electron transport due to Lorentz force</p> <p>Ion/electron energy equations</p> <p>Ionospheric dynamo</p> <p>Coupling with plasmasphere/magnetosphere</p>	<p>Horizontal: 1.9° x 2.5° (lat x lon configurable as needed)</p> <p>Vertical: 81 levels (125 levels) 0~500km</p> <ul style="list-style-type: none"> • < 1.0km in Upper Troposphere/ Lower Stratosphere • 1-2 km in strat. • 0.5 scale height in mesosphere/ thermosphere (0.25 scale height in mesosphere/thermosphere with 125 levels)

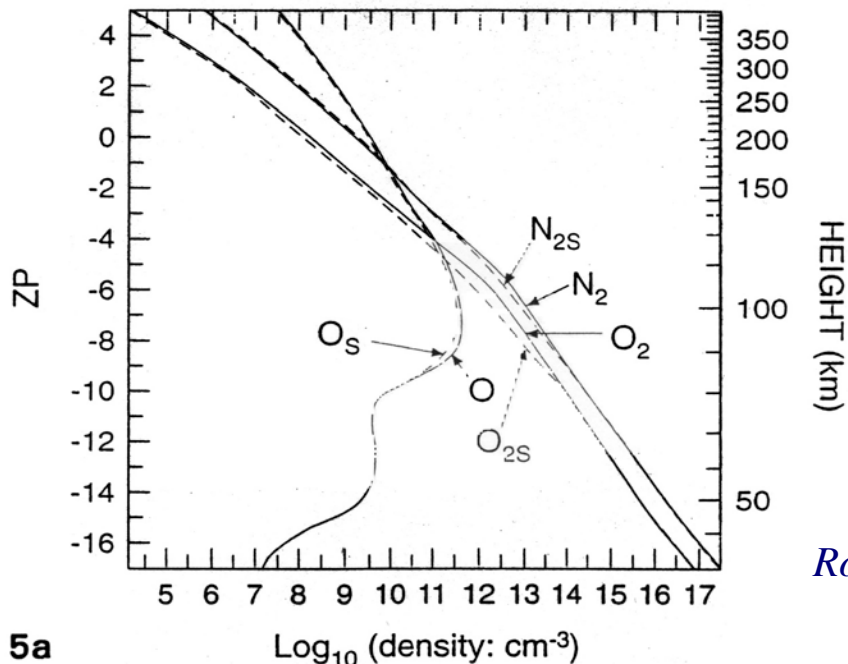
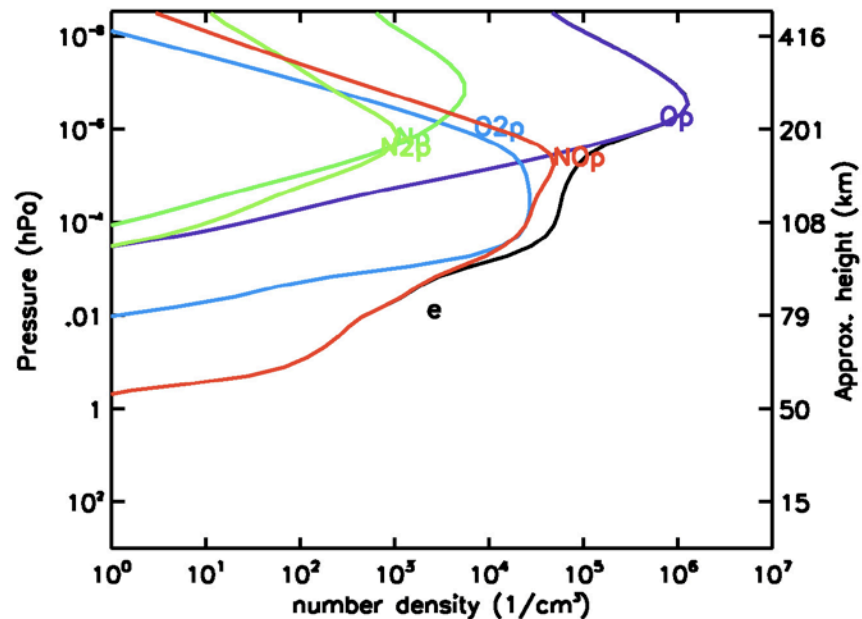


WACCM-X: Compositional Structures

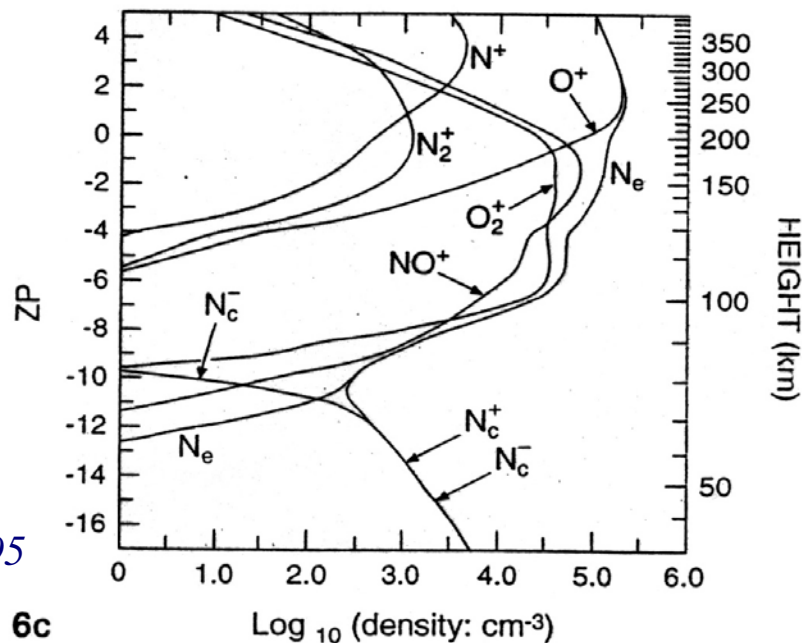
Major Species



Ions and Electrons



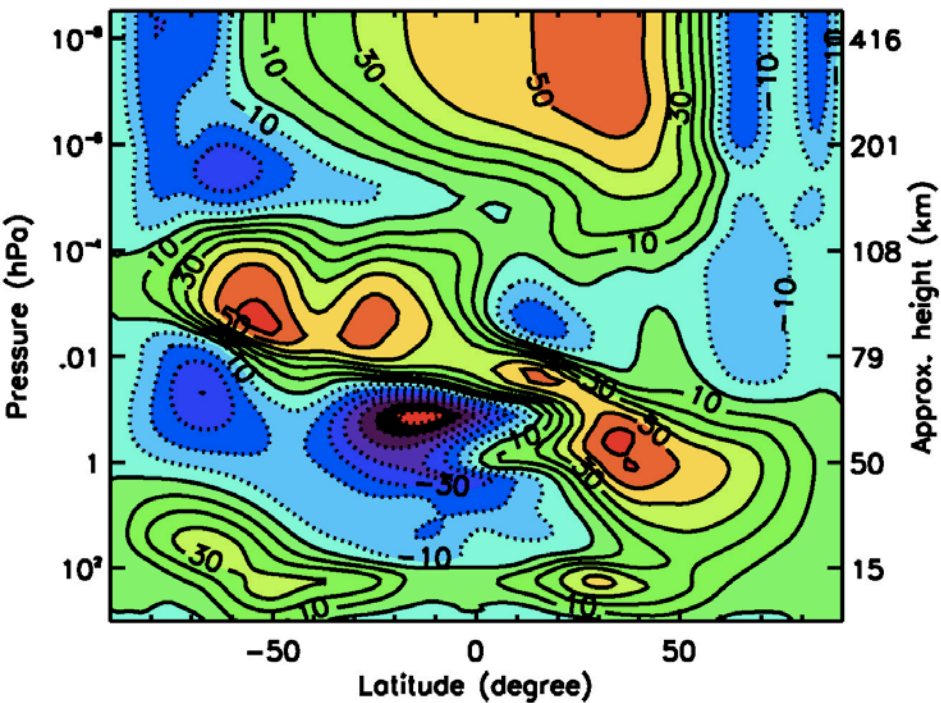
Roble, 1995



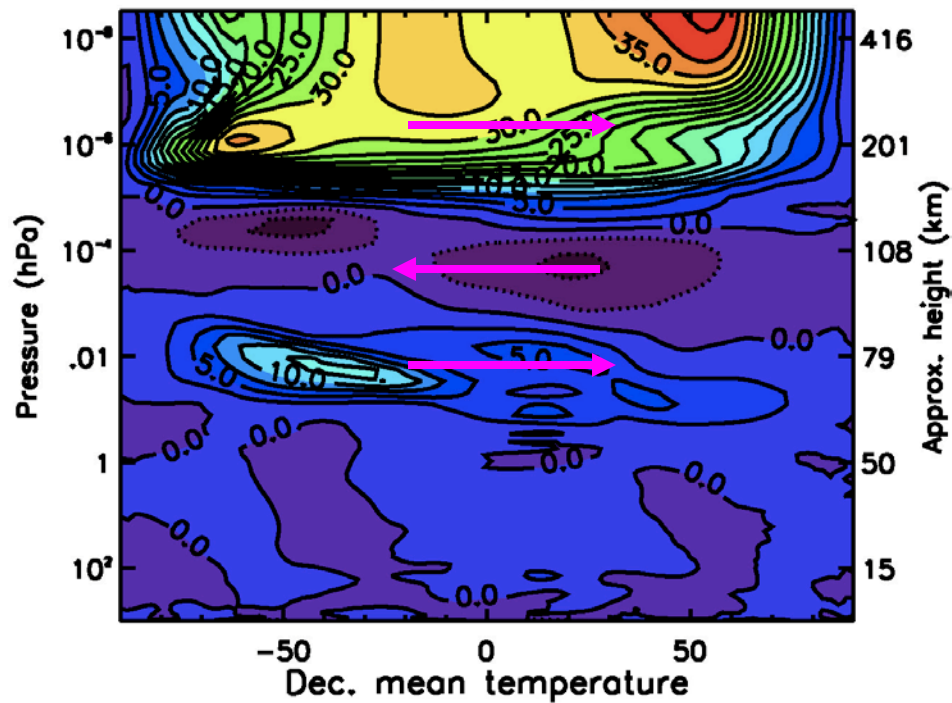
5a

6c

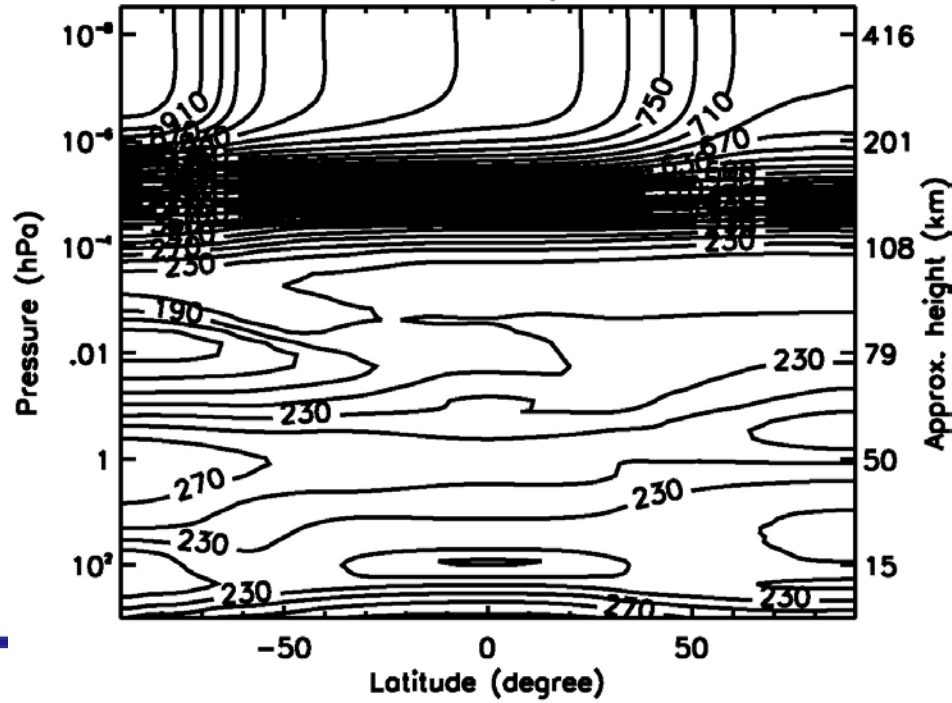
Dec. mean zonal wind



Dec. mean meridional wind



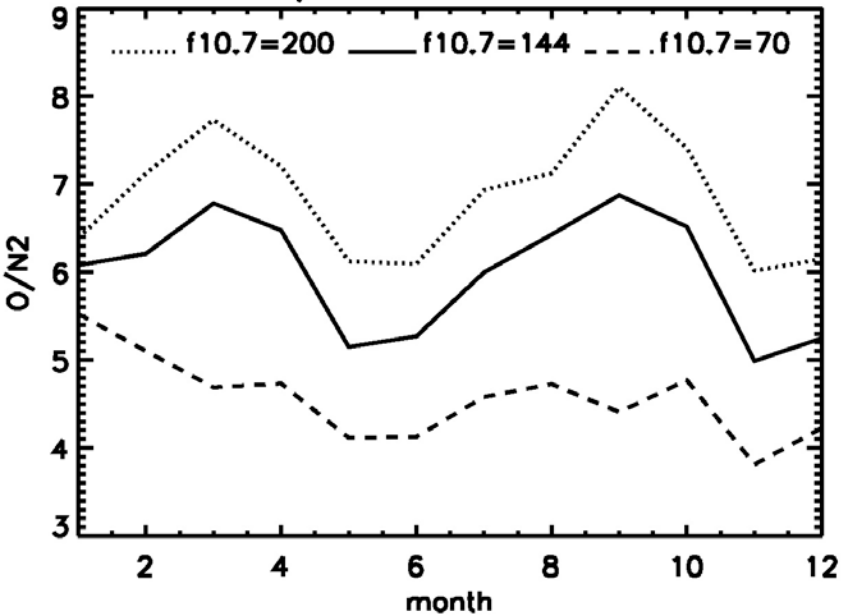
WACCM-X: Winds and Temperature (December)



Thermosphere Semi-annual Variation

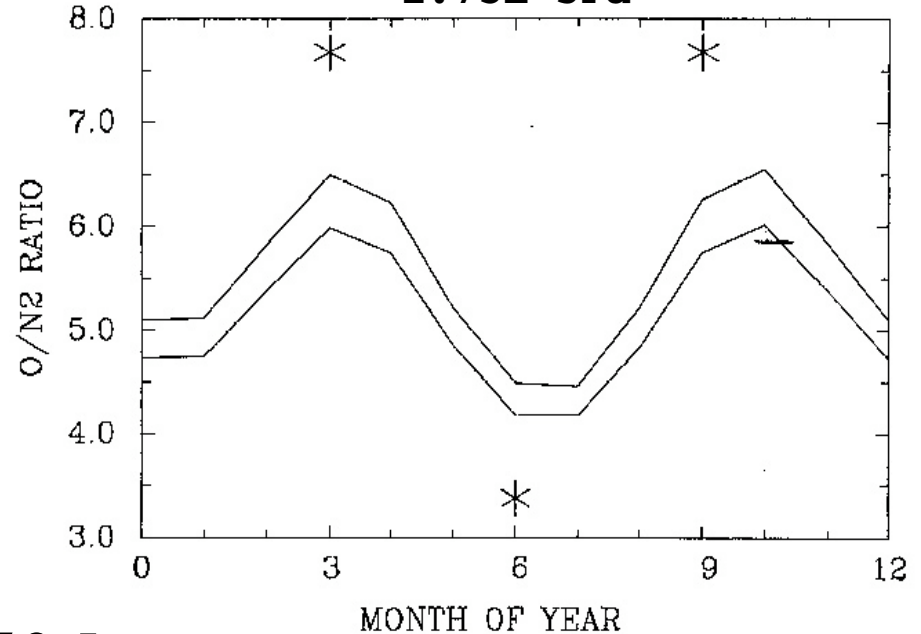
WACCM-X

O/N2 at $1.8E-5$ Pa



MSIS

$1.73E-5$ Pa



~250 km

Migrating Diurnal Tide: Temperature

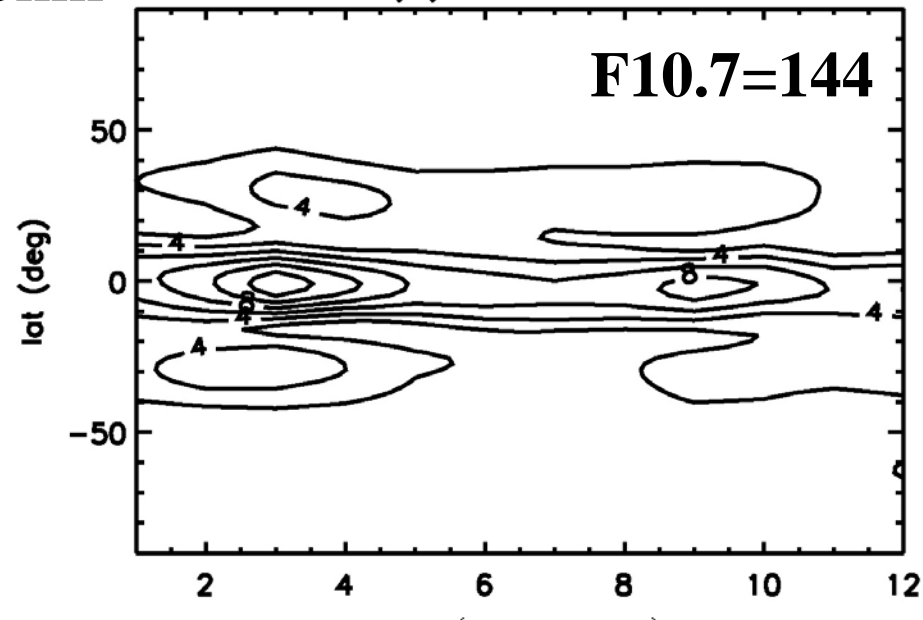
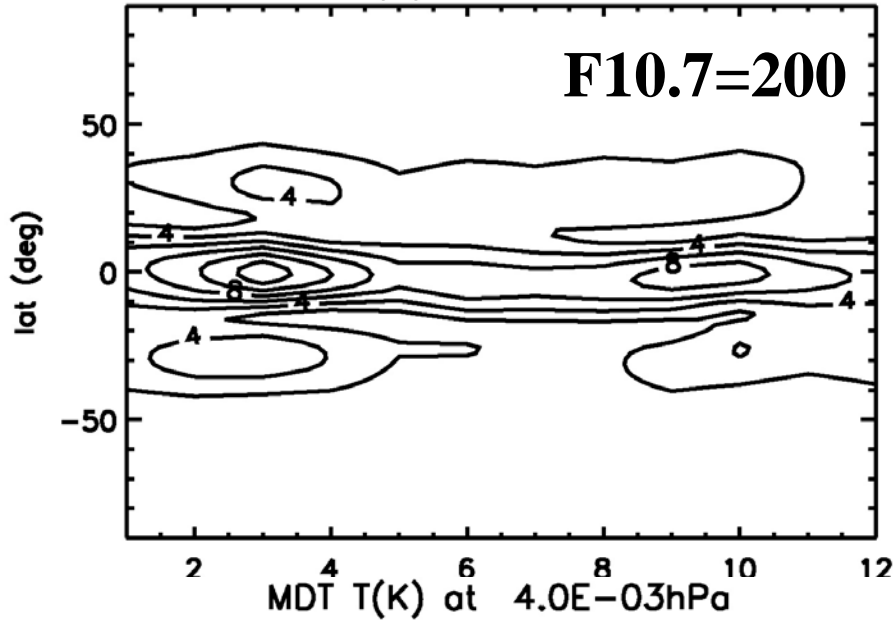
MDT T(K) at $4.0E-03\text{hPa}$

~100km

MDT T(K) at $4.0E-03\text{hPa}$

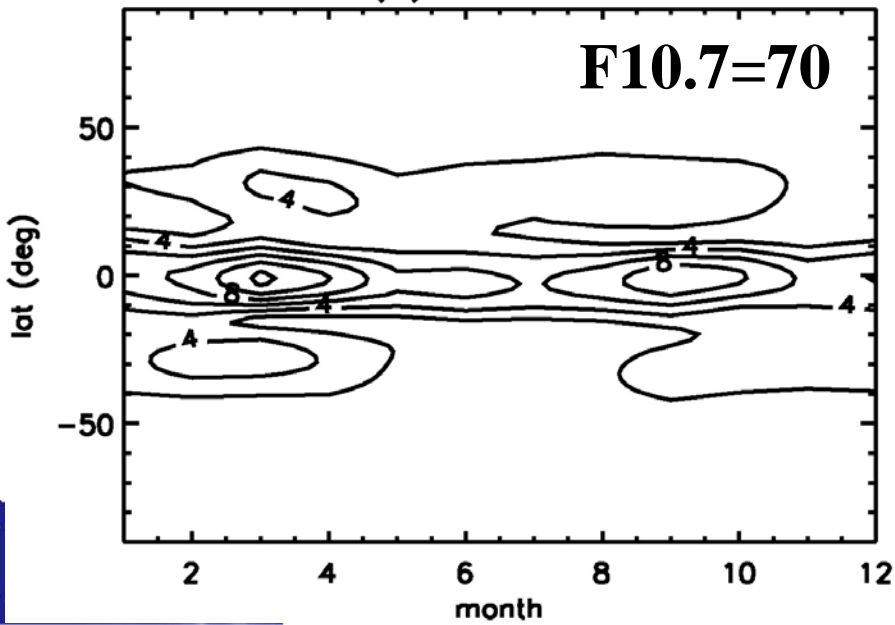
F10.7=200

F10.7=144

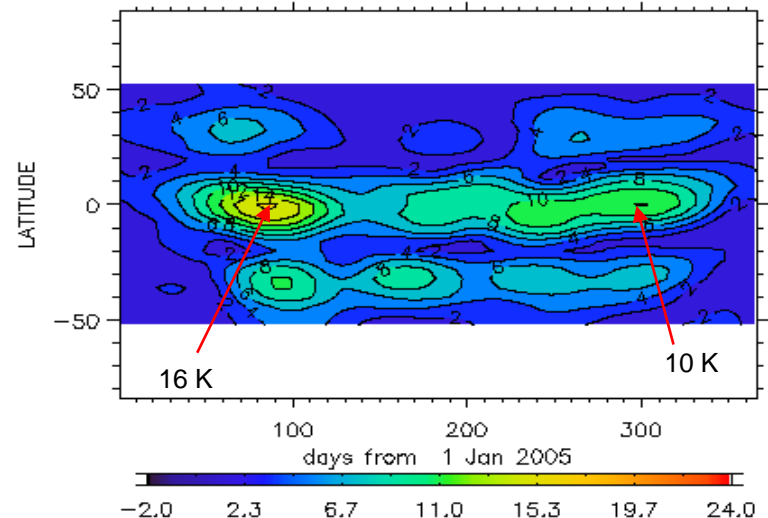


MDT T(K) at $4.0E-03\text{hPa}$

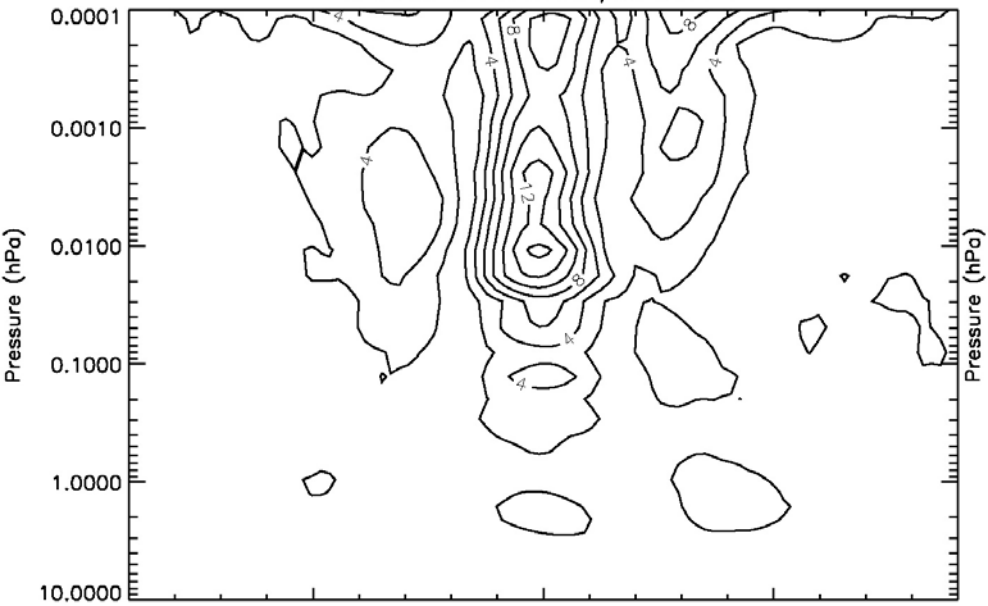
F10.7=70



$m=1, z=12.5 \text{ sh}, f=(0.986, 1.008), \text{ctr}=2.00$
RMS AMP 1 Jan - 31 Dec 2005



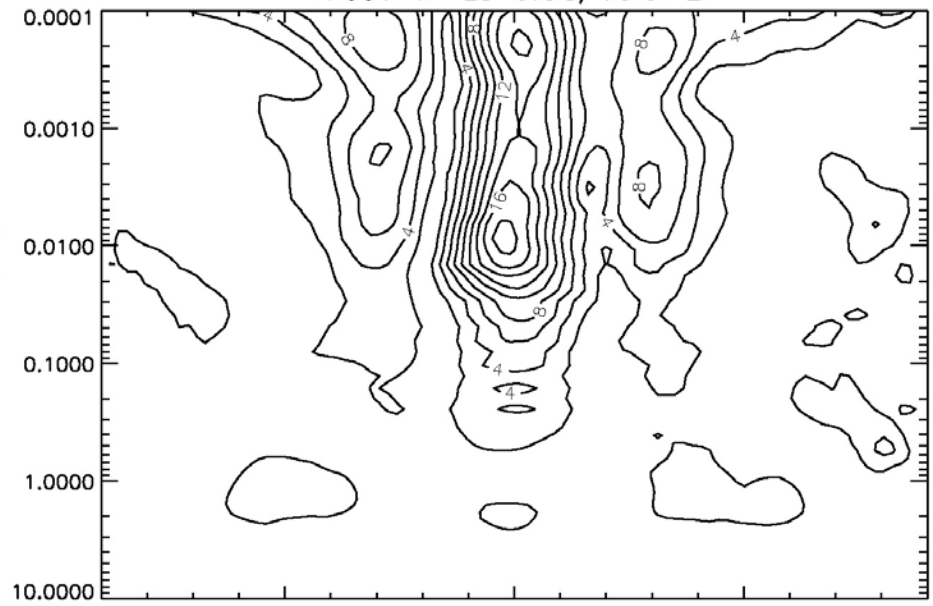
WACCM-X 81 levels, March 21



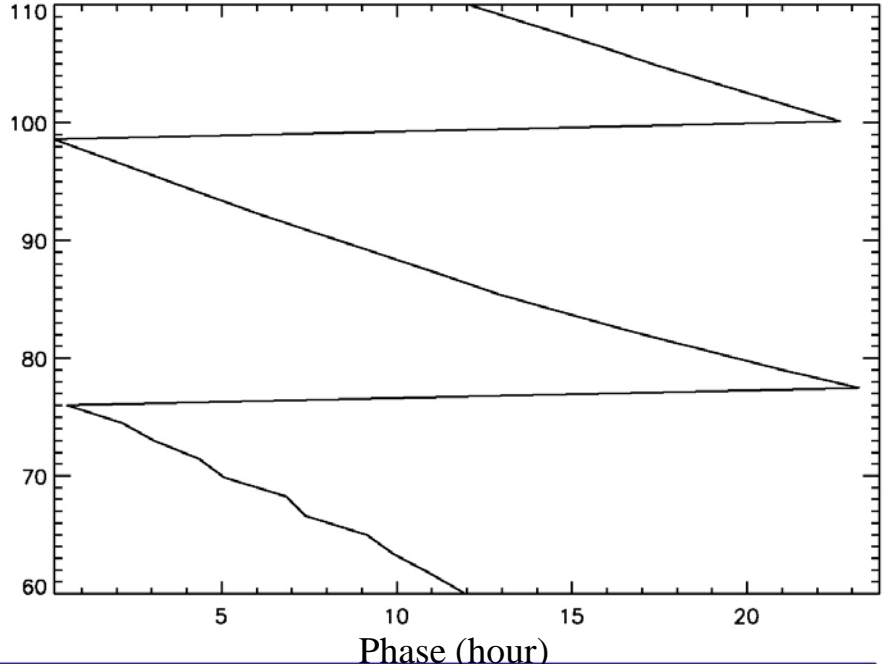
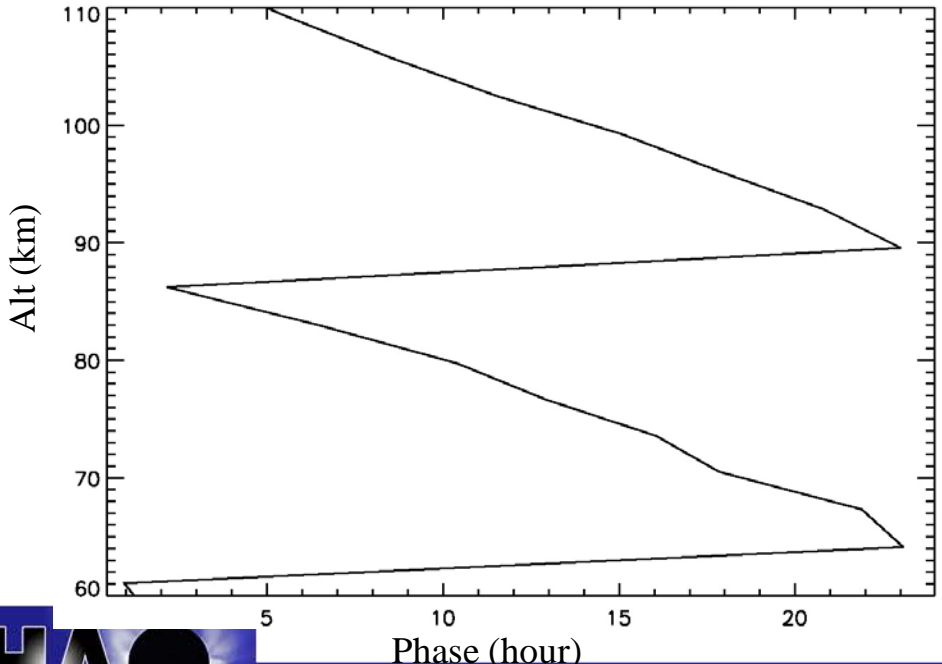
81 levels

Migrating Diurnal Tide

WACCM-X 125 levels, March 21

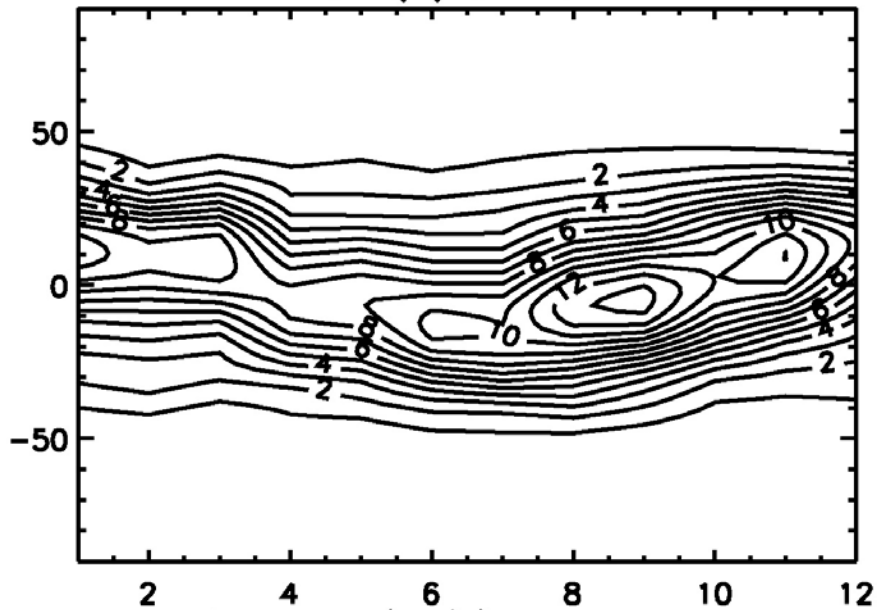


125 levels

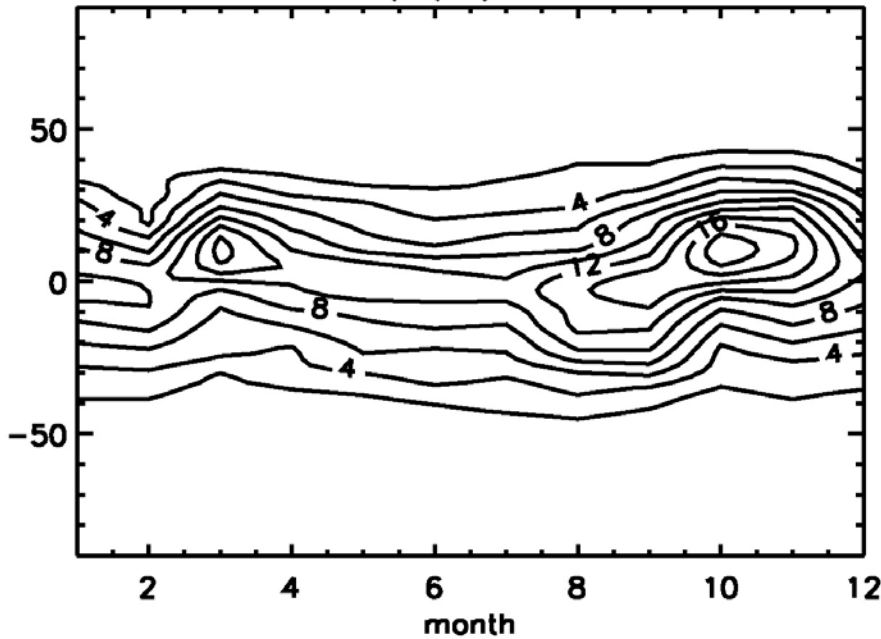


Nonmigrating: Diurnal E3

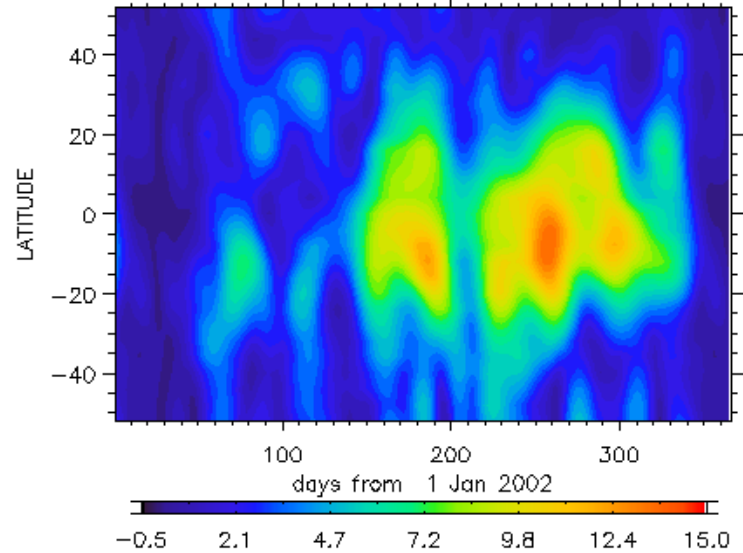
E3 Diurnal T(K) at $1.2E-04\text{hPa}$



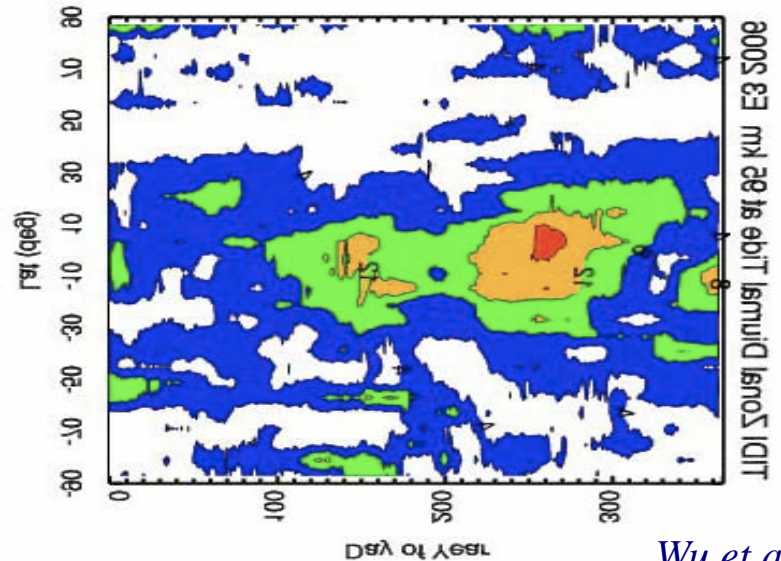
E3 Diurnal UN(m/s) at $8.8E-04\text{hPa}$



$m=3, z=16.1 \text{ sh}, f=(-1.030, -0.972), \text{ctr}=0.50$
 RMS AMP 1 Jan - 31 Dec 2002

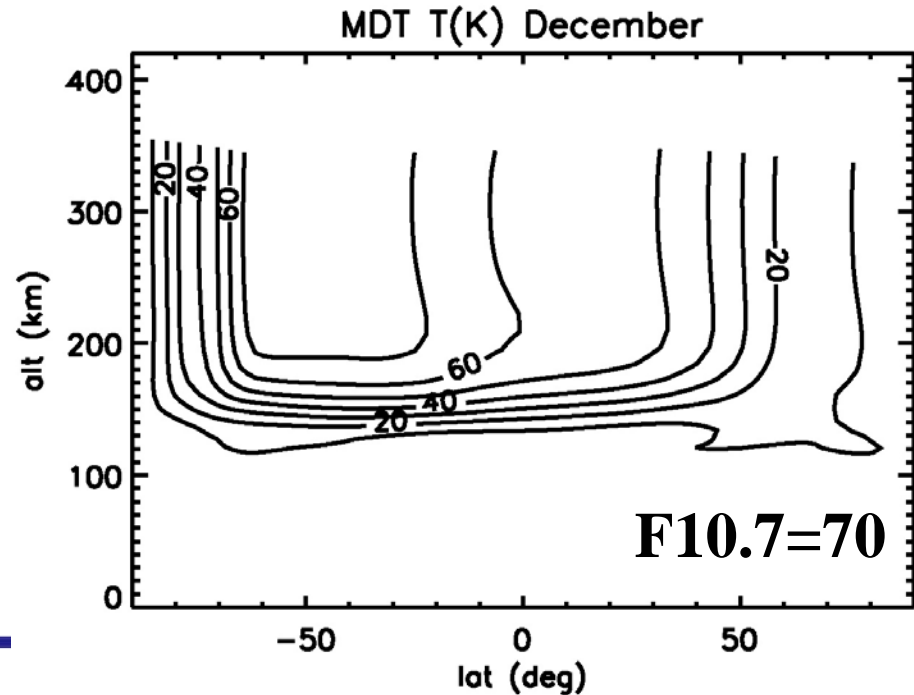
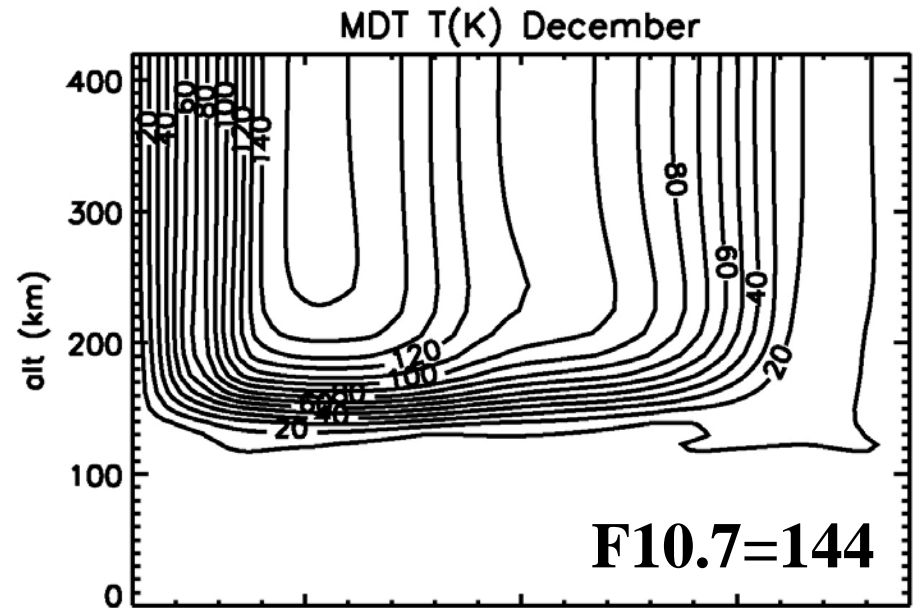
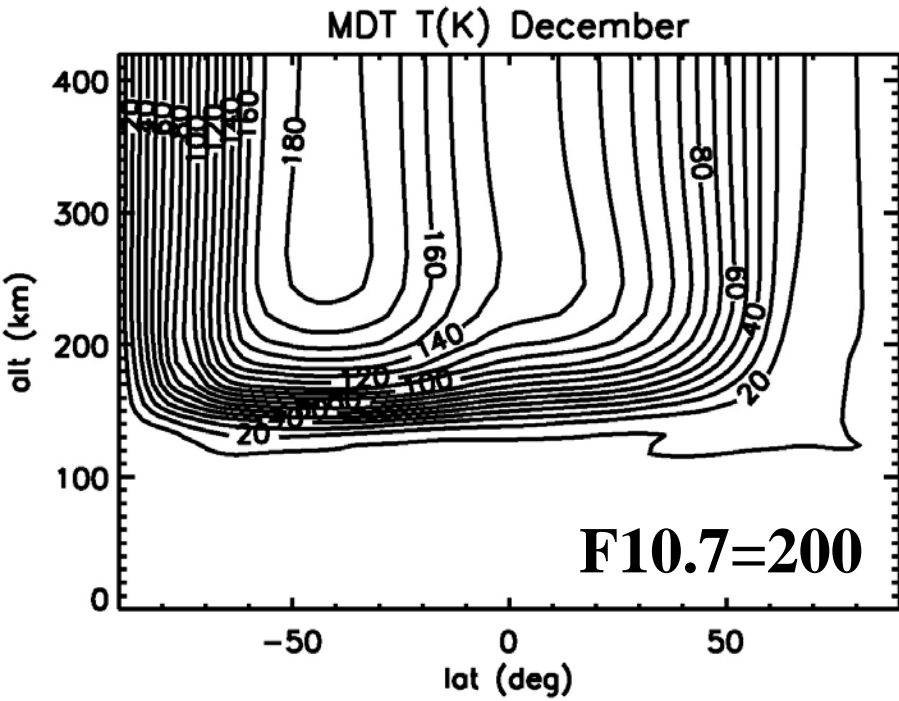


Garcia and Lieberman, 2007

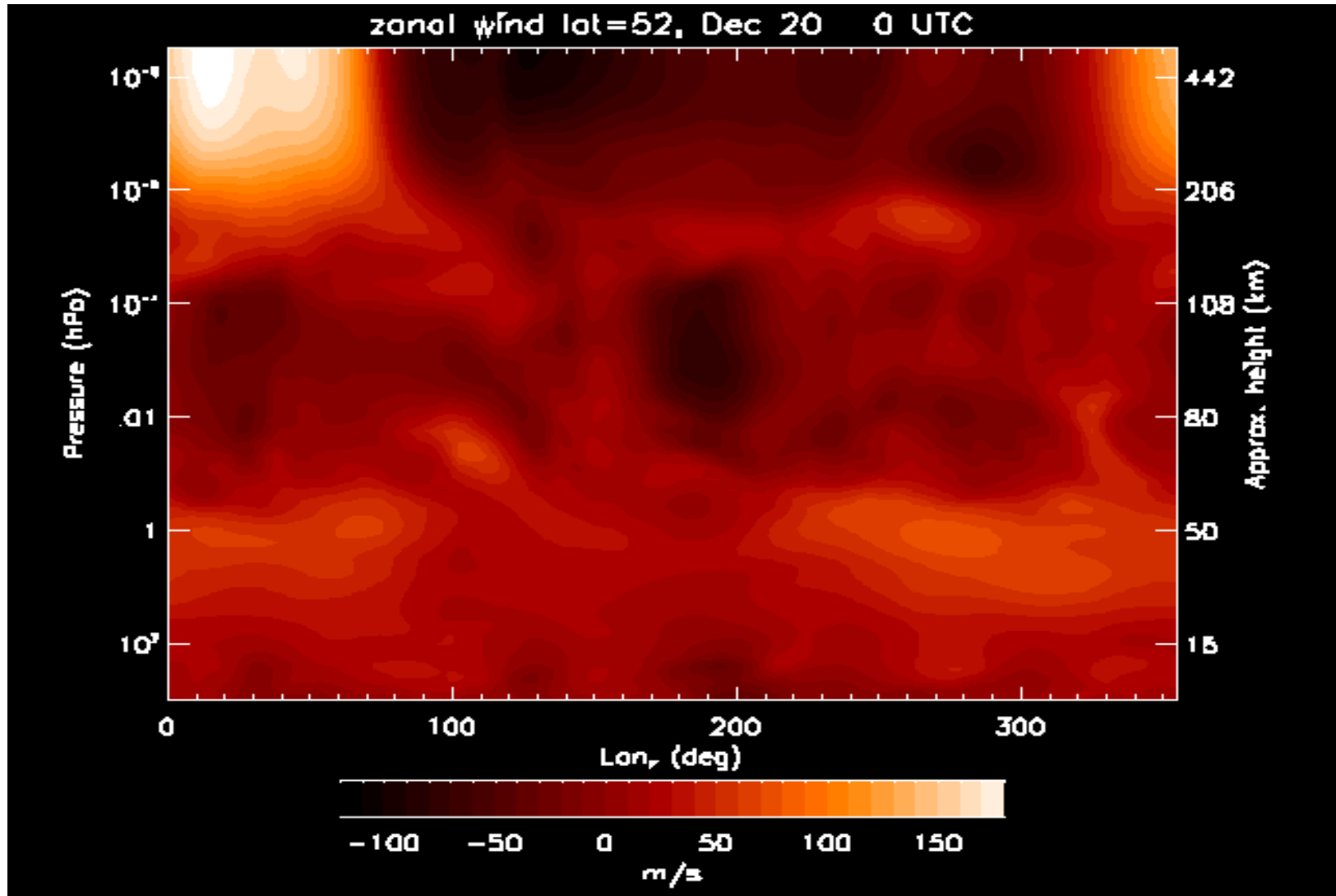


Wu et al, 2008b

Thermosphere Tides



Short-term Variability



Summary

- A whole atmosphere model extending from earth surface to the upper thermosphere
- Self-consistently resolve the dynamical, physical and chemical processes (ionospheric electrodynamics under development)
- A CCSM branch, and is a CCSM build-time option
- Reproduces salient features of
 - Atmospheric composition, temperature and wind of the whole atmosphere
 - Semi-annual variation in the thermosphere
 - Tides
 - Migrating components (good seasonality, amplitude weaker than obs.)
 - DE3 component (excellent agreement)

Summary and Future Development

- Problems:
 - Mesopause and lower thermosphere temperature warmer than observations.
 - Jet splitting in summer stratosphere/mesosphere.
 - Middle and upper thermosphere temperature colder than empirical model and TIME-GCM.
 - Semi-annual variation in thermospheric density not properly reproduced.
- Work with the community to further validate and develop the model.
- Further analysis of thermospheric variability as related to the coupling with the lower atmosphere.
- Further development to include ionospheric physics (module development, coupling with GAIM, GIP).
- Merge into CCSM trunk.