

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

WACCM-X Development Team:

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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.
 - Comparisons with MSIS/HWM and TIE-GCM.
 - Seasonal variability.
 - Tides and short-term variability.
- Summary and future studies.

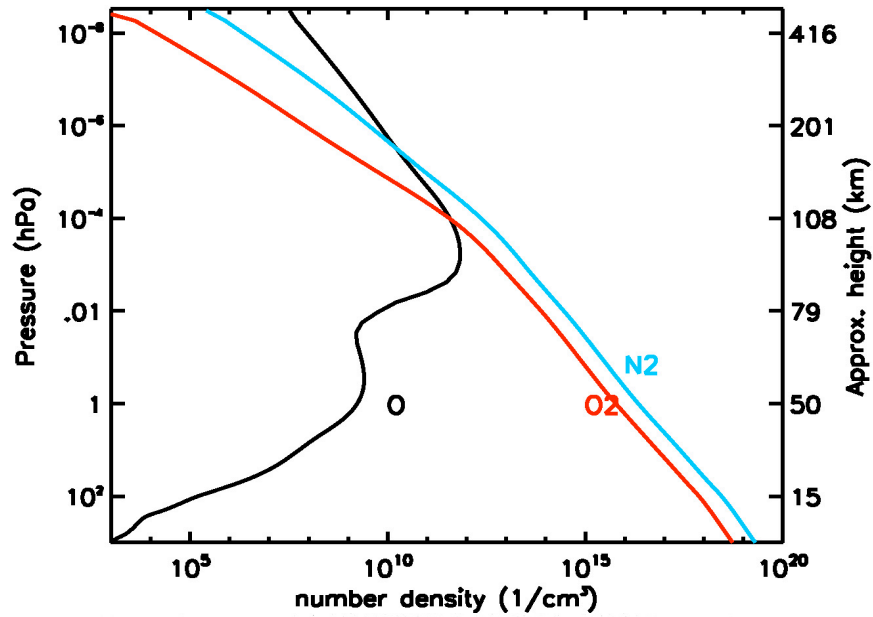
WACCM-X Model Components

| 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 style="color: green;">Green: Thermosphere extension.</p> <p style="color: red;">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 style="color: red;">Ambipolar diffusion</p> <p style="color: red;">Ion/electron transport due to Lorentz force</p> <p style="color: red;">Ion/electron energy equations</p> <p style="color: red;">Ionospheric dynamo</p> <p style="color: red;">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) |

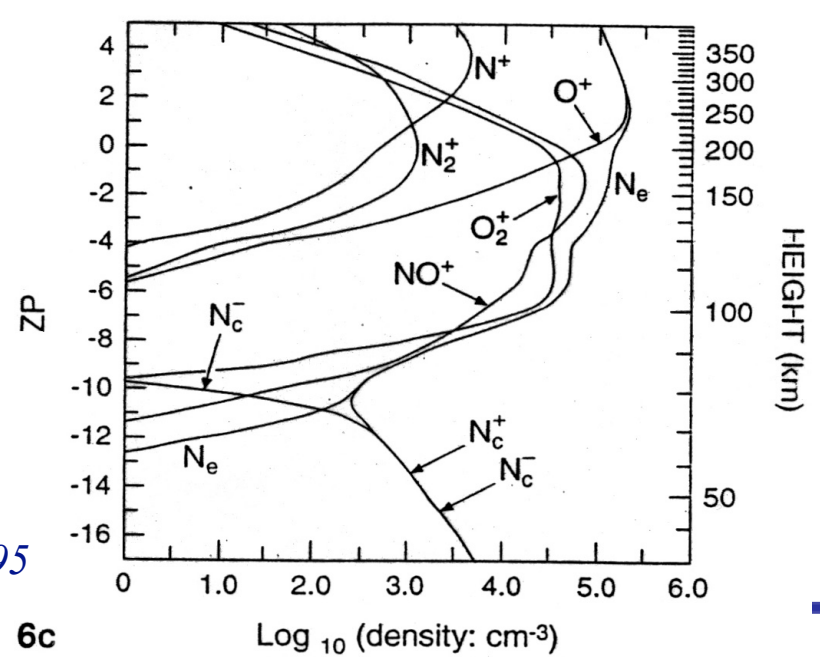
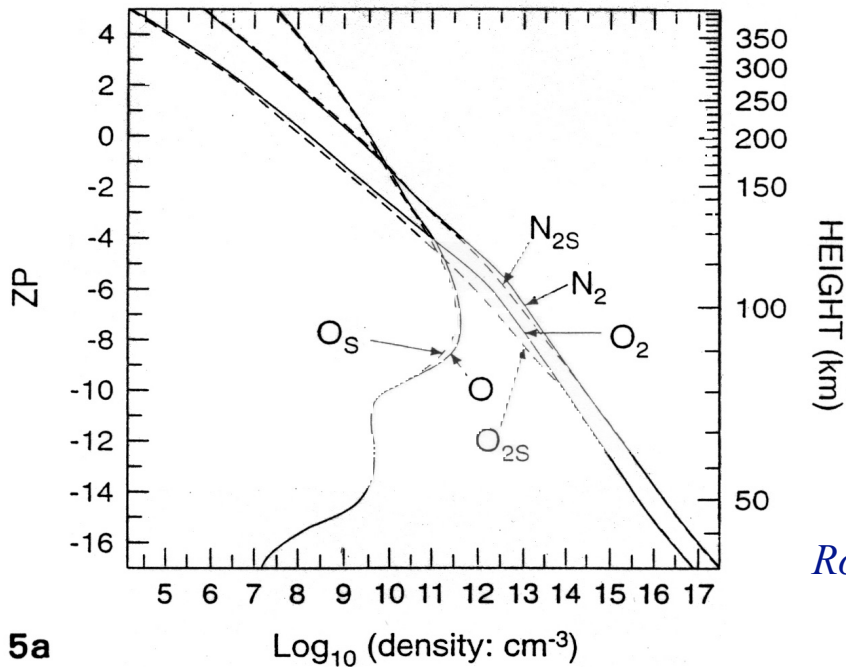
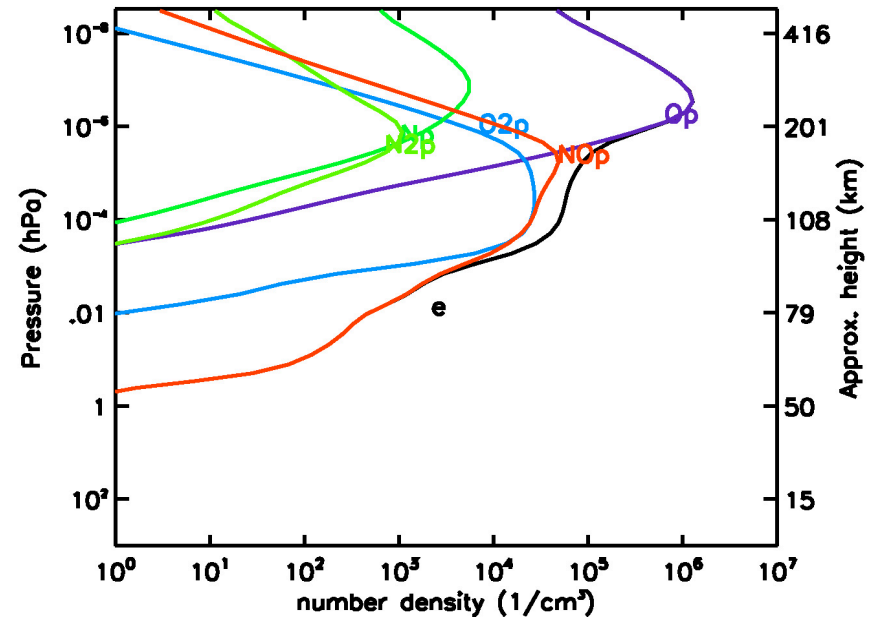


WACCM: Compositional Structures

Major Species



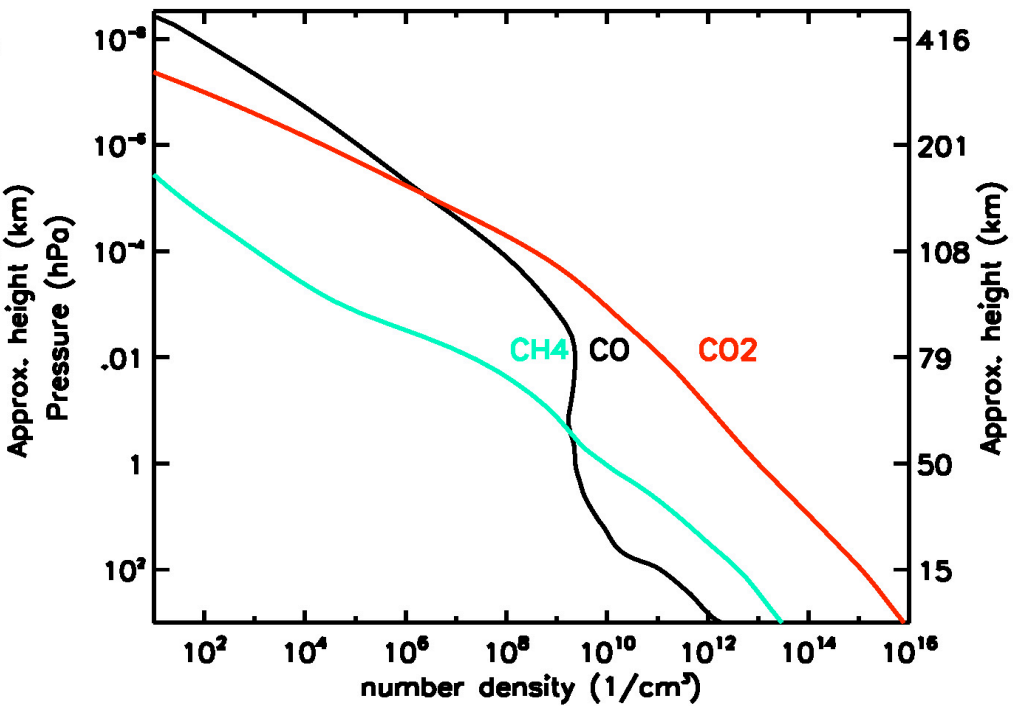
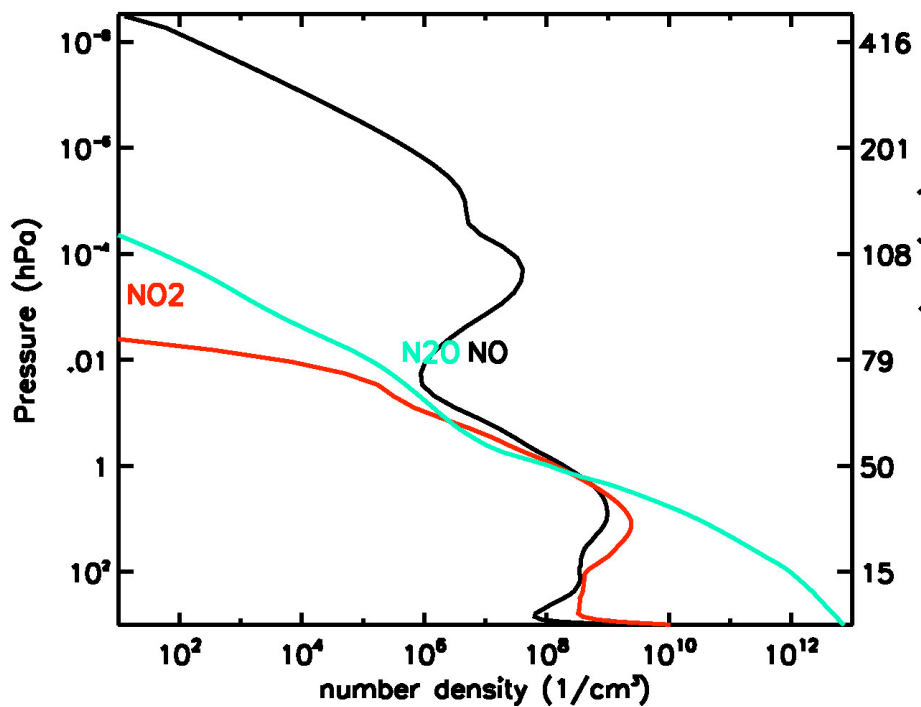
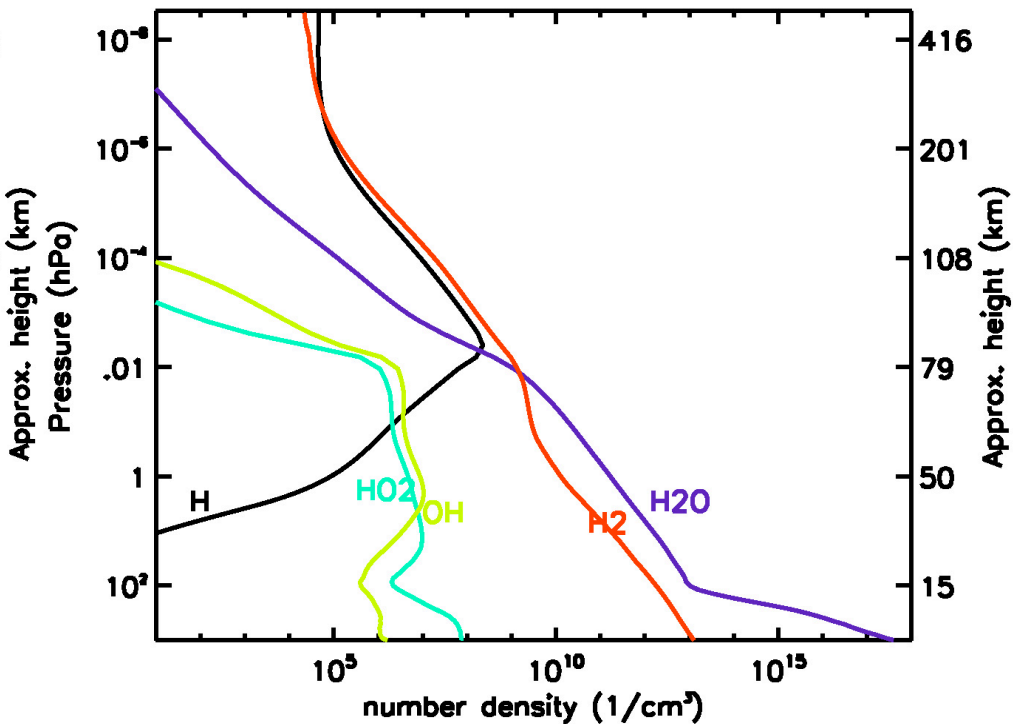
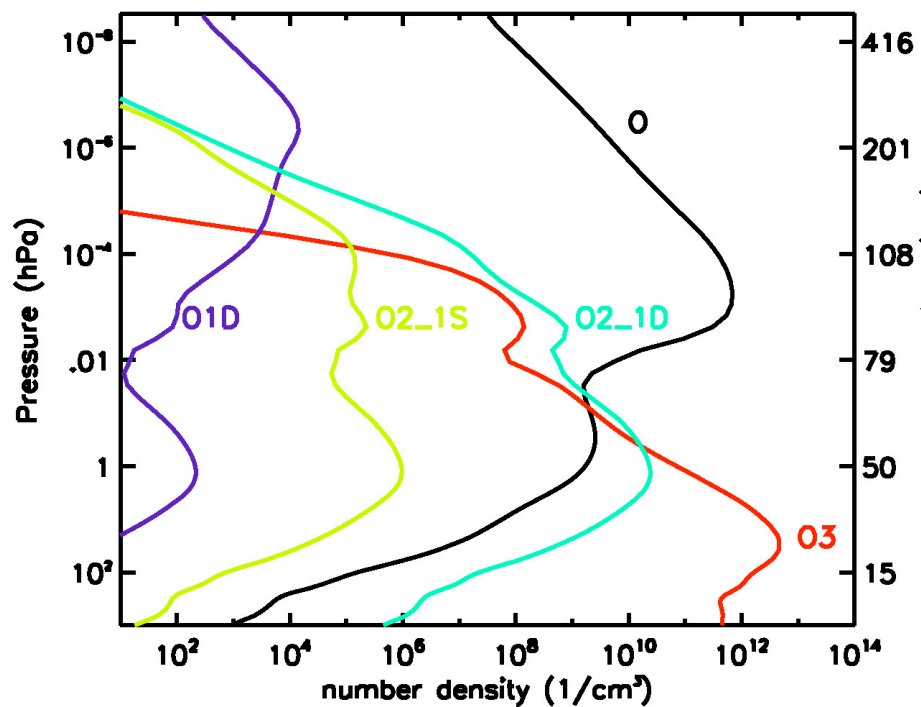
Ions and Electrons

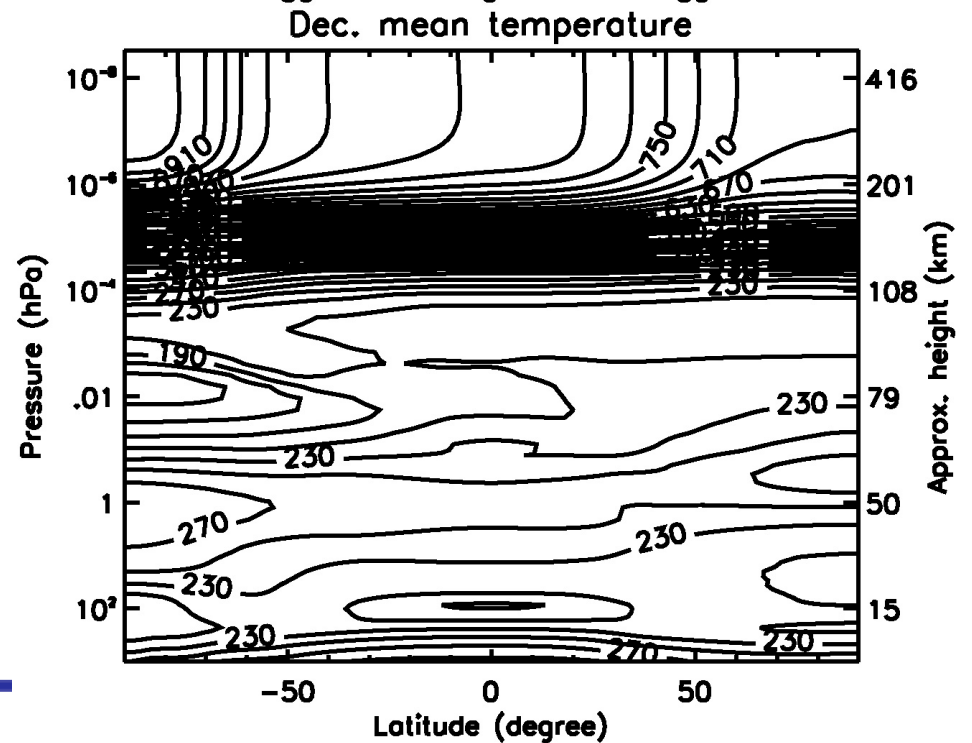
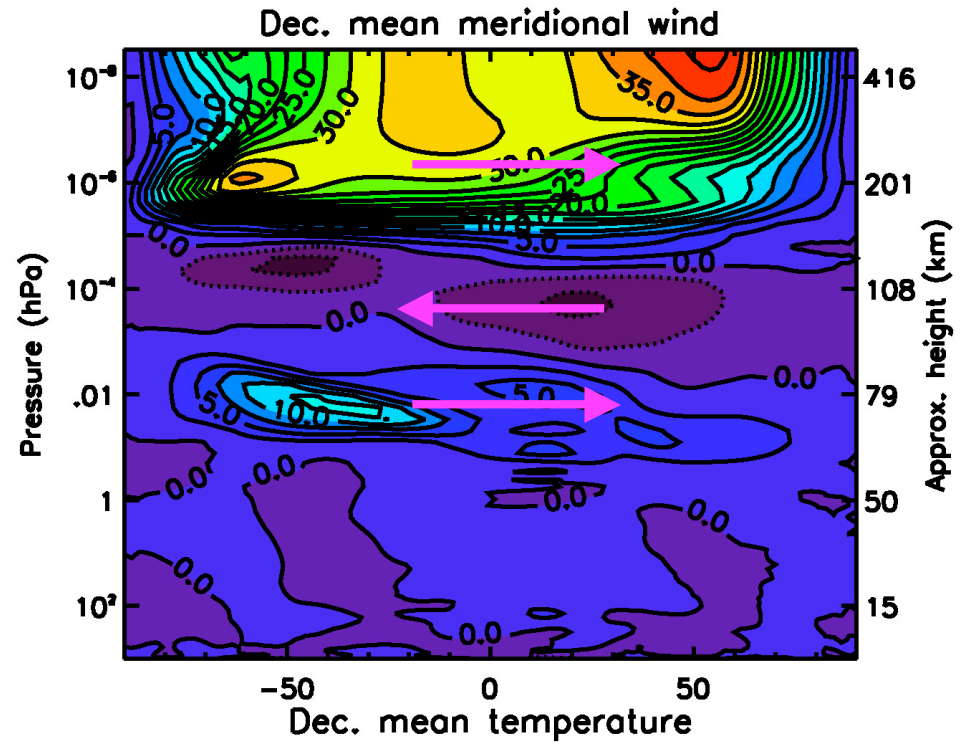
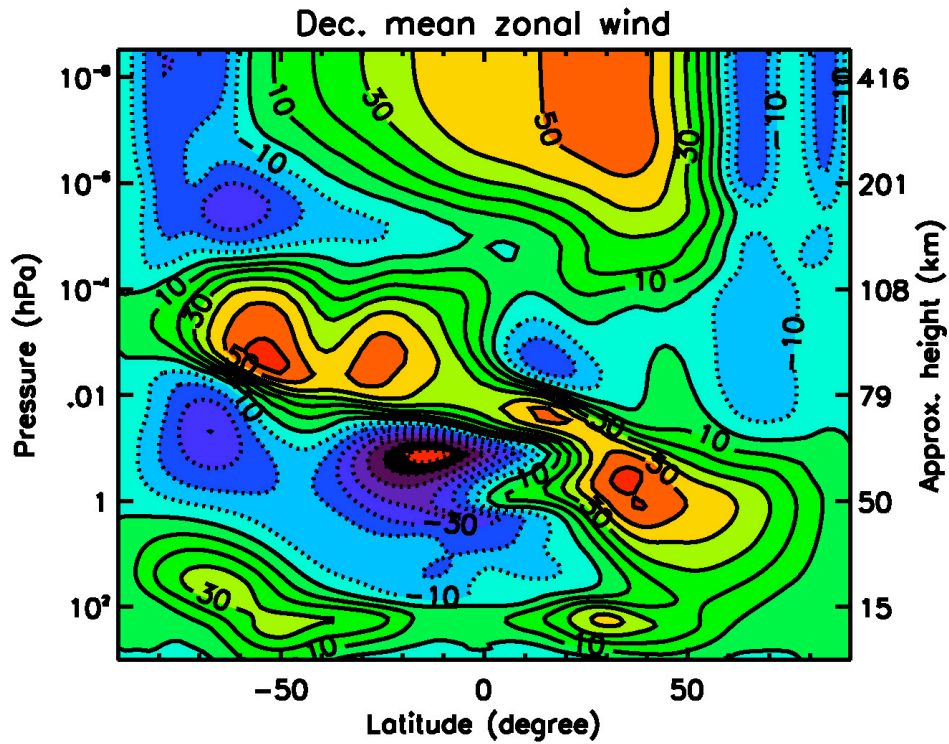


Roble, 1995

5a

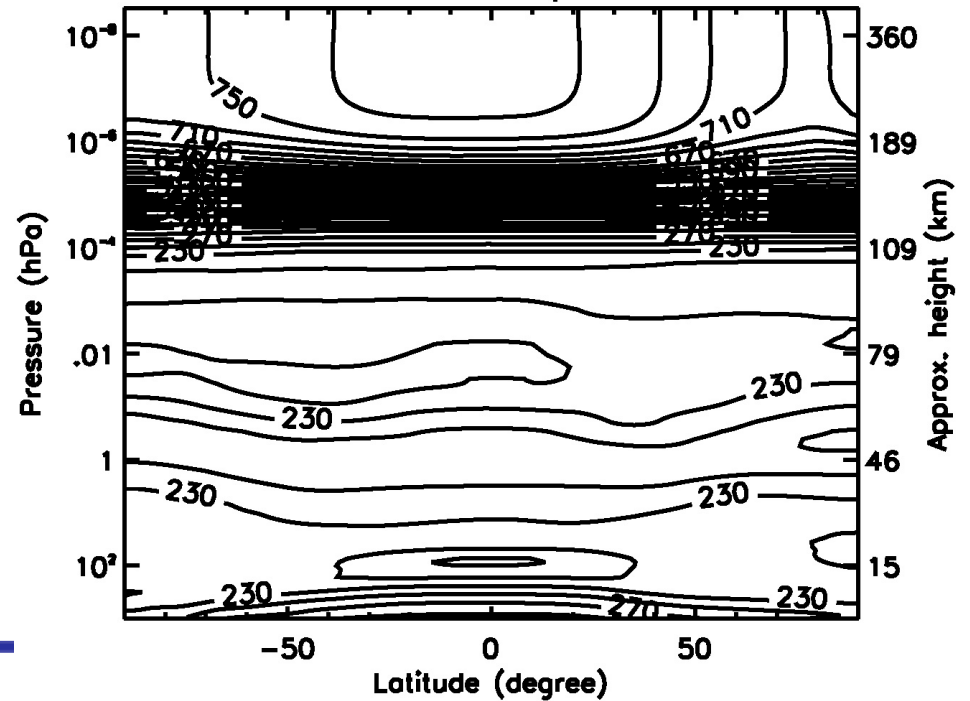
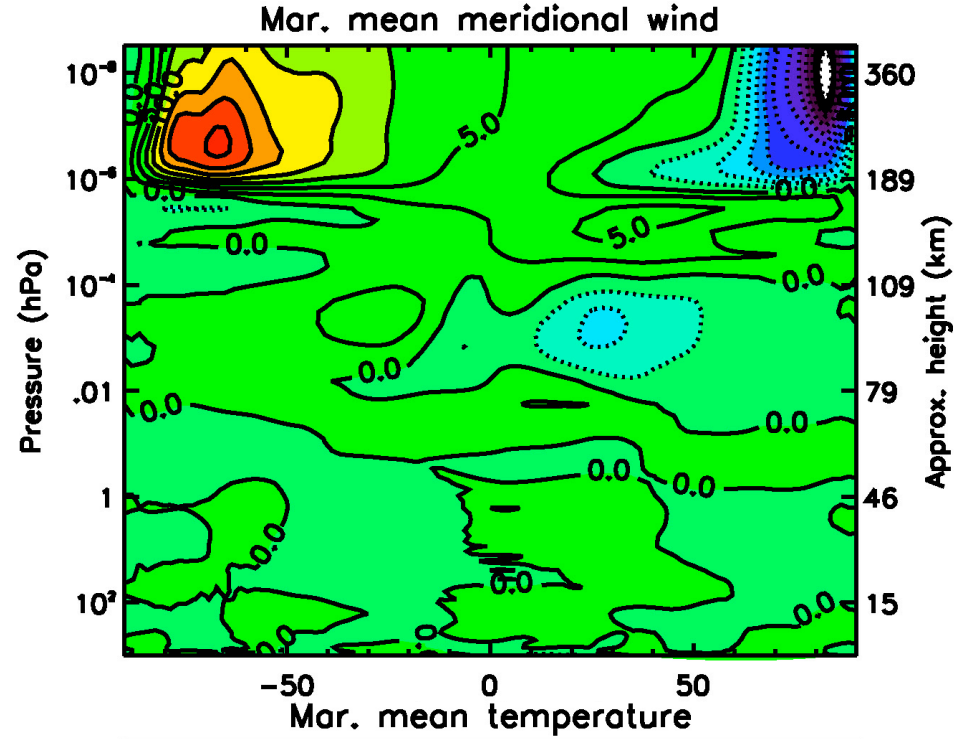
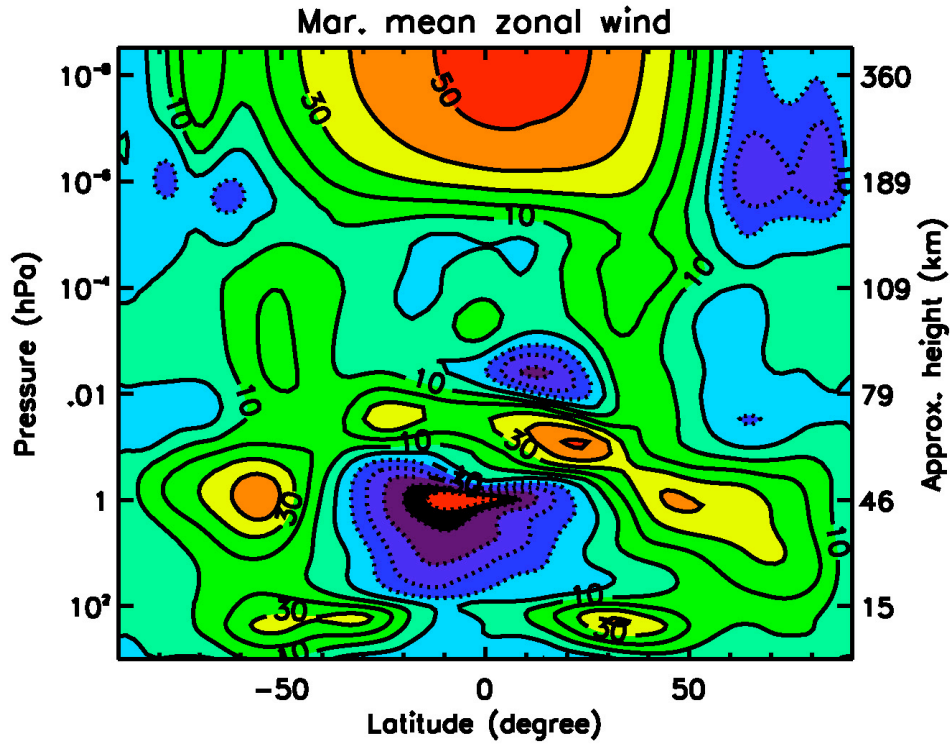
6c





WACCM: Winds and Temperature (December)

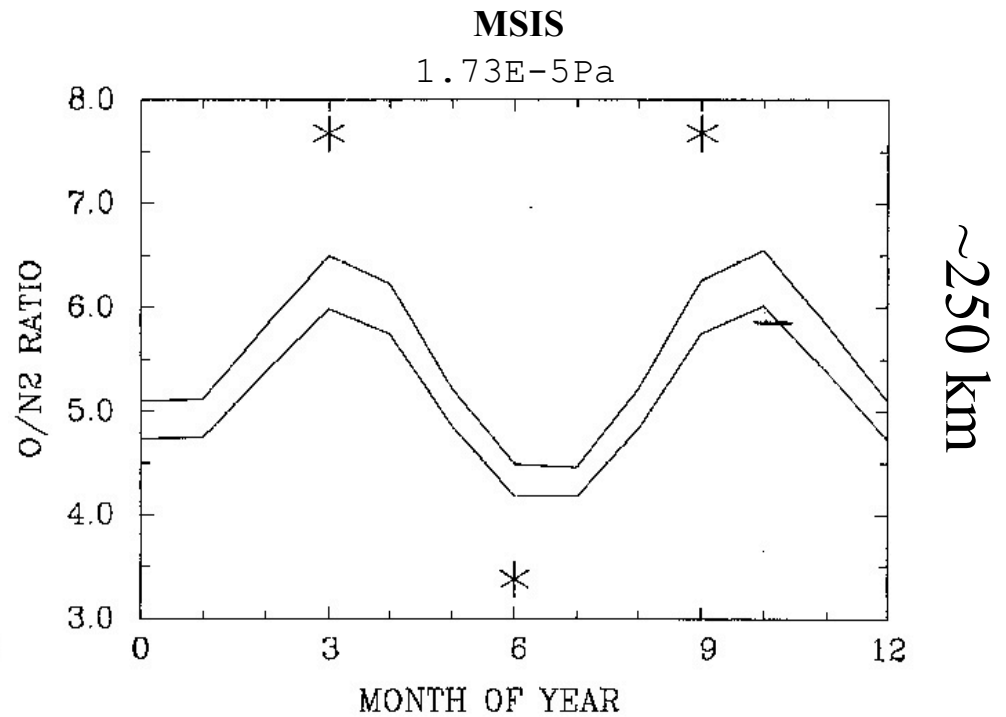
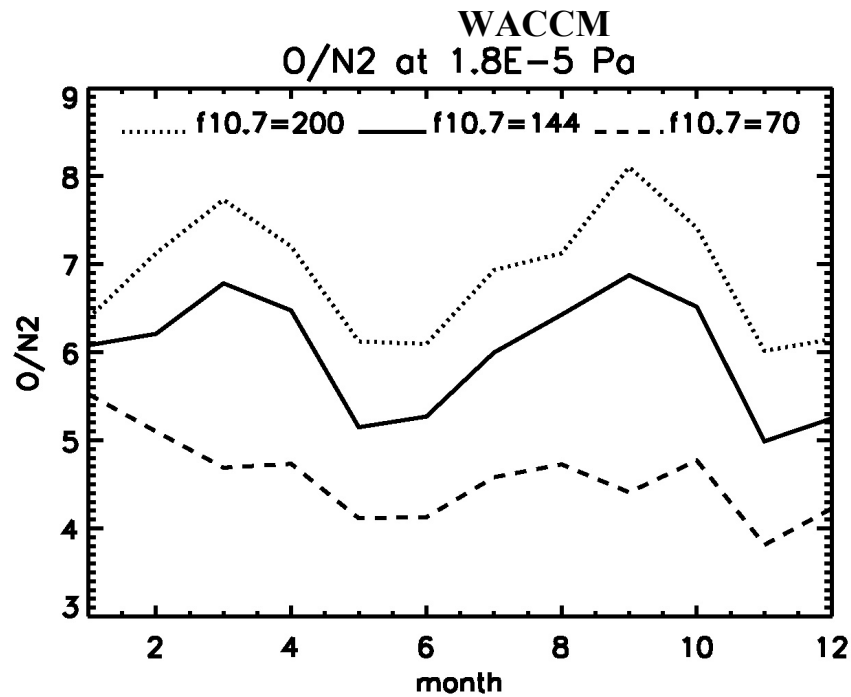


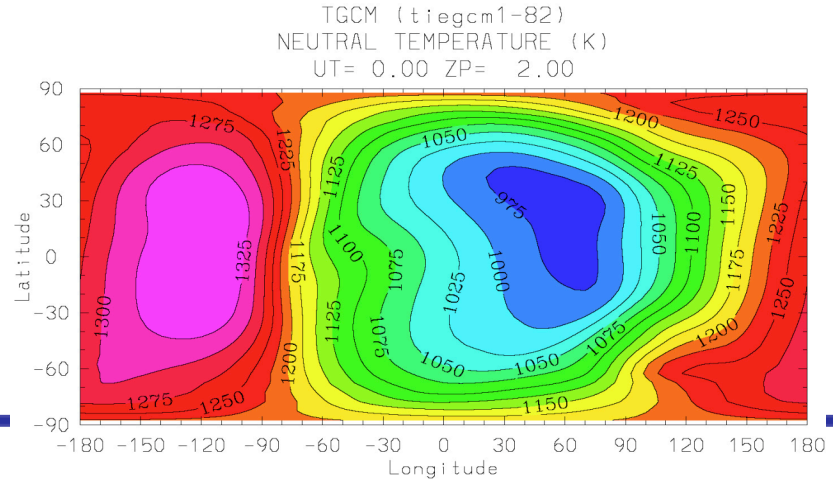
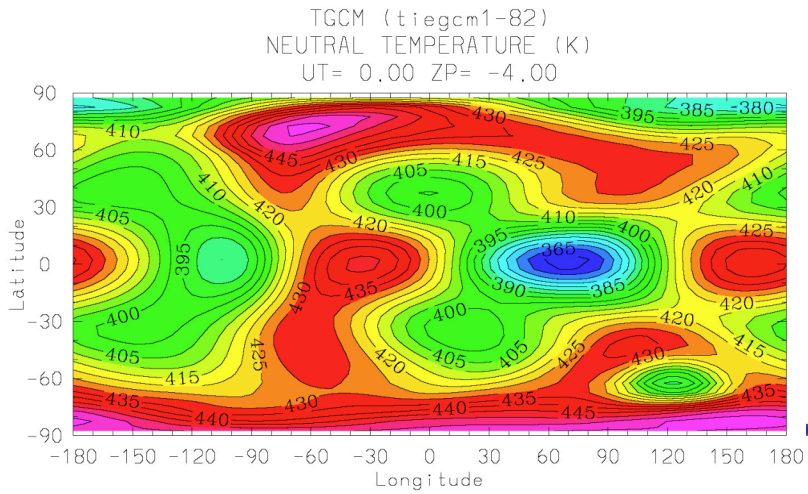
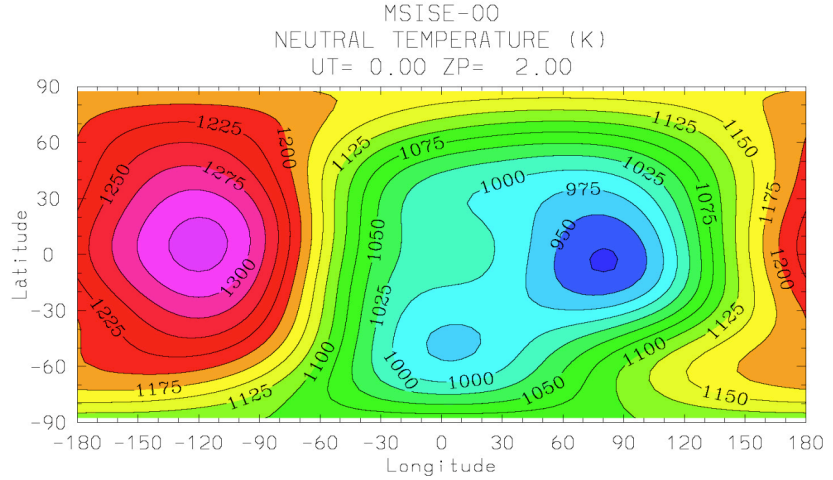
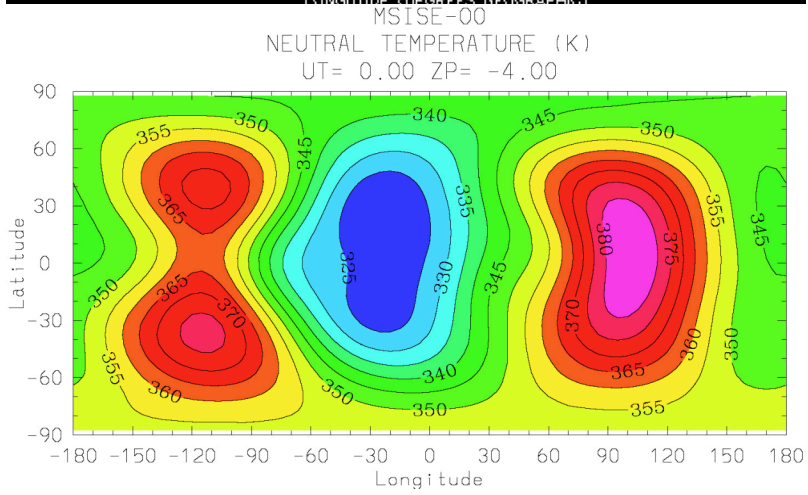
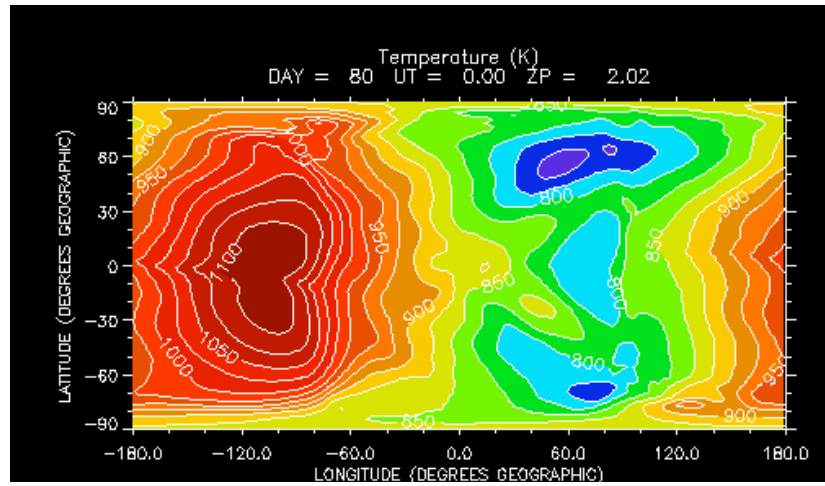
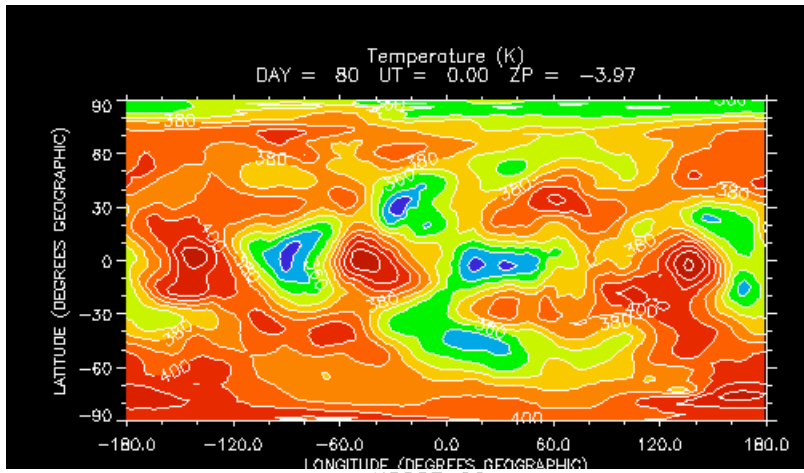


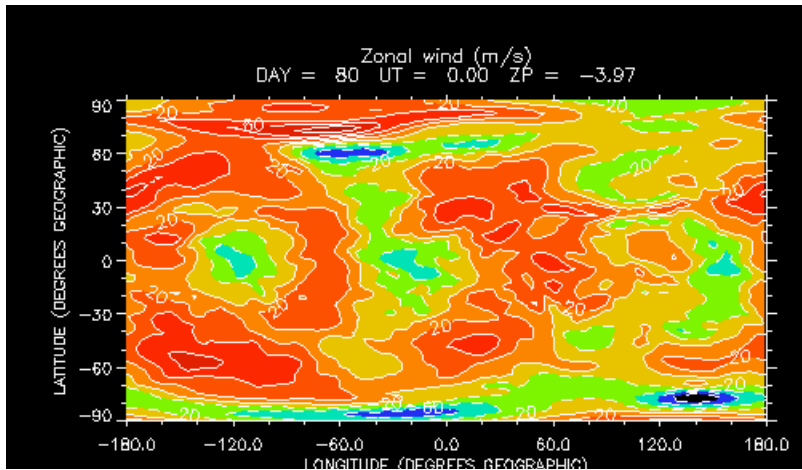
WACCM: Winds and Temperature (March)



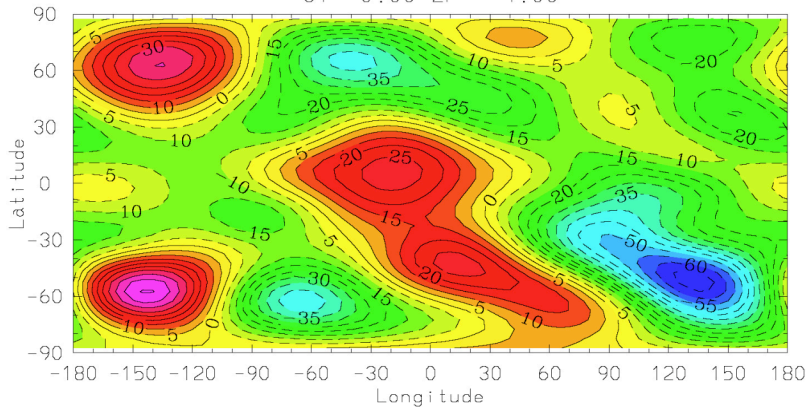
Thermosphere Semi-annual Variation



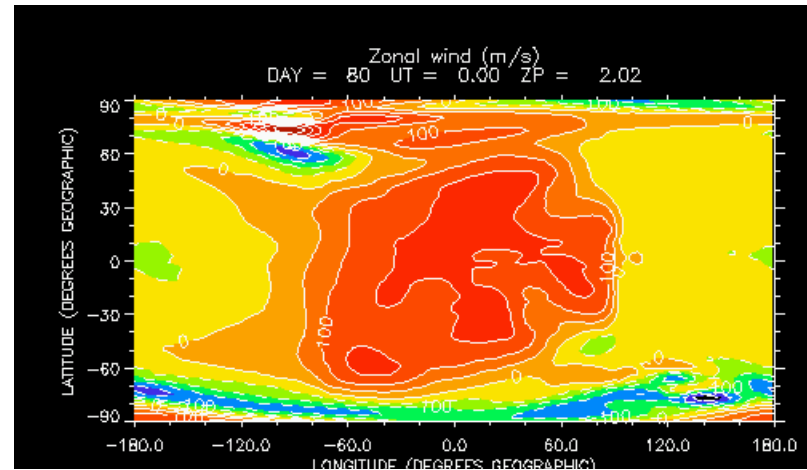
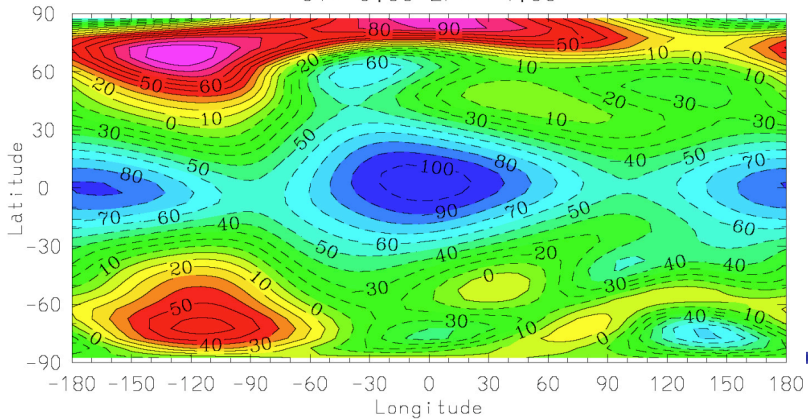




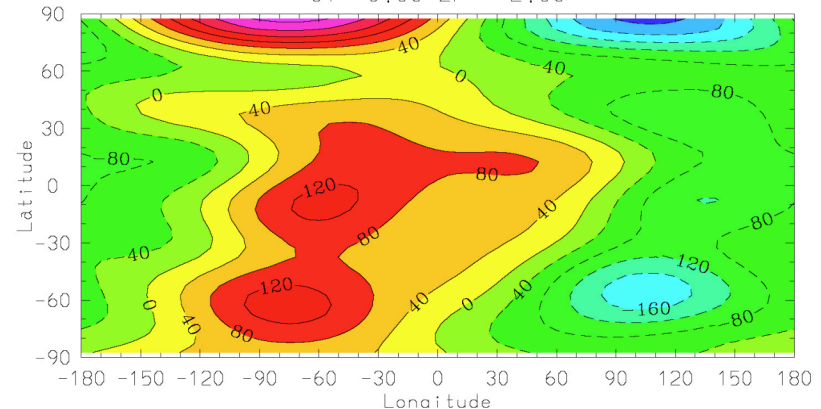
NEUTRAL ZONAL WIND (+EAST) (m/s)
UT= 0.00 ZP= -4.00



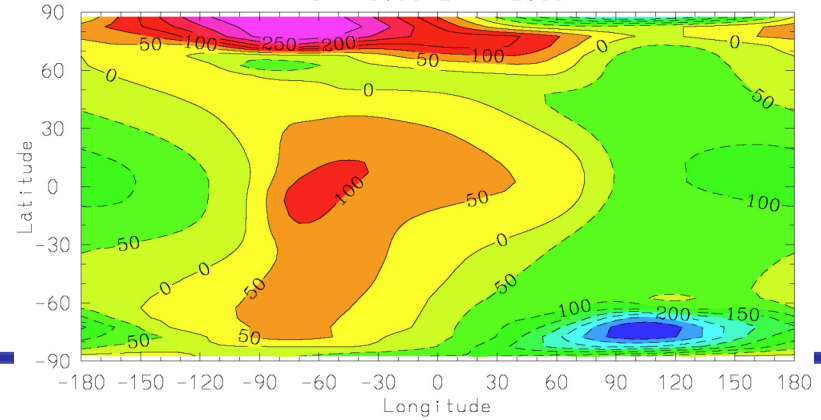
TGCM (tiegcm1-82)
NEUTRAL ZONAL WIND (+EAST) (m/s)
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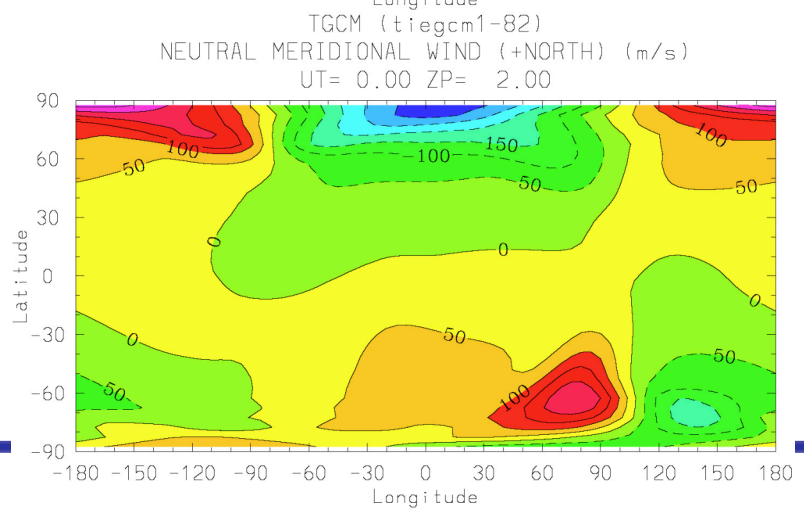
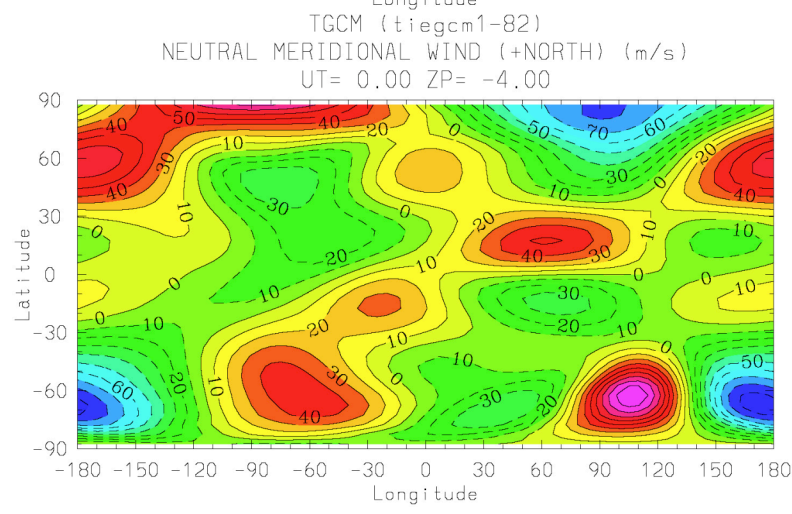
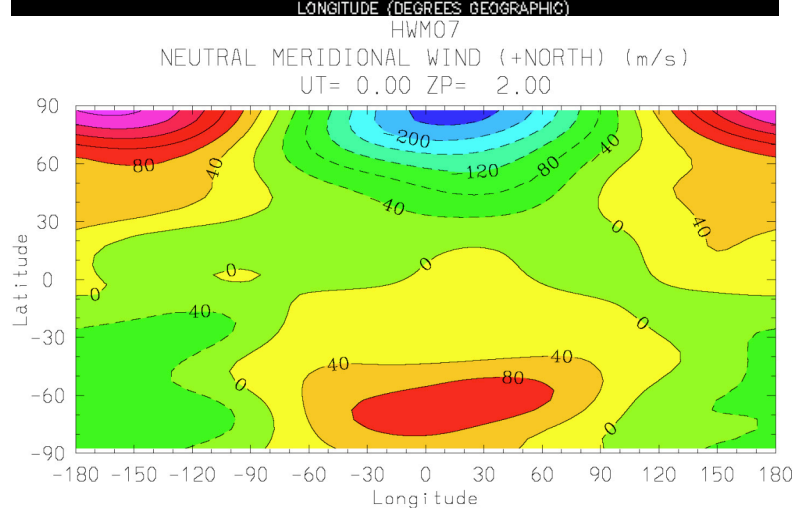
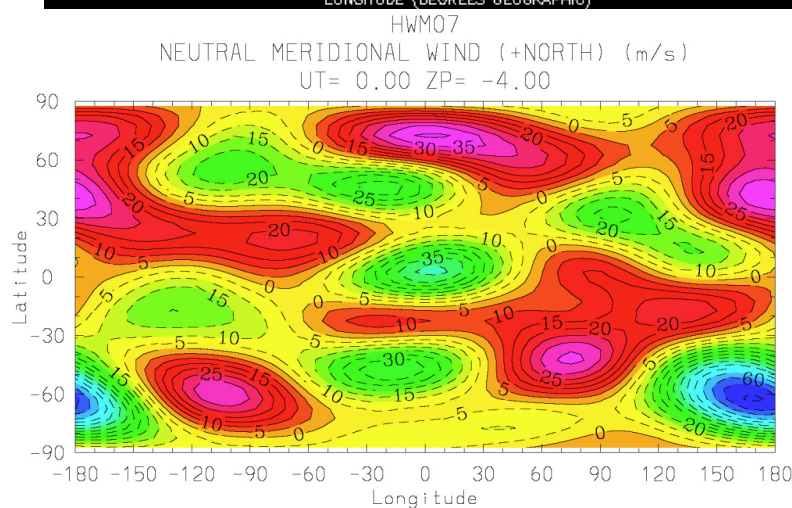
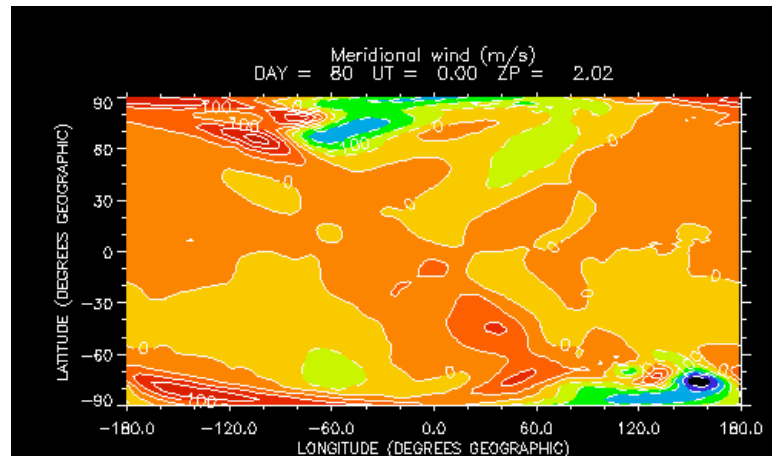
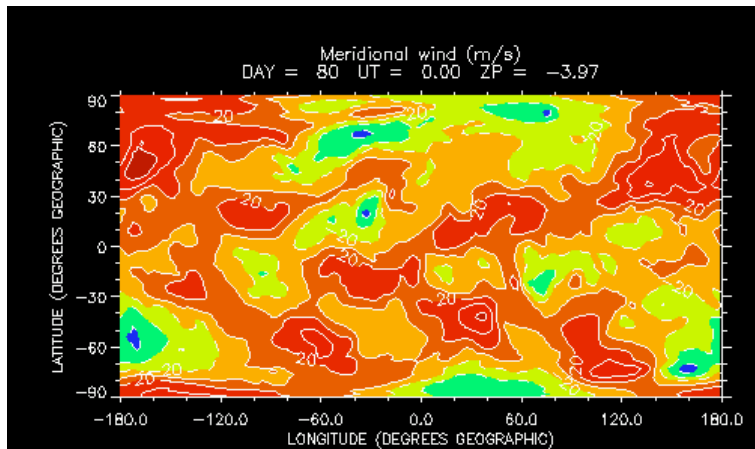


NEUTRAL ZONAL WIND (+EAST) (m/s)
UT= 0.00 ZP= 2.00

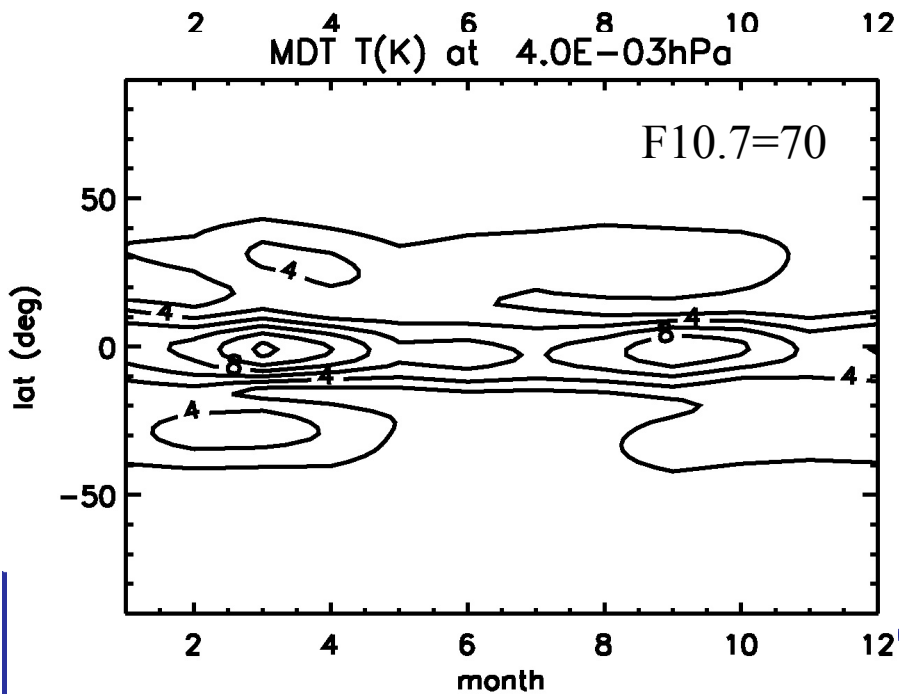
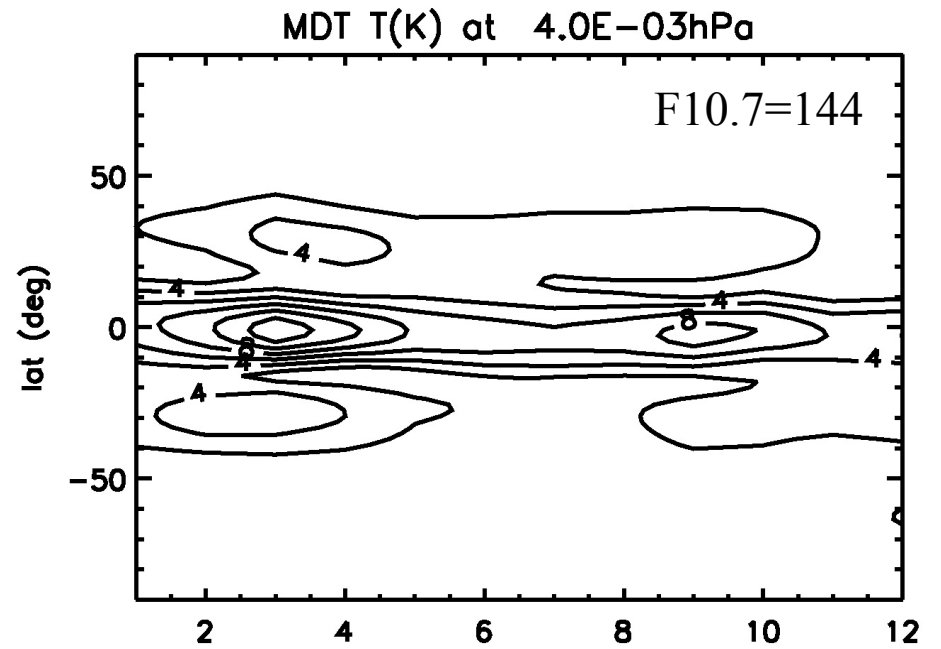
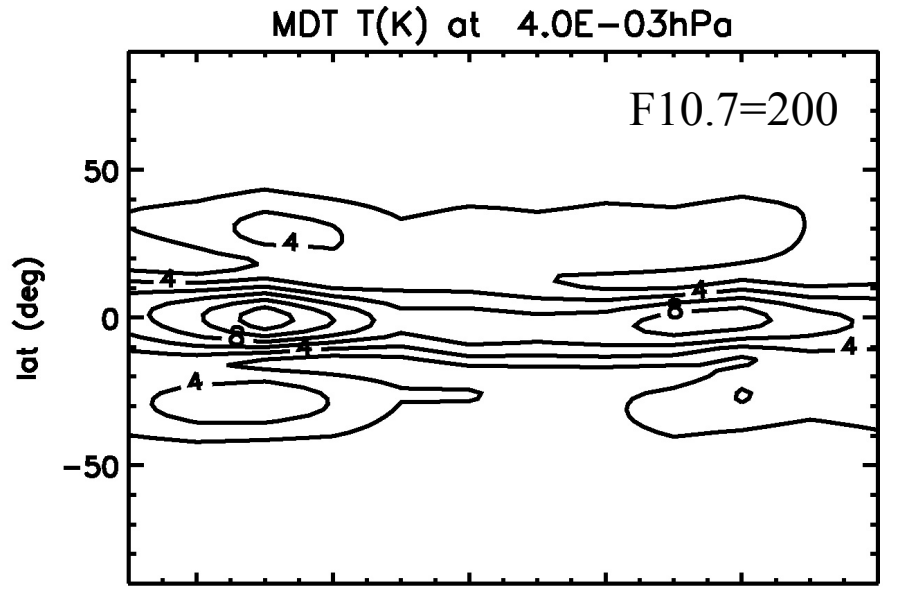


TGCM (tiegcm1-82)
NEUTRAL ZONAL WIND (+EAST) (m/s)
UT= 0.00 ZP= 2.00

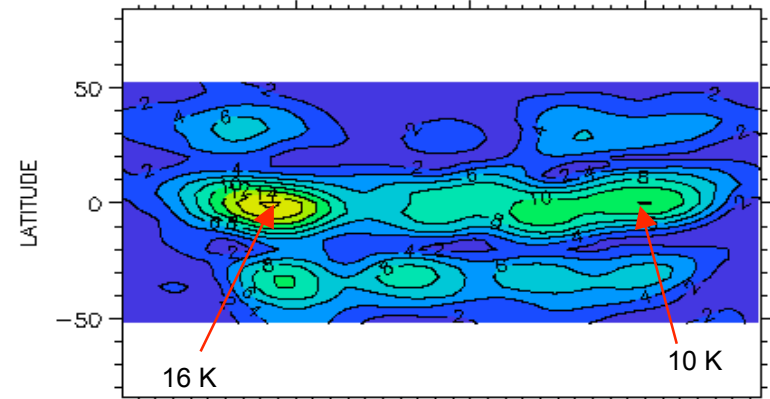




Migrating Diurnal Tide: Temperature



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

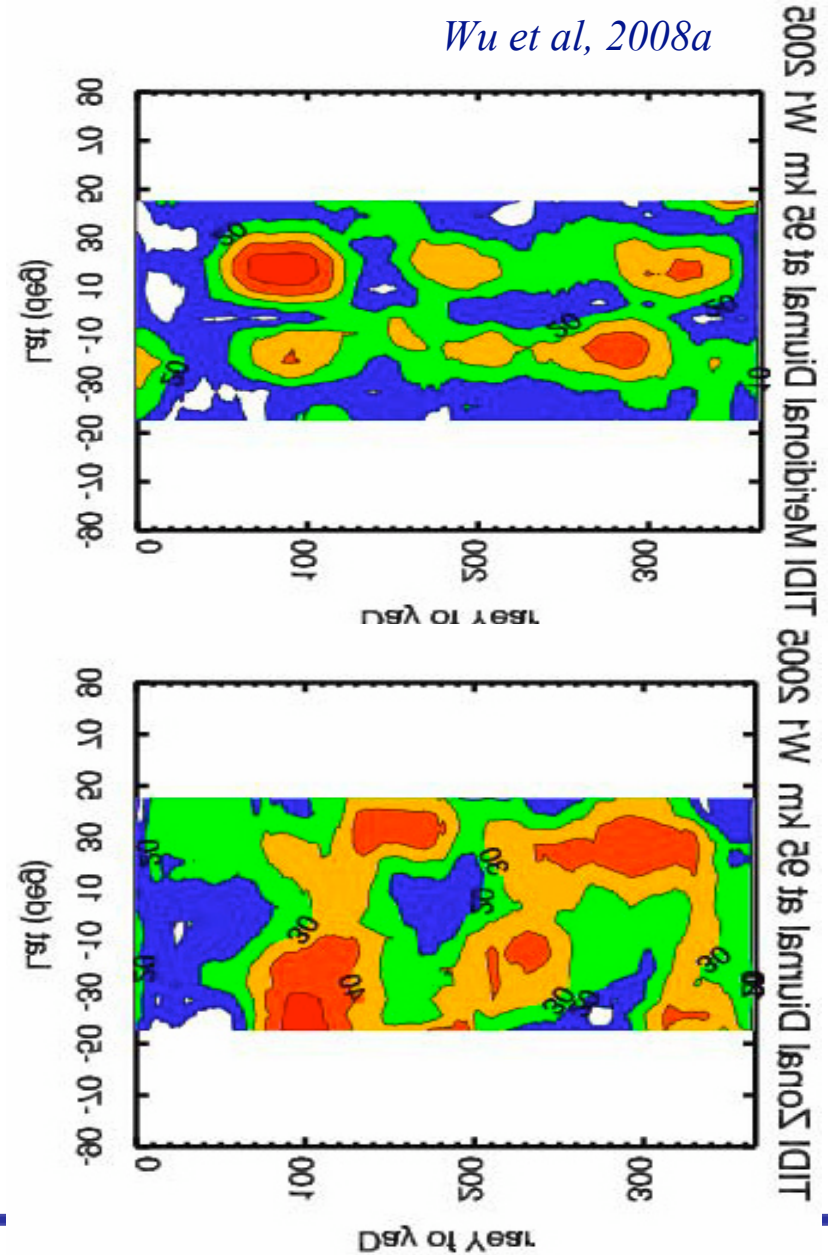
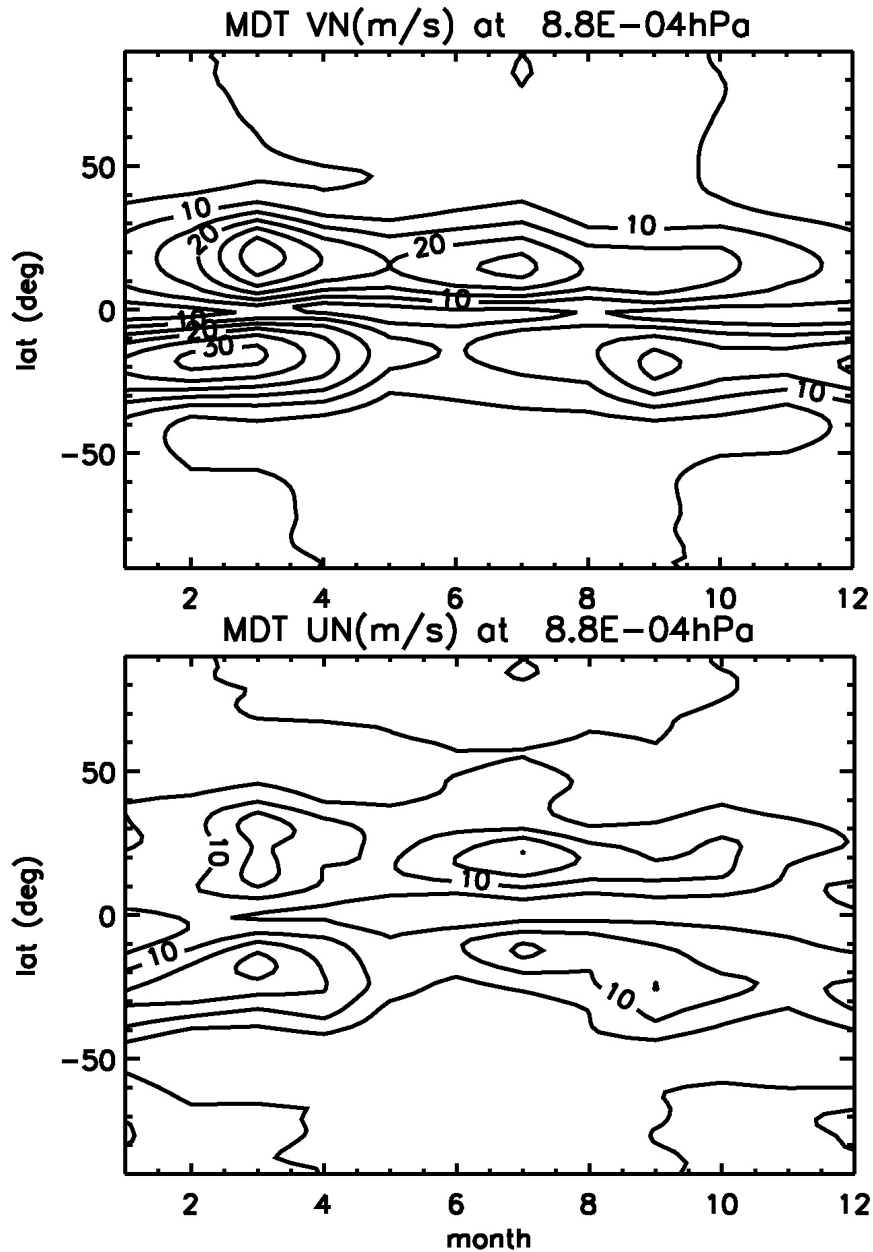


-2.0 2.3 6.7 11.0 15.3 19.7 24.0

Garcia and Lieberman, 2007

Migrating Diurnal Tide: Horizontal Winds

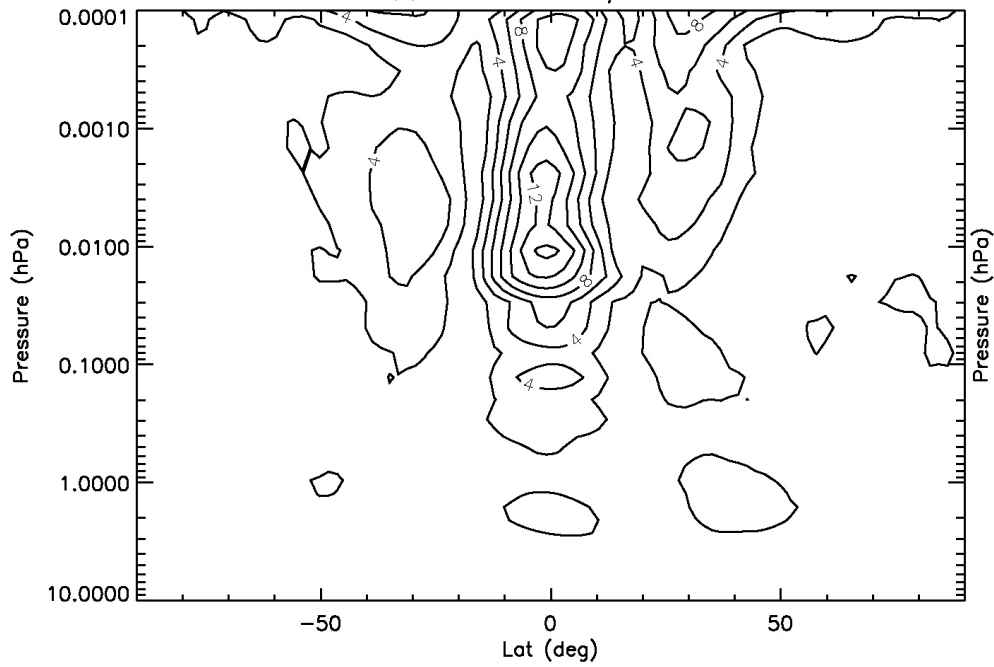
Wu et al, 2008a



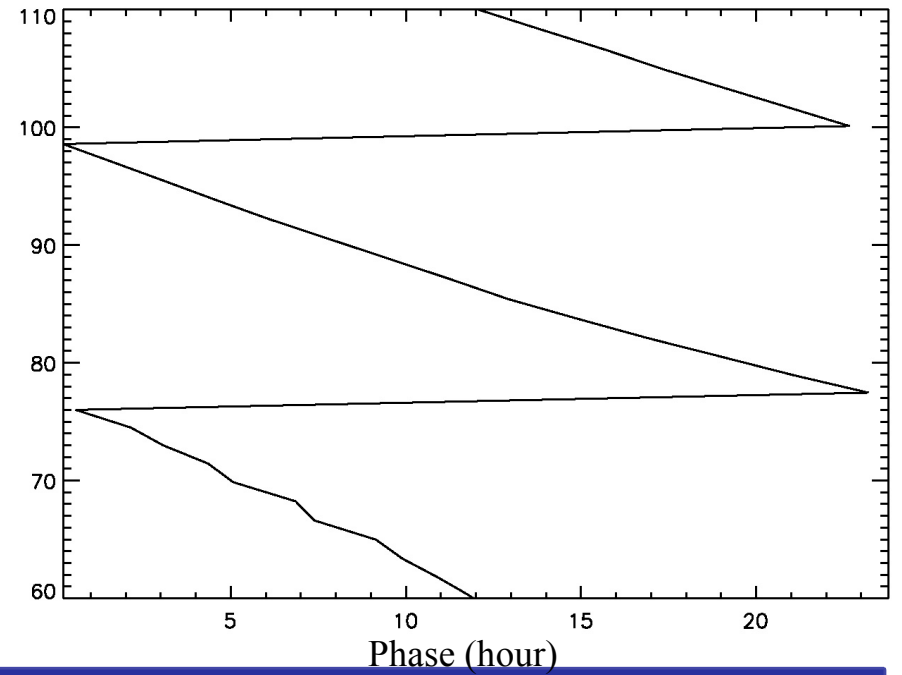
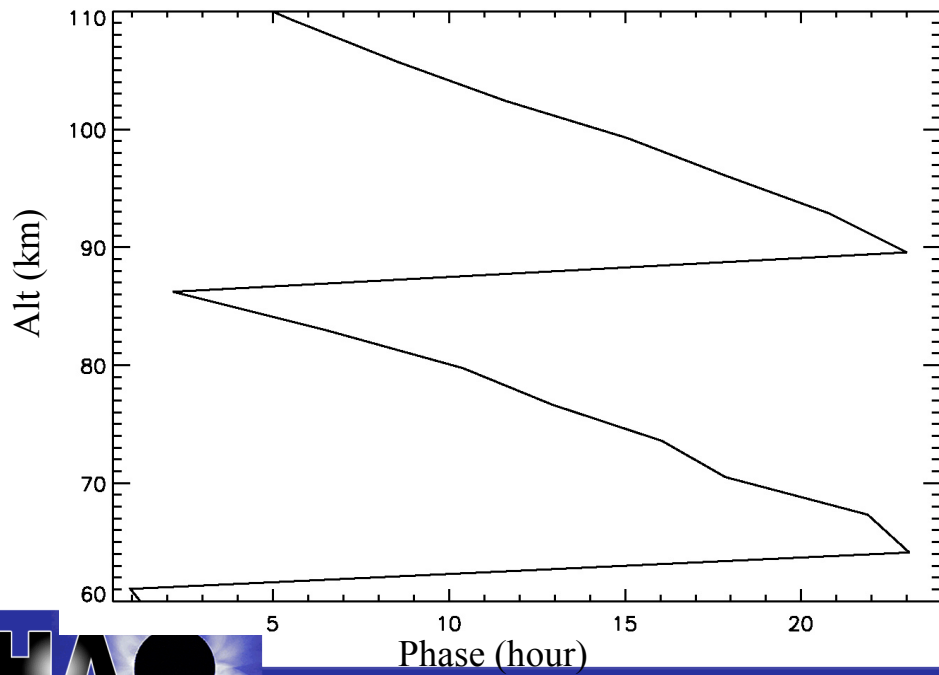
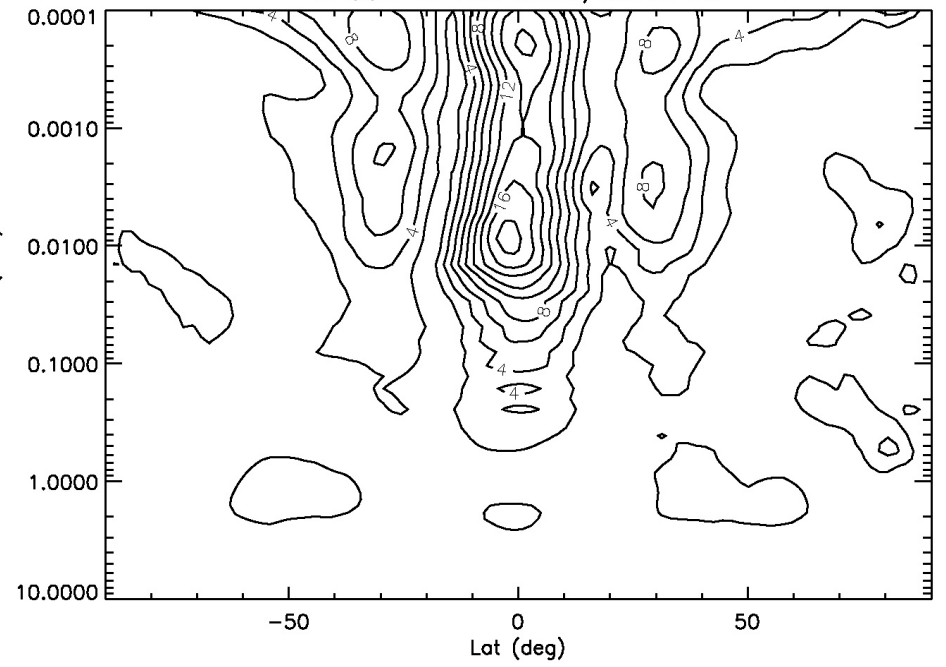
MDT VN(m/s) at $8.8E-04\text{hPa}$

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

WACCM-X 81 levels, March 21



WACCM-X 125 levels, March 21

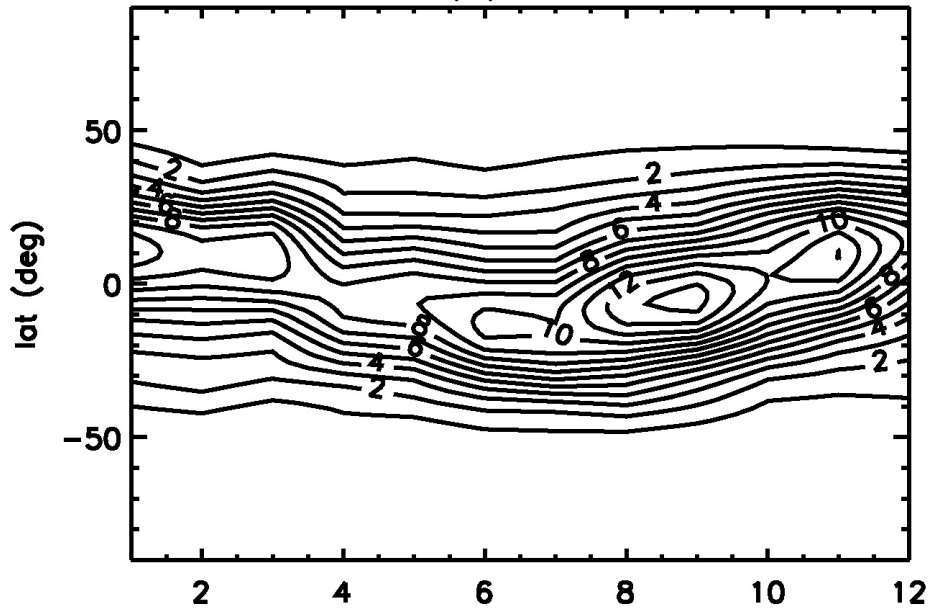


Phase (hour)

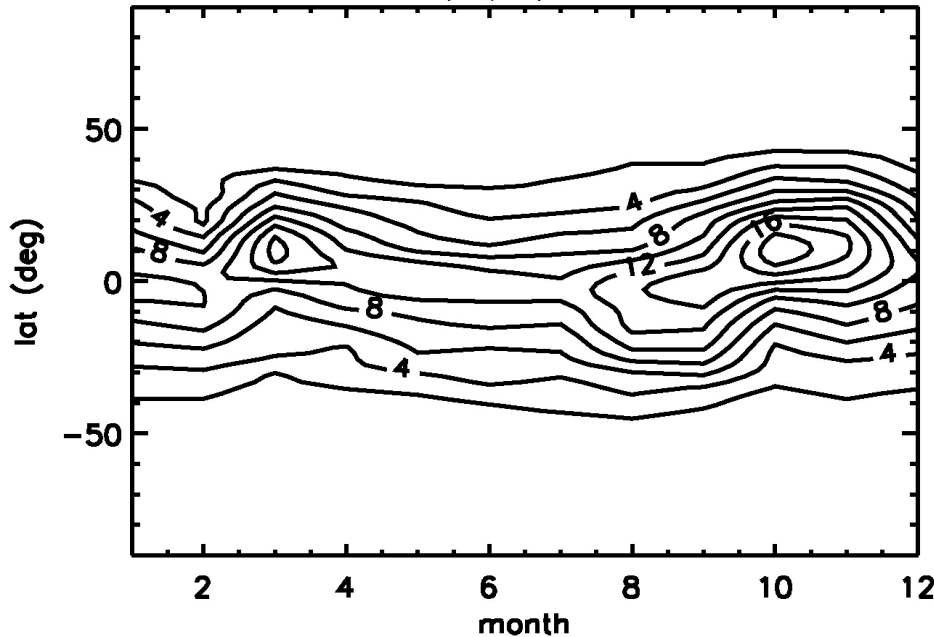
Phase (hour)

Nonmigrating: Diurnal E3

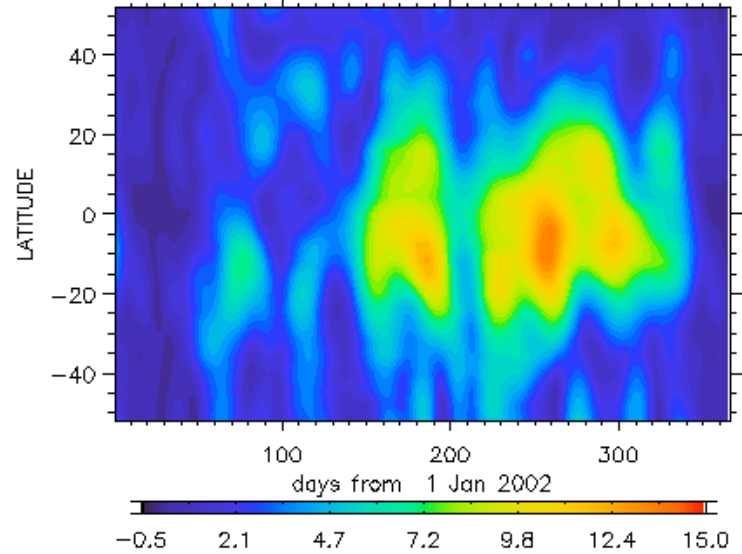
E3 Diurnal T(K) at $1.2E-04\text{hPa}$



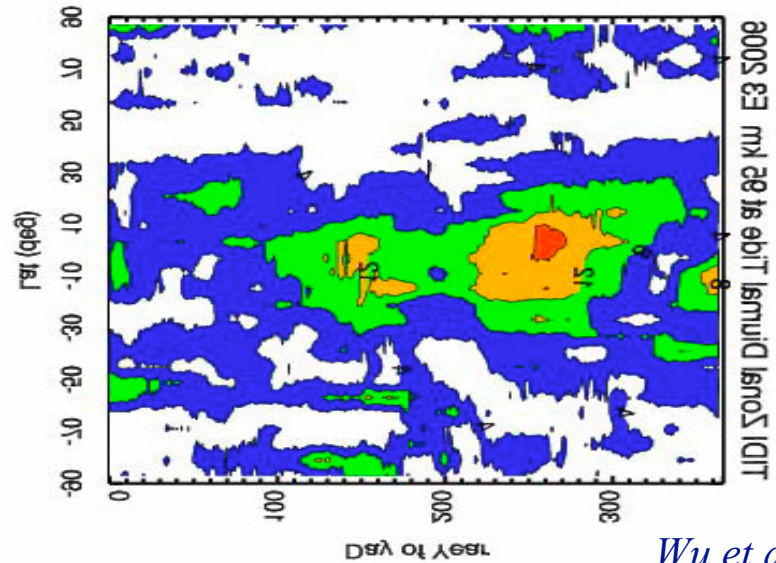
E3 Diurnal UN(m/s) at $8.8E-04\text{hPa}$



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

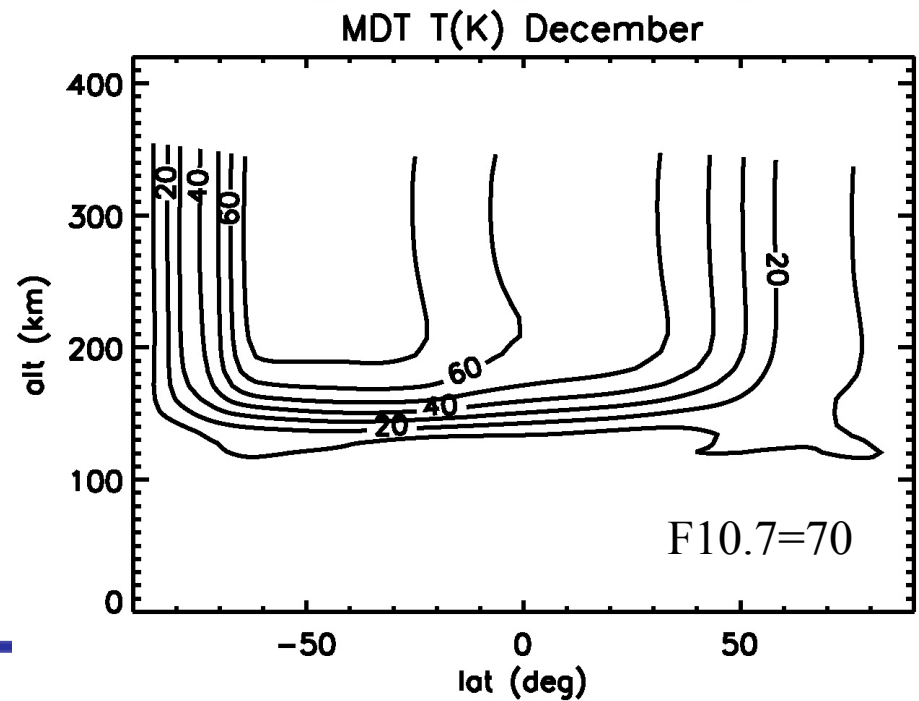
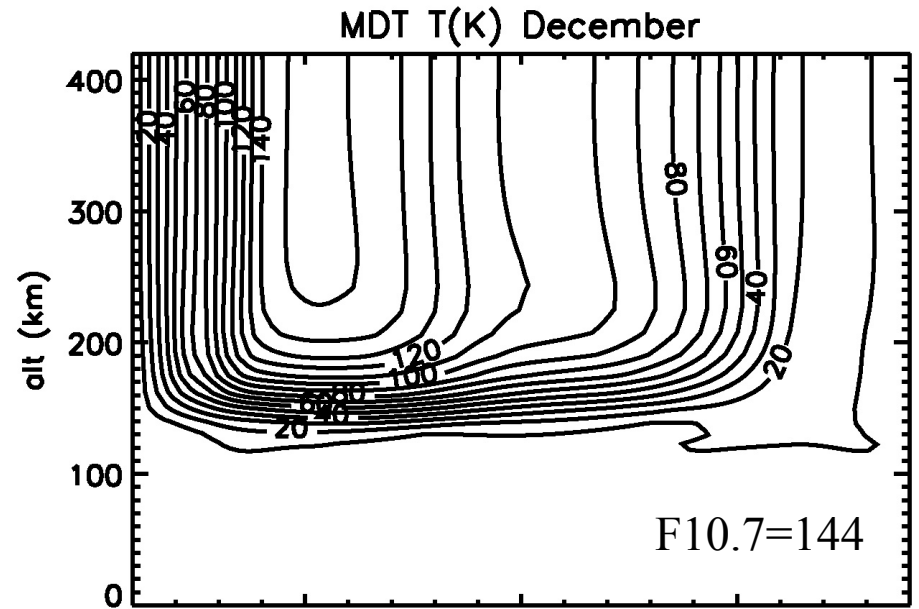
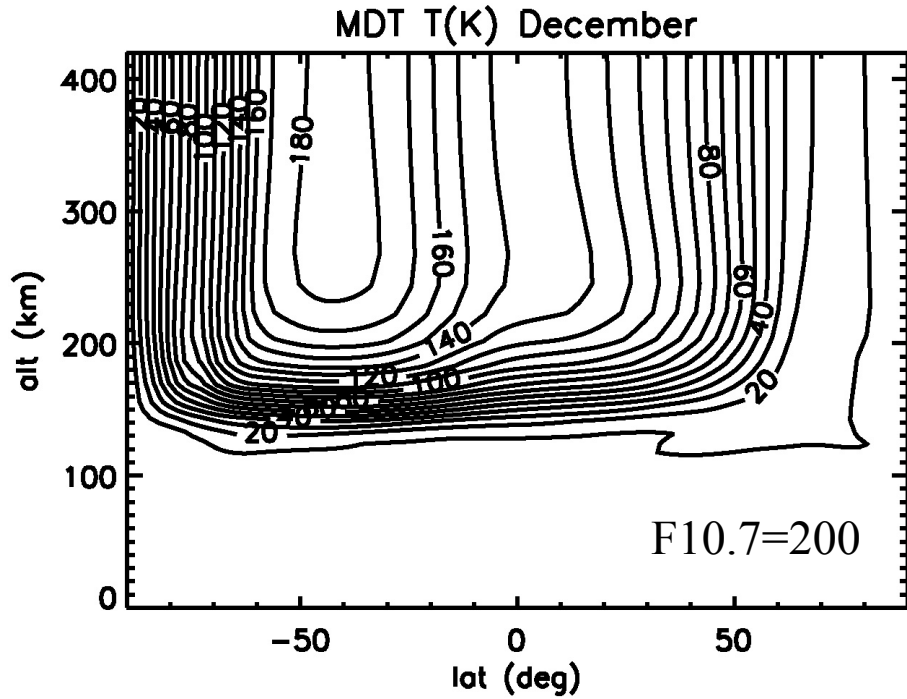


Garcia and Lieberman, 2007

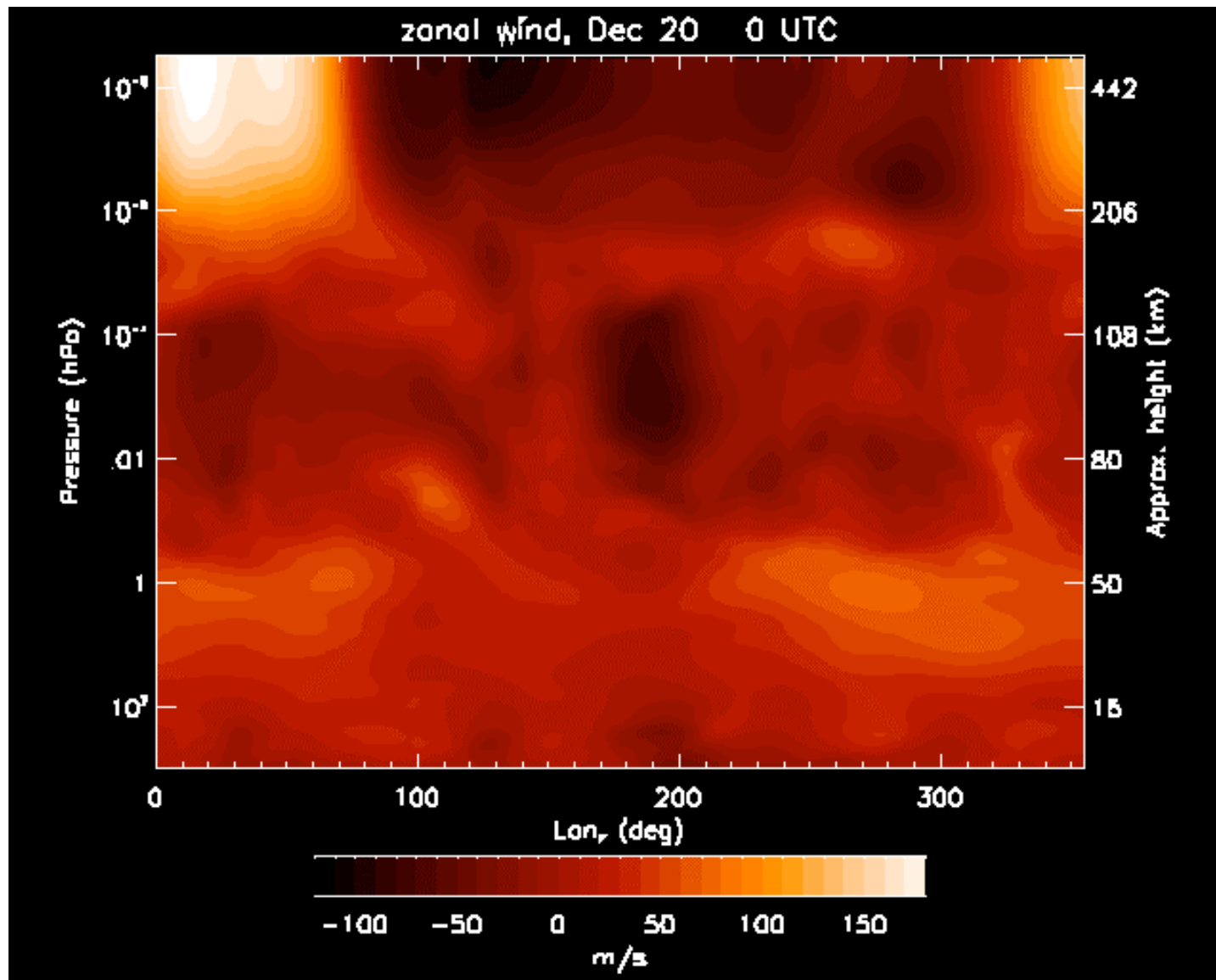


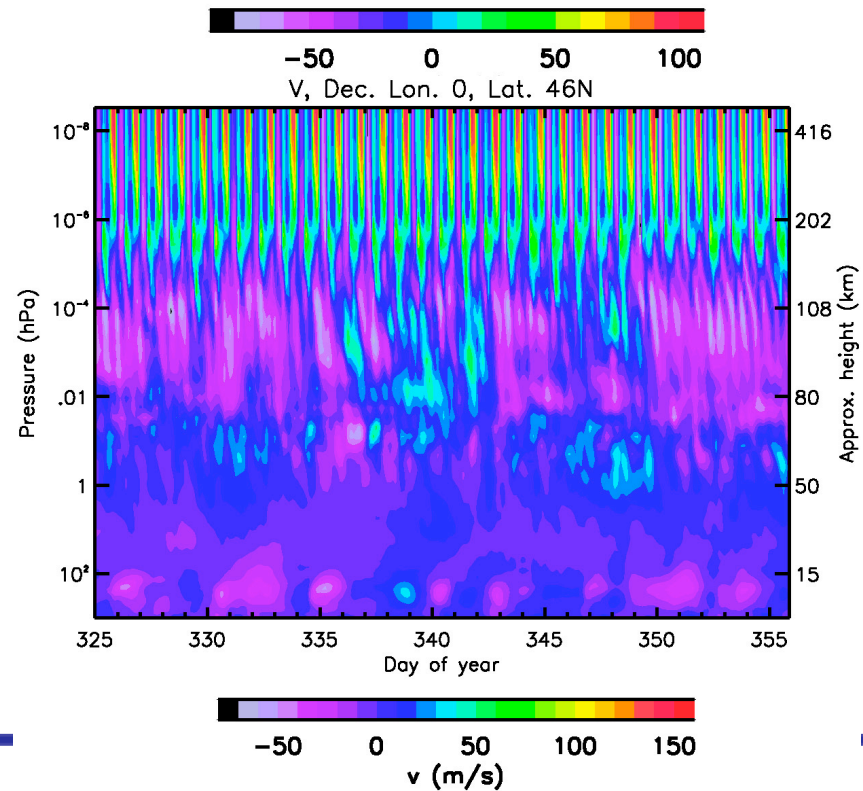
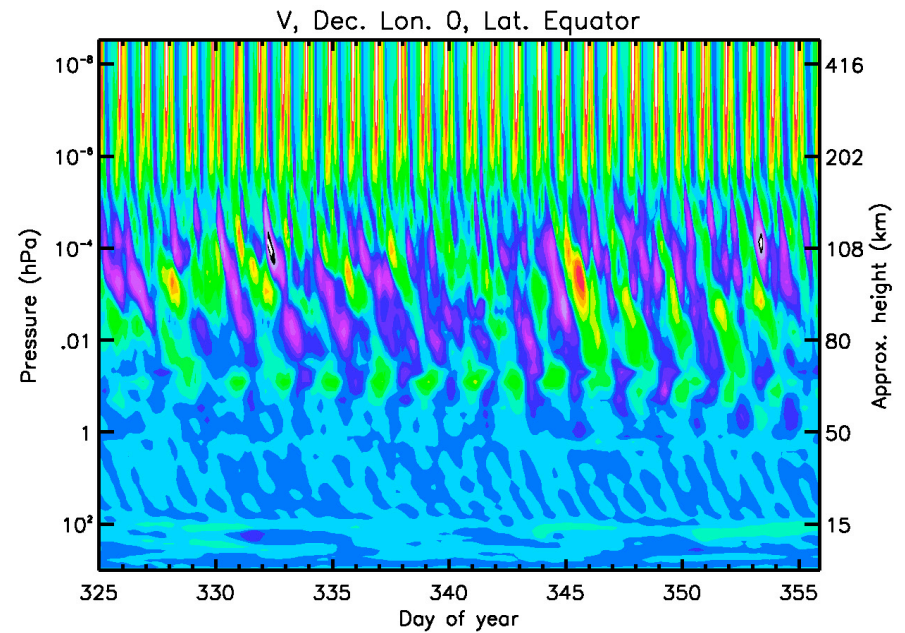
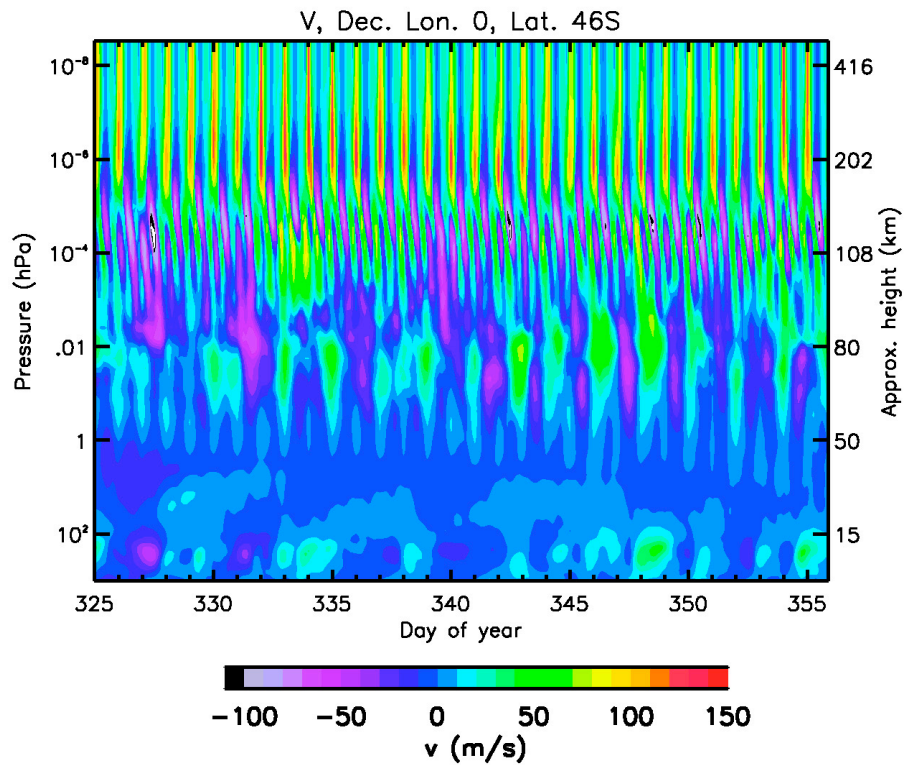
Wu et al, 2008b

Thermosphere Tides

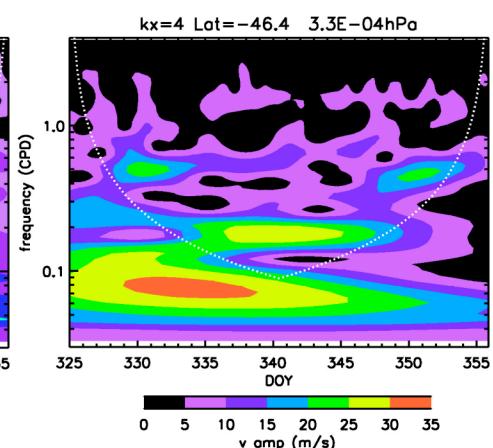
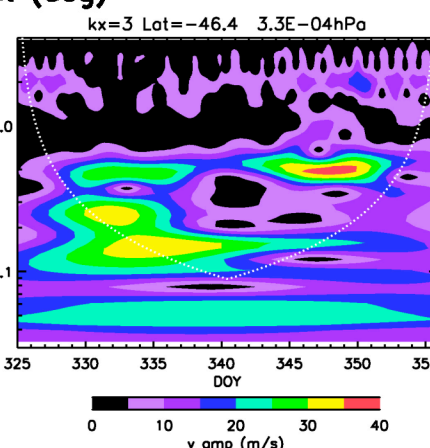
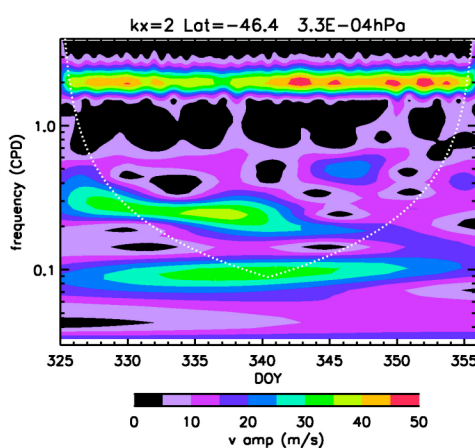
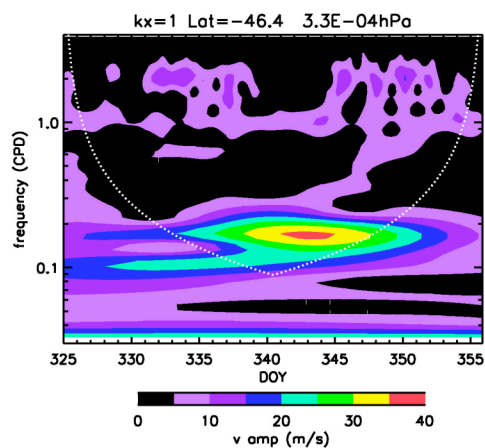
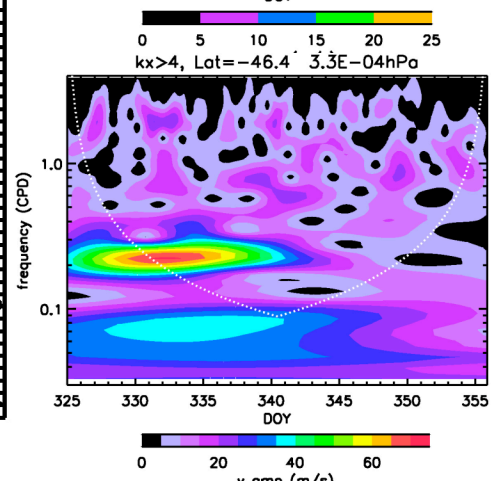
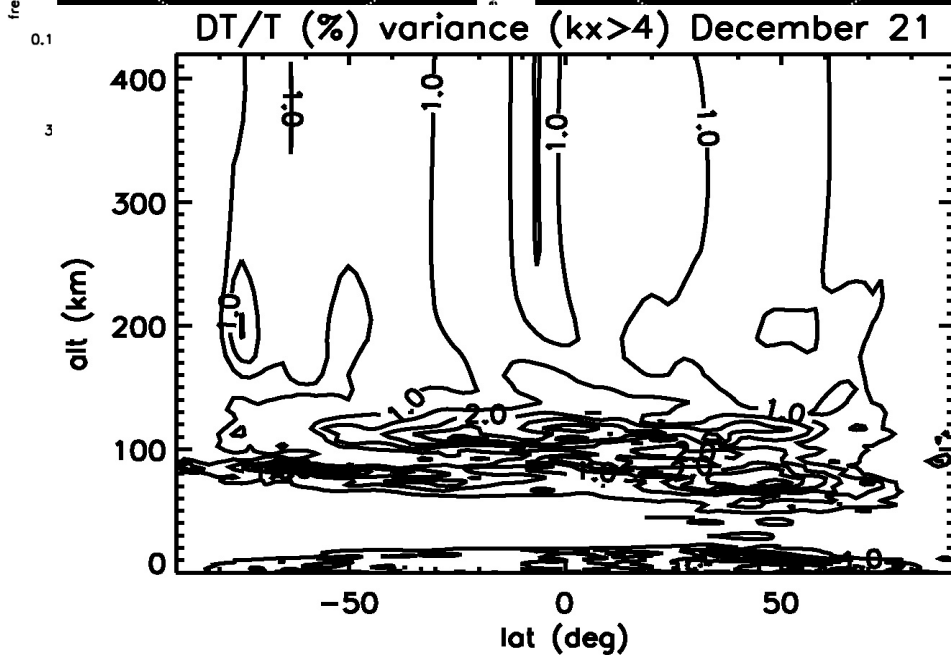
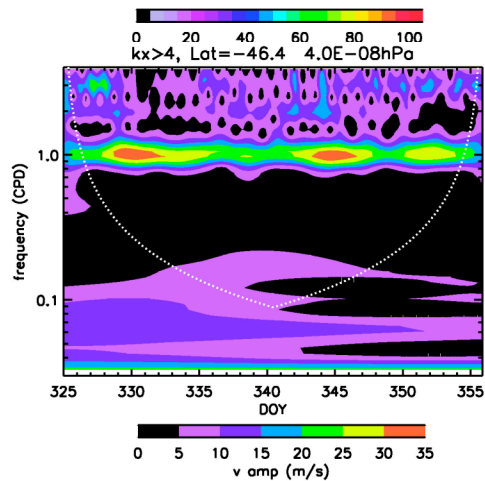
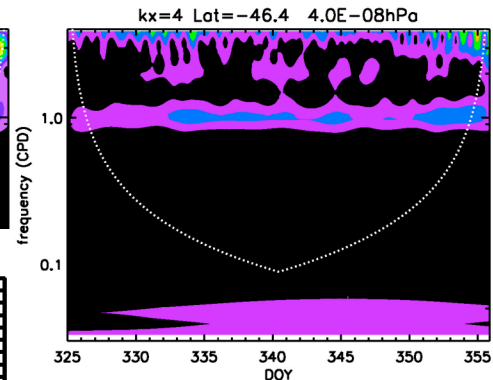
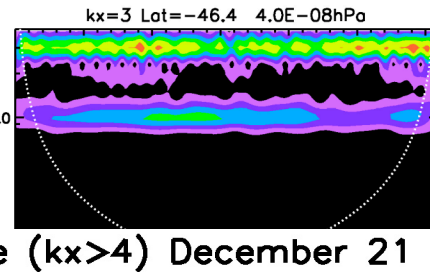
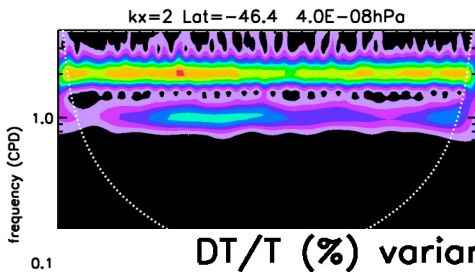
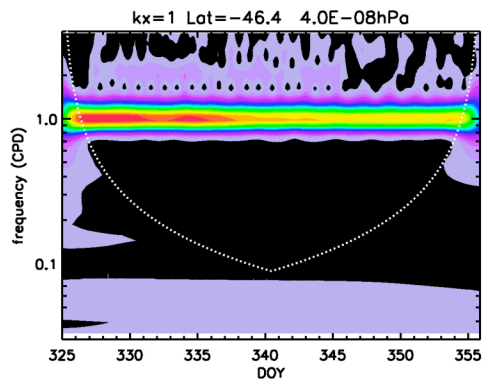


Short-term Variability





Short-term Variability and Latitudinal Dependence



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).
 - Short-term variability:
 - Most variable between 60-140 km.
 - Thermospheric tide variable even with constant solar forcing.



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.

