Simulation of the Atmospheric Tides with the Whole Atmosphere Community Climate Model (WACCM)

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Outline

1. Model
2. Simulations
3. Comparisons with observations
4. Conclusions

Whole Atmosphere Community Climate Model Version 3 (WACCM3)

Model Framework	Dynamics	Tracer Advection	Resolution	Chemistry	Other Processes
Extension of the NCAR Community Atmosphere Model version 3 (CAM3) Based upon CAM3.5.48	Finite Volume Dynamical Core (Lin, 2004) Fully-interactive with chemistry, i.e., consistent with model-derived, radiatively active gases: O_3, CO_2, CH_4, N_2O, H_2O, CFC11, CFC12, O_2, NO	Flux-form Finite Volume (Lin, 2004)	Horizontal: 1.9° x 2.5° (lat x lon) Vertical: 66 levels 0-140km • < 1.0km in UTLS • 1-2 km in stratosphere • ~3 km in MLT	Middle Atmosphere Mechanism • 57 Species including Ox, HOx, NOx, BrOx, and ClOx • No NMHCs • Includes het. chemistry on LBS, STS, NAT, ICE • E-region Ion Chemistry	• GW Param.: convection-, frontal-, and orographically-generated • Molecular Diffusion: Banks and Kockarts, 1973 • Auroral processes, including ion drag, and Joule heating • Longwave, shortwave, and chemical potential heating

WACCM monthly mean tidal output

- **Extract diurnal and semidiurnal harmonics during run (sine and cosine Fourier coefficients)**
- **Currently applied to *u*, *v*, *T*, and P_S. Calculated and output once per month**
- **Post-processing**: migrating and non-migrating modes can be separated by FFT expansion in longitude of the tidal coefficients

Example for the diurnal tide:

The diurnal tide for each month of output can be represented with two coefficients, C_{24} and S_{24}, at each gridpoint (x, y, z):

$$T_d = C_{24} \cdot \cos\left(\frac{2\pi t}{24}\right) + S_{24} \cdot \sin\left(\frac{2\pi t}{24}\right)$$

***t* = local time (hr)**

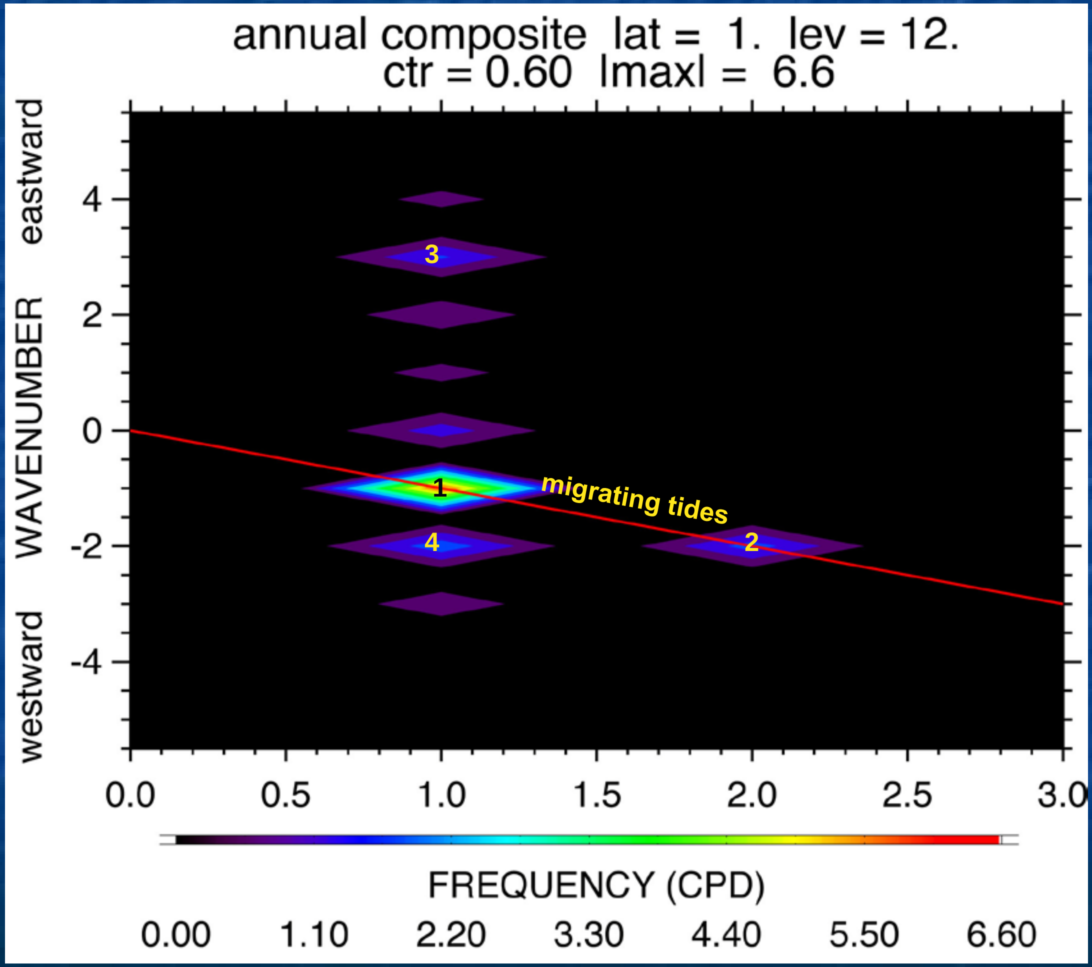
During the model run, calculate C_{24} and S_{24} by accumulating the following sums at each time step:

$$C_{24} = \frac{2}{N}\sum_1^N T(t_n)\cos\left(\frac{2\pi t_n}{24}\right)$$

$$S_{24} = \frac{2}{N}\sum_1^N T(t_n)\sin\left(\frac{2\pi t_n}{24}\right)$$

Which tides does the model produce?

Equatorial Spectrum at 12 sh (~85 km)



Discussed in this talk:

1: m=1 migrating diurnal

2. m=2 migrating semidiurnal

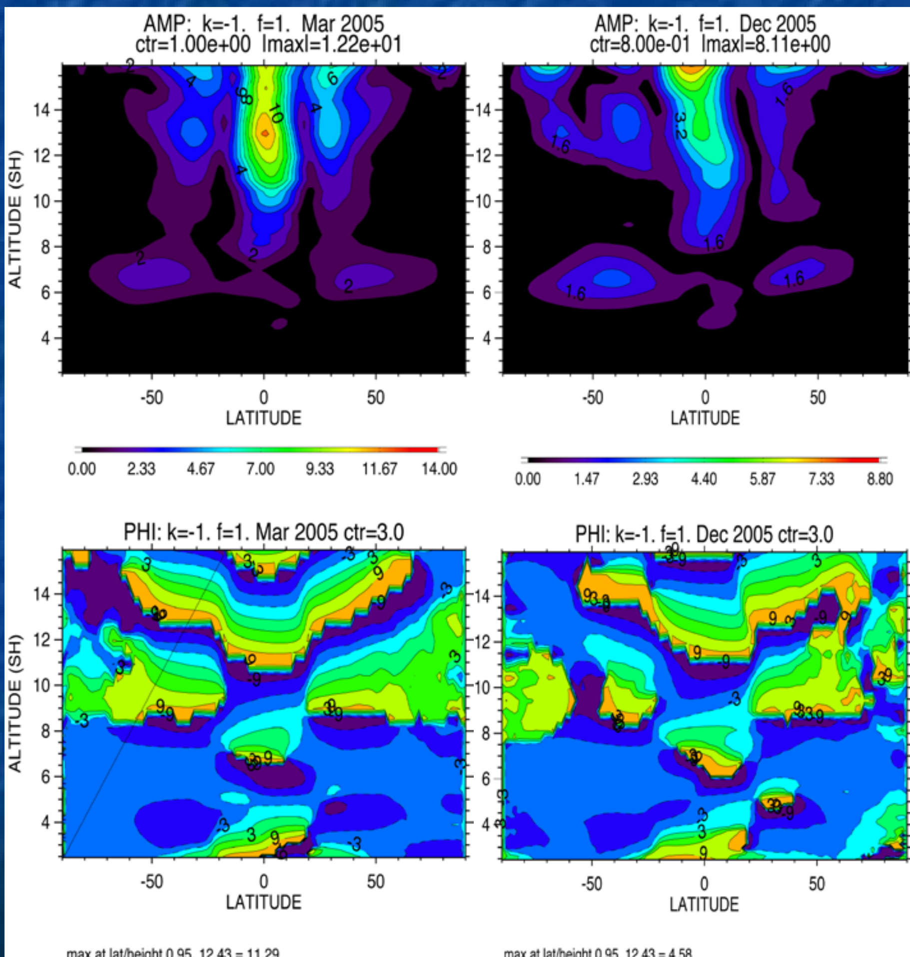
3. m=3 diurnal eastward

4. m=1 semidiurnal westward

Structure of modeled migrating tides

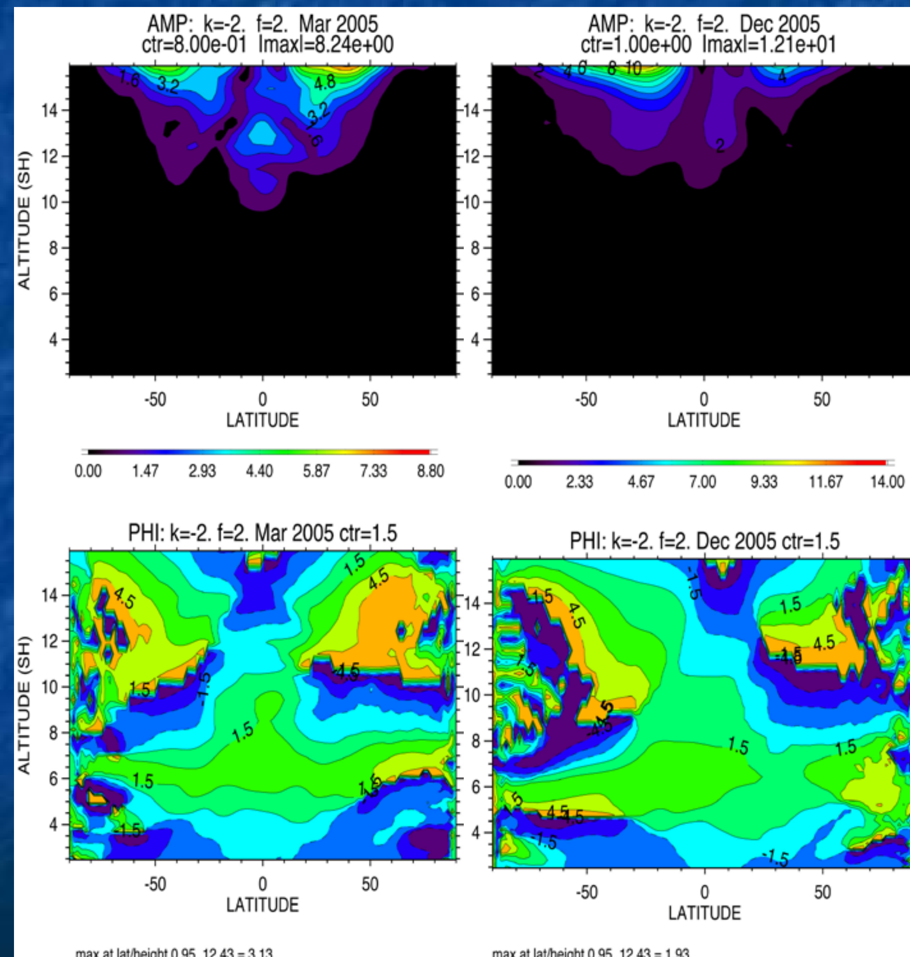
T k=1 diurnal westward

T k=1 march **T k=1 december**



T k=2 semidiurnal westward

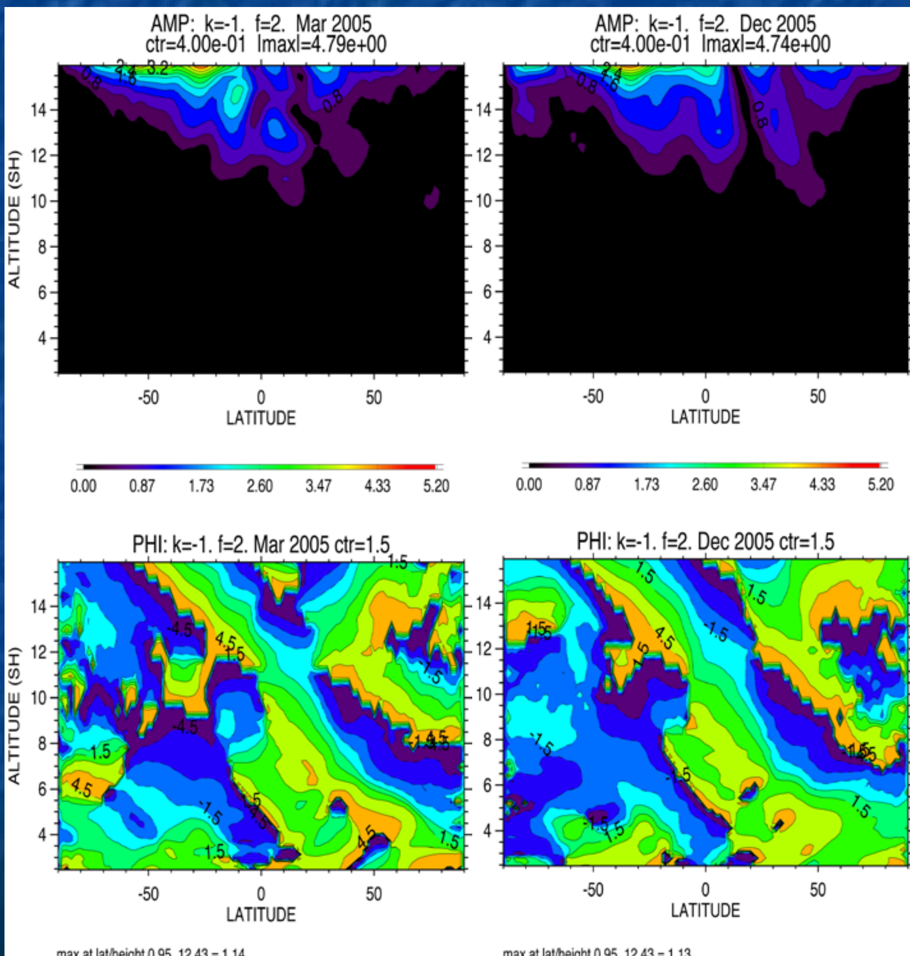
k=2 march **k=2 december**



Structure of two modeled “non-migrating” tides

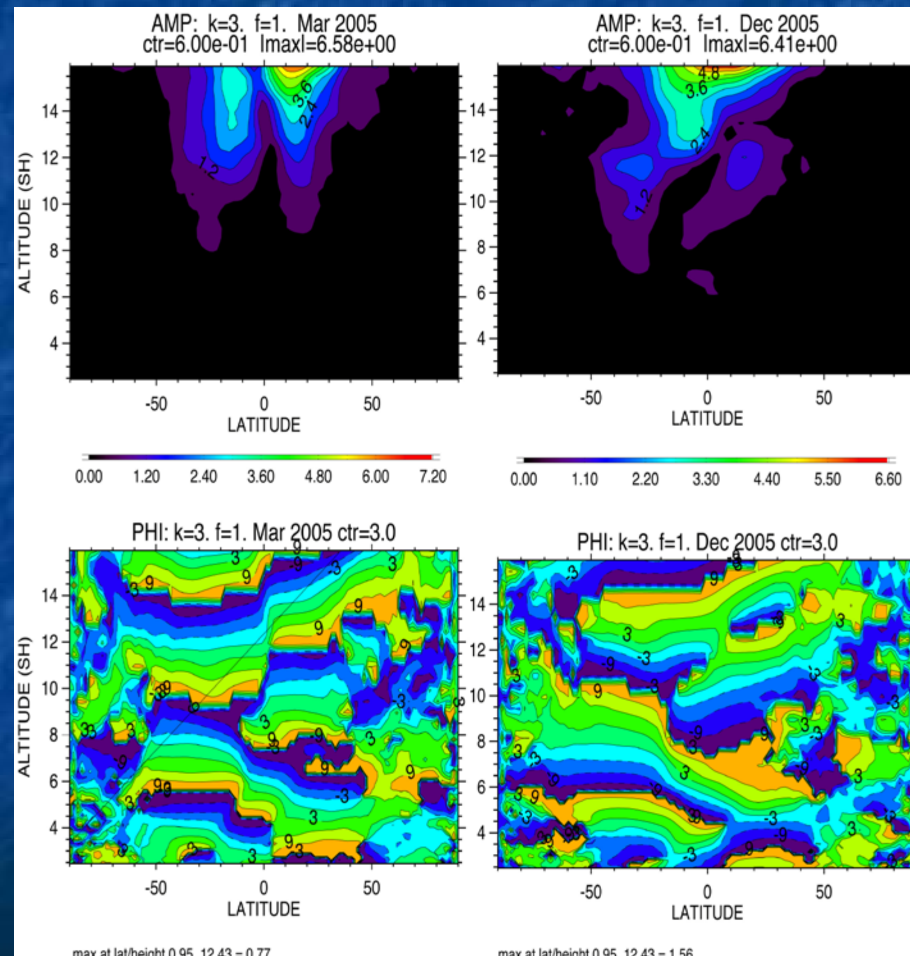
T k=1 semidiurnal westward

march **december**



T k=3 semidiurnal eastward

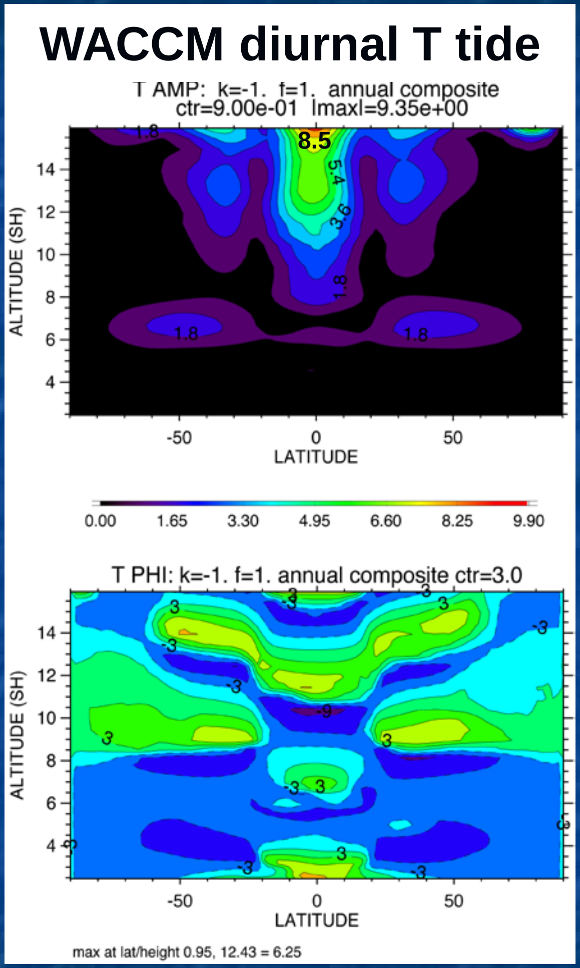
march **december**

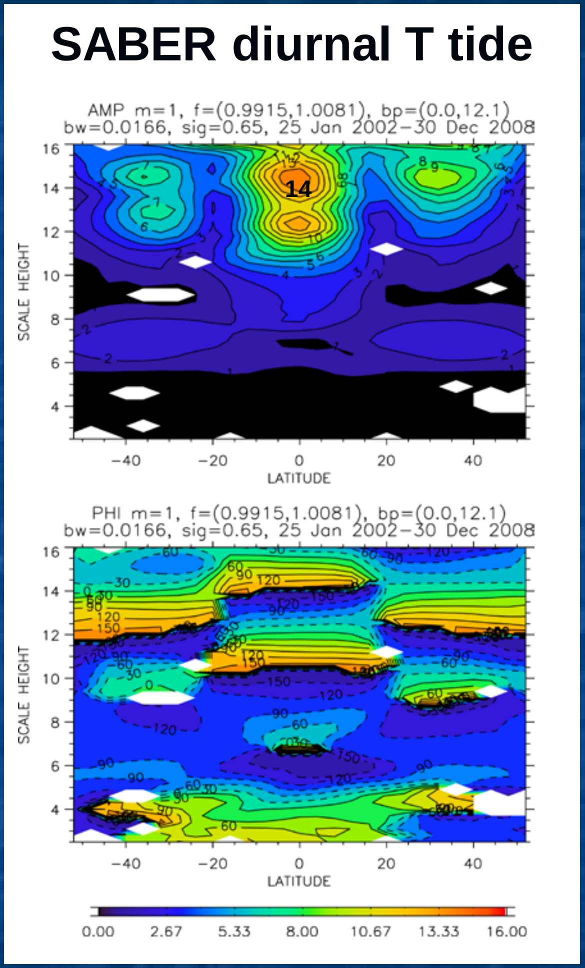


Comparisons with Recent Observations

1. Diurnal migrating T tide: WACCM vs. SABER

- WACCM diurnal tide obtained from monthly amplitude/phase over period of simulation (50 yr)
- Structure shown here is the time-mean over the entire simulation period

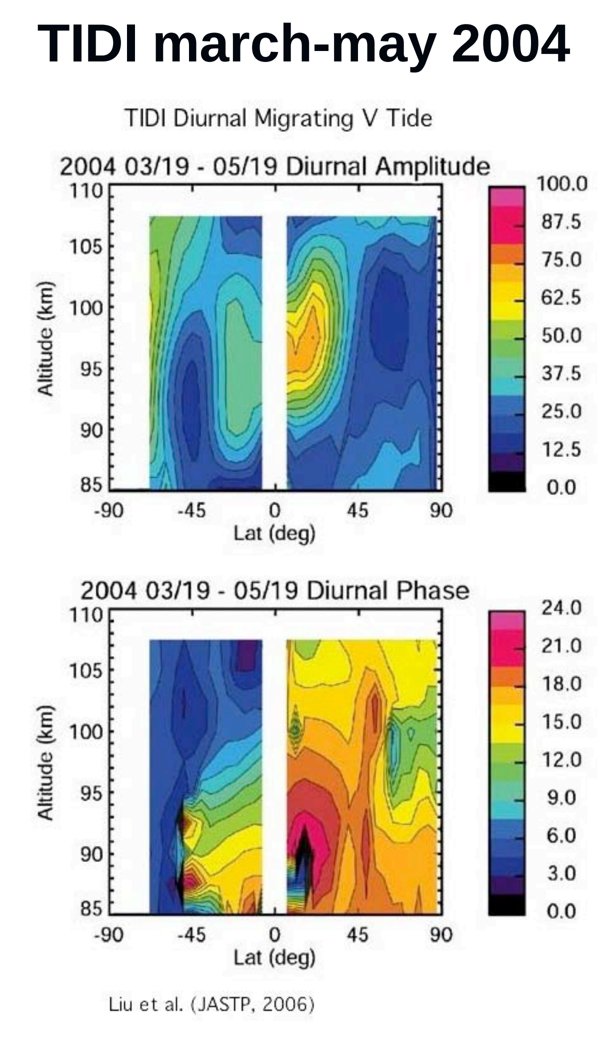


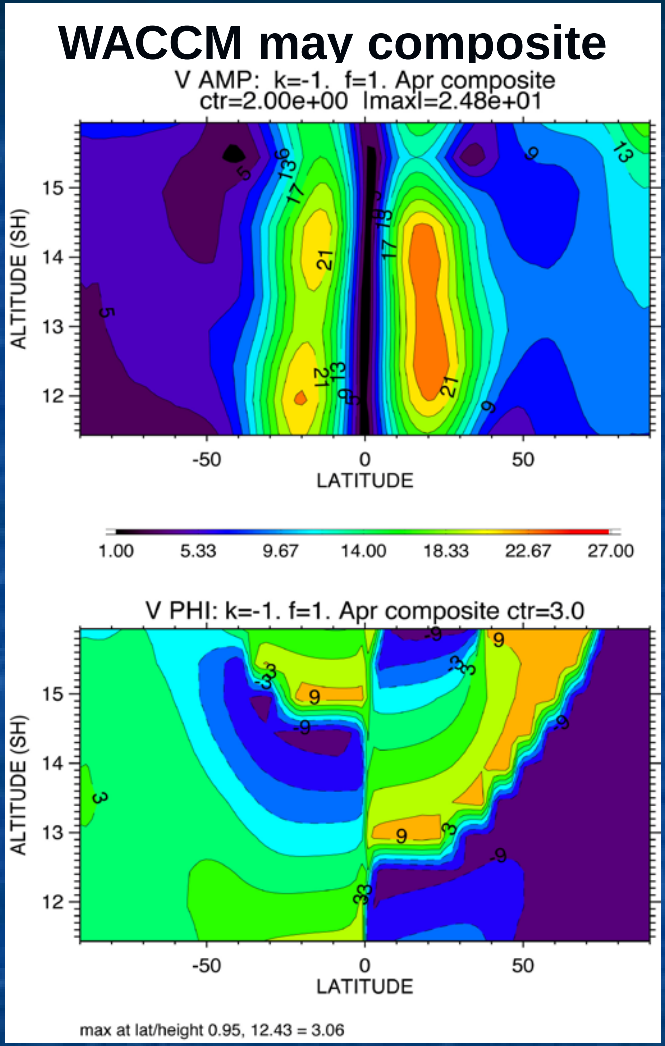


- SABER diurnal tide from Salby spectral analysis of SABER data
- Tide structure determined from coherence of spectrum over a band centered at 1 cpd westward
- Results may be viewed as long-term mean over SABER period, 2002-2007

- The morphology of the tide is generally consistent between WACCM and SABER
- WACCM amplitudes are considerably smaller, especially in the mesosphere and lower thermosphere

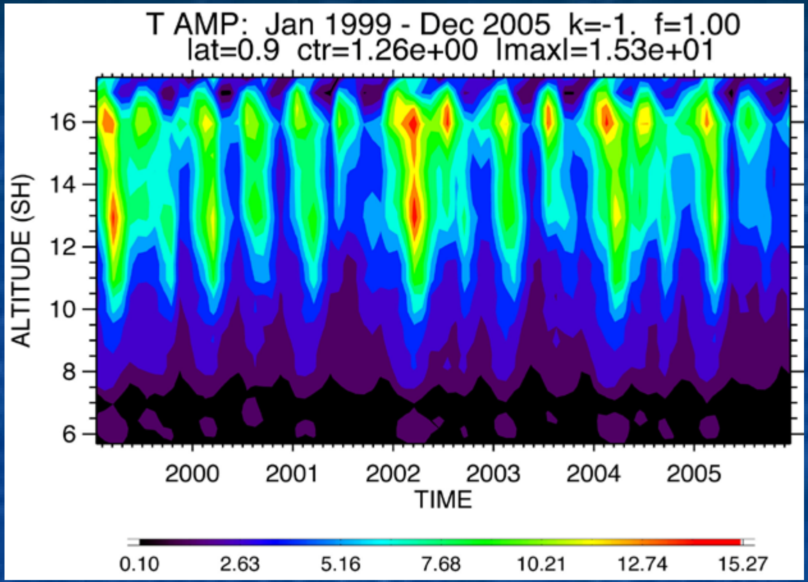
Diurnal migrating V tide structure : TIDI vs. WACCM

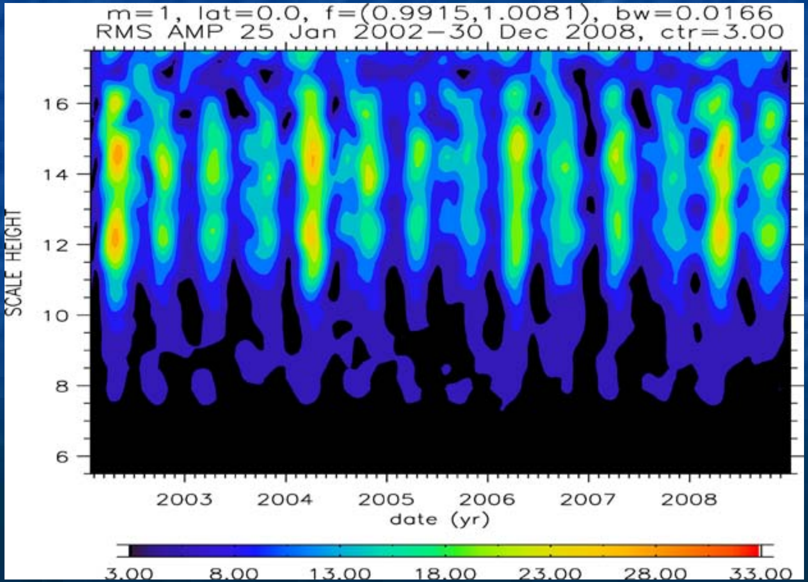




- **TIDI observations by Liu et al (2006)**
- **similar structure in WACCM and TIDI observations, but smaller amplitudes in the model, *much* smaller in the NH**

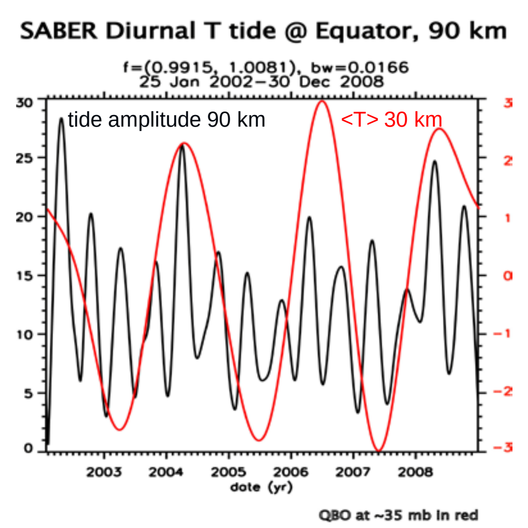
Altitude-time variability of the diurnal tide at the Equator





- model and observations display a clear semi-annual variation, with maxima at the equinoxes
- amplitudes observed by SABER are about 2X larger than calculated with WACCM
- there is also considerable interannual variability (quasi-biennial)

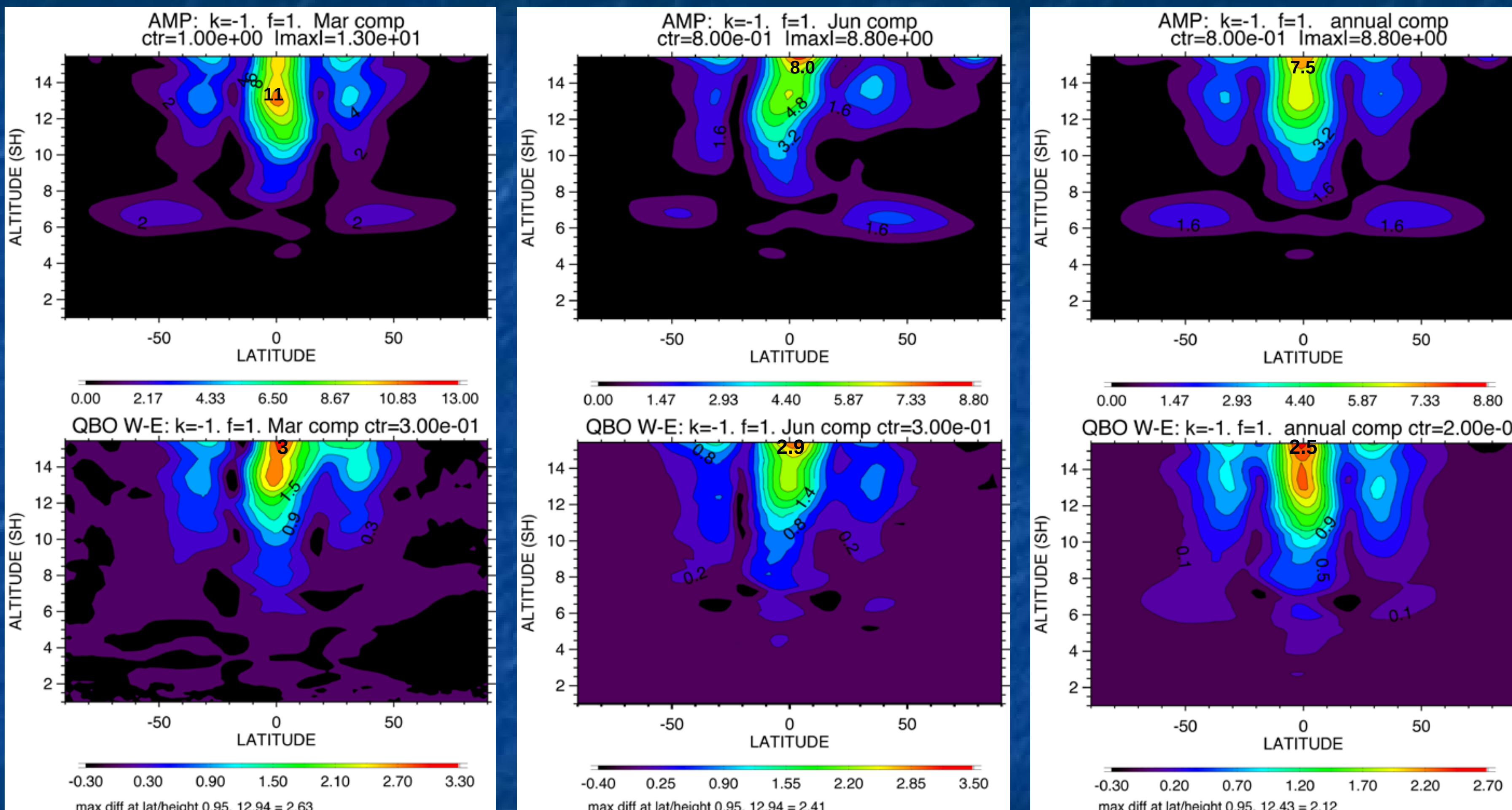
- Similar behavior is seen in SABER data



WACCM Diurnal Tide: QBO W-E Amplitude Differences

composite

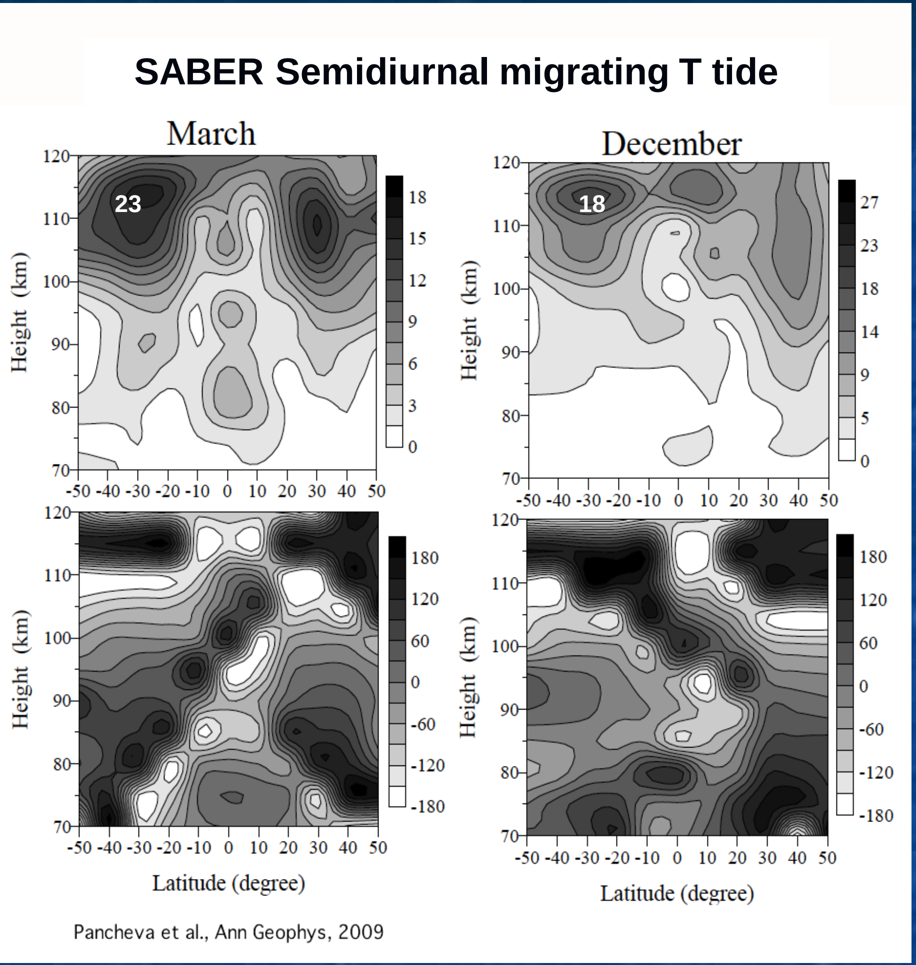
composite difference

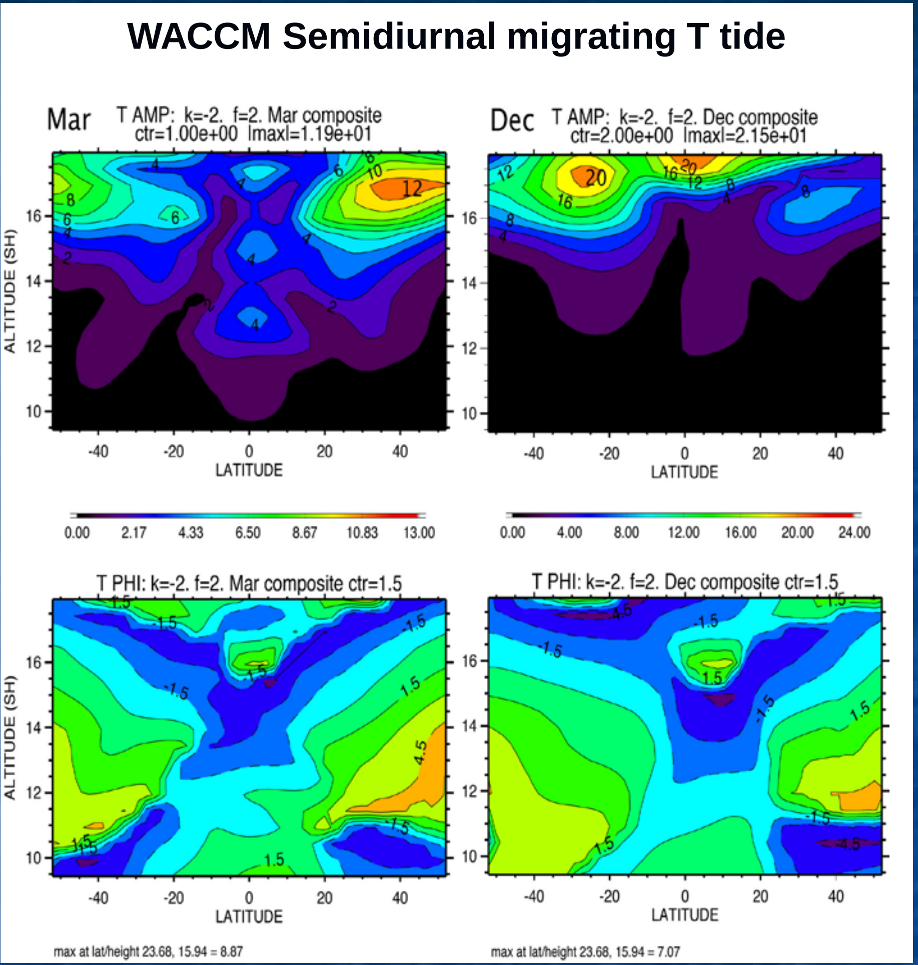


MARCH **JUNE** **ANNUAL**

QBO modulation is substantial in all seasons, about 30% of long-term means

2. Semidiurnal migrating T tide: WACCM vs. SABER

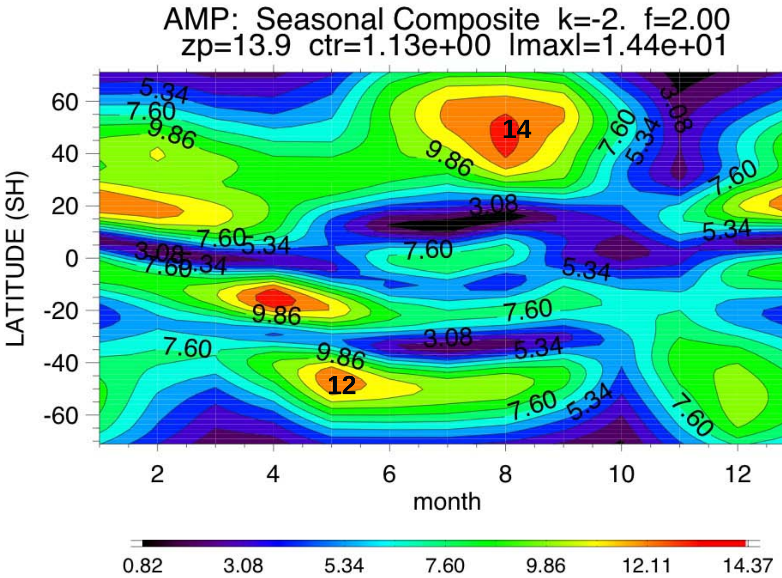




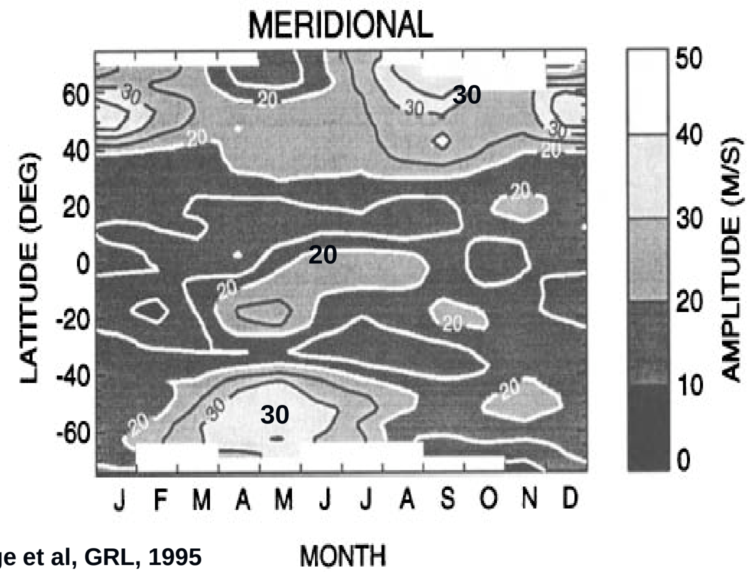
- Semidiurnal T tide obtained by Pancheva et al. via compositing over SABER precession period; may be considered a time mean over the precession period
- WACCM results are long-term means for the month in question
- As with diurnal tide, structures are generally consistent; but WACCM amplitudes are smaller

Seasonal variability of the semidiurnal V tide, 95 km

WACCM composite V seasonal cycle, ~95 km



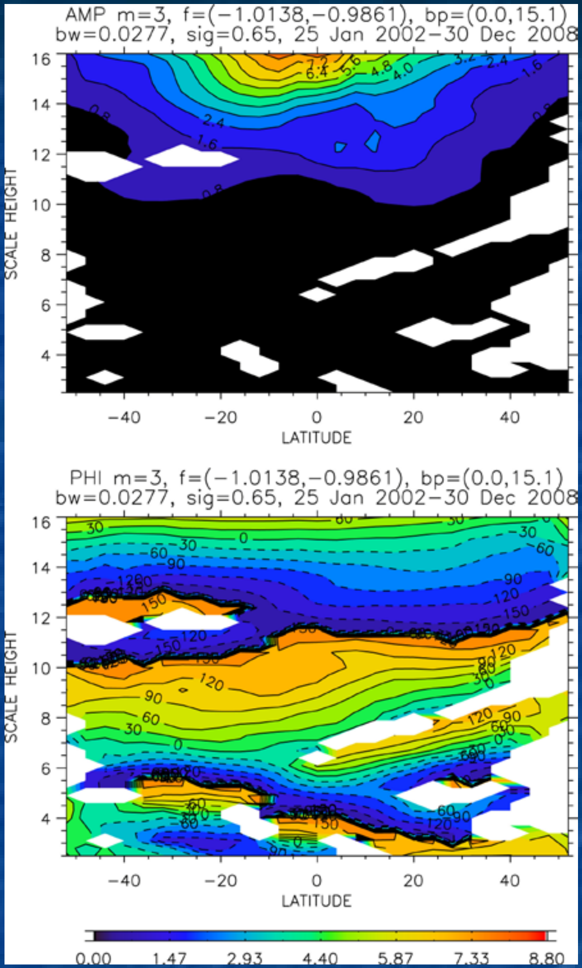
TIDI composite V seasonal cycle @ 95 km

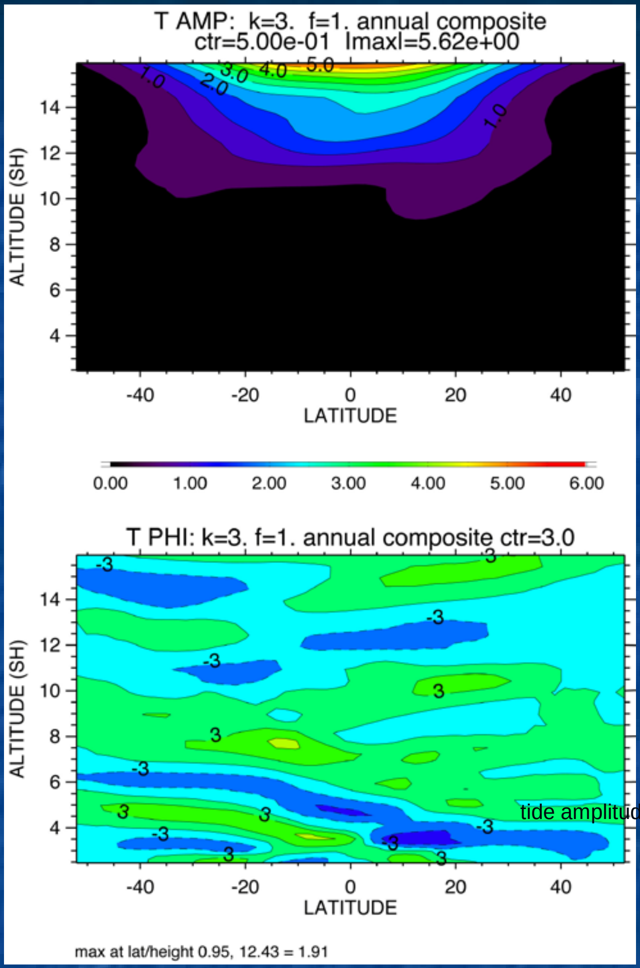


Burrage et al, GRL, 1995

- WACCM results are long-term means for each month for entire 50-year simulation
- UARS/TIDI (Burrage et al, 1995) seasonal cycle is from 2+ years of data (Nov 1991 – July 1994)
- At 95 km, similar seasonal variation in model and observations, but WACCM amplitudes are much smaller than SABER, by a factor of ~2X

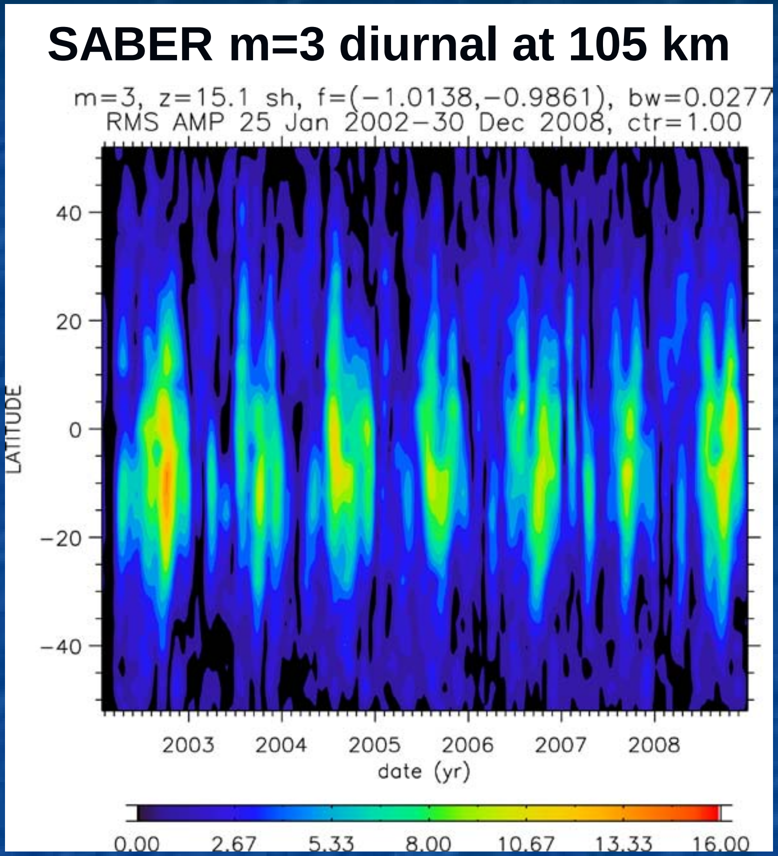
Diurnal eastward k=3 T tide: WACCM vs. SABER

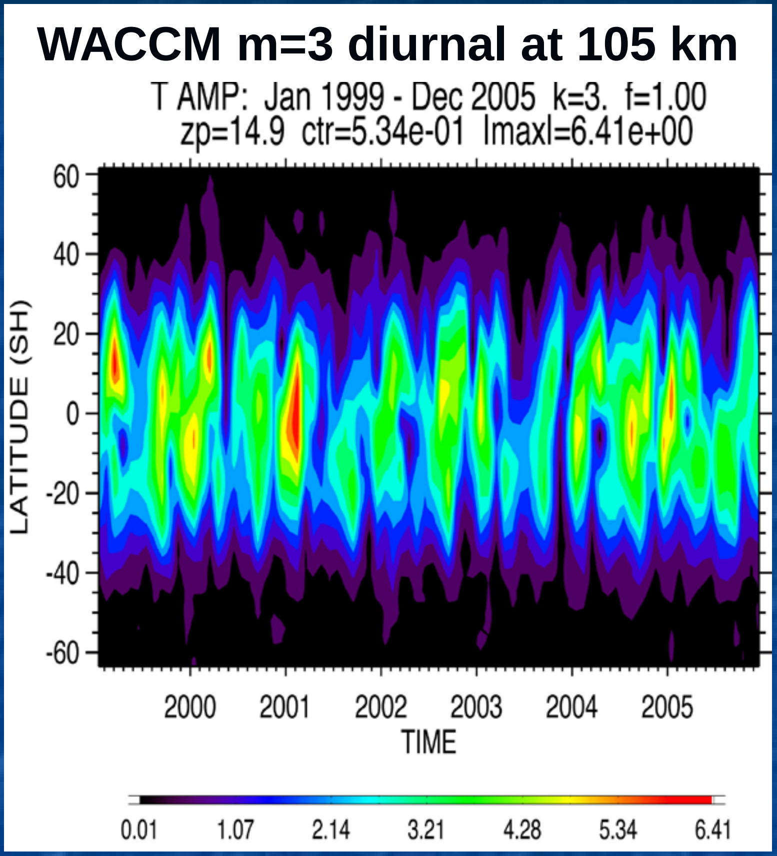




- SABER structure is the long-term mean (2002-2007) determined via coherence analysis
- WACCM is the long-term composite over the 50 years of simulation
- large-amplitude above ~ 10 sh (70 km) has the structure of a Kelvin wave
- phase behavior suggests also RG structure at lower altitudes

Seasonal variation of k=3 eastward T tide: WACCM vs. SABER





- 7 years each of WACCM output and SABER T, at the equator, are shown
- once again, amplitude is considerably smaller in WACCM than observed
- observed seasonal cycle is more regular, with maxima always in late NH summer (~august)
- model displays semiannual variation in most years, with maxima in august *and* january

Conclusions

- WACCM simulates a set of diurnal and semidiurnal oscillations, migrating and “non-migrating”; similar to recent radar and satellite observations
- Although structure and seasonal behavior is usually consistent with observations, amplitudes are smaller by about a factor of two, on average
- Reason for simulated amplitudes is not known; role of forcing, especially tropical latent heat release needs to be investigated
- Seasonal and inter-annual variability of the diurnal tide is very well simulated; inter-annual variability is clearly related to the presence of the QBO in this model