Exploring the Sun and its effects on the Earth's atmosphere and physical environment...

HIGH ALTITUDE OBSERVATORY

Middle and Upper Atmospheric and Ionospheric Variability: What About the Role of Nonmigrating Tides?

Maura Hagan, Astrid Maute, Ray Roble, and Art Richmond
National Center for Atmospheric Research

Jeff Forbes and Xiaoli Zhang
University of Colorado at Boulder

Presentation Overview:

- Numerical experiments with the NCAR TIME-GCM
  thermosphere-ionosphere-mesosphere-electrodynamics
  general circulation model
  that quantify the effects of nonmigrating tides
- Focus on components excited by latent heat release in the troposphere
- Comparisons between TIME-GCM simulation results and TIMED/SABER temperature diagnostics

nonmigrating tide - global scale wave
period is harmonic of a solar day
propagates horizontally faster or slower than the motion of the Sun

TIME-GCM

First-principles global model

- self-consistent dynamics, chemistry, electrodynamics
- ~30 - 500 km; 2.5^o x 2.5^o; 4 grid points per scale height
- parameterized sub-grid-scale gravity waves

Results:

4 months - geomagnetically quiescent solar minimum conditions

- March, June, September, and December
- GSWM-02 perturbations at LBC account for tropospheric tides

"realistic" runs – all tides

- 13 wavenumber (W6 - E6) diurnal & semidiurnal perturbations

"diagnostic" runs – migrating tides only

- DW1 and SW2

"difference fields" – quantify nonmigrating tidal effects

- realistic – diagnostic results

XYZ nomenclature

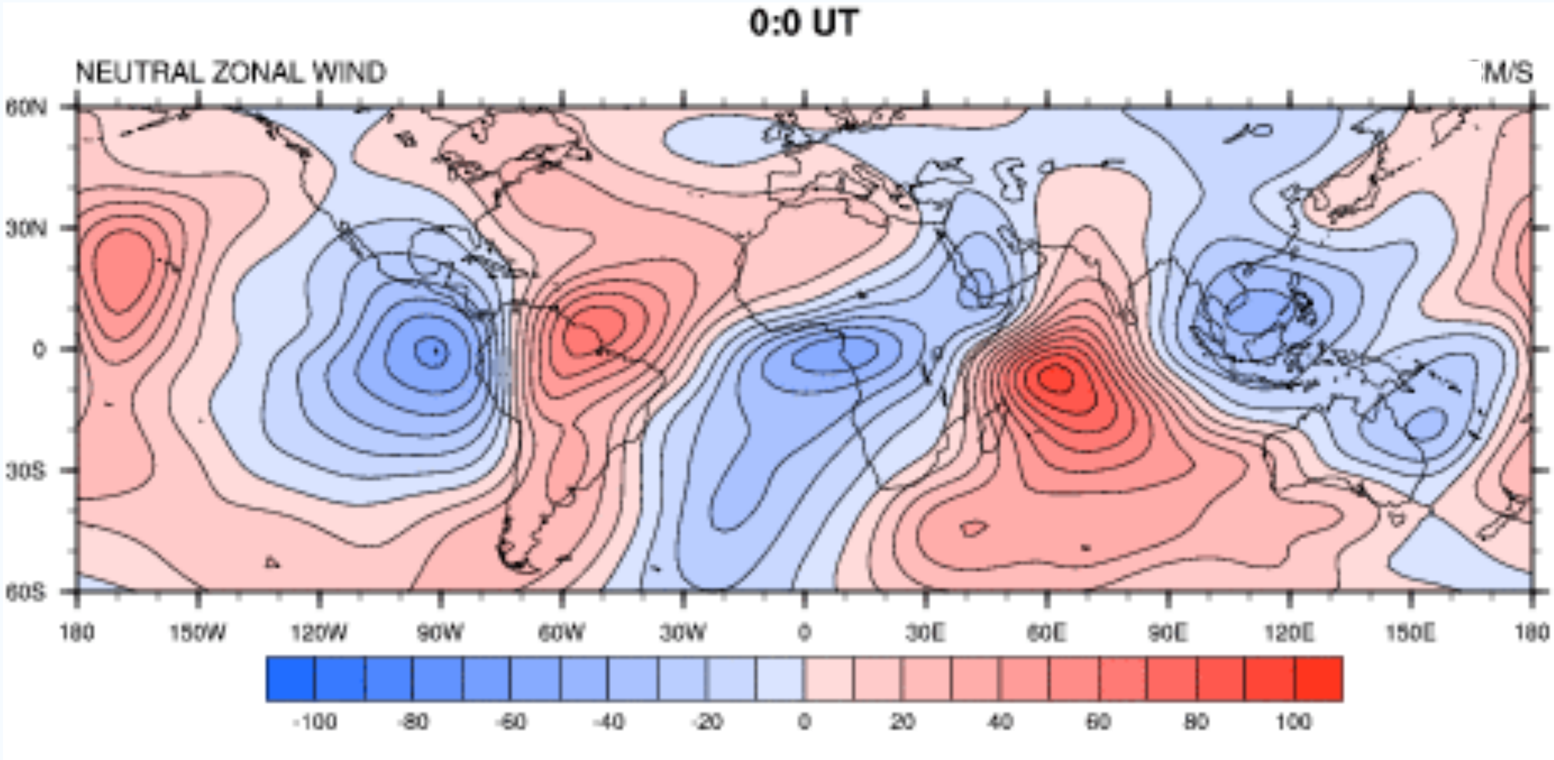
- X - harmonic
- Y - zonal propagation direction
- Z = zonal wavenumber

TIME-GCM/GSWM-02 Results

- Difference fields
  - Zonal Wind
  - Electron Density
- Component wave profiles – realistic simulation
- September

Zonal Wind Differences (m/s) near 120 km - September

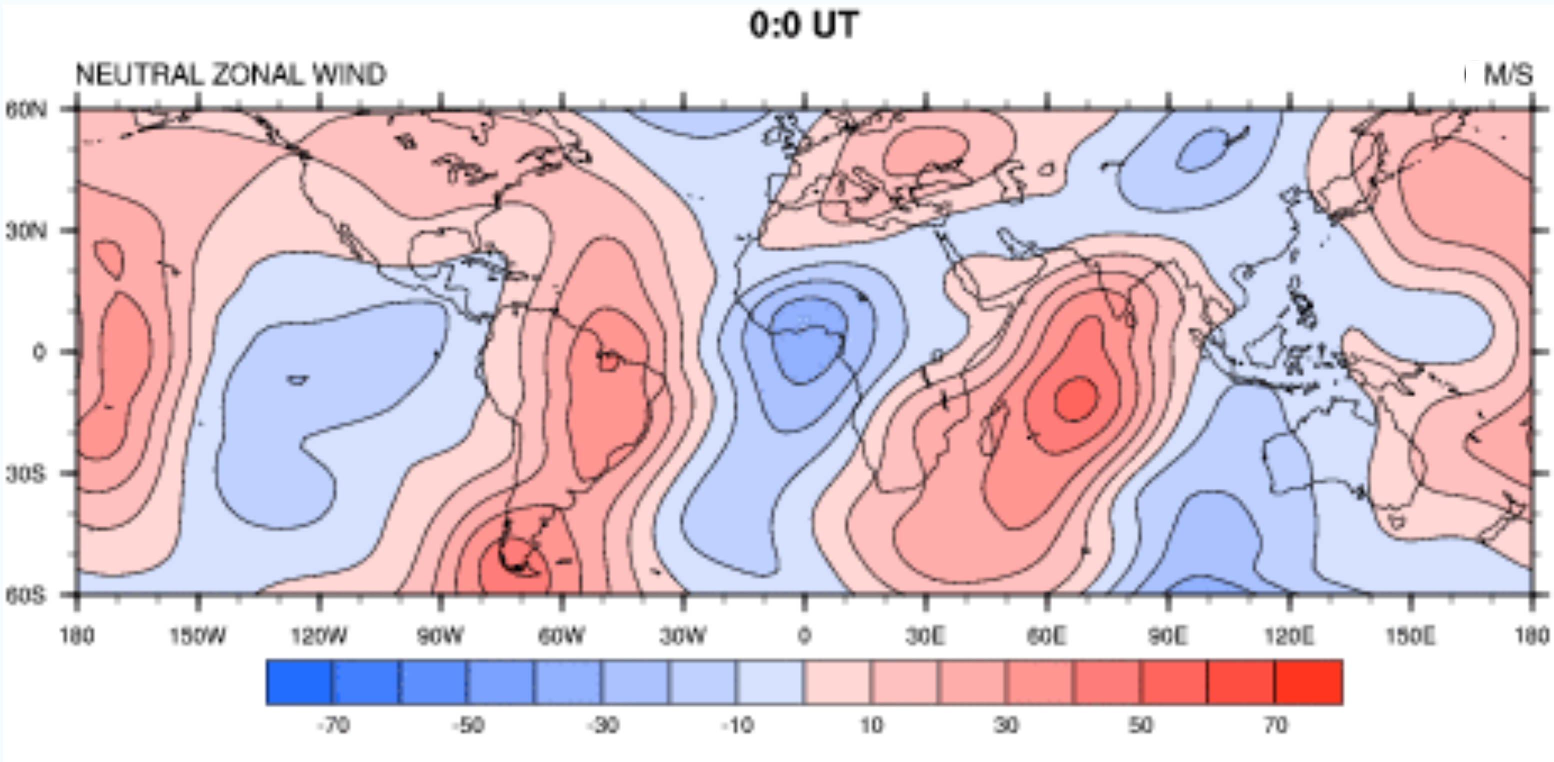
all tides - migrating tides



Nonmigrating tides may introduce zonal wind perturbations that modulate the E-region dynamo process and impact the F-region.

Zonal Wind Differences (m/s) near 325 km - September

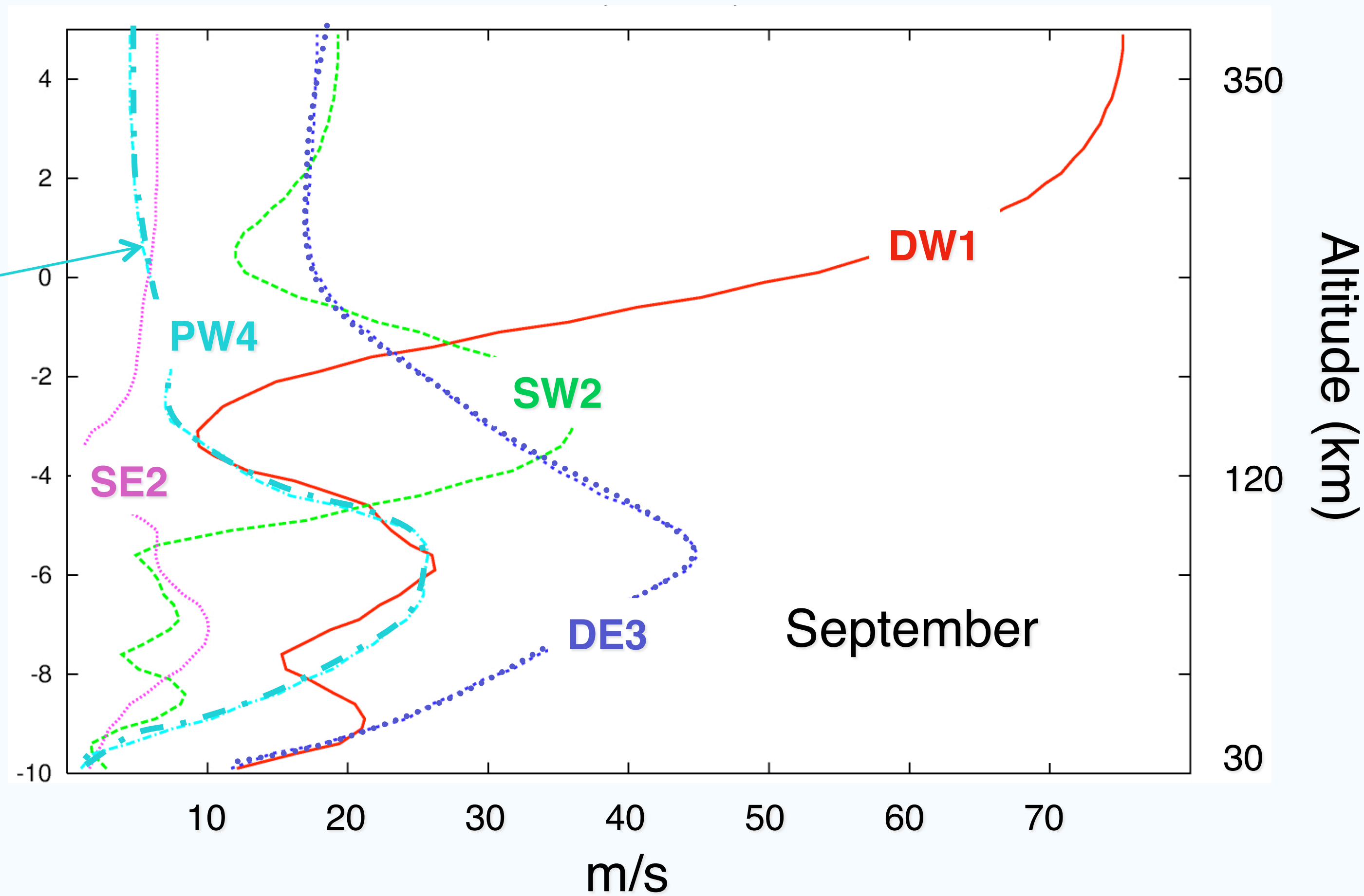
all tides - migrating tides



Nonmigrating tides may also penetrate directly into the upper atmosphere and modulate the thermosphere-ionosphere system.

Equatorial Wave Components - September
Zonal Wind Amplitudes (m/s)

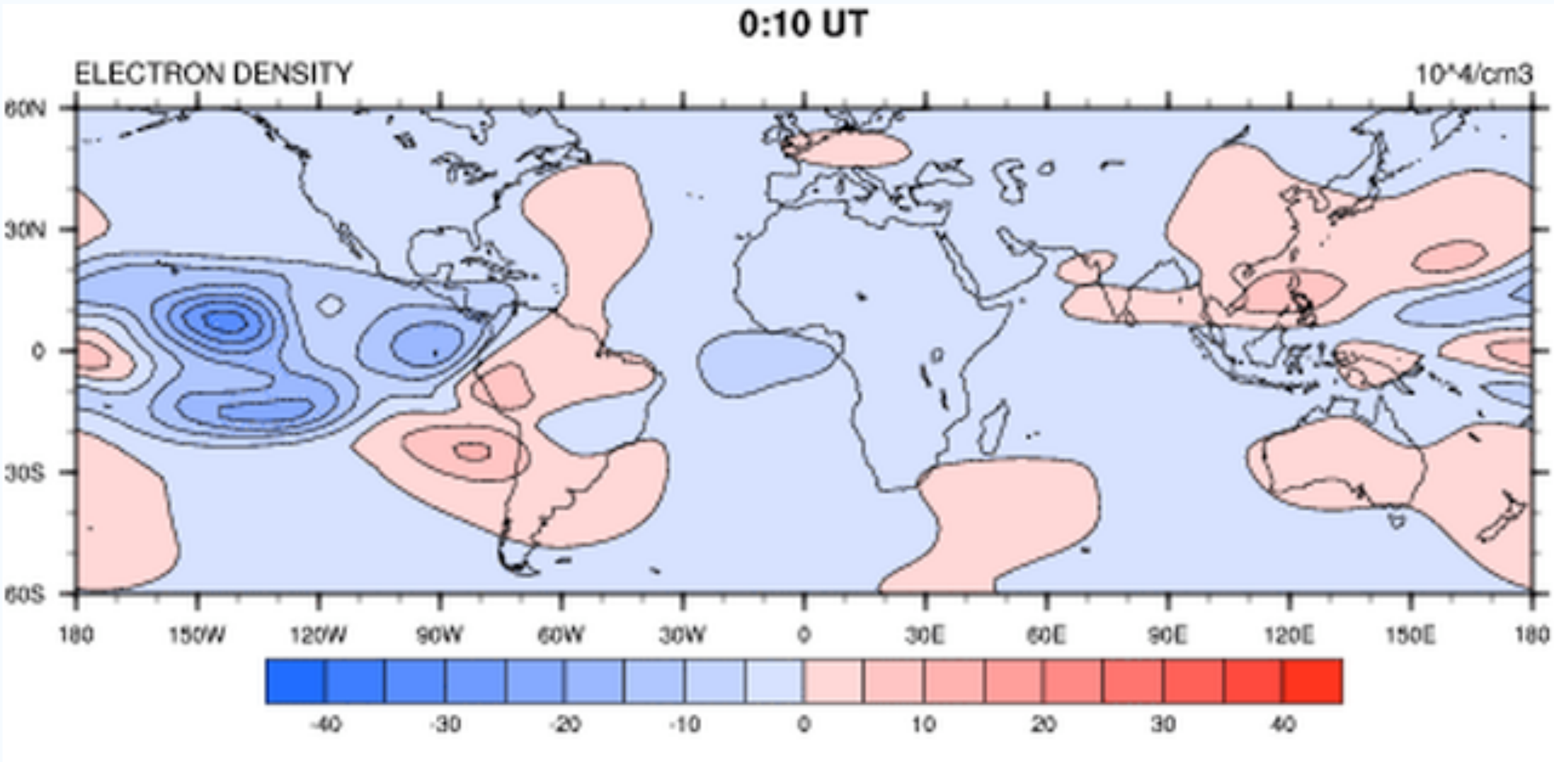
PW4
no LBC forcing
secondary wave
➔ DE3 & DW1



DE3, PW4, and SE2 will all appear as wave-4 features from near Sun-synchronous orbit.

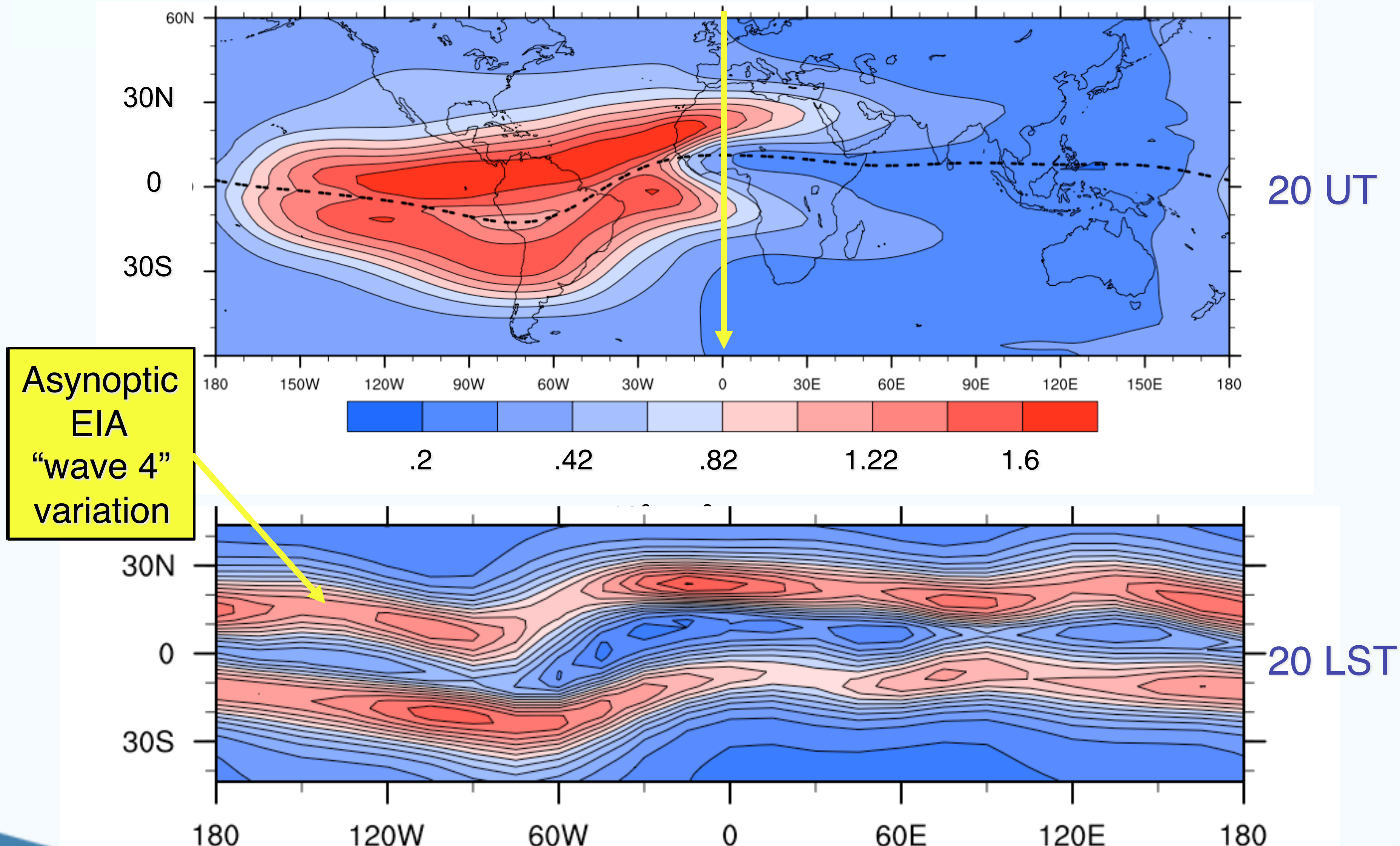
Electron Density Differences ($10^4/cm^3$) near 325 km - September

all tides - migrating tides



Note the measurable and evolving longitudinal variability of the F-region ionosphere that's attributable to nonmigrating tides.

TIME-GCM Electron Density at 450 km - March

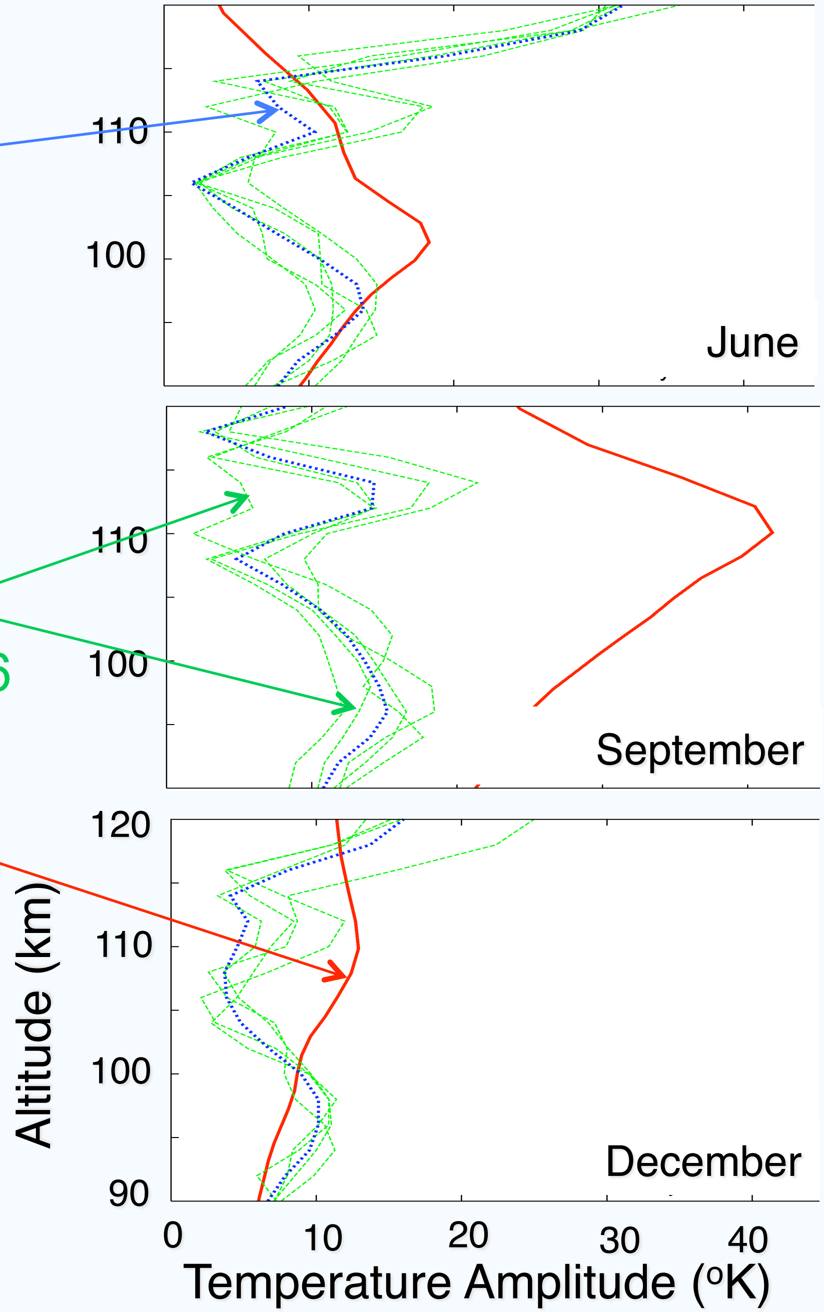


after *Hagan et al.* [2007]

Comparisons between TIME-GCM/GSWM-02 results and SABER observations

- Temperature perturbations
- 90-120 km
- Select components: DW1, DE3, DE2, and PW4
- June, September, December

DW1 - Equator



<u>NOTE</u>:

comparable June/December magnitudes

Significant September model overestimate

vertical structure differences every month

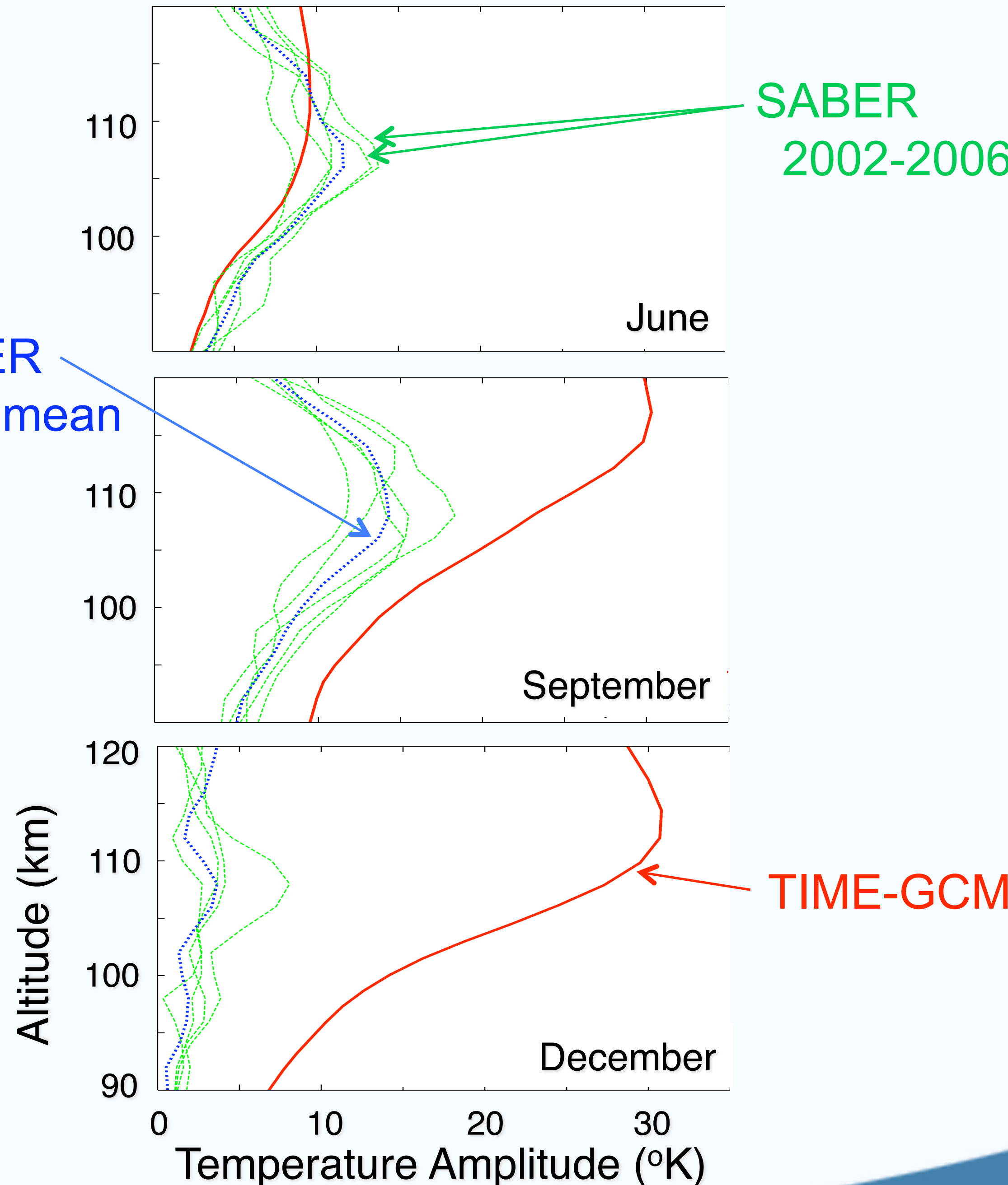
DE3 - Equator

NOTE:
> DW1 June/September

comparable June signatures

September model overestimate

December
weakest - data
strongest - model



DE2 - Equator

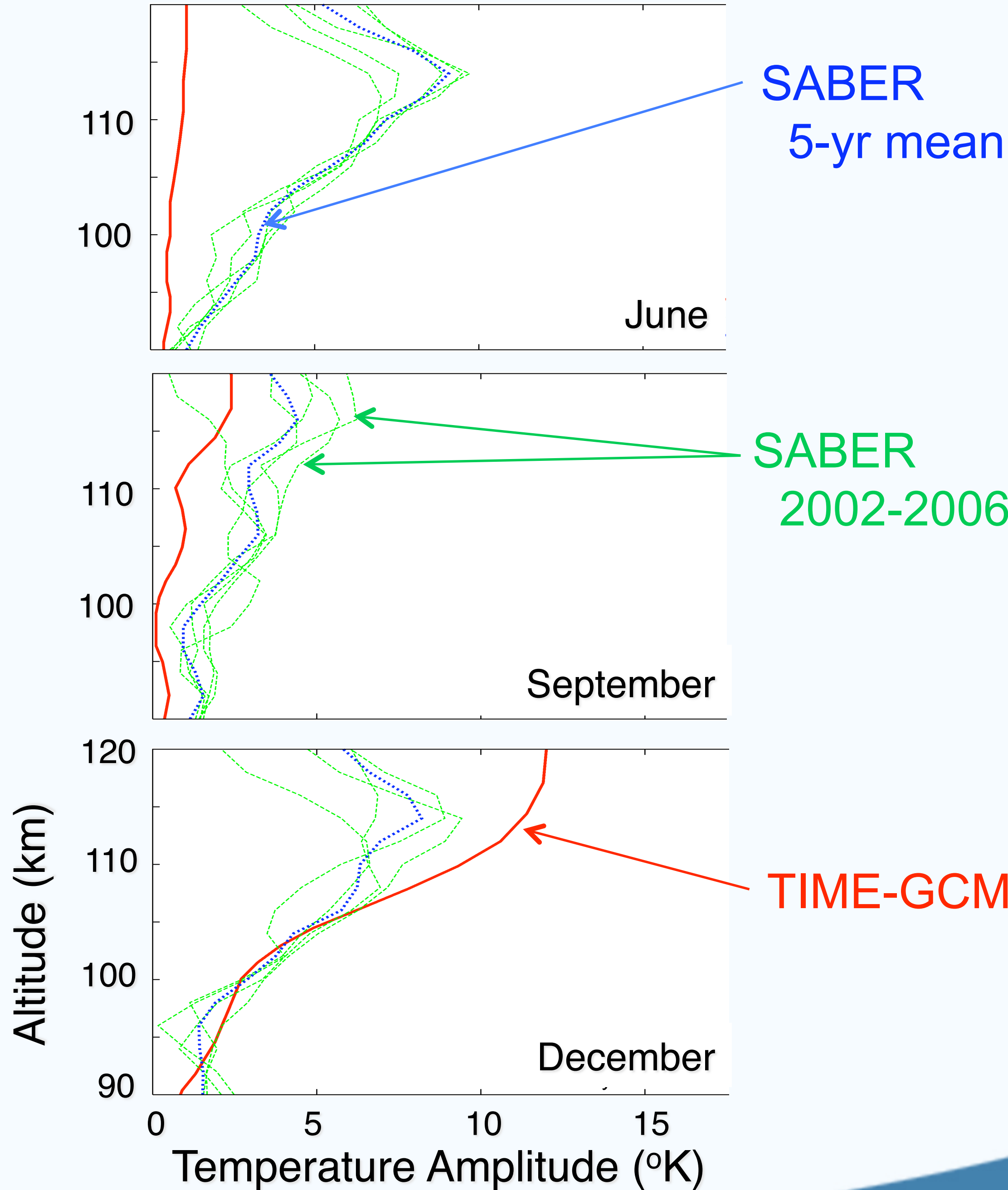
NOTE:

<< DW1 and DE3
June/September

> DE3
December - SABER only

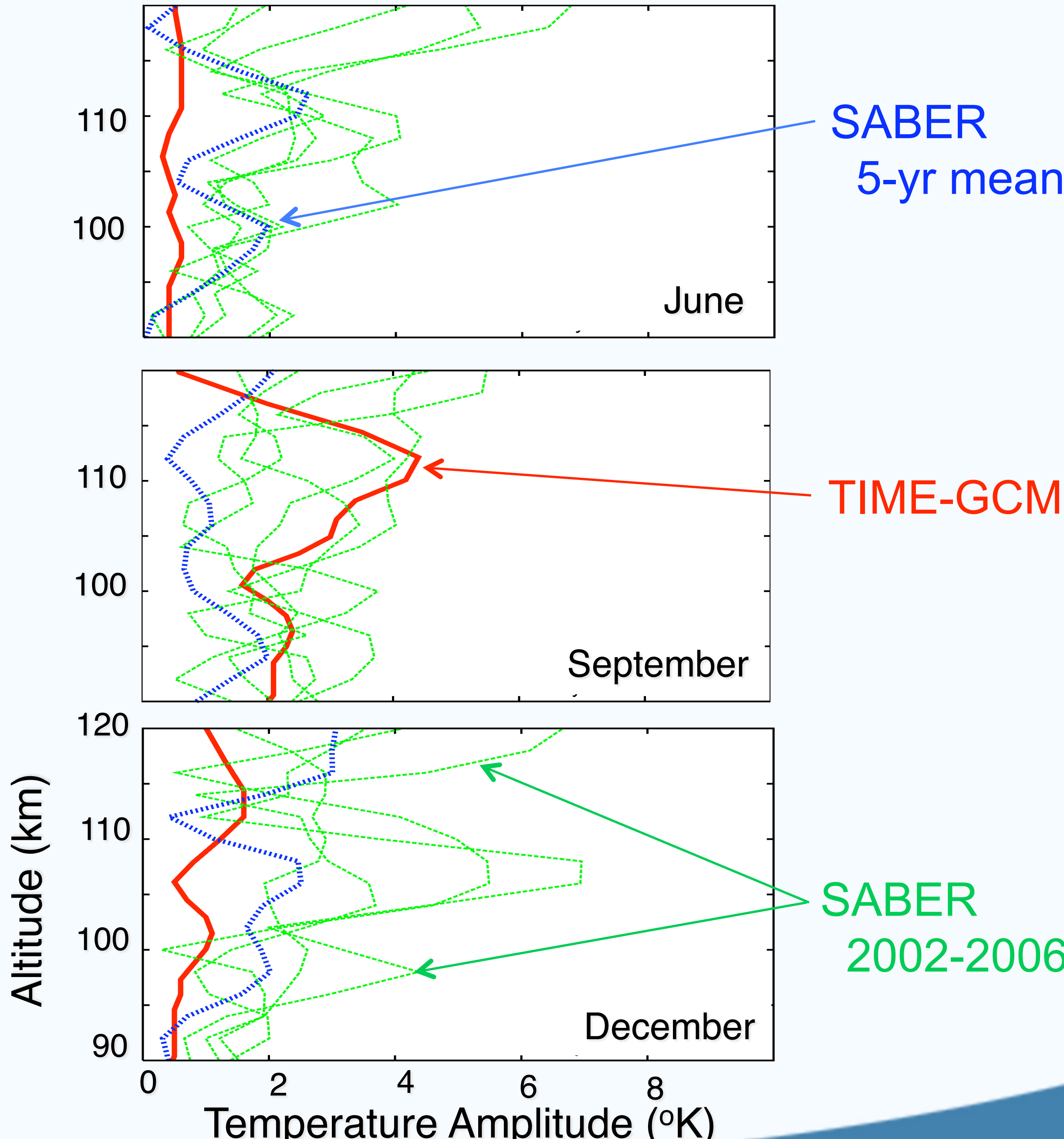
TIME-GCM < SABER
June/September

comparable December
signatures below ~110 km



PW4 - Equator

NOTE:
- smallest wave signature
- interannual variability out-of-phase
  - ➔ weaker 5-yr mean



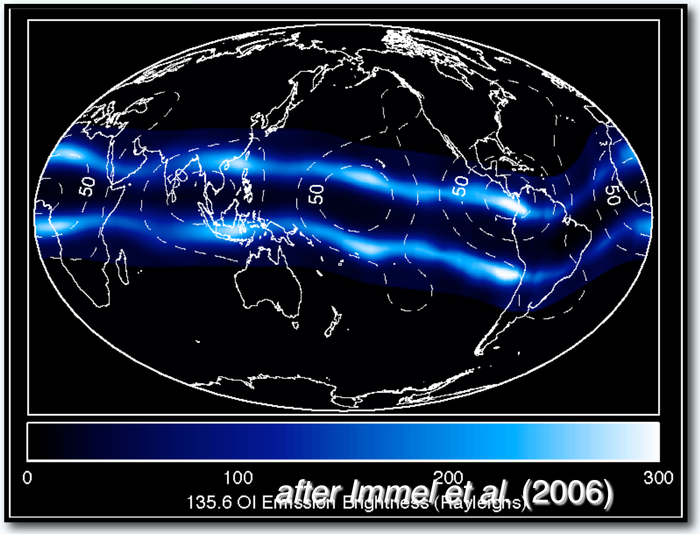
Summary

TIME-GCM simulations suggest that wave-driven longitude variations in the quiescent thermosphere-ionosphere system can arise in at least three ways:

- direct penetration of nonmigrating tides excited by latent heat release in the tropical troposphere
- nonmigrating tidal modulation of the E-region dynamo process
- the dual (as above) effects of secondary stationary planetary waves excited by nonlinear tidal interactions

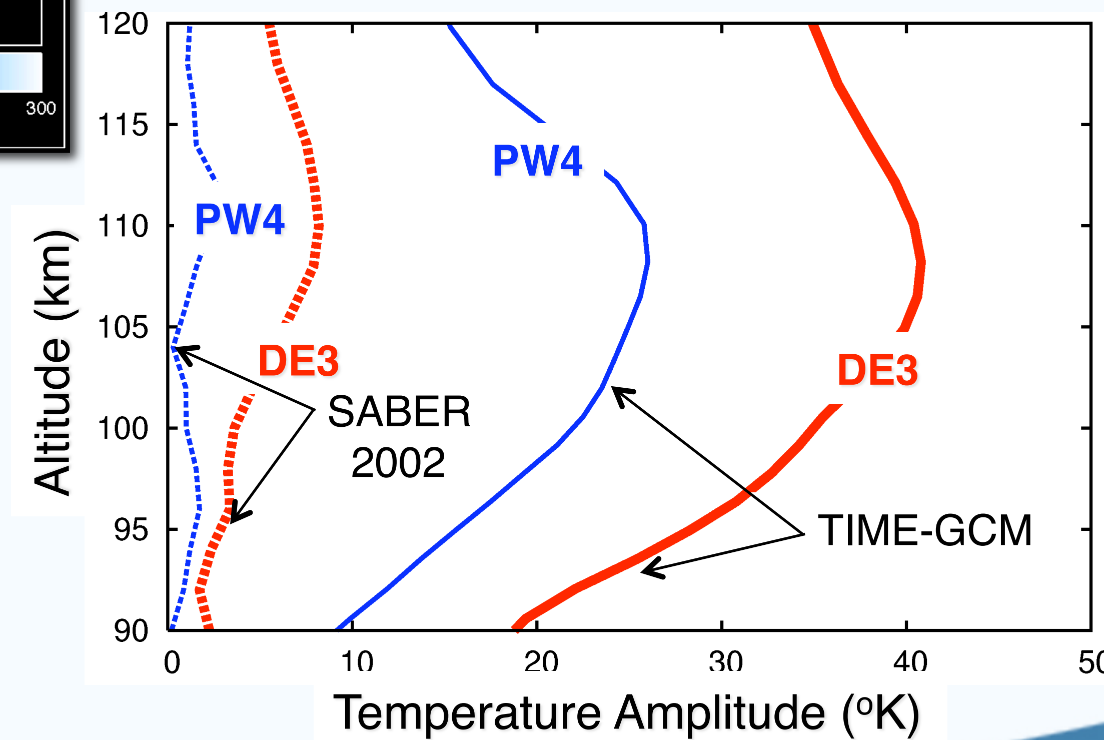
Comparisons with TIMED/SABER temperature diagnostics suggest that TIME-GCM captures some, but not all, features of the observed tides and planetary waves.

Concluding Question

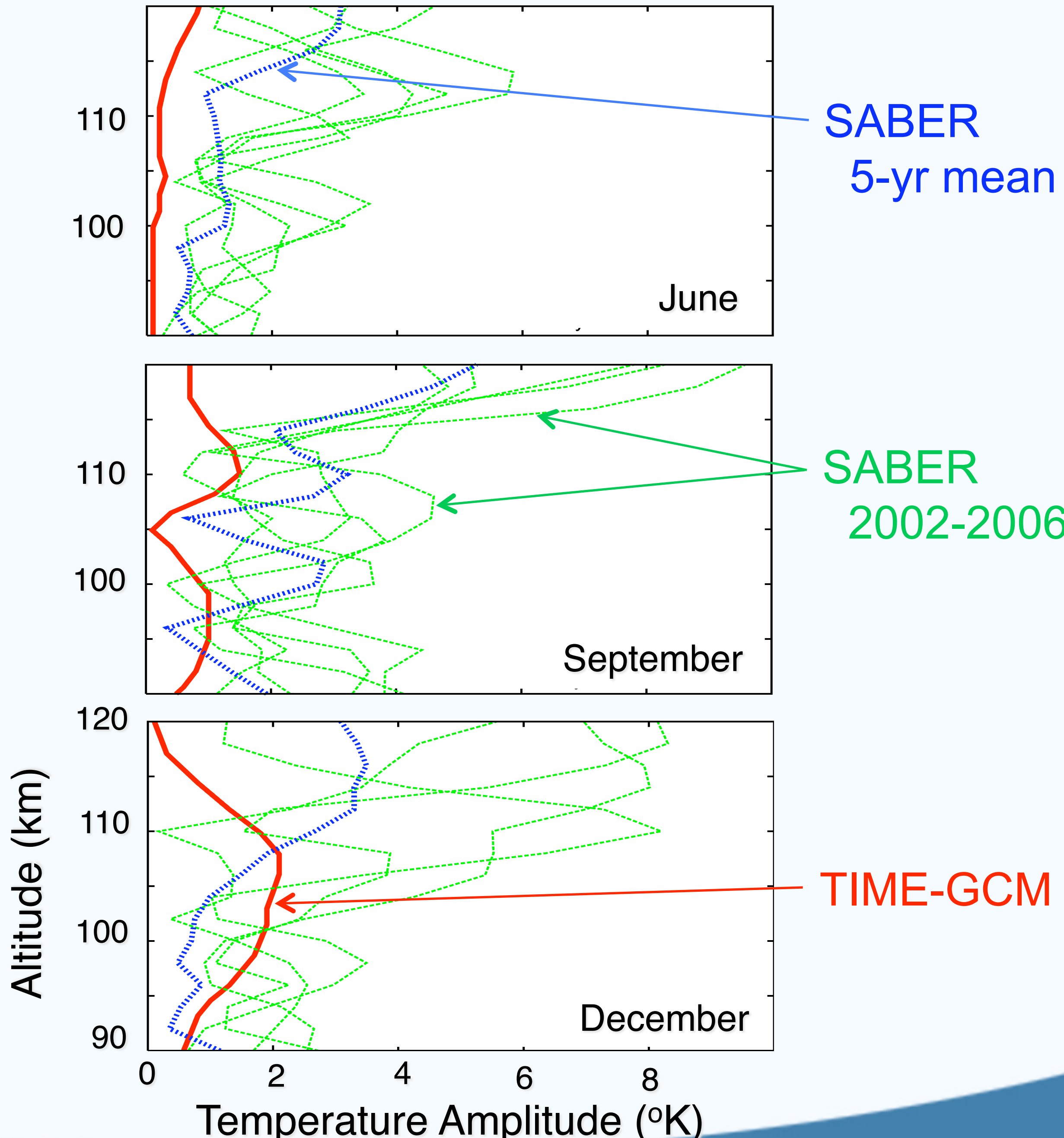


How should we explain the March 2002 wave-4 structure in the equatorial ionization anomaly seen by IMAGE-FUV?

SABER observed weak DE3 and PW4 behavior in March 2002.



PW1 - Equator


110
100
June
110
100
September
120
110
100
90
December
Altitude (km)
0
2
4
6
8
Temperature Amplitude (oK)
SABER
5-yr mean
SABER
2002-2006
TIME-GCM