Changes of the ionosphere and thermosphere during a strong quasi-two-day planetary wave event: a numerical modeling study

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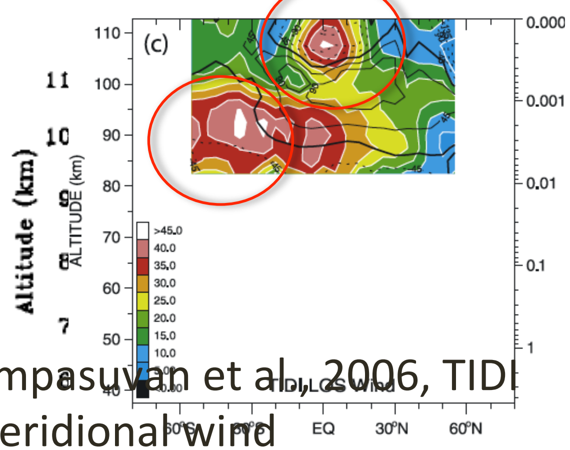
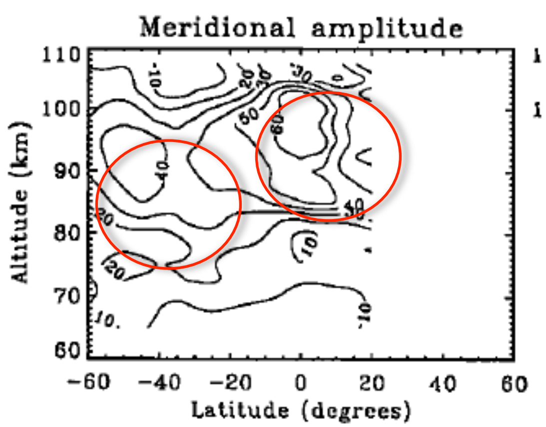
Quasi-two-day waves observed in the MLT and ionosphere

Satellite observations

60 m/s

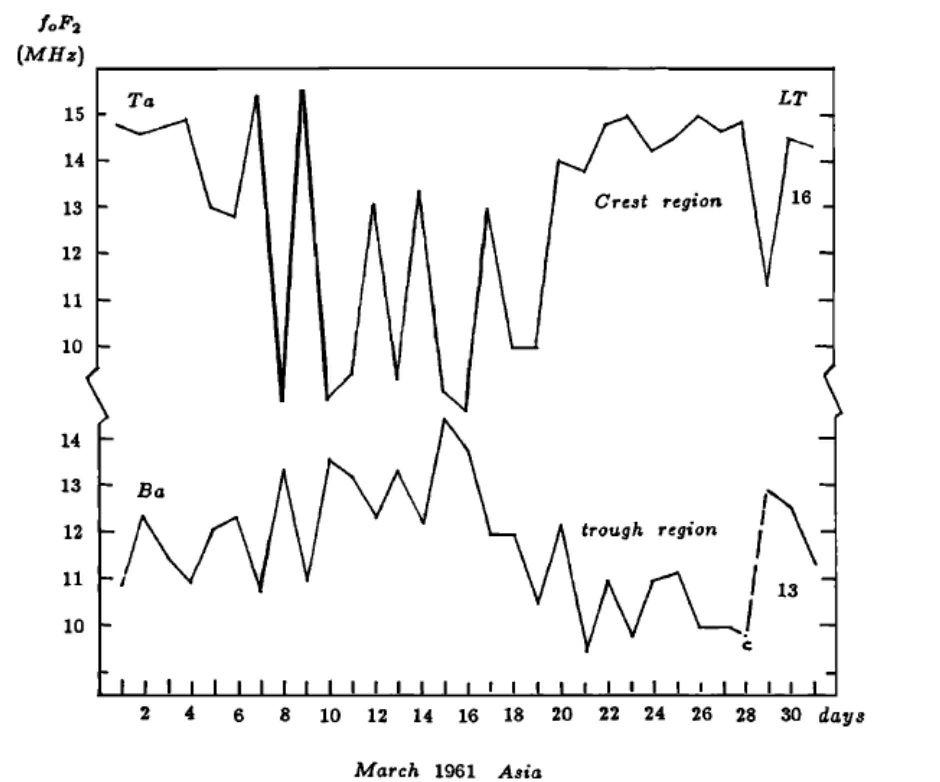


Limpasuvan et al., 2006, TIDI meridional wind



Wu et al., 1993, HRDI meridional wind

ionosondes



Chen et al., 1992, foF2

Model employed: NCAR Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model (TIME-GCM) [Roble et al., 1988; Roble and Ridley, 1994]

Resolution: horizontally 2.5 by 2.5 degrees; vertically 4 grid points per scale height;

Self consistent dynamics and electrodynamics

Geomagnetically quiet: K_p=0.

Solar minimum: F10.7 = 75 SFU

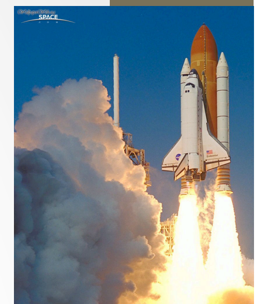
Perpetual day of year = January 15 (maximum QTDW observed)

Lower boundary (30 km) condition:

Migrating Tides from GSWM forced at the lower boundary. No nonmigrating tides forced.

Zonal-wavenumber-3 quasi-2-day travelling planetary wave perturbations prescribed in geopotential height at the lower boundary

Roadmap: to fully understand the QTDW behavior and impacts in the thermosphere and ionosphere using TIME-GCM



Yue J. and H.-L. Liu (2010), Fast meridional transport in the lower thermosphere by planetary-scale waves, *J. Atmos. Solar Terra. Physics*, 1372-1378, doi:10.1016/j.jastp.2010.10.001.

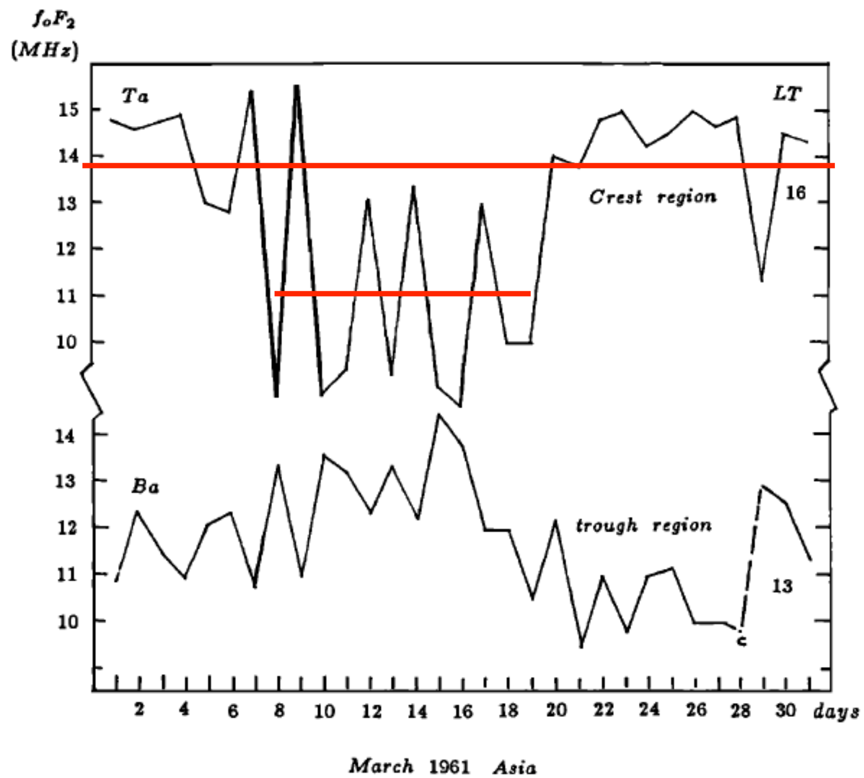
Yue J., H.-L. Liu, L. C. Chang (2012), Numerical investigation of quasi-two-day waves in the mesosphere and lower thermosphere, *J. Geophys. Res*. *Atmosphere*, 117, D05111, doi:10.1029/2011JD016574.

Yue J., W. Wang, A. Richmond and H.-L. Liu (2012), Quasi-two-day wave coupling of the mesosphere and lower thermosphere-ionosphere in the TIME-GCM: Two-day oscillations in the ionosphere, *J. Geophys. Res. Space Physics*, 117, A07305, doi:10.1029/2012JA017815.

Yue J., W. Wang, A. Richmond, H.-L. Liu and L. Chang (2013), Wavenumber broadening of the quasi-two-day planetary wave in the ionosphere, *J. Geophys. Res. Space Physics, 118*, DOI: 10.1002/jgra.50307.

Quasi-two-day waves and the change of foF2 during QTDW events observed in the ionosphere

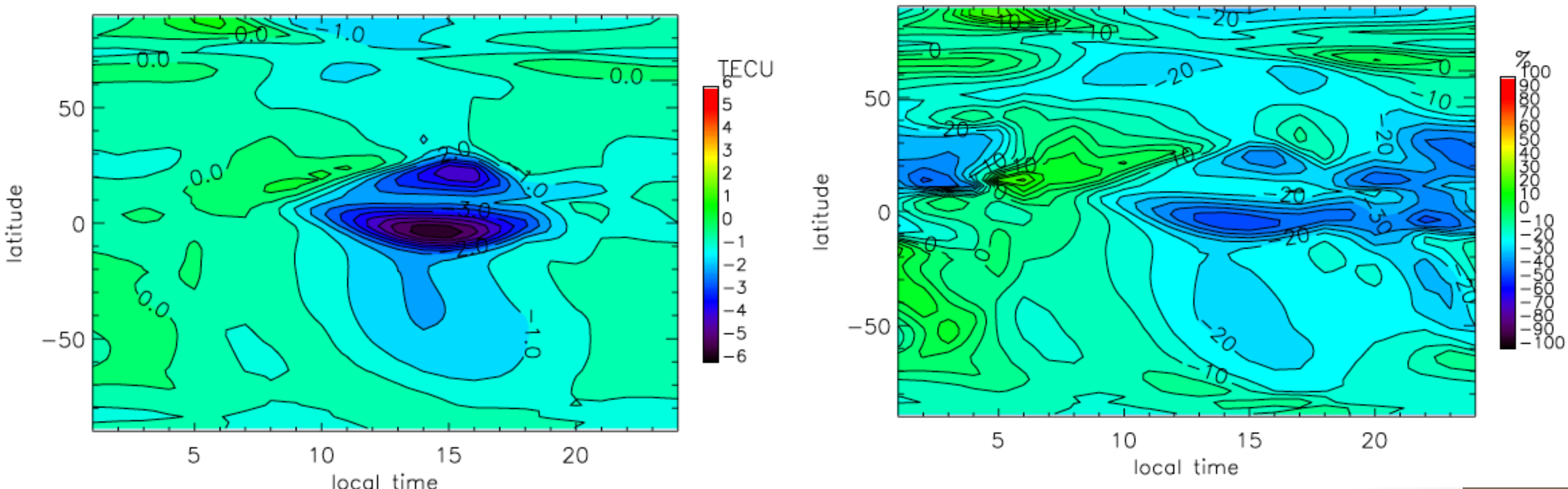
ionosondes



Chen et al., 1992, foF2

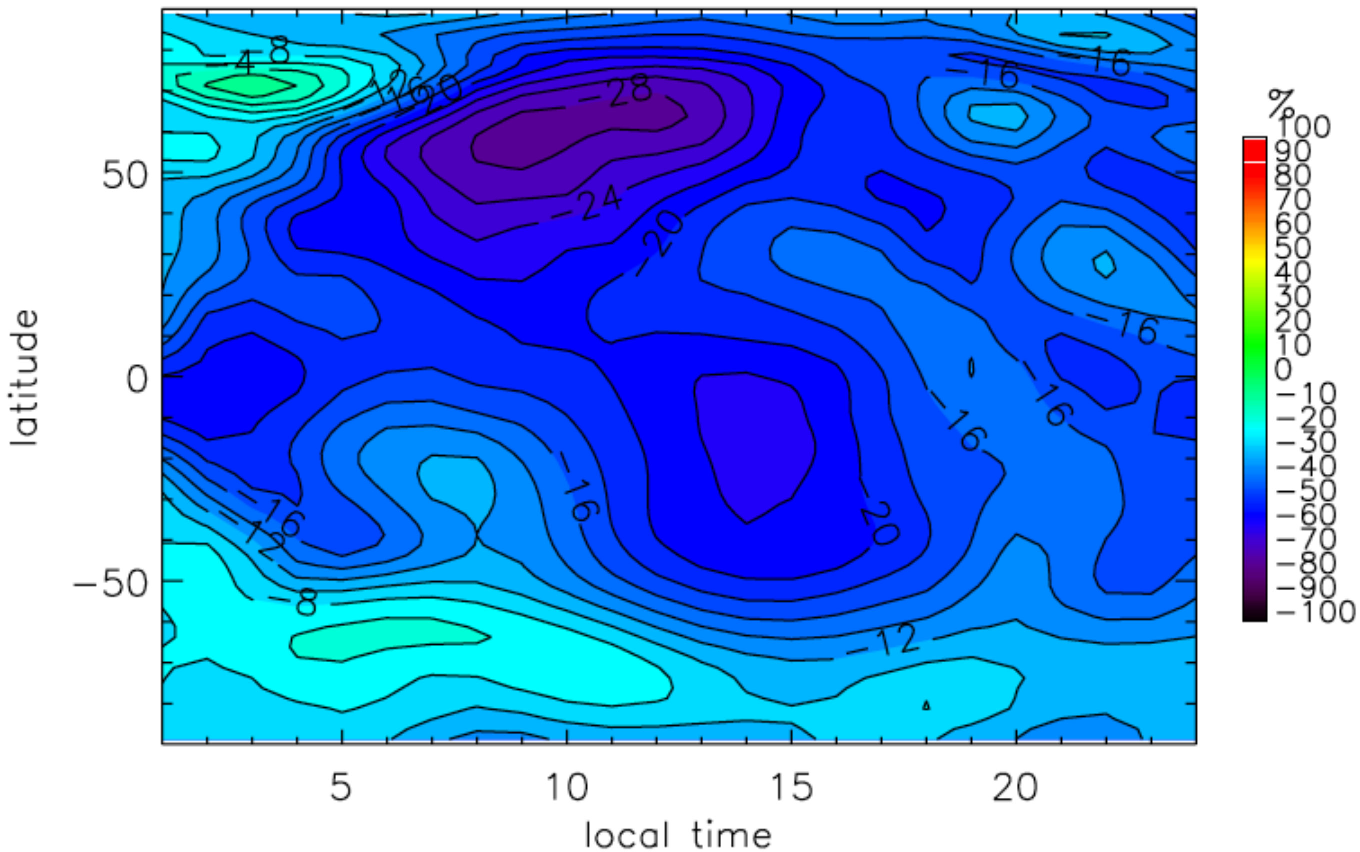
1. Decrease of electron density and TEC near EIA

Absolute and relative TEC changes with QTDW forcing minus without QTDW at 15E



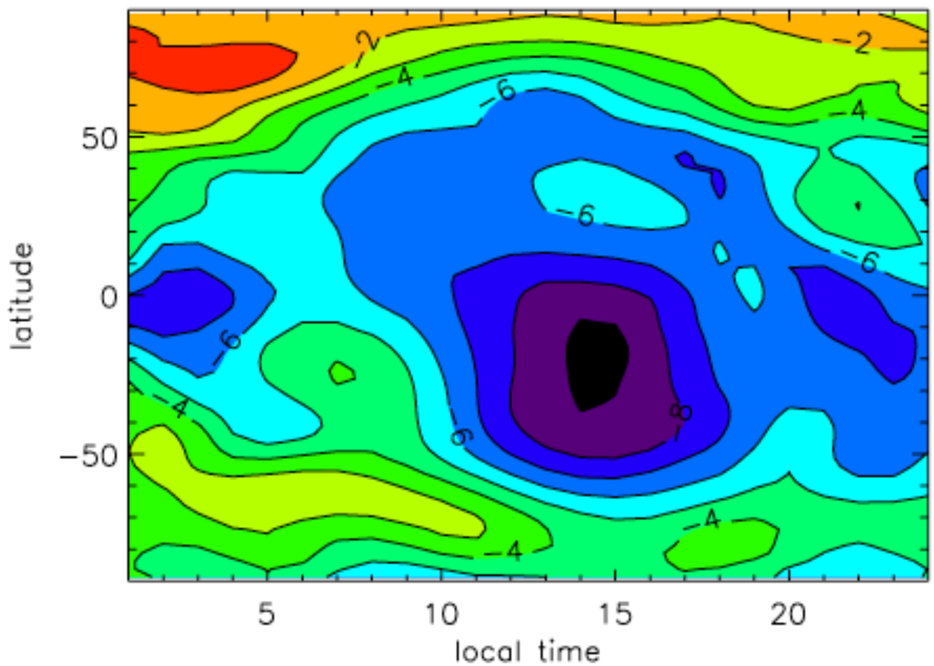
Up to 30-40% decrease of TEC at EIA crests

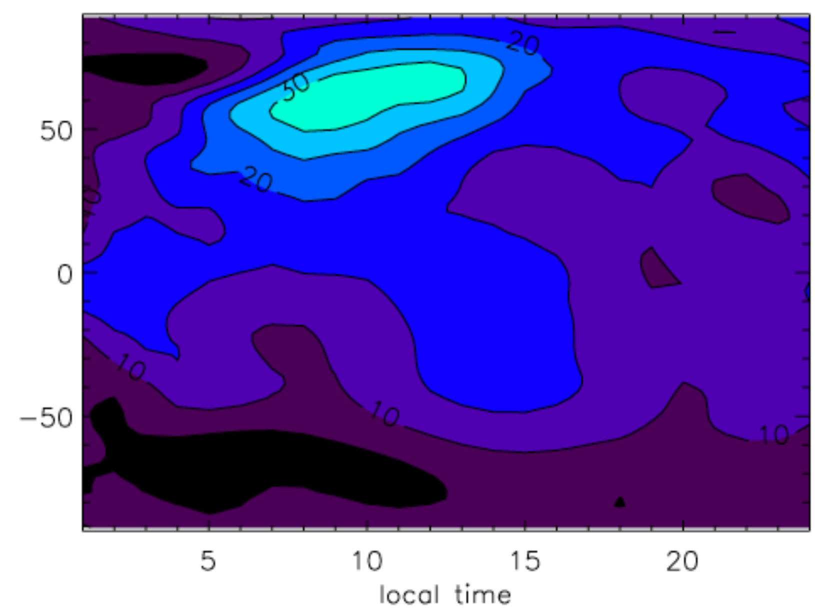
2. Decrease of O/N2 ratio at F2 peak ~270 km



~20% decrease of O/N2 in the afternoon

3. Decrease of O and increase of N2 at F2 peak ~270 km



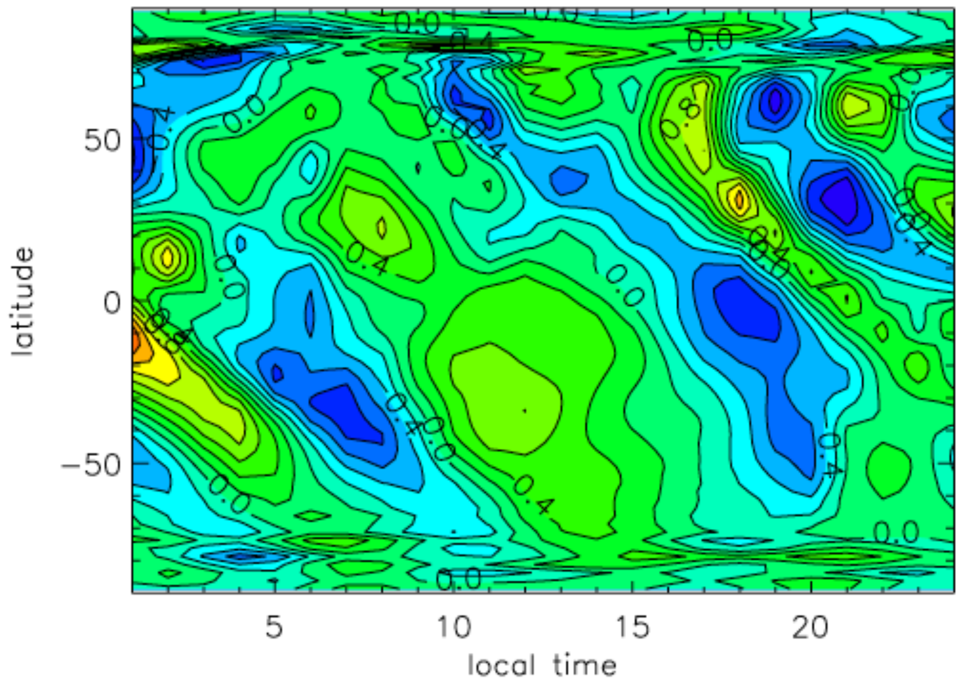


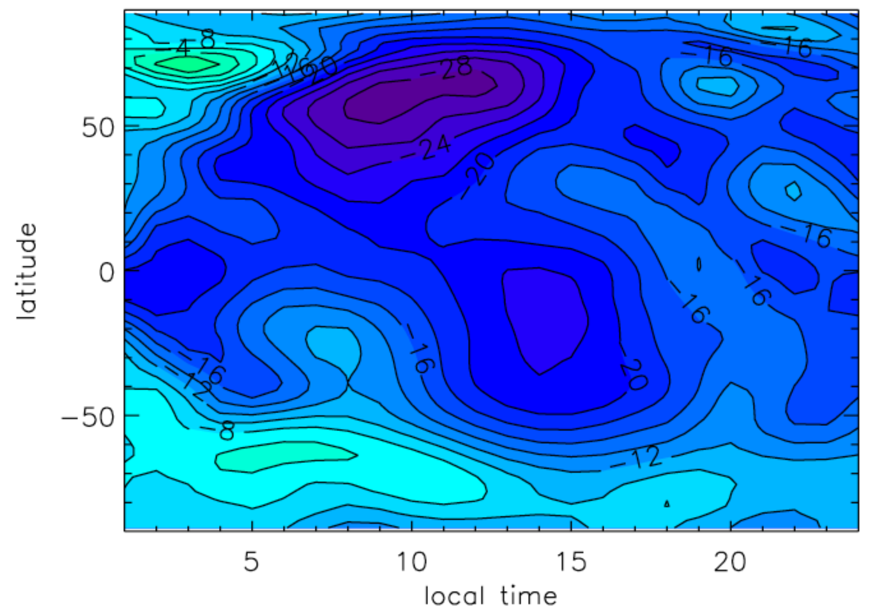
O mixing ratio decrease in percentage at ~270 km. The O decrease at southern midlatitudes around 15 UT is coincident with the TEC and O/N2.

N2 mixing ratio increase in percentage at ~270 km. N2 incre peaking at ~50N around 10 LST. increases around 15 LST.

4. Increase of upwelling in the thermosphere

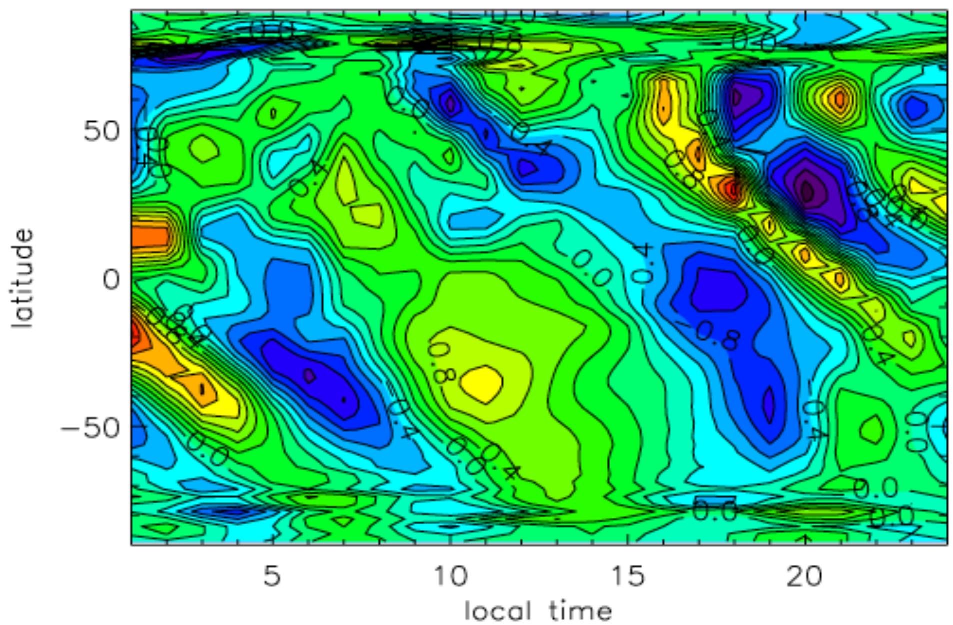
global mean vertical wind in the thermosphere increases by 10-20%



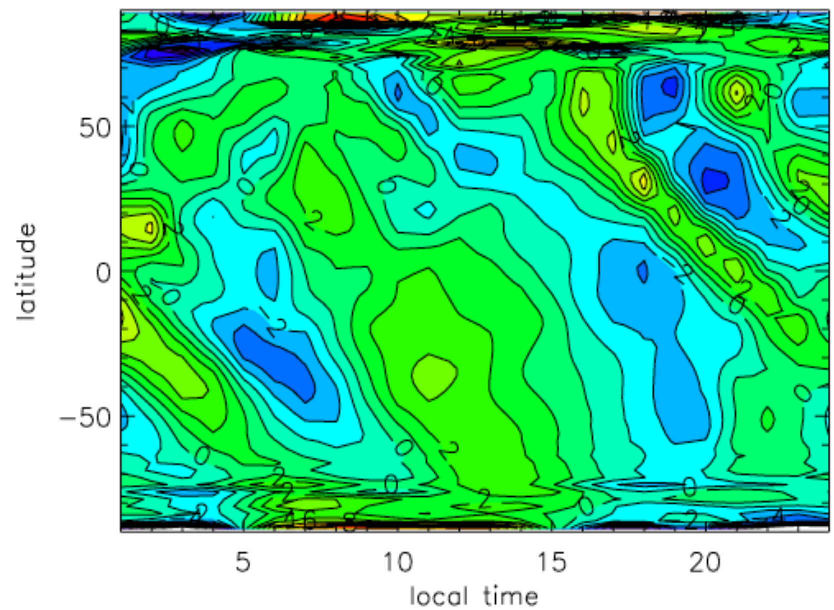


Vertical wind increase most of the day, especially in the afternoon. There is a delay between the change of vertical wind and O/N2.

5. Change of horizontal wind divergence caused by the QTDW



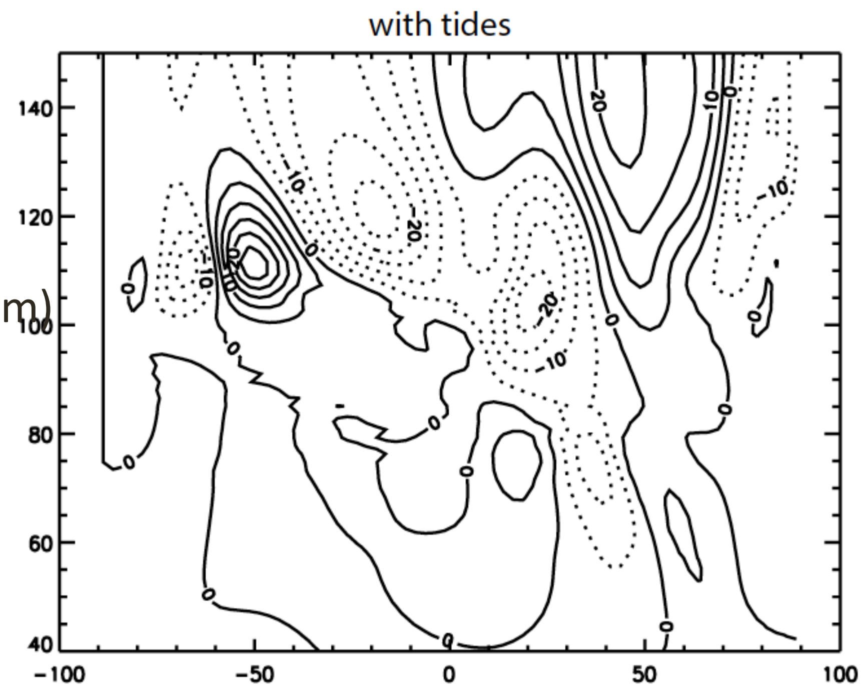
Vertical wind



Horizontal wind divergence dU/dx+dV/dy

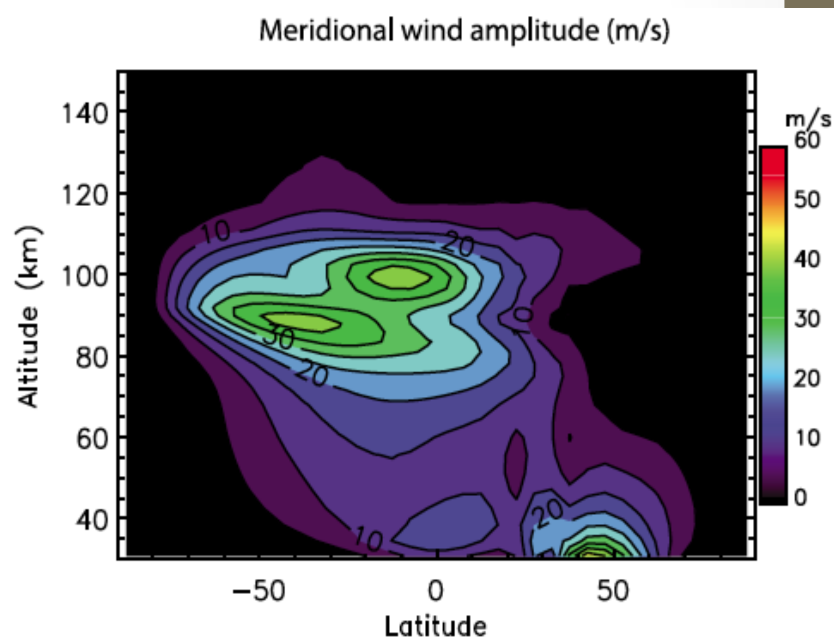
6. Background zonal wind in the E-region is accelerated westward (30 m/s) due to the dissipation of the westward propagating QTDW

Background zonal wind change

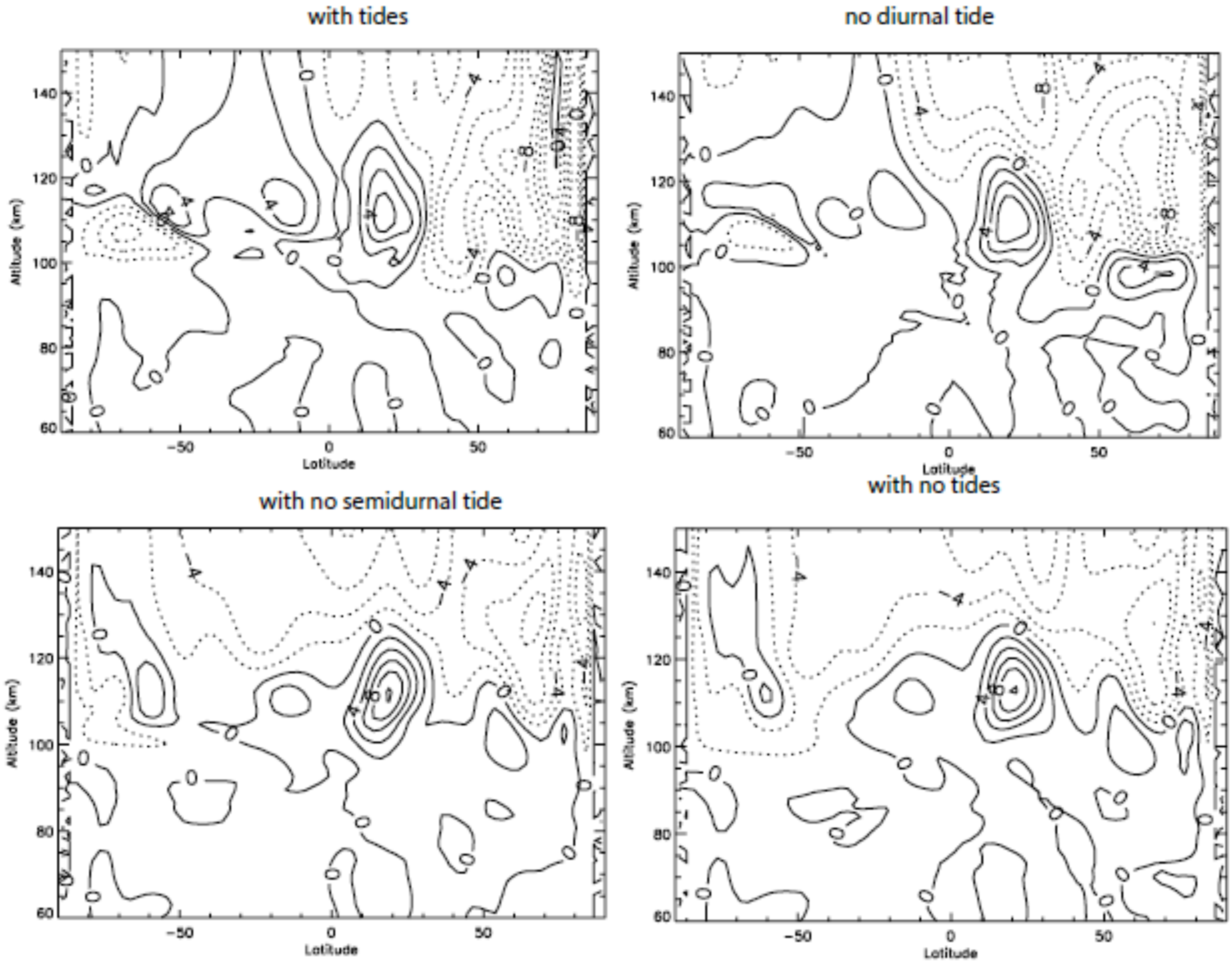


Lat

QTDW damps in the lower thermosphere

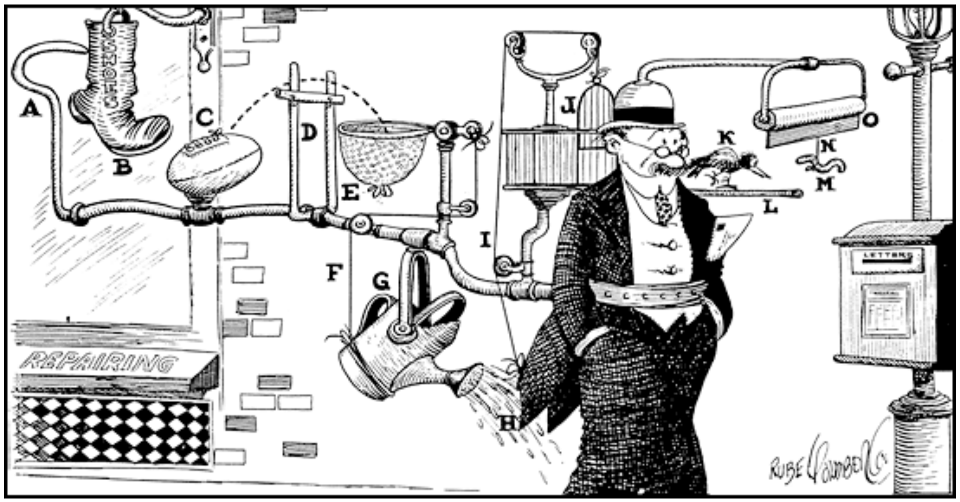


7. Tides changed due to the presence of QTDW



Change of semidiurnal tidal amplitudes
between results with and without the QTDW

Possible mechanism:
thermospheric general circulation is changed, as well as tides by the dissipation of QTDW



Rube Goldberg Machine

A

Forcing in the lower thermosphere by the dissipating QTDW →

B

General circulation and tides changed in the thermosphere →

C

Vertical wind increased →

D

Transport more N_2 and O_2 into higher altitude →

E

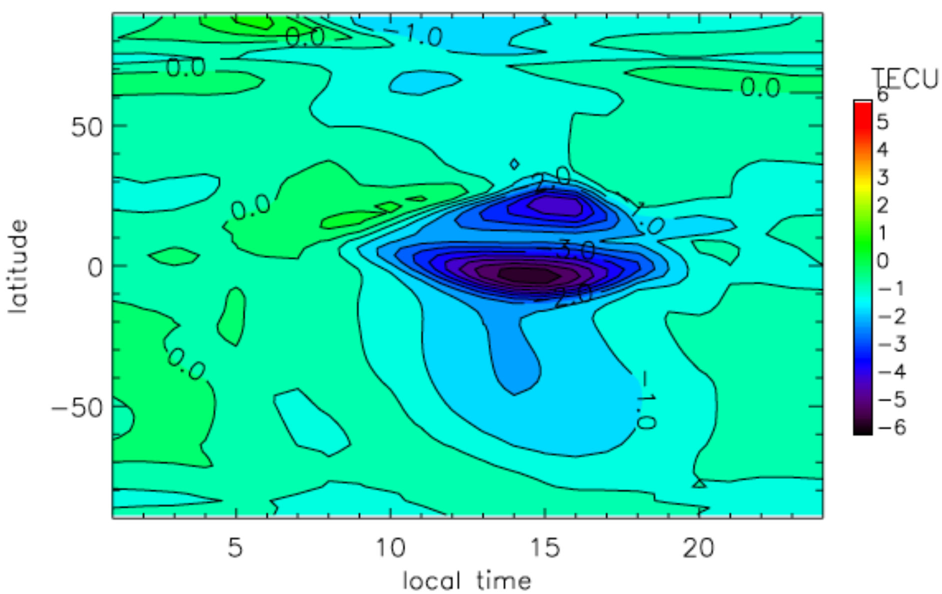
O/N_2 decreases →

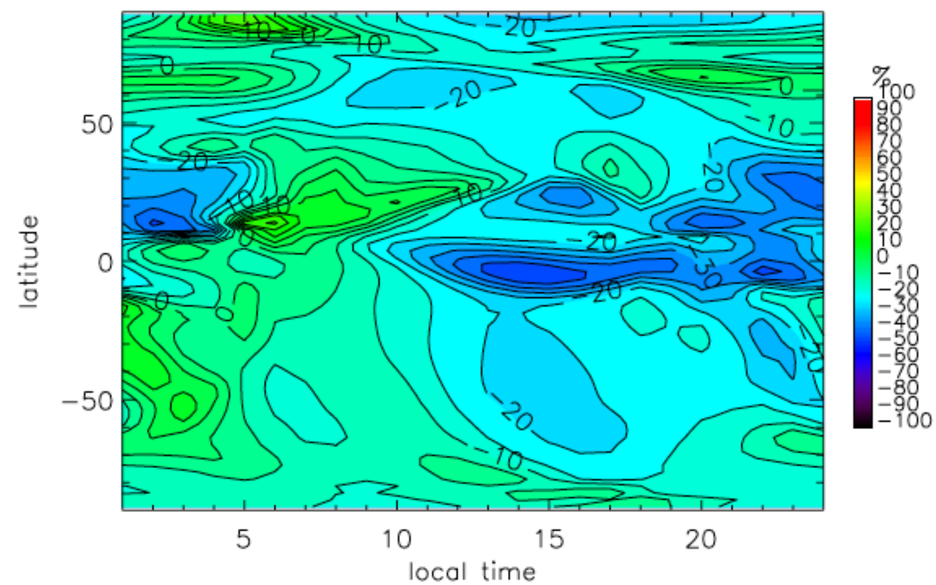
F

Electron density and TEC decrease

1. Decrease of electron density and TEC near EIA

Absolute and relative TEC changes with QTDW forcing minus without QTDW at 15E





Up to 30-40% decrease of TEC at EIA crests

Conclusions

- QTDW/mean wind/tidal interactions in the thermosphere lead to 20-30% decrease of electron density density near the EIA in the afternoon.
- Can the variation of middle atmosphere waves (travelling planetary waves, tides) account for part of the ionospheric and thermospheric day-to-day variability by changing the chemical composition besides via electrondynamics?