



武汉大学

Upper atmospheric responses to tidal and planetary waves

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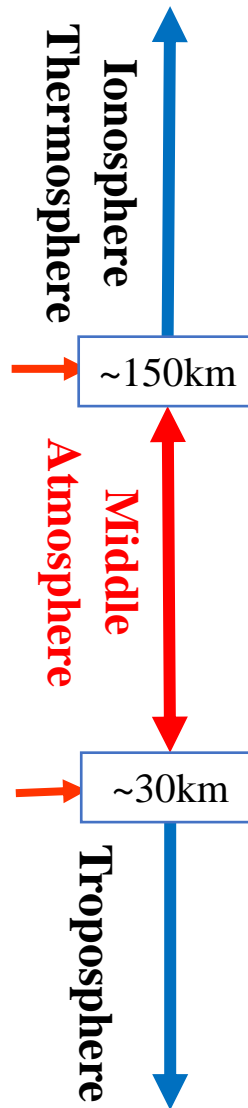
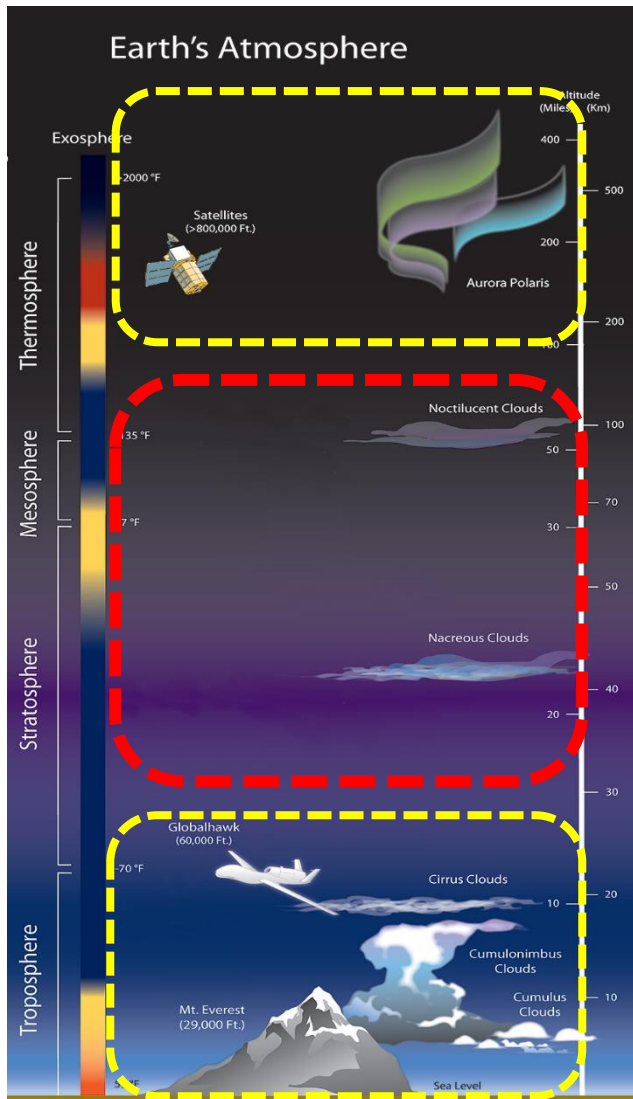


Outline

- Tidal and planetary waves
- Impact on the upper atmosphere
- Summary



Tidal and planetary waves



◆ Ionosphere and Thermosphere (IT) System

- Solar and Geomagnetic forcing
- **Lower atmospheric forcing**

- Tides
- Planetary waves

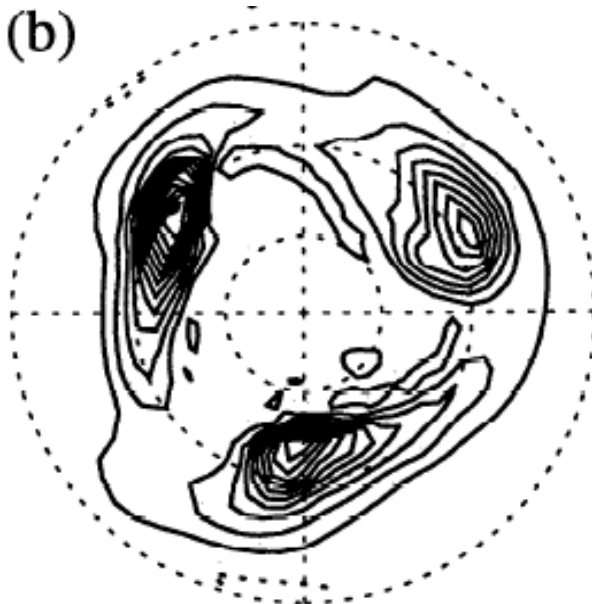
- Gravity waves
- Earthquakes
- ENSO

Example of planetary waves

Quasi-2 day wave

Zonal Wavenumber 3

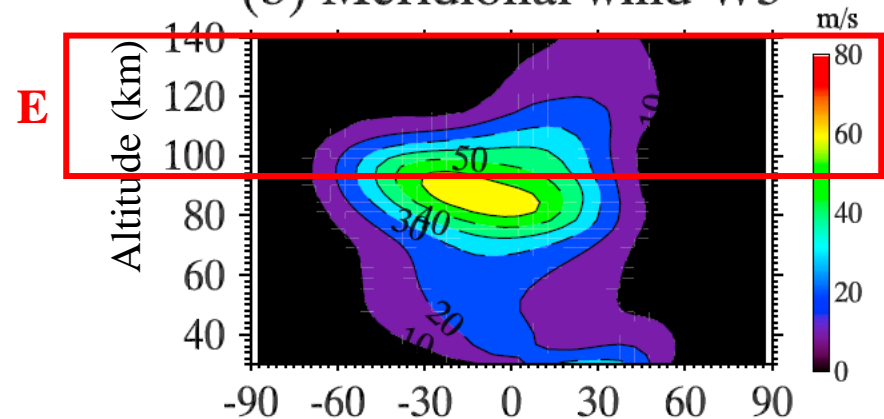
(b)



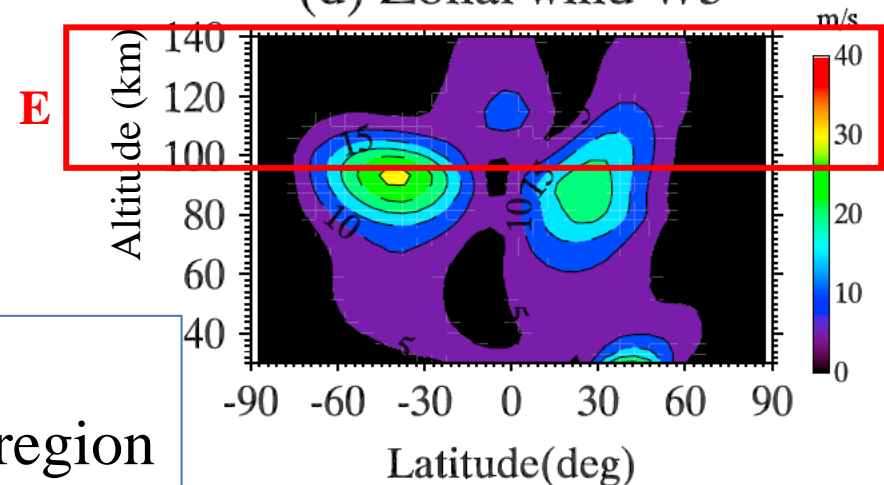
(Norton and Thuburn, GRL, 1996)

Wave Amplitude

(b) Meridional wind W3



(d) Zonal wind W3



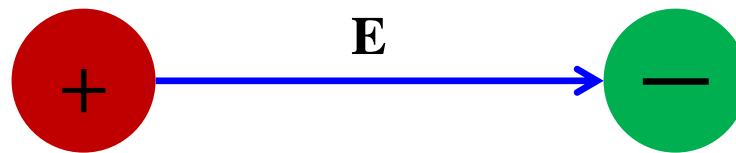
- Global scale oscillations
- Large wind amplitudes in the E region

E region wind dynamo

Wind-driven Hall currents: $J_x^{W,H} = \sigma_H u B$

Wind-driven Pedersen currents: $J_x^{W,P} = -\sigma_P v B \sin I$

The convergence of the wind-driven zonal current determines the accumulation of polarization charges, resulting in polarization electric field and thus ion vertical drift. (Liu et al., 2010)



$$\mathbf{W}_i = \mathbf{E} \times \mathbf{B}$$



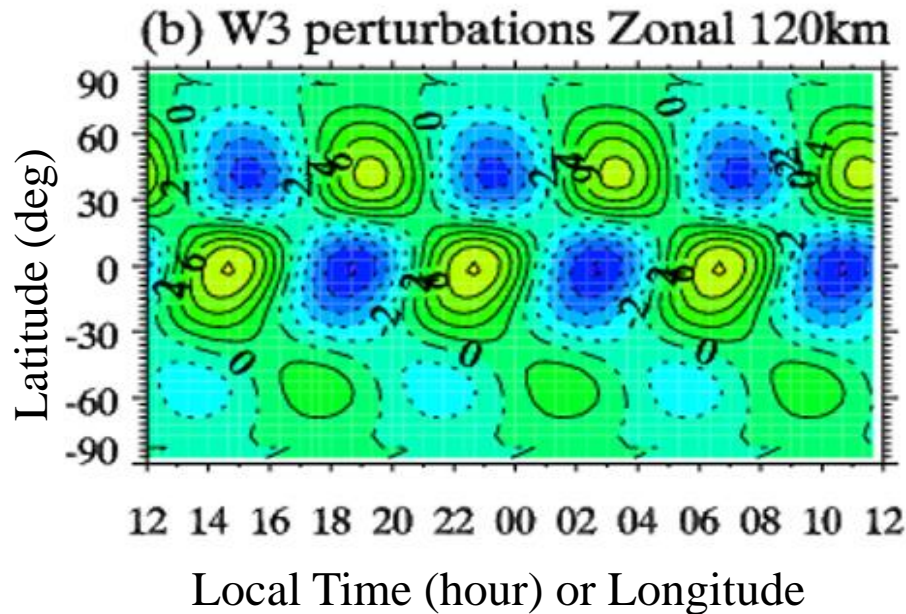
Impact on the upper atmosphere

The Ionosphere and Thermosphere System could be impacted by tidal and planetary wave at least by:

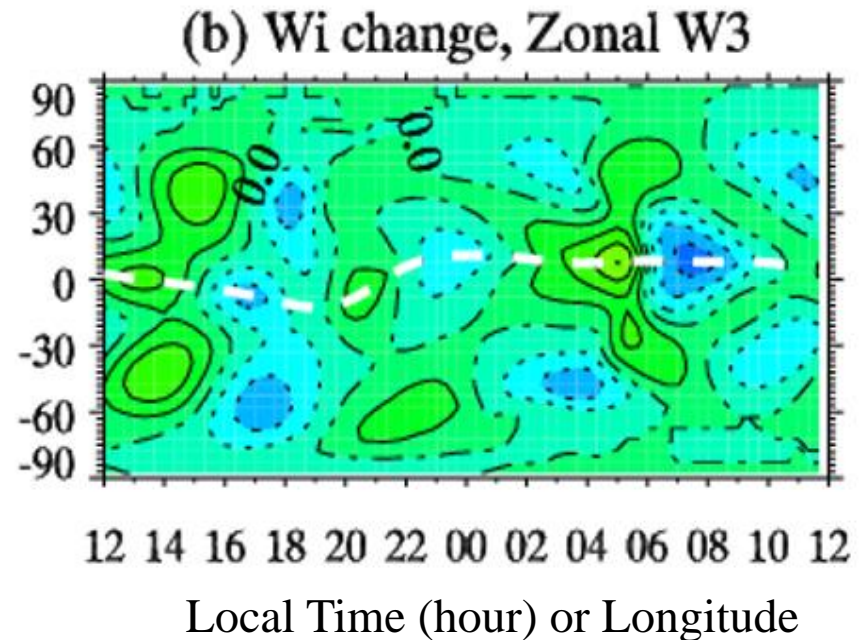
1. Modulation on the E region wind dynamo
 - Strong wind perturbations
2. Direct propagations
 - Long vertical wavelength
3. Change of residual circulations
 - Momentum deposition to the background
4. Nonlinear interactions
 - Making the upper mechanisms more complicated

Modulation on the E region wind dynamo

wind perturbations of W3 Q2DW



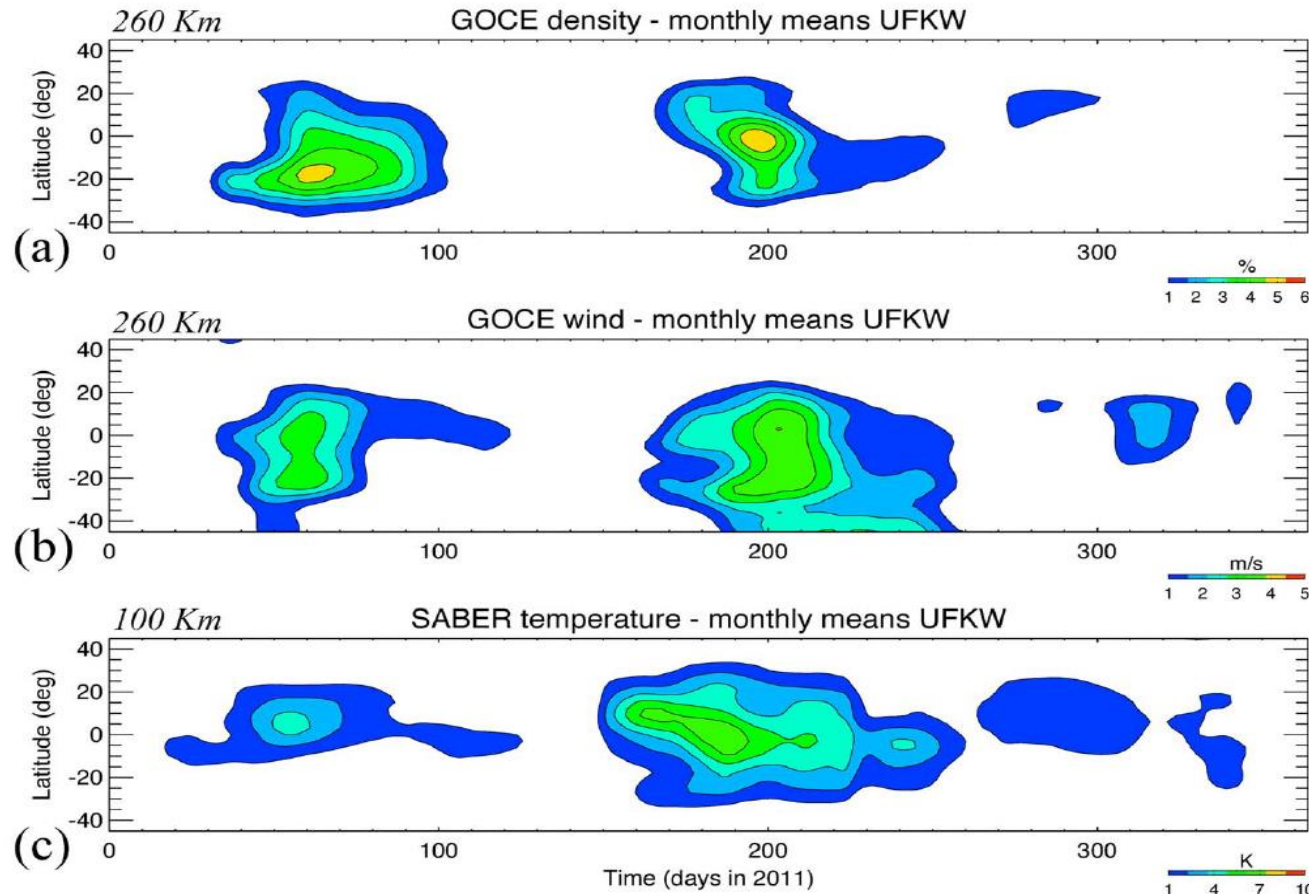
vertical ion drift perturbations



- Zonal wavenumber 3 structure in both wind and ion drift perturbations
- Consistent latitudinal structures with three peaks at middle latitudes and equator

Direct propagation

Ultra-Fast Kelvin Wave



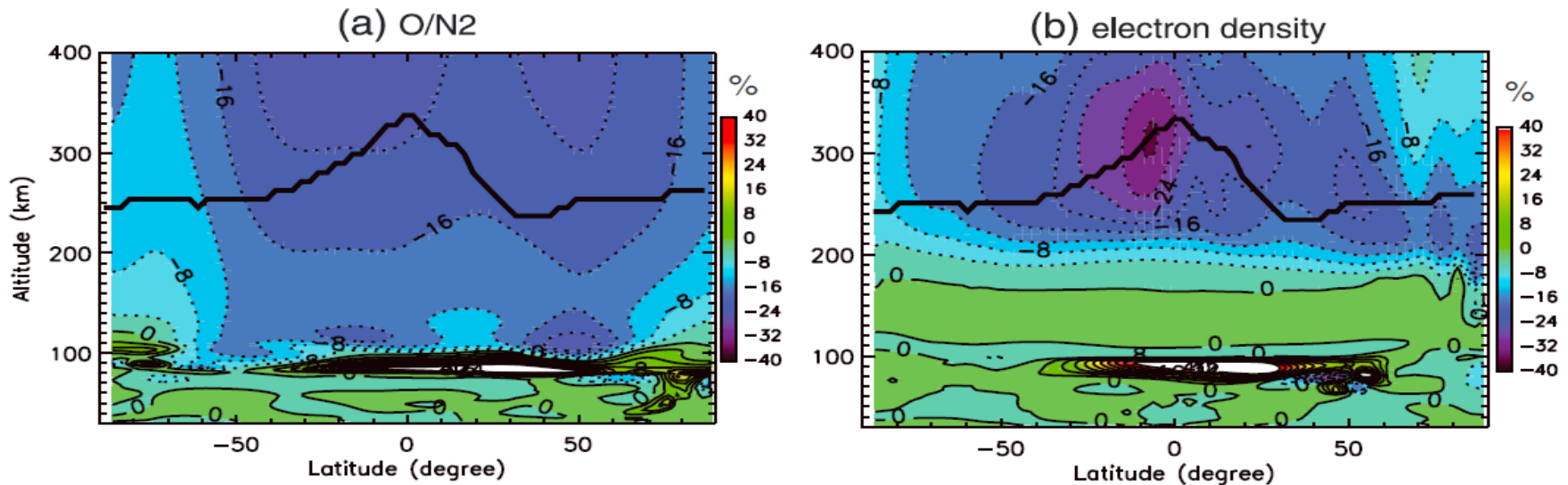
260km
Density

260km
wind

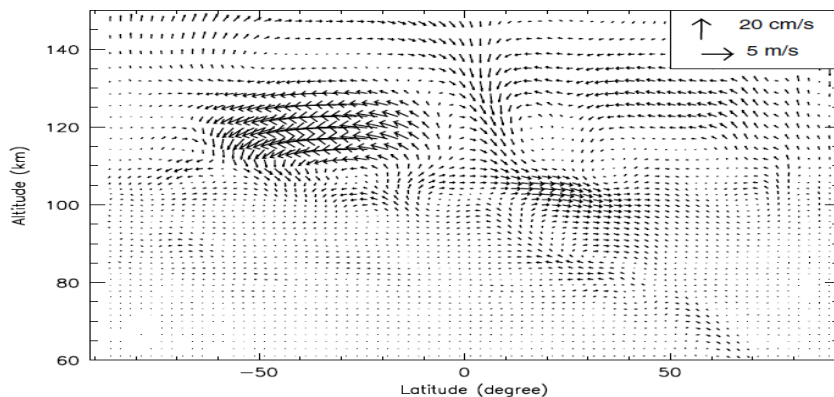
100km
Temperature

Strong evidence for the direct propagation of planetary waves from the mesosphere to thermosphere (Gasperini et al., 2015).

Change of mean circulations



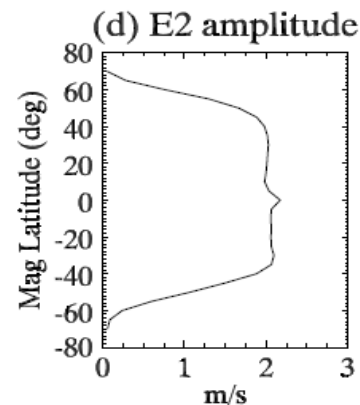
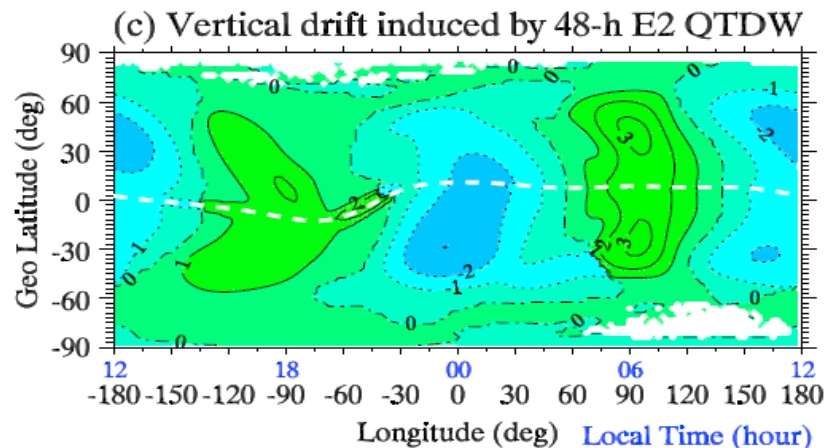
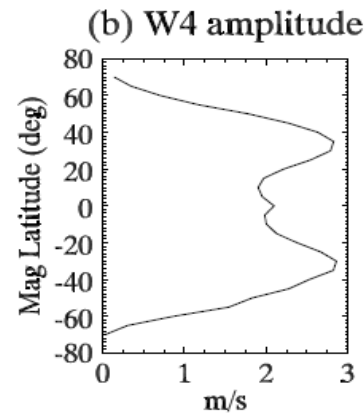
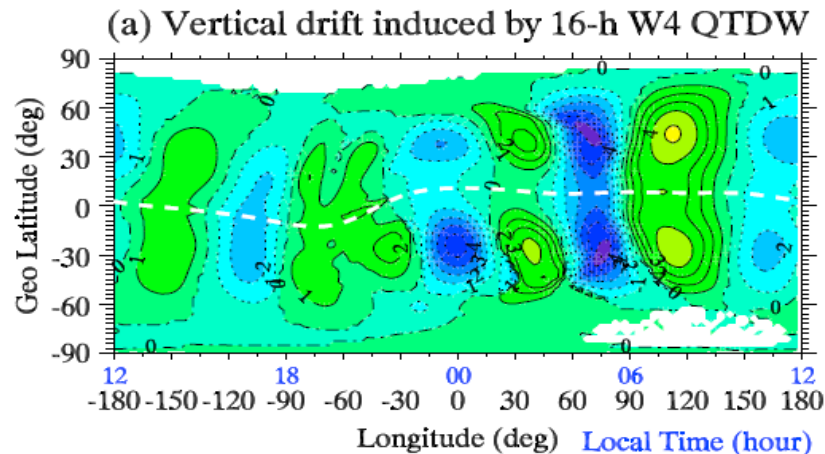
The Q2DW result in reduction of O/N2 and electron density



Change of mean circulation

TIME-GCM simulation results of the thermospheric composition change due to Q2DW. (Yue et al. 2014)

Nonlinear interactions



- Child wave induced ion drift
- Parent wave induced ion drift changes

The nonlinear interaction between W3 Q2DW and W1 diurnal tide results in additional variability in ionospheric vertical ion drift.



Summary

- Tidal and planetary waves are important sources for the variability of the upper atmosphere.
- The mechanisms include E region wind dynamo, direct propagation, as well as the change of mean circulation.
- The variability of the I-T system is complicated by the nonlinear interaction between tides and planetary waves.