Coherent seasonal, annual, and quasibiennial variations in ionospheric tidal/ SPW amplitudes

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Control of equatorial ionospheric morphology by atmospheric tides

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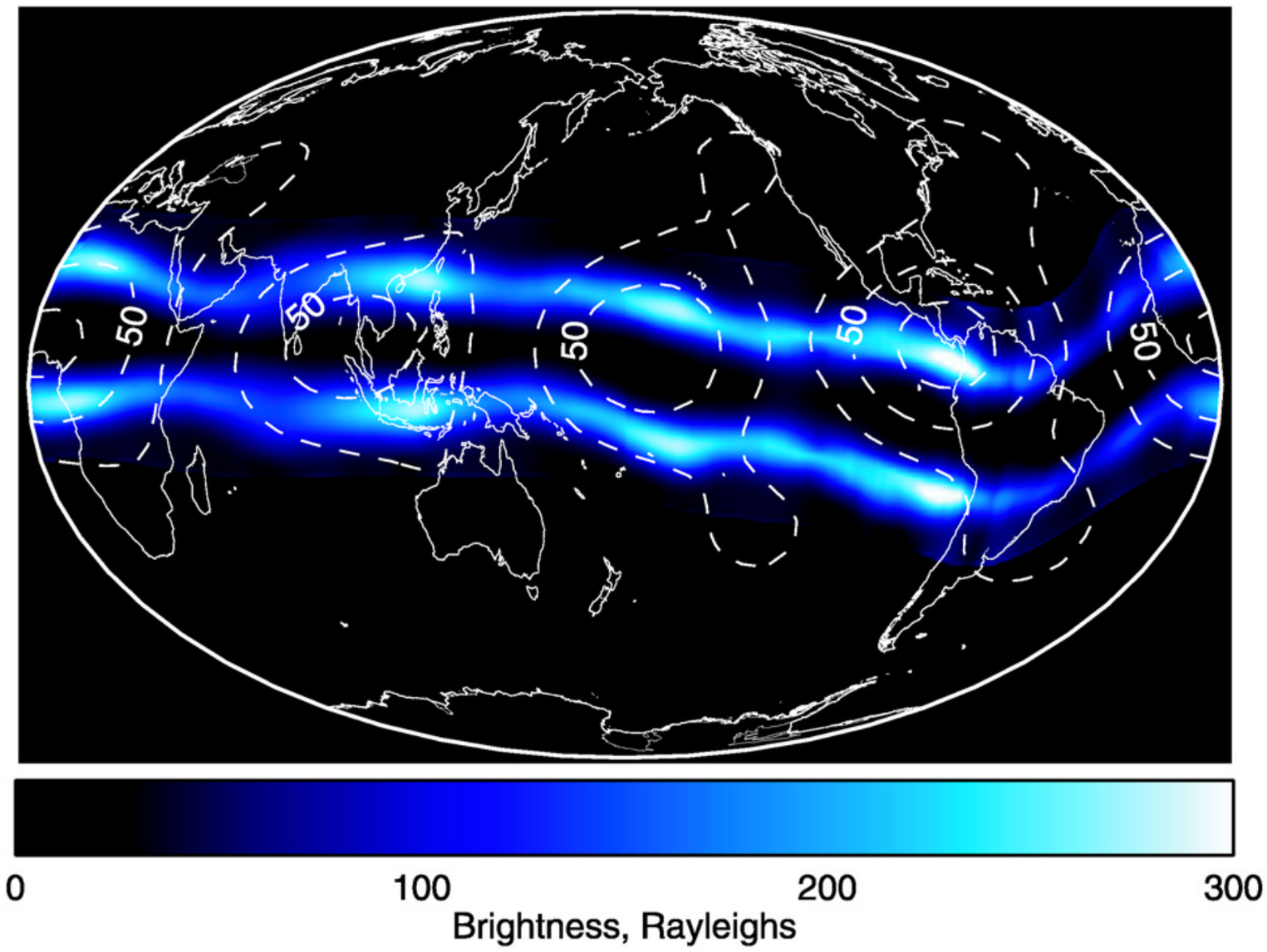
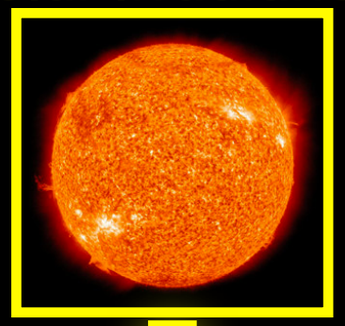
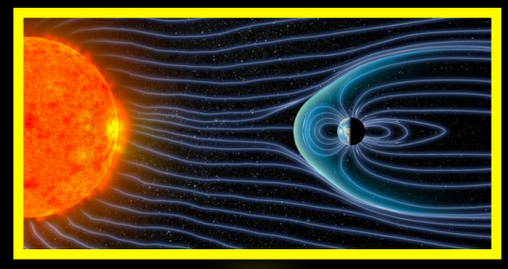
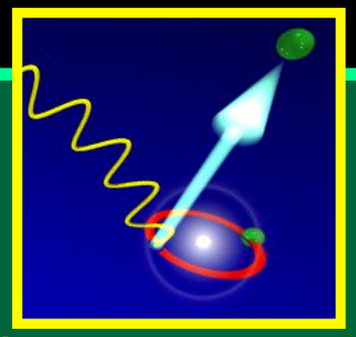


Solar Irradiance



Solar Wind



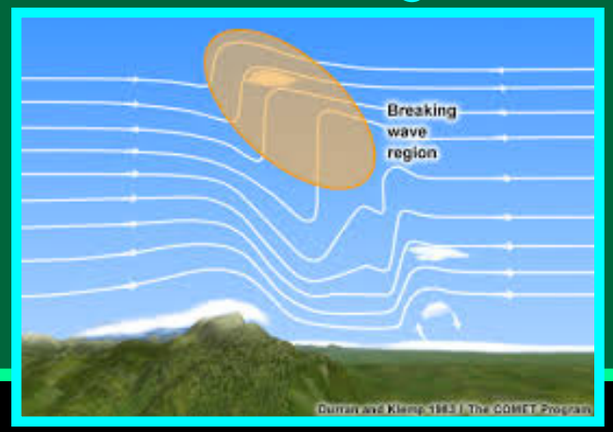


Photoionization

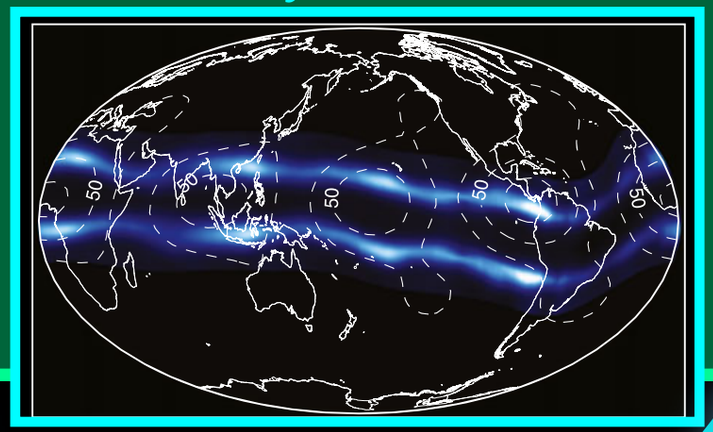
Geomagnetic Storms

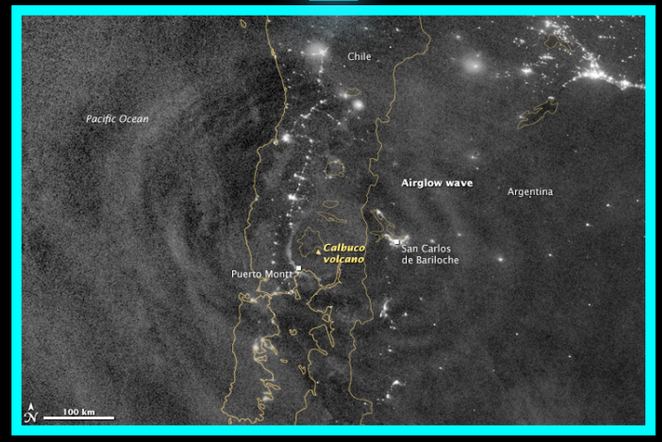
IONOSPHERE

Breaking

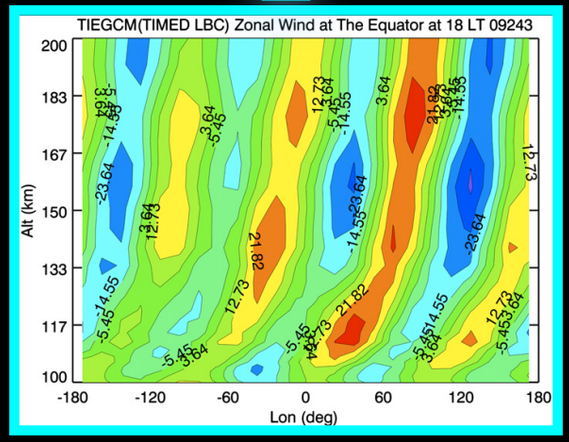


Dynamo

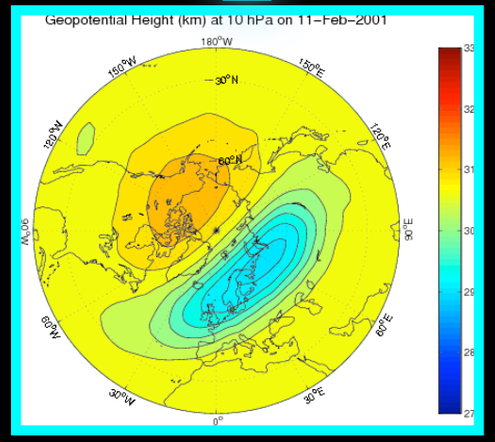




Gravity waves

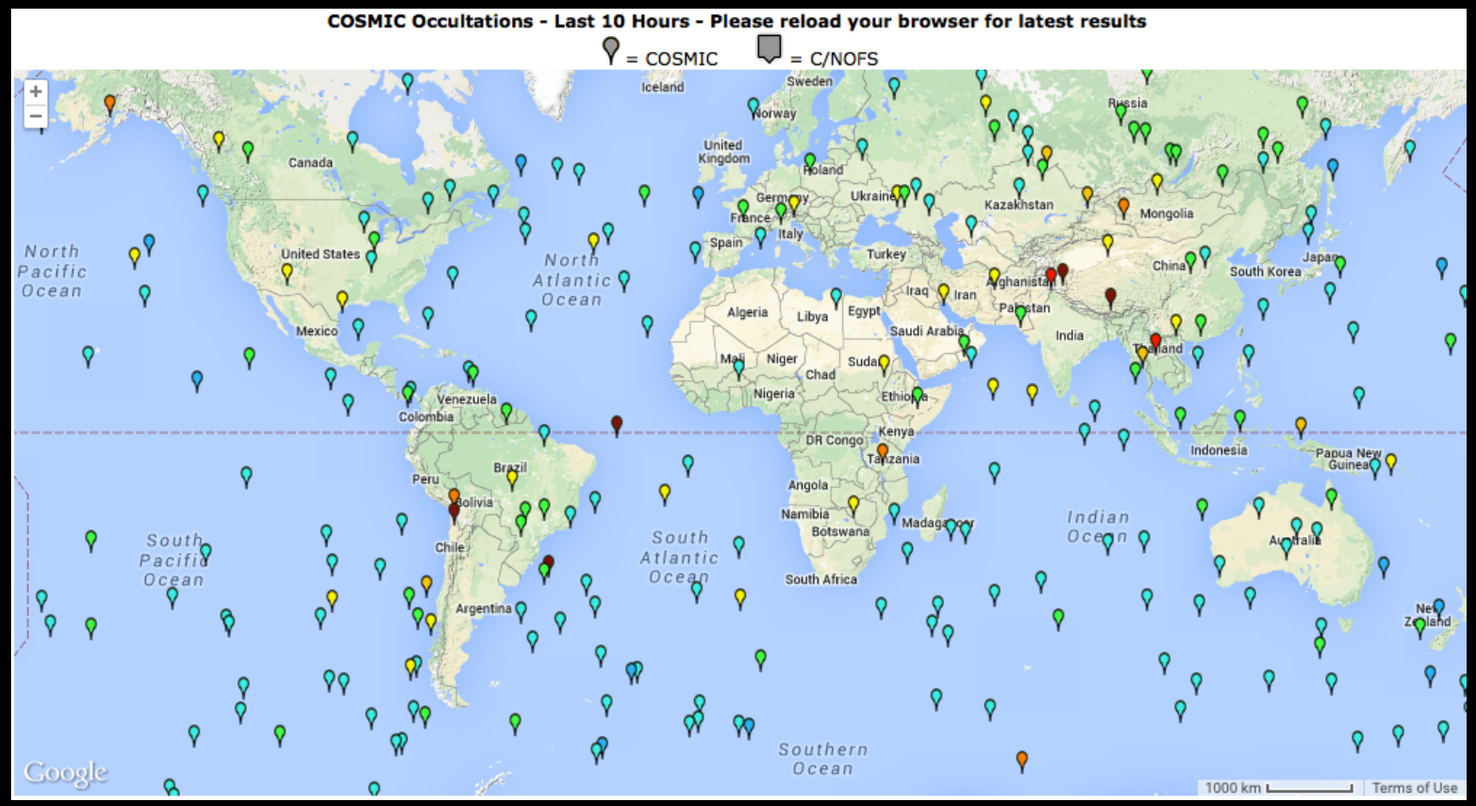


Tides

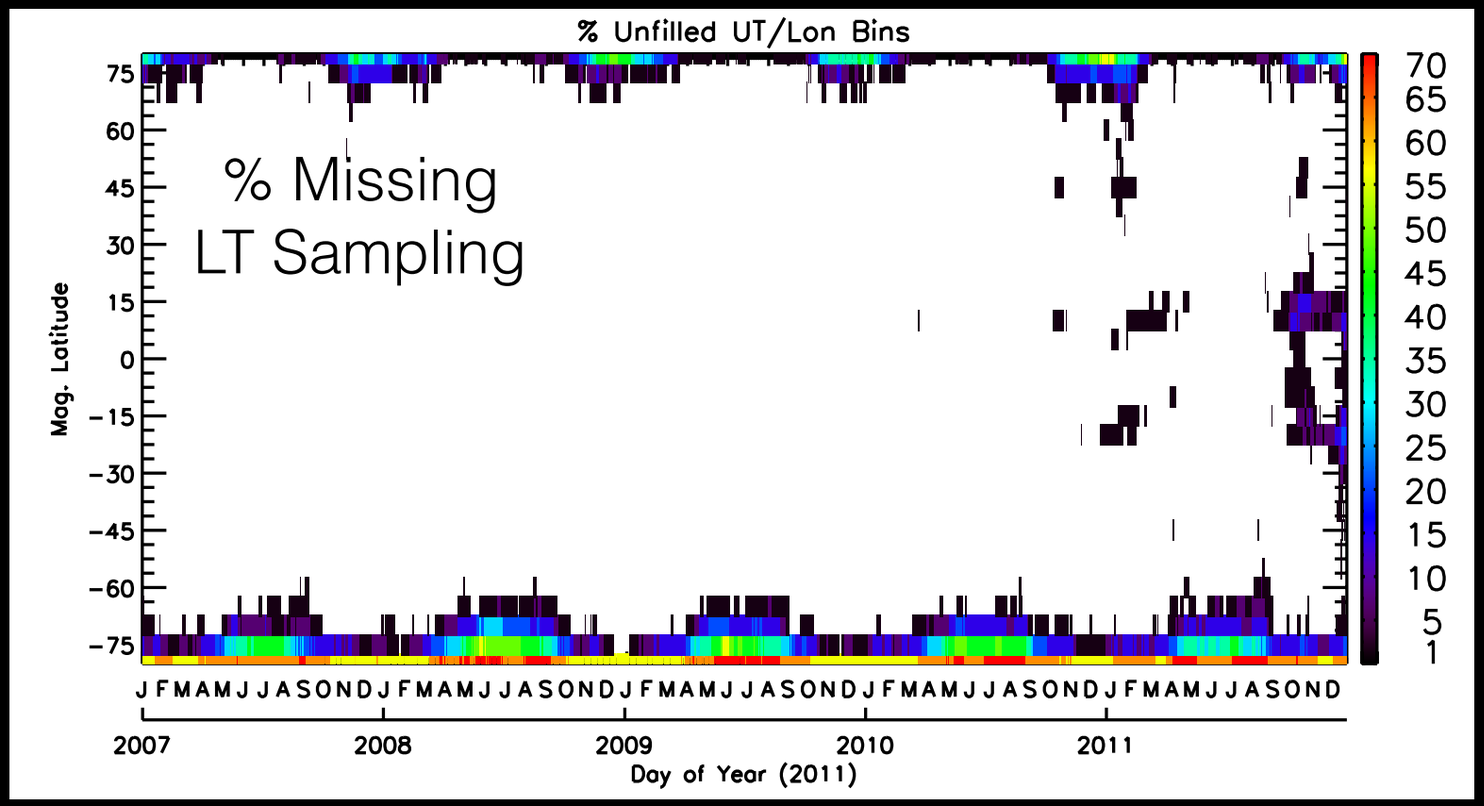


Planetary Waves

FORMOSAT-3/COSMIC

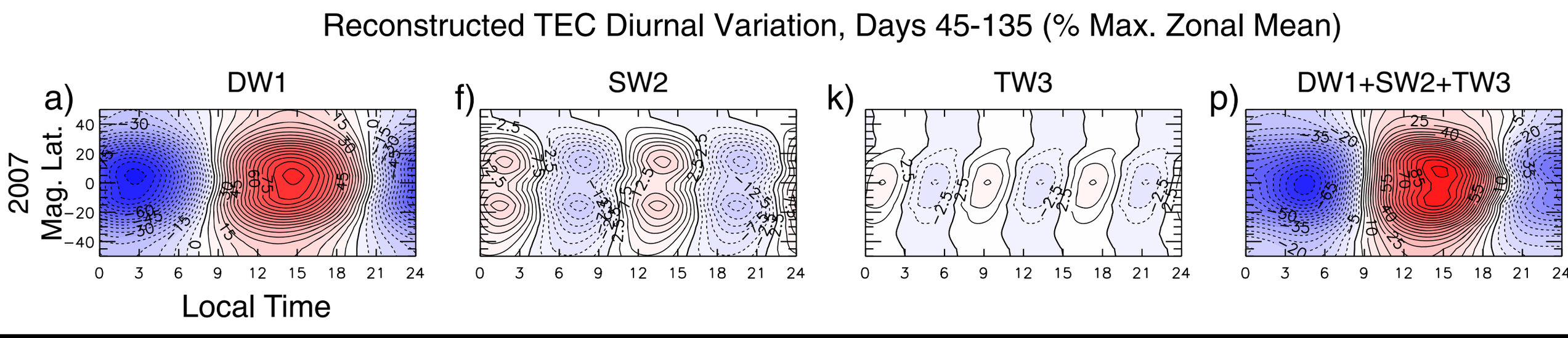


Electron densities from 2007 - 2013 FORMOSAT-3/COSMIC occultations vertically integrated from 200 - 800 km

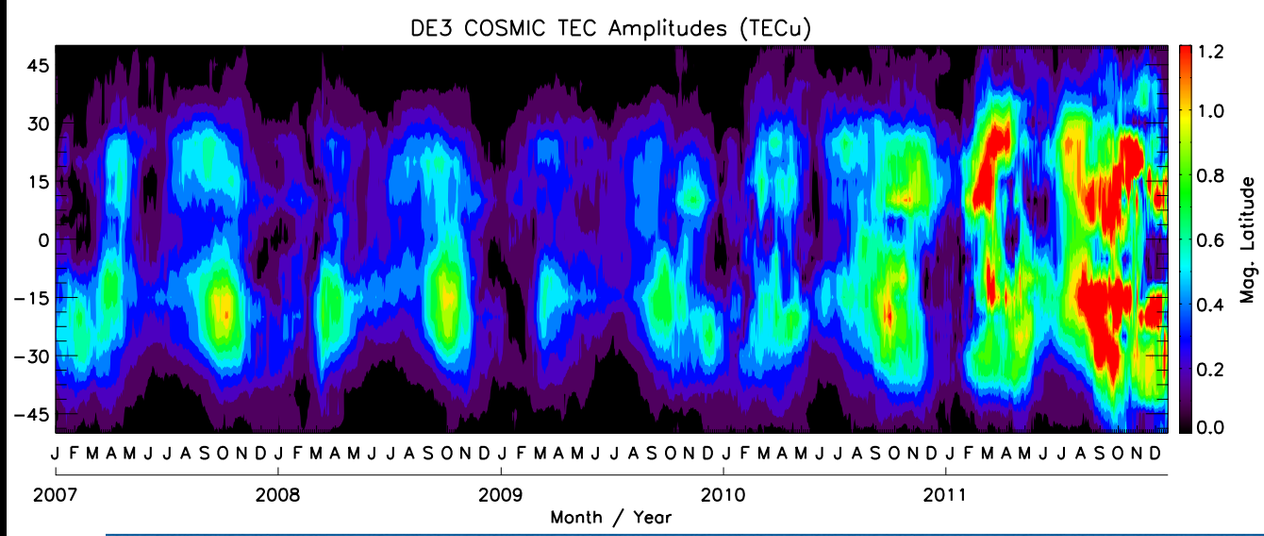


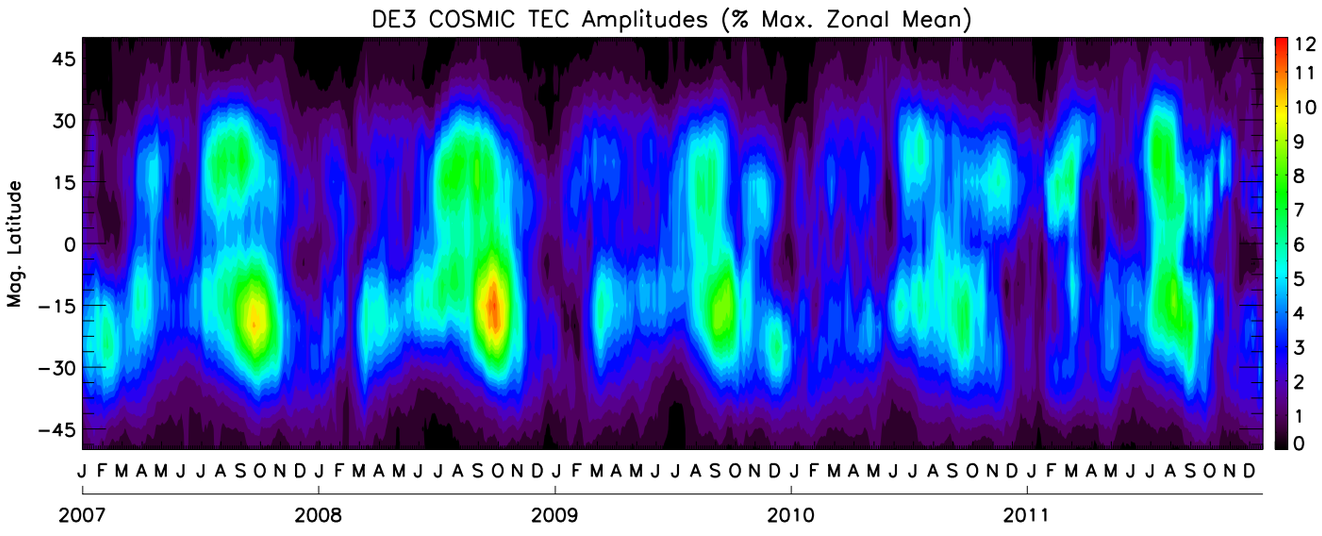
Local time sampling (40 day integration time) sufficient for resolution of zonal wavenumber up to $|s| = 4$, for diurnal, semidiurnal, terdiurnal, and stationary planetary wave (SPW) components in low and mid magnetic latitudes.

Zonal Mean Ionospheric Local Time Variation (Migrating Tides)



Vertical Coupling from E Region Dynamo (DE3)

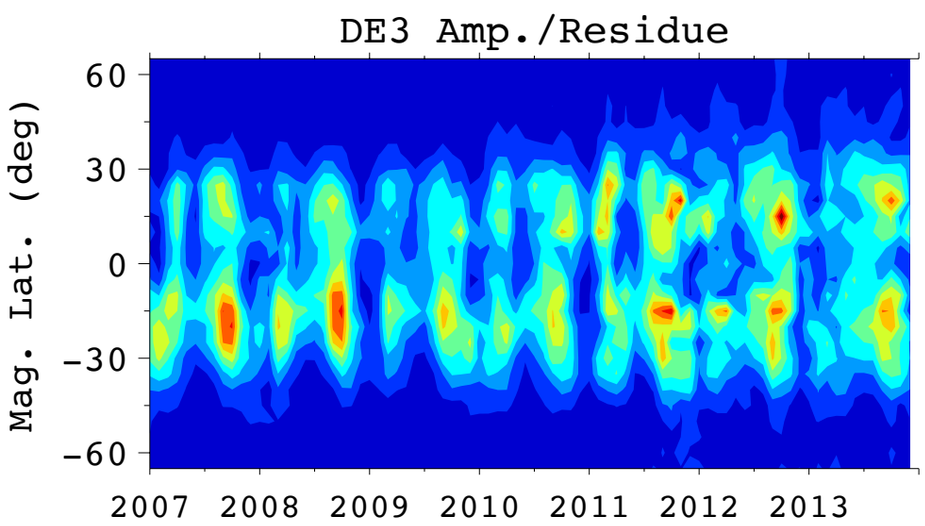


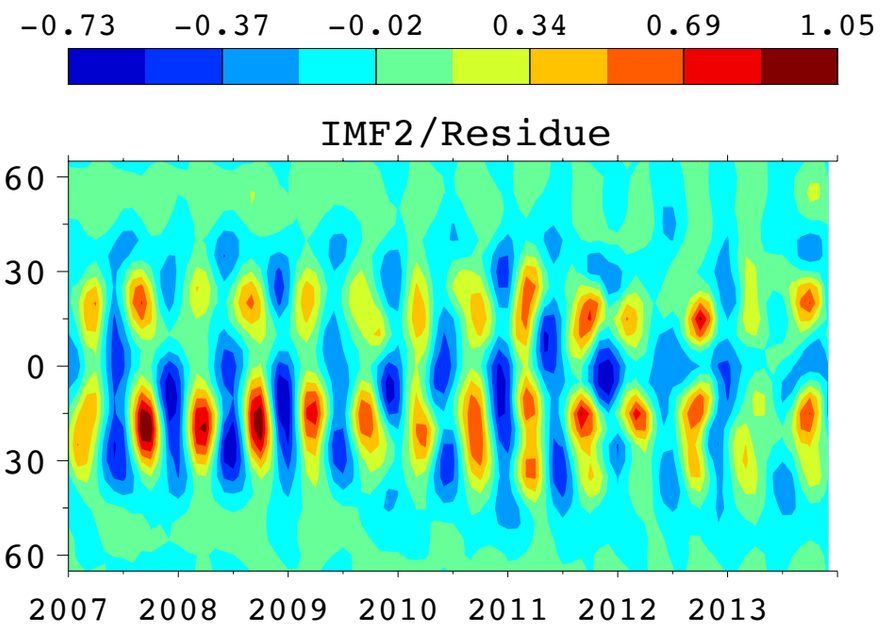


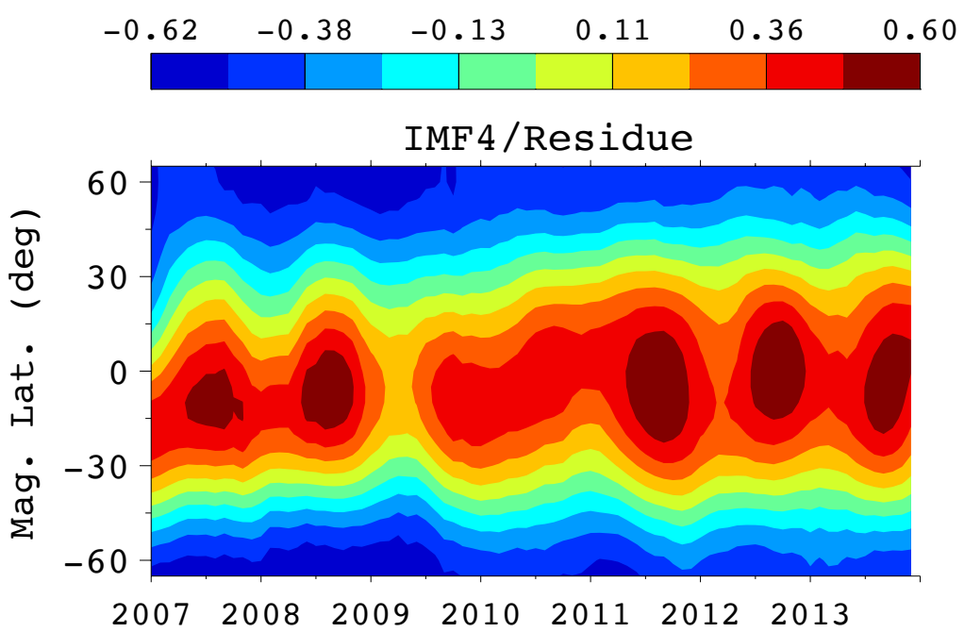
How do these effects vary over seasonal and inter annual time scales?

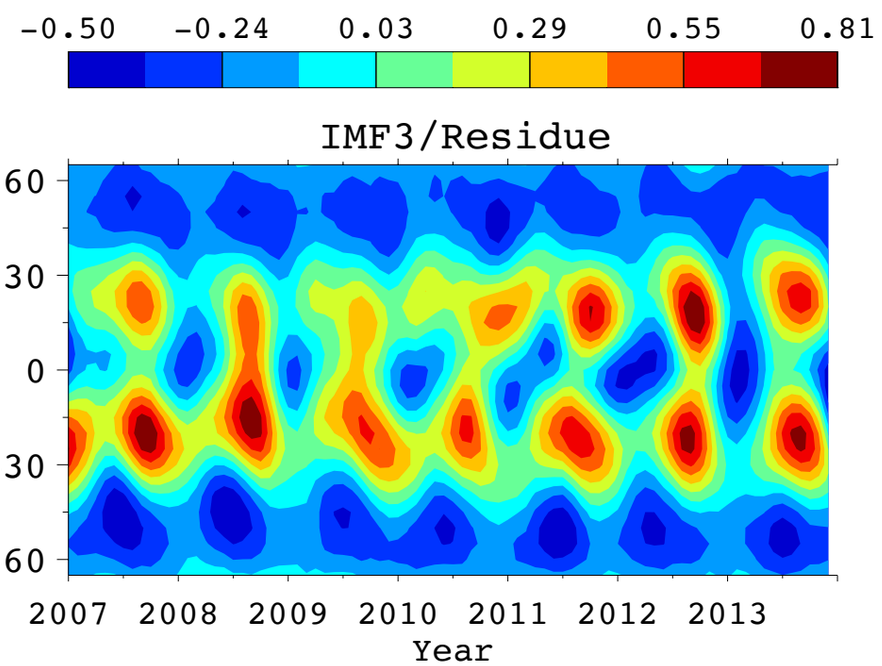
Latitude / Time amplitude trends decomposed using Multi-dimensional Ensemble Empirical Mode Decomposition (MEEMD).

COSMIC DE3 (Dynamo Coupling)

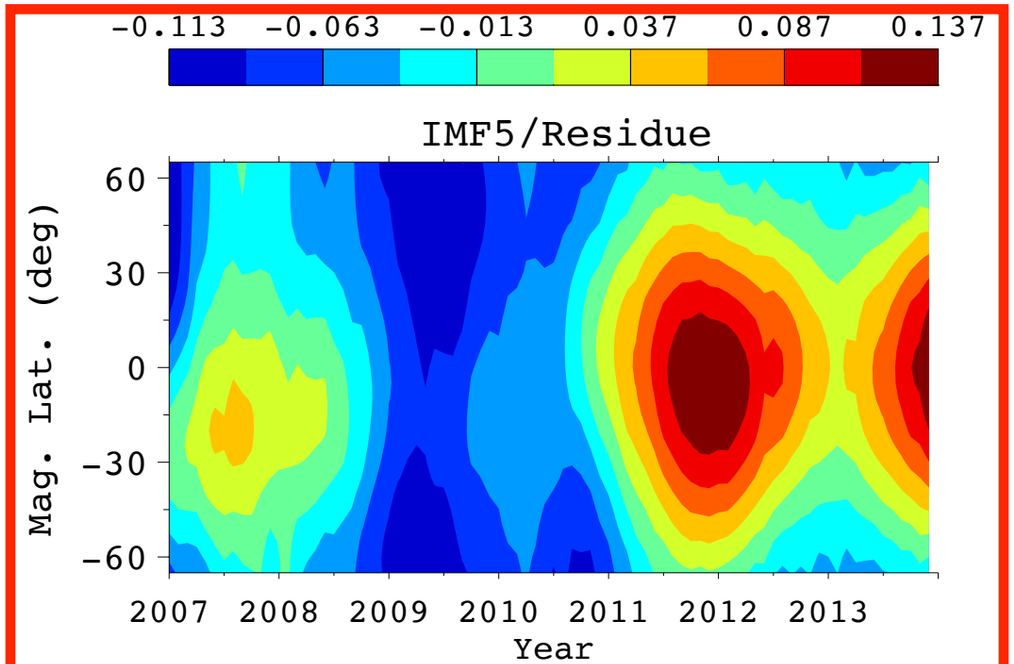




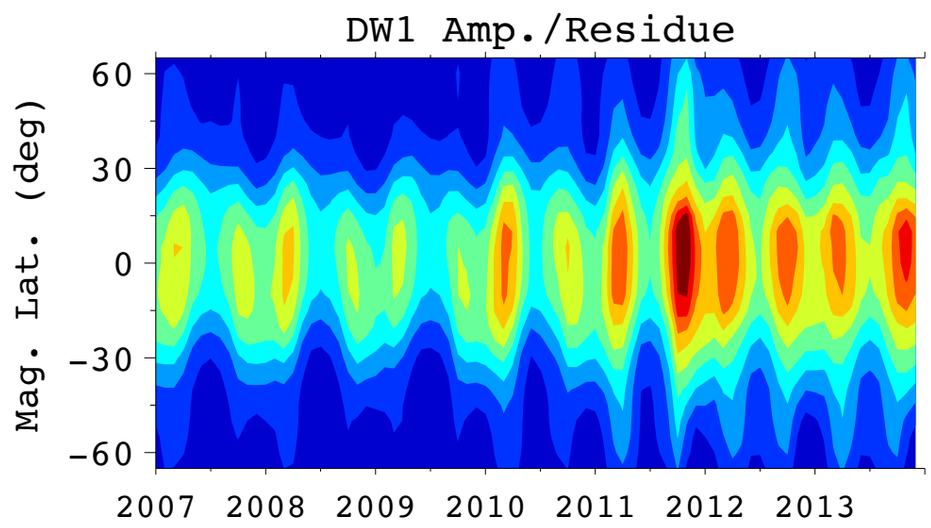




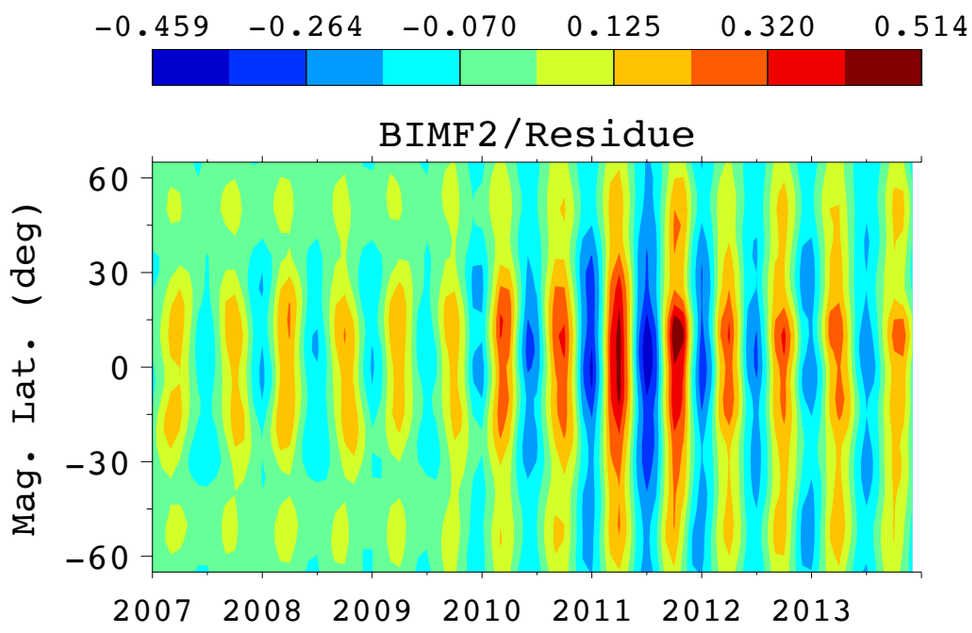
Ionosphere QBO

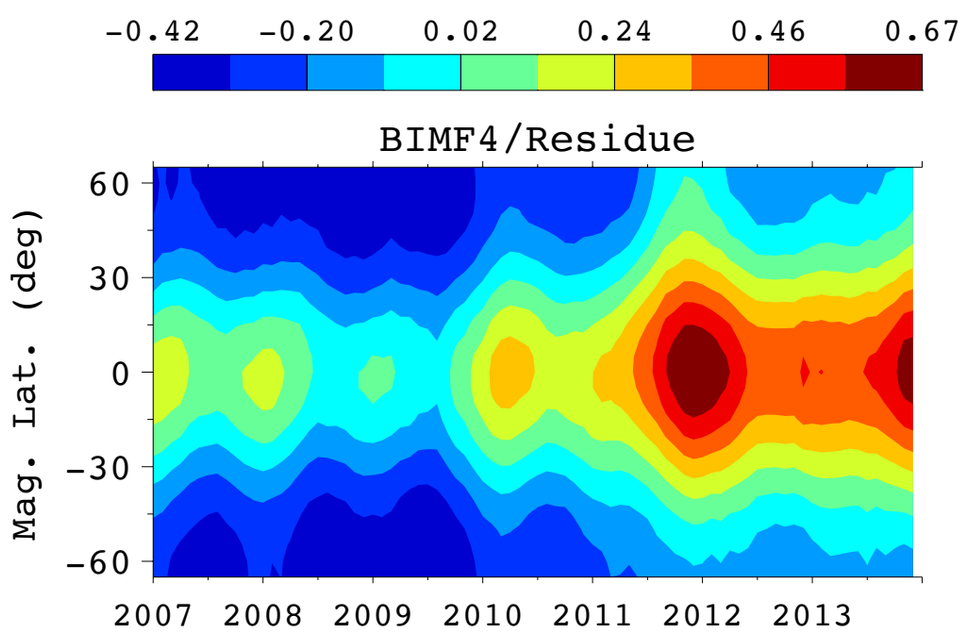


COSMIC DW1 (Photoionization)

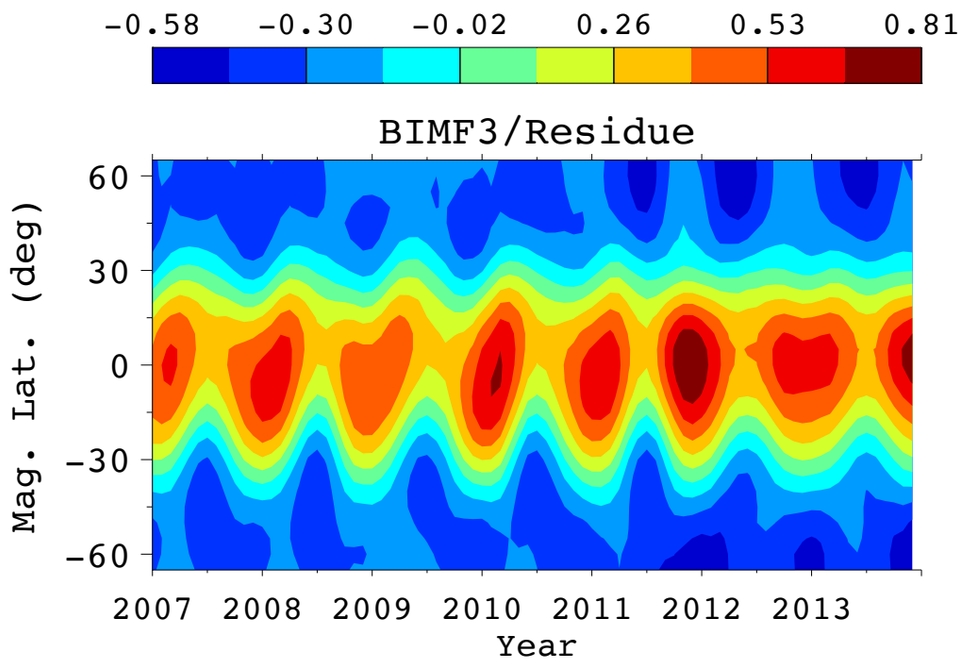


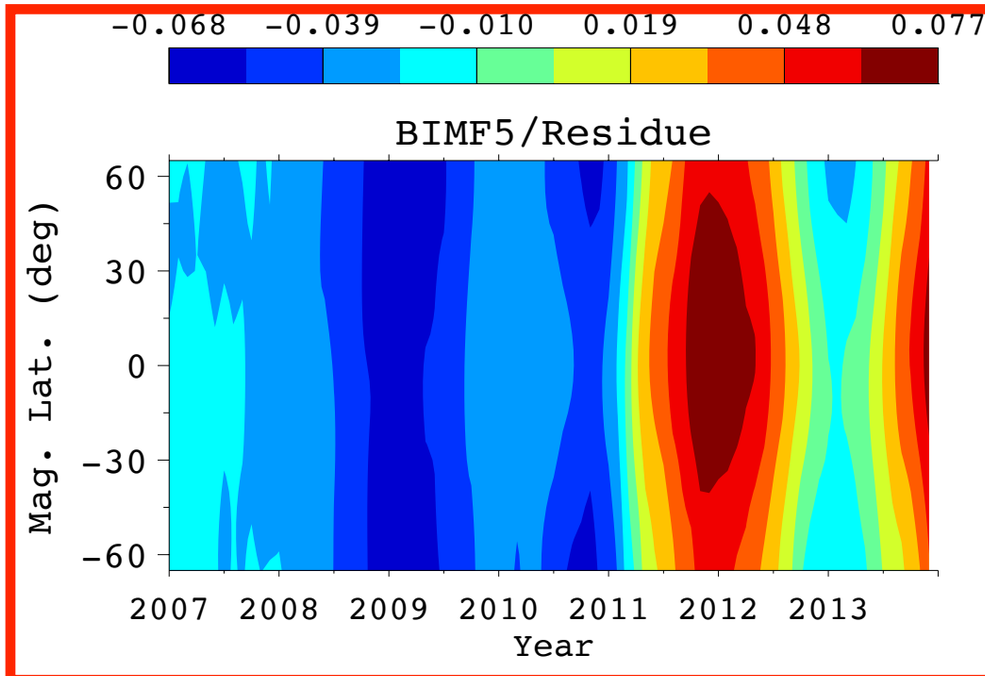
Quasi-Biennial Osccillation present for both in-situ and vertical coupling induced ionospheric tides.





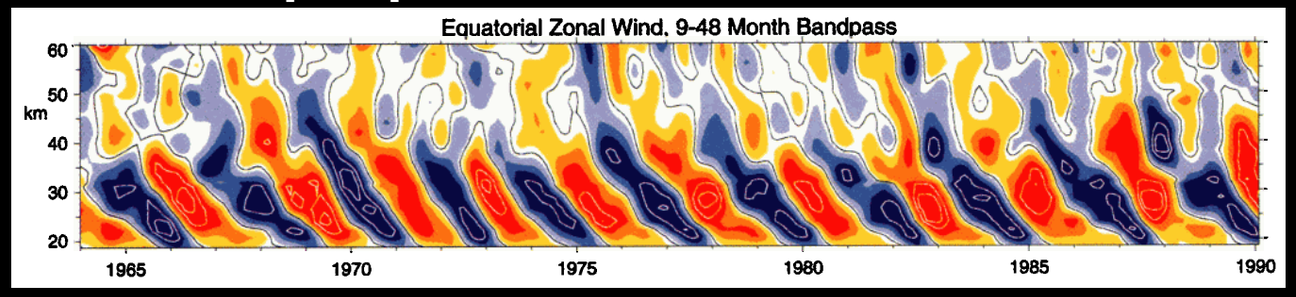
Ionosphere QBO

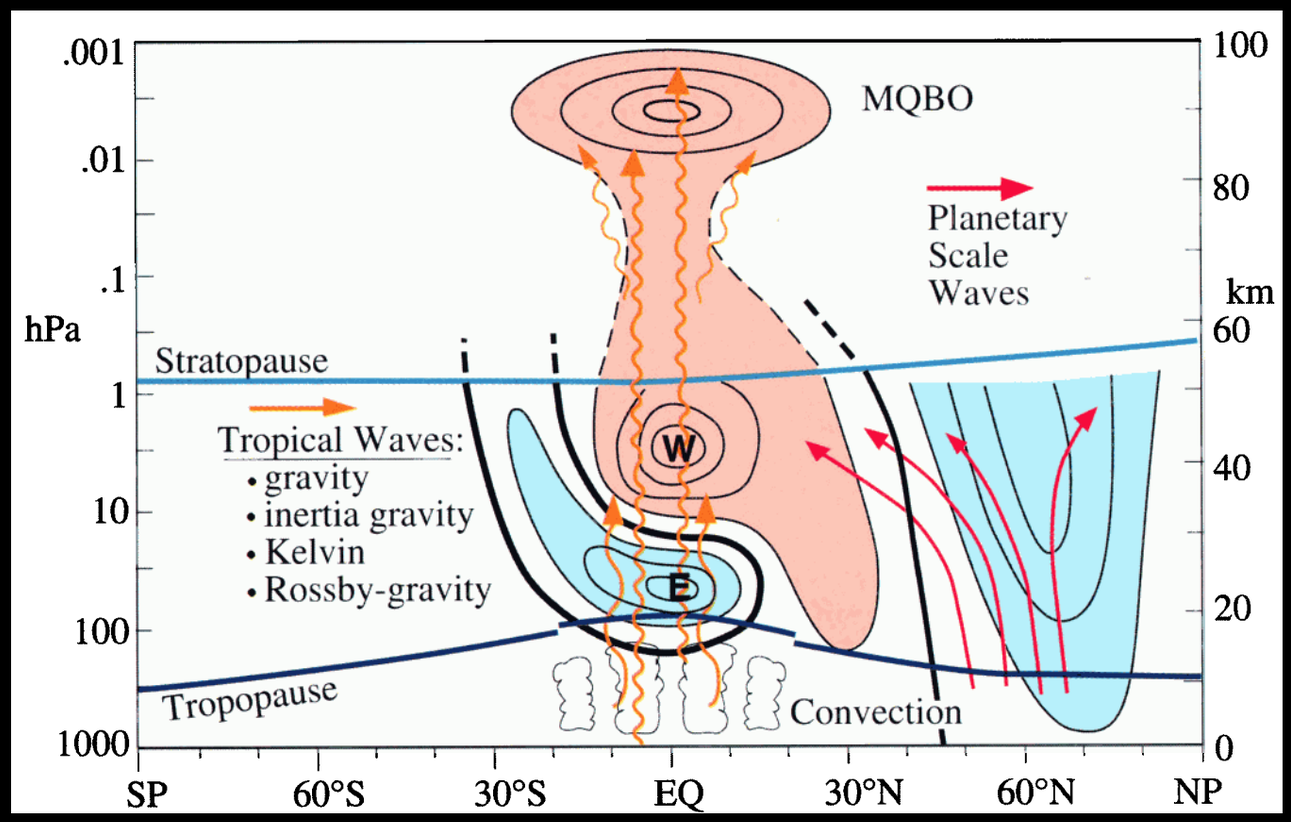


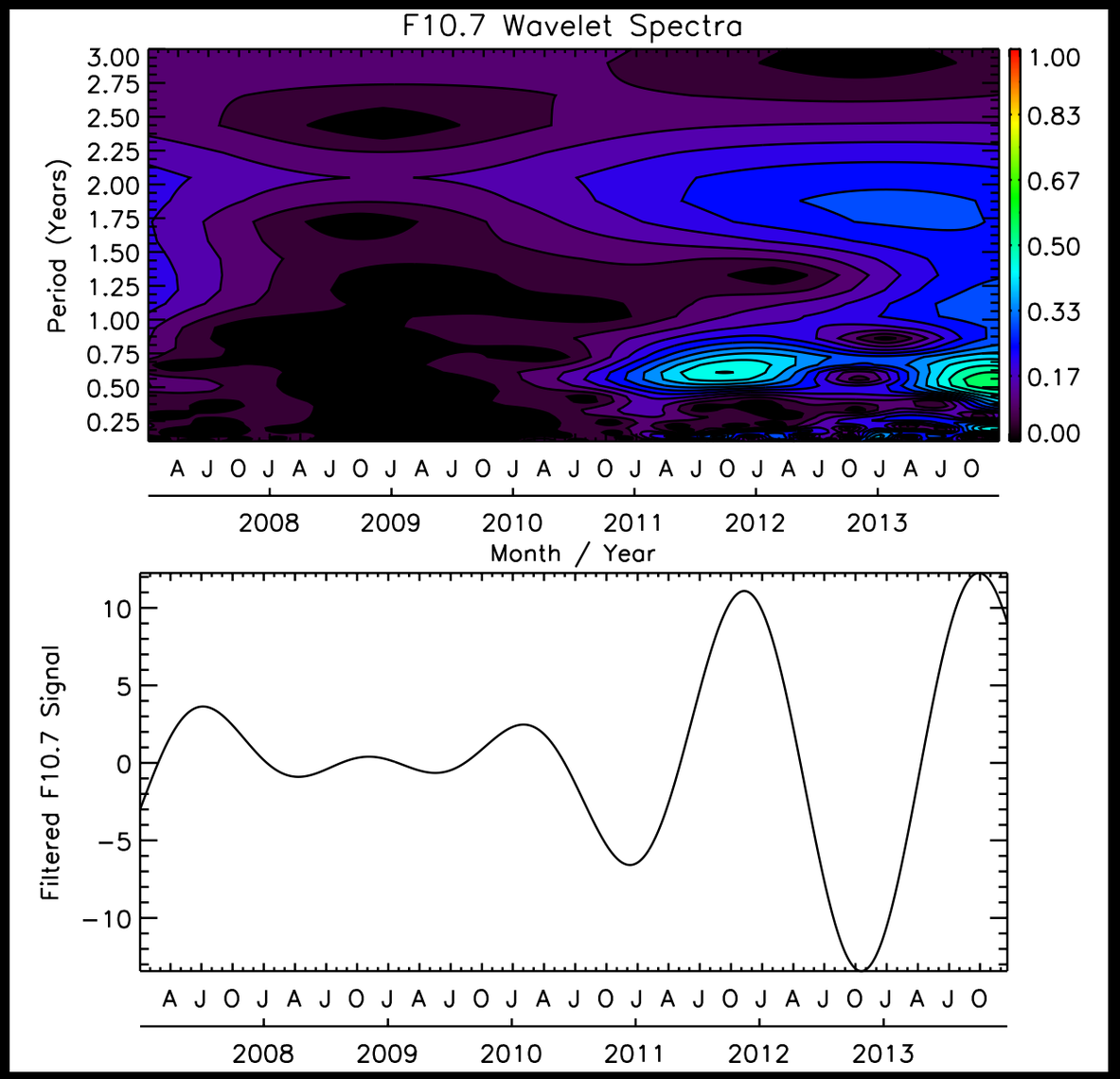


What drives the ionospheric QBO?

Baldwin et al. [1999]







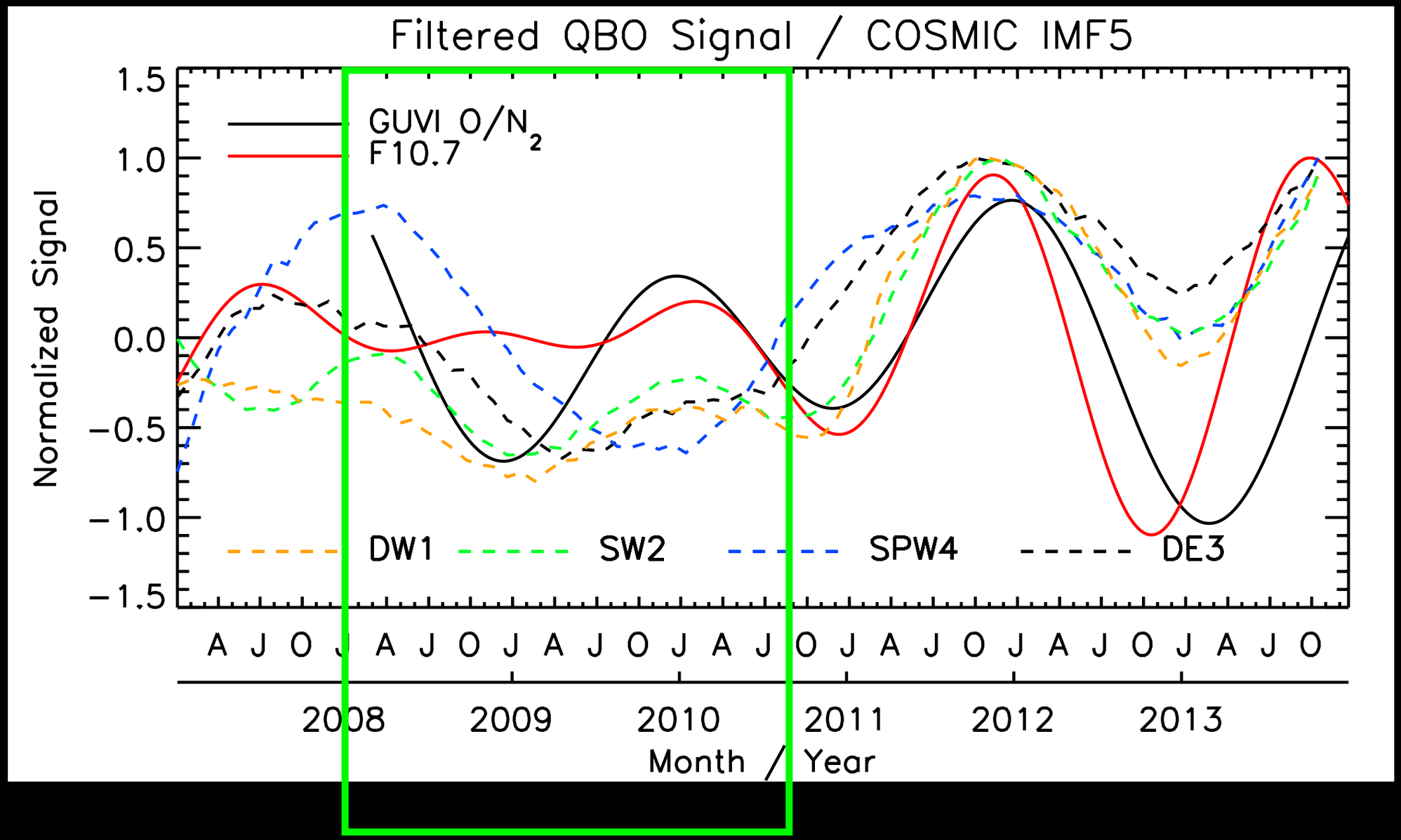
Stratosphere / Mesosphere QBO

Modulates eddy mixing in lower thermosphere from waves / tides.

Solar QBO

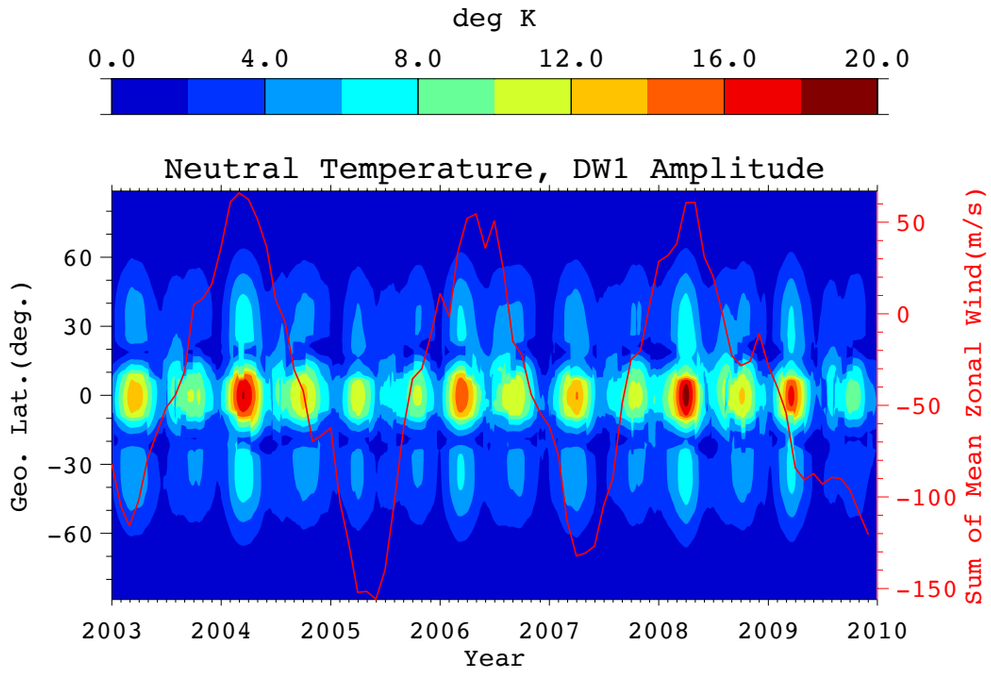
Modulates photoionization.

Ionosphere QBO Drivers



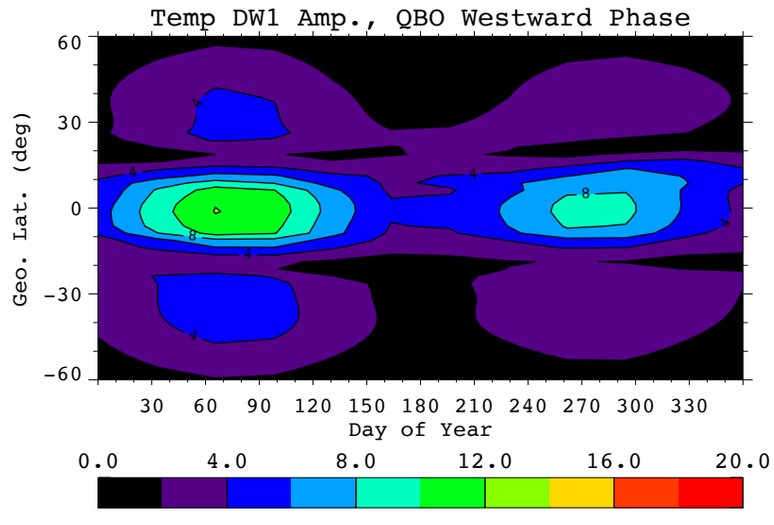
Low Solar Activity: GUVI O/N_2 (composition).
High Solar Activity: F10.7 (solar irradiance) and GUVI O/N_2 (composition).

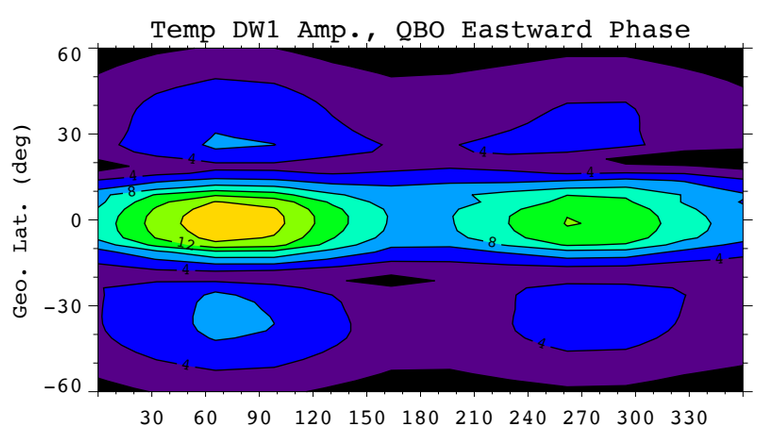
TIE-GCM Sensitivity Study



Strat. QBO West

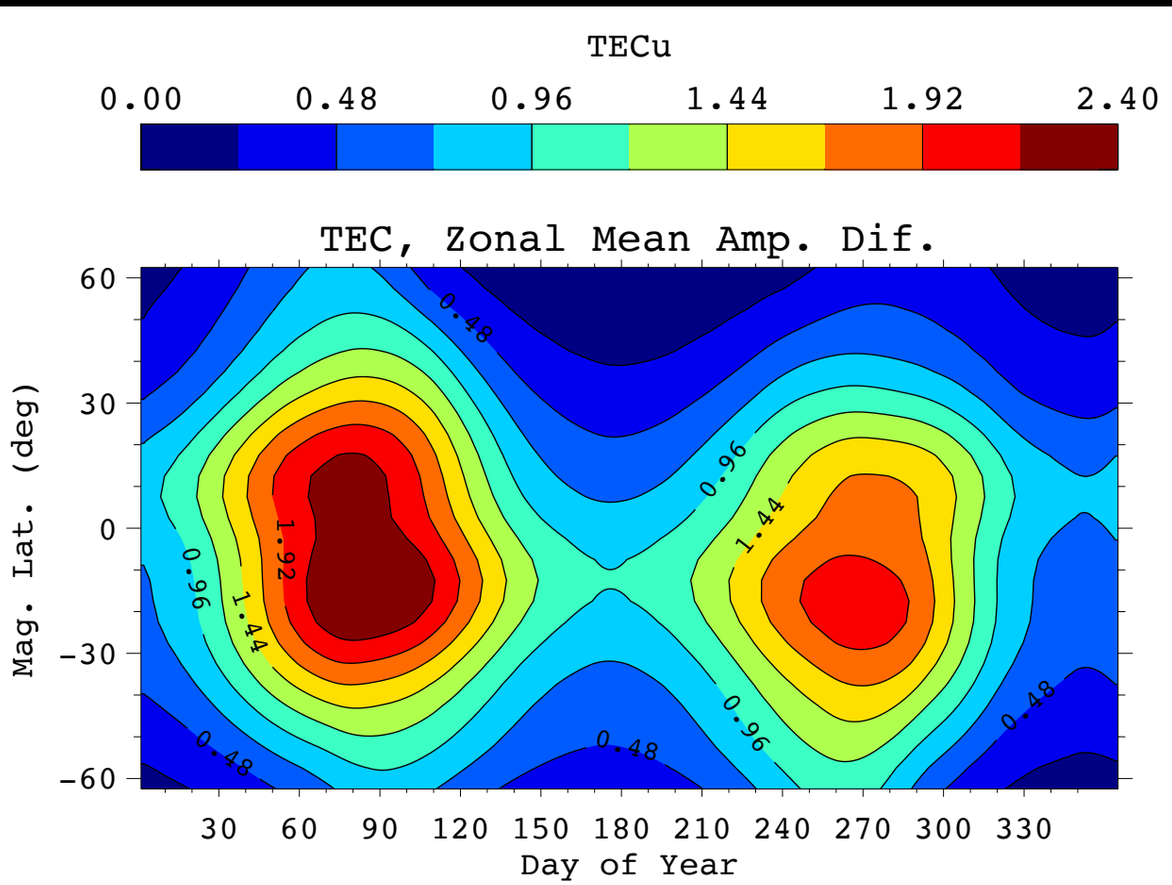
Strat. QBO East

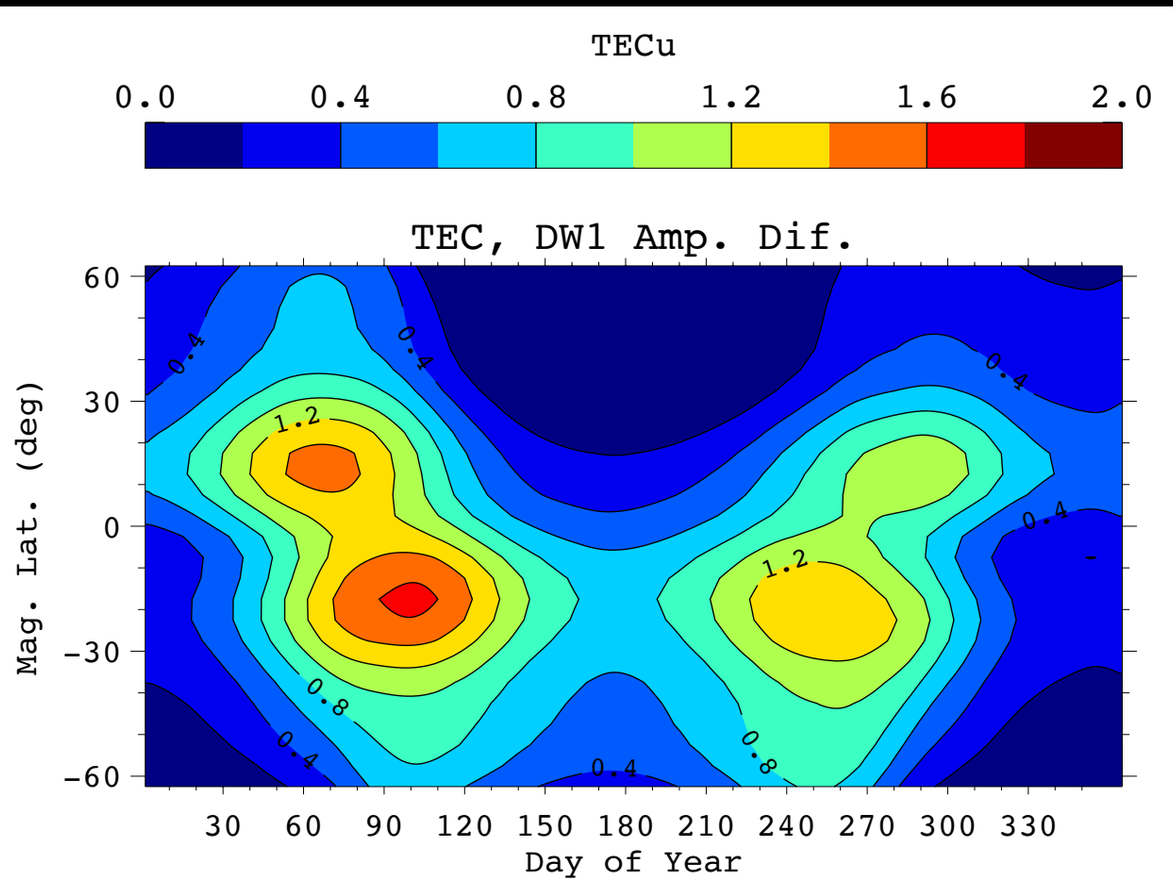




- Atmospheric tides specified at 97 km model lower boundary using assimilated 2003 - 2009 TIMED observations [Wu et al., 2012].
- Empirical tidal model constructed using linear fit of TIMED assimilated tidal amplitudes to stratosphere QBO index.
- Weaker migrating tidal amplitudes during stratospheric QBO westward phases, due to reduced vertical wavelength in westward background winds.

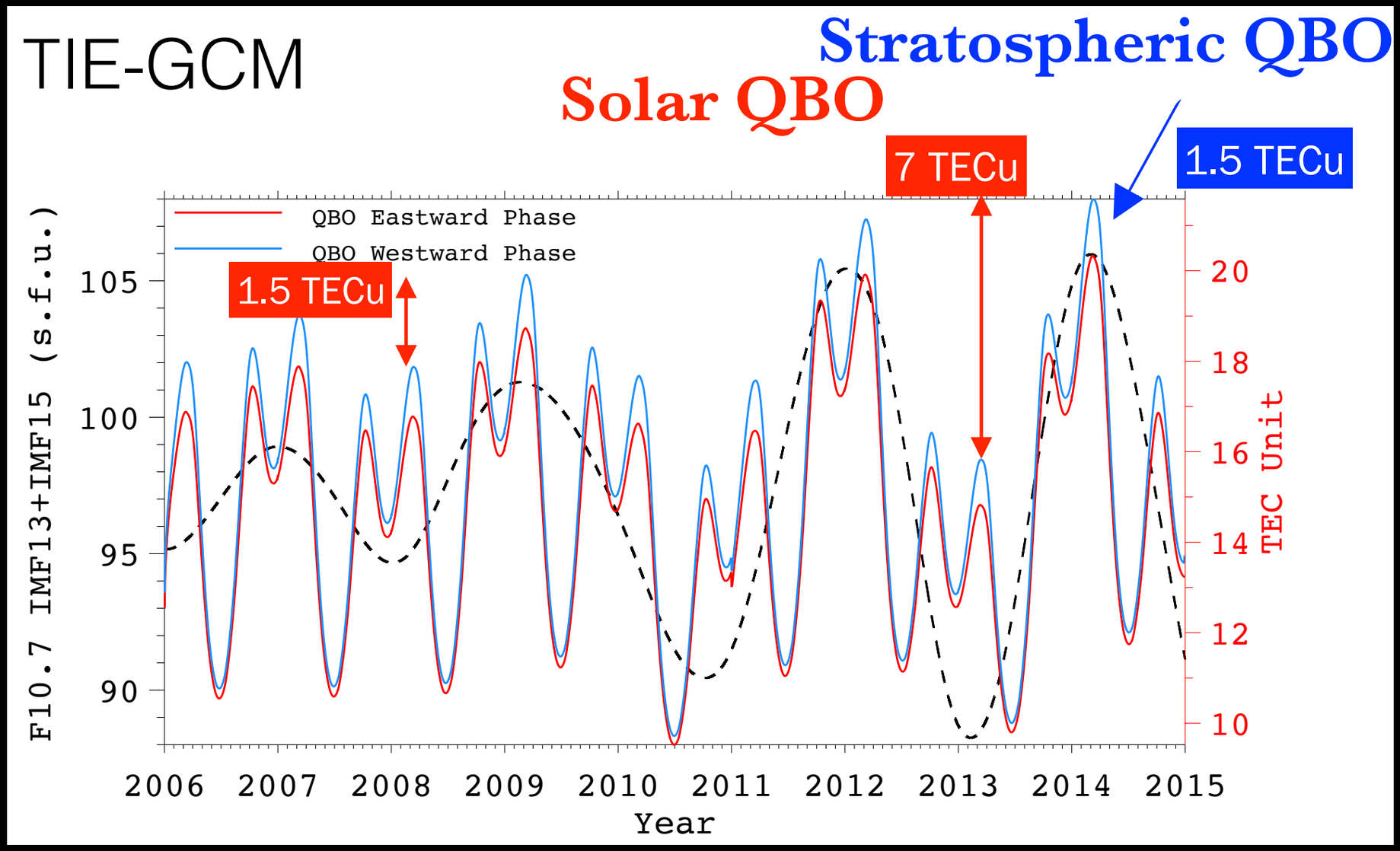
ΔTEC
Strat. QBO West - Strat. QBO East





- Larger zonal mean and DW1 TEC amplitudes during stratospheric QBO westward phase (fixed F10.7 = 180).
- Difference attributed due to reduced O/N2 due to dissipation of increased MLT tidal amplitudes.

Ionosphere QBO Drivers

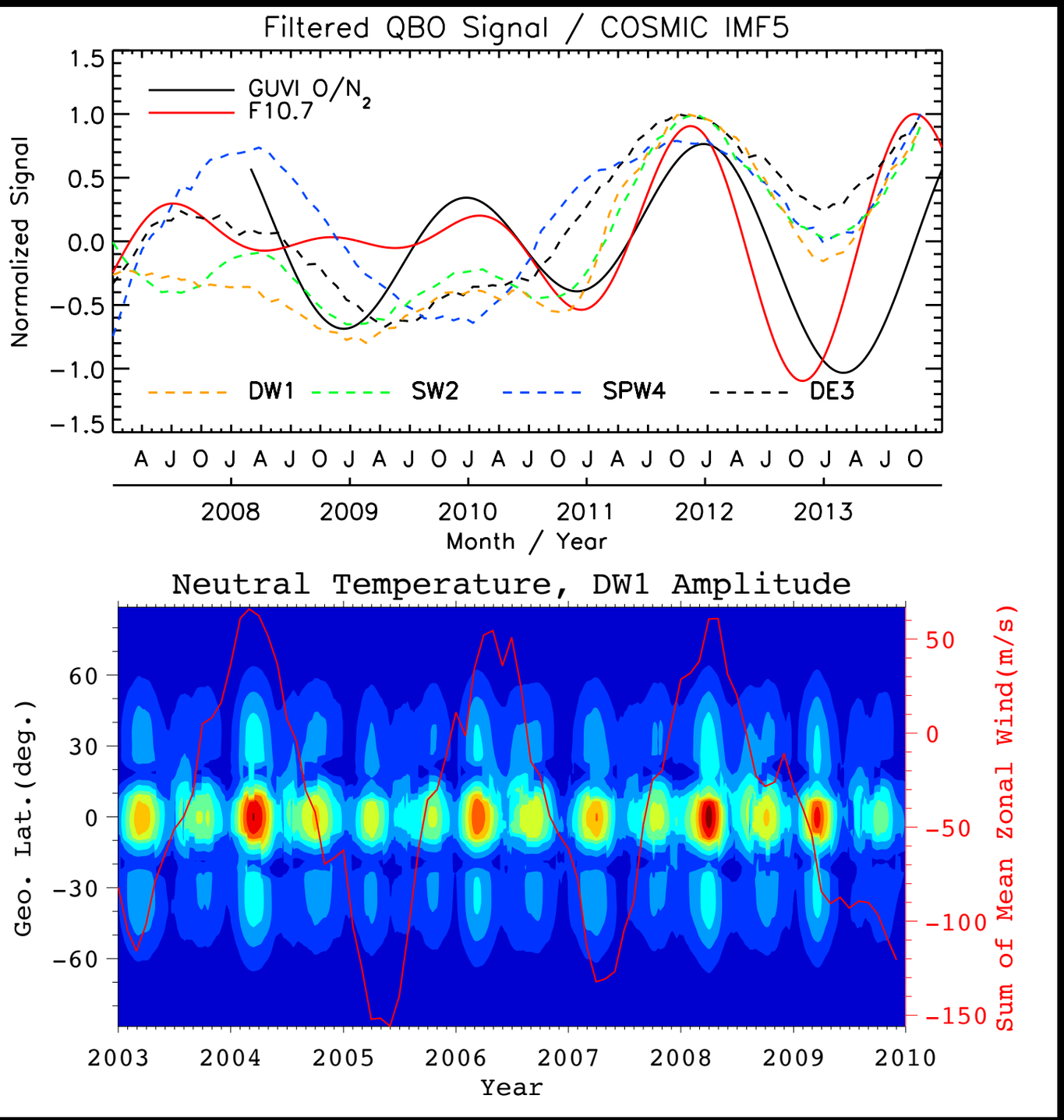


Results confirm drivers postulated from COSMIC / GUVI observational analysis:

High Solar Activity: F10.7 (solar irradiance) and atmospheric tidal dissipation (composition).

Low Solar Activity: Atmospheric tidal dissipation (composition).

Ongoing Work



- Can O/N2 QBO be reproduced using MLT tidal empirical model results?
- Does the 97 km TIE-GCM lower boundary correctly reproduce tidal amplitudes peaking above 97 km? (eg., DE3, SW2)
- What is the relative mixing effect of QBO signals in the atmospheric tides compared to gravity waves?

Conclusions

- Ionospheric tides formed by both in-situ and vertical coupling mechanisms. Amplitudes reflect both solar activity, dynamo coupling, and composition change.
- Identified ionospheric quasi-biennial osccillation (QBO), driven both by solar irradiance, as well as composition changes from eddy mixing by dissipating atmospheric tides in lower thermosphere.
- Preliminary results from observations and sensitivity study show that eddy mixing from tides has a larger effect in driving the ionospheric QBO during low solar activity.

IAGA/ICMA/SCOSTEP

6th Workshop on Vertical Coupling in the Atmosphere-Ionosphere System

July 25 - 29, 2016. Taipei, Taiwan

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