Planetary Wave Type Oscillations seen in ionospheric Total Electron Content

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Summary:

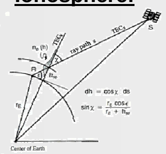
Planetary waves (PW) are responsible for a large part of the middle atmosphere dynamics. They are supposed to impact the thermosphere-ionosphere system, too. The aim of the CAWSES project CPW-TEC is to find evidence for a measurable influence of PW on the Total Electron Content (TEC) of the ionosphere.

Objectives:

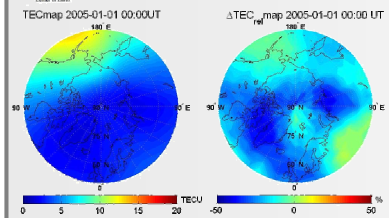
The ionosphere is used as an indicator for thermospheric dynamics and density variations. Empirical PW analyses on ionospheric and stratospheric data as well as related modeling studies are used to trace the vertical propagation of PW energy.

Tools and data base:

Ionosphere:



Ray path geometry for the trans-ionospheric satellite signals. This shows the derivation of the vertical total electron content (TECv) from the slant TEC (TECs) (Jakowski, 1996).



Northern hemispheric TEC map (left) produced by DLR using GPS measurements provided by the International GNSS Service and the percentage deviations of the actual TEC map from the corresponding monthly medians (DTEC, right) on 01/01/2005.

Stratosphere:

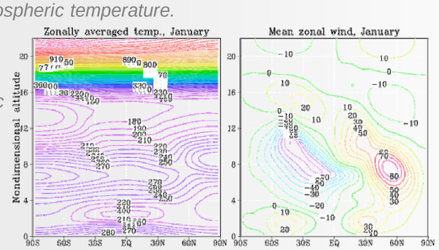
*Global fields of **assimilation data** (UK Met Office, NCEP/NCAR) are used for PW analyses in stratospheric heights.*

Modeling:

***MUAM global circulation model** from the ground to the thermosphere to investigate wave propagation, and interaction with tides.*

Middle and Upper Atmosphere Model (MUAM, Pogoreltsev, 2007)

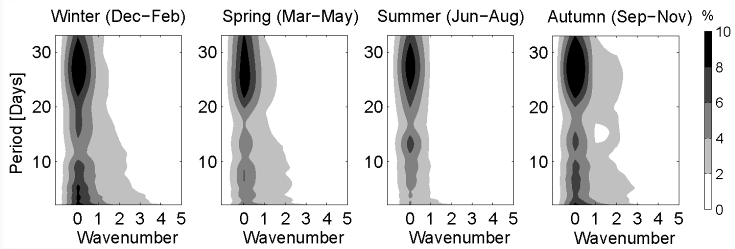
- *3D mechanistic model of the atmospheric circulation, based on COMMA-LIM.*
- *Grid-point model with horizontal resolution of 5°*5.625°*
- *Up to 60 levels in the vertical, with 0.4 scale heights step, upper boundary at 24 scale heights - approx. 300-400 km depending on the thermospheric temperature.*
- *Full radiative scheme including thermospheric EUV heating.*



MUAM is able to enlighten upward PW penetration.

PW type oscillations (PWTO) seen in ionospheric TEC:

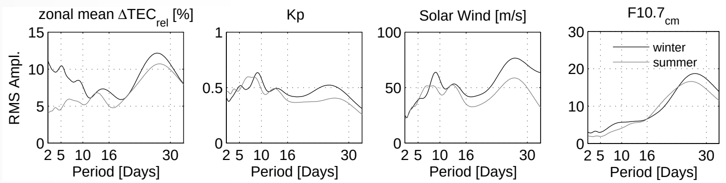
Zonal mean variations are mainly driven by the solar influence



Mean spectra of the standing waves in the DTEC during 2002-2006 show the clear dominance of the variations in the zonal mean.

There is a constant presence of the 27 day solar rotation period.

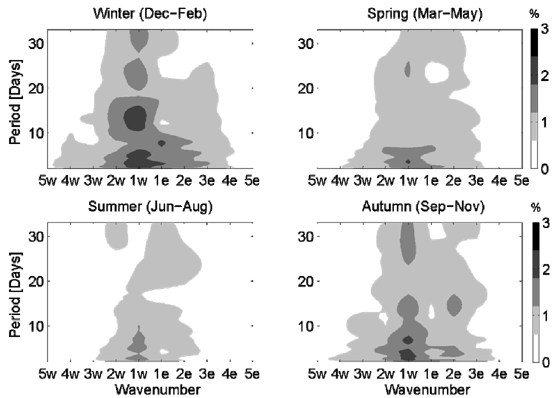
A higher activity in the lower periods is observed during autumn and winter.



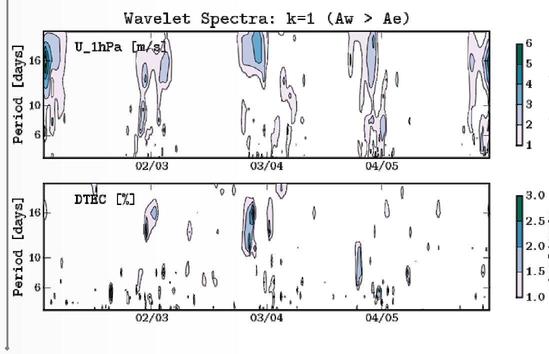
The comparison of the periods found in DTEC during 2002-2006 with periodicities observed in solar and geomagnetic indices reveal a certain coherency especially during summer.

Propagating PWTO reveal typical PW behavior

The mean spectra of the propagating PWTO found in the differential TEC during 2002-2006 display a dominance of the westward propagating waves with wavenumber 1. The strongest amplitudes occur during winter (upper left panel), while their activity is low during summer (lower left panel).

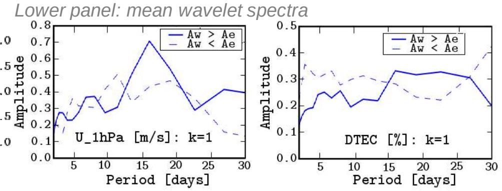


Correlation of stratospheric PW and ionospheric PWTO:



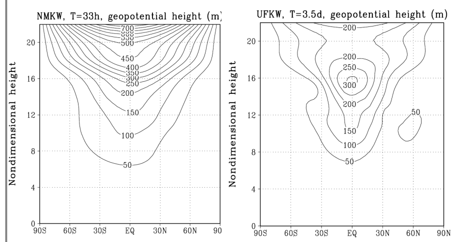
The comparison between the wavelet amplitude spectra of the westward propagating waves with wavenumber 1 in the zonal wind at 1hPa (UKMO, upper panel) and the DTEC (lower panel) show a similar appearance in time and scale of the middle atmospheric and ionospheric waves.

Lower panel: mean wavelet spectra



Modeling using MUAM:

Modeling results indicate a possible upward penetration of the ultra-fast Kelvin and Rossby-gravity waves into the ionosphere at low latitudes, but could not explain the PWTO found at high latitudes.



Geopotential height amplitudes of the Normal mode (NM) and ultra fast (UF) Kelvin waves.

From Pogoreltsev et al. (2007).

Conclusion:

The variability of solar flux as well as ionospheric and geomagnetic storms were found to be the main drivers of PWTO in the zonal mean DTEC. The dominance of the solar influence makes it difficult to extract the probable influence of middle atmosphere PW in the ionosphere. Nevertheless, the signatures of the propagating PWTO reveal a similar behavior like the middle atmosphere PW. A coherency between the propagating middle atmosphere PW and ionospheric PWTO is a reasonable hypothesis, but could not yet be explained by modeling studies.

Further investigation of the mechanisms transporting the PW energy into the ionosphere are necessary. A possible mechanism to produce PWTO in the ionosphere is the modulation of gravity waves, tides, and shorter-period PW by longer-period PW. These fast waves may be able to penetrate into the thermosphere.

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