Recent efforts towards an Ionospheric Monitoring and Prediction Center at the German Aerospace Center

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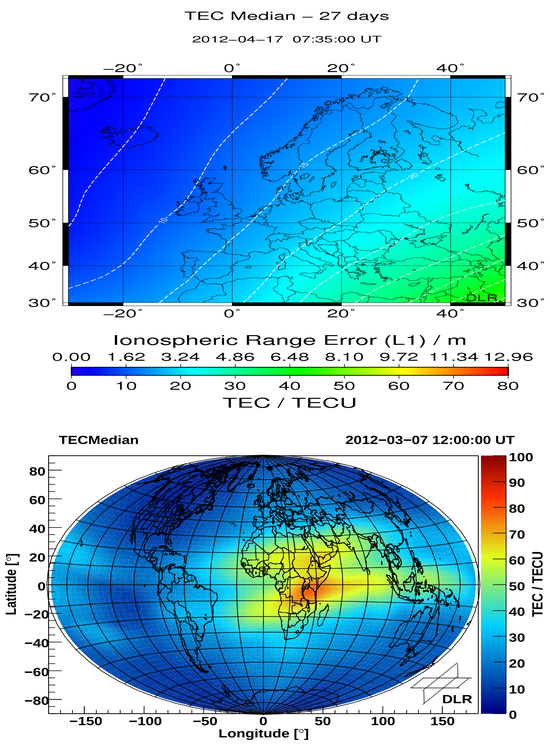
Abstract

Starting in 2007 the research project Space Weather Application Center Ionosphere (SWACI) has grown from simply mapping the total electron content over Europe to a powerful monitoring and prediction tool of the global ionosphere. Products designed within SWACI have improved awareness for space weather research and its applications, giving new insights for scientists and operators of GNSS based services. SWACI maps of the total electron content (TEC) and its model predictions, as well as the electron density profiles retrieved from radio occultation, topside reconstructions of the electron density and slab thickness values over selected European ionosonde stations are of great interest for the scientific community. We present achievements of SWACI and give an overview about recent and future activities in respect to space weather services and research at the DLR in Neustrelitz.

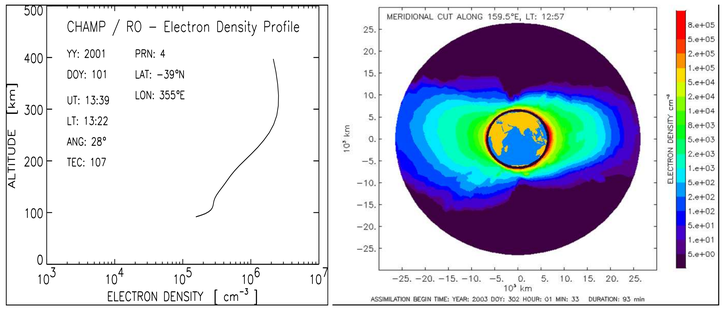
Total Electron Content

The total electron content is defined as the integral of the electron density along the ray path between satellite and receiver. Thus, TEC provides the number of electrons per square meter. The most frequently used unit is 1 TECU = 10^{16} electrons / m^2. TEC is derived from dual frequency code and carrier phase measurements done with Global Navigation Satellite Systems (GNSS). SWACI uses GPS measurements from various European GNSS networks such as IGS, EUREF, ascos distributed by BKG Frankfurt and from SAPOS. The global TEC maps are mainly created by using data provided by the International GNSS Service Real-Time Pilot Project (IGS-RTPP). To generate TEC maps of vertical TEC, the slant measurements have to be transformed to the vertical. In a first approximation the ionospheric range error in GNSS is proportional to TEC. TEC maps over Europe are created every 5 minutes. These TEC maps are used to derive latitudinal and zonal gradients, rate of change of TEC (5 min increments), 27 days medians, hourly forecasts of TEC, and corresponding error estimates.



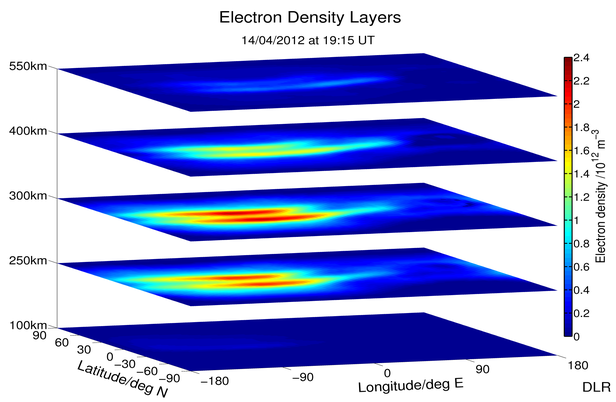
Space based GNSS

GPS radio occultation measurements onboard geo research satellites such as CHAMP, GRACE and SWARM are used for retrieving vertical electron density profiles of the ionosphere (left figure). At present we use only GPS measurements from the GRACE satellite. These data are routinely provided by GFZ Potsdam. Thus, the derived electron density profiles retrieved in SWACI are a common data product of DLR and GFZ Potsdam. The right figure shows the reconstruction of the topside-ionosphere with GRACE-GPS data.



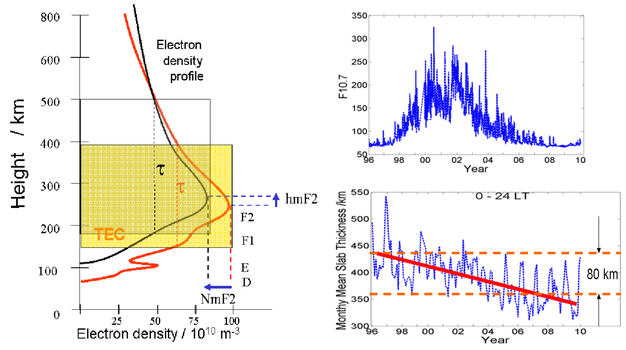
Geo-Plasma 3D

According to the pioneer work of Sir E. Appleton the vertical structure of the terrestrial ionosphere may be devided into different layers (D, E, F1, F2) with different physical characteristics. The layers are primarily characterized by its height and peak electron density. Typical plasma frequencies /electron densities are in the order of 10 MHz /10^{12} electrons / m^3.
Here are shown a global map of the peak electron density of the F2 layer and related electron density maps at selected altitudes. The figure provides a first estimation of the three dimensional electron density distributions around the globe.
The spatial plasma distribution is generated from actual TEC maps by applying a first version of the empirical electron density model NEDM-v1. In correspondance with the update rate of TEC maps the time resoultion of the 3D images is 5 minutes.



Slab Thickness

The shape of the vertical electron density profile reflects the complexity of production, loss and transportation of plasma in the Earths ionosphere. A first order measure of the profile shape is the equivalent slab thickness which is defined as the ratio of the total electron content TEC and the ionospheric peak density NmF2. This ratio is very sensitive to the competition of plasma driving forces such as thermospheric winds and electric fields. Hence, this parameter is very helpful in exploring perturbation processes in the ionosphere.
To get near real time information on these perturbation processes, the equivalent slab thickness is continuously monitored by combining vertical sounding and corresponding TEC data over Juliusruh (Germany) since the beginning of 2009.



Slab thickness during an ionospheric perturbation at Juliusruh

Monitoring results are discussed and compared with long-term studies based on TEC and ionosonde measurements covering the entire solar cycle 23. Whereas the slab thickness is well correlated with thermospheric heating at daytime the slab thickness increases significantly due to the enhanced contribution of the plasmasphere to TEC in the night.

Summary

The Space Weather Application Center Ionosphere (SWACI) is a space weather information and data service for ionospheric weather. Ionospheric data are collected, quality checked, calibrated, adjusted, analyzed, fed into models for generating higher-level data products and finally distributed in near real time. The German Aerospace Center will intensify the efforts to monitor and predict the ionosphere with a continuous and highly reliable service to strengthen the cooperation with international partners and to increase visibility and usability to an even broader group of customers. Taking into account their needs, our current work focuses on developing perturbation models appropriable for predictions.

[1] Jakowski, N., S. M. Stankov, D. Klaehn, *Operational space weather service for GNSS precise positioning* Annales Geophysicae **23** (2005) 3071-3079

[2] URL SWACI: http://swaciweb.dlr.de/

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