IONOSPHERIC MONITORING AND PREDICTION CENTER

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Introduction

In order to provide space weather information, which are in particular relevant for user of communication and navigation systems, the German Aerospace Center (DLR) is operating the online platform Space Weather Application Center Ionosphere (SWACI) since 2004.

SWACI has started as a feasibility study and has been continuously extended and improved and is now a grown up system ready to be transformed into an Ionospheric Monitoring and Prediction Center (IMPC). The IMPC, as a permanent ionospheric weather service, will use ground as well as space based Global Navigation Satellite System (GNSS) data, such as GPS and GLONASS measurements, and non-GNSS data such as vertical sounding data of ionosonde stations, radio beacons and solar wind data to provide relevant information for GNSS users in the area of telecommunication, precise radio-measurements and navigation. DLR is highly experienced in the reception, archiving, distribution and utilization of earth observation data in 24/7 operation mode. Therefore the IMPC is based on a dedicated infrastructure developed at DLR, where a fully automated Data Information and Management System (DIMS) is used for quality control, long-term data archiving as well as for dissemination of data to end users. A very large amount of ionospheric data covering high, medium and low solar activity periods over the globe has been captured, processed and archived since 1995. The captured data is being used for ionospheric research including modelling and characterization of ionospheric parameters and effects. This talk gives an introduction in the future IMPC.

It will demonstrate samples of products, e.g. European and Global maps of the Total Electron Content (TEC) monitored by DLR and available via the SWACI/ IMPC platform in near real-time.

SWACI/IMPC provides solar wind parameters taken with the ACE satellite (and his successor DSCOVR) and models their impact within the

physical interaction chain in the atmosphere to significantly increase the prediction time of hazardous perturbations.

The talk will present an overview of existing facilities and their development to an IMPC.

Why information on the ionospheric state is important?

The ionospheric plasma has various effects on the propagation of electromagnetic waves. It can cause delay, refraction, diffraction, scattering, and absorption of radio signals and rotation of its polarization plane. These ionospheric effects are relevant for technical systems of several kinds (e.g. for communication, navigation and earth observation) using radio frequencies below 10 GHz. Especially for single frequency navigation receiver ionospheric refraction is the biggest error source.

Additional problems arise when the ionosphere is strongly impacted by enhanced electromagnetic and corpuscular radiation of solar origin. Thus, ionospheric key parameters such as electron density, ion composition and plasma temperature are highly variable during a solar cycle, the seasons, the daytime and with geographic/geomagnetic location due to permanently changing solar irradiation conditions that are closely related to space weather.

Monitoring Service

Well established networks of ground and space based GNSS measurements offer a unique opportunity for permanent monitoring of the electron density and its structure of the ionosphere-plasmasphere system. At DLR Neustrelitz the use of own and cooperating GNSS measurement networks for the development and operation of ionospheric models have a long tradition.

The Ionospheric Monitoring and Prediction Center (IMPC) inherited from the online platform Space Weather Application Center Ionosphere (SWACI) will continue and improve the ionospheric monitoring system. Real time monitoring of the ionosphere is important for risk assessment and mitigation of ionospheric threats especially during space weather events.

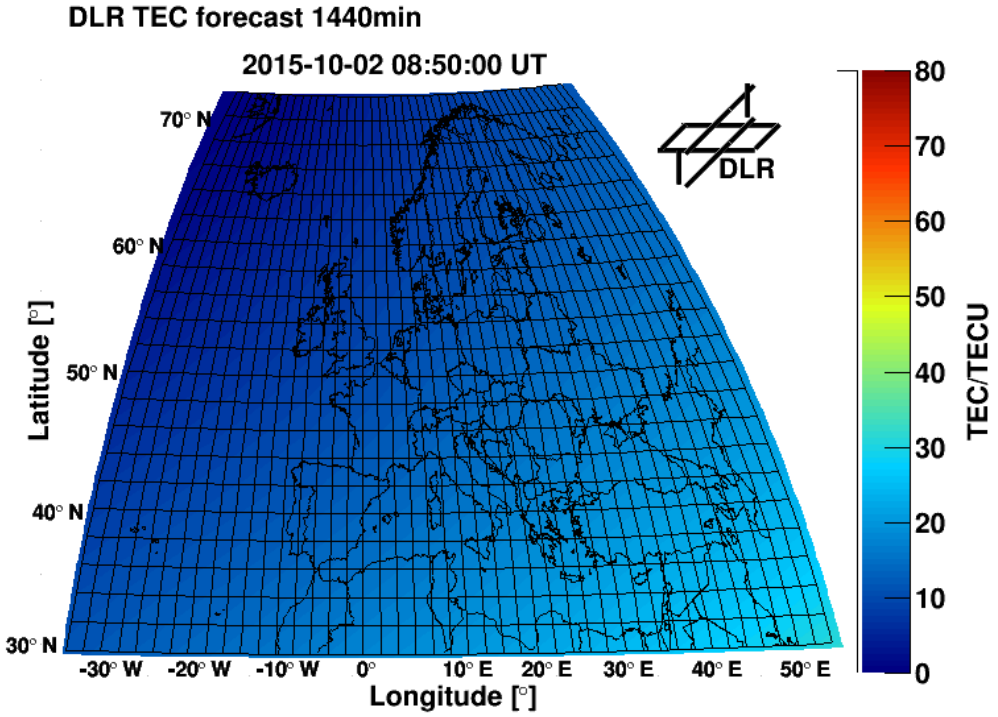

Figure 1 Total Electron Content (TEC) 24 h prediction for Europe

In addition to the determination of the now-state of the ionosphere the developed models give the opportunity to predict TEC over Europe (Figure 1) under quiet and perturbed space weather conditions. The model bases on identified storm patterns in the ionosphere from 1995 till 2011 over Europe and takes into account seasonal, local time, storm time and latitudinal dependencies. A storm onset is estimated using thresholds in Dst and solar wind correlations (source ACE, DSCOVR). If a storm onset is detected the storm model is added to the undisturbed 24 hours TEC forecast.

Data Sources

IMPC takes also advantage of the site location – permanent reception station for satellites in the S-, X- and Ka-band. So beside ground based GNSS measurement networks the IMPC will use Low Earth Orbit (LEO) satellites for GPS sounding of the ionosphere [1].

As member of the Real Time Solar Wind (RTSW) observation network DLR is engaged in the Real-Time (R/T) data transfer and analysis of NASA’s Advanced Composition Explorer (ACE) and its successor Deep Space Climate

Observatory (DSCOVR). Both satellites are placed at the Lagrangian point 1 to monitor the sun (Figure 2). Through this cooperation, IMPC has privileged and fast access to several physical parameters e.g. z-component of the interplanetary magnetic field, proton density, solar wind speed, dynamical pressure. These data make it possible to generate a warning (recently under development) less than 60 minute before a stream of particles and magnetic field reaches Earth and creates geomagnetic storms.

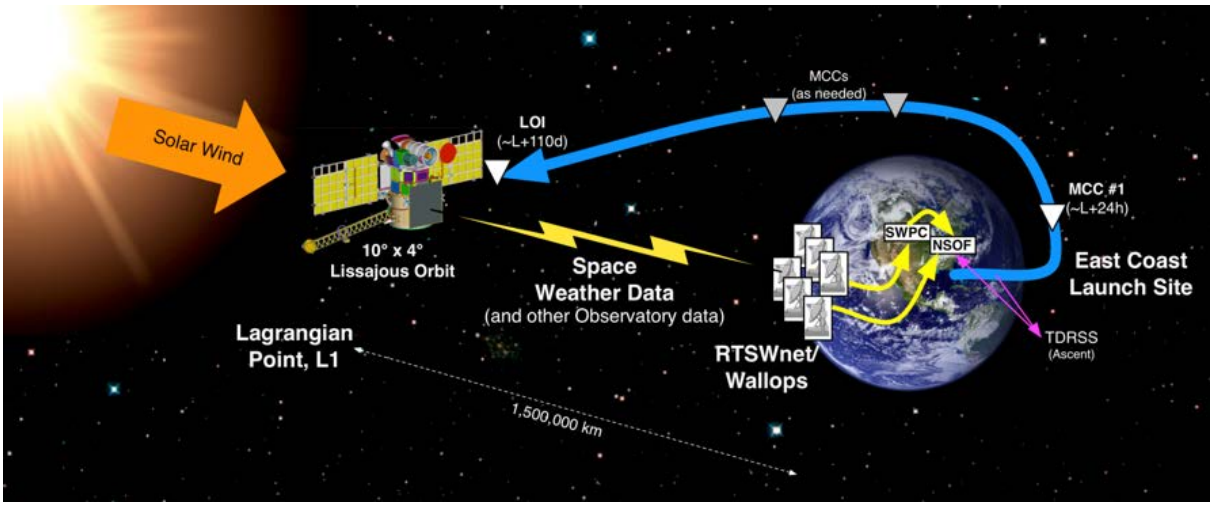

Figure 2 Artist's illustration of the DSCOVR spacecraft at L1 [2]

Ionospheric Monitoring and Prediction Center

The Ionosphere Monitoring and Prediction Center (IMPC) of DLR will provide a near real-time service on the current state of the ionosphere, related forecasts and warnings (Figure 3). IMPC products are disseminated via the website http://impc.dlr.de . Fundament of the IMPC development is a solid and continuous research activity in ionospheric science. The IMPC research addresses amongst others ionospheric perturbation detection, modelling and forecasting, mapping errors, higher order effects in precise point positioning, empirical and physical modelling and 3D electron density reconstructions. A comprehensive warning system is under development within the IMPC with multi-level warnings, ranging from long term predictions with lower accuracy (Level 1, 1-2 days before arrival at Earth) to near real-time alerts with high accuracy (Level 4).

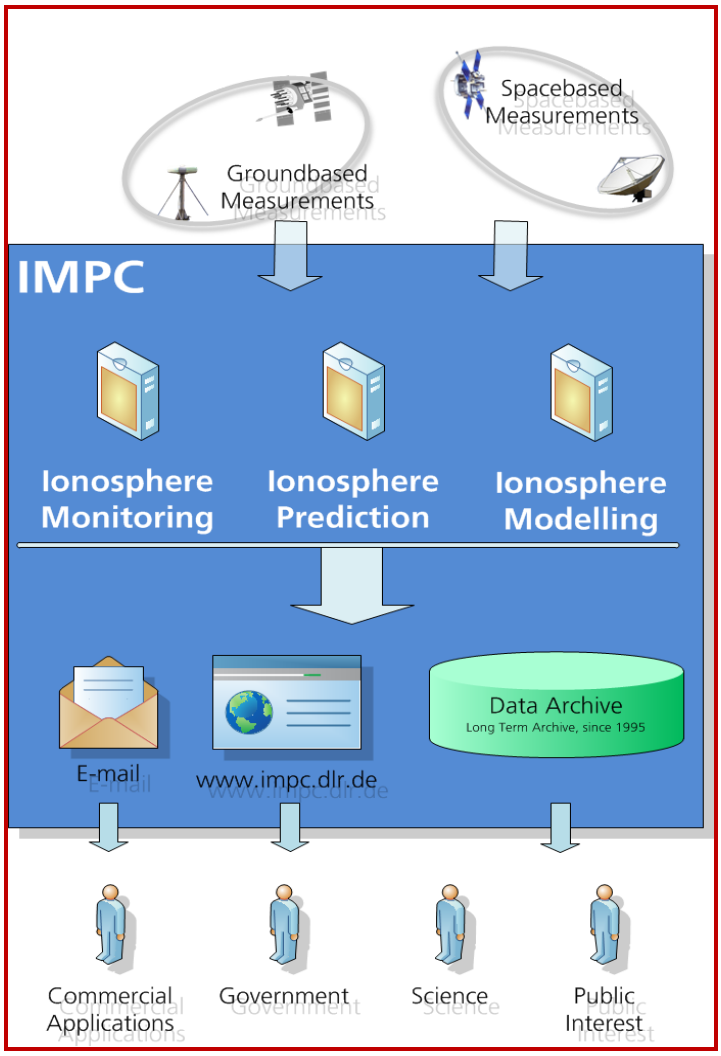

Figure 3 General Structure of IMPC

Data exchange and international cooperation are crucial for operating the IMPC. So it is involved in the Space Weather European Network (SWENET) of ESA, maintains relationships to multitude of European and international facilities in the space weather domain (e.g. NOAA SWPC Boulder (USA)).

IMPC products and expertise is applied in numerous national and international research-, infrastructural- and educational projects funded by EU, ESA and federal agencies. IMPC aims to become the European Expert Center (ESC) for ionospheric weather of ESA SSA (Space Situational Awareness) program. In this frame DLR is responsible for coordination ionospheric weather

activities, the planning and development of the ESC and its data delivery and service.

References

[1] *Heise, S. und Jakowski, N. und Wehrenpfennig, A. und Reigber, Ch. und Lühr, H.* (2001) Initial Results on Ionosphere/Plasmasphere Sounding Based on GPS Data Obtained Onboard CHAMP. 'Space weather workshop', ESTEC, 17-19 December 2001

[2] *William F. Denig, P Mulligan,* "NOAA Operational Space Environment Monitoring," 94th American Meteorological Society Annual Meeting, Atlanta, GA, USA, Feb. 2-6, 2014, URL: https://ams.confex.com/ams/94Annual/webprogram/Handout/Paper238184/denig-ams2013_J1-2.pdf