Forecast System Ionosphere: a new system for predicting space weather effects in Europe

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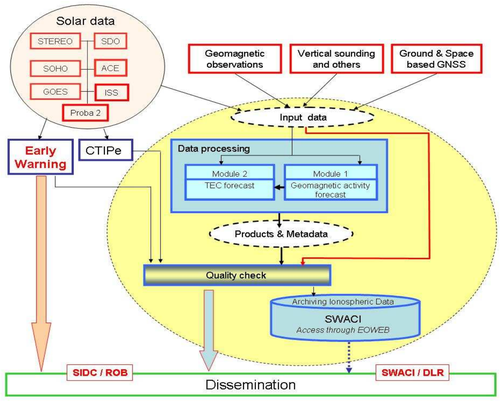
Abstract

A Forecast System Ionosphere (FSI) is developed as part of the FP7 AFFECTS project (Advanced Forecast For Ensuring Communication Through Space*, http://www.affects-fp7.eu/), led by University Göttingen. It is intended to help European citizens mitigating the impact of space weather events on its communications systems. For this purpose the FSI will operationally provide a prediction of space weather related geomagnetic and ionospheric perturbations for Europe. Solar observations and measurements are used for forecasting of geomagnetic activity and Total Electron Content (TEC). Additionally, high latitude geomagnetic monitoring and early warning for GNSS users is incorporated in the FSI. The FSI is developed as a subsystem of the Space Weather Application Center - Ionosphere (SWACI) service (http://swaciweb.dlr.de/), running at the DLR in Neustrelitz, using its approved infrastructure. AFFECTS partners are contributing to the FSI either by provision of data or by delivering processing modules. Here we present the layout and system architecture of the FSI, describing the data input, processing, checking, archiving and output of the FSI.

Introduction

Solar activity affects the entire Earth environment from the magnetosphere down to the ionosphere and even to the lower atmosphere climate system. The natural hazards of space weather do not only modify the atmosphere but also can catastrophically disrupt the operations of many technological systems leading to large impacts on people's lives and work. The AFFECTS collaborative project uniquely addresses these key topics through state of the art analysis and modelling of the Sun-Earth Chain of Effects on the Earth's ionosphere and their subsequent impacts on communication systems. The Forecast System Ionosphere (FSI) will be a major part of the AFFECTS system shown below. A preliminary and rough overview about the software modules and input interfaces to be used in the FSI is indicated in the yellow circle.



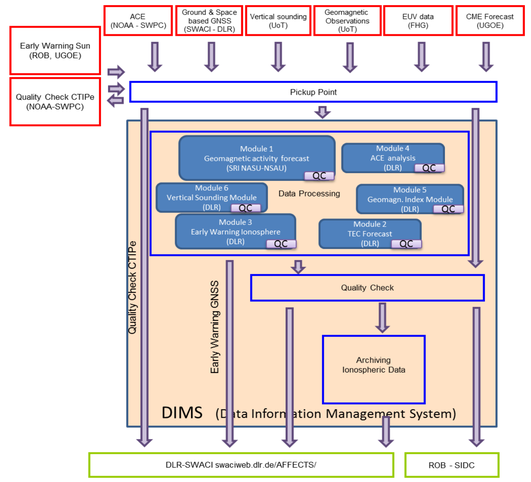
AFFECTS Overview

The list of key input data provided to the FSI by the consortium members is shown below.

Input data	Description	Institution
Solar Wind Data	Advanced Composition Explorer (ACE) measurements (Bulk velocity, proton density and the B_z component of the interplanetary magnetic field)	NOAA-SWPC
GNSS	Total Electron Content (TEC) maps	DLR-SWACI
Vertical Sounding	SAO Files	UoT
Geomagnetic	Geomagnetic indices	UoT
Early Warning Sun	Individual Early Warning Message Sun based on ROB and NOAA-SWPC alerts and data	ROB,UGOE
CTIPe	Global CTIPe and quality maps	NOAA-SWPC
EUV	Provision of EUV data for future improvements of TEC maps.	FHG
CME Forecast	CME forecast for the improvement of TEC forecast and early warning GNSS.	UGOE

System architecture

The FSI uses existing and approved systems like the Data Information Management System (DIMS), the Processing System Management (PSM) and the DIMS Product Library (PL), which already operate within SWACI. The benefit of these systems are their flexibility, controllability and extensibility. The DIMS together with the PSM is the data processing environment. PSMs will control the modules as well as the distribution of the output products to the AFFECTS website and to the data archive. For archiving of the AFFECTS products the PL is used. The following Figure provides an overview of the system architecture of the FSI.



Layout of the Forecast System Ionosphere Architecture

The different data inputs to the FSI are specified on left and top of the Figure (see also previous Table). This includes the solar, GNSS, vertical sounding data and geomagnetic observations. The solar Early Warning message is provided by UGOE (based on NOAA-SWPC) and ROB to the FSI for European distribution and forecast. The data processing includes 6 modules which are described in detail in the Table below. Modules 1 to 5 are handled by a job-order-file generated by DIMS. It contains specific information for data processing such as input and output paths and other parameters. Each processing module incorporates a product specific Quality Check (QC). In addition the FSI contains an overall QC for the system. Data archiving is realised by using the DIMS Product Library (PL). An important precondition for the archiving process is the completeness level of the products and data files for which also meta data are used. Each product meta file is generated as output result by the corresponding module. The generated space weather products will be distributed via the SWACI-AFFECTS website. Products generated within the FSI are for example the Dst index forecast, EU TEC forecast and quality maps as well as geomagnetic and ACE data. The Early Warning message for GNSS users, which is based on information provided at the main AFFECTS, the NOAA-SWPC and ROB websites jointly coordinated, will be additionally distributed to the user through specific mailing lists and other applications.

Module	Description
Geomagnetic activity forecast (SRI NASU-NSAU)	Predicts the geomagnetic index Dst 3 hours in advance. The lead time may be increased in future. Inputs are ACE data and previous Dst values.
TEC forecast (DLR)	Designed to predict TEC over Europe 6, 12 & 24 hours in advance. A new perturbation model will be used, which predicts TEC during disturbances. The module uses geomagnetic forecast, solar wind measurements and CME forecasts.
Early Warning Message (DLR)	Generates an early warning message primarily directed to users of GNSS systems. The module uses solar alerts disseminated by UGOE and ROB.
ACE Analysis (DLR)	Pre-analysis and correlation studies on ACE measurements in preparation for the TEC forecast module.
Geomagnetic Index Module (DLR)	Magnetometer measurements which are provided for the AFFECTS consortium by UoT are analysed and processed as input for the TEC forecast.
Vertical sounding Module (DLR)	Generates equivalent slab thickness profiles.

Quality assurance

To ensure high reliability of the FSI and to provide information which are understandable in terms of their statistical significance we pay particular attention to the quality assurance of FSI products. The Quality Check (QC) is therefore organised in 3 independent parts. The first QC is directly performed within the modules themselves, where the product quality will be defined in two flag parameters given in the meta data. The first flag indicates the completeness and quality of the input data and the second flag indicates the quality of the data output based on the results of difference plots, BIAS, RMS and/or standard deviation methods. The second QC is part of the infrastructure and data management layer and controls the product completeness levels and the activity states of the modules and processors. Based on this information the current status of each processing module (e.g. time of the last run) is written into an overview chart. The second QC concerns also the requirements for archiving and dissemination of the products via the websites, which will be quality checked too. This check includes verification of the meta data. The results and charts will be published on the SWACI-AFFECTS website (http://swaciweb.dlr.de/affects/). The last QC is executed externally by NOAA-SWPC, where CTIPe maps are checked with the help of SWACI global TEC-maps (nowcast, NC) using common methods, such as calculation of standard deviations, difference plots, BIAS and RMS. The SWACI TEC maps are provided on the Pickup Point. The QC results are send back by NOAA-SWPC to the same Pickup Point and will be disseminated on the SWACI-AFFECTS website.

Summary

The impact of space weather phenomena on the functionality of space based radio systems, early warnings and forecasts of expected ionospheric perturbations shall be deduced from solar, geomagnetic and ionospheric data. This requires to process the observations as fast as possible in near real time and to run specific forecast tools to provide ionospheric predictions in time up to 24 hours in advance. For doing this in a proper way, hardware architecture has been designed and processor modules are implemented and tested within AFFECTS. The forecast system ionosphere (FSI) as a major part of the AFFECTS processing system is implemented to provide information about the recent (nowcast) and the predicted conditions (forecast) in the ionosphere over Europe. A continuous verification of the FSI will rate its quality for further improvements on reliability and conclusiveness.

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