PRediction Of Geospace Radiation Environment and Solar wind parameterS

Work Package 3
Forecast of the evolution of geomagnetic indices

Deliverable 3.6
Real-time model implementation

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Summary

The overall aim of WP 3 concerns improvement and new development of models based on data driven modelling, such as neural networks and NARMAX. Existing models for *Dst* and *Kp* will be analysed and verified with the aim of finding weaknesses and to suggest improvements. Solar wind and geomagnetic indices shall also be analysed in order to develop models for the identification of features, such as (but not limited to) shocks, sudden commencements, and substorms. Such categorisation will aid the model development and verification, and can also serve as alternative approach to models providing numerical input-output mapping. In addition to the development of *Dst* and *Kp* models new models will be developed to forecast AE. The models will be implemented for real-time operation at IRF and data and plots will be provided on a web server.

This deliverable describes the implementation of the indices forecast models that have been developed and described in D3.4 and D3.5.

Acronyms

ACE	Advanced Composition Explorer
DSCOVR	Deep Space Climate Observatory
GFZ	GeoForschungsZentrum
GSFC	Goddard Space Flight Center
IRF	Institutet för rymdfysik (Swedish Institute of Space Physics)
L1	Lagrange point 1
NASA	National Aeronautic and Space Administration
NCEI	National Centers for Environmental Information
NOAA	National Oceanographic and Atmospheric Administration
SQL	Structured Query Language
SWPC	Space Weather Prediction Center
UoS	University of Sheffield
URL	Uniform Resource Locator
WDC	World Data Center

1 Introduction

During WP 3 models have been analysed and developed to predict the geomagnetic indices *Dst*, *Kp*, and AE(deliverables D3.1–D3.5). The models are driven by solar wind data from the L1 location. The data can be measured from a spacecraft or predicted from the SWIFT model (WP 2). The models from WP 3 are computationally very light-weight making them suitable for real-time implementation.

This document describes the real-time data sources that are used, the implementation of the models, the database, the generated plots, and the REST service. For the solar wind data only measured data are considered. However, the implemented prediction models can easily be configured to use predicted solar wind data from WP 2, but this will be covered in WP 7 (Fusion).

The predicted data are made available through a REST service. The radiation belt models that require the indices for inputs can thus acquire the predicted data, an activity that is part of WP 7 (Fusion).

2 Data sources

2.1 Measured solar wind

Real-time measured solar wind data are fetched from SWPC at a cadence of one minute. The data are available at

`http://services.swpc.noaa.gov/products/solar-wind/plasma-2-hour.json`
`http://services.swpc.noaa.gov/products/solar-wind/mag-2-hour.json`

where the URLs corresponds to the plasma and magnetic field data, respectively. The data has a temporal resolution of one minute. The files provided by SWPC contain primarily data from the DSCOVR spacecraft, but at times of missing DSCOVR data they can also contain ACE data.

2.2 Near real-time Kp

Near real-time Kp data are provided by GFZ at

`http://www-app3.gfz-potsdam.de/kp_index/qlyymm.tab`

The index is updated approximately every 15 minutes. The IRF server queries the GFZ server once per minute and if new data are available it is downloaded and stored into the IRF database.

2.3 Near real-time Dst

The near real-time Dst index is provided by WDC for geomagnetism in Kyoto. The data are available at

`http://wdc.kugi.kyoto-u.ac.jp/dst_realtime/presentmonth/`

The data are updated once per hour and the IRF server downloads data when new data are available.

2.4 Near real-time AE

Currently no real-time data are available of the AE. The WDC-Kyoto compiles data from 12 stations, however, due to measurement errors at some stations a manual procedure is required before AE can be determined (priv. comm. M. Nosé, WDC-Kyoto). Therefore there is a lag of a few months. However, there are real-time plots at

`http://wdc.kugi.kyoto-u.ac.jp/ae_realtime/today/today.html`

Thus no real-time AE data are downloaded.

3 Implemented models

The models implemented at the IRF server are IRF-Kp-2017, IRF-Dst-2017, and IRF-AE-2017 (see D3.4 and D3.5). The output from the models are:

IRF-Kp-2017 Predicted *Kp* with 0, 1, 2, 3 hours lead times plus additional lead time from L1-Earth propagation.

IRF-Dst-2017 Predicted *Dst* with 1 hour lead time plus additional lead time from L1-Earth propagation.

IRF-AE-2017 Predicted AE, AU, and AL with lead time given by L1-Earth propagation.

The L1-Earth propagation time depends on the solar wind speed and typically varies between 20–80 minutes.

The IRF models run at a cadence of one minute driven by real-time solar wind data. The solar wind data are collected from the IRF database and the forecast values are stored back into the database.

4 Database

An SQL (Postgresql) database is used to store all data. One dataset in the database can be viewed as a table, with one row for each record. Each record has a timestamp and a number of columns corresponding to different physical parameters.

5 Real-time operation

The real-time operation requires a number of steps to be performed:

1. Download data from external sources and store into database.
2. Extract relevant data from database, run model, and store predicted data into database.
3. Extract relevant data from database and create plots.

All the above steps are performed once per minute.

It should be noted that the predicted value at a specific time for a specific index is valid over the same time interval as the model was targeted for even though the models are run once per minute. This means that predicted *Kp* is valid over 3-hour interval, *Dst* over 1-hour interval, and AE, AU, AL over 5-minute interval.

6 REST service

For users interested in accessing the data directly a REST server is available at

`http://lund.irf.se/progress/`

Data can be accessed with various parameter settings, e.g. retrieving the latest 10 predicted *Kp* values

`http://lund.irf.se/progress/rest/datasets/irfkp2017/latest?limit=10`

As the predicted data are generated at a cadence of one minute, while the temporal resolution of the index is lower, the predicted data are transformed to match the resolution of the index. For example, the *Kp* index has a resolution of 3 hours, but for each 3-hour interval there are approximately 180 predicted values. To construct the 3-hour *Kp* series only the predicted *Kp* that comes closest in time to each 3-hour interval is used.

7 Visualization

For each predicted index a plot is generated showing a time series with solar wind data and predicted data. An example for *Kp* is shown in Figure 1. For *Kp* and *Dst* there exist also real-time preliminary data, also shown on the plots.

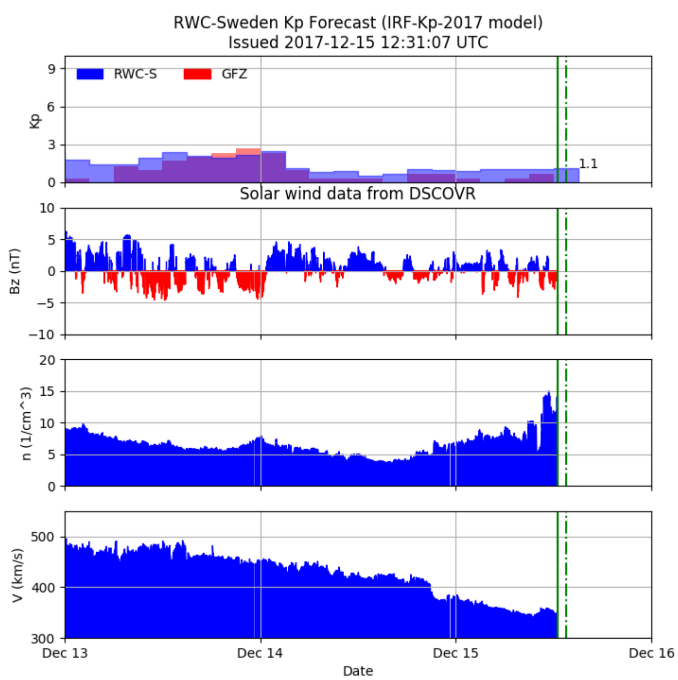

Figure 1: Example showing predicted *Kp* together with real-time *Kp* and solar wind.