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PROGRESS: Fusion of forecasts from the Sun to the Earth

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ABSTRACT

PROGRESS, PRediction Of Geospace Radiation Environment and Solar wind parameterS, is an Horizon 2020 funded project aiming to provide accurate and reliable forecasts of the geospace environment and its response to space weather events. PROGRESS focuses on three broad topics, 1) the forecast of the state of the solar wind at L1 based on gong magnetograms, 2) the evolution of geomagnetic activity as expressed by the geomagnetic indices Kp, Dst, and AE, and 3) the characterisation of the electron environment of the radiation belts. This presentation provides an overview of the models developed and shows example forecasts .

FORECASTS GENERATED BY PROGRESS

The forecasting tools available from the PROGRESS we site , https://ssg.group.shef.ac.uk/progress/html/.

CURRENTLY AVAILABLE FORECASTS

- Geomagnetic Index forecasts for Kp, Dst using Neural Networks
- Geomagnetic Index forecasts for Kp using NARMAX based methodologies
- Electron Fluxes at Geostationary orbit
- Now casts of low energy electron environment in the inner magnetosphere
- High energy electron environment in the inner magnetosphere

TOOLS IN THE PIPELINE

- Forecasts of the solar wind at L1 using AWSoM/ SWIFT
- Geomagnetic index forecasts of AE using Neural Networks
- Geomagnetic index forecasts of Dst, and AE using NARMAX
- Forecasts of the low energy electron environment
- Forecasts of the high energy electrons in the inner magnetosphere using the coupled VERB/NARMAX model
- Electron fluxes along a user requested satellite track

Geomagnetic Indices

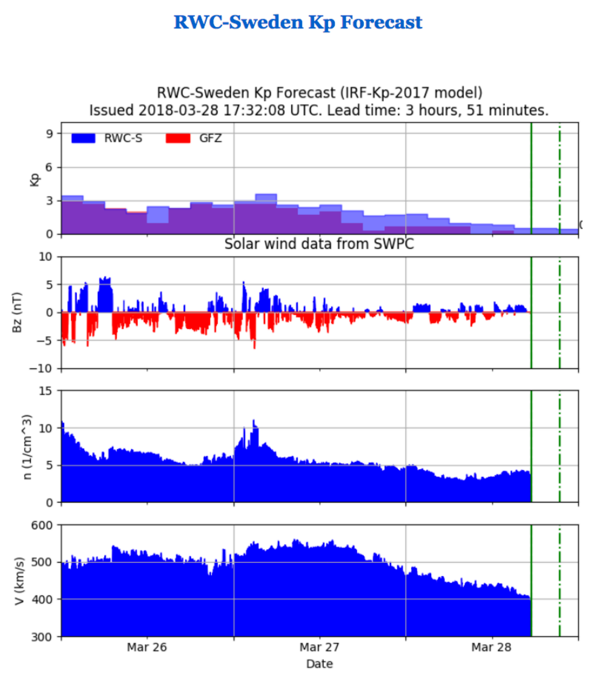

Figure 1: Neural Net Kp forecast

Figures 1 and 2 show the forecasts of Kp and Dst generated using a Feed Forward Neural Net with one hidden layer approach at IRF-LUND (Wintoft et al, 2017). The input parameters were 3 hour averages and limits of the solar wind IMF, velocity, and density

Fit statistics for the Kp model are shown in Table 1 in comparison to a Persistence model and the Boberg 2000 model.

Table 1: Neural Net fit statistics

Model	RMSE	Corr	SS
Persistence	0.90	0.78	0.00
IRF-Kp-2000	0.84	0.83	0.14
IRF-Kp-2017	0.55	0.92	0.63

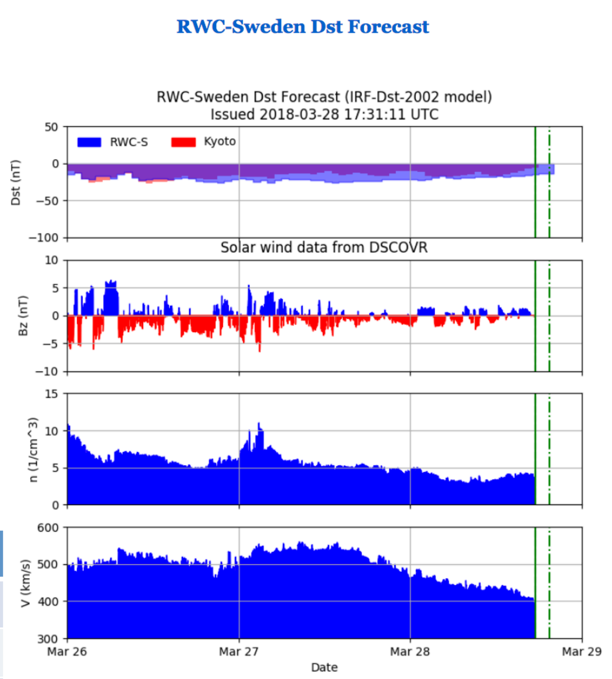

Figure 2: Neural Net Dst forecast

Figure 3 shows an example of the Kp forecast results achieved using a NARMAX model (Ayala Solares, et al. 2017). Due to the nature of the Kp data set, it is found that this particular model does not fully capture the dynamics of the Kp index.

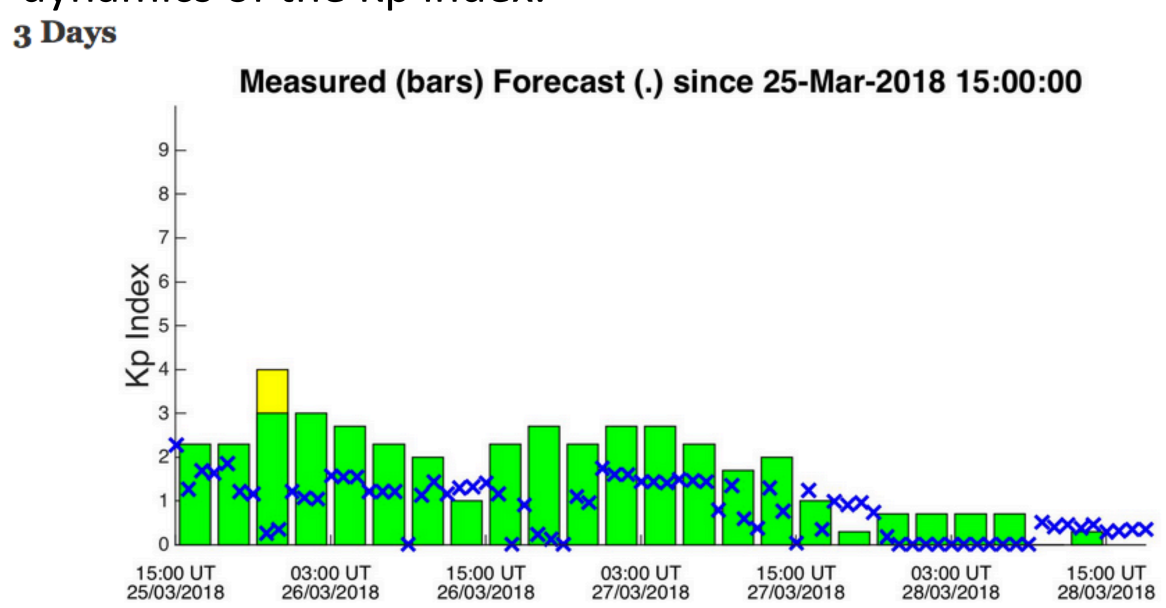

Figure 3: NARMAX Kp forecast

The models for geomagnetic index forecasts above are being constantly improved. The above plots represent a snapshot of their development in time (e.g. see Gu et al., 2017 for a new NARMAX model being developed).

Electron Fluxes

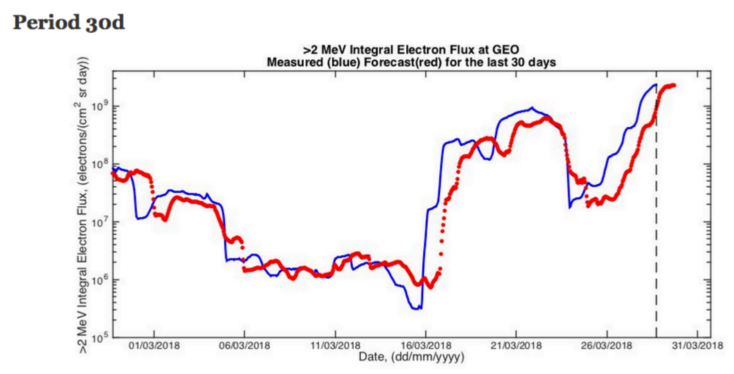

Figure 4: Evolution and forecast of the flux of >2MeV electrons at GEO over a period of 30 days

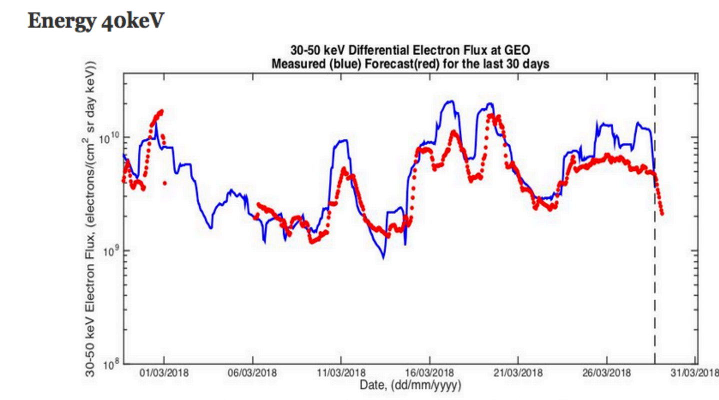

Figure 5: Evolution and forecast of the flux of 40 keV electrons at GEO over a period of 30 days

Figures 4 and 5 show the results of using NARMAX to model the electron fluxes at GEO (Boynton et al., 2013, Boynton et al., 2015). Models are available for all energies observed by the GOES 13, GOES 15 electron detectors. The results of these models has been shown to outperform NOAA REFM (Balikhin et al., 2016).

The above models provide a snapshot of the electron fluxes at GEO. To get an idea of the fluxes throughout the inner magnetosphere we use the numerical codes IMPTAM (e.g. Ganushkina et al., 2012) for lower energy electrons and VERB (e.g. Subbotin et al., 2009) for higher energies. The lower energy range is associated with spacecraft surface charging effects whilst the higher energies lead to the occurrence of internal discharges.

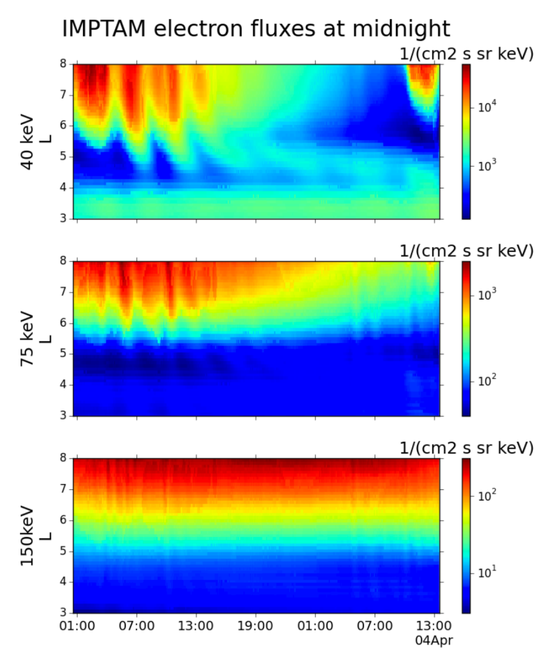

Figure 6: Low energy electron flux forecasts

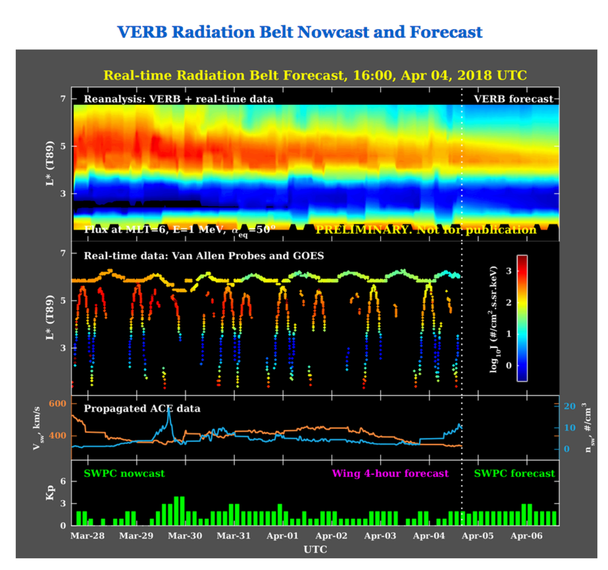

Figure 7: High energy electron flux forecasts

Future developments

Over the coming months we intend to keep developing and improving the models used for the forecasts shown in this poster. These forecasts will be further supplemented with

- Forecasts of the solar wind parameters at L1 generated by the AWSoM/SWIFT coupled models (Arber et al., 2017).
- Models for the forecast of the AE index and substorm occurrene using both Neural Net (Wik and Wintoft, 2017) and NARMAX methodologies.
- Forecasts of the high energy electron environment of the inner magnetosphere based on the coupling between the NARMAX electron flux models and VERB.
- Forecasts of the low energy electron in the inner magnetosphere from IMPTAM.
- The estimate of electron flux levels around a particular spacecraft orbit
- A panel indicating the current solar wind conditions and forecasts for their evolution.

In most cases, publically available reports discussing the development of these tools are available via the PROGRESS web site https://ssg.group.shef.ac.uk/progress/html/.

REFERENCES

Presentations are available from the PROGRESS dissemination web page

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