PROGRESS Meeting 2017-12-05

WP 3
Forecast of the evolution of geomagnetic indices

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WP3 - Forecast of the evolution of geomagnetic indices [Months: 1-36]

Objectives:

The objective of this WP is to provide forecast of Dst, Kp and AE from L1 as measured by ACE.

Participants:

- IRF (P. Wintoft, M. Wik, J. Katkalov)
- USFD (S. Walker)
- SRI NASU-NSAU (V. Yatsenko)

Description:

This WP concerns improvement and new development of models based on data driven modelling, such as CNN 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.

- Task 3.1 – Survey of existing operational models forecasting Kp, Dst, and AE

  Month 1-3 (IRF,USFD,SRI NASU-NSAU)

  Identify existing operational Kp, Dst, and AE forecast models. Analyse their respective requirements and benefits considering, e.g. inputs, latency, lead time, and resources. Detailed knowledge is available for the models available to the team.

- Task 3.2 - Identify and collect relevant data

  Month 4-6 (IRF)

  Collect historic real time ACE data, Science Level 2 ACE data, Kp, Dst, and AE. An SQL database shall be set up where the data are collected. Analyse data sets with respect to quality and coverage. Also include the coming DSCOVR spacecraft in the study.

- Task 3.3 - Evaluate and verify a set of selected existing models

  Month 7-9 (IRF, USFD, SRI NASU-NSAU)

  The models from Task 3.1 that are available to the team shall be verified using the datasets identified in Task 3.2. In this activity it is important to consider both science level data and real time data. This task also includes the identification and application of appropriate verification methodologies. As inputs methodologies from the meteorological domain [Jollife and Stephenson, 2012] and previous COST ES0803 Action [Wintoft et al., 2012] shall be used.

- Task 3.4 - Develop further existing Kp and Dst models

  Month 10-24 (IRF, USFD, SRI NASU-NSAU)

  The verification carried out in Task 3.3 will provide insights on how to improve existing Kp and Dst models. Classifications and categorisation methods will also be developed and applied with the purpose of improving existing models. The formulated verification strategy (Task 3.3) shall also be applied to the models.

- Task 3.5 - Develop new AE forecast models

  Month 16-30 (IRF, USFD, SRI NASU-NSAU)

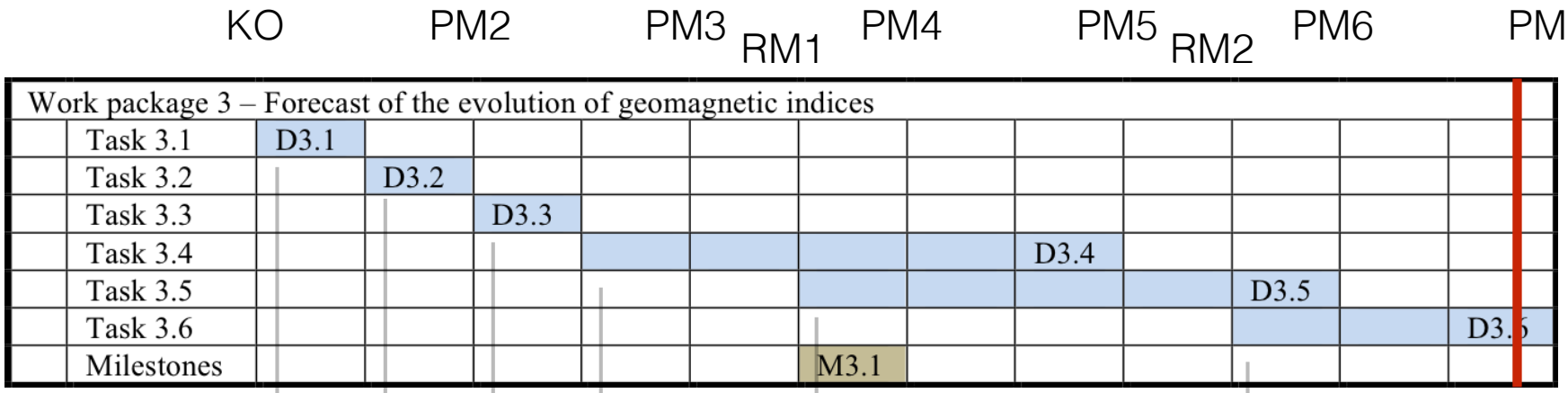
  As a first step to provide a baseline the model in Gleisner and Lundstedt [2001] shall be implemented and verified (Task 3.3). The classifications and categorisation methods (Task 3.4) shall also be applied to provide insight to appropriate parametrisation of the high resolution (minute) solar wind and AE data. E.g., the approach in Gleisner and Lundstedt [2001] was to use 10 minute averages, however, averages are not always the most suitable way of reducing the complexity as important features may be missed. Again, the formulated verification strategy (Task 3.3) shall also be applied to the models.

- Task 3.6 - Implement models for real-time operation

  Month 28-36 (IRF, USFD, SRI NASU-NSAU)

  The improved and developed models shall be implemented for real time operation. The contributing institutes have long experience in this field. The data needed to drive the models shall be downloaded and stored in the database in real time. Various checks considering data quality and timeliness shall be implemented and mitigated. The output from the models shall be stored in the database and also provided over ftp/http. Simple web site with the forecasts shall be implemented tailored for this project.

Timeline



Survey of existing operational models forecasting Kp, Dst, and AE — TN

Identify and collect relevant data — TN+S

Evaluate and verify a set of selected existing models — TN

Develop further existing Kp and Dst models — TN+S

Develop new AE forecast models — TN+S

Implement models for real-time operation — TN+S

Task 3.5: Develop new AE forecast models

- The lead time from L1, using the flat delay propagation, varies from 19 to 109 minutes, with a mean and median value of 60 minutes, which is used for the persistence model.

- The forecasts are verified using the measures: Bias (or mean error), mean absolute error (MAE), root mean square error (RMSE), linear correlation (Corr), mean square error skill score (MSESS) 1-MSE_{model}/$MSE_{persistence}$ and Prediction Efficiency (PE) 1-MSE_{model}/$MSE_{observations}$. The max and min values for the indices are also listed.

- The results are listed for training, validation and test set and all three sets combined. The results for the 60 minute persistence model are also included.

- We achieve the highest correlation, 0.88 for the *AE* index, MSESS of 0.6 and PE of 0.77. This is clearly better than the persistence model.

- Although not shown in the tables, we also predicted the *AE* using predicted *AU* and *AL*. The results have a close agreement with direct predictions of *AE*. This is the reason we used the same data sets for all indices.

- Our results are almost identical to Luo, et al (2013), which might indicate a limit on the forecast efficiency. However, they used different datasets and F10.7 as well.

Verification of models

AL index

	Bias	MAE	RMSE	Corr	MSESS	PE	Max	Min
Model (train)	2.287	56.904	90.394	0.844	0.606	0.713	35.2	-2894.8
Model (val)	1.687	57.345	93.480	0.830	0.575	0.687	32.2	-3330.0
Model (test)	0.830	52.483	87.660	0.837	0.566	0.700	41.4	-3747.4
Model (all)	1.824	56.035	90.544	0.839	0.591	0.704	41.4	-3747.4
Per (all)	0.006	82.650	141.493	0.639	0.000	0.278	41.4	-3747.4

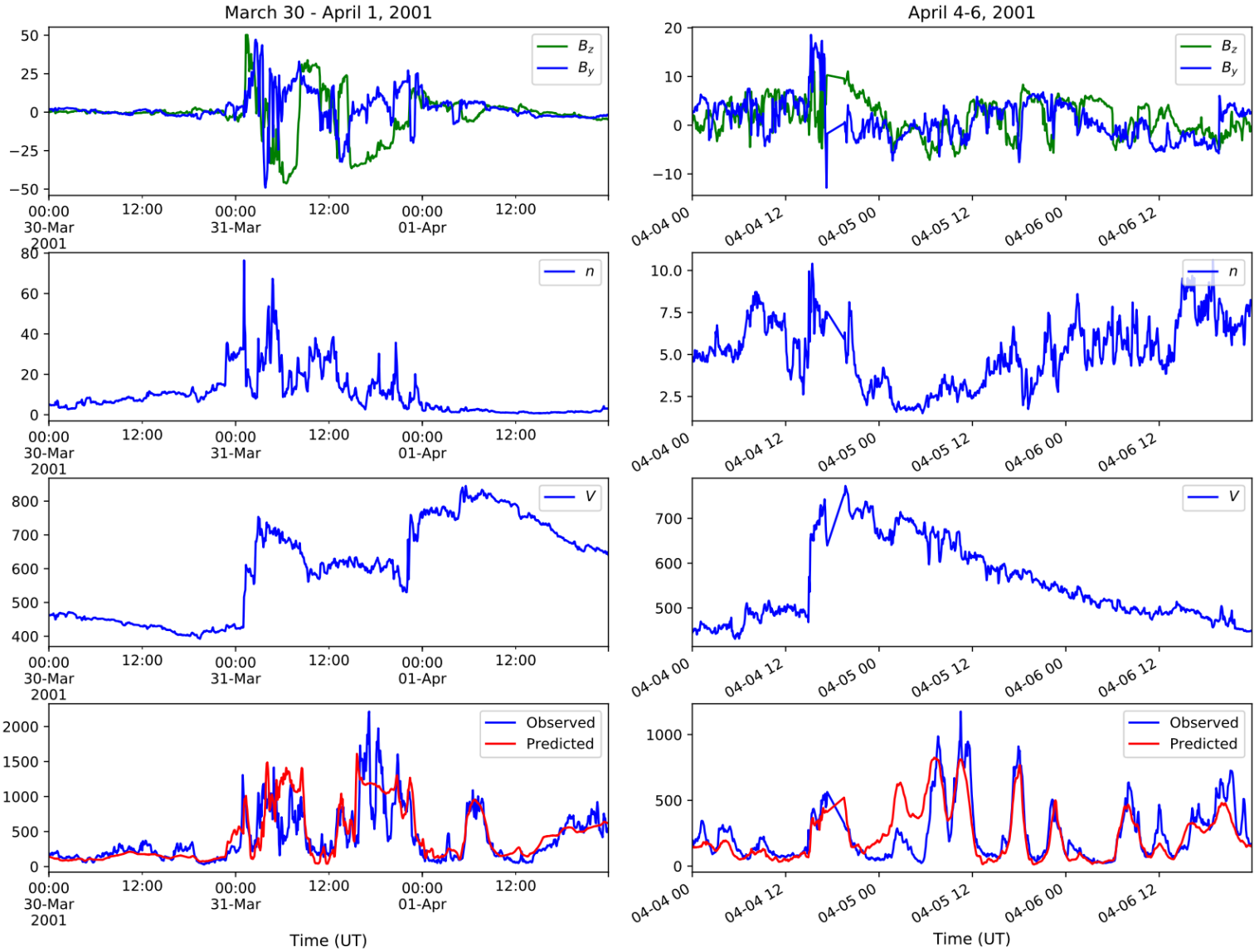
AU index

	Bias	MAE	RMSE	Corr	MSESS	PE	Max	Min
Model (train)	0.586	28.609	43.021	0.842	0.473	0.709	1389.4	-404.2
Model (val)	0.745	29.123	44.644	0.821	0.412	0.674	1106.2	-442.2
Model (test)	1.980	27.562	43.347	0.836	0.410	0.697	1011.0	-352.0
Model (all)	0.930	28.500	43.482	0.836	0.446	0.699	1389.4	-442.2
Per (all)	-0.003	35.952	58.396	0.729	0.000	0.457	1389.4	-442.2

AE index

	Bias	MAE	RMSE	Corr	MSESS	PE	Max	Min
Model (train)	-2.094	69.786	107.216	0.883	0.617	0.779	2987.2	2.8
Model (val)	-1.813	69.874	108.579	0.871	0.589	0.759	3260.0	2.6
Model (test)	-0.443	64.594	103.355	0.883	0.579	0.780	3407.2	2.6
Model (all)	-1.664	68.664	106.705	0.880	0.603	0.775	3407.2	2.6
Per (all)	-0.009	103.484	169.339	0.717	0.000	0.434	3407.2	2.6

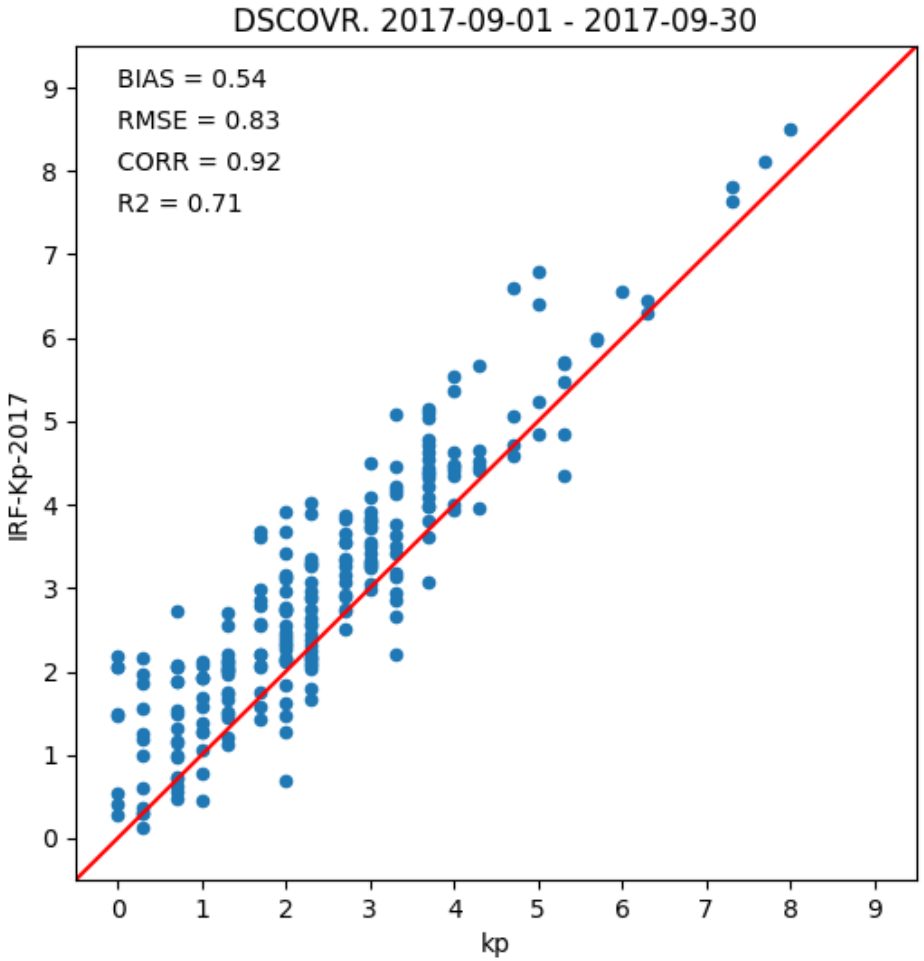
Forecast of 5 min AE



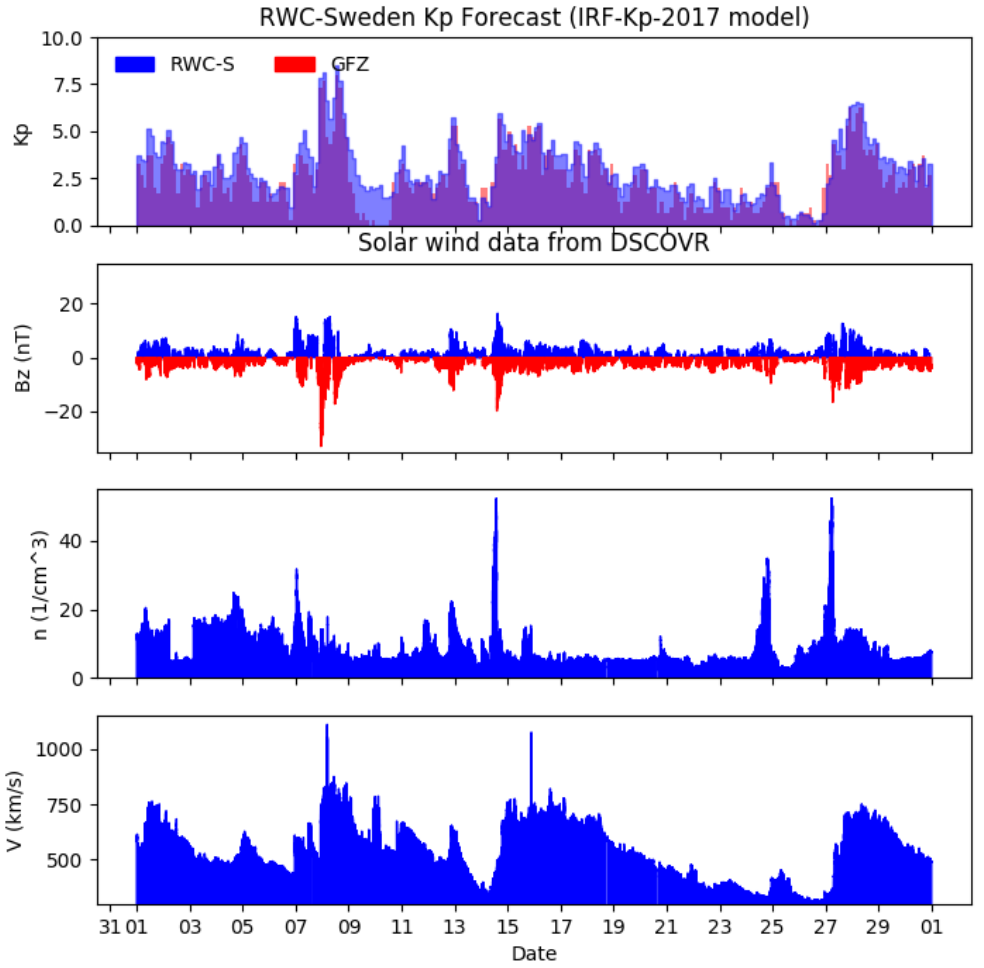
Forecast of 5 minute averaged *AE* during two events, from the test set, in 2001. The top three panels show the propagated 5 minute averaged solar wind magnetic field (B_Z and B_Y), density (n) and speed (V). The bottom panels show observed and predicted *AE*.

D3.6: Implementation

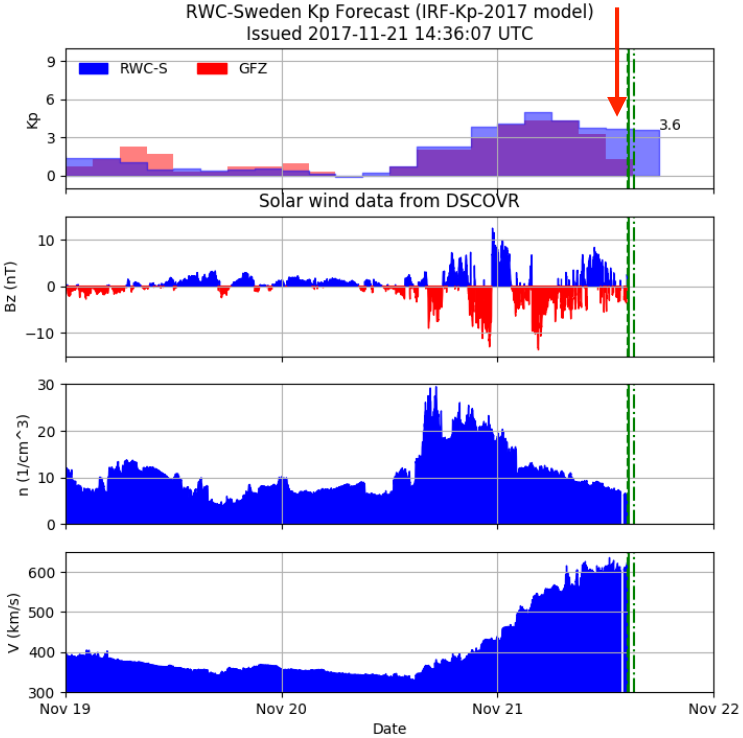
- A dedicated server has been set up for data, models, and service.
- We are collecting both ACE and DSCOVR real-time solar wind data. Data are stored in Postgres database.
- Kp and Dst models have been implemented and AE model will soon be implemented.
- Kp forecasts are provided every minute and stored in database. The Dst and AE forecasts will be added using the same framework.
- Forecasts will be available as plots and as numerical data through REST service.
- The Kp and Dst models will also be implemented as part of ongoing ESA SSA activity.
- Related WP7 Fusion: Ongoing work to specify formats and requirements for inputs to WP3 and outputs from WP3.

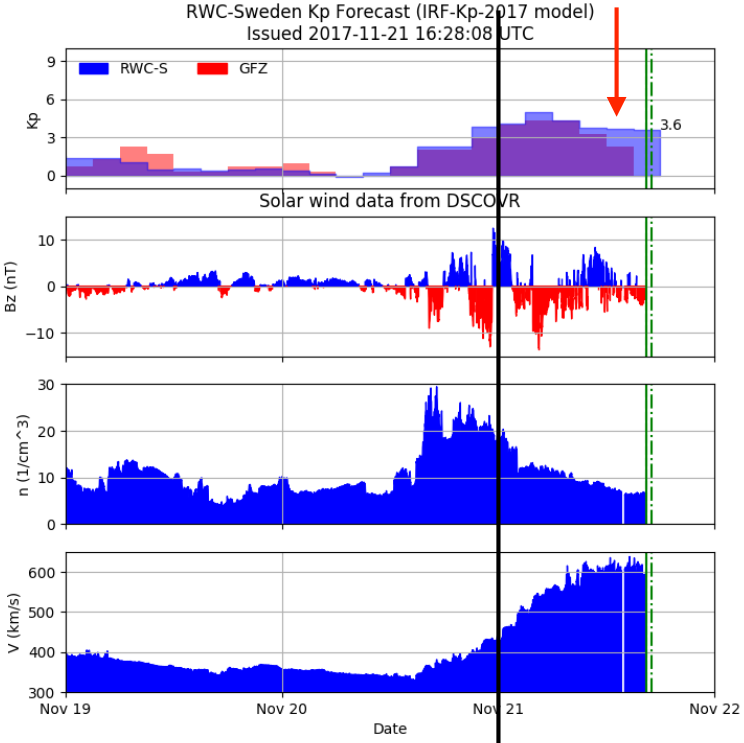


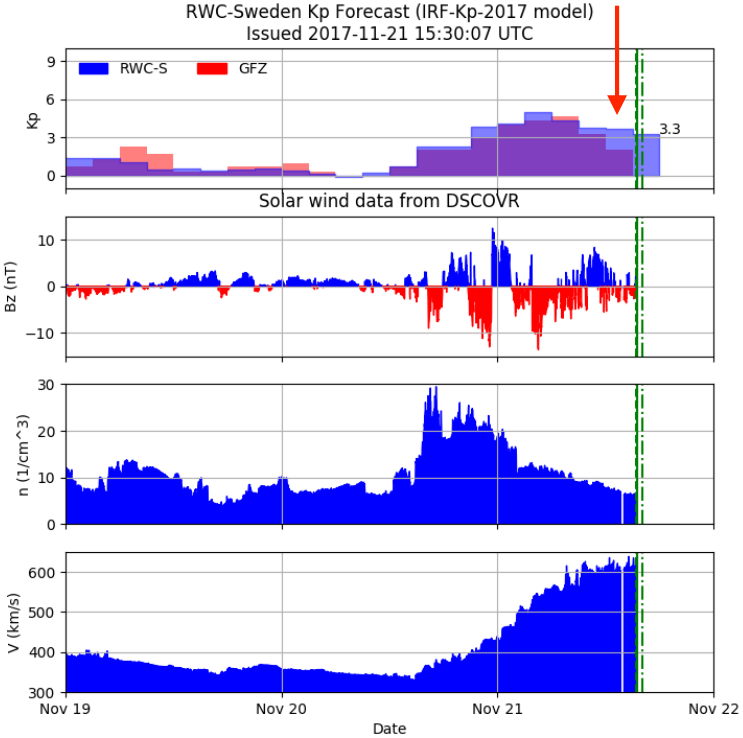
http://lund.irf.se/forecast/kp2017/

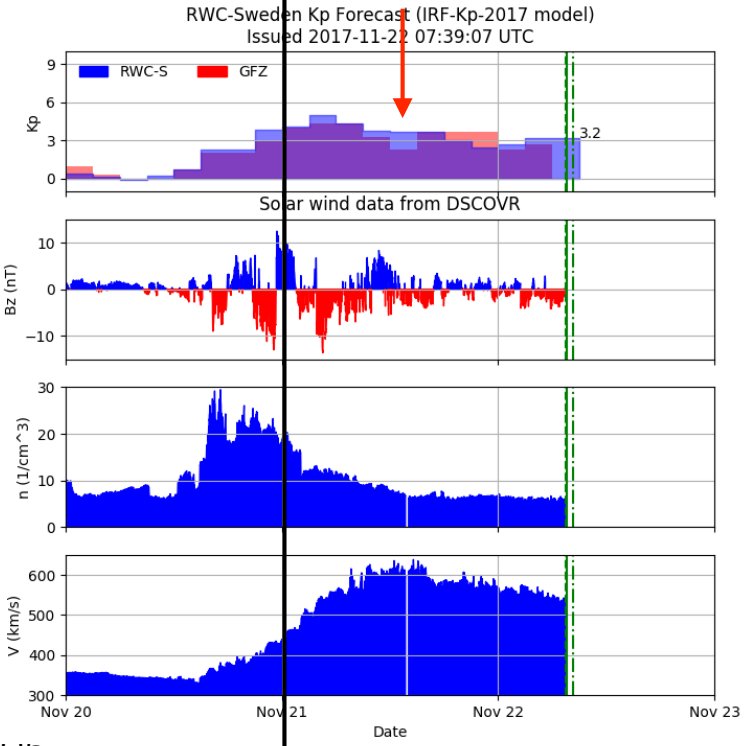


Will be included at ESA SSA ESC-G









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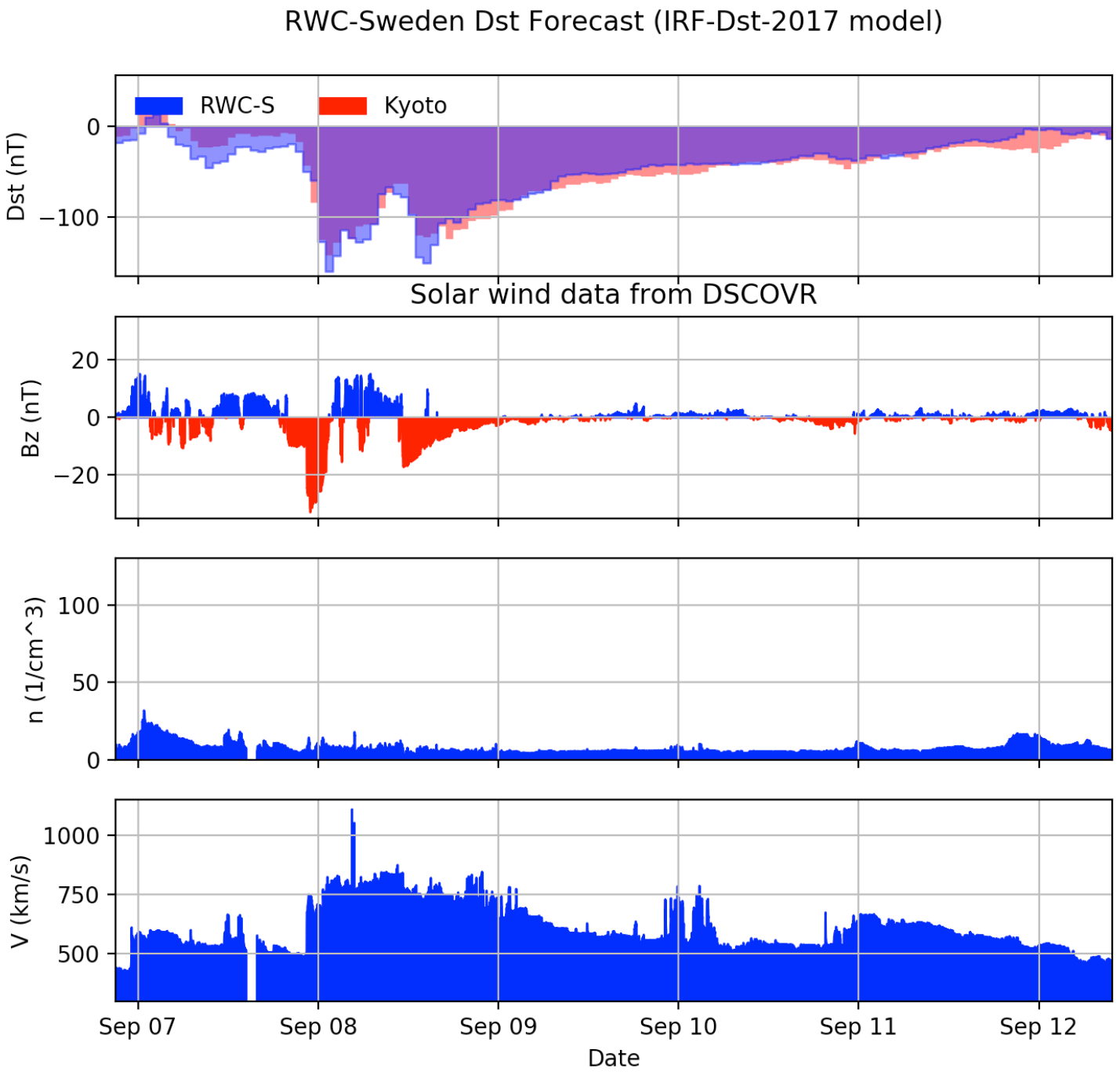
RWC-Sweden Dst Forecast (IRF-Dst-2017 model)
RWC-S
Kyoto
Dst (nT)
0
−100
Solar wind data from DSCOVR
Bz (nT)
20
0
−20
n (1/cm^3)
100
50
0
V (km/s)
1000
750
500
Sep 07
Sep 08
Sep 09
Sep 10
Sep 11
Sep 12
Date

Dissemination

- Two poster presentations on the Kp and AE prediction models were given by Peter Wintoft and Magnus Wik at the workshop “Space Weather: A multidisciplinary approach”, 25-29 Sep, Leiden.

- The paper “Forecasting Kp from solar wind data: input parameter study using 3-hour averages and 3-hour range values”, Peter Wintoft, Magnus Wik, Jurgen Matzka och Yuri Shprits have been published at J Space Weather Space Clim. https://www.swsc-journal.org/articles/swsc/abs/2017/01/swsc160051/swsc160051.html.

- Draft manuscript on AE predictions by Magnus Wik as first author.

- Invited presentation (P. Wintoft on neural network predictions and indices) and poster presentation (M. Wik on AE predictions) were given at the14th European Space Weather Week, Oostende, 27 Nov - 1 Dec.

Summary

- WP 3 *Forecast of the evolution of geomagnetic indices,* with sub-packages, is on schedule.
- Deliverables D3.1–5 have been submitted.
- Task 3.6 is ongoing according to plan. D3.6 before Dec 22.

Question

- WP3 ends Dec 2017.
- WP7 (Fusion) ends mid 2018.
- WP7 may feed back requirements to models (WP3).
- IRFs contribution to WP7 is only 2 man-months.
- Should all work be assigned to WP7?
  - 2 man-months may be exceeded.
  - Or also continue to put hours on WP3?