PROGRESS Meeting 2017-01-09–11

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:

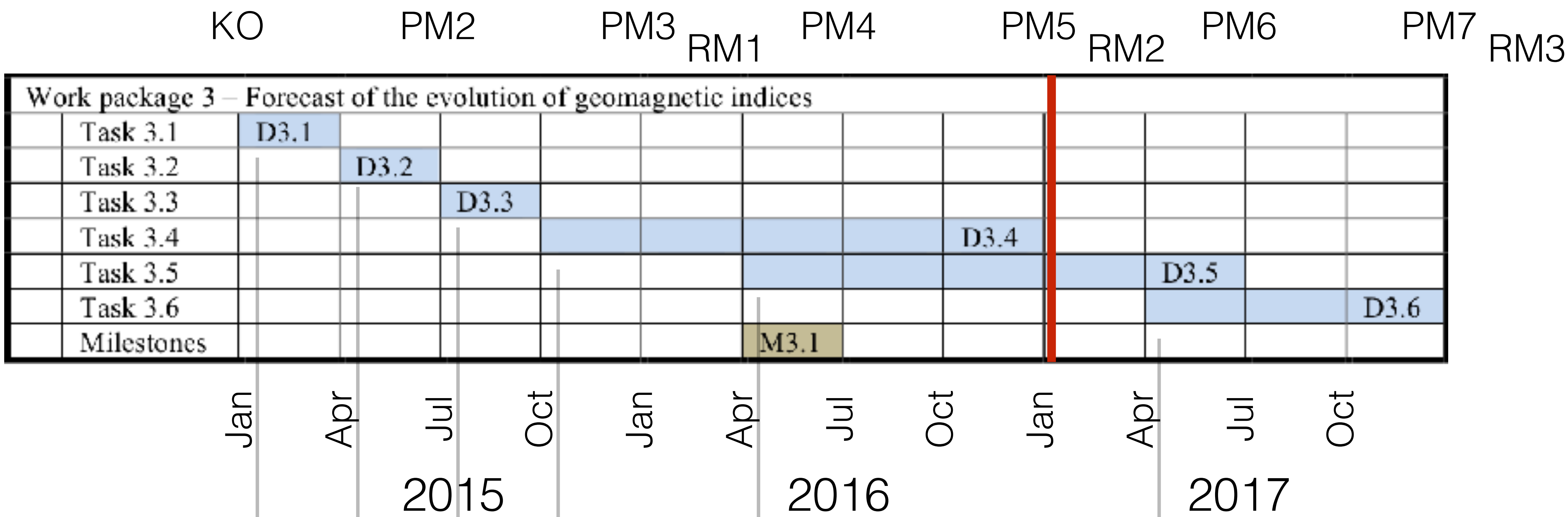
- IRF (P. Wintoft, M. Wik, J. Katkalov)
- USFD (S. Walker)
- SRI NASU-NSAU (V. Yatsenko)

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.

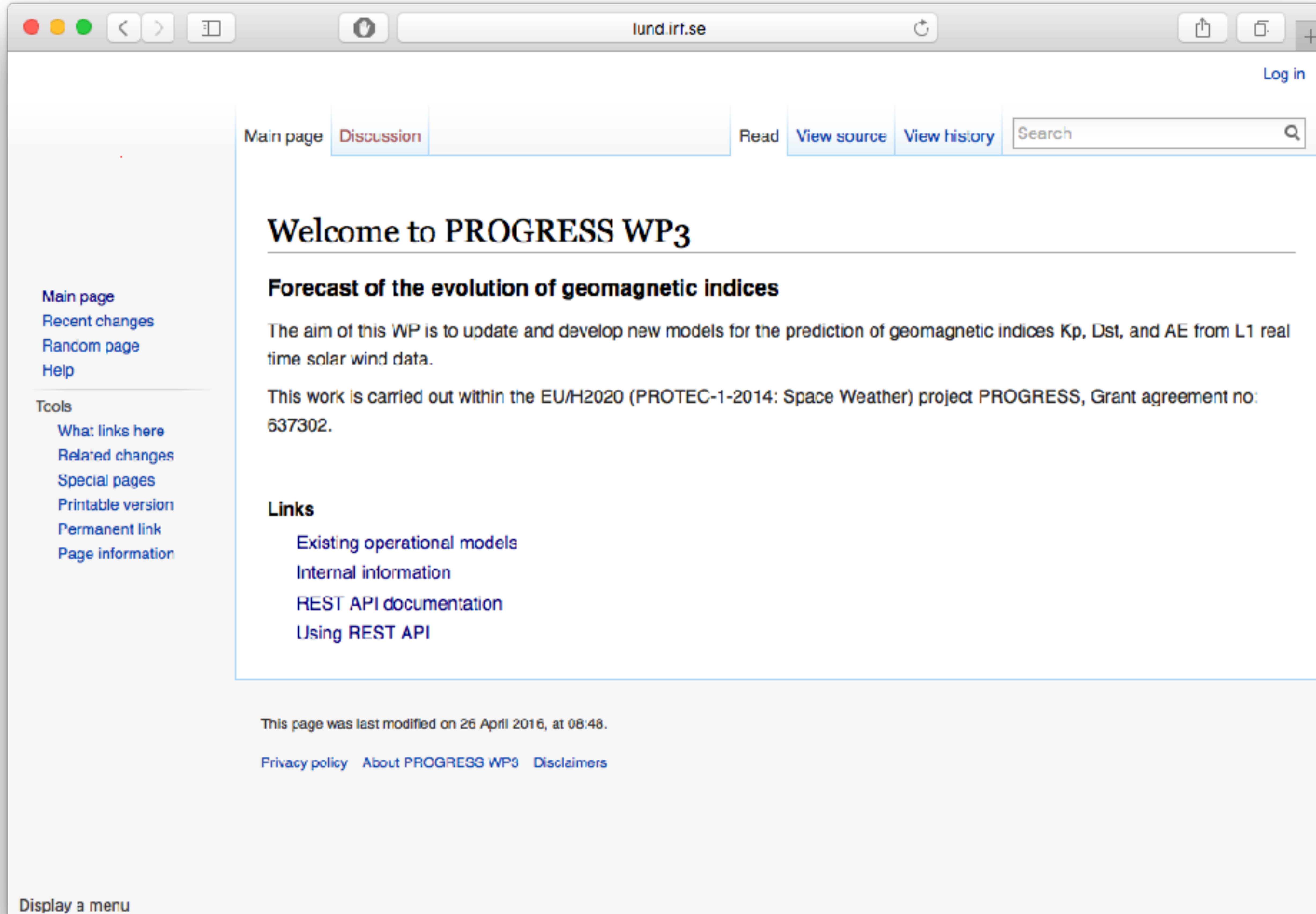
- **Task 3.1 – Survey of existing operational models forecasting Kp, Dst, and AE**
  Month 1-3 (IRF,USFD,SRI NASU-NSAU)
  Identify existing operational Kp, Dst, and AE forecast models. Analyse their respective requirements and benefits considering, e.g. inputs, latency, lead time, and resources. Detailed 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

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



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

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

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D3.3 submitted on Feb 29, 2016.

PROGRESS

PRediction Of Geospace Radiation Environment and Solar wind parameterS

Work Package 3
Forecast of the evolution of geomagnetic indices

Deliverable 3.3
Evaluation and verification of a set of selected existing models

P. Wintoft, M. Wik, R. Boynton, M. Balikhin
February 29, 2016

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 637302.

- Task 3.4 - Develop further existing Kp and Dst models

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

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PROGRESS

PRediction Of Geospace Radiation Environment and Solar wind parameterS

Work Package 3
Forecast of the evolution of geomagnetic indices

Deliverable 3.4
Development of existing Kp and Dst models

P. Wintoft, M. Wik, S. Walker, H.-L. Wei

December 23, 2016

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 637302.

D3.4 submitted on Dec 23, 2016.

D3.4 Kp and Dst models

- Ayala Solares, J. R., Wei, H.-L., Boynton, R. J., Walker, S. N. & Billings, S. A. (2016), 'Modelling and prediction of global magnetic disturbance in near-earth space: A case study for Kp index using narx models', *Space Weather*.

- Wintoft, P., Wik, M., Matzka, J. & Shprits, Y. (2016), 'Forecasting Kp using minute and hour resolution solar wind and implications on lead time', *Journal of Space Weather and Space Climate*, Submitted Nov. 2016.

- Wintoft, P. & Wik, M. (2017), 'Forecasting Dst from the solar wind: An updated IRF-Lund model', *Journal of Space Weather and Space Climate,* Manuscript.

D3.4 Background

- D3.1: Survey of existing operational models forecasting Kp, Dst, and AE
- D3.2: Identify and collect relevant data
- D3.3: Evaluation and verification of a set of selected existing models

D3.2: Data

- Data stored in Postgres database
- Some datasets updated with real-time data
- REST server for convenient access

GET /datasets

Returns all datasets

JSON response fields

field	meaning
resources	A list of API nested resources
resources.<resource>.href	URL of a resource
resources.<resource>.description	Description of a resource
request	URL of actual request

Request example

```
curl 'http://lund.irf.se/progress/rest/datasets'
```

Response example

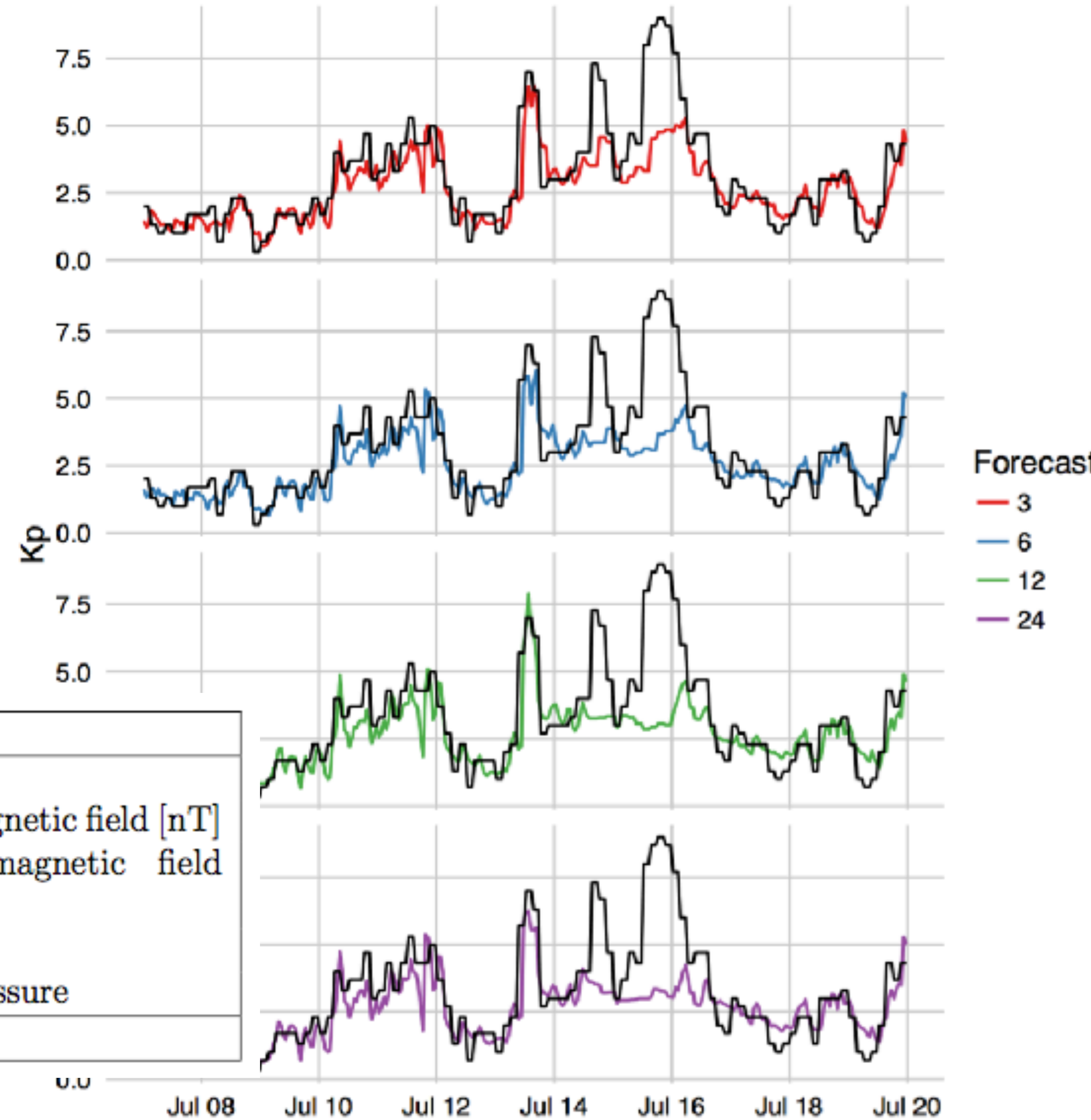

```
{
  "resources": {
    "ace_mag": {
      "description": "Real-Time Solar Wind (RTSW), Magnetometer (MAG) 1-min data",
      "href": "http://lund.irf.se/progress/rest/datasets/ace_mag"
    },
    "ace_swepam": {
      "description": "Real-Time Solar Wind (RTSW), Solar Wind Electron Proton Alpha Monitor (SWEPAM) 1-min
data",
      "href": "http://lund.irf.se/progress/rest/datasets/ace_swepam"
    },
    ..
    "omni_lro": {
      "description": "OMNI low resolution (LRO) data",
      "href": "http://lund.irf.se/progress/rest/datasets/omni_lro"
    }
  },
  "request": "http://lund.irf.se/progress/rest/datasets"
}
```

D3.4: Kp (I)

UoS-Kp-NARX-2016

Horizon	RMSE	Pearson Coefficient	PE
3	0.759	0.871	0.7585
6	0.833	0.842	0.710
12	0.862	0.831	0.690
24	0.872	0.827	0.682

Variable	Symbol	Description
Inputs	V	Solar wind speed [km/s]
	Bs	Southward interplanetary magnetic field [nT]
	VBs	Southward interplanetary magnetic field [VBs = VBs/1000]
	p	Solar wind pressure [nPa]
	Sp	Square root of solar wind pressure
Output	Kp	Index of interest

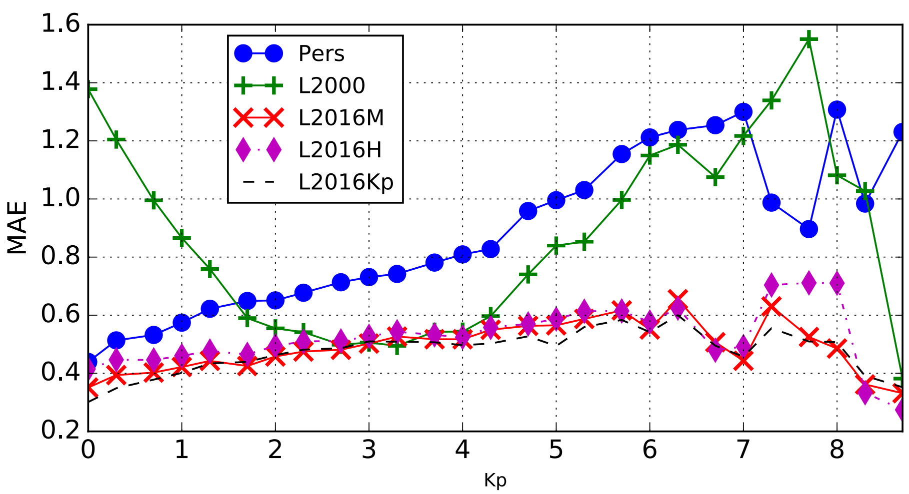


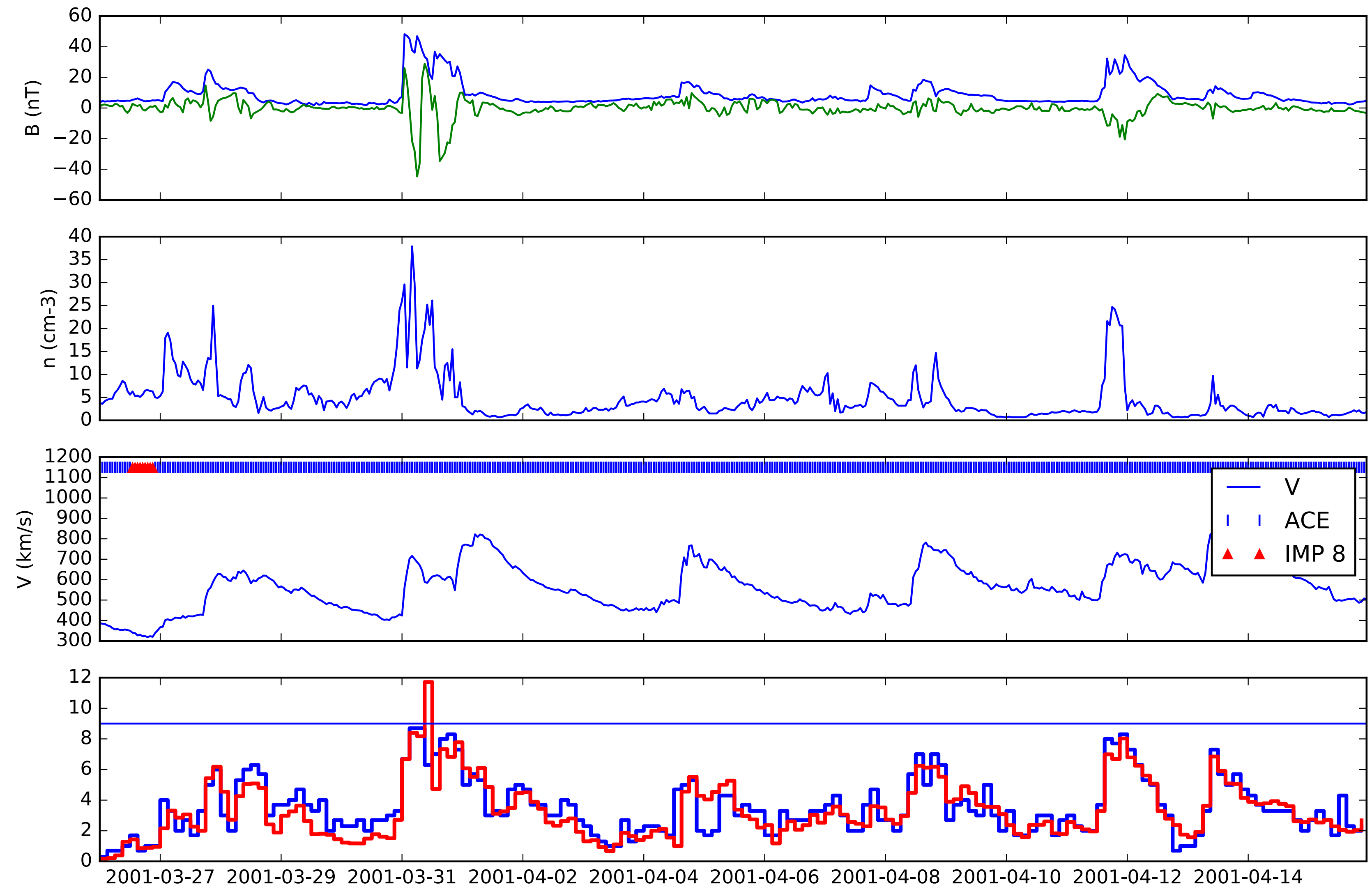
July 2000

D3.4: Kp (II)

IRF-Kp-2016 (h & m)

	BIAS	MAE	RMSE	CORR	MSESS:PERS
Pers	-0.00	0.64	0.87	0.77	nan
IRF-Kp-2000	0.31	0.68	0.84	0.83	0.08
IRF-Kp-2016m	0.04	0.47	0.61	0.90	0.51
IRF-Kp-2016h	0.09	0.51	0.66	0.89	0.43

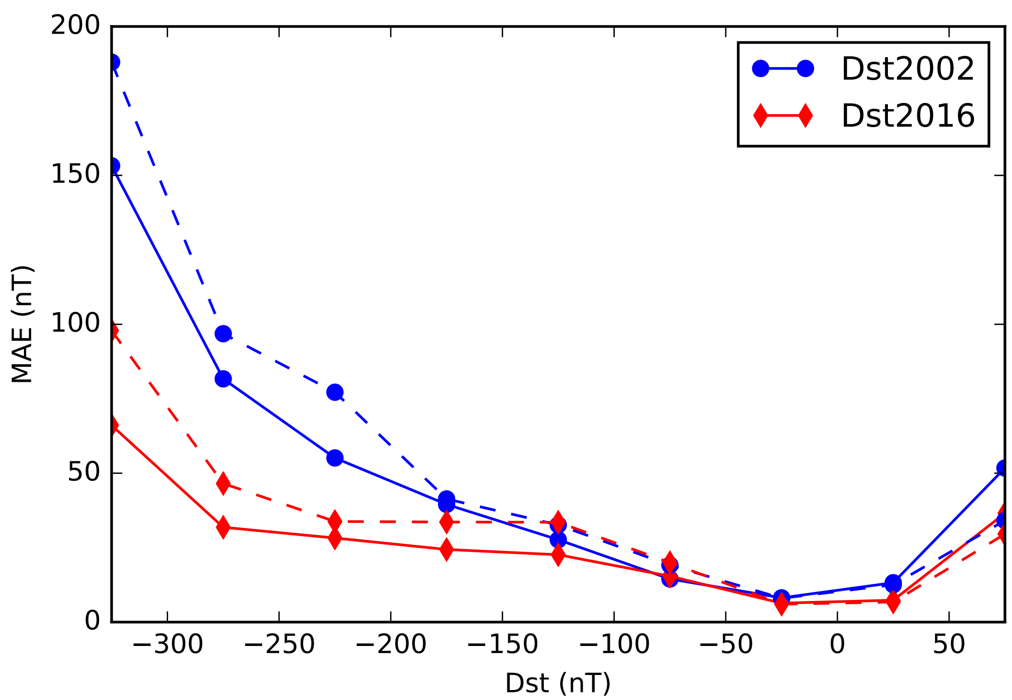


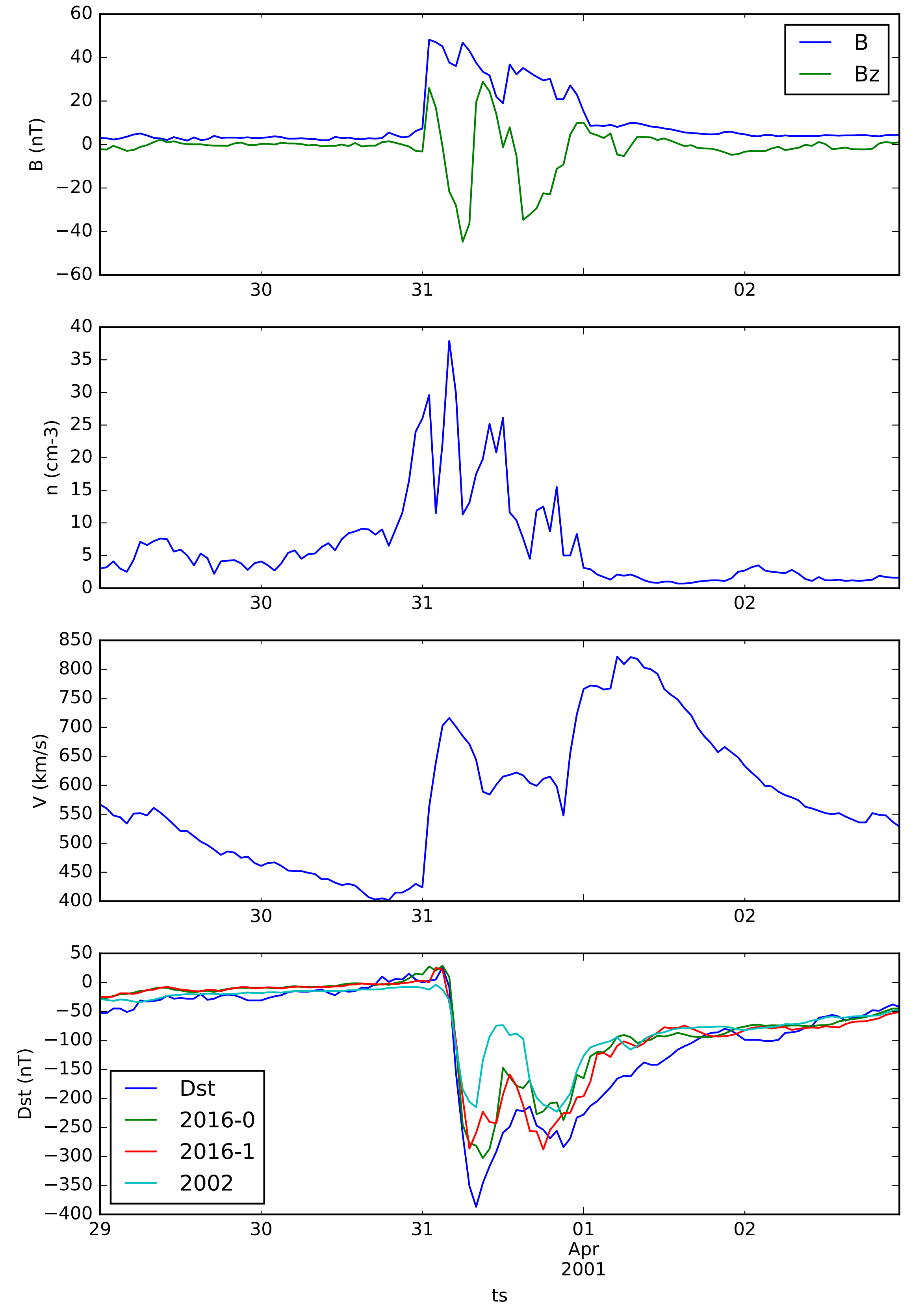


D3.4: Dst

IRF-Dst-2016

Model	Set	n	BIAS	MAE	RMSE	CORR
IRF-Dst-2016	All	177116	0.29	7.03	9.60	0.88
IRF-Dst-2002	All	177116	-6.09	9.65	12.40	0.85
IRF-Dst-2016	A	72511	0.02	7.21	9.58	0.90
IRF-Dst-2002	A	72511	-6.24	10.07	13.05	0.85
IRF-Dst-2016	B	79616	0.27	6.92	9.49	0.86
IRF-Dst-2002	B	79616	-6.17	9.27	11.64	0.85
IRF-Dst-2016	Test	24989	1.13	6.85	9.97	0.89
IRF-Dst-2002	Test	24989	-5.36	9.65	12.83	0.85





WP 3.5 Forecast AE indices

- Forecast models for AL, AU and AE are under development.
- We use the "flat delay" propagation method to propagate ACE data to the magnetopause. OMNI data will also be used but only for comparison.
- Models use back-propagation algorithm with time delays up to 100 min.
- Results so far show correlation of up to 0.8 for the test sets. Will improve data selection and training algorithms.
- Inputs are Bz, By, V and n (mean, max and min) from 5 up to ~60 minutes. Additional inputs are time of year and day.
- Training data have been selected on a yearly basis, using similar distributions. But a new selection algorithm for training, validation and test data is under development.
- Different cross-validation methods will also be examined and the possibility of using ensemble models.

D3.6: Implementation

- We have several Kp and Dst forecasting algorithms that will be implemented.

- We are collecting both ACE and DSCOVR real-time solar wind data. Data are stored in Postgres database.

- Set up access and collection of predicted solar wind from WP 2.

- Run models on all data streams and perform validation.

- Explore causes of remaining prediction errors.

Summary

- WP 3 *Forecast of the evolution of geomagnetic indices,* with sub-packages, is on schedule.
- Deliverables D3.1–4 have been submitted.
- Task 3.5 is ongoing according to plan.
- Task 3.6 has started before schedule.