PROGRESS Meeting 2016-05-30–31

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)

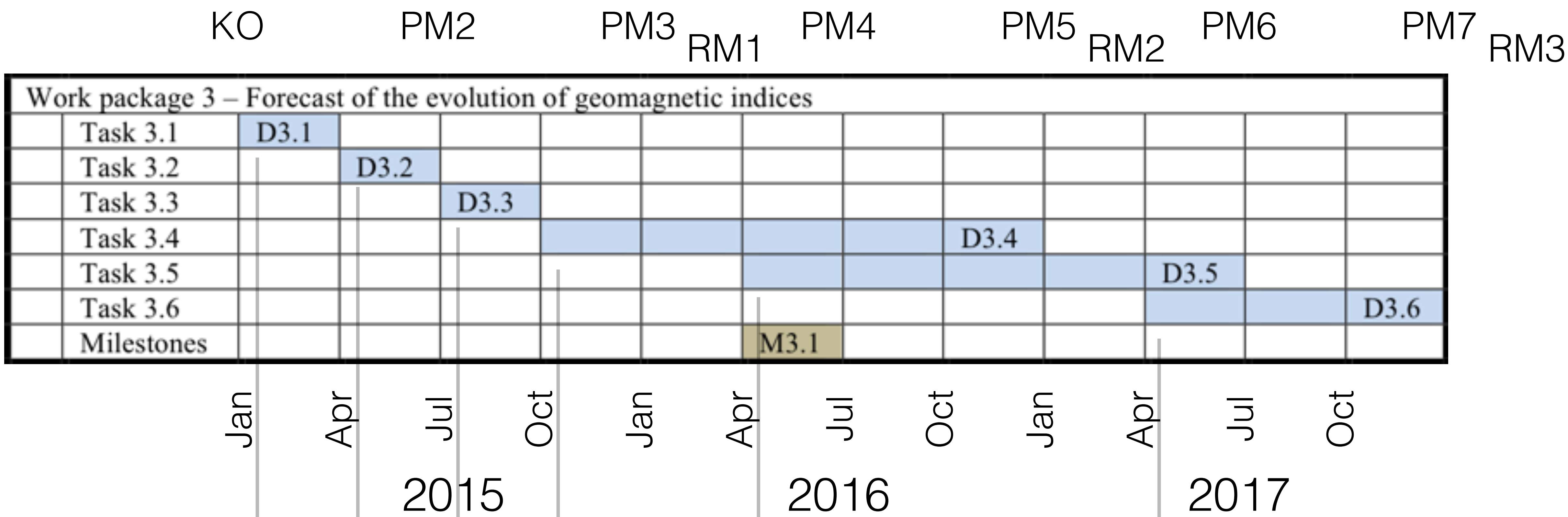
  As a first step to provide a baseline the model in Gleisner and Lundstedt [2001] shall be implemented and verified (Task 3.3). The classifications and categorisation methods (Task 3.4) shall also be applied to provide insight to appropriate parametrisation of the high resolution (minute) solar wind and 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

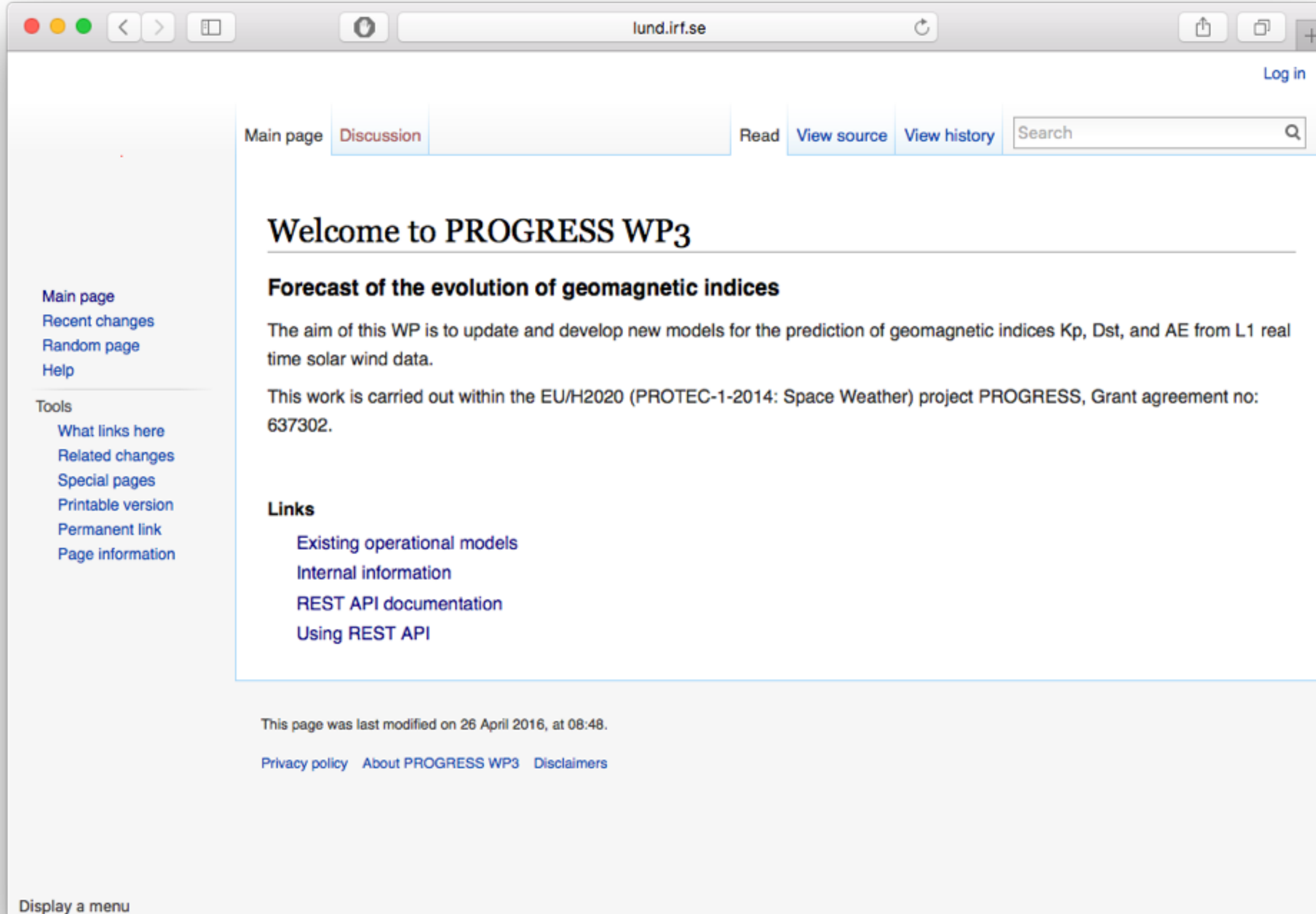
Now

Develop new AE forecast models TN+S

Future

Implement models for real-time operation TN+S

http://www.lund.irf.se/progress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Welcome to PROGRESS WP3

Forecast of the evolution of geomagnetic indices

The aim of this WP is to update and develop new models for the prediction of geomagnetic indices Kp, Dst, and AE from L1 real time solar wind data.

This work is carried out within the EU/H2020 (PROTEC-1-2014: Space Weather) project PROGRESS, Grant agreement no: 637302.

Links

- Existing operational models
- Internal information
- REST API documentation
- Using REST API

This page was last modified on 26 April 2016, at 08:48.

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- 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.

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.

D3.3: Dst

- BMR: Burton et al. (1975)
- OM: O'Brien & McPherron (2000)
- LUND: Lundstedt et al. (2001)
- SN_1: Boynton et al. (2011) and web site[3].

	Dst	LUND	SN_1	BMR	OM	PERS
count	149016	147374	146343	147383	147383	149015
mean	-13	-19	-13	-12	4	-13
std	21	17	20	21	26	21
min	-422	-230	-437	-650	-335	-422
1%	-88	-83	-76	-93	-84	-88
50%	-9	-16	-10	-7	10	-9
99%	20	7	18	7	36	20
max	95	31	62	32	48	95

Table 1: Summary statistics of observed and predicted *Dst* based on the years 1998 to 2014.

D3.3: Dst

	BIAS	MAE	RMSE	CORR	MSESS:PERS	MSESS:BMR
LUND	-6.69	10.06	12.91	0.85	-7.20	0.24
SN_1	-0.96	8.15	11.35	0.84	-5.34	0.41
BMR	0.46	9.94	14.83	0.74	-9.82	nan
OM	16.74	19.60	23.07	0.78	-25.20	-1.42
PERS	-0.00	2.75	4.51	0.98	nan	0.91

Table 2: Measures and scores for observed *Dst* and predicted *Dst* using all data.

	BIAS	MAE	RMSE	CORR	MSESS:PERS	MSESS:BMR
LUND	10.40	19.56	27.86	0.72	-3.79	0.64
SN_1	13.80	20.13	28.18	0.76	-3.90	0.63
BMR	8.26	33.59	46.16	0.73	-12.15	nan
OM	16.44	26.15	33.42	0.72	-5.89	0.48
PERS	1.25	7.59	12.73	0.95	nan	0.92

Table 3: Measures and scores for observed *Dst* and predicted *Dst* when observed $Dst < -50$ nT.

D3.3: Dst

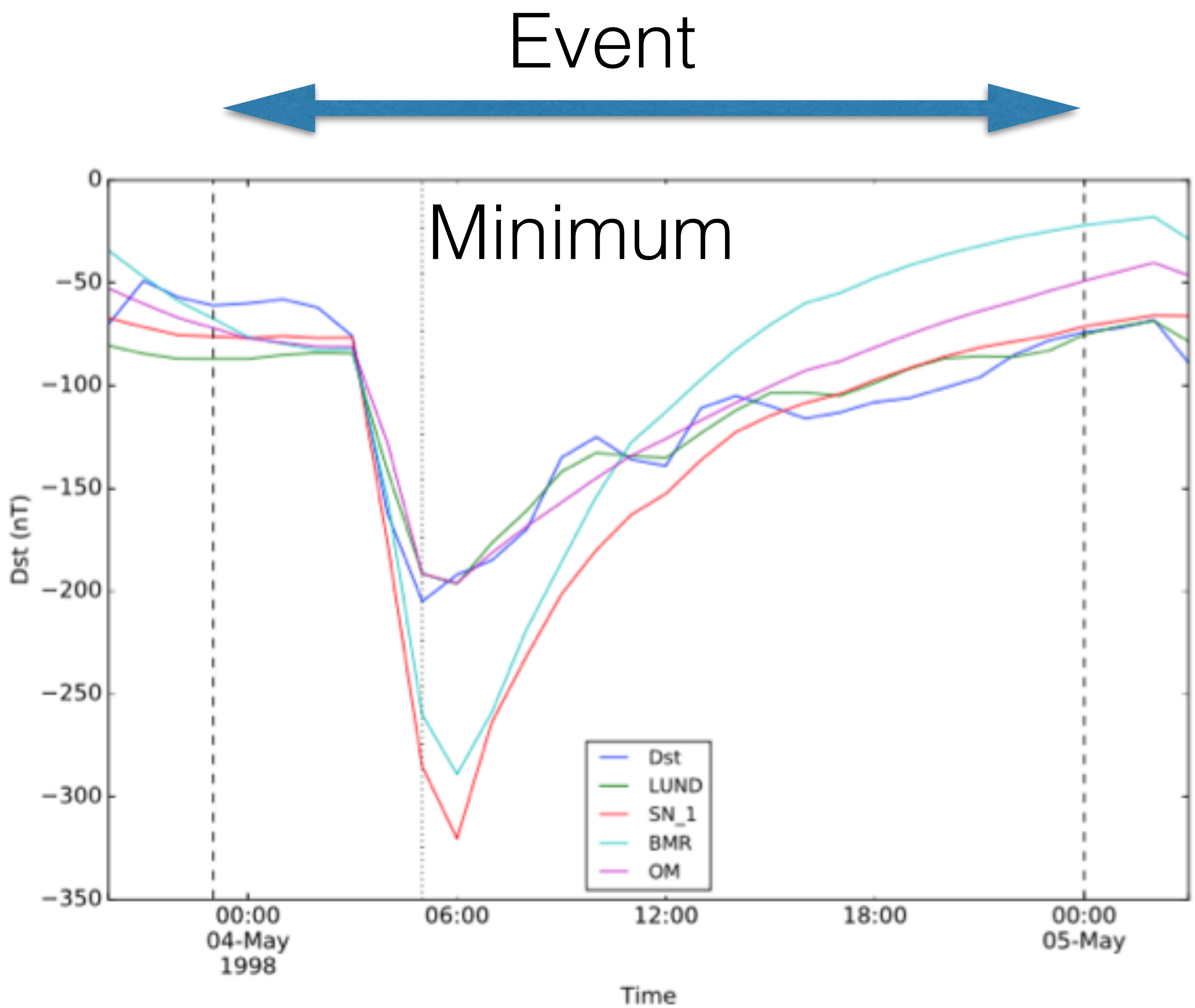


Figure 1: A storm in 1998 with observed and predicted *Dst*. Dashed lines mark start and end of the event, and the dotted line marks observed *Dst* minimum.

Wavelet filtering to identify storms

Compare also

Echer, E., Gonzalez, W. D., Tsurutani, B. T. & Gonzalez, A. L. C. (2008), ‘Interplanetary conditions causing intense geomagnetic storms (dst ≤ -100 nt) during solar cycle 23 (1996–2006)’, Journal of Geophysical Research 113, A05221.

D3.3: Dst

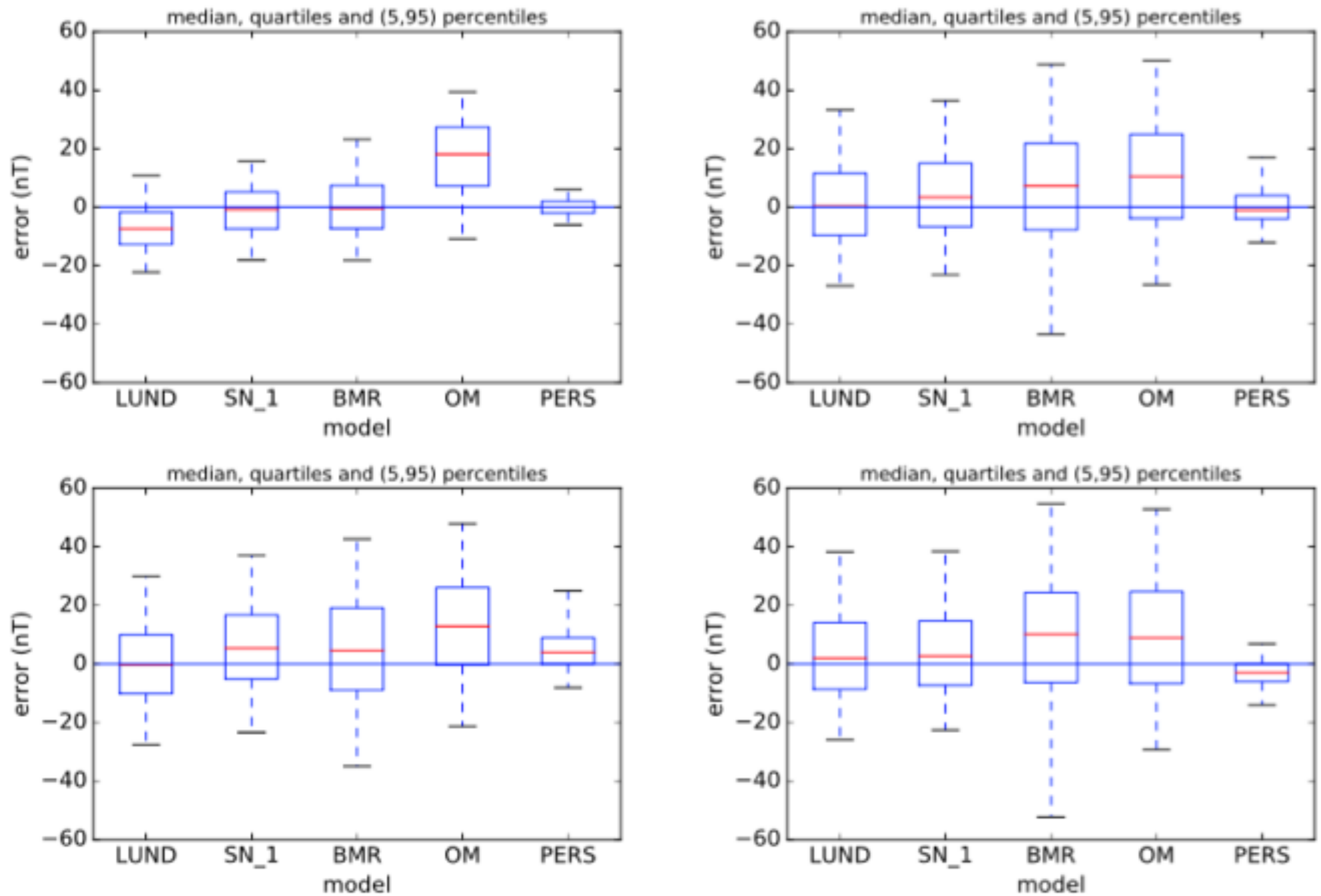


Figure 2: Error box plot of predicted *Dst* vs. observed *Dst*. For each model the median error (red horizontal line), the quartiles (box), and the 5 and 95% percentiles (whiskers) are shown. The errors are computed on all data (top left), storm data (top right), main phase data (bottom left), and recovery phase data (bottom right).

D3.3: Dst

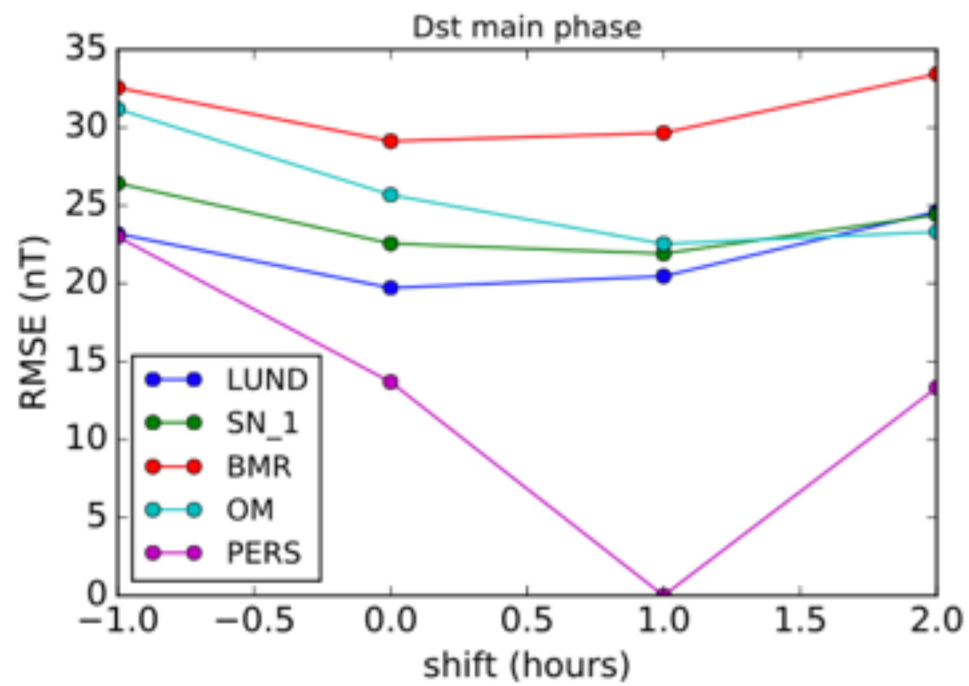


Figure 3: RMS errors of the predictions compared to observed *Dst* shifted by -1, 0, 1, and 2 hours.

	n	p
LUND	273	54
SN_1	174	35
BMR	203	40
OM	123	24
PERS	0	0

a prediction to be timely if the RMSE using observed Dst is smaller than the RMSE on the one hour shifted Dst

Table 4: Number (n) and percent (p) of correctly predicted storm main phases. See text for meaning of correct.

D3.3: Kp

Kp	g = ap	nT
0	0	0
1	4	8
2	7	14
3	15	30
4	27	54
5	48	96
6	80	160
7	132	264
8	207	414
9	400	800

Table 8: Relation between *Kp* and range ap in units of 2 nT and nT.

- LUND_NC: Nowcast of current *Kp* (Boberg et al. 2000)
- LUND_FC: Forecast of next *Kp* (Boberg et al. 2000)

We have received Sheffield Kp forecasts. Will be added in the analysis.

D3.3: Kp

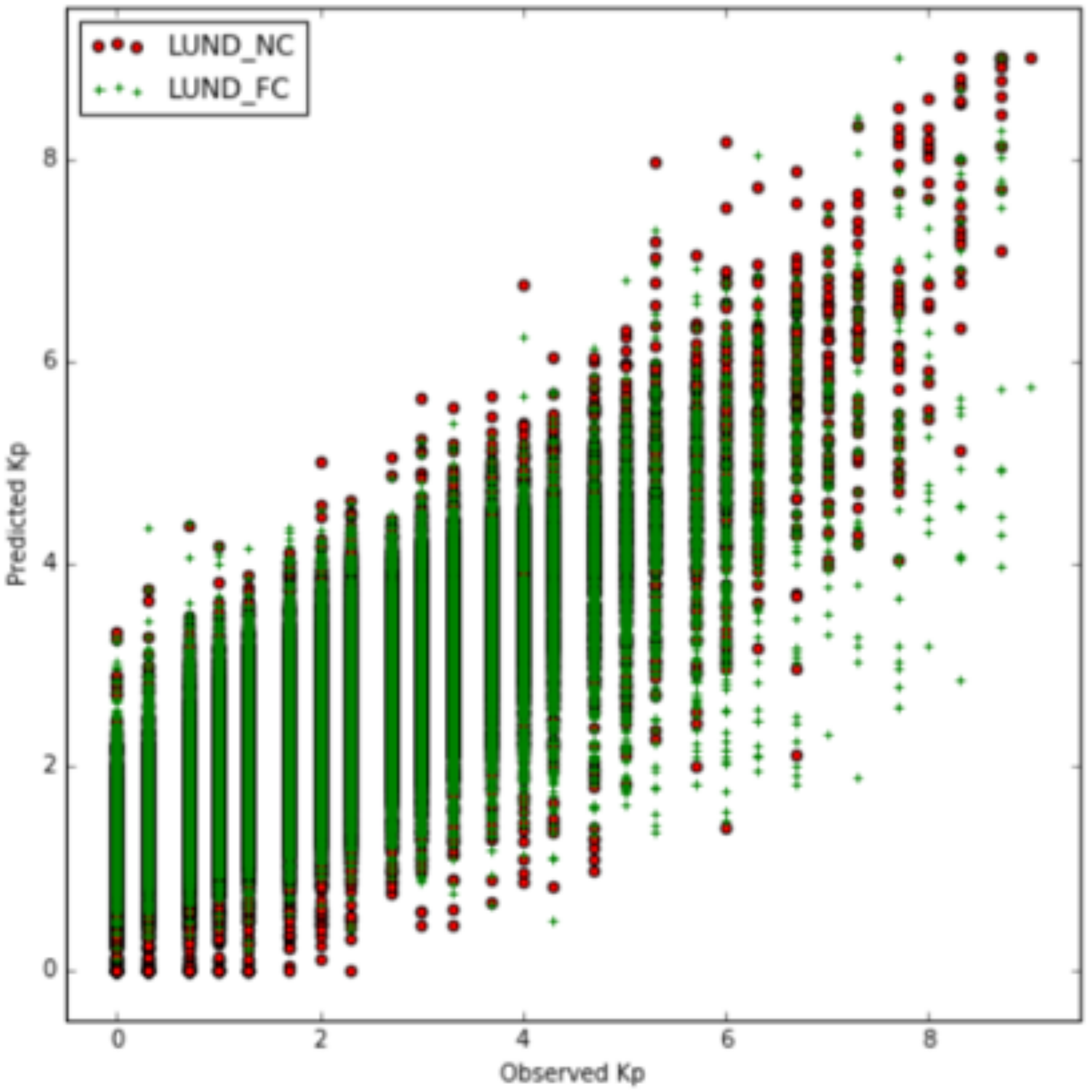


Figure 4: Scatter plot of predicted *Kp* vs. observed *Kp*.

	BIAS	MAE	RMSE	CORR	MSESS:PERS
LUND_NC	0.43	0.72	0.87	0.84	-0.05
LUND_FC	0.54	0.88	1.04	0.78	-0.50
PERS	-0.00	0.63	0.85	0.81	nan

Table 10: Measures and scores for observed *Kp* and predicted *Kp* using all data.

	BIAS	MAE	RMSE	CORR	MSESS:PERS
LUND_NC	0.06	0.58	0.73	0.88	0.44
LUND_FC	-0.02	0.69	0.89	0.79	0.18
PERS	-0.80	0.80	0.98	0.91	nan

Table 11: Measures and scores for observed *Kp* and predicted *Kp* using only data when *Kp* increses.

	BIAS	MAE	RMSE	CORR	MSESS:PERS
LUND_NC	0.67	0.83	0.98	0.78	-0.27
LUND_FC	0.95	1.04	1.19	0.81	-0.86
PERS	0.72	0.72	0.87	0.92	nan

Table 12: Measures and scores for observed *Kp* and predicted *Kp* using only data when *Kp* decreases.

D3.3: Kp

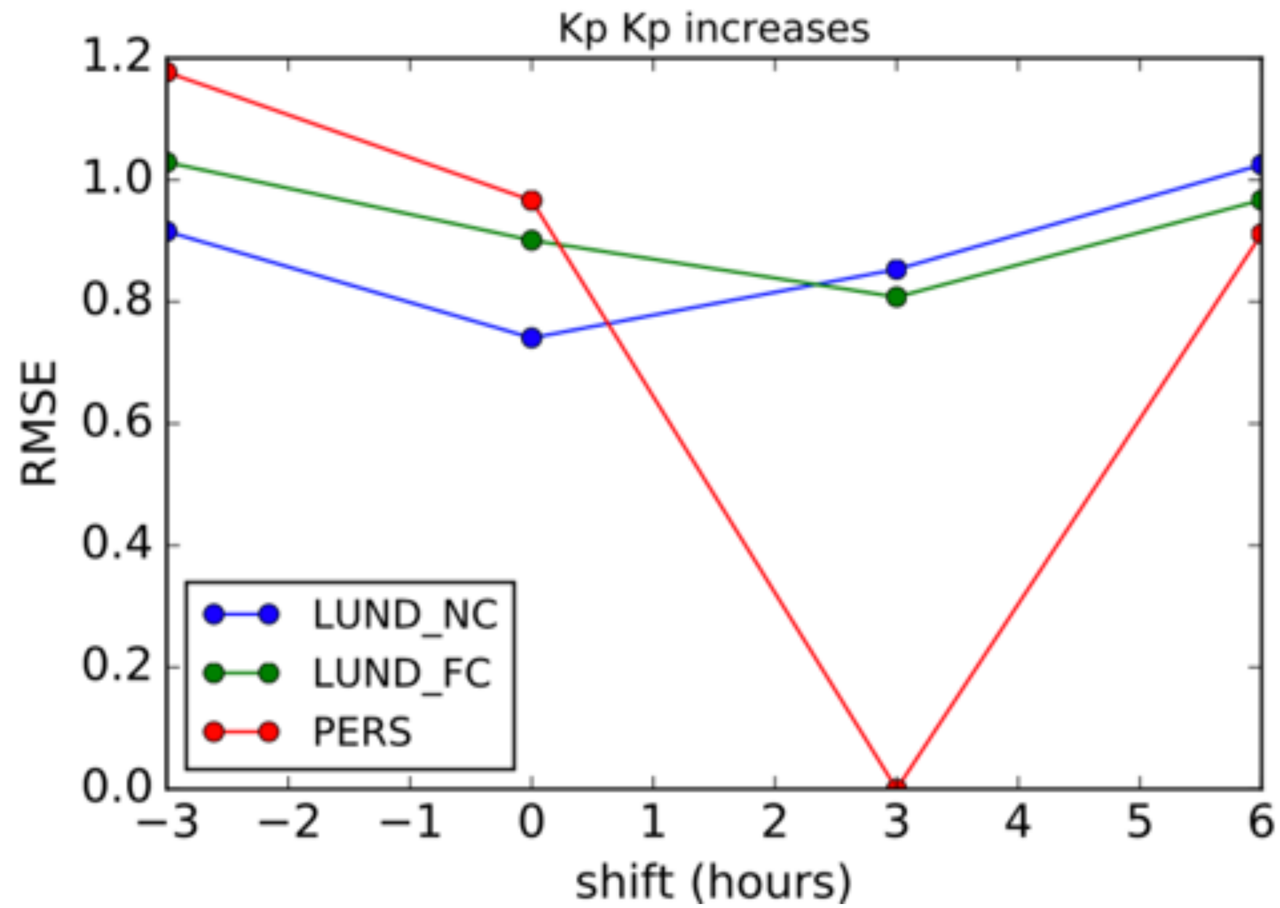
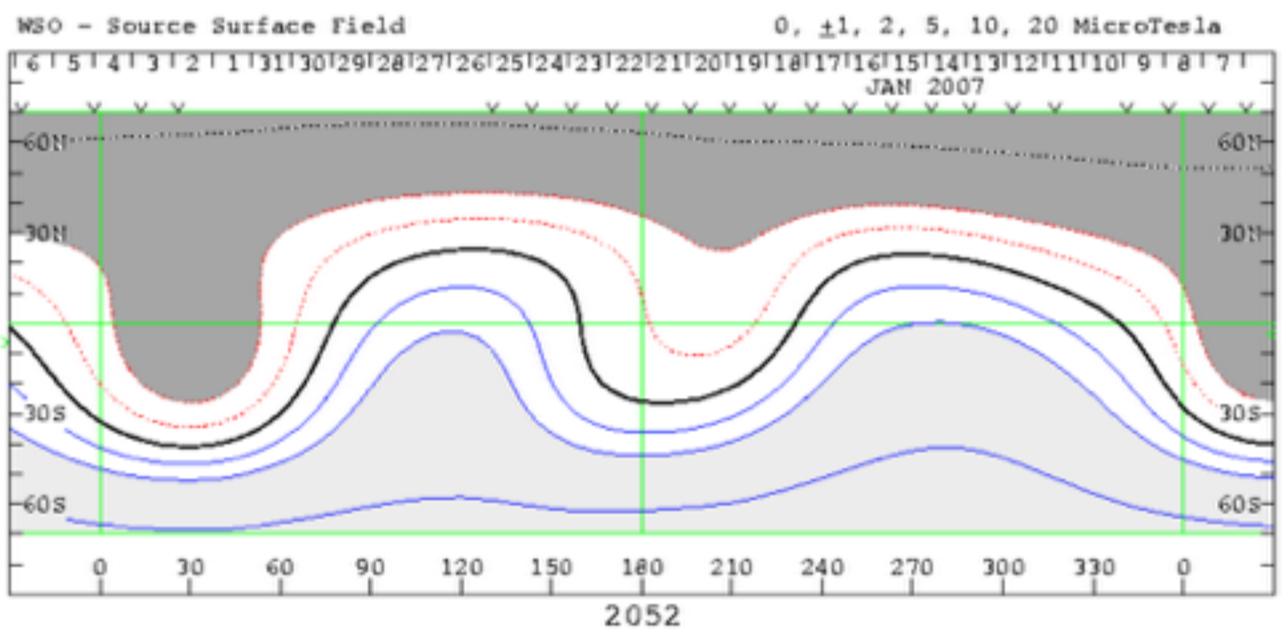


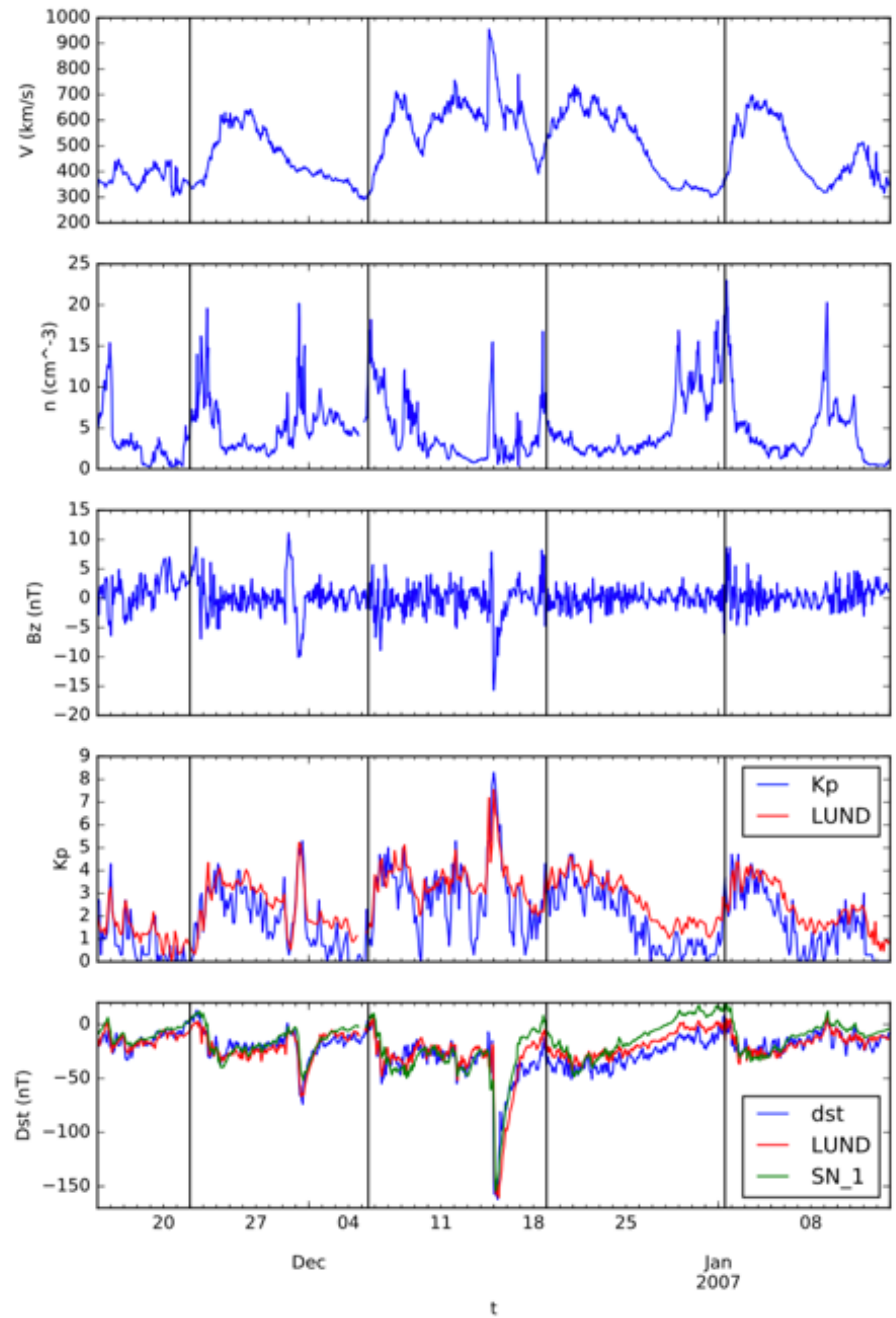
Figure 6: RMS errors of the predictions compared to observed *Kp* shifted by -3, 0, 3, and 6 hours.

	n	p
LUND_NC	10554	78.731816
LUND_FC	9886	73.748601
PERS	0	0.000000

Table 13: Number (n) and percent (p) of correctly predicted *Kp* increase events. See text for meaning of correct.

D3.3: Event based verification





Perform verification on events when driven by predicted s.w.

D3.3: Event based verification – Dst

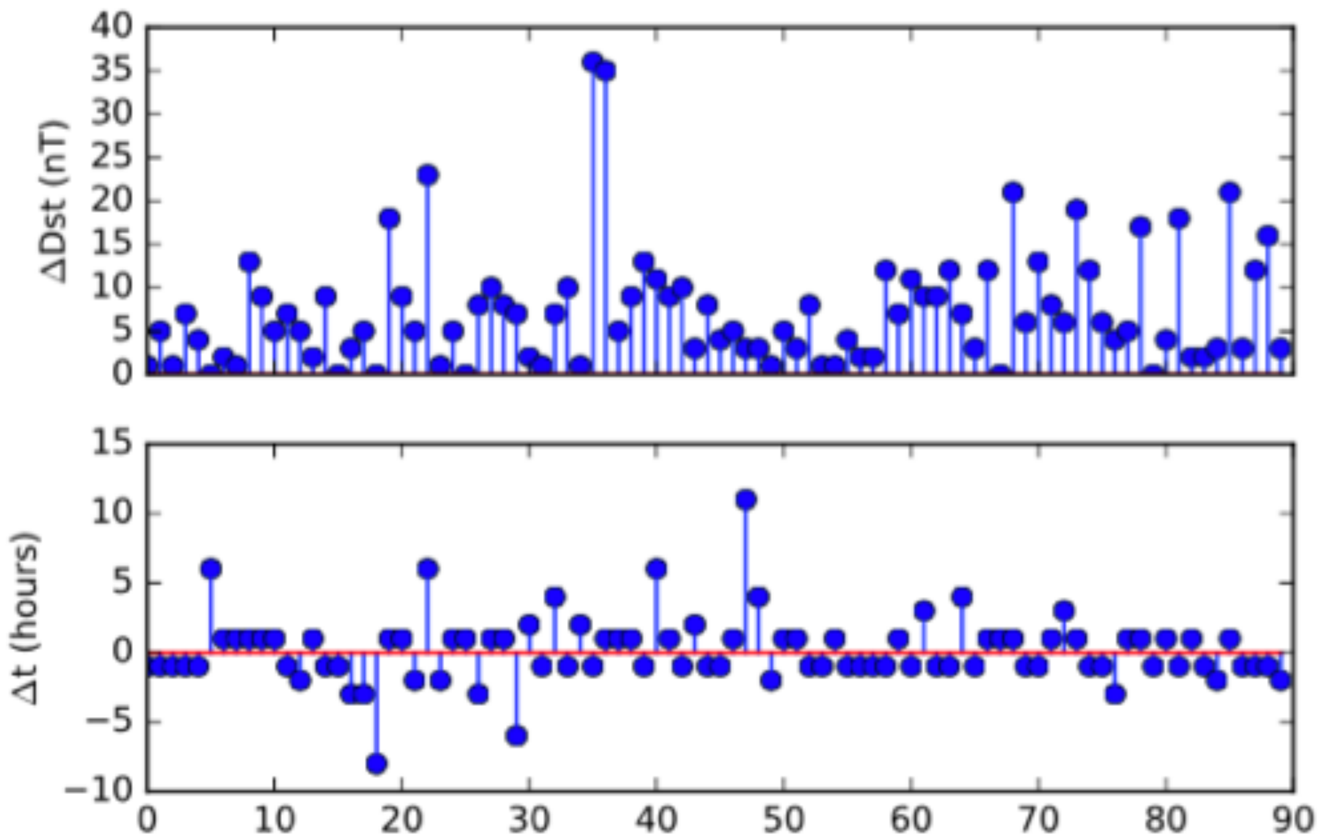


Figure 8: Top: The figure shows the difference between lowest and second-lowest *Dst* values for each event in the list by Echer et al. (2008). Bottom: The difference in hours between the times of the two lowest *Dst* values.

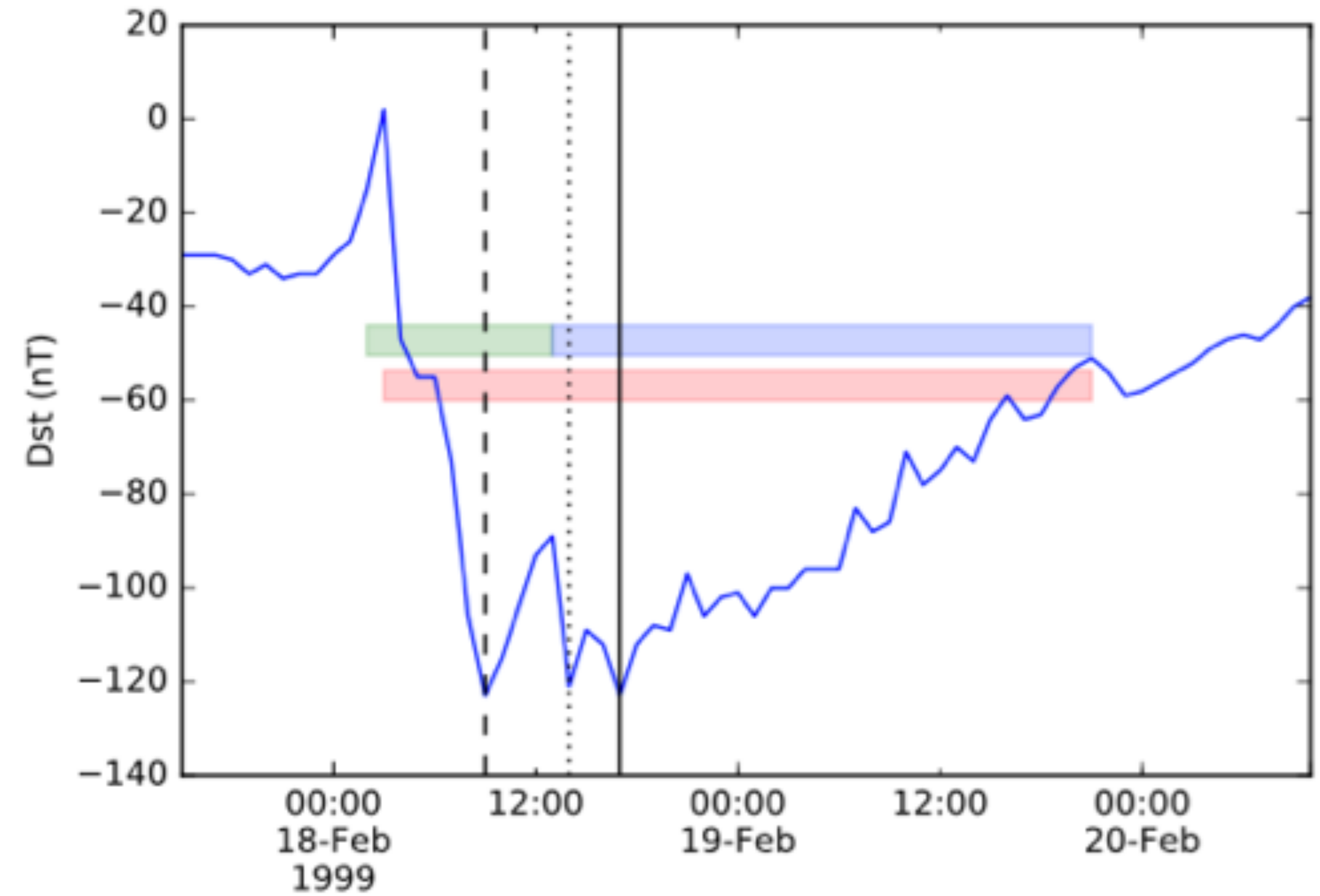
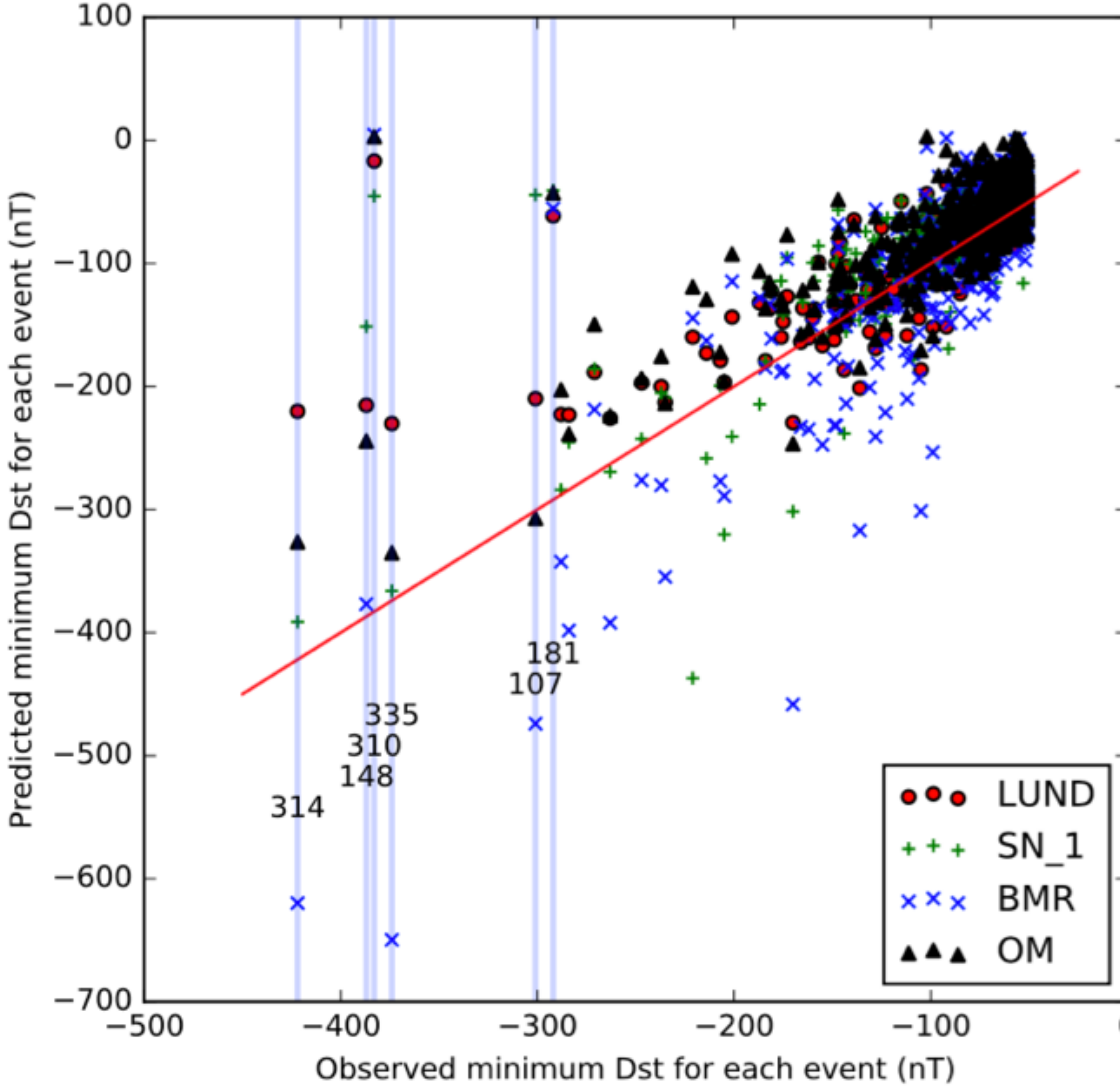


Figure 9: One event illustrating the ambiguity of the time of the *Dst* minimum. Vertical lines show the times of the lowest (solid), second lowest (dashed), and third lowest (dotted) *Dst* values. Coloured bars show extension of events. See text for description.

D3.3: Event based verification – Dst



D3.3: Event based verification – Dst

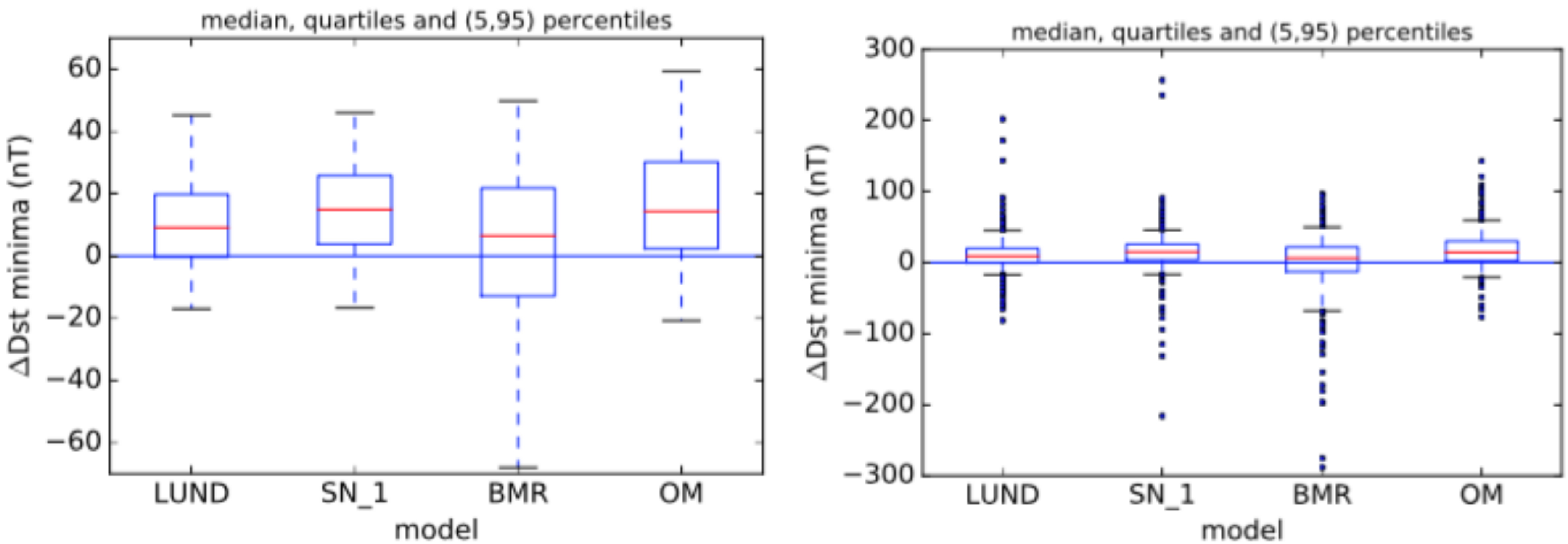


Figure 12: The errors between observed and predicted minima *Dst* for each event. Right plot shows top 10% largest errors as individual points. Events 181 and 310 have been excluded as solar wind data are missing.

D3.3: Event based verification – Kp

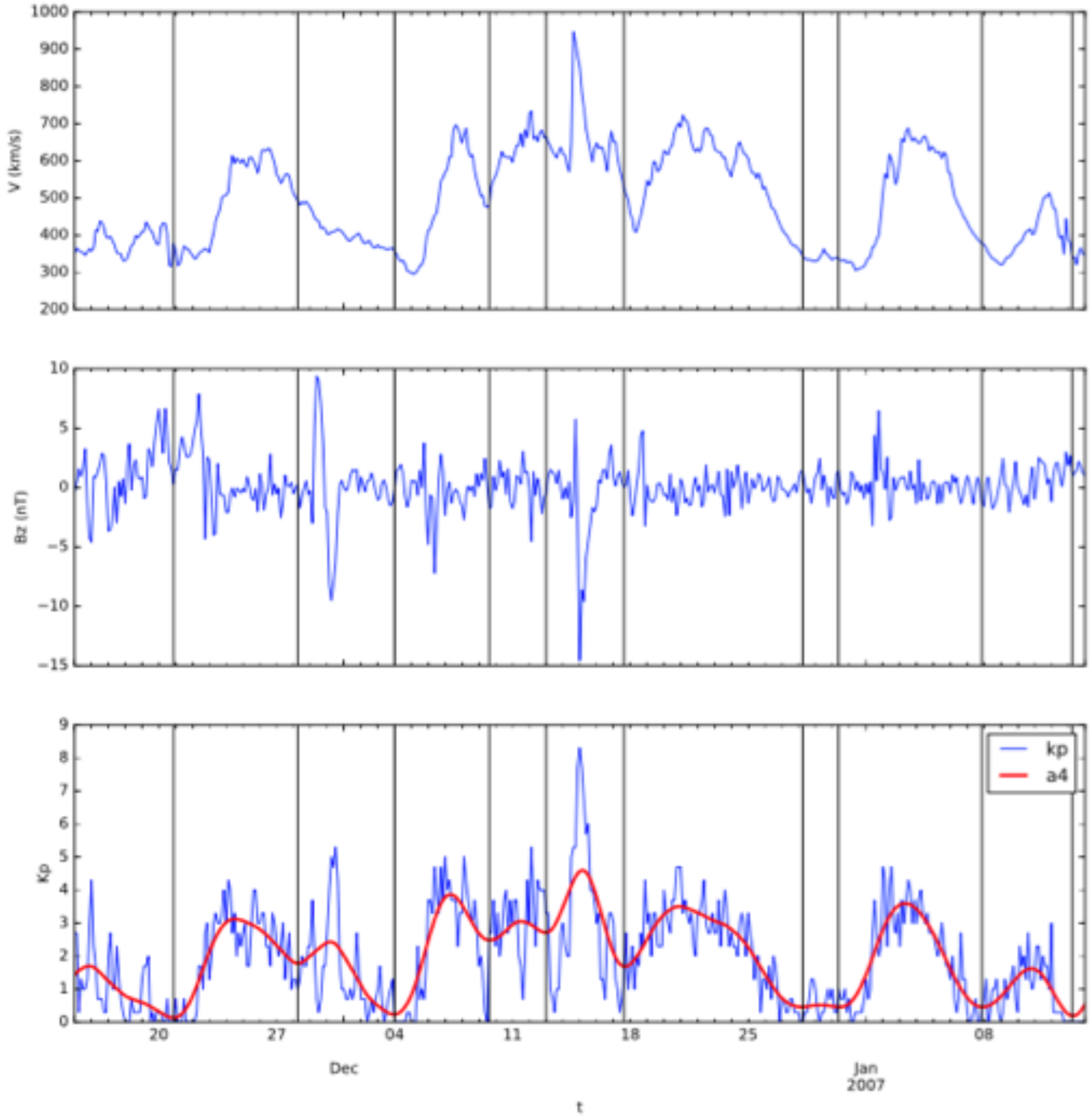
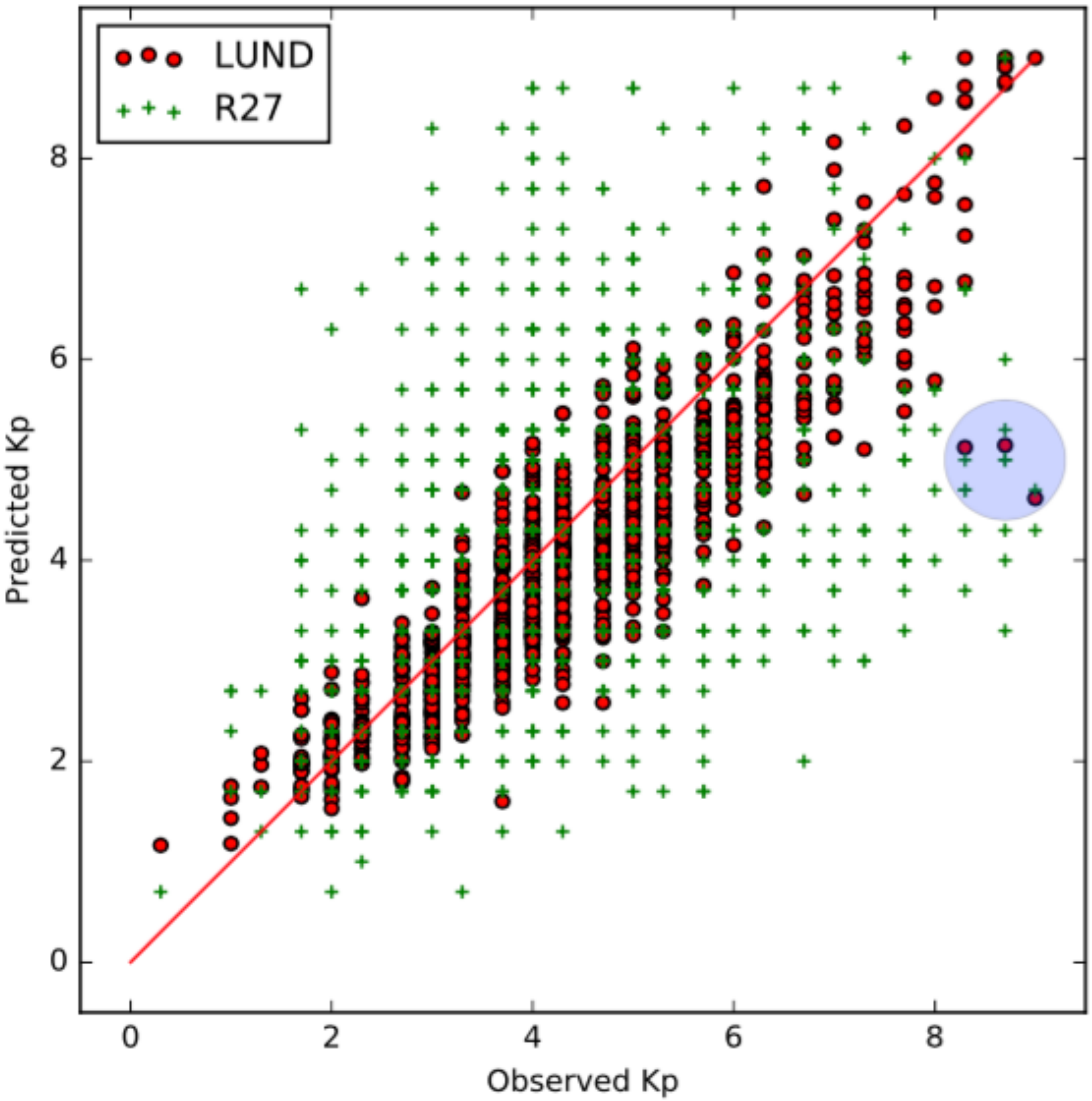


Figure 13: Example of identified times of minima (vertical lines) for filtered Kp (red curve).

Kp	n
0	1
1	7
2	80
3	206
4	323
5	249
6	122
7	51
8	27
9	10

D3.3: Event based verification – Kp

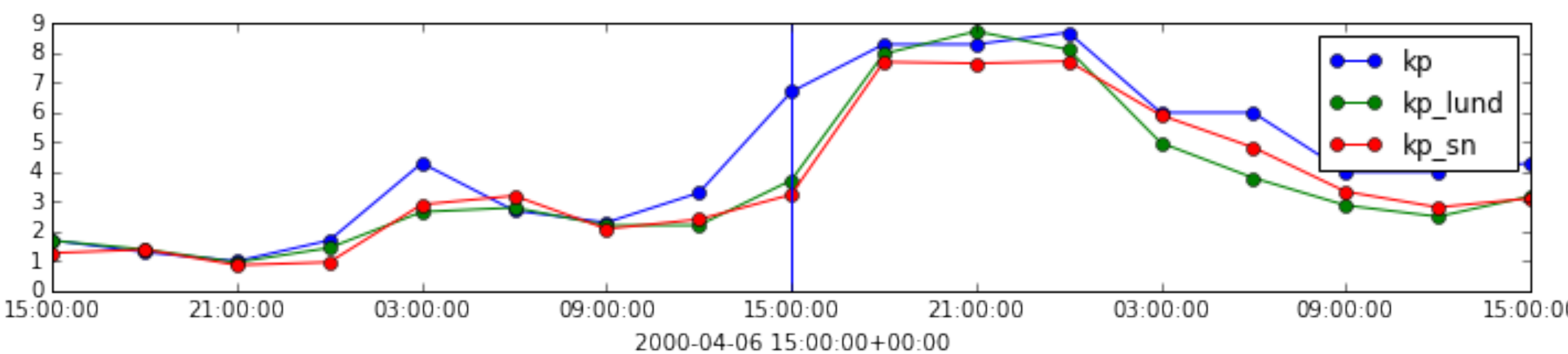


There are three outliers (encircled) for large Kp where two of them are due to solar wind datagaps.

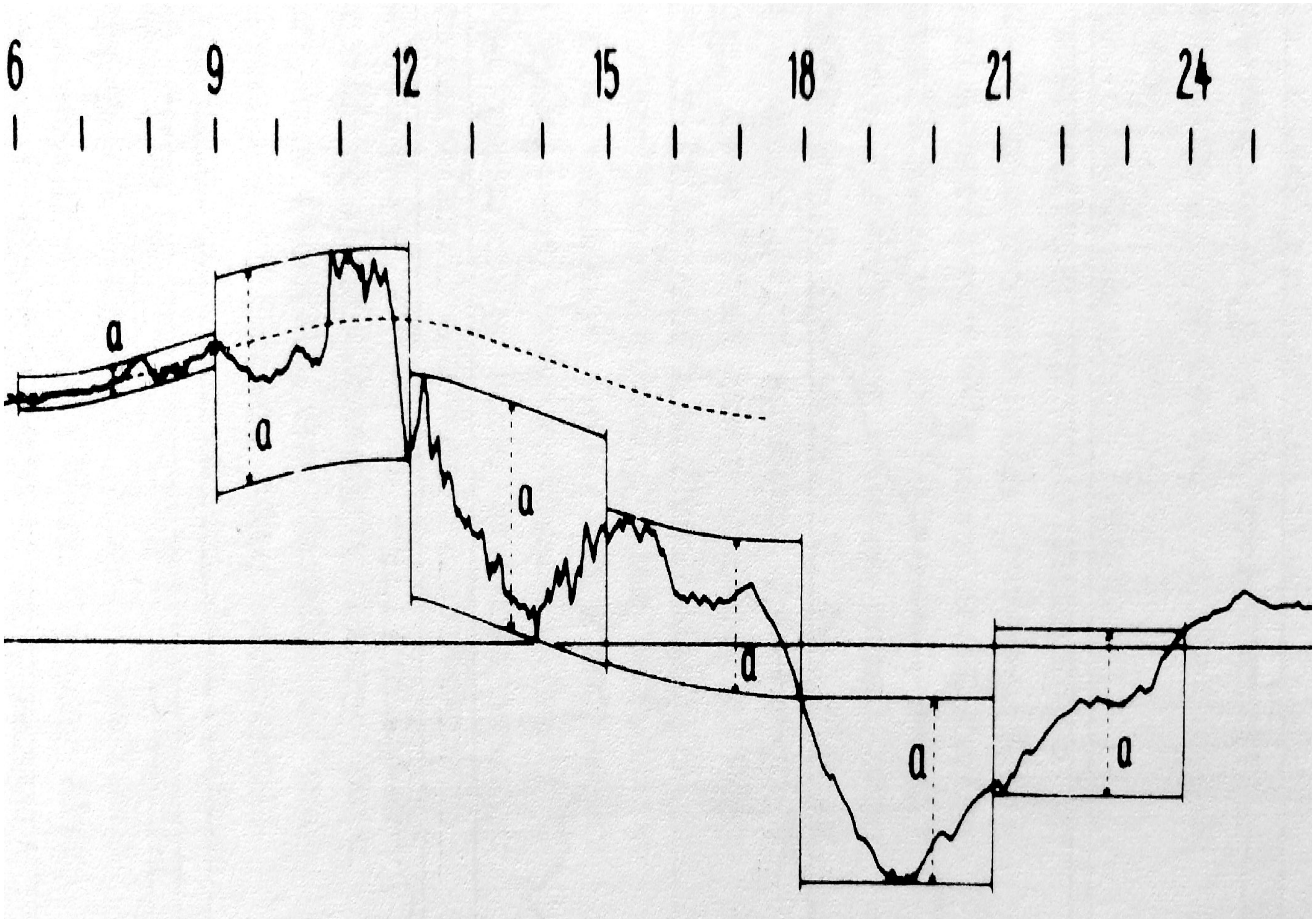
The third might be due to that the solar wind Bz component turned strongly negative but only for a very short time.

=> model improvement

D3.4: Kp updates

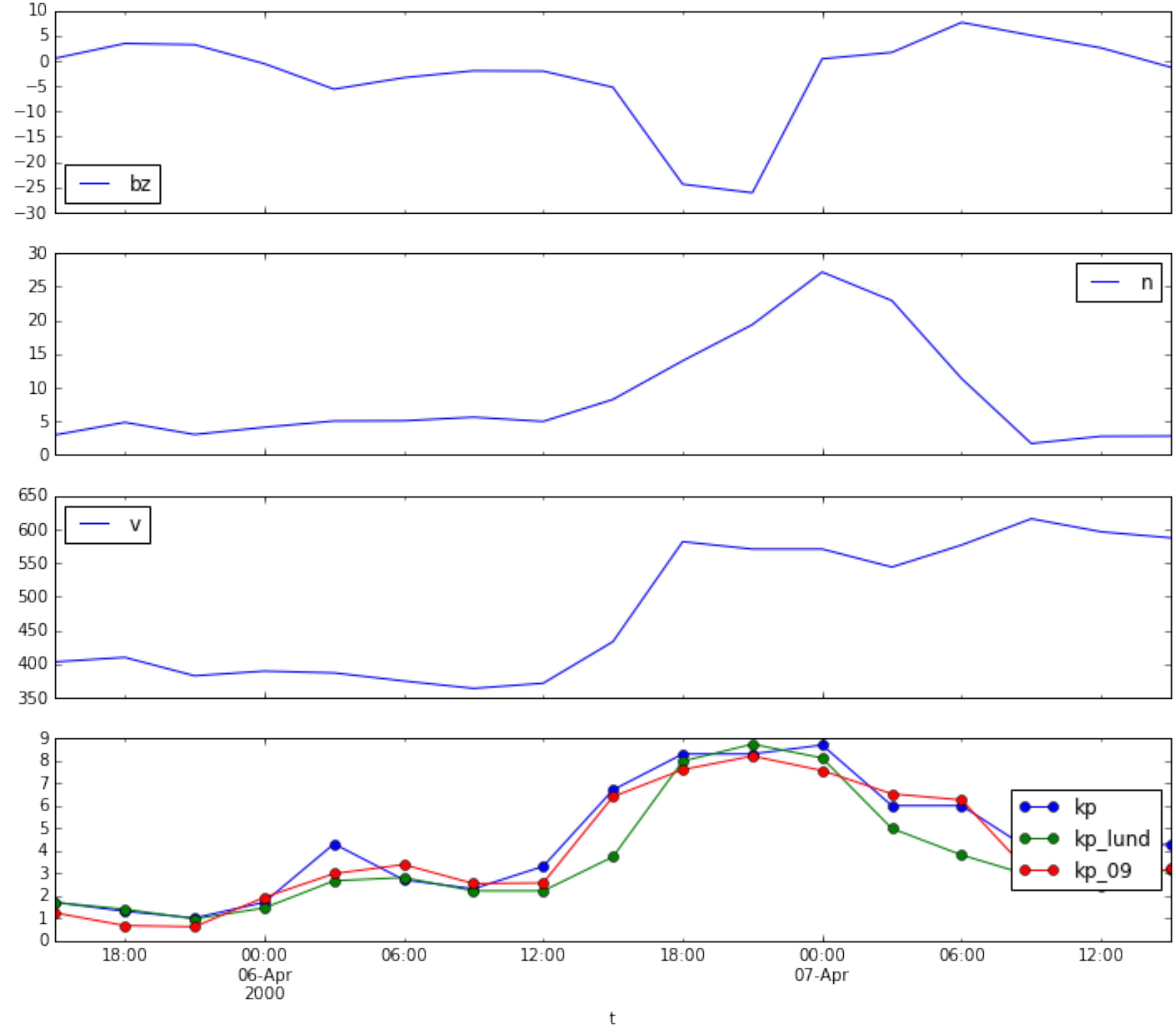


D3.4: Kp updates



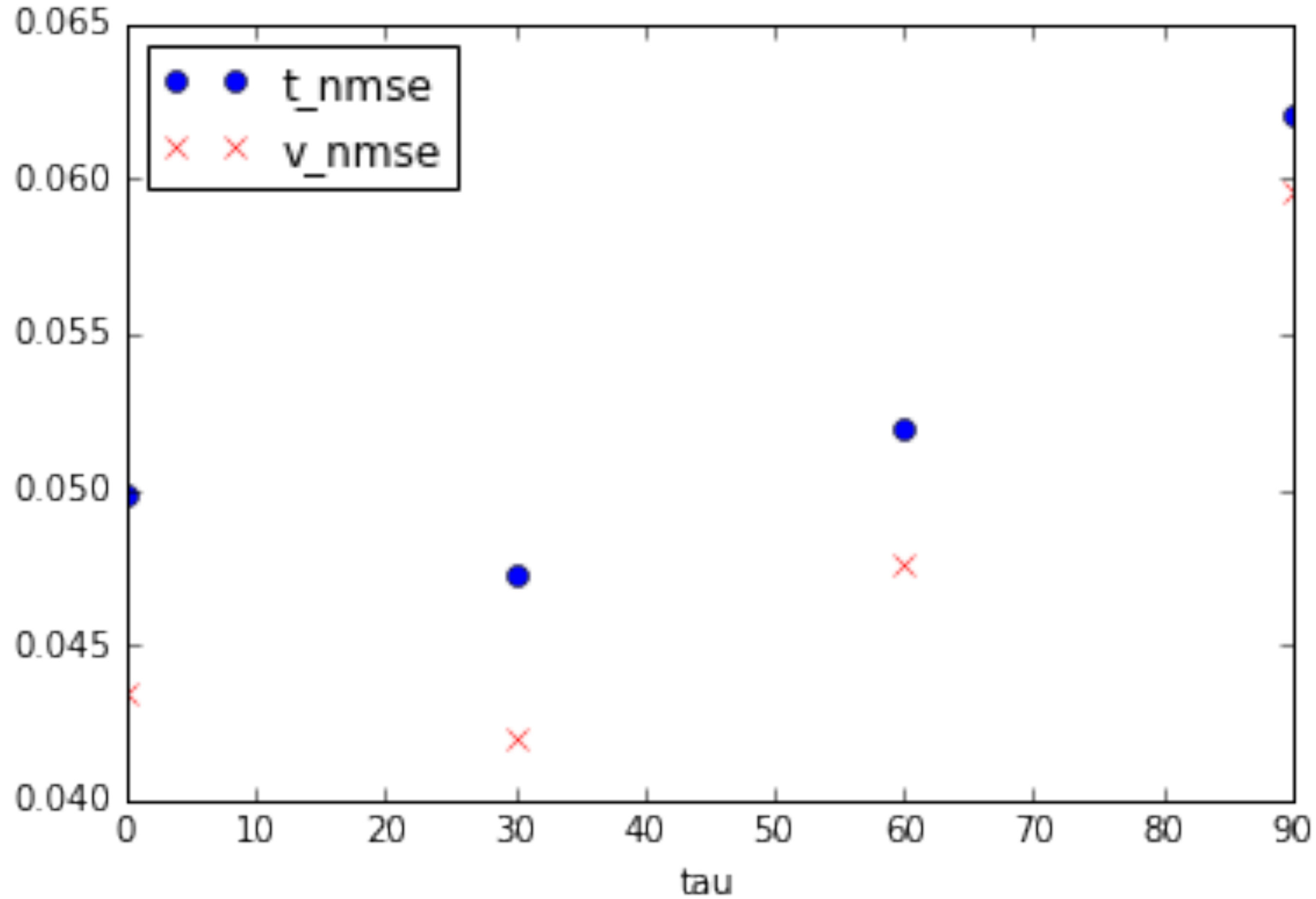
D3.4: Kp updates

3-hour minimum and maximum values formed from propagated 10-minute ACE s.w. data



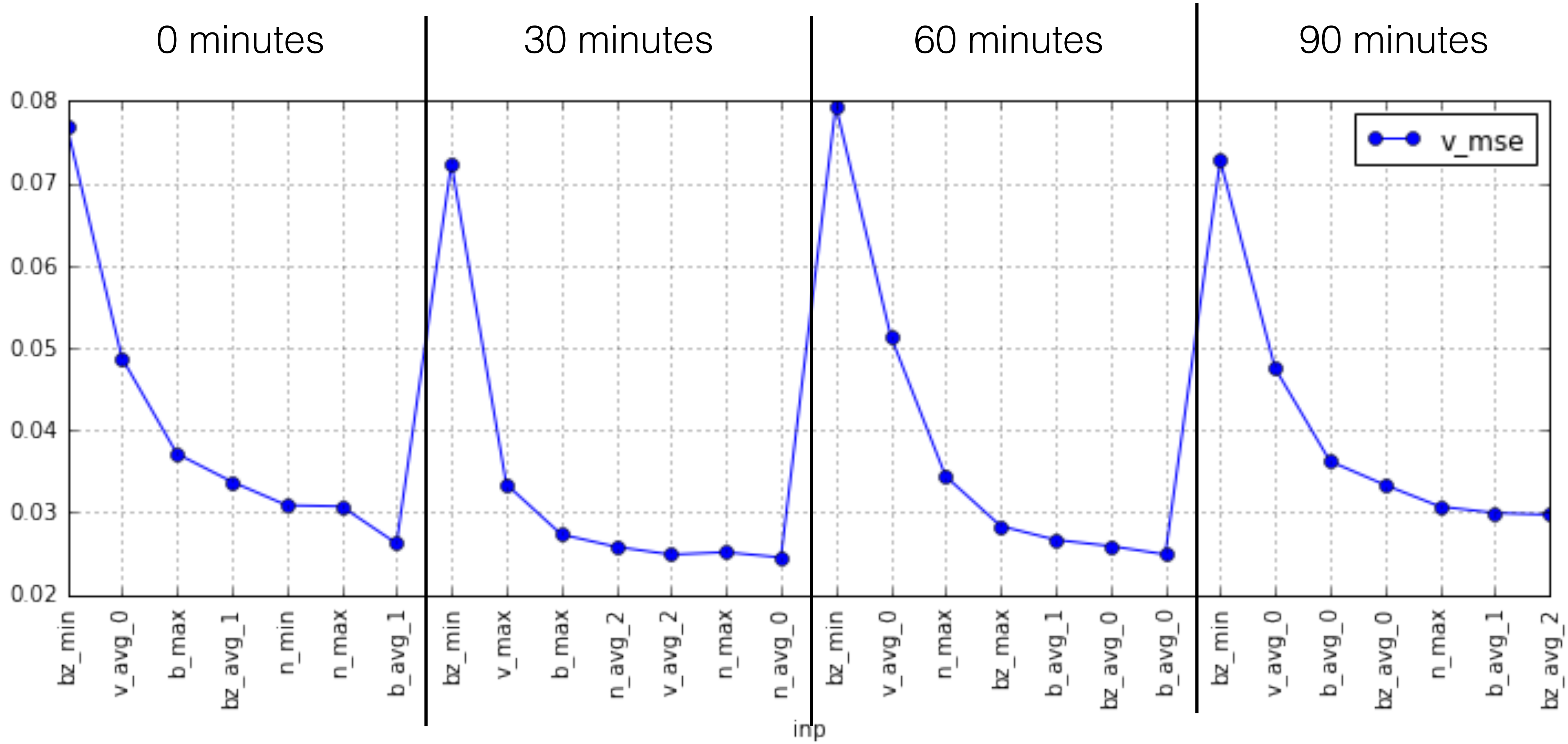
D3.4: Kp updates

Optimal lead time



D3.4: Kp updates

Relevant inputs



D3.4: Kp and Dst updates

- Work has been carried out on Kp improvements using neural networks.
- New Kp model(s) before summer.
- Write paper including
  - results from D3.3
  - new model approach
  - both NN and NARMAX
  - journal?
- Dst model updates during autumn.

D3.5: New AE (AU, AL) models

- Ongoing.
- Will end June 2017.