Predicting Kp from solar wind data using ensemble of neural networks

Peter Wintoft and Magnus Wik
Swedish Institute of Space Physics

Abstract

We present here our latest development of Kp prediction models driven by solar wind data. Three-hour filtering of one-minute solar wind total magnetic field B, Bz component, plasma density and velocity are applied to match the 3-hour Kp. As Kp is a global representation of the maximum range of geomagnetic variation over 3-hour intervals we conclude that sudden changes in the solar wind can have a big effect on Kp. Therefore, the 3-hour filter includes in addition to averages also minimum and maximum values to capture sudden changes in the solar wind. The minima/maxima on the inputs have a large effect on the prediction accuracy. During model development we noticed that different optimal neural networks with the same number of processing units and inputs show very similar predictions for Kp<6, while predictions for larger Kp have a tendency to show a larger variability. We interpret this is an effect of the lower sampling density in the input space for the stronger events, thereby leading to a higher uncertainty in the function estimation. The prediction accuracy can be much improved by taking the median prediction from an ensemble of models. We present various measures of prediction accuracy over time and range of Kp, and also show the latest predictions for the event from Sep. 7 2017.

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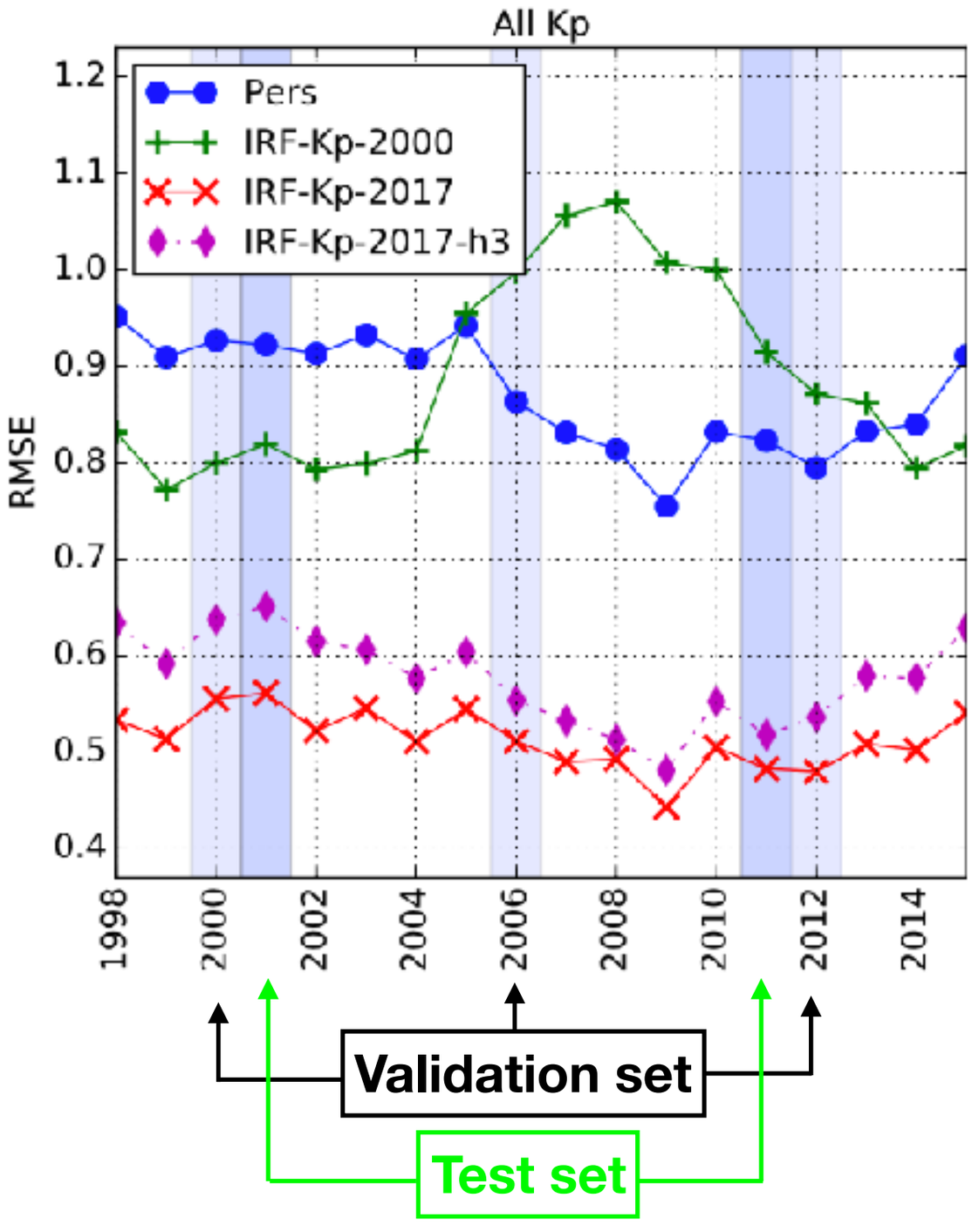
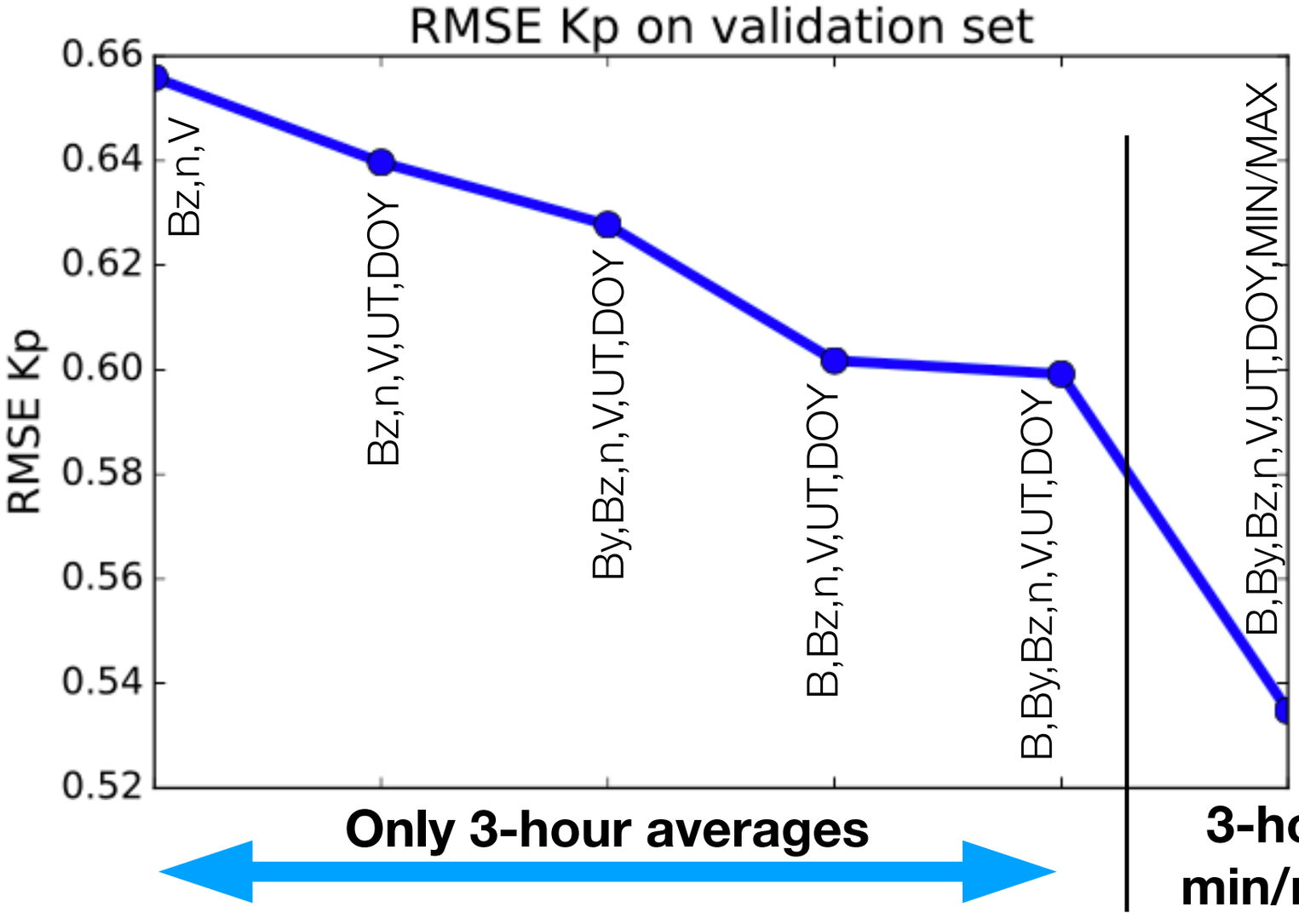
Datasets

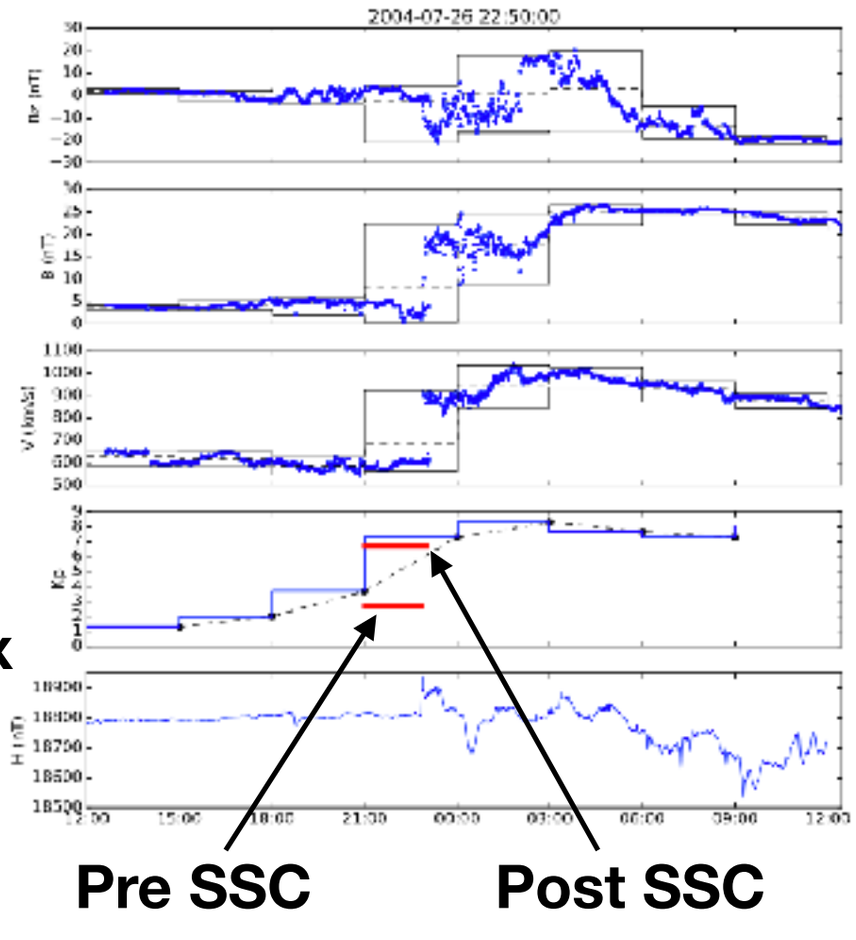
- **ACE Level 2 magnetic field high resolution data shifted from s/c location using bulk speed and resampled to 3 hour values.**
- **Final Kp.**
- **Years 1998 – 2015.**



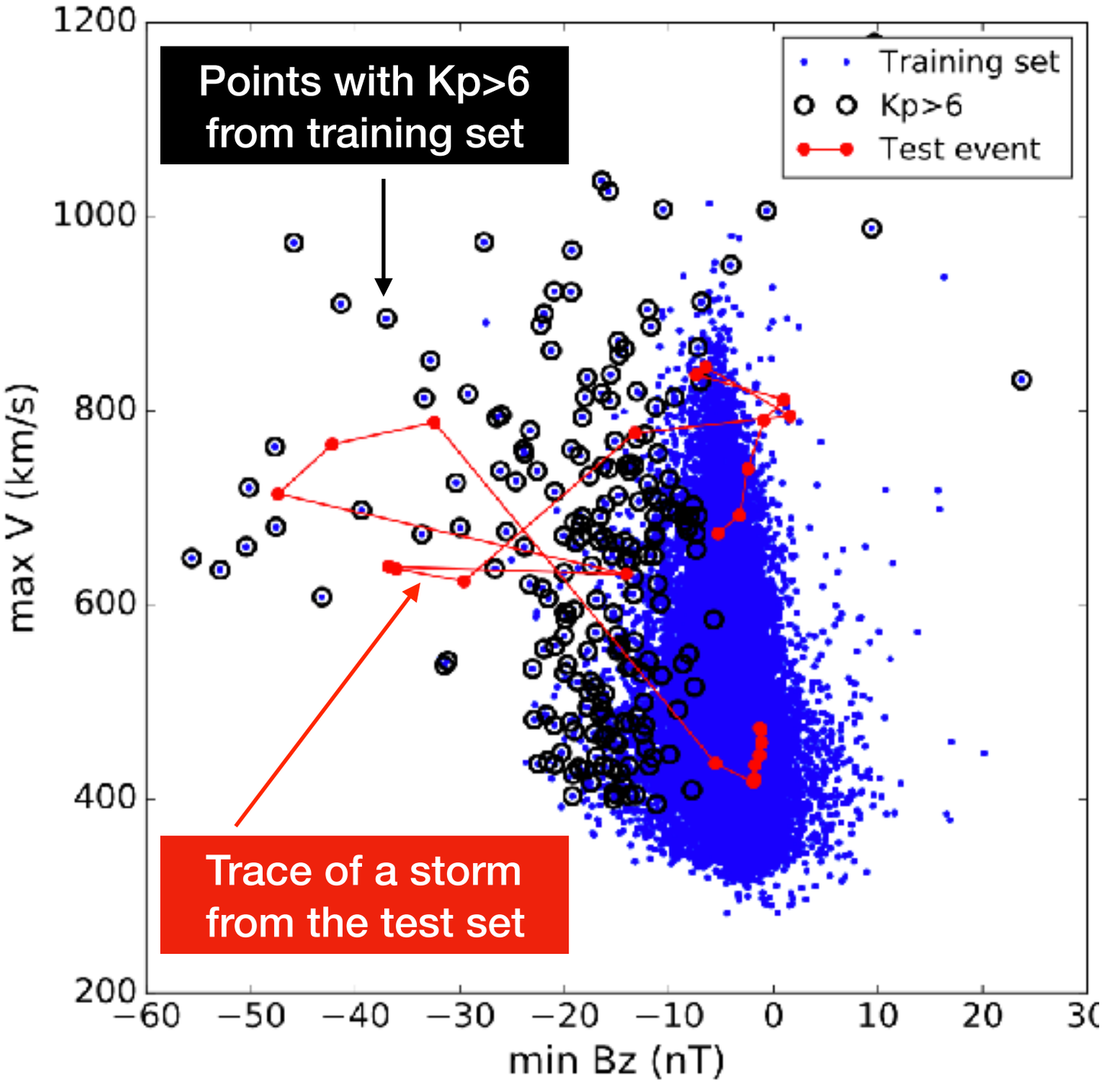
Direct response of Kp on solar wind

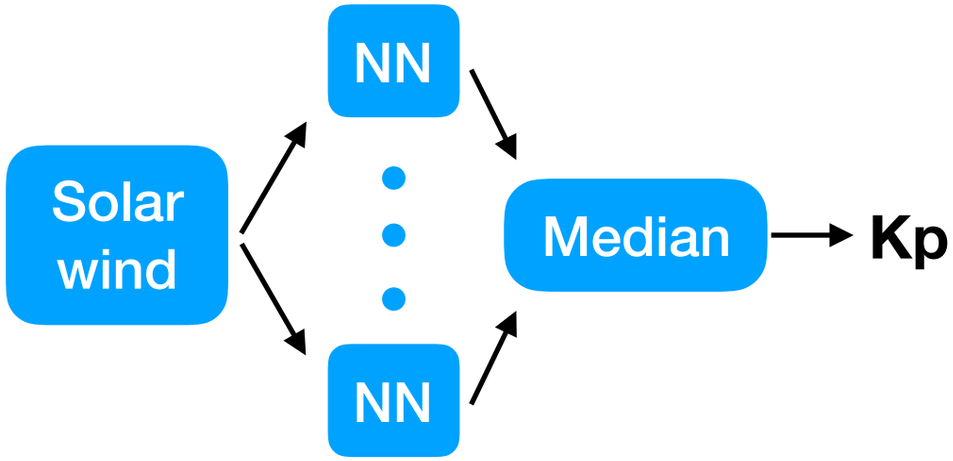


Kp is calculated from the K values from the 13 Kp stations worldwide, where K represents the maximum range of geomagnetic variation with 1-minute resolution over a 3-hour UT interval.

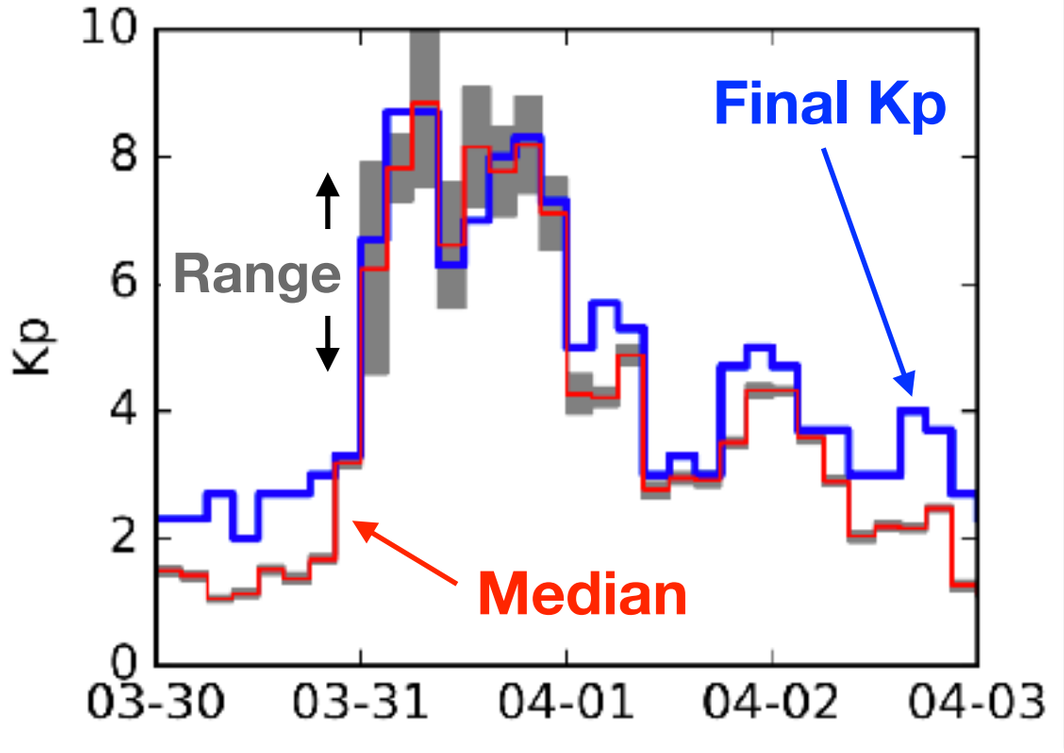


Function estimation in low-density state-space





Ensemble of networks



Model verification

All data

	BIAS	MAE	RMSE	CORR
Pers	0.02	0.67	0.89	0.79
IRF-Kp-2000	0.39	0.72	0.88	0.83
IRF-Kp-2017-h3	-0.00	0.46	0.59	0.91
IRF-Kp-2017	-0.00	0.41	0.52	0.93

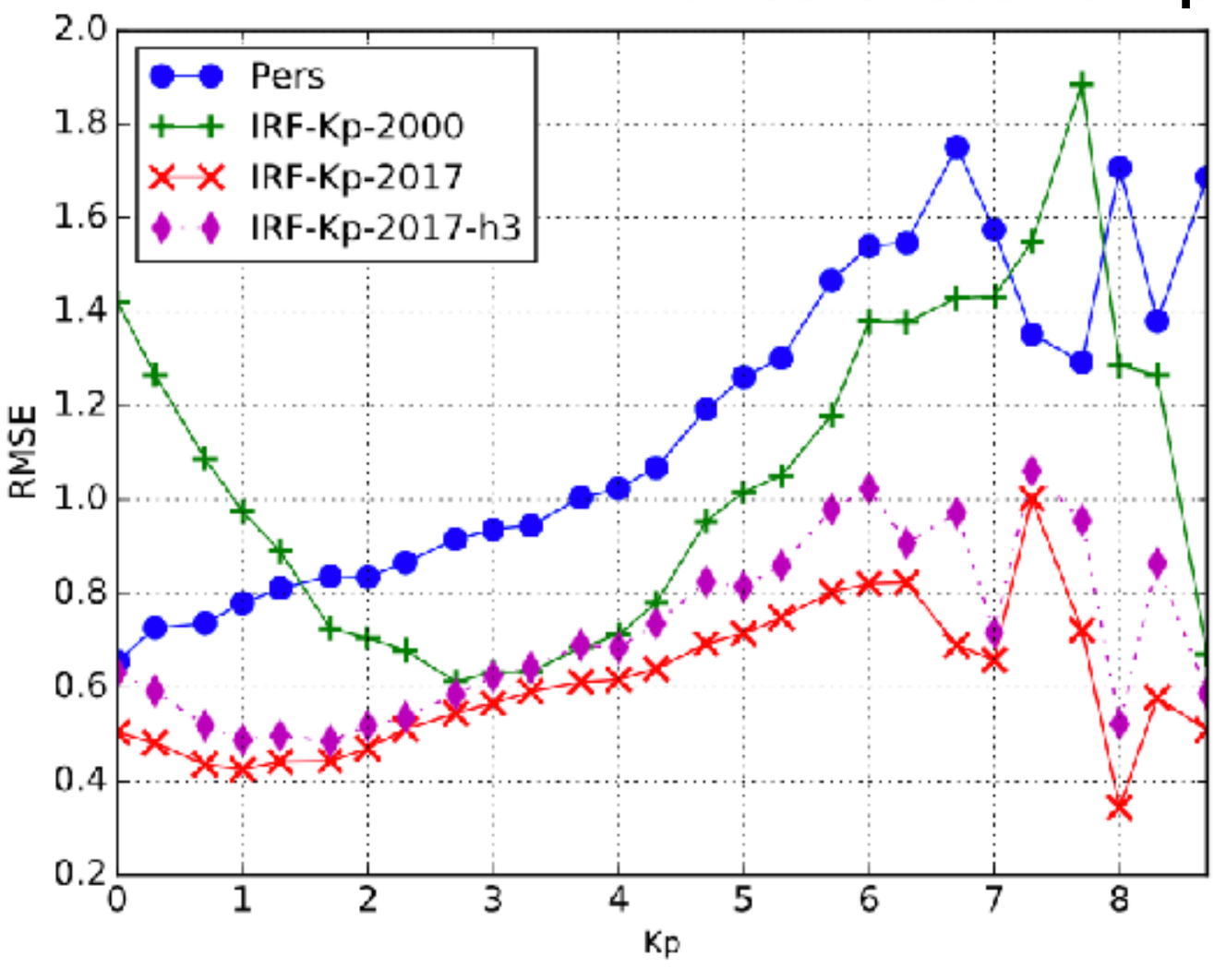
Only averages

Averages & min/max

Test set

	BIAS	MAE	RMSE	CORR
Pers	0.02	0.67	0.89	0.79
IRF-Kp-2000	0.40	0.73	0.89	0.83
IRF-Kp-2017-h3	0.00	0.45	0.58	0.91
IRF-Kp-2017	0.01	0.41	0.52	0.93

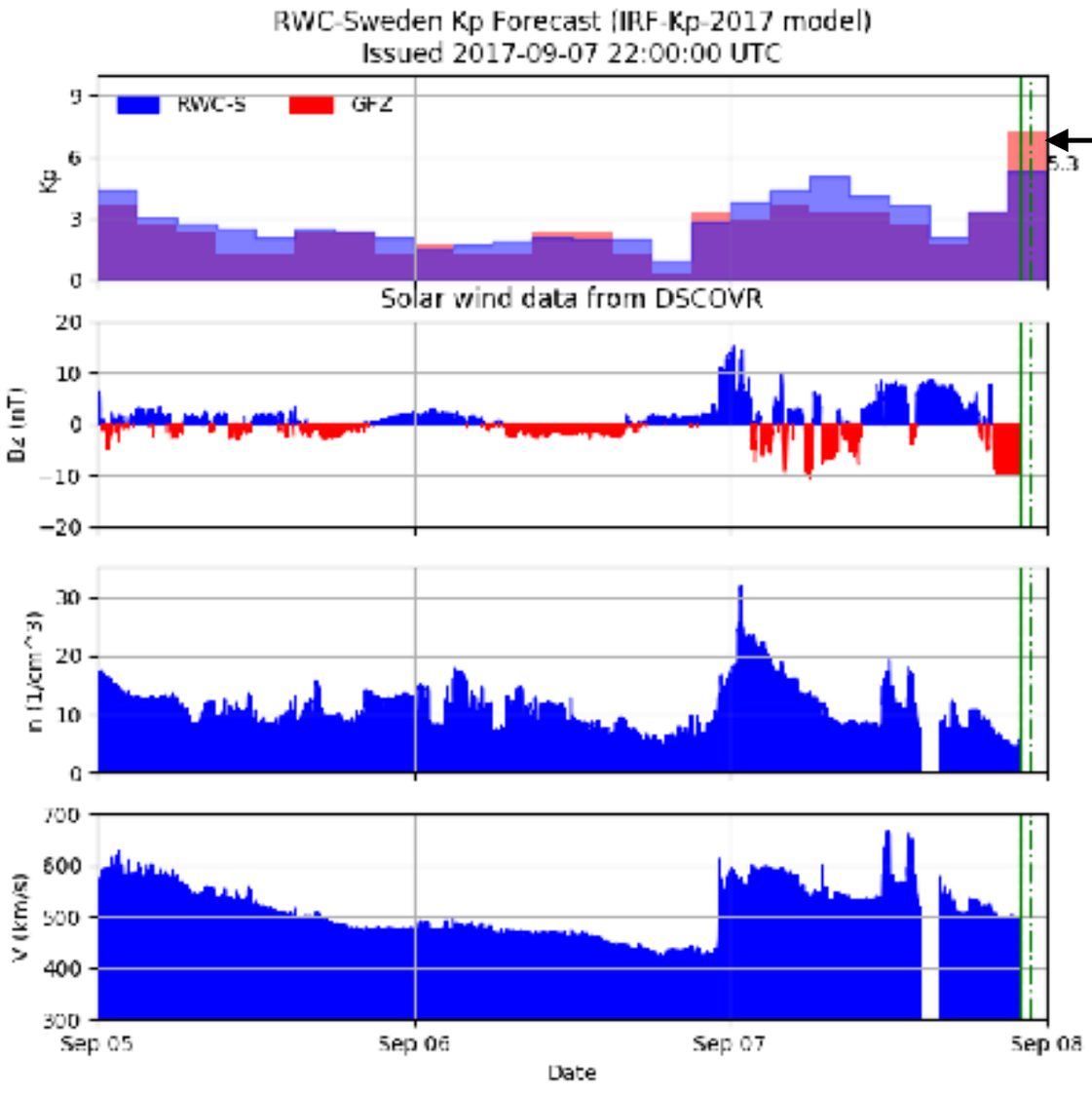
RMSE as function of Kp



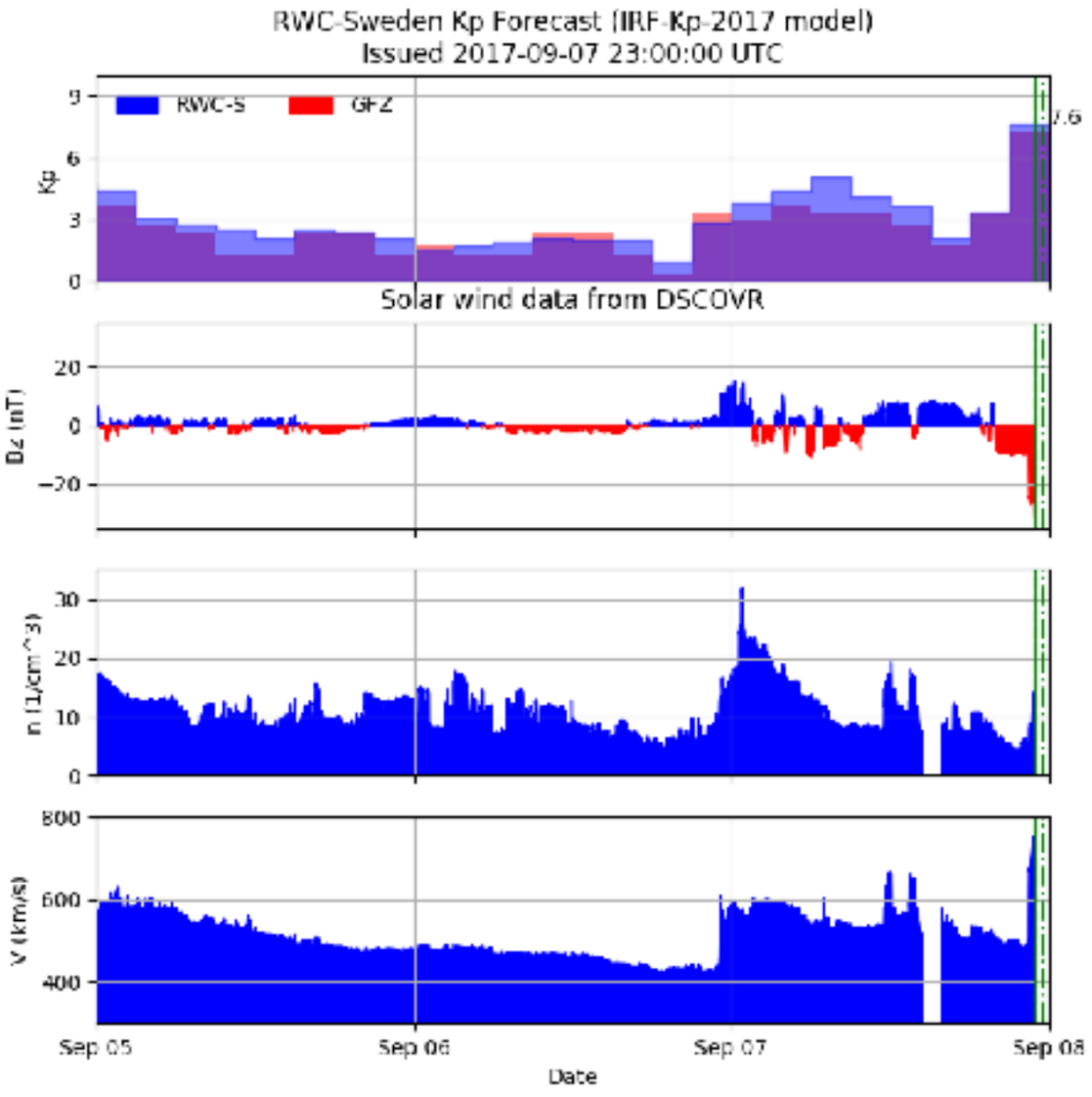
The Sep 2017 events

Series of flares and CMEs during the period Sep 4 - Sep 10 from AR 12673

Before arrival of shock



Arrival of shock



Note that real-time Kp is available after event took place and is shown here for comparison.

See http://lund.irf.se/forecast/kp2017/ for IRF Kp predictions.

See http://www-app3.gfz-potsdam.de/kp_index/qlyymm.html for real-time GFZ Kp.

Summary

- **New Kp prediction models have been developed with improved performance.**
- **Uses 3-hour resampled data, but including min/max values increases accuracy.**
- **Ensemble of networks improves predictions as input-state-space is poorly sampled for large Kp.**
- **Have been tested on independent test set.**
- **Implemented for real-time operation using DSCOVR solar wind data.**
- **Real-time verification using GFZ real-time Kp.**