Predicting Dst and Kp from solar wind data using ensemble of neural networks

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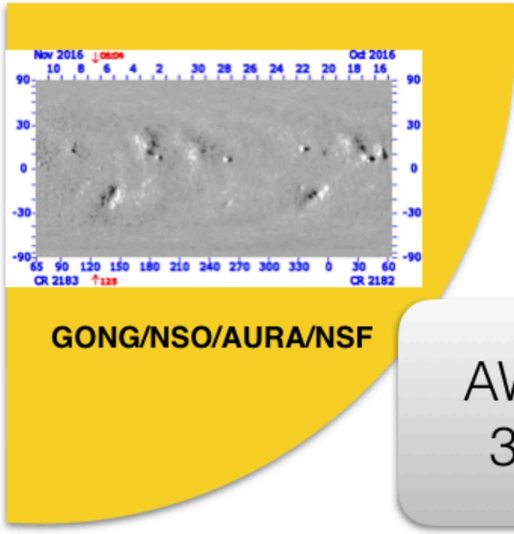
Abstract

We present here our latest development of Dst and Kp prediction models driven by solar wind data. For Kp predictions we apply a three-hour filtering of one-minute solar wind total magnetic field B, Bz component, plasma density and velocity 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. A similar approach is applied for the Dst predictions, where we also compare with various coupling functions and study the semiannual variation. We present various measures of prediction accuracy over time and range, and also show the latest predictions for the event from Sep. 2017. The model has been implemented to operate using real-time data from the NOAA DCSOVR spacecraft, and the predictions are available through the ISES Regional Warning Center - Sweden and the ESA SSA G-ESC.

This work has been supported by the European Union's Horizon 2020 grant agreement No 637302 (PROGRESS) and ESA SSA-SWE-P2-1.5 Geomagnetic Service Enhancement.

The PROGRESS project



AWSoM 30 Rs

SWIFT L1

Neural Network NARMAX

Kp Dst AU, AL, AE

Statistical wave models

VERB IMPTAM

Predicting the radiation belts from observed solar magnetic data.

- Ayala Solares, J. R., Wei, H.-L., Boynton, R. J., Walker, S. N. & Billings, S. A., 'Modelling and prediction of global magnetic disturbance in near-earth space: A case study for Kp index using narx models', *Space Weather, 2016*.
- Wintoft, P., M. Wik, J. Matzka and Y. Shprits, Forecasting Kp from solar wind data: input parameter study using 3-hour averages and 3-hour range values, J. Space Weather Space Clim. Volume 7, A29, 2017

European Union's Horizon 2020 grant agreement No 637302 (PROGRESS)

ESA SSA-SWE-P2-1.5 Geomagnetic Service Enhancement

INSTITUTET FÖR RYMDFYSIK
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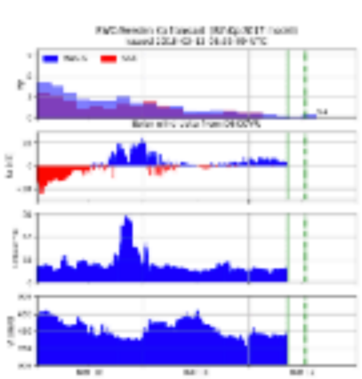
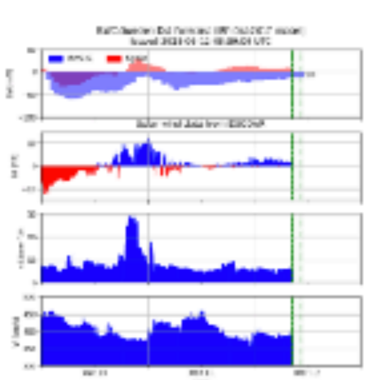
Implementation of IRF-Kp-2017 and IRF-Dst-2017 prediction models at the SSA Space Weather Portal

G.134 IRF KP



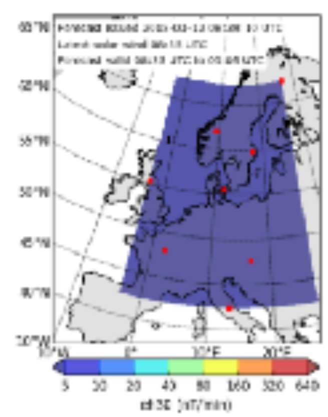
Product description
Real-time / archive plots
Real-time text
Model statistics

G.135 IRF DST

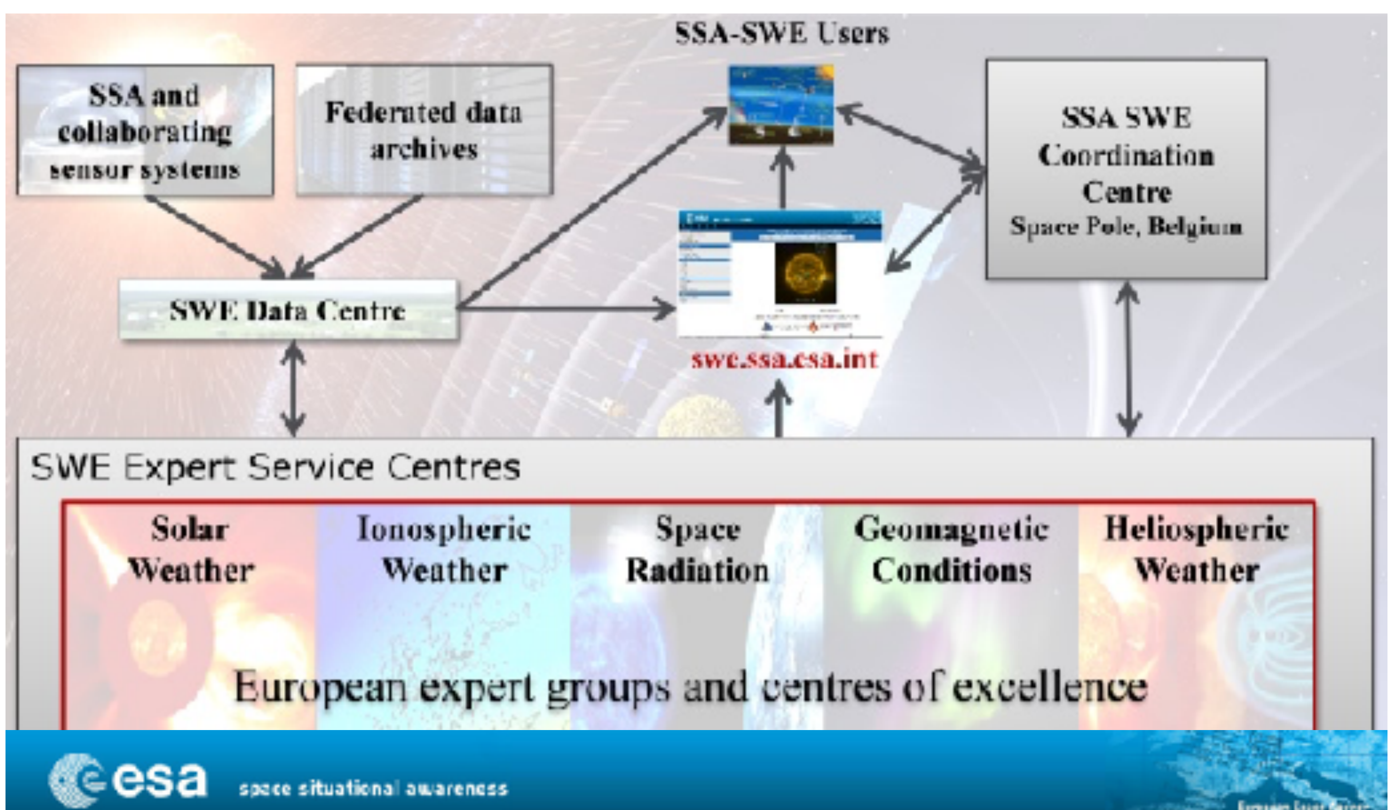


Product description
Real-time / archive plots
Real-time text
Model statistics

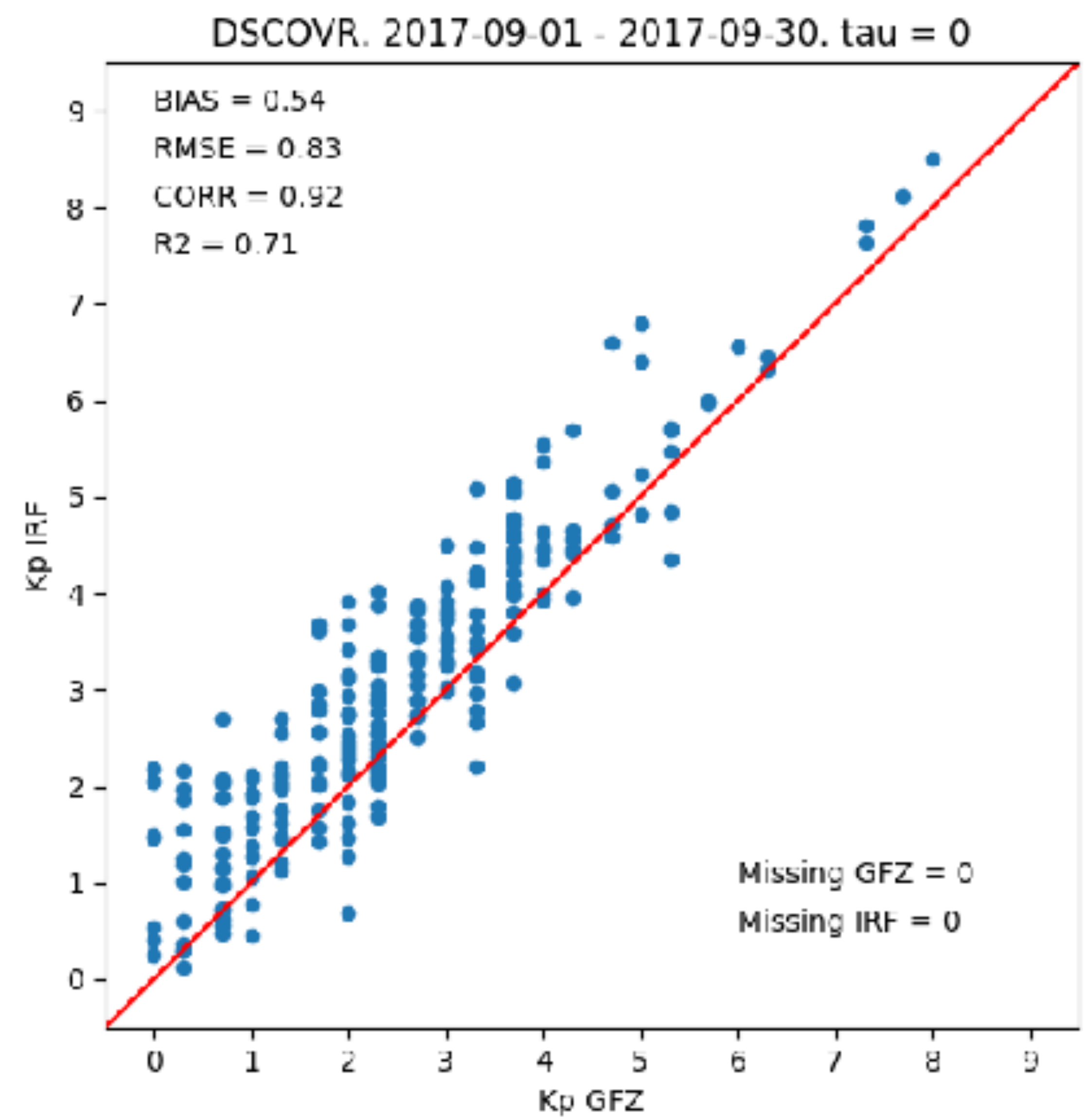
G.113 FORECAST OF DB/DT



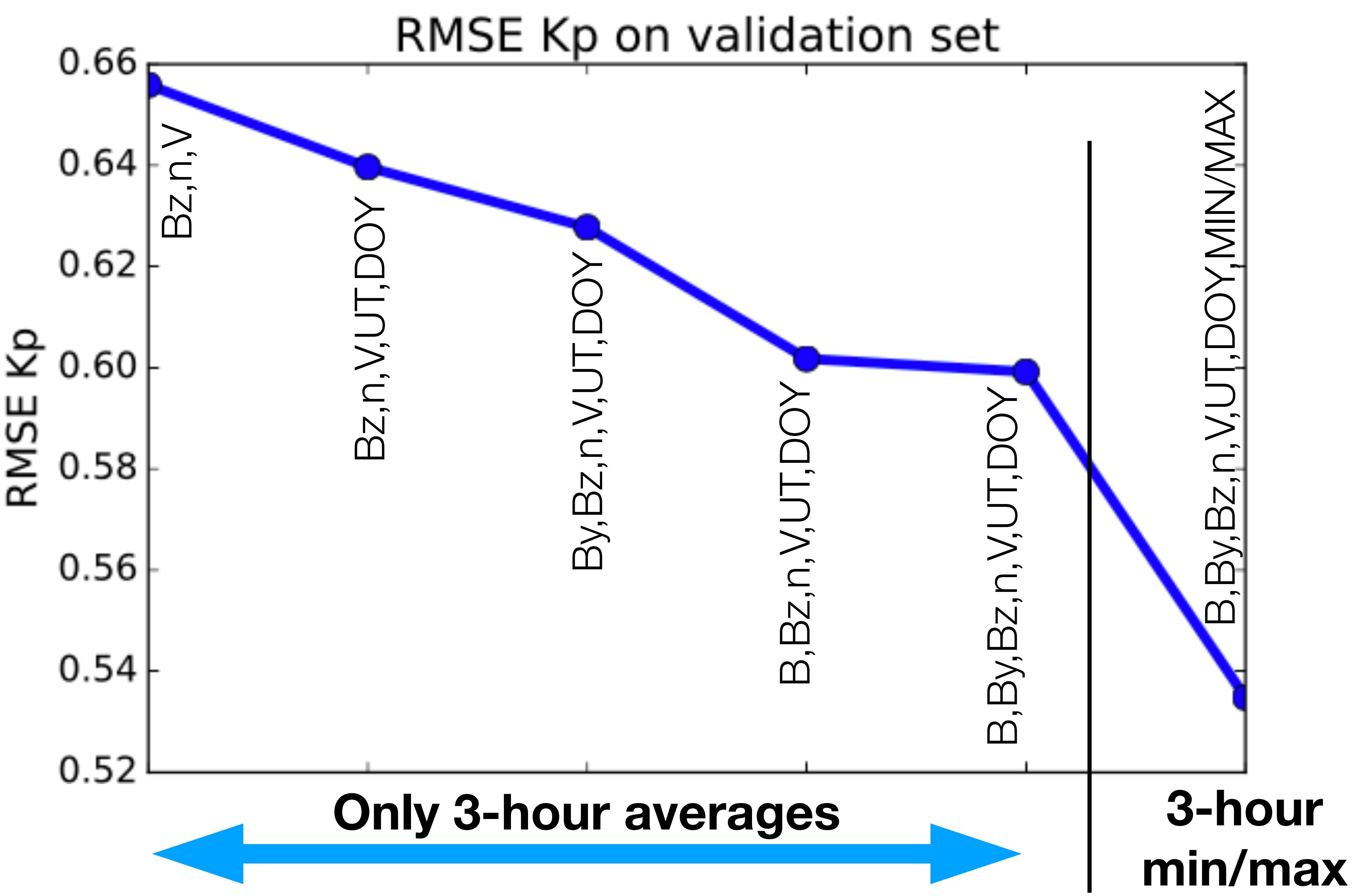
Product description
Real-time plot



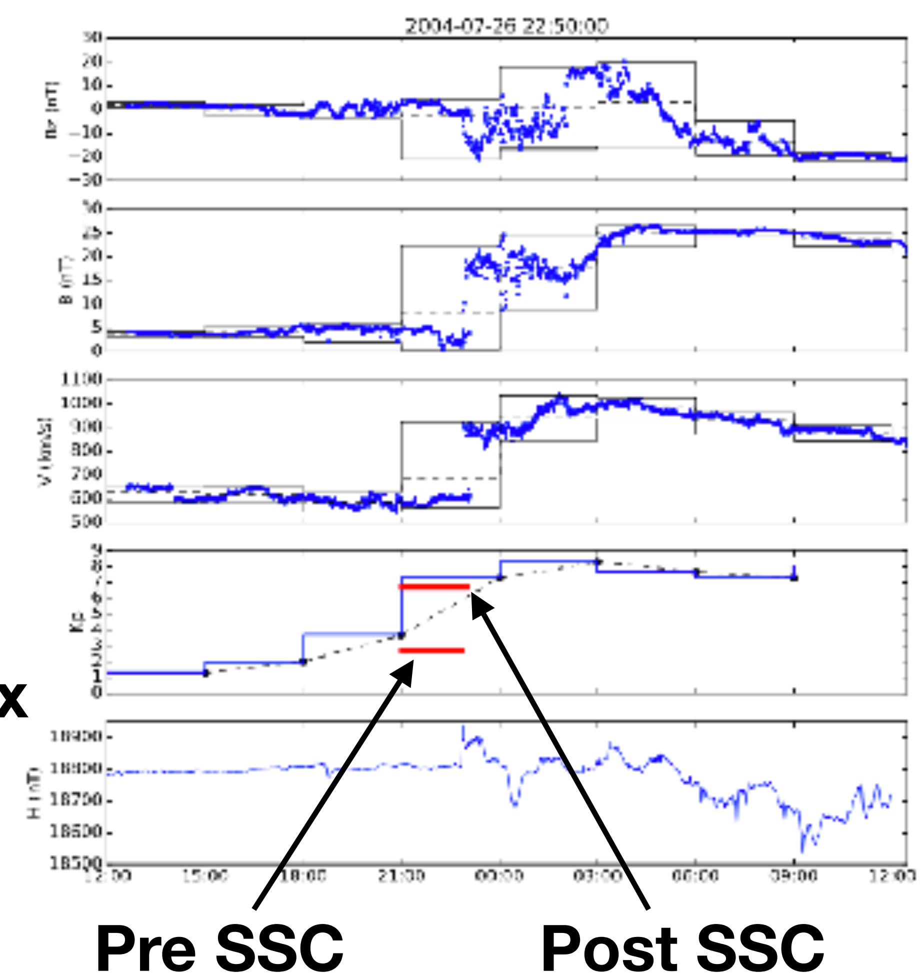
Prediction statistics computed for each month.



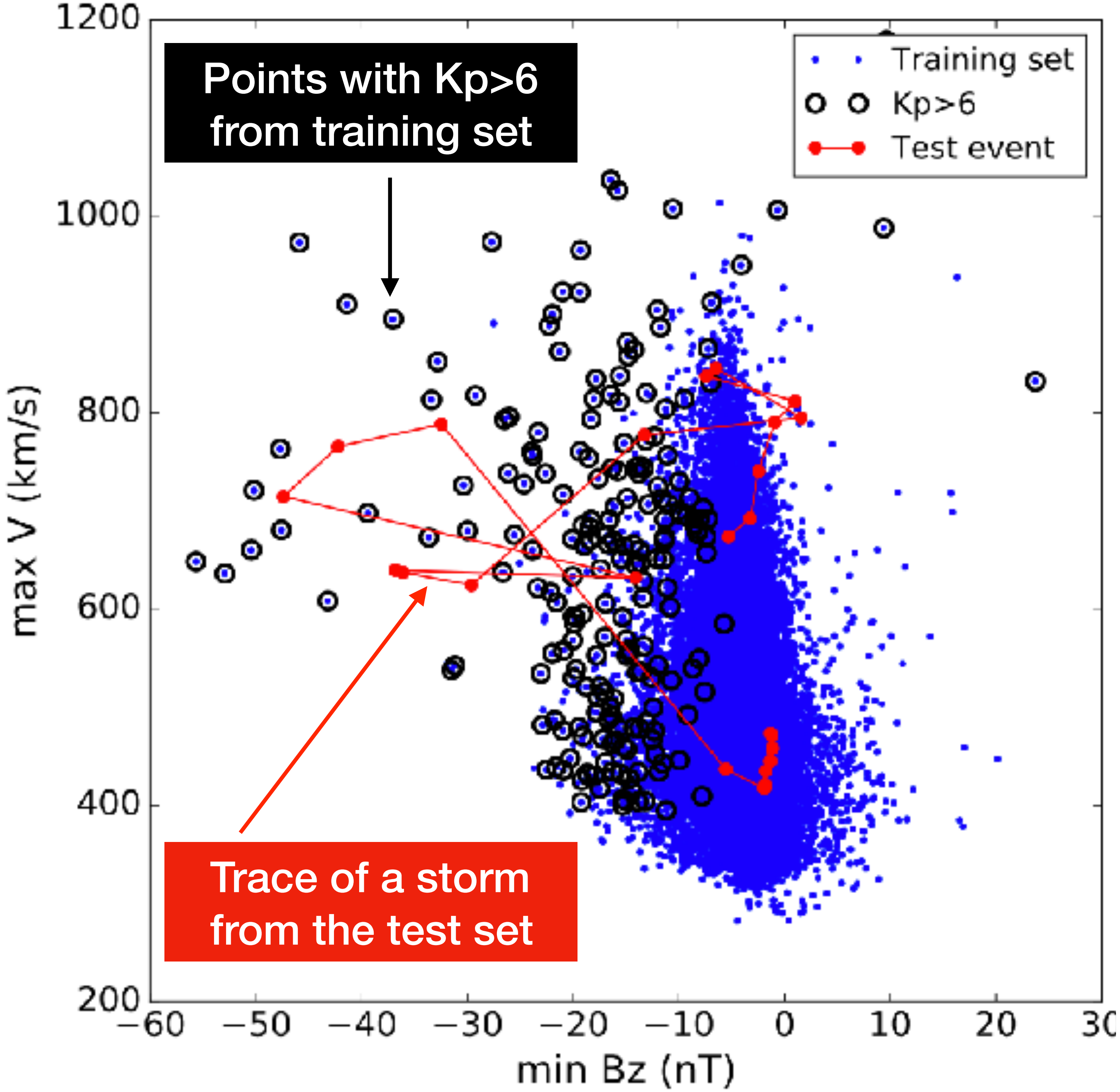
Direct response of Kp on solar wind

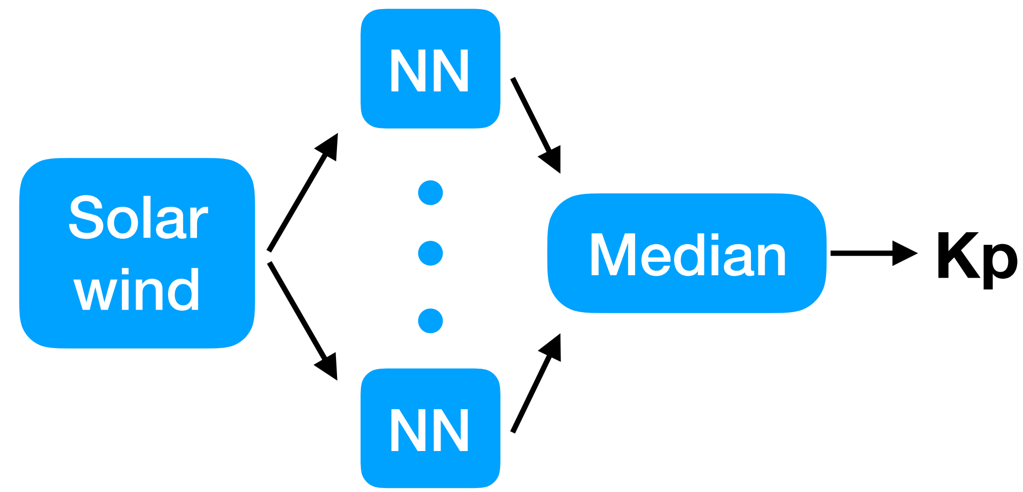


Kp is calculated from the K values from the 13 Kp stations worldwide, where K represents the maximum range of geomagnetic variation with 1-minute resolution over a 3-hour UT interval.

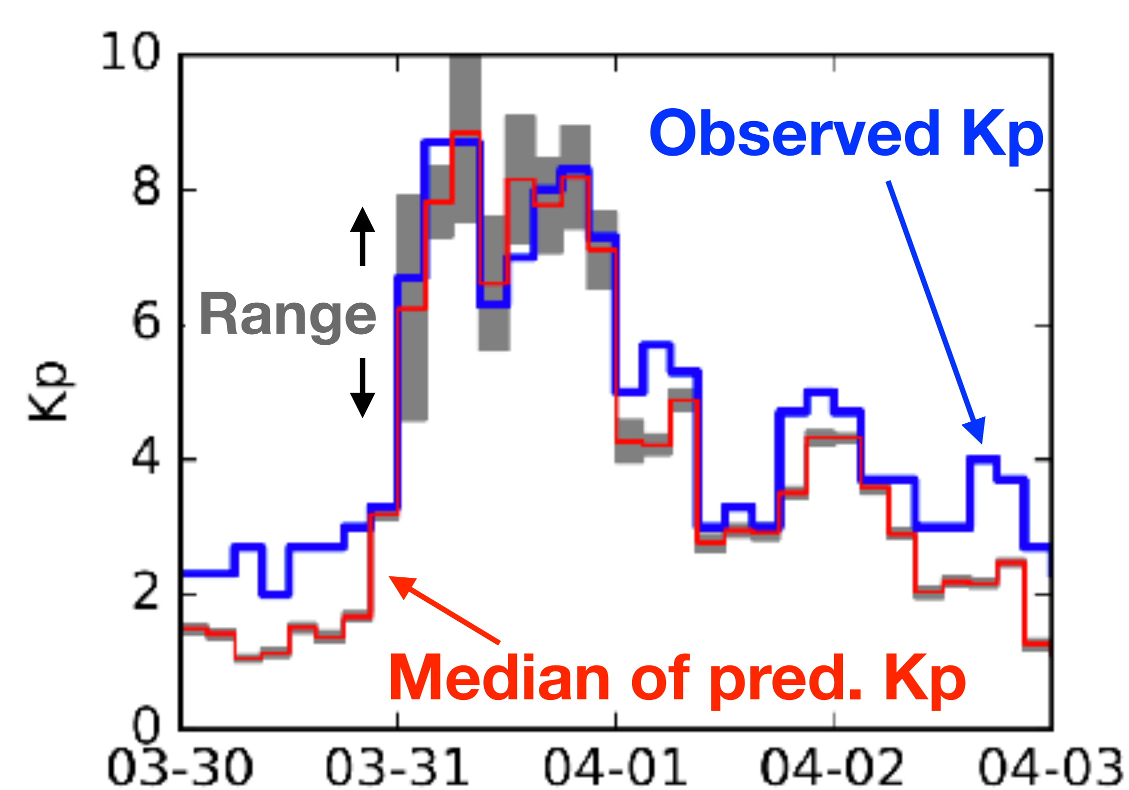


Function estimation in low-density state-space

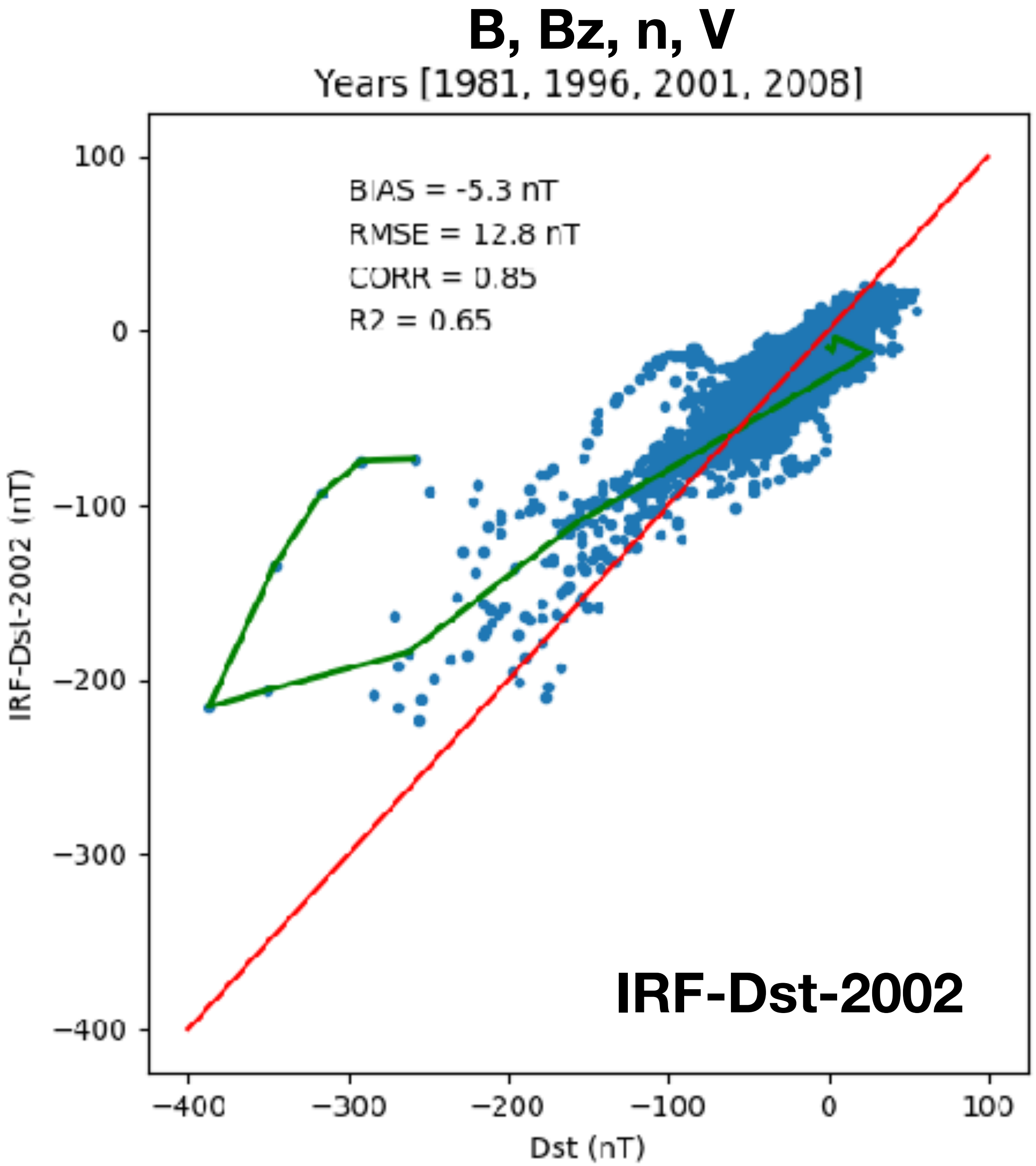


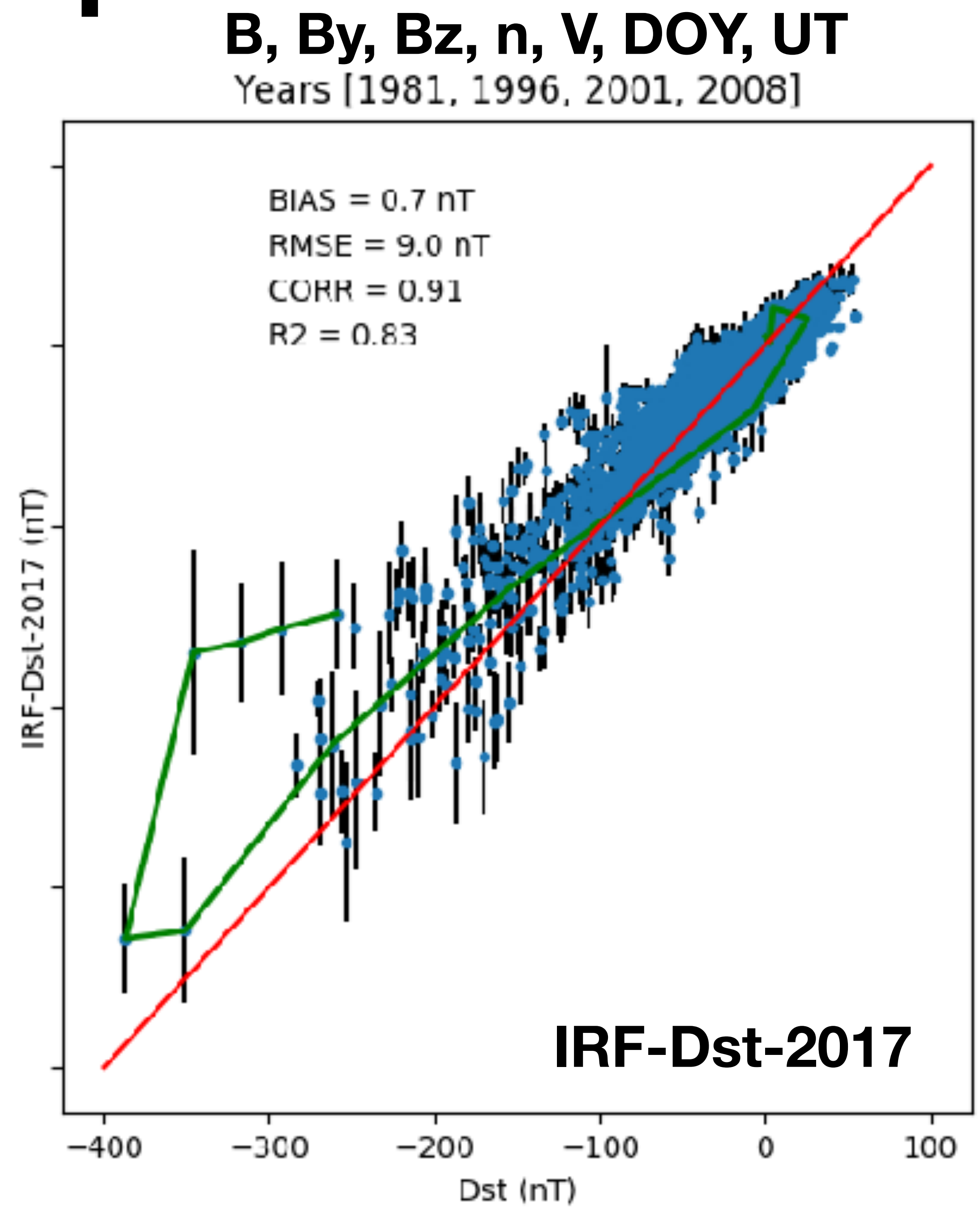


Ensemble of networks

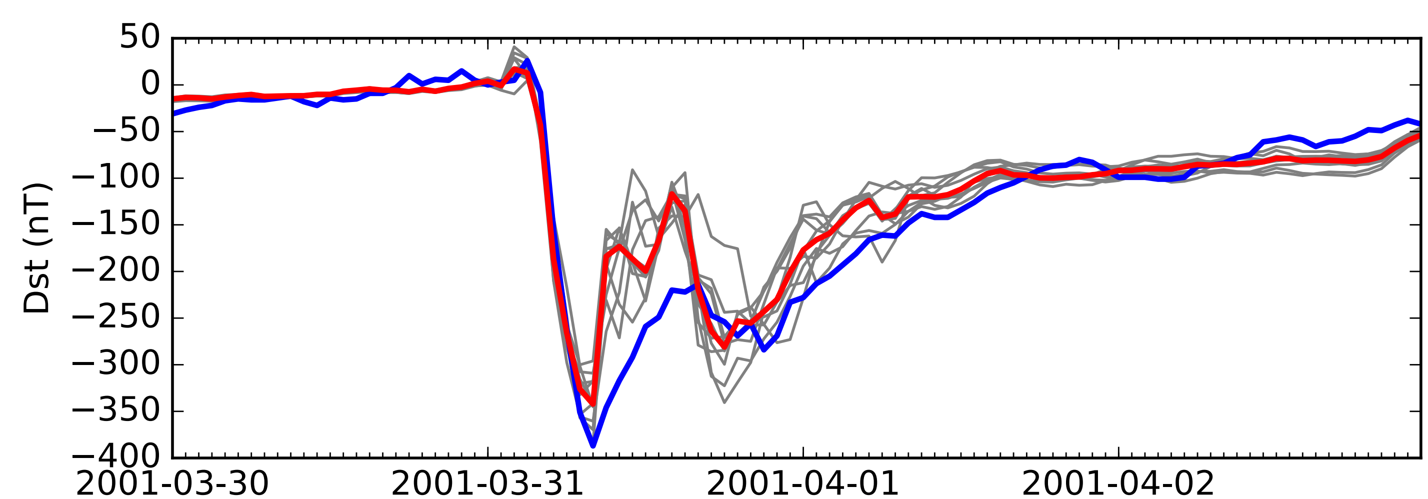


Dst ensemble predictions

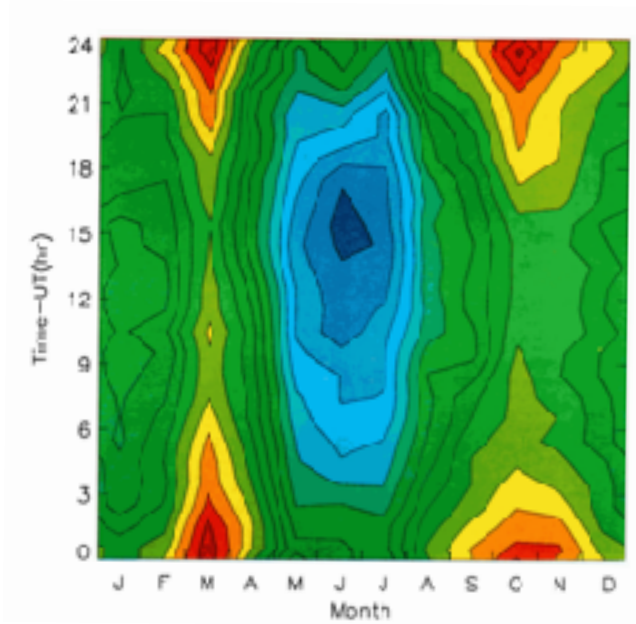




Operational forecasts of the geomagnetic Dst index, H. Lundstedt and H. Gleisner and P. Wintoft Geophysical Research Letters 29, 34-1–4, 2002.

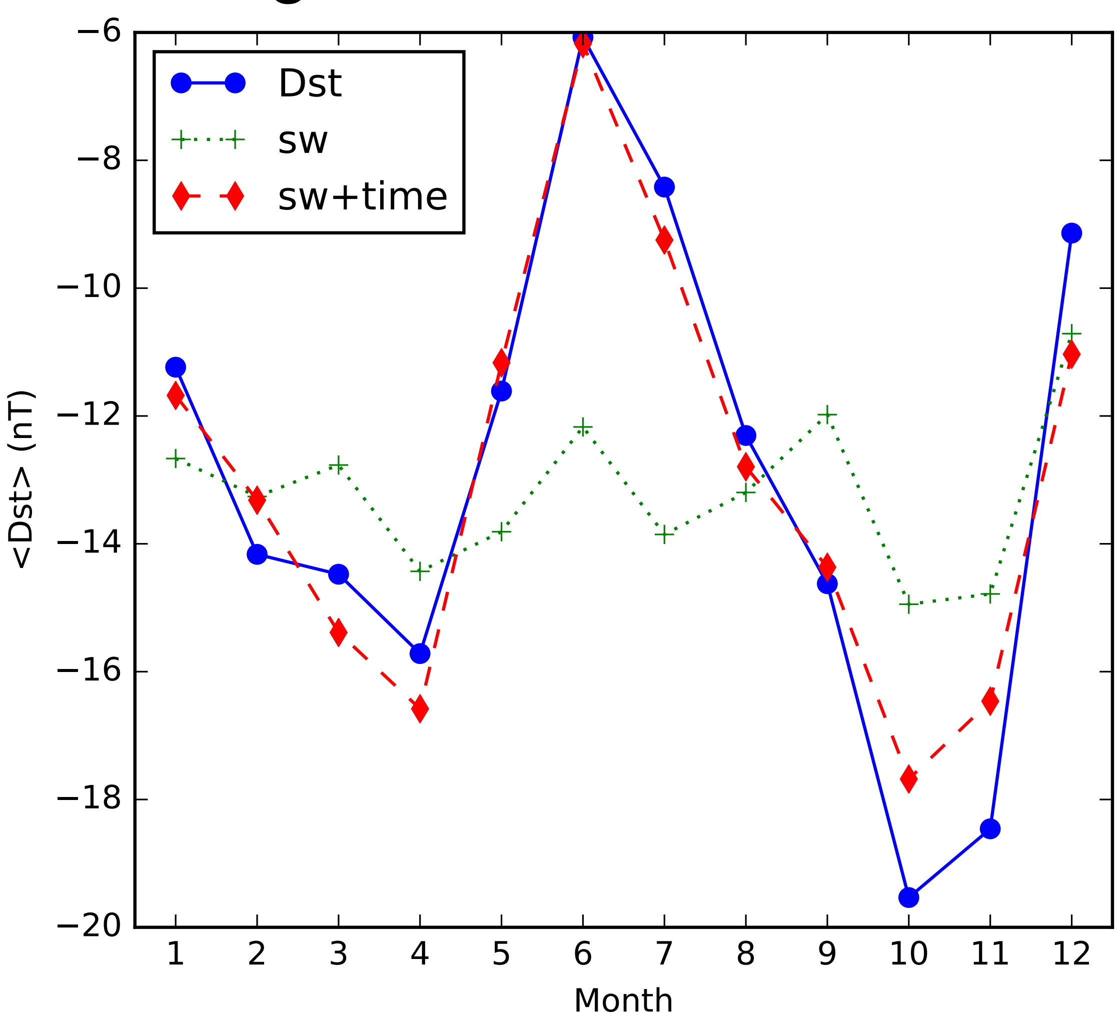


Semiannual variation of Dst

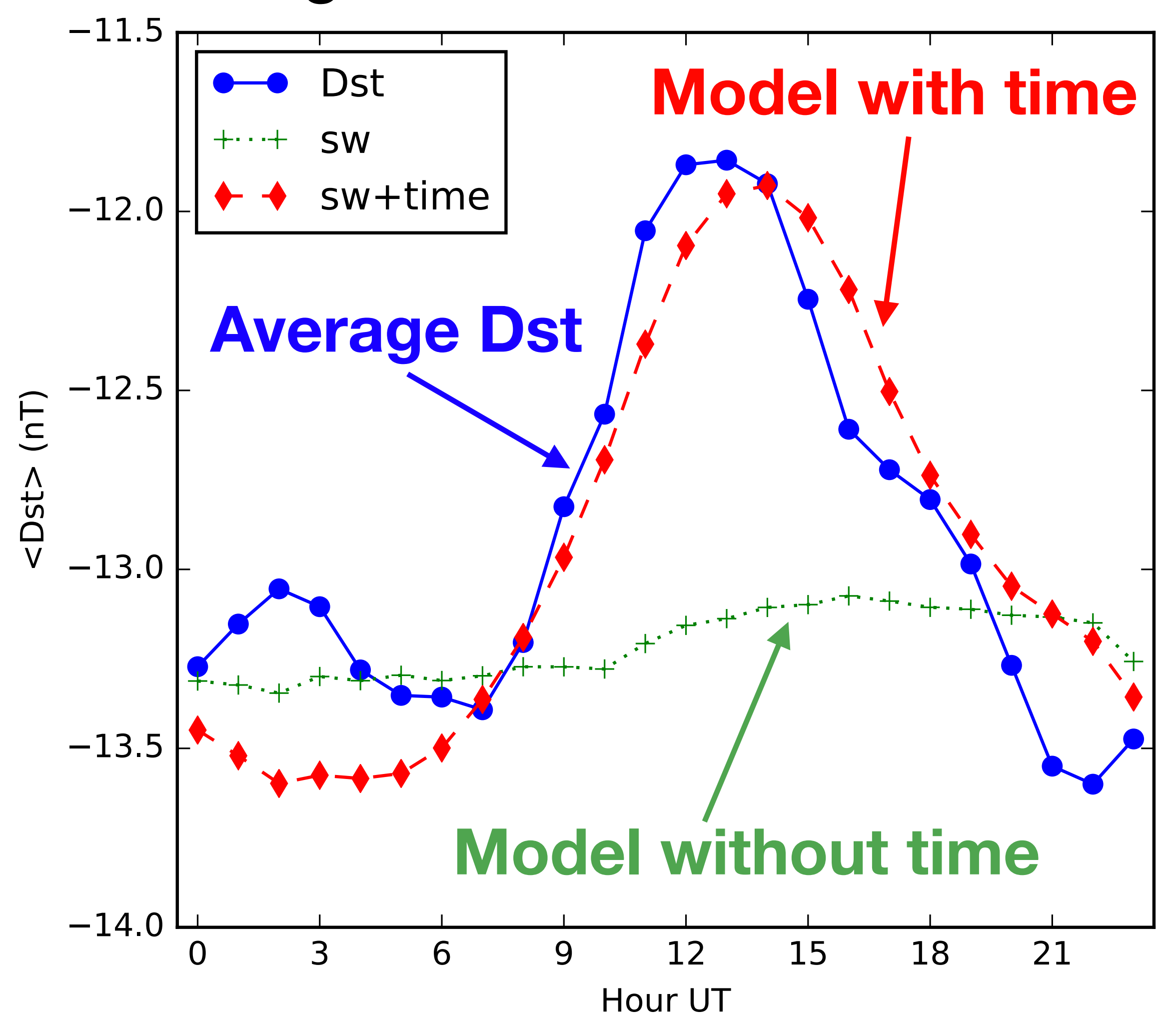


Semiannual variation of the geomagnetic Dst index: Evidence for a dominant nonstorm component, E. W. Cliver and Y. Kamide and A. G. Ling and N. Yokoyama, Journal of Geophysical Research 106 21,297-21,304 (2001)

Average Dst as function of month



Average Dst as function of UT hour



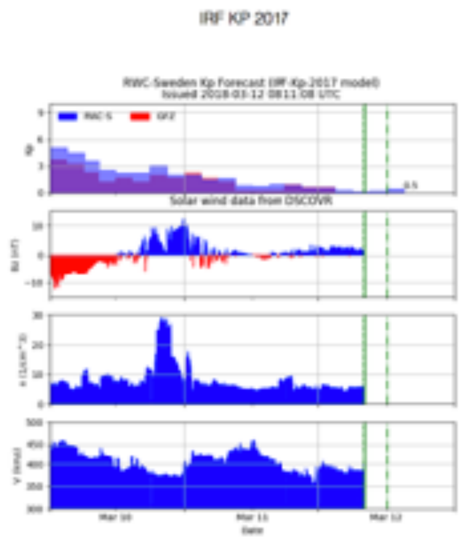
Regional Warning Center - Sweden
Hosted by IRF since 2000

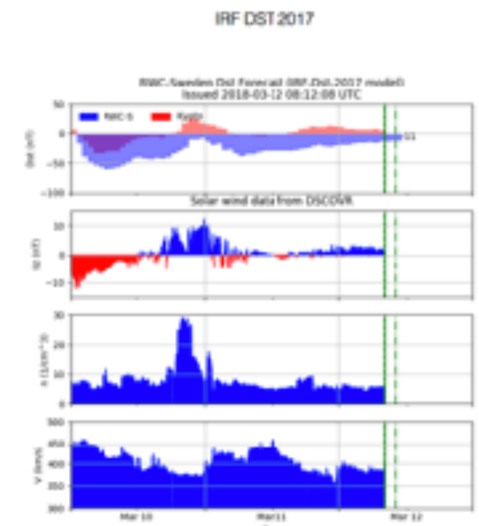
The International Space Environment Service (ISES) is a collaborative network of space weather service-providing organizations around the globe. Our mission is to improve, to coordinate, and to deliver operational space weather services. ISES is organized and operated for the benefit of the international space weather user community.

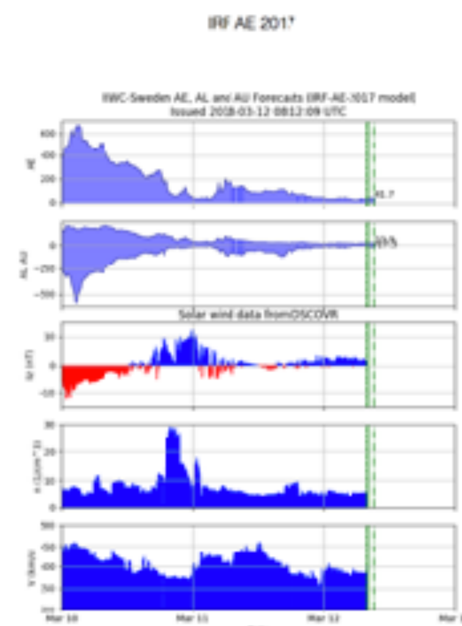
ISES currently includes 16 Regional Warning Centers, four Associate Warning Centers, and one Collaborative Expert Center. ISES is a Network Member of the International Council for Science World Data System (ICSU-WDS) and collaborates with the World Meteorological Organization (WMO) and other international organizations.

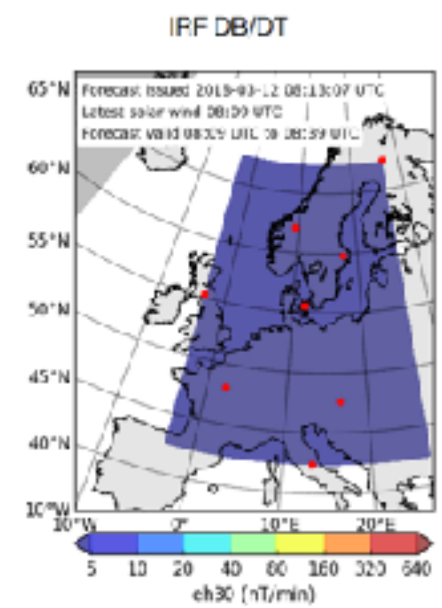
ISES has been the primary organization engaged in the international coordination of space weather services since 1962. ISES members share data and forecasts and provide space weather services to users in their regions. ISES provides a broad range of services, including: forecasts, warnings, and alerts of solar, magnetospheric, and ionospheric conditions; space environment data; customer-focused event analyses; and long-range predictions of the solar cycle.

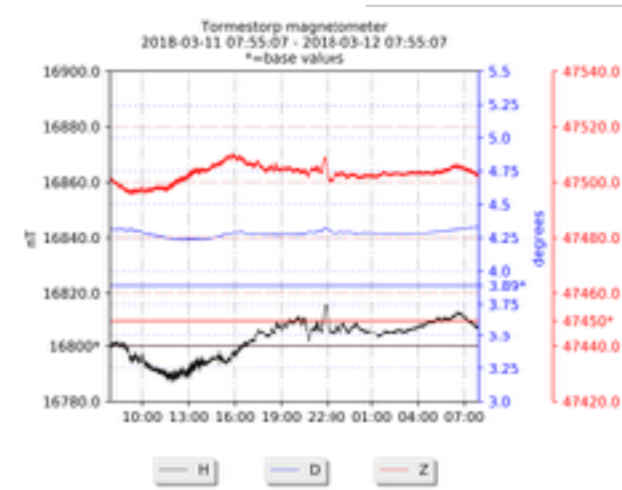
Members







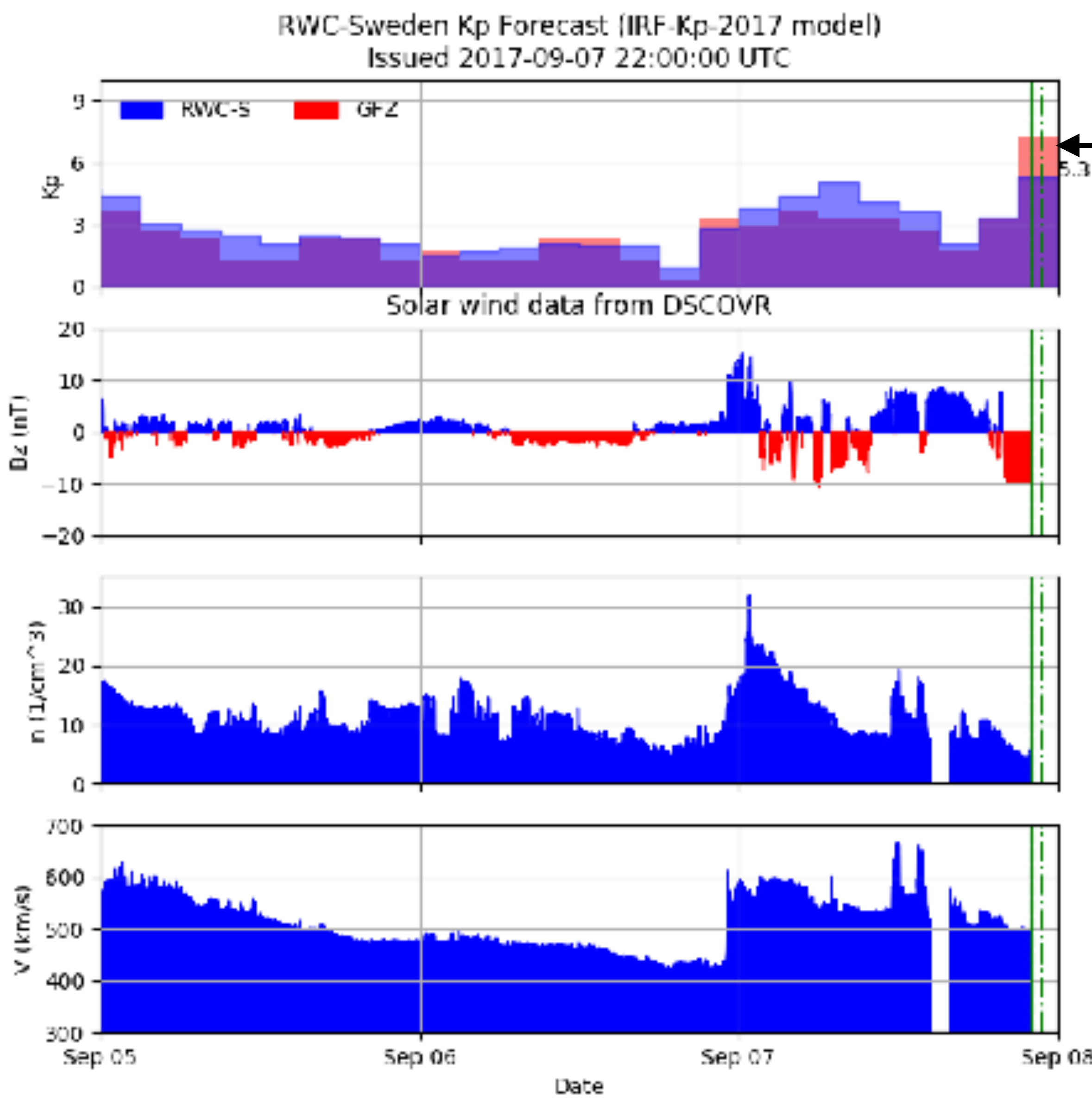




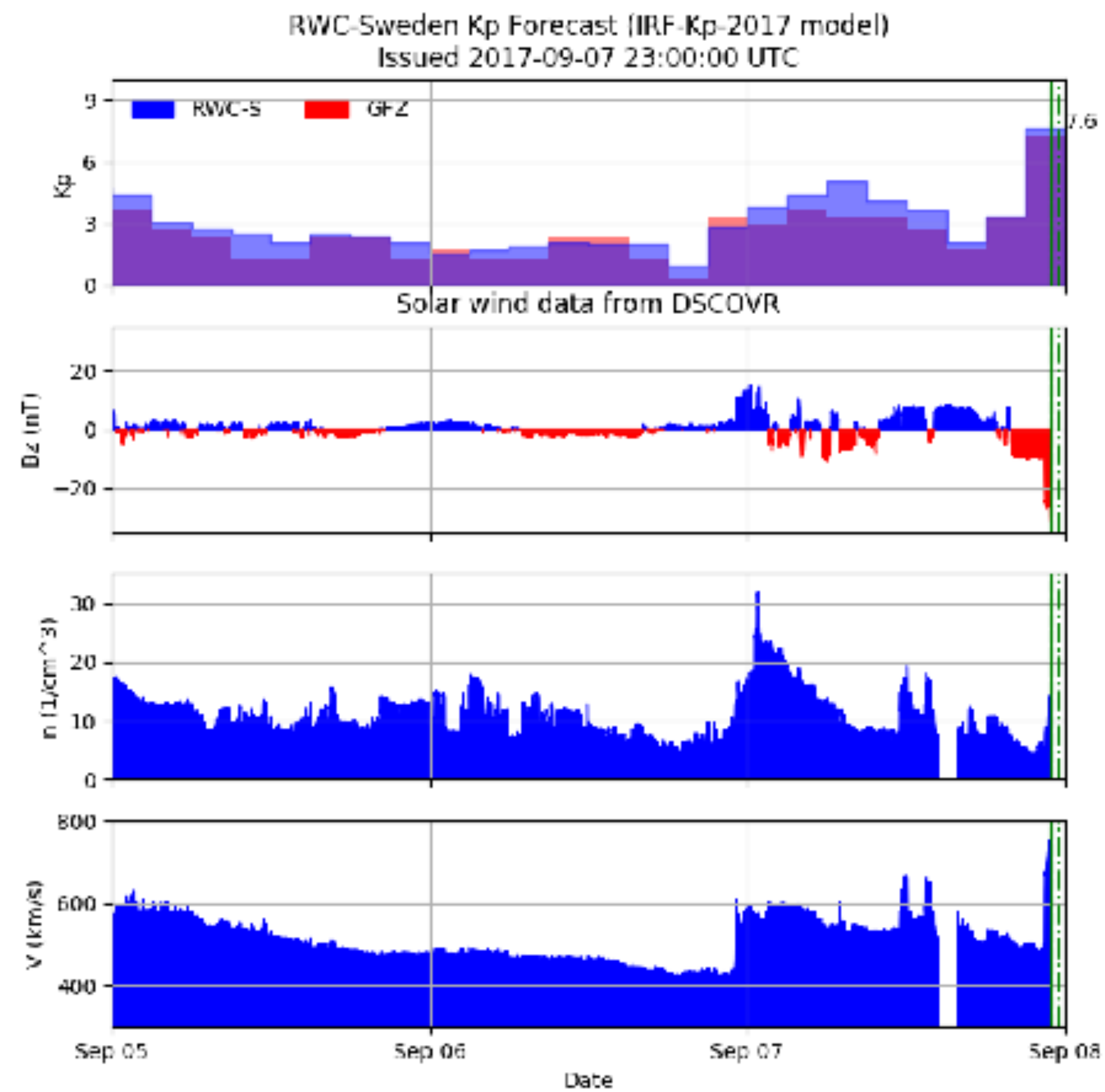
The Sep 2017 events

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

Before arrival of shock



Arrival of shock



Note that observed real-time Kp is available only after the 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.