Forecast of Space Weather Effects with PROGRESS

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ssg.group.shef.ac.uk/progress/html

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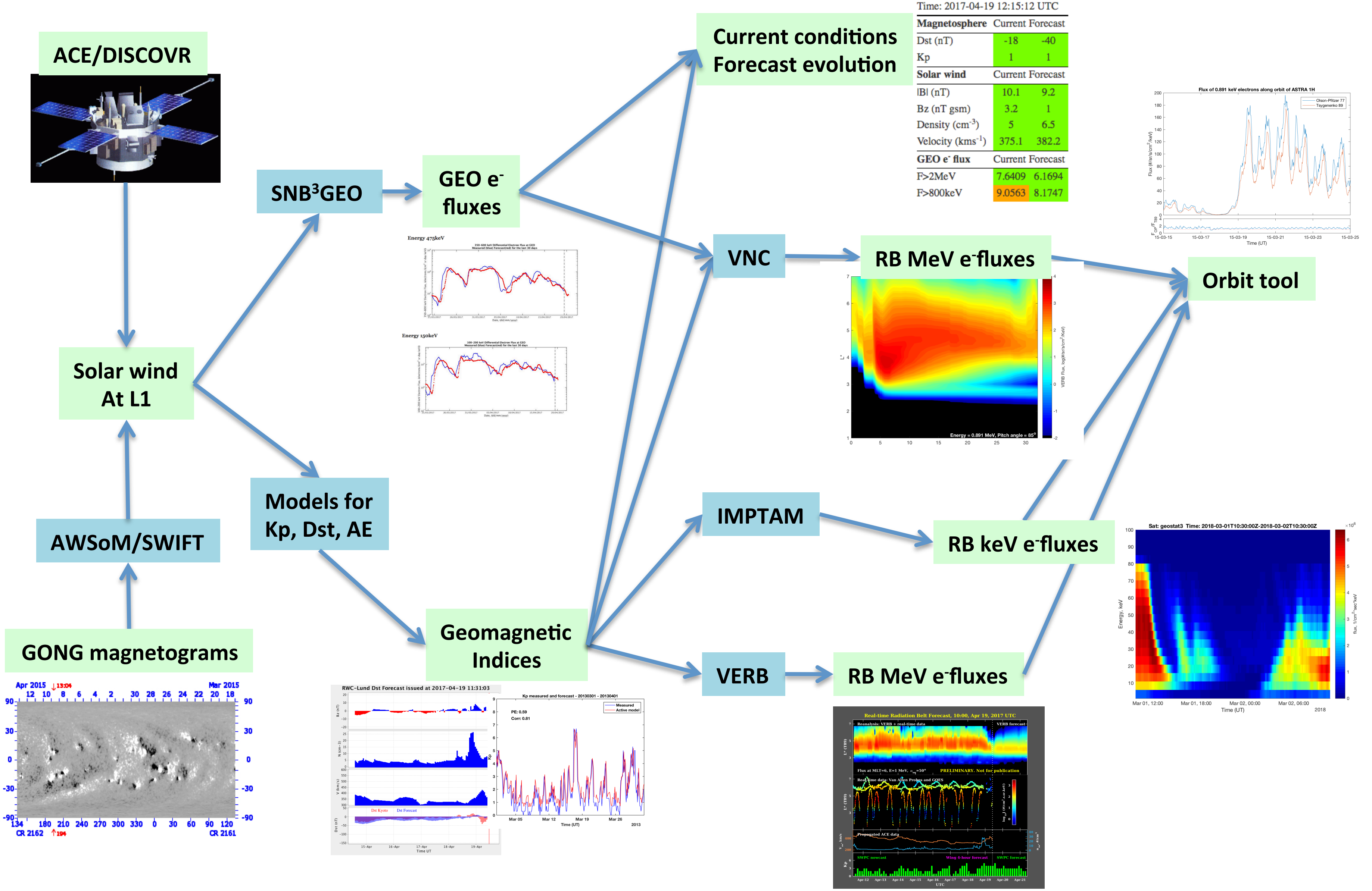
PROGRESS

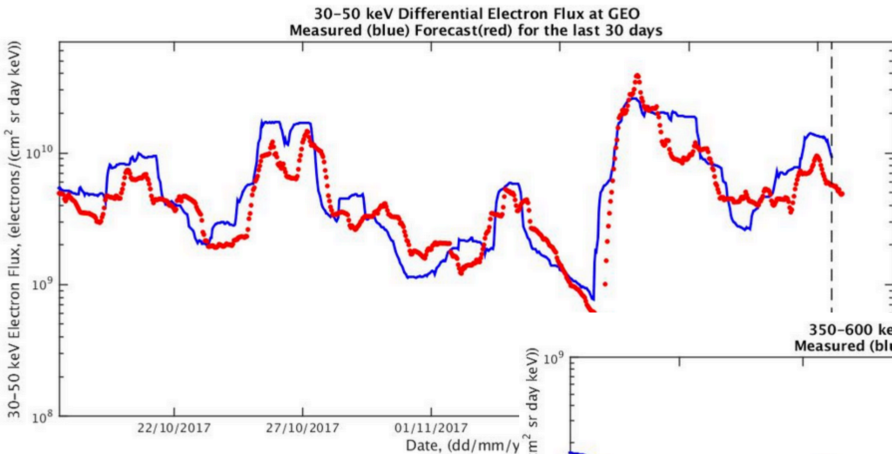


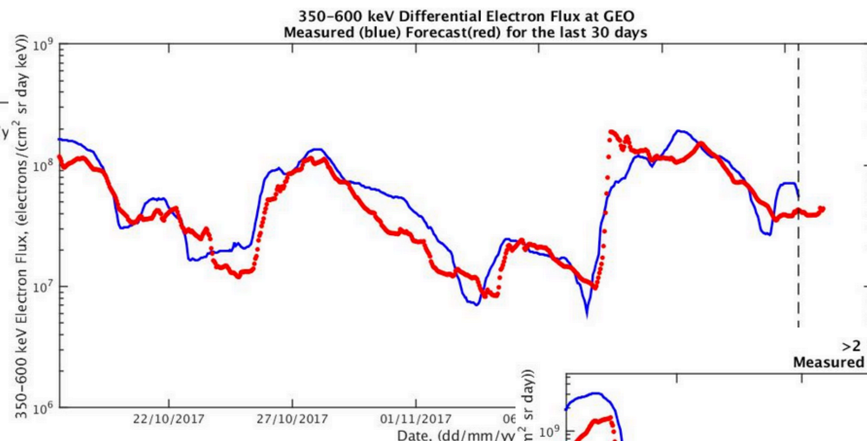
Current Conditions

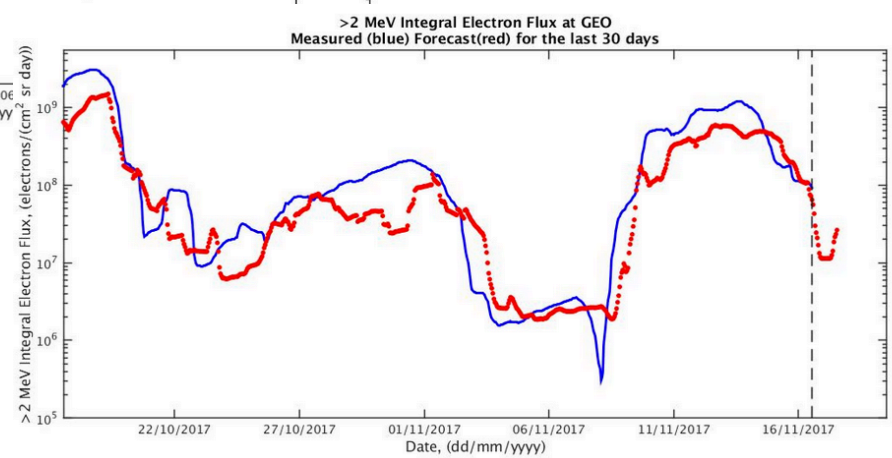
Time: 2017-04-19 12:15:12 UTC

Magnetosphere	Current	Forecast
Dst (nT)	-18	-40
Kp	1	1
Solar wind	Current	Forecast
|B| (nT)	10.1	9.2
Bz (nT gsm)	3.2	1
Density (cm^{-3})	5	6.5
Velocity (kms^{-1})	375.1	382.2
GEO e⁻ flux	Current	Forecast
F>2MeV	7.6409	6.1694
F>800keV	9.0563	8.1747

GSO e$^-$ flux forecasts







Models for

- 30-50 keV
- 50-100 keV
- 100-200 keV
- 200-350 keV
- 350-600 keV
- >800 keV
- >2MeV

View latest forecasts at
https://ssg.group.shef.ac.uk/progress/html/
http://ssg.group.shef.ac.uk/ssg2013/proj_UOSSW.htm

GSO e⁻ flux forecasts

Model comparison

One day ahead forecasted fluxes >2 MeV electrons compared with NOAA REFM

Prediction Efficiency

$$PE = 1 - \frac{1}{N}\sum \frac{(X_i - Y_i)^2}{\mathrm{Var}(X)}$$

Correlation function

$$C_{\log(SNB)} = \frac{1}{N}\sum_{i=1}^{N} \frac{(\log_{10}(F_{2MeV}(i)) - \langle \log_{10}(F_{2MeV}(i))\rangle)(\log_{10}(F_{SNB}(i)) - \langle \log_{10}(F_{SNB}(i))\rangle)}{\sqrt{\mathrm{Var}(\log_{10}(F_{2MeV}))\mathrm{Var}(\log_{10}(F_{SNB}))}}$$

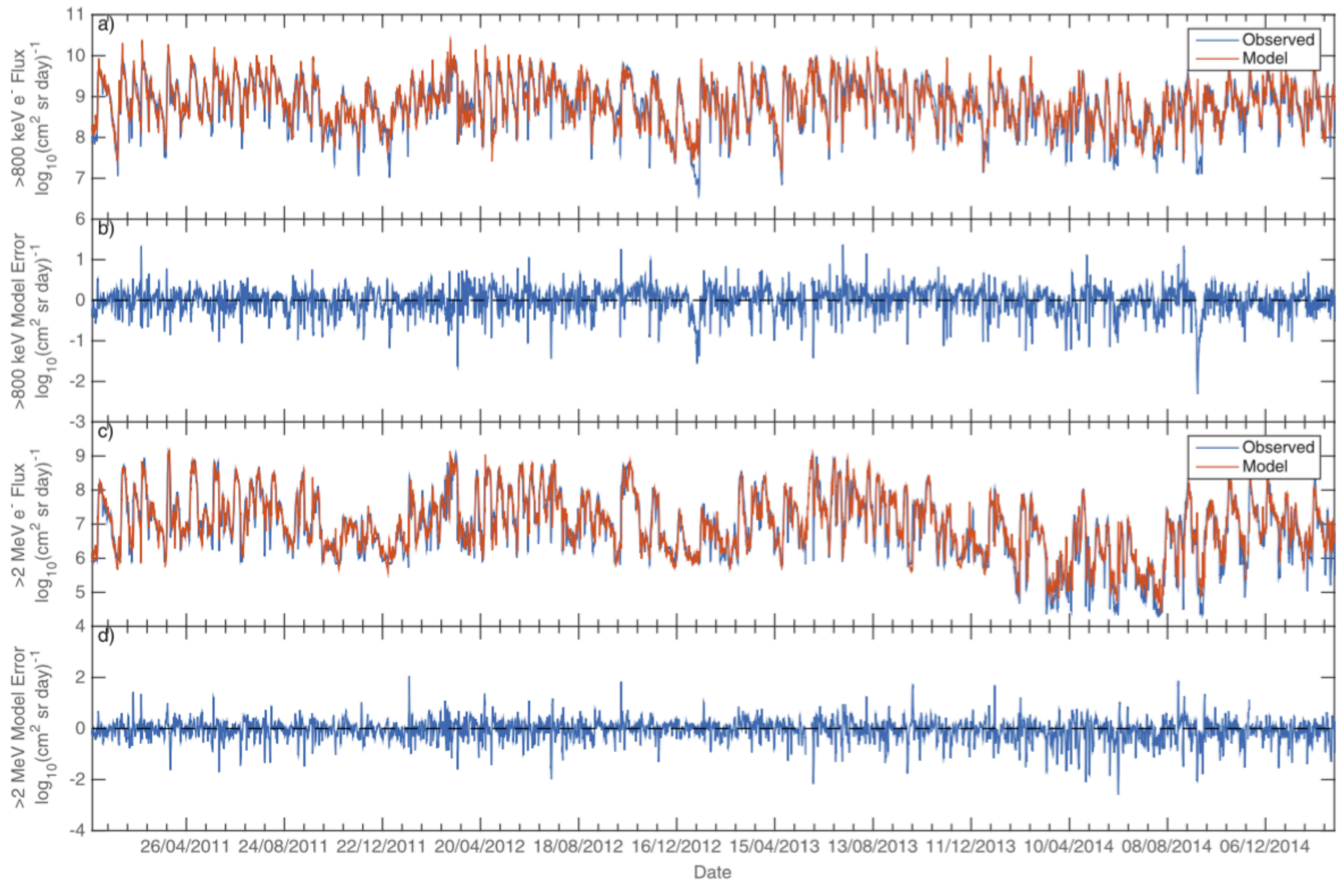
	e^- Flux		Log10(e^- Flux)	
Model	PE	Corr	PE	Corr
REFM	-1.31	0.73	0.70	0.85
SNB^3GEO	0.63	0.82	0.77	0.89

Balikhin, M. A., et al. (2016), Comparative analysis of NOAA REFM and SNB3GEO tools for the forecast of the fluxes of high-energy electrons at GEO, *Space Weather*, *14*, 22–31, doi:10.1002/2015SW001303.

GSO e⁻ flux forecasts

- Initially, models run once per day to generate forecasts
- Re-developed to use 24 hour running averages with a time resolution of 1 hour

Energy	PE	ρ
>800 keV	72.1%	85.1%
>2 MeV	82.3%	90.9%



GSO e⁻ flux forecasts

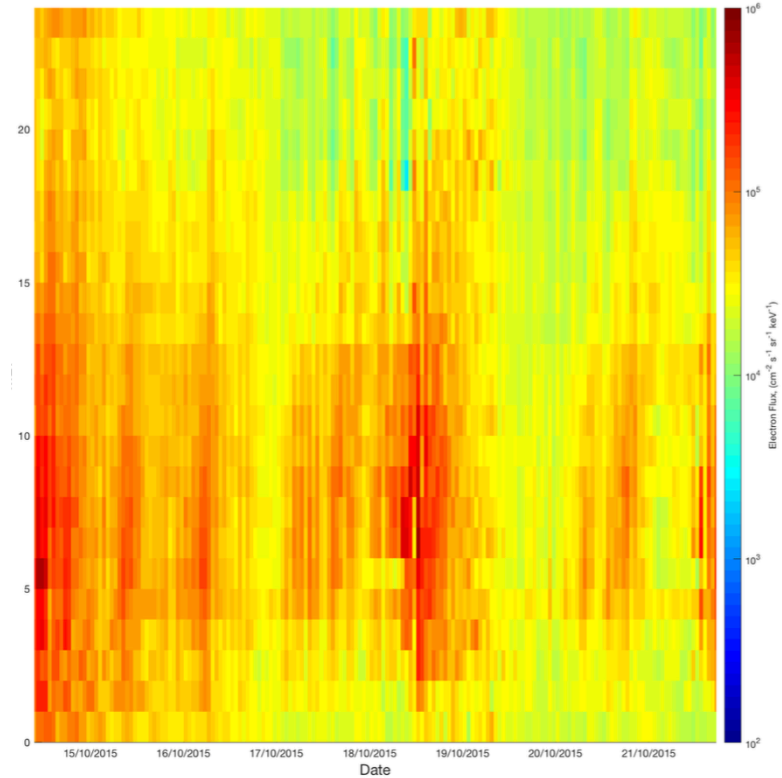
Use of 24 hr running averages looses any MLT structure
Set of MLT models currently under developed
Main problem – lack of continuous measurements in different MLT sectors

Current models based on GOES 13/15 data
Only at specific MLT locations for a short time

Use 1 hr MLT bins

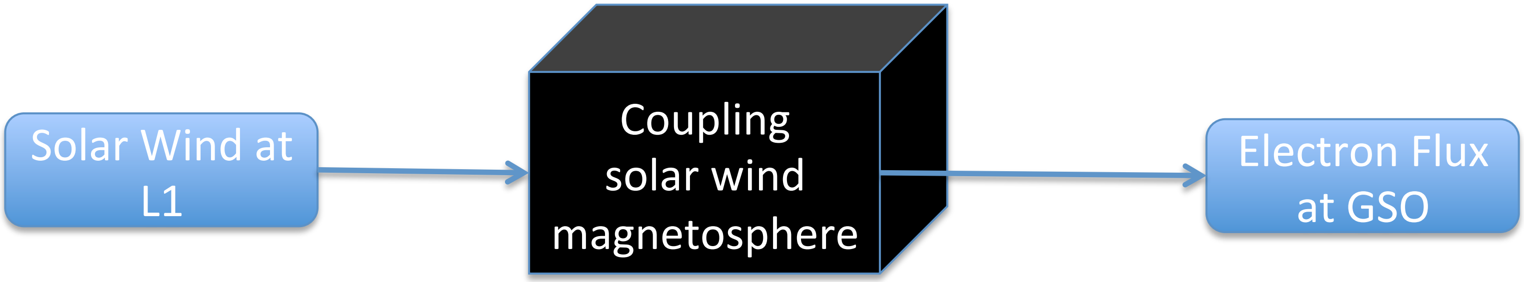
Training period: 1 Jan 2011 – 1 Mar 2013
Test period: 2 Mar 2013 – 31 Dec 2017

Model performance
PE: 47-75%, Correlation 51-79%



Past cast fluxes of 30-50 keV electrons

Electron Fluxes at GSO



Energy	Term 1	%ERR	Term 2	% ERR
90 keV	V(t)	97.0	$V^2(t)$	2.7
127.5 keV	V(t)	74.8	V(t-1)	22.2
172.5 keV	V(t-1)	65.7	V(t)	31.6
270 keV	V(t-1)	97.5	$V^2(t-1)$	2.3
407.5 keV	V(t-1)	84.1	V(t-2)	13.7
625 keV	V(t-1)	75.9	V(t-2)	22.3
925 keV	V(t-2)	96.2	N(t)	0.3
1.3 MeV	$V^2(t-2)$	76.5	nV(t-1)	2.2
2.0 MeV	N(t-1)	53.7	nV(t-1)	13.6
1.8-3.5 MeV	N(t-1)	51.5	$N^2(t-1)$	15.1

Boynton, R. J., et al., (2013), The analysis of electron fluxes at geosynchronous orbit employing a NARMAX approach, J. Geophys. Res. Space Physics, 118, 1500–1513, doi: 10.1002/jgra.50192.

Geomagnetic Indices

AIM: Forecasts of Kp, Dst, and AE

Methodologies – data driven

- Neural Network –IRF Lund, Sweden
- NARMAX – U. Sheffield, UK

Model inputs – solar wind parameters at L1

- Measurements from ACE/DSCOVR
- L1 forecasts from AWSoM/SWIFT

Geomagnetic Indices

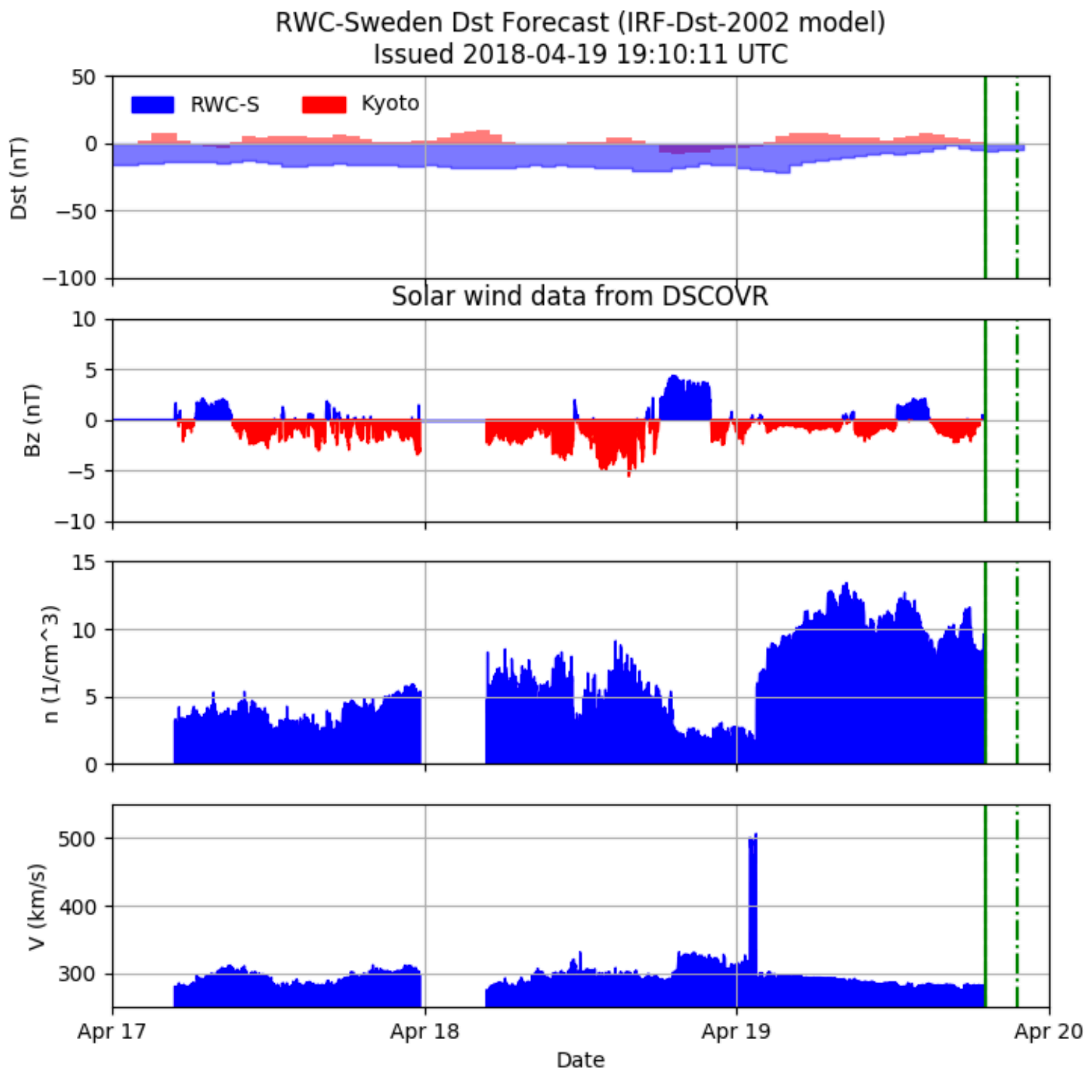
Forecasts available

IRF Lund Dst, and Kp
Methodology: Neural Nets

Plots
http://lund.irf.se/forecast/dst/dst.png,
http://lund.irf.se/forecast/kp/kp.png

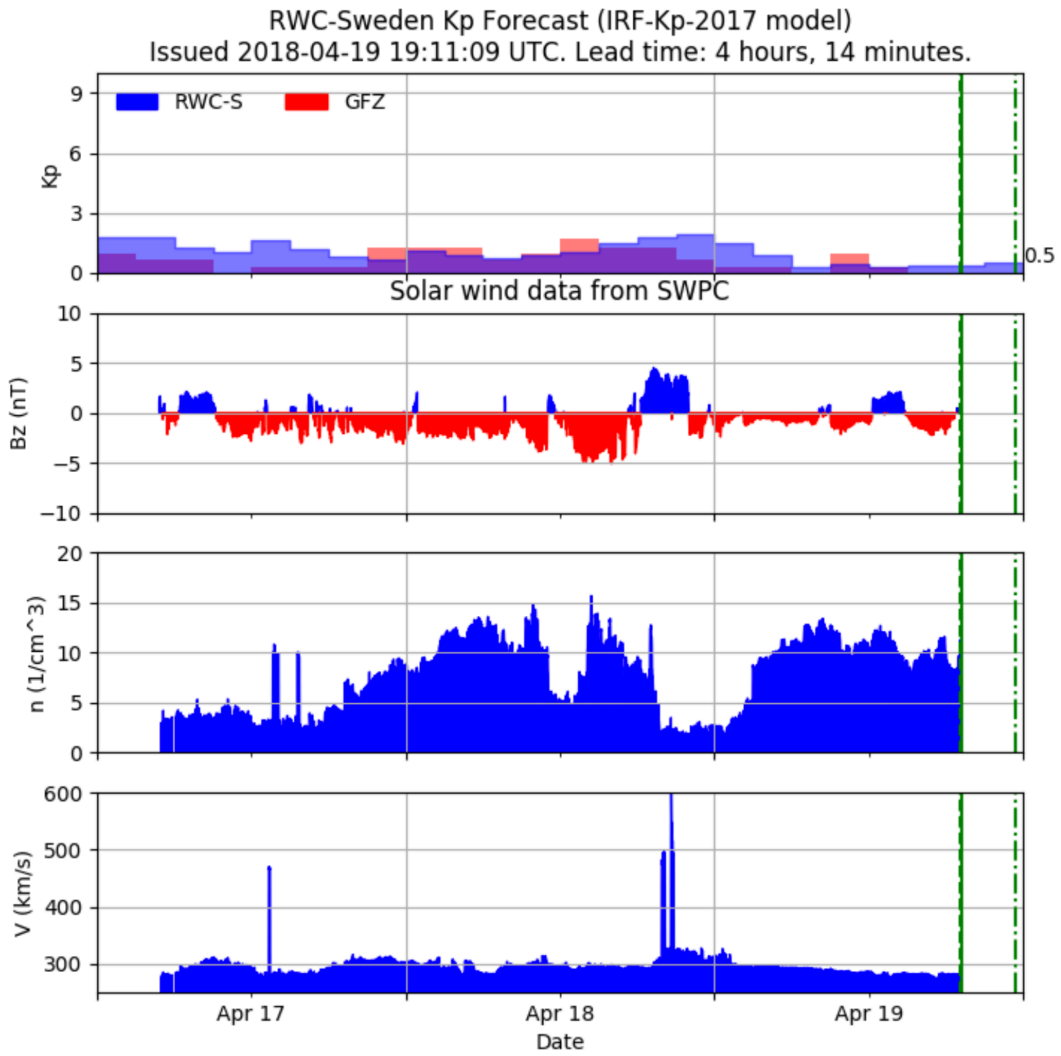
Data (Kp available now, Dst, AE available soon)
RESTful data server created
e.g. latest 10 Kp predictions:
http://lund.irf.se/progress/rest/datasets/irfkp2017/latest?limit=10

IRF Lund Dst



RWC-Sweden Dst Forecast (IRF-Dst-2002 model)
Issued 2018-04-19 19:10:11 UTC
RWC-S
Kyoto
Dst (nT)
50
0
−50
−100
Solar wind data from DSCOVR
Bz (nT)
10
5
0
−5
−10
n (1/cm^3)
15
10
5
0
V (km/s)
500
400
300
Apr 17
Apr 18
Apr 19
Apr 20
Date

IRF Lund Kp


RWC-Sweden Kp Forecast (IRF-Kp-2017 model)
Issued 2018-04-19 19:11:09 UTC. Lead time: 4 hours, 14 minutes.
RWC-S
GFZ
Kp
0.5
Solar wind data from SWPC
Bz (nT)
n (1/cm^3)
V (km/s)
Apr 17
Apr 18
Apr 19
Date

Geomagnetic Indices

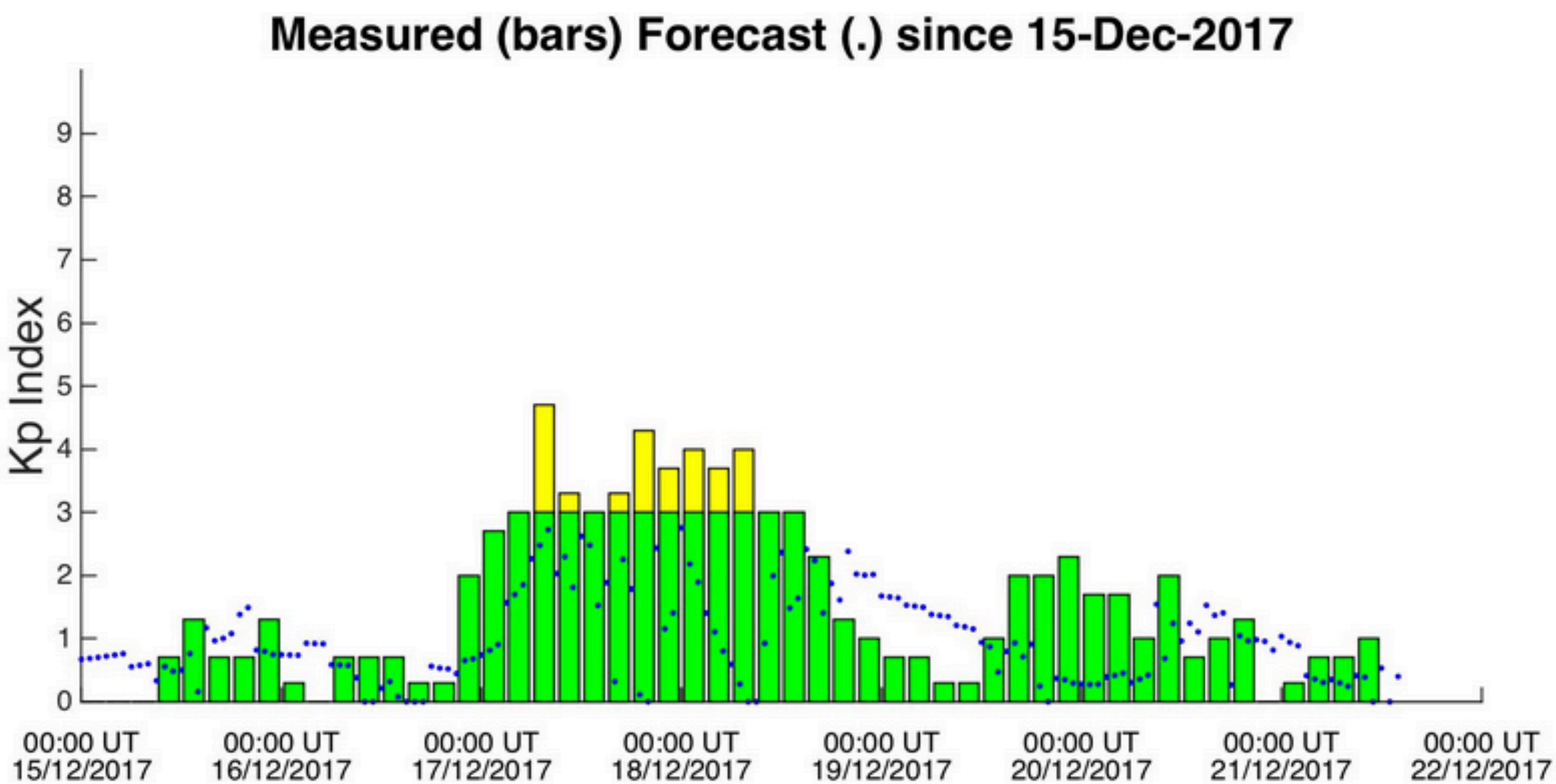
Forecasts available

U. Sheffield Kp – Plots
Methodology: NARMAX

https://ssg.group.shef.ac.uk/USSW2/Kp/fKp_1d.jpg

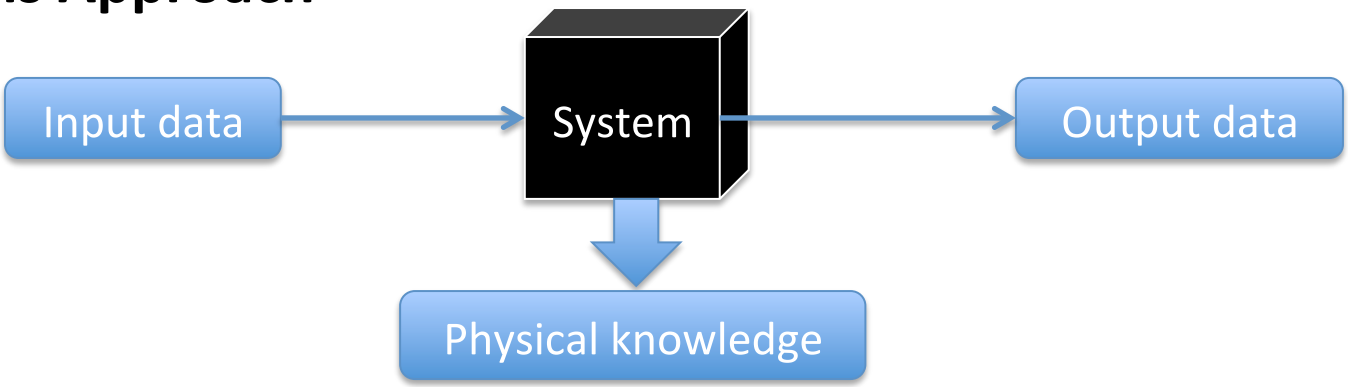
U. Shef Kp

1 Week



Modeling Methodologies

Systems Approach



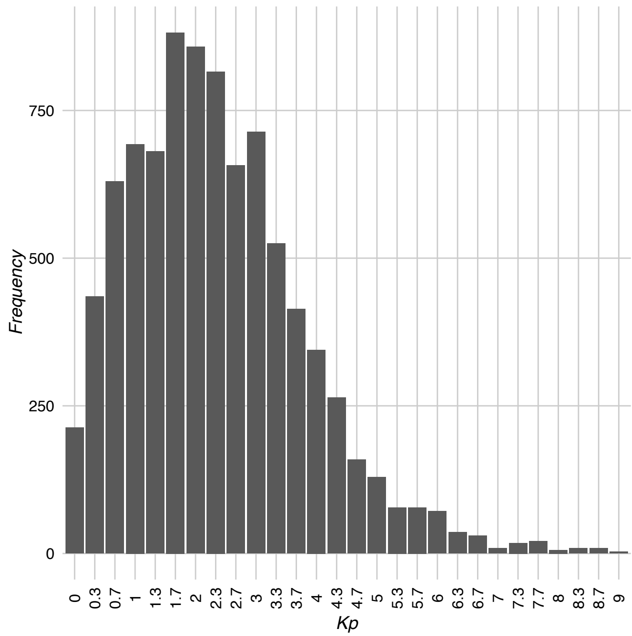
$$y(k) = F[y(k-1),\ldots,y(k-ny),$$ System outputs

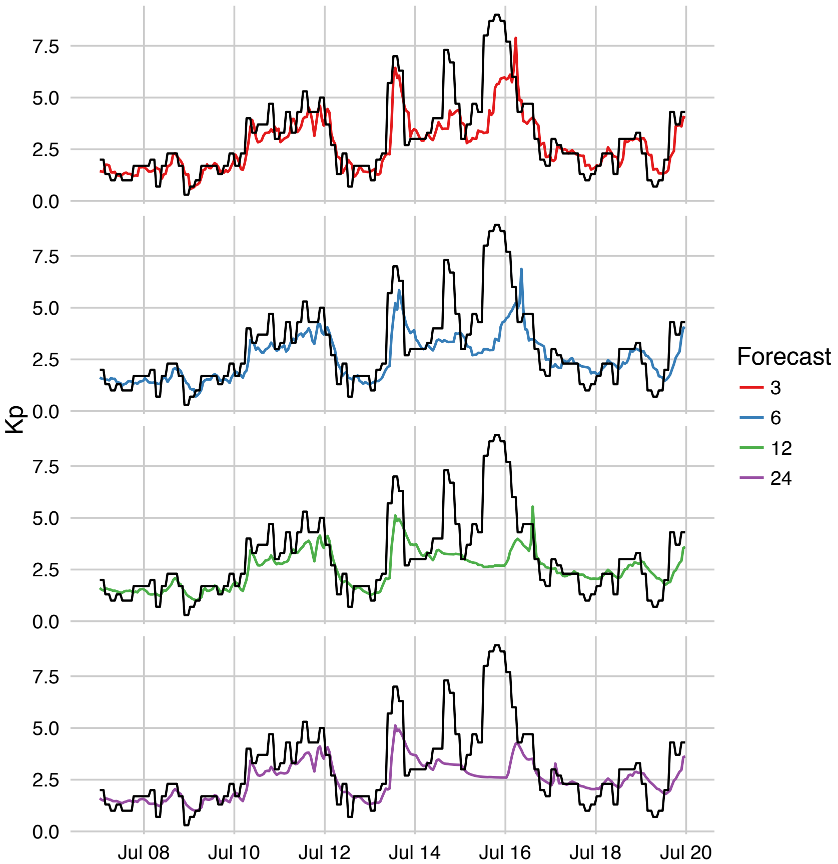
$$u(k),\ldots u(k-nu),$$ System inputs

$$e(k-1),\ldots e(k-ne)]$$ Noise/errors

F[] is a nonlinear function (polynomial, B-spline, radial basis function)

Problem in training data





Kp values are not evenly distributed

Low to mid range values modeled OK

Forecasts of peak Kp values missed

The University Of Sheffield.

Model Parameters

Input parameters

- Kp – GFZ Potsdam
- Solar wind – OMNI data set 5 min

Name	Description
Kp	Kp index
V	solar wind speed/velocity (flow speed) [km/s]
Bs	IMF southward component
P	Solar wind pressure [nPa]
N	Solar wind density [per cc]
VBs	Product of Velocity and Bs
√p	Square root pressure

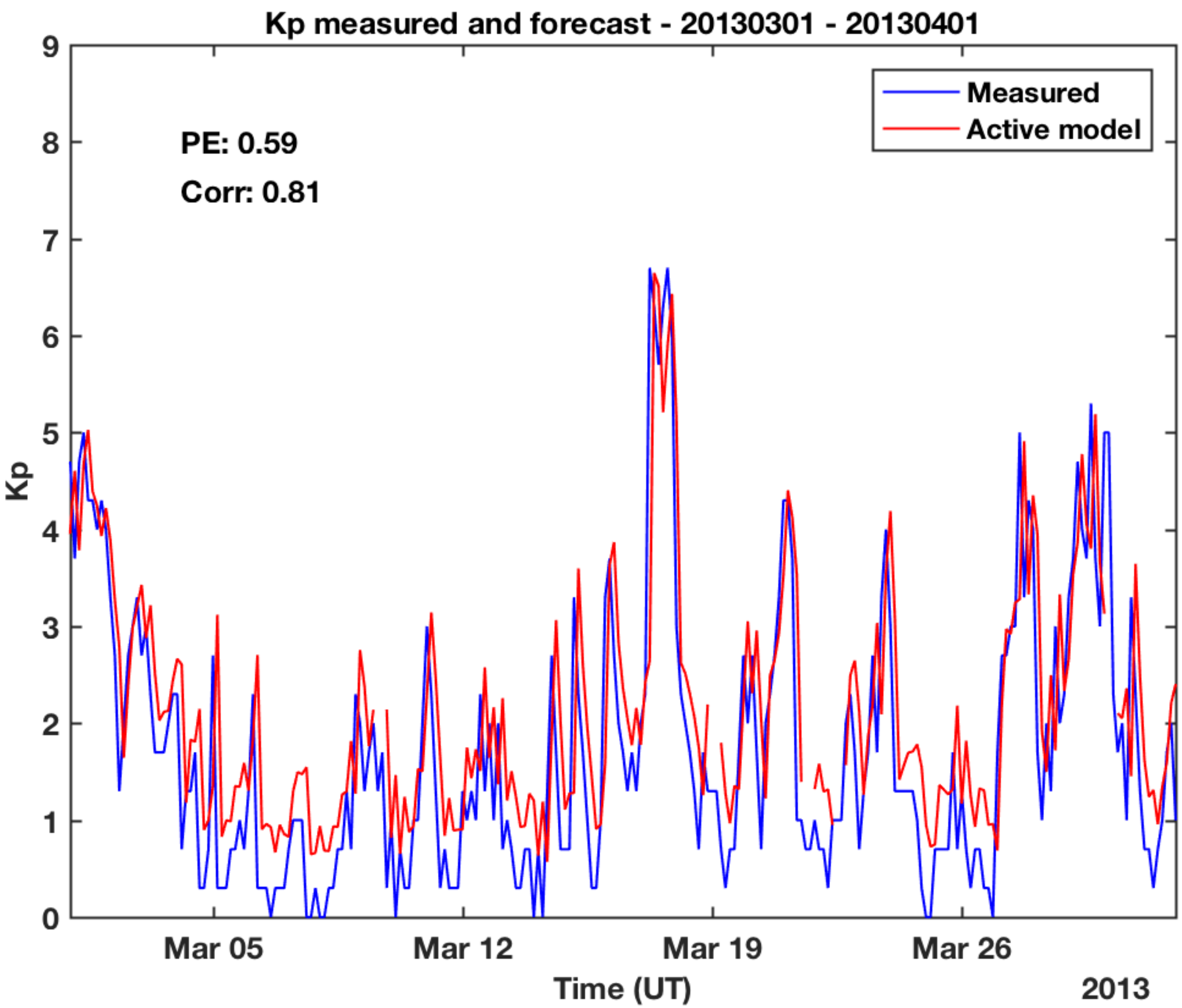
U. Shef Kp model

New model

- Target large Kp values
- Training dataset balanced to give more prominence to high values

```
kp= ...
 8.8088e-1 * Kp(1) +
 7.6502e-1 +
-4.9010e-03 * p(2)*n(2) +
 -1.9820e-04 * V(2) * Kp(2) +
 1.5981e-02 * p(2) * Kp(2) +
 2.3706e-04 * V(1) * VBs(1) +
 -3.7429e-03 * Bs(1) * n(1) +
 -3.9727e-04 * V(2) * VBs(2) +
 5.6176e-02 * Bs(2) * sqrtp(1) +
 -7.1004e-03 * n(1) * VBs(2);
```

St. Patrick's Day 2013



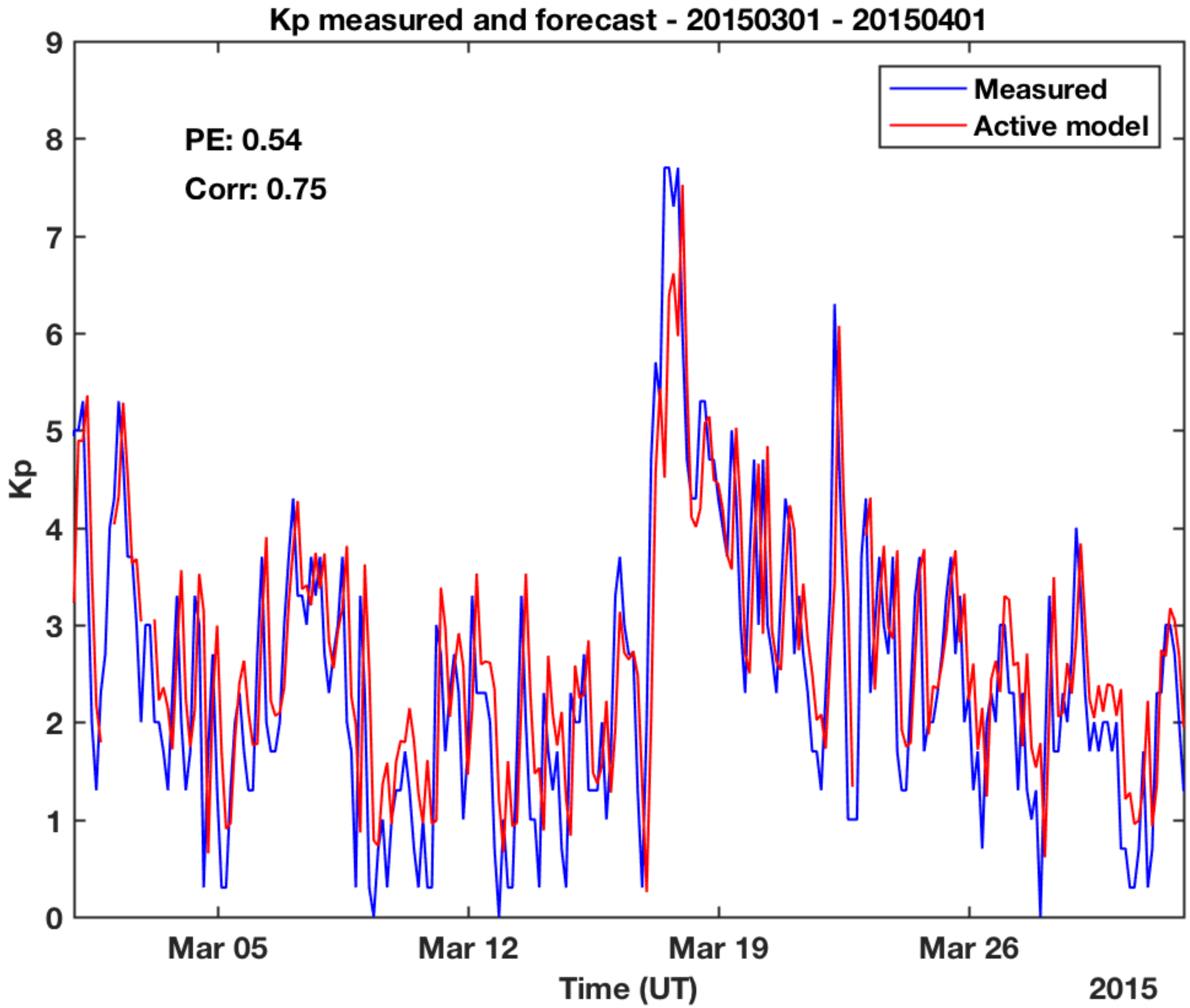
Auto-regressive models

- Good agreement with measured values
- One time step delay

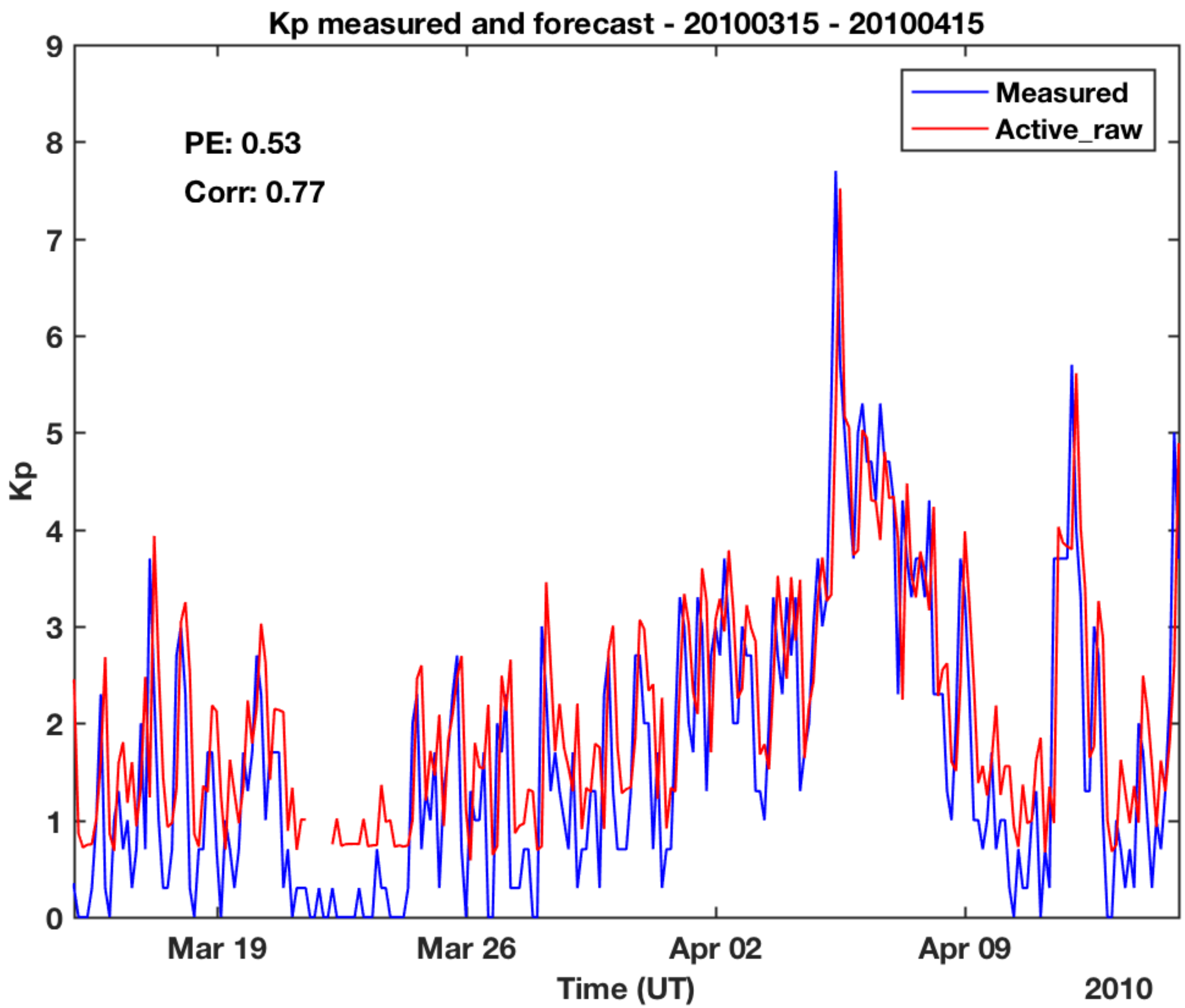
Non-auto-regressive models

- Not particularly good agreement with measured values
- No time delays

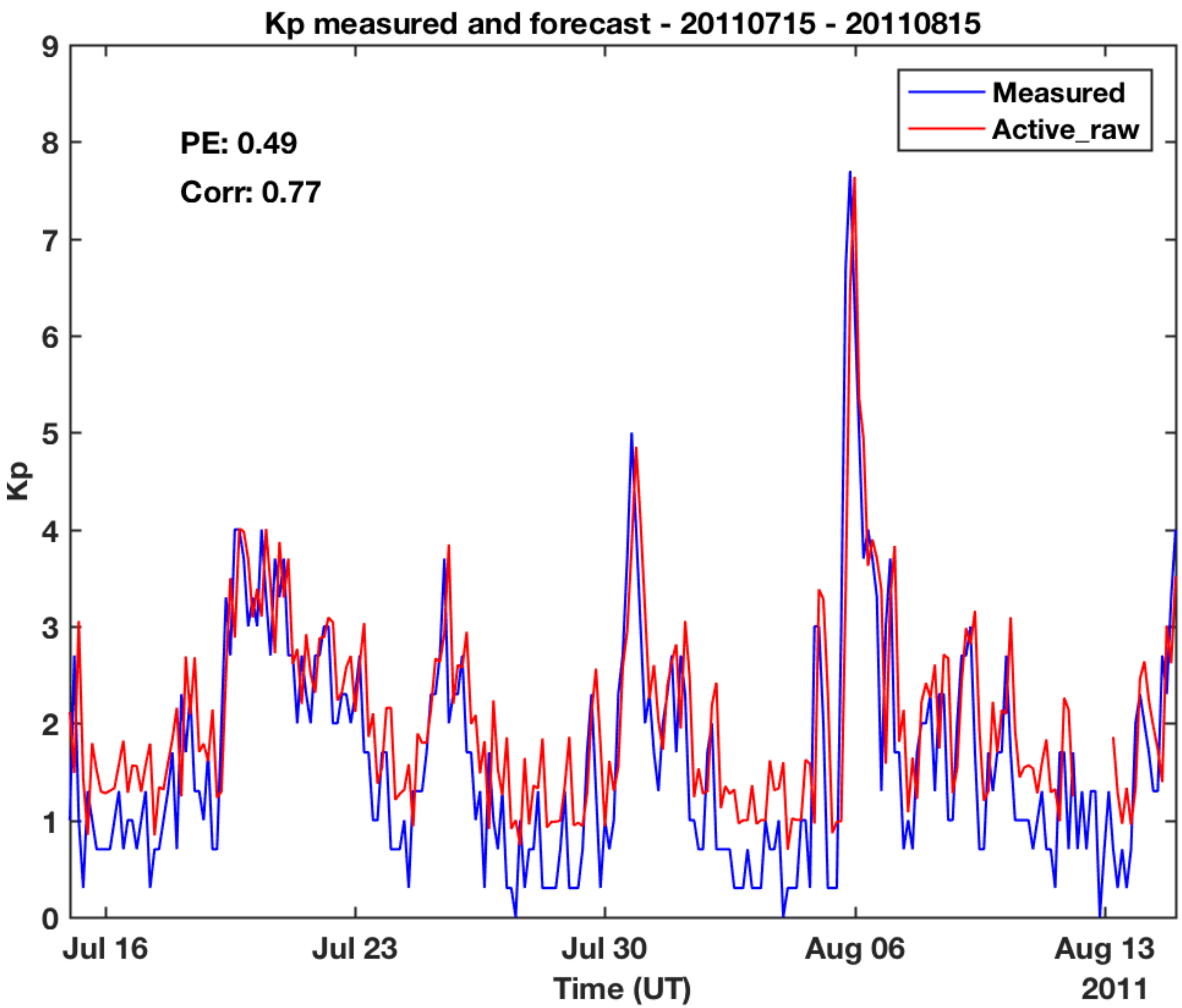
St. Patrick's Day 2015



April 2010

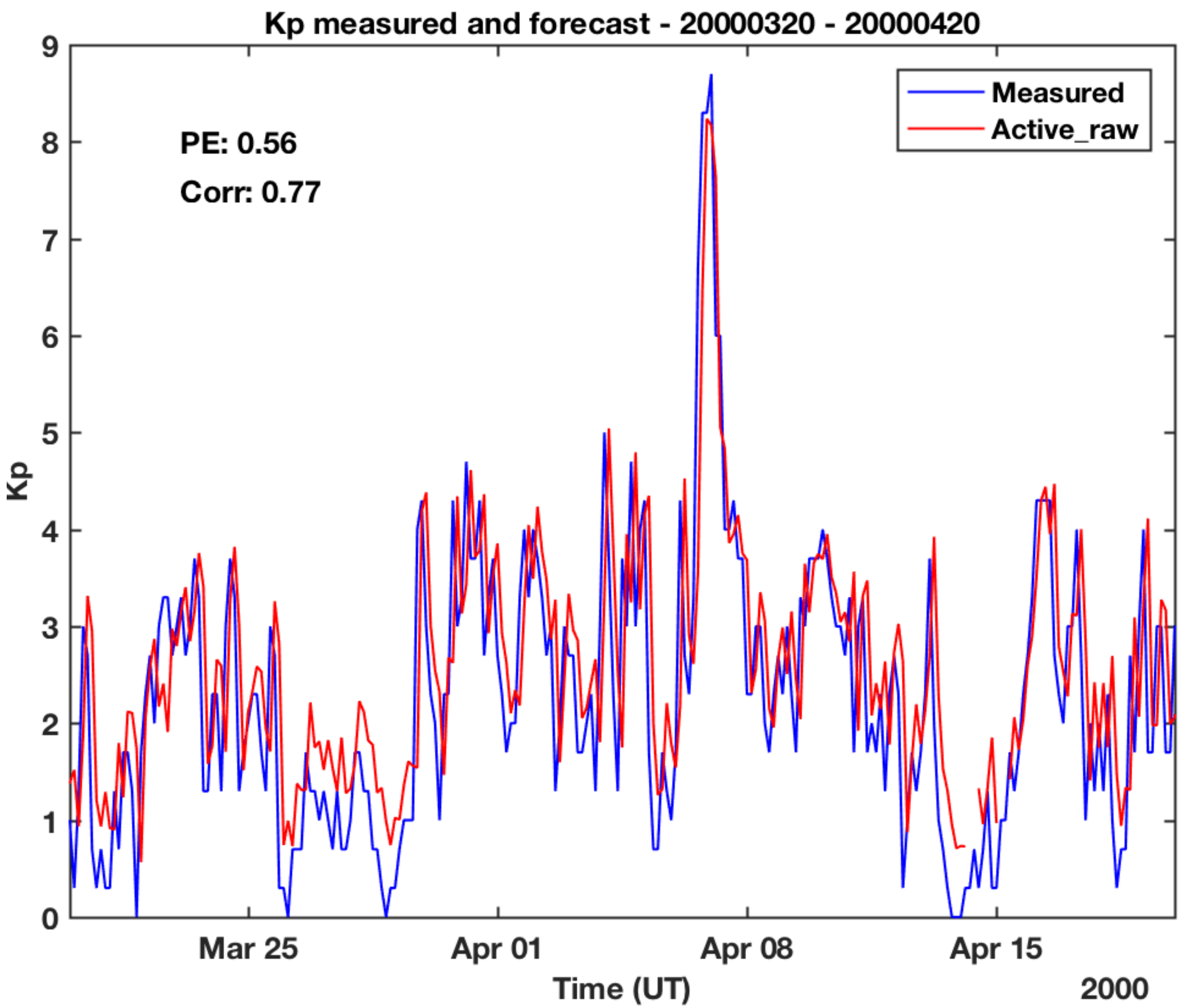

Kp measured and forecast - 20100315 - 20100415
Measured
Active_raw
PE: 0.53
Corr: 0.77
Kp
0
1
2
3
4
5
6
7
8
9
Mar 19
Mar 26
Apr 02
Apr 09
Time (UT)
2010

August 2011

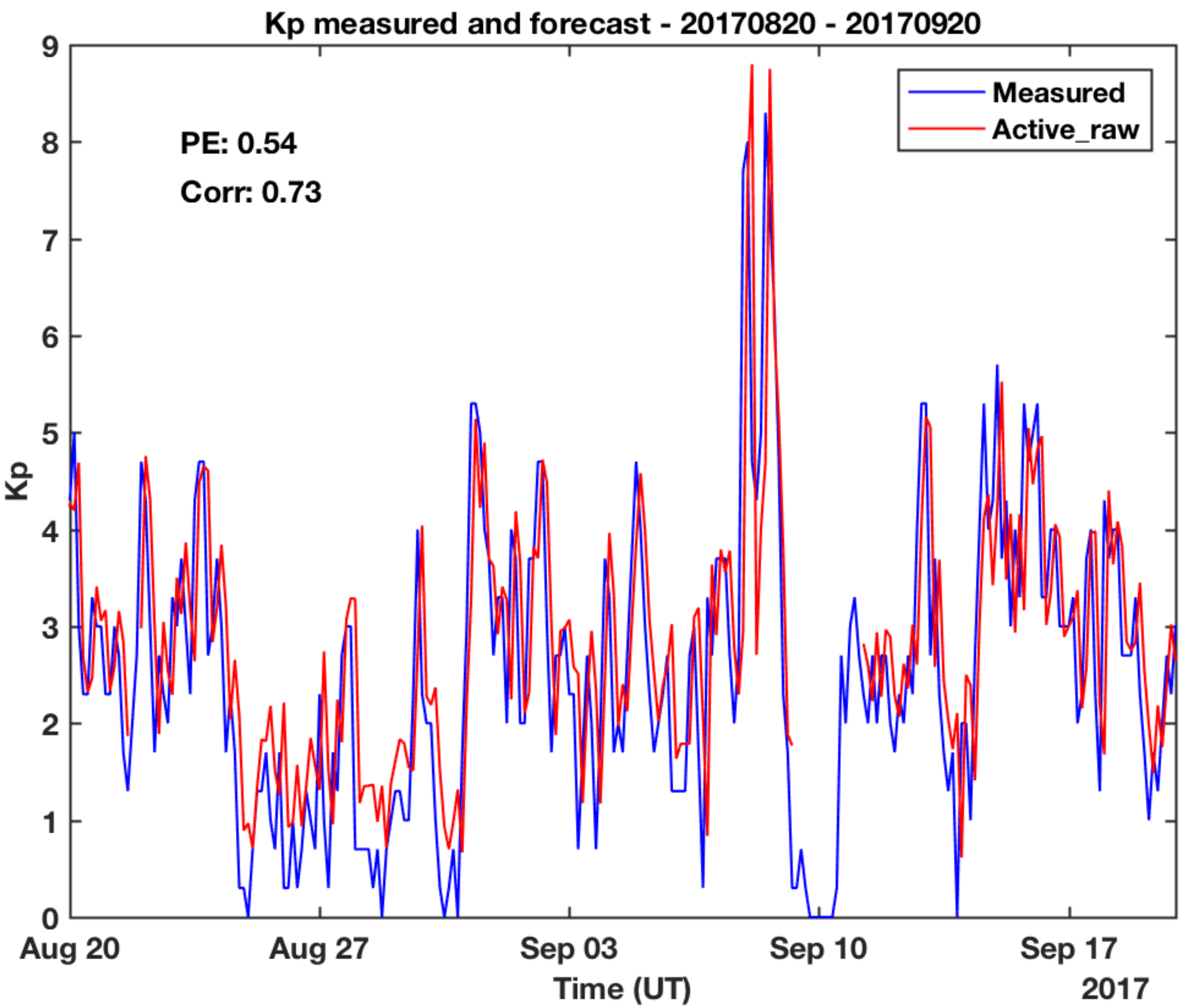


Kp measured and forecast - 20110715 - 20110815
Measured
Active_raw
PE: 0.49
Corr: 0.77
Kp
0
1
2
3
4
5
6
7
8
9
Jul 16
Jul 23
Jul 30
Aug 06
Aug 13
2011
Time (UT)

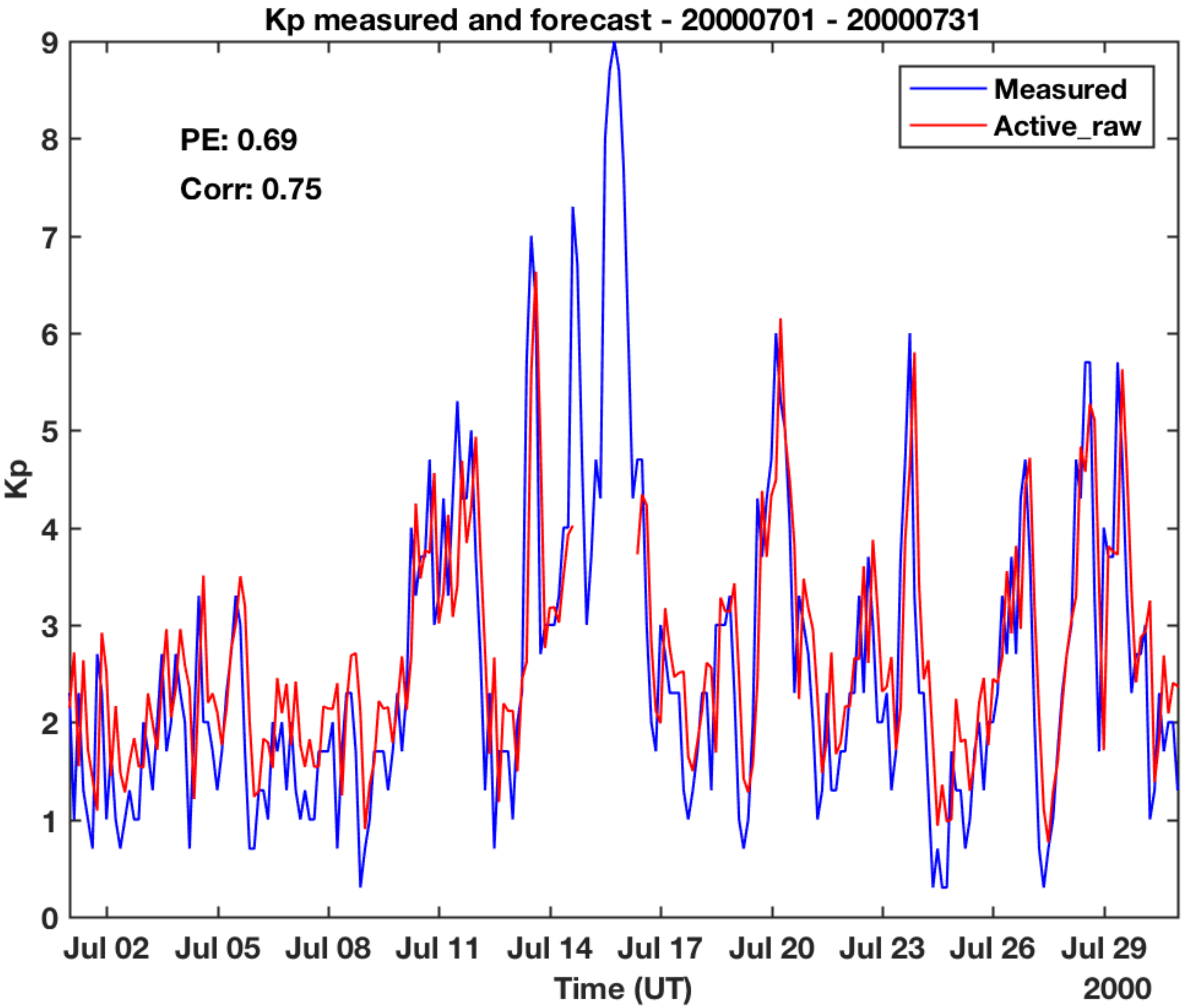
April 2000


Kp measured and forecast - 20000320 - 20000420
PE: 0.56
Corr: 0.77
Measured
Active_raw
Kp
0
1
2
3
4
5
6
7
8
9
Mar 25
Apr 01
Apr 08
Apr 15
2000
Time (UT)

September 2017

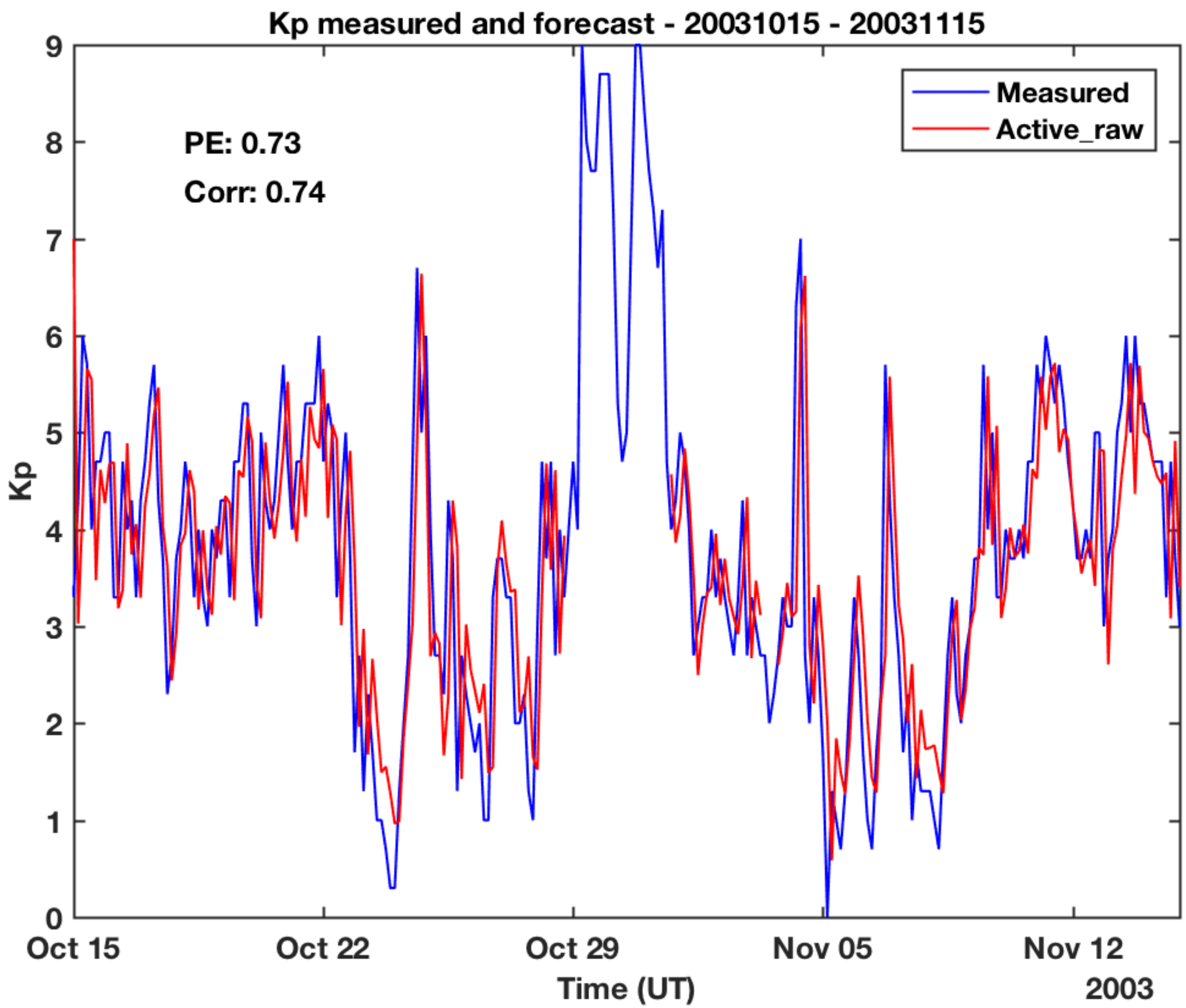


Bastille Day Storm



Gap in OMNI plasma data, therefore no forecast

Halloween Storms



Summary

PROGRESS is a Horizon 2020 funded space weather project.

Main goals are to provide accurate and timely forecasts of

- Solar wind parameters at L1
- The evolution of geomagnetic indices
- The particle environment in the inner magnetosphere

Real time forecasts of interest to

- Scientists modeling these processes
- Satellite operators

All forecast information will be available from the project web site ssg.group.shef.ac.uk/progress/html

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