Evaluating the use of geomagnetic indices for identifying potential damage to power grids

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GICs

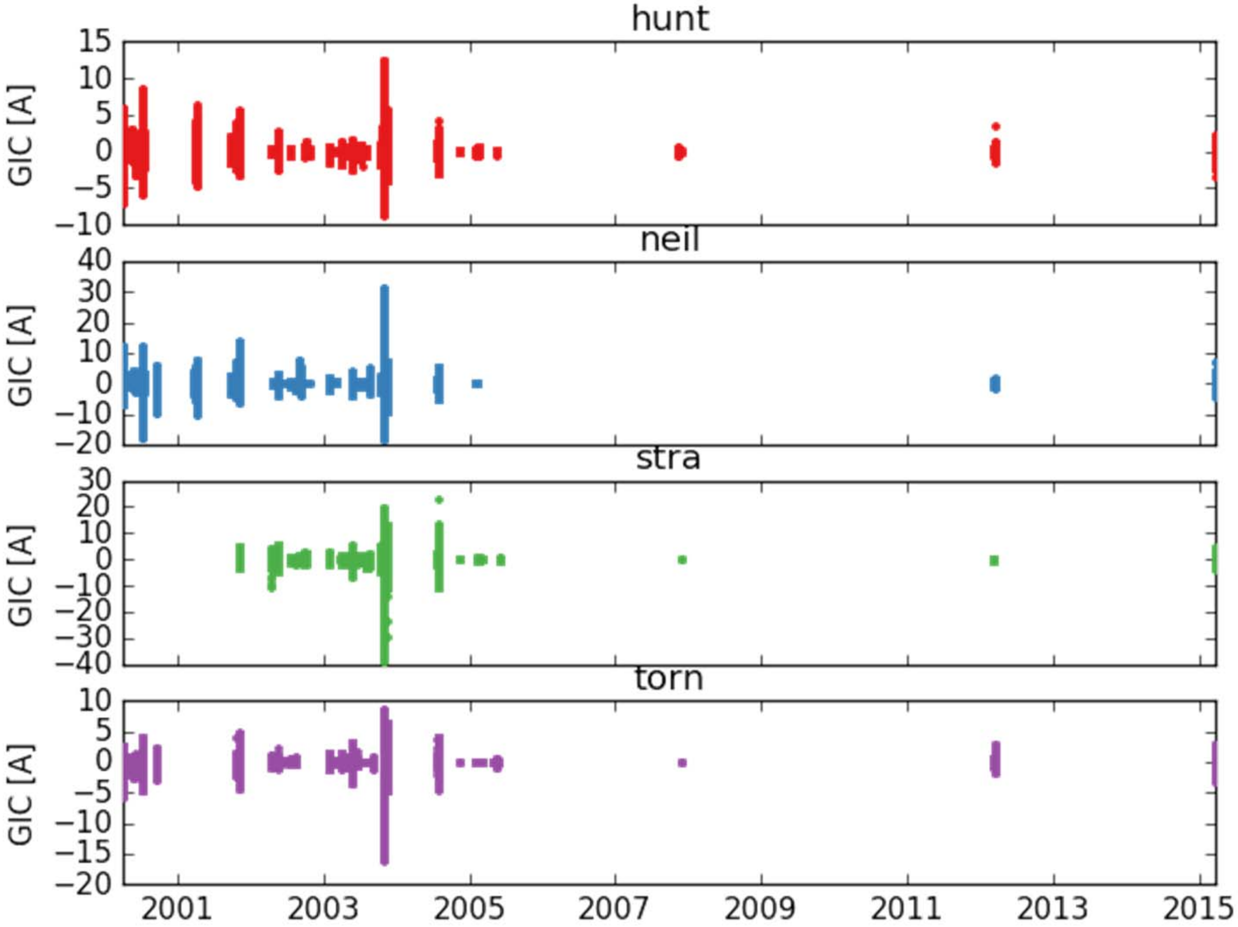
- Geomagnetically induced currents (GICs) are the main space weather risk to power grids

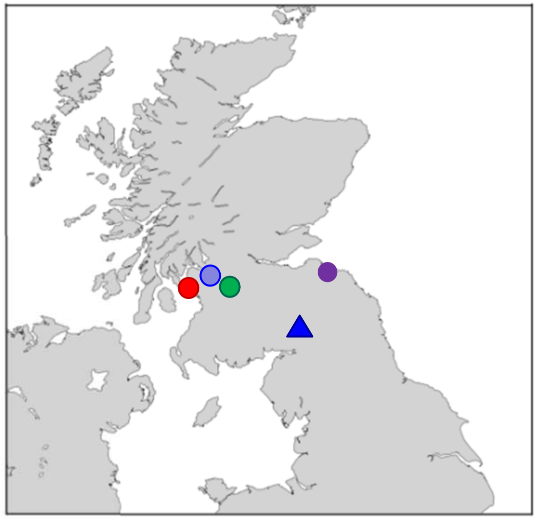
- We would like a way to categorise GICs, particularly for the UK, to better identify times when the system is at risk.

- Ideally we could then provide a forecast with a focus on GICs

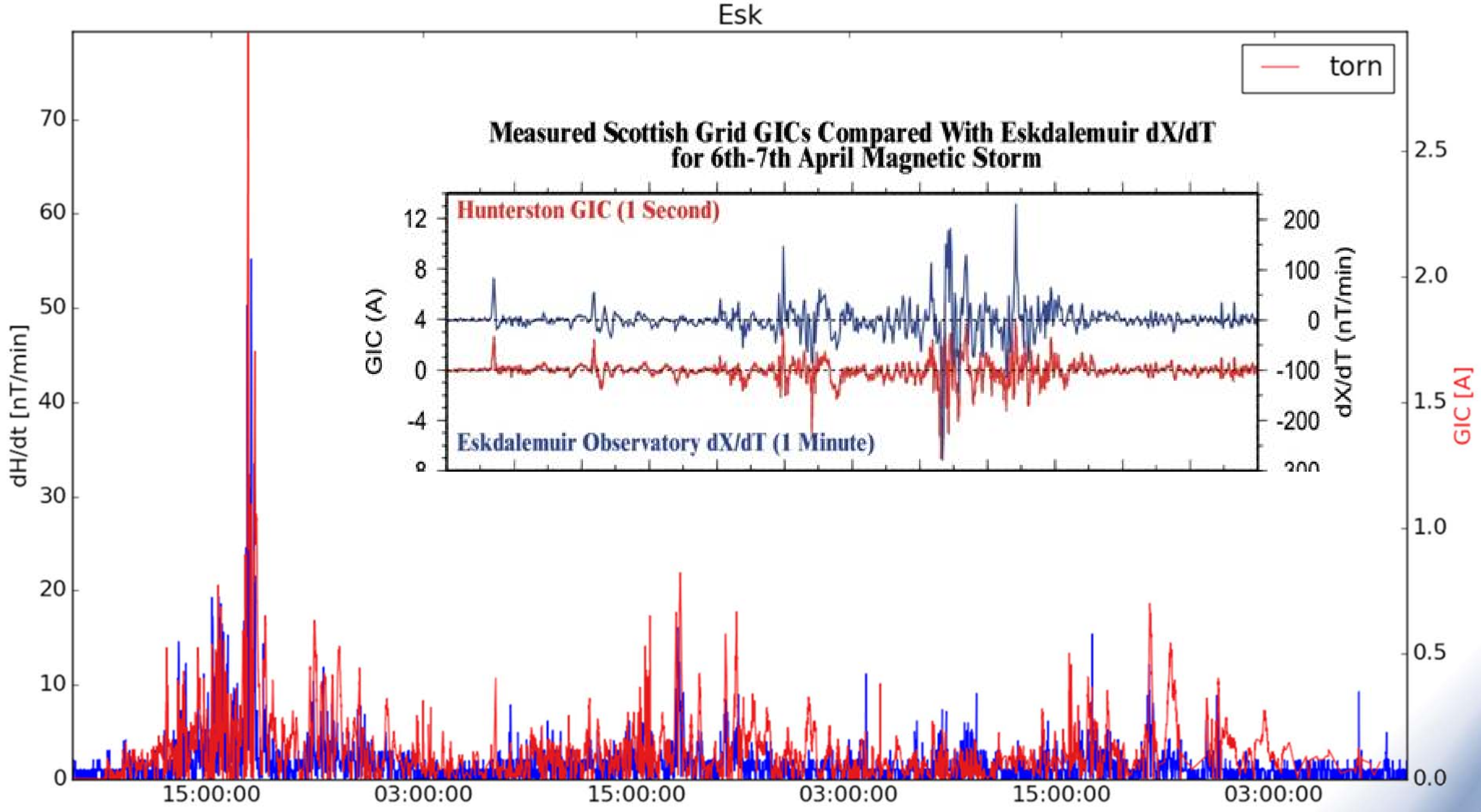
- We generally assume GIC is most closely related to dB/dt – how true is this?

GIC data


hunt
neil
stra
torn
GIC [A]
2001
2003
2005
2007
2009
2011
2013
2015

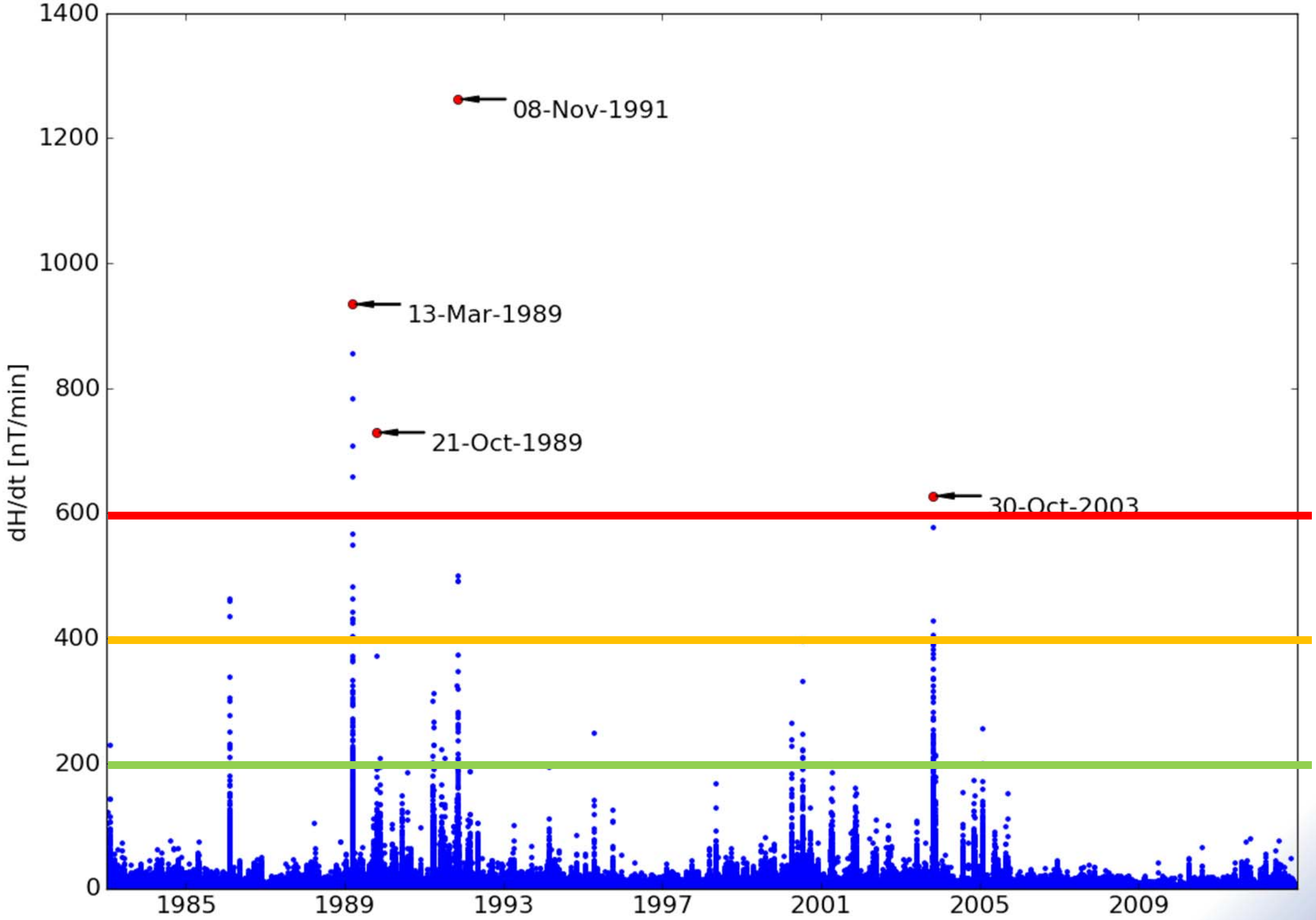


dH/dt and GIC



March 2012 – Torness GIC data (red) against dH/dt at Eskdalemuir (blue)

dH/dt and known GIC impacts



Erinmez et al., *J. Atmos. Sol-Terr. Phys*. 2002

Problem

- Our earlier GIC data need reprocessing
- dB/dt at individual stations is very hard to predict (at the moment)
- We would like to develop an index to identify when there is a risk of large GIC
- We start by investigating what existing indices GIC (dB/dt) in the UK relates to.

NOAA G scales and Kp

- Widely used and recognised
- We use them to forecast and to categorise past activity
- Based on Kp, the 3-hourly geomagnetic index

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
24 JUN-25 JUN	STORM G2	STORM G3
25 JUN-26 JUN	STORM G1	STORM G3
26 JUN-27 JUN	ACTIVE	STORM G1

For more information about the forecast and activity categories see www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 24 hours

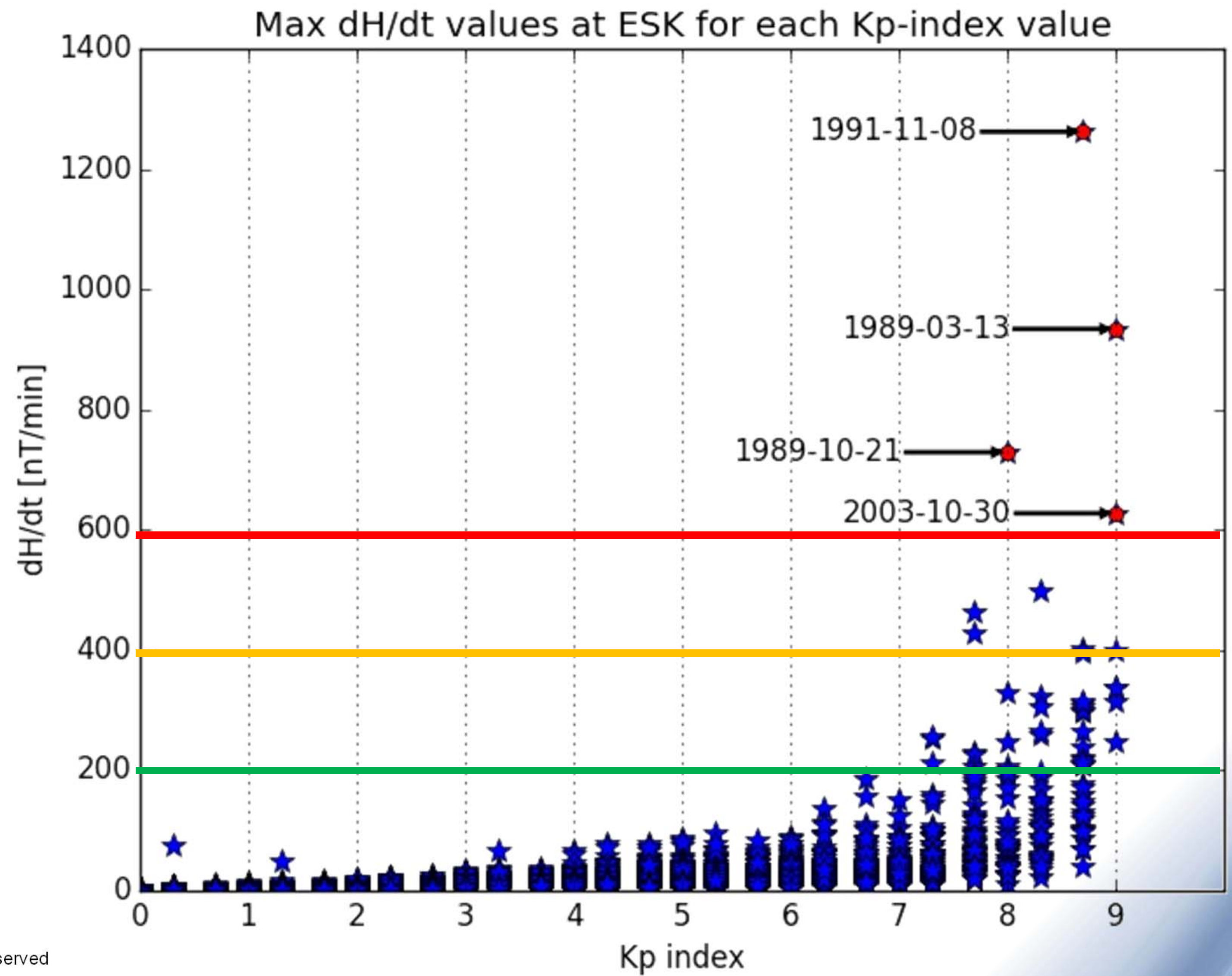
	Global			Local (UK)		
Date	Average	Max	At time (UT)	Average	Max	At time (UT)
23 JUN-24 JUN	ACTIVE	STORM G1	12:00-15:00	ACTIVE	STORM G1	12:00-15:00

Additional Comments

Average geomagnetic activity has decreased back to ACTIVE over the past 24 hours. The strong southward component of the magnetic field, seen in the interplanetary magnetic field in the

Kp	BGS categories since 2014		NOAA G-scales	
	Category	Description	Category	Description
<3+	QUIET	Kp < 3+		
3+	ACTIVE	3+ < Kp < 5-		
4-				
4o				
4+				
5-	STORM G1	5- < Kp < 5+	G1	Kp = 5
5o				
5+				
6-	STORM G2	6- < Kp < 6+	G2	Kp = 6
6o				
6+				
7-	STORM G3	7- < Kp < 7+	G3	Kp = 7
7o				
7+				
8-	STORM G4	8- < Kp < 9-	G4	Kp = 8
8o				
8+				
9-				
9o	STORM G5	Kp = 9o	G5	Kp = 9

dH/dt and Kp



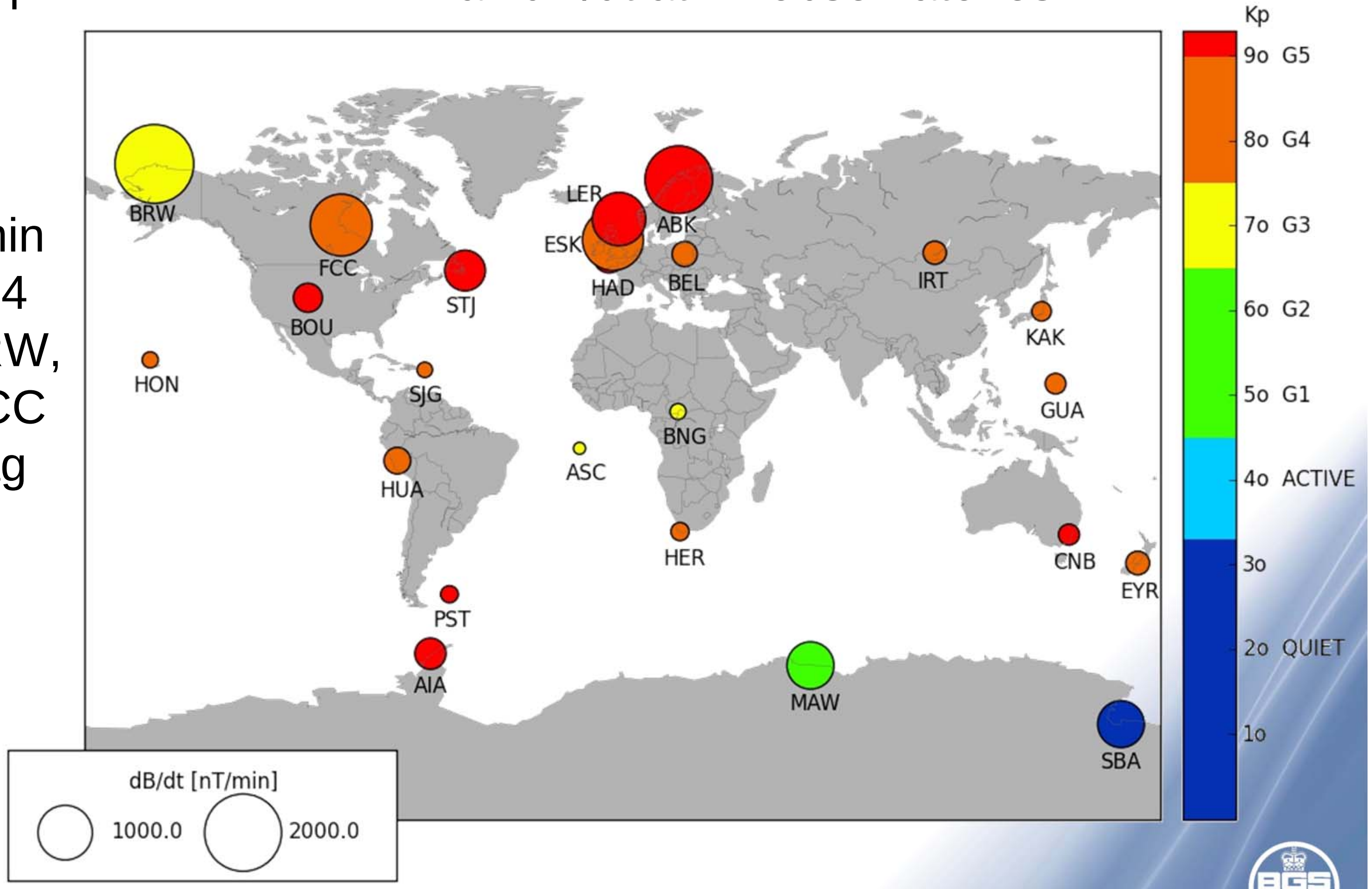
Max dH/dt values at ESK for each Kp-index value
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dH/dt [nT/min]
Kp index
0
200
400
600
800
1000
1200
1400
0
1
2
3
4
5
6
7
8
9

dH/dt and Kp

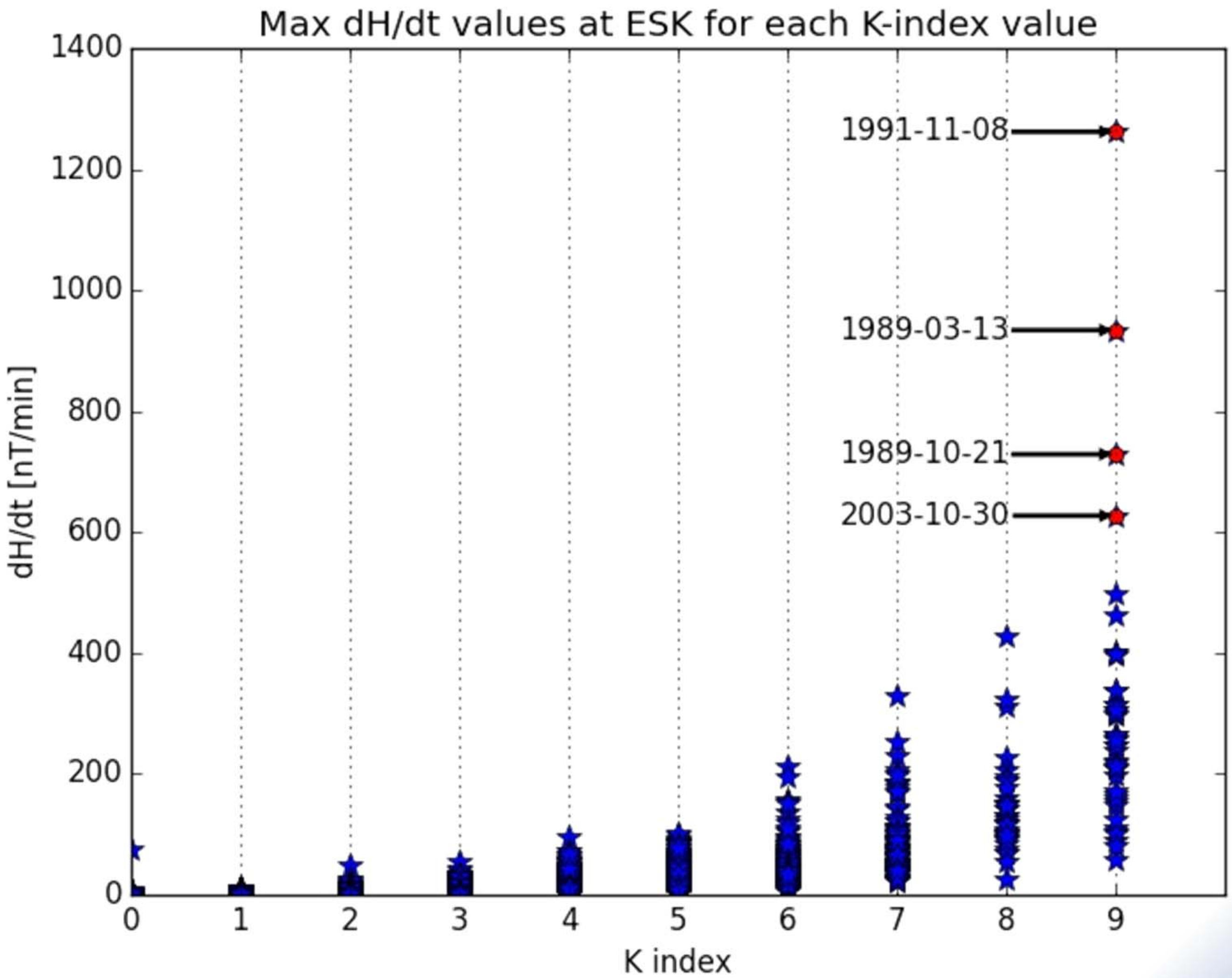
- 24 observatories with >16 years data
- Largest dH/dt at Kp = 9o for only 8 of 24 observatories.

- dH/dt > 1000nT/min was measured at 4 observatories: BRW, ABK, ESK and FCC (all > ±57° geomag latitude)

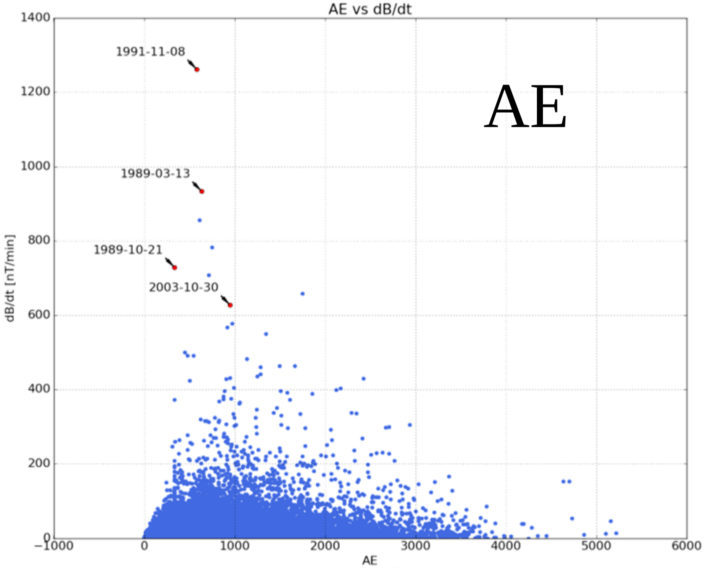
Max dH/dt at 24 observatories

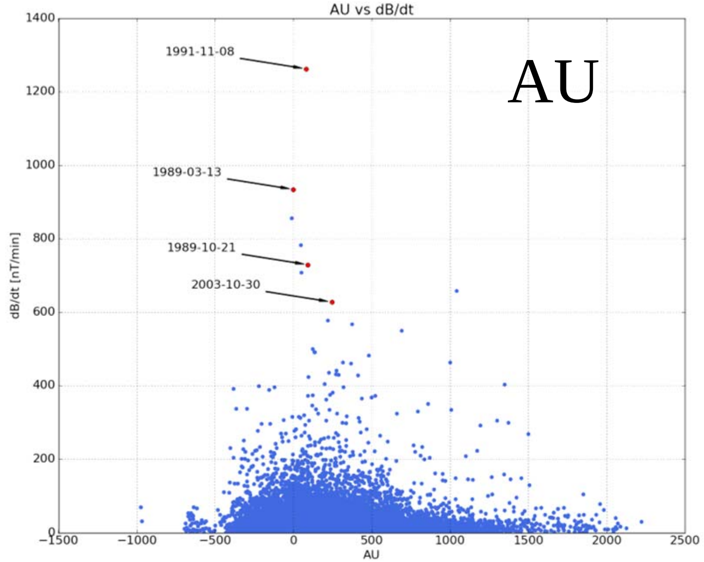


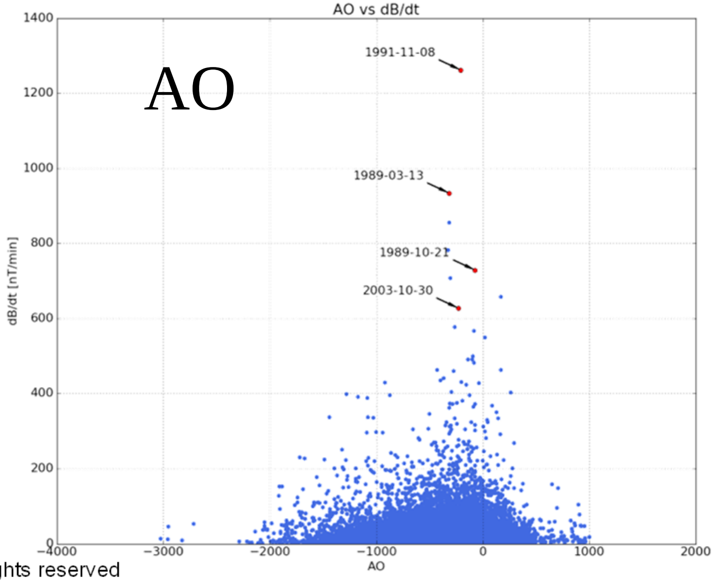
dH/dt and K

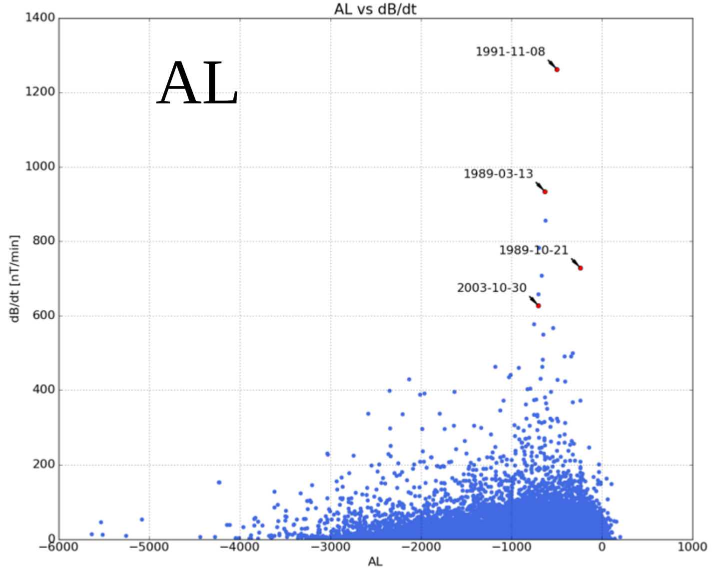

Max dH/dt values at ESK for each K-index value
1400
1200
1000
800
600
400
200
0
dH/dt [nT/min]
0
1
2
3
4
5
6
7
8
9
K index
1991-11-08
1989-03-13
1989-10-21
2003-10-30

dH/dt and AE

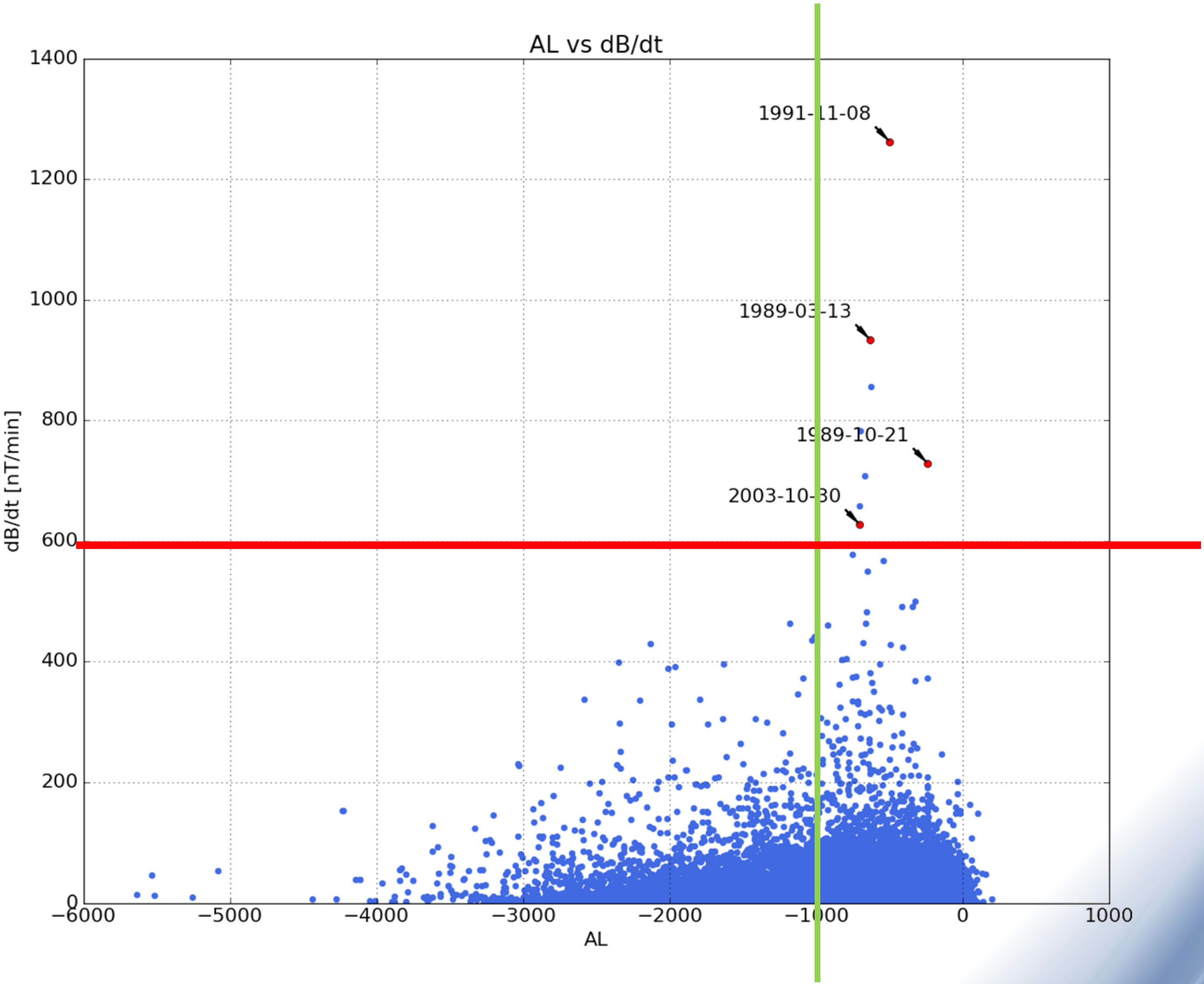

AE vs dB/dt
AE
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dB/dt [nT/min]


AU vs dB/dt
AU
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dB/dt [nT/min]

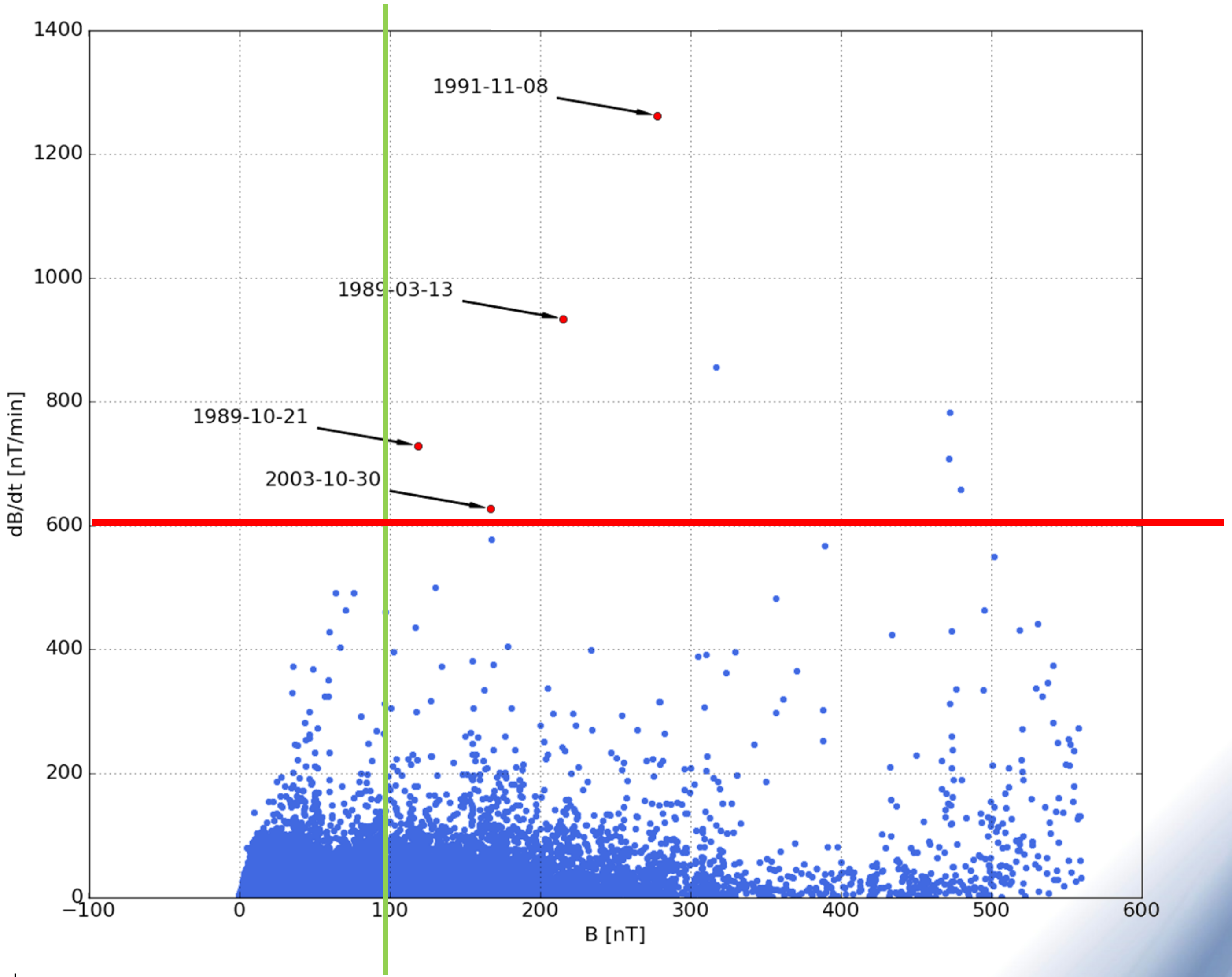

AO vs dB/dt
AO
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dB/dt [nT/min]


AL vs dB/dt
AL
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dB/dt [nT/min]

dH/dt and AL


AL vs dB/dt
1991-11-08
1989-03-13
1989-10-21
2003-10-30
dB/dt [nT/min]
AL
1400
1200
1000
800
600
400
200
0
−6000
−5000
−4000
−3000
−2000
−1000
0
1000

dH/dt HSD

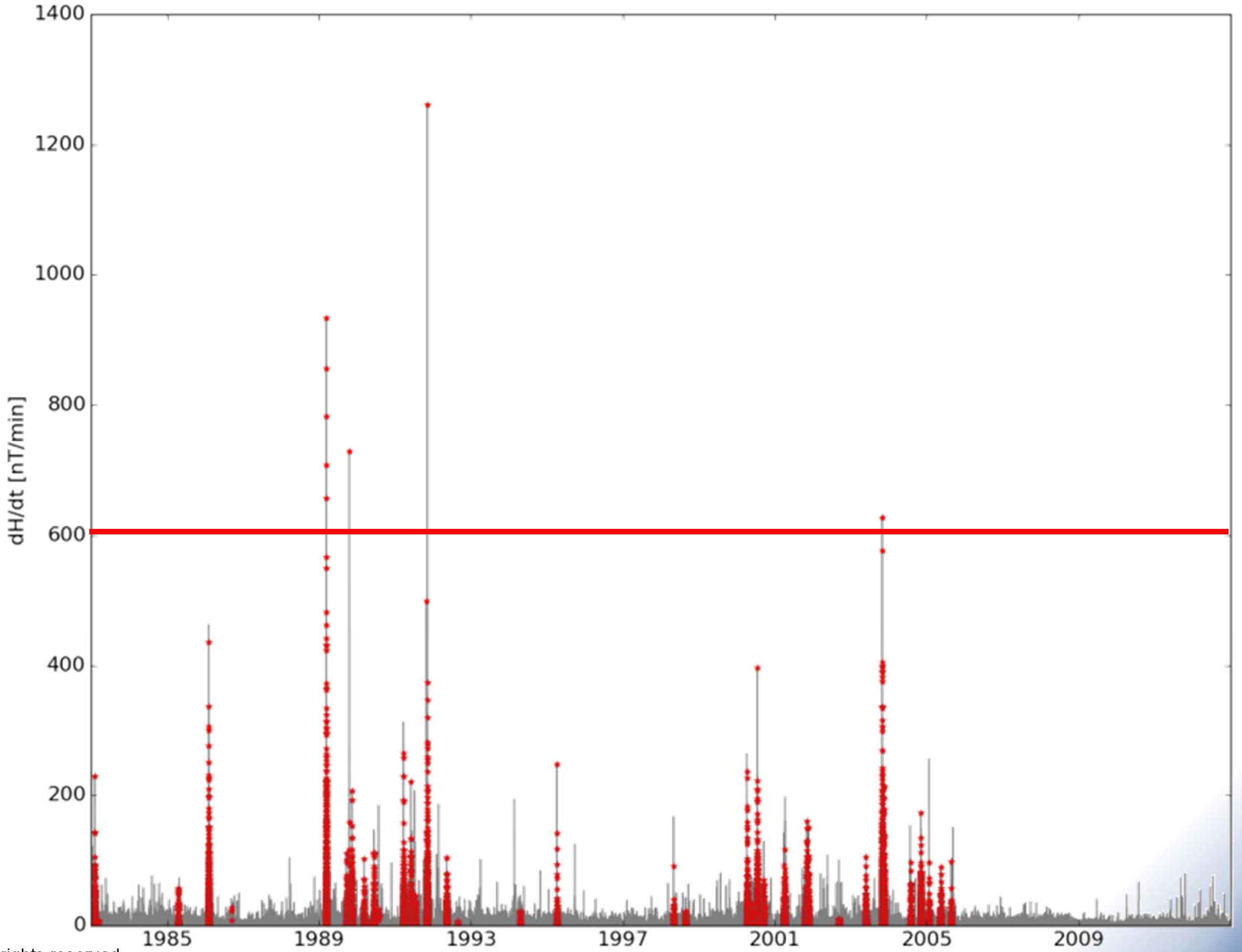


1991-11-08
1989-03-13
1989-10-21
2003-10-30
0
200
400
600
800
1000
1200
1400
dB/dt [nT/min]
−100
0
100
200
300
400
500
600
B [nT]

So how does this help?

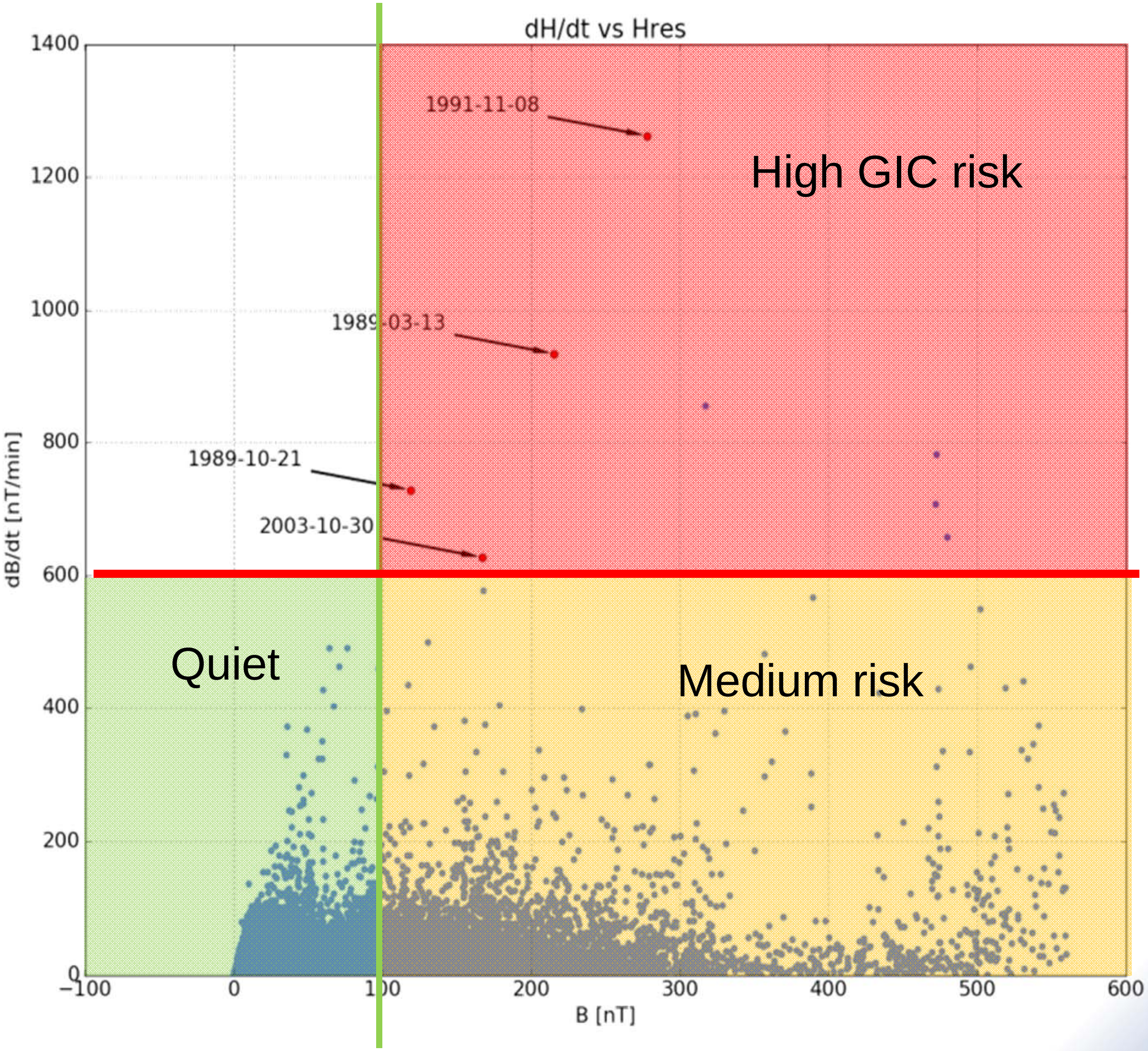
- We can try using some thresholds to see if that helps narrow down times of increased GIC, for example:
  - Kp > 8
  - AL > -1000
  - HSD > 100

Selected data



Future work

- Reprocess the GIC data we hold and repeat and expand the process with that
  - do the other indices add value to dB/dt?
  - Build regression relationships between GIC and other variables
  - Better proxy than ‘just’ dB/dt
  - Forecasts and validation?
- Do something similar with NZ data?
  - Comparative study, similar latitudes
- Investigate whether the dB/dt at Esk is best for UK GIC or whether some combination of data from UK observatories is better


dH/dt vs Hres
1991-11-08
High GIC risk
1989-03-13
1989-10-21
2003-10-30
Quiet
Medium risk
dB/dt [nT/min]
B [nT]
1400
1200
1000
800
600
400
200
0
−100
0
100
200
300
400
500
600

Very simple approach => large number of false alarms

All data Points

		Predicted	
Observed		No storm	Storm
	No storm	15772076	7433
	storm	0	8

Max per day

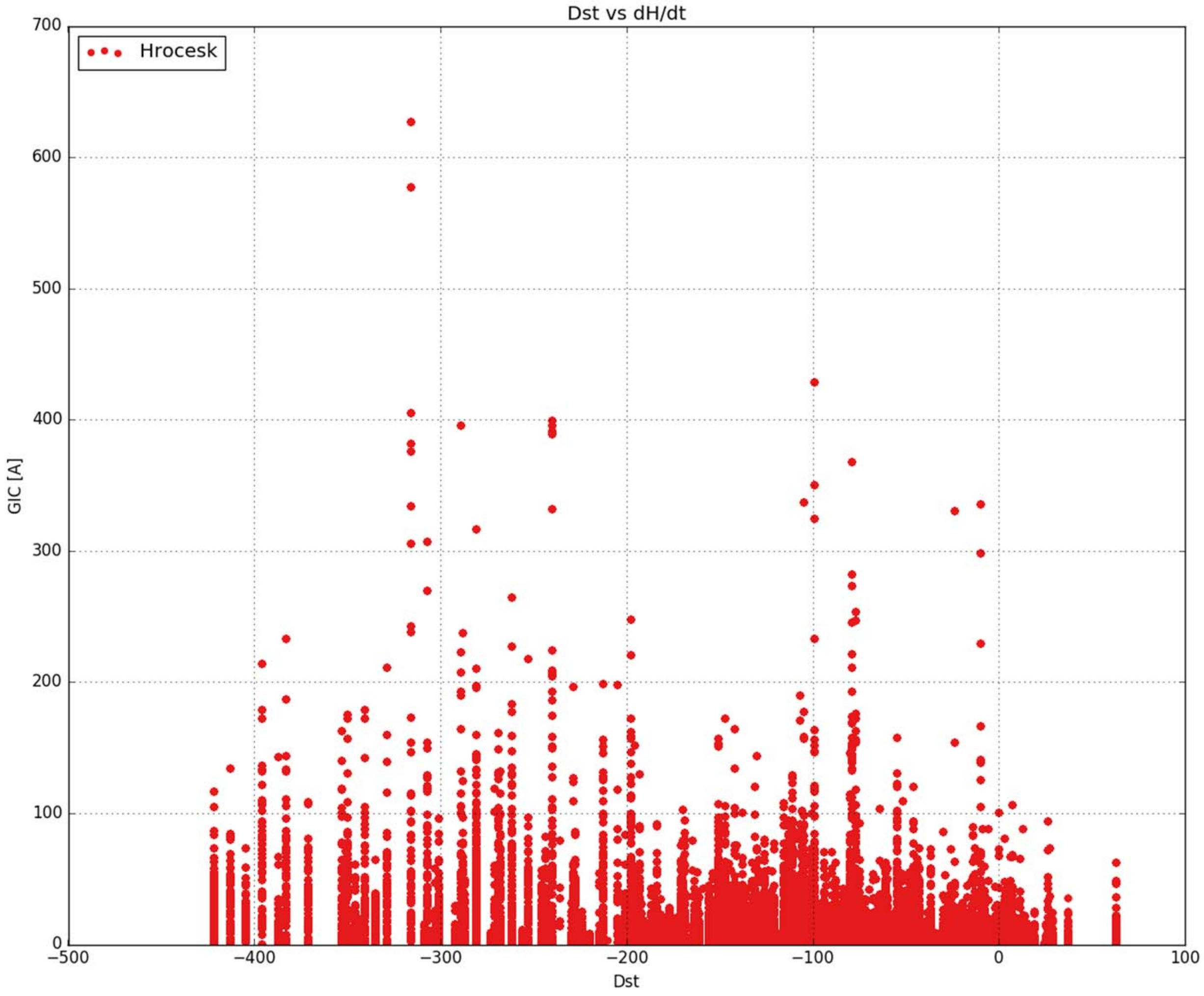
		Predicted	
Observed		No storm	Storm
	No storm	10888	66
	storm	0	4

Accuracy (fraction correct) = correct/total

= (15772076 + 8)/15779517 = 0.9995

False alarm ratio = false alarms/(hits + false alarms)

7433/(7433 + 8) = 0.9989


Dst vs dH/dt
Hrocesk
GIC [A]
Dst
700
600
500
400
300
200
100
0
−500
−400
−300
−200
−100
0
100