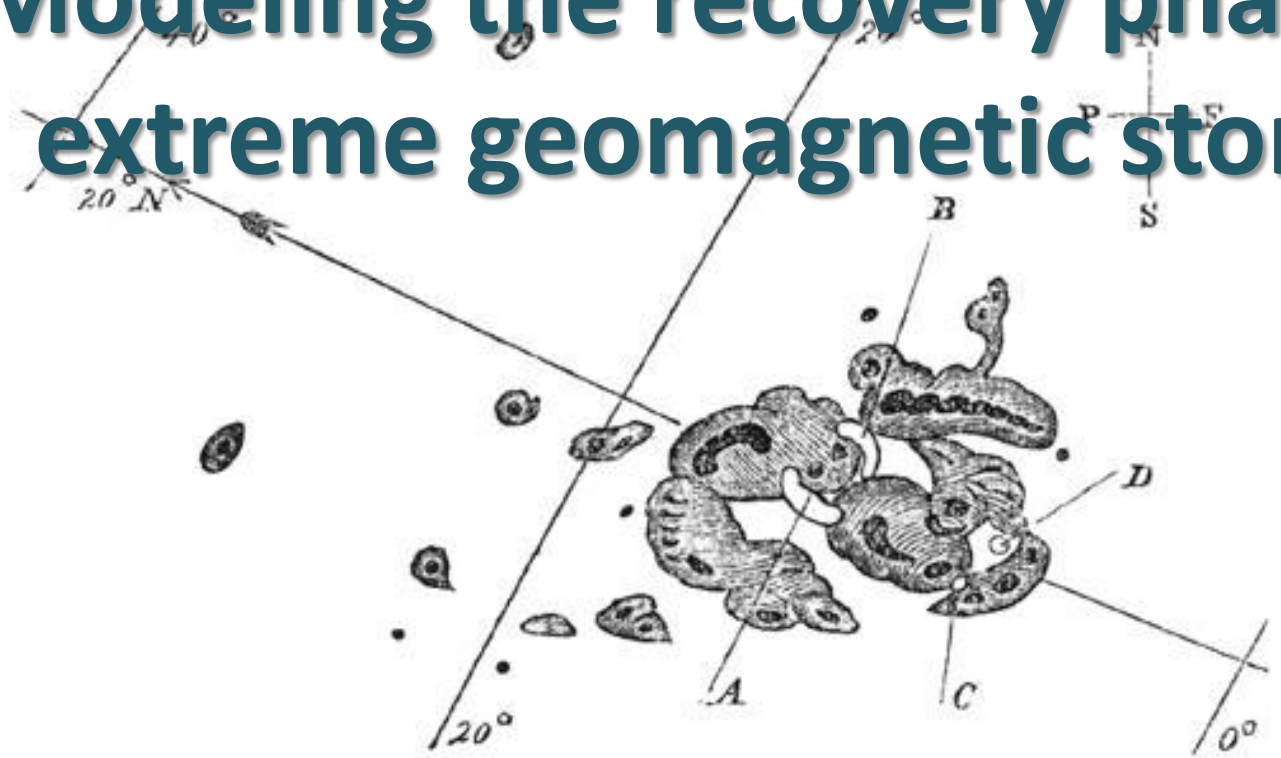
Modeling the recovery phase of extreme geomagnetic storms



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J. Aguado, A. Guerrero

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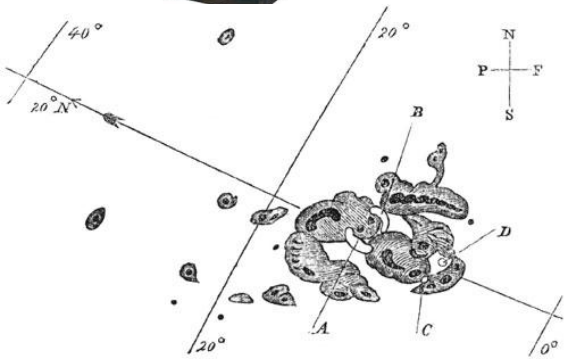
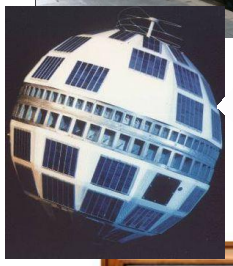
Universidad de Alcalá

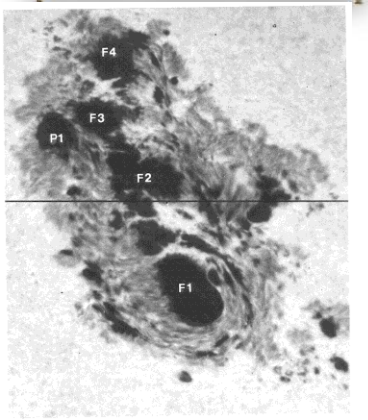
space weather srg

1859

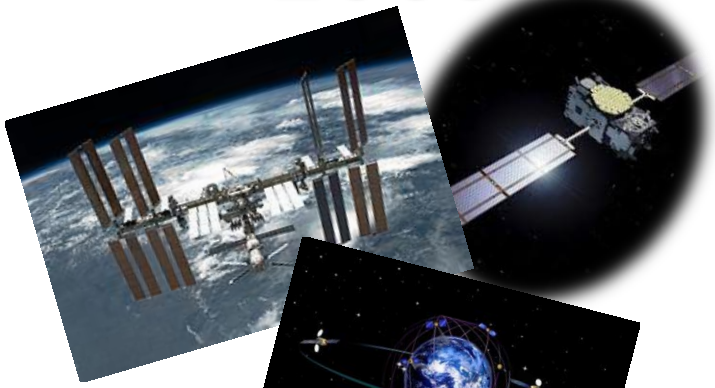


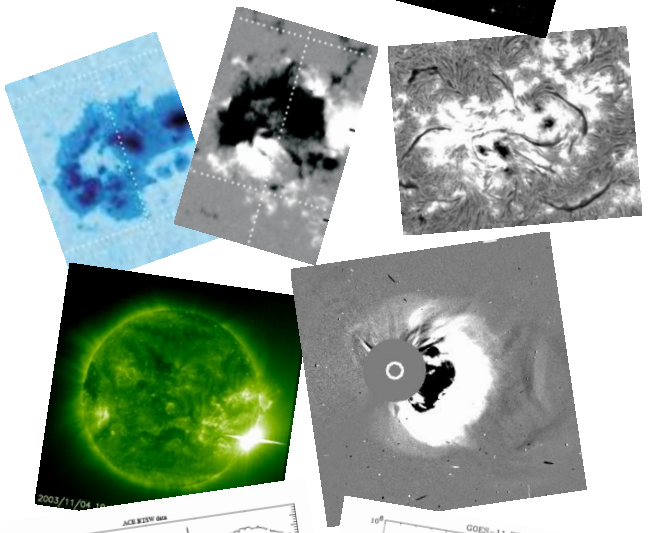
1989

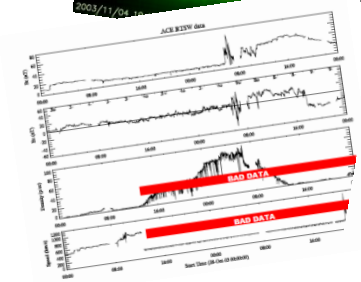


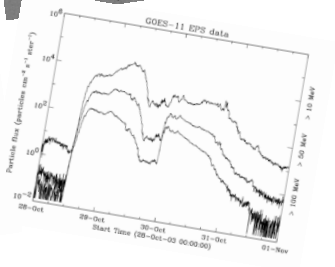


2003









The models have also evolved

Exponential decay
[Burton et al., 1975]

$$Dst(t) = Dst_0 e^{-t/\tau}$$

Constant

$$\frac{-(dDst/dt)}{Dst} = \frac{1}{\tau}$$

Linear

$$-(dDst/dt) \alpha\, Dst$$

Hyperbolic decay
[Aguado et al., 2010]

$$Dst(t) = \frac{Dst_0}{1 + \frac{t}{\tau_h}}$$

Time-dependent

$$\frac{-(dDst/dt)}{Dst} = \frac{1}{\tau_h + t}$$

Quadratic

$$-(dDst/dt) \alpha\, Dst^2$$

The models have also evolved -II

Exponential decay

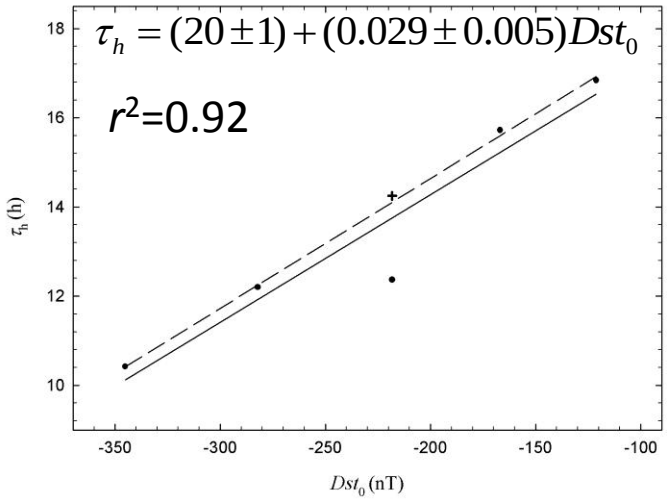
$$Dst(t) = Dst_0 e^{-t/\tau}$$

τ does not depend on Dst_0

Two parameters

Hyperbolic decay

$$Dst(t) = \frac{Dst_0}{1 + \frac{t}{\tau_h}}$$



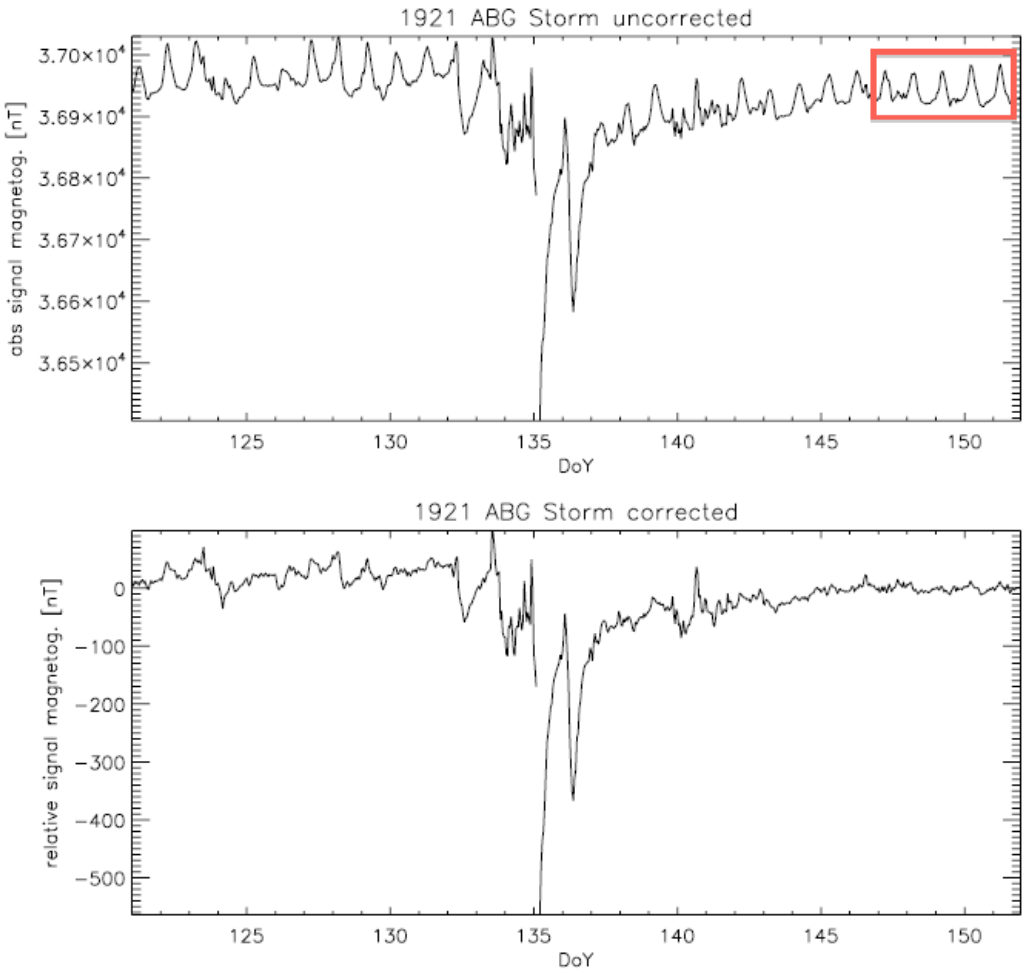
And new models need to be validated...

in the extreme cases!

Event #	Year	Month	Day	Observatory	H range (nT)	Geomagnetic latitude
1	1859	September	1-2	Bombay	1720	9.74
2	1921	May	13-16	Alibag	>700	9.46
3	1928	July	7	Alibag	780	9.45
4	1938	April	16	Alibag	530	9.37
5	1957	September	13	Alibag	580	9.29
6	1958	February	11	Alibag	660	9.29
7	1989	March	13	Kakioka	640	26.6

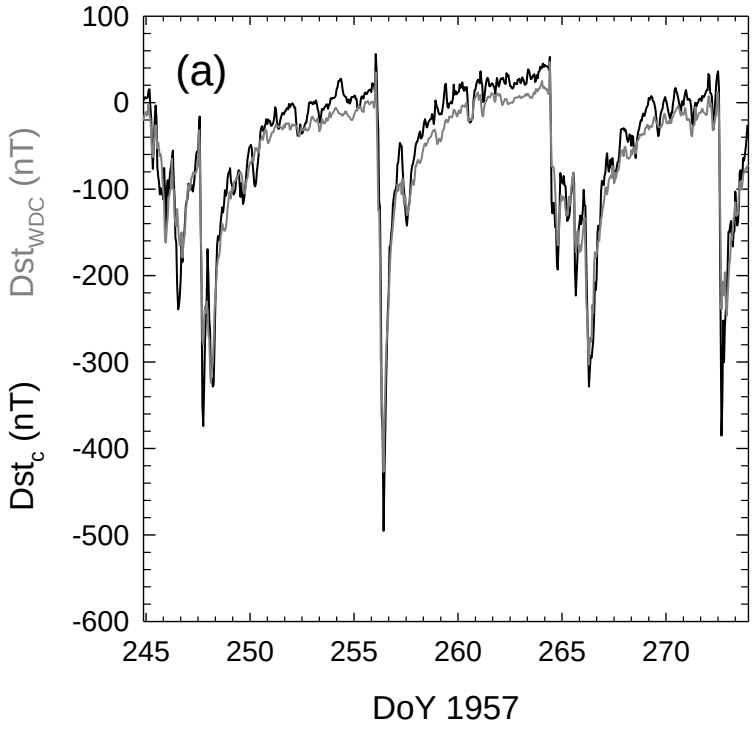
A selection of events from Tsurutani *et al.* [2003]

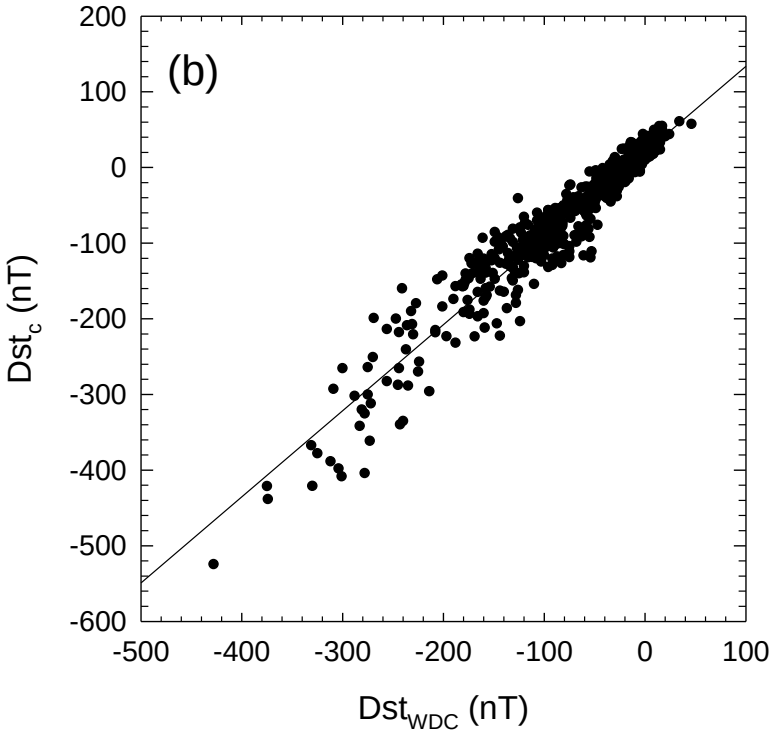
Analysing individual events



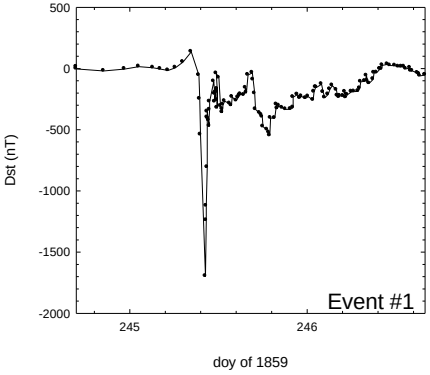
See poster by Palacios et al. in session S12

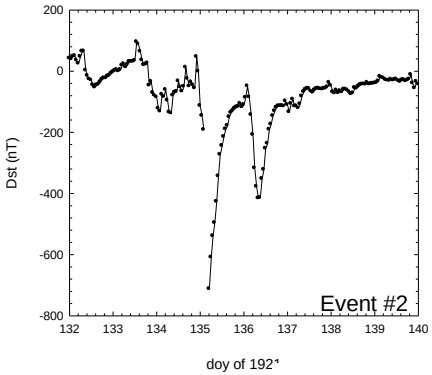
LDi works fine!

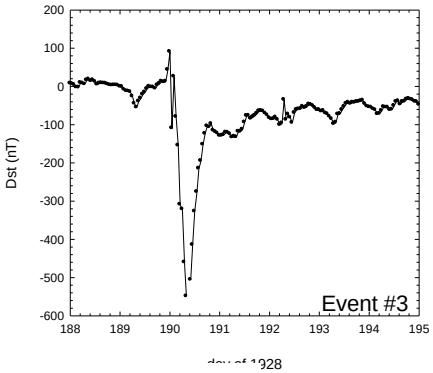


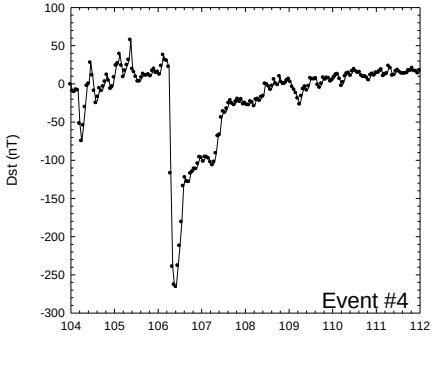


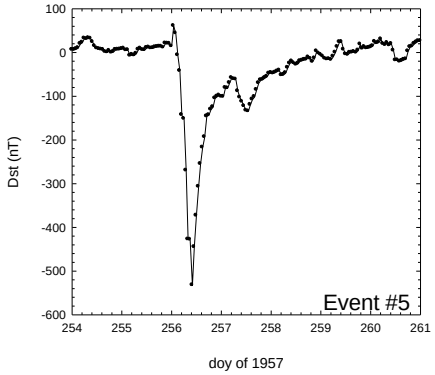
The events ready for checking

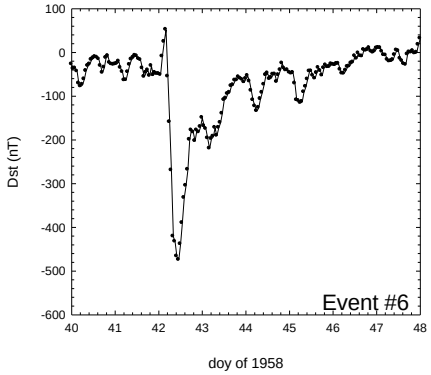


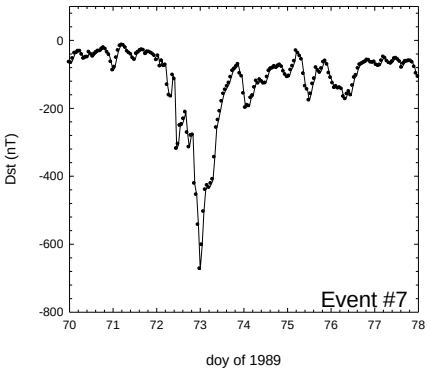




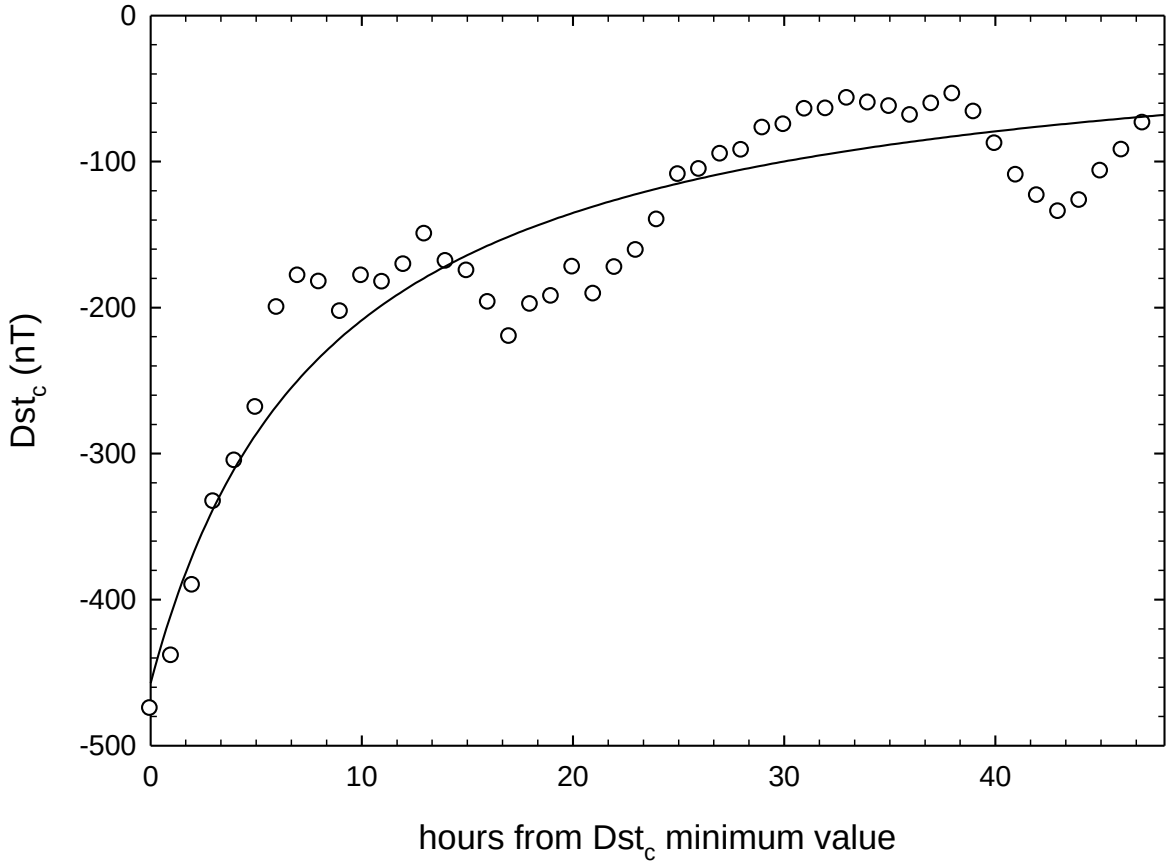




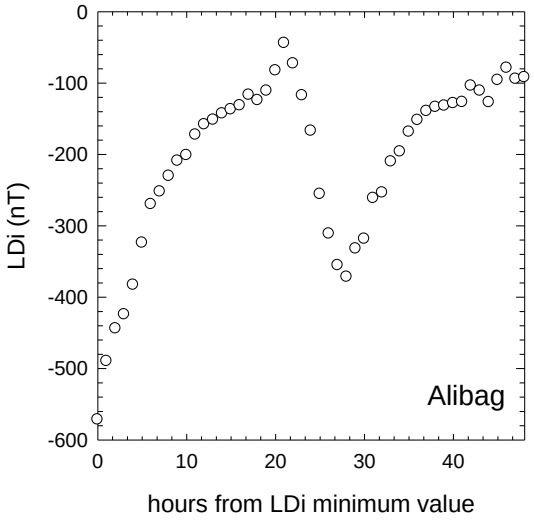


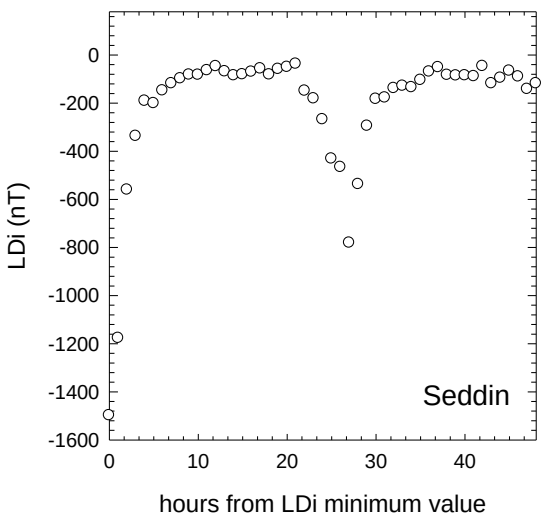


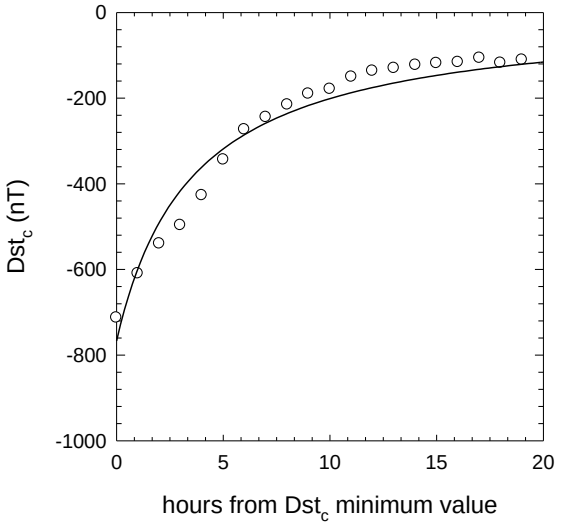
And the results



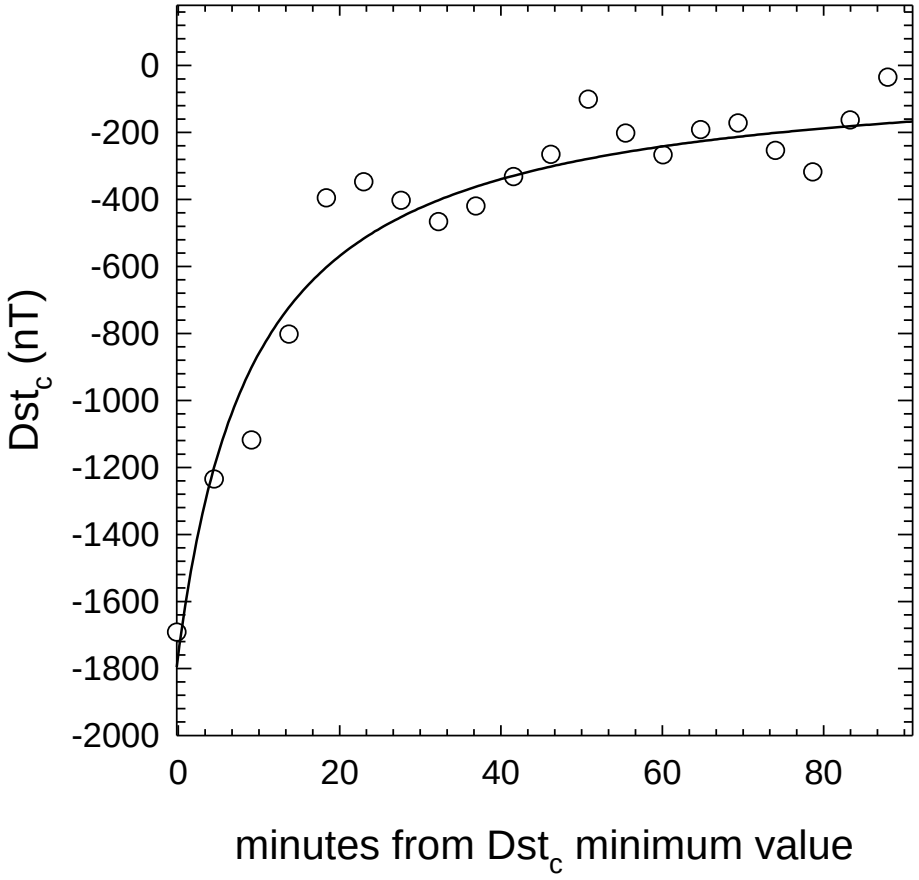
Problems: May 1921 event







More Problems: Carrington event



- Double step: short interval fitted
- High resolution of computed Dst (almost SYM-H)
- Averaging to hourly resolution:

Carrington Dst_{peak} = 685 nT

Comparable to the 1989 March storm! (peak = 640 nT)

The final fitting results

Event #	t_0 (yyyy mm dd hh:mm)	Dst_c min (nT)	Δt (h)	τ_h (h)	Dst_0 (nT)	r^2
1	1859 09 02 10:15[b]	-1697	48	0.10±0.02	-1600±135	0.68
			1.47	0.14±0.02	-1753±103	0.93
2	1921 05 15 05	-713[c]	48	7.27±1.70	-646±73	0.51
			20	3.55±0.34	-767±32	0.96
3	1928 07 08 10	-506	48	4.55±0.45	-585±32	0.88
4	1938 04 16 10	-263	48	6.46±0.65	-267±13	0.91
5	1957 09 13 10	-532	48	3.67±0.30	-541±22	0.93
6	1958 02 11 11	-475	48	8.40±0.90	-457±23	0.87
7	1989 03 14 00	-674	48	6.11±0.61	-688±34	0.88

Cid *et al.* [2013]

The final fitting results

Event #	t_0 (yyyy mm dd hh:mm)	Dst_c min (nT)	Δt (h)	τ_h (h)	Dst_0 (nT)	r^2
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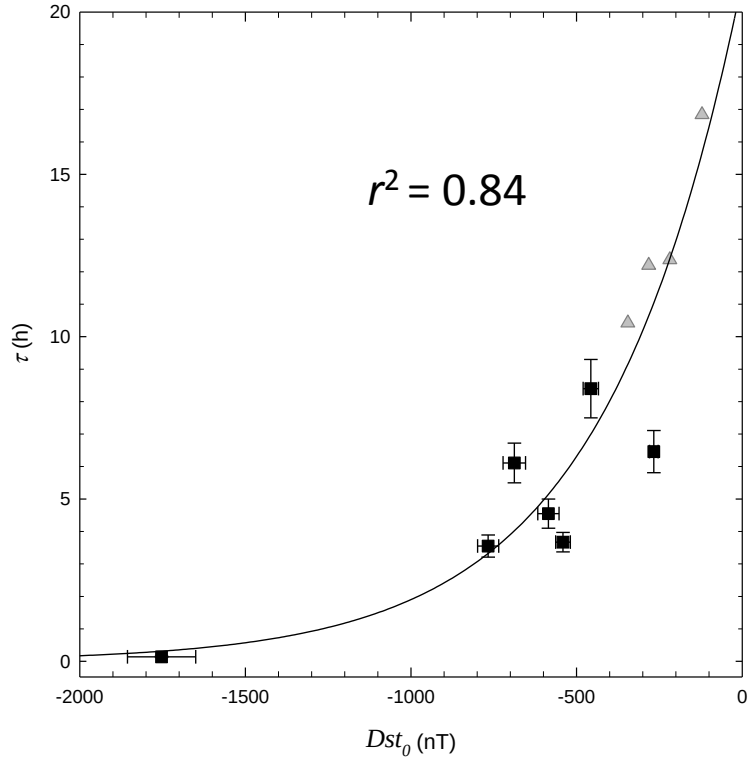
2	1921 05 15 05	-713 [c]	20	3.55±0.34	-767±32	0.96
3	1928 07 08 10	-506	48	4.55±0.45	-585±32	0.88
4	1938 04 16 10	-263	48	6.46±0.65	-267±13	0.91
5	1957 09 13 10	-532	48	3.67±0.30	-541±22	0.93
6	1958 02 11 11	-475	48	8.40±0.90	-457±23	0.87
7	1989 03 14 00	-674	48	6.11±0.61	-688±34	0.88

Cid *et al.* [2013]

Both parameters are still related… but not linearly!

$$\tau_h(\mathrm{h}) = (21 \pm 3)\exp\left[(2.4 \pm 0.5)\times 10^{-3}\, Dst_0(\mathrm{nT})\right]$$



Cid *et al.* [2013]

Conclusions

- The hyperbolic decay function is able to provide by a unique continuous function and with high accuracy the recovery phase of any storm
- Although the Carrington storm is still the most intense geomagnetic storm ever recorded, it is not as extreme as usually stated