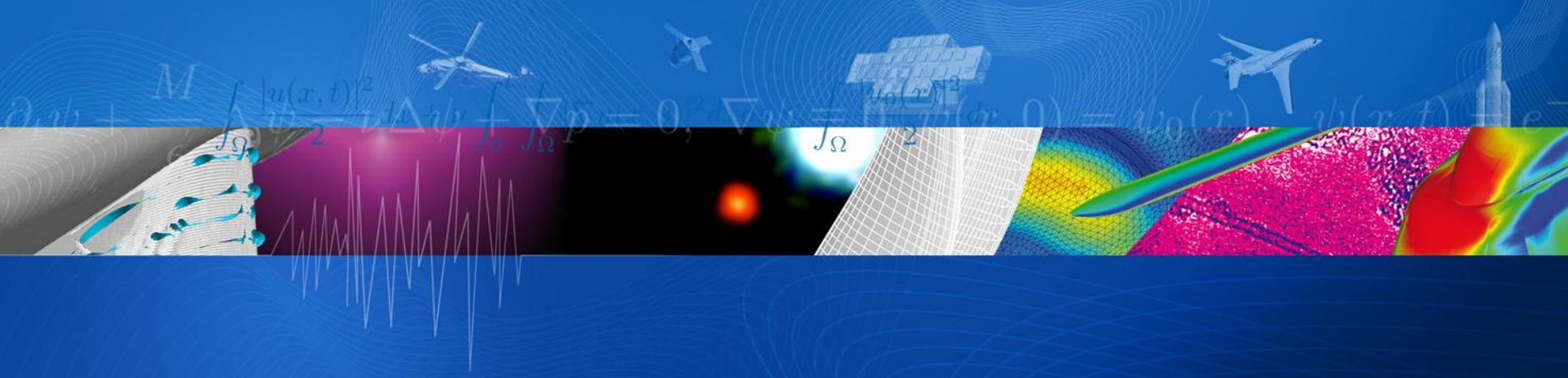

How representative are Van Allen Probes data from extreme events point of view?

V. Maget, G. Bernoux, D. Boscher, A. Sicard, S. Bourdarie, D. Lazaro, S. Rochel, D. Standarovski

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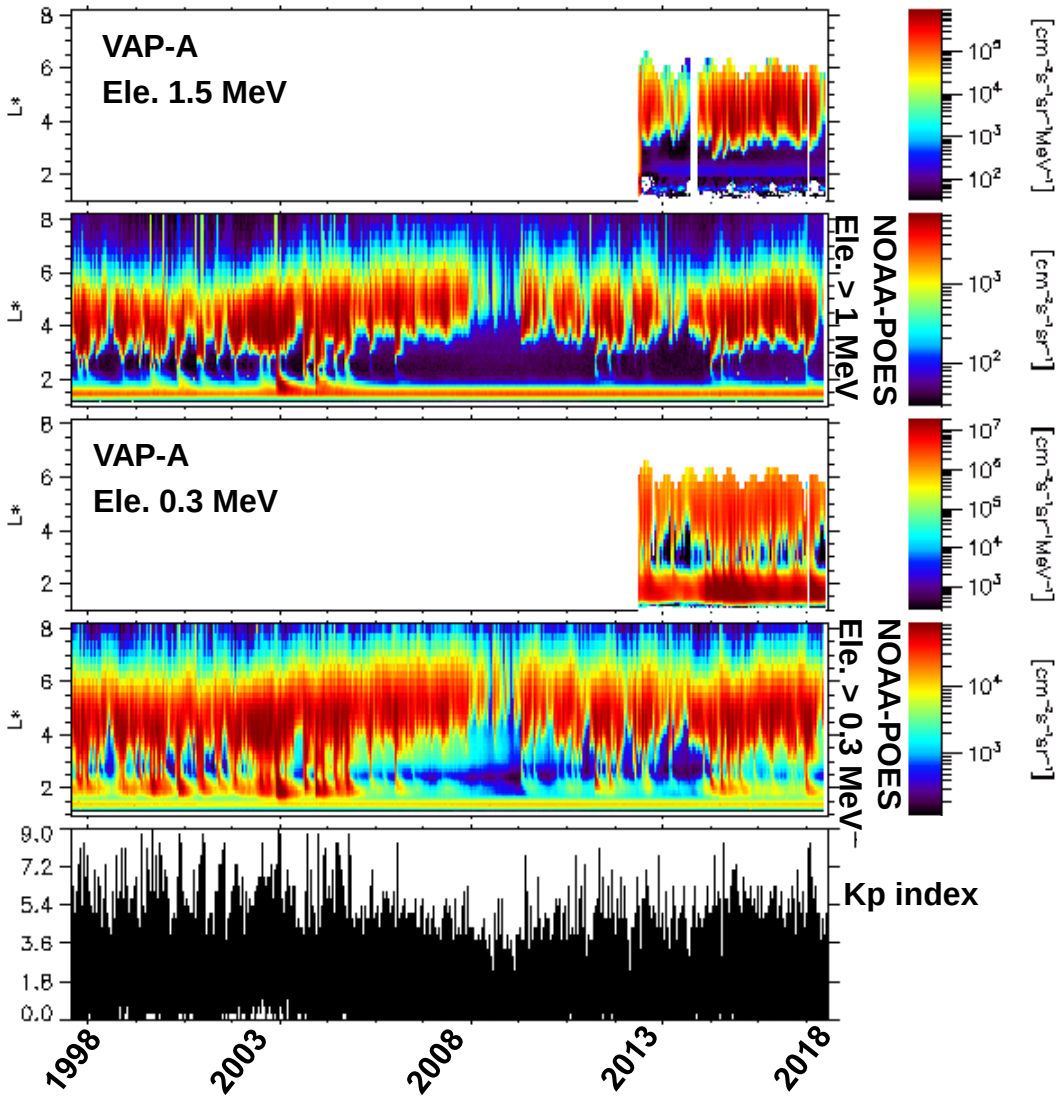
return on innovation

Context



- Extreme Values Analysis methods *(Meredith et al., 2015, 2017)*
- Solar cycle 24 is a weak one
- Can VAP period be used for extreme events analysis?

- **Purpose of this study:**
  - What is an extreme event ?
  - How to characterize it ?
  - How confident can we be in our estimations regarding a given s/c dataset and the method used ?

What is an extreme event ?

- **An extreme event is a <u>rare</u> and <u>intense</u> <u>event</u>**
  - **Rare** : statistics are not easy to do
    → ***Extreme Value Analysis methods***
    → ***Homogeneous and long term dataset***
  - **Intense** : for which orbit, for which kind of effect / risk ?
    → ***Relevant proxy***
  - **Event** : when does an event begin and end ?
    → ***Smooth proxy***

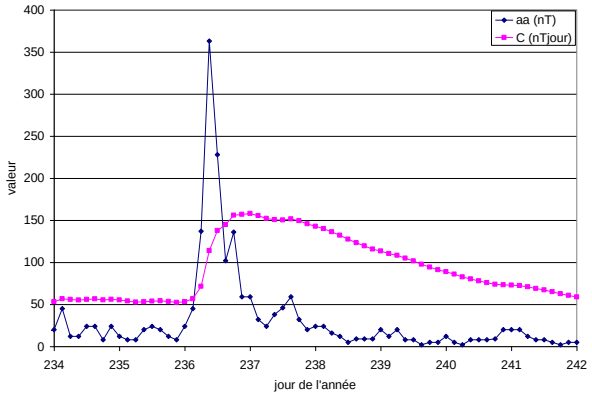
Ground-based geomagnetic indices give a general picture of the perturbations in the inner magnetosphere

Defining a new radiation belt index (Rochel *et al.*, 2016)

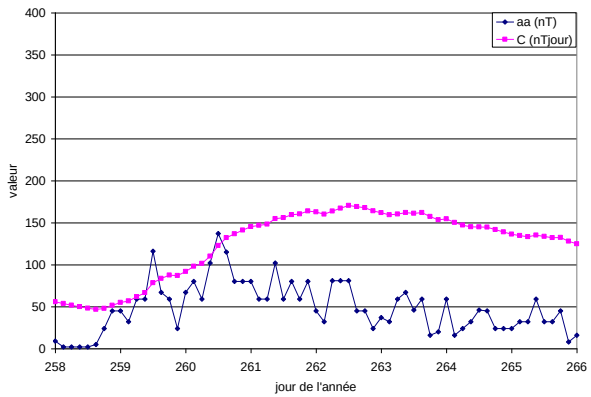
- Aa index is the oldest one (1868 to today) → ***global dynamics of the outer radiation belt***
- Definition of an integrated-like index based on the typical response time of the radiation belts (τ = 4 days):

$$Ca(t) = \frac{1}{\tau}\int_0^{\infty} aa(t-t')exp^{-t'/\tau}dt'$$

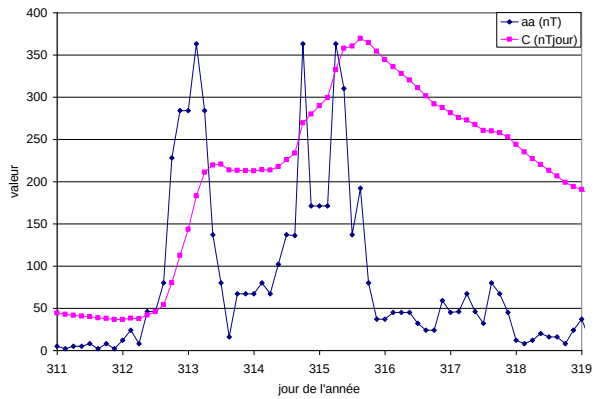
- **Ca is smooth, so it is easier to define events**
- **Ca can be used to quantify the intensity of geomagnetic storms (Ca_{max} for each event)**



August 2005 CME



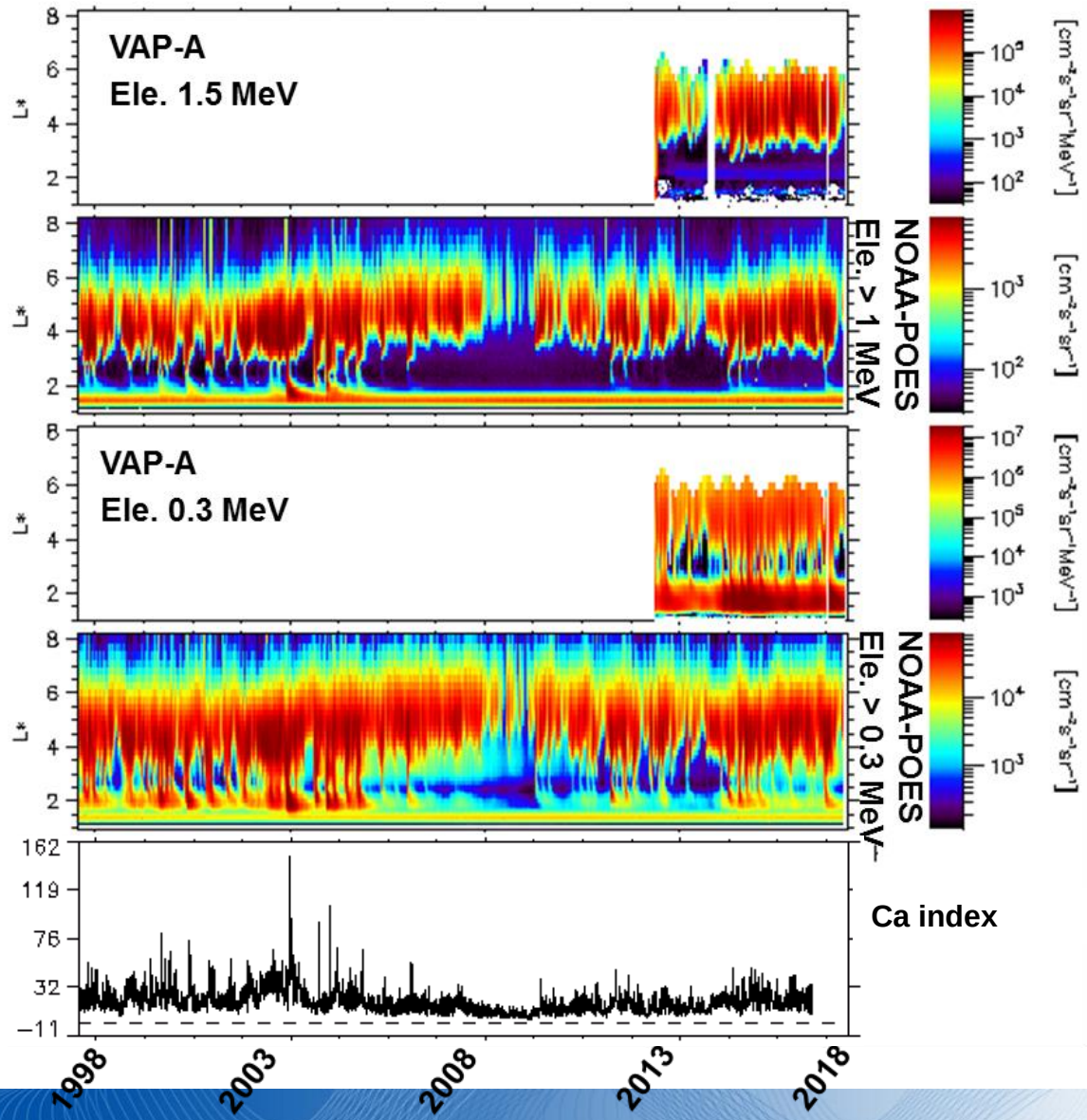
September 2003 CIR



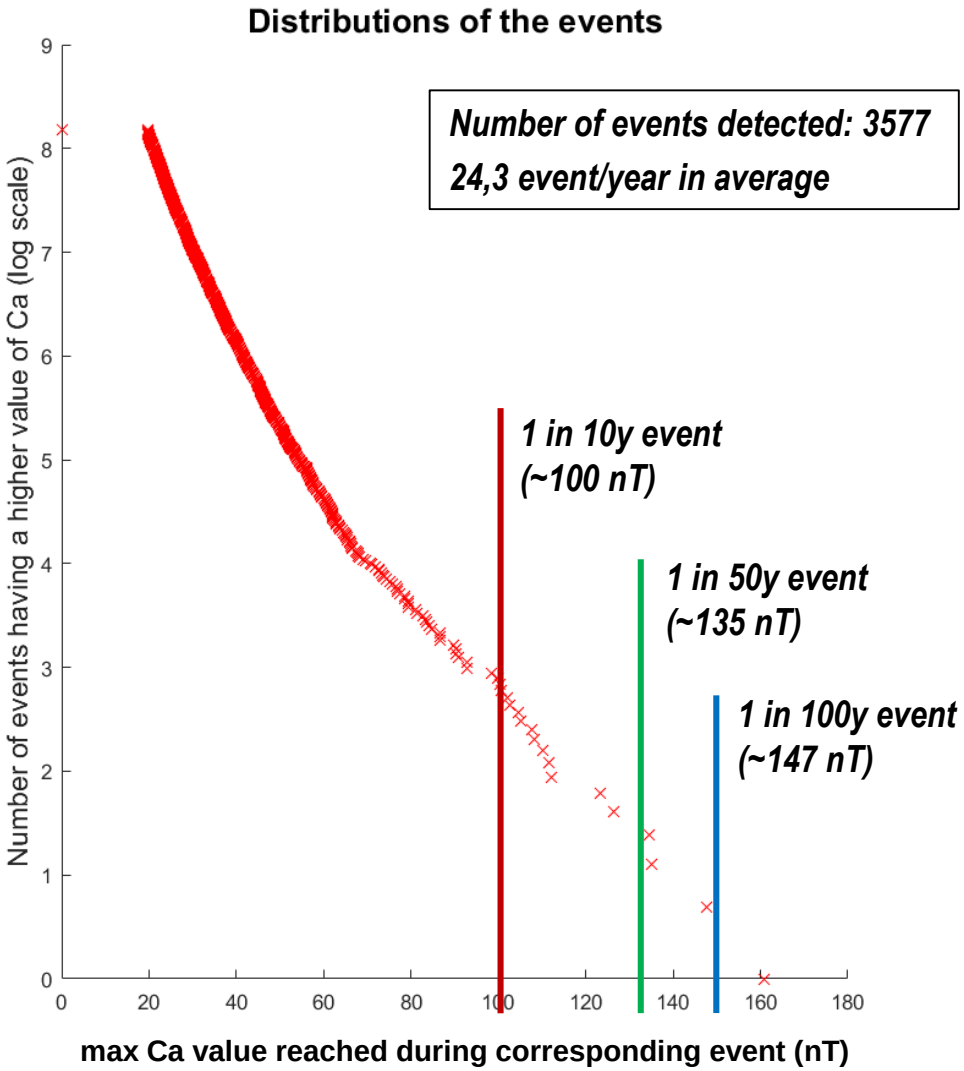
November 2004 multiple CMEs

Rochel, S., Boscher, D., Benacquista, R., & Roussel, J. F. (2016). A radiation belt disturbance study from the space weather point of view. Acta Astronautica, 128, 650–656.

How Ca correlates with strong radiation belts events ?



Reference statistics using 147 years of Ca data



Date	Ca (nT)
20/11/1882	160,9
31/10/2003	147,6
16/05/1921	135,0
14/03/1989	134,4
19/09/1941	126,4
28/03/1946	123,4
31/03/1940	112,1
16/11/1960	111,6
18/10/1872	110,3
26/01/1938	108,3
02/04/1960	107,8
18/07/1959	105,2
28/07/2004	104,4
23/09/1946	102,6
07/10/1960	100,6

Extreme Value Analysis methods

Purpose:

- Fit extreme values with a dedicated distribution

  → ***Generalized Pareto Distribution***

- Scale the distribution parameters to the dataset

  → ***The shape parameter ξ tells if extreme values amplitude is limited or not***

- Estimate the return levels **AND** the confidence levels of our estimations

2 methods have been tested:

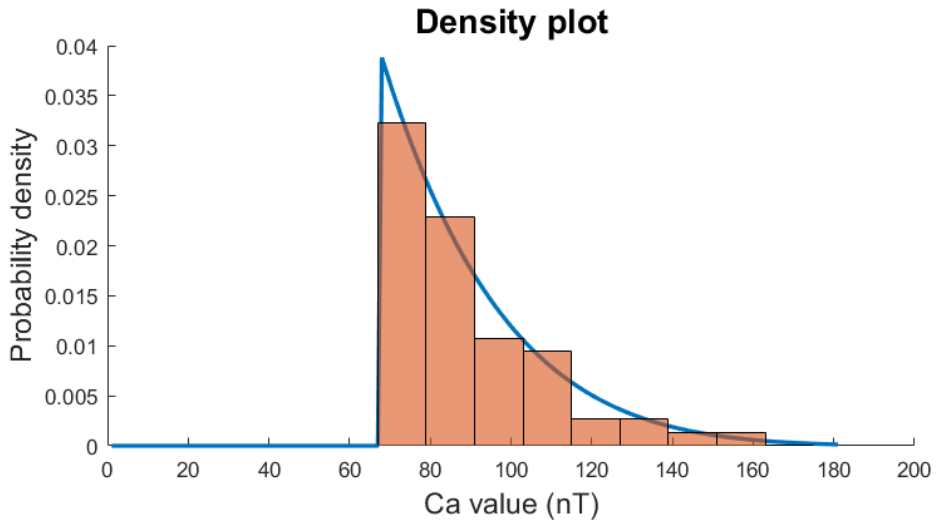
- ***« Block Maxima » (BM)***

- ***« Peak Over Threshold » (POT)*** (used in [Meredith *et al*. 2015,2017])
  - Set a threshold to keep only the tail of the distribution (extreme values)
  - Fit a Generalized Pareto distribution on this subset:

$$\left(H(y) = 1 - \left[1 + \xi\left(\frac{y}{\sigma}\right)\right]^{-\frac{1}{\xi}}\right)$$

  - **If needed, decluster the data to avoid correlations**

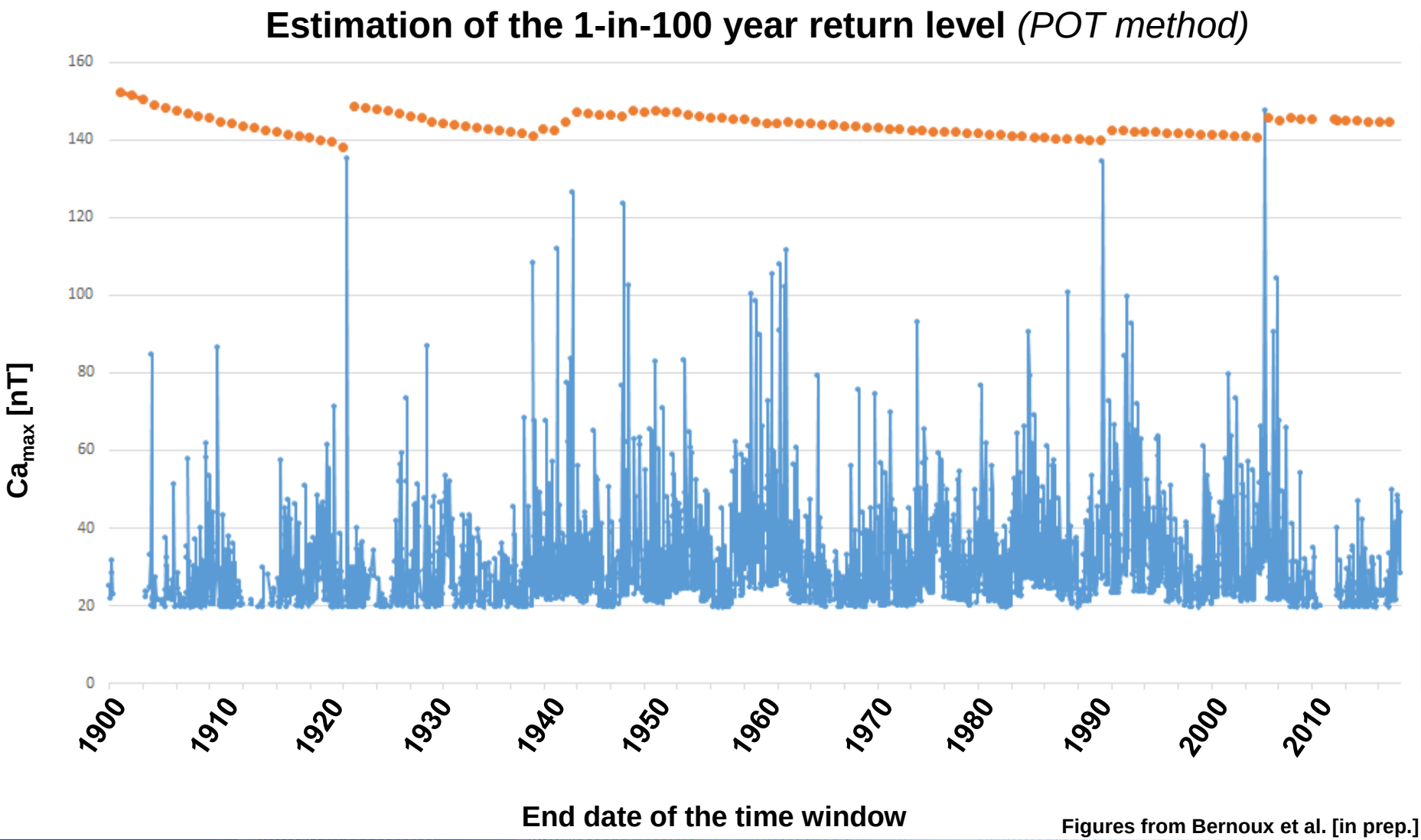
POT method results using the 147 years of Ca data



Comparison with BM method and reference statistics:

Return period	Return Level POT	Return Level BM (+reference)
10 years	100,78 nT	93,02 nT (100,53 nT)
50 years	131,71 nT	132,30 nT (134,43 nT)
100 years	143,15 nT	150,17 nT (147,6 nT)

Influence of the time window width



Figures from Bernoux et al. [in prep.]

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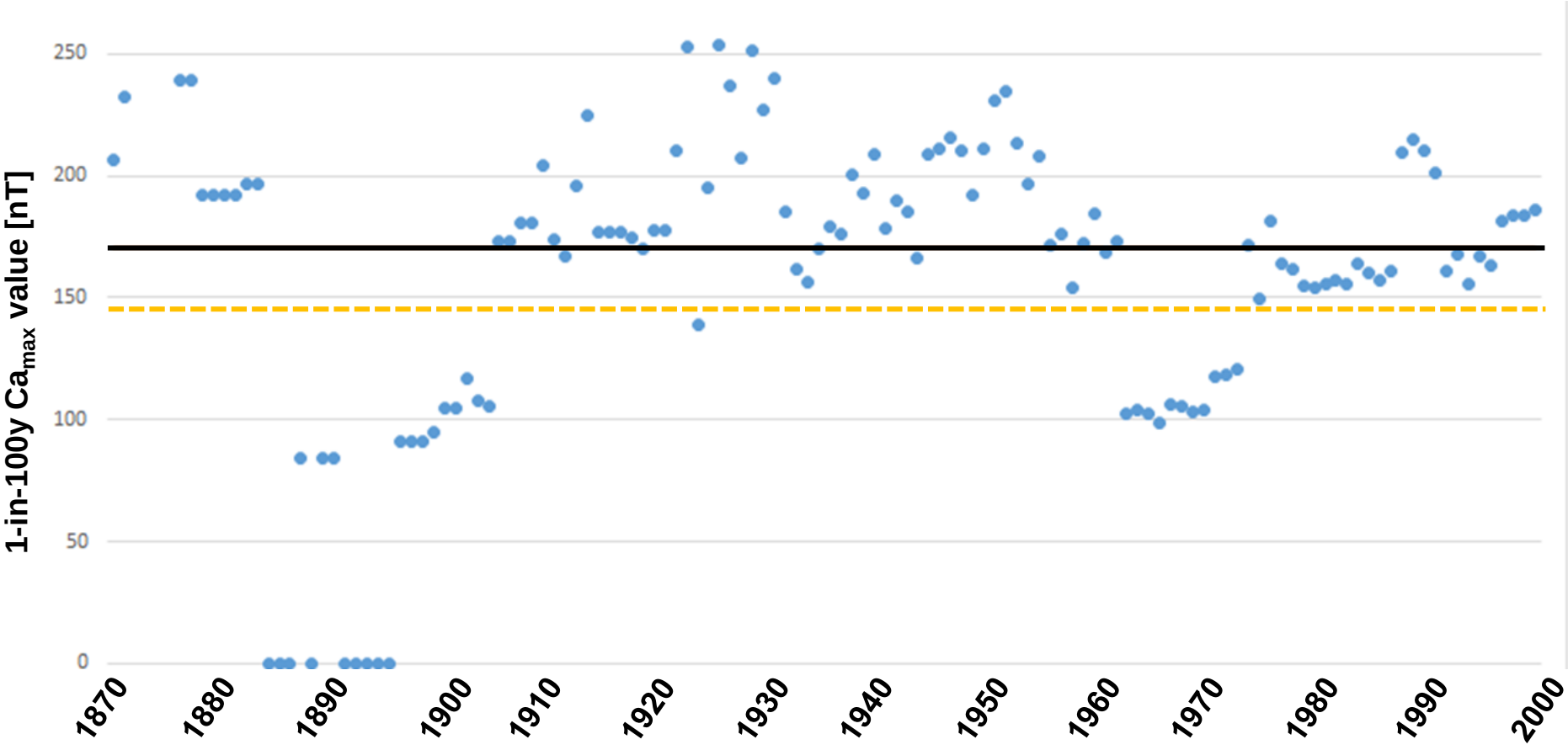
Influence of a sliding time window of 18 years width

Estimation of the 1-in-100 years return level on a 18 years window *(POT method)*



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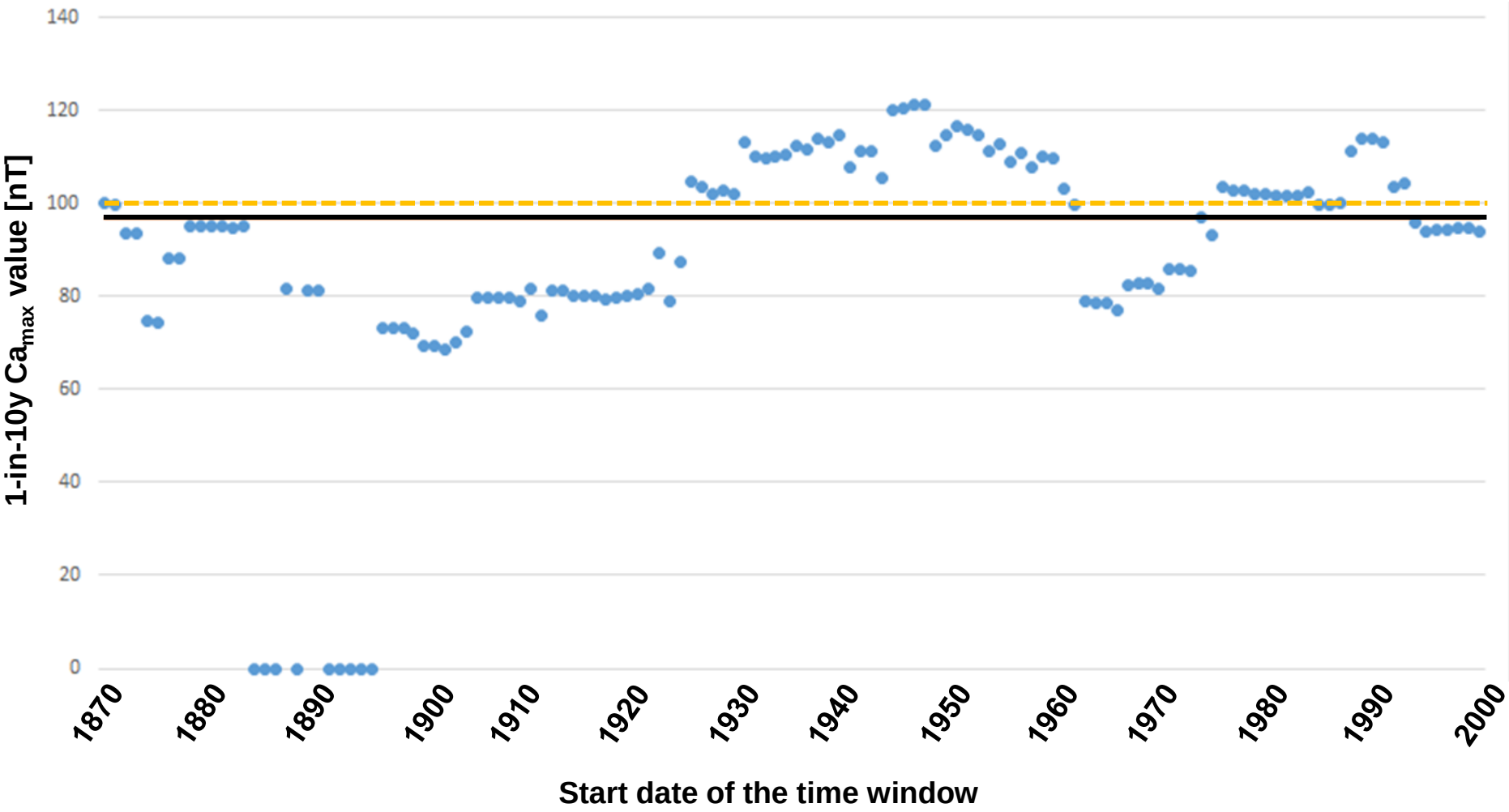
Influence of a sliding time window of 18 years width

Estimation of the 1-in-10 years return level on a 18 years window *(POT method)*



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Conclusions

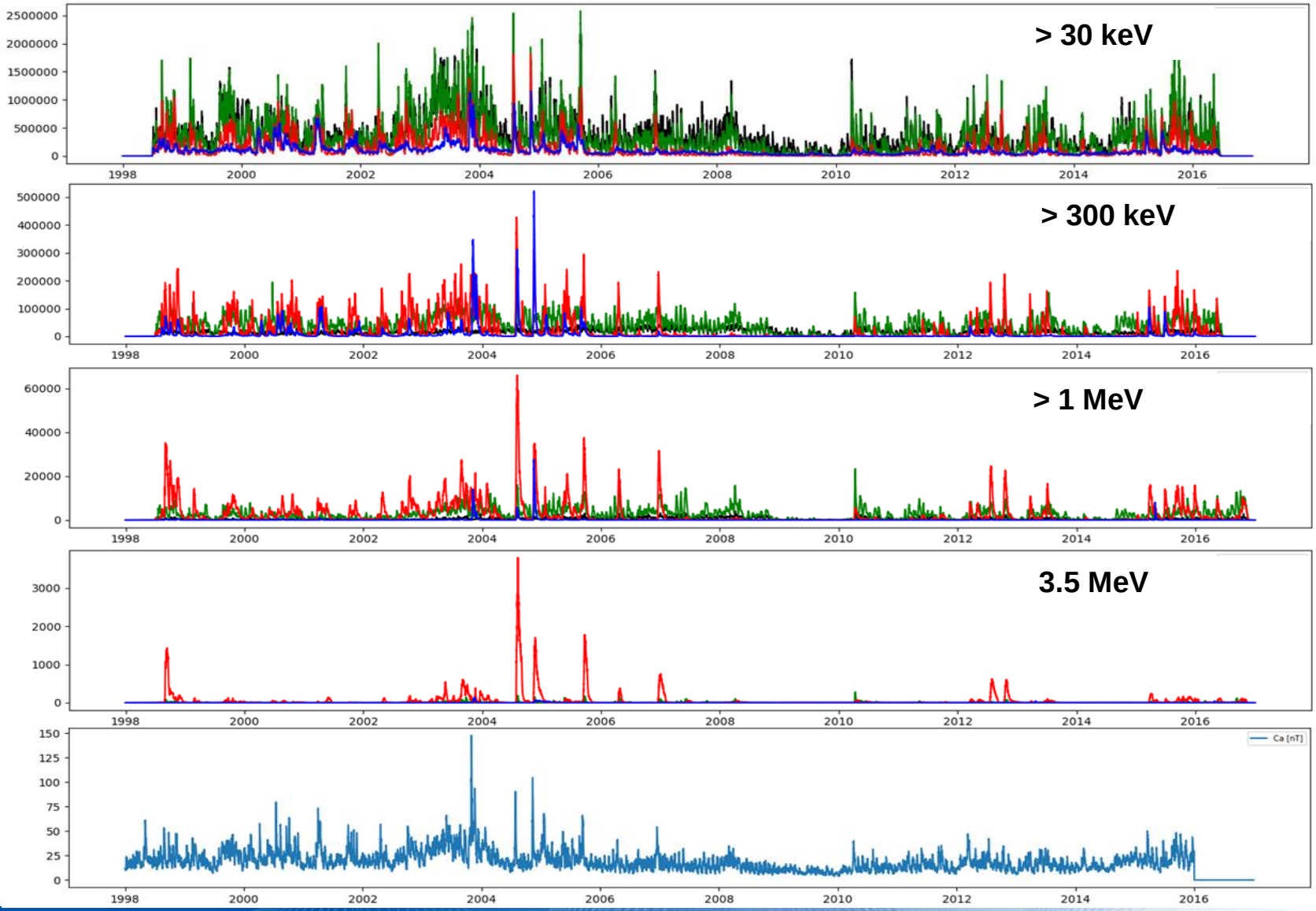
- We see a different classification of extreme events when using Ca index compared to flux-based analysis

- EVA methods works well on long-term datasets
  → $\xi < 0$ indicating a saturation in the geomagnetic activity

- **BUT** on a short-term dataset (s/c missions) results are very variable
  → extrapolation mode
  → $\xi > 0$ on different 18-years windows thus expecting no saturation

- Influence of the dataset used and the temporal window
  → Current solar cycle is not a good candidate for extreme events analysis
  → Reliable time windows can be chosen (for example **1989 to 2007**)

Ca and Cflux dynamics



L* = 6

L* = 4.75

L* = 3.5

L* = 2.25

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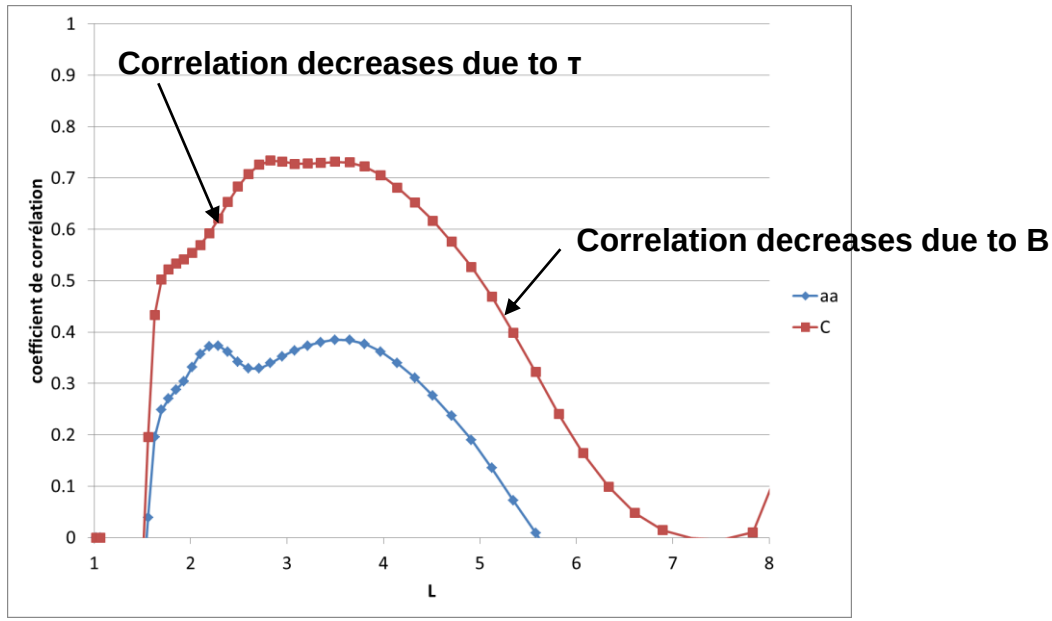
Ca correlation with radiation belt dynamics

Correlation of aa and Ca with log(flux)

NOAA-POES 15 data

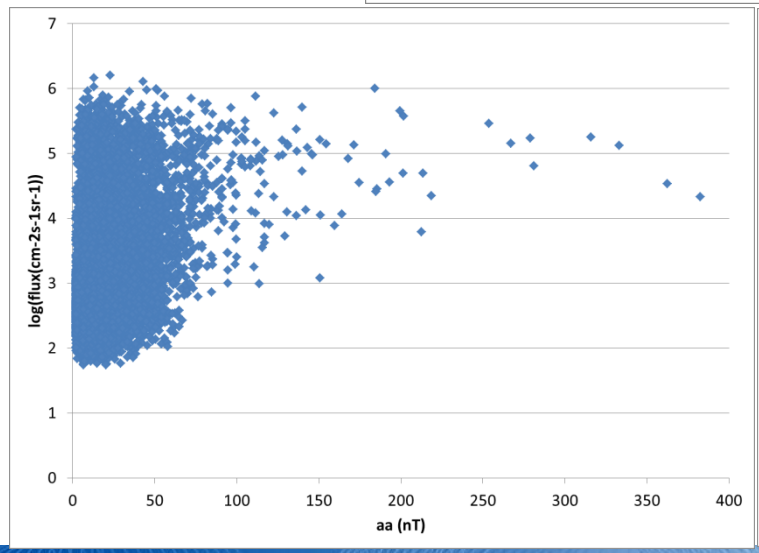
1998→2013

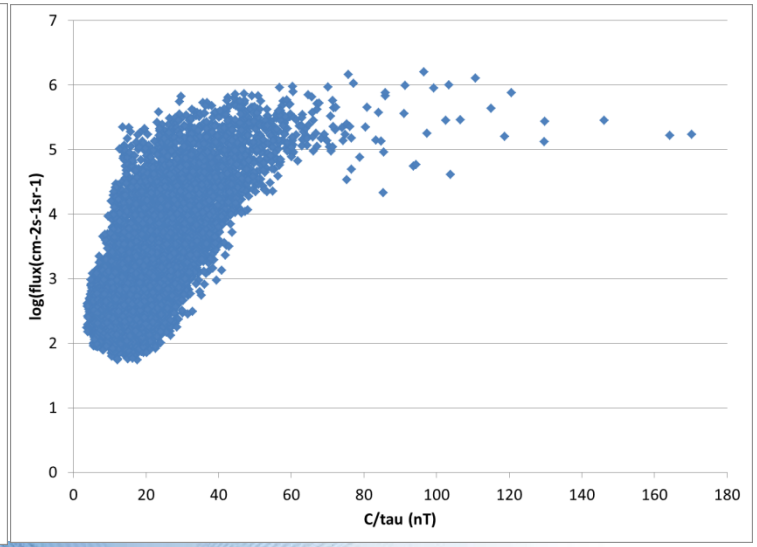
E>300keV



L=2.95

(in the « slot » region)





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