

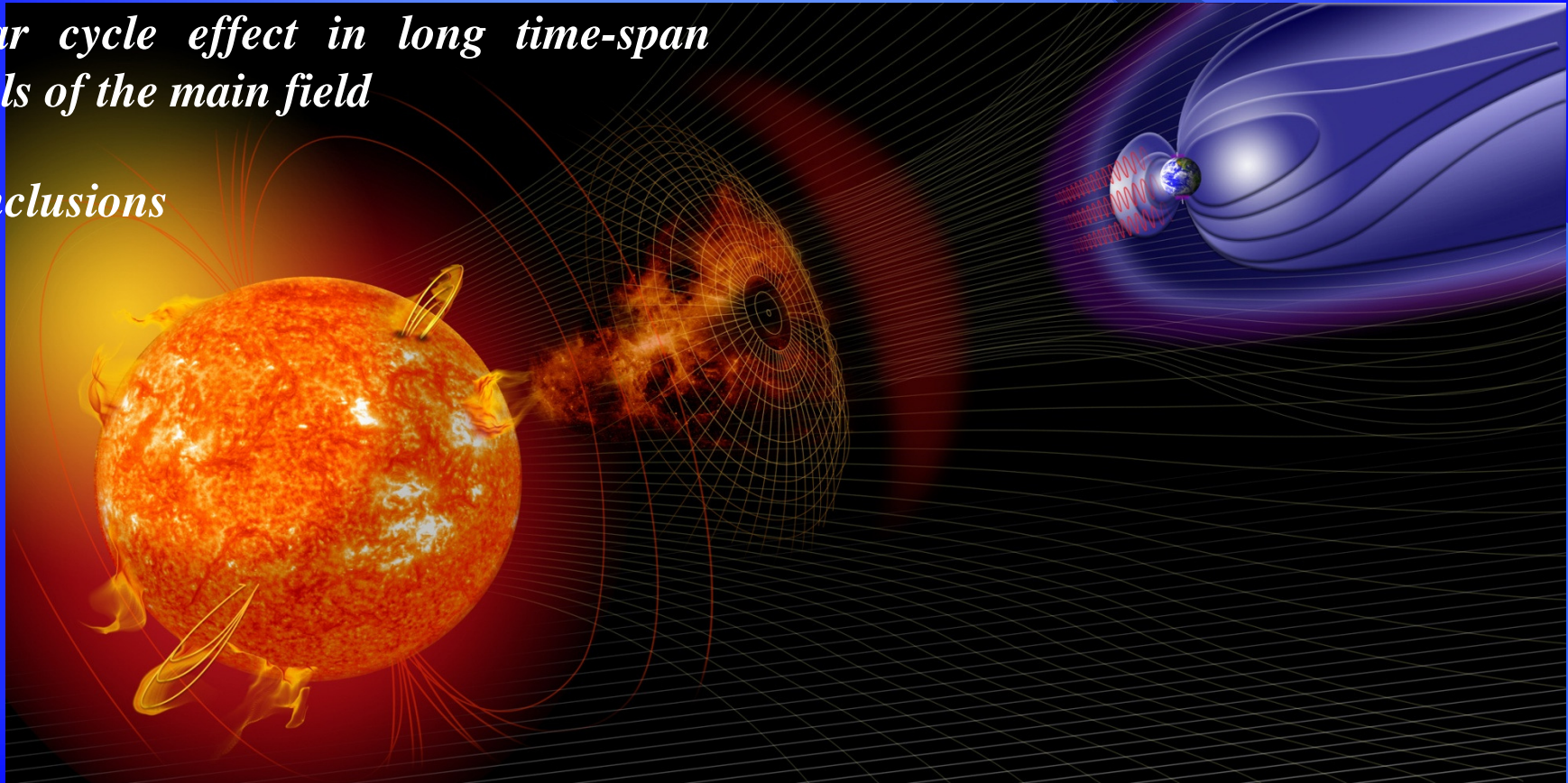
Magnetosphere response to solar activity during the Maunder Minimum

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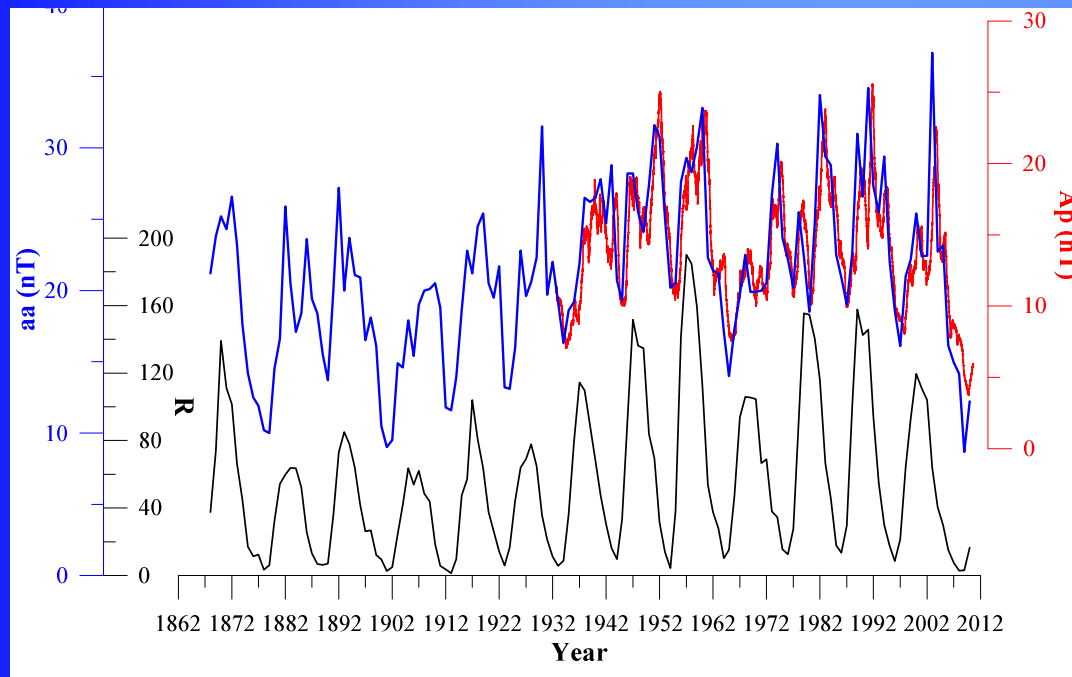
Outline

- *Motivation*
- *Solar cycle effect in observatory data*
- *Solar cycle effect in long time-span models of the main field*
- *Conclusions*



Motivation

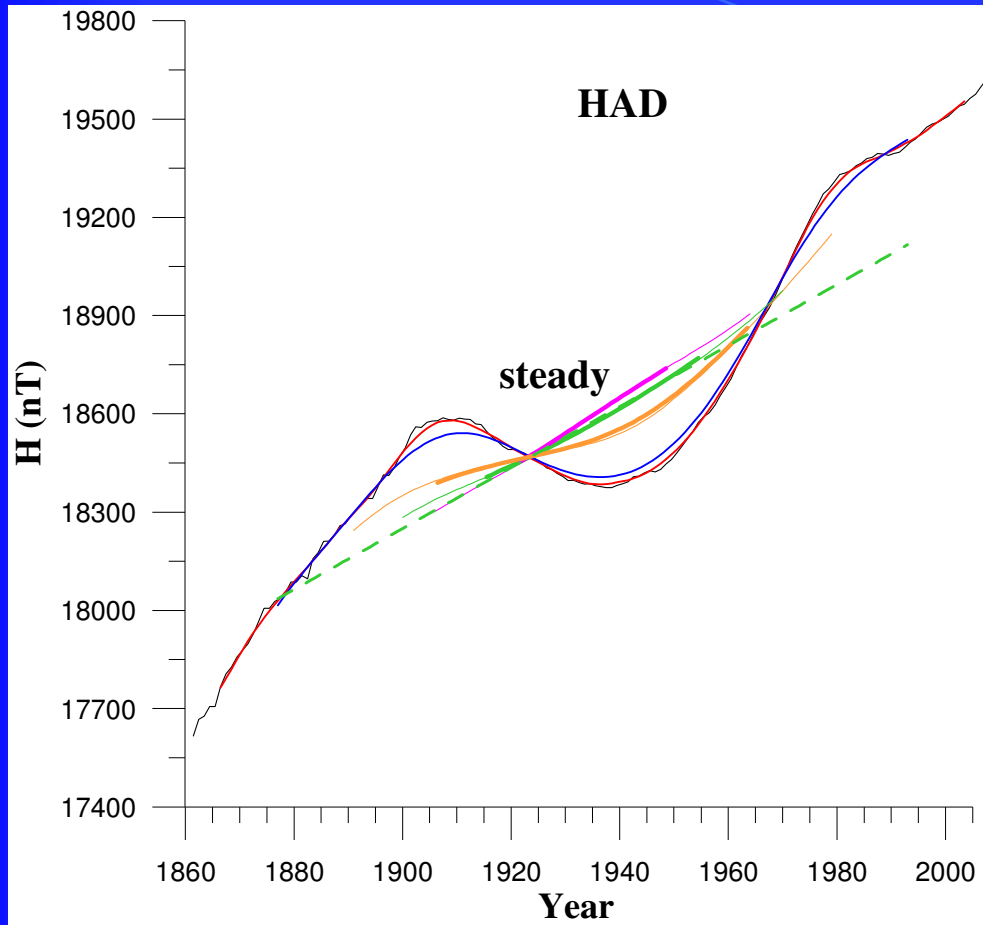
- the study of geomagnetic phenomena known as geomagnetic activity has long contributed to progress in solar-terrestrial science.
- the long geomagnetic time series recorded at geomagnetic observatories have provided means to characterize the Sun-Earth interaction at times prior to space era, via geomagnetic indices.



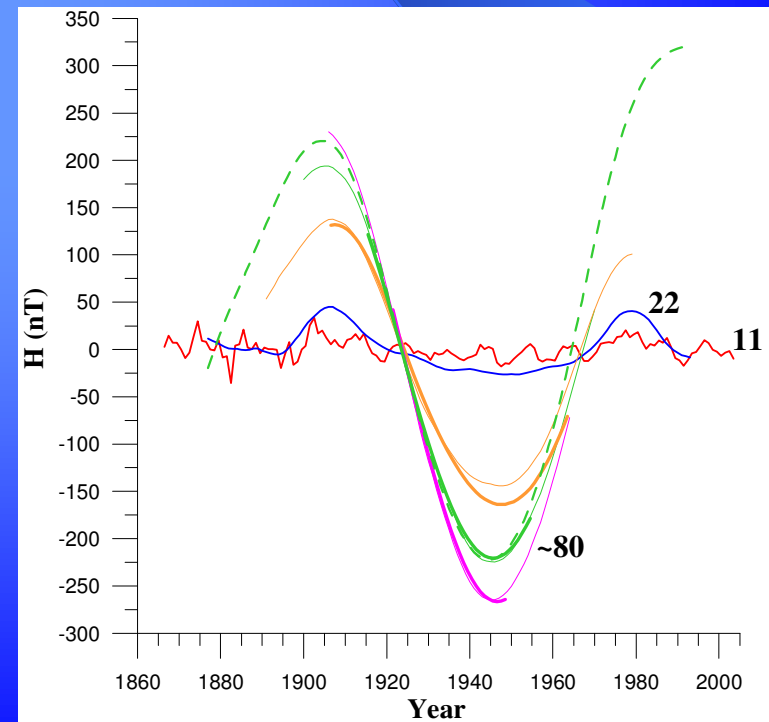
- no information
prior to 1868

- looking for information at
the main field model *gufm1*
(1590-1990)

Ingredients of the geomagnetic field

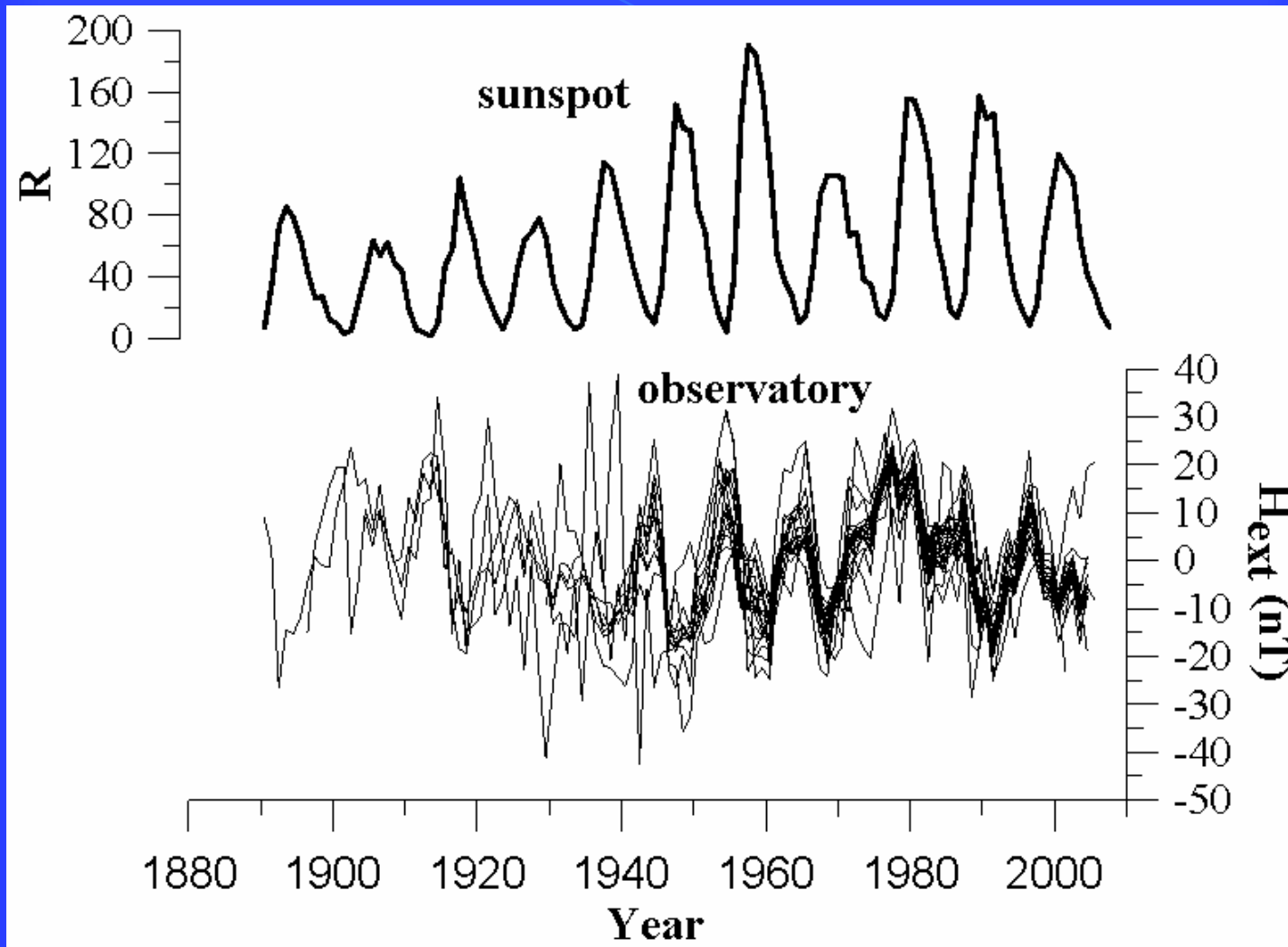


Trends in time series of annual means

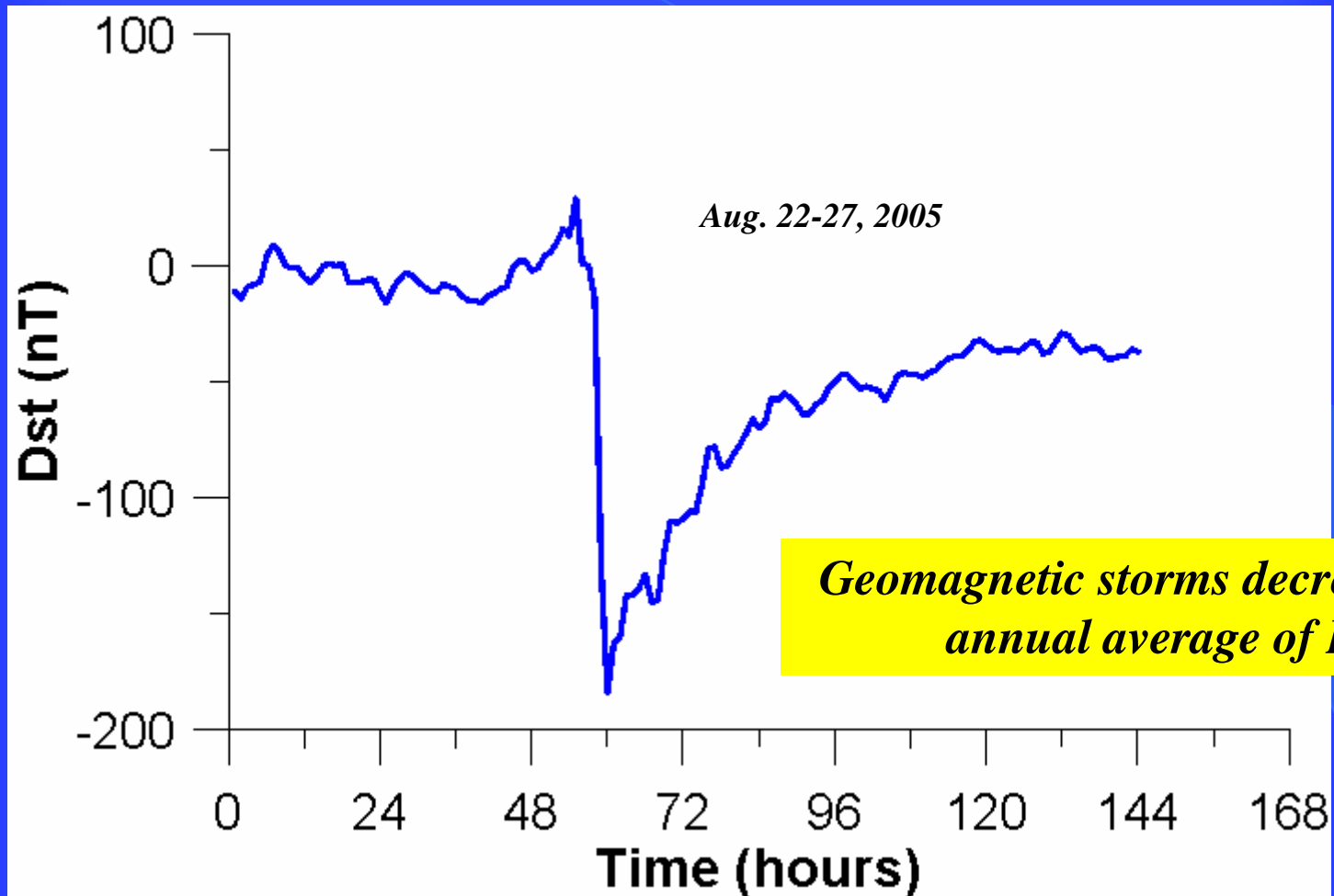


(Quasi)cyclic ingredients

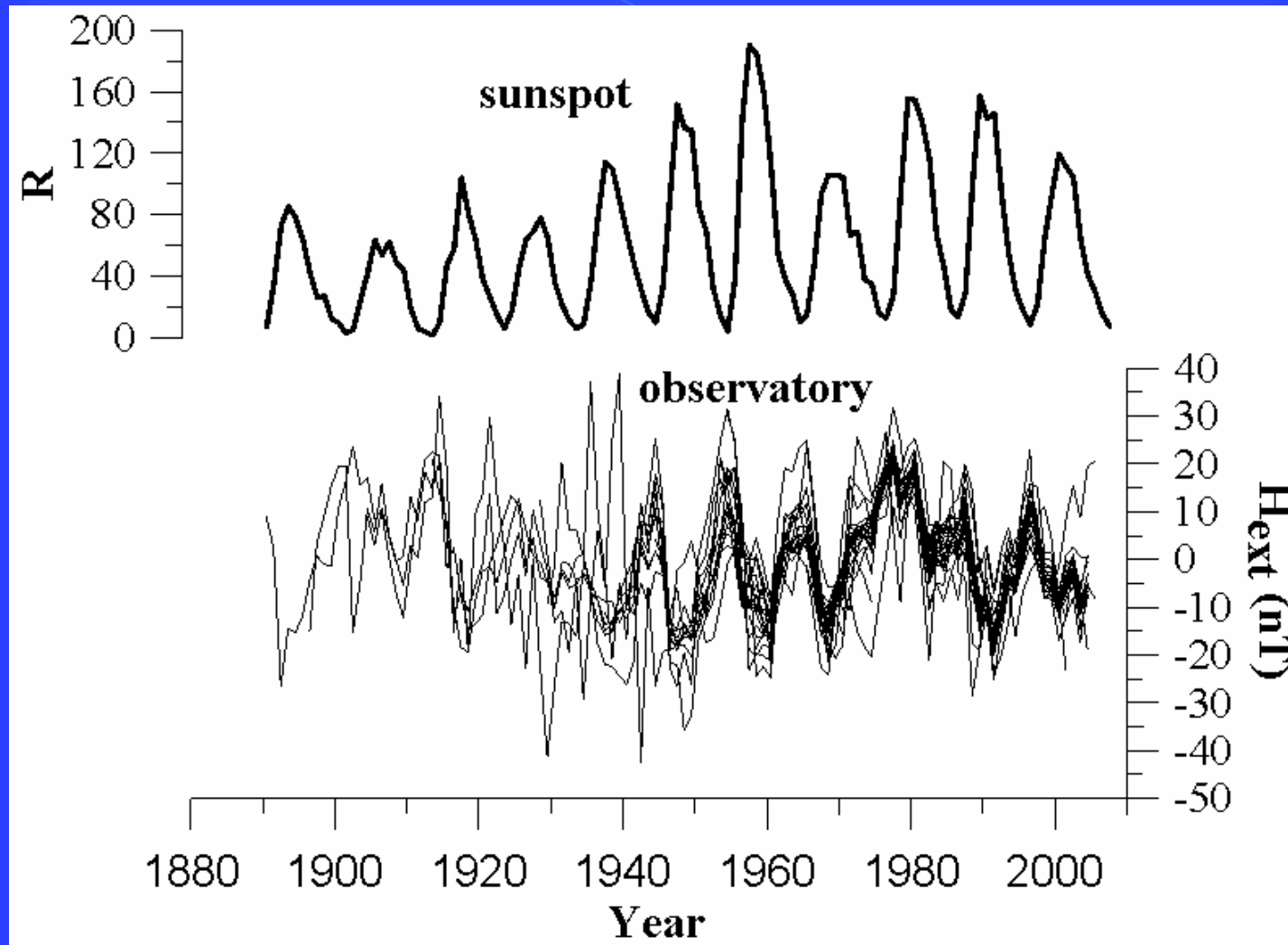
*External signal in annual means
(11-year cycle related)*



Geomagnetic storms

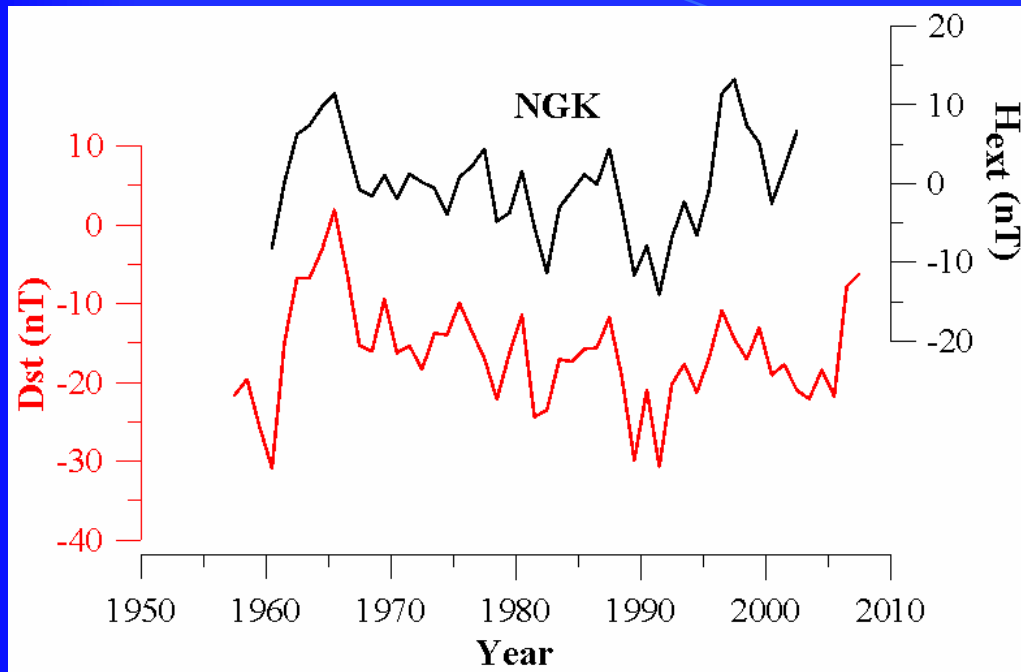


External signal

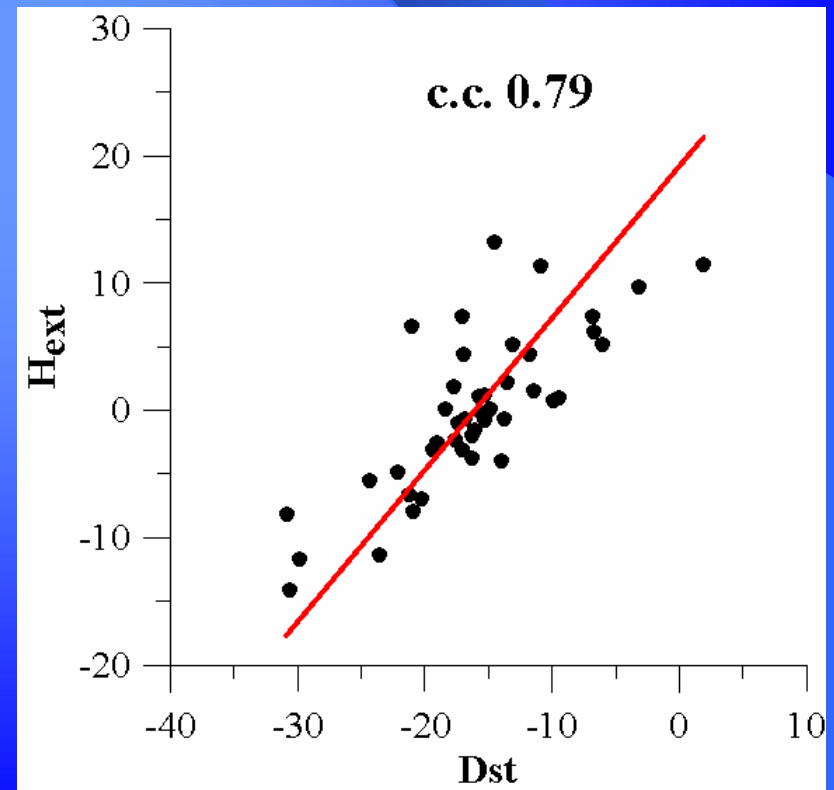


The external signal is anticorrelated with the solar activity

External contribution



*The external contribution
is related to storm-time activity*



Main field models

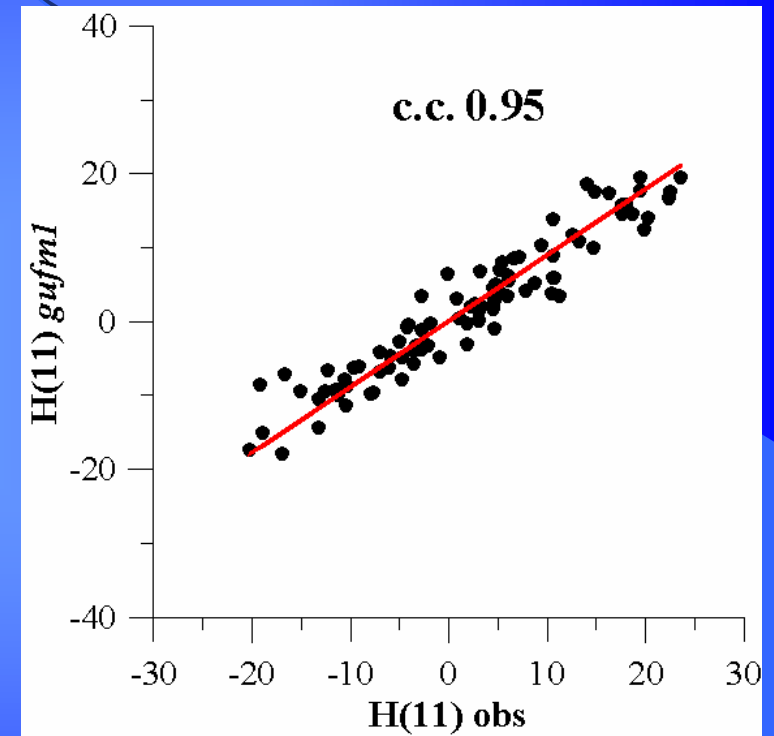
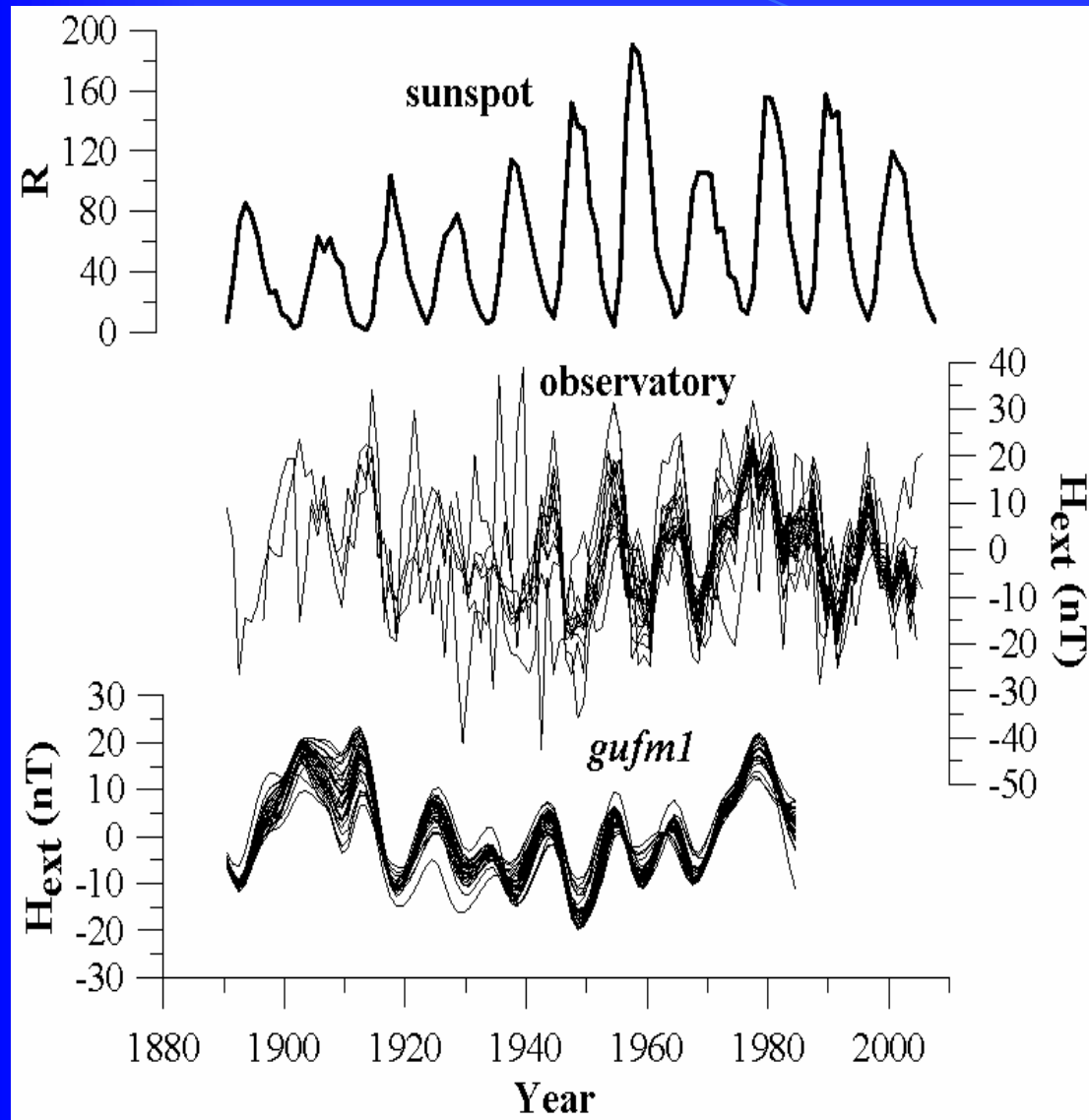
$$\mathbf{B} = -\nabla V$$

$$V(r, \theta, \lambda) = a \sum_{n=1}^{n_{\max}} \left(\frac{a}{r} \right)^{n-1} \sum_{m=0}^n (g_n^m \cos m\lambda + h_n^m \sin m\lambda) P_n^m(\theta)$$

Model	Time interval	Types of data	External effects
gufm1	1590-1990	Historical, Observatory + Satellite	No provision for external effects
IGRF-11	1900-2010	Observatory + Satellite	
CM4	1960-2002		Modeled separately
CHAOS-3	1997-2010	Satellite + Observatory	Quiet time
GRIMM2x	2001-2010		
gufm-sat	2000-2010		

Unaccounted for, external variation in data leaks into the models

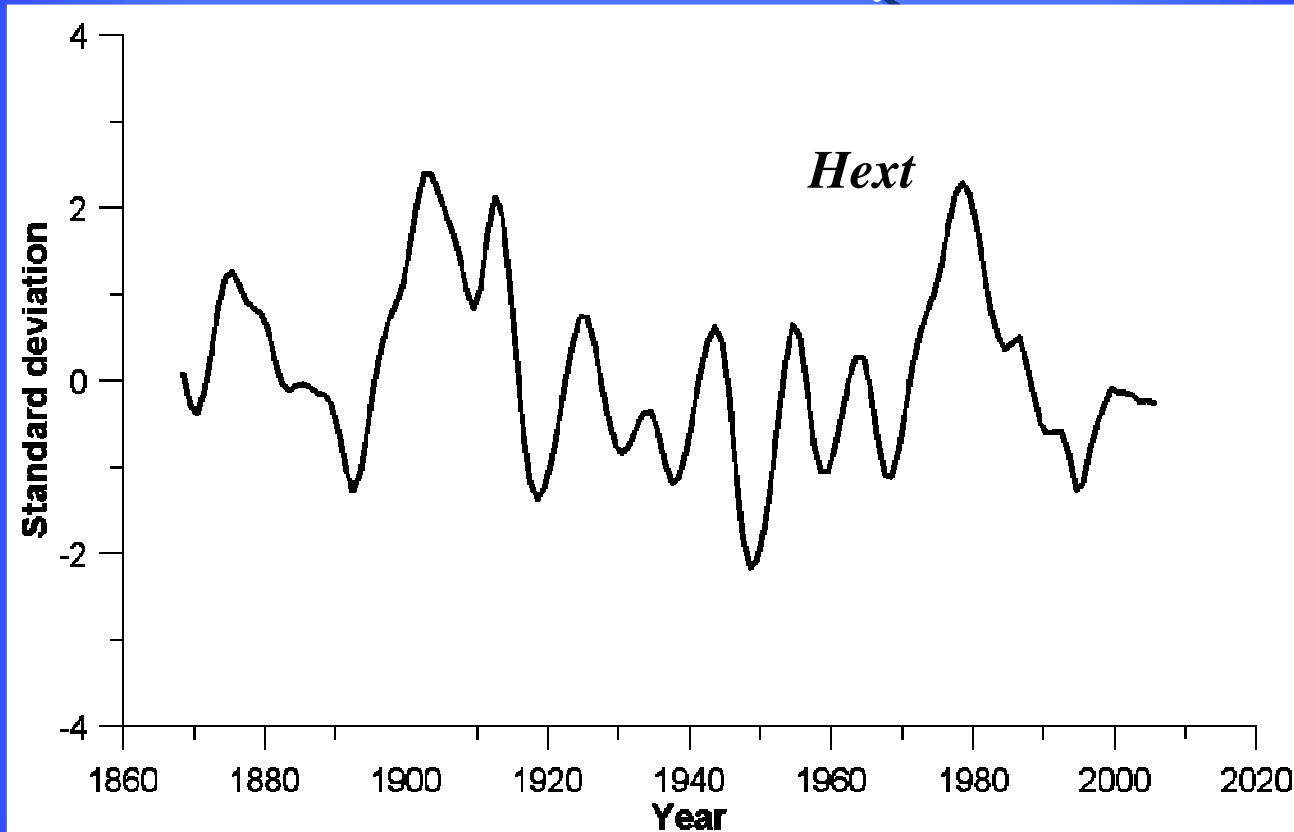
11-year effect in gufm1 model



H_{ext} → noise in main field models based (mainly) on observatory annual means

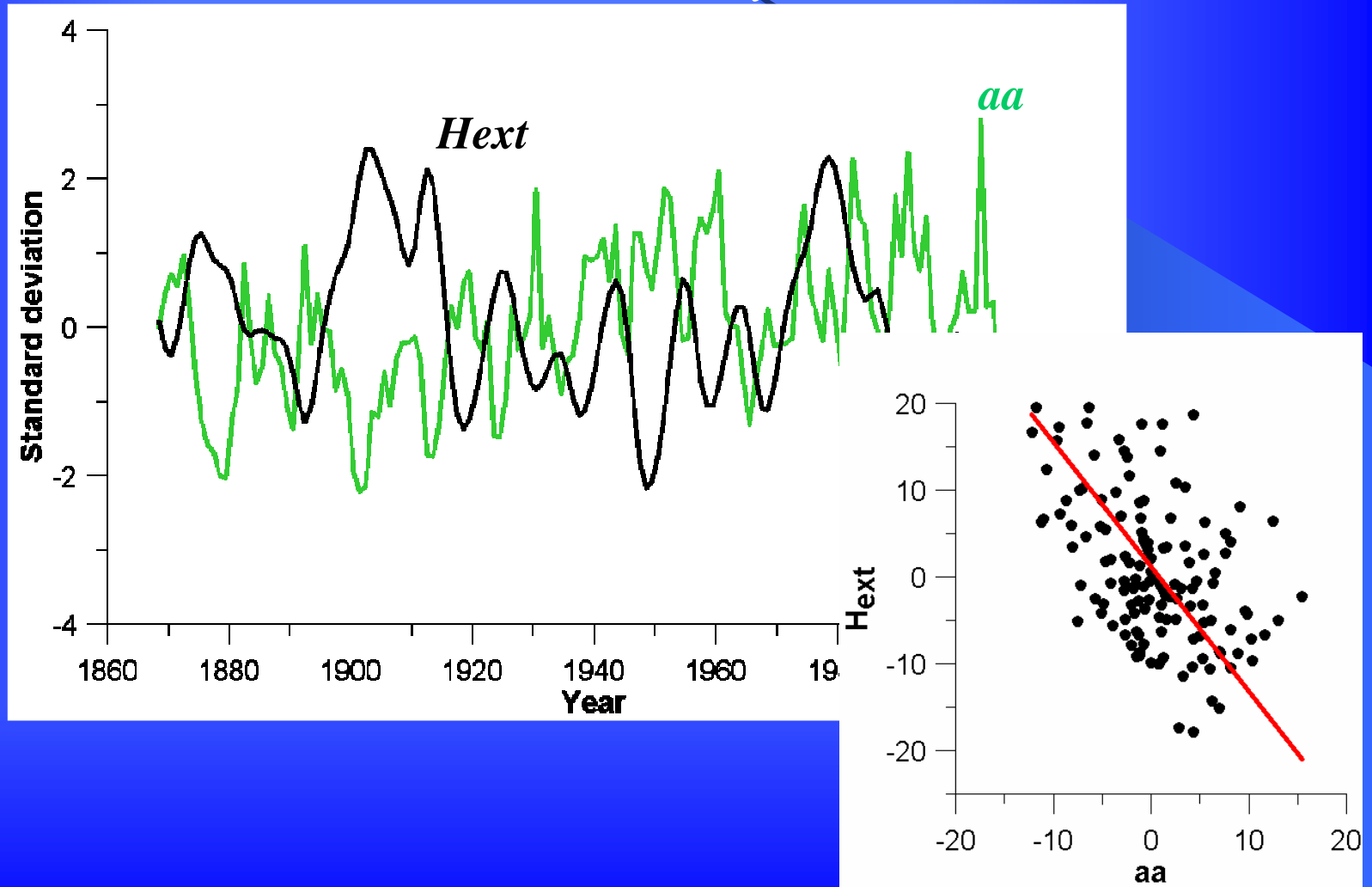
External signal in gufm1

NGK observatory



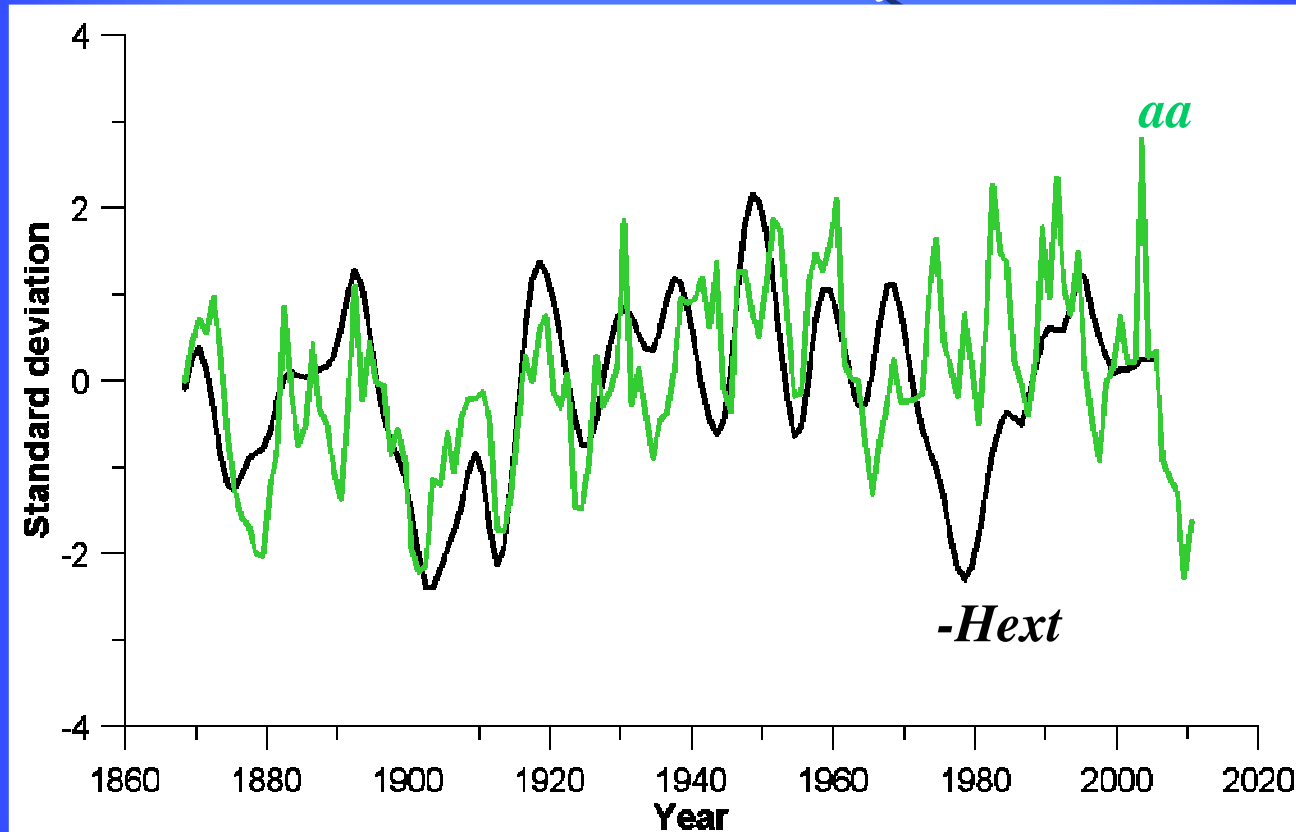
External signal in *gufm1*

NGK observatory



External signal in gufm1

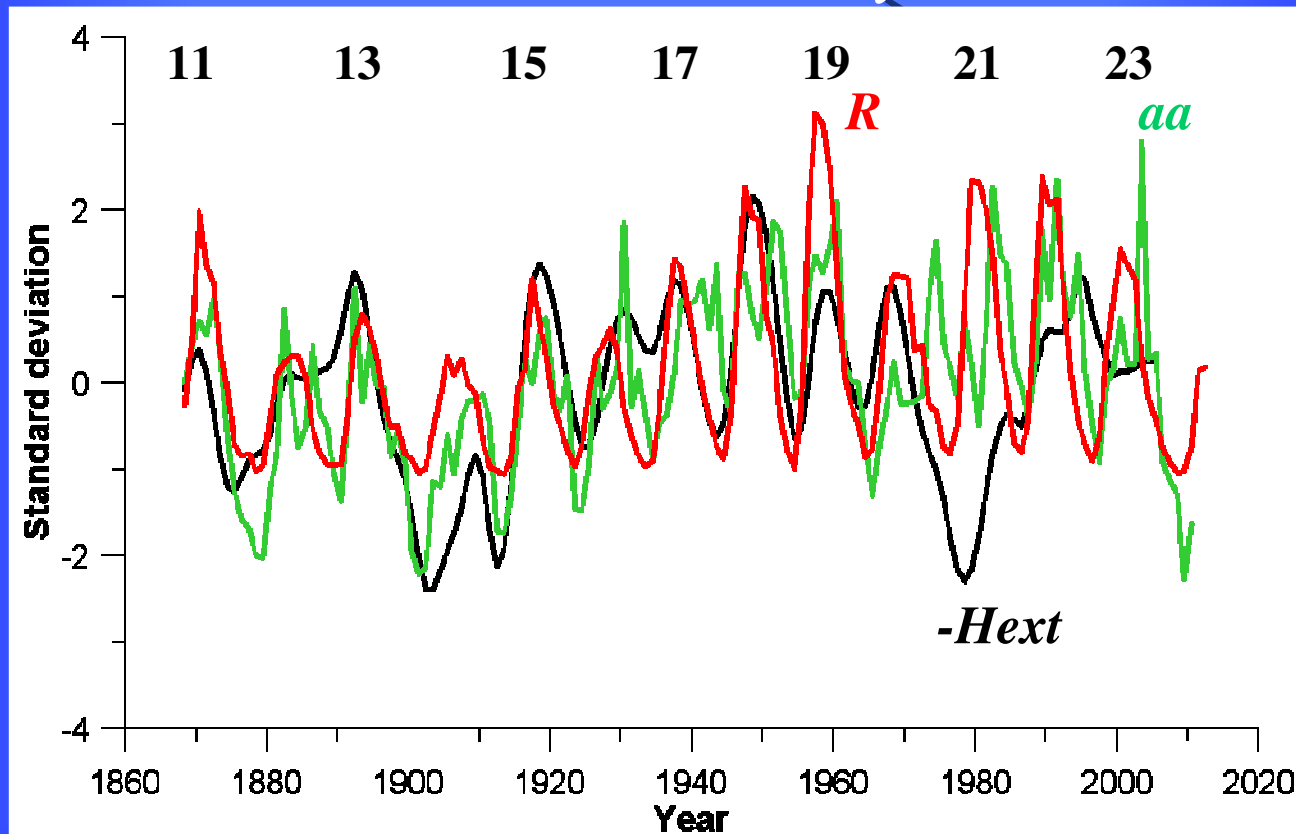
NGK observatory



-Hext → proxy for storm-time geomagnetic activity

External signal in gufm1

NGK observatory

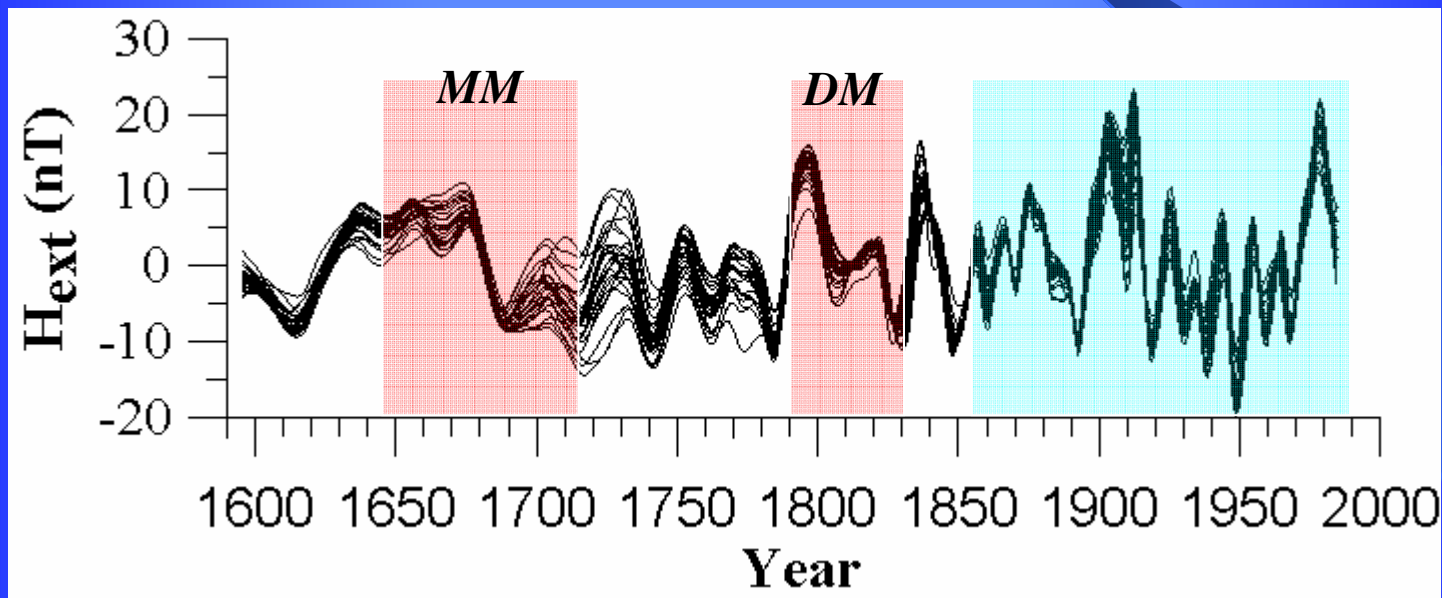


What about times prior to ~1850 ?

400 years of information on geomagnetic activity

gufm1 - Jackson et al. (2000), based on:

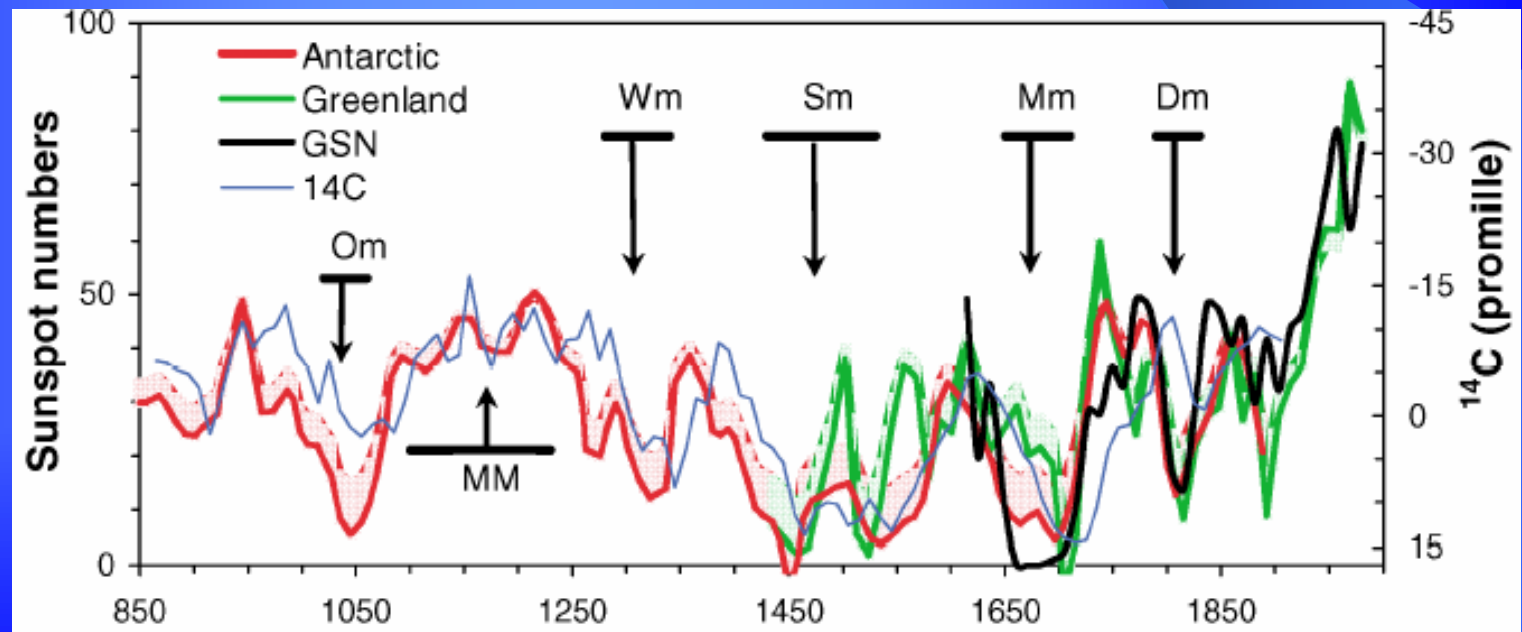
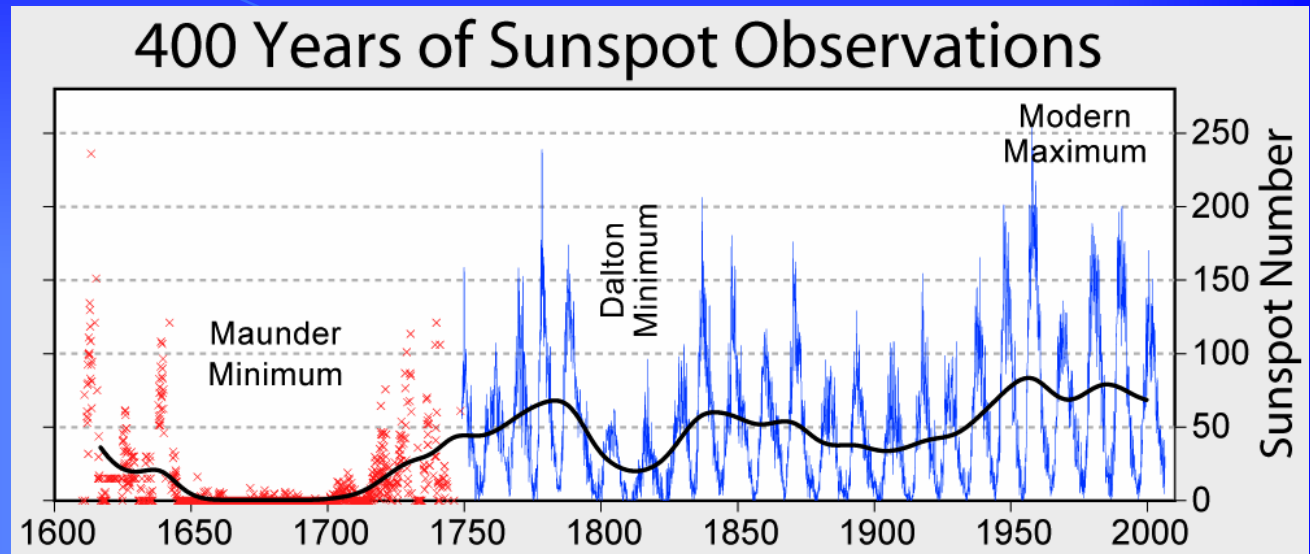
- *prior to 1850: D&I measured during sea voyages*
- *after 1850: observatory data*



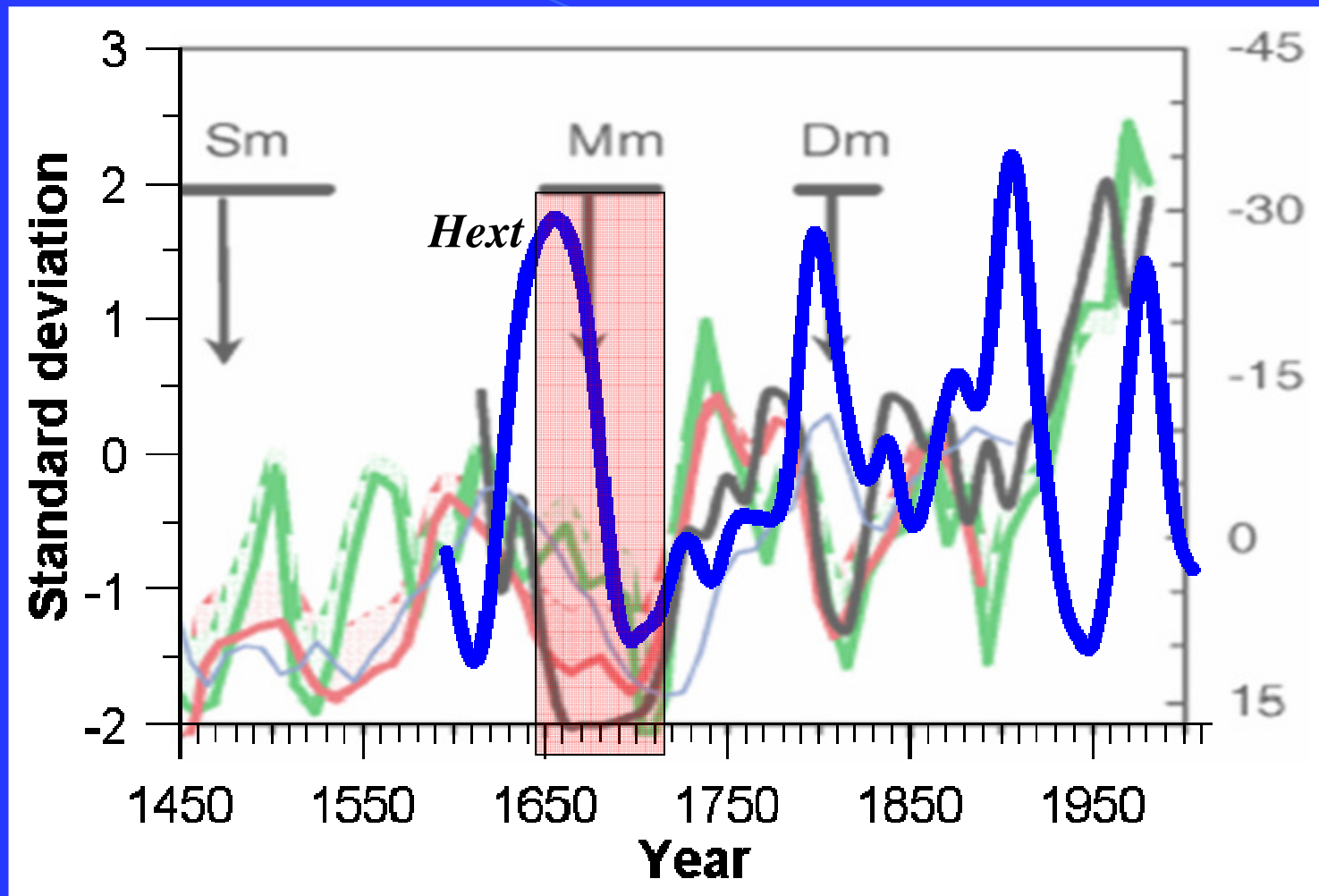
← 22 year → ← 11 year →

There is geomagnetic activity during MM and DM !

Comparison with solar activity



Timescale of the solar magnetic cycle (~22-year)

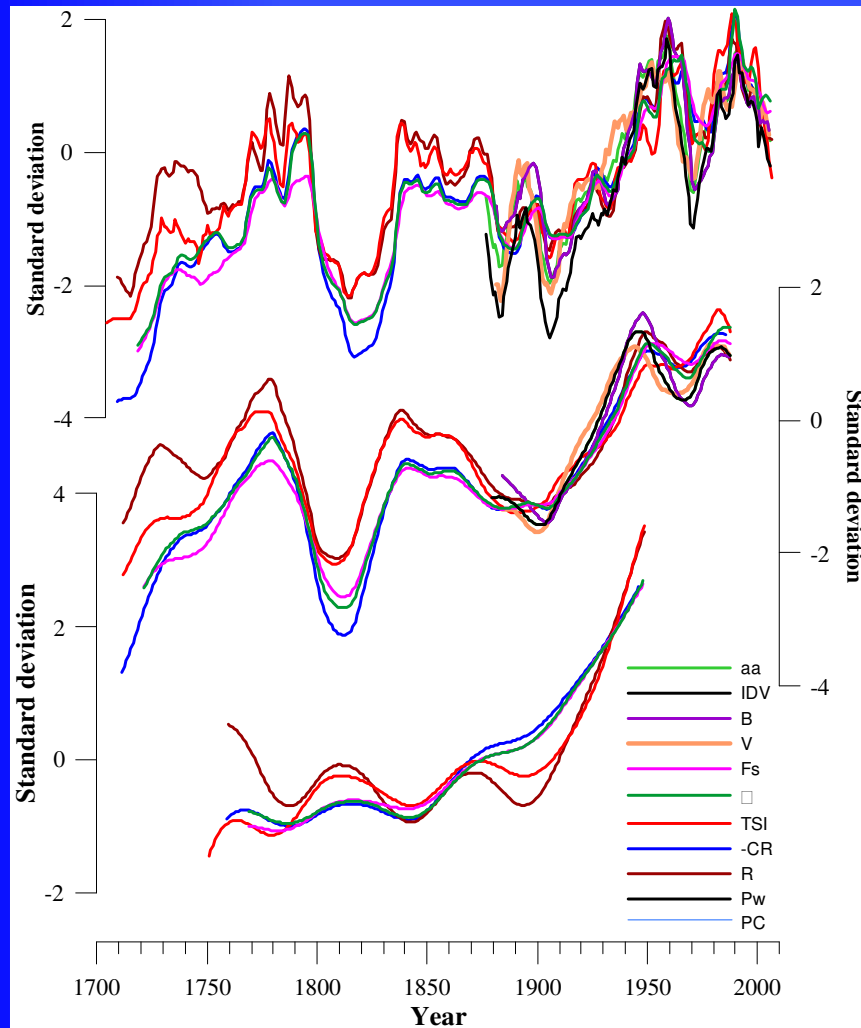


Indication for low geoeffective solar activity only in the first part of the MM
Caution: details to be studied

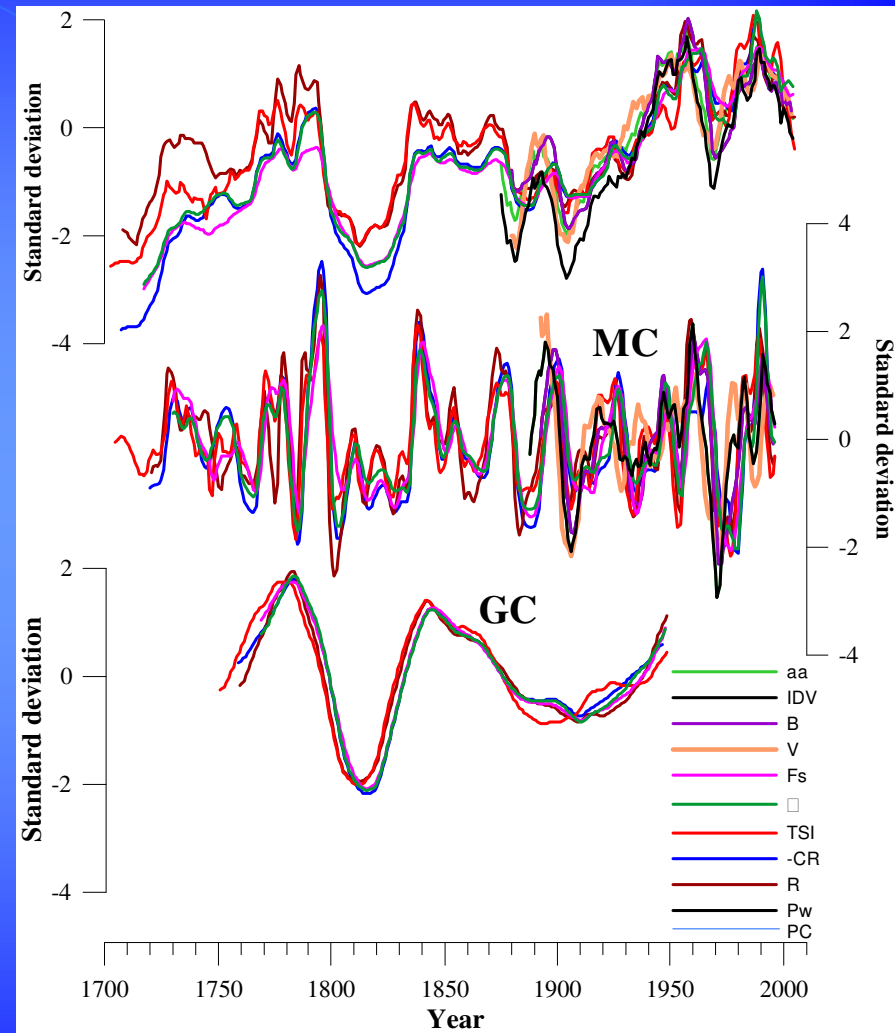
The solar-heliospheric-magnetospheric environment

Trends in data (interdecadal and centennial)

Standardized 11, 22 and ~88-year running averages



Signature of the Hale and Gleissberg cycles



Demetrescu&Dobrica, JGR 2008

Demetrescu et al., ASR 2010

Curves are reduced to their means over the common time interval and scaled with their standard deviations about the mean as a unit

Conclusions

- *Annual means provided by geomagnetic observatories are contaminated with an external contribution*
- *The external contribution in annual means is related (mainly) to storm-time activity*
- *Unaccounted for, this contribution leaks into main field models based (mainly) on observatory data*
- *The corresponding external signal (H_{ext}) is noise in main field models*
- *- H_{ext} in *gufm1* is a proxy for storm-time geomagnetic activity back to 1600*
- *There is geomagnetic activity during MM and DM, at least at the time scale of the solar magnetic cycle. No information on the 11-year cycle is retrievable*
- *Indication for low geoeffective solar activity only in the first part of the MM*
Caution: details to be studied