Geomagnetic data as a source of information on past evolution of the solar activity / space climate

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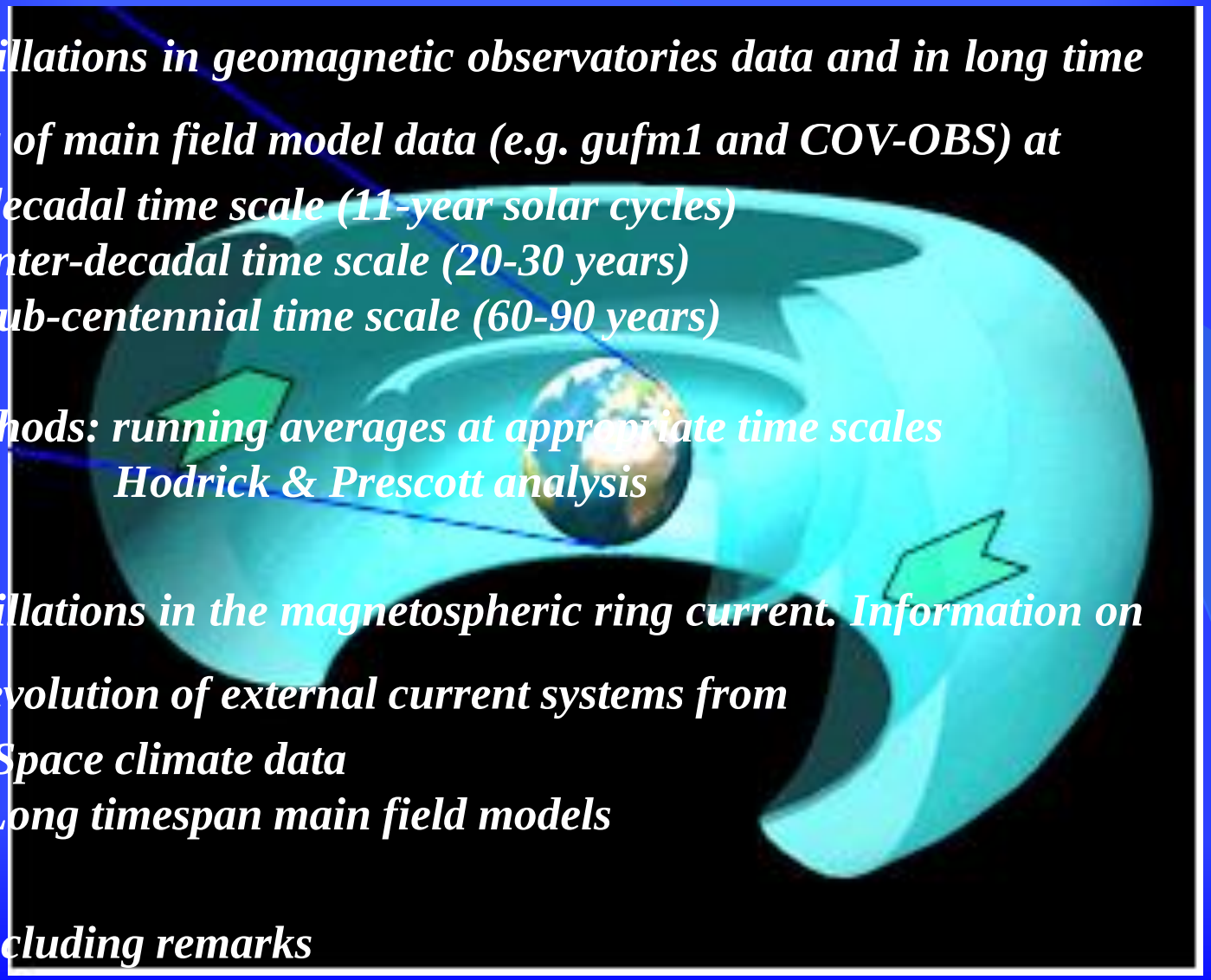
Outline



- Oscillations in geomagnetic observatories data and in long time series of main field model data (e.g. gufm1 and COV-OBS) at

- *decadal time scale (11-year solar cycles)*
- *inter-decadal time scale (20-30 years)*
- *sub-centennial time scale (60-90 years)*

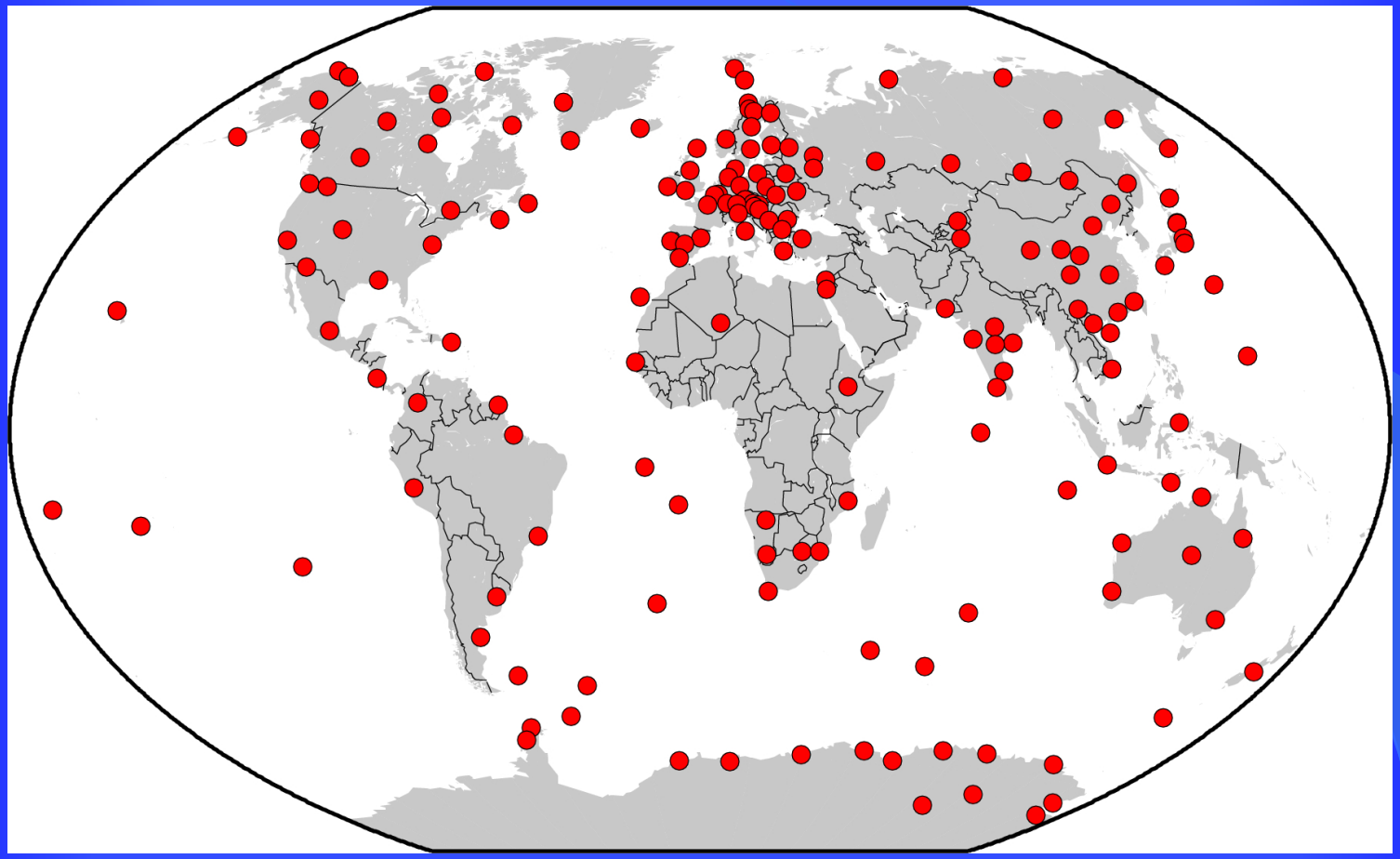
- Methods: running averages at appropriate time scales
Hodrick & Prescott analysis

- Oscillations in the magnetospheric ring current. Information on past evolution of external current systems from

- *Space climate data*
- *Long timespan main field models*

- Concluding remarks

Geomagnetic data



Methods

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

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

- running averages *(Demetrescu &Dobrica, PEPI, 2014)*

- Hodrick and Prescott analysis (Hodrick&Prescott, 1997) *(Dobrica et al., se, 2018)*

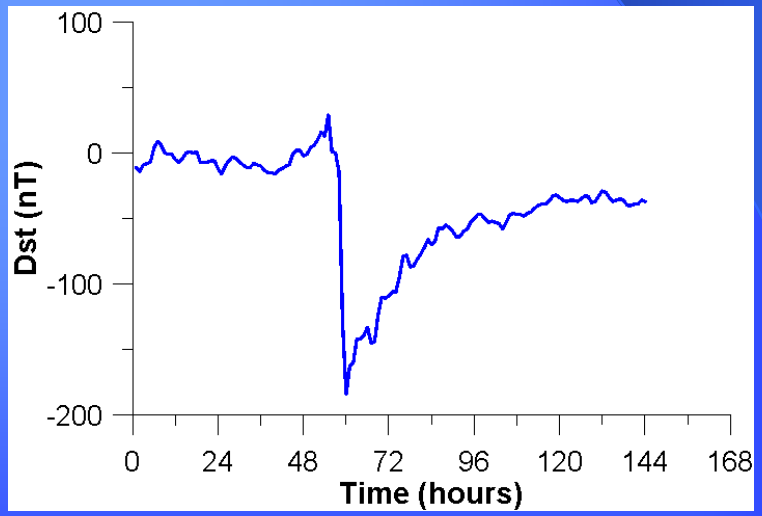
$$y_t = T_t + C_t$$

$$\sum_{t=1}^{n} C_t^2 + \lambda \sum_{t=1}^{n}\left[(T_t - T_{t-1}) - (T_{t-1} - T_{t-2})\right]^2$$

Ring current effects in observatory data and in main field models

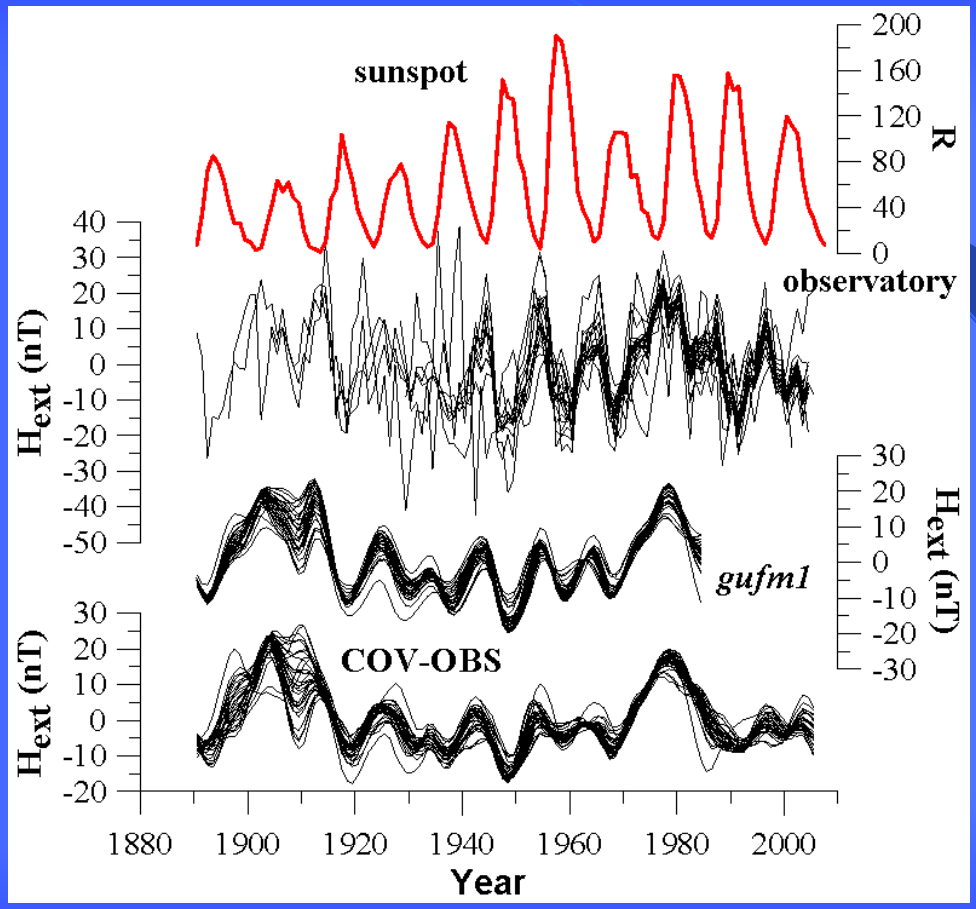
Annual means contain a residual, not averaged out disturbance field at sub-centennial time scales. Not accounted for, it leaks into main field models

Aug. 22-27, 2005



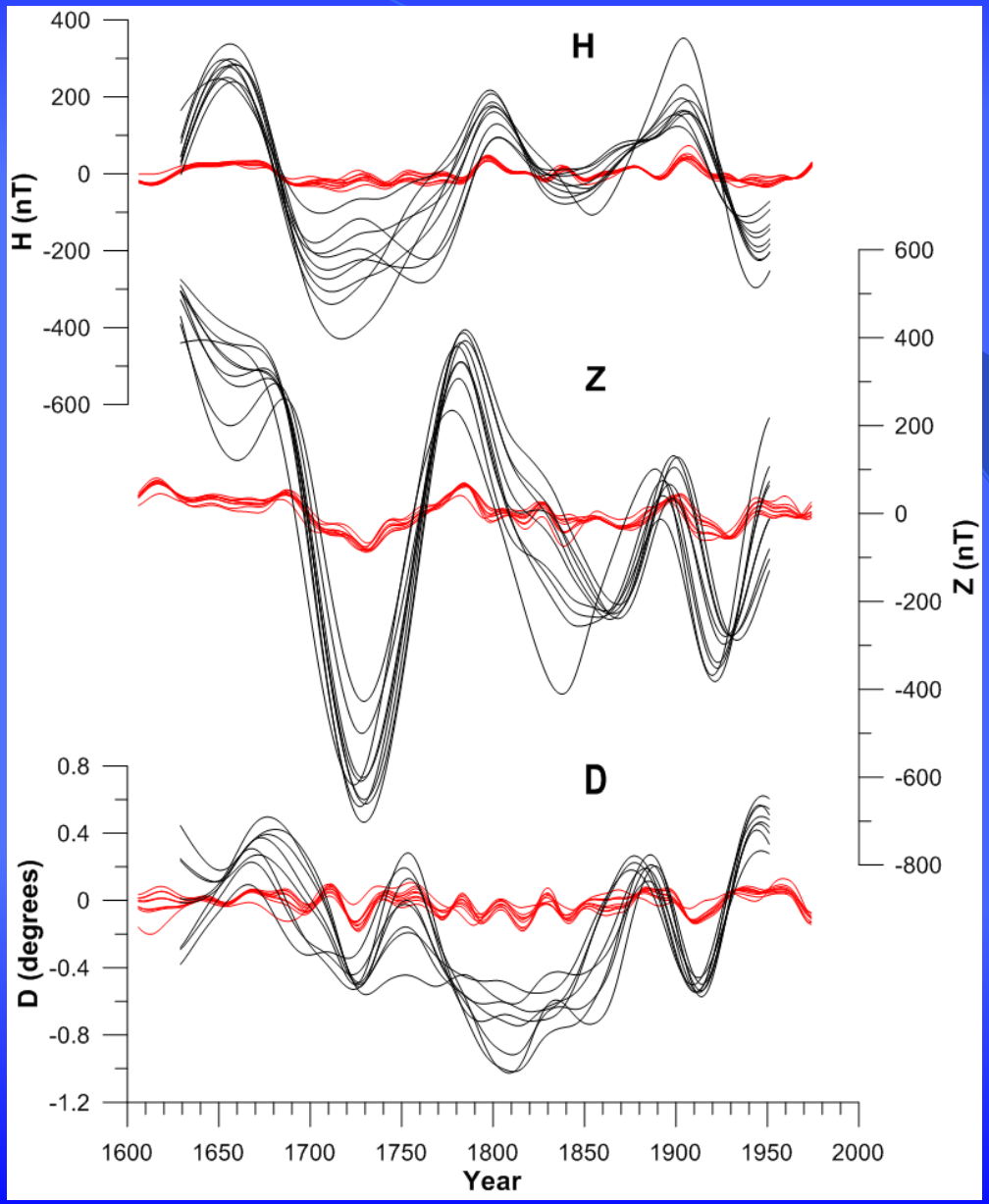
The external signal is anticorrelated with solar activity at all sub-centennial time scales

Running averages
11- years

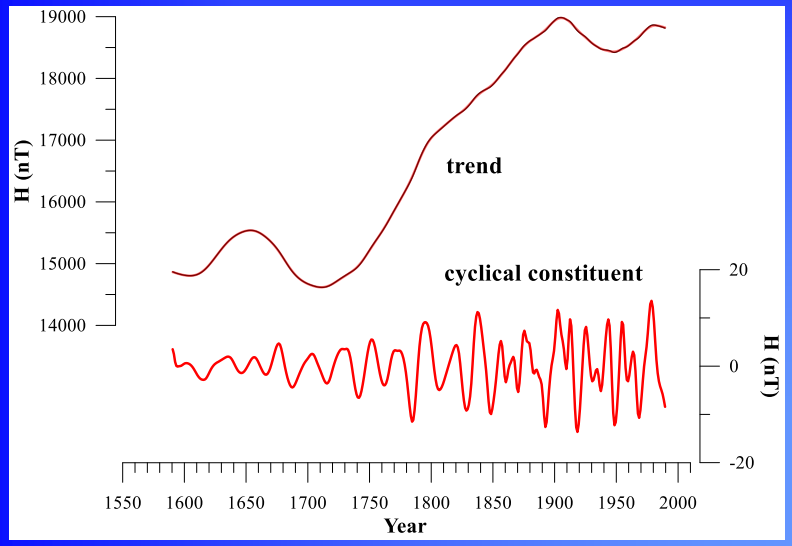


- obvious relationship with solar activity

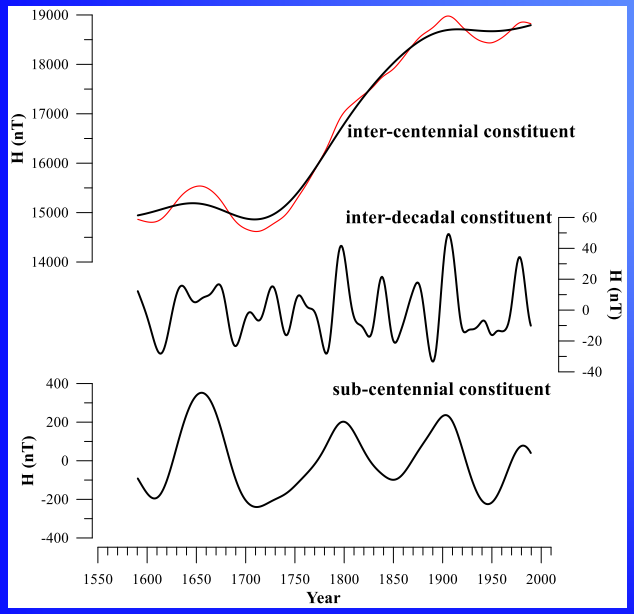
Interdecadal and sub-centennial oscillations
Running averages, European observatories, gufm1

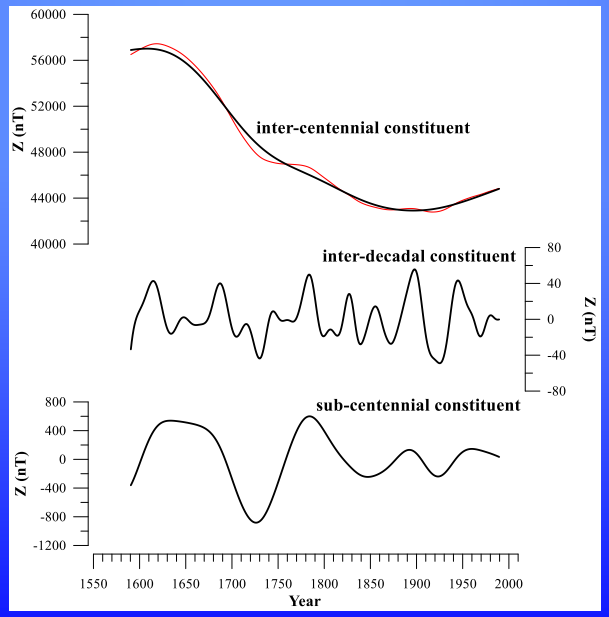


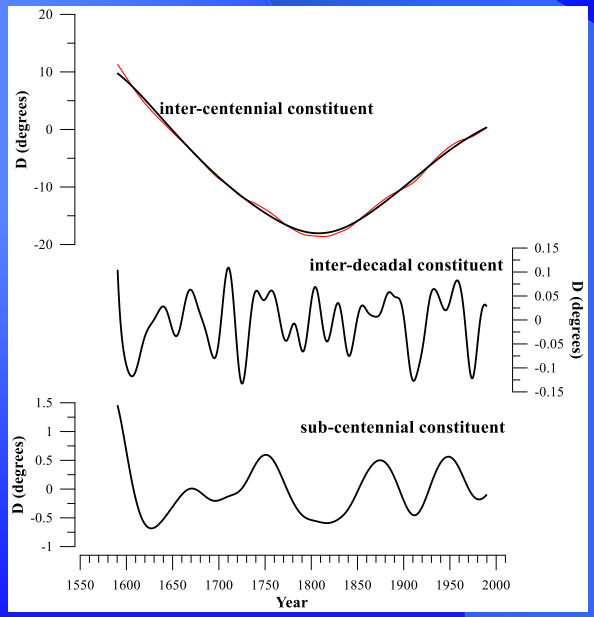
Hodrick & Prescott analysis gufm1, NGK



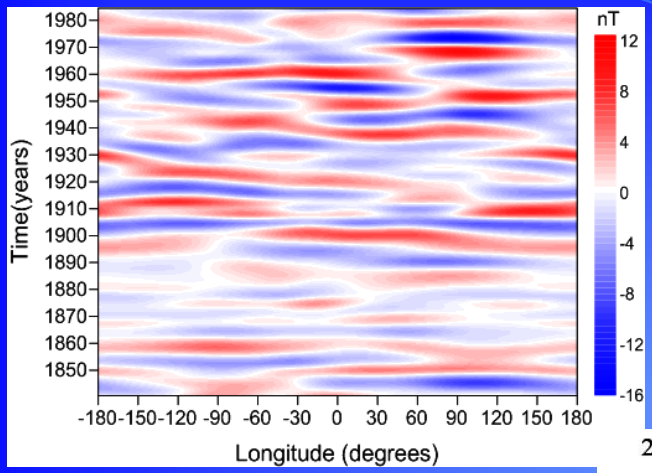
- *Data:* ⟶ *Trend + cyclic*
  HP filter — *Hodrick&Prescott (1997)*
- *Butterworth filtering of trend:* *inter-decadal (20-30 years)*, *sub-centennial (60-90 years)*



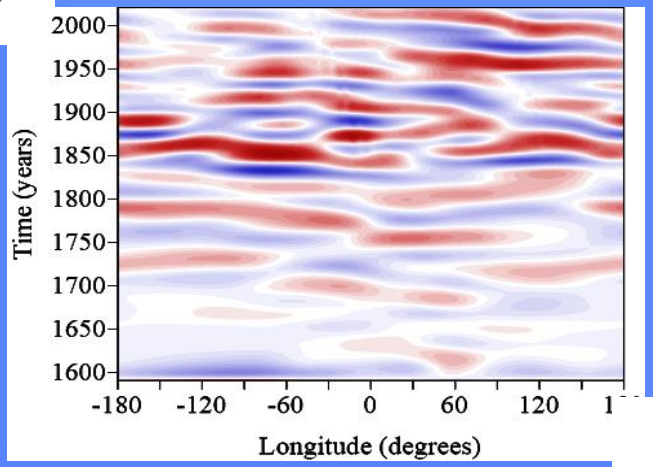




Sub-centennial oscillations, t –λ plots

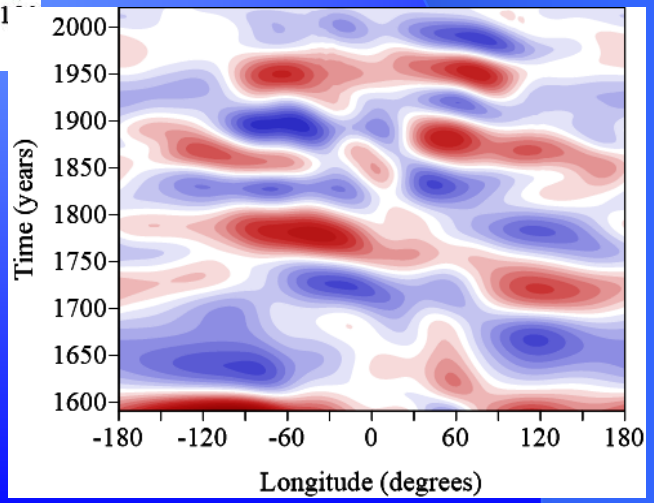


Decadal (~ 11-year)



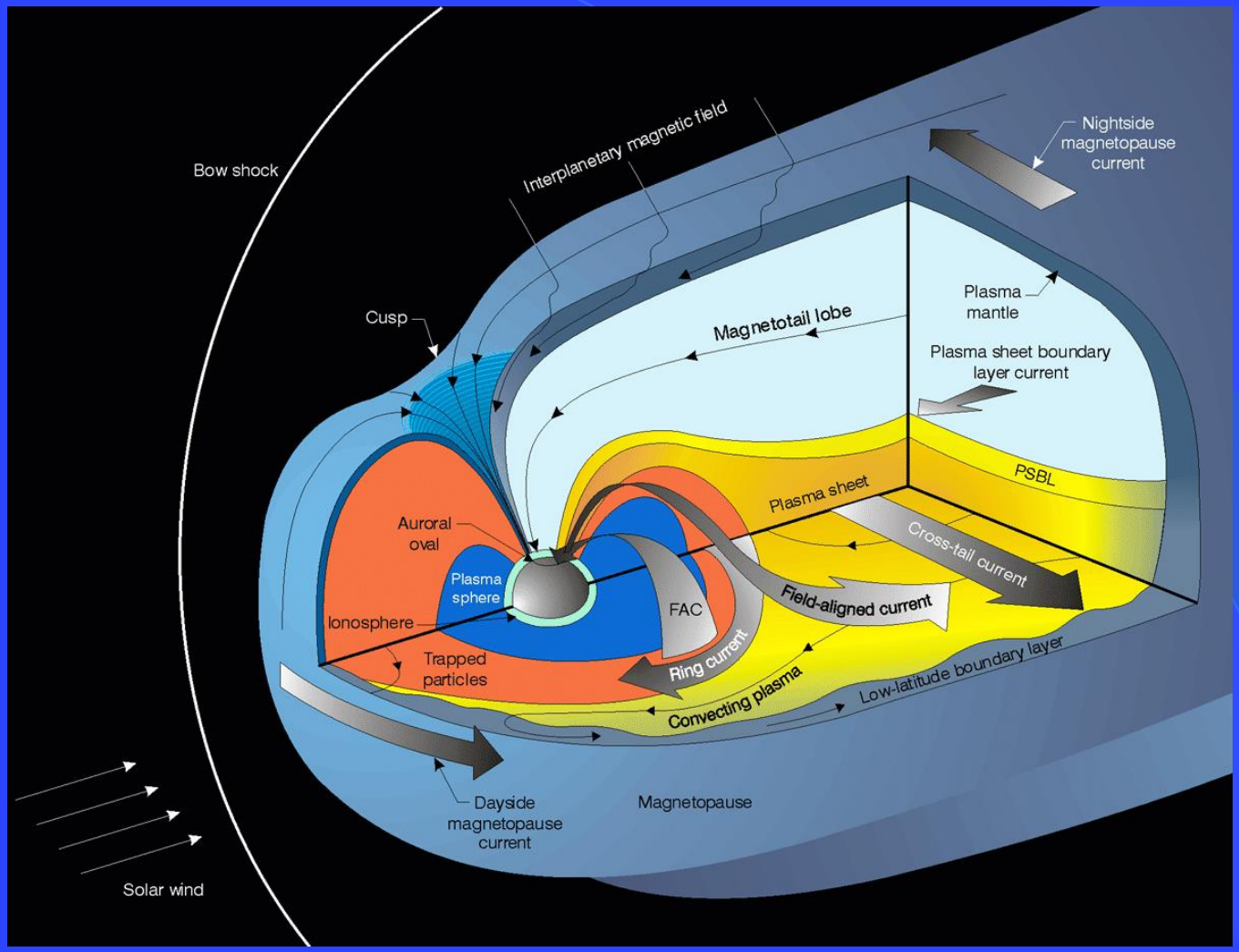
Inter-decadal (20-30 years)

Sub-centennial (60-90 years)

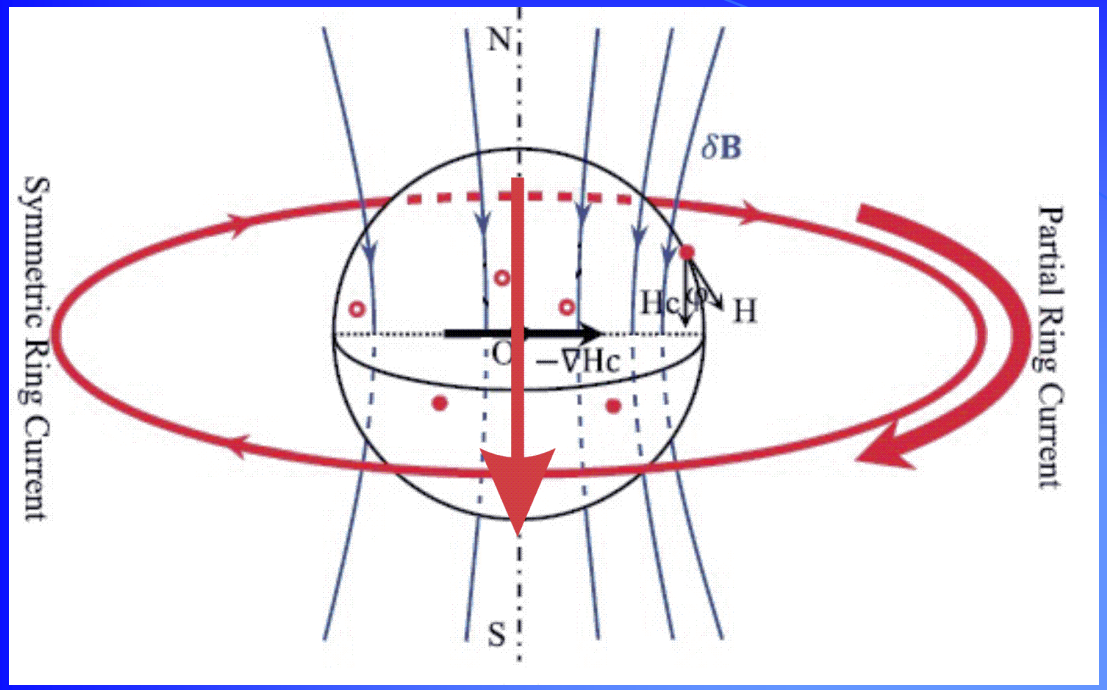


- pointing to external sources

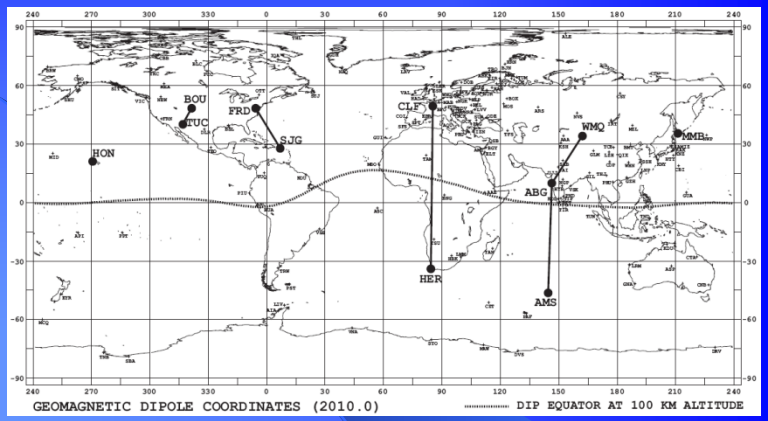
Current systems in the magnetosphere



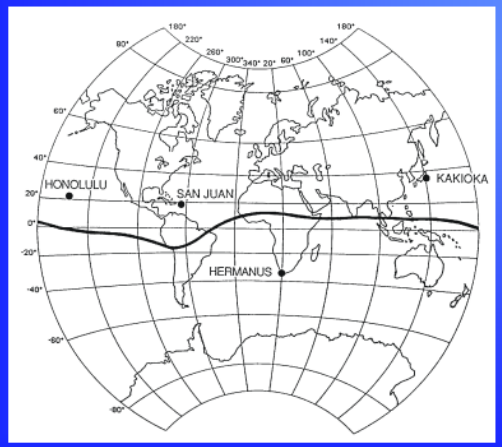
Magnetospheric ring current and geomagnetic indices



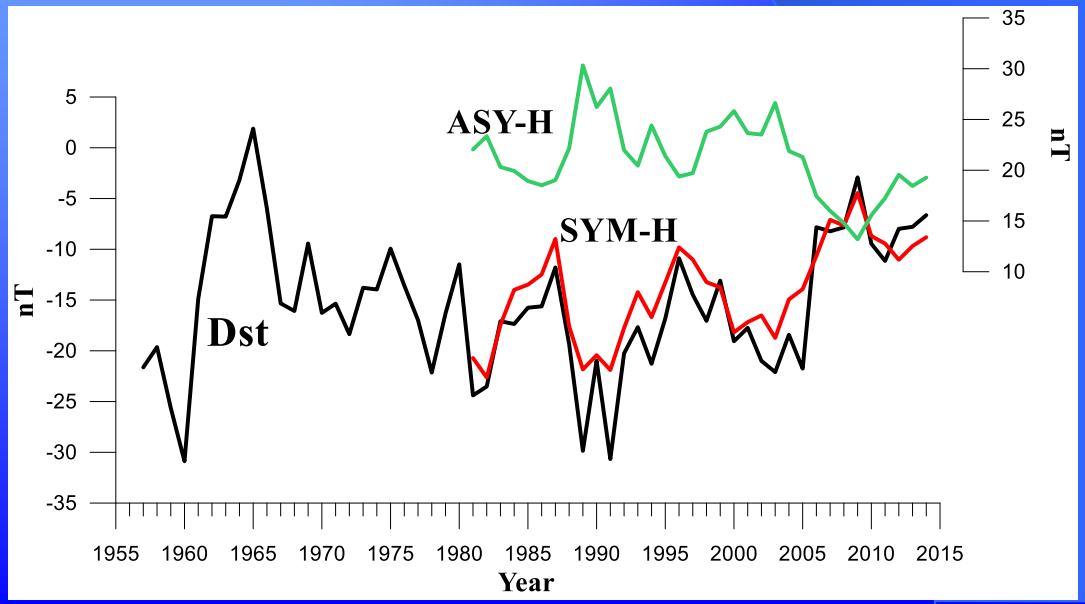
adapted from Shen et al. (2015)



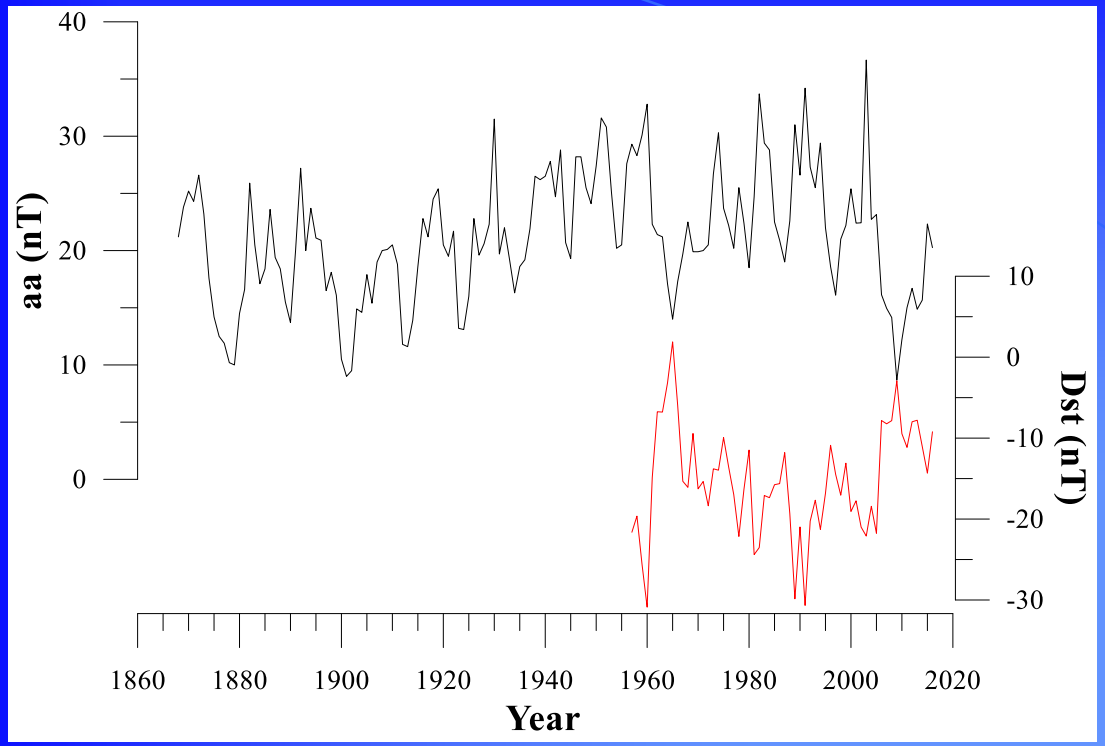
Iyemori (1990); http://wdc.kugi.kyoto-u.ac.jp/



Sugiura (1964); http://wdc.kugi.kyoto-u.ac.jp/



Past information on the magnetospheric ring current evolution



A. Reconstruction to 1868, based on correlation with other, longer time series of geomagnetic indices

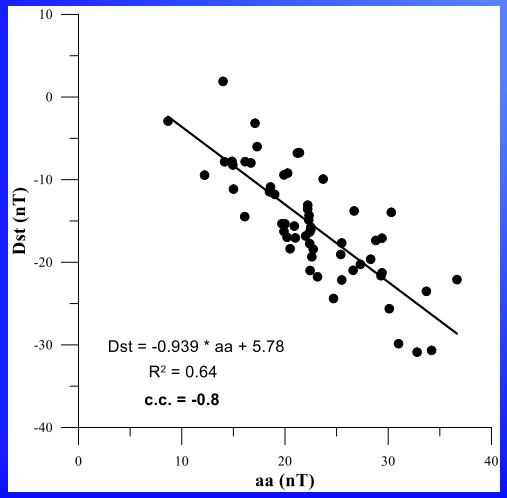
B. Reconstruction to ~1600 based on space climate data

C. Recostructions based on information from

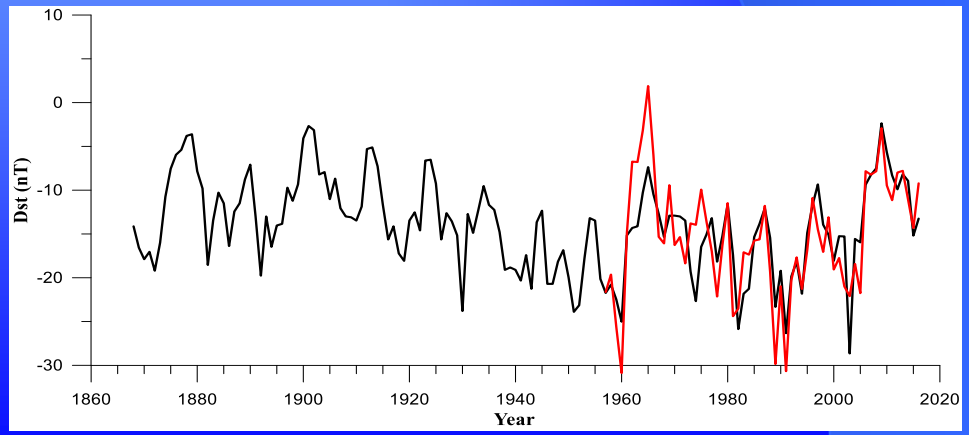
C1. geomagnetic observatories data - to 1868 – decadal

C2. main field models - to ~1600 - decadal

C3. - multi-decadal

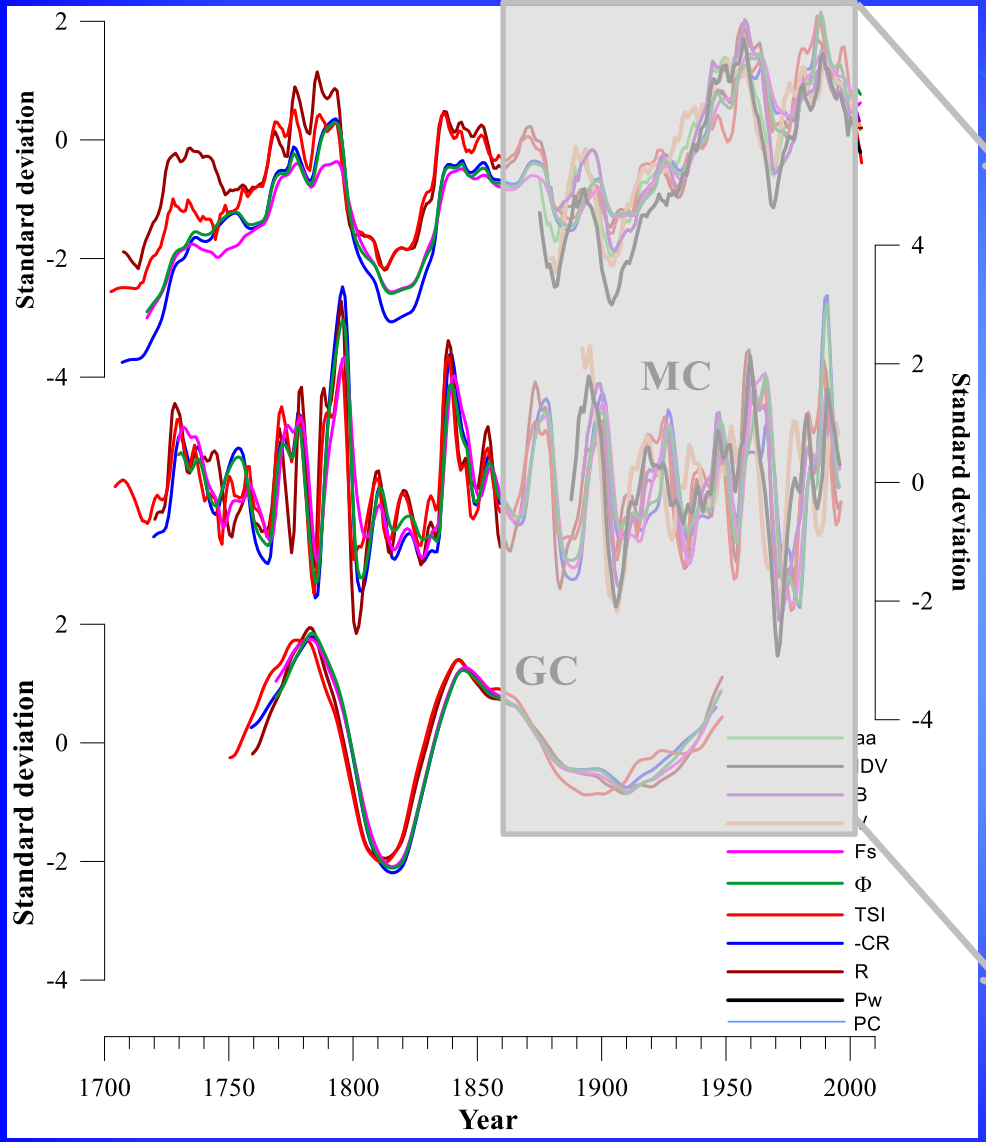


A. Reconstruction to 1868

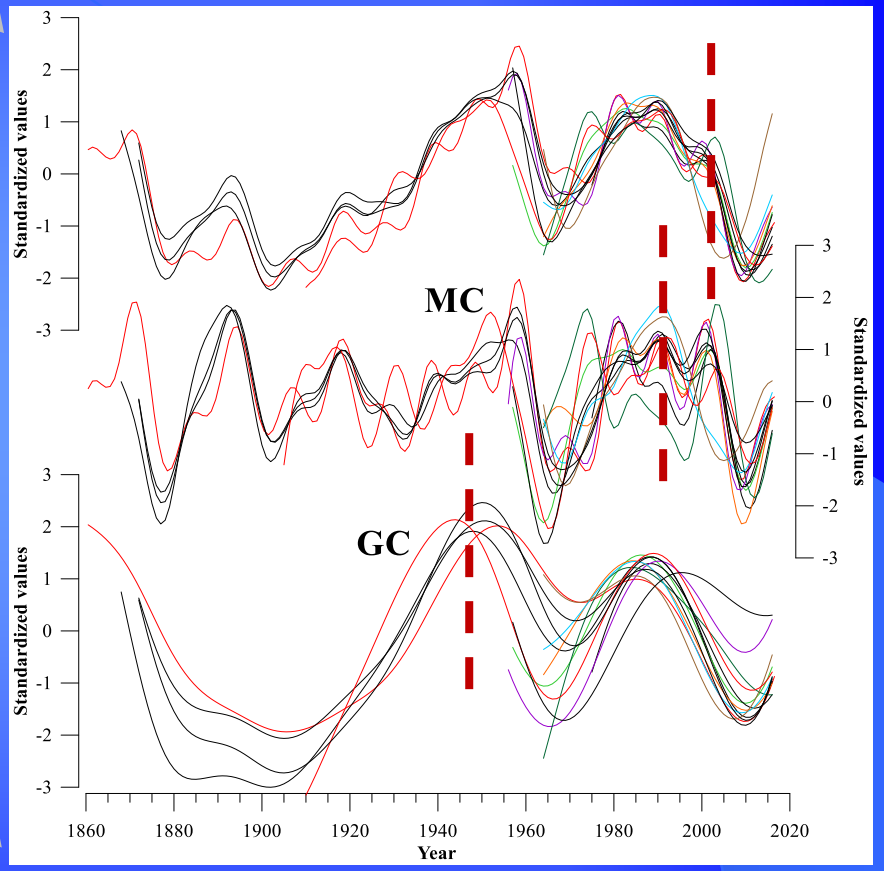


MC and GC signature in space climate data

- moving averages filtering



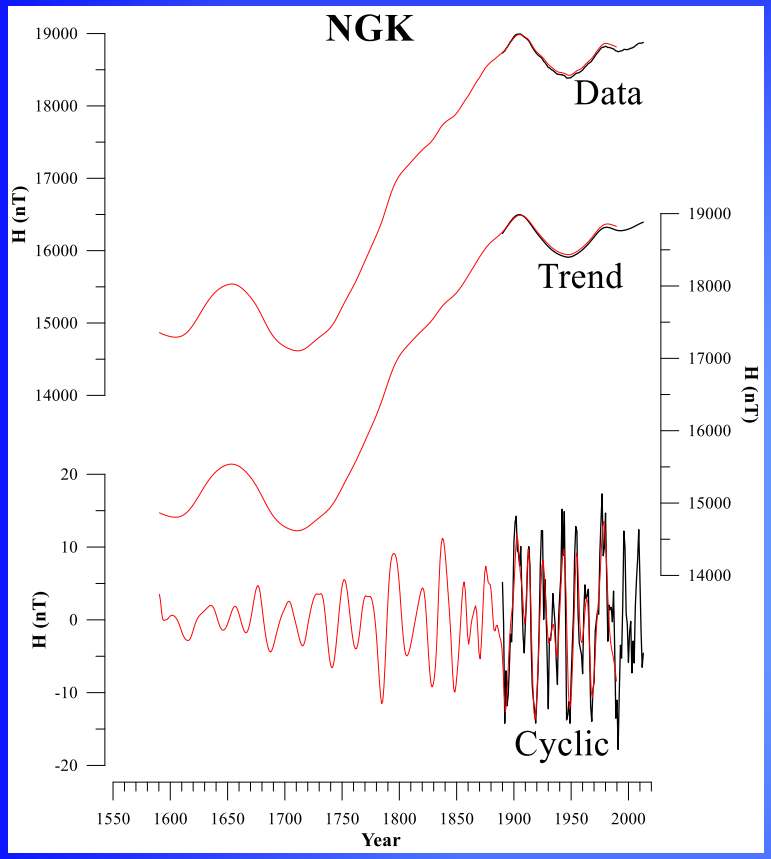
- Hodrick and Prescott (HP) type analysis and Butterworth filtering



Demetrescu&Dobrica, JGR 2008

Demetrescu et al., ASR 2010

C2. *Information back in time – gufm1 + COV-OBS main field models (Jackson et al., 2000; Gillet et al., 2013), 1590 - 2010*



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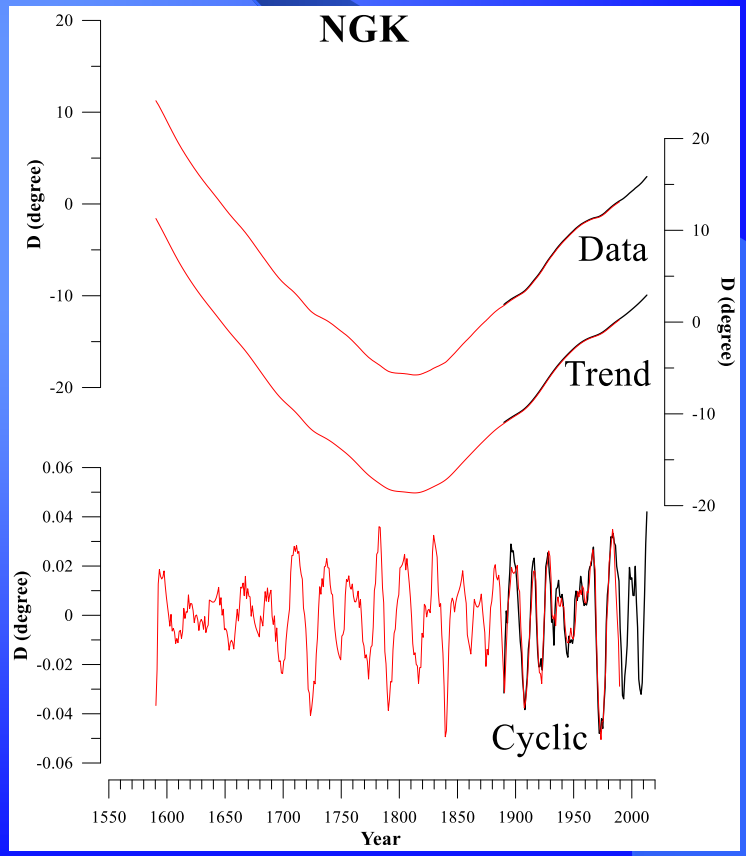


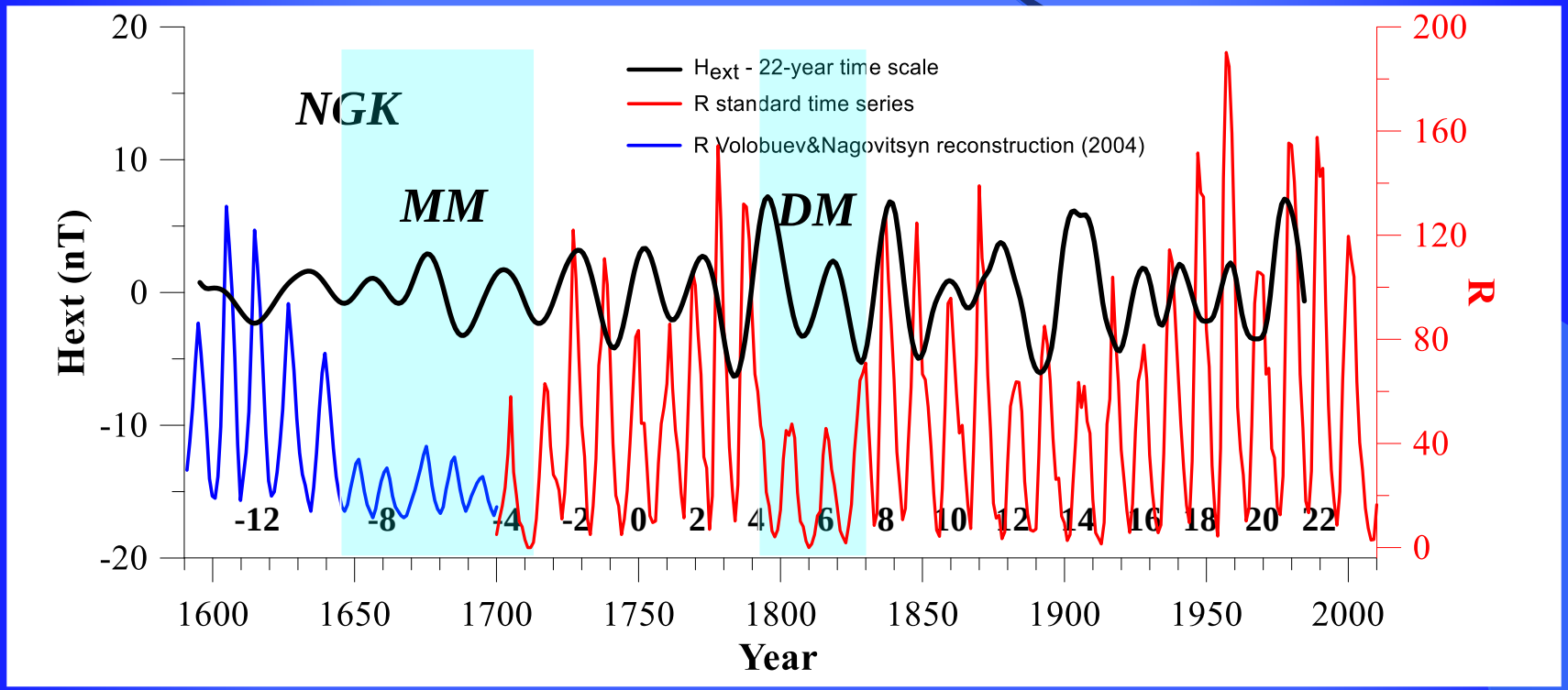
gufm1 - Jackson et al. (2000), 1590-1990, based on:
- prior to 1850: D&I measured during sea voyages
- after 1850: observatory and satellite data to 2000

COV-OBS (Gillet et al., 2013)

-Same observatory data
--Satellite data to 2010

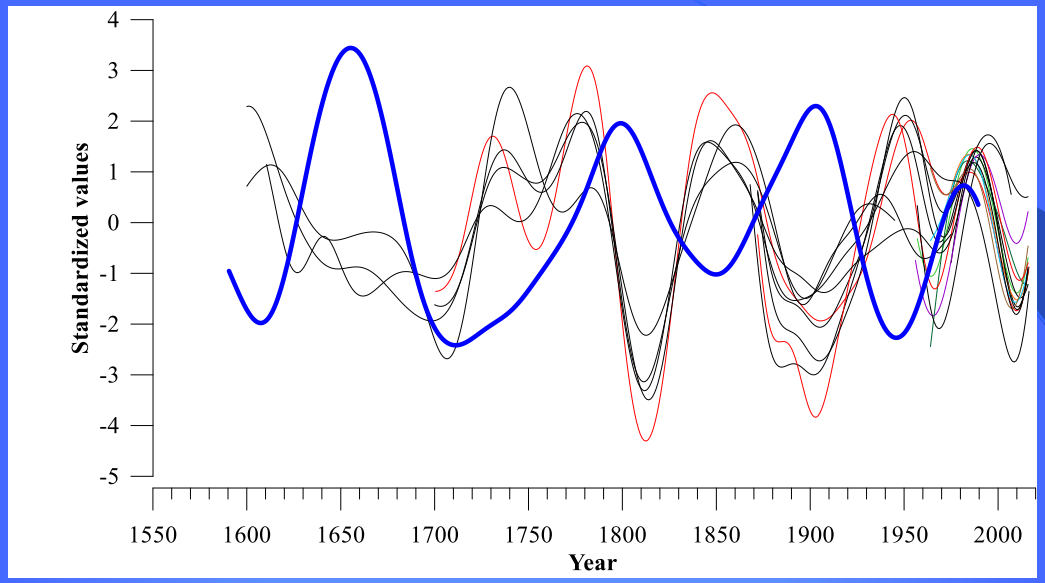
C2. *Information back in time – gufm1 main field model, decadal time scale, 1590 - 1990*

The 22-year time scale

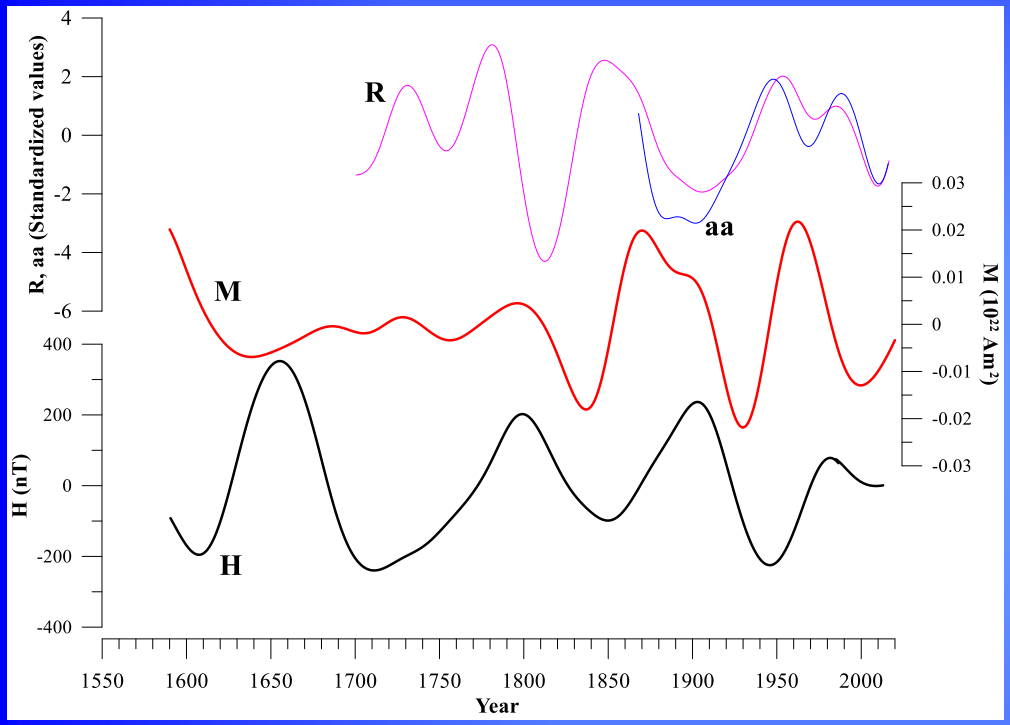


- only a 22-year signal can be retrieved before 1868
-there is geomagnetic activity during MM and DM

C3. *Sub-centennial oscillations (H). External drivers*

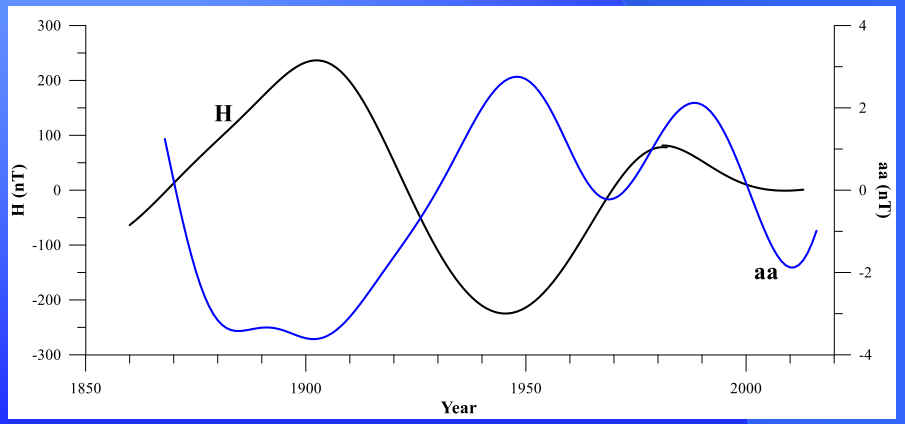


C3. Sub-centennial oscillations. External drivers
- 1590 – 2010; 1860 – 2010 -



Possible induction by magnetospheric ring current variations of oscillations we found in the main field

- geomagnetic activity, geomagnetic field -



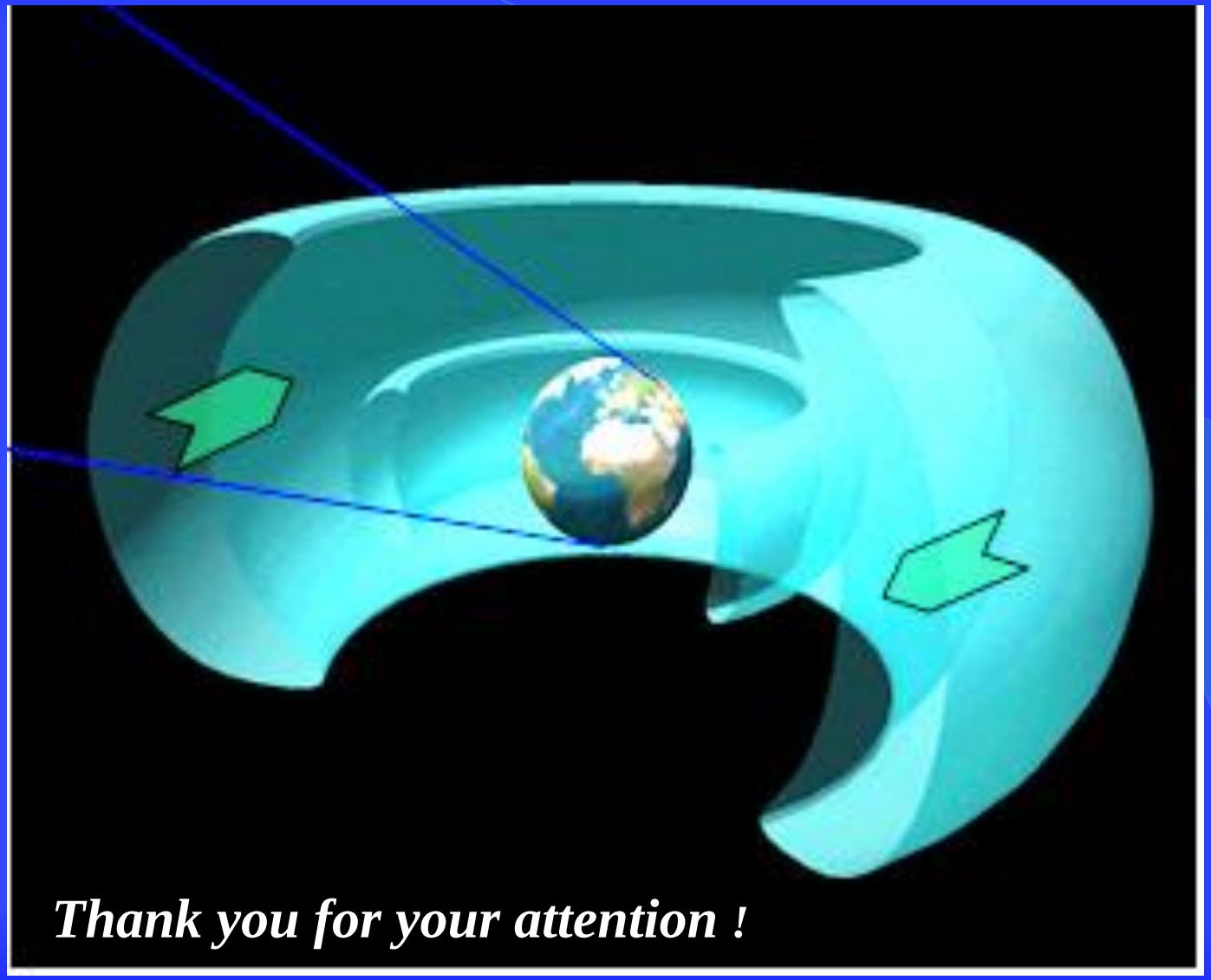
Conclusions

- ***Oscillations at sub-centennial timescales found in observatory data manifest also in field models. Possibility to study these oscillations back to 1590 based on* gufm1 *(Jackson et al., 2000) and COV-OBS (Gillet et al., 2013) models***

- ***Our previous experience showed variations at the same timecales in the heliospheric and magnetospheric processes: solar wind, heliospheric magnetic field, magnetospheric ring current, geomagnetic activity***

- ***Oscillations in the geomagnetic field at sub-centennial timescales could possibly be linked to induction in the Earth by external current systems, the magnetospheric ring current included***

- ***Future work: elaborate on***
  - ***the role of the magnetospheric ring current in inducing corresponding oscillations in the electrically conducting Earth's interior***
  - ***changes in the solar activity in cycles 20+21 (1960-1980)***


Thank you for your attention !