Separation of different ionospheric and magnetospheric contributions to the geomagnetic field variations

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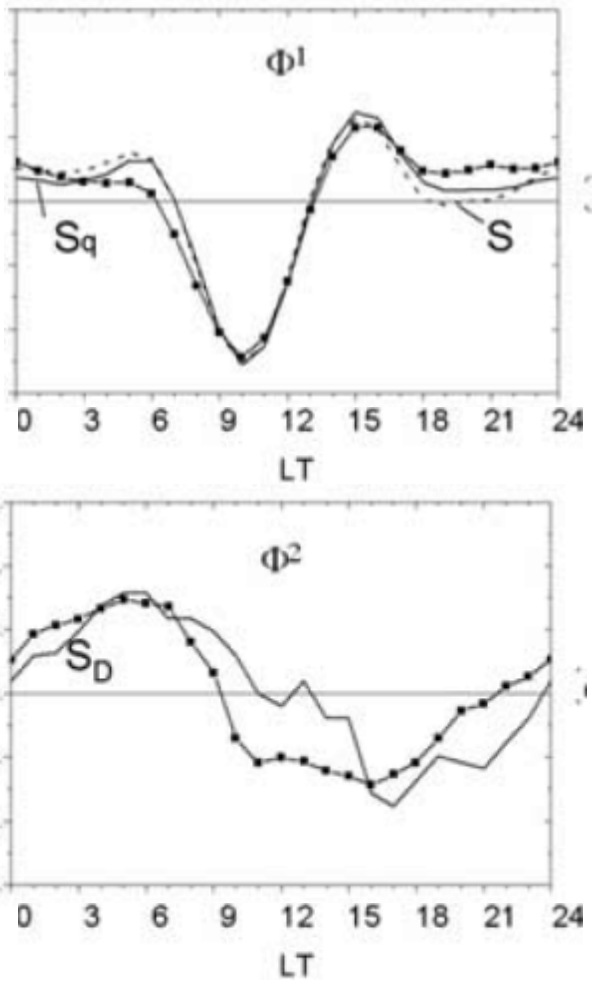
Daily geomagnetic field variations

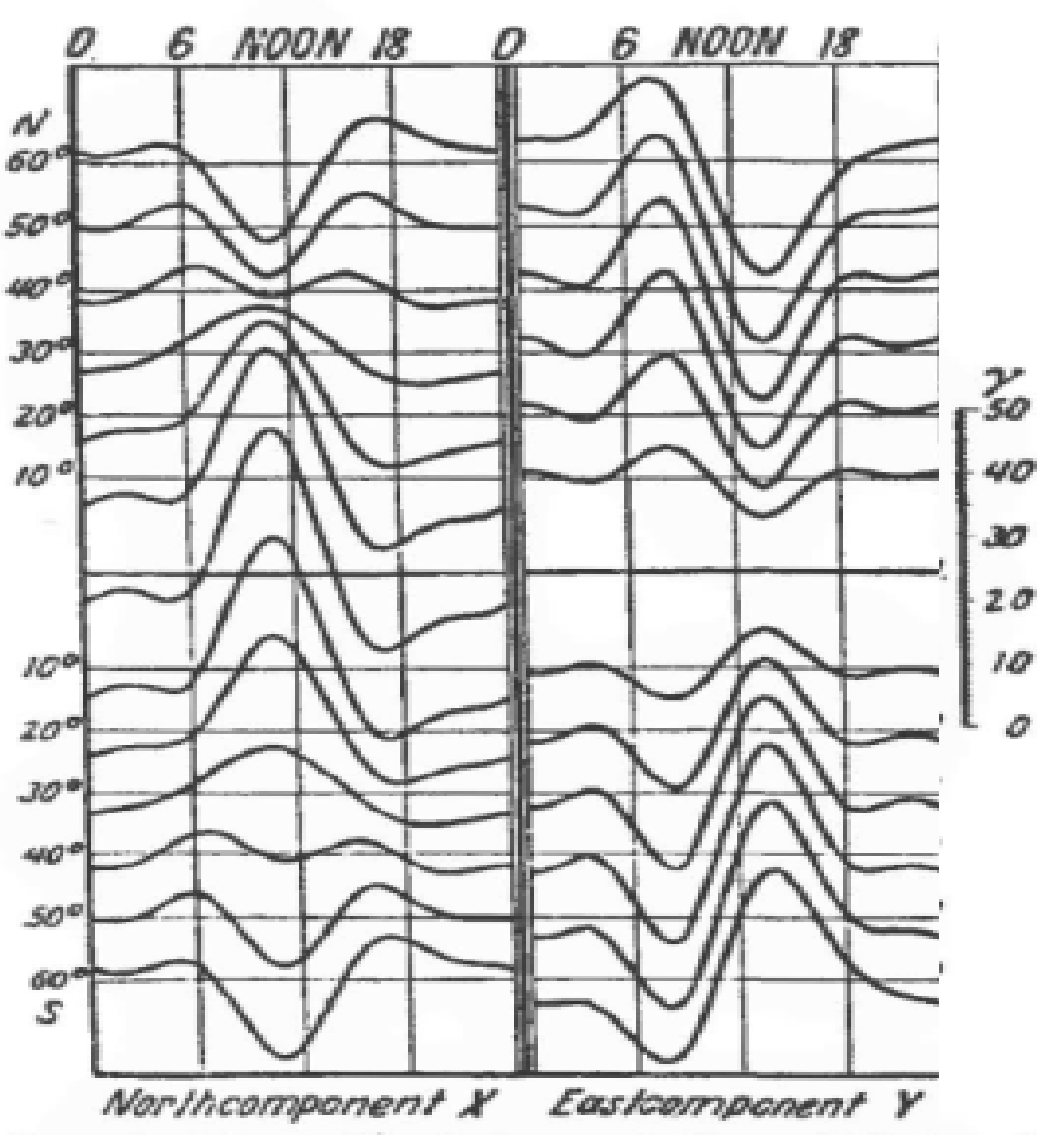
"solar" = "diurnal"

- "solar quiet" (**Sq**):
  - Sq = μ (daily variations) for 5 most quiet days of a month

- "solar disturbed" (**S_D**)
  - S_D = S – Dst
    - S = μ(daily variations) for all days of a month
    - Dst = μ (daily variations) for 5 most disturbed days of the month
  - S_D similar form to Dst



”solar quiet” (**Sq**)

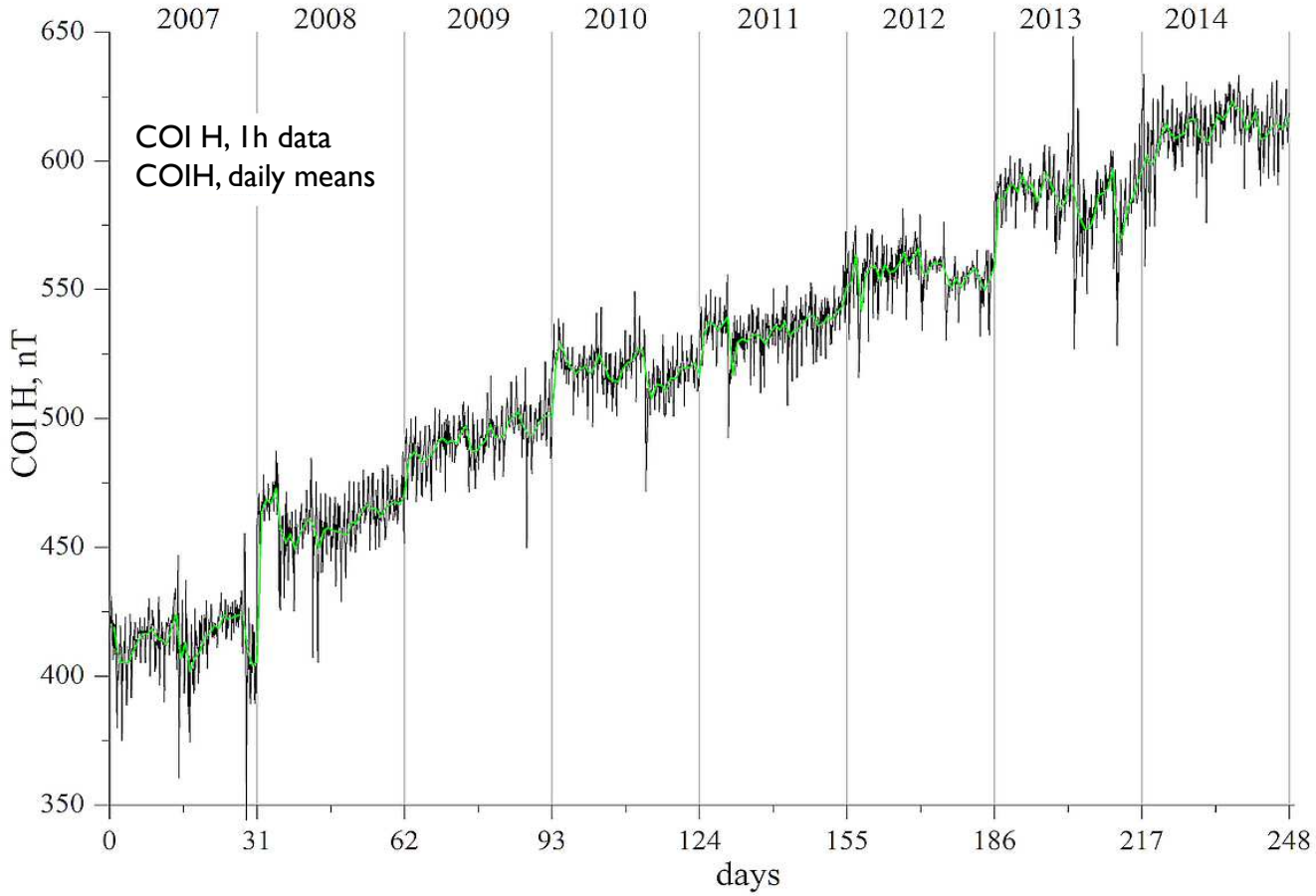


equinox

Sq:
PCA vs standard

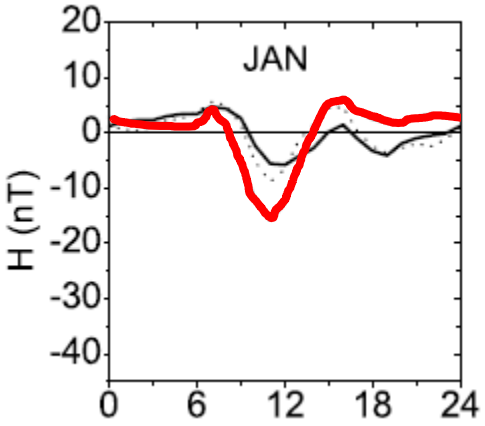
Data: all Januaries 2007-2014 (COI H – 25 000 nT)

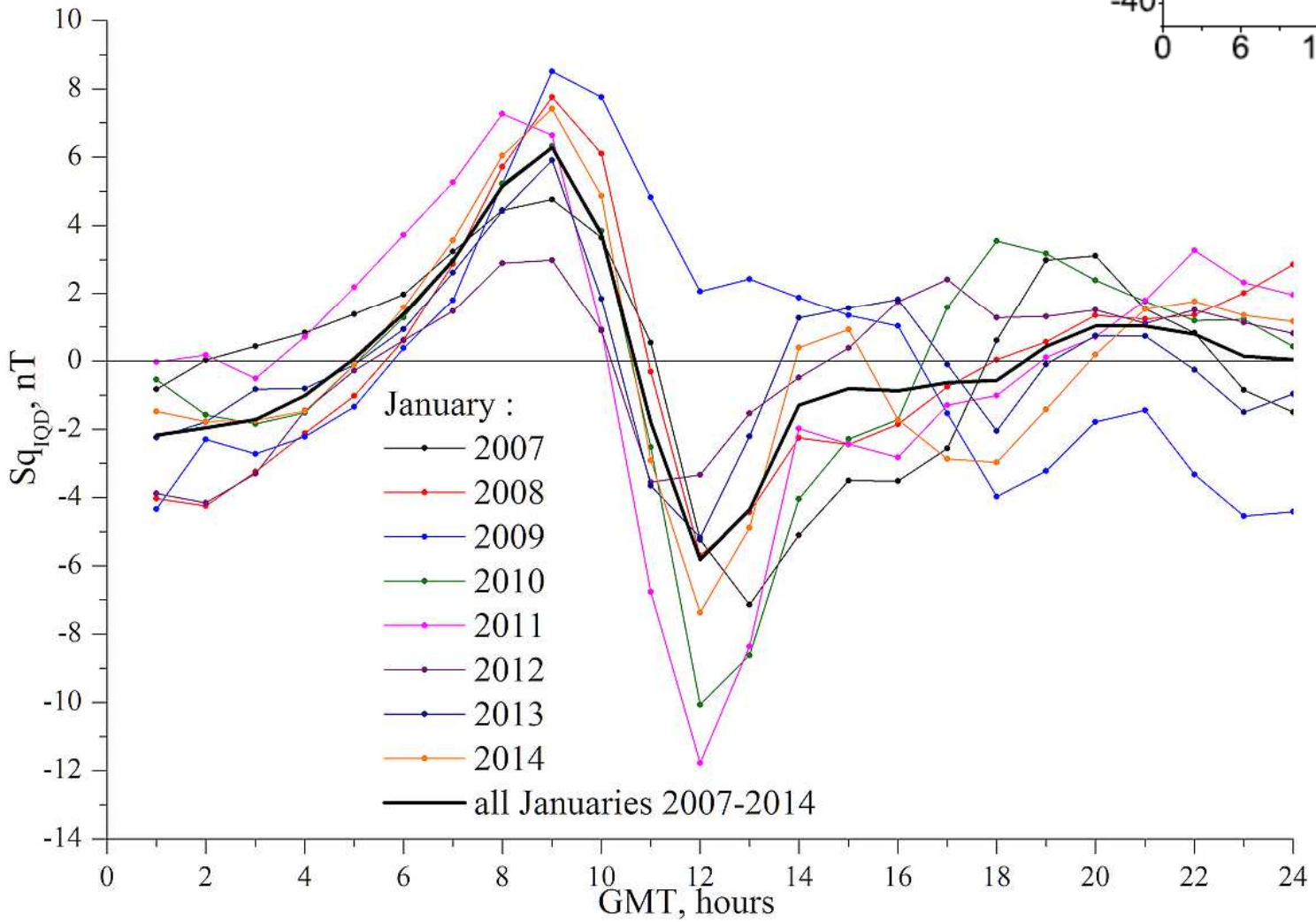
- 2007 -2014
- 1 h series
- interpolated gaps



Methods to calculate Sq

1. Quiet days (Sq_{QD})



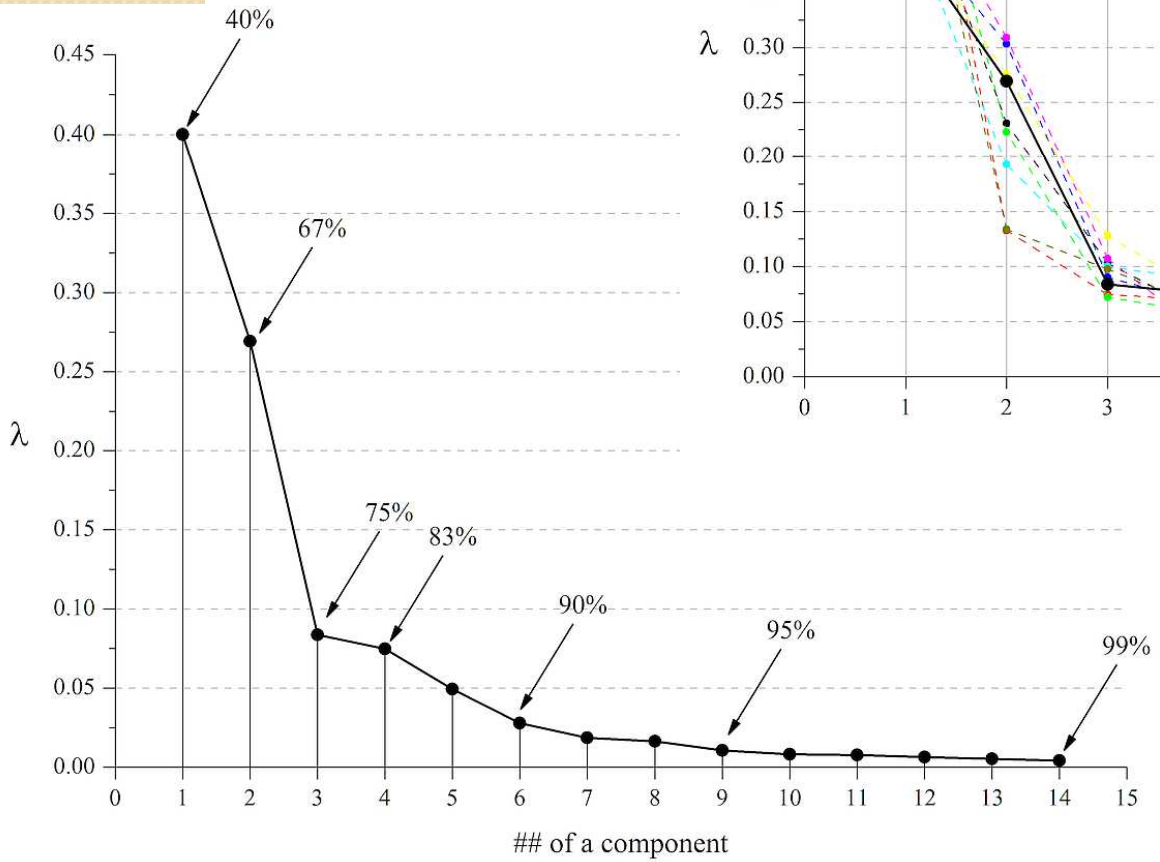


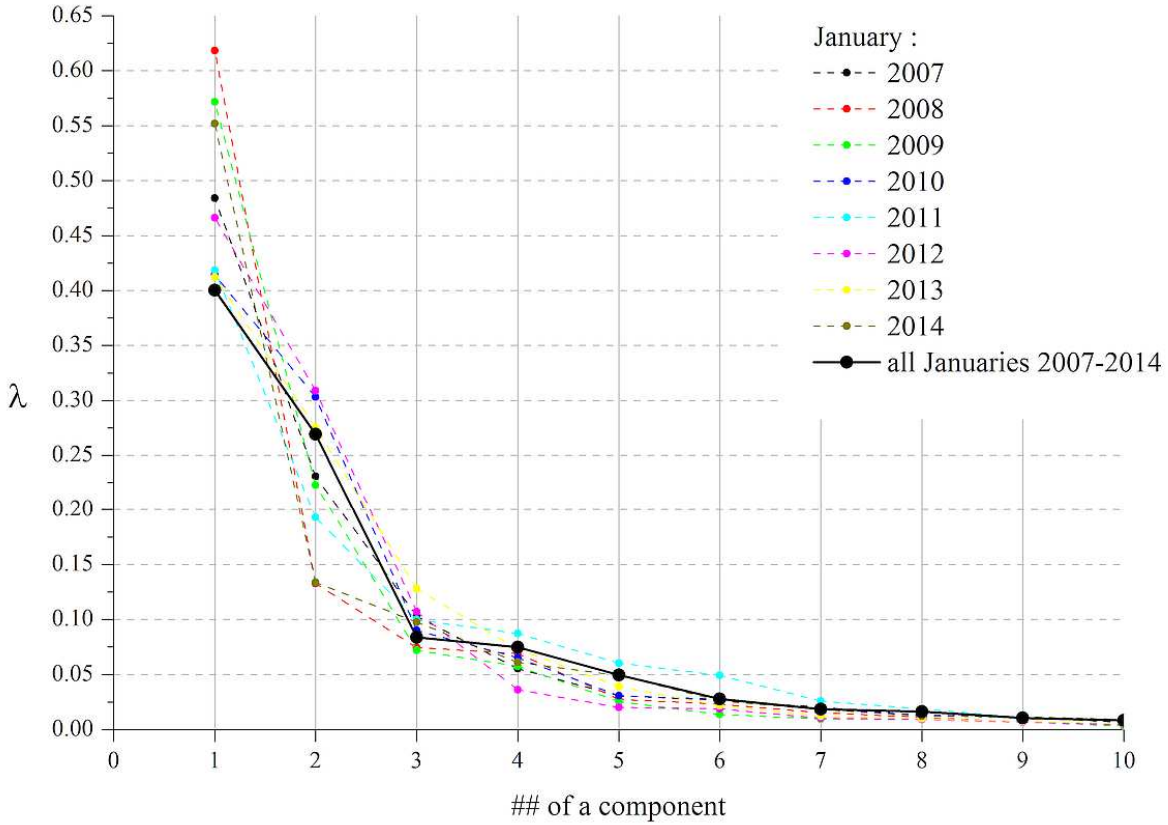
Methods to calculate Sq

2. Principal Component Analysis (Sq_{PCA})

- Input matrix:
  - Rows: hours (1, ..., 24)
  - Columns: days (1 Jan Y1, ..., 31 Jan Y1, 1 Jan Y2, ...31 Jan Y2 etc.)
- Time interval:
  - all Januaries 2007-2014 , together & separately

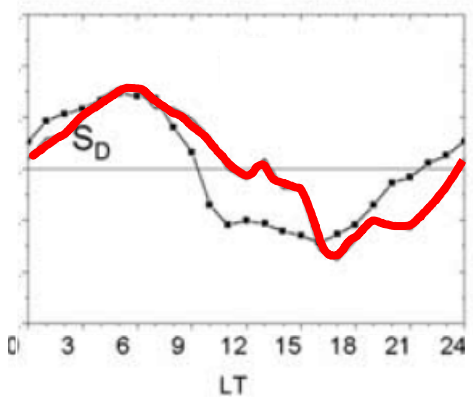
PCA: January - Variance fraction

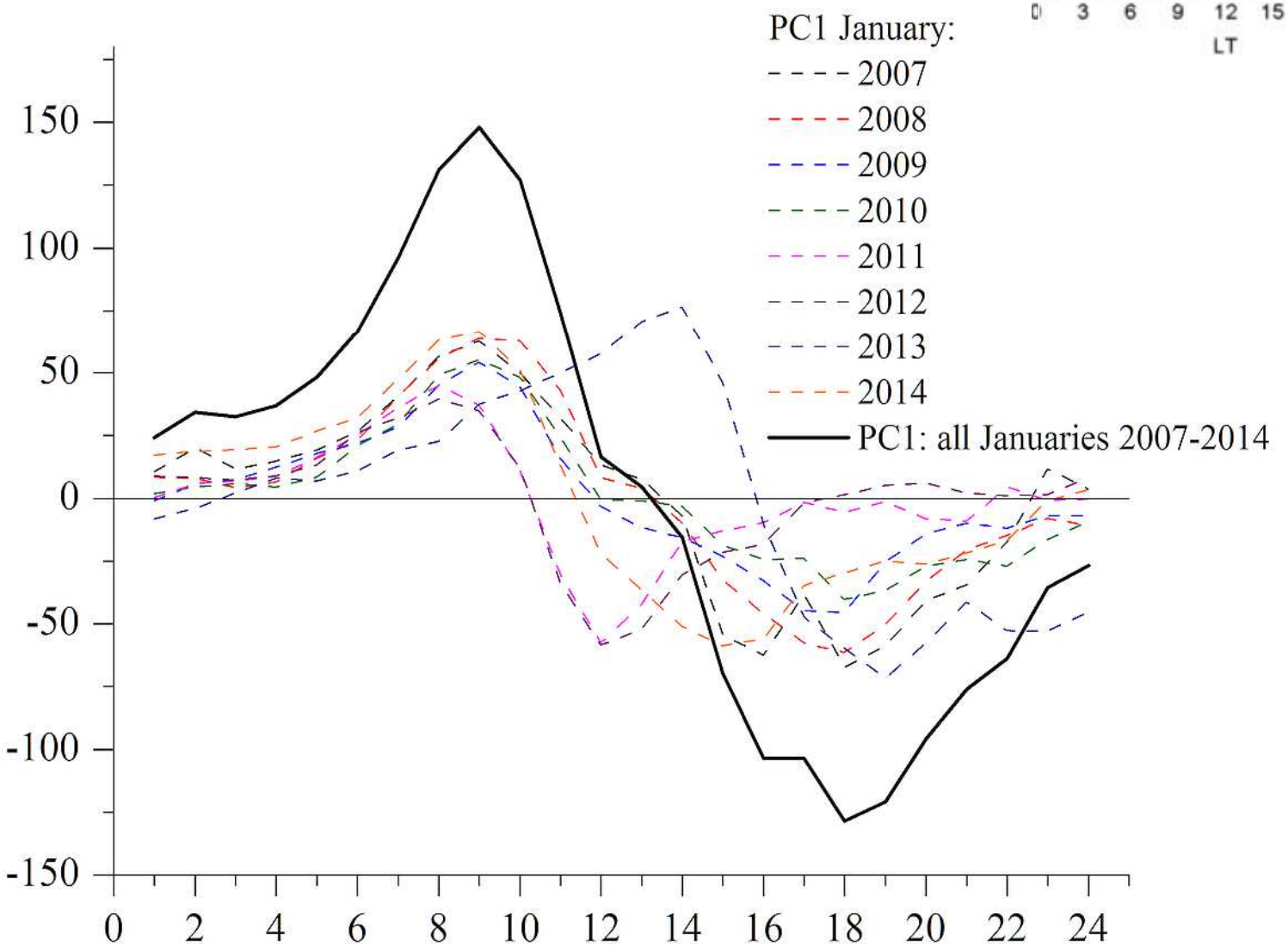




Sq_{PCA}: January

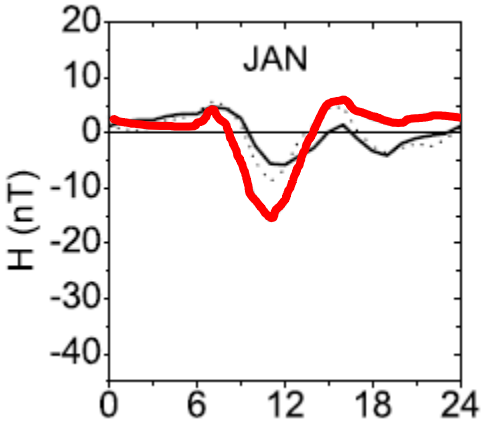
- PC1

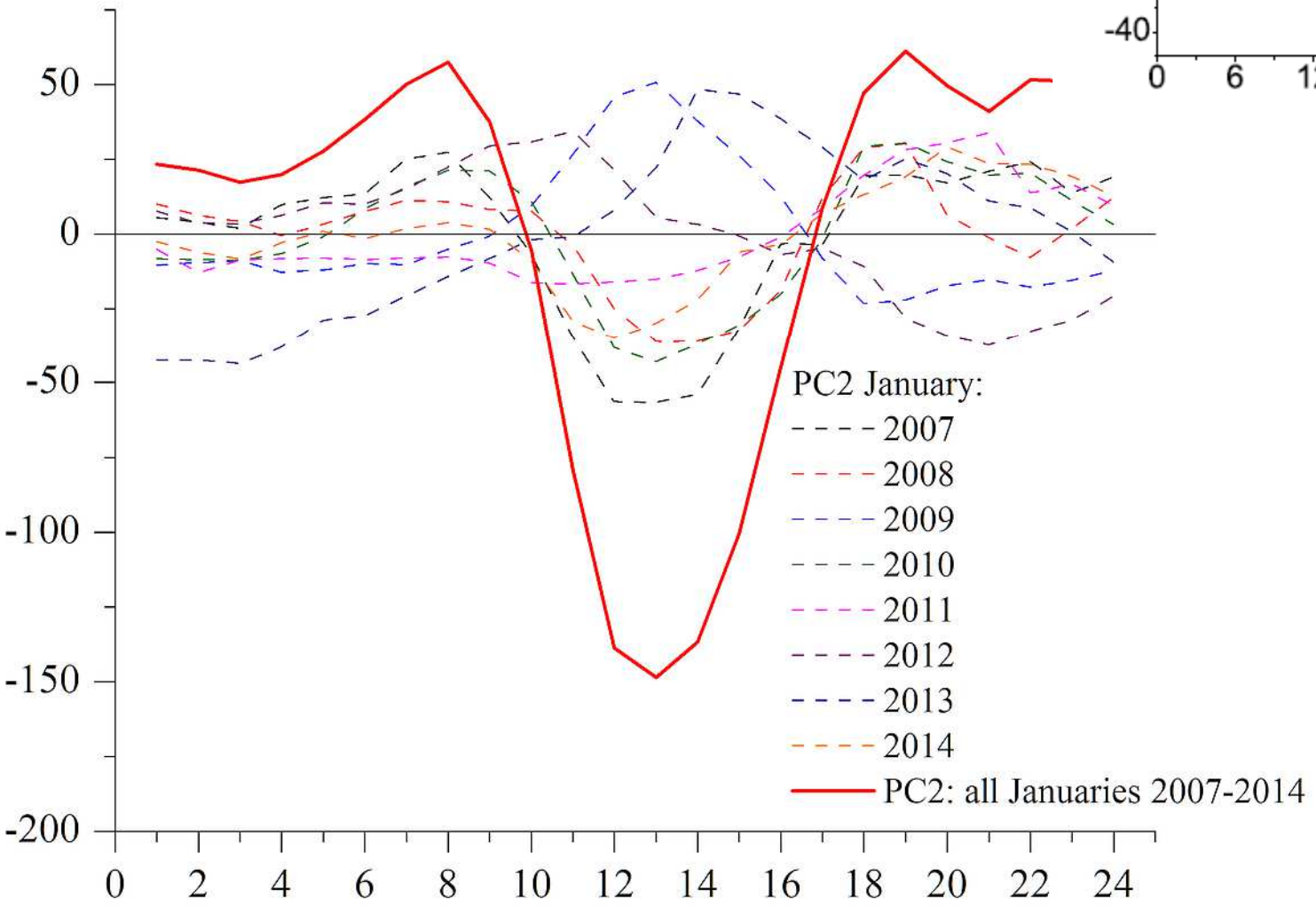




Sq_{PCA}: January

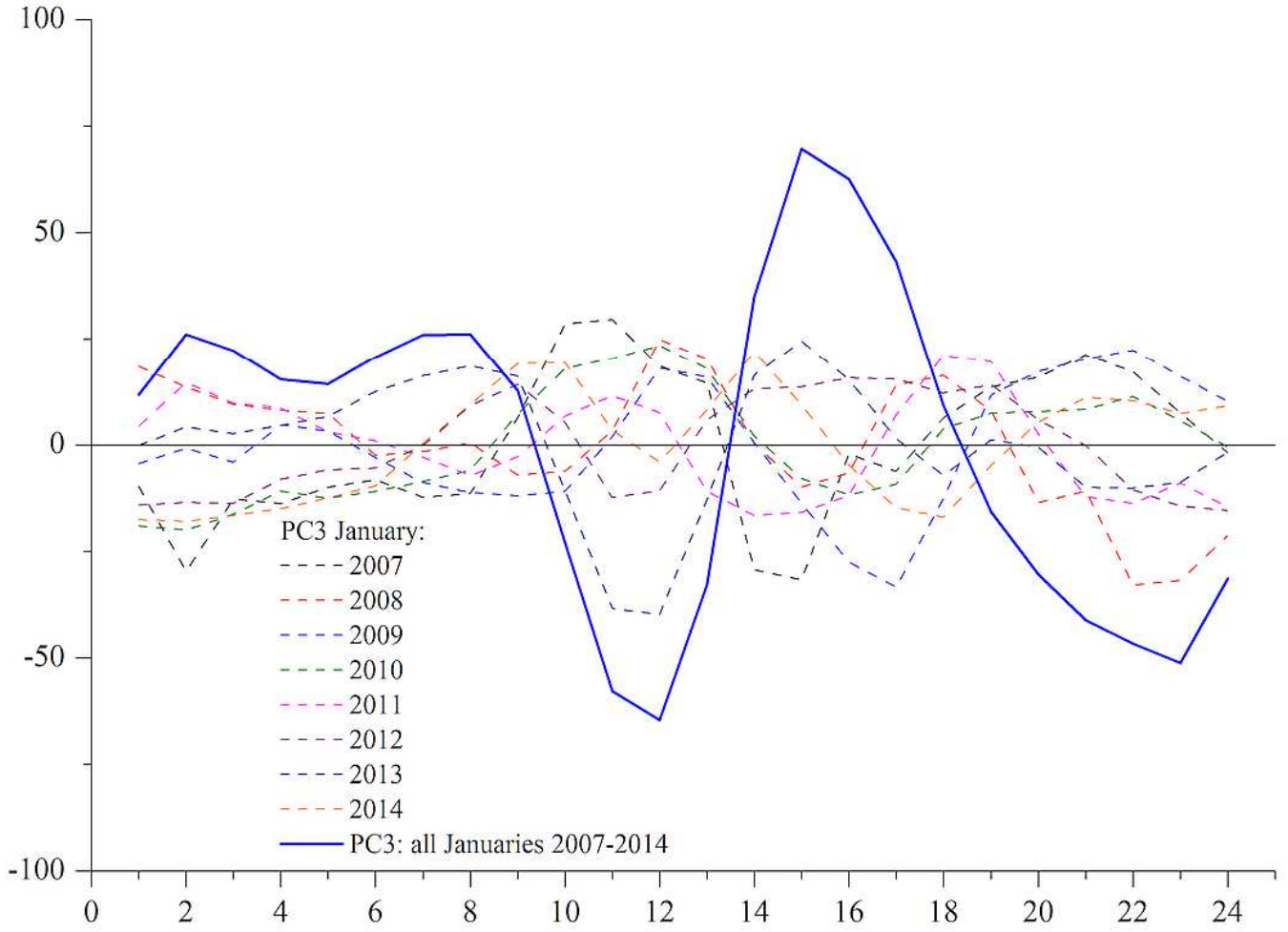
- PC2





Sq_{PCA}: January

- PC3



Sq_{QD} vs PCs: correlation coefficients

	2007	2008	2009	2010	2011	2012	2013	2014	all
PC1	0.34	0.42 (0.12)	**0.62**	0.2	**0.94 (<0.01)**	0.46	0	**0.59 (0.02)**	0.4 (0.1)
PC2	**0.77 (0.05)**	0.47	**0.55**	**0.9 (<0.01)**	0.25	0.3	0	0.41	**0.62 (0.08)**
PC3	0.18	**0.57 (0.06)**	0.31	0.18	0.16	**0.63 (0.02)**	**0.76 (0.02)**	**0.55 (0.1)**	0.18
PC1 + PC2	**0.76 (0.02)**	**0.5 (0.04)**	**0.71**	**0.63 (0.07)**	**0.94 (<0.01)**	0.36	0.11	**0.65 (0.01)**	**0.62 (<0.01)**

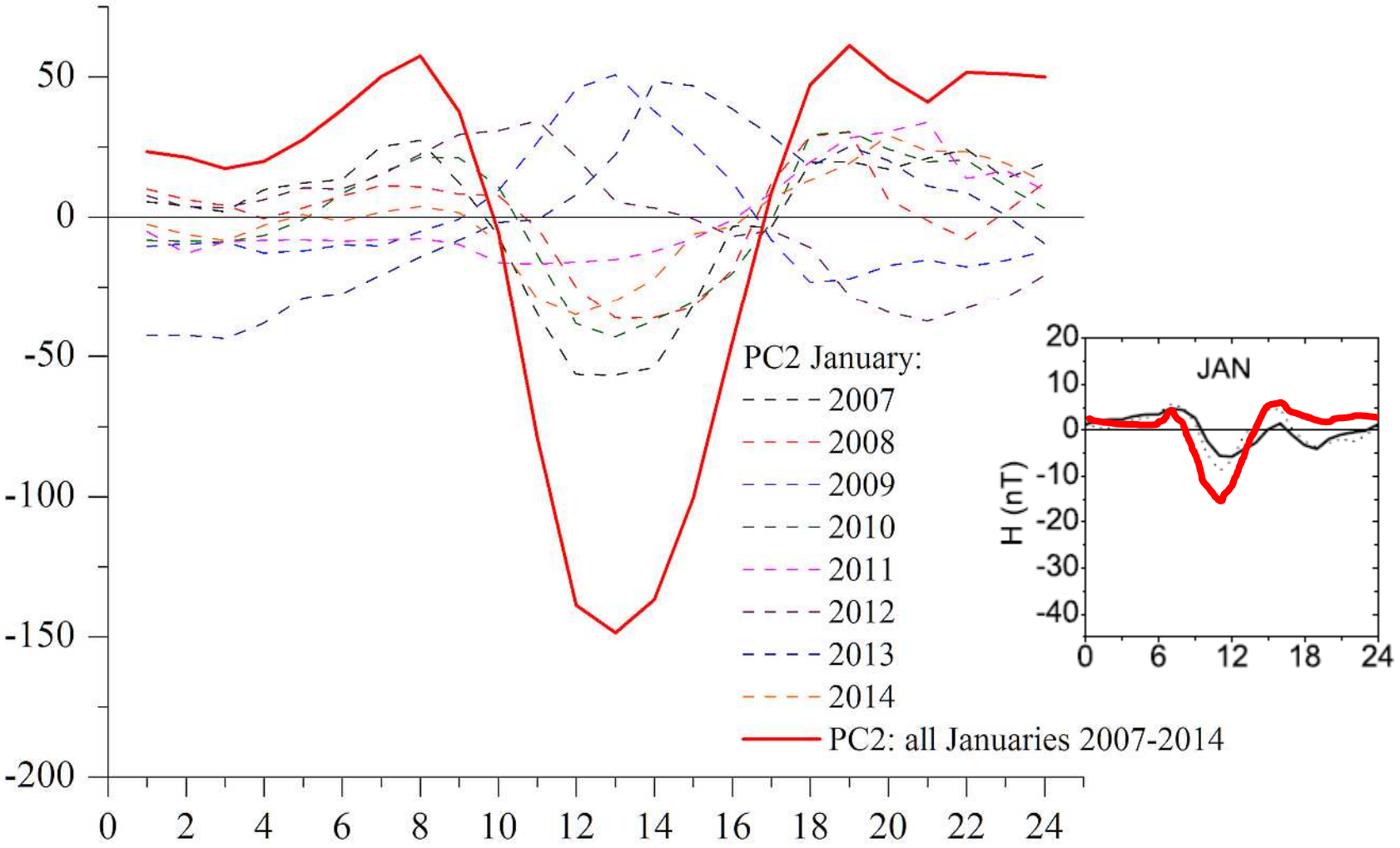
PCA vs QD: preliminary conclusion

- PCA is a good method to extract Sq-type variations
- In most cases (PC1 + PC2) explains 25-88% of the Sq_{QD} variations ($r = 0.5 \div 0.94$)
- For the geomagnetically disturbed time intervals PC3 is needed

- But...

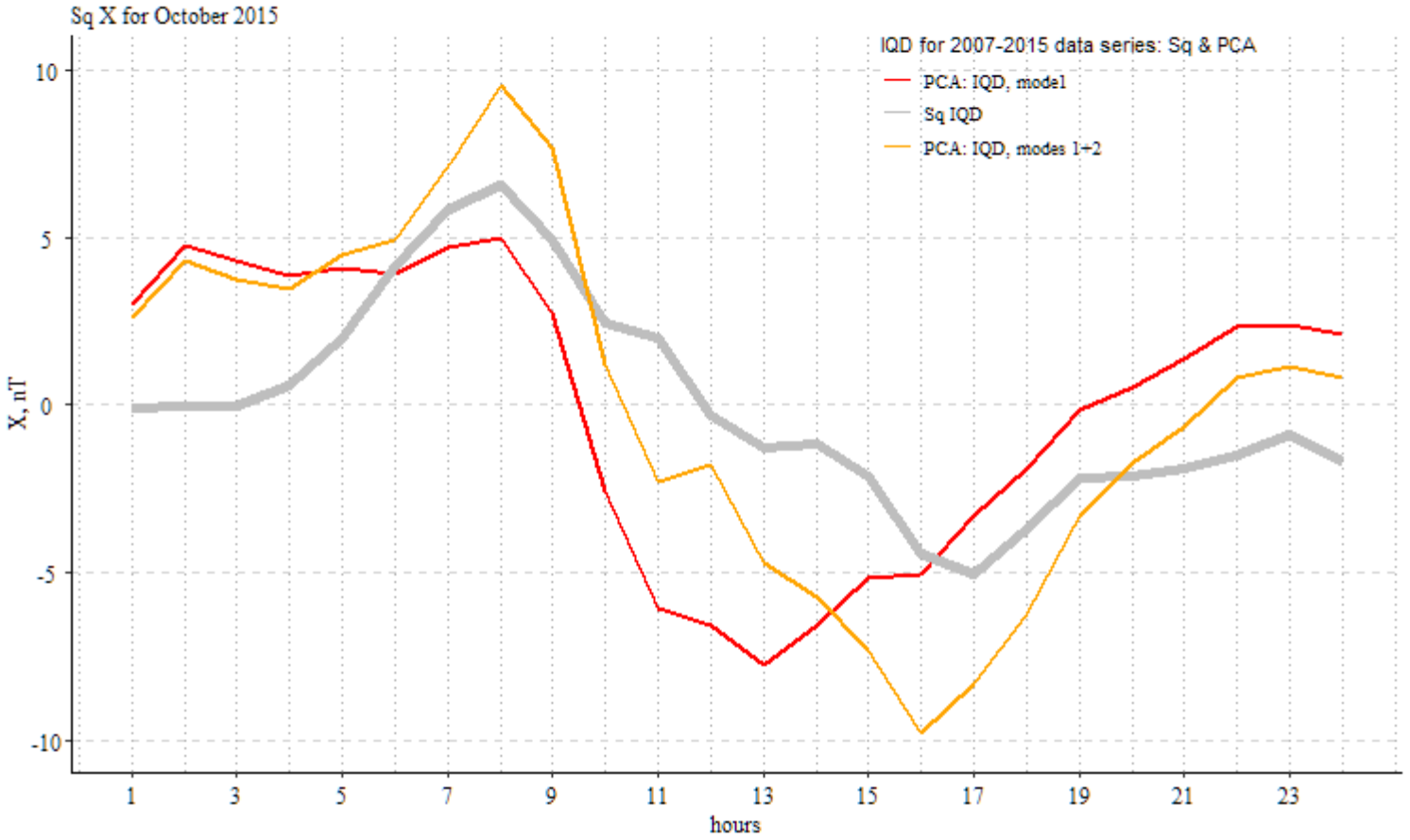
Ionospheric model vs Sq_{PCA}

- PC2 for [8*31 days] ≈ "true" Sq



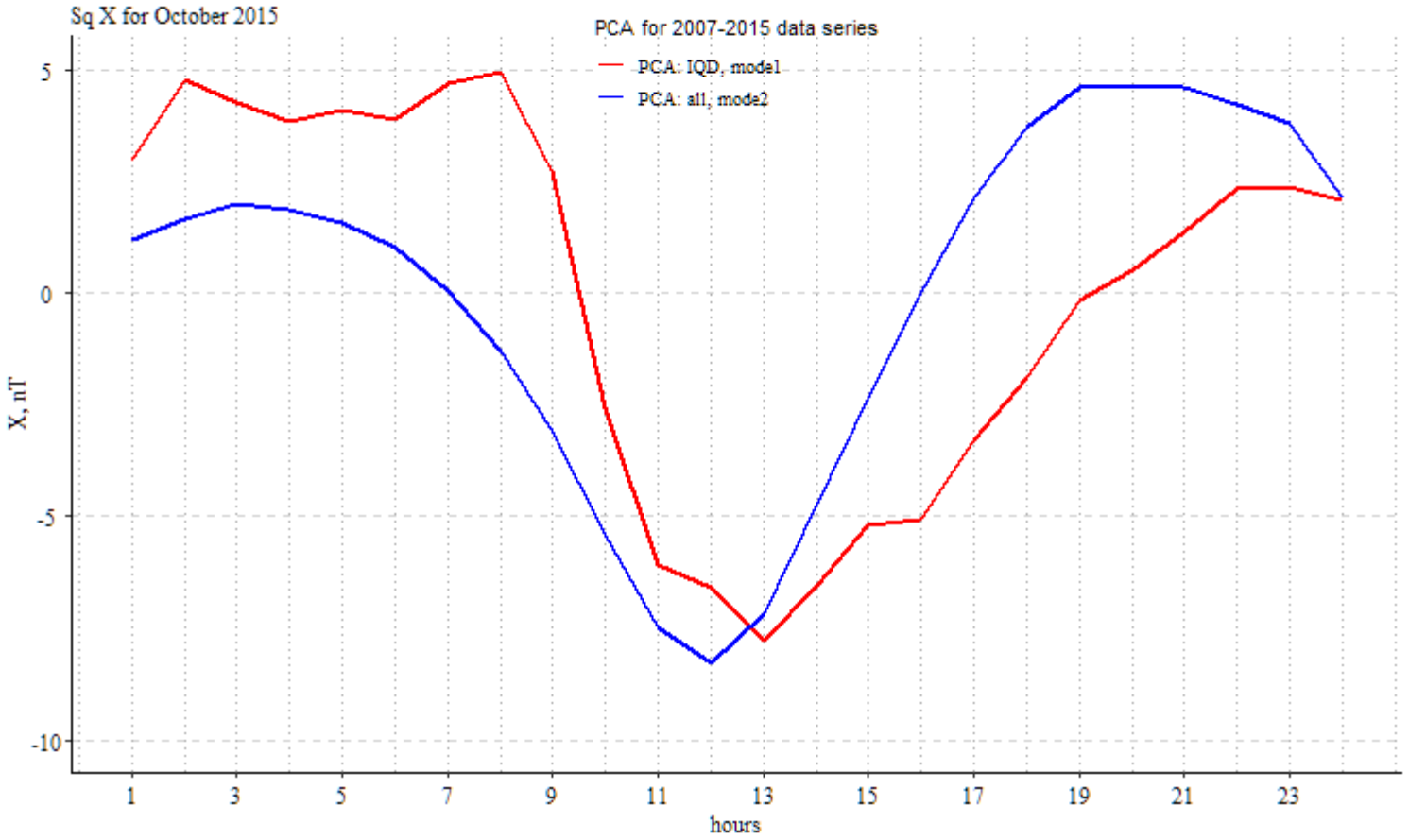
Sq_{IQD} contamination by the disturbance field

- 9 yrs of data
- Only IQD are used (5 days*month) → PCA of IQD
  - Mode 1 – "true" Sq?
  - Mode 2 – "disturbance" contamination? (mode 1 + mode 2 ≈ Sq_{IQD})



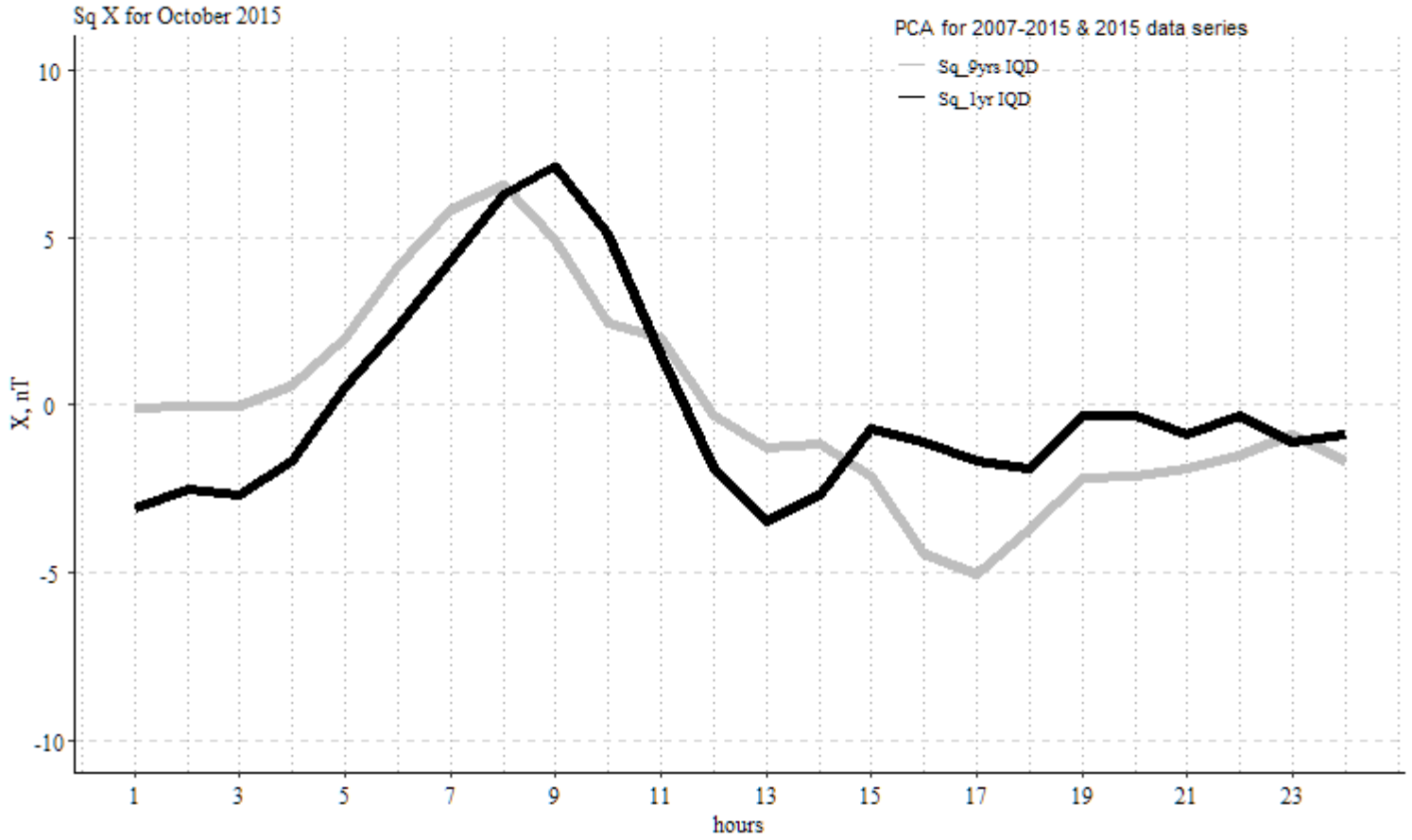
PCA: IQD vs all days

- 9 yrs of data
  - PCA $_{IQD}$ Mode 1 – "true" Sq?
  - PCA $_{all\ days}$ Mode 2 – "true" Sq?
  - They are similar!



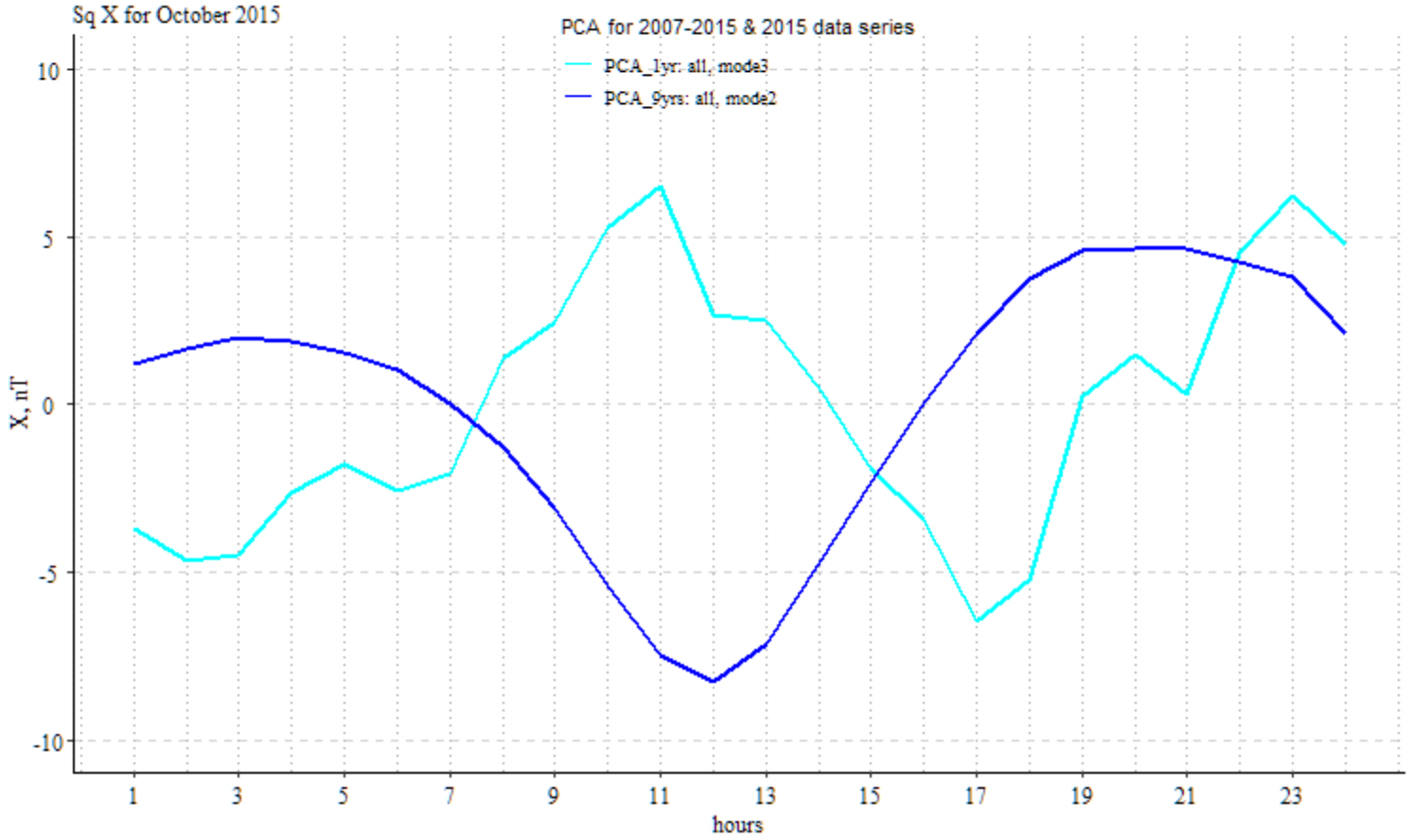
IQD: 1 yr (= 1 month) vs 9 yrs (= 9 x1 month)

- 9 yrs of data
  - Sq – contaminated?
- 1 yr of data
  - Sq – even more contaminated?



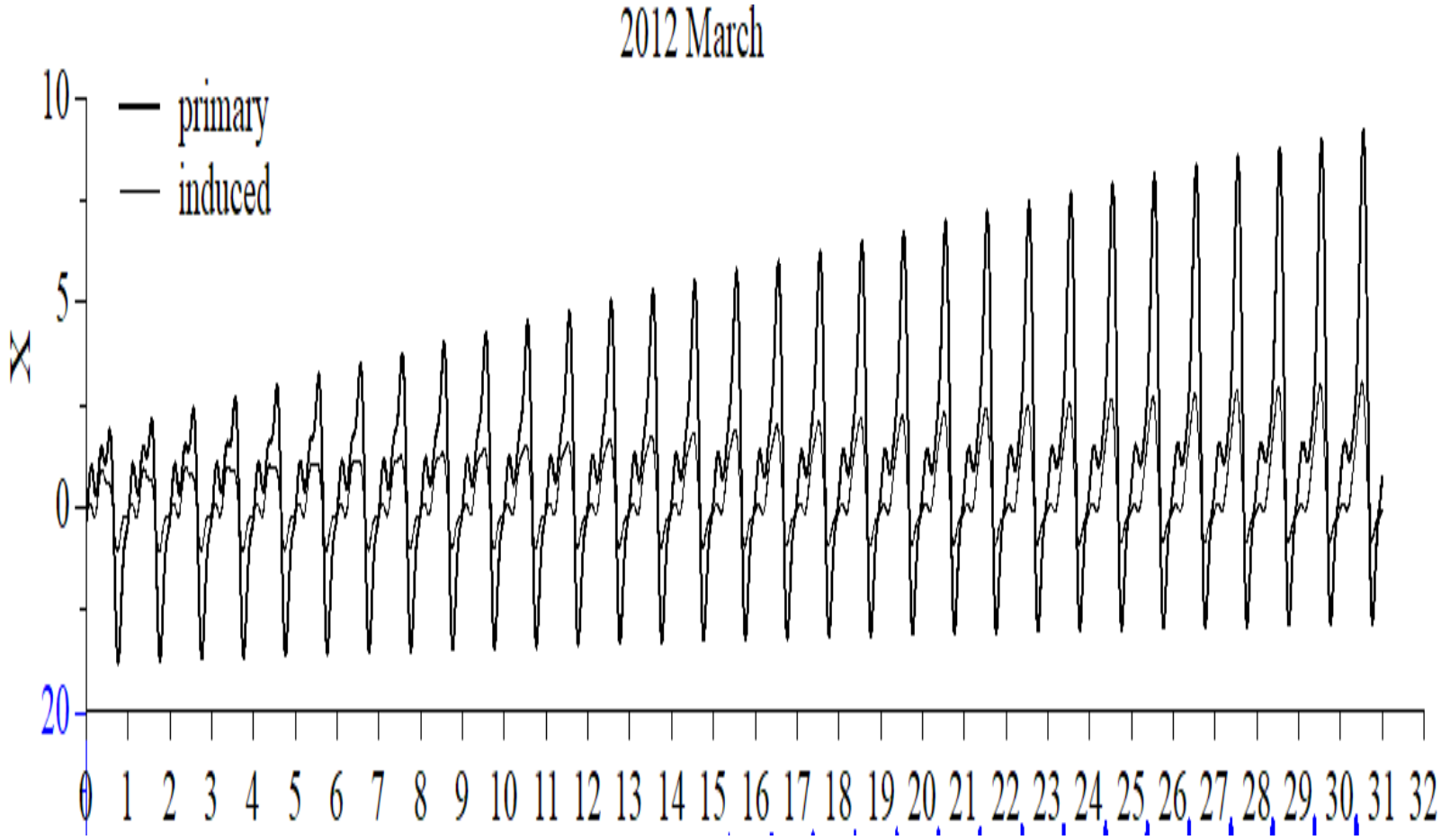
PCA: 1 yr (= 1 month) vs 9 yrs (= 9 x1 month)

- 9 yrs of data
  - PCA $_{\text{all days}}$ Mode 2 – "Sq"?
- 1 yr of data
  - PCA $_{\text{all days}}$ Mode 3 – "contaminated Sq"?



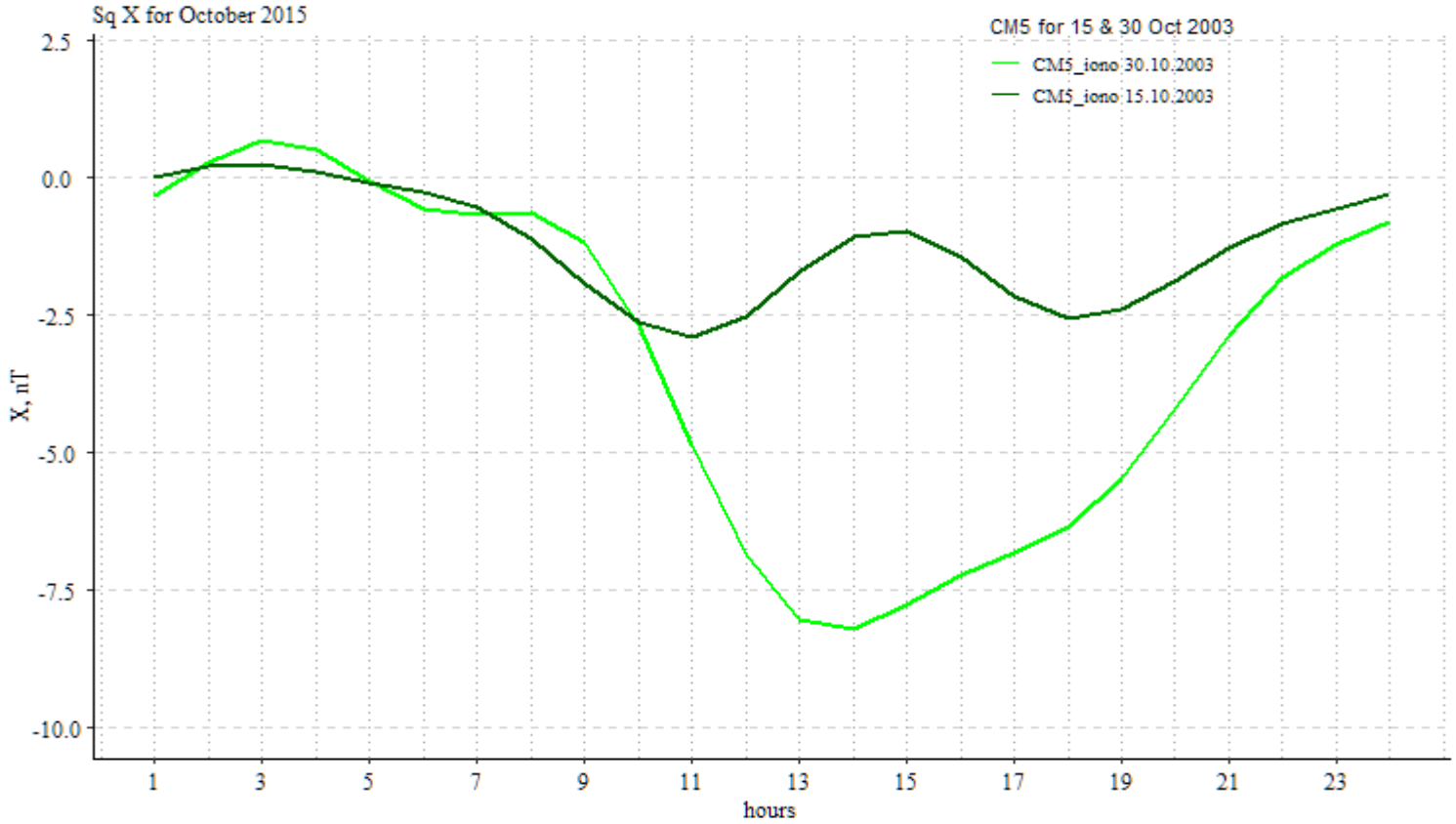
How to test if a signal is “Sq”?

- Simulations???
- CM5 model: Primary & Induced ionospheric filed - seasonal variations



How to test if a signal is "Sq"?

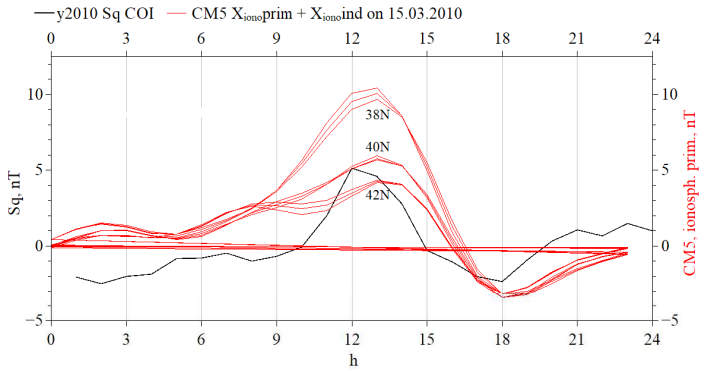
- CM5 model: Primary & Induced ionospheric filed - seasonal variations
  - Harmonics (6, 8, 12, 24 h)
  - Annual + semi-annual modulation
  - Solar activity – scaling only!

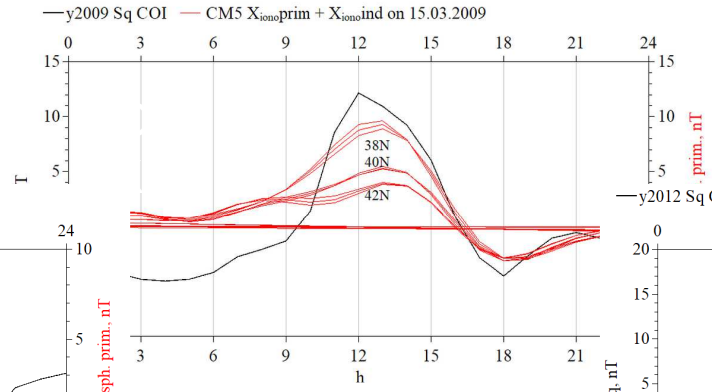


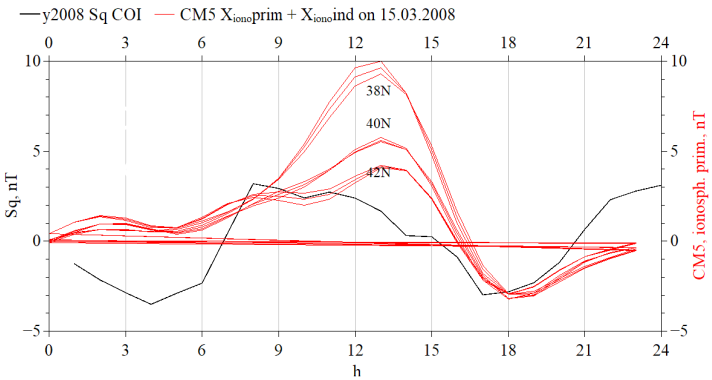
Ionospheric model vs Sq_{QD}

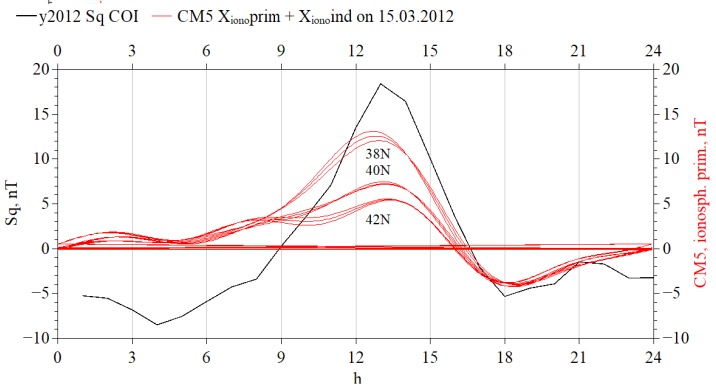
CM5 is an empirical inverse model derived from pre-Swarm satellite data & ground observatory data from August 2000 to January 2013.

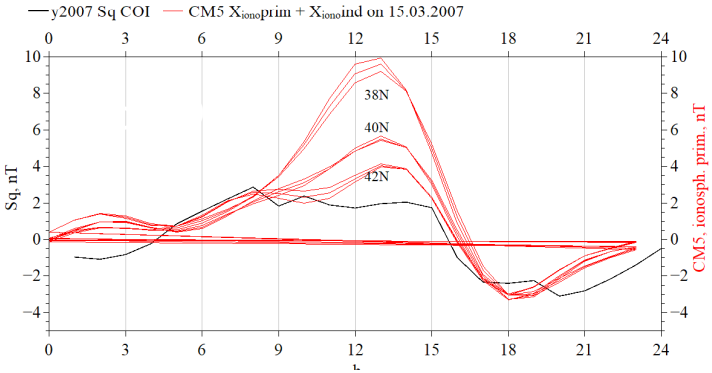
Sq contaminated by Dst











March, 2007 - 2012