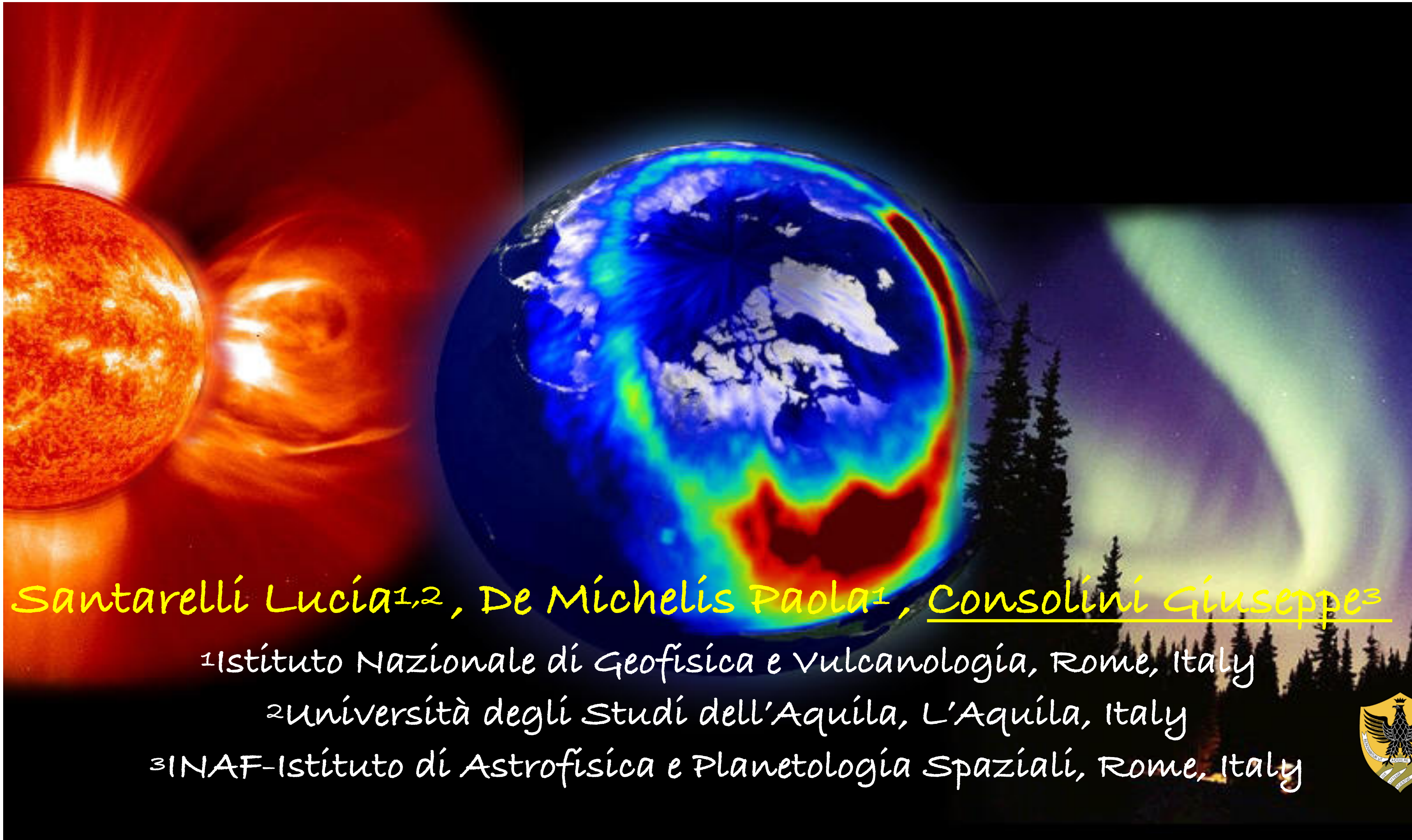
Characterization of the geomagnetic field fluctuations during St. Patrick's Day Storm



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AIM

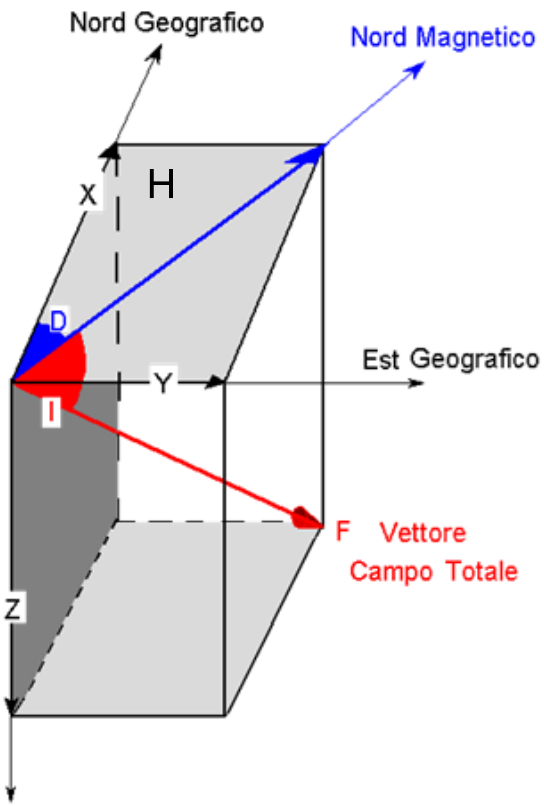
To characterize the spatial distribution of the short time scale magnetic field fluctuations recorded on the ground during the St Patrick's day geomagnetic storm occurred on 17 March 2015.

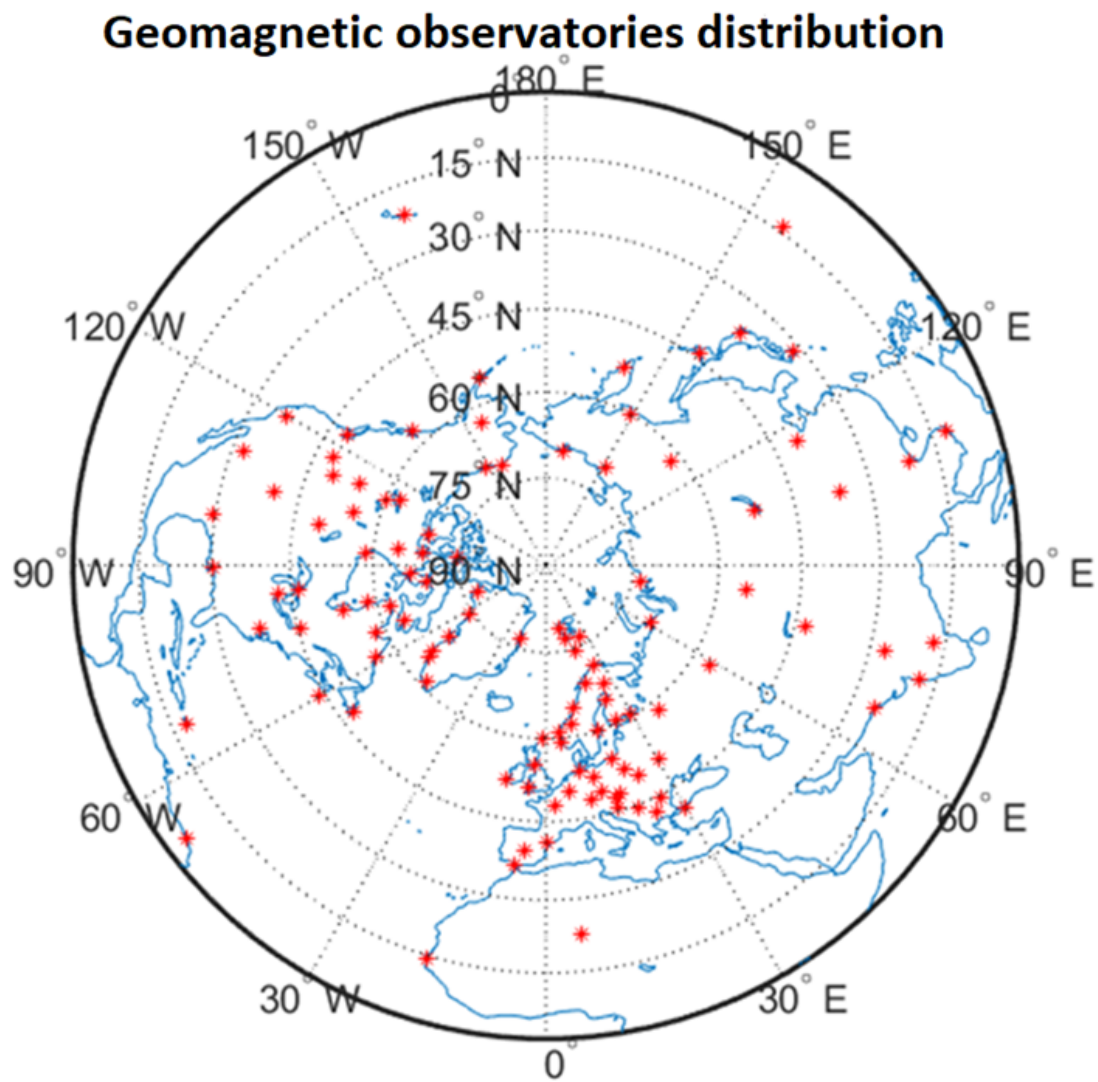
We apply EMD method, that permits us to separate **short-timescale/fast** (τ < 200 min) and **long-timescale/slow** (τ > 200 min) magnetic fluctuations, in order to better investigate the different magnetospheric processes: those mainly directly driven from the solar and interplanetary parameters and those mainly due to internal magnetospheric dynamics although triggered by interplanetary changes.

DATA SET: Ground-based geomagnetic observatories distributed in the Northern Hemisphere

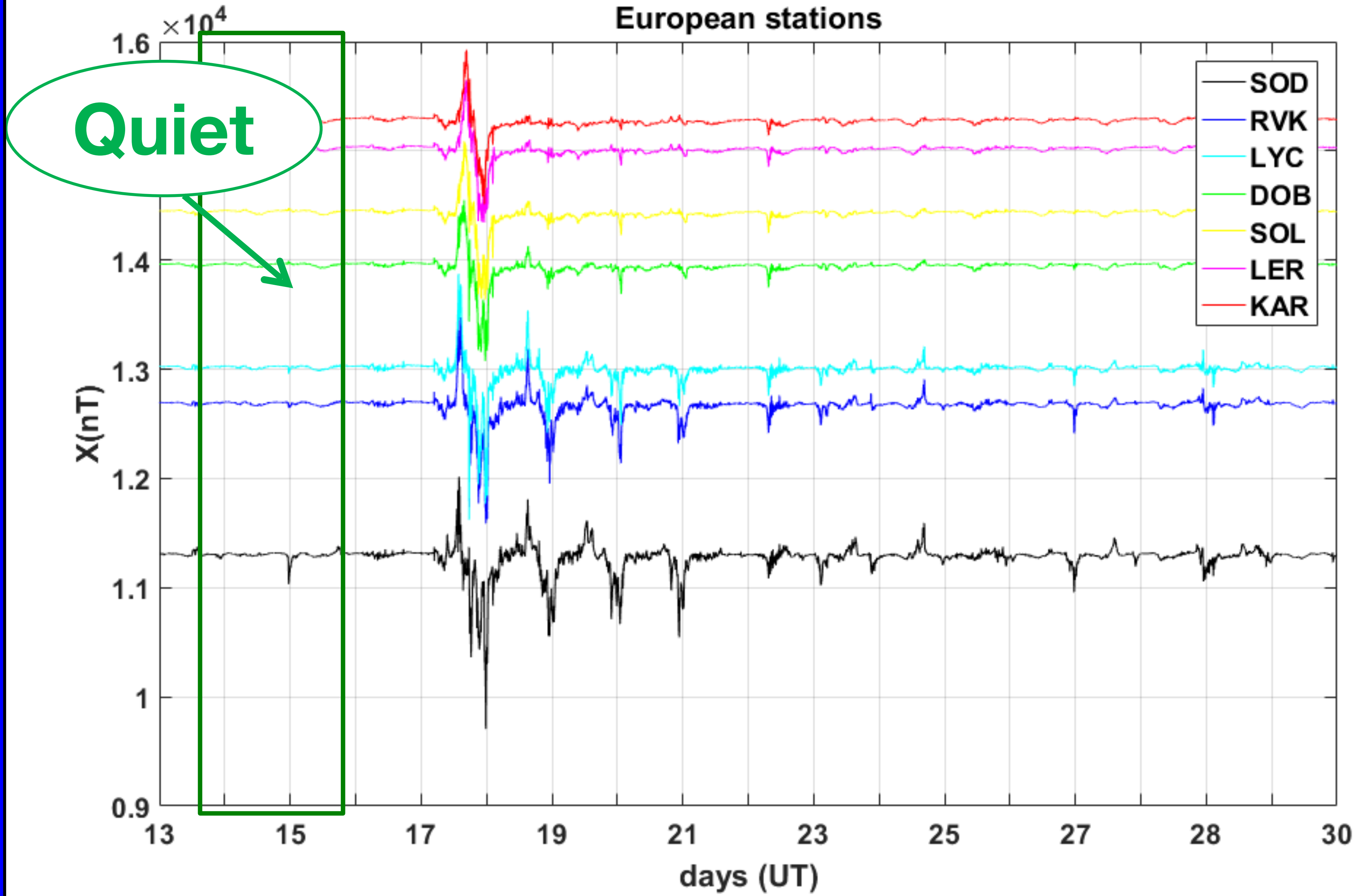
~ 80 Intermagnet stations (X,Y,Z)
~ 30 Supermag stations (H,D,Z)

Period: 13 - 30 marzo 2015





Example of dataset characterized by different levels of geomagnetic activity



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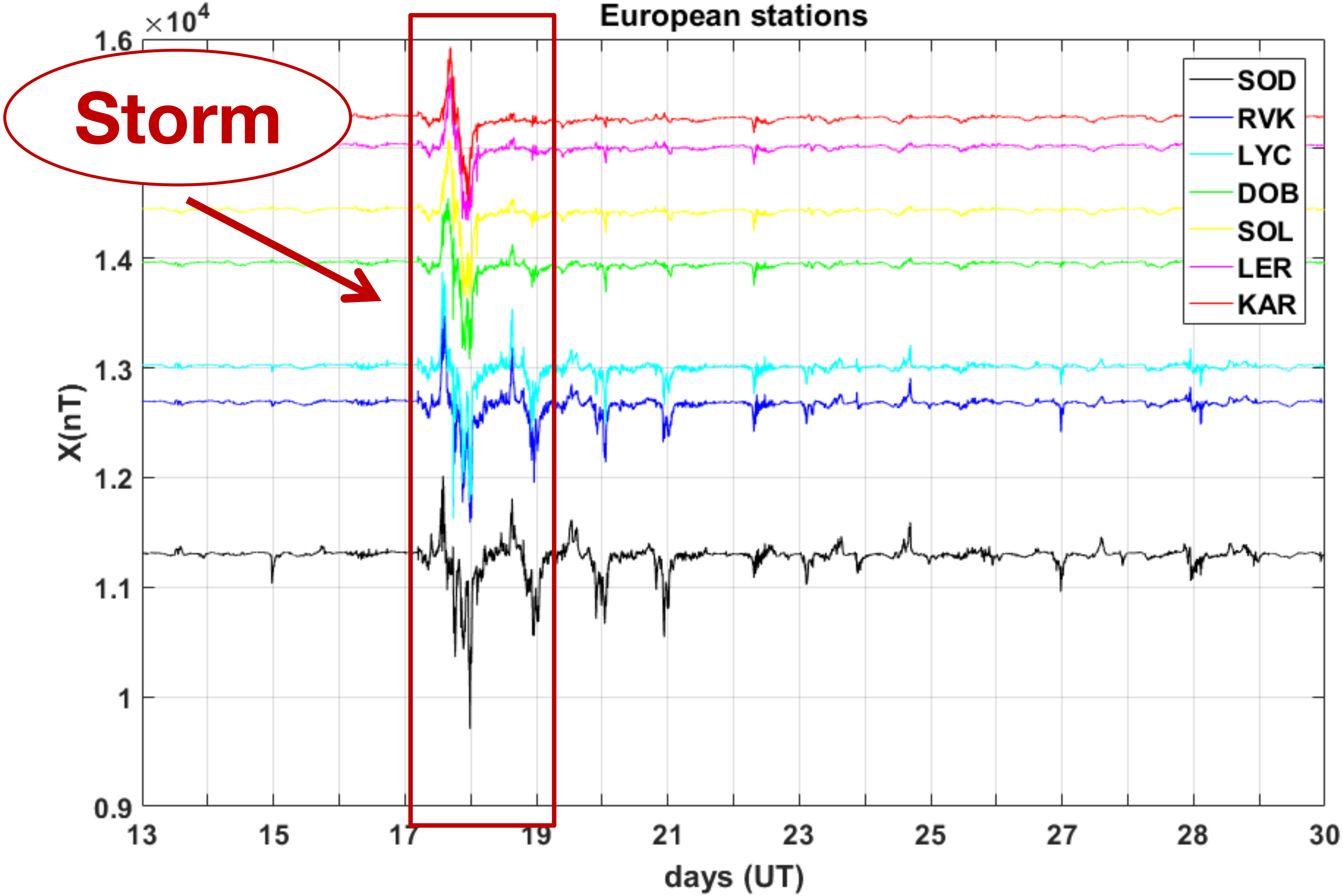
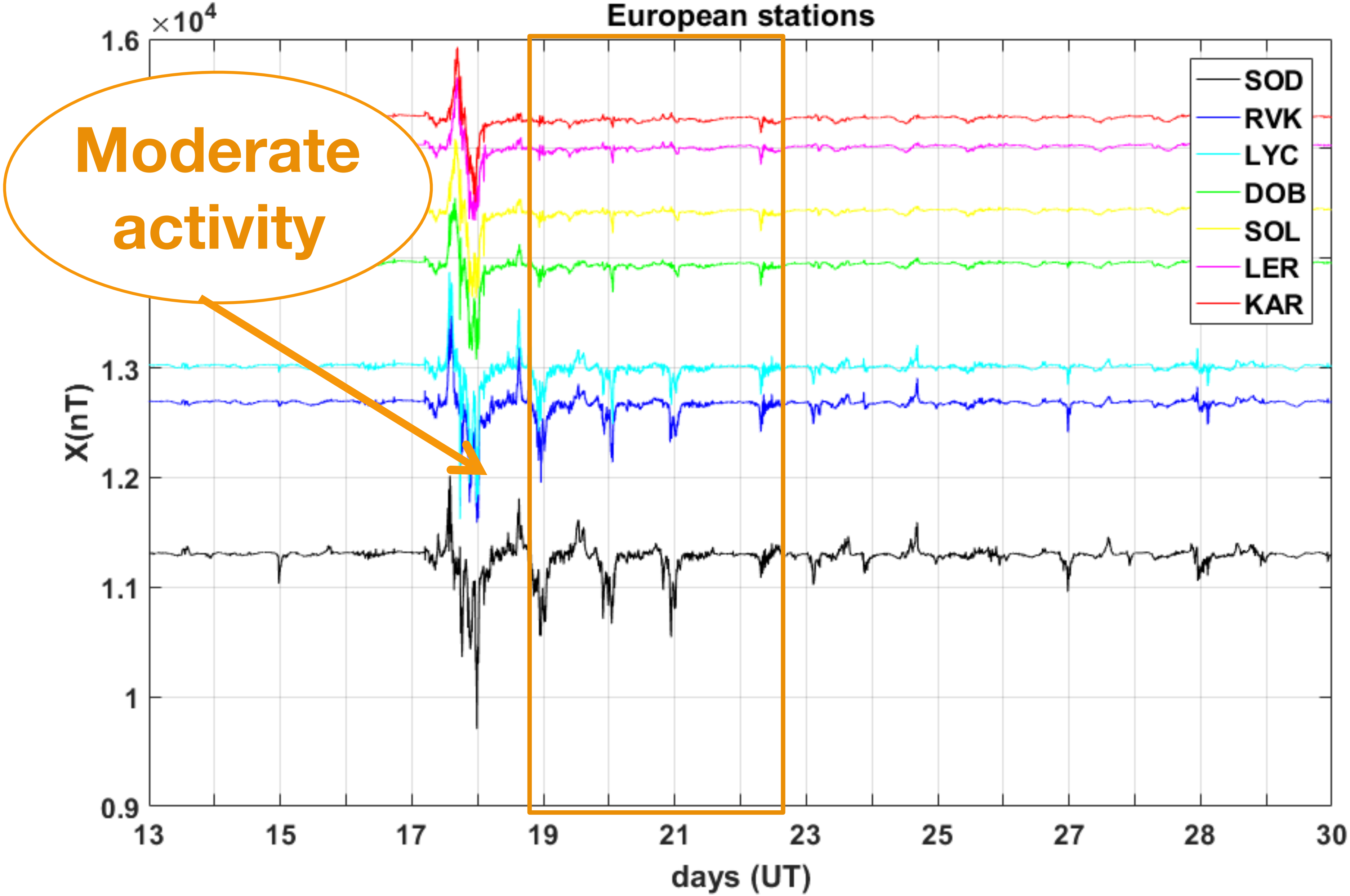
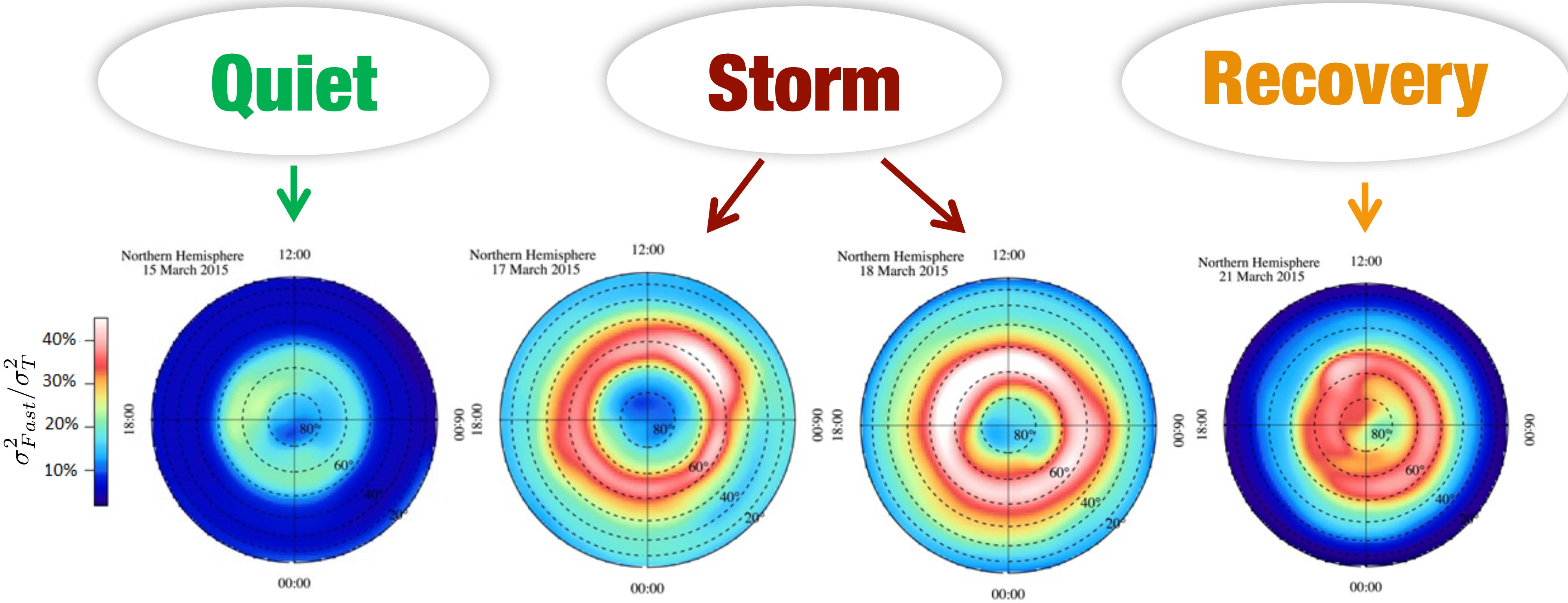


Example of dataset characterized by different levels of geomagnetic activity



Results

An example of the spatial distribution of the short-timescale fluctuations (in terms of variance, i.e., associated energy) of the Y geomagnetic field component during the selected period.



Main Results

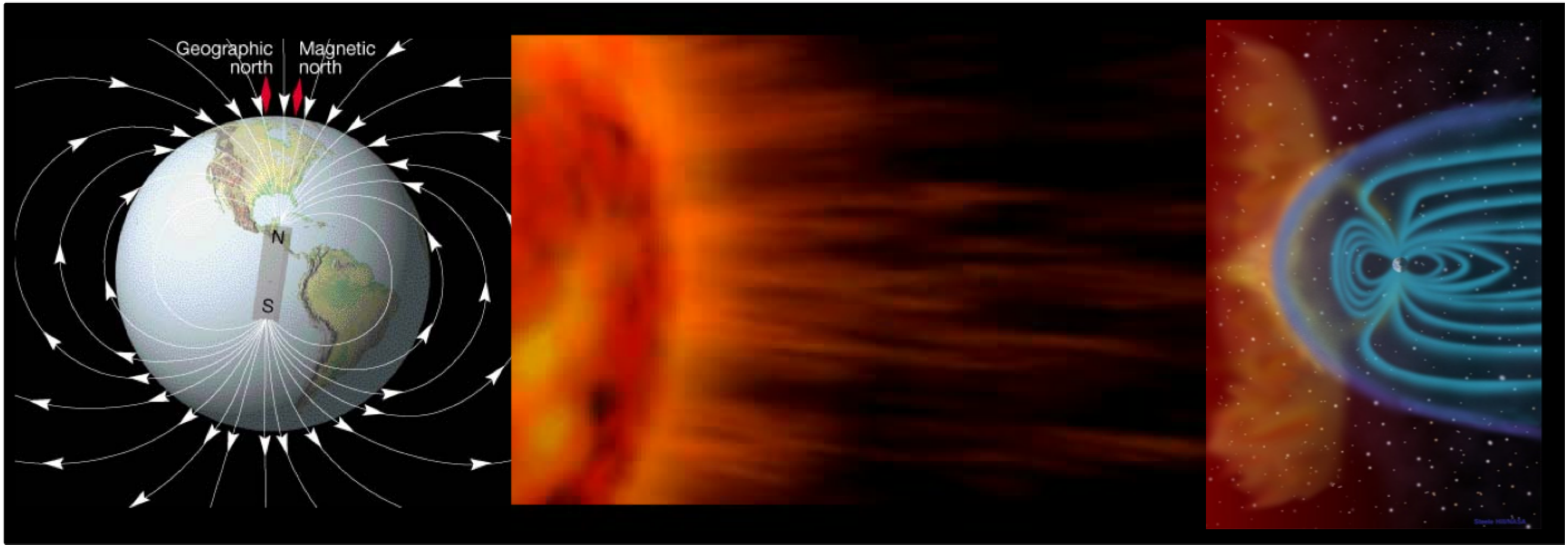
Our main results are:

At short timescales (τ <200 min) the magnetic field fluctuations, that are essentially related to internal magnetospheric processes, play a fundamental role in the total recorded signal.

The weight of the signal related to the fluctuations on short-timescales can contribute to the total signal until 40%. It depends on the latitude and geomagnetic activity level.

AIM

Analysis of the geomagnetic field fluctuations during a period characterized by different levels of geomagnetic activity (St. Patrick’s Day Storm) with particular attention to the characterization of the multiscale nature of these fluctuations.



Context – Recent studies

The dynamics of the Earth's magnetosphere in response to changes in solar wind conditions and the interplanetary magnetic field during a magnetic storm and under-storm is the result of both externally driven processes and internal processes. Recent studies (Alberti et al., 2017) have highlighted the existence of a significant separation of timescales in the solar wind-magnetosphere coupling which occurs at approx. 200 minutes and in particular:

➢Long time fluctuations ($T > 200$ min) show a high degree of correlation with the parameters of solar wind and magnetospheric dynamics

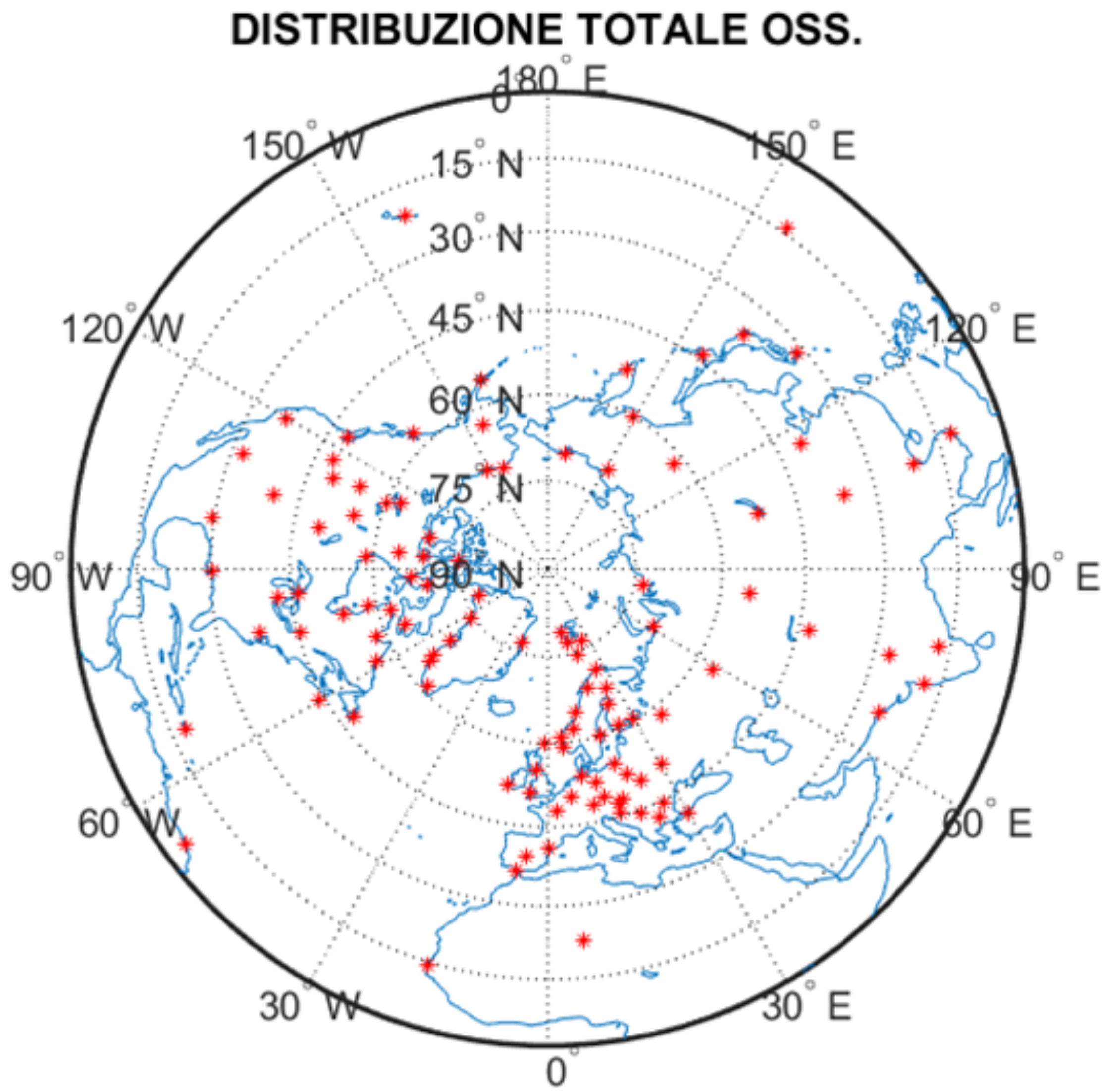
➢Fluctuations with time-scale $T < 200$ min, although triggered by changes in interplanetary conditions, are mainly dominated by internal processes and are not directly driven (correlated) by the SW/IMF.

The identification in a magnetic signal of the contribution related both to the external variability of the SW and to the internal magnetosphere dynamics is important in the framework of Space Weather.

How is it possible to study the magnetospheric dynamics in response to changes in the solar wind and the conditions of the interplanetary magnetic field, as result of both externally driven processes and internal processes, using the measurements of the Earth's magnetic field?

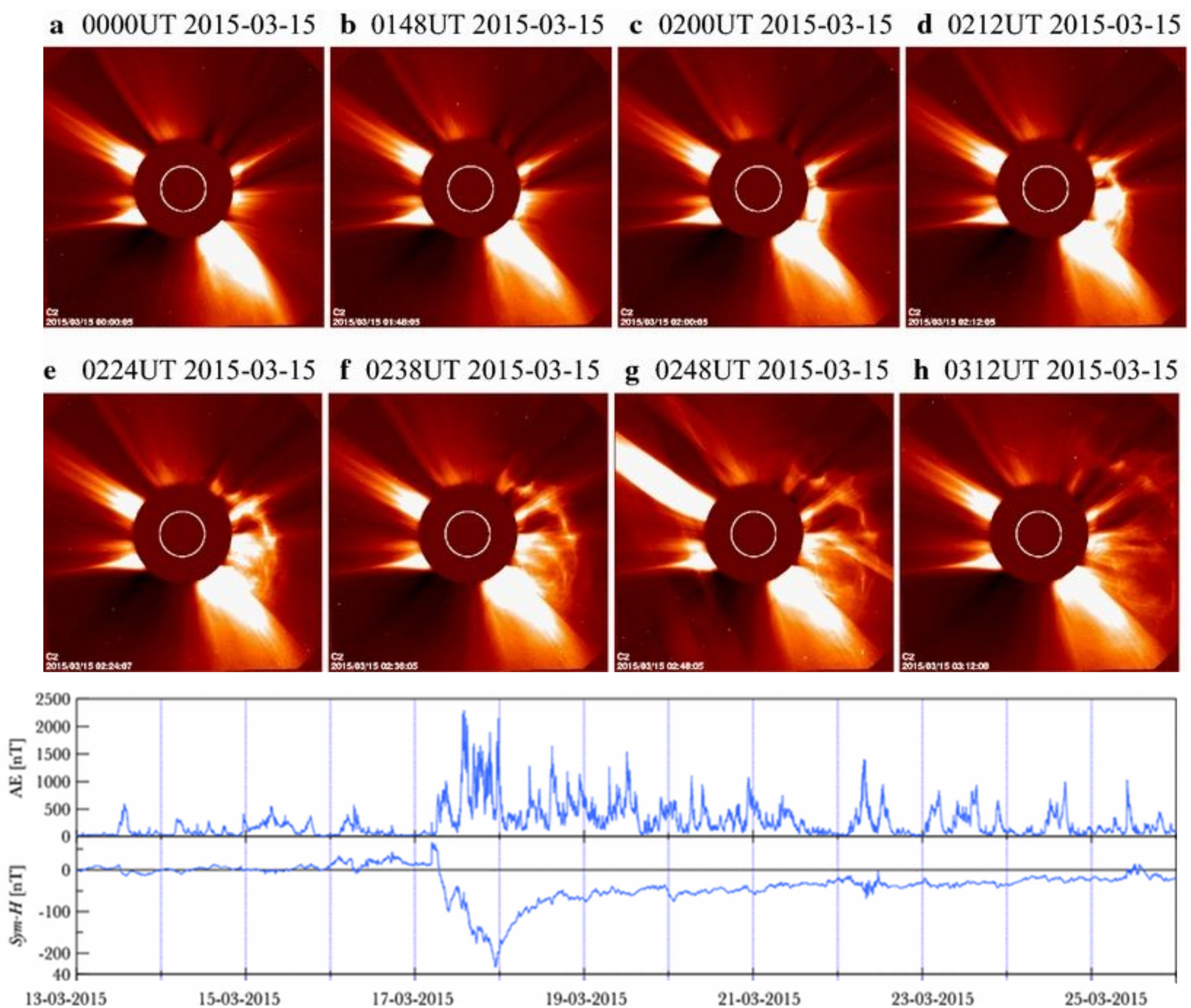
Context

A contribution to understanding the dynamics of the magnetosphere can come from the study of magnetic field fluctuations in periods of different geomagnetic activity recorded by geomagnetic observatories located to different latitudes and longitudinally distributed.

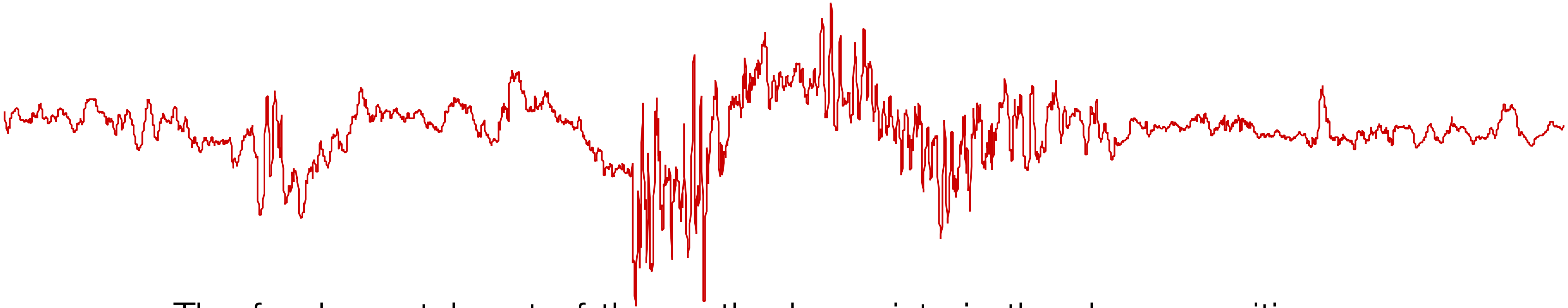


St. Patrick's day storm: 17/03/2015 – 19/03/2015

- ➢ The most intense storm of cycle n.24
- ➢ Origin: CME at 02:00-02:30UT on 15/03/2015.
- ➢ Duration:~18 hours (G3/G4 conditions for 12 hours)
- ➢ High latitude variation: AE~2400nT
- ➢ Medium latitude variation Sym-H: -234 nT.



Empirical mode decomposition (EMD)

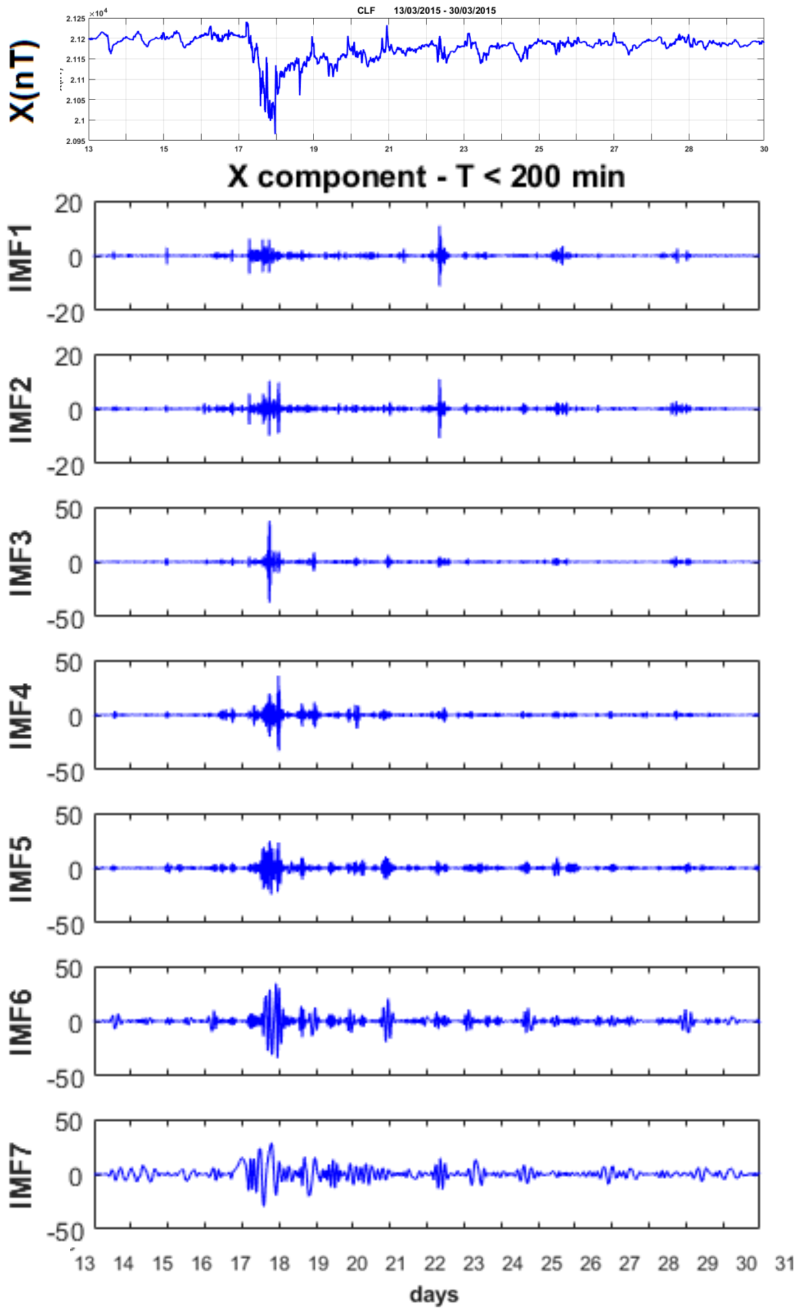


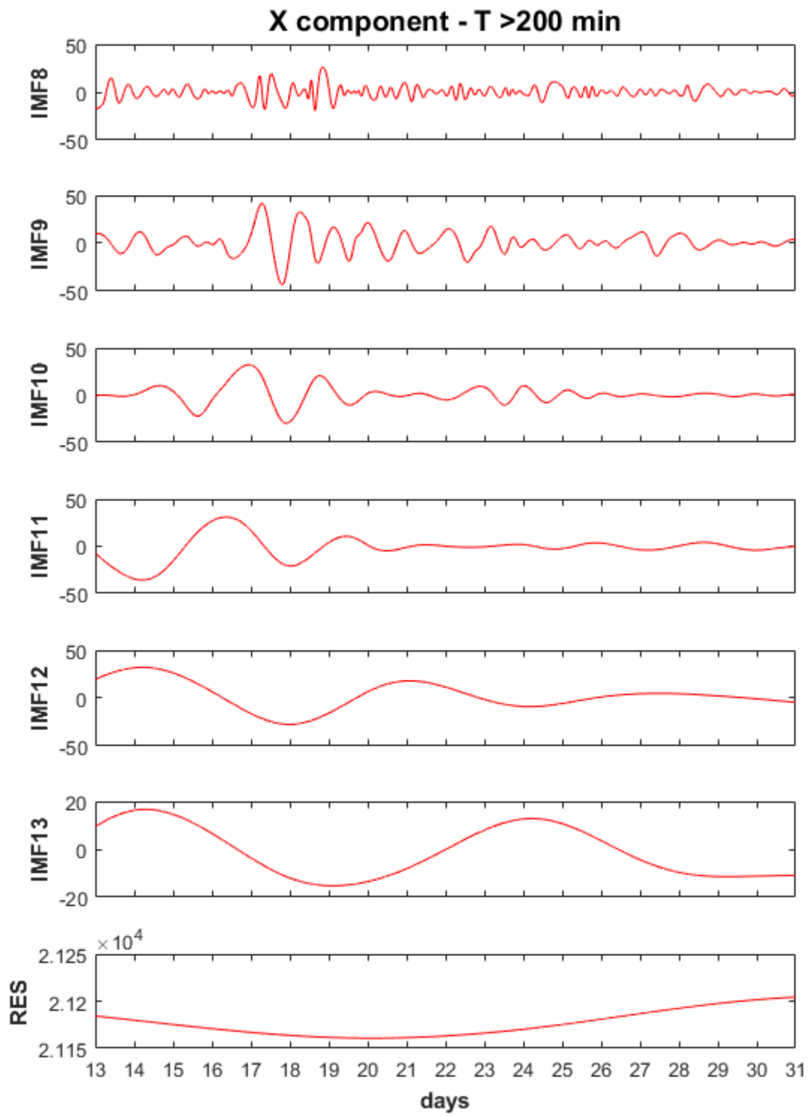
The fundamental part of the method consists in the decomposition of the signal in empirical modes based on the assumption that any signal can be decomposed into a finite and limited number of intrinsic modes (IMF) of oscillation characterized by significantly different frequency values.

$$H(t) = \sum_{i=0}^{n} IMF(t) + residue$$

EMD: an example

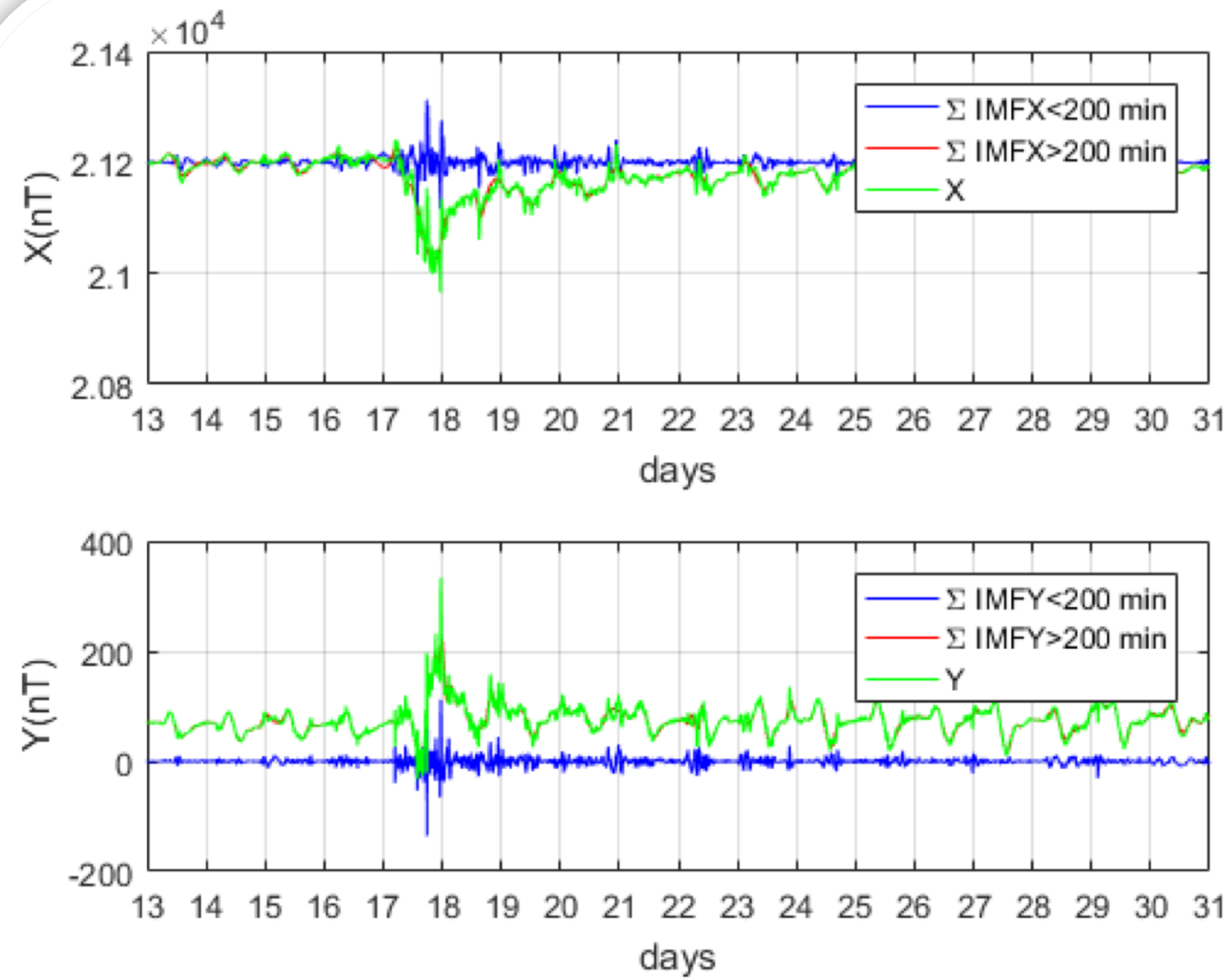
$$x(t) = \sum_{i=1}^{n} IMF_n(t) + res$$



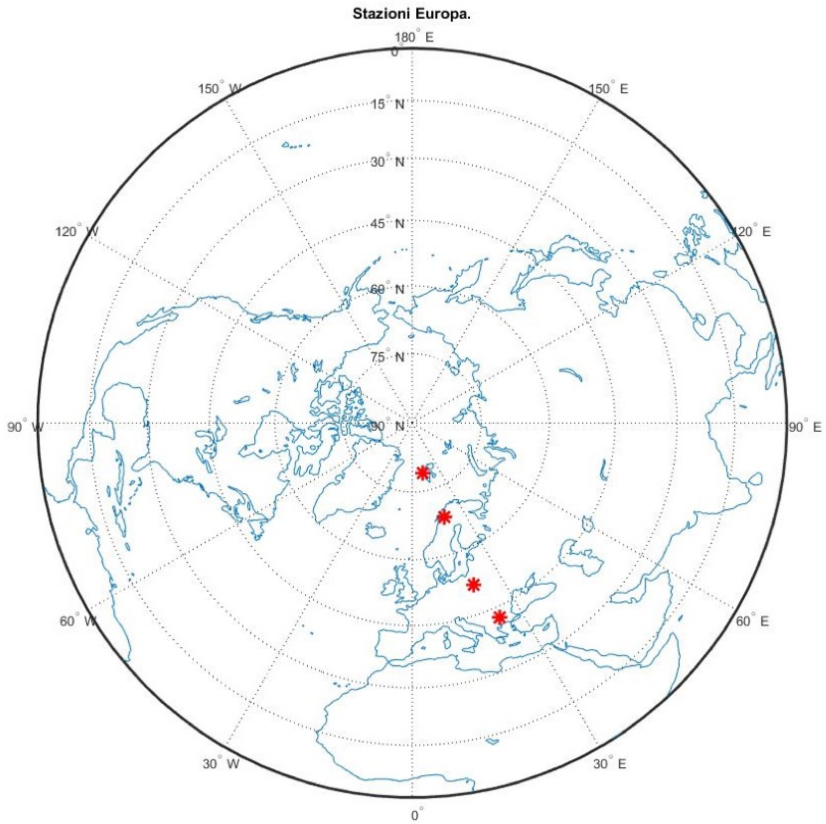


EMD: an example

Example of decomposition of the measured signal at the CLF observatory in two components that describe the fluctuations with T> 200 min and T <200 min. The decompositions refer to the X and Y components of the field, respectively.

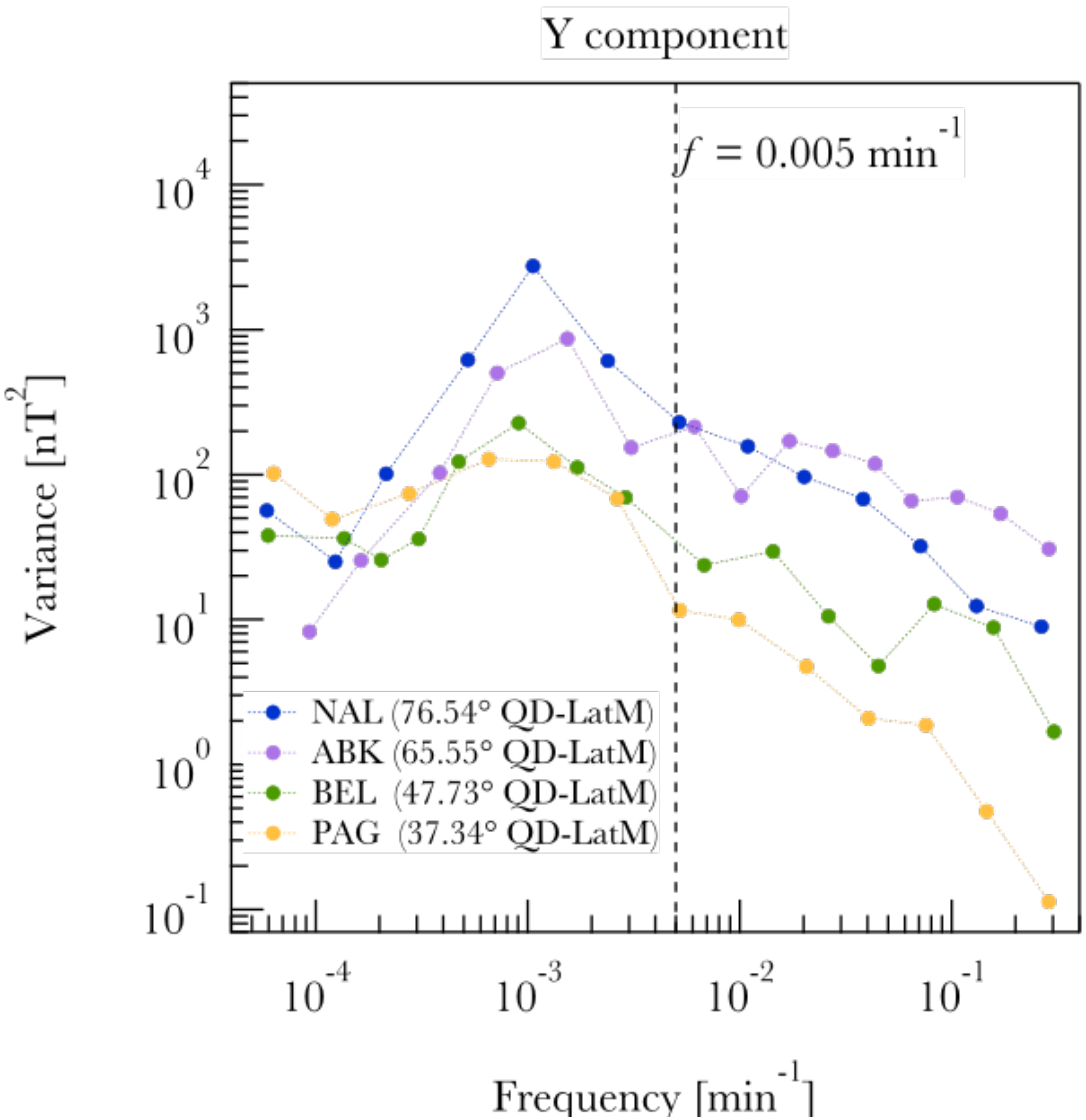


Characterization of the signal T< 200 min



CODICE	LAT(°N)	LON(°E)	LATM	LONM	MLT	L-shell
NAL	78.92	11.95	76.54	108.77	21.13	999.99
ABK	68.358	18.823	65.53	100.74	21.61	5,92
BEL	51.84	20.79	47.69	95.90	21.92	2.24
PAG	42.50	24.20	37.08	97.39	21.81	1.60

Characterization of the signal T< 200 min



The figure shows the energy (expressed in terms of variance) associated with each IMF for the four observatories selected in the case of the Y component.

The dotted line separates IMFs characterized by higher and lower frequency f=0.005 min^{-1} (T=200 min).

The trend of energy of the modes f>0.005 (T<200 min) seems to depend on the observatories latitude.

As the latitude increases, the weight of all IMFs relating to short oscillations increases with respect to the overall signal.

Characterization of the signal T< 200 min

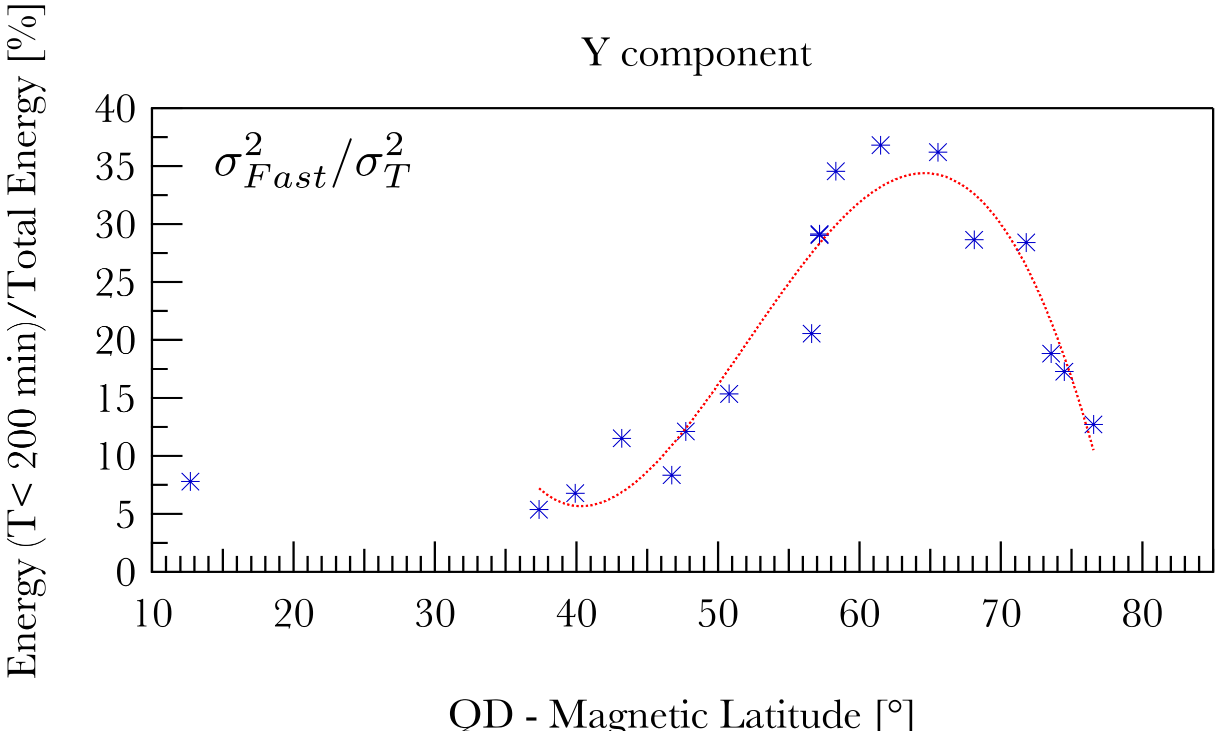
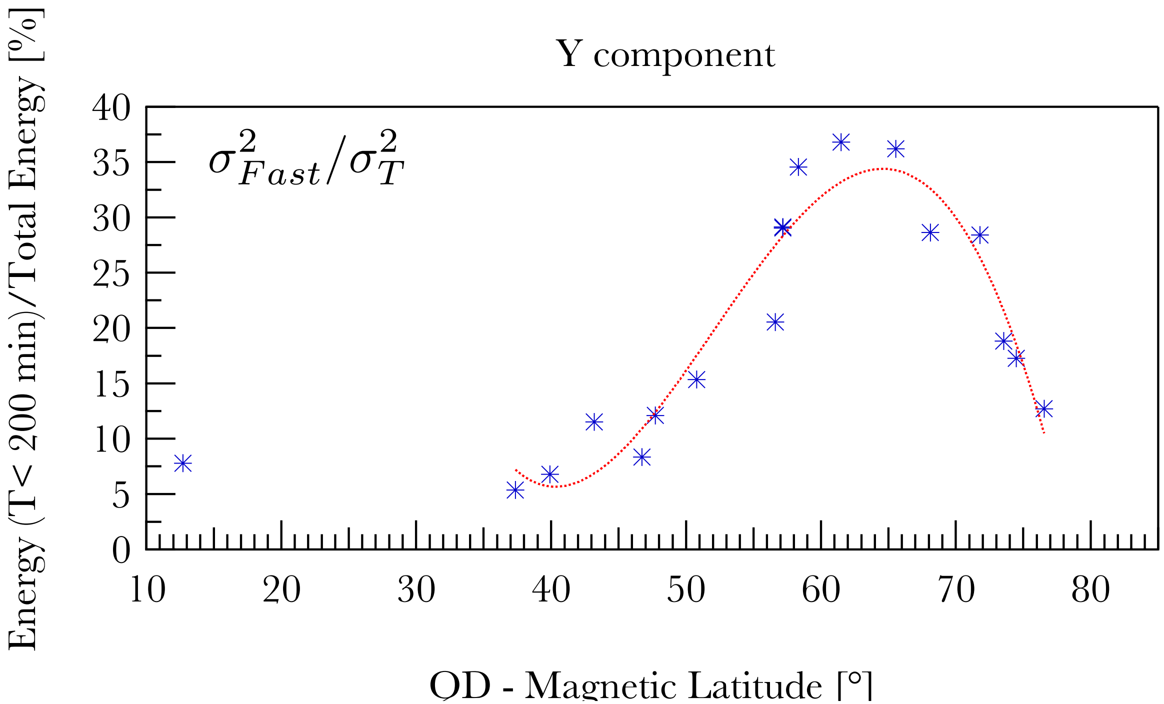
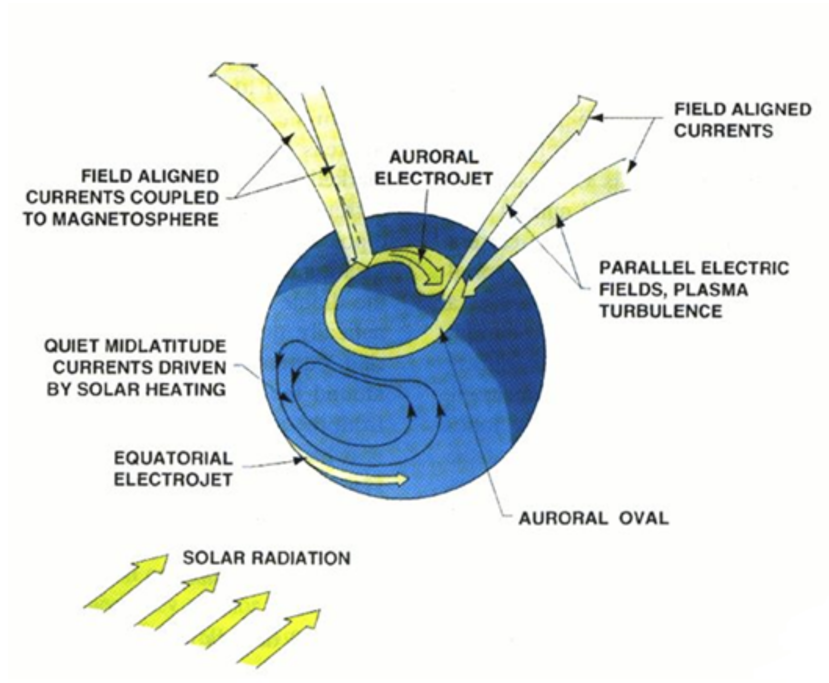


Figure shows the ratio, expressed as a percentage, between the reconstructed magnetic signal relative to the T<200 minutes fluctuations and the overall measured signal.

The weight of the signal relative to fluctuations on a short time scale shows a dependence on latitude, passing from a contribution <10% at low latitudes to almost 40% at auroral latitudes.

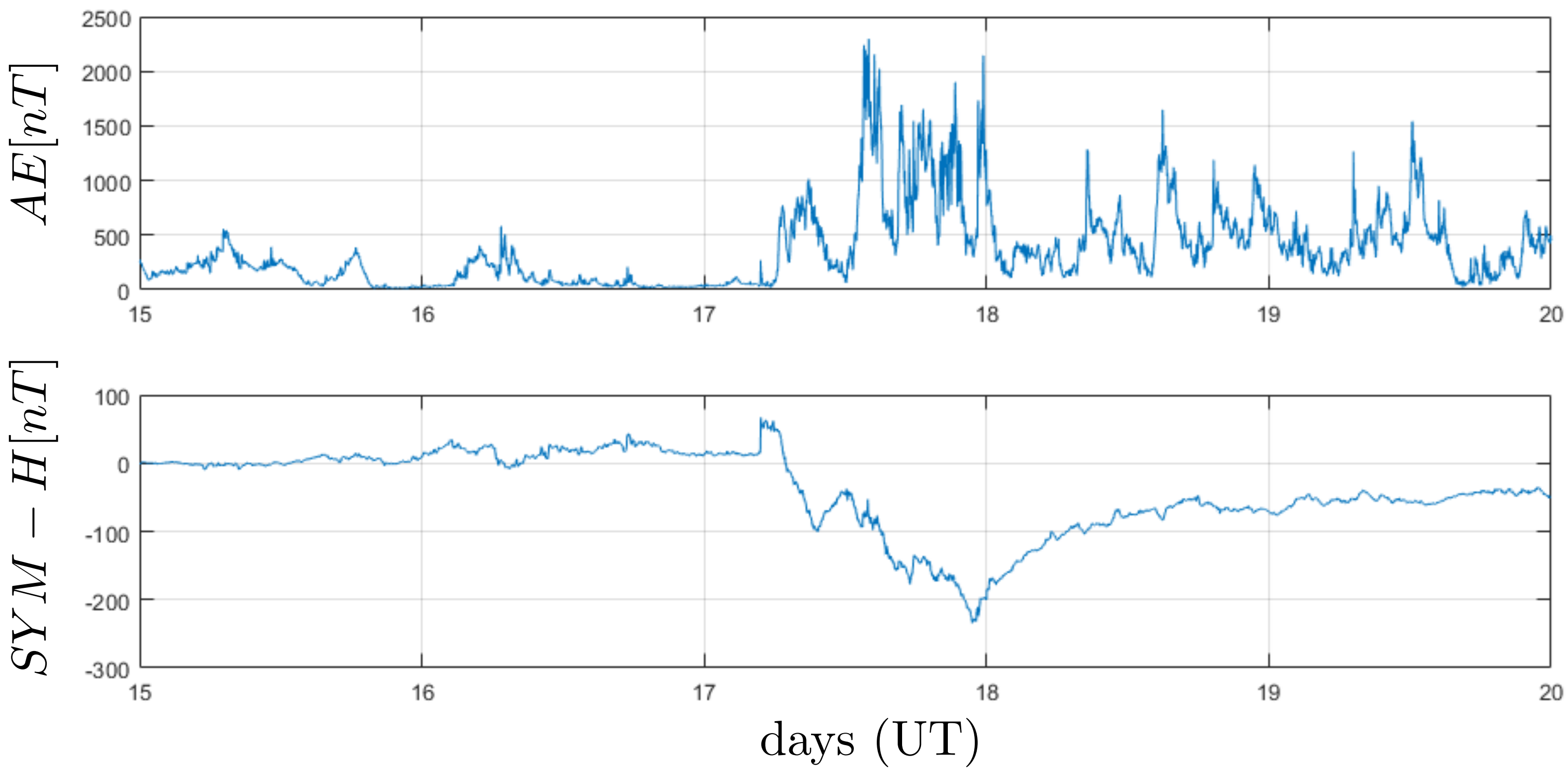
Characterization of the signal T< 200 min

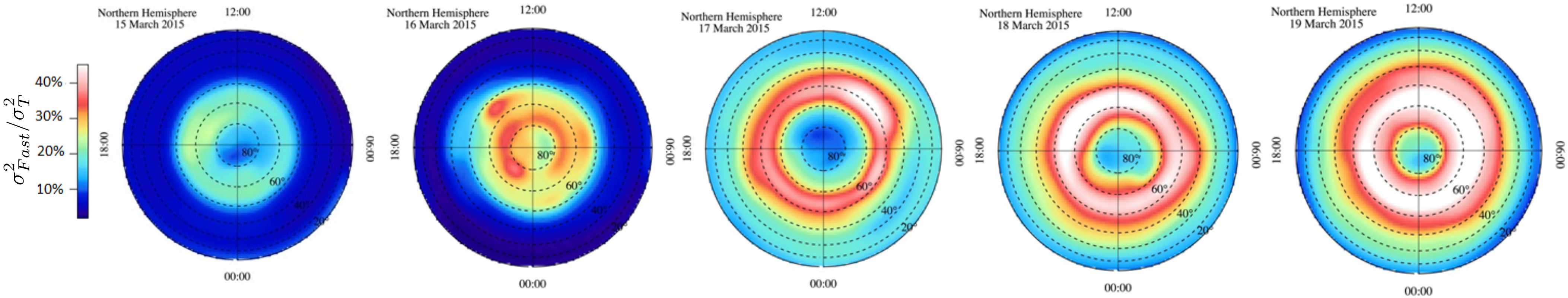




This result supports the two components' picture of magnetic substorms dynamics: the increase of plasma convection, directly driven by the solar wind (direct-driven process), which occurs on time scales T>100 min, and the fast release of energy from the geomagnetic tail (loading-unloading process) characterized by timescales T<100 min (Consolini and De Michelis, 2005)

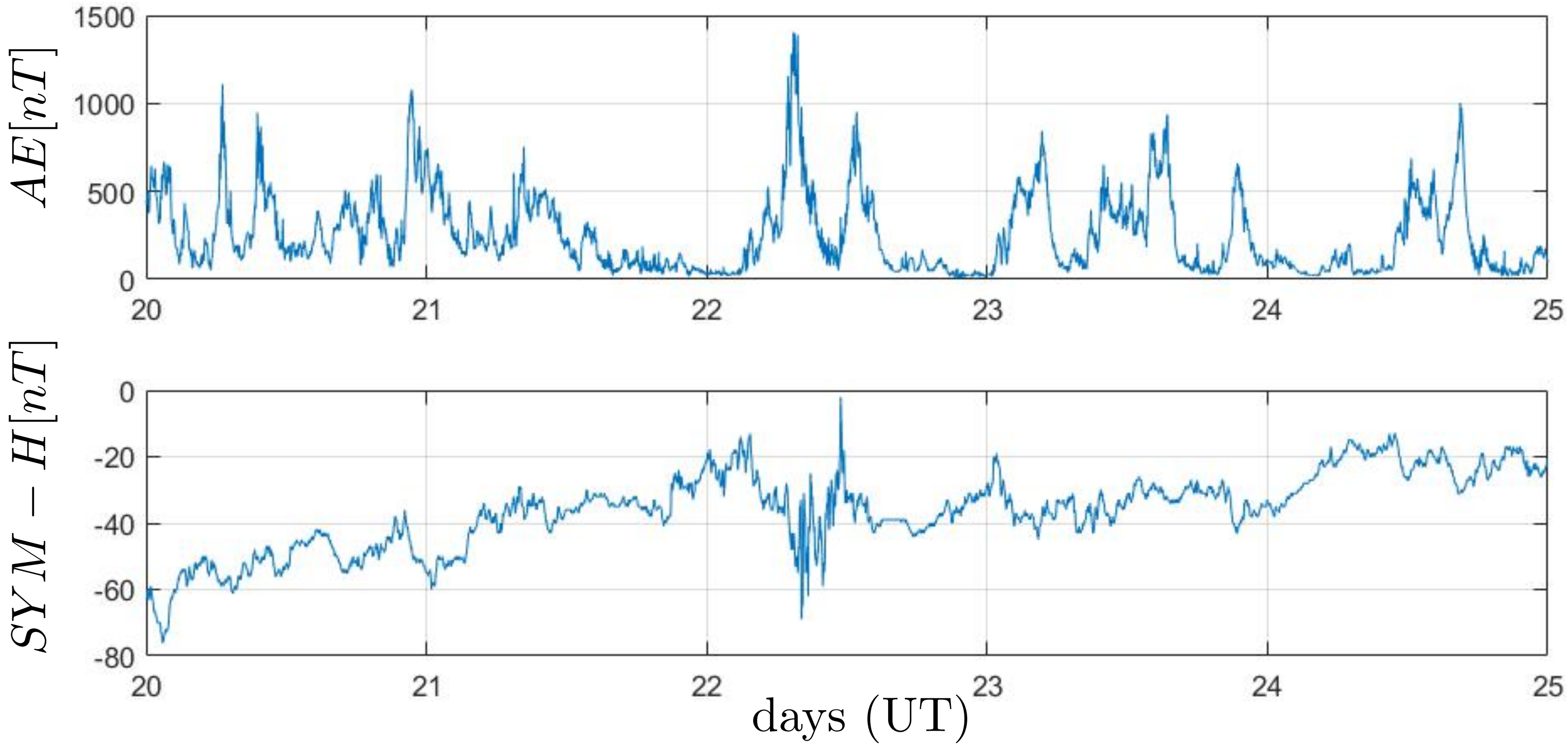
Polar view maps of $\sigma^2_{\mathbf{Fast}}$ during the period (15-19) march 2019

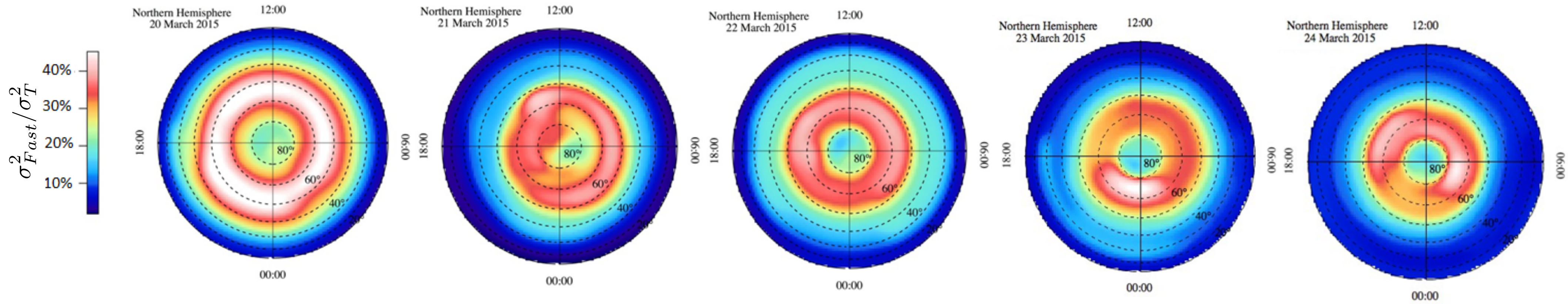




Y − component

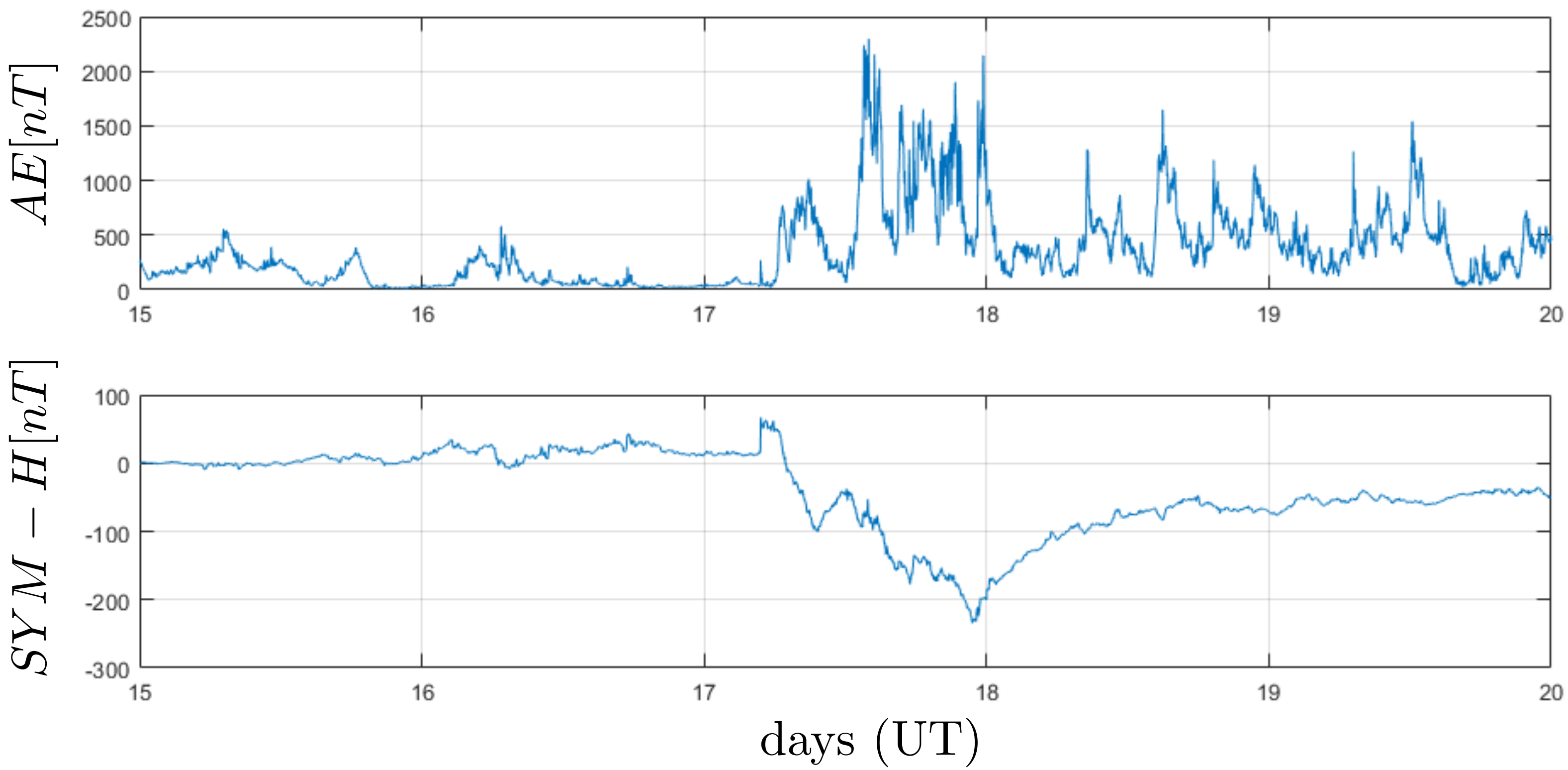
Polar view maps of $\sigma^2_{\mathbf{Fast}}$ during the period (20-24) march 2019

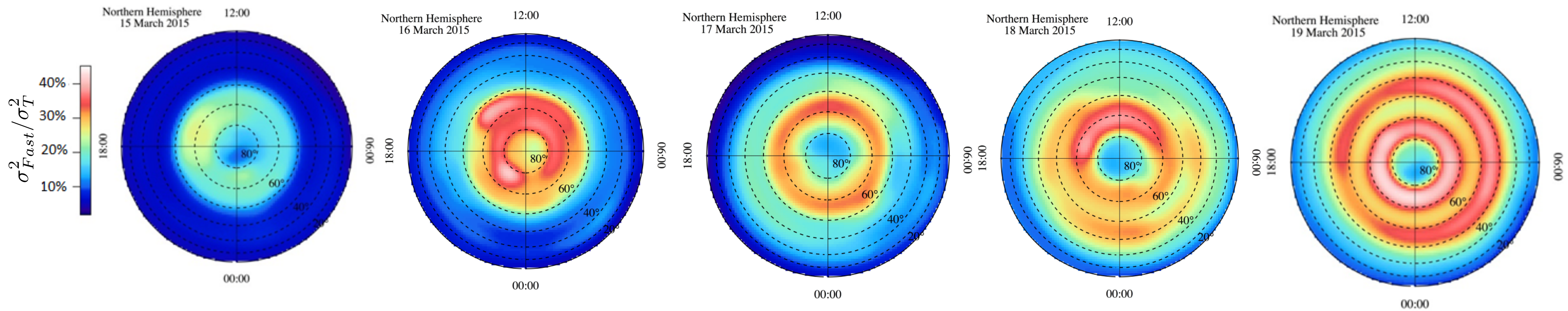




$\mathbf{Y-component}$

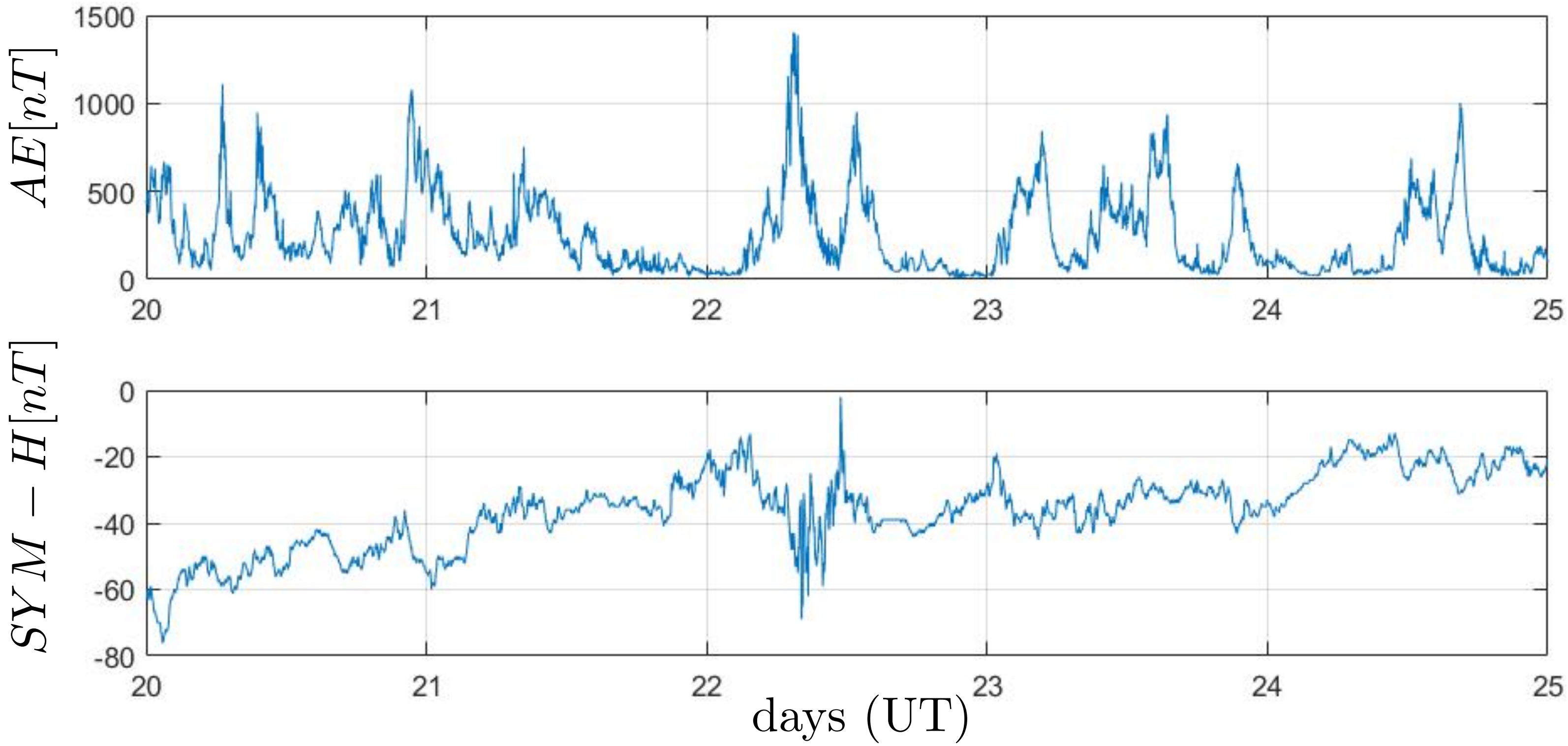
Polar view maps of $\sigma^2_{\mathbf{Fast}}$ during the period (15-19) march 2019

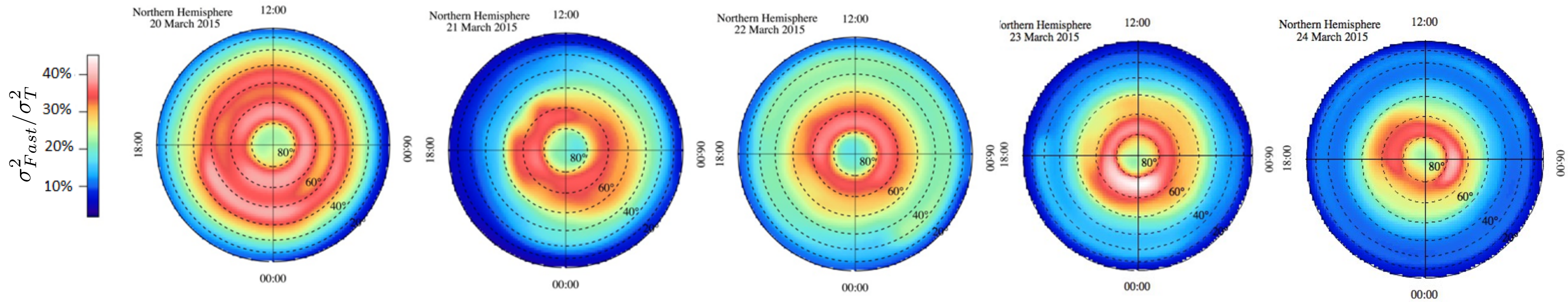




H – component

Polar view maps of σ^2_{Fast} during the period (20-24) march 2019





H − component

Summary

We present a preliminary study of the properties of shot-timescale magnetic field fluctuations during the St. Patrick's Day geomagnetic storm occurred on 17 March 2015.

We analyze the minute values of the geomagnetic field recorded simultaneously by several geomagnetic observatories located at different latitudes in the Northern Hemisphere.

We apply the Empirical Mode Decomposition (EMD) method to the X (North) and Y (East) components of the geomagnetic field recorded during a period (13 - 30 March 2015) covering the whole duration of the storm. It permits us to separate fast (τ<200 min) and slow (τ>200 min) magnetic fluctuations, which are related to different magnetospheric processes.

The different energy contribution of the fast fluctuations is investigated as a function of latitude during the selected period. The weight of the signal related to the fluctuations on a short time scale shows a dependence on the latitude and geomagnetic activity level.