Short timescale magnetic field fluctuations and their impact on space weather forecasting

Lucia Santarelli[1,2], Paola De Michelis[2] and Giuseppe Consolini[3]

[1]Università degli studi dell'Aquila, L'Aquila, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
[3]INAF-Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy

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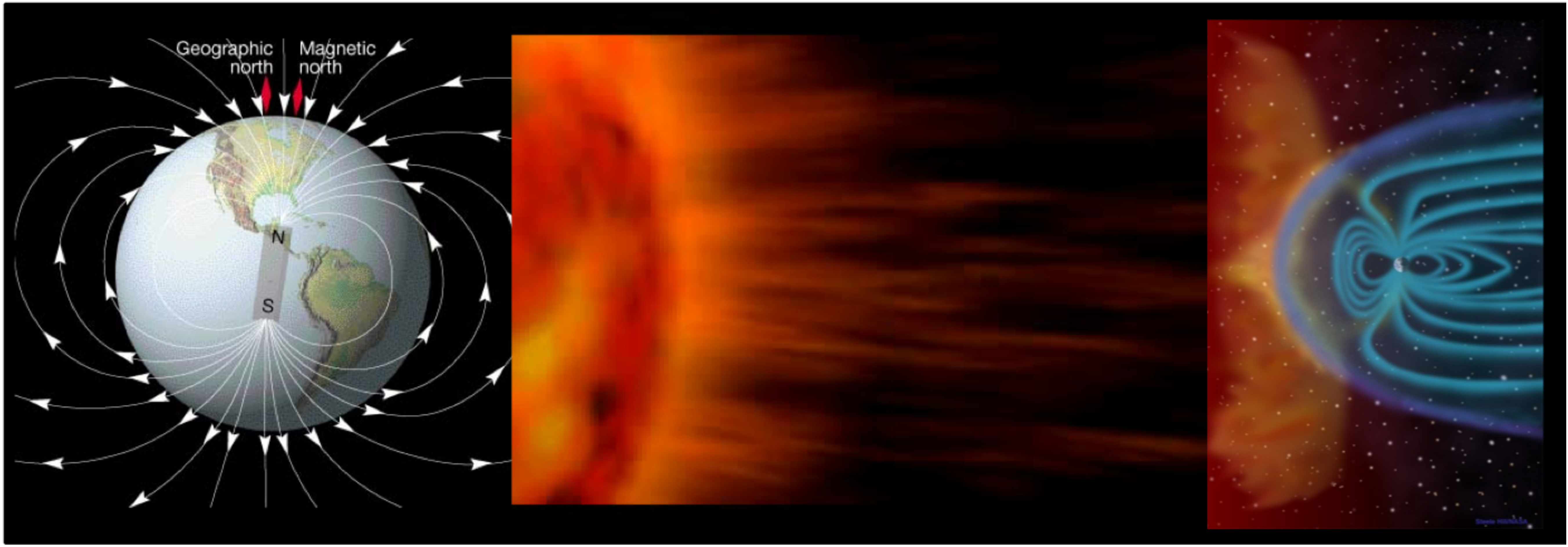
AIM

To characterize the spatial distribution of the **short-timescale/fast** (τ < 200 min) and **long-timescale/slow** (τ > 200 min) magnetic field fluctuations recorded on the ground during the St Patrick's day geomagnetic storm occurred on 17 March 2015.



Context – Recent studies

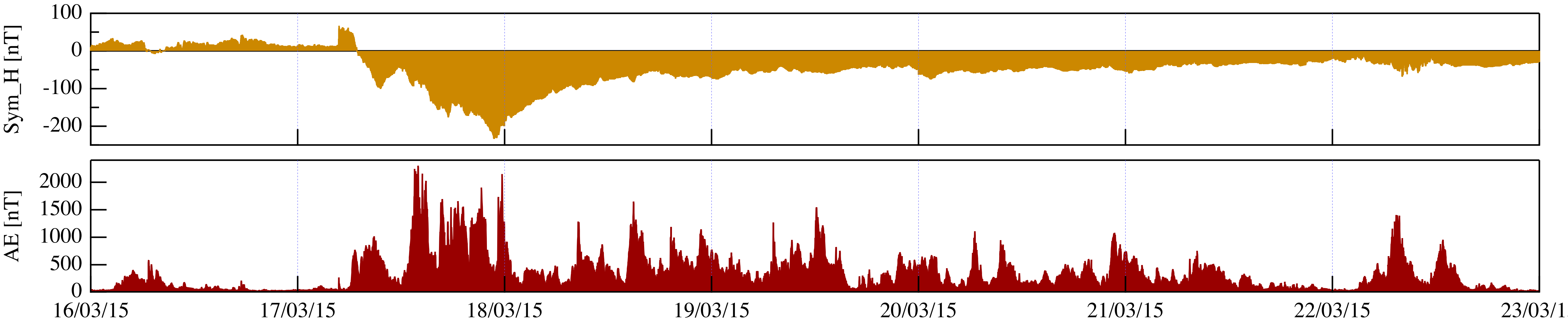
The dynamics of the Earth's magnetosphere in response to the solar wind and interplanetary magnetic field conditions is the result of both externally driven processes and internal processes. Recently Alberti et al. (2017) have highlighted the existence of a separation of timescales in the solar wind-magnetosphere coupling occurring at approx. 200 minutes:

- Long timescale magnetic fluctuations (T > 200 min) show a high degree of correlation with solar wind and magnetospheric dynamics proxies

- Magnetic 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 by solar wind/IMF.

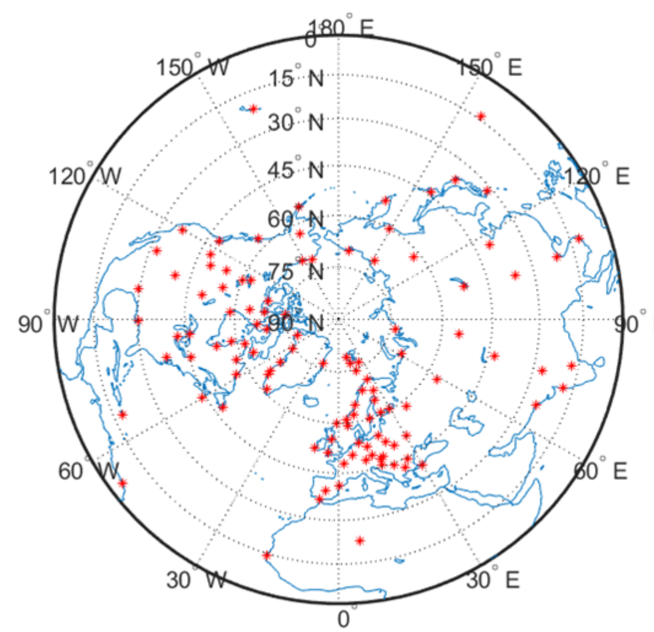
To identify in a magnetic field signal recorded on the ground the two different contributions is important in the framework of Space Weather.

DATASET

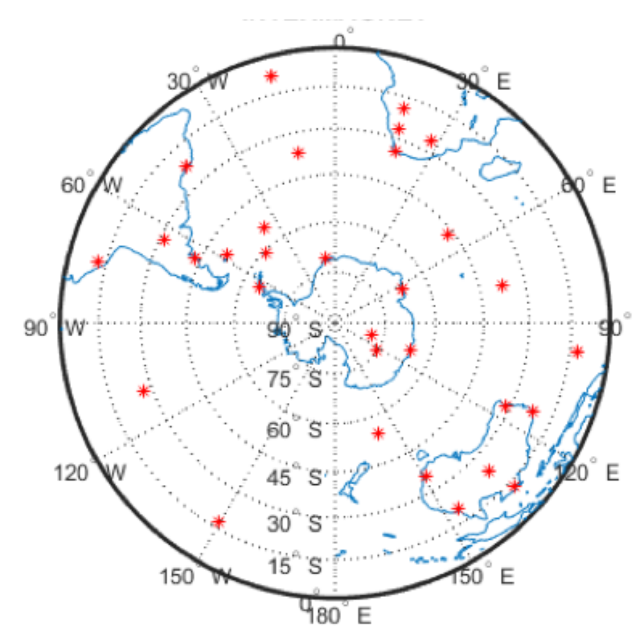


We used the **X** and **Y component** of the Earth's magnetic field recorded at 60 geomagnetic observatories located in the Northern Hemisphere and 30 in the Southern Hemisphere. They are part of the worldwide network of observatories known as INTERMAGNET.

We consider a period of some days around the 2015 St. Patrick's magnetic event.

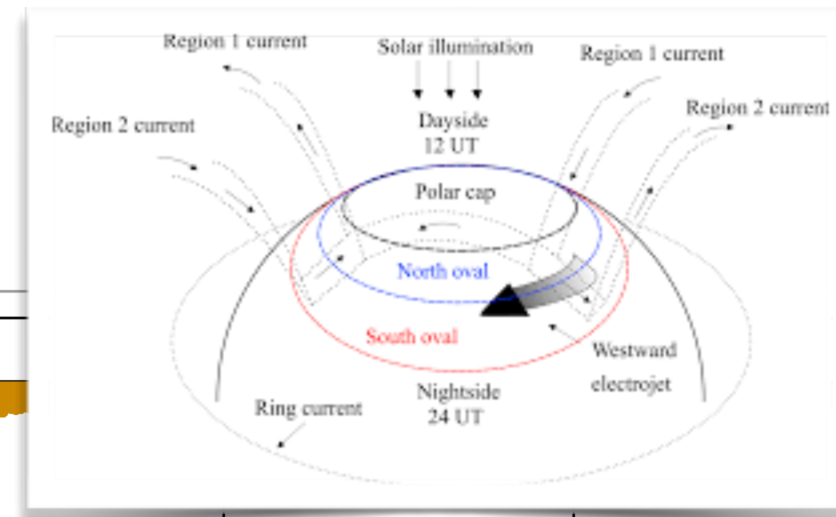


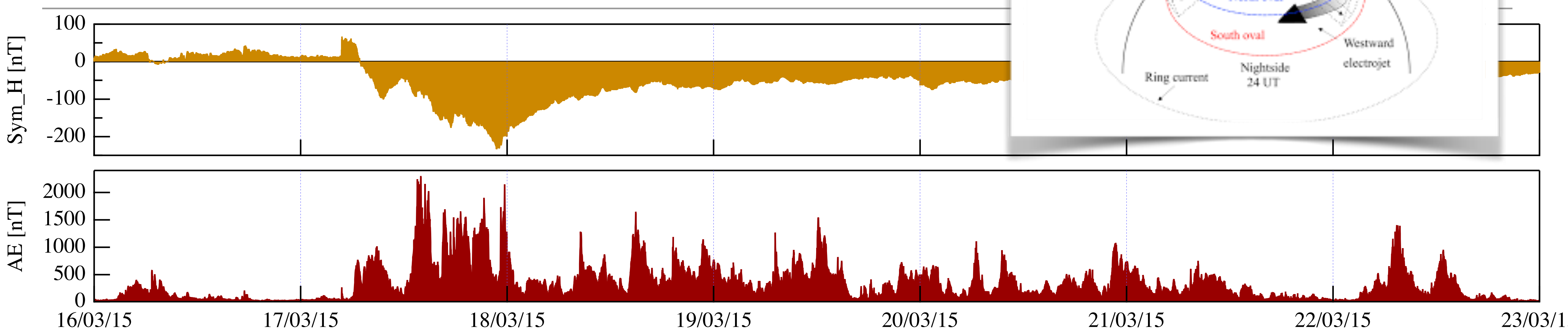
North Hemisphere

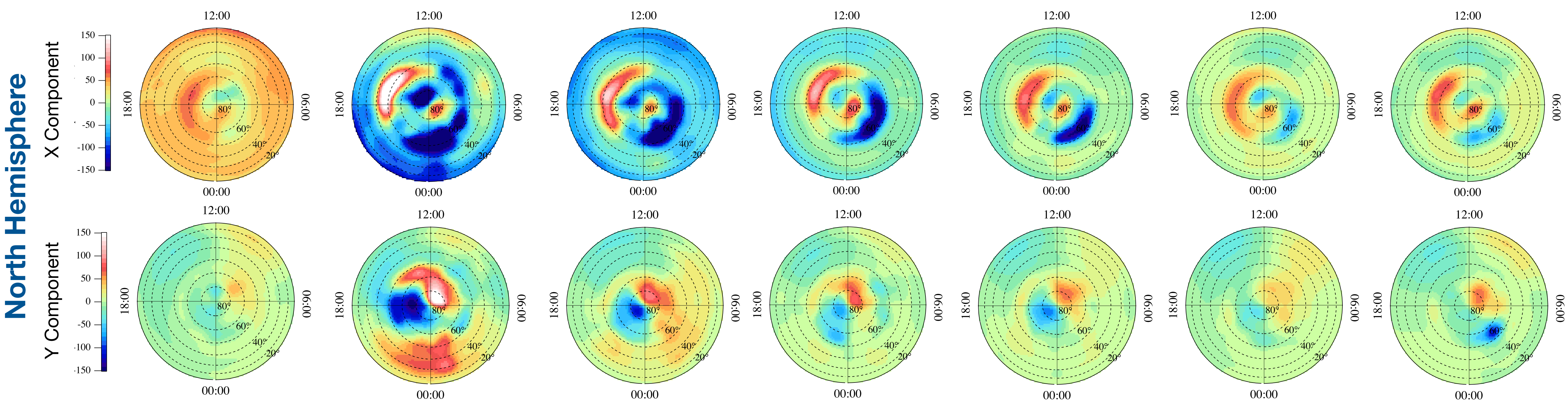


South Hemisphere

DATASET

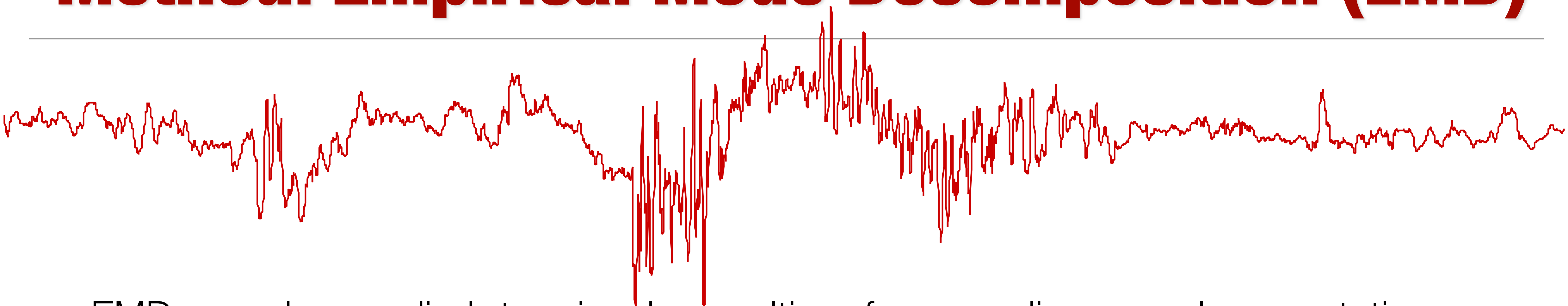






Daily distributions of X and Y magnetic field components describing the magnetic field perturbations due to external sources. The main contributions to this external fields that produce relevant signatures in magnetic field observations are the polar ionospheric currents, such as the polar electrojets, and the magnetospheric currents such as the Chapman-Ferraro currents and in particular the magnetospheric ring current.

Method: Empirical Mode Decomposition (EMD)



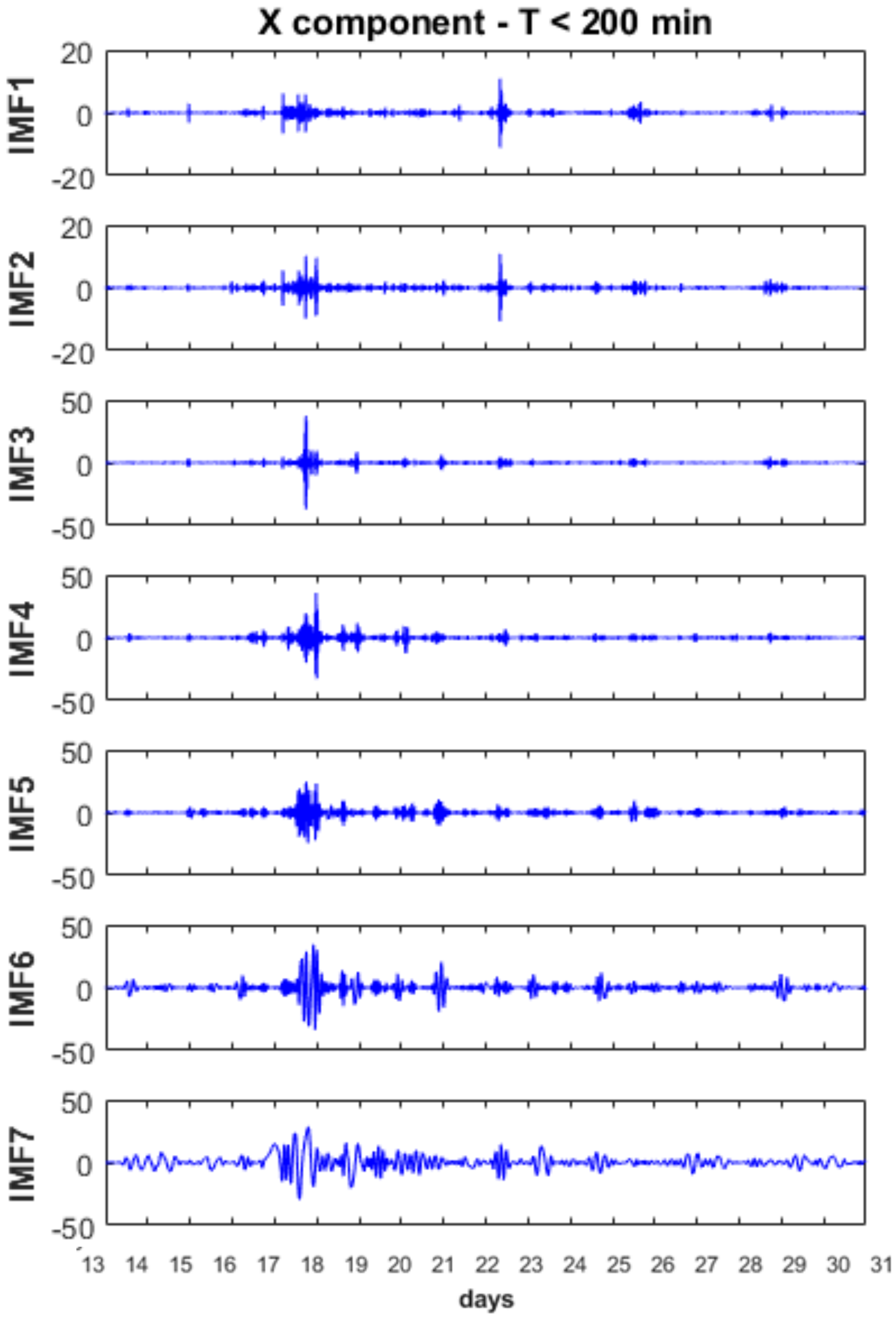
EMD can be applied to signals resulting from nonlinear and non stationary processes. It is capable of decomposing a time series into a sum of different time series (modes) each one having a characteristics frequency.

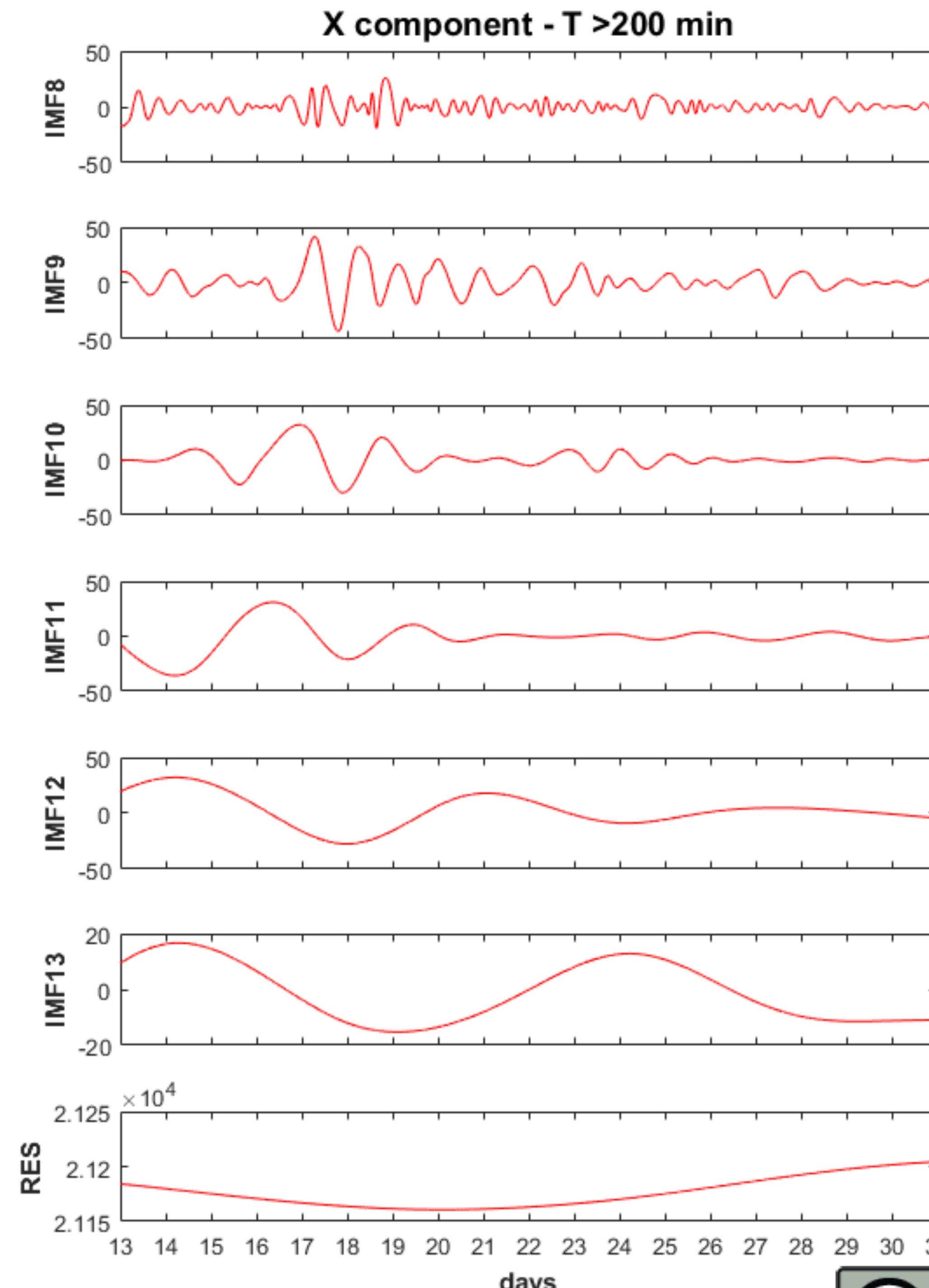
These modes are called Intrinsic Mode Functions (IMFs) and satisfy the following two conditions:1) the difference between the number of local extrema and the number fo zero-crossings must be zero or one; 2) the running mean value of the envelope defined by the local maxima and the local minima is zero.

$$x(t) = \sum_{i=0}^{n} IMF_i(t) + residue$$

EMD: an example

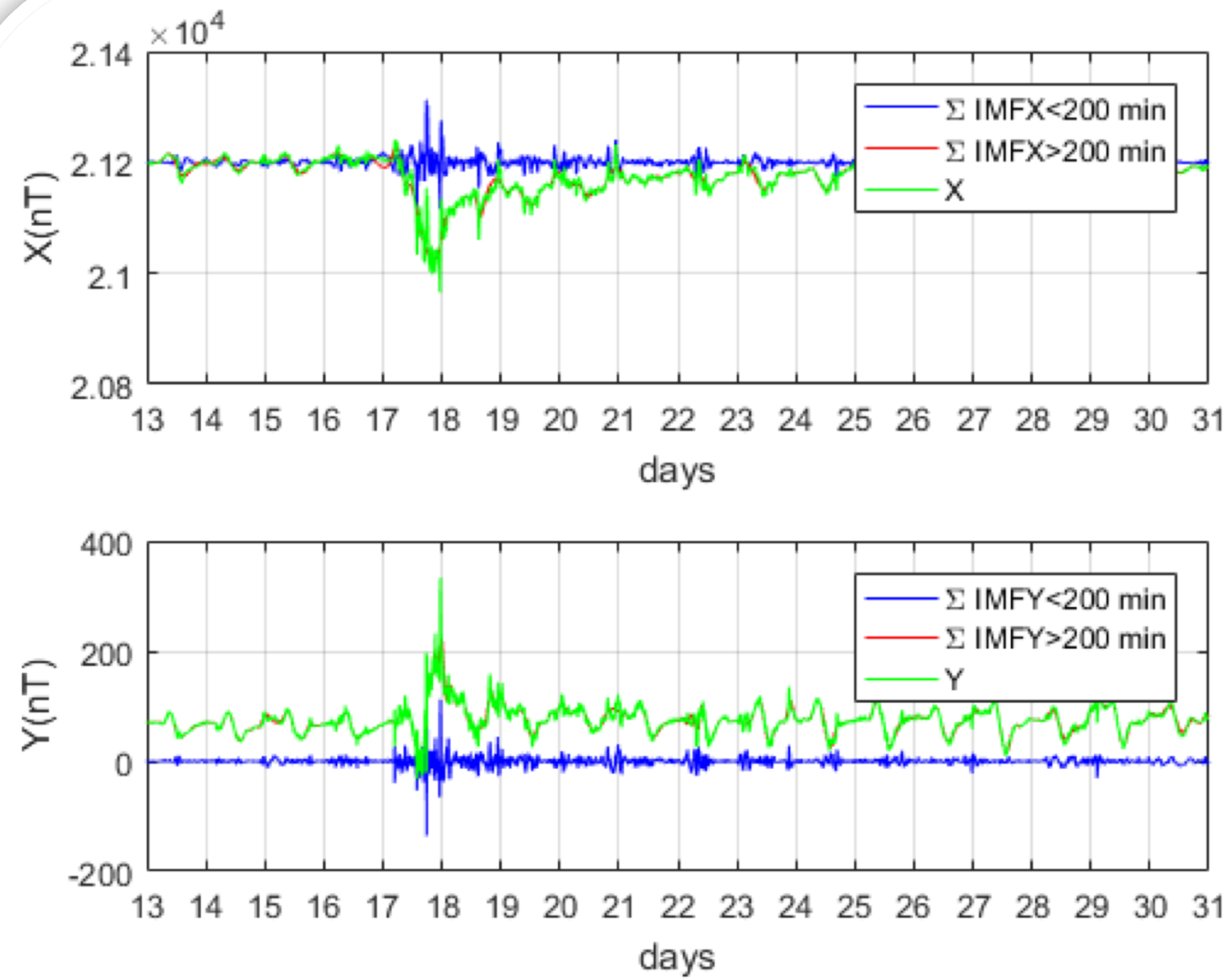
$$x(t) = \sum_{i=0}^{n} IMF_i(t) + res$$



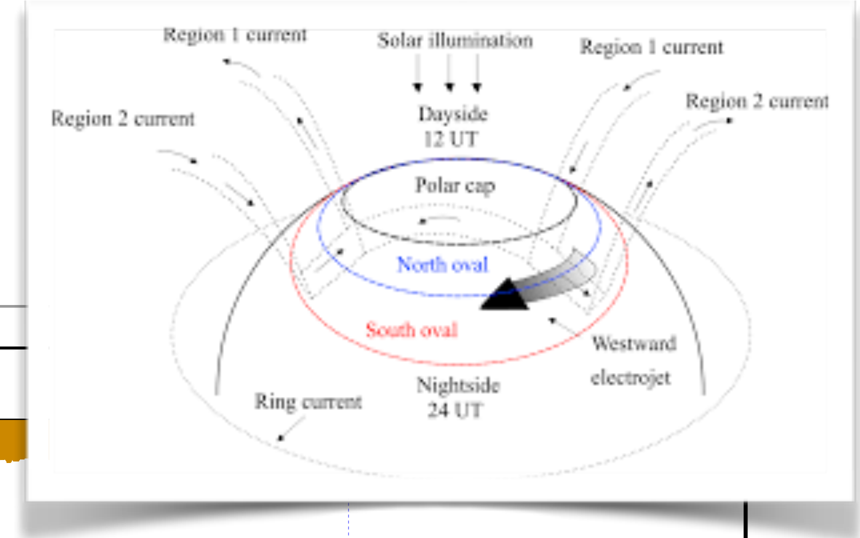


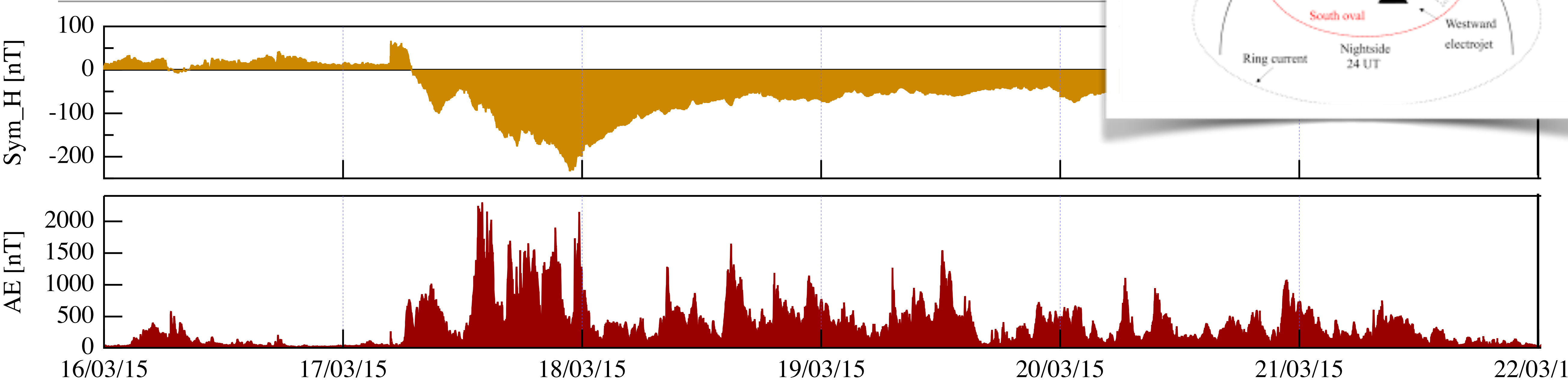
EMD: an example

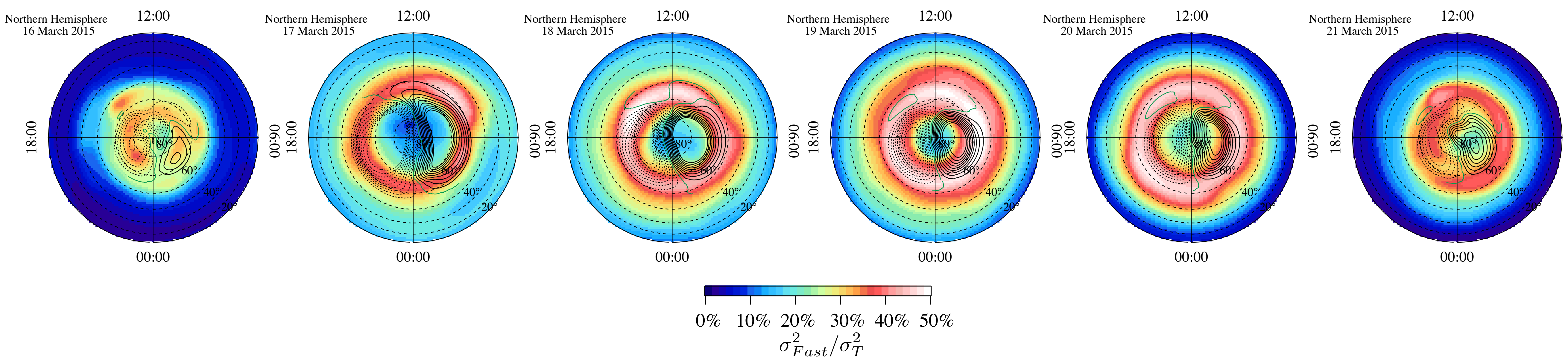
Example of decomposition of the measured signal at the CLF observatory in two components that describe the fluctuations with **T> 200 min** and **T <200 min**. The decompositions refer to the X and Y components of the field, respectively.



RESULTS: Y component for T<200 min

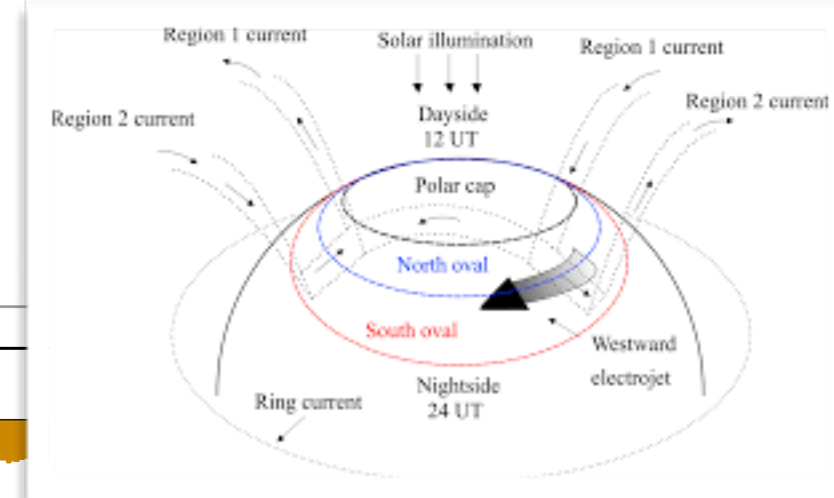


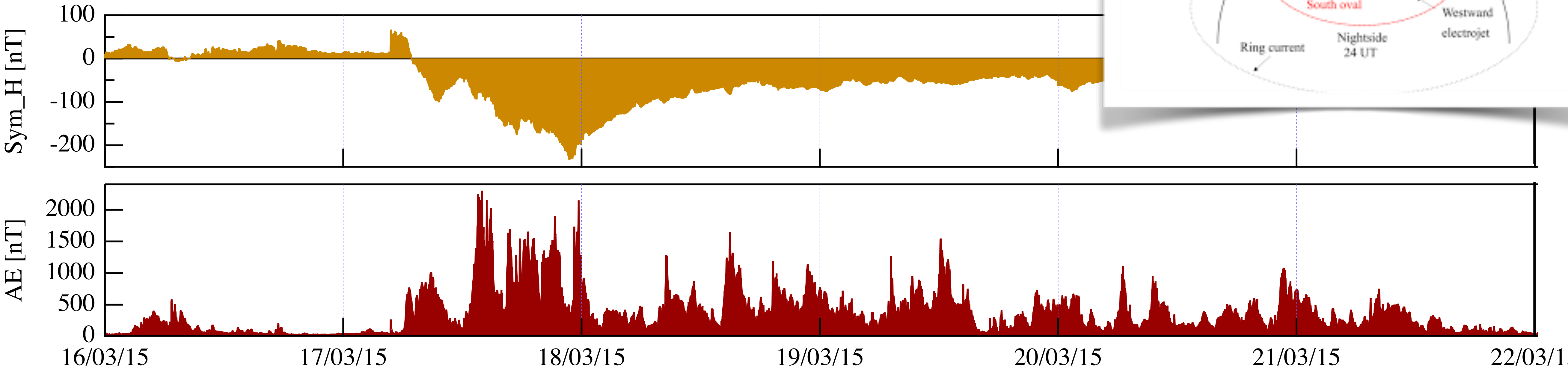


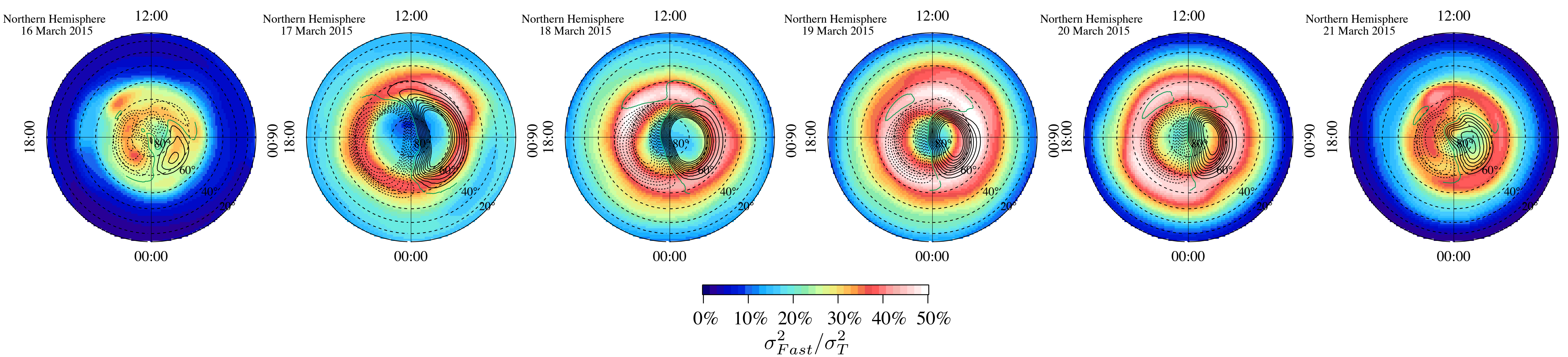


Daily maps of the ratio between the variance of magnetic fluctuations below 200 minutes and that of the overall signal. The weight of the signal relative to fluctuations on a short time scale shows a dependence on latitude and geomagnetic activity level.

RESULTS: Y component for T<200 min





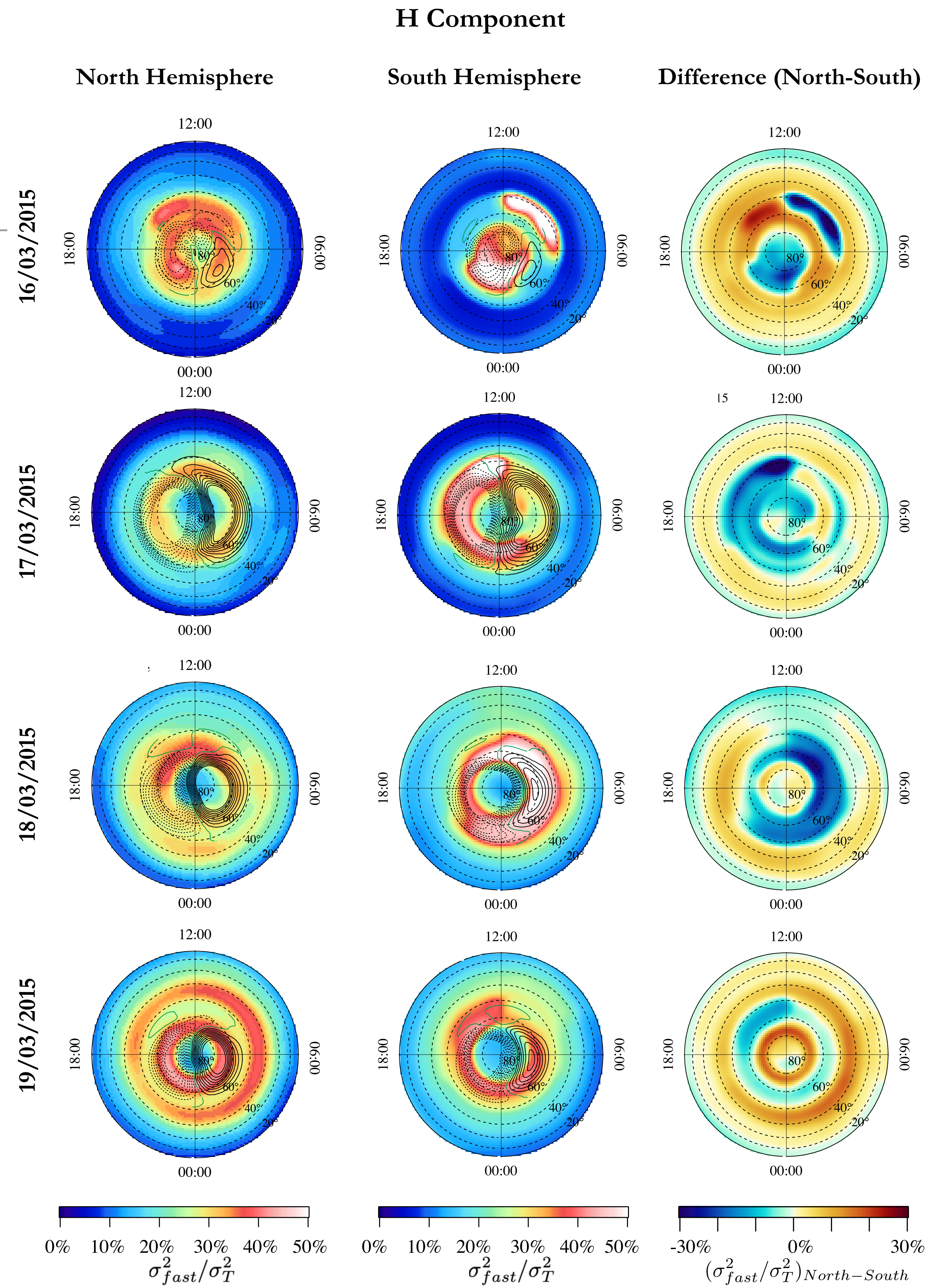


At high-latitude the fluctuations on short-time scale have an important weight, in terms of energy, on the total magnetic signal. During the disturbed periods the fast fluctuations have the highest values in the auroral oval. This region, although triggered by the variations of interplanetary conditions, is strongly dominated by internal processes and is not directly driven (correlated) by the SW/IMF.

RESULTS:
H component for T<200 min

Daily maps of the ratio between the variance of the **fast magnetic fluctuations** and that of the overall signal obtained in the two hemispheres

The results obtained in the two hemispheres are similar although the ratio between the variance of fast magnetic fluctuations and that of the total signal is higher in the Southern Hemisphere than in the Northern one.

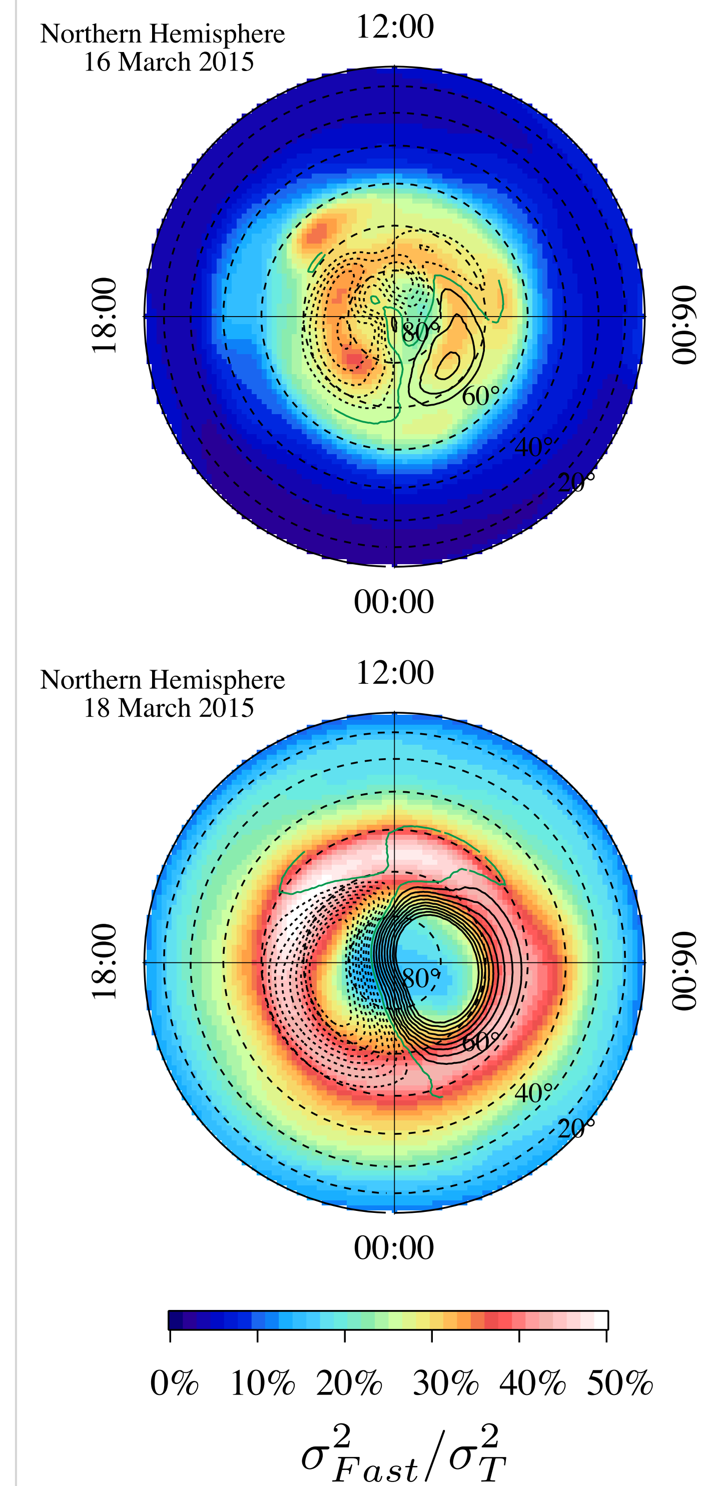


Summary

We focus on the **properties of shot-timescale magnetic field fluctuations** during the 2015 St. Patrick's Day geomagnetic storm.

We apply the **EMD method to the X and Y components of the geomagnetic field recorded on the ground** 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 short-timescale fluctuations is investigated as a function of latitude during the selected period. The **weight** of the signal related to the **fluctuations on a short-timescale** (that although triggered by changes in interplanetary conditions, are mainly dominated by internal processes) **shows a dependence on the latitude and geomagnetic activity level.**



Summary

Impact on Space Weather

During the disturbed periods the magnetic field fluctuations on short-timescale can play an important role in the total magnetic signal. These fluctuations are mainly dominated by internal processes, although triggered by changes in interplanetary conditions.

In order **to forecast the high-latitude geomagnetic disturbances** it is necessary to develop model that take into account both **the changes in interplanetary conditions and in the magnetospheric dynamics.**