Multi-Scale Nature of the High-Latitude Magnetic Field Fluctuations

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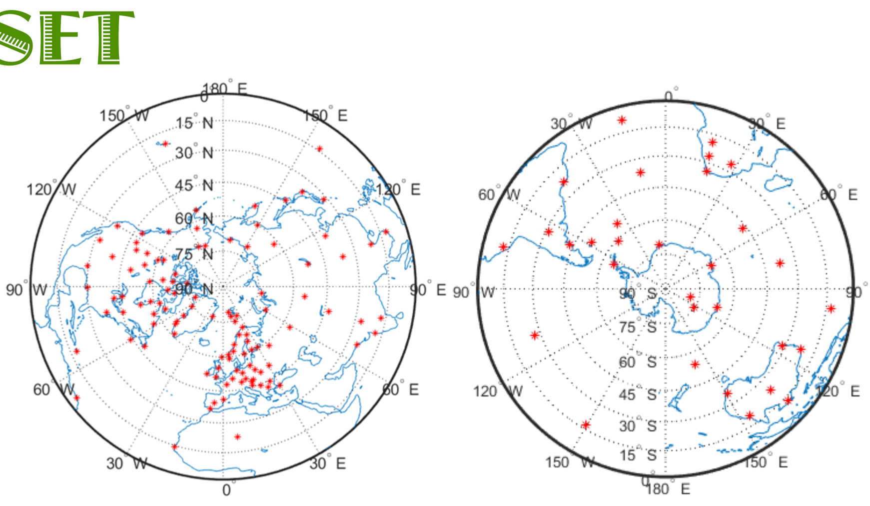
FRAMEWORK

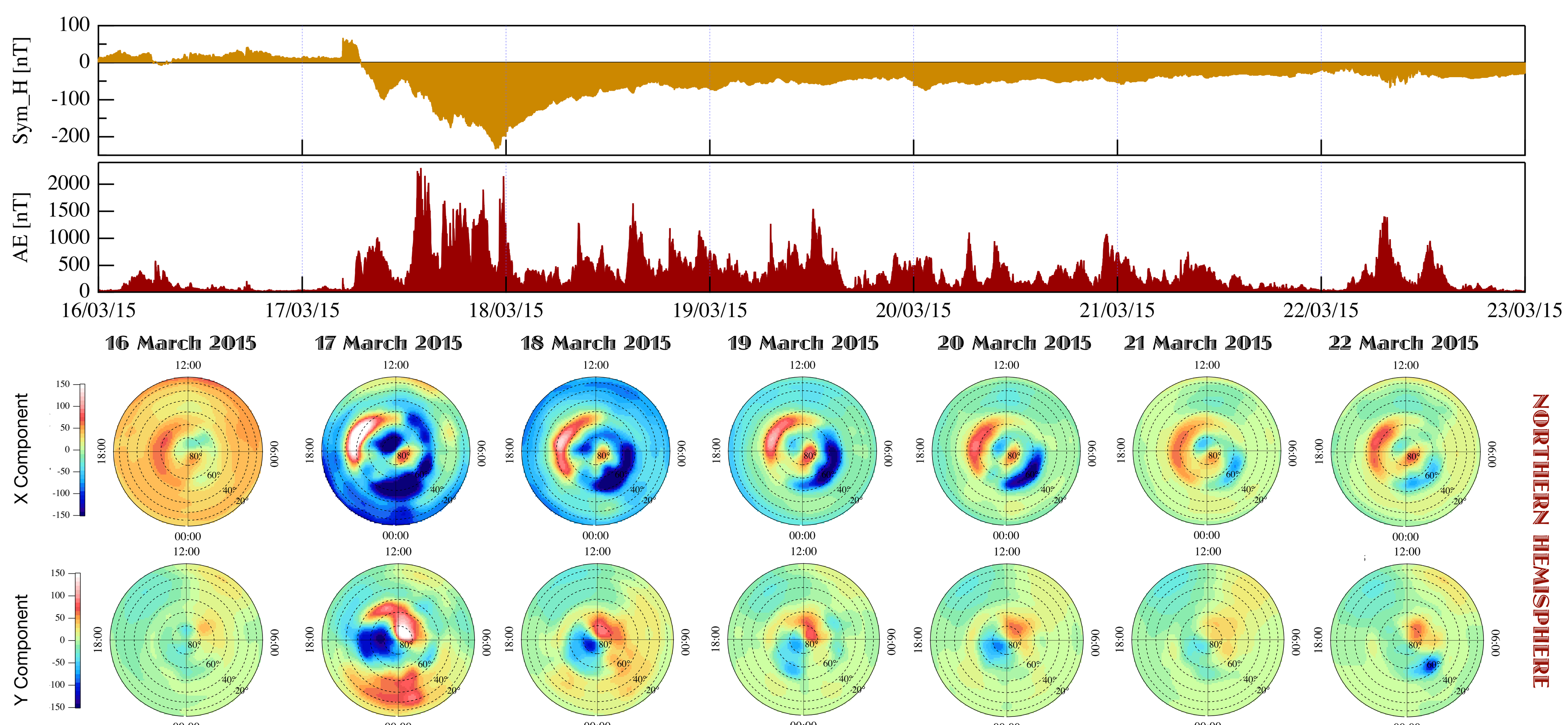
The dynamics of the Earth's magnetosphere in response to changes in solar wind conditions and the interplanetary magnetic field during a magnetic storm and under-storm is the result of both externally driven processes and internal (magnetospheric) processes. Recent studies (*Alberti et al., JGR, 2017*) 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 (slow fluctuations - T > 200 min) show a high degree of correlation with the parameters of solar wind and magnetospheric dynamics.**
- **Fluctuations with short time-scale (fast fluctuations - T < 200 min), although triggered by changes in interplanetary conditions, are mainly dominated by processes that occur in the magnetosphere and are not directly driven (correlated) by the SW/IMF.**

DATASET

Data relative to the X and Y component of the Earth's magnetic field recorded at 60 and 20 geomagnetic observatories located in the Northern and Southern Hemisphere, respectively. 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.





Daily distributions of the X and Y magnetic field components. Maps describe the magnetic field perturbations on the ground 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 ring current.

Method of Analysis

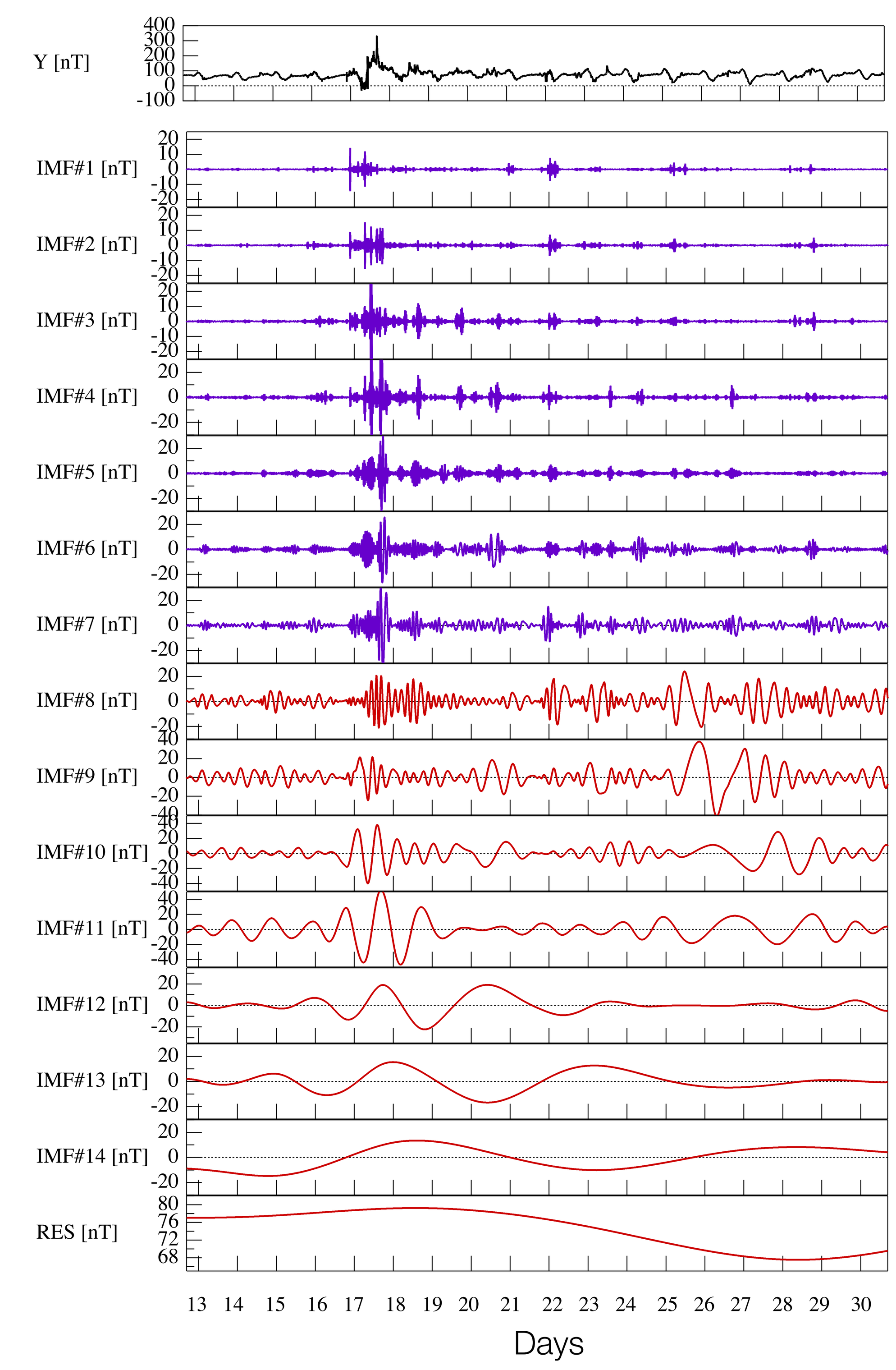
The EMD method (*Huang et a.,Proc. Royal Soc., 1998*) is a powerful tool for investigating natural signals that result from non-stationary and non-linear processes. EMD moves from the assumption that most signals are multi-components, involving many scales simultaneously, so that a signal can be considered as a superposition of oscillations from fast to slow ones at a very local level.

Each component (IMF_i) is defined as any function having:

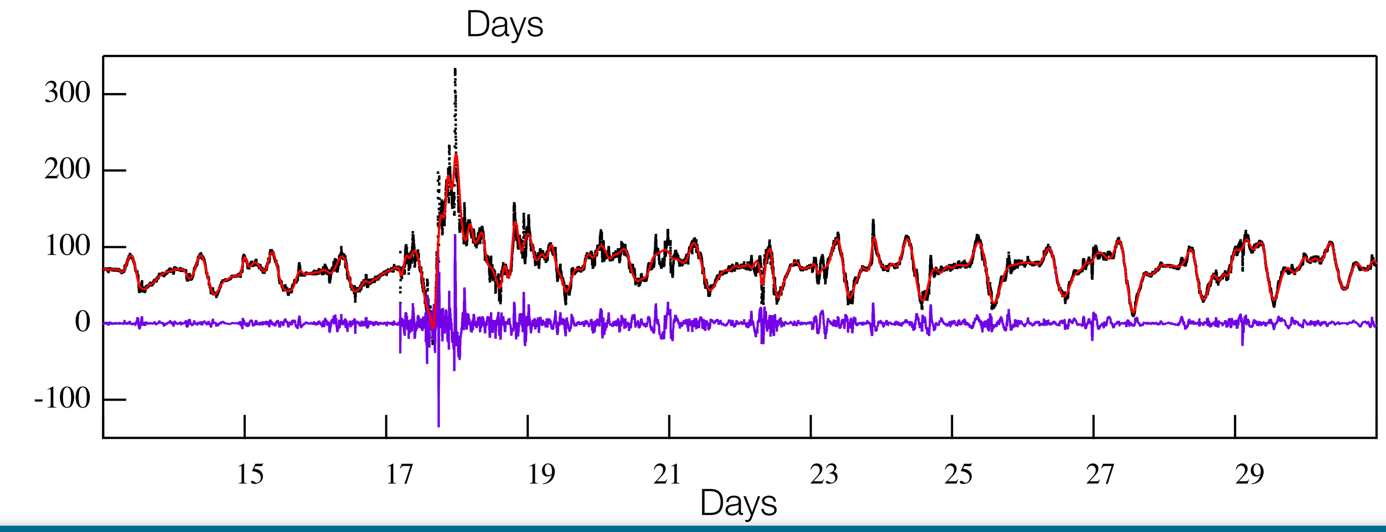
1) the same number of extrema and of zero-crossings in the whole dataset

2) a mean value of the envelope defined by the local maxima and the envelope defined by the local minima equals to zero at any point.

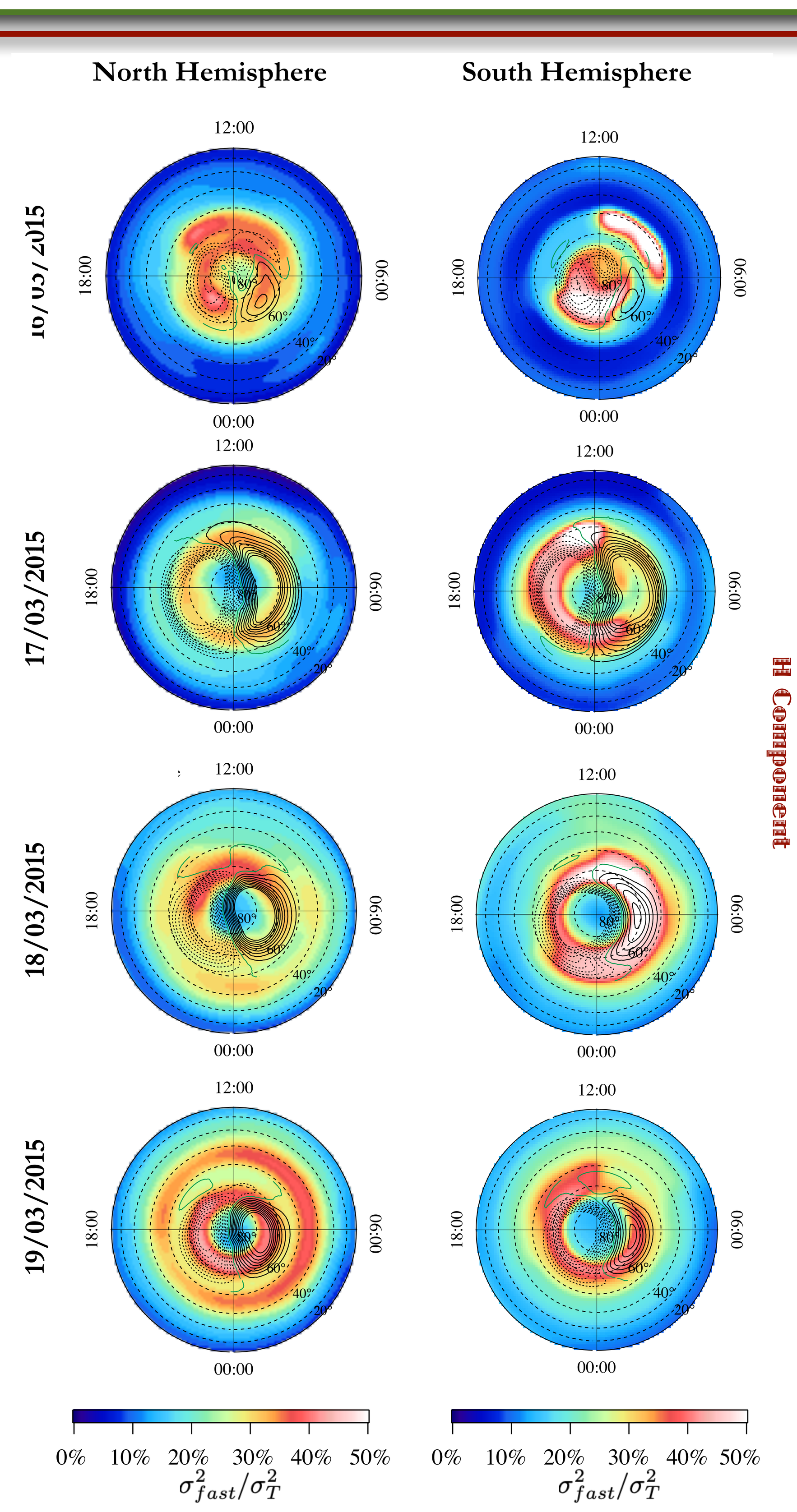
$$y(t) = \sum_{i=0}^{n} IMF_i(t) + res$$



Example of decomposition of the Y component recorded at the CLF observatory. The original signal can be decomposed in 14 different IMFs and a residue. The time scale is increasing with the IMF; each mode has a different mean frequency, which is estimated by considering the mean frequency in the Fourier power spectrum. Taking into account the different values associated with each IMF, we have splitted them in two groups: IMFs with T< 200 min and T >200 min. On the bottom the reconstructed signals.



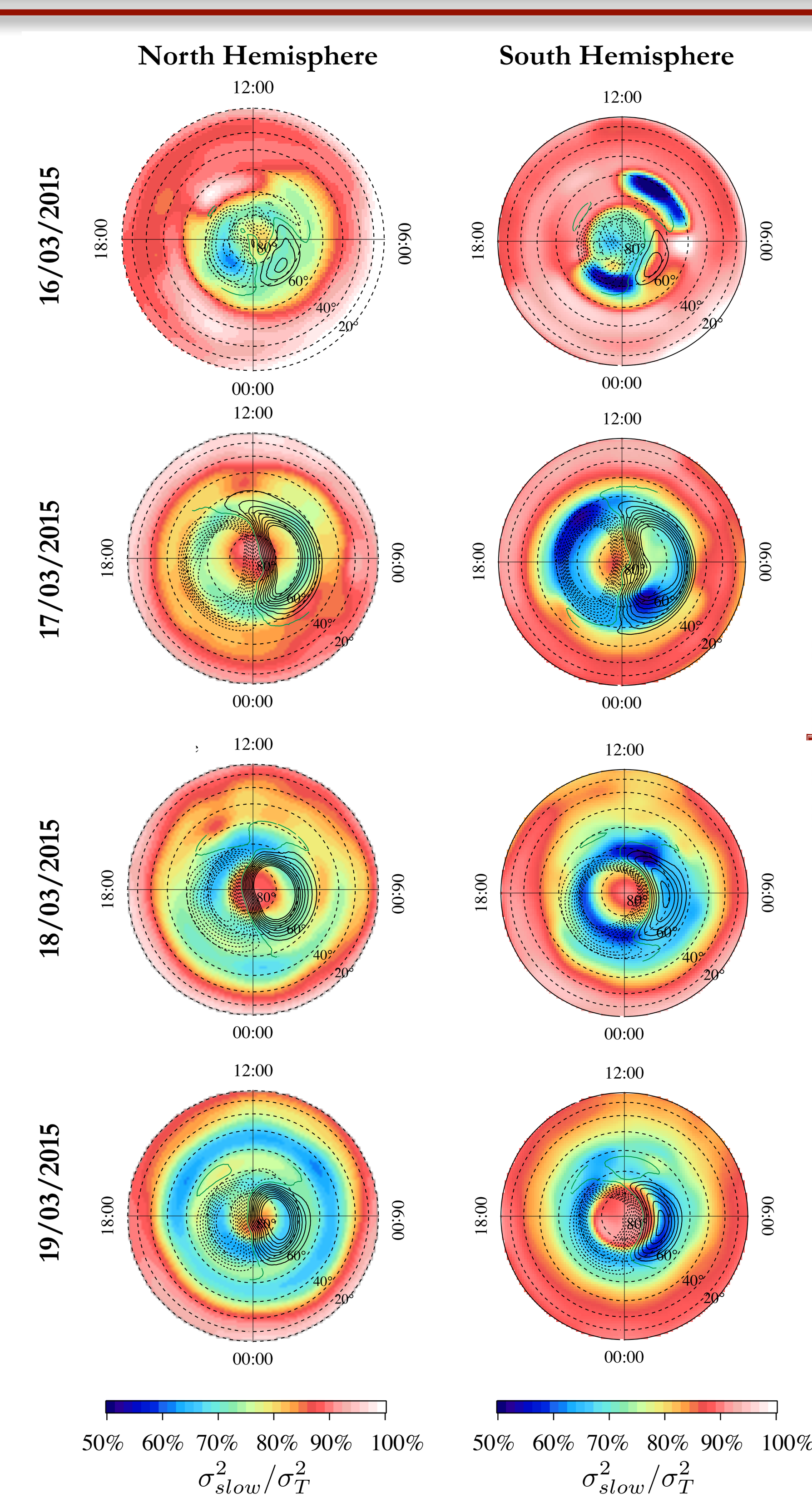
Analysis and Results



On the left: Daily maps of the ratio between the variance of the **fast magnetic fluctuations** and that of the overall signal. The weight of the signal relative to the fast fluctuations shows a dependence on latitude and geomagnetic activity level.
During the disturbed periods the fast fluctuations have the highest values in the auroral oval. This region is mainly dominated by internal processes and is not directly driven (correlated) by the SW/IMF.

On the right: Daily maps of the ratio between the variance of the **slow magnetic fluctuations** and that of the overall signal.
The weight of the signal related to the fluctuations on a long-timescale (that is triggered by changes in interplanetary conditions) shows a minimum in the auroral regions and a maximum moving towards the equator.

Impact on Space Weather: During the disturbed periods the fast magnetic field fluctuations 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 magnetic signals it is necessary to develop model that takes into account both the changes in interplanetary conditions and in the magnetospheric dynamics.



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