ESA/Contract No.4000125663/18/I-NB
EO Science for Society Permanently Open Call For Proposals EOEP-5 BLOCK4- (INTENS)

Characterization of Ionospheric turbulence level by Swarm constellation

P. De Michelis Paola[1], Consolini Giuseppe[2], Balasis Georgios[3], and INTENS team(*)

[1]Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
[2]INAF-Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy
[3]IAASARS, National Observatory of Athens, Greece

*A. Anastasiadis, A.Z. Boutsi, I. Coco, I. A. Daglis, F. Giannattasio, O. Giannakis, M. F. Marcucci, C. Papadimitriou, S. Pau, M. Pezzopane, A. Pignalberi, R. Tozzi and G. Vasalos

AIM

★To analyse the dynamical changes of the scaling features of the electron density fluctuations recorded by Swarm constellation in order to obtain information about **the turbulent nature of the ionospheric plasma** during the St. Patrick's storm.

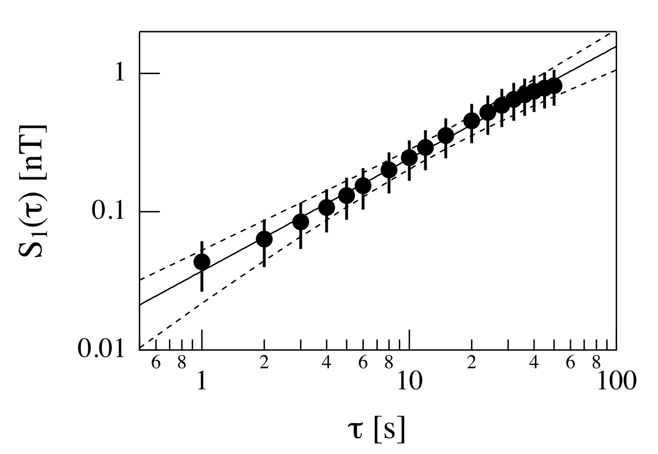
WHY

Turbulence plays a central role in several processes involving the plasma and particle transport. In the Earth's ionosphere, it plays a fundamental role in the overall dynamics. It is able to generate/create magnetic and plasma structures that can strongly affect the homogeneity of the plasma in the ionospheric regions playing a relevant role in space weather.

How can we study the features of turbulence in the electron density fluctuations ?

In order to study of the **properties of the turbulence** in the electron density fluctuations it is necessary to analyze:

1) the properties of **scale invariance**
2) the **spectral features**
3) the occurrence of **intermittency**



How to investigate scale-invariance ?

The **scale invariance** means that the main characteristics of a process are self-similar over a range of scales (the so-called inertial range) and that we deal with a multi scale process. A system, function, or statistics are characterized by scale invariance if changing the scale by a certain factor does not change the system, function, or statistics. We consider **q^th^-order structure function** $S_q(\tau)$, which for a signal $x(t)$ defined over an interval T is given by

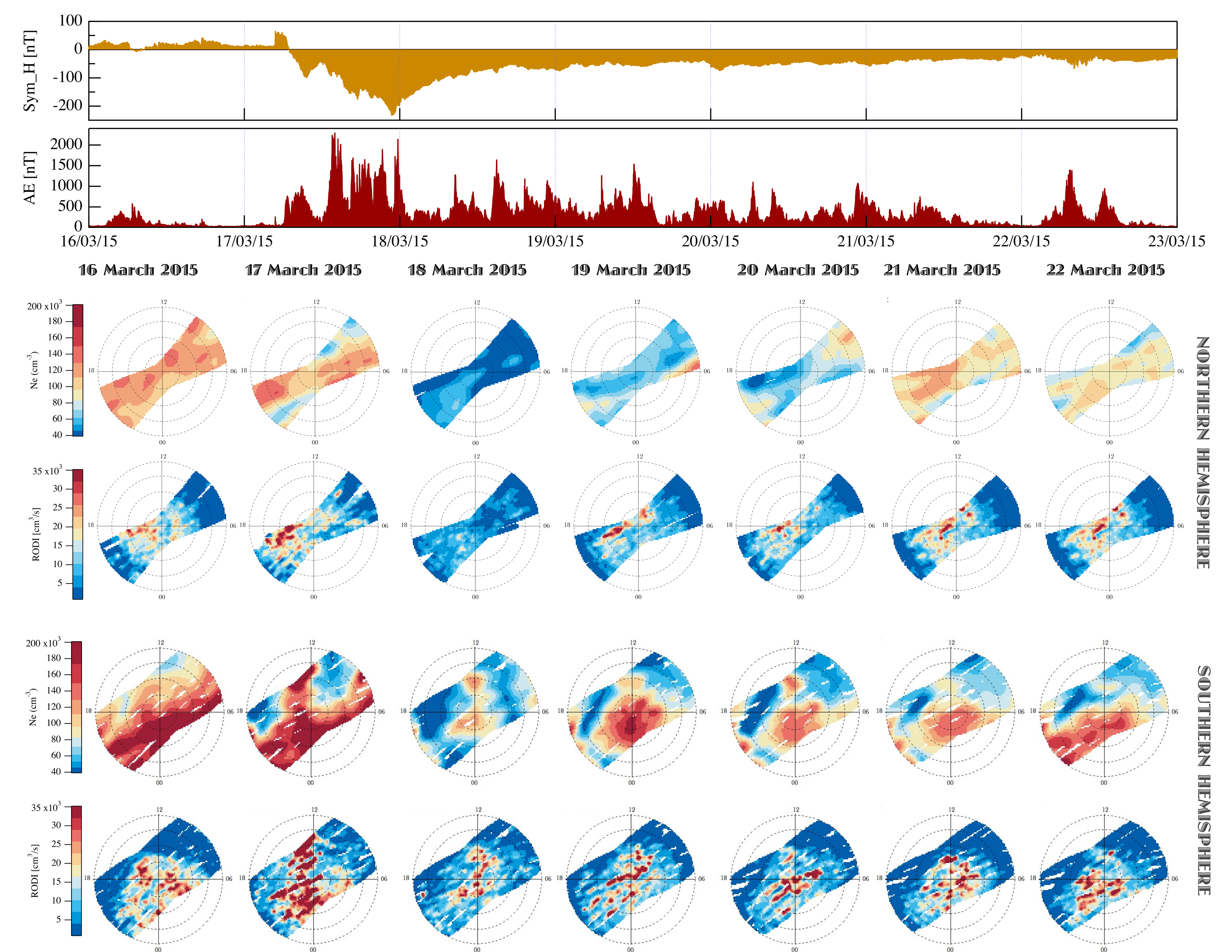
$$S_q(\tau) = \langle | \, x(t+\tau) - x(t) \, |^q \rangle_T$$

when we deal with a scale-invariant signal the $S_q(\tau)$ exhibits a power law behaviour as a function of the time separation

$$S_q(\tau) \sim \tau^{\gamma(q)}$$

In the case of the 1st-order structure function $S_1(\tau)$ the scaling exponent is called Hurst exponent H.

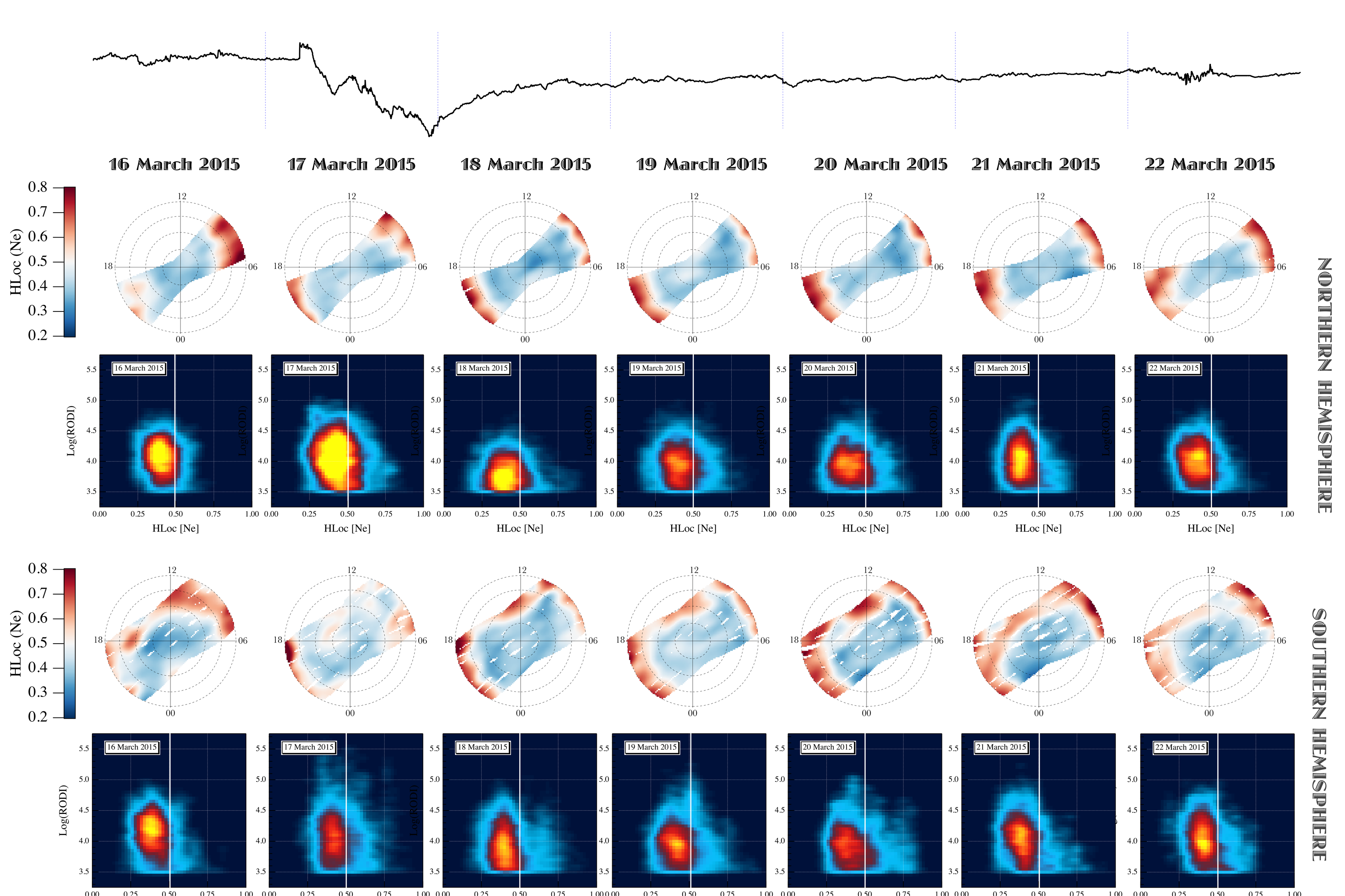
DATASET:
Electron Density and RODI (Rate Of change of Density Index) from Swarm constellation



Electron density recorded onboard of the three satellites of Swarm constellation is reported day by day during the St. Patrick's day storm together with the RODI index evaluated using method described by Jin et al. (JGR 2019). Data are relative to the Northern and Southern high latitudes and are reported in magnetic local time (MLT) and quasi-dipole magnetic latitude in a polar representation. Dashed circles are drawn at magnetic latitudes of 50°, 60°, 70°, and 80°, respectively.

Results:
Local Hurst Exponent and its relationship with RODI

The local **Hurst exponent** quantifies the relative tendency of a time series either to regress strongly to the mean (HLoc<0.5), that means to be characterized by an **anti-persistent** behavior (blue color in the figure below), or to cluster in a direction (HLoc>0.5), that means to be characterized by a **persistent** behavior (red color in the figure below).



- The scaling properties of the electron density fluctuations change during the development of the geomagnetic storm. The zone where the fluctuations are characterized by an anti-persistent behavior is larger during the main phase of the storm. This change is evident in both hemispheres.
- High values of the RODI index, which is the variance of electron density fluctuations and indicates structuring of the plasma within a fixed time interval (in our case 10 s), are correlated with an anti-persistent character of the electron density fluctuations.
- This can be an effect of the occurrence of turbulence which may generate multi scale plasma structures. Indeed, the relative tendency of a time series to regress strongly to the mean (HLoc<0.5) is one of the possible indication of small scale structuring.

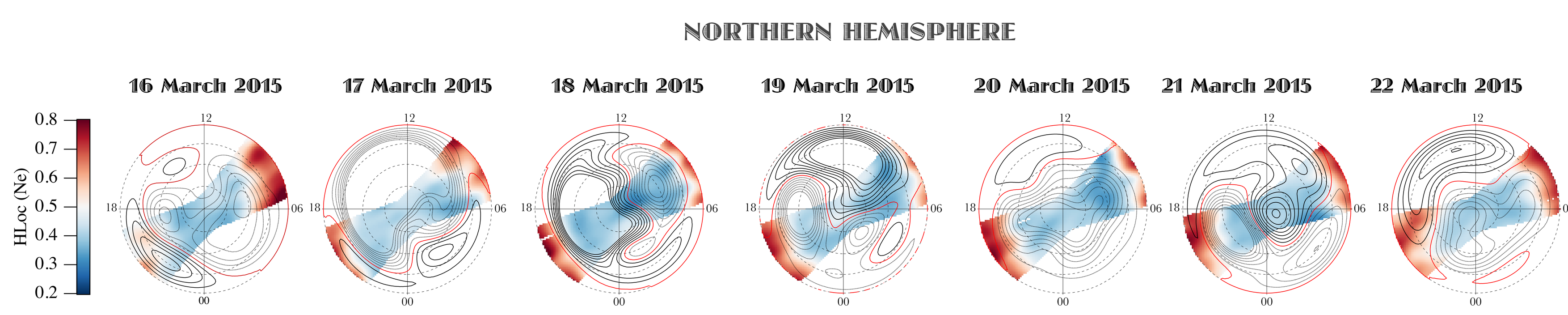
Results:
Local Hurst Exponent and SuperDARN Data

The SuperDARN network of high frequency (HF) coherent scatter radars currently includes 21 radars located in the Northern Hemisphere and 9 in the Southern one. Observations by multiple radars provide coverage over a large area. This large data set may be used to generate global-scale maps of the ionospheric convection.The large field of view of the SuperDARN radar network makes it an ideal candidate for combination with the Swarm data set for convection mapping.

We compare the distribution of the Hurst exponent describing the scaling features of the electron density fluctuations with the contours of electrostatic potentials reconstructed using data from SuperDARN network in the Northern Hemisphere. SuperDARN data, which are relative to the time intervals spent from each satellite in its crossings of the high-latitude region.

The comparison shows a correspondence between the two convection cells structure and the region where the electron density fluctuations have an anti-persistent nature. That means that we are in presence of small scale fluctuations of the density.

Furthermore, the anti-persistent nature of density fluctuations in the convection cells could be related to the emergence of a turbulence regime due to an instability mechanism that could be at the origin of these small scale structures. This point clearly requires a more detailed investigation.



"Characterization of IoNospheric TurbulENce level by Swarm constellation (INTENS)" is a study recently approved by ESA in the framework of "EO Science for Society Permanently Open Call". The aim of the study is to investigate the nature of geomagnetic field and plasma parameters (i.e., electron density and temperature) fluctuations, as well as their scaling features during different geomagnetic disturbance conditions, to unveil the role played by the magnetohydrodynamic (MHD) turbulence on the ionospheric environment in creating multi-scale plasma structures and plasma inhomogeneities.