UNIVERSITÀ DELLA CALABRIA
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Space Weather Italian Collaboration

THE MAIN PERIODICITIES OF THE ULF GEOMAGNETIC POWER AND THEIR RELATIONSHIP WITH SOLAR WIND AND MAGNETOSPHERIC ELECTRON FLUXES

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Introduction

- Solar wind is a plasma with high conductivity that allows to have a "frozen" magnetic field [1]
- Earth's magnetosphere-solar wind complex system is characterized by different phenomena (e.g. energy transport, waves, instabilities) which play a key role in the definition of space weather conditions
- Plasma instabilities are able to generate wave-like impulses called geomagnetic micropulsations named ultra-low frequency (ULF) waves (frequency range: $[10^{-3} \div 1]$ Hz)
- Our aim is to study Pc5 (2-7 mHz) waves periodicities, the relationships with solar wind speed but also their effects on magnetospheric electrons motion

Data and Methods

- Spectral power of magnetic field variations (Pc5) obtained from Terra Nova Bay (TNB) station which is located in Antarctica [2]
- Solar wind speed and electron fluxes datasets obtained from OMNIWeb (http://omniweb.gsfc.nasa.gov)

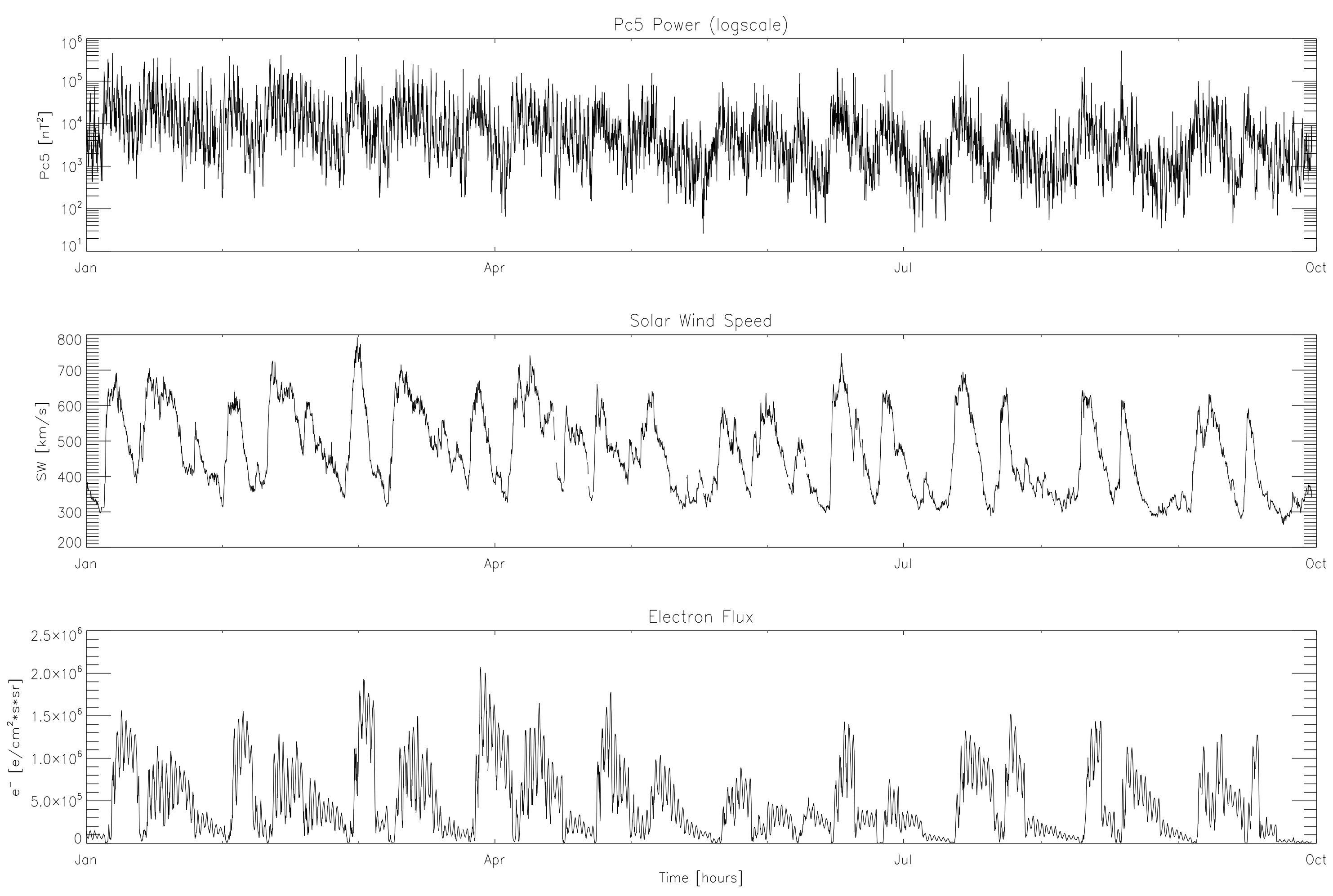

Figure 1: Data sets used in our study.

- Methods: Empirical Mode Decomposition
- Investigation of non-stationary and non-linear data [3, 4], successfully applied in many different fields [5]
- Each data set $X(t)$ is decomposed in m empirical modes, called Intrinsic Mode Functions (IMF), and a residue $r_m(t)$ which provides the mean trend:

$$X(t) = \sum_{j=0}^{m-1} C_j(t) + r_m(t) \quad (1)$$

- $C_j(t)$ represents a zero mean oscillation $C_j(t) = A_j(t)\sin(\phi_j(t))$ (being $\phi_j(t)$ and $\omega_j(t) = d\phi_j/dt$ the istantaneous phase and frequency respectively)
- A typical average period T_j can be estimated for all the IMFs
- The decomposition is local, complete and orthogonal, and can be used as a filter by recostructing partial sums of Eq. (1)

Periodicities in the Sun-Earth system

- Identification of short-term processes involved into the coupling of solar wind and magnetosphere
- The ensemble of significant j-modes can be divided in three dominant groups and we obtain three non-linear waveforms

$$W_k(t) = \sum_{j \in S_k} C_j(t) \quad (2)$$

- The set S_1 is used to reconstruct waveform with an average characteristic period $P_1 \simeq 1-2$ days
- The set S_9 contains IMFs with characteristic period $P_9 \simeq 5-14$ days
- The set S_{27} is finally used to reconstruct waveform with characteristic period $P_{27} \simeq 20-34$ days

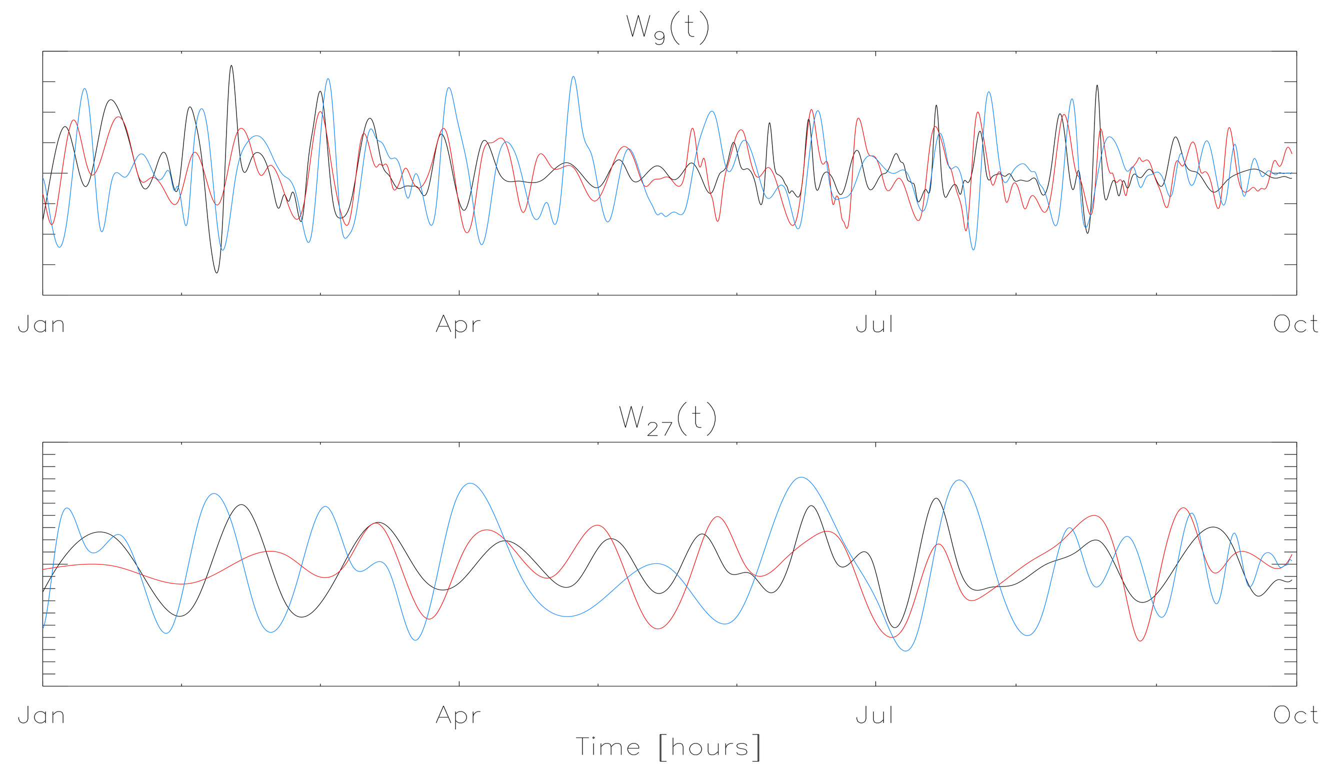

Figure 2: Time evolution of waveforms $W_9(t)$ and $W_{27}(t)$ for Pc5 Power [black line], Solar Wind Speed [red line] and Electron Flux [blue line].

- Cross-correlation analysis allows to measure similarity of two waveforms, as a function of a time-lag applied to one of them

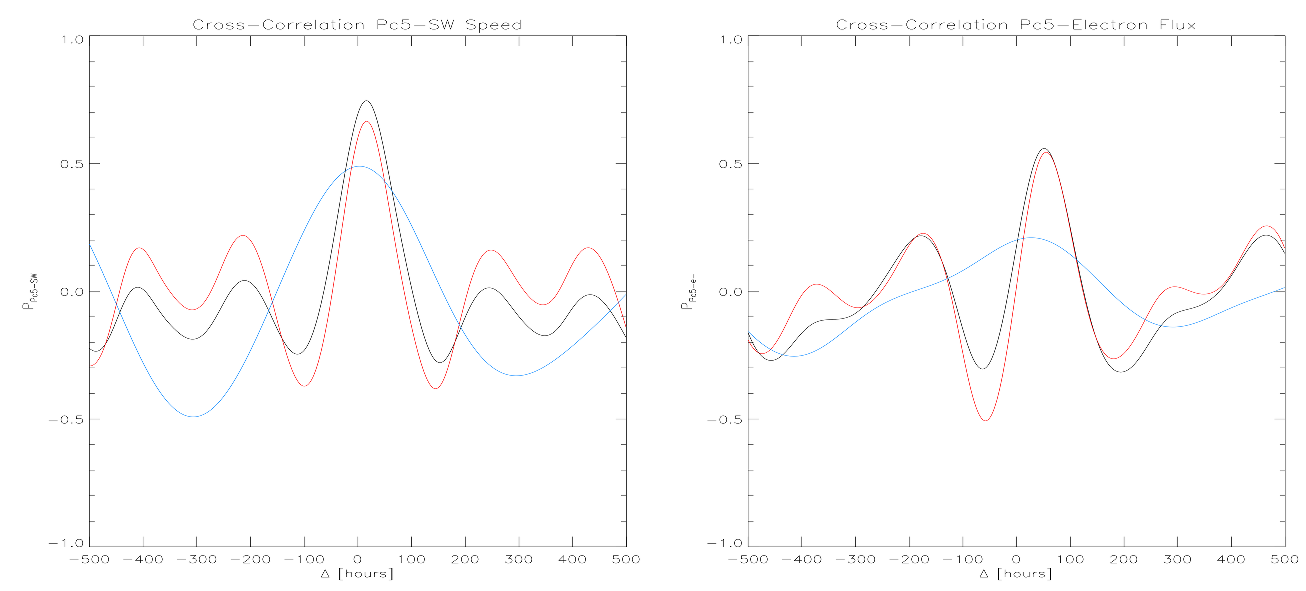

Figure 3: Cross-correlation coefficient between Pc5 and solar wind speed [left panel], Pc5 and electron flux [right panel] as a function of time lag Δ. The black line corresponds to the cross-correlation obtained by using the three waveforms, while the red line has been obtained by using the $W_9(t)$ waveform and the blue line by using the $W_{27}(t)$ waveform.

Conclusions

- Three main mechanisms characterize periodicities in solar wind-magnetosphere system and two of these can be identified: P_1 periodicity is related to the Earth's rotation and P_{27} periodicity is due to the solar rotation
- The novel result is the presence of the waveform with average period of $\simeq 9$ days that could be related to solar structures such as high-speed streams and corotating interaction regions [6, 7]
- High-speed streams, formed by higher speed solar wind originating from coronal holes, occurring with an average period of about 9 days, could trigger P_9 periodicity. This interpretation is supported by the fact that solar wind high-speed stream pumps energy into the magnetosphere which can cause geomagnetic activity and produce energetic electron flux enhancements in the radiation belt
- The waveform W_1 does not significantly contribute to cross-correlation (see Fig. 3)
- Pc5-Solar wind speed correlation results: a time delay of $\Delta = 0$, corresponding to a maximum of $\simeq 0.5$ for W_{27} and a lag of $\Delta \sim 16$ hours for W_9, corresponding to a maximum of $\simeq 0.66$ (in the latter case Pc5 leads solar wind speed)
- Pc5-Electron flux correlation results: a lag of $\Delta = 55$ hours, corresponding to a maximum of $\simeq 0.54$, for W_9 and a delay of $\Delta = 8$ hours, corresponding to a maximum of $\simeq 0.2$ for W_{27} (in both cases Pc5 wave power leads electron flux)
- Due to the continuous coupling between the solar wind and the Earth environment, it is quite reasonable to figure out that geomagnetic micropulsations can be generated by Kelvin-Helmholtz instability. Assuming that the coupling via KHI might be roughly instantaneous, we can expect no temporal lag at all, or, at least, we can expect that the solar wind velocity will lead Pc5 wave activity. The leading of Pc5 with respect to solar wind velocity seems to be somewhat inconsistent with the KHI mechanism. The W_9 waveform in the Pc5 wave power could not be affected by solar wind speed but probably is generated through fluctuations in other solar wind parameters that are directly involved in the KHI such as pressure or density
- ULF waves can enhance electron flux through a wave-particle mechanism [9] governed by processes at the characteristic time scale of $\simeq 9$ days. The diffusion time due to this processes can be estimated from numerical simulations to be of the order of few times the radial diffusion time, which to be estimated of the order of about 15 hours [10]

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