The main periodicities of the geomagnetic Pc5 wave power and their relationship with solar wind flow pressure and electron flux

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SWICO Space Weather Italian Collaboration

1. 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 pressure and magnetospheric field but also their effects on magnetospheric electrons motion

2. Data

- Spectral power of magnetic field variations (Pc5) obtained from Terra Nova Bay (TNB) station [2]
- Solar wind pressure and electron flux ($E > 0.6$ MeV) datasets obtained from OMNIWeb (http://omniweb.gsfc.nasa.gov)

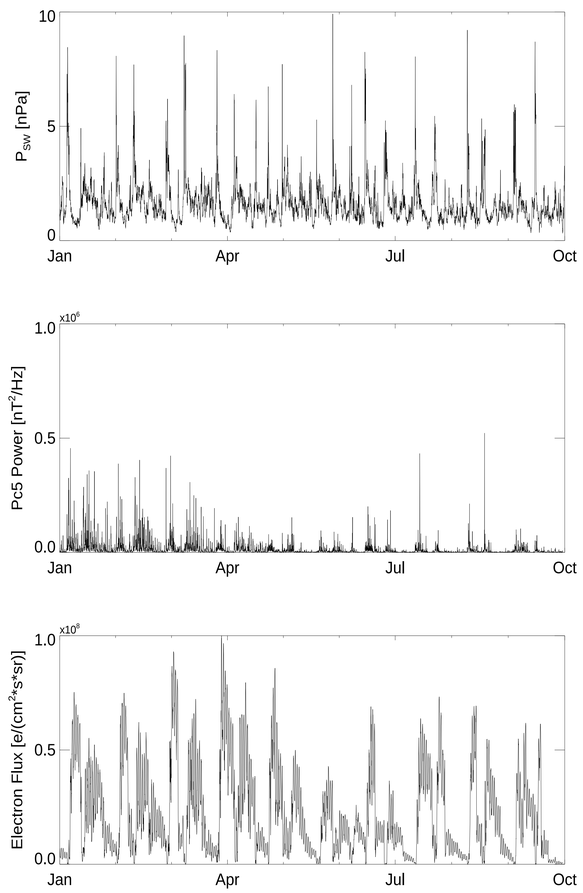

Figure 1: Original datasets

3. Methods

- Empirical Mode Decomposition (EMD)
- Investigation of non-stationary and non-linear data [3], successfully applied in many different fields [4]
- 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)
- Standardized Mean Test (SMT)
- Timescale separation

$$X(t) = X_{HF}(t) + X_{LF}(t) \quad (2)$$

- $X_{LF}(t)$ is the low-frequency component
- Properties of X_{HF}:
  1. identifies fluctuations around a time-dependent average value $X_0(t)$
  2. has a close to zero standardized mean
  3. represents high-frequency contribution to the time series

4. Results

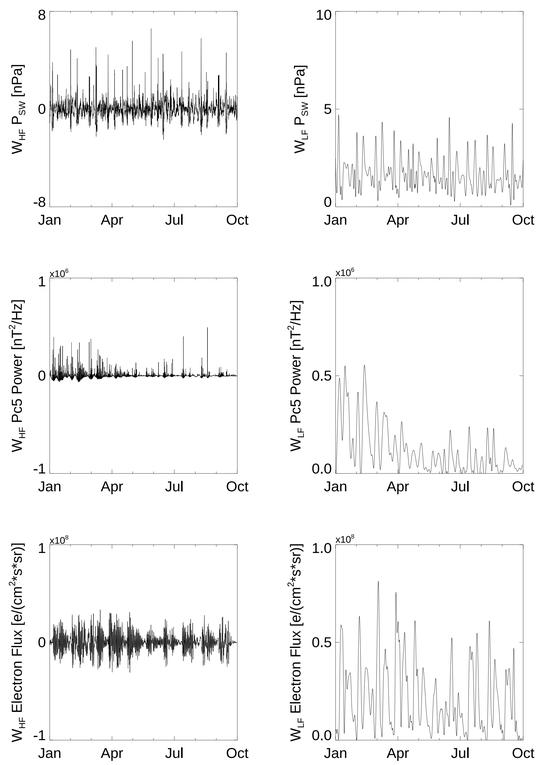

Figure 2: High-frequency contributions (left panels) and low-frequency reconstructions (right panels) for each dataset

5. Cross-correlation analysis

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

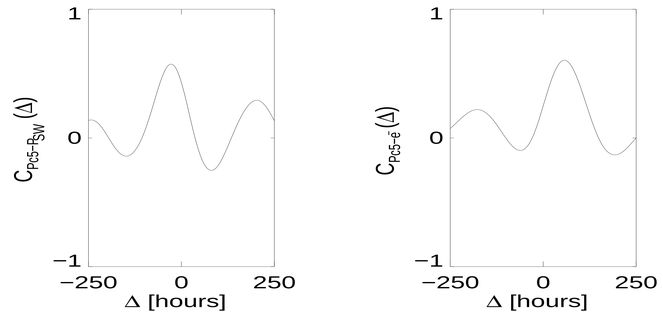

Figure 3: Cross-correlation coefficients between couples of low-frequency reconstructions

6. Discussion & Conclusions

- Two main contributions characterize periodicities in solar wind-magnetosphere system
- High-frequency contribution $W_{HF}(t)$
  1. characterizes processes with timescale $\tau \lesssim 3$ days
  2. has a close to zero standardized mean
  3. has a relatively small amplitude contribution into the decomposition
  4. is obtained from a partial sum of modes with time-dependent instantaneous frequencies
- Low-frequency contribution $W_{LF}(t)$
  1. is related to mechanisms with a timescale $\tau \sim 5 - 100$ days
  2. involves characteristic timescales which can be associated with solar rotational periodicities such as $\tau \sim 9, 13.5, 27$ days
  3. has the largest amplitude contribution into the decomposition
  4. is obtained from a partial sum of modes with instantaneous frequencies close to be constant
- Cross-correlation results evidence that:
  1. Solar wind pressure leads geomagnetic micropulsations with a time delay $\Delta \sim 30$ hours (peak value ~ 0.65)
     - This underlines the relevant role of the pressure balance into the coupling between solar wind and Earth's magnetosphere
     - The characteristic timescales associated with the generation of geomagnetic micropulsations are related with solar rotational periodicities
  2. Geomagnetic micropulsations lead enhancements in electron flux with a lag $\Delta \sim 54$ hours (peak value ~ 0.6)
     - This result is consistent with that found by Mann et al. [5] (~ 2 days time delay)
     - The higher correlation is found using low-frequency reconstructions which remanks the importance of solar wind structures into the magnetosphere dynamics

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