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

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1. Introduction

- Solar wind is a plasma with high conductivity that allows to have a "frozen" magnetic field.
- Earth’s magnetosphere-solar wind complex 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 with frequency range: [10⁻³ - 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)

3. Methods

- Empirical Mode Decomposition (EMD)
- Investigation of non-stationary and non-linear data [3], successfully applied in many different fields [4]
- Each dataset X(t) is decomposed in m empirical modes, called Intrinsic Mode Functions (IMF), and a residue cm(t) which provides the mean trend:
  \[ X(t) = \sum_{j=0}^{m-1} C_j(t) + c_m(t) \]  
- Cj(t) represents a zero mean oscillation \( C_j(t) \sim A_j(t) \sin(\omega_j(t)) \) (being \( \omega_j \) and \( \phi_j \) the instantaneous 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 reconstructing partial sums of Eq. (1)

4. Results

- 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

6. Discussion & Conclusions

- Two main contributions characterize periodicities in solar wind-magnetosphere system
  - High-frequency contribution \( W_{HF}(t) \)
    1. characterizes processes with timescale \( \lesssim 3 \) 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 \( \gtrsim 5 - 100 \) days
    2. involves characteristic timescales which can be associated with solar rotational periodicities such as \( \sim 9.13 \text{S} \) 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 \( \Delta \sim 30 \text{ hours} \) (peak value \( \sim 0.65 \))
  2. This underlines the role of the pressure balance into the coupling between solar wind and Earth's magnetosphere
  3. The characteristic timescales associated with the generation of geomagnetic micropulsations are correlated with solar rotational periodicities
  4. Geomagnetic micropulsations lead enhancements in electron flux with a lag \( \Delta \sim 54 \text{ hours} \) (peak value \( \sim 0.6 \))
  5. This result is consistent with that found by Mann et al. [5] (\( \sim 2 \) days time delay)
  6. The higher correlation is found using low-frequency reconstructions which remark the importance of solar wind structures into the magnetosphere dynamics

References


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