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On the origin of Ultra-Low Frequency (ULF) waves in sudden and quasiperiodic solar wind dynamic pressure variations penetrating into Earth's magnetosphere

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Several observational studies have shown that external (i.e. solar wind and magnetosheath) dynamic pressure variations can drive quasi-periodic perturbations of the geomagnetic field. In this study, we utilise multi-spacecraft (ARTEMIS, Cluster, GOES, and THEMIS) mission measurements and investigate step-like increases and quasi-periodic variations of solar wind dynamic pressure as the source mechanism of geomagnetic pulsations with frequencies between ~0.5 to 15 mHz. During intervals of slow solar wind and low geomagnetic activity — to exclude waves generated by velocity shear at the magnetopause and substorm contributions — common periodicities in electromagnetic field oscillations inside the magnetosphere and the solar wind driver are detected in Lomb-Scargle periodograms. The causal relationship is examined in frequency and polarisation signatures of waves detected at the various probes using continuous wavelet transform, cross-wavelet spectra and wavelet transform coherence. The observed dependence of wave properties on their localisation offers excellent source verification for ULF Pc4-5 waves originating in dynamic pressure variations in the upstream solar wind and propagating in the dayside magnetosphere through the field line resonance process.

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ULF waves originating in solar wind dynamic pressure variations

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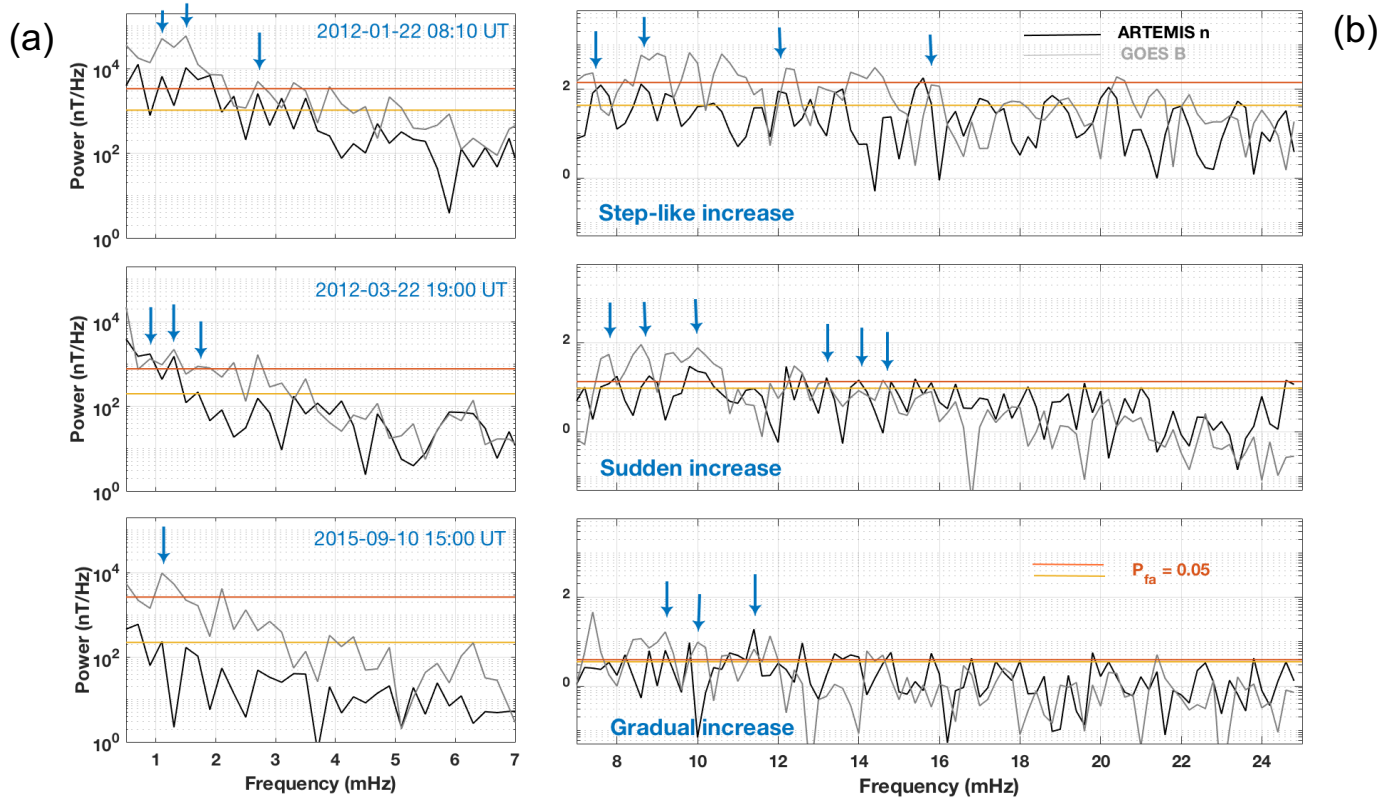
Variations in solar wind dynamic pressure are common and occur over a number of timescales. We focus on:

Sudden: short-lived (30 min to a few hours) density (dynamic pressure) increase with N_{max} > 18 [1/cc]

Gradual: long-lasting (several hours) density (dynamic pressure) increase with dN/dt << and N_{max} > 18 [1/cc]

Shock: step-like increase of density (at least by a factor of 2), dynamic pressure and magnetic field indicating a shock

Complex: combination of the aforementioned categories



Lomb-Scargle periodograms depicting ULF fluctuations in solar wind density and geomagnetic field with Pc5 (panel (a)) and Pc4 (panel (b)) frequencies

Data set used for this study of ULF waves:

Solar wind plasma and IMF measurements from ARTEMIS located at 14 < MLT < 10, combined with THEMIS and GOES measurements within the magnetosphere

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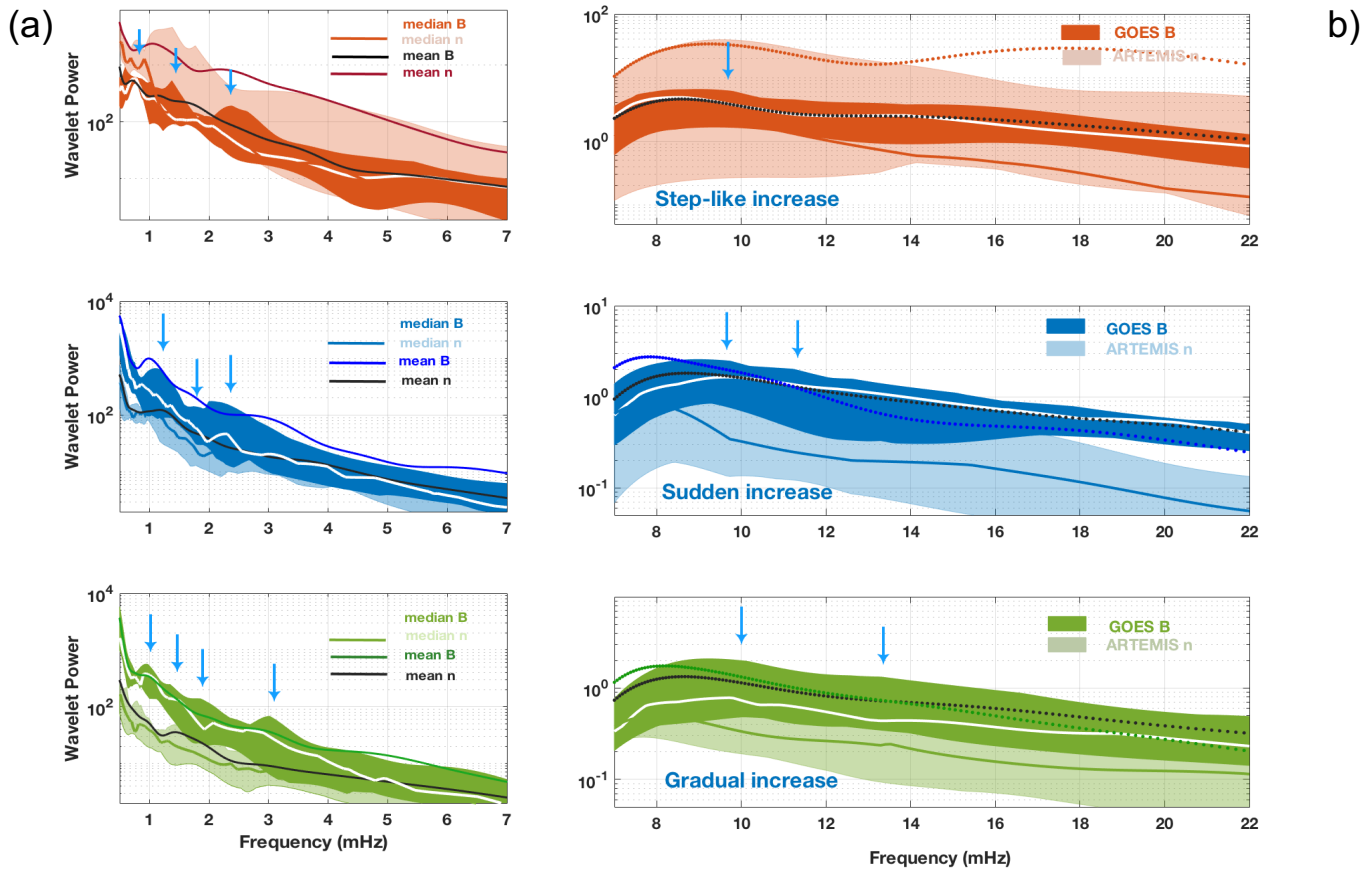
Key findings:

- Step-like, short-lived and gradual density (pressure) increases in solar wind are followed by magnetospheric magnetic field fluctuations
- Periodic fluctuations identified at discrete Pc5 (0.5 – 7 mHz) and Pc4 (7 – 22 mHz) frequencies
- Solar wind pressure variations leave different signatures on geomagnetic field fluctuations along geosynchronous orbit



Superposed epoch analysis of global power spectra of solar wind density and geomagnetic field at geosynchronous orbit, covering the Pc5 (panel (a)) and Pc4 (panel (b)) frequency bands

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