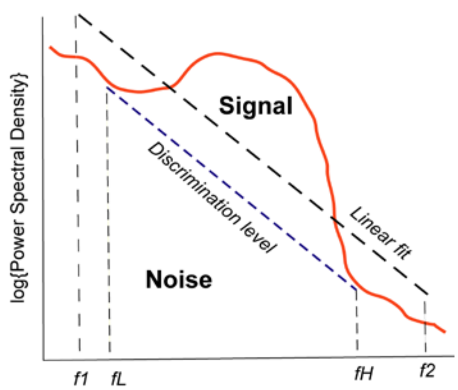
Construction of a ULF wave index

We derive a ground ULF wave index using the spectral features of ULF power in the Pc5 band averaged over 1 hour from a global array of stations in the Northern hemisphere. The data have been decimated to a common sampling period, 1-min, whenever necessary.

The data were inspected for quality, and any daily files with strong interference or large data gaps were purged from the database. The data have been detrended with a cut-off frequency of 0.5 mHz and converted into a geographic (X,Y) coordinate system. For any UT hour, the magnetometer stations in the chosen MLT sector (from LT_1 to LT_2), and in a selected CGM latitude range (from Φ_S to Φ_N) are selected.

For selected stations, the power spectral density $F_f = B_f^2 [\mathrm{nT}^2/\mathrm{Hz}]$ are calculated of two horizontal components in a selected frequency band with the use of Filon's formula from Discrete Fourier Transform (DFT) in a 1 hour time window. The signal and background noise spectral contents have been estimated in the following way. In a log-linear plot the linear fit *LF(f)* is applied, which fits the data to a linear model by minimizing the chi-square error *σ,* in the frequency band from f_1=1 mHz to f_2=8 mHz (the Nyquist frequency for a 1-min sampling period is 8.3 mHz). Then, a discrimination line, separating the background noise and signal spectra, is considered as $\log F_B(f) = LF(f) - \sigma$ (as schematically illustrated in Figure). The bump above the discrimination line is considered to be the contribution from a band-limited signal.



The frequency range selected for construction of the ULF index is bounded by the lower and upper frequencies f_L and f_H. Noise spectral power in this frequency range is calculated at each *j*-th station as the area beneath the discrimination level (or background spectrum), F_B

$$N_j = \int_{fL}^{fH} F_B(f)df \qquad (1)$$

Signal spectral power is the area of the bump above the discrimination level, that is

$$S_j = \Delta f \sum_{fL}^{fH} \{F(f) - F_B(f)\}$$

The global ULF wave index is calculated from the band-integrated total power $T_j = S_j + N_j$ at each station by the summation with respect to those N_{st} stations where the power of the signal is maximal, and normalized to the number of components N_{comp}

$$T = \frac{1}{N_{st} N_{comp}} \sum_{j=1,N} T_j \qquad (3)$$

The threshold parameter *K* may be reasonably chosen between 0.5 and 1.0 (the latter case corresponds to the selection of one station only with maximal amplitude). Similar to (3), the total power of signal and noise components are defined

$$S = \frac{1}{N_{st} N_{comp}} \sum_{j=1,N} S_j \qquad N = \frac{1}{N_{st} N_{comp}} \sum_{j=1,N} N_j \qquad (4)$$

The dimension of the ULF index is [nT].

Additional hourly ULF wave indices

Ground magnetic fluctuations are not always a perfect image of the ULF fluctuations in the magnetosphere. For example, there is a class of ULF waves, called storm-related Pc5 pulsations, that occur during the recovery phase of magnetic storms in the dusk and noon sectors of the magnetosphere. Despite their high amplitudes in the magnetosphere, these pulsations are rarely if ever seen on the ground because their small azimuthal scales cause effective screening by the ionosphere. Thus, the ground global index needs to be augmented by a similar index, estimated from data from magnetometers in space. This wave index, coined the GEO ULF index (namely, T_{GEO}, S_{GEO}, and N_{GEO}), is calculated from 1-min 3-component magnetic data from the geostationary GOES spacecraft to quantify the short-term magnetic variability in the region of geosynchronous orbit.

To quantify the short-term IMF variability, an interplanetary ULF index (further named the IMF ULF index, namely, T_{IMF}, S_{IMF}, and N_{IMF}) is estimated using 1-min data from the interplanetary satellites Wind, ACE, and IMP8. The data from these satellites were time-shifted to account for the ballistic propagation of the solar wind from the satellite location towards the nominal bow shock position (~15 R_E).

Index to quantify the short-term solar wind fluctuations *Tn* is calculated from the 1-min plasma data from the interplanetary satellites WIND, ACE. Additionally, we have applied the wavelet technique to estimate the integrated power of N fluctuations *Wn* with time scales 4 - 64 min to provide a separate database.

The following parameters have been used for the calculation of the ULF index. The selection of magnetic stations has been made in the MLT sector from MLT_1=03 to MLT_2=18, and in the CGM latitude range from $\Phi_S = 60^o$ to $\Phi_N = 70^o$. The frequency range is from f_L=2.0 mHz to f_H=7.0 mHz, and the discrimination level has been estimated by a linear fit in the frequency interval f_1=1mHz to f_2=8 mHz. The threshold parameter *K* is set to 1.0, which means that only the station with peak ULF power in this time interval was selected. The data from interplanetary satellites have been time-shifted according to the Weimer propagation model.

Despite many seemingly arbitrarily chosen parameters the output index is rather robust and is not strongly influenced by slight deviations of these parameters from selected values.

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