106° CONGRESSO NAZIONALE
SOCIETÀ ITALIANA DI FISICA
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Auroral oval layers detection by using CSES plasma and electric field data

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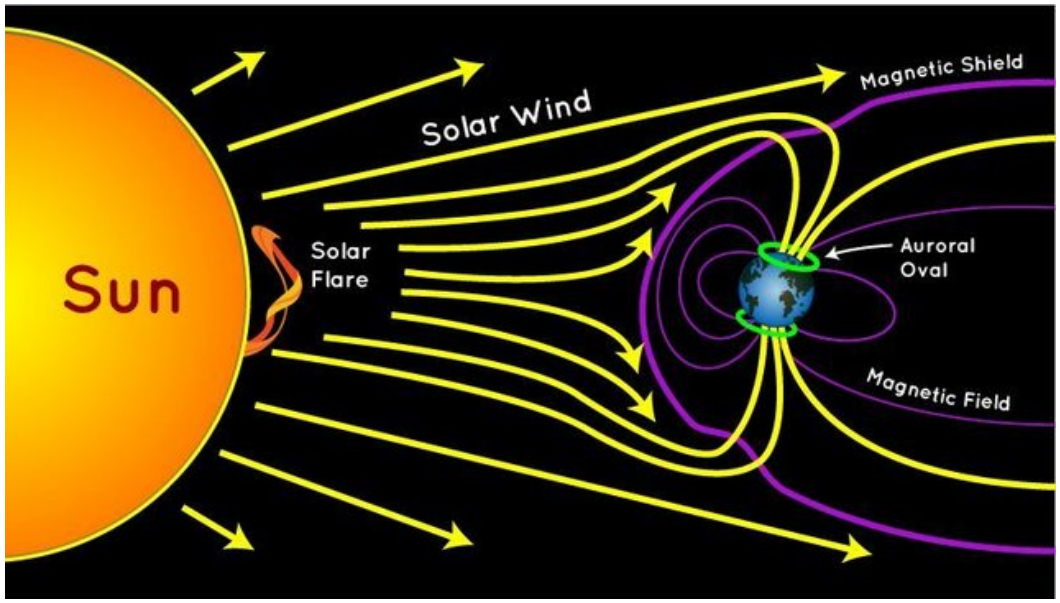
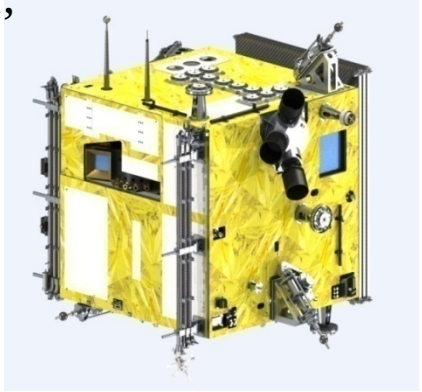
September 14-18, 2020

GOAL: characterize the plasma irregularities in the equatorward boundary of the auroral oval



From Ningchao Wang Ph.D. Thesis "Lagrangian coherent structures in ionospheric-thermospheric flows"

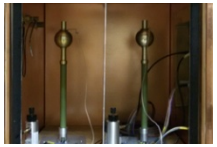
DATA: Chinese Seismo-Electromagnetic Satellite (CSES) mission CSES-01, which is part of a CNSA and ASI collaboration program



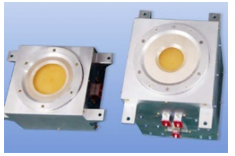
CSES-01 Instruments

High-Energy Particle Detector

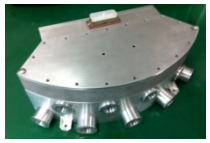
Electric Field Detector



Plasma Analyzer

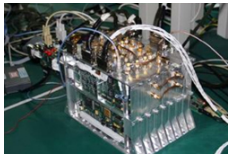


High-Energy Particle Package



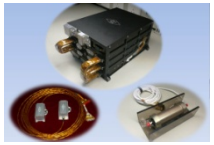
Langmuir Probe

GNSS Occultation Receiver



Search-Coil Magnetometer

High-Precision Magnetometer



Tri-Band Beacon

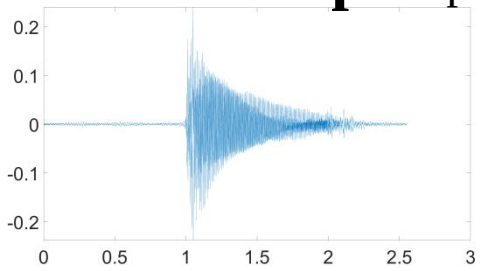
Fast Iterative Filtering (FIF) decomposition method

Given any nonstationary signal, FIF allows to decompose it in a few quasi-stationary and quasi-orthogonal oscillatory components

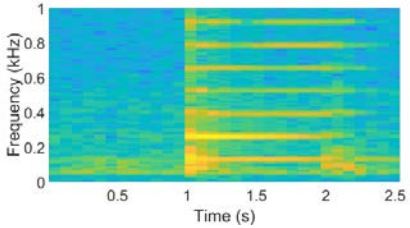
Fast Iterative Filtering Algorithm $\text{IMF} = \text{FIF}(s)$

$\text{IMF} = \{\}$
while the number of extrema of $s \geqslant 2$ **do**
  compute the filter length l for $s(x)$ and the corresponding filter w
  compute the DFT of the signal s and of the filter w
  while the stopping criterion is not satisfied **do**
    $\hat{s}_{m+1} = (I - \text{diag}\,(\text{DFT}(w)))^m \text{DFT}(s)$
    $m = m + 1$
  end while
  $\text{IMF} = \text{IMF} \cup \{\text{iDFT}\,(\hat{s}_m)\}$
  $s = s - \text{iDFT}\,(\hat{s}_m)$
end while
$\text{IMF} = \text{IMF} \cup \{s\}$

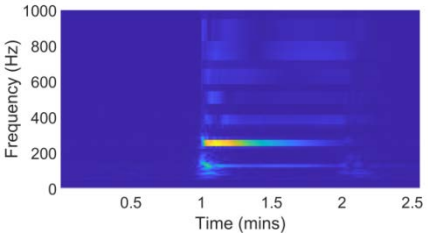
Example: piano C4 note 261.63 Hz



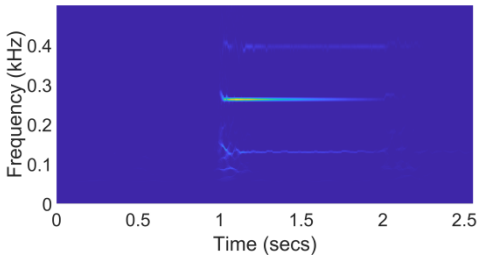
Signal



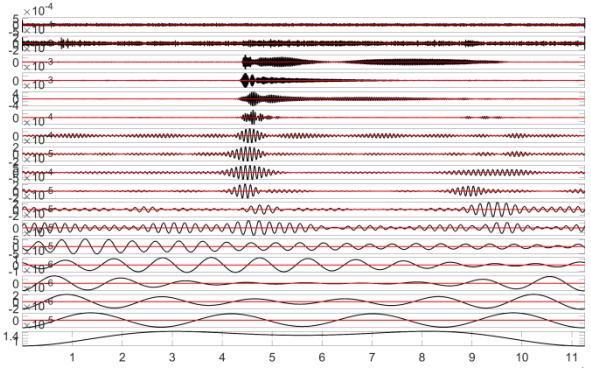
STFT



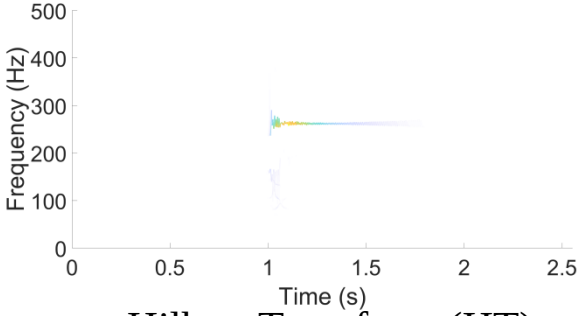
CWT



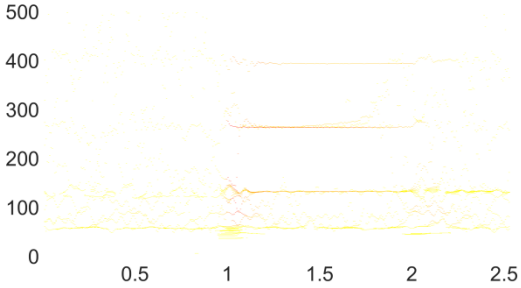
Synchrosqueezing (SST)



FIF decomposition



Hilbert Transform (HT)



FIFogram

STFT	CWT	SST	FIF+HT	FIF+FIFogram
0.7 s	1.9 s	16.9 s	4.3 + 3.3 s	4.3 + 0.6 s

Multiscale Statistical Analysis (MSSA)

Considering a highly erratic time series $X(t)$, we can decompose it via FIF as

$$X(t) = X_0(t) + \sum_{\tau} \delta_{\tau} X(t),$$

where $X_0(t)$ is the "low pass component", and $\Sigma_{\tau} \delta_{\tau} X(t)$ contains the fluctuations.

Given the previous decomposition, we can compute the following statistical quantites to caracherize the different time scales τ

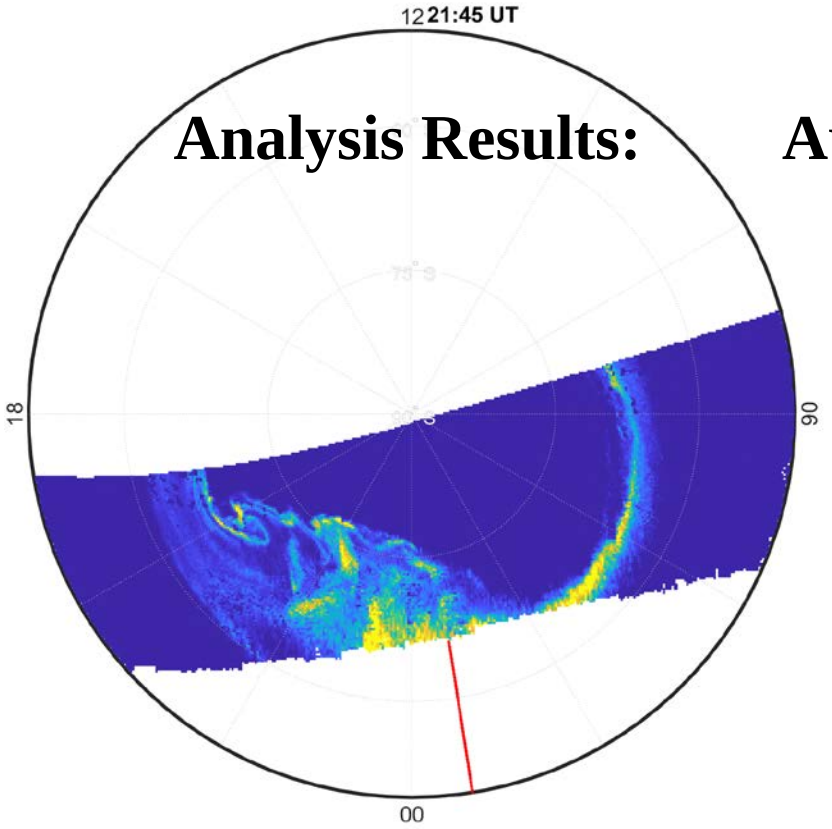
Probability Distribution $P_I(\delta_\tau X)$

Kurtosis Excess $K_I^{ex}(\tau) = K_I(\tau) - 3$

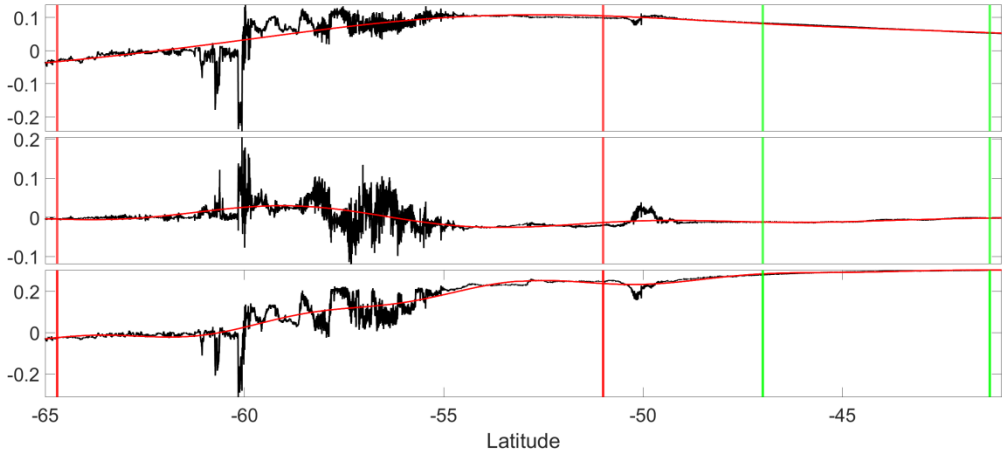
Relative Energy $\varepsilon_{\text{rel}}(t,\tau) = \dfrac{|\delta_\tau X(t)|^2}{\int d\tau' |\delta_\tau X(t)|^2}$

Squared Local Intermittency Measure $\text{LIM}^2(t,\tau) = \dfrac{|\delta_\tau X(t)|^4}{\left\langle |\delta_\tau X(t)|^2 \right\rangle_t^2}$

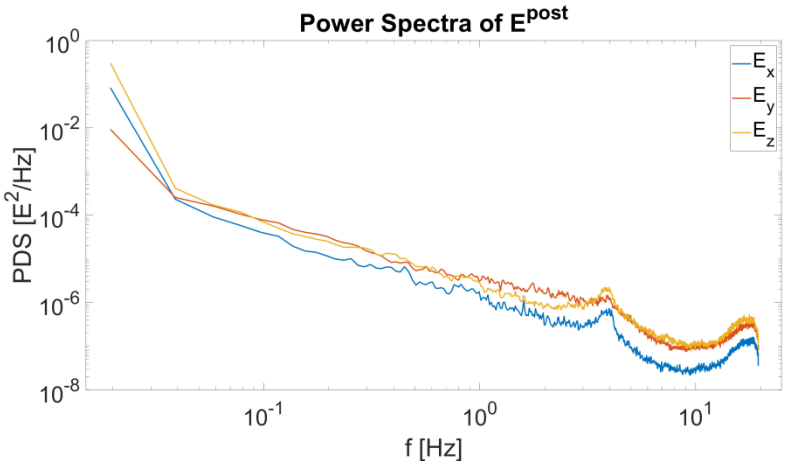
Analysis Results: August 11, 2018 case event

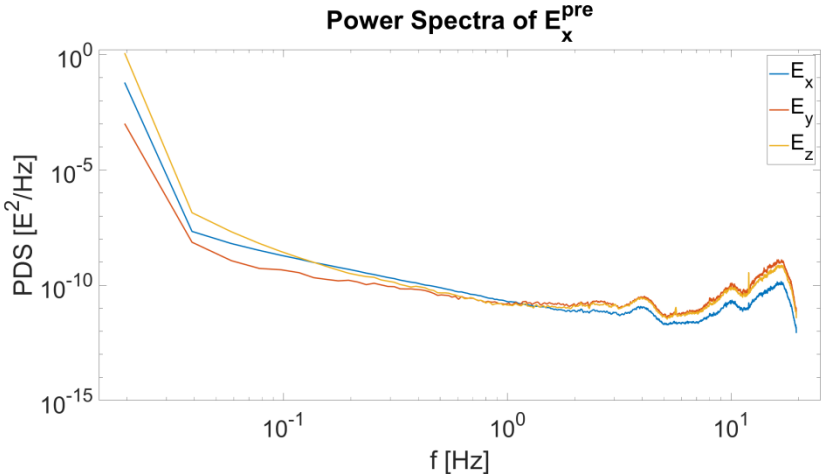


The trace CSES-01 orbit (red) on the top of the Auroral Oval map on August 11, 2018. The map of Auroral Oval emission is taken at UT 21:45

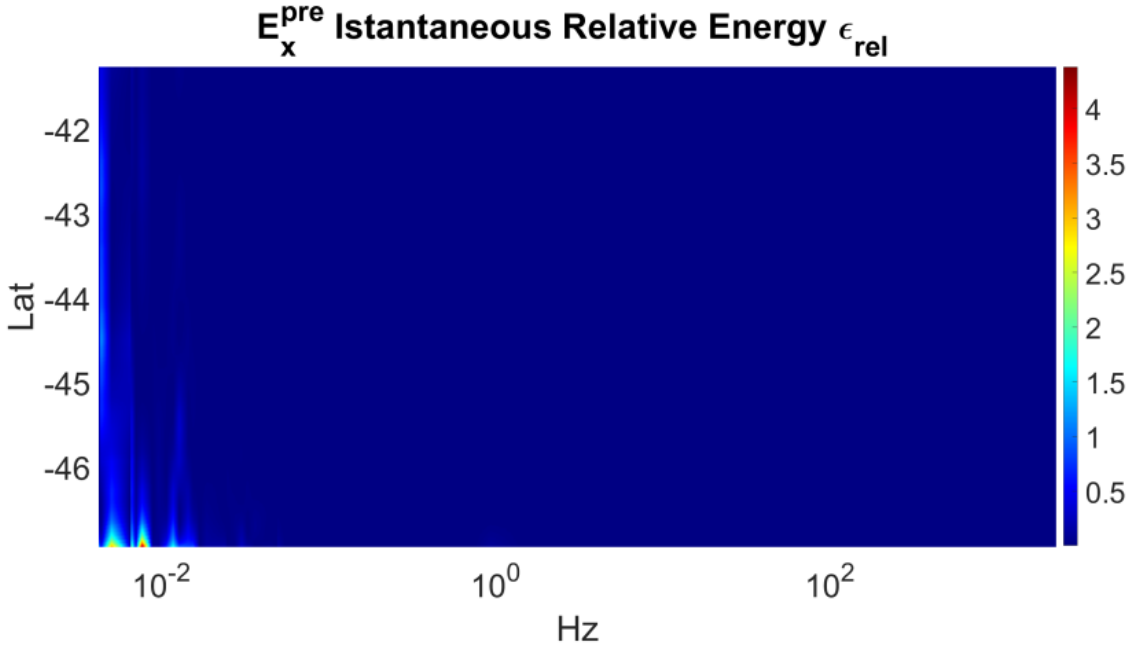


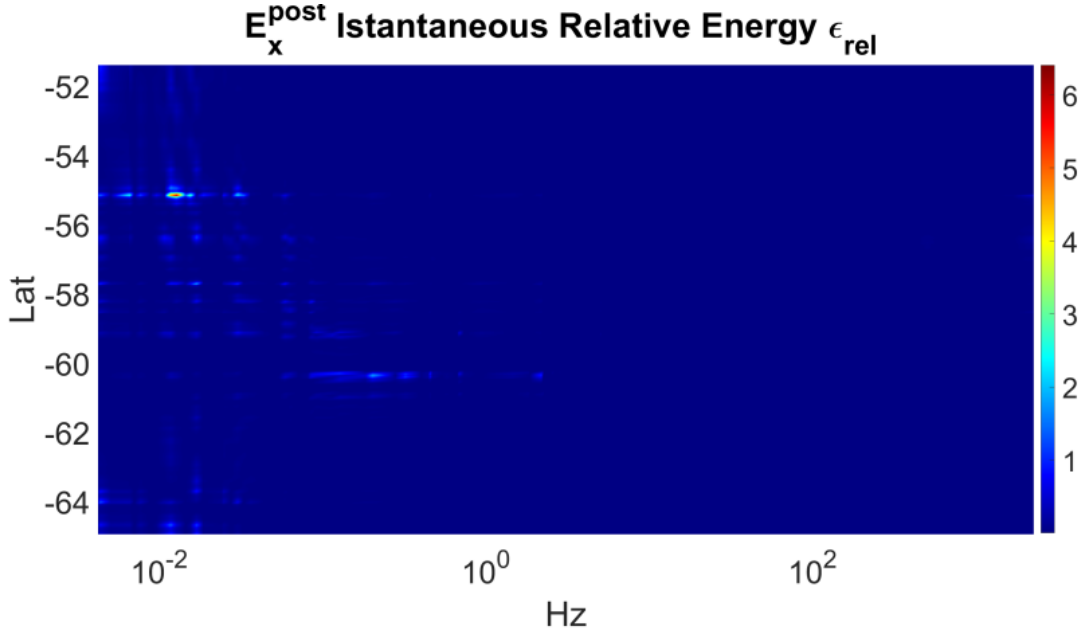
In black the three components of the Electric Field measured by the Langmuir Probe. In red their trends, $X_0(t)$. The red and green vertical lines limit the post- and pre-boundary region, respectively.



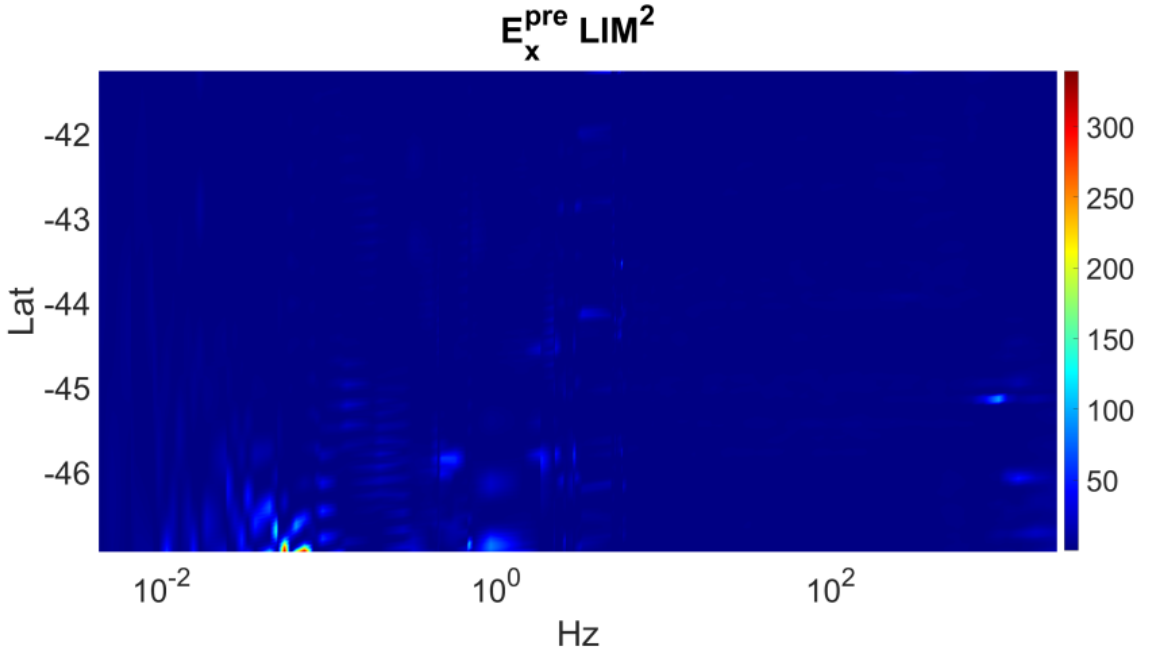


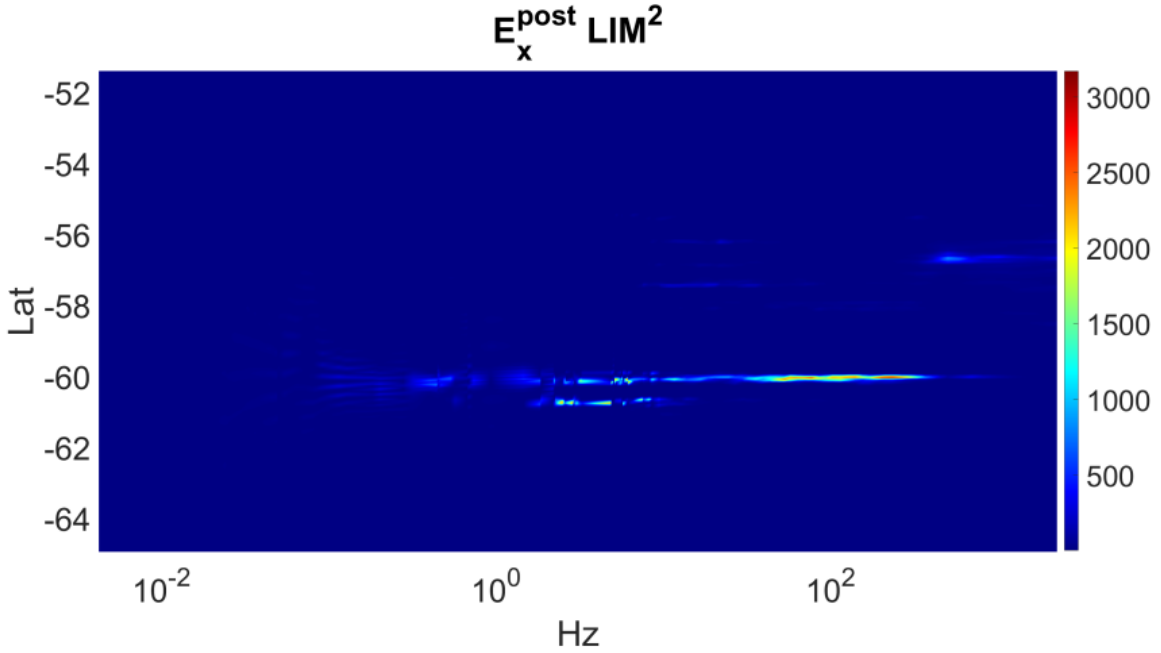
Analysis Results: August 11, 2018 case event - Cont'ed





Analysis Results: August 11, 2018 case event - Cont'ed





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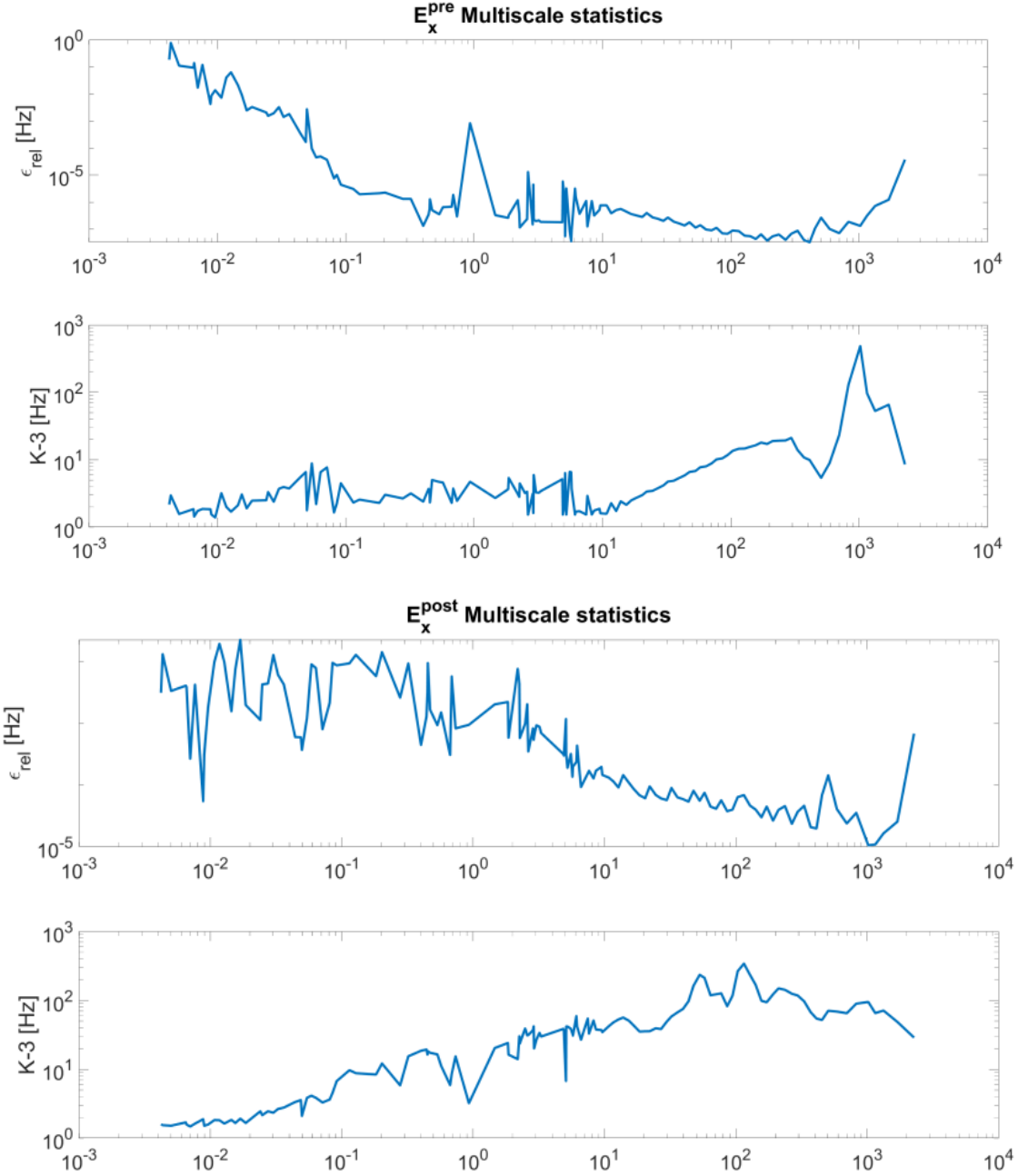

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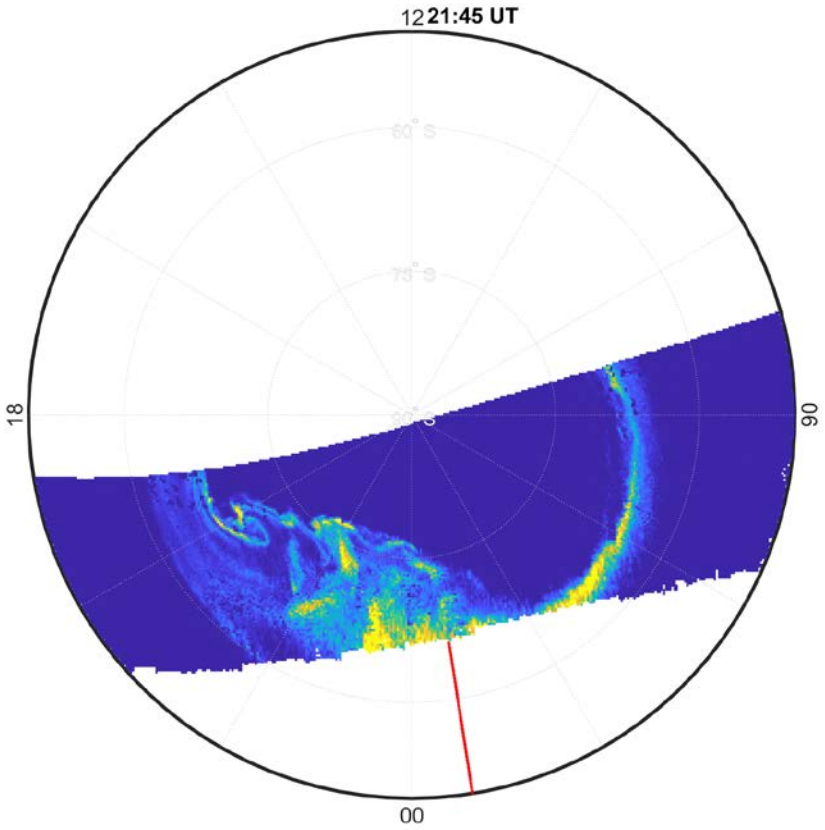

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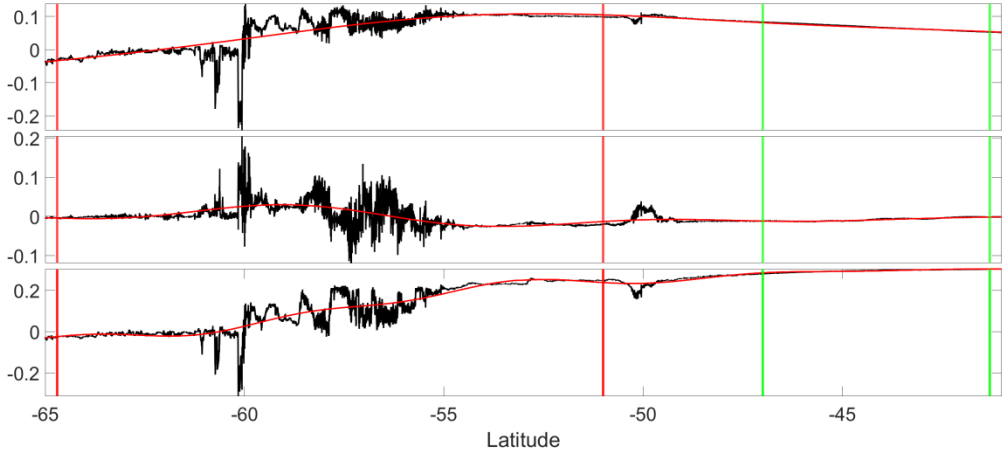

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