Daytime ULF wave intensity index - space weather relevant?

Work by Pilipenko et al.

compiled and presented by Jurgen Watermann

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ULF wave indices

developed and promoted by V. Pilipenko

Institute of Physics of the Earth, Moscow

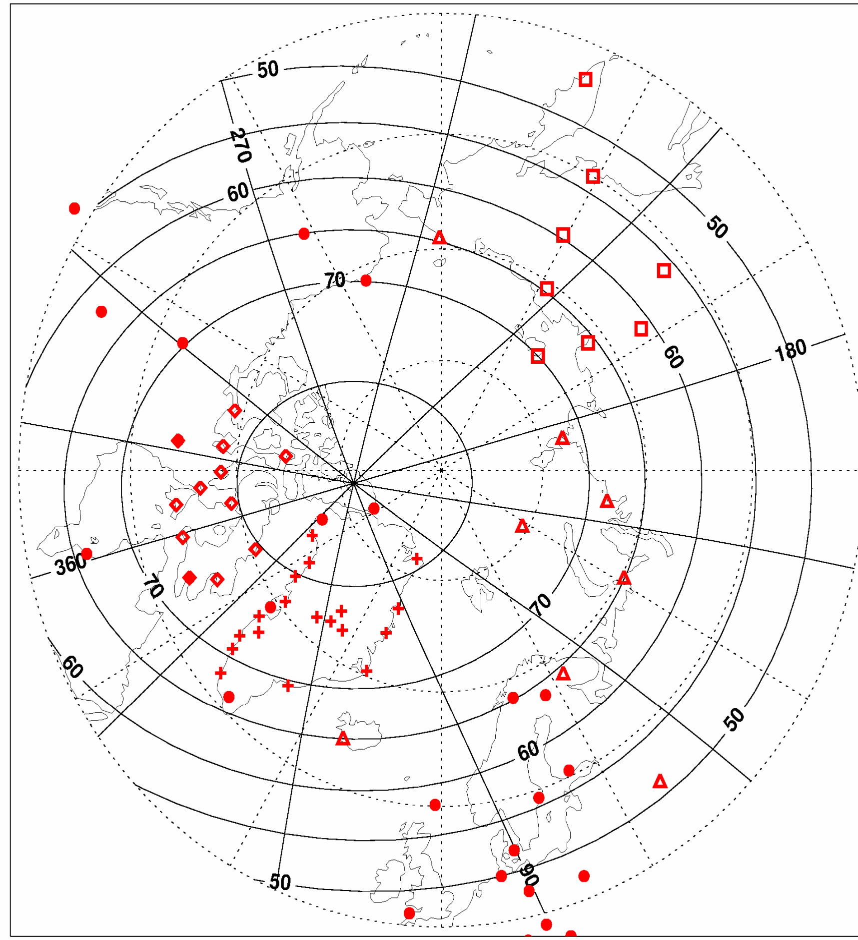
several slides and figures are taken from his presentations
and only slightly modified by JFW

Construction of ULF wave indices

• **INTERPLANETARY ULF wave index**
to quantify the IMF and SW variability is calculated from 1-min data from **interplanetary spacecraft**. The data are time-shifted to the bow shock.

• **MAGNETOSPHERIC ULF wave index**
is calculated from 1-min 3-component magnetometer data from GOES satellites to quantify the magnetic variability at **geostationary orbit**.

• **GROUND ULF wave index**
of global Pc5 activity is reconstructed from 1-min horizontal field data from **arrays of geomagnetic ground stations in the Northern hemisphere.**



For any UT, stations in the **03–18 MLT sector** are selected (to avoid substorm-related disturbances), and in the **latitudinal range 60°– 70° CGL.** ULF spectra (2-7 mHz) of detrended (cut-off 0.5 mHz) time series are calculated in a 1-hour running window

Algorithm for construction of the ground ULF wave index

- ✓ For any UT, magnetic stations in the MLT sector 05 – 15 and in the latitudinal range 60° - 75° CGM are selected. *(MLT and CGML boundaries are selectable)*
- ✓ Spectra of two detrended (cut-off 0.5 mHz) horizontal components are calculated using Filon's method in an 1-hour time window. *(frequency range considered: $f1=1mHz \le f \le f2=8mHz$, $f_{NY}=8.33$ mHz)*
- ✓ The frequency range for the index definition is the Pc5 band (fL=3 mHz, fH=7mHz) – the range of the most intense fluctuations. *(fL and fH are selectable, f1 < fL < fH < f2)*
- ✓ In order to distinguish broad-band and narrow-band variations we apply an algorithm based on the determination of the "bump" above the linear fit to the background "colored-noise" spectra.

Global ULF wave index

$$ULF_{INDEX} = \log_{10}\left\{\frac{1}{N}\sum_{i=1,N}\int_{fL}^{fH} df\, B_f^2\right\}$$

The summation is performed over all *N* stations where the signal amplitude is above *K*Bmax* where Bmax is the maximum spectral power in the selected MLF sector and *0.5* ≤ *K* ≤ 1.0
(K is selectable and is in effect a discriminator for including or excluding certain stations)

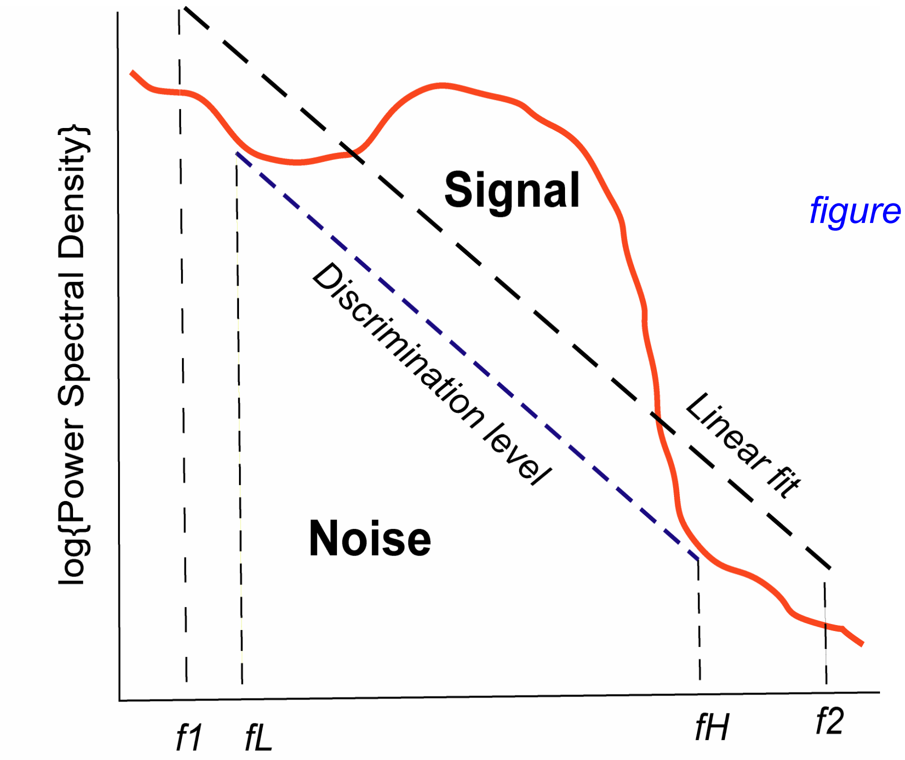
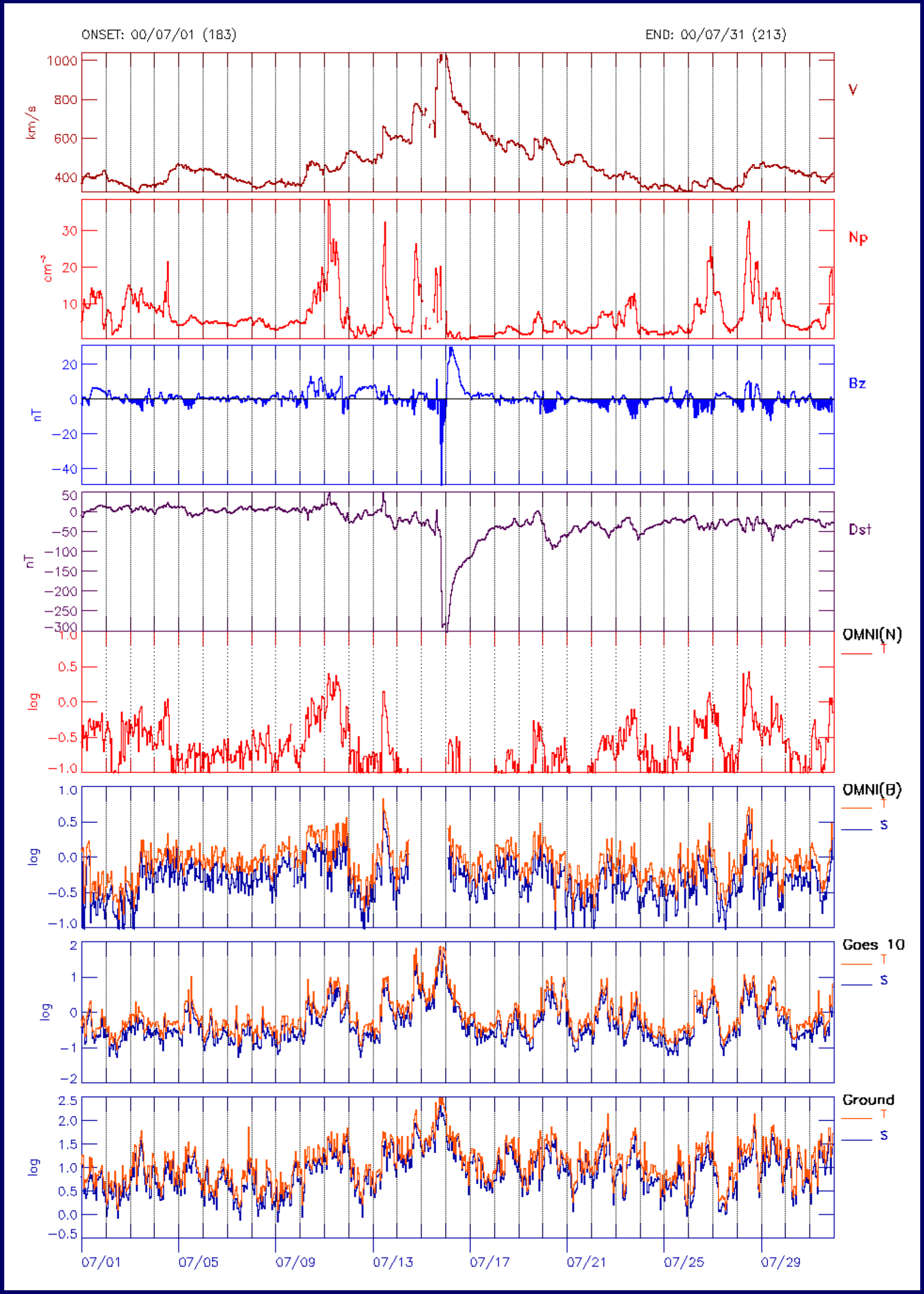


figure from Kozyreva et al., 2007

discrimination level = linear fit – σ

As a result one obtains:

- Noise spectral power (N)
  the band-integrated area beneath the background spectra;
- Signal spectral power (S)
  the area of the bump above the background spectra;
- Total spectral power (T)   T=S+N
  a measure of the fraction of narrow-band power R=S/T (R=0-1)



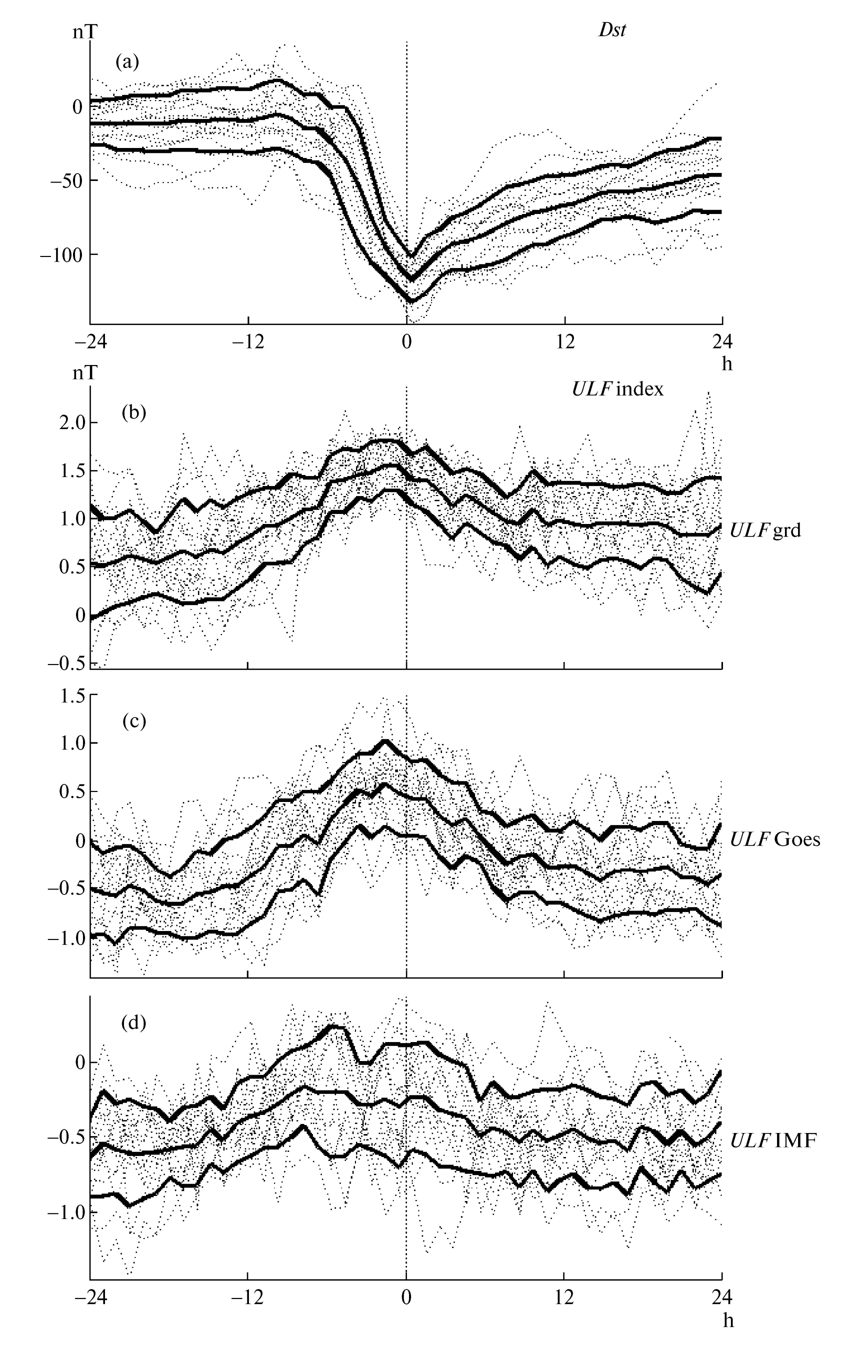
OMNI and WDC parameters

- solar wind velocity
- solar wind density
- IMF Bz
- Dst

ULF indices

- solar wind density (OMNI)
- IMF total (OMNI)
- mag. field (GOES)
- mag. field (ground network)

figure by V. Pilipenko

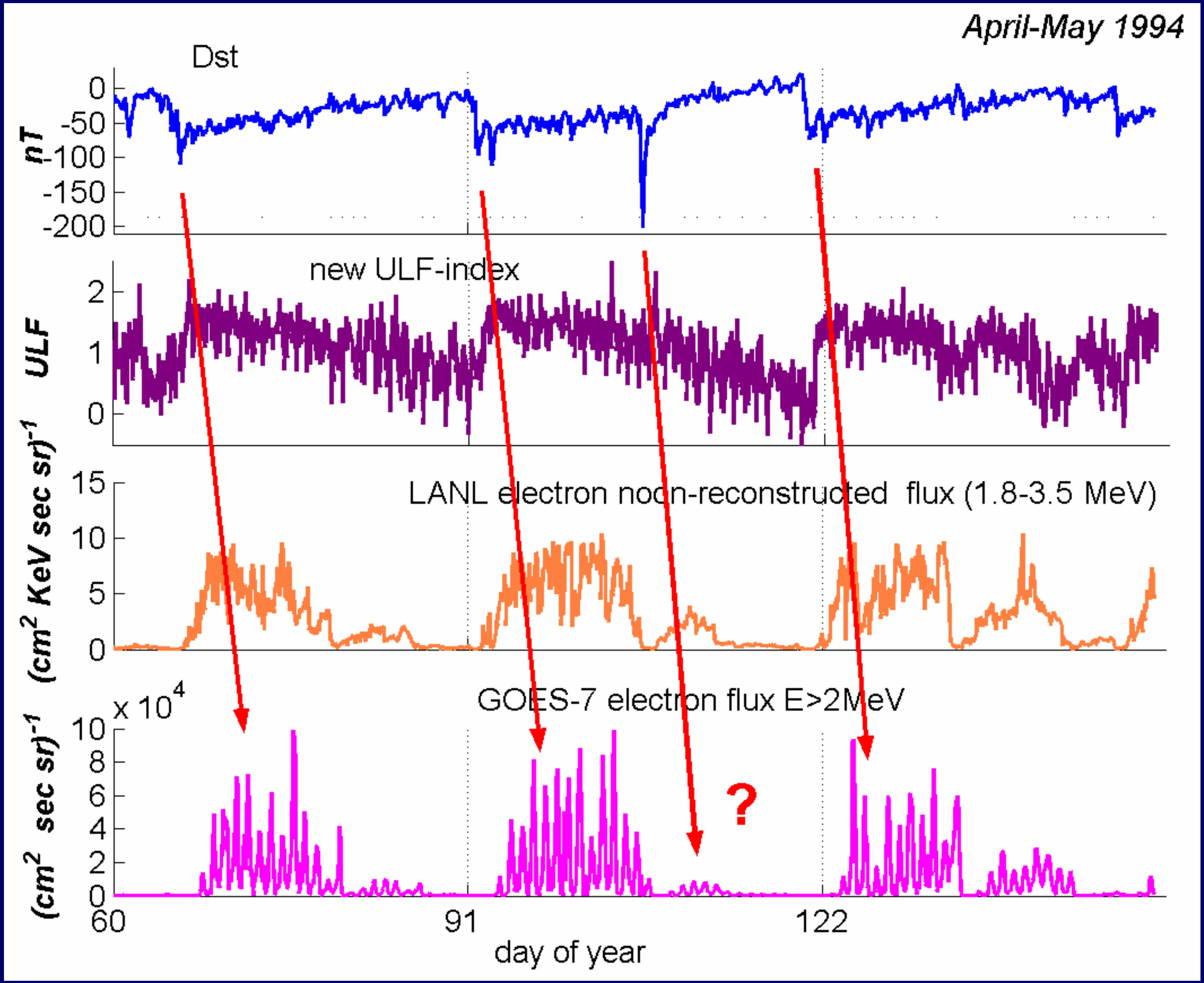


ULF indices in relation to phases of 19 strong storms (Dst < -100 nT)

figure from Kozyreva et al. (2008)

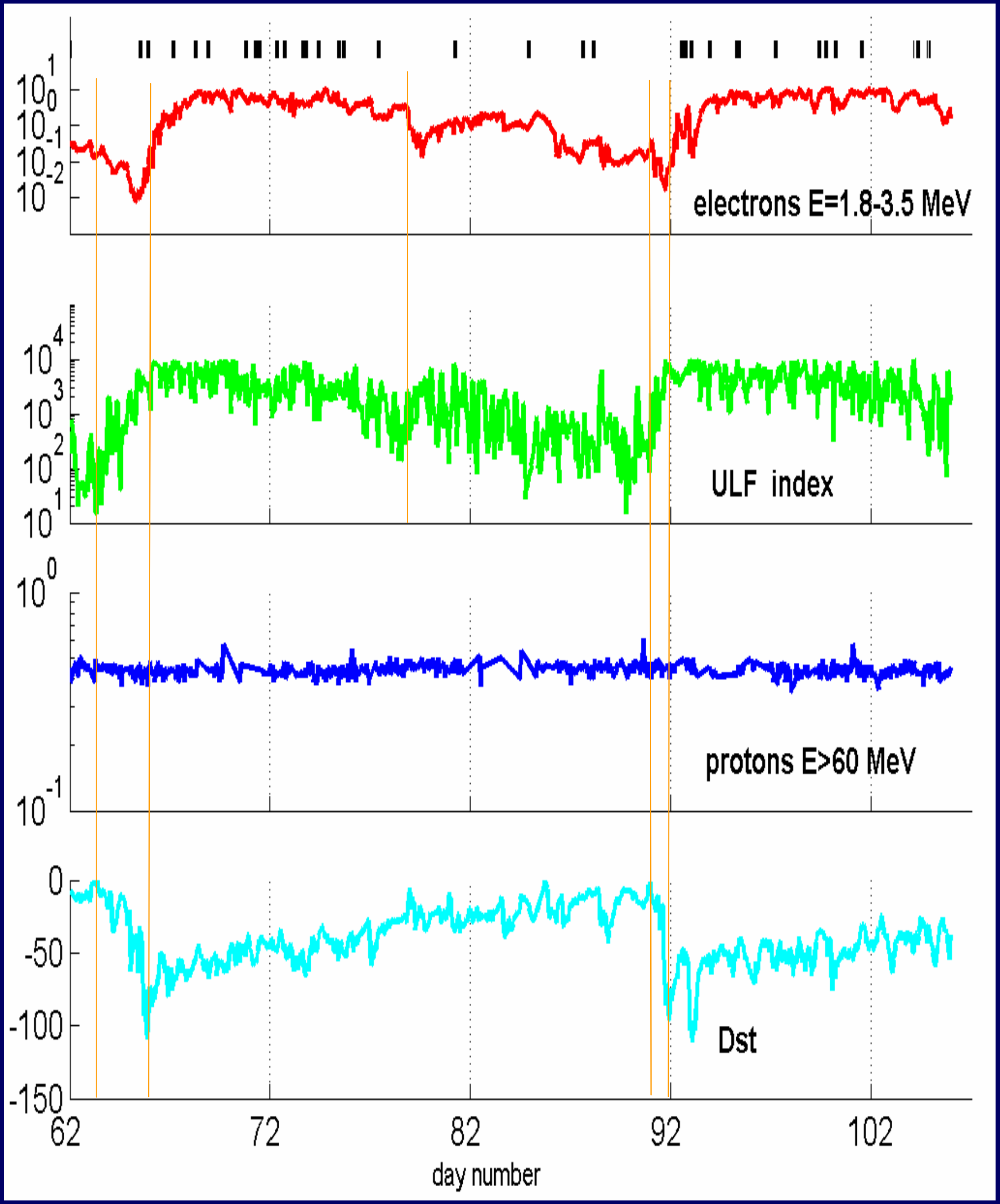
Note JFW:

the largest time derivatives of the high-latitude geomagnetic field were often observed during the steepest descend of Dst.



The electron flux matches well the variation of the ground ULF index

In the wake of the weaker storms (Dst~-100nT) both increase much more and remain elevated for a longer period than after the severe storm (Dst~-200nT)



LANL geostationary satellite data

Storms with Dst ~ –100 nT
Substantial electron flux enhancement
No proton flux enhancement

Relativistic electron flux increases after magnetic ULF wave intensity in the magnetosphere

Possible scenario:
Electrons gain energy from interaction with magnetospheric ULF waves

JFW's Conclusion

The daytime ULF indices have the potential to become space weather proxies

Work done so far is encouraging, however, more extensive studies are needed