Perturbations triggered in the ionosphere by intense positive cloud-to-ground lightning

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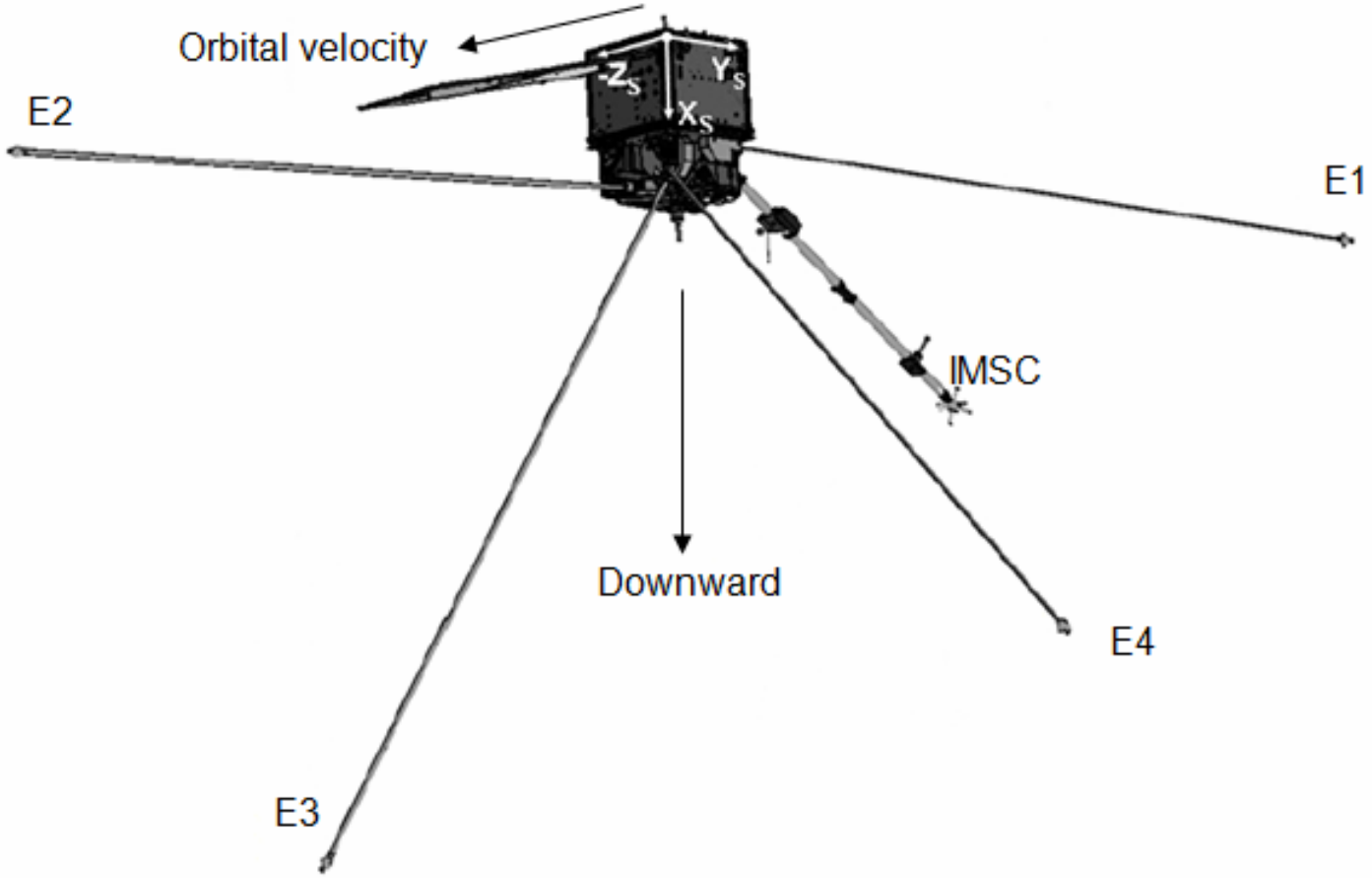
Motivation

•Strong positive cloud-to-ground (+CG) lightning discharges are known for their influence on higher atmospheric layers below 90 km of altitude.

•These discharges are linked to high-altitude luminous phenomena, sprites, which occur above the thunderclouds, and which originate from an electric field pulse traveling upward to the ionosphere.

•Can DEMETER observe ionospheric disturbances linked to +CG lightning?

DEMETER



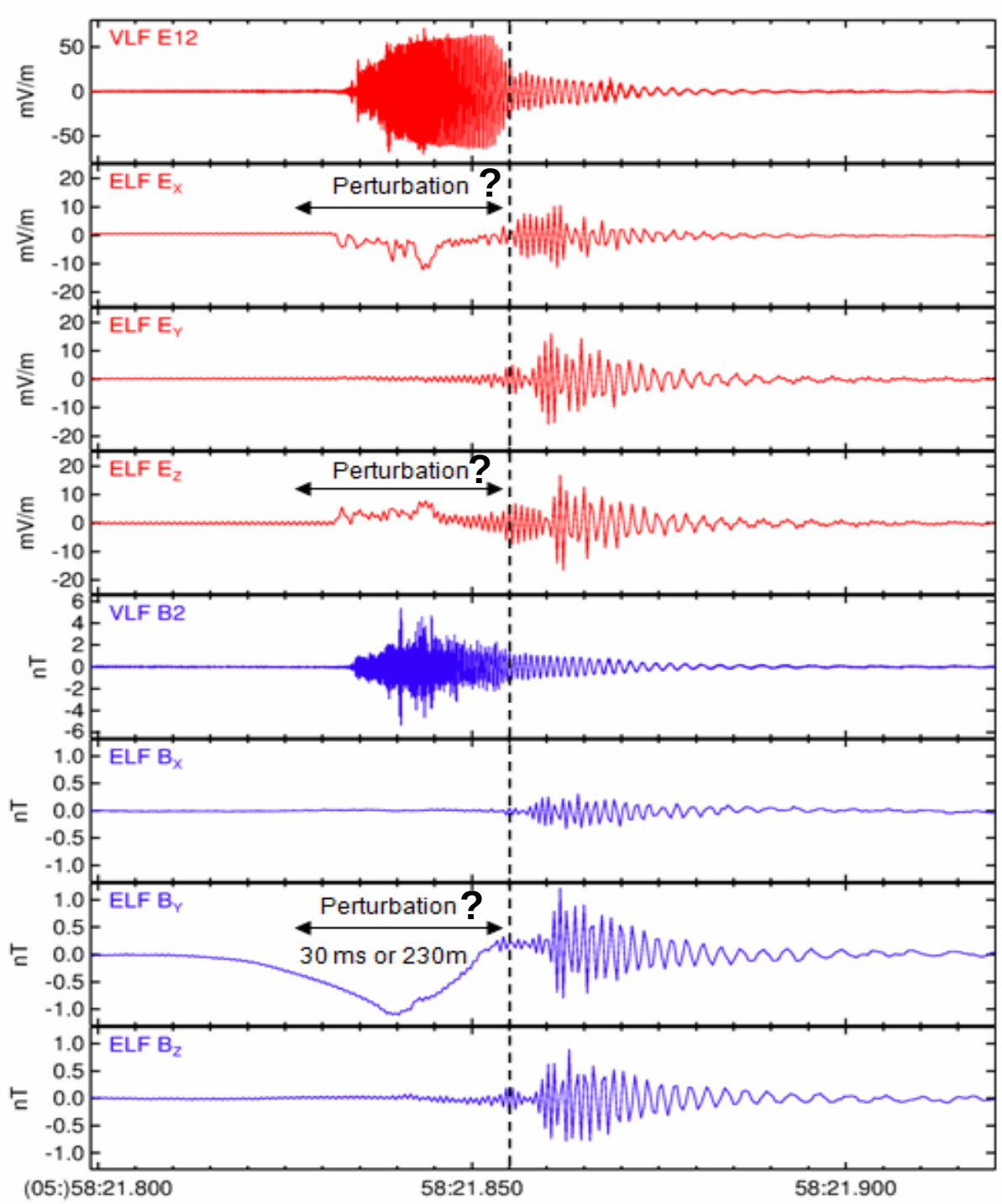
ICE electric antennas E1, E2, E3, and E4 : 30-mm spheres on 4.5-m booms.
Three-axial search coil magnetometer IMSC: on a 2.5-m boom.
The spacecraft coordinate system X_S, Y_S, Z_S.

Waveform measurements of the electric and magnetic fields

27 February 2007 during 120 ms after 05:58:12.800 UT.
668 km above OR Pacific coast

VLF 24 Hz -17.5 kHz (E12 - approximately in the $-Y_S$ direction, B2 - mounted in the Y_S-Z_S plane, at 45° between $+Y_S$ and $+Z_S$

ELF range from 20 Hz to 1 kHz, three-axial measurements E_X, E_Y and E_Z, along the axes of the spacecraft coordinate system.



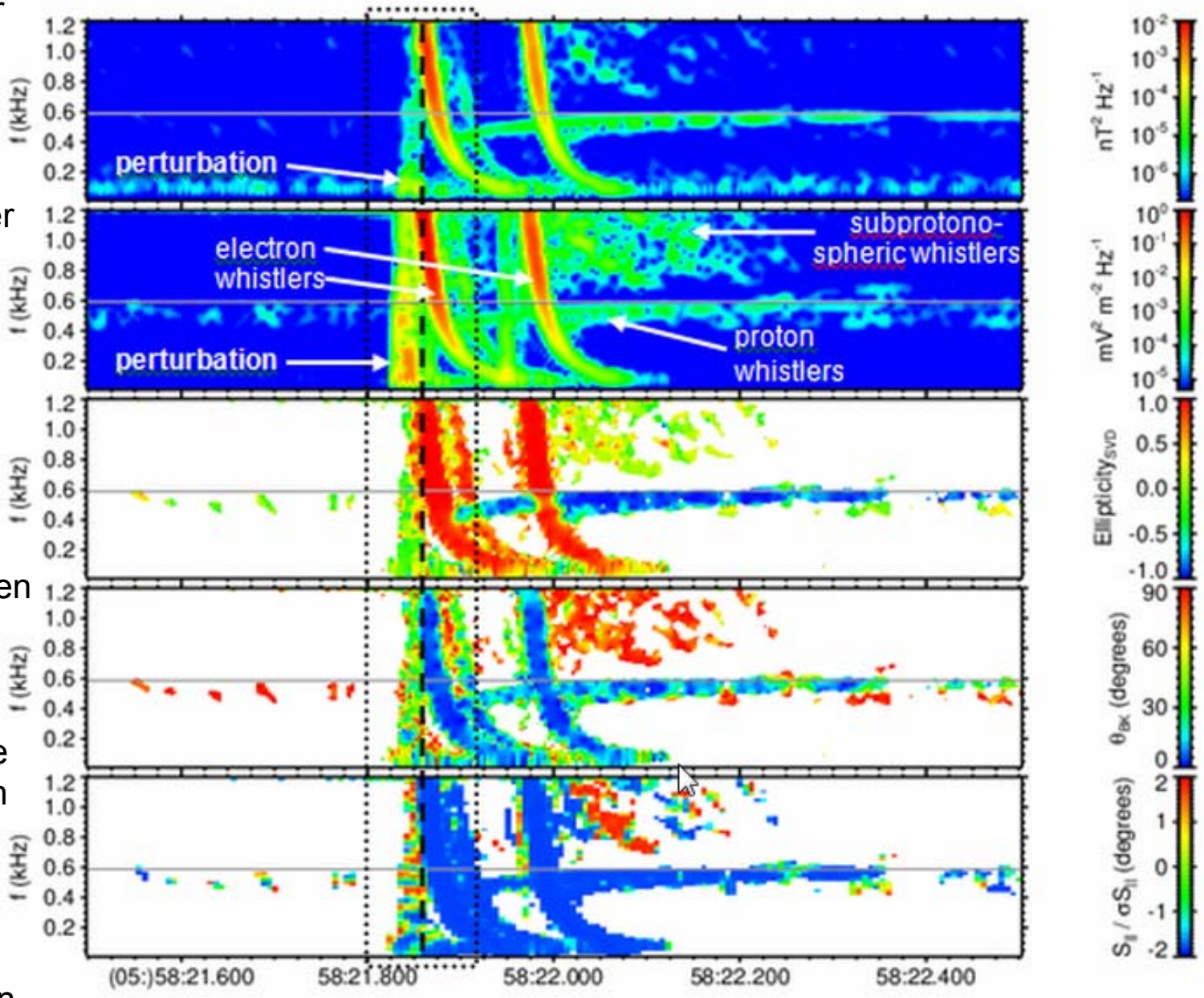
Sum of the power spectral densities of the magnetic components

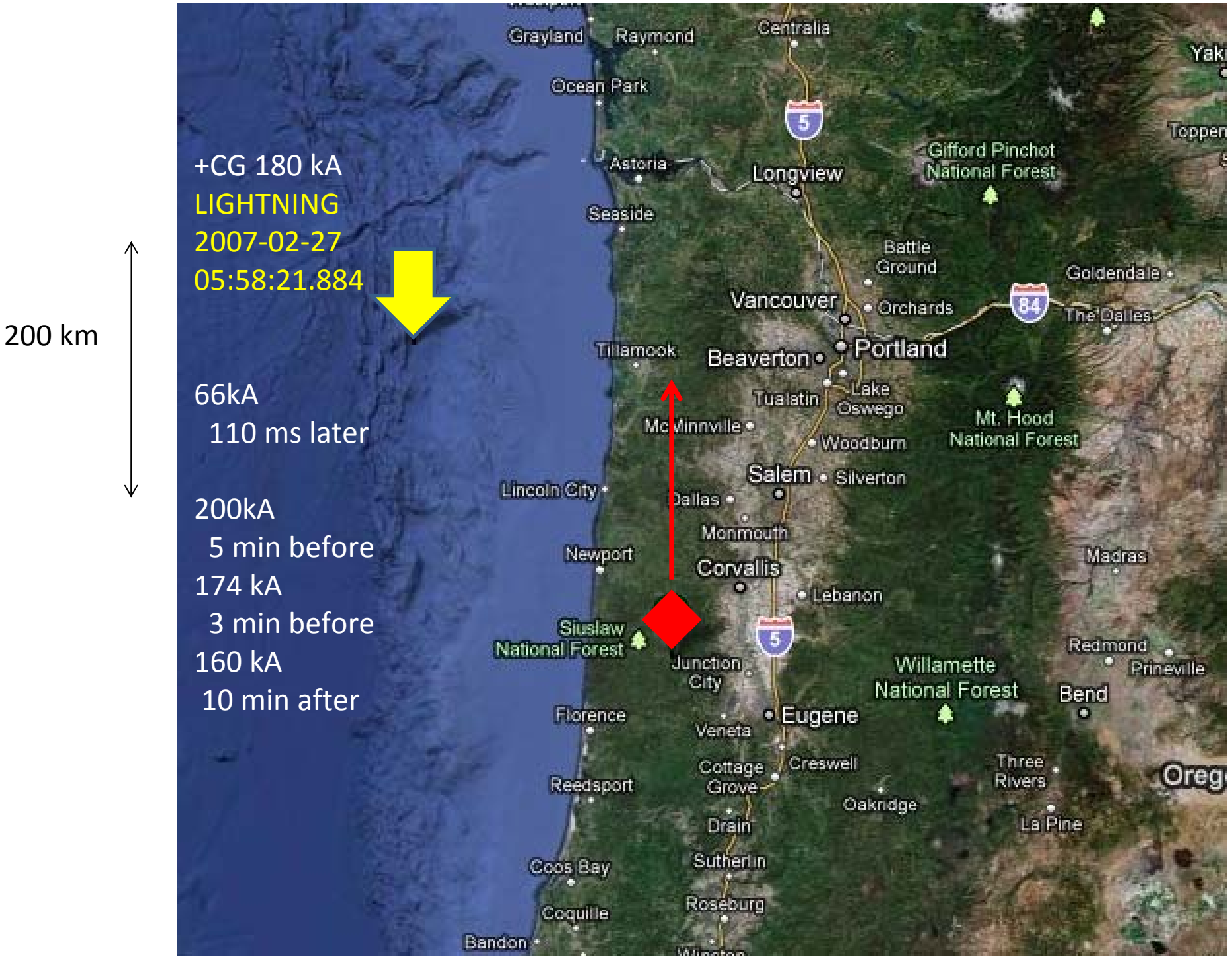
Sum of the power spectral densities of the electric components

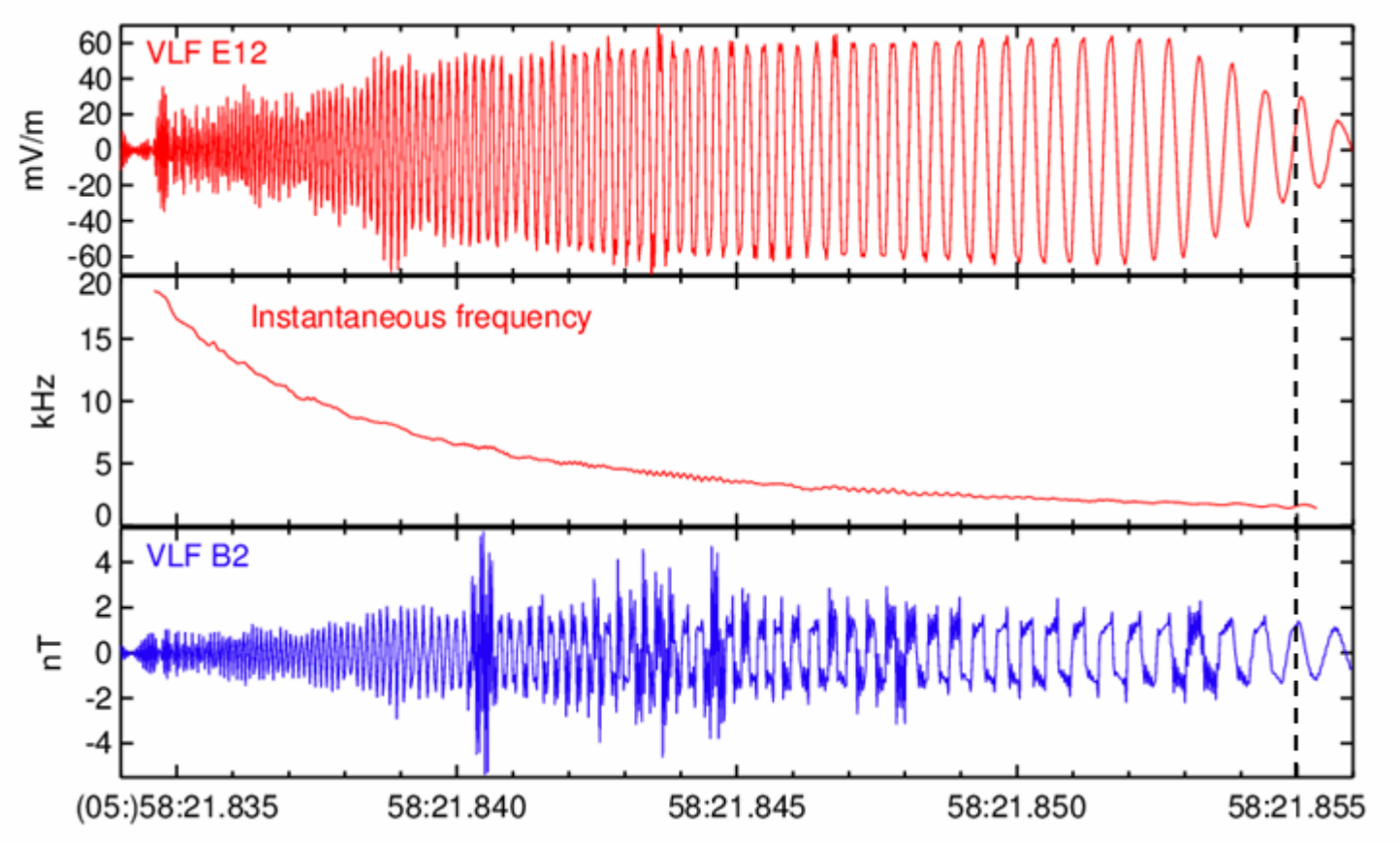
Ellipticity *L* of the magnetic field polarization

Angle θ_{BK} between the wave vector and B_0

Component of the Poynting vector in the direction parallel to B_0, normalized by its theoretical standard deviation.




+CG 180 kA
LIGHTNING
2007-02-27
05:58:21.884
66kA
110 ms later
200kA
5 min before
174 kA
3 min before
160 kA
10 min after
200 km
Grayland
Raymond
Centralia
Ocean Park
Astoria
Longview
Gifford Pinchot National Forest
Seaside
Battle Ground
Goldendale
Vancouver
Orchards
The Dalles
Tillamook
Beaverton
Portland
Tualatin
Lake Oswego
McMinnville
Mt. Hood National Forest
Woodburn
Salem
Silverton
Lincoln City
Dallas
Monmouth
Newport
Corvallis
Madras
Lebanon
Siuslaw National Forest
Junction City
Willamette National Forest
Redmond
Prineville
Bend
Florence
Veneta
Eugene
Cottage Grove
Creswell
Three Rivers
Reedsport
Oakridge
La Pine
Drain
Coos Bay
Sutherlin
Roseburg
Coquille
Bandon



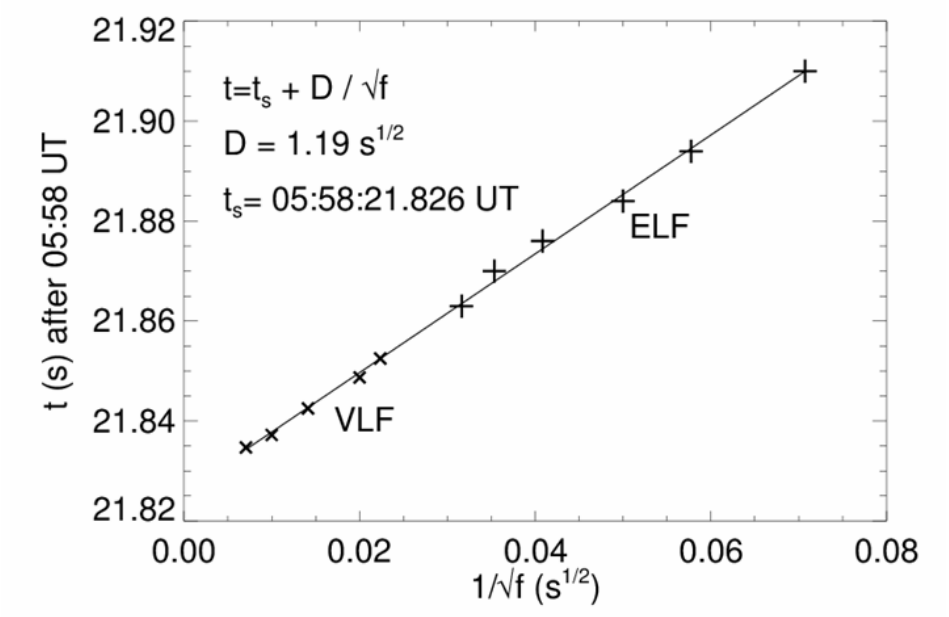
VLF electric and magnetic signals.

Instantaneouos frequency from the time derivative of the instantaneous phase of an analytic signal (using the discrete Hilbert transform)

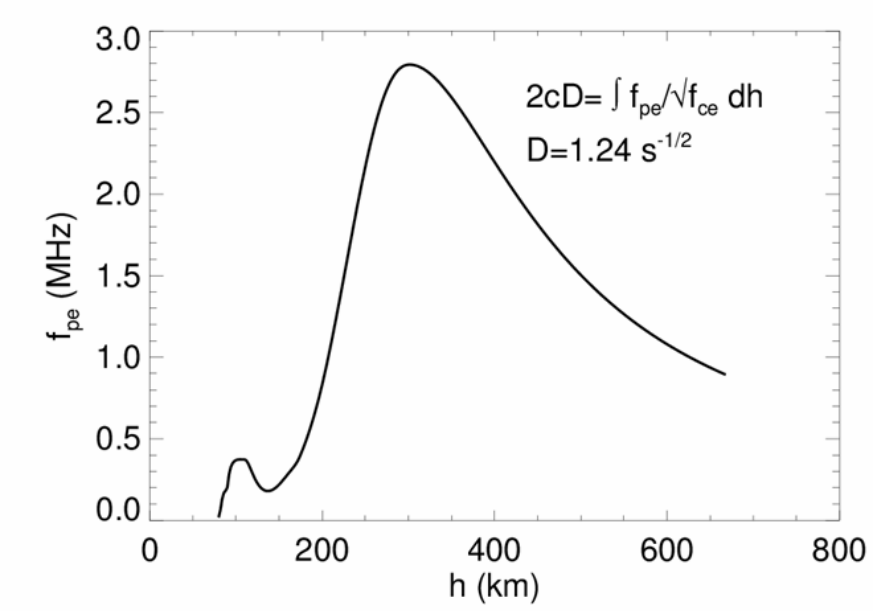
Time *t* of arrival of the electron whistler signal as a function of $f^{-1/2}$

VLF (x)
ELF (+)

Linear least-squares fit of Eckersley law

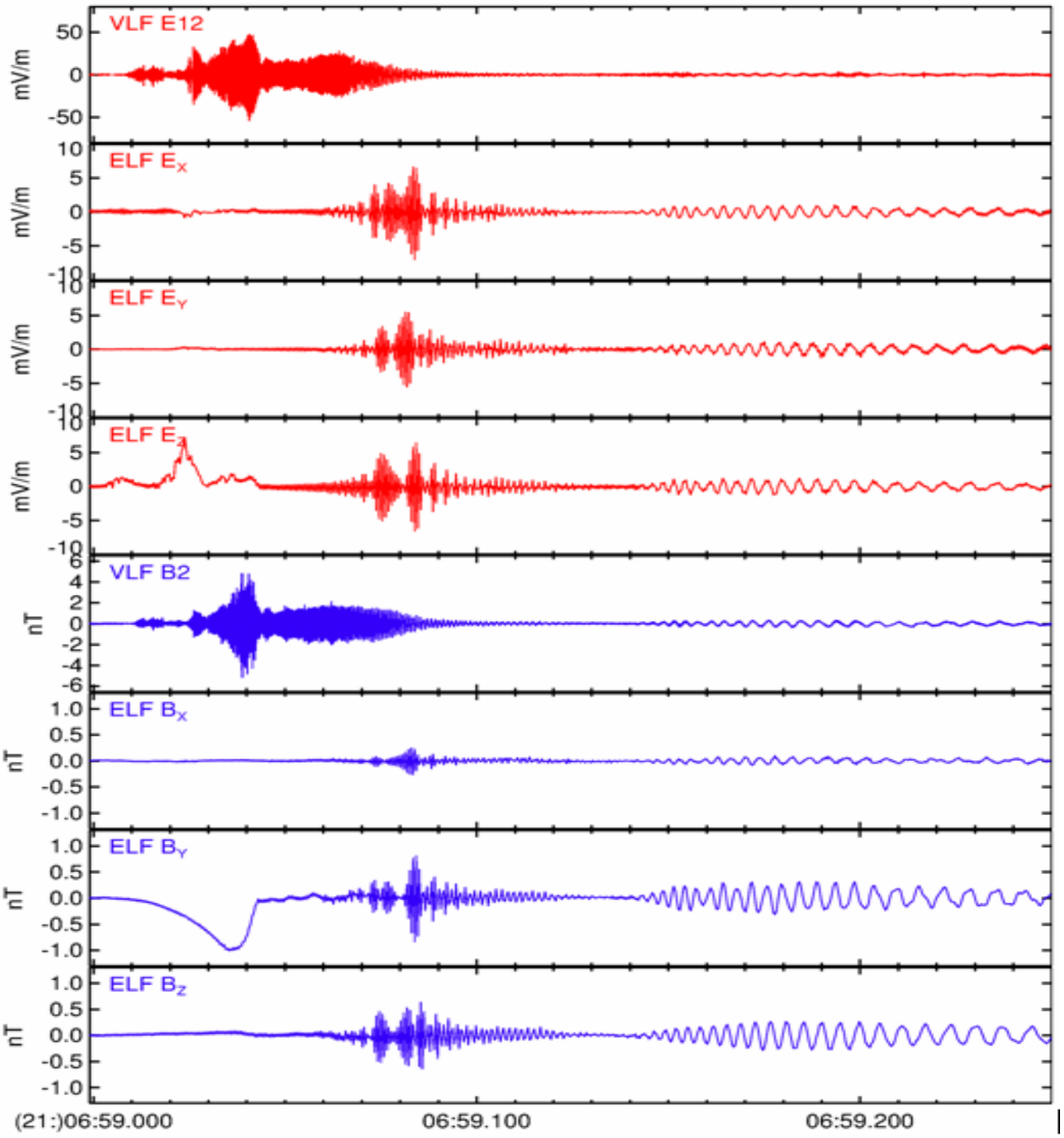


Theoretical calculation of dispersion D from IGRF and IRI 2007



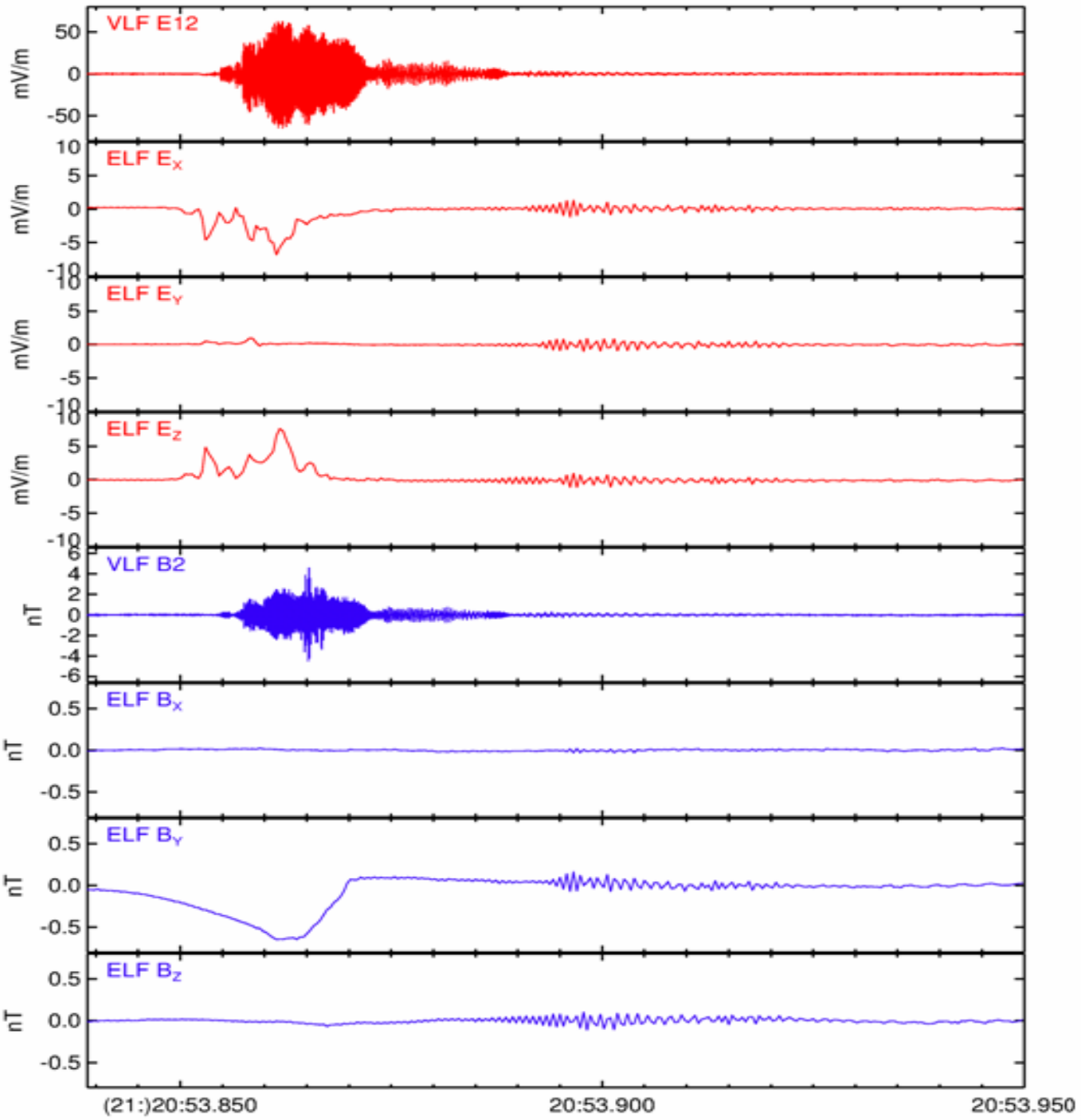
April 11, 2005.

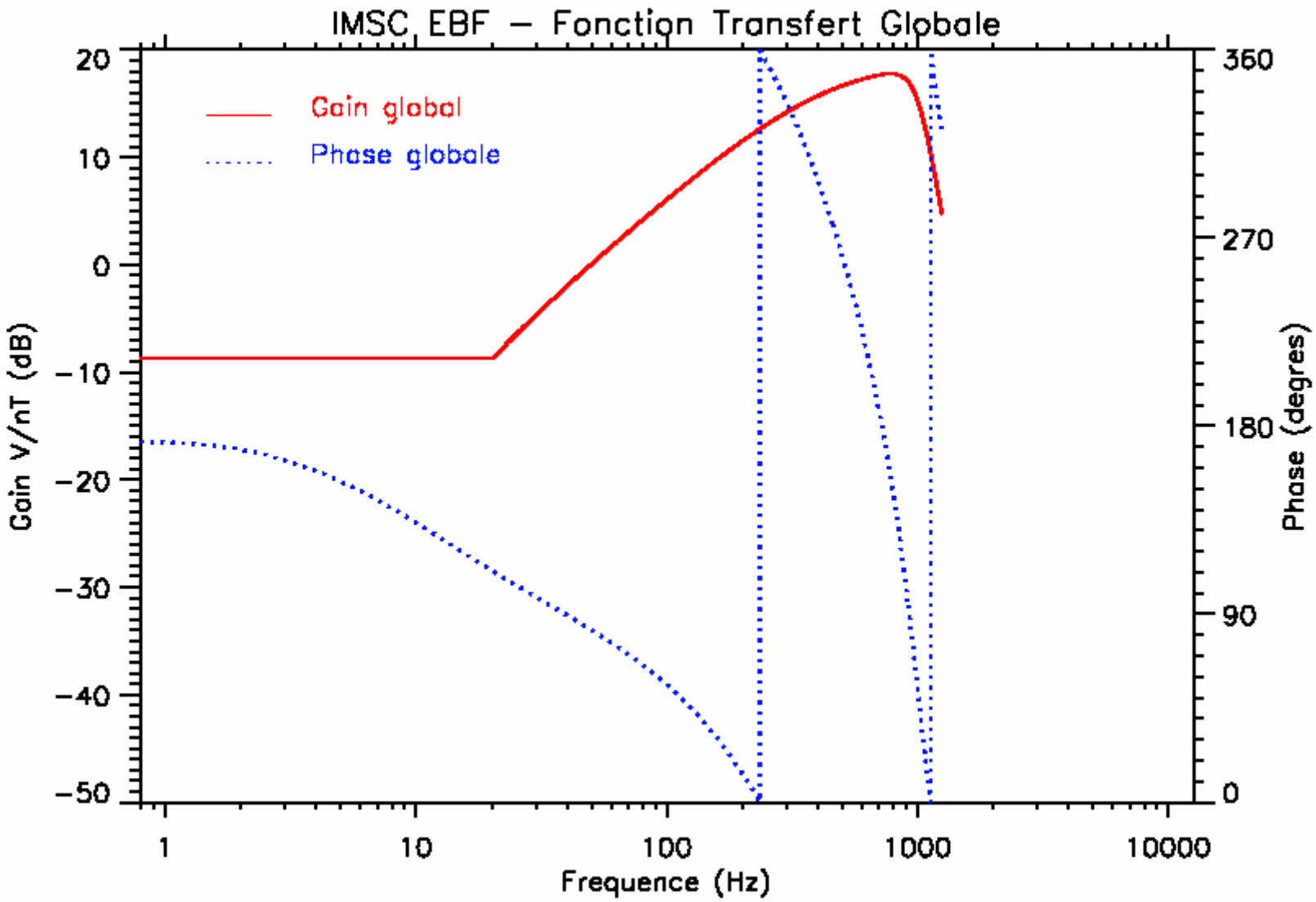
The vertical footprint of the DEMETER spacecraft was located in the Mediteranean sea, 3 km from the coast, close to the town of Ksour Essef, Tunisia.



December 20, 2006.

The DEMETER spacecraft was located above Tunisia, 200 km inland from the Mediteranean coast, close to the town of Umm Al Arais.



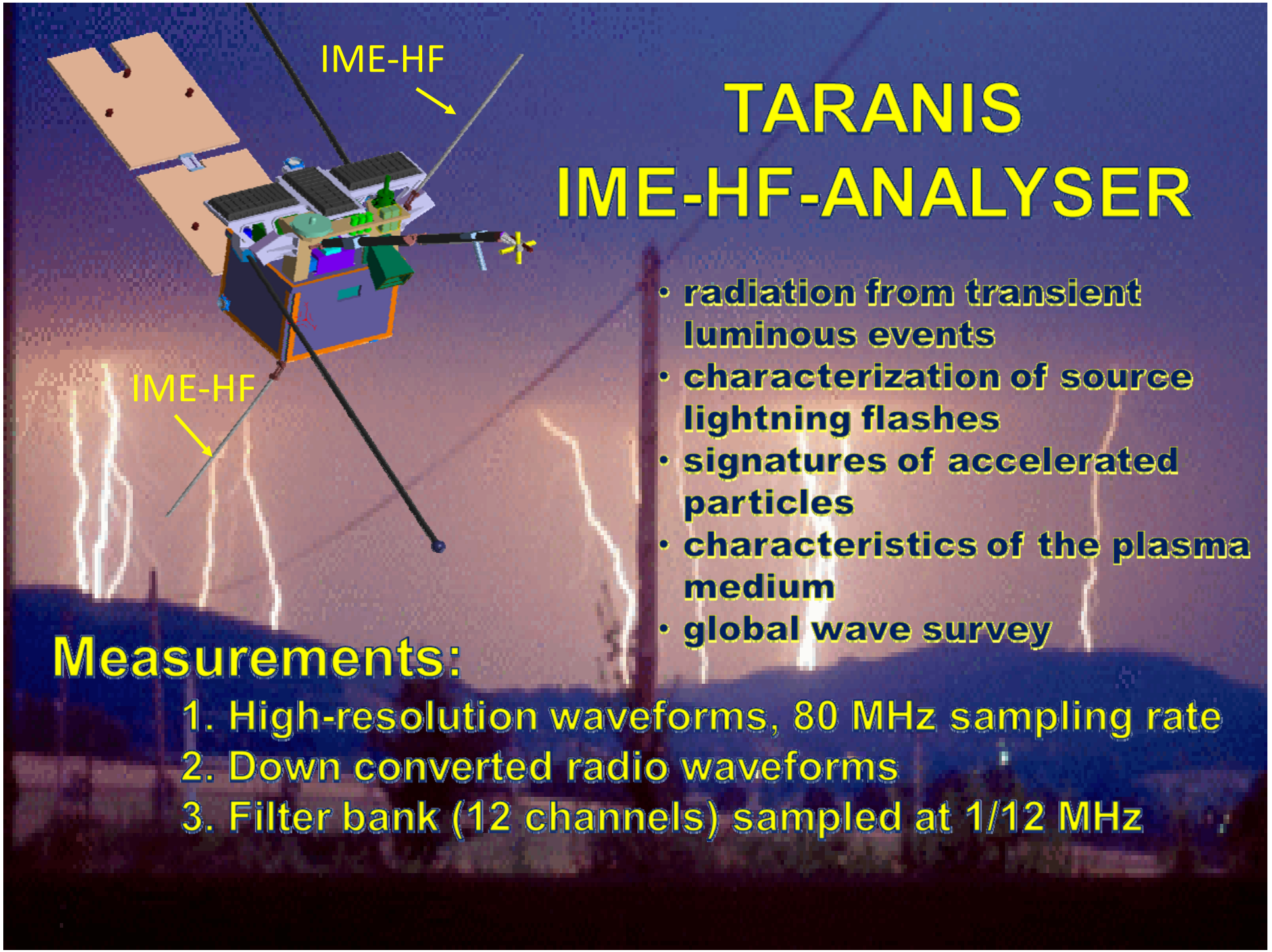

IMSC EBF – Fonction Transfert Globale
Gain global
Phase globale
Gain V/nT (dB)
Phase (degres)
Frequence (Hz)
20
10
0
−10
−20
−30
−40
−50
360
270
180
90
0
1
10
100
1000
10000

CONCLUSIONS

•In connection with a +CG lightning stroke carrying an extreme peak current of 180 kA, we have identified a very intense 0+ whistler at the spacecraft altitude of 668 km, spanning through different frequency bands of DEMETER wave measurements. Nonlinear magnetic-field waveforms are observed.

•Broad-band unipolar electric pulse (10 mV/m) preceding the whistler in the ELF range might be linked to saturation of preamplifiers in the presence of very strong whistler.

•We also observe peculiar unipolar perturbation of the magnetic field with an amplitude of 1 nT, in the direction perpendicular to the spacecraft orbit. This perturbation is probably an artifact of the calibration procedure.


IME-HF
IME-HF
TARANIS
IME-HF-ANALYSER
• radiation from transient luminous events
• characterization of source lightning flashes
• signatures of accelerated particles
• characteristics of the plasma medium
• global wave survey
Measurements:
1. High-resolution waveforms, 80 MHz sampling rate
2. Down converted radio waveforms
3. Filter bank (12 channels) sampled at 1/12 MHz

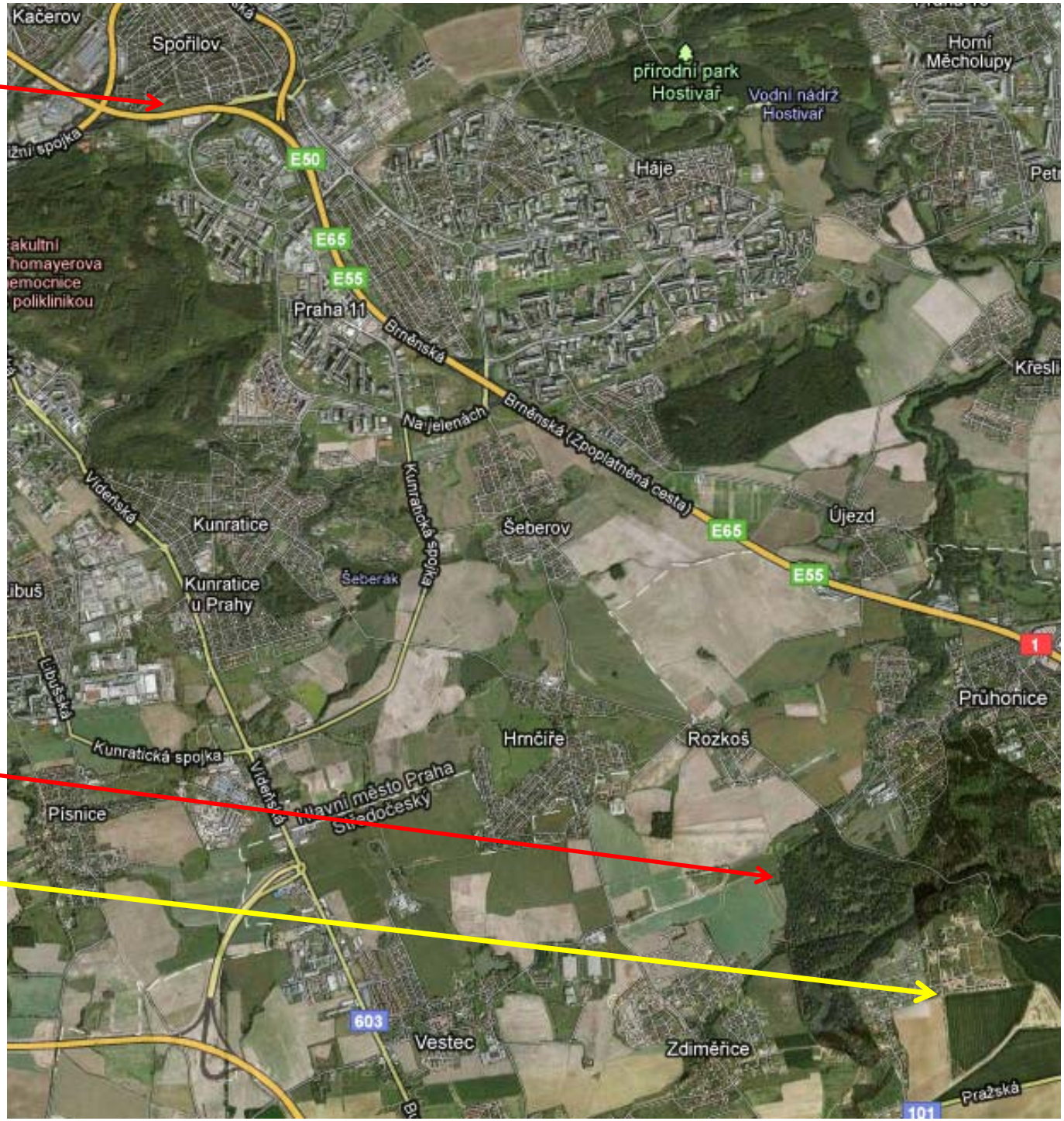
HF analyzer

+CG lightning
2011-06-14
19:10:10.279 UT
14.5551E
49.9823N
64 kA

1km

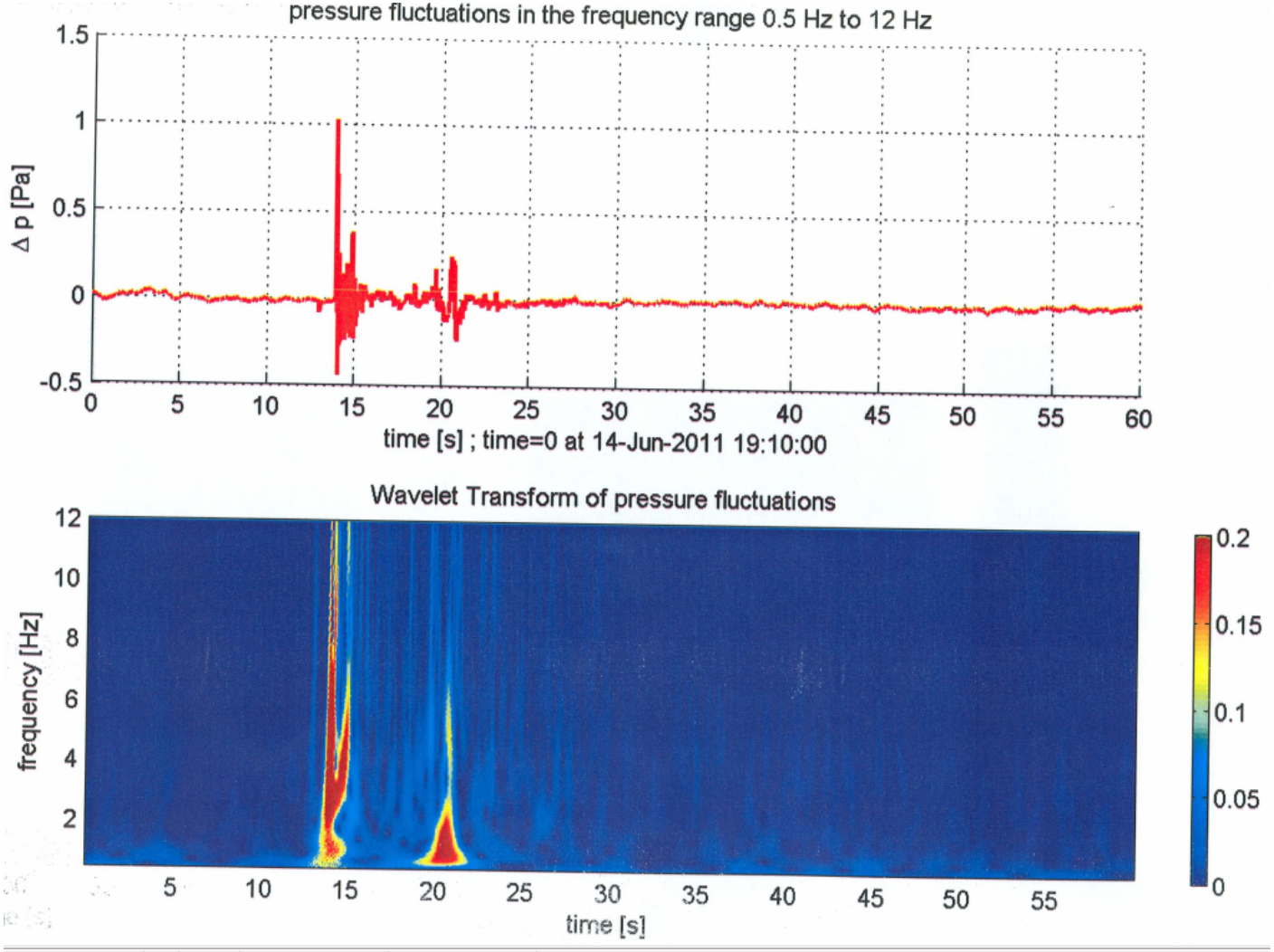
Microbarograph

Lightning location



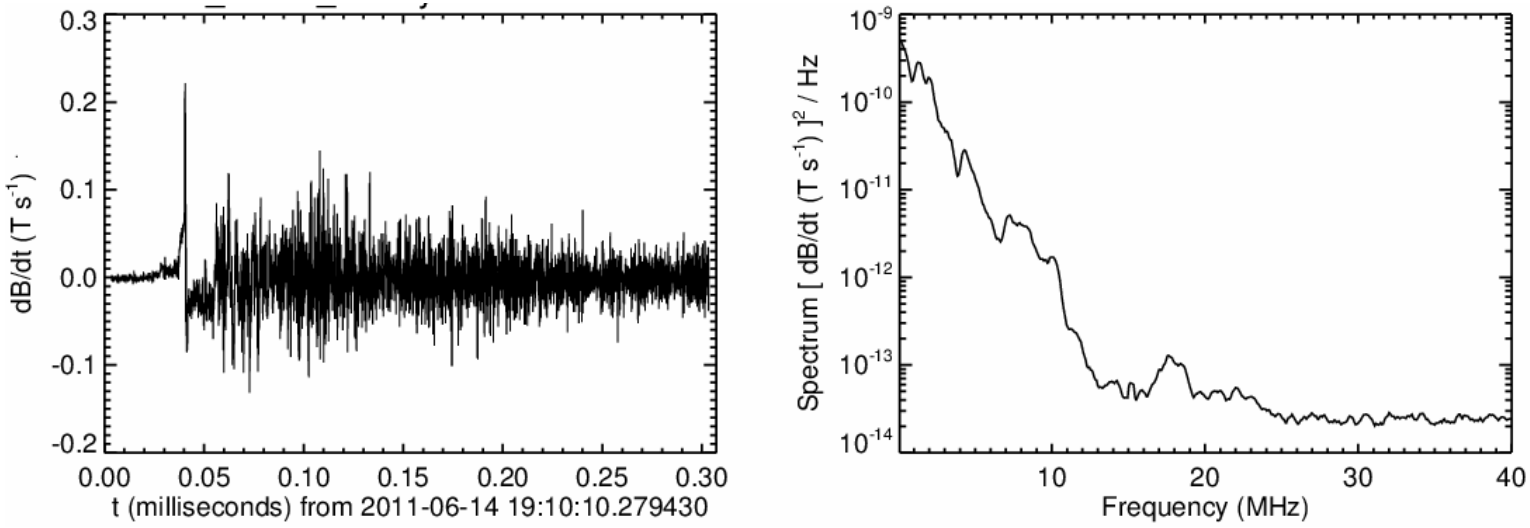
+CG lightning 2011-06-14 19:10:10.279 14.5551E 49.9823N 64 kA

Thunder from a microbarograph at the Pruhonice observatory



+CG lightning 2011-6-4 19:10:10.279 14.5551E 49.9823N 64 kA

Input signal from a 1-m magnetic loop antenna



Integrated signal