Practical nano-satellite monitoring of ionospheric earthquake precursors

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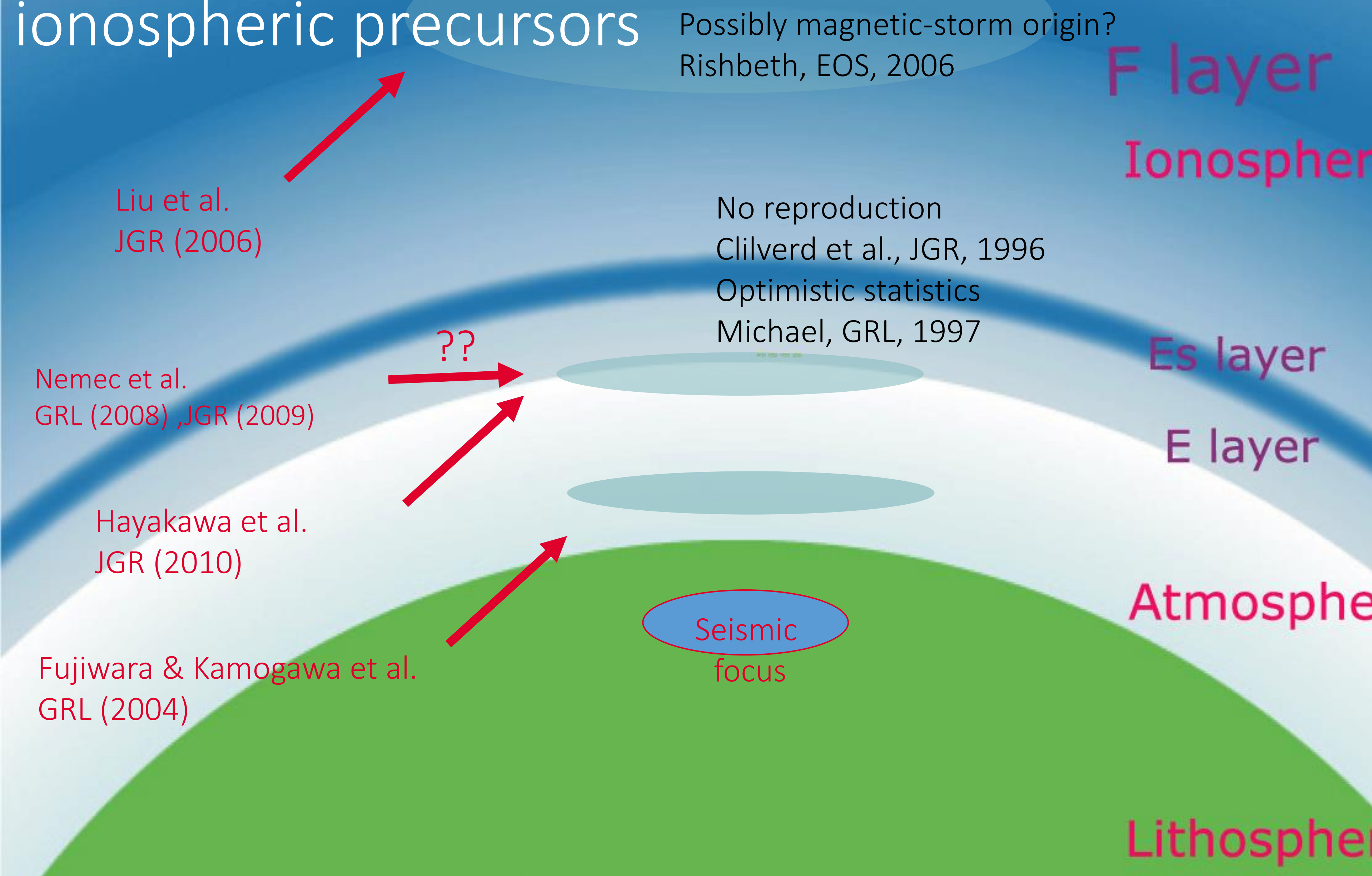
Earthquake prediction

- Short-term earthquake prediction is still very difficult.
- For this prediction, observable precursors are required.
- Many kinds of precursors have been reported, but controversial.
- Ionospheric precursors are plausible phenomena for the prediction, because the statistical verification can simply be done using satellite.

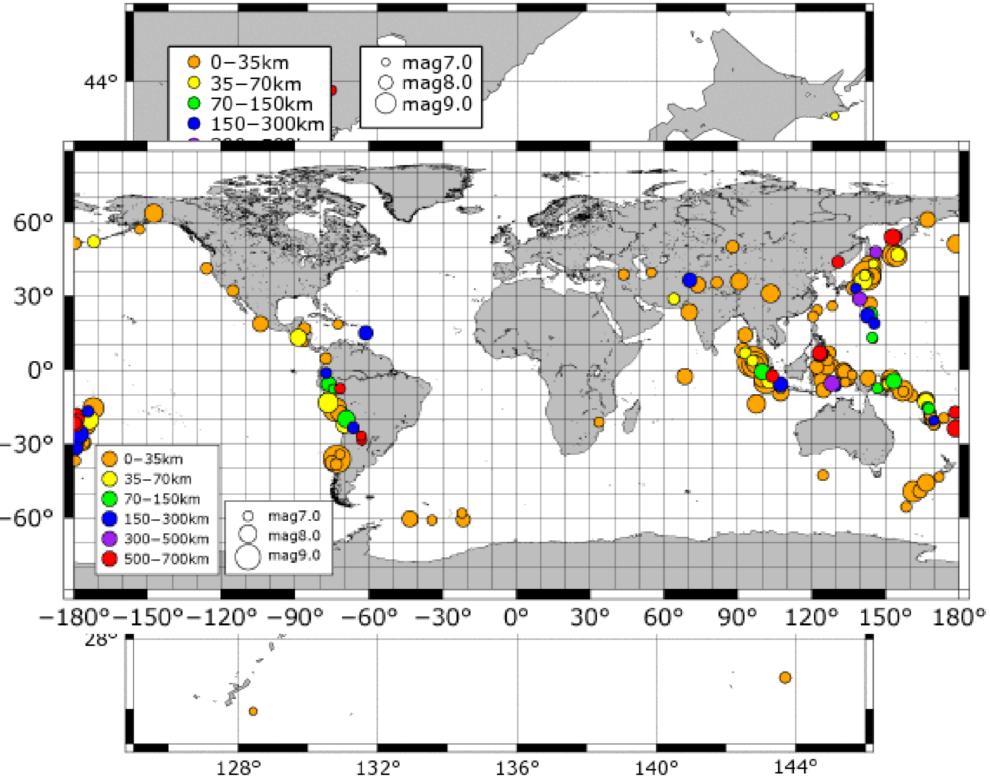
Plausible atmospheric ionospheric precursors

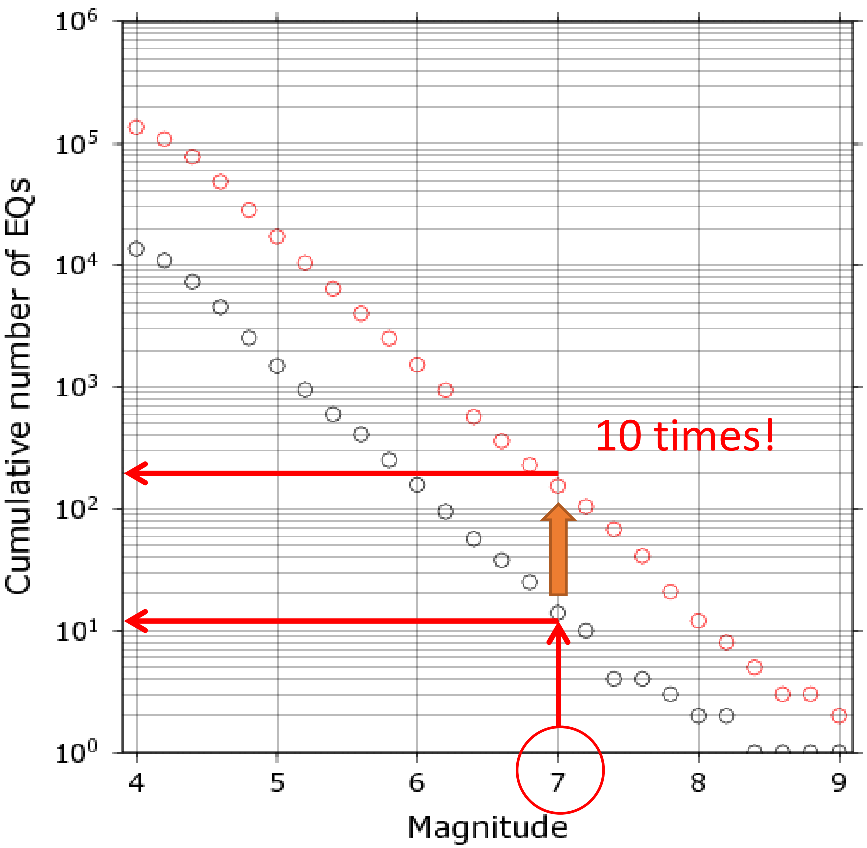


Kamogawa, Eos (2006) with adding recent reviews

Global seismicity

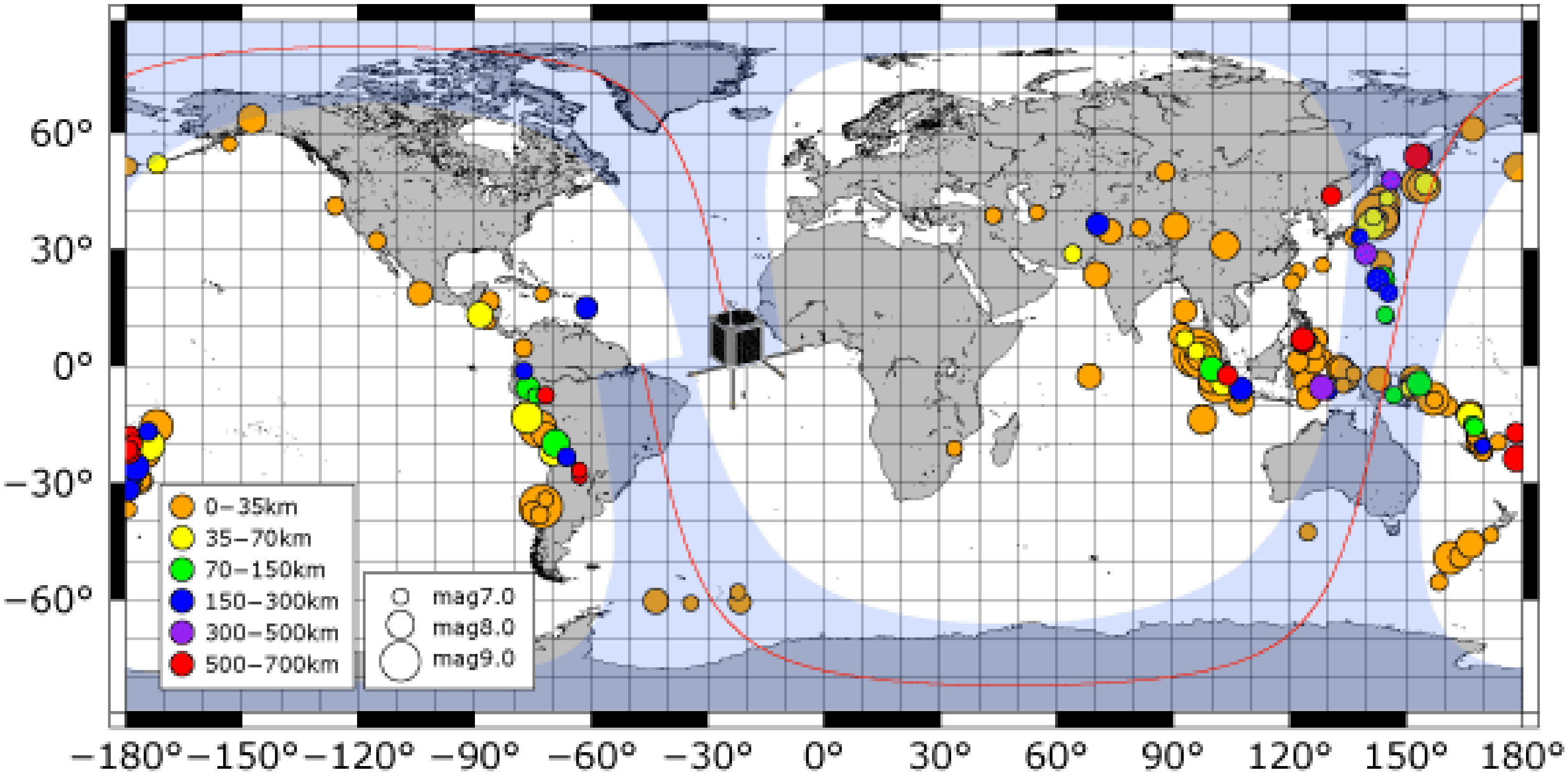
(USGS, 2000-2011)





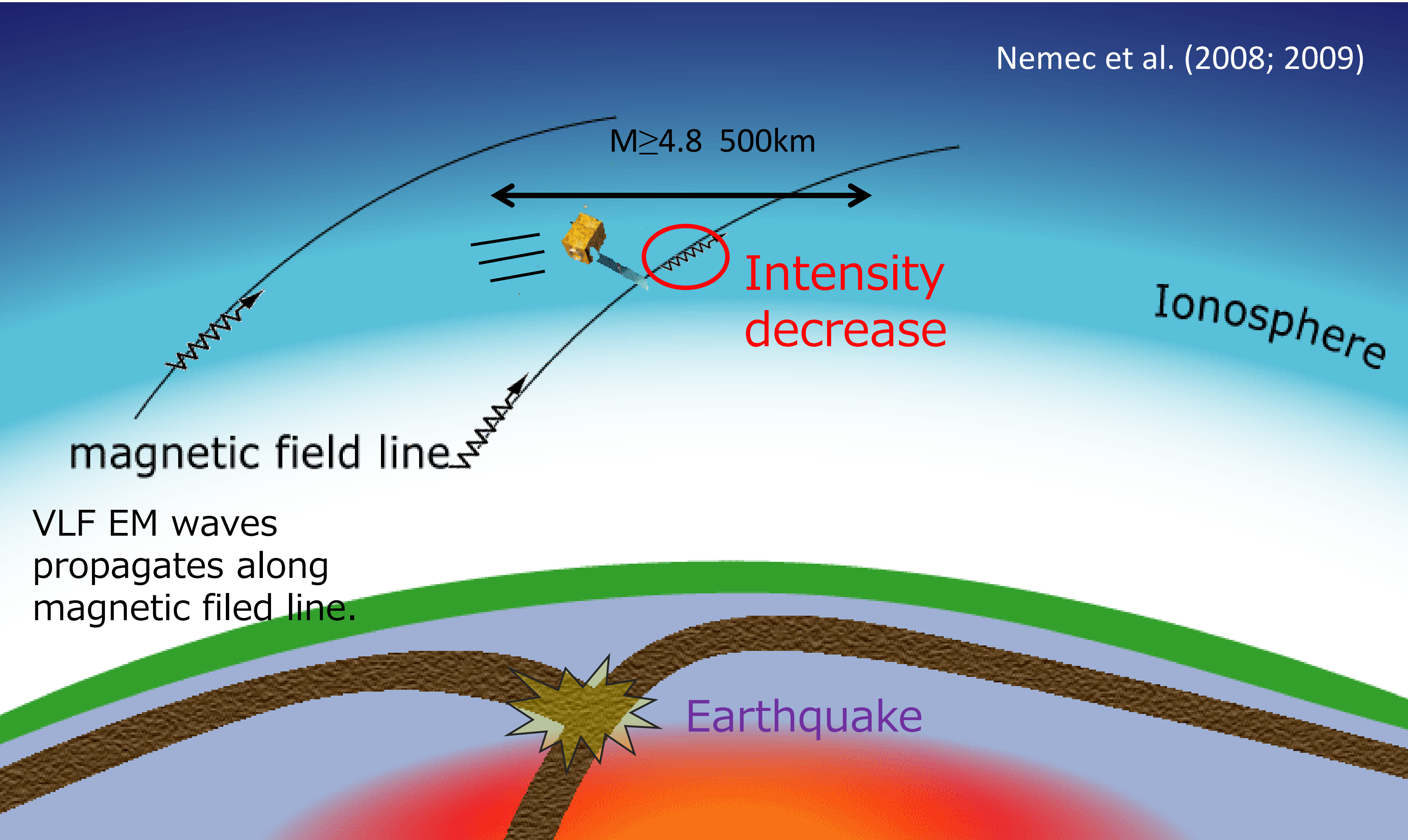
Satellites easily monitor global seismicity!

Satellite observation is useful!



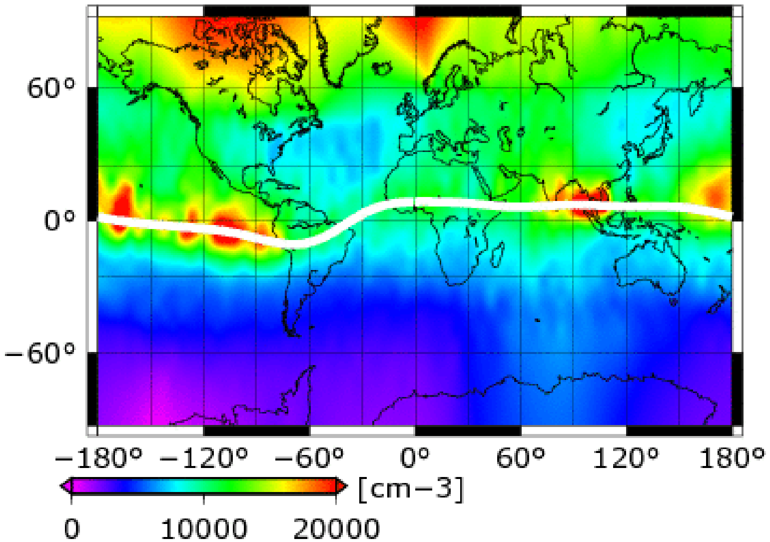
Satellites easily monitor global seismicity!

Plausible precursor:
Intensity decrease of VLF electromagnetic waves



How to identify a precursor?

We should know standard ionosphere .
So, we construct standard ionospheric model.

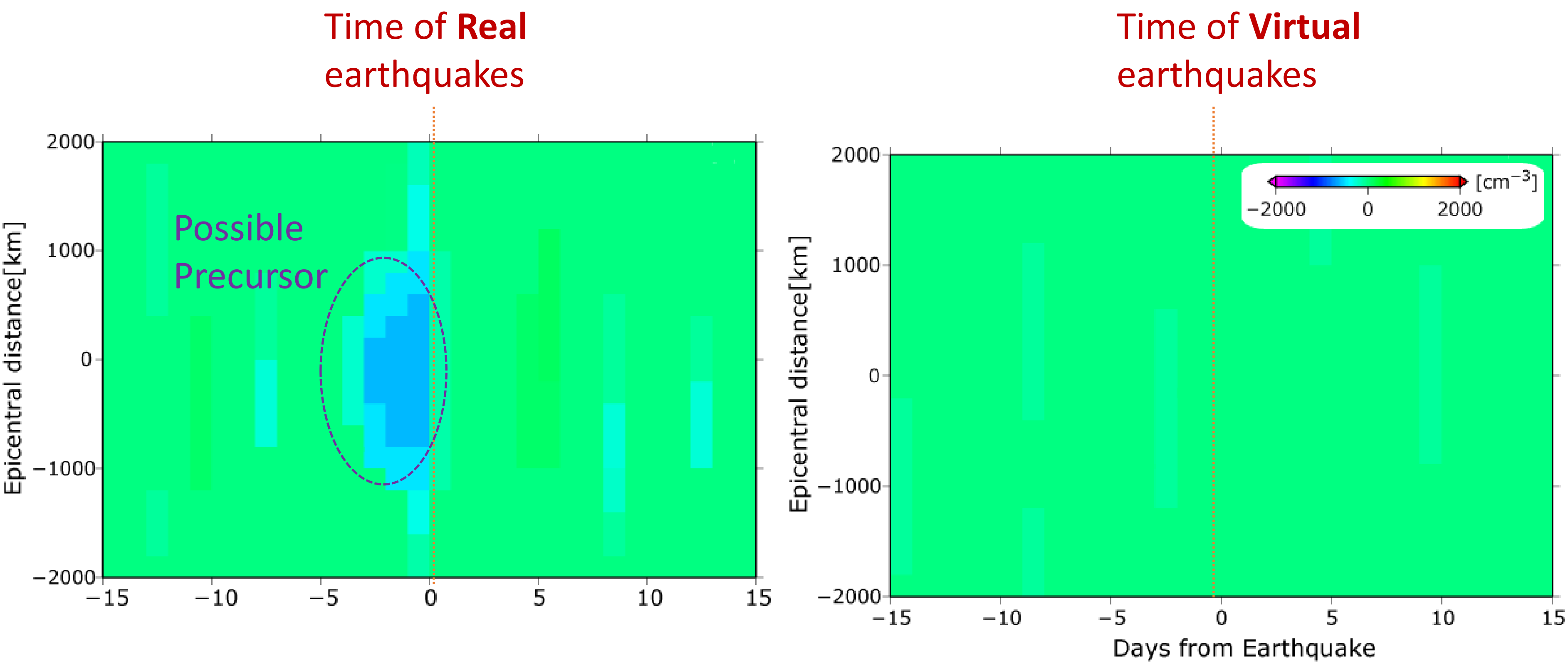


Example of electron density map
during geomagnetically quite period

Model depends on..

Local time
Latitude
Longitude
Altitude
Solar flux
Geomagnetic activity
etc….

Accumulate residual values between model and observed data.



Note: This is a conceptual view.

Statistical study of pre-seismic VLF intensity decrease (=Background VLF intensity)

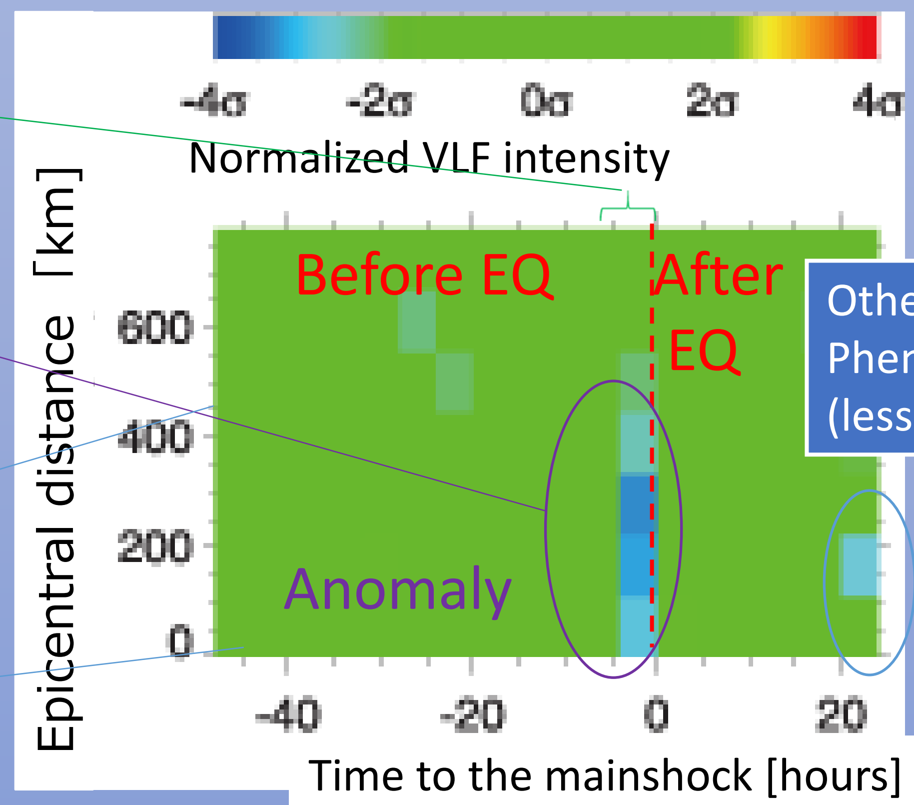
Superposed epoch analysis from staking 100 events

Model parameter

M>4.8
Within 4 huors

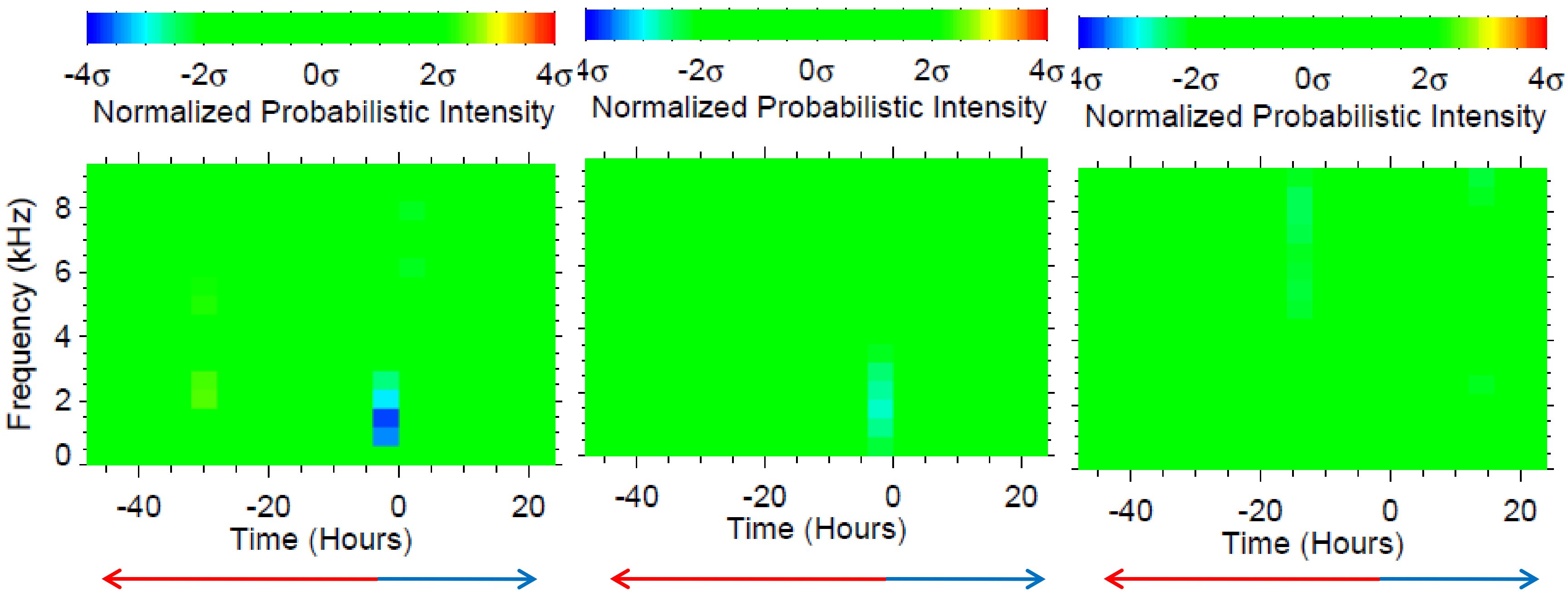
More than 3σ of normalized intensity

Epicentral distance
Within 500 km



Other Phenomenon? (less than 3σ)

Comparison: Large and Small Magnitude EQ
Real and virtual EQs



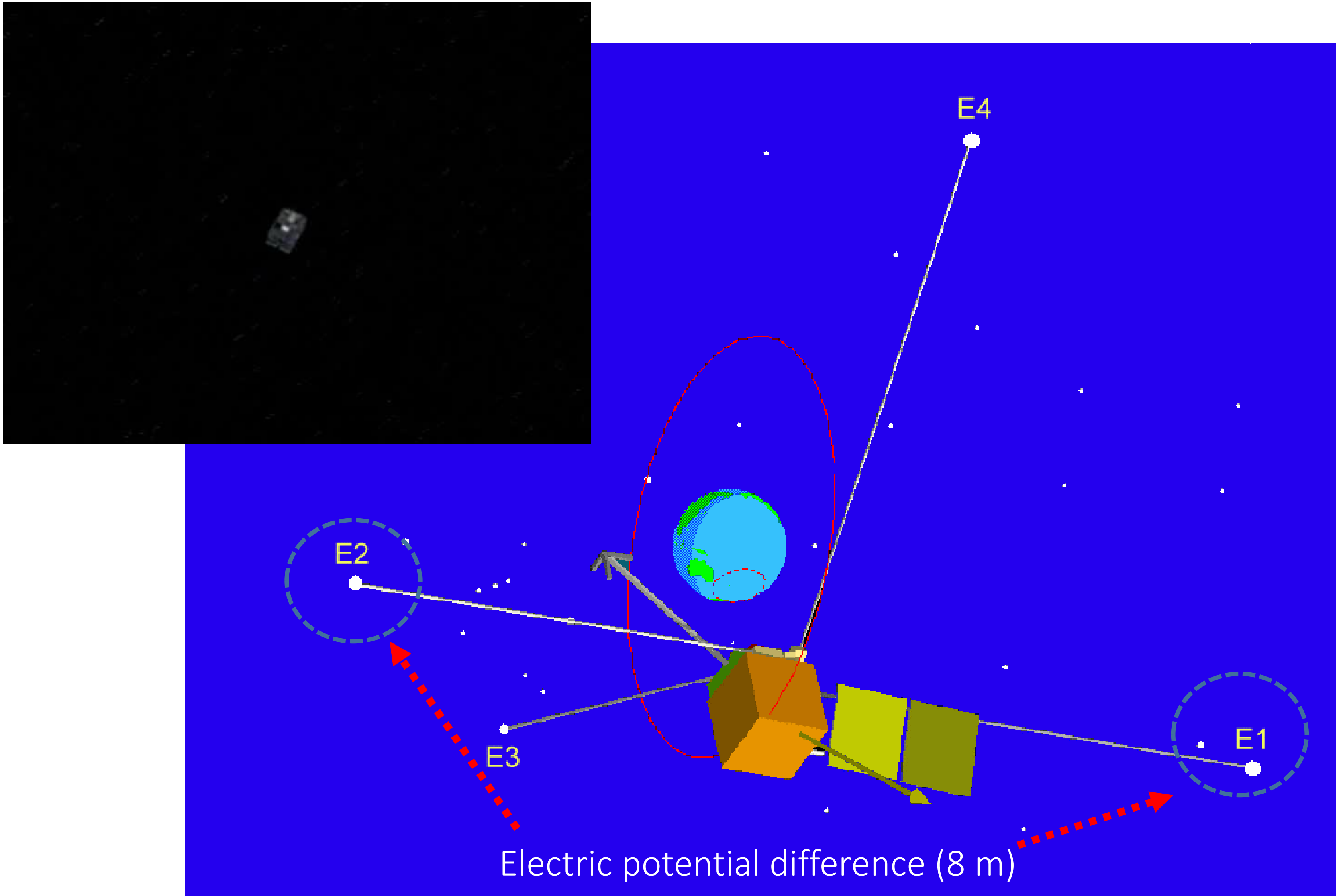
Before M>5.0 EQs — After

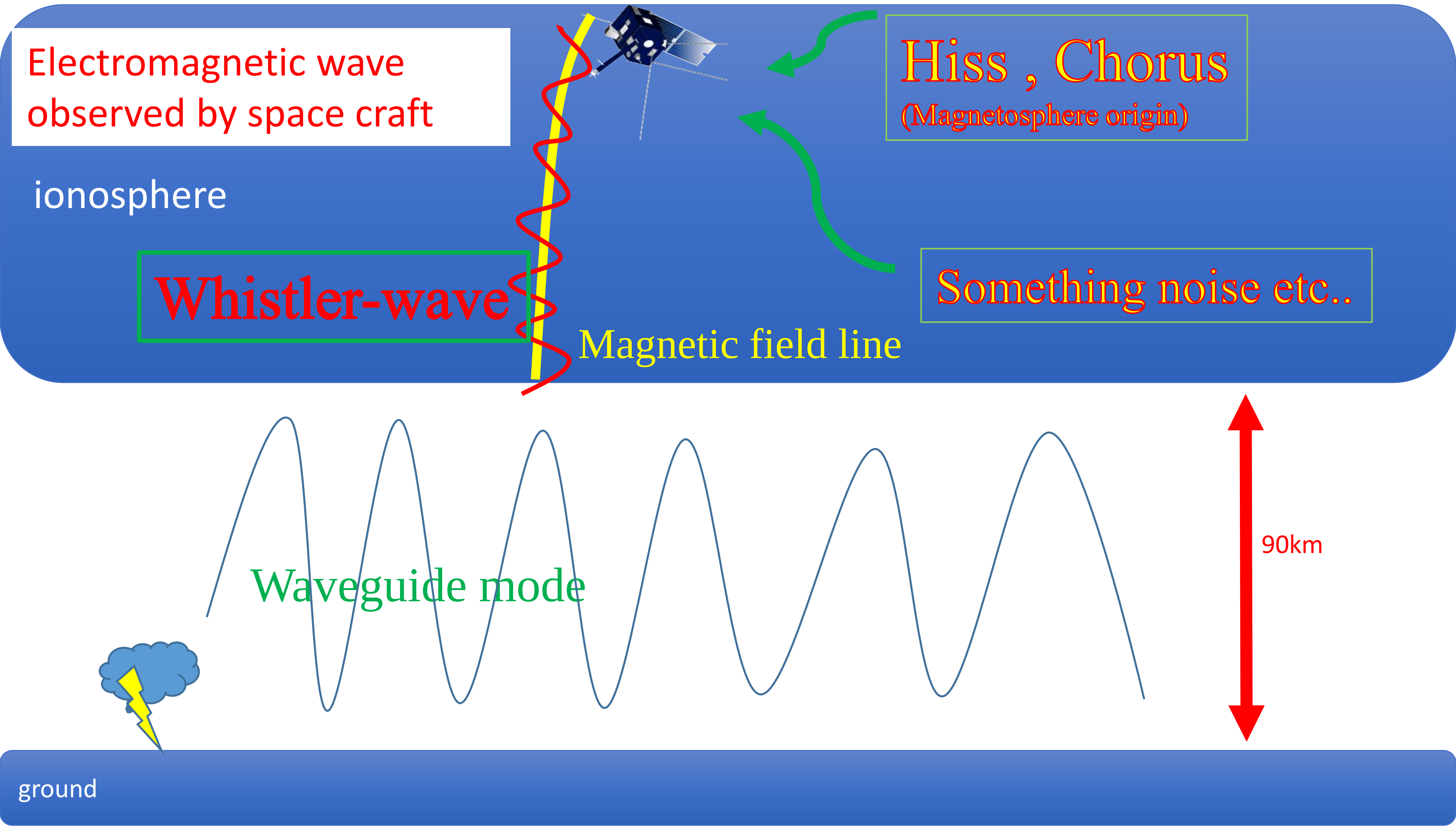
Before M>4.8 EQs (9000) — After

Before Random Eqs (M>4.8) — After

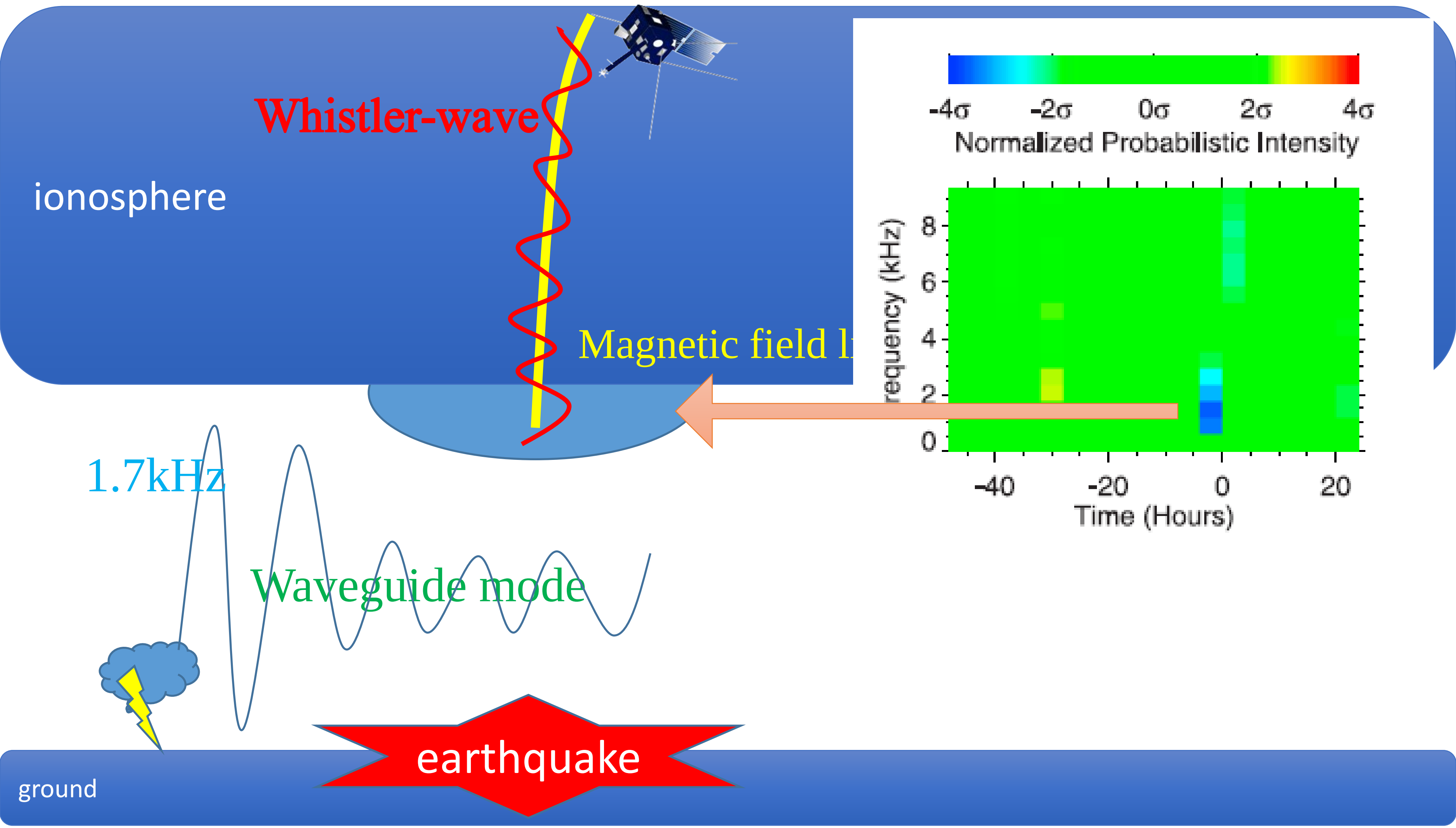
Nemec et al., GRL (2008)

DEMETER electric field measurement





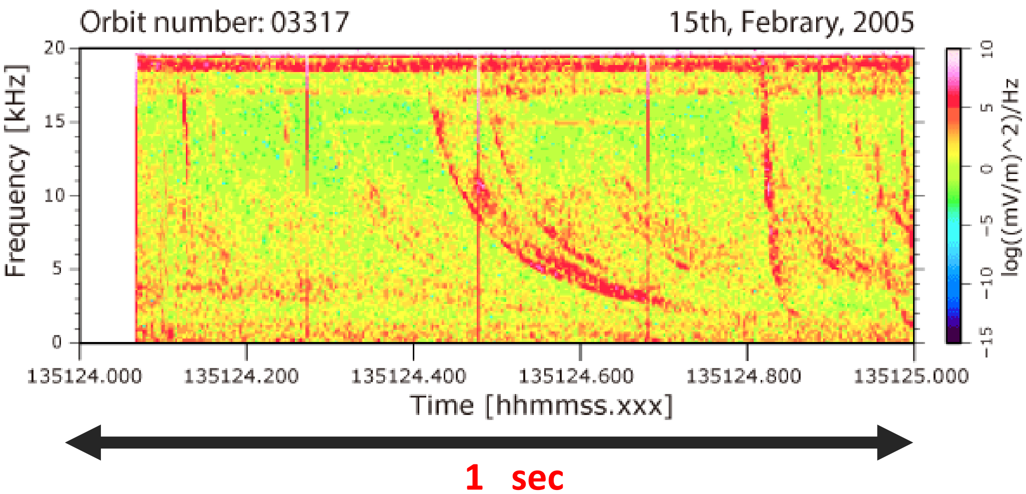
Electromagnetic wave
observed by space craft
ionosphere
Hiss , Chorus
(Magnetosphere origin)
Something noise etc..
Whistler-wave
Magnetic field line
Waveguide mode
90km
ground



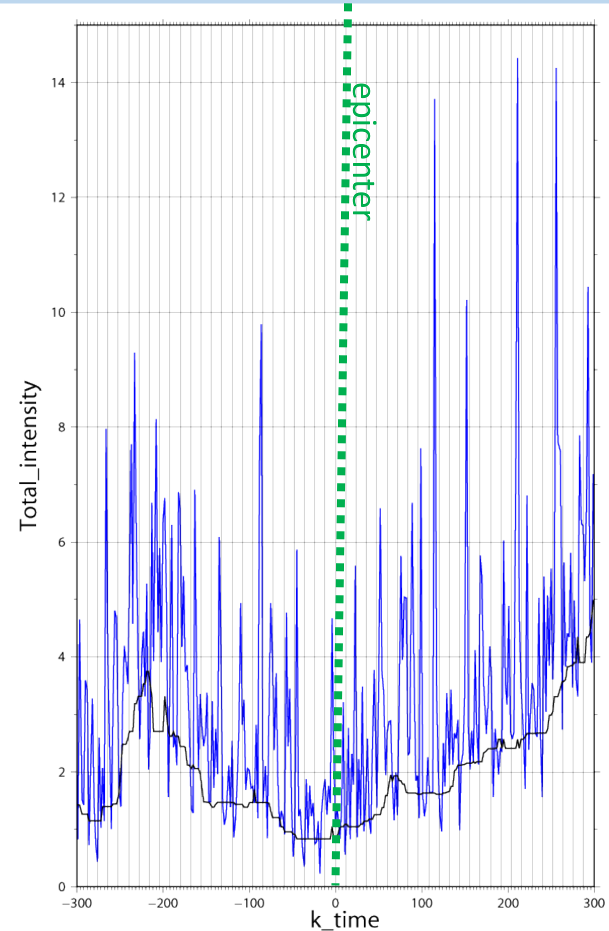
Whistler-wave
ionosphere
Magnetic field li
-4σ -2σ 0σ 2σ 4σ
Normalized Probabilistic Intensity
requency (kHz)
8
6
4
2
0
-40
-20
0
20
Time (Hours)
1.7kHz
Waveguide mode
earthquake
ground

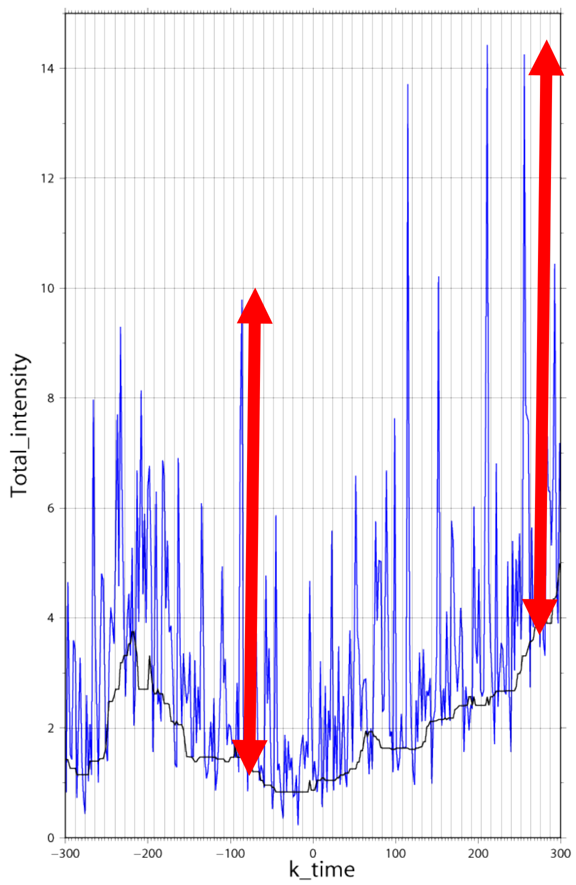
Whistler wave intensity

DEMETER high sampling burst-mode data



DEMETER 2sec sampling survey-mode data



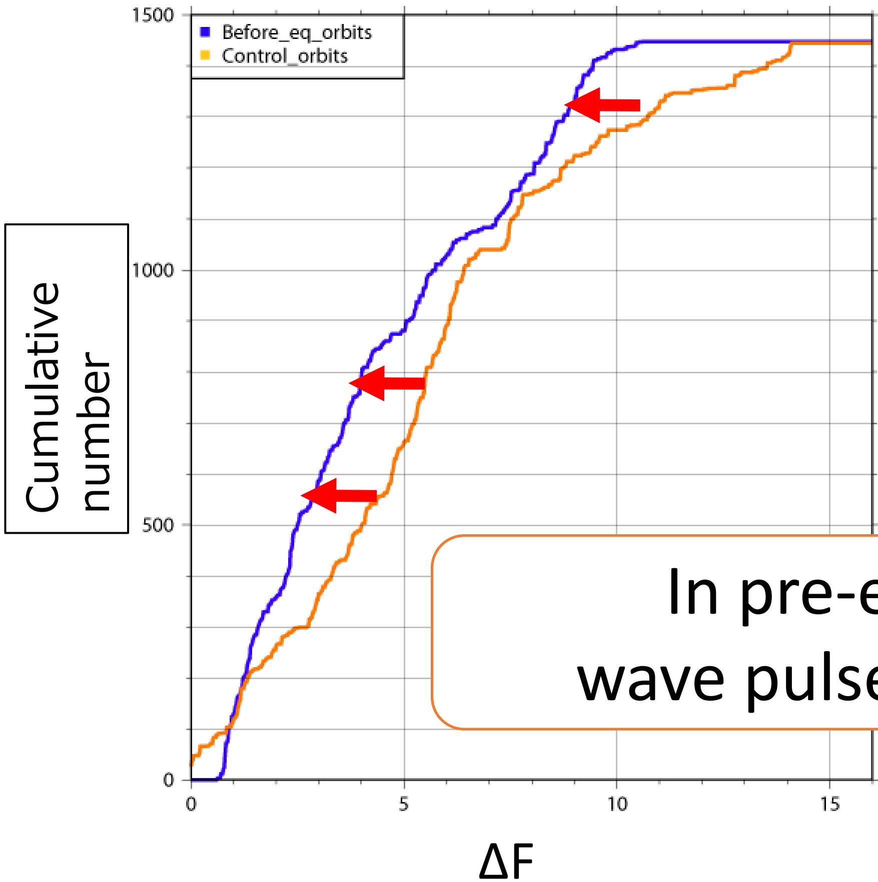


$\Delta F = F - B$

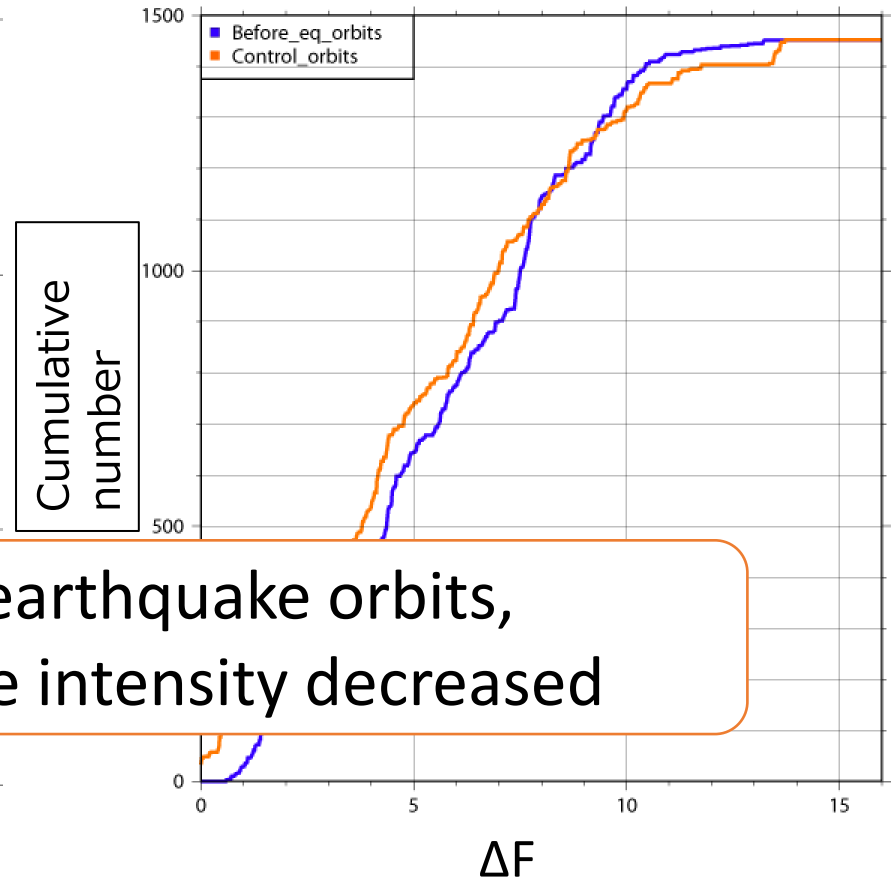
F : total power
B : baseline

ΔF roughly denotes the whistler wave intensity attributed to lightning activity.

Above the epicenter



Far from the epicenter



In pre-earthquake orbits,
wave pulse intensity decreased

Conclusion: Feasible Nano-Sat

- Two spherical electrode probes (3 cm radius) are equipped with the end of tow 40 cm booms.
- Bootstrap are set up at both the sides of probe.
- Only nighttime observation
- Two mode sampling

  a. SURVEY MODE

  (Continuous 1 sec)

  Averaged electric field of 2-8 kHz after FFT analysis of 20 kHz sampling is observed. (180KB/day)

  b. BURST MODE

  (Event command request)

  20kHz sampling electric field for two days is overwritten in on-board memory. 300s raw data within 4 hours before the earthquake is transmitted by the command.

  (1.2 MB/day, 10 days = 1 EQs)