The induced surface electric response in Europe to 2015 St. Patrick's Day geomagnetic storm. Comparison to strongest storms in cycle 23

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Outline

- Motivation

- In situ signatures and interpretation

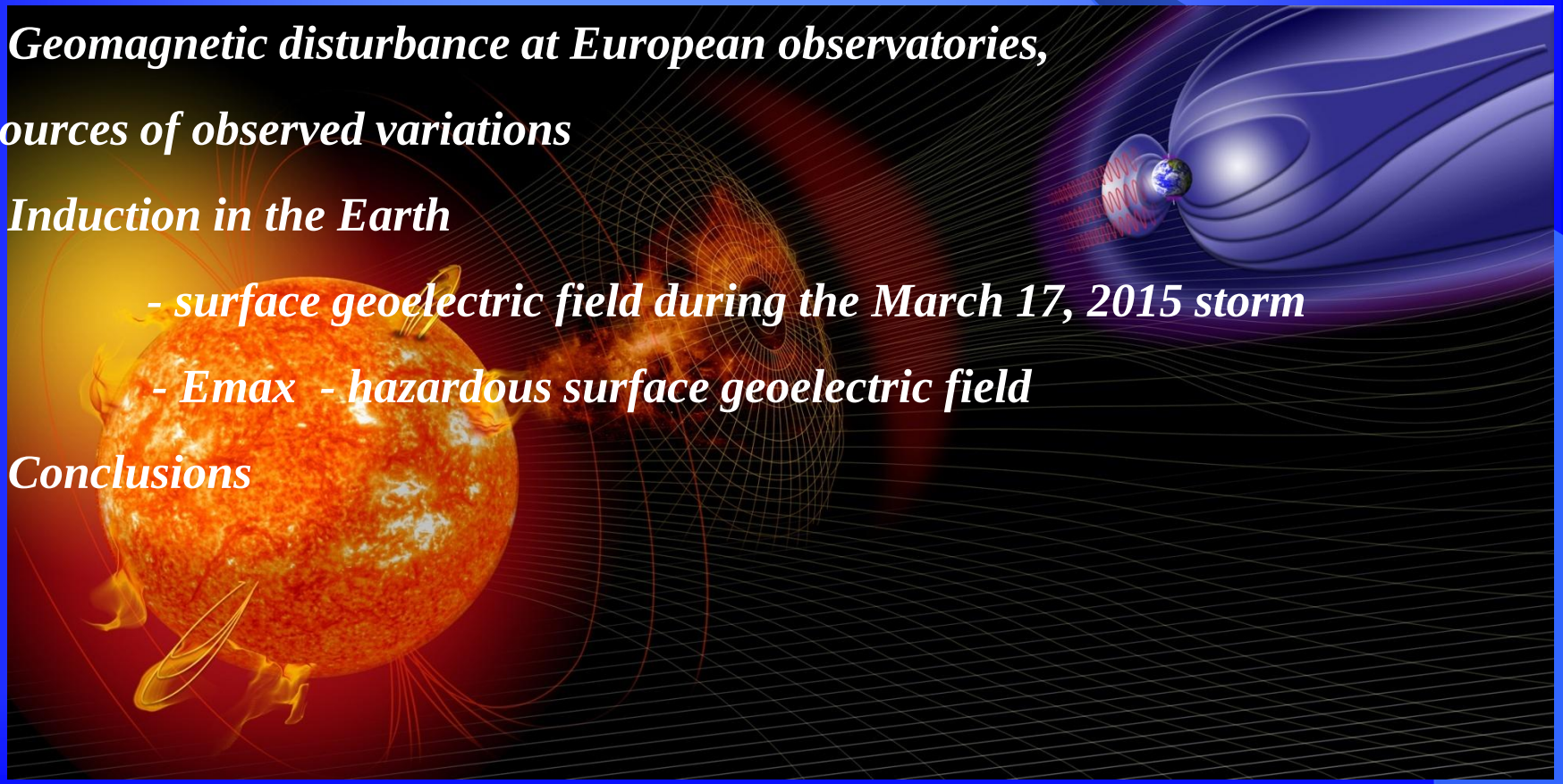
- Geomagnetic disturbance at European observatories, sources of observed variations

- Induction in the Earth

- surface geoelectric field during the March 17, 2015 storm

- Emax - hazardous surface geoelectric field

- Conclusions



 # FAST WARNING 'PRESTO' MESSAGE from the SIDC (RWC-Belgium) #
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A partial halo coronal mass ejection (CME) was reported by CACTus and first seen in LASCO/C2 images at 02:00UT on 15-Mar-2015. This CME was related to a C9.1 flare from NOAA 2297 peaking at 02:13UT. The related CME had a plane of the sky speed of 712 km/s, and a width of 160 degrees. The bulk of the CME is directed away from Earth to the West, but a glancing blow can not be ruled out based on current imagery. The CME is estimated to arrive at Earth on 16 March at 18:00UT (+/- 12 hours).

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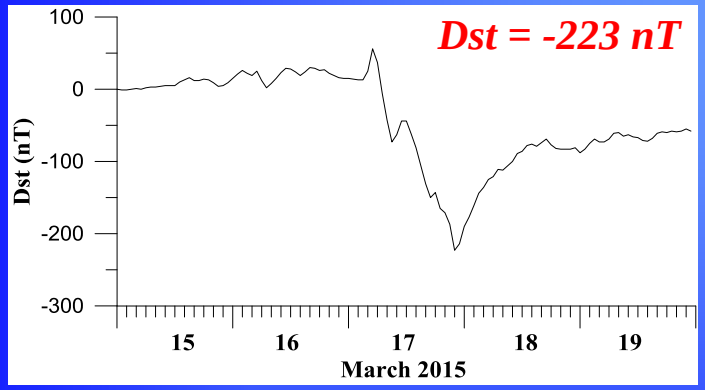
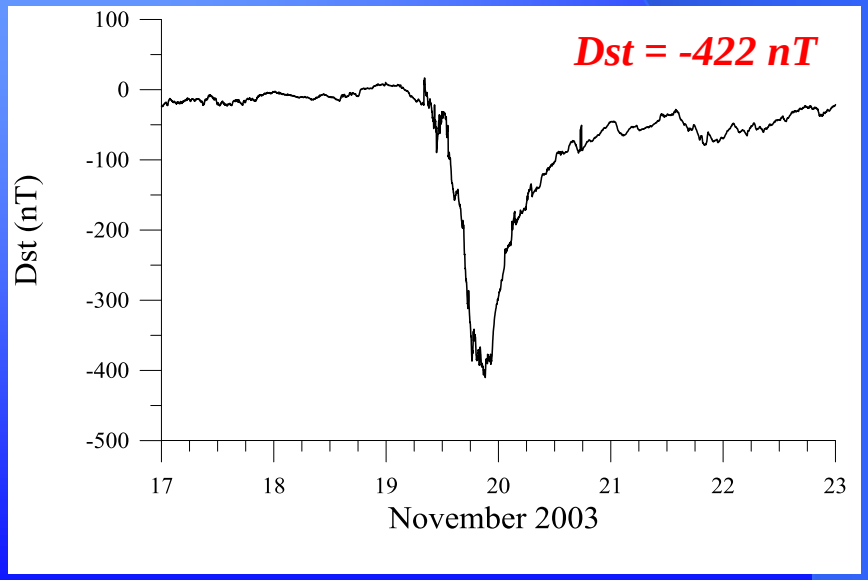
http://www.sidc.be/products/presto

March 2015



November 2003

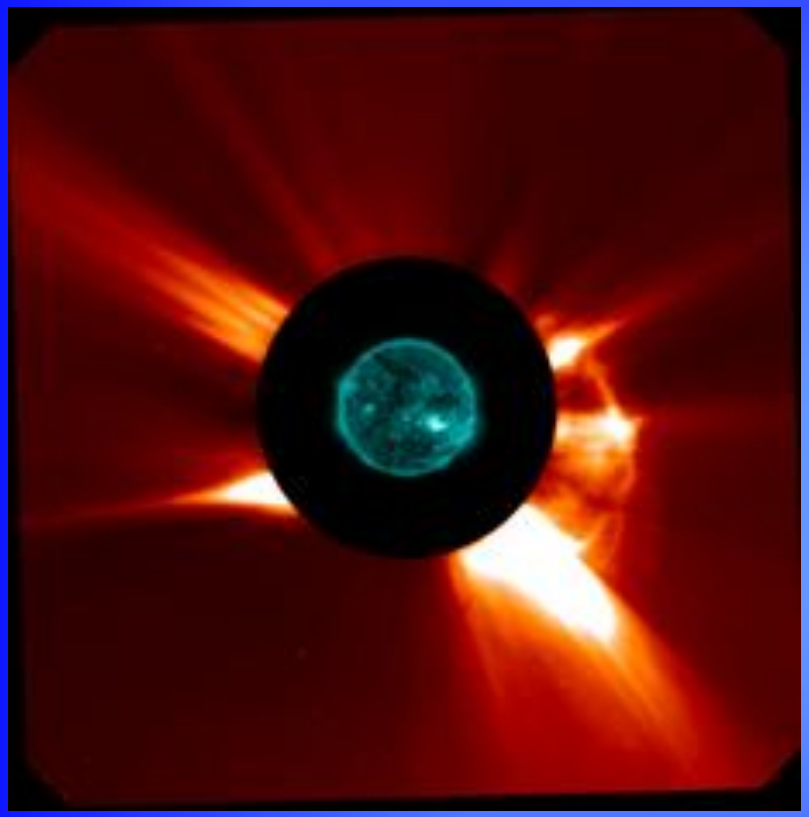


Pileup accident – 2 interpretations

March 17, 2015 storm

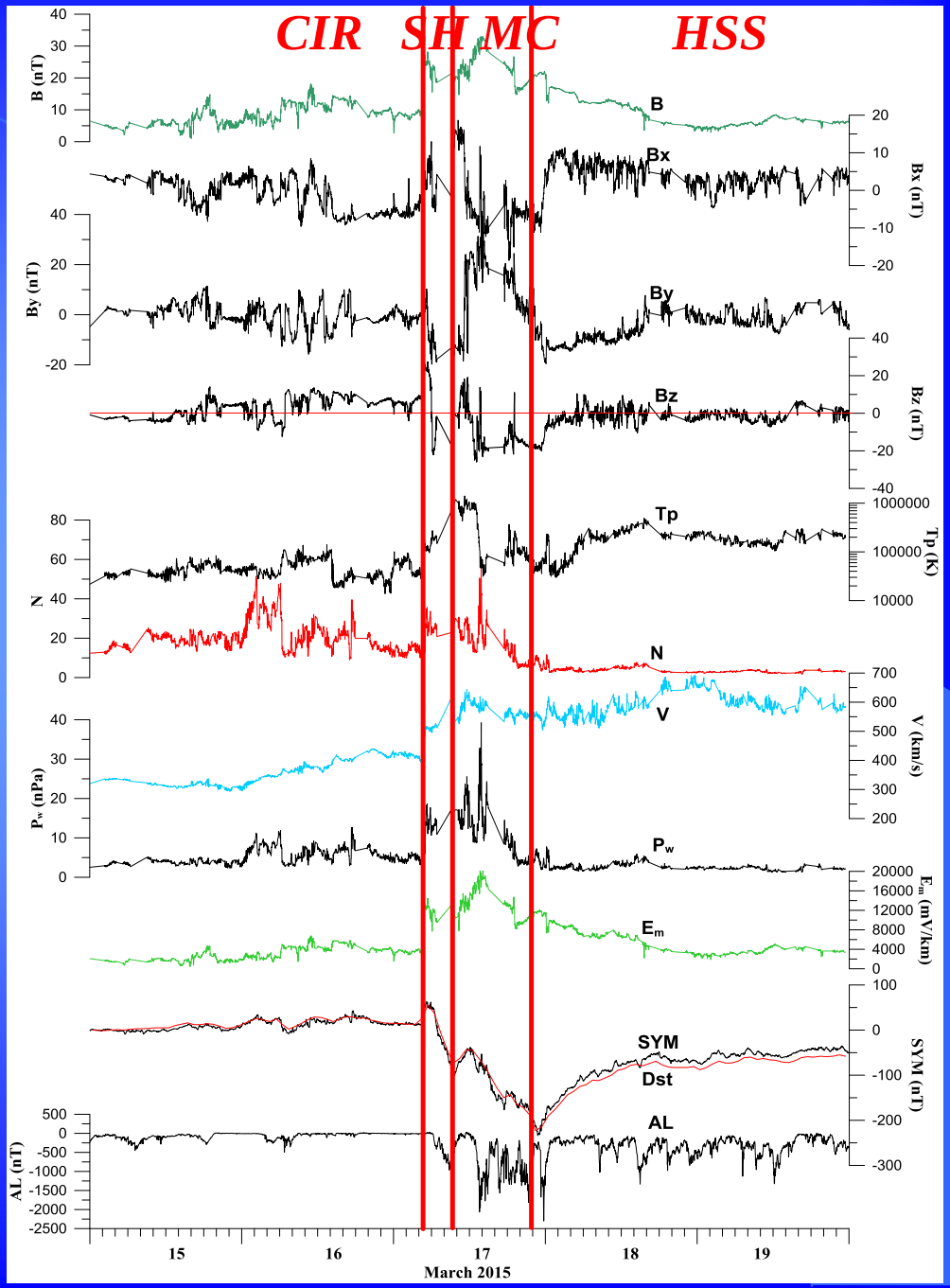
Kataoka et al., GRL 2015; Gopalswamy, 2015

Sheath - Magnetic Cloud - HSS scenario



March 15, 2015
C9.1 flare 02:13 UT
CME 02:00 UT

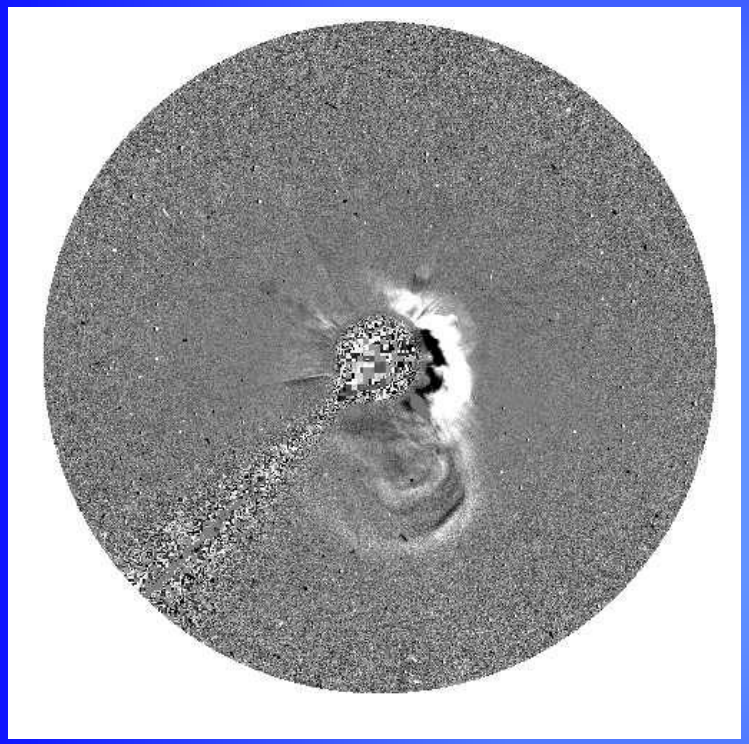
SSC, March 17, 2015, 04:01 UT
min Dst = -223 nT



March 17, 2015 storm

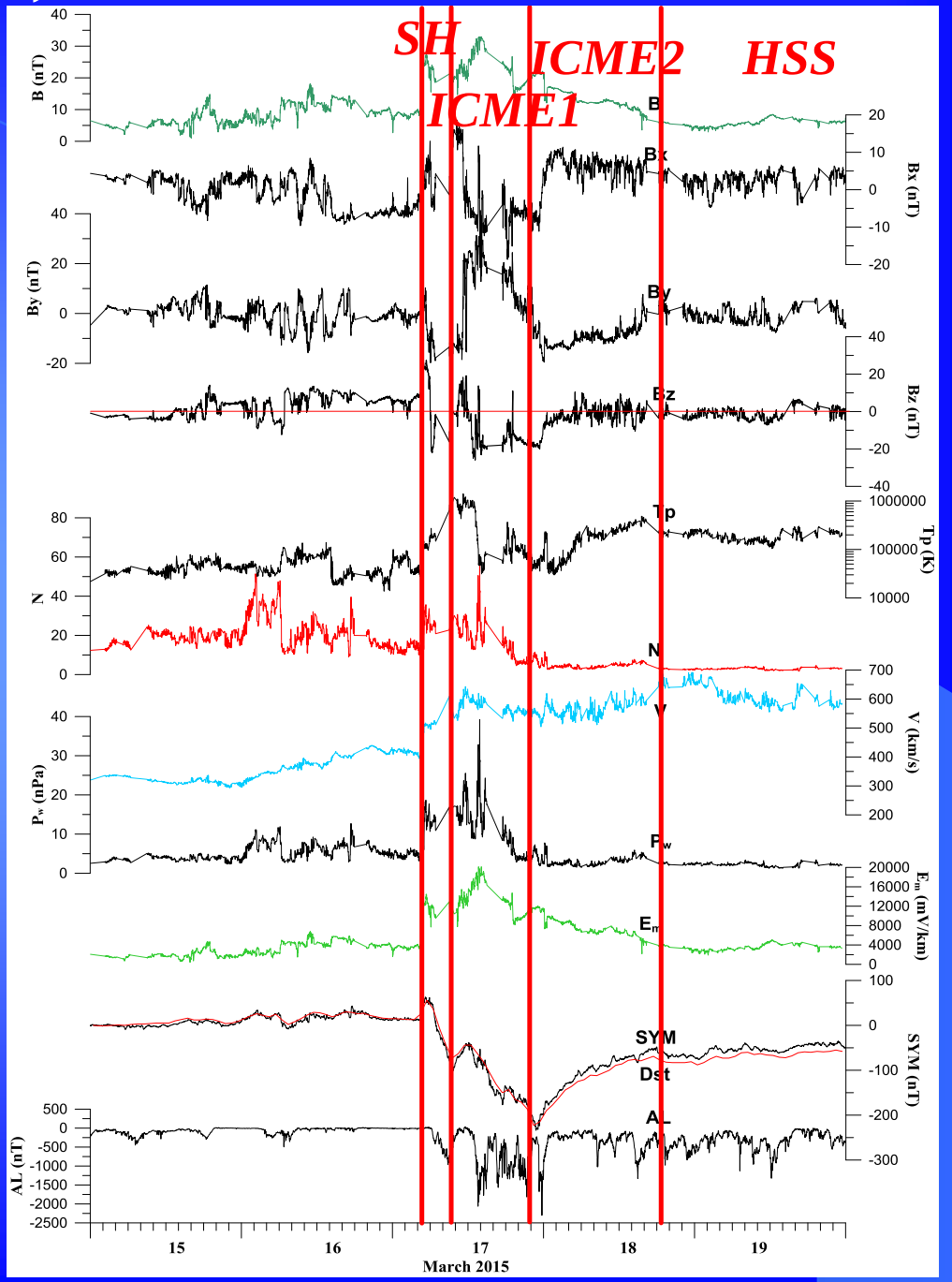
Liu et al., ApJL 2015

Sheath - ejecta - ejecta - HSS scenario

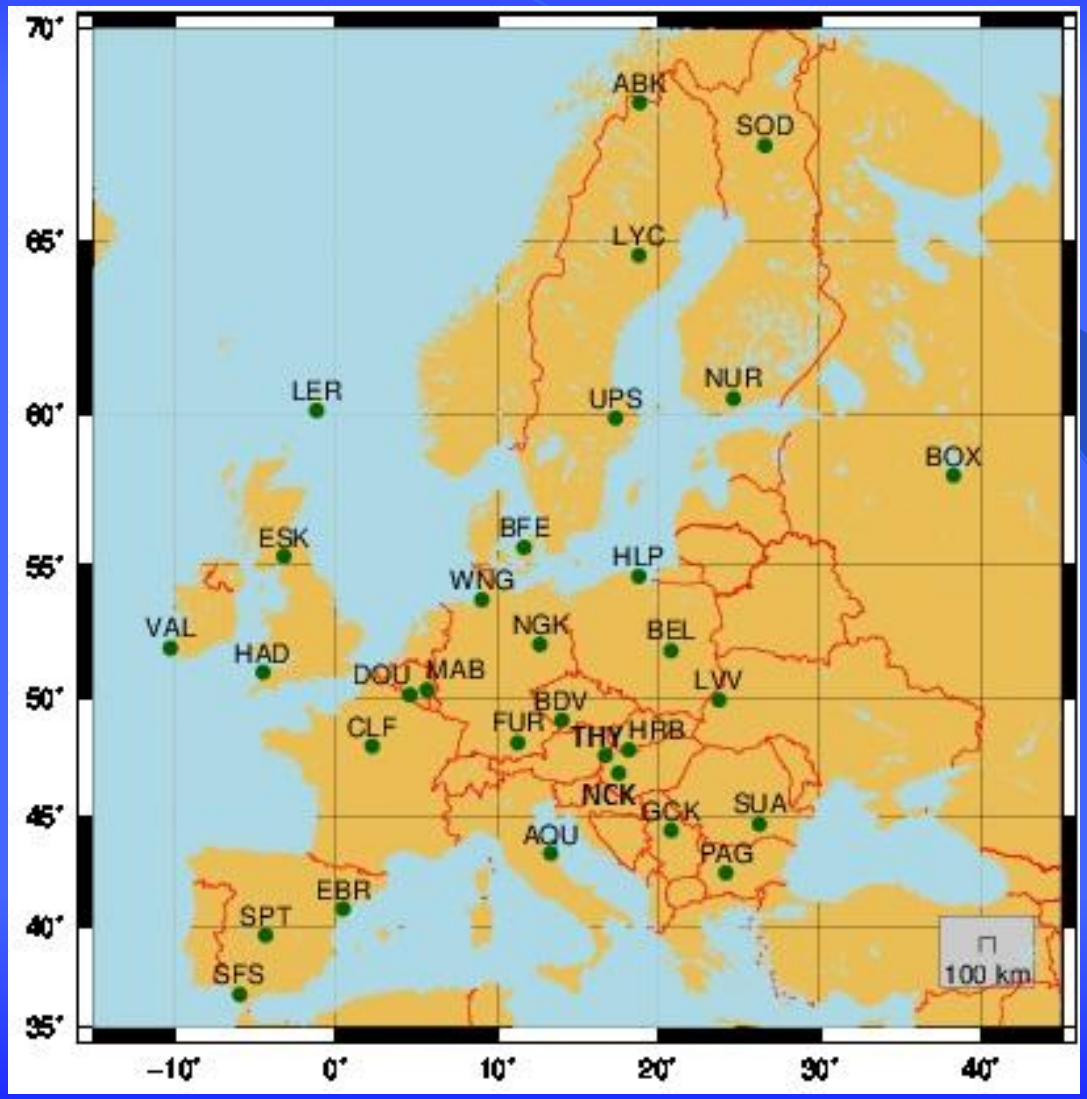


March 14, 2015
C2.6 flare 11:55 UT
CME1

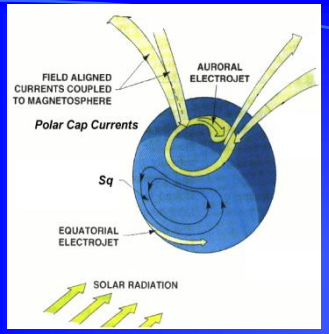
March 15, 2015
C9.1 flare 02:13 UT
CME2 02:00 UT

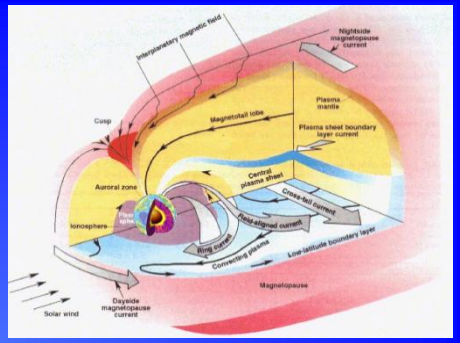


European geomagnetic observatories

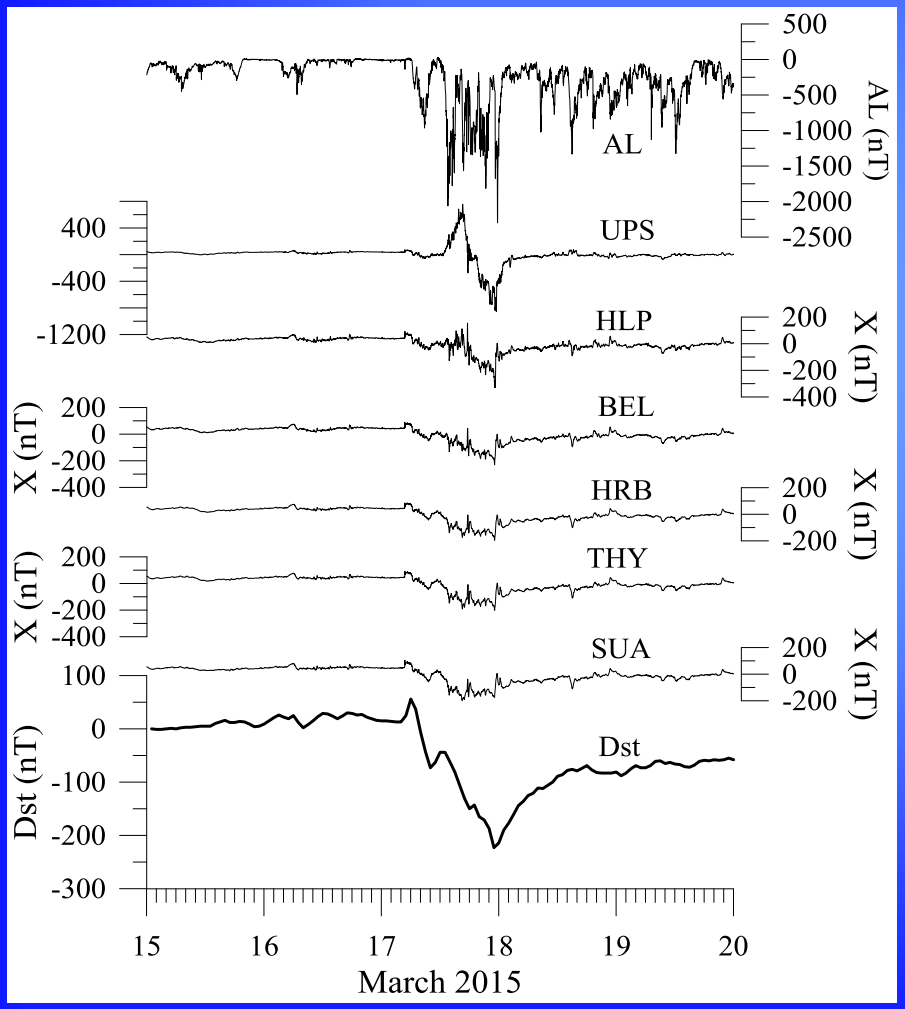


Geomagnetic disturbance

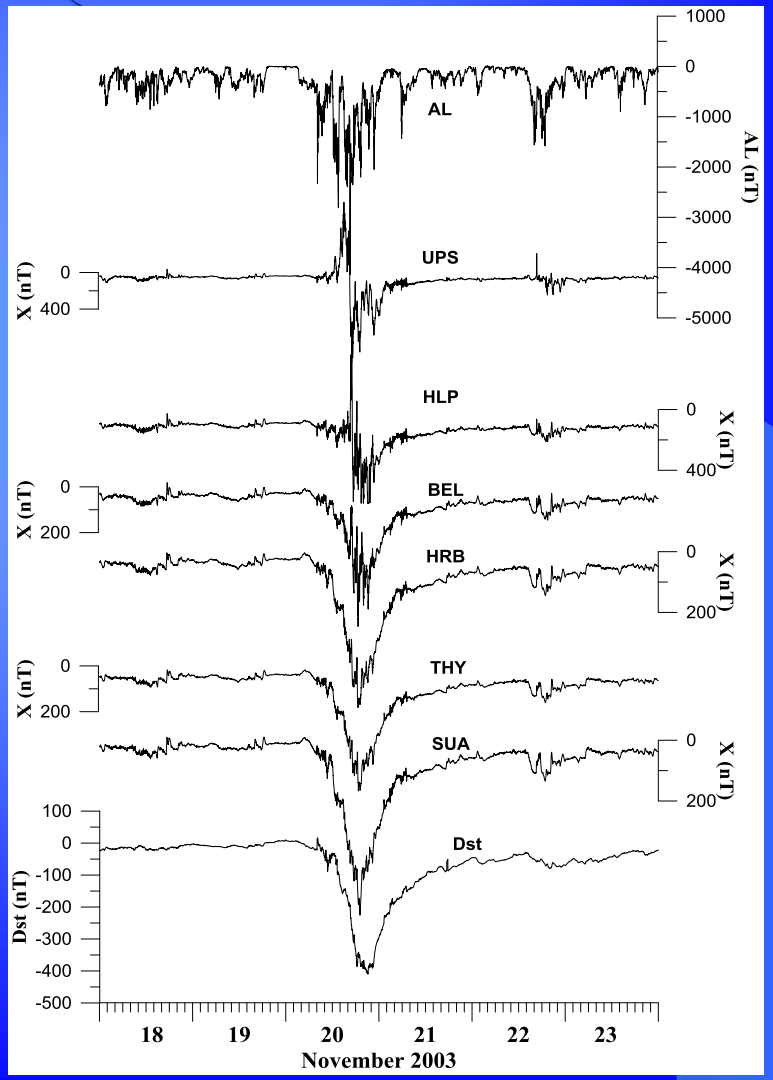




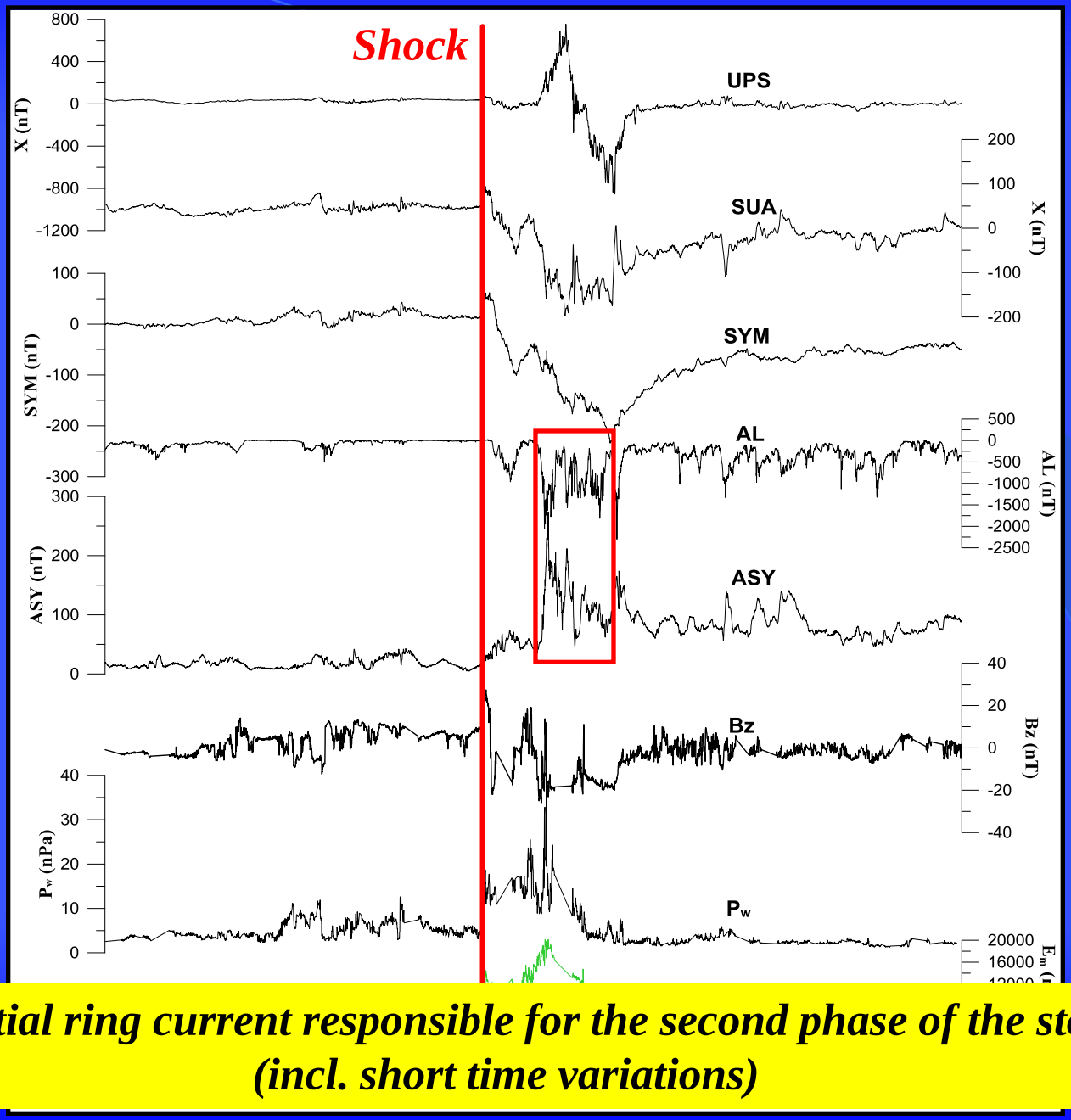
March 2015 storm ~105°E



November 2003 storm ~105°E



Geomagnetic disturbance



- ***partial ring current responsible for the second phase of the storm (incl. short time variations)***

Induction in the Earth

Space weather hazard (GICs)

Variable external magnetic field

↓

Telluric currents

↓

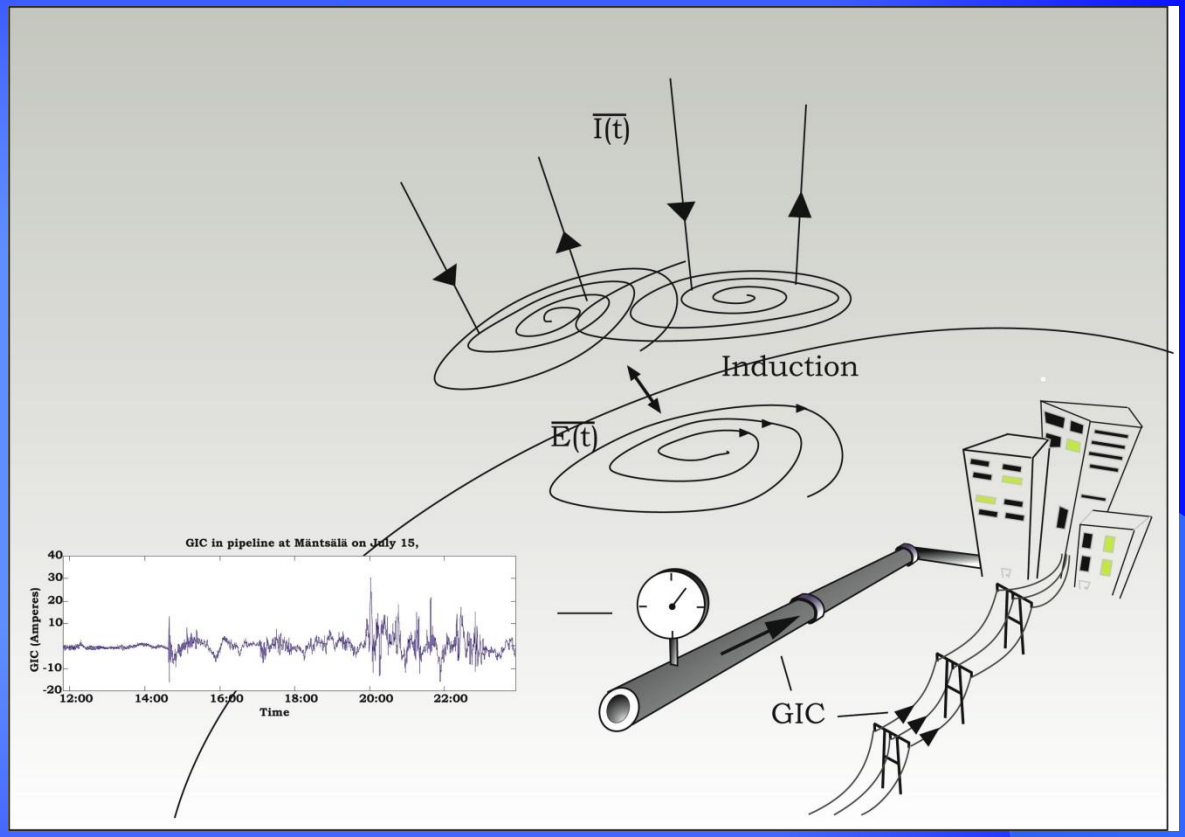
Secondary magnetic field

↓

Surface electric field

↓

Electric currents (GICs)



http://en.wikipedia.org/

Surface geoelectric field

$$E_x(\omega) = \frac{Z(\omega)}{\mu_0} B_y(\omega), E_y(\omega) = \frac{Z(\omega)}{\mu_0} B_x(\omega)$$

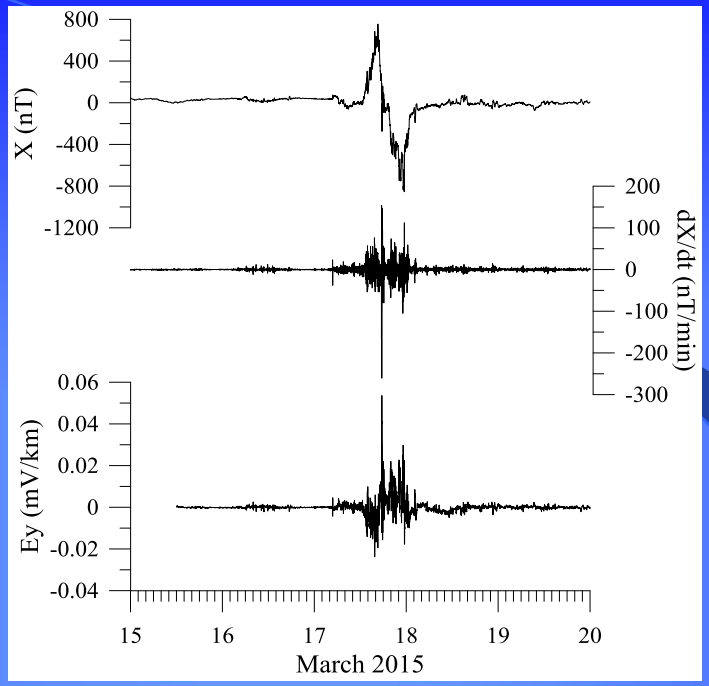
$$E_y(t) = -\frac{1}{\sqrt{\pi \mu_0 \sigma}} \int_{-\infty}^{t} \frac{g_x(u)}{\sqrt{t-u}} du$$

$$E(T_N) = \frac{2}{\sqrt{\pi \mu_0 \sigma}} (R_{N-1} - R_N - \sqrt{M} b_{N-M})$$

$$R_N = \sum_{n=N-M+1}^{N} b_n \sqrt{N-n+1}$$

Viljanen & Pirjola, 1989

$$E(T_N) = \sqrt{E_x^2 + E_y^2}$$



UPS

Intermagnet observatories

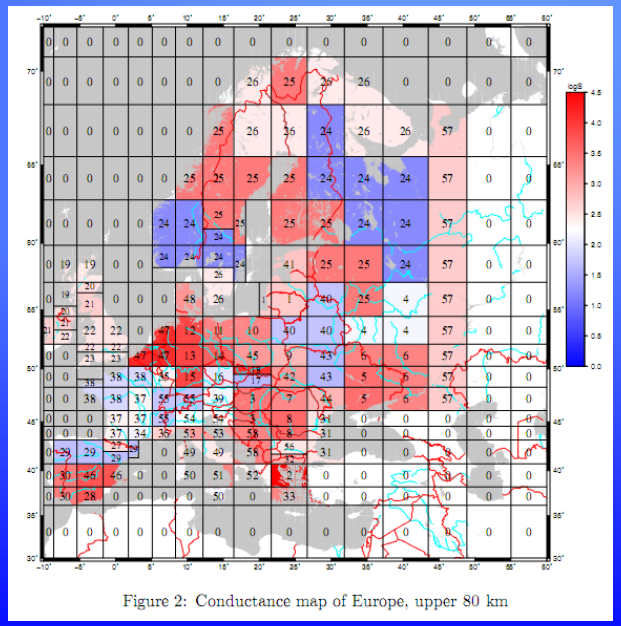
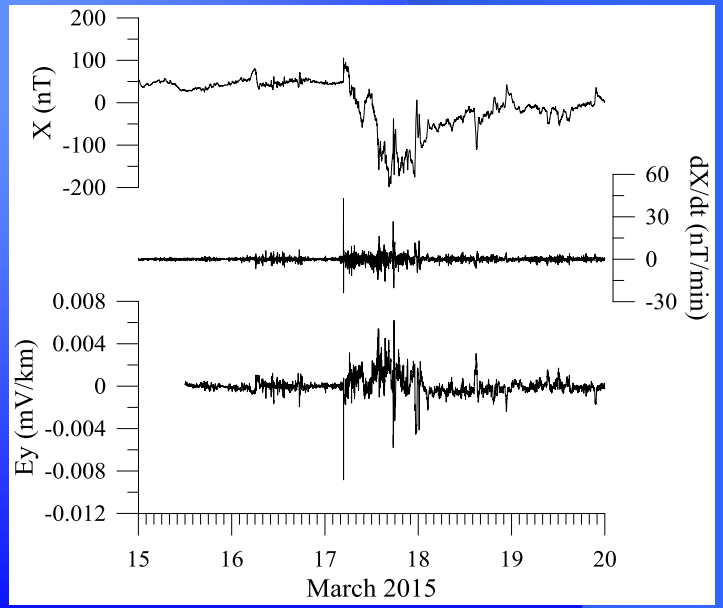


Figure 2: Conductance map of Europe, upper 80 km

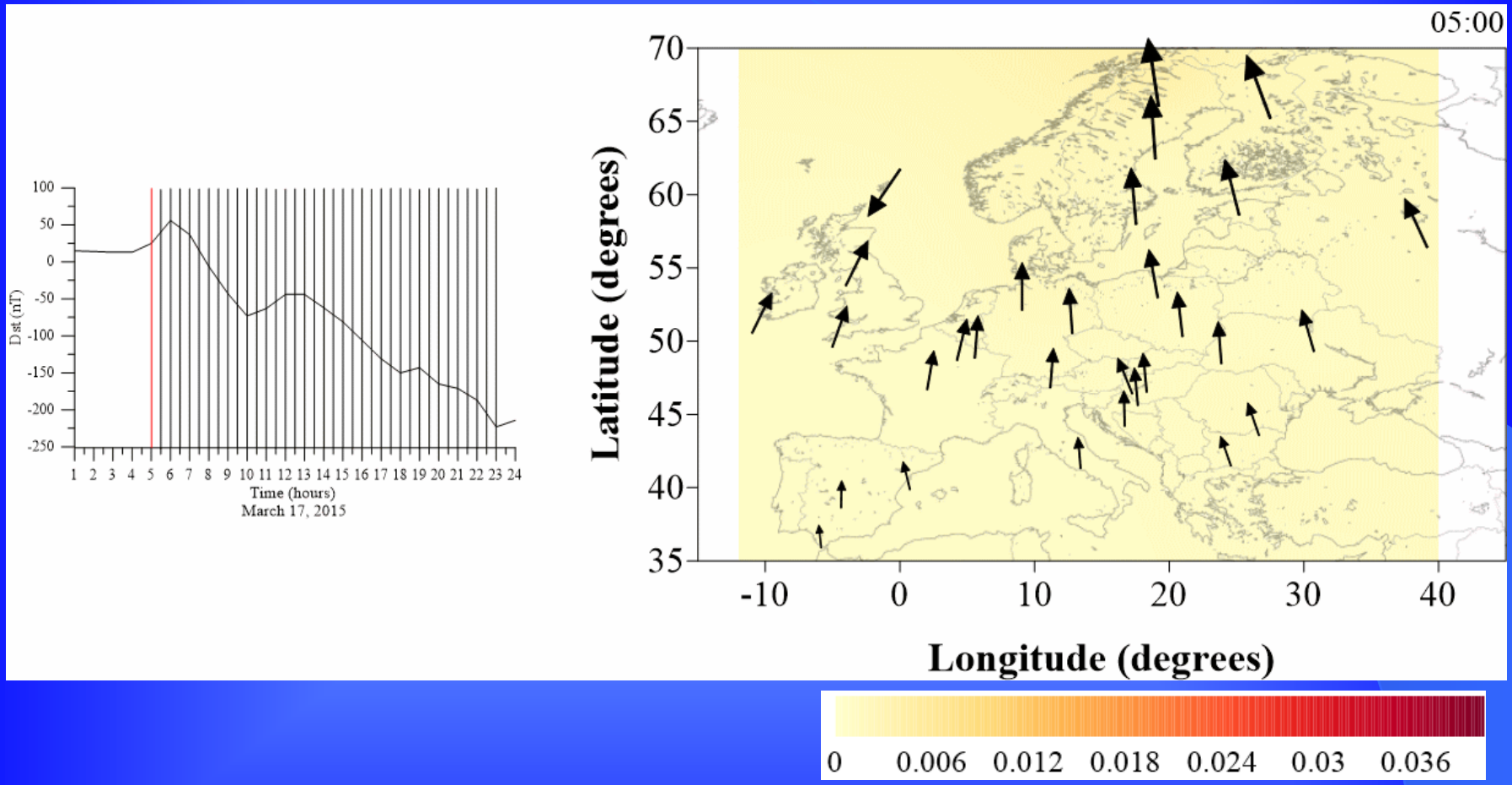
SUA



www.eurisgic.eu

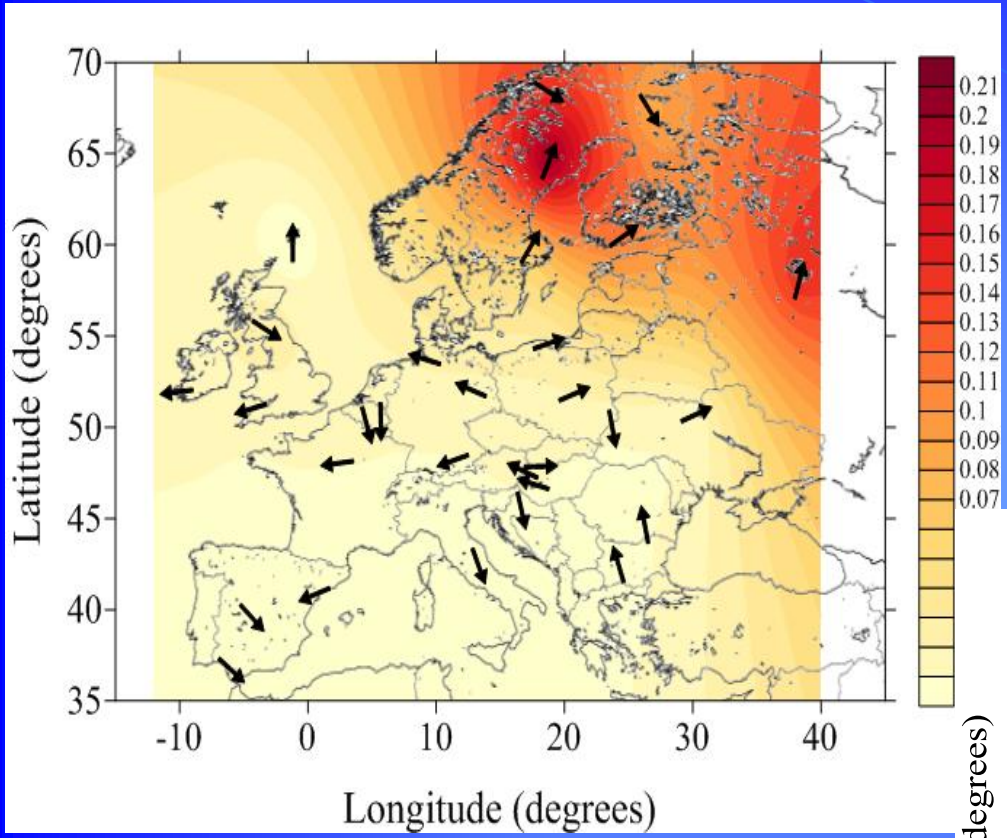
Geoelectric field evolution

Initial & main phase – March 17, 2015 storm

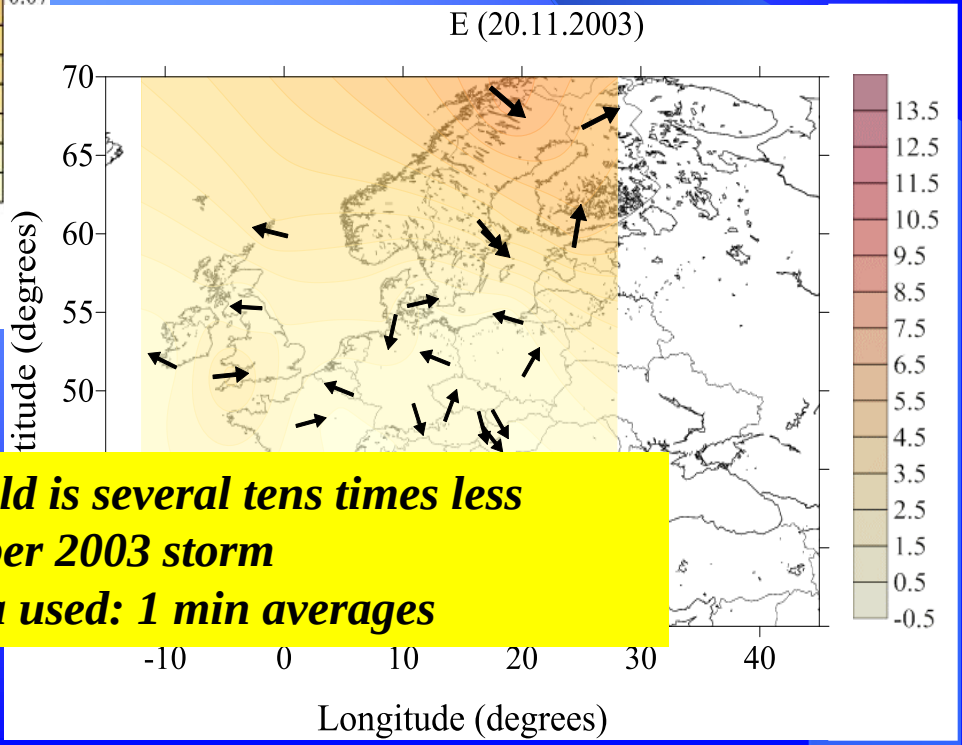


Emax maps

March 2015



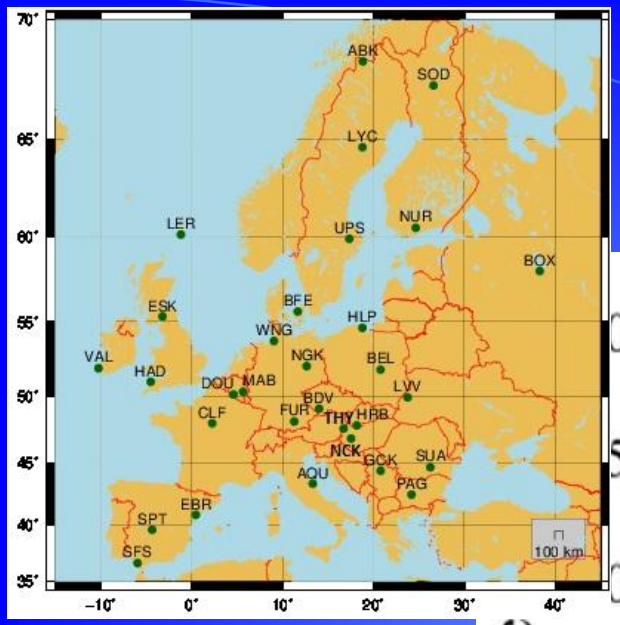
November 2003

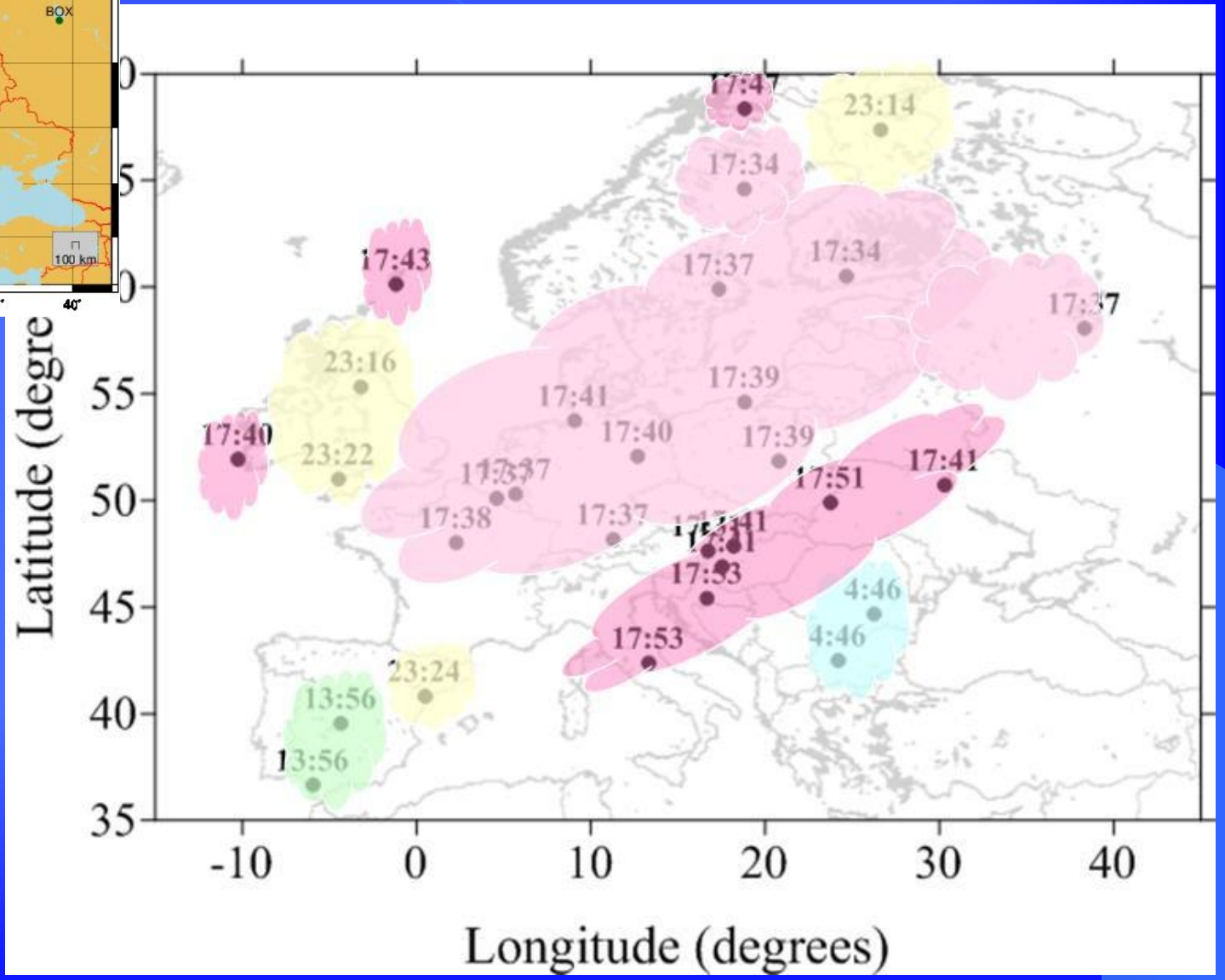


- the amplitude of the geoelectric field is several tens times less than in case of November 2003 storm

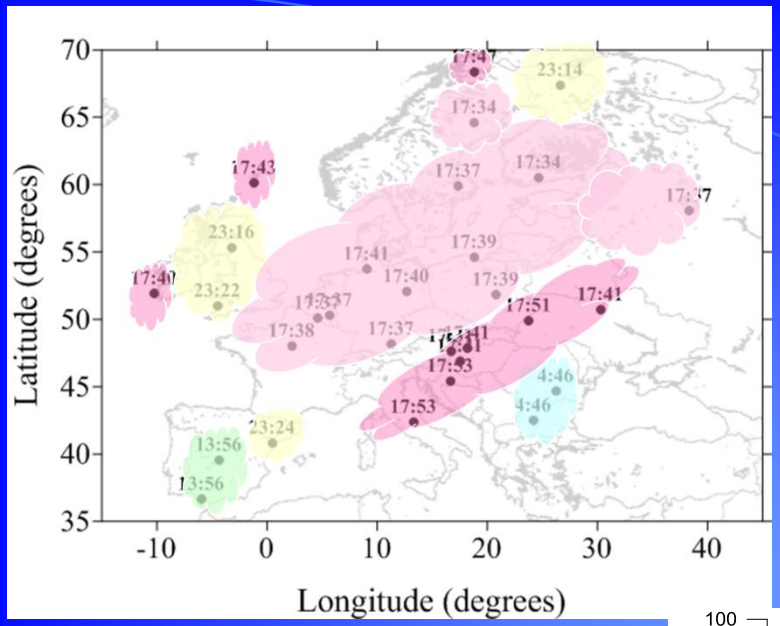
- limitation of geomagnetic data used: 1 min averages

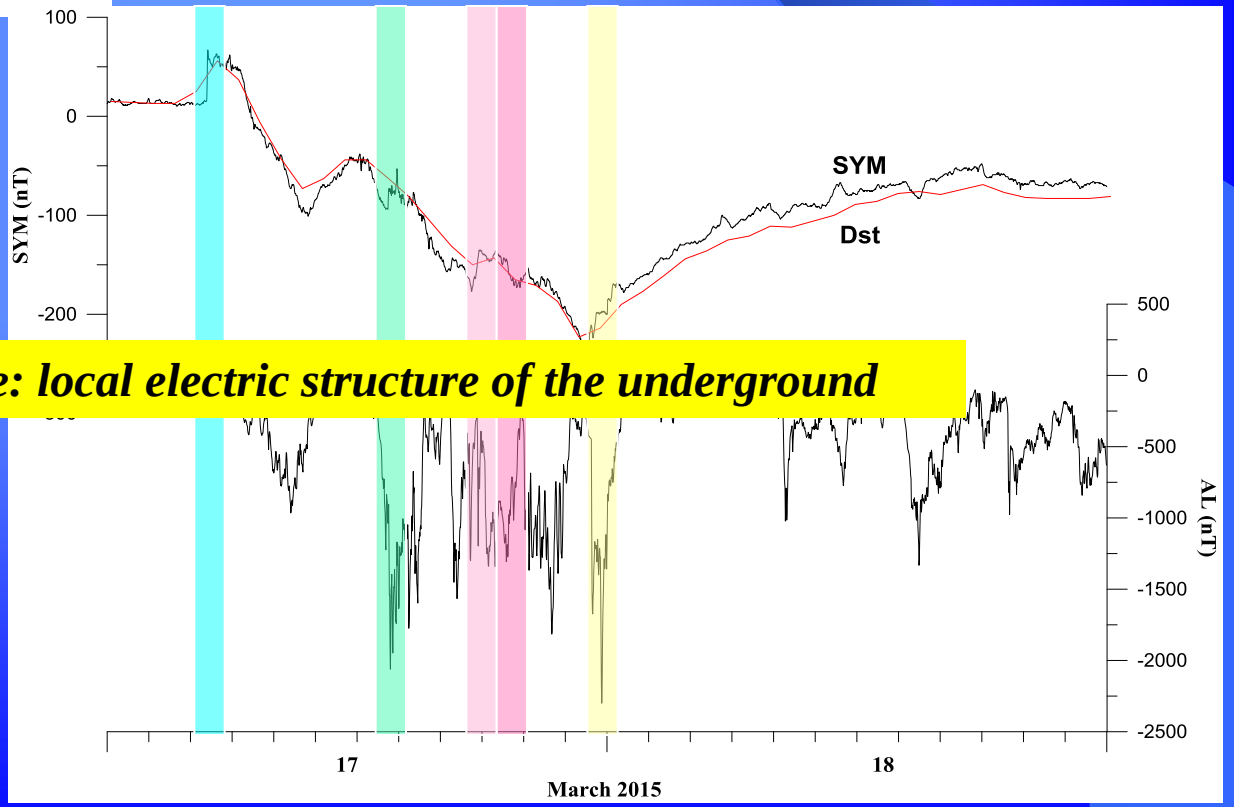
Timing of Emax





Timing of Emax





Probable cause: local electric structure of the underground

Conclusions

- *the disturbance in X is 2-3 times larger at northern latitudes than at mid&southern latitudes;*
- *the amplitude and morphology of the geomagnetic disturbance is a result of the evolution of the two main direct sources of the geomagnetic activity: the magnetospheric ring current & the auroral ionospheric electrojets;*
- *the amplitude of the geoelectric field produced by magnetic variations is several tens times less than in case of November 2003 storm;*
- *the maximum E value is not reached at the same moment at all observatories and its orientation depends on that moment of the storm development. Probable cause: local electric structure of the underground;*
- *future work: look at local effects and explore the role of magnetopause currents;*
- *the present approach concerns only the geophysical problem of GIC hazard. Engineering solutions are the next step.*