Geophysically Induced Currents, a space weather hazard.

Case study – Europe under intense geomagnetic storms of the solar cycle 23

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Outline

- *Motivation*

- *Intense storms (Dst < -150 nT) of cycle 23*

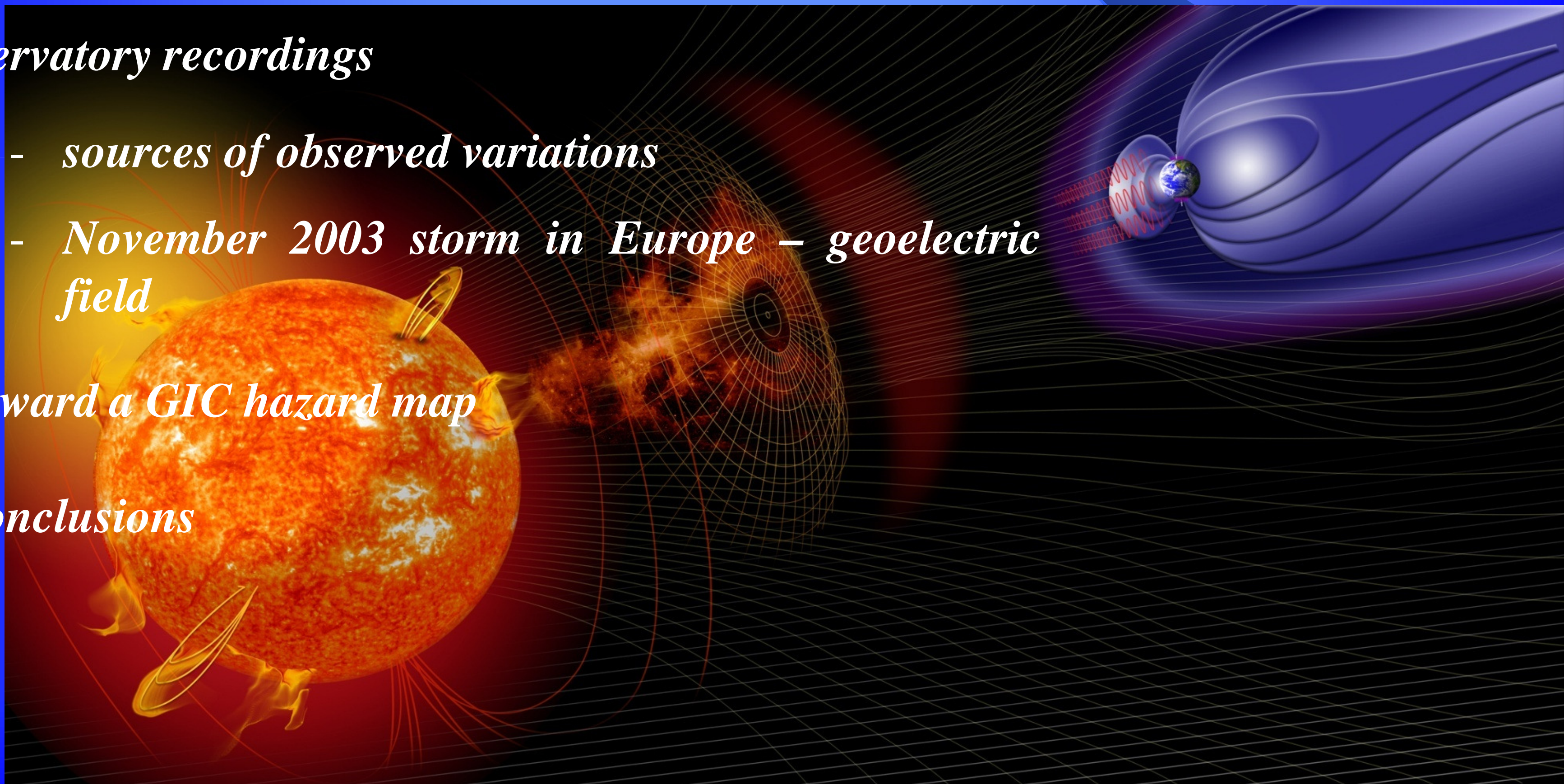
- *Calculation of geoelectric field from geomagnetic observatory recordings*

    - *sources of observed variations*

    - *November 2003 storm in Europe – geoelectric field*

- *Toward a GIC hazard map*

- *Conclusions*



Motivation

Variable external magnetic field

↓

Telluric currents

↓

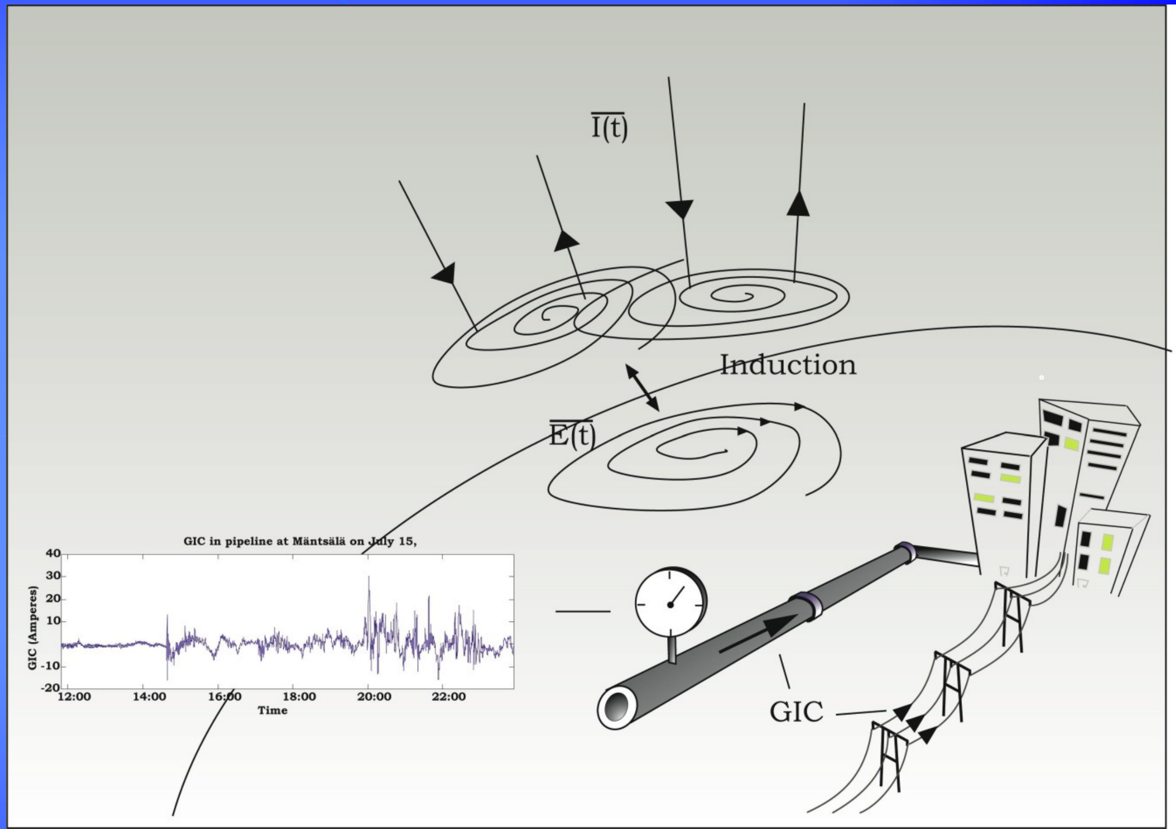
Secondary magnetic field

↓

Surface electric field

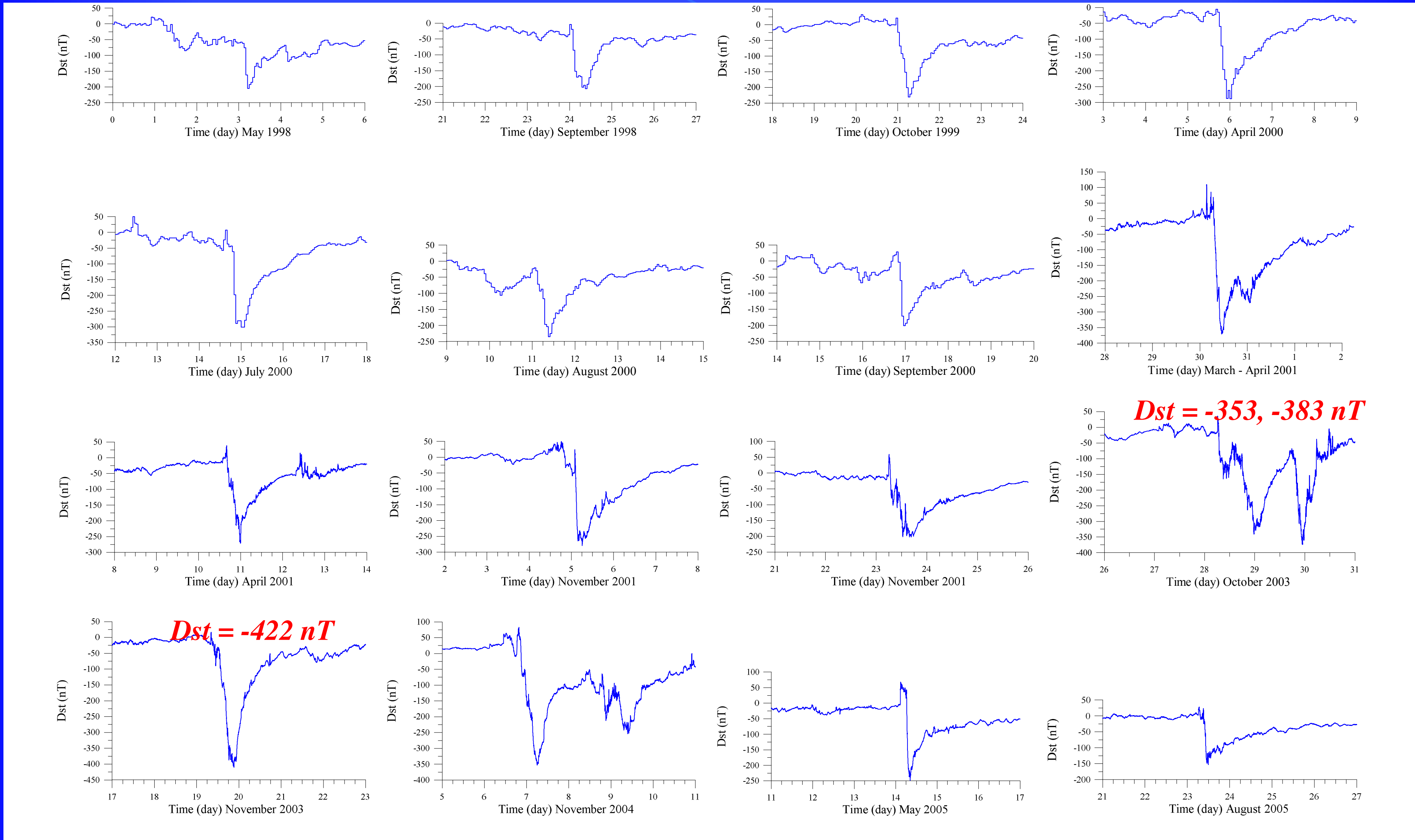
↓

Electric currents (GICs)



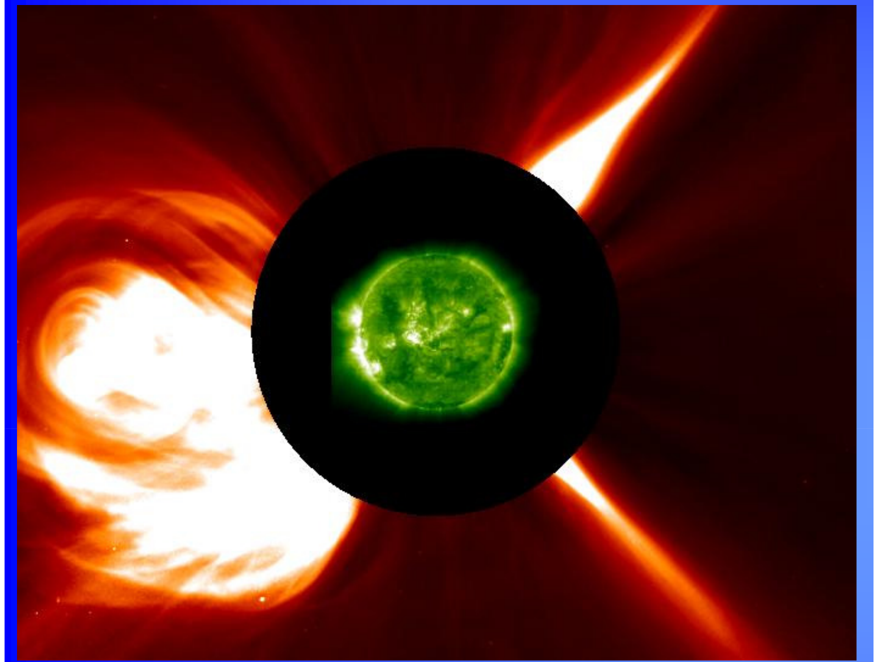
http://en.wikipedia.org/

Intense (Dst<-150 nT) storms – cycle 23



November 2003 storm

CME

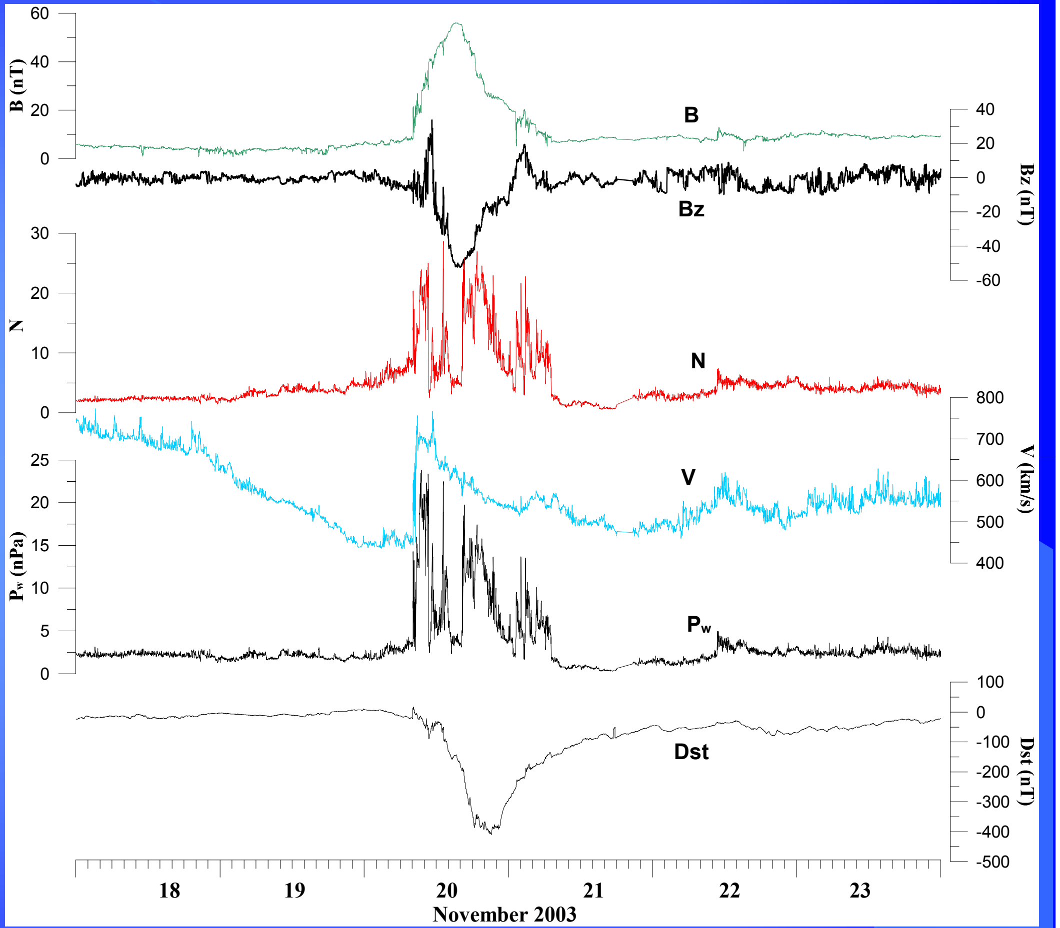


November 18, 2003
10:24 UT

GOES
LASCO C2 image (jhelioviewer.org/)

Solar eruption November 18, 2003, 8:12 UT

ICME



www.omniwebdata

SSC, November 20, 2003
8:03 UT

Surface geoelectric field (1)

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

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

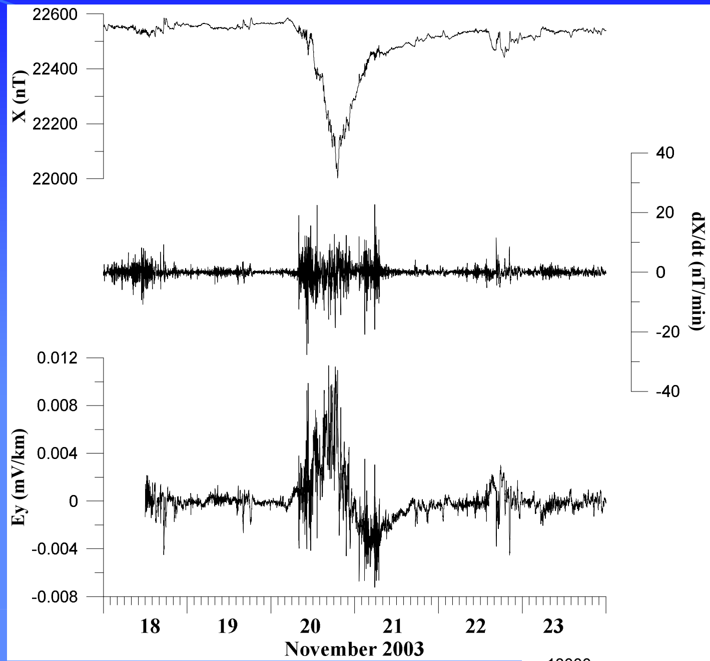
$$E(T_N) = \frac{2}{\sqrt{\pi\mu_0\sigma}} (R_{N-1} - R_N - \sqrt{M} b_{N-M})$$

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

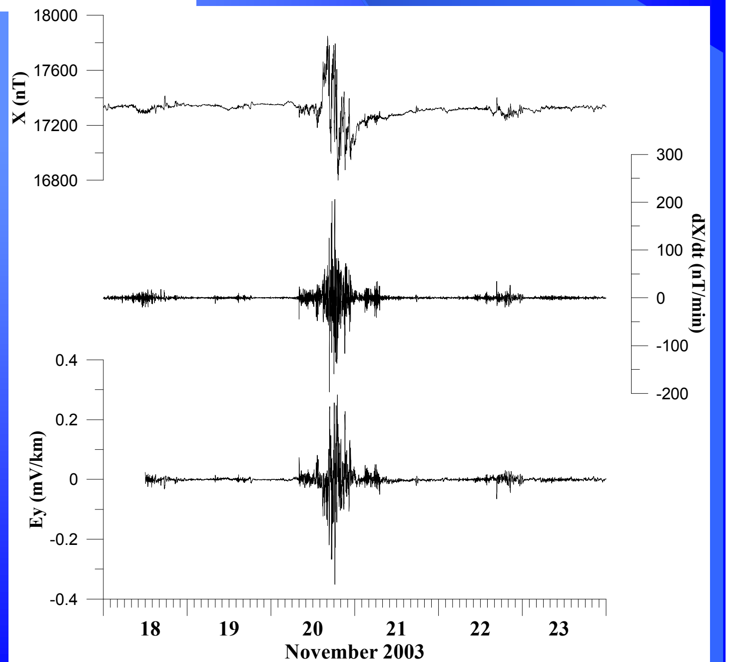
Viljanen & Pirjola, 1989

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

SUA



ESK



Intermagnet observatories

Surface geoelectric field (2)

Conductivity model of the European GIC project

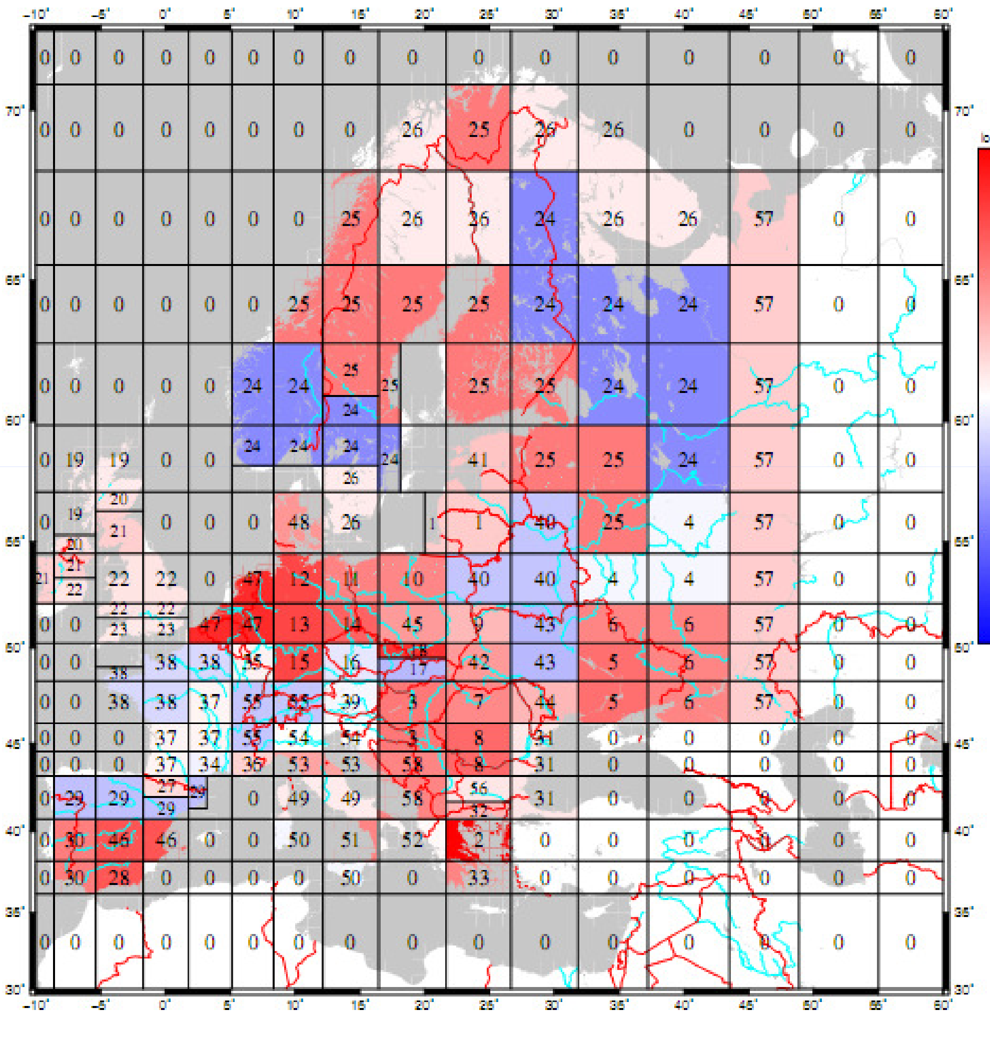
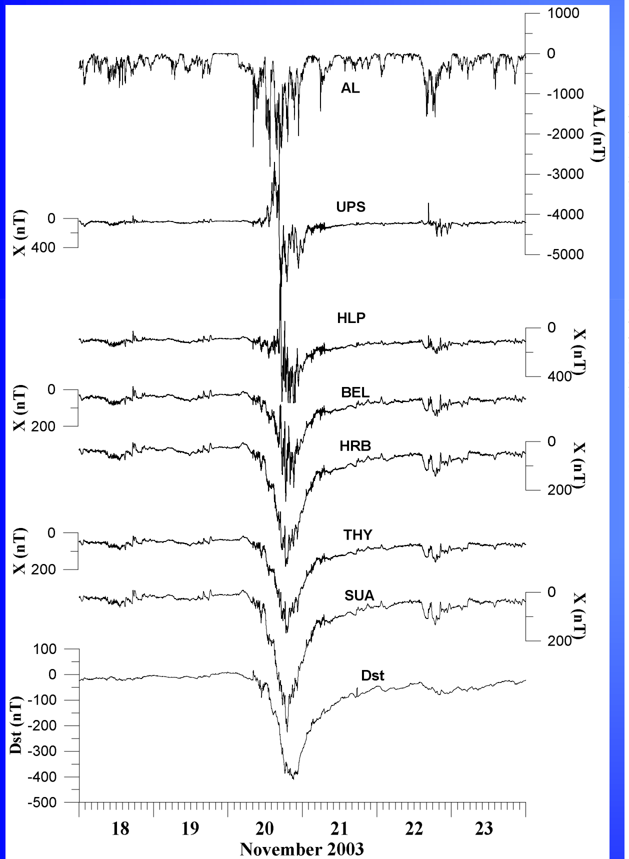


Figure 2: Conductance map of Europe, upper 80 km

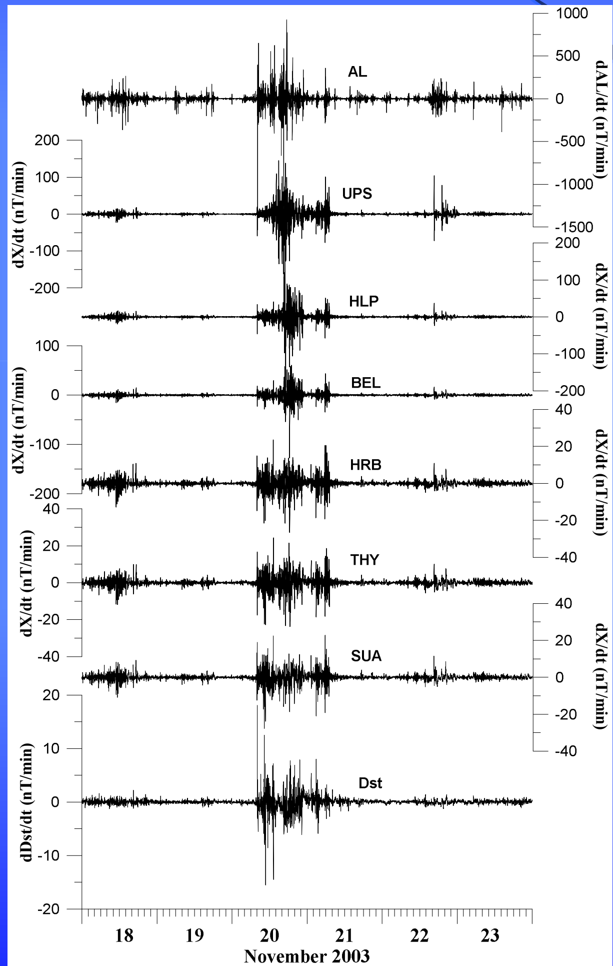
Surface geoelectric field (3)

November 2003 storm
~105°E

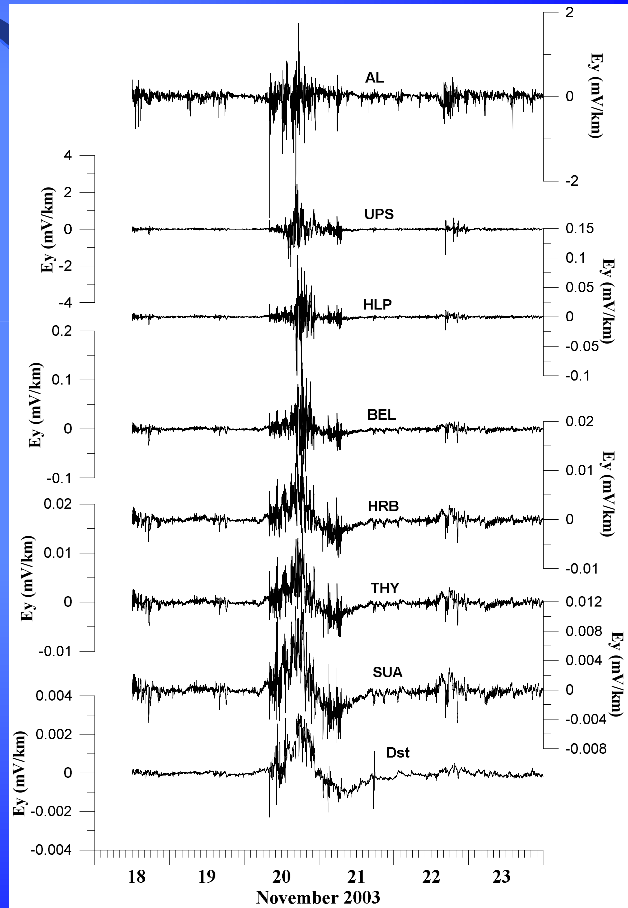
X (nT)



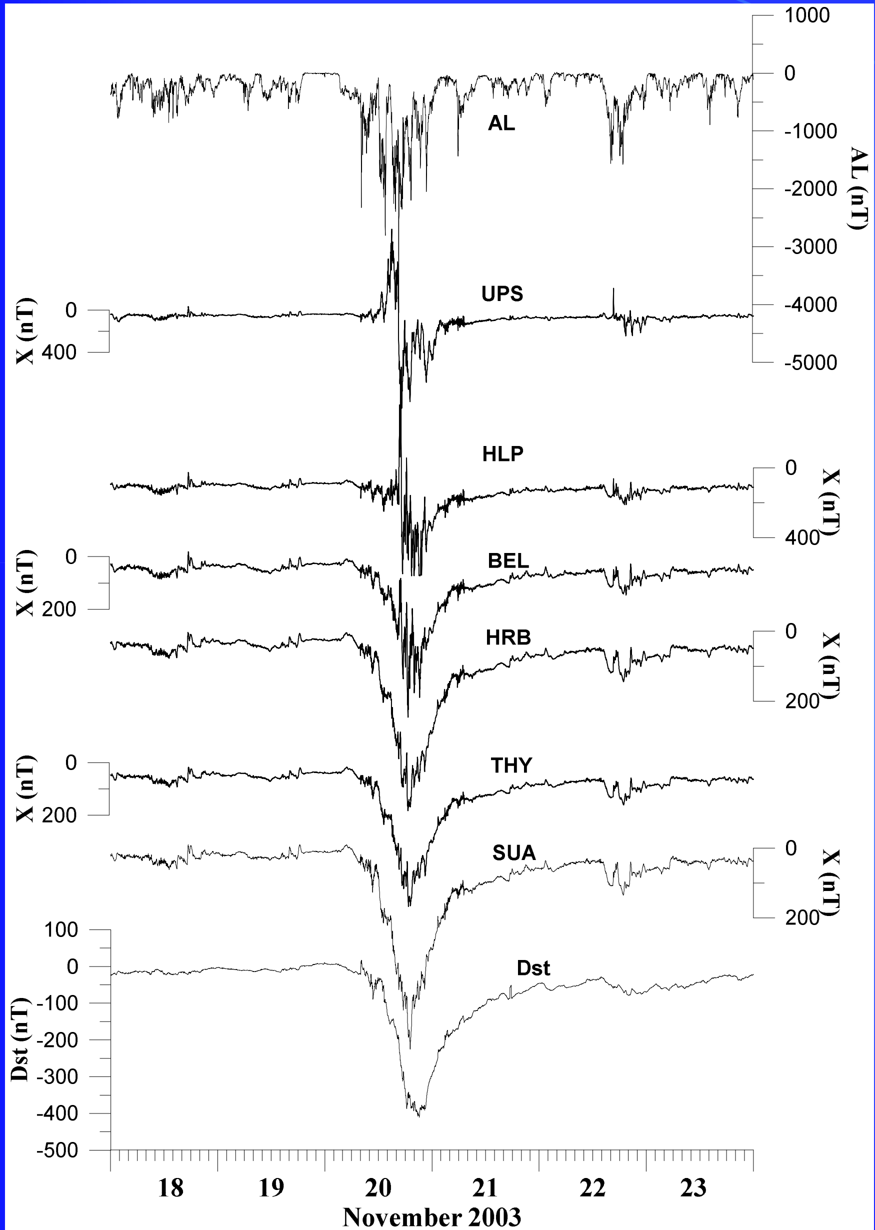
dX/dt (nT/min)

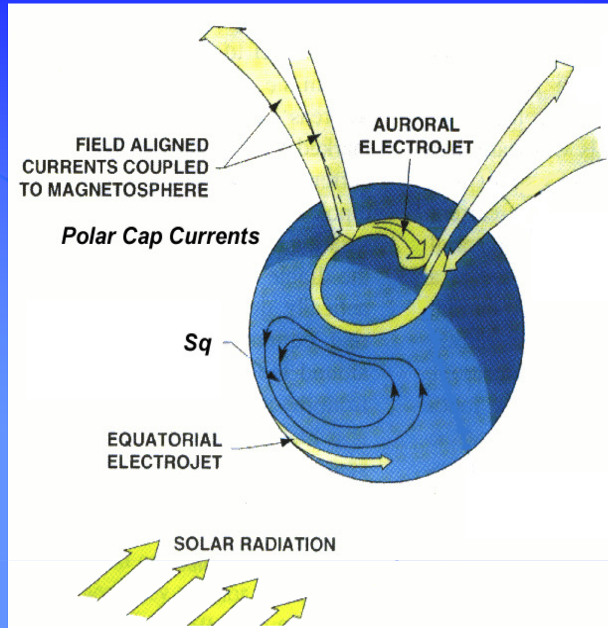


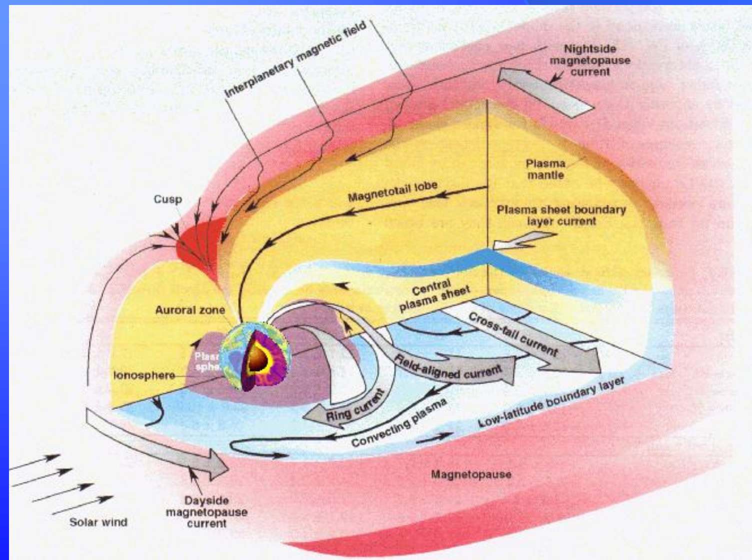
Ey (mV/km)



Sources of geomagnetic disturbance (1)

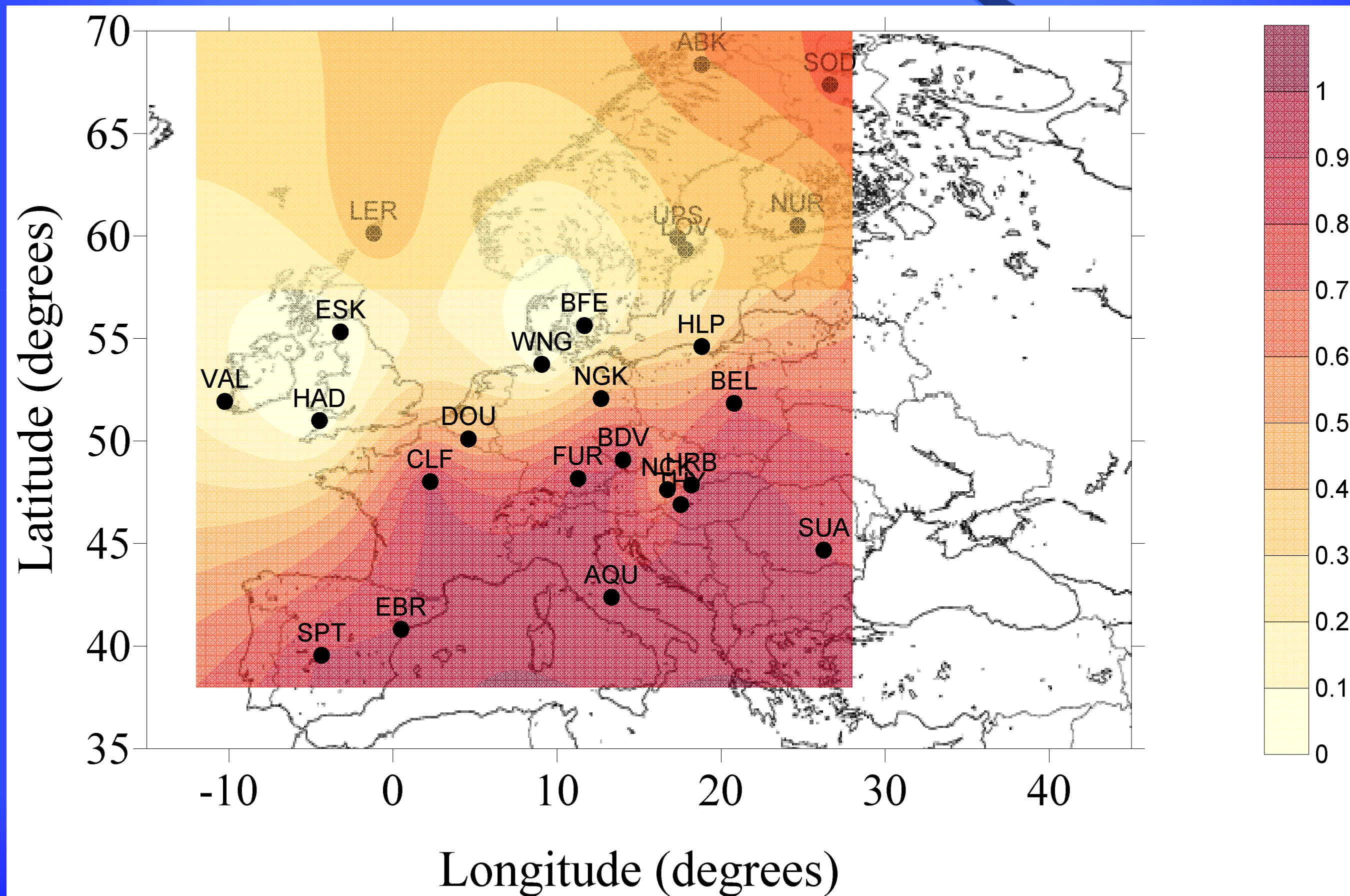




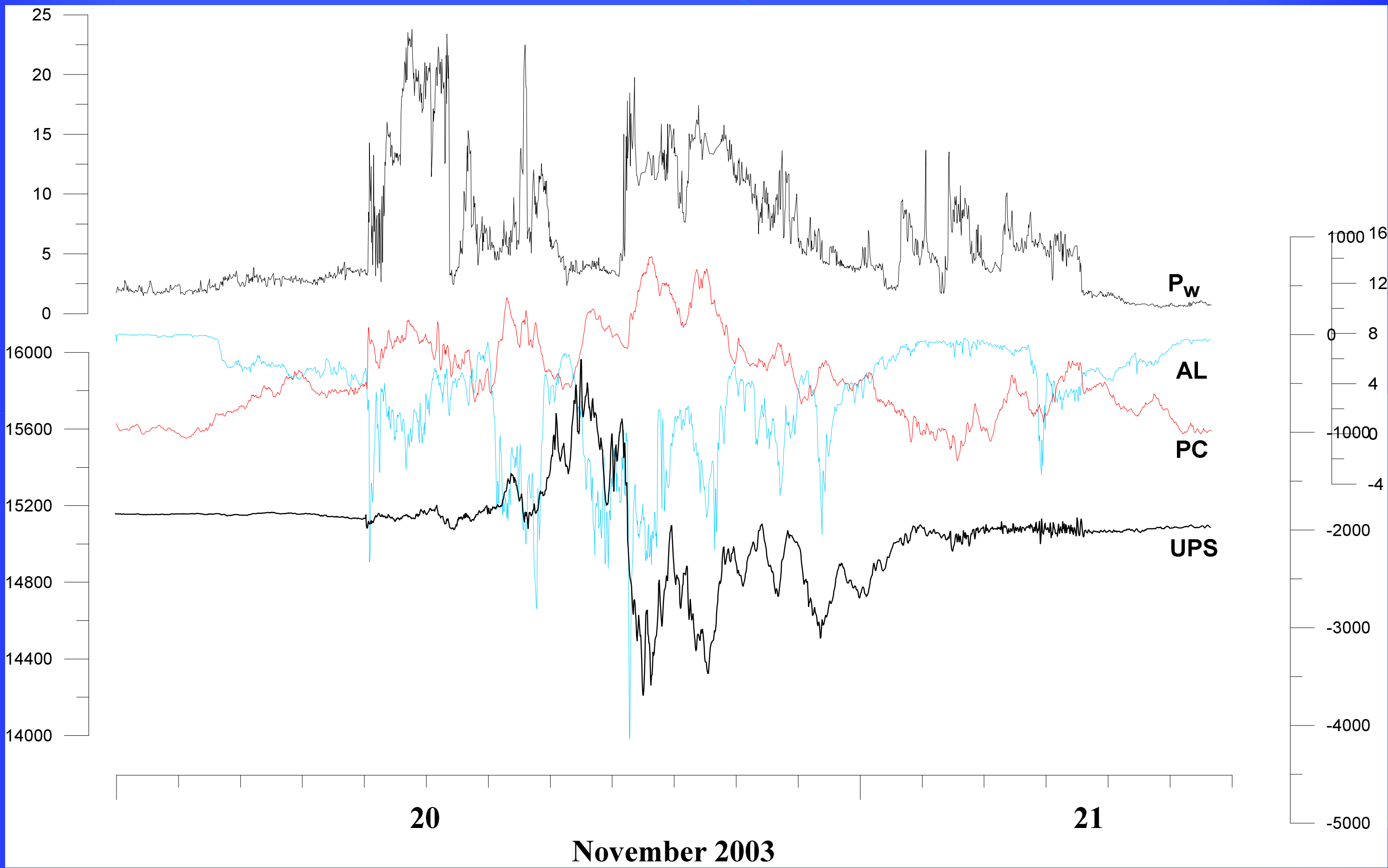


Sources of geomagnetic disturbance (2)

Ring current contribution

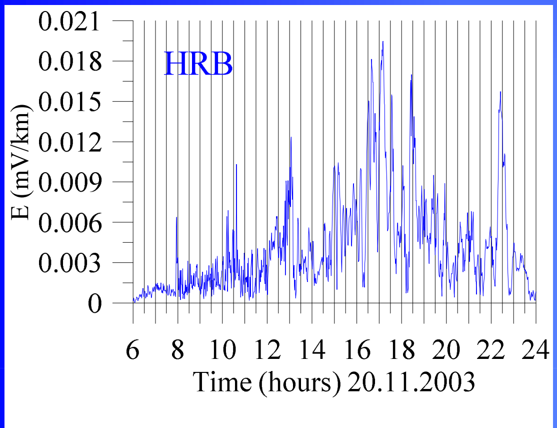


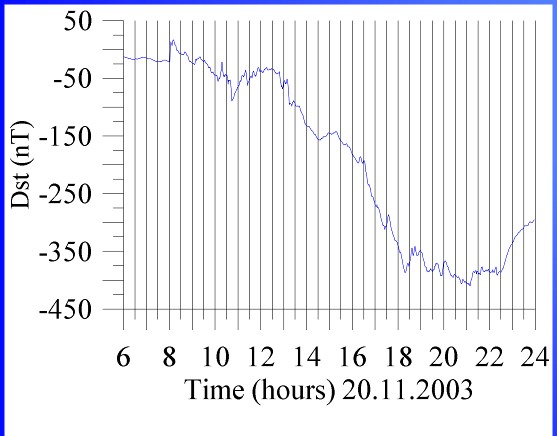
Sources of geomagnetic disturbance (3)

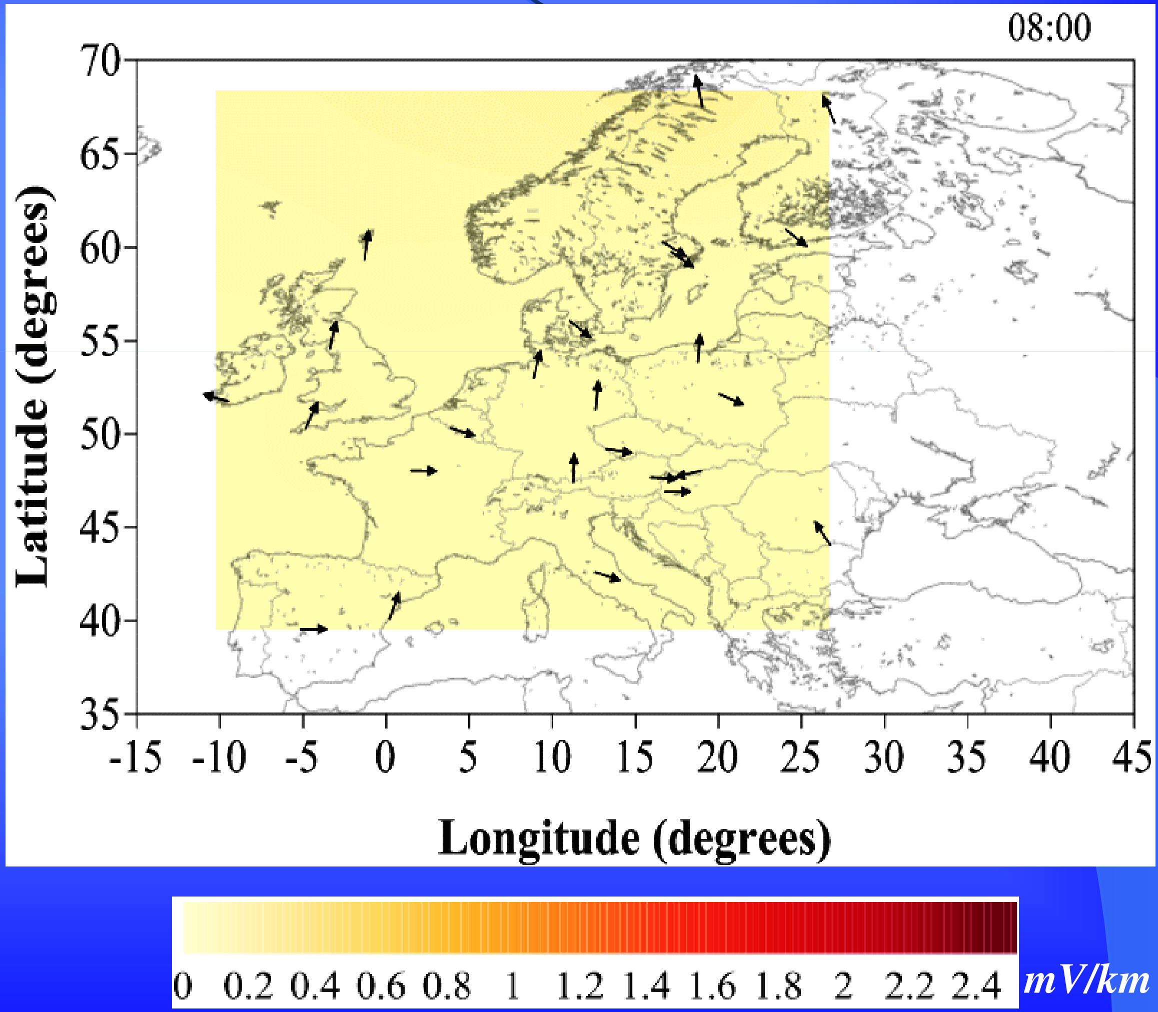


Geoelectric field evolution

Initial & main phase – November 2003 storm

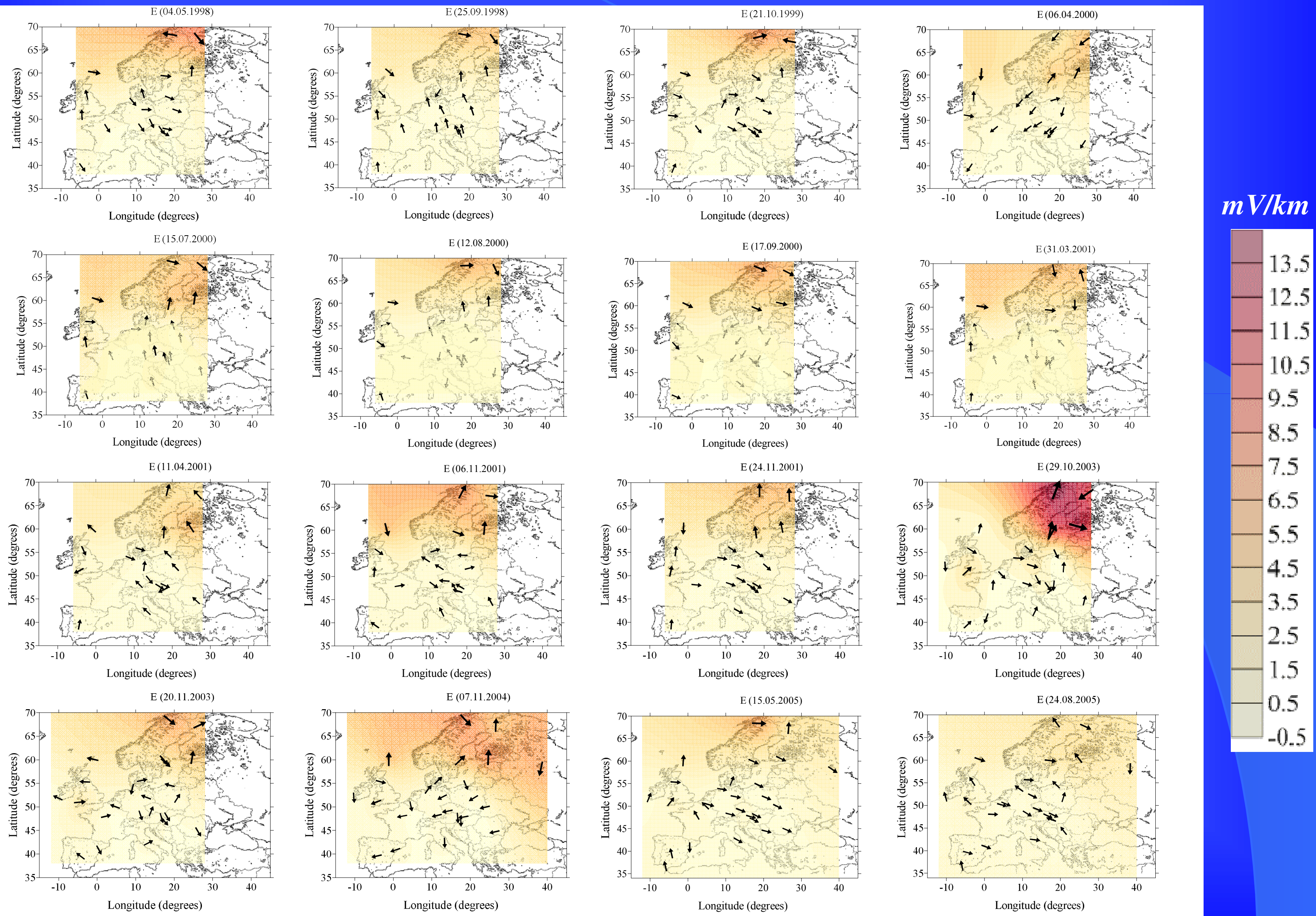






Toward GIC hazard assessment

Emax maps



Conclusions

- *the disturbance in X is 2-3 times larger at northern latitudes than at mid&southern latitudes;*
- *during the geomagnetic storm, effects of auroral electrojets superimpose at all latitudes on the disturbance created by the magetospheric ring current;*
- *the amplitude of the geoelecric field produced by magnetic variations is of the order of hundreths of mV/km in case of SUA (45°N), and of 1-2 mV/km in case of UPS (60°N);*
- *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;*
- *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.*