



ACADEMY
OF FINLAND



The Earth's magnetic environment dancing in the rhythm of solar storms

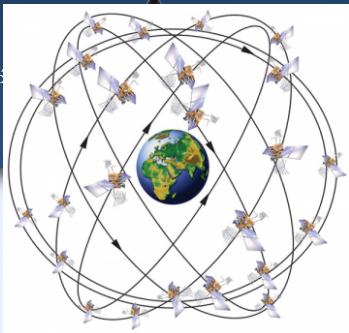
Eija I. Tanskanen

ReSoLVE Centre of Excellence

Aalto University

Dancing aurora & solar storms

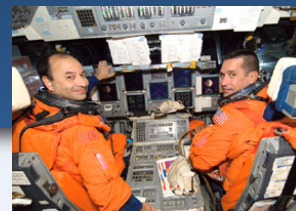




Telecommunication



Satellite safety



Space safety



Aviation, navigation



Transportation

Electric cars

IMPACT



Nuclear power safety

Electricity

Energy supply

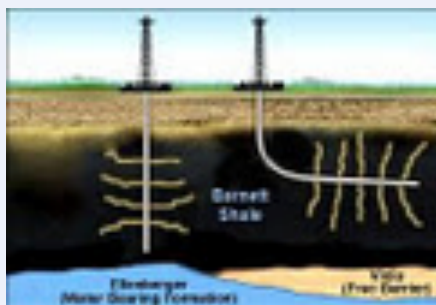


Food and water supply

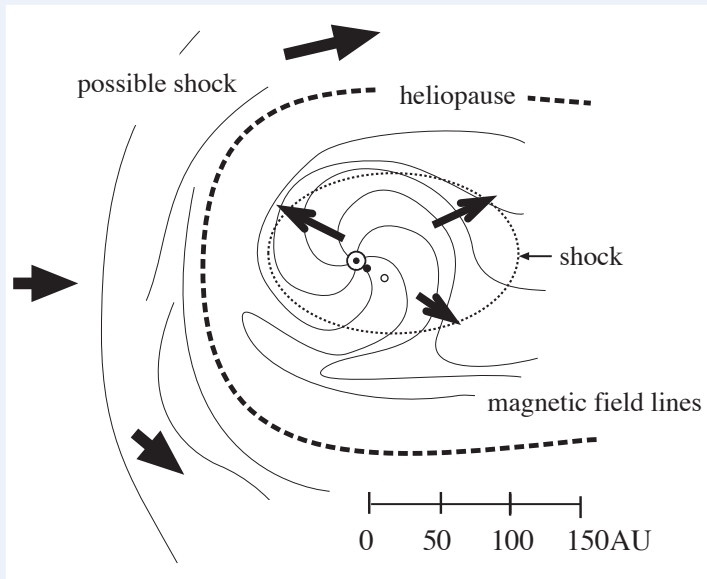
Synchronized data systems



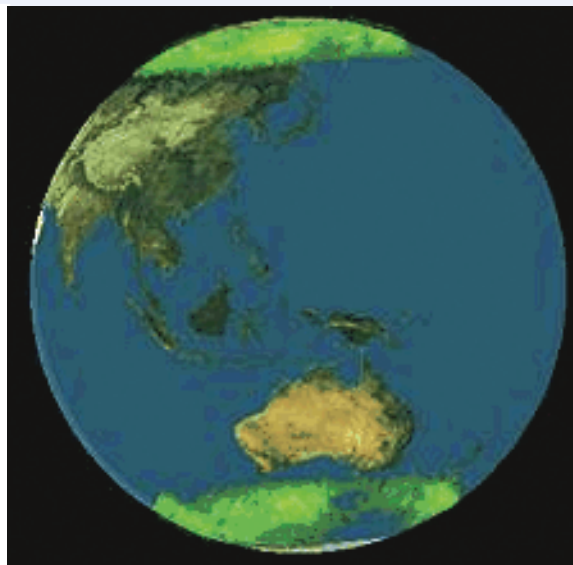
Oil drilling, mining



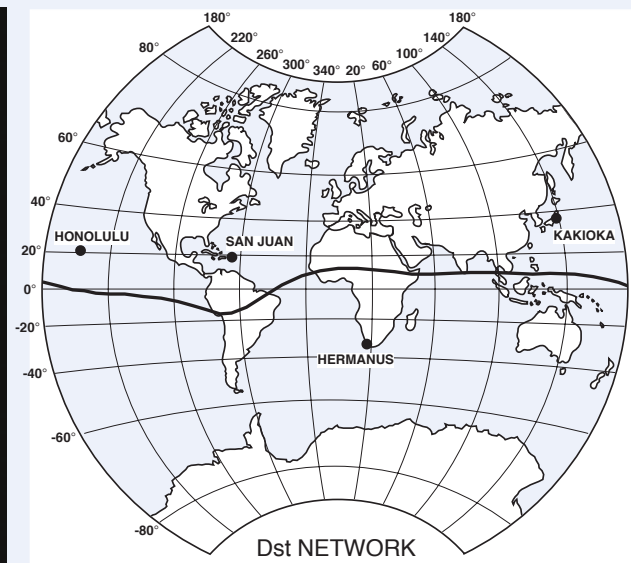
Heliospheric magnetic field



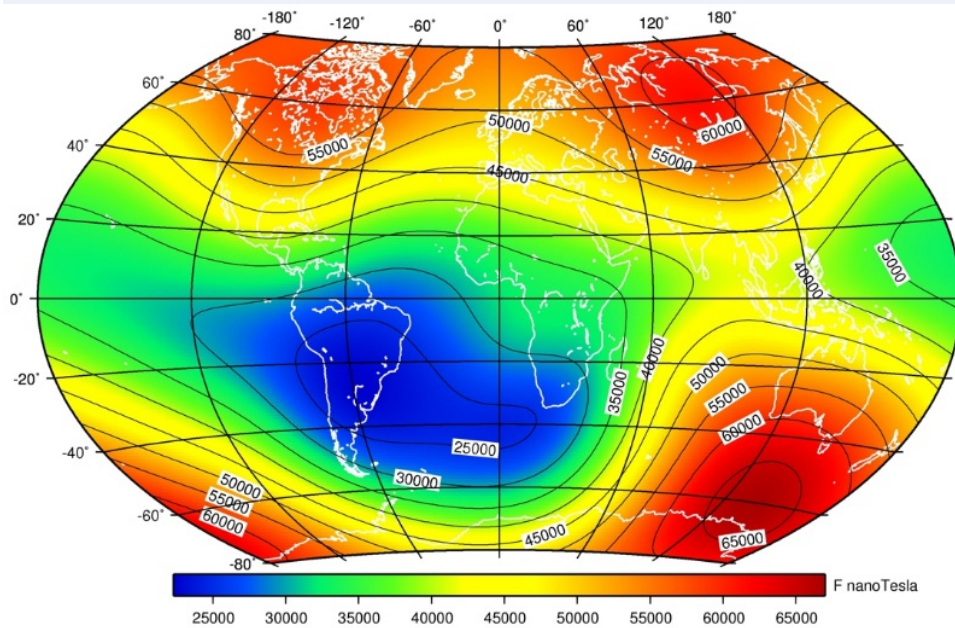
Auroral regions



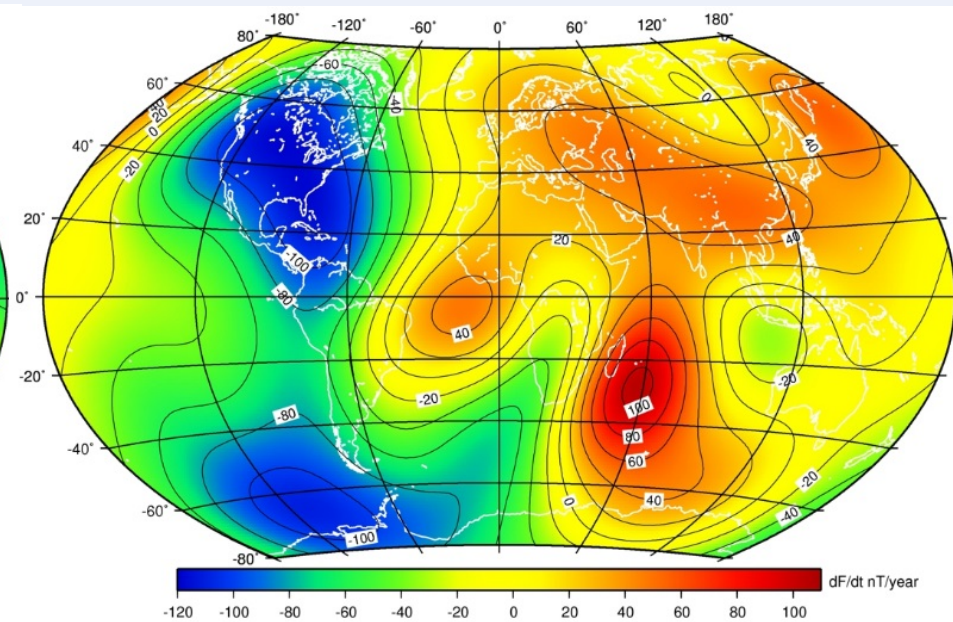
Magnetic equator



Earth's total field in 2015



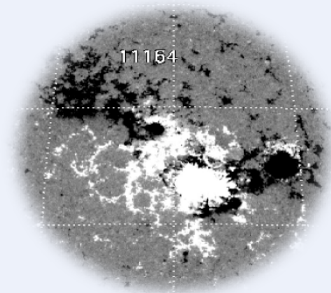
Year-to-year variability



The variability of the ground field...

... is due to the changes in the Sun, solar wind and solid Earth.

Solar B-field complexity



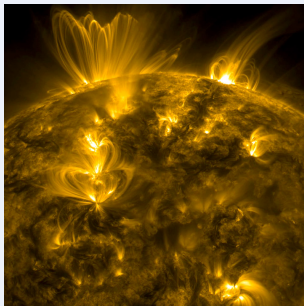
The Sun-Earth geometry



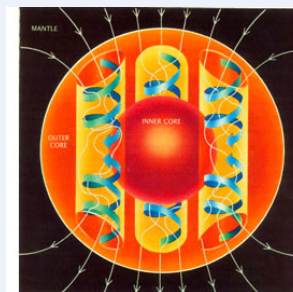
Dipole tilt



The solar storms



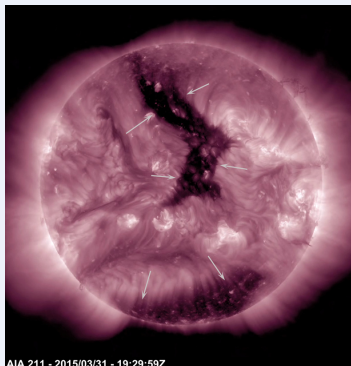
Core convection



Ionospheric conductivity

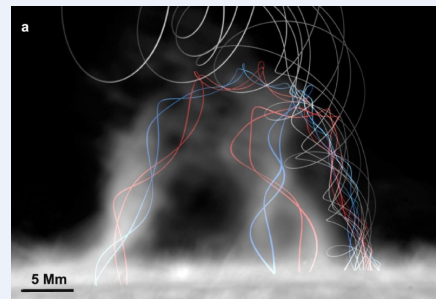


Surface morphology

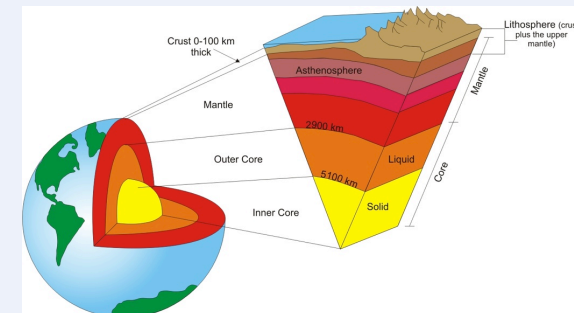


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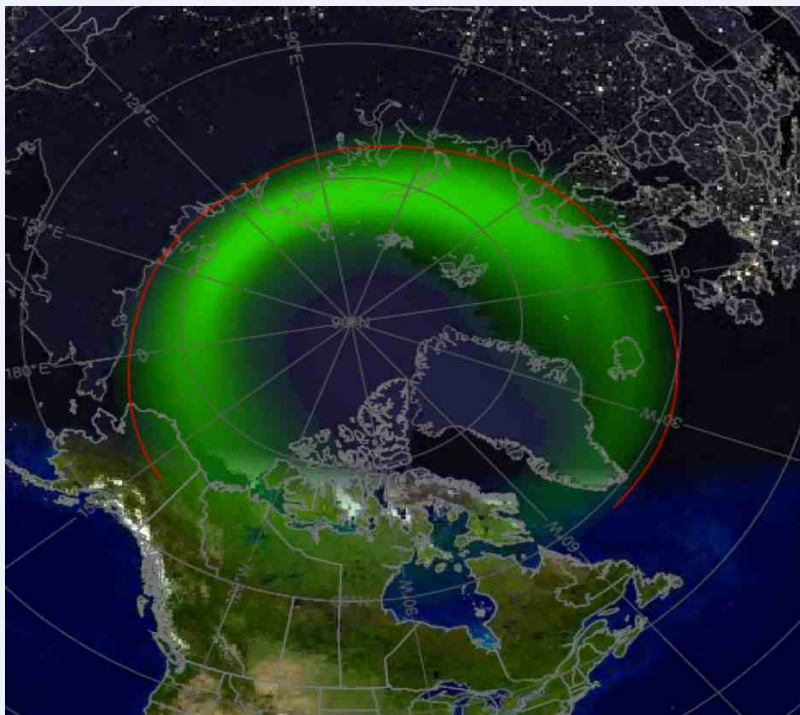
Solar wind helicity



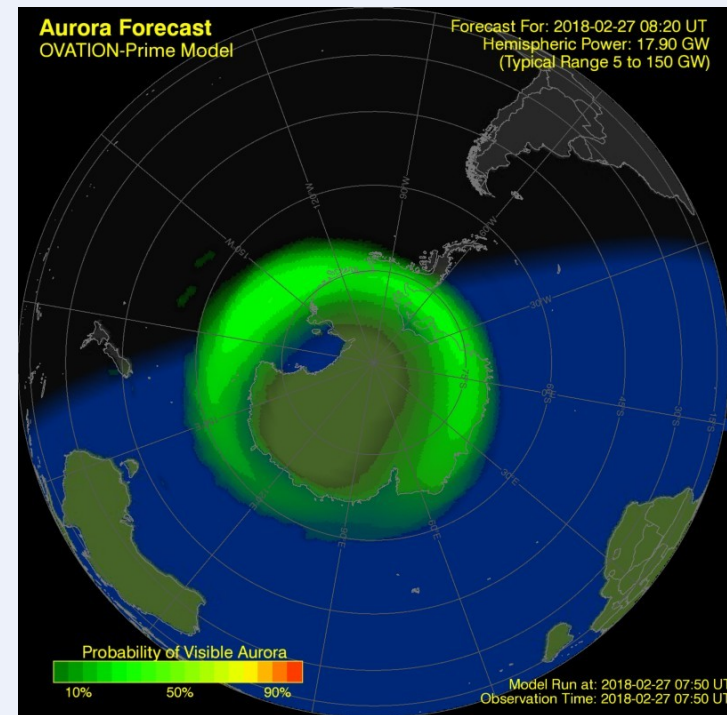
Lithosphere structure



- The variation of ground magnetic field is due to the external and internal (induction) sources
- Our goal is to find the time intervals and locations when the role of induction is the largest

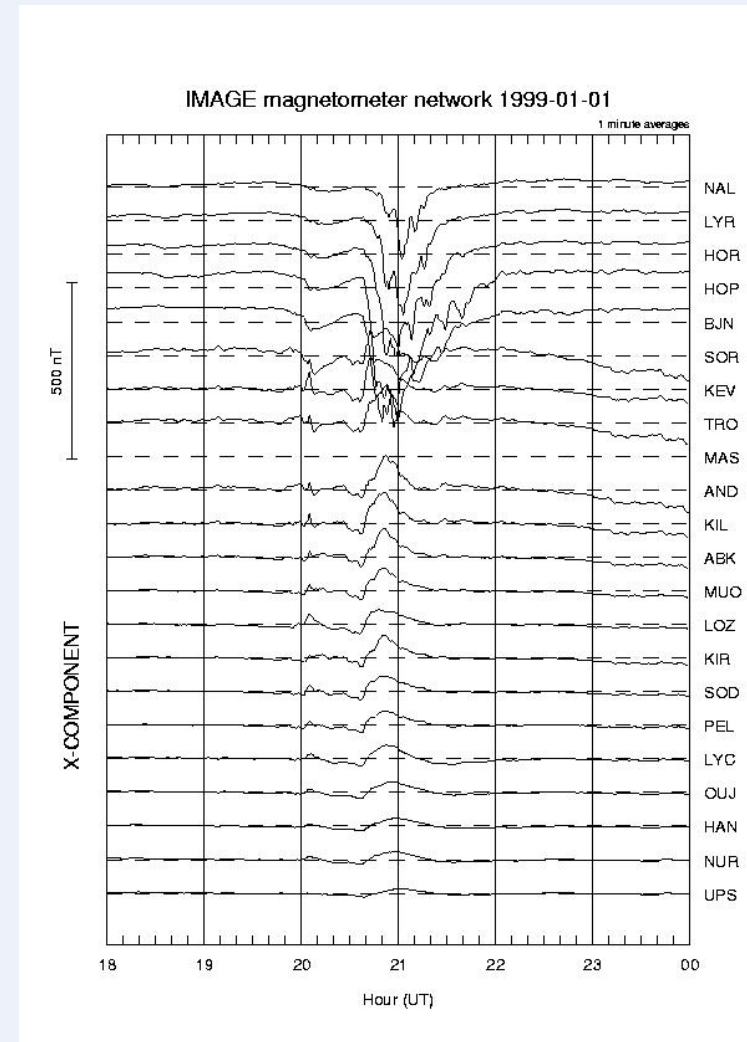
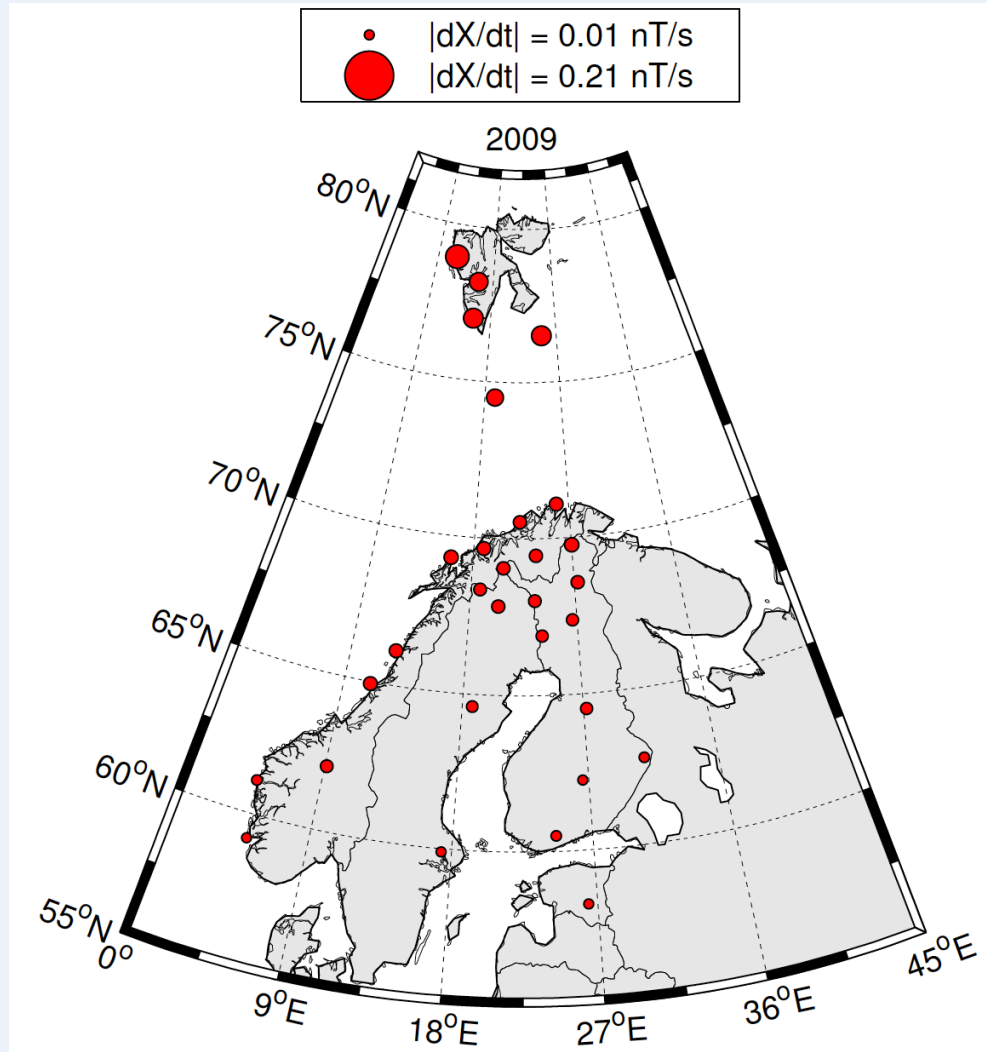


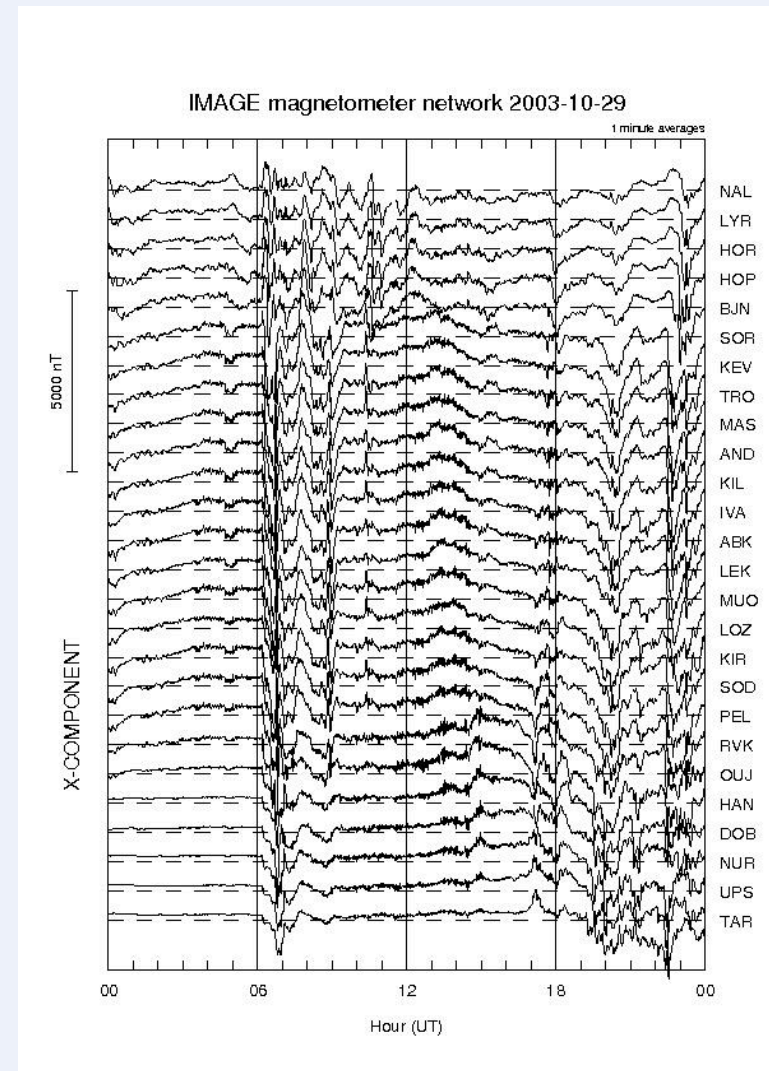
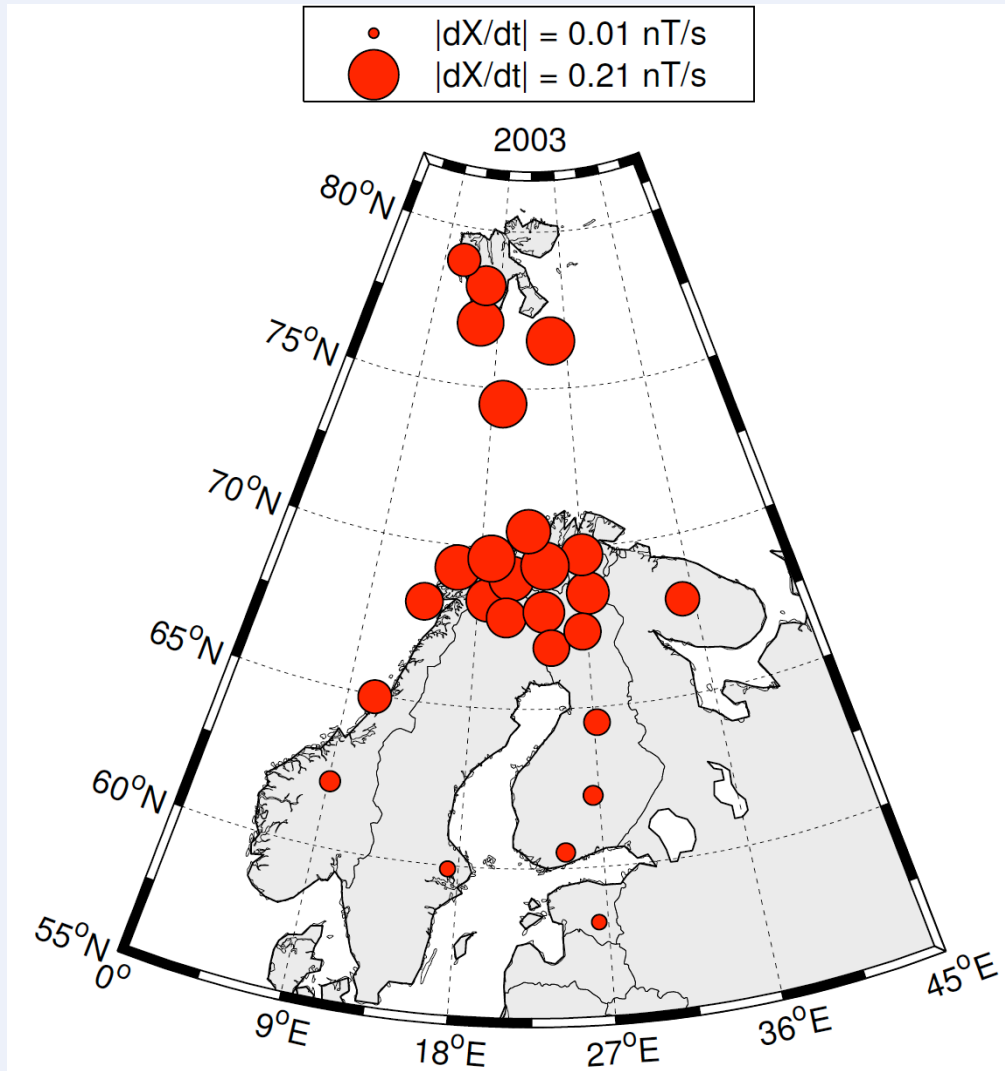
Northern hemisphere



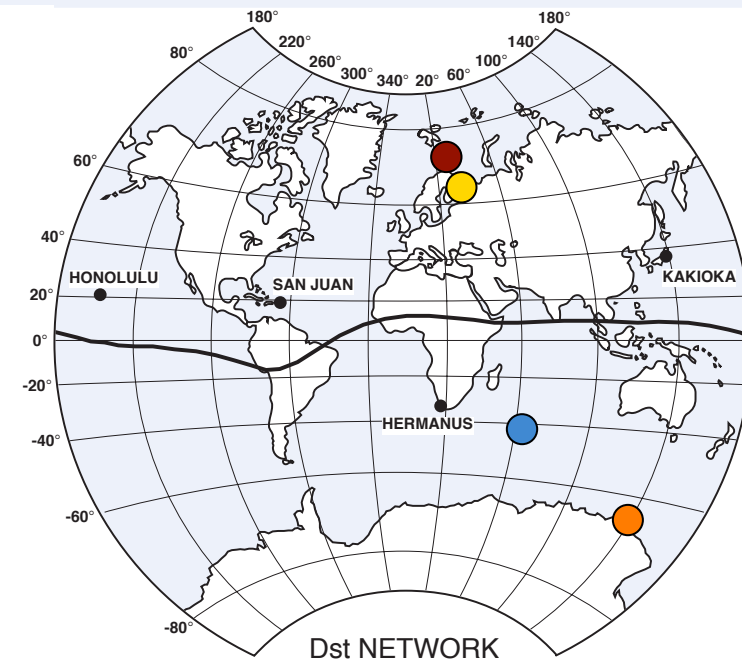
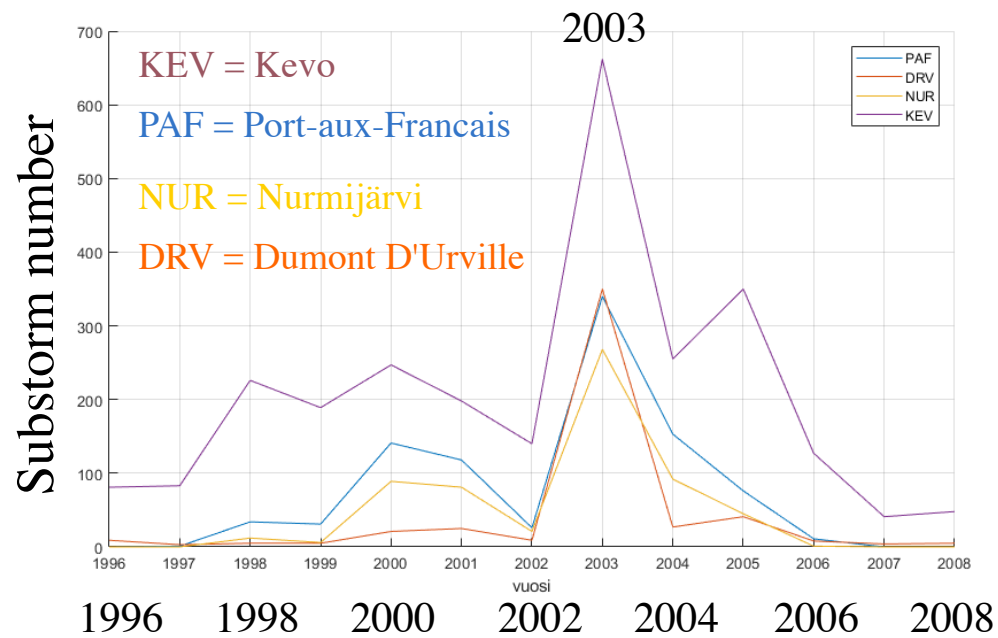
Southern hemisphere

Quiet = weak geomagnetic fluctuations (dB/dt) over a limited latitudinal range



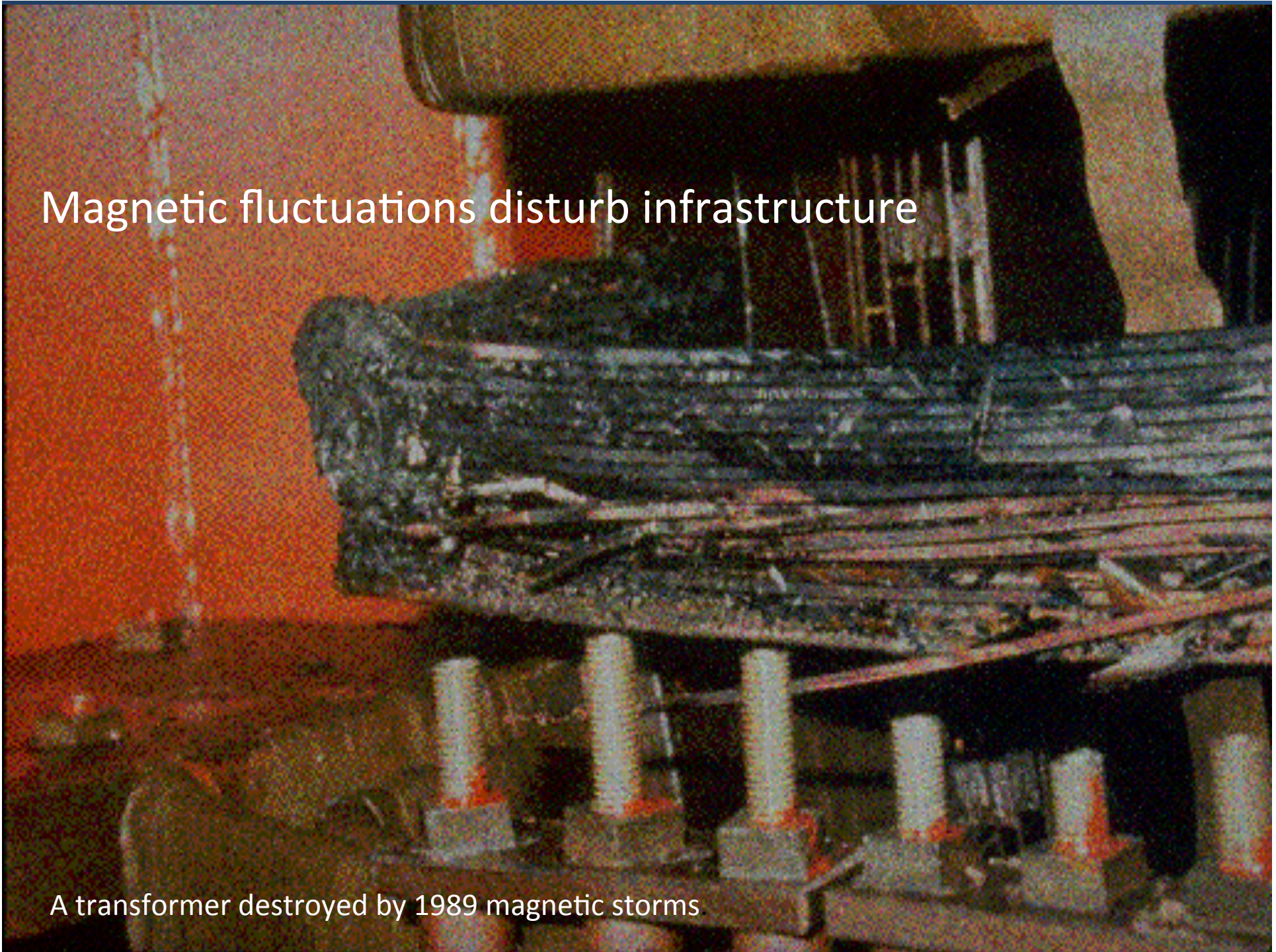


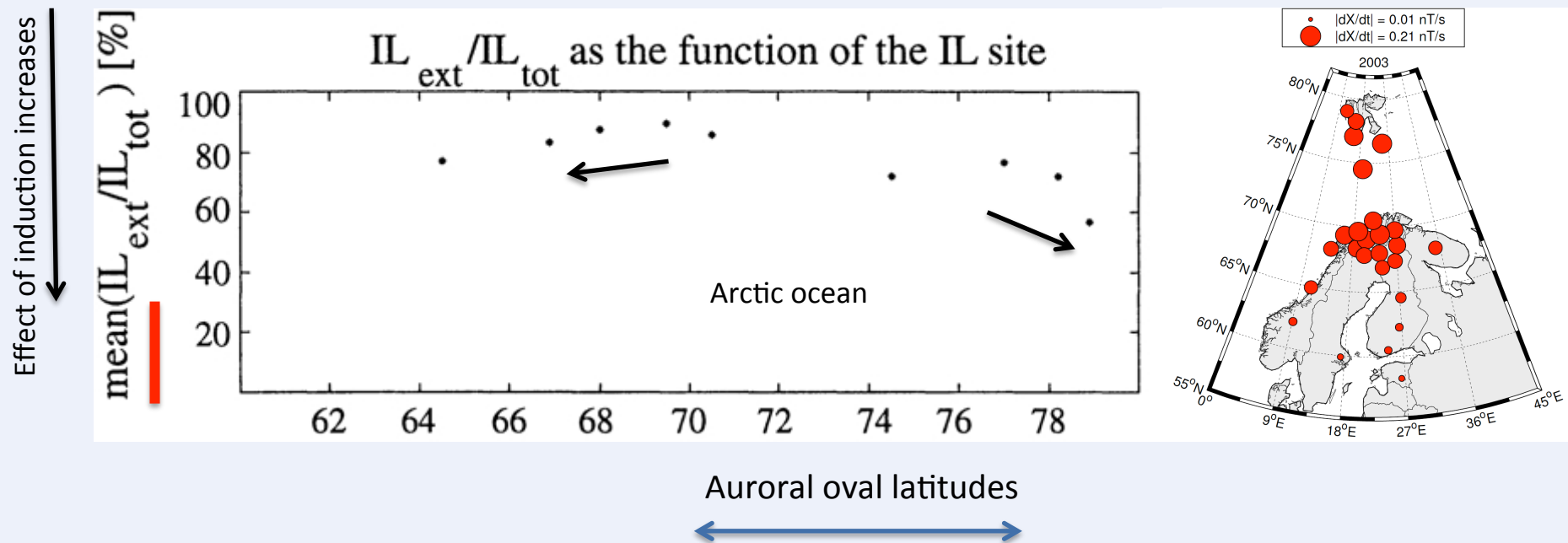
→ Similar year-to-year variability in the northern and southern hemispheres



Magnetic fluctuations disturb infrastructure

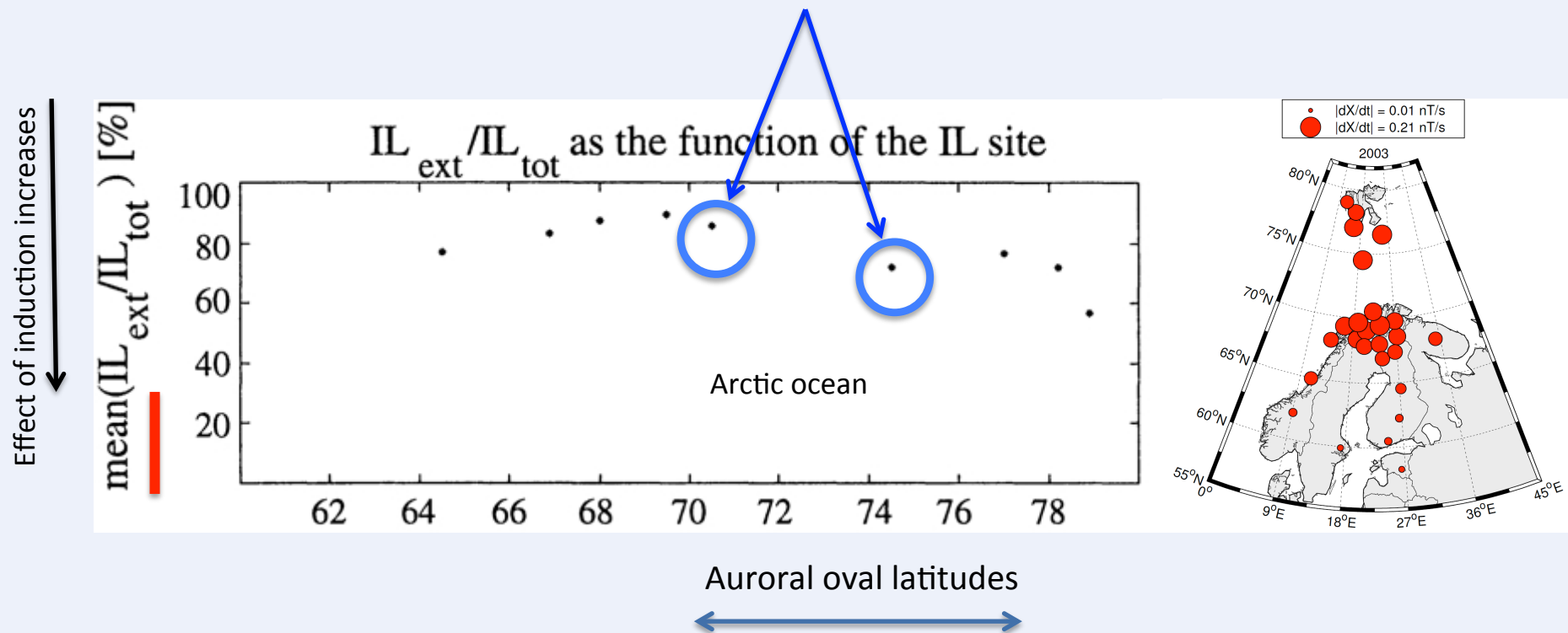
A transformer destroyed by 1989 magnetic storms.





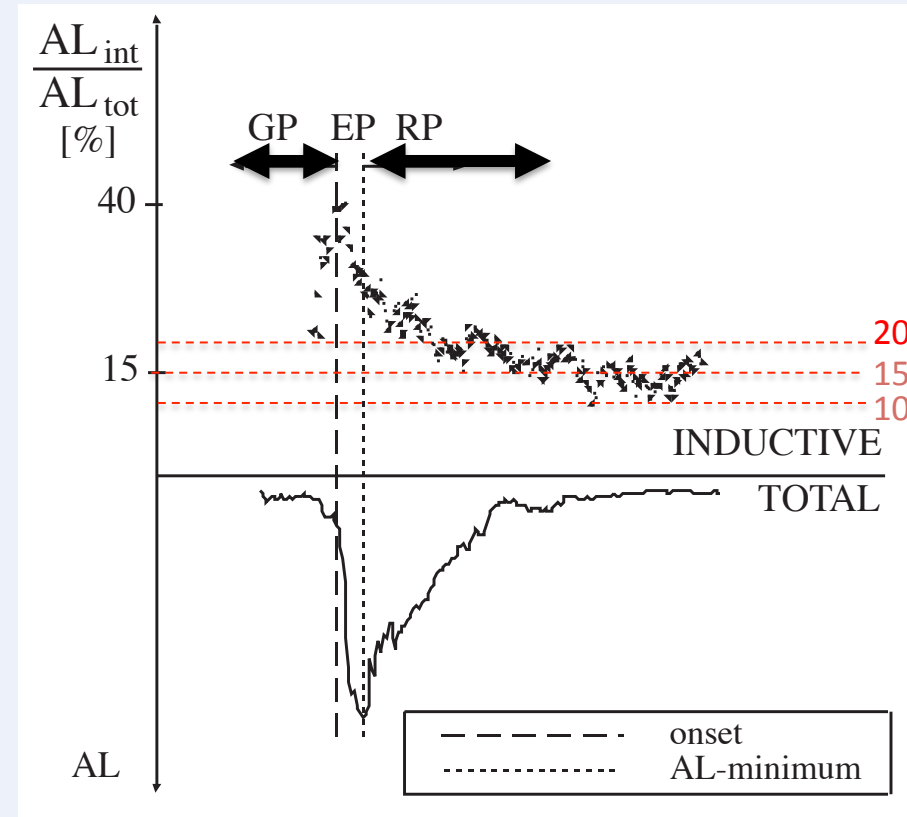
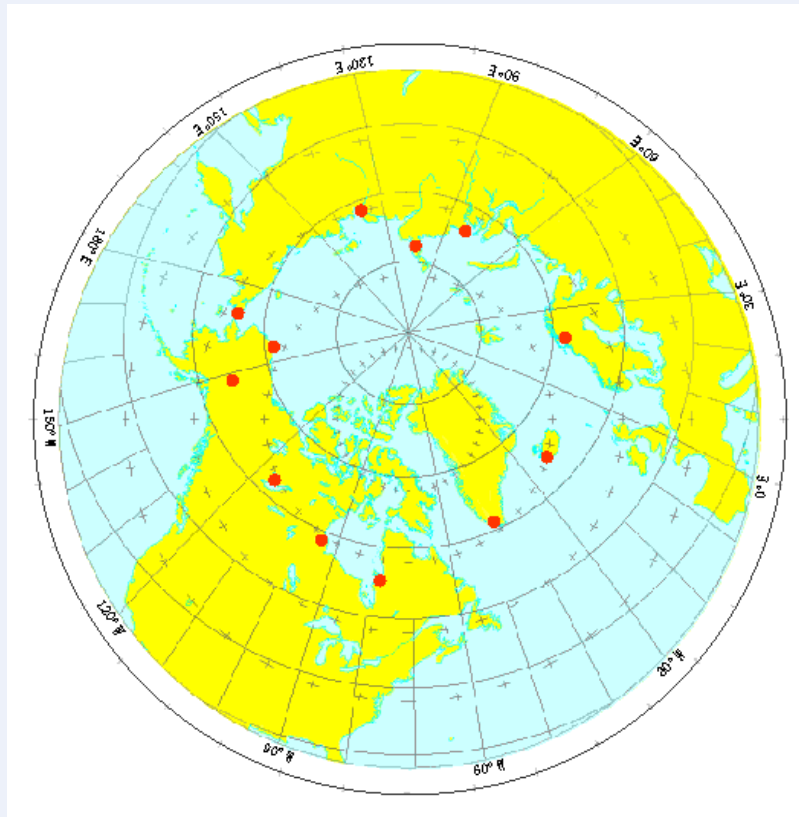
→ The role of induction increases away from the auroral oval due to the Sun-Earth geometry

The role of induction increases towards the coastal stations



→ The role of induction increases close to the sea due to the crustal structure differences

The typical internal field contribution is 40% during the rapid field variations (0.2 nT/s and 120 nT/10 min) e.g. during Pc5 pulsations or substorm onsets.

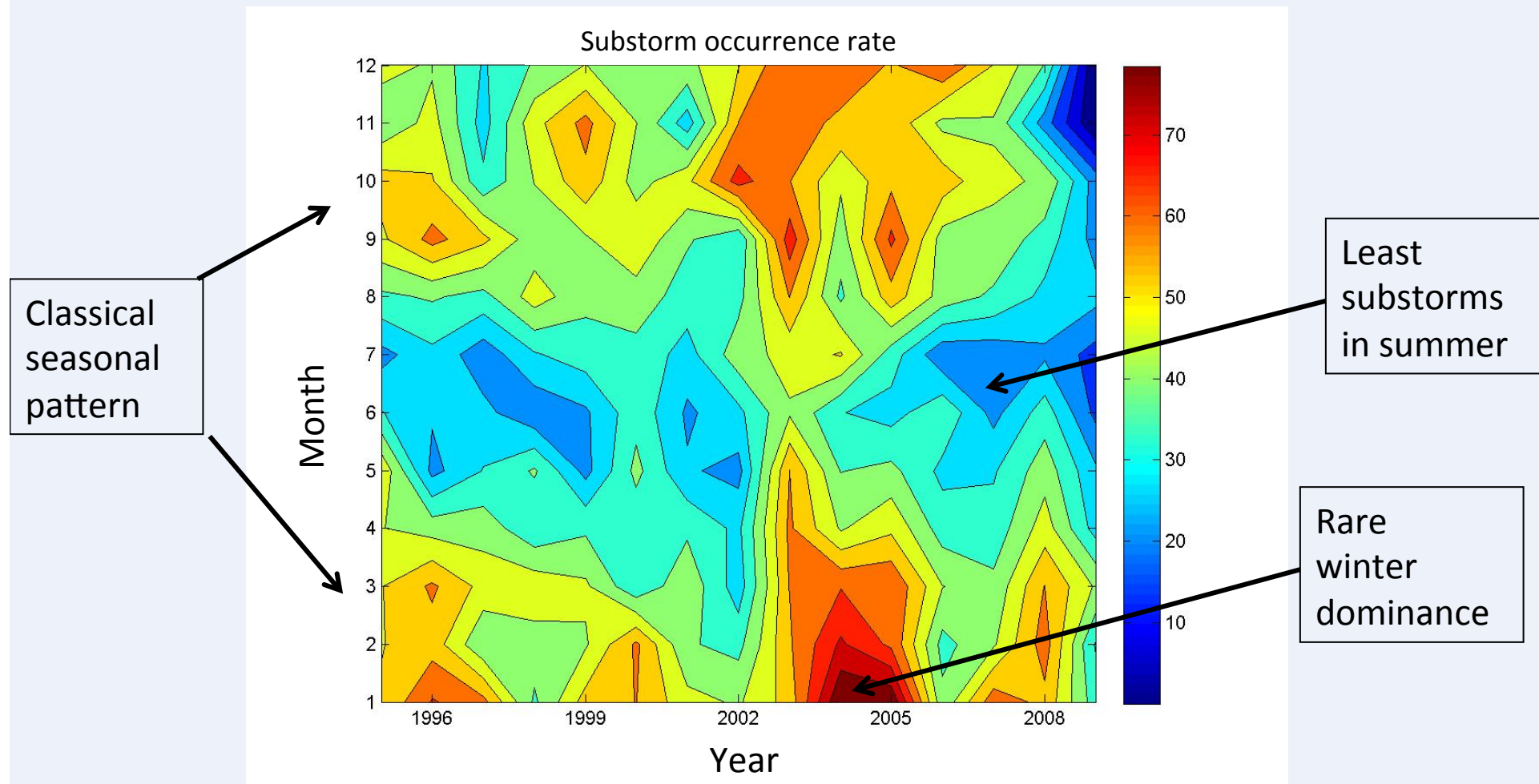


The inductive is on average about 40% of the IL during substorm onset, while during other substorm phases it is about **20%** and at the geomagnetically quiet times around **10-15%**.



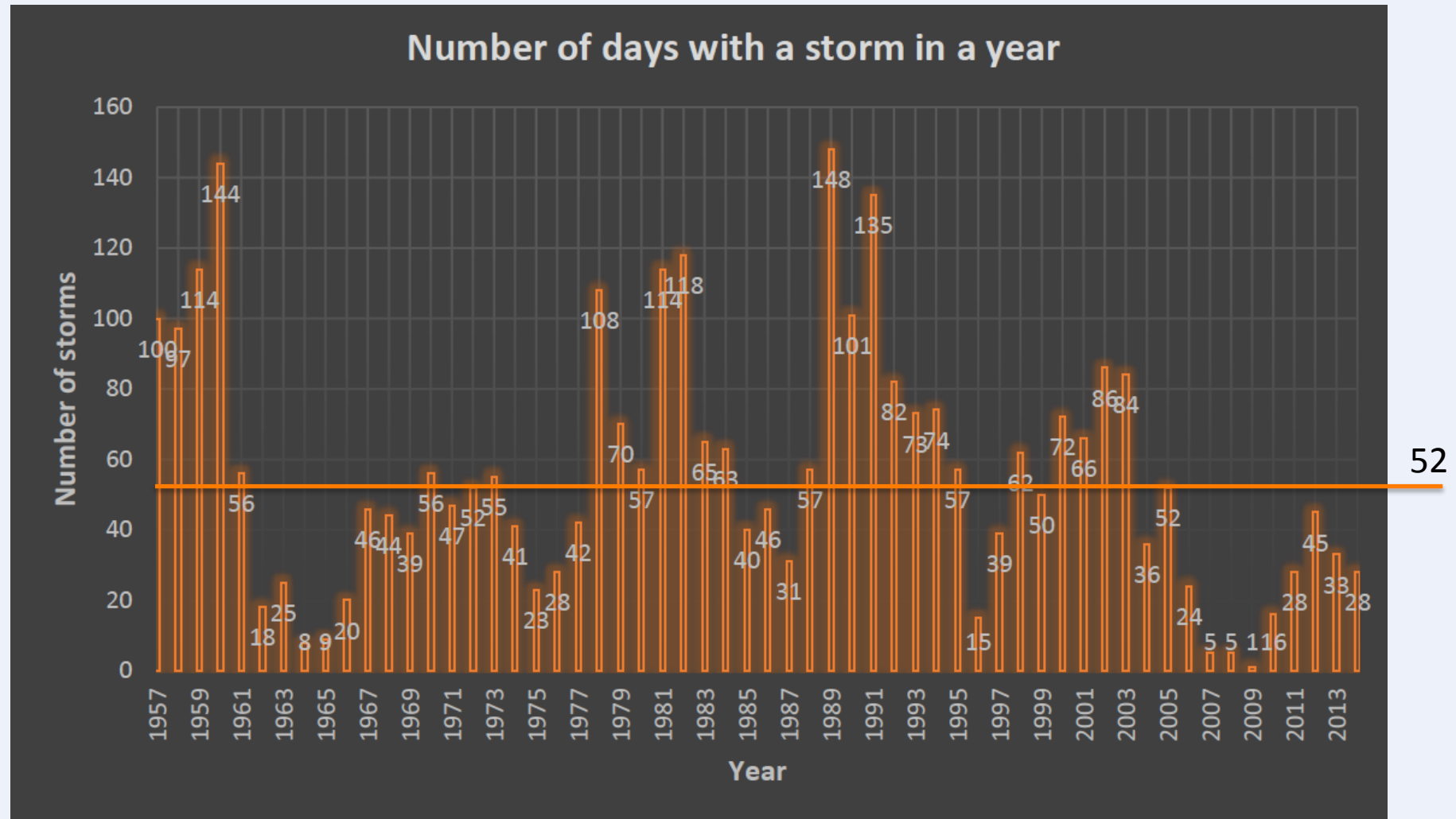
Solar wind speed modulates high-latitude geomagnetic activity

Courtesy: SWARM mission

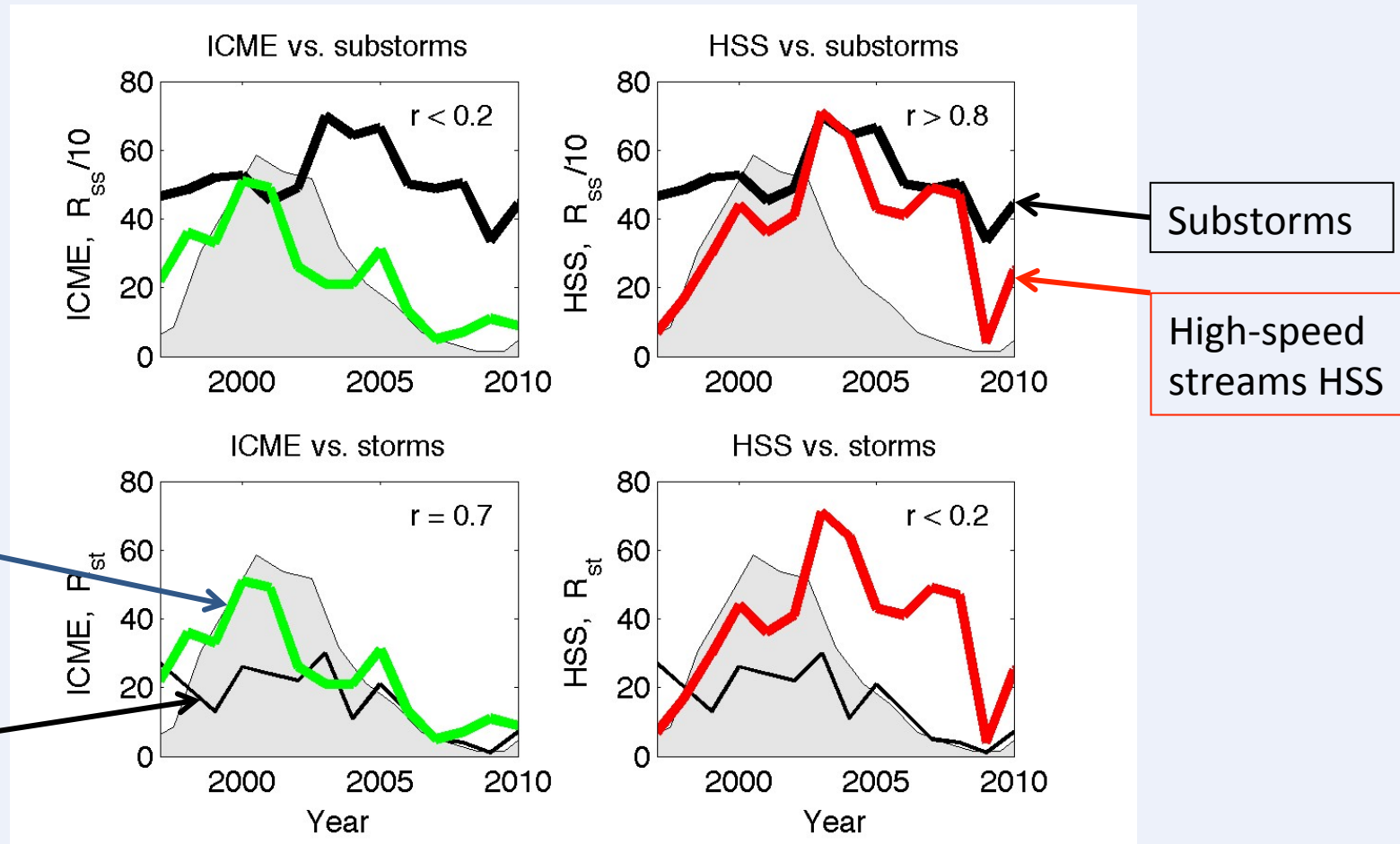


Tanskanen & Franzia, Earth climate response to a changing Sun, 2015b

Geomagnetic storms occur typically once per week.



... and ICMEs low latitudes.



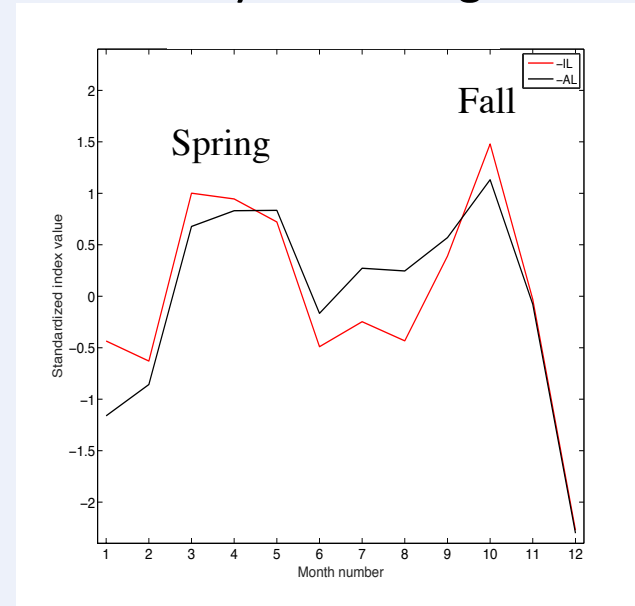
Old paradigm:
Geomagnetic activity maximizes in spring and fall.

New paradigm:
Geomagnetic activity can maximize at any solar cycle phase depending on the state of the solar wind and the Sun.

“While mechanisms leading to the classical two-equinox maxima pattern are in operation, the long-term change of solar wind speed tends to mask the effect of these mechanisms for individual years.”

Tanskanen et al., JGR, 2017b, Peitso et al., Space Weather 2018.

Multiyear averages

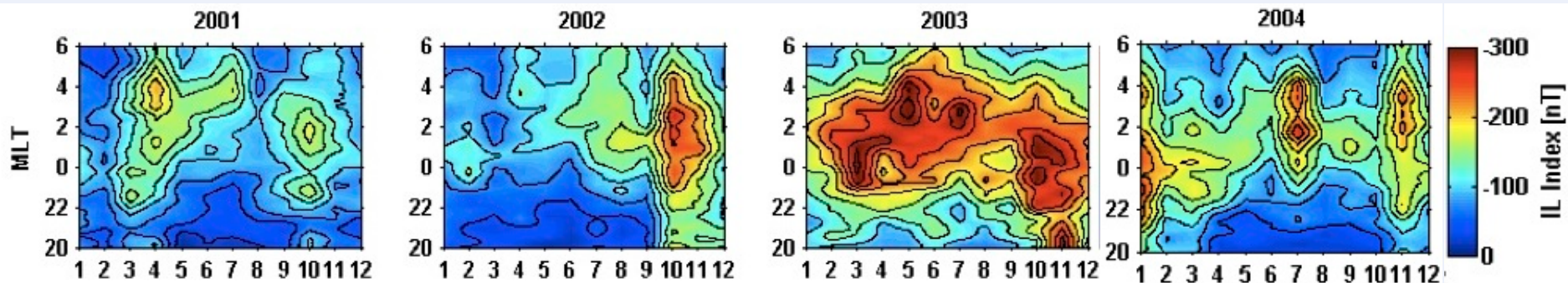


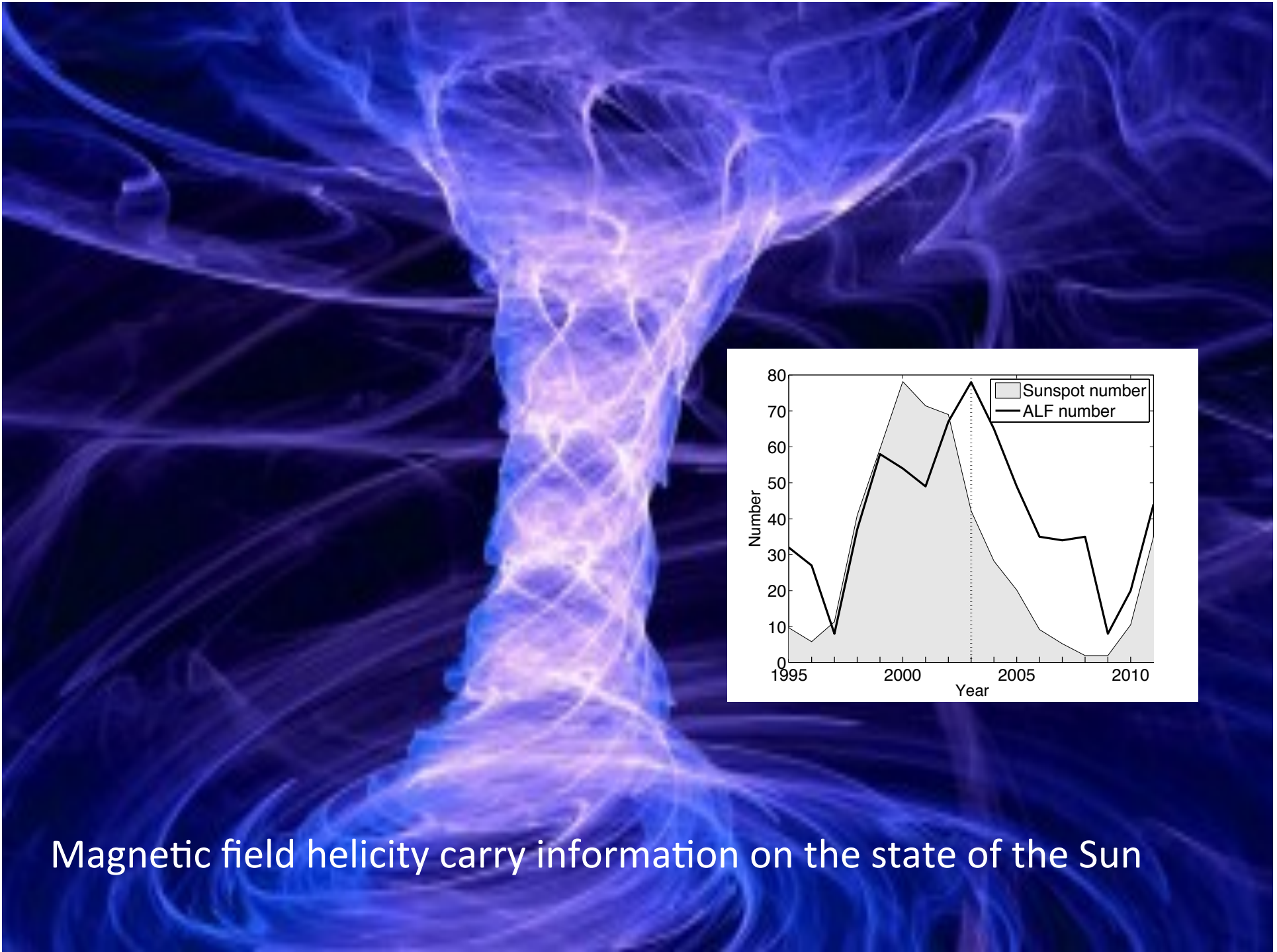
Close-to-classical semiannual variation

Fall-dominance

Entire year active

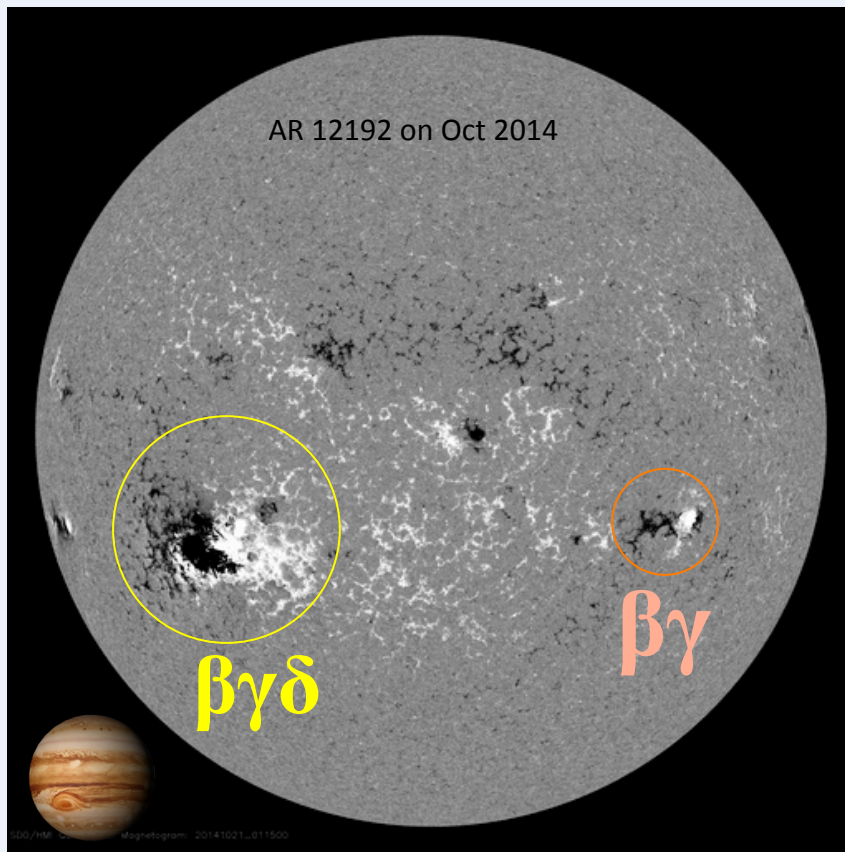
Solstice-dominance



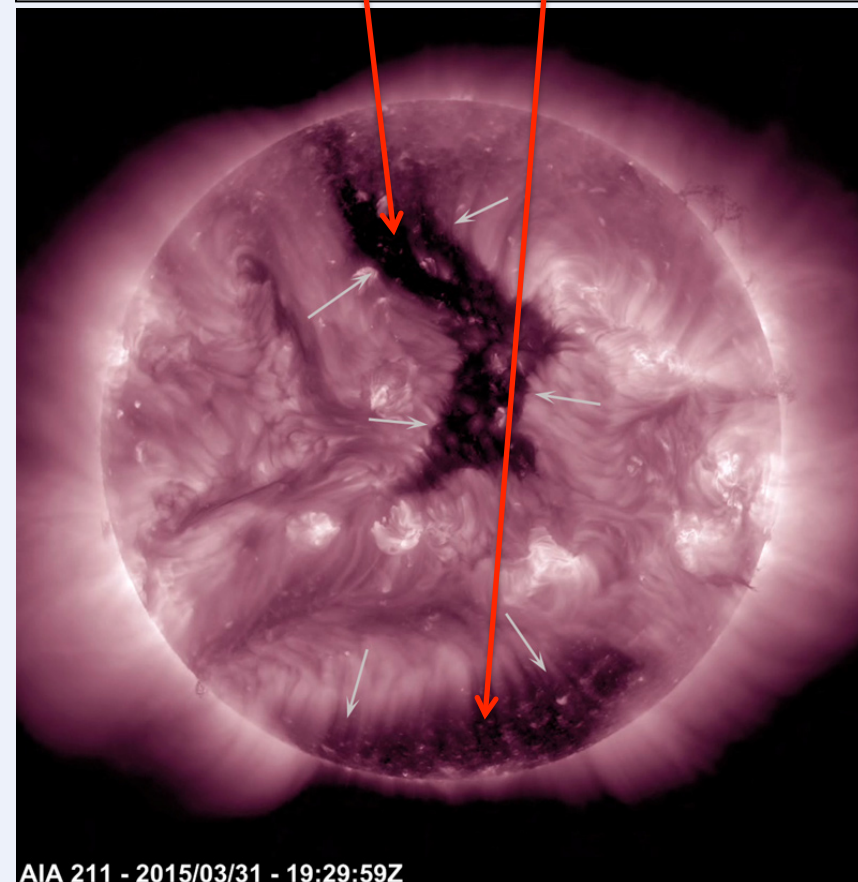


Magnetic field helicity carry information on the state of the Sun

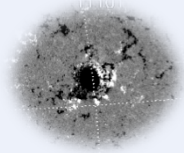
Complex active regions (CARs) produce complex interplanetary magnetic field. Hale classification used: α , β , $\beta\gamma$, $\beta\gamma\delta$...



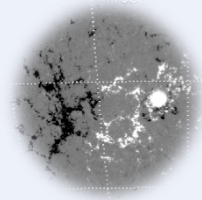
Fast solar wind originating from the polar coronal holes carry solar wind fluctuations from the Sun towards the Earth.



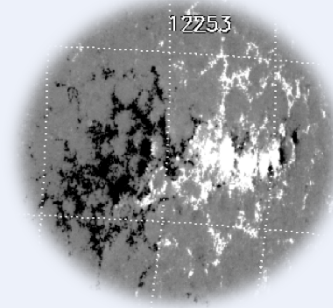
Tanskanen et al., JGR, 2017a



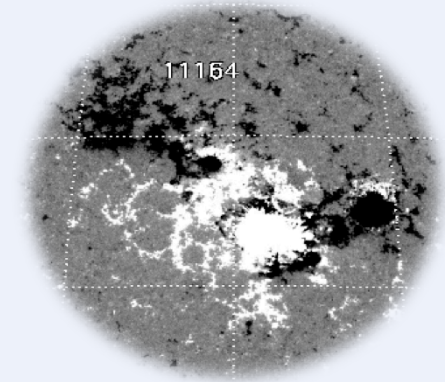
α



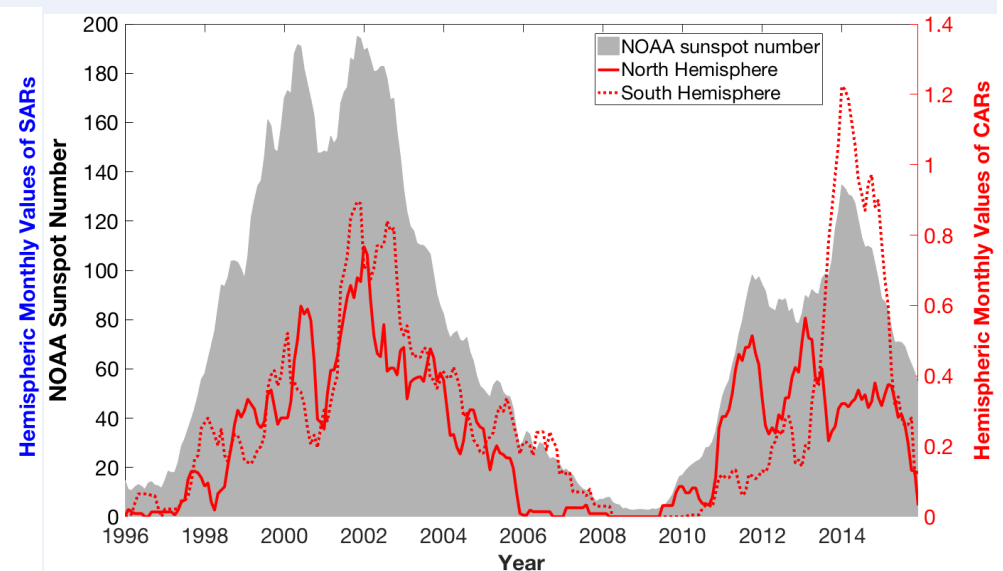
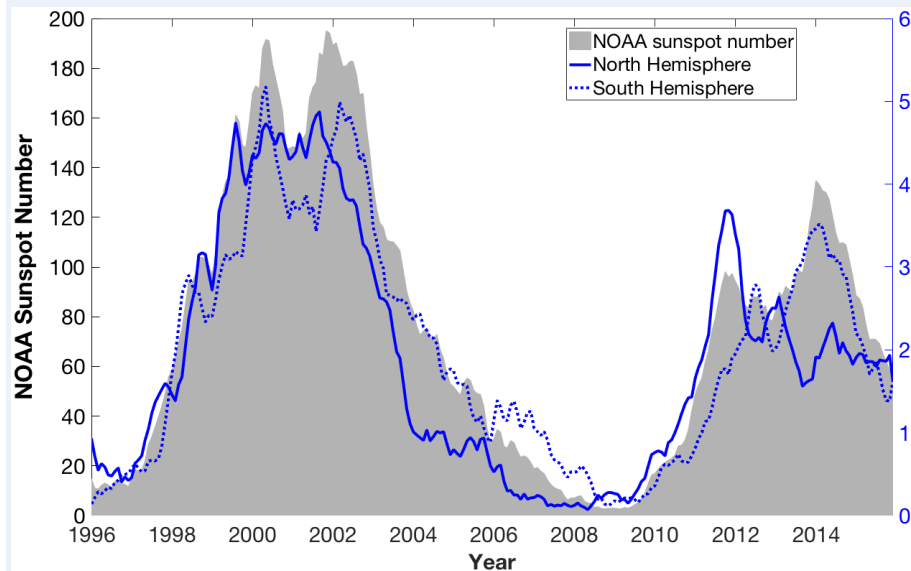
β



$\beta\gamma$



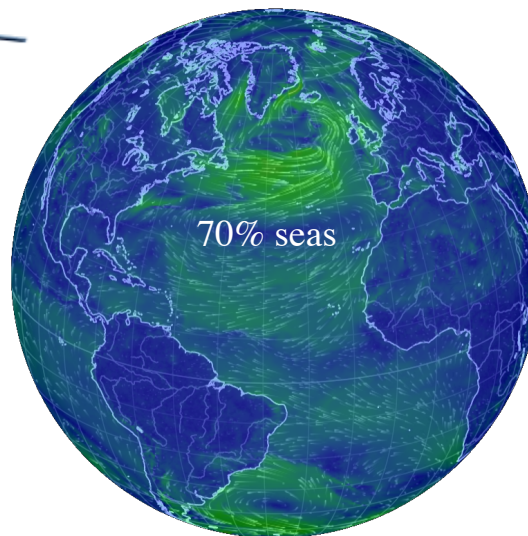
$\beta\gamma\delta$



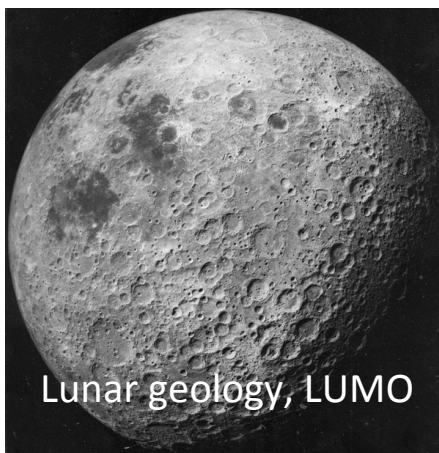
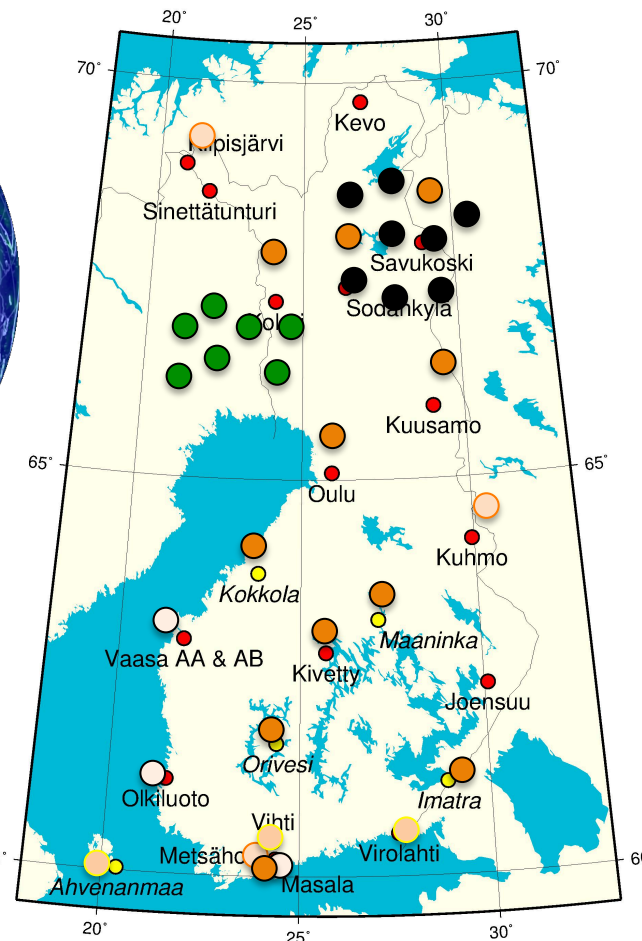
DroneMAG, DroneKit



SeaMAG

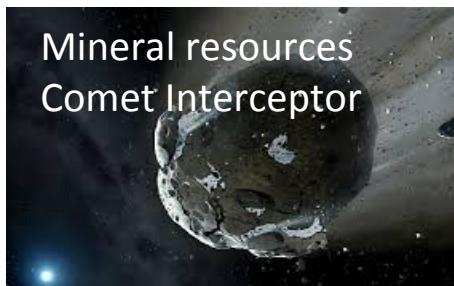
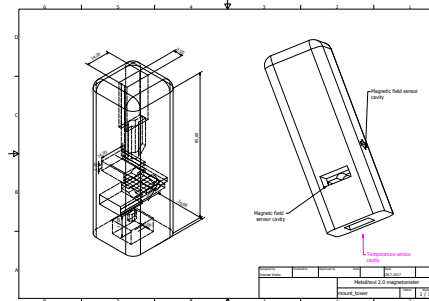


FlexEPOS superstations



Lunar geology, LUMO

CubeMAG, ESTCube-2, Aalto-3



Mineral resources
Comet Interceptor