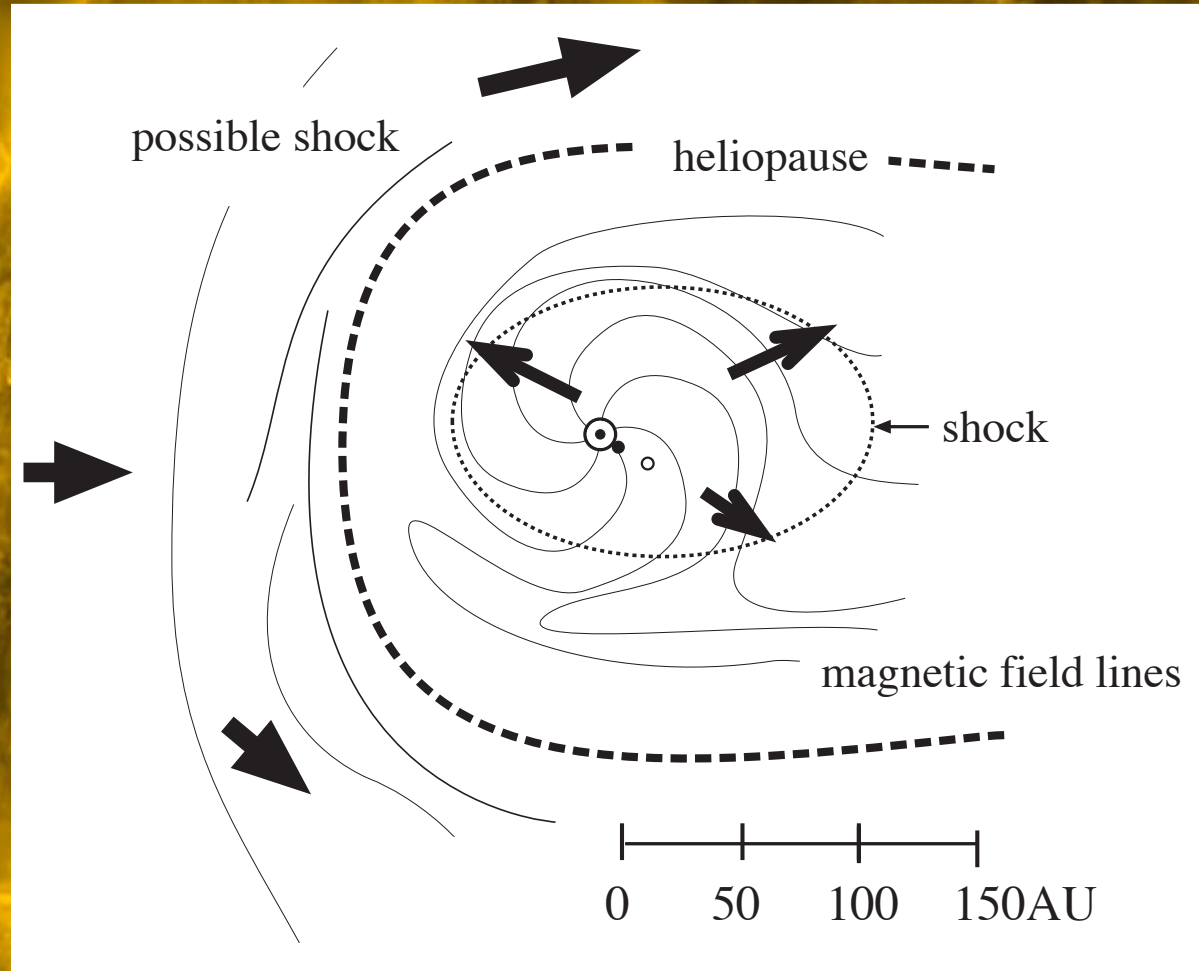


The Sun-Earth magnetic coupling during last 100 years

Eija Tanskanen

Aalto University, ELEC, Espoo, Finland
University of Oulu, Sodankylä Geophysical Observatory

Magnetic environment

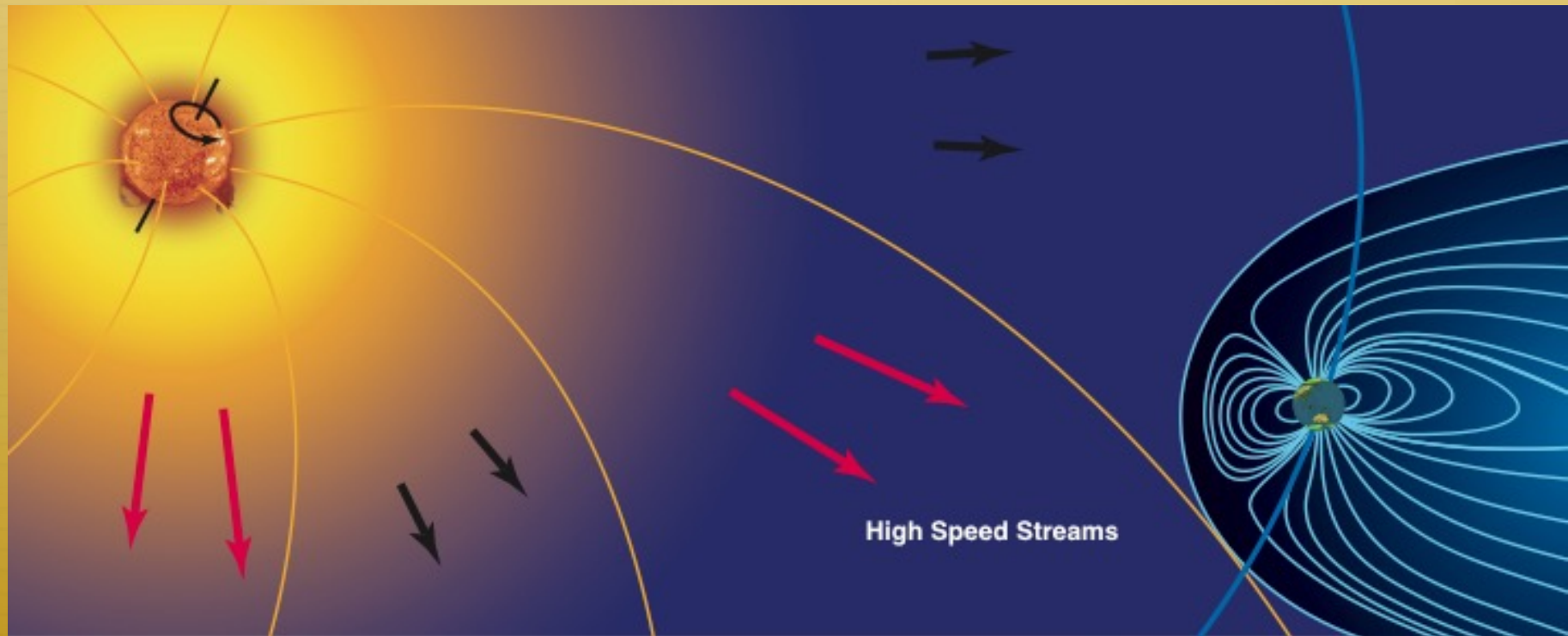


Solar storms regularly released

● — Approx. size of Earth

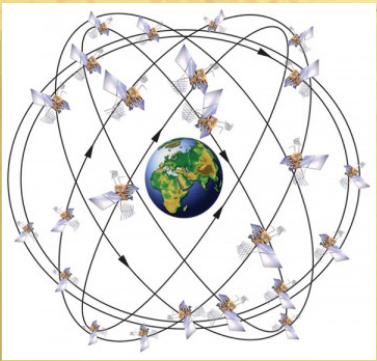


The Sun and Earth are magnetically coupled



Burned transformer due to the bad space weather conditions





Telecommunication



Satellite safety



Space safety



Aviation, navigation



Transportation

Electric cars



Nuclear power safety

Energy supply

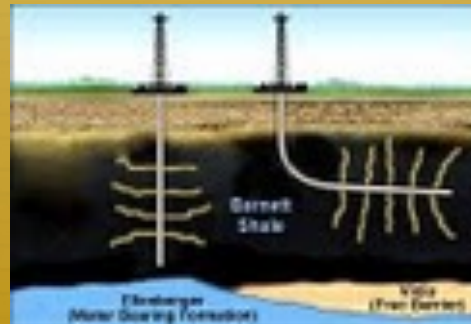


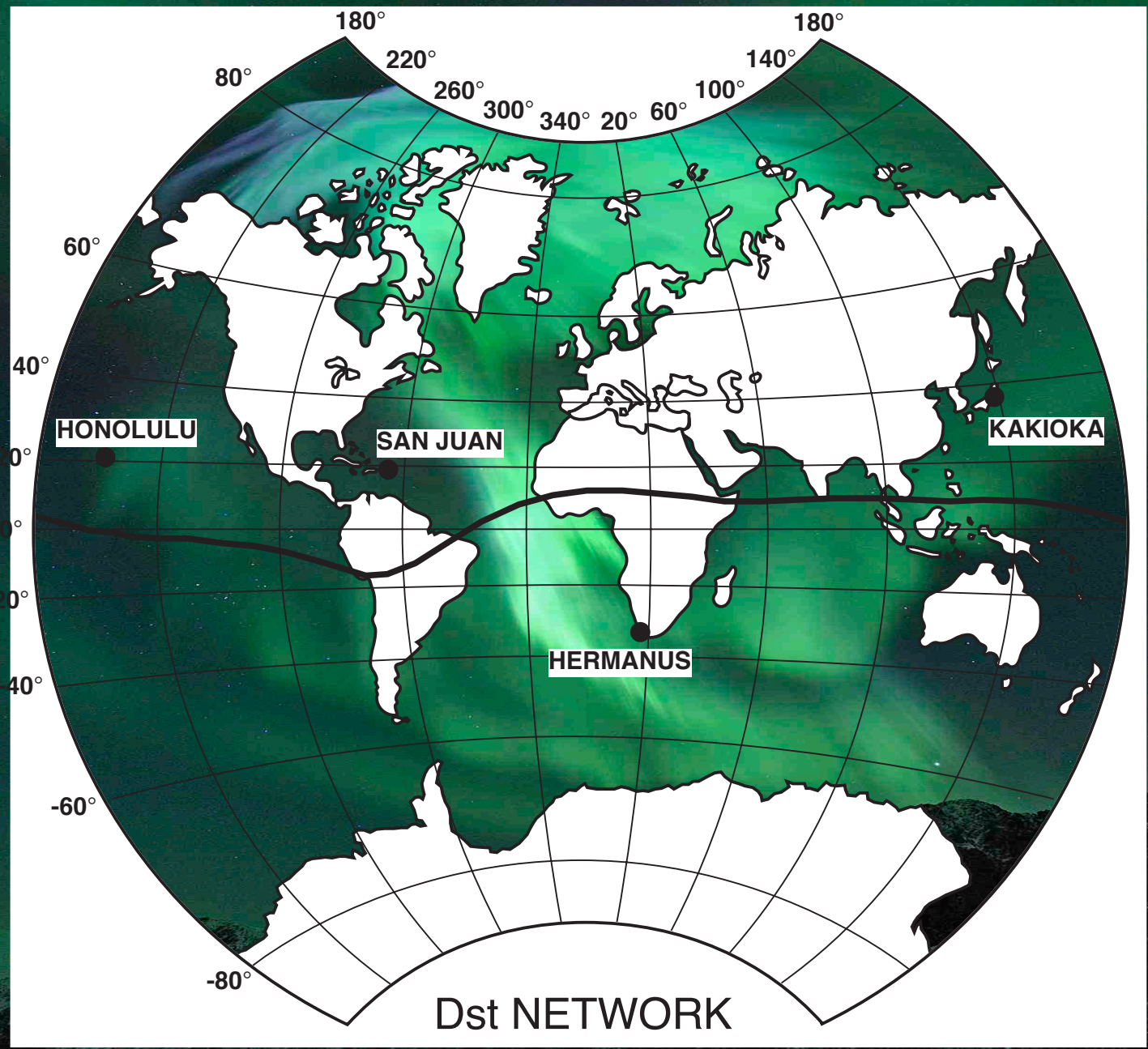
Electricity



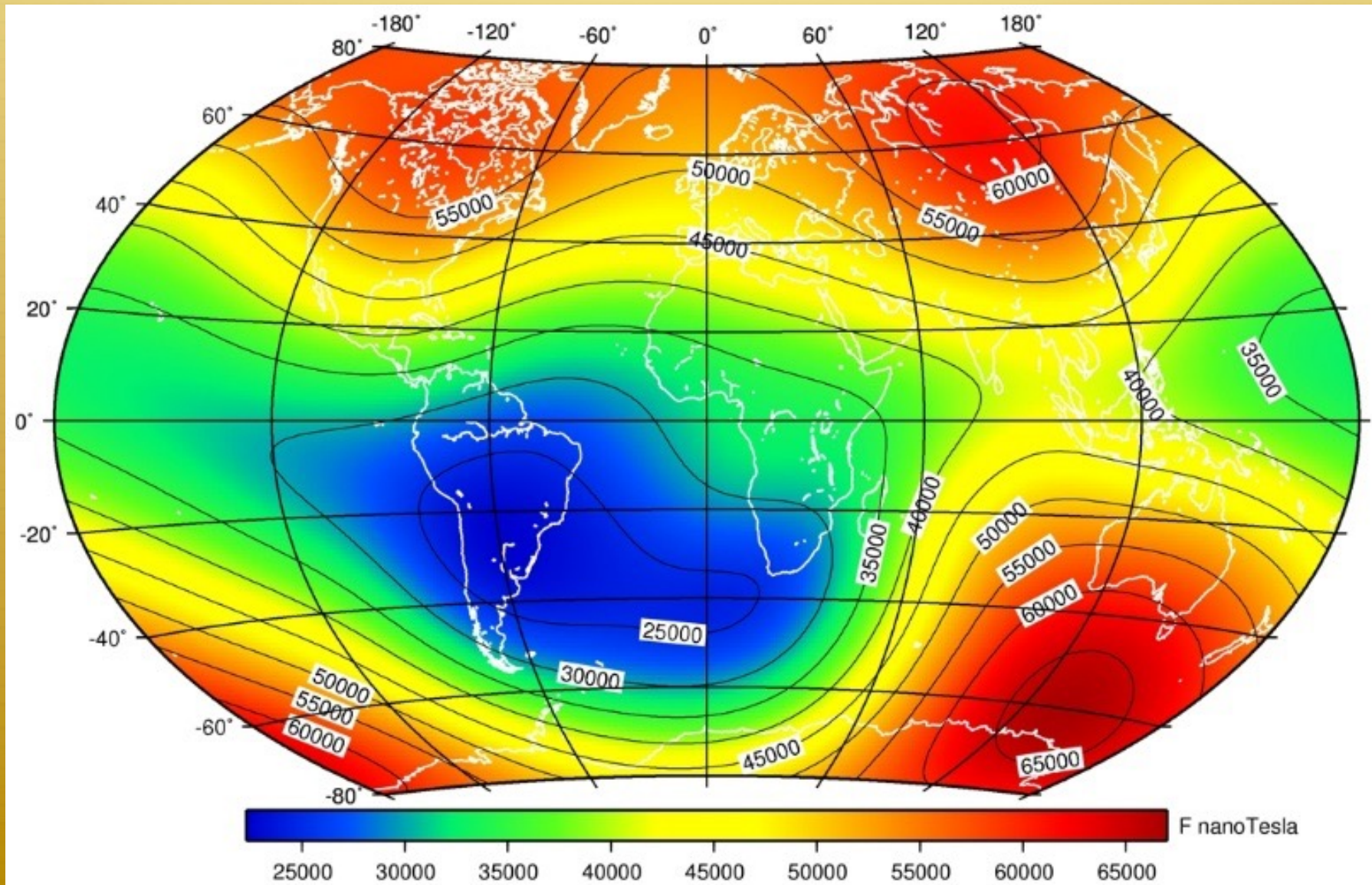
Food and water supply

Synchronized data systems Oil drilling, mining





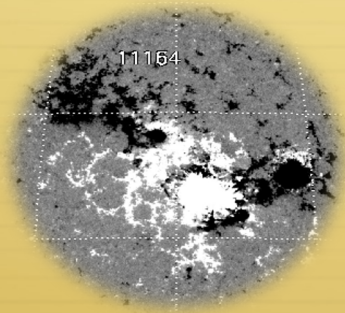
Earth's total field in 2015



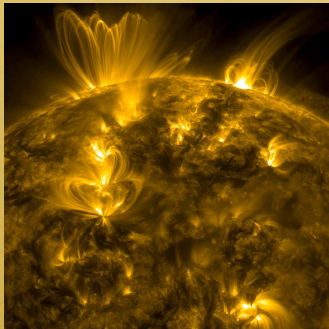
The variability of the ground field...

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

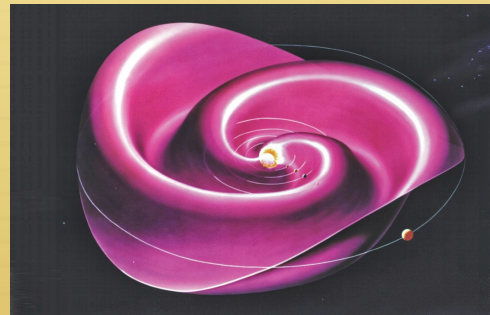
Solar B-field complexity



The solar storms



The Sun-Earth geometry



Dipole tilt



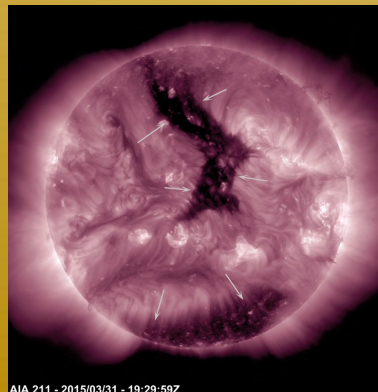
Core convection



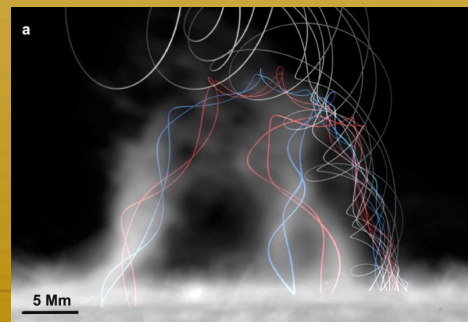
Ionospheric conductivity



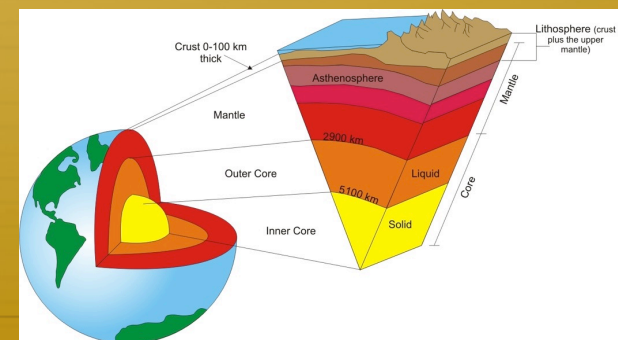
Surface morphology



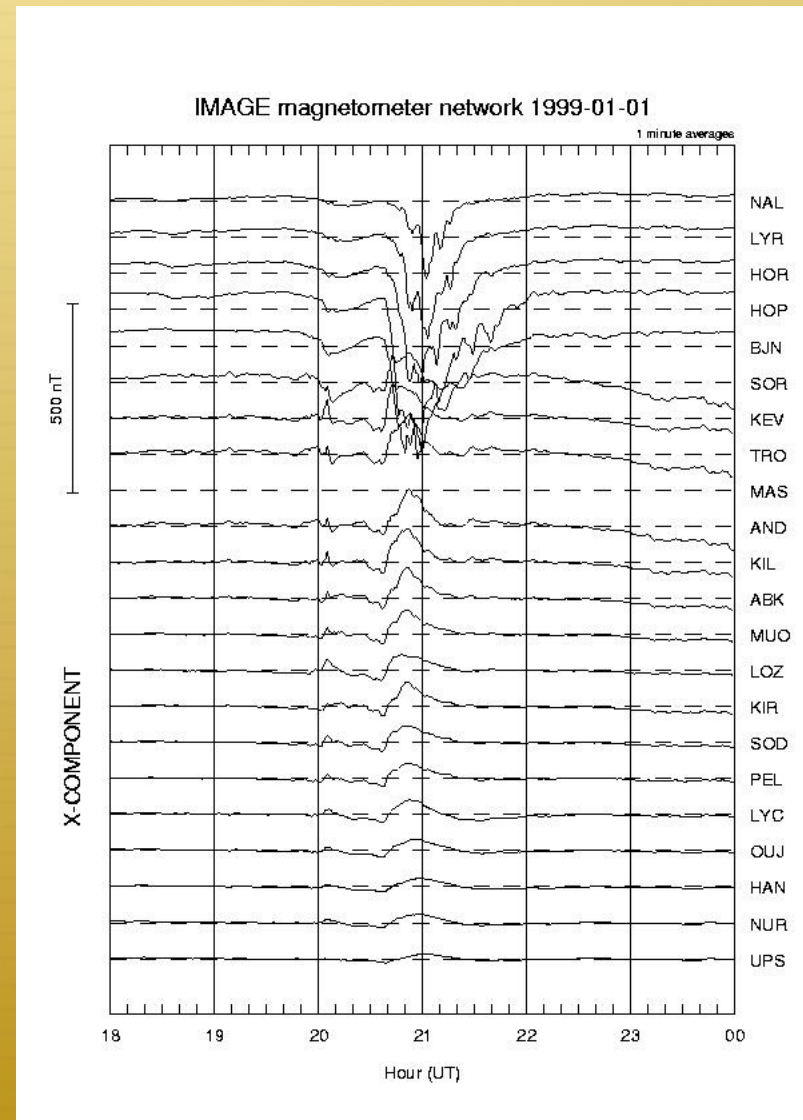
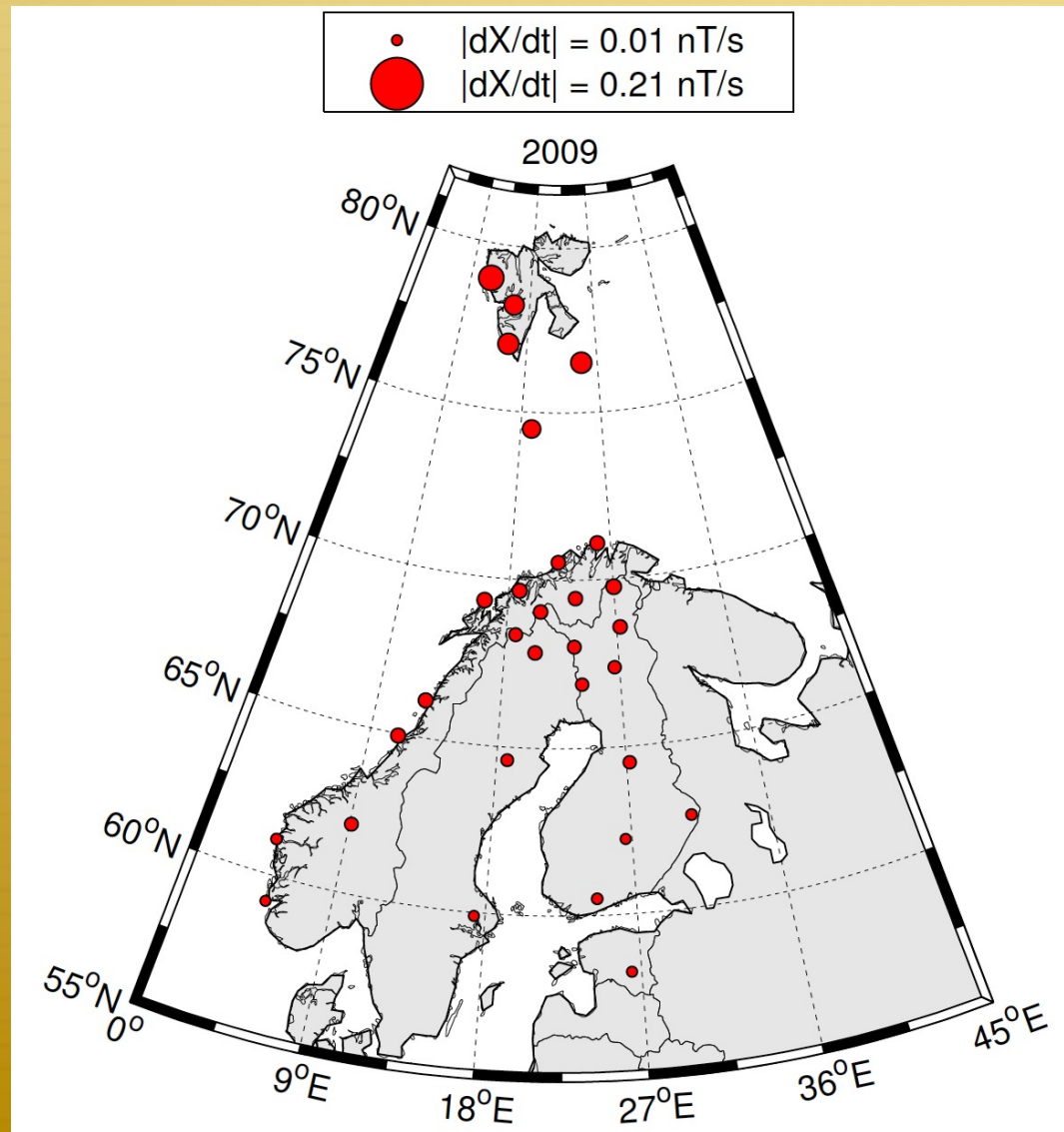
Solar wind helicity



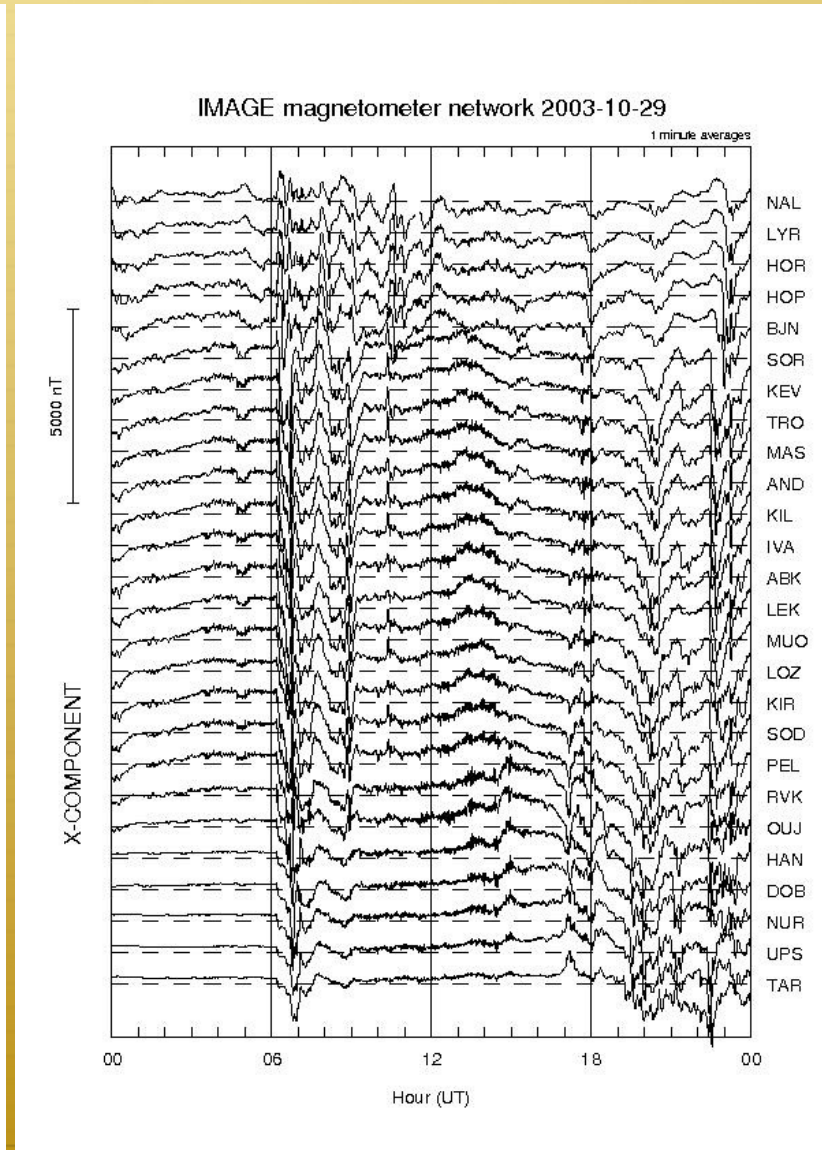
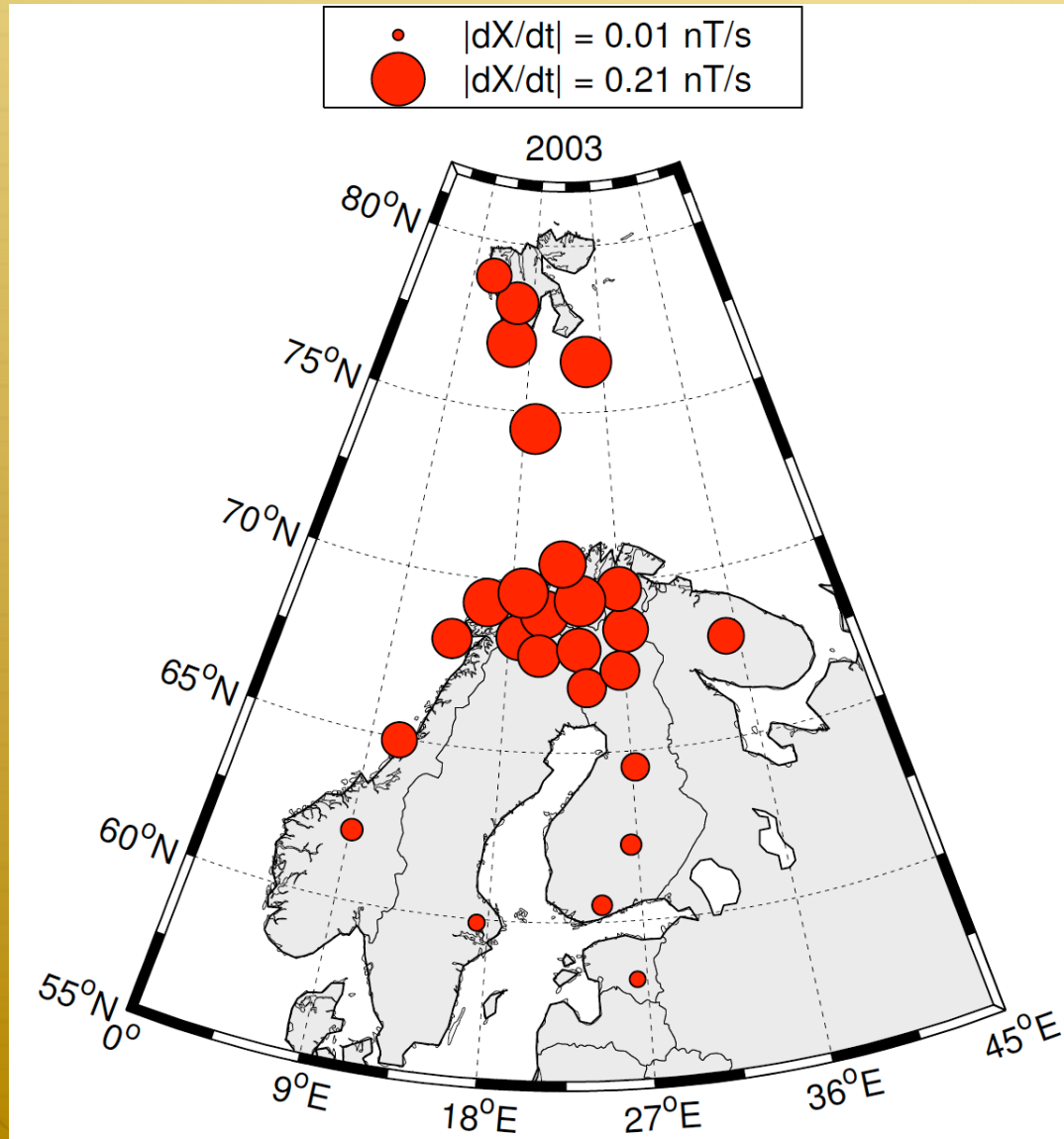
Lithosphere structure



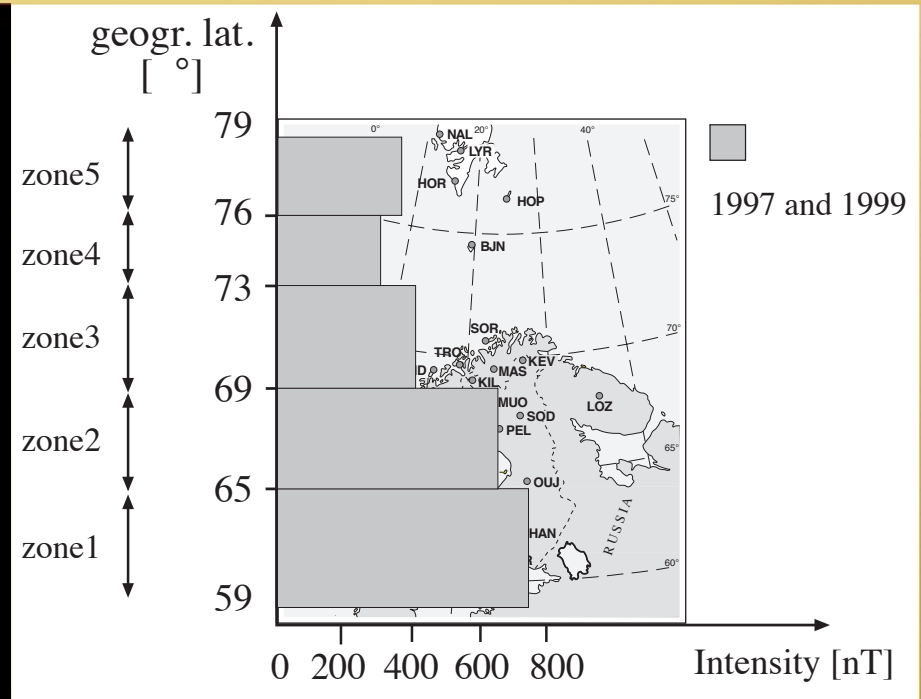
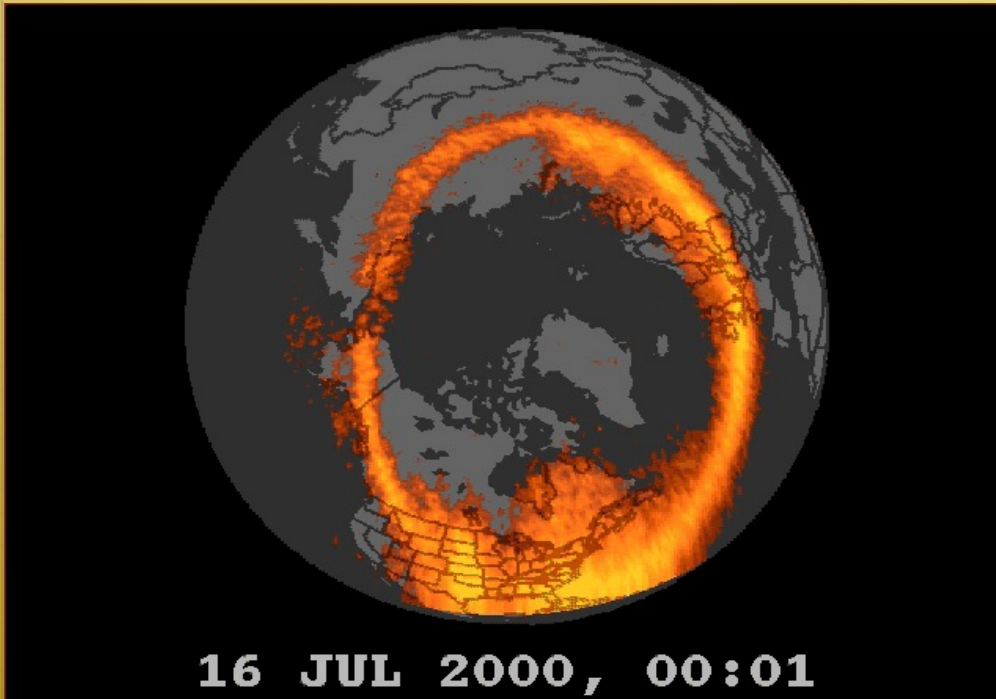
Non-storm substorm at high-latitudes



Storm-time substorm at high-latitudes



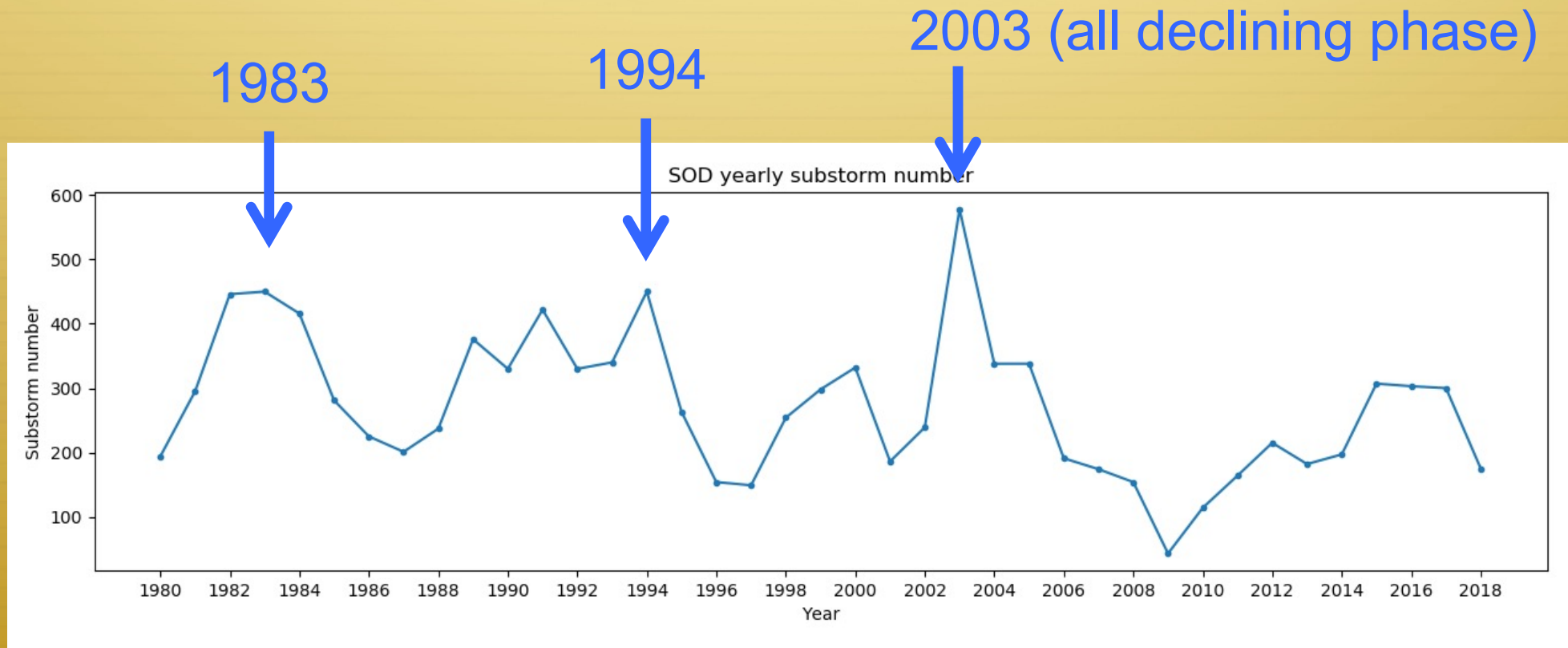
Stronger substorms toward mid-latitudes



Decadal Sun-Earth coupling

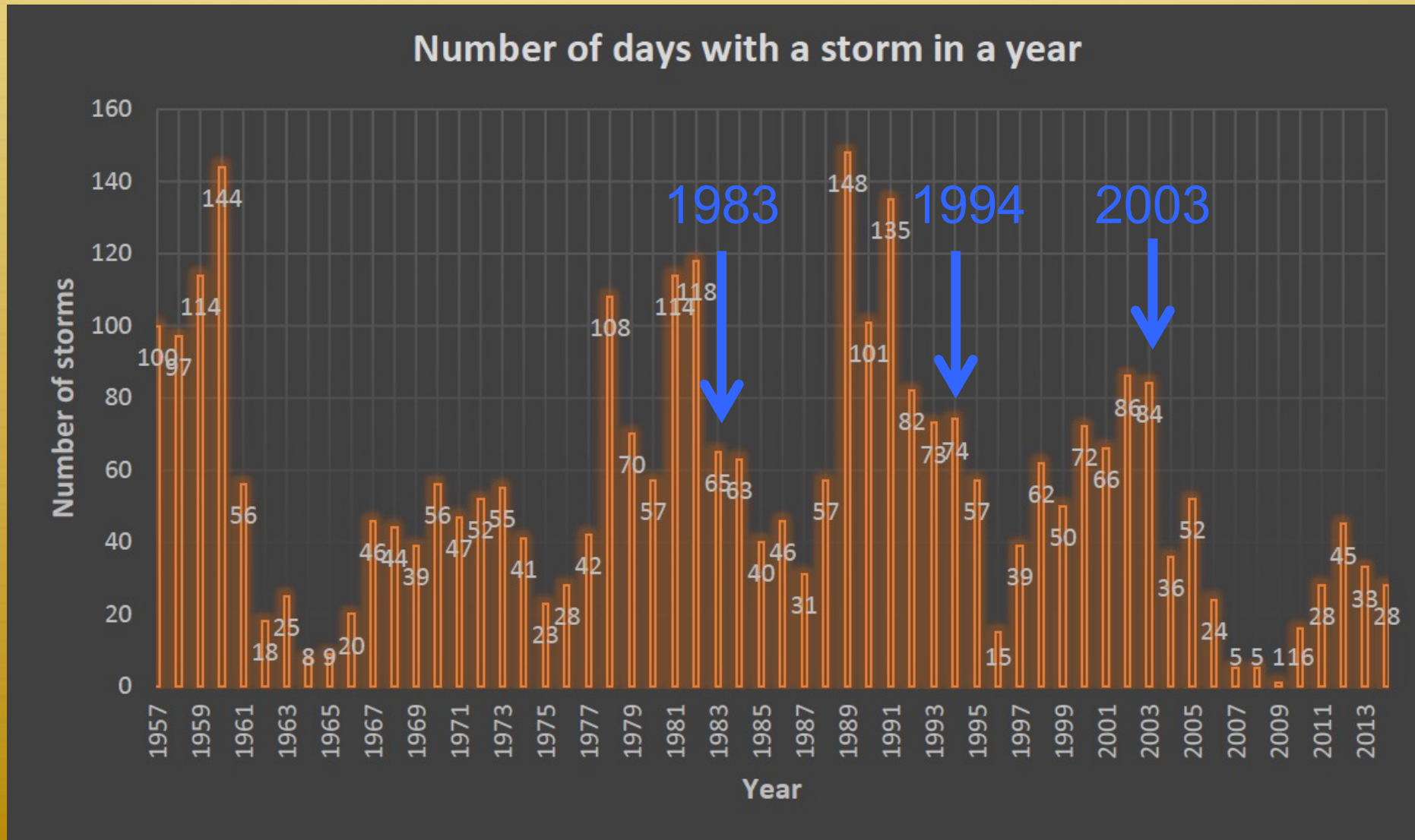


Decadal evolution of substorms

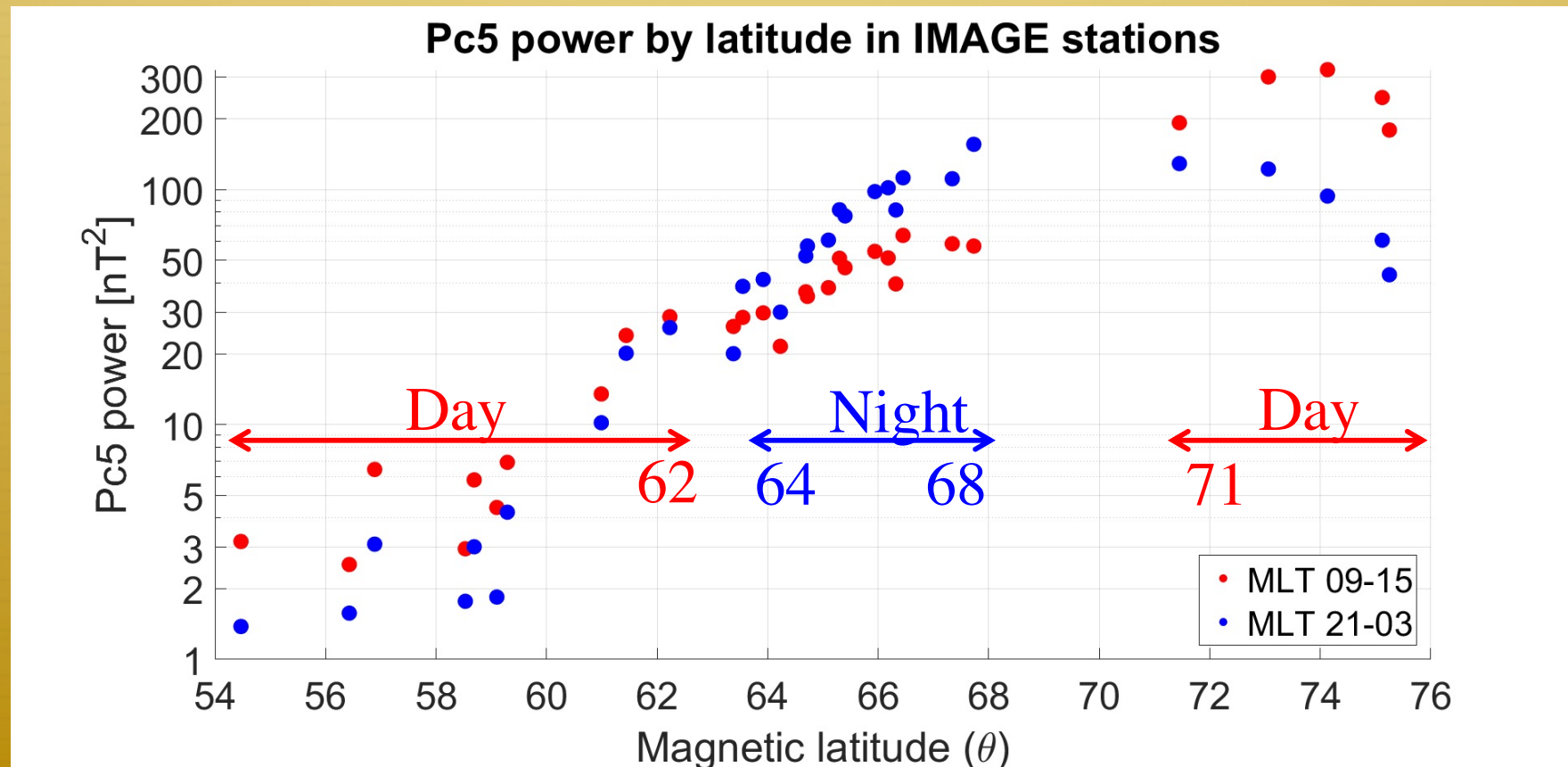


Substorm identification by search engine (Tanskanen, 2009)

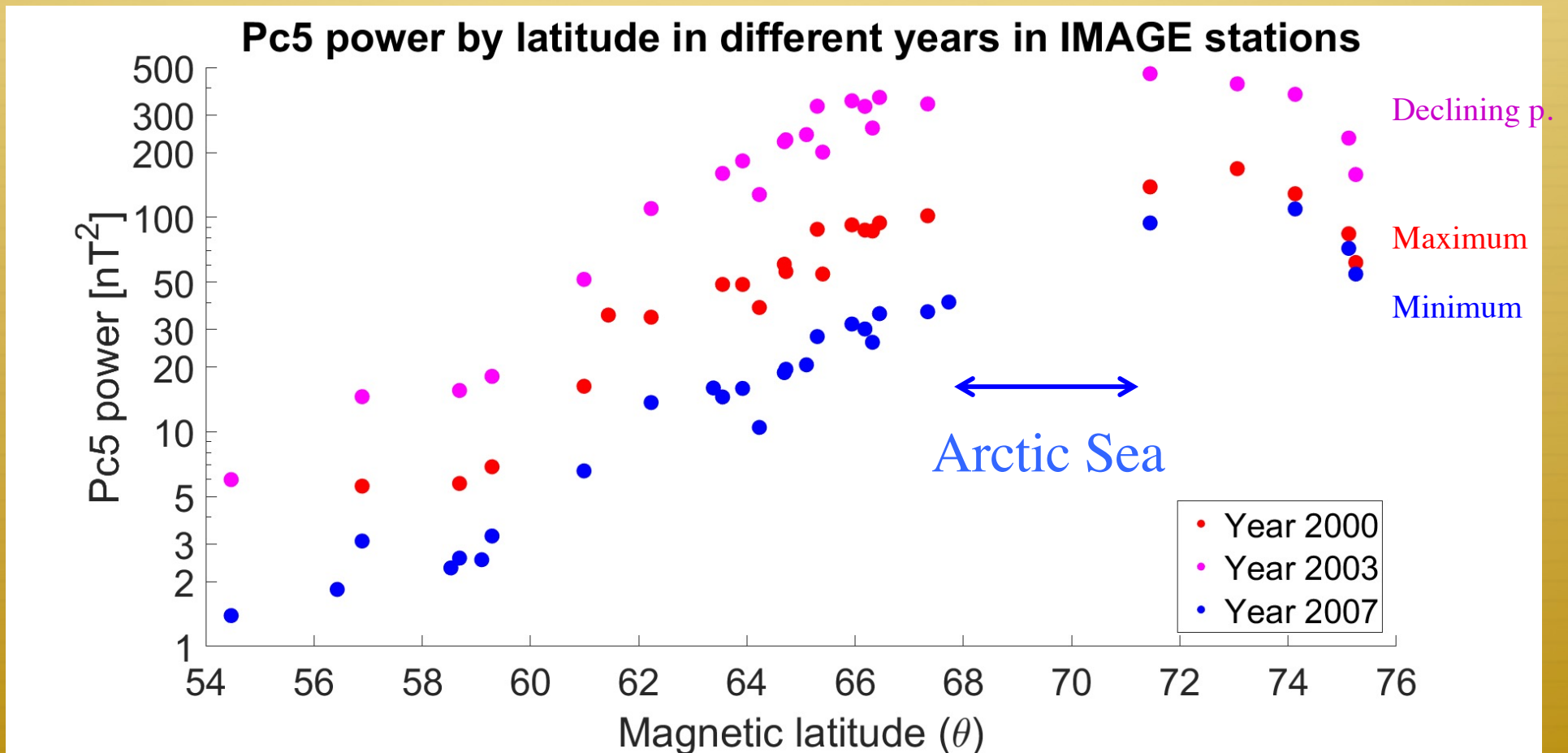
Decadal evolution of storms



Latitudinal variability of the coupling

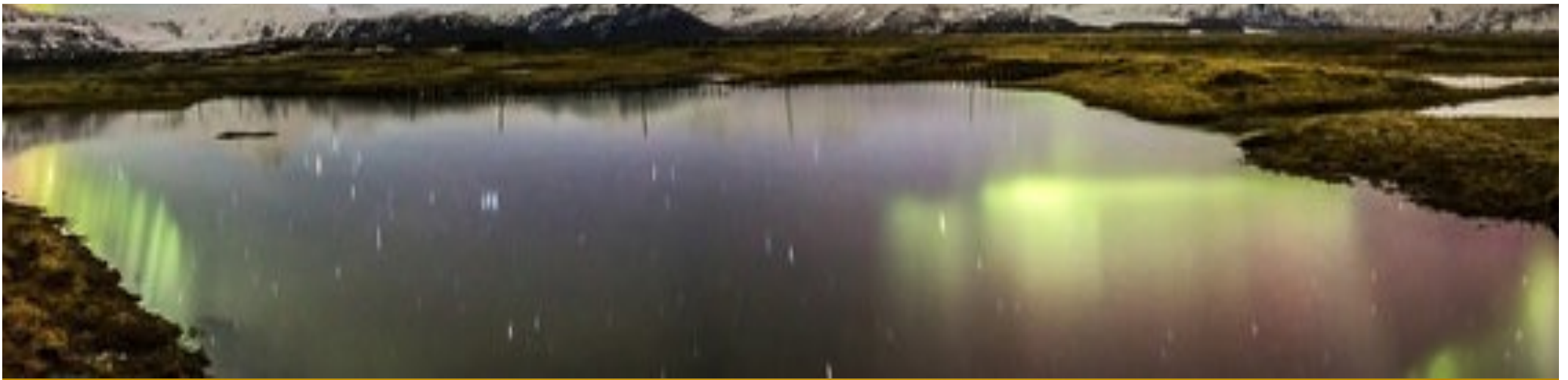
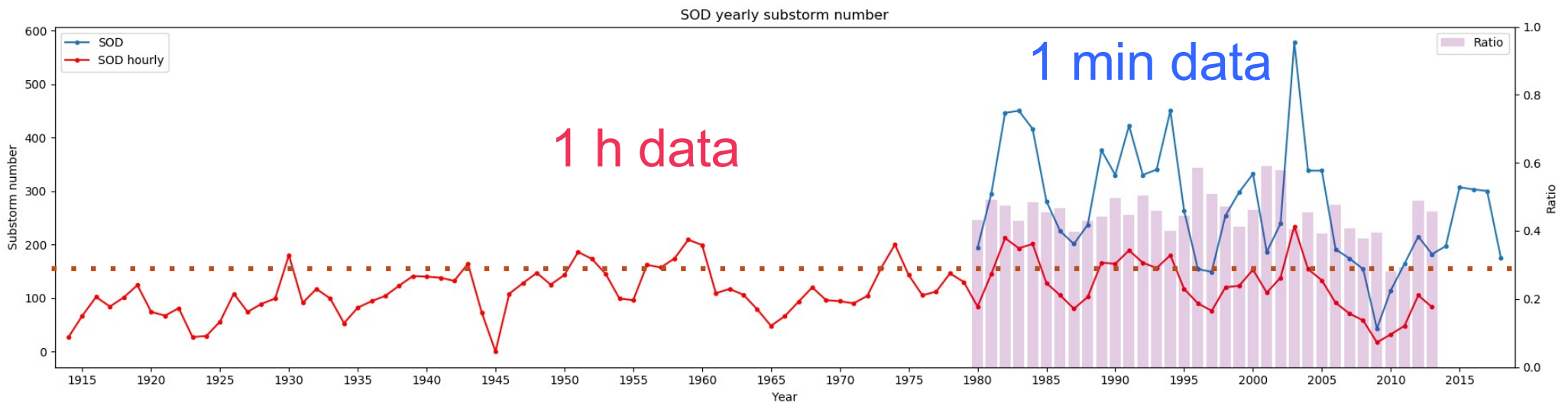


Solar cycle changes of Pc5 power

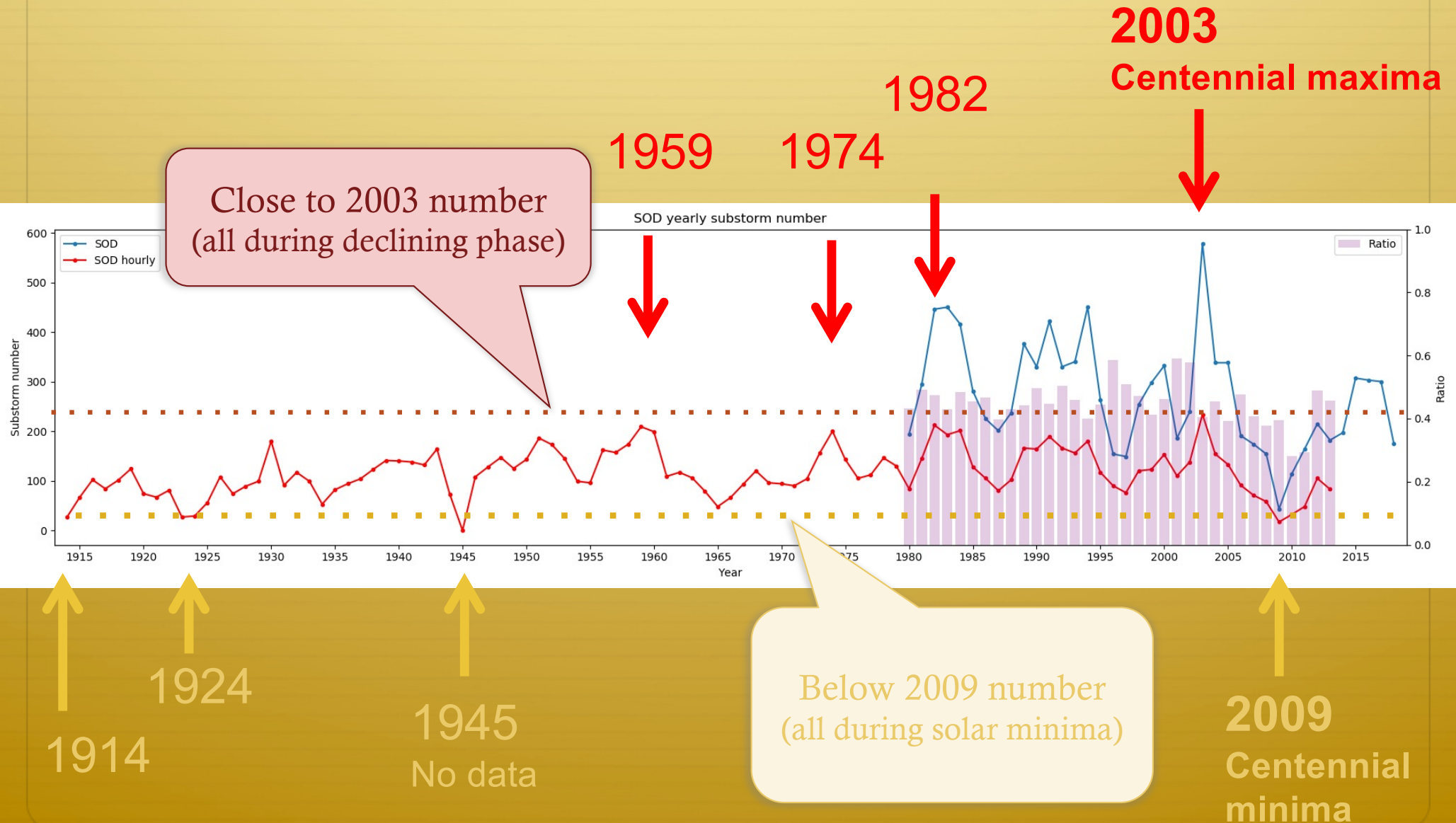


→ All latitudes enhanced during declining phase

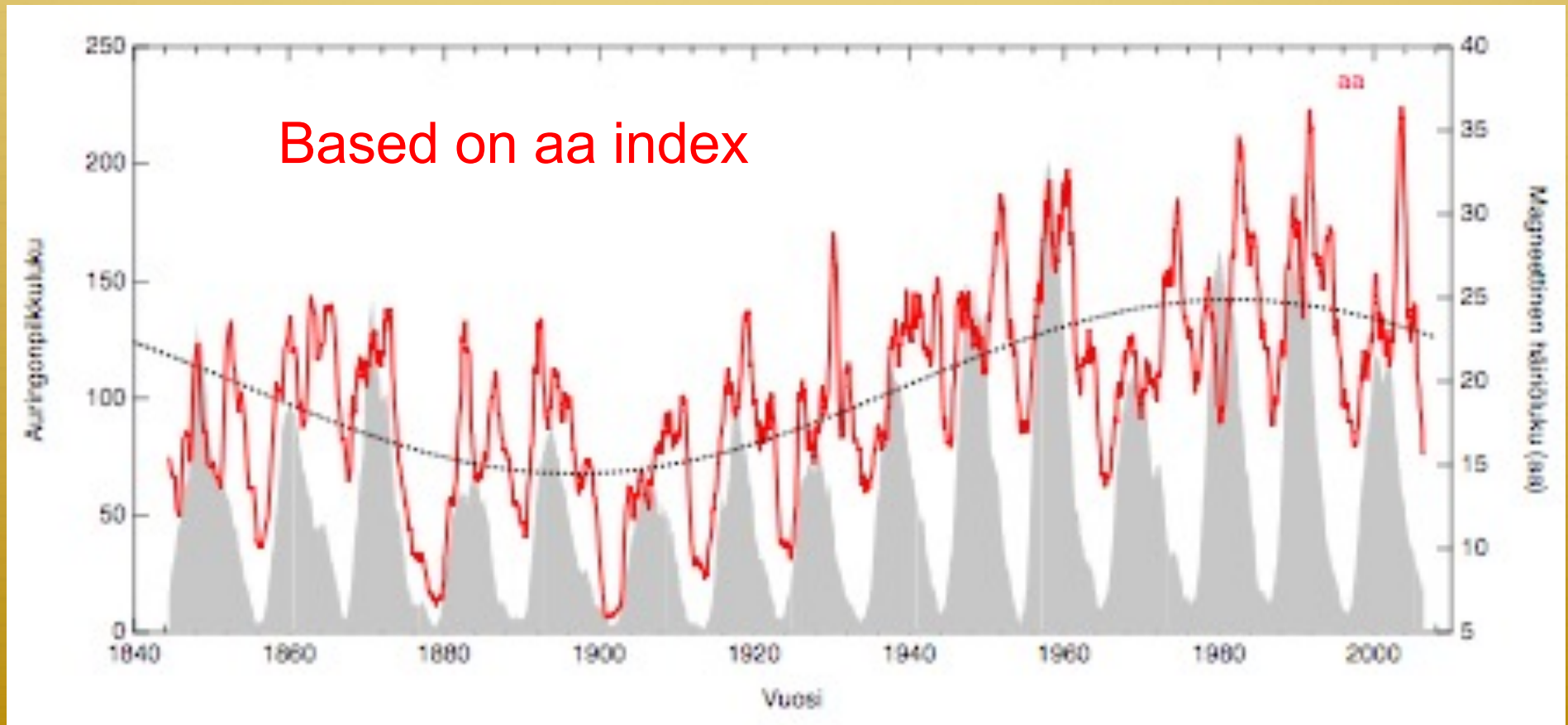
Centennial variability of substorms



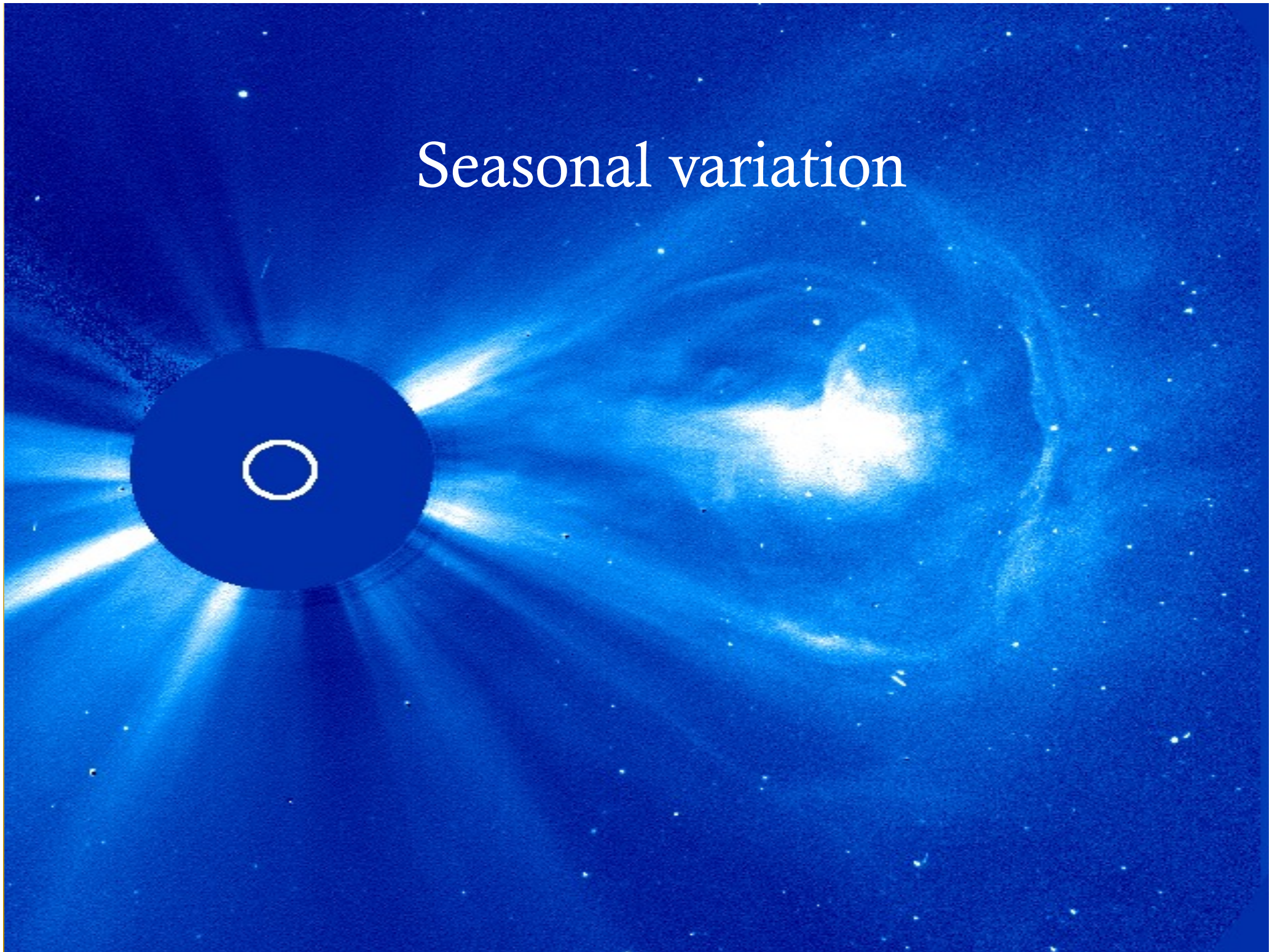
Centennial variability of substorms



The Sun-Earth coupling since 1844

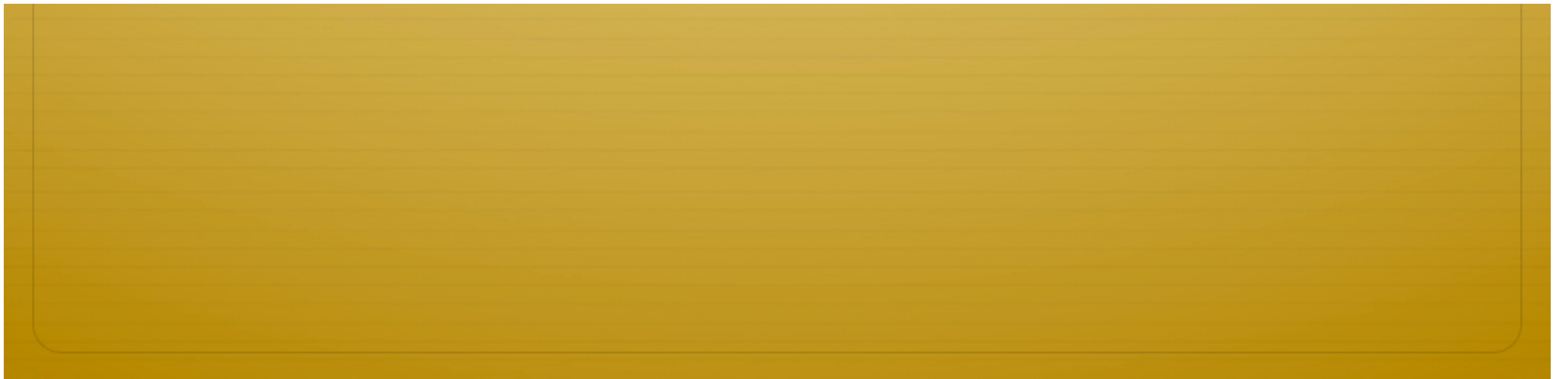
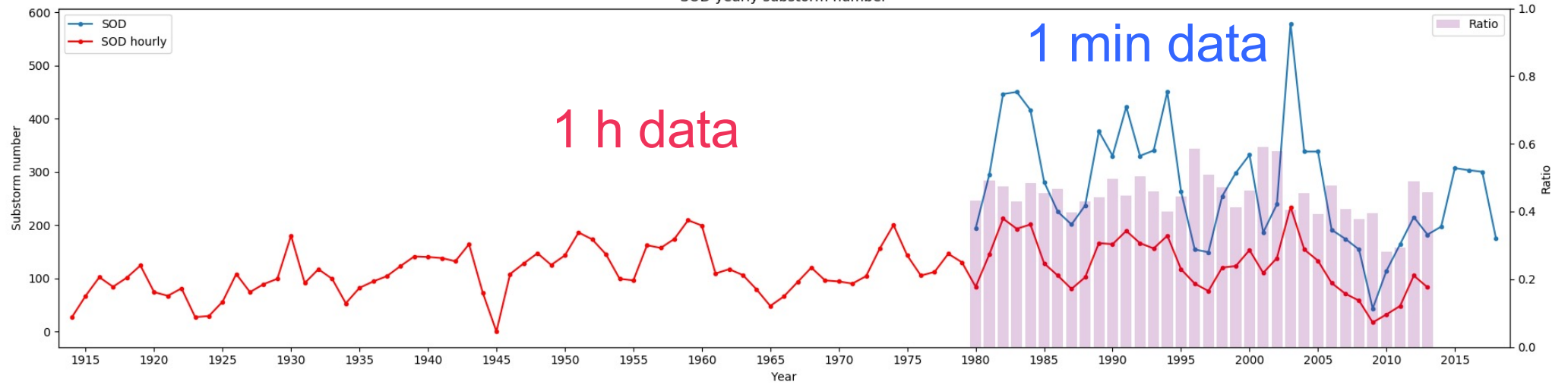


Seasonal variation

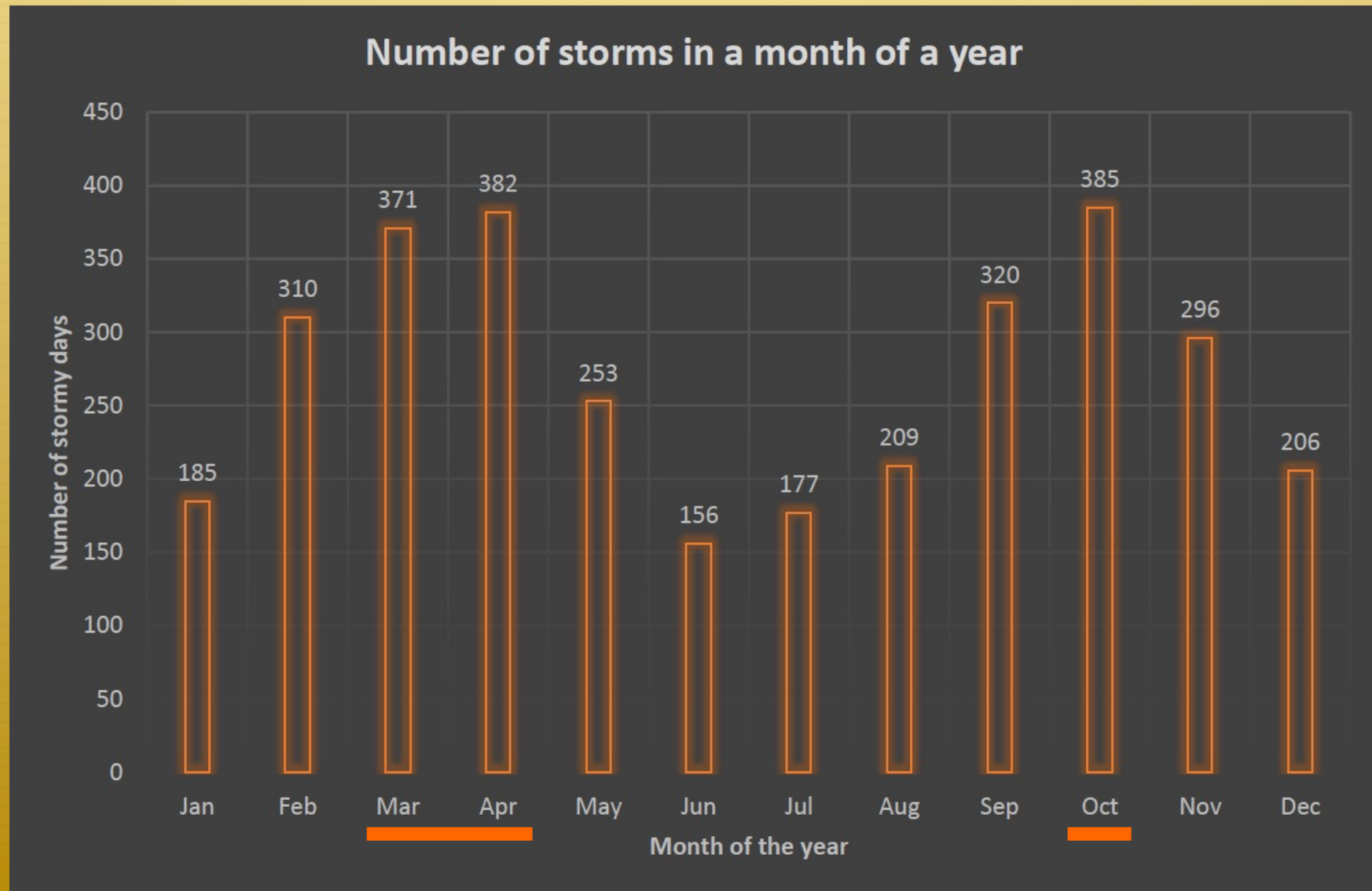




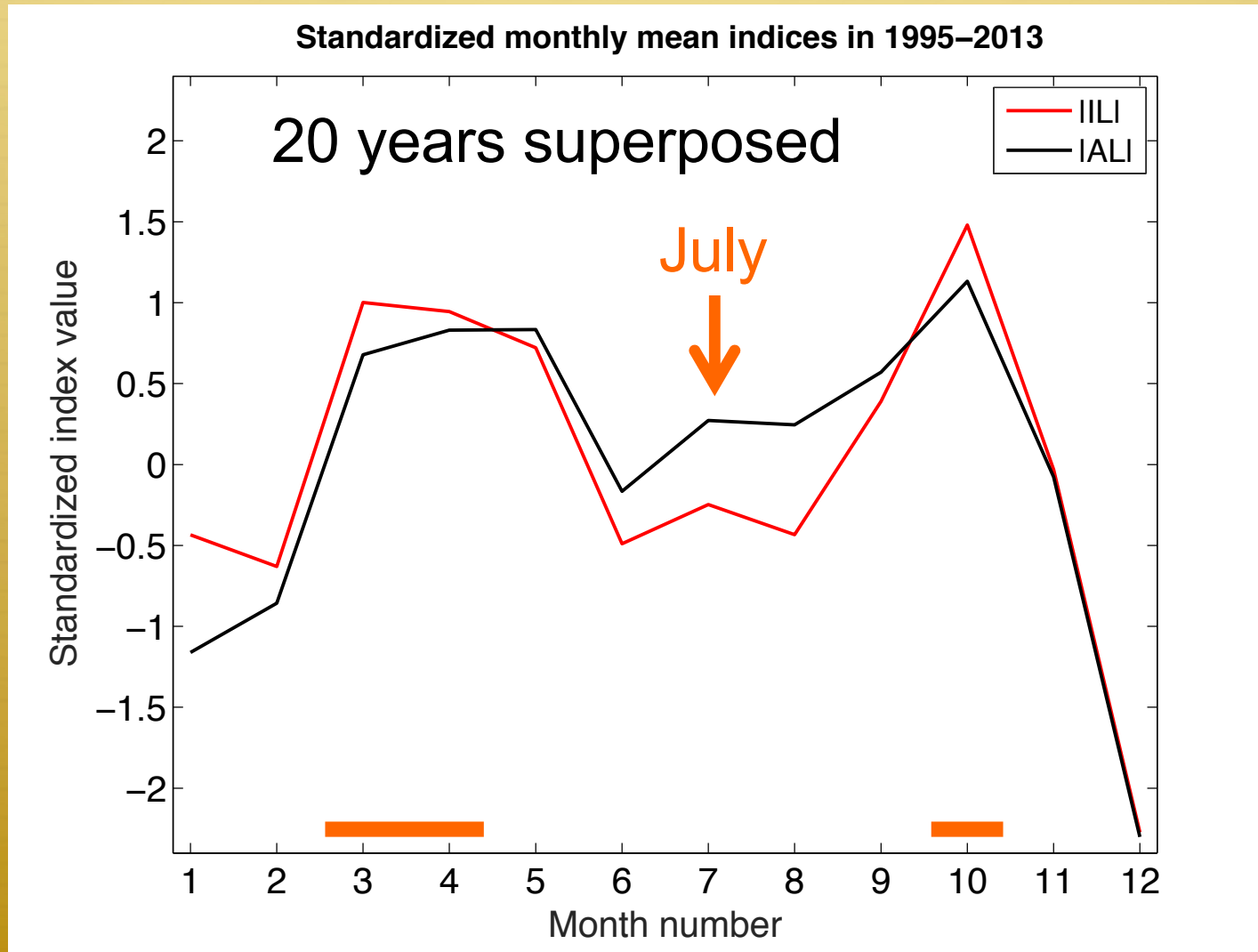
SOD yearly substorm number



Seasonal variation of storms

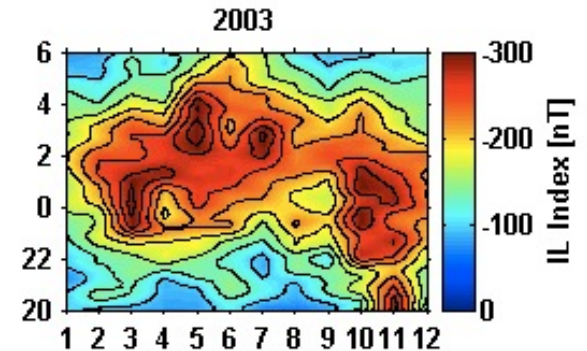
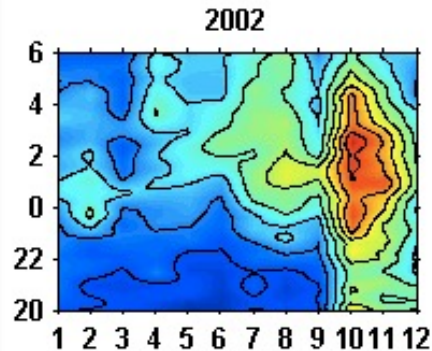
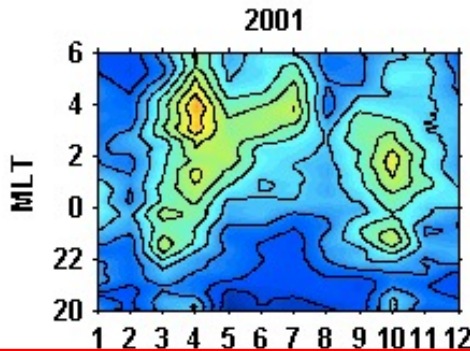


Seasonal variation of substorms

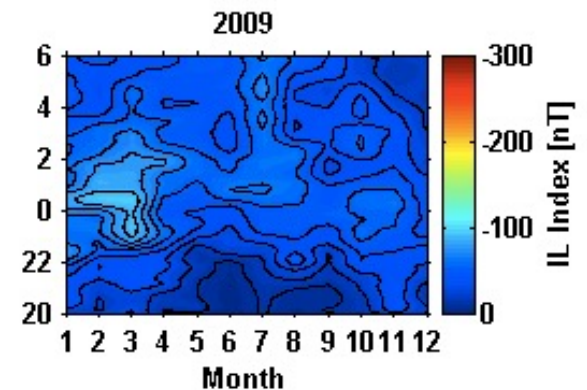
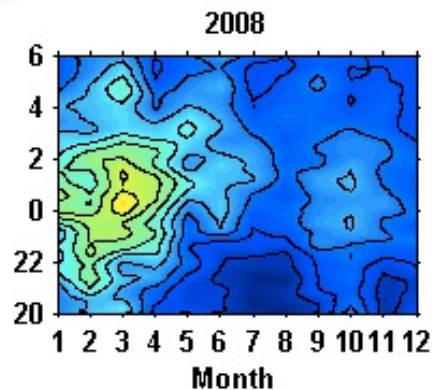
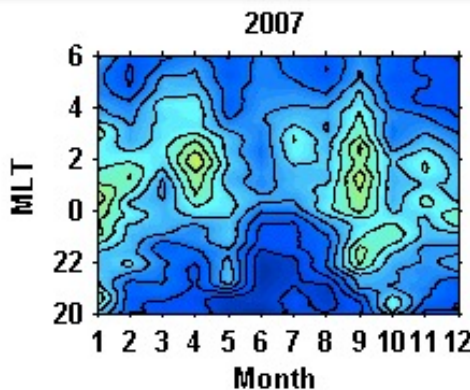
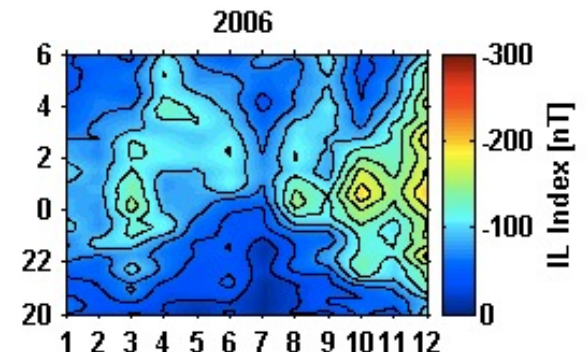
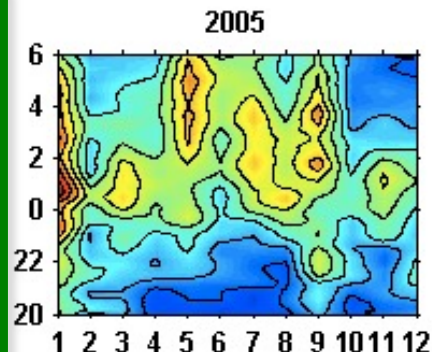
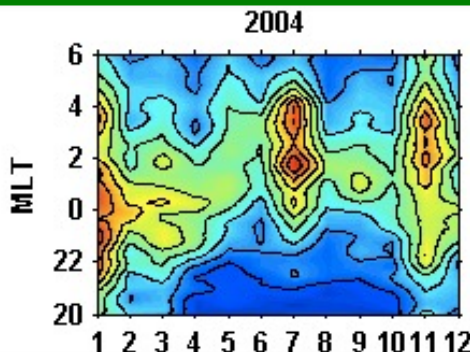


Seasonal variation in individual years

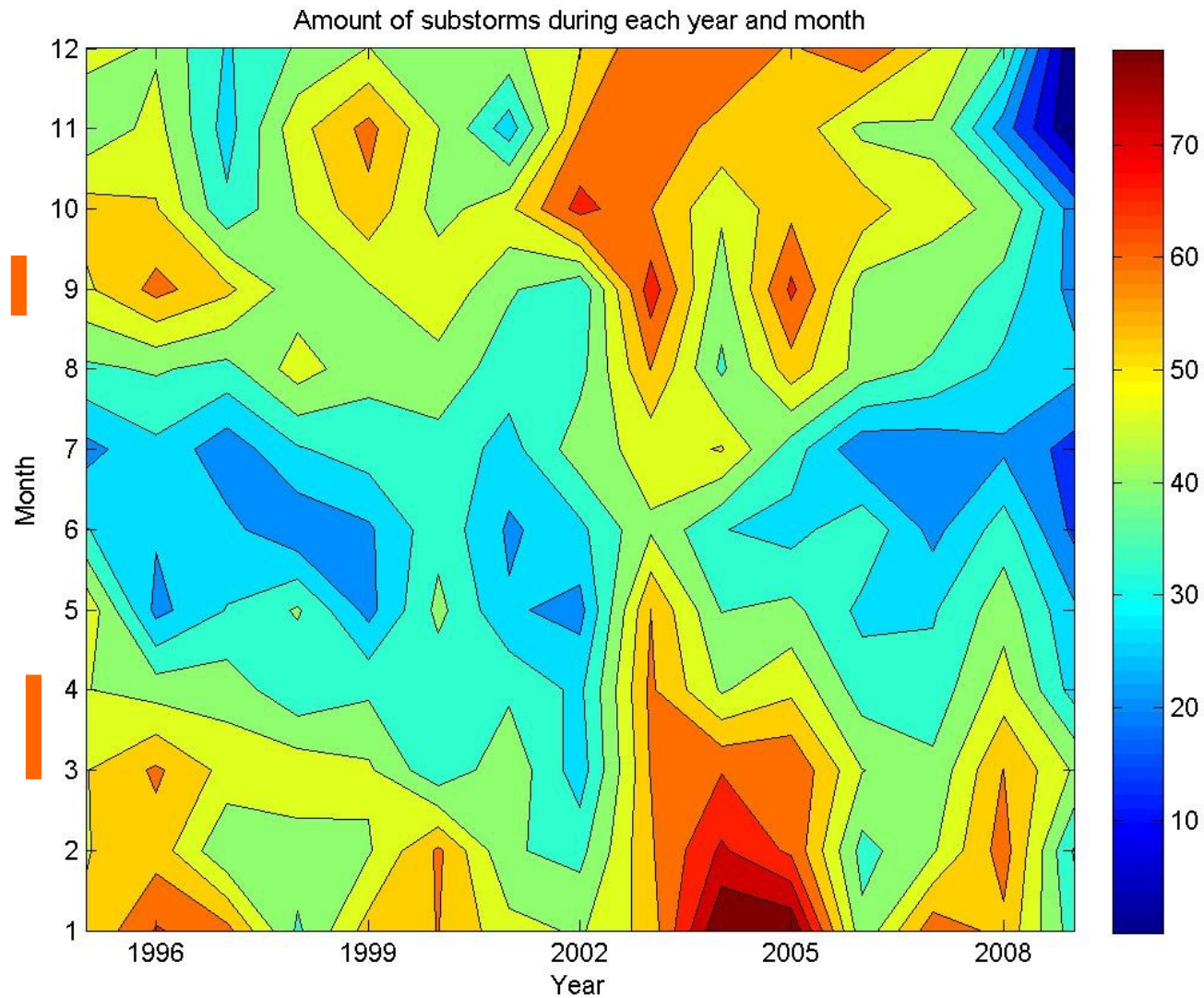
Equinox dominance



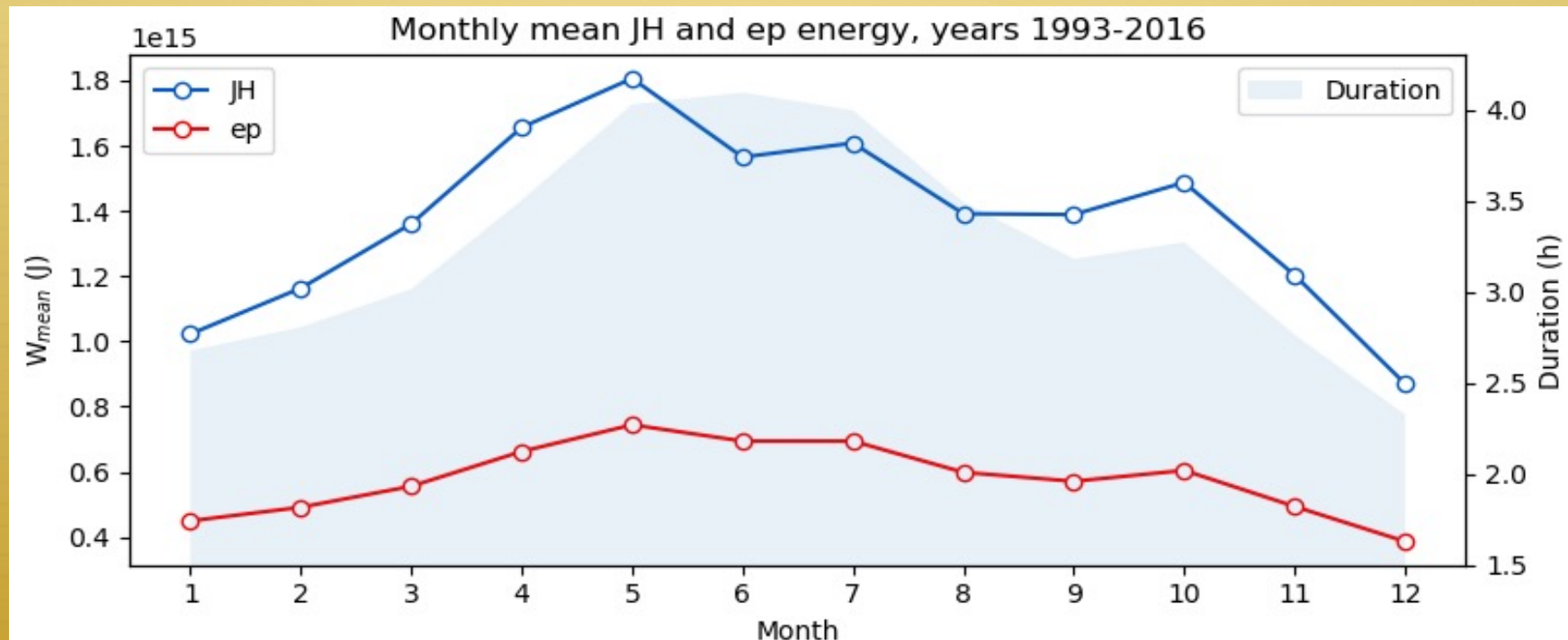
Solstice dominance



Seasonal variation during SC23

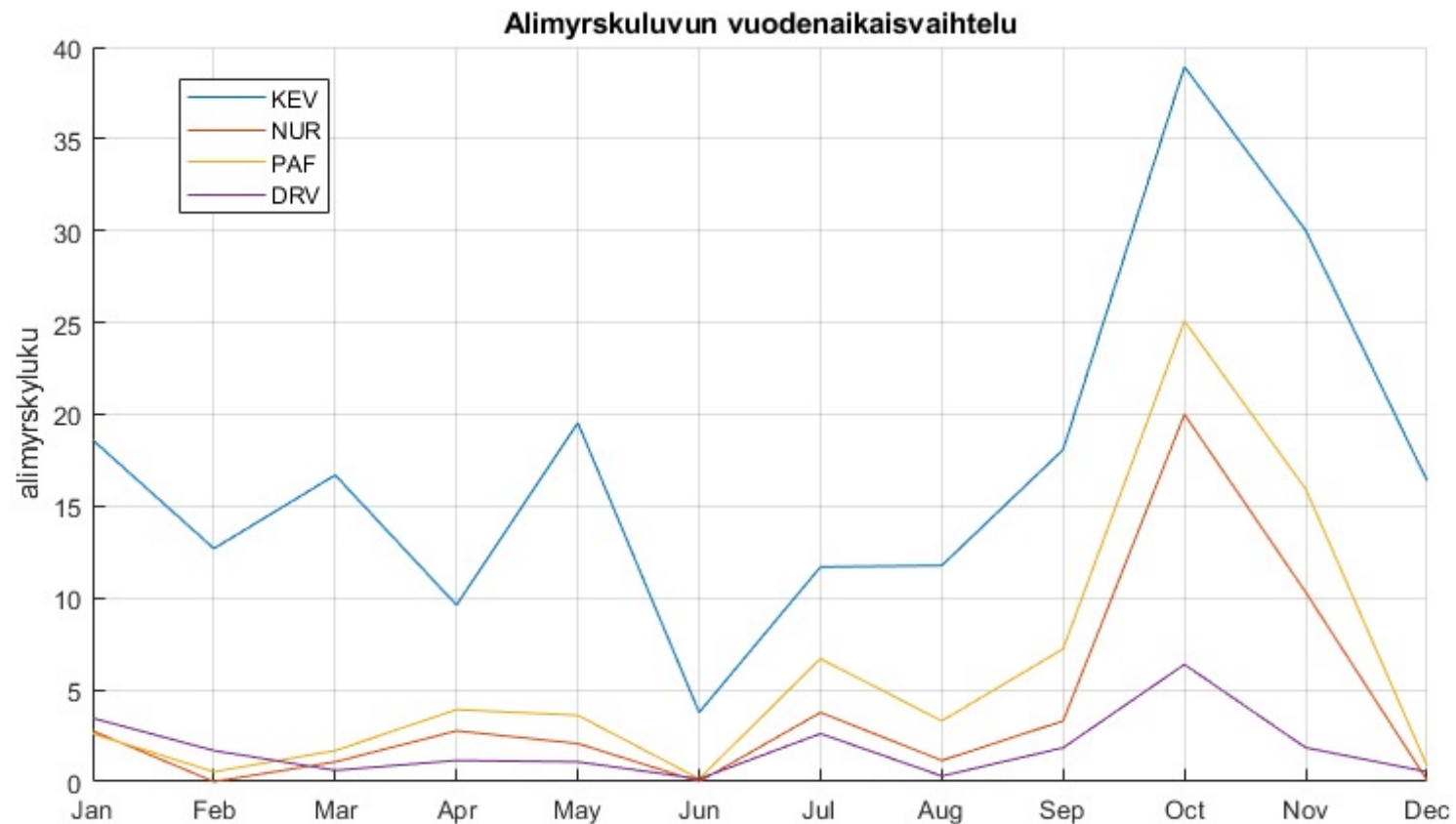


Substorm energetics



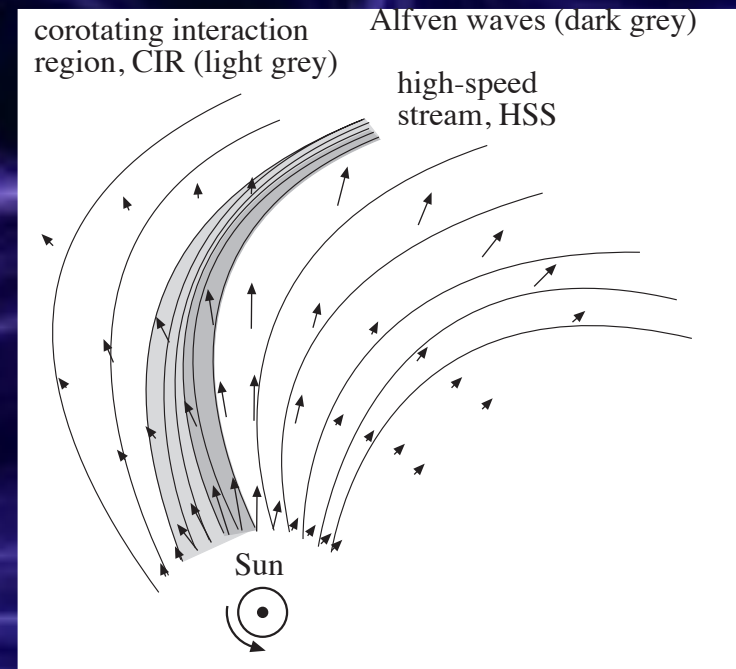
→ Each substorm dissipate more energy into the ionosphere in late spring and summer compared to other seasons.

Seasonal variation in southern hemisphere

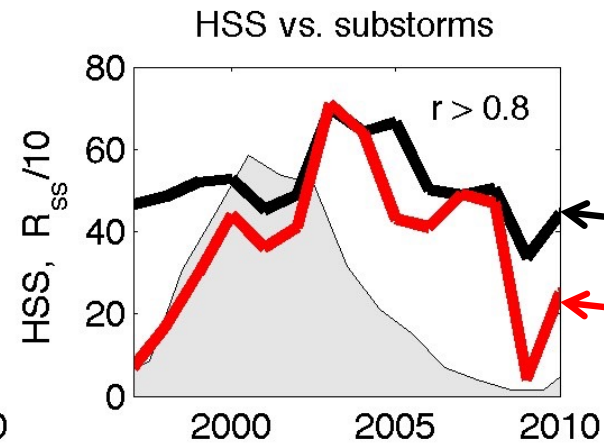
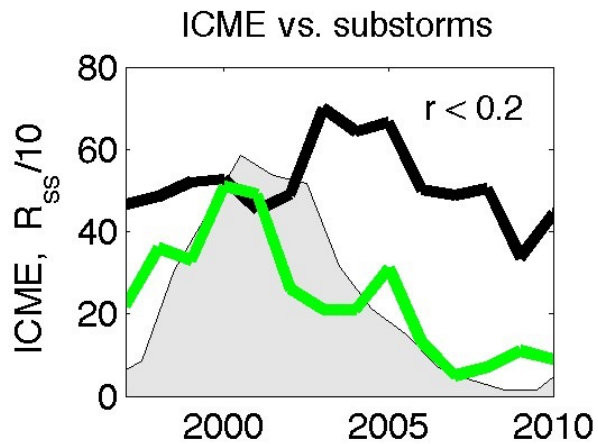


- Similar variation than in the northern hemisphere
- The cause cannot be due to the dipole tilt or conductivity

Solar wind carry information on the Sun

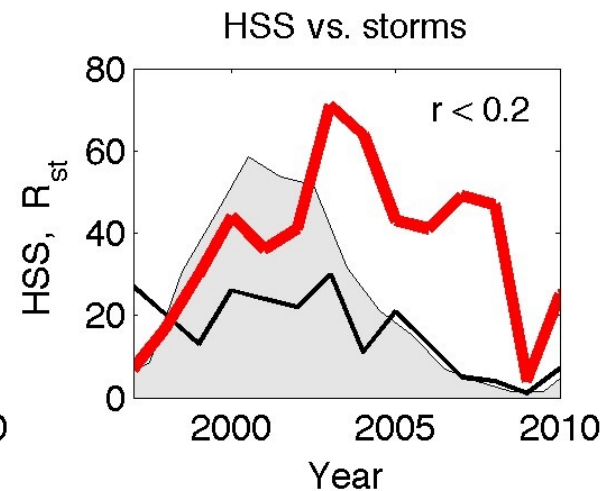
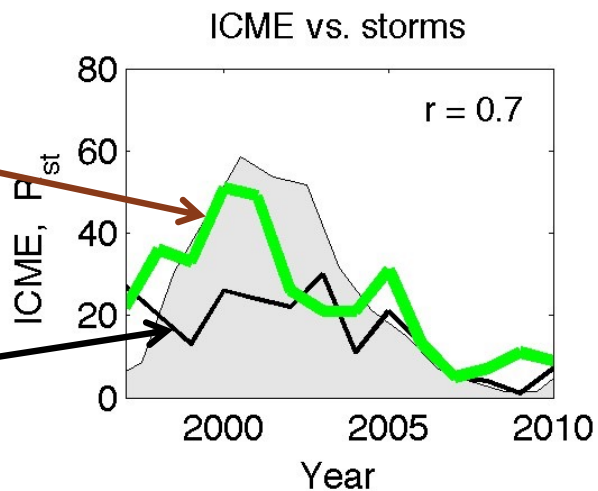


Solar wind drivers of storms and substorms



Substorms

High-speed streams



Coronal Mass ejections

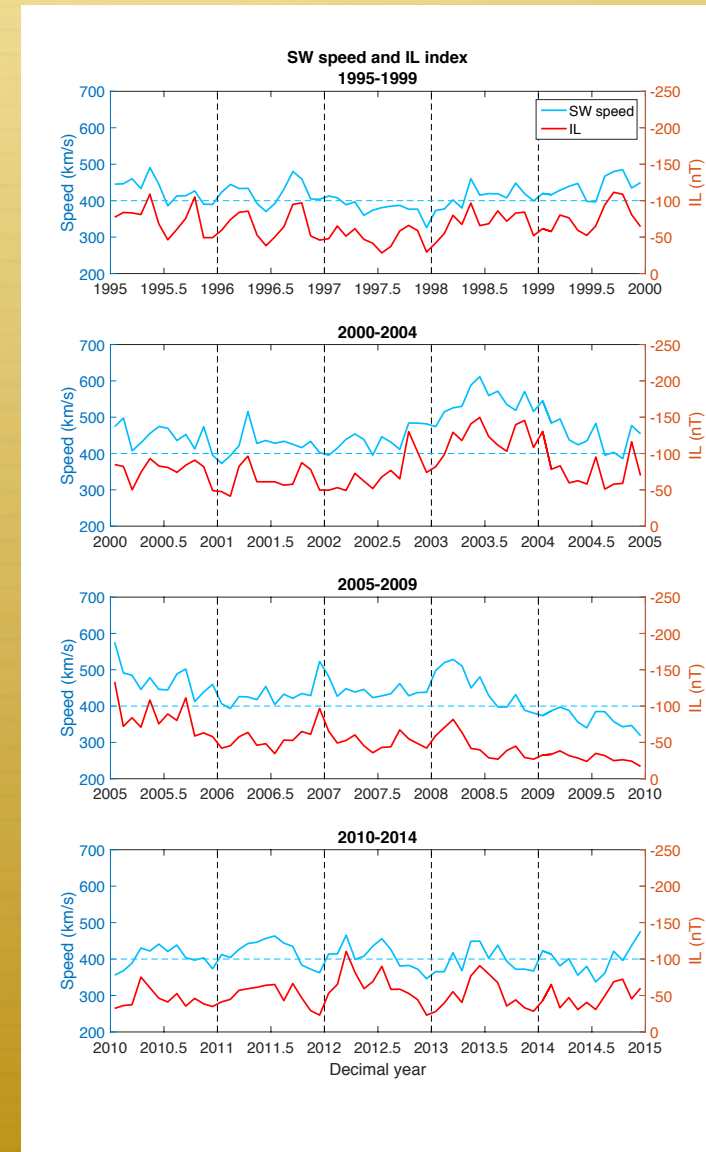
Storms

Solar wind speed modulates geomagnetic activity

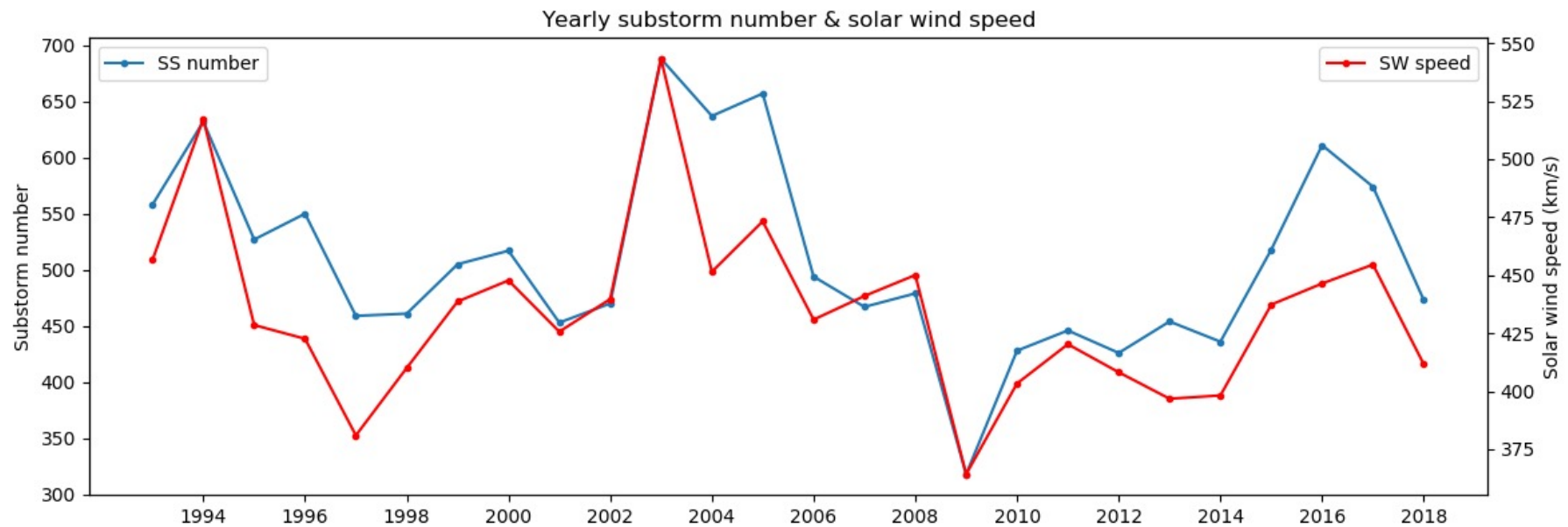
It is known that solar wind speed modulates geomagnetic activity in yearly time-scales. Here we have shown that the IL index follows solar wind speed also in monthly time-scales.

Linear correlation coefficient for v and IL index is $r = 0.82$ with the p-value $1.5 * 10^{-44}$!

→ Solar wind speed alone explains two third of the variability of the IL index at monthly time resolution ($r^2 = 0.67$).



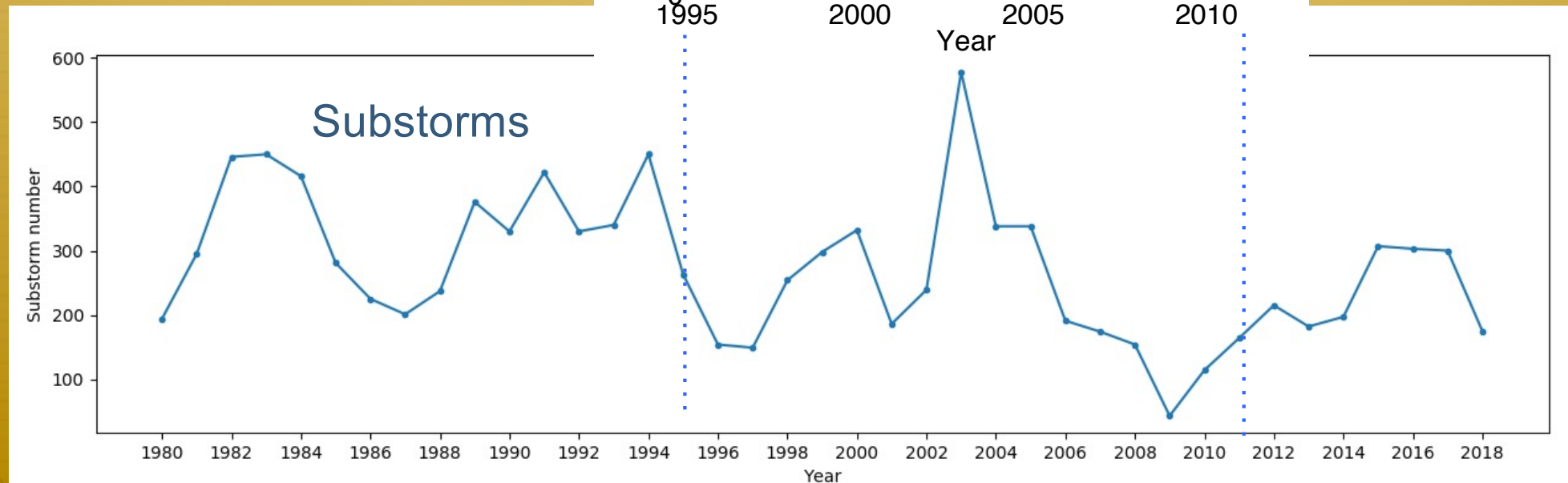
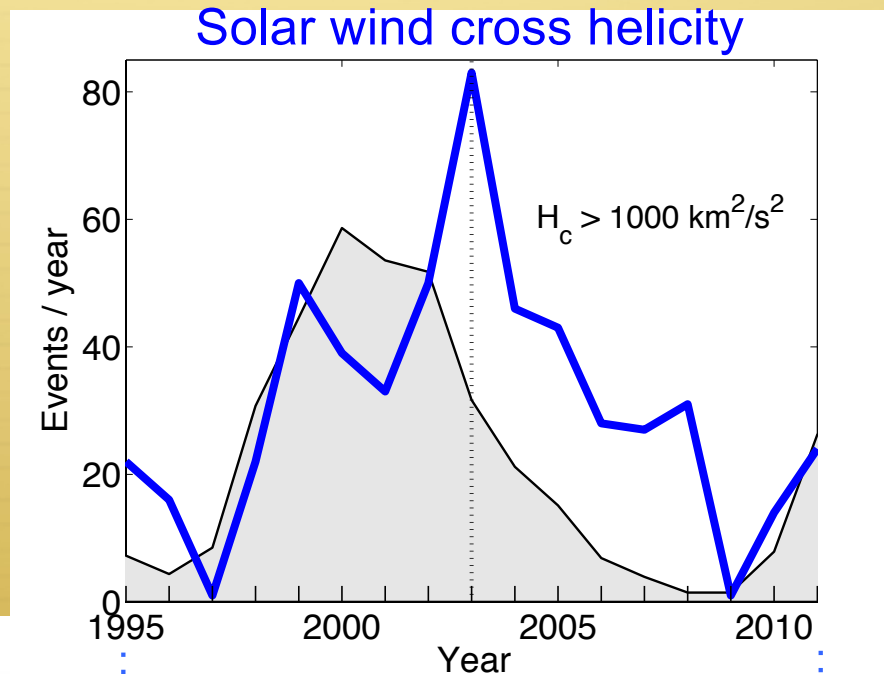
Solar wind speed and substorm number



→ Substorm number follows closely solar wind speed.

Why?

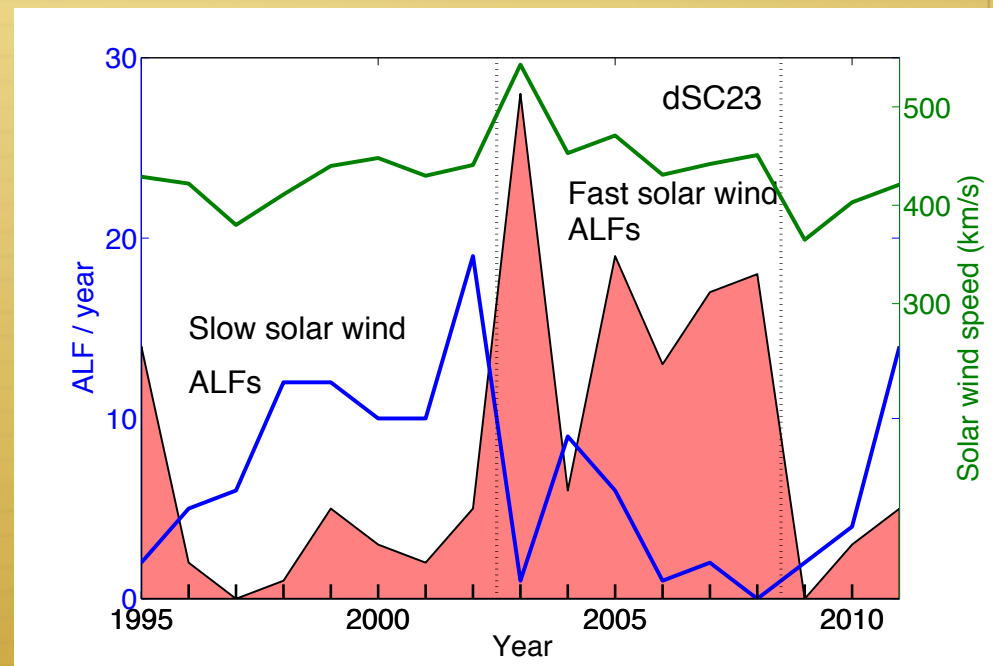
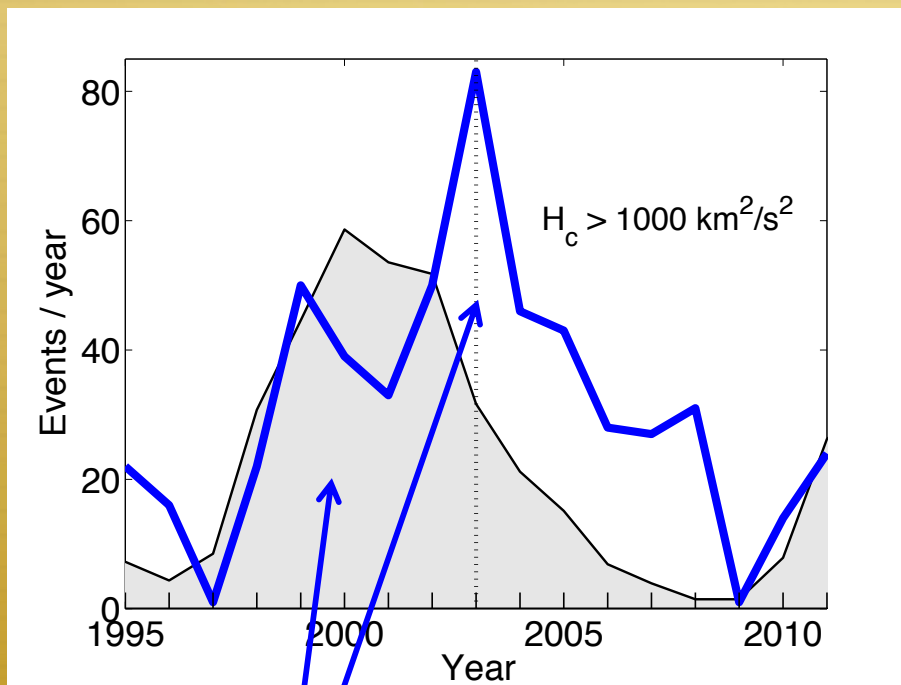
Solar wind cross helicity plays a role



Alfvénic fluctuations embedded to fast speed

Extremely aligned and large-amplitude fluctuations peak in 2003 and enhance geomagnetic activity.

An abrupt transition from ALFs being embedded in slow wind until 2002 to ALFs being dominantly in fast wind since 2003



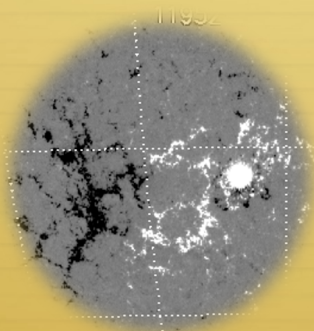
Double-peak structure in solar wind cross helicity

→ Magnetic fluctuations embedded to fast solar wind best enhance geomagnetic activity.
Tanskanen et al., 2017a

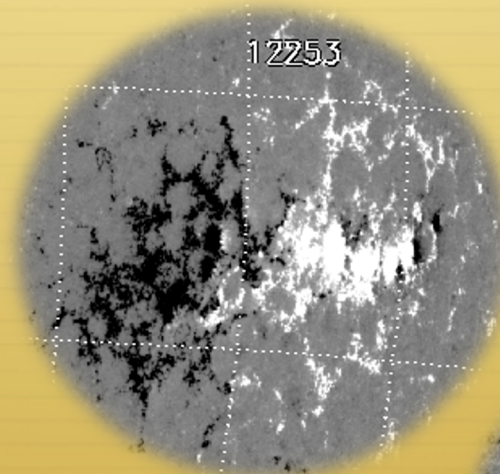
Active region complexity

Simple active regions

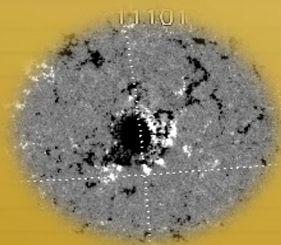
Complex active regions



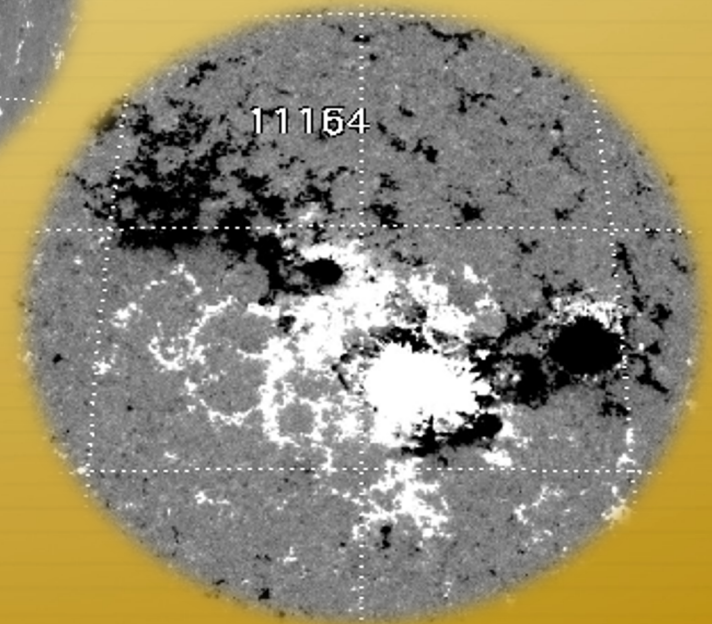
β



$\beta\gamma$



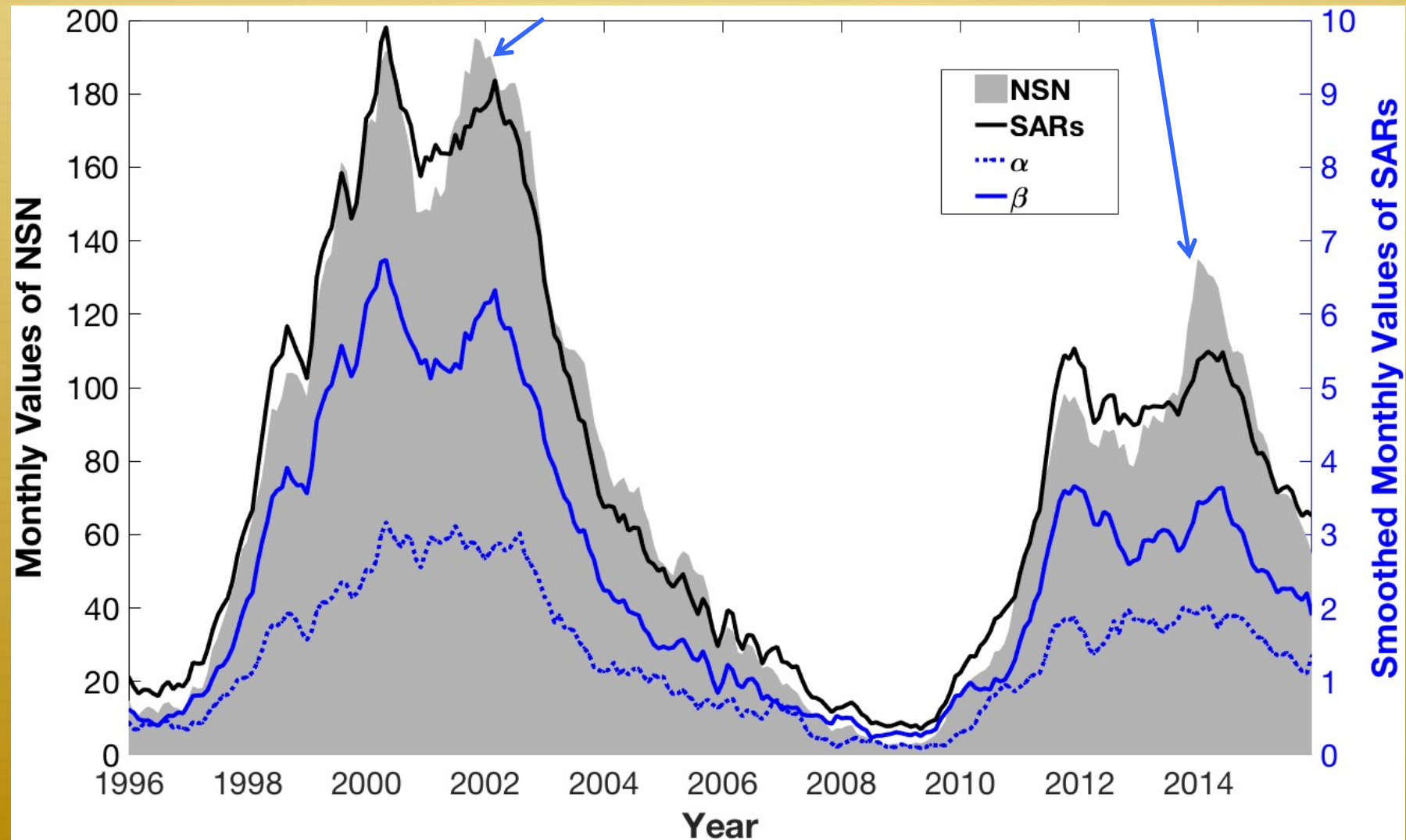
α



$\beta\gamma\delta$

Solar cycle evolution of simple active regions

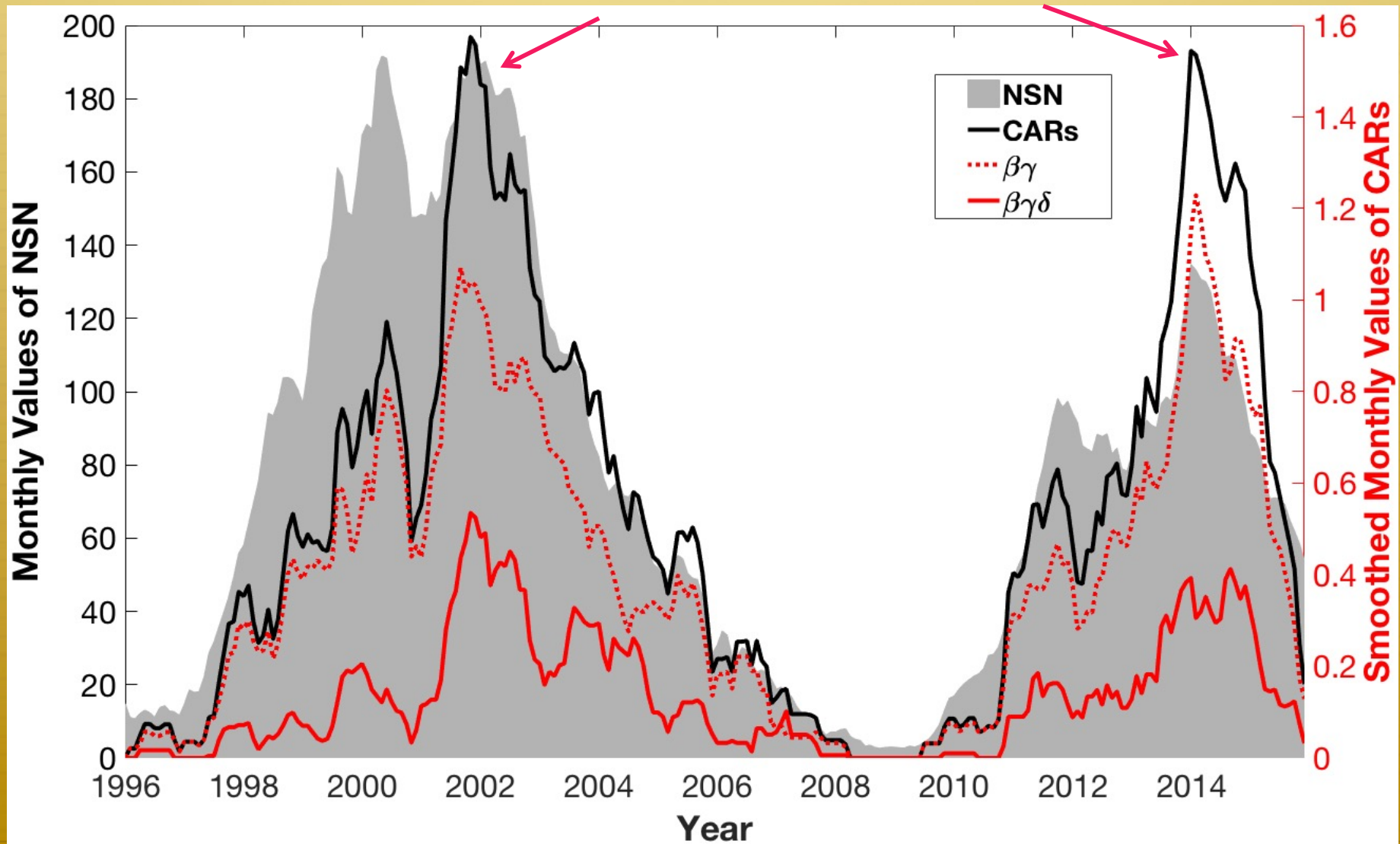
Second peak of SC24 not caused purely by simple active regions



Simple active region = unipolar or bi-polar active region

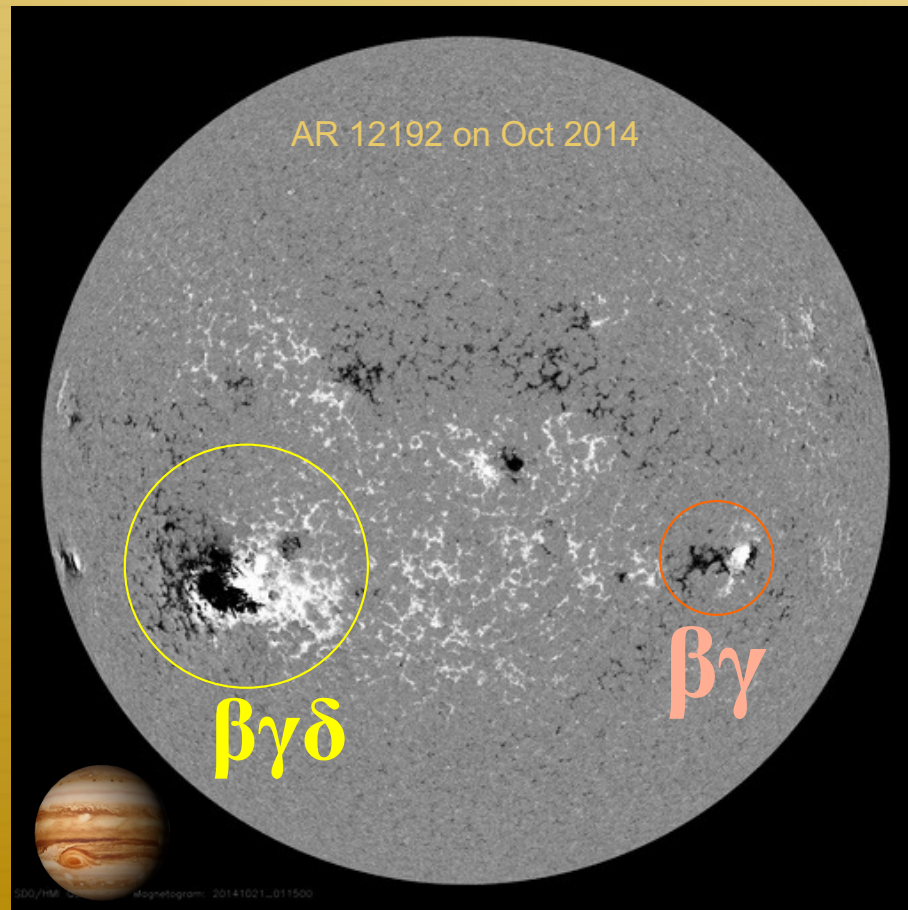
Complex active regions, CARs

CARs maximize during second peak

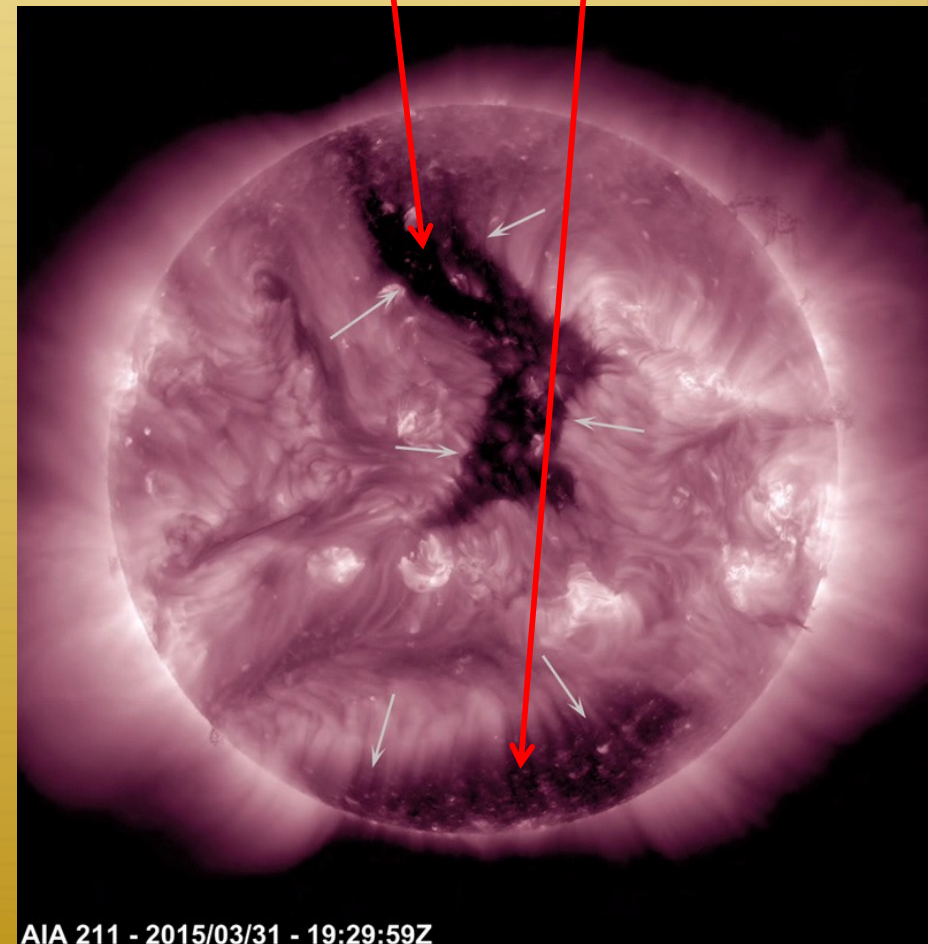


Sun-Earth magnetic coupling

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.



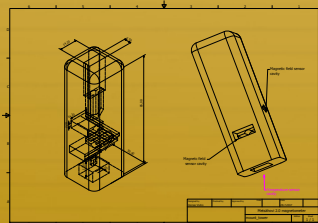
Tanskanen et al., JGR, 2017a

Thank you !

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CubeMAG team, other collaborators and funding agencies.



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