Centennial evolution of the Sun-Earth magnetic coupling

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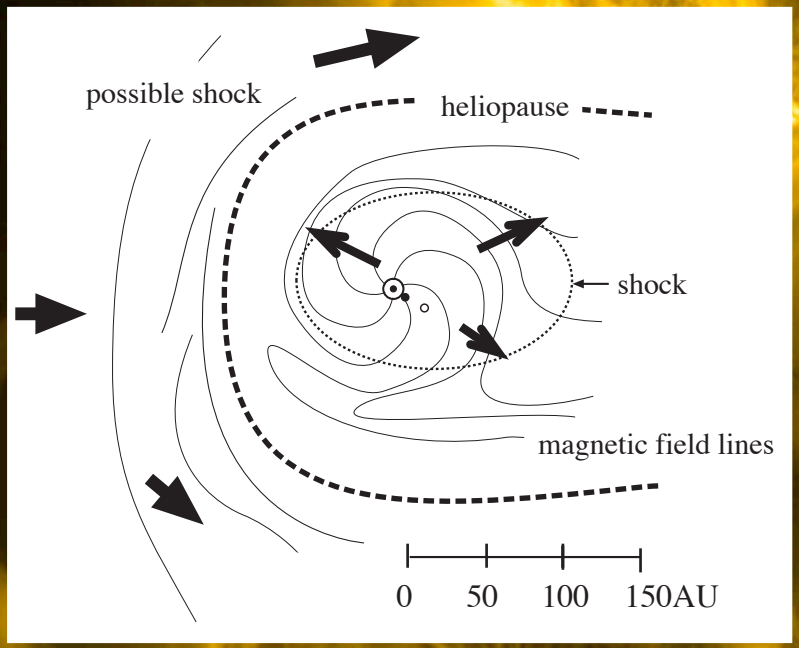
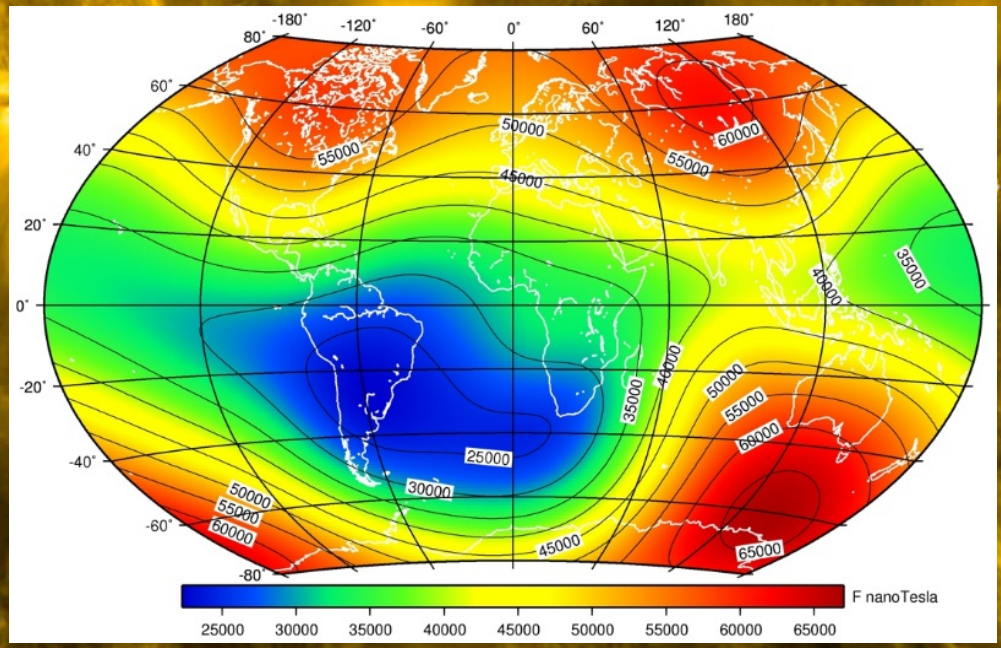
Content:

- Latitudinal variability of substorm intensity and energetics
- Seasonal and centennial variability of substorm number
- Role of complex active regions in Sun-Earth magnetic coupling

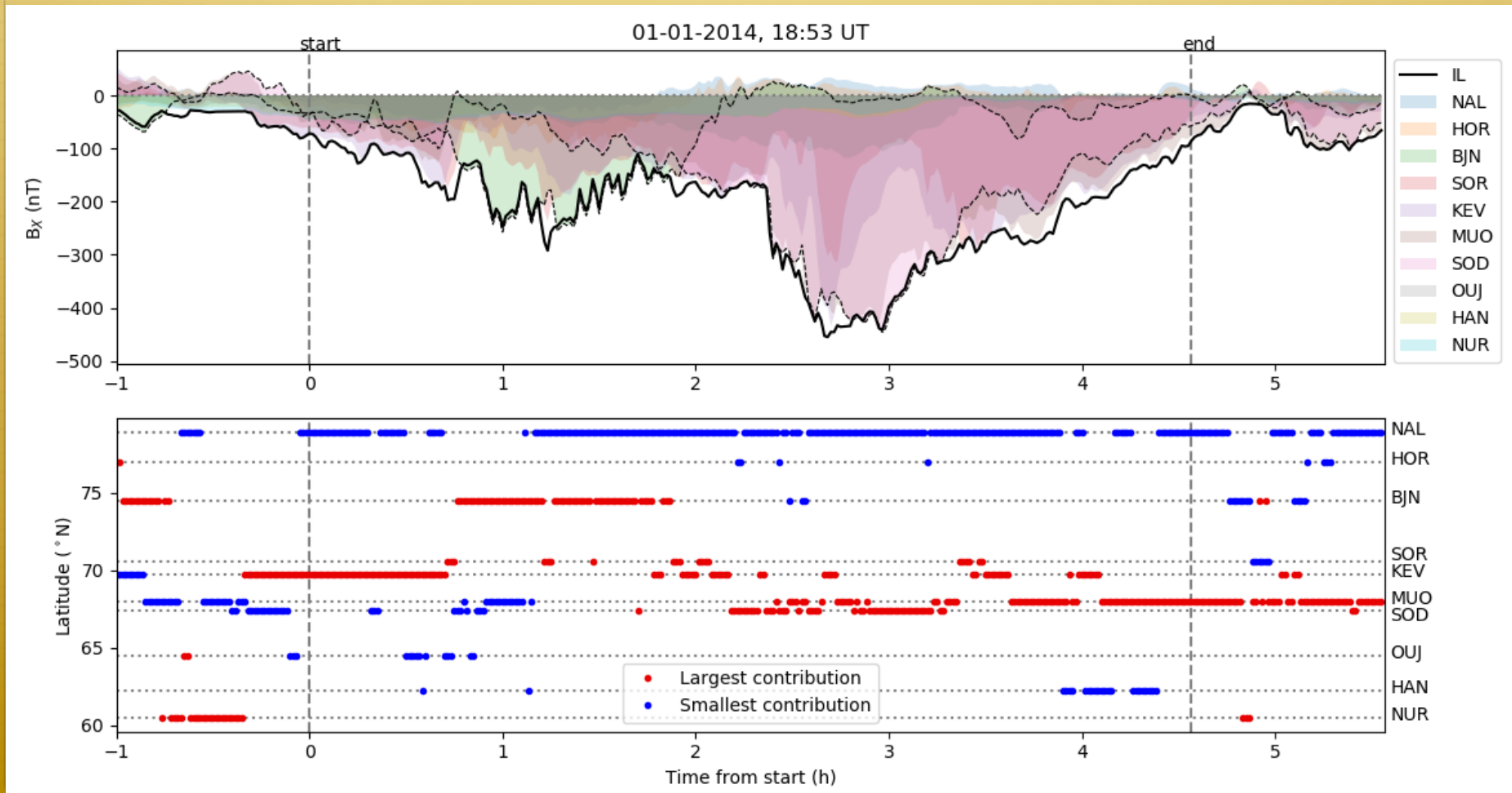
Magnetic environment





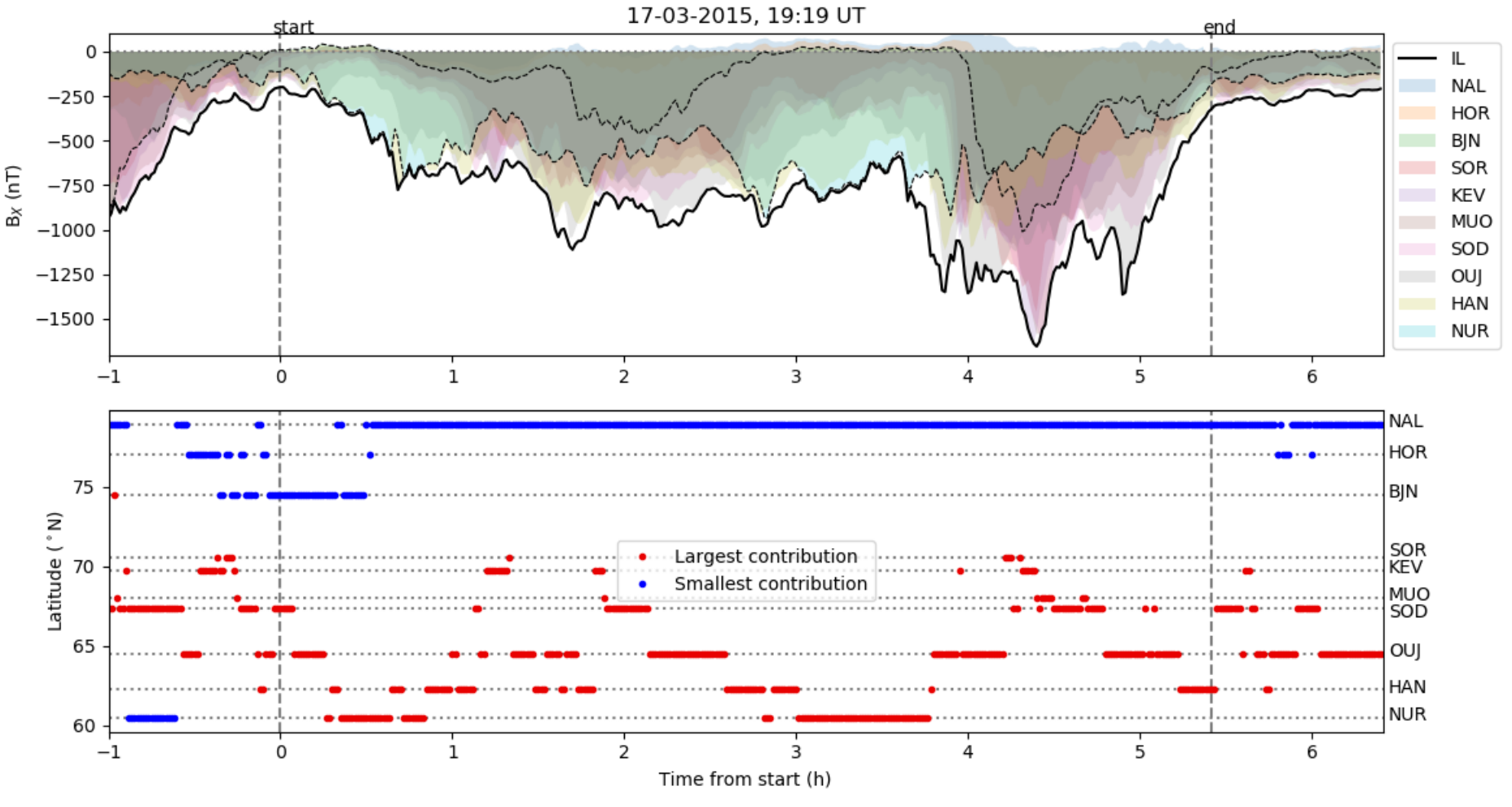
Substorm on 1st January 2014

The peak amplitude during the first expansion in Bear Island and during main expansion around Muonio & Sodankylä. Several expansions and contractions of auroral oval seen.



Substorm on 17th March 2015

The latitude of the peak substorm intensity varies a lot between Kevo and Nurmijärvi. Several southward expansions detected during 5 h interval.



How well single station data can be used to estimate substorm characteristics?

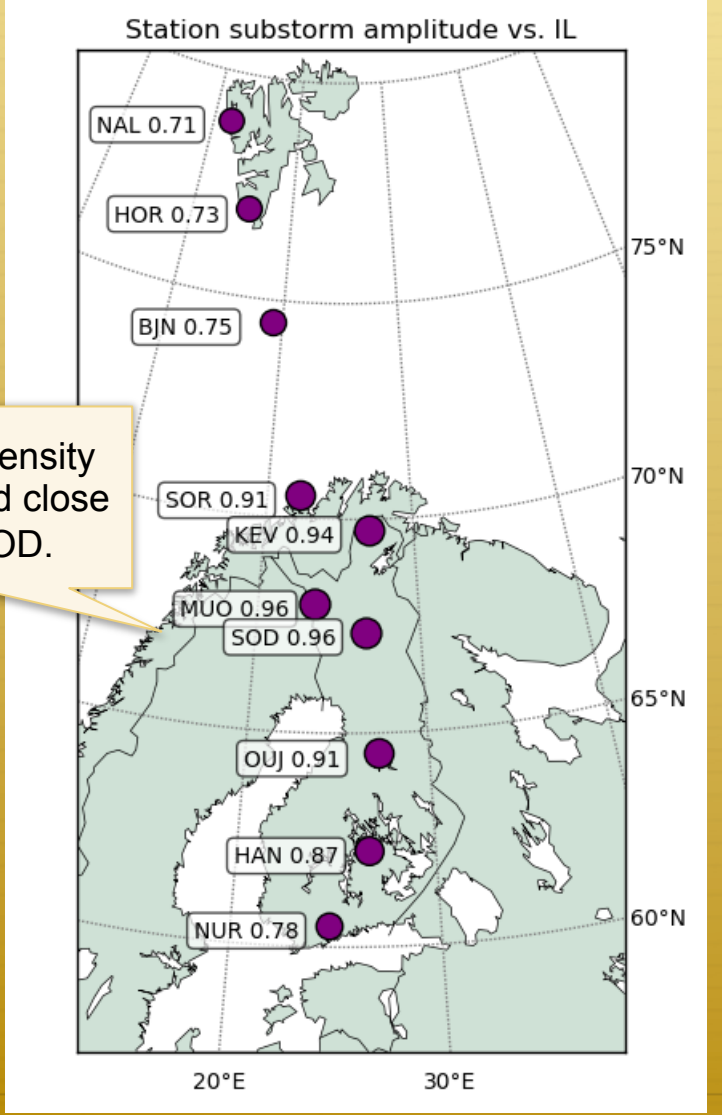
- Substorm intensity and length
- Substorm occurrence rate
- Ionospheric energy dissipation

For simple events (such as example 1) maybe quite well but for dynamic substorms (such as example 2) maybe not.

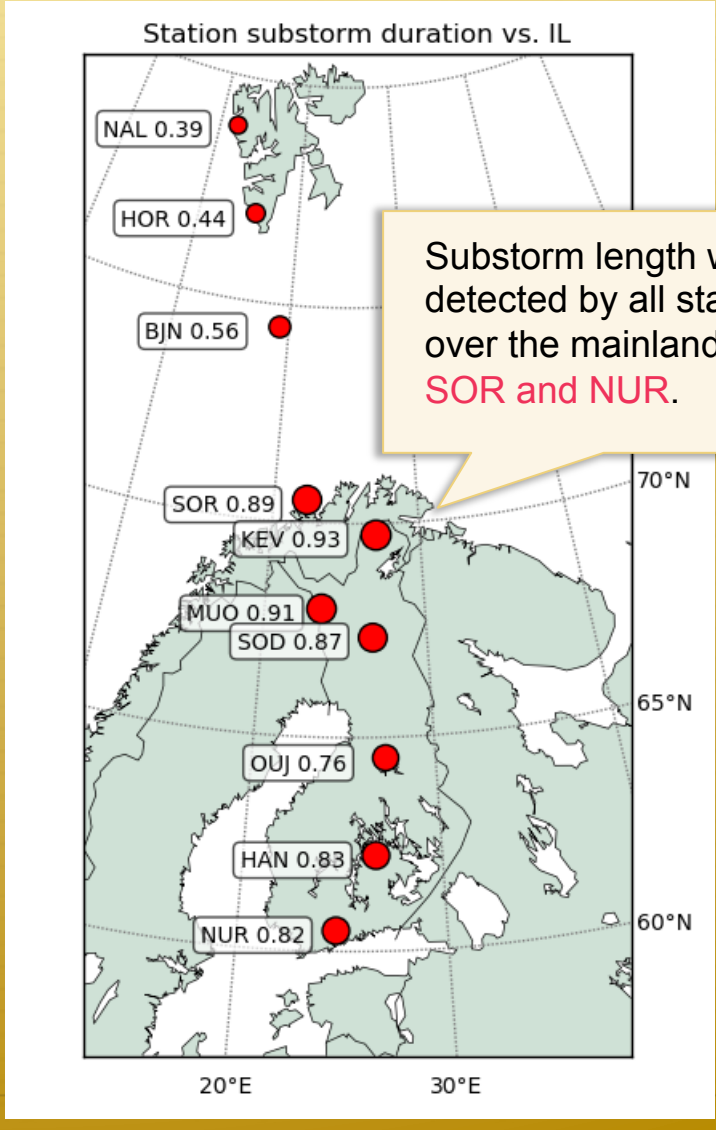
Let us take a closer look.

Substorm intensity and length

Simple AI method used to identify substorms from 1993 to 2018 (Tanskanen, 2009).



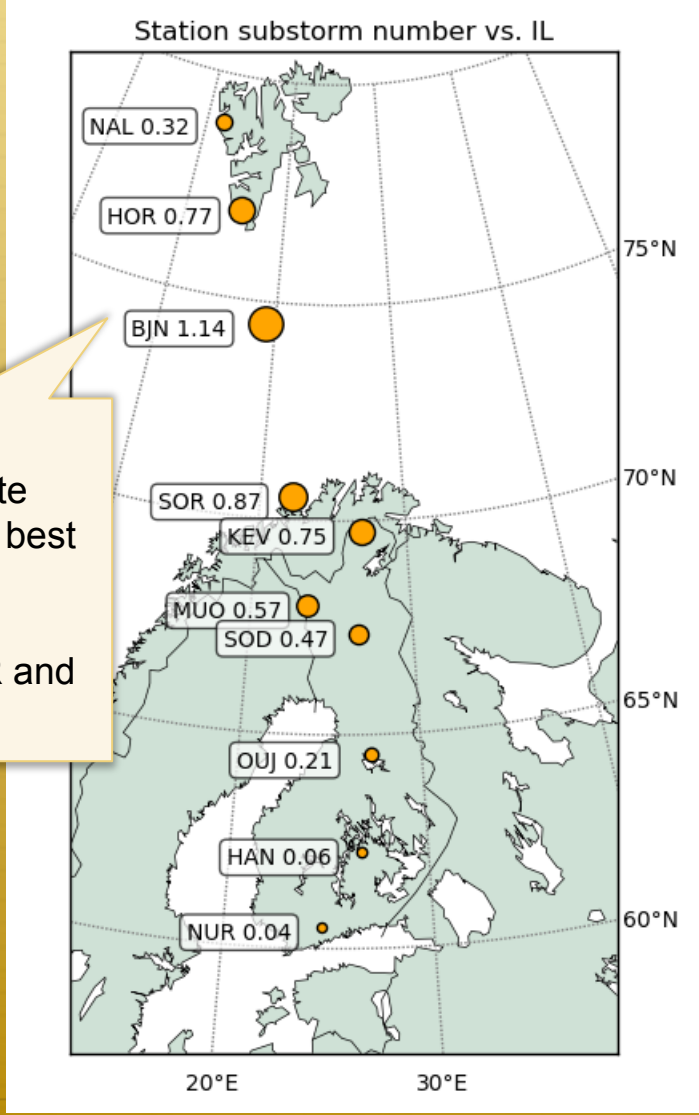
Substorm intensity best detected close to MUO & SOD.



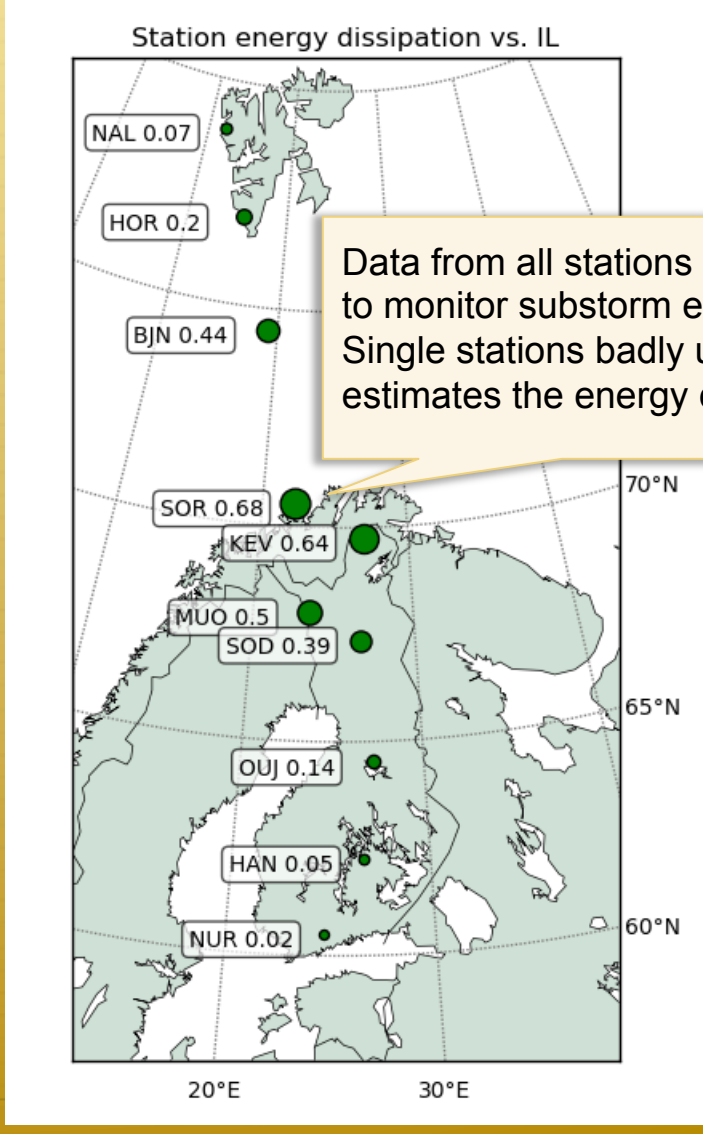
Substorm length well detected by all stations over the mainland between SOR and NUR.

Substorm number and dissipation

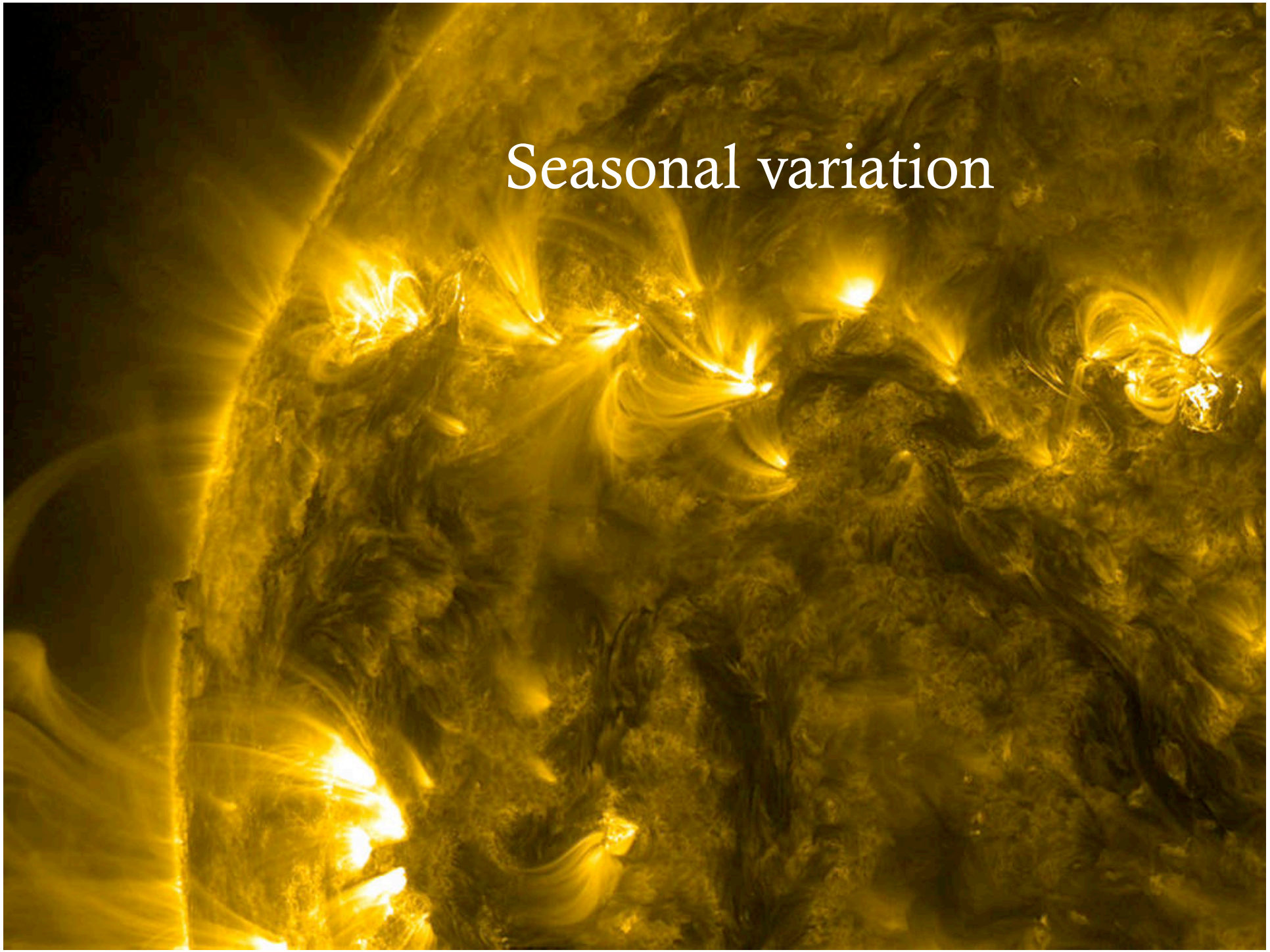
Jaakonaho I., MSc thesis, 2019



Substorm occurrence rate from IL match best with ground observations between HOR and SOR.

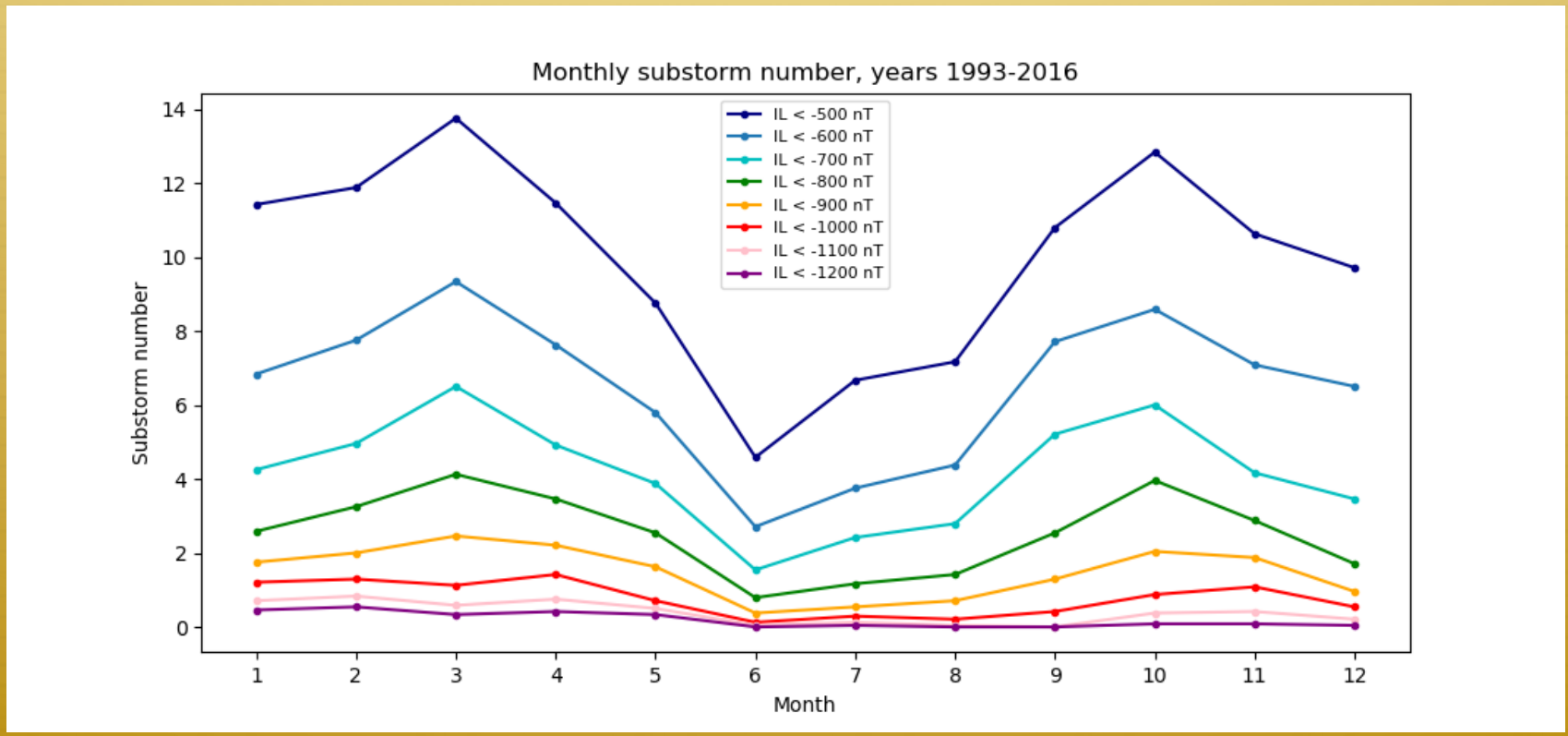


Data from all stations is needed to monitor substorm energetics. Single stations badly under-estimates the energy dissipation.


Seasonal variation

Seasonal variation of substorms in different activity levels

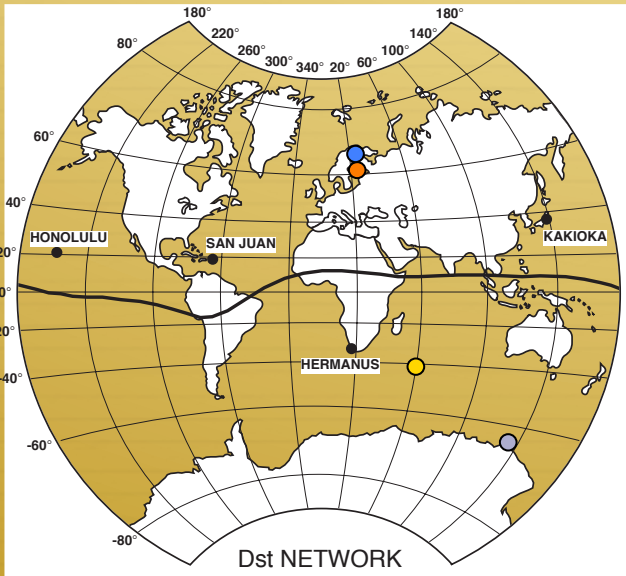
→ Seasonal variation less pronounced for large substorms.

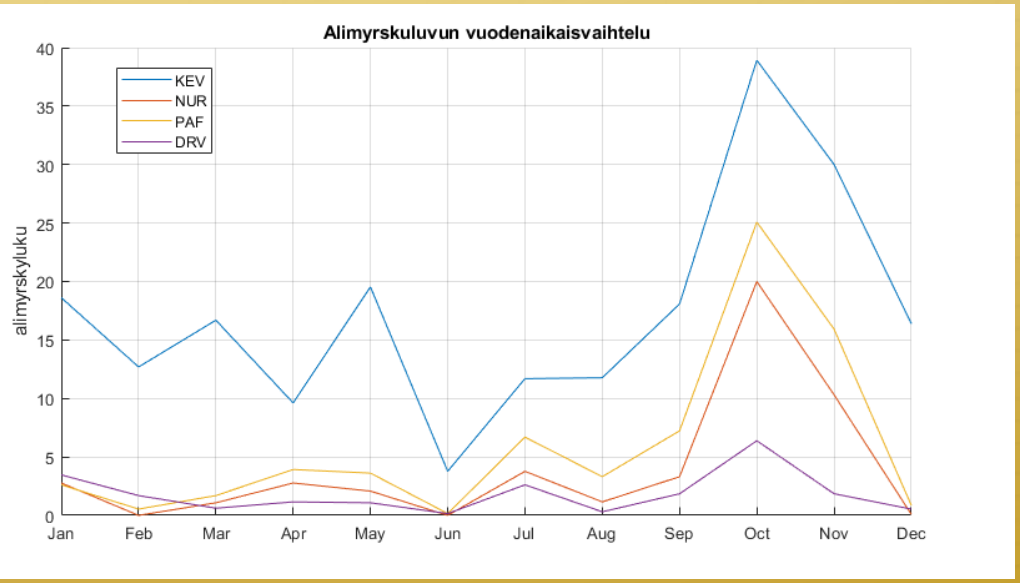


Tanskanen et al., 2017b; Tanskanen and Jaakonaho, 2019

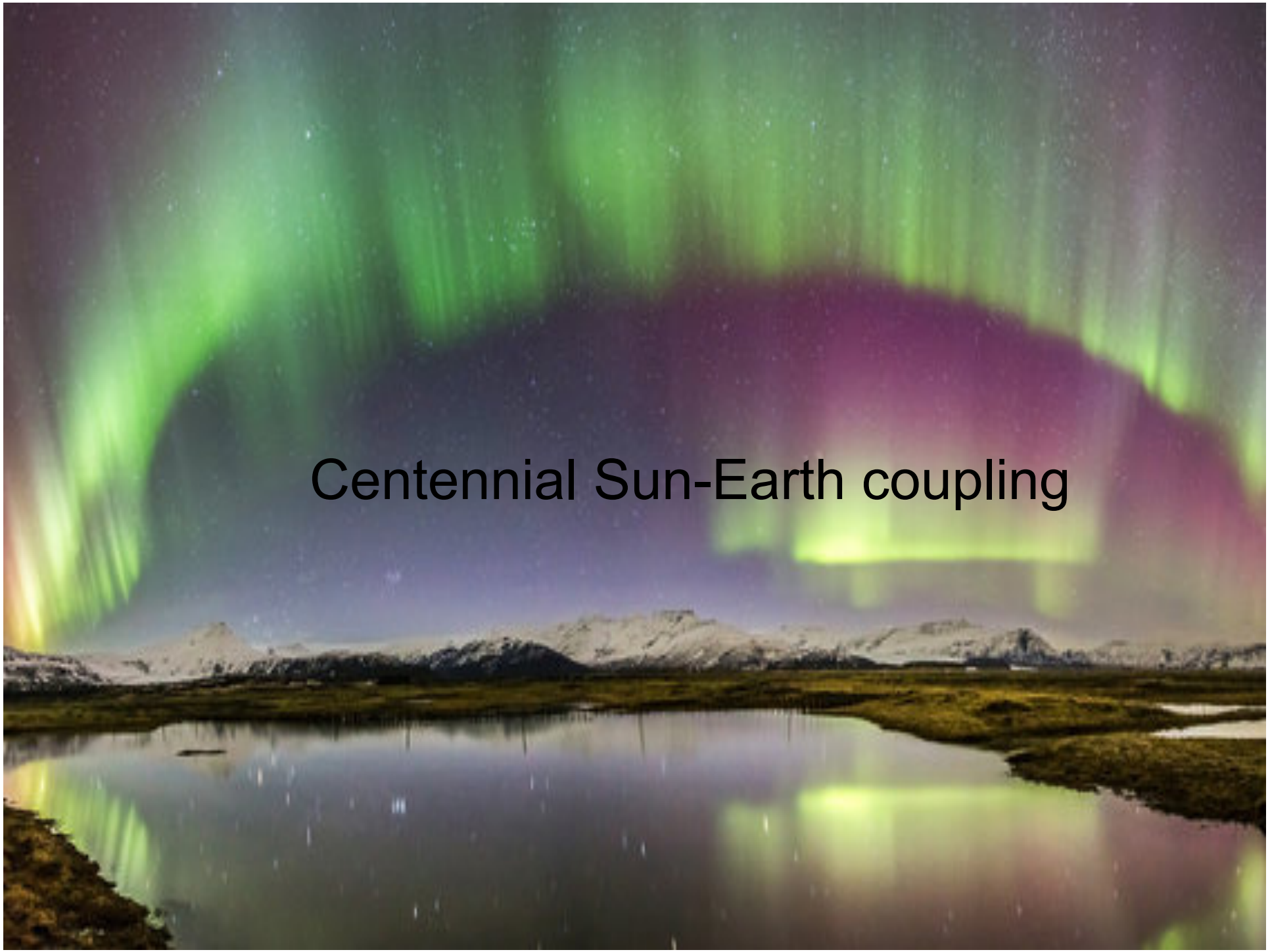
Seasonal variation in the southern hemisphere

Luomanen, J., BSc thesis, 2018

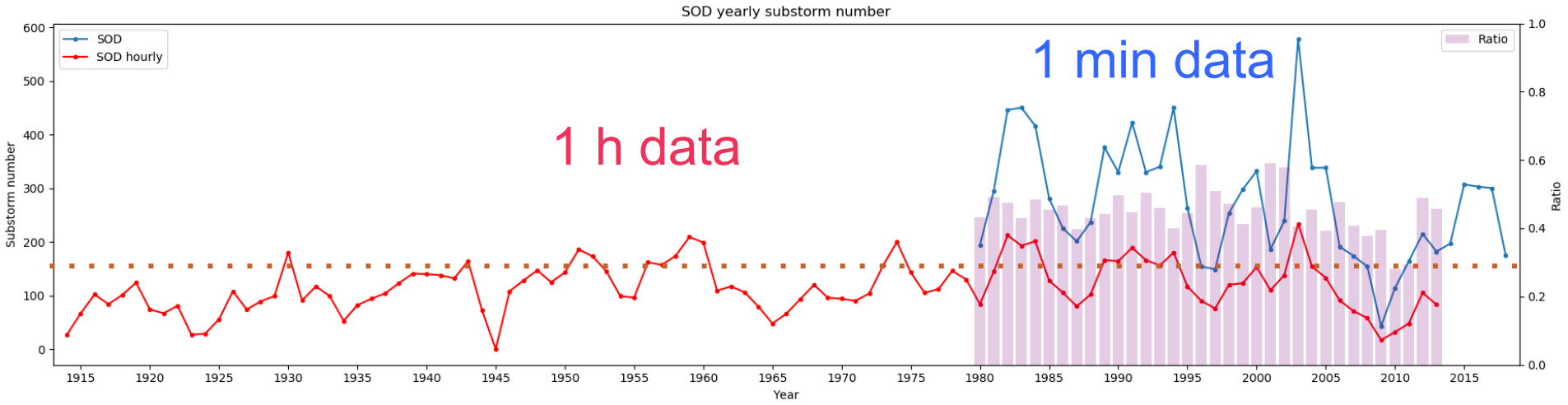




→ Similar variation in the southern and the northern hemisphere.
→ The cause cannot be purely due to the dipole tilt or conductivity.


Centennial Sun-Earth coupling

Centennial variability of substorms



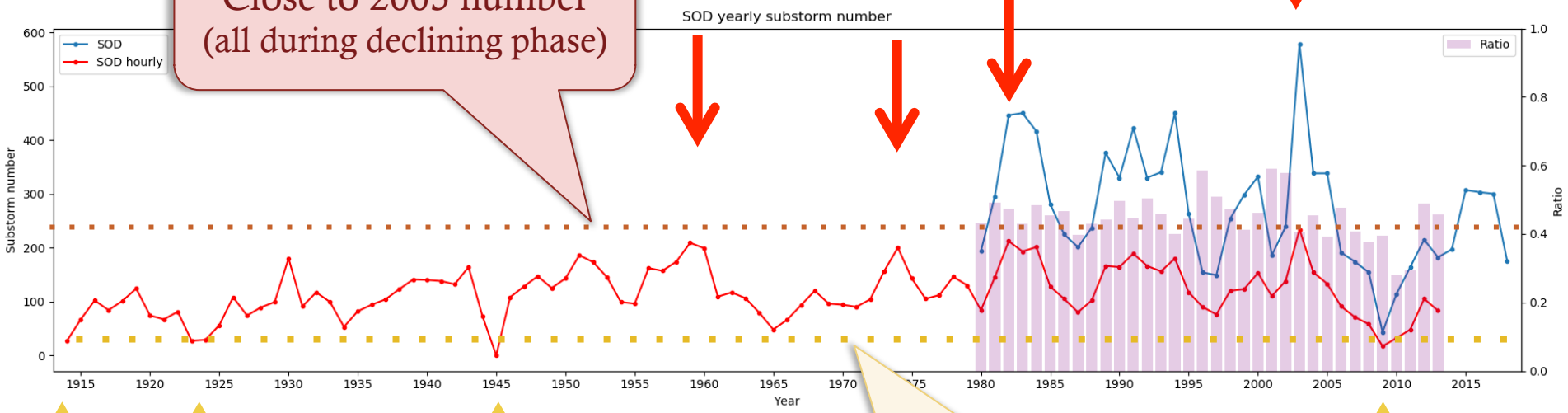
Centennial variability of substorms

2003
Centennial maxima

1982

1959 1974

Close to 2003 number
(all during declining phase)



1914

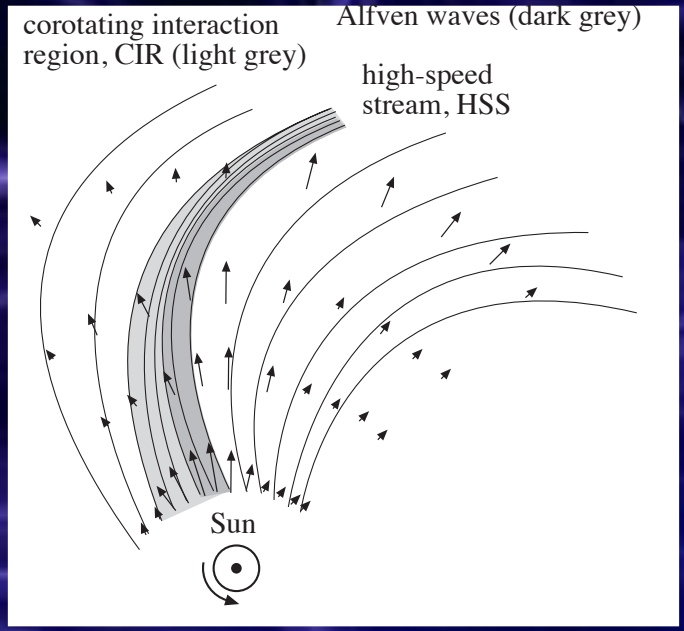
1924

1945
No data

Below 2009 number
(all during solar minima)

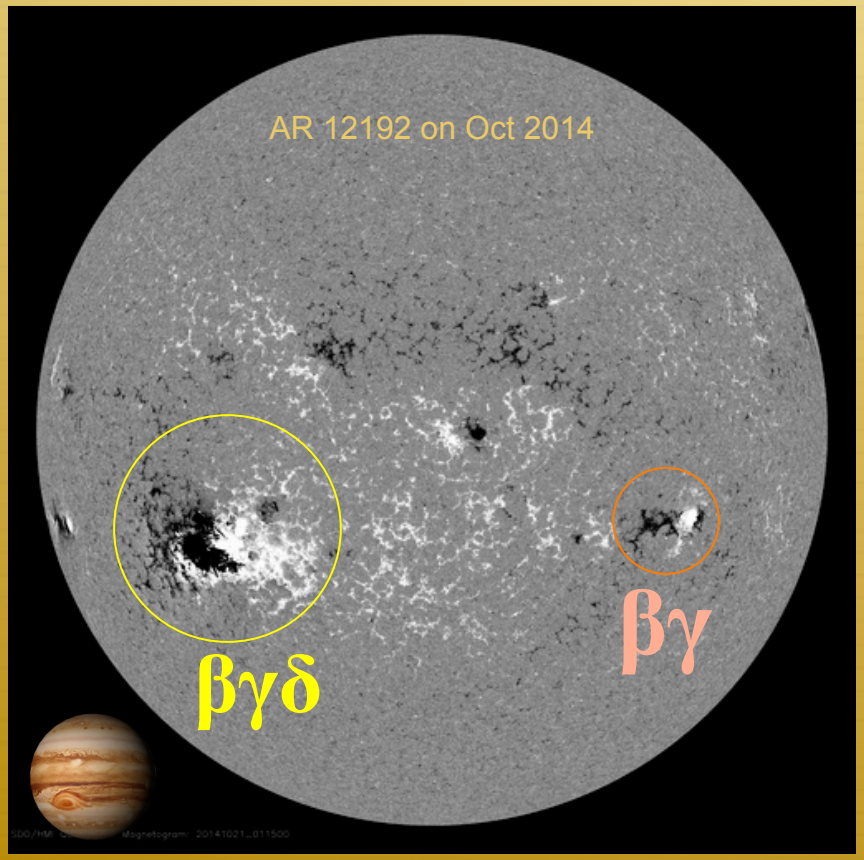
2009
Centennial minima

The Sun is the ultimate source of magnetic disturbances



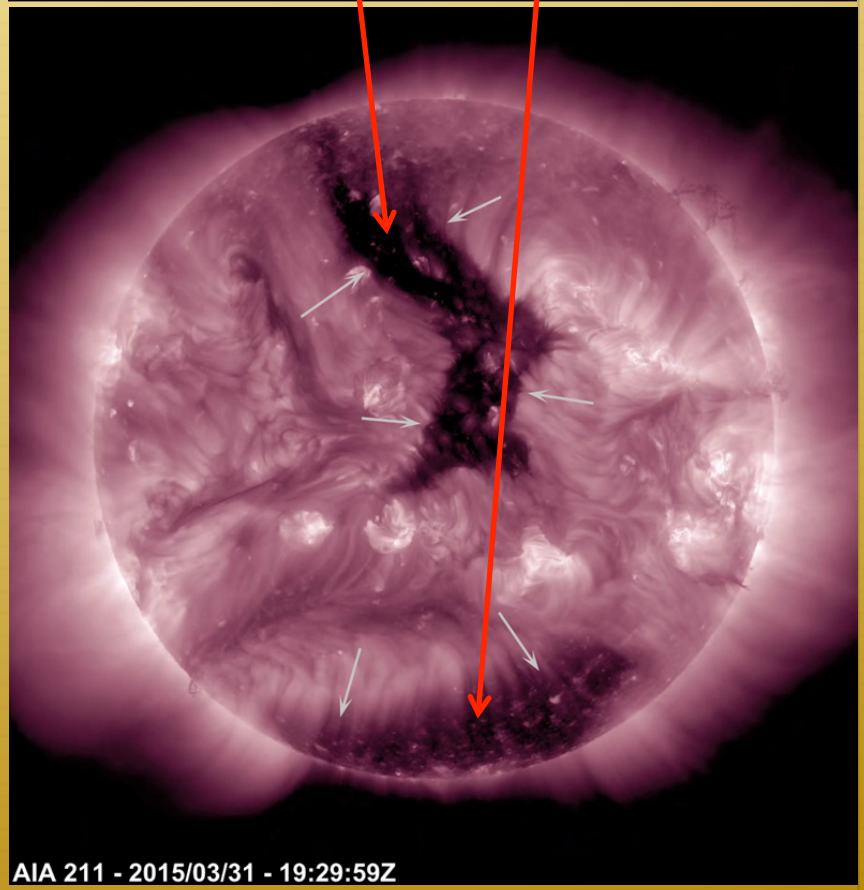
Sources of geomagnetic activity:
active regions and coronal holes

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



Nikbakhsh et al., A&A, 2019

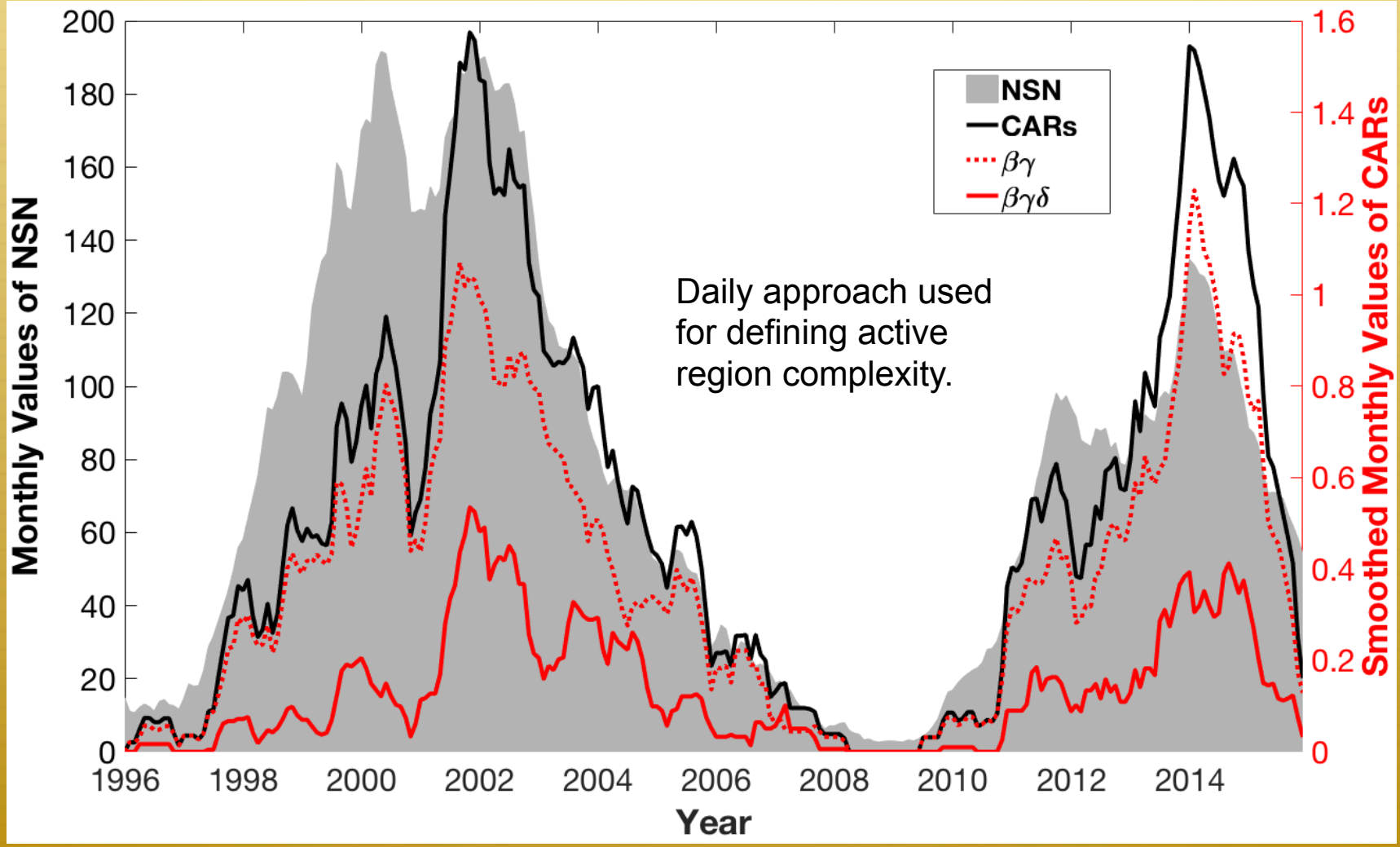
Fast solar wind originating from the polar coronal holes carry solar wind fluctuations from the Sun towards the Earth.



Tanskanen et al., JGR, 2017a

Solar cycle evolution of complex active regions, CARs

Nikbakhsh et al., A&A, 2019



Hale & Nicholson (1938): Average magnetic class was used, no correlation with sunspot cycle was found.

Summary of results

- Substorm length and amplitude can be estimated surprisingly well with single station data. Data from all stations is needed to monitor substorm energetics.

- Similar seasonal variation is seen in the northern and southern hemisphere indicating the important role of external sources such as coronal hole shape and active region magnetic field morphology.

- Seasonal variation is less classical for stronger substorms (substorm intensity above 1000 nT) possibly due to the storm-substorm interaction.

- Centennial analysis underlines the importance of declining phase phenomena for auroral oval dynamics.

Thank you !

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