dB/dt spikes during Space Weather events

Audrey Schillings

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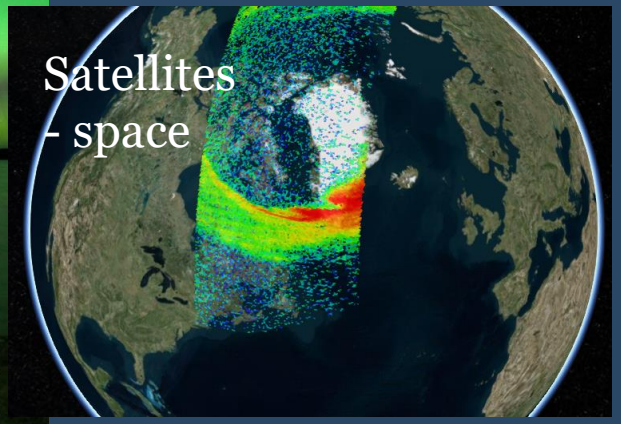
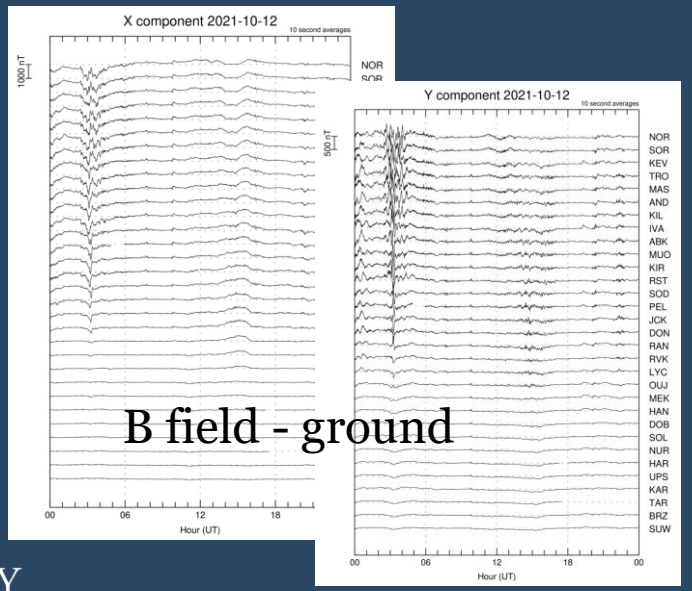
Credits: Oscar Stål/Fotoräven.
12 Oct 2021, Umeå, Bäcksjön



Credits: DMSP F17/SSUSI. Orbit 77091.
12 Oct 2021



Credits: IMAGE network

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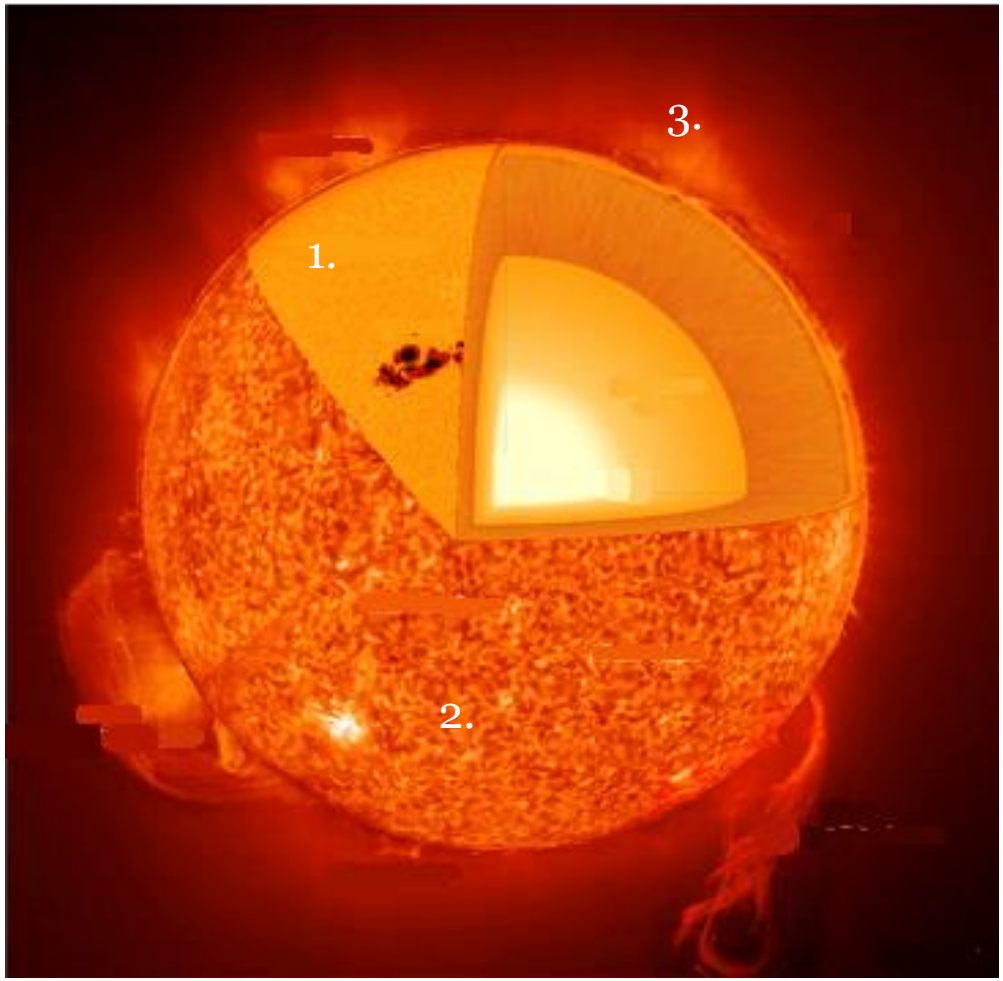
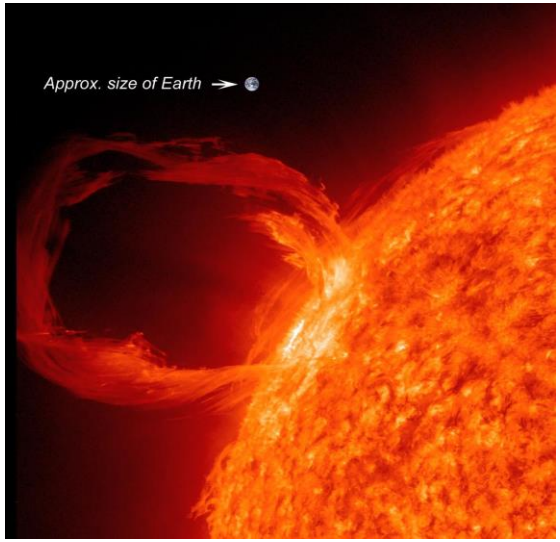
The Sun and its atmosphere



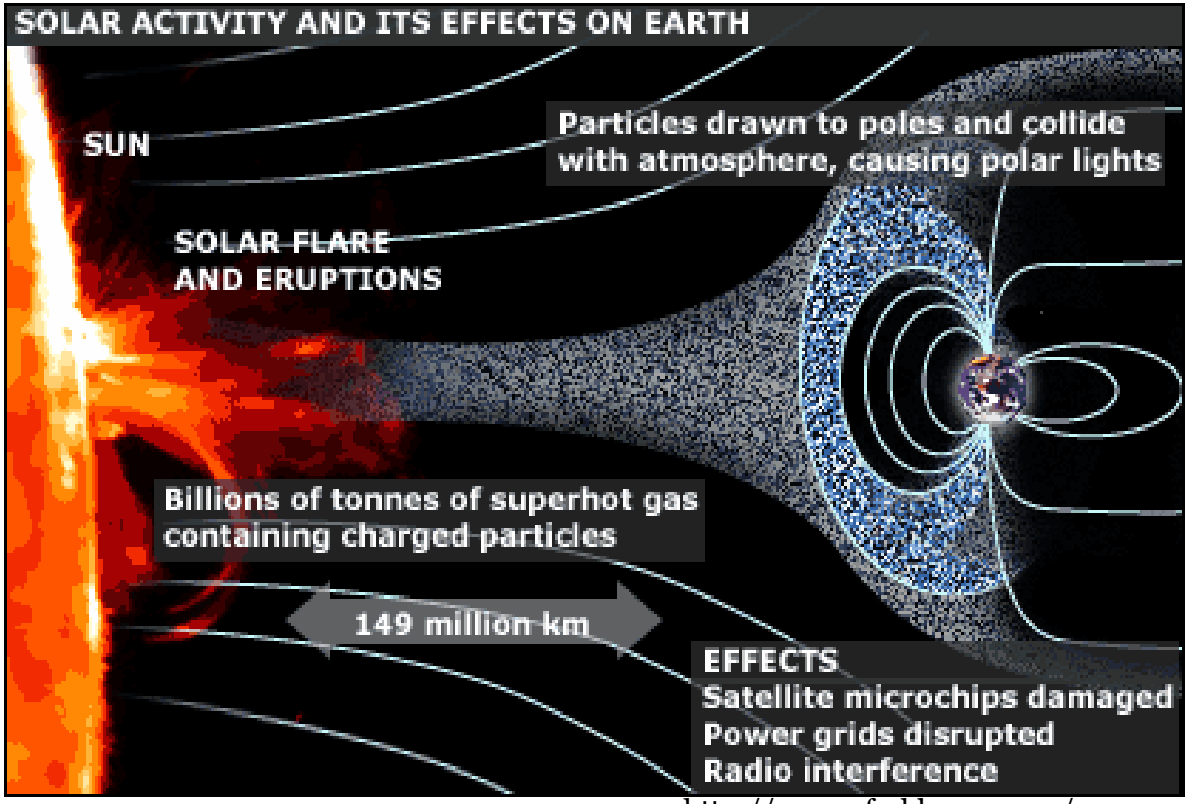
Credits: http://study.com

1. **Photosphere**
   → Most of the Sun light, sunspots
2. **Chromosphere**
   → Active regions
3. **Corona**
   → Observed solar flares, coronal holes

The solar-terrestrial environment



https://www.nasa.gov/



http://www.ufo-blogger.com/

1. Solar flares
2. Coronal mass ejections or CMEs
3. High-speed solar wind (CH)
4. Solar energetic particles or SEP

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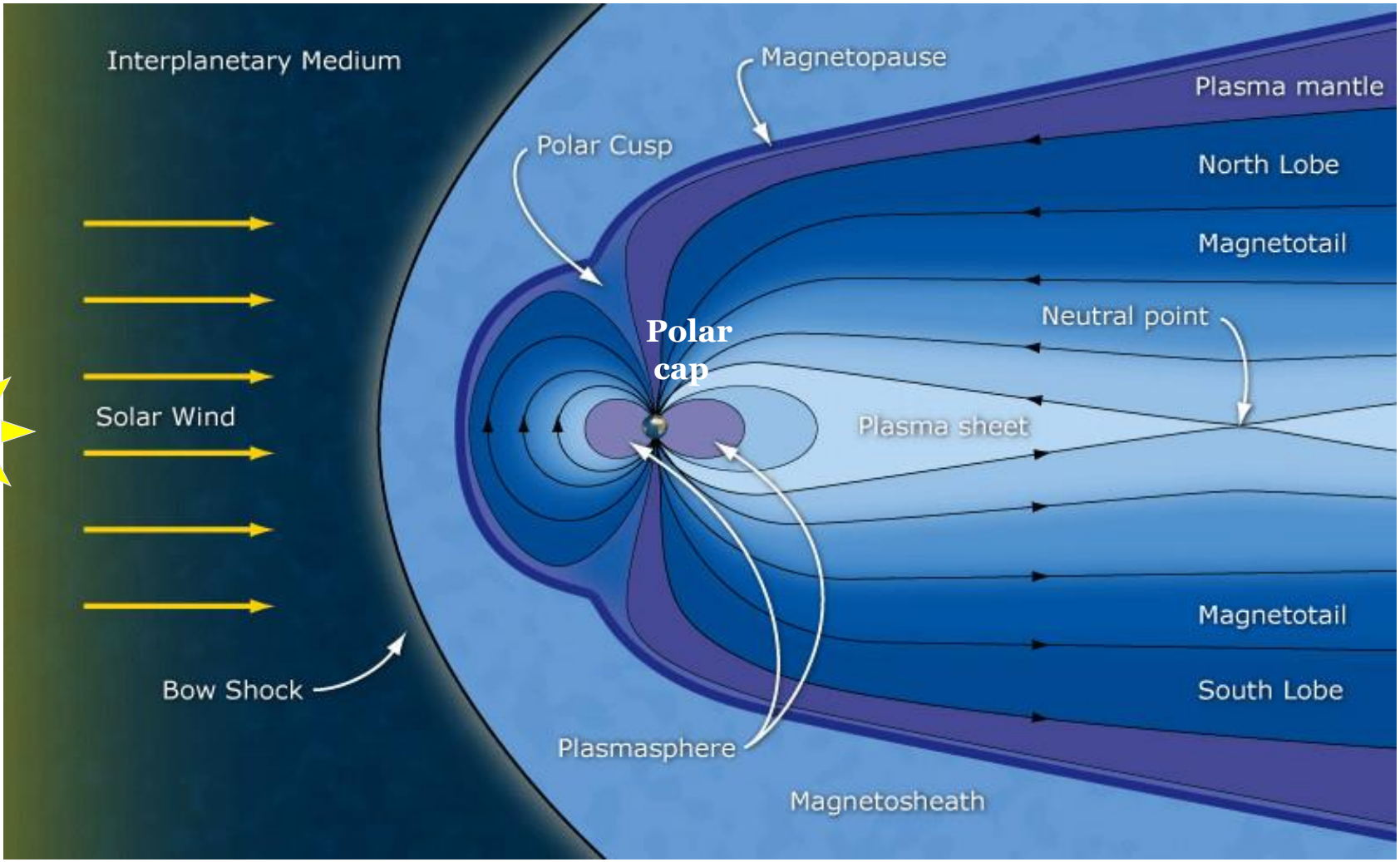
The **solar wind** is a stream of charged particles coming from the solar atmosphere.

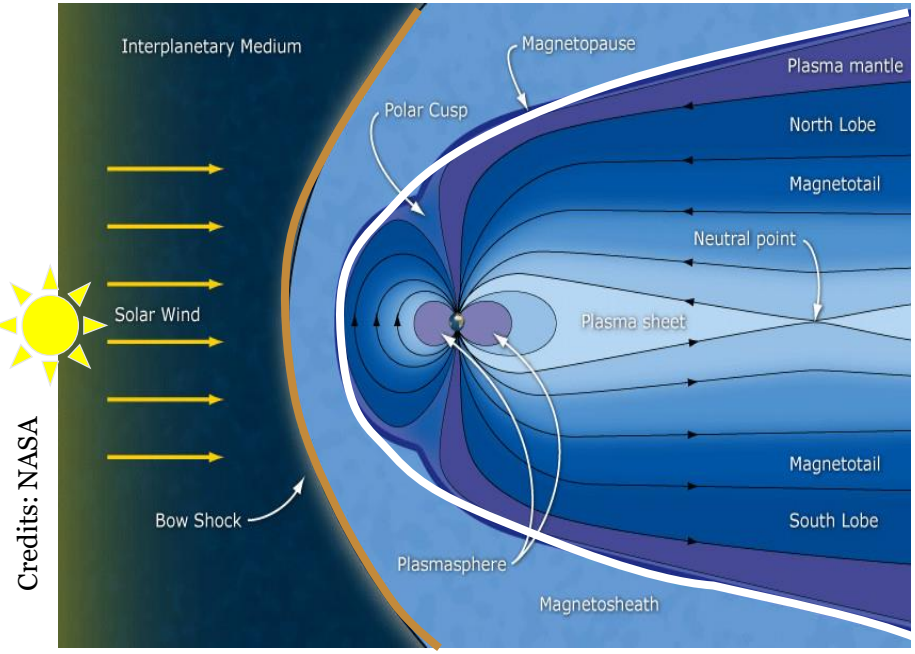
Earth's magnetosphere



Credits: NASA

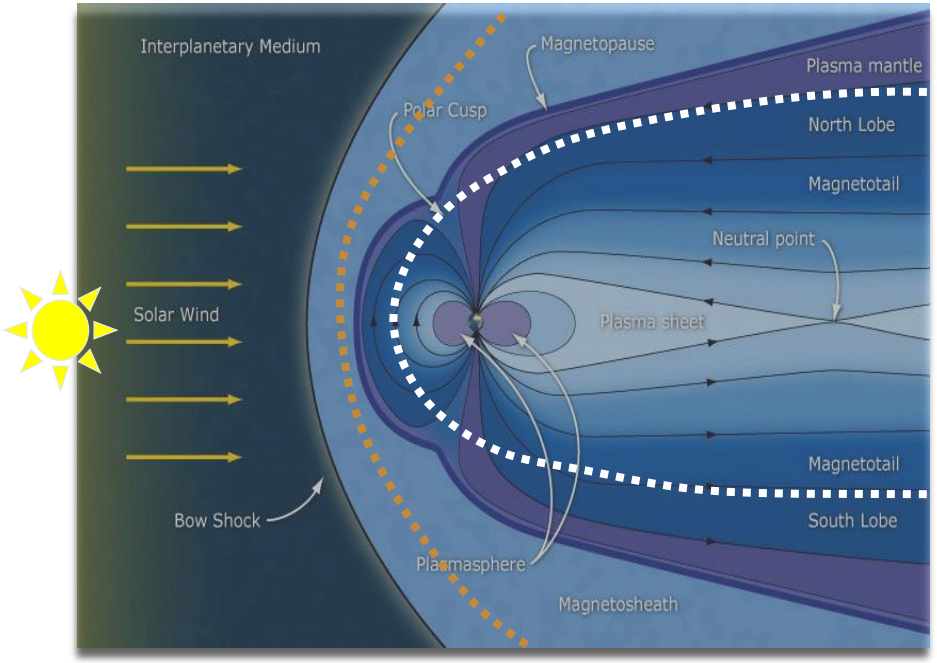
Impacts of geomagnetic storms on the Earth's magnetosphere

Quiet time



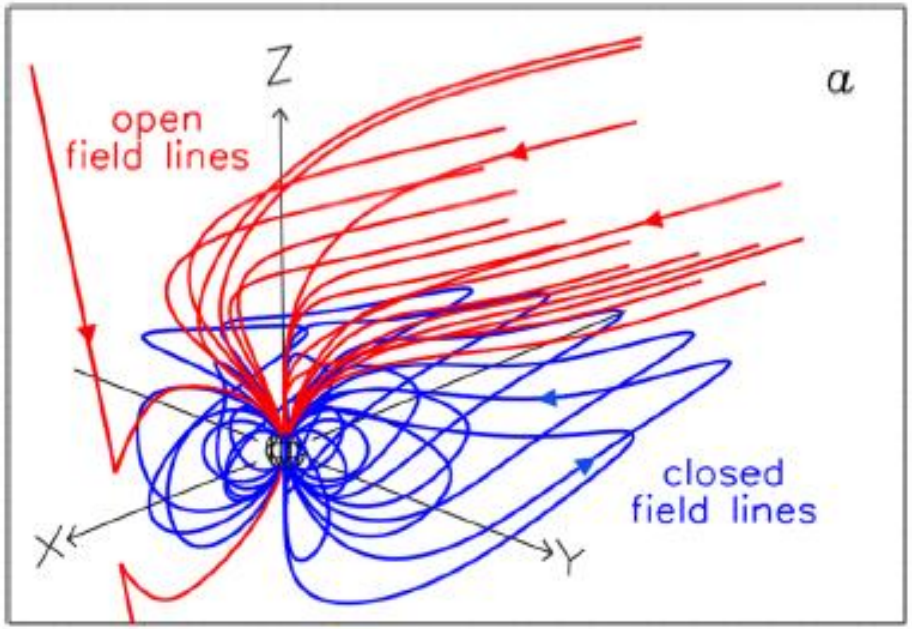
Credits: NASA

Active time



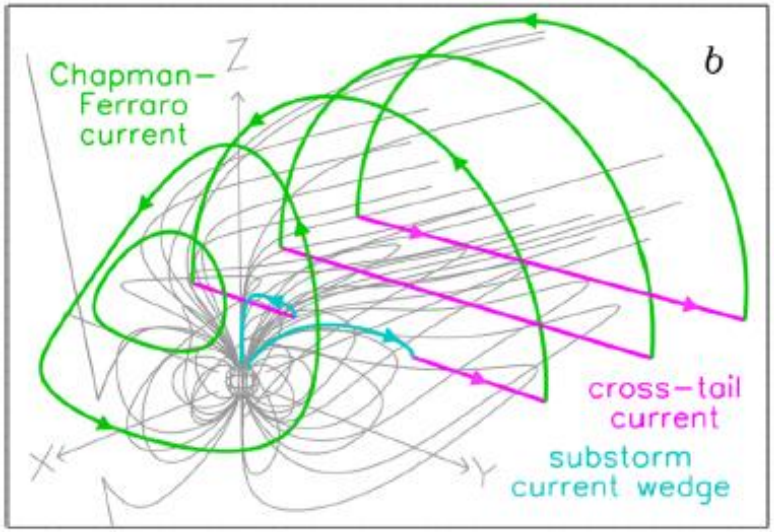
Earth's magnetosphere

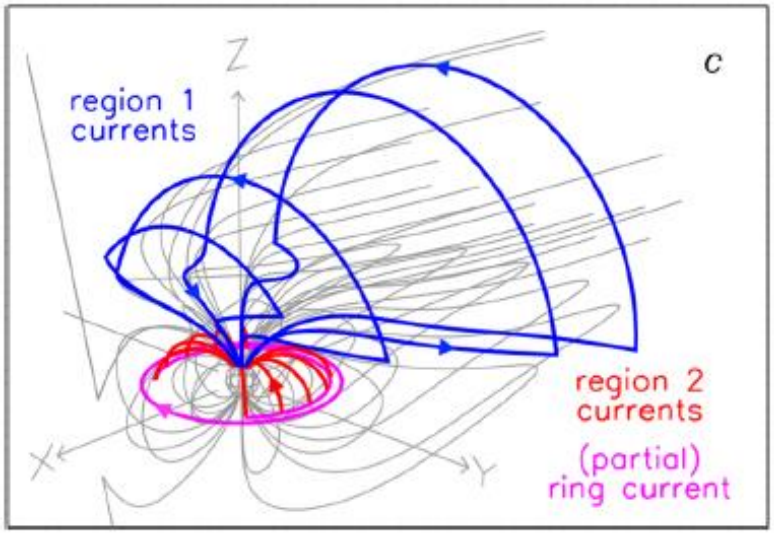
B field lines



Credits: S. Milan et al., 2017

Magnetospheric currents systems





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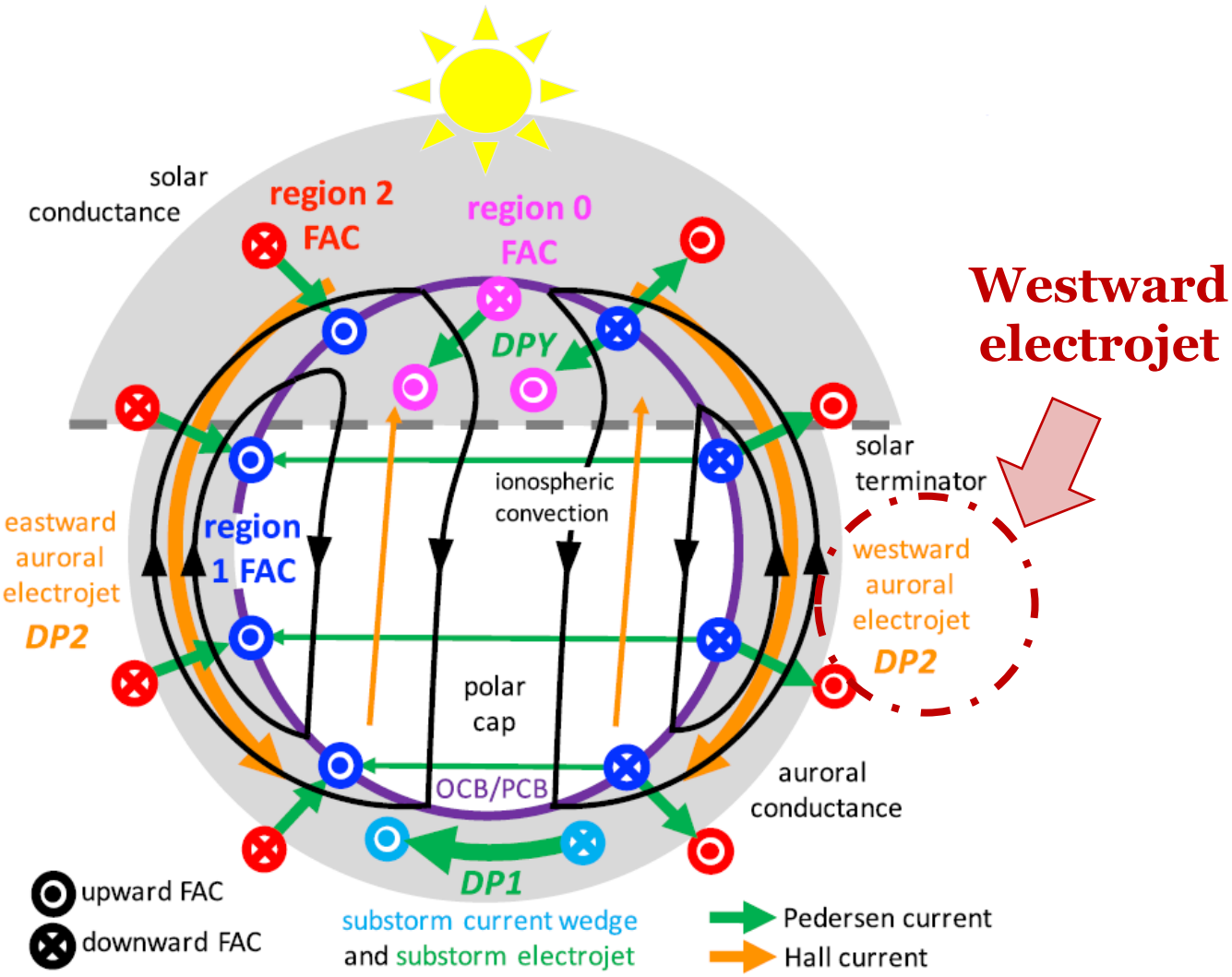
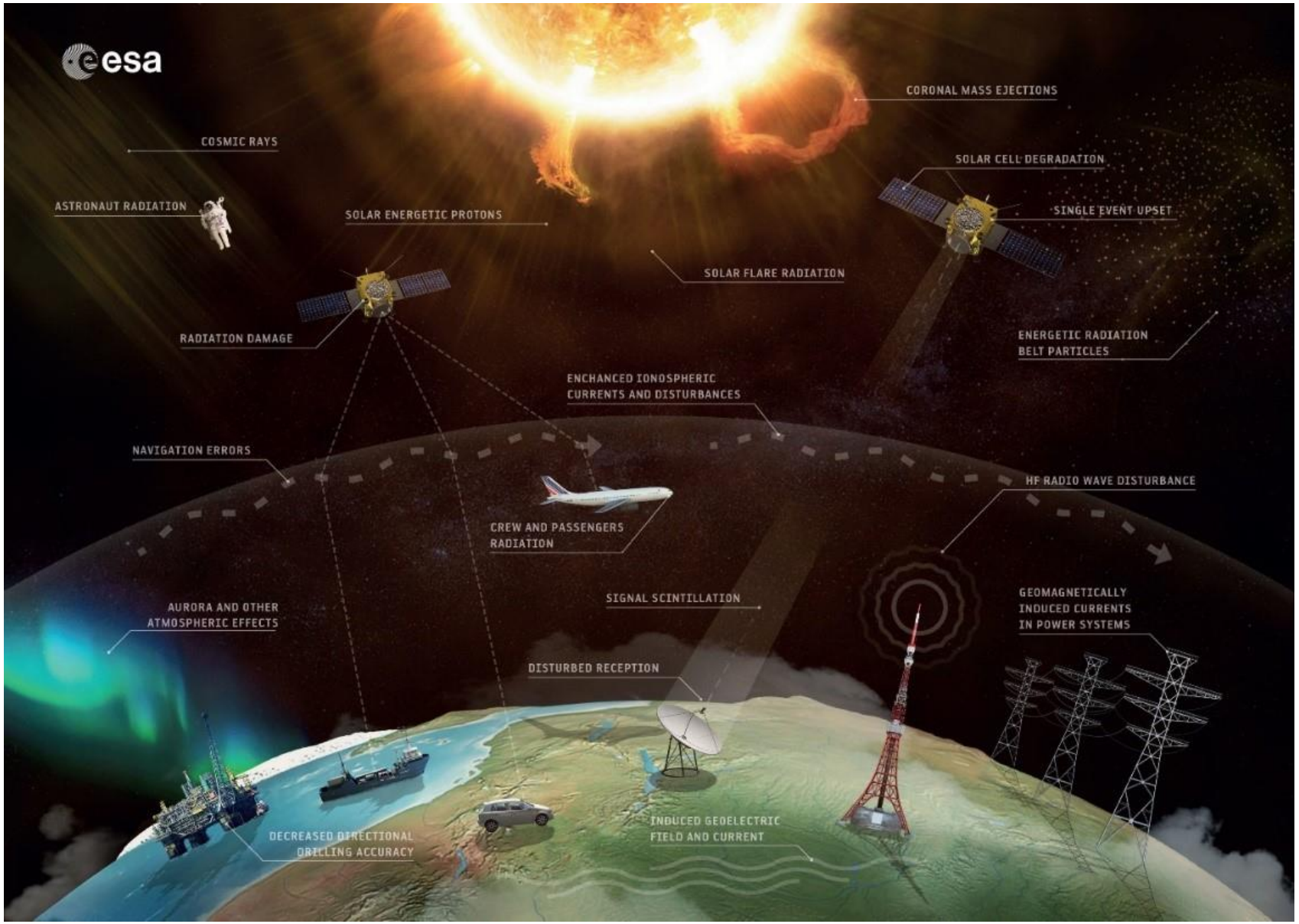
Earth's current system in the polar regions

Top view from the pole



Credits: S. Milan et al., 2017

Space weather

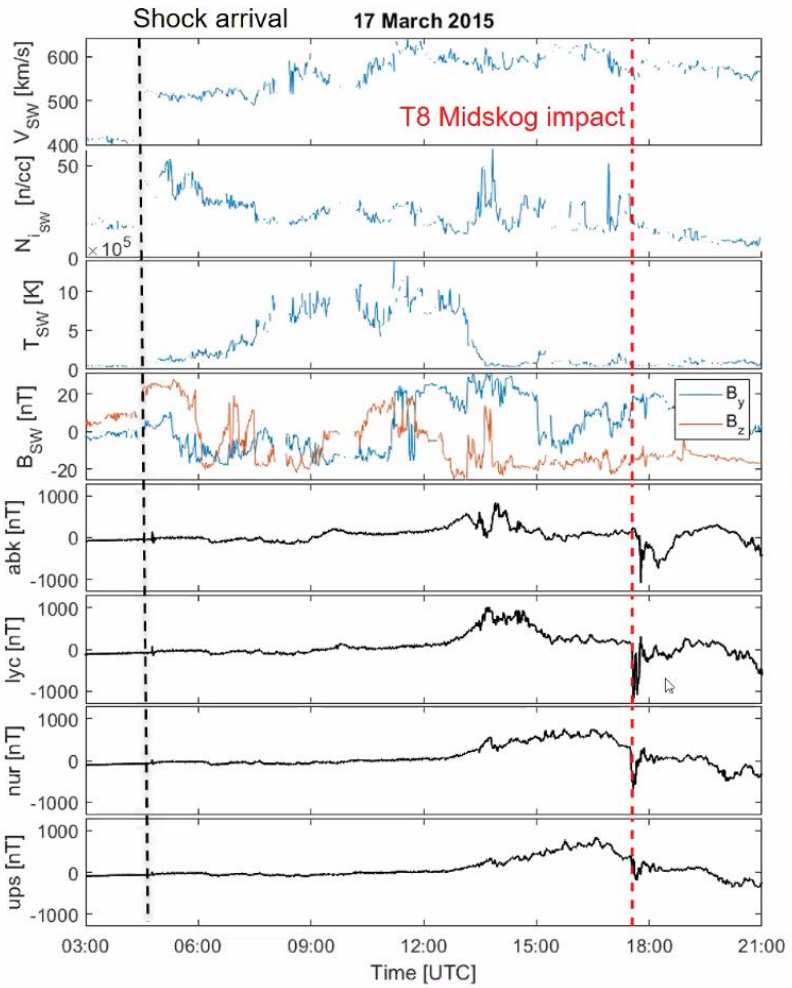


Credits: ESA

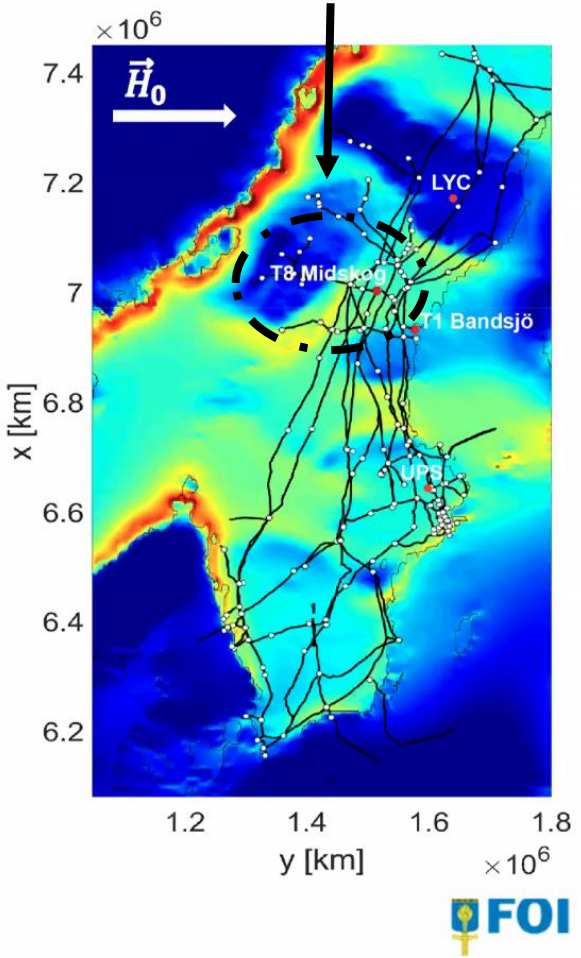
The St Patrick's storm: Mar 17, 2015

GICs in Scandinavia

Disturbances in part of the grid 17:33 UT



T8 Midskog ~200 km south of LYC



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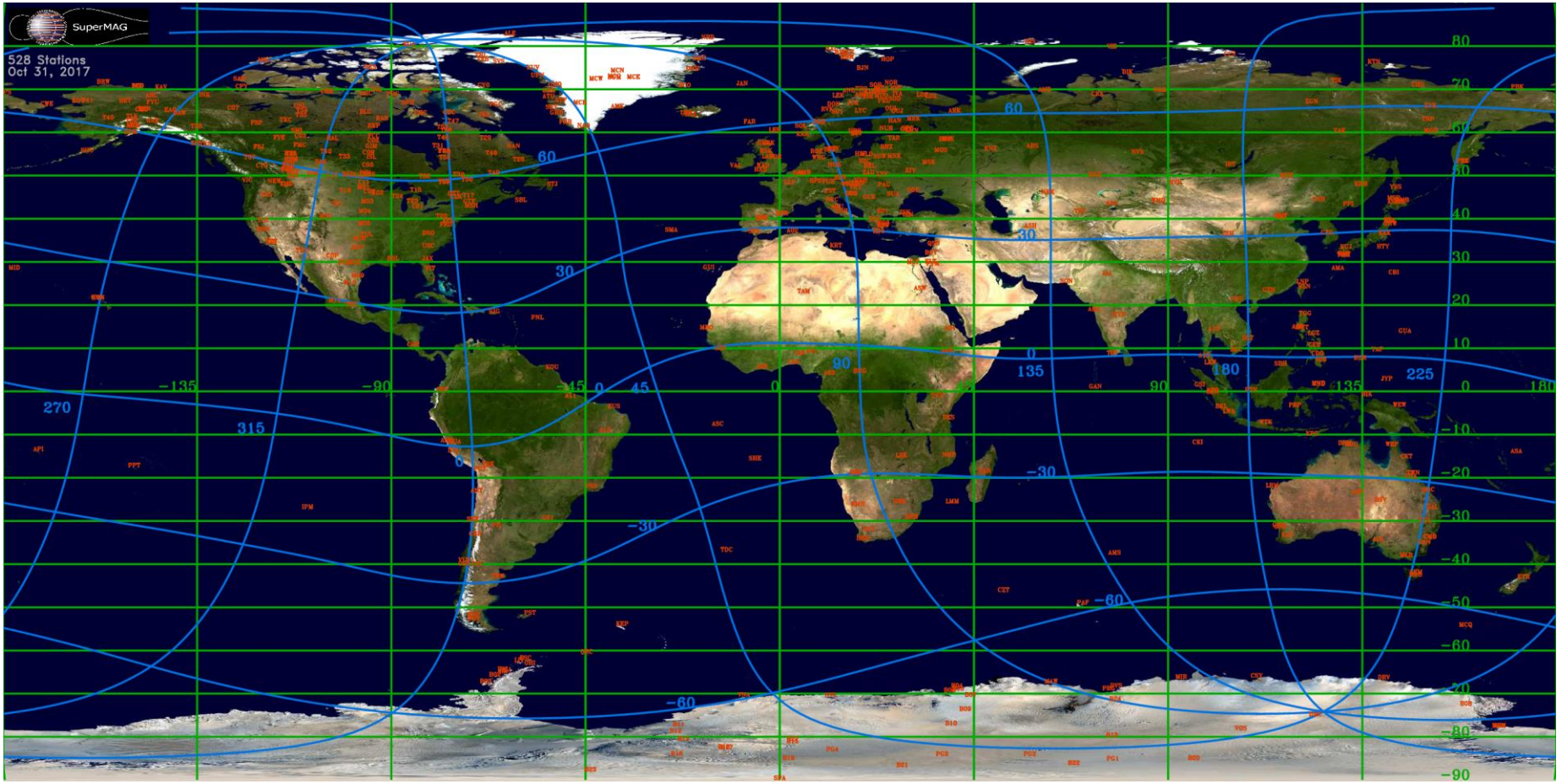
Credits: L. Rosenqvist, SWx workshop 2021, FOI

Map of the SuperMAG stations

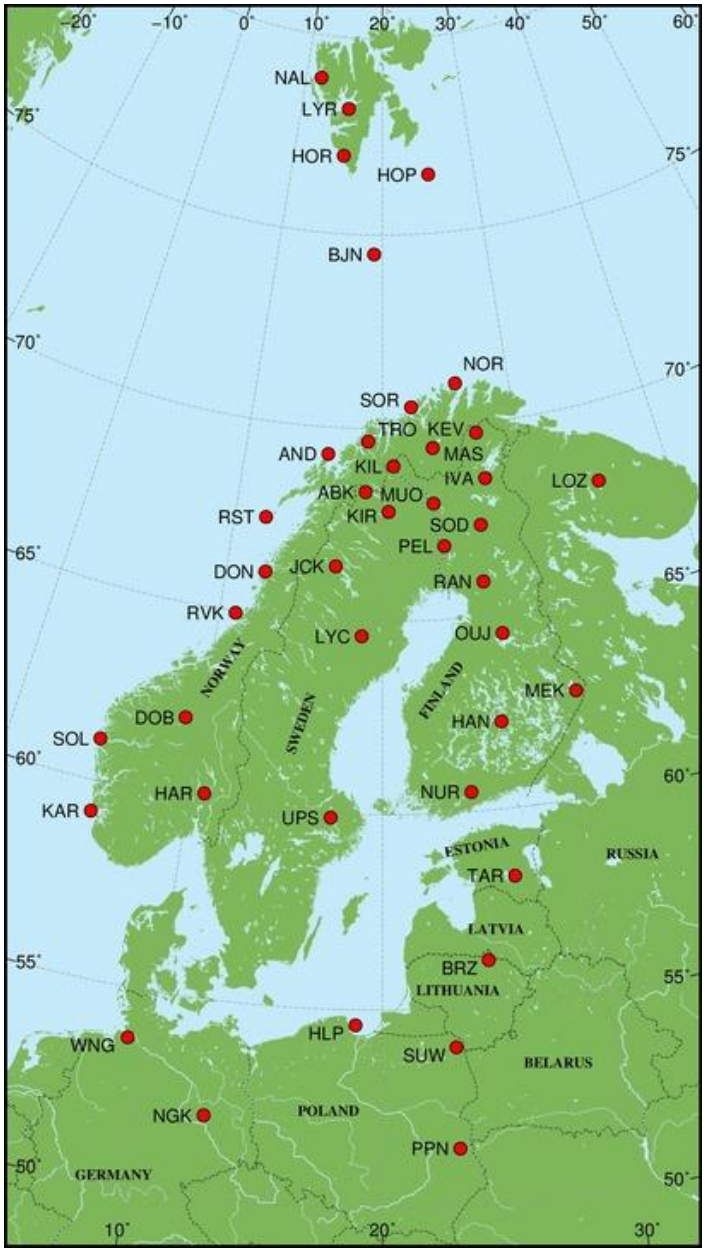
- Worldwide coverage (ESA, NASA, NSF)
- Green = geographic coordinates
- Blue = geomagnetic coordinates



https://supermag.jhuapl.edu/

Map of the IMAGE stations

- Scandinavia coverage (SGU, IRF, FMI, nfu, UiT, Un. Of Oulu, GFZ, In. of Geo. Polish Aca. Of Sci.)
- 41 stations
- 10 sec and 1 sec resolution



https://space.fmi.fi/image/

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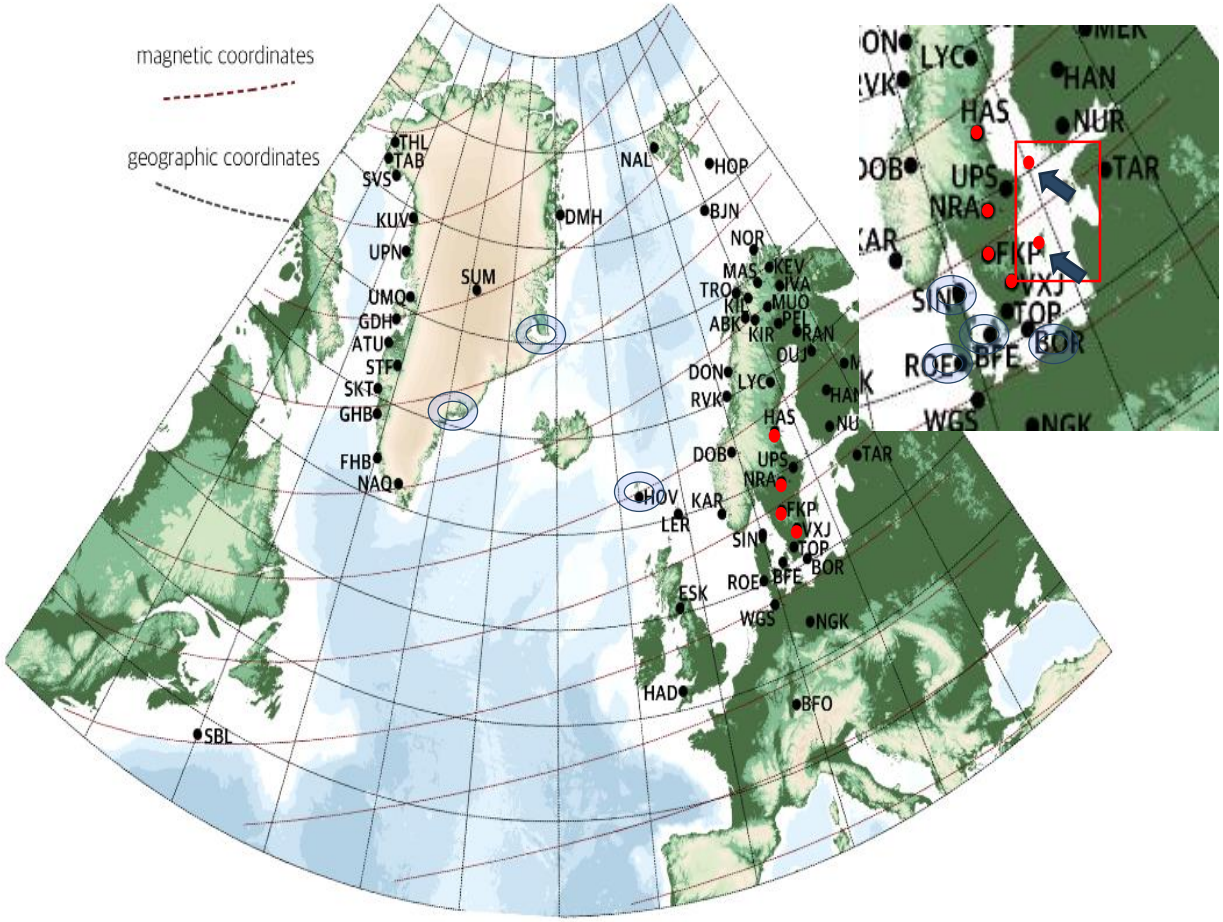
Map of the MAG-SWE-DAN stations

- Extended Scandinavia coverage (SGU, DTU, ESA)



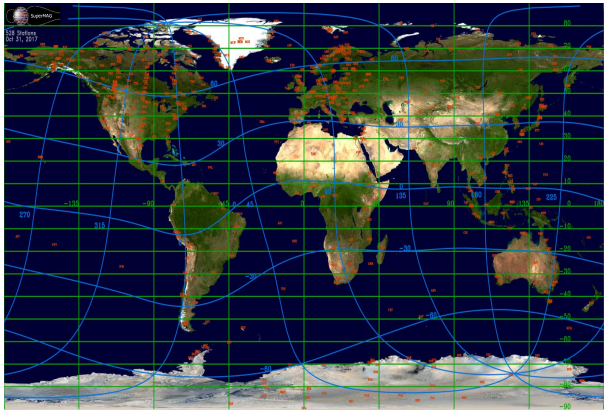
- Växjö
- Falköping
- Nora
- Hassela
- Åland
- Gotland
- Sindal
- Bornholm
- Rømø
- Brorfelde
- Hov -Farør
- Greenland

Credits: Map from DTU, Denmark

Detection of dB/dt spikes during storms Statistics

- **Storms**: Storm list created for this study by M. T. Walach (Oct 2020)
- 307 storms with a SYM-H index < -100 nT

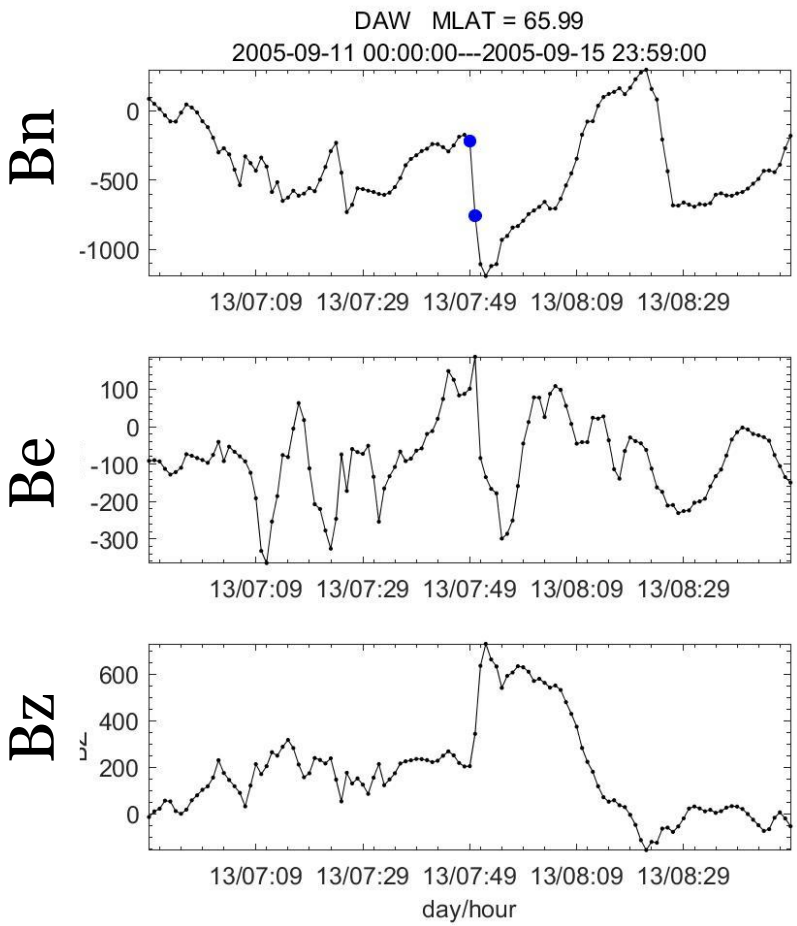
- **Magnetic data**: SuperMAG global magnetometer network (Gjerloev, 2012)
- 1 min data, NEZ coordinates, all stations available for the storm
- Threshold:
    1. Moderate spikes |500| nT/min < |dB/dt| < |1000| nT/min
    2. Extreme spikes > |1000| nT/min
- 3 categories of spikes :
    1. good,
    2. after/before data gap,
    3. doubtful



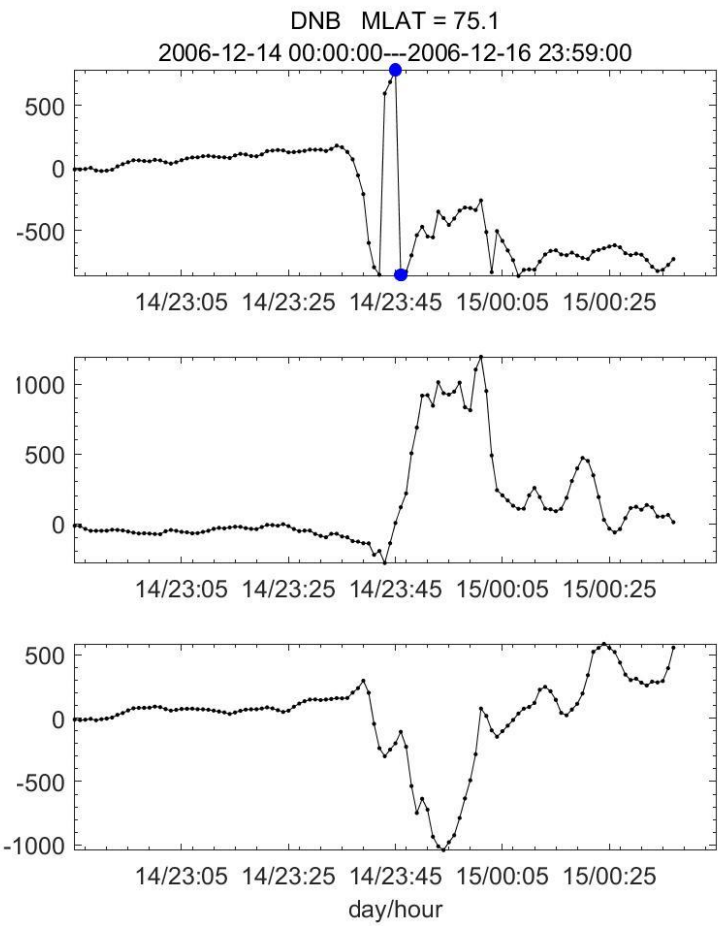
https://supermag.jhuapl.edu/

Examples of dB/dt spikes

Good data



Doubtful data

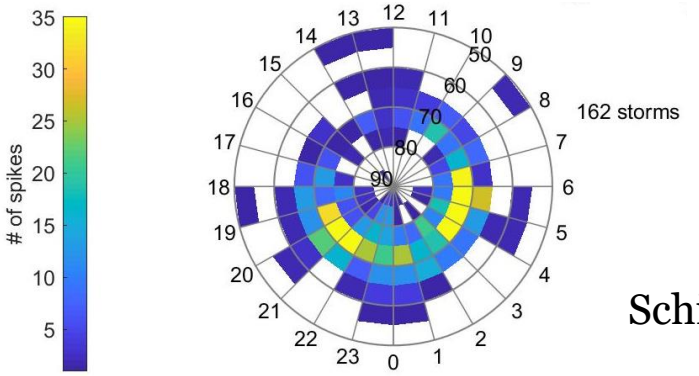


Schillings et al., 2022, under revision

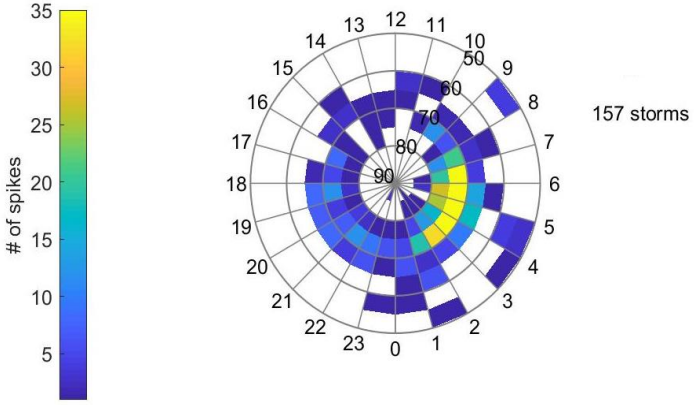
Evening and morning hotspots for dB/dt

- Moderate spikes (|500| nT/min < |dB/dt| < |1000| nT/min)
- Clear hotspots in the evening and morning sector (MLT)
- Global coverage

+/- dB_N/dt



+/- dB_E/dt



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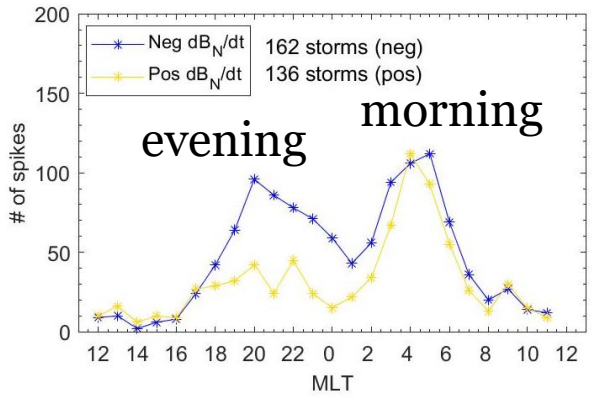

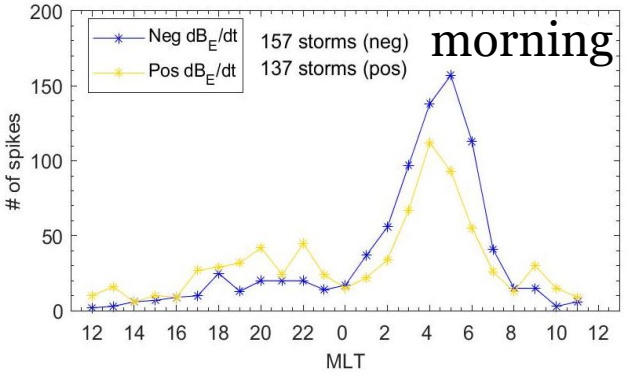

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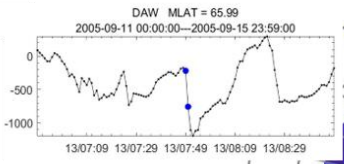
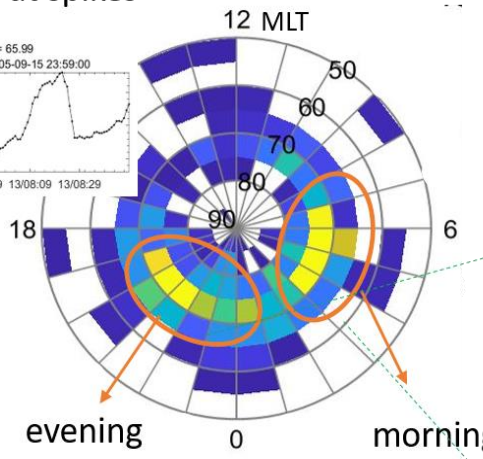
Statistics of dB/dt spikes during storms

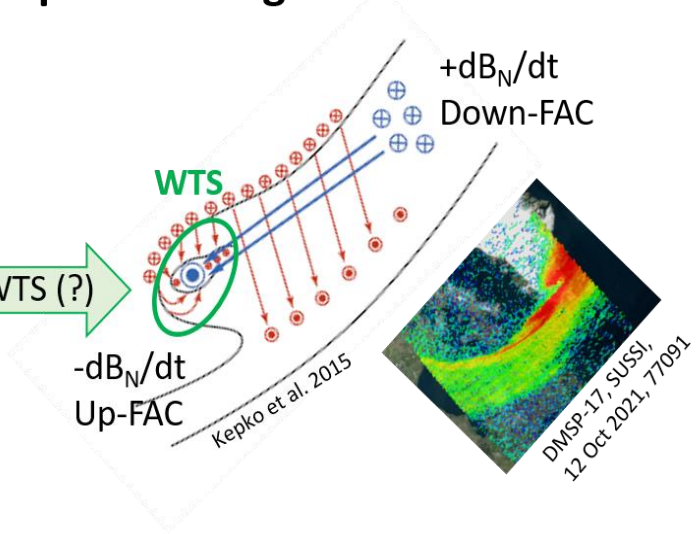
dB_N/dt spikes



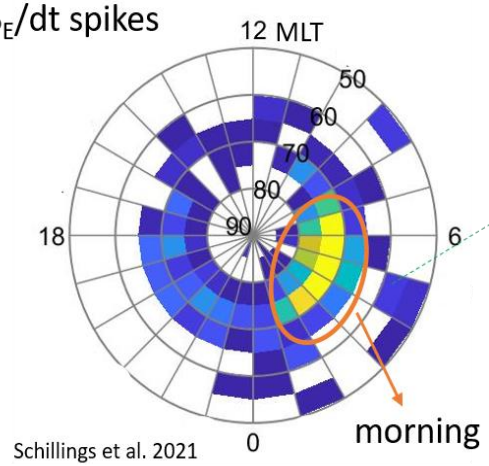


Schillings et al. 2021

SCW + WTS (?)

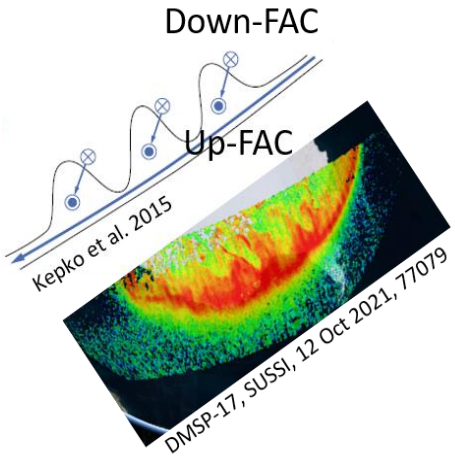


dB_E/dt spikes



Schillings et al. 2021

Omega bands



Legend:
SCW = substorm current wedge
WTS = westward travelling surge
dB/dt (E or N) = dB/dt spikes east (E) or north (N) comp.
MLT = magnetic local time
FAC = field-aligned current (downward and upward)

Schillings et al., 2022, under revision

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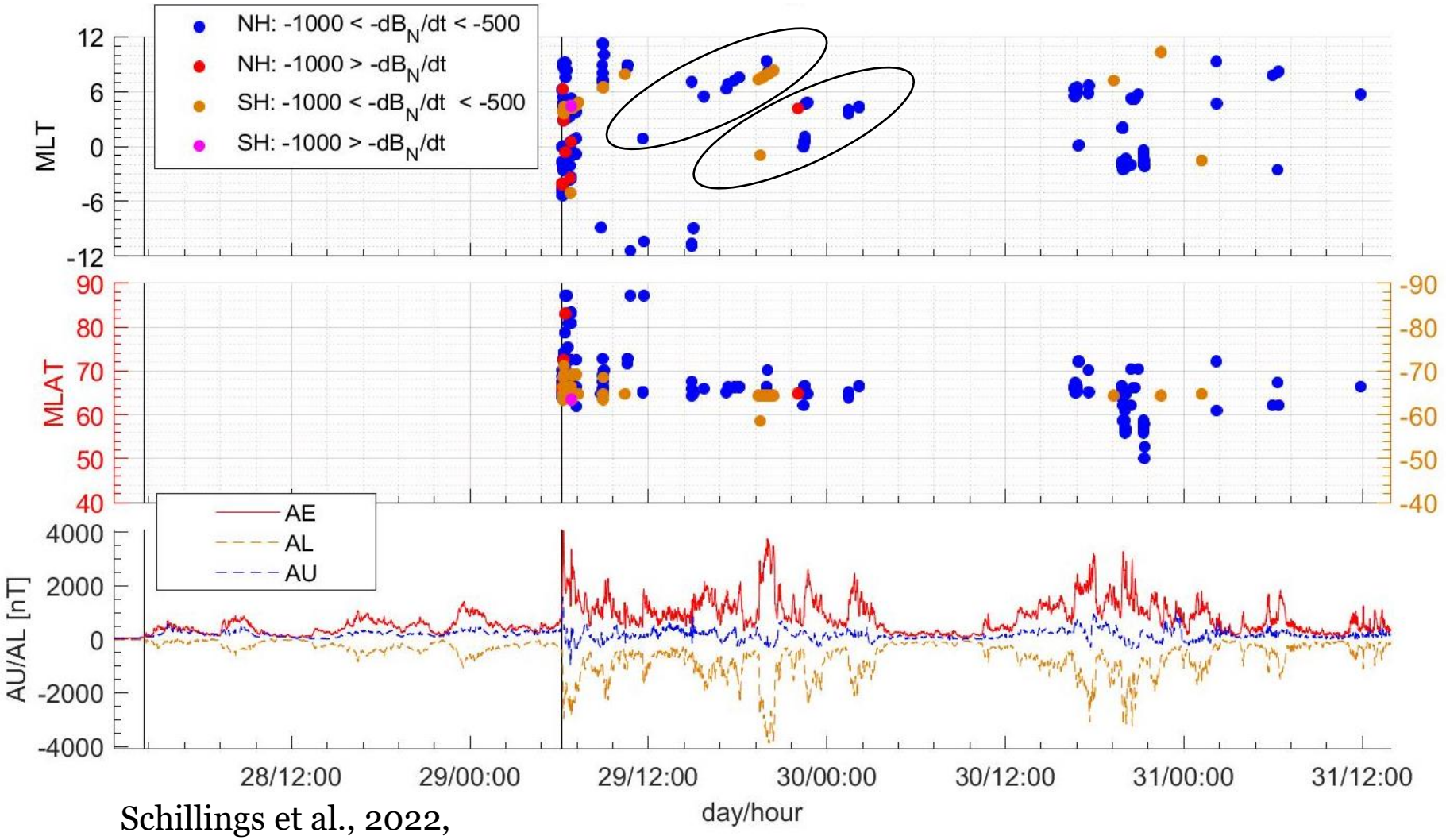
Spatio-temporal sequence Halloween 29 Oct 2003 -dB_N/dt



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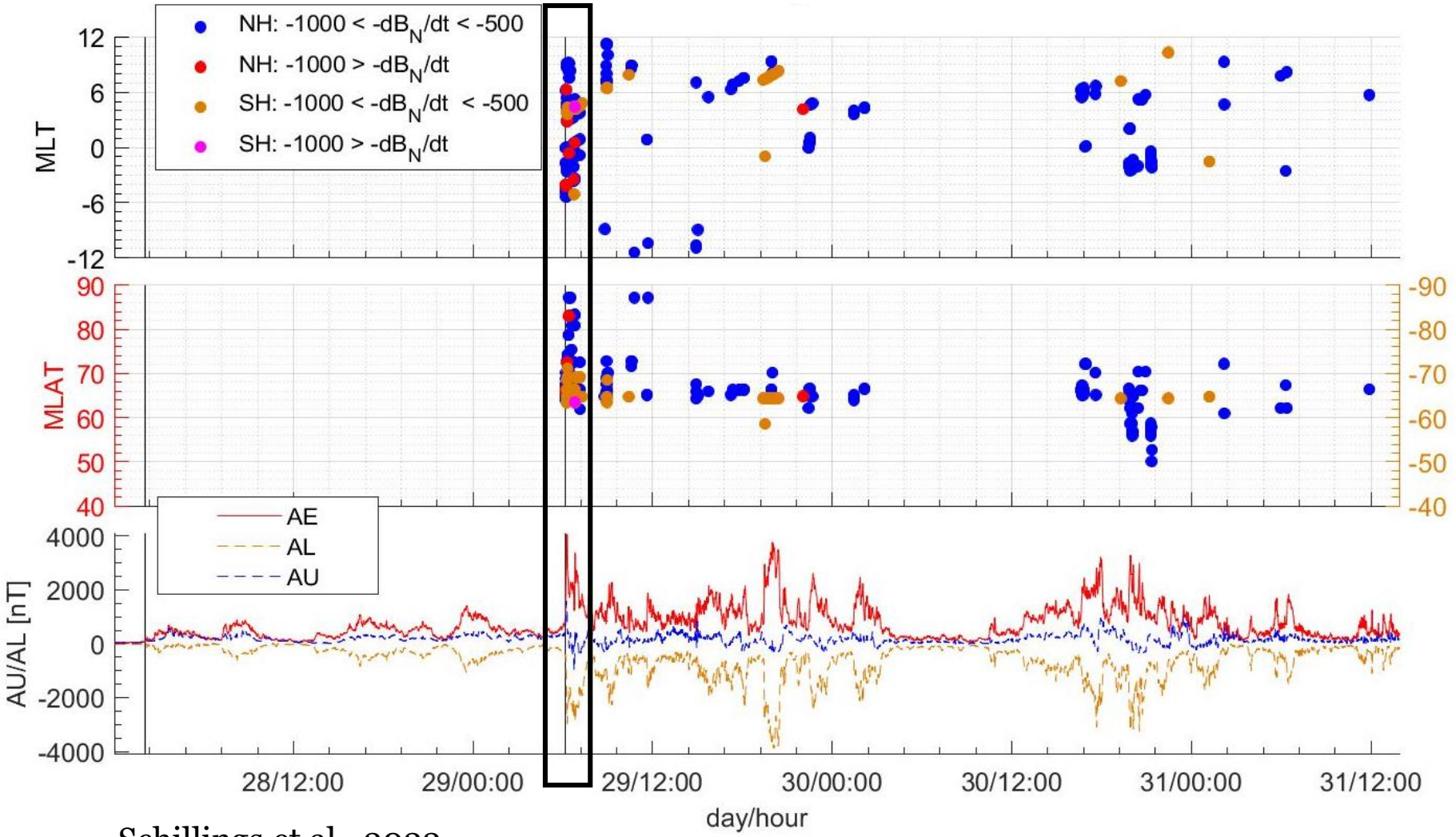

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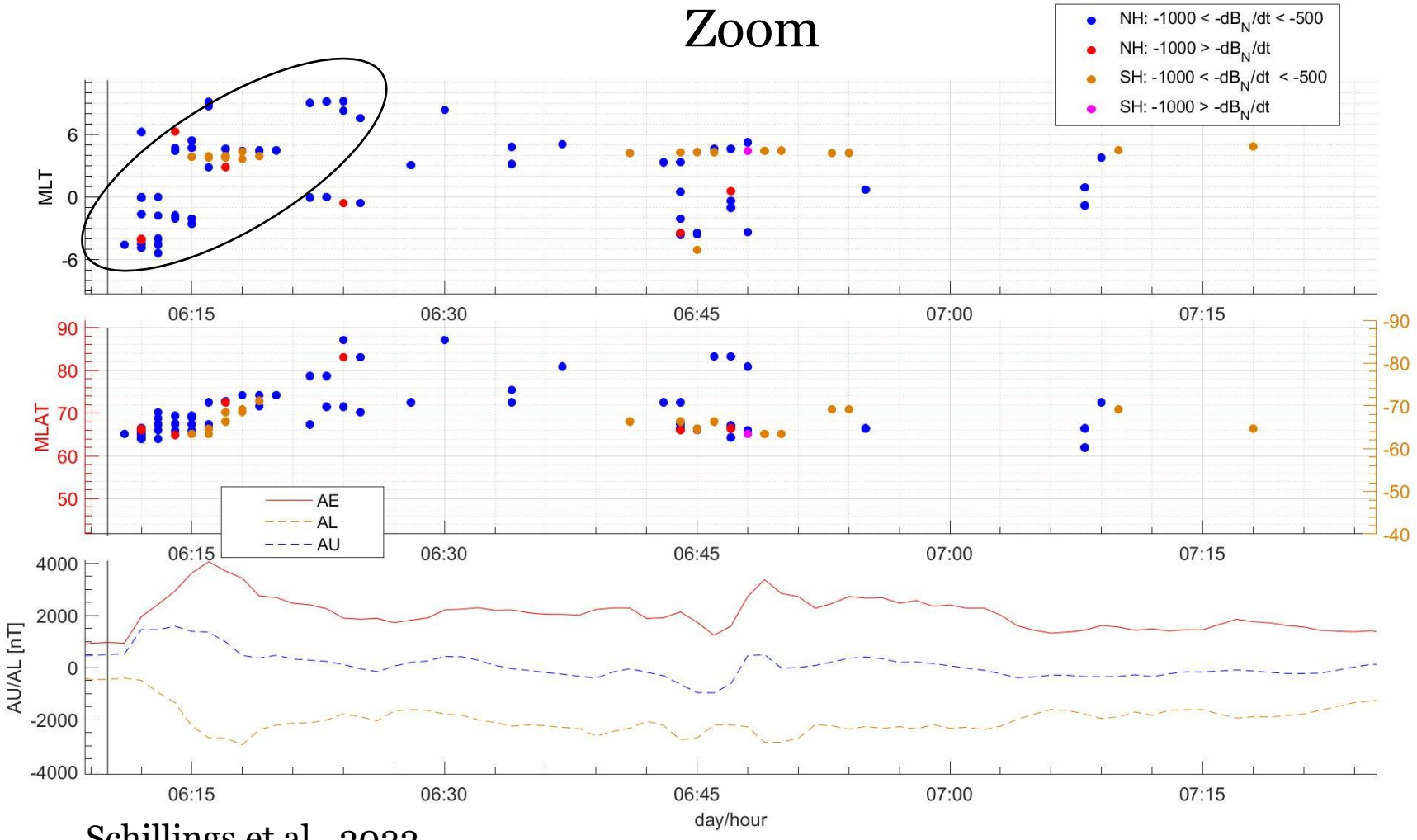

Schillings et al., 2022, under revisions

Individual storms and spikes

St Patrick's storm

Confidential content not displayed

Schillings et al., 2022,
in preparation

The St Patrick's storm: Mar 17, 2015

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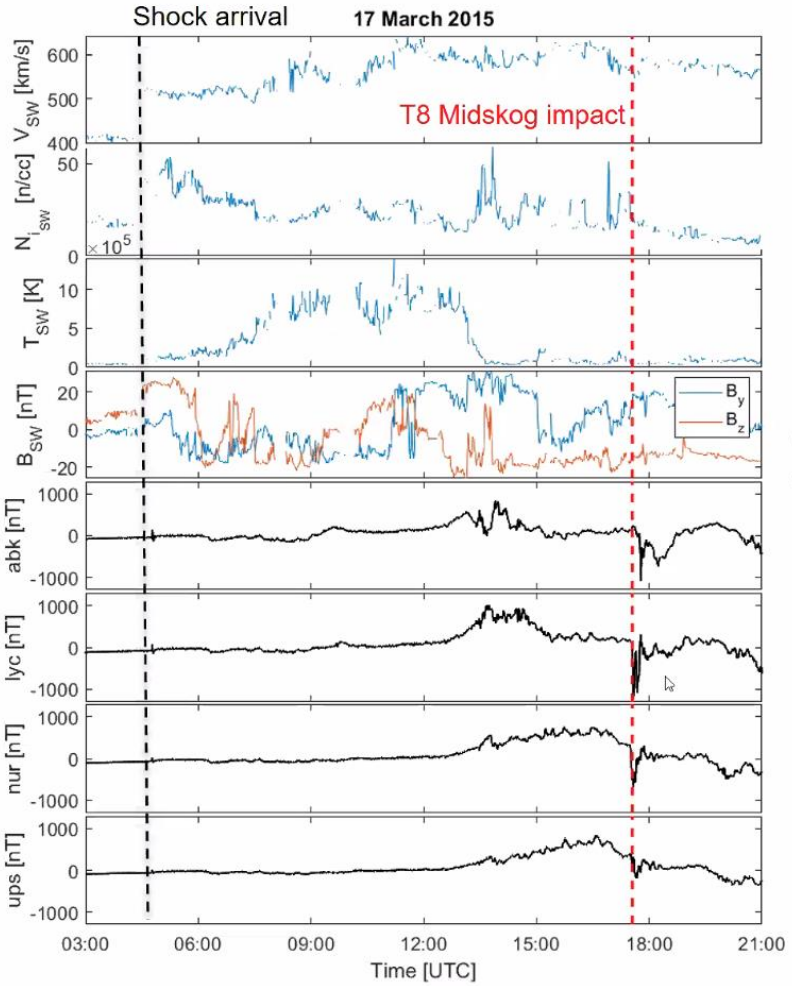

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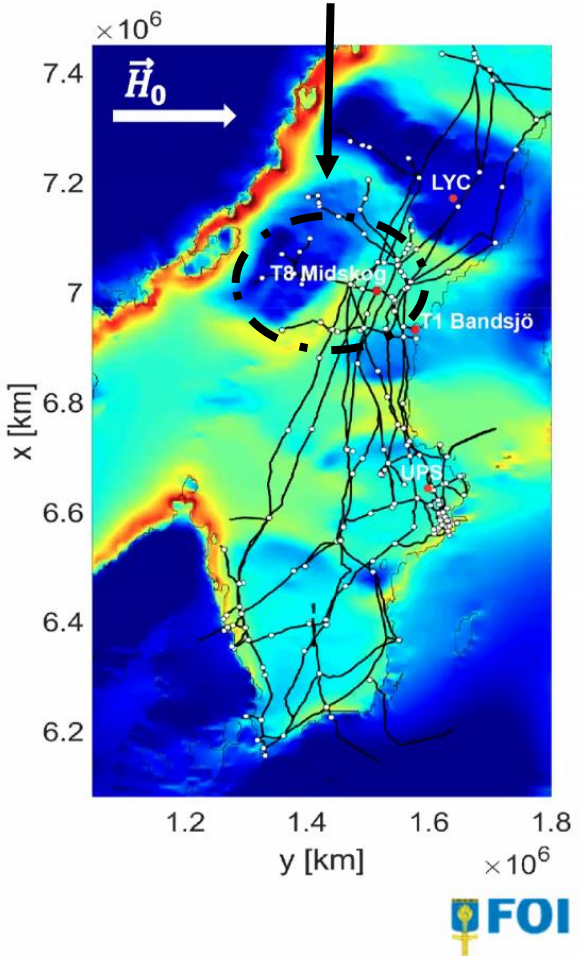

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Credits: L. Rosenqvist, SWx workshop 2021, FOI

Individual storms and spikes

- MAG-SWE-DAN stations
- 1 sec data
- Under investigation

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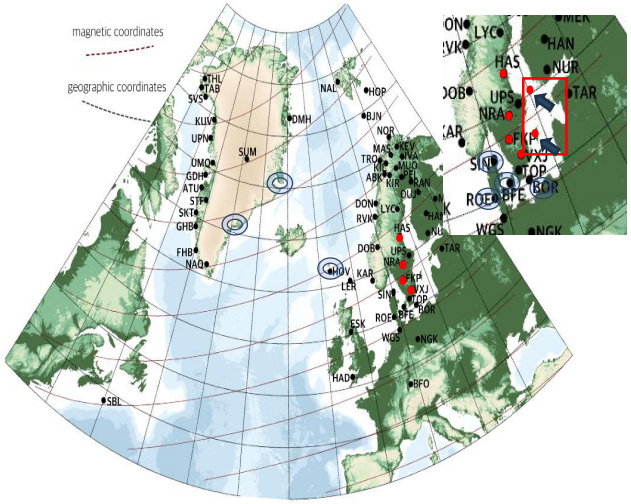

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Conclusions

- Solar eruptions create (strong) perturbations in the Earth's environment and particurlarly in the geomagnetic field -> induced currents at the surface/disturbances in GNSS
- Clear MLT periods where dB/dt spikes are more likely to occur
- Spatio-temporal evolution of the dB/dt spikes during storms
- The St Patrick's storm (Mar 17, 2015) is an example of a space weather event, where GNSS signals perturbations and impact on transformators

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