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Space weather on Earth: how could we better preserve our technologies from space weather events?

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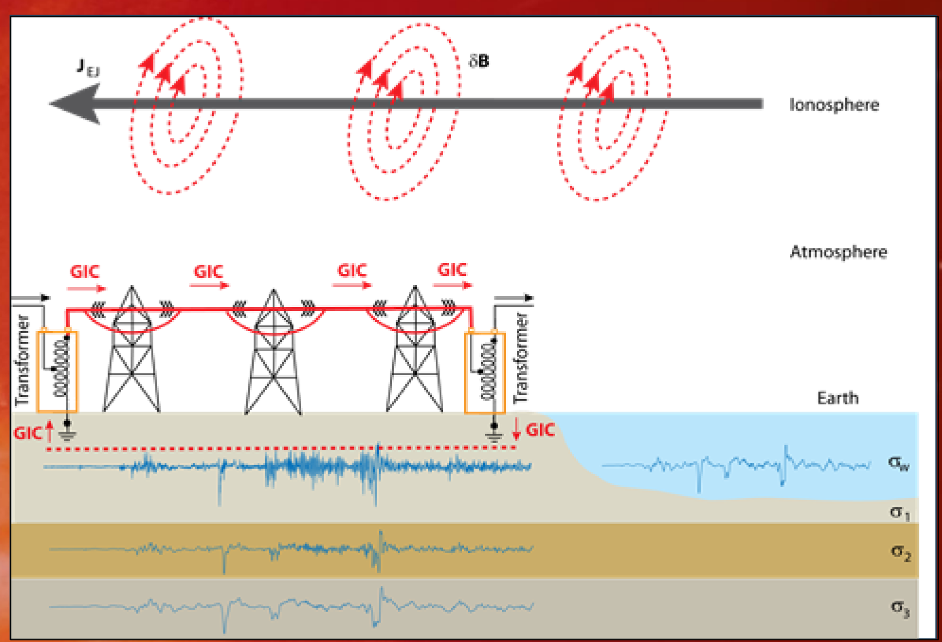
Summary

We investigated short-lived and strong spikes in the northward and eastward components of the Earth's magnetic field during stormy and non-stormy times for 40 years. These spikes are associated with an enhancement of the westward electrojet and can be investigated with the ionospheric equivalent currents. These **studies emphasize the importance of interdisciplinary research between ground-based and space instruments** and show that (small) short-lived and localized structures at different locations could potentially be harmful for our technologies. These studies could help to potentially predict strong and, in some case, very localized space weather effects.

Introduction

Time variations in the Earth's magnetic field by Faraday's law produce geo-electric fields and in turn these geo-electric fields produce induced currents by Ohm's law at the Earth's surface, called geomagnetically induced currents or GICs, see **Fig. 1**. GICs are harmful for human infrastructures and technologies.

Figure 1. Illustration of geomagnetically induced currents. Credits: L. Rosenqvist



Statistical studies during stormy and non-stormy times

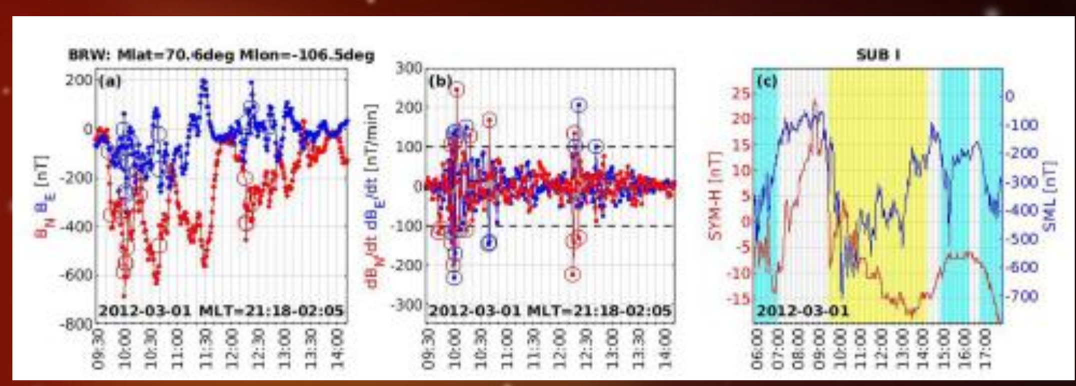
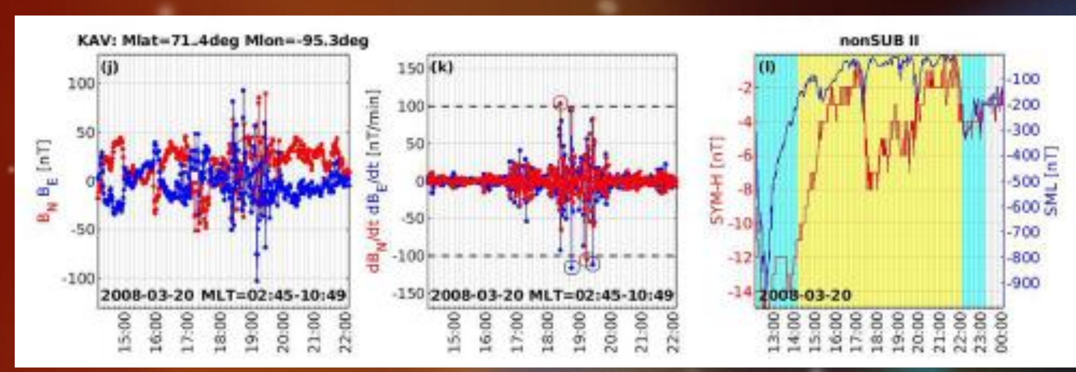


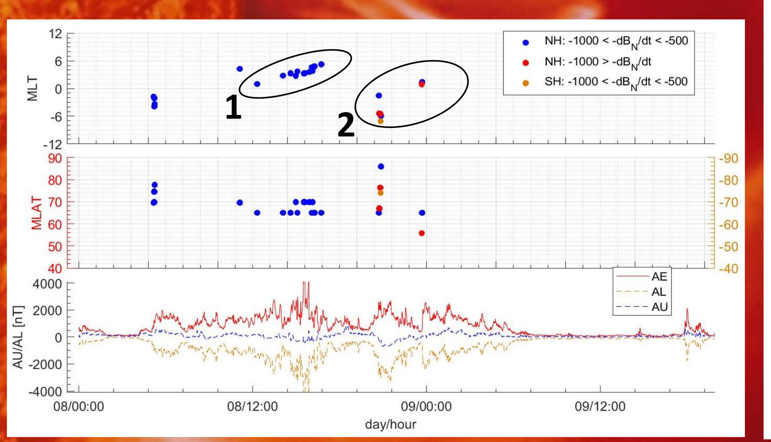
Figure 3. Non-stormy times. (Top) Example of substorm and spikes > |100| nT. **(Bottom)** Example of time in between substorms.

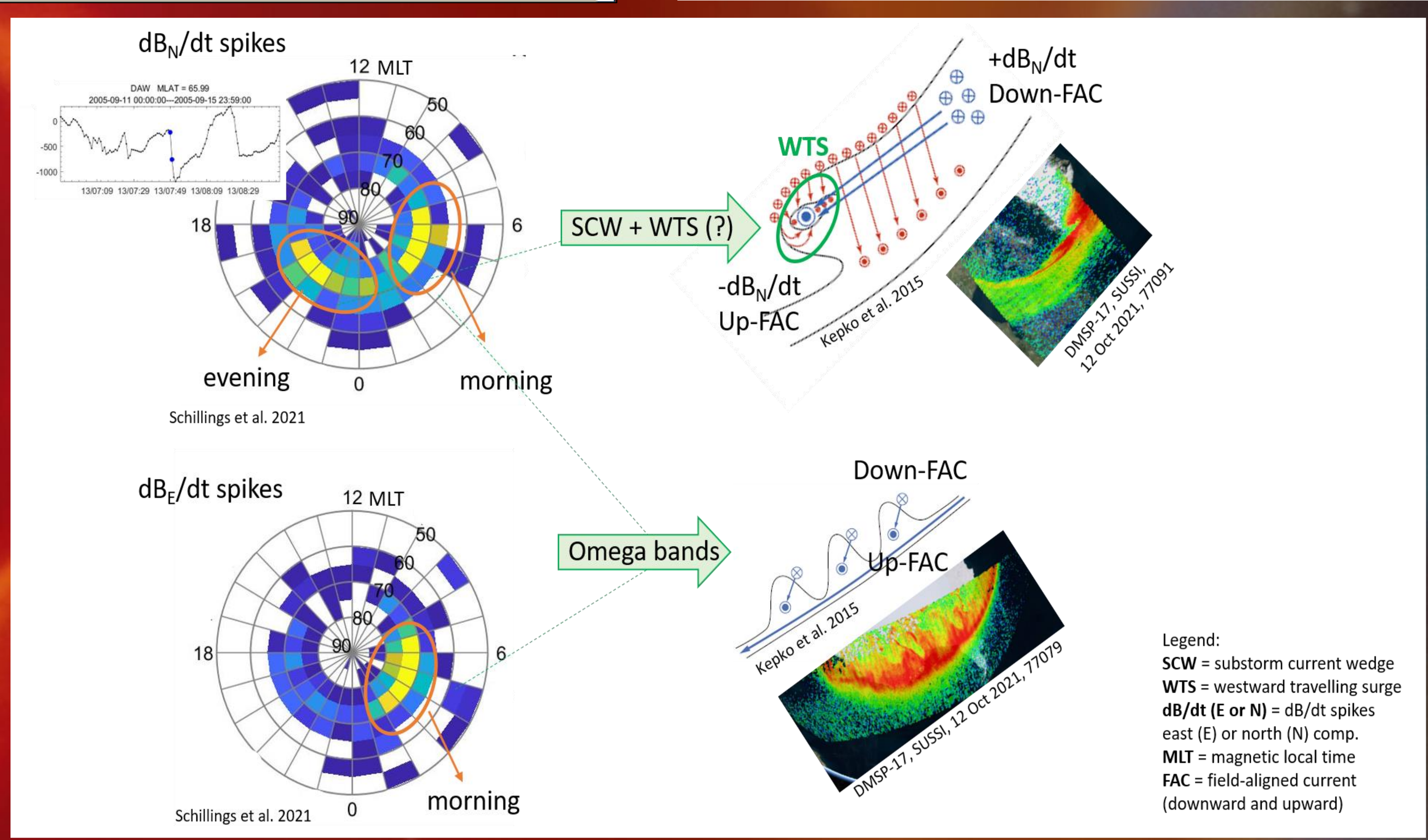


We investigated the Earth's magnetic field using SuperMAG network for ~40 years during storm times and non-stormy times. We found dB/dt spikes in both cases as well as a spatio-temporal variation of spikes from the evening MLT sector toward the morning.

Some spikes during non-stormy times are associated with pulsations and/or ULF waves. During stormy times, we confirmed the existence of two hotspots, one in the evening and one in the morning MLT sector. The evening spikes are most probably related to the substorm current wedge (westward travelling surge) and the morning spikes to the omega bands.

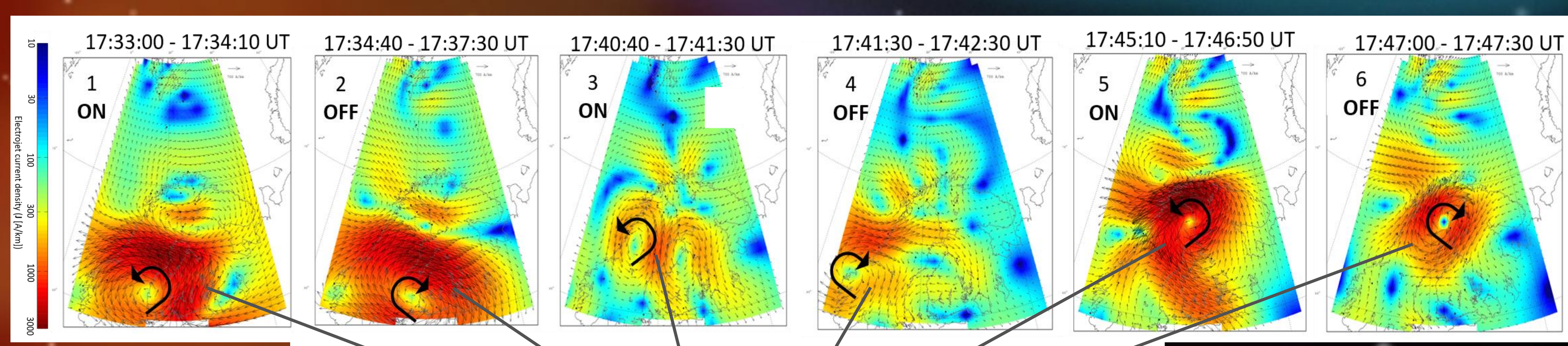
Figure 2. (Right) 2 hotspots detected for storms and probably related to substorm current wedge (westward travelling surge) for the evening sector and omega bands for the morning sector. (Bottom) spatial temporal evolution of the dB/dt spikes from the evening towards the morning. 8 Feb 1986.





Localized space weather event over Fennoscandia: St Patrick's storm - Mar 17, 2015

Substorm onset is often associated with substorm current wedge. However, in the recent years the substorm current wedge model was revisited and several studies suggested the possibility of small-scale substorm wedge called wedgelets to be part of the large scale substorm current wedge [1],[2]. These wedgelets are associated with localized field-aligned currents (FACs), which are added to the pre-existing field-aligned current system. We found three signatures of such wedgelets and its associated FACs during the main phase of the geomagnetic storm. The top panels of **Fig. 4** show the appearance (ON) and disappearance (OFF) of the small-scale FACs for each of the B_x spikes showed in the bottom right panel. The B_x spikes are very localized and, each B_x spikes corresponds to an enhancement of the westward electrojet as observed in the bottom left panel of **Fig. 4**. We also investigated the optical auroral emissions during the spikes and found a burst of brightness at 2 locations. **Figure 4 (bottom)** displays the auroral images of the All-Sky Camera in Kevo (left) and the difference in optical emission within 20 sec in the right. The brightening of the aurora corresponds to the timing of the appearance of the small-scale FAC system. This study shows that **within ~15 min, three potentially harmful spikes** associated to significant westward electrojet enhancements occurred at localized part of Fennoscandia. **These spikes could lead to localized space weather effects.**



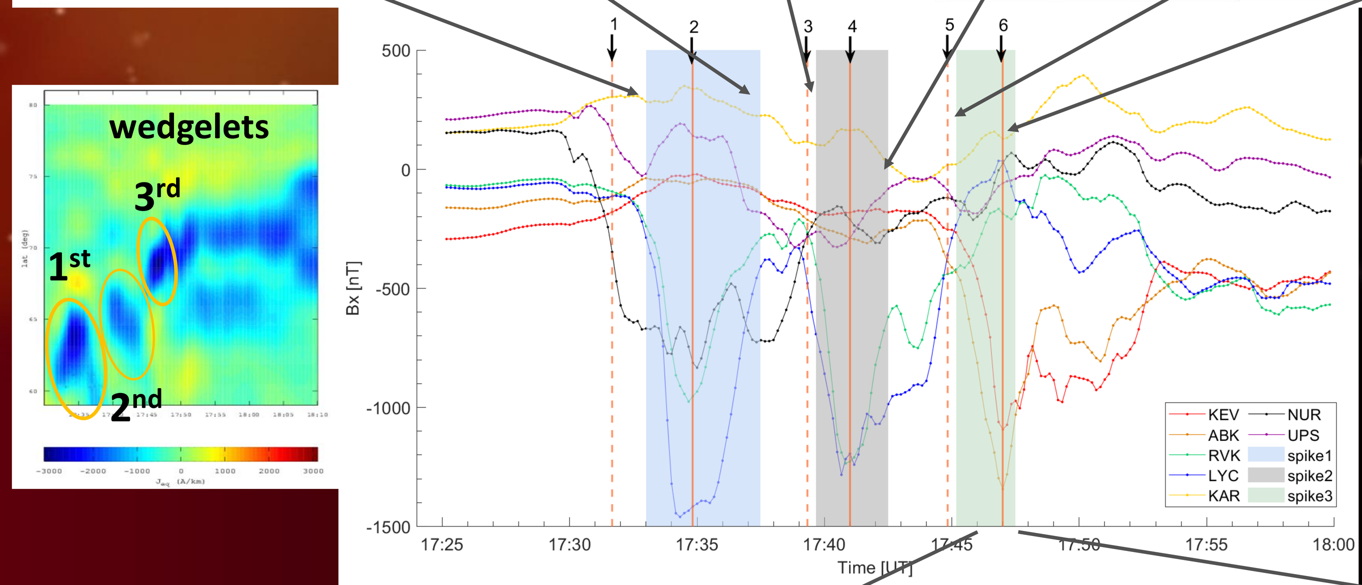


Figure 4. (Top) Differential equivalent currents associated with three Bx spikes. **(Middle)** IMAGE data for some of the stations. Shaded areas correspond to the interval chosen for the differential equivalent currents. **(middle left)** 1D equivalent current, blue colour = westward electrojet. Credits: A. Schillings et al. (2023)

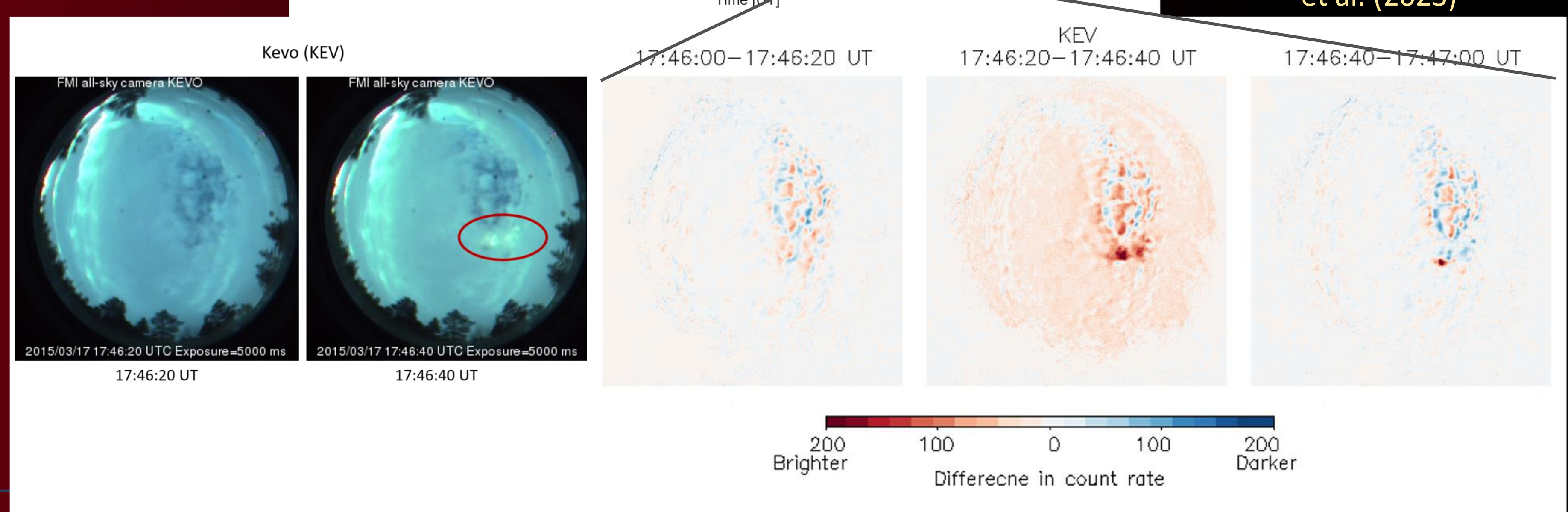


Figure 4. (Bottom) Auroral All-Sky Camera Images from MIRACLE network. **(left)** Optical auroral emission. **(Right)** Difference in count rate of the auroral emission. Red = brighter, Blue = darker. Credits: A. Schillings et al. (2023)

Read more:
Schillings et al. (2002), Space Weather
Schillings et al. (2023), JSWSC
Hamrin, Schillings et al. (2023), JGR: Space Physics

References
[1] Liu et al. 2018; [2] Ohtani & Gjeleroev 2020

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