

Geomagnetic effects of flare radiations: SFEs

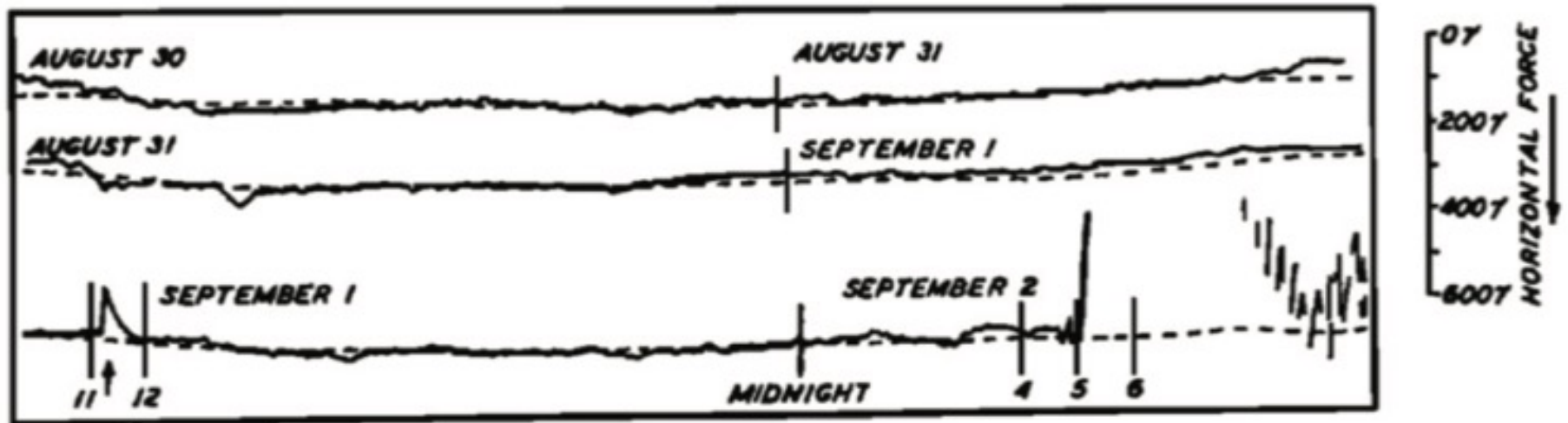
Hugh S. Hudson
U of Glasgow, UC Berkeley, WKU

Synopsis

- I've been working with the geomagnetic data obtained at the Glasgow teaching observatory
- SFEs (crochets) have caught my interest!
- An unusual SFE: MNRAS **532**, 3120–3125 (2024)
- Calibrating the Carrington event
- **Goal at ISSI: learn more about atmospheric currents driven externally**

What is an SFE?

- “Solar Flare Effect”, a.k.a. “crochet”
- First example in the Carrington event

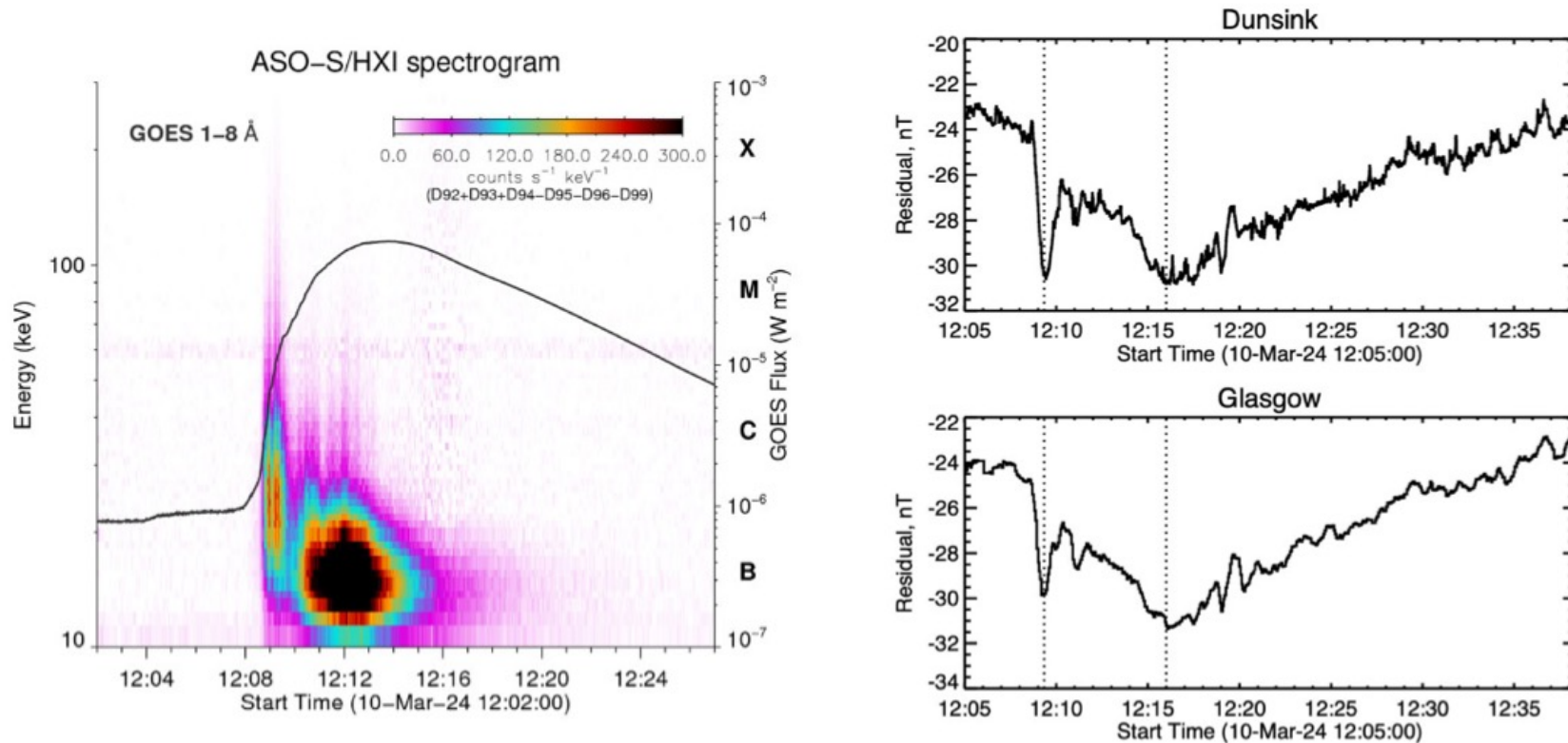


Three days in September 1859 via the earliest recording magnetometer

The basic idea

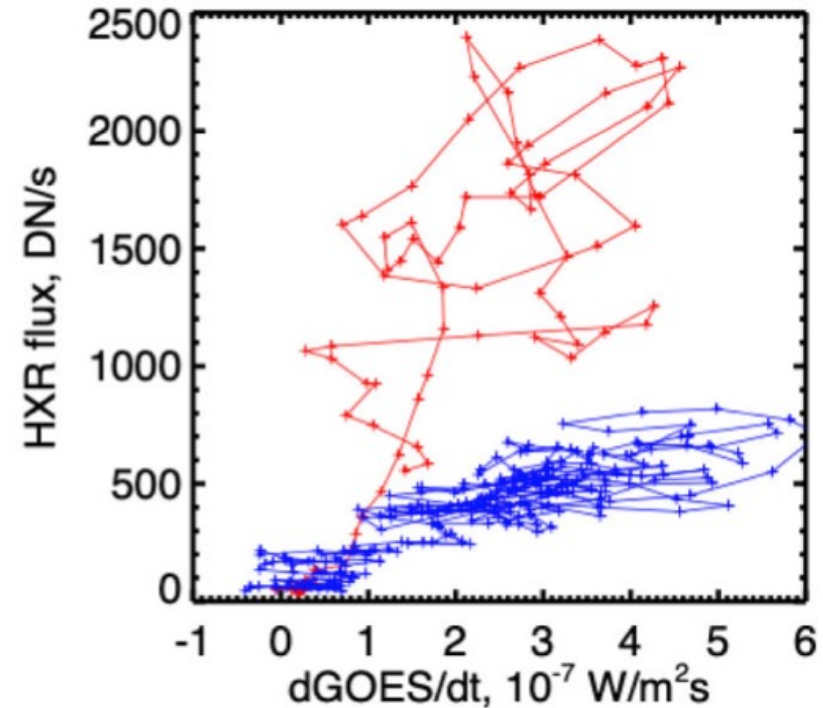
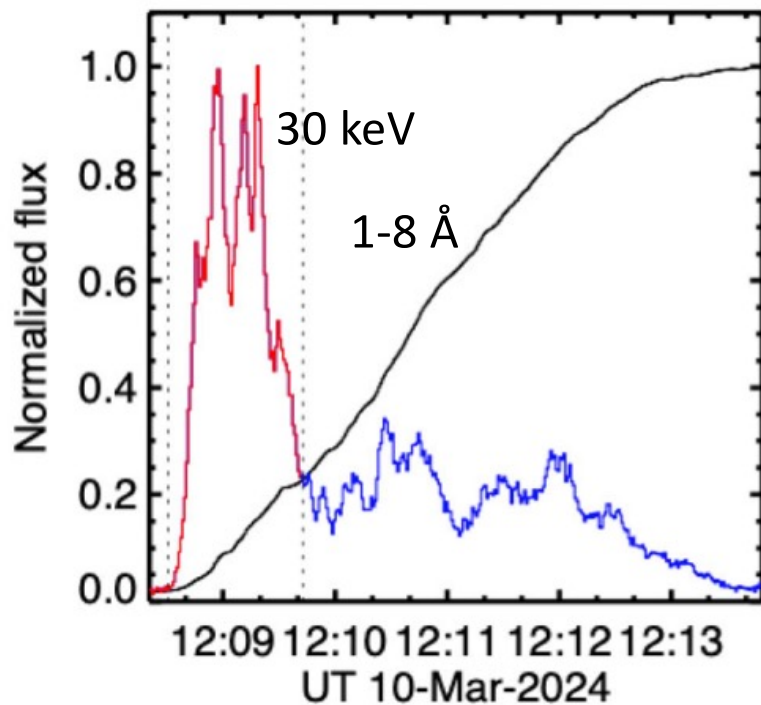
- Solar hard radiation increases the ionization in Earth's atmosphere
- Dynamo action via high-altitude winds drive transient currents
- Ground-based magnetometers observe deflections
- The Earth's atmosphere and the resulting current systems are complicated!

SOL2024-03-10 and an SFE



- A strong SFE from an M7 flare: about 7 nT
- An unusual early-impulsive spike

Neupert-effect complications

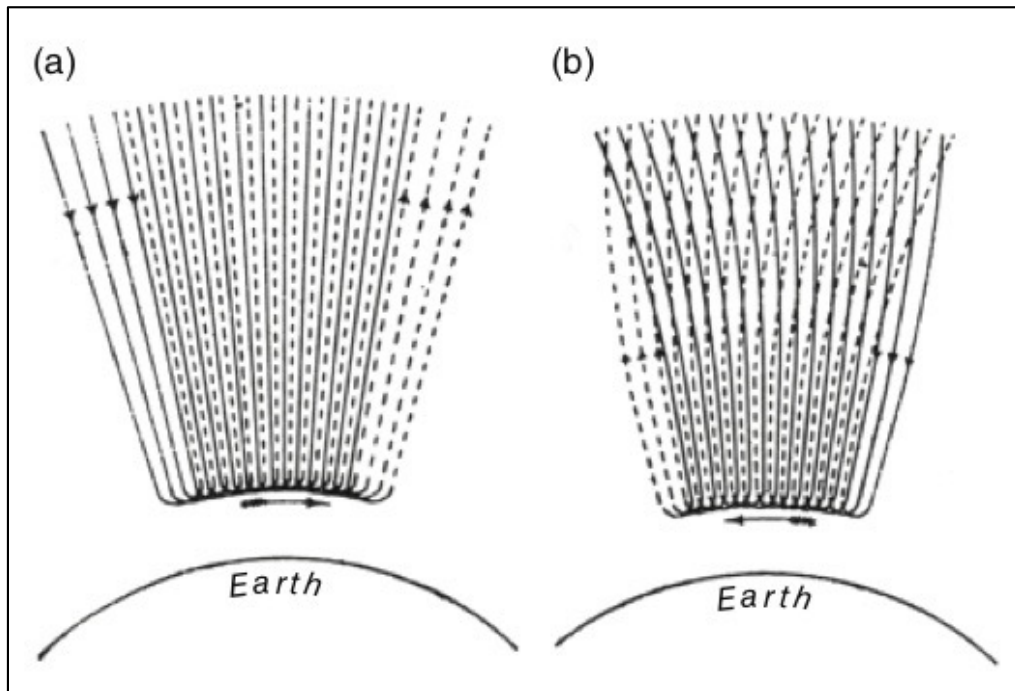


- “Early-impulsive” flare
- Short time scales
- The troposphere?

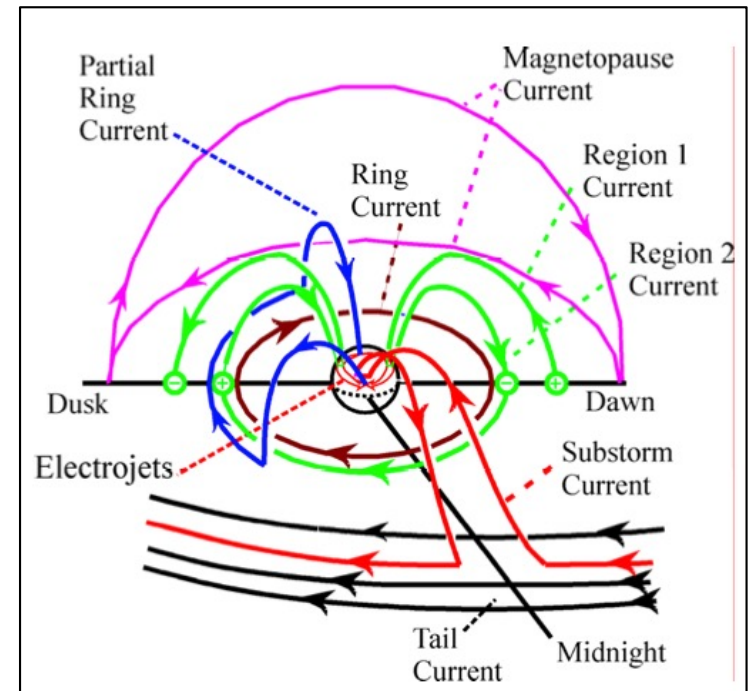
SFE physics

- The SFE current system is reputed look like Sq , but it has a very different spatial and temporal pattern.
- Geomagnetic sampling of SFE currents is complete (the Intermagnet array) but inherently low-resolution (~ 100 km).
- There may be chemistry.
- My naïve question: Do SFEs involve FACs?

Field-aligned currents, FACs (Birkeland currents)

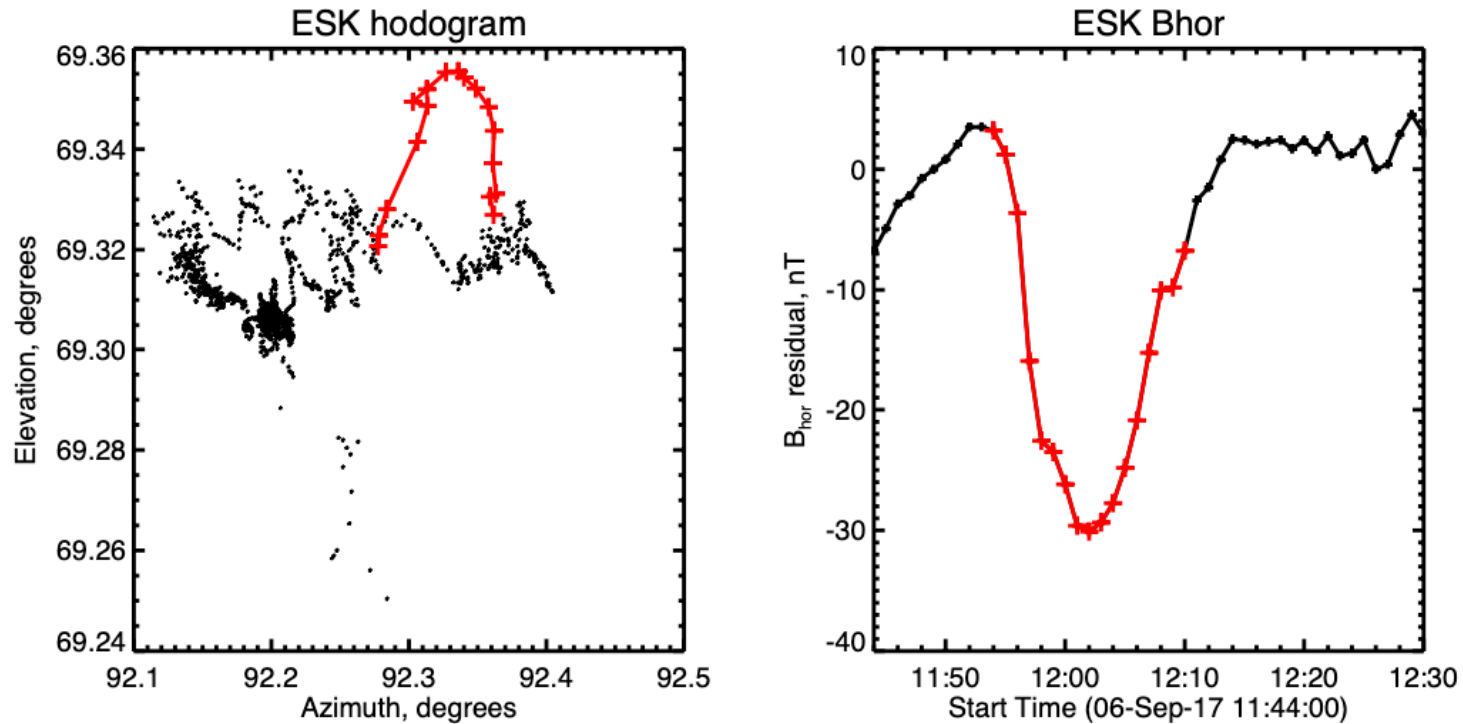


Birkeland 19th century?



McPherron 21st century

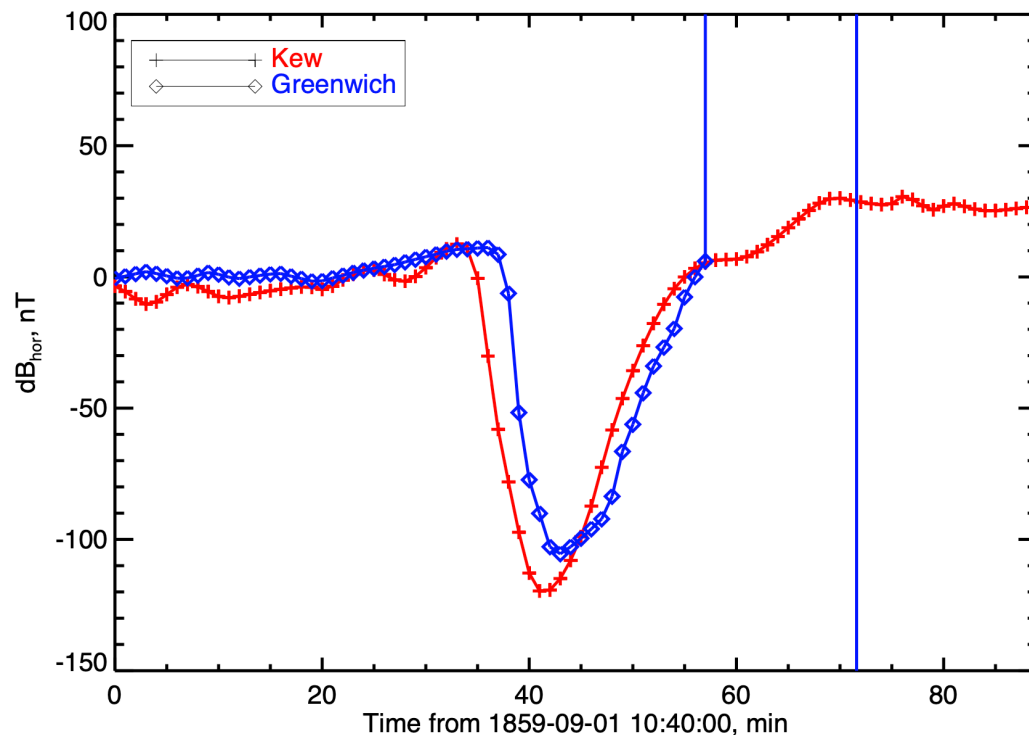
Hodograms



- Biot-Savart says that a compass deflection (azimuth here, or geomagnetic “declination”) hints at a vertical current (Birkeland)
- But this may be ambiguous

Useful application of SFEs

- The Carrington event had a well-observed SFE, with two sites (Kew and Greenwich)

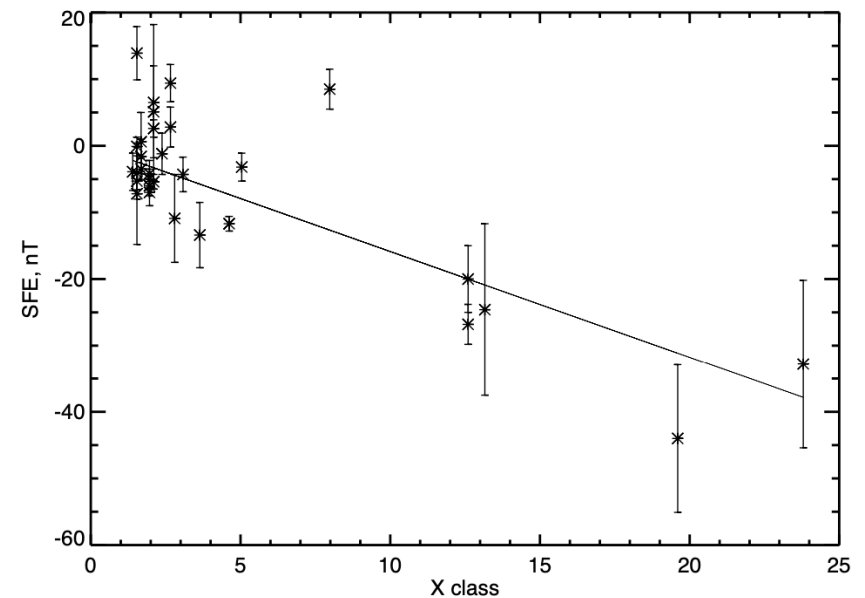


- SOL1859-09-01 (X???)
- Recent digitizations by Beggan et al. (2024)
- A 10% measure, but what about systematic errors?

Intermagnet near Kew/Greenwich



- The Hartland site (HAD, in the UK) is the closest geographical counterpart
- Note that the sampling is not optimal in the Nyquist sense
- HAD has observed about 40 X-class flares near local noon



Conclusions

- The geomagnetic field is really well measured, and a treasury for undergraduate lab work
- There is probably a lot to learn from SFEs
- Improved data have let us “calibrate” the effective GOES class of the Carrington event (hint: it was a superflare, but not a superduperflare).

Prospectus: ISSI activities?

- Systematic study of GOES Ly α vs SXR contributions to SFEs: SFE physics
- Do SFEs have tropospheric or Birkeland currents?
- General study of SFEs in Intermagnet data
 - The existing literature is very weak
 - There are some very clean events
 - Toy models with the Biot-Savart law
 - Summed-epoch analysis