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AMPERE

AMPERE and the Electric Circuit of Geomagnetic Storms

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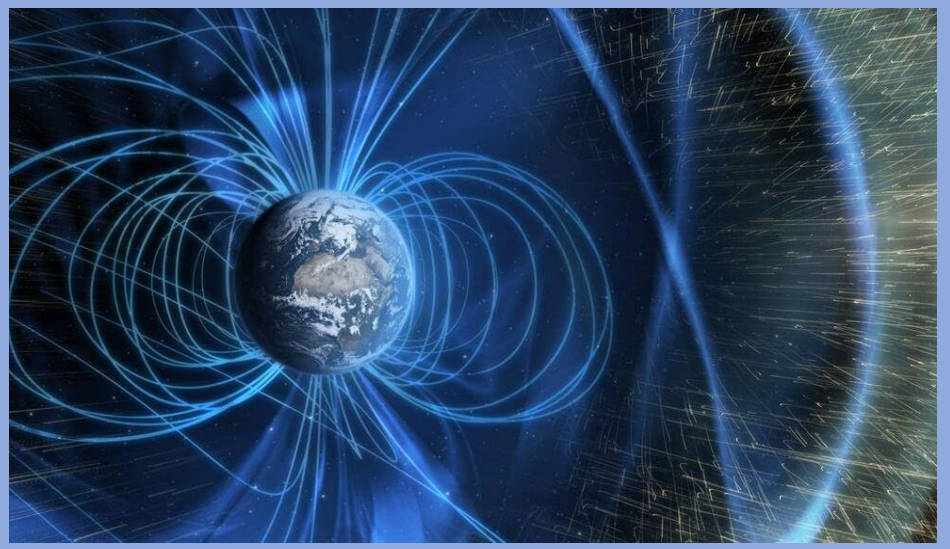
The Geomagnetic Storm

- This PhD study investigates the mechanisms and responses of high geomagnetic driving that result in geomagnetic storms.
- These storms are usually defined as periods where there the ring current is enhanced.
- The key investigation strands within this study consist of:
  1. How the ring current couples to the ionosphere through R2 currents.
  2. How strong coupling between the magnetosphere and IMF is communicated to the ionosphere through R1 currents.
  3. How the FACs change in response to the compressions of the magnetopause.
  4. Does polar cap potential saturation reveal itself in FACs?



Graphic: https://spaceweather.app/help-geomagnetic-storm

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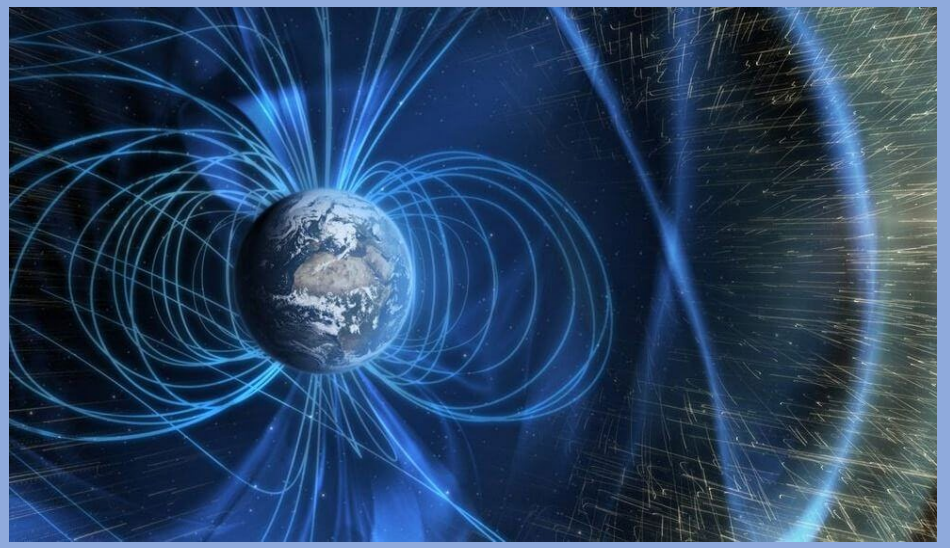
Cross Polar Cap Potential Saturation

- The solar wind drives magnetic reconnection and, as a result, cross polar cap potential within the ionosphere.
- Previous studies have identified a potential 'saturation' during periods of particularly intense solar wind driving.
- In this scenario, the solar wind can continue to increase in driving intensity, however the potential across the polar cap will deviate from a linear increase and 'saturate'.
- In this study, we use AMPERE data to verify if an analogous saturation occurs within the current systems of the polar cap and if so, offer insights into the potential mechanisms involved.



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Cross Polar Cap Potential Saturation

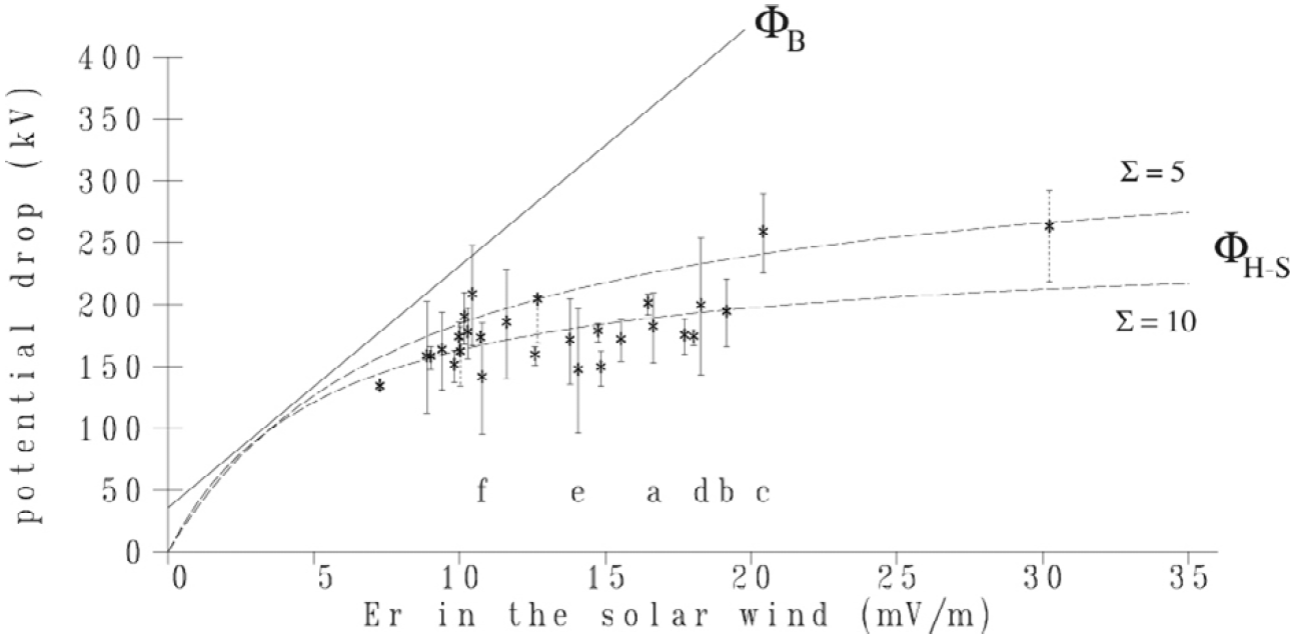

Figure 2. Plot of the same six data points along with data from an additional 22 DMSP passes during the 1988–2002 time period that also show evidence of saturation. The line showing the predicted potential from the Boyle formulation (here labeled Φ_B) and the predicted potential from the Hill-Siscoe model (using nominal values of $\Sigma = 5$ and 10 S) based on the 31 March 2001 conditions are included as a baseline.

Hairston, M., Drake, K. and Skoug, R., 2005. Saturation of the ionospheric polar cap potential during the October-November 2003 superstorms. *Journal of Geophysical Research: Space Physics*, 110(A9).

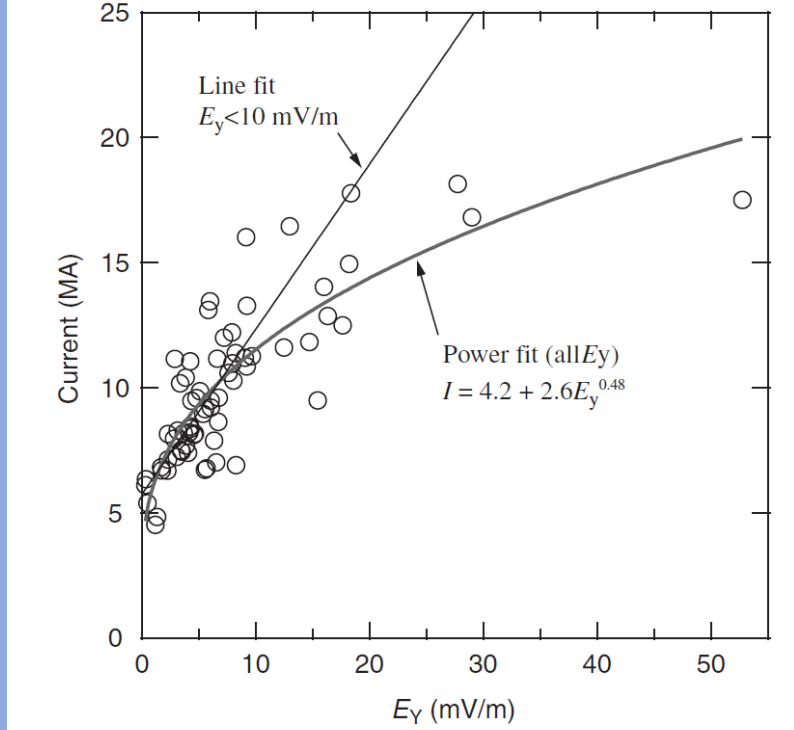

Fig. 4. Storm-time total Birkeland currents (1999–2003) versus IMF E_y.

Anderson, B. and Korth, H., 2007. Saturation of global field aligned currents observed during storms by the Iridium satellite constellation. *Journal of Atmospheric and Solar-Terrestrial Physics*, 69(1-2), pp.166-169.

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The AMPERE Project

- Spearheaded by Johns Hopkins University, AMPERE utilises telecommunication satellites, collectively known as the Iridium constellation.
- AMPERE measures the field aligned current systems over both hemispheres, allowing great insight into the transmission of stress within the magnetosphere.
- This transmission ultimately results in the ionospheric convection pattern.

https://www.iridium.com/network/

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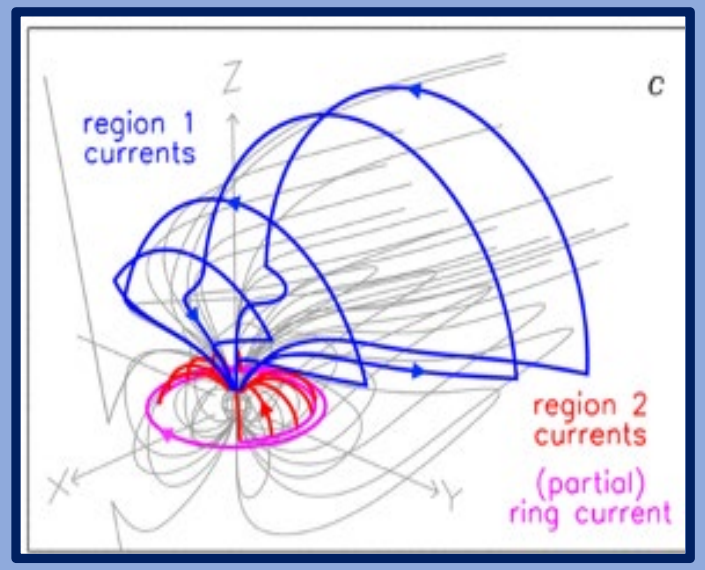
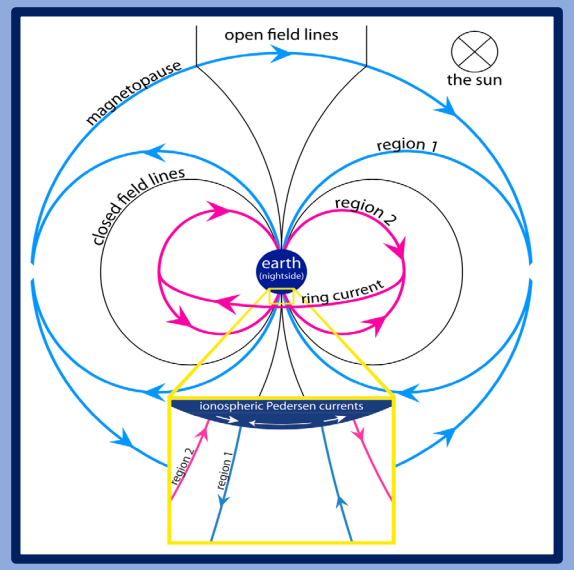
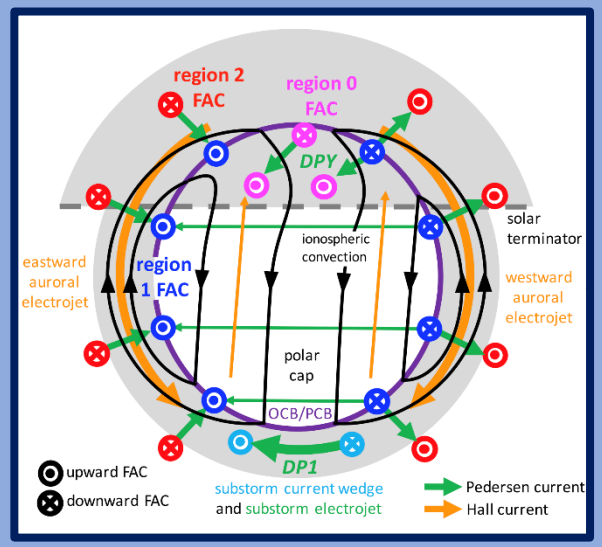
The Magnetospheric Current System

- The Region 1 and 2 field aligned current systems consist of two concentric current rings, present above both poles of Earth.
- The region 1 currents, the inner ring, connects the ionosphere to the magnetopause and magnetotail through Chapman- Ferraro currents.
- The outer current ring, the region 2 currents, connect the partial ring current to the inner magnetosphere (See graphics).







Top left: Milan et al. 2017
Top Right: Coxon et al. 2014
Bottom: Milan et al. 2017

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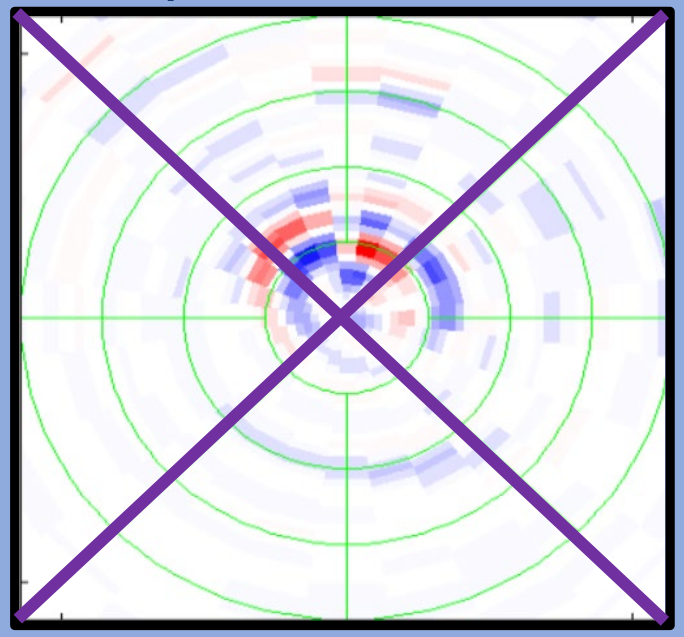
Separating the System

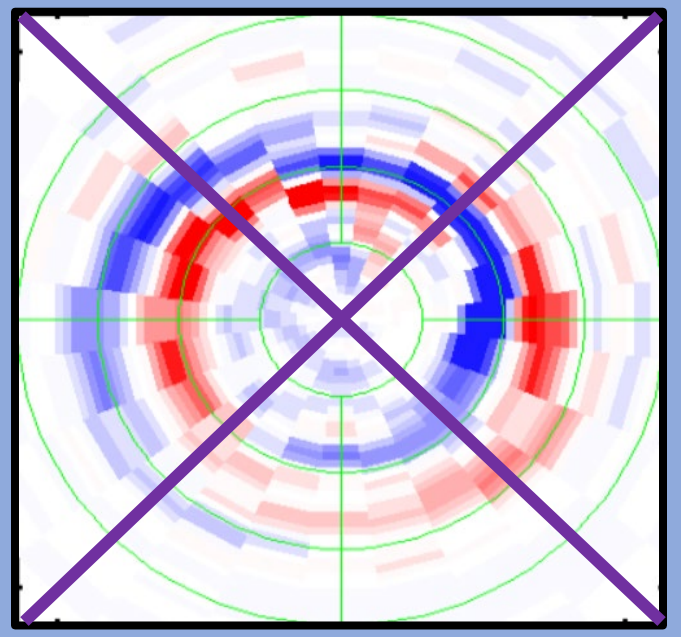
Northward IMF (B_z Positive)

- Currents induced, predominantly, by lobe reconnection.
- Generally lower in magnitude and polar cap size.



Southwards IMF (B_z Negative)

- Most efficient driving of magnetic reconnection, located at the magnetopause.
- High current magnitudes and polar cap size.



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Solar Wind Parameters

- Separating the solar wind into individual parameters allows us to investigate current saturation dependencies on each driver.
- The key parameters isolated:
  - Solar wind speed
  - Solar wind density
  - B_z Component of the IMF
  - A loose approximation of the solar wind Electric Field ($B_z * V_{sw}$)
  - Milan et al. (2012) Coupling Parameter
- These were looked at across all individual months and years, in order to identify any seasonal or solar cycle features.
- 2010-2016 data was binned with the averages of the total integrated current over each hemisphere, taken for each bin in order to reduce outlier effects.

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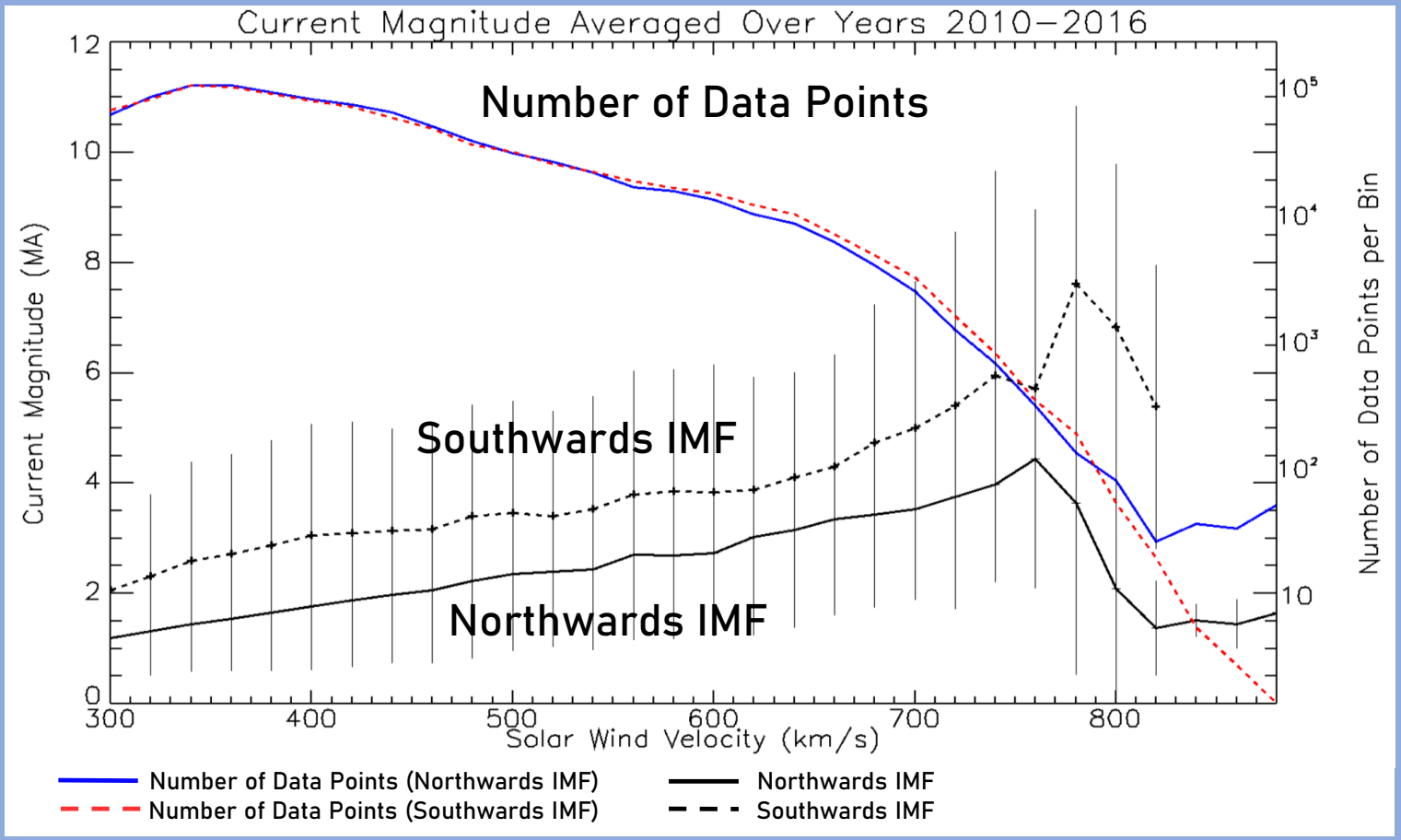
Current Saturation- Solar Wind Speed



- General increase in current magnitude with solar wind speed.
- Suggested decrease in current during northwards IMF B_z.
- Current magnitude does not recover after drop during northward IMF

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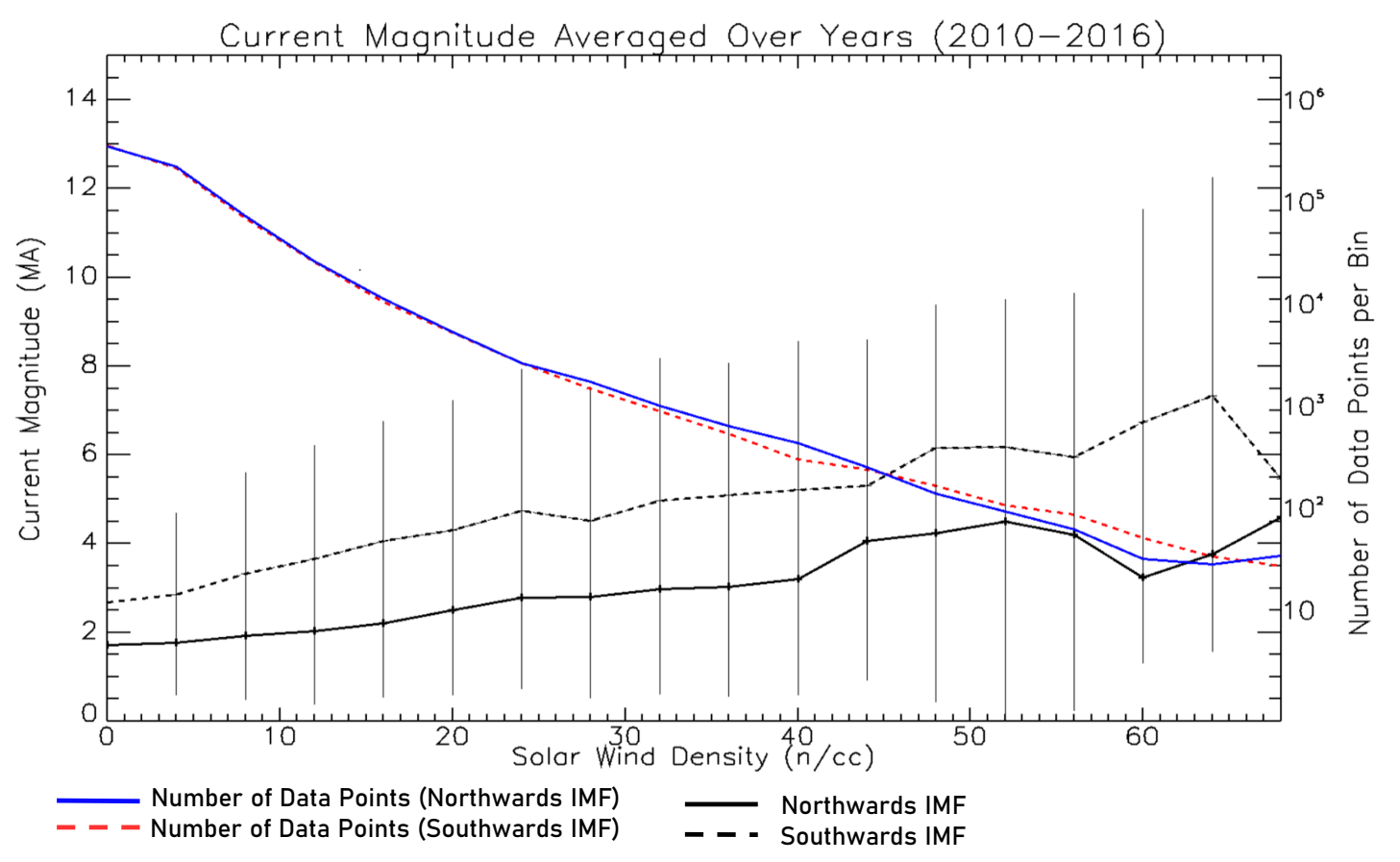
Current Saturation- Solar Wind Density



- Solar wind density has little dependency upon the current magnitude.
- A general increase in current magnitude as solar wind density increases.
- No unique trends to any quadrant.
- Some suggestion of saturation seen in southward IMF.

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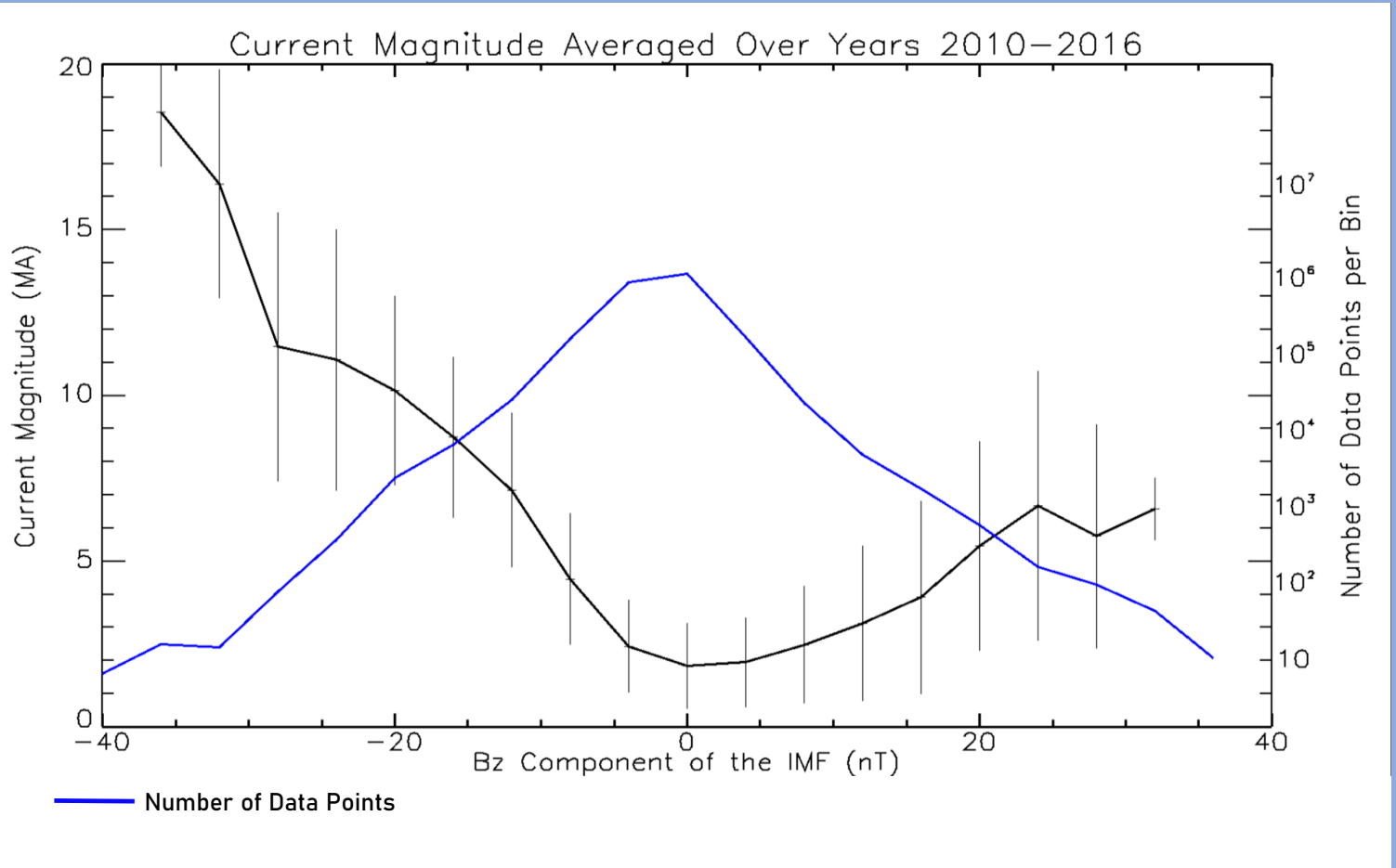
Current Saturation- Bz Component of the IMF



- B_z is a key solar wind parameters driving reconnection.
- No clear signs of saturation for southward IMF.
- Lack of data points at extreme values limits conclusions that can be confidently drawn.

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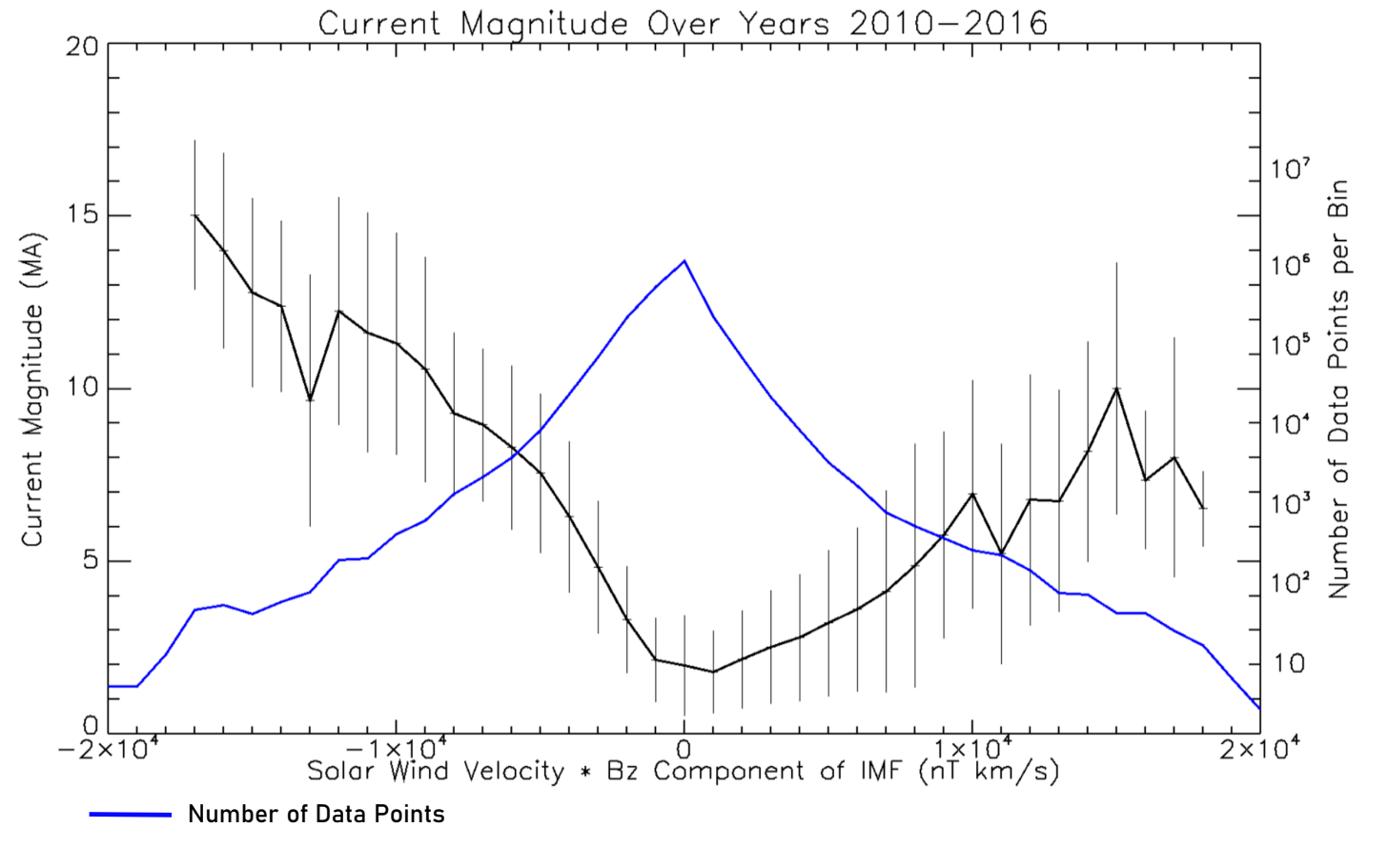
Current Saturation- Bz * Vsw (E field approximation)



- During southwards IMF, some discernible saturation is seen .
- During Northwards IMF, saturation features suggested towards 2.5 X 10^4 nT kms^{-1}.
- Indicative of the saturation seen in V_{sw}.

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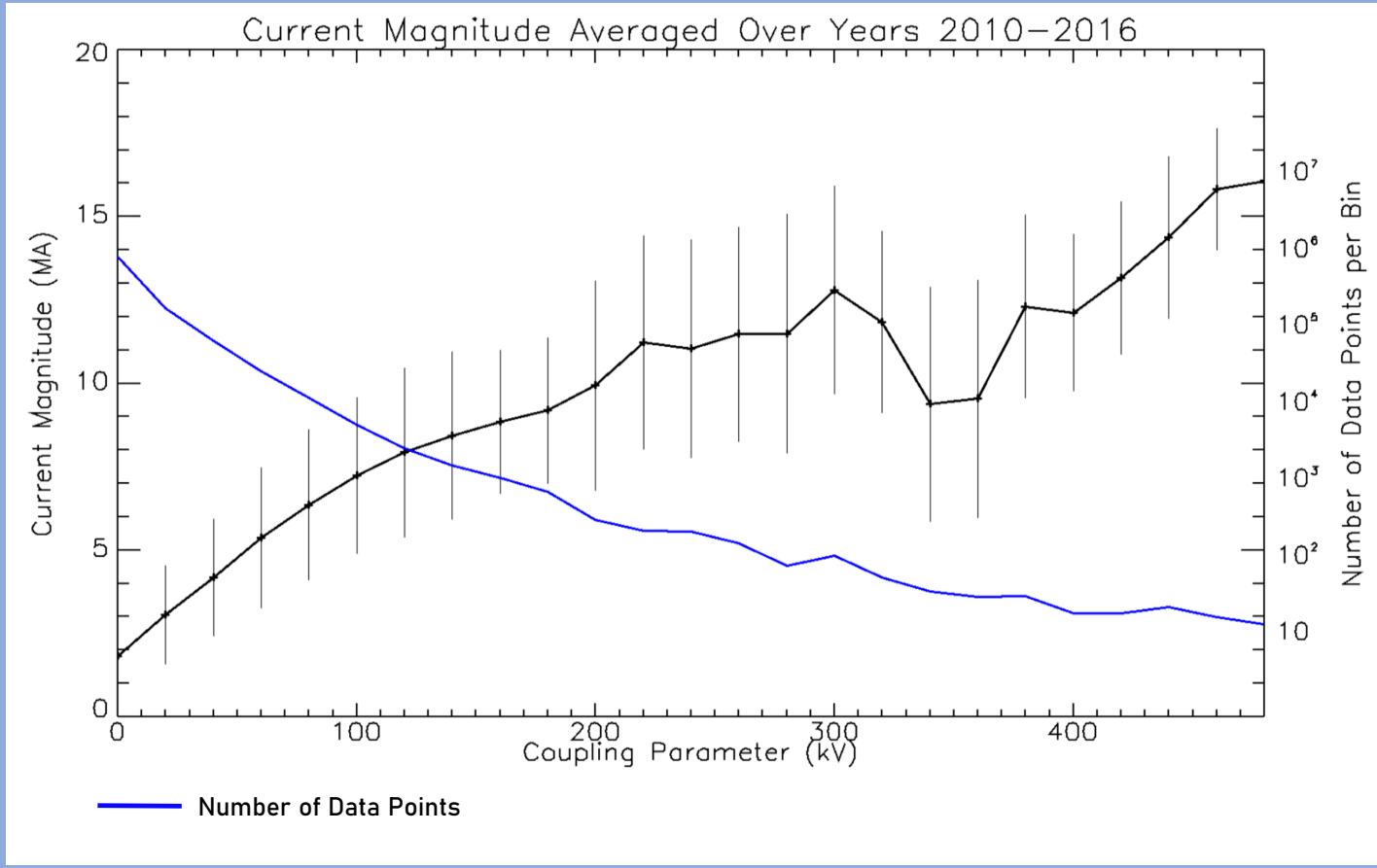
Current Saturation- Milan et al. Coupling Parameter



- Coupling Parameters give a measure of how effectively the solar wind is driving reconnection.

$$\Phi_D = \Lambda V_X^{\frac{4}{3}} B_{YZ} \sin^{\frac{9}{2}} \frac{1}{2}\theta$$

- No discernible saturation is seen. There is suggestions of non-linearity, however

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Summary

- No clear indications of complete saturation within the AMPERE data available to us, however Milan et al. (2012), coupling parameter shows some suggestion of non-linear response.
- There is clearly a strange feature in the current magnitude for northwards IMF data, when looking at solar wind speed dependencies.
  - Caution should be taken when considering the importance of these higher solar wind speed trends as, shown in the plots, the number of data points in these bins are very close to the minimum allowed.
- Given previous observations of saturation in cross polar cap potential and the lack of analogous saturation in the current magnitudes (despite some non-linearity), it may suggest ionospheric conductance could play a significant role in modulating the strength of solar wind-magnetosphere- ionosphere coupling.

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Further Work- The Next Steps

- The suggested depression in current magnitude for high, northward IMF values of solar wind speed, requires further study.
- We will isolate the instances where these events occur and look at them in more detail.
- Hemispherical current maps will be produced in order to get a clearer picture of the system during these times.
- Investigations into how the current density or current area (or both) increases will also be undertaken to give us further insight into the system.

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Any Questions?

Thank you for listening and feel free to get in touch if you have any further questions:

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