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On the origins of an explicit IMF By dependence on solar wind - magnetosphere coupling

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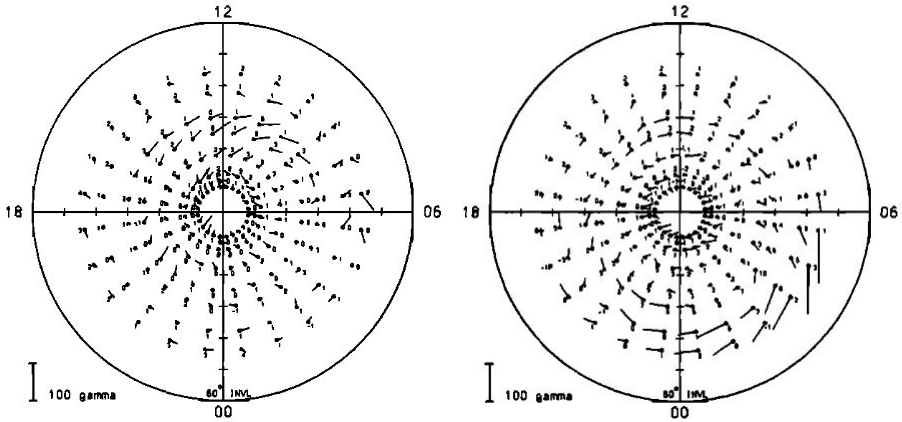
What is the “explicit By effect”?

“During local winter, northern hemisphere westward electrojet is significantly stronger during positive IMF By than negative IMF By.”

Figure below is likely the first mention of this effect, showing “residual equivalent current”.

IMF By < 0 IMF By > 0

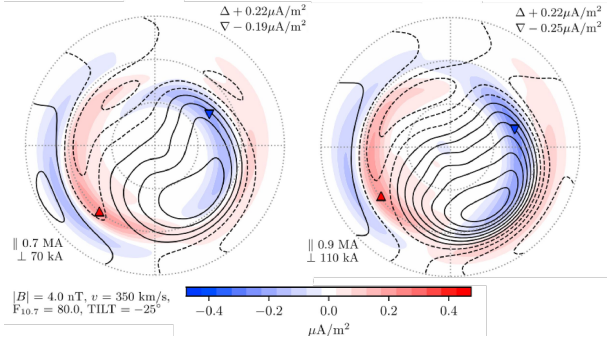


Friis-Christensen and Wilhjelm, 1975

Recently this has been studied in more detail [Smith et al., 2017, Holappa and Mursula, 2018].

Local winter difference in electrojet intensity: ~50%, and appear in both hemispheres but during opposite IMF By conditions.

During the same conditions, similar explicit IMF By effects are seen in the postmidnight Birkeland currents [Laundal et al. 2018]

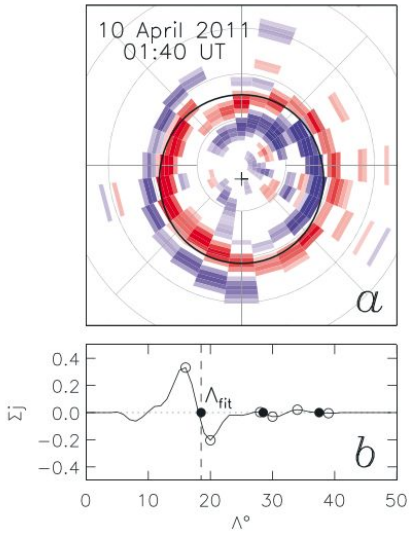


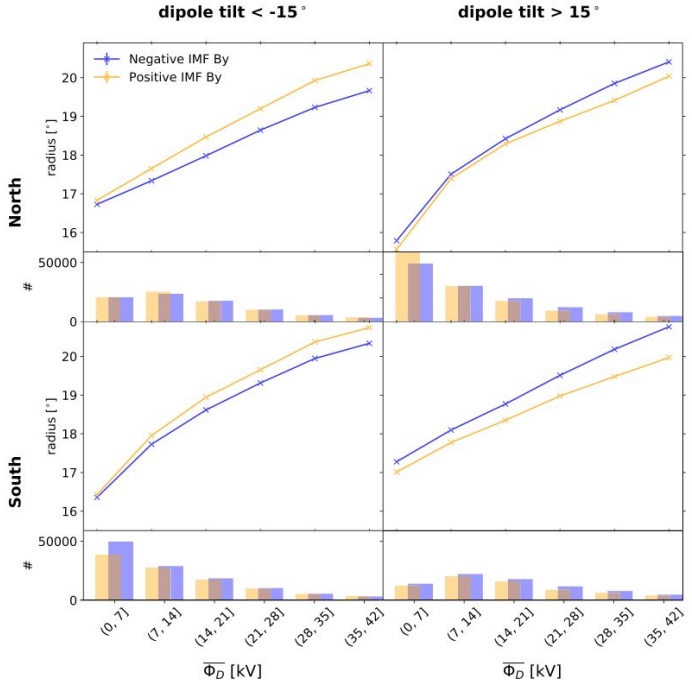
During local summer, only minor explicit By effects are seen on the westward electrojet.

Explicit By effect: Size of auroral oval

Reistad et al. 2020 investigated the average size of the auroral oval during conditions of similar dayside driving.

Used radius of a circle fitted to the region between the region1/region2 currents (from AMPERE) as a measure of the size of auroral oval [Milan et al., 2015]





During the same dayside coupling, ϕ_D, opposite sign of dipole tilt and IMF By lead to significantly larger auroral oval radius compared to the opposite IMF By polarity. Consistently seen in both hemispheres.

Explicit By effect: Ionospheric conductivity

Recently, Holappa et al., 2020 presented evidence of an explicit By effect also in the precipitation of >30 keV electrons. Similar to the Reistad et al. 2020 study, the explicit By effect was consistently observed in both hemispheres during both local summer and winter conditions.

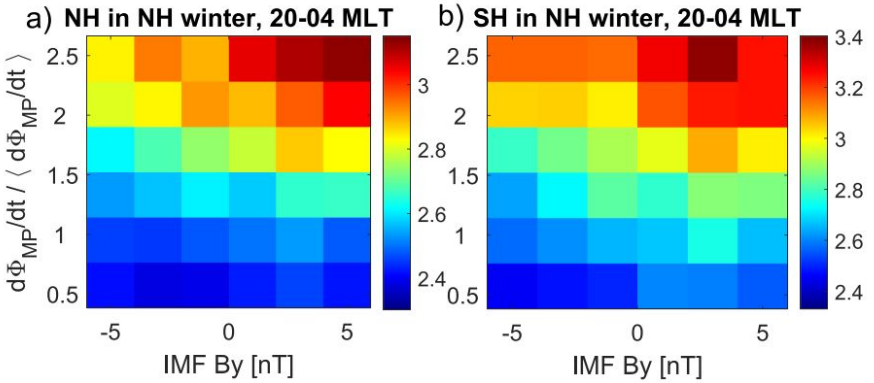


Figure 1 from Holappa et al., 2020 showing average number flux of precipitating electrons > 30 keV from NOAA satellites in color, normalized dayside coupling on y-axis and IMF By on x-axis.

Explicit By effect: What are the responsible processes?

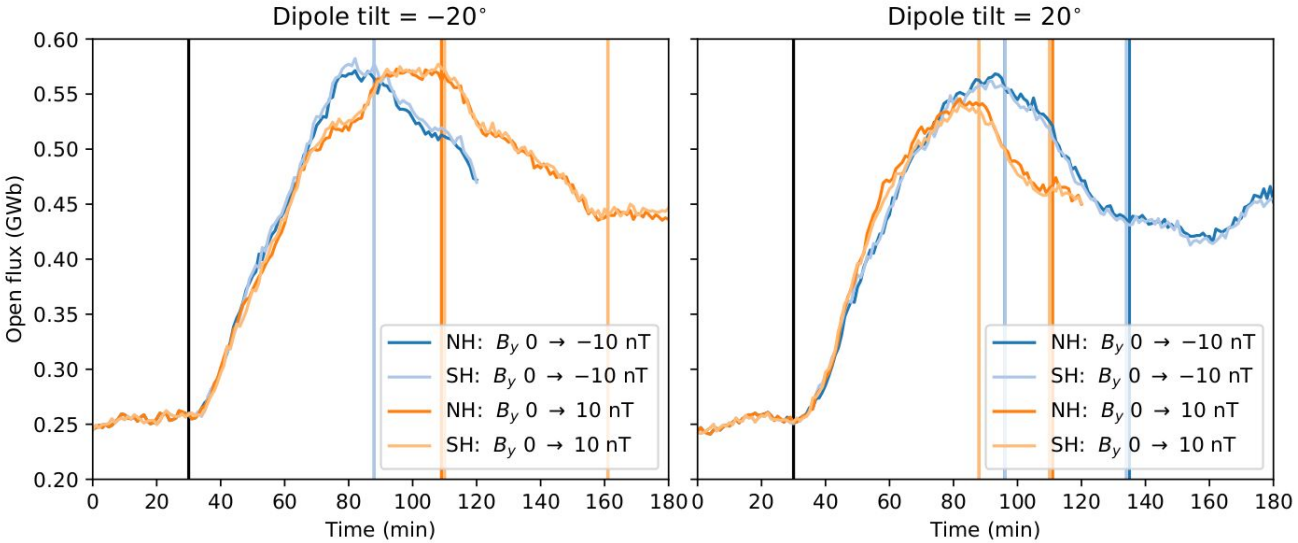
Two types of explanations are suggested:

1) Dayside coupling is asymmetric in the presence of a dipole tilt and IMF By
   - Stronger coupling when for opposite signs
2) Dipole tilt and IMF By modulate the response of the magnetotail
   - Allow for a larger polar cap
   - Modulate the substorm occurrence

Explicit By effect: What are the responsible processes?

Global MHD runs:

- LFM model runs at CCMC with the four dipole tilt / IMF By sign combinations
- dipole tilt = +/- 20^{o}
- First 30 min: IMF Bz = -1 nT, IMF By = 0
- Rest of run: IMF Bz = -1 nT, IMF By = +/- 10 nT (to trigger enhanced dayside reconnection)



1) No apparent difference in slope of open flux cureves between +/- IMF By
   - Does the model include the necessary physics and resolution to address dawn-dusk asymmetries in reconnection in the shocked solar wind?

Explicit By effect: What are the responsible processes?

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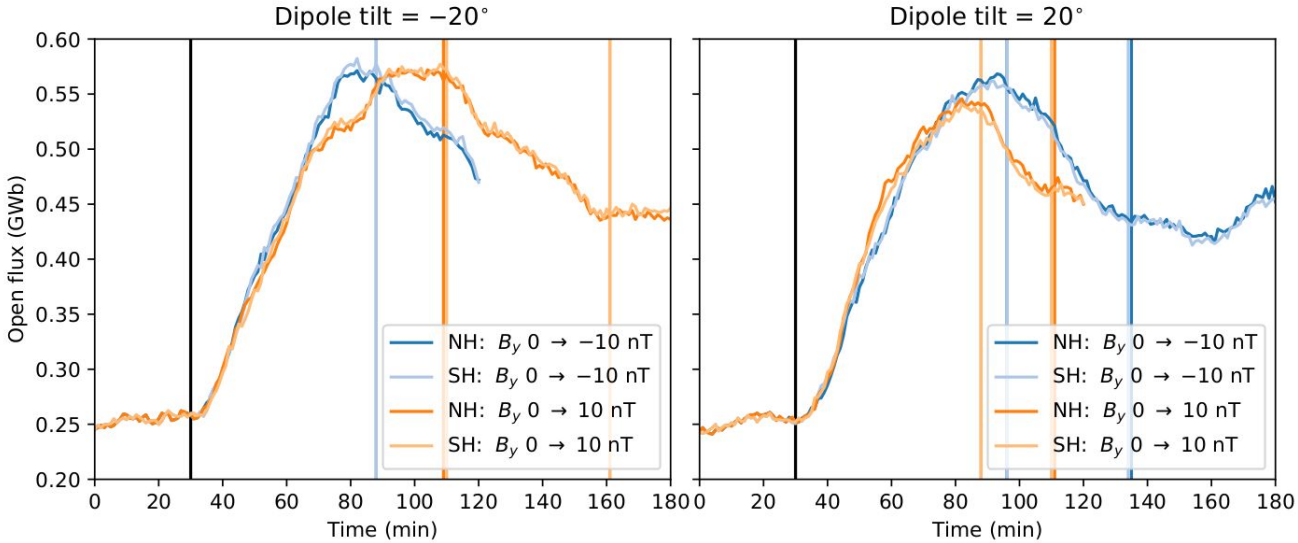

2) IMF By seem to affect the initiation of tail reconnection
   a) Delayed tail reconnection when signs are opposite
   b) Need further investigations

Explicit By effect: What are the responsible processes?

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Summary

Earlier studies [e.g. Holappa and Mursula 2018] focusing on currents in the ionsphere mainly see an effect in local winter

Due to the more recent results [Holappa et al. 2020, Reistad et al. 2020], the effect is global, and is likely more pronounced in ionospheric currents during winter due to aspects of the M-I coupling (e.g. conductivity less affected by precipitation in local summer)

The question whether the mechanism 1) or 2) listed above is the most important one, remains open. The MHD simulations shown here suggests that 2) might be of most importance, but the limitations of the model to address 1) must be further considered.

Comments and suggestions are highly welcome.