Geoeffectiveness of IP shock impact angles: results of global MHD simulations

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Introduction

The interaction of IP shocks with the Earth's magnetosphere is both complex and important. An example is the shock-shock interactions between an IP shock and the Earth's bow shock. Such remote interactions are difficult to observe, but can be readily observed with in-situ measurements in the magnetosphere. On the other hand, strong IP shock impacts on the magnetosphere have substantial space weather effects, for example, they produce ground-induced currents (GICs), which can impact power grids, and they can energize particles in the inner magnetosphere.

Motivation

Takeuchi et al. [2002] predicted that the shock normal (SN) orientation plays an important role in predicting space weather effects. They showed that a SN inclined in the equatorial plane led to an unusual SSC rise-time (∼30 min). In the context of numerical MHD simulations, Guo et al. [2005] confirmed this idea. Their magnetosphere-ionosphere system responded in a longer time to an IP SN inclined in the x-y plane in comparison to a head-on shock.

The goal of this research is to study the geoeffectiveness of inclined IP shocks in relation to the sun-Earth line. Therefore, our simulations are carried out using the OpenGGCM MHD code with the SNs lying in the noon-midnight meridian with different inclination angles.

Simulation setup

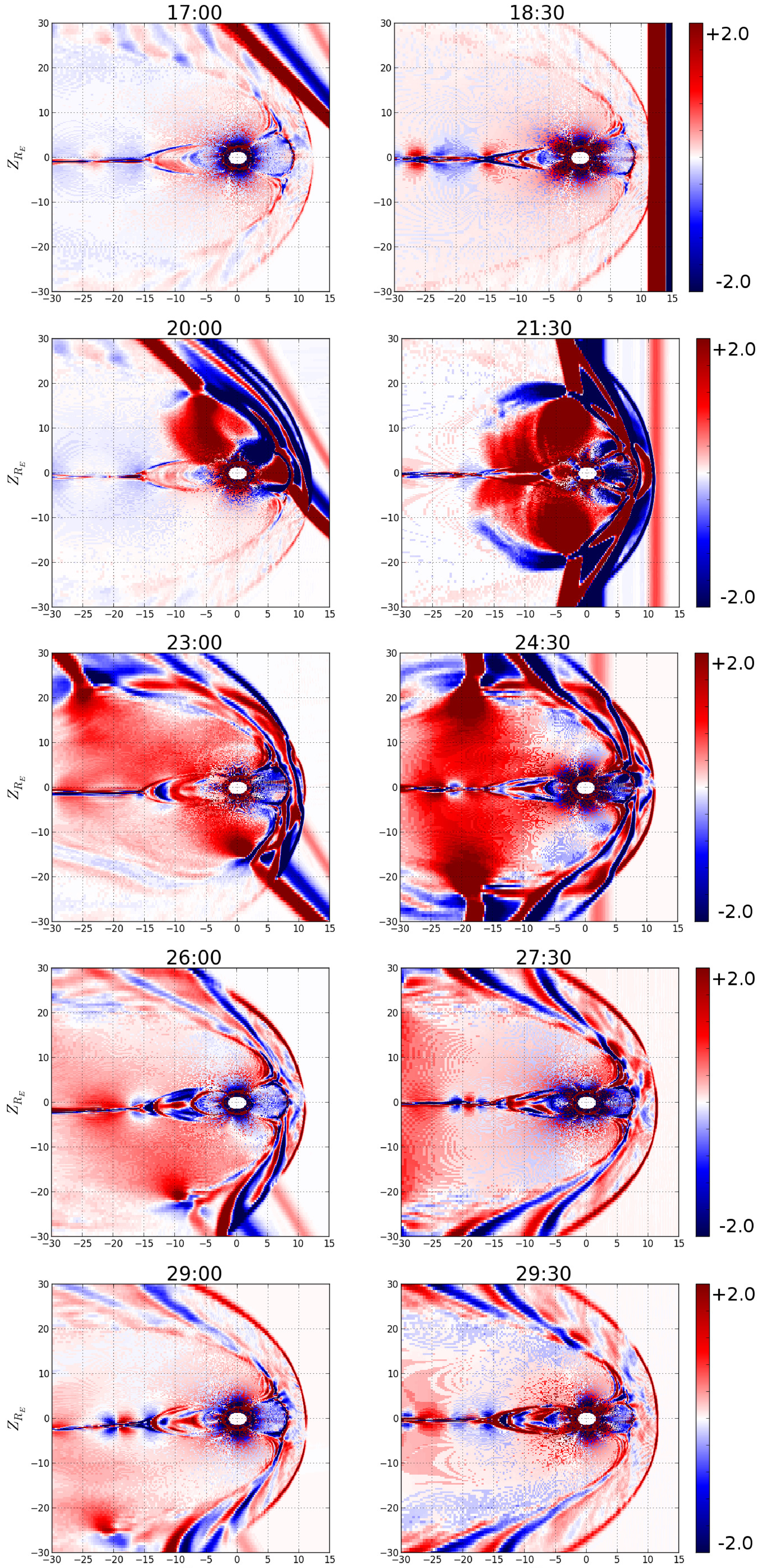
The shock speed was set to be 650 kms^{-1}. We assumed a quiet solar wind as initial condition (table). We selected two cases:

- an **inclined oblique shock, IOS**, $\theta_{x_n} = 30^o$ and $\theta_{B_n} = 45^o$
- a **frontal perpendicular shock, FPS**, $\theta_{x_n} = 0^o$ and $\theta_{B_n} = 90^o$

n in the y-z plane	B_x	B_z	v_x	v_z	P	n
upstream	1.83	-6.83	400.00	0.00	20.0	5.0
downstream, IOS	0.52	-9.09	434.15	-17.65	67.45	7.5
upstream	0.00	-7.07	400.00	0.00	20.0	5.0
downstream, FPS	0.00	-10.61	483.33	0.00	192.99	7.5

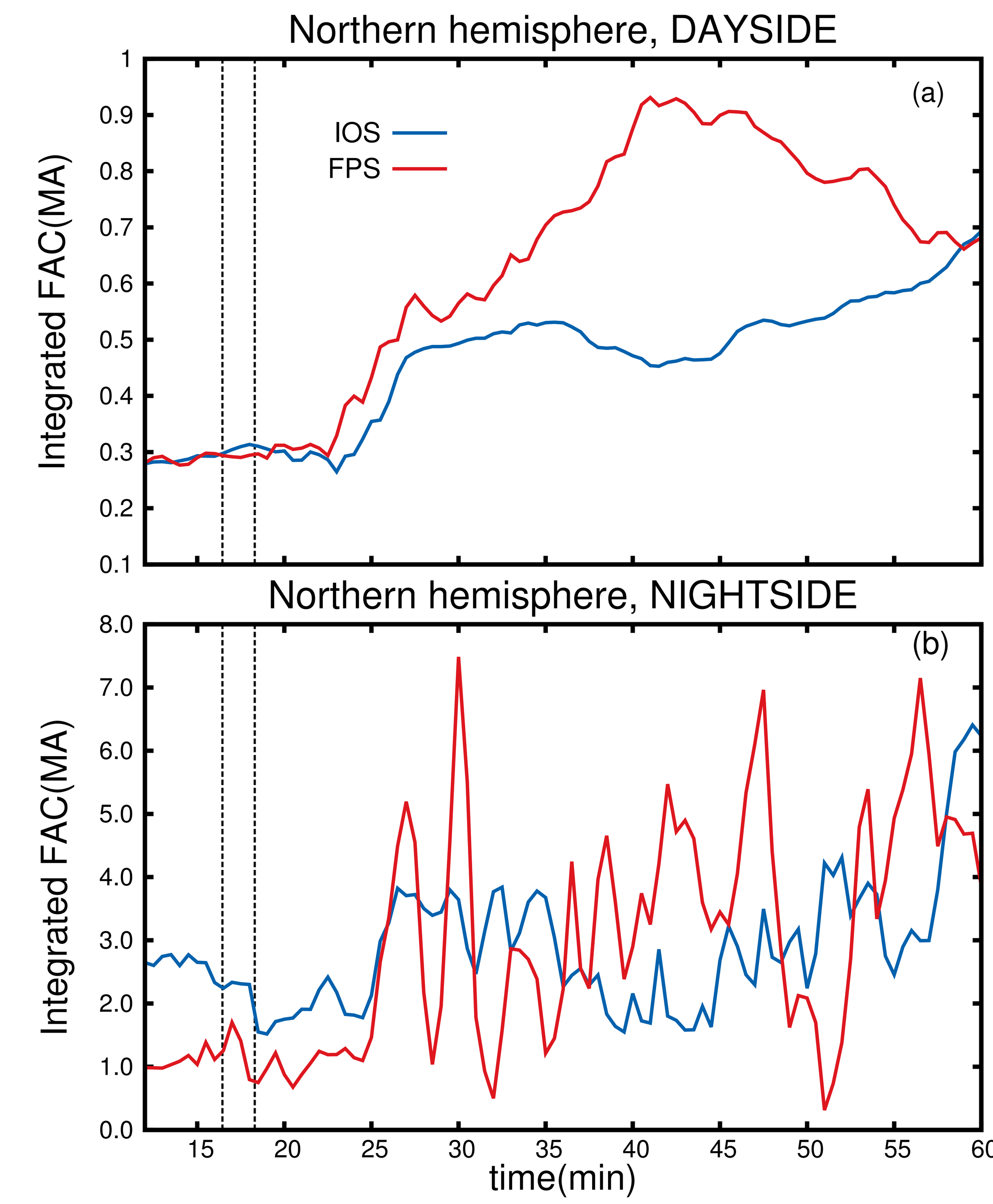
Shock impacts

Below, on left, plots of ΔB(nT), for the IOS case. On right, same sequence in the FPS case. Due to the north-south asymmetry, the plasma sheet was deflected southward by the IOS to around z = -2R_E (t=29 min). Waves propagated by the plasma sheet flanks, without much compression. The plasma sheet was much more compressed by the FPS with no deflection. More energy was realeased in the tail and reconnection may have been triggered there. Both systems evolved to nearly the same final state.



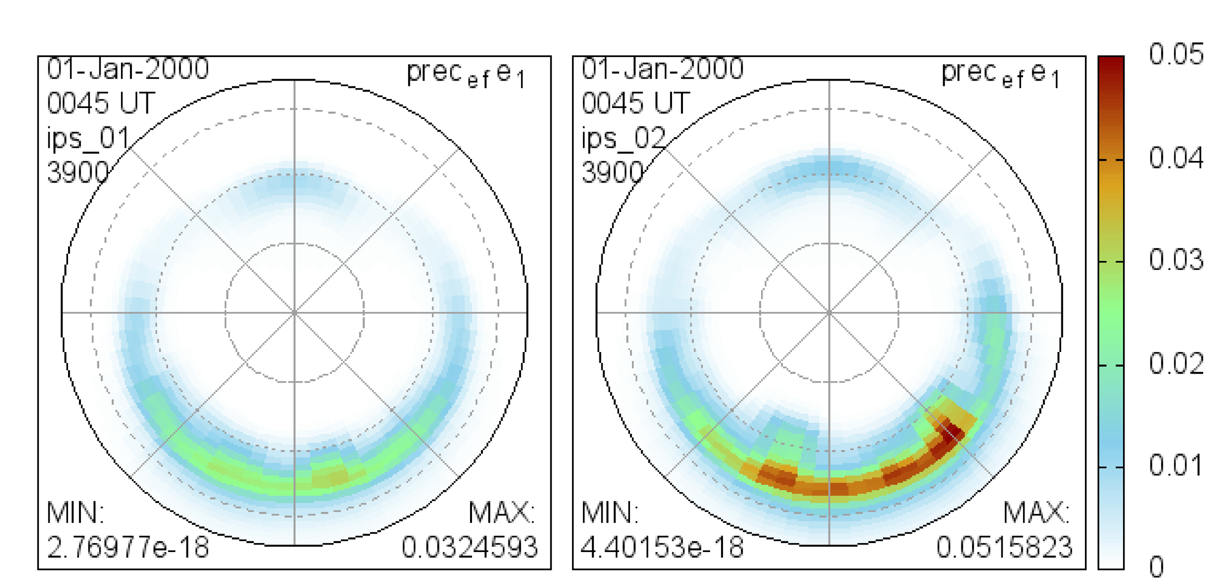
Northern Hemisphere FACs

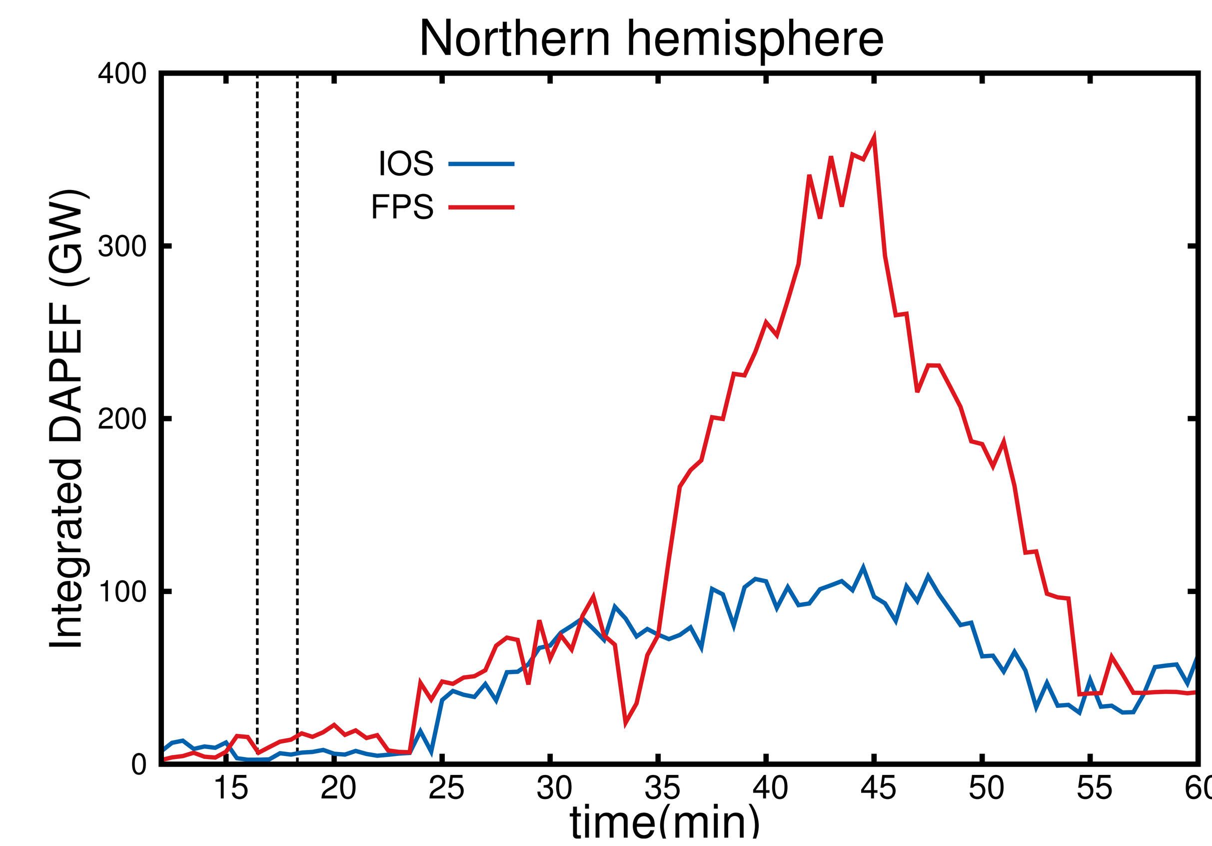
Integrated field-aligned currents (FACs, in MA) in the northern hemisphere. After the IOS impact, on the dayside (top), FACs were weakly enhanced, being stronger in the FPS case, as was expected. FACs oscillated as a result of the IOS impact on the nightside (bottom). On the other hand, FACs oscillated more clearly with large amplitude after the FPS swept over the magnetosphere.



Auroral precipitation

Diffusive auroral e^- energy flux, in W/m^2, is represented below nearly 30 minutes after shock impacts. On left, the IOS case, on right, FPS case. The auroral substorm followed by the FPS was much stronger than the auroral substorm followed by the IOS (see plot at the top of next column).





Conclusion

We conclude that the Earth's magnetosphere and ionosphere respond to IP shocks in different ways depending on the shock impact angle. We investigated effects of SN lying in the x-z plane inclined in relation to the x-line.

- The plasma sheet is more compressed for more perpendicular IP shocks with smaller impact angles. Oblique shocks with larger impact angles are less geoeffective.
- Such compressions can trigger reconnection in the tail and more intense effects on the nightside of the ionosphere. For example, auroral substorm might be triggered in the ionosphere.
- FACs were enhanced in both simulations. However, FACs had an oscillatory behavior followed by the FPS impact.

References

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