Role of interplanetary shock impact angles in substorm triggering

University of New Hampshire

Denny M. Oliveira[†] and Jimmy Raeder

EOS Space Science Center, University of New Hampshire, Durham, NH USA

ICS-12 The 12th International Conference on Substorms

Introduction

The interaction of IP shocks with the Earth's magnetosphere is both complex and important. 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. Another important response of the magnetosphere/ionosphere system to IP shocks is the triggering of substorms. It is known that a long period of southward IMF B_z followed by IP shocks is a good condition for substorm triggering. In this work we investigate the role of IP shock impact angles in substorm triggering.

Motivation

Takeuchi et al. [2002] suggested 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 a particular event. 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 recently published research [Oliveira and Raeder, 2014] is to study the geoeffectiveness of inclined IP shocks in relation to the sun-Earth line. Our simulations are carried out using the OpenGGCM MHD code with the SNs lying in the noon-midnight meridian plane with different inclination angles.

Simulation setup

We choose three IP FFSs: IOS-1 and IOS-2, inclined oblique shocks, and an FPS, frontal perpendicular shock. The main shock parameters are listed in the table below. The shock speeds are given in km/s.

	θ_{x_n}	θ_{B_n}	v_s	X	Ma
IOS-1	30^o	51^o	380	1.5	3.7
IOS-2	30^o	45^o	650	1.5	7.4
FPS	0^o	90^o	650	1.5	3.7

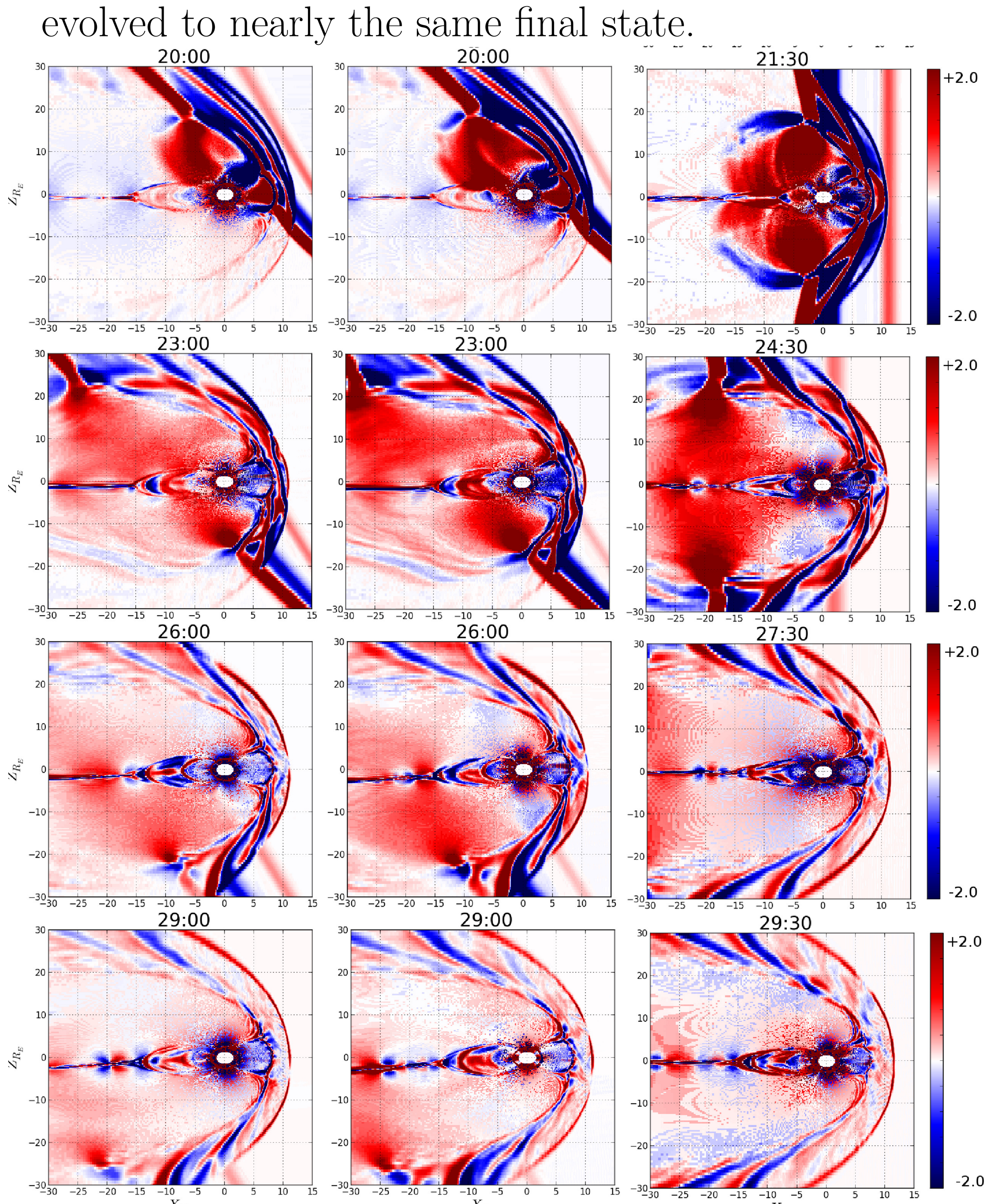
Solar wind input data

[a]	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-1	-0.52	-9.09	-434.15	-17.65	67.45	7.5
upstream	-1.83	-6.83	-400.00	0.00	20.0	5.0
downstream, IOS-2	-0.52	-9.09	-461.53	-28.61	109.74	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

[a] v in km/s, B in nT, P in pPa, and n in particles/cm^3

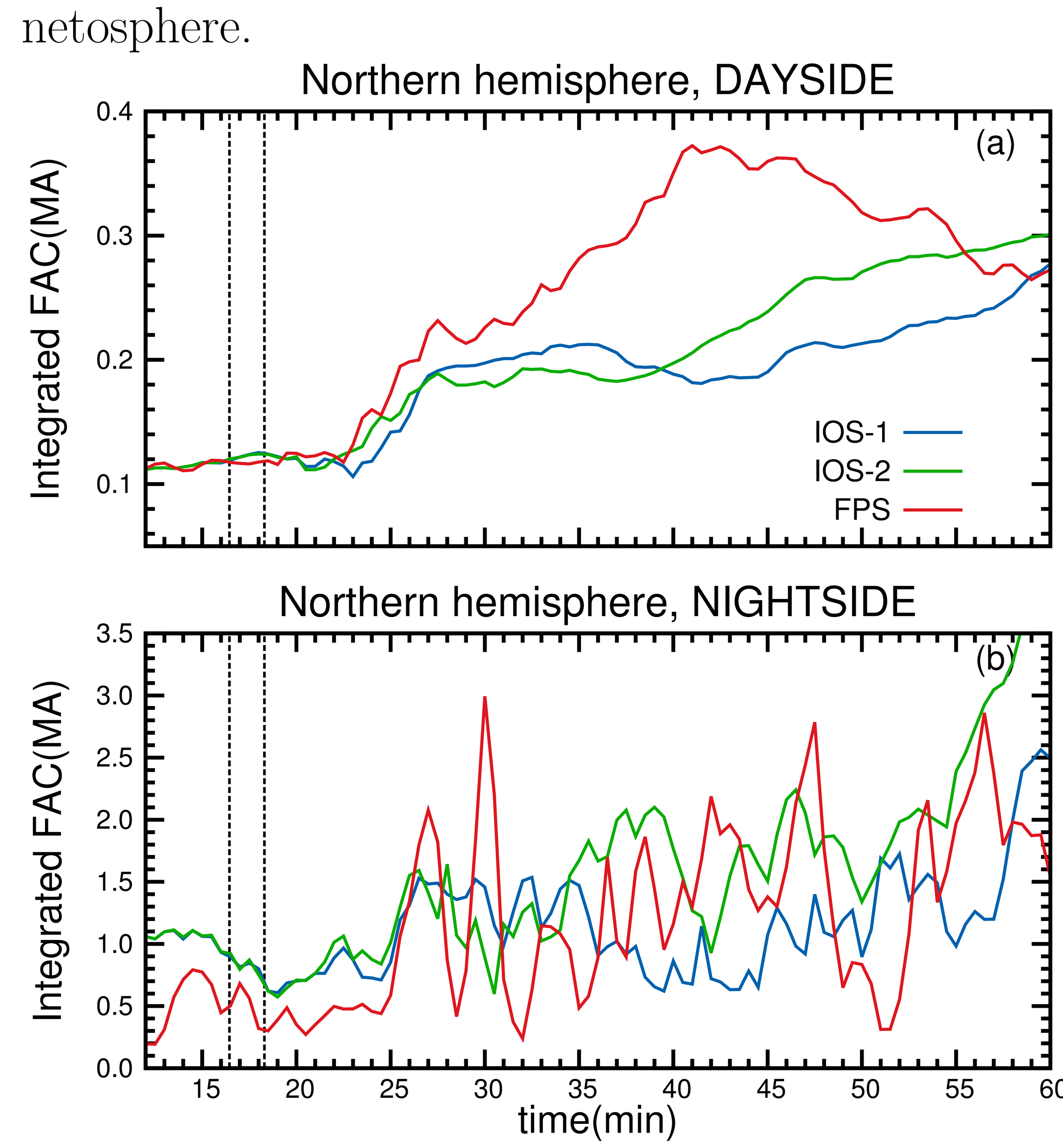
Shock impacts

Below, on left and in the middle, plots of ΔB(nT), for the IOS-1 and IOS-2 cases, respectively. On right, same sequence in the FPS case. Due to the north-south asymmetry, the plasma sheet was deflected southward by both IOS cases to around z = -3R_E and z = -4R_E, respectively (t=29 min). Waves propagated through the plasma sheet flanks, without much compression. The plasma sheet was much more compressed by the FPS with no deflection. More energy was released in the tail and reconnection may have been triggered there. Both systems evolved to nearly the same final state.



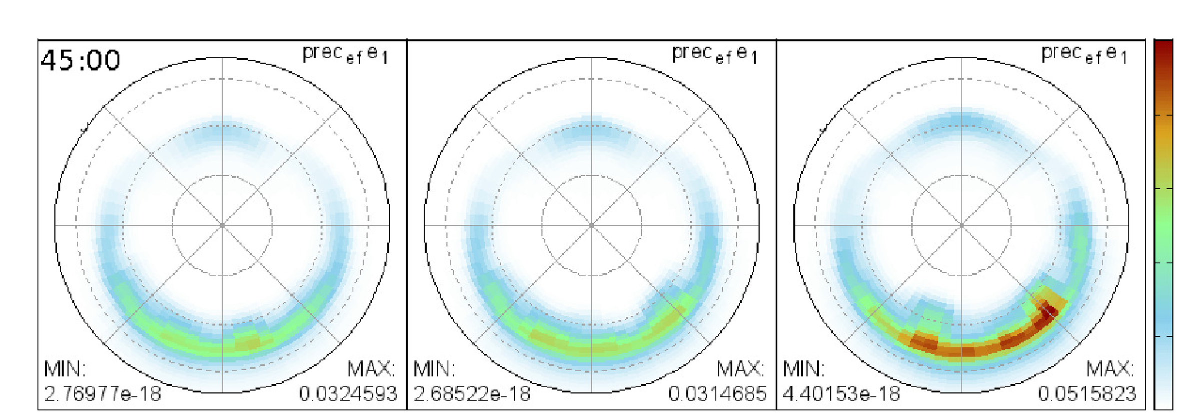
Northern Hemisphere FACs

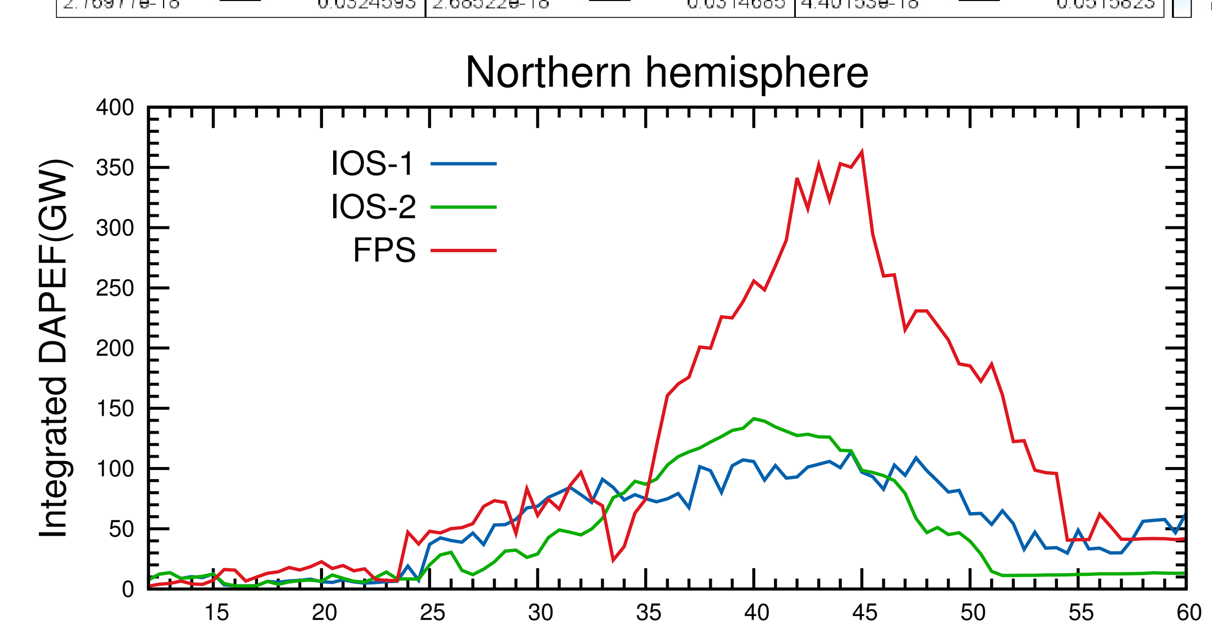
After the IOS impacts, on the dayside (top), FACs were weakly enhanced, being stronger in the FPS case, as was expected. FACs oscillated as a result of the IOS impacts on the nightside (bottom). On the other hand, FACs oscillated more clearly with large amplitude after the FPS swept over the magnetosphere.



Auroral precipitation

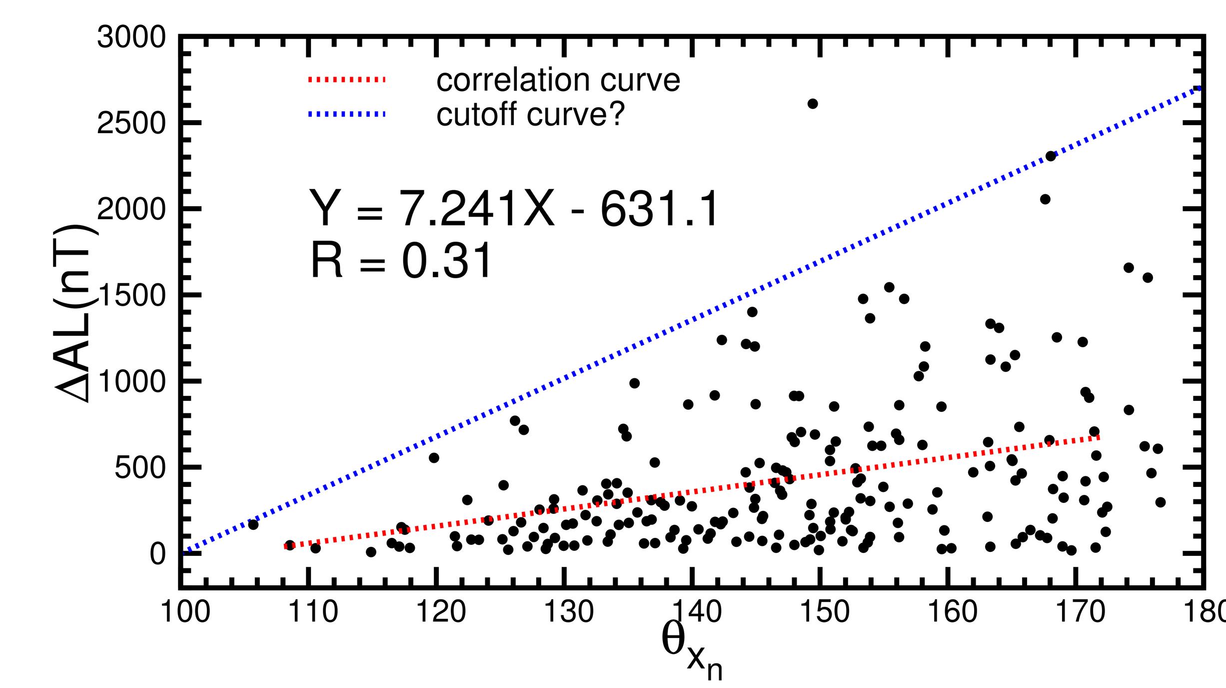
Auroral precipitations ∼30 min after shock impacts. The two inclined cases did not trigger substorms. The auroral activity is more intense in the FPS case, even though it was weaker than the IOS-2.





Initial statistical results

Correlation between impact angles θ_{x_n} of 213 IP shock events (ACE and WIND data), and geomagnetic index AL, in nT, from the World Data Center for Geomagnetism, Kyoto, Japan (http://wdc.kugi.kyoto-u.ac.jp/). Angles closer to 180^o represent almost frontal shocks.



Conclusion

We conclude that the Earth's magnetosphere and ionosphere respond to IP shocks in different ways in relation to substorm triggering depending on the shock impact angle.

- The plasma sheet is more compressed for more perpendicular IP shocks with smaller impact angles. Oblique shocks with larger impact angles are less likely to trigger substorms, even if they have larger Mach numbers.
- FACs were enhanced in all simulations. However, FACs had an oscillatory behavior with large amplitudes followed by the FPS impact.
- Such compressions can trigger reconnection in the tail and more intense effects on the nightside ionosphere. For example, stronger auroral substorm might be triggered there.

References

X.-C. Guo, Y.-Q. Hu, and C. Wang. *Chinese Phys. Lett.*, 22(12):3221–3224, 2005.

D. M. Oliveira and J. Raeder. *J. Geophys. Res.*, 119, 2014.

T. Takeuchi, C. T. Russell, and T. Araki. *J. Geophys. Res.*, 107(A12): 1423, 2002.

Acknowledgments

D.M.O. would like to thank the ICS-12 organizers, specially Dr. Kazuo Shiokawa, for the opportunity to present this work. D.M.O. also thanks NIPR (National Institute for Polar Research) for the partial financial assistance.

[†]Email: dmz224@wildcats.unh.edu