Geomagnetic avtivity triggered by interplanetary shocks: The shock impact angle as a controlling factor

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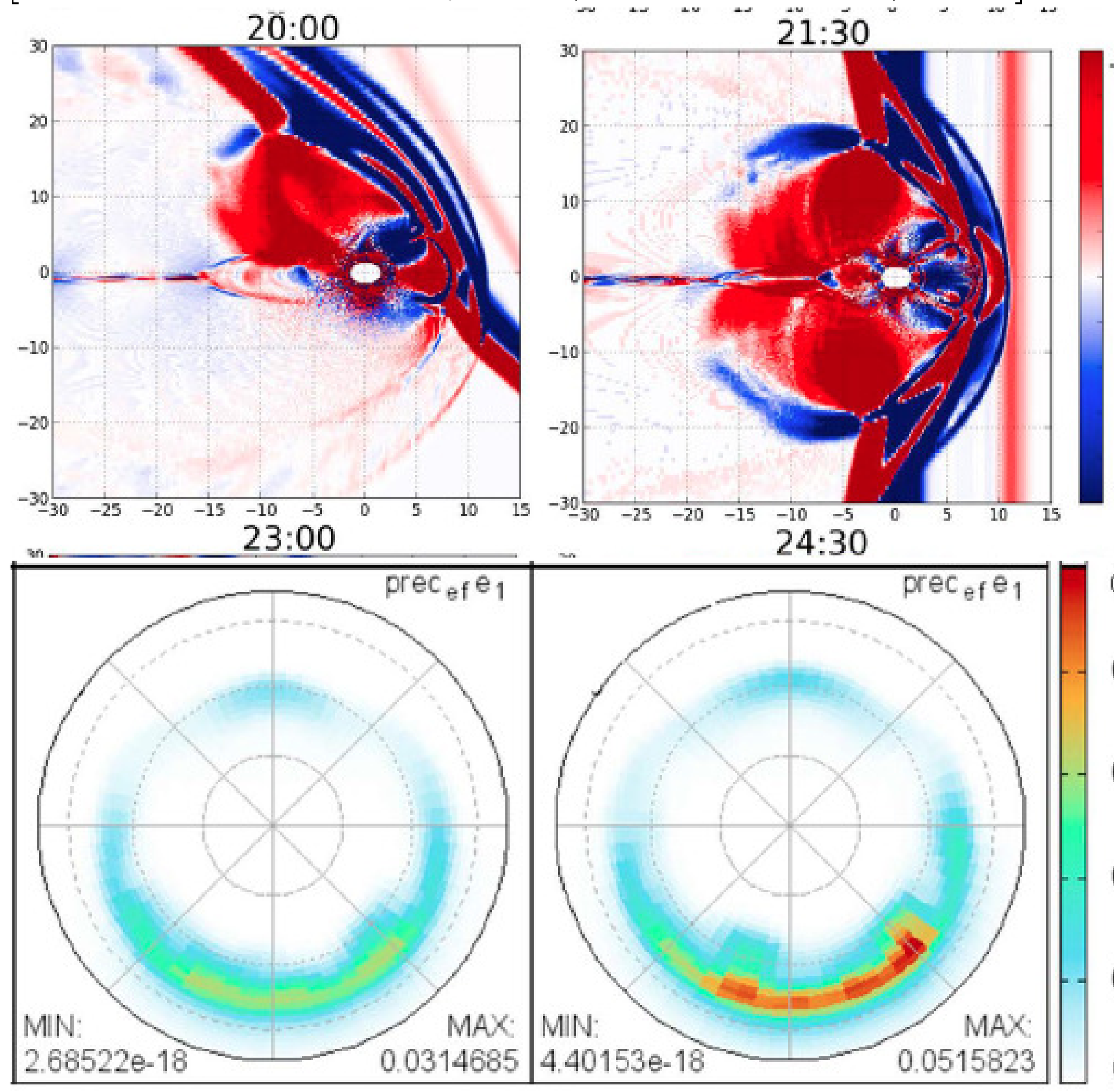
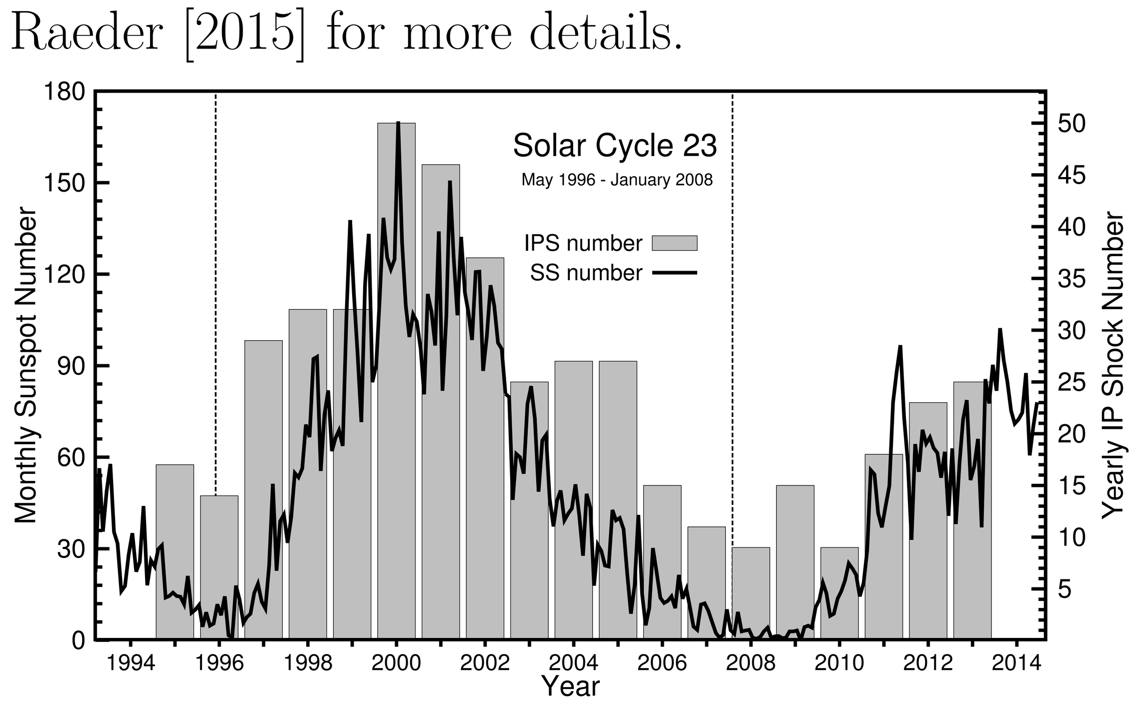
Motivation

The motivation for this research is the understanding of how interplanetary (IP) shock inclination angles affect the shock geoeffectiveness. In a paper recently published by Oliveira and Raeder [2014], it is shown with simulations that the shock geoeffectiveness depends on the IP shock inclination in relation to the Sun-Earth line, where shocks with small impact angles (θ_{x_n}) are more geoeffective (below). We then performed a statistical study to confirm these results with geomagnetic and solar wind data [Oliveira and Raeder, 2015, Oliveira et al., 2015].



Data

We use plasma and IMF data from ACE and Wind spacecraft (shock parameter determination), SuperMAG ground magnetometer data (geomagnetic activity), and SDC sunspot number. See Oliveira and Raeder [2015] for more details.



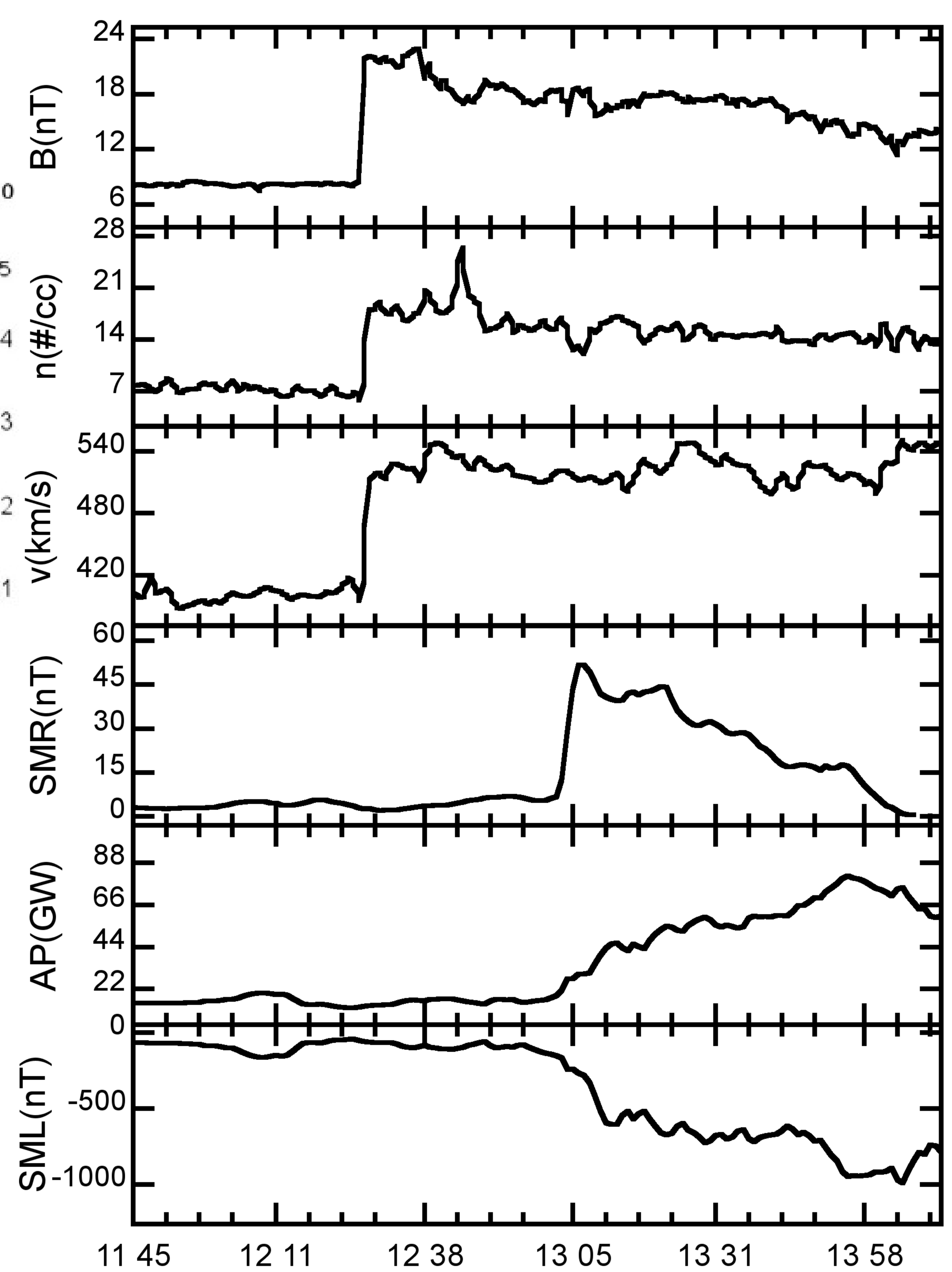
Geomagnetic activity analysis

- We investigate jumps in the SuperMAG SML and AP (auroral power) indices in a time lag of ~2 hours after shock impacts.
- The time resolution of the SuperMAG data is 1 minute.
- The SME SuperMAG index is used as a proxy for auroral power determination:

$$AP = 0.48 \times SME + 0.241 \times SME^{1/2}$$

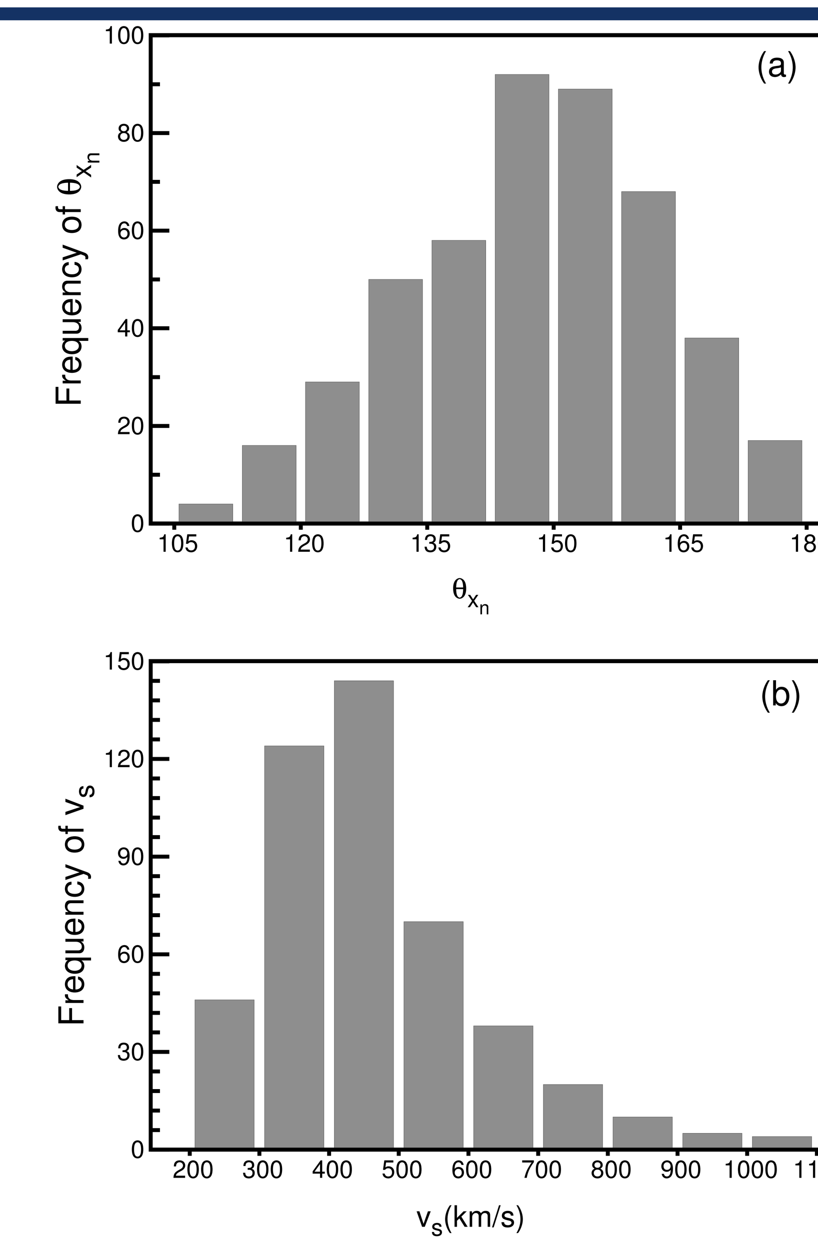
Example of an event

The figure below is an example of an event on 2000 Jun 23 at 1226 UT as seen by ACE at (240, 36.6,-0.7) R_E upstream of the Earth. This shock triggered intense geomagnetic activity.

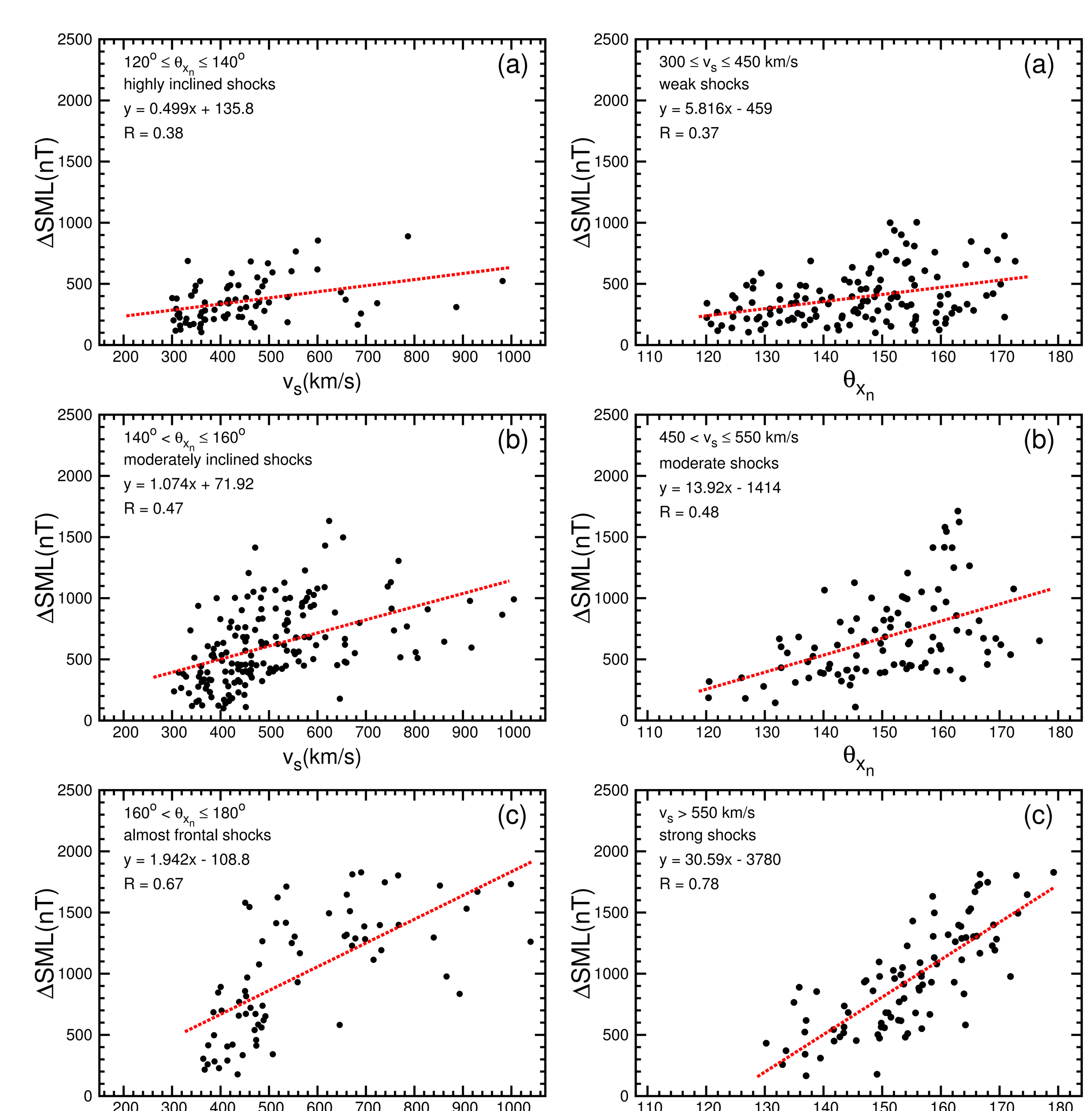


Statistical results

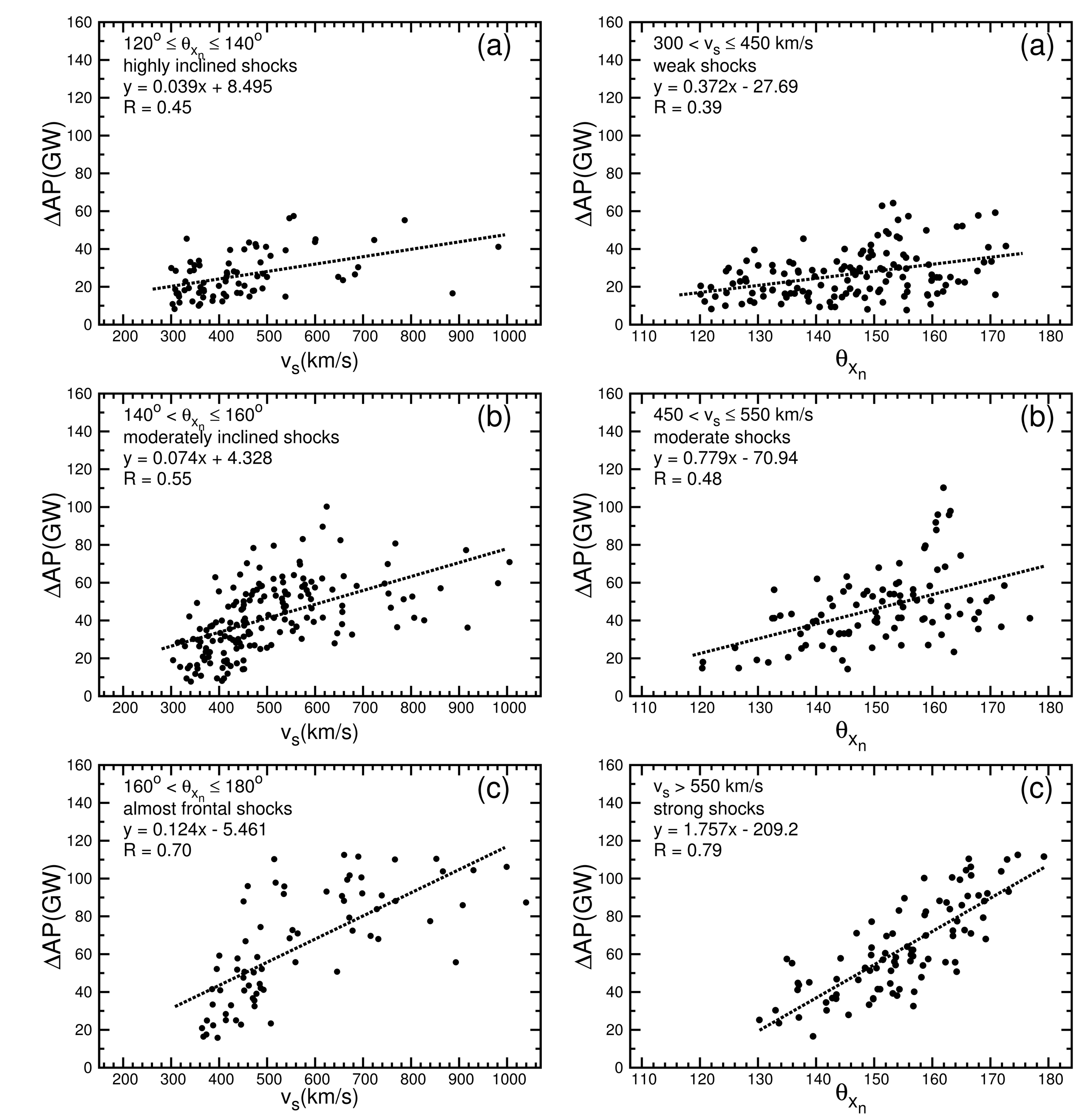
Our shock list contains 461 identified IP shocks from 1995 to 2013, covering the whole solar cycle 23 [Oliveira and Raeder, 2015]. Shock speed and inclination angle distributions are shown in the next column.



- Below, jumps in SML plotted against $v_s(\theta_{x_n})$ with fixed intervals of $\theta_{x_n}(v_s)$.
- Highly inclined shocks tend to be slower than almost frontal shocks.
- The highest correlation coefficient (R = 0.78) was obtained for the case of almost frontal and fast shocks. Shocks with small θ_{x_n} are in general more geoeffective.



The results for ΔAP are quite similar to those for ΔSML. This shows the good quality of the SuperMAG data.



Conclusion

- The number of IP shocks correlates well with the monthly sunspot number.
- The shock average is about 500 km/s. The majority of shocks in the solar wind at 1 AU are not strong shocks.
- Most shocks (78%) have their shock normals close to the Sun-Earth line, or $\theta_{x_n} \ge 135^o$.
- Fast shocks are more geoeffective if they strike the Earth the most head-on as possible. This shock feature was predicted by a modeling work [Oliveira and Raeder, 2014] and confirmed with experimental data [Oliveira and Raeder, 2015, Oliveira, 2015, Oliveira et al., 2015].

References

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