Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-9-AC2, 2018

Annales Geophysicae Discussions
Open Access
ANGEOD

Interactive comment

Interactive comment on "Statistical survey of day-side magnetospheric current flow using Cluster observations: Bow shock" *by* Evelyn Liebert et al.

Evelyn Liebert et al.

e.liebert@tu-bs.de

Received and published: 25 April 2018

Response to Referee #2

We thank the referee for his constructive and helpful comments.

1) Comment on current calculation for quasi-parallel shocks:

We will add an example event to demonstrate the identification and calculation of the currents after the application of the curlometer tool. In our study the currents are identified directly by inspection of the curlometer results. The categorization into quasi-perpendicular and quasi-parallel shocks follows afterwards. Currents are identified as

Printer-friendly version

Discussion paper

bow shock currents when the following cirteria are fulfilled: 1) clear current peak within the curlometer results visible. 2) current event coincides with particle data signatures that are consistent with a bow shock crossing.

There are cases where the current or the particle data (or both) show very fluctuating behavior making it difficult to identify current structures at a bow shock crossings. In cases, where the identification becomes presumably unreliable, the events were omitted and not included in our study.

The categorization into quasi-perpendicular and quasi-parallel geometries in the following step revealed a significant imbalance. Almost three times more quasi-perpendicular events were identified. It is very likely that this imbalance is caused especially by the fact, that the shocks are more "noisy“, fluctuating, and less "clear“ in the quasi-parallel case and were therefore more often omitted.

2) Accuracies of the current determination:

The accuracies are mentioned at p2 l25.

3) 30 sec winow, results with other windows:

We tried different sized averaging windows. The direction of the currents prove to be quite insensitive to a window size between about 20 and 40 sec. When the window is chosen too long, for example above 60 sec at the bow shock, the directions alter significantly. For small windows below 10 sec the variations within the current direction determination rise as well because of the influence of small scale fluctuations.

The current magnitudes are more sensitive to the averaging window. The damping of high frequency flucutations and the influence of the associated spatial averaging directly leads to smaller current peak magnitudes calculated by the curlometer. This effect is less intense when the average magnitudes per event are calculated. In this study we analyze the average magnitudes instead of the peak magnitudes.

The window size also influences the current identification. For very small windows, surrounding high frequency fluctuations lead to additional very sharp current peaks which reach similar magnitudes as the crossing itself, making it harder to identify the correct current structure associated with the crossing. Recurring features resembling a series of non-similar delta functions or single delta functions are filter out by the application of the averaging window. Step functions (resembling a simple "clear“ bow shock transition) are not filtered out but are maintained less sharp which mainly affects the current density's peak magnitude. Recurring features that can be interpreted as a series of similar delta functions (for example multiple encounters with a bow shock of stable configuration within a short time) are merged by the windowing process and maintained too. The described effects of the windowing becomes clear for example in the attached figure 1 which is taken from our previous publication. It shows a comparison of 0 sec and 100 sec averaging at multiple magnetopause crossing.

With too small averaging windows, the reliability of the curlometer results becomes small as well, as the basic assumptions of the curlometer technique are violated to a larger extent. Overall, the 30 sec window proved to be a practical and reliable choice for the bow shock current investigation.

4) IMF-aligned Coordinate-System, rotation around x-axis:

Thanks to both referees for pointing out that the description of the motivation for this transformation should be improved. The current directions at the bow shock are directly controlled by the IMF orientation via Amperè's law. As we do not confine our study to mainly north-south orientated IMF, the presentation of the resulting current directions in a GSE-system like in Fig. 4 but without the rotation around the x-axis leads to a quite chaotic looking distribution of the current arrows making it impossible to extract any useful information from it as indeed the required information of the IMF would not be included in such a picture. In contrast, by using the rotated system, aligned to the IMF x-z-component for each event, the collective orientation of the currents becomes visible as presented in Fig. 4. Also, the differences between the quasi-parallel and the quasi-perpendicular bow shock currents are plain to see after the transformation. In our revision we will add additional words about the motivation and advantage of using it. In principle, the choice of aligning the IMF to the positive z-direction is arbitrary. But as it is quite common in other publications to distinguish especially between northward and southward IMF and to use pure northward and southward IMF configurations as basic situations for magnetospheric simulations, it seemed natural to us, to chose the positive z-direction.

5) Data fit, p4 l5:

Probably you are referring to fig 6, which is located on page 7 in the preview version we have access to. We will add a linear fit to the data points (see attached figure 2). The correlation coefficient is 0.84.

In the limit of high Mach number one can derive J = 3 B_IMF,t/(μ0 L) where L is the bow shock thickness. The slope of the linear fit provides an estimate of the average bow shock thickness of about 1600 km. As the current magnitudes are influenced by the averaging in time and space (averaging window, spacecraft separation, average current density along event trajectory), it is more likely that current magnitudes tend to be underestimated than overestimated. A direct comparison of some events which were analyzed in the study by Tang et al. 2012 as well as in our study show that the current density magnitudes calculated with the curlometer technique are by a factor between 2.7 and 4.5 smaller than those calculated by determination of the layer thickness and the jump in the magnetic field. The value of 1600 km therefore represents an upper estimate of the shock thickness. Bale at al. 2003 performed an extensive study of the bow shock thickness which gives a typical scale of a few hundreds of kilometers.

6) No quasi-parallel shocks at high latitudes:

We have not investigated this effect yet. From basic theory it is expected, that the oscillations and variations which are triggered at the quasi-parallel shock develop within the foreshock region while they are convected towards the shock. At higher latitudes, there is more space/time available for this development before the bow shock is encountered. Because of that one can expect stronger disturbances and variations at the quasi-parallel bow shock at higher latitudes than at lower ones. As mentioned above, we only use events within our study, where a reliable identification of the shock current was possible. It might well be that high latitude quasi-parallel events were unintentionally omitted due to this restriction. Still, this is only speculation as we have not studied this in detail yet.

7) Accuracy of distinction between quasi-perpendicular and quasi-parallel cases:

It is possible, that some events are not categorized correctly because of uncertainties within the determination of the shock normal and the IMF direction, mainly when the angle is near 45°. This leads to some quantitative uncertainties within the results. As the differences between the quasi-perpendicular and the quasi-parallel events are still very obvious, these uncertainties to not significantly alter the qualitative results.

8) Rearragement of bars within figures 3 and 5:

Thank you for this suggestion. Putting them side by side makes the distribution for the quasi-parallel events much clearer.

9) Language issues:

Thanks for pointing them out. We will correct them in the revision.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-9, 2018.

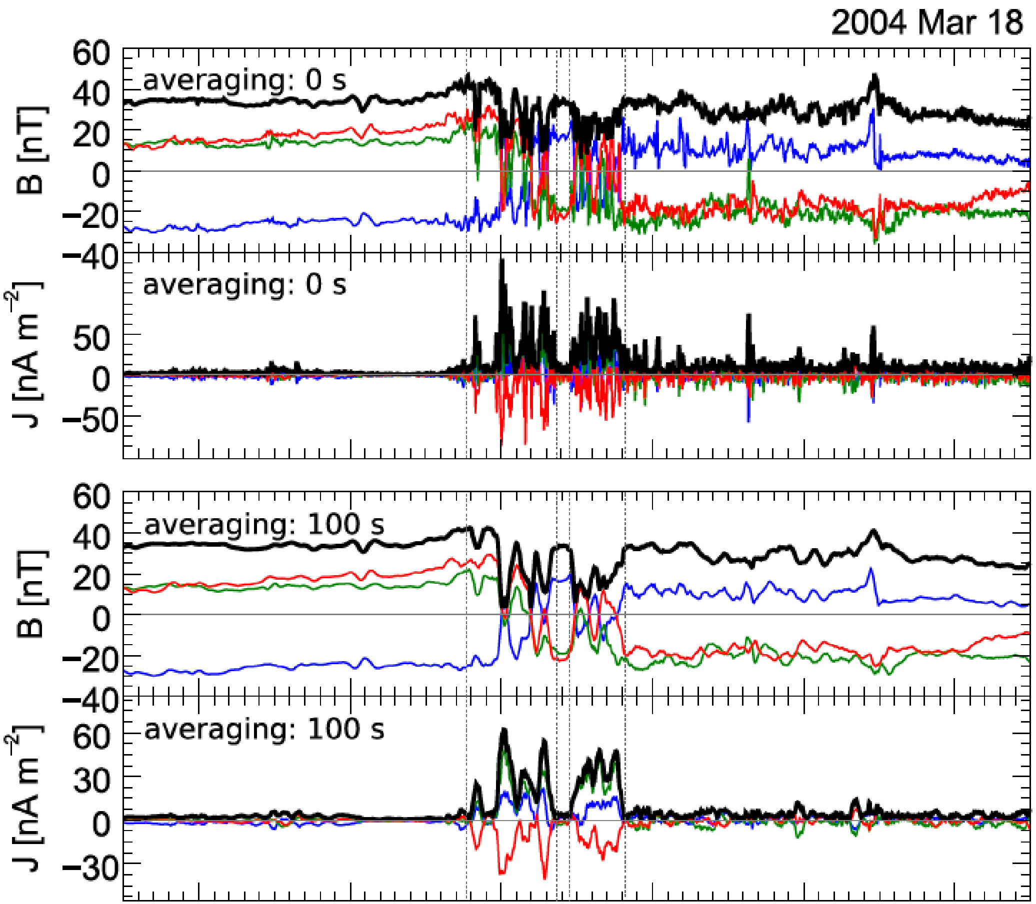
2004 Mar 18
averaging: 0 s
B [nT]
60
40
20
0
−20
−40
averaging: 0 s
J [nA m⁻²]
50
0
−50
averaging: 100 s
B [nT]
60
40
20
0
−20
−40
averaging: 100 s
J [nA m⁻²]
60
30
0
−30

Fig. 1.

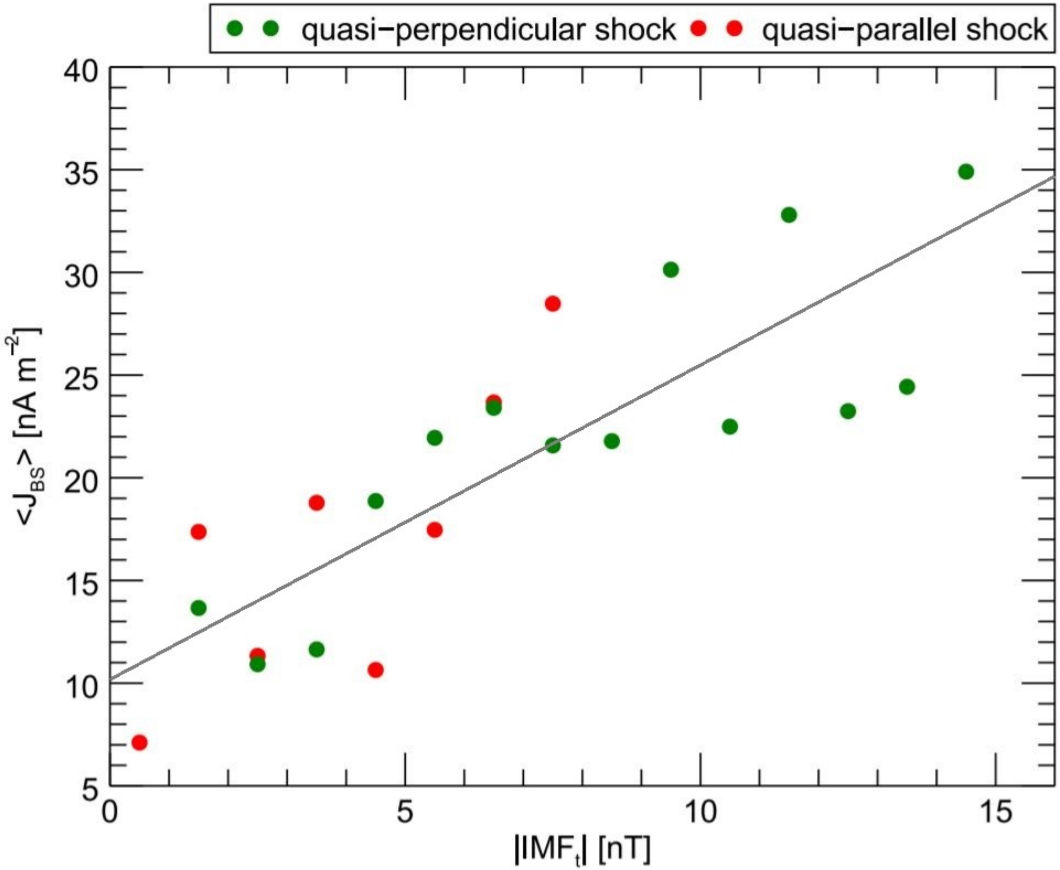

Fig. 2.

Printer-friendly version

Discussion paper