Magnetic field within **magnetosheath jets** during northward and southward IMF conditions

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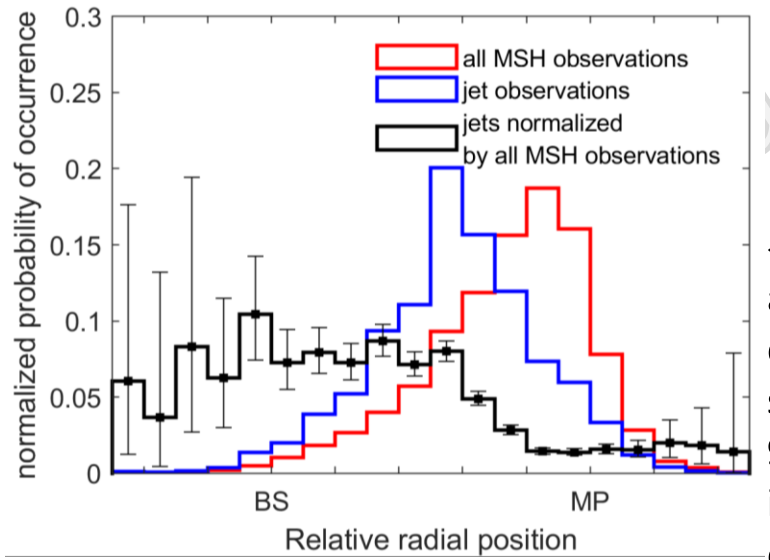
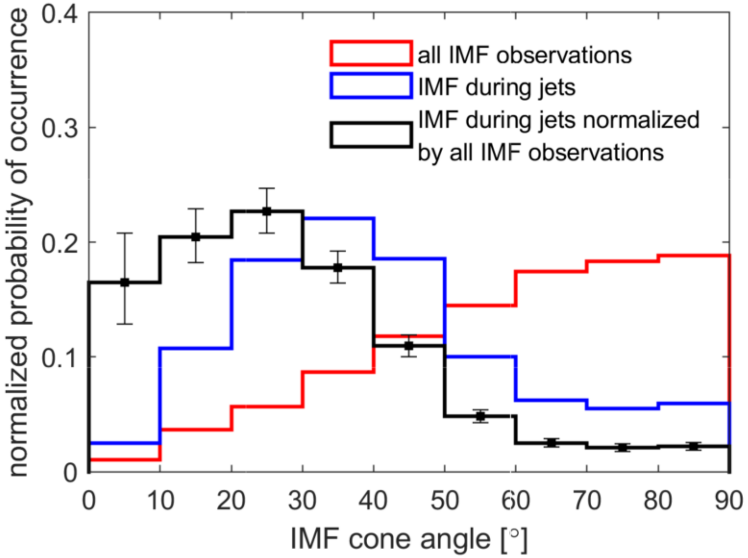
How does the GSM B_Z distribution within magnetosheath jets compare to the non-jet magnetosheath during northward and southward IMF?

Are the magnetic fields within jets statistically favorable for triggering magnetopause reconnection during quiet northward IMF?

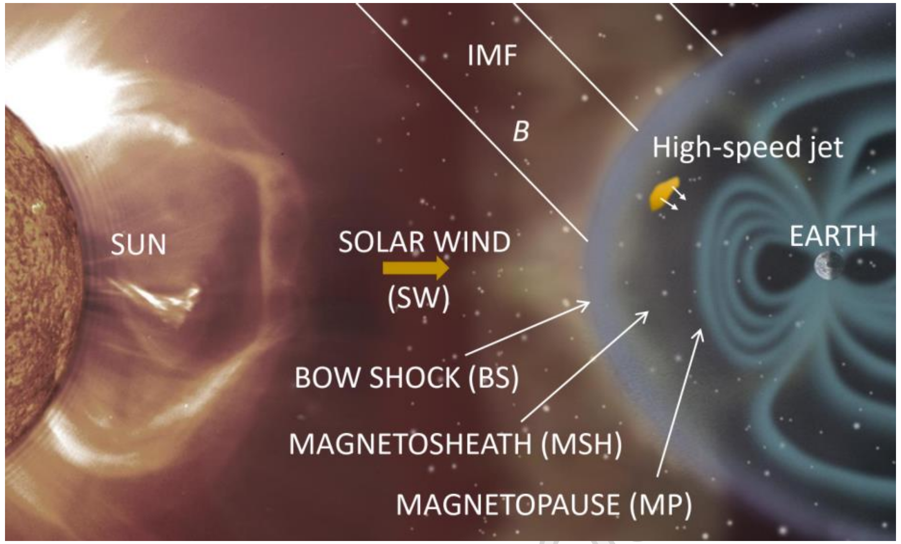
1. Magnetosheath jets: enhancements of $P_{\mathrm{dyn}} = \rho v^2$





← **Fig. 2:** Relative position and IMF cone angle distributions of our data set. Error bars represent 95 % binomial confidence intervals. Credit: Plaschke et al., (2013).

→ **Fig. 1:** The background image credit: SOHO (ESA & NASA).



- Mostly observed downstream of the quasi-parallel shock (e.g., Archer et al., 2013 and Plaschke et al., 2013)
- Jets are common: jets larger than 1 R_{E} in diameter are estimated to impact the subsolar magnetopause around 5–60 times per hour depending on IMF cone angle (Vuorinen et al., 2019)

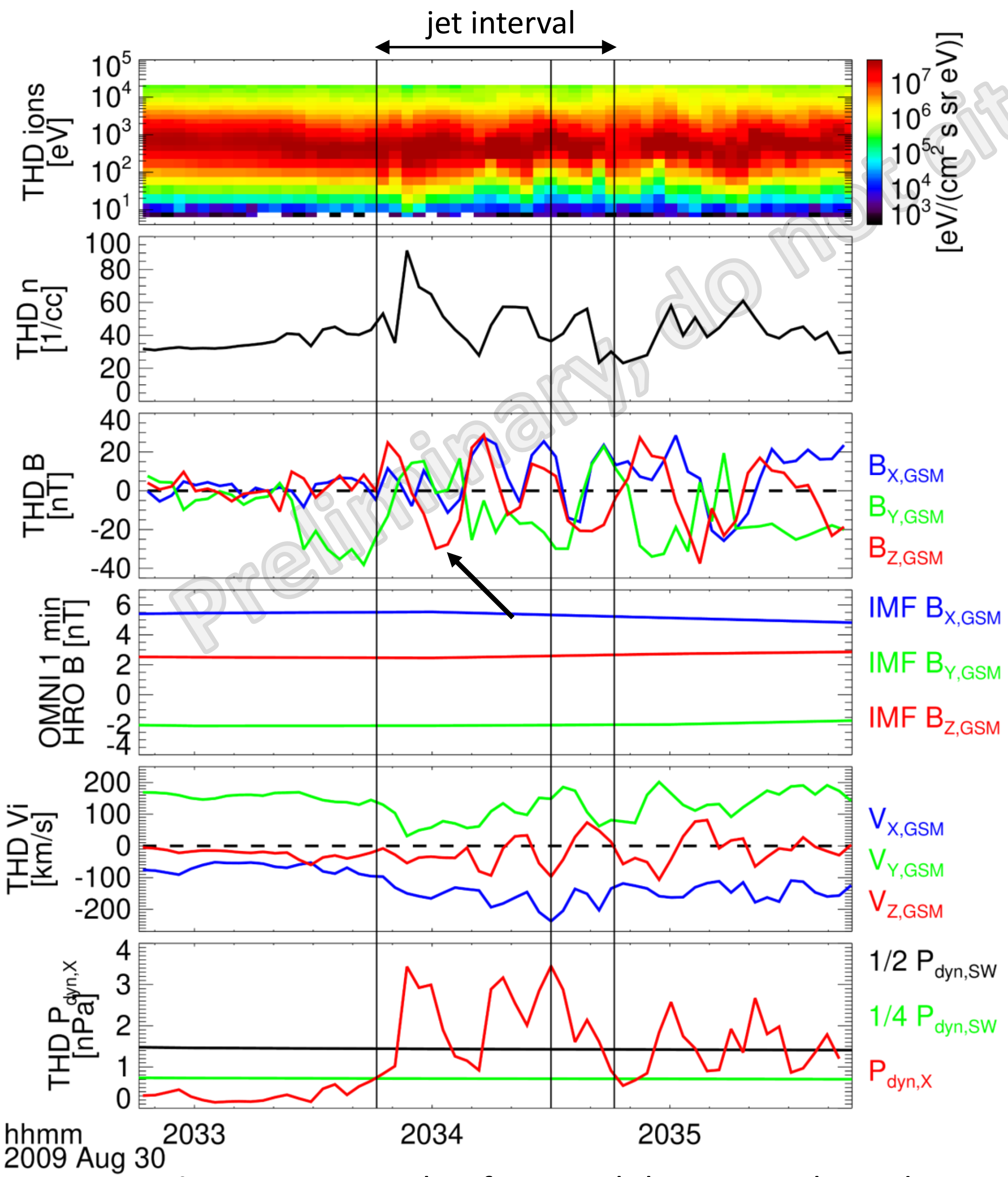


Fig. 3: An example of a jet exhibiting southward magnetic field during northward IMF.

- Southward magnetic fields have been observed within jets during northward IMF
- Jets with southward fields linked to triggering magnetopause reconnection and a substorm during northward IMF (Nykyri et al., 2019)

How common is this? Can jets be expected to statistically affect the occurrence of magnetopause reconnection via their magnetic fields?

2. Data and methods

- 2,736.9 hours of THEMIS 2008–2011 data from the subsolar magnetosheath (Angelopoulos, 2008)
- OMNI solar wind data (King and Papitashvili, 2005)
  - Running average over the preceding 5 minutes
- 2,859 jet intervals following the definition by Plaschke et al. (2013):
  - Within a jet, the dynamic pressure in the $-X_{\mathrm{GSE}}$ direction goes above 1/2 of the total SW dynamic pressure
  - The jet interval is defined as the period when it is above 1/4 of the total SW dynamic pressure

- Normalization of positions between the model magnetopauses (Shue et al., 1998) and bow shocks (Merka et al., 2005)
- Inverse transform sampling to generate magnetosheath samples that match the jet interval observations by relative position and IMF cone angle distribution
- Sampling magnetosheath intervals that are similar to jet intervals in duration
- **GSM $\boldsymbol{B_Z}$** is the most important parameter for reconnection at the subsolar magnetopause

  → **Statistical comparison of $\boldsymbol{B_Z}$ within jets and non-jet magnetosheath samples as a function of relative position between the bow shock and the magnetopause**

3. Results: Can jets make it through the magnetic pile-up layer?

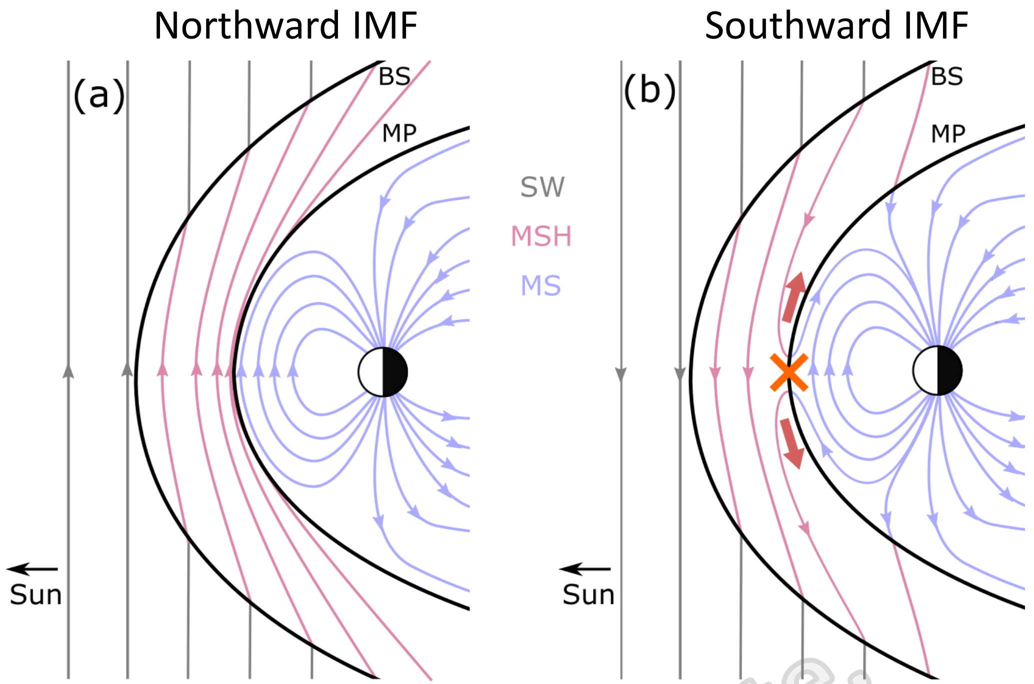


Fig. 4

Magnetic pile-up during northward IMF

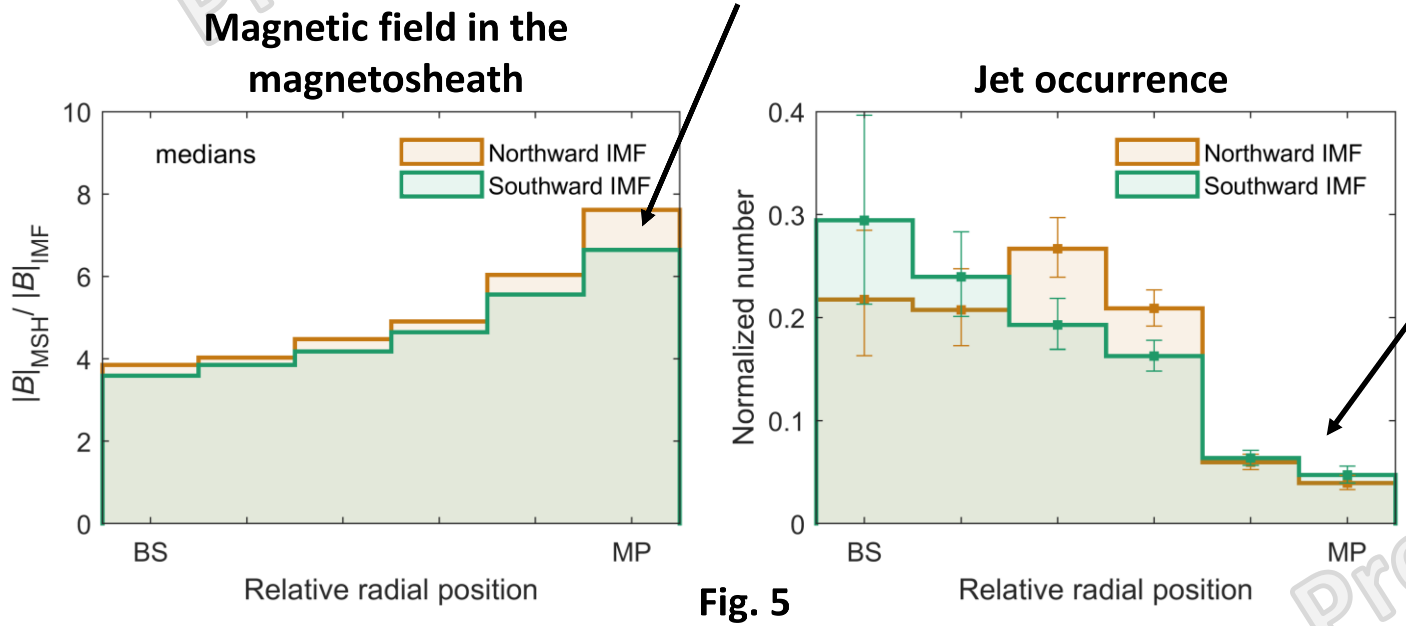


Fig. 5

... does not affect the occurrence of jets.

B_Z distributions

Comparison of B_Z within jets and non-jet magnetosheath samples. We have taken multiple non-jet samples of the same size as the jet sample and averaged their 10th, 50th (medians), and 90th percentiles. Error bars represent the standard deviations of the percentiles.

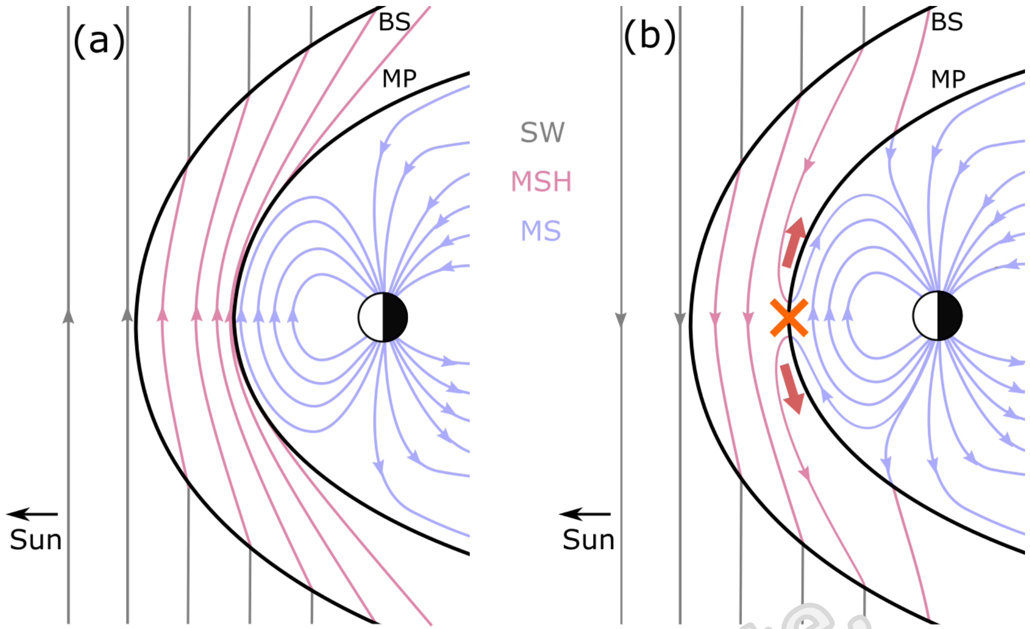


Fig. 4

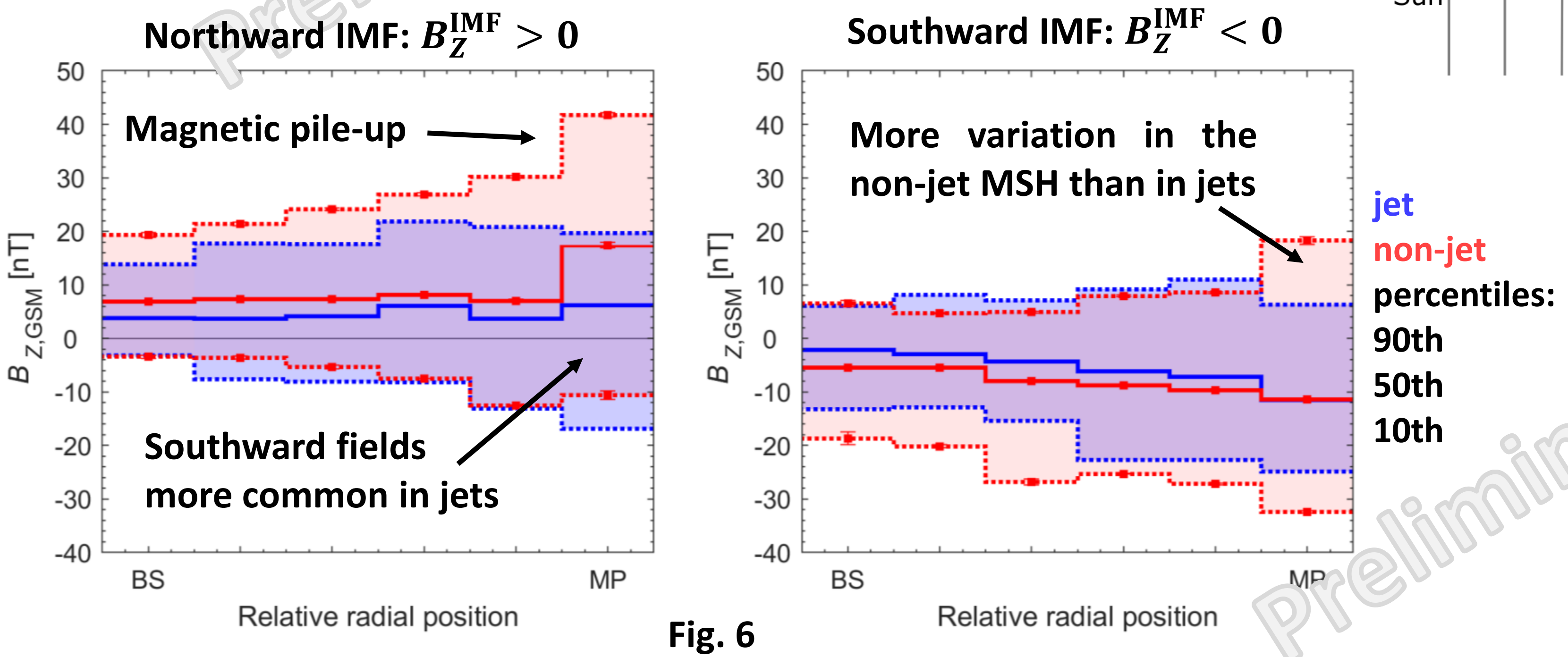


Fig. 6

B_Z variability within intervals

We also compare the distributions of minima and maxima within the jet intervals and similar non-jet intervals to see how jets compare to inherent variability of the magnetosheath.

During northward IMF, jets exhibit southward fields much more often than non-jet intervals. During southward IMF, the variations in jets are comparable to the background variations.

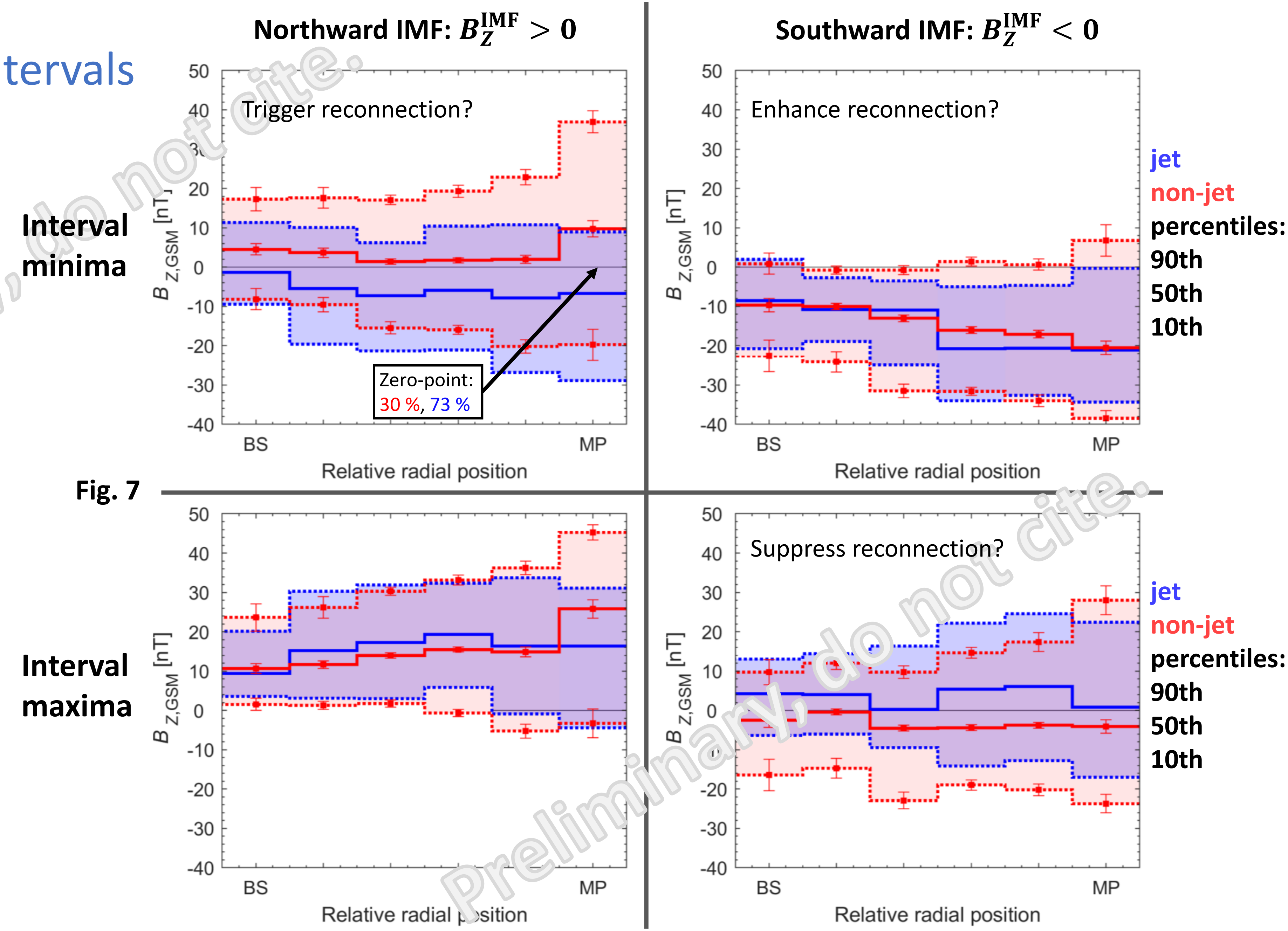
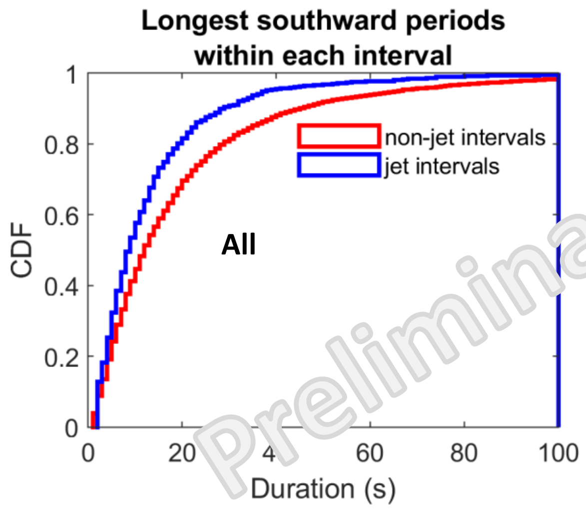
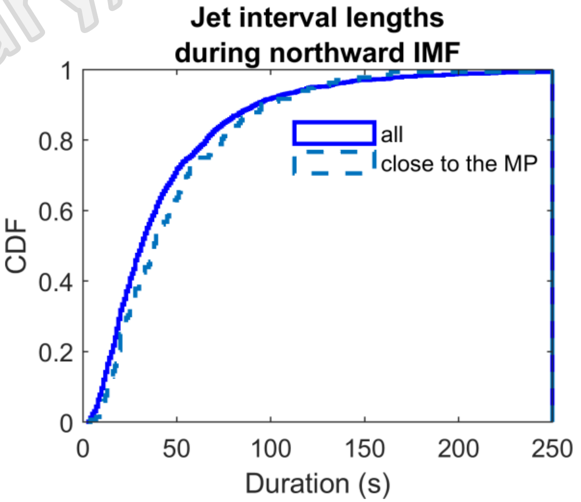


Fig. 7

How long are these southward periods in jets during northward IMF, and vice versa?

Northward IMF: $B_Z^{\mathrm{IMF}} > 0$





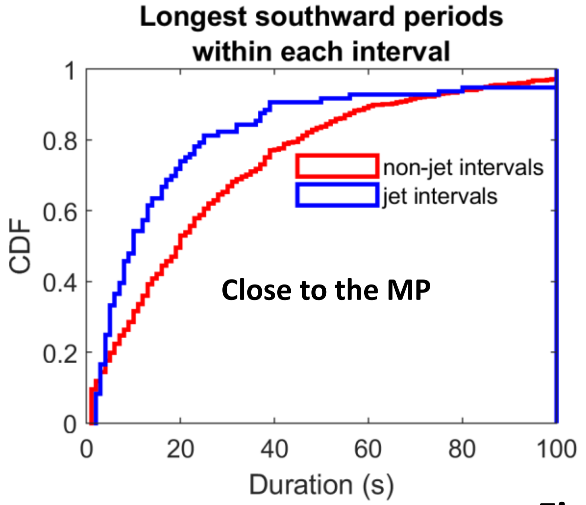
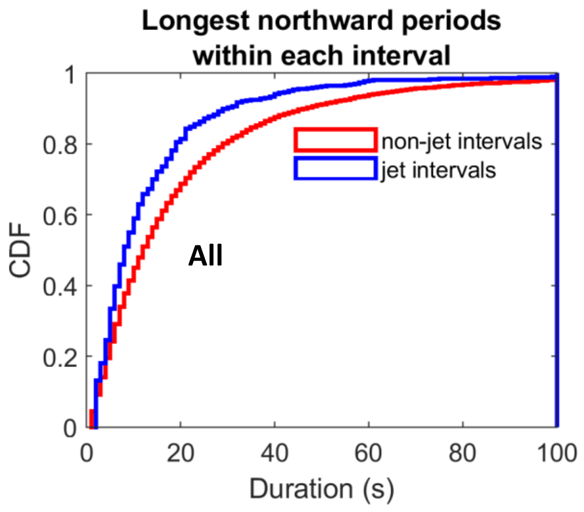
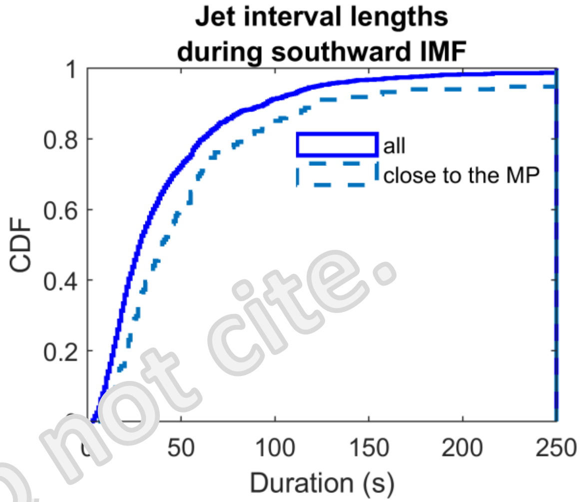


Fig. 8

Southward IMF: $B_Z^{\mathrm{IMF}} < 0$





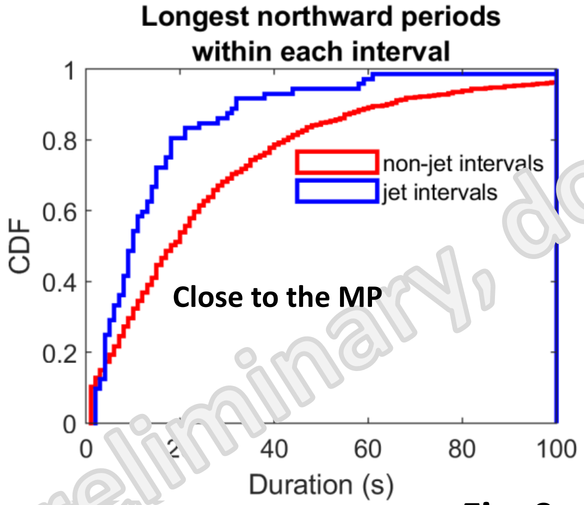


Fig. 9

Periods of opposite polarity B_Z to B_Z^{IMF} are shorter but more common in jet intervals than in non-jet intervals.

***Close to the MP*: the right-most bin in the percentile plots**

IMF cone angle dependency

We study how the distributions in the two right-most bins, near the magnetopause, of the percentile plots (Fig. 5 and Fig 6) vary as a function of IMF cone angle.

The non-jet distributions have stronger dependencies on the IMF cone angle than the jet distributions. During northward IMF, the differences between the jets and non-jet samples get large, most likely due to the pile-up effect.

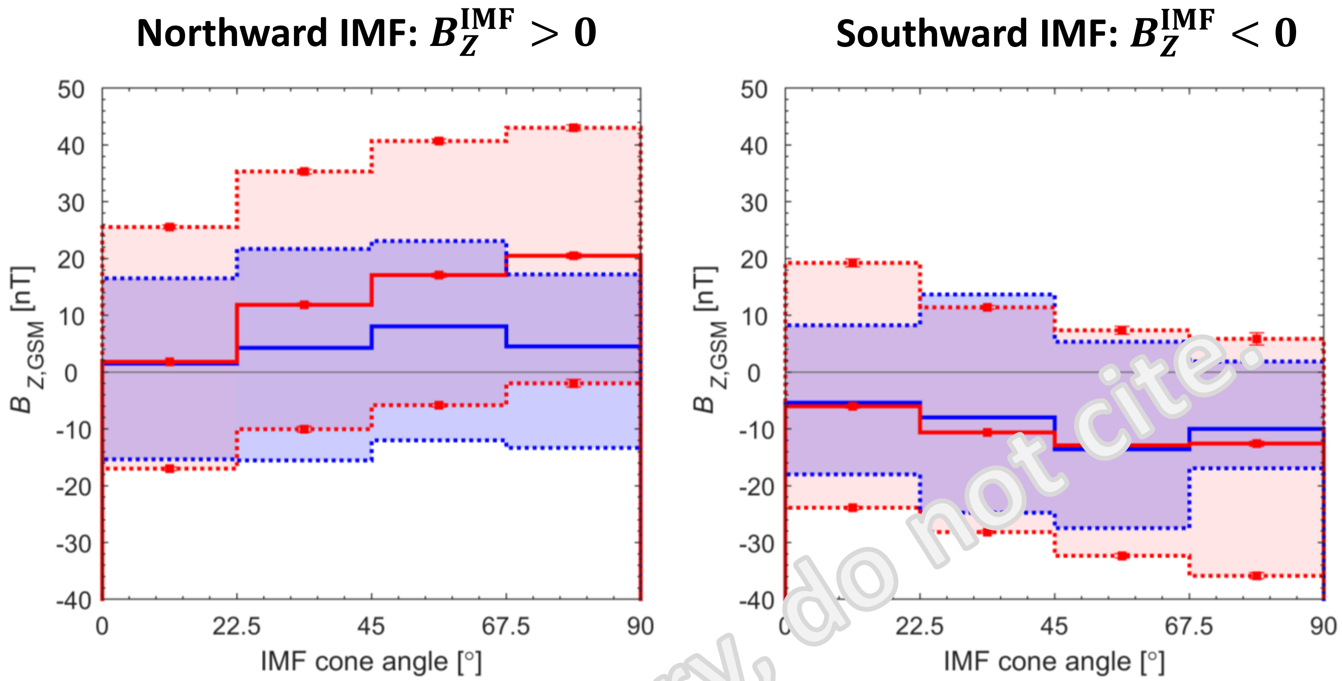


Fig. 10

Preliminary, do not cite.

IMF cone angle dependency

Fig. 6 and Fig. 7 show that jet distributions are not strongly affected by the IMF cone angle, which indicates that draping of the background field around the jets does not explain the results.

We also normalized the distributions for seasons and hemispheres (not shown), which cannot explain the results, either.

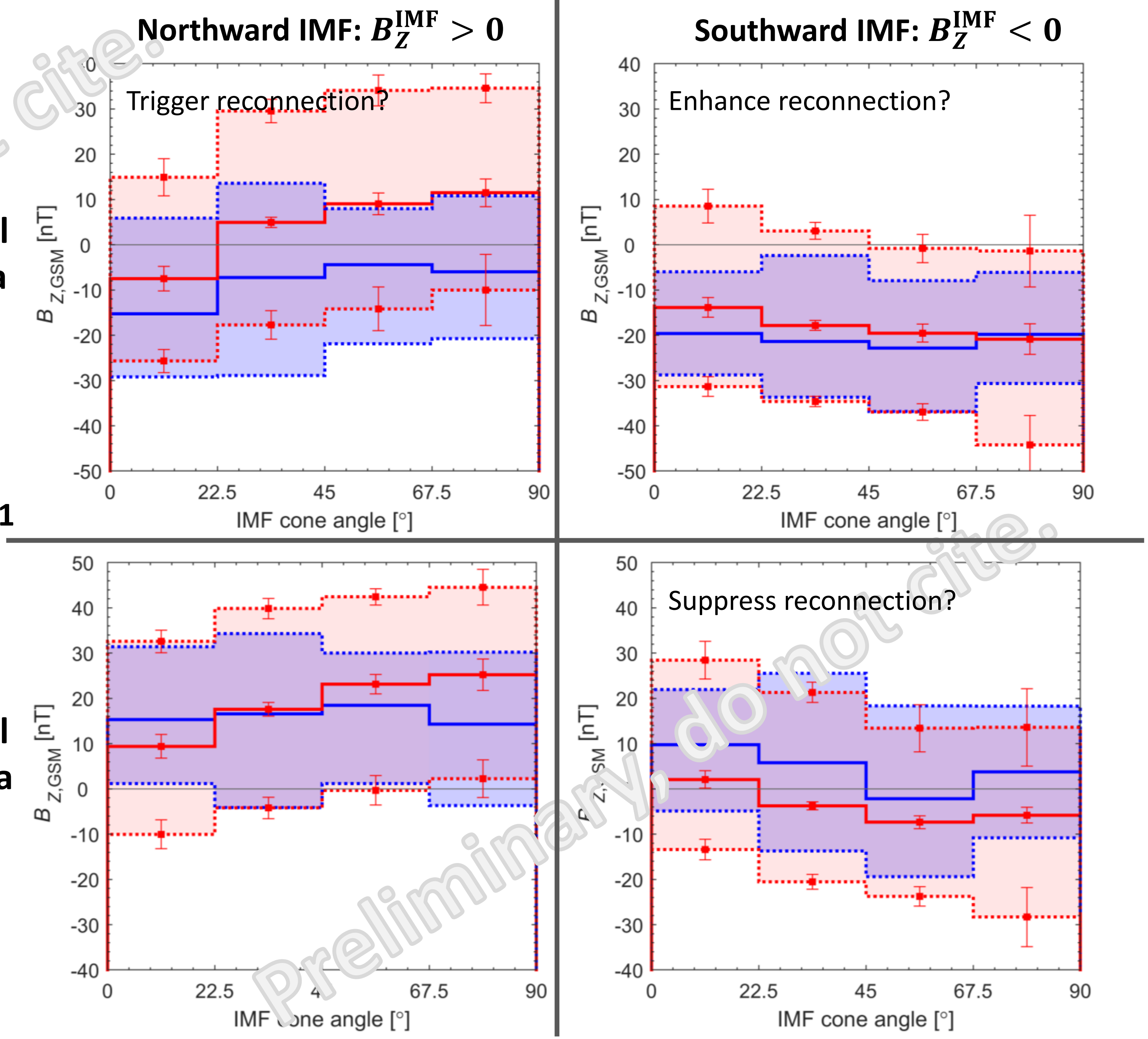


Fig. 11

4. Summary and conclusions

- We compared GSM B_Z distributions of jets during northward and southward IMF to the non-jet magnetosheath during similar conditions:
  - **Southward IMF:**
    - Variations in the non-jet magnetosheath are larger or comparable to those in jets close to the magnetopause

      $\rightarrow$ According to our results, jets cannot be expected to statistically affect magnetopause reconnection during southward IMF.
  - **Northward IMF:**
    - Southward fields more common within jets than in the non-jet magnetosheath close to the magnetopause
    - It is much more likely for a jet to exhibit southward B_Z compared to similar non-jet intervals close to the magnetopause (around 70 % and 30 % of intervals, respectively, in our data set)

      $\rightarrow$ **The magnetic fields within jets are statistically favorable for enhancing the occurrence of magnetopause reconnection during northward IMF.**
    - Continuous southward periods within the intervals are shorter within jets but there are more of them

5. Outlook

- What are the physical mechanisms behind these results?
    - *Draping of the background field or variations caused by seasons or hemispheres do not explain the results.*
    - Case studies of jets needed

- Are the southward periods within jets enough for triggering reconnection during northward IMF?

Preliminary, do not cite.

6. References

Angelopoulos, V.: The THEMIS Mission, Space Science Reviews, 141, 5, https://doi.org/10.1007/s11214-008-9336-1, 2008.

Archer, M. O. and Horbury, T. S.: Magnetosheath dynamic pressure enhancements: occurrence and typical properties, Annales Geophysicae, 31, 319-331, https://doi.org/10.5194/angeo-31-319-2013, 2013.

King, J. H. and Papitashvili, N. E.: Solar wind spatial scales in and comparisons of hourly Wind and ACE plasma and magnetic field data, Journal of Geophysical Research: Space Physics (1978-2012), 110, https://doi.org/10.1029/2004JA010649, 2005.

Merka, J., Szabo, A., Slavin, J. A., and Peredo, M.: Three-dimensional position and shape of the bow shock and their variation with upstream Mach numbers and interplanetary magnetic field orientation, Journal of Geophysical Research: Space Physics, 110, 1-13, https://doi.org/10.1029/2004JA010944, 2005.

Nykyri, K., Bengtson, M., Angelopoulos, V., Nishimura, Y., and Wing, S.: Can Enhanced Flux Loading by High-Speed Jets Lead to a Substorm? Multipoint Detection of the Christmas Day Substorm Onset at 08:17 UT, 2015, Journal of Geophysical Research: Space Physics, 124, 4314-4340, https://doi.org/10.1029/2018JA026357, 2019.

Plaschke, F., Hietala, H., and Angelopoulos, V.: Anti-sunward high-speed jets in the subsolar magnetosheath, Annales Geophysicae, 31, 1877-1889, https://doi.org/10.5194/angeo-31-1877-2013, 2013.

Shue, J.-H., Song, P., Russell, C. T., Steinberg, J. T., Chao, J. K., Zastenker, G., Vaisberg, O. L., Kokubun, S., Singer, H. J., Detman, T. R., and Kawano, H.: Magnetopause location under extreme solar wind conditions, Journal of Geophysical Research: Space Physics, 103, 17691-17700, https://doi.org/10.1029/98JA01103, 1998.

Vuorinen, L., Hietala, H., and Plaschke, F.: Jets in the magnetosheath: IMF control of where they occur, Annales Geophysicae, 37, 689-697, https://doi.org/10.5194/angeo-37-689-2019, 2019.