Manuscript: Niklas Grimmich et al., egusphere-2024-2956
Investigation of the occurrence of significant deviations in the magnetopause location: Solar wind and foreshock effects.

General Comments
The manuscript "Investigation of the occurrence of significant deviations in the magnetopause location: Solar wind and foreshock effects" by Niklas Grimmich et al. contains a huge statistical analysis for the magnetopause location. It combines two empirical models of the magnetopause (Shue et al. (1988), Nguyen et al. (2022)) and data from three different spacecraft missions, CLUSTER, THEMIS and MMS. He tries to study the deviations between the models and the data using different solar wind conditions, different θBn angles and different regions of the magnetosphere. He concludes that foreshock is in some cases responsible for these deviations. From my point of view, this is a work that includes a lot of information and tries to cover all the aspects and possibilities of the deviation issue between the real and the model location of the MP. However, I believe that there are some problems that are not addressed or they are not addressed properly. In this respect, the material presented in this research is valuable and appropriate for publication after a few important points are discussed.

Scientific Comments/ Major Points
− You are using Shue et al. (1998) and Nguyen et al. (2022b) models and you explain the reasons behind these choices very well in the discussion part. However, I think it is necessary to mention other models like Lin et al. (2010) and Petrinec and Russel (1996) and the reason why you are **not** using them instead. Aghabozorgi et al. (2023) showed that Lin model is the more accurate for the MP. Also, you are not referring at all to Formisano et al. (1979), who were the first people to examine MP location.
− In Line 25, you refer to "some internal processes". Which processes are those? Can you give some examples to the reader?
− I think that on lines 77-82 that you are referring to the SW plasma categorisation you should put more info (I know you have extensive explanation later), at least for the SW velocity.
− Why are you using above 0.75 probability for the crossings? Why not 0.85 for example? How many crossings did you exclude using this criterion?
− How many crossings did you exclude from your data do to the OMNI criterion you set and why did you choose 8-minute intervals and not 5-minute for example?
− You make some argument between θBn<45 and θBn<60. You have to make clear what you use here (it is visible from the graphs but still). Also, on line 45 you say that errors may not be significant. How can you be certain about this? How did you check it?
− The sketch explains very nicely the deviations but you should mention that Fig. 1 is obviously not on scale.
− Solar Wind separation issues: (1) you do not expect the observations on the boundary to be a problem but this is not right. They can very easily skew your statistics. Maybe you could impose some measure and remove some of them to be sure. (2) why did you use this data classification if you want to make a connection with the foreshock? I believe SW velocity should be enough for classification. The ejecta type is very susceptible to which phase of the ICME you collect the data.
− Mean or median: In your study you decided to use the mean value as an estimator but I believe this makes the study less trustworthy. The median is a way more robust measure, meaning it is not affected by outliers as much as the mean value. The problem is also visible in Table 1, where your interquartile values are huge, for example T(ion) can go negative? This is extremely weird. In line, 173 you have a mistake saying Table 1 shows mean and media values, whereas it shows Median plus/minus the interquartile. Also, I think the "all sources column" make your sample look problematic, where in reality the solar wind measurements are very variable. I am not sure why you included this.

- In Table 2, I think you should consider changing the lines "deviant from…" from absolute numbers to percentages of the original set (equator subsolar, equator flanks etc.). also, I know you address it later, but if you have only 7 observations this creates a real problem to the results and these results should be explicitly addressed as unreliable. Moreover, a very important question is: when you have many crossings really close to each other of the MP (since MP is dynamic), let's say 6, did you consider all these 6 into your data set or you just chose only one MPC in your data set?
- Figures 2-5: I think that the figures are very small and borderline unreadable. I would prefer 2, 4and 5 to be presented horizontally. In Fig.2 label you write "coloured" for red and blue, but grey is also a colour. Thus, the label needs updating. In Fig. 3 you can write on x-axis the model and on Figs. 4,5 the light purple should become more intense for example magenta or deep purple.
- A large difference between the models is not visible to me. Actually, in many cases the very simple Shue et al. (1998) predicts much better the MPC (equatorial).
- I find the separation dawn/dusk very important due to the MP asymmetry. Could you elaborate a little bit more on why you chose this classification in you text?
- I think there is a mistake in your text (line 264) where you say that Fig.4g, h panels seem to have negative deviations, but I see positive.
- I understand why Figs. 6,7 are important in your analysis but they are so full of information that the reader gets totally lost and they are deemed unreadable. I had to write a separate post-it to understand what I am looking at. I think you should consider some other way to present these results, or restrict some part to the text. The results themselves and the explanation are fine.
- It was my perception in the beginning of the paper that you are going to **compare** the two models, however you just group your results. So, this was not part of the research?
- Additionally, this research is a huge statistical analysis and contains any possibility in terms of position or SW conditions. But I can't find a very strong conclusion. You mention that foreshock **is responsible** for the occurrence of deviant MPCs. I do not exactly agree with this. Foreshock **can be responsible** of course but there are examples of very quiet foreshocks without any transients that are followed by strong MSHs with jets, that can actually travel to the MP and deform it. We can't be sure, or at least we have not proved yet, that foreshock is responsible for what you see. So, I believe you should ease a little bit this conclusion to a strong based argument, for example you can say that the foreshock presence seems to be important but not necessarily crucial and this connection needs further investigation.
- An equivalently strong conclusion is made in lines 401-409. It needs more physical explanation, because I do not see any panel to support your argument.
- In your discussion you do not refer to SRR plasma at all. Could you please add some thoughts?
- Can it be that the models predict the shape of the MP more poorly at the flanks? And if yes, why?

Technical corrections/ Minor Mistakes
<u>Abstract</u>
- Lines 2-4: the meaning is clear but the sentence in line 4 is too repetitive.
- Line 3: "in response to" → "with respect to"
- Line 5: … understood, since deviations…
- Line 13: "most frequently" → "more frequently"
<u>Introduction</u>
- Lines 19-21: are exactly the same as lines 1-2. I would suggest that you rephrase one of them.
- Line 31: "undulated", I think you should find a simpler word, "moves" → moving
- Line 31: "due to" (the second) → because of
- Line 40: "due to instabilities" → and instabilities

- Line 44: "another explanation": I can't find which was the first explanation, so maybe you should rephrase. Also, the sentence is too big, maybe you can rephrase like "…from MHD theory. The reduction…"
- Line 45: the subsequent distribution, the magnetosheath, "resulting in" → results in
- Line 52: "a constant motion" → the constant motion
- Line 54: The simplest magnetopause models…, rotational asymmetry does not need article "a"
- Line 56: "…shape as basis, include…" → shape, including
- Line 57: "take into" → taking into
- Line 61: I would rephrase to "These errors, that have the inability to capture the constant motion around the mean location of the magnetopause, could have several causes."
- Line 66: "problems" → complications
- Line 68: "deviation of observed" → deviation of the observed
- Line 69: problem, important mechanisms of the interaction
- Line 71: location, based on
- Line 72-73: wave activity and increased occurrence rate
- Line 74-75: "Thus, one of these overlooked processes could be the modification of the parametres affecting the MP by the formation of…"
- Line 77: Another point of consideration is the…
- Line 84: "too simple" → too simplistic, "the origins of the deviations" → how the deviations originate
- Line 88: and the modelled MP

Datasets and Methods
- Line 91: For our investigation, we…, "collect" → contain
- Line 96: "collected" → include
- Line 98-99: "for details on the coordinate system see" in not necessary, the reference is enough
- Line 101: previous publications
- Line 104: "at a cadence" is not necessary
- Line 106: "crossings is" → crossings are
- Line 151: "might be" → is
- Line 175: "did not" → does not

Results
- Line 190: "to the distributions" is not necessary
- Line 193: "ever" → either
- Line 197-201: I think these lines should be moved after line 183.
- Lines 223-227: Explain the test and these lines seem to be written in a very complex way.
- Line 227: MPCS, $\theta Bn < 45^o$ is a favourable condition.
- Line 229: "a foreshock" → foreshock
- Line 264: "it looked" → looked, "were" → are
- Line 265: "revealed" → reveals

Discussion
- Line 310: Our investigation
- Line 315: "the difference in orbits" → the different orbits
- Line 318: "be even better" → better
- Line 319: previous studies, …
- Line 366: In Figs.
- Line 376: "quasi-radical" → quasi-radial
- Line 399: rather scarce or rather sparse?

Conclusions

- Line 443: "In short" → I don't like this expression, you can use "In summary", "To sum up", "To summarise", three different spacecraft missions, "last two decades" → say the year range
- Line 444: "that occur" is not necessary
- Line 447: "and the" → "when the"
- Line 448: "foreshock is" → you are **not** sure so "foreshock can be"
- Line 450: may lead
- Line 453: in relation with
- Line 457: MPCs may occur