Report #2

Author general comment

We would like to thank the reviewer for reviewing manuscript "ICME impact at Earth with low and typical Mach number plasma characteristics" and thus helping to improve it. We considered carefully every comment made by the reviewer and prepared responses accordingly. Please find our responses to the comments below.

General comments

This paper studies the effect of two ICMEs of different characteristics on the Earth's magnetosphere, focussing on the saturation of the cross polar cap potential (CPCP). The majority of the abstract talks about the properties of the ICMEs, and is lacking in actual results, or the motivation of the paper. The introduction has a good overview of the relevant literature.

However, like the abstract, it is missing the aims and motivation of the paper. Whilst the results are interesting, I have concerns about their validity. The validation performed in the paper is minimal, only comparing simulation to spacecraft magnetic field data and the position of the magnetopause with the Shue model.

We thank the reviewer for this comment. The manuscript is revised carefully to increase the amount of validation. Every parameter considered comes now with validation. Based on this, conclusions are also made of the accuracy of GUMICS-4 results.

The comparison with spacecraft data is missing a key aspect, the plasma data, and there is little explanation for why GUMICS-4 underestimates the magnetic field strength.

While the plasma motions are critically important, in this case it is not easy due to the fact that the S/C reside most of the time in the low-density lobe regions, where the observations suffer from the very low counts. Furthermore, there are large data gaps in the observations hindering the comparisons.

The comparison of the Shue model with the simulation magnetopause is also missing key details, such as the definition of the "dayside magnetopause" and whether errors include the full 3D simulation magnetopause. A two or three dimensional comparison would be more appropriate.

The Shue magnetopause nose position is a single grid point in GUMICS-4 results. This is explained in the revised manuscript. See page 7, line 29. Similarly, the dayside magnetopause is a 3D surface computed from its nose position, extending from 0 RE in Sunward direction. See page 7.

This leads to the other issue with the paper, the calculation of the total energy into the magnetosphere. The Shue model is an axisymmetric model, and does not include features such as the cusps, hence using the Shue model for this calculation is potentially incorrect, capturing the sheath or magnetosphere.

When computing the 3D Shue magnetopause for evaluating the amount of transferred energy, we have displaced its nose position by 30% Sunward to avoid inclusion of

magnetosphere. The methods are explained in detail in the revised manuscript. Moreover, earlier studies have demonstrated the robustness of the energy computations (Palmroth et. al. (doi:10.1029/2002JA009446)). See pages 8-9.

The overall quality of the writing in the paper is adequate with a few spelling, grammatical and citation style errors. These have been pointed out in the specific and technical comments, though the authors should thoroughly proof read. Though the results are interesting, I would not recommend the paper for publication in its current form. However, with a little more analysis and responding of the questions posed in this review, it has the potential for publication.

Specific comments

• Pg 3, Section 2.1: Do you consider a dipole tilt or rotation? This should be stated

We agree. Dipole field was rotating and the angle was nonzero. This is explained in the revised manuscript (see page 4).

• Pg 4, Ln 14: You should be specific in why it's not feasible. Does it run too slowly, or are there memory issues?

Simulations would take way too much time, probably months. In the revised manuscript we state that "...not feasible due to long simulation physical time (up to 3.5 days) and resulting long simulation running times." (see page 4).

• Pg 4, Ln 11: Should list the solar wind values you're referencing to make it easier to understand

We agree. The used solar wind values are listed in the revised manuscript. (see page 4).

• Pg 6, Ln 26: Why do you use the Shue magnetopause for this calculation, not the simulation magnetopause? I would have thought this would be a more consistent calculation with the simulation. The general 3D structure of the Shue magnetopause likely not in the correct position, especially near the cusps. Does this mean you'd be capturing energy flux through an arbitrary surface either in the sheath or inside the magnetopause? Also, does this use the 3D magnetopause surface and how far does the dayside region extend to? The details of this calculation should be more clearly stated in the paper (or cited).

We thank the reviewer for this comment. Previously, Palmroth et. al. (doi:10.1029/2002JA009446) computed the shape of actual magnetopause from GUMICS-4 results and compared energy transfer to epsilon parameter. They also showed that the energy perpendicular to the boundary did not change with small displacement of the boundary thus demostrating the robustness of the method to calculate the incoming energy. Instead, we consider the dayside (extends to 0 RE) Shue magnetopause 3D surface by displacing its nose 30% Sunward. We use 30% since it is maximum relative difference in magnetopause position between GUMICS-4 and the Shue model. This prevents underestimation of the size of the magnetosphere. The method used here gives values for energy of the same order of magnitude compared to study by Palmroth (mentioned above). Thus, we have good confidence in the methodology. We provide detailed explanation of the used method in the revised manuscript. See pages 8-9.

• Pg 7, Lns 1-5: Continuing on from the previous comment, are these percentages over the whole 3D dayside surface of the magnetopause? If they aren't then they probably aren't a good metric as they don't account for the full shape of the magnetopause.

The percentages are for the nose position. As the 3D Shue magnetopause structure is characterized by the position of the nose, we (and several other authors whose work we cite) strongly believe that this gives a good overview of the accuracy of the GUMICS-4 magnetopause position. Different models (empirical and simulations) produce different flaring in the distant magnetotail, but mostly agree within the dayside and near-tail region. Thus, considering the entire magnetopause Sunward of -30 RE would lead to similar conclusions. We do mention several times in the text that we only consider magnetopause nose to make that point clear.

• Pg 7, Ln 10: The author mentions both runs are consistent; this should be shown with a figure of the GUMICS magnetosphere data (e.g. cuts through the noon-midnight and ecliptic planes).

We agree. However, as section 4.1 is revised, the paragraph in question is not relevan anymore and has been removed.

• Fig 4c: What is the strange artefact in the position of Geotail? It seems to jump to a different position?

The artefacts are errors made when interpolating SC location over data gaps. These errors are removed from the revised figure 4.

• Fig. 5: More odd artefacts: (c) position of geotail jumps throughout dataset; (b) jumps in the magnetic field strength of Cluster at approx. April 30 (06:00) and April 30 (09:00)

Regarding (c): Also interpolation error, which does not show in the revised version of figure 5. Regarding (b): The measured Bmag increases from approx. 10 nT to 30 nT, which is on par with the increase of measured Bmag at 12:00 (April 30). At same time the magnetopause is in motion toward the Earth, and the S/C resides close to it, which probably explains those rapid increases.

Technical comments

• Pg 4, Ln 10: Need brackets around Lakka et al. (2017)

Corrected in the revised manuscript. See page 4.

• Pg 5 Ln 6: "rotate", not "rotated"

Corrected in the revised manuscript. See page 5.

• Pg 5, Ln 30: Citation should have parentheses

Corrected in the revised manuscript. See page 6.

• Pg 6, Ln 11: replace “proper” with “properly”

Word “proper” is referring to the “actual” part of the magnetic cloud, and that’s why we think that its usage in the context of the text is justifiable.

• Fig 8. Ln 4: replace “are showing” with “show”

Corrected in the revised manuscript. See figure 8 caption.

• Pg 10: Ln 2: unnecessary hyphen in front of “line”

Corrected in the revised manuscript. See page 11.

• Pg 10, Ln 8: Citation should not have parentheses

Corrected in the revised manuscript. See page 11.

• Pg 10, Ln 20: Citation should have parentheses

Corrected in the revised manuscript. See page 12.

• Pg 11, Ln 14: Citation should have parentheses

Corrected in the revised manuscript. See page 13.