Title: Ionospheric signatures of Bursty Bulk Flows in the 6D Vlasiator simulations

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Replies to Referee #1

We thank Referee #1 for comments and constructive suggestions on our manuscript. Below, we provide point-by-point responses to all comments. The referee's comments are presented in black, while our replies are shown in blue directly below each comment. We have carefully considered all suggestions and, where appropriate, will make corresponding revisions in the manuscript. We hope our answers and the corresponding suggested changes (where necessary) in the manuscript are satisfactory.

General comments:

In this paper, numerical simulation results from the 6D hybrid-Vlasov code Vlasiator are utilised to study the ionospheric signatures of a bursty bulk flow (BBF). This is the first time when an ionospheric model enabling a two-way magnetosphere-ionosphere coupling is used with Vlasiator. The magnetospheric signatures of the BBF include a flow channel of earthward fast plasma flow, which has a significant azimuthal orientation at the farther parts, and an appearance of oppositely directed vorticity on the flanks of the BBF channel. The flow vortices/vorticity induces field-aligned currents flowing into the ionosphere on the dawnside and flowing out from the ionosphere on the duskside of the BBF channel. The ionospheric signatures include a localised enhanced equatorward plasma flow corresponding to the earthward part of the magnetospheric BBF and signatures of enhanced FACs and vortical plasma flow on the flanks of the enhanced flow channel consistent with the magnetospheric counterpart. In addition, observable signatures in ionospheric conductances, precipitation energy flux and both Pedersen and Hall currents can be seen in association with the BBF.

This is the first time when ionospheric signatures of BBFs obtained from the Vlasiator are presented. Although the BBF in the simulation is generated rather close to Earth, the simulation produce many signatures reported in previous observational and simulation studies. This suggests that the simulation codes used can be utilised to study dynamical magnetosphere-ionosphere coupling and the results are reasonably well and can be used in comparison with observations. The manuscript is clearly worth publishing, but before I could recommend publication, the authors could address a few comments, which are presented below.

Specific comments:

1. Comment (1): The authors present only one BBF case. The authors could consider modifying the manuscript title to "Ionospheric signatures of a bursty bulk flow in the 6D Vlasiator simulation".
   We thank the reviewer for the suggestion. We agree and will modify the manuscript title to "Ionospheric signatures of a Bursty Bulk Flow in the 6D Vlasiator simulation."

2. Comment (2): When discussing the FAC pair, the authors focus now on the earthward-most part of the BBF. However, the signatures of weaker upward FAC on the duskside

flank and downward FAC on the dawnside flank of the BBF are visible both in the magnetosphere and in the ionosphere also in the tailward (more dusk-dawn oriented) part the BBF (see e.g, the vorticities and FACs in Figure 3). The authors could consider adding some discussion about that.

We propose adding the following text to the manuscript: "In addition to the stronger R1/R2 FAC pairs at the earthwardmost part of the BBF, weaker upward (duskside) and downward (dawnside) FACs are also evident along the flanks. These are associated with counterclockwise and clockwise vortical flows in the plasma sheet, respectively."

3. Comment (3): It seems that the vortical flows on the flanks of the BBF structure do not form complete vortices. The authors might want to point that out in the text.
   We propose adding the following text in the manuscript to point out that: "On the dawnside flank of the BBF, the clockwise vortical flow develops into a closed vortex (see the velocity vectors at the most earthward flank in Figure 3). In contrast, the counterclockwise vortical flow on the duskside flank does not appear to form a fully closed structure."

4. Comment (4): Line 19 and elsewhere: The use of brackets for the reference is a bit weird: Angelopoulos et al. (1992). Should it be written (Angelopoulos et al., 1992) here? Compare the citation style on line 24.
   Thank you for pointing this out. We will revise the manuscript to ensure consistent citation formatting throughout.

5. Comment (5): Lines 37-40: Discussion of Sergeev et al. (2020) on these line is not accurate. Sergeev et al. (2020) do not present any BBF observations in their paper. Also the last statement about the arcs tending to align with the direction of the electric field appears not to be based on Sergeev et al. (2020). Please, check again Sergeev et al. (2020) and rewrite this paragraph if you want to introduce Sergeev et al. (2020) work here.

   We agree with the reviewer that Sergeev et al. (2020) do not present BBF observations. Instead, they discuss the potential link between auroral arcs and BBFs based on auroral arc observations. To clarify this, we propose modifying the paragraph in the manuscript as follows: "Using a combination of observational data and empirical magnetospheric models, Sergeev et al. (2020) investigated the origins and orientations of nightside auroral arcs. They found that the majority of nightside arcs originate from the magnetotail current sheet region and argued that magnetospheric flow channels, such as BBFs, are the most likely source of these arcs. Furthermore, they demonstrated that structures, which appear nearly sun-aligned in the plasma sheet, become increasingly azimuthally aligned when mapped to the ionosphere."

6. Comment (6): Figure 3 (and Figure 7e): Is the length of the Vxy vector shown on the top of the Figure 3 on the right hand side of the magenta text "Vx = 400 km/s" 400 km/s?

   The magenta line at the top right corner of Figures 3 and 7e marks the boundary of the BBF structure where $V_x = 400$ km/s. The black arrow adjacent to it represents the V_{xy} velocity vectors plotted on the current sheet. We will clarify this distinction in the figure captions to avoid any confusion.

7. Comment (7): Line 223: Should the clockwise vortex be indicated by X and counterclockwise by O? Compare e.g. to lines 224-225. Double-check and correct the text if necessary.

Thank you for pointing that out. Yes, O and X markers correspond to counterclockwise and clockwise vortices, respectively. The text will be updated accordingly to ensure consistency.

8. Comment (8): Line 305: Do you mean here southwest-directed plasma flow channel in the ionosphere? You write southeast-directed plasma flow channel.

   Yes, thank you for pointing this out. The text will be updated to "southwest-directed plasma flow channel in the ionosphere".

9. Comment (9): Lines 355-356: On lines 149-151 the authors describe the general evolution of the BBF structure in the magnetosphere. Double-check if your statements on lines 355-356 agree with the description on lines 149-151.

   On lines 149–151 describe the state of the BBF at simulation times t = 500 s and t = 550 s (Figures 1g and 1j), while lines 355–356 aim to explain how the BBF evolves from its initial generation onwards. We acknowledge the reviewer's point and will revise the text to ensure consistency between the two statements.

10. Comment (10): Lines 366-367: Do you mean Figure 7b instead of Figure 7d? The enhanced ionospheric flow channel seems to correspond to the earthwardmost part of the BBF. Maybe specify that on these lines. Actually, the authors could discuss somewhere in section 3.x that one cannot see the enhanced ionospheric flows for the entire magnetospheric BBF channel. Could the authors say anything for the possible reason for that?

    Yes, we meant Figure 7b, and the manuscript will be updated accordingly.

    Regarding the reviewer's suggestion, it is correct that enhanced ionospheric flows are not seen across the entire BBF channel. Strong ionospheric signatures typically occur at the BBF flanks, where flow shear and braking generate FACs that couple effectively to the ionosphere. The central part of the BBF couples only weakly, and ionospheric conductivity further influences the visibility of these signatures.

    To reflect this, we propose adding the following text in Section 3.3: "It is important to note that an enhanced ionospheric flow channel is not observed along the entire magnetospheric BBF channel. Strong ionospheric signatures arise mainly at the flanks of the BBF, where flow shear generates FACs that couple efficiently into the ionosphere. In contrast, the central part of the BBF couples only weakly, and the visibility of the flows is further controlled by local ionospheric conductivity. As a result, the relatively broad BBF in the plasma sheet is typically associated with localised ionospheric flow channels rather than wide, uniform enhancements."

11. Comment (11)/Recommendation: Finally, I encourage the authors to continue to carry out studies related to BBFs and their ionospheric signatures using Vlasiator in the future, for instance, when BBFs are observed in the different parts of the magnetotail, such as in the postmidnight region, for comparison. And using different simulation runs.

    We thank the reviewer for this constructive suggestion. Indeed, future work will aim to examine the ionospheric signatures of dawnside BBFs using new Vlasiator simulation runs and compare these results with those from duskside BBFs.