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Interactive comment on "The fate of O^+ ions observed in the plasma mantle and cusp: particle tracing modelling and Cluster observations" *by* Audrey Schillings et al.

Anonymous Referee #1

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This manuscript presents a test particle tracing study of O^+ ions from sites where Cluster observed O^+ outflow in the cusp and mantle. The topic is well within the purview of Annales Geophysicae. However, the description of the model omits a number of important details, and there are significant issues with the implementation. Since the implementation issues affect an unknown but possibly substantial fraction of the particle trajectories traced, this is arguably a major revision. Nevertheless, the paper is likely to be publishable once the authors address these issues.

1. Implementation issues

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Discussion paper

The model is based on tracing test particles in a magnetosphere described by the T96 and Weimer 2001 models for magnetic field and potential, respectively. It is implied, but not directly stated, that the authors use the actual solar wind conditions for the events they study. Both T96 and Weimer 2001 are statistical models based on averages of observations under particular solar wind and IMF conditions. Some of the T96 input parameters take into account the history of relevant solar wind and IMF conditions. However, the Weimer models are known to have unphysically rapid responses to shocks and other interplanetary transients, as well as Alfvénic fluctuations in the IMF. Some caveats will be needed in cases where a shock or other interplanetary transient impacts the magnetosphere during the period covered in the modeling.

The model is a test particle model which, as noted in the manuscript, neglects wave-particle interactions. This is a reasonable approximation in the outer magnetosphere but not in the inner magnetosphere, where some combination of chorus, EMIC, and ULF waves can produce pitch angle scattering and therefore affect loss rates (precipitating ions should not be considered losses in the context of this paper). Some caveats on this issue are also needed.

The simulation domain covers $-60 \leq X \leq 10R_E$. The justification for the upper limit is the magnetopause location. But $X = 10R_E$ is merely the average location of the subsolar magnetopause; the actual location can move inward or outward depending on solar wind dynamic pressure. The simulation box should therefore be extended a bit sunward to cover the case of reduced solar wind pressure.

The authors treat the boundary of the inner magnetosphere as spherical and constant in time at a distance of $10R_E$. The real boundary is neither static nor spherical: when solar wind dynamic pressure is elevated the nose of the magnetopause can be pushed inside $10R_E$, which is its nominal location, and the relevant coordinate in the inner magnetosphere is the McIlwain parameter L rather than the radial distance R used in the manuscript.

2. Clarifications about the model

Equation (1) as written in the manuscript is not correct, because it has a scalar quantity on the left-hand side and a mixture of scalars and vectors on the right-hand side. If this was intended to be a vector equation, then all terms in the equation should be vectors. If the left-hand side was intended to be a scalar, then the right-hand side should be the square root of the sums of the squares of the components.

Although the reader can deduce this from the subsequent figures, there should be an explicit statement in section 3.1 that the code traces the full 3-D velocity vector rather than using the guiding center approximation.

The authors do not give the X location for the listed magnetopause location of $|Y| = 13R_E$ and $|Z| = 13R_E$. The magnetopause can be approximated as cylindrical in the deep tail but still usually has some flaring at the $X = 0$ plane, which is where I think the quoted numbers are supposed to apply.

In section 3.2, the authors should be explicit about using time-varying solar wind and IMF inputs.

3. Miscellaneous issues

The result that the O^+ outflow increases by 1.5 orders of magnitude during active times compared to quiet times (specifically using Kp as an activity indicator) is not original with Slapak et al. (2017). The same result was obtained from DE data by Yau et al. (1985), JGR 90, 8417, doi:10.1029/JA090iA09p08417, which paper should be cited in that paragraph.

In the data selection thresholds given at line 119, I think the "and" should be an "or", since the intent is to exclude a velocity range in which the O^+ channel is contaminated by protons.

The quantity plotted on the X axis of Figure 4c is described as "minimum X distance" in the text, the figure caption, and the axis label. I do not think this is an accurate description of the quantity being plotted, since it covers the full range of the simulation box. A clearer description of this quantity would provide better insight into its physical significance.

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