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Interactive comment on "A New Perspective and Explanation to the Formation of Plasmaspheric Shoulder Structure" *by* Hua Zhang et al.

Anonymous Referee #2

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The manuscript describes an alternate method for reproducing plasmaspheric shoulders that have been modeled previously. Based on their Test Particle Model (TPM), it is suggested that a new mechanism is observed to form shoulders. Language usage needs to be significantly improved in the abstract and body of the manuscript. The conclusions, insofar as I understand the text, are not adequately supported. As a consequence the manuscript does not demonstrate a significant contribution to the field. Figure 4 does not appear to contribute to the conclusions derived from it. Additional detail about the TPM simulation are needed, in addition to discussion of simulation limitations and artifacts resulting from its design. Contrary to the conclusions, use of the Weimer empirical electric field model in TPM appears to preclude making conclusions about the physical processes that cause subcorotation of the plasmasphere.

Specific concerns are described in the comments. I do not recommend publication of the manuscript in its present form.

1. Line 83: Plasmasphere ions are defined in the introduction as having energies of less than 1 eV. Here the definition given is that the plasmasphere consists of "several eV or less". The two descriptions need to agree; <1 eV is generally used, but there is flexibility. Citing a source for whatever is used is worthwhile.

2. Line 85: It is stated that the intensity of the electric field model is a superposition of the convection and corotation electric fields. The electric field model this line refers to is not directly stated. Line 54 states that the TPM uses the Weimer statistical electric field model. The Weimer model is empirical, based on observations. It is not a superposition of simple electric fields. The extent to which the Weimer model accurately represents measured electric fields and those measurements accurately represent actual electric fields, then this empirical model incorporates all the physical processes that produce large to small-scale features in inner magnetospheric electric fields. It also means that nothing about the underlying physical processes are available to be determined by use of the Weimer model in the TPM simulation. This point is of particular importance in the Section 4 Discussion and in the conclusions stated for the paper.

3. Line 94: Only 10 particles per simulation box is quite course. What are the boundary conditions for the simulation? Are particles allowed to leave or enter the simulation to maintain the number within the simulation? Only black and white is used to represent model results in Figure 3. If black means there is at least one particle in a simulation box, then that needs to be stated.

4. Line 96: Why is it stated that the density variation goes as Lˆ-3? Most authors report a variation of approximately Lˆ-4. Whatever is used here needs to be justified in the text or by citation.

5. Lines 114-116: Can this simulation produce a smooth plasmapause boundary when there are so few particles in the simulation? What is considered to be smooth given

the small number of particles in each simulation box?

6. Lines 114-116: What particle injections are referred to here? An “injection” of particles would normally be expected to come from outside the simulation, whether along the field or transverse to it. Quantitatively, what does smooth or irregular mean as it is used here and how can it be “seldom smooth or irregular” as stated?

7. Line 129: How is a sharper plasmapause boundary model result shown in Figure 3? “Sharper” has previously been used to qualitatively refer to the density gradient across the plasmapause. The black and white representation of the model result shown in Figure 3 cannot show a gradient. Small irregularities in the plasmapause can be seen in Figure 3, however this may be due to the small number of particles in simulation cells, a modeling artifact rather than a physical result.

8. Lines 129-131: The model result in Figure 3 does not show peeling off of plasmaspheric plasma in the predawn region. The formation of a shoulder does not constitute a peeling off of the plasmasphere. The plumes evident in all panels of Figure 3 show the plume extending sunward in afternoon and early evening magnetic local time. I am unaware of any observation of the outer plasmasphere being peeled away at predawn magnetic local times. The post-dawn outer plasmasphere has been found to sometimes contribute to a broad early-plume that then narrows to afternoon MLT only.

9. Lines 352-354: I do not find this reference in the journal as cited. Could there be an error in the citation?

10. Lines 141-142: The plume features shown in Figure 3 exist before the shoulder convects into afternoon magnetic local times where the plume(s) is(are) connected to the plasmasphere. The shoulder is first indicated in Figure 3c near 9 hours magnetic local time. In panel (d) three hours later a plume is forming between roughly 16 hours and 18 hours magnetic local time. This shoulder feature has not azimuthally convected further than about 13 hours MLT. Another 3 hours later in panel (c) a plume appears to be forming where the shoulder has come to be located. That does not mean the

shoulder had a causal role in forming the plume. It is more likely it only happened to be there when geomagnetic activity increased, which changed the global convection pattern in your electric field model so as to form a new plume that would have formed whether the shoulder was there or not. A specific explanation must be provided in order to substantiate the statement that the shoulder is functionally responsible for the plume as currently stated.

11. Lines 142-143: The simulation shows that the TPM simulation for the conditions during this event period resulted in a shoulder forming in at post-midnight MLT. One simulation cannot establish a pattern of shoulders forming at post-midnight MLTs as currently stated.

12. Lines 148-150: The feature at 12 hours MLT in Figure 3a appears to be a remnant plume originally formed in at afternoon MLT due to earlier activity. It does not have the characteristics of a shoulder. The discussion in the last paragraph on page 8 is at least poorly expressed if not also poorly conceived, as suggested in the previous few comments. It needs to be corrected or removed.

13. Line 168: Notch structures and the outer plasmasphere do not refill from the plasma sheet as currently stated in the text. The injection of plasma ions discussed by Gallagher et al. (2005) refers to a potential source of meso-scale electric field due to charge separation in the injected energetic plasma. It is suggested in that study that this meso-scale electric field may cause the interior “W” shaped feature.

14. Line 173: What is meant by “inward convection?” Convection inward to lower L-shell does not appear to happen during storm-time recovery. Isopotential contours are not axially symmetric, however, therefore there can be inward and outward radial motion of the plasmapause without a change in plasmasphere content. The dusk bulge is an example.

15. The first paragraph of the Discussion section: Figure 4a shows paths taken by semi-corotating plasma, but does not show the formation of a sharp radial change

in the plasmapause as stated. Goldstein et al. (2002) state that their model shows the shoulder forming across a narrow 3-5 hour MLT region. Figure 4a shows a gradual outward motion of a radial group of particles from 3-9 hours MLT. For a shoulder to form there must be a transient and narrow MLT region where plasma is differentially moved in L-shell, which cannot be shown with the test particle simulation presented. Even if an adjacent and leading parcel of plasma did not move outward in L-shell after 1300UT, only a difference of 0.1-0.2L appears to have taken place between 3-5 MLT, not 0.5-0.7L as stated. Figure 3b-c show shoulder-2 formation much better, though a shorter time interval between these panels would do that much better. In fact a sequence of model images between these two might provide a more useful display than the current Figure 4a. Reversal of relative semi-corotation with L-shell shown in 4b is interesting as an explanation for steepening the leading eastward edge of a shoulder.

16. Line 220: "increase of the MLT-profile of the shoulder" does not say what is needed here. Perhaps "steepening of the MLT-profile of the shoulder" would be a better word to use.

17. Lines 247-260: Which model does not include electric field shielding in the inner magnetosphere? Is this referring to your TPM? If so, the statement is not substantiated in the text. While shielding is not explicitly included in the Weimer electric field model, the fact that the Weimer model is empirical means that the model includes whatever physical processes are active. That will include shielding if it is happening, as discussed in previous papers. The Weimer model, hence TPM, provide no information about the physical processes taking place that produce the measured electric field.

18. Lines 259-260: Gallagher et al. (2005) specifically report not finding a day-night asymmetry in subcorotational flow. They also do not report finding supercorotational flow, only speculate that asymmetry in the dawn-dusk convection pattern may cause net subcorotational motion.

19. Conclusions: I posit that you cannot investigate the physical mechanisms for shoul-

der formation using the Weimer empirical electric field model, as that model only represents the measured net electric fields resulting from whatever physical processes are involved in their formation without distinction for those processes. Please substantiate how this can be done.

20. Conclusion 1: It has not been demonstrated that IMF Bz must be lower than the previous 24 hours for a shoulder to form. A statistical study or theory is required before there is adequate basis for the conclusion. The statement on lines 184-186 is an observation that might be used to suggest correlation or dependence, but no more than that.

21. Conclusion 2: The conclusion does not add to what has previously been found. It is incumbent on you to be clear how this new work contributes in the context of previous work. This statement does not do that.

22. Conclusion 3: No significance has been established between the position of a shoulder and the formation of a plume connected to the plasmasphere at that location. Given that plumes form at the onset of convection enhancement, which is not connected to the earlier formation of a shoulder, the presence of a shoulder where a plume begins to form is likely no more than coincidence. It is well established that plumes form in the afternoon/dusk region without the presence of a shoulder feature.

23. Line 75: "Shoulder-like structure" is acceptable, but "shoulder-like" is not used by itself and if it is shoulder-like, then it would be better to simply refer to it as a shoulder. Lines 66-68 refer to the shoulder structure and define it in words and in Figure 1. That is adequate to subsequently refer to it as a "shoulder". Unless you consider the feature you are referring to as something different from what has previously been described as a plasmaspheric shoulder, then I recommend you simply use that description or just shoulder.

24. Lines 12-14: This sentence is not grammatically correct. Perhaps the authors intend it to be something like, "The plasmapause formation is simulated using the

Test Particle Model (TPM), which is based on drift motion, which reproduces various plasmapause structures and evolution of the Shoulder feature."

25. Lines 14-18: These sentences are grammatically incorrect. English language usage needs to be improved throughout in the paper. No further comment about that will be made in this review.

26. "Plume" is misspelled in Figure 3e as "plumer".

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