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Interactive comment on "Strong Southward and Northward Currents Observed in the Inner Plasma Sheet" *by* Yanyan Yang et al.

Anonymous Referee #2

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The authors present an original research manuscript which aims to explain observations performed in the northern nightside magnetosphere, where northward and southward currents are detected along with oscillations in the field curvature. In this region, the dominant currents are field-aligned currents and the ring current, which should exist mostly in the X-Y-plane. The authors propose that these currents are due to curvature drifts of energetic particles. The authors base their analysis on two mid-latitude storm time vents and Cluster spacecraft data, and various analysis techniques using multiple instruments from the Cluster mission.

The manuscript has generally good structure, a well-chosen selection of figures and good language. The authors take into account some of the important potential sources of errors in their analysis. The topic of research is interesting, and indeed worth pur-

suing. However, I have some fundamental questions regarding the logic behind this analysis and the application of the methods, and would appreciate if the authors could substantially clarify the issue, as well as improve the methods which would make the results more robust.

Major issue: The authors present MRA-method analysis of magnetic curvature and compare it with measured current densities, postulating that the current is due to curvature drift. However, the whole method of measuring currents aboard Cluster is based on the Curlometer technique, which calculates the curl (curvature) of a magnetic field and calculates the current from that. I feel that the authors need to give more reasoning as to why they consider it a new finding that one magnetic curvature analysis technique explains currents calculated via another magnetic curvature analysis technique.

Major issue: page 6 lines 13-17: If I'm interpreting this correctly, the coordinate system in use (j_B, j_N, j_R) changes constantly with the magnetic field measurements (as referred to as a local natural coordinate system in the caption of Figure 2). Is this calculated pre- or post IGRF (or dipole field?) deduction? I'm worried that the coordinate system is not well defined when the direction of the curvature changes abruptly. Looking at the evolution of the theta and phi angles for the direction of curvature, it looks to me like j_N is mostly in the east-west-direction, and has a north-south component only at the extrema of the curvature oscillation. A re-decomposition of currents into cartesian or SM coordinates would have been important to answer questions arising from this coordinate selection, and would help with evaluation of results.

A question that arises directly from this, is how much of the observed j_N is actually new current density in the north-south direction, and how much of it is existing ring current simply re-mapped due to an abruptly changing coordinate system?

Major issue: page 12, description of how the authors evaluate plasma pressure via the kappa distribution and CIS/CODIF: I believe the authors should further clarify how they perform this analysis in order to quell concerns regarding the trustworthiness of the method. I shall try to elaborate. A Kappa distribution behaves wholly differently (quasi-Maxwellian) at low energies where CODIF data is available, than at higher energies, in the tail. As seen in Figure 1, the energy spectrogram varies wildly during the storm, and thus, assuming the plasma to be in something like a steady state and describable with a kappa distribution is a bold suggestion. After all, during storms is when there is strong acceleration of particles and deviation from the mean distribution.

The authors could explain in better detail how is the fit performed exactly, and what are the deduced kappa values? Both parameters "a" and "kappa" are being fitted using the low-energy portion of the population - some estimation of the quality and reliability of this fit should be presented.

Also, is the population assumed to be isotropic? Equation (3) takes only the parallel pressure, after all. Figure 6 shows the final result, but comparing that with Figure 5 suggests that the pressure contribution to the calculated current is minimal, and rather, it is dominated by the curvature component (as shown in Figure 5). And if the result is dominated by curvature, then of course it will match up with the MRA method (and the inherent curlometer technique). Thus, I am not convinced that energetic particle curvature drifts are particularly important here.

Minor issues / clarification requests:

page 2 line 9: Although others have called the curlometer technique "direct" measurement of the current, in truth, direct calculation would be counting charged particle fluxes. Perhaps briefly state that it uses magnetic curvature to calculate currents via Maxwell-Ampère's law.

page 2 line 20: A normal can be defined for a plane, not directly for a field line, unless you assume it to be in a plane within which the local curvature is. Please clarify.

page 2 lines 24-26: Could the authors please clarify, why they state that they subtract the IGRF field, yet then proceed to describe the standard dipole formulation?

page 5, Figure 2: Could the authors please explain why they plot a dipole field for comparison, instead of the IGRF field they state they use in the text?

page 6 line 5: Evaluation of Figure 2 panel c shows that contrary to what is written here, the radius of curvature is nearly everywhere much greater than that of the dipole field. Only in NH3 and NH6-8 does it drop below the dipole field value, and only then in the middle of the domain.

page 8 line 7: Stating that the field lines were severely deviated would be more readily confirmed had the authors included x,y,z components of the magnetic field. The radius of curvature is a challenging method of showing this, as it becomes most important at very small values, which are not clearly visible in the plots.

page 10 lines 16-18: The text should reference Figure 5, panels a and b. I would recommend stating more clearly what is being shown and analyzed, instead of simply referring to "a result", which here is simply the cross product of the curvature and the magnetic field. Also, the authors claim that the z component of this has the same variation trend as j_z, but j_z has not been shown in any figure. If the authors claim that this is the same as j_N, the questions regarding stability of the chosen coordinate system apply again. I think the manuscript would be much improved if these doubts could be clarified.

page 10 line 19-21: I believe the authors should clarify their reasoning for disregarding the possibility of the third term of gyromotion drift to cause currents in the j_z direction. On line 15, they stated that both the magnetic field and its gradient are pointed towards the dayside, so this term might be non-negligible.

Figure 5: The caption states that the plot shows "results deduced from the radius of curvature of the cross magnetic field" - I would recommend the authors be more explicit and exact in their statements.

page 13, line 6: Now the authors compare with the T96 model, but provide no reference. Does comparison with the T96 model provide some benefit over using the IGRF or dipole models, which are used(?) in the rest of the analysis? Remaining consistent would improve the readability of the manuscript.

page 13, lines 12-16: The error caused by planarity or elongation of the tetrahedron could do with a clear statement that deformation remains low. If I have understood correctly, neither the standard curlometer technique nor the MRA method attempt to remove the error, and this could be clarified.

page 14, Figure 7: The caption should be improved - what are the red vertical lines in panels a and b? Apparently the cross-lines in panels c and d indicate the region applicable for these two events, but this could be clearly stated - it looks like the panels were identical at first glance.

Technical corrections:

page 10 line 4: The reference is incorrectly formatted; it should read "De Michelis et al., 1999"

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