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Reply to Comment on "Evaluation of the Tail Current Contribution to *Dst*"

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Reply

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[1] *Turner et al.* [2000] analyzed the contribution of cross-tail currents to the *Dst* index. In order to estimate this contribution we used modified versions of the Tsyganenko models which had been adjusted to match spacecraft data in the tail, and we isolated a tail region and calculated its influence. We concluded that the tail currents were responsible for around 25% of the *Dst* response during moderately disturbed times. *Maltsev and Ostapenko* [2002] conclude that our estimate was low by a factor of 2, owing to that fact that we neglected dayside currents and that the model we used systematically underestimates the cross-tail current system. We appreciate their insightful analysis of our work, but we disagree with their conclusions. The models we used were modified to match spacecraft data in the tail, so we do not feel they underestimate the tail currents, and we consider the tail currents to be primarily located in the magnetotail, so we feel our decision to neglect dayside currents was justified. Additionally, we feel that some of the discrepancies between our results and theirs are due to different definitions of tail and ring currents and our decisions on whether to include the induced ground current contribution in our estimates of the tail current contribution to *Dst*. Here we respond briefly to their arguments and conclude that we still find the approximate magnitude of the tail current contribution to *Dst* to be around 25%. Additionally, Maltsev and Ostapenko include their own analysis of the tail current contribution to *Dst*, but we will limit our response to those comments which directly relate to our work. *INDEX TERMS:* 2708 Magnetospheric Physics: Current systems (2409), 2744 Magnetospheric Physics: Magnetotail, 2778 Magnetospheric Physics: Ring current, 2788 Magnetospheric Physics: Storms and substorms

1. Intensity of the Cross-Tail Current

[2] In their comment the authors point out the limitations of the Tsyganenko empirical magnetic field models. In particular, they point out their work, which has shown the T96 model to underestimate tail currents by ~30%. We agree with many of their comments on the models and their inherent limitations, but we would like to clarify that we used modified versions of these models in order to perform our calculations. For the events analyzed by *Turner et al.* [2000] the model magnetic field was compared with the observed one, in many cases at several locations in the magnetotail. Furthermore, in five of the six events studied, the model was specifically adjusted to produce the observed time variations in the magnetic field using methods developed by *Pulkkinen et al.* [1992]. Therefore we do not believe that we have seriously underestimated the cross-tail current intensity in these cases.

2. Inclusion of Dayside Cross-Tail Current

[3] *Maltsev and Ostapenko* [2002] conclude that our estimate of the tail current contribution to *Dst* is 1.6 times smaller than it would be had we included the dayside part of the current system.

[4] *Turner et al.* [2000] evaluated the tail current contribution during disturbed times, especially during the substorm growth phase, when the cross-tail currents are strongly enhanced. During such periods the current is mainly enhanced tailward of geosynchronous orbit, whereas the dayside currents are not as strongly modified. As the *Dst* index is a variation index, where the quiet time currents have been eliminated by subtraction of the *Sq* curve, the *Dst* index measures only variations from the quiet time state, and hence any quasi-static current system is not present in the index.

3. Ring Versus Tail Current Systems

[5] In our analysis we considered the cross-tail current to be comprised of straight line currents closing at infinity. Because the inner edge currents should, in fact, have some curvature and leaving them straight would underestimate the tail effect, we calculated the tail current as far earthward as 6 R_E. This we feel was far enough in, as the tail current exists primarily beyond geosynchronous orbit.

[6] However, we believe there may be a semantic difference in our respective analyses that exaggerates the differences between our results. We regard the cross-tail current as the dawn-dusk current system flowing in the magnetotail which closes over the tail lobes. We regard the ring current as comprising both the closed ring of trapped particles that are known as the symmetric ring current, as well as the asymmetric, or partial, ring current of particles which are acting under the influences of gradient and curvature drifts but are not on closed drift paths. Perhaps some of what we would identify as partial ring current is regarded by our colleagues *Maltsev and Osta-*

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penko [2002] as inner-edge cross-tail current. We do regard the partial ring current as having a significant impact on the ground-based *Dst* index, and thus this terminology difference may explain some of the discrepancy in our results.

4. Ground Currents

[7] It is also important to clarify that when we stated in our paper that the tail currents are responsible for around 25% of the *Dst* variation, we were strictly referring to currents flowing in the geomagnetic tail, and not including the ground currents they induce in the Earth. If these currents are included, as we mentioned in our paper, the contribution will increase accordingly. Recent estimates suggest that the influence of the internal currents is ~25–30% of that of the external currents [*Langel and Estes*, 1985; *Häkkinen et al.*, 2002].

5. Conclusions

[8] We feel that the moderate differences between our respective results have been exaggerated by a difference in the definitions of the current systems and by our different conventions regarding whether to include ground currents in our estimations. We have considered all the points raised by *Maltsev and Ostapenko* [2002], but the assessments have not led us to change our view that the tail current contribution to *Dst* is around 25%. The fraction of the *Dst* which is due to tail currents may, of course, vary from event to event or change during strongly disturbed periods not included in our study. It should therefore be considered an average estimate.

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[10] Michel Blanc thanks the referee for his assistance in evaluating this paper.

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