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Final report on "Characterization of Iononspheric Flow Patterns During Times of Unusual Auroral Activity Using DE and DMSP Data"

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Summary

This final report describes the work done by Dr. Marc Hairston and Dr. Rod Heelis on NASA SR&T grant NAGW–4411 studying the theta aurora using DE–1 ultraviolet imager data and DMSP particle data. This report covers the period from summer 1995 through summer 1996 along with a review of the previous work.

Previous work on this grant looked at the time period from the launch of DMSP–F8 in June 1987 through the end of mission of DE–1 in summer 1991. Despite the sporadic and decreasing frequency of observations from DE–1 over this time period, we were able to identify six events for study where the DE–1 imager observed a theta aurora occurring during a period in which the DMSP–F8 satellite flew through the region of the aurora at an altitude of 800 km. We focused on the best two events where the theta aurora persisted for an extended period so that we could observe the DMSP particle signatures in both the hemisphere observed by DE–1 and in the other polar hemisphere immediately before or afterwards. These results were presented at the Fall 1994 meeting of the AGU.

Initially we had hoped to expand on this work. However, further work showed that none of these events gave a clear enough signature in the DMSP data for us to identify a theta aurora in the hemisphere opposite to the hemisphere imaged by DE–1. Without that, there were no results from this work that were new enough to warrant publication. So instead we used the final year of the grant to work with our colleague, J. A. Cumnock on a similar project using DE data to study the evolution of theta auroras as a function of the IMF. A paper from that work was published which acknowledged this grant and a copy of that paper is included with this final report.

Results

The work began as an effort to study theta aurora events where a low–altitude satellite with *in situ* plasma instruments (such as DMSP–F8 and F9) was flying through the region of the theta aurora as identified by the ultraviolet imager on board DE–1. Such work was done earlier with DE–1 and DE–2 (Frank *et al.*, The Theta Aurora, *J. Geophys. Res.*, *91*, pp. 3177–3224, 1986) but between the short lifetime of DE–2 and the relatively short duty cycle of the instruments, only four such events were found in the 20 month lifetime of DE–2. The plasma DMSP instruments (both the ion flow velocity detectors and the ion/electron energy spectrum analyzer) were running on a near 100% duty cycle from their launches in June 1987 (F8) and February 1988 (F9) through the end of the DE–1 mission (summer 1991), so we had hoped that we could find a fair number of new events to study as a compliment to these earlier studies of the theta aurora

However, the observational runs of DE–1 were very infrequent during this time period, so there were not as many useful data periods as we had hoped for. Only 92 images taken by DE–1 during this three and a half year window coincided with DMSP polar crossings. Further examination showed that some of those passes only skimmed the polar region and thus reduced the number of usable events to below 60. Of these remaining usable events, only six contained a theta aurora.

Our main goal was to see if it was possible to determine a signature in the plasma flow data and the plasma energy spectrum that would uniquely identify a theta aurora, or more specifically the bar portion of the theta. Currently, the only way to definitely identify the occurrence of a theta aurora is to use the images from a high–altitude polar satellite such as DE–1 or (now) POLAR. If such a unique signature for the theta aurora in the low altitude plasma data could be found, then we could use that signature to search the extensive DMSP database for other theta aurora data for analysis without having to rely on a high altitude imager.

We focused first on the two events where the theta aurora lasted long enough for the DMSP to make one complete orbit or more so that it would pass through the aurora in both hemispheres. We were basing this work on the fact that theta aurora can occur simultaneously in both hemispheres (J. D. Craven *et al.*, *Geophys. Res. Lett.*, *18*, pp. 2297–2300, 1991) and so we were looking to see if the signature found in the plasma data in the hemisphere observed by DE–1 would also appear in the plasma data from the opposite hemisphere. The first event was on 25 September 1987 when DMSP–F8 passed first through the southern hemisphere while a theta aurora was observed by DE–1 in the northern hemisphere, followed by a DMSP pass through the northern hemisphere while DE–1 continued to observe the theta aurora. The second event occurred on 27 September 1987 when DMSP–F8 made a southern/northern/southern set of passes while DE–1 observed a steady theta aurora in the northern hemisphere.

The results of the analysis of these two events were presented as a poster paper at the Fall 1994 AGU meeting, and a copy of that paper is attached as an appendix to this report. This poster is also available on the World Wide Web at **http://utd500.utdallas.edu/~hairston/thetahp.html**. We took the image data from DE–1 and recast it in geographic polar coordinates so that we could also plot the cross–track ion flow from DMSP onto the dial. From this and the other northern pass on 27 September we confirmed the observation by Frank *et al.* (1987) that the theta bar occurs in the region where there is a strong gradient in the cross–track flow. When we examined the plasma energy spectrum we expected to see that the region between the theta bar and the dawnside aurora would be occupied by open field lines, while the theta bar and the auroral region would be on closed field lines. Instead we found a continuous spectrum of plasma, most likely from the mantle, throughout this region. Thus the theta bar appears not to be separate from the auroral oval, but rather the bar is only the bright edge of an extension of the auroral oval into the polar cap region. The three passes through the southern hemisphere gave ambiguous data. Because of the inclination of the orbit of DMSP–F8 combined with the tilt of the Earth's magnetic axis, the track of the spacecraft through the auroral oval in the southern hemisphere is more sunward than it is in the northern hemisphere. While there are gradients in the cross–track plasma flow observed in the southern passes, and these flows occur while the plasma energy spectrum shows it to be in regions of closed field lines, these flow gradients are not as large as those observed in the northern hemisphere. We cannot say whether this difference is a real one, in which case the flow gradients increase towards the nightside, or whether we simply are not observing any theta aurora in the southern hemisphere during these events.

Since the presentation of these results at the AGU meeting, we examined the remaining set of passes. However, none of them turned out to present any unambiguous signature in the plasma data which we could use to identify a theta aurora without the benefit of a high altitude imager. Without such a signature we felt that the results shown at the AGU meeting, while interesting, were not worth presenting as a refereed paper, so we dropped our plans to publish these data. So in the final year of the grant we turned our efforts to some earlier DE–1 data dealing with theta aurora. Dr. Judy Cumnock, a former student of ours, was working at UTD for half a year on theta aurora, so we combined our efforts.

Using the winter 1981–82 DE–1 data for the northern hemisphere DE–1, we identified five periods where theta aurora were seen to emerge from the auroral oval and evolve into a final theta form. Using the IMF data from the ISEE–3 spacecraft during these events we showed several things about this evolution. First, that the formation of a theta requires both northward IMF and a change in the sign of B_y in order to trigger the beginning of the theta's evolution. Second, that the side from which the theta emerges from the auroral oval depends on the sign change in B_y. If B_y goes from positive to negative, then the theta emerges from the duskside of the auroral oval and vice versa. And third, that once a theta aurora develops, it will persist for some time regardless of the subsequent IMF orientations, even if the IMF turns southward. Thus the theta aurora configuration cannot be associated with a unique orientation of the IMF.

The results of this work were submitted to the *Journal of Geophysical Research* and accepted. A reprint of this paper from the August 1, 1997 issue of *JGR* is included with this report. Part of the visualization program we developed during the first portion of this grant for reformatting the DE–1 image so that is is presented on a polar dial was used to generate the color plates in this paper. Full credit to this grant was given in the acknowledgments section.