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Study of Ring Current Dynamics During Geomagnetic Storms

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Accomplished Research

This research program considered modeling the dynamical evolution of the ring current during several geomagnetic storms. The first year (6/01/1997-5/31/1998) of this successful collaborative research between the University of New Hampshire (UNH) and the University of California Los Angeles (UCLA) was supported by NASA grant NAG5-4680. The second and third years (6/01/1998-5/31/2000) were funded at UNH under NASA grant NAG5-7368. Research work at UNH concentrated on further development of a kinetic model to treat all of the important physical processes that affect the ring current ion population during storm conditions. This model was applied to simulate ring current development during several International Solar-Terrestrial Physics (ISTP) events, and the results were directly compared to satellite observations. A brief description of our major accomplishments and a list of the publications and presentations resulting from this effort are given below.

Jordanova et al. [1998; 1999] studied ring current development accompanying the January 10-11, 1997, ISTP storm. This period was characterized by a magnetic cloud with a south-to-north B_Z excursion and minimum *Dst*=-83 nT. An interplanetary shock was observed by WIND at 01 UT, January 10. In the magnetic cloud interval from 04 UT, January 10 to 03 UT, January 11, the magnetic field executed a large rotation, going from a south-easterly to a due northward orientation. At the rear of the cloud, a high density plug was observed at WIND, which was thought to be prominence material [*Burlaga et al.*, 1998]. Several substorm particle injections occurred during the period of strong $B_Z<0$ [*Thomsen et al.*, 1998]. Elevated electron temperature was observed at F region heights during the main phase of the storm by the Millstone Hill radar [*Foster et al.*, 1997] within a limited latitude extent (~5°) and progressed equatorward through the radar field of view. Two overflights of the DMSP F13 satellite near the Millstone longitude observed a similar spatial extent and equatorward progression of the region of enhanced temperature.

We used our ring current model to simulate the evolution of H^+, He^+, and O^+ ion distributions during this period and associated aeronomical effects. We addressed for the first time in a global simulation the role of energy diffusion caused by wave-particle interactions on ring current distributions. The bounce-averaged approach allowed us to calculate the ion distributions for different magnetic latitudes and to compare with off-equatorial POLAR data. Model results during the main phase of the storm compared well with HYDRA, TIMAS, and CAMMICE data from POLAR. Calculations showed that energy diffusion due to wave-particle interactions smoothed the spectrum and caused the distribution function to decrease at energies from ~8 keV to ~50 keV within the unstable regions at dusk and to increase at higher energies.

We computed plasmaspheric heating through Coulomb collisions as the storm evolved and found that maximum heating occurred initially on the nightside near $L\cong3.5$ and subsequently moved earthward to $L\cong2.75$, in agreement with Millstone Hill radar observations. However, the magnitude of the energy transferred to plasmaspheric electrons through Coulomb collisions was insufficient to yield the observed elevated electron temperature, suggesting that additional energy sources should be considered during this event (e.g., Landau damping of ion cyclotron waves by thermal electrons [*Cornwall et al.*, 1971; *Thorne and Horne,* 1992]).

During this research program, we studied the effect of a high density plasma sheet on ring current evolution [*Jordanova*, 1999; *Kozyra et al.*, 1998]. The plasma sheet ion population represents the main source for ring current ions. During magnetic storms, plasma sheet ions are transported earthward, energized, and become trapped, thus increasing the preexisting ring current population. Significant enhancements of ion density (above 2 cm^{-3}) in the plasma sheet have been observed during intense magnetic storms and have been called superdense plasma sheet. A burst of superdense plasma sheet was observed at geostationary orbit during the October 18-19, 1995, and the November 2-6, 1993, geomagnetic storms. The time evolution of the two major ring current ion species (H^+ and O^+) during these storm periods was simulated using data measured by the instruments on the LANL spacecraft at geosynchronous orbit to model the plasma inflow on the nightside. To see the contribution of the stormtime plasma sheet ion population to ring current formation, we made a test simulation assuming plasma sheet ion densities equal to the prestorm quiet time values. It was demonstrated that the factor of 3 increase in the plasma sheet density from quiet to active times during the November 1993 storm produced a factor of 3 enhancement in the strength of the simulated ring current. Stormtime plasma sheet density enhancements contributed significantly to the ring current buildup during the October 18-19, 1995, magnetic storm as well. While dayside losses were included in the simulation of ring current development during the October 1995 magnetic storm, the study focused mainly on the relative effect of various collisional mechanisms on ring current decay. It was thus found that charge exchange was the most important loss mechanism of the collisional losses considered, followed by Coulomb collisions and ion precipitation resulting from convective transport.

Mechanisms contributing to proton precipitation from the ring current during the May 14-16, 1997, geomagnetic storm were studied by *Jordanova et al.* [2000]. This storm was caused partly by $B_Z<0$ fields in the sheath region behind an interplanetary shock and partly by the magnetic cloud driving the shock. The equatorial growth rate of electromagnetic ion cyclotron waves and the integrated wave gain were calculated for all phases of the storm. A time-dependent global wave model was constructed to model the spatial and temporal evolution of precipitating proton fluxes. We found that the global patterns of proton precipitation are very dynamic: located at larger L shells during prestorm conditions, moving to lower L shells as geomagnetic activity increased during storm main phase, and receding back toward larger L shells with storm recovery. Both magnetospheric convection and plasma wave scattering played significant roles in causing ion precipitation. The most intense fluxes were, however, observed along the duskside plasmapause, during the main and early recovery phase of the storm, and were caused by plasma wave scattering.

List of Publications

Jordanova, V. K., New results in ring current modeling using multi-satellite observations, *Recent Res. Devel. Geophysics*, in Research Signpost, ed. by S. G. Pandalai, Trivandrum, India, v. 2, p. 33, 1999.

Jordanova, V. K., C. J. Farrugia, J. M. Quinn, R. M. Thorne, K. W. Ogilvie, R. P. Lepping, G. Lu, A. J. Lazarus, M. F. Thomsen, and R. D. Belian, Effect of wave-particle interactions on ring current evolution for January 10-11, 1997: Initial results, *Geophys. Res. Lett.*, *25*, 2971, 1998.

Jordanova, V. K., R. B. Torbert, R. M. Thorne, H. L. Collin, J. L. Roeder, and J. C. Foster, Ring current activity during the early $B_Z<0$ phase of the January 1997 magnetic cloud, *J. Geophys. Res.*, *104*, 24895, 1999.

Jordanova, V. K., C. J. Farrugia, R. M. Thorne, G. V. Khazanov, G. D. Reeves, and M. F. Thomsen, Modeling ring current proton precipitation by EMIC waves during the May 14-16, 1997, storm, *J. Geophys. Res.*, *in press*, 2000.

Kozyra, J. U., V. K. Jordanova, J. E. Borovsky, M. F. Thomsen, D. J. Knipp, D. S. Evans, D. J. McComas, and T. E. Cayton, Effects of a high density plasma sheet on ring current development during the November 2-6, 1993 magnetic storm, *J. Geophys. Res.*, *103*, 26285, 1998.

List of Presentations

Jordanova, V. K., Ring current modeling using multiple spacecraft data, Invited paper presented at Spring AGU Meeting, Boston, Massachusetts, May 26 to May 29,1998.

Jordanova, V. K., New results in wave scattering losses, Invited paper presented at GEM Meeting, NSF, Snowmass, Colorado, June 15 to June 19, 1998.

Jordanova, V. K., C. J. Farrugia, J. M. Quinn, L. F. Burlaga, K. W. Ogilvie, R. P. Lepping, G. Lu, A. J. Lazarus, R. D. Belian, and M. F. Thomsen, A study of ring current activity during passage of the January 1997 magnetic cloud, *EOS Trans. AGU*, *78*, S288, 1997.

Jordanova, V. K., C. J. Farrugia, H. L. Collin, J. L. Roeder, J. U. Kozyra, and R. M. Thorne, Aeronomical consequences of ring current energization during the early $B_Z<0$ phase of the January 1997 magnetic cloud interval, *EOS Trans. AGU*, 78, F601, 1997.