Geophysical Research Abstracts
Vol. 13, EGU2011-9353, 2011
EGU General Assembly 2011

Magnetic Flux Transfer During the April 5, 2010 Galaxy 15 Event: An Unprecedented Observation

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The ICME-driven shock which encountered Earth's magnetosphere at approximately 0825 UT on April 5, 2010 was followed by a series of magnetic disturbances of large amplitudes on Earth and in the magnetosphere. Slightly more than an hour later, the Galaxy 15 geosynchronous commercial satellite suffered a costly failure, possibly associated with these extreme space weather conditions. The driving conditions were southward IMF (average value close to -15 nT), maintained for nearly an hour under high dynamic pressure (10 nPa) conditions. Following a growth phase, a localized depolarization took place in the midnight sector at 0847 UT. Large dipolarizations at 0903 UT and 0908 UT were observed by GOES spacecraft and by three THEMIS spacecraft near X=-11, Y=-2 Re . In the latter, a large (100 mV/m) -By electric field detected at the THEMIS spacecraft corresponds to Earthward transport of magnetic flux. Such a large electric field is consistent with amount of flux transfer to the inner magnetosphere needed to explain the observed "overdipolarization" to a value of 140 nT (Bz: typically 80 nT), at GOES 11 in the midnight sector. On the ground in the midnight sector, currents flowing across the meridian of the Alaska Geophysical Institute magnetometer chain produced perturbations exceeding 2000 nT in magnitude, which corresponds to approximately 3 MA. In addition, the locations of field aligned currents associated with the boundaries of the current wedge may be deduced from subauroral Y (eastward) component perturbations. A calculation of the magnetic field at GOES 11 produced by 3 MA of electric current, following magnetic field lines for maximally stretched conditions in the position deduced for the substorm current wedge (and including both hemispheres), is consistent with the overdipolarization magnetic signature detected. Separately, the observation of 100 mV/m By electric field, overdipolarization to 140 nT, and auroral zone perturbations of 2000 nT each are rare. In this event, a fortuitously good placement of spacecraft and ground assets allows a consistent picture of the relation of electric field to flux transfer, with its manifestation in the inner magnetosphere also able to be quantitatively explained through perturbations from the currents of the substorm current wedge. We also infer a large (comparable to Ey in magnitude) Ez component electric field. This is colocated at the plasma sheet boundary layer with a large change in tangential B (mostly Bx) and density. Similar observations from Cluster have been interpreted as shocks associated with the X-line. A coherent picture of the 0908 UT onset in terms of reconnection at an X-line downtail from the -11 Re location of the THEMIS spacecraft is thus established. Particle data from THEMIS indicates the largest electron injection seen since 2007 and the in-situ data from GOES-11, very near the location of Galaxy 15, indicate the largest increase in subrelativistic proton flux in a decade. The location and the magnitude and timing of these signals of extreme space weather conditions, suggest that these unusual conditions played a role in the anomaly on Galaxy 15. We thank instrument PIs J. W. Bonnell and K.-H. Glassmeier for THEMIS EFI and FGM measurements.