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Lobe crossing events observed by the Van Allen Probes as tests of magnetic field line mapping

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Abstract

In this paper we examine a series of lobe crossing events witnessed by the twin Van Allen Probes spacecraft between 0200 and 0515 on November 14th 2012. The events occurred on the flank between 0400 and 0635 local time and at altitudes between 5.6 and 6.2 R_E. During the events Dst was less than 100nT with the IMF being strongly southward (B_z = -15nT) and eastward (B_y = 20 nT). Other observations at geosynchronous orbit also show lobe crossings at dawn and dusk flanks. These events provide a chance to examine the magnetic field topology in detail and compare it with models. We will show that the spacecraft were in locations with access to the open field lines by comparison to the CRCM + BATS-R-US models as well as comparing spacecraft encounters with the lobe to the predicted magnetic field topology.

1. Introduction

Previous observations have been made of spacecraft at near geosynchronous altitudes moving between regions of open and closed field lines, which have been shown to be either magnetopause crossings[1] or tail-lobe entries [2].

Moldwin et al[3] defined tail-lobe entry events as fitting into two distinct classes, those that occurred around local midnight and those that occur out on the flanks of the magnetosphere. The former being associated with stretching of the near-Earth field, leading to a thinning of the plasma sheet during a substorm growth phase and the latter with large scale reconfigurations caused by unusual IMF strength and abnormal IMF orientations ie: very strong By. These lobe crossing events are characterized by a sharp dropout of energetic particle fluxes, followed by a rapid recovery to previous levels[4] indicative of the spacecraft moving between two distinct plasma regimes.
The occurrence of these events during very strong IMF By has been previously studied[3] using the Tsyganenko T87 model to show what the expected magnetic field topology should be during these conditions. An asymmetry was found in the magnetic field configuration which predicts that regions of open field lines should be brought closer to geosynchronous orbit for south/dawn and north/dusk sectors for By < 0 and the reverse for By > 0. It is these magnetospheric reconfigurations combined with a large geomagnetic storm that they propose are responsible for the majority of flank lobe crossing events.

2. November 14th 2012 Event

Over a five hour period on 14/11/2012 the twin Van Allen Probes observed multiple rapid decreases and then recoveries of energetic particle fluxes, shown in Figure 1. Simultaneous increases and then decreases in magnetic field strength were also observed (not shown). These signatures are consistent with the spacecraft crossing the open/closed field line boundary (OCB) and entering the lobe.

During this event four of the six LANL geosynchronous satellites also observed dropouts of proton fluxes consistent with lobe entries.

A total of twenty one entries into the lobe over six spacecraft in the south/dawn (RBSP-A, RBSP-B & LANL 04-A), north/dawn (LANL-97A) and south/dusk (1991-080 & LANL-01A) are observed.

These multi-point observations of the OCB are compared to its simulated location using the CRCM + BATS-R-US global MHD model outlined in Glocer et al 2013[5].

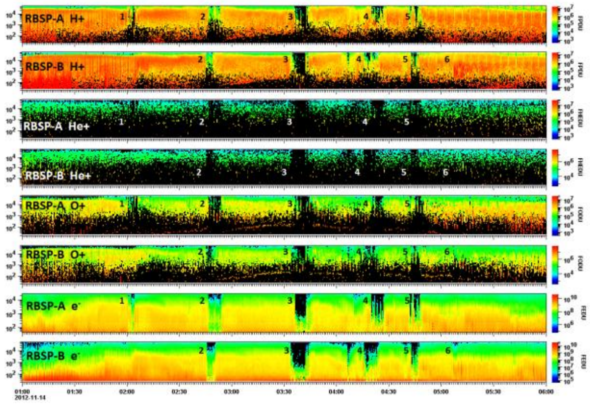

Figure 1: Van Allen Probes HOPE instrument energetic particle fluxes. Lobe entries numbered 1-6 with five being seen by each spacecraft.

3. Data - Model Comparison

The position of the OCB observed in the spacecraft data is compared to that predicted by the model. The calculated distance between the spacecraft and the boundary and the times the spacecraft entered the lobe are shown in Figure 2.

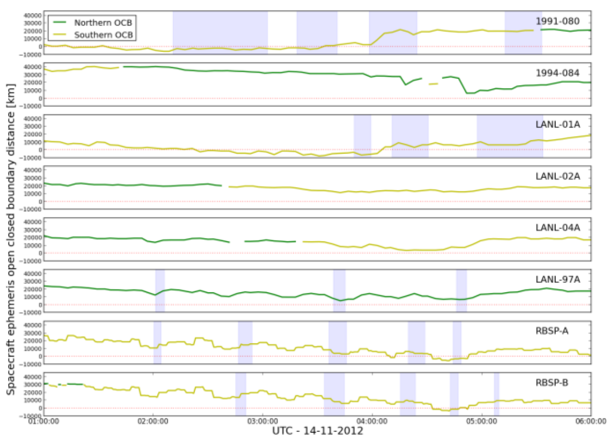

Figure 2: Calculated distances between spacecraft and modelled open/closed field line boundary. Trace coloured green or yellow depending on whether the spacecraft is closer to the northern or southern lobe. Blue shaded regions show the lobe entries observed in the spacecraft data. Negative distance values represent the distance to the boundary from inside the lobe once the spacecraft has crossed the boundary.

6. Summary and Conclusions

Both spacecraft data and model show expansion and contraction of the OCB, with some agreement between them. Discrepancy between data and simulation could be a result of coarseness of model not being able to reproduce dynamic changes in B-field topology. Some spacecraft lobe entry durations shorter than model resolution (10 minutes).

Better tools for comparing OCB location in data and model needed, this work is a first step. Improved method using full 3-D dataset in production.

Analysis of other events seen by the Van Allen Probes and comparison with further BATS-R-US data needed to find whether discrepancies are unique to this event.

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