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A survey of multi-point observations of the open-closed field line boundary by the Van Allen Probes

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Abstract

We perform a survey of encounters with the open/closed field line boundary (OCB) by the Van Allen Probes (October 2012 - October 2014). The work follows on from previous work investigating the November 14th 2012 lobe entry event [Dixon & MacDonald et al, under review 2015]. Previous work using the CRRES and GOES spacecraft (e.g. Thomsen et al, 1994; Moldwin et al, 1994) found that spacecraft near geosynchronous orbit were more likely to encounter the lobe in the dawn region of the magnetosphere. During the period examined, the Van Allen Probes have had apogee which precessed through all MLTs, allowing a detailed investigation. These events are comparatively rare; we use Superposed Epoch Analysis of IMF data prior to each event to provide insight into the conditions required to make the lobe accessible to the Van Allen Probes.

1. Introduction

Spacecraft encounters with the magnetospheric lobes are characterized by a rapid decrease of particle fluxes to background levels at energies from 1 eV to 40 keV [1], followed by a rapid recovery to previous levels. A strong, stretched and tail-like field is also seen when crossing into the lobes [2], especially during times of increased geomagnetic activity and southward IMF [3].

Multiple studies [e.g. 4,5] have shown a preference for lobe encounters to occur in the morning sector of the magnetosphere, with suggested causes being an asymmetry in the rate of reconnection [4] or an unbalanced inflation of the magnetosphere on the dusk side, caused by an asymmetry in the storm time ring current [6].

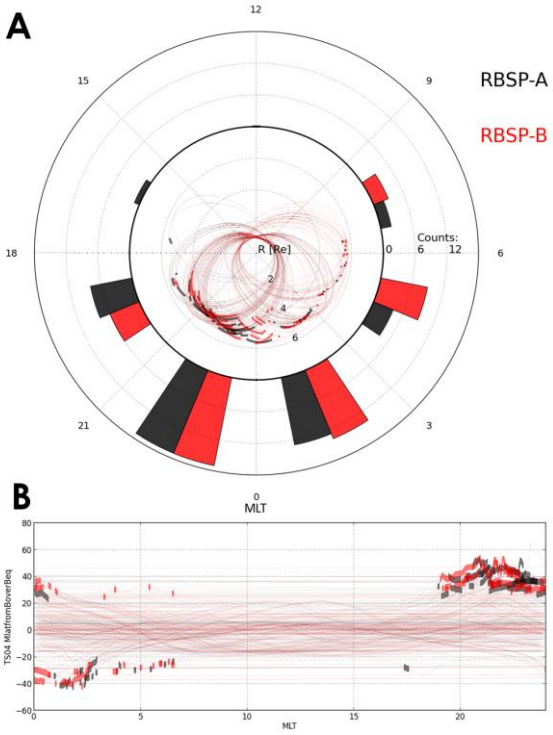

Figure 1: A) Central plot shows the orbits of the Van Allen Probes (pale lines) and the shaded boxes mark periods where the spacecraft entered the lobe. Outer plot is a histogram separated in bins of 3 MLT e.g. 0-3, 21-24 and counting the number of events that occurred in each region. B) Pale lines show the orbits of the Van Allen Probes in MLT and magnetic latitude, with shaded boxes marking periods where the spacecraft entered the lobe

2. Lobe Encounter Survey

Over a two year period (October 2012 – October 2014) the Van Allen Probes observed flux dropouts and increases in magnetic field strength consistent with crossing the open/closed field line boundary (OCB) and entering the lobe. A total of one hundred events were observed between the two spacecraft, with sixty one occurring within three hours of midnight (Figure 1).

All events occur at large magnetic latitudes - either above 20˚ in the northern hemisphere or lower than -20˚ in the southern hemisphere. There is a slight preference for dusk events, but this may be skewed

due to there being a greater number of geomagnetic storms while the Van Allen Probes had apogee in the dusk region.

3. Superposed Epoch Analysis (SEA)

Data from the EMFISIS instrument aboard the Van Allen Probes were analysed to show magnetic field characteristics as the spacecraft cross the OCB and enter the lobe. Before SEA is performed, the background magnetic field calculated using the TS04 Tsyganenko model is removed.

The signatures shown by the SEA are consistent with the spacecraft encountering a region of highly stretched magnetic field, flattened towards the x-y plane. Similar magnetic field topology was observed by the Van Allen probes for the November 14th OCB crossings [7]. As an example, one signature of this stretched field is shown for B_y in Figure 2.

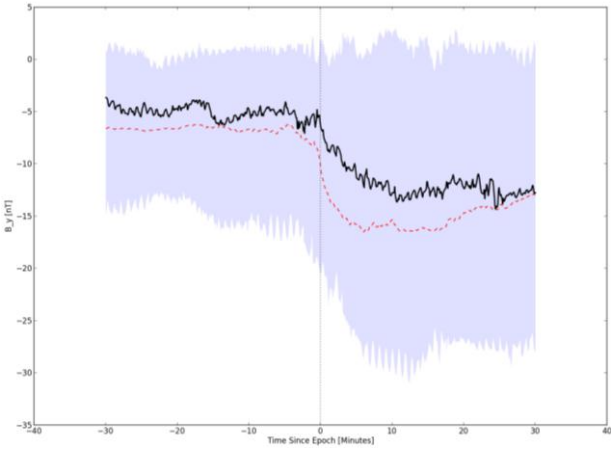

Figure 2: Superposed Epoch Analysis of B_y observations taken from the EMFISIS instrument aboard the Van Allen Probes . Epochs are defined as the start of each lobe encounter and the window size is set to thirty minutes before and after each event. The black line represents the mean, the red dashed line the median and the blue, shaded areas the limits of the upper and lower quartiles.

4. Conclusions

Over a two year period the Van Allen Probes encountered the lobe one hundred times, always at large magnetic latitudes ($> \pm 20^{\circ}$), with a slight preference for the dusk region which is possibly due to varying levels of geomagnetic activity. Fifty-one of the events were associated with a substorm injection and the majority of these events occurred near local midnight. These were most likely the result of plasma sheet thinning during the substorm growth phase.

Superposed Epoch Analysis (SEA) of the IMF conditions prior to each event show a strong signature in B_z similar to that expected for a substorm, in agreement with injections seen in the particle data. SEA of EMFISIS magnetic field data shows the spacecraft encountering a strong, highly stretched field which is consistent with lobe entry and observations of the November 14th 2012 event.

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