EPSC Abstracts
Vol. 9, EPSC2014-809, 2014
European Planetary Science Congress 2014

Effect of the ring current on preconditioning the magnetosphere for steady magnetospheric convection

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Abstract

Steady magnetospheric convection (SMC) occurs when reconnection rates on the dayside and in the distant tail are balanced. An enhanced ring current could support this, by stabilizing the tail against near-Earth reconnection and by facilitating the prompt return of magnetic flux to the dayside. We use 32 years of magnetic index and solar wind data to study the effect of the ring current on preconditioning Earth's magnetosphere for SMC. The ring current is found to be enhanced during SMCs. Solar wind driving is similar but the ring current is weaker before the SMC, and the ring current is similar but solar wind driving is either weaker or stronger after the SMC than during it. This indicates that the magnetosphere cannot enter the SMC mode until the ring current has enhanced sufficiently for the prevailing driving conditions, and that when the driving exceeds a certain level, the ring current stabilization will fail.

1. Introduction

A common mode of response of the magnetosphere to enhanced solar wind energy input is a cycle of loading and unloading of magnetic flux (substorm). When the dayside and nightside reconnection rates are occasionally balanced, a mode called steady magnetospheric convection (SMC) results [6]. [5] reported that during SMCs, the solar wind velocity is typically below 450 km/s and IMF $B_z \approx -3$ nT. However, they also demonstrated that the occurrence of such solar wind conditions alone is not sufficient for driving an SMC. The main difference seemed to be the preconditioning of the magnetosphere: After a period of modest activity, an SMC occurred, whereas after very quiet conditions, a substorm occurred. During an SMC, reconnection is thought to take place quasi-steadily in the distant tail without the formation of a new near-Earth X-line [6]. [4] has speculated that the intensity of the ring current plays a role in controlling the rate at which open flux is reclosed in the magnetotail, by modifying the level of stretching of the tail field and hence its stability to the onset of nightside reconnection. [3] suggested that balancing of the dayside and nightside reconnection rates is not a sufficient condition for an SMC state, but that the magnetic flux closed by the nightside reconnection needs to be promptly returned to the dayside to replace the flux depleted by the dayside reconnection. They showed that during SMCs, pressure in the inner magnetosphere is enhanced. Consequently, earthward fast flows are deflected toward the dawn and dusk, instead of piling up magnetic flux in the inner nightside magnetosphere. An enhanced ring current could both stabilize the tail against the formation of a new reconnection site close to Earth and contribute to the increase of the total pressure in the inner magnetosphere. We will examine the possible connection between the SMC state and the ring current.

2. Observations

We defined an SMC as an (1) at least 90 min long interval during which (2) AL $\leq$ –130 nT, and (3) AL(t) - AL(t - 1 min) $\geq$ -25 nT. Figures 1 and 2 show the percentual duration of SMC observations relative to all observations as a function of the SYM-H index (proxy for the ring current intensity) and IMF Bz or solar wind speed Vx, respectively. Figure 1 shows that the occurrence frequency of SMCs increases for southward IMF Bz and enhanced ring current conditions. Figure 2 shows that the occurrence frequency of SMCs increases for slow solar wind speed conditions, but SMCs can also occur for higher solar wind speeds if the ring current is sufficiently strong. Comparison of Figure 1 with a similar presentation of pre-SMC conditions (not shown, see [2]) reveals that while the IMF Bz tends to be fairly similar to or slightly more negative for pre-SMC intervals than for SMC intervals, the ring current is clearly weaker. Comparison of Figure 1 with a similar presentation of post-SMC conditions (not shown) reveals that the ring current amplitude remains approximately the same after the SMC has ended but IMF Bz becomes either stronger or, in some cases, weaker.

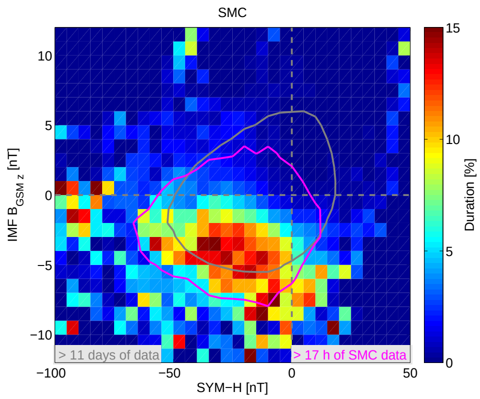

Figure 1: Duration of SMC observations relative to all observations (%) as a function of the SYM-H index and IMF Bz. The gray and magenta curves mark the regions inside of which the majority of all data points and SMC data points, respectively, are concentrated.

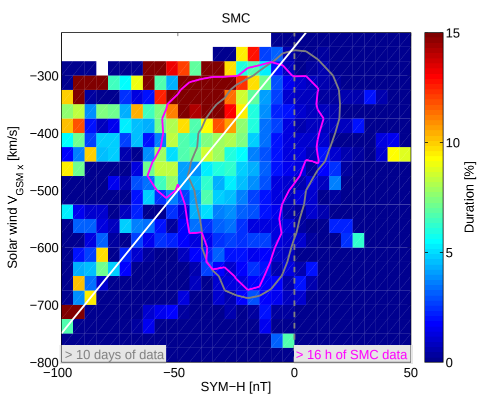

Figure 2: Same as Figure 1 except that the data are shown as a function solar wind Vx instead of IMF Bz.

3. Summary and Conclusions

We have used 32 years of observations (1981–2012) to study the effect of the ring current for preconditioning the magnetosphere for steady convection. SMC intervals were found based on the AL index, the SYM-H index was used as a proxy for the ring current amplitude, and solar wind speed and IMF Bz for the prevailing solar wind driving. We found that 1) The ring current is enhanced for the majority of SMCs. 2) Although SMCs tend to take place during slow solar wind speeds, they can also occur during higher solar wind speeds if the ring current is intense enough. 3) Pre-SMC intervals are characterized by solar wind driving that is similar to that during SMC intervals, but a weaker ring current. This indicates that the magnetosphere cannot enter the SMC mode until the ring current has enhanced sufficiently. 4) Post-SMC intervals are characterized by ring current conditions that are similar to those during SMC intervals, but either stronger or weaker solar wind driving. The former implies that when the driving exceeds a certain level, the ring current stabilization fails. The latter indicates that magnetospheric convection ends when the IMF turns northward.

References

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