On the relationship between recurrent substorm-look activations and IMF variations

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Abstract

The relationship between recurrent substorm-look activations and the variations of the interplanetary magnetic field (IMF) was studied with 10 events of two consecutive bursts of Pi2 pulsations at SMALL and 6 at IGPP/LANL in 1999. The occurrence of these Pi2s associated with the substorm-look activation relevant to the IMF variation is justified with the cycle of growth and subsequent decay in the *AL* index, enhanced *H* component at low latitudes and multi-satellite observations in the upstream region. By mapping the ground Pi2 onset to the satellite, the first burst occurs in 47.6 +/- 19.9 min after southward turning of the IMF. The second burst often occurs after a time that is correlated with the amount of southward IMF convected to the magnetopause. This correlation is most strong when only the events in which the IMF turns northward are considered. When the IMF remains southward until well after the burst pair, the second Pi2 occurrence is not correlated to the amount of convected southward IMF and the interplanetary induced field but associated with a decreasing *By* magnitude. Consequently for two consecutive substorm-look activations, there is a spontaneous tendency for the first onset to occur when the IMF turns southward. As for the second onset, northward IMF turning plays the primary triggering role but a declining *By* magnitude does while the IMF remains southward.

Introduction

Recurrent onsets in an associated disturbance sequence are so common that they must be an essential part of magnetospheric physics but their cause remains poorly understood. Before advent of space-borne measurements, ground magnetometer data showed that groups of Pi2 pulsations, the geomagnetic perturbations with a period 40-150 s, generally occurred in succession during substorms (see Saito, 1969). Other early studies (e.g., Clauer and McPherron, 1974) reported evidence of multiple onsets accompanied by Pi2 pulsations in a magnetospheric substorm. However, recent studies (Sutcliffe, 1998; Sutcliffe and Lyons 2002) showed that a train of low-latitude Pi2s can simultaneously occur in the dayside and nightside during quiet solar wind conditions. When the solar wind interaction is weak, one may expect that the input of external momentum into the magnetosphere is not strong enough to cause substorm or substorm-related activations. One would even be preoccupied by a view that the cause of quiet-time Pi2s is different from those triggered by the IMF variation during substorm times. Thus to distinguish if quiet-time Pi2s (or substorm-look activations) are internally or externally excited is an important issue in magnetospheric physics.

In this study, we focus on two recurrent substorm-look activations and their relationships with two kinds of the IMF variation in which one has northward IMF turning and the other does not. First, we investigate what allows the first onset to occur spontaneously when the IMF turns southward for a period of time. Is it the magnetic flux pileup by the incident southward IMF, or the interplanetary electric field? Secondly, while the IMF in a period of south, does the IMF switching to strong north (i.e., *Bz* becomes positive) (simply denoted as northward IMF turning henceforth) have a higher tendency for triggering with comparison to the change of *By* magnitude? To attack these questions, we resort to using a statistical approach by extending the Cheng et al. (2002) work with addition of two consecutive Pi2 bursts data at IGPP/LANL in 1999.

Data Presentation

Since 1998, both the SMALL and IGPP/LANL magnetometer arrays have been set up to investigate hydromagnetic disturbances from the interaction between the Earth's magnetosphere and the solar wind. On the other hand, the ACE satellite was designed to monitor the solar wind with an orbit in between the Earth and the Sun. Thus, the incident IMF structure related to magnetospheric disturbances can be monitored by ACE. Due to all-year-round measurement on the ground and at ACE in 1999, it is feasible to make a statistical study of the relationship between the recurrent substorm-look activations and the IMF variation in this study.

According to Cheng et al. (2002), two Pi2 bursts are defined to be consecutive while the oscillating amplitude of the first Pi2 burst decreases under half of its peak value before the onset of the second burst. They are also defined to have a time interval between onsets of the first and second bursts of at least 3 minutes longer than the largest of Pi2 period. Following the above selection criteria, we identify 6 events of two consecutive Pi2 bursts at IGPP/LANL in addition to 10 events at SMALL in 1999.

Moreover, Pi2 pulsation bursts are studied when the IMF has a particularly simple structure in which the IMF initially turns southward after at least 30 min period of being northward with $Bz>0$. A subsequent northward turning was not a criterion of event selection. By using minimum variance analysis (e.g., Weimer et al., 2003), the IMF structure in the upstream region is simulated to be in front of the Earth at *XGSM* ~ 17.0 *Re*. Geotail, IMP 8 and Wind data are also used for comparison with those seen by ACE while available.

Figure 1 shows an example of IMF variations related to ground Pi2 onsets. The vertical dashed line denotes the equivalent onset time of ground Pi2 bursts at satellite. #1 and #2 denote the burst 1 and the burst 2 seen by the ground station, respectively. The dotted line denotes the IMF *By* component and the solid line for the IMF *Bz* component. Table 1 displays a statistical analysis of the IMF *By* variations at ACE related to two ground Pi2 onsets. Figures 2-3 show the correlation analysis of the delay time of two consecutive Pi2 bursts versus the southward IMF flux, and the interplanetary electric field, respectively. The southward flux before the first Pi2 onset is denoted as Φ_1 and the southward flux before the second Pi2 onset is marked as Φ_2. Prior to each Pi2 onset, the average magnitude of the interplanetary electric field Ey_1 and Ey_2 are estimated according to the plasma frozen-in condition.

Summary and Conclusion

By mapping the onset time of ground Pi2s to the IMF variation seen by ACE with minimum variance method, the first burst occurs in 47.6 +/- 19.9 min after southward turning. The second burst often occurs after a time that is correlated with the amount of southward IMF convected to the magnetopause. This correlation is most strong when only events in which the IMF turns northward are considered. When the IMF remains southward until well after the burst pair, the second Pi2 onset is not correlated to the amount of convected southward IMF and the interplanetary induced field but associated with a decreasing *By* magnitude.

These results can be explained with the two-neutral-point model (Russell, 2000). The first Pi2 burst initiates as the reconnection occurs at the near Earth neutral-point at a time controlled by the IMF and the state of the tail while southward turning. The second Pi2 signals that reconnection reaches the tail lobes after the IMF returns to a northward value. The time delay since the first Pi2, the onset of closed field line reconnection in this model appears to be shorter when the tail contains more magnetic flux. When the IMF remains southward, the supply of new magnetic flux and plasma to the tail for the situation with an a greater IMF *By* magnitude is less than that with a smaller one, possibly because of the control of tail reconnection by the relative angle of the fields in the two lobes that deviate from antiparallel for increasing magnitude of IMF *By*. Thus for two recurrent substorm-look activations, there is a tendency for the first onset to occur spontaneously when the IMF turns southward. As for the second onset, northward IMF turning plays the primary triggering role but a declining *By* magnitude does while the IMF remains southward.

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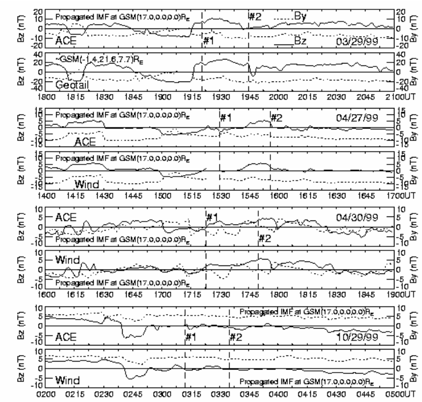

Figure 1. See text for detail.

Table 1. The propagated IMF *By* variations at ACE related to two ground Pi2 onsets

IMF *By* magnitude	Burst 1 (NT)[a]	Burst 2 (NT)	Burst 1 (NNT)	Burst 2 (NNT)	Burst 1	Burst 2	ALL Bursts
Increase	1	4	5	2	6 (37%)[b]	6 (38%)	12 (37%)
Decrease	2	4	5	4	7 (44%)	8 (50%)	15 (47%)
Unchanged[c]	1	1	2	1	3 (19%)	2 (12%)	5 (16%)

[a] NT denotes northward turning of the IMF; NNT denotes no northward turning of the IMF.

[b] The occurrence percentage of IMF *By* magnitude changes for this study.

[c] The absolute magnitude of IMF *By* variation less than 0.01 nT in 10 min.

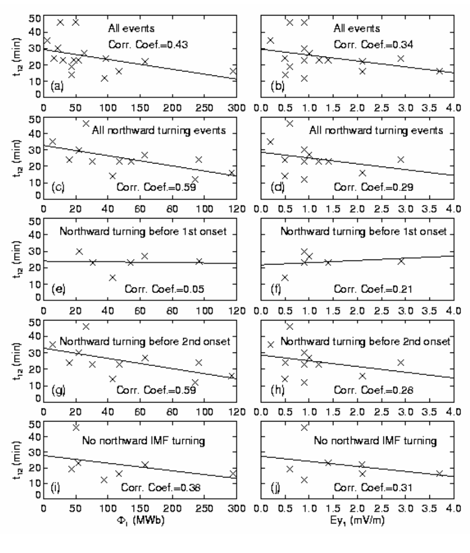

Figure 2. See text for detail.

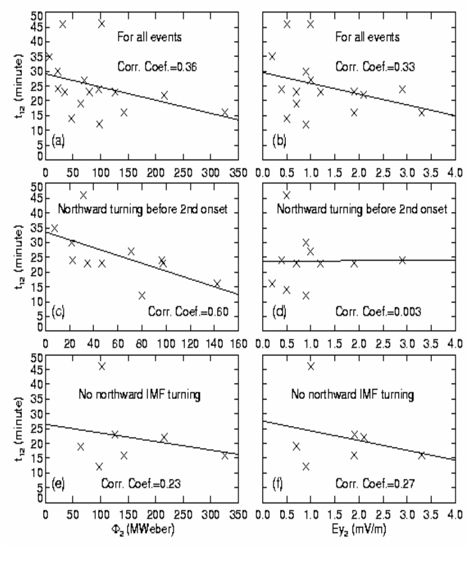

Figure 3. See text for detail.