Ann. Geophys. Discuss.,
https://doi.org/10.5194/angeo-2018-116-RC3, 2018

Annales Geophysicae Discussions

Interactive comment on "Characteristic study of double substorm onsets in response to IMF variations" *by* Ching-Chang Cheng et al.

Anonymous Referee #3

Received and published: 17 December 2018

This paper studied two-step development of substorm expansion or two successive substorm expansions by examining fast earthward flows and dipolarization in the magnetotail from multipoint THEMIS spacecraft, auroral breakups, geomagnetic field bay changes, and Pi2 and lower-frequency pulsations from high and low latitude ground stations, and IMF changes for the four substorm events. The authors concluded that the first onset occurs during southward IMF, while the second one is caused by IMF northward turning.

The substorm onset and development mechanism is an important issue, and the present results may potentially give a clue to understanding of a substorm external trigger, i.e., IMF northward turning. I, however, do not think that the manuscript is well written, and hence I cannot recommend to accept this manuscript for publication

in its present form. The manuscript needs to be substantially revised by describing the observational results and related discussion in more detail, as I point out below. First, the authors state that each of the first and second onsets of the double-onset events had all of the magnetotail and ground signatures. Some onsets, however, do not seem to have all signatures, or some signatures are not clearly shown and specifically described. The reason for the lack of the signatures should be discussed, along with more detailed description of the observations. Second, the authors did not consider the propagation time of the effect of the solar wind and IMF changes from the bow shock nose or the spacecraft to the near-Earth tail and ground through the tail reconnection site. Without this consideration, the conclusion would not be convincing.

Specific comments:

Page 3, line 20: For the first and second events (quiet time events shown in Figs. 2 and 3), it is difficult to understand the locations of the THEMIS spacecraft and the relative locations of their footprints and the ground stations only from this manuscript. Currently the paper by Cheng et al. (submitted, 2018a) does not seem open, so the readers need to refer other sources by themselves to know the locations. I suggest to add figures and/or more detailed description of the locations to this paper.

Page 4, lines 11-14, and the captions of Figs. 2 and 5: It is not clear what the vertical lines in Figs. 2-5 indicate. Do they indicate the first time when the Vx component of the ion flow exceeded 100 km/s or the time when the earthward flow started to grow fast? Some vertical lines appear to correspond to either of these timings. Some other vertical lines, however, do not correspond to any fast earthward flows (e.g., D in Fig. 2b, C1 in Fig. 4b, and PS and #1 in Fig. 5). Furthermore, some other vertical lines are drawn at a later time, although they correspond to fast earthward flows (e.g., A in Fig. 3b, and #2 in Fig. 5b). Please make this point clear and check the timings of the vertical lines.

Figs. 2-5 keograms: What is the meridian for the keograms? The center of the field of

view?

Page 4, lines 22-24: The AL index as well as the IMF is not shown later in this paper for the 18 March 2009 event. Also, the AL index should grow (become more negative), not decline, associated with the second onset (E2), similar to the first onset (E1). The H component at SNAP show this negative bay change at E2 (Fig. 2c). This is the case with the events shown in Fig. 9.

Page 4, lines 30-31, and page 5, line 2 (Fig. 2c): Where were the SNAP, FSMI, and LETH stations located, relative to the footprints of the THEMIS spacecraft?

Page 4, line 31 to page 5, line 1: It is not clear which auroral activity the authors link to the second onset E2. That is, it does not seem to me that further poleward expansion occurred at a higher latitude at E2, although the negative bay was observed at SNAP then.

Page 5, line 3: The negative bay at SNAP began before E2, not after E2.

Page 5, line 17: Again, it is not clear which auroral activity the authors link to the second onset C2. That is, it does not seem to me that further poleward expansion occurred at a higher latitude at C2, although the negative bay was observed at SNAP then.

Page 5, lines 22-25: This statement of two-step development does not seem to be clearly supported by the auroral observations, because of the lack of auroral breakup or poleward expansion at the second onset, as mentioned above.

Page 5, line 28: No clear dipolarization, i.e., Bz increase and |Bx| decrease, seems to be observed by any THEMIS spacecraft at the second onset C2.

Page 5, lines 29-33, Fig. 4c: The keograms are difficult to see the auroral activity associated with the onsets, particularly B and C2. Is this due to too high maximum of the color scale or the meridians for the keograms different from the auroral activity? Otherwise, it seems that no aurora was activated at B and further poleward expansion was not clearly seen at the second onset C2.

Also, the H component of the geomagnetic field does not show two-step development. That is, bay changes did not newly start at C2, but the H component just continued to increase or decrease around C2.

Fig. 5c. The keograms are difficult to see the auroral activity. The color scale should be adjusted to see the auroral activity more easily.

Page 6, line 9: The description of the geomagnetic field changes is too rough. In particular, the H bays at RANK and GILL for #2 should be mentioned, since the authors focus on two-step development at #1 and #2.

Section 2.2: The authors did not describe the results of the geomagnetic pulsations for all of the present four events in this section. Since the authors regard the pulsations as further evidence of the double onsets, the onset times and characteristics of the pulsations, for example, should be described.

Furthermore, for discussion about the causal links between the onset signatures, it would be helpful to describe the more detailed relative timings between the onset signatures in the magnetotail (fast earthward flow and dipolarization) and on the ground (auroral breakup, geomagnetic field changes, and pulsation), with consideration of the relative locations of the spacecraft footprints and the ground stations. For example, for the first event (Fig. 2), the E1 activity began nearly at the same time as the flow burst, while the E2 negative bay at SNAP began 1 min to 30 s before the flow burst. Such relative timings and their explanation may be helpful for the interpretation of the events.

Page 7, lines 8 and 11: Were the unclear pulsations at DOB and DON real? Are these due to the lower time resolution of these data? (What is the time resolution of these data?)

Section 2.5: The definition of the IMF clock angle should be described. In addition, is the clock angle calculated correctly? For example, at $\sim$0220 UT in Fig. 9a, the OMNI IMF was directed almost duskward, while the Geotail IMF was duskward and

southward. Hence the clock angle difference between them should be 45 deg, but that in Fig. 9a is $\sim$180 deg. Furthermore, it seems strange that even the sign of them differ.

When the authors examined the correspondence between the IMF change and the substorm onset, they compared the IMF at the bow shock nose or the spacecraft (Geotail and Cluster) with the onset timing and did not consider the propagation time of the effect of IMF change from the bow shock nose or the spacecraft to the tail reconnection site as well as the propagation time of the reconnection effect from the tail reconnection site to the near-Earth tail and the ground. Considering these propagation times, it should be confirmed whether the IMF changes really correspond to each of the first and second onsets.

Other minor corrections:

Page 3, line 21: three –> four

Page 3, line 30: on 18 March 2009 and 3 April 2009 –> on 16 February 2008 and 24 February 2010

Fig. 1b: Add the labels of the vertical axis of the two panels.

Fig. 8a, bottom: CHNG –> CHBG

Fig. 11 caption, line 3: The vertical line –> The vertical solid line

---

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-116, 2018.