



Relation among total magnetotail magnetic flux, solar wind triggers, and substorm onsets during sawtooth events

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It has been debated for many years whether all substorm onsets are triggered by a sudden change in the solar wind. Because there is not a generally accepted definition of external triggers, a solar wind change may be identified to be an external trigger by some investigators but not a trigger by others. In this paper, we study the substorm onset from the magnetospheric state (the total magnetic flux in the magnetotail) during sawtooth events. We do not try to determine whether a solar wind change around the onset is a trigger. Instead, we examine whether an external trigger from the solar wind is always necessary for substorm onset and why large changes in the solar wind do not always trigger sawtooth/substorm onset. Sawtooth events are quasi-periodic substorms during intense magnetic storms and cause much larger magnetospheric-ionospheric disturbances than quiet-time isolated substorms. We have analyzed 54 sawtooth onsets and corresponding changes in the solar wind. The mean value of the total magnetic flux in the magnetotail at the sawtooth onsets is 0.98 GWb. Sawtooth onset can occur when the changes in the solar wind are very small (0.5 nPa in the solar wind dynamic pressure and 1 nT in the IMF Bz). We have also identified a number of large changes in the solar wind without occurrence of sawtooth onset, and the mean value of the magnetotail magnetic flux is 0.74-0.79 GWb. However, the large changes in the solar wind do not cause sawtooth onset when the magnetotail magnetic flux is generally smaller than 0.85 GWb in these cases. The observations suggest that sawtooth onset will occur when the magnetotail magnetic flux is close to a critical value (~ 1 GWb, depending on the solar wind and geomagnetic activity), no matter whether the corresponding change in the solar wind is large or small. The observations also suggest that no sawtooth/substorm onset can be triggered by a solar wind change if the magnetotail magnetic flux is $\sim 25\%$ lower than the critical value of the onset, no matter how large the change in the solar wind is. Sawtooth onset appears to be an internal magnetospheric instability process, and a large change in the solar wind is not necessary for the occurrence of sawtooth onset.