

Supplementary Information for “Substorm Expansion Embedded in a Planetary-Scale Auroral Current Cycle”

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Figure S1 presents the solar wind conditions and geomagnetic indices associated with a sequence of intense substorms embedded within the main phase of the 17 March 2015 geomagnetic storm. Following 12:00UT, IMF B_z remains persistently southward, fluctuating around -20nT to -30nT with brief excursions northward. This prolonged

period of strong southward IMF and fast solar wind drives a series of intense substorms. The first substorm reaches a peak intensity with AL dropping below -2000nT around 13:30UT. AL index in the expansion phase of subsequent substorms exhibit minimum values ranging from -1300nT to -2400nT .

Figure S2, Figure S3, Figure S4 show that the auroral current cycle identified in the main text appear to be common for many intense substorms.

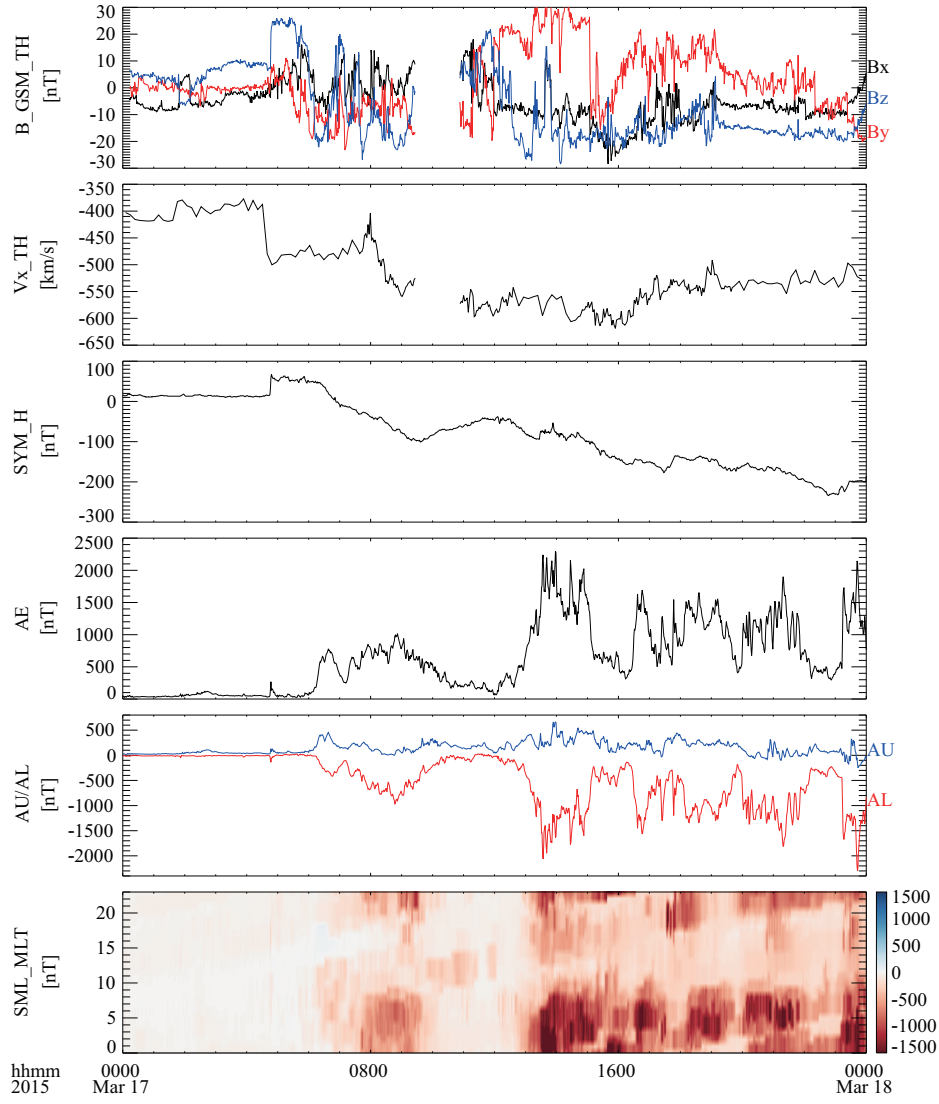


Fig. S1 Overview of a Series of Intense Substorms During the 17 March 2015 Storm. (a) The interplanetary magnetic field (IMF) in geocentric solar magnetosphere (GSM) coordinate system from THEMIS-B satellite. (b) Solar wind velocity V_x component in GSM from THEMIS. (c) SYM-H index; (d) AE index. (e) AU (blue) and AL (red) index. (f) The distribution of regional SML index as a function of MLT.

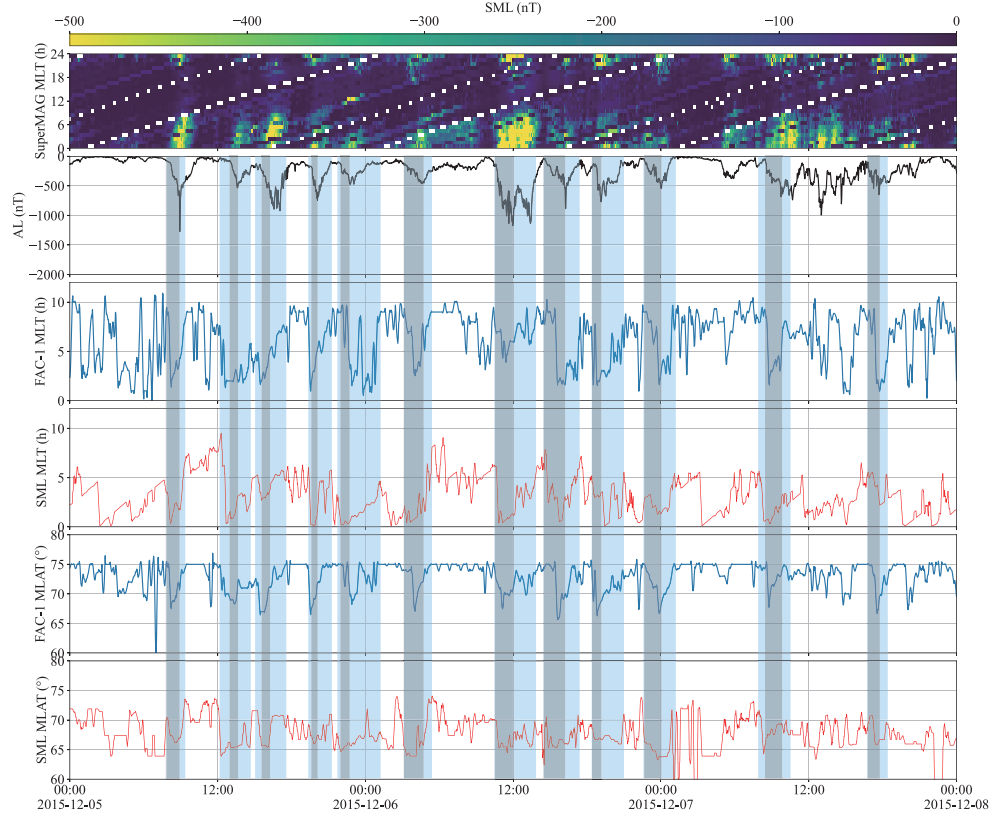


Fig. S2 Substorm expansions and Auroral Current Cycle from Dec 05, 2015 to Dec 08, 2015. From top to bottom: SML index, Magnetic local time (MLT) location of the peak upward Region 1 FAC and peak westward AEJ on the dawnside. Magnetic latitude (MLAT) location of the peak upward Region 1 FAC and peak westward AEJ on the dawnside. Grey box correspond to substorm expansion phase. Blue boxes correspond to MLT-MLat cycle of aurora currents.

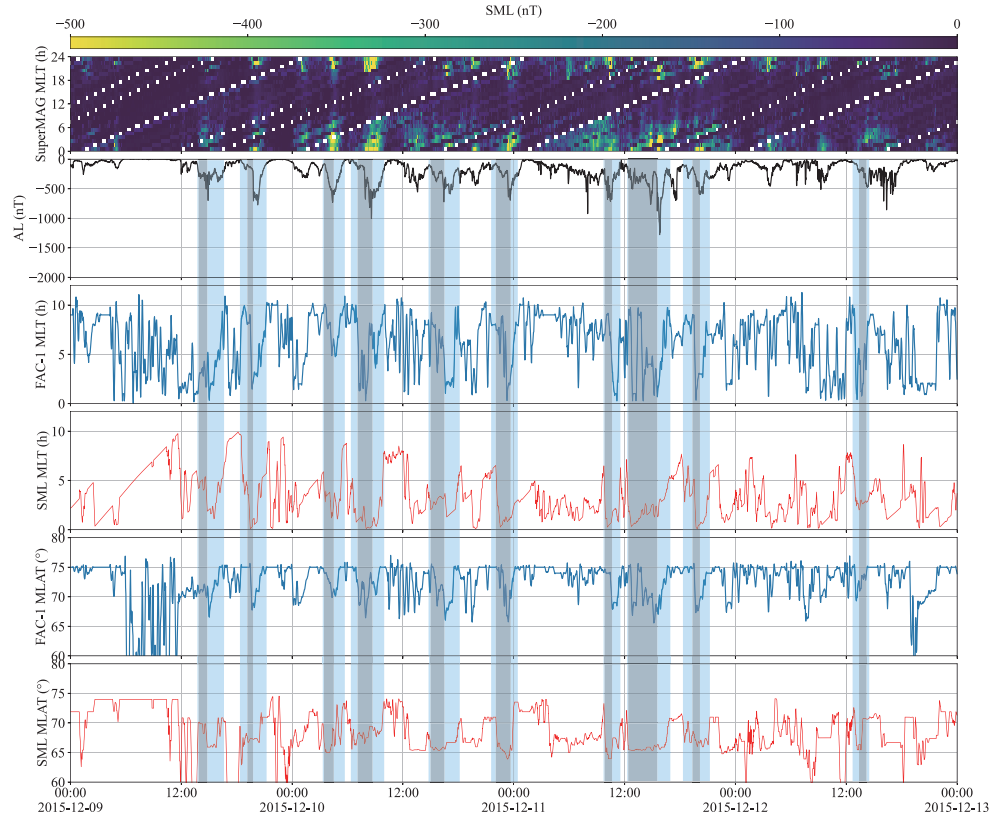


Fig. S3 Substorm expansions and Auroral Current Cycle from Dec 9, 2015 to Dec 13, 2015. The format is the same as Fig.S2.

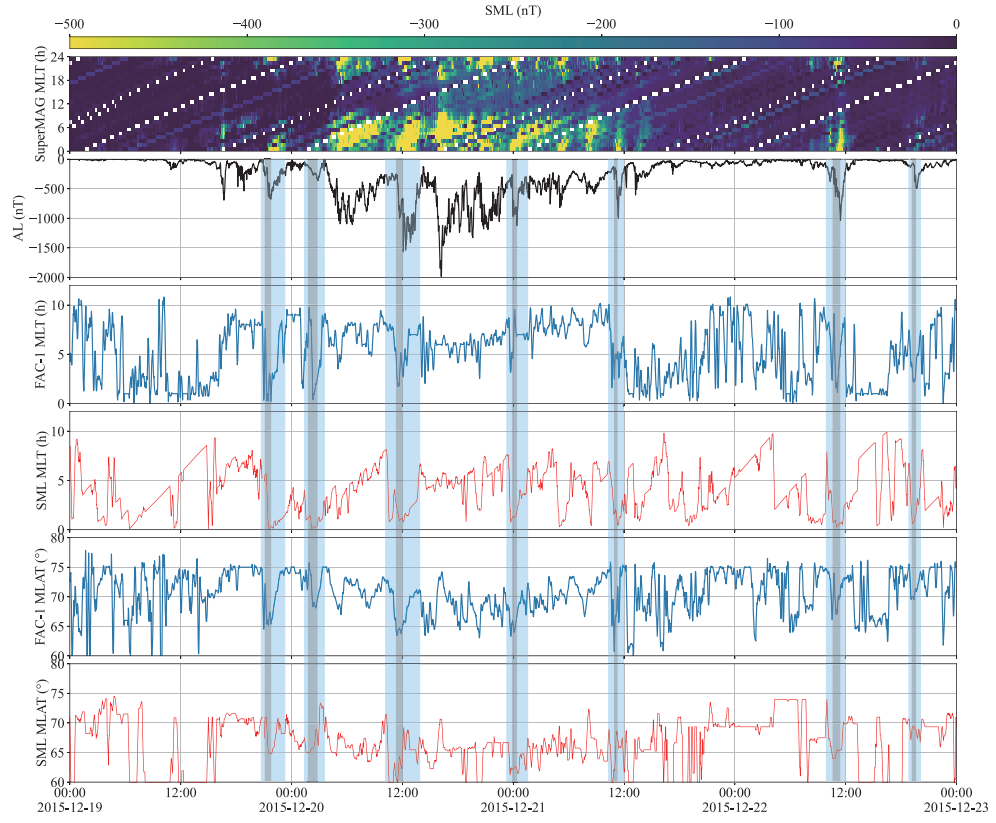


Fig. S4 Substorm expansions and Auroral Current Cycle from Dec 19, 2015 to Dec 23, 2015. The format is the same as Fig.S2.