Remote sensing of the magnetic reconnection rate at the separatrix boundary

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In the Earth's magnetotail, magnetic reconnection releases stored magnetic energy and drives global magnetospheric convection. The rate at which magnetic flux is transferred from the reconnection inflow to outflow regions is determined the reconnection electric field E_r at the X-line. This so-called reconnection rate is a key parameter to evaluate the efficiency of the reconnection process and the resulting energy conversion. In this study, a remote sensing technique to obtain the peak E_r based on multi-point spacecraft observation is proposed. In this technique, the increment of the reconnected magnetic flux is estimated by integrating the in-plane magnetic field during the sequential observation of the reconnection separatrix boundary by multi-point measurements. We tested this technique by applying it to virtual observations in a two-dimensional fully kinetic particle-in-cell simulation of magnetic reconnection without a guide field, and confirmed that the estimated reconnection rate indeed agrees well with the exact rate computed at the X-line. We then applied this technique to an event observed by the Magnetospheric Multiscale (MMS) mission when crossing an energetic plasma sheet boundary layer during an intense substorm. The estimated reconnection rate for this event is E_r~15 mV/m, which is nearly one order of magnitude higher than a typical value of magnetotail reconnection. Given that past studies have found E_r of the order 1 mV/m during weak geomagnetic activities, these results indicate that the local Er in magnetotail reconnection may be an important parameter controlling the amplitude of geomagnetic disturbances.