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New estimation methods of the reconnection rate using in-situ measurements

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The out-of-plane component of the electric field at the reconnection X-line corresponds to the rate of magnetic flux transfer from the reconnection inflow to outflow regions, measuring the efficiency of reconnection process. This so-called reconnection rate can be directly measured by the electric field instrument on board of a spacecraft if it crosses the electron diffusion region (EDR). However, such a direct encounter of the EDR, whose dimension is of the order 0.1-10 km in a typical density in Earth's magnetosphere, is basically very challenging. In this presentation, we introduce two new methods that estimate the rate using in-situ measurements along the reconnection separatrix boundary, whose length is usually much longer than the EDR. One of the methods (i) measures the opening angle of the separatrix boundary outside the EDR, while another (ii) integrates the in-plane component of the magnetic field during a sequential multi-point measurement, which should be the increment of the reconnected flux during the observation interval. We tested these methodologies by applying them to virtual observations in fully kinetic particle-in-cell simulations of reconnection, and demonstrated a good agreement with the exact rate measured at the X-line. Furthermore, we successfully applied these methods to some events observed by MMS in the Earth's magnetotail. The results indicate that the reconnection rate in the magnetotail may positively correlate with the amplitude of geomagnetic activities.