Boundary layer sciences feasible with simultaneous multi-spacecraft measurements

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We present what sciences become possible with simultaneous multi-spacecraft observations of the magnetospheric boundary layers, with respect to the boundary layer phenomena such as the Kelvin-Helmholtz instability (KHI) and flux transfer events (FTEs). The KHI has been proposed to be an important ingredient for plasma transport across the boundary, whereas FTEs are believed to result from transient and/or localized reconnection at the magnetopause, although their formation mechanism remains controversial. As a demonstration of the multi-spacecraft capability, we show what issues can be addressed depending on the separation distance of the four Cluster spacecraft: when the separation is of the order of 1000 km, MHD-scale rolled-up KH vortices can be identified unambiguously. When it is of order 100 km, on the other hand, the meso-scale structure of the oscillatory boundary surface such as its orientation, motion, and thickness, which would provide constraints on the microphysical transport mechanism, can be studied in great detail. While Cluster can resolve only one spatial/temporal scale (MHD- or ion-scale), the planned “Cross-Scale” mission will allow us to get hold of simultaneously all three scales, including electron-scale. With such ideal measurements, we will be able, for example, to understand in what phase of the KHI development, the microphysical process responsible for plasma transport is initiated; we can also study the motion, axis orientation, magnetic topology, and large-scale structures of FTEs at the same time, and such a simultaneous monitoring enables us to establish what type of magnetopause reconnection (transient and patchy reconnection, reconnection involving an extended X-line, equatorial reconnection, and/or anti-parallel reconnection) is responsible for the FTE creation. Moreover, potential simultaneous observations by Cluster and THEMIS will permit us to understand evolution as well as large-scale structures of FTEs and KH vortices, which may further be complemented with global monitoring by ground-based observation networks.