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Transition from Meso-scale to Macro-scale Field-aligned Currents as Observed by Magnetospheric Multiscale

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The four spacecraft Magnetospheric Multiscale (MMS) mission allows for current densities to be derived from the differences in the magnetic fields as measured at the four spacecraft, a technique that is referred to as a curlometer. The curlometer-derived currents densities at the magnetopause can be very large, of the order of 100s of nA/m^2. These current densities are sufficiently large that they are readily observable in the corresponding particle measurements, and the current densities derived from the curlometer and the corresponding particle fluxes are often in close agreement. But there is also a consequence of such large current densities in terms of current closure. In particular, field-aligned currents of this magnitude on closed field lines almost certainly do not propagate to the ionosphere, since the change in flux-tube area is about a factor of 1000. The corresponding current densities would be of the order 100s of μA/m^2 if mapped to the ionosphere. In addition, the spatial scale in the ionosphere would only be a few km. However, while the larger density field-aligned currents appear to close locally, lower density field-aligned currents are observed away from the higher density magnetopause-related currents. This suggests that the magnetopause field-aligned currents are meso-scale currents closing locally, which transition to the lower density macro-scale currents associated with the larger scale Region-1 class of currents that are in turn required in order to impose convection on the high latitude polar and auroral-zone ionosphere.