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Magnetotail twist revisited: effect on polar-cap flow

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The twist of the open magnetic field lines in a planetary magnetotail is usually calculated, following Hill et al. (1983) and Isbell et al. (1984), on the basis of the assumption that the magnetic field is related to the outward flow and the rotation rate in the same way as in the case of the Parker spiral in the solar wind. This assumption, however, overlooks a fundamental difference between the two regions. In the solar wind, the plasma dominates dynamically over the magnetic field; the flow streamlines remain straight while the magnetic field lines become twisted into spirals. In the magnetotail, on the other hand, the magnetic field is dominant; if there is plasma outflow, e.g. polar wind from a rotating ionosphere, it is the flow streamlines that are twisted into spirals while the magnetic field lines remain straight. The relation between field and flow invoked by Hill et al. and Isbell et al. can nevertheless be established in a different way, from boundary conditions across the open magnetopause. The connection of field lines in the magnetotail to the external solar wind flow must be explicitly taken into account, but this has the further consequence that the plasma flow perpendicular to the magnetic field is fixed, throughout the lobes of the magnetotail and down to the polar cap, entirely by the solar wind flow at the boundary and by the geometry of the magnetic field (including any time variations). There is thus only one flow pattern in the polar cap; the idea recently proposed by some, that the quasi-uniform polar-cap flow of Dungey and the partial corotation of Hill et al. and Isbell et al. should be superposed, is not valid. The quasi-uniform flow is well known to occur for a steady-state magnetotail, with negligible planetary rotation. I show that, in the presence of a rotating ionosphere, partial corotation as calculated by Hill et al. and Isbell et al. occurs only for a time-dependent magnetotail in which there would be no polar cap flow in the absence of rotation. More generally, the solar wind flow at the magnetopause, when mapped to the polar cap along field lines deformed by rotational stresses at the ionosphere, acquires some corotational components; the flow pattern can be approximated by a superposition of uniform flow plus partial corotation as long as all flow

streamlines do cross the polar cap.