The points of controversy in magnetic storm study (review)

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For the last decade the following four problems concerning the magnetic storm have been the subjects of dispute.
1) What electric currents are responsible for Dst variation? Four "elementary" current systems contribute to Dst: a) the symmetrical ring current, b) cross-tail current together with the closure currents on the magnetopause, c) partial ring current closing to the region 2 field-aligned currents, d) shielding currents on the magnetopause. The contribution of the symmetrical ring current can be estimated from the plasma energy content in the dayside sector. Greenspan and Hamilton [2000] found from the AMPTE data that the dayside energy content does not correlate with Dst. Turner et al. [2001], using the Polar satellite data, obtained 40% contribution of the symmetrical ring current to Dst. The nightside ($x < -6\ R_E$) part of the cross-tail current contributes 25% to Dst [Turner et al., 2000]. If one takes into consideration the flank parts of the cross-tail current as well as the closure currents on the magnetopause, the contribution grows up to 50% [Alexeev et al., 2001] or to 80% [Maltsev and Ostapenko, 2002]. Antonova [2000] points out that the concept of a strong cross-tail current requires an improbably high pressure in the near-Earth plasma sheet. The partial ring current yields about 30% of Dst in average [Ostapenko and Maltsev, 2003], though Liemohn et al. [2001] find 80% on the storm main phase.
2) Which parameters affect the Dst index and what is the physics of their influence? It is well-known that large and prolonged southward IMF is a necessary and sufficient condition of magnetic storms. The controversy is which of two parameters is more geoefficient: the duskward electric field [Burton et al., 1975; Feldstein et al., 1984; Pudovkin et al., 1985; McPherron and O'Brien, 2000] or the ε parameter [Akasofu, 1981]. Comparative analysis shows that the electric field is more geoefficient [Feldstein, 1992; Maltsev and Rezhenov, 2003]. The observed coupling function was theoretically explained by Arykov and Maltsev [1996] using the formula of Maltsev [1991] for the geomagnetic depression $Bz(0) = -F/3S$ where F is the magnetic flux through the auroral oval and polar cap, S is the equatorial cross-section of the stable trapping region. The growth of the depression in this model is caused by accumulation of the magnetotail magnetic flux. Dremukhina and Feldstein [1999] revealed a satisfactory agreement of this formula with the observed Dst(t).
3) What is the cause of the lowering of the auroral oval and auroral electrojet latitude during storms? Siscoe [1979b], Arykov and Maltsev [1993], Schultz [1997] obtained that the ring current can provide only 20-30% of the observed shift of the oval. Siscoe [1979a] obtained the 100% shift by a current flowing in the magnetosphere at distances mapping to the auroral oval, i.e. actually by the magnetotail current. The crucial role of the magnetotail current in lowering of the oval latitude was also emphasized by Alexeev et al. [1992, 1996], Maltsev et al. [1996], Arykov et al. [1996].
4) Do substorms affect storms? For decades there has been dominating the view that substorms intensify storms. Iyemory and Rao [1996] having used one-minute analogue of Dst have shown that the storm-time depression subsides after the substorm onset. On the other hand, Sun and Akasofu [2000], supposing that storms are initiated by successive strong substorms, suggest to modify the Dst index by including to it the effect of the field-aligned currents.