Bifurcation and hysteresis of the magnetospheric structure with a varying Southward IMF: Field topology and global three-dimensional full particle simulations

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Using a three-dimensional full electromagnetic particle model (EMPM), we have performed global simulations of the interaction between the solar wind and the terrestrial magnetosphere, and have investigated its asymptotic stability. The distance between the dayside magnetopause subsolar point and the Earth center, Rmp, is measured, as the intensity of southward IMF $|B_z|$ is slowly varying. Based on the field topology theory, one analyzes the variation of Rmp as a reference index of the dynamics of this interaction, when IMF $|B_z|$ successively increases and decreases to its original value. Two striking results are observed. First, as the IMF $|B_z|$ increases above a critical value, the variation of Rmp suddenly changes (the so-called bifurcation process in field topology). Above this critical value, the overall magnetic field topology changes drastically and is identified as being the signature of magnetic reconnection at the dayside magnetopause region. Second, this subsolar point recovers its original location Rmp by following different paths as the IMF $|B_z|$ value successively increases from zero to a maximum fixed value and decreases from this maximum to zero while passing through some critical values. These different paths are the signature of a hysteresis effect, and are characteristic of the so-called subcritical-type bifurcation. This hysteresis signature indicates that dissipation processes take place via an energy transfer from the solar wind to the magnetosphere by some irreversible way, which leads to a drastic change in the magnetospheric field topology. This hysteresis is interpreted herein as a consequence of the change of the magnetospheric field topology, or magnetic reconnection taking place at the dayside magnetopause. Sometimes, this is also called bifurcation in the nonlinear theory. The field topology reveals itself to be a very powerful tool to analyze (i) the signatures of three-dimensional magnetic reconnection without the obligation for determining the responsible mechanisms, and (ii) the consequences of reconnection on the overall magnetospheric dynamics.