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Three-dimensional magnetic reconnection in Earth's magnetosphere

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Magnetic reconnection is thought to be the primary mode by which the solar wind couples to the terrestrial magnetosphere, driving phenomena such as magnetic storms and aurorae. While the theory of two-dimensional reconnection is well developed, and has been applied with great success to axisymmetric and toroidal systems such as laboratory plasma experiments and fusion devices, it is difficult to justify the application of two-dimensional theory to nontoroidal plasma systems such as Earth's magnetosphere. Unfortunately, the theory of three-dimensional magnetic reconnection is much less well developed, and even defining magnetic reconnection has turned out to be problematic. In this talk, we review recent progress in the use of MHD to address the physics of three-dimensional reconnection in Earth's magnetosphere. The talk consists of two parts. In the first part, we review the various definitions of three-dimensional reconnection which have appeared in the literature in the last twenty years. Our goal here is to map these definitions to sets of physical phenomena which have been identified as "reconnection" in various three-dimensional contexts. In the second part of the talk, we present our latest magnetosphere MHD simulation results and indentify two qualitatively distinct types of reconnection phenomena (organized by the orientation of the Interplanetary Magnetic Field): 1) steady separator reconnection under generic northward IMF conditions, involving plasma flow across magnetic separatrix boundaries, and 2) time-dependent reconnection under generic southward IMF conditions, involving a global change in the topology of the magnetic field. While neither of these types of reconnection is well described by two-dimensional theory (indeed, we argue that attempts to apply two-dimensional ideas to the magnetopause have resulted in more confusion than clarification), both can be easily categorized according to existing definitions of three-dimensional reconnection.