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Numerical modeling of fast CMEs from Sun to Earth

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Coronal mass ejections (CMEs) are the main driver of space weather disturbances near Earth. The most severe disturbances are caused by fast CMEs with coronal speeds in excess of 1000 km/s and magnetic orientations favorable for interaction with the Earth's magnetosphere. A proper assessment of the impact of CMEs from numerical simulations requires the self-consistent modeling of both CME initiation and its propagation through interplanetary space. Such simulations are very challenging, in particular because of the enormous disparity of scales involved. Here we present our recent attempts to model fast CMEs all the way from Sun to Earth.

We first simulate the initiation and propagation of CMEs in the corona using our "thermodynamic" MHD model, which includes empirical coronal heating, thermal conduction, and radiation losses. After the initial configuration, consisting of a large-scale dipole field and an idealized active region, is relaxed to a steady-state solar wind solution, we insert a flux rope in magnetic equilibrium into the active region and trigger its eruption by imposing localized converging flows. We perform a small series of simulations, varying the geometry and field strength of the flux rope. The resulting CMEs produce a shock low in the corona and reach peak velocities of up to 3000 km/s, after which they slow down to constant propagation speeds of 1000 km/s or less. We then use our recently developed heliospheric model to simulate the further propagation to 1 AU for one of the model CMEs.