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On the Origin of Coronal Mass Ejections: How Does the Emergence of a Magnetic Flux Rope Reorganize the Solar Corona?

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The physical effects responsible for the occurrence of Coronal Mass Ejections (CMEs) on the Sun have been debated for almost four decades now. One of the leading mechanisms suggests that a CME may occur as the result of the emergence of a twisted magnetic flux rope from the convection zone into the solar corona. This process has been investigated by a number of researchers over the years, and it has been demonstrated that an eruption of the coronal magnetic field can in principle occur. The majority of these studies, however, involve some ad-hoc prescription of the electric field at the photosphere resembling flux emergence, and they neglect the ambient coronal magnetic field. In addition, most of these flux-emergence simulations are performed in a Cartesian domain, which extends into the corona up to only a few dozen pressure scale-heights. Because of this, it is difficult to assess how strongly the ad-hoc character of the driving motions and the limited computational domain affect the simulation results for the evolution of the erupting coronal magnetic field. In this paper, we present a new model of CMEs that mitigates these two effects. To achieve this, we couple the "local" magnetic-flux-emergence (MFE) model of Archontis et al. (2004) with a global MHD model of the solar corona and solar wind. The model coupling is performed using the Space Weather Modeling Framework. In the coupled model, the MFE simulation provides time-dependent boundary conditions for all MHD quantities into the global model, where the physical coupling is done at the photospheric boundary. The physical evolution of the system is followed using the BATS-R-US "ideal" MHD code well beyond the complete emergence of the magnetic flux from the convection zone. We discuss the dynamics of the flux emergence process and the related response of the pre-existing coronal magnetic field in the context of CME production.