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From Sun to Earth: Exploring the strengths and challenges of the complete MHD modelling chain with COCONUT+Icarus

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Coronal Mass Ejections (CMEs) are the main drivers of interplanetary shocks and space weather disturbances. One of the key parameters that determines the geo-effectiveness of the CME is its internal magnetic configuration. Strong CMEs directed towards Earth can severely impact our planet, and their prediction can mitigate possible damage. Thus, efficient space weather prediction tools are necessary to produce timely forecasts for the CME's arrival at Earth and their strength upon arrival.

We recently obtained a complete 3D MHD modelling chain from Sun to Earth using COCONUT to reconstruct the coronal model and Icarus to model the inner heliosphere. COCONUT (Perri et al. 2022) is a 3D global MHD model that covers the domain from the solar surface to 0.1 AU. The model is coupled to the heliospheric models EUHFORIA and Icarus. The implemented source terms, such as radiative losses, thermal conduction, and approximated coronal heating, allow bi-modal solar wind configuration at the outer boundary, making the model suitable for space weather purposes.

The novel heliospheric model Icarus (Verbeke et al. 2022, Baratashvili et al. 2022), implemented within the framework of MPI-AMRVAC (Xia et al. 2018), introduces new capabilities to model the heliospheric solar wind and actual CME events. Ideal MHD equations are solved in the co-rotating reference frame with the Sun. Different CME models are injected in the domain superposed on the stationary solar wind. Advanced techniques, such as adaptive mesh refinement and gradual radial grid stretching, are implemented to optimise the simulations. The most significant advantage of the AMR in MPI-AMRVAC is that one can design the refinement criteria according to the purpose of the simulation run.

The obtained fully physics-based MHD chain from Sun to Earth allows the modelling of the CMEs from the solar surface and their dynamic propagation into the heliosphere, paving the way to the most accurate and realistic simulation setups.

References

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