From Sun to Earth with EUHFORIA: The Chain of Forecasting Space Weather Conditions

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Space Weather is a newly emerging field in physics, which studies the conditions in the space, focusing on Earth surroundings. The conditions in space can become 'stormy' at times, but during other periods they can remain calm and slowly-varying. This dynamic behaviour is affected by a variety of factors, including the solar activity cycle, eruptions from the sun's surface, and interactions between different phenomena as they propagate from the sun to Earth. The effects of space weather can manifest in different ways. While some events are responsible for the stunning Aurora Borealis, others can cause significant damage to power and telecommunication systems.

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

In order to perform such predictions, the inner heliospheric model EUHFORIA (EUropean Heliospheric FOrecasting Information Asset) (Pomoel & Poedts, 2018) was developed at the Centre for mathematical Plasma-Astrophysics, KU Leuven. It consists of two main parts. First, the semi-empirical coronal model, which produces reliable plasma values at the inner heliospheric boundary. Then, the physics-based heliospheric model, which is driven with the input from the coronal model extending to the orbit of Mars. The modelling chain produces 3D data for the heliosphere that contains information about the conditions surrounding various satellites, as well as the propagation of CMEs and co-rotating interaction regions (CIRs).

Recently, upgraded models have been developed for coronal and heliospheric modelling with a focus on increased optimization and efficiency. In order to model more complex phenomena, a new magnetohydrodynamics (MHD) coronal model COCONUT (Perri & Leitner, 2022) was developed. Additionally, another heliospheric model Icarus (Verbeke et al., 2022) was implemented, which uses advanced techniques to perform simulations efficiently. EUHFORIA is freely available through VSWMC (Virtual Space Weather Modelling Center). The accessibility and overview of the available models are presented, together with the results regarding the new developments in the big forecasting chain.

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