EUHFORIA 2.0 / EUHFORIA in PARADISE

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Objectives and scope

The EUHFORIA 2.0 project addresses geoeffectiveness, impacts and mitigation, including extreme events, related to solar eruptions, solar wind streams and Solar Energetic Particles, with particular emphasis on its application to forecast *Geomagnetically Induced Currents* (GICs) and *radiation on geospace*

The overall project goal is to develop a revolutionary space weather forecasting tool for forecasting geomagnetic disturbances and SEP events and their effects.

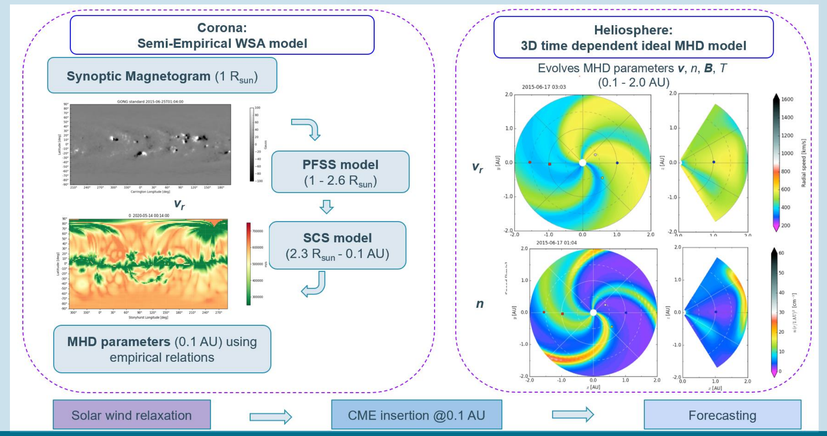
Consortium

- Katholieke Universiteit Leuven (Belgium)
- Koninklijke Sterrenwacht van België (Belgium)
- Turun yliopisto (Finland)
- Helsingin yliopisto (Finland)
- Universitat de Barcelona (Spain)
- United Kingdom Research and Innovation (British Geological Survey, UK)
- Centre National de la Recherche Scientifique (CNRS, France)
- Christian-Albrechts-Universitaet zu Kiel (Germany)
- Andrey Kochanov (Belgium)
- Space Consulting International LLC (USA)
- Space Applications Services (Belgium)

Specific objectives

- Accurate SW predictions by improving EUHFORIA by implementing data-assimilation techniques and advanced flux-rope models constrained by data-driven and machine learning techniques
- To develop a global coronal MHD model for EUHFORIA
- To integrate state-of-the-art SEP transport models for simulation of SEP emission from coronal shocks and to develop methodology and tools for predicting the SEP emission from CMEs.
- To develop an operational prediction tool for Geomagnetically Induced Currents (GICs) in power grids.
- To develop more reliable operational prediction tools for harsh radiation in geospace
- To create novel space weather forecasting service facilities tailored carefully to the needs of selected target groups.

EUHFORIA model (Pomoell & Poedts, 2018)



Some scientific results (so far)

Improved coronal models: polytropic MHD model

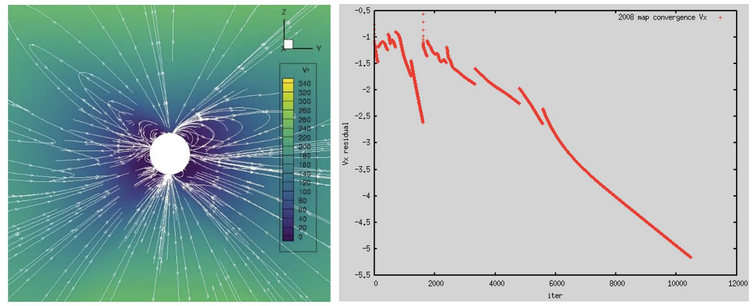


Fig. 1: *Example 2D cut of a converged coronal model based on a magnetogram of 2008 using unstructured grid code with implicit solver.* Left: *Magnetic field lines are superposed on coloured contours of the radial component of velocity. Right: convergence history. The final CFL number was 64 for this particular case.*

Global non-potential model coronal model

Development of a global non-potential model of the coronal magnetic field as an alternative to the current PFSS + Schatten current sheet model in EUHFORIA

Formation of a sheared arcade structure in a multipolar magnetic field structure. The evolution of the Coronal field is efficiently computed using the Magneto-frictional relaxation model developed at University of Helsinki.

Source: Jens Pomoell

MULTI-VP coupled to EUHFORIA heliosphere

HSS bulk speed at Earth as modeled by WSA+EUHFORIA (red) and MULTI-VP+EUHFORIA (blue) for 6 days of forecasting. Both runs have been conducted with the GONG synoptic magnetogram taken on 2018-01-17T23:14. The MULTI-VP+EUHFORIA output captures the real HSS while this is not the case for the WSA+EUHFORIA.

3D visualizations of the structures produced by WSA+EUHFORIA and MULTI-VP+EUHFORIA throughout the inner heliospheric domain. The heliospheric current sheet is indicated in grey while the colorful isosurfaces represent solar wind speeds between 520 and 600 km/s. Earth is shown in light blue color.

Source: Samara et al. 2021

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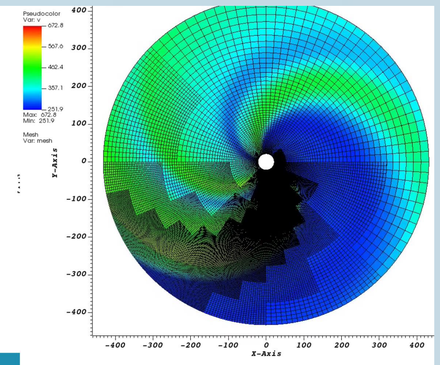
Advanced solar wind and CME modelling

AMR refinement criterion depending on application:

- CME erosion/deformation ⇒ tracing function (ex.: 3 refinement levels)
- CIR shocks ⇒ $\nabla.\mathbf{v}_{SW}$ (normalised)
  - Expanding Solar wind ⇒ deceleration
  - Compression / shock waves ⇒ acceleration
- CME shocks ⇒ $\nabla\rho$ and/or $\nabla.\mathbf{v}$ (normalised)



Source: Verbeke et al. 2021

CME models integrated in EUHFORIA

Cone-like model (unmagnetised) Pomoell & Poedts, 2018

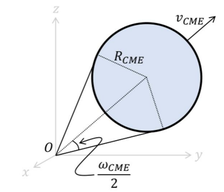


Image courtesy: Camilla Scolini

Spheromak CME (flux rope - spherical geometry) Verbeke et al, 2019

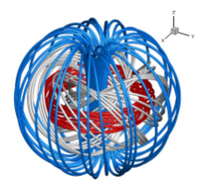
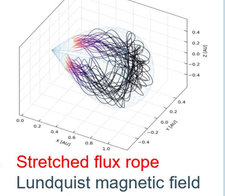


Image courtesy: Camilla Scolini

FRi3D model (flux rope - extended geometry) Isavnin et al, 2016



- Stretched flux rope
- Lundquist magnetic field

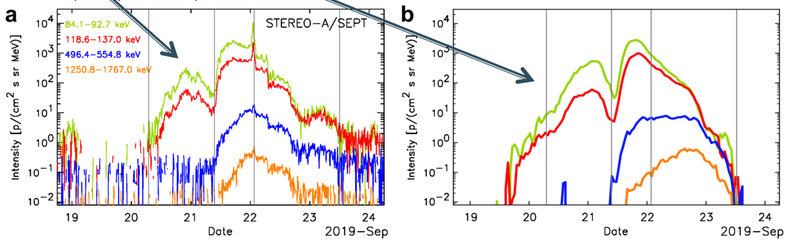
$$B_\rho = 0$$
$$B_\phi = B_0 J_1(\alpha r)$$
$$B_z = B_0 J_0(\alpha r)$$

Credit: Anwesha Maharana

Toroidal CME model (Grad-Shafranov solution): validation ongoing

PSP case study with PARADISE-EUHFORIA

Observed (left) and **simulated** (right) omni-directional ion intensities at STEREO-A. The vertical lines indicate the onset time of the SIR (stream interaction regions) event (Sep 20 09:00 UT), the stream interface (Sep 21 09:30 UT), the developing reverse shock (22 Sep 01:35 UT), and the stop time of the SIR event (23 Sep 12:00 UT).



Credit: N. Wijsen et al., 2021

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More info: ***euhforia.com***

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