ESA VSWMC-Part 2

Status report

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Contents

- **General project overview**
  - *Consortium, Prime GOALS, Planning and time line, …*
- **VSWMC ≠ CCMC**
- **Architectural design**
  - *Components: Model repository / Model couplings / etc.*
- **Detailed design**
  - *Models, model couplings, and nodes to be included in this project*

(previous) VSWMC-Phase 1 results:

- **A proof-of-concept prototype** version of an **open end-to-end** (Sun to Earth) space weather modeling system,
- enabling to **combine ("couple") various space weather models** in an integrated tool,
- with the models located **either locally or geographically distributed**,
- so as to *better understand the challenges* in creating such an integrated environment.

➢ **VSWMC combines <u>three roles</u>:**

- *A repository for models and data*
- *A facility offering a model coupling infrastructure*
- *A facility that executes coupled model simulations*

New VSWMC-P2 objective and scope

- The **further development of the VSWMC** building on the Phase 1 prototype system and *focusing on the interaction with the SSA SWE system*.
- Efficient integration of **new models and new model couplings**, including a first demonstration of an *end-to-end simulation capability*.
- Further development and wider use of the **coupling toolkit** and **the front-end GUI** which will be designed to be accessible via the SWE Portal.
- Availability of more **accessible input and output data** on the system and development of **integrated visualization tool** modules.

Consortium overview

1. **KU Leuven/CmPA** (prime contractor)
2. **Belgian Institute for Space Aeronomy** (sub-contractor)
3. **Royal Observatory of Belgium** (sub-contractor)
4. **Von Karman Institute** (sub-contractor)
5. **DH Consultancy** (sub-contractor)
6. **Space Applications Services** (sub-contractor)
7. **British Antarctic Survey** (sub-contractor)

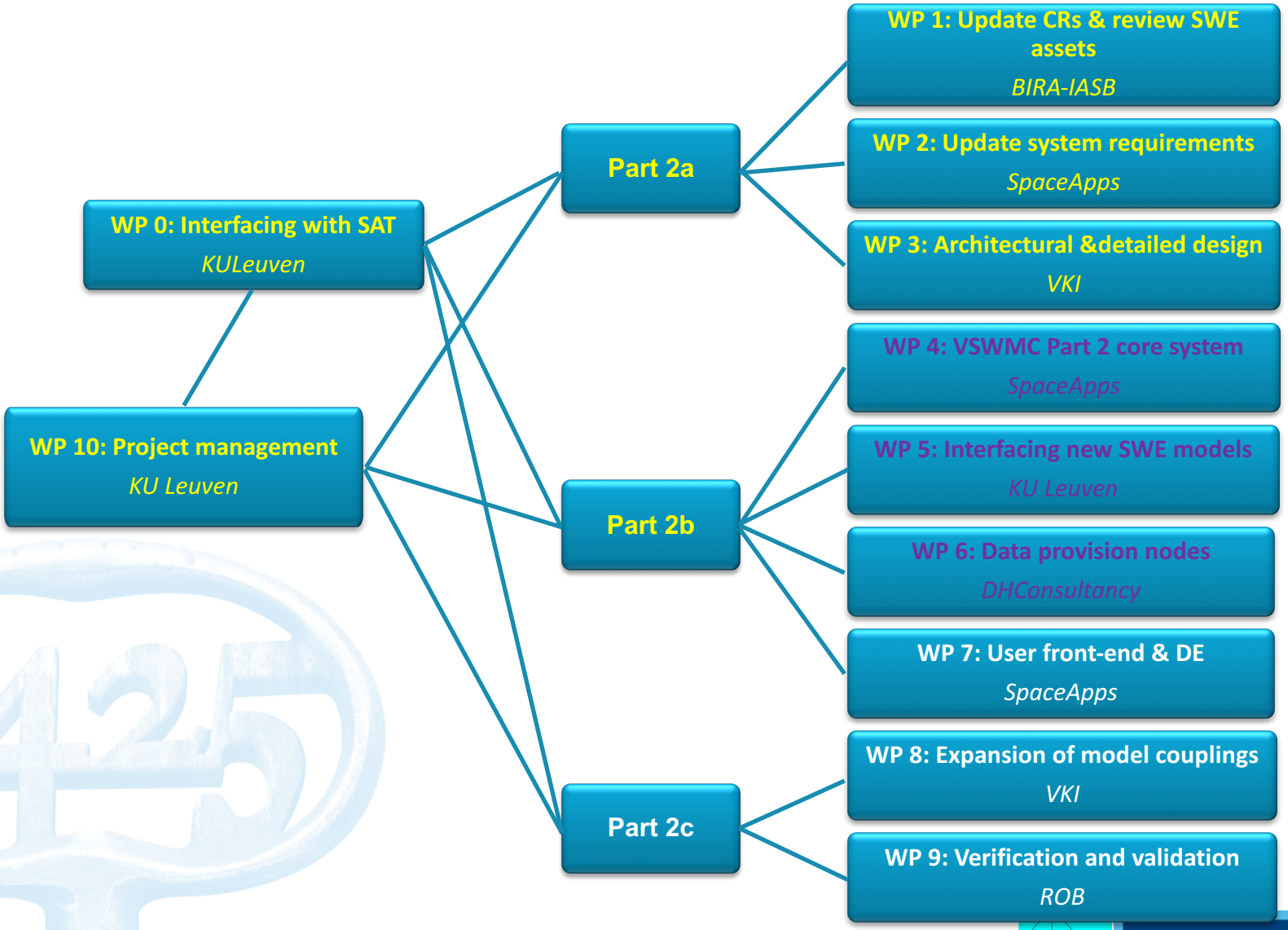
***Science Advisory Team*:**

A. Aylward, S. Bruinsma, P. Janhunen, T. Amari, D. Jackson, S. Bourdarie, B. Sanahuja, P.-L. Blelly, R. Vainio

ESA: *J.-P. Luntama, P. Jiggens, R. Keil, A. Hilgers*

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
DH CONSULTANCY
spaceapplications services
esa
cpa
KU LEUVEN

Work breakdown



Similarities with CCMC…

Like CCMC, the VSWMC is/will provide:

- *A repository for models (and data!)*
- *A facility that enables to execute models and coupled model simulations*

… and differences!

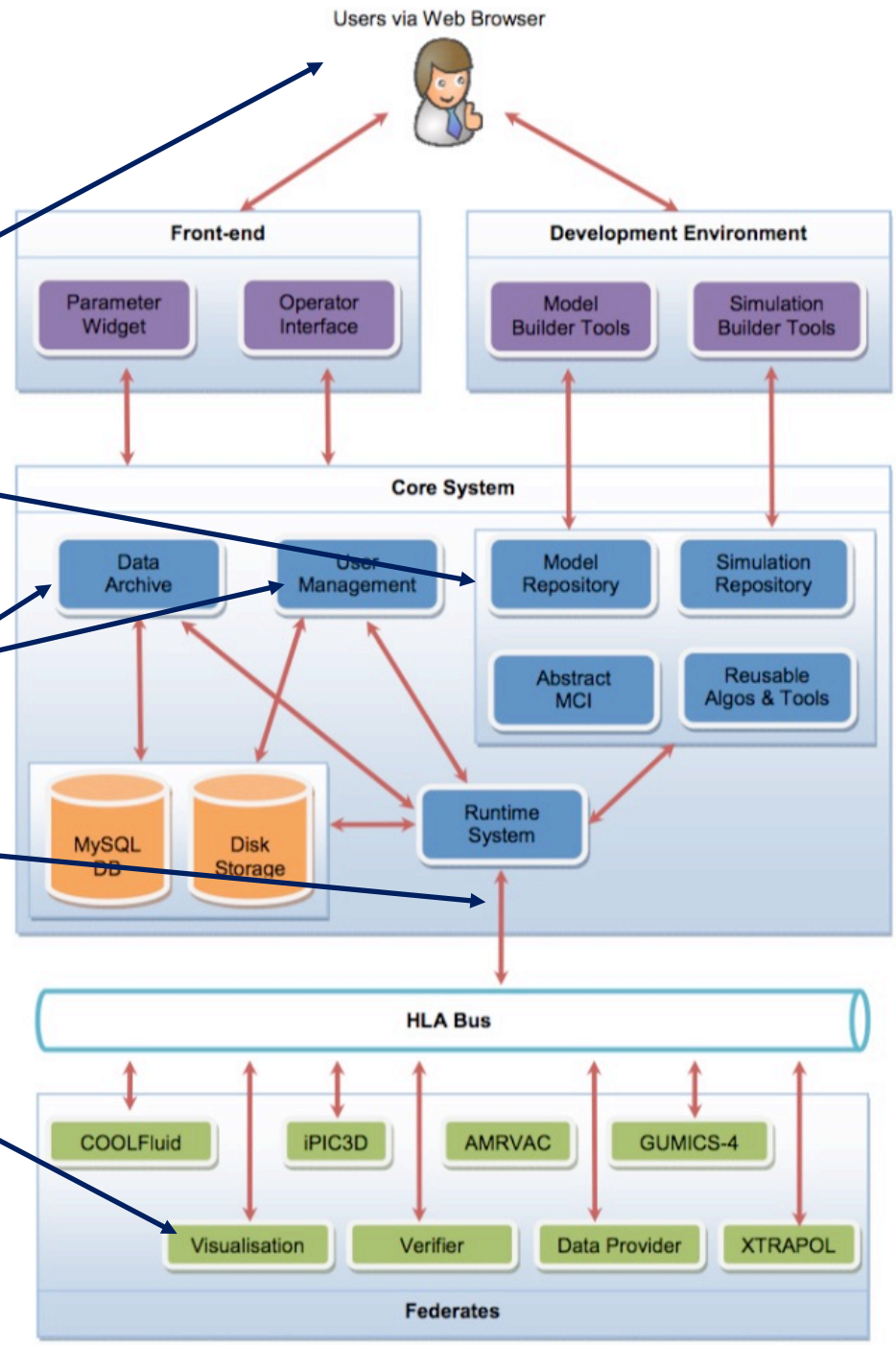
- **VSWMC-P2 is being developed**: only a prototype version is available at the moment
- **Combination of local and distributed models**, so models can run remotely and are coupled over the internet
- **Visualization tools** will be integrated as 'models' that can be coupled to any other integrated model
- **Interactive**: via a **'developer tool'** the modelers will be able to install/adjust their own model and couple it to another model in the repository (at end of Part 2 project)

… and even more differences!

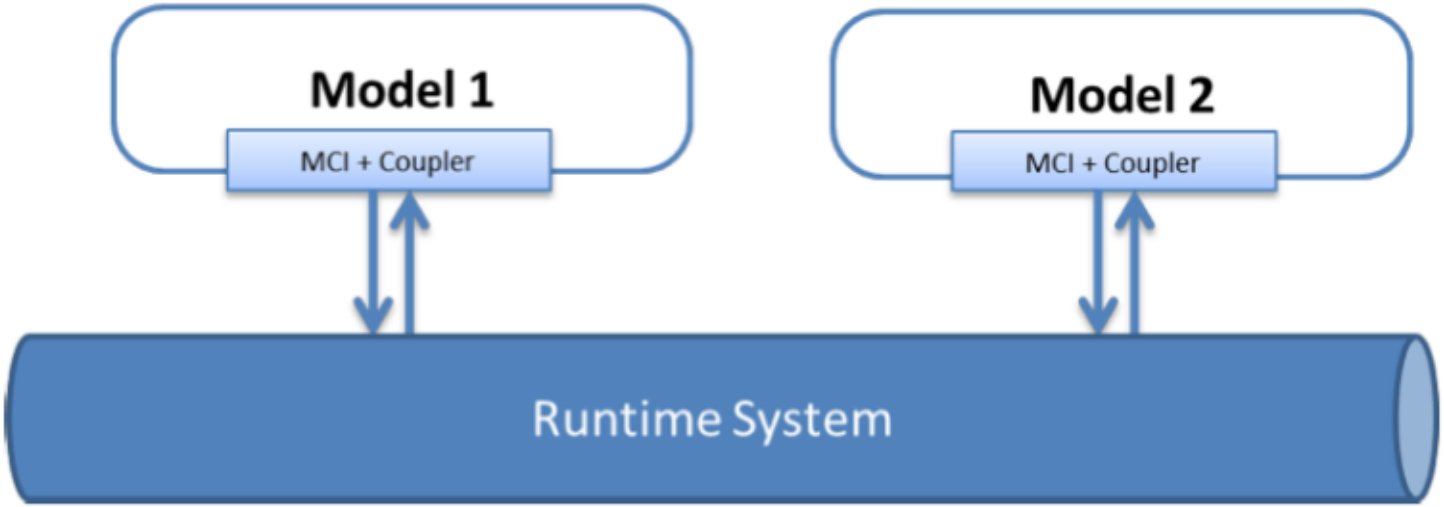
- **Different operation mode(s), because of different kinds of 'users':**
  - **System operator(s):** need ***operator interface***, statistics (use, demand, waiting times, I/O, etc.), alarms (when model did not run, communication failed, etc.), …
  - **Model contributors:** need ***developer tool*** to provide (updates of) their own models, integrating them into the system and coupling them to other models or data providers and/or visualization models
  - **Different 'end users':** *e.g.*
    - ***Forecasters:*** running *pre-installed simulations* on a regular basis and integrated in the operational procedures
    - ***scientists/researchers*** using the *models and couplings for setting up and performing individual simulations runs* in the framework of their research

VSWMC-P2 overview

- Users interface via a web portal (in SSA SWE system)
- Developer environment with 4 service components
- Core system also contains data archive and user management component
- Only the runtime system interacts with HLA bus to coordinate simulations
- visualizations will be implemented as 'federates'

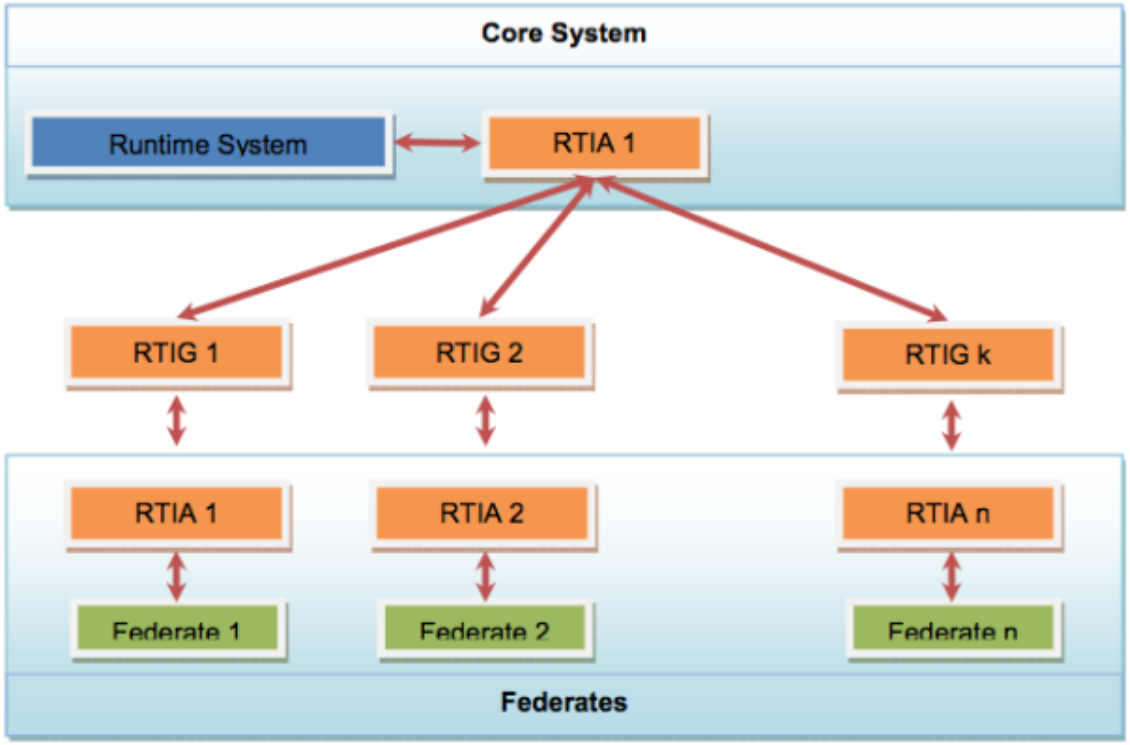


Run-time system (RTS)



- Prepares models for execution and manages data exchange between models
- Is capable of executing parameterized simulation (or federation) runs. As a simulation is interpreted, different models are retrieved from the Model Repository.
- **Short demo**

CERTI RTI Gateway (RTIG)



- RTI Gateways (RTIG) manage the simulations and transfers messages between federates
- VSWMC-2 will support multiple RTIG to tackle high communication loads

VSWMC Part 2 core system: **models**

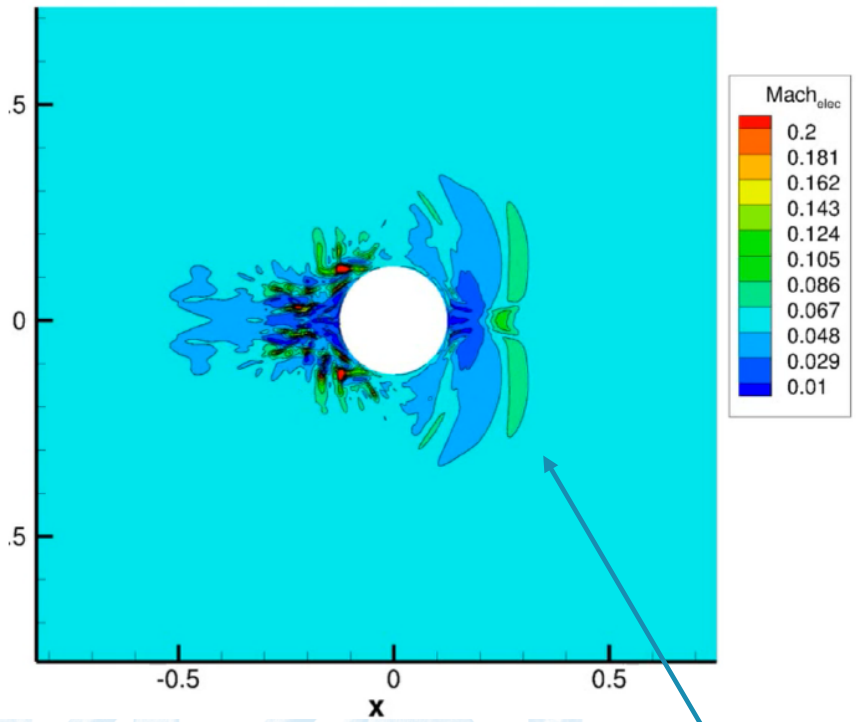
Model repository *contains the different models installed (binary or source code, MCI, model metadata, input and visualization widgets). Shortlist:*

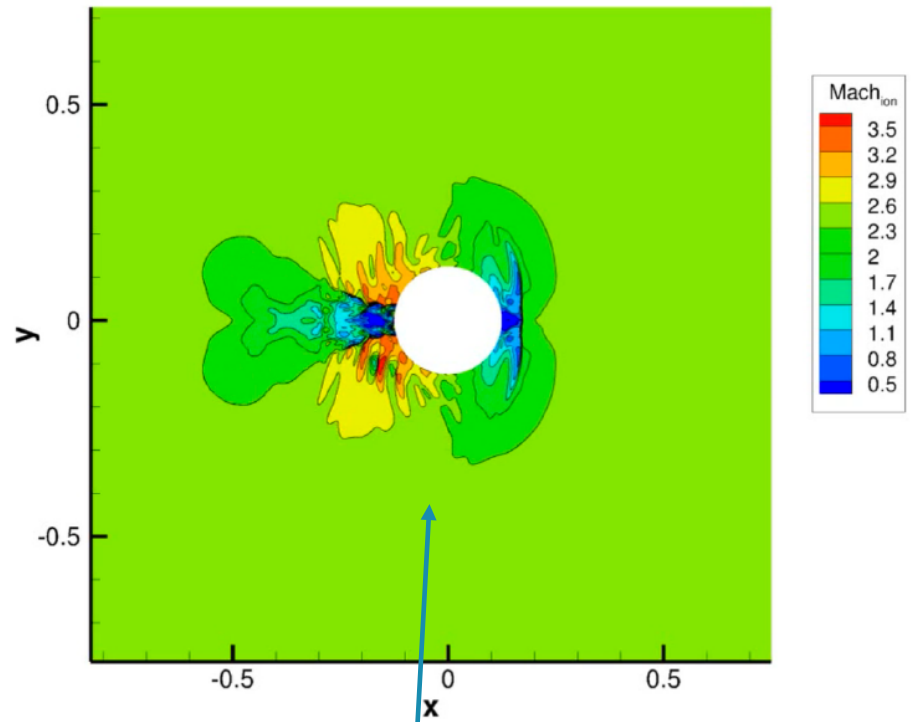
- ***XTRAPOL*** *solar model* *(running in Paris)*

- ***AMRVAC*** *2.5D solar wind + CMEs* *(running in Leuven)*
- ***GUMICS-4*** *magnetosphere* *(")*
- ***Euhforia1*** *coronal model* *(")*
- ***Euhforia2*** *inner heliosphere + CMEs* *(")*
- ***CMAT2*** *ionosphere* *(")*
- ***iPIC3D*** *magnetotail* *(")*

- ***BAS-RBM*** *radiation belt* *(running at BAS)*
- ***COOLFluiD*** *magnetosphere* *(running at VKI)*

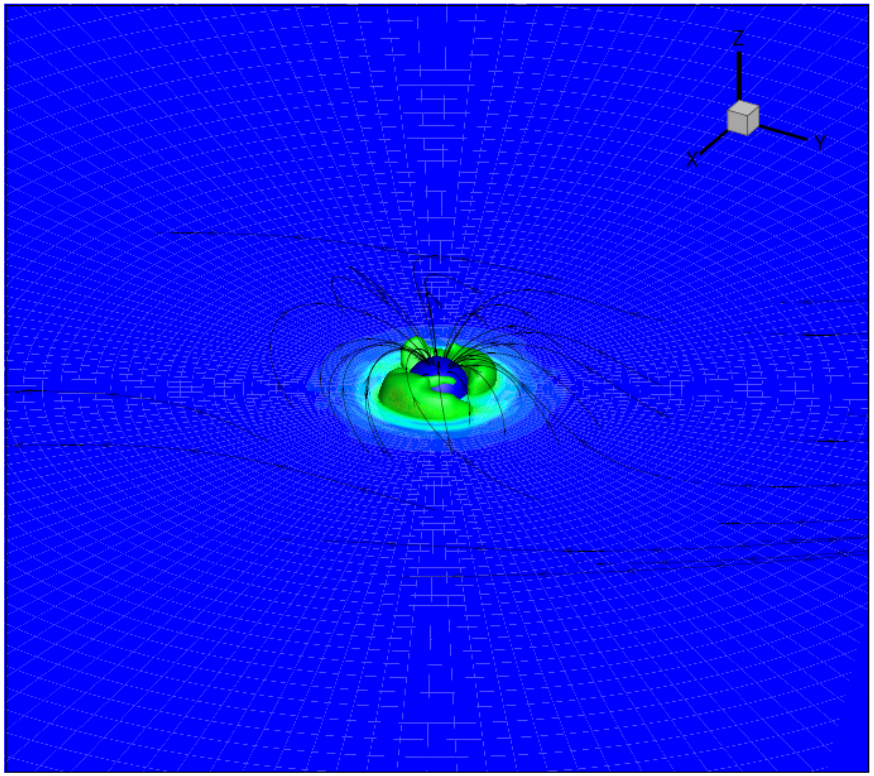
Two-fluid modeling of the Earth's magnetosphere

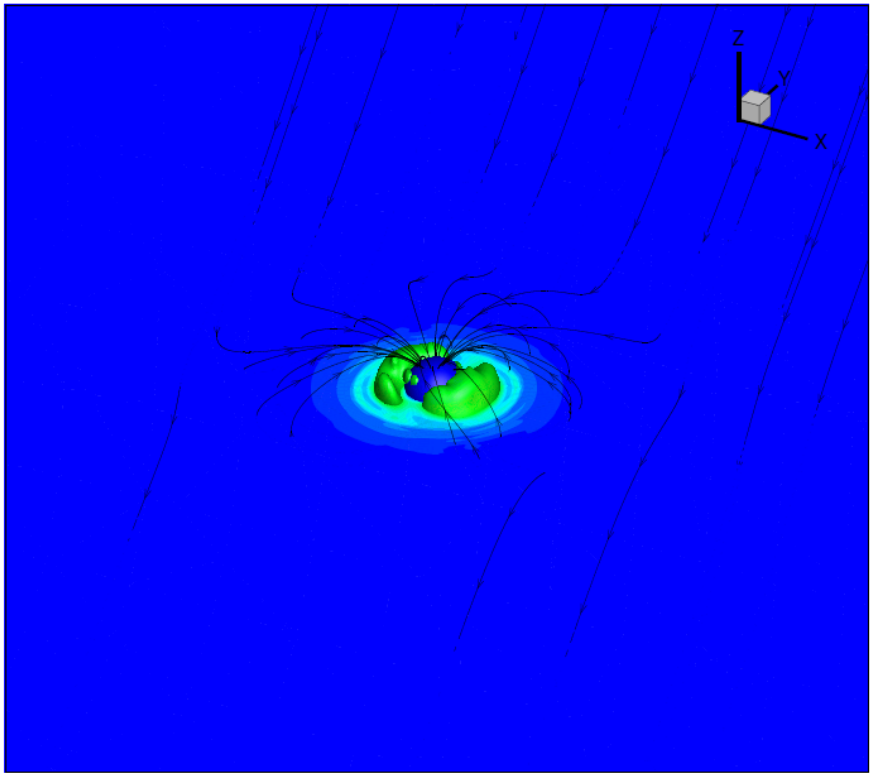




Global two-fluid COOLFluiD model: Electron (left) and ion (right) Mach contours. The plasma flows from right to left. Notice the complexity of the wake: electrons are subsonic, ions are supersonic.

Two-fluid modeling of the Earth's magnetosphere





Global two-fluid COOLFluiD model: Formation of the ring current in the two-fluid magnetospheric simulation. Contours correspond to the electric current and the lines to the magnetic field.

Simulation repository

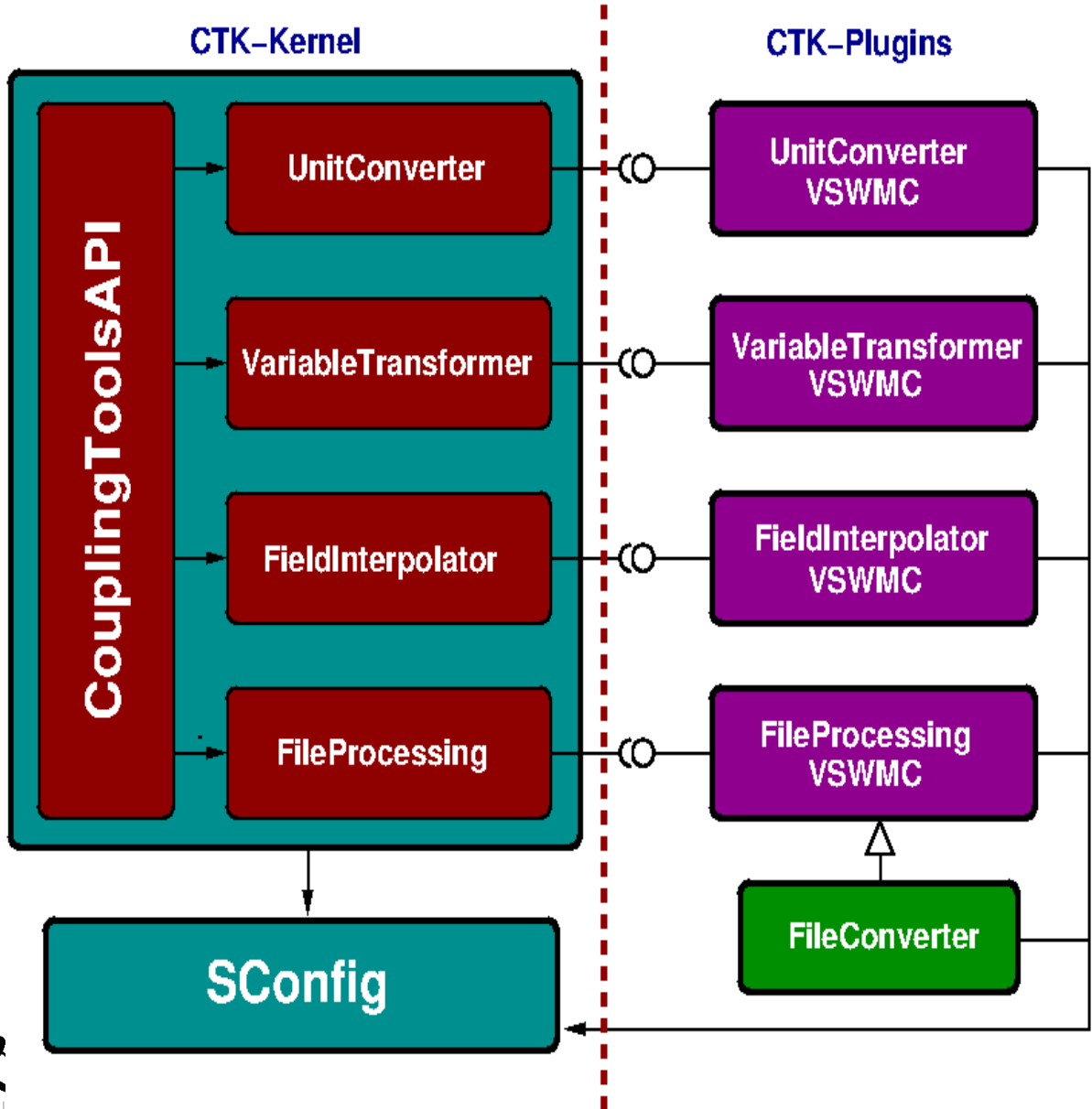
- Contains the Simulations that have been installed.
- For each Simulation it shall contain the following types of data:
  1. Simulation configuration file (can be generated via GUI)
  2. Coupler metadata, Models' metadata, CTK's conguration
  3. Reference simulation runs (including I/O data)

DATA archive

- file directory tree (where downloaded data are stored, either permanently or temporarily);
- Download scripts and utilities to retrieve the data;
- Cron jobs to continually download real-time data.

Coupling Toolkit overview

Core architecture (**CTK kernel**) provides abstract interfaces for implementing 4 utitlities, which are actually implemented under the form of dynamic module (**CTK-plugin**), making the CTK architecture truly open-ended



Model couplings

Coupling Toolkit (CTK) *will get new functionalities that will be integrated as dynamical plugins.* ***Targeted couplings in P2:***

One-way couplings:

- ETRAPOL → Euhforia1
- Euhforia1 (Corona) → Euhforia2 (heliosphere/CME evolution)
- ACE L1 Data Stream → GUMICS-4
- EUHFORIA → GUMICS-4
- EUHFORIA → COOLFluiD

Two-way couplings:

- COOLFluiD ↔ CMAT2
- COOLFluiD or GUMICS-4 ↔ BAS-RBM

Sun-to-Earth chain scenario

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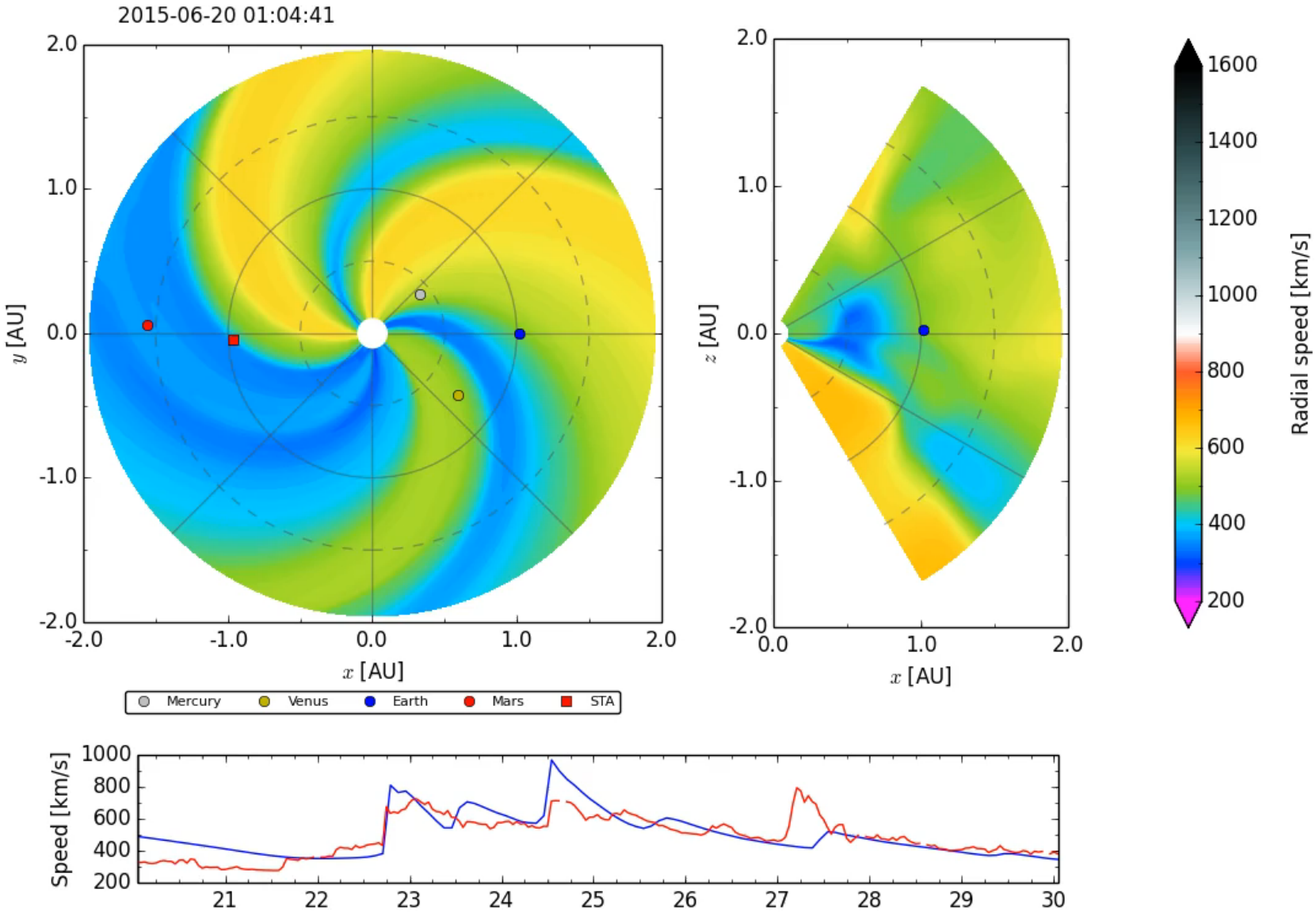
- ACE L1 Data Stream → GUMICS-4
- EUHFORIA → GUMICS-4
- Euhforia2 → COOLFluiD

Two-way couplings :

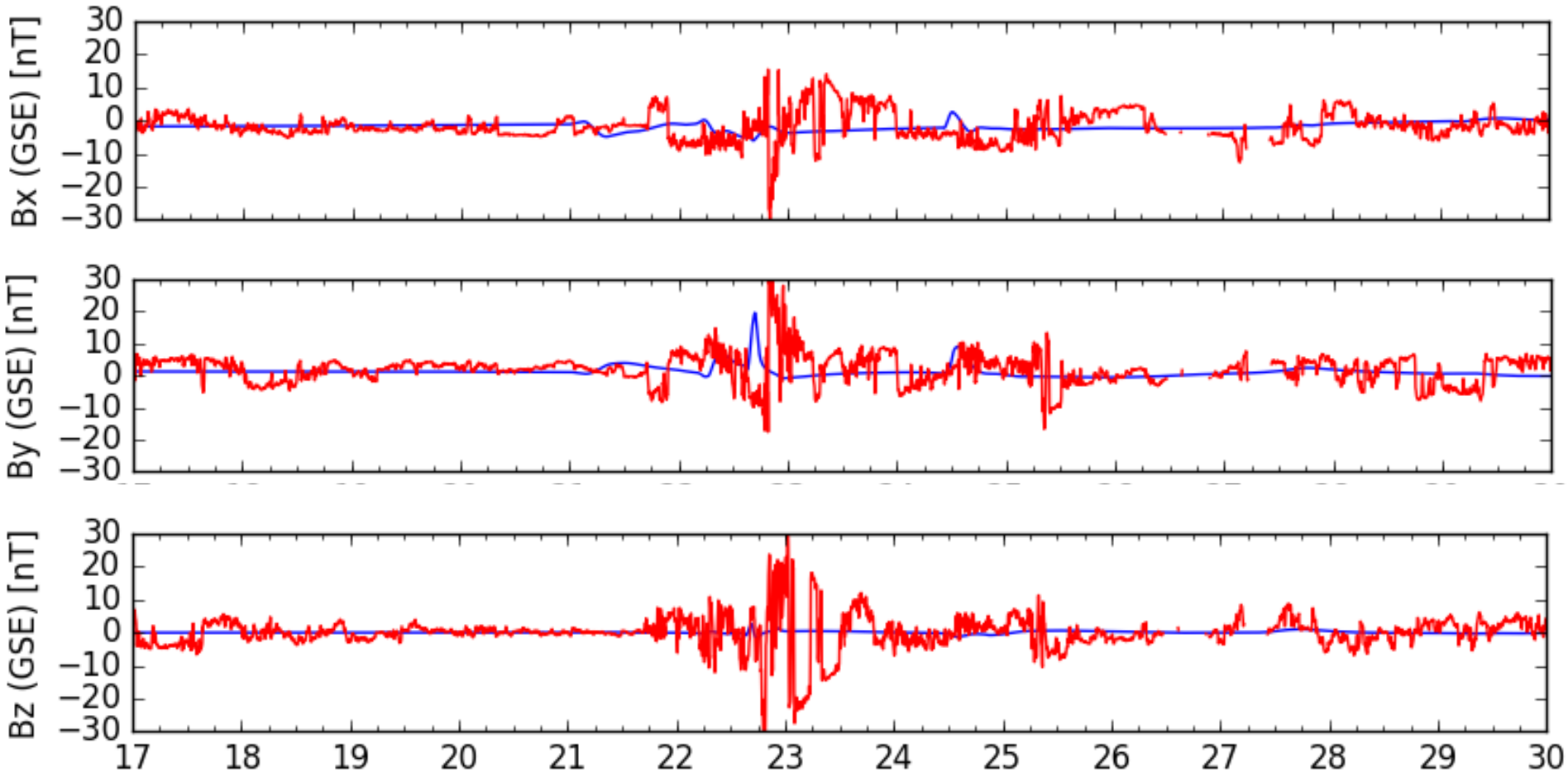
- COOLFluiD ↔ CMAT2
- COOLFluiD (or GUMICS-4) ↔ BAS-RBM

Central role for EUHFORIA

EUHFORIA example: *radial velocity* V_r

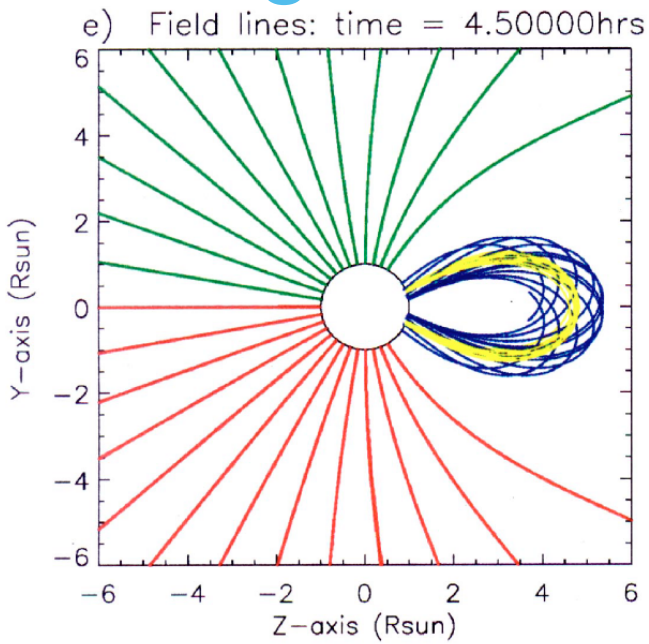


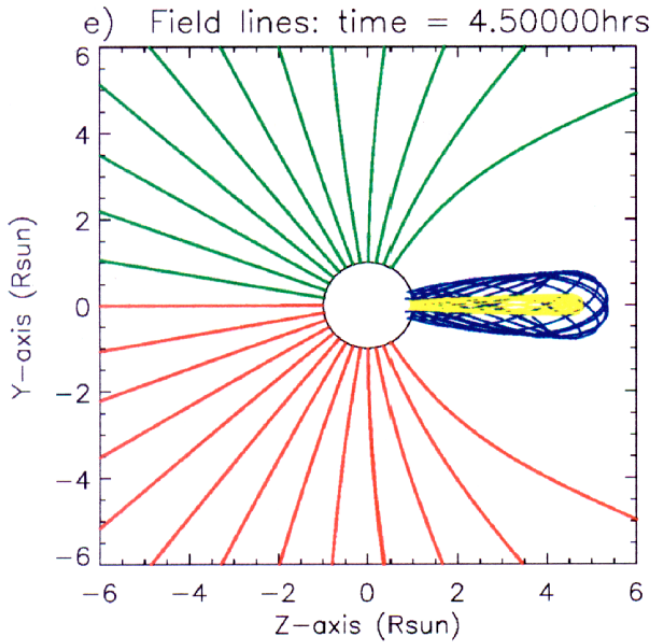
Magnetic field at 1AU with cone CME



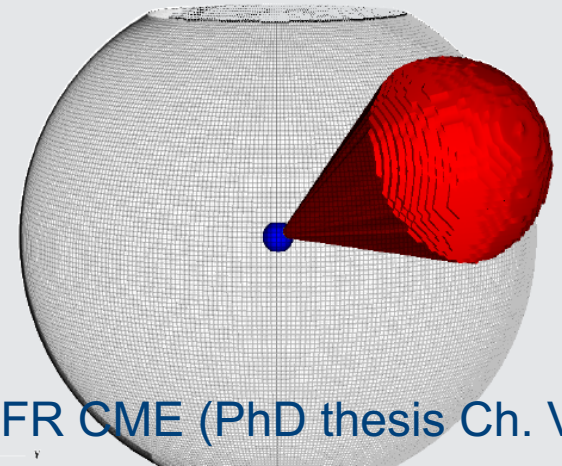
Credit: Jens Pomoell

Building in Gibson & Low FR CME

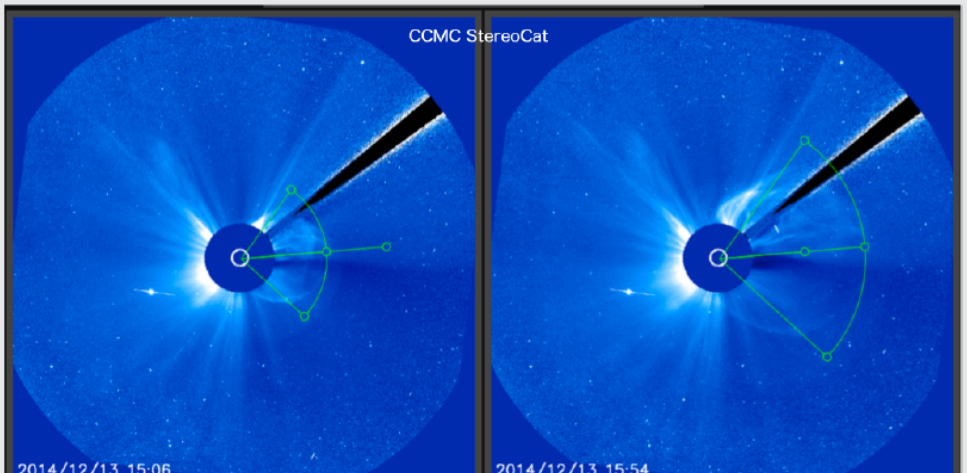




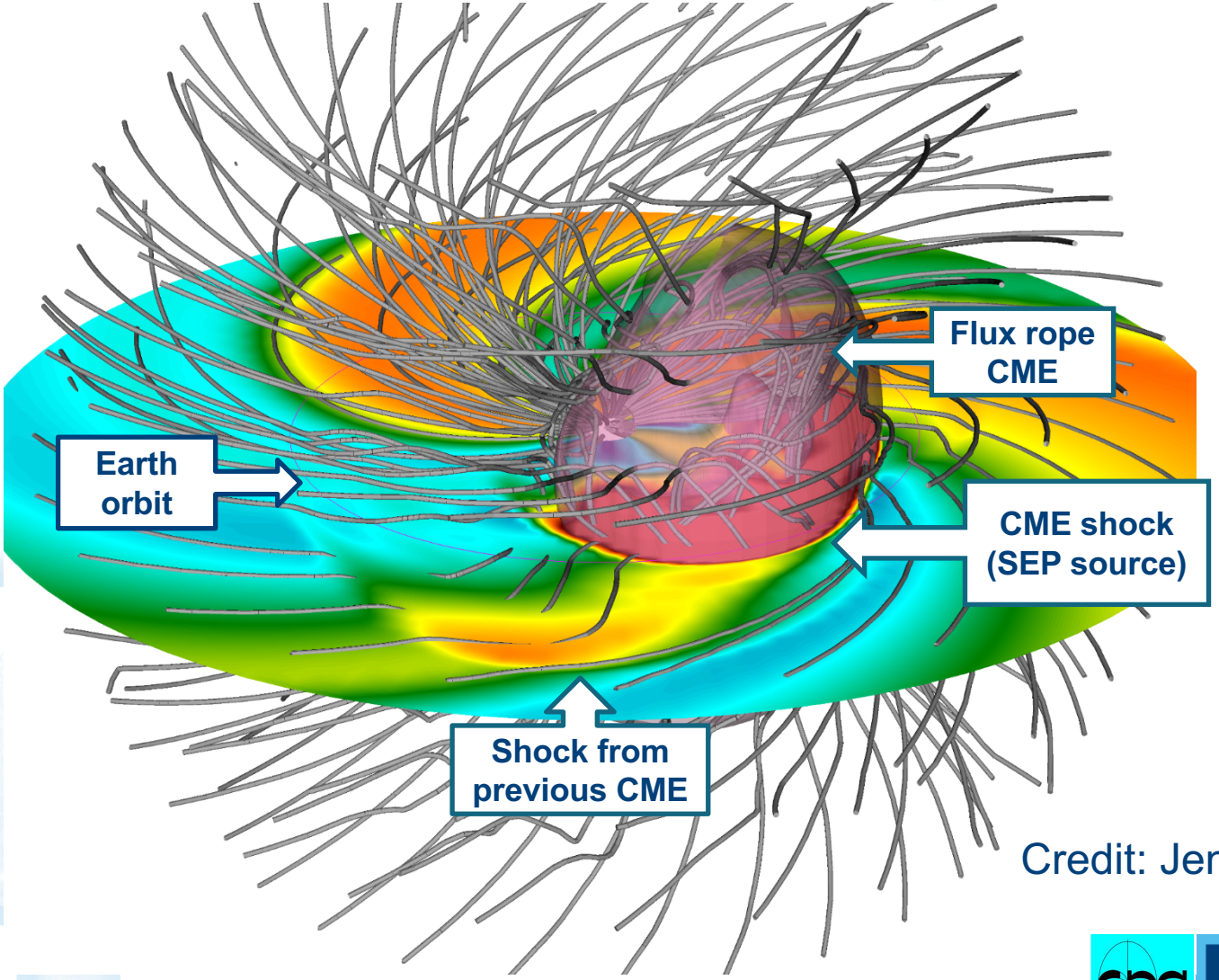
Cone-model CMEs inserted at 21.5 AU as time-dependent boundary condition



FR CME (PhD thesis Ch. Verbeke)



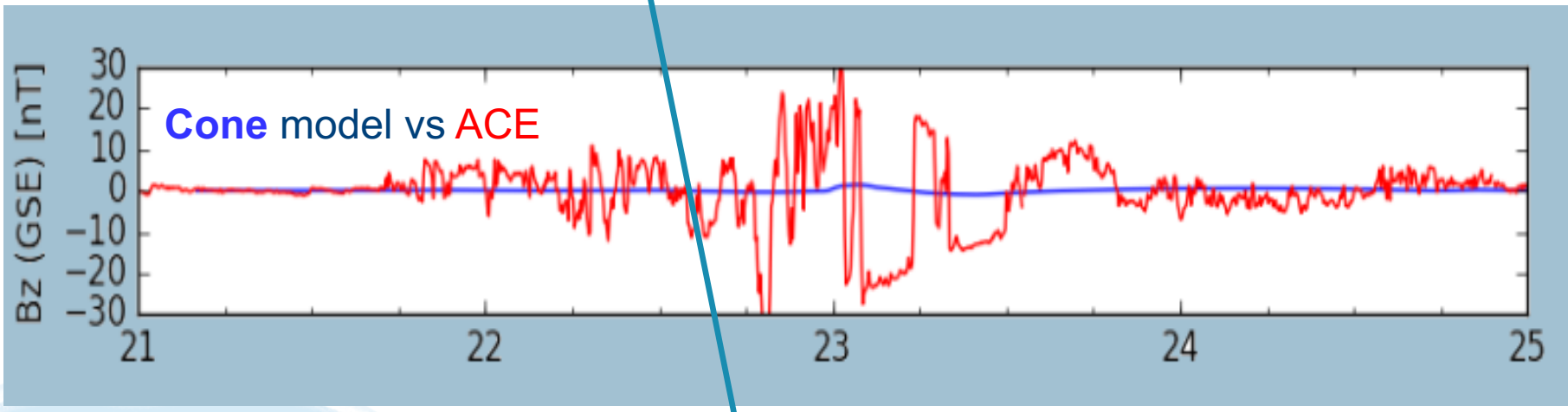
Gibson-Low flux-rope CMEs

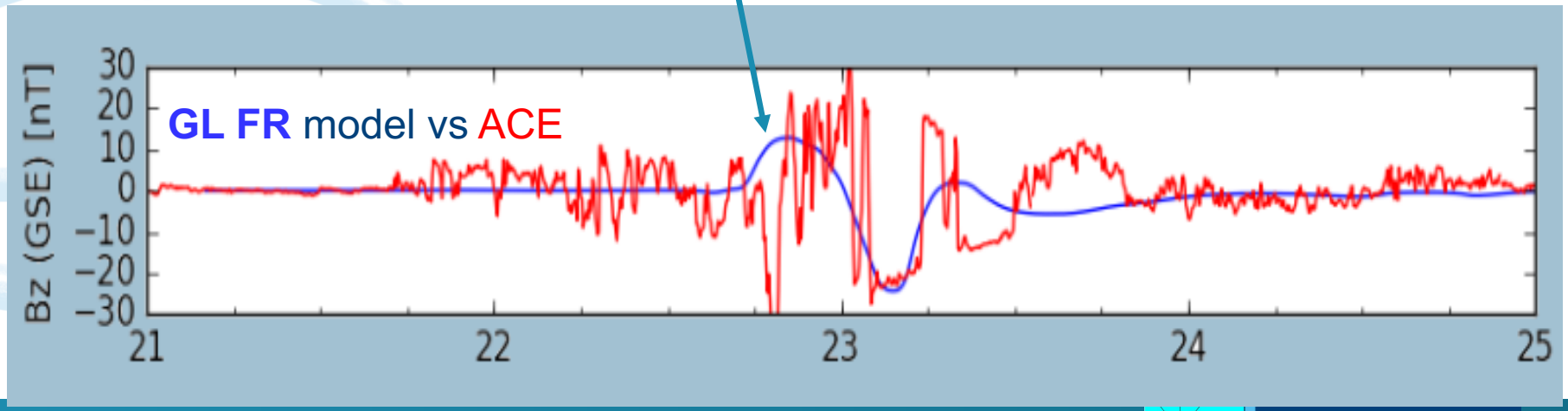


Credit: Jens Pomoell

Comparison Cone - Gibson & Low FR CME

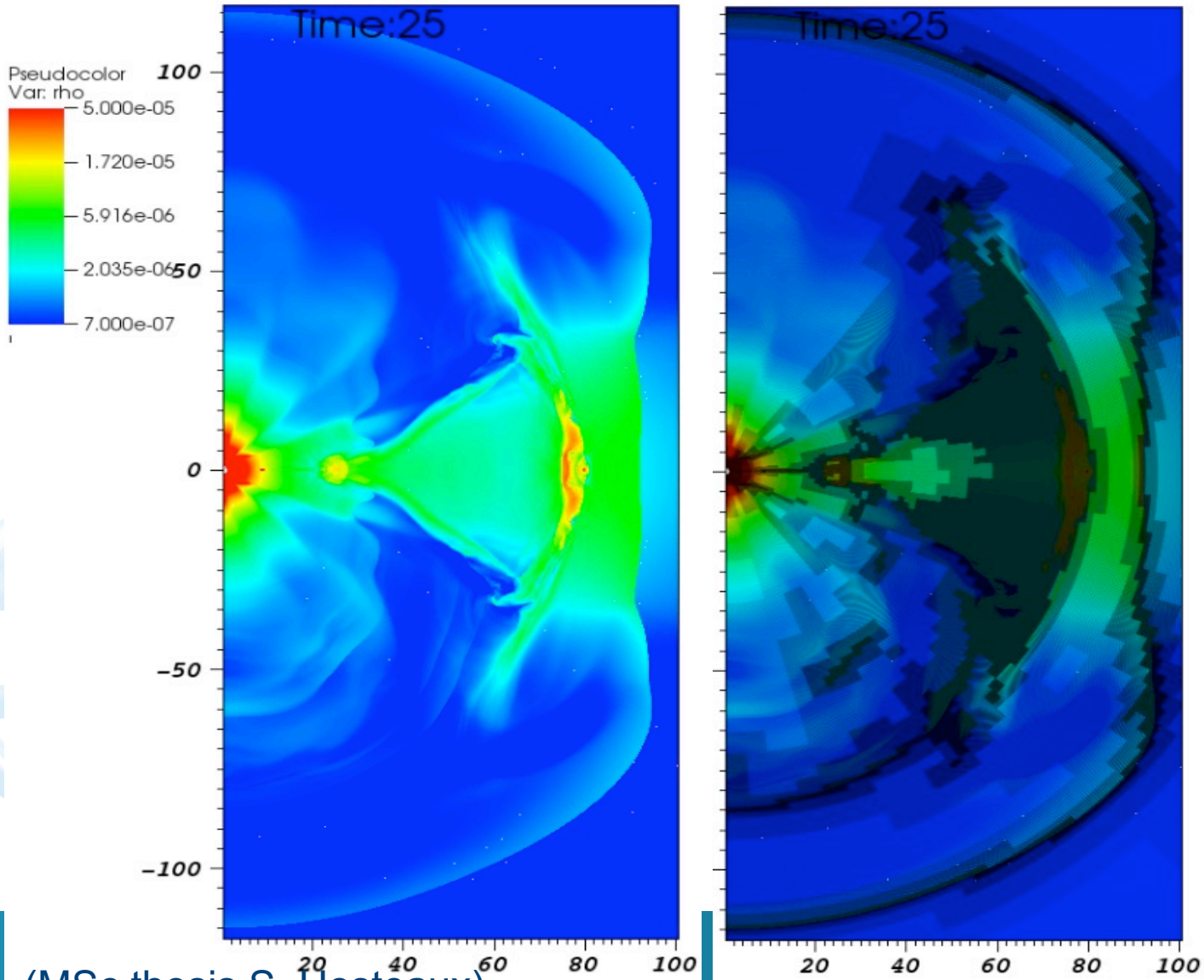
B_z component requires higher resolution





FR CME (PhD thesis Ch. Verbeke) Credit: Jens Pomoell

New ultra-high resolution results: CME



2D color plot of the density at 30h when the CME is ejected with an initial velocity of 1000 km/s.

AMR has been applied on the whole grid (5 levels) according to the gradient of the density.

(MSc thesis S. Hosteaux)

Developer Environment (DE)

- local workbench that assists model developers in making a Model compatible with the VSWMC
- should be an integrated DE, including:
  1. Visually editing the Model metadata;
  2. Configuring a local or remote VSWMC instance;
  3. Deploying a Model or Simulation to that VSWMC instance;
  4. Composing a Simulation visually based on the components available in the repositories of a particular VSWMC instance.

Summary

- The VSWMC-2 design phase is finished
- The VSWMC-2 will be **integrated in the SSA SWE system**, contain new models and new model couplings, including a first demonstration of an end-to-end simulation capability, a developed coupling toolkit, a front-end GUI (accessible via the SWE Portal), and an integrated visualization tool
- Will contain a **Developer Environment** (DE) (*which will not be imposed on a Model Developer seeking compatibility with the VSWMC: it will be possible to deploy a Model without using the DE)*