From Research to Operations: The Success of H3lioviz in Space Weather Visualization

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Abstract

We have developed a sophisticated 3D heliosphere visualization engine and user interface available at https://swx-trec.com/h3lioviz, which integrates actual operational model runs from NOAA's Space Weather Prediction Center (SWPC), NASA's Community Coordinated Modeling Center (CCMC), and the UK Met Office. The design of this tool has been shaped by our interactions with both forecasting centers and researchers. Often, we would think "this is a really nice feature and toggle" only to be told it was too confusing or not all that useful. This feedback may be hard to hear at first for researchers trying to transition their tools, but it really enhanced the final product to make it more useful to all stakeholders involved, highlighting the importance of regular collaboration amongst all entities in the R2O2R chain.

A Success Story for R2O2R In Action: Co-production

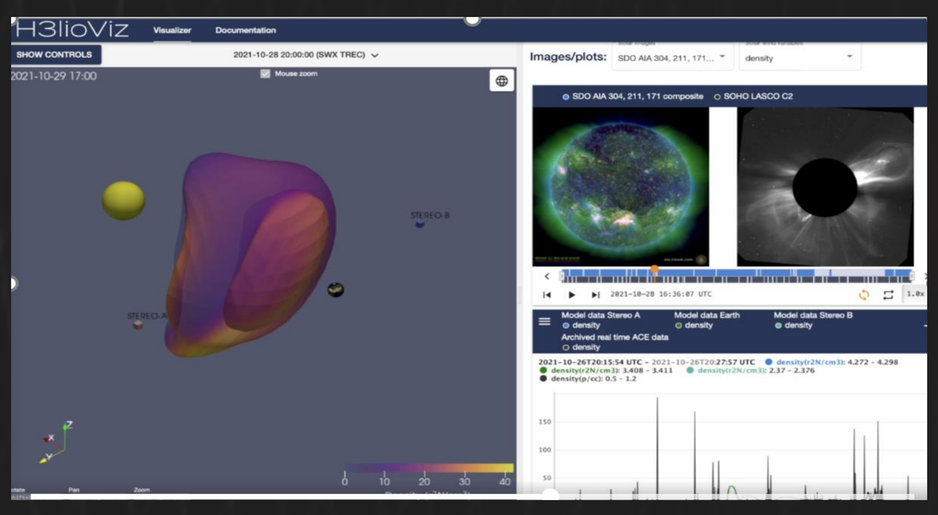
Development Process:
- Agile methodology driven by **continuous stakeholder engagement**
- Monthly development sprints with direct **end-user testing and feedback**
- Cross-pollination through **mixed research / operational meetings**
- Real-time incorporation of operational requirements and research needs

Prinicipal Collaborations:
- University of Colorado Space Weather Technology, Research, and Education Center (SWx-TREC) and Laboratory for Atmospheric and Space Technologies (LASP)
- NOAA Space Weather Prediction Center (SWPC)
- UK Met Office Space Weather Operations Centre (MOSWOC)
- George Mason University (GMU)
- NASA's Community Coordinated Modeling Center (CCMC)

Results:
- A tool that forecasters want to use
- A demonstration of how R2O2R collaboration enhances both operational forecasting and scientific insight

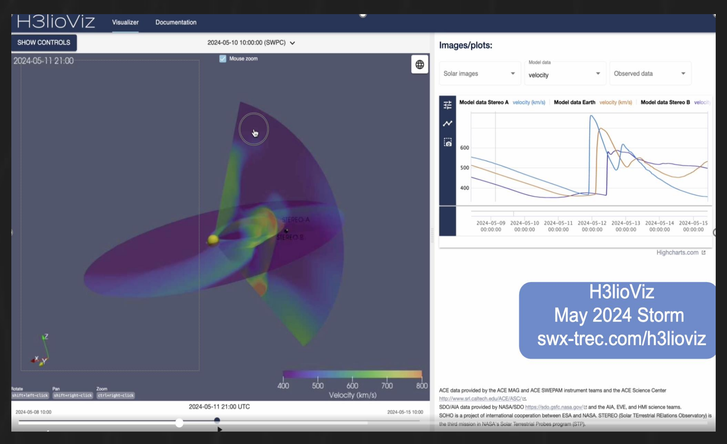
3D Data Visualization

The rich mutli-dimensional output from the Enlil model begs for a powerful 3D visualization interface to enable researchers and forecasters to fully explore the evolution of the solar wind as it propagates towards Earth. We are able to show the full 3D volume of the CME showing how the CME is expanding as it moves towards Earth.



We are developing a practical 3D visualization user-interface by leveraging the existing and mature open-source Paraview software package (https://www.paraview.org/) to produce the 3D rendered graphics. Paraview was designed at Sandia National Laboratories to visualize extremely large data cubes produced by simulations run on their high-performance supercomputers. Paraview was designed to run in remote HPC environments, and we will leverage this ability by running it on high performance Cloud resources available through SWx TREC.

Our 3D visualization interface utilizes the native Python API that Paraview provides to calculate new derived quantities for enhanced visualizations. We will tailor the set of features available to the specific needs of researchers and forecasters as end users to eventually provide a streamlined interface that allows users to focus on their data analysis tasks most efficiently.



H3lioviz – 3D CME Data Visualization in the Cloud

- Standards-based web interface (nothing to install!)
- Interactive 3D visualization
- Cloud-resident (AWS)
- Access to multiple Enlil runs from different centers (diverse data)
- Open-source (GitHub)
- Developed collaboratively for researchers, forecasters, and modelers
- No data transfer needed (transmit images, not data files)
- Deployable across various architectures (containerized, GPUs)

Publicly Available!

https://swx-trec.com/h3lioviz

Feedback is Invaluable

- What do you like?
- Are there things you'd like to see that we are missing?
- Can you envision another use-case for your large 3D datasets?
- We are a collaborative group excited to work with external centers and provide our lessons learned and experiences, don't hesitate to reach out!

Overview of the Enlil Model

The Enlil solar wind forecasting model [Odstrcil 2003] is a critical tool for space weather forecasters, who use the model to aid predictions of coronal mass ejection (CME) arrival times and space weather impacts at Earth [Pizzo et al. 2011; Pizzo et al. 2015]. In addition to forecasters, the code is also widely used by researchers [Odstrcil et al. 2004; Odstrcil et al. 2005] through NASA's CCMC on-demand runs. The Enlil code is a full 3D magnetohydrodynamics (MHD) model that propagates plasma parameters from the inner heliosphere [Arge et al. 2000; Arge et al. 2003] out into the heliosphere in a self-consistent manner.

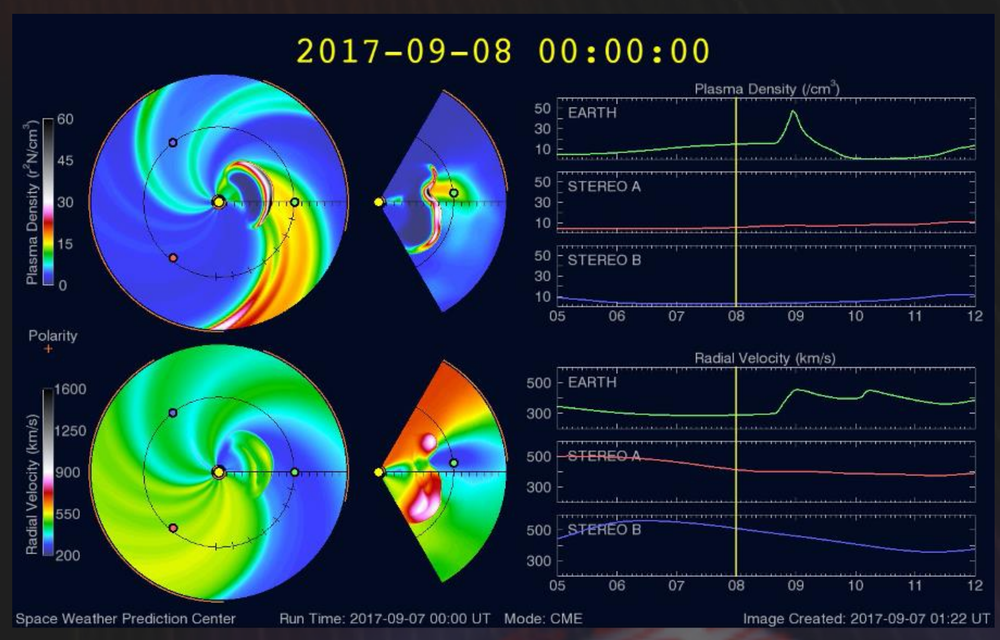


Figure: Example Enlil output visualization

The full output from the code is often extremely large (512 x 60 x 180 x ntimes) and can be prohibitively expensive to store and transmit back to forecasters and researchers. Because of the large data volumes, the output is typically processed into down-sampled 2D slices and time-series at specific satellites and areas of interest before analysis by forecasters and researchers, which can significantly limit the insight they are able to gain, and also limits the full utility of the Enlil model.