NASA/NSF Partnership For Collaborative Space Weather Modeling

ENLIL:

Updates from on-going LWS-SC project

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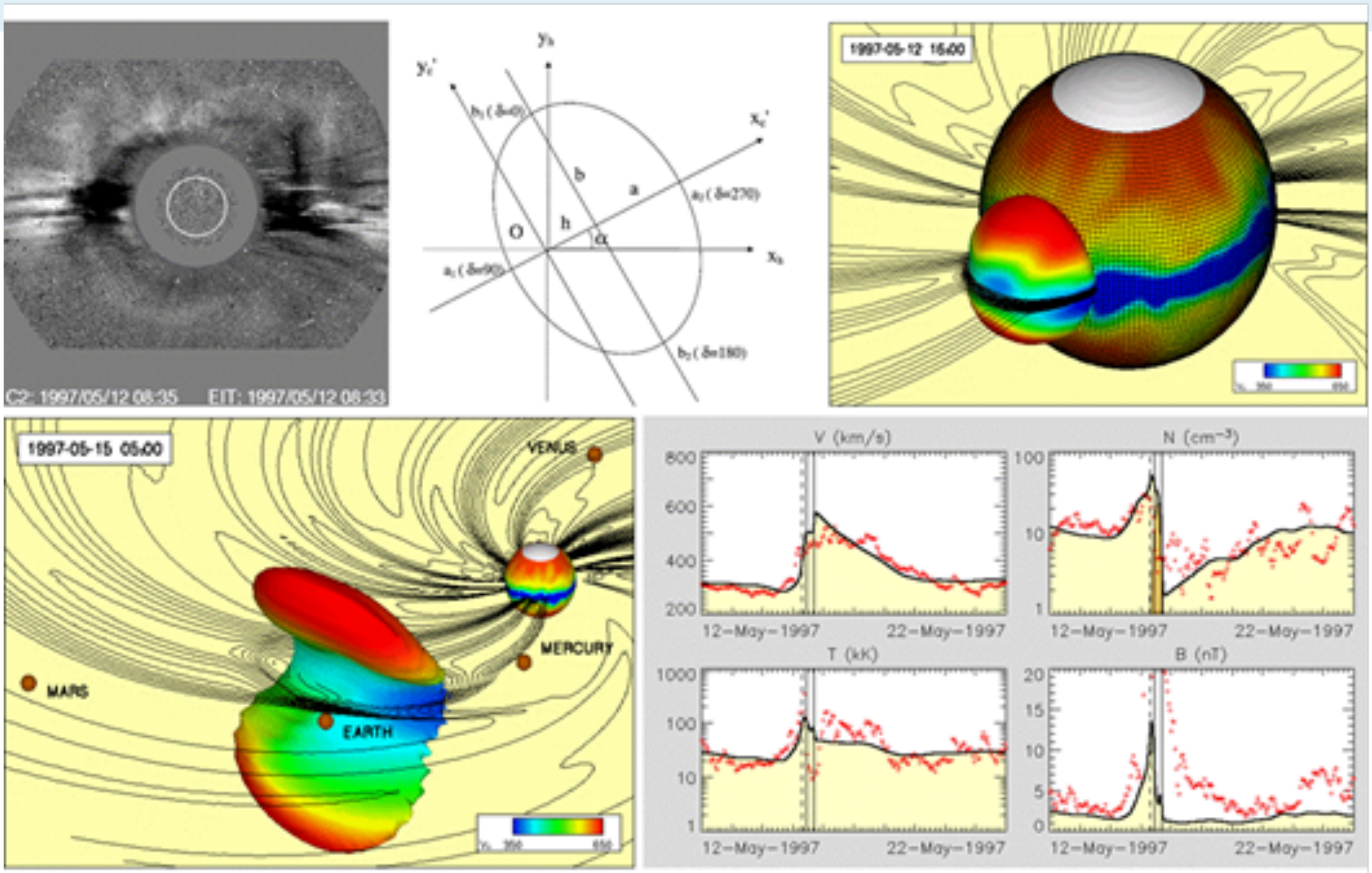
CCMC 2014 Workshop, Annapolis, MD, 31 March – 04 April, 2014

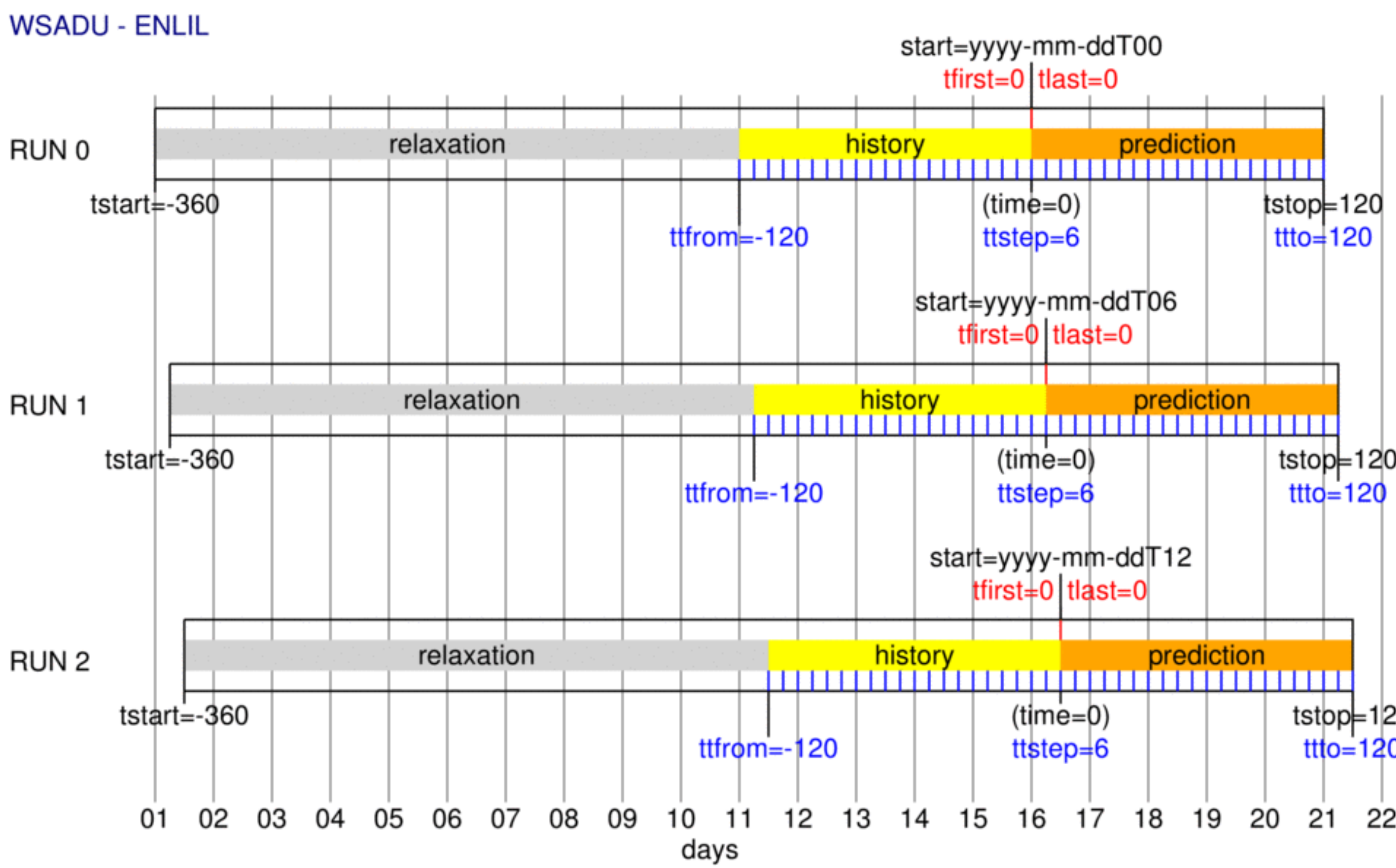
WSA-ENLIL-Cone Modeling System



- Observationally driven, near-real time modeling system
- Routine simulation of corotating streams and CMEs, event-by event
- Much faster than real-time

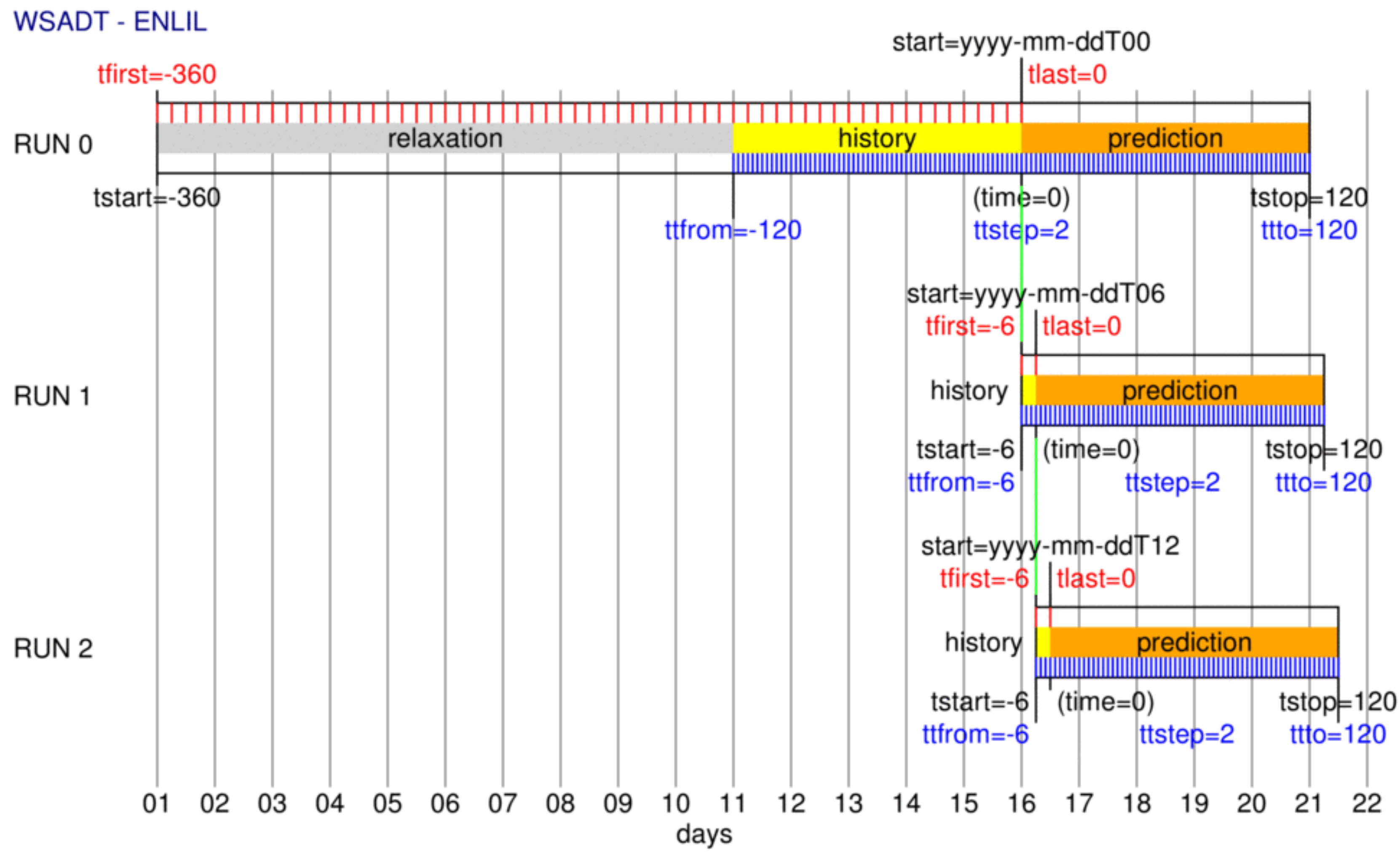
Evolving Ambient Solar Wind

Run Schematic (Old) – “Single-map”, Corotating Background



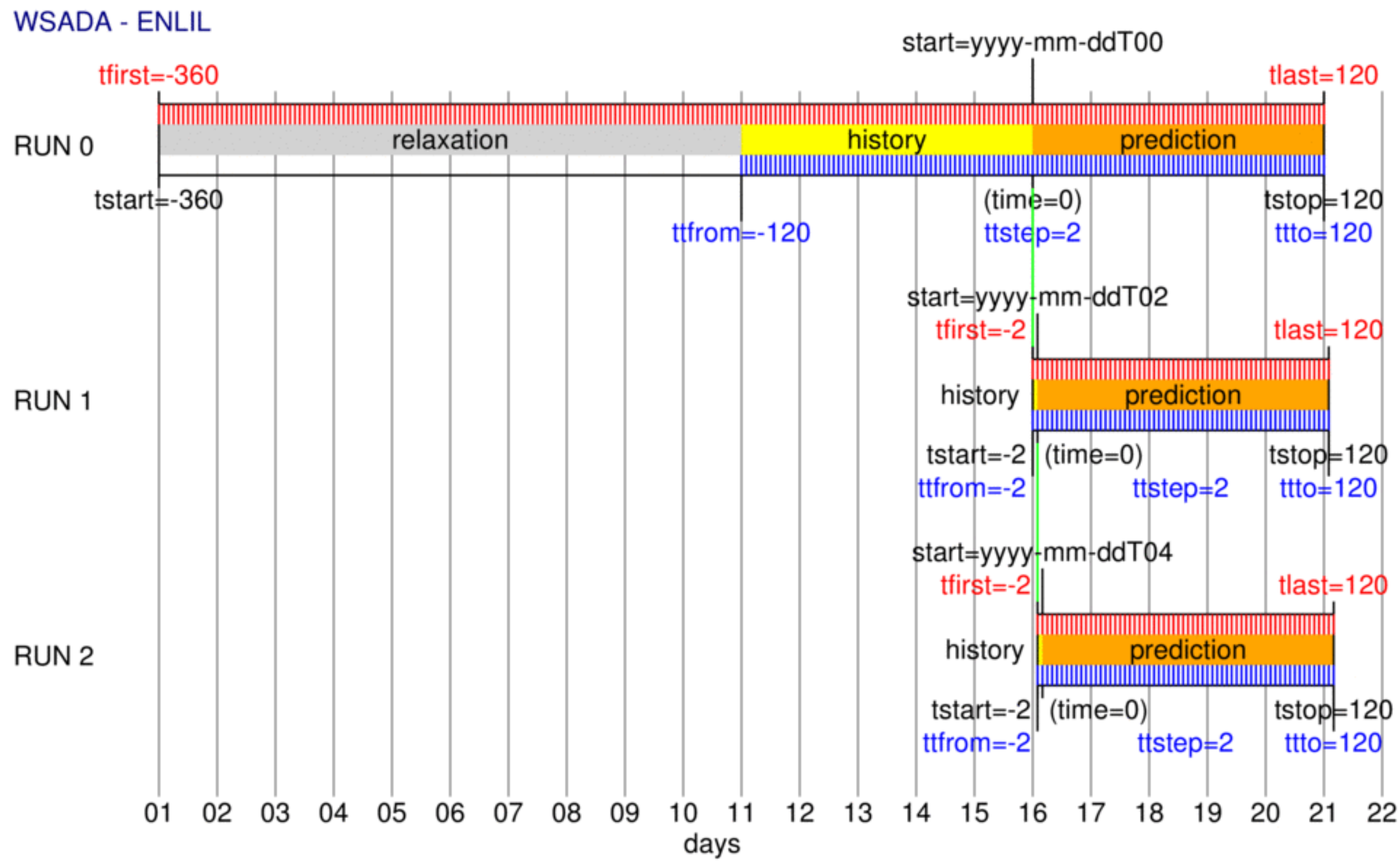
- Numerical relaxation is needed to establish self-consistent background in the computational domain – about 10 days up to Mars
- Numerical relaxation is needed for each prediction

Run Schematic (New) – “Multiple-Maps”, Evolving Background



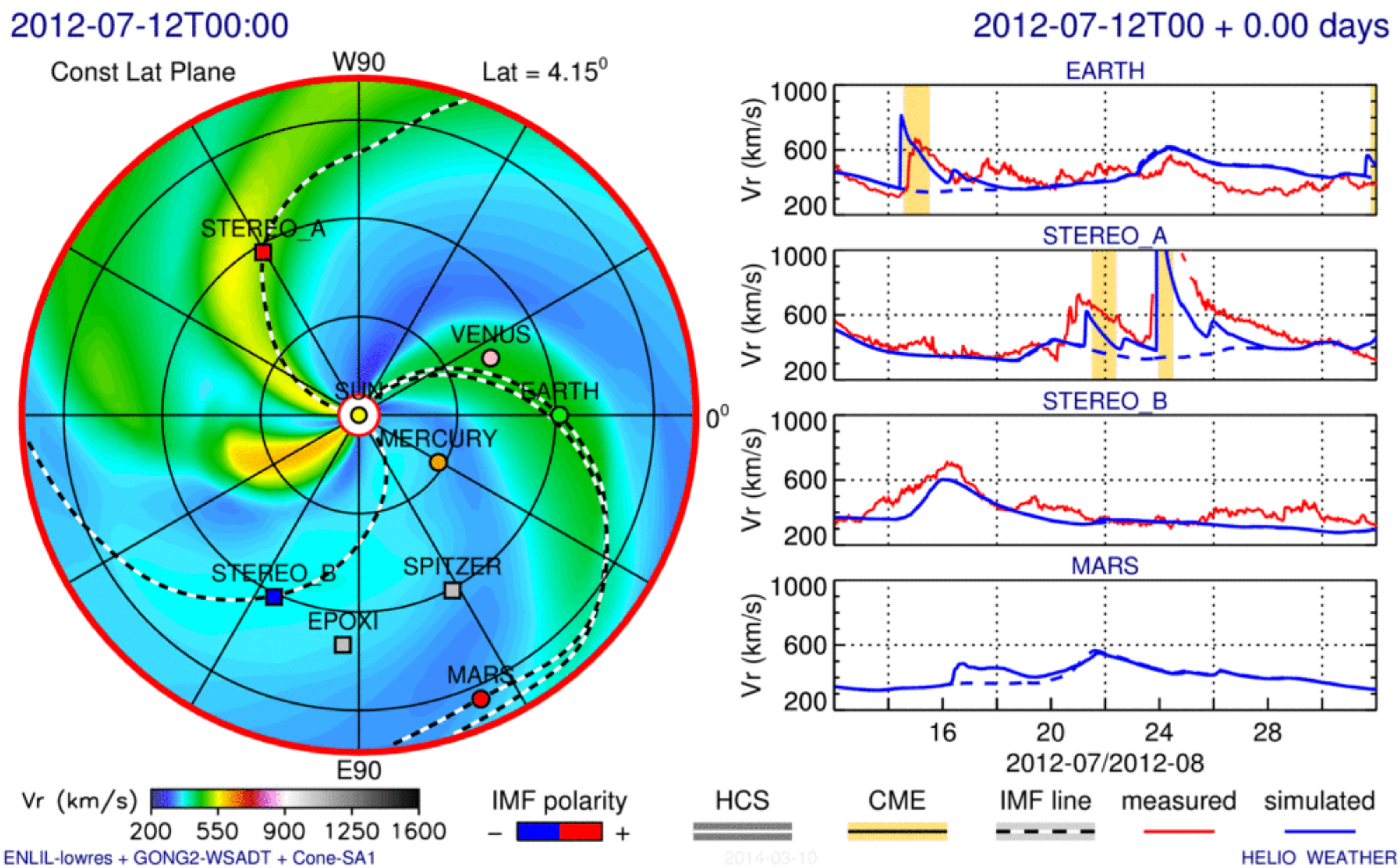
- Continuously evolving background is achieved be resuming from previous runs
- Significant savings in computational time

Run Schematic (New) – “Multiple-Maps”, Evolving Background

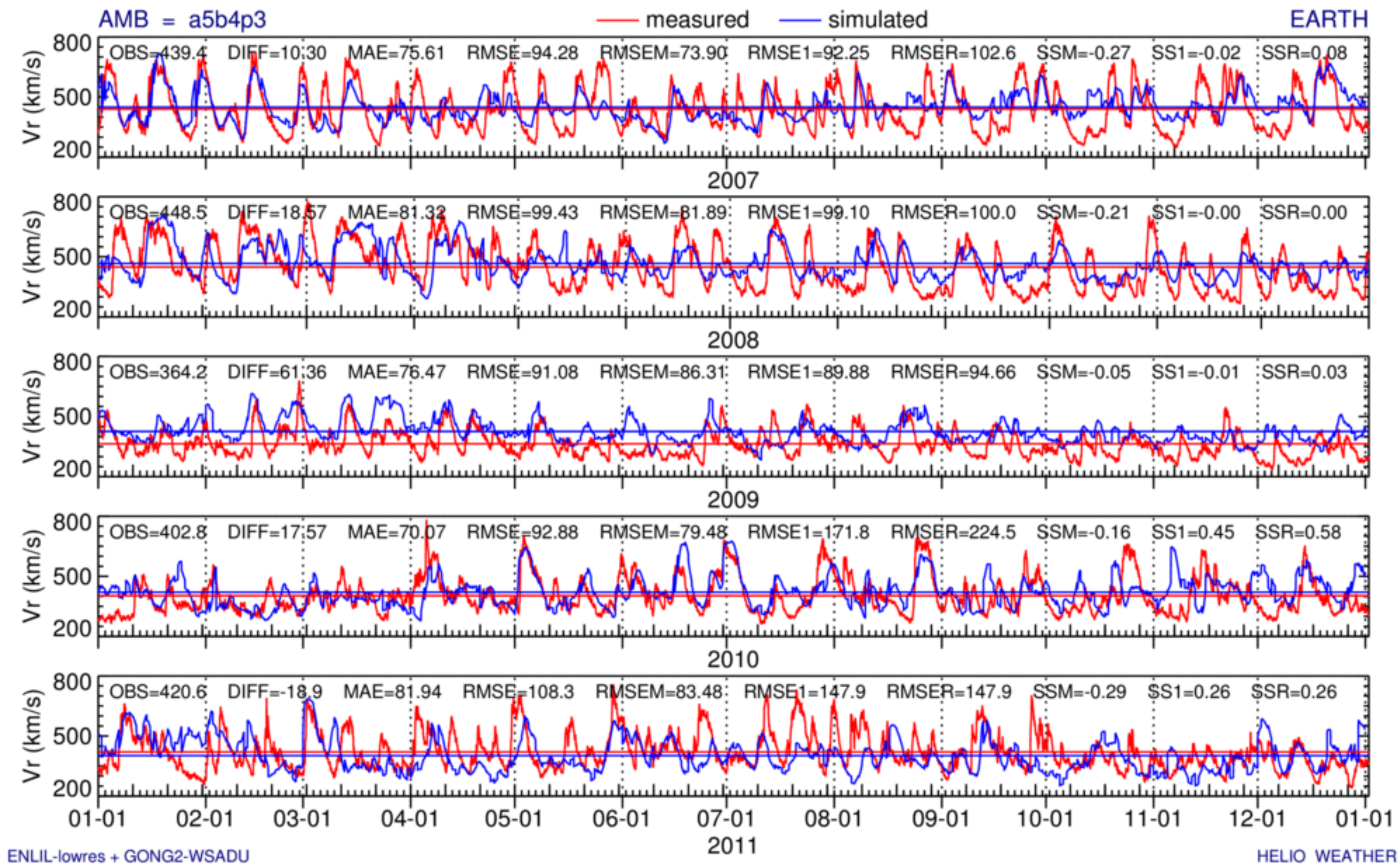


- Preparation for using ADAPT-WSA coronal maps.
- Resources needed for larger computational domain (up to Jupiter) and ensemble forecasting

Validation – CMEs in 2011-2013

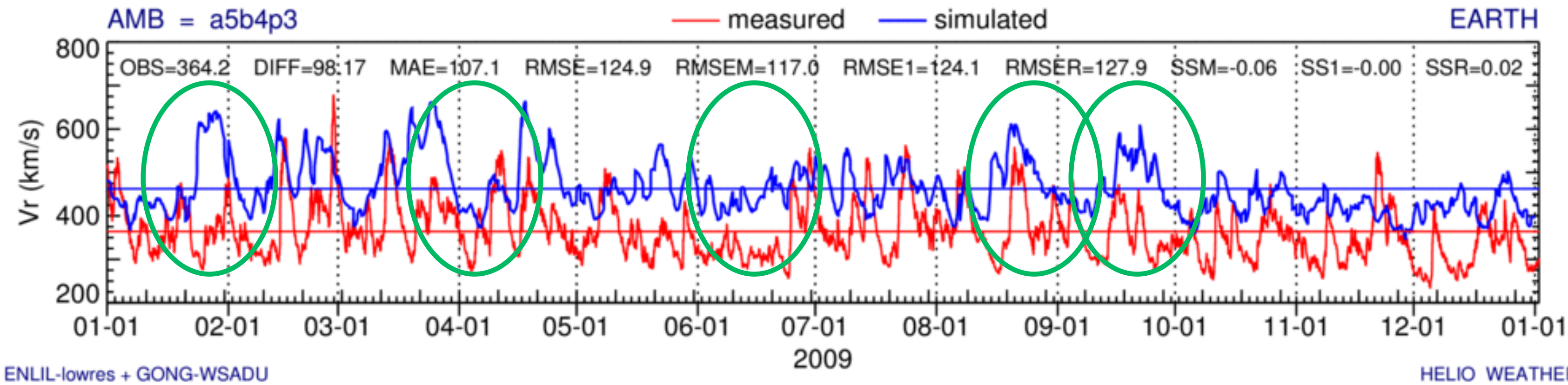


Solar Wind Velocity: GONG2-WSADU: 2007-2011

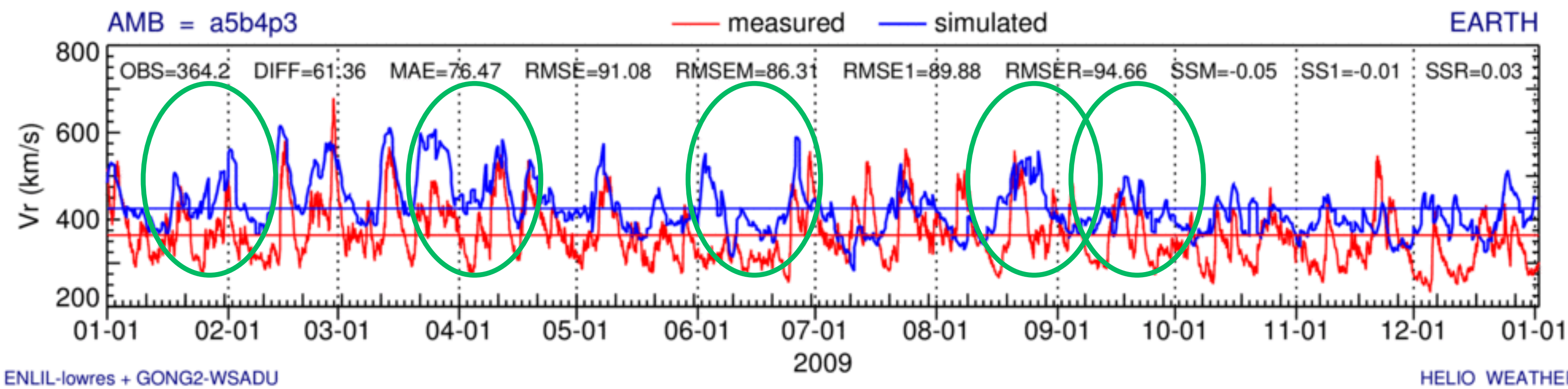


- Prediction of global solar wind parameters at Earth (blue) depends on the coronal model input and also on the heliospheric model free parameters
- WSA maps based on the NSO/SOLIS full-rotation magnetograms provide positive skill scores for 1-day persistency (SS1) and 27-day recurrence (SSR)

Solar Wind Velocity: GONG – 2009

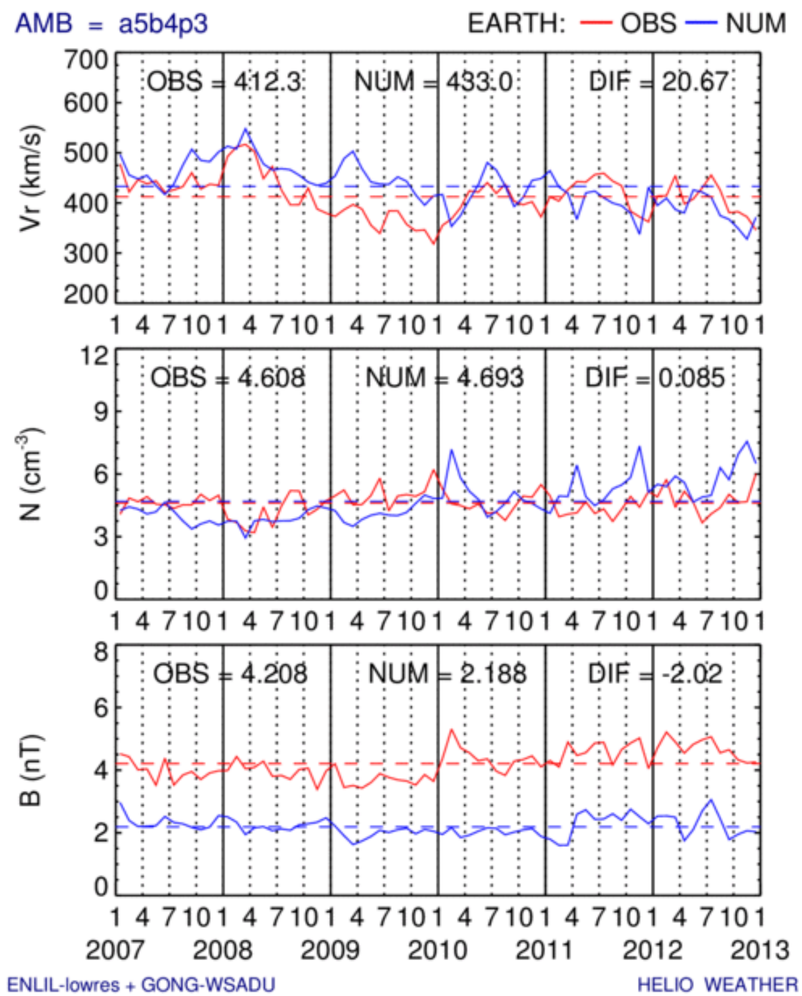


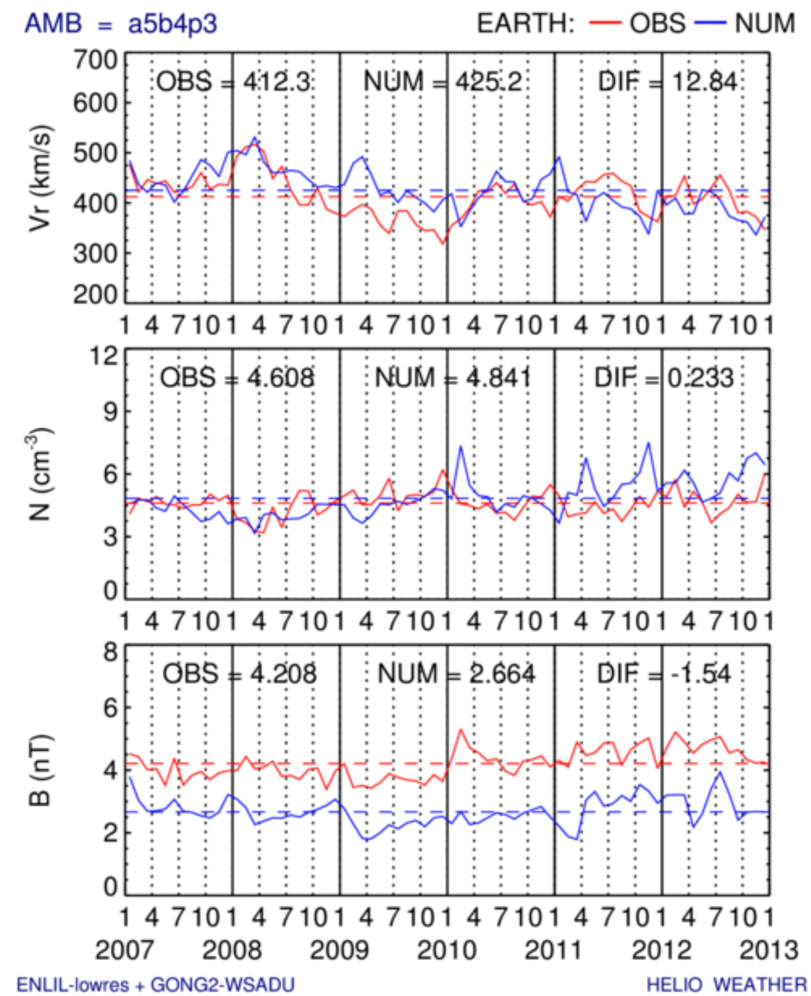
Solar Wind Velocity: GONG2 – 2009



- Prediction during solar minima is difficult, it was especially difficult in 2007 with mean solar wind velocities up to 100 km/s faster
- Meanwhile, NSO revised processing of GONG observations (magnetic bias term and pole filter)
- Improved prediction (labeled as GONG2) periods are indicated by green ovals

Monthly Averages: GONG (left) vs GONG2 (right)



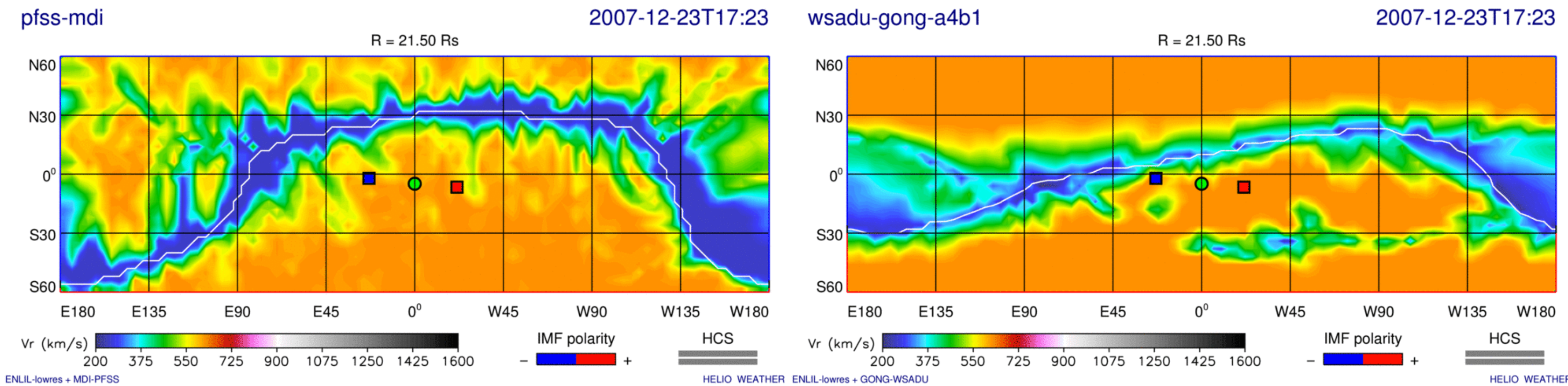


- Availability of new GONG magnetograms requires re-calibration of the model free parameters
- Results for one particular set: bscl=4, dfast=150 cm^{-3}, tfast=2 MK, vrfast(slow)=25(75) km/s
- Mean velocity is better for new magnetograms; mean magnetic field is slightly better but needs to be further increased (if computational robustness allows)

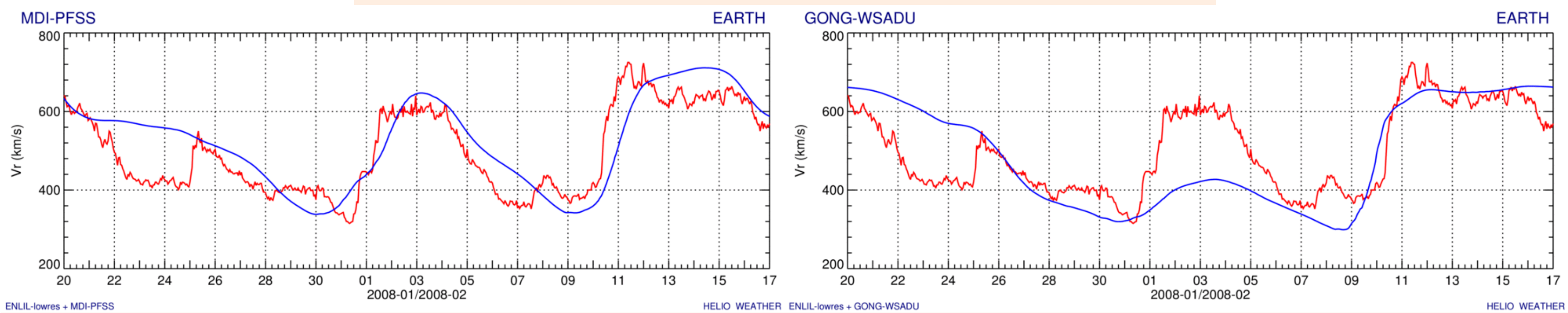
Incorporation of Remote Observations

Ambient Solar Wind – Two Different Predictions

Boundary Conditions – Solar Wind Velocity at 0.1 AU

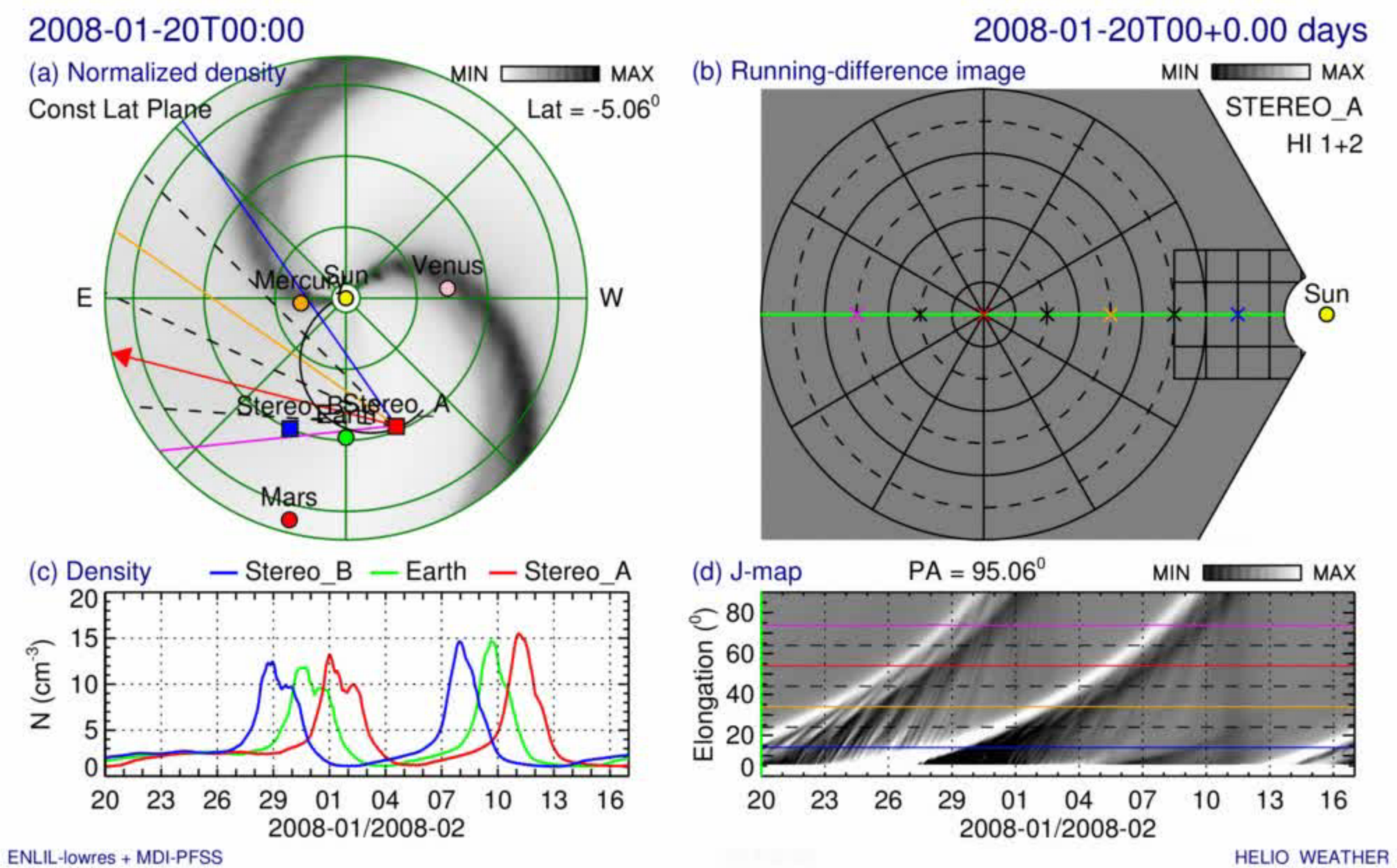


Predicted Solar Wind Velocity at Earth



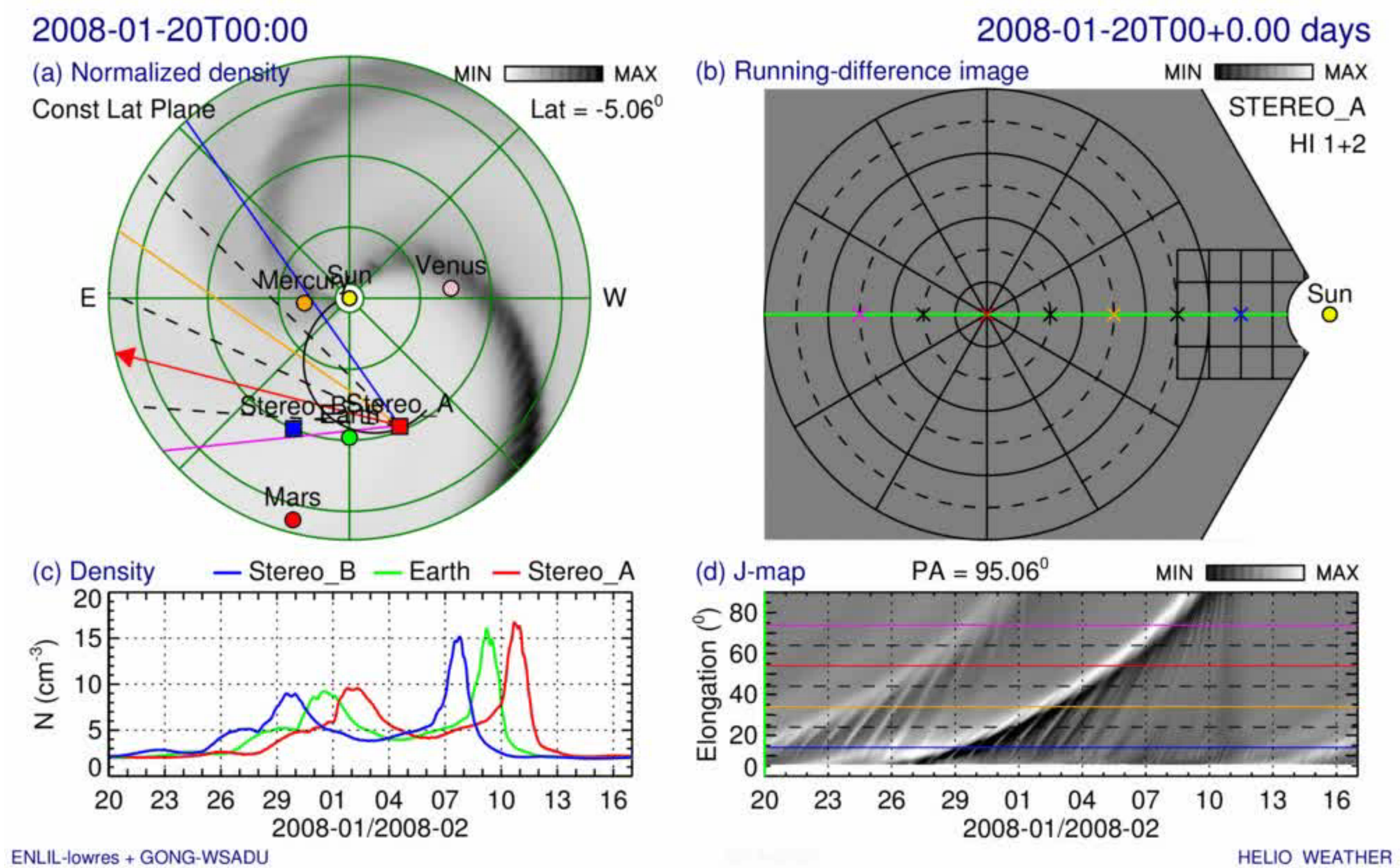
- Different remote observations of the photospheric magnetic field and/or different coronal models produce different synoptic maps of the solar velocity at 0.1 AU
- These maps drive heliospheric simulations and it is unclear which prediction is more accurate until "it is too late" and values can be compared with in-situ measurements at Earth

Prediction of High-Speed Streams – PFSS/MDI



- Remote observations by heliospheric imagers can provide evaluation of various numerical predictions well before corotating and/or transient disturbances arrive at Earth
- Numerical results are presented with streams visibility enhanced by small-scale "blobs"

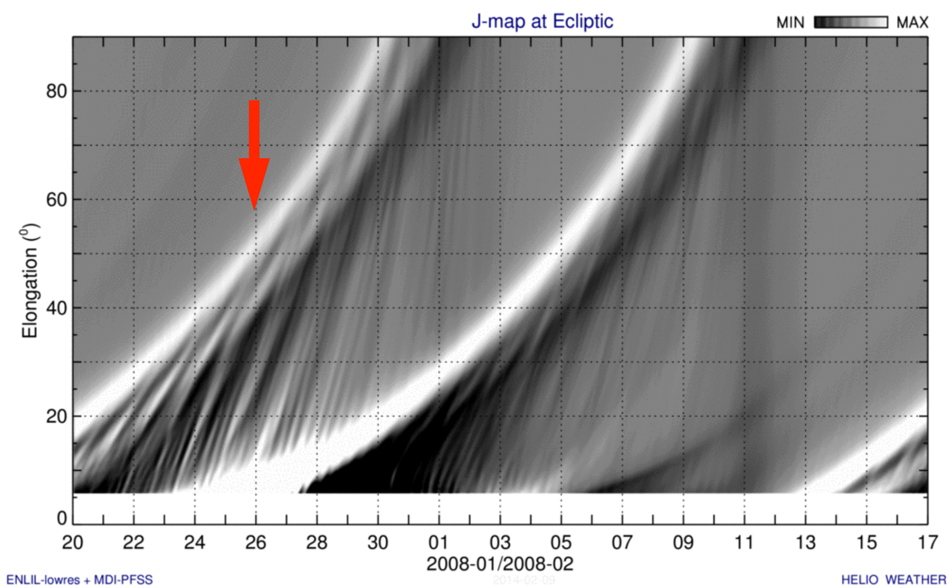
Prediction of High-Speed Streams – WSA/GONG



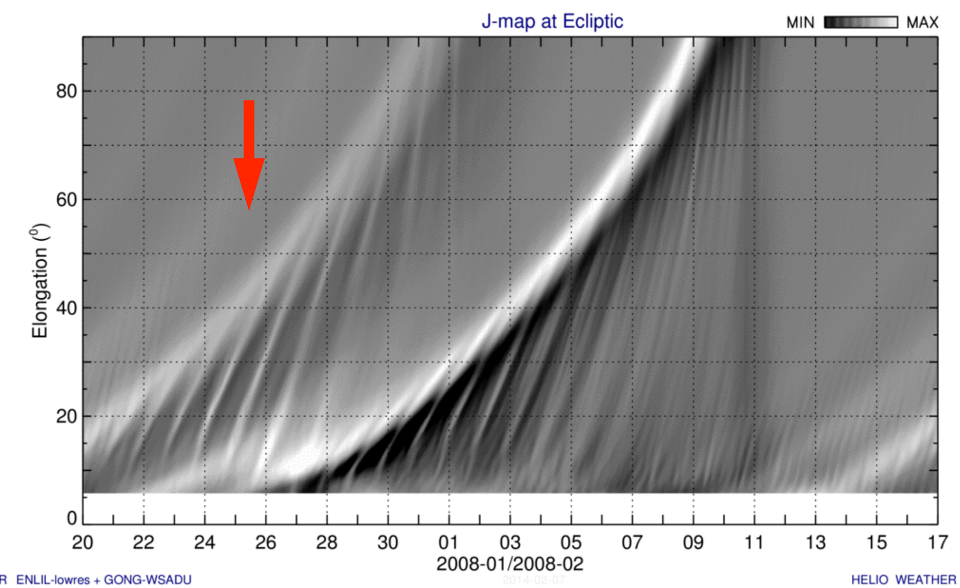
- Remote observations by heliospheric imagers can provide evaluation of various numerical predictions well before corotating and/or transient disturbances arrive at Earth
- Numerical results are presented with the same grey scale

Comparison of Predictions by J-Maps

Run with MDI-PFSS



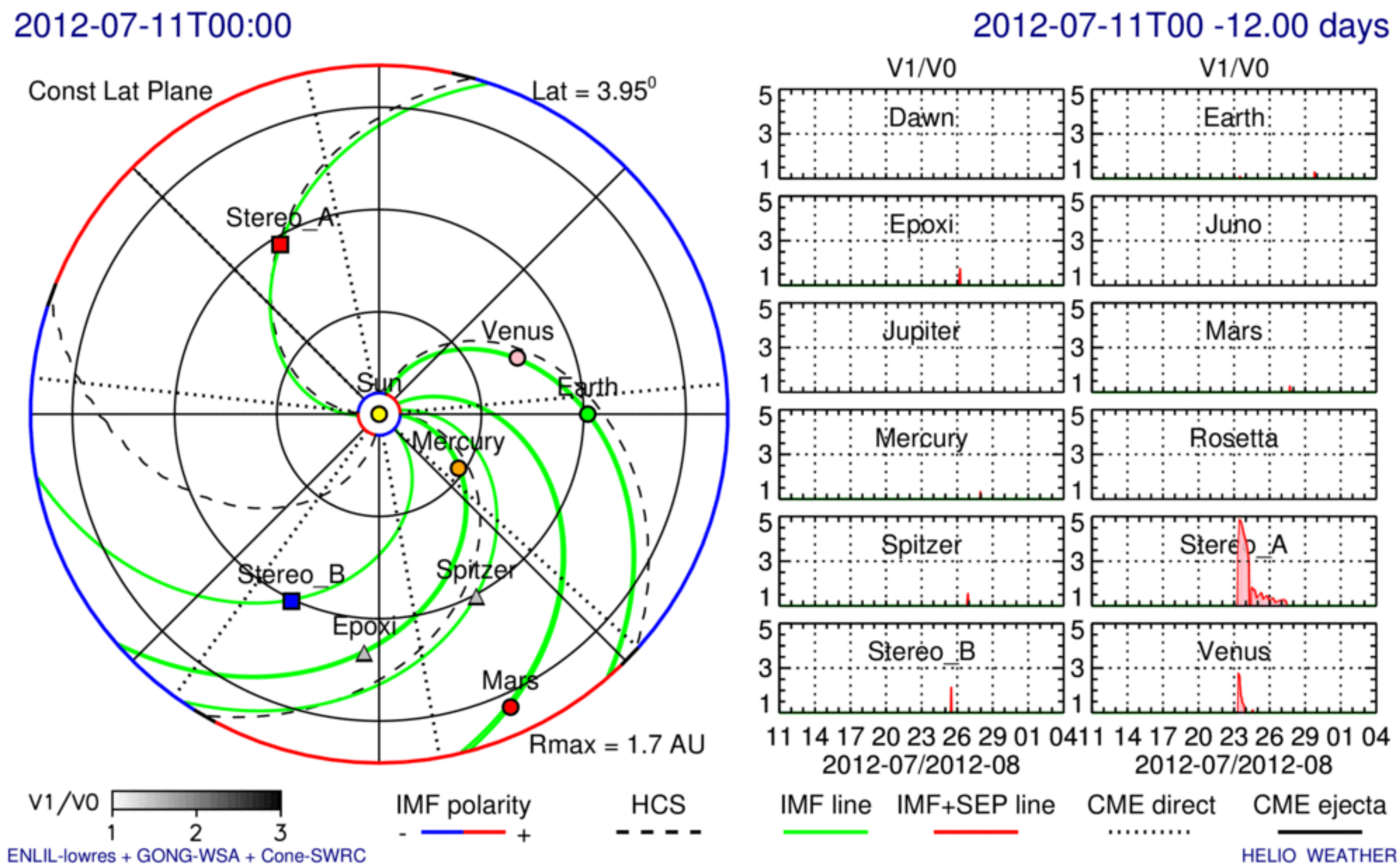
Run with GONG-WSADU



- Both runs show two bright structures – compressed density by solar wind stream interaction
- Converging patterns of small-scale structures correspond to blobs that are overtaken by fast streams (this helps to differentiate between CMEs and streams)
- Difference in the brightness and slope can be clearly seen for the first streamer track while the second stream is about the same
- This suggests that the MDI-PFSS run will cause stronger streamer with earlier arrival to Earth
- Since the stream interaction regions can be seen well before their arrival to Earth, scientific (i.e., no need for beacon) data can be also used to suggest which prediction is more accurate

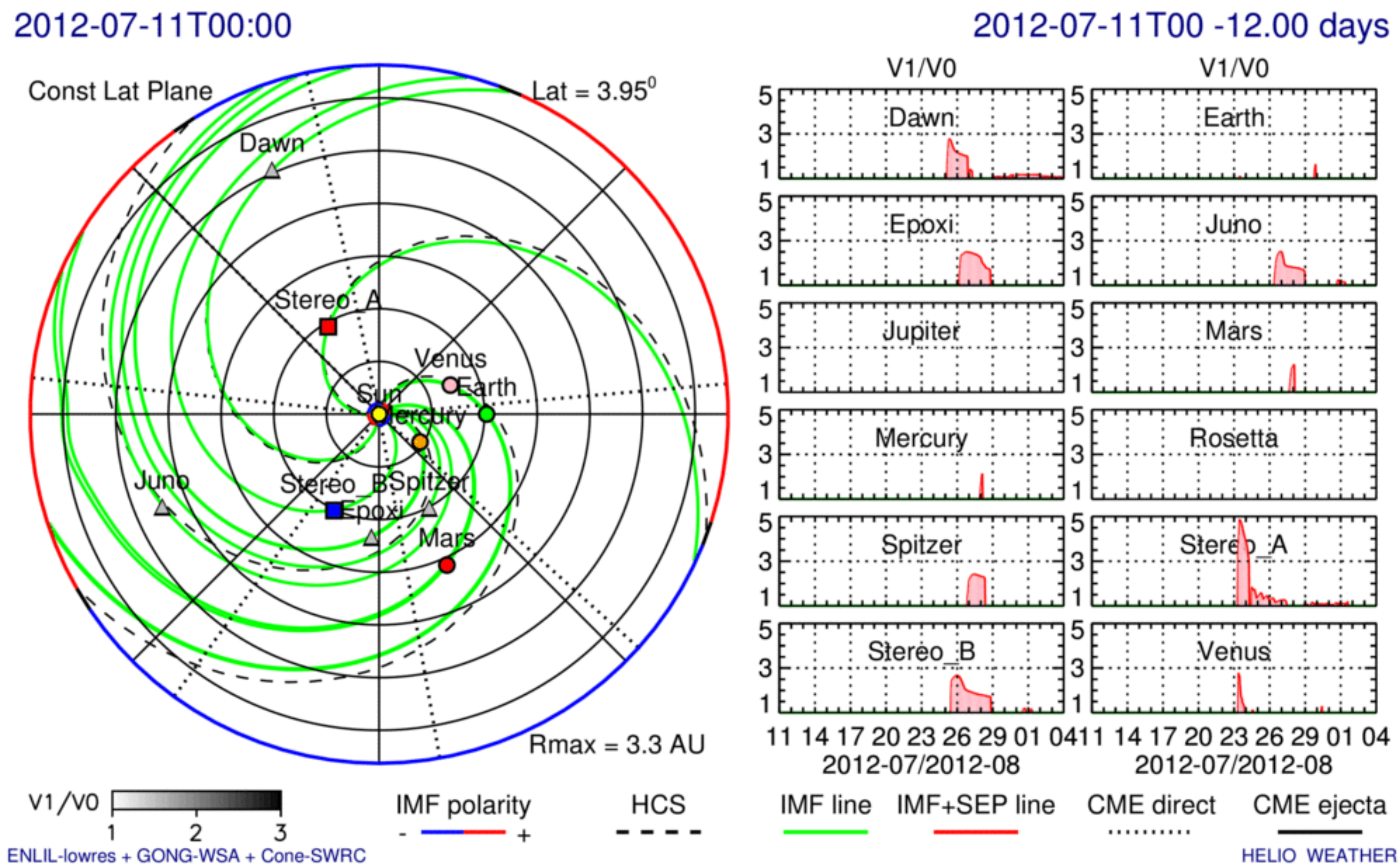
Automatic Detection of Shock Parameters

2012 July 23 CME Event – 1.7 AU



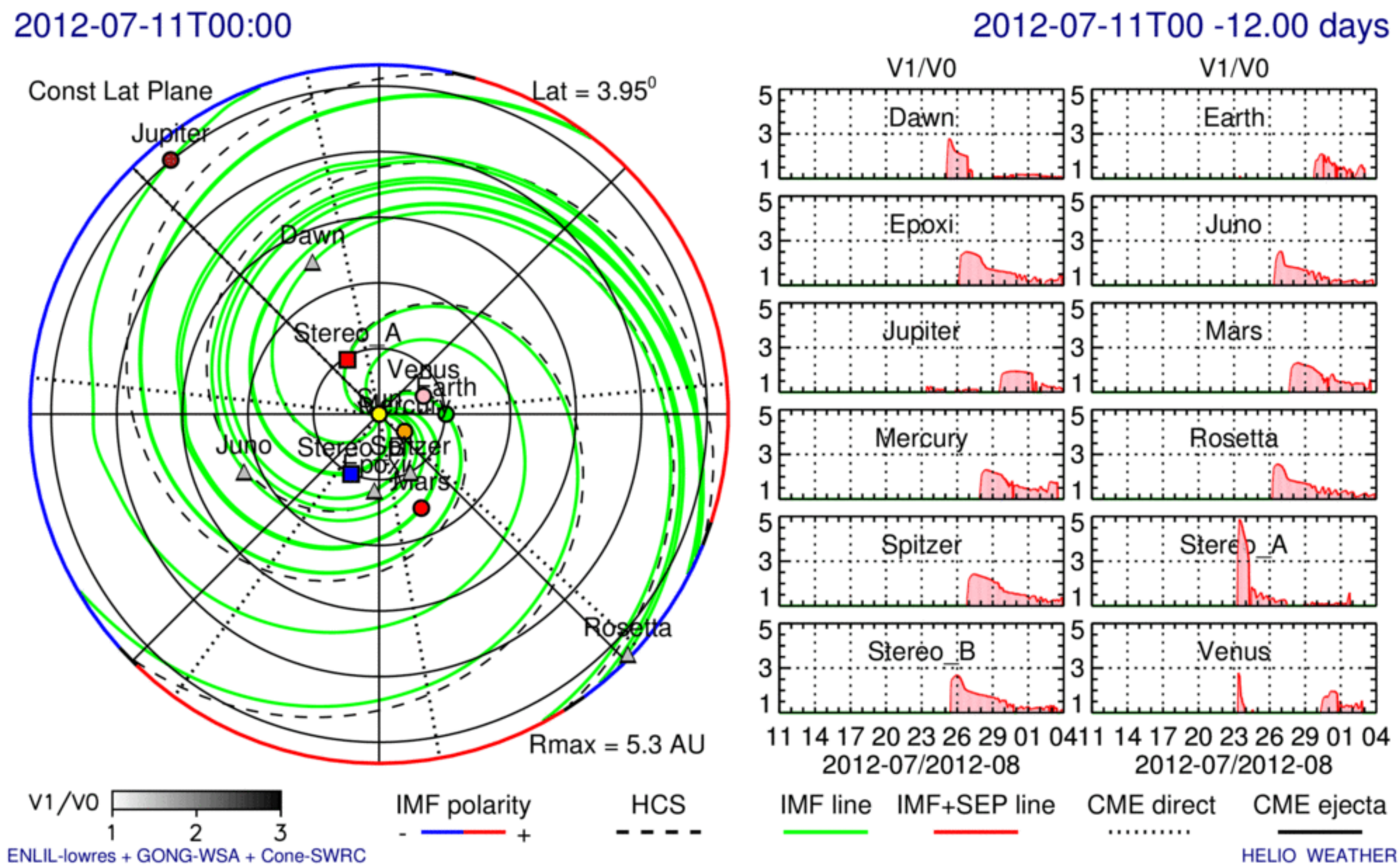
- Simulation of the 2012-07-23 CME in the "inner-heliospheric" domain up to 1.7 AU
- IMF lines connected to planets and spacecraft are shown by red (green) if they pass (do not pass) through a CME-driven shock; velocity jumps at the shock are shown at right
- Results suggest that shock-accelerated SEPs may hit STEREO_A and Venus

2012 July 23 CME Event – 3.3 AU



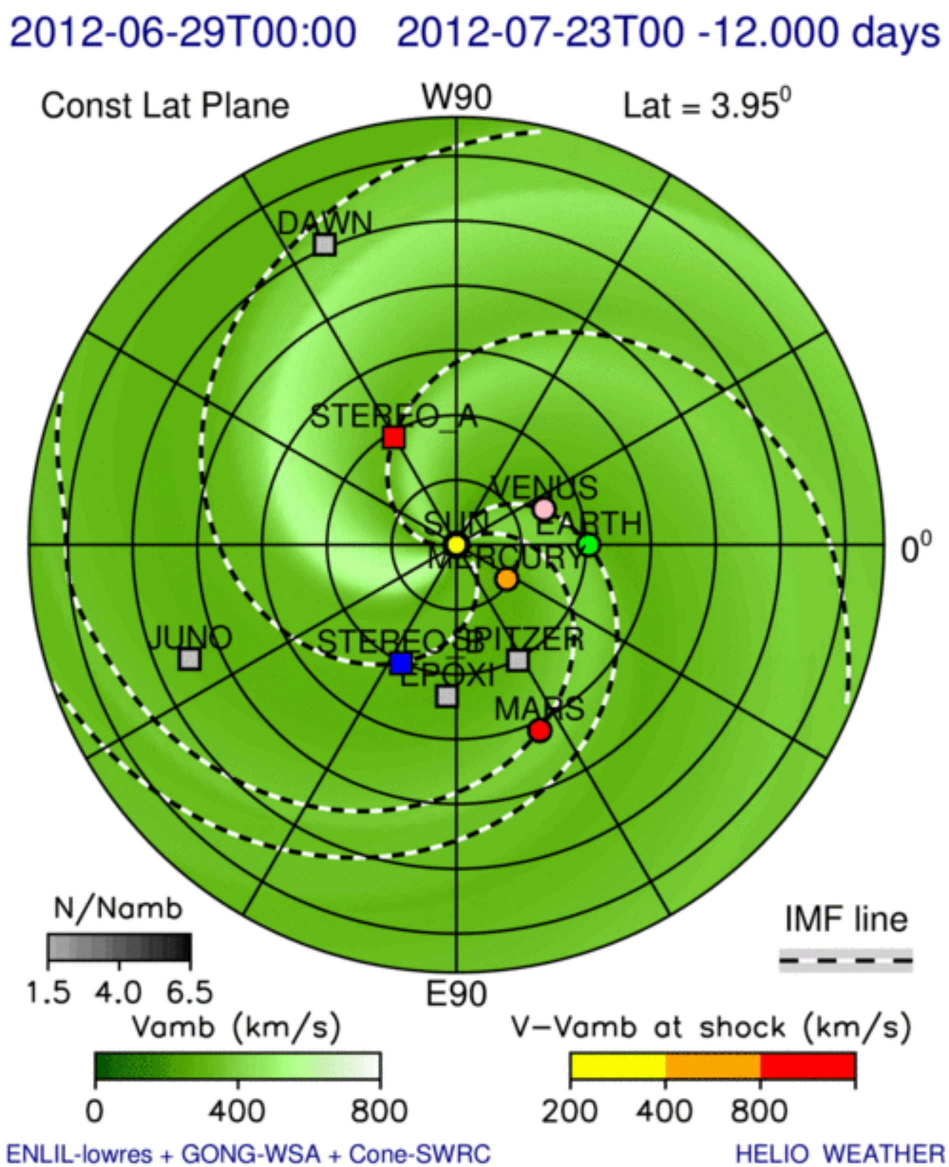
- Simulation on the computational domain extended up to 3.3 AU shows that the shock encounters spiraling IMF lines
- Thus, as time goes on, the shock is magnetically connected with additional objects
- SEPs may hit other planets and spacecraft if the shock accelerates particles “backward”

2012 July 23 CME Event – 5.3 AU



- Simulation on the computational domain up to 5.3 AU (mid-heliosphere) suggest that all planets and spacecraft may be hit by SEPs
- This stems from launching very fast and broad "circular-cone-model" ejecta
- Absence or presence of SEPs can be used to constrain shape and size of ejecta models

Solar Energetic Particles – Revised Outlook

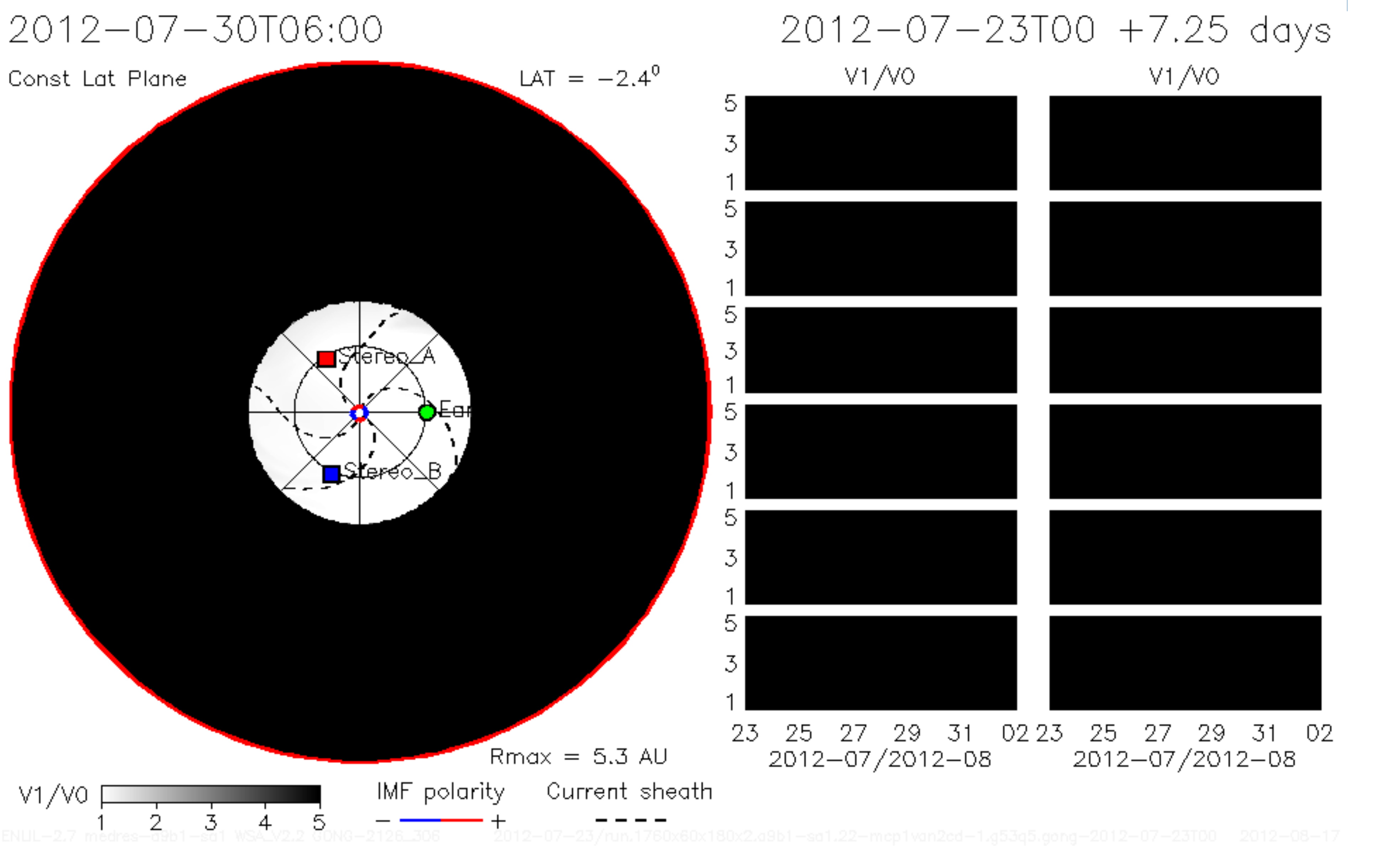


- A simpler task is prediction of estimated "all-clear" conditions

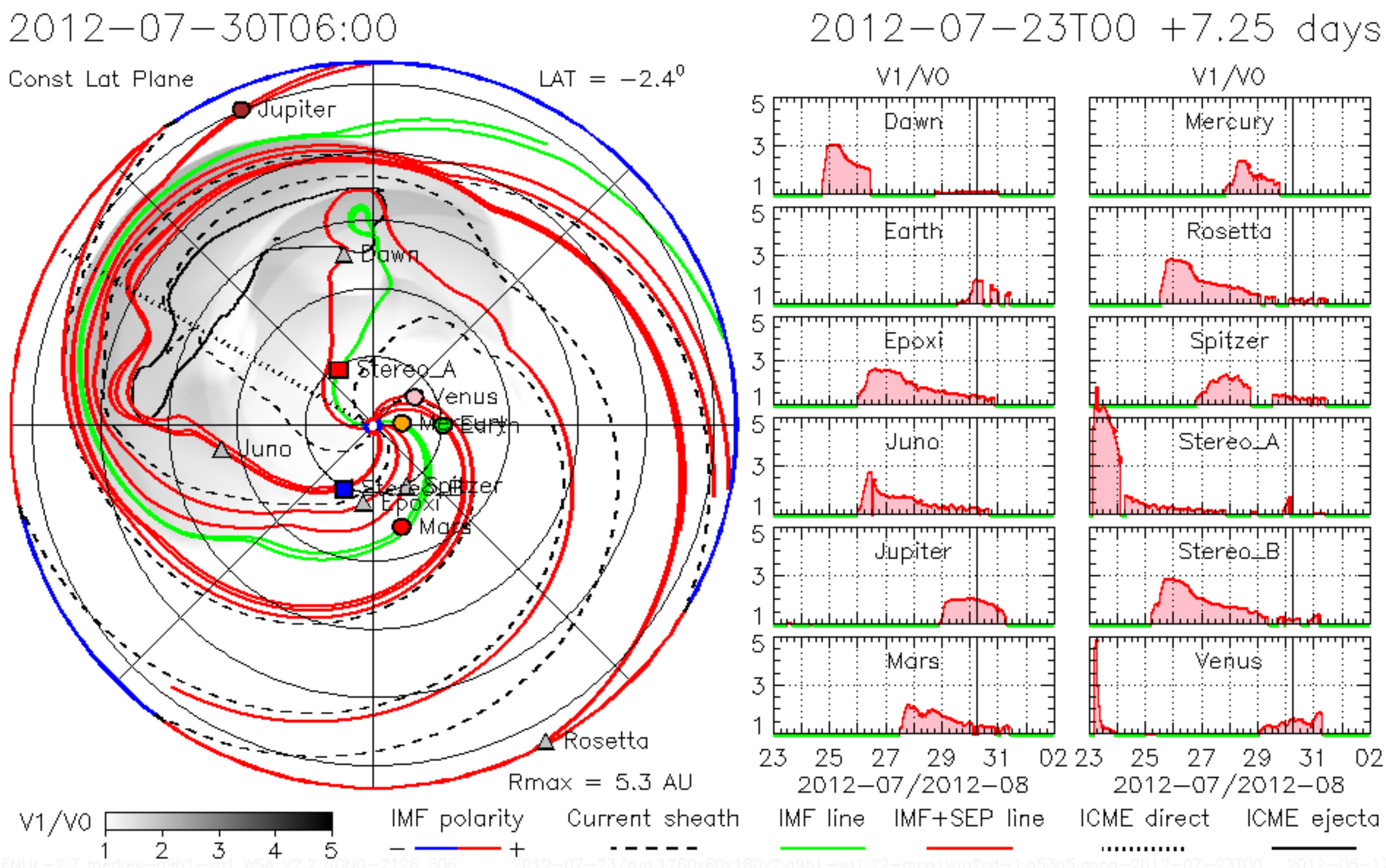
- Visualization shows:
  - ambient velocity (green)
  - transient disturbance (grey)
  - possible SEP affected area (yellow, orange, red)

Space Weather Prediction for Heliospheric Missions

2012-07-23 CME Event – 1.7 AU Simulation



2012-07-23 CME Event – 5.3 AU Simulation



Summary and Acknowledgments

- NASA+NSF PCWM (NASA-LWS) supports “next-generation” ENLIL development
- NASA/GSFC and NASA/CCMC provides additional support and staff to accelerate development of SEPs and helio-imagers applications
- NOAA/SWPC provides additional support to utilize upcoming ADAPT-WSA results for prediction of more realistic background
- New ENLIL version 2.8 has been delivered to NOAA/SWPC & NASA/CCMC/SWRC
- New applications may require up to 10-100 times more computational resources