# WSA-Enlil Cone Transition to Operations at NWS/SWPC

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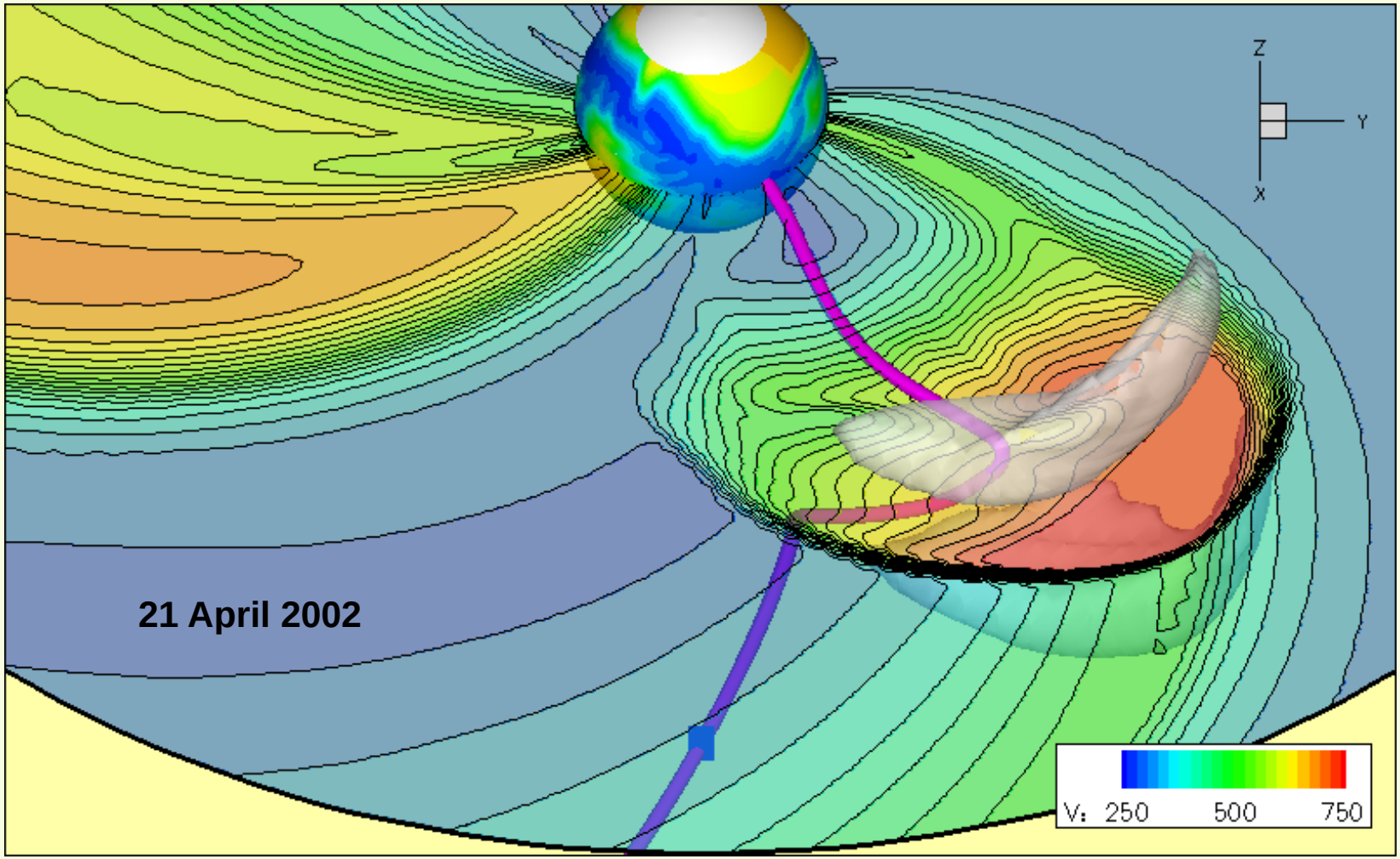
# WSA-Enlil at SWPC/NCEP

**Is a comprehensive, 3D, time-dependent, forecast model of the inner heliosphere (solar wind)**



# Why this project ?

- 1st in line of space weather models to be brought into full NWS operations
- Model judged to be developed enough to offer some improvements now, more later
- To provide fully operational forecast capability
  - 24/7 support and readiness
  - Full backups for inputs, processing, outputs
  - Formal product line
  - Fully documented and CM'd
- Baseline of consistently run models and outputs will enable ongoing improvements (O2R)

# Intended SWx Benefits

- Provide improved warning of CIRs

  Time of arrival at Earth
  KP response

- Provide 1-4 days advance warning of oncoming CMEs

  Time of arrival at Earth
  Storm intensity
  Storm duration

- Pave the way for future generations of SWx models:

  geospace
  ionosphere
  upper atmosphere
  energetic particles

# Transition Team

- 5+ FTE of SWPC Feds and CIRES support

  (project scientist, manager, technical lead)

  (networking, database graphics, V&V, docs)

| | | |
|---|---|---|
| Eduardo Araujo | Rob Craver | Curt de Koning |
| Ratina Dodani | Kent Doggett | Leslie Mayer |
| Ann Newman | Larry Puga | Josh Rigler |

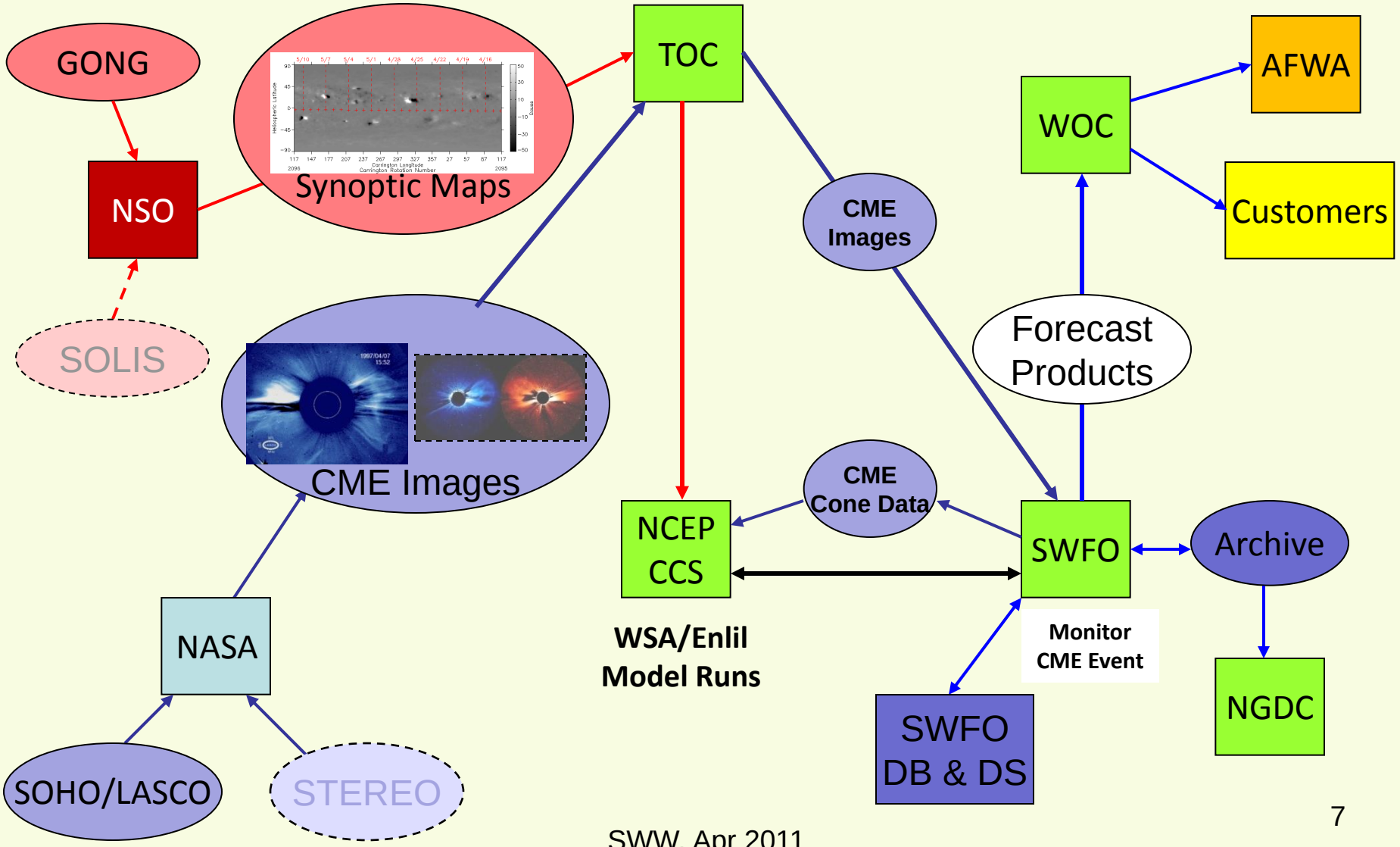
- SWPC support staff (dev & transition, IT, etc)
- SWFO
- Model Developer/Originator
- NGDC

- Funded from FY10/11 increment to base funding

# Partnerships

- NOAA / NWS / NCEP / EMC & NCO (computing) / NGDC (archive)
- DoD / AFWA
- DoD / AFRL (Nick Arge, WSA model developer)
- DoD / NRL (Cone development, STEREO) & ONR (WSA support)
- George Mason University (Dusan Odstrcil, Enlil model developer)
- NASA / ESA (SOHO / LASCO / STEREO)
- NASA / CCMC (Cone model development)
- NSF / CISM / NCAR / LASP
- NSF / NSO (GONG)
- Basic research community

# Enlil CONOPS



# Operational Supercomputing at NCEP

IBM Power6 p575

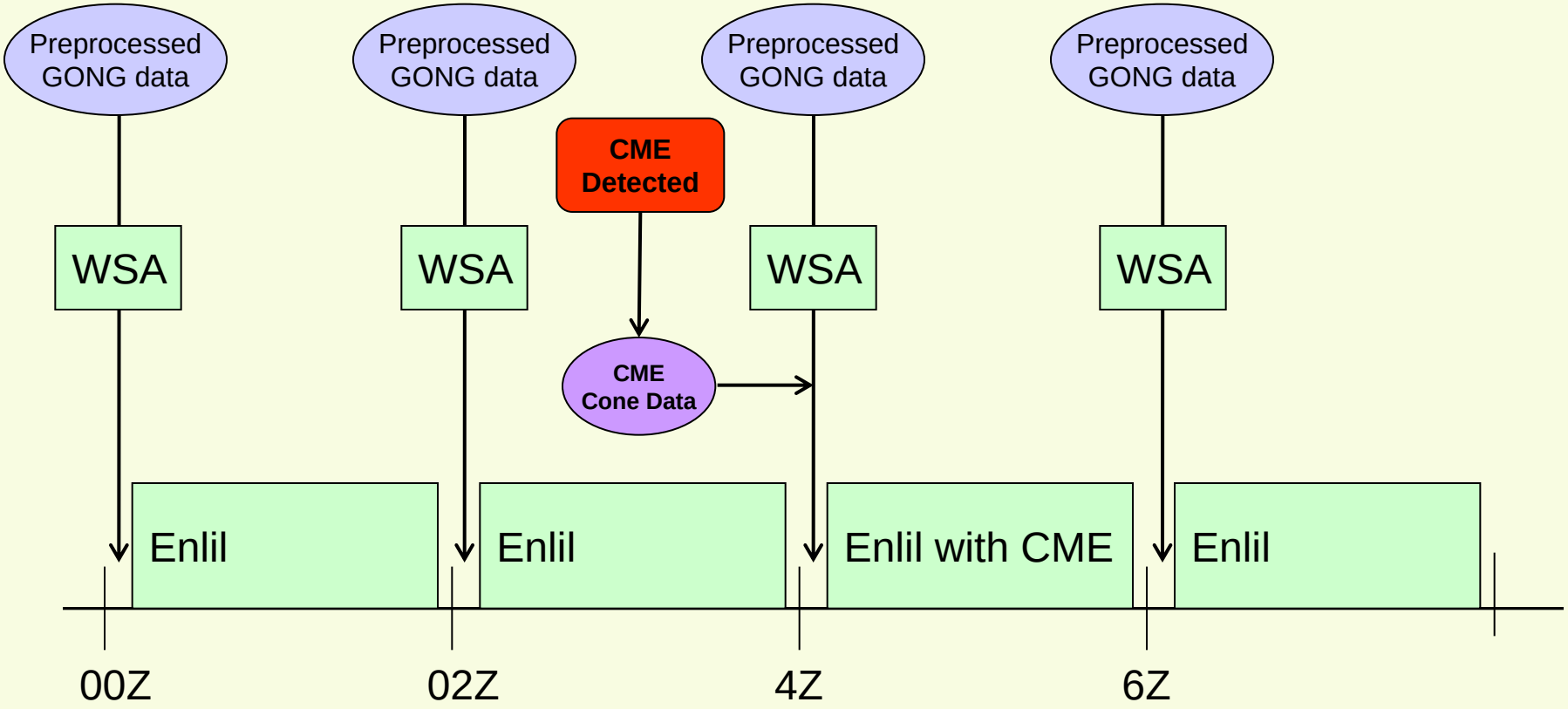
- 69.7 Teraflops Linpack (#36 Top 500 Nov 2008)
- 156 Power6 32-way Nodes
- 4,992 processors @ 4.7GHz
- 19,712 GB memory
- 170 TB of disk space
- 13 PB tape archive

Stratus— (primary)
Gaithersburg, Maryland

Cirrus — (backup)
Fairmont, West Virginia

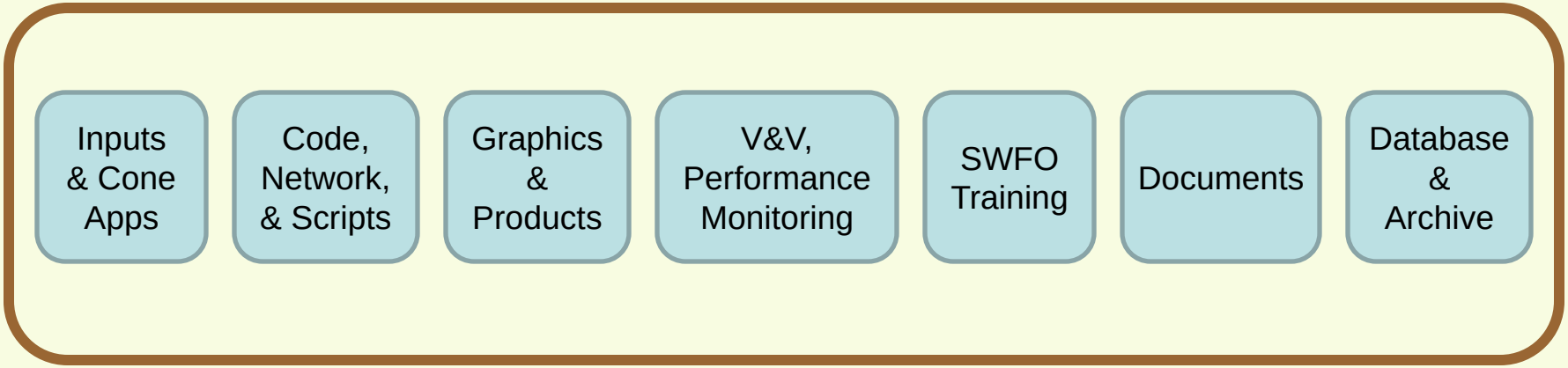
(Also, EMC development machine)

# WSA-Enlil production run cycle at NCO



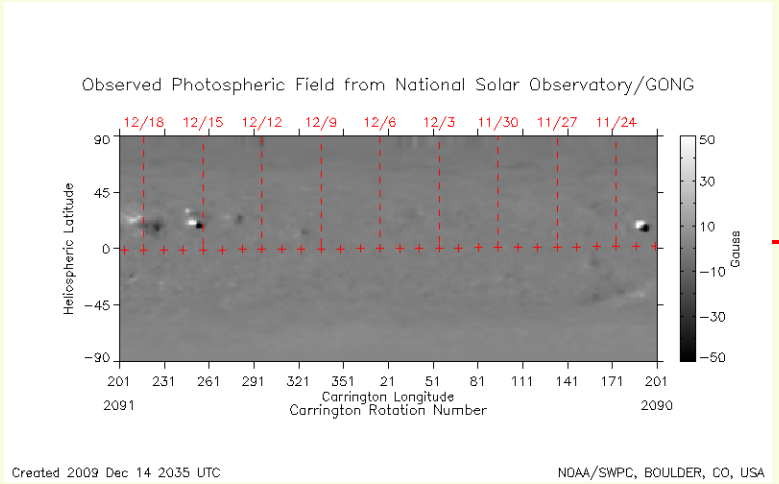
# Core Functionality

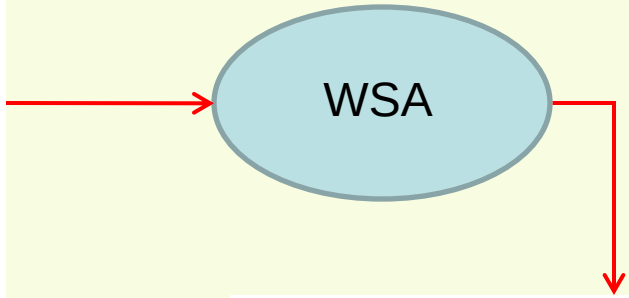
- Key idea is to ensure we deliver a system with “core functionality” on time
- Trade-offs to be made between what is really necessary and what is desirable
- Build flexibility into project structure, so as to enable future expansion

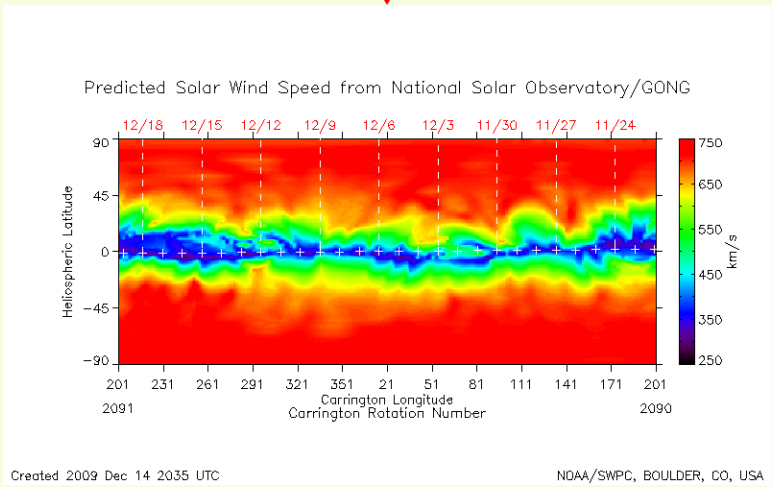


# Wang-Sheeley-Arge (WSA) model:

Utilizes synoptic map of the Sun's Photospheric magnetic field
Generates global velocity and magnetic polarity map

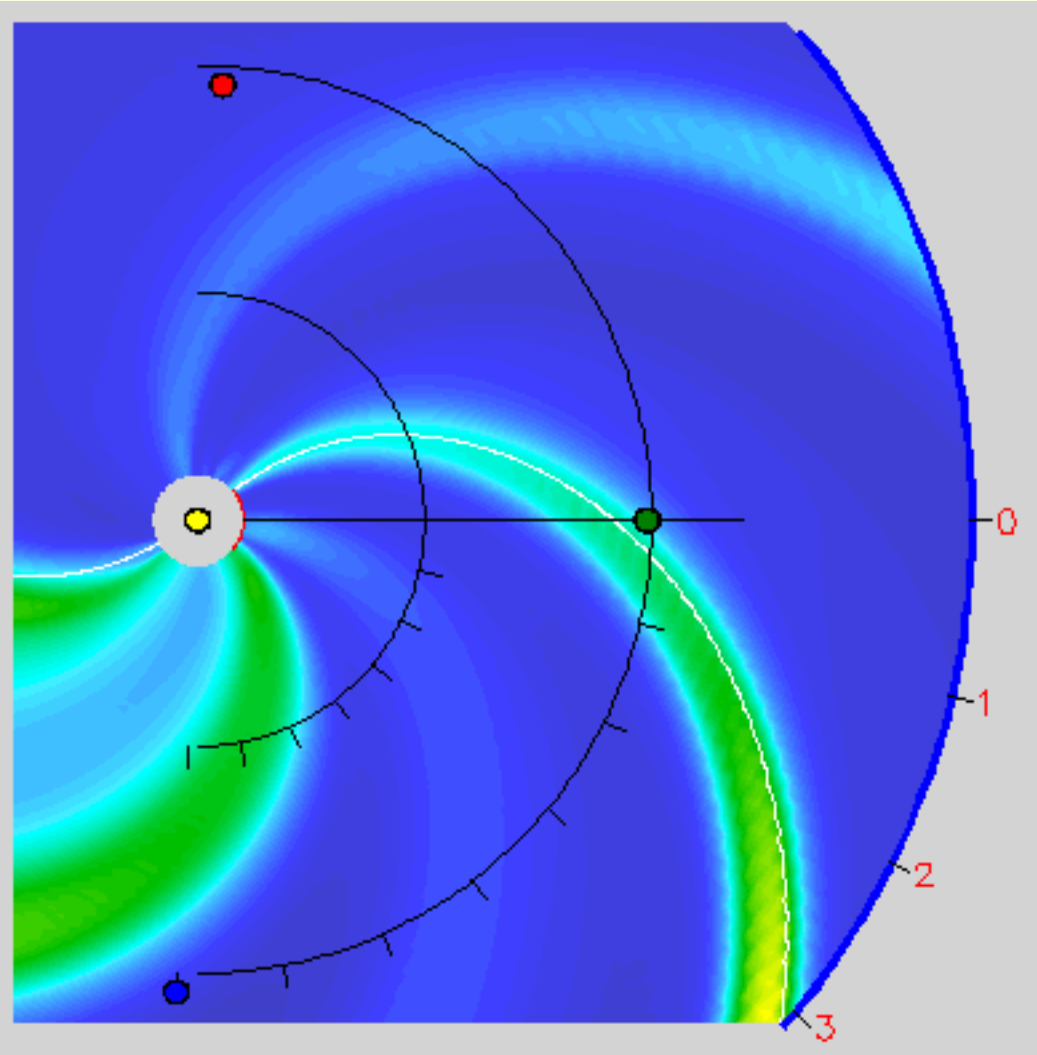


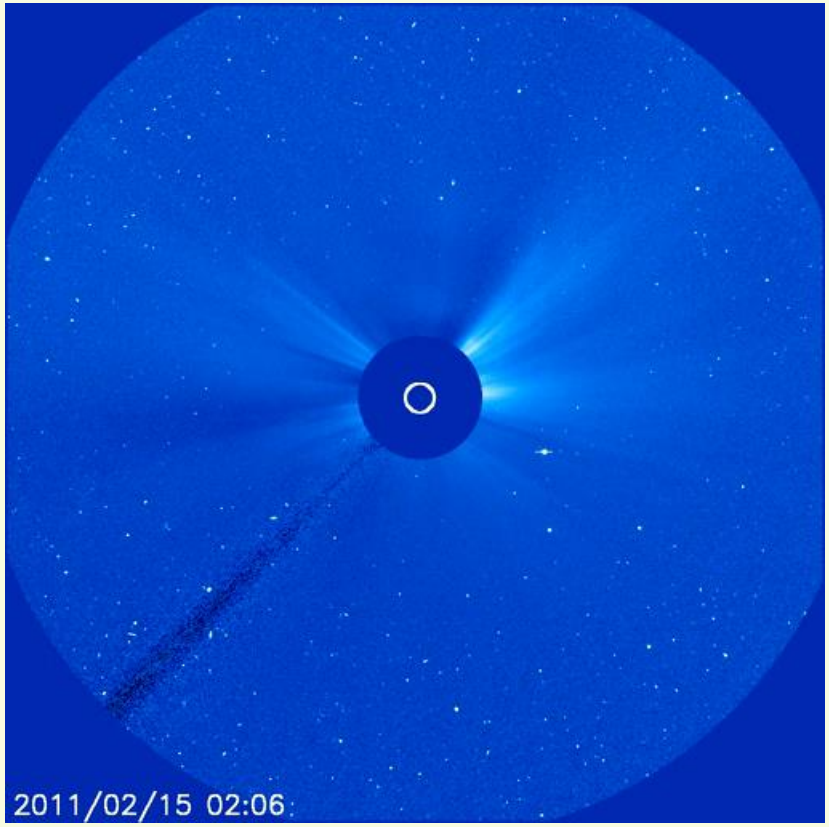

Generates, steady, corotating "ambient" background flow

# 14 Feb 2011 Ambient SW Density Structure

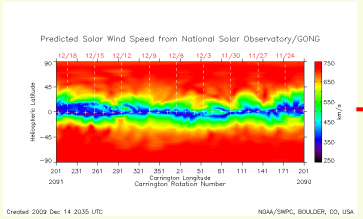


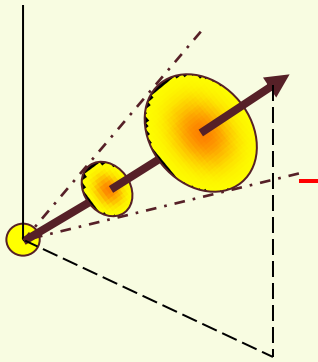
# Forecasting CME Events

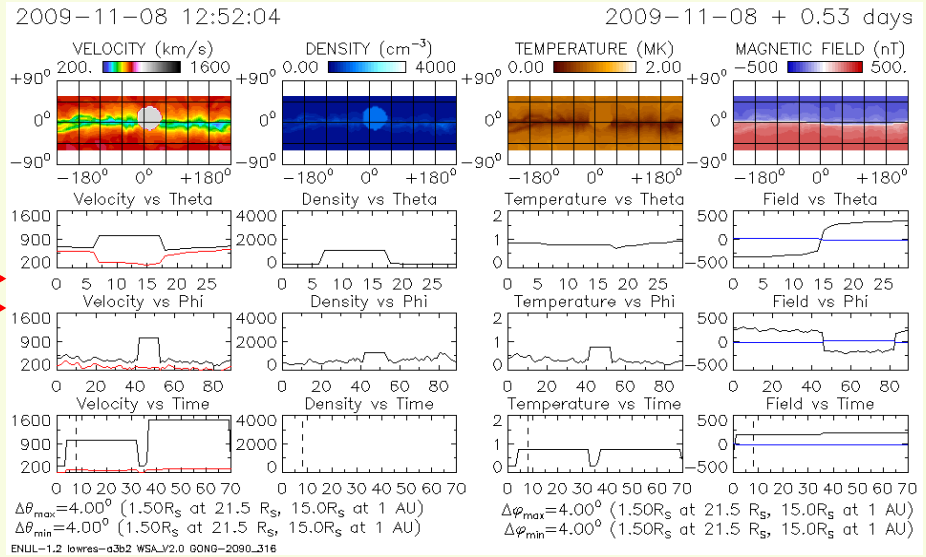
SOHO LASCO C3 Coronagraph Movie:
2011 “Valentine’s Day” CME

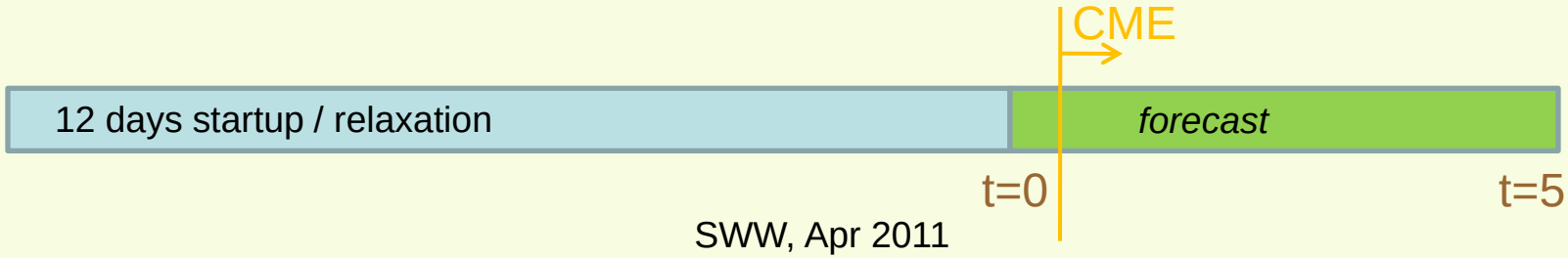


In the modeling system, a CME is represented as a “cone” of enhanced speed and density injected into the pre-existing ambient at the Enlil inner boundary at 21.5 Rsun

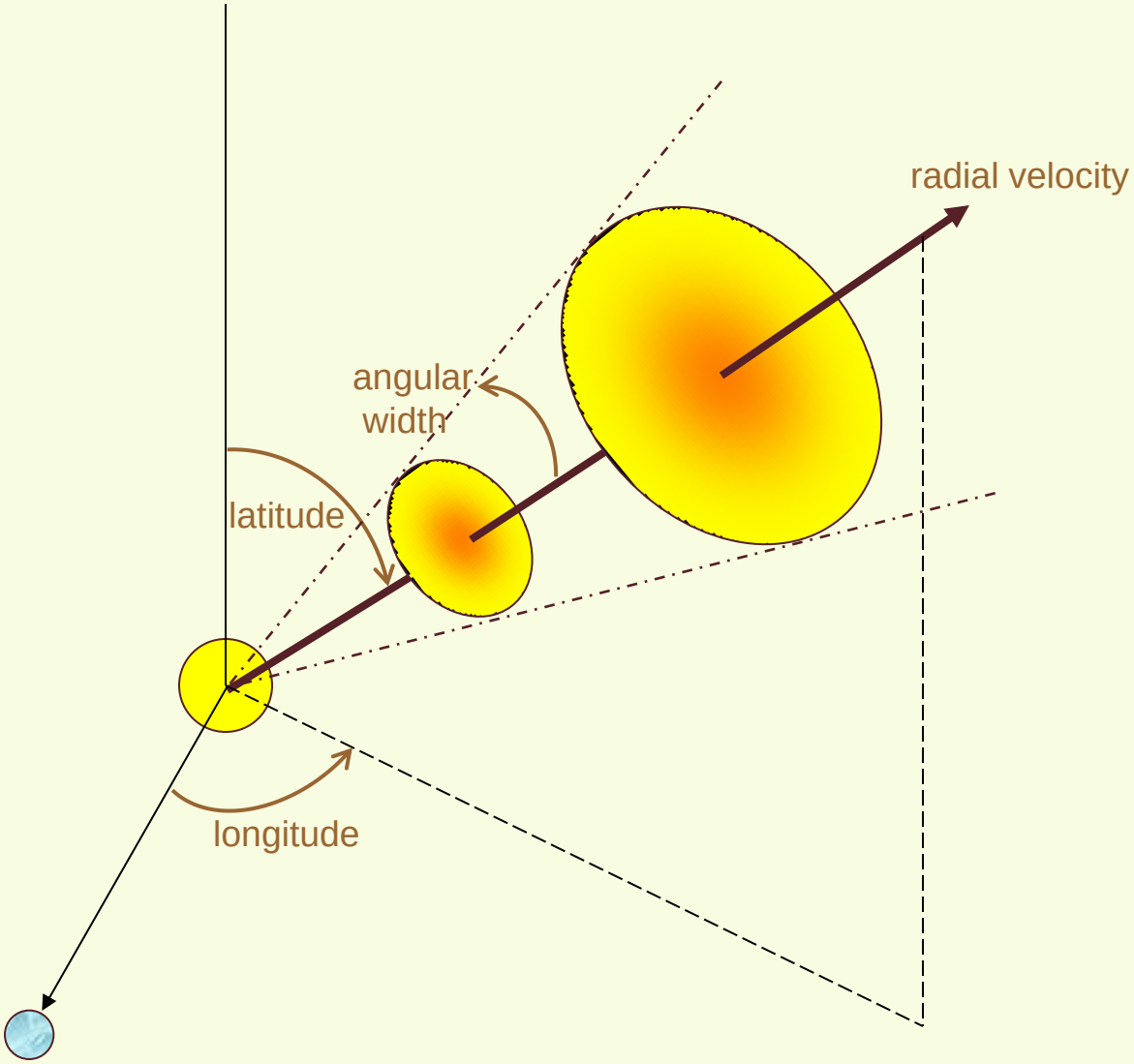




# CME cone geometry



# Cone Tools

The fundamental parameters of the injected model CME are determined from coronagraph observations

For a circular cone, these include:

speed, direction, angular width, and timing

Drawing upon work in the research community, we are developing a variety of graphical software tools to enable consistent, reliable determination of these parameters by SWFO forecast staff

This has involved substantial development effort

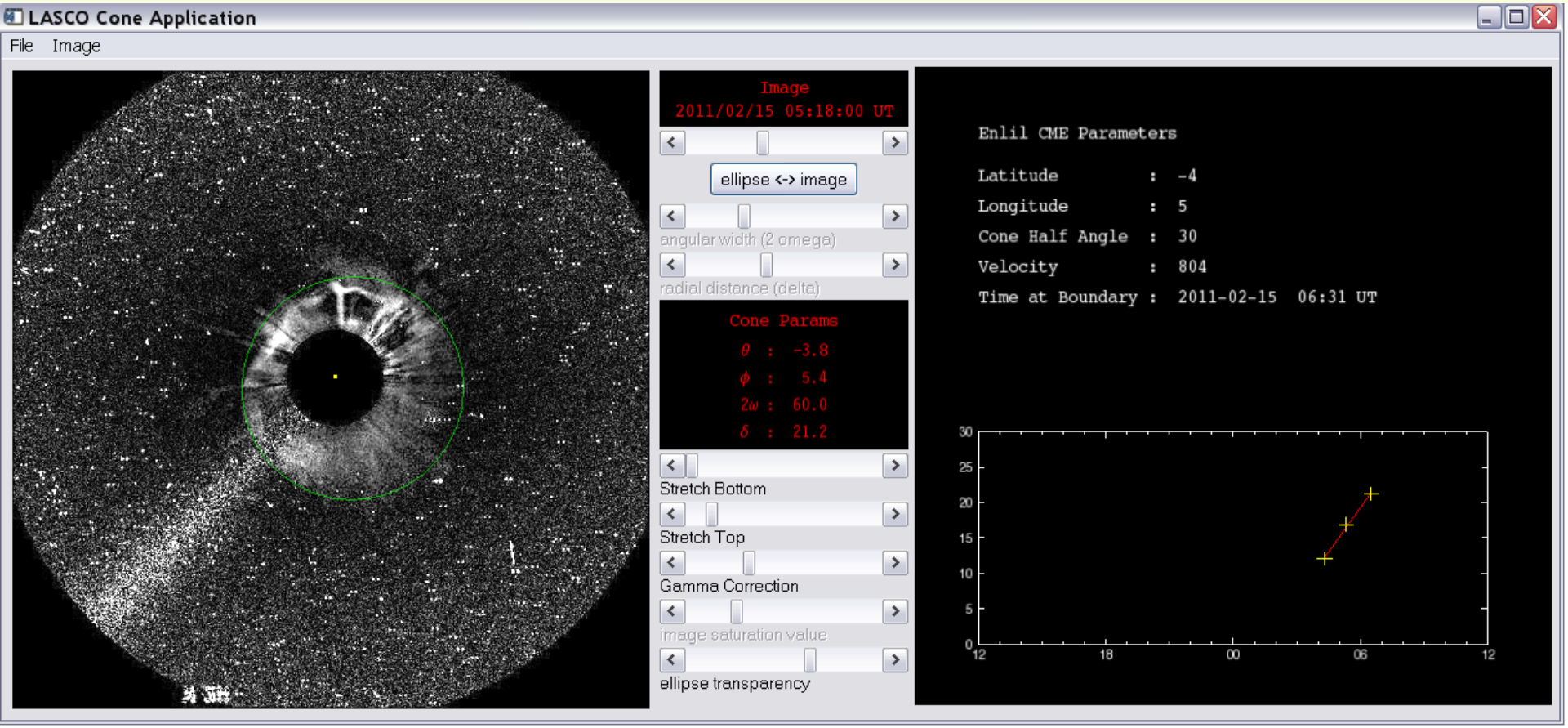
# SWPC Cone Toolset

- LASCO C2/C3 cone-fit tool (2 versions), for Earth-directed CMEs

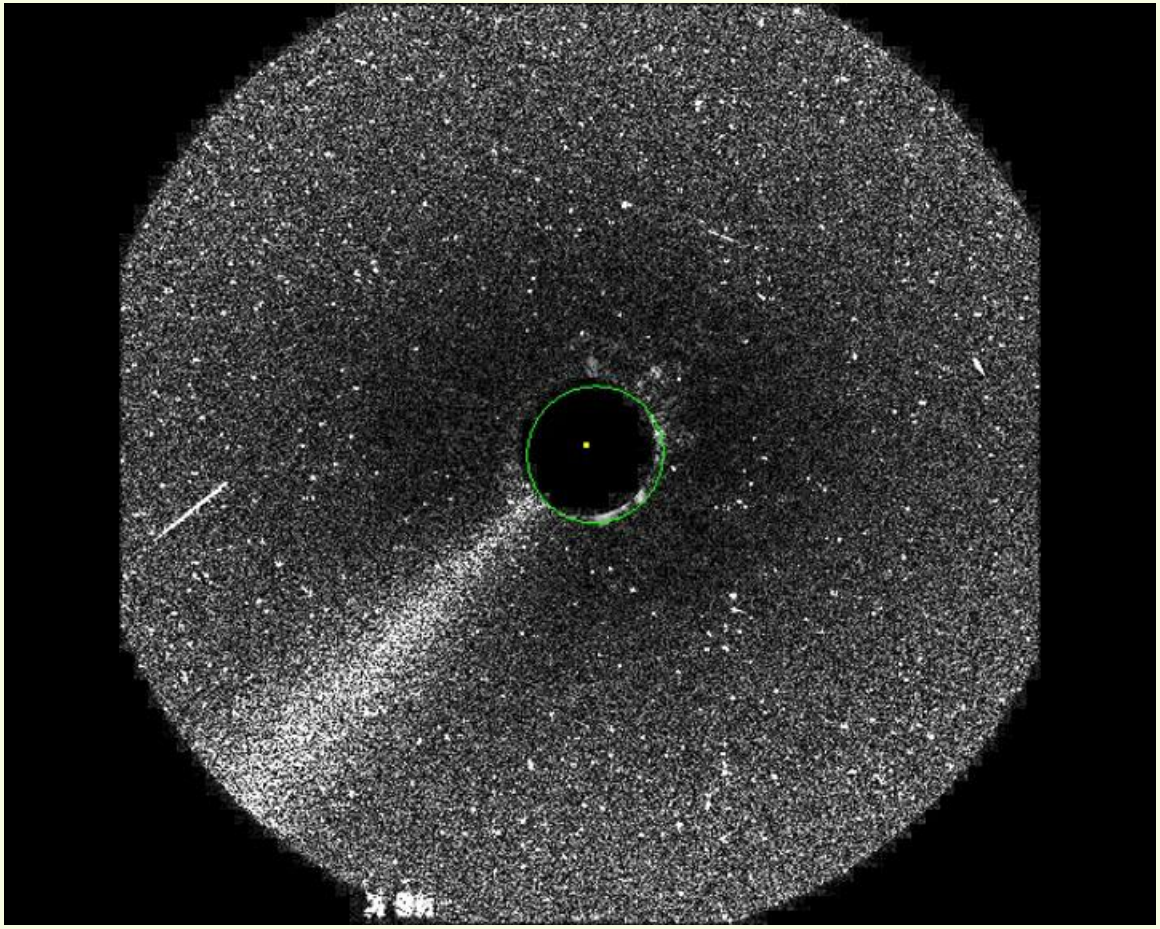
- STEREO geometric triangulation tool, which takes advantage of the differing perspectives of the two spacecraft to locate the CME in 3-space

- STEREO polarization tool, to provide supplementary information on CME location

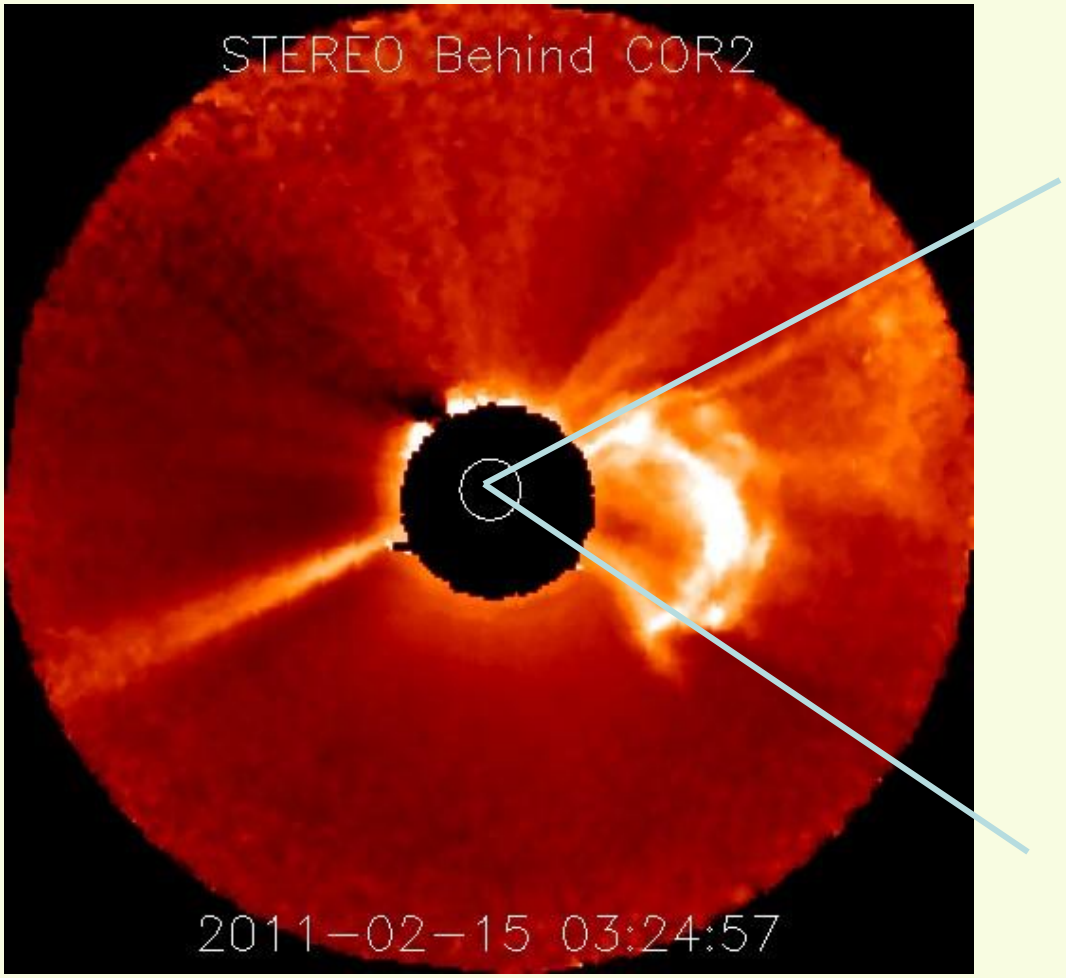
# SWPC V2.0 LASCO Cone Tool



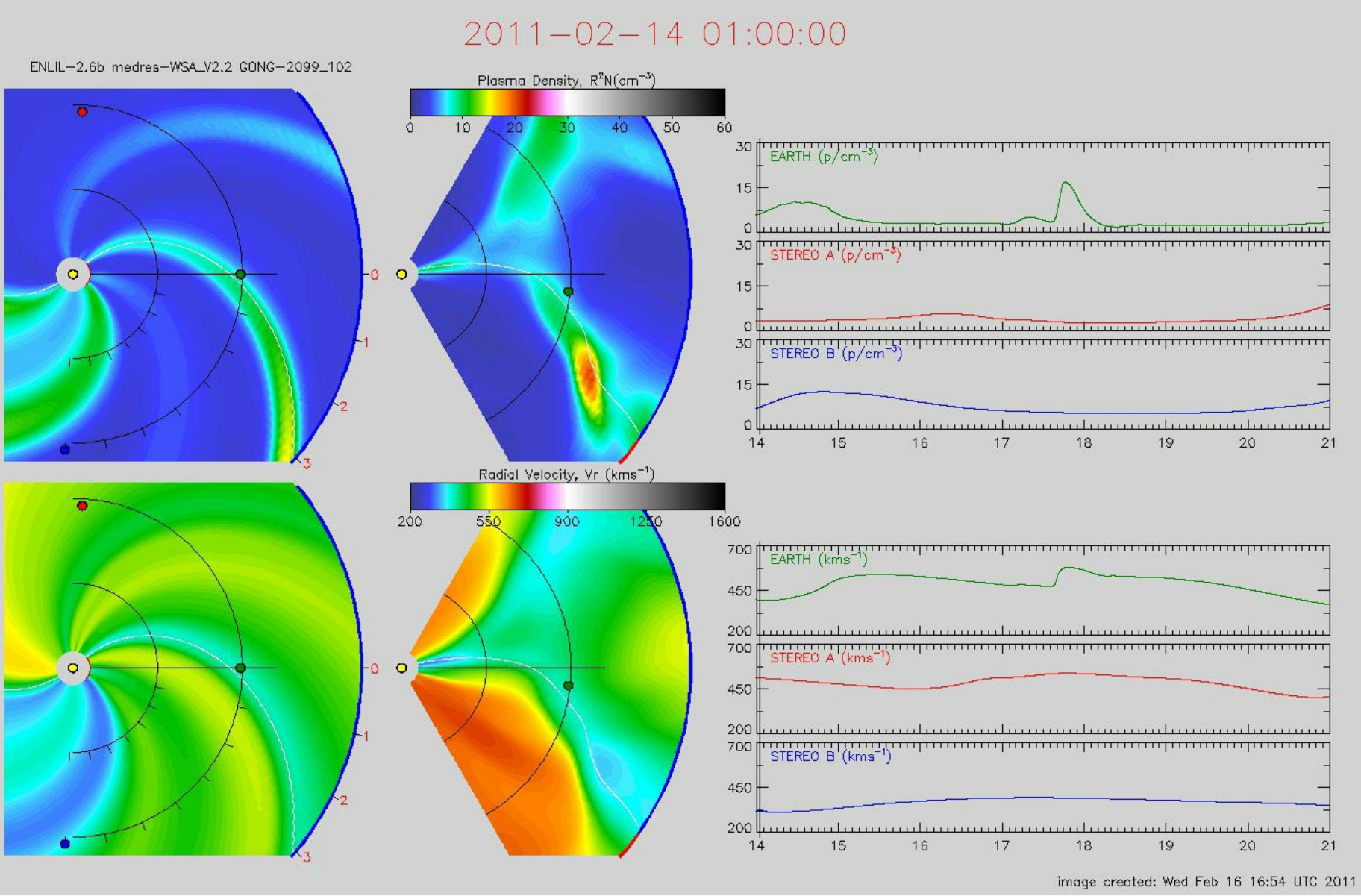
# 14-15 Feb 2011 Event



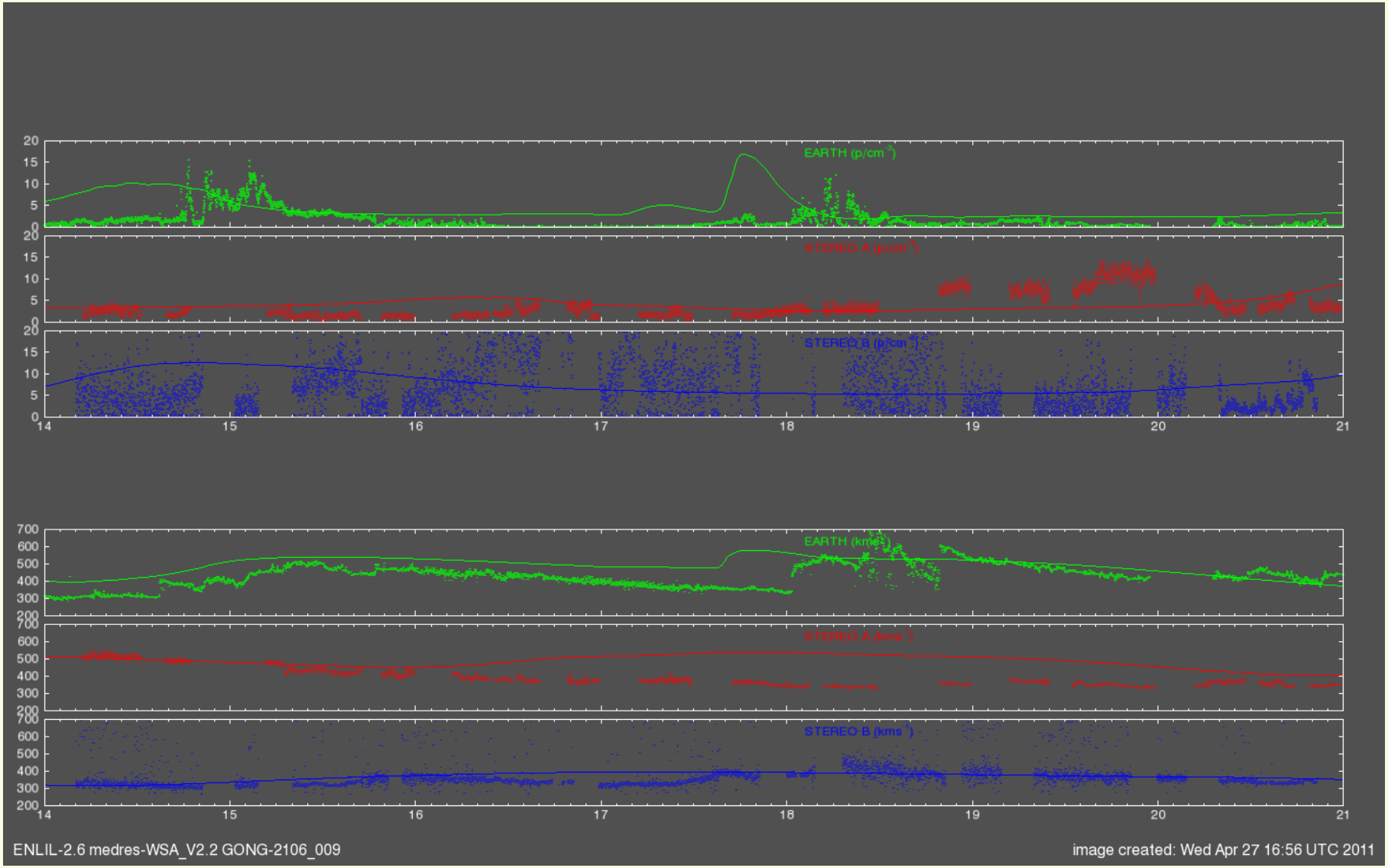
# View from STEREO B



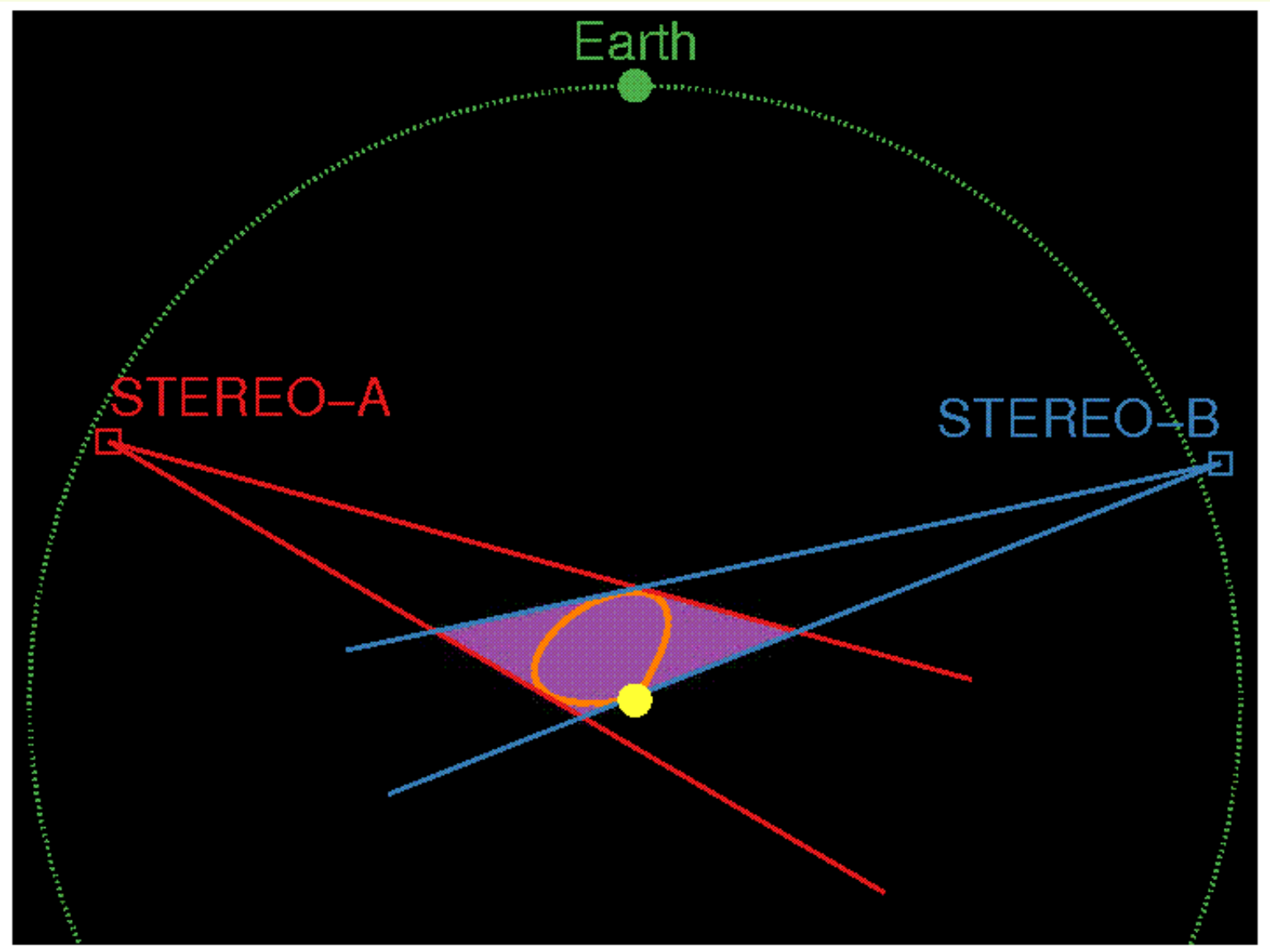
# WSA-Enlil Forecast for 14-15 Feb 2011 Event



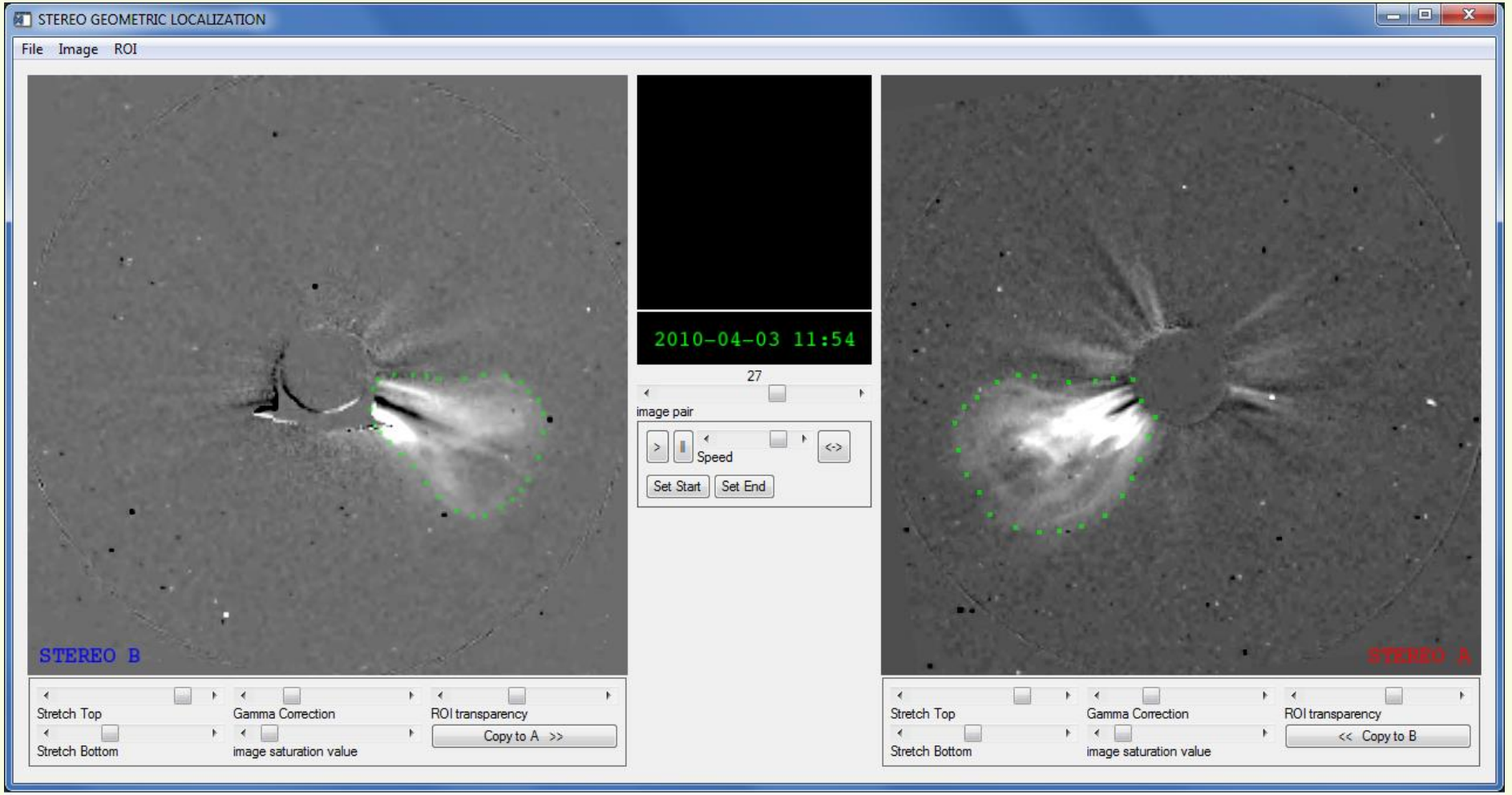
# WSA-Enlil 2011 Valentine's Day Prediction



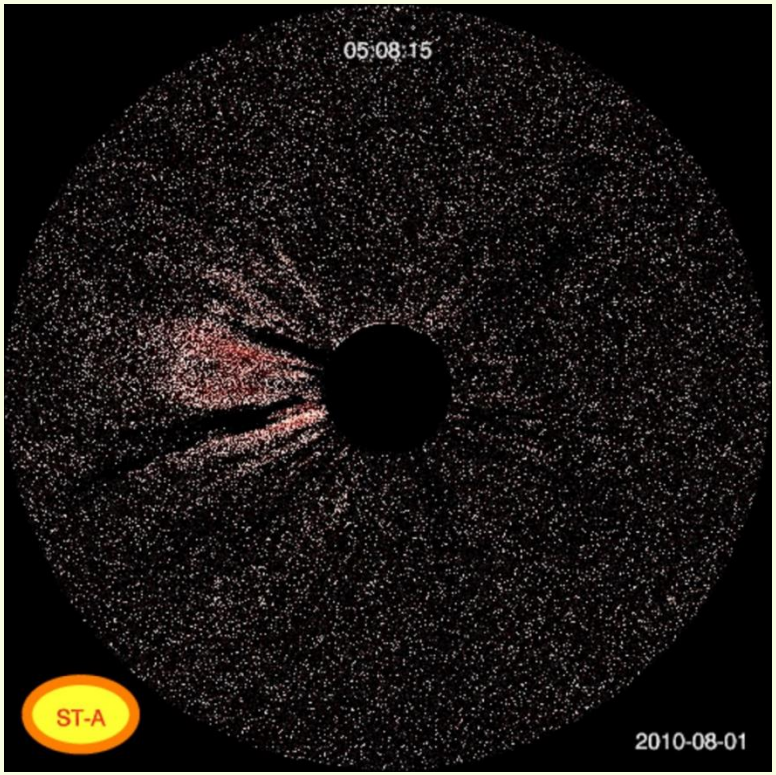
# STEREO CME Triangulation

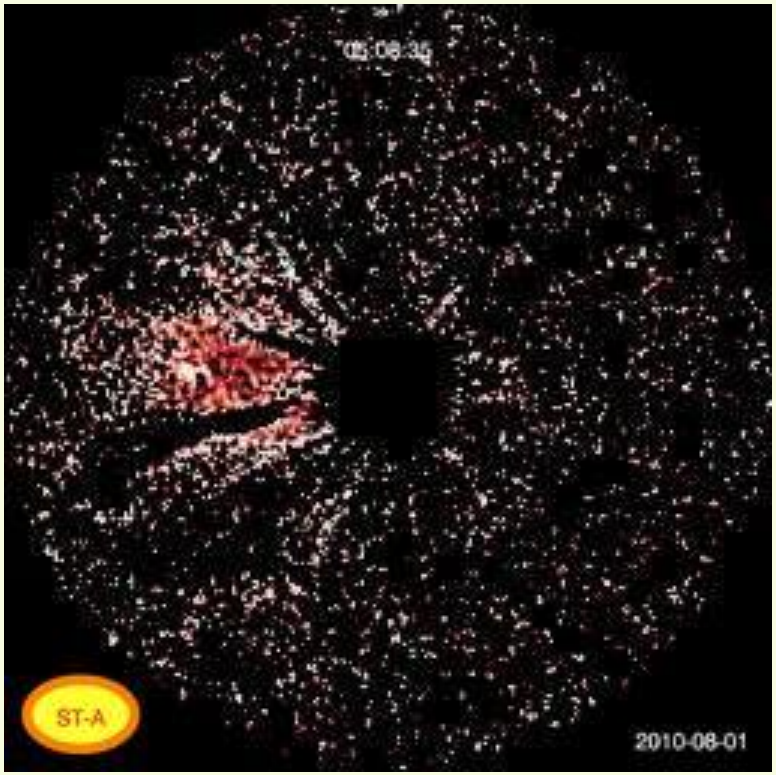


# SWPC STEREO Triangulation Tool

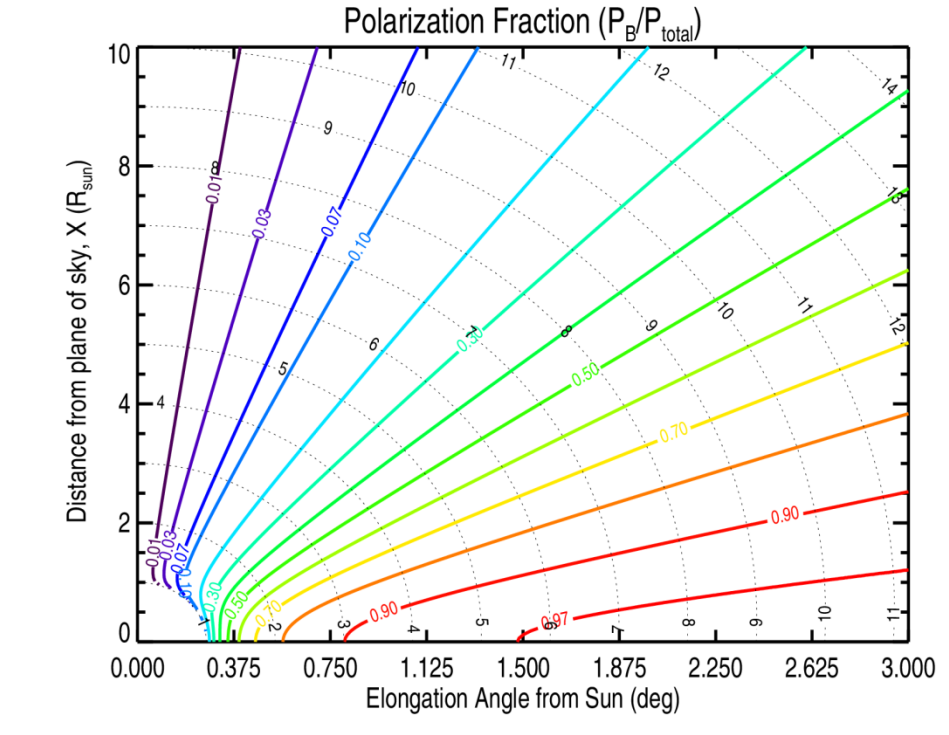


# Practicality of Polarization Analysis with STEREO Beacon Images

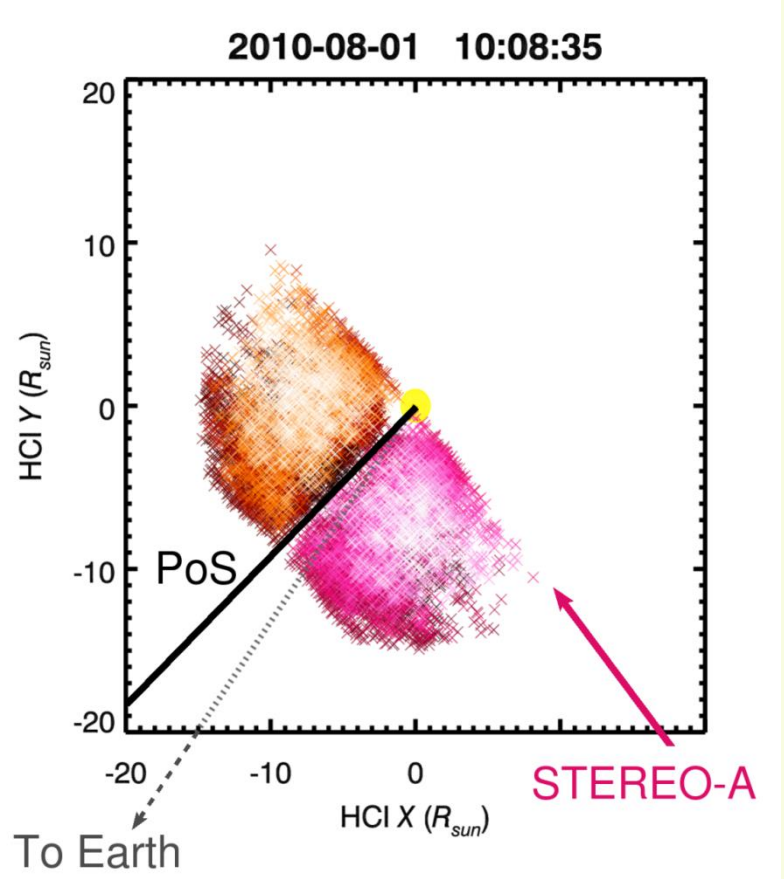


# Stereo polarization tool




(Moran & Davila, *Science*, **305**, 66, 2004)




CME Polarization Application
(de Koning & Pizzo, *SWJ*, **9**, 2011)

# WSA-Enlil V&V (Pre-deployment)

- V&V Goal 1
  - Develop a forecaster CONOPS for determining the WSA-ENLIL inputs under all possible data availability scenarios
- V&V Goal 2
  - For each methodology, determine the expected error in predicting the time of event onset at Earth

# WSA-Enlil V&V (Post-deployment)

- Comprehensive validation to cover conditions that occur over a full solar cycle
  - Must necessarily include analysis with non-STEREO tools, since those data only available since 2007
- On-going validation
  - Day-by-day and event-by-event validation
  - Analysis to include estimates based w/wo multi-view data

# Forecaster (SWFO) Participation

A critical aspect is engaging forecasters in the process

- Involvement in system planning and development
  - forecaster perspective early on in the development of tools, outputs, and model database content
  - forecaster help in *β*-testing of system components
- Training
  - seminars to enhance knowledge of pertinent physics
  - training for software tools used to:
    - generate model inputs (e.g.,“cone” analysis tools)
    - interpret outputs (graphics)
  - joint discussions of events occurring during the transition

# Database Gateway (in $\beta$-testing mode)

# Current Status

- Running on EMC “Vapor” development machine

- Have migrated to NCEP "Cirrus“ and “Stratus” operational systems, running 4x per day mode on hot backup

- Most data flow infrastructure in place, the rest in progress

- Delivery of ready-to-go system: end of FY11

# FY12

## System Test Year (“Shakedown Cruise”)

- Modifications to Enlil
  - Continuous updating mode
  - Incorporation of AFRL/WSA-“ADAPT” system
- Performance Tracking (distinct from V&V)
- Continued training
- Adjustable cone inputs (use mass estimates)
- Improved graphics (incl 3D)
- Refinement of cone tools (Multi-View tool)

# O2R

Database of uniformly treated CME events

Sharpen requirements for better observational input

Make software tools available for broader use

Grants for applied research?

# Availability of Predictions and Forecasts on the Web and Archives

Near term – private pages for both forecasts and archives

FY12 – public access via SWPC web page and NGDC archive site

# Looking forward…

- **Keep the input data flowing**

  Timely replacements for ground & space platforms

- CME internal magnetic structure

  Coronal magnetic observations? MWA?

- Enroute tracking

  STEREO HI-1 at $L_5$, improved SMEI, IPS?

- Energetic particles

  CME shock-associated generation/propagation