From Research To Operations: Transitioning CISM Models

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Overview

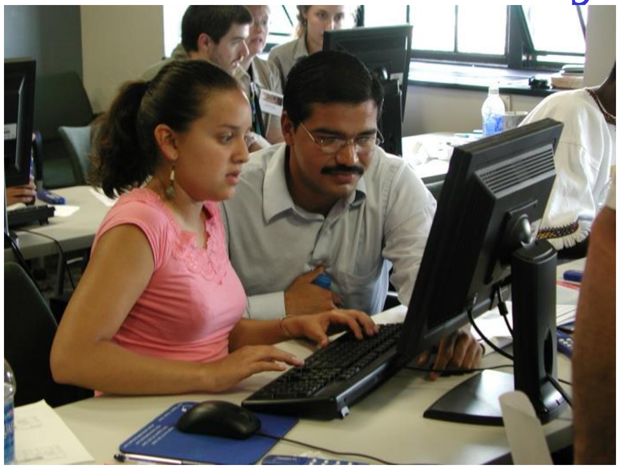
- CISM
- Models in transition or being readied for transition.
  - WSA-Enlil – in transition
  - CMIT – ready for transition
  - SEPMod – under development and testing
- Lessons Learned
- Future of Space Weather Modeling

Center for Integrated Space weather Modeling

- An NSF Science and Technology Center
  10-year lifetime: August 2002 – July 2012
- Developing a Sun-to-Earth suite of models
- A multi-institutional center led by Boston University involving 11 other institutions
- Strong partnerships and working relationships with SWPC, AFRL, CCMC
- Efforts in research, education, knowledge transfer, and increasing diversity in science.

The CISM Space Weather Summer School

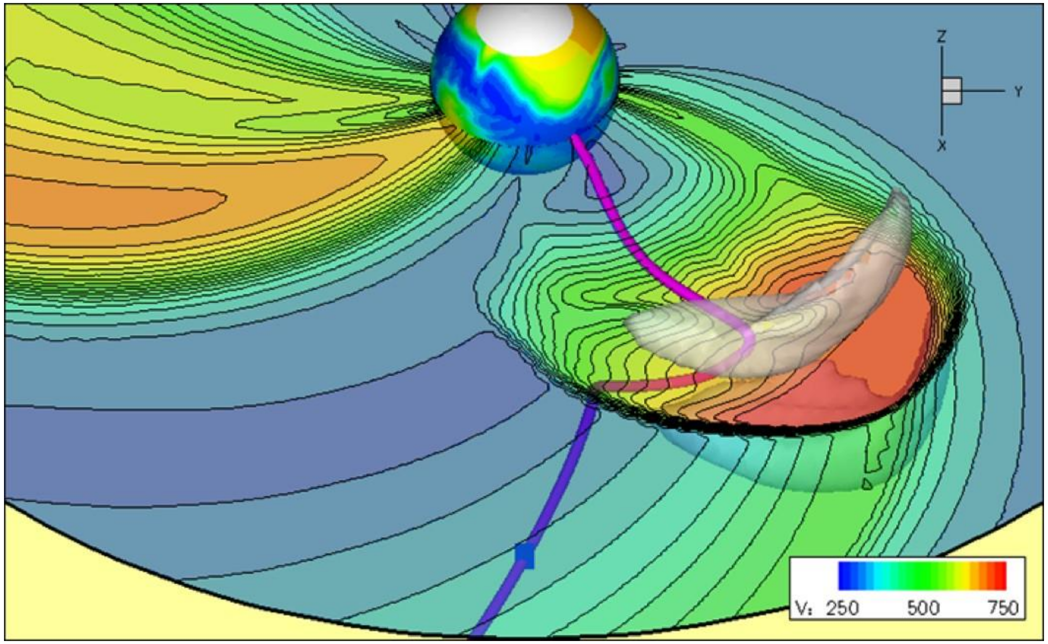
This year: July 19 - 30, 2010



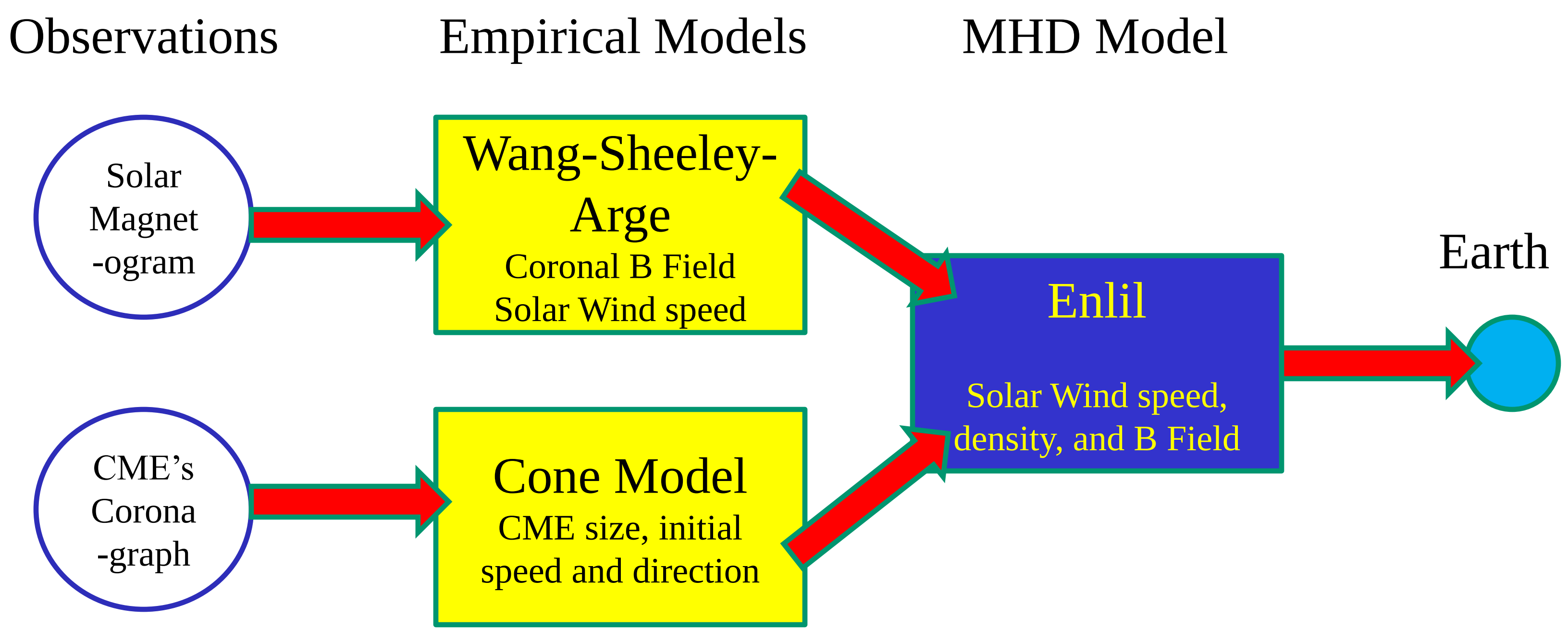
Students and faculty working at the CISM Summer School – a two-week school held each year.

WSA-ENLIL-Cone Transient Solar Wind

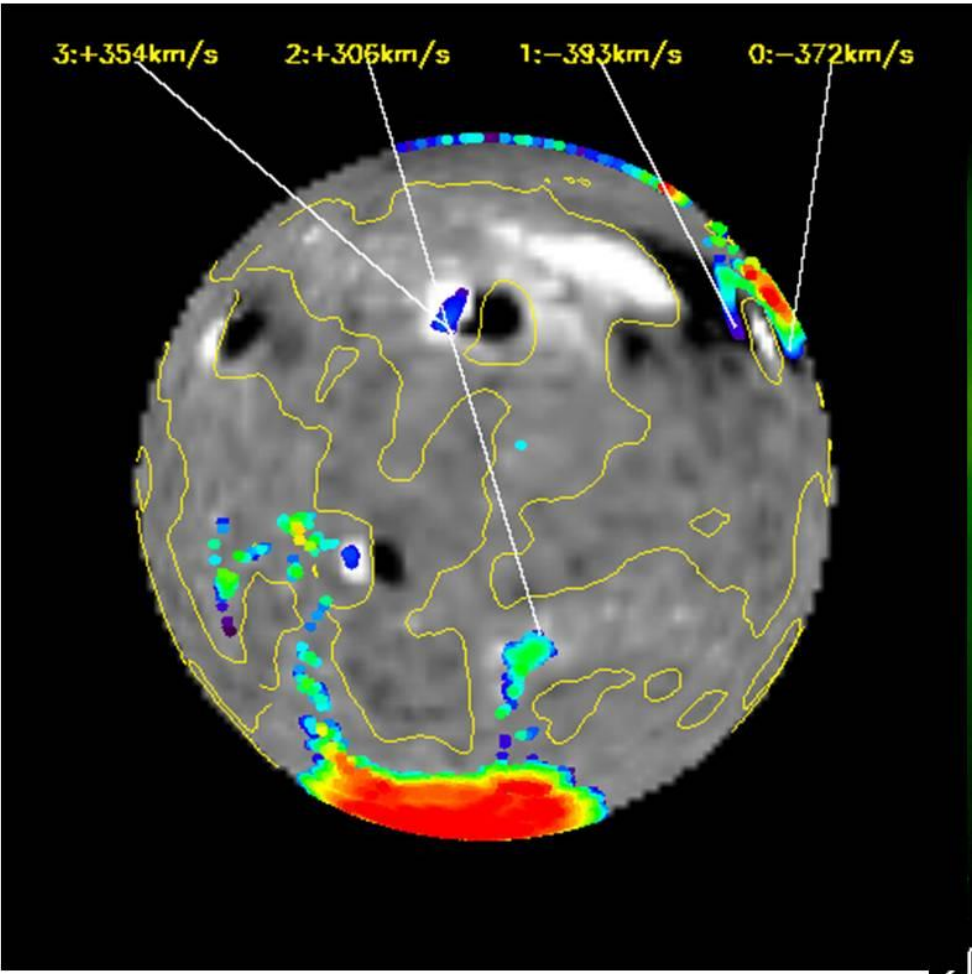
- Undergoing formal transition to NCEP operations.
- Transition now largely out of CISM hands.
- Research on cone parameter specification & sensitivities for forecast involves CISM and partners.

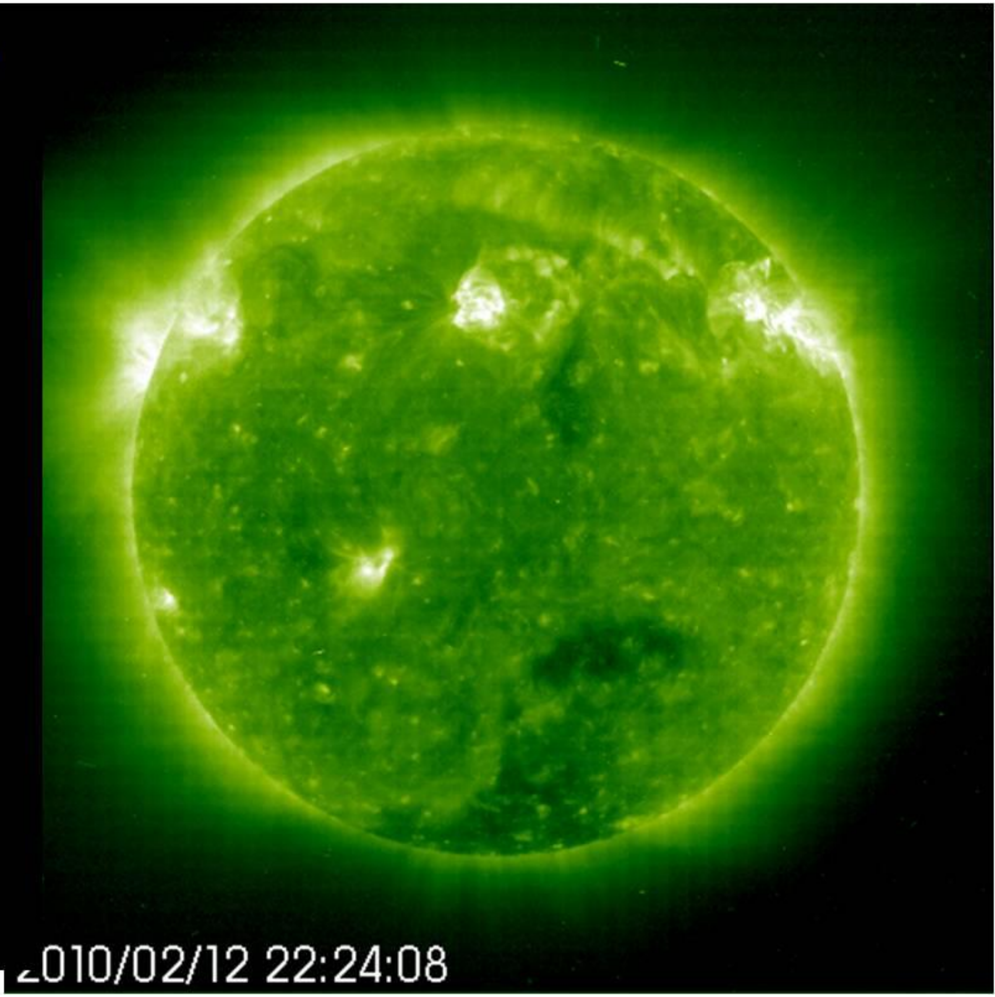


WSA-Enlil-Cone model



Wang-Sheeley-Arge Model Visualization Tool

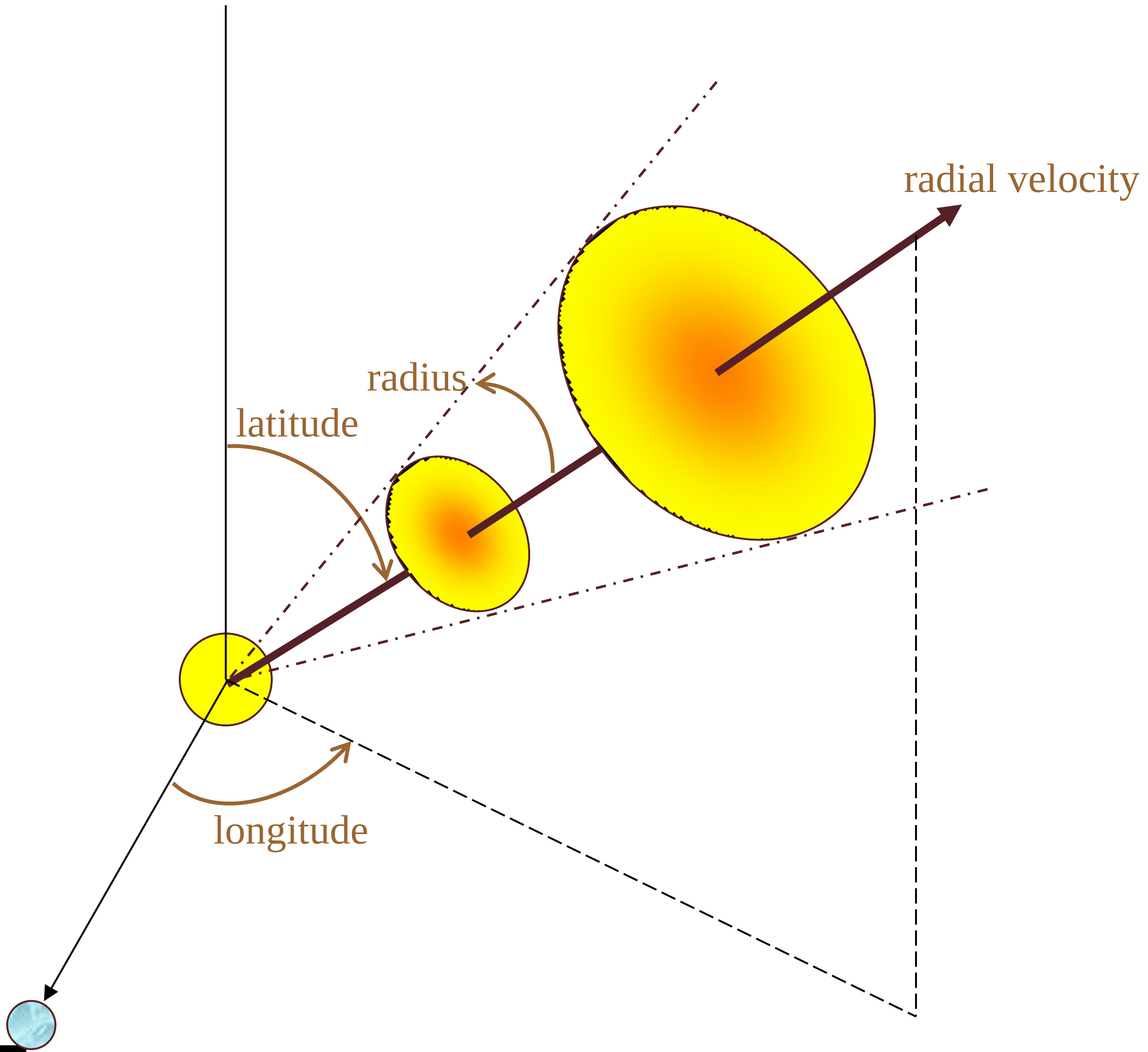




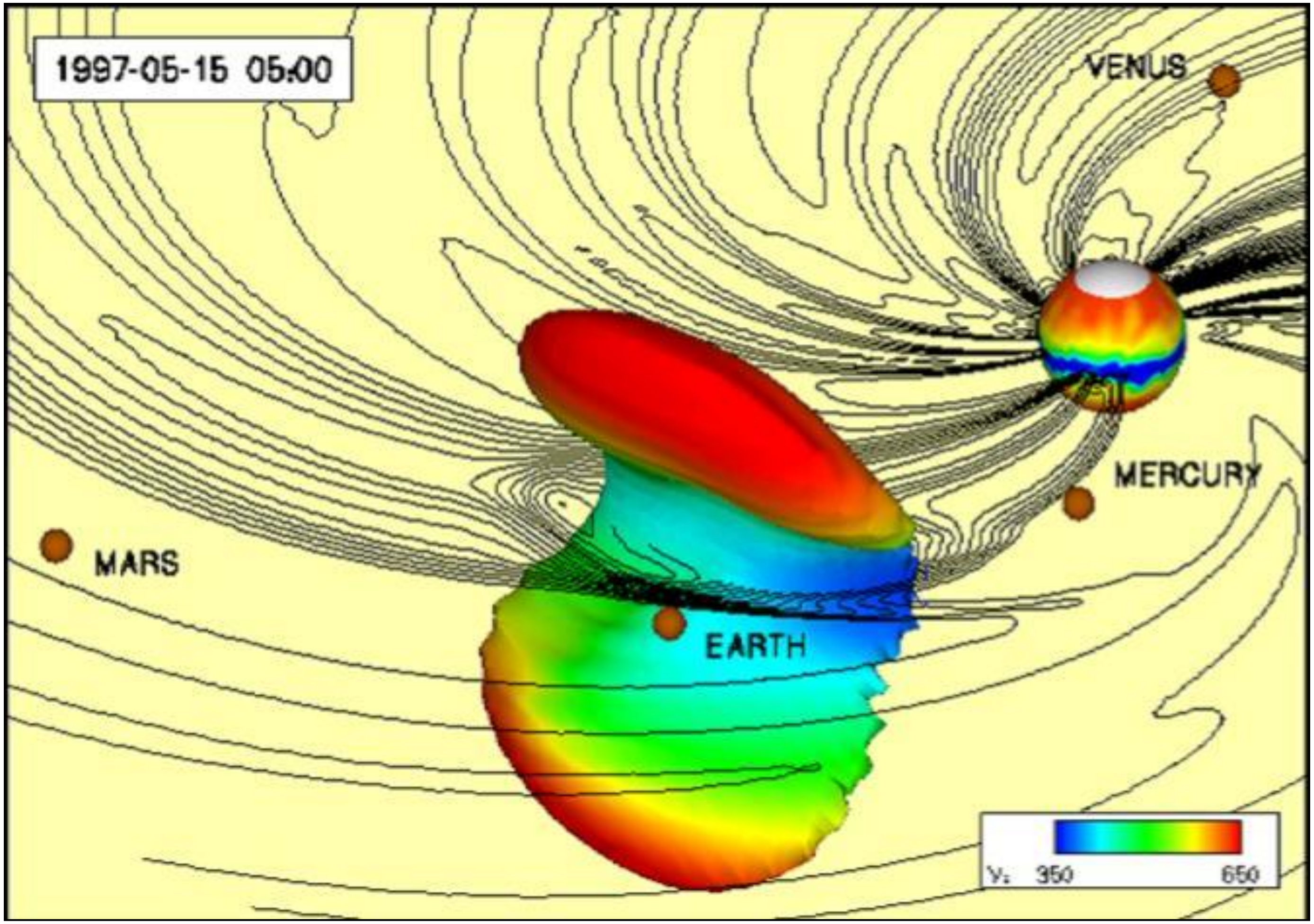
Grey – surface magnetic field strength
Color – open mag field with solar wind speed

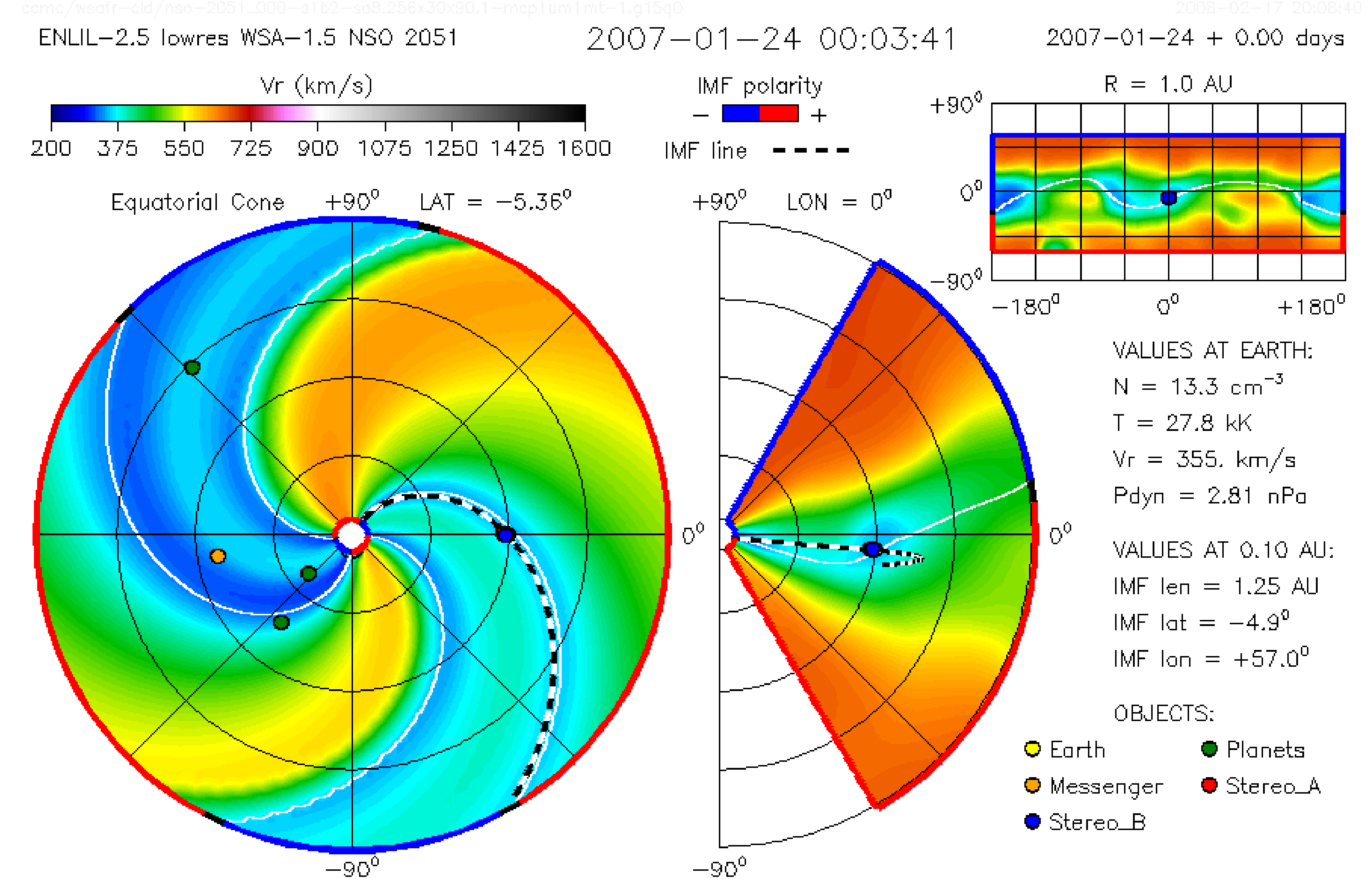
SOHO EIT image for comparison

CME cone geometry



CME Visualization




ENLIL-2.5 lowres WSA-1.5 NSO 2051
2007-01-24 00:03:41
2007-01-24 + 0.00 days
Vr (km/s)
200 375 550 725 900 1075 1250 1425 1600
IMF polarity
− +
IMF line
R = 1.0 AU
+90°
0°
−90°
−180° 0° +180°
Equatorial Cone
+90°
LAT = −5.36°
−90°
0°
+90°
LON = 0°
−90°
0°
VALUES AT EARTH:
N = 13.3 cm^{-3}
T = 27.8 kK
Vr = 355. km/s
Pdyn = 2.81 nPa
VALUES AT 0.10 AU:
IMF len = 1.25 AU
IMF lat = −4.9°
IMF lon = +57.0°
OBJECTS:
Earth
Planets
Messenger
Stereo_A
Stereo_B

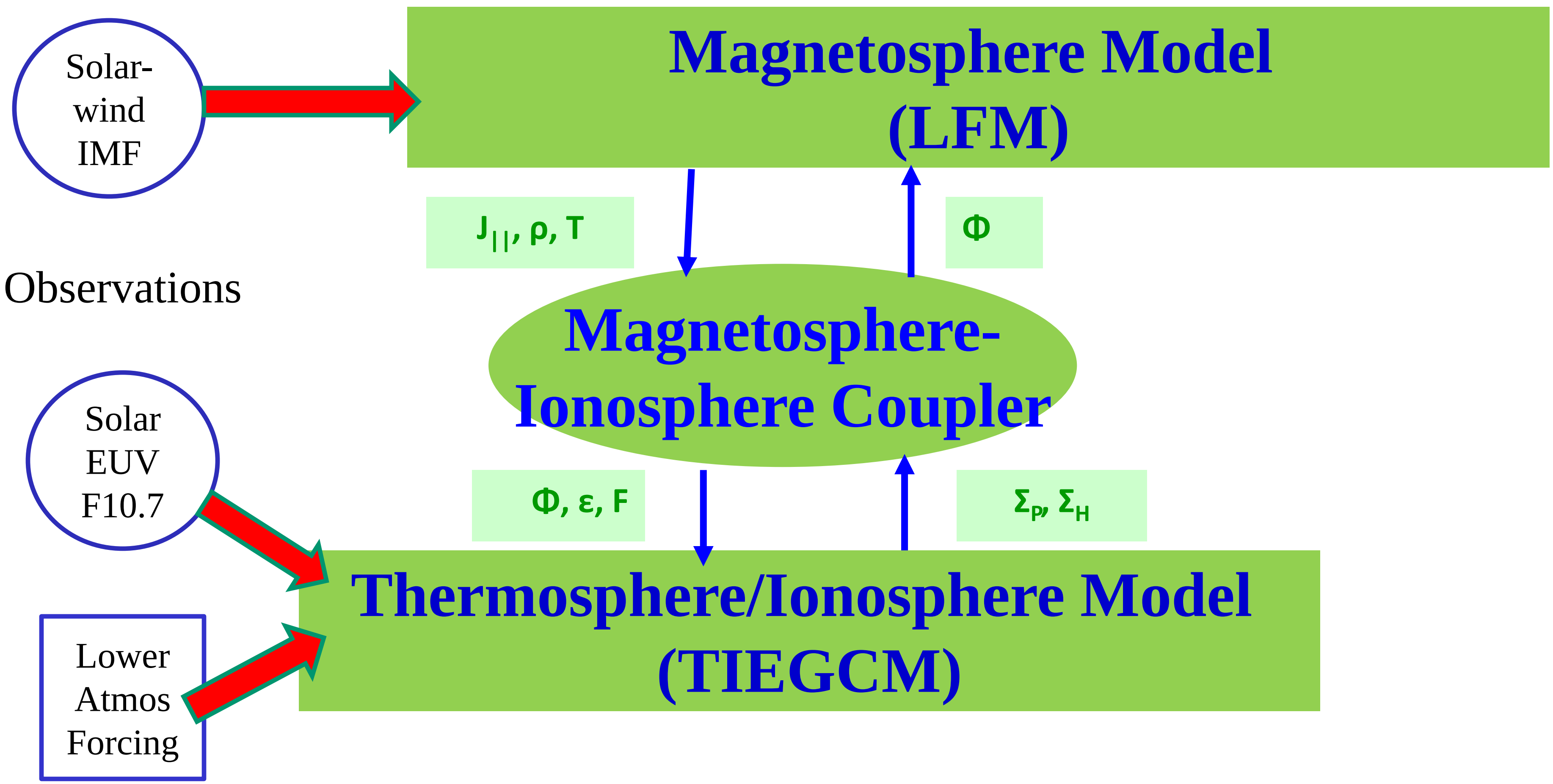
Intended SWx Benefits

- Provide 1-4 days advance warning of oncoming CMEs
- Provide improved warning of CIRs
- Pave the way for future generations of SWx models:
  - Geospace
  - Ionosphere
  - Upper atmosphere
  - Energetic particles

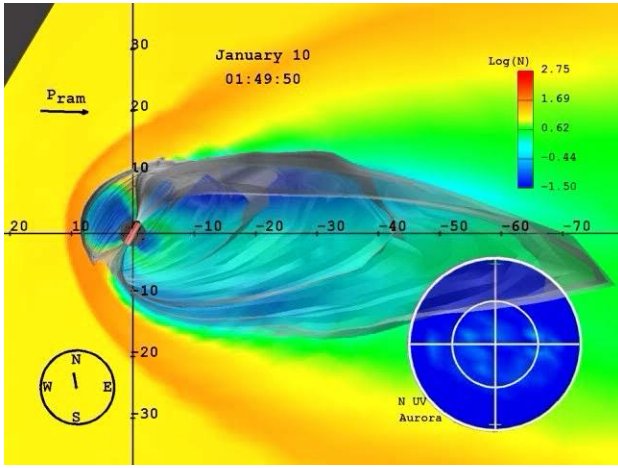
Coupled Magnetosphere Ionosphere Thermosphere model -- CMIT

- CMIT Model Overview
  - LFM, MIX, TIEGCM Components
  - Resolution and Performance
- Previous Validation efforts
  - Magnetospheric climatology
  - Regional dB/dt

CMIT – models the geospace system

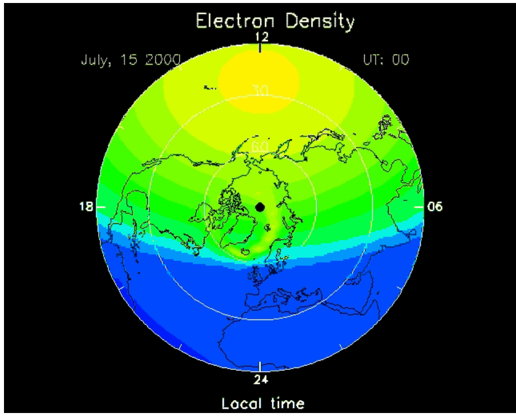


LFM Magnetospheric Model



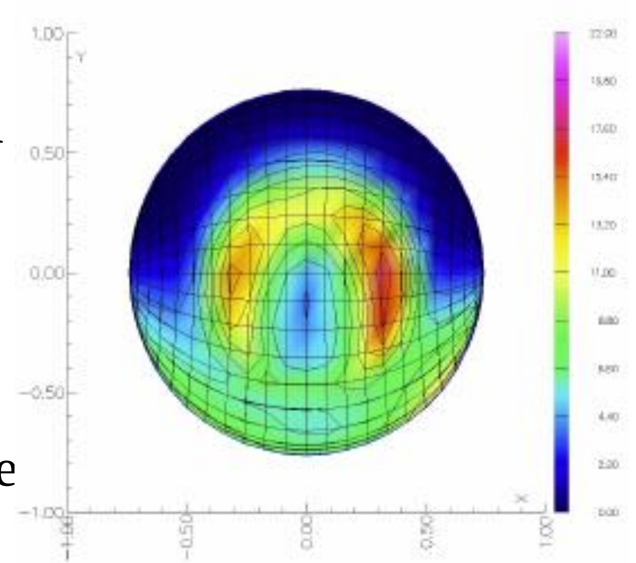
- Uses the ideal MHD equations to model the interaction between the solar wind, magnetosphere, and ionosphere
  - Computational domain
    - 30 R_E < X < -300 R_E & ±100R_E for YZ
    - Inner radius at 2 R_E
  - Calculates
    - full MHD state vector everywhere within computational domain
  - Requires
    - Solar wind MHD state vector along outer boundary
    - Empirical model for determining energy flux of precipitating electrons
    - Cross polar cap potential pattern in high latitude region which is used to determine boundary condition on flow

TIEGCM



- Uses coupled set of conservation and chemistry equations to study mesoscale process in the thermosphere-ionosphere
  - Computational domain
    - Entire globe from approximately 97km to 500km in altitude
  - Calculates
    - Solves coupled equations of momentum, energy, and mass continuity for the neutrals and O^+
    - Uses chemical equilibrium to determine densities, temperatures other electrons and other ions (NO^+, O_2^+,N_2^+,N^+)
  - Requires
    - Solar radiation flux as parameterized by F10.7
    - Auroral particle energy flux
    - High latitude ion drifts
    - Tidal forcing at lower boundary

MIX Ionospheric Simulation

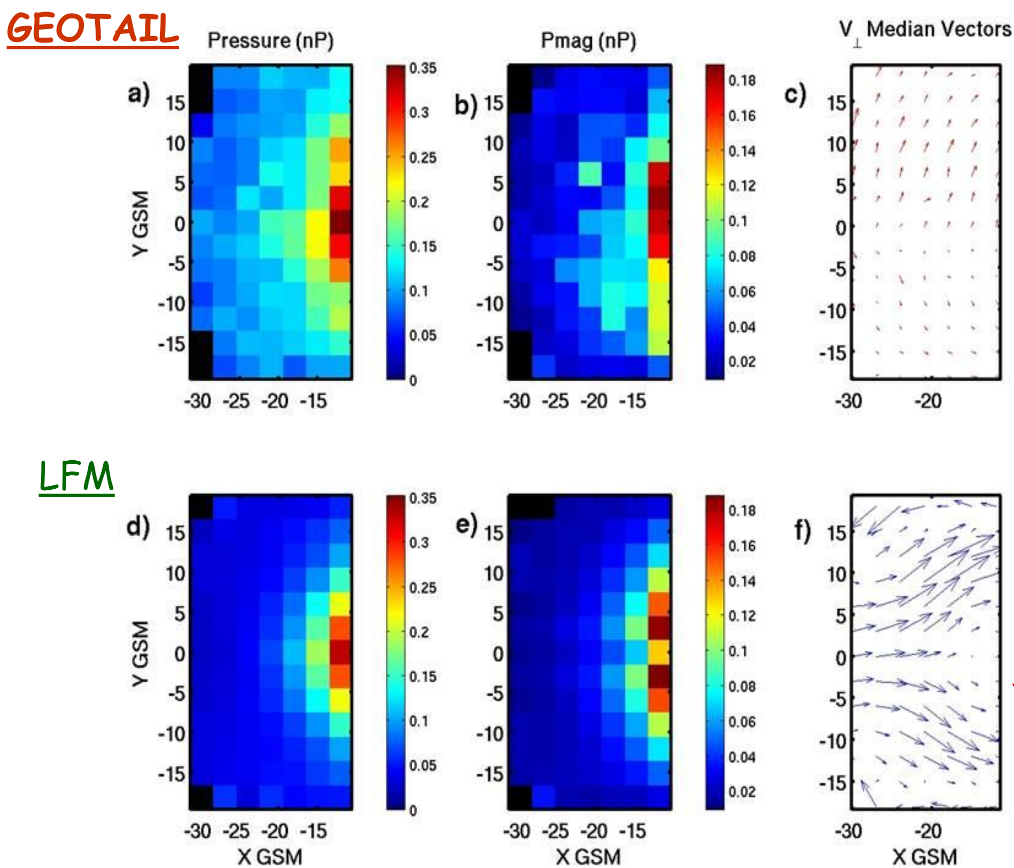


- Uses the conservation of current to determine ionospheric currents and the cross polar cap potential
  - Computational domain
    - 2D slab of ionosphere, usually at 120 km altitude and from pole to 45 magnetic latitude
  - Calculates
    - $\nabla \cdot \left(\Sigma_P + \Sigma_H\right) \nabla \Phi = J_{\parallel} \sin(\eta)$
  - Requires
    - FAC distribution
    - Energy flux of precipitating electrons
    - F10.7 or conductance

Performance

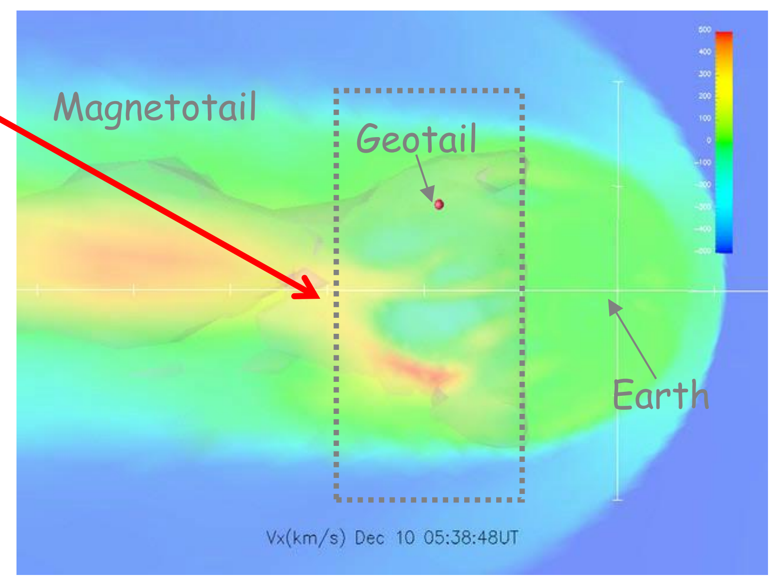
- CMIT Performance is a function of resolution in the magnetosphere ionosphere system
  - Low resolution
    - 53x24x32 cells in magnetosphere with variable resolution smallest cells ½ RE
    - 5° x 5° with 49 pressure levels in the ionosphere-thermosphere
    - On 8 processors of an IBM P6 it takes 20 minutes to simulate 1 hour
  - Modest resolution
    - 53x48x64 cells in the magnetosphere with variable resolution smallest cells ¼ RE
    - 2.5° x 2.5° with 98 pressure levels in the ionosphere-thermosphere
    - On 24 processors of an IBM P6 it takes an hour to simulate and hour

Magnetospheric Climatology



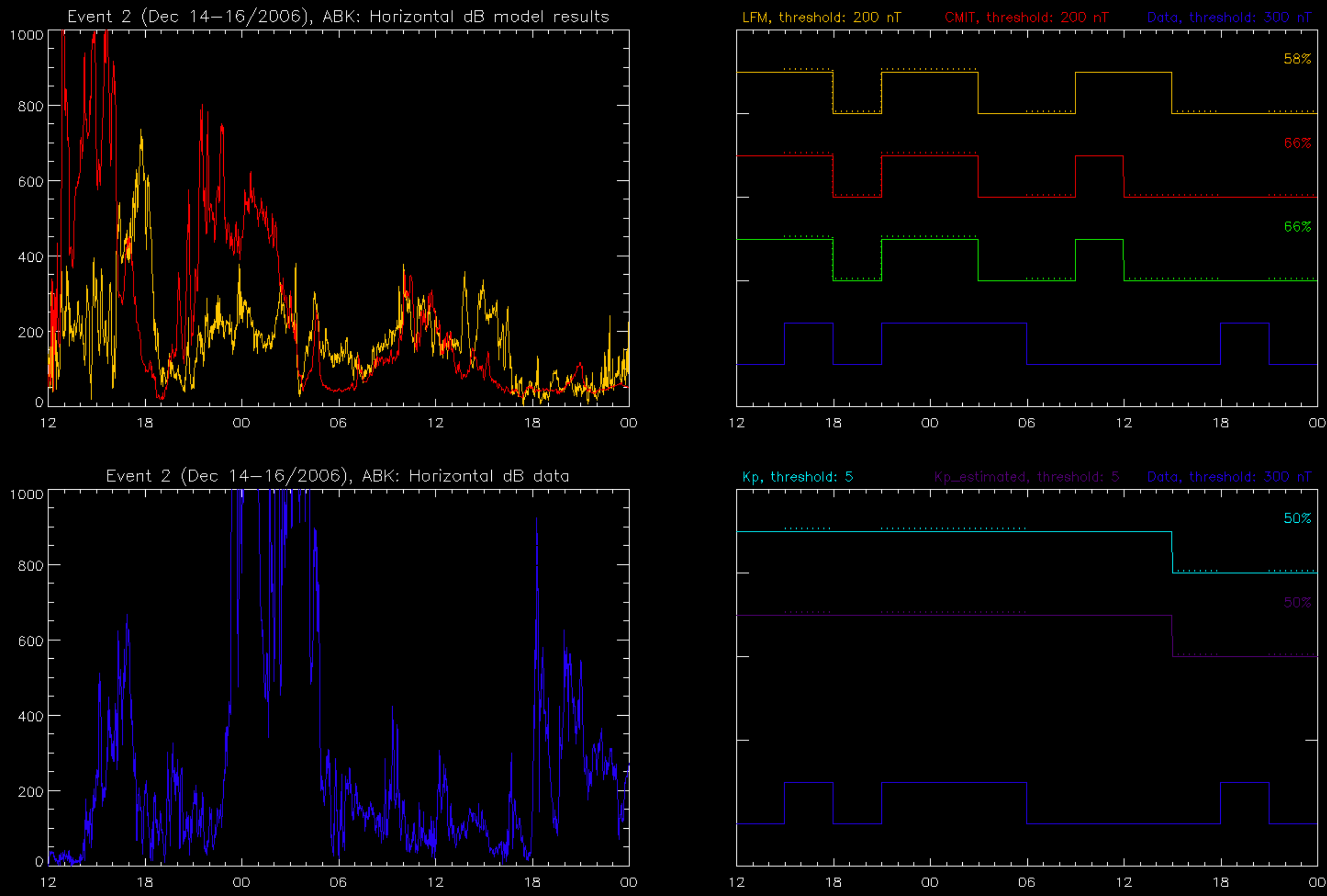
- Comparison of time-averaged Geotail (top row) and LFM (bottom row) thermal pressure (a,d), magnetic pressure (b,e), and perpendicular flows (c,f) in magnetotail equatorial plane.
- Millions of data samples comprise each average map.
- Similarities and differences in magnetotail climatology reveal strengths/weaknesses of model

(Details described in Guild et al., 2004)

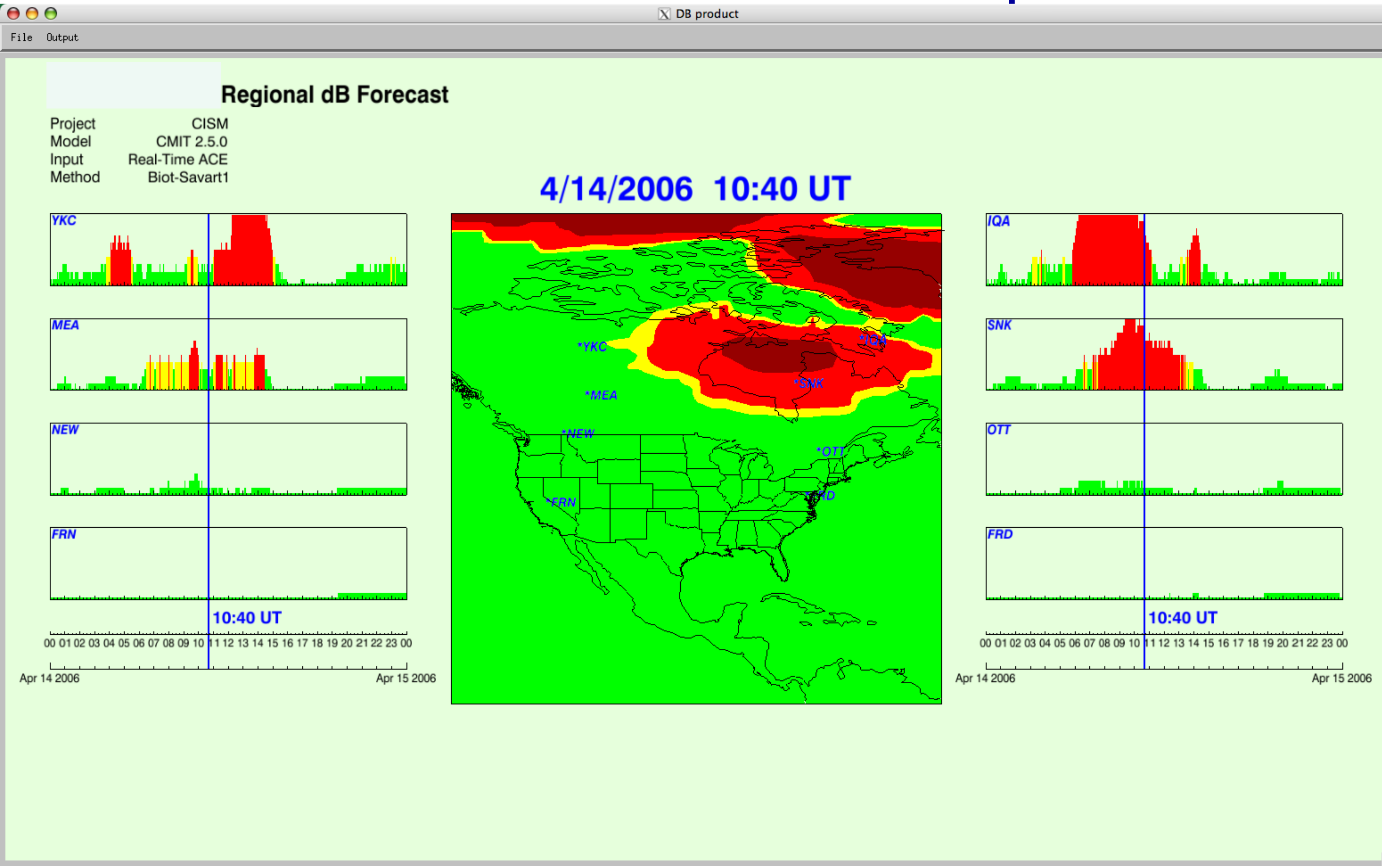


*Equatorial cross-section showing snapshot of LFM magnetotail, Sun to right, solar wind blows from right to left. Color coding indicates plasma flow velocity (*Red/Yellow = sunward flow, Green/Blue = antisunward flow*).*

CMIT dB/dT analysis at an observatory



Forecast Products in Development



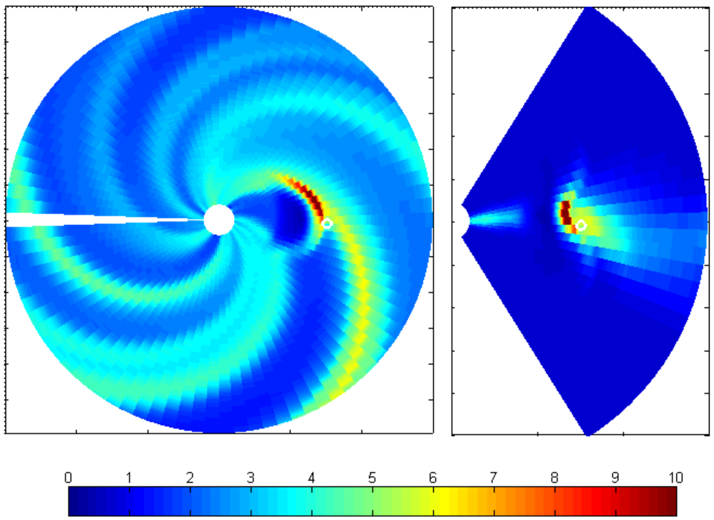
Solar Energetic Particle Model – SEPMod

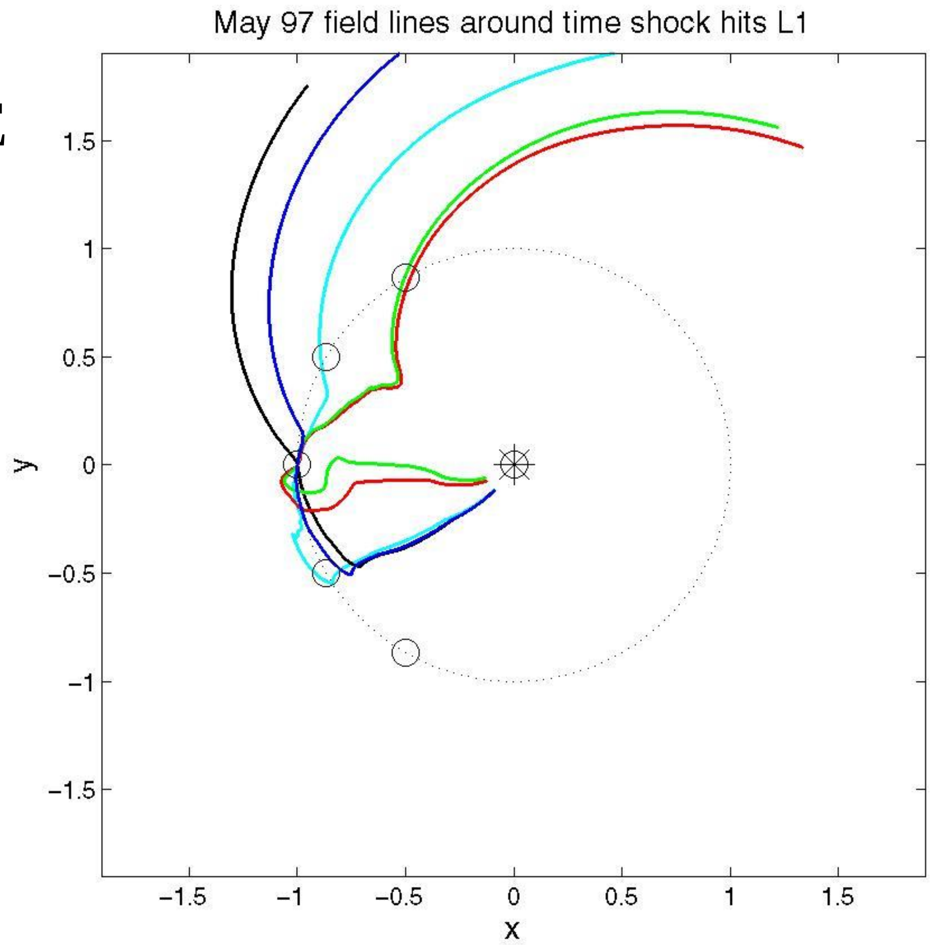
- Models the SEP's created at the shock waves generated by Interplanetary Coronal Mass Ejections (ICME) in the heliosphere.
- SEPMod uses as input a ICME in a heliospheric model such as WSA-Enlil-Cone
- SEPMod relies on a sufficiently accurate description of the underlying solar wind and ICME shock structure. This is needed to determine:
  - Shock source strength and attributes
  - Shock connectivity to an observer

  Both of which are time dependent

Earth field line traced at 5 time different times

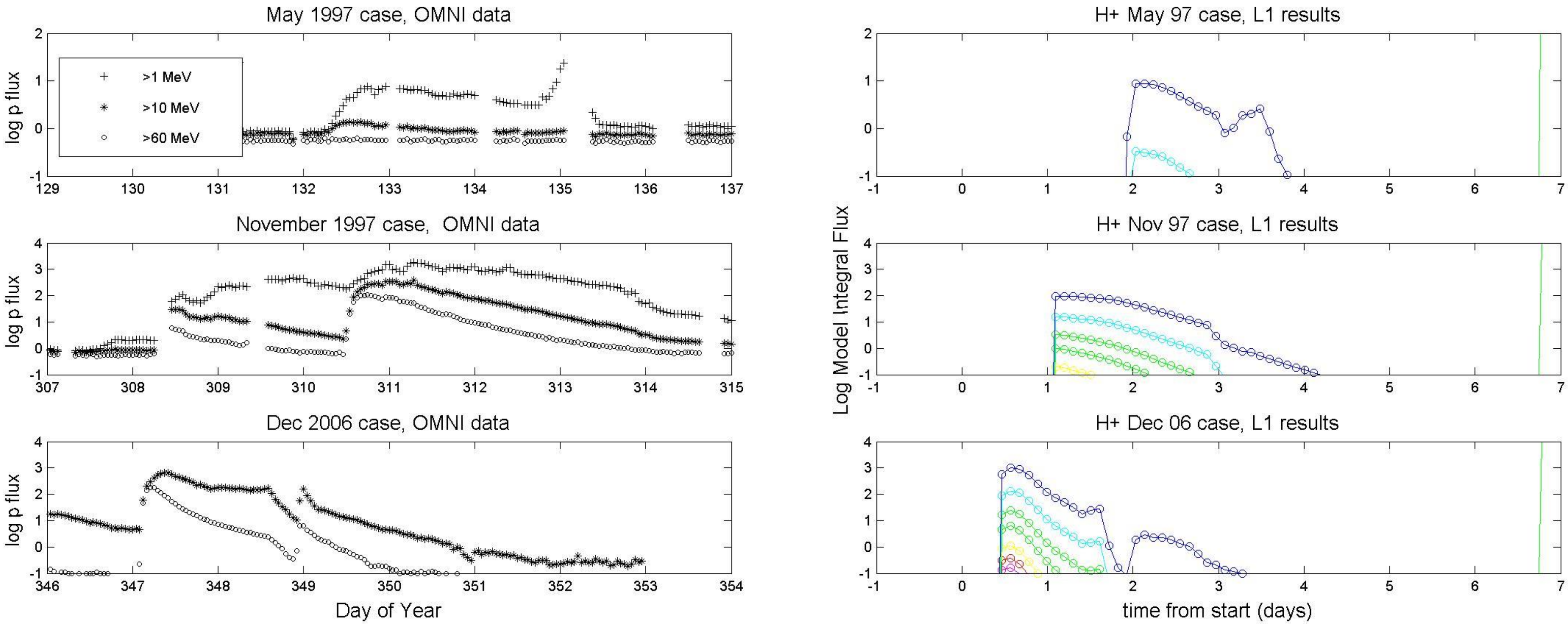
WSA-Enlil-Cone run showing ICME





SEPMod traces field lines to find how the earth is connected to the interplaneary shock then populates that field line with a particle spectrum that depends on the shock properties

Comparison of model SEP fluxes with observations for three ICME events: May 1997; Nov 1997; Dec 2006.



Lessons Learned from SWPC Transitions*

- Sophisticated models can't be "thrown over the wall". A sustained interaction is needed.
  - Modelers don't know what forecasters need.
  - Forecasters don't know what models can (or could) do.
  - Defining & developing what's needed is non-trivial.
  - Iteration is required to derive good forecast products.
- A "transition team" approach is workable (forecasters, developers, computation experts, scientists, managers).
- As an STC, CISM has unique opportunity as pathfinder.
- NSWP needs mechanisms that support such collaborations.

* "Building and Using Coupled Models for the Space Weather System: Lessons Learned", Quinn et al., accepted *Space Weather*, 2009

Future of Space Weather Modeling

An unfortunate coincidence of end dates:

- NSF: CISM Science and Technology Center ends July 2012
- NASA: Living With a Star Strategic Capabilities projects end in 2012
- DoD: Space weather related MURIs end in 2012
- Approximately $9 million less funding per year into space weather model development and validation after 2012 (Tamas Gombosi – informal communication)