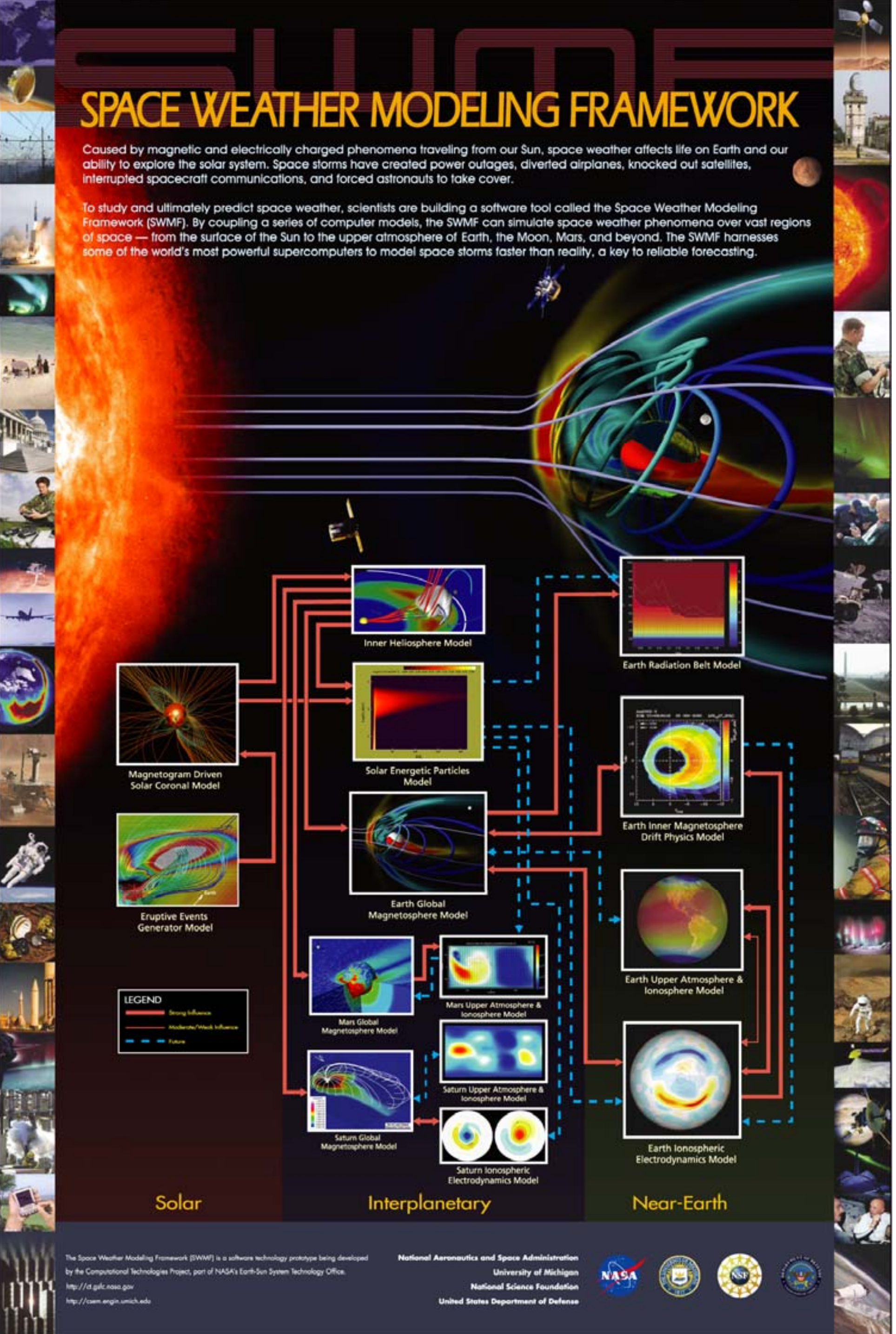


CCMC-CSEM Collaboration

Tamas I. Gombosi

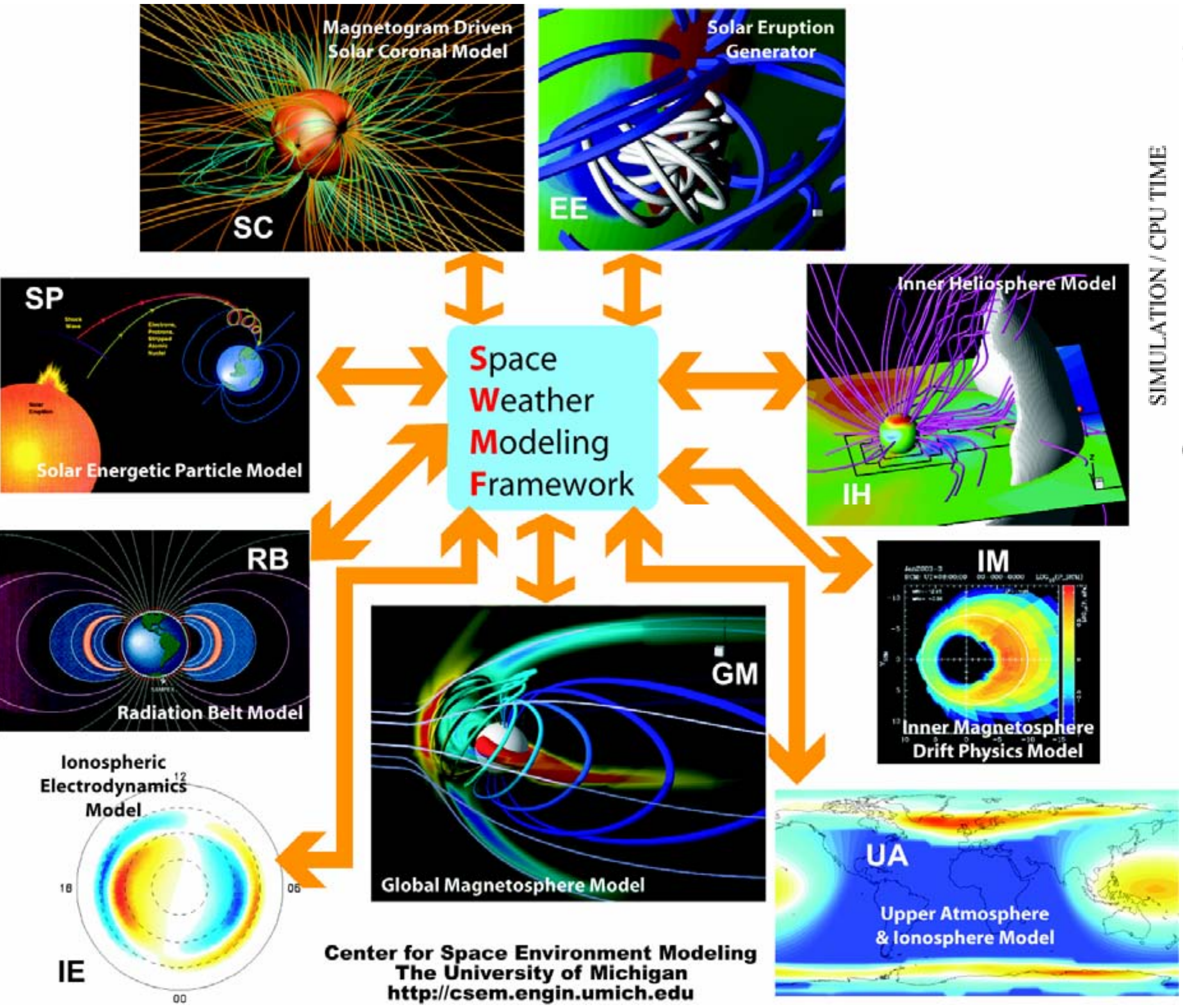
Center for Space Environment Modeling
The University of Michigan

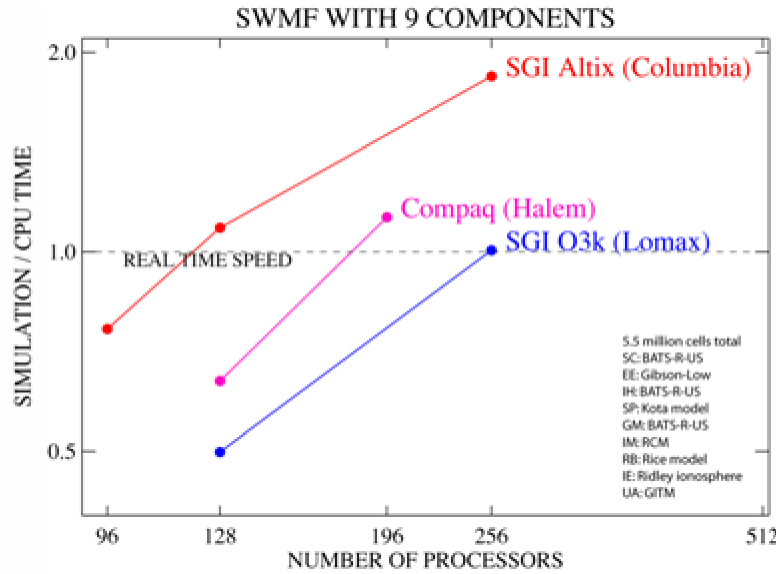
- CSEM is comprised of a tightly integrated group of faculty and students from Aerospace Engineering, Atmospheric, Oceanic and Space Sciences, and Electrical Engineering and Computer Science.
- The overall goal of CSEM is to develop high-performance, first-principles based computational models to describe and predict hazardous conditions in the near-earth space environment extending from the sun to the ionosphere, called space weather
- In order to achieve predictive capability, the models must run considerably faster than real time on mid-size parallel computers.
- CSEM members combine expertise in modern numerical algorithms, high-performance computational science, and solar, interplanetary, magnetospheric, and ionospheric physics.

CSEM and CCMC

- BATS-R-US was the first model in CCMC (2000)
  - 5 peer reviewed papers by CCMC (first authors)
  - 16 scientific presentations by CCMC
  - 310 of the 450 CCMC runs (currently listed on the CCMC web page) have been done with BATS-R-US (70%)
  - Experimental real-time global MHD simulation is being done with BATS-R-US
- SWMF has been delivered to CCMC
  - SWMF is a flexible, high-performance tool coupling 9 models together
  - Peter MacNeice of CCMC verified SWMF basic functionality for the NASA ESTO CT project
  - CCMC is testing the first version of SWMF and it will offer runs on request soon

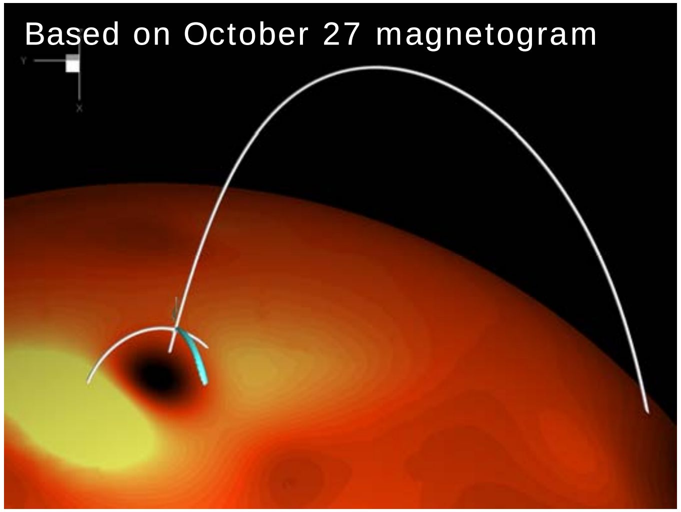
Space Weather Modeling Framework



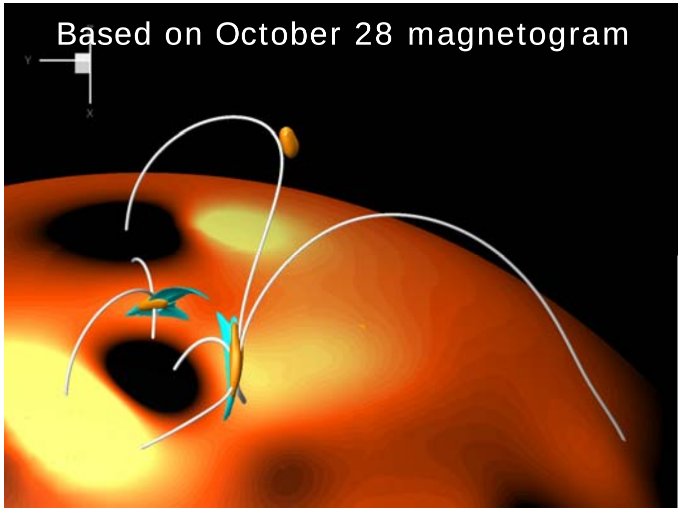


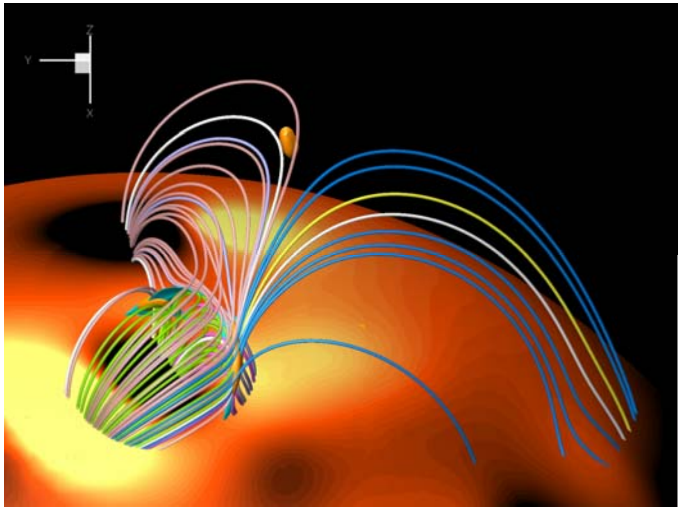
On 128 PEs SWMF is slightly faster than real time,
On 256 PEs SWMF is twice as fast as real time

Close View of Active Region 10486 on Oct 28 at 9:35UT



32 hours later





There are more magnetic flux systems of interest now, and therefore more colors…

The emergence of AR10488 results in the appearance of second null point!

QuickTime™ and a
Sorenson Video 3 decompressor
are needed to see this picture.

Magnetic Field & Velocity at 1 AU

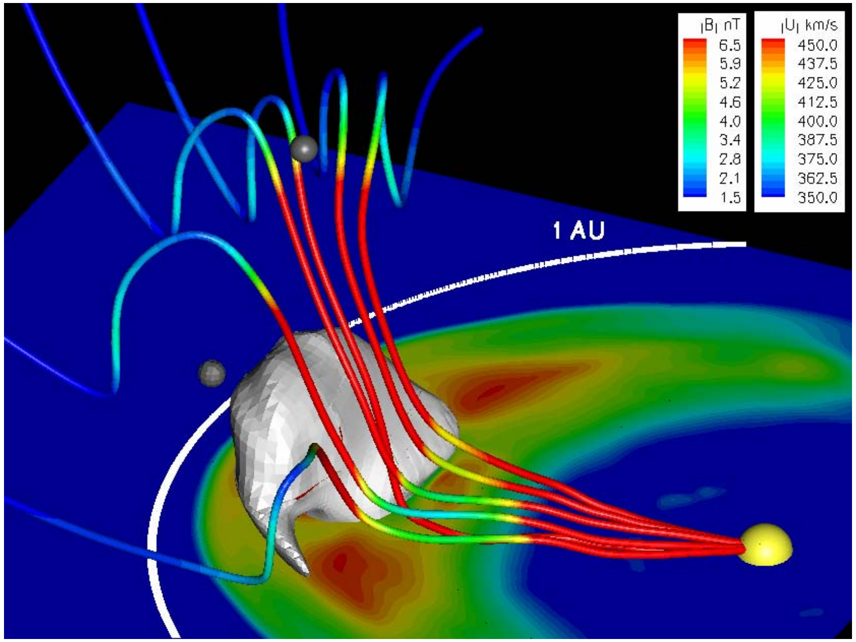
QuickTime™ and a
BMP decompressor
are needed to see this picture.

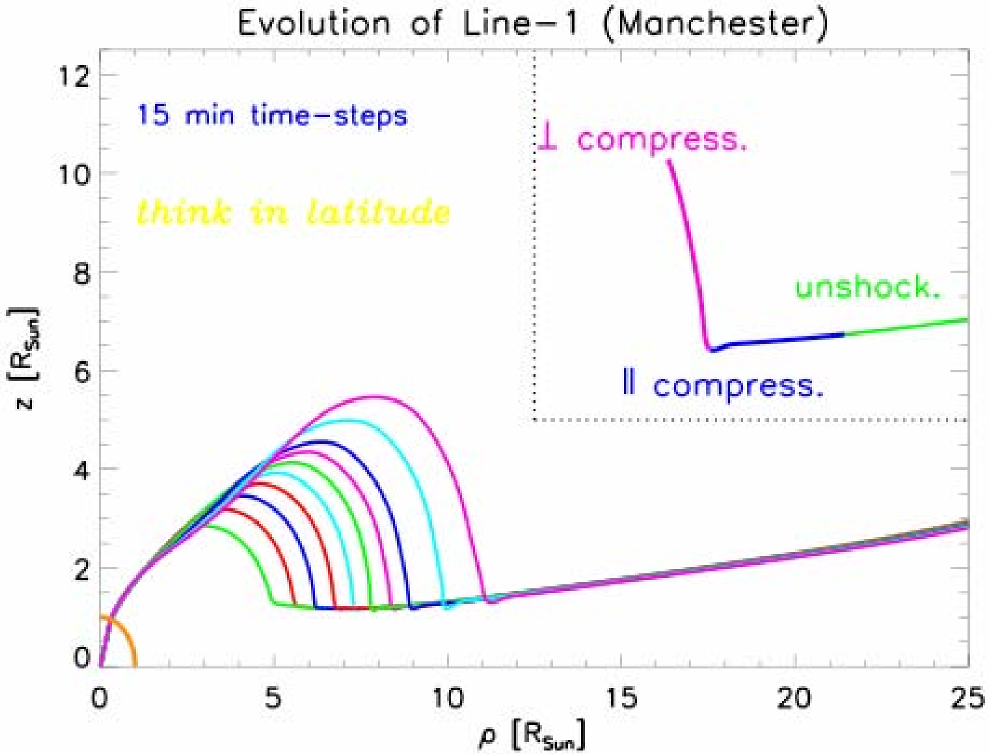
QuickTime™ and a
BMP decompressor
are needed to see this picture.

Radial magnetic field

Radial velocity

CME at 1 AU

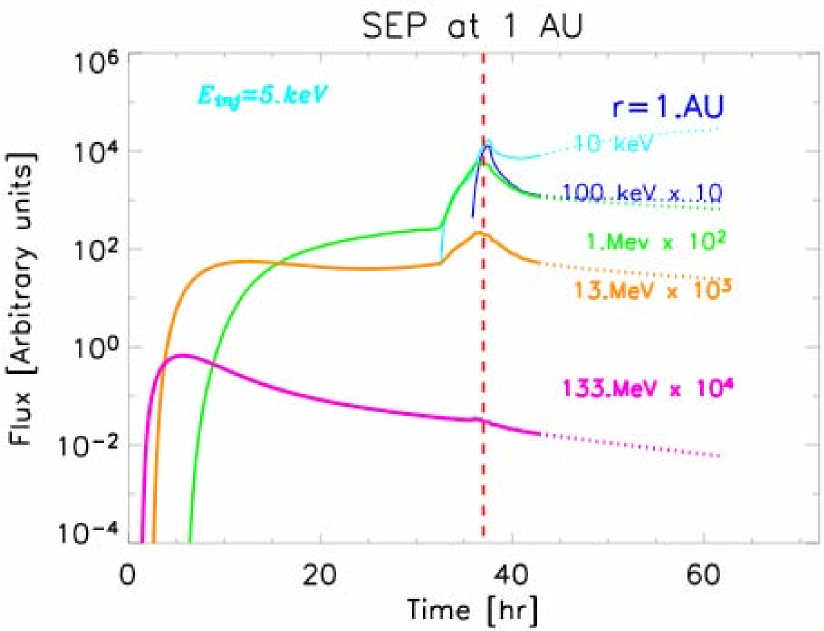


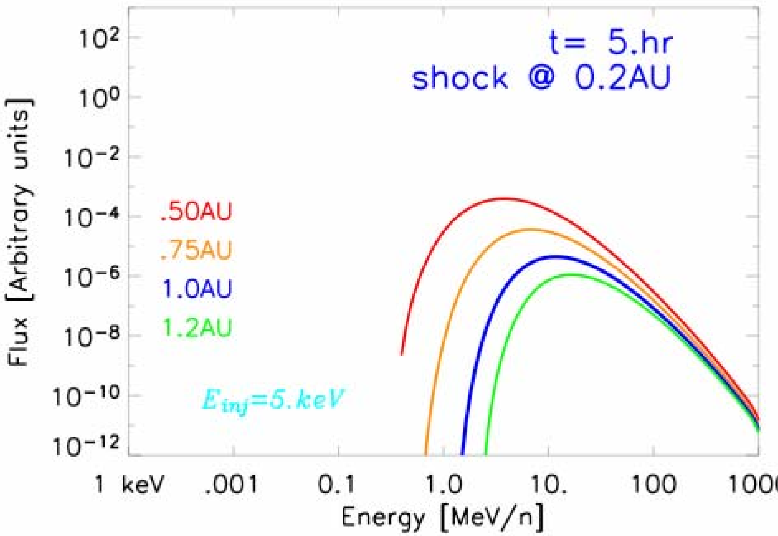


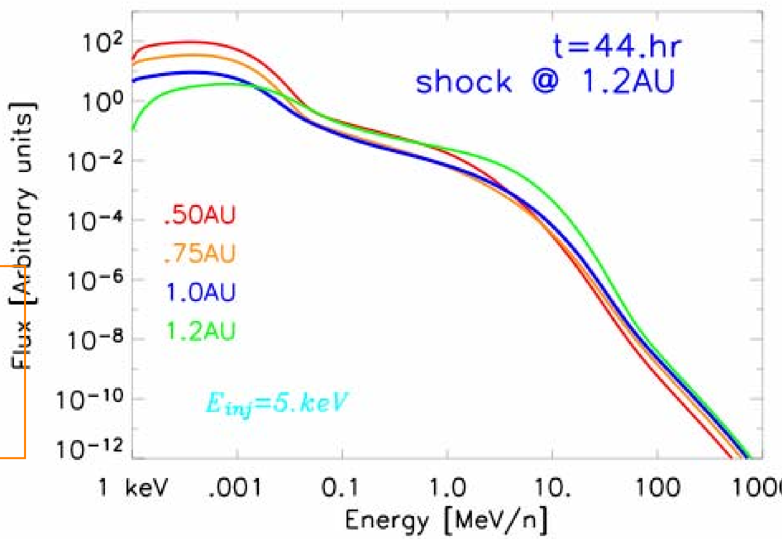
- Note the stronger magnetic field at the deflection.
- We get more acceleration than with a simple parallel shock.

Time-Profile at 1 AU for Different Energies

For space weather purposes we estimate the penetrating component of the SEP population (~20 MeV/n can penetrate 2 mm Al)

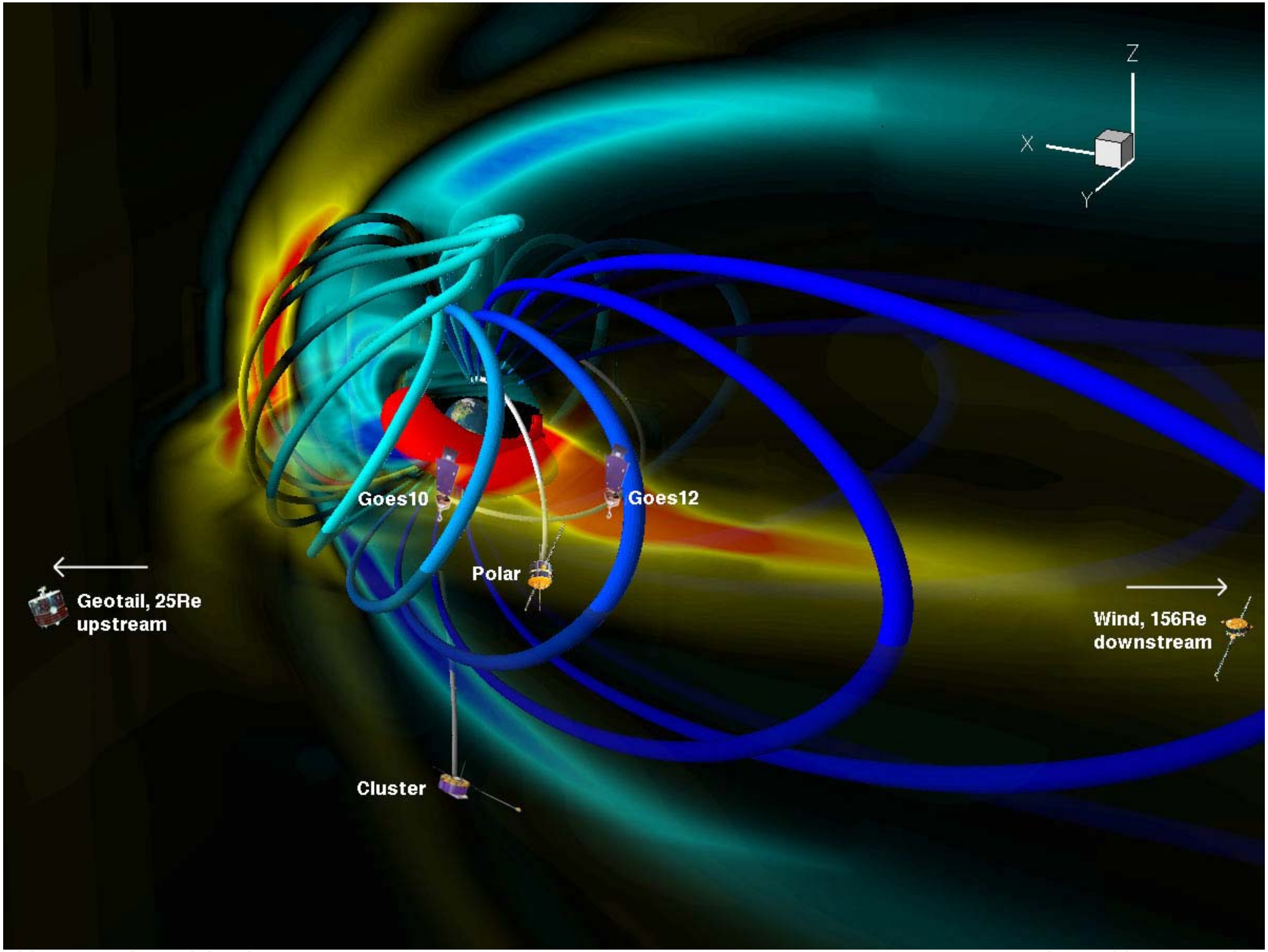




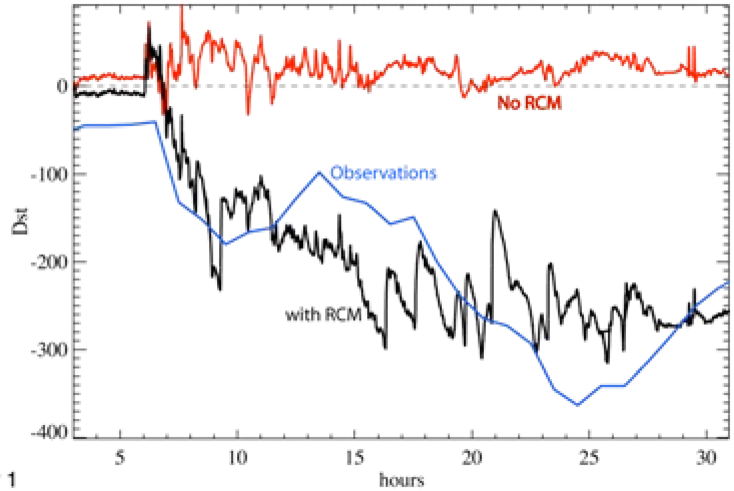


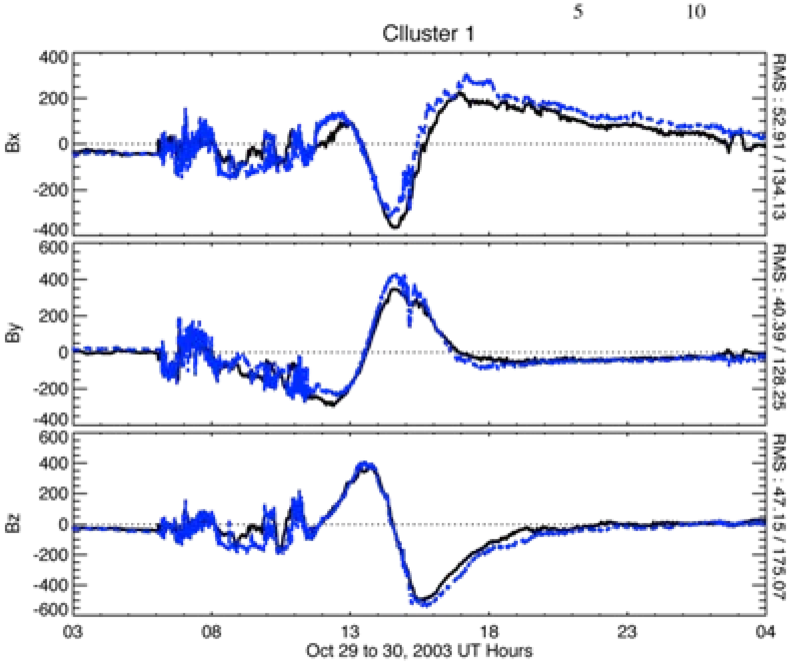
- Particles are injected at about 5 keV.
- The important part of the time profile is the evolution before the arrival of the shock

October 29-30, 2003 Storm Simulation: BATS-R-US/RCM

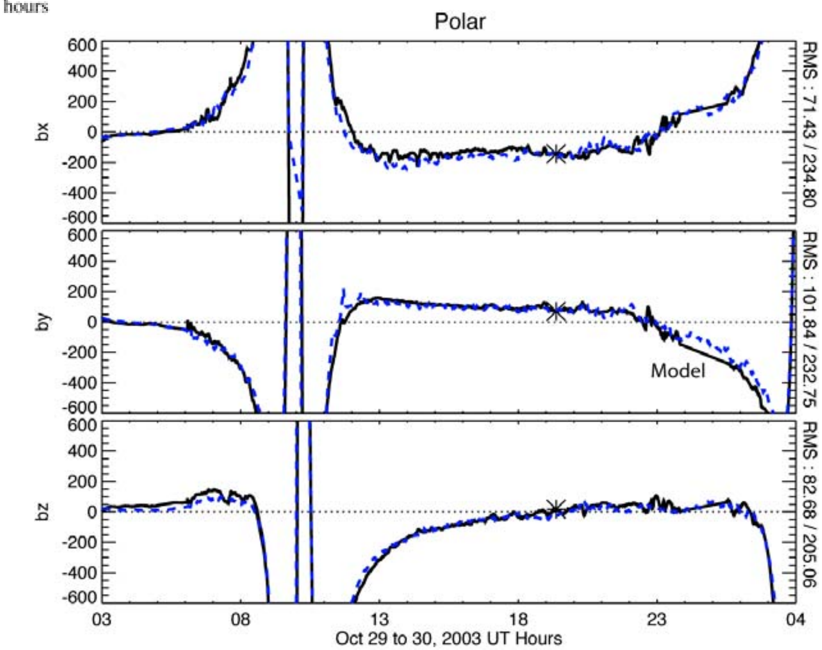


Comparison with Observations, I



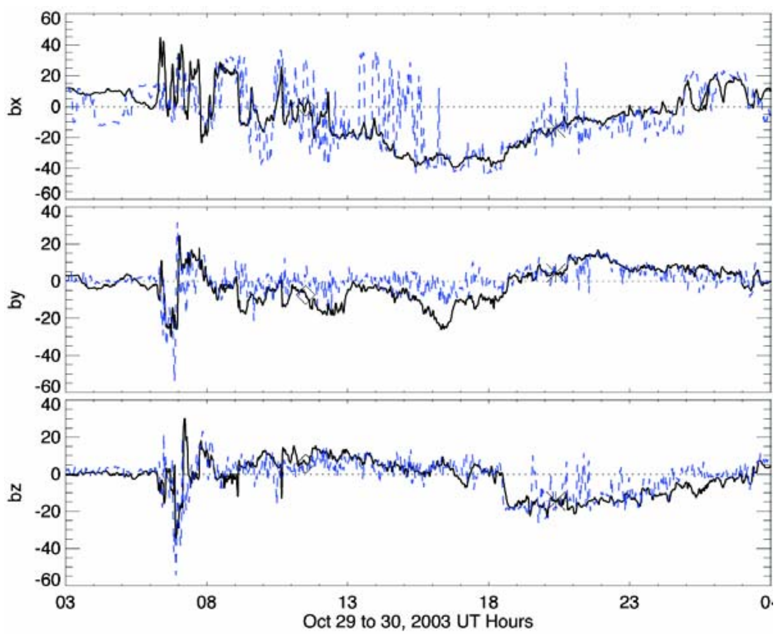


Dayside magnetosphere

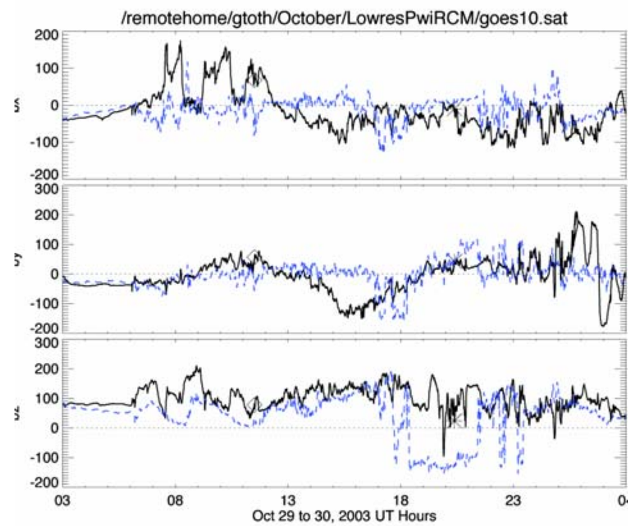


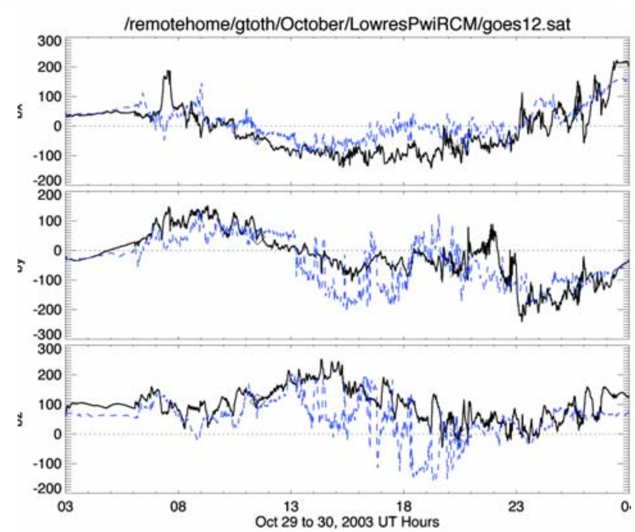
High-latitude magnetosphere

Comparison with Observations, II



Wind, 156 Re downtail





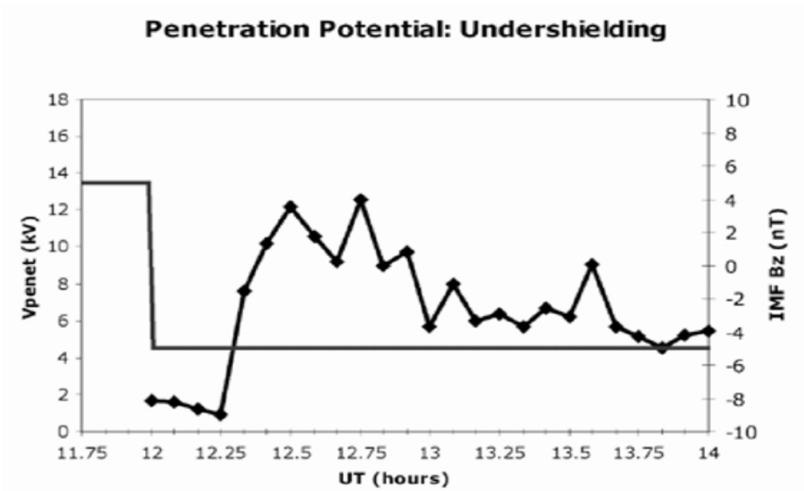
GOES-10 and GOES-12
Closed field line region

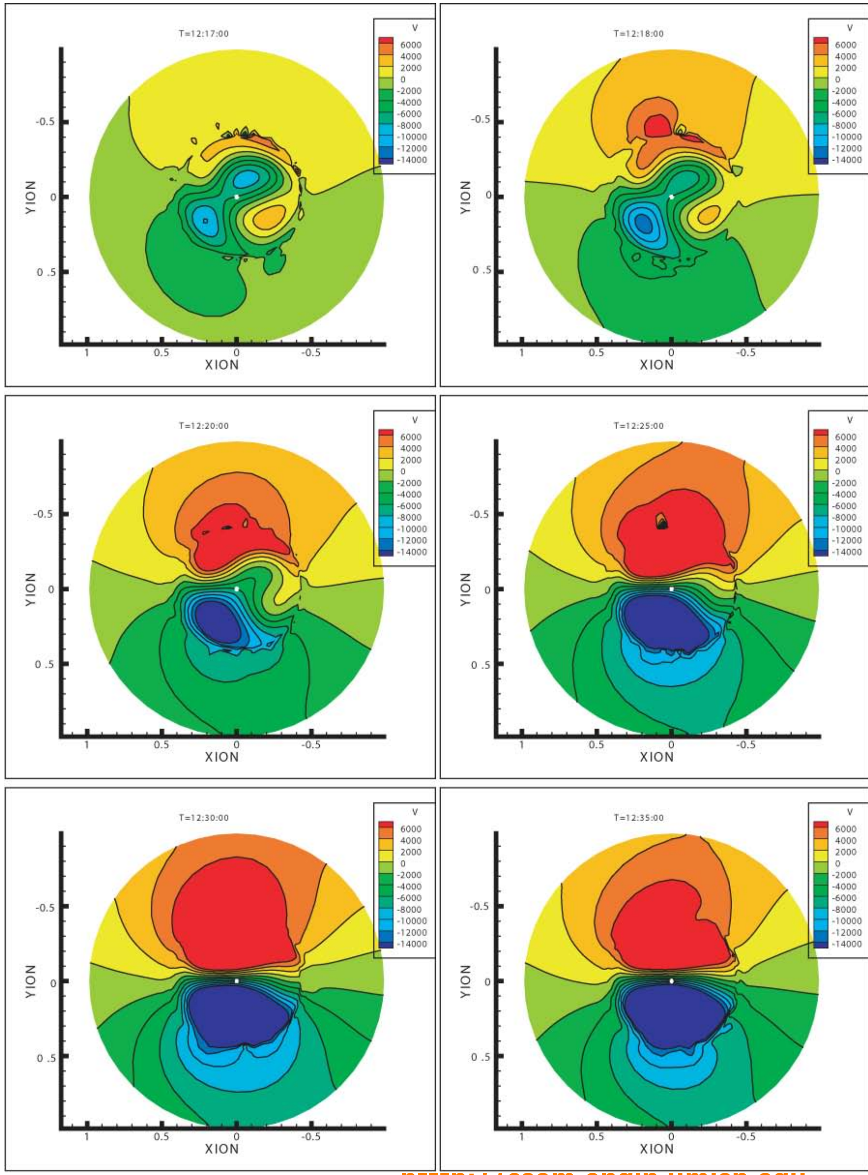
We are able to describe the magnetic field throughout the entire magnetosphere reasonably well.

BATS-R-US with RCM

The ionospheric disturbance starts approximately simultaneously in the entire ionosphere and gradually builds in strength. The penetration field occur simultaneously with similar strengths on both day and night sides.

The penetration potential peaks about 11 minutes after the southward IMF hits the dayside MP. IMAGE-EUV observations show a 10-30 minute time delay between the arrival of a southward turning at the dayside magnetopause and the beginning of erosion of the nightside plasmapause, which is thought to be due to the penetration electric field.





Community Use

- SWMF is publicly available including all components
  - Step 1. Register on the SWMF website and specify scientific use
  - Step 2. Legitimate scientific users get download access
  - Step 3. User downloads .tar file with
    - Code
    - User manual
    - Examples and test cases
  - Step 4. User can use code for studies specified in the registration
  - Step 5. User can send bug reports and comments to CSEM, but CSEM is not funded to provide support
- CSEM only provides support to collaboration partners
  - CCMC
  - U. Alberta
  - Rice
- SWMF can be used to model other physics problems
  - Outer heliosphere
  - Planets and comets (Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Io, Titan, Ganimede, Europa, Enceladus, etc)
  - Fusion plasmas
  - These features can only be used with partnership agreements

The Core Question

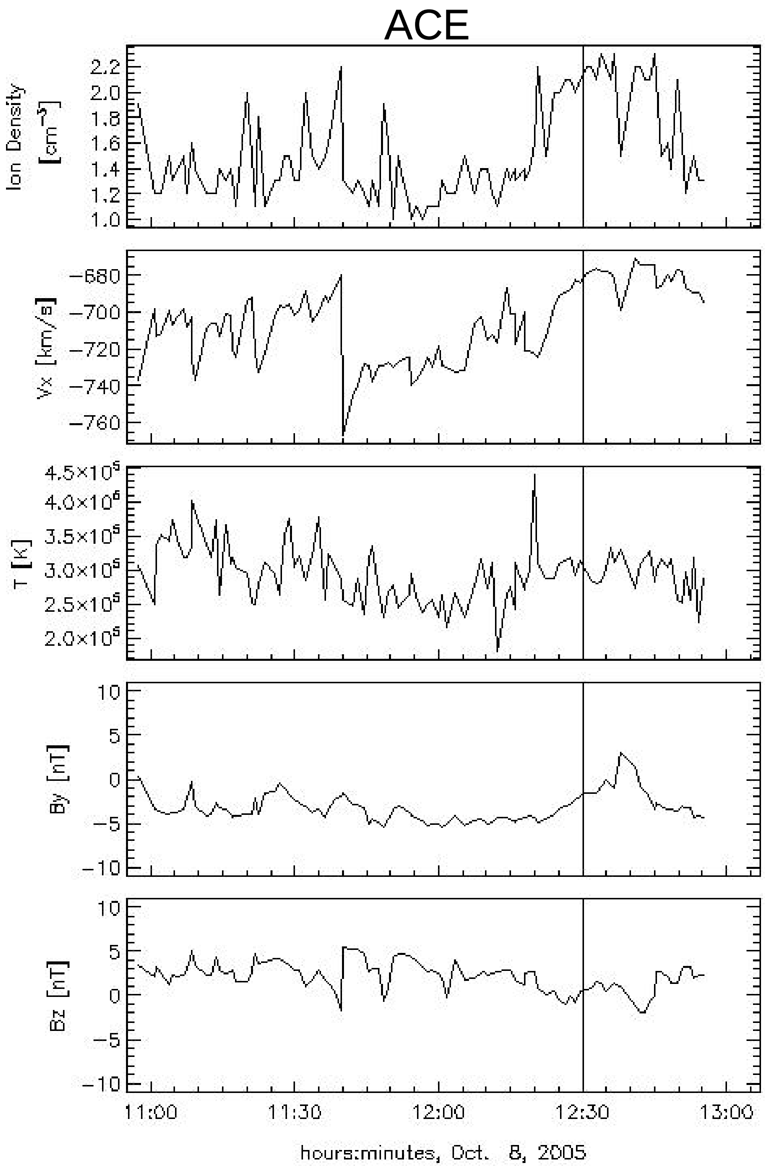
"A capitalist will sell you the rope to hang him with"
Vladimir Ilich Lenin

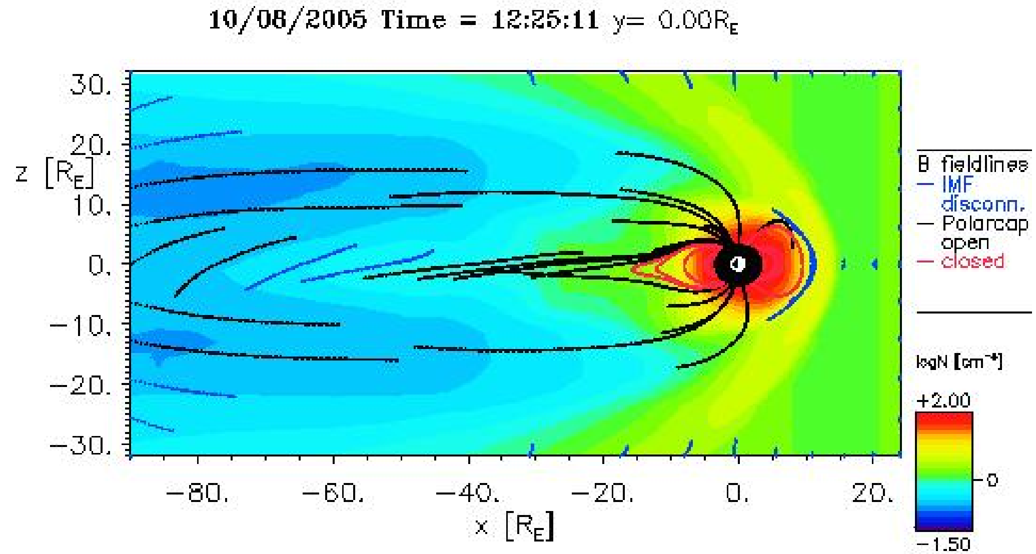
- How can a model developer provide models for community use, validation and transition at CCMC without risking his/her future funding?
- Model developers are paranoid by nature
- Model development costs are comparable to developing space instruments
- Specific concerns:
  - Model comparison and validation without the participation of the developer
  - Model modification by CCMC scientists
  - Model coupling by CCMC scientists
  - New applications of the model
- CCMC runs not optimized for individual physics problems
  - Challenging science applications can benefit from collaborations with the code/model developers
  - Model developers know the limitations of their models and are usually careful not to over-interpret simulation results

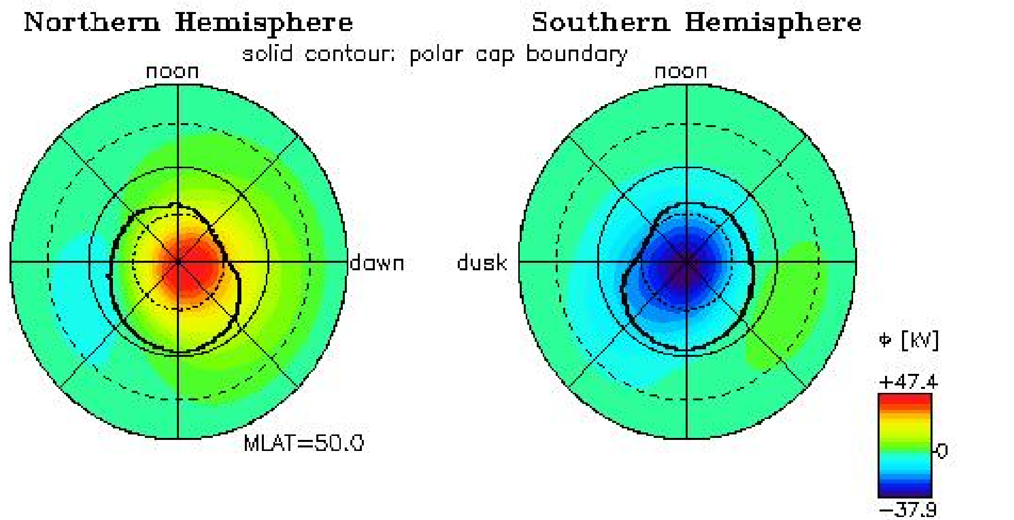
Why Do We Collaborate?

- Wide science use
  - Model developers love to see their models being used by the community
  - Overall science return is higher
  - Increases the code's name recognition and the chances of positive peer reviews in the future
  - CCMC provides user support
- Feedback
  - CMMC uses our codes somewhat differently than we do
  - CCMC has provided us valuable bug reports
  - CCMC started data comparisons with BATS-R-US
- Validation an transition
  - Independent validation is very important
  - Transition to DoD and SEC is important but time consuming
- Agency pressure
  - NSF GEO Upper Atmosphere
  - NASA ESTO CT
- Overall benefit/cost>>1 for CSEM

CCMC Results: Real-time BATS-R-US with Fok Ring Current Model







Various Frameworks

	ESMF	SWMF	CISM
Approach	Tightly coupled, single executable, high-performance portable, highly structured modeling environment.		Loosely coupled, multiple executable, rapidly prototyped, not necessarily high-performance.
Infrastructure	Provides data structures and common utilities that components use 1. to organize codes 2. to improve performance & portability 3. for common services.		Minimal infrastructure and minimal science code modification.
Coupling	Grid mapping is presently limited to 2D regular grids.	Focuses on 3D overlapping interfaces and can handle 3D AMR grids.	▪ Uses uniform buffer grids for data exchange. ▪ Will use 3D overlapping interfaces in the future.
Implementation	▪ Adheres to high software eng. standards ▪ Separate framework and applications teams. ▪ Provides a high level of flexibility.	▪ Uses minimal software engineering tools ▪ Integrated framework and application development team.	▪ Presently uses flat files for data exchange. ▪ Will use InterComm package for communication and Overture for grid interpolation.
Status	▪ ESMF is operational. ▪ ESMF is just becoming usable for science investigations	▪ SWMF with science models is operational and transitioned to CCMC. ▪ SWMF is regularly used in science investigations	Loose coupling of components are used in test runs.