

End to End Modeling: The Community Coordinated Modeling Center Perspective

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SHINE

Kona

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OVERVIEW

- Summarize recent additions to solar and heliospheric model support at CCMC
- CCMC vision of its role in supporting community efforts to develop the ultimate modeling framework
- Reflections on the process of framework development from a CT project insider



What is CCMC?

Multi-agency (NASA, NSF, AFx4, NOAA SEC, ONR) activity to

- Aid in the development of space weather prediction models
- Bridge the transition from research to operations
- Provide access to state-of-the-art research models to the scientific community
- Supporting model coupling was emphasized in the original charter of the CCMC



CCMC Activities

- Model Validation and Metric Studies
- Realtime model execution
- Execute Runs on Request (<http://ccmc.gsfc.nasa.gov/>)
- Transfer Models to the Operational Community

- Perform Data Format Studies
- Advanced visualization studies



Current Models

- Solar (currently all driven from daily or monthly synoptic magnetograms)
 - PFSS
 - **WSA**
 - MAS
- Heliospheric
 - **ENLIL**
 - Heliospheric Tomography
 - Exospheric Solar Wind
- Magnetospheric
 - BATSRUS
 - Open GGCM
 - Fok RCM
- Ionospheric/Thermospheric
 - CTIP
 - SAMI2
 - WEIMER-2K
- Frameworks
 - **U.Mich/CSEM SWMF.**



Run On Request Facility

Web-accessed facility <http://ccmc.gsfc.nasa.gov/>

The Community Coordinated Modeling Center
CCMC NASA AFMC AFOSR AFRL AFVA NOAA NSF ONR

Step 1: Fill in the Form and Generate a Registration Number for each Request

The Registration Number is composed of your first name (FirstName), your last name (LastName), date (mmdyyy), model type (GM - Global Magnetosphere, IT - Ionosphere/Thermosphere, Solar/Heliosphere), and run identification number (RunNumber):

FirstName_LastName_mmdyyy_ModelType_RunNumber, e.g., George_Siscoe_060601_SH_1.

At the present time you are allowed to make up to 4 different submissions on the same date (mmdyyy) for each model type. For each new submission made on the same date you need to choose a new Run Number ("1", "2", "3", or "4"). Multiple submissions made on the same date with the same Run Number and Model Type will overwrite the previous submission. If you decide to cancel or modify your submission at a later date, please contact the CCMC staff.

e-mail: requests@ccmc.gsfc.nasa.gov
tel.: Masha Kuznetsova (301-286-9571), Lutz Rastaetter (301-286-1085).

Please have registration numbers when making inquiries about your requests. You will need your registration number to view the results when the simulations have finished.

First Name: (required)
Last Name: (required)
Address:
Telephone: (required)
E-mail:
Run Number:

Step 3: Set The Simulation Time Interval

Choose Carrington rotation or date of interest

Select:
 Carrington rotation number between 1625 and 2007:
or
 Date (MM/DD/YYYY) between 02/18/1975 and 08/29/2003: / /

Selection of Carrington rotation numbers and dates is subject to change.

Specify the duration of the run

hours
Maximum duration of the run is 80 hours of real time.
Minimum duration of the run is 5 hours of real time.

Step 4: Set The Simulation Grid

Select grid resolution (NRxNTxNP) from predefined list:

Step 5: Set The Boundary Conditions

Confirm selection of Carrington Rotation based on available data
Rotation: 2007 Start: 08/29/2003 End: 09/26/2003

Select coronal base temperature and density

Coronal base temperature: x 10⁶ [K]
Coronal base density: x 10⁸ [particles cm⁻³]
(density range: (1.0 - 4.0) x 10⁸ [particles cm⁻³])

Select filter parameters for magnetogram data

Selected simulation grid: medium resolution (85x81x64)
Recommended maximum longitudinal mode number: 8
Recommended number of latitude filter passes: 3
Recommendations and ranges for filter parameters are based on grid resolution.

Maximum longitudinal mode number (Range: 1 - 9):
Number of latitude filter passes (at least 2):

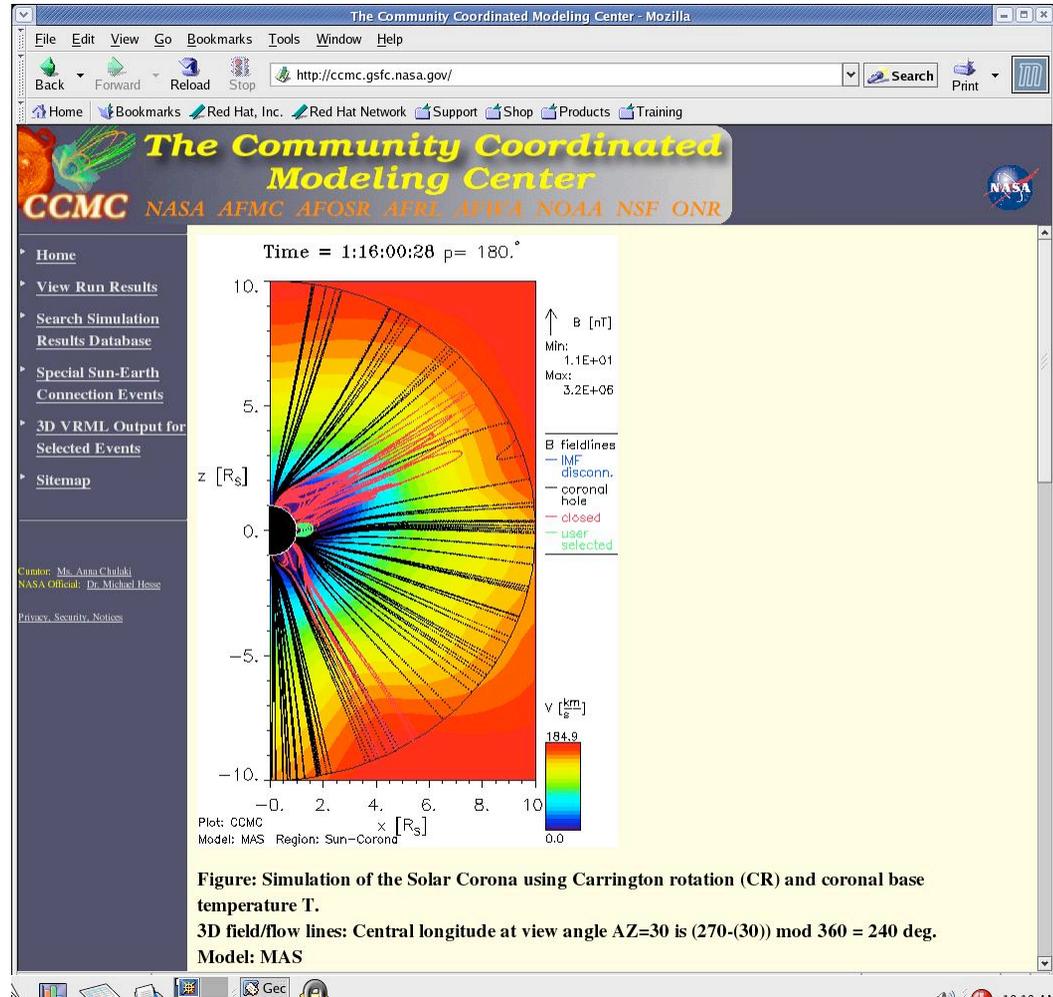
Filtered Kitt Peak Magnetogram

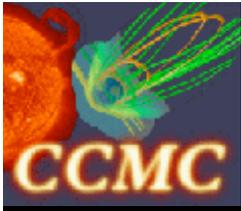
Filter Parameters:
Maximum longitudinal mode number: 8
Number of latitude filter passes: 3



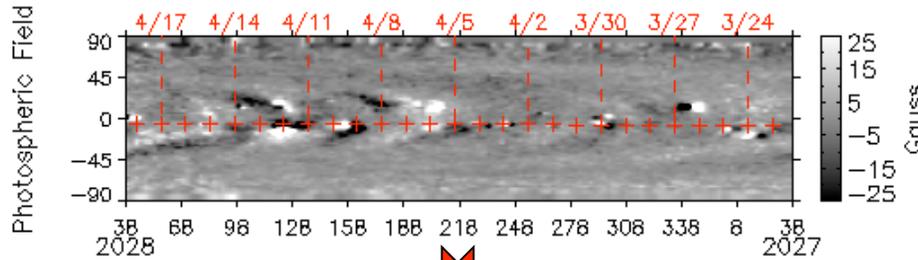
Run On Request Facility

Web accessed graphics tool
visualizes output
(Rastaetter)





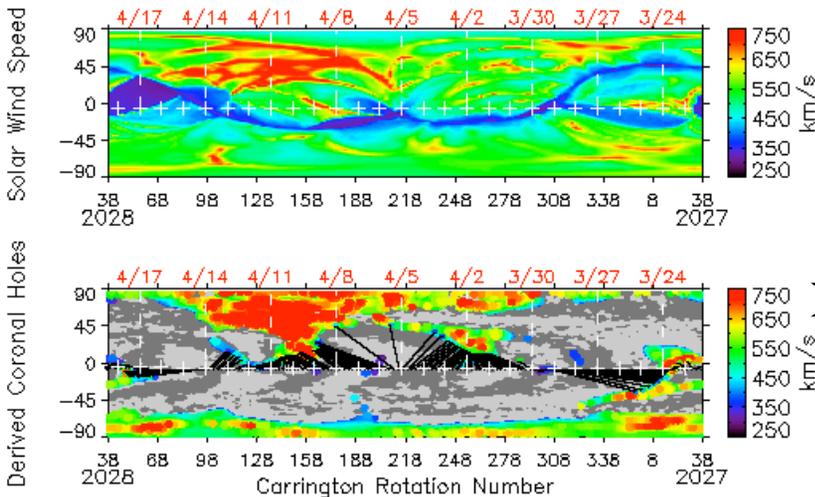
Photosphere to Heliosphere



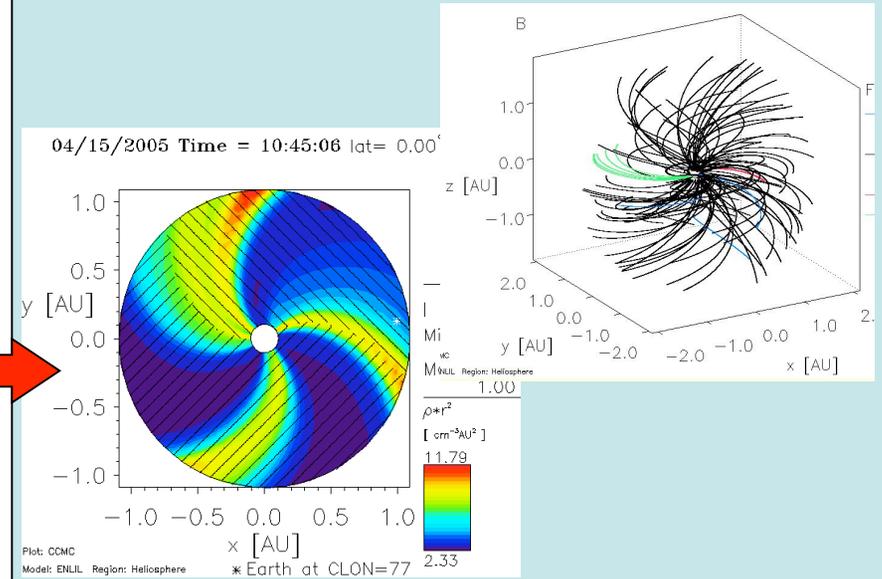
Photospheric Synoptic magnetograms

Running in realtime – Arge, Odstrcil, Kuznetsova, Rastaetter, MacNeice

http://ccmc.gsfc.nasa.gov/cgi-bin/RTdisplay_Hel_RA.cgi



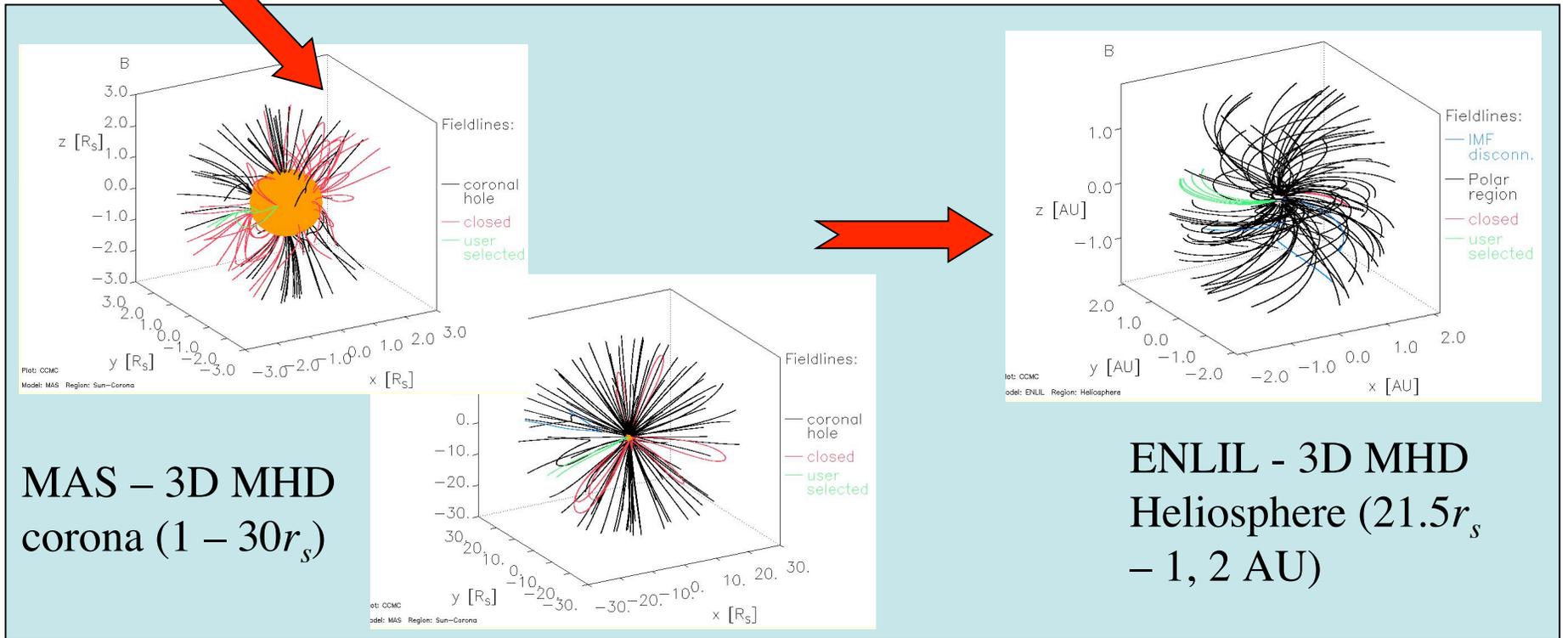
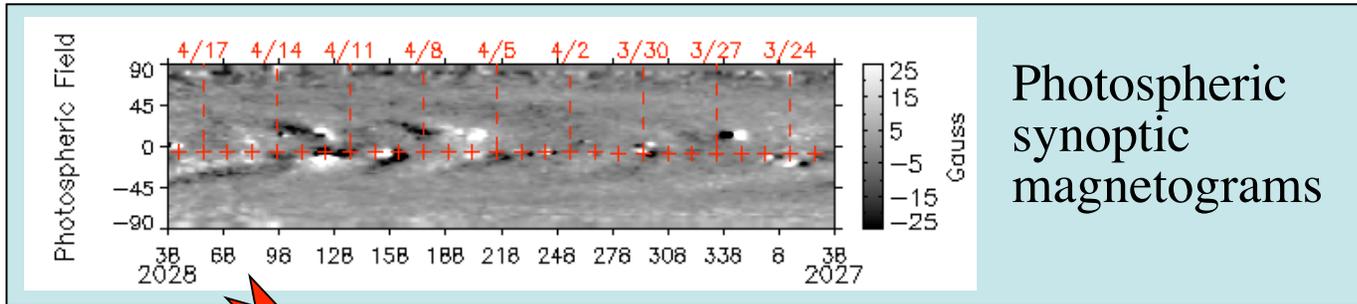
WSA – potential field + current sheet model ($1-21.5r_s$)

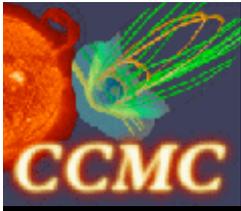


ENLIL - 3D MHD Heliosphere ($21.5r_s - 1, 2$ AU)



Photosphere to Heliosphere – soon!





Photosphere to Heliosphere –soon!

```

program mas_magnetogram
use rdtxt2d_arrays
implicit none
character(len=21) :: fname
integer          :: i,j

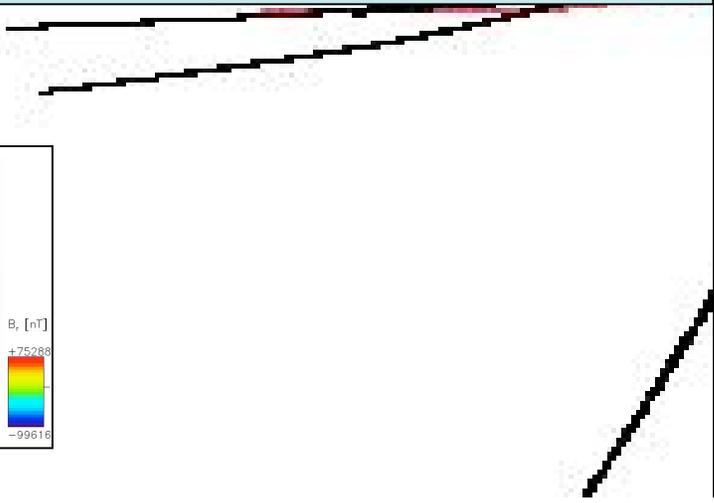
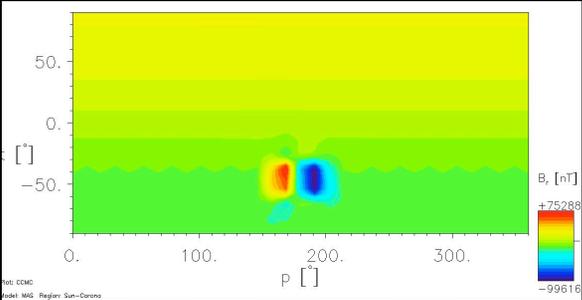
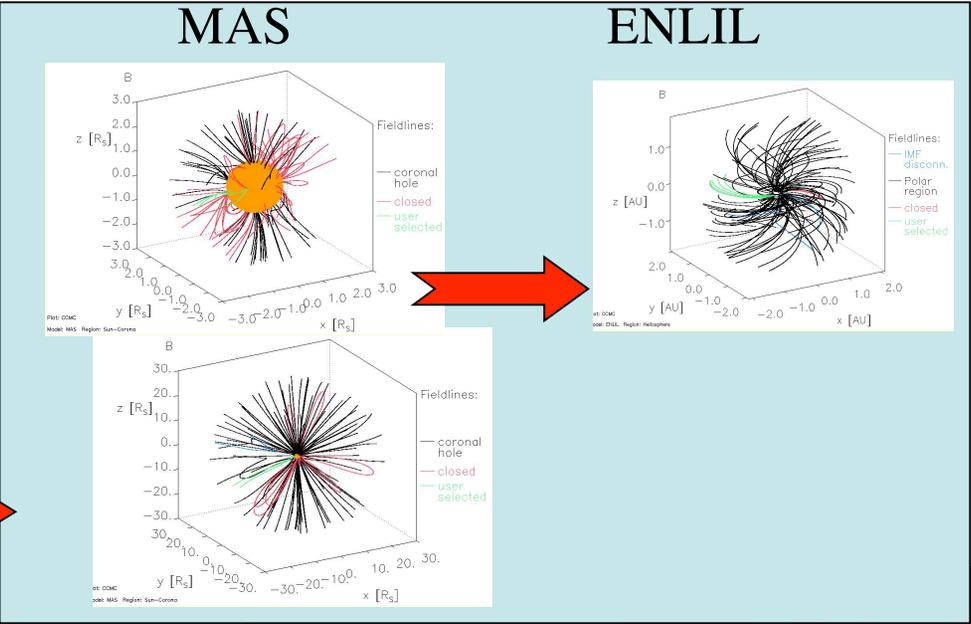
ndim = 2
ifscale = 1

!-----
! User set
nx = 90      ! user modify size of magnetogram grid in latitude(theta) direction
ny = 181     ! user modify size of magnetogram grid in azimuthal(phi) direction
allocate (f_rdtxt2d(nx,ny))
allocate (x_rdtxt2d(nx,ny))
allocate (y_rdtxt2d(nx,ny))

do i=1,nx
  x_rdtxt2d(i) = ????? ? user enter theta grid points
enddo
do i=1,ny
  y_rdtxt2d(i) = ????? ? user enter phi grid points
enddo
do j=1,ny
do i=1,nx
  f_rdtxt2d(i,j) = ????? ? user enter Br at every grid point on
                        ! solar surface
enddo
enddo

fname='mas_inputfile.dat'
call wrtxt2d (fname)
deallocate (f_rdtxt2d)
deallocate (x_rdtxt2d)
deallocate (y_rdtxt2d)
stop
end program mas_magnetogram
  
```

User generated
artificial synoptic
magnetograms!





... with transients – slightly later than soon!

User generated time series of magnetograms

```

program mas_magnetogram
use rdtxt2d_arrays
implicit none
character(len=21) :: fname
integer          :: i,j

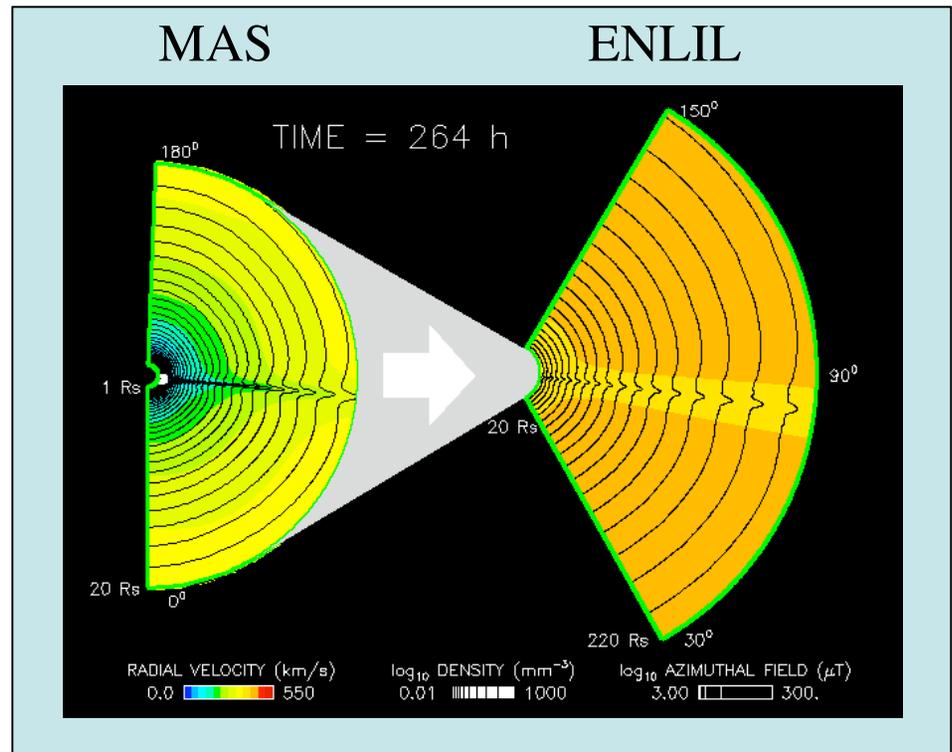
ndim = 2
ifscale = 1

!-----
! User set
nx = 90      ! user modify size of magnetogram grid in latitude(theta) direction
ny = 181     ! user modify size of magnetogram grid in azimuthal(phi) direction
allocate (f_rdtxt2d(nx,ny))
allocate (x_rdtxt2d(nx,ny))
allocate (y_rdtxt2d(nx,ny))

do i=1,nx
  x_rdtxt2d(i) = ????? ? user enter theta grid points
enddo
do i=1,ny
  y_rdtxt2d(i) = ????? ? user enter phi grid points
enddo
do j=1,ny
do i=1,nx
  f_rdtxt2d(i,j) = ????? ? user enter Br at every grid point on
                        ! solar surface
enddo
enddo

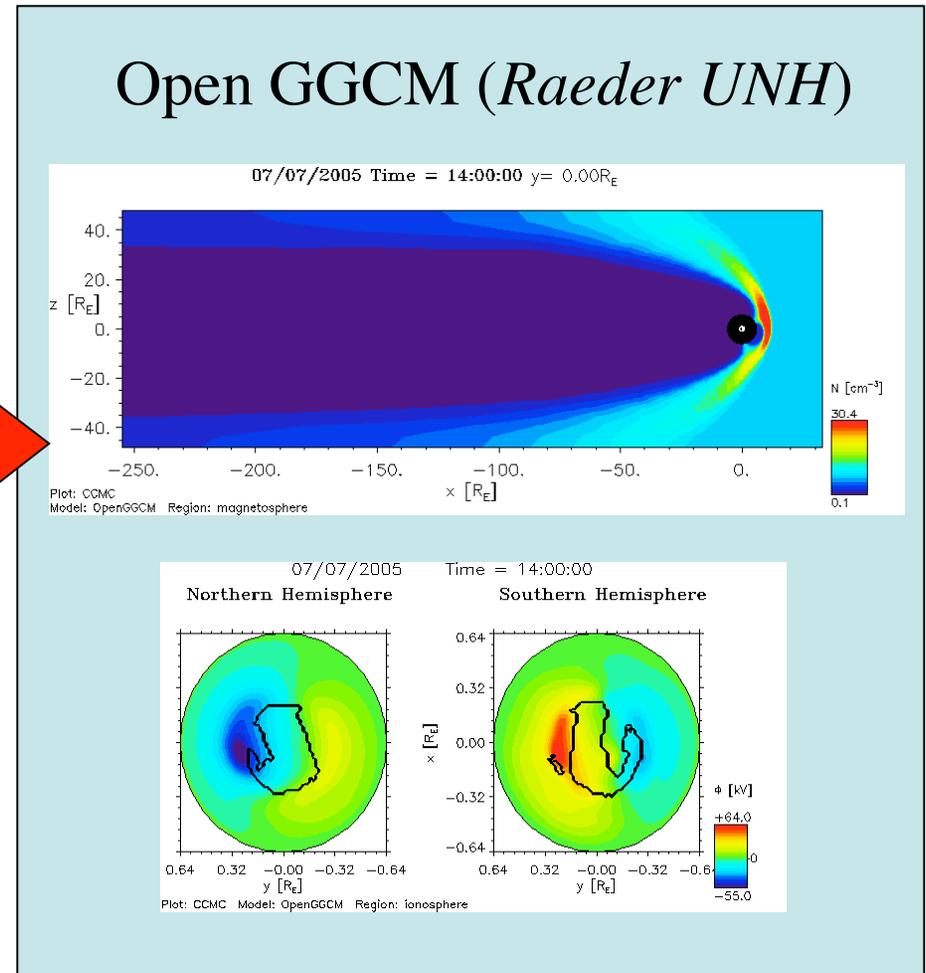
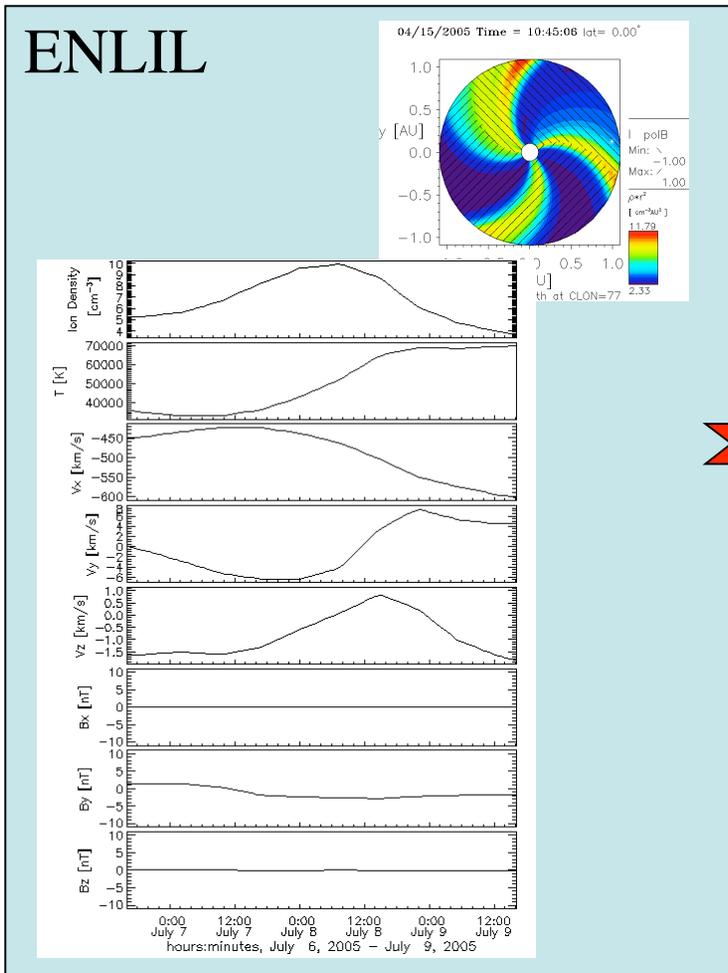
!-----

fname='mas_inputfile.dat'
call wrtxt2d (fname)
deallocate (f_rdtxt2d)
deallocate (x_rdtxt2d)
deallocate (y_rdtxt2d)
stop
end program mas_magnetogram
  
```





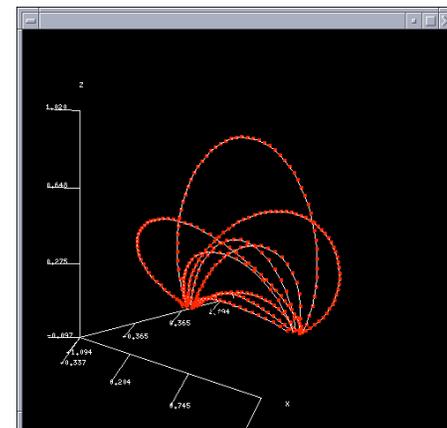
Photosphere to Ionosphere – demo





Future Solar and Heliospheric plans

- Switch on Arge's solar wind prediction routines in WSA.
- Enable MAS runs to drive ENLIL just as WSA now does.
- ~~Enable MAS runs with user generated synoptic magnetograms.~~
- Offer cone model transients in ENLIL ROR page.
- Longer term: offer modeling of transients using MAS+ENLIL with ROR facility.
- Set up automated use of SWMF coronal component to model 'background' corona from MDI magnetograms.
- Add more models eg
 - Fluxons - DeForrest.
 - AN-MHD - Abbett/Fan (Berkeley)
 - ARMS - DeVore





Two Threads

The CCMC will:

- host prototype frameworks (eg. U. of Michigan, CISM)
 1. Exercise them in a quasi-operational setting
 2. Experiment with their coupling mechanisms
- seek natural couplings between models hosted at CCMC (eg BATS-R-US and the Fok RCM)
 1. A more diverse range of potential model couplings (more models, more modelers, more diverse physical approximations)
 2. These developers will need support to migrate toward emerging framework standards
- NOT invent its own framework!!!

Our Goal is to help the community frameworks to succeed.



Frameworks at CCMC

- SWMF (*Gombosi et al*, Univ. of Mich.) – already playing with this!
 - SC, IH, GM – BATS-R-US
 - SP – Kota's SEP or FLAMPA
 - IM – Rice Convection Model (RCM)
 - RB – Rice RBM
 - IE – Ridley Ionosphere
 - UA – Global Iono. Thermosp. Model (GITM)
- CISM – MOU in place. Expect to begin experimenting with coupling mechanism later this year.



Implicit Assumptions

The ultimate ‘suite’ of space weather forecasting tools **MUST** achieve

- Accuracy
 - Robustness
 - Efficiency (both cpu and memory)
-

- Maximum software reuse
- Portability
- Ease of component replacement
- Ease of component addition
- Flexible data assimilation support
- Standardization of
 1. General framework design
 2. Datafile formats
 3. Interface Specs
 4. Documentation
 5. Visualization and feature extraction tools
 6. Archival and database interfaces
 7. Validation strategies



Attributes which make the CCMC contribution unique

- Independence
- Inclusiveness
- Convenience
- Ability to maintain an infrastructure focus
- Exposure to restricted operational environment



Independence

- Model robustness can only be convincingly displayed when the model is out of the hands of the developers.
 - Users have less fear than developers in demanding that models be driven by more extreme input.
 - Models are often least robust at their boundaries.
 - End-to-end modeling will expose these weaknesses.
 - An independent testing environment is the only way we can convincingly characterize component and framework robustness.
- Independent hosting involves validation which will eventually promote benchmarking which often uncovers unadvertised ‘design features’.
 - Developers of competing components can be adversarial to the extent that they become too guarded in disclosure



Inclusiveness

- Many models and modelers outside SWMF and CISM.
- In the early days most useful forecasting tools are likely to be partial frameworks incorporating empirical, parameterized or otherwise ‘physically limited’ models.
- Typically small codes with little incentive to invest in the expensive software buy-in required to participate in the large abstract frameworks. CCMC can offer them this buy-in on the cheap
- ‘Model assimilation’ with these limited physics models will be essential for progression to more and more accurate forecasting with the ‘first principles mega-frameworks’.



Convenience

- Personnel familiar with other hosted models
- Common usage of the datafile standard developed for use at the CCMC
- Common usage of the visualization tools
- Access to more complete sets of validation problems.



Long Term Infrastructure Focus

- CSEM and CISM researchers primary goals are scientific.
- Framework development only happens with explicit framework funding.
- Framework funding has a history of ebbing and flowing.
- How will the framework developers maintain their frameworks focus through the lean years?
- CCMC support for CSEM and CISM framework impetus by creating interfaces for additional models.



Exposure to quasi-Operational Environment

- Testing robustness - Definition of usable parameter ranges, grid resolutions, driving signals.
- Characterization of required computational resources.
- Validation against community standard test problems.
- Sociology in R&D and Operational worlds present an ‘impedance mismatch’ – CCMC can help !



CT Project

NASA CT (Computational Technology) project

- funded 3 year grants for development of 9 grand challenge frameworks
 - funding conditional upon achieving pre-negotiated milestones
 - included Michigan/CSEM SWMF, and ESMF (Earth System Modeling Framework)
 - CCMC was the main part of the review board for the SWMF
-
- Earth Science community more advanced in forecasting and data assimilation technologies.
 - Contrast of SWMF and ESMF experiences tells an interesting story.



SWMF

- Intra-CSEM effort.
- Most successful of the 9 teams – delivered everything that they promised.
- Yet to expose its framework beyond the core development team.
- Most compelling demo of the framework functionality will occur when they swap in an alternate MHD solver in place of BATS-R-US.



ESMF

3 institution (NCAR, MIT, NASA-GSFC) effort designed to make components of intra-institution mini-frameworks compatible. Nominally open source.

Hurdles

- Dusty decks
- Programming paradigm shift to OOP
- F90 and OOP
- Need to build community consensus
- Funding restrictions



ESMF

Successes

- Initial requirements document
- Common component interface accepted by community
- Portable encapsulation of F90 arrays
- Survival

Failings (as perceived by the project - 10/04)

Almost all related to people management, politics and other sociological factors.

- Hiring
- Funding distribution
- Lost some focus on sequence of priorities
- The most difficult design choices were not all made early enough
- Lost time reinventing some existing capabilities
- Data assimilation features still in a design phase
- Achieved deliverable schedule poorly matched to funding agency timeframes – only 1 of 8 component models is functional AND esmf compliant.



Final Statement

CCMC will support end-to-end modeling by:

- offering model developers lower buy-in overhead into frameworks.
- exercising the main frameworks and providing feedback
- offering coupled model runs to support data analyses

ESMF lessons:

- we will eventually reach their starting point – needing to meld two frameworks into a standard.
 - Recognize importance of project politics and mundane personnel issues on the development cycle.
- To avoid design oversights, it is never too early to expose your frameworks to outsiders.
- Start developing data assimilation technologies now.