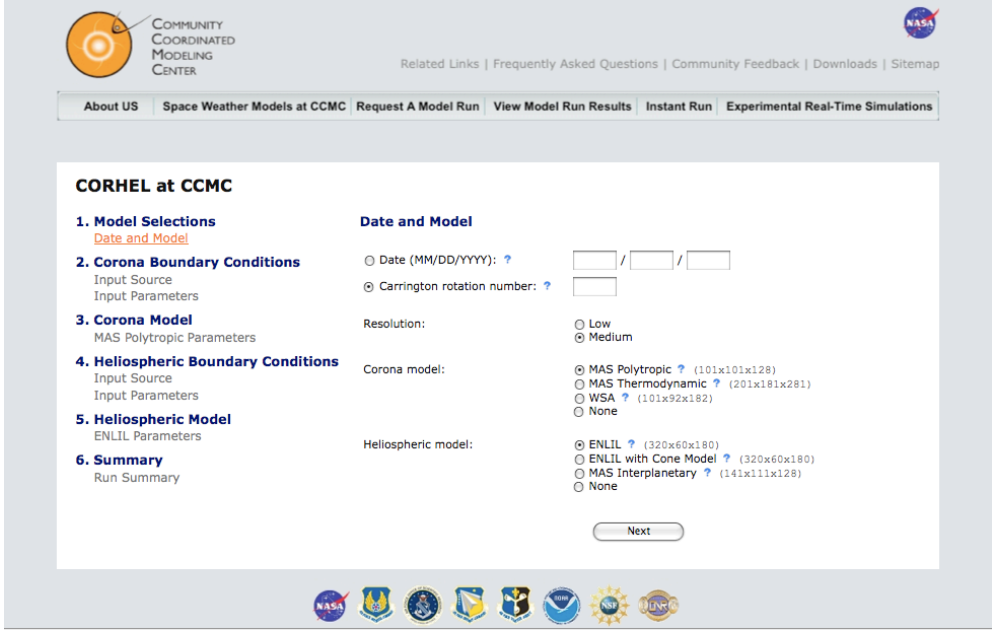
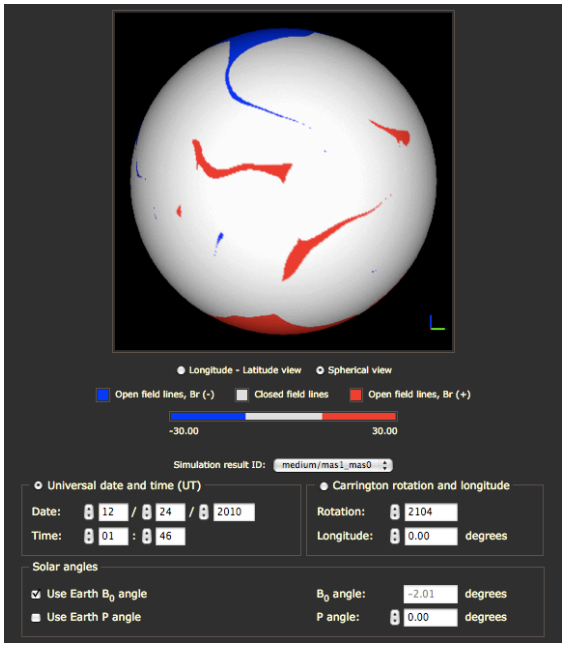
CORHEL at the CCMC





Jon Linker, Zoran Mikic, Pete Riley, Roberto Lionello, Janvier Wijaya, & Slava Titov

Predictive Science, Inc. (PSI), San Diego, CA, USA

http://www.predsci.com

Dusan Odstrcil

NASA GSFC, Greenbelt, MD and George Mason University, Fairfax, VA

Nick Arge

Space Vehicles Directorate, AFRL, Kirtland AFB, NM

Predictive Science, Inc.

Introduction

- The ambient solar corona and solar wind play a key role in how the Sun influences the Earth's space environment
- The region is vast in both real and parameter space
- Present/future missions sample the corona & inner heliosphere
- Coronal/solar wind models are required to synthesize these measurements into a coherent picture
- Important aspects of the physics of the corona and solar wind are still unknown or highly controversial.
- Models in different approximations are required for studying different aspects of solar and heliosperic physics.

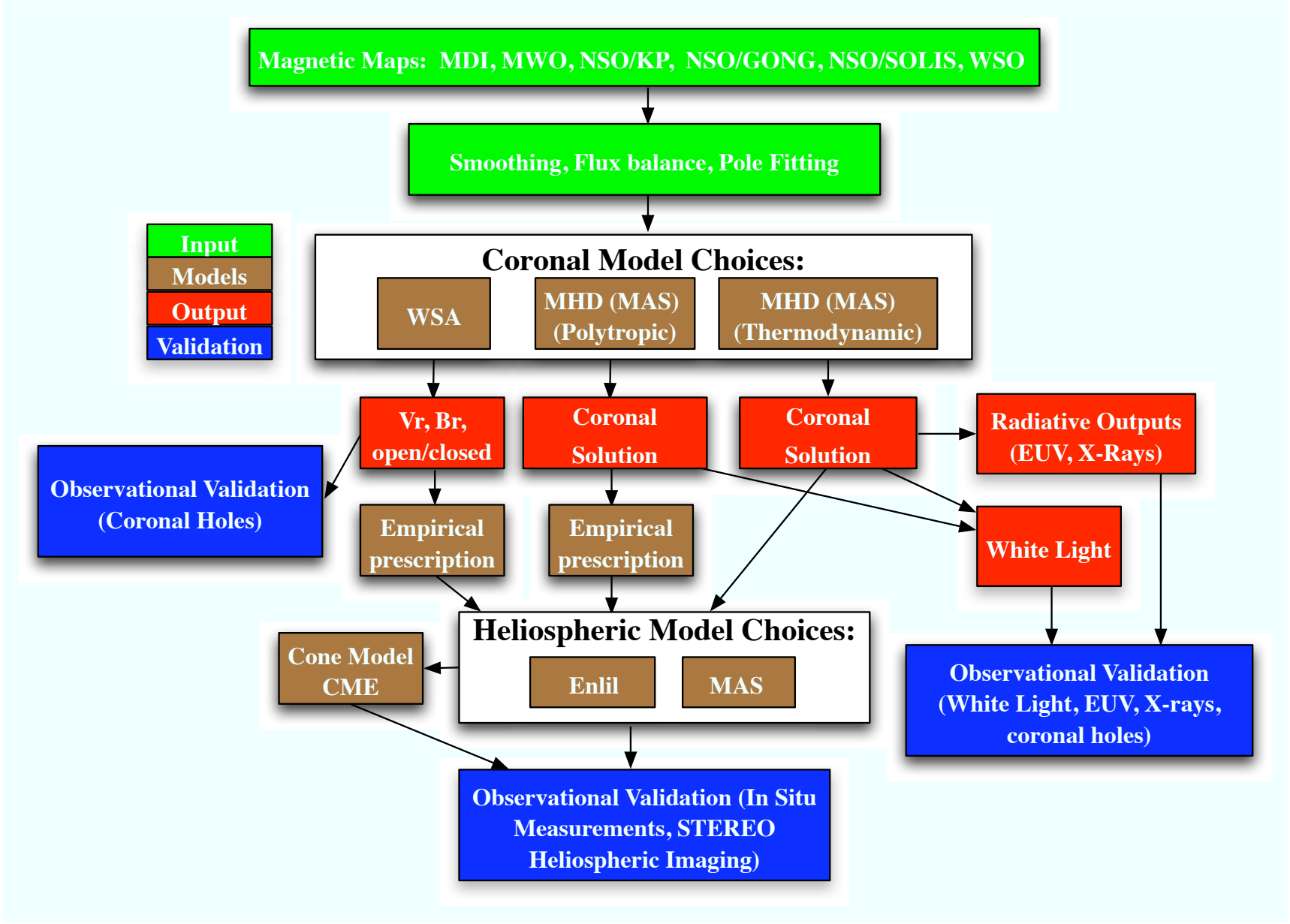
What is CORHEL?

- CORHEL - “Corona-Heliosphere”
- A coupled set of models and tools for quantitatively modeling the ambient solar corona and solar wind
- The principal observational input to CORHEL are maps of the radial magnetic field at the photosphere, derived from solar magnetograms
- CORHEL provides coronal solutions using 3 approximations:
  - WSA model (numerical potential solver)
  - Polytropic MHD (MAS Code)
  - Thermodynamic MHD (MAS code)
- CORHEL provides two different heliospheric codes: Enlil & MAS
- CORHEL outputs plasma and magnetic field quantities in 3D space
- It also outputs observable quantities for validation
- CORHEL has been delivered to AFRL, CCMC, and CISM

CORHEL Features

- Allows input from 6 (soon to be 7) different Solar magnetographs
- Processes synoptic maps into boundary data for calculations
- The map processor is web based and interactive:
  - Interactive display of the raw magnetogram and processed map
  - Interactive display of pole fitting and smoothing
- Can provide cone model CMEs
- CORHEL has PSI's implementation of the WSA model (with help from N. Arge)
  - Numerical Potential Solver
  - Allows consistent processing between WSA and MAS input
  - Allows for meaningful comparisons between WSA and MHD models, and comparison of different magnetograms
- Codes run on parallel architectures using MPI

CORHEL: Present Status

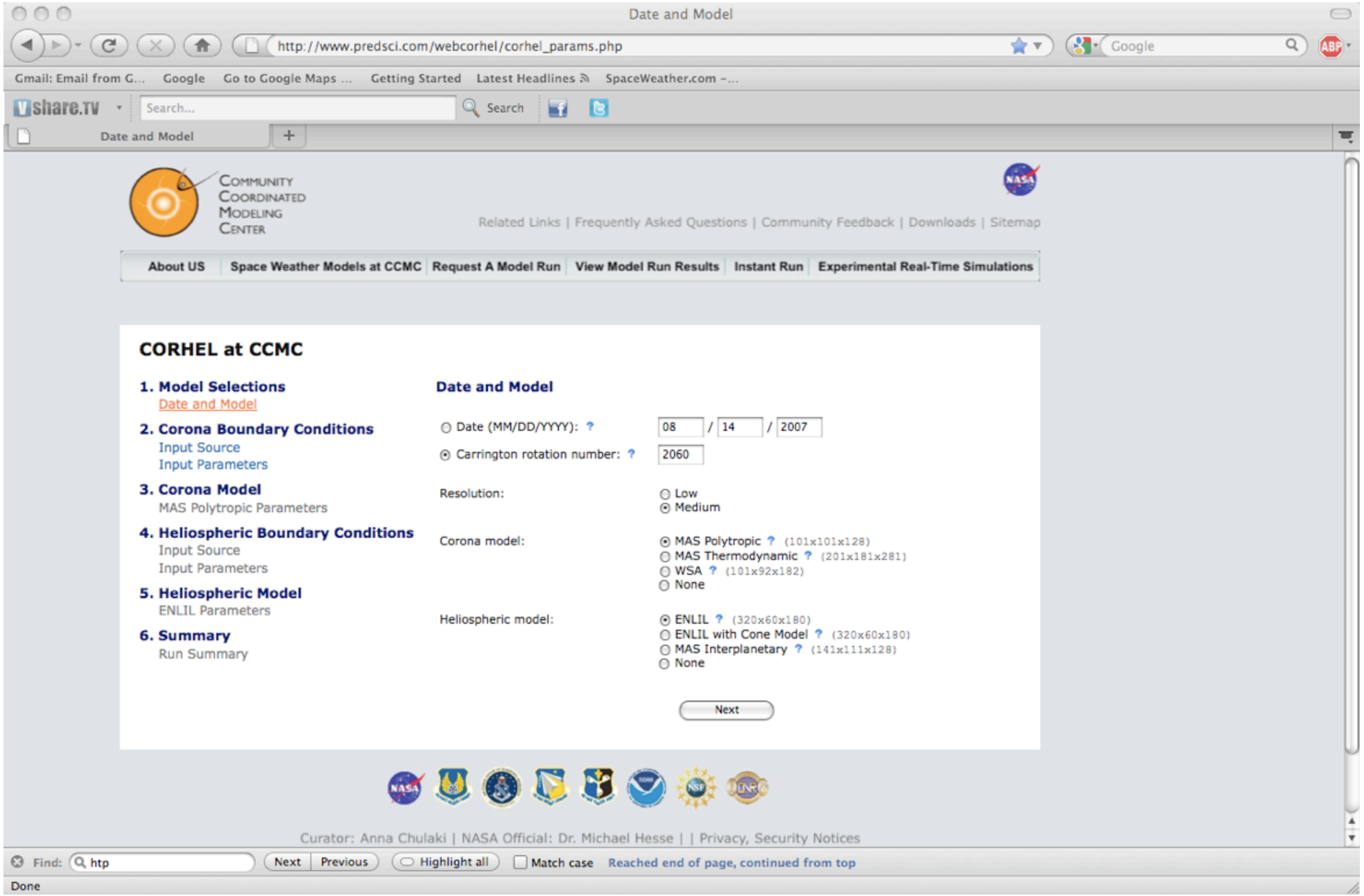


MAS and CORHEL at the CCMC

- The MAS (Magnetohydrodynamic Algorithm outside a Sphere) code has been available at the CCMC for 9 years.
- The original MAS at CCMC was a serial code that provided MHD solutions for the solar corona, using Kitt Peak photospheric magnetic maps as boundary conditions.
- CCMC developed the original interface to MAS. CCMC supplied all of the manpower, with guidance from us.
- CORHEL is a far more complex product than the original MAS.
- As CORHEL has expanded in capability and sophistication, there are many more choices and uses not envisioned by the original interface.

A New Interface for CORHEL

- Users want more flexibility to tailor their runs.
- To access all of the features of CORHEL, users need an intuitive interface that guides them through different choices
- We have also found that users like certain products derived from the solutions (e.g. coronal hole boundaries, pB, emission) that we provide on our web site
- Interface development requires deep knowledge of CORHEL:
  - Requires many more man-hours for someone outside our team.
  - It is unrealistic to expect the CCMC to provide all of this manpower.
- We developed a new interface for CORHEL, and in close collaboration with CCMC staff, have ported it to the CCMC.
- The new interface and capabilities is currently undergoing testing and should be available soon.


Date and Model
http://www.predsci.com/webcorhel/corhel_params.php
Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com –...
Vshare.TV Search... Search
Date and Model
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Input Parameters
3. Corona Model
MAS Polytropic Parameters
4. Heliospheric Boundary Conditions
Input Source
Input Parameters
5. Heliospheric Model
ENLIL Parameters
6. Summary
Run Summary
Date and Model
Date (MM/DD/YYYY): ? 08 / 14 / 2007
Carrington rotation number: ? 2060
Resolution: Low Medium
Corona model: MAS Polytropic ? (101x101x128) MAS Thermodynamic ? (201x181x281) WSA ? (101x92x182) None
Heliospheric model: ENLIL ? (320x60x180) ENLIL with Cone Model ? (320x60x180) MAS Interplanetary ? (141x111x128) None
Next
Curator: Anna Chulaki | NASA Official: Dr. Michael Hesse | | Privacy, Security Notices
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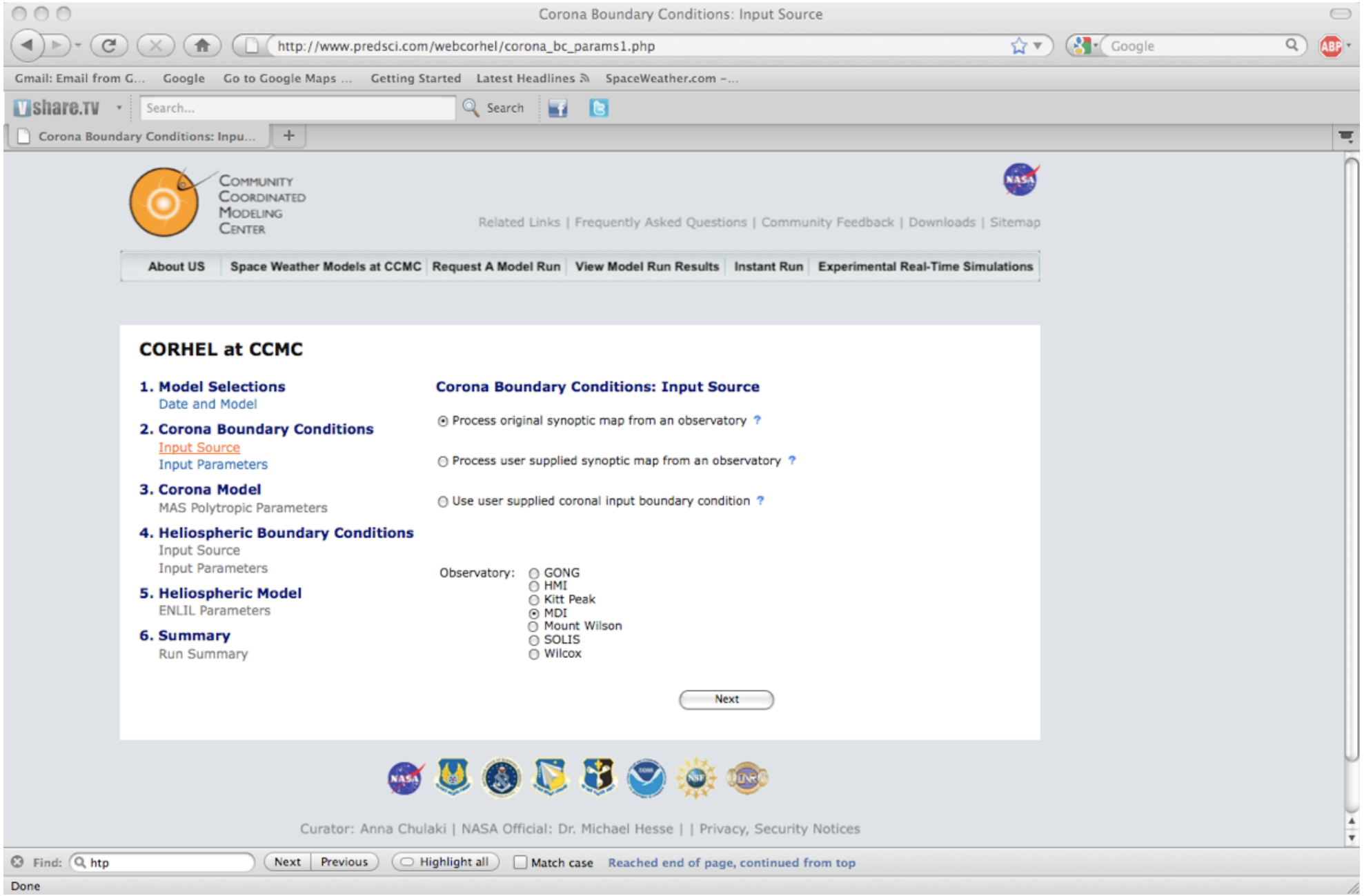
Corona Boundary Conditions: Input Source
http://www.predsci.com/webcorhel/corona_bc_params1.php
Google
Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com –...
Vshare.TV Search... Search
Corona Boundary Conditions: Inpu...
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Input Parameters
5. Heliospheric Model
ENLIL Parameters
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Run Summary
Corona Boundary Conditions: Input Source
Process original synoptic map from an observatory ?
Process user supplied synoptic map from an observatory ?
Use user supplied coronal input boundary condition ?
Observatory:
GONG
HMI
Kitt Peak
MDI
Mount Wilson
SOLIS
Wilcox
Next
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Corona Boundary Conditions: Input Parameters

http://www.predsci.com/webcorhel/corona_bc_params2.php

Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com -...

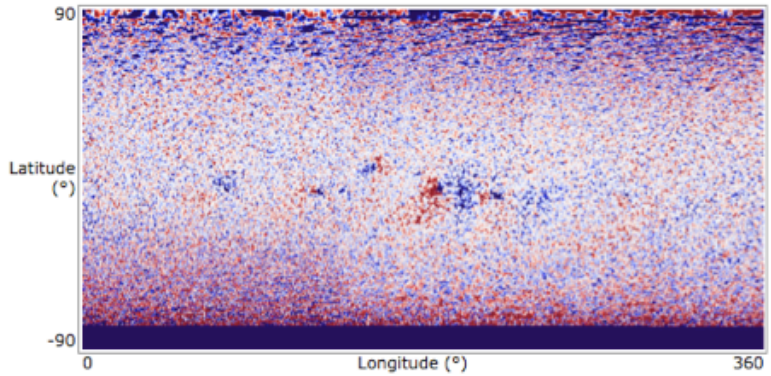
Corona Boundary Conditions: Inpu...

CORHEL at CCMC

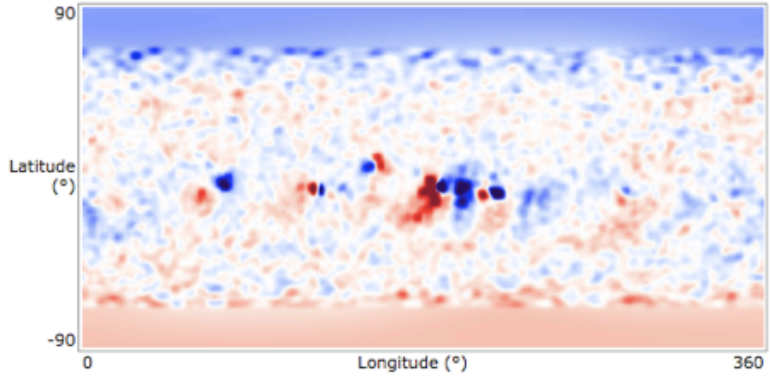
1. **Model Selections**
   Date and Model
2. **Corona Boundary Conditions**
   Input Source
   Input Parameters
3. **Corona Model**
   MAS Polytropic Parameters
4. **Heliospheric Boundary Conditions**
   Input Source
   Input Parameters
5. **Heliospheric Model**
   ENLIL Parameters
6. **Summary**
   Run Summary

Corona Boundary Conditions: Input Parameters

MDI Raw Synoptic Map for Carrington Rotation 2060



MDI Filtered Synoptic Map for Carrington Rotation 2060



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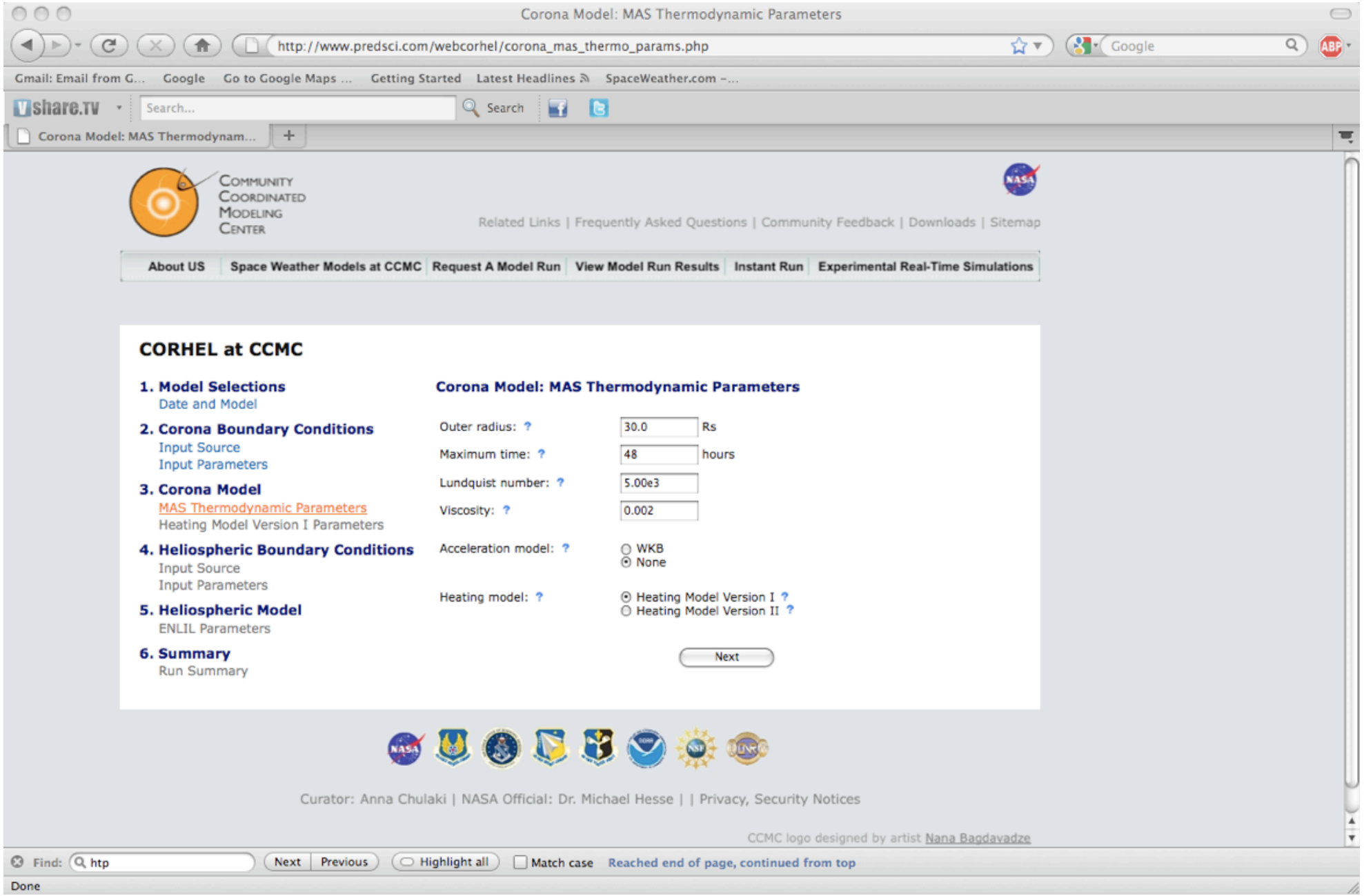
Corona Model: MAS Thermodynamic Parameters
http://www.predsci.com/webcorhel/corona_mas_thermo_params.php
Google
Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com –...
Vshare.TV Search... Search
Corona Model: MAS Thermodynam...
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Heating Model Version I Parameters
4. Heliospheric Boundary Conditions
Input Source
Input Parameters
5. Heliospheric Model
ENLIL Parameters
6. Summary
Run Summary
Corona Model: MAS Thermodynamic Parameters
Outer radius: ? 30.0 Rs
Maximum time: ? 48 hours
Lundquist number: ? 5.00e3
Viscosity: ? 0.002
Acceleration model: ? WKB None
Heating model: ? Heating Model Version I ? Heating Model Version II ?
Next
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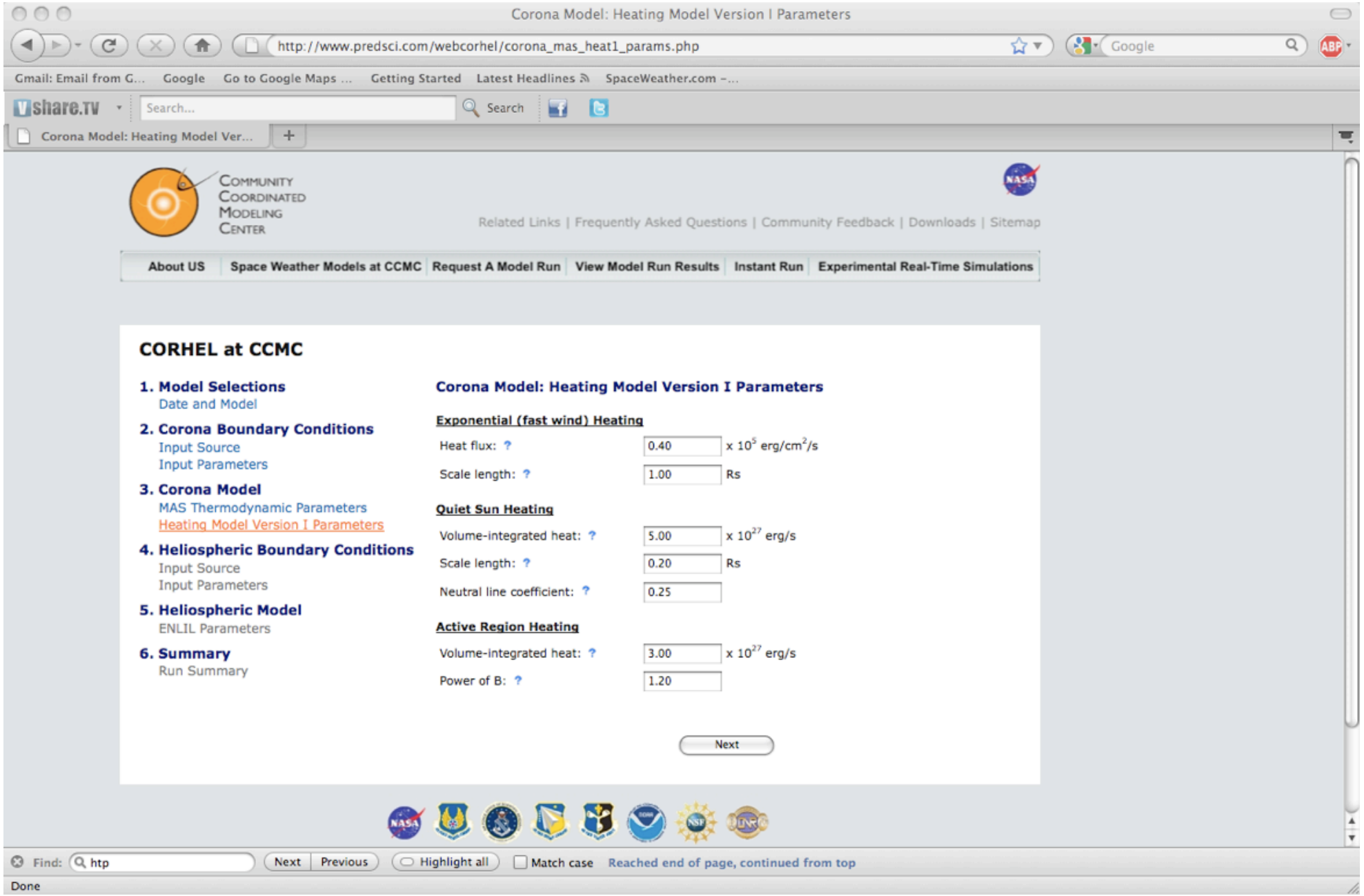
Corona Model: Heating Model Version I Parameters
http://www.predsci.com/webcorhel/corona_mas_heat1_params.php
Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com –...
Search...
Search
Corona Model: Heating Model Ver...
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Heating Model Version I Parameters
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ENLIL Parameters
6. Summary
Run Summary
Corona Model: Heating Model Version I Parameters
Exponential (fast wind) Heating
Heat flux: ? 0.40 x 10^5 erg/cm^2/s
Scale length: ? 1.00 Rs
Quiet Sun Heating
Volume-integrated heat: ? 5.00 x 10^27 erg/s
Scale length: ? 0.20 Rs
Neutral line coefficient: ? 0.25
Active Region Heating
Volume-integrated heat: ? 3.00 x 10^27 erg/s
Power of B: ? 1.20
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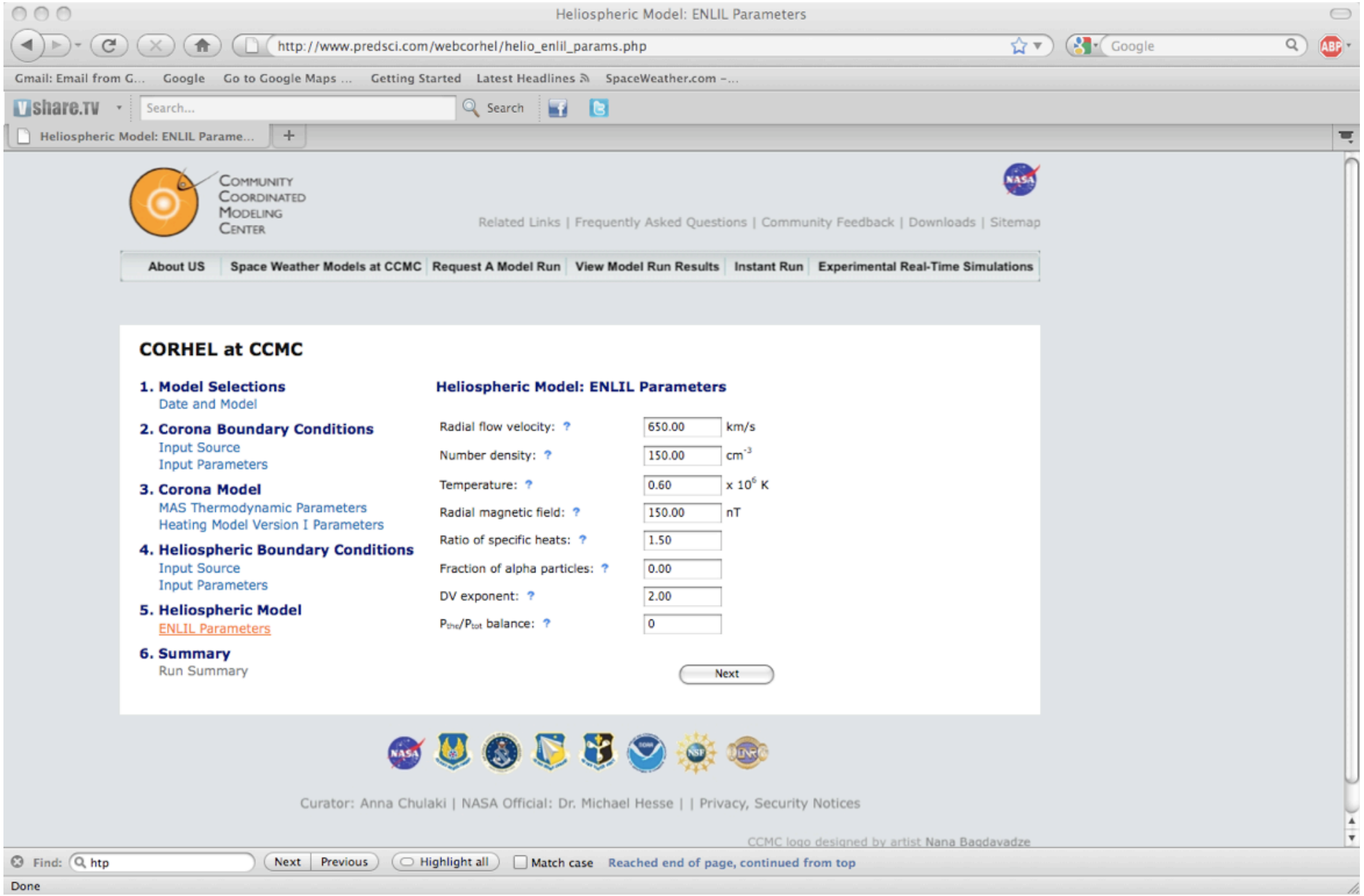
Heliospheric Model: ENLIL Parameters
http://www.predsci.com/webcorhel/helio_enlil_params.php
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Input Source
Input Parameters
5. Heliospheric Model
ENLIL Parameters
6. Summary
Run Summary
Heliospheric Model: ENLIL Parameters
Radial flow velocity: 650.00 km/s
Number density: 150.00 cm-3
Temperature: 0.60 x 10^6 K
Radial magnetic field: 150.00 nT
Ratio of specific heats: 1.50
Fraction of alpha particles: 0.00
DV exponent: 2.00
Pthe/Ptot balance: 0
Next
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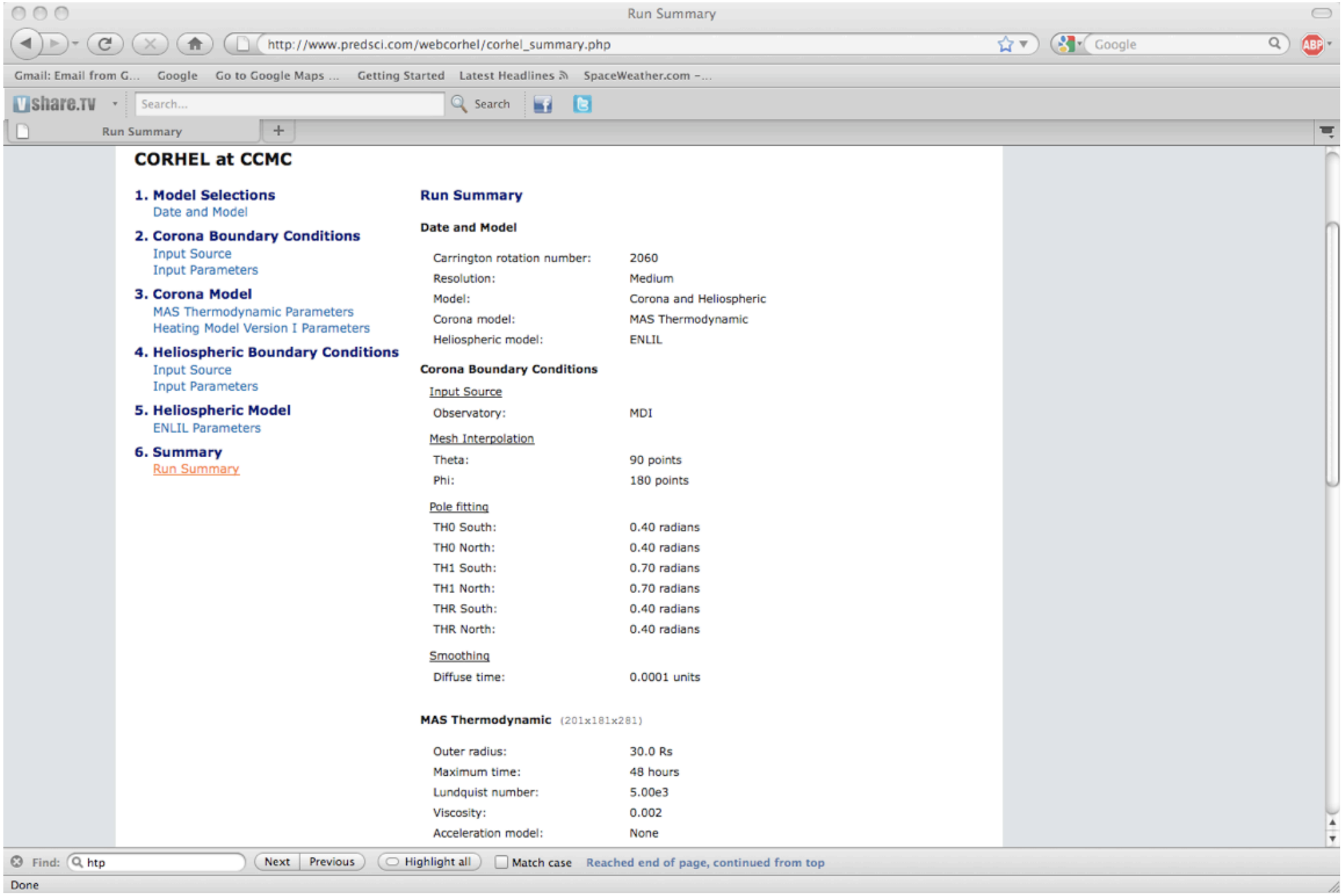
Run Summary
http://www.predsci.com/webcorhel/corhel_summary.php
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Gmail: Email from G... Google Go to Google Maps ... Getting Started Latest Headlines SpaceWeather.com -...
share.tv
Search...
Search
Run Summary
CORHEL at CCMC
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Input Source
Input Parameters
3. Corona Model
MAS Thermodynamic Parameters
Heating Model Version I Parameters
4. Heliospheric Boundary Conditions
Input Source
Input Parameters
5. Heliospheric Model
ENLIL Parameters
6. Summary
Run Summary
Run Summary
Date and Model
Carrington rotation number: 2060
Resolution: Medium
Model: Corona and Heliospheric
Corona model: MAS Thermodynamic
Heliospheric model: ENLIL
Corona Boundary Conditions
Input Source
Observatory: MDI
Mesh Interpolation
Theta: 90 points
Phi: 180 points
Pole fitting
TH0 South: 0.40 radians
TH0 North: 0.40 radians
TH1 South: 0.70 radians
TH1 North: 0.70 radians
THR South: 0.40 radians
THR North: 0.40 radians
Smoothing
Diffuse time: 0.0001 units
MAS Thermodynamic (201x181x281)
Outer radius: 30.0 Rs
Maximum time: 48 hours
Lundquist number: 5.00e3
Viscosity: 0.002
Acceleration model: None
Find: htp
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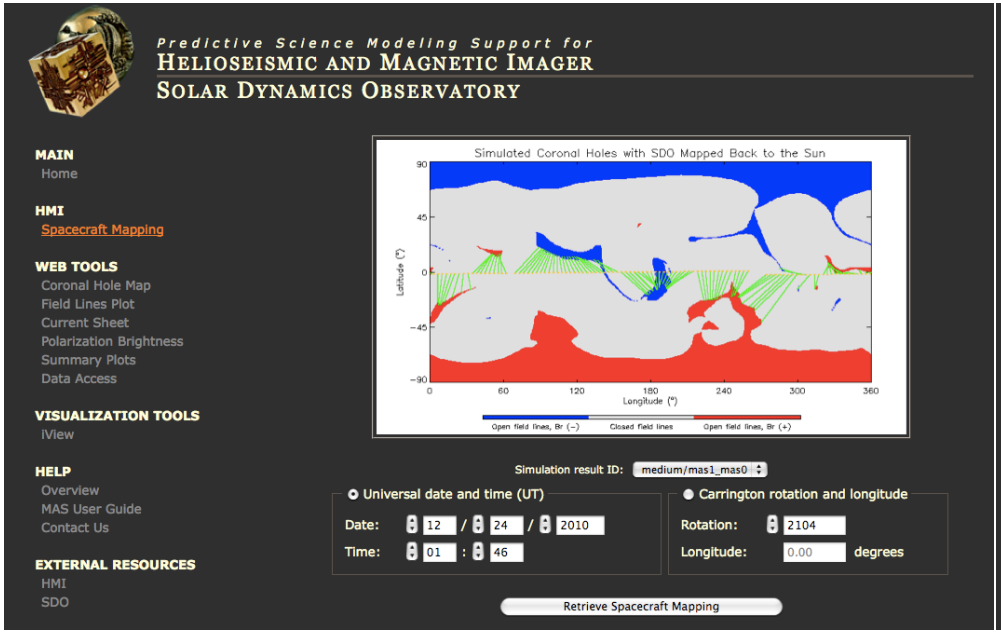
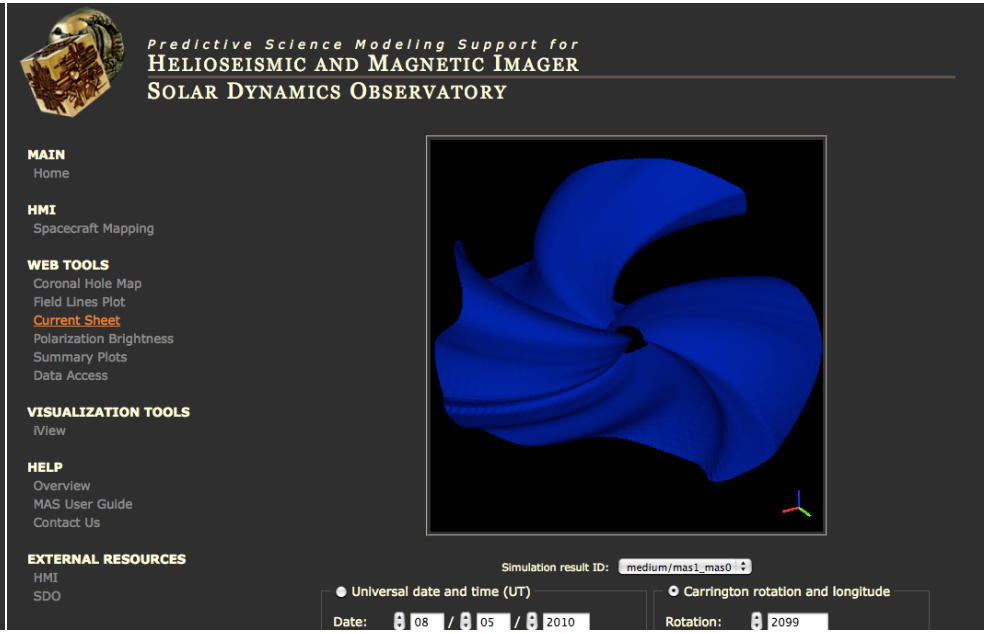
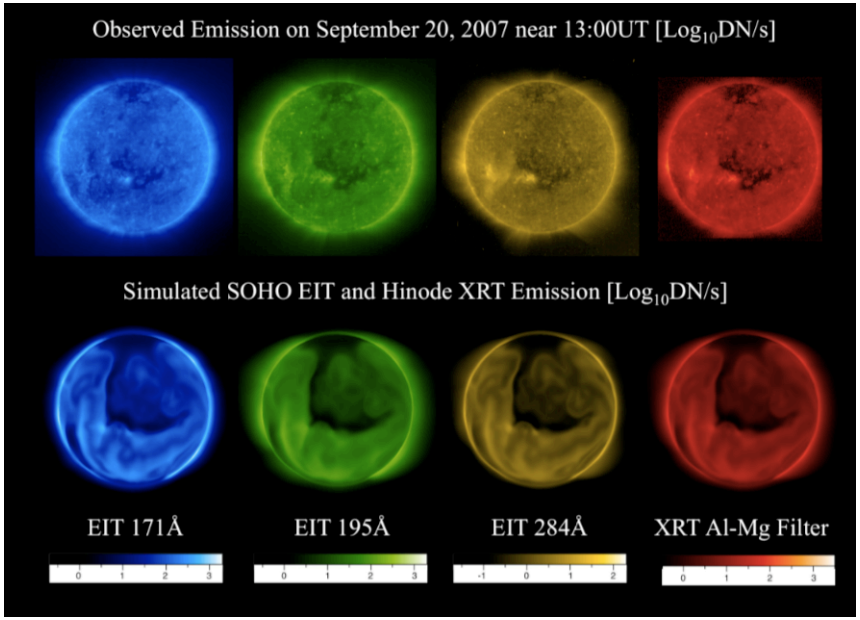
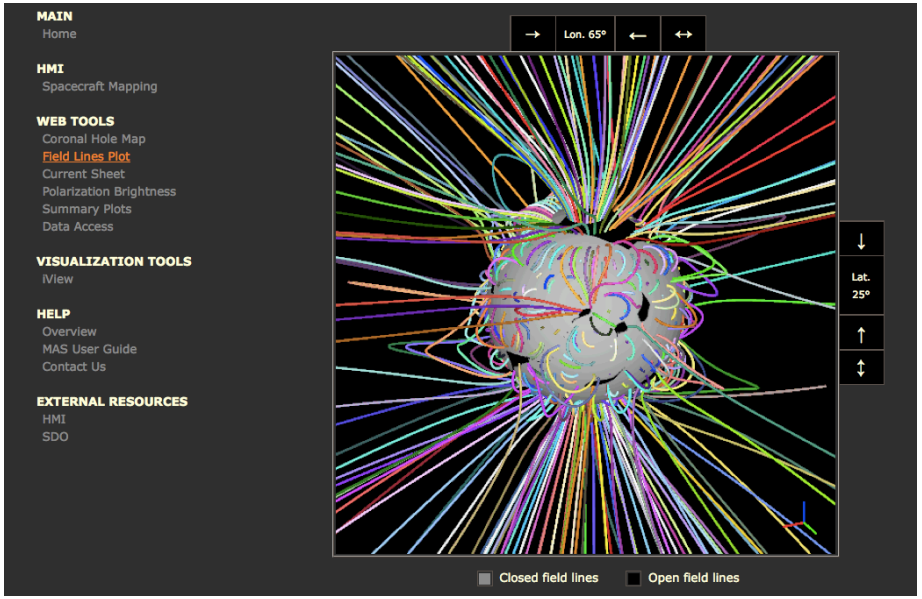
New Output Diagnostics From CORHEL









Plan to Implement in the Near Future

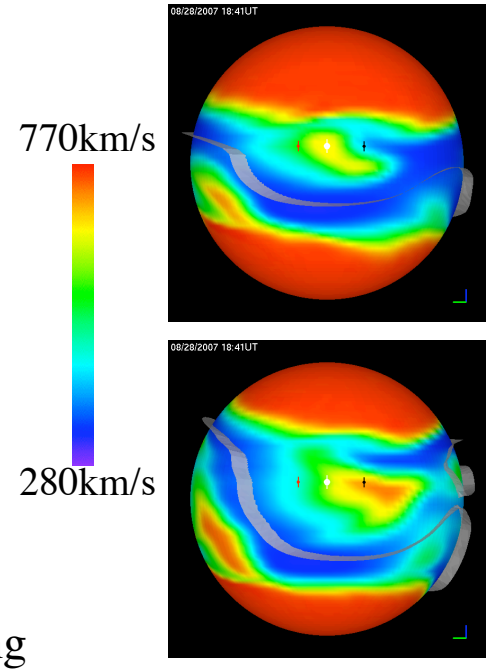
Some Applications

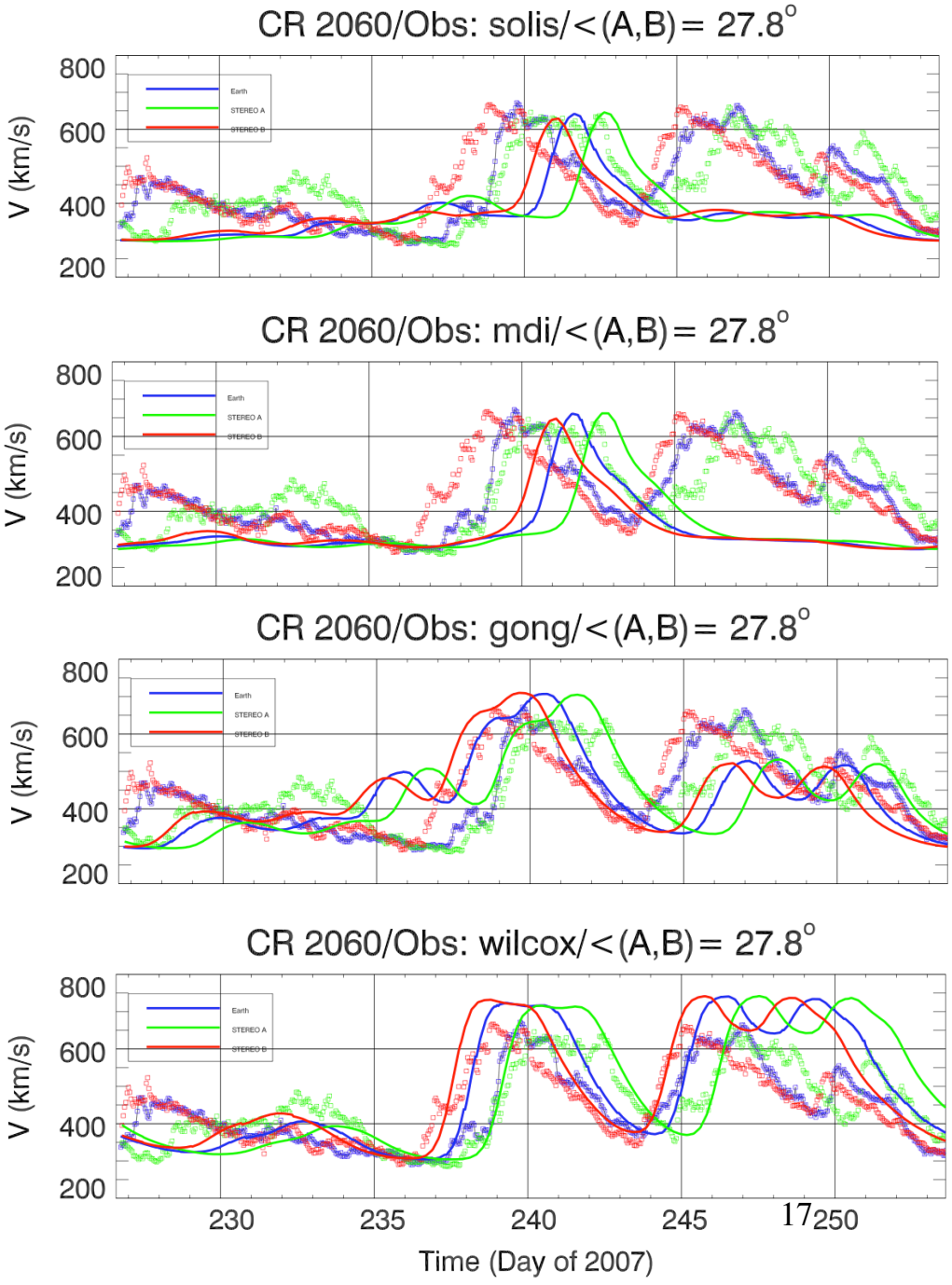
- Corotating Interaction Regions
- Unusual Solar Minimum preceeding Solar Cycle 24
- Topology and Structure
- A New Hypothesis for the Origin of the Slow Solar Wind

CORHEL Simulations for CR2060: Different Results for Different Observatories

- Simulations using NSO/SOLIS and SOHO/MDI are similar, predict 1 stream

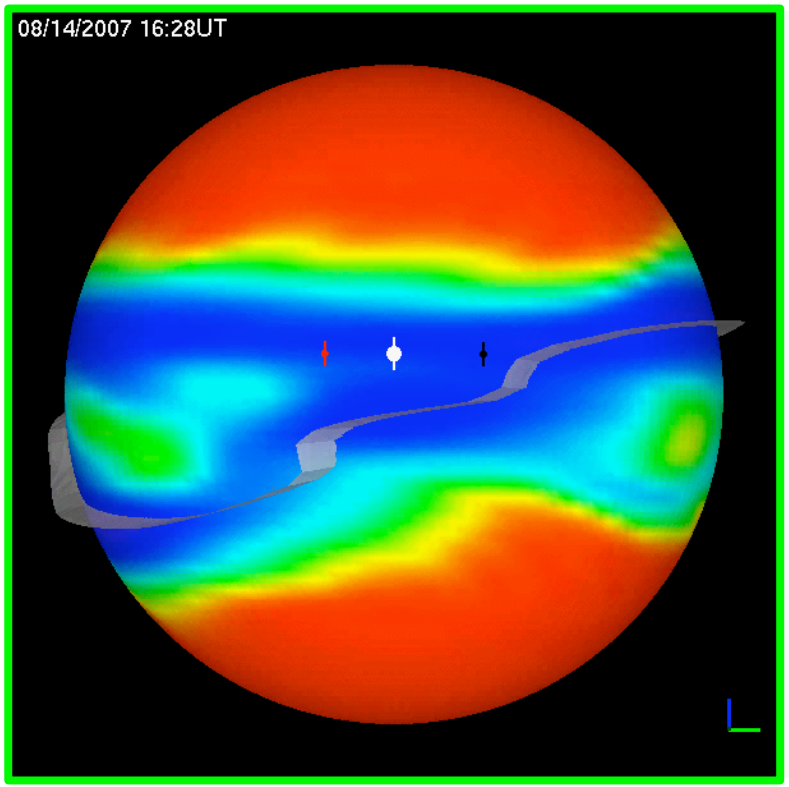
- Simulations using NSO/GONG and Wilcox predict 2 streams



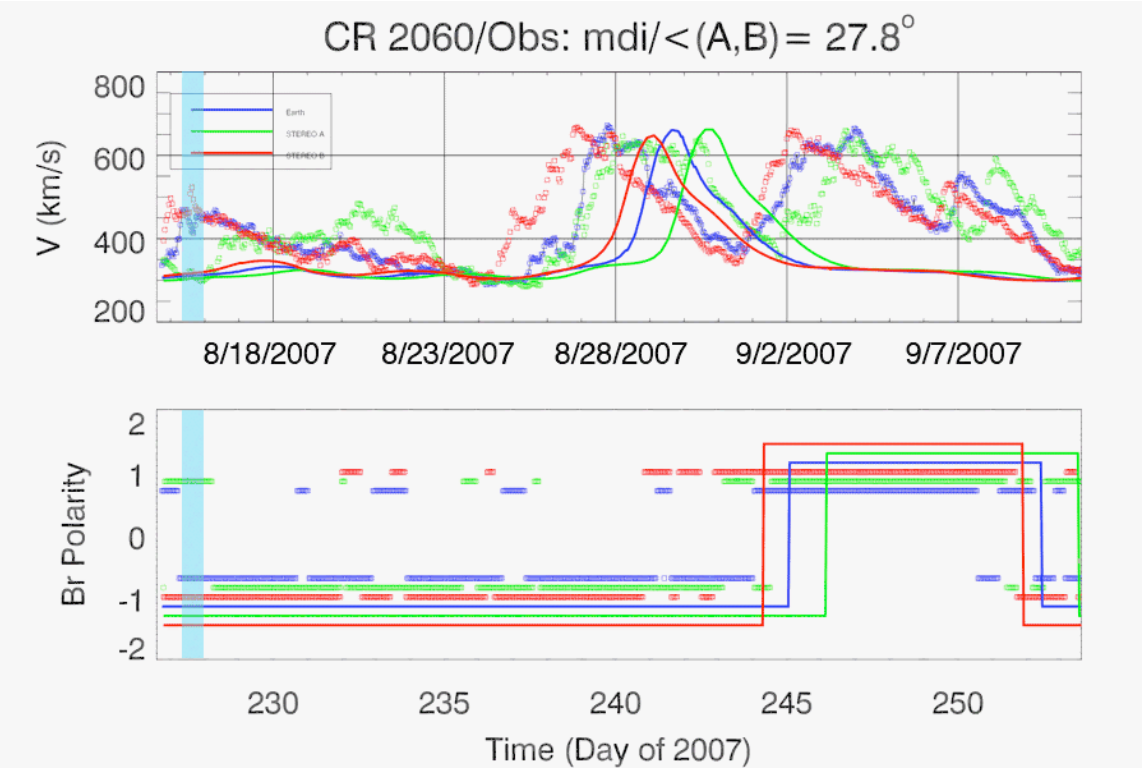


CORHEL Simulations for CR2060: Different Results for Different Observatories

SOHO/MDI



280km/s 770km/s



CORHEL Simulations for CR2060: Different Results for Different Observatories

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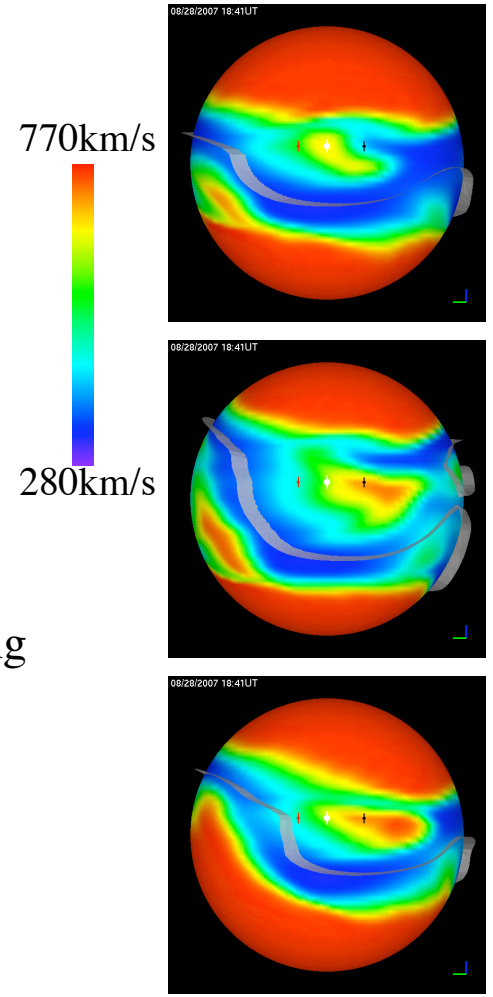
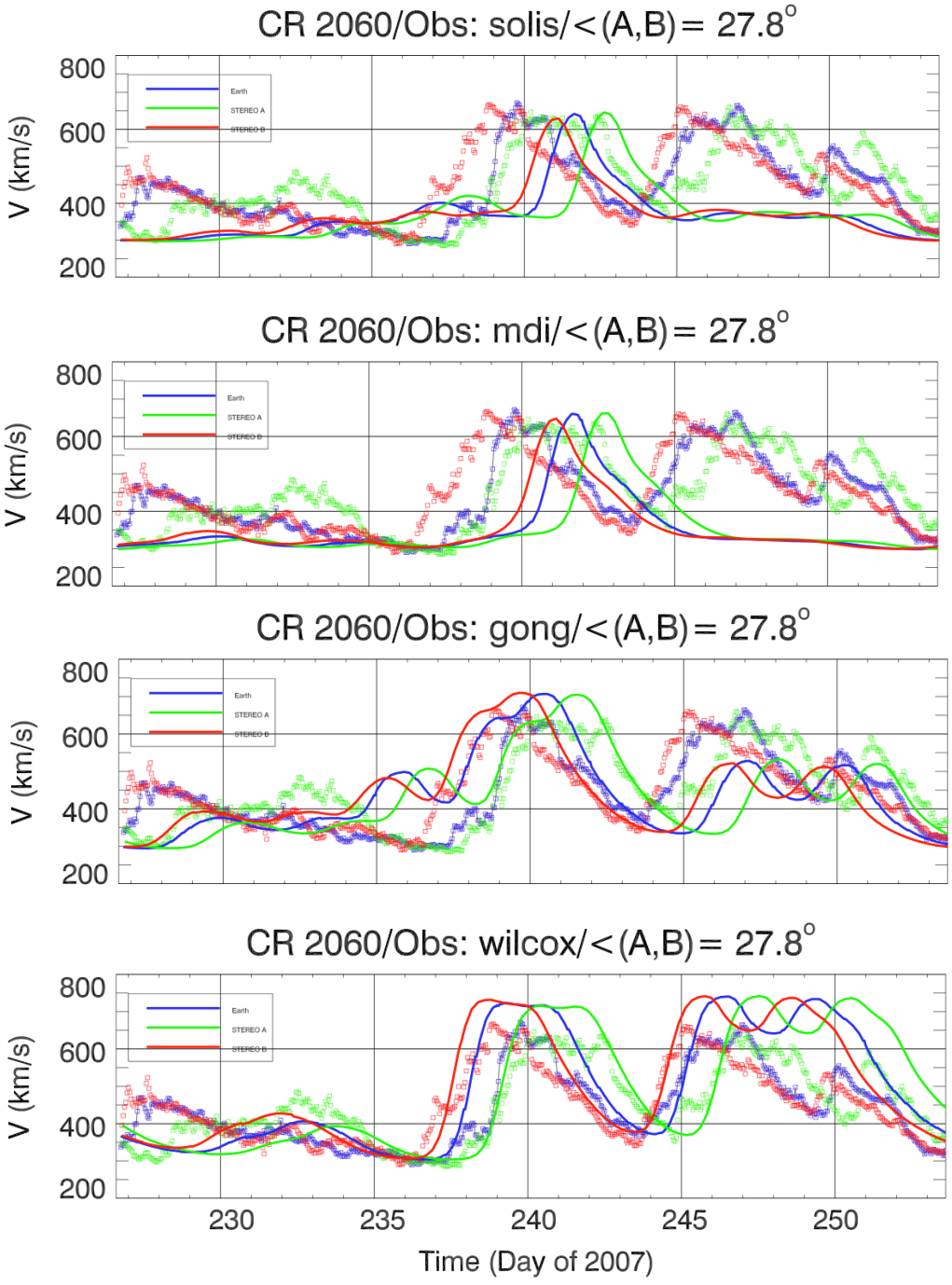
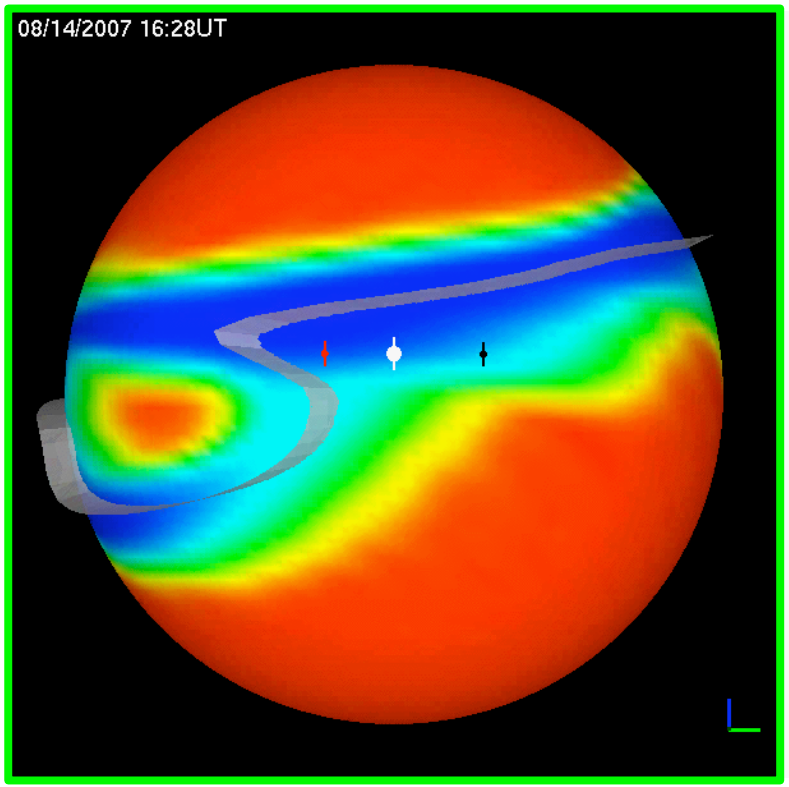


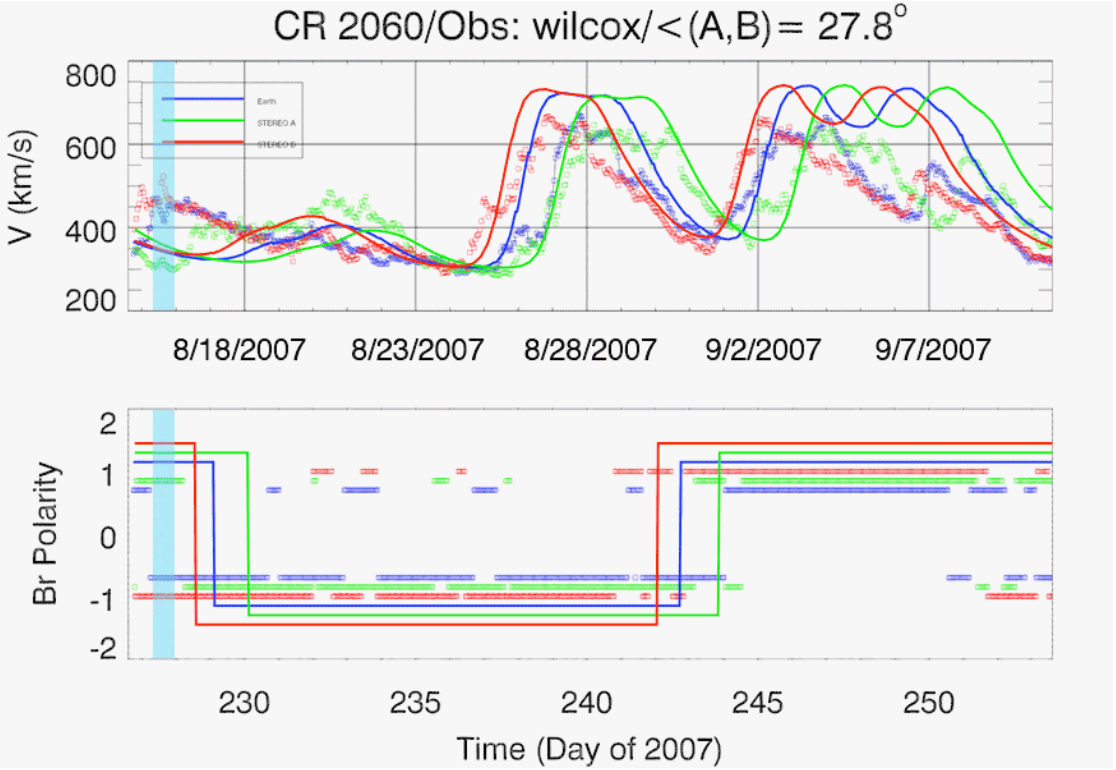


CORHEL Simulations for CR2060: Different Results for Different Observatories

Stanford/Wilcox



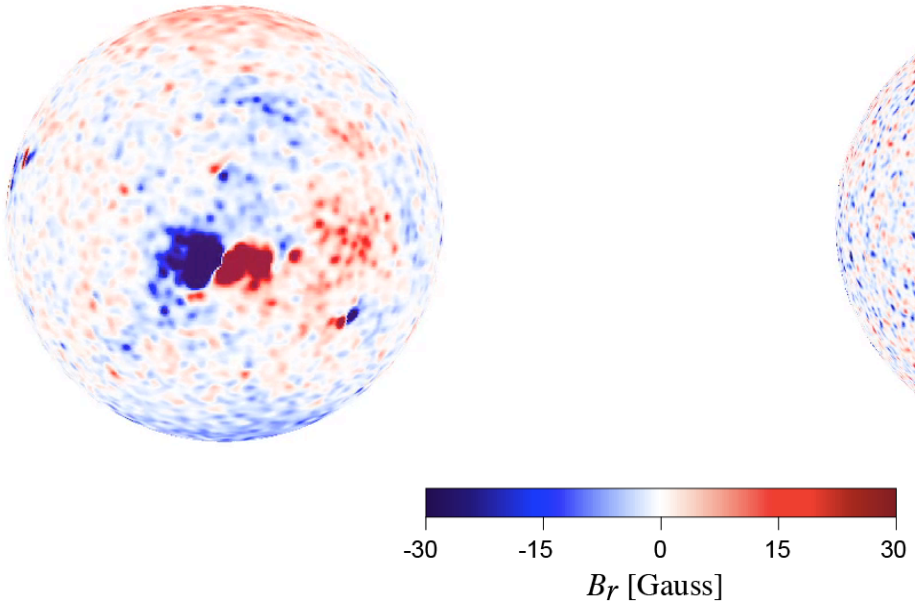
280km/s 770km/s



Photospheric Magnetic Field: Boundary Conditions for MHD Computations

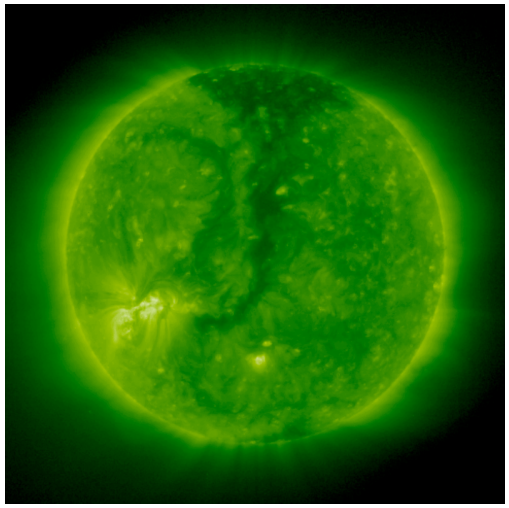
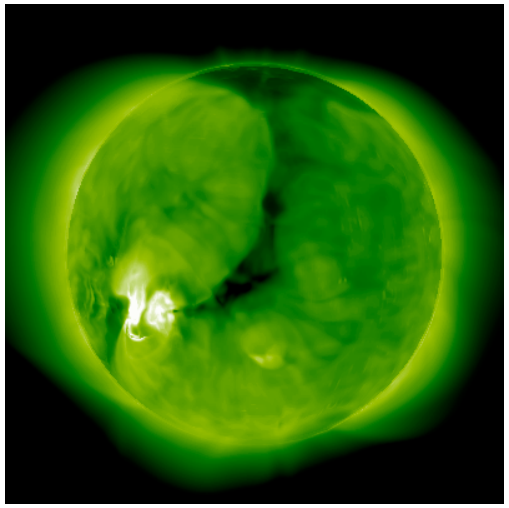
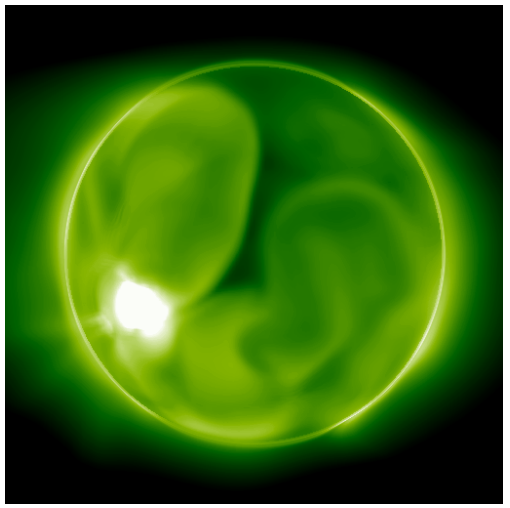
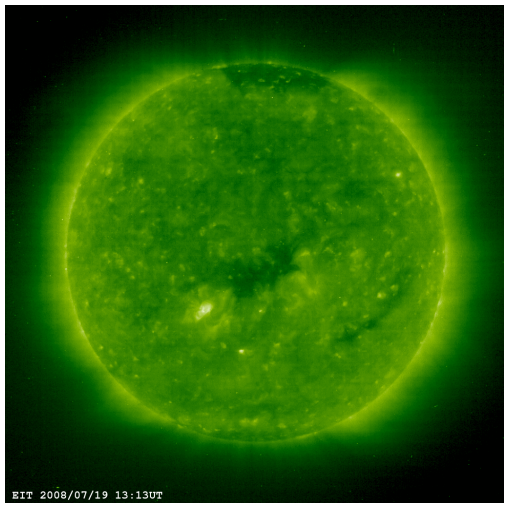
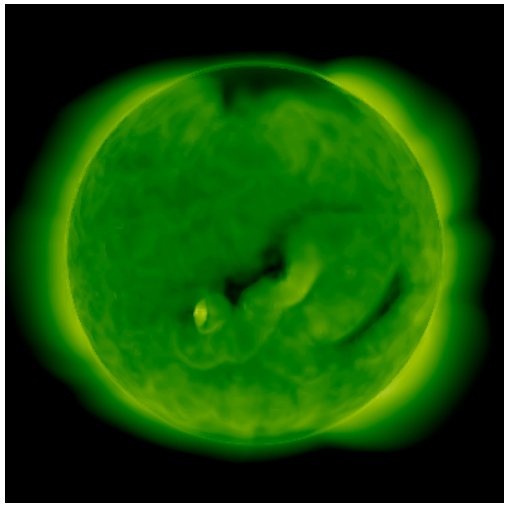
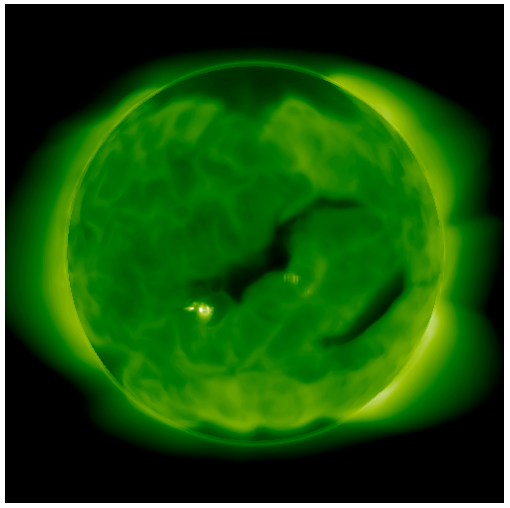
Whole Sun Month, August 1996
View on August 30 at 01:00 UT

Total Solar Eclipse, August 2008
View on August 1 at 10:00 UT
(Eclipse Day)



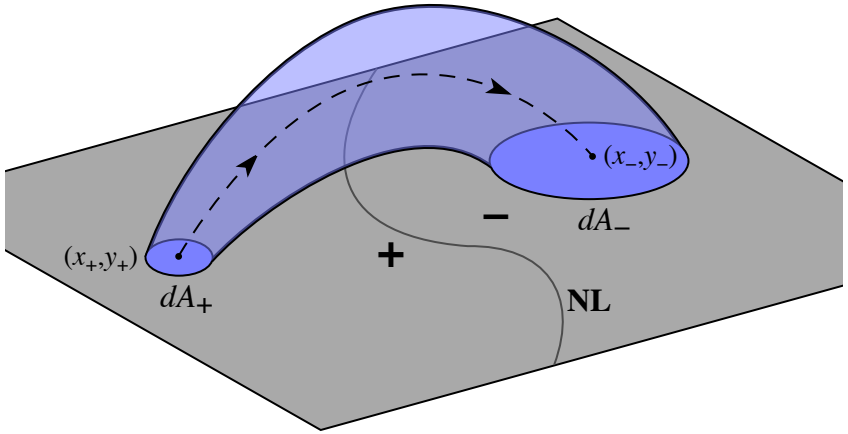
- We used MDI synoptic maps
- These are built up over a solar rotation

Solar Cycle 22.5 (1996) and Cycle 23.5 (2008) Minima

	Observations SOHO EIT 195A	MHD Solution New Heating	MHD Solution Lionello et al. (2009) Heating
CR1913 (WSM, 8/1996)			
CR2072 (8/1/2008 Eclipse)			

Analysis of Field Structure - Squashing Factor (Titov et al. 1999; Titov 2007)

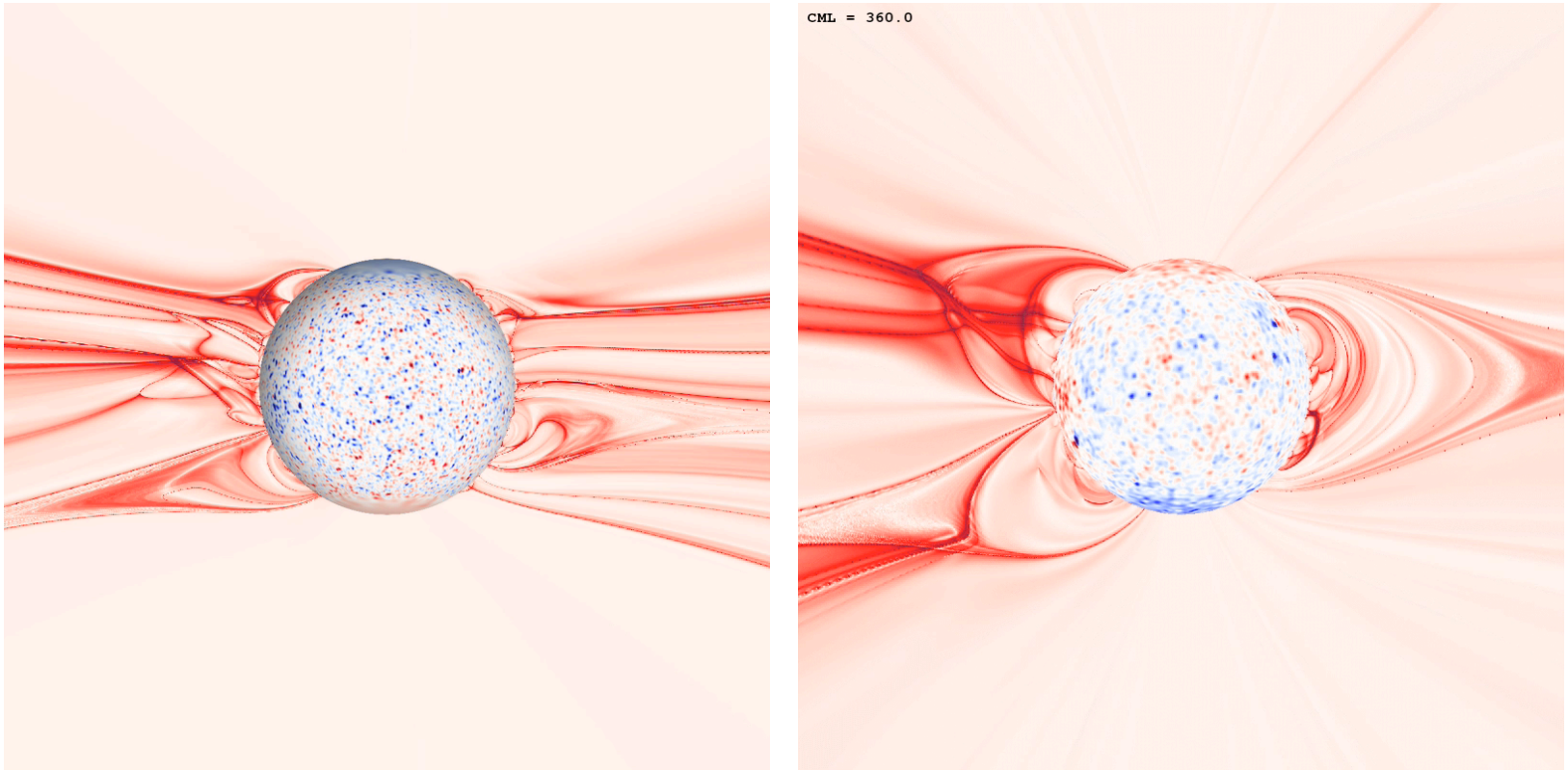
Definition of Squashing Factor, Q



- Measures the deformation of a flux tube from a circular to an elliptical cross section
- High values of Q:
  - Nulls and Separators
  - Coronal hole boundaries
  - Quasi-Separatix layers

Coronal Structure in High-Resolution Simulations

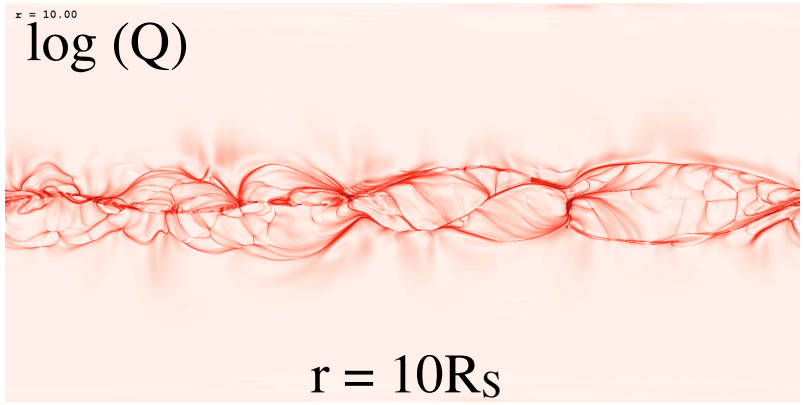
- The squashing factor Q is a measure of the deformation of a fluxtube - large at separators and quasi-separatrix layers (QSLs)

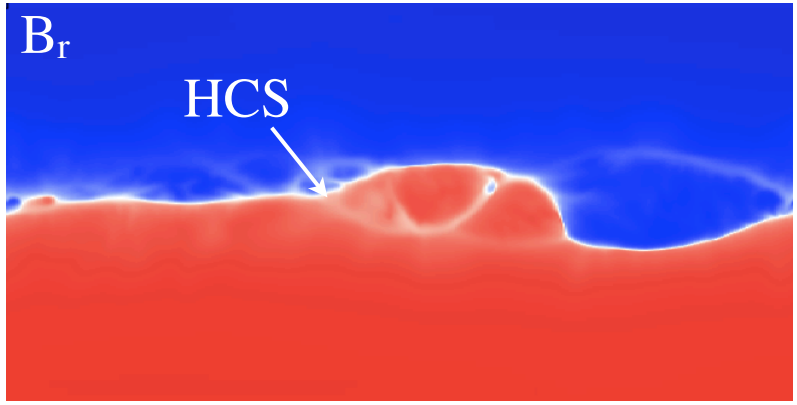


- Log (Q) reveals detailed structure in the corona

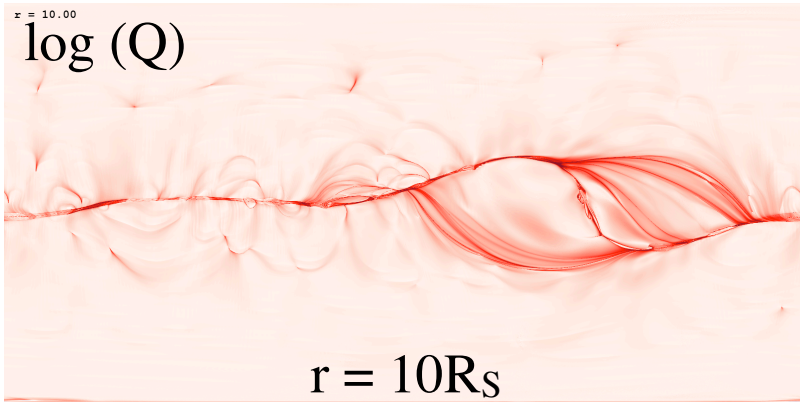
Comparison of the S-Web: Solar cycle 22.5 (1996) and 23.5 (2008) minima

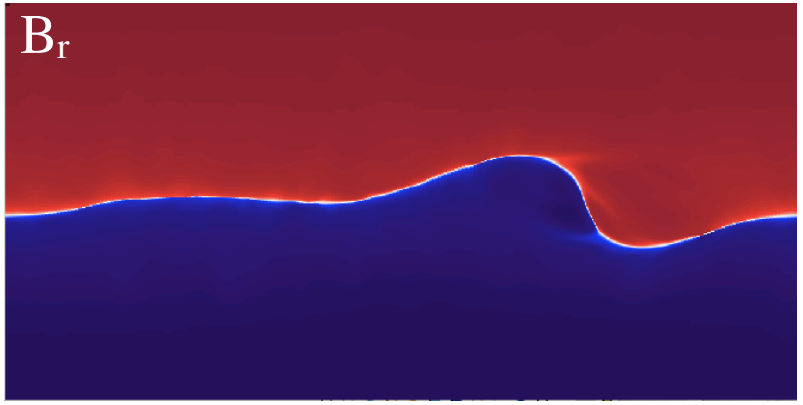
July - August 2008





August - September 1996





- The S-Web is indeed substantially different between the two minima

Future Improvements

- Time-dependent solar wind based on evolving photospheric B_r
  - Use Air Force Data Assimilative Photospheric Flux Transport (ADAPT) model to evolve the flux
  - May improve polar field estimates
- CME initiation and propagation in the corona
- Physics-based heating/acceleration models (wave-turbulence formalism)

Conclusions

- We have had a long and fruitful collaboration with CCMC (~ 9 years)
- We expect this to continue
- Our collaboration with the CCMC has allowed us to successfully deliver our research models to the community
- The new interface we have developed in collaboration with CCMC will make more features of CORHEL accessible
- Its extensibility will allow new features to be added relatively easily