Current Status of and Future Plans for MAS at the CCMC

Structure of the Corona on May 12, 1997

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SAIC, San Diego, CA.
Arecibo Observatory, November 6, 2007

Radial Flow Velocity

Plasma Temperature

Magnetic Field Lines

Photospheric Radial Magnetic Field

CME Source Active Region
This talk reviews the current implementation of MAS at the CCMC and our future plans.

Current version of MAS at CCMC: Polytropic, serial, lower resolution, AND robust.

Our latest in-house version: Thermodynamic, parallel, higher resolution, BUT more temperamental.

Leveraging other programs: CISM and the LWS Strategic Capability “A Next Generation Model of the Corona and Solar Wind.”
The ‘old’ version of MAS at the CCMC relies on a polytropic relationship

\[ \nabla \times A = B, \]
\[ \frac{\partial A}{\partial t} = \mathbf{v} \times \mathbf{B} - \frac{c^2}{4\pi} \nabla \times \mathbf{B}, \]
\[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0, \]
\[ \frac{1}{\gamma - 1} \left( \frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T \right) = -T \nabla \cdot \mathbf{v}, \]
\[ \rho \left( \frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} \right) = \frac{\nabla \times \mathbf{B} \times \mathbf{B}}{4\pi} - \nabla p + \rho \mathbf{g} + \nabla \cdot (\nu \rho \nabla \mathbf{v}), \]
\[ \gamma = 1.05. \]
Schematic of how corona/heliospheric solutions are computed in the ‘old’ MAS

1 – 30 Rs

Coronal Model

Density, temperature constant

$B_r$ at inner boundary

Line-of-sight Photospheric Magnetic field (e.g., Kitt Peak)
Schematic of how corona/heliospheric solutions are computed in the ‘old’ MAS

- **Line-of-sight Photospheric Magnetic field** (e.g., Kitt Peak)
- **Coronal Model**
  - Density, temperature constant
  - \( B_r \) at inner boundary
  - Speed from magnetic topology
  - Momentum Flux balance \( \Rightarrow \) density
  - Pressure balance \( \Rightarrow \) temperature

- **Heliospheric Model**
  - 30 Rs – 5 AU

1 – 30 Rs
The old MAS code provides robust solutions for the solar corona and inner heliosphere.
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Comparisons with in situ data demonstrate that the model can reproduce essential observations.
The latest version of MAS includes energy transport processes

\[ \nabla \times B = \frac{4\pi}{c} J \]
\[ \nabla \times E = -\frac{1}{c} \frac{\partial B}{\partial t} \]
\[ E + \frac{1}{c} v \times B = \eta J \]
\[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0 \]
\[ \rho \left( \frac{\partial v}{\partial t} + v \cdot \nabla v \right) = \frac{1}{c} J \times B - \nabla p - \nabla p_w + \rho g + \nabla \cdot (v \rho \nabla v) \]
\[ \frac{\partial p}{\partial t} + \nabla \cdot (p v) = (\gamma - 1)(-p \nabla \cdot v - \nabla \cdot q - n_e n_p Q(T) + H) \]
\[ \gamma = 5/3 \]
\[ q = -\kappa \hat{b} \hat{b} \cdot \nabla T \] (Close to the Sun, \( r \leq 10R_s \))
\[ q = 2\alpha n_e T \hat{b} \hat{b} \cdot v/(\gamma - 1) \] (Far from the Sun, \( r \geq 10R_s \))

+ WKB equations for Alfvén wave pressure \( p_w \) evolution
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The new MAS can reproduce white-light and emission measurements.
The new MAS provides 3-D views of the solar corona
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The new version of MAS will require multi-processor cluster capabilities
The NSF-funded CISM program is developing an ambient coronal/heliospheric model (CORHEL).
An SAIC-led LWS Strategic Capability will ultimately provide a near-real time SW model

A Next-Generation Model of the Corona and Solar Wind

Photospheric and Chromospheric Magnetograms

Magnetogram Processing (polar fields, active regions, flux evolution)

Sequence of Magnetic Maps

Coronal Model Choices:
- WSA
- MHD (Polytropic)
- MHD (Thermodynamic)

Daily Updated Ambient Coronal Solution

3-D MHD Heliospheric Model

Daily Updated Ambient Solar Wind Solution

Radiative Outputs (White Light, EUV, X-Rays)

Observational Validation (White Light, EUV, X-rays)

Observational Validation (In Situ Measurements, STEREO Heliospheric Imaging)
In summary, we are very pleased with our interactions with the CCMC and look forward to delivering ever-more sophisticated coronal models.

- **Improved physical processes**
  - Thermal conduction
  - Radiation
  - Coronal heating
  - Alfvén Waves

- **Fully parallel code**
  - Runs Columbia, Datastar, & clusters
  - Higher resolution
  - Non-uniform meshes
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Questions?