Coronal Modeling and Synchronic Maps*

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Introduction

• Coronal models typically rely on so-called “synoptic” magnetic maps to derive boundary conditions for these models
  • Maps are built up from line-of-sight (LOS) magnetograms taken over a solar rotation
  • Really “diachronic” not synoptic

• Two well-known problems:
  • Sun’s magnetic flux is always evolving, but synoptic map data can be as much as 27 days old
  • The LOS field at the Sun's poles is poorly observed, and the polar fields in these maps are filled with a variety of interpolation/extrapolation techniques

• Photospheric flux evolution models can help to address both these issues - “synchronous” maps

• Today I focus on the evolutionary aspect
Where We Would Like to Go: 
Towards A Near-Real Time Coronal Description

• We presently provide steady solutions for each Carrington Rotation, e.g. http://www.predsci.com/hmi

• Even at solar minimum, the corona and solar wind are always evolving in response to changes in the photospheric magnetic field

• If we observed the entire Sun’s photospheric field continuously and simultaneously, we could drive MHD models with this boundary data

• Flux evolution models have a long history and have been successful in describing the photospheric field response to known flows.

• We can use these models to assimilate magnetic data (magnetograms) where the field is observed, and fill in the gaps where it is not

• Emergence of active regions in unobserved portions of the Sun can significantly change the coronal evolution - how important is this effect?

• Today I illustrate some of the concepts using potential field source-surface (PFSS) models
The ADAPT flux transport model (Arge et al. 2009) is based on Worden & Harvey (2000), which accounts for known flows in the solar photosphere:

- Differential rotation
- Meridional flow
- Supergranular diffusion
- Random flux emergence
- Polar fields arise from long-term evolution

ADAPT improves on the Worden&Harvey model by incorporating rigorous data assimilation methods into it.

Present ADAPT maps are to be considered preliminary.

Presently experimenting with the incorporation of far side images
The Positions of the STEREO Spacecraft on July 11, 2010
• Coronal structure is strongly influenced by magnetic flux evolution.
• This is illustrated by coronal hole evolution.
• STEREO and SDO spacecraft provide us with a global view of this evolution.
• A number of extended coronal holes were visible during this time period.
• We focus on the extension of the coronal hole near longitude 270°.
Coronal Hole Evolution (June-July 2010)

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- We focus on the extension of the coronal hole near longitude 270°.
• SOHO/MDI synoptic maps for CR2098 and CR2099 are shown.
• Note the new active region complex in CR2099 at ~338° longitude.
• When did this AR actually emerge?
• Active regions on the far side of the Sun can be detected with helioseismology
• Field strength can be estimated
• Polarity must be guessed - use Hale and Joy rules
Comparison of Photospheric B Approximations

• Maps from ADAPT are approximations of the state of the photospheric magnetic flux at a given time

• We consider 4 different maps and examine the coronal structure they predict using source-surface models:
  • An ADAPT flux evolved map for 6/23/2010
  • An ADAPT flux evolved map for 7/7/2010, standard evolution
  • An ADAPT flux evolved map for 7/7/2010, new active region inserted based on GONG far side image
  • An ADAPT flux evolved map for 7/7/2010, new active region inserted but with leading and trailing polarities reversed
• PFSS solution using ADAPT flux-evolved map to 6/23, no further evolution
• PFSS coronal holes agree reasonably well with those observed by SDO on 6/23 and STEREO A on 6/28
Coronal Hole Comparison (PFSS solution for 6/23/2012)

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PFSS coronal holes agree reasonably well with those observed by SDO on 6/23 and STEREO A on 6/28
• PFSS solution using ADAPT flux-evolved map to 6/23, no further evolution
• PFSS coronal holes agree reasonably well with those observed by SDO on 6/23 and STEREO A on 6/28
• They do not agree well on with STEREO B observations on 7/14 (after the active region emerged on the far side)
Coronal Hole Comparison: Flux-evolved map without AR

- PFSS solution using ADAPT with standard flux evolution to 7/7/2010.
- New active region is not present in the map.
- Still not very good agreement between the modeled coronal holes and the STEREO B observation.
• PFSS solution using ADAPT with the far side active region assimilated into the map on 7/1.
• Map evolved with flux evolution to 7/7/2010.
• Noticeable change in the modeled coronal holes that agrees better with the observations.
What Happens if we get the Polarity Wrong?

- PFSS solution using ADAPT with the far side active region assimilated into the map on 7/1.
- Leading/trailing polarity reversed relative to previous case (and what was eventually observed)
- String of modeled coronal holes appear that don’t agree that well with observations
Summary

- Connecting solar and heliospheric observations ultimately requires a time-dependent coronal description.
- Flux evolution models that assimilate photospheric fields are a promising technique for driving time-dependent MHD models.
- Active region emergence on the unobserved portions of the Sun can significantly affect coronal structure.
- We have demonstrated that incorporating active regions estimated from far-side acoustic imaging can improve models of coronal structure.
- Magnetograms from a mission like Solar Orbiter, or an eventual L5 mission, could provide even more reliable data for predicting coronal structure.