Global Solar Magnetic Maps

L5 in Tandem with L1 Workshop
07 Mar 2017

Carl J. Henney¹, Nick Arge², and Kathleen Shurkin³

1. AFRL/Space Vehicles Directorate, Kirtland AFB, NM
2. NASA Goddard Space Flight Center, Greenbelt, MD
3. ISR, Boston College, Chestnut Hill, MA
Global solar magnetic maps are utilized to drive:

- **coronal & solar wind models** used to forecast the solar wind and Coronal Mass Ejection (CME) arrival times
- **indices & irradiance models** to forecast $F_{10.7}$, Mg II, and bands of EUV/FUV irradiance 1 - 7 days in advance for thermospheric modeling
Global Solar Magnetic Maps: 
ADAPT* Modeling Framework

- L1 observation in “sky frame” at obs_time
- Magnetogram data & uncertainty remapped into heliographic coordinates: longitude vs. latitude (180 x 180 deg).
- ADAPT pre-processing aligns all B_r input data (far & near) within model frame (i.e., 360x180; Carrington)

Model ensemble provided by each Observatory (SDO/HMI, NSO GONG & VSM)

Model ensemble from previous time step

Forward Modeling
Differential Rotation
Meridional Circulation
Supergranulation

Data Assimilation using EnLS Method

Model ensemble at obs_time

30 June 2010
NSO SOLIS/VSM

* ADAPT - Air Force Data Assimilative Flux Transport
(Arge et al. 2013, Henney et al. 2015, Hickmann et al. 2015)
Global Solar Magnetic Maps:
L5 Magnetograph Specification

- **L5 magnetograph specification**\(^1\) (*based on ADAPT WSA-Enlil and F10.7 & EUV irradiance modeling experience*):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed Area</td>
<td>Active Regions(^2)</td>
<td>Full-disk</td>
</tr>
<tr>
<td>Spatial Scale</td>
<td>2”/pixel</td>
<td>1”/pixel</td>
</tr>
<tr>
<td>Polarimetry</td>
<td>LOS(^3) (I, V)</td>
<td>I, Q, U, V</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>+/- 2500 G</td>
<td>+/- 3500 G</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>&lt; 1 G/pixel</td>
<td>&lt; 1 G/pixel</td>
</tr>
<tr>
<td>Zero-point error(^4)</td>
<td>&lt; 0.1 G</td>
<td>&lt; 0.05 G</td>
</tr>
<tr>
<td>Cadence</td>
<td>2 hours</td>
<td>15 minutes</td>
</tr>
</tbody>
</table>

**Notes**
1. Assuming L1 magnetograph (or ground based network) support with mostly optimal specifications.
2. Also need daily scan of polar regions
3. Assuming ARs remapped to Br with, e.g., potential-field reconstruction (ops version needs to be developed; see Leka, Barnes, Wagner 2017).

- **Coordinate Information Requirement:** need the L5 image central meridian offset from \(L_o\) viewed from L1. It is key to remap both L1 & L5 magnetograms into a fixed frame, e.g., Carrington (i.e., not centered on individual CM), to avoid unnecessary and diffusive interpolation.
Global Solar Magnetic Maps:  
Future Model Development

### Improvements with L5 Magnetograph

<table>
<thead>
<tr>
<th>Coronal &amp; Solar Wind Models</th>
<th>EUV Irradiance Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Full-Disk obs at:</strong></td>
<td></td>
</tr>
<tr>
<td>Polar Observation Gap</td>
<td>East Limb AR Polarity Split</td>
</tr>
<tr>
<td><strong>L1</strong></td>
<td>~6 months</td>
</tr>
<tr>
<td><strong>L1 &amp; L5</strong> (and with L4 -&gt; 2months)</td>
<td>~4 months</td>
</tr>
</tbody>
</table>

**Future Model Development Areas:**

- **Active region emergence & evolution modeling:**
  - estimate AR evolution during the ~10 days (~130°) on the farside [key for: C&SW]
  - near-side emergence growth & peak size from helioseismic subsurface flows? [EUV]
  - coupling far-side with L5 & L1 AR observations to generate 4D-Var type maps [C&SW]

- **Ensemble modeling:**
  - capture uncertainty for unobserved regions (polar/farside) [C&SW & EUV]
  - include forward modeled AR evolution & uncertainty for future maps [EUV]
  - validation/metrics feedback (e.g., CH boundaries) to “prune” ensemble [C&SW]
Summary

• Full-disk imaging from L5 will provide ~4 days of warning with regards to farside AR emergence.
• Space Weather modeling is dependent on how well we know the solar global magnetic field distribution. An L5 magnetograph will greatly improve global magnetic maps (i.e., longitude coverage ~210 degrees), improving solar wind, EUV irradiance, and CME arrival time predictions.
• From STEREO, improved CME speeds & size estimates are expected with a L5 coronagraph.
• In addition, a solar soft X-ray instrument at L5 would enhance particle/SEP event predictions. And, helioseismic capability from L5 & L1 would enhance detection of farside AR emergence/evolution.

Recent ADAPT Related References:

• Forecasting Solar Extreme and Far Ultraviolet Irradiance, Henney, Hock, Schooley, Toussaint, White, Arge 2015, Space Weather, 13, 141
• Data Assimilation in the ADAPT Photospheric Flux Transport Model, Hickmann, Godinez, Henney, Arge 2015, Solar Physics, 209, 1105

• Near real-time ADAPT maps, and $F_{10.7}$ & Mg II forecasts (1, 3, 7 day), are public via the National Solar Observatory (NSO) at: ftp://gong2.nso.edu/adapt

Acknowledgements
ADAPT is supported by the AFRL & NASA, and this work utilizes data produced collaboratively between AFRL/ADAPT and NSO/NISP.