Air Force Research Laboratory

Global Solar Magnetic Maps

AFRL HERITAGE | 1917–2017

100 YEARS OF U.S. AIR FORCE SCIENCE & TECHNOLOGY

L5 in Tandem with L1 Workshop
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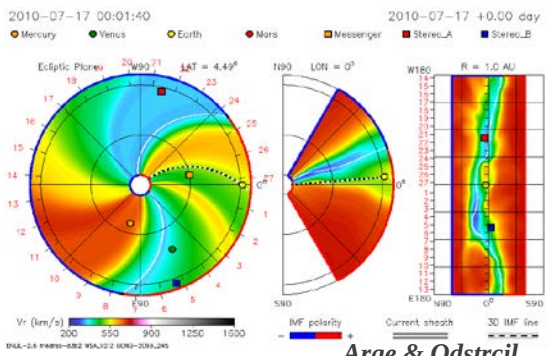
Integrity ★ Service ★ Excellence

Global Solar Magnetic Maps:
driver for space weather modeling/forecasting

Global solar magnetic maps are utilized to drive:

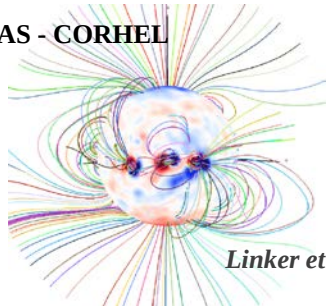
- coronal & solar wind models used to forecast the solar wind and Coronal Mass Ejection (CME) arrival times

WSA-Enlil



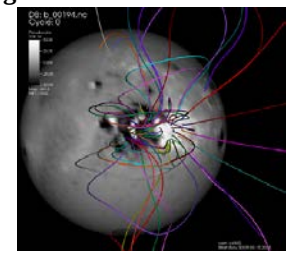
Arge & Odstrcil

MAS - CORHEL



Linker et al.

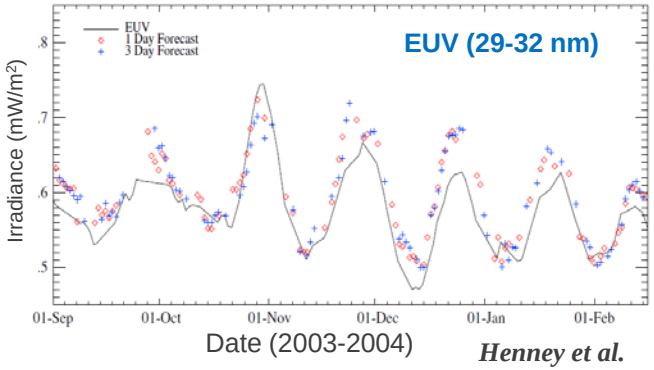
Magneto-Frictional Model



Weinzierl & Yeates

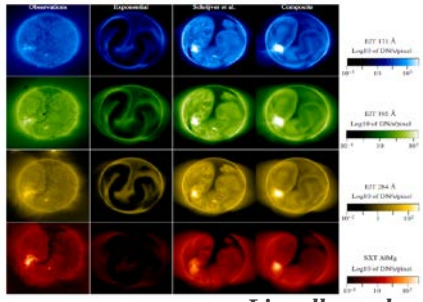
- indices & irradiance models to forecast $F_{10.7}$, Mg II, and bands of EUV/FUV irradiance 1 - 7 days in advance for thermospheric modeling

Empirical Models



Henney et al.

Physics Based Models

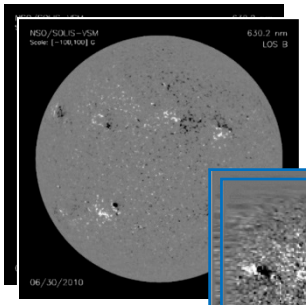


Lionello et al.

Global Solar Magnetic Maps:
*ADAPT** Modeling Framework

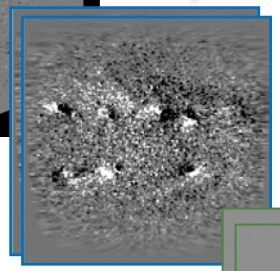
Provided by each Observatory (SDO/HMI, NSO GONG & VSM)

L1 observation in "sky frame" at obs_time

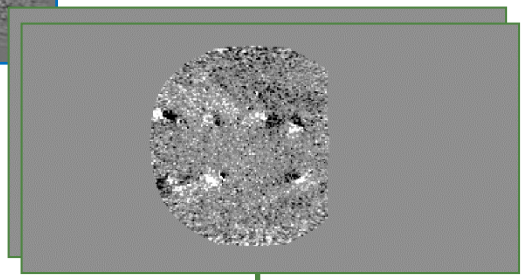


30 June 2010
NSO SOLIS/VSM

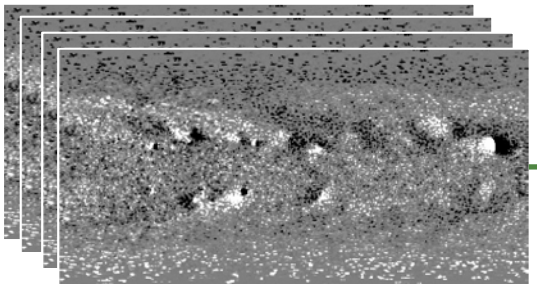
Magnetogram *data & uncertainty* remapped into heliographic coordinates: longitude vs. latitude (180 x 180 deg).



ADAPT pre-processing aligns all B_r input data (far & near) within model frame (i.e., 360x180; Carrington)



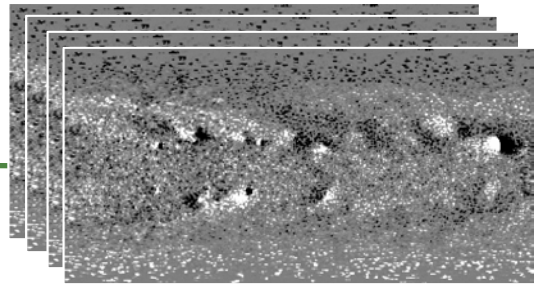
Model ensemble from *previous time step*



Forward Modeling
Differential Rotation
Meridional Circulation
Supergranulation

Data Assimilation
using EnLS Method

Model ensemble *at obs_time*



Time

** 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*):

Parameter	Baseline	Optimal
Observed Area	Active Regions[2]	Full-disk
Spatial Scale	2”/pixel	1”/pixel
Polarimetry	LOS[3] (I, V)	I,Q,U,V
Dynamic Range	+/- 2500 G	+/- 3500 G
Sensitivity	< 1 G/pixel	< 1 G/pixel
Zero-point error[4]	< 0.1 G	< 0.05 G
Cadence	2 hours	15 minutes

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).
4. Corrected spatially & temporally with estimates of uncertainty.

- **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					
Coronal & Solar Wind Models				EUV Irradiance Models	
Full-Disk obs at:	**Polar Observation Gap [each pole/year]**	**East Limb AR Polarity Split**	**Longitude Coverage (degrees)**	**Background Irrad. Forecasting (w/o emerging AR)**	**Continuous days of AR observations for evolution modeling**
L1	~6 months	Yes, *with options*	~150°	~4 days	~8 days
L1 & L5	~4 months (and with L4 -> 2months)	Yes, *more options*	~210°	~8 days	~12 days

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:
  - Ensemble Modeling of the 23 July 2012 Coronal Mass Ejection,
    Cash, M. D., Biesecker, D. A., Pizzo, V., et al. 2015, ***Space Weather*, 13, 10**
  - 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***
  - A New Technique for the Photospheric Driving of Non-Potential Solar Coronal Magnetic Field Simulation,
    Weinzierl, M., Yeates, A., Mackay, D., Henney, C. J., Arge, C. N. 2016, ***ApJ*, 823, 55**
- 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
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