ADAPT/HMI Effort for the Integrated Global-Sun Model

Carl Henney[1], C. Nick Arge[2], Kathleen Shurkin[3,1]

1. AFRL/Space Vehicles Directorate, KAFB, NM
2. NASA Goddard Space Flight Center, Greenbelt, MD
3. ISR, Boston College, Chestnut Hill, MA

NASA TIM 2017

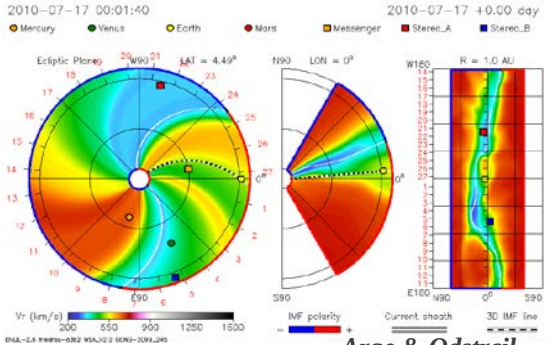


Global Solar Magnetic Maps

Global solar magnetic maps are utilized to drive:

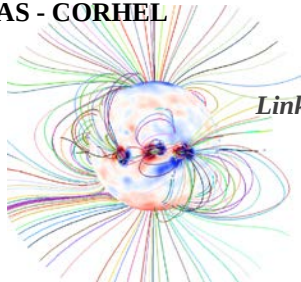
- **coronal & solar wind models used to forecast the solar wind and Coronal Mass Ejection arrival times**
- **indices & irradiance models to forecast $F_{10.7}$, Mg II, and bands of EUV/FUV irradiance 1 - 7 days in advance for thermospheric modeling**

WSA-Enlil



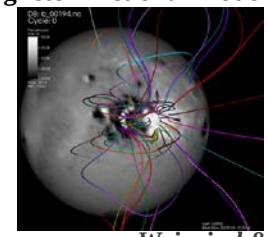
Arge & Odstrcil

MAS - CORHEL



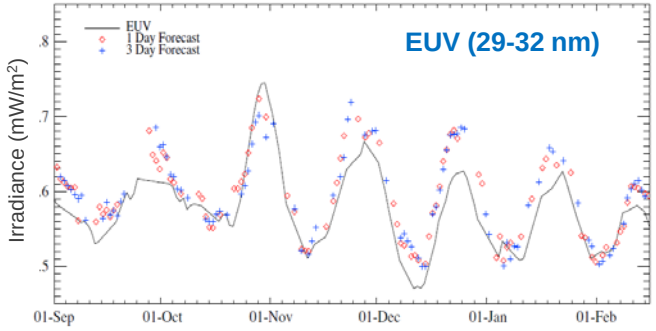
Linker et al.

Magneto-Frictional Model



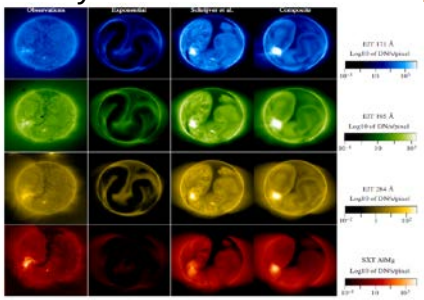
Weinzierl & Yeates

Empirical Models



Henney et al.

Physics Based Models



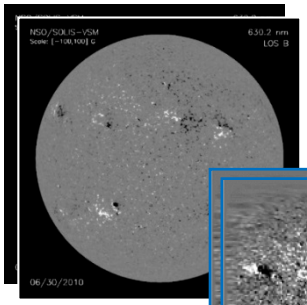
Lionello et al.

Driver for space weather modeling/forecasting

ADAPT* Model: modeling framework

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

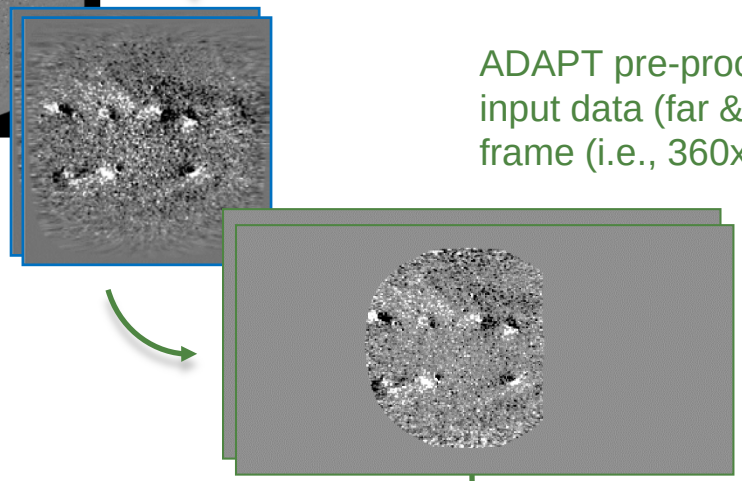
L1 observation in "sky frame" at obs_time



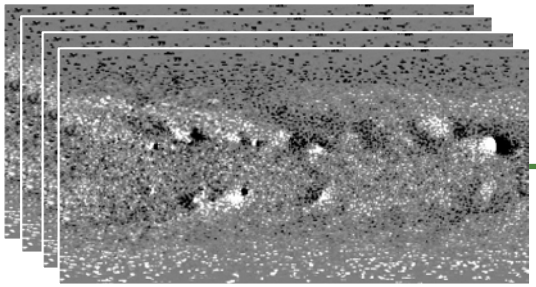
30 June 2010
NSO SOLIS/VSM

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)



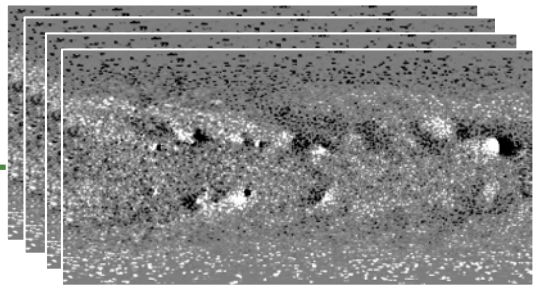
Model ensemble from *previous time step*



Forward Modeling
Differential Rotation
Meridional Circulation
Supergranulation

Data Assimilation
using EnLS Method

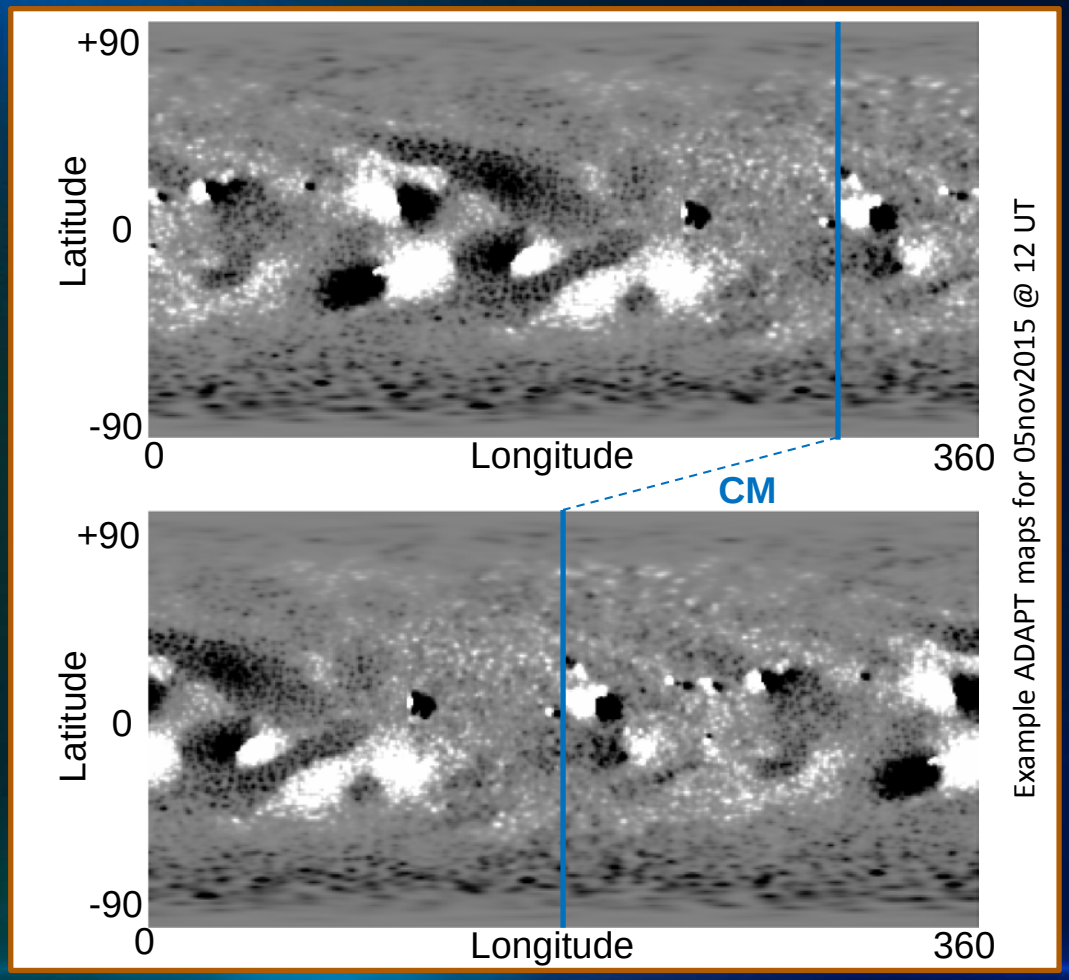
Model ensemble *at obs_time*



* ADAPT - Air Force Data Assimilative Photospheric Flux Transport

ADAPT Model: global maps *online*

Two types of ADAPT/GONG maps are generated daily at the National Solar Observatory (NSO) at: **ftp://gong2.nso.edu/adapt/maps/**



Carrington Frame

Sub-directory: public/gong/.
Prefix: "adapt403"
Cadence: 12 hours
Realizations: 12*

Central Meridian Frame

Sub-directory: noaa/.
Prefix: "adapt413"
Cadence: 2 hours
Realizations: 12*

* *Currently, realizations only differ by supergranulation flow pattern.*

ADAPT Model: solar magnetogram sources



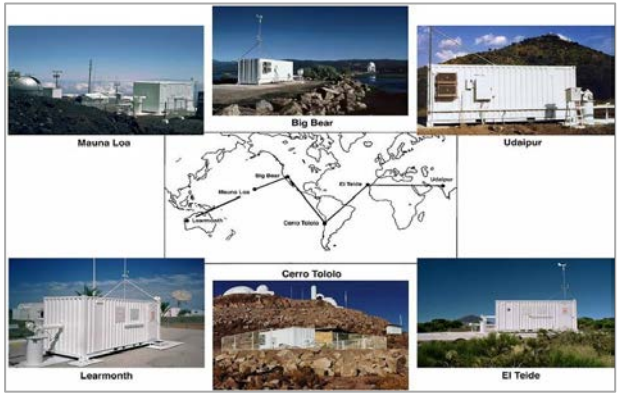
Kitt **P**eak **V**acuum **T**elescope

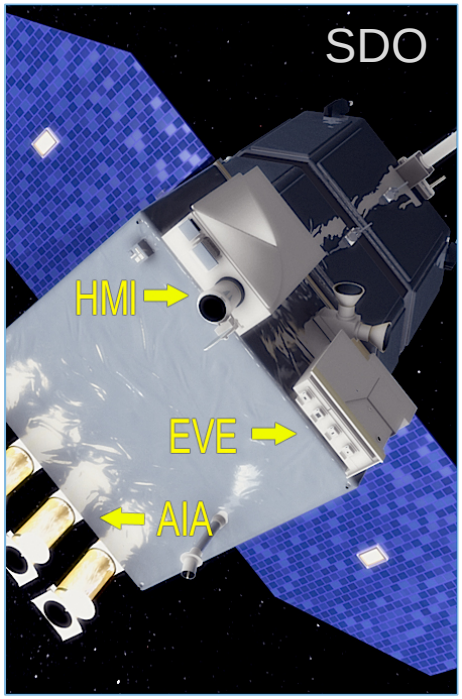


Vector **S**pectro**M**agnetograph

KPVT: 1977 – 2003
[24 hr, single site, 868.8 nm]
VSM: 2003 – present
[24 hr, single site, 630.2 nm]
GONG: 2006 – present
[10 min, 6 sites, 676.8 nm]
HMI: 2010 – present
[12 min, Sat-GEO, 617.3 nm]

Global **O**scillation **N**etwork **G**roup



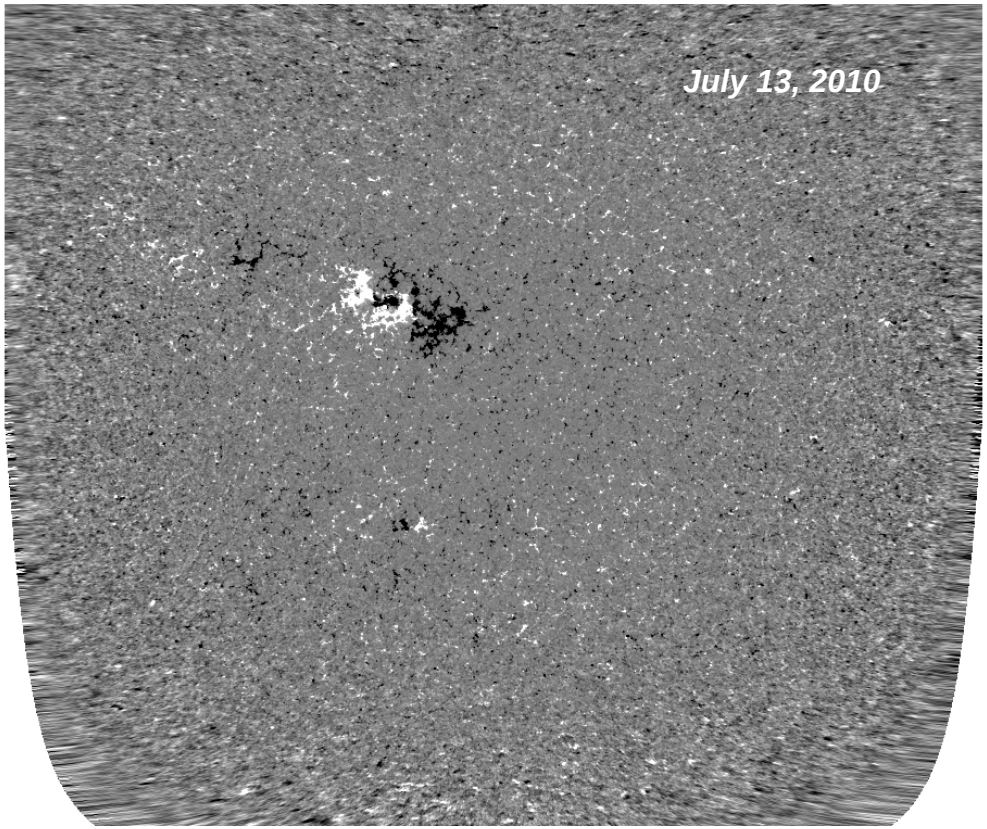


Helioseimic and **M**agnetic **I**mager (on the Solar Dynamics Observatory)

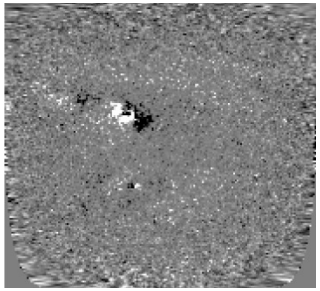
ADAPT maps can be generated with KPVT, VSM, GONG, and HMI

ADAPT with HMI

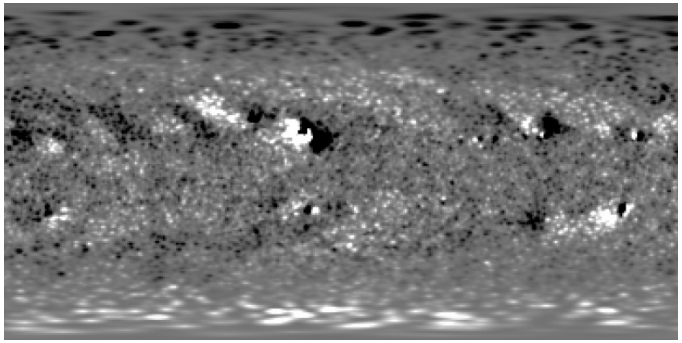
HMI heliographic 900x900 (latitude vs. longitude, i.e., "hmi.[Mrmap, bmap]_latlon_900x900_720s") maps* are available via the JSOC:



HMI: 900x900



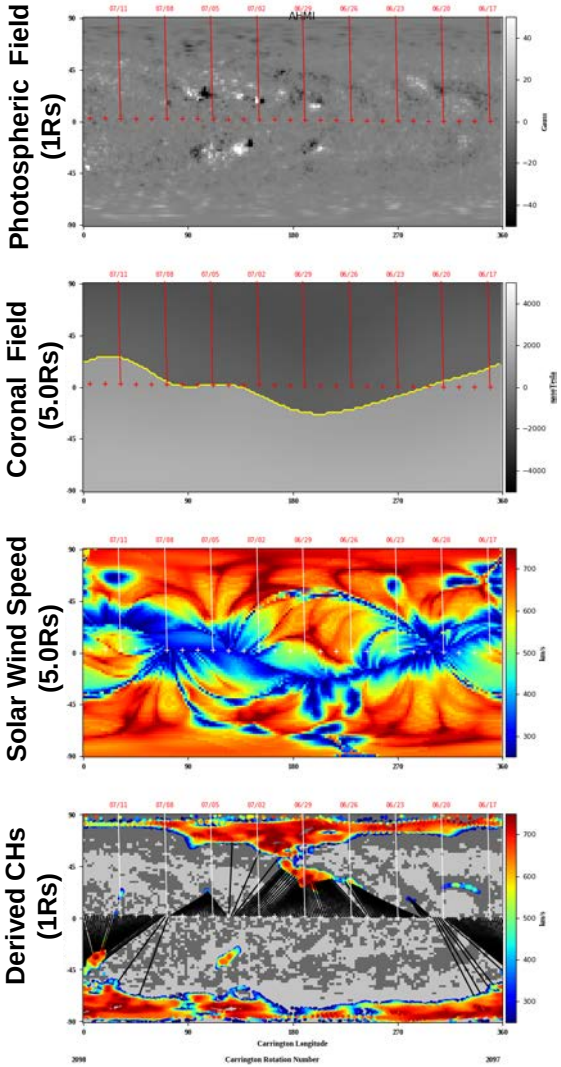
HMI: 180x180

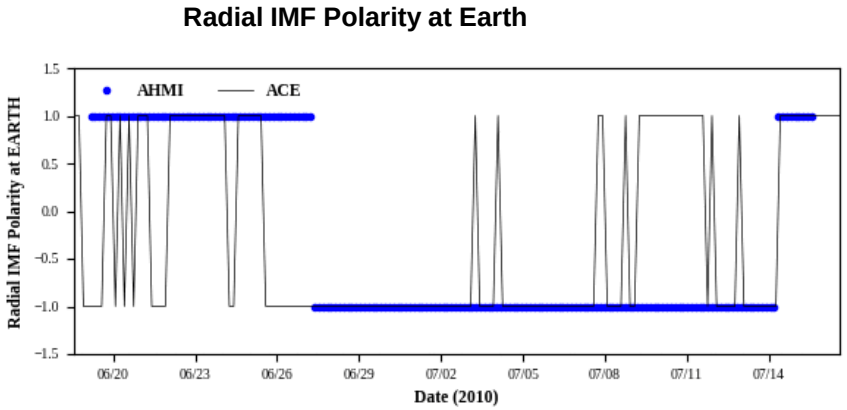


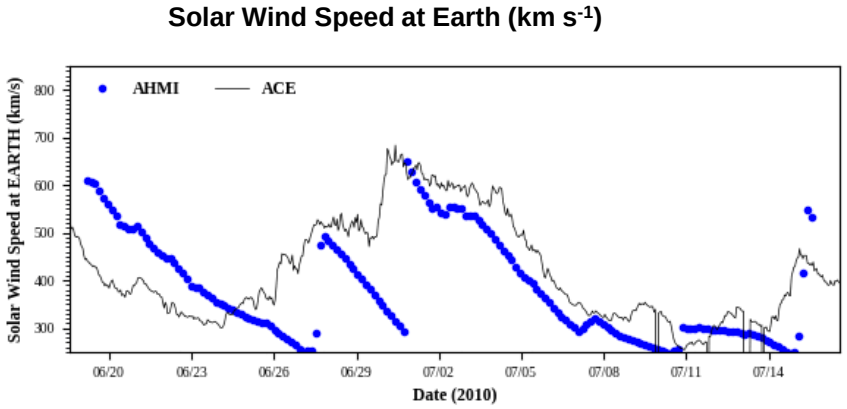
ADAPT: 360x180

** remapped into fixed Carrington frame (Thanks Yang & Jeneen!)*

WSA 4.2 ADAPT HMI-LOS: coronal solutions & solar wind solutions

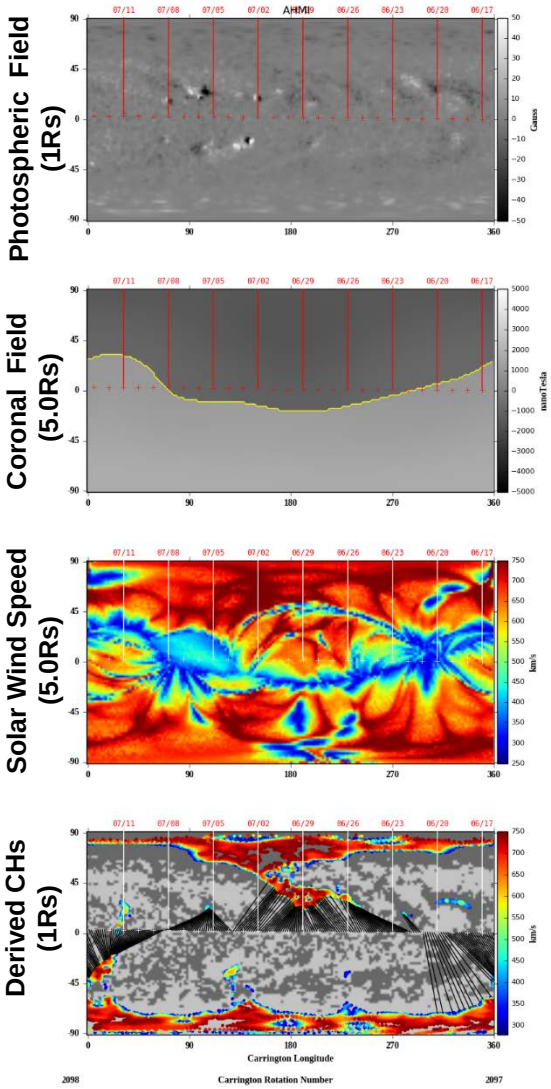


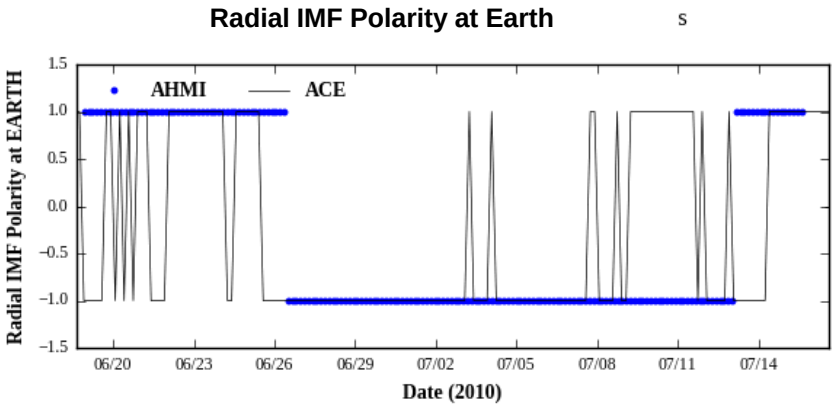


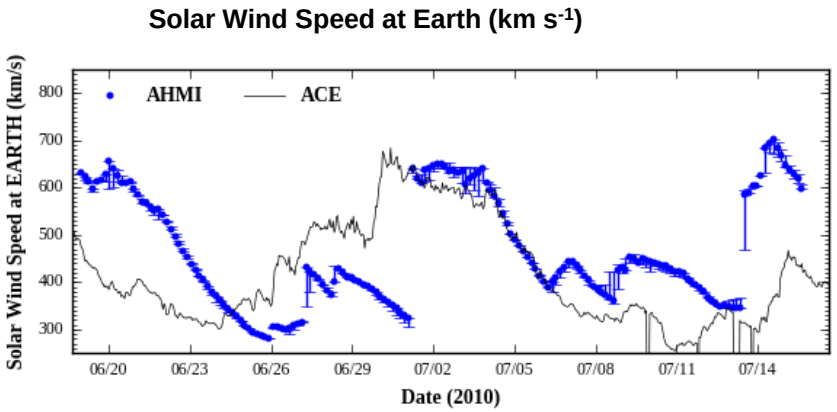


July 8, 2010 @ 20 UT

WSA 4.2 ADAPT HMI-Vector: coronal solutions & solar wind solutions







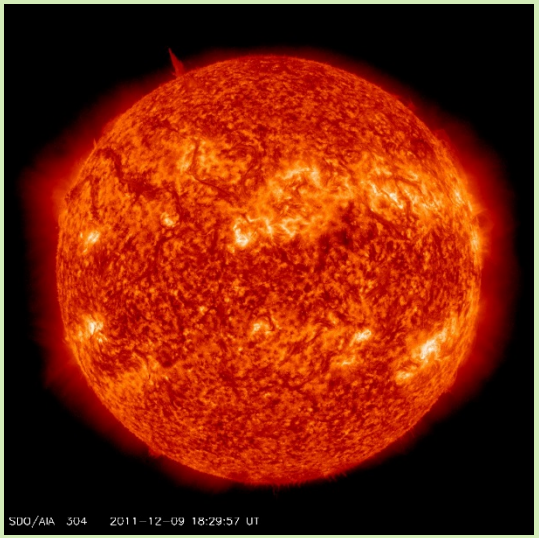
July 8, 2010 @ 20 UT

- ADAPT-HMI maps fully integrated into WSA 4.2
- Working on tuning solar wind empirical relationship

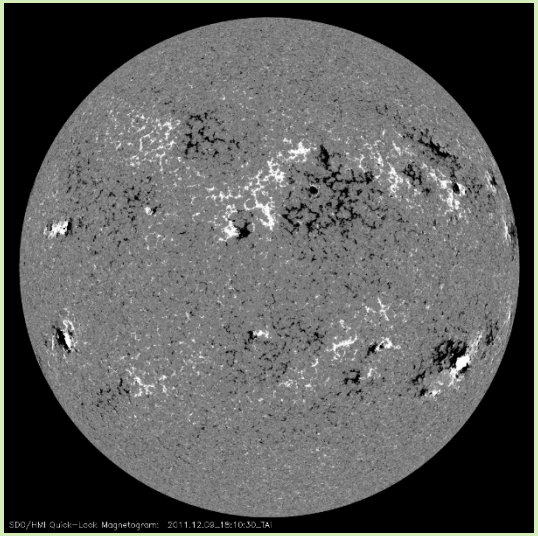
Modeling *EUV* & $F_{10.7}$

EUV, Magnetic, and 10.7 cm Full-Disk Images of the Sun

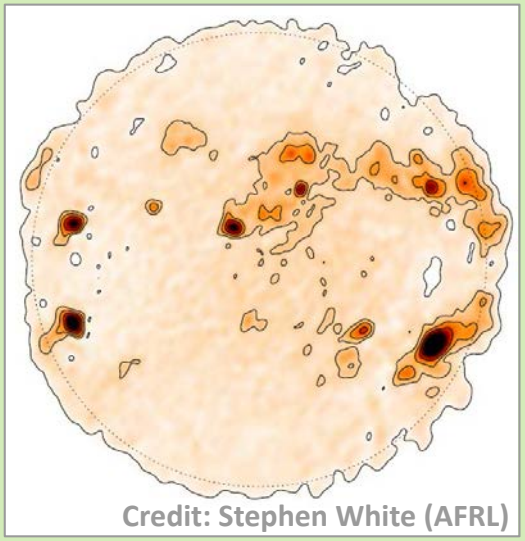
Solar EUV (30.4 nm) Image (SDO)



Solar Magnetic Image (SDO)



Solar 10.7 cm Image (VLA)



- EUV & radio 10.7 cm signal sources align with concentrations of magnetic flux
- Integrated full-disk singles are a contribution of strong & weak field regions

SIFT $F_{10.7}$ & *VUV* Empirical Models

The SIFT* F10.7 & VUV empirical models, based on Henney et al. 2012 & Henney et al. 2015, use the near-side magnetic field estimates from future ADAPT maps:

$$F_{model} = m_0 + m_1 S_w + m_2 S_s$$

where

$$S_w = \frac{1}{\sum \omega_\theta} \sum_{25\text{G} < |\text{B}_r| < 150\text{G}} |\text{B}_r| \omega_\theta$$

Weak Field Sum

and

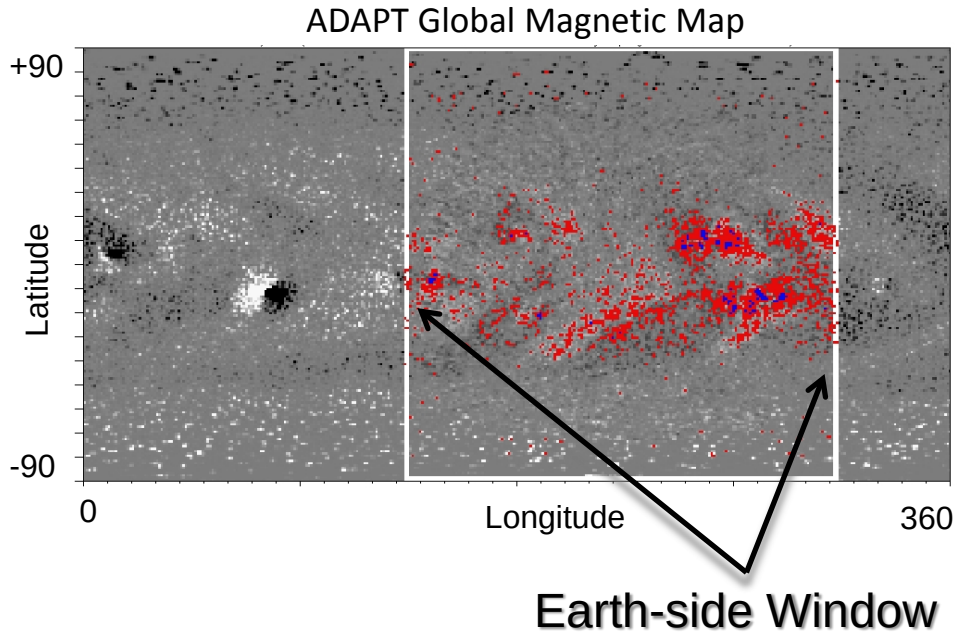
$$S_s = \frac{1}{\sum \omega_\theta} \sum_{150\text{G} \le |\text{B}_r|} |\text{B}_r| \omega_\theta$$

Strong Field Sum

Total Window Area

Unsigned Radial Magnetic Field

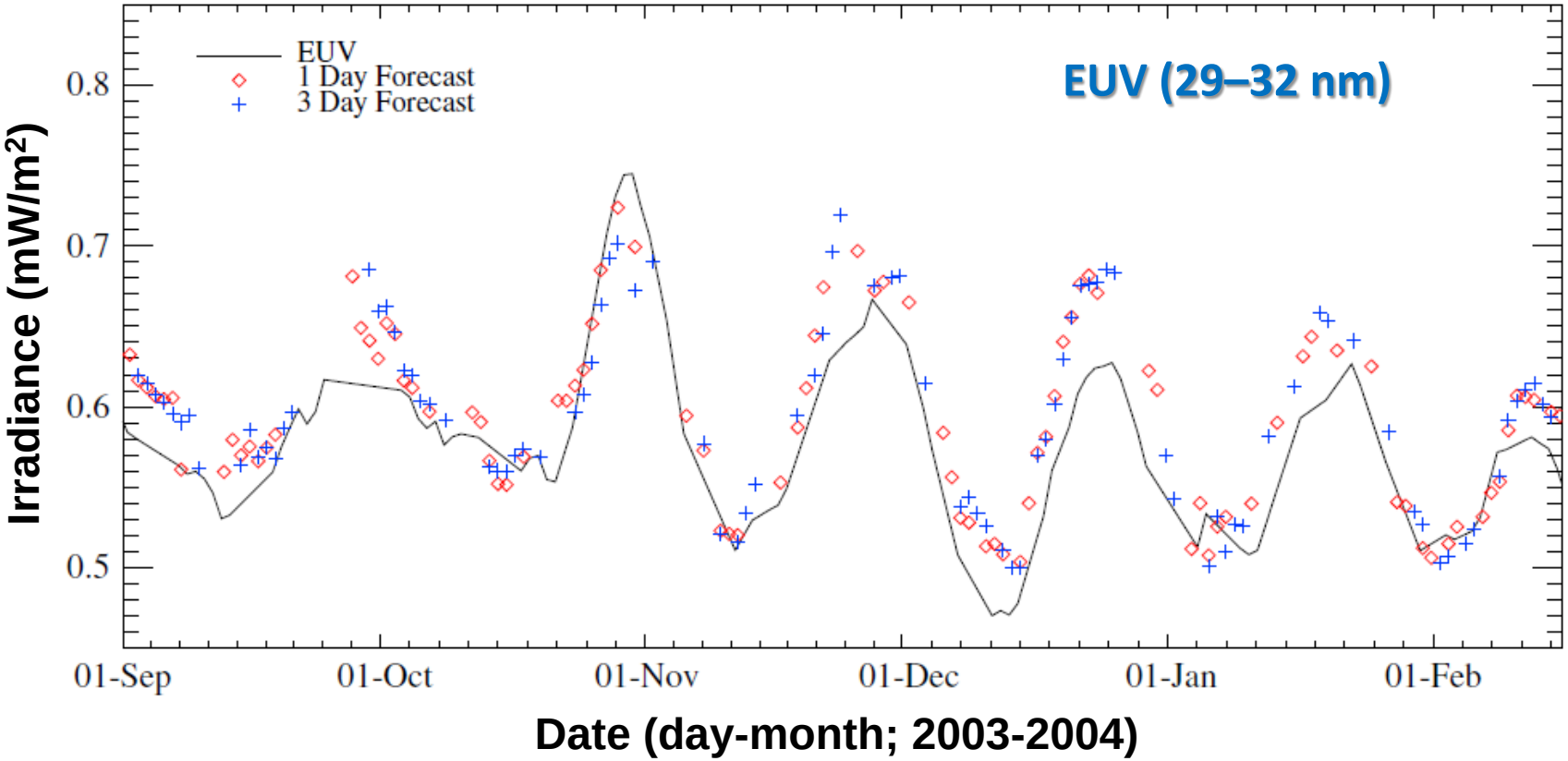
Area



For more discussion on the $F_{10.7}$ & VUV modeling, see: *Henney et al. 2015, Space Weather, 13*

* SIFT – *Solar Indices Forecasting Tool*

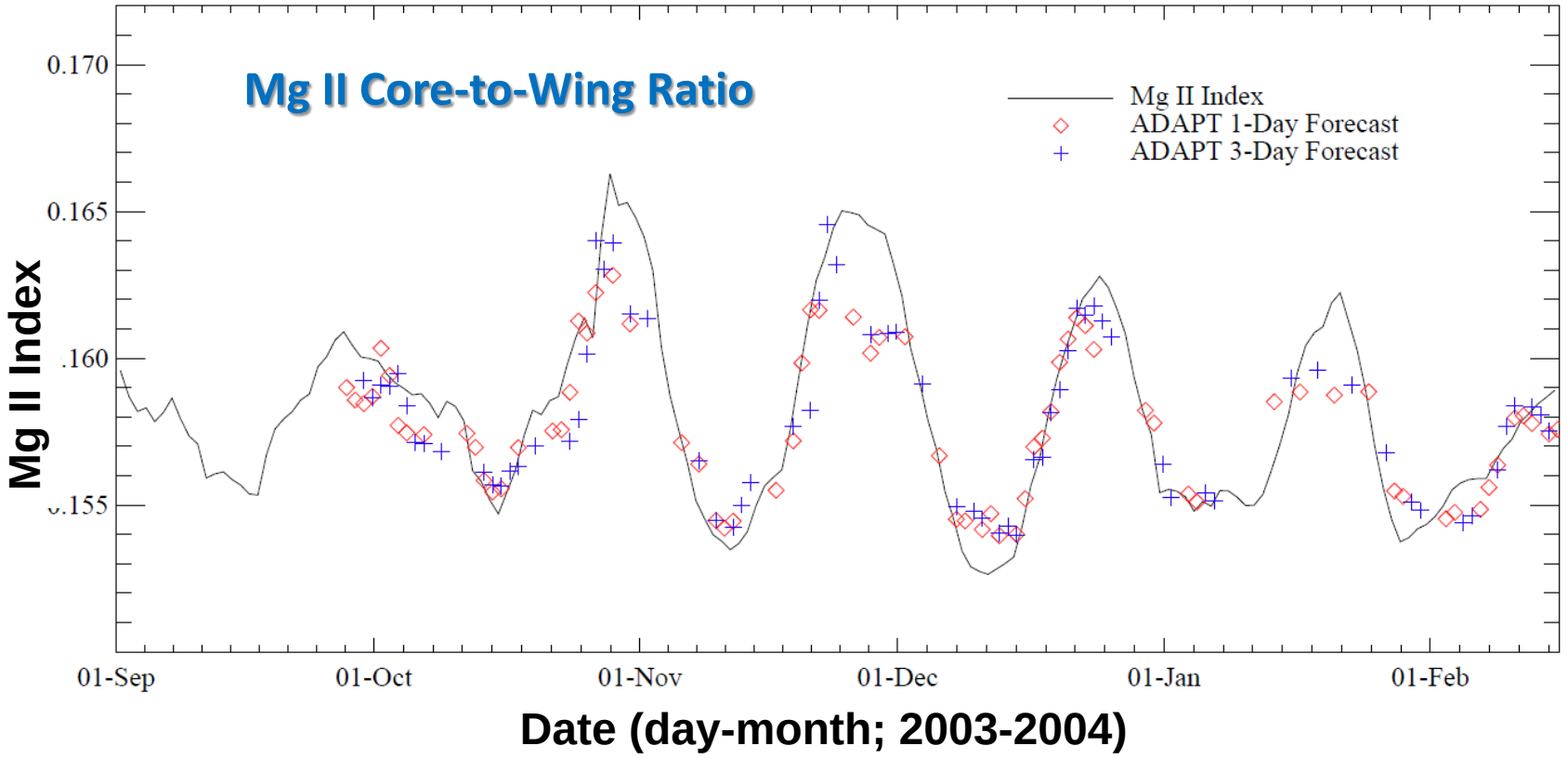
ADAPT/SIFT Forecasting: EUV



Henney et al. 2015, Space Weather, 13, 141-153

- Observed solar irradiance measured by the Solar EUV Experiment (SEE) on NASA's TIMED mission [Woods et al. 2002].

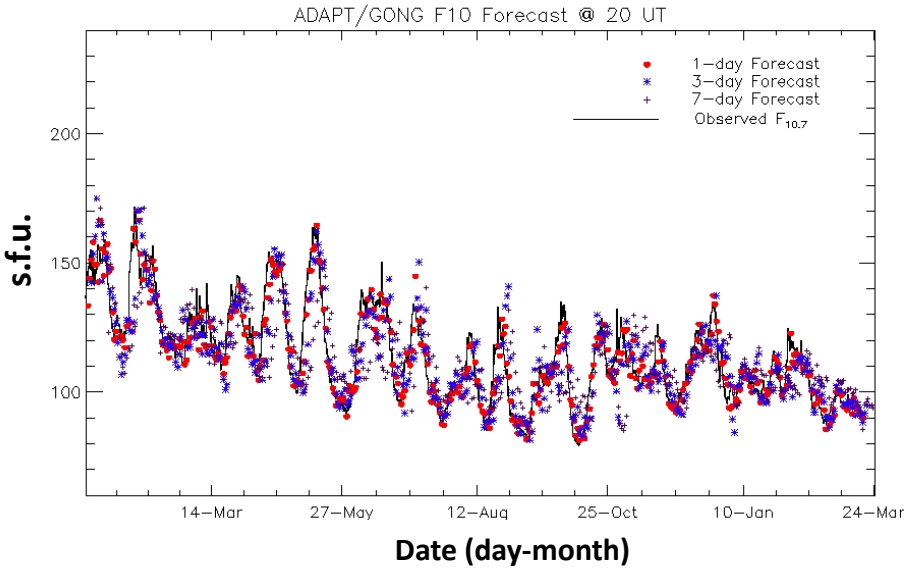
ADAPT/SIFT Forecasting: Mg II index



ADAPT/SIFT Predictions Online

ADAPT Maps and SIFT Forecasts are now online:

- ADAPT runs 24/7 at the National Solar Observatory (NSO) generating global maps every 2 hours
- SIFT utilizes the ADAPT maps in near real-time, providing 1, 3, and 7 day advance forecast values of F10.7, SSN, & Mg II core to-wing



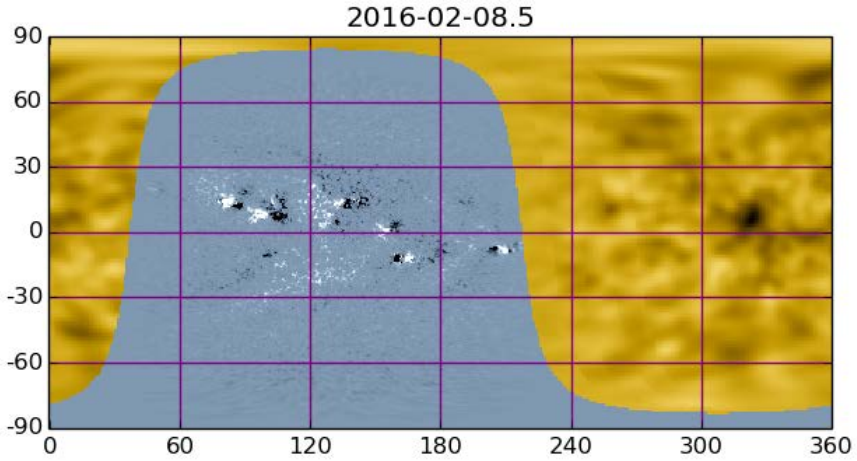

```
: Product : adapt_f107_forecast.txt
: Created : 2014 10 24 2147 UT
: Date : 2014 10 24
: DOY : 297
: Model: ADAPT-F10.7
: Version :  5.0212
: POC : CJ Henney (USAF/AFRL)
: POC Email : adapt@noao.edu
: Data Input : GONG
: Resolution [deg / pixel] : 1.00
: Fit-function : m0 + m1*M_P + m2*M_A
: Forecast :  0,     1,     3,     7
: m0 :      66.08,  65.00,  64.00,  63.00
: m1 :       8.51,   8.00,   9.00,  10.00
: m2 :      16.56,  17.00,  18.00,  19.00
: M_P (plage mag-field) Lower Limit [G] :  25.0
: M_A (active region mag-field) Lower Limit [G] : 150.0
: Missing Value :  -1.0
: Record Count : 12
#
#| Table Notes
#
#   JD - Julian Date
#    M - Missing = 0 - forecast available
#              = 1 - forecast missing or pending
#    Q - Quality = 0 - input data nominal
#              = 1 - entry with >2 days w/o model input data
#    H - Heliosesmic data within forecast window:
#              = 0-none, 1-farside, 2-nearside, 3-both farside & nearside
#   UT - forecast time, Coordinated Universal Time, HHMM format
#   LastMag - fractional days since last mag data assimilation
#   NearF10 - fractional days since last F10 obs differenced w/ 0d value
#   Diff - obs_model offset = (F10.7 obs value) - (0-day model prediction)
#    F10.7 Forecast - 0day, 1day, 3day, 7day model estimates plus diff offset
#
#| Observed F10 Data Source
#
#    http://www.swpc.noaa.gov/ftpdir/lists/radio/7day_rad.txt
#
#| ADAPT - F10.7 Forecast [s.f.u. @ earth distance]
#
#      JD        M  Q  H   UT    LastMag  NearF10  Diff     0d      1d      3d      7d
#-------------------------------------------------------------------------------------
  2456954.5000  0  0  0  0000    0.087    0.042    33.0   202.0   207.2   212.4   144.0
  2456954.5833  0  0  0  0200    0.011    0.125    33.0   204.9   209.9   214.8   144.7
  2456954.6667  0  0  0  0400    0.004    0.208    33.0   204.2   209.1   213.9   143.9
  2456954.7500  0  0  0  0600    0.087    0.292    33.0   203.1   208.5   212.5   143.0
  2456954.8333  0  0  0  0800    0.171   -0.375    52.9   222.0   227.8   231.0   162.3
  2456954.9167  0  0  0  1000    0.254   -0.292    52.9   221.0   227.4   230.5   161.7
  2456955.0000  0  0  0  1200    0.338   -0.208    52.9   220.1   227.1   230.0   161.4
  2456955.0833  0  0  0  1400    0.421   -0.125    52.9   219.3   226.7   229.4   161.3
  2456955.1667  0  0  0  1600    0.504   -0.042    52.9   217.7   226.5   228.6   160.9
  2456955.2500  0  0  0  1800    0.587    0.042    52.9   215.7   226.3   228.0   160.8
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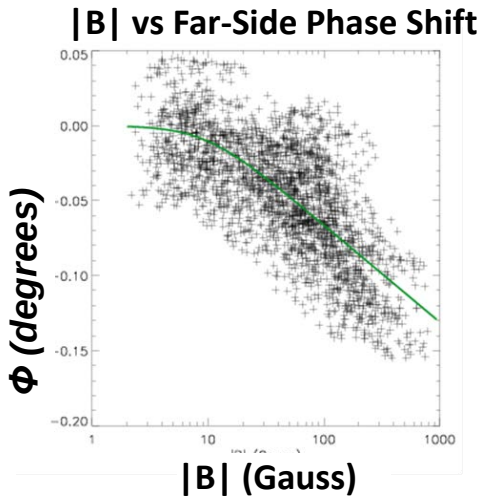
Example SIFT $F_{10.7}$ Forecast File

Maps & Forecasts available at: ftp://gong2.nso.edu/adapt

Future ADAPT Development: incorporating HMI far-side data

Far-side detections from HMI:



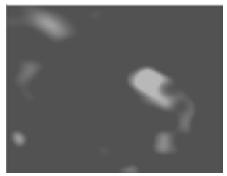


from Gonzalez-Hernandez et al., 2007

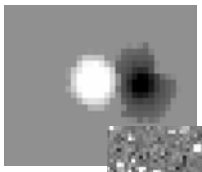
Far-side data provides an estimate of the:

- **magnetic field strength**
- **position**

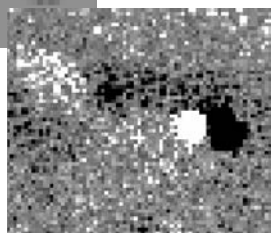
The polarity distribution can be approximated with Hale's rule & Joy's rule.



Far-side signal (GONG 07/1/10)



New polarity estimation

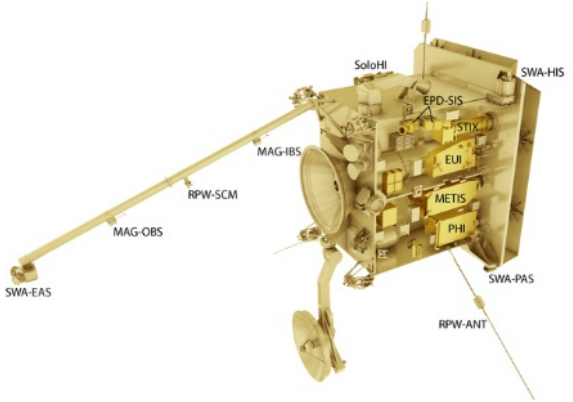


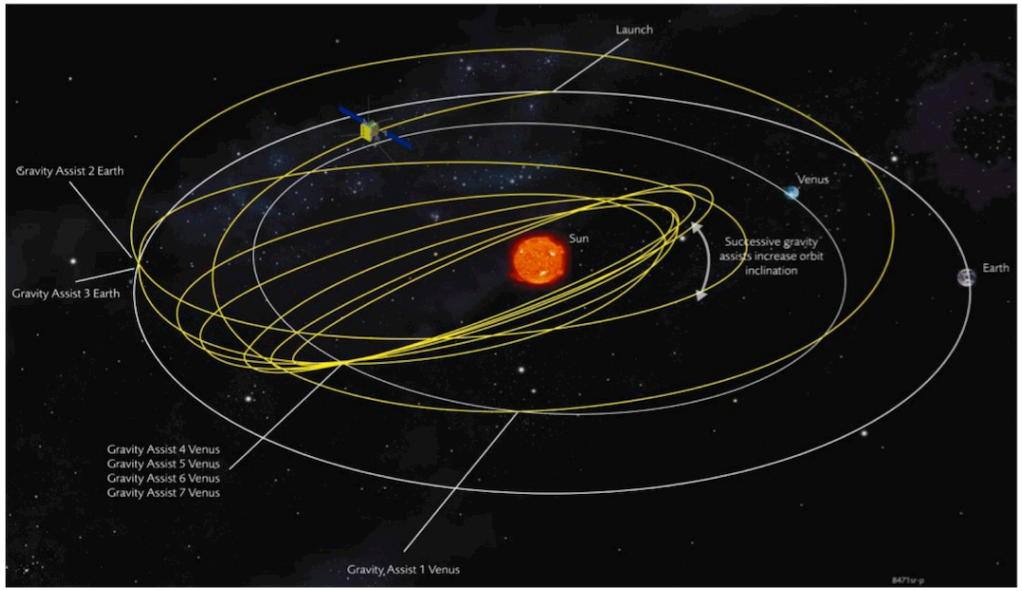
New estimation merged with ADAPT map

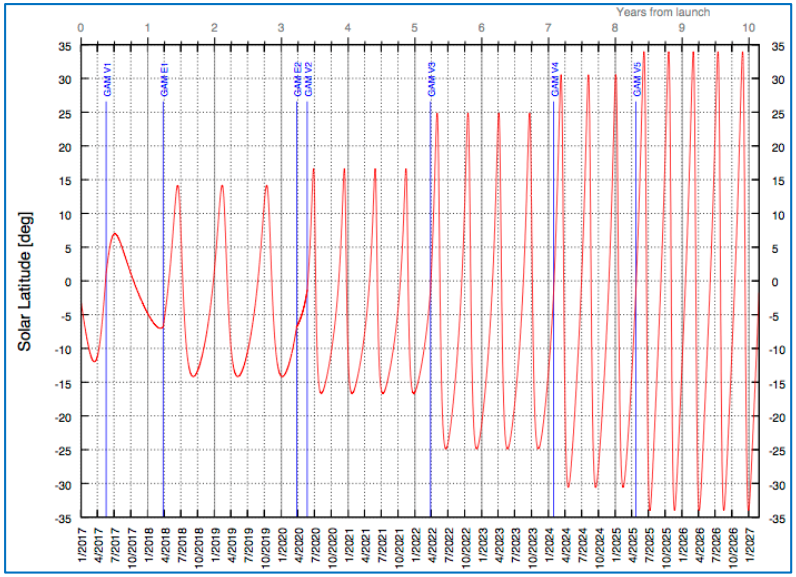
Future ADAPT Development: direct far-side & polar observations

Solar Orbiter:

- Expected launch Feb 2018 (*previously Jul 2017*)
- Polarimetric and Helioseismic Imager (PHI):
  - full-disk vector magnetograms
- Far-side & high latitude observations
- Telemetry limited to 4 to 8 hours daily
  - observations stored on-board during outage



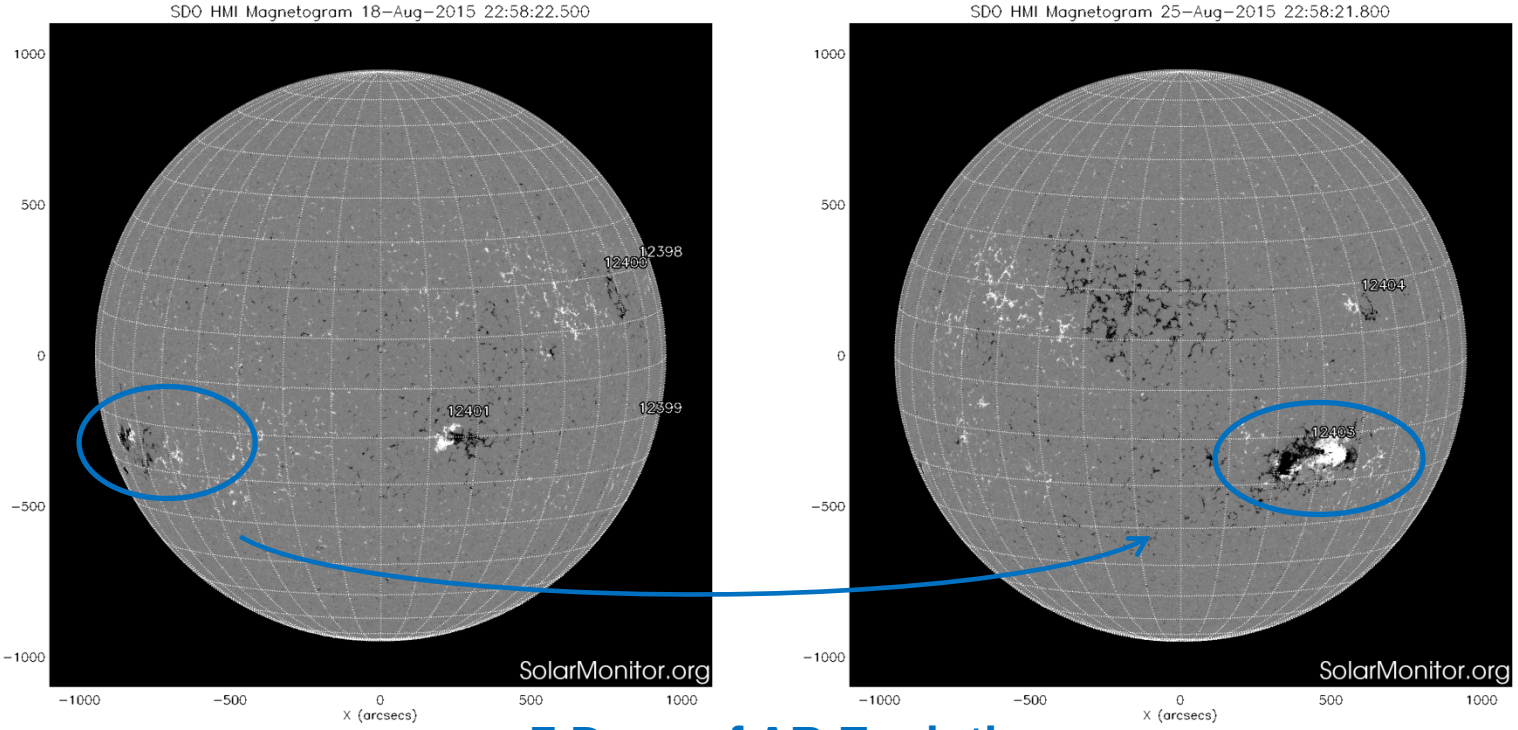




Preparing ADAPT for input from Solar Orbiter PHI Magnetograms

Future ADAPT Development: near-side AR emergence

- Besides helioseismic far-side detections, EUV/F10.7 and coronal & solar wind advance predictions require the modeling of AR evolution for near-side emergence. For example:



7 Days of AR Evolution

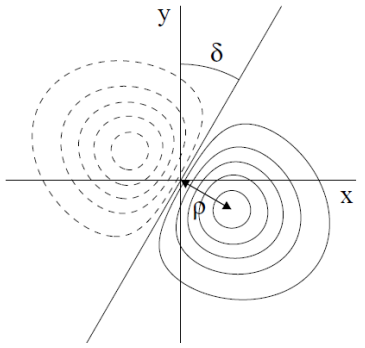
Future ADAPT Development: AFOSR supported research

ADAPT project activities currently include exploring how best to generate smoothly evolving maps, for example:

1) Forward model near-side & far-side active region emergence with a “model bipole”.

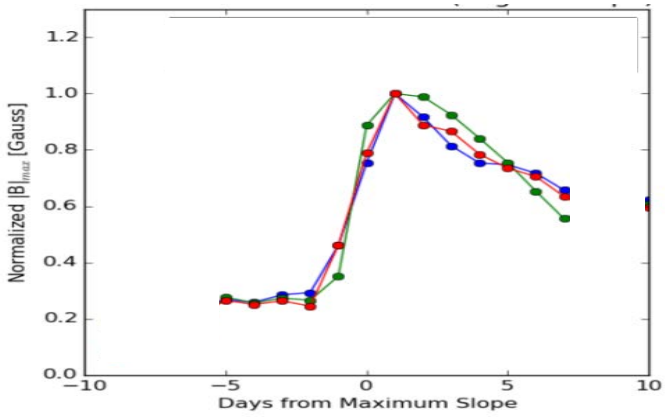
2) Reverse-model observed near-side active regions (near east-limb) to the estimated time of emergence.

3) And ultimately, combine near-side observations & far-side detections to produce smooth evolution within ADAPT global solar magnetic maps.



$$B_r = -B_0 e^{0.5} \frac{x}{\rho} \exp\left[-\left(\frac{x^2/2 + y^2}{\rho^2}\right)\right]$$

from Yeates et al., 2007



HMI ADAPT - Year 5

ADAPT Model Year 5 goals:

- finish validation study using HMI data inputs (i.e., line-of-sight, far-side emergence, and vector) by performing a systematic comparison of WSA predictions with observations using maps that incorporate the FEPT MHD results of flux emergence
- deliver updated version of ADAPT to NSO or CCMC
- deliver to CCMC a software tool that assimilates the flux emergence active region areas produced by the MHD FEPT model into ADAPT maps
- deliver latest WSA model version to the CCMC having the capability to ingest all ADAPT map products