Air Force Research Laboratory

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ADAPT Model

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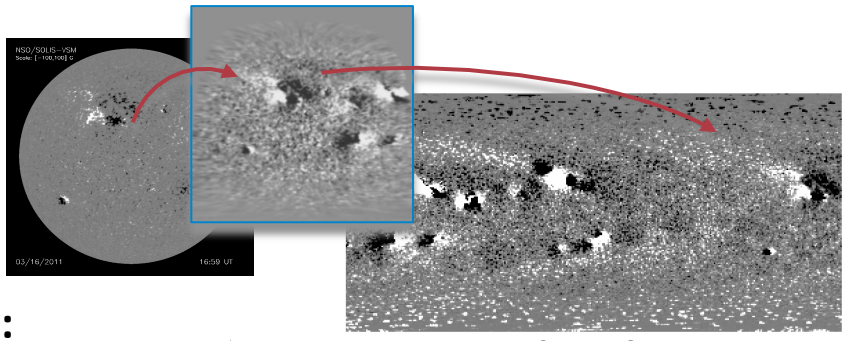
AFRL

Air Force Data Assimilative Photospheric Flux Transport (ADAPT)

The ADAPT* model generates global solar photospheric magnetic field maps.



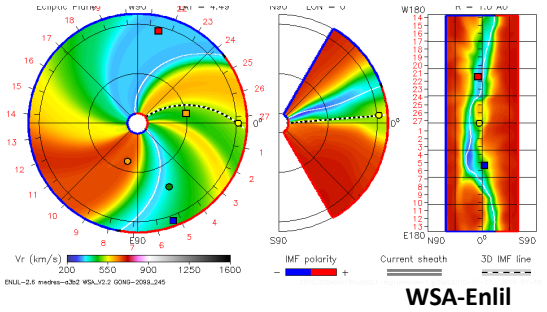
Example ADAPT Global Solar Magnetic Map

ADAPT generates 1 to 7 day future forecast maps using flux transport that accounts for known surface flows in the solar photosphere:

- ***differential rotation, meridional circulation, supergranular diffusion***

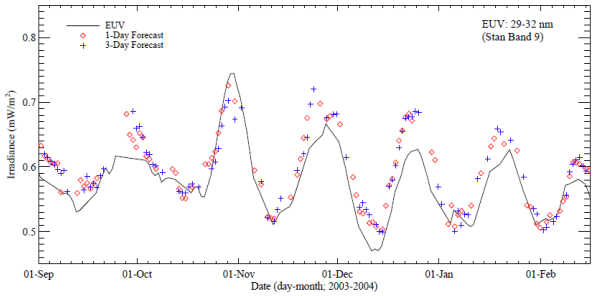
Global maps are utilized to drive:

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



WSA-Enlil

- **empirical models to forecast $F_{10.7}$ and XUV/ EUV/FUV irradiance 1 to 7 days in advance for thermospheric modeling**



Recent References:** ***Arge et al. 2013; Hickmann et al. 2015

ADAPT Maps *Online*

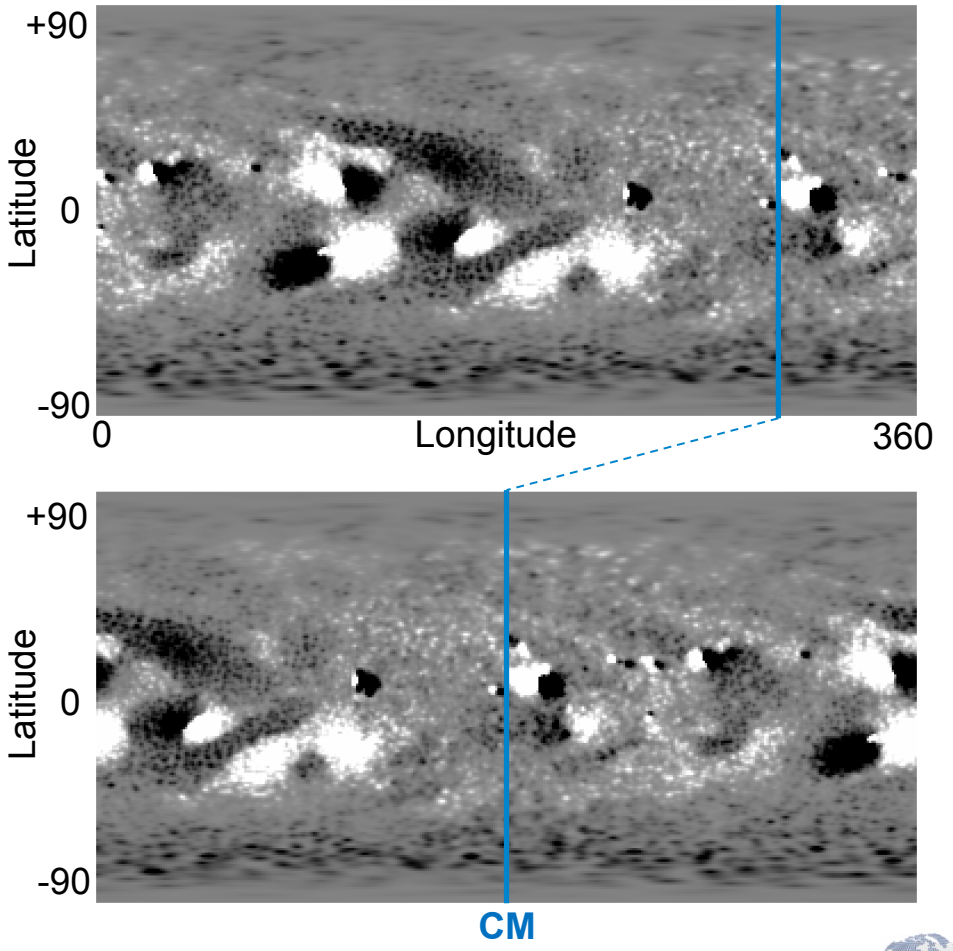
Two types of ADAPT/GONG maps are generated daily at the National Solar Observatory (NSO) at: **ftp://gong2.nso.edu/adapt/maps/**

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*



Example ADAPT maps for 05nov2015 @ 12 UT

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

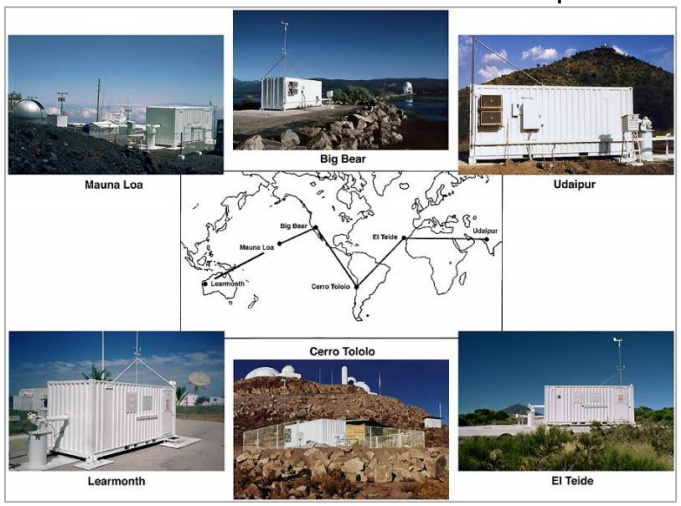
ADAPT Solar Magnetogram Sources

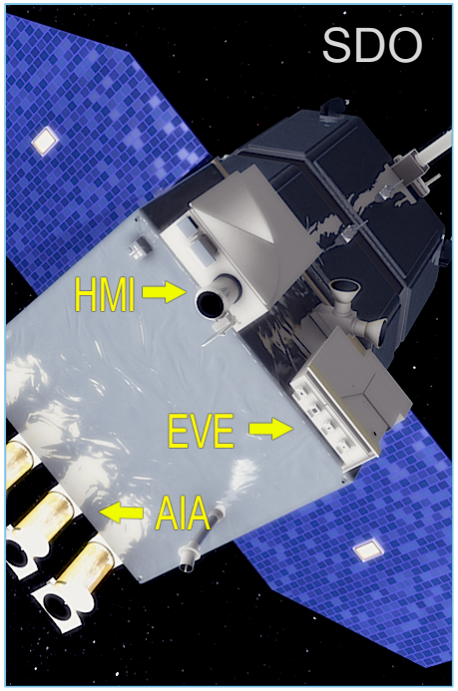
Kitt **P**eak **V**acuum **T**elescope

NSO **I**ntegrated **S**ynoptic **P**rogram - **V**ector **S**pectro**M**agnetograph

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

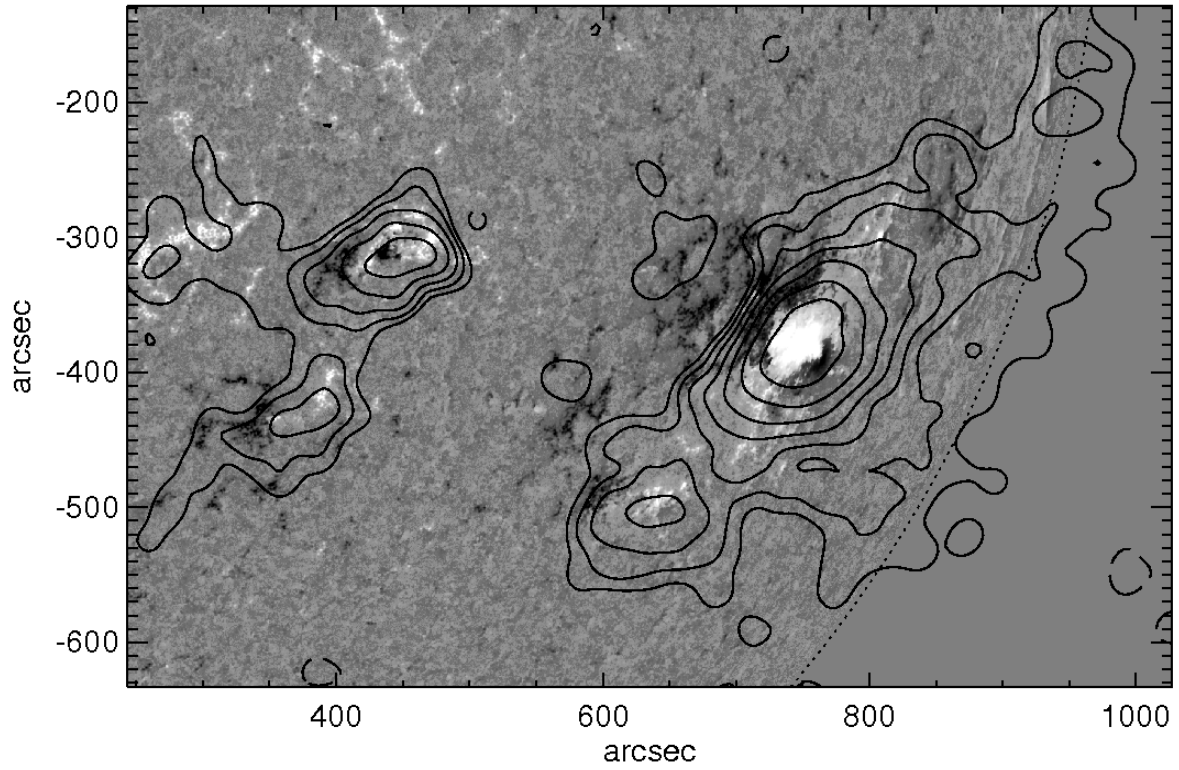
NSO **I**ntegrated **S**ynoptic **P**rogram - **G**lobal **O**scillation **N**etwork **G**roup





Helioseismic and **M**agnetic **I**mager (on the **S**olar **D**ynamics **O**bservatory)

Solar $F_{10.7}$ & Magnetic Field



VLA observation at 2.8 GHz (10.7 cm) from Dec 9, 2011; courtesy of Stephen White (AFRL). Contours are radio flux; background image SDO/HMI magnetogram.

For more discussion on *$F_{10.7}$* sources, see:
Schonfeld et al. 2015, ApJ, 88, 29

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

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

$$\mathrm{F_{model}} = m_0 + m_1 S_\mathrm{P} + m_2 S_\mathrm{A}$$

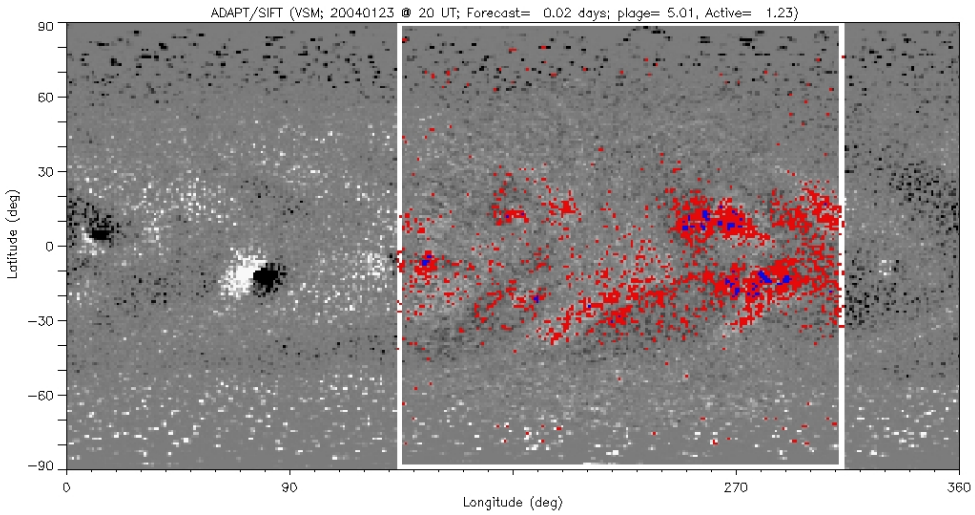
where

$$S_\mathrm{P} = \frac{1}{\sum \omega_\theta} \sum_{25\mathrm{G}<|\mathrm{B_r}|<150\mathrm{G}} |\mathrm{B_r}| \omega_\theta$$

Solar Weak Field
["**Plage**"]

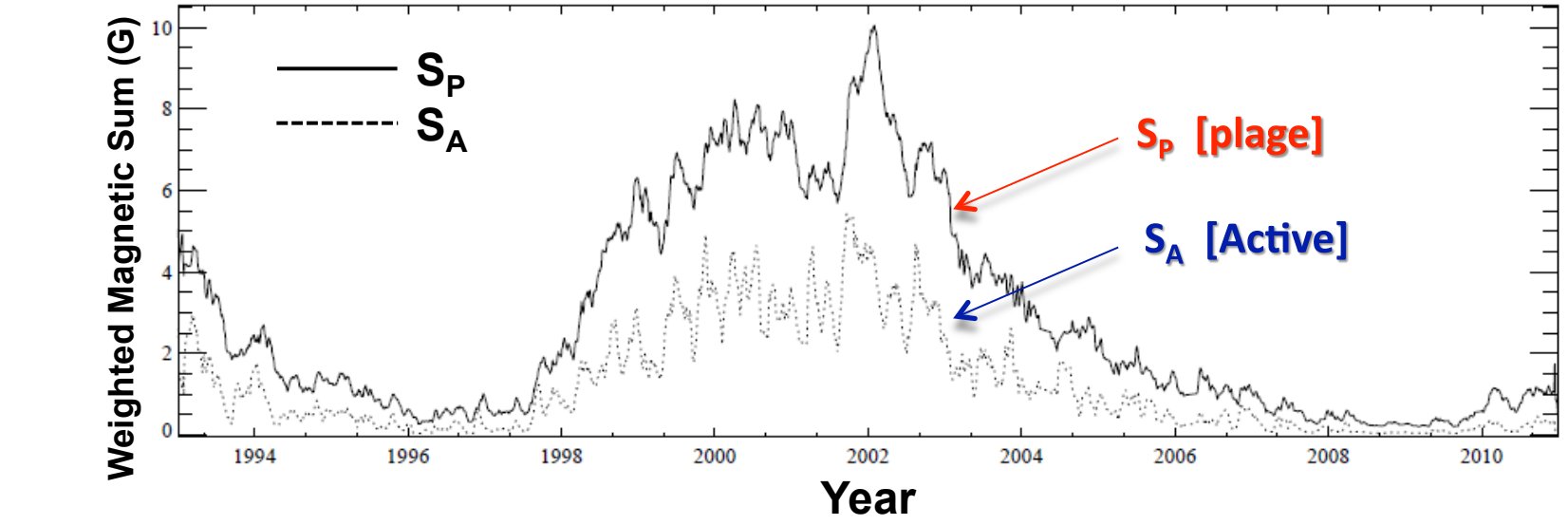
$$S_\mathrm{A} = \frac{1}{\sum \omega_\theta} \sum_{150\mathrm{G}\le|\mathrm{B_r}|} |\mathrm{B_r}| \omega_\theta .$$

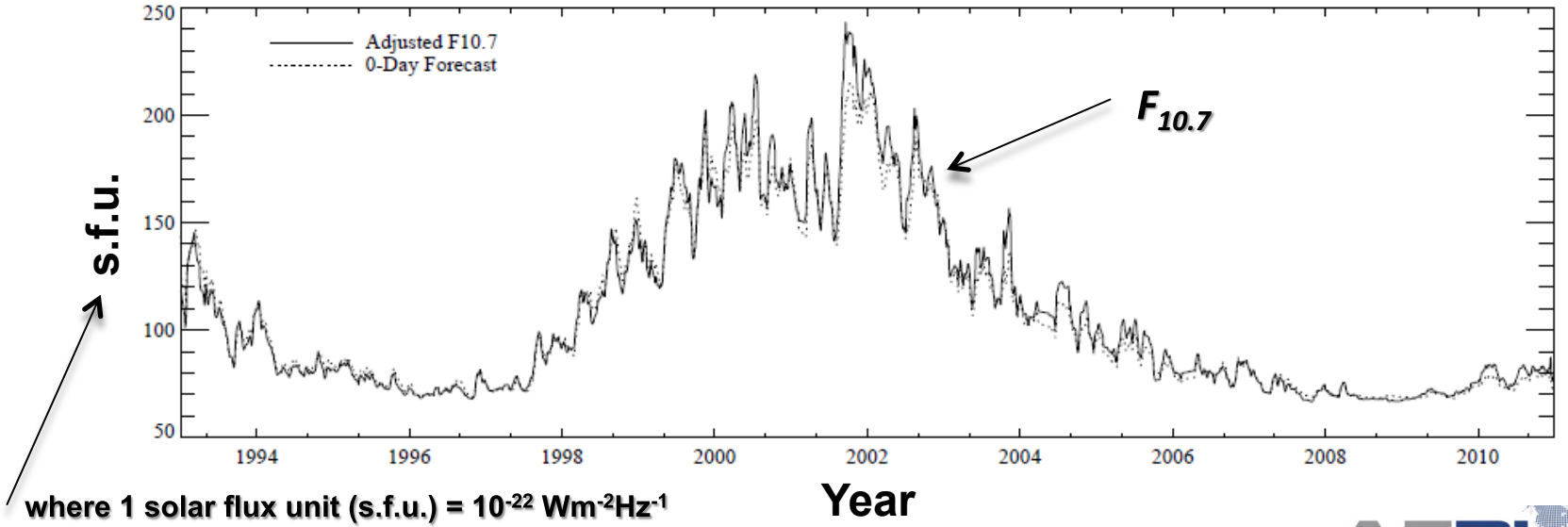
Solar Strong Field
["**Active**"]



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

ADAPT $F_{10.7}$ Model Nowcast





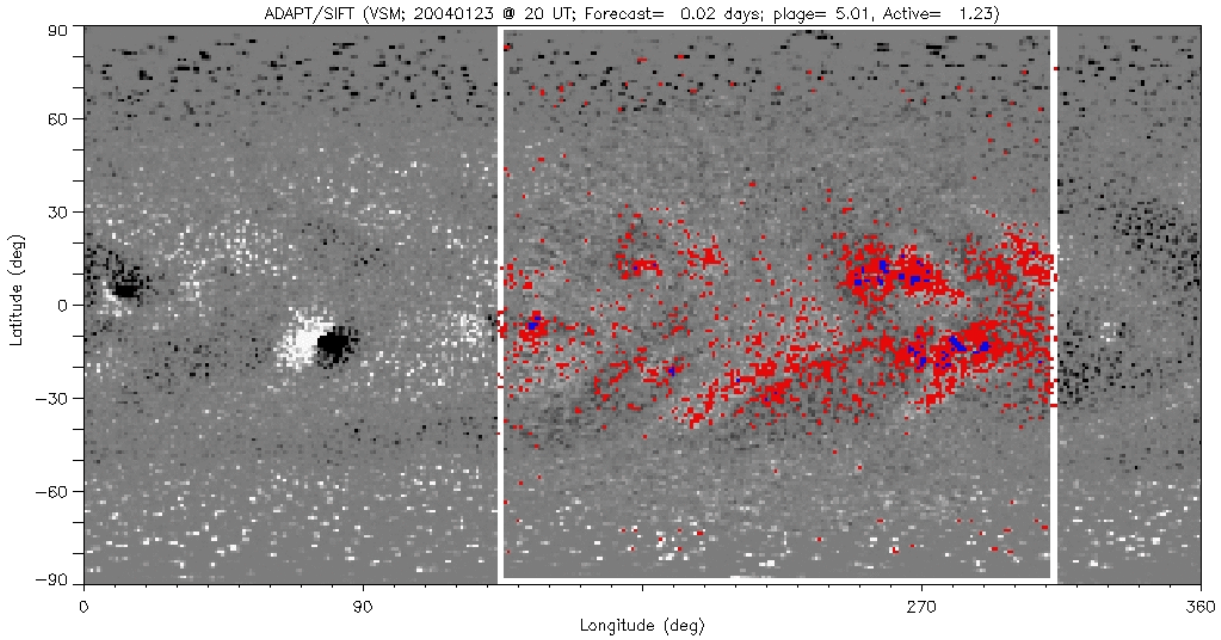
where 1 solar flux unit (s.f.u.) = 10^{-22} $Wm^{-2}Hz^{-1}$

Henney et al., Space Weather, 10, S02011, 2012

Forecasting with ADAPT

ADAPT can generate global forecast maps, e.g., 1 to 7 days in the future, using magnetic flux transport modeling:

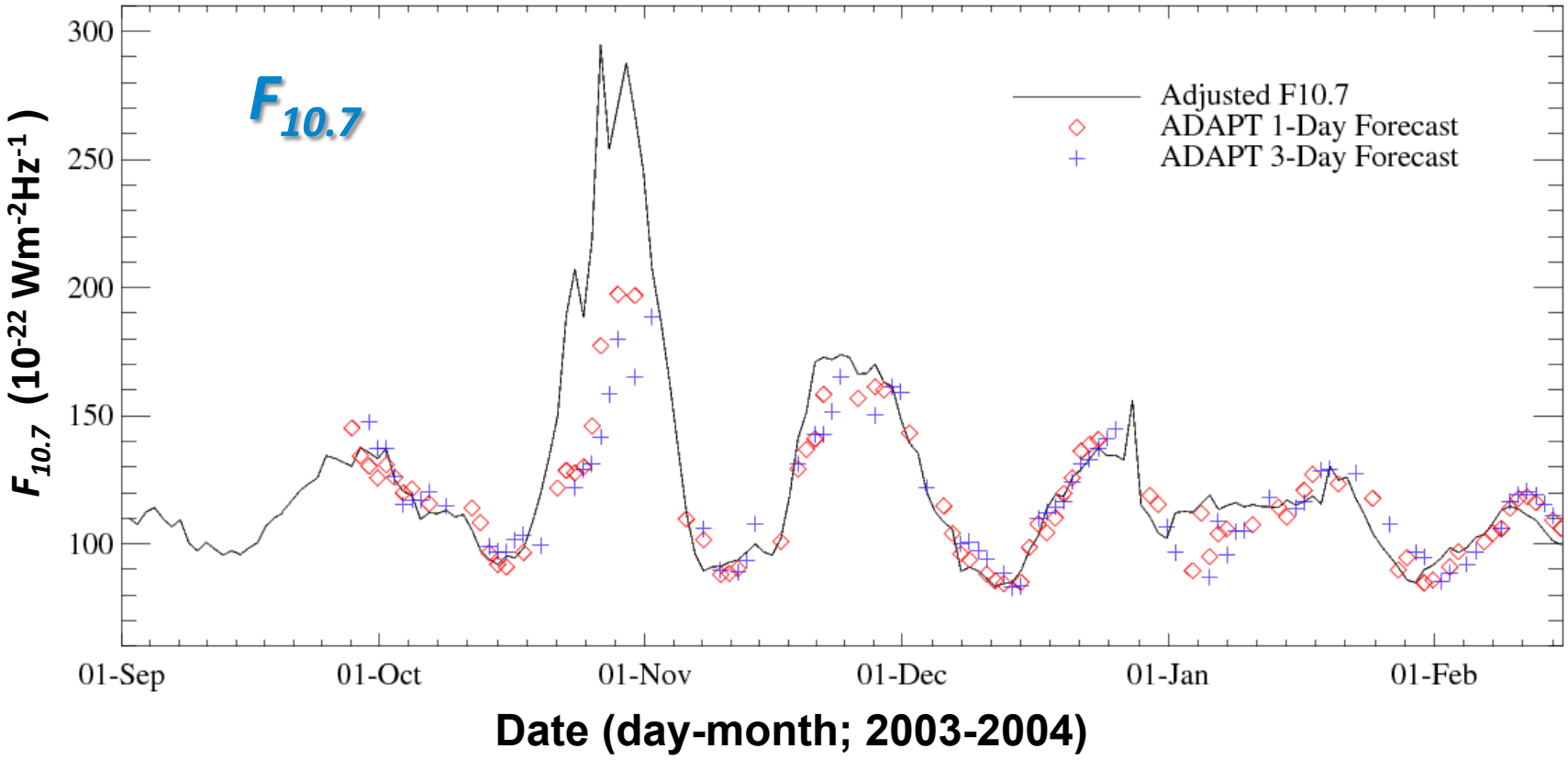
7-day 3-day 0-day



Global solar magnetic map (360 x 180 deg) created by ADAPT using NISP/SOLIS VSM data as input.

- ADAPT utilizes flux transport (*based on Worden & Harvey 2000*) to account for known surface flows in the solar photosphere:
  - **differential rotation, meridional circulation, supergranular diffusion**

ADAPT Forecasting: $F_{10.7}$



Henney et al. 2012, Space Weather, 10, S02011

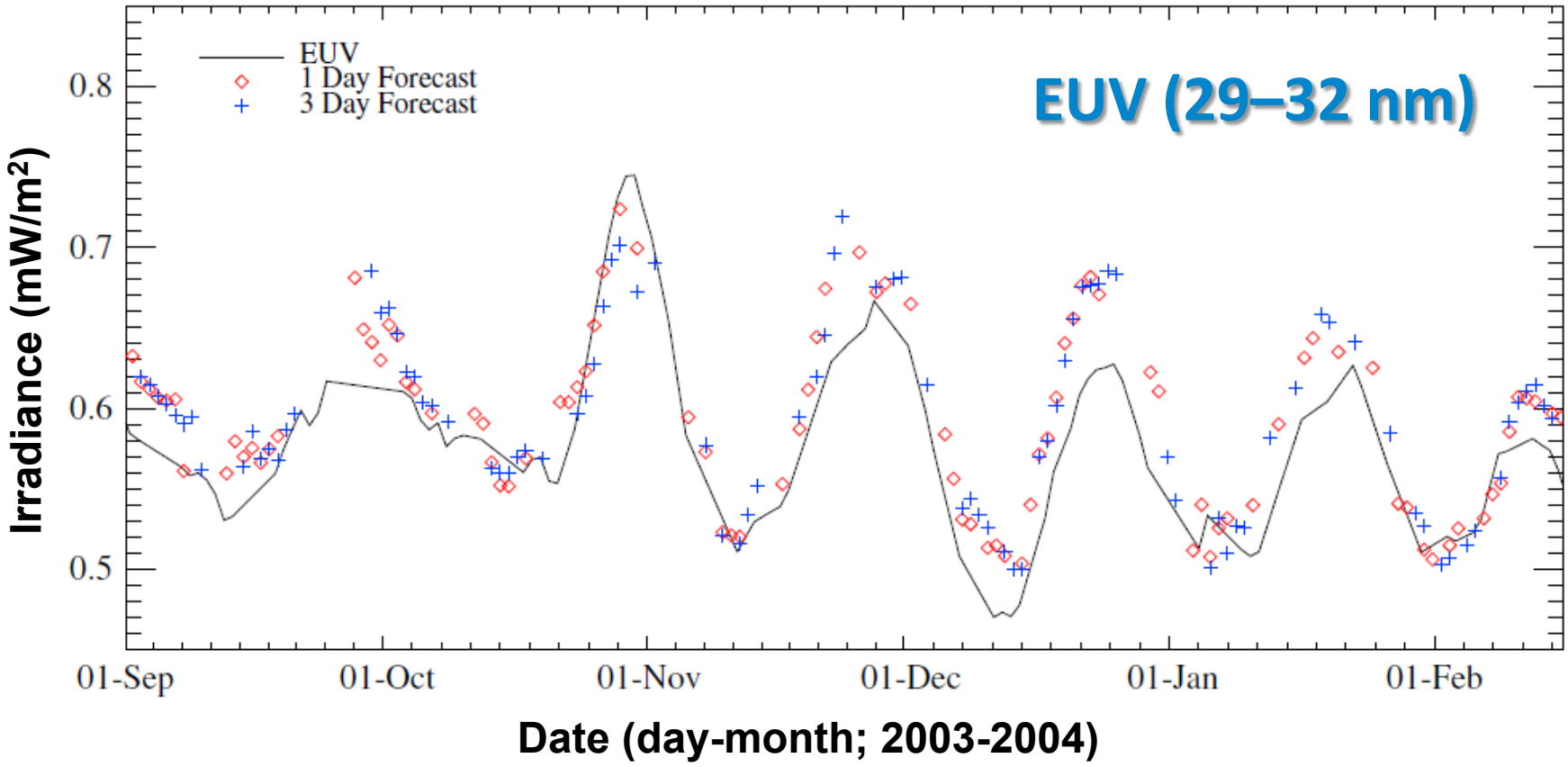
Modeling XUV, EUV, & FUV

Thermospheric models typically divide the VUV spectral regions of interest into 37 bands within the **XUV/ EUV/FUV** intervals, where XUV is 0.1-10 nm, EUV is 10-121 nm, and FUV is 121-200 nm [Solomon and Qian, 2005]:

#	Wavelength	#	Wavelength	#	Wavelength	#	Wavelength
1	0.1-0.4nm	11	54.0-65.0nm	21	98.7-102.7nm	31	140.0-145.0nm
2	0.4-0.8nm	12	65.0-79.8nm (low)	22	102.7-105.0nm	32	145.0-150.0nm
3	0.8-1.8nm	13	65.0-79.8nm (high)	23	105.0-110.0nm	33	150.0-155.0nm
4	1.8-3.2nm	14	79.8-91.3nm (low)	24	110.0-115.0nm	34	155.0-160.0nm
5	3.2-7.0nm	15	79.8-91.3nm (mid)	25	115.0-120.0nm	35	160.0-165.0nm
6	7.0-15.5nm	16	79.8-91.3nm (high)	26	121.6nm Lyman-α	36	165.0-170.0nm
7	15.5-22.4nm	17	91.3-97.5nm (low)	27	120.0-125.0nm	37	170.0-175.0nm
8	22.4-29.0nm	18	91.3-97.5nm (mid)	28	125.0-130.0nm		
9	29.0-32.0nm	19	91.3-97.5nm (high)	29	130.0-135.0nm		
10	32.0-54.0nm	20	97.5-98.7nm	30	135.0-140.0nm		

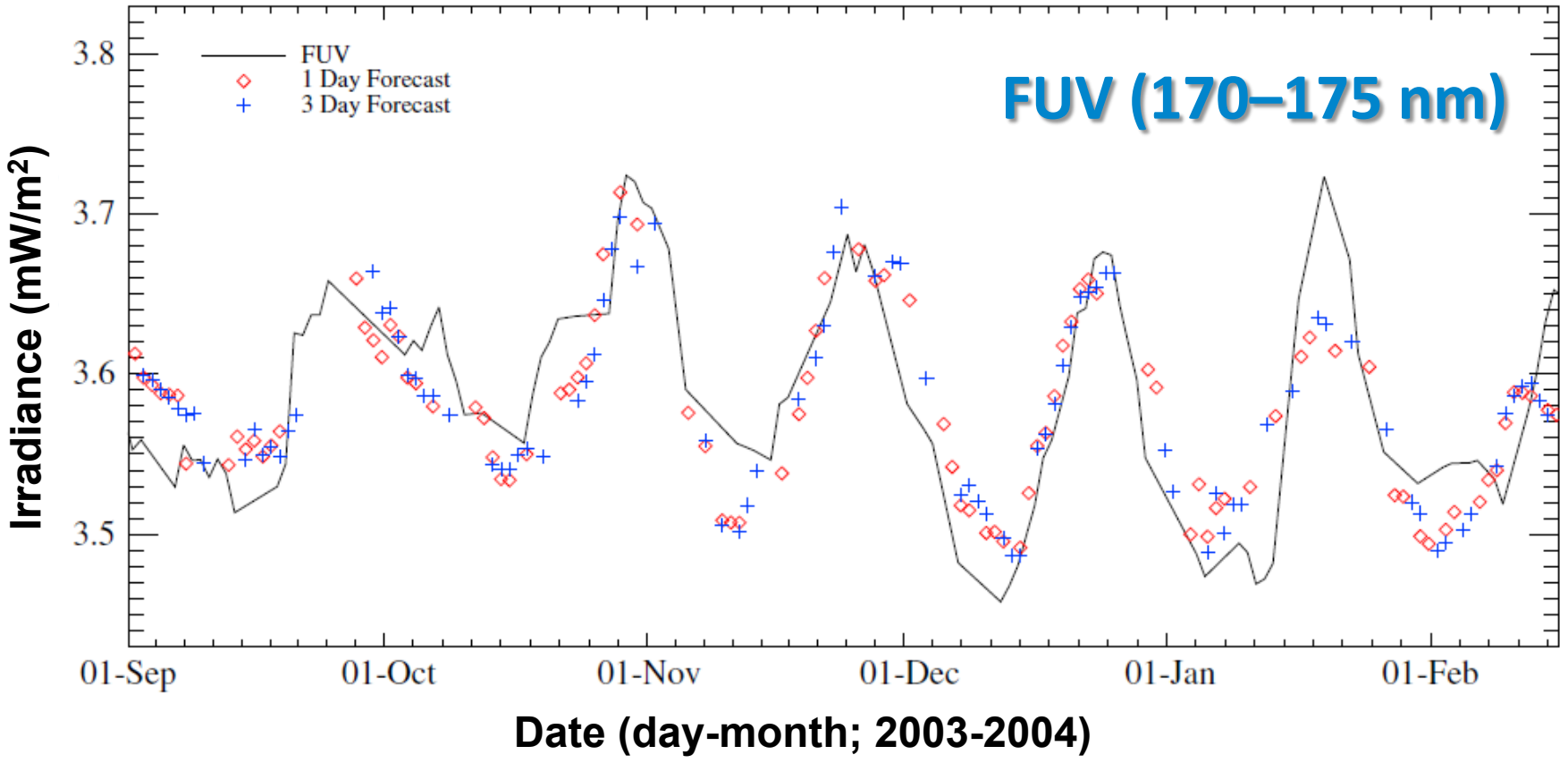
- For this study, we used solar irradiances measured by the Solar EUV Experiment (SEE) on NASA's TIMED mission [Woods et al. 2002], which has been operating since early 2002.

ADAPT Forecasting: EUV



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

ADAPT Forecasting: FUV



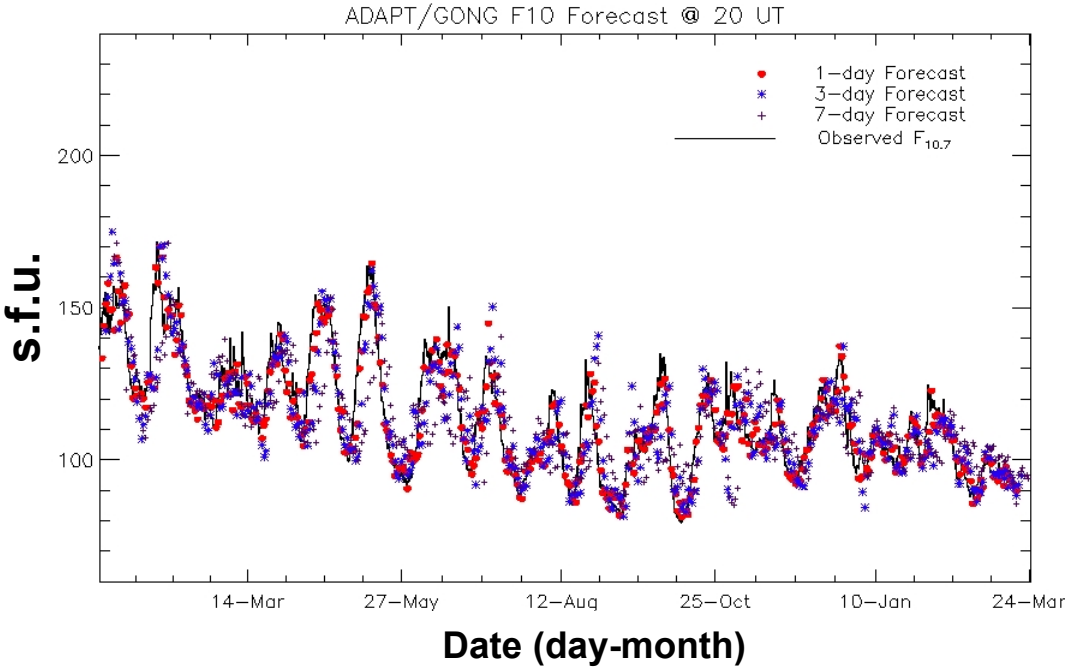
Henney et al. 2015, Space Weather, 13, 141-153

ADAPT *F10.7 Model Online*

$F_{10.7}$ model forecasts are now online:

- **ADAPT runs 24/7 at the National Solar Observatory (NSO) generating global maps every 2 hours**

- **F10.7 model utilizes the ADAPT maps in near real-time, providing 1, 3, and 7 day advance forecast values of *F10.7***

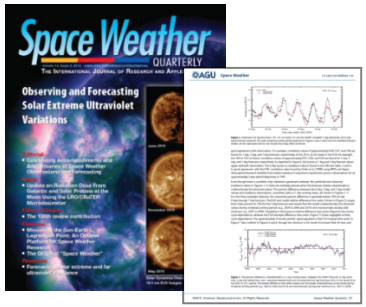



```
: Product : adapt_f107_forecast.txt
: Created : 2014 10 24 2147 UT
: Date : 2014 10 24
: DOY : 297
: Model: ADAPT-F10.7
: Version :  5.0212
: POC : CJ Henney (USAF/AFRL)
: POC Email : adapt@noao.edu
: Data Input : GONG
: Resolution [deg / pixel] : 1.00
: Fit-function : m0 + m1*M_P + m2*M_A
: Forecast :  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 - Helioseismic 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
  2456955.3333  1  1  0  2000   -1.000   -1.000    -1.0    -1.0    -1.0    -1.0    -1.0
  2456955.4167  1  1  0  2200   -1.000   -1.000    -1.0    -1.0    -1.0    -1.0    -1.0
```

Example ADAPT $F_{10.7}$ Forecast File

Summary

- **Near real-time ADAPT maps & $F_{10.7}$ forecasts (1, 3, and 7 day) are public via the NSO at: ftp://gong2.nso.edu/adapt/f10/.**
- **EUV power (0.8-105 nm) & Mg II Index forecasts are planned for 2016.**
- **Related References:**



Forecasting Solar Extreme and Far Ultraviolet Irradiance

Henney, Hock, Schooley, Toussaint, White, Arge 2015,

Space Weather, 13, 141-153

& Space Weather Quarterly, 12, 19-31

Data Assimilation in the ADAPT Photospheric Flux Transport Model

Hickmann, Godinez, Henney, Arge 2015,

Solar Physics, 209, 1105-1118

Acknowledgements

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