Solar data for space weather forecasts from GONG

Frank Hill, National Solar Observatory

SWPC Space Weather Workshop
Boulder, CO April 14-17 2015

What is GONG?

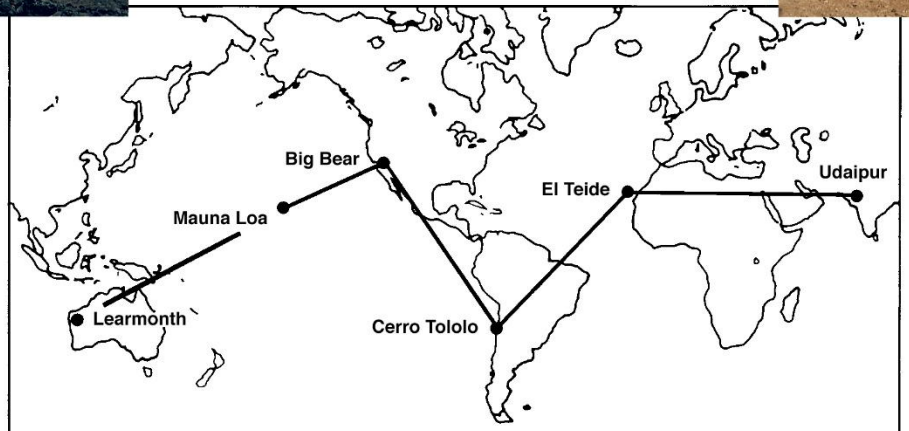
- Global Oscillation Network Group
- Set of six identical solar observing stations
- Geographically distributed
- Nearly continuous solar observations 24/7 since deployment in 1995
- Operated by the National Solar Observatory
- Originally intended for helioseismology
- Role expanded to provide space weather operational data
- Cost-effective, maintainable, upgradable, and robust

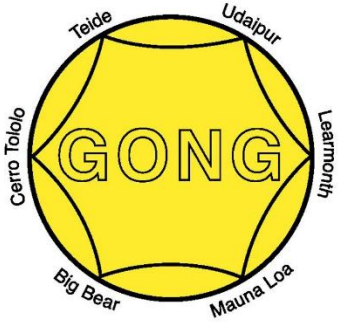
Mauna Loa

Global Oscillation Network Group

Big Bear

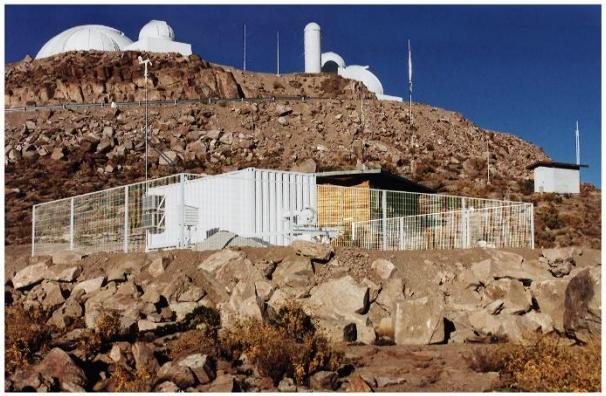
Udaipur



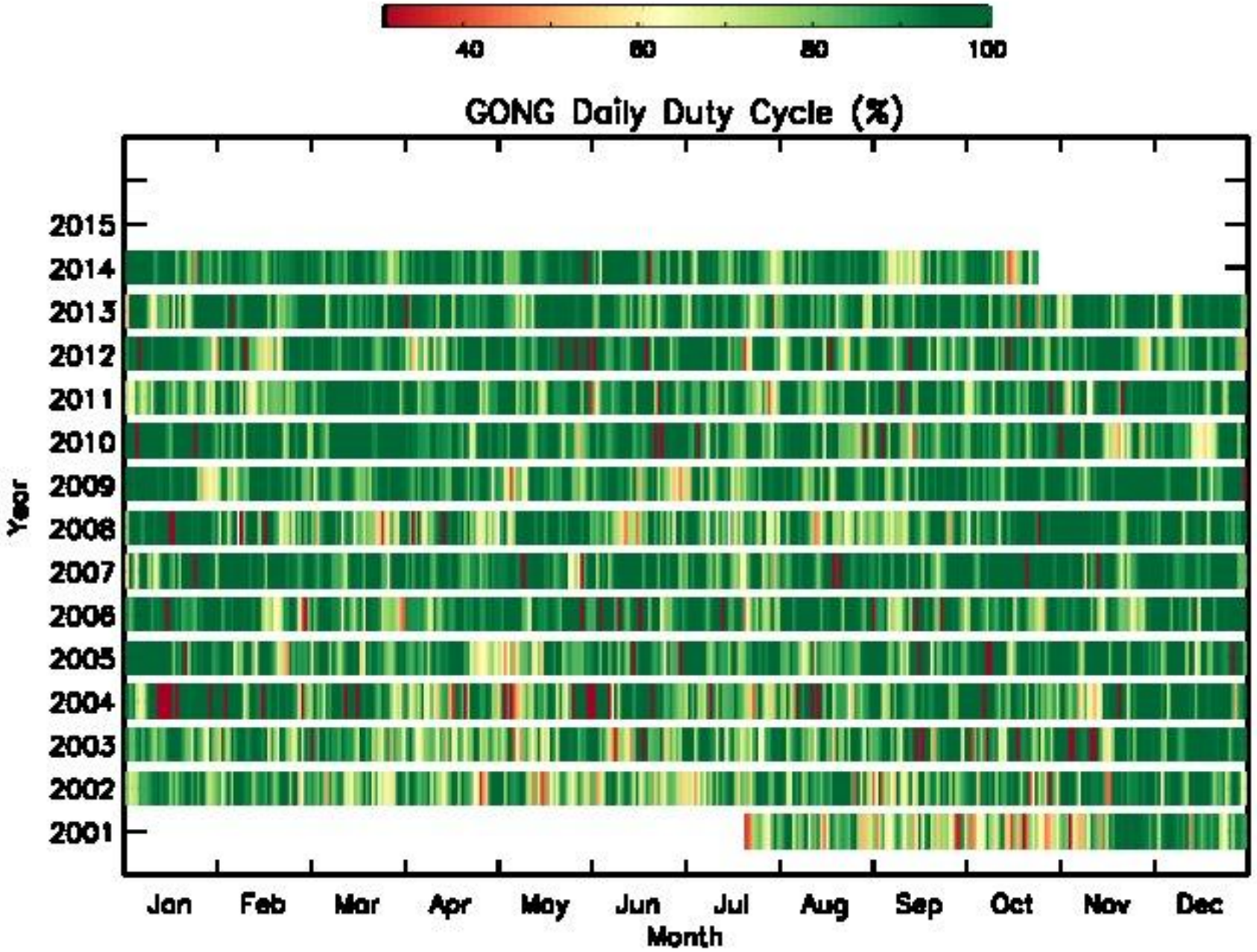


Learmonth

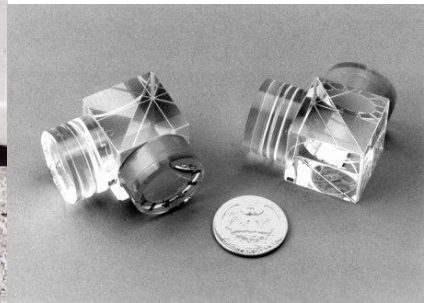
Cerro Tololo



El Teide



Median value: 0.91



Gong Shelter Layout


Objective Lens

Turret


Oven Power Supply (Under Table)


Cal-Wheel 2 Box

H-Alpha Sled


Instrument Rack


Workstation Cart

Camera Power Supply (Under Table)

Optical Table


Camera & Rotator


Waveplate Rotator


Sensaphone


Oven


UPS Bypass & Shut-Off Switch

Main Door


Clean Air System


UPS


Battery Cabinet

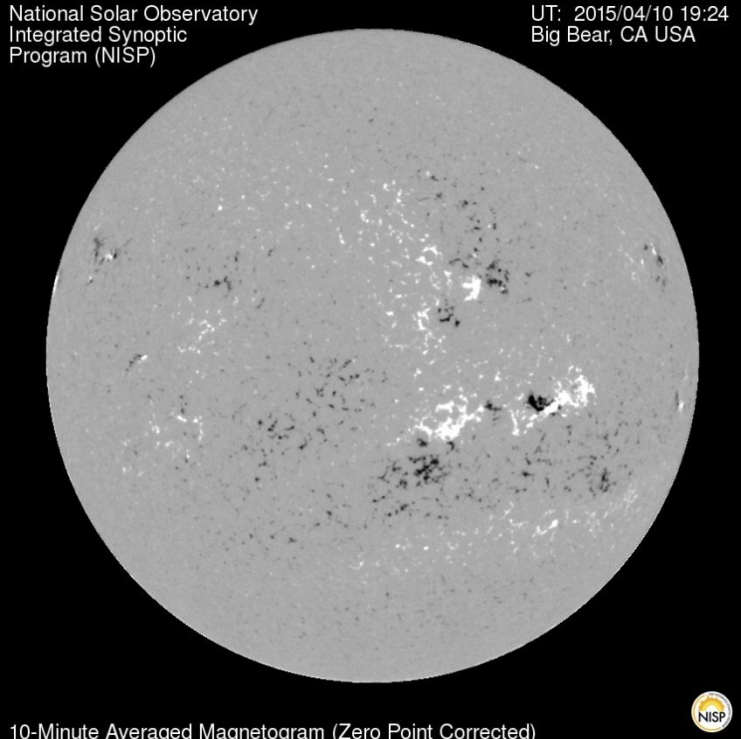

Air Conditioners

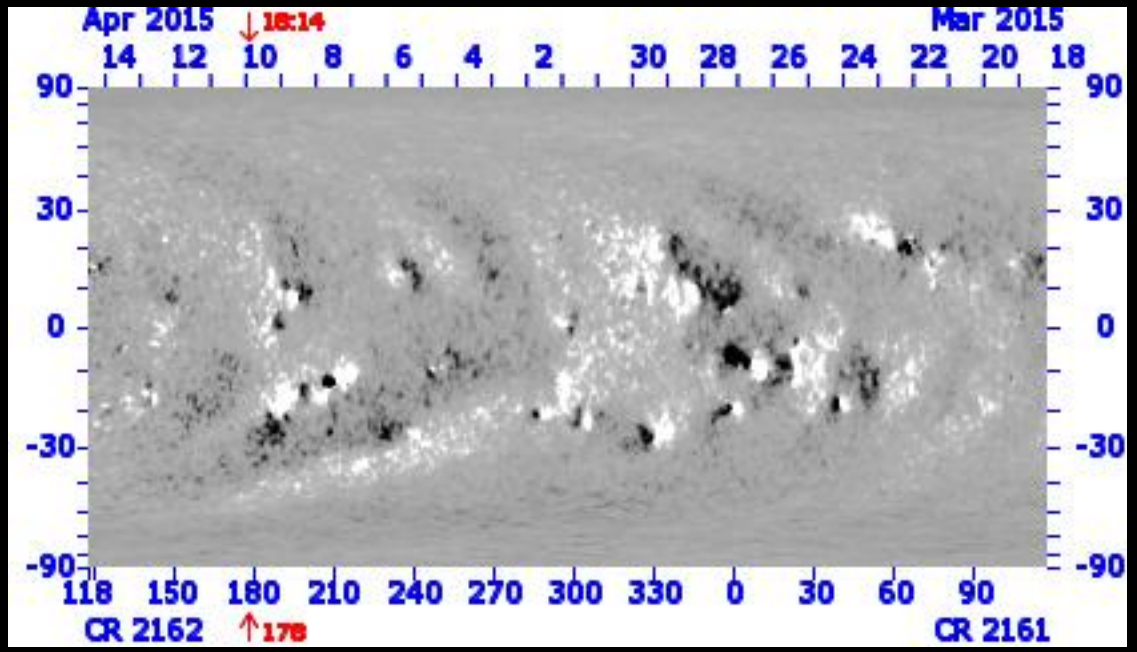
Basic data products

- Full-disk solar observations
- 1k X 1k images of Doppler velocity and line-of-sight magnetic field
  - Ni I line 676.8 nm
  - 60-sec cadence
- 2k X 2k images in Hα spectral line center
  - 60-sec cadence at one site, 20-sec cadence around network

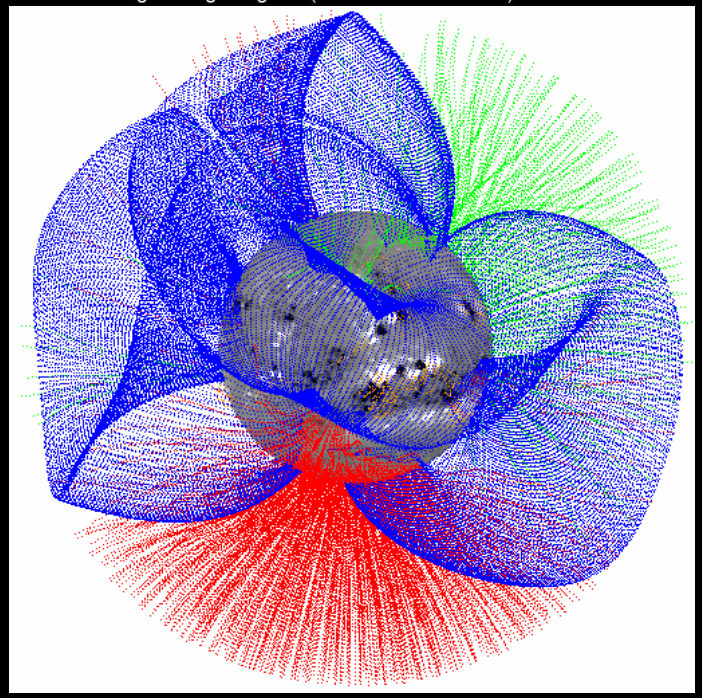
Derived magnetic field data products

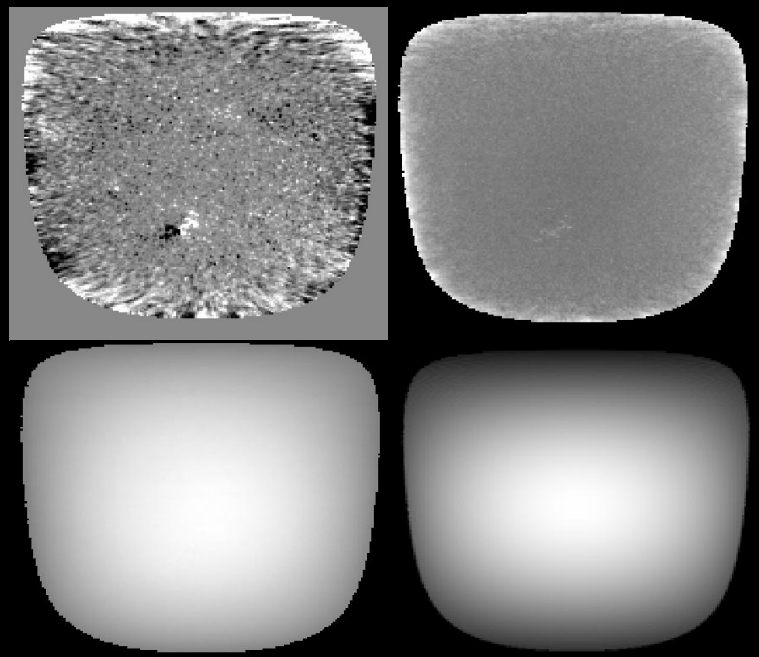
- 10-min averaged magnetograms
- Processed at sites, returned in near-real time
- Zero-point corrected
- Combined into hourly synoptic maps based on ~9000 images
- Extrapolated coronal fields, PFSS with source surface at 2.5 $R_{\odot}$
- Noise estimate from temporal variance
- Used as inputs for SWPC WSA+Enlil model, AFRL ADAPT system





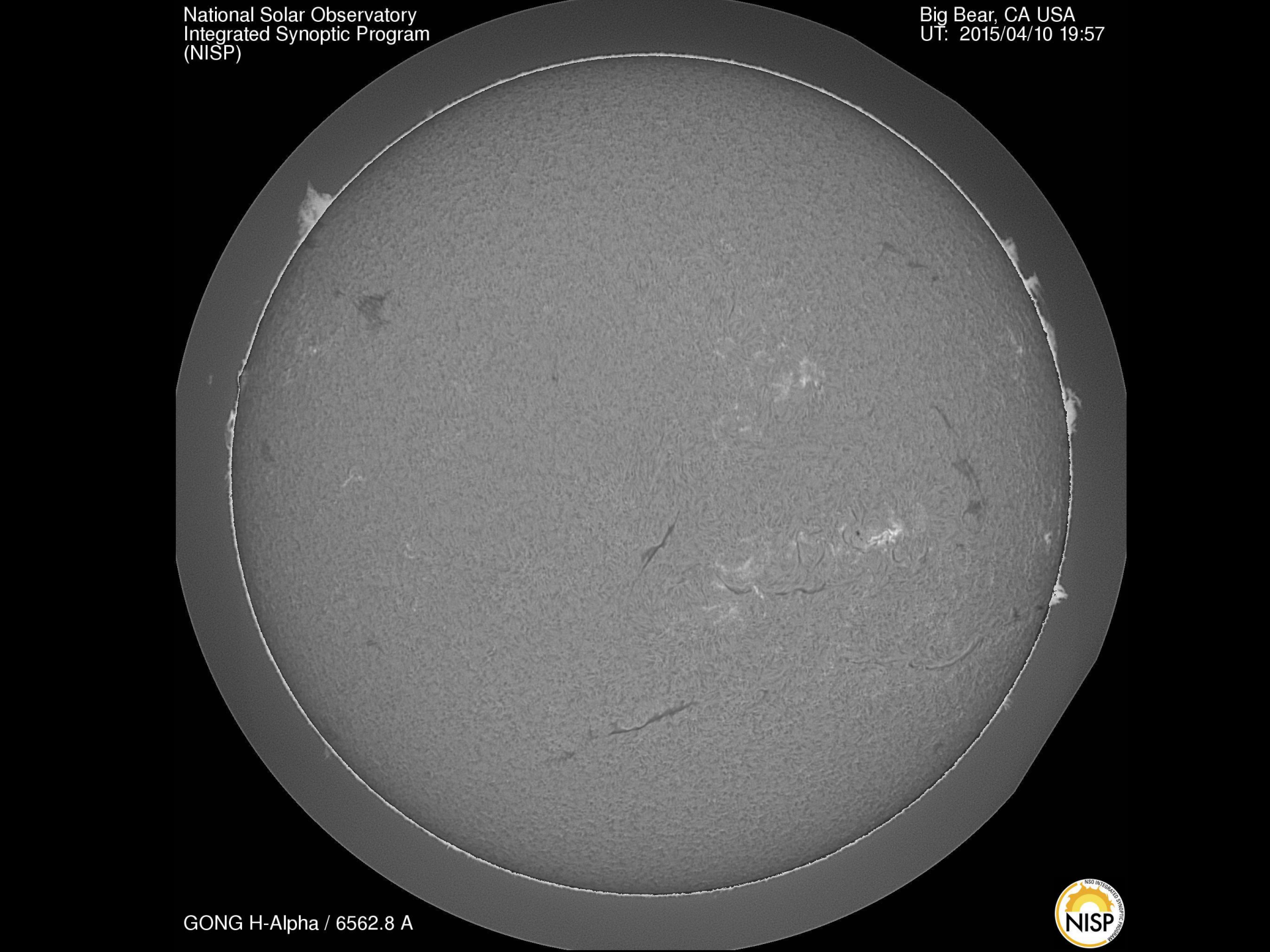
10-Minute Averaged Magnetogram (Zero Point Corrected)





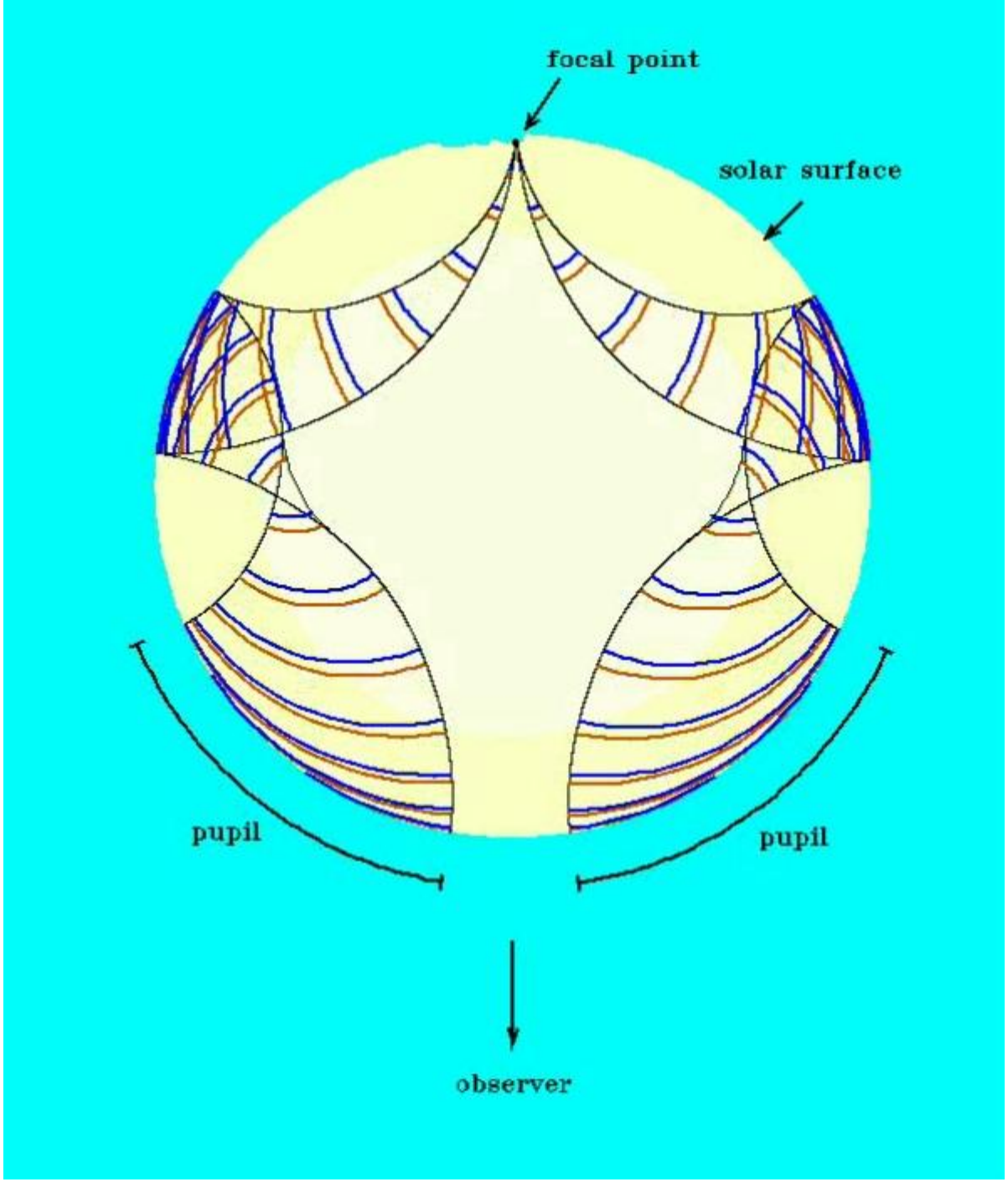
H-α Data Processing

- Images from all sites are:
  - Circularized to a common radius
  - Registered to a common center
  - Rotated so that solar North is up to within about ¼ degree
- For web display:
  - Gain and bias set to show both on- and off-disk features
  - Contrast and brightness normalized across all images to eliminate flickering
- Actual data values also provided
- Processing completed and data available in one minute after acquisition at the sites
- Data is currently pushed to AFWA and pulled by SWPC


National Solar Observatory
Integrated Synoptic Program
(NISP)
Big Bear, CA USA
UT: 2015/04/10 19:57
GONG H-Alpha / 6562.8 A
NISP

Maps of the far-side magnetic field

- Uses helioseismology to sense the presence of magnetic fields on the side of the Sun facing away from the Earth
- Presence of magnetic field alters local reflection properties of the photosphere and creates a phase shift of p-mode waves hitting that position
- Magnitude of the phase shift is a function of magnetic field strength and (probably) filling factor
- Can be detected for strong fields, large active regions
- Useful for:
  - Long-term solar activity forecasts
  - Studies of active region emergence and evolution
  - Improvement of space weather forecasts
  - Backup for STEREO

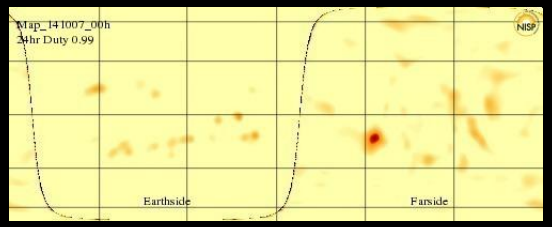


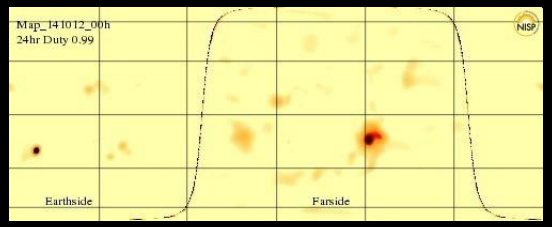
Analysis steps:

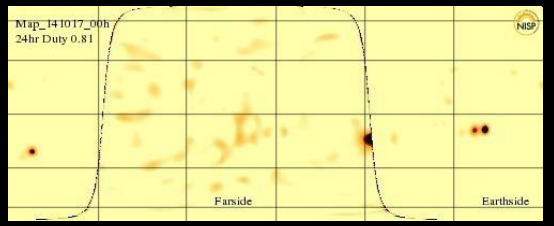
1) Select pupil position/area and apply filters to isolate waves that converge on a specific far-side point
2) Measure phase of these waves
3) Move pupil to select another point on far side
4) Create map of far-side spatial variation of phase shifts
5) Can select different wave ray paths for better sensitivity across far side

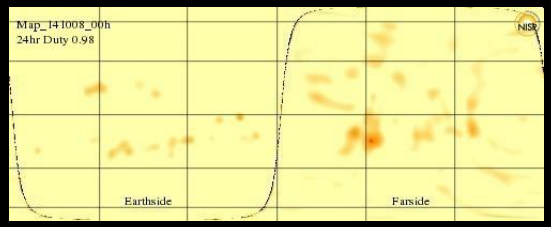
GONG Far-side Maps (October 7 – 21, 2014)

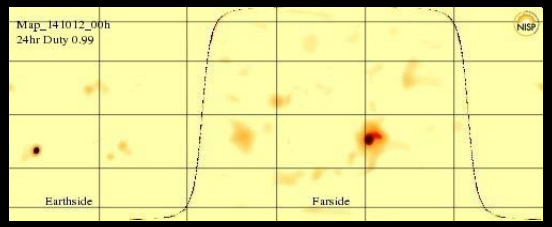
Front-side AR 2192 is clearly visible in these maps.

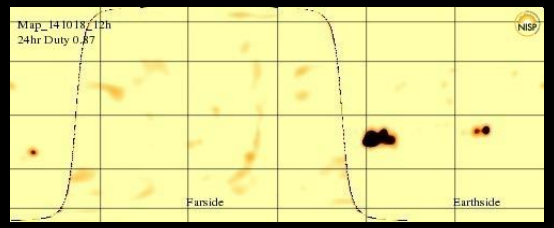


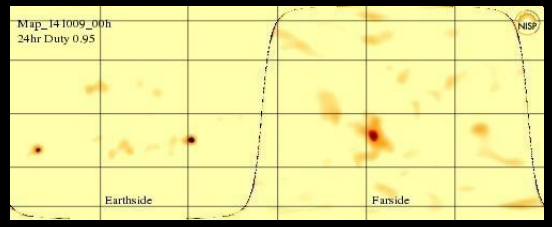


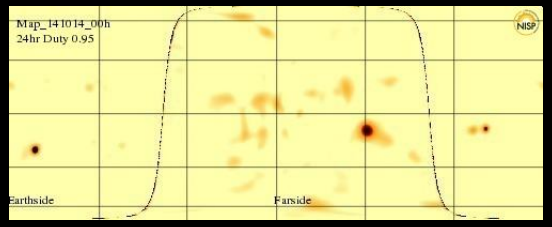


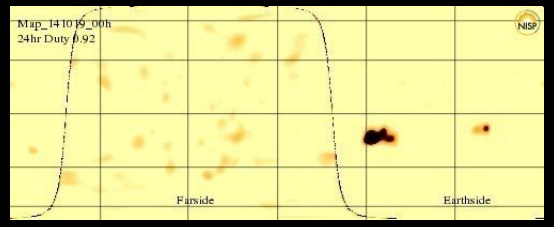


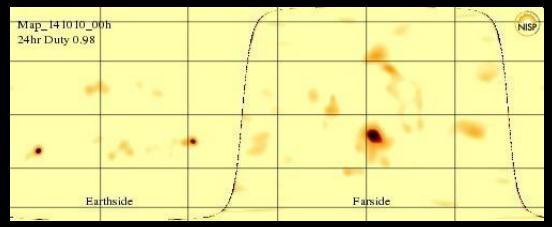


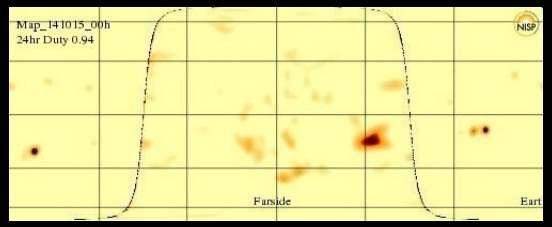


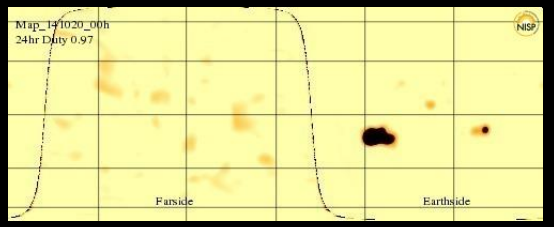


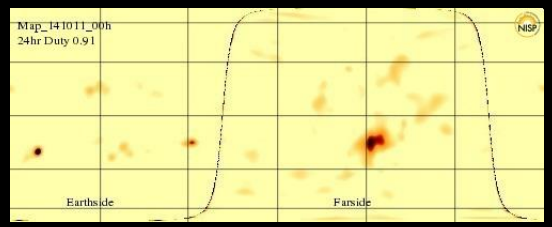


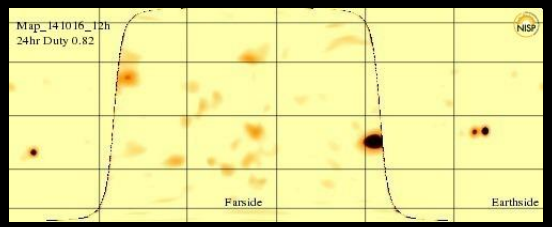


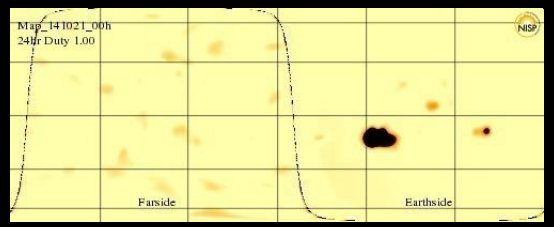












Synoptic maps and space weather forecasts are improved by far-side measurements

- Inclusion of far-side in synoptic maps greatly reduces discontinuity at edges
- All space-weather forecasts based on synoptic maps are thus improved:
  - Solar wind forecasts from WSA
  - SWPC geomagnetic storm predictions
  - F10.7 flux
  - FUV flux
  - ADAPT output

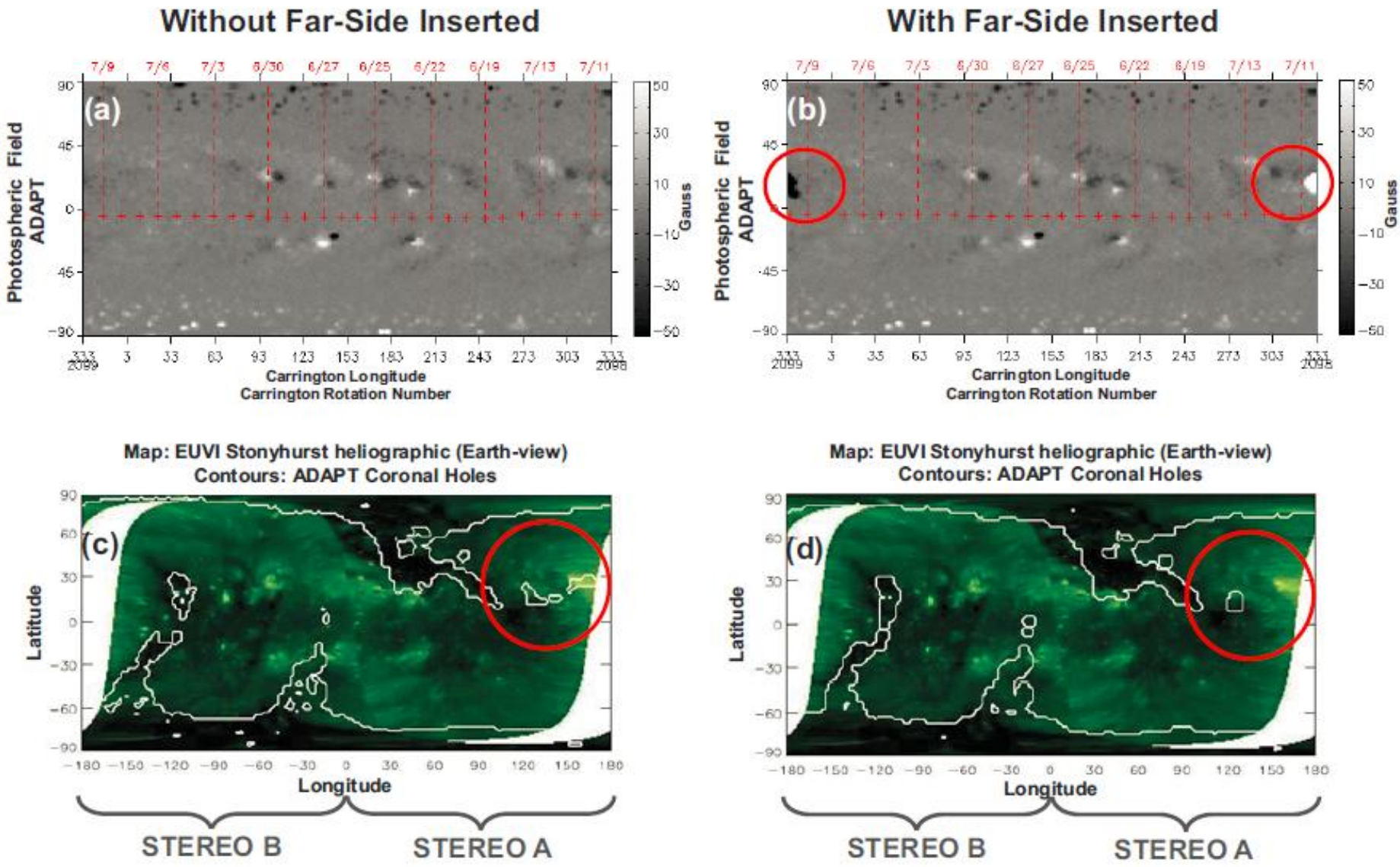


FIGURE 1. ADAPT photospheric magnetic field without far-side active region included (a) and with the far-side active region included (b) shown in upper row. The comparison of global STEREO EUVI map (green image) and WSA coronal hole predictions (white contours) rendered in (c) and (d) were obtained using (a) and (b), respectively, as inputs to the WSA model. Note that the small coronal hole positioned on top of the bright area of EUV emission (circled in red) in (c) has disappeared in (d).

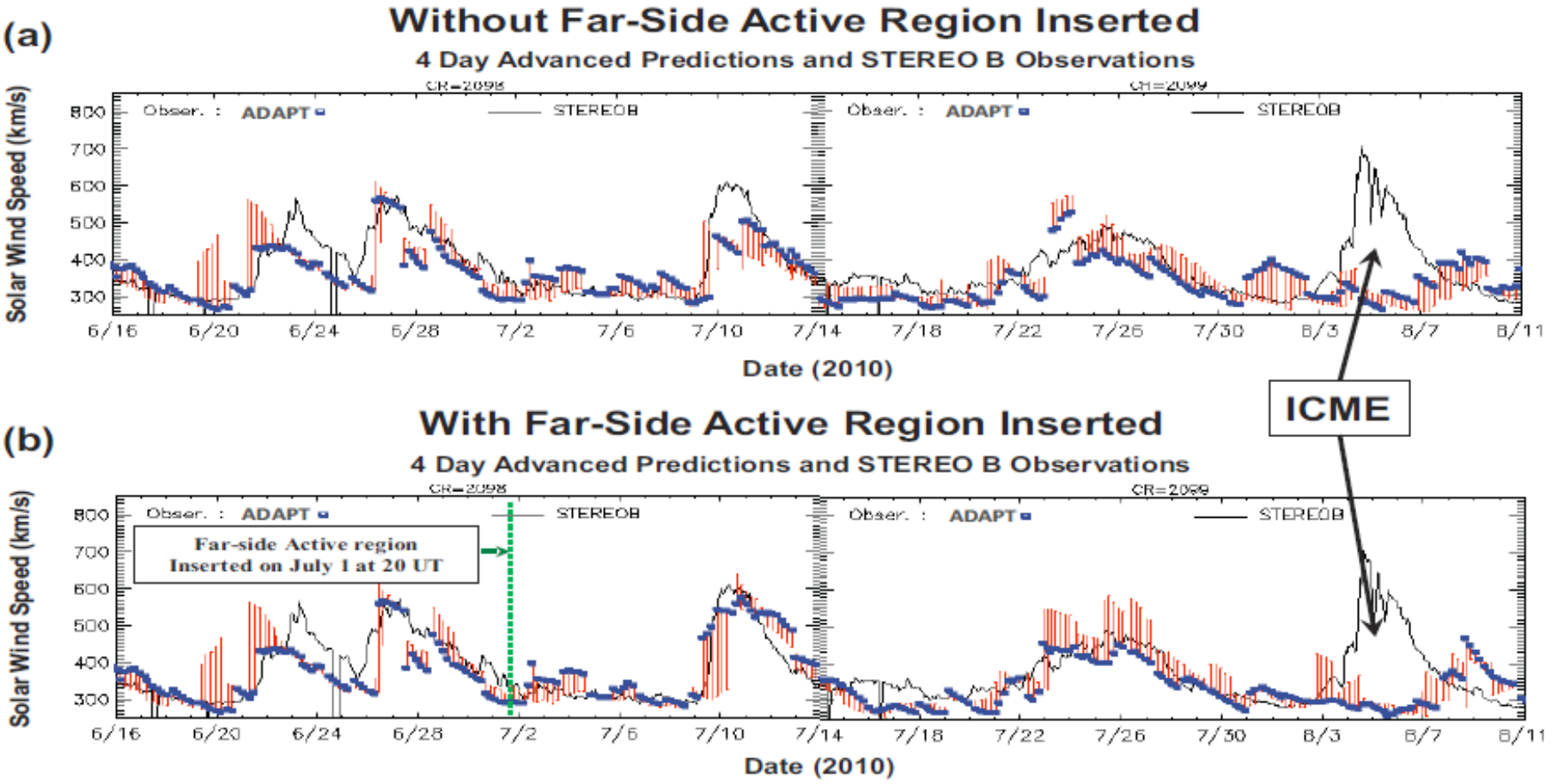
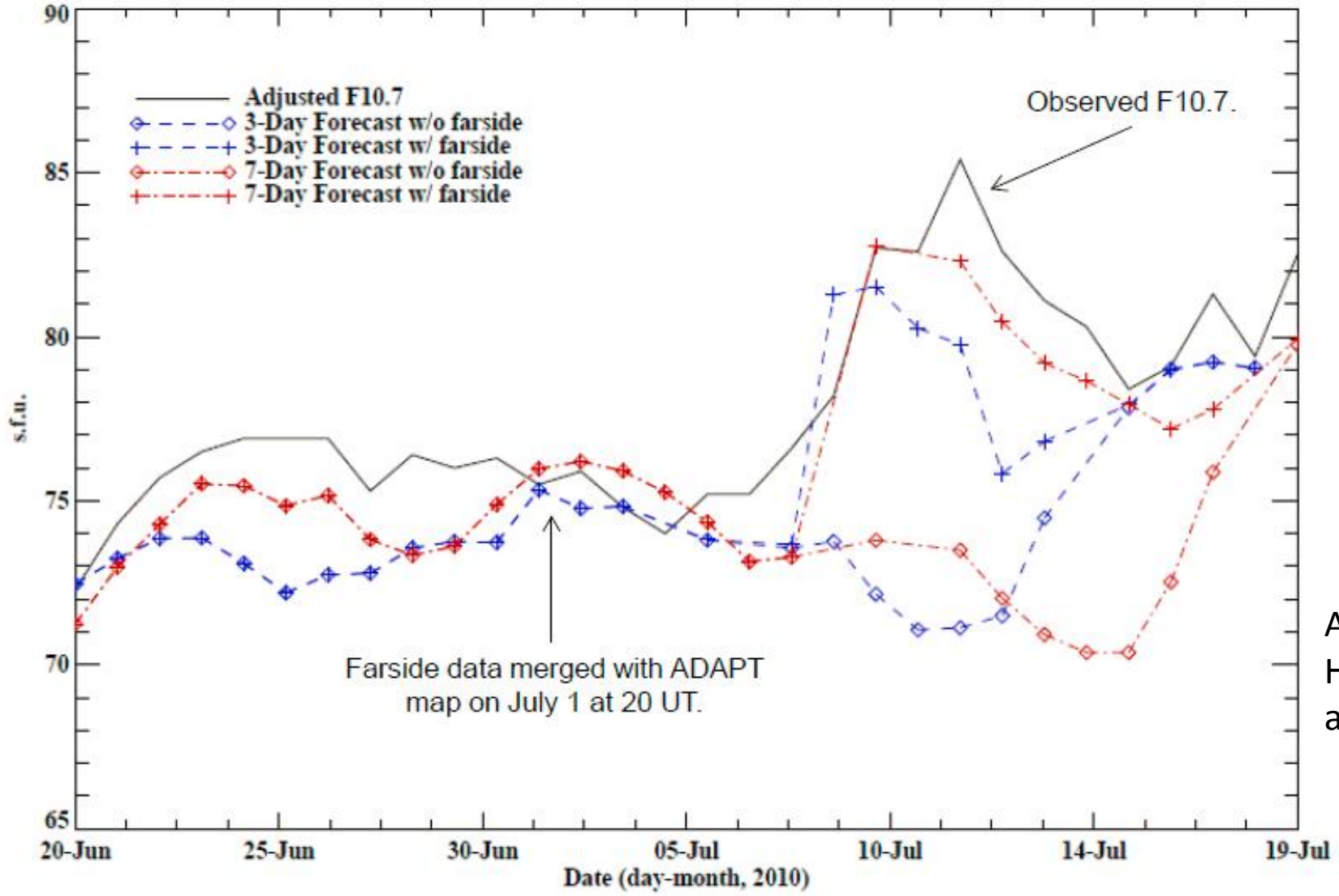


FIGURE 2. Solar wind speed observations from STEREO B (black solid lines) vs. WSA predictions (blue dots) using daily ADAPT maps without the far-side active region included (a). The lower time series (b) is the same as (a) except now using ADAPT maps with the far-side active region included.

Arge, Henney et al.

Far side improves F10.7 forecast



Arge, Henney et al.

Far side improves Lyman-α forecasts

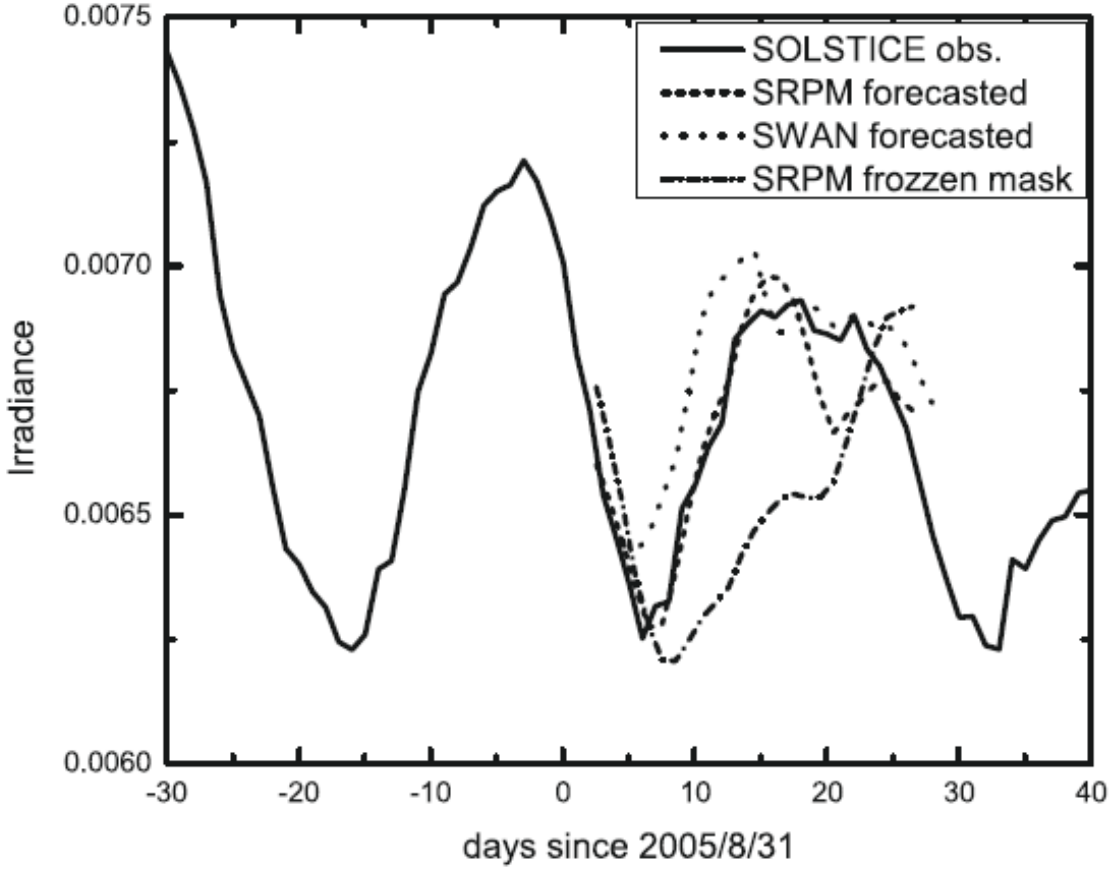


Fig. 7. Lyα irradiance at 1 AU measured by the SORCE/SOLSTICE instrument (solid line) compared with the forecast from the refined synoptic map shown in Fig. 6 (dashed line). Also shown are: (1) the forecast from SWAN made on 9/4 (dotted line), and (2) the irradiance resulting from the synoptic map without refinement shown in Fig. 2 (dot-dashed line).

Fontenla et al.

Future directions

- Magnetograms:
  - Modify modulator position for further improvement to zero-point correction
  - Improve software for zero-point correction
- H-α:
  - New filter to provide line wing measurements for Doppler shift
  - Merge images from different sites
  - Other spectral lines?
- Far side:
  - Quantify noise characteristics
  - Improve analysis methods
- Helioseismology:
  - Further development of sub-surface vorticity flare forecast