The need for synoptic solar observations from the ground.

“Breaking news: Monstrous CME hits the Earth”

Alexei A. Pevtso

US National Solar Observatory

NSO INTEGRATED SYNOPTIC PROGRAM
NISP
NSO

Brief History of Early Synoptic Programs

- Sunspot numbers (1600-present; Rudolf Wolf, 1848), sunspot drawings, RGO photographic observations (1874-1976), CaK observations (Kodaikanal, India 1907-1999, MWO 1915-1985), Meudon synoptic maps (1919-), sunspot field strength measurements (MWO, 1917-present), etc (other e.g., NAOJ).

- Modern era (late-1940th): Kislovodsk Mountain Astronomical Station (1948), Sacramento Peak Observatory (1949), radio (2800 MHz/10.7 cm, Ottawa/Dominion 1946-present), magnetographic measuremets (NSO, MWO, WSO).

- Networks (late-1950th): "Sun Service" program (USSR, mid-1950th-2010), the Solar Observing Optical Network (SOON, 1970th-present), helioseismology networks, GONG (1995-present) , global high resolution H-alpha network (GHN).

Synoptic. But Why?

Pure science (curiosity):

- Solar and stellar processes and their change (cycle).
- Sun-planetary connections and space climate

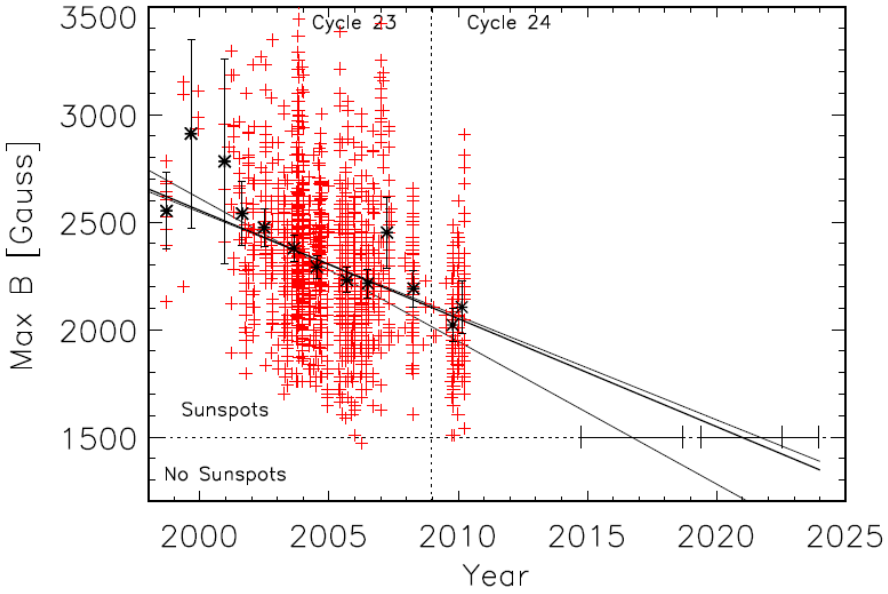
Applied science (space weather):

- Providing routine observations for space weather forecasting.

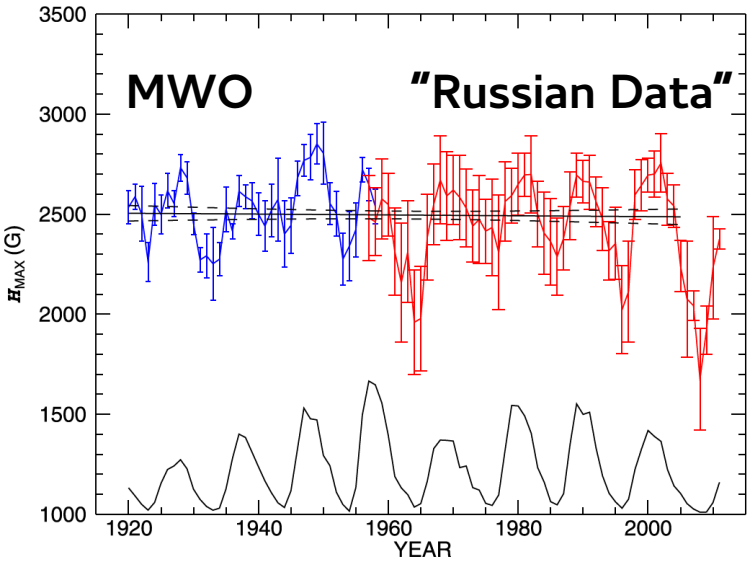
Observations are not well-defined.
Monitor as long as possible !

Observations are well- (better) defined.
Monitor as long as needed !

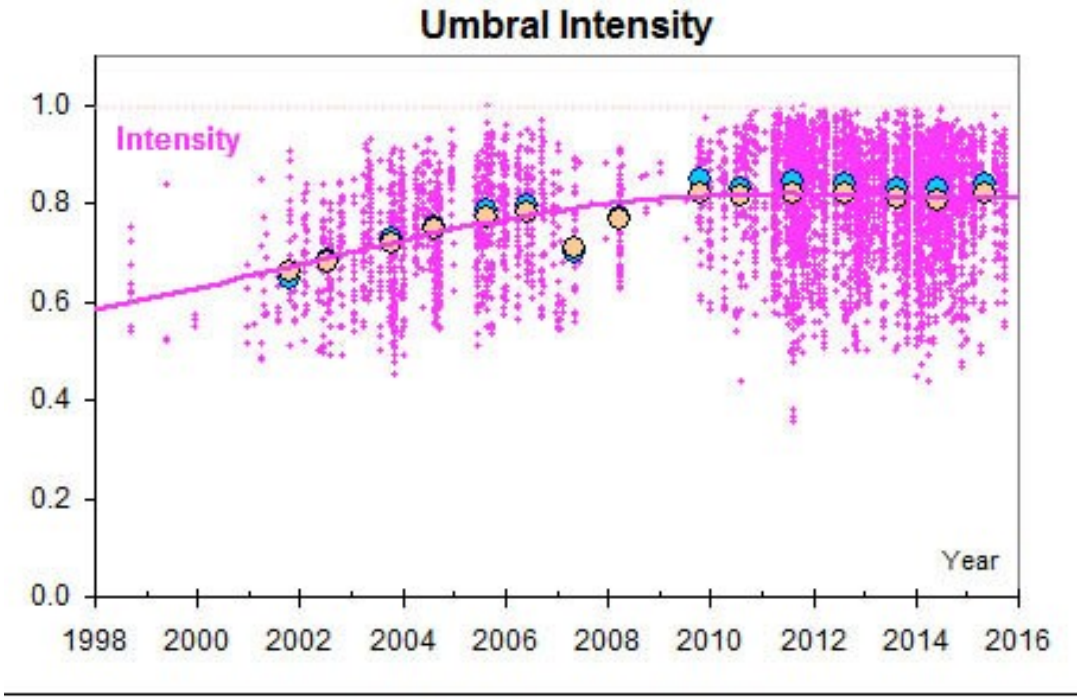
Example 1: Do properties of sunspots change?

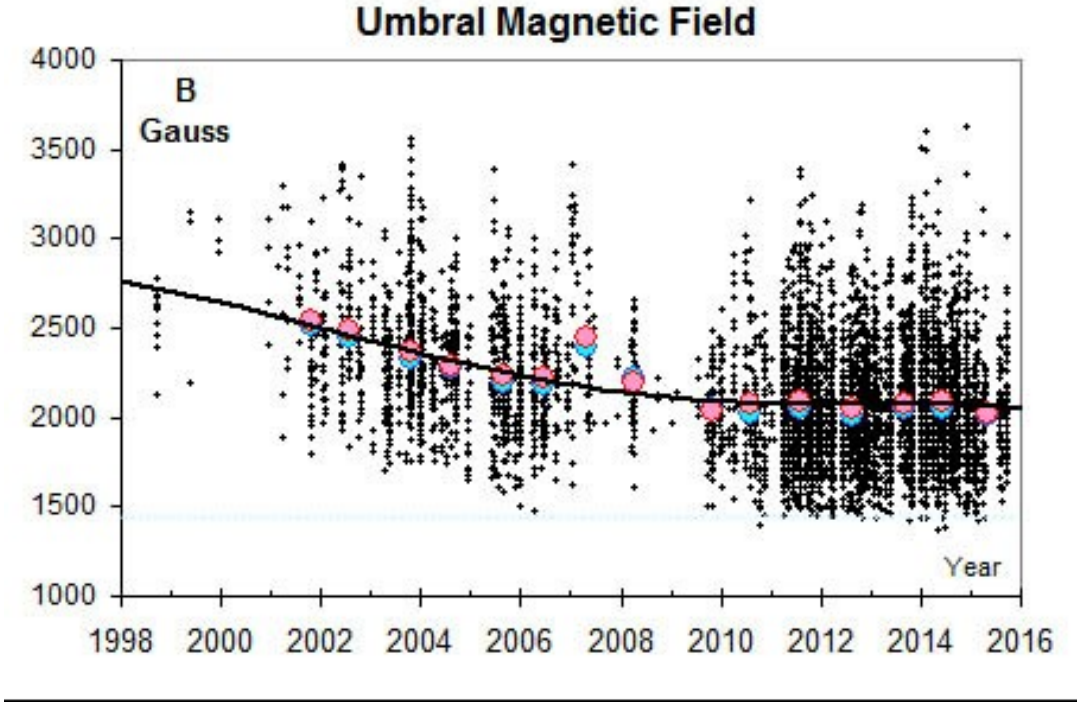


Penn and Livingston (2011)



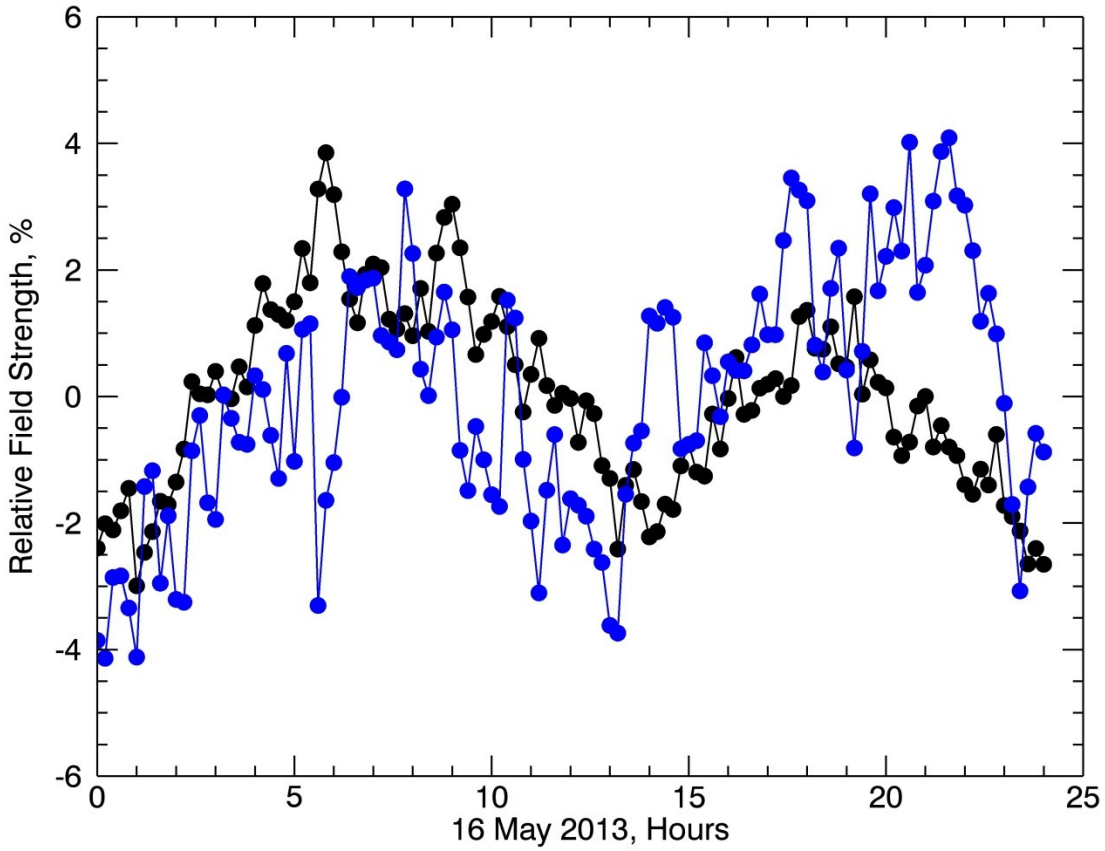
Pevtsov et al (2014)


Umbral Intensity
Intensity
1.0
0.8
0.6
0.4
0.2
0.0
Year
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016


Umbral Magnetic Field
B
Gauss
4000
3500
3000
2500
2000
1500
1000
Year
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Space - vs. Groundbased

Day-n cycle/ seeing		tigated via use of e optics
Exten covera		exist)
Longe		50 yrs+), can be repaired and
Cost		n
Flexib		ts can be added
Intern		stricted

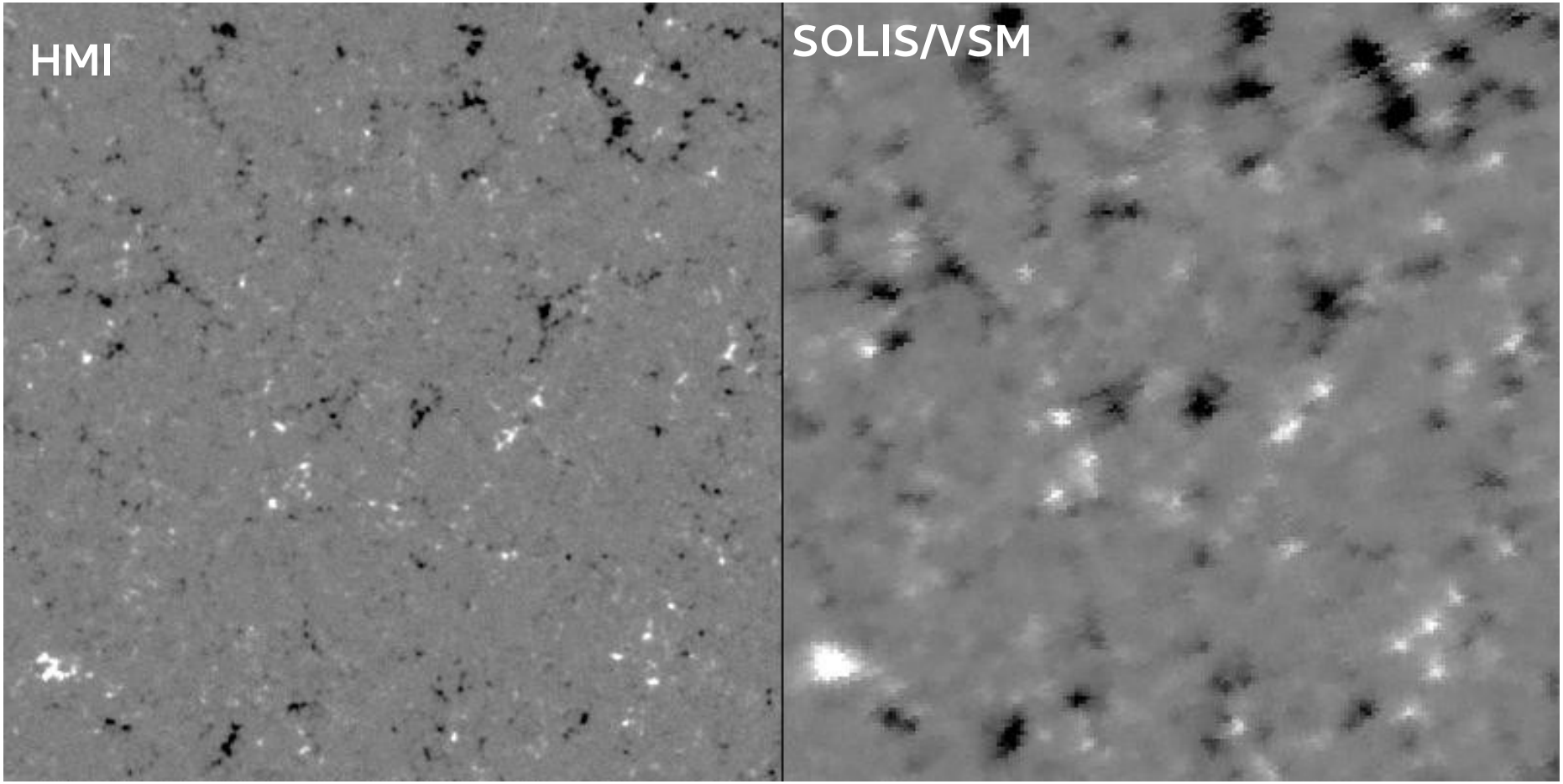


largely unrestricted

Requires central coordination

Can be run under a loose coordination

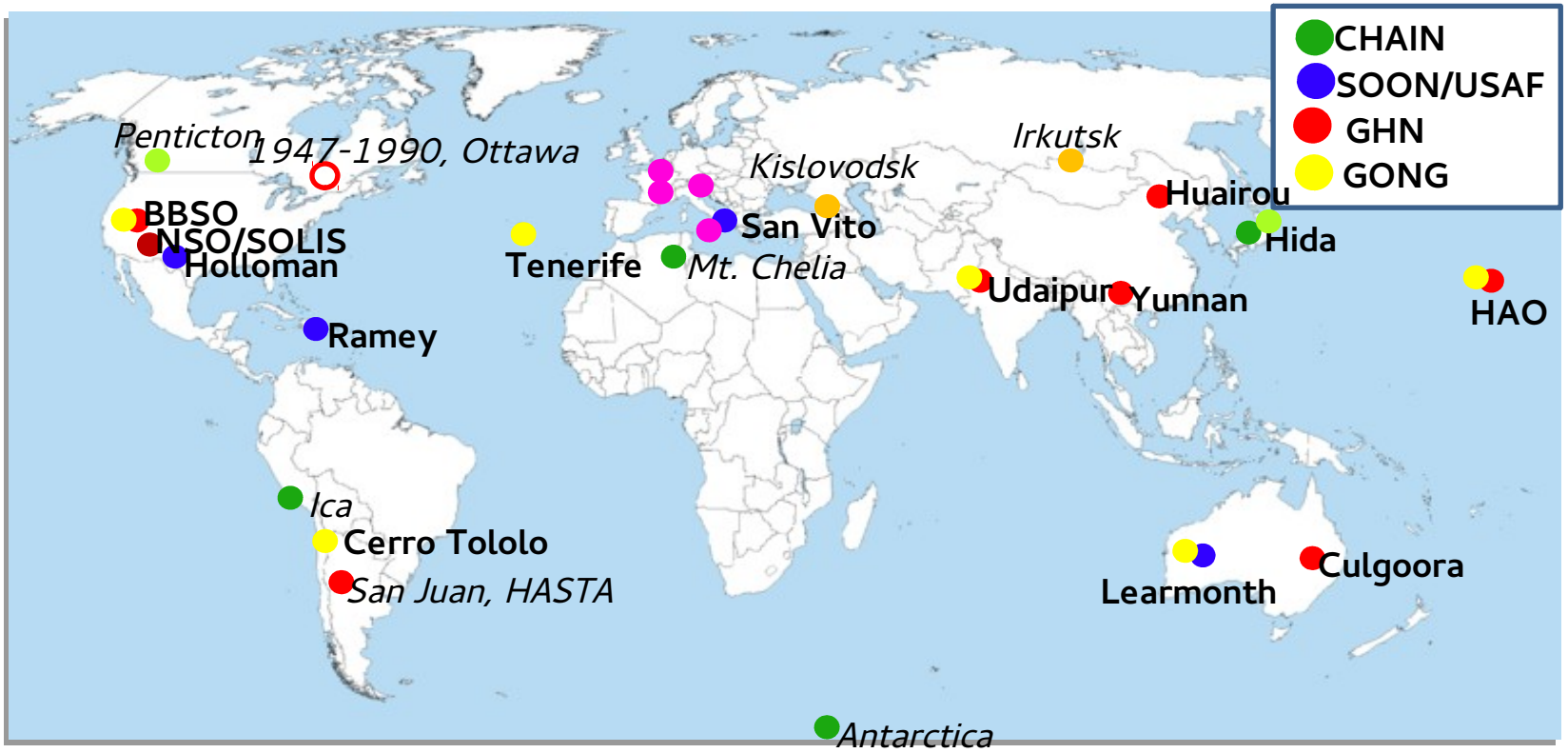
Space vs. Ground



- Data are largely comparable (depending on goals); higher resolution and cadence could be achieved if needed.

Main international solar monitoring networks

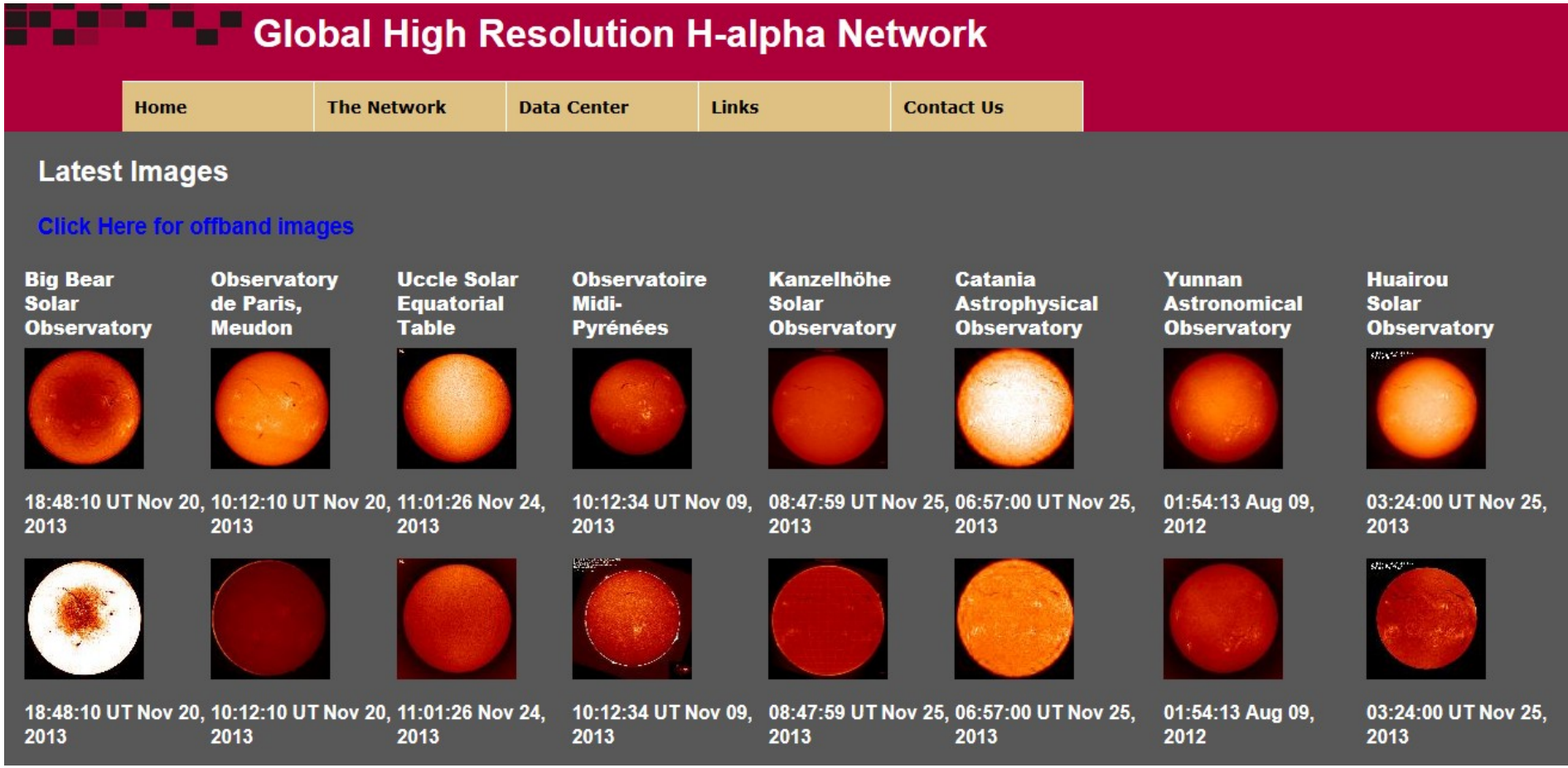
- SOON/ISOON: visual, WL, H-alpha, 5 stations, NSO-USAF (USA)
- GONG: helioseismology, magnetograms, WL, H-alpha, 6 stations (NSO, USA)
- CHAIN:FMT: WL, H-alpha (core-wings), 2 stations + 2 (Hida, Japan)
- GHN, Global H-alpha High-Resolution Network: informal portal (NJIT, USA)



Some current issues

- Lack of coordination between national programs/observatories (non-uniform/ duplicate data).
- No critical evaluation (what do we need to observe, what is missing etc).
- Lack of long-term planning (not well-defined goals, diminishing funding, aging facilities).
- Data preservation...

- Lack of coordination - “Everybody observes H-alpha” syndrome
- No uniformity in instrumentation and data reduction



Observatory	BBSO	KANZELHÖHE	CATANIA	MEUDON	Uccle	Pic du Midi	YUNNAN	HUAIROU
Time zone	UTC-8	UTC+1	UTC+1	UTC+1	UTC+1	UTC+1	UTC+8	UTC+8
APT	10 cm	10 cm	15 cm	25 cm	8 cm	9 cm	18 cm	14 cm
F/S	Filter	Filter	Filter	Spctrgrp	Filter	Filter	Filter	Filter
B-PASS	0.025nm	0.07nm	0.05/0.025 nm	0.025nm	0.05nm	<0.05nm	0.06nm	0.05 nm
Range	±0.3nm	±0.3nm	±0.1 nm	N/A	±0.25nm*	±0.05nm	±0.05nm	±3.2nm
CCD	2048x 2048	2048 x 2048	1360 x 1200	1500 x 1340	2048x 2048	2048x 2048	2Kx2K	2Kx2K
Bits	12	12	16	14	12	16	8	8
Cadence				1/min – one image	15 min, 1/d, 20/ sec			10 min

Some current issues

- Lack of coordination between national programs/observatories (non-uniform/ duplicate data).
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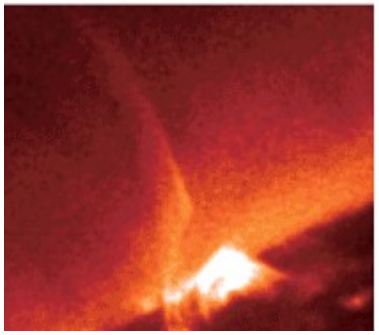
Should be "Define clear goals and revisit them on a regular basis?"

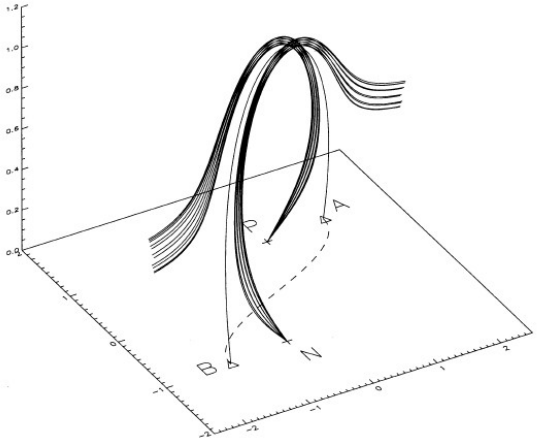
- Q: Understanding energy flow through solar atmosphere.
  - Importance: chromospheric/coronal heating, flares.

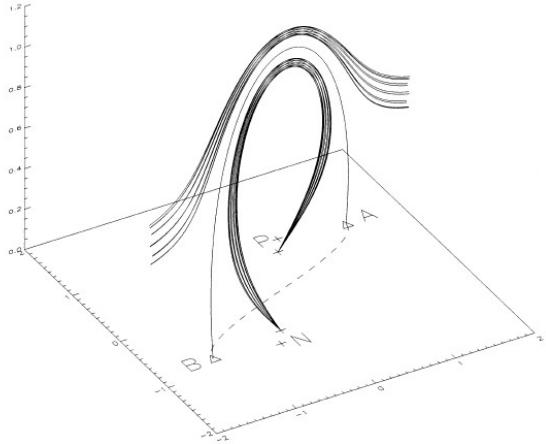
Small scale, rapid processes:
- **Jets, flare triggers**

Large-scale connectivity:
- **remote eruption triggering**



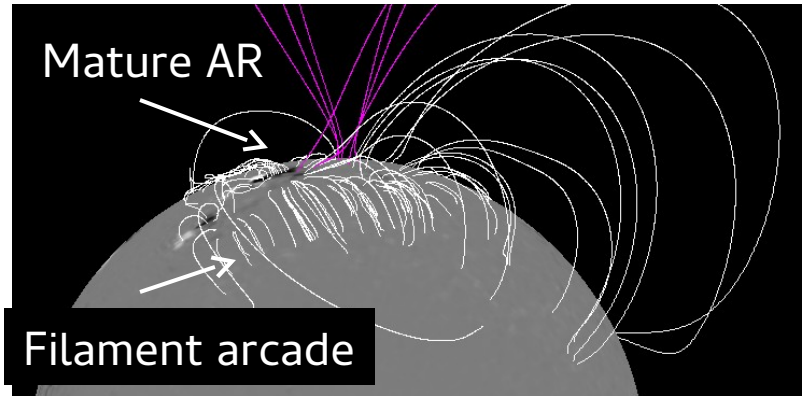
Cheung et al. 2014

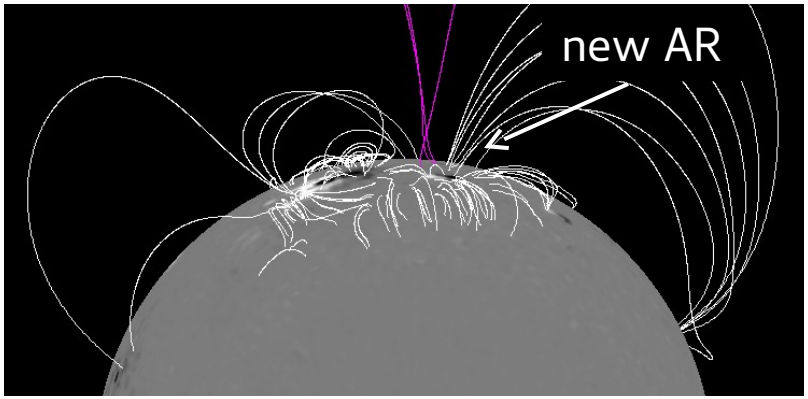




Longcope & Kankelborg (1999)

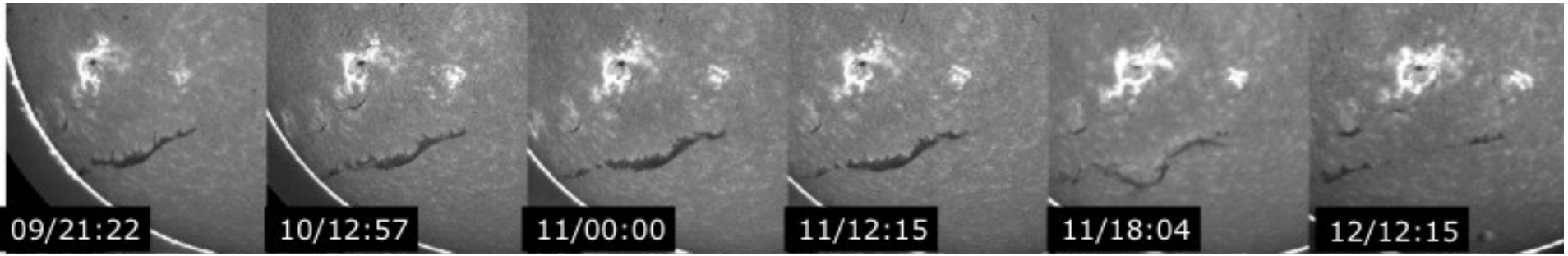
Large-scale connectivity





9 June 2003

11 June 2003



Magnetic field of emerging AR reconnects with mature AR, which in its turn, "steals" field lines from magnetic arcade above filament.

Historical Data Preservation

- H-alpha flare patrol data (~1955-2002)
- Sunspot drawings (1947-2004)
- Filament, plage drawings
- Historic photographs, slides (e.g., DST construction, telescopes, scientists).
- Spectroheliograms (H-alpha (on-/off band), CaK (on-/off band), $D_{3,}$ 1965-2002).
- White light patrol film (~1960-2002)
- "Green" corona (film, ~1954-mid-1970th?)
- H-alpha prominences (film, ~1950-mid-1970?)
- Coronal spectra (glass plates, 35-mm film ~1950-mid-1970?)
- One shot coronagraph (H-alpha disk and prominences (1970?-1990?, 4-inch film)
- (...)
- Other "stuff" (IR and UV spectra from Feb. 5, 1962 total eclipse, data on Exabyte, 9-track tapes, records from ATST (DKIST) sites survey, educational movies, flare spectra from DST, observing logs, official copy of Skylab spectra, etc).

Current developments/Future Plans

- SPRING: new network to replace GONG/SOLIS (aimed at multi-wavelength helioseismology and vector magnetography) – Markus Roth
- NAOJ and Nat. Obs. of Athens' plans (see posters by Hanaoka and Kontogiannis).
- Digitization of historical data (Sac Peak, BBSO, Kodaikanal, MWO, Baikal Astrophys. Observatory)
- IAU Working Group on Coordination of Synoptic Observations of the Sun

Develop requirements for data?

- Wavelength ranges
- Cadence, spatial and spectral resolution
- Derived parameters (magnetic field/vector or LOS), Doppler velocities?
- Which data are necessary/supplementary?

Affiliations with Inter-Division B-E WG

Coordination of Synoptic Observations of the Sun

CO-CHAIRS

Clette, Frederic Pevtsov, Alexei

NATIONAL SOLAR OBSERVATORY Kitt Peak Sacramento Peak DKIST NISP VSO

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IAU Inter-Division B and E Working Group

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IAU

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Inter-Division B and E WG on Coordination of Synoptic Observations of the Sun

The mission of this working group is to facilitate international collaboration in synoptic long-term solar observations, which includes past, current, and future synoptic programs, preservation, calibration, and access to synoptic solar data products. The working group provides a forum for discussion of all issues relevant to synoptic long-term observations of the Sun including (but not limited to) coordination between synoptic programs in different countries (both in respect to exchange of information and planning for future synoptic programs) and a proper calibration of historic data from different sources (e.g., sunspot drawings, CaK plage indices, magnetic field measurements etc).

Get Involved!

http://www.nso.edu/IAU-Com12

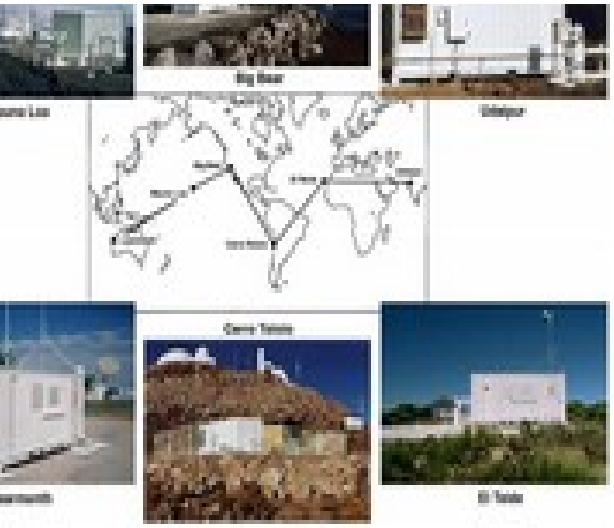
Other developments

- ILWS (2013) meeting encouraged creation of WGs on closer collaboration between space missions and groundbased observatories: Solar-Probe Plus – Ground Based Network working group (white paper in preparation)
- L5 mission (Carrington?); working group on groundbased observatories

NSO INTEGRATED SYNOPTIC PRO

NISP

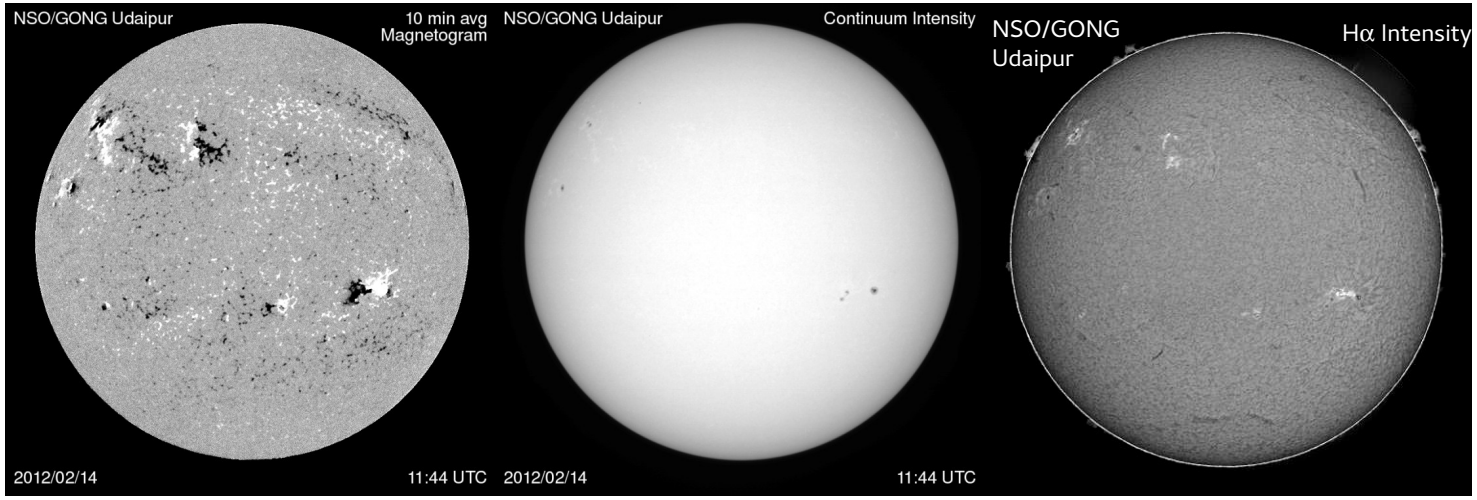
The NSO Integrated Synoptic Program (NISP) provides long-term synopt observations of the Sun to national and international solar and solar-terrestrial physics communities in support of scientific research and for operational forecast applications in the framework of space weather and climate. NISP operates a suite of instruments from the Global Oscillation



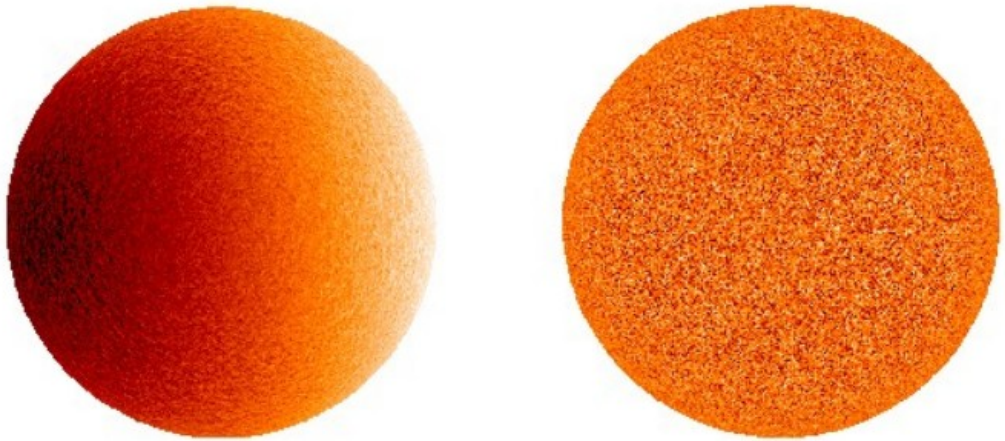
The GONG Network

SOLIS instrumentation on Kitt Peak

Basic Data from GONG



The above images are returned in near-real time and are available on the Internet



Dopplergrams for helioseismology. Left – full velocity field. Right – oscillatory velocity field

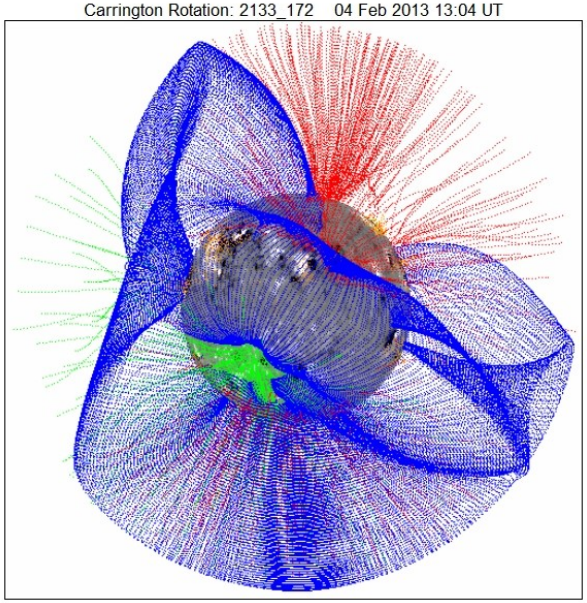
Space Weather Products from GONG

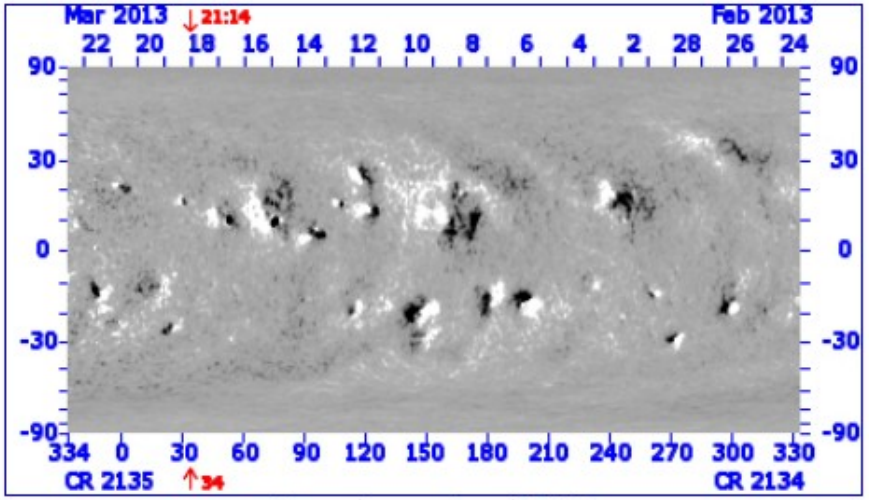
- Far-side helioseismic maps every 12 hours
  - Used by NOAA/SWPC
- Magnetic field
  - 10-min average & variance
  - Synoptic magnetic field map & PFSS coronal field extrapolation
  - Used by NOAA/SWPC for solar wind and geomagnetic storm forecasts
  - Used by NASA/CCMC
- H-α intensity every 20 sec around the clock
  - Used by US Air Force Weather Agency

Data products from SOLIS

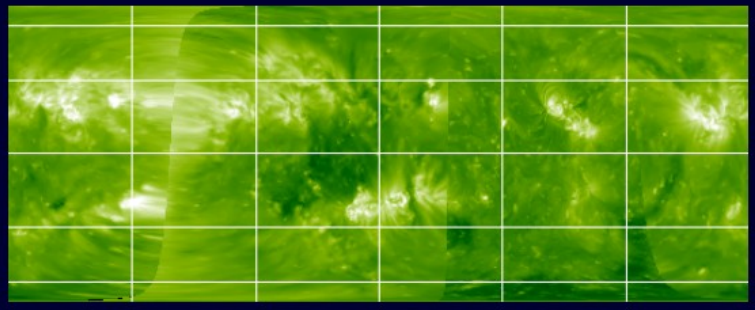
- Full disk LOS and vector magnetic field maps (photosphere and chromosphere); 1-2 per day
- Full disk narrow band images (H-alpha, He10830, …); 10 second cadence
- Sun-as-a-star spectra in 8 wavelength bands.

Carrington Rotation: 2133_172 04 Feb 2013 13:04 UT

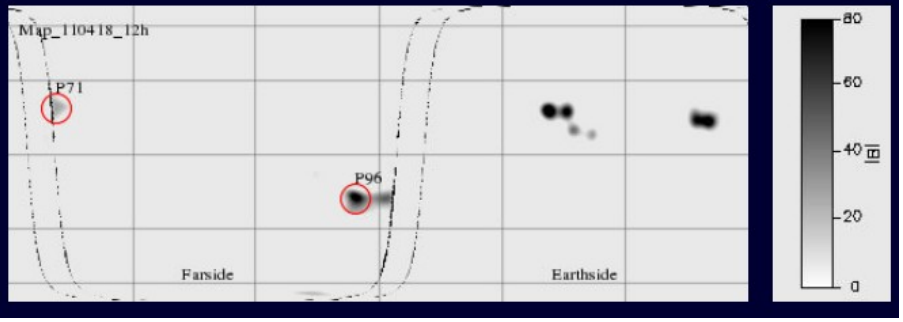




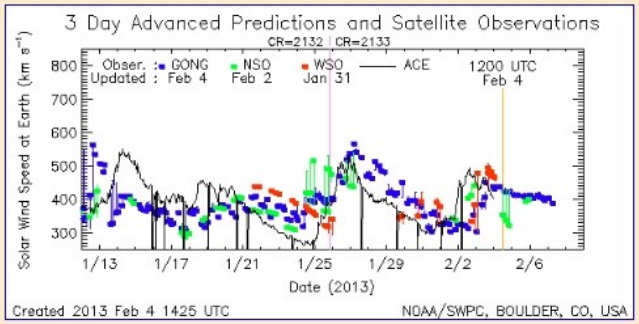
Magnetogram Count: 8991



EUVI image revised: Tuesday, 19-Apr-2011 17:05:32 EDT

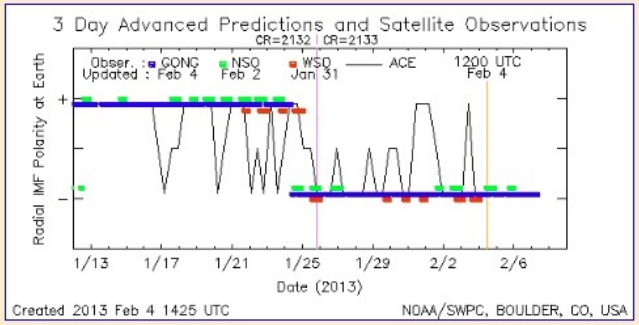


Predicted Solar Wind Speed at Earth



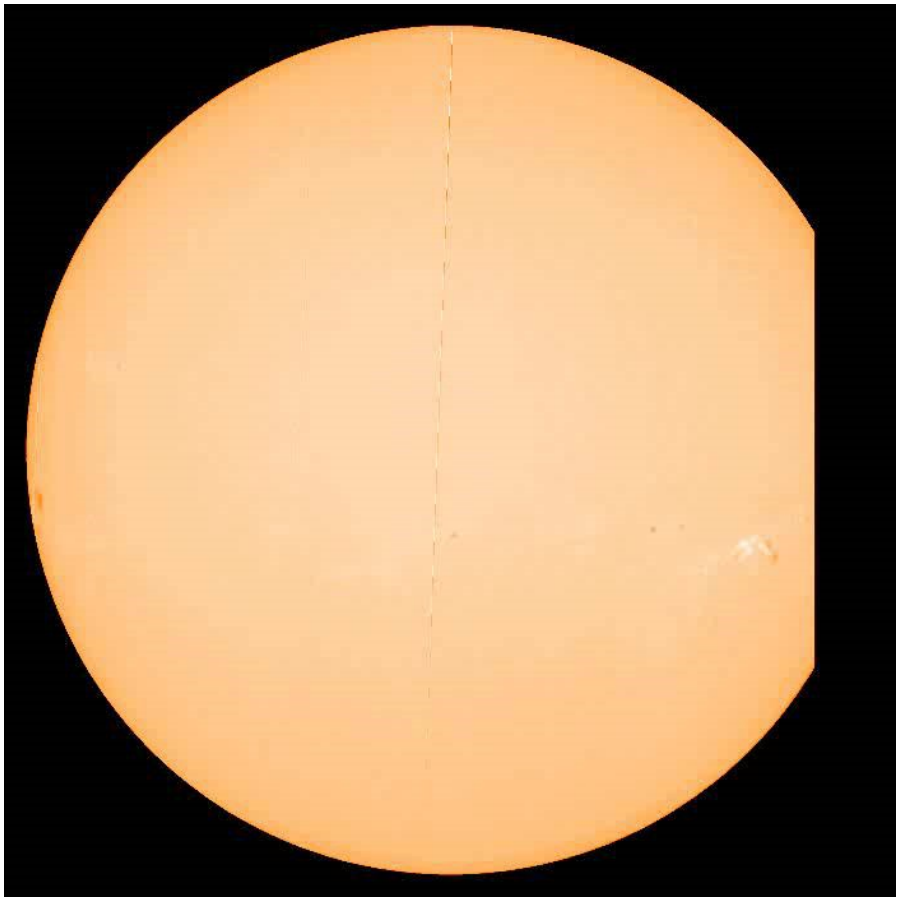
Click on plot to see last three rotations

Predicted Interplanetary Magnetic Field (IMF) Polarity at Earth



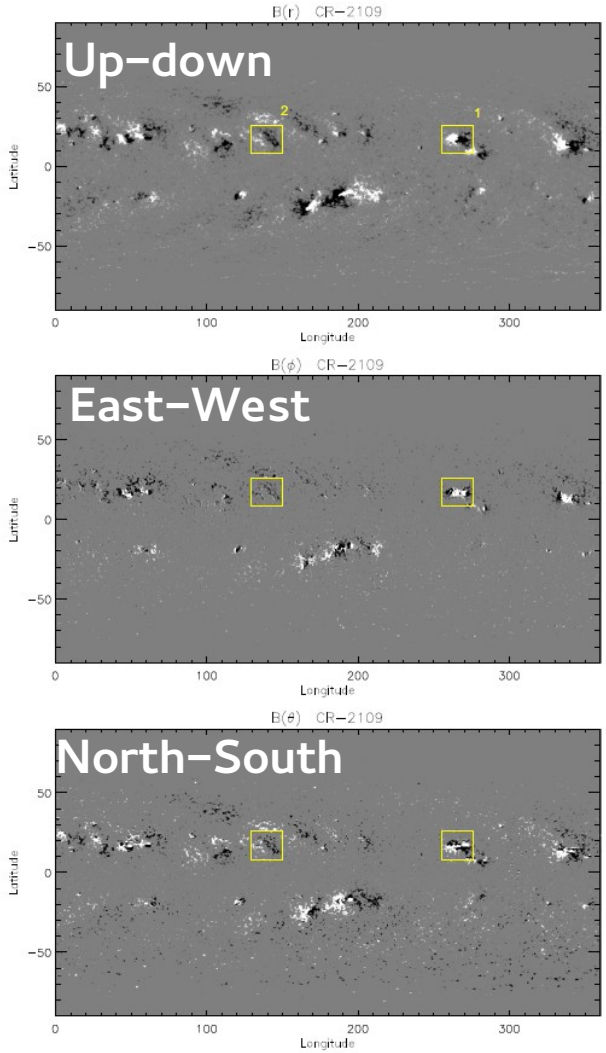
Solar Atmosphere in 3D

- Set of full-disk spectroscopic data in Ca II IR 854 nm taken with SOLIS
- About 2,000,000 profiles
- Time for inversion: about 1 week with a single job
  - SOLIS data are taken daily…
- "Flight" through solar atmosphere

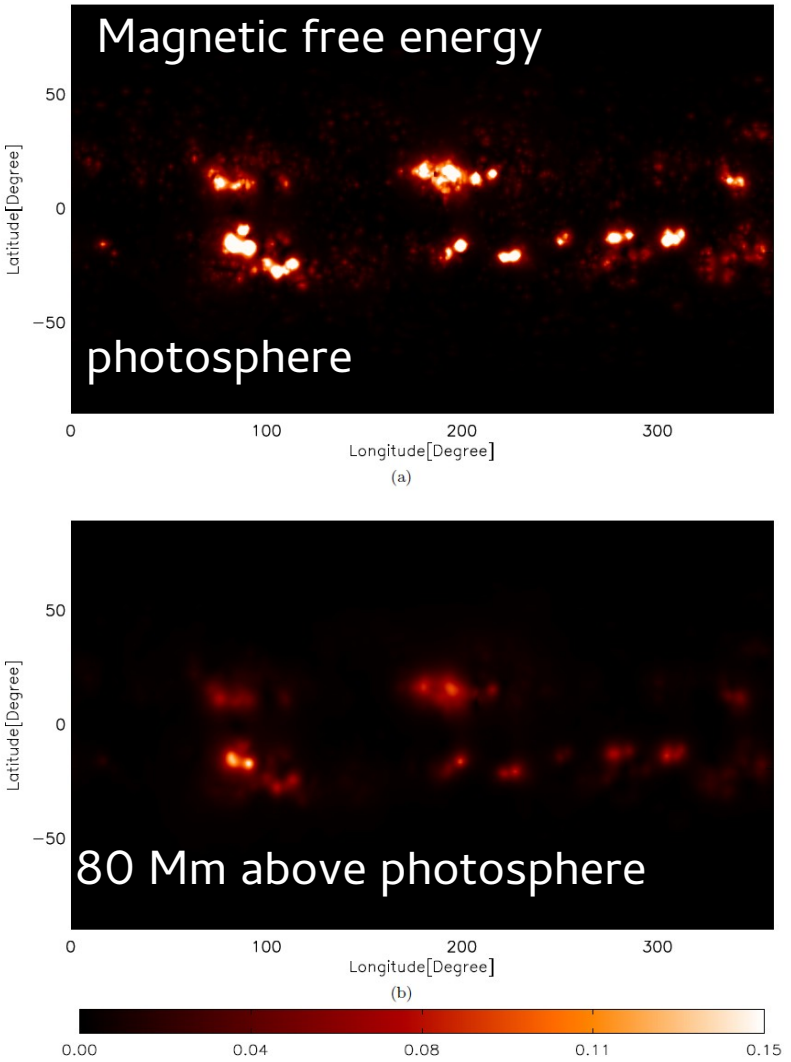


Beck et al in prep.

New synoptic data?

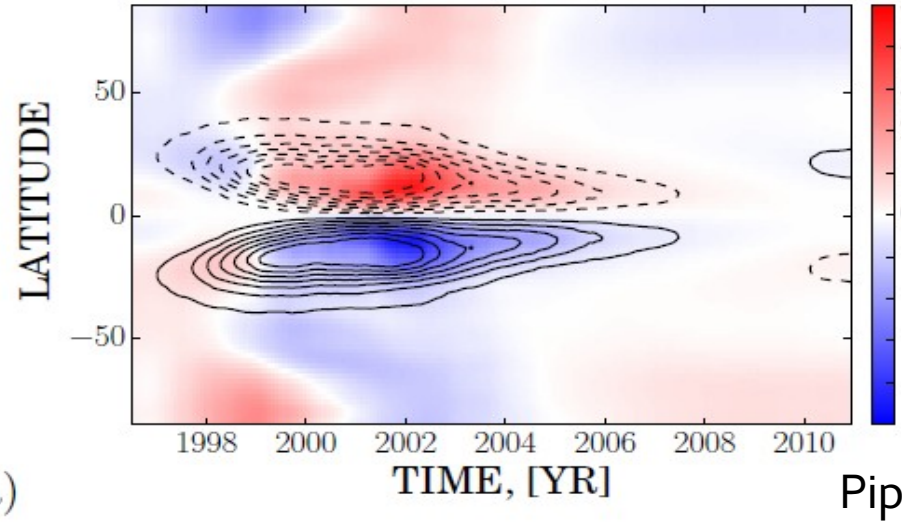


Gosain et al (2013)



Tadesse et al (2013)

Helicity?



Pipin & Pevtsov (2014)

Fig. 7.— The magnetic helicity density for the asymmetric (relative to solar equator) part of the large-scale magnetic field. The panel a) shows the $\bar{\mathcal{A}} \cdot \bar{\mathbf{B}}$ (background images) and the toroidal magnetic field (contours) for the radial field approximation;

$$\int \bar{\mathcal{A}}_\phi \bar{B}_\phi d\mu \approx \int \bar{\mathcal{A}}_r \bar{B}_r d\mu$$

$$\mathcal{H}_S = \int_{-1}^{1} (\bar{\mathcal{A}}_\phi \bar{B}_\phi + \bar{\mathcal{A}}_r \bar{B}_r) d\mu =$$

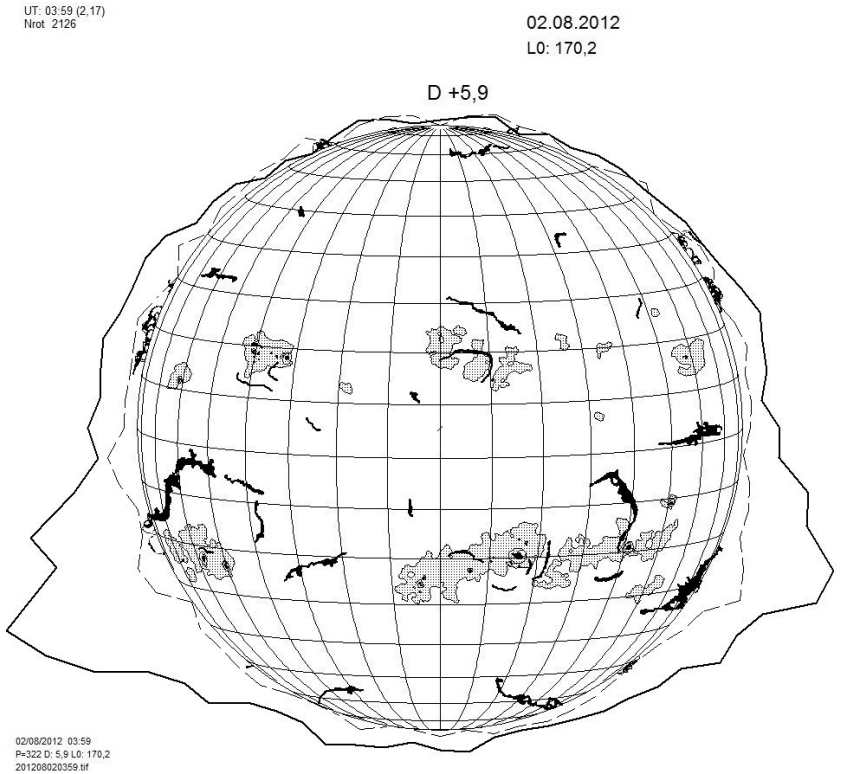
$$= 2 \int_{-1}^{1} \bar{\mathcal{A}}_\phi \bar{B}_\phi d\mu + \sin\theta \bar{\mathcal{A}}_r \bar{\mathcal{A}}_\phi \Big|_{-1}^{1}$$

0

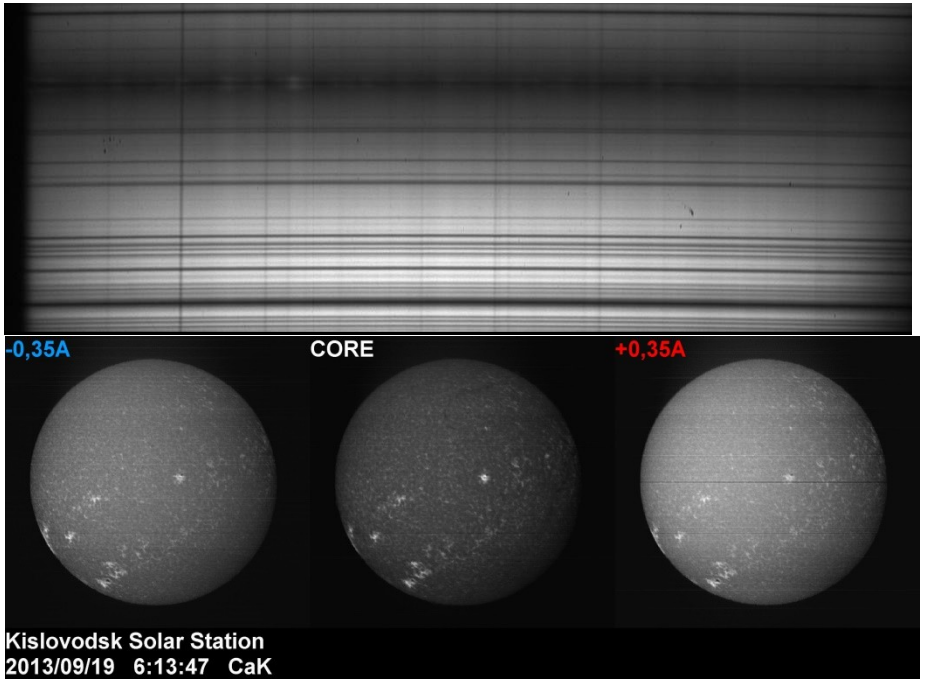
Kislovodsk Mountian astronomical station of Pulkovo observatory.

Founded in 1948 by M. Gnevyshev.

- H-alpha filaments and prominences (1960-present)
- Plages in CaIIK (from 1957-)
- Sunspots (from 1948-)
- Solar corona 5303 и 6374 (from 1953)
- Radio observations 5 и 3 cm.
- Sunspot field strengths 1960th – 1995.

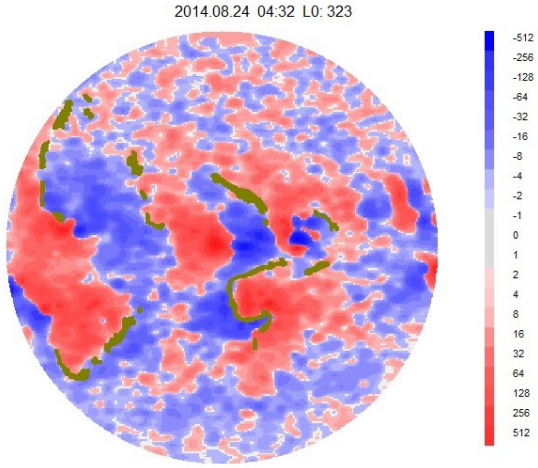


Programs under development: (1) new observing capabilities at permanent observatories (corona, large-scale magnetic fields) and (2) observing capabilities at university observatories

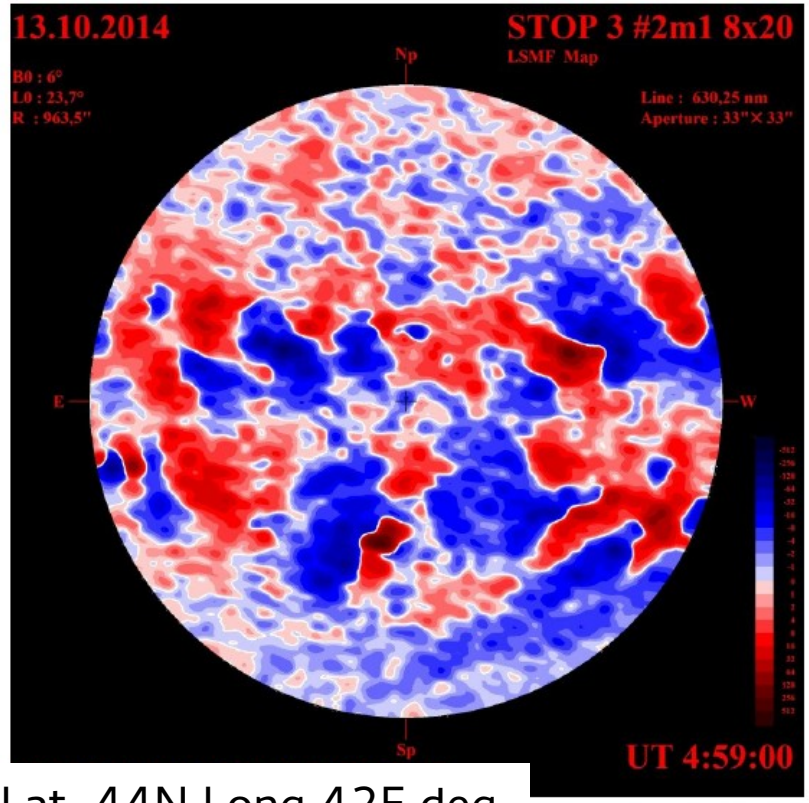


Development of a network of automatic telescopes/spectro-heliographs for universities for observing in H-alpha and Ca II K.

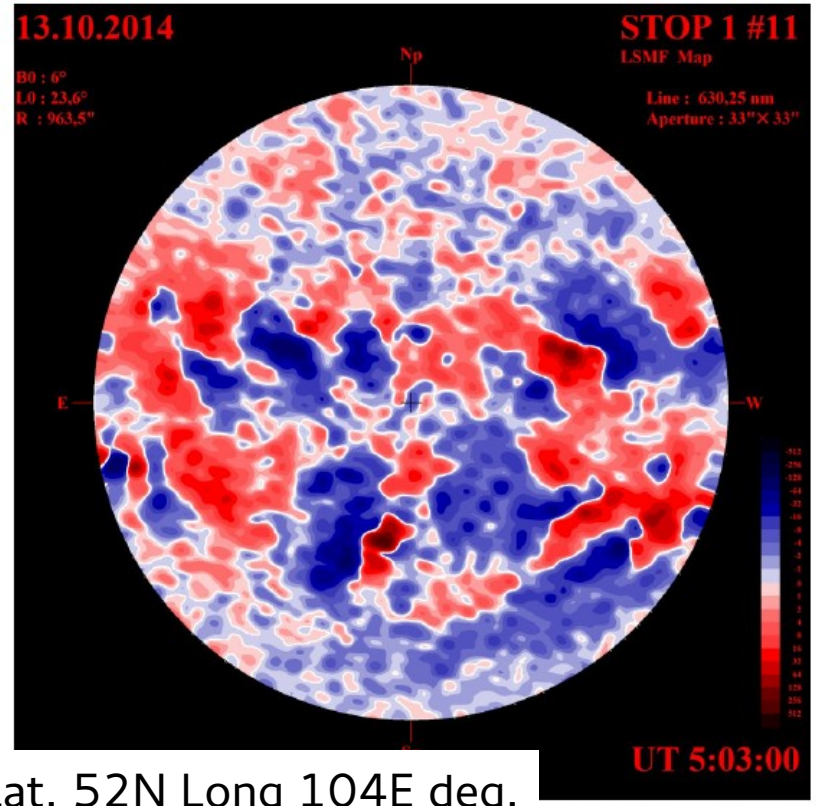
Programs under development: (1) new observing capabilities at permanent observatories (corona, large-scale magnetic fields) and (2) observing capabilities at university observatories



New full disk longitudinal magnetograph for observing large-scale magnetic fields and forecasting the of recurrent streams of solar wind.



Lat. 44N Long 42E deg.



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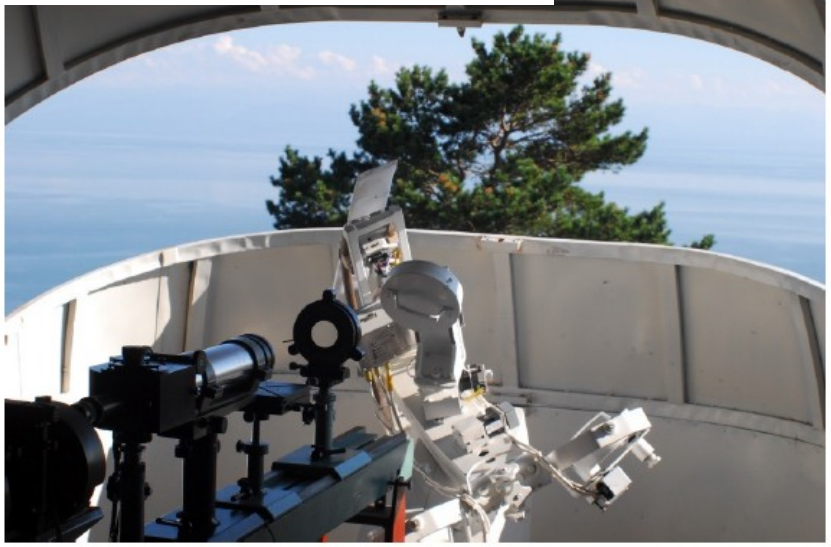
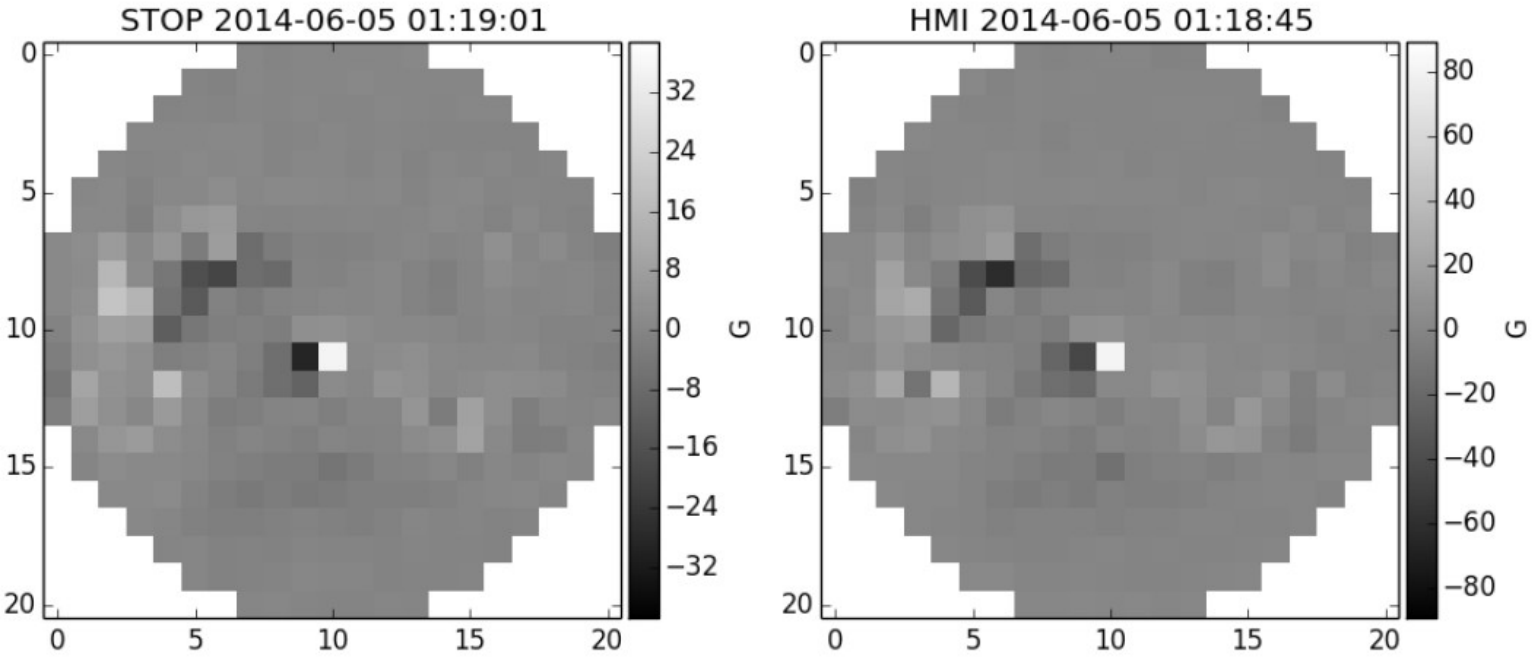
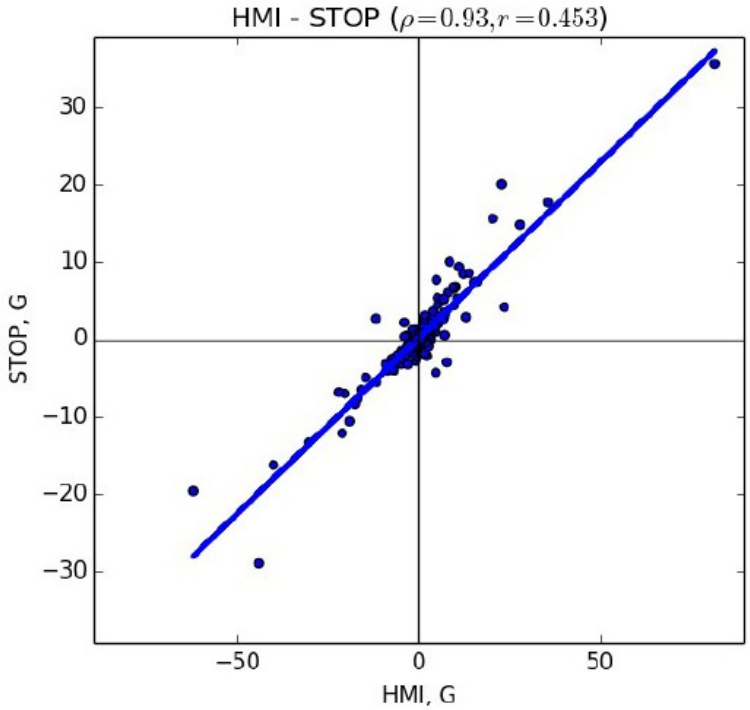






Institute of Solar-Terrestrial Physics, Irkutsk, Russia

Badary Solar Radio Observatory of ISTP
Siberian Radio Heliograph

http://ssw.iszf.irk.ru

1999-2013y

SSRT daily images - Windows Internet Explorer

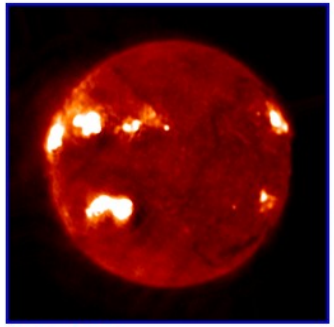
http://ssw.iszf.irk.ru/ssrt_daily/

Избранное | http://www.isprs.org/proce... | SSRT daily images | Страница | Безопасность | Сервис

Siberian Solar Radio Telescope

Daily images of the Sun

June 2011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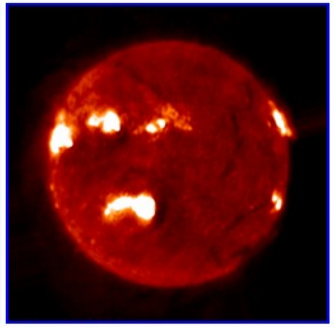
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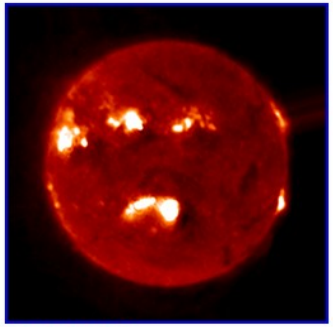
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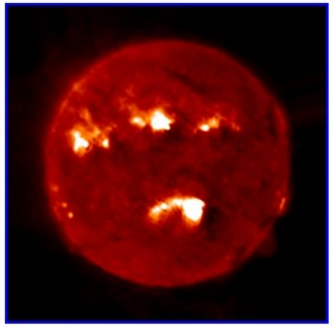
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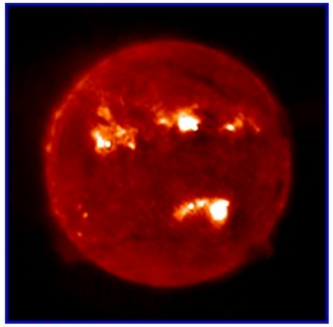
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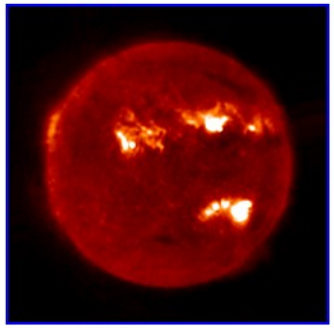
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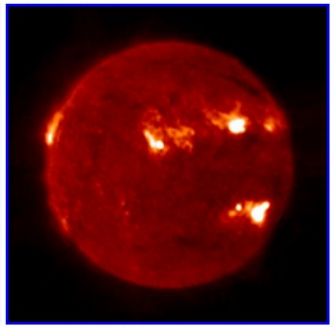
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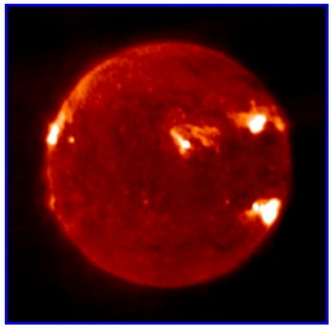
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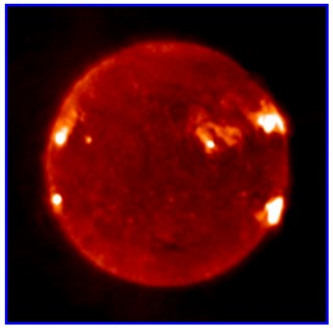
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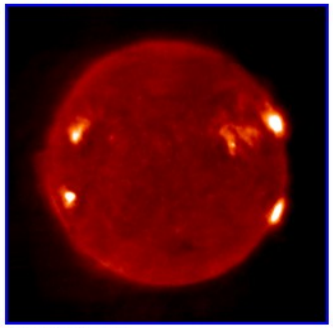
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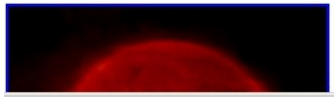

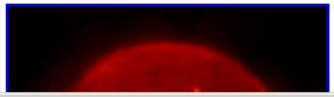

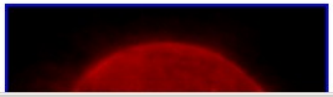

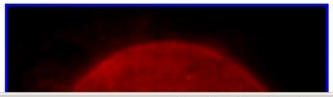

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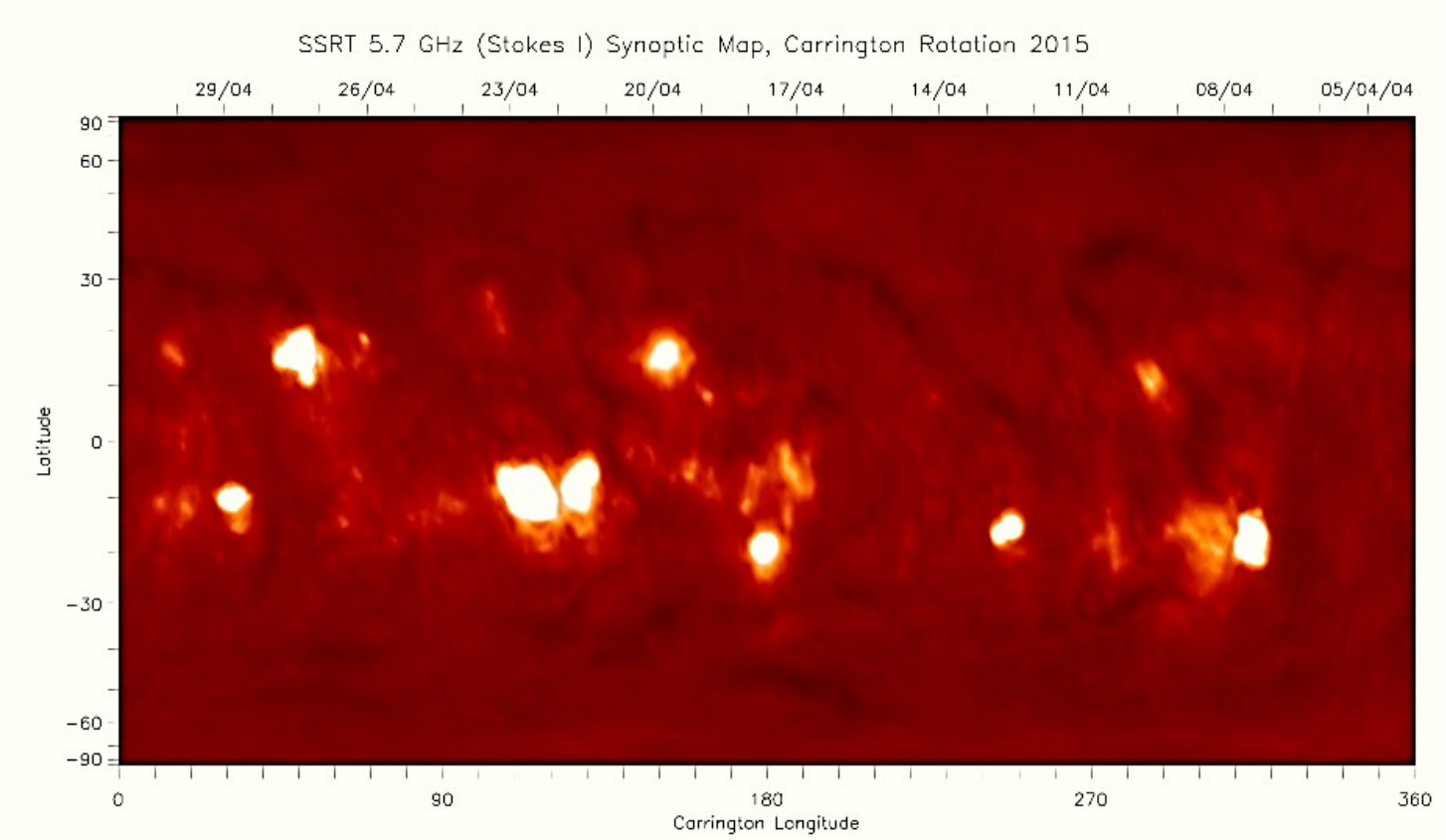
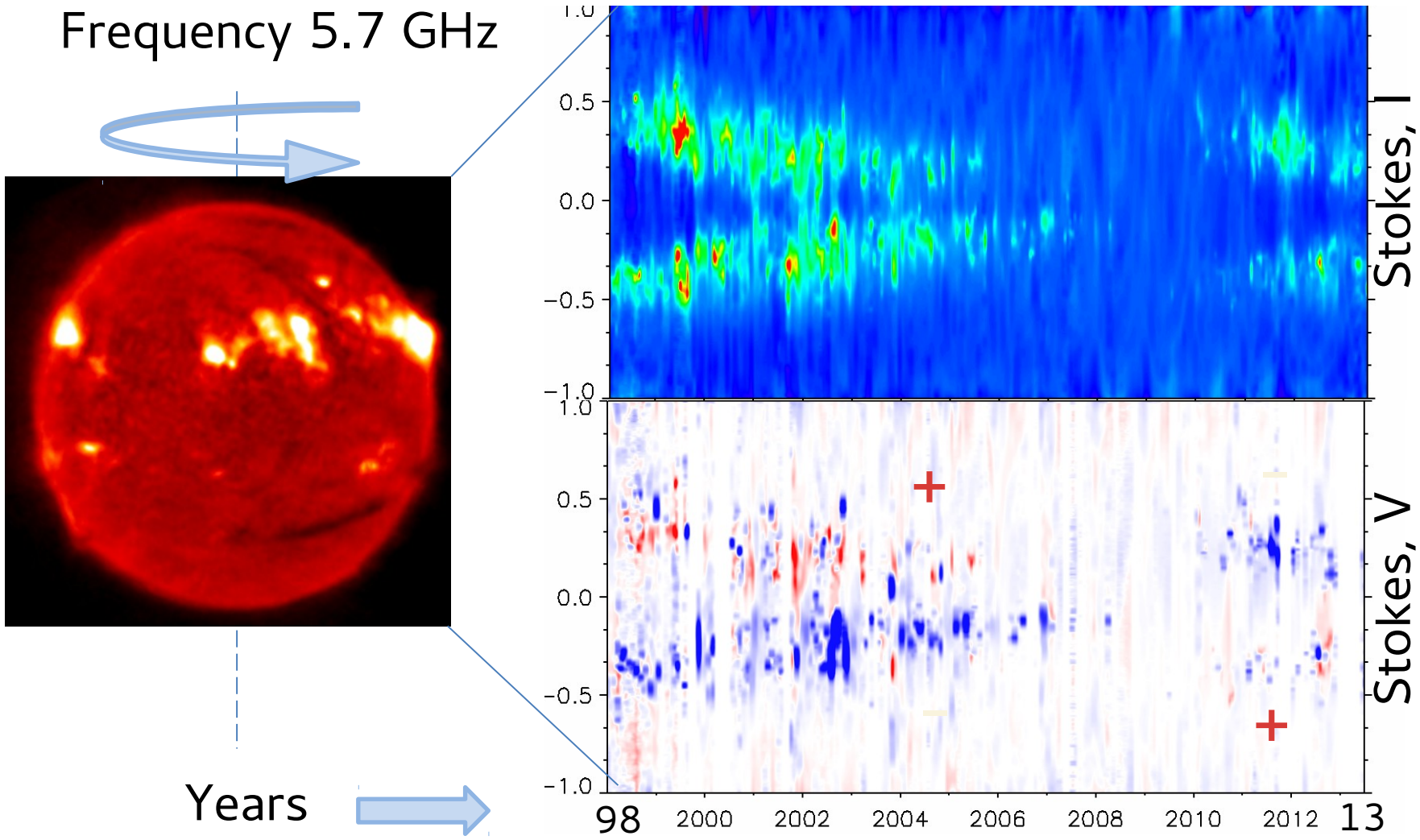
Synoptic Radio Observations at 5.7 GHz:

- ✓ Daily radio brightness distributions of the total intensity and the polarized emission are accumulated in our data base for the period of 1998-2013.
- ✓ Synoptic distributions for the Carrington rotations of the Sun are calculated.



- ✓ Global synoptic maps are obtained for the period of 1998-2013.

Long-term solar activity in microwaves



Summary

- Groundbased synoptic observations are necessary both for research and space weather forecast.
- It is necessary to develop close coordination between national synoptic programs/ observatories on the long-term goals, data requirements and data sharing.
- Strategy should be developed for historical data preservation and calibration.