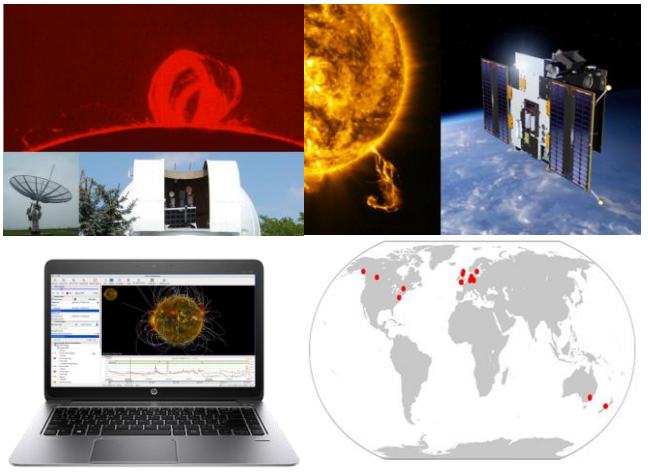
SPACE WEATHER INTRODUCTORY COURSE

Collaboration of

Solar-Terrestrial Centre of Excellence

Koninklijke luchtmacht

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu



Sensors & measurements

Jan Janssens, Dr Christophe Marqué

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H-alpha picture: https://www.windows2universe.org/spaceweather/ESF_loop.html (NSO/Sacramento Peak)

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    - Dourbes

- **Spacebased sensors**
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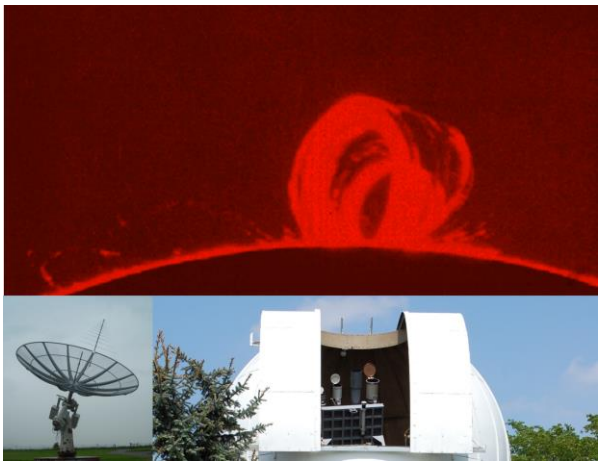
  - SDO
  - PROBA2
  - SOHO
  - ACE
  - DSCOVR
  - STEREO



Groundbased sensors

Jan Janssens, Dr Christophe Marqué

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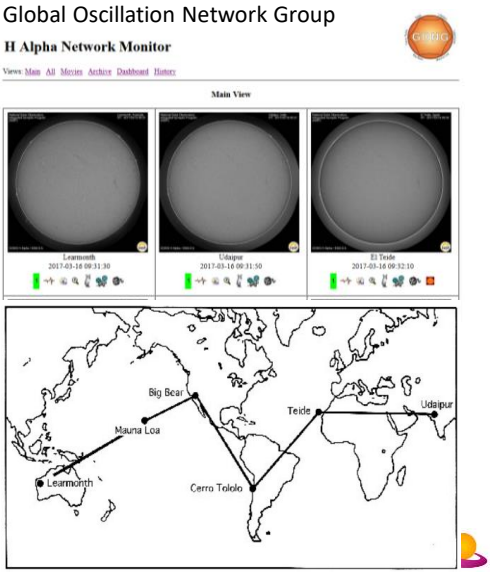
H-alpha picture: https://www.windows2universe.org/spaceweather/ESF_loop.html (NSO/Sacramento Peak)

Visible light

- GONG Network
  - White Light (WL)
  - H-alpha (Hα)
  - Magnetogram
- SILSO
  - Sunspot number (Sn)
  - USET
    - WL, Hα, CaIIK
    - 250 obs. days / year
- Catania
- NOAA / SOON



GONG: **Global Oscillation Network Group (http://gong.nso.edu/)**
Originally developed to study solar oscillations
6 observing stations worldwide observing the Sun 24/7
The six sites comprising the GONG Network are:
The Big Bear Solar Observatory in California, USA.
The High Altitude Observatory at Mauna Loa in Hawaii, USA.
The Learmonth Solar Observatory in Western Australia.
The Udaipur Solar Observatory in India.
The Observatorio del Teide in the Canary Islands.
The Cerro Tololo Interamerican Observatory in Chile.
Links
H-alpha: https://gong2.nso.edu/products/tableView/table.php?configFile=configs/hAlpha.cfg
White Light:
https://gong2.nso.edu/products/tableView/table.php?configFile=configs/averageIntensity10min.cfg
Magnetogram:
https://gong2.nso.edu/products/tableView/table.php?configFile=configs/averageMagnetogram10min.cfg

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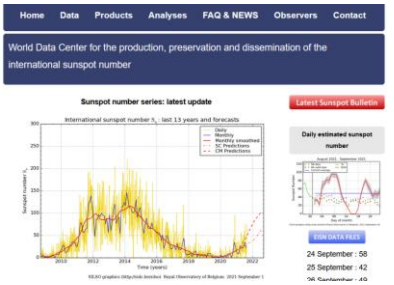

Links
SILSO: http://sidc.oma.be/silso/ (Sunspot Index and Long-term Solar Observations)
USET: http://www.sidc.be/uset/ (Uccle Solar Equatorial Table)
Catania: http://web.ct.astro.it/sun/draw.jpg

Catania and NOAA data are used as input for SIDC SWx forecasting

From the solar event listing at ftp://ftp.swpc.noaa.gov/pub/indices/events/README
Obs - The reporting observatory.
CUL - Culgoora, Australia
HOL - Holloman AFB, NM, USA
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SVI - San Vito, Italy
Events from GOES satellites data show the SWPC Primary or Secondary GOES spacecraft for the observatory, e.g. G12

SOON: https://en.wikipedia.org/wiki/Solar_Observing_Optical_Network
The SOON observatories are operated by detachments of AFWA's 2nd Weather Group at the following sites: RAAF Learmonth, Western Australia, Australia
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ISOON: http://nsosp.nso.edu/isoon
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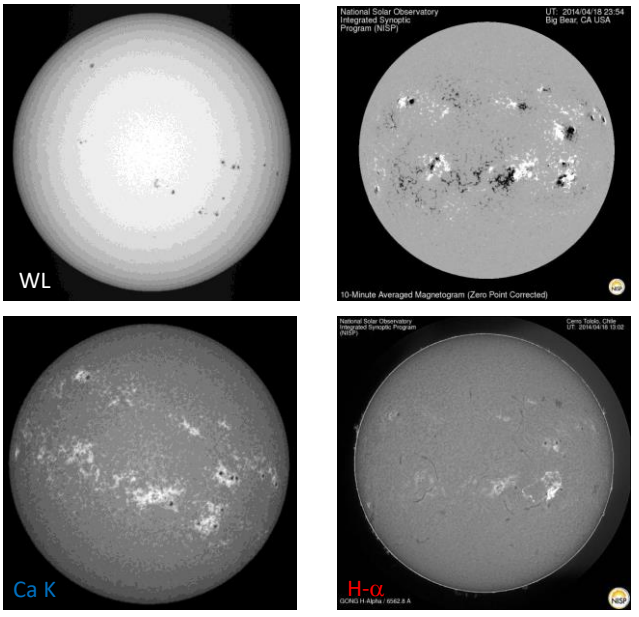
K-cor: http://download.hao.ucar.edu/d5/www/fullres/latest/latest.kcor.gif
Provides coronagraphic imagery. Large data gaps

Ground views from the Sun



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Links
USET: http://www.sidc.be/uset/ (Uccle Solar Equatorial Table)
NSO GONG Magnetograms:
https://gong2.nso.edu/products/tableView/table.php?configFile=configs/averageMagnetogram10min.cfg
NSO GONG H-alpha: http://halpha.nso.edu/

Top left: USET: white light (rotated)
Top right: GONG: magnetogram
Bottom right: GONG: H-alpha (Hydrogen alpha ; 656.3 nm)
Bottom left: USET: Ca K (Calcium K ; 393.4 nm) – (rotated)

White Light: sunspots
Magnetogram: magnetic properties of sunspot groups and whole disk
H-alpha: filaments/prominences, flares
Ca K: plages (solar radiation)

NOAA/SWPC glossary at https://www.swpc.noaa.gov/content/space-weather-glossary
Sunspot: An area seen as a dark spot, in contrast with its surroundings, on the photosphere of the Sun. Sunspots are concentrations of magnetic flux, typically occurring in bipolar clusters or groups. They appear dark because they are cooler than the surrounding photosphere. Larger and darker sunspots sometimes are surrounded (completely or partially) by penumbrae. The dark centers are umbrae. The smallest, immature spots are sometimes called pores.
Filaments/Prominences: A mass of gas suspended over the chromosphere by magnetic fields and seen as dark ribbons threaded over the solar disk. A filament on the limb of the Sun seen in emission against the dark sky is called a prominence.
Plages: A brighter, hotter patch in the Sun's chromosphere, visible in H-alpha light and the calcium K line. Plages are the chromospheric equivalent of faculae on the photosphere, as can be seen when an active region is near the limb. Faculae have a strong influence on the solar constant, and the more readily detectable (because chromospheric) plage areas traditionally are used to monitor this influence.

Also good explanations at NASA/MSFC: https://solarscience.msfc.nasa.gov/feature2.shtml and at
https://astronomyconnect.com/forums/articles/7-observing-the-sun-in-ca-k-ca-h-and-other-narrow-bandwidths.38/

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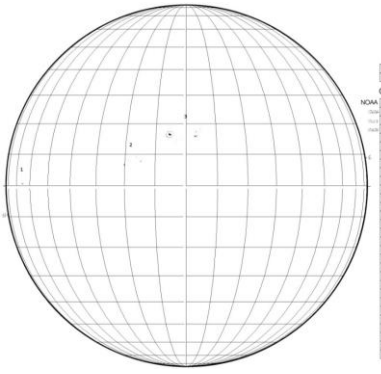

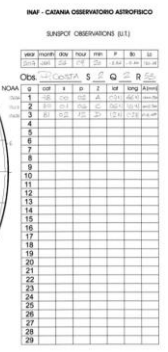

Catania info (Last update: 2017-Jan-24)						NOAA info (Last update: 2017-Jan-24)					Probabilities for			
Number	area	nspots	Zurich	Longitude	Latitude	Number	Macintosh	Mag. type	Longitude	Latitude	C flare	M flare	X flare	Proton
78	1	2	A	66.0	7.0	2626	Hsx	Alpha	63.0	8.0	--	--	--	--
80	3	7	C	16.0	6.0	2627	Dsi	Beta	12.0	6.0	--	--	--	--
81	19	14	D	-2.0	12.0	2628	Dso	Beta	-7.0	12.0	--	--	--	--

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Catania solar observations: http://ssa.oact.inaf.it/oact/index.html

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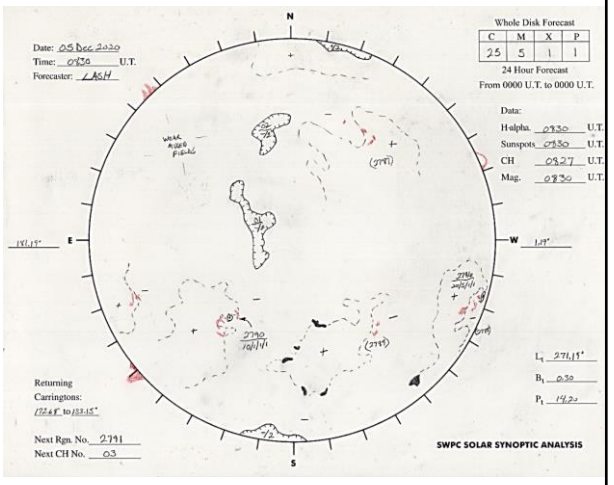

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Giersch et al. (2018) - Reanalysis of Solar Observing Optical Network Sunspot Areas
http://adsabs.harvard.edu/abs/2018SoPh..293..138G
SOON began operations in the mid-1970s with four sites (Holloman, New Mexico, USA; Ramey, Puerto Rico; Learmonth, Western Australia; and Palehua, Hawaii, USA) operating by 1980. In 1987, San Vito, Italy, became operational. … In 1996, the Palehua SOON equipment was returned to the National Solar Observatory at Sacramento Peak, New Mexico, to be used in the development of the Improved Solar Observing Optical Network (ISOON). However, **ISOON has never been deployed.** The Ramey site was closed in 2002. Thus, currently, there are only three SOON sites operating.

K-cor: http://download.hao.ucar.edu/d5/www/fullres/latest/latest.kcor.gif
Also at https://www2.hao.ucar.edu/cosmo/k-cor
Provides coronagraphic imagery. Large data gaps, limited time coverage during the day.

:Issued: 2014 Apr 17 1325 UTC
:Product: documentation at http://www.sidc.be/products/tot
#----------#
DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC
#----------#
SIDC URSIGRAM 40417
SIDC SOLAR BULLETIN 17 Apr 2014, 1304UT

SIDC FORECAST (valid from 1230UT, 17 Apr 2014 until 19 Apr 2014)
SOLAR FLARES : Active (M-class flares expected, probability >=50%)
GEOMAGNETISM : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet

PREDICTIONS FOR 17 Apr 2014 10CM FLUX: 180 / AP: 013
PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007
PREDICTIONS FOR 19 Apr 2014 10CM FLUX: 188 / AP: 005

Finding your way in the URSIgram

Catania & NOAA regions

COMMENT: Eleven sunspot groups were reported by NOAA today. NOAA ARs 2035,2036, and 2037 (Catania numbers 24, 25, and 26 respectively) maintain the beta-gamma configuration of the photospheric magnetic field. The strongest flare of the past 24 hours was the M1.0 flare peaking at 19:59 UT yesterday in the NOAA AR 2035 (Catania number 24). The flare was associated with an EIT wave and a weak coronal dimming, but the associated CME was narrow and is not expected to arrive at the Earth.
We expect further flaring activity on the C-level, especially in the NOAA ARs 2035 and 2037 (Catania numbers 24 and 26 respectively) as well as in the NOAA AR 2042 (no Catania number yet) that yesterday appeared from behind the east solar limb, with a good chance for an M-class event.

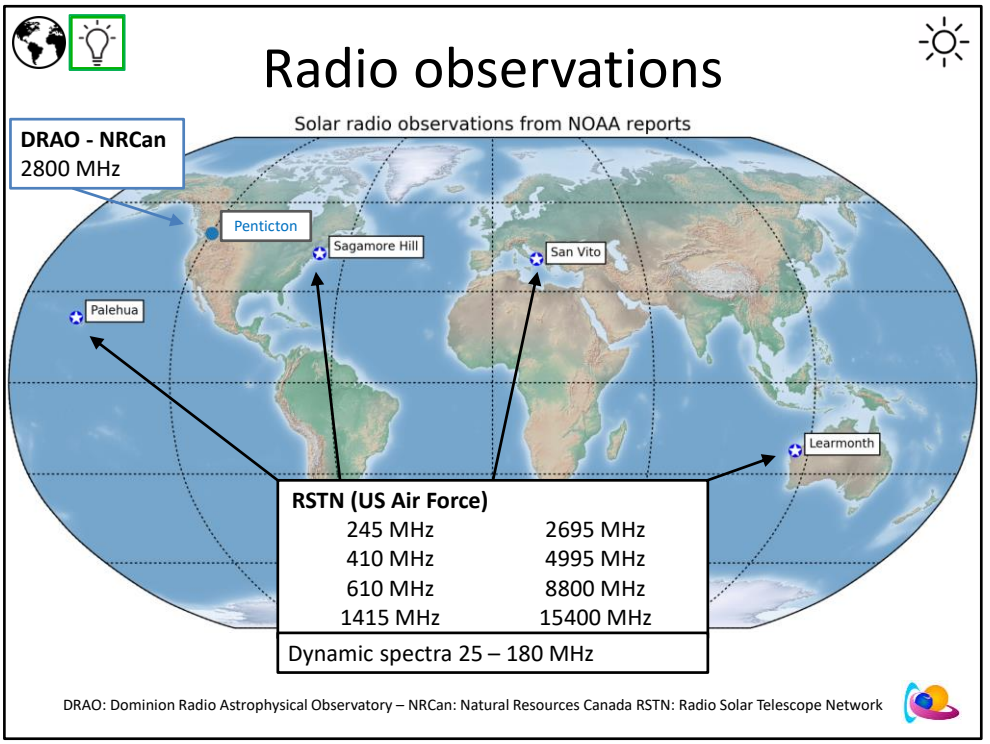
Since yesterday evening the Earth is situated inside a solar wind structure with an elevated interplanetary magnetic field magnitude (occasionally up to 10 nT). It may be a weak ICME or the compression region on the flank of an ICME that missed the Earth. The solar origin of this structure is not clear. The north-south magnetic field component Bz was not strong, so no significant geomagnetic disturbance resulted (K index stayed below 4). Currently the solar wind speed is around 380 km/s and the IMF magnitude is around 8 nT.
We expect quiet to unsettled (K index up to 3) geomagnetic conditions, with active geomagnetic conditions (K = 4) possible, but unlikely.

TODAY'S ESTIMATED ISN : 145, BASED ON 17 STATIONS.
99999

SOLAR INDICES FOR 16 Apr 2014
WOLF NUMBER CATANIA : ///
10CM SOLAR FLUX : 184
AK CHAMBON LA FORET : 012
AK WINGST : 004
ESTIMATED AP : 004
ESTIMATED ISN : 139, BASED ON 29 STATIONS.

Sunspot numbers

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2
END



The flux at 2800 MHz (10.7 cm) is measured since 1946-1947 in Canada. First in Ottawa, then in 1962 in Algonquin Radio observatory, 250 km away from Ottawa, and since 1990 in Penticton. This is the longest time series reflecting the solar activity besides the Sunspot Index (to which it highly correlates). More info in : K. F. Tapping, "The 10.7 cm solar radio flux (F10.7)", Space Weather, 11, 394, 2013

DRAO: Dominion Radio Astrophysical Observatory
(https://www.nrc-cnrc.gc.ca/eng/solutions/facilities/drao.html)

The Radio Solar Telescope Network (RSTN) started its operation during the 1970s and is operated by the US Air Force. It consists of an ensemble of flux monitoring instruments and a set of radio spectrometers. Data are not available in real time, but reports of events are provided through NOAA. Data become available for scientists several months (or years!) afterwards.

Radio flux expressed in solar flux units, with 1 sfu = 10^{-22} W m^{-2} Hz^{-1}

Radio burst magnitudes

Typ. Quiet Sun values [SFU]

Frequency	Solar min.	Solar max. (Z=200)
245 MHz	10	15
410 MHz	25	35
610 MHz	30	45
1415 MHz	50	100
2695 MHz	70	200
2800 MHz	70	200
4995 MHz	100	200
8800 MHz	220	290
15400 MHz	580	650

1 sfu = 1 solar flux unit = 10^{-22} W·m^{-2}·Hz^{-1}

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The left table reports typical values observed for the quiet Sun during minimum and maximum conditions. There can be lower and higher values but this is just to give an idea.

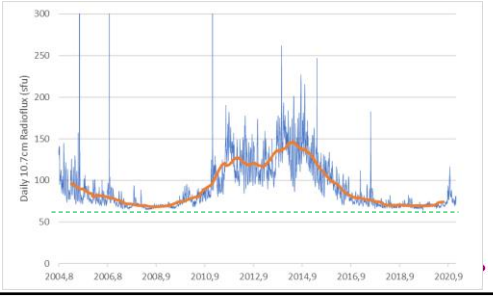
Values from the tables to the Right are derived from the paper by Nita et al. 2002. This gives in how many days on average a burst of a certain magnitude happens in each band. If we take a finer frequency band definition, the numbers can be different.

Nita et al., 2002
The Peak Flux Distribution of Solar Radio Bursts
http://adsabs.harvard.edu/abs/2002ApJ...570..423N

Daily radio fluxes (other wavelengths) at ftp://ftp.swpc.noaa.gov/pub/lists/radio/rad.txt

Penticton

- Flux measurement at 2800 MHz (10.7 cm), 100 MHz bandwidth
- 3 times per day
- “official” value for the day is the one of 20:00 UT (local noon)
- Accuracy:
  - < 100 sfu: 1 sfu
  - > 100 sfu: 1% of flux
- Uncorrected for solar flares
- R-, S-, Q-component



Information from: K. F. Tapping, “The 10.7 cm solar radio flux (F10.7)”, Space Weather, 11, 394, 2013 http://adsabs.harvard.edu/abs/2013SpWea..11..394T

Daily 10.7cm solar radio fluxes from Penticton at https://www.spaceweather.ca/forecast-prevision/solar-solaire/solarflux/sx-en.php

Daily radio fluxes (other wavelengths) at ftp://ftp.swpc.noaa.gov/pub/lists/radio/rad.txt

Solar flux unit:
1 sfu = 10–22 W m–2 Hz–1

The Humain solar radio observatory efforts to develop 10.7cm radio flux measurements were halted after it became clear there was too much interference from Military instruments. http://www.sidc.be/humain/index.php

From Tapping (2013):
[7] The early measurements of solar centimetric emissions were made using relatively small antennas, having beams subtending solid angles larger than that subtended by the solar disk, so no determinations of the distribution of emission could be made on any routine basis. These spatially integrated emissions were categorized on the basis of their characteristic timescale of variation into three identifiable components: a rapidly varying or R component, comprising emissions varying over timescales in the second-minute range, perhaps as long as an hour. Slower variations were lumped into a slowly varying or S component. Extrapolation to zero activity suggested an underlying constant, base level, which became called the quiet sun, or Q component. The terms R and Q have fallen out of use, and these components are now known, respectively, as bursts and the quiet sun background emission. The slowly varying component originates primarily in active regions; its intensity is a measure of the overall level of solar magnetic activity and has a broad spectral peak at about 10 cm wavelength. The F10.7 values comprise contributions from the S component and the quiet sun background, and sometimes from radio bursts.

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SOLAR FLARES : Active (M-class flares expected, probability >=50%)
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PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007
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10CM SOLAR FLUX : 184
AK CHAMBON LA FORET : 012
AK WINGST : 004
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10.7cm Radio flux

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DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2
END

Humain: Solar instruments

- 6-m dish
- Automated operations, Sun tracking ~7h30 – 16h00 UT
- VHF antenna (piggy back)
- UHF antenna at focus

- VHF antenna (45 – 450 MHz)
  - Callisto receiver
  - ARCAS receiver
- UHF antenna (275 – 1495 MHz)
  - HSRS receiver

Data available in near realtime
http://sidc.be/humain

- VHF: Very High Frequency (30-300 MHz)
- UHF: Ultra High Frequency (300-3000 MHz)
- Callisto: Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory
- ARCAS: Augmented Resolution Callisto Spectrometer
- HSRS: Humain Solar Radio Spectrograph

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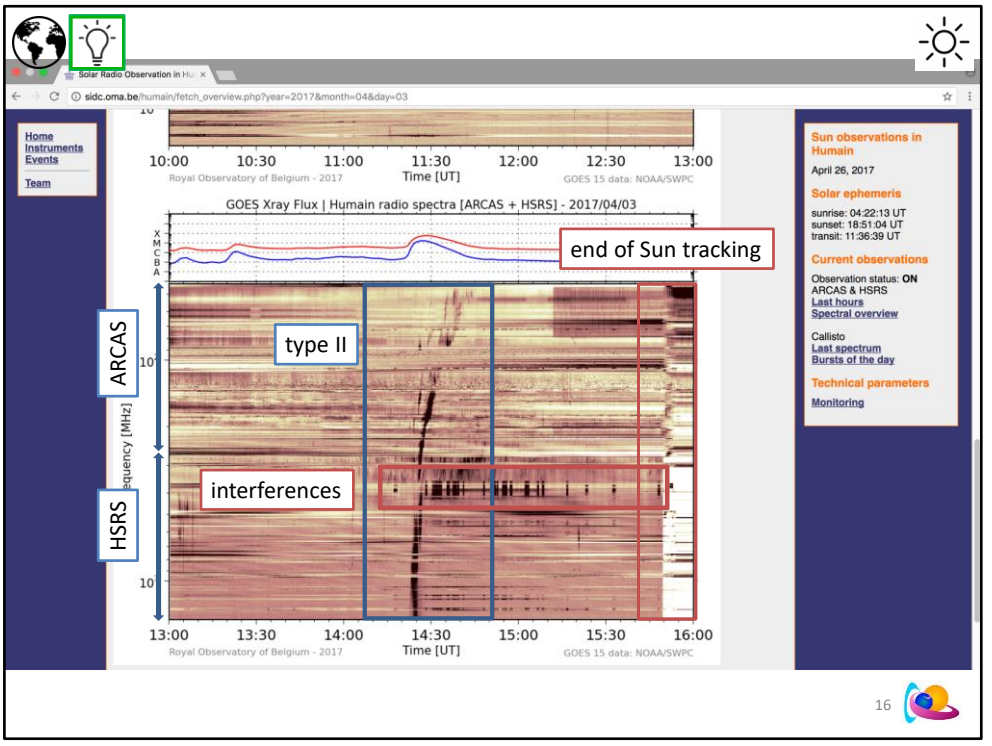
The ARCAS and HSRS receivers are based on commercial Software Defined Radio receivers. The RF signal is digitized and all operations needed to create the dynamic spectrum is made by programming on a control PC. The development of ARCAS and HSRS was made at ROB.

Callisto stands for: Compound Astronomical Low cost Low frequency Instrument for Spectroscopy and Transportable Observatory
ARCAS stands for Augmented Resolution Callisto Spectrometer - http://www.stce.be/news/369/welcome.html
HSRS stands for HUMAIN Solar Radio Spectrograph - http://www.stce.be/news/326/welcome.html

Real-time Humain radio spectra at http://www.sidc.be/humain/humain_spectra_realtime.php



See also the news item at http://www.stce.be/news/384/welcome.html for this event.

https://www.cv.nrao.edu/course/astr534/Introradastro.html
The Earth's ionosphere prevents ground-based observations at frequencies below 10 MHz (wavelengths higher than 30 m).

Back-ups for Radio spectra:
E-Callisto: http://www.e-callisto.org/Data/data.html
Learmonth: https://www.sws.bom.gov.au/Solar/3/2/1

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AK WINGST : 004
ESTIMATED AP : 004
ESTIMATED ISN : 139, BASED ON 29 STATIONS.

Radio bursts

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2
END

Magnetosphere - Ionosphere

Magnetosphere

- Magnetometers
- Neutron monitors
- …

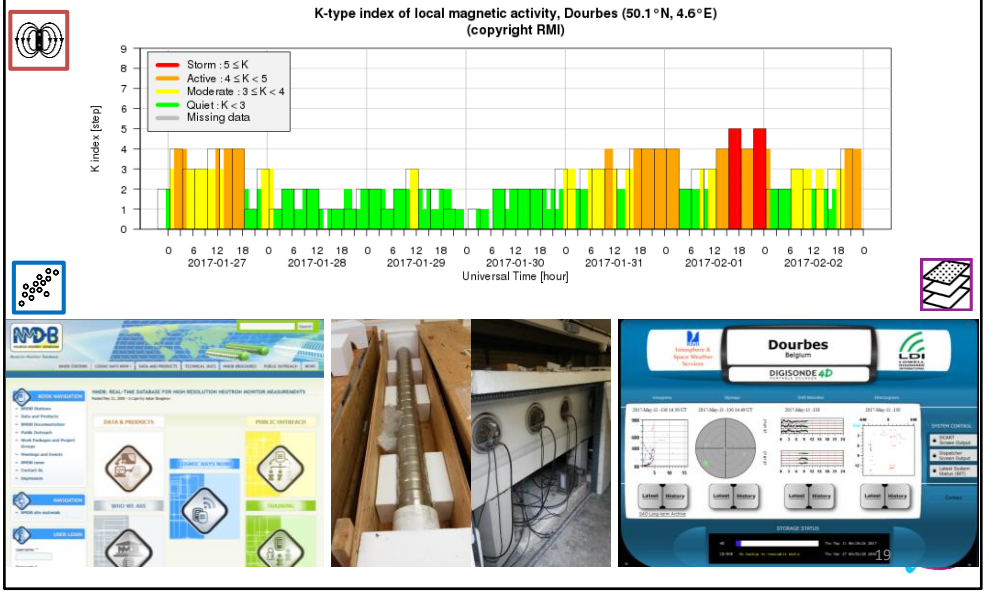
⇒ **Magnetosphere**
⇒ **SWx effects**

Ionosphere

- Ionospheric sounders
- Riometers
- …

⇒ **SWx effects – Aviation**
⇒ **Ionosphere**

Dourbes



Dourbes:
Geomagnetism: http://ionosphere.meteo.be/geomagnetism/ground_K_dourbes
Neutron monitor: http://www.nmdb.eu/
Ionosphere: http://digisonde.oma.be/

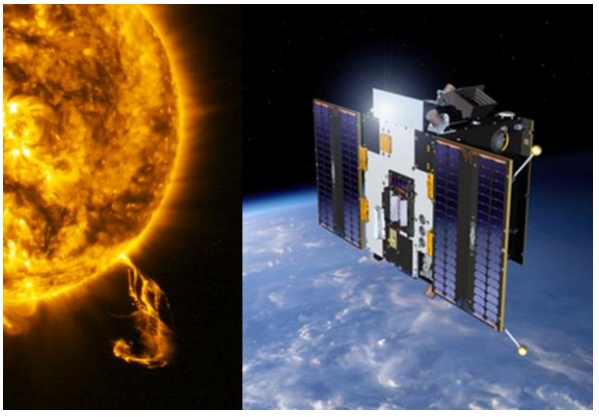
Exercise: 10.7cm Radio Flux

- It is 7 January 2014, and the solar cycle (SC24) is in its period of maximum solar activity. The 10.7cm radio flux at 18UT is reported to be 592.4 sfu. This is:
  - A typical value for the radio flux during SC max
  - A radio flux value affected by a strong solar flare

Contents

- **Groundbased sensors**
  - Visible light
  - Radio domain
    - Humain
  - Magnetosphere-Ionosphere
  - Geomagnetism
  - Neutron monitors
    - Dourbes

- **Spacebased sensors**
  - GOES
  - SDO
  - PROBA2
  - SOHO
  - ACE
  - DSCOVR
  - STEREO



Spacebased sensors

Jan Janssens

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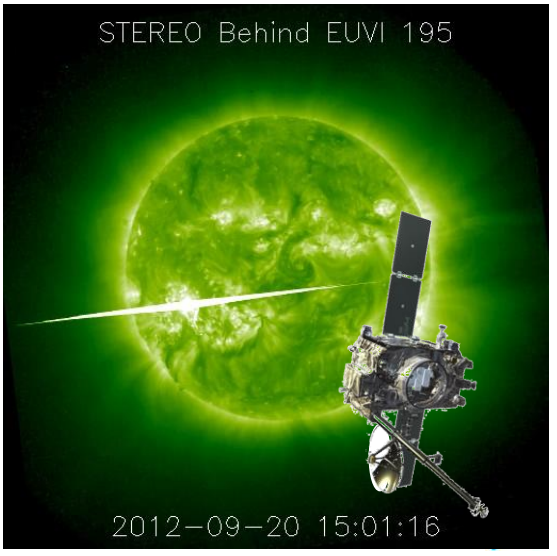
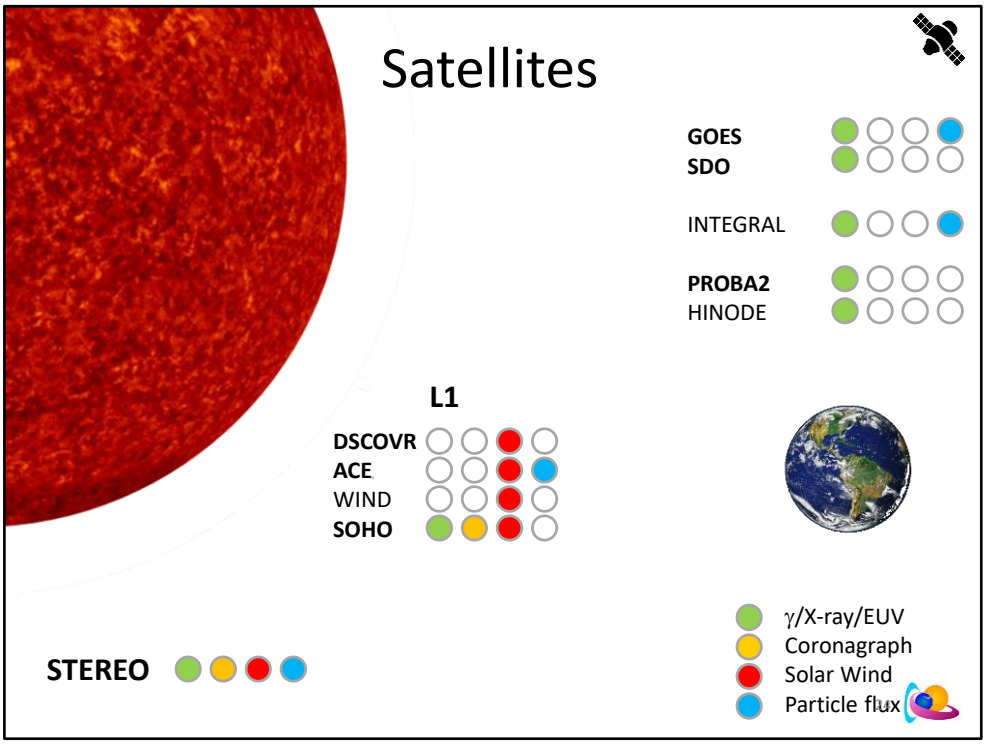
PROBA2 and picture of the Sun

Why do we need SWx satellites?

- EUV and X-ray (solar atmosphere)
  - Flares & Coronal holes
- Coronagraphs
- Solar wind (in-situ)
- Solar farside
  - 20 September 2012
  - 23 July 2012
  - …
- Radio
  - Triangulation
  - Low frequencies
- Science
- White light (24hrs)
- …



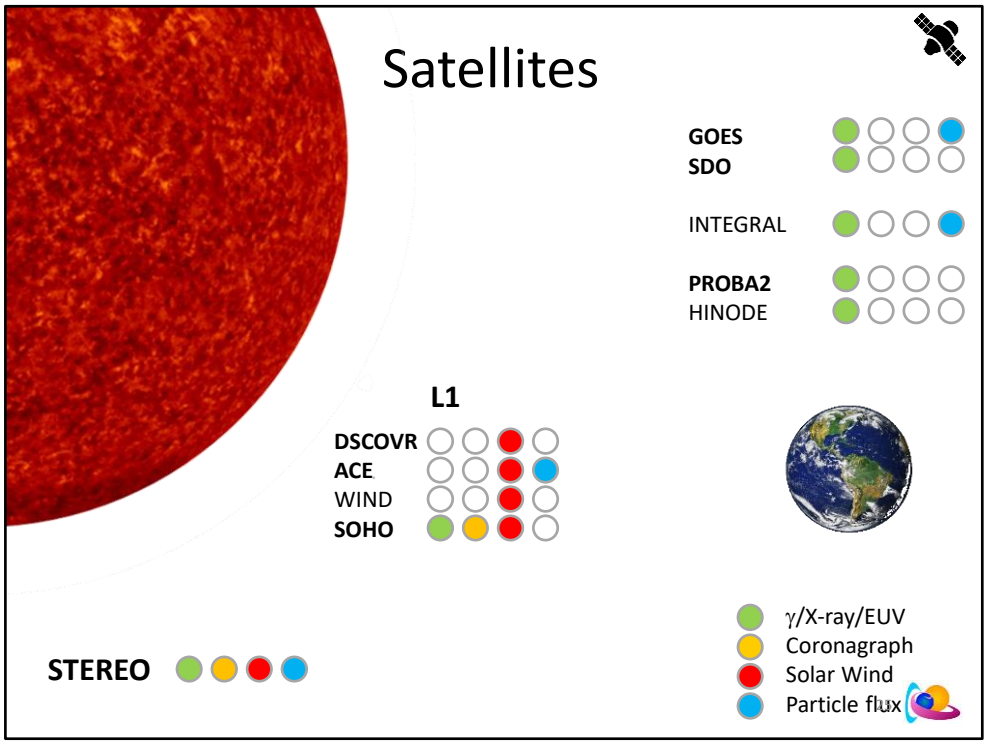
More on the 20 September 2012 flare at http://www.stce.be/news/263/welcome.html



Lagrangian points: https://en.wikipedia.org/wiki/Lagrangian_point

Earth orbits: https://en.wikipedia.org/wiki/List_of_orbits#Altitude_classifications_for_geocentric_orbits

* GEO: GOES, SDO (inclined)
Advantages and disadvantages of SDO in GEO at https://sdo.gsfc.nasa.gov/mission/project.php
Orbit
The rapid cadence and continuous coverage required for SDO observations led to placing the satellite into an inclined geosynchronous orbit. This allows for a nearly-continuous, high-data-rate, contact with a single, dedicated, ground station.
Nearly continuous observations of the Sun can be obtained from other orbits, such as low Earth orbit (LEO). If SDO were placed into an LEO it would be necessary to store large volumes of scientific data onboard until a downlink opportunity. The large data rate of SDO, along with the difficulties in managing a large on-board storage system, resulted in a requirement of continuous contact.
The disadvantages of this orbit include higher launch and orbit acquisition costs (relative to LEO) and eclipse (Earth shadow) seasons twice annually, During these 2-3 week eclipse periods, SDO will experience a daily interruption of solar observations. There will also be three lunar shadow events each year from this orbit.
This orbit is located on the outer reaches of the Earth's radiation belt where the radiation dose can be quite high. Additional shielding was added to the instruments and electronics to reduce the problems caused by exposure to radiation. Because this is a Space Weather effect, SDO is affected by the very processes it is designed to study!



Lagrangian points: https://en.wikipedia.org/wiki/Lagrangian_point

Earth orbits: https://en.wikipedia.org/wiki/List_of_orbits#Altitude_classifications_for_geocentric_orbits

* M/HEO: **INTEGRAL** (INTErnational Gamma-Ray Astrophysics Laboratory)
https://space-env.esa.int/srem-data-plotting/
SREM: Standard Radiation Environment Monitor
https://space-env.esa.int/r-and-d/instrumentation/srem/
Integral is the last remaining operational radiation monitor.

* LEO: PROBA2, HINODE, RHESSI, FERMI
Hinode: http://hinode.nao.ac.jp/gallery/latest/
XRT: X-Ray Telescope ; Also at https://www.solarmonitor.org/
~~**RHESSI**: Reuven Ramaty High Energy Solar Spectroscopic Imager~~
~~https://hesperia.gsfc.nasa.gov/rhessi3/~~ (retired)
PROBA2: PRoject for Onboard Autonomy
http://proba2.oma.be/ssa
FERMI: Fermi Gamma-ray Space Telescope
http://www.astronomerstelegram.org/?read=10720 (detections of solar gamma ray bursts)

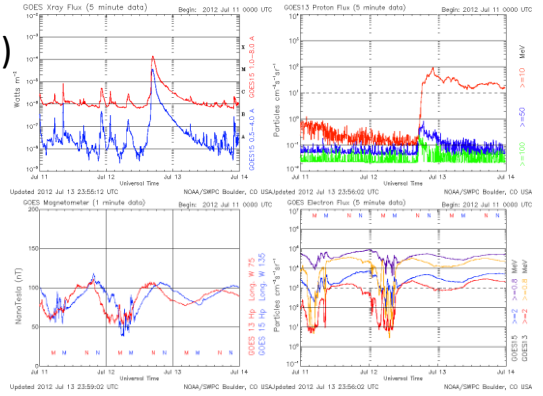
* L1: First Lagrangian point
DSCOVR, ACE, SOHO
Wind: https://pwg.gsfc.nasa.gov/windnrt/

* Solar orbit
STEREO

GOES

Geostationary Operational Environmental Satellite

- X-ray flux
  - X-ray Sensor (XRS)
- Proton flux
- Magnetic field
- Electron flux
- Imagery



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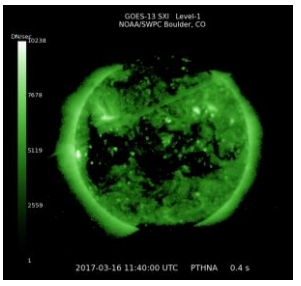
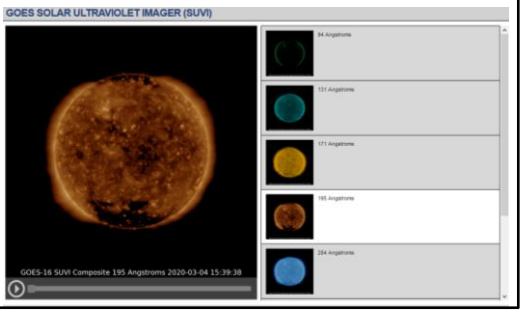
X-ray flux: https://www.swpc.noaa.gov/products/goes-x-ray-flux
More info at https://www.ngdc.noaa.gov/stp/satellite/goes/doc/GOES_XRS_readme.pdf
Proton flux: https://www.swpc.noaa.gov/products/goes-proton-flux
Magnetic field: https://www.swpc.noaa.gov/products/goes-magnetometer
Electron flux: https://www.swpc.noaa.gov/products/goes-electron-flux

GOES

Geostationary Operational Environmental Satellite

- X-ray flux
- Proton flux
- Magnetic field
- Electron flux
- Imagery
  - GOES-12-15
    - X-ray: SXI
      - Solar X-ray Imager
      - Discontinued
  - GOES-16-17
    - EUV: SUVI
      - Solar Ultraviolet Imager
      - Operational





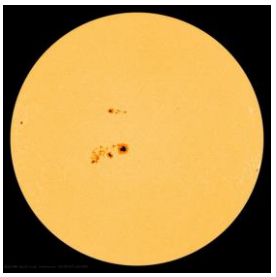
Imagery (X-ray): SXI: https://www.swpc.noaa.gov/products/goes-solar-x-ray-imager-sxi (discontinued)
SXI: Solar X-ray Imager
SUVI: https://www.swpc.noaa.gov/products/goes-solar-ultraviolet-imager-suvi

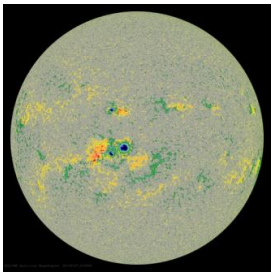
GOES-16/SUVI has been operationally checked out.
SUVI and 4 other instruments onboard GOES-16 have been put in safe mode as of 20 December 2017.
Entering operation in December 2019, becoming primary solar imager on 9 December 2019.
https://www.swpc.noaa.gov/news/noaanesdis-has-extended-operational-period-both-goes-1415-02-march-2020
https://www.swpc.noaa.gov/products/goes-solar-ultraviolet-imager-suvi
https://www.nesdis.noaa.gov/GOES-R-Series-Satellites

Imagery (SUVI): https://www.goes-r.gov/spacesegment/suvi.html
Solar UltraViolet Imager

SDO

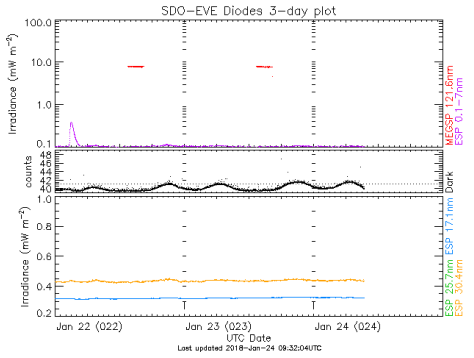
Solar Dynamics Observatory





< HMI

- Helioseismic and Magnetic Imager
- « White light » and Magnetograms



EVE ^

- Extreme ultraviolet Variability Experiment
- Scaled to GOES x-ray measurements

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ESP: EUV SpectroPhotometer
MEGS: multiple EUV grating spectrograph (-A no longer operational)
SAM: Solar Aspect Monitor (no longer operational)

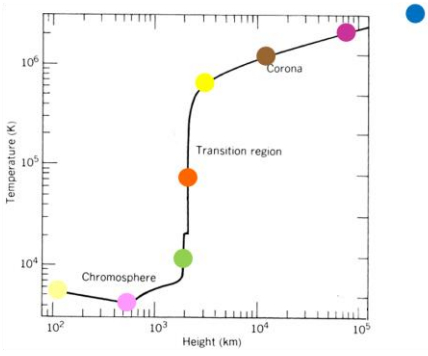
The EVE proxy for x-ray flux is at http://lasp.colorado.edu/eve/data_access/sdo-goes-eve-flare-watch/index.html
B9.5 flare on 22 January 2018
http://lasp.colorado.edu/eve/data_access/

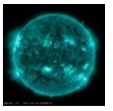
Crotser et al. (2004): SDO-EVE multiple EUV grating spectrograph (MEGS) optical design
http://adsabs.harvard.edu/abs/2004SPIE.5563..182C
The NASA Solar Dynamics Observatory (SDO), scheduled for launch in 2008, incorporates a suite of instruments including the EUV Variability Experiment (EVE). The EVE instrument package contains grating spectrographs used to measure the solar extreme ultraviolet (EUV) irradiance from 0.1 to 105 nm. The Multiple EUV Grating Spectrograph (MEGS) channels use concave reflection gratings to image solar spectra onto CCDs that are operated at -100°C. MEGS provides 0.1nm spectral resolution between 5-105nm every 10 seconds with an absolute accuracy of better than 25% over the SDO 5-year mission. MEGS-A utilizes a unique grazing-incidence, off-Rowland circle (RC) design to minimize angle of incidence at the detector while meeting high resolution requirements. MEGS-B utilizes a double-pass, cross-dispersed double-Rowland circle design. MEGS-P, a Ly-α monitor, will provide a proxy model calibration in the 60-105 nm range. Finally, the Solar Aspect Monitor (SAM) channel will provide continual pointing information for EVE as well as low-resolution X-ray images of the sun. In-flight calibrations for MEGS will be provided by the on-board EUV Spectrophotometer (ESP) in the 0.1-7nm and 17-37nm ranges, as well as from annual under-flight rocket experiments. We present the methodology used to develop the MEGS optical design.

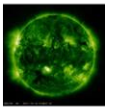
SDO

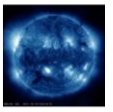
Solar Dynamics Observatory

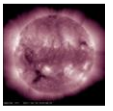
- AIA
  - Atmospheric Imaging Assembly
  - EUV imagery in 9 filters
  - Some filters peak at multiple temperatures
  - AIA 4500 no longer in use

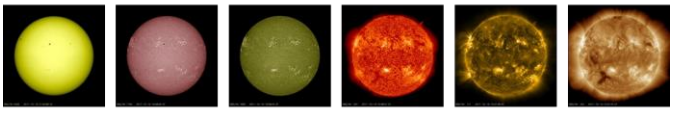












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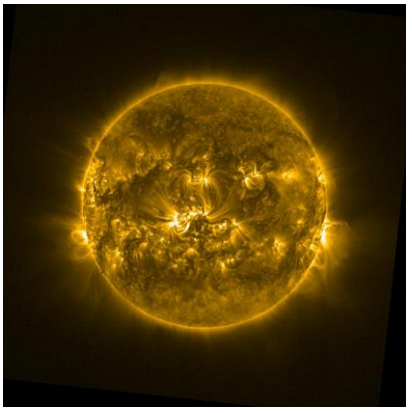
More info at http://aia.lmsal.com/public/instrument.htm
And at https://www.nasa.gov/content/goddard/how-sdo-sees-the-sun

PROBA2

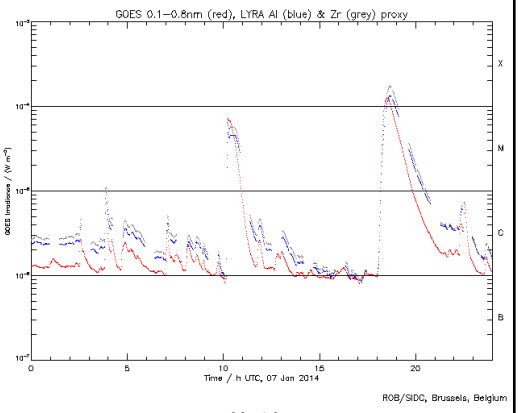
PRoject for OnBoard Autonomy

SWAP



Sun Watcher using APS detector and image Processing

LYRA



Large Yield RAdiometer

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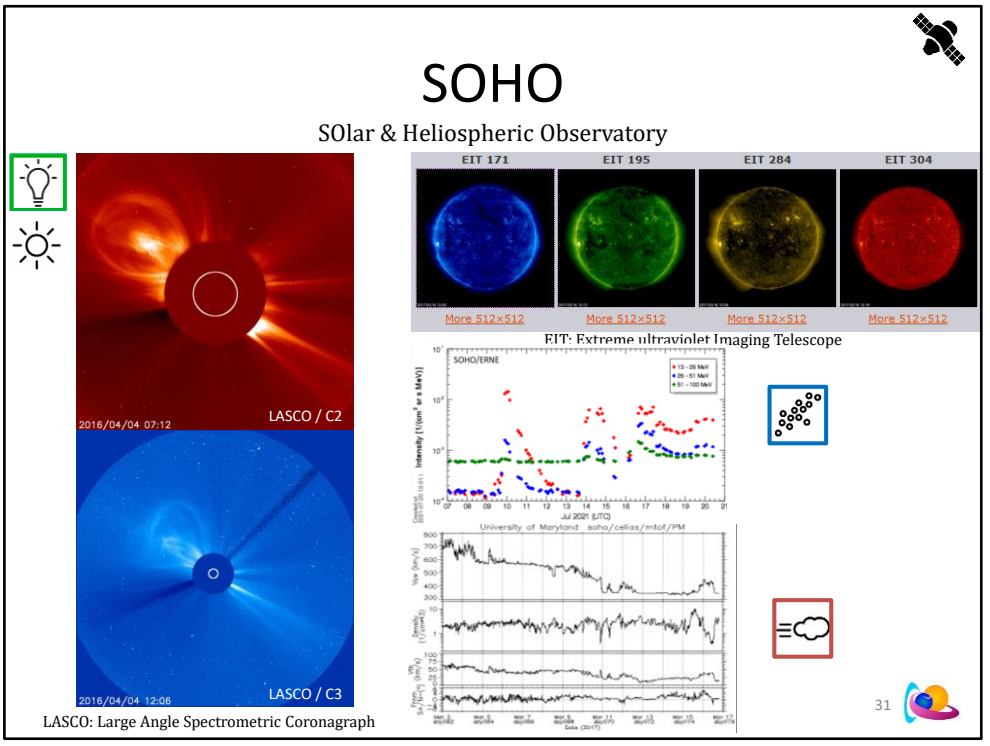
Data and imagery at https://proba2.sidc.be/ssa

From P2SC: http://p2web.oma.be/about/sciencePayload

LYRA (**L**arge **Y**ield **RA**diometer, formerly **LY**man alpha **RA**diometer) is an ultraviolet irradiance radiometer that observes the Sun in four passbands, chosen for their relevance to solar physics, aeronomy and space weather. This instrument can also detect flares and analyze the atmospheric composition of the Earth.

LYRA is composed of three units, each of them constituted of the same four channels:
•the 120-123 nm Lyman-α channel,
•the 190-222 nm Herzberg continuum channel,
•the Aluminium filter channel (17-80 nm + a contribution below 5 nm), including the strong He II at 30.4 nm
•the Zirconium filter channel (6-20 nm + a contribution below 2 nm), rejecting He II.

SWAP (**S**un **W**atcher using **A**ctive Pixel System detector and Image **P**rocessing) is a small EUV telescope that images the solar corona with a bandpass around 17.4 nm, corresponding to a temperature of 1 million degrees, with a cadence of 1 image per 1-2 minutes, and field of view (FOV) of 54 arcmin.. SWAP continues the systematic CME watch program of EIT at an improved cadence and monitors events in the lower solar corona that might be relevant for space weather.



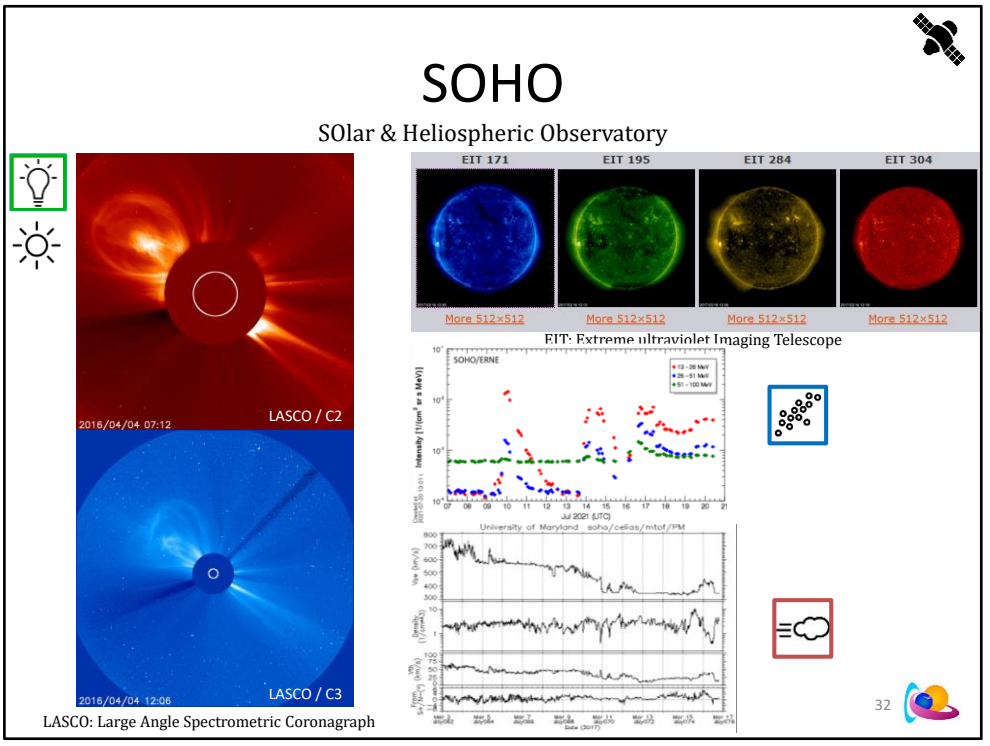
SOHO: Solar and Heliospheric Observatory
Launched on 2 December 1995 and still observing from the L1 point!

EIT and coronagraphic imagery at https://sohowww.nascom.nasa.gov/data/realtime-images.html
The passbands and related temperatures are similar to SDO/AIA, with the 28.4 nm filter corresponding to 2 million degrees.

Solar wind data (and shocks) at http://umtof.umd.edu/pm/

EIT: Extreme ultraviolet Imaging Telescope
CELIAS: Charge, Element, and Isotope Analysis System
MTOF: Mass Tome-of-Flight sensor
ERNE: Energetic and Relativistic Nuclei and Electron (https://srl.utu.fi/erne_data/)
LASCO: Large Angle and Spectrometric Coronagraph
http://star.mpae.gwdg.de/
- C2 (1.5-6 solar radii)
- C3 (outer: 3-32 solar radii)

The C1 (inner: 1.1-3 solar radii) is no longer operational following SOHO's summer holidays in 1998:
https://lasco-www.nrl.navy.mil/index.php?p=content/intro
LASCO comprises of three telescopes (C1, C2 and C3), each of which looks at an increasingly large area surrounding the Sun. For the first year-and-a-half of the SOHO mission, all three instruments worked perfectly. However, in 1998 SOHO was accidentally "lost" in space after it received a bad command. The entire spacecraft lost power and essentially froze solid for several weeks. Eventually -- miraculously! -- the SOHO team were able to relocate the spacecraft, regain control and slowly power-up and thaw out the instruments. Sadly, the LASCO C1 camera was lost as a result of this but the rest of spacecraft came through almost completely unscathed! Eighteen years later -- and over twenty years since launch -- LASCO C2 and C3 (and most of the rest of SOHO!) continue to work extremely well, sending back images and data on a daily basis.

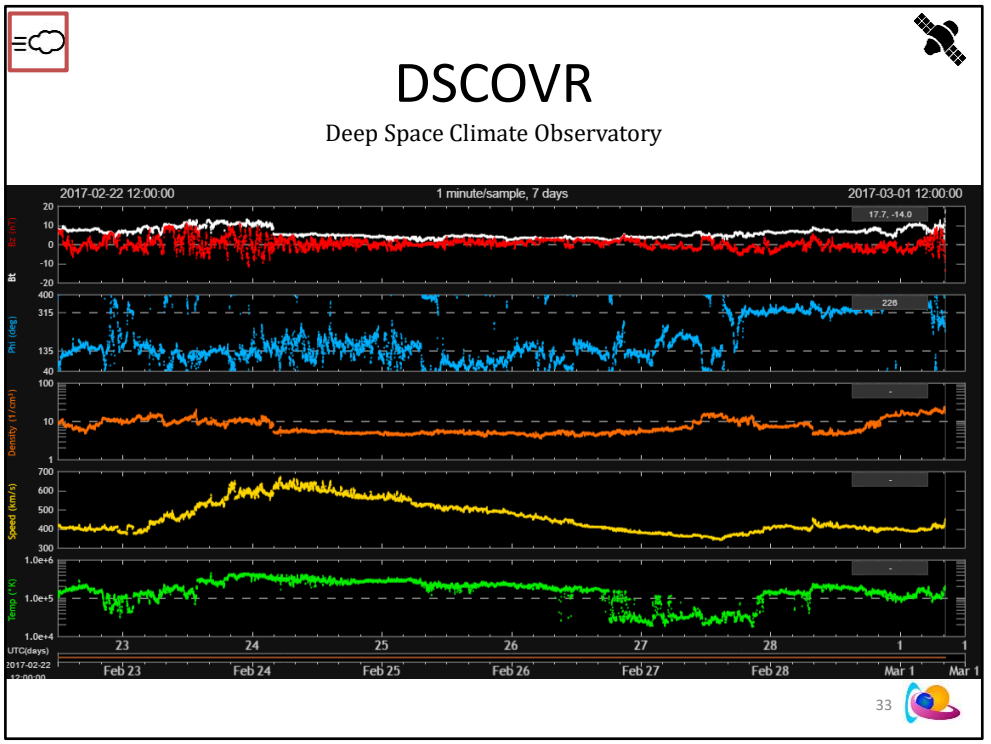


The weak CMEs/structures become better visible in difference imagery (one image subtracted from the other). Movies for the last 4 days can be found at https://sohowww.nascom.nasa.gov/data/realtime/mpeg/ (resp. LASCO C2 combo and LASCO C3 combo).

SOHO/LASCO is also a notorious comet chaser, discovering its 3000th comet on 14 September 2015.

SOHO has/had many other instruments, amongst which was the famous MDI (Michelson Doppler Imager) which made images of the Sun in “white light” as well as magnetograms. This program was terminated in 2011 as it was superseded by SDO/HMI. It was exceptionally switched on again for the Mercury transit 2016 (https://soho.nascom.nasa.gov/pickoftheweek/). The MDI archives are at http://soi.stanford.edu/

Descriptions of the other instruments can be found at https://sohowww.nascom.nasa.gov/about/instruments.html



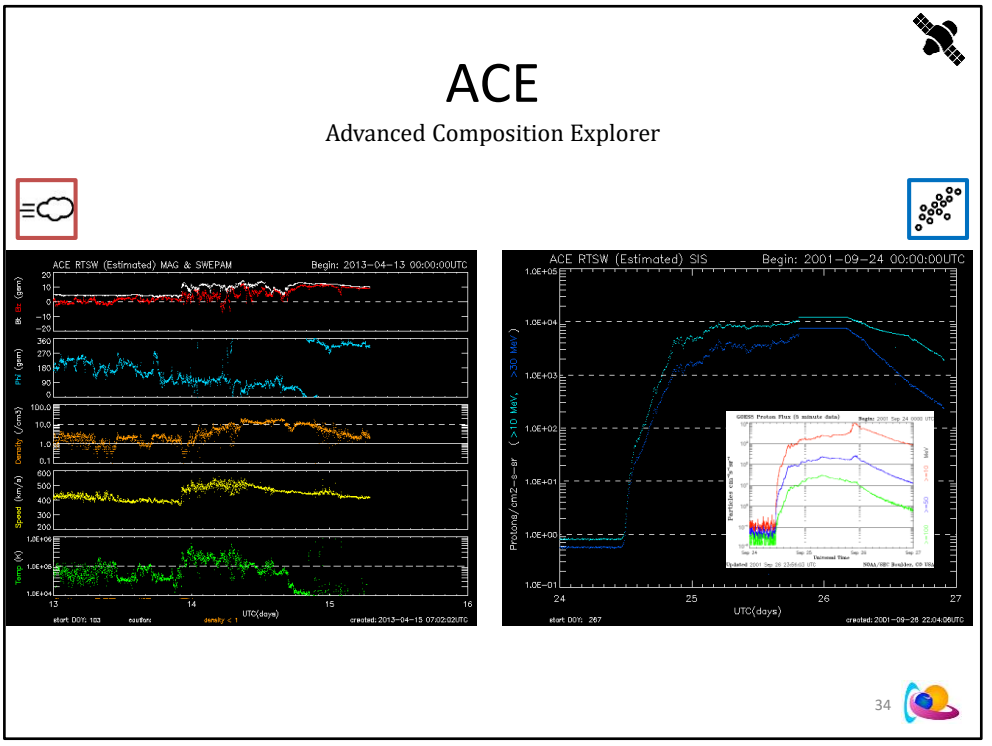
DSCOVR: Deep Space Climate Observatory
https://www.nesdis.noaa.gov/content/dscovr-deep-space-climate-observatory

Solar wind data are available at https://www.swpc.noaa.gov/products/real-time-solar-wind

From NOAA/SWPC: Real-Time Solar Wind (RTSW) data refers to data from any spacecraft located upwind of Earth, typically orbiting the L1 Lagrange point, that is being tracked by the Real-Time Solar Wind Network of tracking stations. The NOAA DSCOVR satellite became the operational RTSW spacecraft on July 27, 2016 at 1600UT (noon EDT, 10am MDT).
SWPC maintains the ability to instantaneously switch the spacecraft that provides the RTSW data. During times of outages in DSCOVR data or problems with the data, this page may instead display the data from the NASA/ACE spacecraft.

The two DSCOVR instruments for which data are available:
Faraday Cup (FC) of the Harvard Smithsonian Astrophysical Observatory(link is external)
Magnetometer (MAG) of the University of NASA Goddard Space Flight Center (link is external)

Note that DSCOVR is vulnerable to GCR, which introduces spurious measurement readings from time to time. The correctness of the values can be checked against the ACE data. More on this issue at http://www.nature.com/news/cosmic-rays-may-threaten-space-weather-satellite-1.20880
DSCOVR was in safe mode from 27 June 2019 till 02 March 2020 due to a technical glitch.
https://www.nesdis.noaa.gov/content/noaas-dscovr-satellite-operating-again



ACE: Advanced Composition Explorer (launched 25 August 1997)
http://www.srl.caltech.edu/ACE/

All data at NOAA/SWPC: https://www.swpc.noaa.gov/products/ace-real-time-solar-wind

EPAM: Electron Proton Alpha Monitor
- measurements of low-energy electrons and protons

SWEPAM: Solar Wind Electron Proton Alpha Monitor
- measurements of solar wind density, speed and temperature

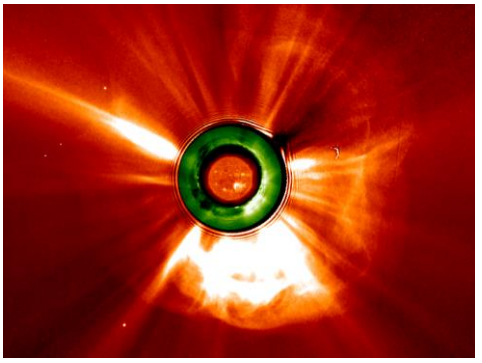
MAG: Magnetometer instrument
- Measurements of solar wind magnetic field

SIS: Solar Isotope Spectrometer
- Measurements of high-energy protons (>10 MeV, > 30 MeV)

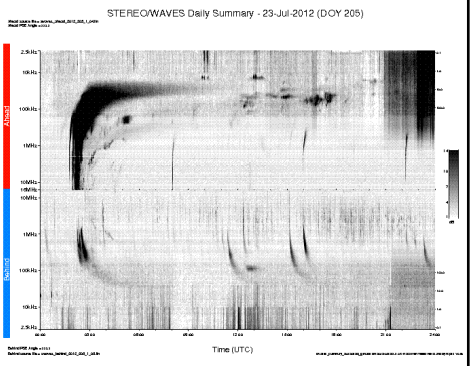
ACE measurements of e.g. solar wind speed are sometimes unreliable in case of strong proton events, which is annoying when a CME arrives.
As of 27 July 2016, ACE is superseded by the DSCOVR satellite, and as such there's no longer a 24hr data coverage anymore.

STEREO

Solar-TErrestrial RElations Observatory



EUVI: Solar EUV imager
COR: Coronagraphs
HI: Heliospheric Imagers



WAVES: radio observations

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STEREO: Solar-Terrestrial Relations Observatory - SSC: STEREO Science Centre
All data and info are at https://stereo-ssc.nascom.nasa.gov/beacon/beacon_secchi.shtml

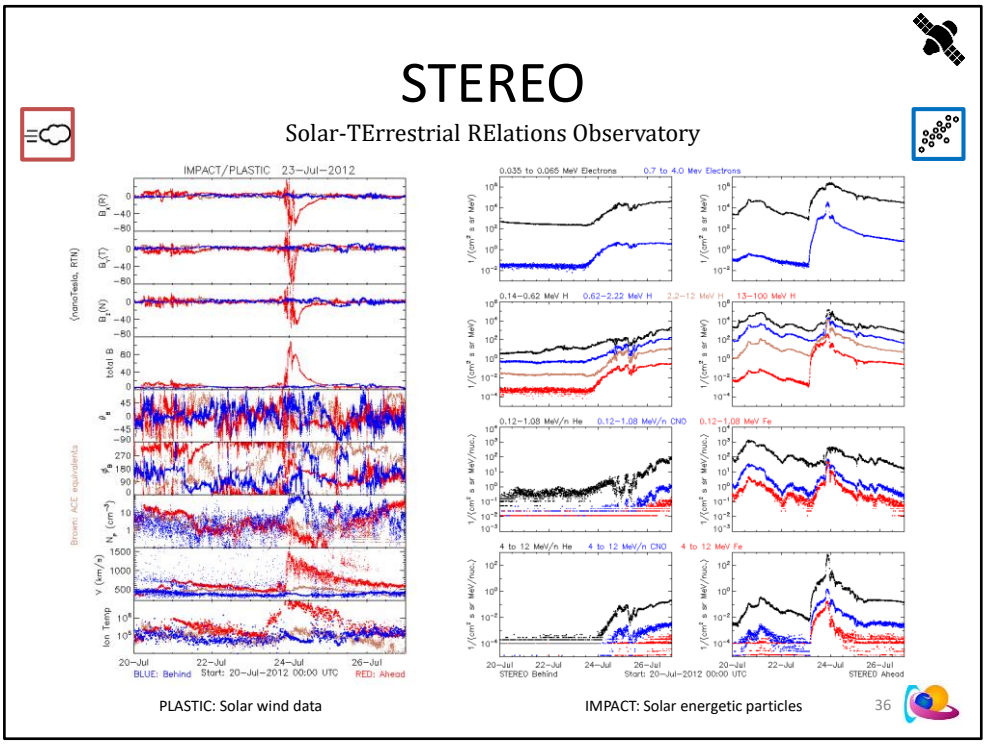
Twin spacecraft in sun orbit, one ahead (ST-A) of Earth in its orbit, the other trailing behind (ST-B). They were launched on 25 October 2006.
Contact with ST-B was lost on 1 October 2014 during a test. Re-establishing contact will be tried again in June 2017.
Both spacecraft have passed the anti-solar point in 2015, heading back to earth, but now ST-A is trailing the earth (not re-labelled).
Spacecraft will be close to earth again somewhere in 2023.

The main SWx advantages of the STEREO mission are

- A stereoscopic view of the Sun and CMEs, allowing e.g. a much better determination of the speed and direction of a CME.
- A direct view on the Sun's farside and its solar activity.
- Knowing 1-2 weeks in advance on the strength of CH HSS or active sunspot groups that may rotate over the east limb as seen from earth.

There are 4 main instrument packages:

- SECCHI: Sun Earth Connection Coronal and Heliospheric Investigation
    - EUVI: extreme ultraviolet imager (4 passbands: 171, 195, 284, 304 Angstrom or 17.1, 19.5, 28.4, 30.4 nm)
    - COR1/2: white-light coronagraphs (inner: 1.3 to 4 solar radii/outer: 2-15 solar radii)
    - HI1/2: heliospheric imagers
- PLASTIC: PLAsma and SupraThermal Ion Composition
    - Specifically interesting for proton and SEP events
- IMPACT: In-situ Measurements of Particles and CME Transients
    - Solar wind measurements
- SWAVES: STEREO Waves instrument
    - Track radiobursts from the Sun



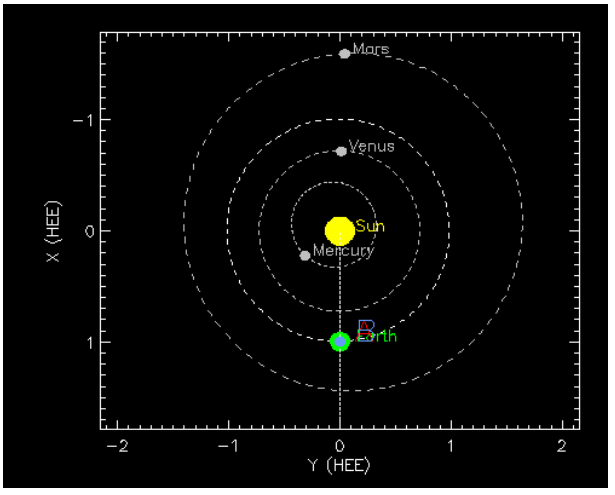
The example is from the Carrington-like event from 23 July 2012 (Sun's farside), showing:
Previous slide

- The EUVI304, COR1 and COR2 shortly after the maximum of the flare (but before the start of the proton event);
- The Type II and III radiobursts associated to the event (SWAVES)

This slide:

- The solar wind data from from PLASTIC/IMPACT for 7 days centered on 23 July 2012. Notice the strength of the event as observed by ST-A, and the lack of impact as observed by ST-B which was at the other side of the Sun
- The SEP data from the IMPACT instrument for 7 days centered on 23 July 2012. Notice the obvious differences between a well-connected (ST-A) and a poorly connected (ST-B) observer (much later, gradual and weaker with ST-B).

STEREO orbit (2006-2022)



37

https://stereo-ssc.nascom.nasa.gov/cgi-bin/make_where_gif

Exercise: Space-based instruments

- You want to have a clear EUV view of a solar flare that was visible on the Sun. Which instrument(s) would you use?
  - SOHO / LASCO C2
  - STEREO / Waves
  - SDO / AIA 193
  - GOES / XRS

Exercise: Space-based instruments

- Which satellites have instruments to make observations of the solar energetic particles?
  - PROBA2
  - SDO
  - STEREO
  - GOES

:Issued: 2014 Apr 17 1325 UTC
:Product: documentation at http://www.sidc.be/products/tot
#----------#
DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC
#----------#
SIDC URSIGRAM 40417
SIDC SOLAR BULLETIN 17 Apr 2014, 1304UT

SIDC FORECAST (valid from 1230UT, 17 Apr 2014 until 19 Apr 2014)
SOLAR FLARES : Active (M-class flares expected, probability >=50%)
GEOMAGNETISM : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet

PREDICTIONS FOR 17 Apr 2014 10CM FLUX: 180 / AP: 013
PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007
PREDICTIONS FOR 19 Apr 2014 10CM FLUX: 188 / AP: 005

Finding your way in the URSIgram

COMMENT: Eleven sunspot groups were reported by NOAA today. NOAA ARs 2035,2036, and 2037 (Catania numbers 24, 25, and 26 respectively) maintain the beta-gamma configuration of the photospheric magnetic field. The strongest flare of the past 24 hours was the M1.0 flare peaking at 19:59 UT yesterday in the NOAA AR 2035 (Catania number 24). The flare was associated with an EIT wave and a weak coronal dimming, but the associated CME was narrow and is not expected to arrive at the Earth.
We expect further flaring activity on the C-level, especially in the NOAA ARs 2035 and 2037 (Catania numbers 24 and 26 respectively) as well as in the NOAA AR 2042 (no Catania number yet) that yesterday appeared from behind the east solar limb, with a good chance for an M-class event.

Since yesterday evening the Earth is situated inside a solar wind structure with an elevated interplanetary magnetic field magnitude (occasionally up to 10 nT). It may be a weak ICME or the compression region on the flank of an ICME that missed the Earth. The solar origin of this structure is not clear. The north-south magnetic field component Bz was not strong, so no significant geomagnetic disturbance resulted (K index stayed below 4). Currently the solar wind speed is around 380 km/s and the IMF magnitude is around 8 nT.
We expect quiet to unsettled (K index up to 3) geomagnetic conditions, with active geomagnetic conditions (K = 4) possible, but unlikely.

TODAY'S ESTIMATED ISN : 145, BASED ON 17 STATIONS.
99999

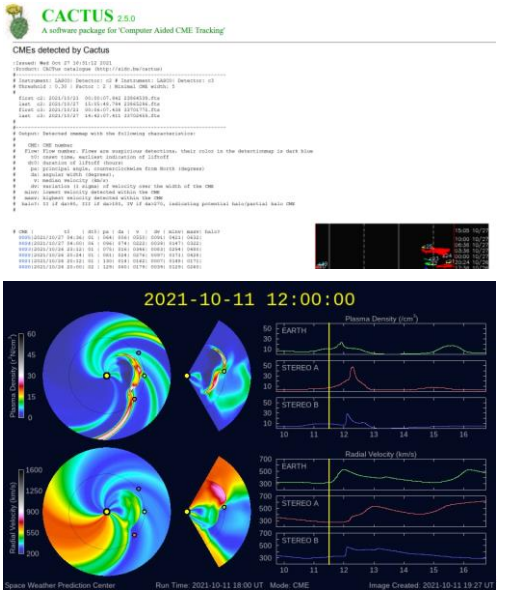
SOLAR INDICES FOR 16 Apr 2014
WOLF NUMBER CATANIA : ///
10CM SOLAR FLUX : 184
AK CHAMBON LA FORET : 012
AK WINGST : 004
ESTIMATED AP : 004
ESTIMATED ISN : 139, BASED ON 29 STATIONS.

Satellites and instruments

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
16 1954 1959 2004 S14E09 M1.0 1N 24/2035 II/2
END

Tools

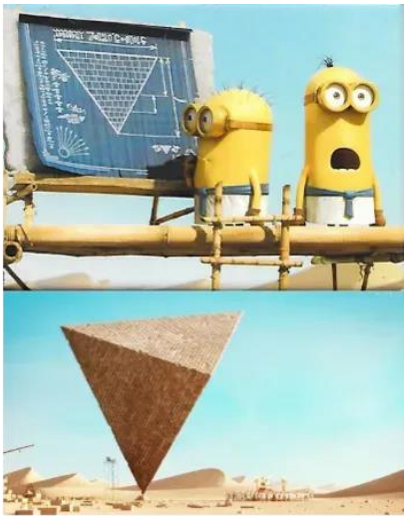
- Various
  - Soteria
  - Solar Demon
  - CACTus
  - Drag model
  - JHV (SWHV)
  - STAFF
  - COR2 J-plots
  - COMESEP
  - EUHFORIA
    - WSA-ENLIL (SWPC)



Soteria: https://wwwbis.sidc.be/soteria/soteria.php
Solar Demon: https://wwwbis.sidc.be/solardemon/flares.php
CACTus: https://wwwbis.sidc.be/cactus/out/latestCMEs.html
Drag model: https://oh.geof.unizg.hr/DBM/dbm.php
JHV (SWHV): http://www.jhelioviewer.org/ ; http://swhv.oma.be/user_manual/
STAFF: http://www.staff.oma.be/
COR2 J-plots:
https://wwwbis.sidc.be/spaceweatherservices/applications/cor2speed/cor2speed.html#canvas_position
COMESEP: https://swe.ssa.esa.int/web/guest/bira-comesep-federated (registration required)
10.7cm radioflux: will not be developed due to military interference)
EUHFORIA: https://wwwbis.sidc.be/spaceweatherservices-private/data/euhforia/py3v1.0.4/SWdaily/
- EUropean Heliospheric FORecasting Information Asset ; https://euhforia.com/
WSA-ENLIL: https://www.swpc.noaa.gov/products/wsa-enlil-solar-wind-prediction

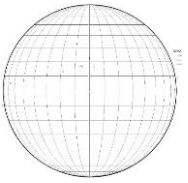
Other:
Solar Monitor: https://www.solarmonitor.org/index.php
SWPC synoptic diagram: https://www.swpc.noaa.gov/products/solar-synoptic-map
Spacecast: http://fp7-spacecast.eu/
EURISGIC: http://eurisgic.org/

Reversed engineering

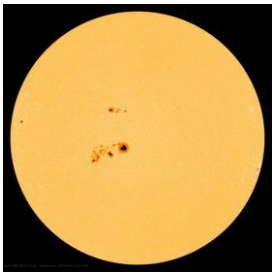


White light solar imagery

Ground-based



Space-based

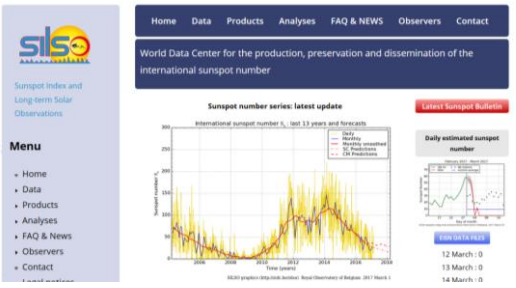


GONG: Global Oscillation Network Group
USET: Uccle Solar Equatorial Table
Catania Astrophysical Observatory
SDO: Solar Dynamics Observatory
HMI: Helioseismic and Magnetic Imager

Sunspot number

Ground-based

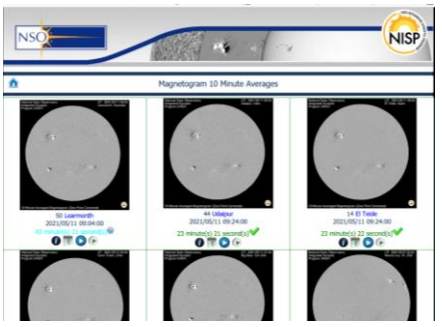
Space-based



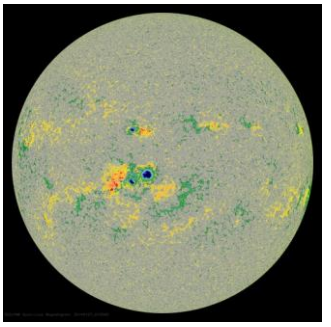
SILSO: Sunspot Index and Long-term Solar Observations

Solar magnetograms

Ground-based



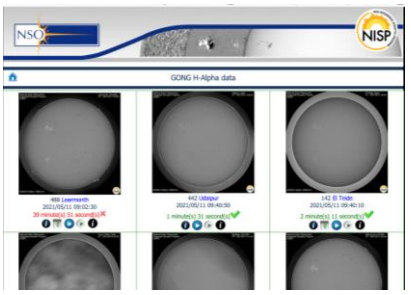
Space-based



GONG: Global Oscillation Network Group
SDO: Solar Dynamics Observatory
HMI: Helioseismic and Magnetic Imager

H-alpha solar images

Ground-based



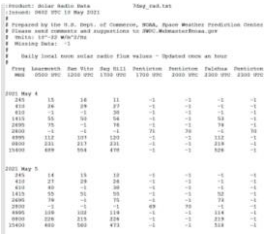
Space-based

GONG: Global Oscillation Network Group
USET: Uccle Solar Equatorial Table
Kanzelhöhe Observatory

Kanzelhöhe: http://cesar.kso.ac.at/

Solar radio flux

Ground-based

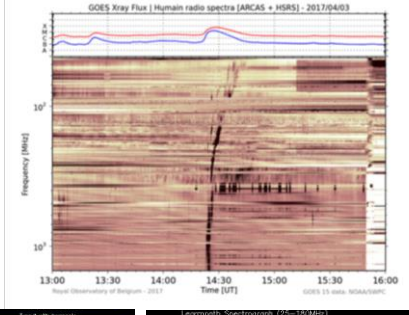


Space-based

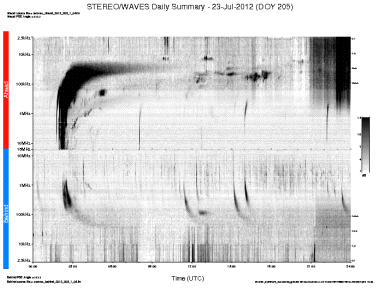
DRAO: Dominion Radio Astrophysical Observatory
NRCan: Natural Resources Canada
RSTN: Radio Solar Telescope Network

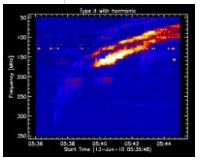
Solar radio spectra

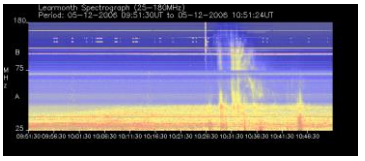
Ground-based



Space-based







Humain Radioastronomy Station
eCallisto
Learmonth
STEREO: Solar-TErrestrial RElations Observatory

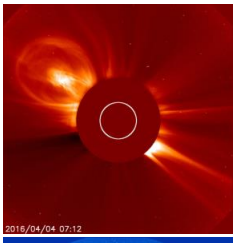
48

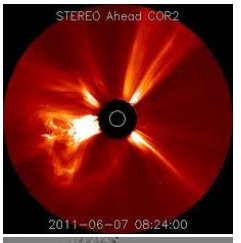
e-Callisto extended Compact Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory

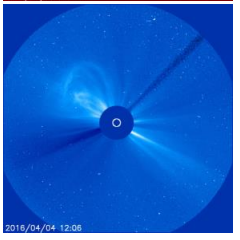
Solar coronagraphic imagery

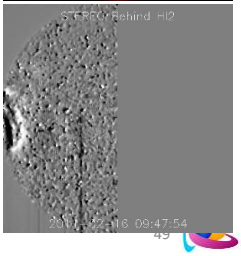
Ground-based

Space-based







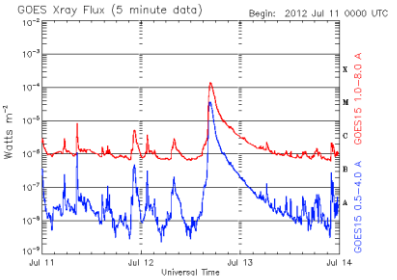


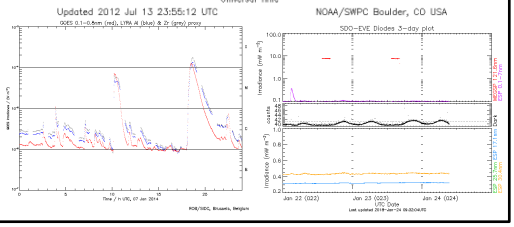
SOHO: SOlar & Heliospheric Observatory
LASCO: Large Angle Spectrometric Coronagraph
STEREO: Solar-TErrestrial RElations Observatory
COR: Coronagraph
HI: Heliospheric Imager

Solar X-ray flux and proxies

Ground-based

Space-based



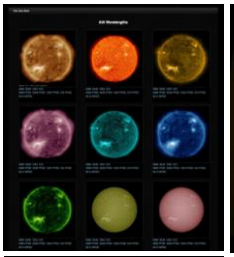


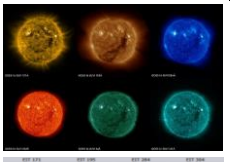
GOES: Geostationary Operational Environmental Satellite
XRS: X-Ray Sensor
SDO: Solar Dynamics Observatory
EVE: Extreme ultraviolet Variability Experiment
PROBA2: PRoject for OnBoard Autonomy
LYRA: Large Yield RAdiometer

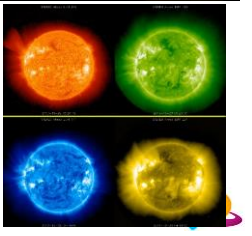
Solar EUV imagery

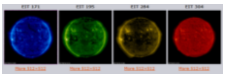
Ground-based

Space-based







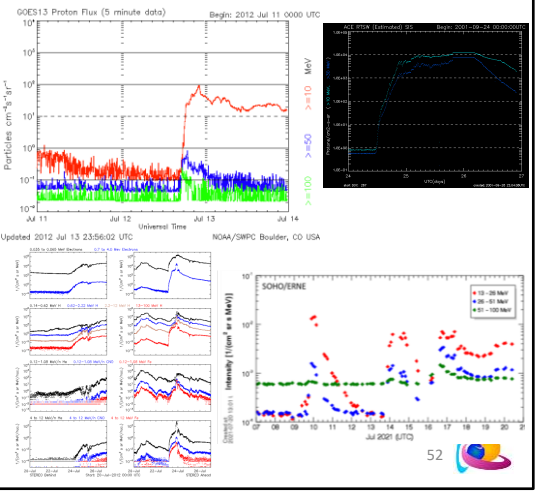


GOES: Geostationary Operational Environmental Satellite
SUVI: Solar Ultraviolet Imager
SDO: Solar Dynamics Observatory
AIA: Atmospheric Imaging Assembly
PROBA2: PRoject for OnBoard Autonomy
SWAP: Sun Watcher using APS detector and image Processing
SOHO: SOlar & Heliospheric Observatory
EIT: Extreme ultraviolet Imaging Telescope
STEREO: Solar-TErrestrial RElations Observatory
EUVI: Extreme UltraViolet Imager

Solar proton flux

Ground-based

Space-based

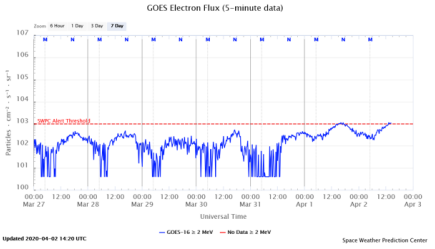


GOES: Geostationary Operational Environmental Satellite
ACE: Advanced Composition Explorer
STEREO: Solar-TErrestrial RElations Observatory
SOHO: SOlar and Heliospheric Observatory

≥ 2 MeV electron flux

Ground-based

Space-based

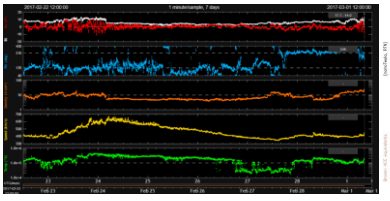


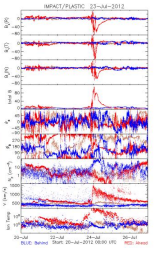
GOES: Geostationary Operational Environmental Satellite

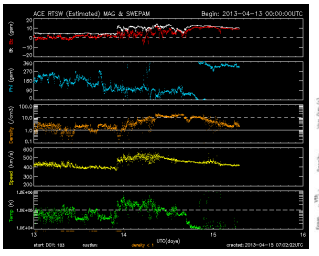
Solar wind

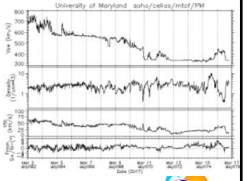
Ground-based

Space-based









SOHO: SOlar & Heliospheric Observatory
DSCOVR: Deep Space Climate Observatory
ACE: Advanced Composition Explorer
STEREO: Solar-TErrestrial RElations Observatory

Exercises

Identify the ground-based stations, satellites, sensors, tools,… in the following URSIgrams (Comment)

URSIgram 1

```
:Issued: 2020 Feb 27 1230 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----------------------------------------------------------------#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC  #
#-----------------------------------------------------------------#
SIDC URSIGRAM 00227
SIDC SOLAR BULLETIN 27 Feb 2020, 1230UT
SIDC FORECAST (valid from 1230UT, 27 Feb 2020 until 29 Feb 2020)
SOLAR FLARES  : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM  : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 27 Feb 2020  10CM FLUX: 071 / AP: 010
PREDICTIONS FOR 28 Feb 2020  10CM FLUX: 071 / AP: 006
PREDICTIONS FOR 29 Feb 2020  10CM FLUX: 071 / AP: 004
COMMENT: Solar activity was at very low levels. The Sun is still spotless, but this may change
as two small active regions at resp. latitudes S10 and N25 are about to rotate over the east limb
as seen in SDO/AIA and STEREO-A/EUVI imagery. No earth-directed coronal mass ejections (CMEs) have
been observed in available coronagraphic imagery. The greater than 10 MeV proton flux was at
nominal values. Some small and patchy equatorial coronal holes (CHs) are present on the solar disk.

Solar activity is expected to remain at very low levels.

Solar wind conditions were at background levels. Solar wind speed varied steadily between 330 and
370 km/s (ACE). Bz undulated between -5 and +5 nT. The direction of the interplanetary magnetic
field (phi angle) was variable. Geomagnetic conditions were at quiet levels, with an unsettled
episode (09-12UT) recorded at Dourbes.

Geomagnetic activity is expected to remain mostly at quiet levels, with an isolated unsettled
interval remaining possible.
```


URSIgram 2

```
:Issued: 2018 Oct 13 1230 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----------------------------------------------------------------#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC  #
#-----------------------------------------------------------------#
SIDC URSIGRAM 81013
SIDC SOLAR BULLETIN 13 Oct 2018, 1230UT
SIDC FORECAST (valid from 1230UT, 13 Oct 2018 until 15 Oct 2018)
SOLAR FLARES  : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM  : Minor storm expected (A>=30 or K=5)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 13 Oct 2018  10CM FLUX: 072 / AP: 006
PREDICTIONS FOR 14 Oct 2018  10CM FLUX: 072 / AP: 029
PREDICTIONS FOR 15 Oct 2018  10CM FLUX: 072 / AP: 021
COMMENT: Beta region NOAA AR 2724 near the East limb has produced a B2.1 flare peaking at 01:50UT
on October 12, associated with a Type II radio burst observed at Learmonth, and a B7.1 flare
peaking at 14:08 UT, associated with a Type II radio burst registered in Humain. The chance for a
C flare in the next 24 hours is estimated at 35%.

No Earth-directed Coronal Mass Ejections (CMEs) were observed in available coronagraphic imagery.

The greater than 10 MeV proton flux was at nominal levels in the past 24 hours, and is expected to
stay at nominal levels in the next 24 hours.

Solar wind speed near Earth as registered by DSCOVR decreased from about 400 to 340 km/s about in
the past 24 hours. The Interplanetary Magnetic Field (IMF) was predominantly directed away from
the Sun and its magnitude varied between about 1 and 8 nT. Bz was never below -5 nT.  A high speed
stream from a negative polarity equatorial coronal hole is expected to arrive at Earth near the
start of October 14, enhancing the solar wind conditions.

Quiet geomagnetic conditions (K Dourbes between 1 and 2; NOAA Kp between 1 and 3) were registered
in the past 24 hours. Quiet to unsettled levels (K Dourbes < 4) are expected on October 13. Active
geomagnetic levels (K Dourbes = 4) are possible on October 14 and 15 due to the expected arrival
of a high speed stream from a negative polarity equatorial coronal hole, with a chance for minor
storm (K Dourbes = 5) intervals.
```


URSIgram 3

:Issued: 2017 May 24 1310 UTC
:Product: documentation at http://www.sidc.be/products/tot
#---#
DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC
#---#
SIDC URSIGRAM 70524
SIDC SOLAR BULLETIN 24 May 2017, 1310UT
SIDC FORECAST (valid from 1230UT, 24 May 2017 until 26 May 2017)
SOLAR FLARES : Quiet conditions (<50% probability of C-class flares)
GEOMAGNETISM : Active conditions expected (A>=20 or K=4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 24 May 2017 10CM FLUX: 076 / AP: 004
PREDICTIONS FOR 25 May 2017 10CM FLUX: 075 / AP: 007
PREDICTIONS FOR 26 May 2017 10CM FLUX: 076 / AP: 013
COMMENT: Over the past 24 hours solar activity has been very low. There has been one B4.4 flare peaking at 14:21 UT on 23-May-2017, coming from NOAA Active Region (AR) 2660 (McIntosh class:Bxo; Mag.Type:Beta). There are three more decaying NOAA AR on the visible side of the solar disk. Solar activity is expected to remain low over the next 24 hours with a probability of C-class flares.

A slow partial halo CME, with projected speed of about 192 km/s and angular width of about 122 degrees, was detected at 05:24 UT by CACTUS on 23-May-2017. The PROBA2/SWAP images analysis indicates strong dimming near solar disk centre as the source of the CME. WSA-ENLIL model predicts the arrival of CME at Earth around noon on 26-May-2017.

The total electron flux for electrons with energies above 2 MeV reached high levels. The total proton flux for protons with energies above 10 MeV remained at background level. The greater than 2 MeV electron flux is expected to reach high levels today and tomorrow (25-May-2017) in response to elevated solar wind speeds.

The solar wind speed decreased from about 520 km/s to values around 470 km/s during last 24 hours. The total interplanetary magnetic field (IMF) strength, as recorded by the DSCOVR satellite, was around 4 nT. Bz fluctuated between -3 and +3 nT being mostly negative. Geomagnetic conditions were ranged K Dourbes between 1 and 3; NOAA Kp between 1 and 2. The geomagnetic field is expected to be quiet today and tomorrow. Unsettled to active conditions are expected, with a minor storm possibility after noon 26-May-2017 due to the arrival of the 23-May-2017 CME.

URSIgram 4

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:Issued: 2017 Oct 21 1236 UTC
:Product: documentation at http://www.sidc.be/products/tot
#-----------------------------------------------------------------#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC  #
#-----------------------------------------------------------------#
SIDC URSIGRAM 71021
SIDC SOLAR BULLETIN 21 Oct 2017, 1236UT
SIDC FORECAST (valid from 1230UT, 21 Oct 2017 until 23 Oct 2017)
SOLAR FLARES  : C-class flares expected, (probability >=50%)
GEOMAGNETISM  : Active conditions expected (A>=20 or K=4)
SOLAR PROTONS : Quiet
PREDICTIONS FOR 21 Oct 2017  10CM FLUX: 077 / AP: 017
PREDICTIONS FOR 22 Oct 2017  10CM FLUX: 077 / AP: 007
PREDICTIONS FOR 23 Oct 2017  10CM FLUX: 077 / AP: 007
COMMENT: From the East limb, returning NOAA region 2682 produced a long duration M1.1 flare peaking at
23:28 UT on October 20. An associated dimming was detected by Solar Demon, and an associated Type II
radio burst was observed by Palehua at 23:35 UT with a corresponding speed of 344 km/s. SOHO LASCO C2
and C3 and STEREO COR2 A have observed an associated bright CME, first seen in LASCO C2 at 00:00 UT on
October 21, from the northeast to the southeast. Analysis of COR2 A jplots revealed a plane of sky speed
of about 385 km/s, yielding a full speed of 770 km/s. Due to the position of the source, this CME will
not be geoeffective. C flares are likely in the next 24 hours (70% probability), with a chance for an
M flare (30% probability).

No Earth-directed Coronal Mass Ejections (CMEs) were observed in available coronagraphic imagery.

The greater than 10 MeV proton flux was at nominal levels.

A small, fast forward shock in the solar wind occurred at 5:16 UT on October 21. Solar wind speed
registered by DSCOVR jumped from about 340 to 365 km/s, while the magnitude of the Interplanetary
Magnetic Field (IMF) jumped from about 4 to 6 nT. Current solar wind speed is about 360 km/s and current
IMF magnitude is about 8.5 nT. The IMF was directed away from the Sun until it started pointing towards
the Sun around 7:40 UT on October 21. Quiet to unsettled conditions (K Dourbes between 1 and 3; NOAA Kp
between 1 and 2) were registered in the past 24 hours. There is a chance for active geomagnetic levels
(K Dourbes = 4) on October 21. Quiet to unsettled geomagnetic levels (K Dourbes < 4) are expected on
October 22 and 23.
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Summary

- Both ground- and space-based data and imagery are used in SWx
  - Depends on the SWx user community and the purpose
  - Tools
- Multiple stations are a must
  - Back-up, cross-check & continuous monitoring
  - Reversed engineering