STCE Newsletter

6 Jan 2014 - 12 Jan 2014

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The Solar-Terrestrial Centre of Excellence (STCE) is a collaborative network of the Belgian Institute for Space Aeronomy, the Royal Observatory of Belgium and the Royal Meteorological Institute of Belgium.

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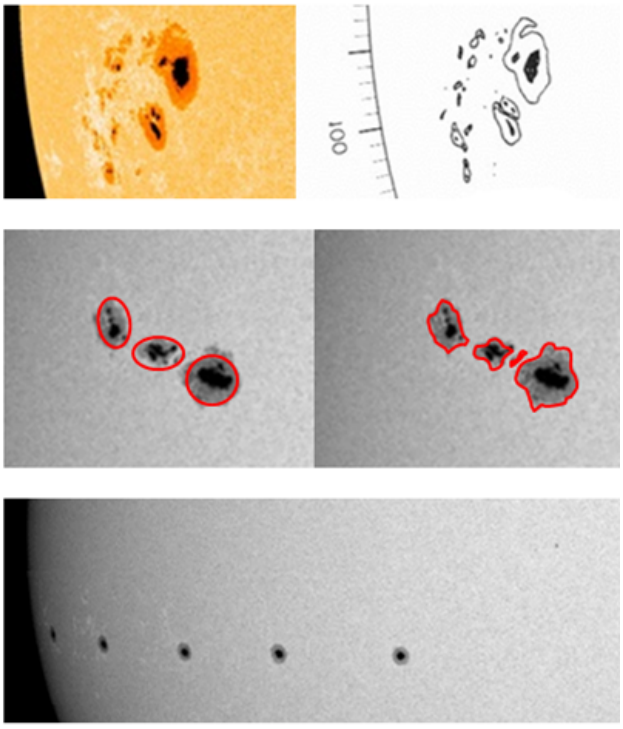
1. Stupendous NOAA 1944! (6 Jan 2014 - 12 Jan 2014)

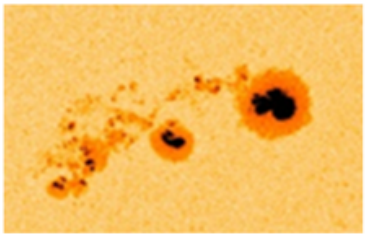
Without a doubt, the big and complex sunspot group NOAA 1944 was the talk of the week. During its transit over the solar disk (1-14 January), it produced 1 X- and 7 M-class solar flares. Here we will deal with some of the more enigmatic aspects of the group's size and the X-class flare it produced.

1. Was NOAA 1944 the largest sunspot group so far this solar cycle?

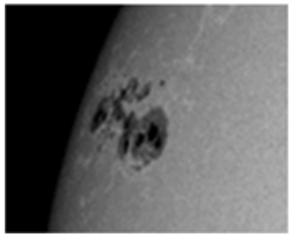
The short answer is yes. We have to go back to July 2004 (previous solar cycle SC23) to find a significantly bigger group (NOAA 10652). However, determining the area of a sunspot group is not an easy task. It depends on factors such as the medium used (drawing, picture, filter,...) and the calculation methodology (e.g. area of individual spots or one size fits all,...), as can be seen in sketches underneath. Moreover, if one wants to know the true size of the group, one has to correct for the line-of-sight. Indeed as the Sun is a sphere, a sunspot near the limb looks a lot smaller than an equally sized sunspot near the disk's center. Hence, small deviations in the measurements may result in a very different outcome for the sunspot area.



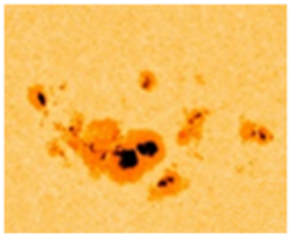
For all these reasons, the area data can differ substantially from one source to the other. Applying this consistently on SDO/HMI imagery, it turns out that the maximum area for NOAA 1944 (7 January 2014) seems indeed to be slightly larger than that of NOAA 1339 (3 November 2011, limb!) and NOAA 1520 (10 July 2012), resp. about 1% and 4%. These three groups were significantly larger than 3 other substantial groups of SC24: NOAA 1654 (11 January 2013), NOAA 1429 (7 March 2012), and NOAA 1302 (24 September 2011), by about 40%. A family portrait of these sunspot regions can be found underneath.



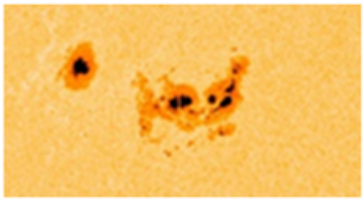
NOAA 1944



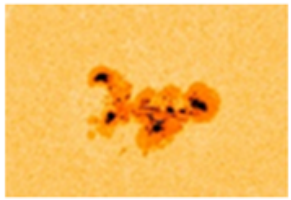
NOAA 1339



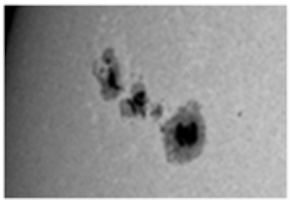
NOAA 1520



NOAA 1654



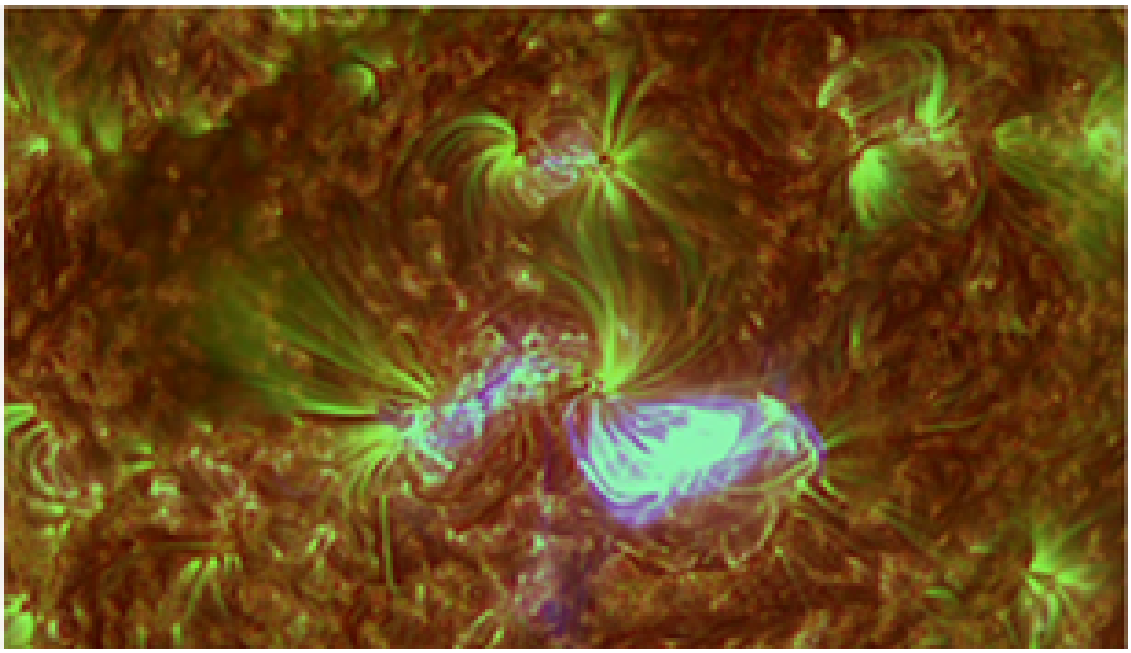
NOAA 1429



NOAA 1302

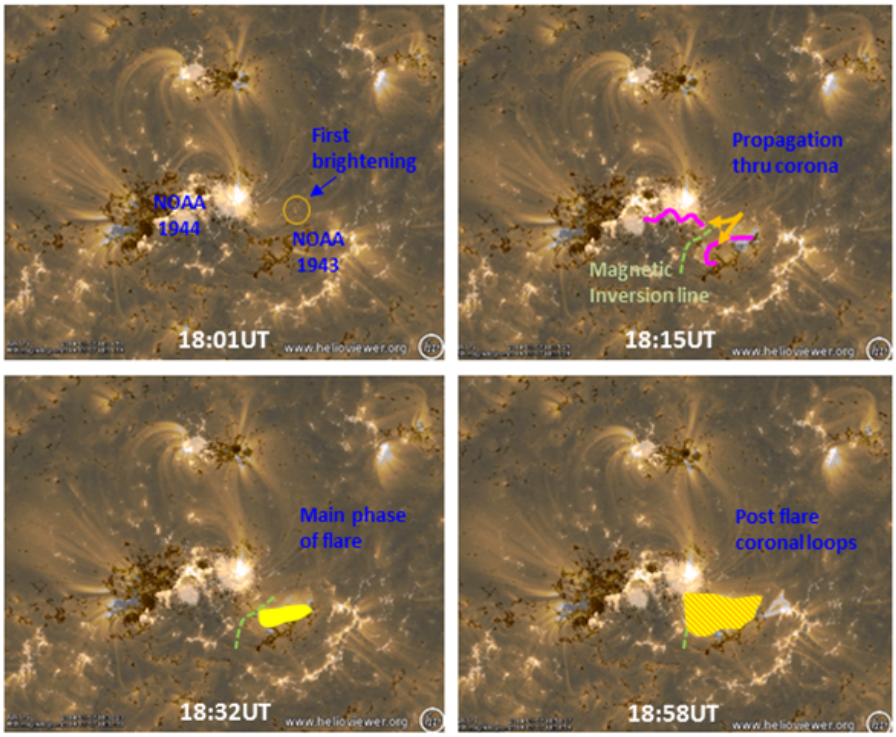
2. Did the X1.2-flare take place in NOAA 1943 or 1944?

On 7 January, NOAA 1944 produced 2 strong flares: An M7 flare peaking at 10:13UT, and a few hours later at 18:32UT, a powerful X-class flare (number 28 of the ongoing solar cycle 24). The M-class flare clearly took place in the trailing part of NOAA 1944, but ascribing the location of the X1.2 flare to NOAA 1944 proved to be a little more difficult, as can be seen in this movie at http://youtu.be/Khru9ig_pS4



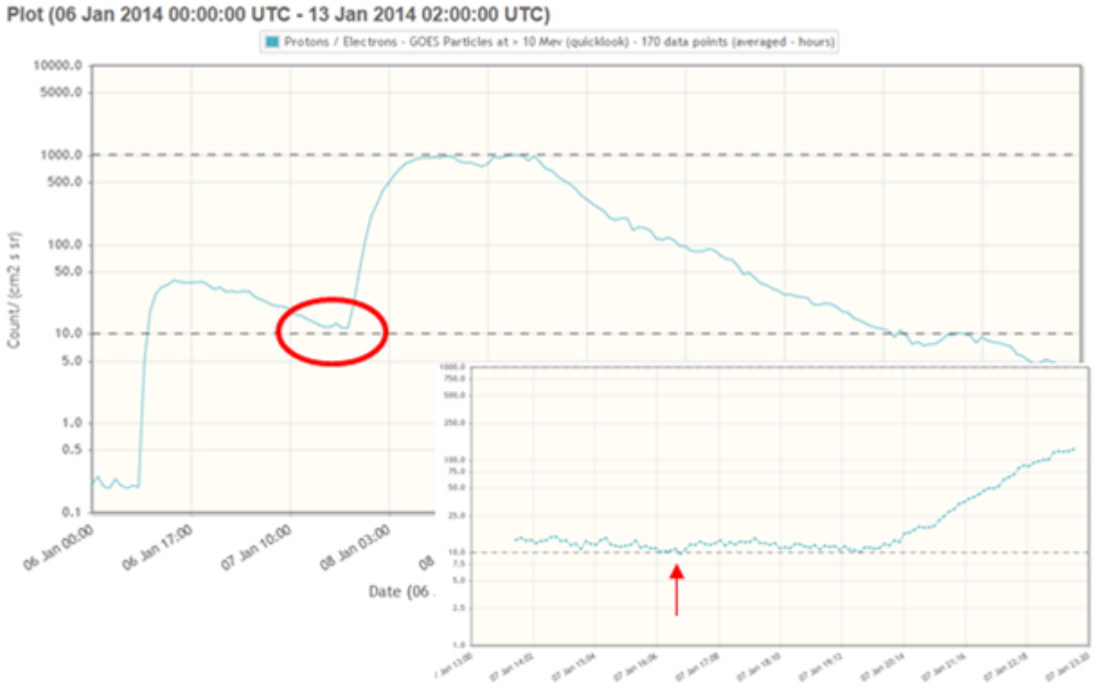
The reason for the problem was that the brightest part of the flare was located over the trailing part of the -at that time- spotless region NOAA 1943. The movie shows that the initial brightening took place to the north of the trailing part of NOAA 1943, and to the west of NOAA 1944's main spot. Then, it propagated southwards alongside the magnetic inversion line (see sketch underneath). Clearly, there's an interaction between the two regions, i.e. the positive (white) magnetic polarity part of NOAA 1944 and the negative (black) spotless portion of NOAA 1943. From a forecaster's point of view, the attribution of the X-class

flare to NOAA 1944 is certainly a great decision. Indeed, it avoids exceedingly high probabilities on X-class flares for future spotless active regions! But on what exactly happened during the 7 January event in the solar corona, the jury is still out.

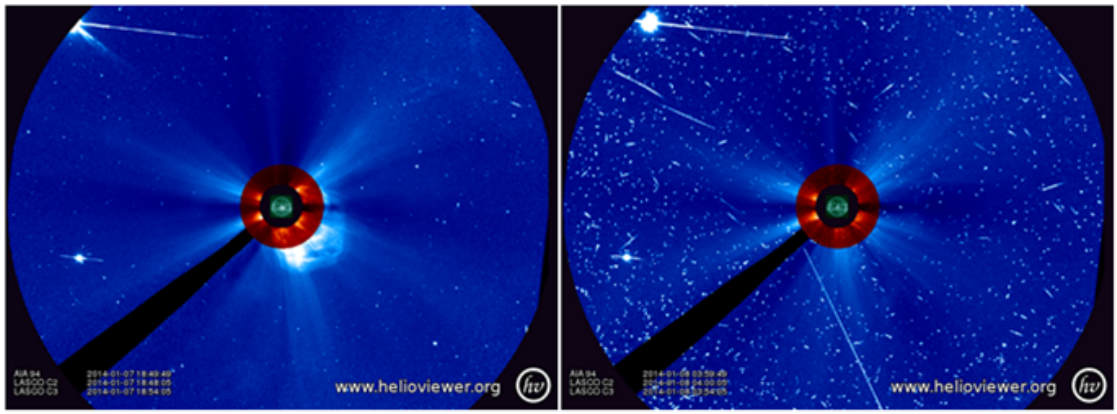


3. Is the X1.2 proton flare considered as a separate proton event?

The issue here is that proton flares are not considered as separate events if the proton flux (particle energies larger than 10 MeV) at the time of the event is still above the threshold of 10 protons per flux unit (pfu). A nice example is the sunspot group NOAA 10720 from January 2005 (very similar in size as NOAA 1944): There was one single proton event covering 3 strong X-class solar flares (all from NOAA 10720) that kept the proton flux well above the 10-pfu-threshold for nearly a week (16-22 January 2005)!



In the case of the 7 January X1-flare, the proton flux was already elevated due to a flare from NOAA 1936 which had rounded the west solar limb 2 days before (so not visible anymore from Earth!). As a result, this flare did not leave an x-ray signature, but the protons started to increase the flux on 6 January at 08:20UT. The flux peaked already at 42 pfu in the afternoon of the same day. The flux only gradually decreased, and by the time it started to increase again due to the X1-flare (around 19:00UT the next day), it was still slightly above the event threshold. However, at one data-point (16:30UT), it had dipped just below the threshold. So technically, this can be considered as a separate proton flare. The proton events are currently listed as separate items on the NOAA's Solar Energetic Particle page (http://umbra.nascom.nasa.gov/SEP/). In the end, the proton flux rose to 1033 pfu, making it the strongest event since 22-25 May 2013.



7 January – 18:50UT 8 January – 04:00UT

Credits - Data and imagery were taken from SDO (http://sdo.gsfc.nasa.gov/), SOHO (http://sohowww.nascom.nasa.gov/), Kanzelhohe (http://cesar.kso.ac.at/), NOAA/GOES (http://

www.swpc.noaa.gov/ftpdir/lists/particle/), and NOAA/SESC (http://umbra.nascom.nasa.gov/SEP/). Tools used were STAFF (http://www.staff.oma.be/#) and (J)Helioviewer (http://www.helioviewer.org/).

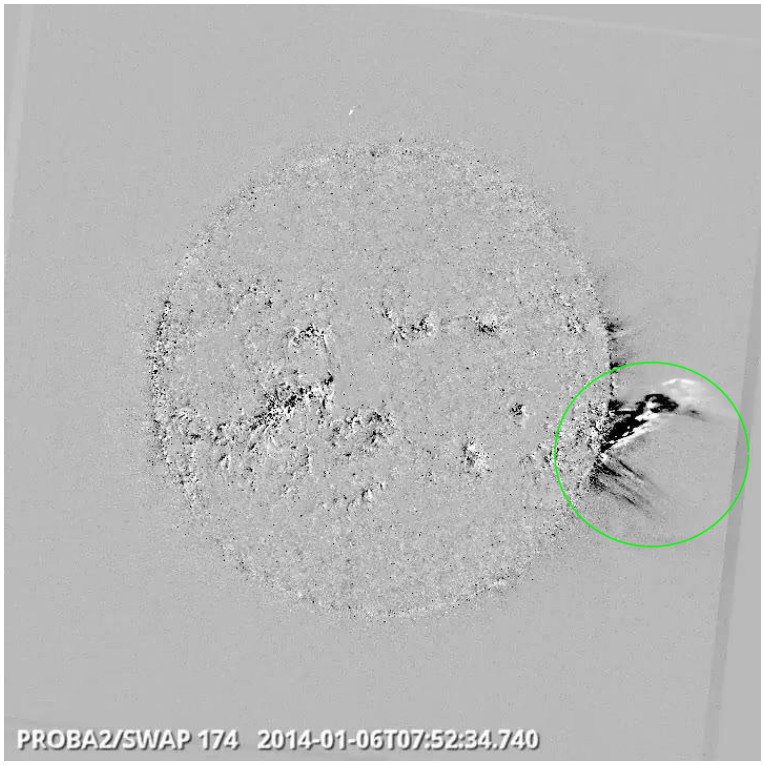
2. PROBA2 Observations (6 Jan 2014 - 12 Jan 2014)

Solar Activity

Solar flare activity fluctuated between low and high during the week.
In order to view the activity of this week in more detail, we suggest to go to the following website from which all the daily (normal and difference) movies can be accessed: http://proba2.oma.be/ssa
This page also lists the recorded flaring events.
A weekly overview movie can be found here (SWAP week 198).
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/weekly_movie_2014_01_06.mp4
Details about some of this week's events, can be found further below.

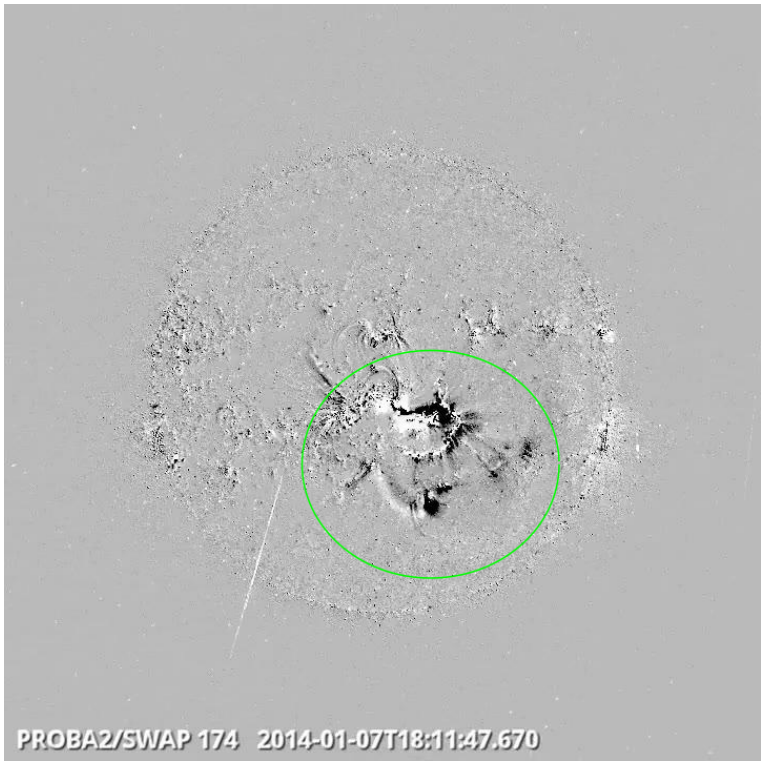
Monday Jan 06:

Eruption on the north east limb @ 06:23 SWAP difference image
Find a movie of the events here (SWAP difference movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140106_Eruption_NortEastLimb_0623_swap_diff.mp4
Find a movie of the events here (SWAP movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140106_Eruption_NortEastLimb_0623_swap_movie.mp4



Eruption on the west limb @ 07:52 SWAP difference image
Find a movie of the events here (SWAP difference movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140106_Eruption_WestLimb_0752_swap_diff.mp4
Find a movie of the events here (SWAP movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140106_Eruption_WestLimb_0752_swap_movie.mp4

Tuesday Jan 07:



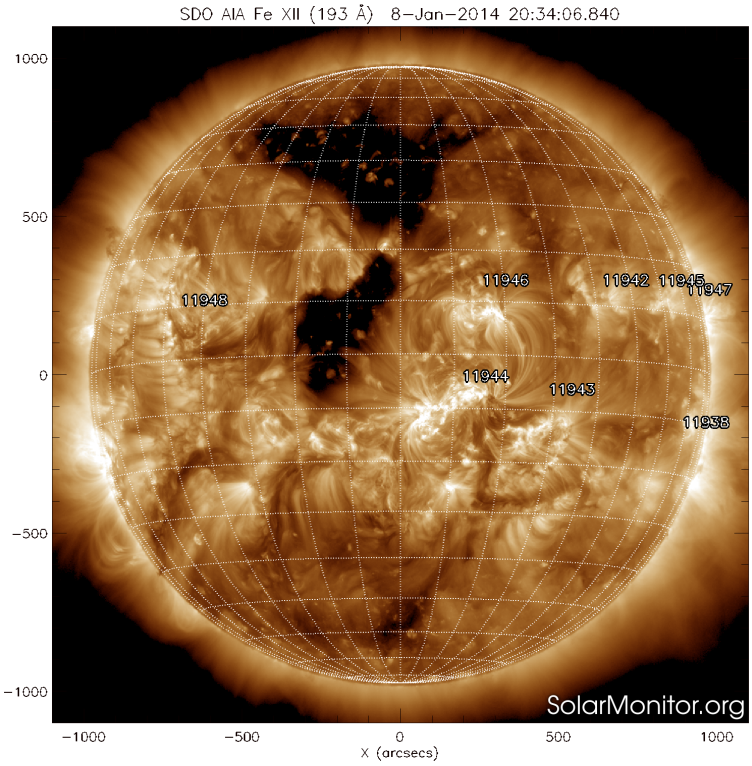
Xflare and eitwave on the south half @ 18:11 SWAP difference image
Find a movie of the events here (SWAP difference movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140107_XflareEitwave_SouthHalf_1811_swap_diff.mp4
Find a movie of the events here (SWAP movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140107_XflareEitwave_SouthHalf_1811_swap_movie.mp4

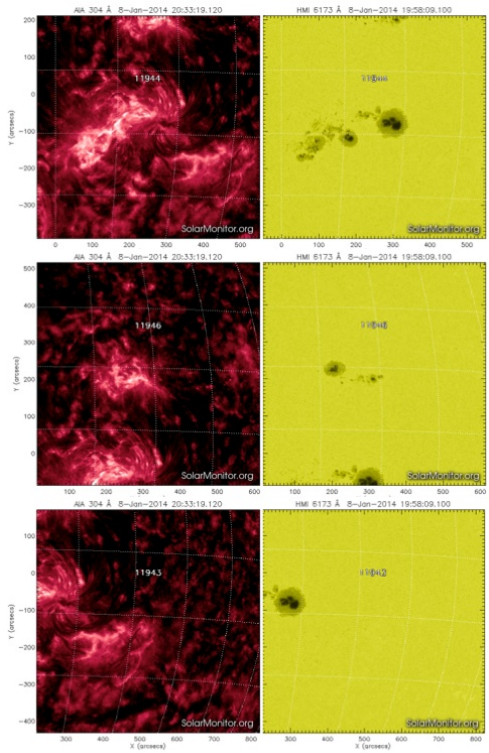
Wednesday Jan 08:

Eruption on the southeast Limb @ 17:16 SWAP difference image
Find a movie of the event here (SWAP difference movie)
http://proba2.oma.be/swap/data/mpg/movies/WeeklyReportMovies/WR198_Jan06_Jan12/Events/20140108_Eruption_SouthEastLimb_1716_swap_diff.mp4

3. Review of solar activity (6 Jan 2014 - 12 Jan 2014)

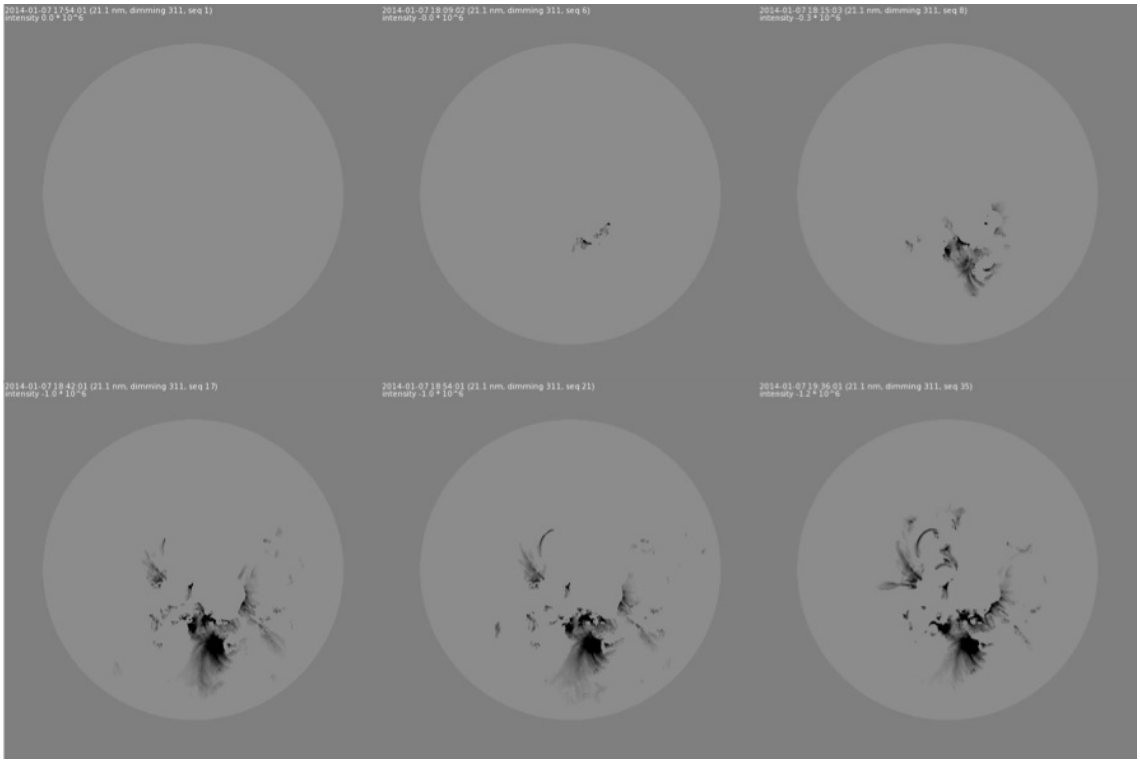
In the week of January 6 to January 12, 34 C flares, 3 M flares and one X flare were observed.
Catania sunspot group 98 (NOAA AR 1944), classified as a beta-gamma-delta group, was the most active throughout the whole week. The sunspot group was magnetically connected with Catania sunspot group 97 (NOAA AR 1946) and spotless region NOAA AR 1943. See below the active regions and underlying sunspots as they appeared in SDO/AIA 193, 304 and HMI 6173.



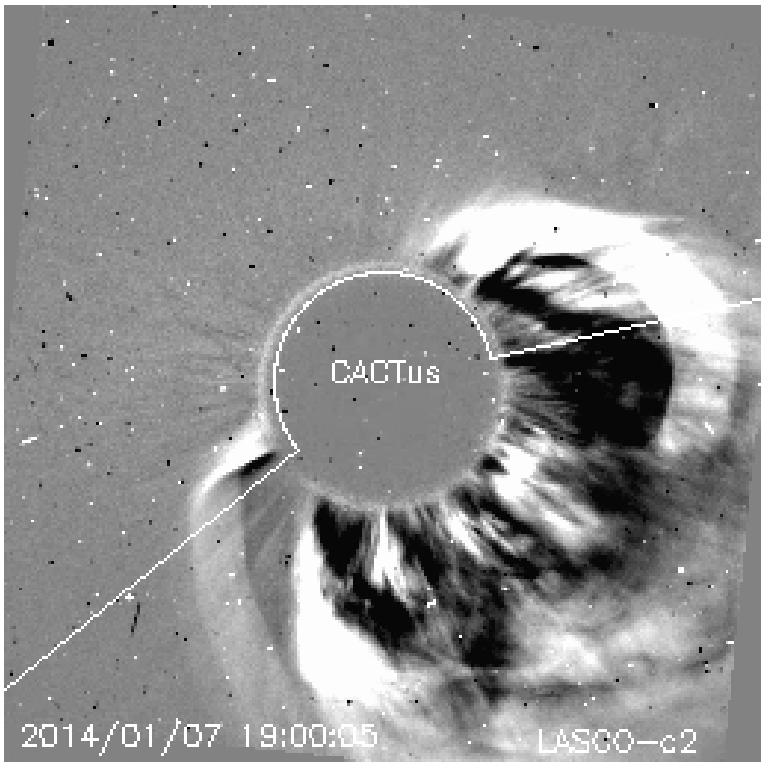


The X1.2 flare, erupting on January 7, peak time 18h32 UTC, originated from the western edge of Catania sunspot 98 and the trailing part of NOAA AR 1943. The event was associated with an asymmetric halo CME, metric type II radio burst, EUV wave and a large dimming region.
The area from where plasma is ejected, is left black. A dimming is an on disk indicator of coronal mass ejection. It flows radially out with the flare source as middle point. The pictures below show the dimming

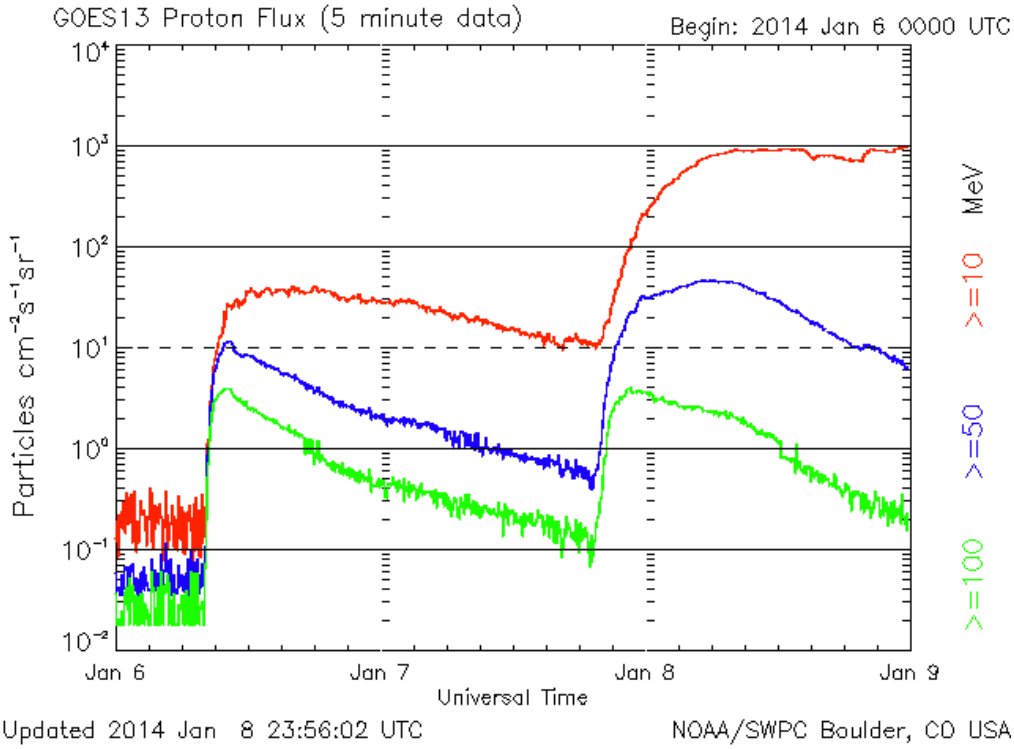
area which increases as the event progresses. More on http://solardemon.oma.be/dimmings.php?did=311



The CME was travelling to the southwest with an estimated speed of 1500 to 2300 km/s (depending on the model and data used).



Two proton events occurred; one starting on January 6, passing the event threshold (10pfu) at 9h15 UTC for >10MeV energy levels and another one starting on January 7. The first proton event was due to a strong flare erupting from NOAA AR 1936, which had already turned around the west limb. The second proton event was related to the X flare from Catania sunspot group 98 and started during the declining phase of the proton flux of the first event. The proton flux reached a maximum value of 1030 pfu during the second proton event. Both a CME front as a flare are able to accelerate particles to relativistic speeds. When the curve peaks suddenly, it is mainly the flare that gave its energy to the particles. When the curve increases more gradually, it is a CME front that accelerated the particles. Both mechanisms can be at work of course at the same time.



Most other flares originated from Catania sunspot group 98, but Catania sunspot groups 97 and 94 (NOAA AR 1946 and 1947) were also responsible for several flares.

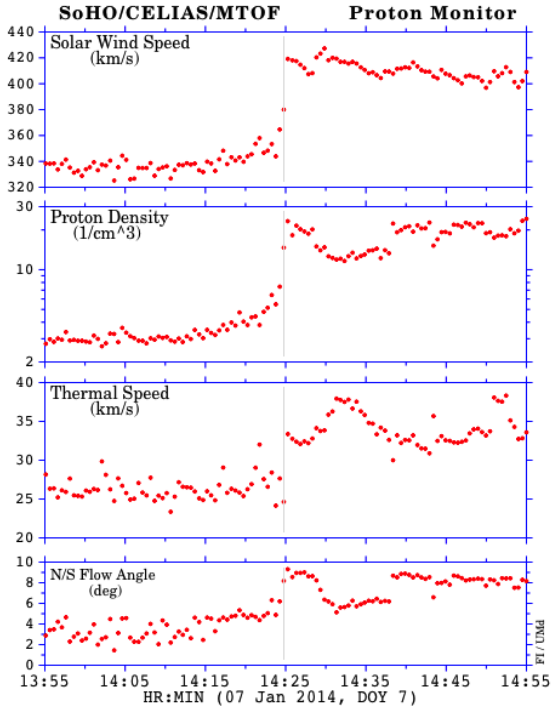
4. Noticeable Solar Events (6 Jan 2014 - 12 Jan 2014)

DAY	BEGIN	MAX	END	LOC	XRAY	OP	10CM	TYPE	Cat	NOAA
07	0349	0353	0356	N7E8	M1.0	1N			97	1946
07	1007	1013	1037	S13E11	M7.2	2B	480		98	1944
07	1804	1832	1858	S15W11	X1.2	2N	8300	II/2	98	1944
08	0339	0347	0354	N11W81	M3.6	SF	100	III/2II/2		1947

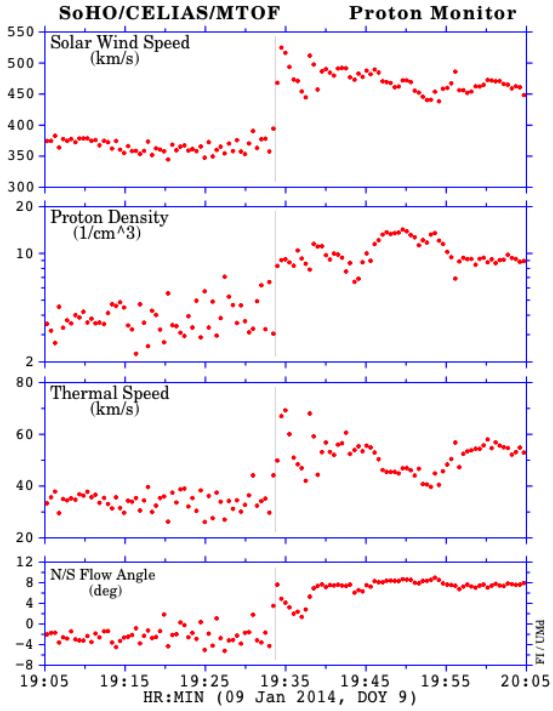
LOC: approximate heliographic location
XRAY: X-ray flare class
OP: optical flare class
10CM: peak 10 cm radio flux
TYPE: radio burst type
Cat: Catania sunspot group number
NOAA: NOAA active region number

5. Review of geomagnetic activity (6 Jan 2014 - 12 Jan 2014)

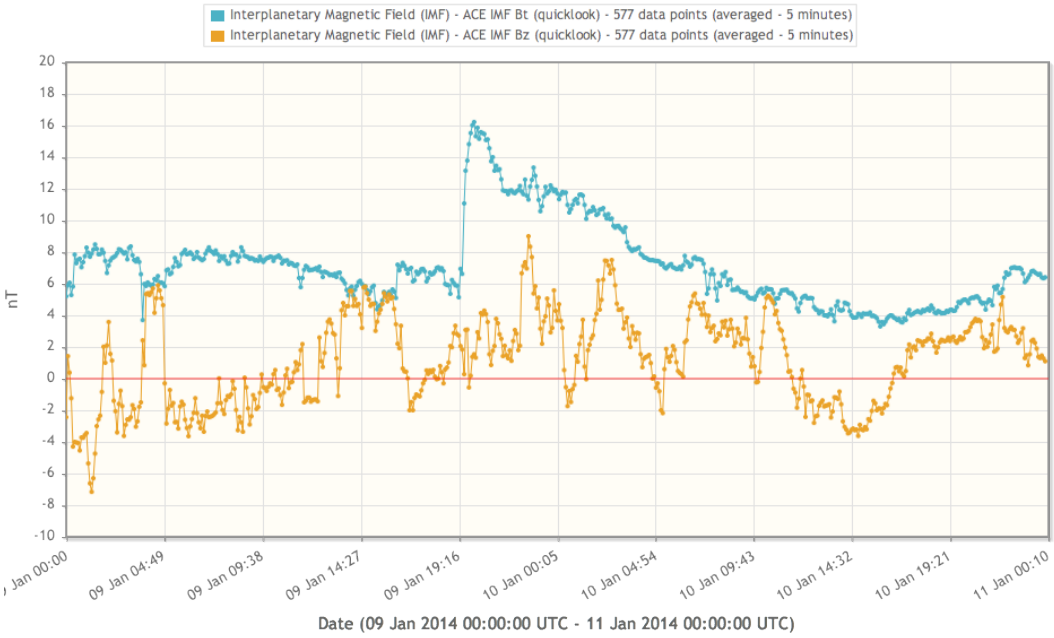
A shock in the solar wind data was observed on January 7 at 14:20 UTC. The shock was related to the arrival of the CME erupting on January 4 which came according into the LASCO/C2 FOV at 21:48 UTC (check http://sidc.oma.be/cactus/catalog/LASCO/2_5_0/qkl/2014/01/latestCMEs.html)



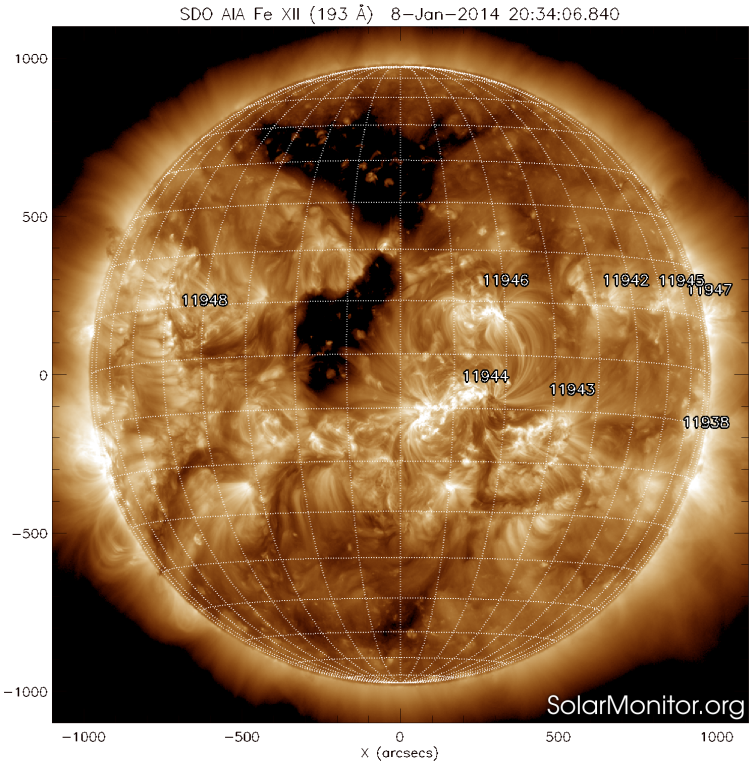
A second shock was observed on January 9 at 19:30 UTC, related to the CME of January 7 which came into the LASCO/C2 FOV at 18:24 UTC. You can check it at the same link as above.

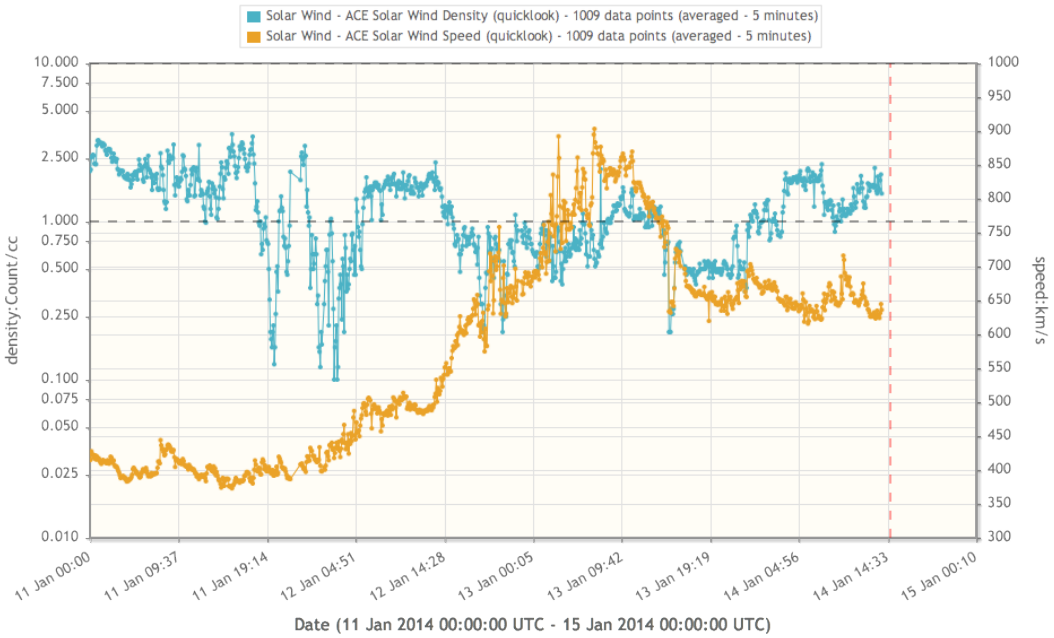


The magnitude of the interplanetary magnetic field reached a maximum value of 17 nT. The Bz-component was mainly positive and ranged from -8 to +8 nT. Solar wind speed stayed between 300 and 400 km/s at the begin of the week.



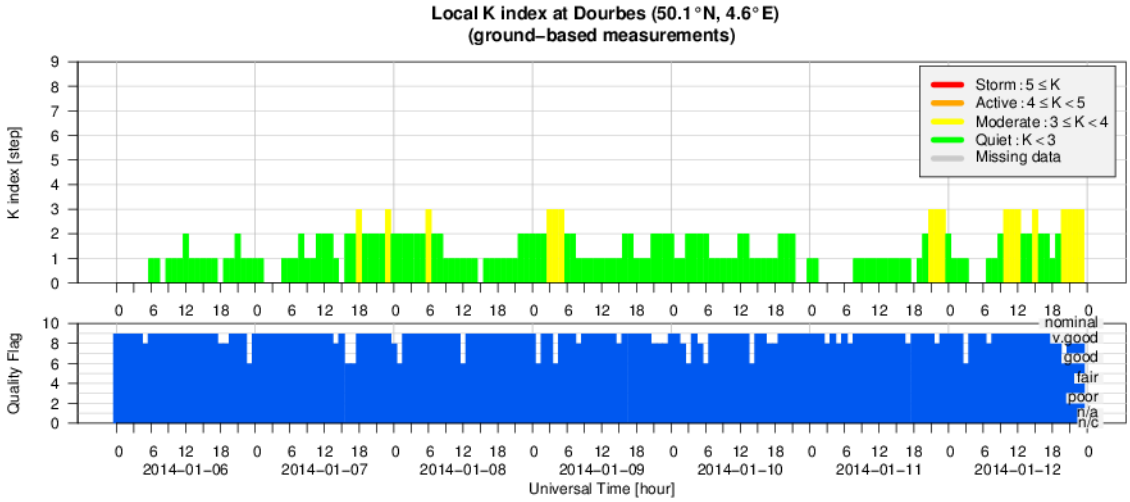
At the end of January 11, the arrival of a coronal hole high speed stream (CH HSS) was observed. It was the northern coronal hole that reached the central meridian on January 8. The CH HSS resulted in an increase of the solar wind speed to about 700 km/s.



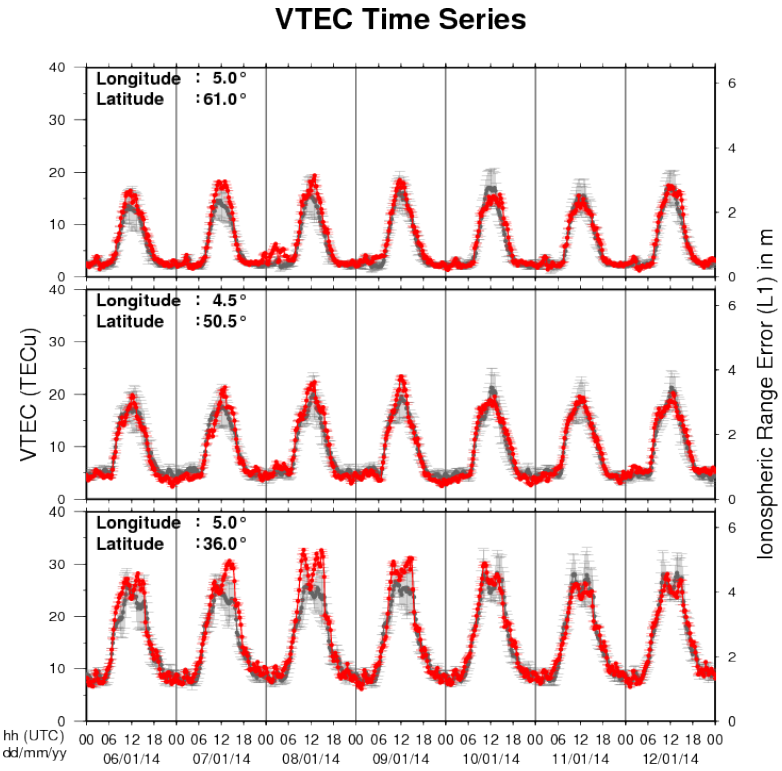


The local K index at Dourbes and Izmiran and the estimated NOAA planetary Kp index reached quiet to unsettled levels for most of the week: check the newsletter tab Geomagnetic Observations at Dourbes. NOAA Kp had a K=4 for one single time slot (January 12 at 21-24 UTC).

6. Geomagnetic Observations at Dourbes (6 Jan 2014 - 12 Jan 2014)



7. Review of ionospheric activity (6 Jan 2014 - 12 Jan 2014)



The figure shows the time evolution of the Vertical Total Electron Content (VTEC) (in red) during the last week at three locations:
a) in the northern part of Europe(N61°, 5°E)
b) above Brussels(N50.5°, 4.5°E)
c) in the southern part of Europe(N36°, 5°E)

This figure also shows (in grey) the normal ionospheric behaviour expected based on the median VTEC from the 15 previous days.

The VTEC is expressed in TECu (with TECu=10^16 electrons per square meter) and is directly related to the signal propagation delay due to the ionosphere (in figure: delay on GPS L1 frequency).
The Sun's radiation ionizes the Earth's upper atmosphere, the ionosphere, located from about 60km to 1000km above the Earth's surface.The ionization process in the ionosphere produces ions and free electrons. These electrons perturb the propagation of the GNSS (Global Navigation Satellite System) signals by inducing a so-called ionospheric delay.

See http://stce.be/newsletter/GNSS_final.pdf for some more explanations ; for detailed information, see http://gnss.be/ionosphere_tutorial.php