STCE Newsletter

1 Sep 2025 - 7 Sep 2025

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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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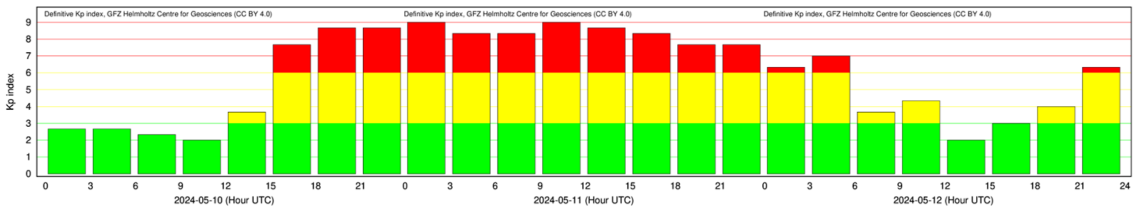
1. Long-duration geomagnetic storms

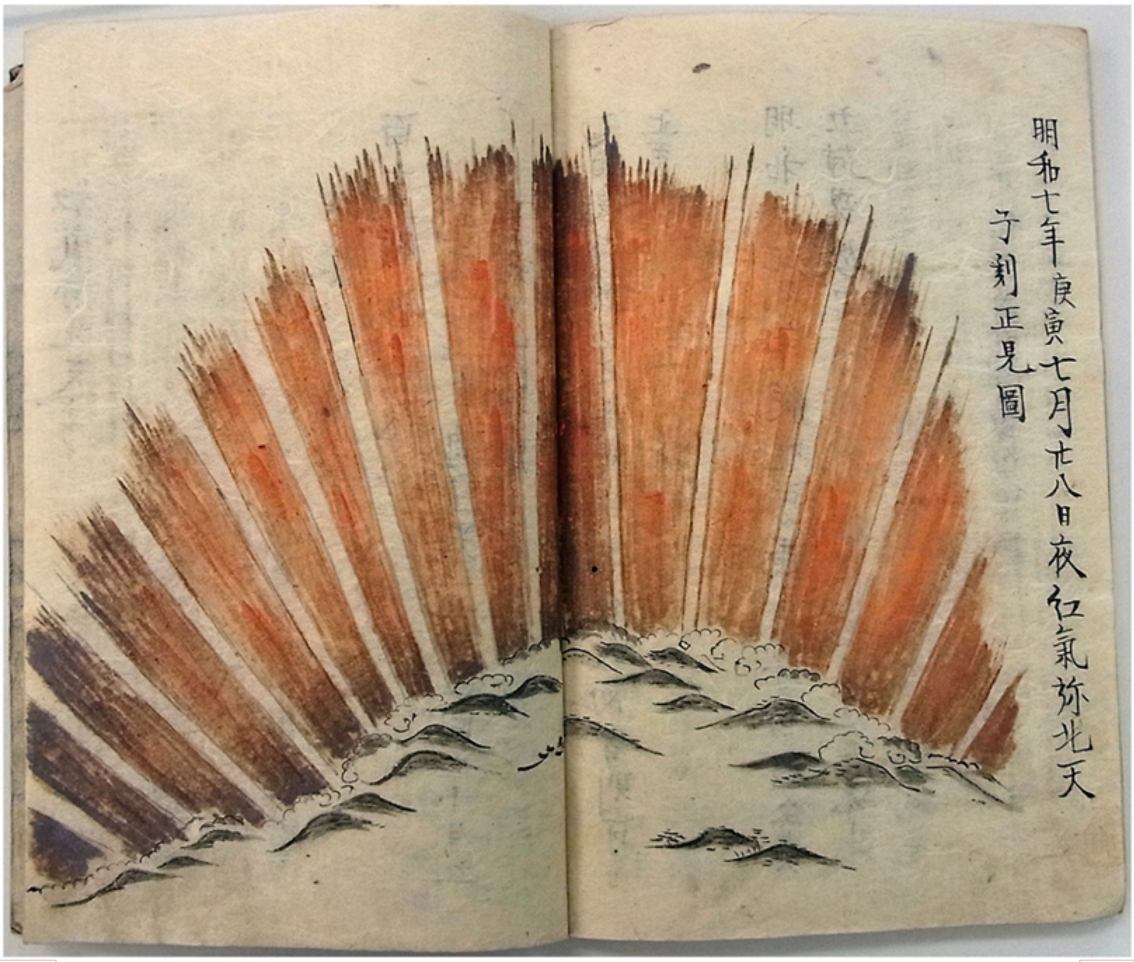
The 10-11 May 2024 geomagnetic storm was the most severe storm in over 2 decades. It also had a very long duration. According to the final Kp values published by GFZ Potsdam (https://kp.gfz.de/en/), the Kp index (https://www.stce.be/educational/classification#geomag) was at 8- or higher, i.e. at severe or extremely severe levels, for no less than 33 consecutive hours or 11 3-hour intervals (see graph underneath). This duration is very comparable with the 13-14 March 1989 and 18-19 September 1941 storms, the trio exceeding most of the other long and severe storm durations (since 1932) by 3 to 5 3-hour intervals. On some occasions, a succession of passing coronal mass ejections (CMEs) resulted in a near-continuous level of geomagnetic storming. An example are the Halloween storms in 2003, when two CMEs distinctly separated in time by nearly a half day passed the geospace resulting in extreme geomagnetic storms on 29-30 and 30-31 October. Observers in Belgium saw the aurora on both nights, getting the impression this was one continuous storm - which it wasn't. Of course, when the CMEs are launched in quick succession and with increasing speed, the more recent CMEs may catch up with the preceding ones ("CME cannibalism") or follow each other in close time intervals (hours or less) when they pass the earth environment. Then the result is one strong, long-lasting geomagnetic storm, such as the May 2024 event when "... the fast and dense solar wind structures from (up to 6) CMEs interacted with one another, forming a composite interplanetary CME (ICME) with complex solar wind density and magnetic field structures embedded. ... " (Tulasi Ram et al. 2024 - https://doi.org/10.1029/2024SW004126).



It can be worse... The famous Carrington storm of 2-3 September 1859 seems to have been the result of a single CME. Yet, based on worldwide aurora observations, polar lights were visible from locations below 50 degrees latitude for at least 42 hours (Green and Boardsen 2006 - https://doi.org/10.1016/j.asr.2005.08.054). From this, one can reasonably assume that Kp was at severe and extremely severe levels for at least that duration, so at least 14 3-hour intervals! Mind-boggling.

It can get even worse... A few years ago, Hisashi Hayakawa and co-workers (2017 - https://doi.org/10.3847/2041-8213/aa9661) as well as Kataoka and Iwahashi (2017 - https://doi.org/10.1002/2017SW001690) reported from historical documents in East Asia that low-latitude, i.e. below 30 degrees magnetic latitude (MLAT), auroral displays appeared in succession for almost nine nights from 10 to 19 September 1770, except for the 12th. The most equatorward sightings were from 18.8 MLAT from Dòngtínghú (Hunan, China), and from near Timor Island in the southern hemisphere (-20.6 MLAT) as observed by Joseph Banks and Sydney Parkinson on board HMS Endeavour as specialist members of Captain Cook’s crew. Hence, these observations are now known to be the earliest record of simultaneous auroral observations in both hemispheres. The latitudinal extents of 1770 auroral events were at least comparable with those of the Carrington event.

The aurorae were extremely bright, especially on 17 September when they were as bright as the full moon according to local reports. The color was deep red, and many suspected fires in distant cities. As the aurora grew higher and brighter in the sky, people protectively started pouring water on the roofs of their houses because they thought the fire from the sky might rain onto their roofs. Others started divine dances and prayed to the Buddha, fearing the end of the world had arrived. Still others commented also on the luminous stripes within the red vapour, comparable to solar rays shining through the clouds.



Credits: Seikai / Matsusaka City (Japan) – Kataoka & Iwahashi (2017)

There are not many solar drawings from that time (Clette et al. 2015 - https://doi.org/10.1007/s11214-014-0074-2), with September 1770 being just one year after the maximum of moderate solar cycle 2. Though the accuracy and level of detail of Johann Caspar Staudacher's drawings are not of the best quality, his sunspot drawings revealed an extremely large and complex sunspot group that rotated over the solar disk from 12 to 22 September 1770 (see Hayakawa et al. 2017 - https://doi.org/10.3847/2041-8213/aa9661). This large active region looked like a (large) bunch of grapes and was even observed by naked eye in Japan around 17 September 1770. Measurements on the drawing from the day before indicates a sunspot area up to 6000 millionths of the Sun's visible hemisphere (MH ; https://www.stce.be/educational/acronym#M), more than twice the size of the sunspot group during the Carrington event in 1859 and comparable to the largest known sunspot group that appeared in April 1947 (see the STCE newsitems https://www.stce.be/news/457/welcome.html and https://www.stce.be/news/280/welcome.html).

The low-latitude aurorae were almost continuously observed for nine nights, but most likely only the aurora from 15 to 19 September were due to eruptions (and associated CMEs) from the large sunspot region. Most of the storm highlights date from 16 to 18 September. But even then, a duration of 3 to 5 days of severe to extremely severe geomagnetic storming is exceptionally long. In many geomagnetic storms, the duration is only one or two nights. The long duration of the auroral observations in 1770 indicates long-lasting geomagnetic storm activities resulting from continuous solar activity, such as multiple, consecutive CMEs most likely -in this case- originating from the same sunspot group.

2. Review of space weather

Solar Active Regions (ARs) and flares

The solar flaring activity was low to moderate, with 30 C-class flares and 3 M-class flares. There were 15 sunspot groups (SG) observed on the visible solar disk. SIDC SG 624 (NOAA AR 4207) and SIDC SG 614 (NOAA AR 4197) produced most of the flaring activity. SIDC SG 614 (NOAA AR 4197) rotated off the visible disk at the end of the week. The largest flare was an M1.4-flare (SIDC Flare 5430), with peak time 01:16 UTC on September 05 and was associated with SIDC SG 624 (NOAA AR 4207).

Coronal mass ejections

A Coronal mass ejection (CME) was seen in LASCO-C2 data at 02:24 UTC on September 03, which is associated with a filament eruption seen in SDO/AIA 194 and 304 at 01:28 UTC on September 03 on the northwest quadrant of the solar disk. A faint halo CME was seen in LASCO-C3 data at 20:36 UTC on September 04, which is associated with an eruption in SDO/AIA 304 at 19:22 UTC on September 04 near the center of the solar disk.

Coronal Holes

Three positive polarity coronal holes crossed the meridian during the week.
Returning, equatorial SIDC Coronal Hole 123 reached the central meridian on September 02. Its previous crossing time was on August 06. Its high-speed stream (HSS) reached Earth on September 06.
Equatorial SIDC Coronal Hole 128 reached the central meridian on September 03 and equatorial SIDC Coronal Hole 129 on September 04.

Proton flux levels

The greater than 10 MeV GOES proton flux was still elevated on September 01. This was due to a CME that left the Sun on August 30.

Electron fluxes at GEO

The greater than 2 MeV electron flux, as measured by the GOES-19 was above the 1000 pfu threshold between 18:55 UTC and 22:50 UTC on September 05. The greater than 2 MeV electron flux, as measured by the GOES-18 was below the threshold throughout the week.
The 24-hour electron fluence was nominal.

Solar wind near Earth

The solar wind got disturbed by the arrival of an ICME on September 01 at 20:20 UTC. This disturbance lasted until September 03.
On September 06, the solar wind gradually speeded up due to a high-speed stream associated with SIDC Coronal Hole 123.
At 13:50 UTC that day, the signature of an Interplanetary CME was seen in the solar wind. This ICME could be associated with the CME seen on September 03 or with the CME from September 04.
During both disturbed periods, the solar wind speed was above 600 km/s. The interplanetary magnetic field was for a few hours below zero with a minimum of - 23 nT during the first period.
The phi-angle was in the negative sector until September 02 when it switched to the positive sector for the rest of the week.

Geomagnetism

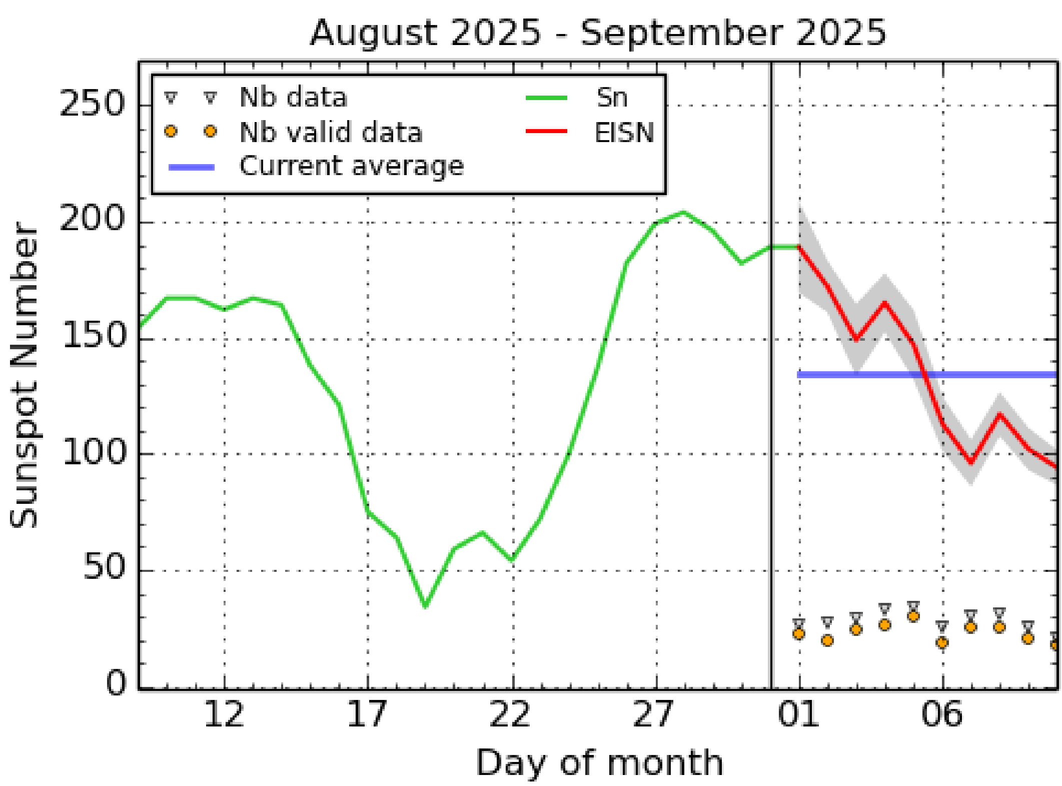
The geomagnetic conditions reached moderate storm conditions globally (Kp 6) and minor storm conditions locally (K BEL 5) at the start of the week under the influence of the first ICME, by September 03 they had returned to quiet to unsettled conditions. They reached minor storm levels globally and locally (Kp 5 nd K BEL 5) on September 06 under the influence of a high-speed stream and the second ICME arrival. The period ended with quiet geomagnetic conditions.

3. Noticeable Solar Events

DAY	BEGIN	MAX	END	LOC	XRAY	OP	10CM	TYPE	Cat	NOAA
04	1336	1344	1349	N30E8	M1.0	1B			8	4207
05	0108	0116	0121	N28E0	M1.4	1N		III/2VI/2		4207
06	2207	2215	2217		M1.2					4207

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

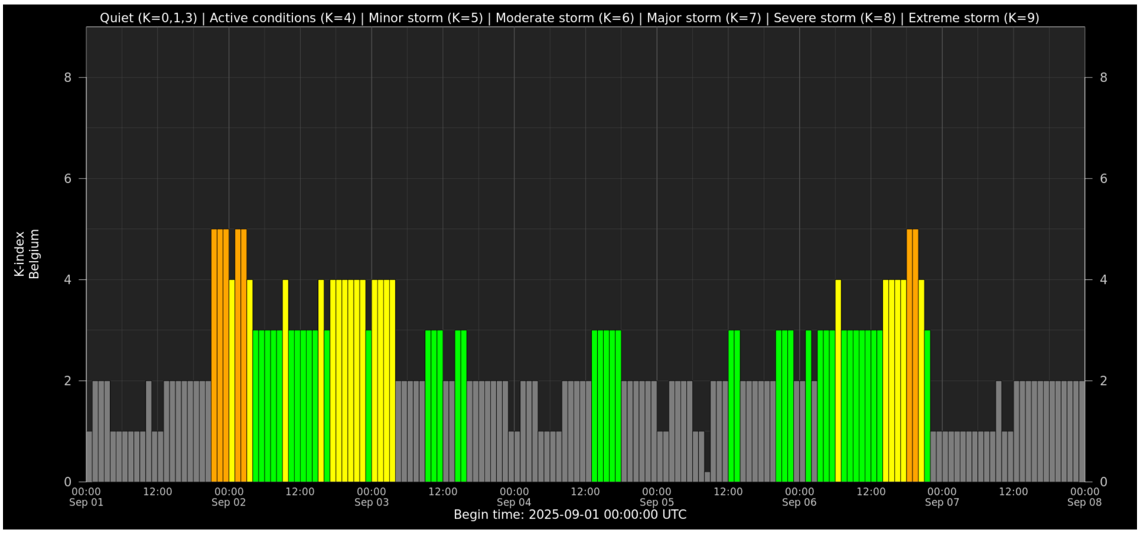
4. International Sunspot Number by SILSO



SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium, 2025 September 10

The daily Estimated International Sunspot Number (EISN, red curve with shaded error) derived by a simplified method from real-time data from the worldwide SILSO network. It extends the official Sunspot Number from the full processing of the preceding month (green line), a few days more than one solar rotation. The horizontal blue line shows the current monthly average. The yellow dots give the number of stations that provided valid data. Valid data are used to calculate the EISN. The triangle gives the number of stations providing data. When a triangle and a yellow dot coincide, it means that all the data is used to calculate the EISN of that day.

5. Geomagnetic Observations in Belgium



Local K-type magnetic activity index for Belgium based on data from Dourbes (DOU) and Manhay (MAB). Comparing the data from both measurement stations allows to reliably remove outliers from the magnetic data. At the same time the operational service availability is improved: whenever data from one observatory is not available, the single-station index obtained from the other can be used as a fallback system.
Both the two-station index and the single station indices are available here: http://ionosphere.meteo.be/geomagnetism/K_BEL/

6. PROBA2 Observations (1 Sep 2025 - 7 Sep 2025)

Solar Activity

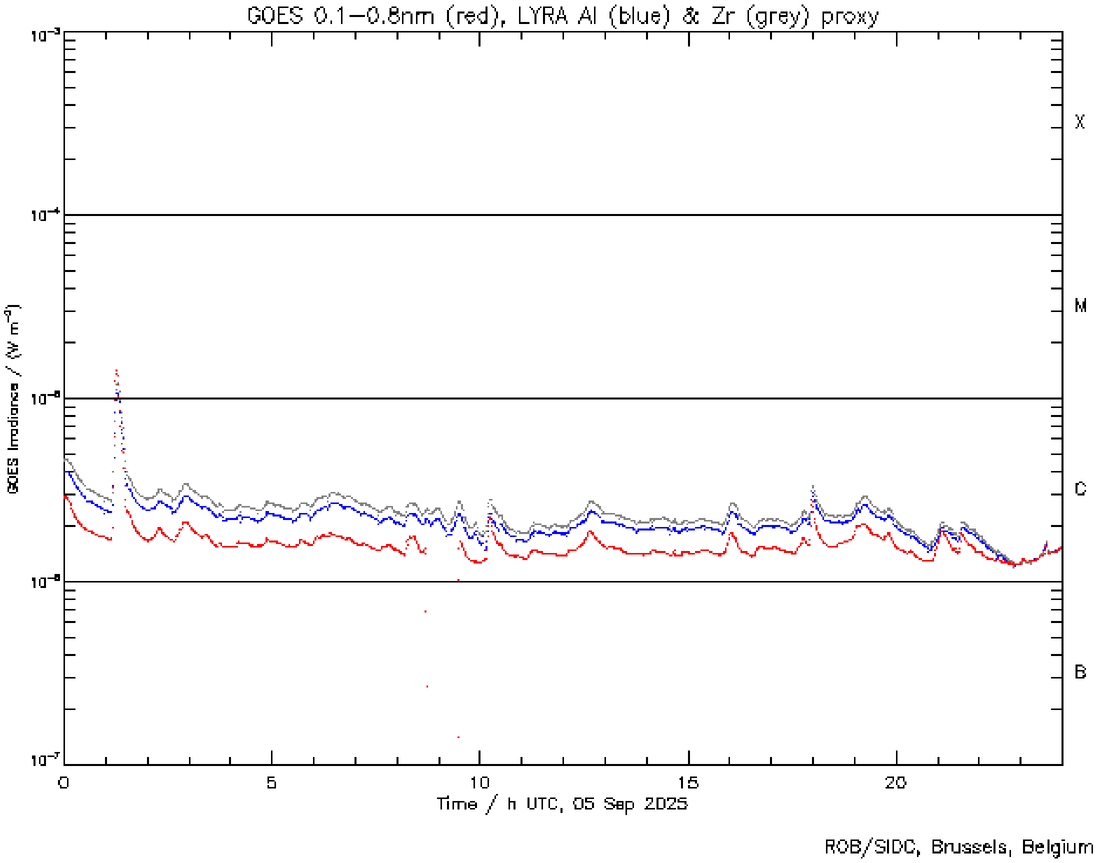
Solar flare activity fluctuated from low to moderate during the week.
In order to view the activity of this week in more detail, we suggest to go to the following website from which all the daily (normal and difference) movies can be accessed: https://proba2.oma.be/ssa
This page also lists the recorded flaring events.

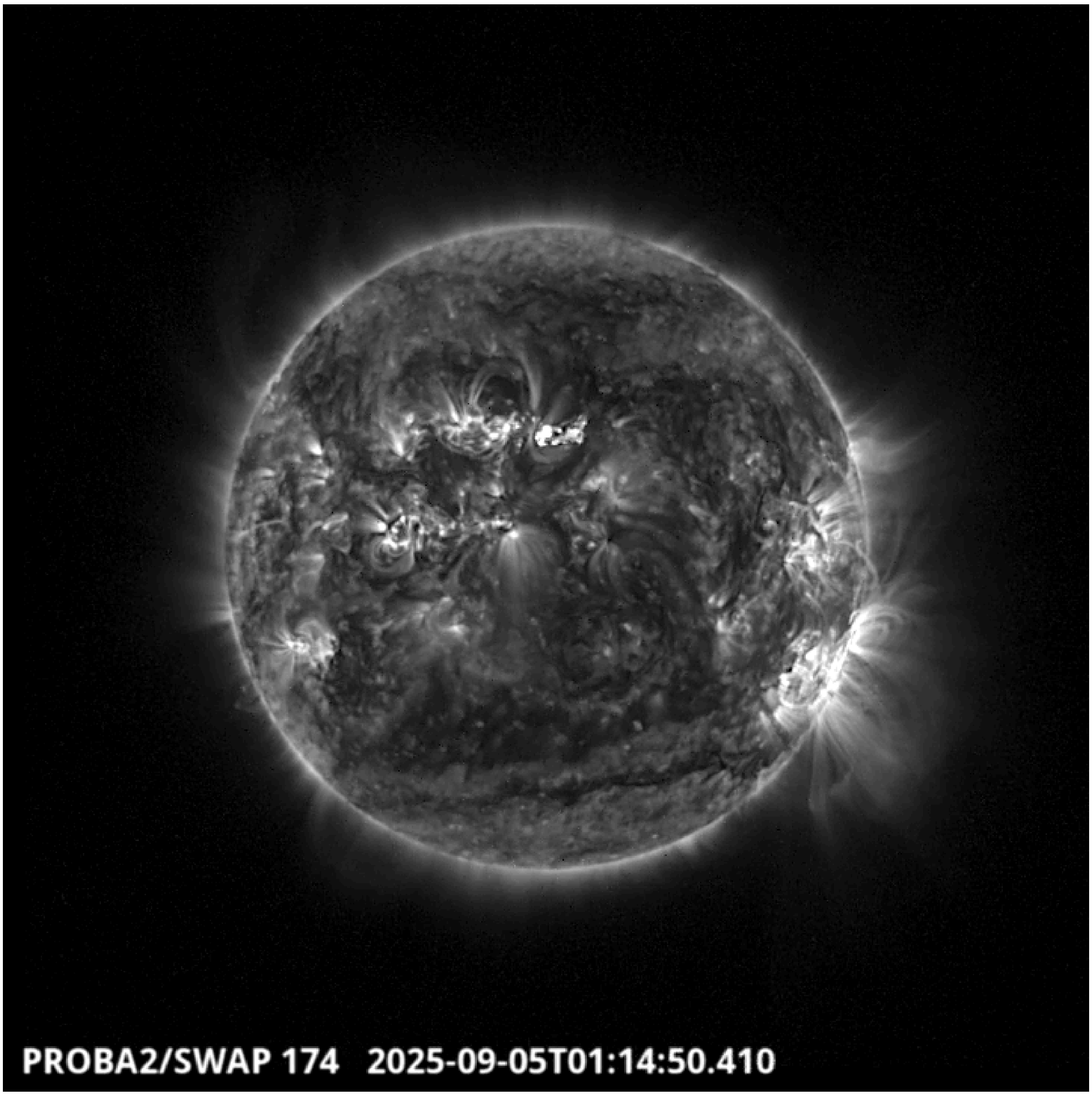
A weekly overview movie (SWAP week 806) can be found here: https://proba2.sidc.be/swap/data/mpg/movies/weekly_movies/weekly_movie_2025_09_01.mp4.

Details about some of this week's events can be found further below.

If any of the linked movies are unavailable they can be found in the P2SC movie repository here: https://proba2.oma.be/swap/data/mpg/movies/.

Friday September 05





The largest flare of this week was an M1.4, and it was observed by LYRA (top panel) and SWAP (bottom panel). The flare peaked on 2025-Sep-05 at 01:16 UT and occurred close to the central meridian, in the northern hemisphere of the Sun, originating from active region NOAA4207 (SIDC 624).
Find a SWAP movie of the event here: https://proba2.sidc.be/swap/movies/20250905_swap_movie.mp4.

7. The SIDC space Weather Briefing (1 Sep 2025 - 7 Sep 2025)

The forecaster on duty presented the SIDC briefing that gives an overview of space weather from September 1 to 7.
The pdf of the presentation: https://www.stce.be/briefings/20250908_SWbriefing.pdf

SIDC Space Weather Briefing

01 September 2025-07 September 2025

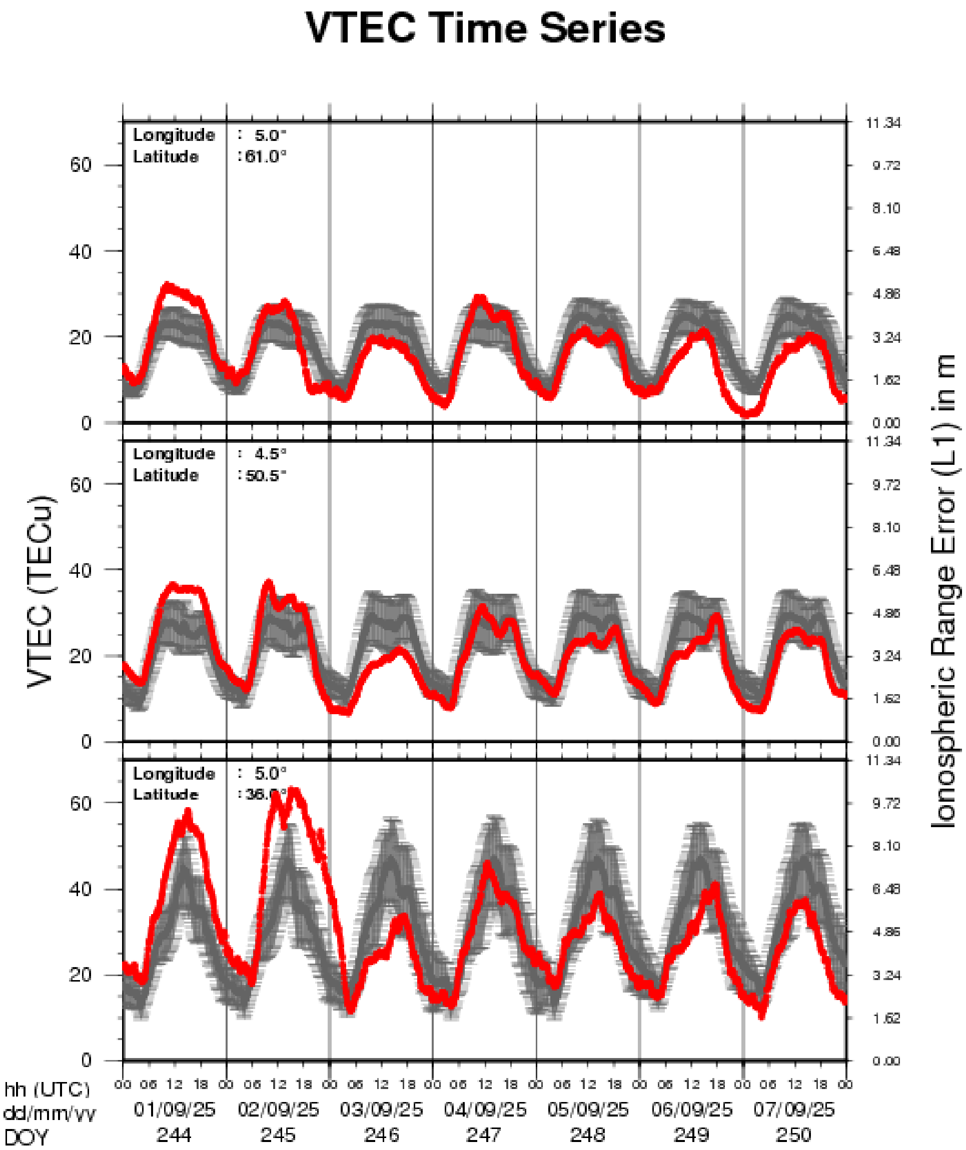
Vansintjan Robbe

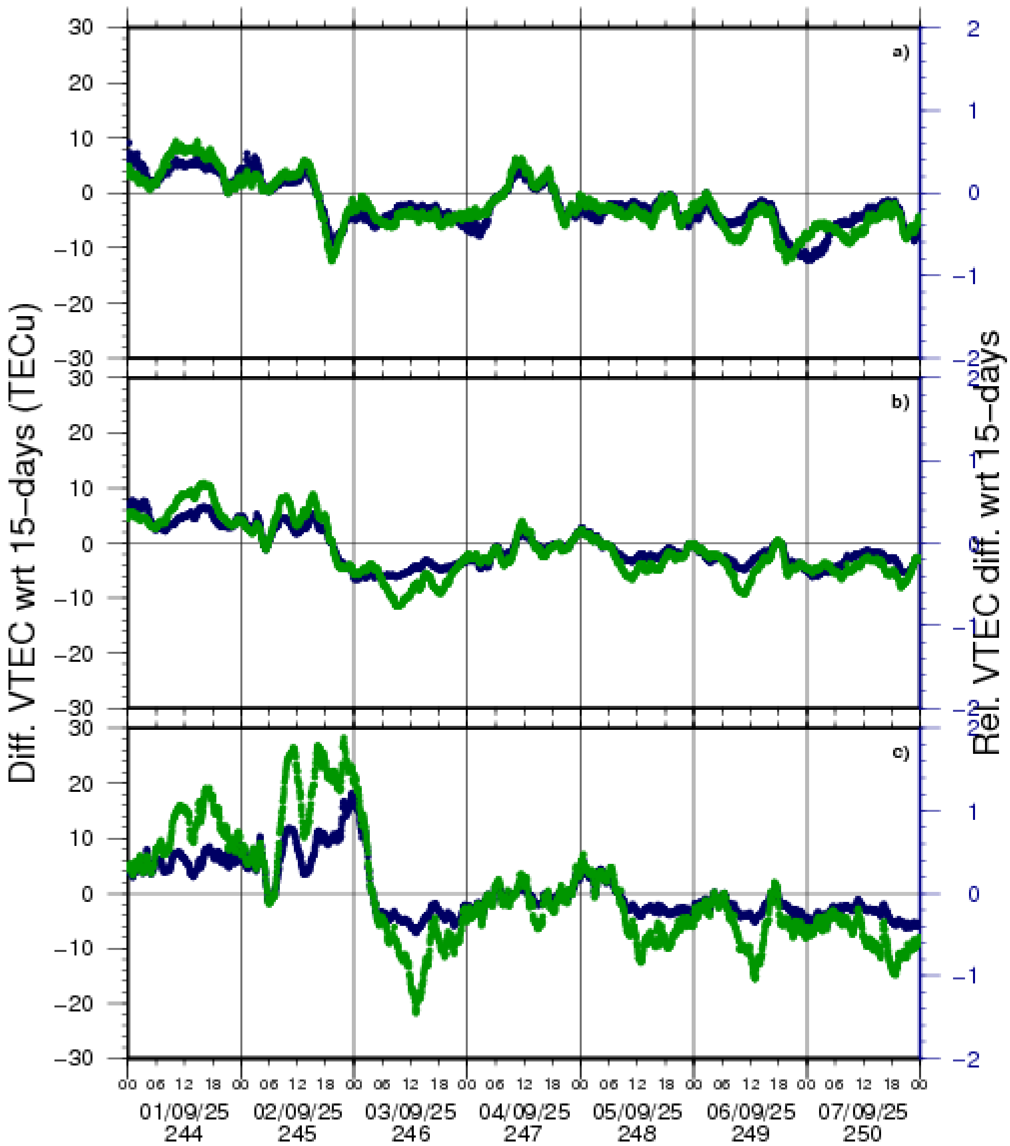
& the SIDC forecaster team

Royal Observatory of Belgium

Solar Influences Data analysis Centre
www.sidc.be

8. Review of Ionospheric Activity





VTEC time series at 3 locations in Europe from 1 Sep 2025 till 7 Sep 2025

The top 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(N 61deg E 5deg)
b) above Brussels(N 50.5deg, E 4.5 deg)
c) in the southern part of Europe(N 36 deg, E 5deg)
This top figure also shows (in grey) the normal ionospheric behaviour expected based on the median VTEC from the 15 previous days.

The time series below shows the VTEC difference (in green) and relative difference (in blue) with respect to the median of the last 15 days in the North, Mid (above Brussels) and South of Europe. It thus illustrates the VTEC deviation from normal quiet behaviour.

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 more information, see https://gnss.be/SpaceWeather

9. STCE trainings and presentations

Courses, seminars, presentations and events with the Sun-Space-Earth system and Space Weather as the main theme. We provide occasions to get submerged in our world through educational, informative and instructive activities.

* Sep 20, Public Lecture: België op weg naar de zon met Proba-3, UGhent Volkssterrenwacht Armand Pien, Gent, Belgium
* Oct 23-25, ESWW Space Weather Training by Umea University and STCE, Kiruna, Sweden - Full
* Oct 27-31, European Space Weather Week, Umea, Sweden - https://esww.eu/
* Nov 17-19, STCE Space Weather Introductory Course, Brussels, Belgium - register: https://events.spacepole.be/event/217/

To register for a course and check the seminar details, navigate to the STCE Space Weather Education Center: https://www.stce.be/SWEC
If you want your event in the STCE newsletter, contact us: stce_coordination at stce.be

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