STCE Newsletter

17 Mar 2025 - 23 Mar 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. Partial Solar Eclipse on March 23

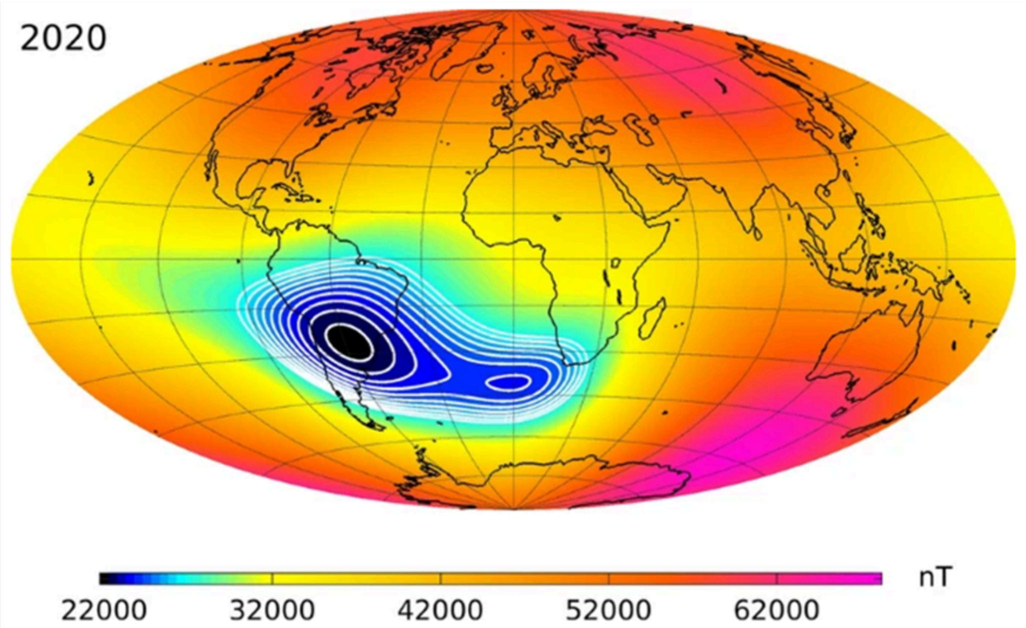
On Saturday, March 29 2025 will take place a partial solar eclipse visible from Belgium. In Brussels, it will start at 11:14 (local time), with a maximum at 12:07 and will end at 13:01.
The solar physics department from the Royal Observatory of Belgium will broadcast live the progression of the eclipse as seen by its ground based optical and radio telescopes on the following website: https://www.sidc.be/uset/Eclipse2025/

The Belgian satellite PROBA-2 will also observe the eclipse and its data will be online as soon as they are received. More info is available here: https://proba2.sidc.be/NearlyTotalEclipse

Watch out: Do never stare directly at the Sun as it can permanently damage your eyesight !

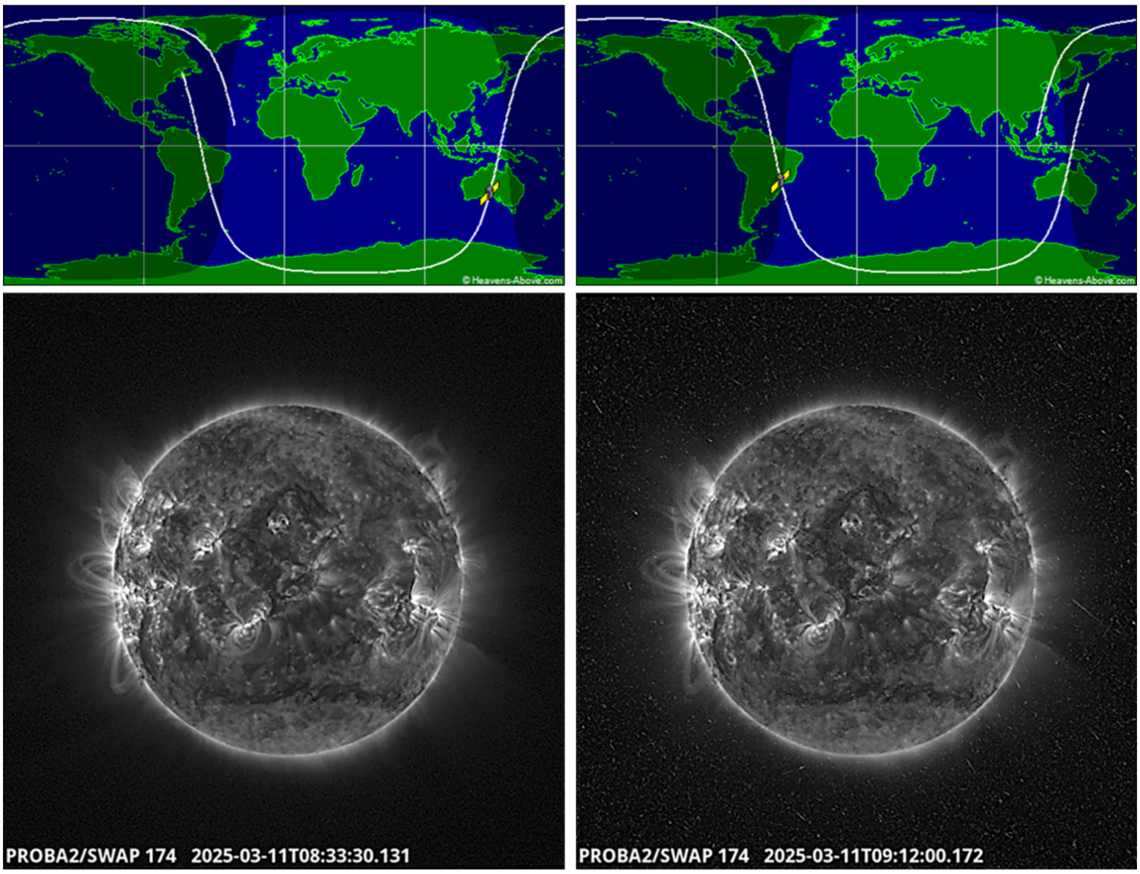
2. Radiation in space

On 18 March, the American astronauts Sunita Williams and Barry Wilmore landed safely in the Gulf of Mexico after having spent 286 days in the International Space Station (ISS). The record for longest single-mission stay in space is 437 days, set by the Russian cosmonaut Valeri Polyakov on board the MIR space station in 1994-1995. Long stays in space are not a blessing for the human body. In particular with the ambition to travel to Mars, astronauts face several threats, neatly captured by NASA in the acronym "RIDGE", which is short for Space *R*adiation, *I*solation and Confinement, *D*istance from Earth, *G*ravity fields, and Hostile/Closed *E*nvironments (NASA/Cranford and Turner, 2021). These hazards have both medical and psychological effects on the astronauts, with an elaborate list of issues (from loss of bone density and muscle mass over sleep disorders and hormonal changes to cancer and DNA damage) in e.g. Tomsia et al. (2024), Straume (2015), and a more digestable article by ESA (see the reference list at the end of this newsitem).

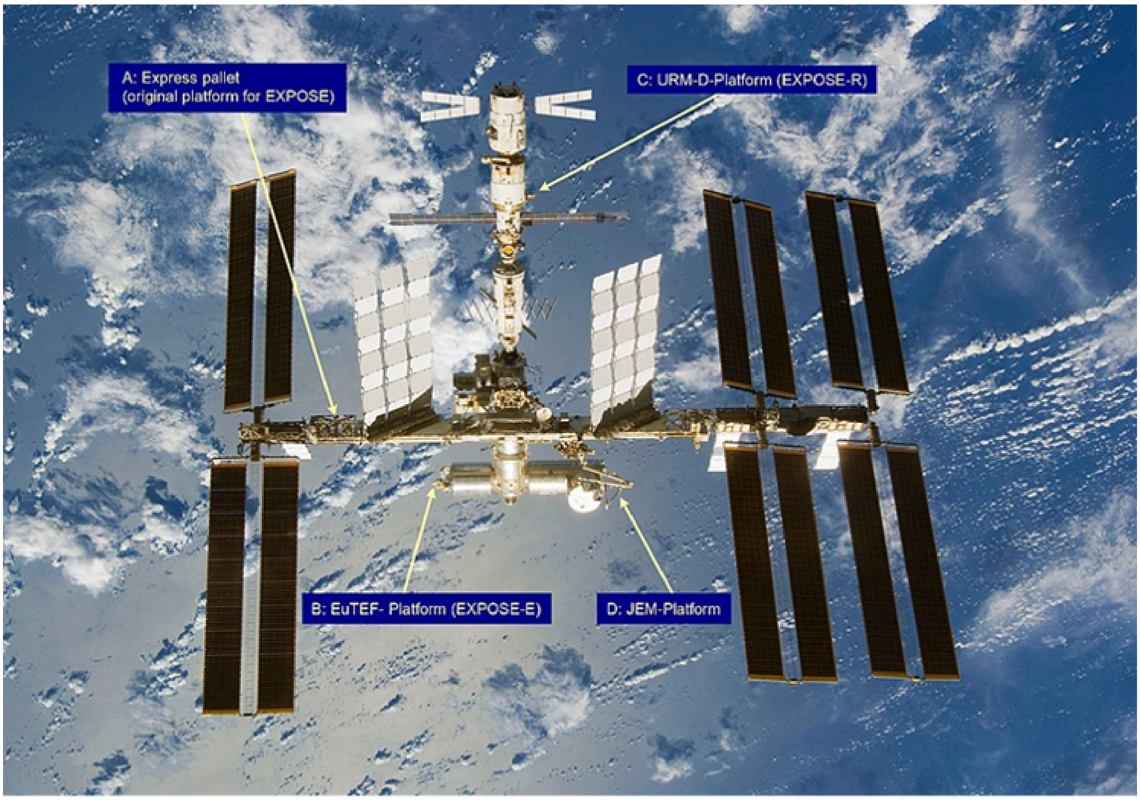


Field strength of Earth's magnetic field as of 2020, as measured by ESA's SWARM satellite constellation. The SAA is visible over South America. – Credits: Christopher C. Finlay, Clemens Kloss, Nils Olsen, Magnus D. Hammer, Lars Tøffner-Clausen, Alexander Grayver & Alexey Kuvshinov (CC BY-SA 4.0)

For interplanetary travels, being outside the protective cocoon of the Earth's magnetic field, the main sources of space radiation are the galactic cosmic rays (GCR - https://www.stce.be/news/433/welcome.html) and the solar energetic particles (SEP - https://www.stce.be/content/sc25-tracking#proton). The radiation dose is two to three times higher than that received on the ISS. Indeed, the Earth's magnetic field provides a reasonable protection against these particles. However, there's a third major source of energetic particles here, due to a weakness in the geomagnetic field over South-America. This "South Atlantic Anomaly" (SAA - see image above) allows the inner radiation belt to move closer to Earth, and thus there are more energetic particles closer to the Earth. This can be seen in the comparison of PROBA2 images underneath. In the left column is a solar image made by PROBA2 (https://proba2.sidc.be/ssa) while it was flying just south of Australia (upper image; https://heavens-above.com/). Barely 40 minutes later, PROBA2 is flying through the SAA (right column) and the effects are clearly visible: the corresponding solar image suffers considerably from the noise generated by the energetic particles slamming into the pixels of PROBA2's camera (SWAP).

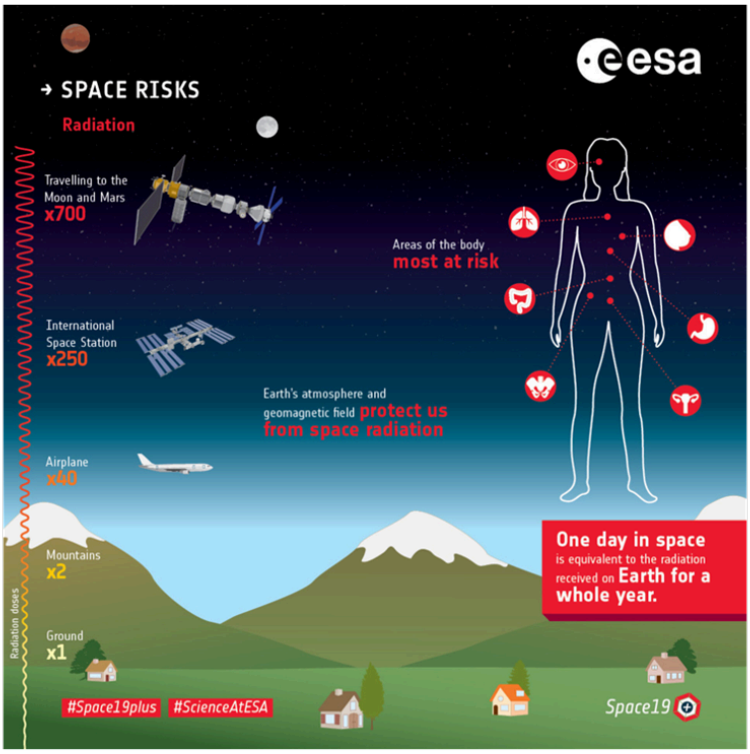


A study by Dachev et al. (2017), using ESA's EXPOSE-R2 facility and covering the period October 2014 - January 2016, indicated that 20% of the space radiation outside the ISS is coming from GCR, 57% from the SAA, 22% from highly energetic electrons precipitating from the Van Allen radiation belts following geomagnetic activity (Dachev 2018), and only 1% from SEP. The latter is because during the observation period, there were only a few and weak proton events generated by the Sun. In practice, these percentages are quite variable, depending -amongst other- upon the phase and intensity of the solar cycle during which the observations are made.



Credits: NASA – Location of the EXPOSE-R (and -R2) aboard the ISS

Crews aboard the space station receive an average dose of 80 mSv (millisievert ; a unit to quantify the amount of radiation absorbed by the body) for a six-month stay during solar cycle maximum, and an average of 160 mSv for a six-month stay during solar cycle minimum (NASA/MSFC, 2017). This difference is because during higher solar activity, there are more coronal mass ejections which effectively act as magnetic shields against the incoming GCR. For a six-month journey to Mars an astronaut would be exposed to roughly 300 mSv, and that's one way only. On Earth, we receive an average of 2 to 3 mSv every year from natural background radiation alone. Note that the dose may vary drastically - from 0.5 mSv up to 70 mSv (!) per year- from one region to another (Restier-Verlet et al., 2021). For reference: Although the type of radiation is different, 1 mSv of space radiation is approximately equivalent to receiving 10 chest x-rays.



Credits: ESA - https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Radiation_sensitive

So, from the above, it is likely that Sunita Williams and Barry Wilmore have accumulated somewhere between 150 and 250 mSv during their 286-day stay at the ISS, with the actual value most likely closer to the lower end. This comes on top of the space radiation accumulated during previous space flights. Indeed, Sunita Williams and Barry Wilmore have clocked resp. 608 and 464 days in space, including resp. 62 and 31 hours of extra-vehicular activitities (space walks). The career limits for space radiation currently set by NASA and ESA are resp. 600 and 1000 mSv (Boscolo et al. 2022). Thus, it looks like both astronauts still have margin for a few more space flights.

Credits: NASA - https://www.nasa.gov/image-article/sunita-williams-spacewalk/

References and further literature

- NASA/Cranford and Turner, 2021 - The human body in space - https://www.nasa.gov/humans-in-space/the-human-body-in-space/
- Tomsia et al., 2024 - Long-term space missions'effects on the human organism: what we do know and what requires further research - https://doi.org/10.3389/fphys.2024.1284644
- Straume, 2015 - Medical Concerns with Space Radiation and Radiobiological Effects - https://doi.org/10.1007/978-3-319-03952-7_4
- ESA - Radiation and life - https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Lessons_online/Radiation_and_life
- Dachev et al., 2017 - Overview of the ISS Radiation Environment Observed during the ESA EXPOSE-R2 Mission in 2014–2016 - https://doi.org/10.1002/2016SW001580
- Dachev, 2018 - Relativistic electron precipitation bands in the outside radiation environment of the International space station - https://doi.org/10.1016/j.jastp.2017.11.008
- NASA/MSFC, 2017 - Space faring: The radiation challenge - https://www.nasa.gov/wp-content/uploads/2017/04/radiationchallenge.pdf?emrc=ba69fb
- Restier-Verlet et al., 2021 - Radiation on Earth or in Space: What Does It Change? - https://doi.org/10.3390/ijms22073739
- Boscolo et al. 2022 - Dose Limits and Countermeasures for Mitigating Radiation Risk in Moon and Mars Exploration - https://doi.org/10.3390/physics4010013

3. Promo Space Weather

Amateur astronomer clubs are a valuable partner of the STCE to promote our activities and research towards the general public.

The STCE offered them a tailored Space Weather Introductory Course. We released during 2 days loads of info and showed them around.
Two days of nice interactions and enthusiasm!

4. Review of space weather

Solar Active Regions (ARs) and flares

Solar flaring activity was low to moderate. Twenty four (24) numbered active regions were observed on the Sun. Three (3) isolated M-class flares were recorded. The largest was an M1.5 flare (SIDC Flare 3879) peaking on March 19 at 20:40 UTC and was produced by SIDC Sunspot Group 440 (NOAA Active Region 4031). The other M-class flares were an M1.0 flare (SIDC Flare 3870) peaking on March 17 at 19:33 UTC, which was associated with a filament eruption near SIDC Sunspot Group 445 (NOAA Active Region 4033), and an M1.2 flare (SIDC Flare 3887) peaking on March 21 at 15:58 UTC, which was associated with SIDC Sunspot Group 405 (NOAA Active Region 4028). At the end of the week, the largest and most complex region on disk (with Beta-Gamma magnetic configuration) was SIDC Sunspot Group 450 (NOAA Active Region 4036). The other regions on the disk at the end of the week were simple and quiet.

Coronal mass ejections

Three possible Earth-directed Coronal Mass Ejections (CMEs) were detected in coronagraph imagery. A partial halo CME observed on March 16, was associated with on disk activity in the north-east of the solar disk. A filament erupted in the north-west quadrant on March 17 around 10:30 UTC with a CME seen in SOHO/LASCO-C2 data from 11:24 UTC. Thirdly, a faint partial halo CME to the south-east detected on March 21 16:00 UTC. This CME appears to originate from a dimming that occurred near the central meridian around 15:45 UTC March 21.

Coronal Holes

A small negative polarity equatorial coronal hole (SIDC Coronal Hole 93) began to cross the central meridian on March 19. At the end of the week SIDC Coronal Hole 60 (a mid-latitude coronal hole with a positive polarity) began to traverse the central meridian on March 23.

Solar Protons

The greater than 10 MeV proton flux measured by GOES-18 was below the 10pfu threshold.

Electron flux at GEO

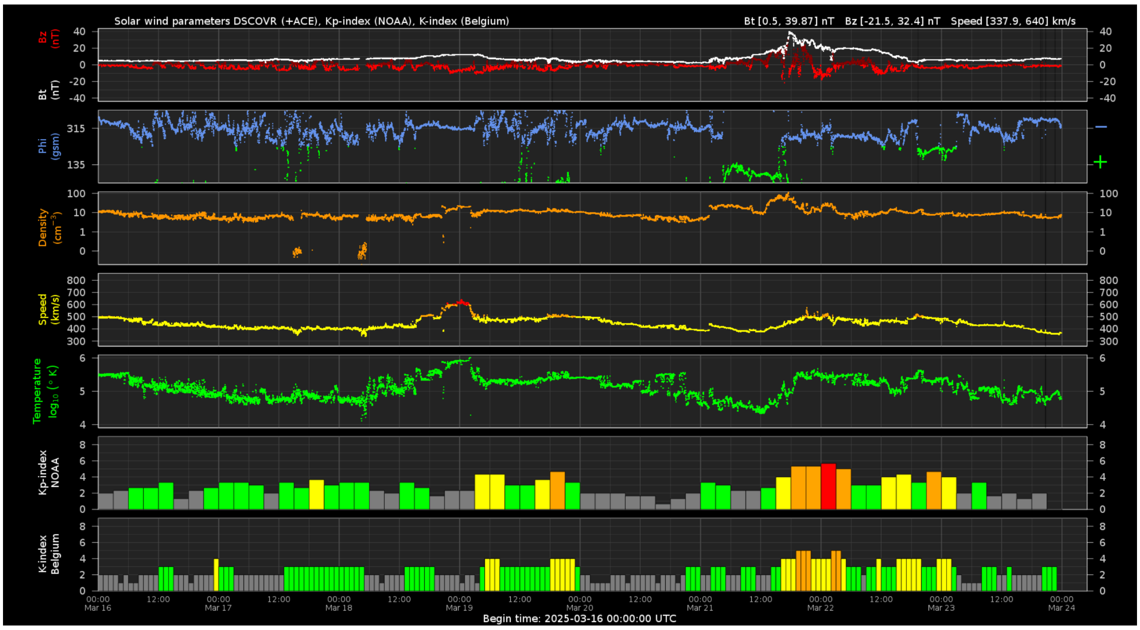
The greater than 2 MeV electron flux was above the 1000 pfu threshold between March 16 and March 19. It remained below the threshold for the remainder of the week. The 24h electron fluence was moderate luntil March 19. After this date, it was nominal.

Solar wind at L1

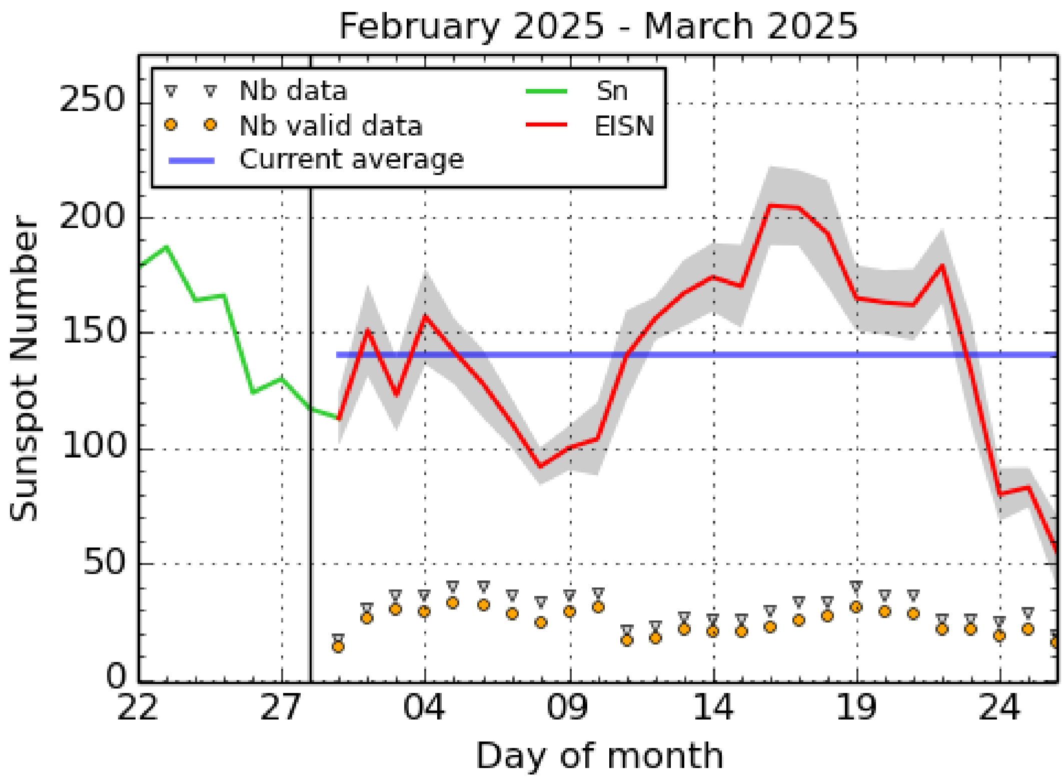
The solar wind was slow at the start of the week.
From 14:00 UTC on March 18, its magnetic field and speed was enhanced. The speed reached values near 600 km/s. This was likely a combination of a high-speed stream and a glancing blow from a CME. A shock was observed around 01:40 UTC on March 21. At this time, the total interplanetary magnetic increased from 3 nT to 6 nT, with the Bz component reaching a minimum of -6 nT. The solar wind speed jumped from 388 km/s to 440 km/s. The interplanetary magnetic field strength increased further reaching a maximum value of 39 nT at 17:43 UTC March 21. The Bz reached a minimum value of -22nT and was consistently negative for a sustained period between 22:30 UTC March 21 and 02:30 UTC March 22. The solar wind speed gradually increased during this time from 380 km/s to a maximum of around 550 km/s on March 22 around 21:00 UTC.
The top 5 panels in the image below describe the solar wind at the L1 point.

Geomagnetism

Geomagnetic conditions were mostly quiet to unsettled on March 16 to 18. On March 19 the conditions were active with one period of minor storm conditions. Moderate storm conditions (NOAA Kp 6-) were reached between 00:00 and 03:00 UTC on March 22. This was due to the ICME arrival and extended period of strong negative Bz. On March 23, the geomagnetic conditions reduced and were at unsettled to active conditions.
The 2 panels below in the image describe the geomagnetic conditions.



5. International Sunspot Number by SILSO



SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium, 2025 March 26

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.

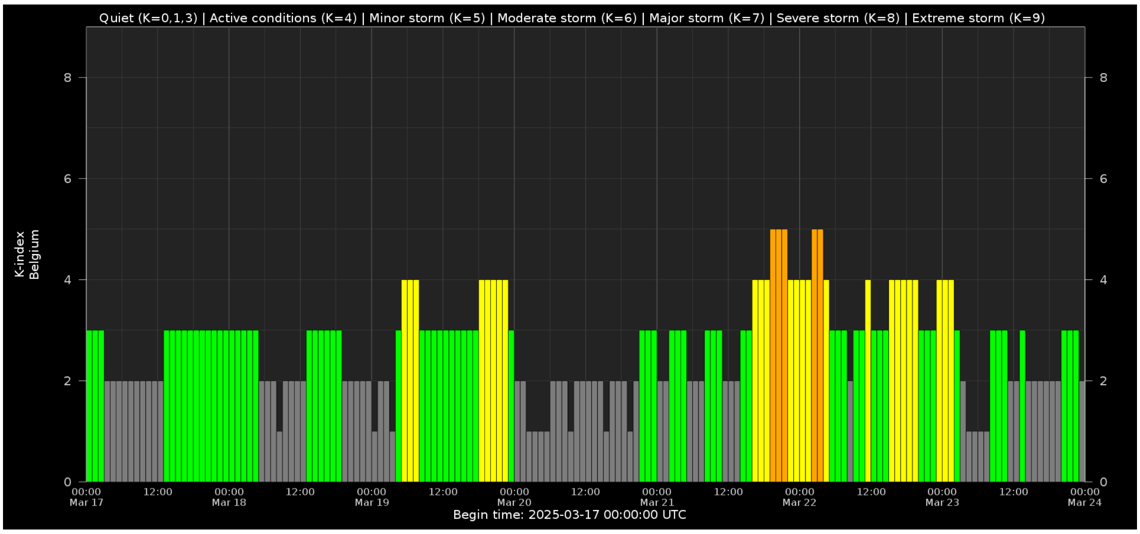
6. Noticeable Solar Events

DAY	BEGIN	MAX	END	LOC	XRAY	OP	10CM	TYPE	Cat	NOAA
17	1925	1933	1940		M1.0				95	4033
19	2021	2040	2047	N14W36	M1.5	1N			94	4031
21	1534	1558	1623	S19W31	M1.2	1N		TM/1I/1I/13	91	4028

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

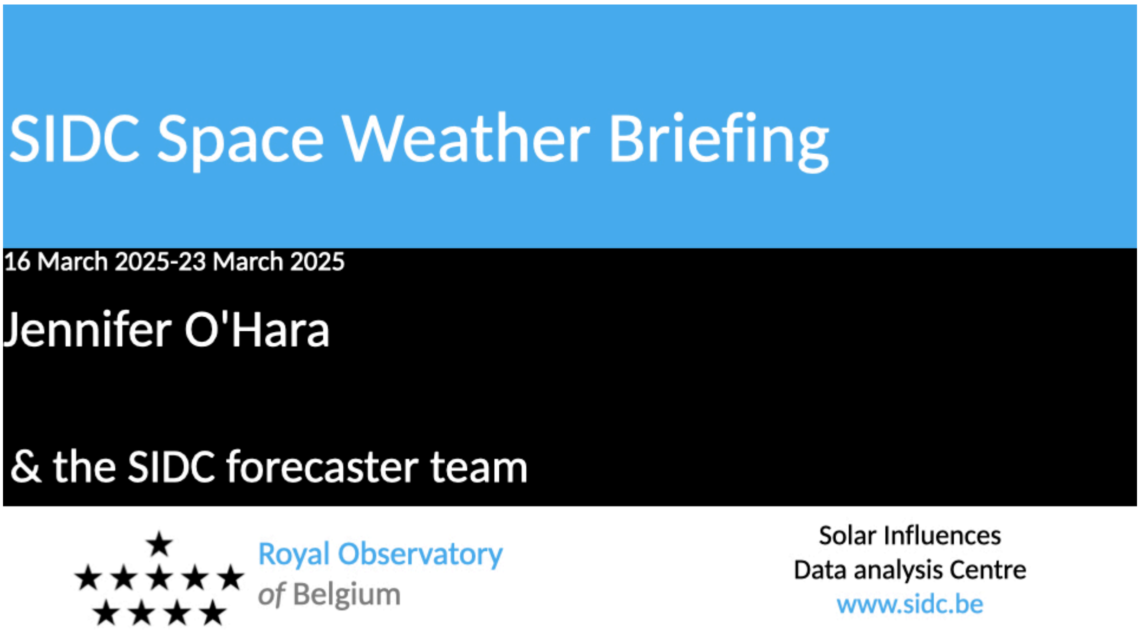
7. Geomagnetic Observations in Belgium



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/

8. The SIDC Space Weather Briefing

The forecaster on duty presented the SIDC briefing that gives a weekly overview of space weather.
The pdf of the presentation can be found here: https://www.stce.be/briefings/20250324_SWbriefing.pdf



9. PROBA2 Observations

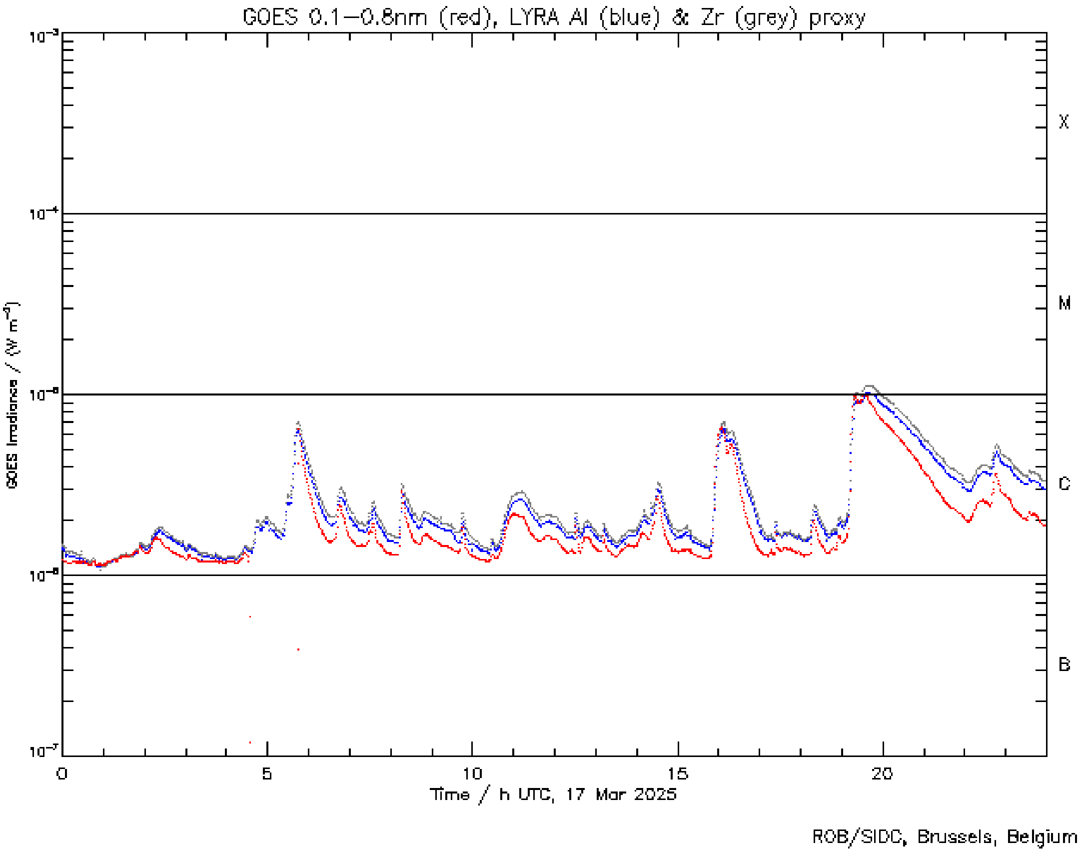
Solar Activity

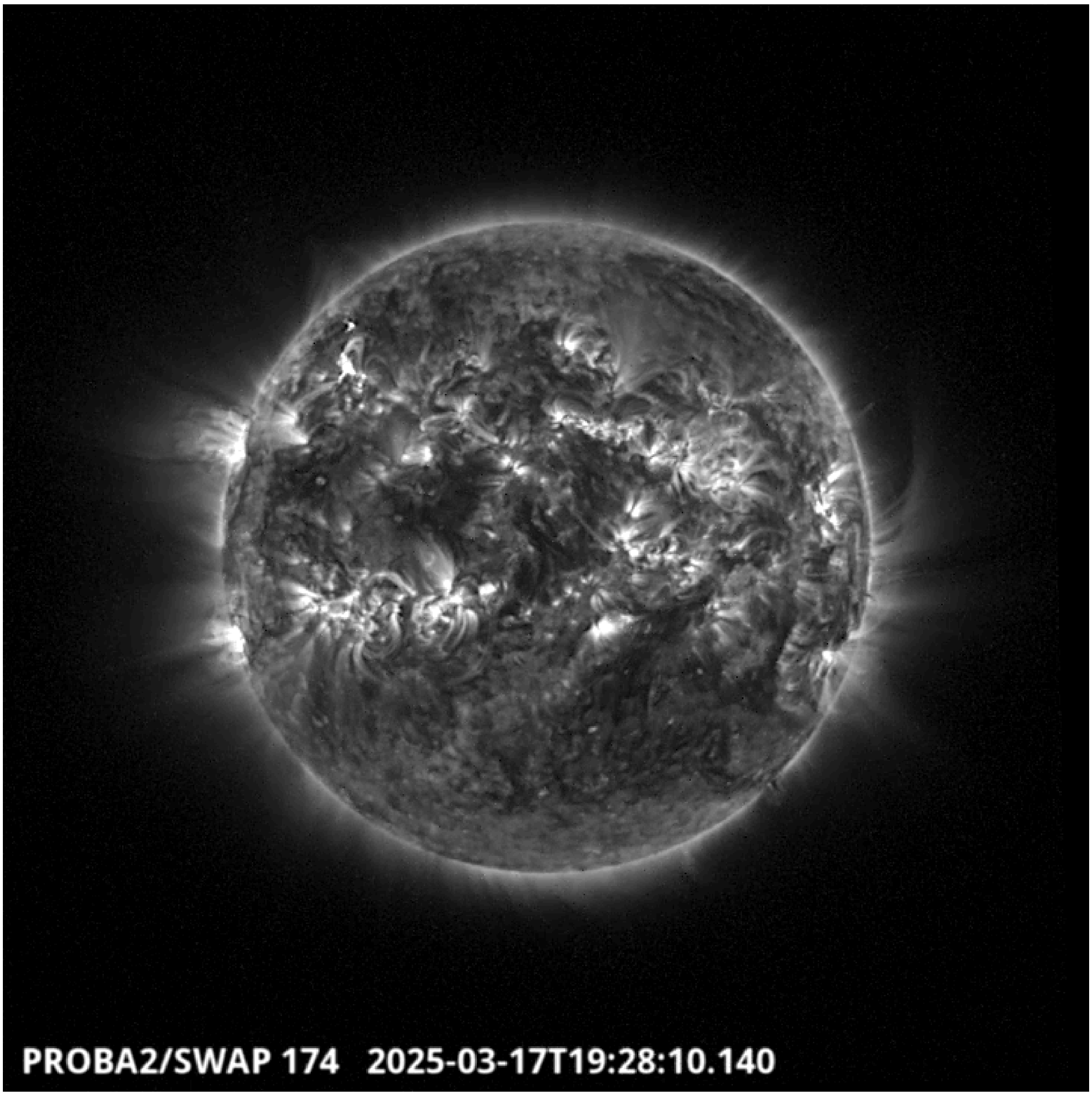
Solar flare activity fluctuated from low to moderate during the week.
In order to view the activity of this week in more detail, we suggest to go to the following website from which all the daily (normal and difference) movies can be accessed: https://proba2.oma.be/ssa

This page also lists the recorded flaring events.
A weekly overview movie can be found here (SWAP week 782). https://proba2.sidc.be/swap/data/mpg/movies/weekly_movies/weekly_movie_2025_03_17.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.sidc.be/swap/data/mpg/movies/

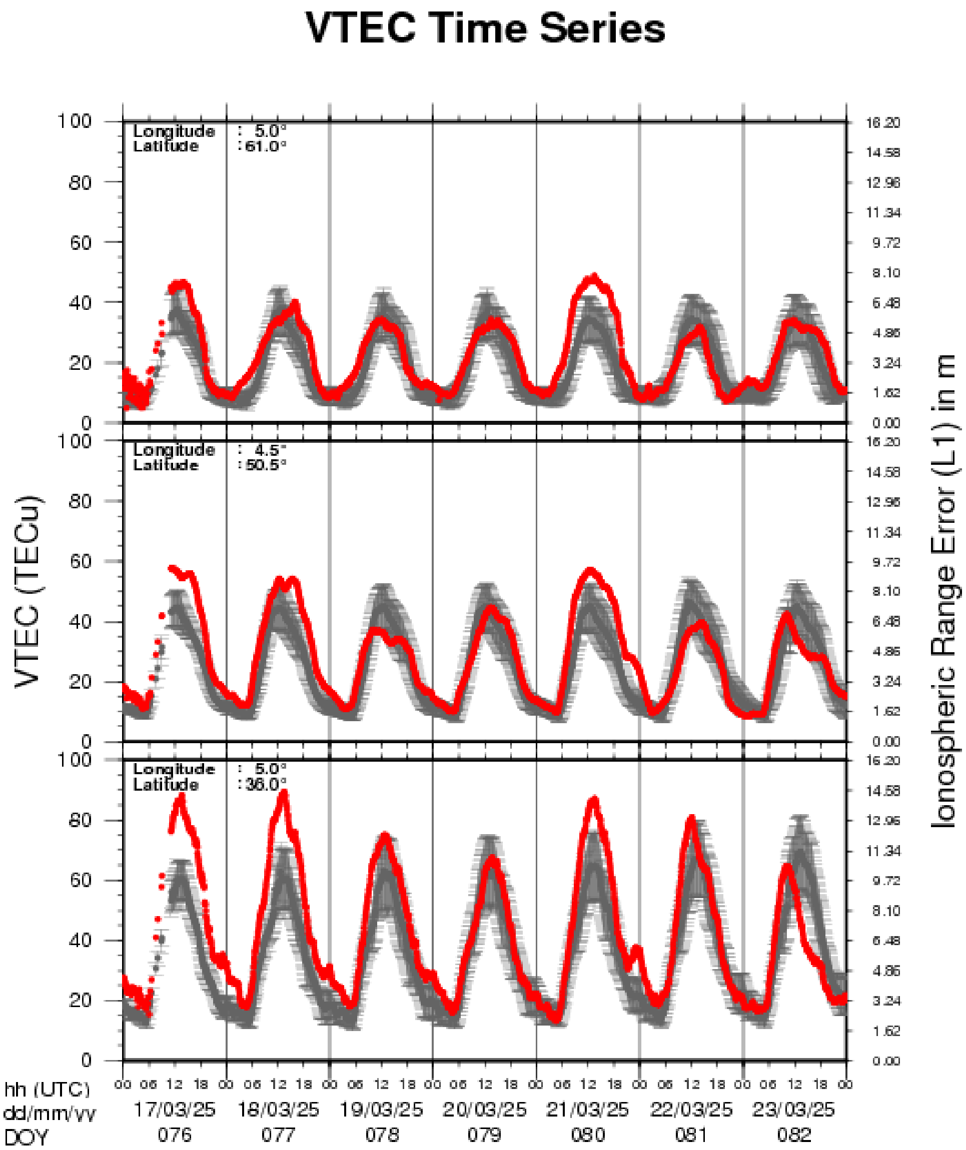
Monday Mar 17

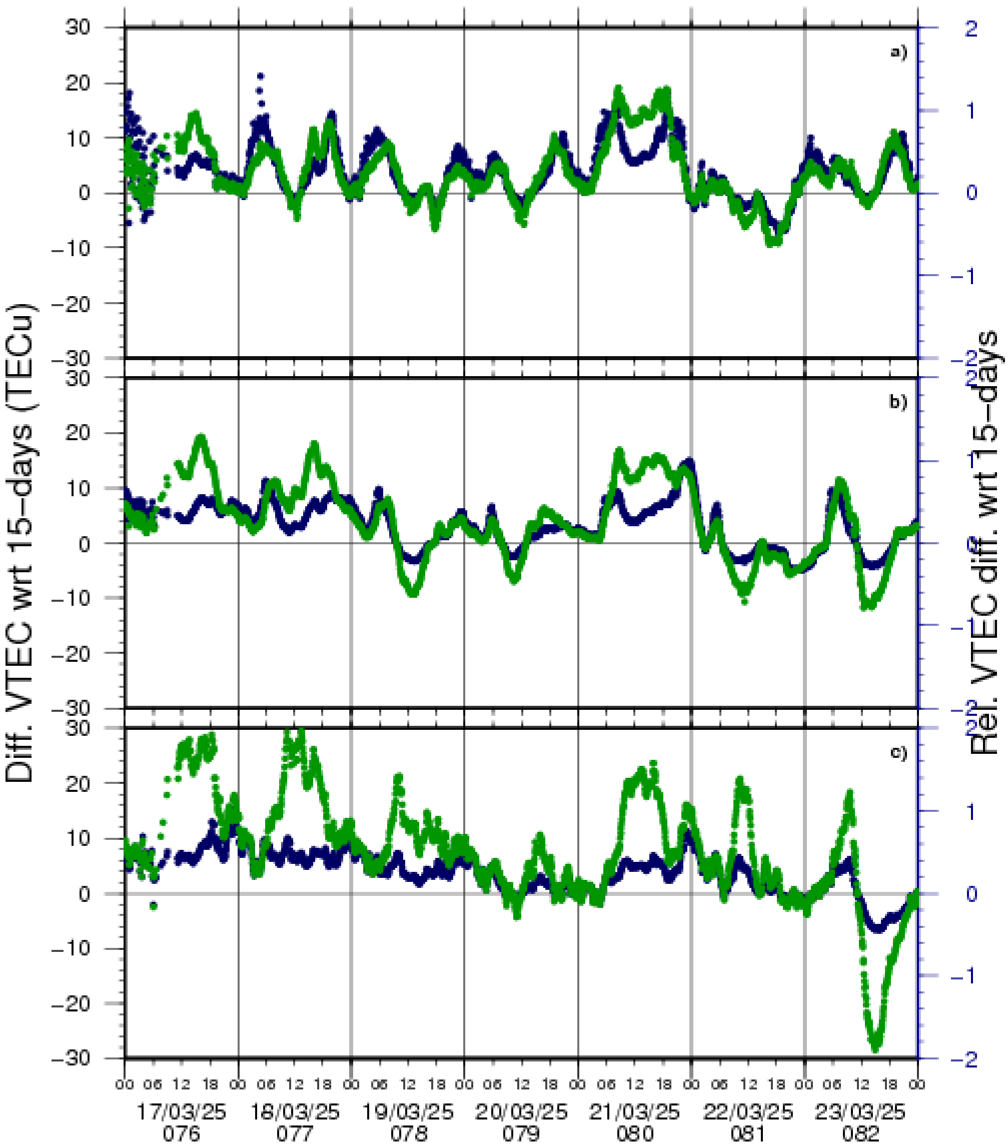




A M1.0 flare peaking on March 17 at 19:33 UT was associated with a filament eruption.
They were located near the NOAA active region 4033 on the North East part of the solar disk.
This event has also been recorded by LYRA. Find a SWAP movie of the event here https://proba2.sidc.be/swap/movies/20250317_swap_movie.mp4

10. Review of Ionospheric Activity





VTEC time series at 3 locations in Europe from 17 Mar 2025 till 23 Mar 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

11. STCE courses and seminars

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.

* March 29, Partial Solar Eclipse, https://www.sidc.be/uset/Eclipse2025/, https://proba2.sidc.be/NearlyTotalEclipse
* April 1, 2PM, STCE seminar: GRMB project: Cluster satellites in the geospace environment, RMI conference room, Brussels, Belgium
* April 28-30, 2025, STCE Space Weather Introductory Course, Brussels, Belgium - register: https://events.spacepole.be/event/214/
* May 26-27, 2025, STCE Course Space Weather impacts on aviation, online - register: https://events.spacepole.be/event/215/
* Jun 23-25, 2025, STCE Space Weather Introductory Course, Brussels, Belgium - register: https://events.spacepole.be/event/216/
* Sep 15-16, 2025, STCE Course Space Weather impacts on aviation, online - register: https://events.spacepole.be/event/218/
* Nov 17-19, 2025, 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

Website: https://www.stce.be/SWEC