

# ESA Space Weather System for GNSS Applications

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# Space Weather hazards on infrastructure



Astronaut radiation

Solar cell degradation



Radiation damage, charging/discharging

Increased atmospheric drag

Satellite navigation errors

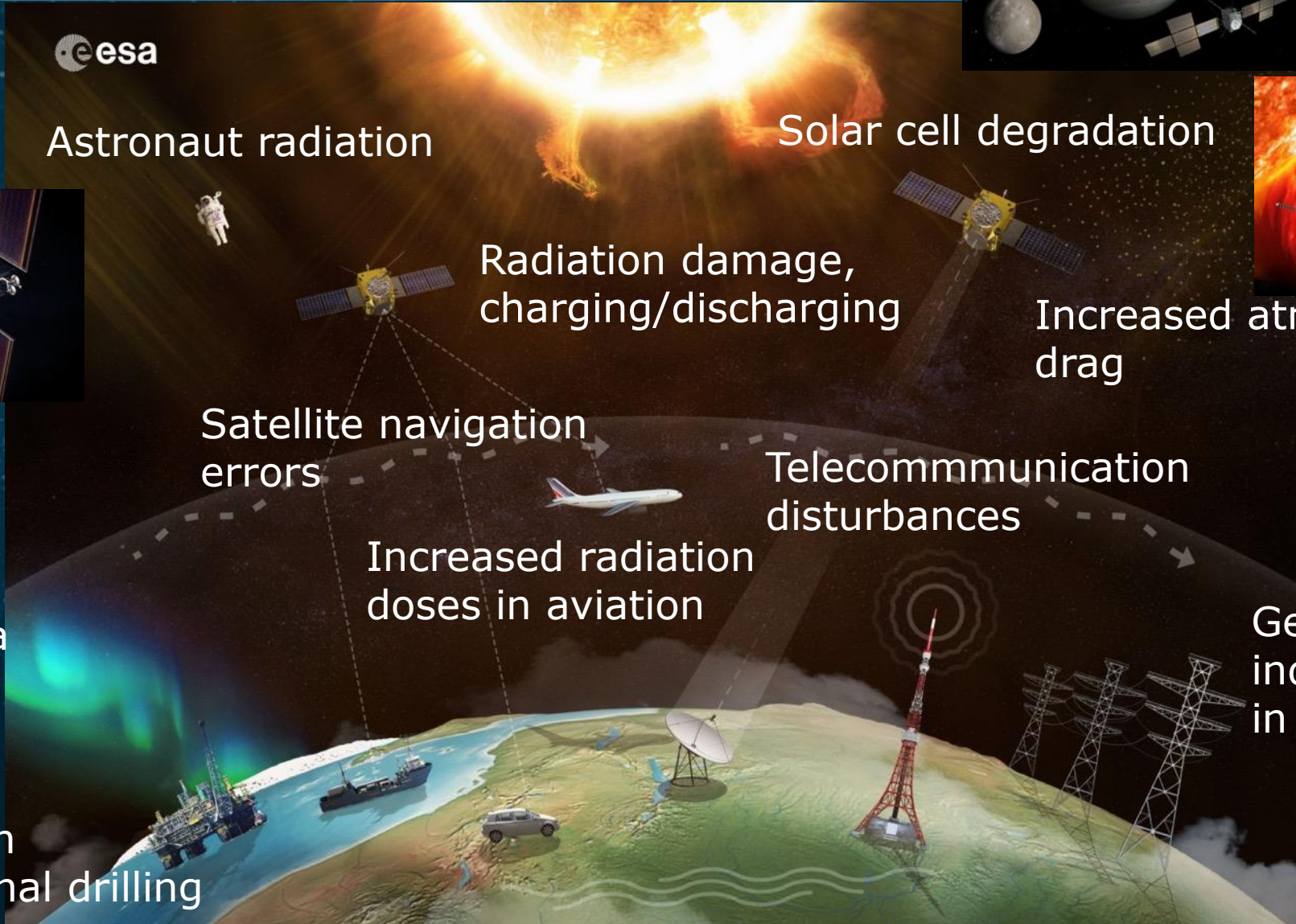
Telecommunication disturbances

Increased radiation doses in aviation

Geomagnetically induced currents in power grid

Aurora

Errors in directional drilling





# ESA Space Weather System - Objectives



Early warnings with actionable information

Space weather monitoring

- Data acquisition
- Solar activity and heliospace
  - Near Earth space
  - Global coverage of ground based observations

Tailored space weather services

Space Weather protection for Europe

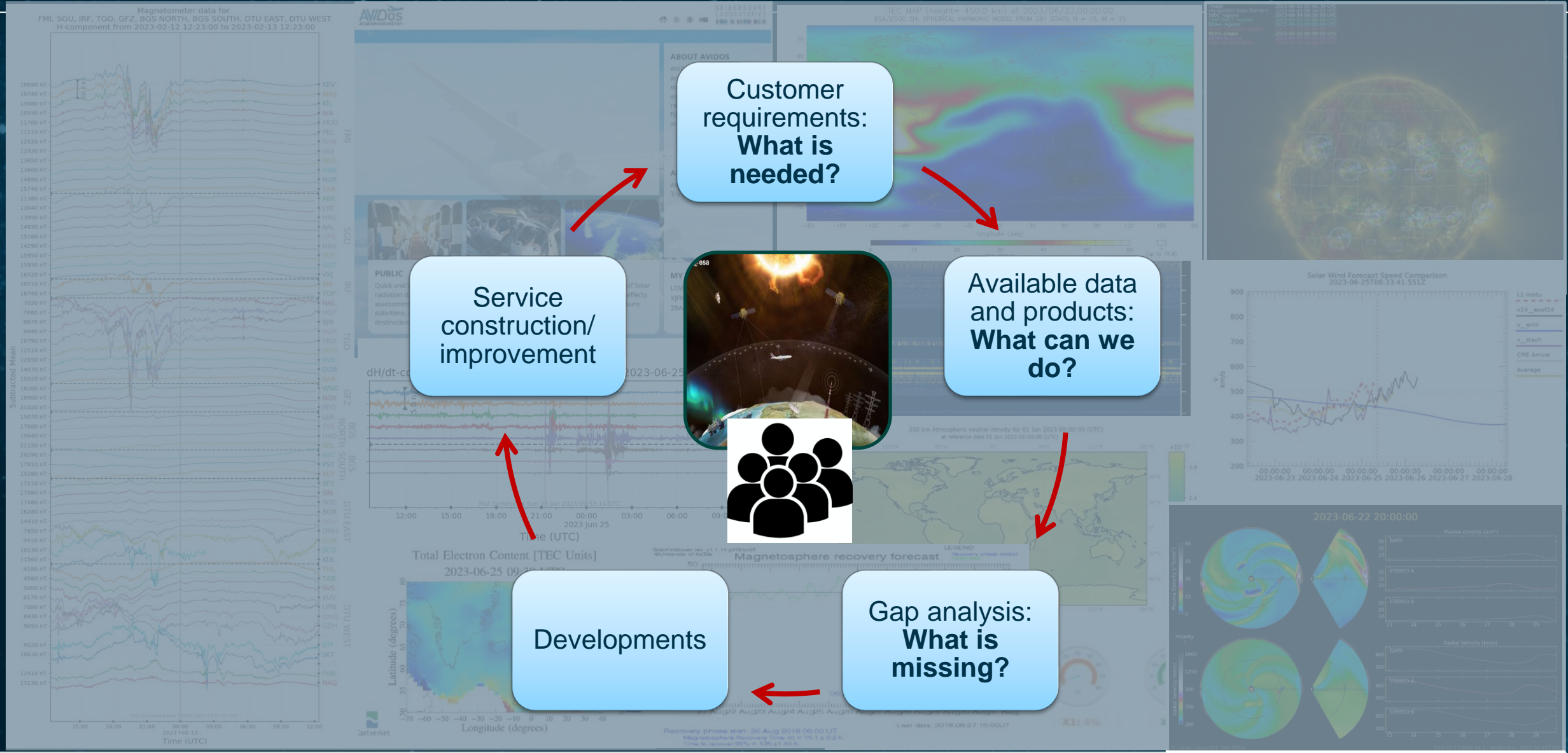
Resilient society

- User engagement
- Impact studies
- CBAs
- Focussed tools and apps
- Awareness

S2P Developments



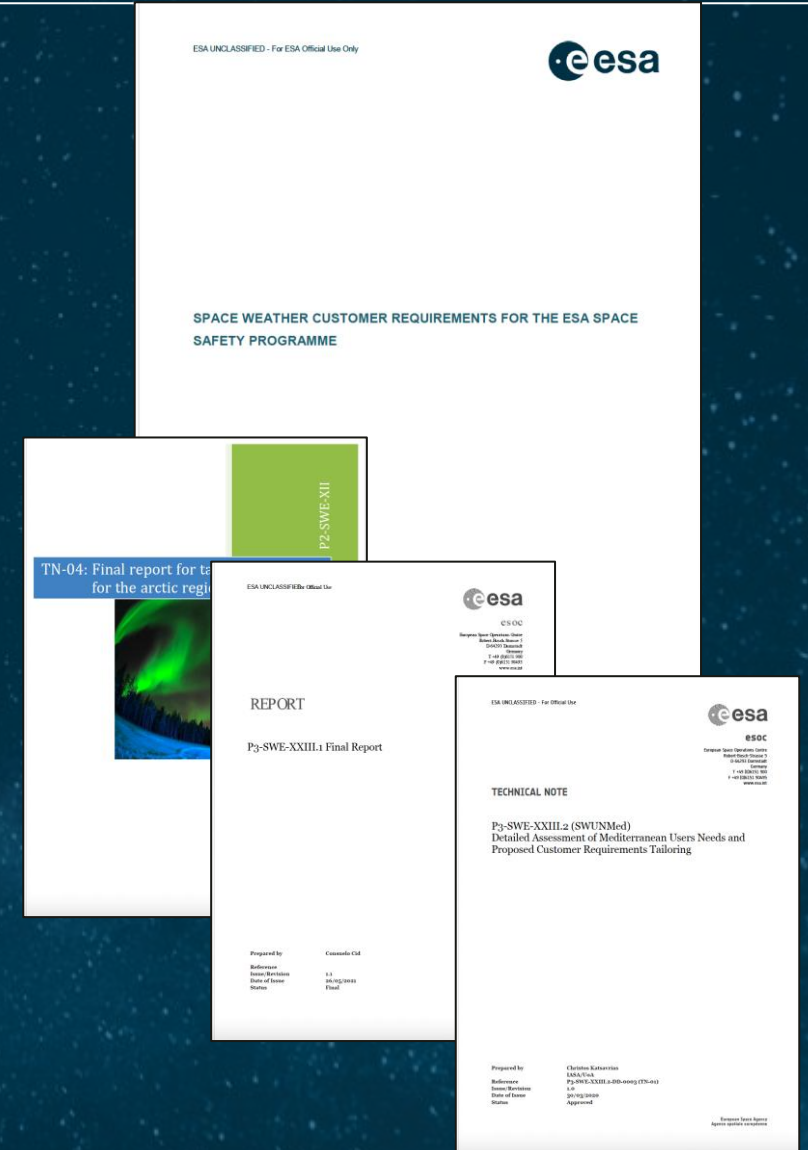
# How to Develop Space Weather System





# Identification of User Needs

- Space Weather Customer Requirements Document (CRD)
  - Defines the user needs targeted by ESA Space Weather System
  - Initial version in 2010 based on Consultation with ESA Space Situational Awareness (SSA) User Representative Group
  - Continuous collection of user needs and feedback during development, testing and validation activities in SSA and Space Safety Programme (S2P)
- Three dedicated studies for regional user needs:
  - Tailoring SWE services for the Arctic region” (2015 – 2016)
  - Two parallel studies: Space Weather User Needs for the Mediterranean Region (2019 – 2021)
- Consultation of S2P Advisory Group, ESA Space Weather Working Team, dedicated user sessions in European Space Weather Week,...



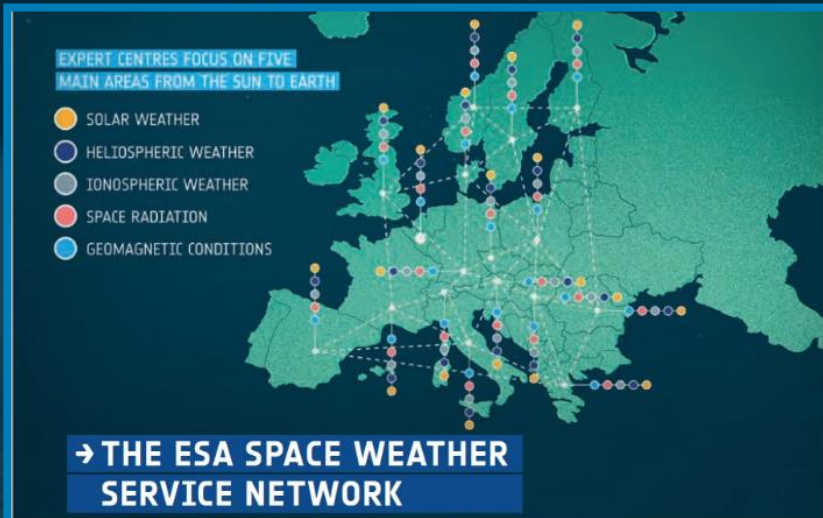
=> Latest update of CRD in spring 2023

User Types	Characteristics
USR-01	Users of GNSS <b>Single frequency services with average accuracy, no integrity</b> (e.g. GNSS mass market user)
USR-02	Users of GNSS <b>Single frequency services with average accuracy, using integrity</b> (e.g. EGNOS user)
USR-03	Users of <b>multi-frequency GNSS systems with average multifrequency accuracy, no integrity</b> (commercial services, PRS)
USR-04	Users of <b>multi-frequency GNSS systems with average accuracy, integrity</b> (aeronautical multifrequency)
USR-05	Users of <b>multi-frequency GNSS systems with very high accuracy</b> (e.g. GNSS geodetic users, RTK)
USR-06	Users of <b>satellite data communications with high availability/continuity</b> (e.g. Search-and-Rescue, Air Traffic Control/Management via Satellite, <b>high availability/continuity data networks</b> such as Galileo Ground Segment Data Network). Other <b>space-based services/products users affected by the ionosphere</b> (UHF - C-band radars, GNSS-R altimetry, UHF/low microwave radioastronomy and deep space communications)





# ESA Space Weather Service Portal and Network



Spacecraft Design	Spacecraft Operation
Human Spaceflight	Launch Operation
Transionospheric Radio Link	Space Surveillance and Tracking
Power Systems Operation	Aviation
Resource Exploitation System Operation	Pipeline Operation
Auroral Tourism	General Data Service

- 29 pre-operational services based on >250 products
- Service user support and staffed helpdesk
- European Service Network of >50 participating entities
- > 4000 registered users
- > 3M hits on service portal monthly
- Coordinated Communication Protocol for major events

<https://swe.ssa.esa.int>





**CURRENT SPACE WEATHER**

**SPACE WEATHER SERVICES**

- Spacecraft Design
- Spacecraft Operation
- Human Spaceflight
- Launch Operation
- Transionospheric Radio Link**
  - Near Real-Time TEC Maps
  - Forecast TEC Maps
  - Quality Assessment of Ionospheric Correction
  - Near Real-Time Ionospheric Scintillation Maps
  - Monitoring and Forecast of Ionospheric Disturbances
- Space Surveillance and Tracking
- Power Systems Operation
- Aviation
- Resource Exploitation System Operation
- Pipeline Operation
- Auroral Tourism
- General Data Service
- Preview Dashboard

**SPACE WEATHER AT ESA**

**EXPERT SERVICE CENTRES**

**INFORMATION FOR USERS**

**USER FEEDBACK**

Space Weather Services / Transionospheric Radio Link /

## Transionospheric Radio Link Services

The purpose of the Transionospheric Radio Link dashboard is to present an overview of the current and forecasted ionospheric conditions with the different types of available data (measurement, nowcast, and forecast) at a global or local level.

Further products, data and archives can be found in the specific services of this domain, which are listed below.

Near Real-Time TEC Maps

Forecast TEC Maps

Quality Assessment of Ionospheric Correction

Near Real-Time Ionospheric Scintillation Maps

Monitoring and Forecast of Ionospheric Disturbances

[Read more](#)

### Notifications

#### Ionospheric activity index at ionosonde locations

Real Time Activity Index Map  
2023/10/25 15:45 UT

Percentage deviations of the foF2 in respect to the 30 days running median  
Low: lower than 25 and higher than -25  
Disturbed: between -50 and -25 or between 25 and 50  
Extremely disturbed: higher than 50 and lower than -50

### Current Conditions

#### TEC map (Global), current

Total Electron Content (TEC) 2023-10-24T15:30:00 UT

Ionospheric Range Error (L1) / m

TEC/TECU

[Full product](#) Provided by: German Aerospace Center

### Current Conditions

#### TEC map (Europe), current

Total Electron Content (TEC) 2023-10-24T15:25:00 UT

Ionospheric Range Error (L1) / m

TEC/TECU

[Full product](#) Provided by: German Aerospace Center

### Forecast

#### TEC map (Europe), 1hr forecast

One Hour TEC Forecast  
2023-10-25 17:00:00 UT

Ionospheric Range Error (L1) / m

TEC / TECU

[Full product](#) Provided by: German Aerospace Center

#### European maps of foF2 long term predictions

Median condition October 2023 - 0700 UT



Current Space Weather | Welcome to the ESA Space Weather Service Network | Please note that all ESA-SWE Services are under review/construction

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## Space Weather Services / Transionospheric Radio Link / Quality Assessment of Ionospheric Correction

### Welcome to the *Transionospheric Radio Link - Quality Assessment of Ionospheric Correction* service

#### Overview

The service "**Transionospheric Radio Link - Quality Assessment of Ionospheric Correction**" aims to provide information on whether standard corrections to GNSS signal are applicable, including for the TEC core products a-posteriori and estimated parameters and near-real-time alarms to indicate the level of degradation of ionospheric correction models with respect to the actual state of the ionosphere. This latter assessment shall be established by considering the update rate for the different service users among the following:

- Users of GNSS Single frequency services with average accuracy, no integrity (e.g. typical GNSS mass market user)
- Users of GNSS Single frequency services with average accuracy, using integrity (e.g. EGNOS user)
- Users or multi-frequency GNSS systems with very high accuracy (e.g. GNSS geodetic users, RTK).

This service is implemented through a combination of products, tools and alerts which can be found through the following sections along with expert support provided by the teams constituting the SWE Network. Should you require further guidance in the use of this service, or have specific questions about any aspects of the service presented here, don't hesitate to contact the Helpdesk.

[Read more about this service](#)

#### Highlights

- GNSS Performance Indicator
- QURG-GIM - rapid 15-minute resolution global VTEC maps
- Global Scintillation Indices
- Nowcasting of TEC over Italy

#### Announcements

**Update:** New Service Page design for release 3.7! Let us know what you think about our services in our Survey.

#### Products and Alerts

The following products are associated with this service:

##### Products

- ▶ Ionosphere, Nowcast
- ▶ Ionosphere, Archives

##### Alerts

- ▶ Ionospheric Disturbance Detection

#### TEC map (Europe), current

Total Electron Content (TEC) 2023-10-25T03:40:00 UT

Ionospheric Range Error (L1) / m

TEC/TECU

Full product | Provided by: German Aerospace Center

#### TEC map (Global), current

Total Electron Content (TEC) 2023-10-25T00:50:00 UT

Ionospheric Range Error (L1) / m

TEC/TECU

Full product | Provided by: German Aerospace Center







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**CURRENT SPACE WEATHER**

Space Weather Services / General Data Service /

**SPACE WEATHER SERVICES**

- Spacecraft Design
- Spacecraft Operation
- Human Spaceflight
- Launch Operation
- Transionospheric Radio Link
- Space Surveillance and Tracking
- Power Systems Operation
- Aviation
- Resource Exploitation System Operation
- Pipeline Operation
- Auroral Tourism
- General Data Service**
  - Space Weather Data Archive
  - Latest Data Service
  - Space Weather Nowcast and Forecast Products (Daily, Weekly)
  - Alert Service
  - Preview Dashboard
- SPACE WEATHER AT ESA
- EXPERT SERVICE CENTRES
- INFORMATION FOR USERS
- USER FEEDBACK
- CONTACT THE HELPDESK

## Products

Alert products

- All Quiet Alert
- End-of-quiet Alert
- Solar Flare Detection
  - UGraz/KSO Latest Solar flare alert
  - SIDC Latest Solar GOES-flare alert
  - SIDC Latest human moderated alert
  - Latest ICAO Space Weather Advisory browser
- Solar Flare Detection and Location
- CME Onset
- Halo CME Onset
- Coronal Hole Notification
- CIR Alert
- Solar Particle Event Onset
- Geomagnetic Storm Warning / Solar Wind Shock Arrival
- Geomagnetic Storm Onset
- Ionospheric Disturbance Detection
  - Latest ICAO Space Weather Advisory browser
  - EIS Alerts for ionospheric disturbances in the European sector
  - SISTED warning
  - SOLERA-drift warning
  - TechTIDE LSTID detector maps
  - TechTIDE LSTID parameters over station
  - TechTIDE TID Activity Report
- Micro Particle Flux Warning
- Debris Cloud/Meteoroid Stream Warning
- All Archive
- Ground Level Enhancement Detection

Alert++ Status

**QUIET**

Alert	[00]	Quiet	[22]
Warning	[00]	Delayed	[01]
Watch	[00]	Offline	[04]
Total [27]			

**Ne.Mo.S** 25 Oct 2023, 16:41:00 UTC

Proton flux alerts

stamp of latest data considered 2023-10-19 18:24:00 UTC

Proton energies	5.5 MeV	9 MeV	45 MeV
SEP activity	NO	NO	NO
Relative hourly difference	▼ 0	▼ 0	▼ 0

AWARE Near Earth Warnings Plot



# Ionospheric Services for User Domains: Aviation

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Welcome to the ESA Space Weather Service Network

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**SPACE WEATHER AT ESA**

**EXPERT SERVICE CENTRES**

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**CONTACT THE HELPDESK**

**TERMS OF USE**

Space Weather Services / Aviation /

**Aviation Services**

The purpose of the Service to Aviation dashboard is mainly to provide graphical information about the impact of solar activity on the radiation environment and ionospheric conditions. The dashboard is organised in three sections (columns) according to the main impact domains i.e. Radiation – GNSS – HF communication.

Further products, data and archives can be found in the specific service listed below.

Service to Aviation

**RADIATION**

**AVIDOS Current cosmic radiation map**

Effective dose rate in  $\mu\text{Sv/h}$   
Altitude: 9.00 km  
Last Update: 25.10.2023 18:31

Full product      Provided by: Seibersdorf Laboratories

**GNSS**

[Latest ICAO Space Weather Advisory browser](#)

[TEC map \(Europe\), current](#)

[VTEC maps \(Northern Europe\)](#)

[ROTI maps \(Northern Europe\)](#)

ROTI [TECU/min]

2023-10-25 16:30 UTC

Full product      Provided by: No

[S4 maps \(Northern Europe\)](#)

Scintillation index S4 for L1 f

2023-10-25 16:25 UTC

Real Time Activity Index Map

2023/10/25 16:00 UT

**Latest GNSS Advisory:**

0000046601  
 FNXX01 KWP 211609  
 SWX ADVISORY  
 DTG: 20231021/1609Z  
 SWXC: SWPC  
 ADVISORY NR: 2023/280  
 NR RPLC: 2023/279  
 SWX EFFECT: GNSS MOD  
 OBS SWX: 21/1601Z NO SWX EXP  
 FCST SWX +6 HR: 21/2300Z NO SWX EXP  
 FCST SWX +12 HR: 22/0500Z NO SWX EXP  
 FCST SWX +18 HR: 22/1100Z NO SWX EXP  
 FCST SWX +24 HR: 22/1700Z NO SWX EXP  
 RMK: THE IONOSPHERIC DISTURBANCE HAS ENDED. SCINTILLATION RELATED GNSS SIGNAL DEGRADATION IS NO LONGER EXPECTED.  
 NXT ADVISORY: NO FURTHER ADVISORIES=



# Space Weather Nanosat Mission

## Mission objectives:

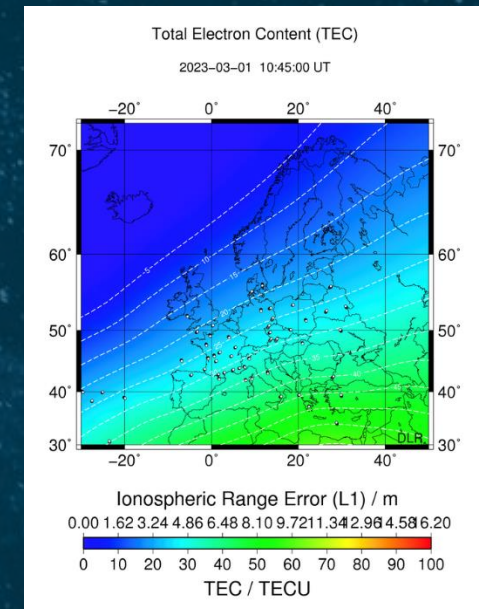
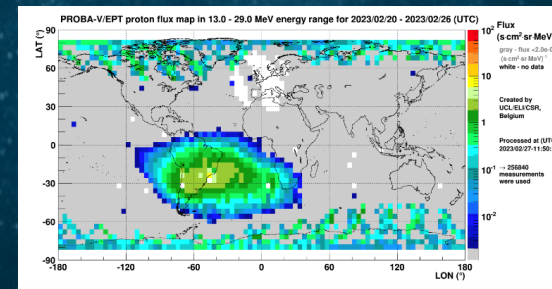
- Data on space environment and effects in LEO
- Demonstrate “new space” and commercialisation approach with mission/data-as-a-service
  - => Industry responsible for implementation, mission operation & Level 1 data processing
  - => ESA an anchor customer



## Baseline measurements:

- High energy Proton and Electron flux
- Thermal electrons' and ions' flux, density and temperature
- 3D electron density in the ionosphere
- Scintillation parameters (S4, Sigma\_phi)

Launch: 2026





# Vigil mission to L5



Coronagraphy:  
CCOR

Heliospheric  
Imaging: HI

Magnetography: PMI



EUV imaging:  
NIO

Solar wind: PLA

IMF: MAG

- Continuous observations of Sun and heliosphere between Earth and the Sun
- Data availability in near real-time => operational applications
- Complementing observations from Sun-Earth line
- Launch: 2030



[https://www.esa.int/Space\\_Safety/Vigil](https://www.esa.int/Space_Safety/Vigil)



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**TERMS OF USE**

Contact the Helpdesk /

### SWE Service

The SWE Service is only accessible to... please get in touch

**Web form:**  
Click here.

**Email:**  
helpdesk.swe@esa

**Phone:**  
Call +32-2-7903-9

**Address:**  
SSA Space Weather  
Space Pole  
Avenue Circulaire  
1180 Uccle - Ukkel

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0%

## ESA Space Weather Services - User Survey

The ESA Space Weather Services provide targeted data and information addressing the needs of a number of targeted user communities, from spacecraft operators to auroral tourism. This survey has been prepared in order to ask for feedback on your experience, our current capabilities and recommendations for future evolution. By sharing your experience this will help ensure that we provide the most useful services for all of our users. Thank you in advance for your participation!

*This survey contains 30 questions and will take around 10 minutes to complete. Note that not all questions are compulsory and all feedback given will be anonymous.*

There are 30 questions in this survey.

Next

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**THANK YOU**

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