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EGNOS

Provision of GNSS Advisories for the ICAO Space Weather Service

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ESSP

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Agenda

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2. Impact of Ionosphere on GNSS and SBAS
3. The ICAO Space Weather Service
4. Use of EGNOS data via EDAS for ICAO Space Weather service
5. EGNOS: From Supporting Space Weahter Monitoring to Facing the Storms (May 2024 case)
6. Advisories Disseminated During May 2024 Event
7. Challenges for GNSS advisories
8. Conclusion & Ways forward

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Introduction :Space Weather and Aviation Context

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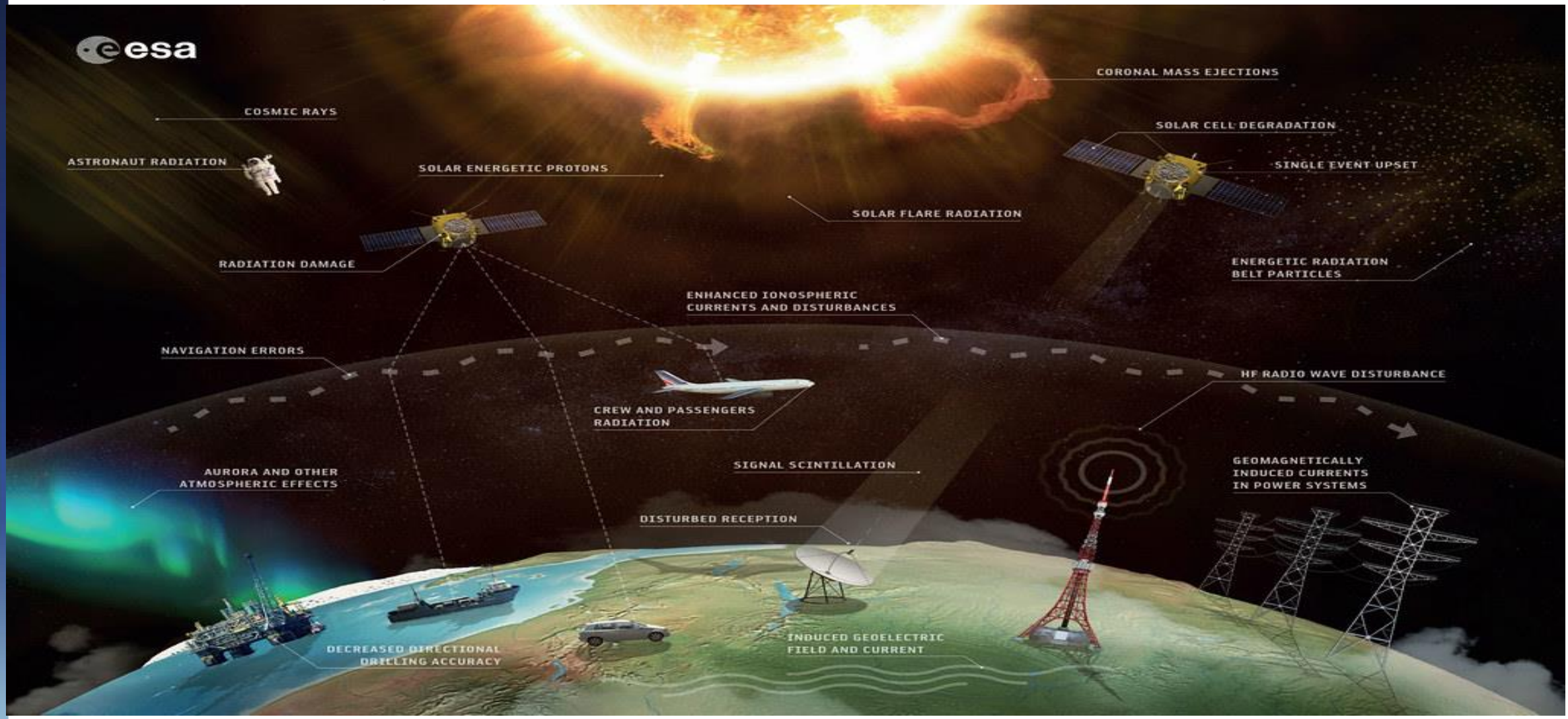
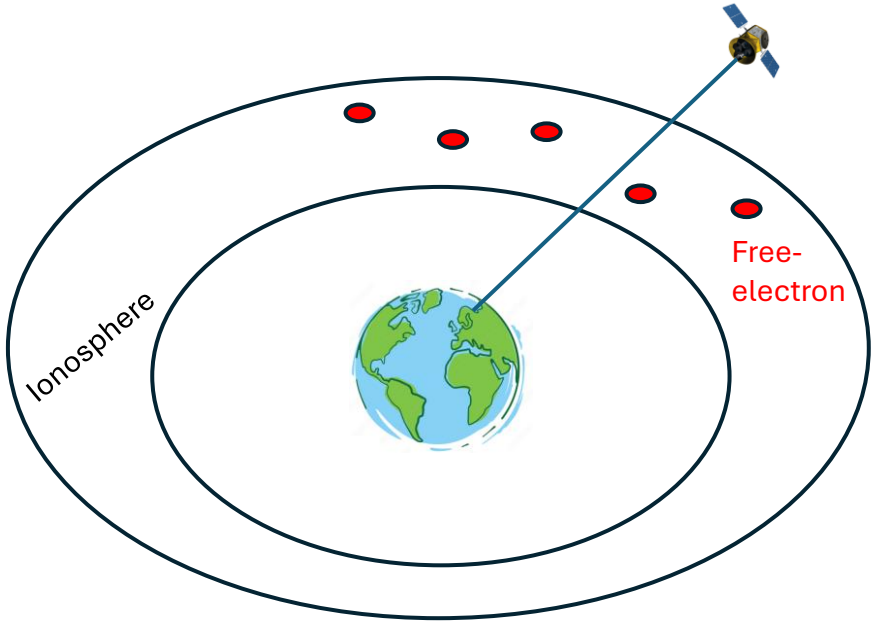
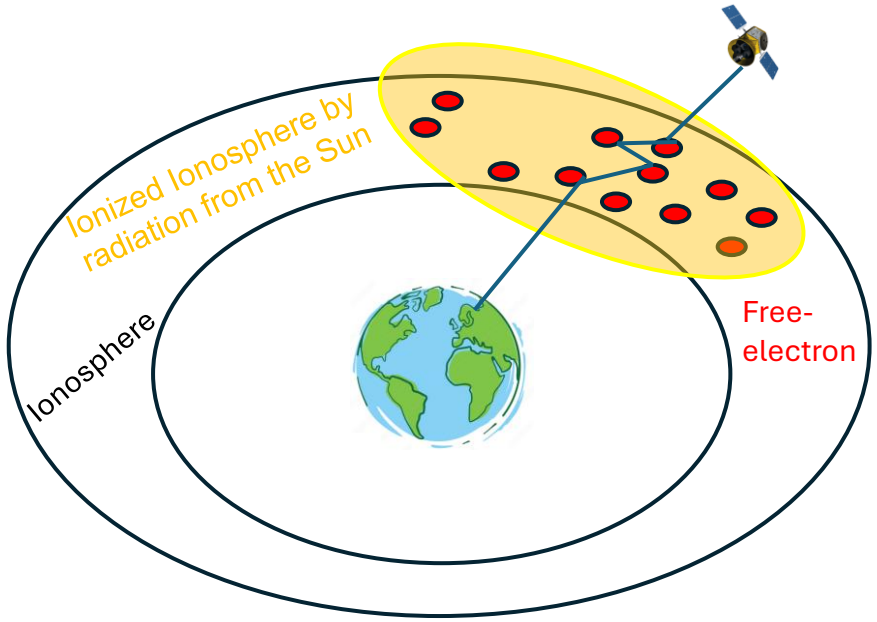
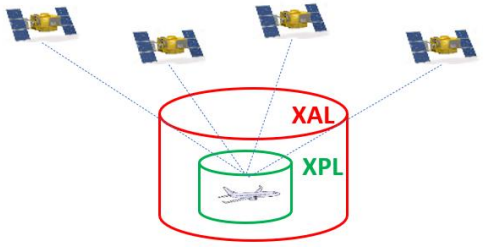


Impact of Ionosphere on GNSS and SBAS

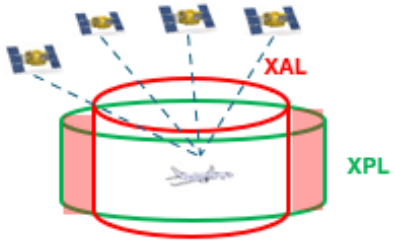




- Solar activity changes the ionosphere → GNSS signals are delayed/distorted
- This leads to errors in pseudorange and degraded positioning accuracy
- Models struggle during strong disturbances → less reliable corrections
- In SBAS (e.g. EGNOS), ionospheric disturbances impact GIVD & GIVE estimates
- This drives the evolution of Protection Levels
- If Protection Levels exceed the Alert Limit -> Service unavailable.



SBAS available



SBAS NOT available

The ICAO Space Weather Service

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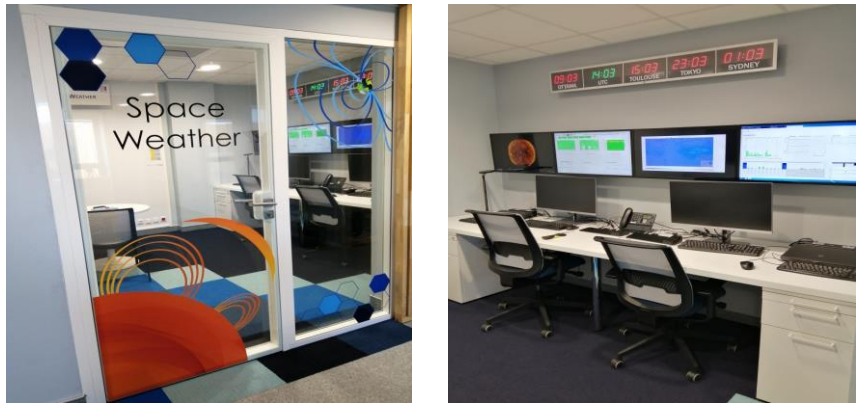
ICAO space weather service provides space weather advisories used by the aviation industry across the World.

- The purpose is to issue advisories to aviation community in case Space Weather affects :
  - HF Communications
  - GNSS-based navigation and surveillance systems
  - Or poses a radiation risk to flight crew members and passengers.

The ESSP Space Weather operations room



The ICAO initiative

June 2017

ICAO Request for interest to states

September 2017

France Application submitted

DGAC oversees SPECTRA composed of Météo-France, CLS, and ESSP with support of French scientific community

February 2018

France assessed compliant

Audit by World Meteorological Organisation on behalf of ICAO

April 2018

ACFJ Formed

Australia, Canada, France and Japan joined their forces and becam the ACFJ consortium led by France

November 2018

ACFJ Global Space Weather center

ACFJ officially selected by ICAO to be a Global Space Weather Center together with SWPC and PECASUS

November 2019

Service Started

Global Space Weather centers started to deliver a 24/7 monitoring service

December 2021

CRC Global Space Weather center

CRC is officially the fourth Global Space Weather Center

Use of EGNOS data via EDAS for ICAO Space Weather service

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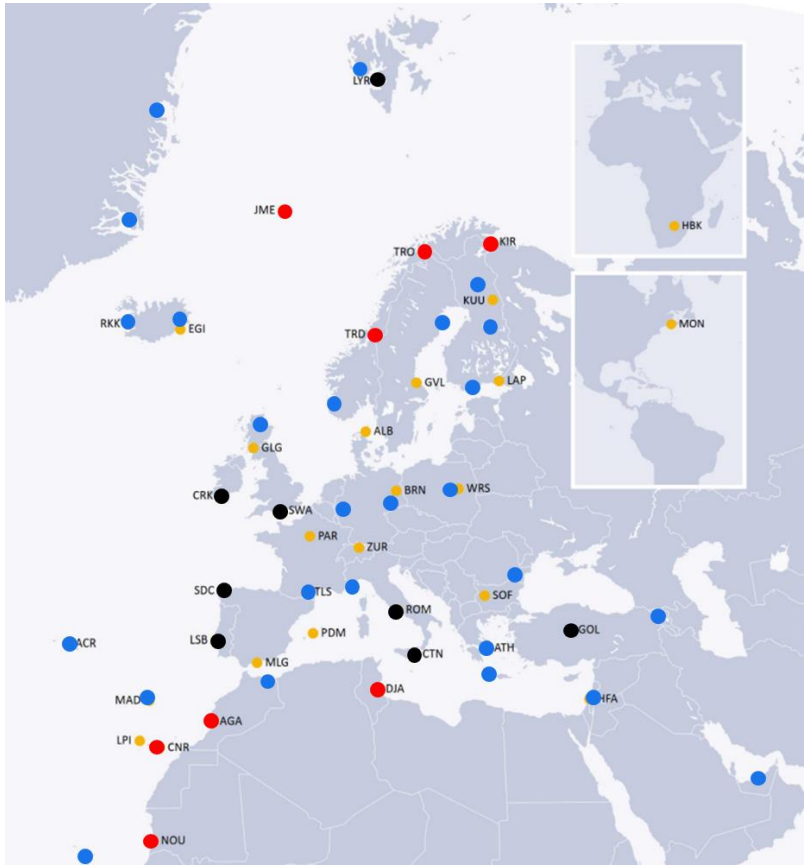


- RIMS station used by CLS / RINEX on FTP
- RIMS station used by CLS / RT NTRIP stream
- RIMS station not used by CLS
- Other stations used by CLS

STATISTICS AS OF BEGINNING OF SEPT 2025

Number of EGNOS RIMS stations used by CLS for the ICAO Space Weather service:

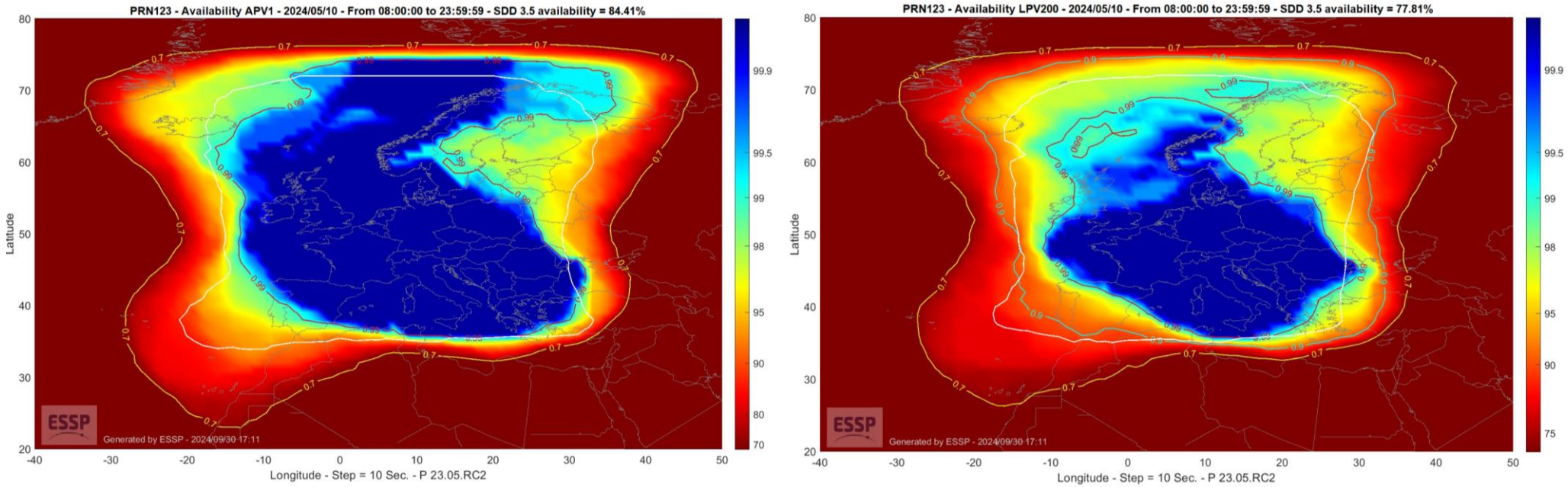
- 8 stations from the EDAS FTP server
- 8 stations from the NTRIP Real Time stream

In 2025, 16 EGNOS RIMS stations (7% of the global GNSS data network) were used by CLS via EDAS FTP and RT streams.

EGNOS RIMS showed the **highest data availability** across all networks: 95% (RINEX), 92% (RT).

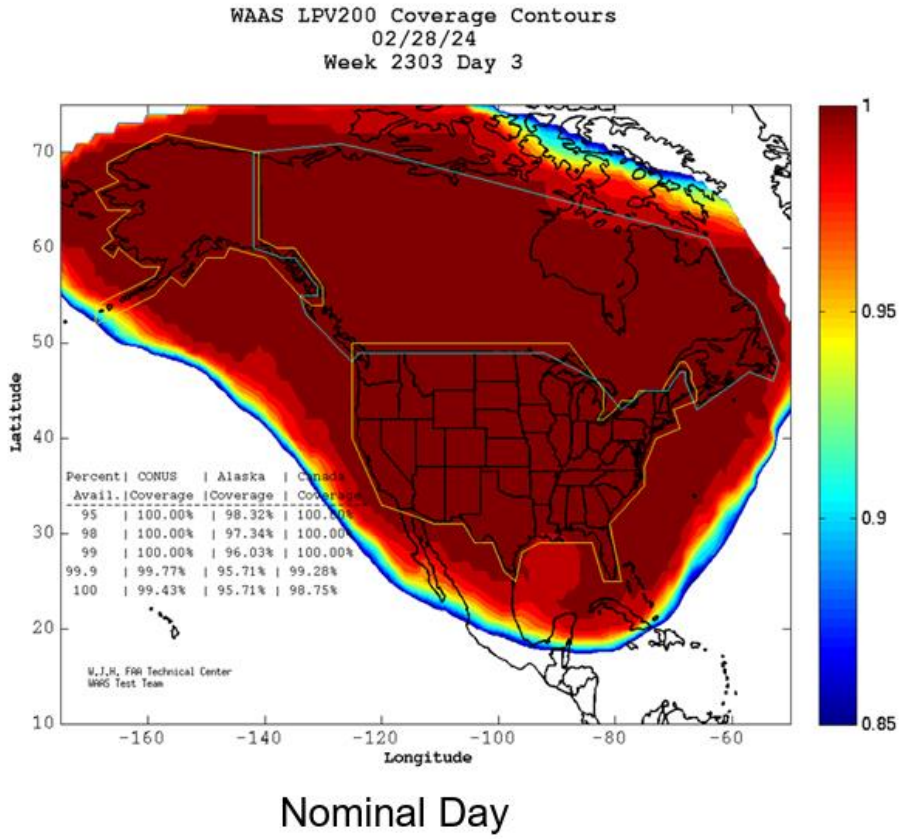
Between 68% and 87% for the other networks

From Supporting Space Weahter Monitoring to Facing the Storms (May 2024 case)

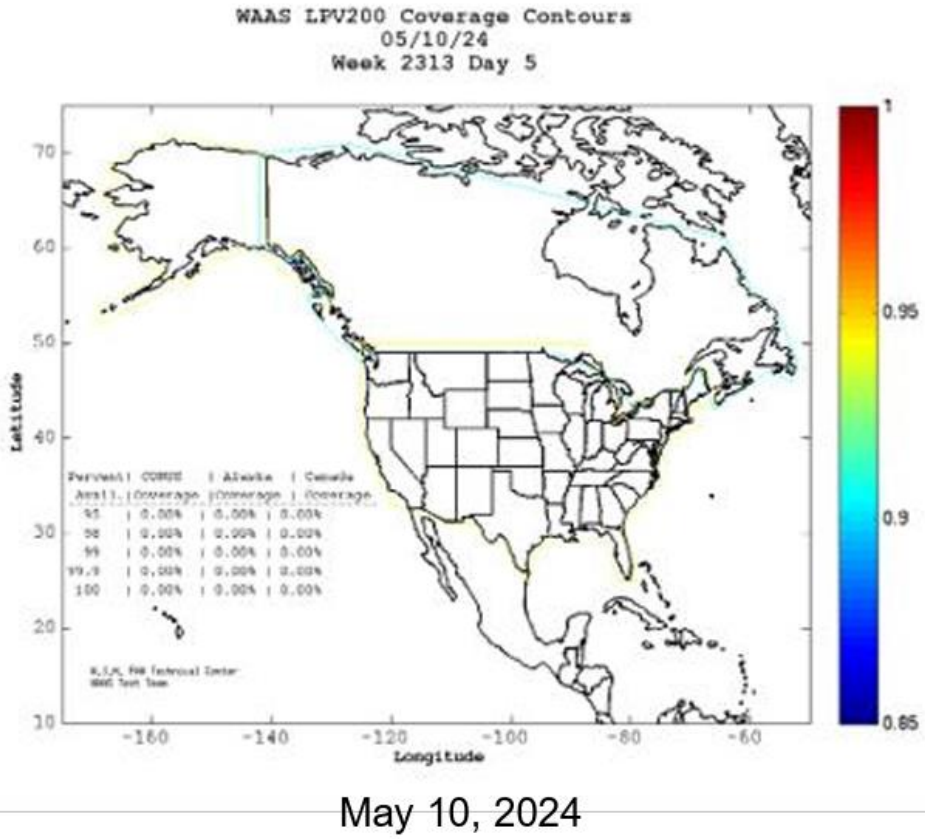


- **Ionospheric corrections:** GIVE values increased (up to ~28 m in ECAC)
- **EGNOS Integrity maintained:** ranging & ionospheric components preserved
- **Accuracy:** GPS-only showed large errors; EGNOS errors only slightly increased
- **Signal loss:** up to +50% L2 loss at northern RIMS → LPV-200 reduction
- **Availability:** LPV-200/APV-1 dropped to ~84% / ~78% (ECAC coverage)
- **Resilience:** EGNOS resisted well thanks to ESR 2.4.2B (Nov 2023)

Extreme ionospheric Impacts on WAAS



Nominal Day



May 10, 2024

May 2024 was the first time the WAAS Extreme Storm Detector Tripped – Shuts down WAAS vertical service for 8 hours during periods of extreme volatility*

*Source: Federal Aviation Administration (FAA), FAA Navigation Programs Update, September 2024.

Advisories Disseminated During May 2024 Event

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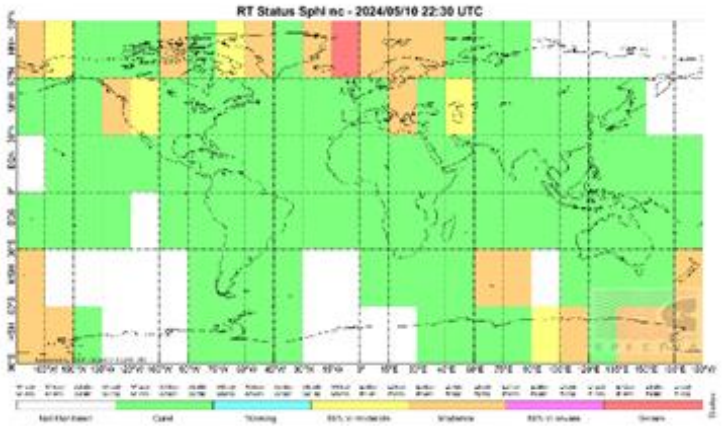
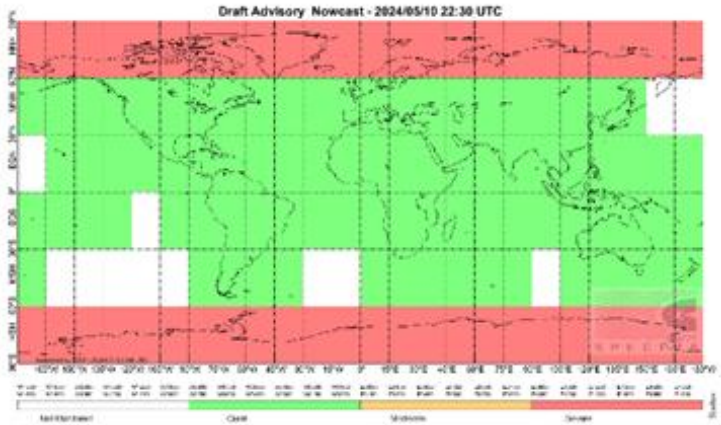
Active Regions identified

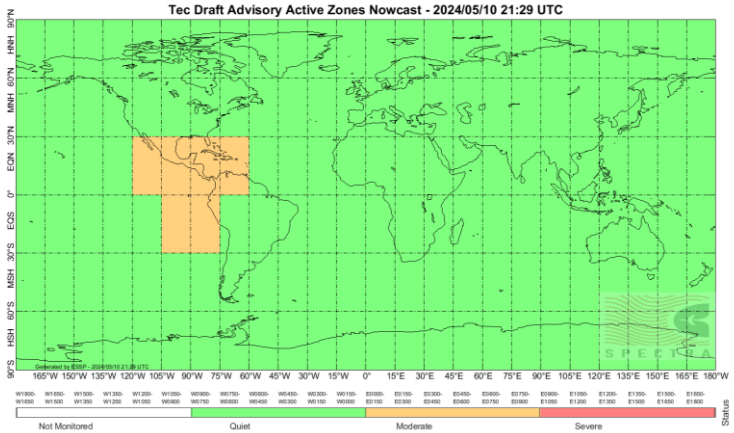
Advisory disseminated

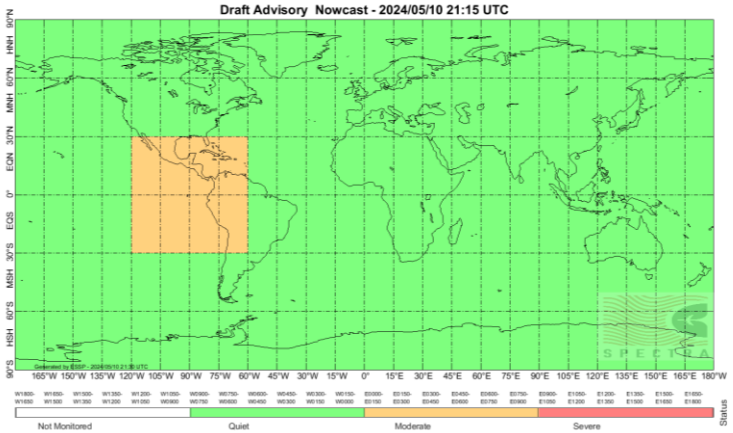
Scintillation advisory





TEC advisory





ICAO Service

Challenges with GNSS advisories

- **Integration of data sources**: combining near real-time information from diverse sensors, networks, and collection tools into a coherent advisory.
- **Decision thresholds**: defining clear criteria for issuing significant alerts without overloading civil aviation with minor, highly localised, or sporadic events.
- **Alert integrity**: ensuring accuracy and consistency of advisories before dissemination.
- **Severe event management**: handling extreme space weather events with timely updates and reliable service continuity.
- **User alignment**: tailoring advisories to operational needs and maintaining feedback loops with end users.
- **International harmonisation**: coordinating with global centres and data providers to improve service consistency and interoperability.

Conclusion & Ways forward

Conclusions:

- **Space weather disrupts GNSS** → models degrade during storms
- **EGNOS improves resilience** → maintains accuracy & integrity even under disturbances
- **EGNOS contribution**:
  - ❑ 16 RIMS for ICAO Space Weather service
  - ❑ highest data availability (95% RINEX / 92% RT) outperforming other networks
- **Preparedness matters** → monitoring & prediction are key to protect aviation

Way forward :

- Global coordination: contribute to ICAO data sharing & consistency.
- User engagement: feedback with aviation stakeholders.
- Service evolution: richer GNSS/space weather advisories.
- Forecasting capability: develop and integrate prediction data to anticipate impacts.
- Collaboration: with ICAO centres & scientific community.

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The May 2024 Event – Space Weather parameters and ionospheric response

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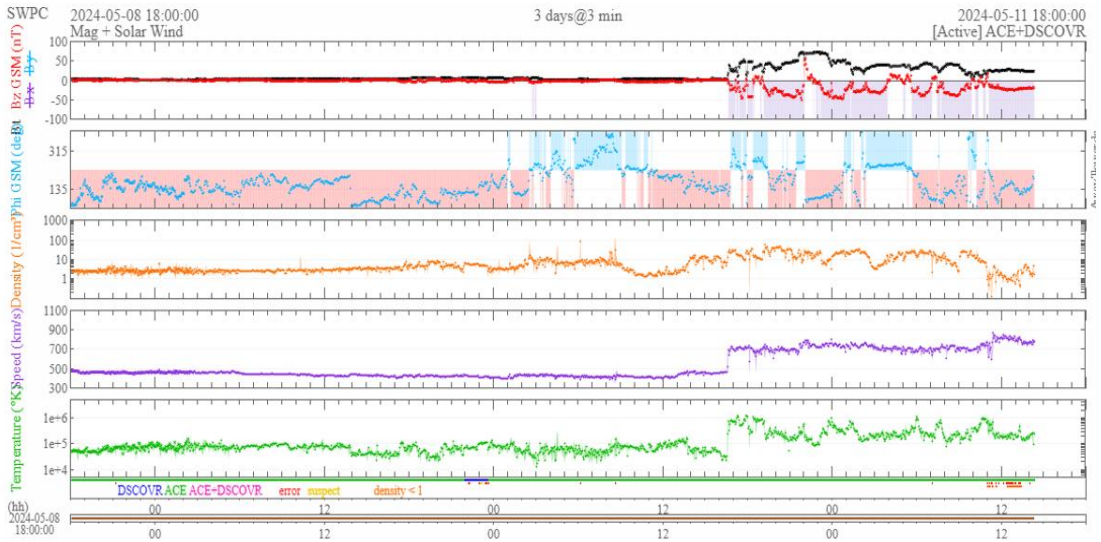
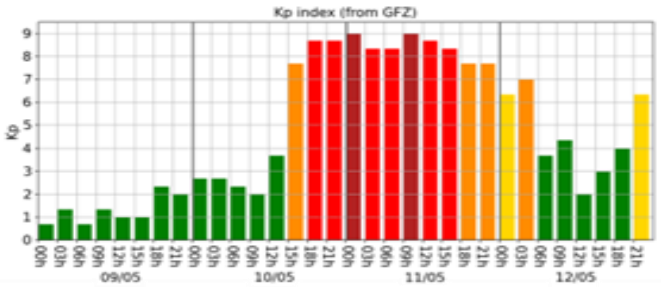


https://www.swpc.noaa.gov/products/real-time-solar-wind



https://kp.gfz-potsdam.de/en/

- Coronal Mass Ejection shock arrived on 10th May between 16:00 -17:00 UTC as observed in the solar wind parameters from ACE-DSCOVR.
- Strongly southwards Bz throughout evening of 10th, enabling stronger solar wind interaction with Earth's magnetic field.
- Elevated solar wind density, speed, and temperature, peaking in the evening of 10th May.
- Kp consistently at severe storm levels of 8-9 through the night of the 10th to 11th May.

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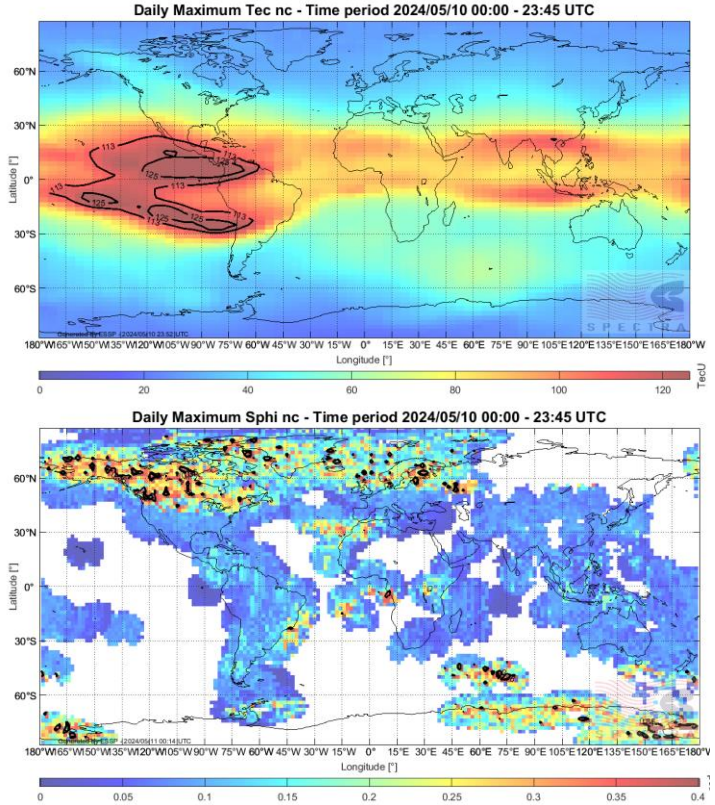

- Total Electron Content (TEC) reached very high levels on the 10th May, especially over Central America. Anomalously high TEC was also seen across much of Europe.
- Strong scintillation was observed across much of high latitudes, including Northern Europe. Significant scintillation was also seen at lower latitudes, for example over the Canary Islands and in mid latitudes, including Mediterranean area.