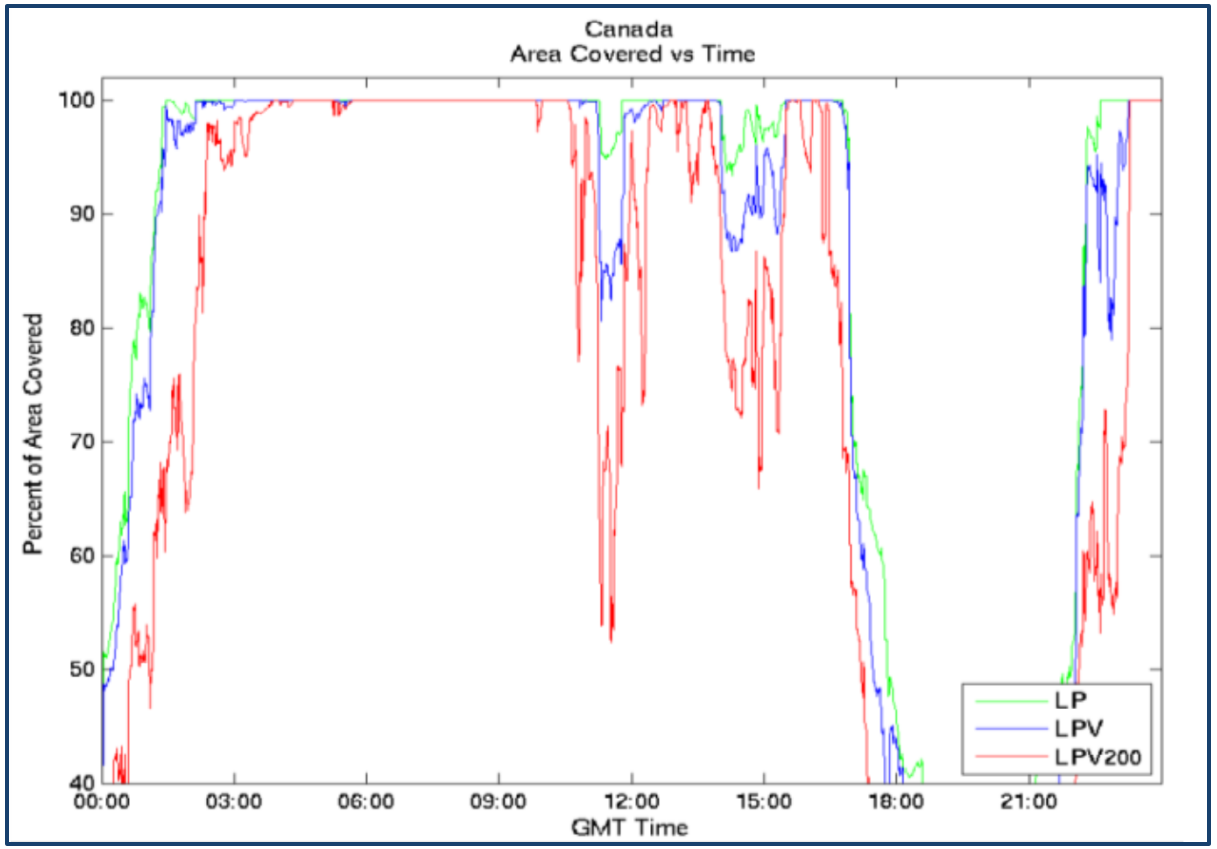
METEOROLOGY PANEL

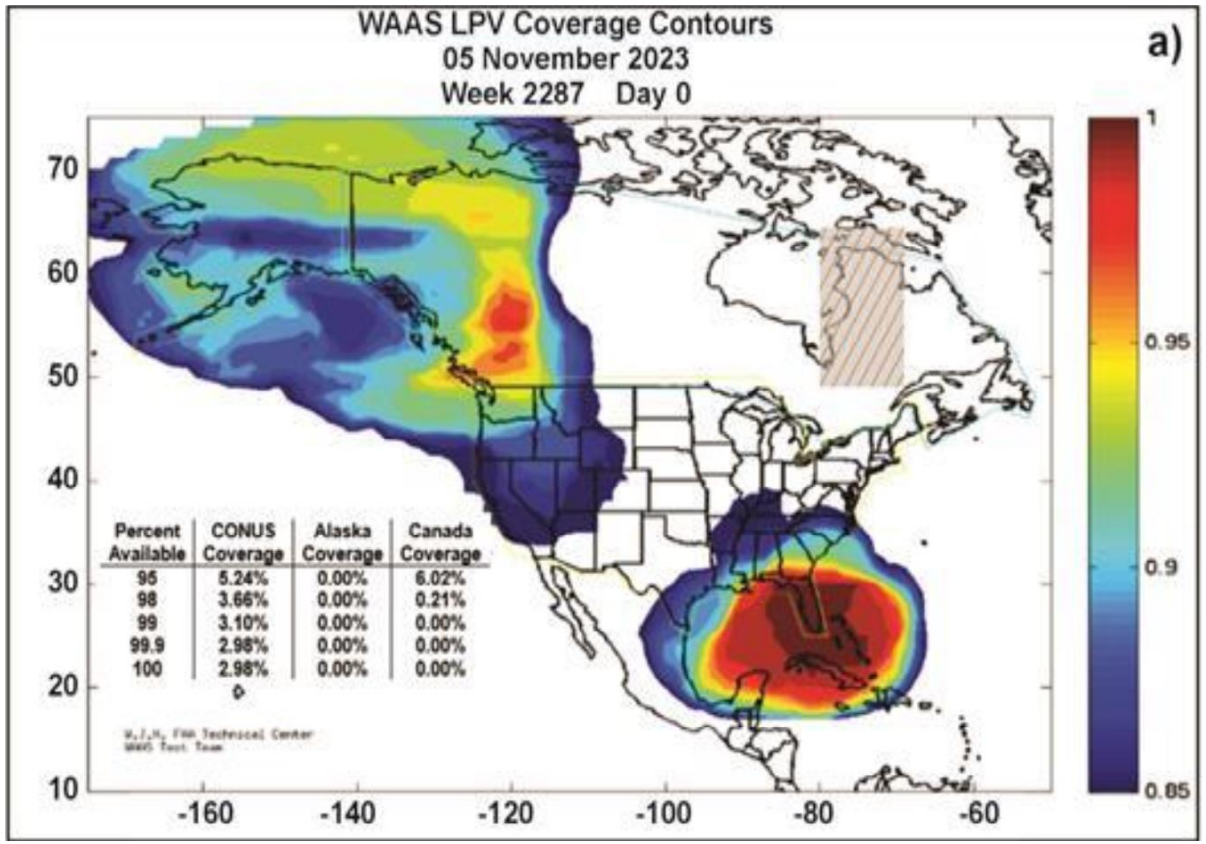
ICAO Space Weather Information Service (SWIS)

Education and Guidance Materials

Yana Maneva, Ph.D.
Solar-Terrestrial Center of Excellence
on behalf of the Space Weather Coordination Group

SWIS Motivation: SWX and Aviation





CADORS LPV reports

(https://tc.gc.ca)

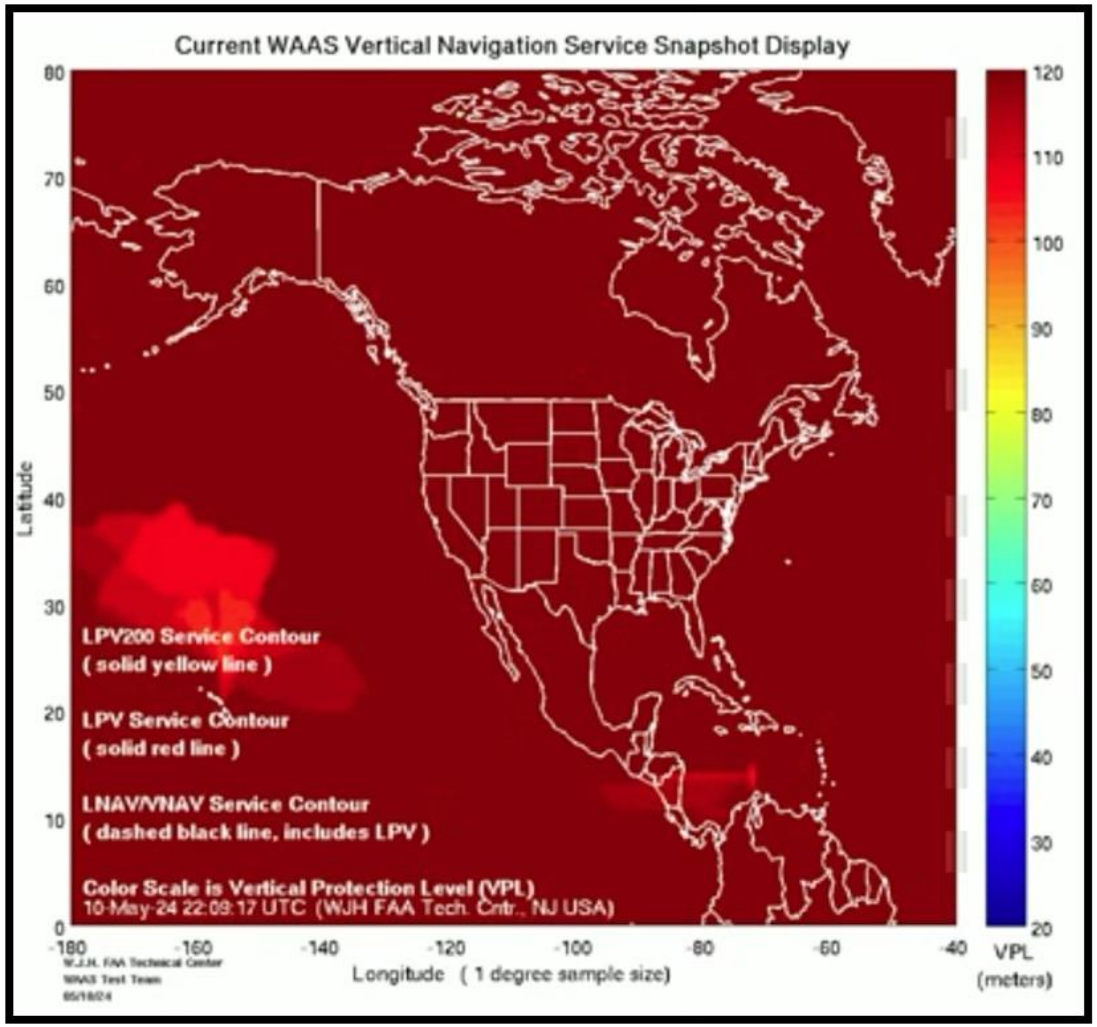
2023-11-05	16:51	Kuujjuaq Airport QC (CYVP)	A Canadian North Boeing 737-406 (C-FFNE/AKT162) from Montreal/Pierre Elliott Trudeau, QC (CYUL) to Kuujjuaq, QC (CYVP) lost localizer performance with vertical guidance (LPV) on approach for Runway 25. AKT162 landed on Runway 25 without incident at 1701Z.

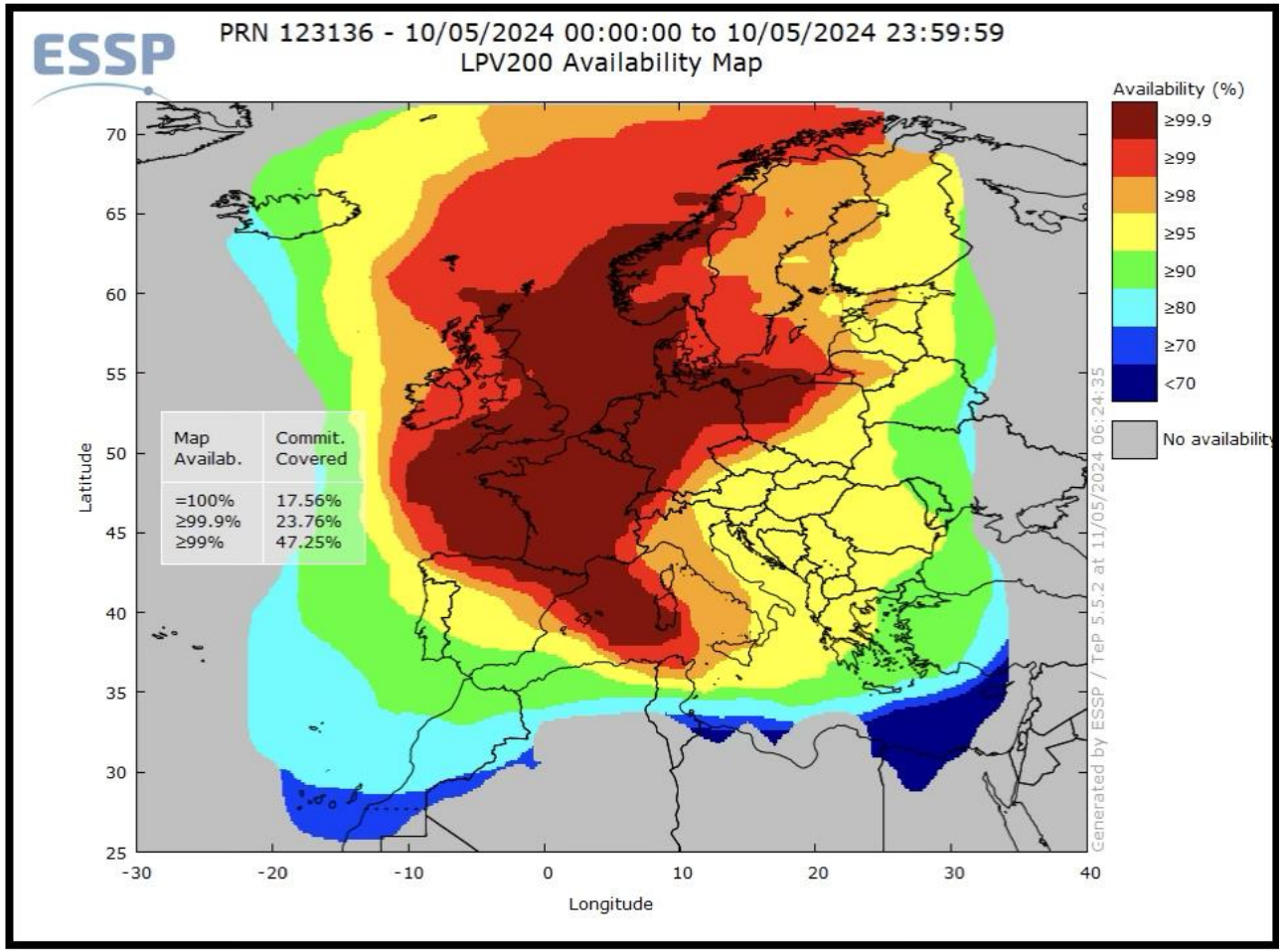
Nov 05 2023

https://www.nstb.tc.faa.gov

Nikitina et al, SWJ 2025

SWIS Motivation: SWX and Aviation





May 10-11 2024

SWIS Motivation: SWX and Aviation

10th May

Actual HF condition

0-4 N: Fairly good
4-8 N: Fairly good
8-12 N: Fairly good
12-16 N: Weak
16-20 N: Weak
20-24 N: Weak

11th May

Actual HF condition

0-4 N: Weak
4-8 N: Weak
8-12 N: Black out
12-16 N: Black out
16-20 N: Black out
20-24 N: Black out

12th May

Actual HF condition

0-4 N: Black out
4-8 N: Black out
8-12 N: Black out
12-16 N: Scarcely perceptible
16-20 N: Scarcely perceptible
20-24 N: Weak

13th May

Actual HF condition

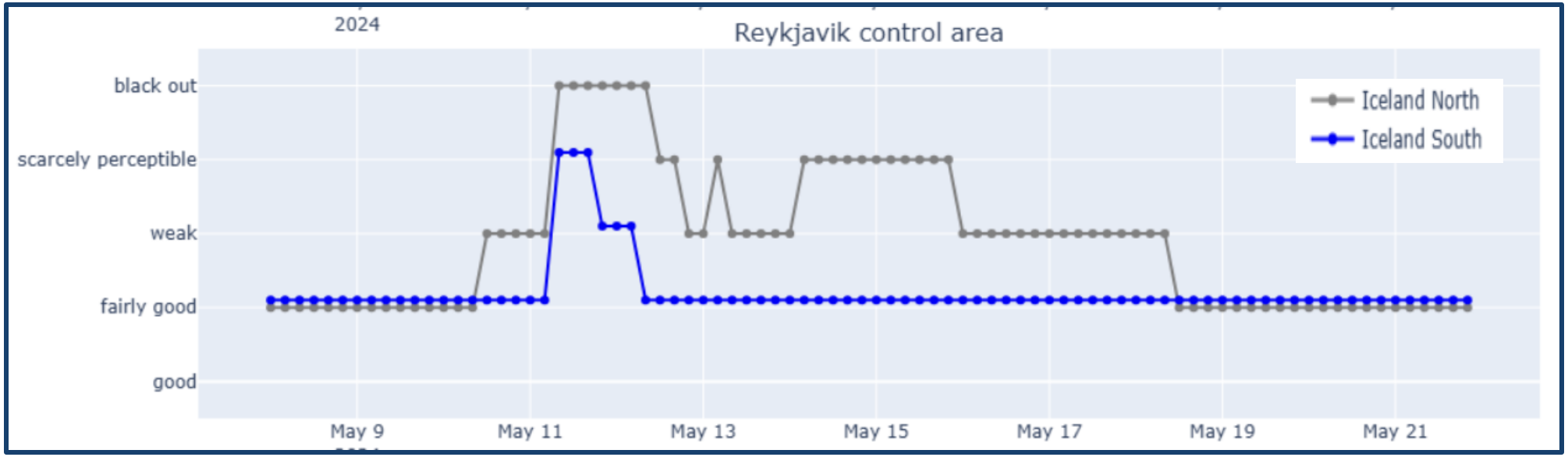
0-4 N: Weak
4-8 N: Scarcely perceptible
8-12 N: Weak
12-16 N: Weak
16-20 N: Weak
20-24 N: Weak

14th May

Actual HF condition

0-4 N: Weak
4-8 N: Scarcely perceptible
8-12 N: Scarcely perceptible
12-16 N: Scarcely perceptible
16-20 N: Scarcely perceptible
20-24 N: Scarcely perceptible

HF COM Conditions in May 2024



isavia ANS
Air Navigation Services

SWIS Objective and Goal

- Goal:

  To advise aviation users when space weather (SWX) events are expected to cause a moderate or severe impact related to the deterioration or loss of

  - satellite navigation (GNSS)
  - HF communication (long-distance radio)

  To advise aviation users in case of enhanced radiation dose rates at specific flight levels (FL250-FL580)

- Advisories are recommended for completeness of flight documentation

SWIS Framework and Requirements

Impact Area	Parameter (Unit)	Moderate	Severe
GNSS	Amplitude scintillation S4 (dimensionless)	0.5	0.8
	Phase scintillation σ_ϕ (radians)	0.4	0.7
	Vertical TEC (TEC Unit)	125	175
Radiation	Effective dose (μSievert/hour)	30	80
HF	Auroral absorption (Kp)	8	9
	PCA (dB from 30 MHz riometer data)	2	5
	Solar X-ray (W/m^2) (0.1–0.8 nm)	10^{-4}	10^{-3}
	MUF (%)	30	50

ICAO

Similar to volcanic ash and tropical cyclone service definitions and advisories structure

```
SWX ADVISORY
DTG:                20250815/0555Z
SWXC:               PECASUS
ADVISORY NR:        2025/18
NR RPLC:            2025/17
SWX EFFECT:         HF COM SEV
OBS SWX:            15/0535Z EQS W045 - E045
FCST SWX +6 HR:     15/1200Z NOT AVBL
FCST SWX +12 HR:    15/1800Z NOT AVBL
FCST SWX +18 HR:    16/0000Z NOT AVBL
FCST SWX +24 HR:    16/0600Z NOT AVBL
RMK:                SPACE WEATHER EVENT (MAXIMUM USABLE
FREQUENCY DEPRESSION) IS IN PROGRESS. IMPACT ON HIGHER HF
COM FREQUENCY BANDS EXPECTED. LOWER FREQUENCY BANDS MAY BE
LESS IMPACTED.
NXT ADVISORY:       WILL BE ISSUED BY 20250815/1155Z=
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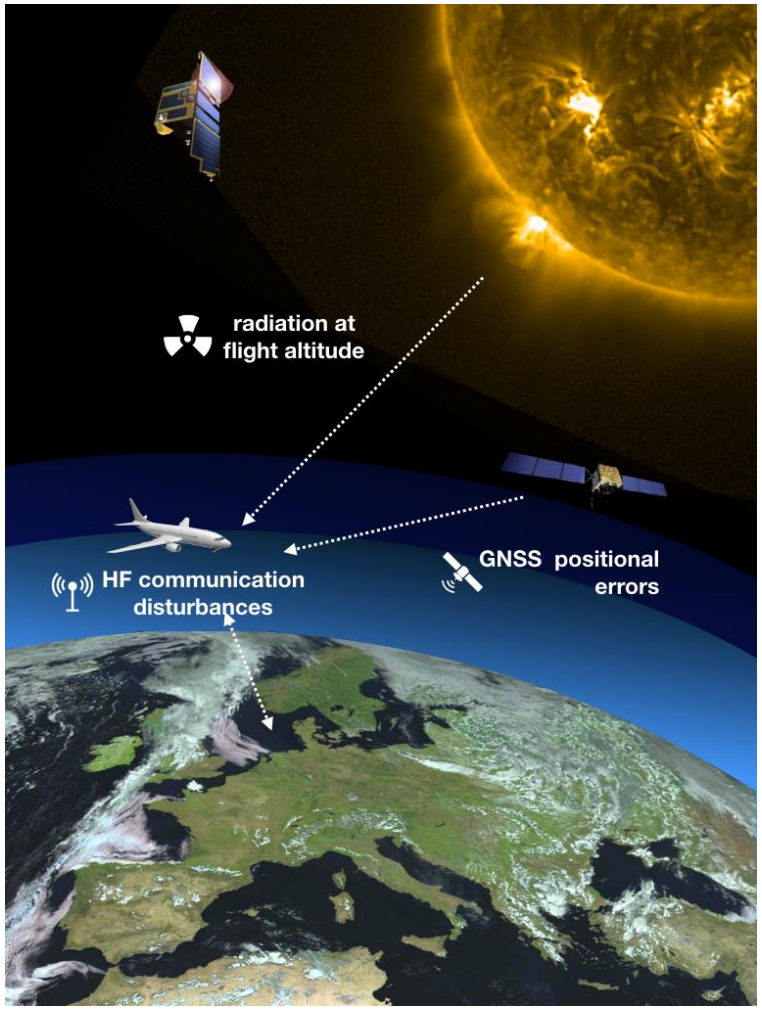
References

- ICAO Annex 3-Meteorological Service for International Air Navigation
- Manual on Space Weather Information in Support of International Air Navigation (ICAO Doc 10100)
- WMO message templates for SWX Advisories

SWIS Service Domains and Definitions



Effect	Sub-effect	Parameter used	Moderate	Severe
GNSS	Amplitude Scintillation	S4 (dimensionless)	0.5	0.8
GNSS	Phase Scintillation	Sigma-phi (radians)	0.4	0.7
GNSS	Vertical Total Electron Content (TEC)	TEC units	125	175
RADIATION		Effective dose (micro-Sieverts/hour)*	30	80
HF COM	Auroral Absorption (AA)	Kp	8	9
HF COM	Polar Cap Absorption (PCA)	dB from 30MHz riometer data	2	5
HF COM	Shortwave Fadeout (SWF)	Solar X-rays (0.1-0.8 nm) ($W-m^{-2}$)	$1x10^{-4}$ (X1)	$1x10^{-3}$ (X10)
HF COM	Post-Storm Depression	MUF**	30%	50%
SATCOM***	N/A	N/A	N/A	N/A

Radiation at flight altitude

HF COM disturbances

GNSS disturbances

SWX Advisory vs general SWX products

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HOME | ABOUT SPACE WEATHER | PRODUCTS AND DATA | DASHBOARDS | MEDIA AND RES

Home > Products and Data > Forecasts > 3-Day Forecast

CURRENT SPACE WEATHER CONDITIONS on NOAA Scales

3-DAY FORECAST

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"
A. NOAA Geomagnetic Activity Observation and Forecast

The greatest observed 3 hr Kp over the past 24 hours was 5 (NOAA Scale
G1).
The greatest expected 3 hr Kp for Oct 13-Oct 15 2025 is 4.67 (NOAA Scale
G1).

NOAA Kp index breakdown Oct 13-Oct 15 2025

             Oct 13       Oct 14       Oct 15
00-03UT       4.67 (G1)    2.67         2.00
03-06UT       4.67 (G1)    2.67         2.67
06-09UT       3.33         2.67         2.00
09-12UT       4.00         2.00         1.67
12-15UT       4.67 (G1)    1.67         1.00
15-18UT       3.00         1.00         1.67
18-21UT       2.67         1.00         2.67
21-00UT       3.67         2.00         3.67

Rationale: Periods of G1 (Minor) geomagnetic storms are expected on 13
Oct in response to continued negative polarity CH HSS influences.

B. NOAA Solar Radiation Activity Observation and Forecast

Solar radiation, as observed by NOAA GOES-18 over the past 24 hours, was
below S-scale storm level thresholds.

Solar Radiation Storm Forecast for Oct 13-Oct 15 2025
```

DTG	20240129/2359Z
SWXC	PECASUS
ADVISORY NR.	2024/4
NR. RPLC	2024/3
SWX Effect	HF COM MOD
OBS SWX	29/2348Z HNH HSH W180 - E180
FCST SWX + 6 HR	30/0600Z NO SWX EXP
FCST SWX + 12 HR	30/1200Z NO SWX EXP
FCST SWX + 18 HR	30/1800Z NO SWX EXP
FCST SWX + 24 HR	31/0000Z NO SWX EXP
RMK	SPACE WEATHER EVENT (HF COM POLAR CAP ABSORPTION) IN PROGRESS. IMPACT ON LOWER HF COM FREQUENCY BANDS EXPECTED AT HIGH LATITUDES. STRONGER IMPACT ON THE SOUTHERN POLE.
NXT ADVISORY	WILL BE ISSUED BY 20240130/0548Z=

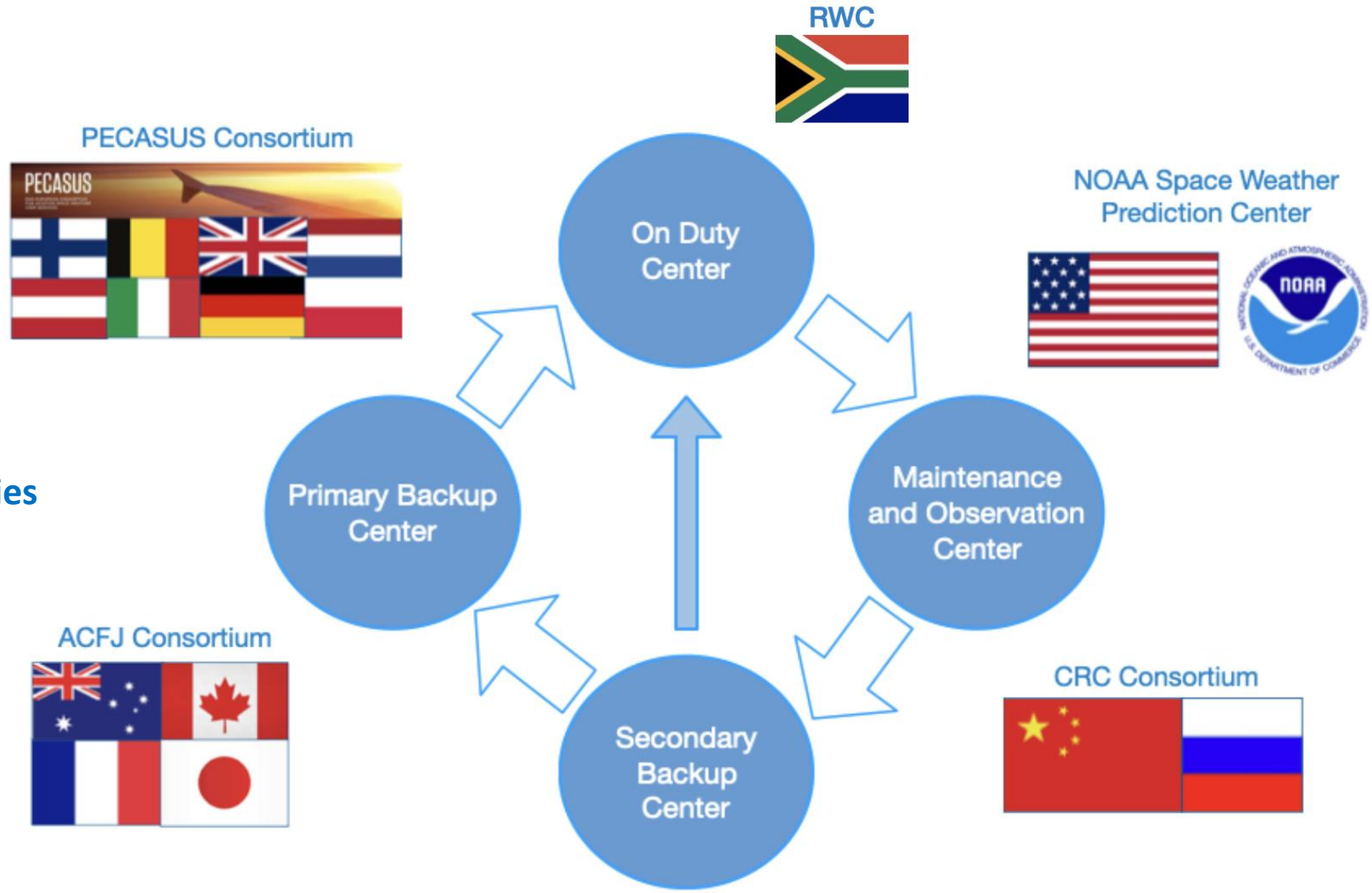
Note: SIGMETs and NOTAMs are NOT issued based on SWX Advisories

Why SWX Advisory?

- 24/7
- Near real-time
- Impact oriented
- Updates within 6h
- Worldwide
- Tailored to Aviation

SWIS Service Provision Centers

24/7 service:
space weather advisories
(Nov 2019)



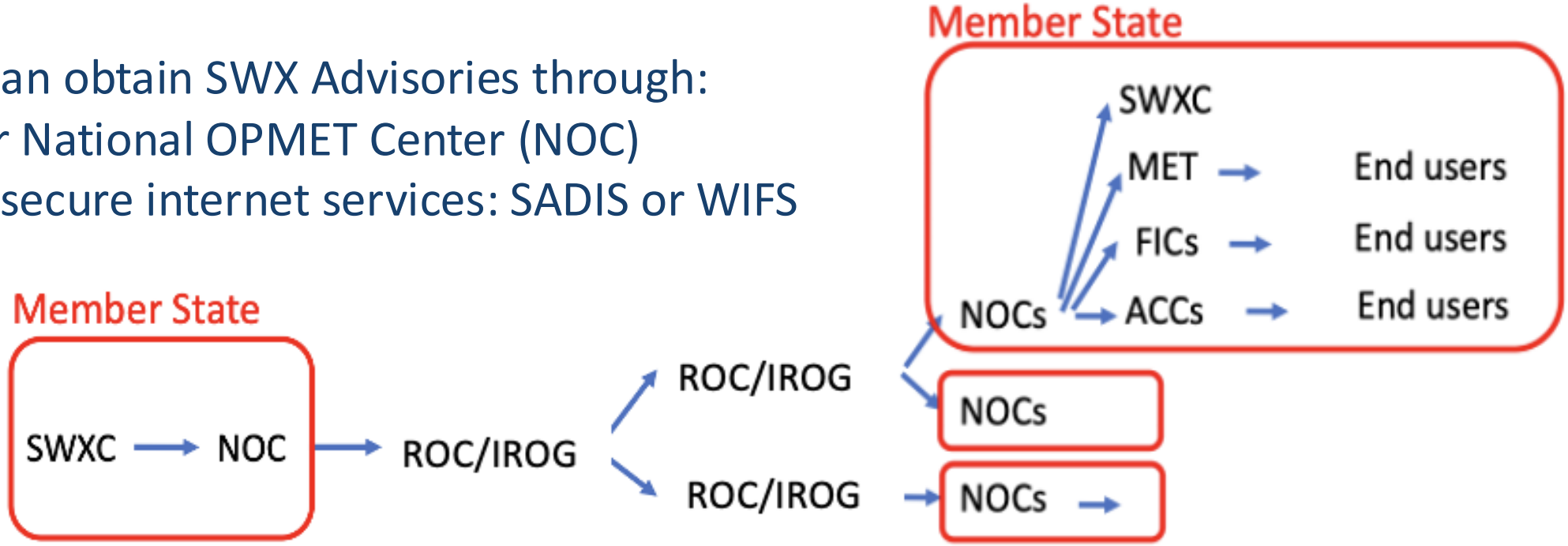
Dissemination of SWX Advisories

Dissemination via Aeronautical Fixed Service/Aeronautical Fixed Telecommunication Network (AFS/AFTN) network like all Operational Meteorological Information (OPMET) data:

- the secure aviation data information service (SADIS)
- the World Internet File Service (WIFS)

Users can obtain SWX Advisories through:

- their National OPMET Center (NOC)
- The secure internet services: SADIS or WIFS



Compliant with WMO standards

WMO message headers

- SWX advisories with different effects (GNSS, HF COM,..) have different WMO headers
- TAC and IWXXM format advisories have different WMO headers
- Every SWX center has own WMO header

	WMO Headers	
	TAC Advisory	IWXXM Advisory
ACFJ – Australia	FNXX01 YMMC	LNXX01 YMMC
ACFJ – France	FNXX01 LFPW	LNXX01 LFPW
PECASUS – Finland	FNXX01 EFKL	LNXX01 EFKL
PECASUS – UK	FNXX01 EGRR	LNXX01 EGRR
CRC – China	FNXX01 ZBBB	LNXX01 ZBBB
CRC – Russia	FNXX01 UUAG	LNXX01 UUAG
SPWC – USA	FNXX01 KWNP	LNXX01 KWNP

01 = GNSS

02 = HF COM

03 = RADIATION

04 = SATCOM

GNSS SWX Advisories

Global Navigation Satellite System (GNSS):

Ionosphere's Role: The ionosphere, a top layer in our atmosphere ionized by sunlight, affects satellite navigation signals.

Signal Disruption: Solar storms can cause ionospheric disturbances, altering GNSS signal strength, velocity and phase.

Scintillation: This rapid change can prevent receivers from locking onto signals, making it hard to determine position.

VTEC: Increased vertical total electron content in the ionosphere during solar storms can cause positioning errors in satellite navigation.

Advisory Severity Levels: GNSS MOD; GNSS SEV

Impact area:

HNH/HSH

EQN/EQS

Duration:

~ few hours

HF COM

HF communication (HF COM) :

HF Radio Waves: These waves (3-30 MHz) are used for long-distance communication, especially important for polar and transatlantic flights.

Ionosphere's Role: The ionosphere reflects HF radio waves, enabling communication beyond the horizon by bouncing signals between the Earth and the ionosphere.

Impact of Solar Storms: Events like solar flares and coronal mass ejections add extra energy to the ionosphere, highly disturbing it.

Communication Disruption: This extra energy can cause unexpected absorption or reflection of HF radio waves, leading to communication failures.

Affected Areas: Disruptions can occur near the poles, on the sunlit side of the Earth or even affect the entire globe, depending on the type and severity of the solar storm.

MUF Reduction: Ionospheric changes after geomagnetic storms can significantly lower the maximum usable frequency (MUF) for HF communication, affecting any location on Earth.

Advisory Severity Levels: HF COM MOD; HF COM SEV

Impact area:

HNH/HSH

DAYSIDE

Anywhere

Duration:

~ 0.5 hour
to few days

RADIATION

Increased radiation dose at flight levels (RAD):

Energetic Particles: During solar storm events, high-energy solar particles like protons can be rapidly accelerated and travel towards Earth.

Radiation Increase: Once energetic particles reach Earth, they can penetrate the atmosphere, especially close to the magnetic poles, creating a shower of particles, possibly reaching the ground.

Impact on Flights: This can affect crew and passengers by exposing them to increased levels of ionizing radiation, especially at high altitudes and polar routes.

Advisory Severity Levels: RADIATION MOD; RADIATION SEV

***Note**: MOD advisories will only be issued at and below FL460.

Impact area:

HNH/HSH
(polar region)

Duration:

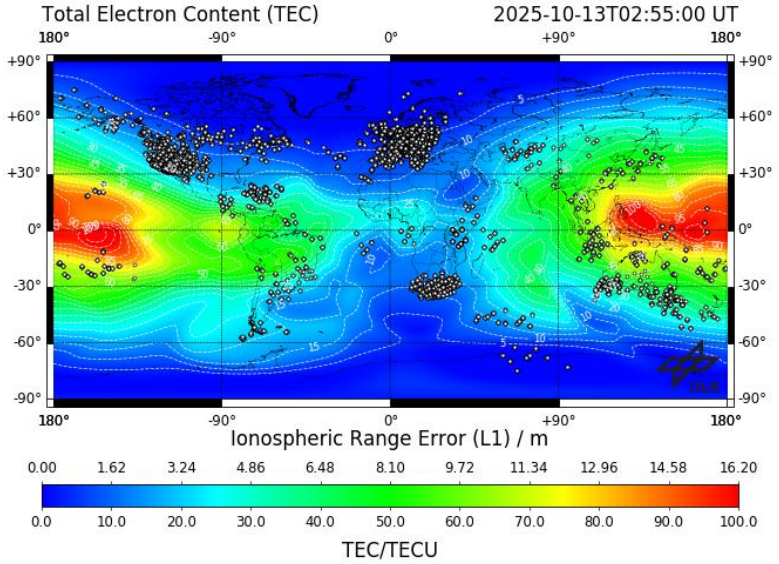
~ few hours

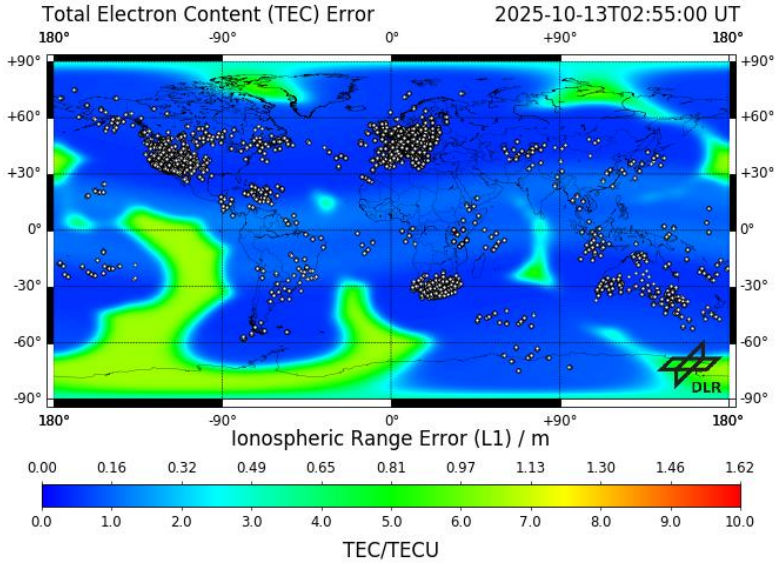
SWIS Impacts Summary Table

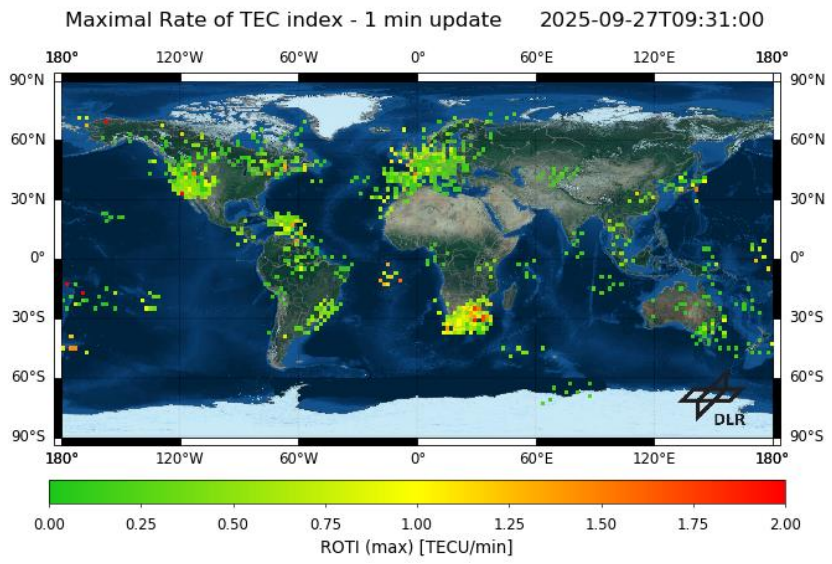
Phenomena		High Energetic Particle	Communication Blackout	Polar Cap Absorption	Auroral Absorption	Ionospheric Storm	Plasma Bubble
Critical Areas		High latitude region	Dayside region	Polar region	Auroral Oval	Mid-high latitude region	Low latitude region
Occurrence/dependency		• Once in several years • Depends on solar activity	• Several times a year • Depends on solar activity	• One to a few times a year • Depends on solar activity	• One to a few times a year • Strongly depends on solar activity	• Moderate: several times a year • Severe: several times a decade	• Solar activity dependence • Seasonal dependence
Impact	GNSS					Signal and Positioning degradation; Scintillation	Scintillation
	HF (radio) communication	HF waves absorption and signal degradation or loss. Especially at lower frequency range.				Decreasing maximum usable frequency	
	Radiation	Solar energetic particles					
Typical Impact Duration		• hours to days	• 30 mins ~ 1 hour	• hours to days	• several hours	• hours to days	• 1 hour ~ 1 day

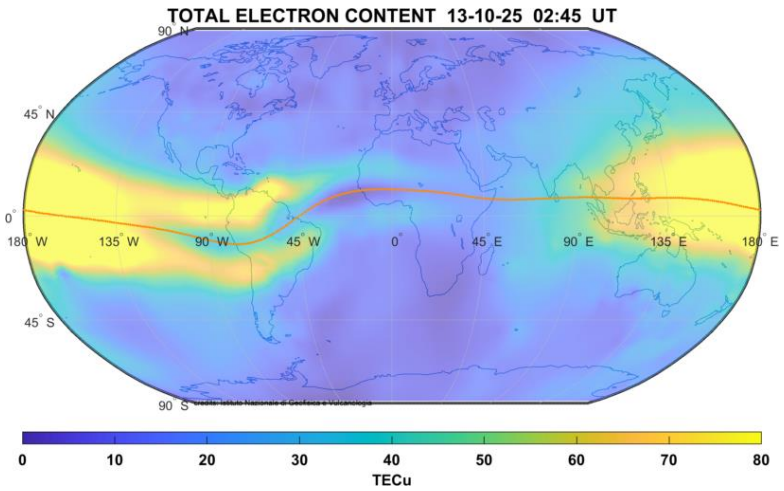
SWX Monitoring Tools: PECASUS

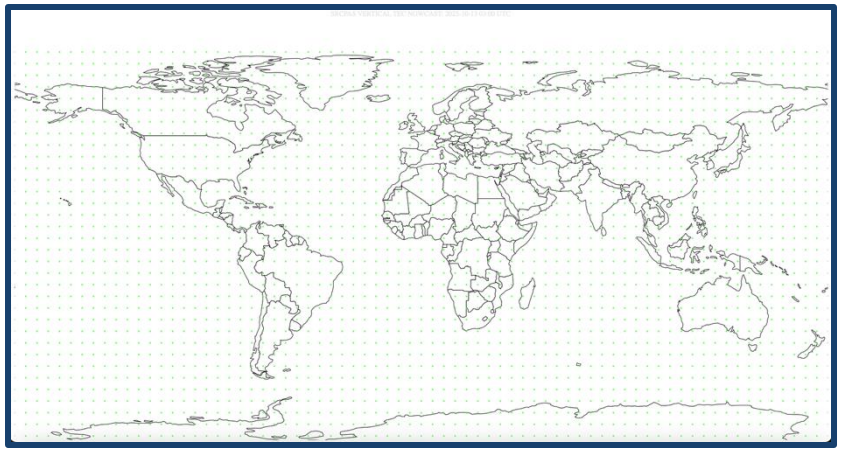
GNSS products

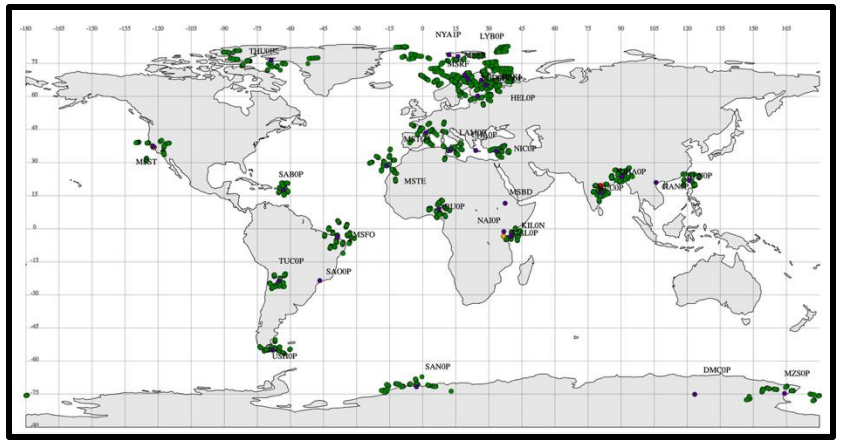












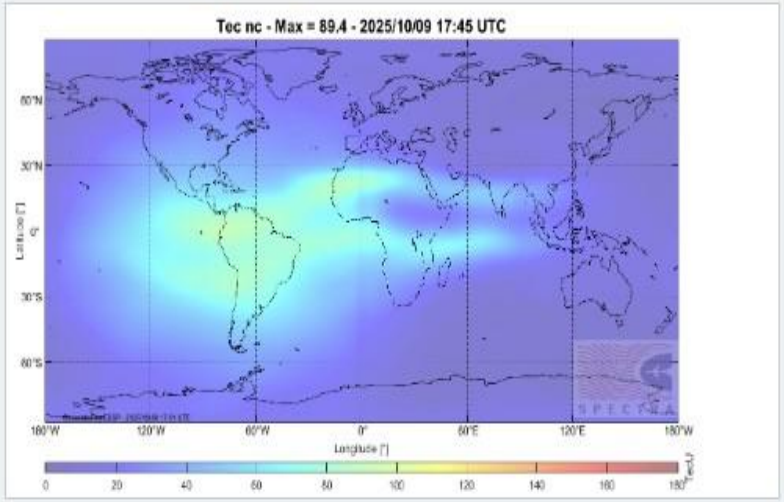
SWX Monitoring Tools: ACFJ

GNSS products

GNSS Conditions

Checked every 10 minutes, last checked 9-Oct-2025 18:06:28Z

GNSS Delay (TEC)

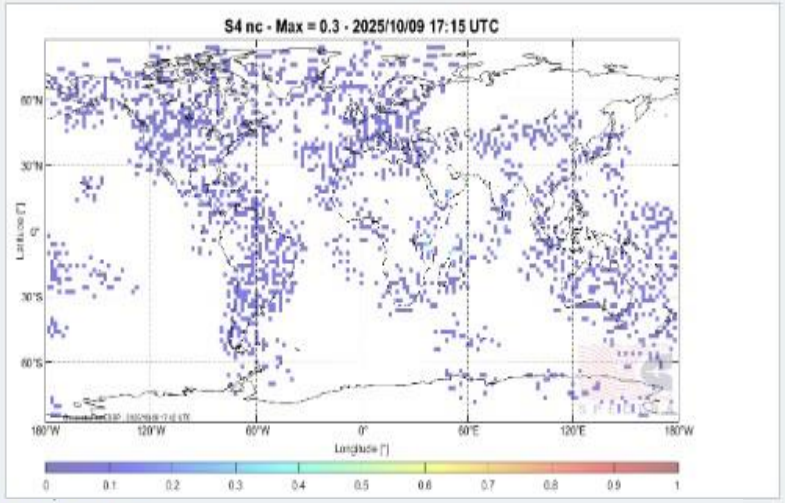


SWS/Bureau

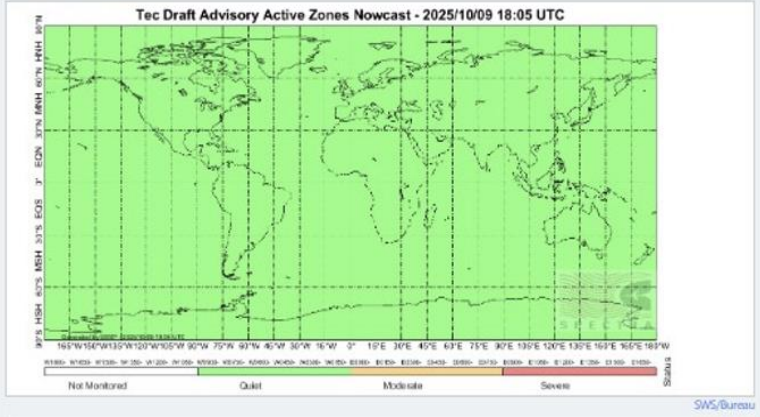
GNSS ionospheric delay latest conditions, expressed in terms of TEC.

Checked every 10 minutes, last checked 9-Oct-2025 18:06:28Z

Amplitude Scintillation (S4)



TEC Active Zone



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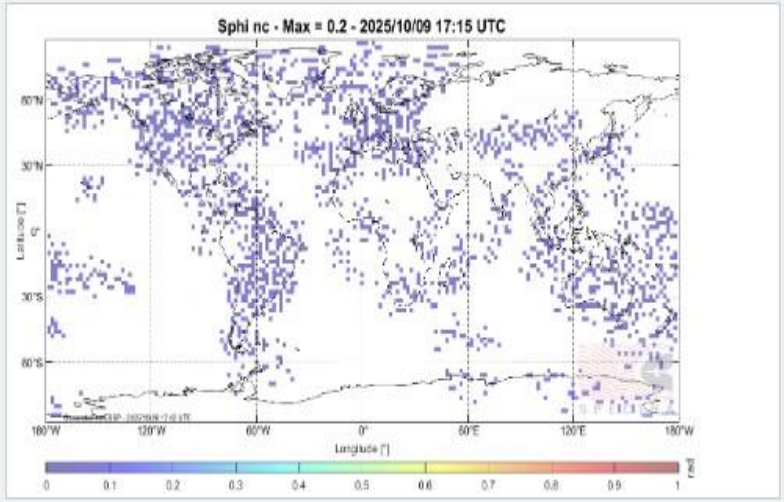
Phase Scintillation (SPHI)

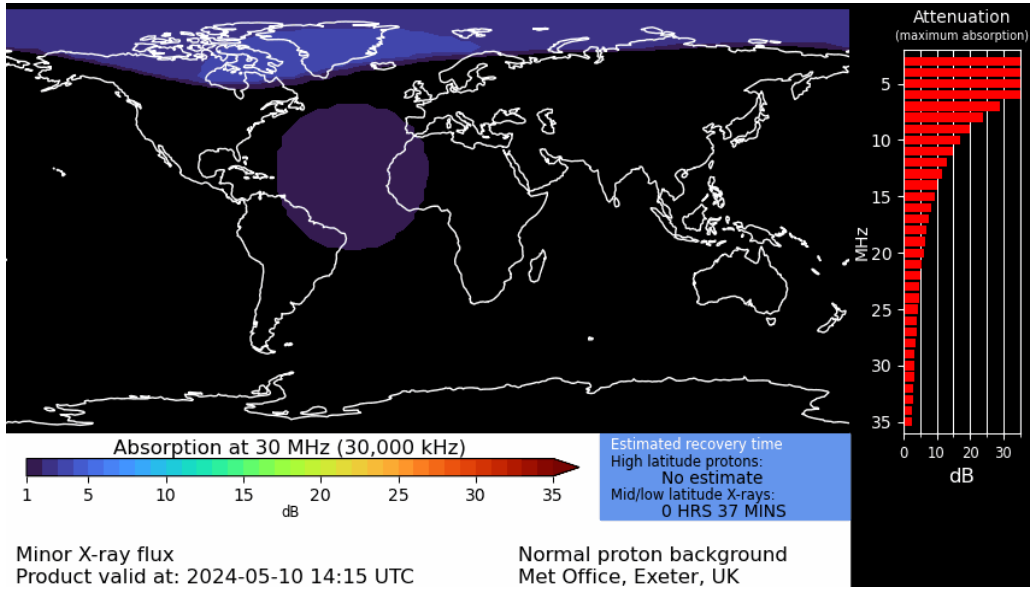


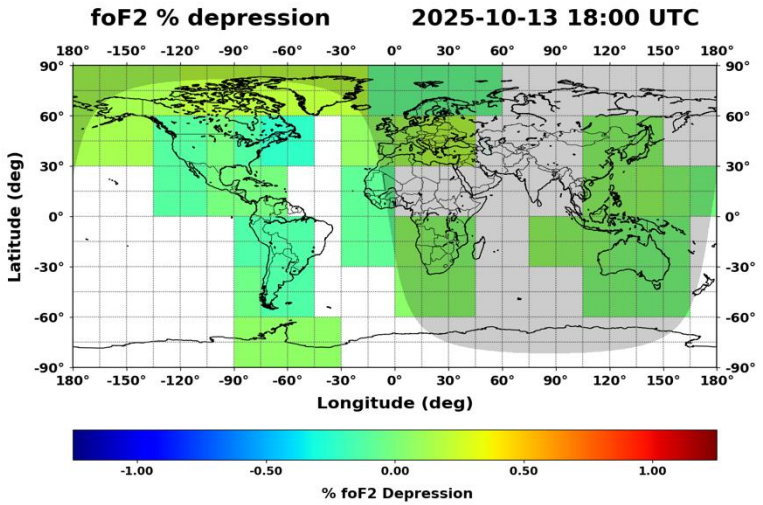
SWS/Bureau

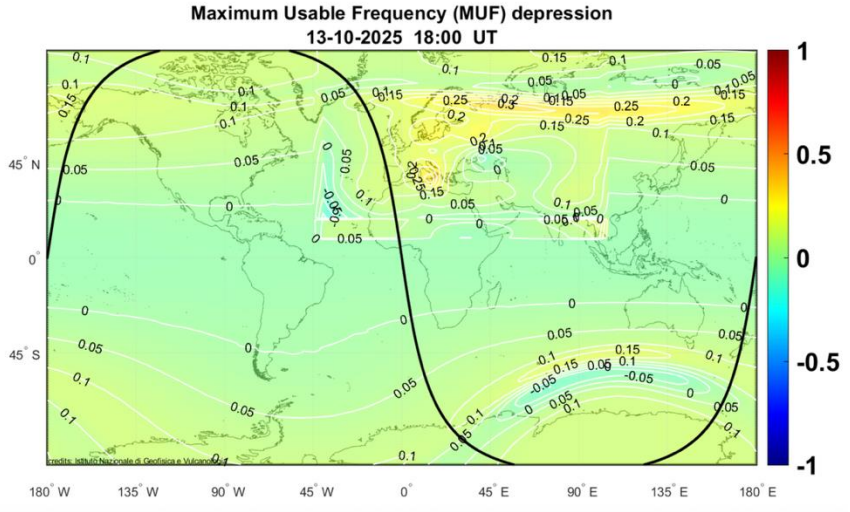
GNSS ionospheric phase scintillation latest conditions, expressed in terms of Sigma_phi index

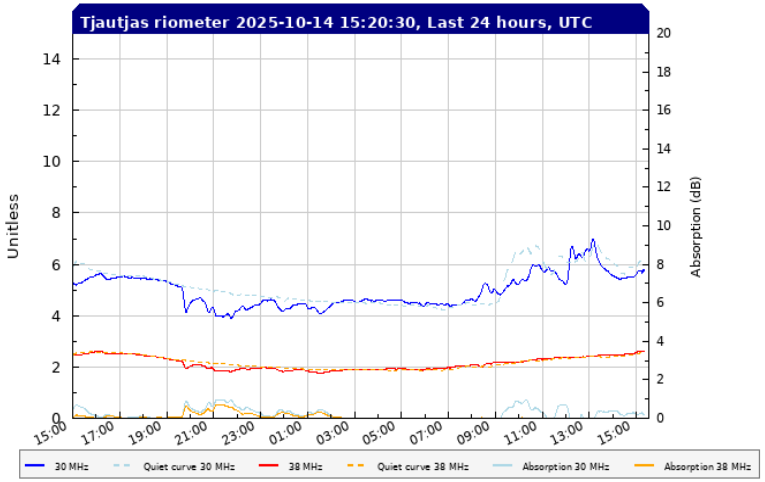
SWX Monitoring Tools: PECASUS

HF COM products









SWX Monitoring Tools: ACFJ

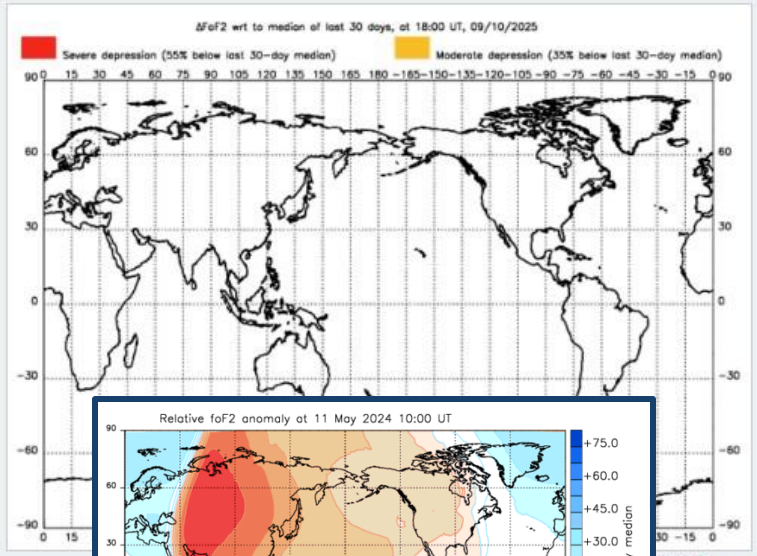
HF COM products

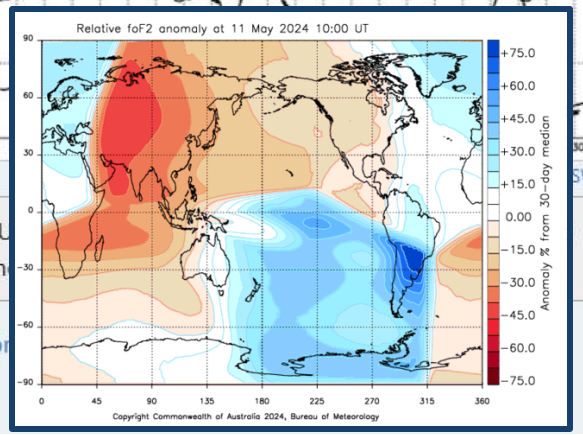
Latest Maps

HF Comm Conditions

Checked every 10 minutes, last checked 9-Oct-2025 18:06:28Z

HF Depression





SWS/Bureau

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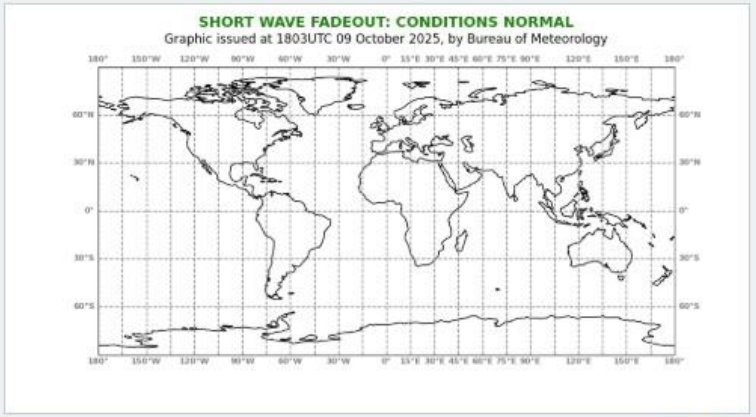
Checked every 10 minutes, last checked 9-Oct-2025 18:06:28Z

Shortwave Fadeout



SWS/Bureau

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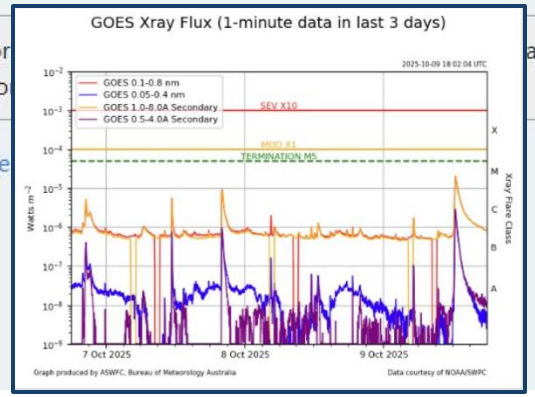
Shortwave



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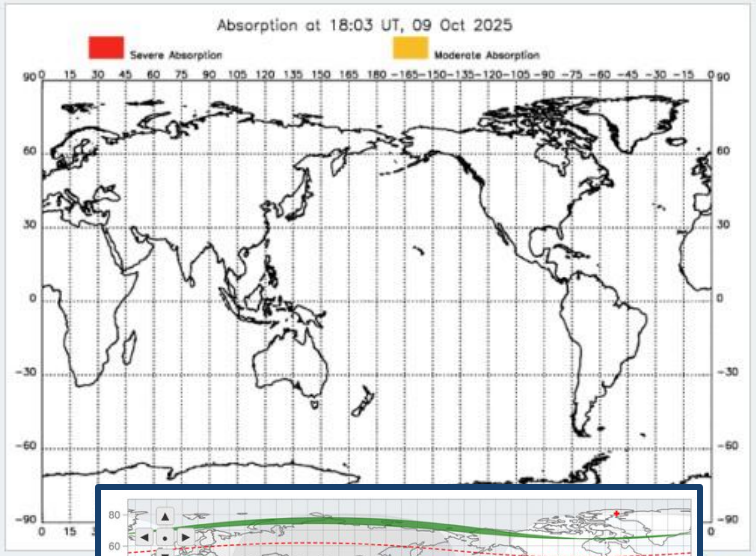
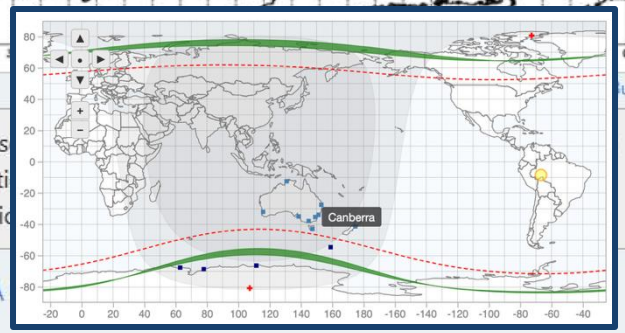
PCA/AA





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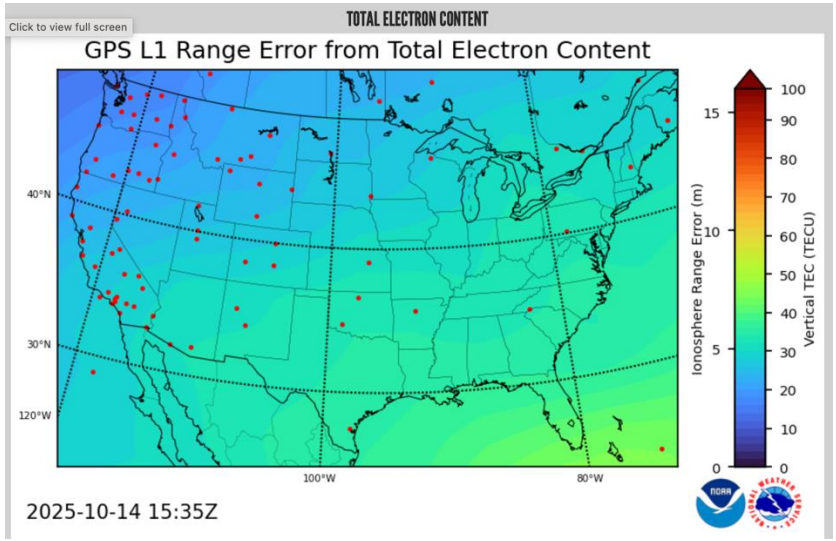
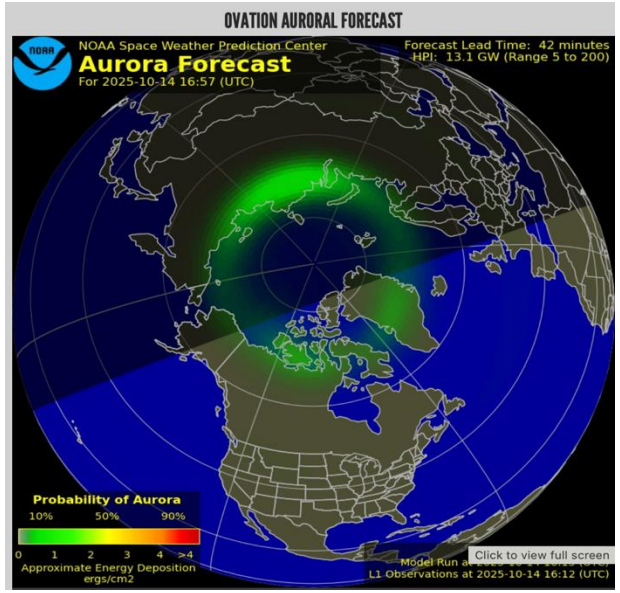
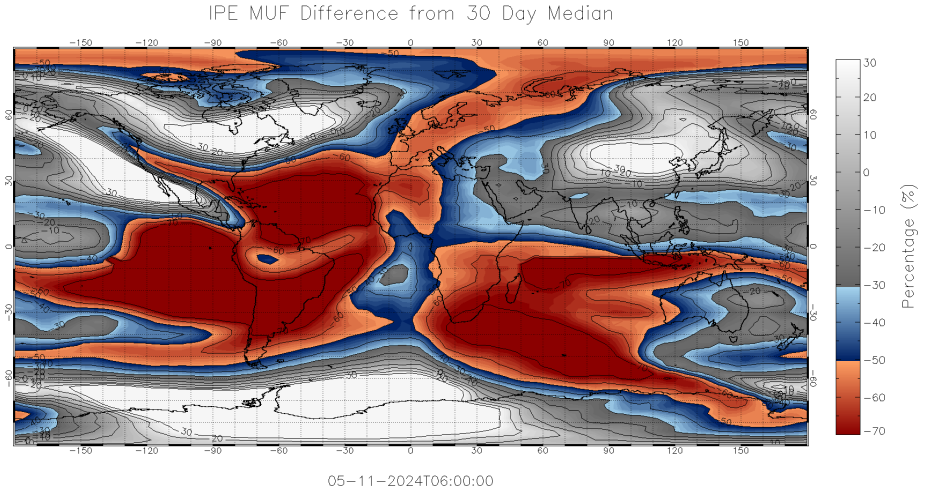
METEOROLOGY PANEL

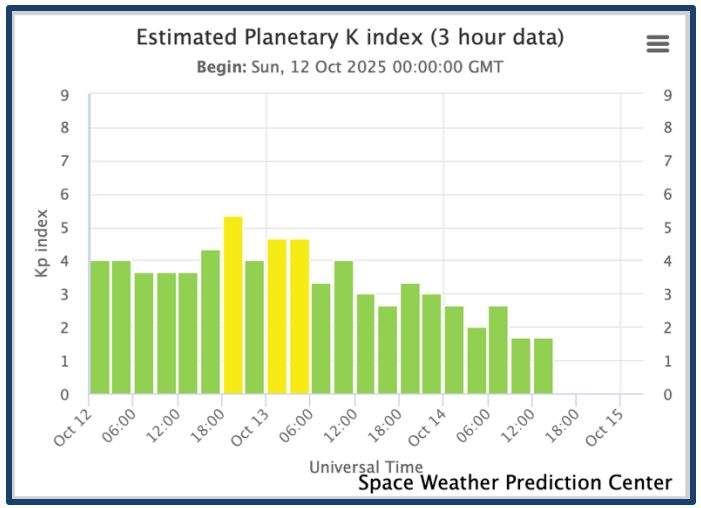
SWX Monitoring Tools: SWPC

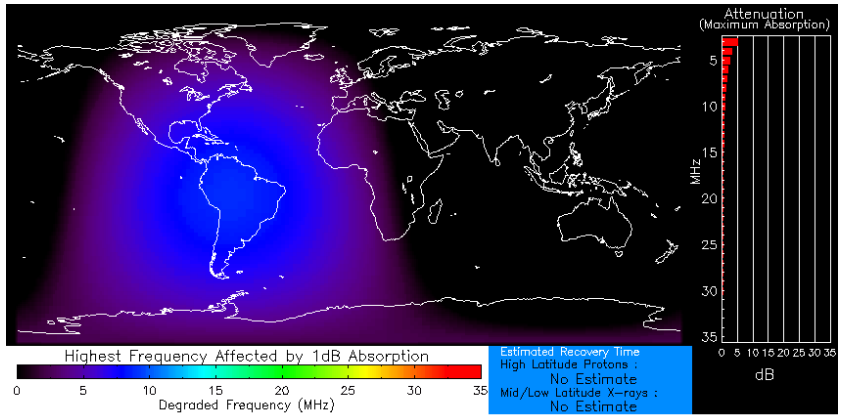
GNSS and HF COM products





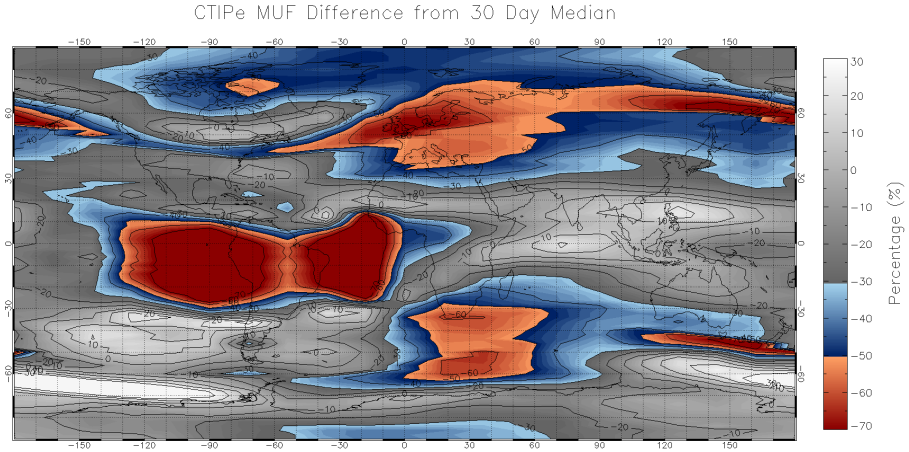






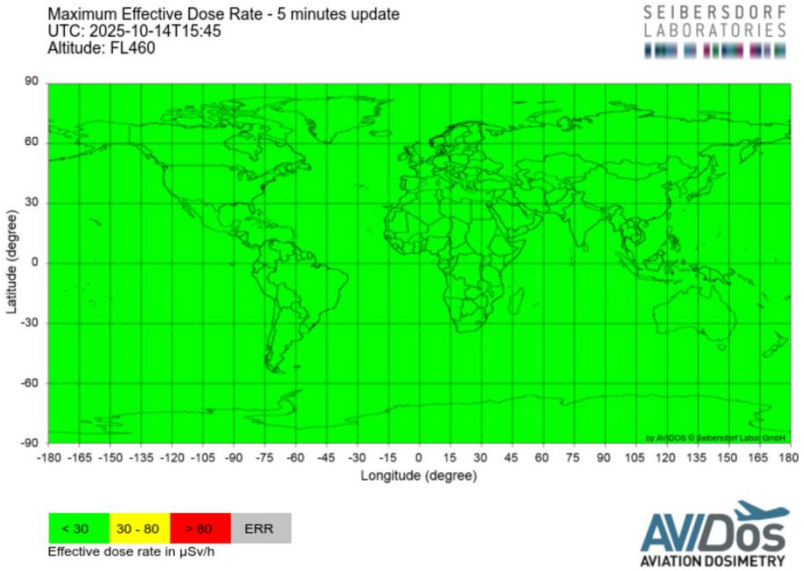
Elevated X-ray flux
Product Valid At : 2025-10-14 16:16 UTC

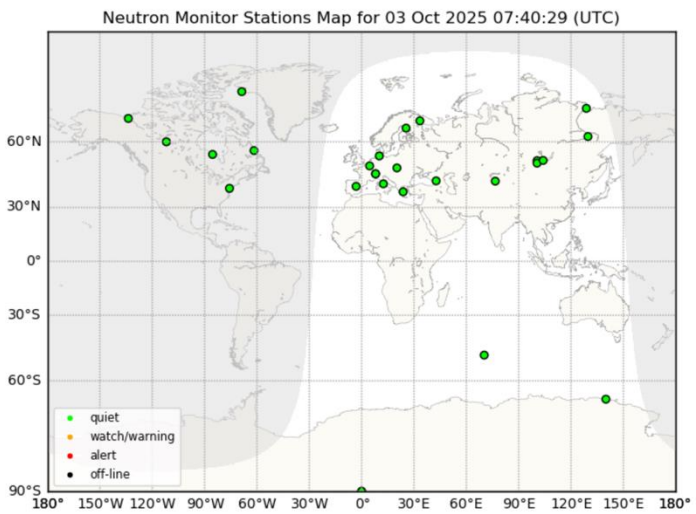
Normal Proton Background
NOAA/SWPC Boulder, CO USA

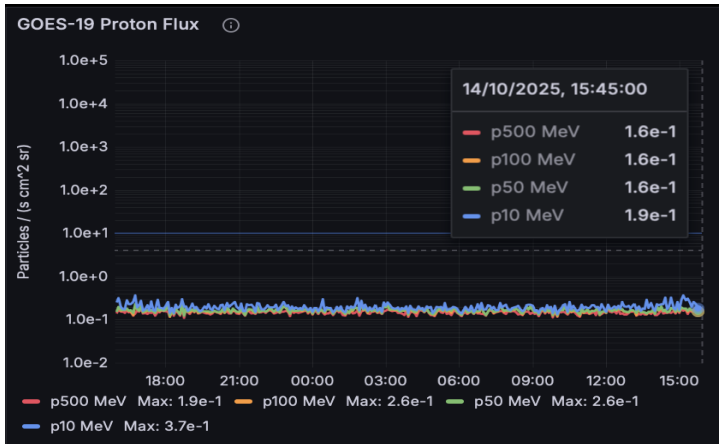


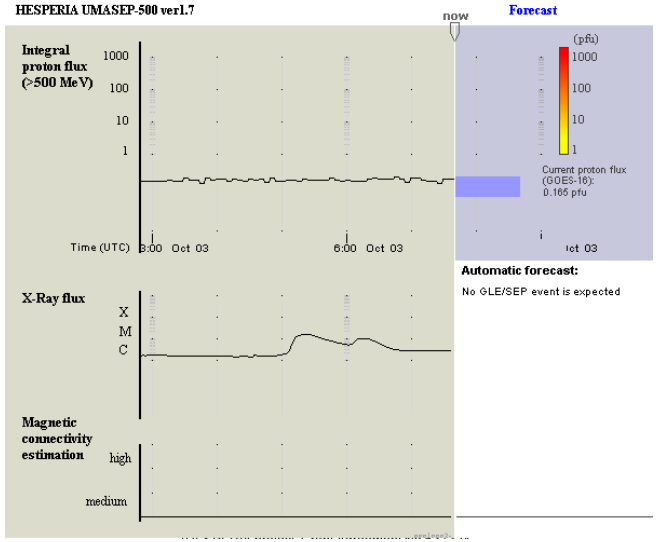
SWX Monitoring Tools: PECASUS

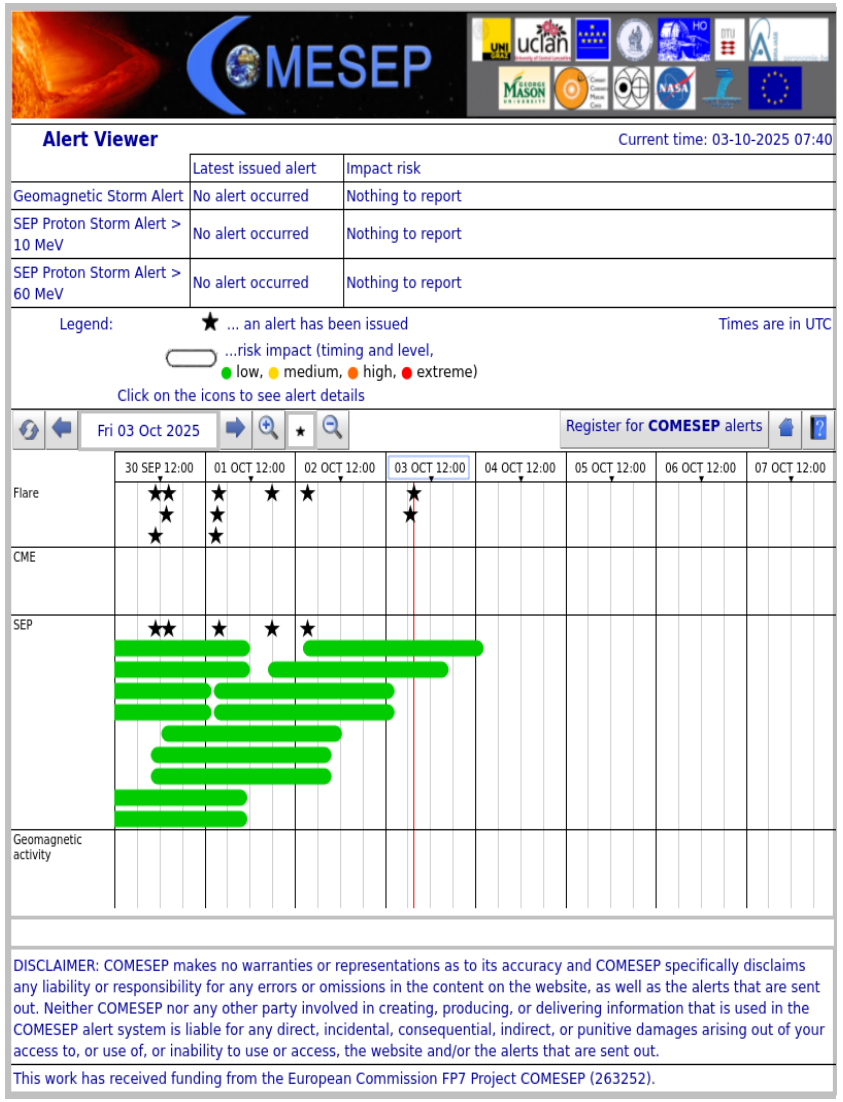
RAD products











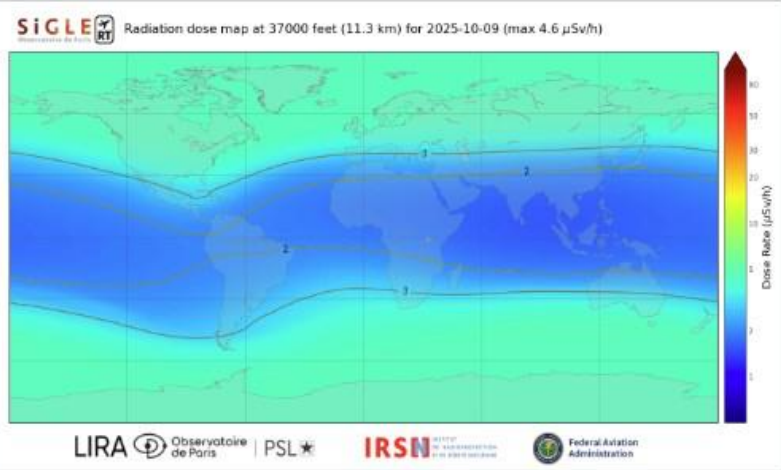
SWX Monitoring Tools: ACFJ

RAD products

Radiation Conditions

Checked every 5 minutes, last checked 9-Oct-2025 18:06:28Z

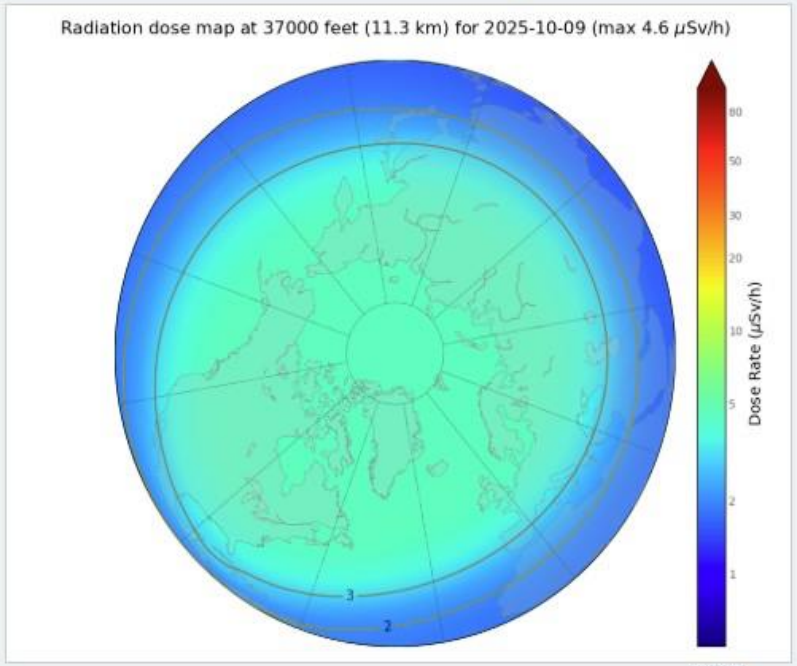
Dose Rate Map FL370



SWS/Bureau

Modelled radiation dose rate at FL370, latest conditions. Image provided by Paris Observatory.

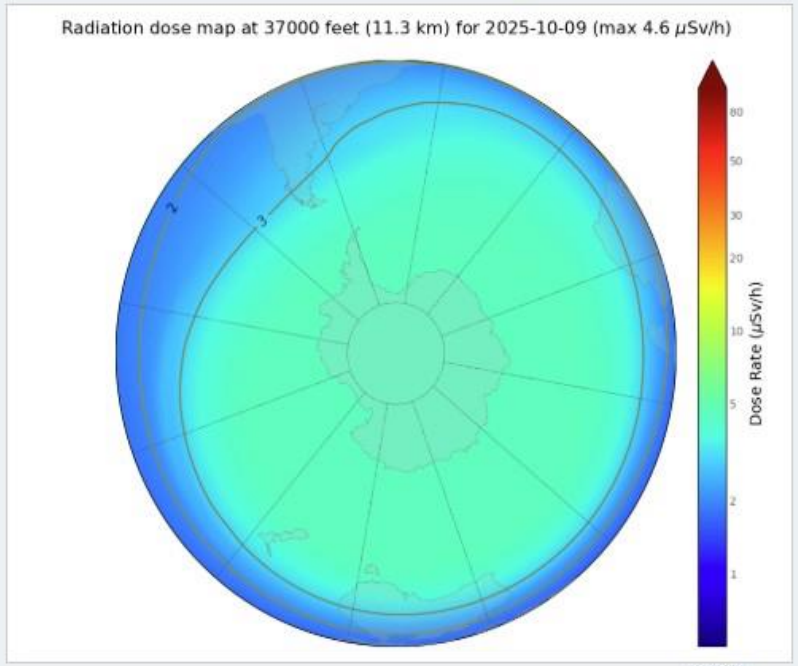
Northern Polar Dose Rate Map FL370



SWS/Bureau

Modelled radiation dose rate at FL370, latest conditions. Image provided by Paris Observatory.

Southern Polar Dose Rate Map FL370

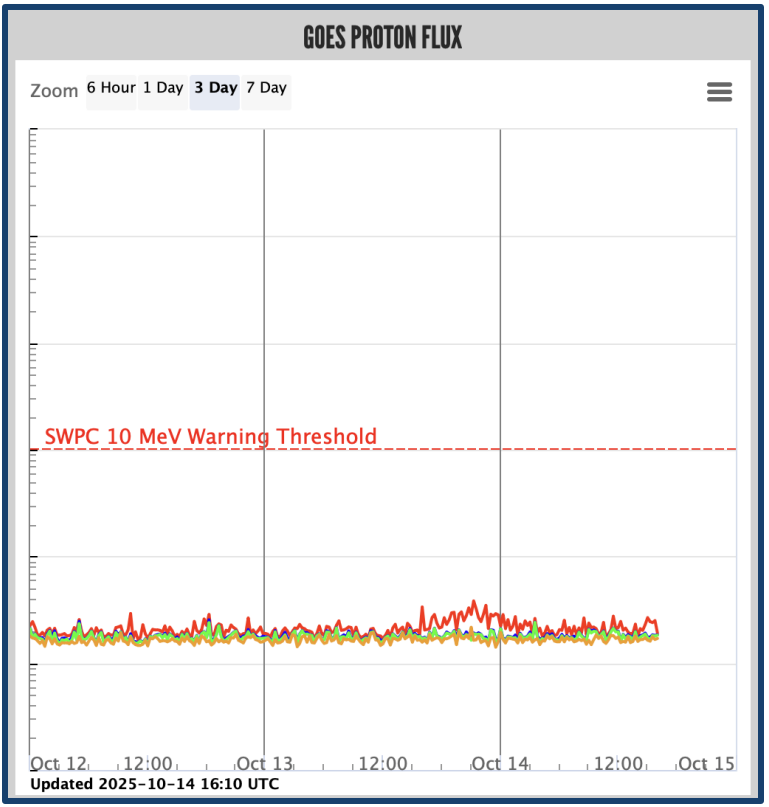


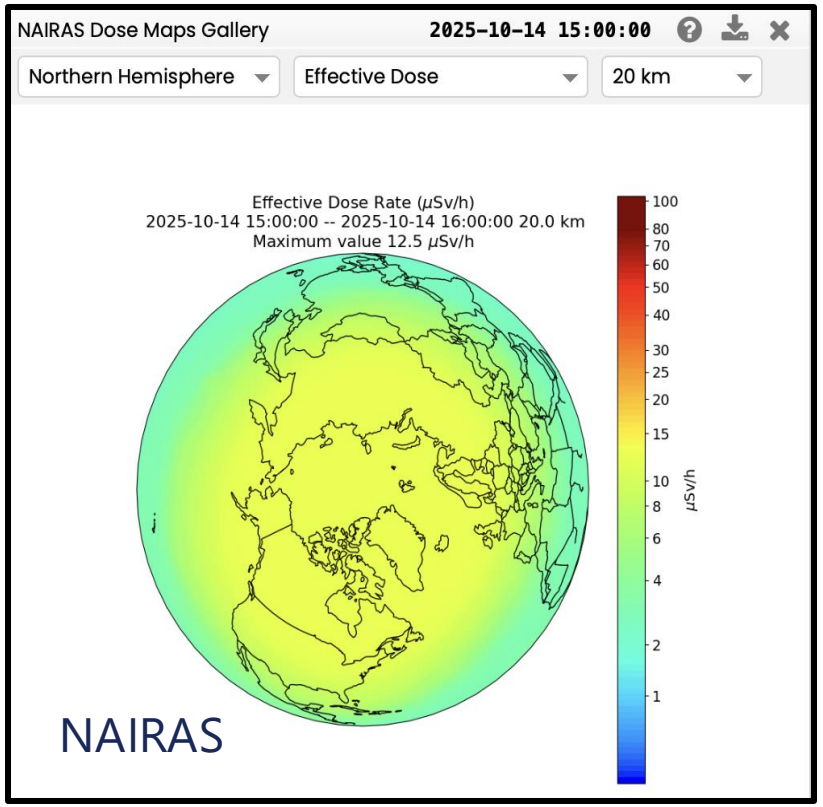
SWS/Bureau

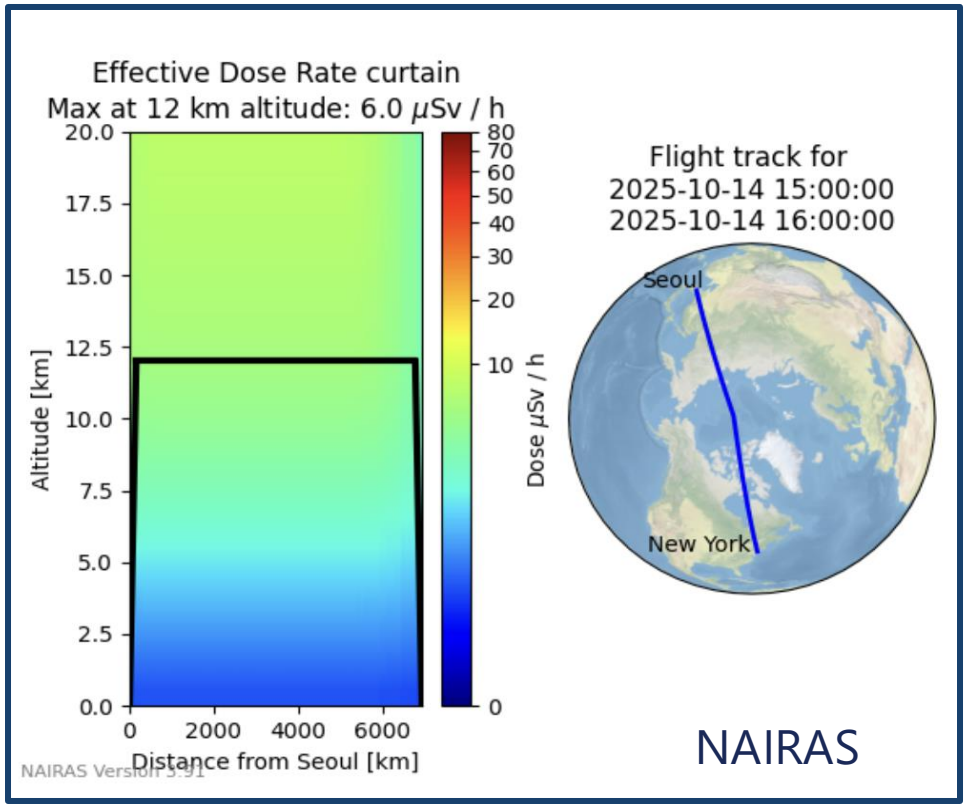
Modelled radiation dose rate at FL370, latest conditions. Image provided by Paris Observatory.

SWX Monitoring Tools: SWPC

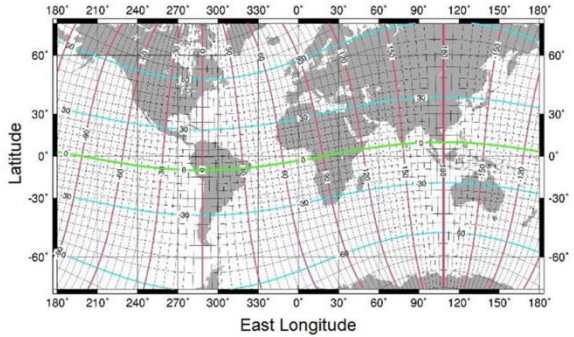
RAD products







CARI-7 and CARI-7A



Information Materials

SWX service informational bulletins and documentation by IATA, EASA, FAA, …

IATA

EASA
European Union Aviation Safety Agency

Federal Aviation Administration

Training and Educational Materials

https://www.stce.be/PECASUS_guide4pilots

https://events.spacepole.be/category/4/

SWEC

Space Weather Education Centre

Thank You!