METEOROLOGY PANEL

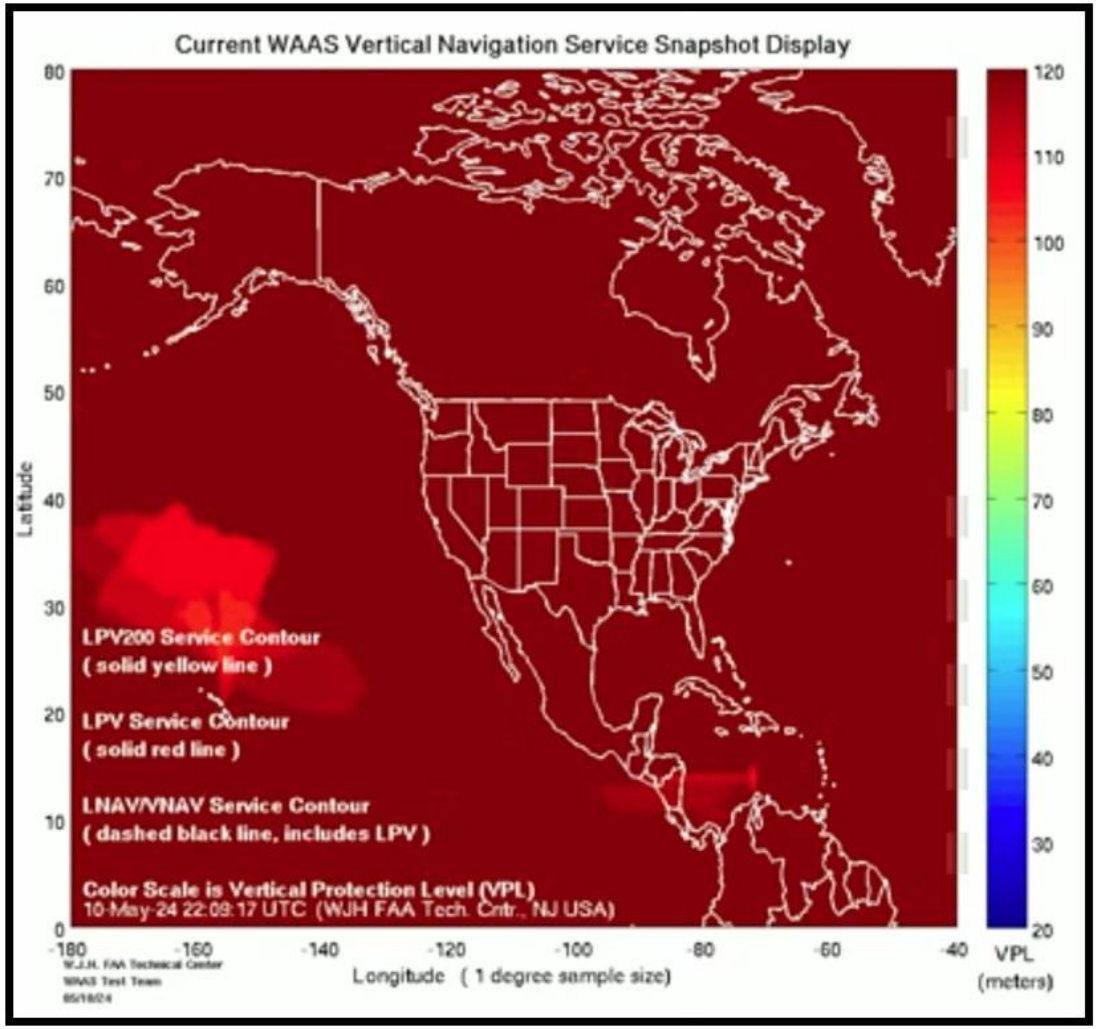
2nd Space Weather User Workshop, 8-9 June 2026, Hermanus

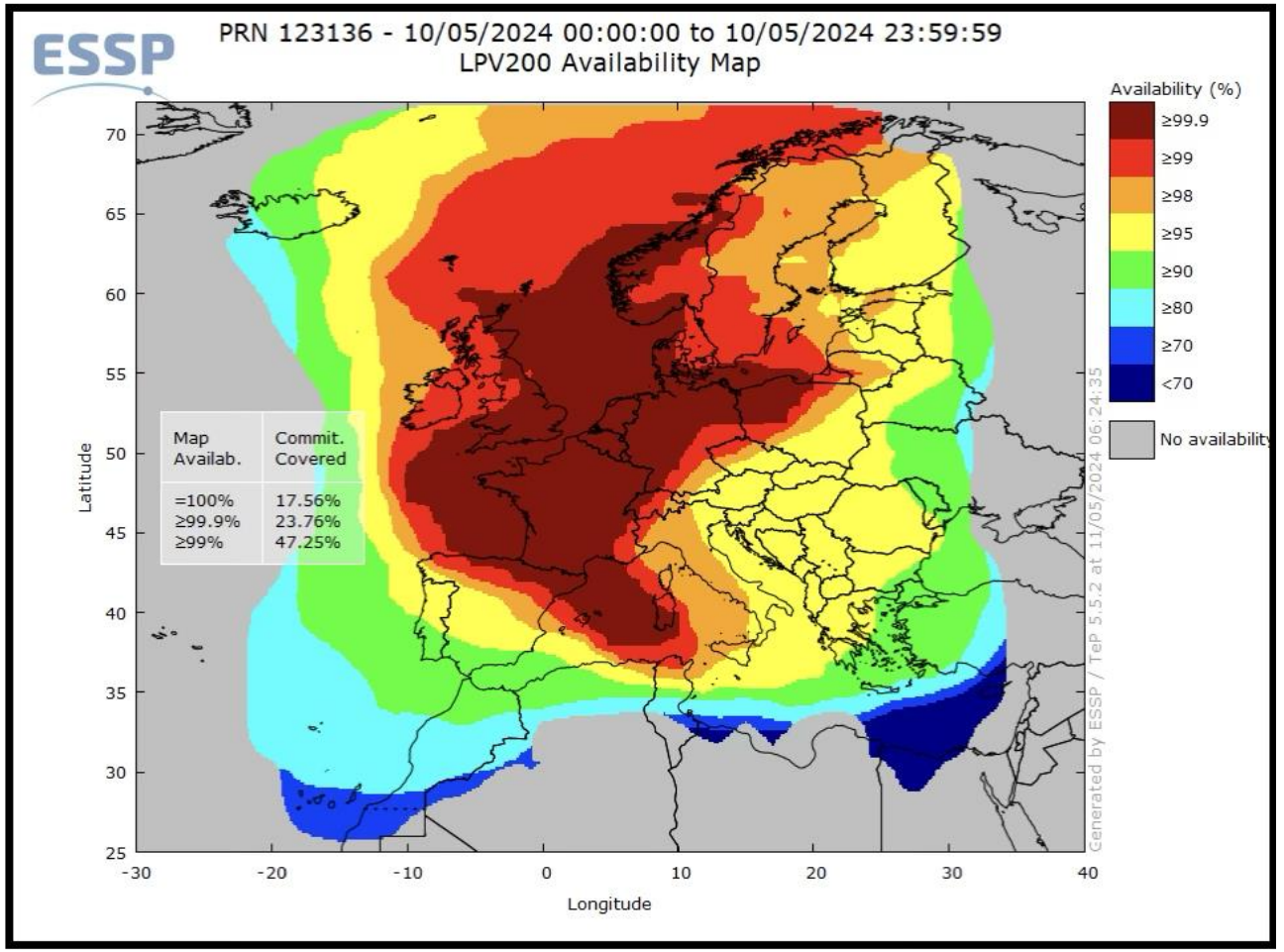
ICAO Space Weather Information Service

Education and Guidance Materials

Yana Maneva, Ph.D.
Solar-Terrestrial Center of Excellence
on behalf of the SWIS User Engagement Ad Hoc Group

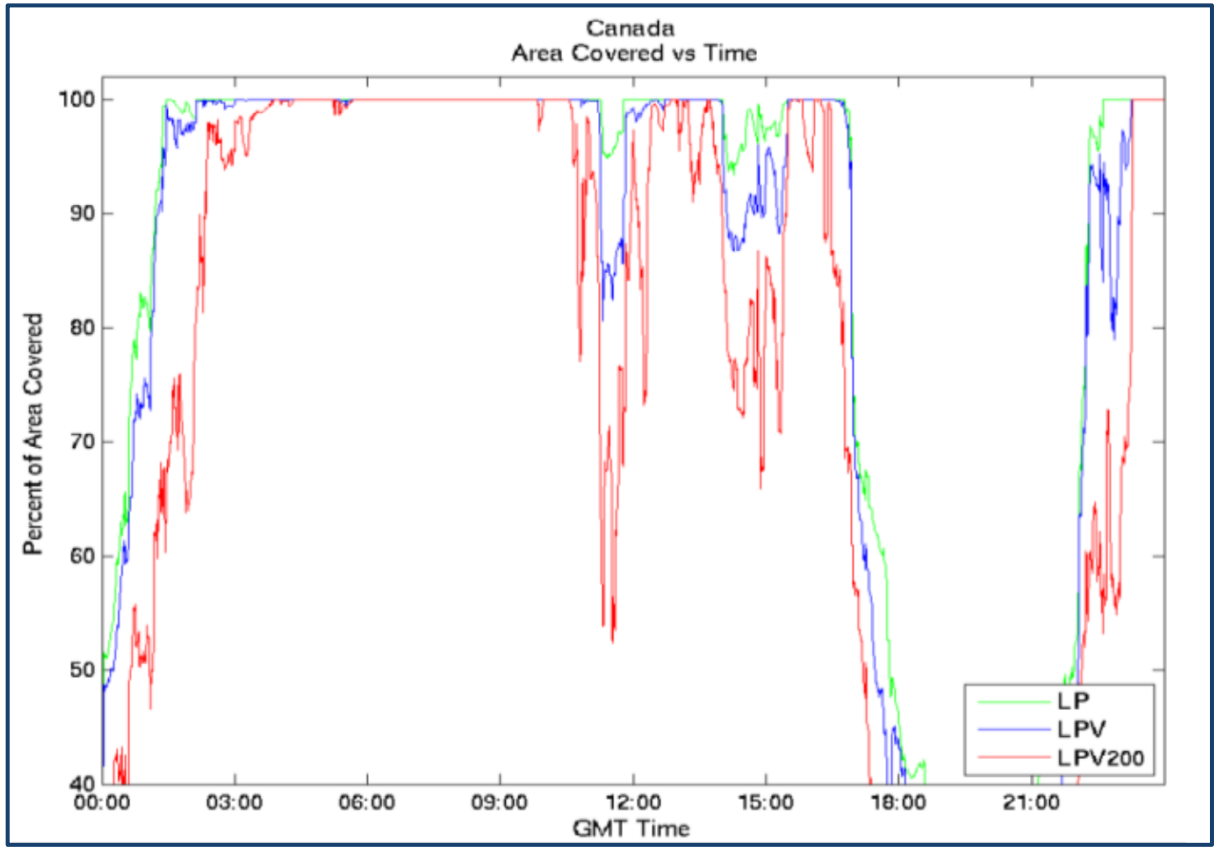
SWIS Motivation: SWX and Aviation

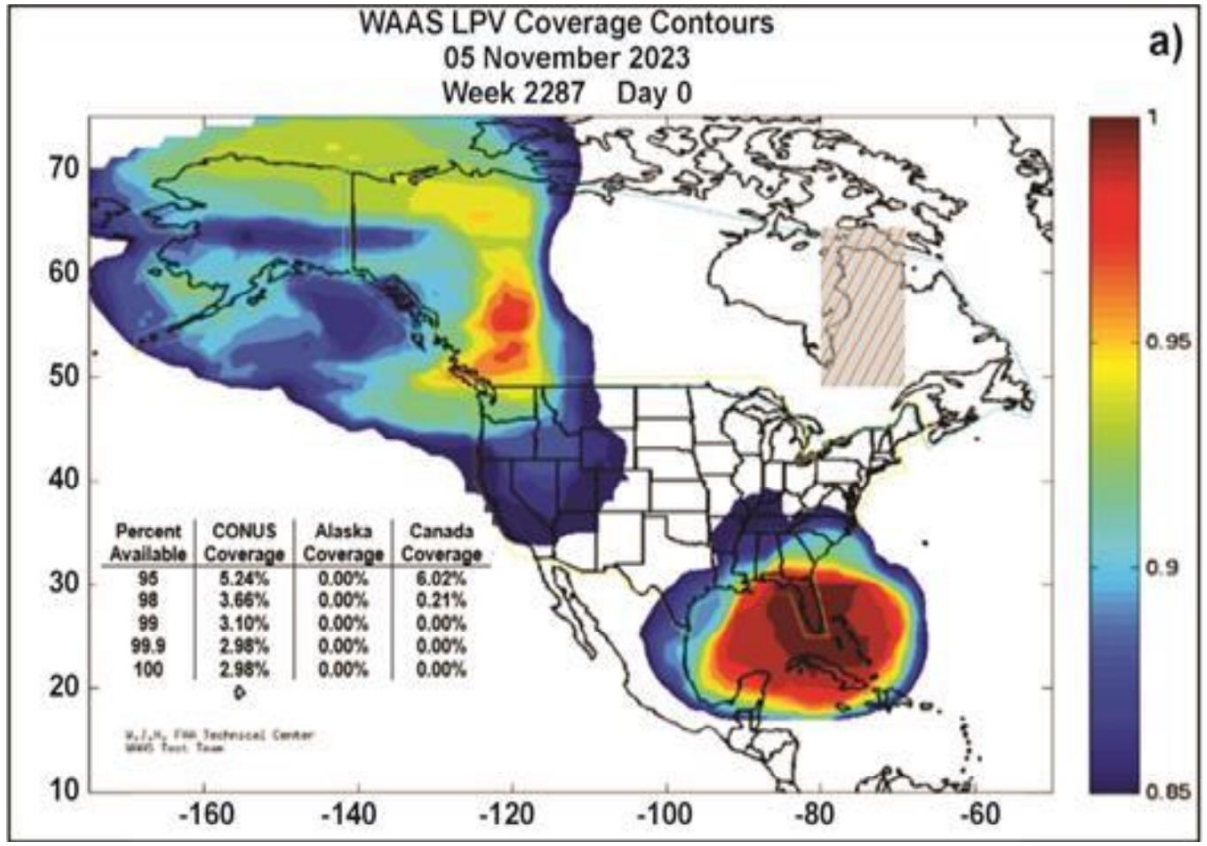




May 10-11 2024

SWIS Motivation: SWX and Aviation





CADORS LPV reports

(https://tc.gc.ca)

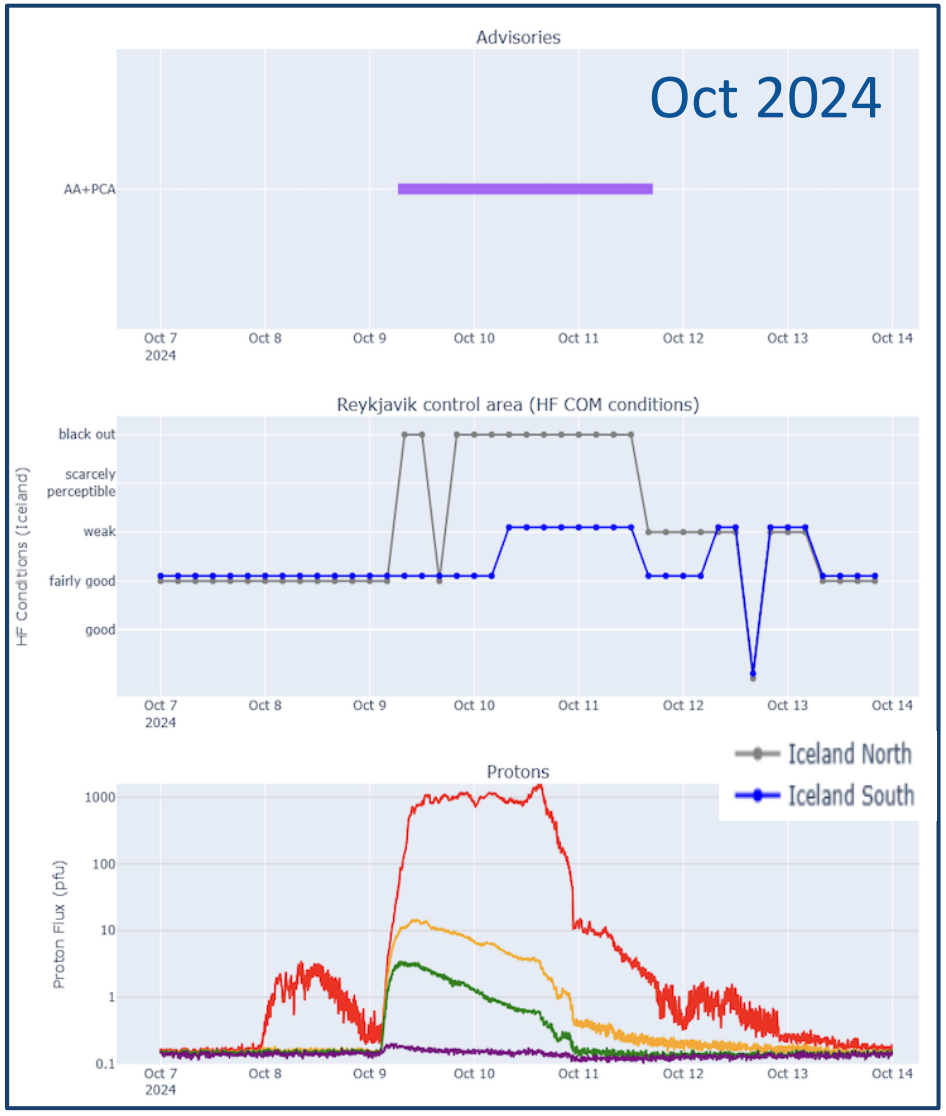
2023-11-05	16:51	Kuujjuaq Airport QC (CYVP)	A Canadian North Boeing 737-406 (C-FFNE/AKT162) from Montreal/Pierre Elliott Trudeau, QC (CYUL) to Kuujjuaq, QC (CYVP) lost localizer performance with vertical guidance (LPV) on approach for Runway 25. AKT162 landed on Runway 25 without incident at 1701Z.

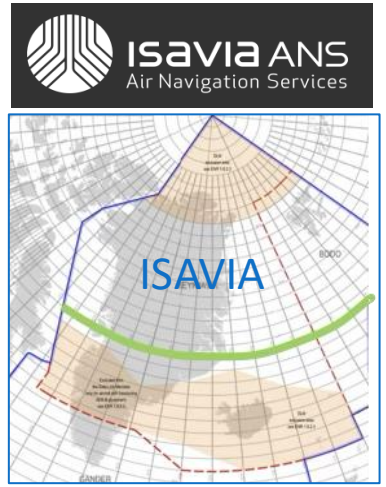
Nov 05 2023

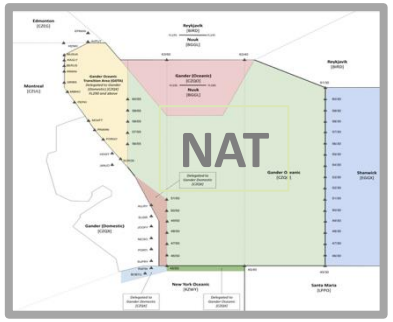
https://www.nstb.tc.faa.gov

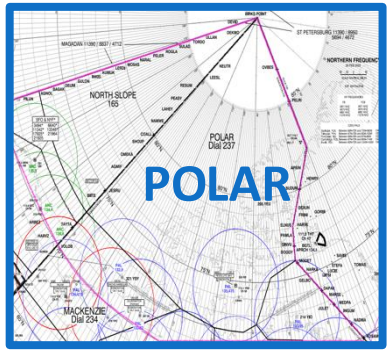
Nikitina et al, SWJ 2025

SWIS Motivation: SWX and Aviation









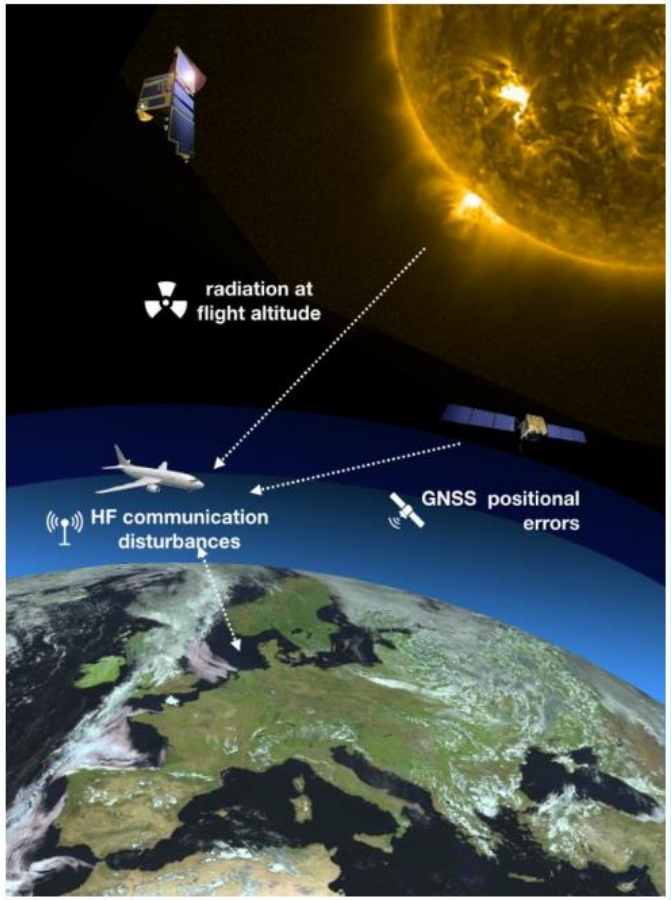
The ICAO Space Weather Information Service

Space Weather (SWX) and Aviation:

What is SWX? The Sun drives our planet's weather and climate patterns and is the main driver for space weather. SWX relates to the dynamic processes on the Sun which affect the interplanetary space and can impact various technological systems as well as human well-being on Earth.

Impacts on Aviation: SWX effects can impact GNSS, positioning and navigation, deteriorate and limit radio communications, or cause an increased radiation exposure at certain flight altitudes[4,5].

ICAO SWX Information Service: The goal is to advise aviation users when SWX events are expected to cause a moderate or severe impact related to the deterioration or loss of satellite navigation or HF communication (long-distance radio) or enhanced radiation dose at specific flight levels. Advisories are disseminated through ICAO's standard communication channels[6] and are required for completeness of flight documentation.



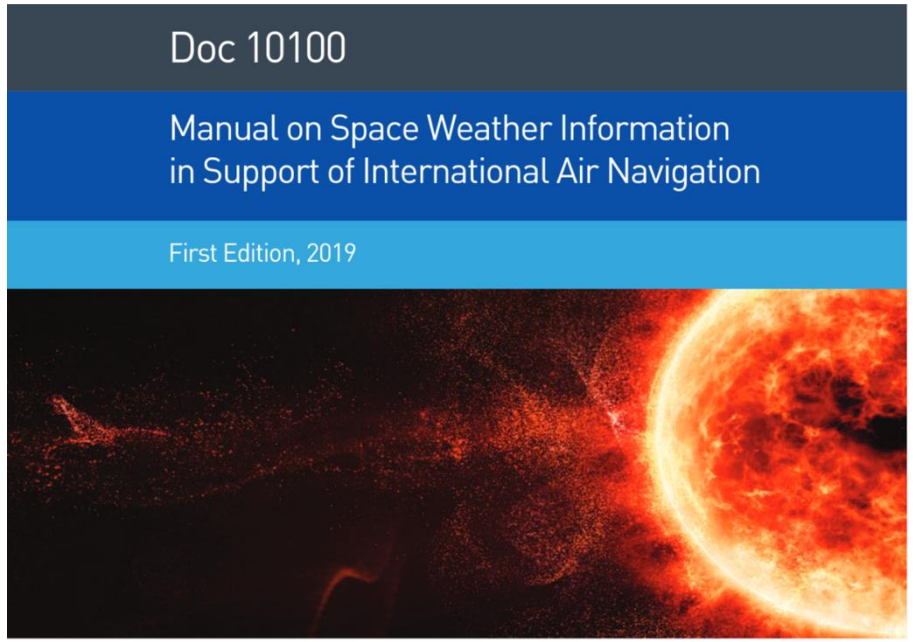
SWX Advisories definitions:

- Similar in structure to volcanic ash and tropical cyclone advisories.
- Advisory triggers and relevant thresholds are defined in the Manual on Space Weather Information in Support of International Air Navigation, ICAO Doc 10100[1]; detailed service specification including advisory format, and upcoming changes are provided in Annex 3[2] and PANS-MET (Doc 10157)[3].
- Spatial range of SWX Advisory can vary largely from isolated sectors to large areas on Earth.
- Duration of a SWX impact can range from tens of minutes to several days.
- Impacted areas are given in terms of polygons with maximum 6 corners (7 points) based on geographic coordinates with resolution of 5° in latitude and longitude; alternatively, one or more pre-defined latitude bands may be used varying by 30° (e.g. HNH, MNH, EQN) and a longitude range with 5° increments.

SWIS Framework and Definitions

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 cyclon service defitions and advisories structure

```
0000057501
FNXX02 EFKL 220239
SWX ADVISORY
DTG:          20260122/0239Z
SWXC:         PECASUS
SWX EFFECT:   HF COM
ADVISORY NR:  2026/44
NR RPLC:      2026/43
OBS SWX:      22/0227Z MOD EQN MNH W090 - E045
FCST SWX +6 HR:  22/0900Z NOT AVBL
FCST SWX +12 HR: 22/1500Z NOT AVBL
FCST SWX +18 HR: 22/2100Z NOT AVBL
FCST SWX +24 HR: 23/0300Z NOT AVBL
RMK:          SPACE WEATHER EVENT (MAXIMUM USABLE FREQUENCY
DEPRESSION) IS IN PROGRESS. IMPACT ON HIGHER HF COM FREQUENCY BANDS
EXPECTED.
NXT ADVISORY:  WILL BE ISSUED BY 20260122/0827Z=
```

Specification

- 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

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
```

0000077101
FNXX02 EFKL 211535
SWX ADVISORY
DTG: 20260121/1525Z
SWXC: PECASUS
SWX EFFECT: HF COM
ADVISORY NR: 2026/41
NR RPLC: 2026/39
OBS SWX: 21/1519Z MOD S90 E180 - S75 E180 - S75 W180 - S90 W180 - S90 E180 MOD N55 W045 - N65 W045 - N65 W090 - N55 W090 - N55 W045
FCST SWX +6 HR: 21/2200Z MOD S90 E180 - S75 E180 - S75 W180 - S90 W180 - S90 E180
FCST SWX +12 HR: 22/0400Z MOD S90 E180 - S75 E180 - S75 W180 - S90 W180 - S90 E180
FCST SWX +18 HR: 22/1000Z NOT AVBL
FCST SWX +24 HR: 22/1600Z NOT AVBL
RMK: SPACE WEATHER EVENT (HF COM POLAR CAP ABSORPTION) IN PROGRESS. IMPACT ON LOWER HF COM FREQUENCY BANDS EXPECTED AT HIGH LATITUDES.
NXT ADVISORY: WILL BE ISSUED BY 20260121/2119Z=

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

Why SWX Advisory?

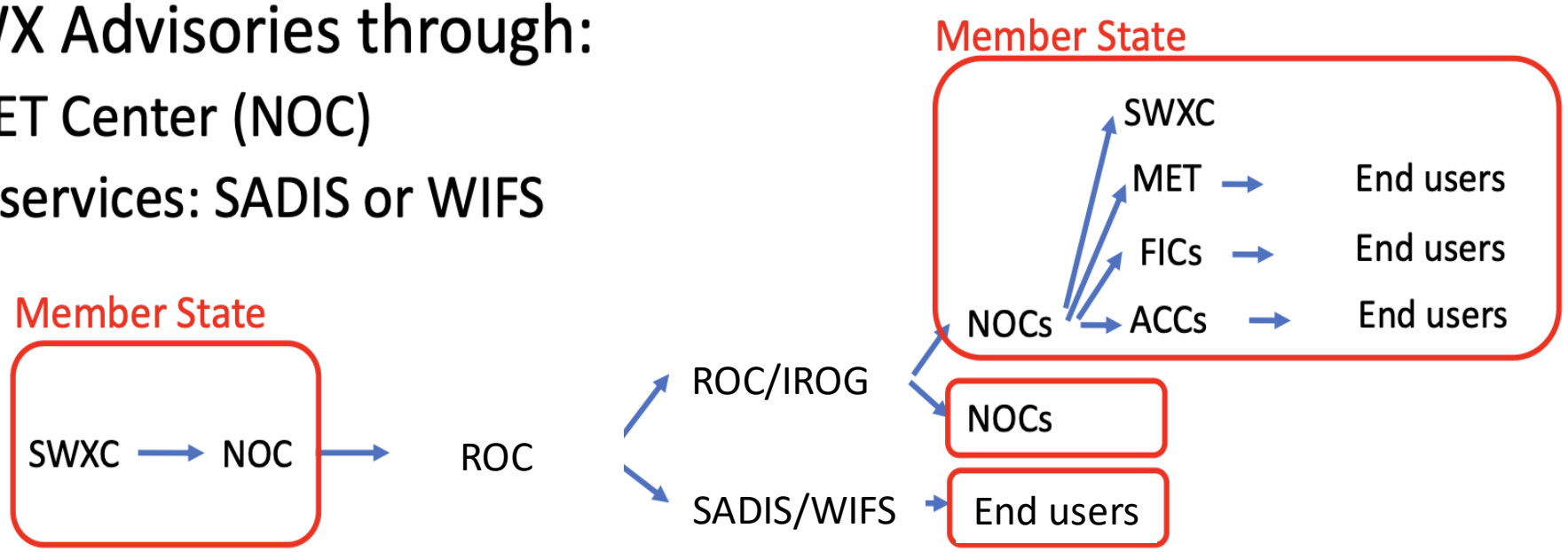
- 24/7
- Near real-time
- Impact oriented
- Updates within 6h
- Worldwide
- Tailored to Aviation

Dissemination of SWX Advisories

Dissemination via AFS (AFTN) network like all 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

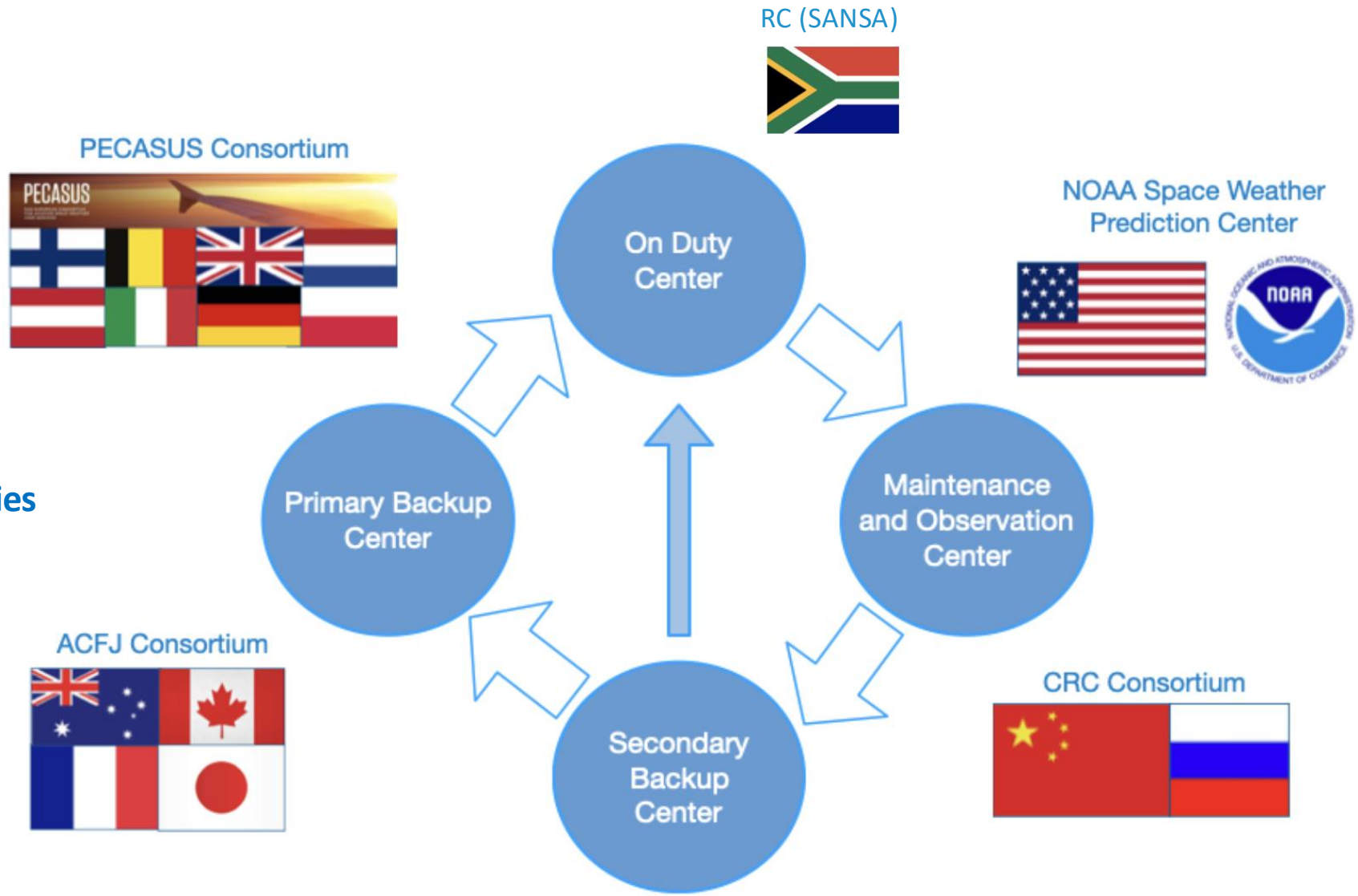
03 = RADIATION

04 = SATCOM

NB: 04 is not used

SWIS Service Provision Centers

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



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:

Polar regions

equatorial regions

Duration:

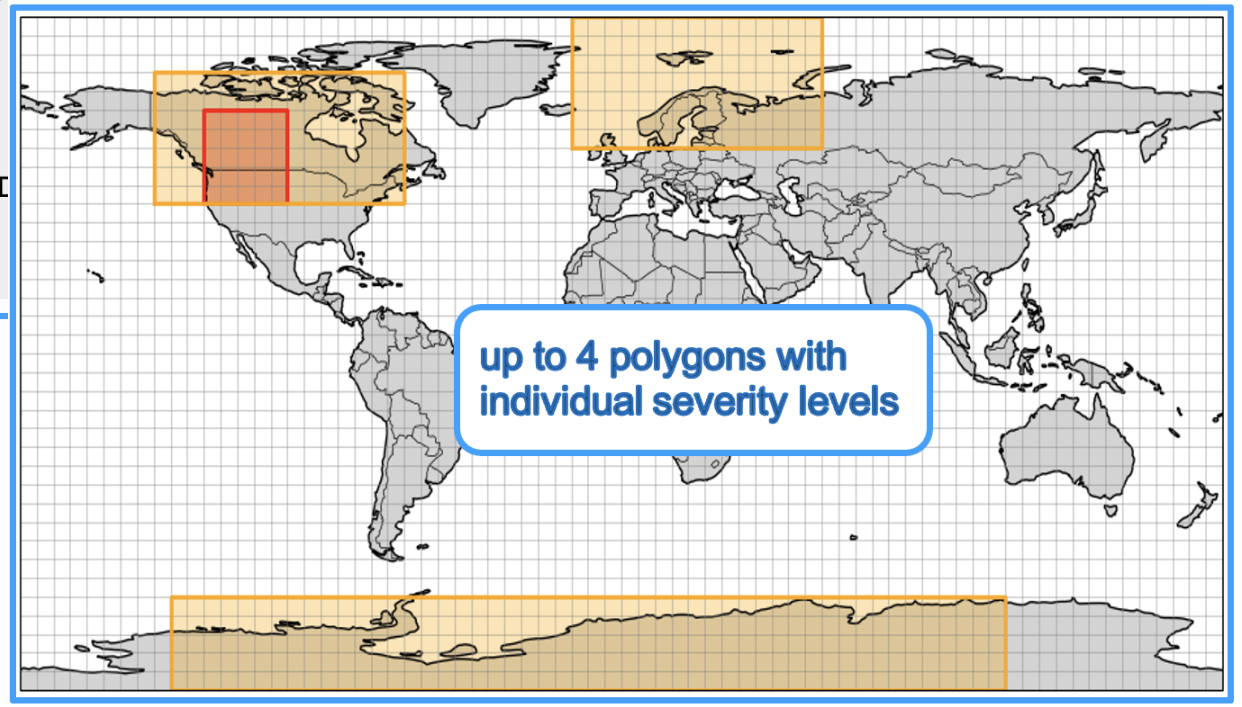
~ few hours

GNSS SWX Advisories

0000073001
FNXX01 LFPW 192237
SWX ADVISORY
DTG: 20260119/2233Z
SWXC: ACFJ
SWX EFFECT: GNSS
ADVISORY NR: 2026/30
NR RPLC: 2026/29
OBS SWX: 19/2220Z SEV N40 W125 - N40 W100 - N65 W100 - N65 W125 - N40 W125
MOD S90 E115 - S90 W135 - S65 W135 - S65 E115 - S90 E115 MOD N40 W140 - N40
W065 - N75 W065 - N75 W140 - N40 W140 MOD N55 W015 - N55 E060 - N90 E060 - N90
W015 - N55 W015
FCST SWX +6 HR: 20/0500Z NO SWX EXP
FCST SWX +12 HR: 20/1100Z NO SWX EXP
FCST SWX +18 HR: 20/1700Z NO SWX EXP
FCST SWX +24 HR: 20/2300Z NO SWX EXP
RMK: SWX EVENT (SCINTILLATION) INPR POSSIBLY IMPACTING GNSS PER. COULD
LEAD TO LOSS OF GNSS SIGNALS AND/OR DEGRADATION OF TIMING AND
POSITIONING PER.
NXT ADVISORY: WILL BE ISSUED BY 20260120/0433Z=

MOD and SEV areas can be reported in one advisory

Scintillation example



HF COM SWX Advisories

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:

Polar regions

DAYSIDE

Anywhere

Duration:

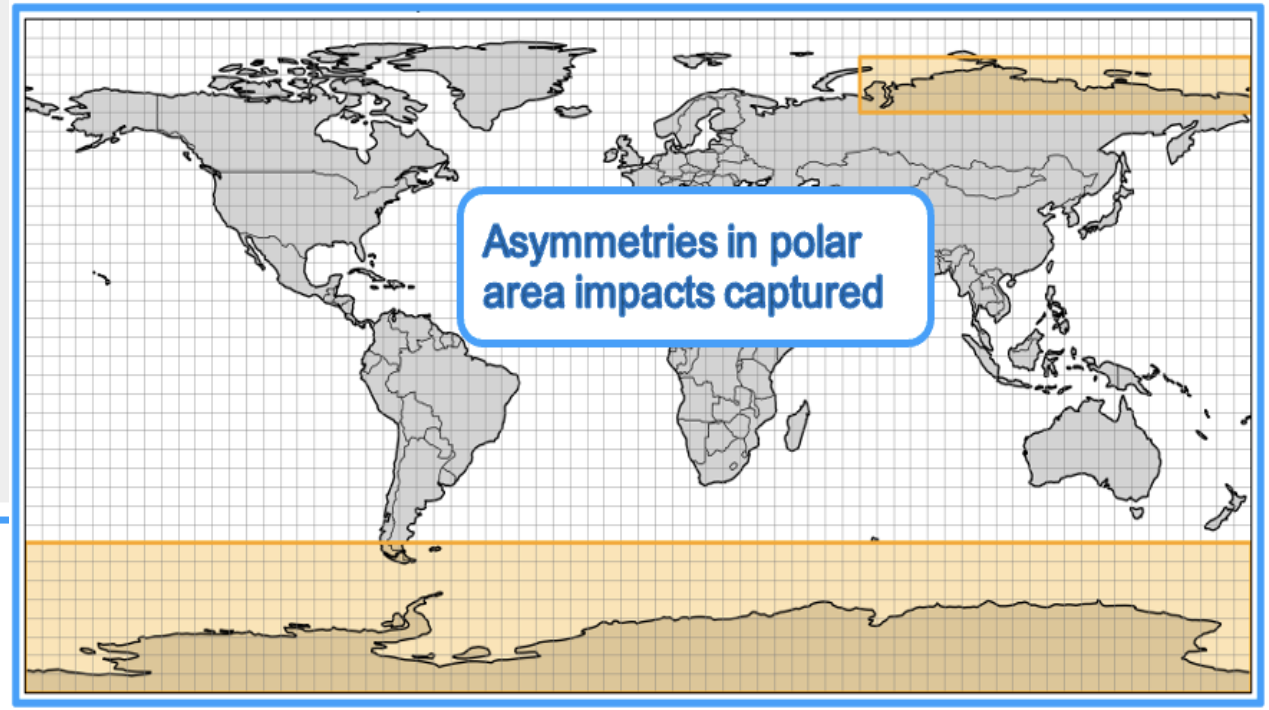
~ 0.5 hour
to few days

HF COM SWX Advisories

0000090201
FNXX02 EFKL 210425
SWX ADVISORY
DTG: 20260121/0425Z
SWXC: PECASUS
SWX EFFECT: HF COM
ADVISORY NR: 2026/37
NR RPLC: 2026/35
OBS SWX: 21/0410Z MOD N65 E180 - N80 E180 - N80 E065 - N65 E065 - N65 E180 MOD S90 E180 - S50 E180 - S50 W180 - S90 W180 - S90 E180
FCST SWX +6 HR: 21/1100Z MOD N65 E070 - N80 E070 - N80 W030 - N65 W030 - N65 E070 MOD S90 E180 - S50 E180 - S50 W180 - S90 W180 - S90 E180
FCST SWX +12 HR: 21/1700Z MOD N65 E010 - N80 E010 - N75 W080 - N65 W080 - N65 E010 MOD S90 E180 - S50 E180 - S50 W180 - S90 W180 - S90 E180
FCST SWX +18 HR: 21/2300Z NOT AVBL
FCST SWX +24 HR: 22/0500Z NOT AVBL
RMK: EVENT UPDATE. SPACE WEATHER EVENT (HF COM POLAR CAP ABSORPTION) IN PROGRESS. IMPACT ON LOWER HF COM FREQUENCY BANDS EXPECTED AT HIGH LATITUDES.
NXT ADVISORY: WILL BE ISSUED BY 20260121/1010Z=

5 deg resolution for polygon lats and lons

PCA example



RADIATION SWX Advisories

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)

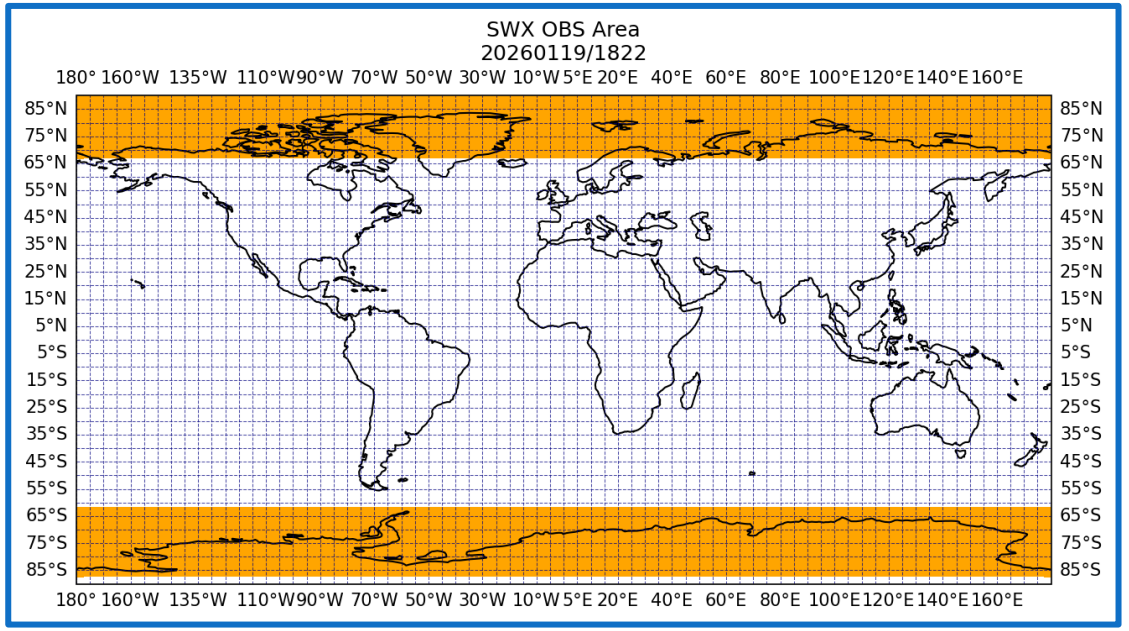
Duration:

~ few hours

RADIATION SWX Advisories

00000XXXXX
FNXX03 EFKL XXXXXX
SWX ADVISORY
STATUS: EXERCISE*
DTG: 20260119/1822Z
SWXC: PECASUS
SWX EFFECT: RADIATION
ADVISORY NR: 2026/1
OBS SWX: 19/1820Z MOD N60 E180 - N90 E180 -
N90 W180 - N60 W180 - N60 E180 MOD S90 E180 - S60 E180 - S60 W180 - S90
W180 - S90 E180 FL340-420
FCST SWX +6 HR: 20/0100Z NO SWX EXP
FCST SWX +12 HR: 20/0700Z NO SWX EXP
FCST SWX +18 HR: 20/1300Z NO SWX EXP
FCST SWX +24 HR: 20/1900Z NO SWX EXP
RMK: EXERCISE. THIS IS AN EXERCISE SPACE
WEATHER RADIATION ADVISORY. PLEASE, DISREGARD.
NXT ADVISORY: WILL BE ISSUED BY 20260120/0020Z=

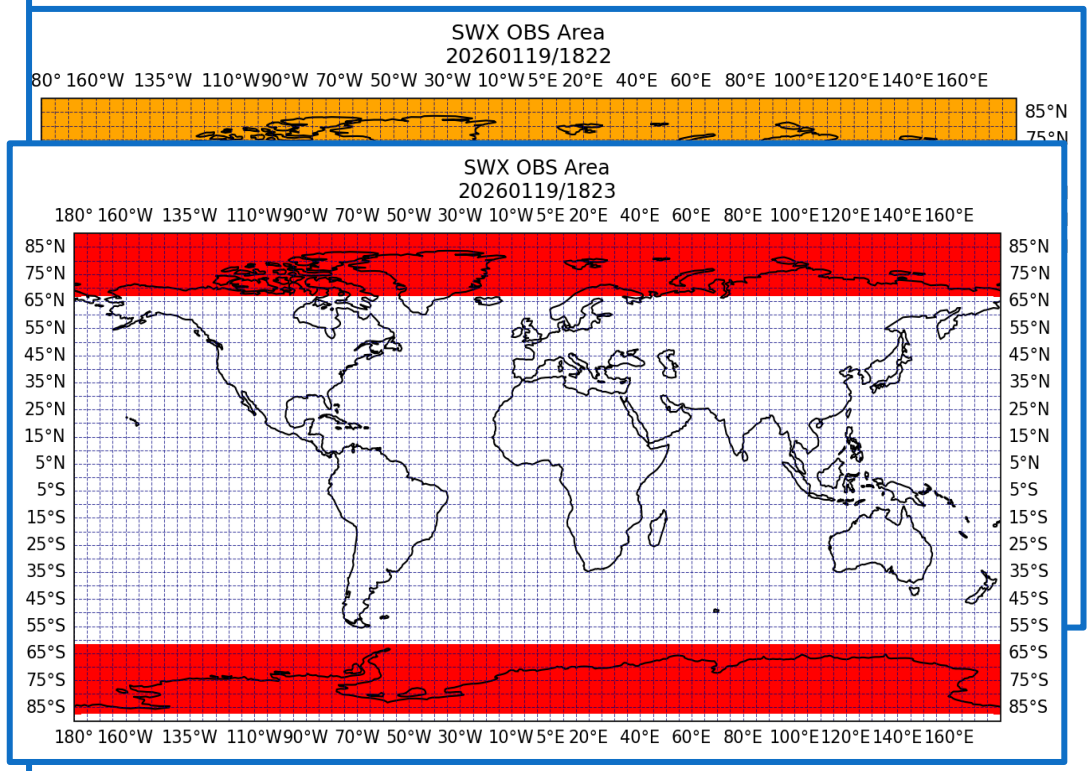
Exercise RAD adviosiry Example



RADIATION SWX Advisories

Exercise RAD adviosiry Example

00000 XXXXX
FNXX03 EFKL XXXXXX
SWX ADVISORY
STATUS: EXERCISE*
DTG: 20260119/1823Z
SWXC: PECASUS
SWX EFFECT: RADIATION
ADVISORY NR: 2026/2
OBS SWX: 19/1820Z SEV N60 E180 - N90 E180 - N90 W180 - N60 W180 - N60 E180 SEV S90 E180 - S60 E180 - S60 W180 - S90 W180 - S90 E180 ABV FL420
FCST SWX +6 HR: 20/0100Z NO SWX EXP
FCST SWX +12 HR: 20/0700Z NO SWX EXP
FCST SWX +18 HR: 20/1300Z NO SWX EXP
FCST SWX +24 HR: 20/1900Z NO SWX EXP
RMK: EXERCISE. THIS IS AN EXERCISE SPACE WEATHER RADIATION ADVISORY. PLEASE, DISREGARD.
NXT ADVISORY: WILL BE ISSUED BY 20260120/0020Z=



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

Upcoming changes to SWIS

Upcoming changes to the SWX Advisories:

- ★ 7-points polygon implementations
- ★ L-shaped or arbitrary shaped polygons

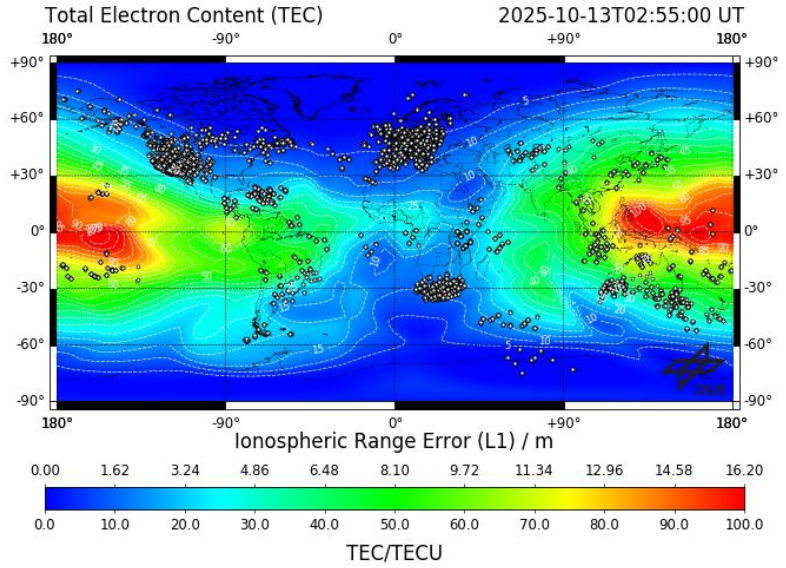
Changes coming in Nov 2027:

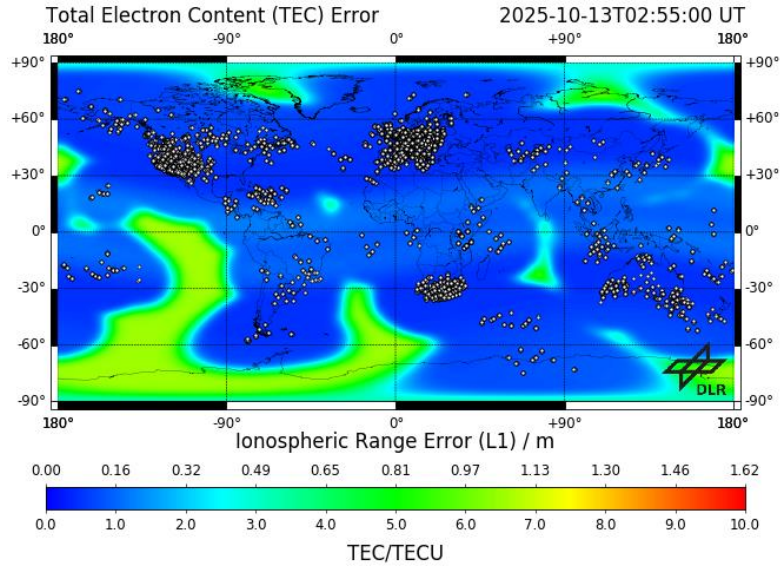
- ★ Forecast fields change from +6h, +12h, +18h and + 24h to +3h, +6h, +9h and +12h (effective Nov 2027).
- ★ Flight levels resolution for RAD advisories changes from 1000 ft to 5000 ft.

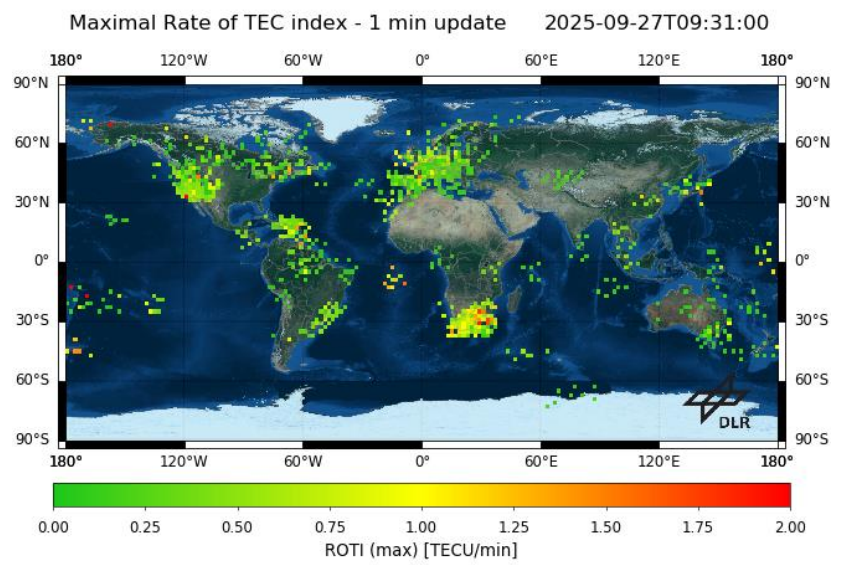
Outlook/Forecast Information Product

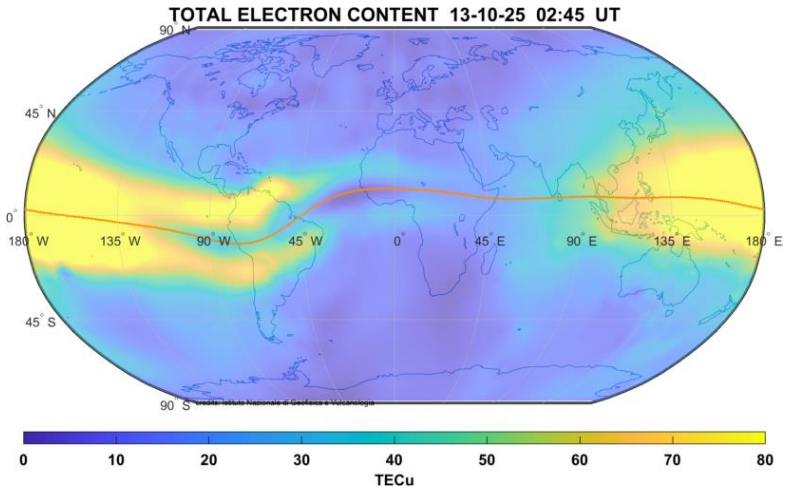
SWX Monitoring Tools: PECASUS

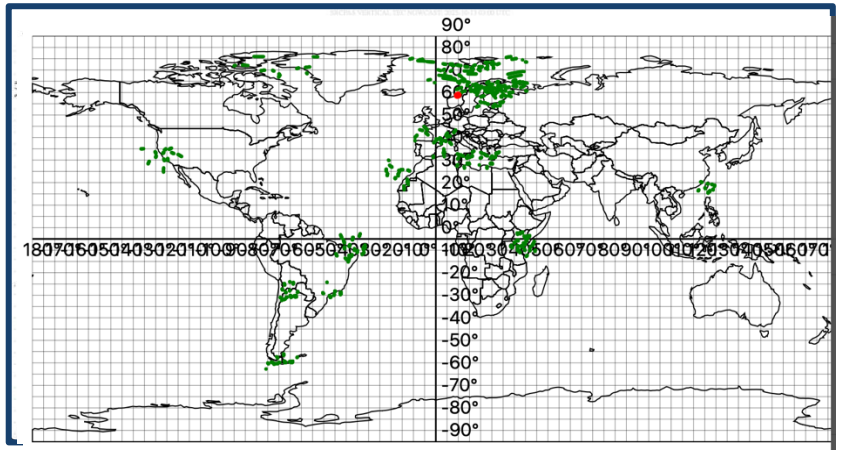
GNSS products

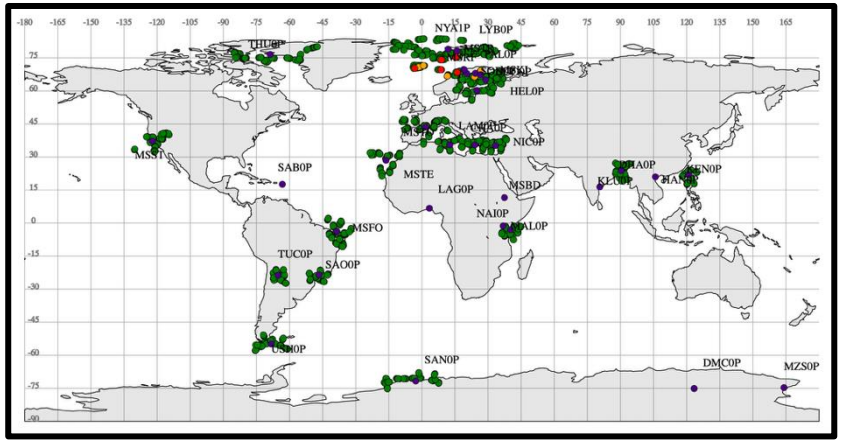












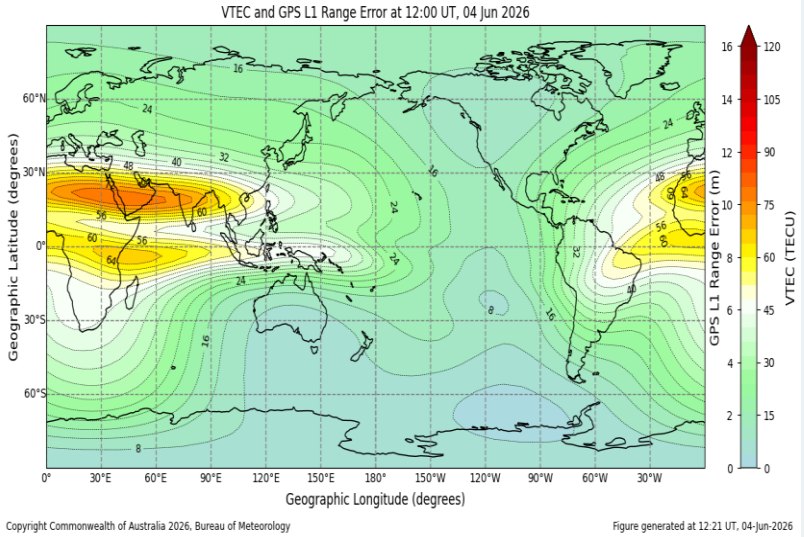
SWX Monitoring Tools: ACFJ

GNSS products

GNSS Conditions

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

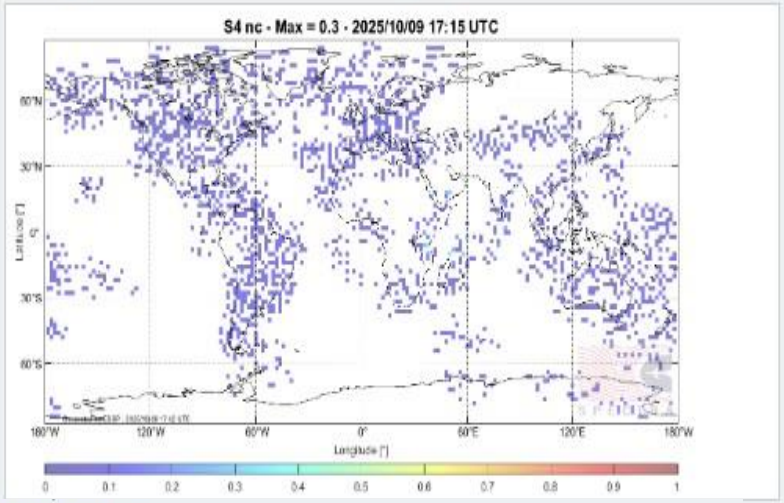
GNSS Delay (TEC)



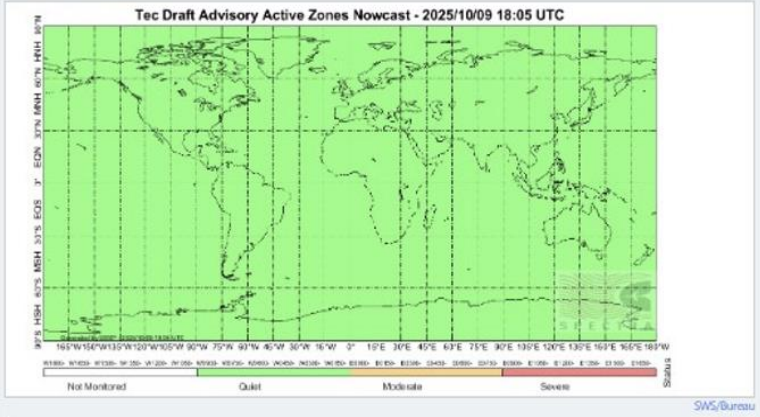
GNSS ionospheric delay latest conditions, expressed in terms of TEC.

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

Amplitude Scintillation (S4)



TEC Active Zone



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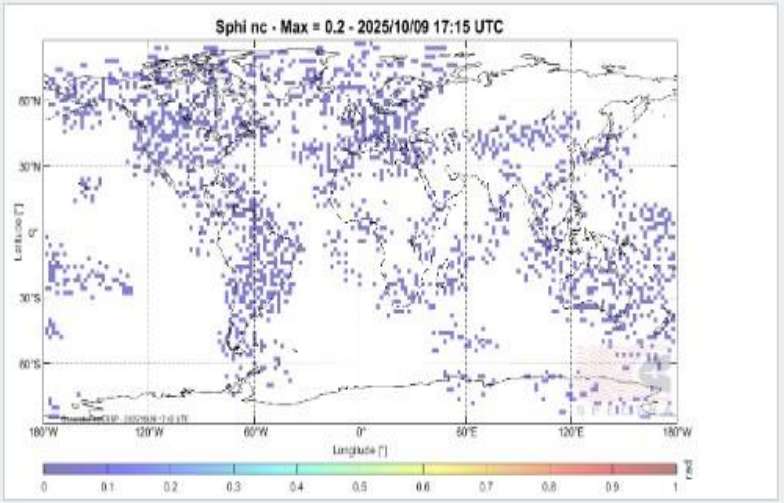
Phase Scintillation (SPHI)



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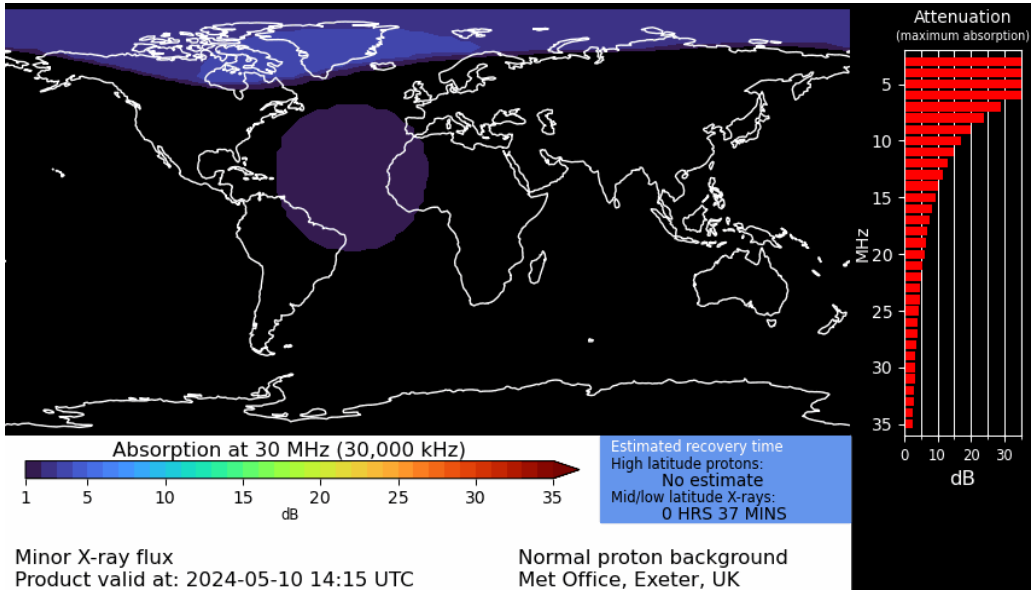
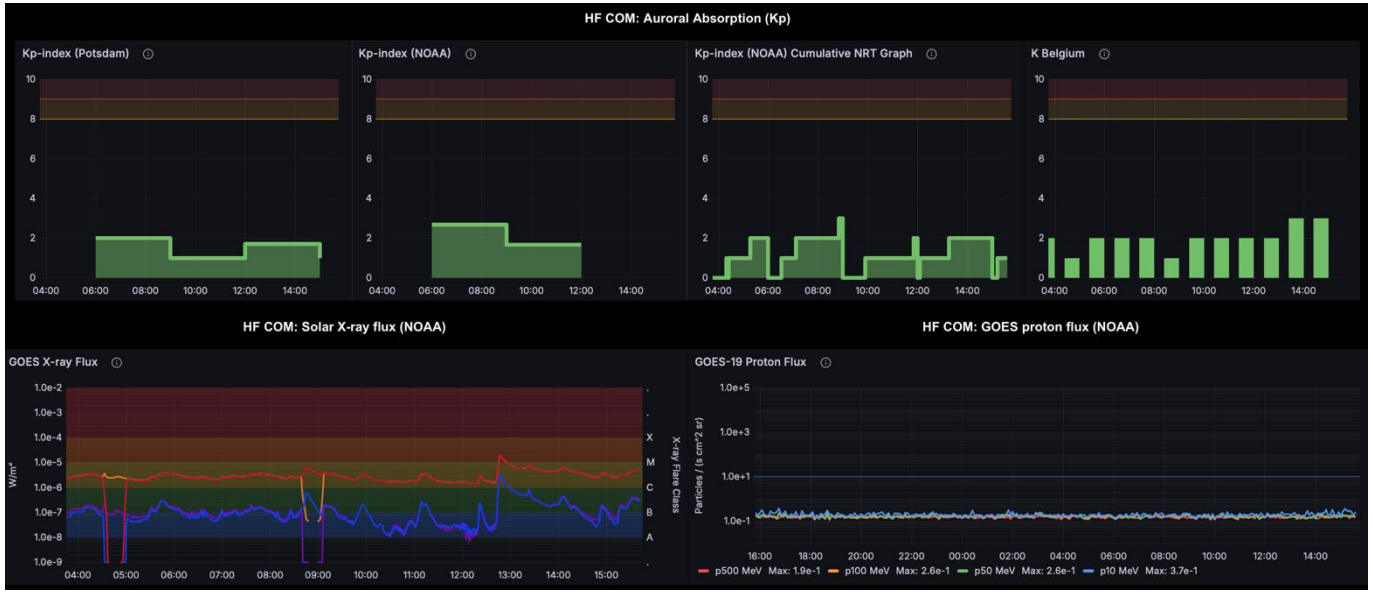
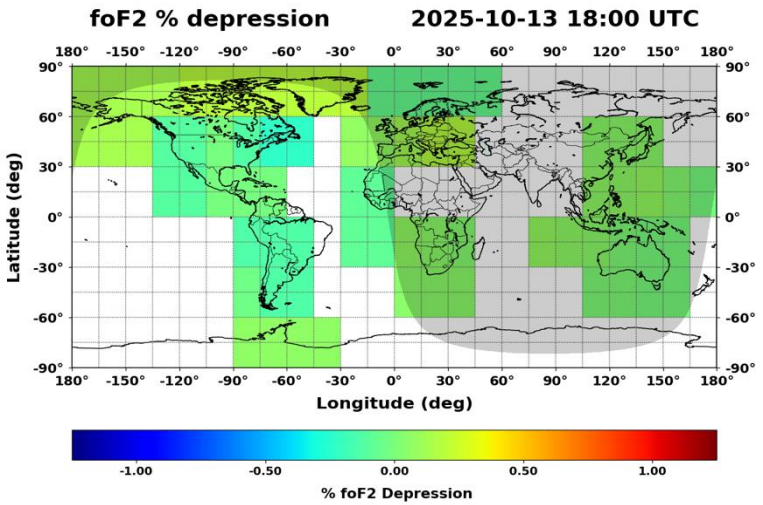
GNSS ionospheric phase scintillation latest conditions, expressed in terms of Sigma_phi index

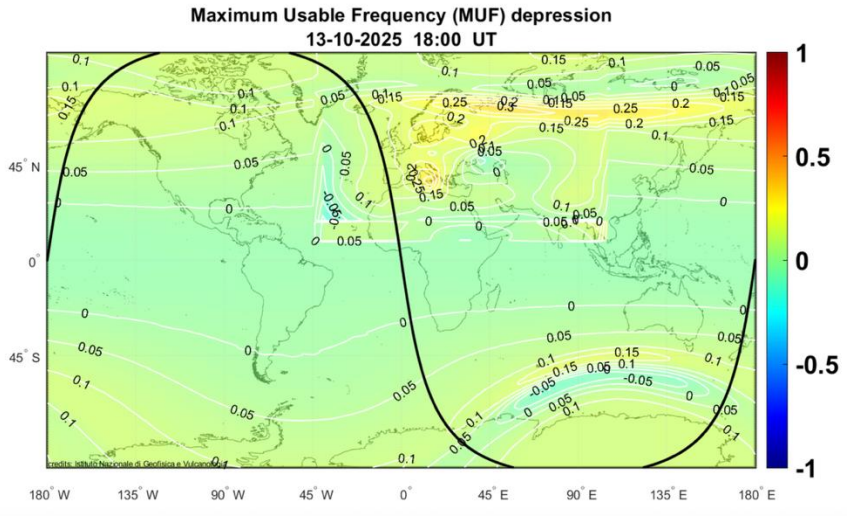
SWX Monitoring Tools: PECASUS

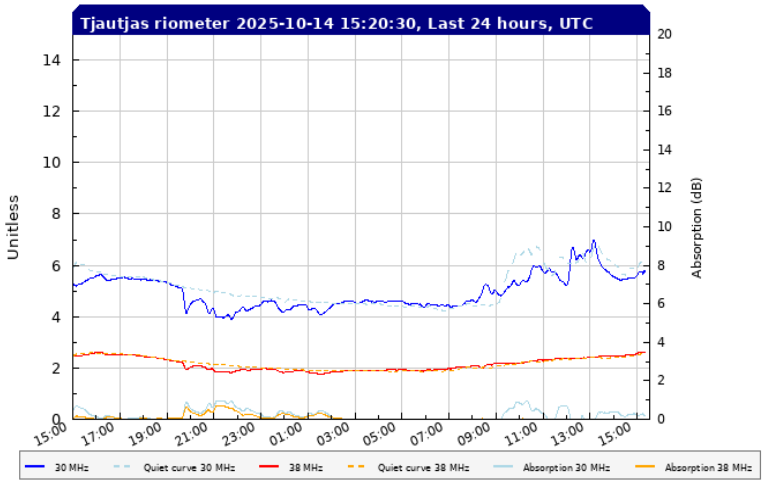
HF COM products











SWX Monitoring Tools: ACFJ

HF COM products

Latest Maps

HF Comm Conditions

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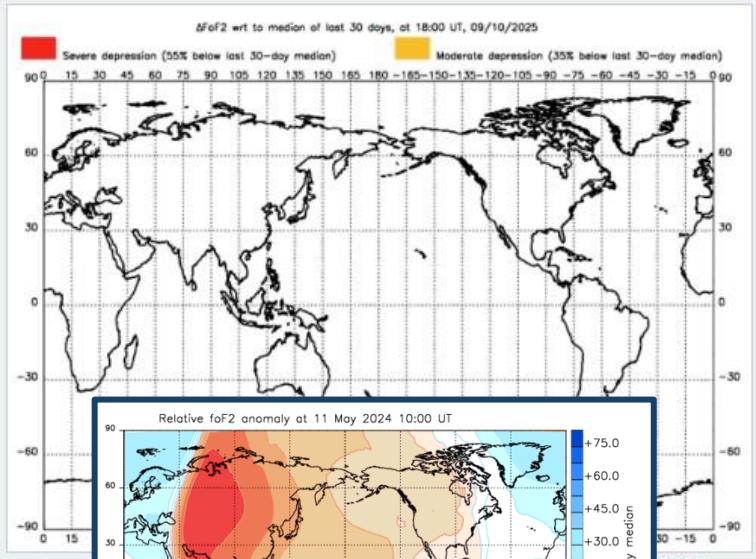
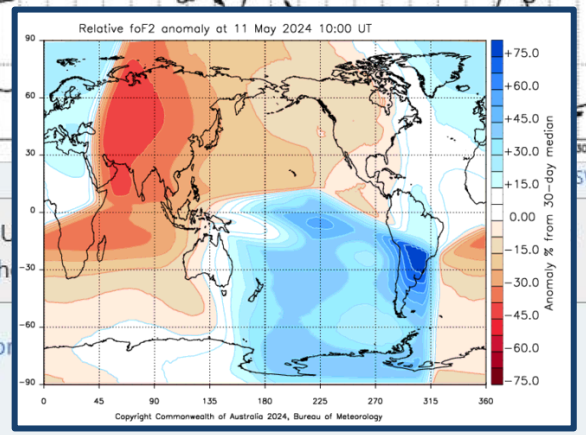
HF Depression





SWS/Bureau

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HF Depr

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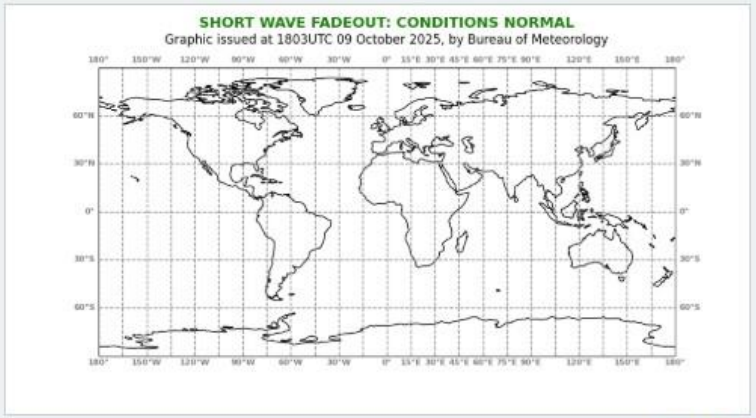
Shortwave Fadeout



SWS/Bureau

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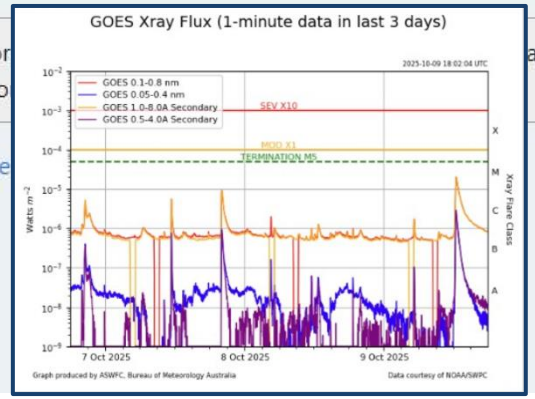
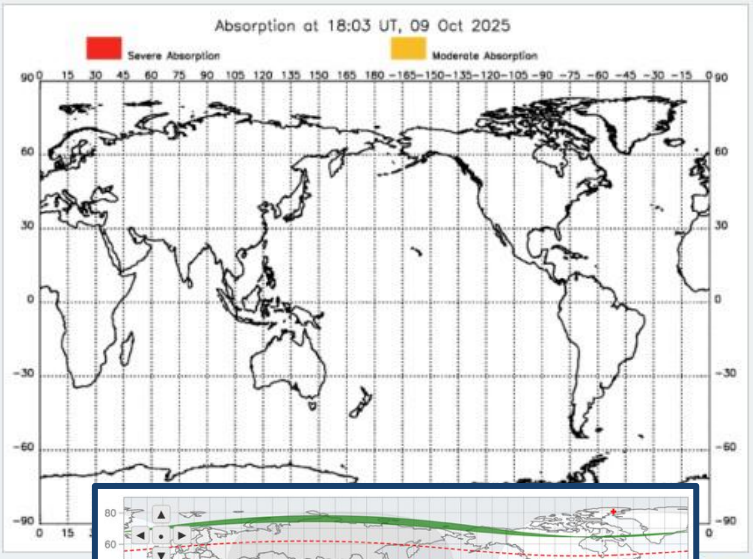
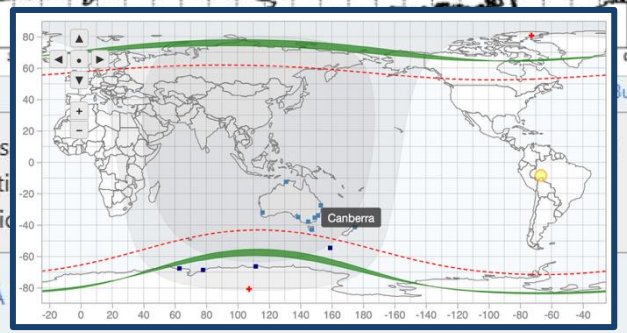


Shortwave

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

PCA/AA





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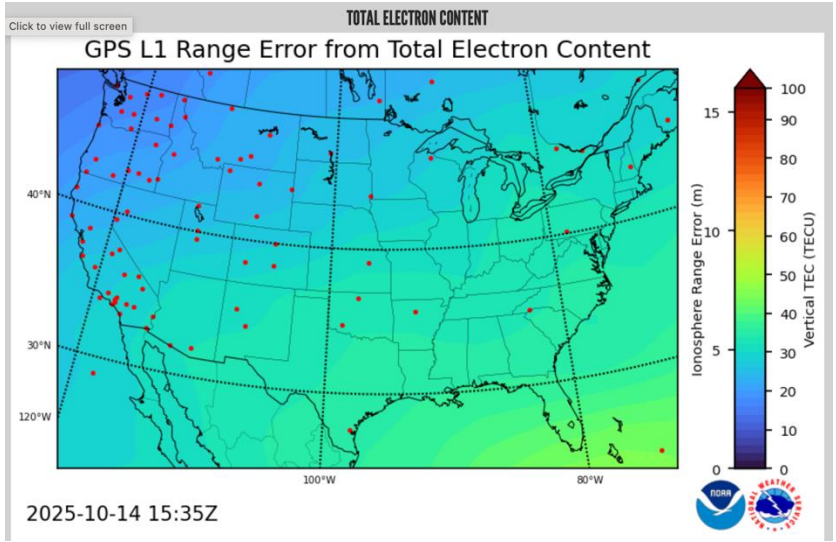
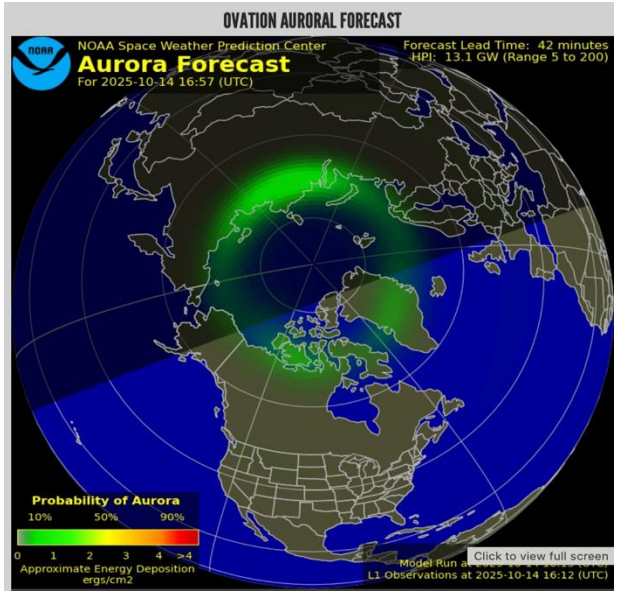
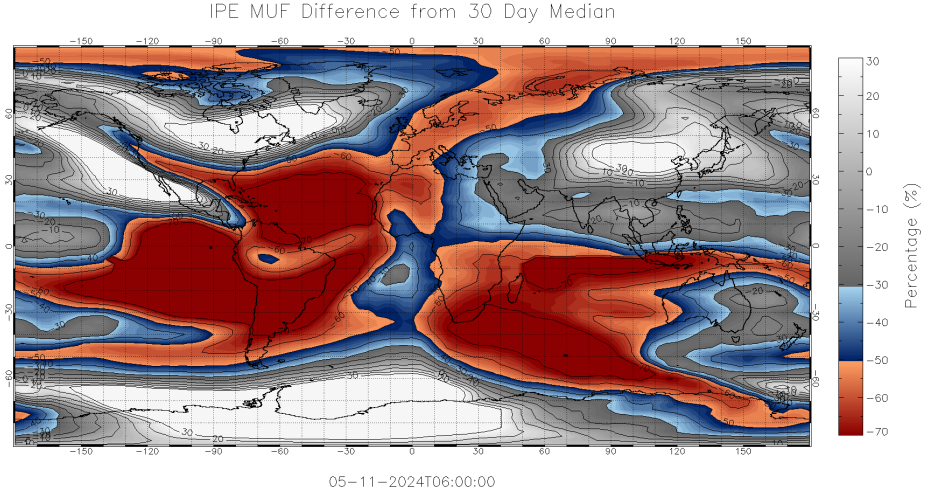
PCA/AA

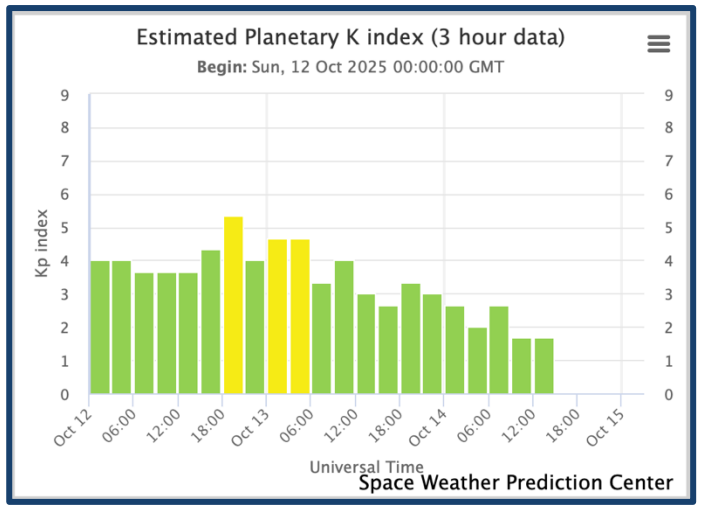
SWX Monitoring Tools: SWPC

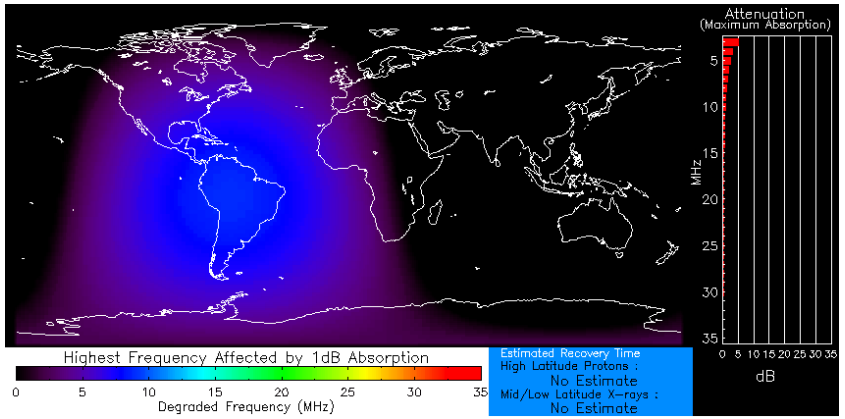
GNSS and HF COM products





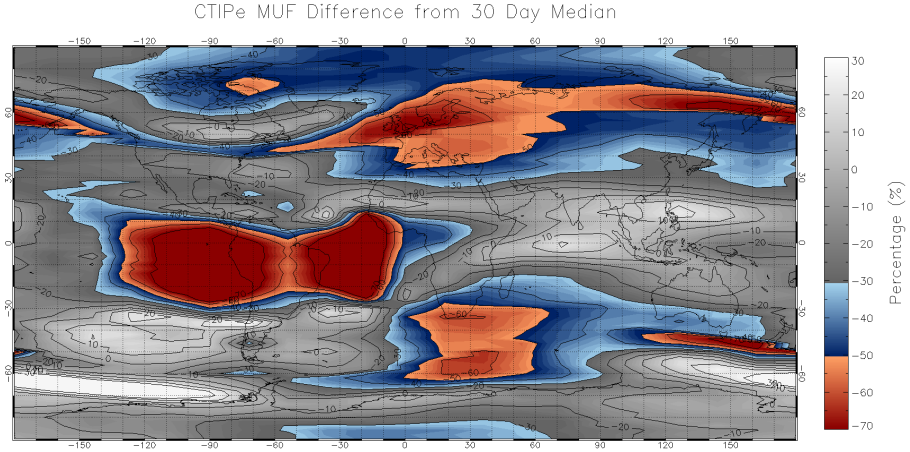






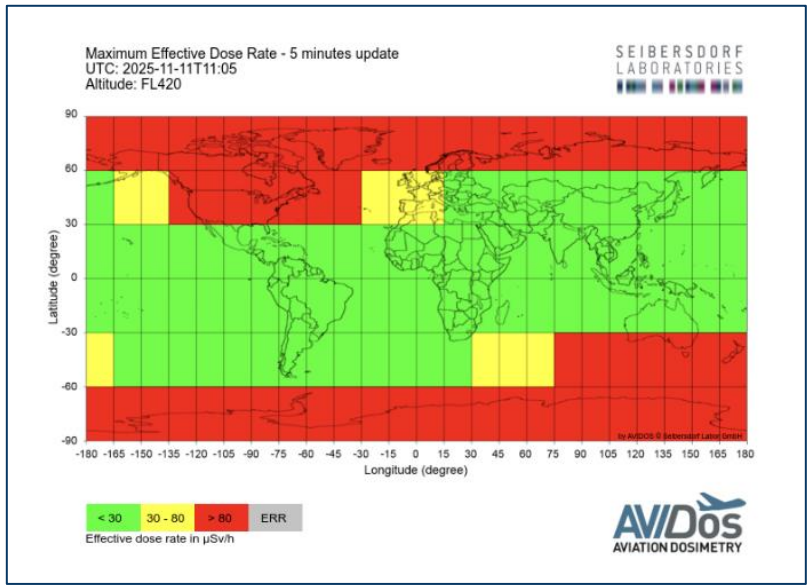
Elevated X-ray flux
Product Valid At : 2025-10-14 16:16 UTC

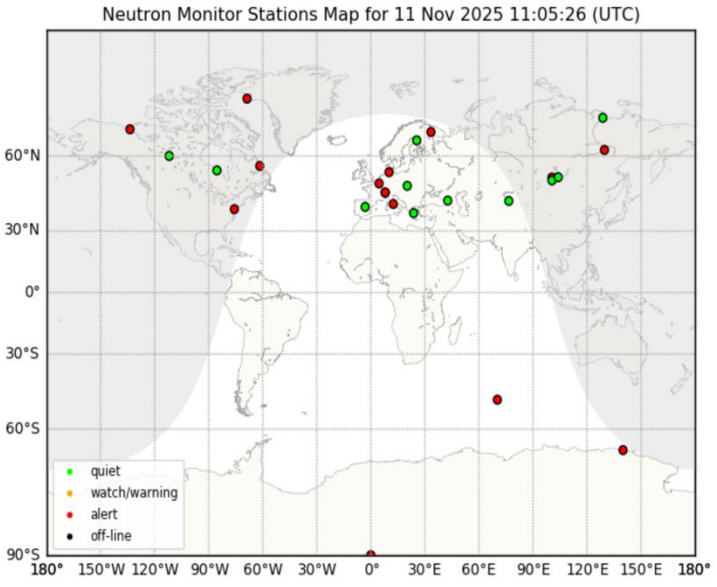
Normal Proton Background
NOAA/SWPC Boulder, CO USA

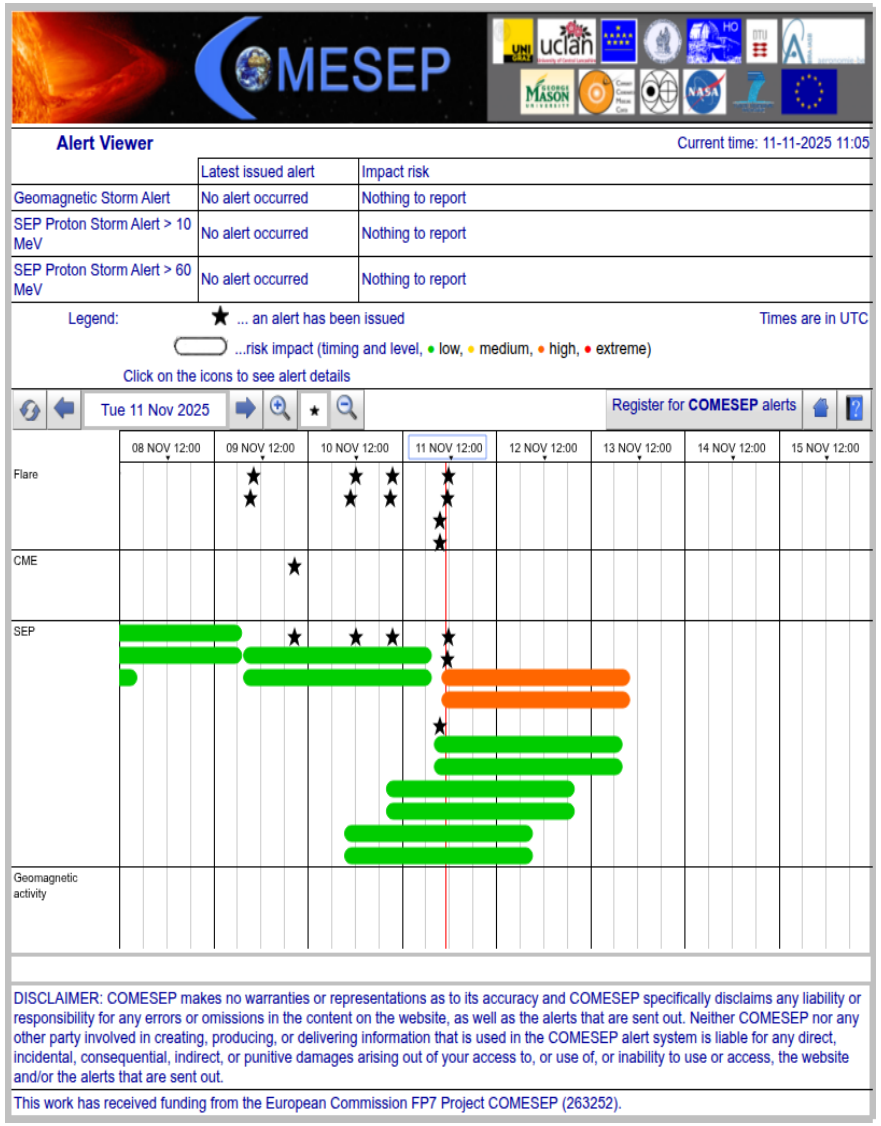


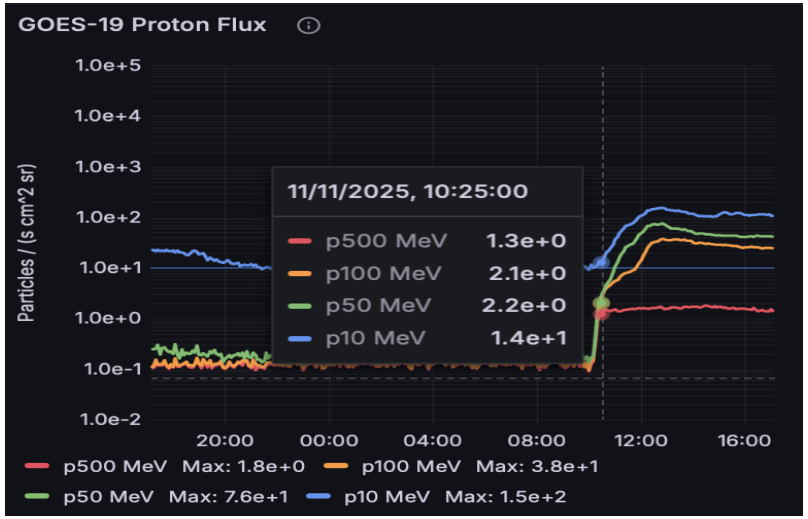
SWX Monitoring Tools: PECASUS

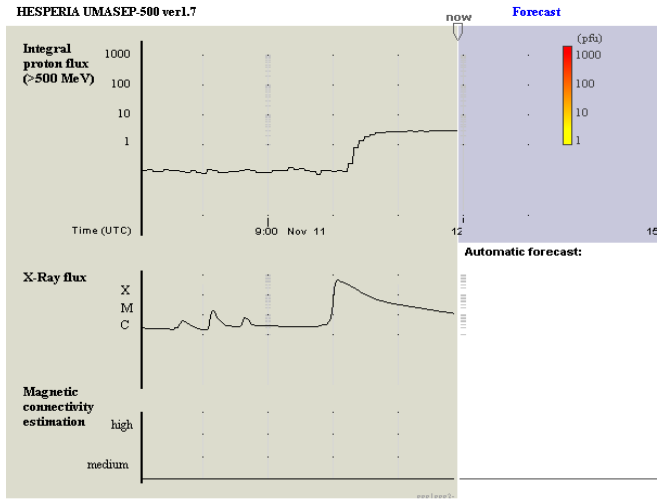
RAD products











We acknowledge the National Observatory of Athens which hosts the HESPERIA UMASEP-500 tool (https://www.hesperia2.astro.noa.gr/images/umasep/realtime/result500.gif)
(HESPERIA project, Grant Agreement No 637324,
European Union's Horizon 2020 research and innovation programme)

SWX Monitoring Tools: ACFJ

RAD products

Radiation Conditions

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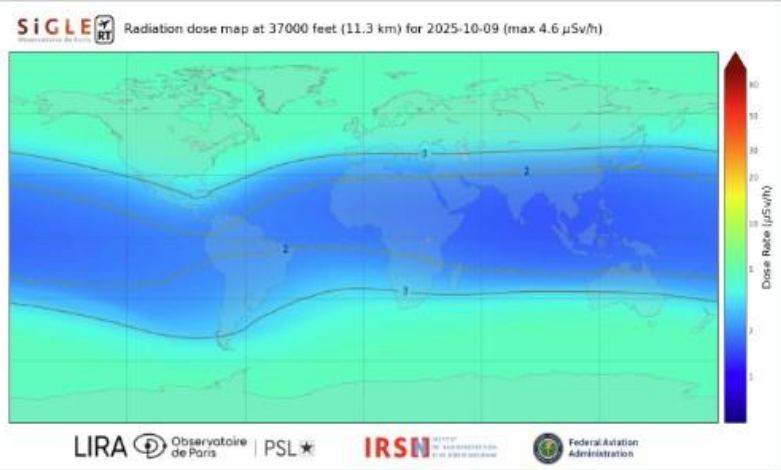
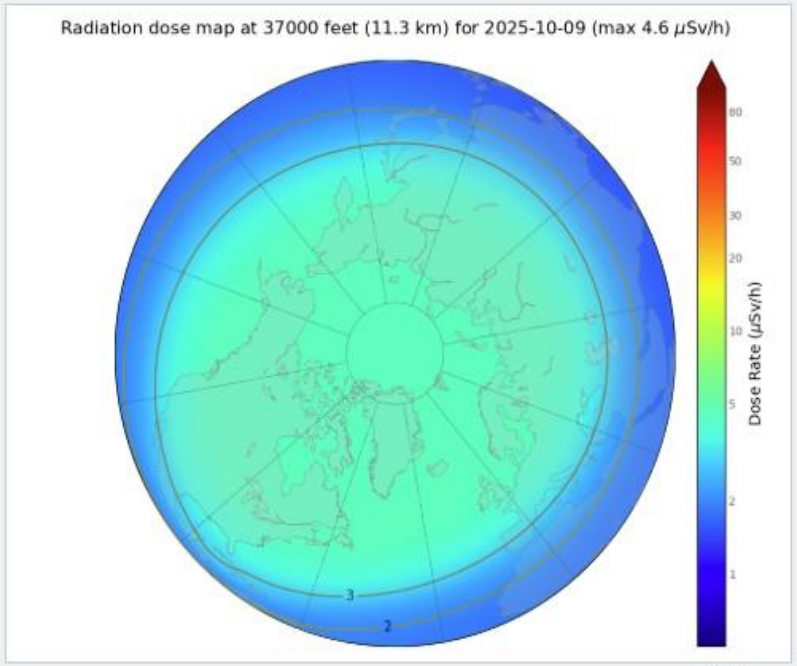
Dose Rate Map FL370



SWS/Bureau

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

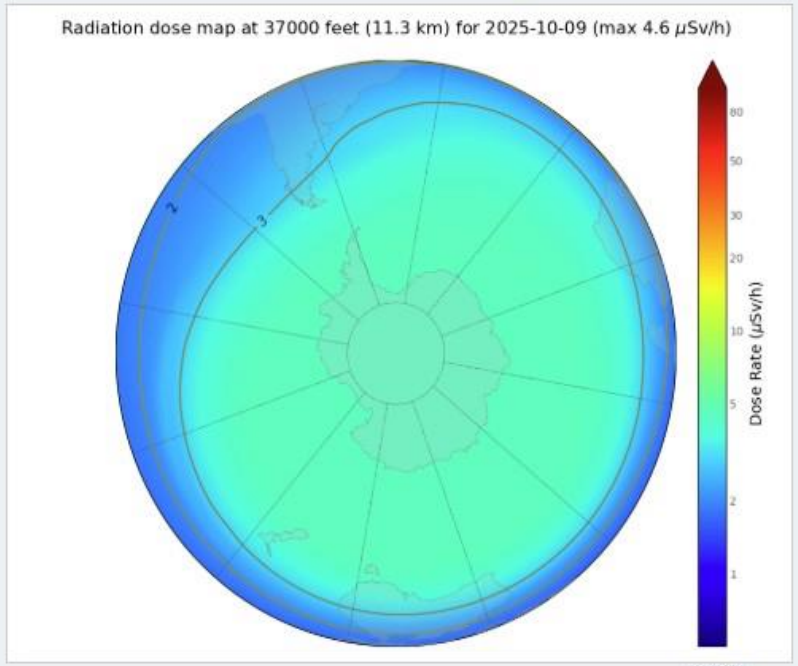
Northern Polar Dose Rate Map FL370



SWS/Bureau

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

Southern Polar Dose Rate Map FL370



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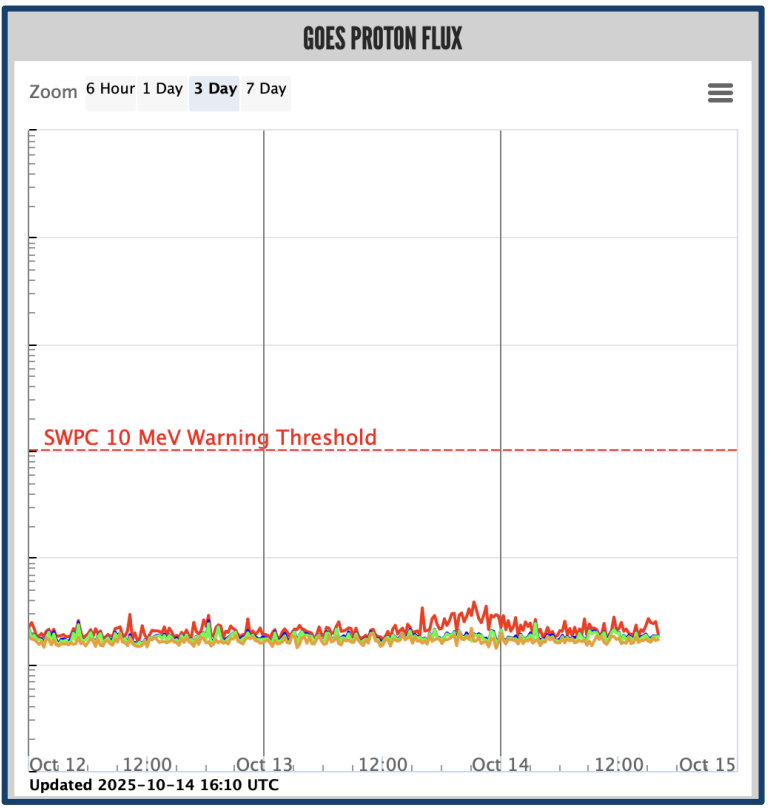
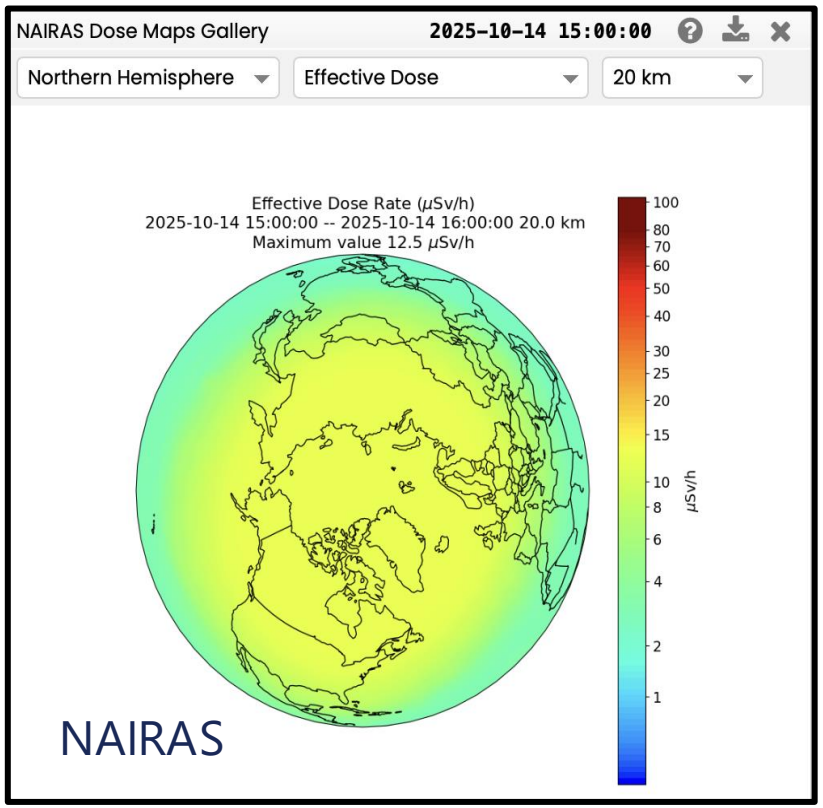
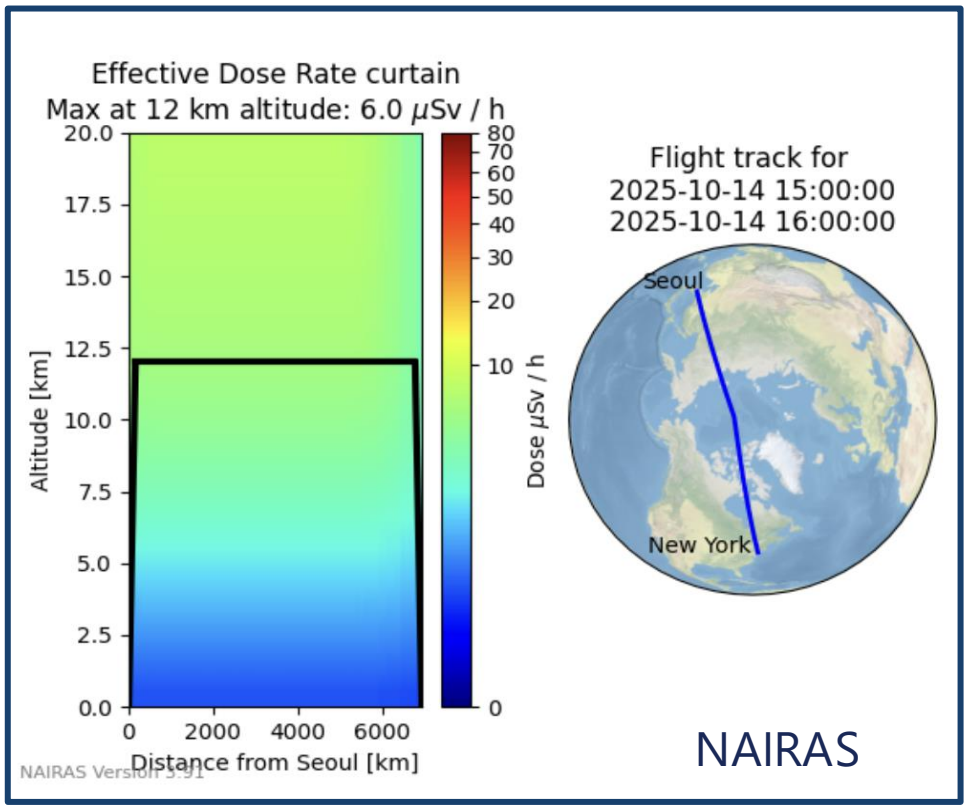
Modelled radiation dose rate at FL370, latest conditions. Image provided by Paris Observatory.

SWX Monitoring Tools: SWPC

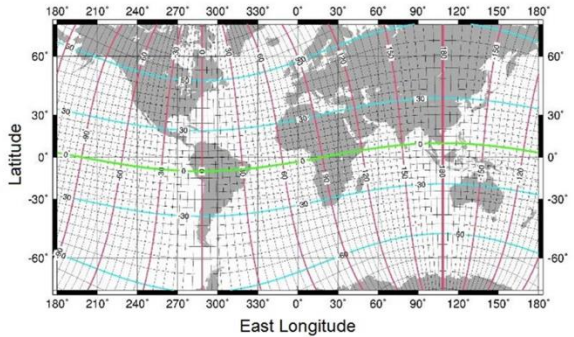
RAD products







CARI-7 and CARI-7A



Information Materials

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

ICAO

EASA
European Union Aviation Safety Agency

Federal Aviation Administration

METEOROLOGY PANEL

2nd ICAO SWX End-User Workshop, June 8-9 2026, Hermanus

Training and Educational Materials

https://www.stce.be/PECASUS_guide4pilots

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

SWEC

Space Weather Education Centre

Thank You!