



METEOROLOGY PANEL



METP SWX User Workshop, 20 October 2025, Rome, Italy

# ICAO Space Weather Information Service

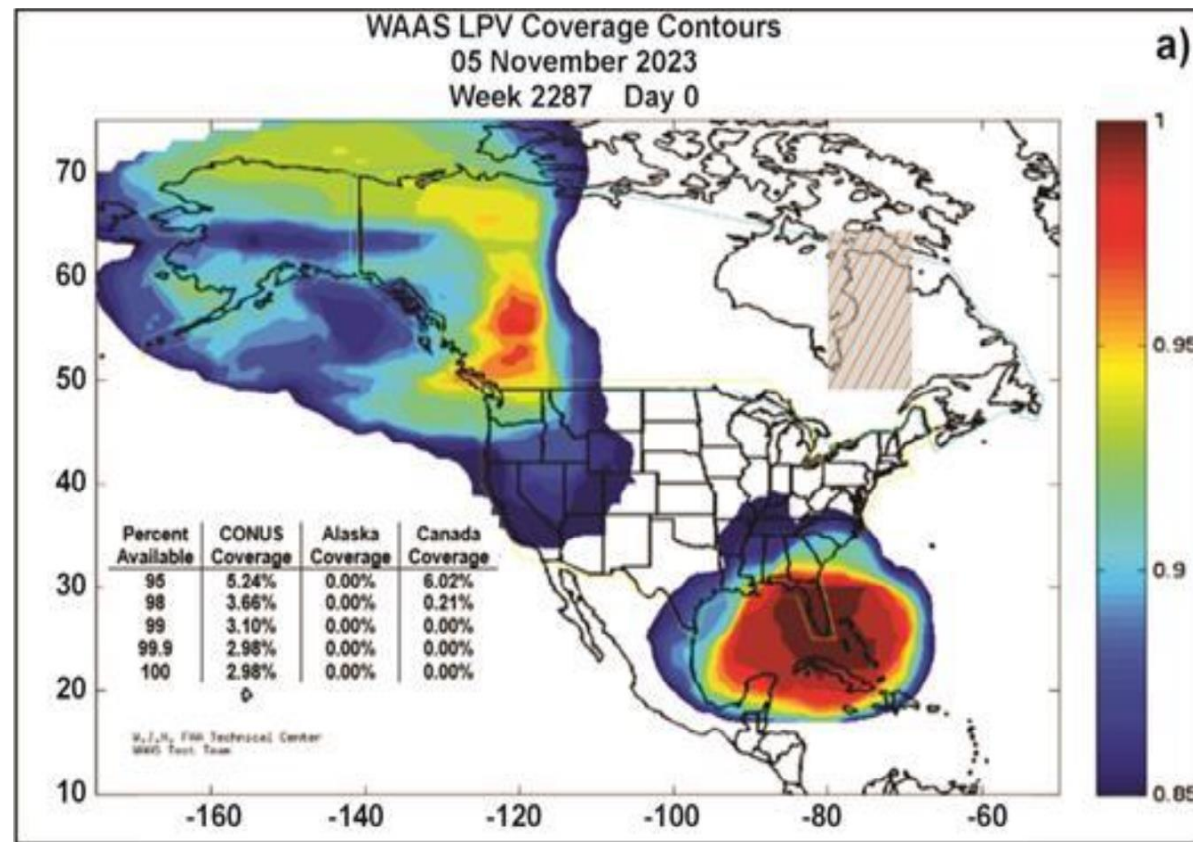
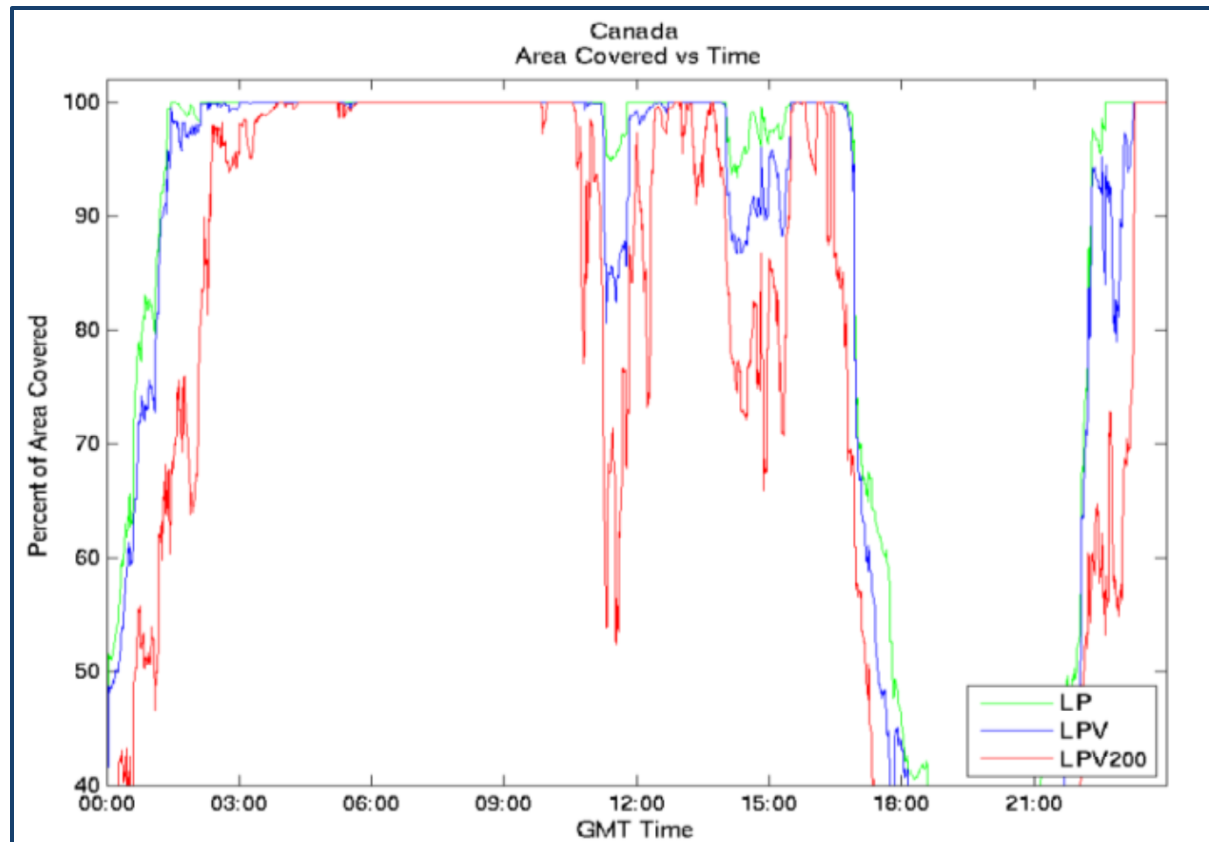
## Education and Guidance Materials

*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

Kuujuuaq Airport QC  
(CYVP)

A Canadian North Boeing 737-406 (C-FFNE/AKT162) from Montreal/Pierre Elliott Trudeau, QC (CYUL) to Kuujuuaq, 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

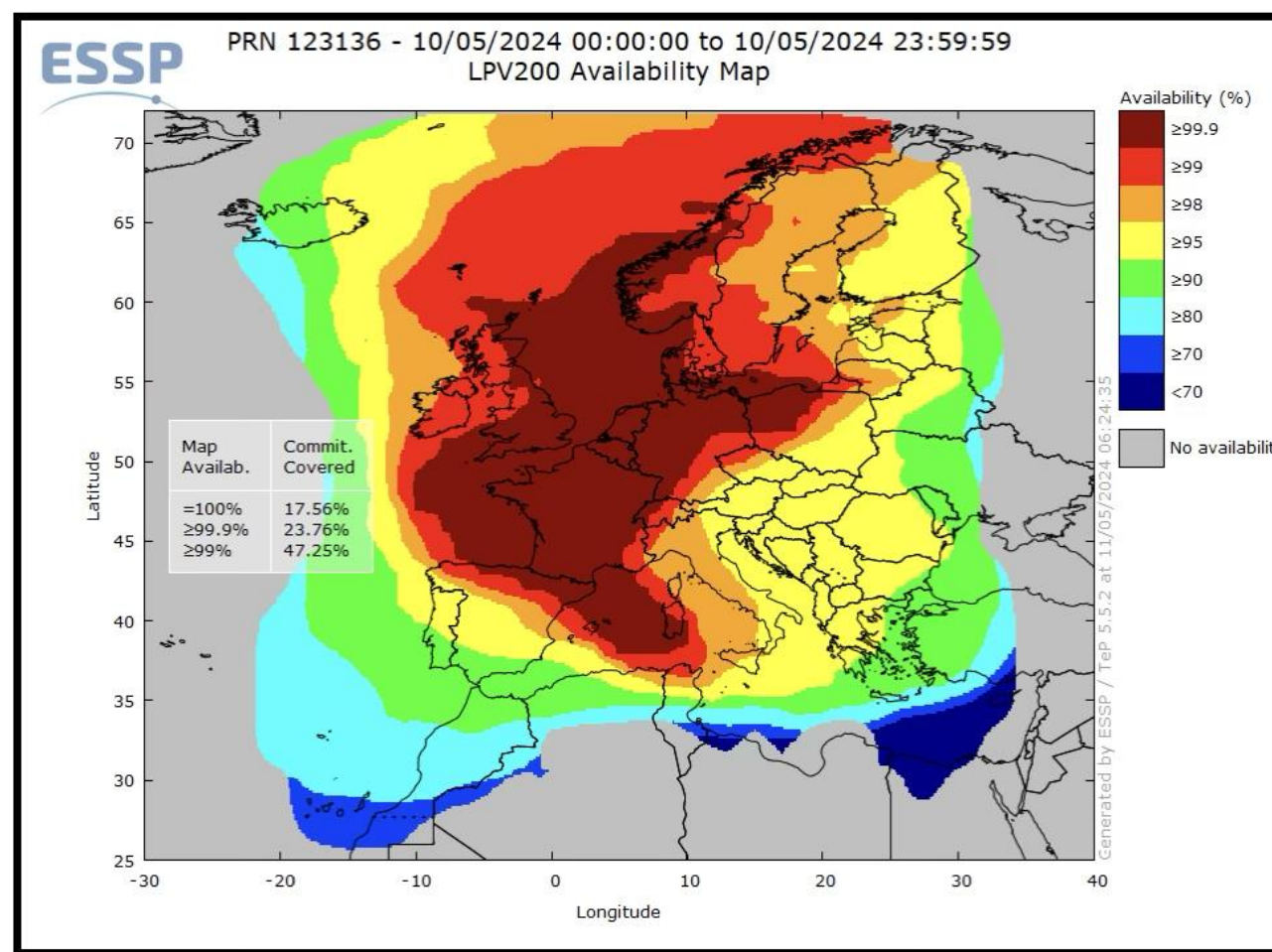
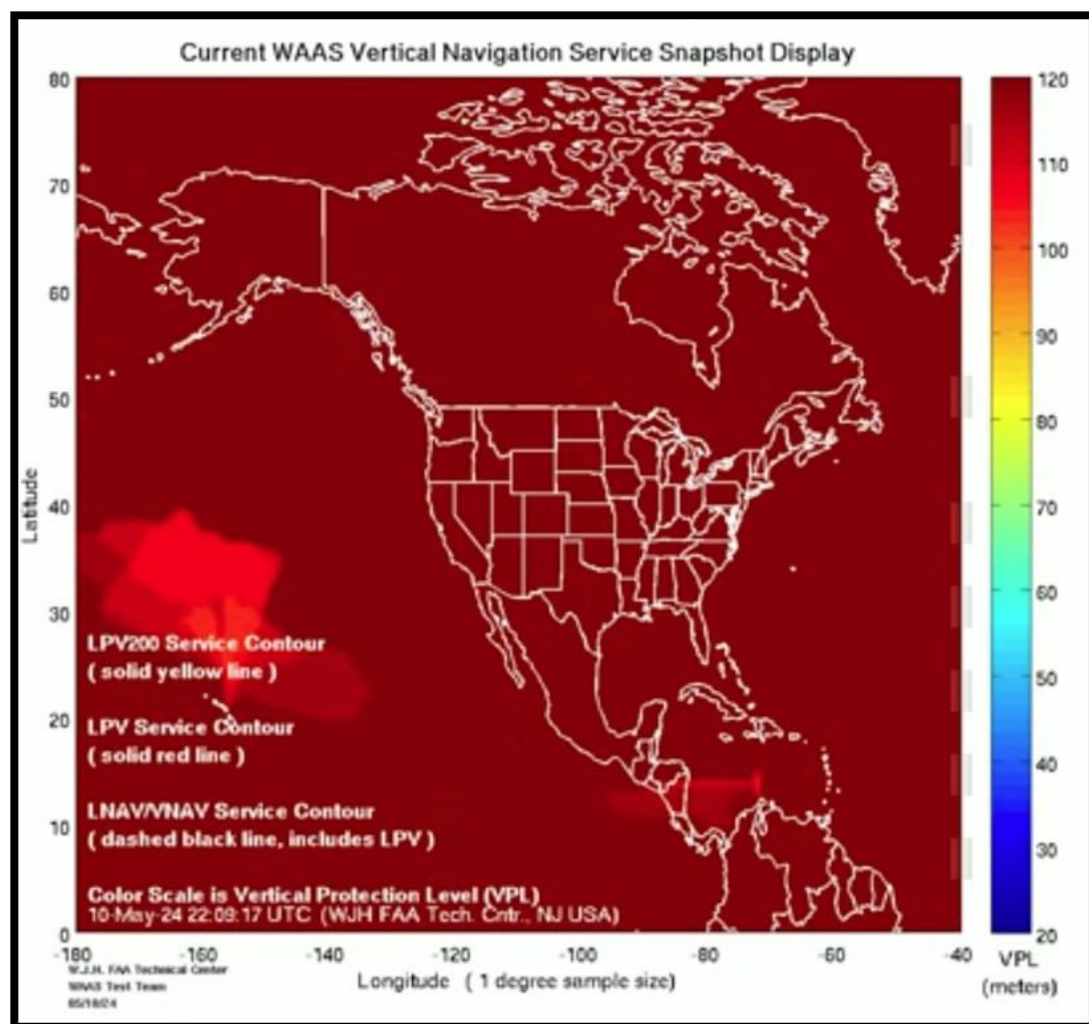
<https://www.nstb.tc.faa.gov>

Nikitina et al, SWJ 2025





# SWIS Motivation: SWX and Aviation



May 10-11 2024

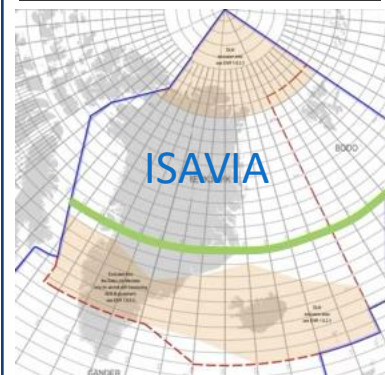
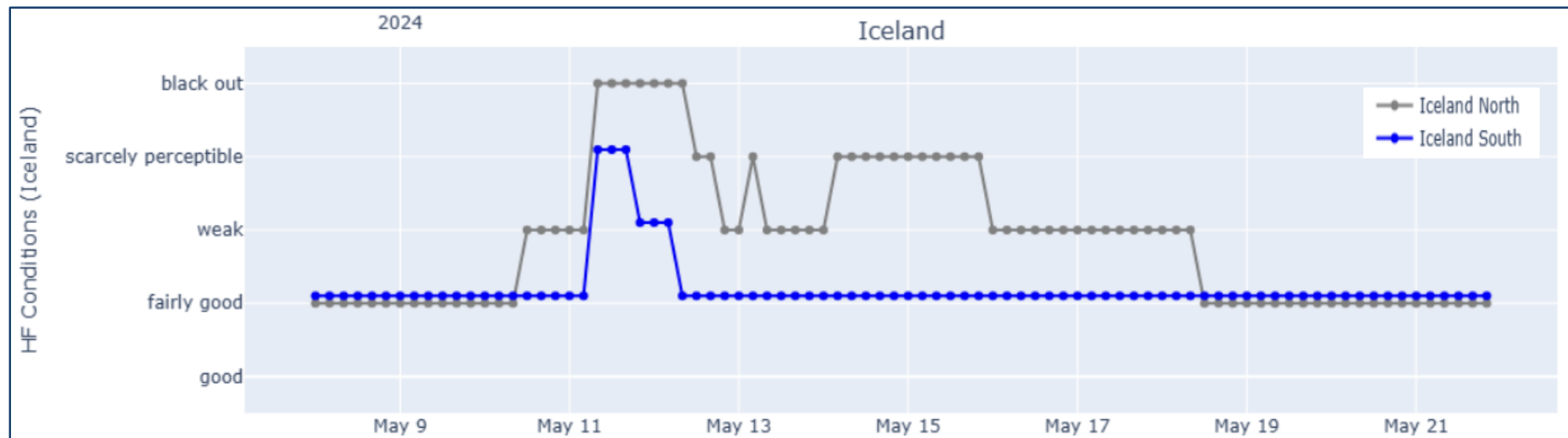


# SWIS Motivation: SWX and Aviation



| 10 <sup>th</sup> May | 11 <sup>th</sup> May | 12 <sup>th</sup> May          | 13 <sup>th</sup> May        | 14 <sup>th</sup> May          |
|----------------------|----------------------|-------------------------------|-----------------------------|-------------------------------|
| Actual HF condition  | Actual HF condition  | Actual HF condition           | Actual HF condition         | Actual HF condition           |
| 0-4 N: Fairly good   | 0-4 N: Weak          | 0-4 N: Black out              | 0-4 N: Weak                 | 0-4 N: Weak                   |
| 4-8 N: Fairly good   | 4-8 N: Weak          | 4-8 N: Black out              | 4-8 N: Scarcely perceptible | 4-8 N: Scarcely perceptible   |
| 8-12 N: Fairly good  | 8-12 N: Black out    | 8-12 N: Black out             | 8-12 N: Weak                | 8-12 N: Scarcely perceptible  |
| 12-16 N: Weak        | 12-16 N: Black out   | 12-16 N: Scarcely perceptible | 12-16 N: Weak               | 12-16 N: Scarcely perceptible |
| 16-20 N: Weak        | 16-20 N: Black out   | 16-20 N: Scarcely perceptible | 16-20 N: Weak               | 16-20 N: Scarcely perceptible |
| 20-24 N: Weak        | 20-24 N: Black out   | 20-24 N: Weak                 | 20-24 N: Weak               | 20-24 N: Scarcely perceptible |

May 2024





# 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

- Advisories are disseminated through ICAO's standard communication channels and are required 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 $\sigma_\phi$ (radians) | 0.4       | 0.7       |
|             | Vertical TEC (TEC Unit)                     | 125       | 175       |
| Radiation   | Effective dose ( $\mu$ Sievert/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  
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=
```

Doc 10100

Manual on Space Weather Information  
in Support of International Air Navigation

First Edition, 2019



Approved by and published under the authority of the Secretary General

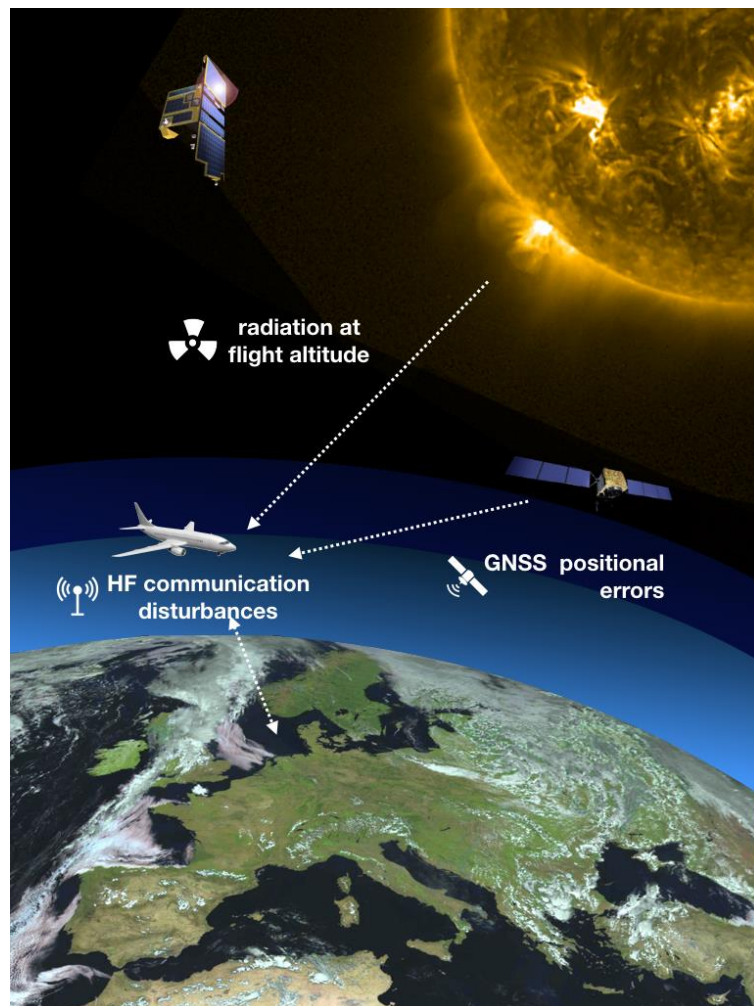
INTERNATIONAL CIVIL AVIATION ORGANIZATION

## 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



# 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 <sup>-2</sup> ) | 1x10 <sup>-4</sup> (X1) | 1x10 <sup>-3</sup> (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



CURRENT SPACE WEATHER CONDITIONSon NOAA Scales

3-DAY FORECAST

"

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

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

|                  |                                                                                                                                                                         |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| DTG              | 20240129/2359Z                                                                                                                                                          |
| SWXC             | PECASUS                                                                                                                                                                 |
| ADVISORY NR.     | 2024/4                                                                                                                                                                  |
| NR. RPLC         | <a href="#">2024/3</a>                                                                                                                                                  |
| 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=                                                                                                                                       |

Why SWX Advisory?

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

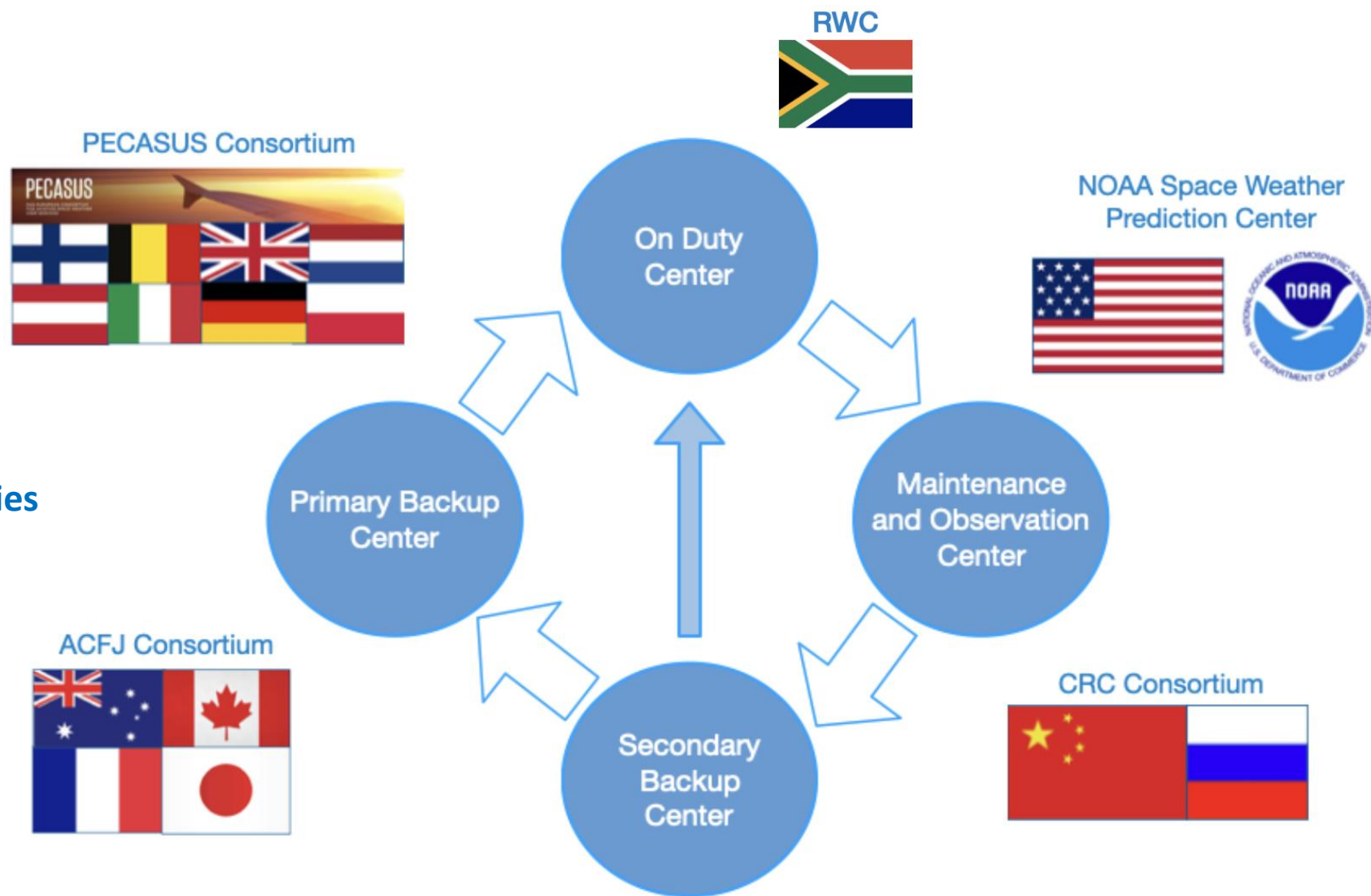




# SWIS Service Provision Centers



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





# Dissemination of SWX Advisories



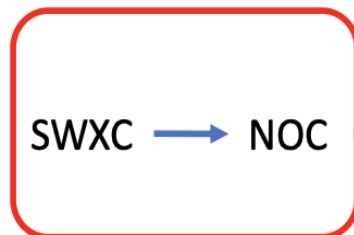
Dissemination via AFS (AFTN) network like all OPMET data:

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

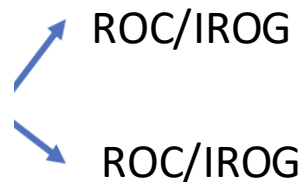
• Users can obtain SWX Advisories through:

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

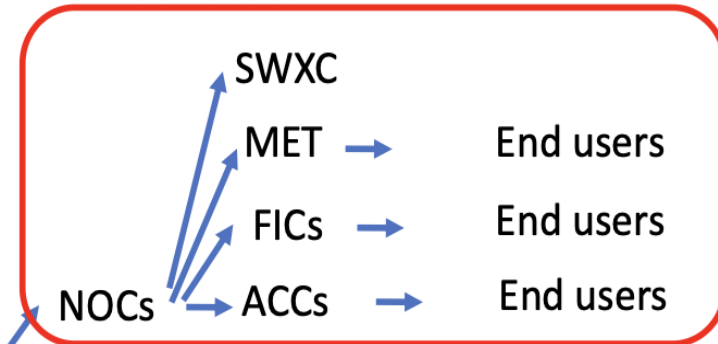
Member State



ROC/IROG



Member State



NOCs

NOCs



# 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





## 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**



| Illustrative image/dataset | Effect on Aviation                    | Affected Area                                    | ROM of Duration                |
|----------------------------|---------------------------------------|--------------------------------------------------|--------------------------------|
|                            | GNSS Loss<br>and/or<br>Position Error | Equator at local sunset<br>Follows day/nightline | Few hours<br>(start at sunset) |
|                            |                                       | Poles                                            | Few hours                      |
|                            |                                       | To be studied                                    | Few hours                      |





## 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.





| Illustrative image<br>(Eye catcher) |                                  | Effect on Aviation                | Affected Area         | ROM of Duration               |
|-------------------------------------|----------------------------------|-----------------------------------|-----------------------|-------------------------------|
|                                     | Absorption following Solar Flare | Loss of LOWEST HF                 | Dayside               | Minutes to several hours      |
|                                     | Polar Cap Absorption             |                                   | Poles                 | Several hours to several days |
|                                     | Auroral Absorption               |                                   |                       | 1 to several days             |
|                                     | Post Storm Depression            | MUF reduced<br>Loss of HIGHEST HF | Anywhere<br>(erratic) | Several Days (2-4 days)       |





## 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.



# RADIATION

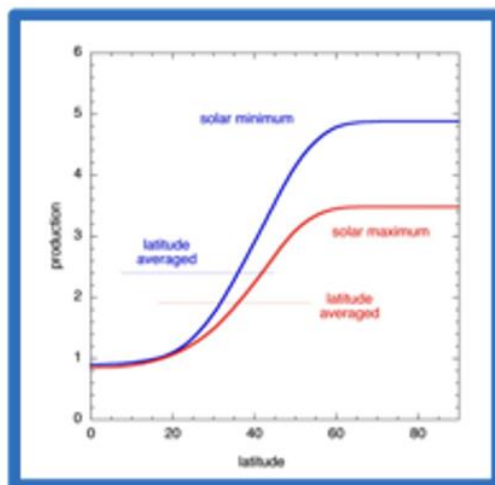


Illustrative image  
(Eye catcher)

Effect on Aviation

Affected Area

ROM of Duration

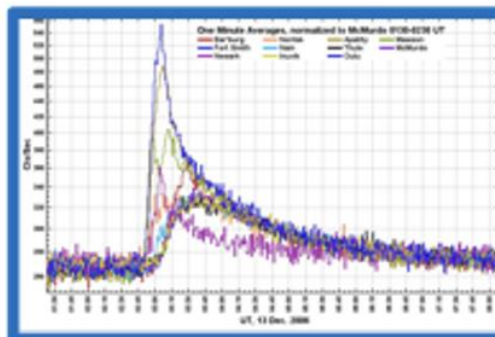


Galactic  
Cosmic  
Rays

Effective dose

Poles  
High FL

Always



GLE

Effective dose  
increased

Poles  
High FL

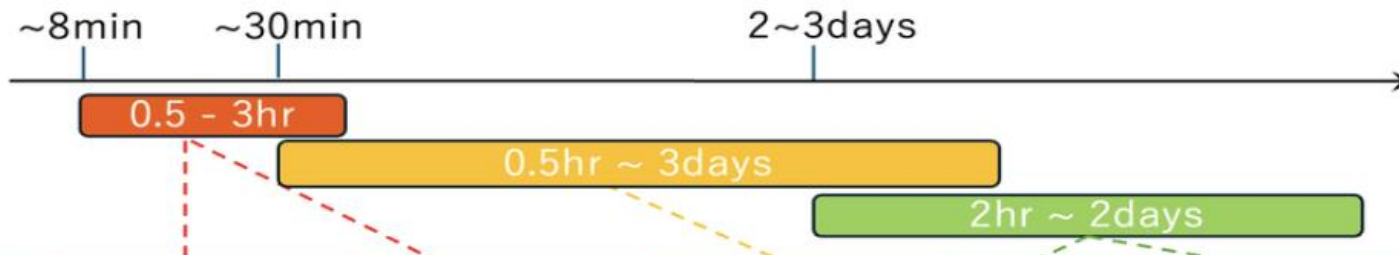
Few hours







# SWIS Impacts Summary



| 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   |                          | <ul style="list-style-type: none"> <li>Once in several years</li> <li>Depends on solar activity</li> </ul> | <ul style="list-style-type: none"> <li>Several times a year</li> <li>Depends on solar activity</li> </ul> | <ul style="list-style-type: none"> <li>One to a few times a year</li> <li>Depends on solar activity</li> </ul> | <ul style="list-style-type: none"> <li>One to a few times a year</li> <li>Strongly depends on solar activity</li> </ul> | <ul style="list-style-type: none"> <li>Moderate: several times a year</li> <li>Severe: several times a decade</li> </ul> | <ul style="list-style-type: none"> <li>Solar activity dependence</li> <li>Seasonal dependence</li> </ul> |
| 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                                                                                         |

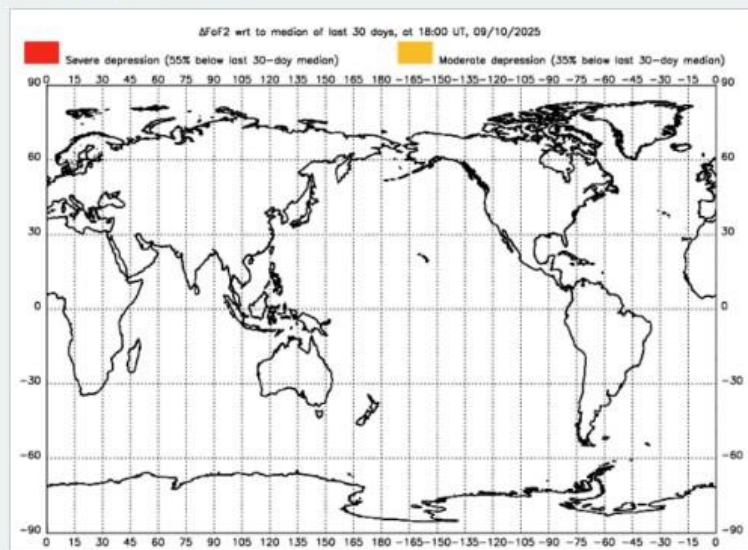


## Latest Maps

### HF Comm Conditions

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

#### HF Depression

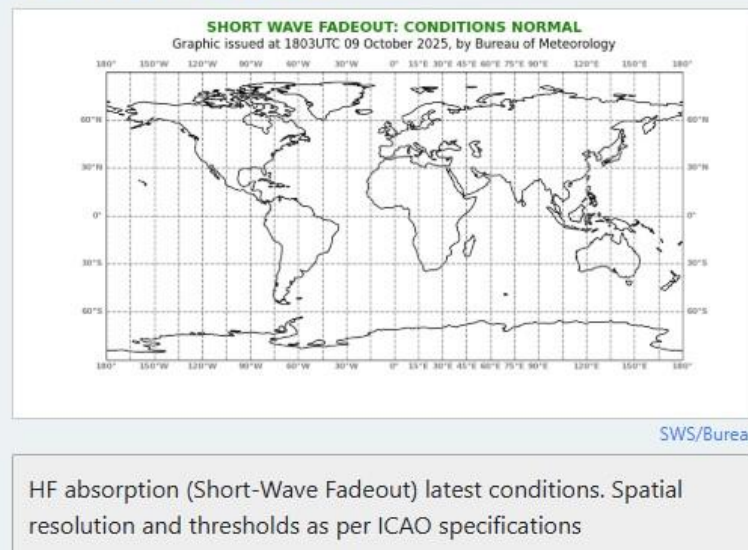


HF MUF depression latest conditions. Spatial resolution and thresholds as per ICAO specifications

HF Depression Viewer

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

#### Shortwave Fadeout

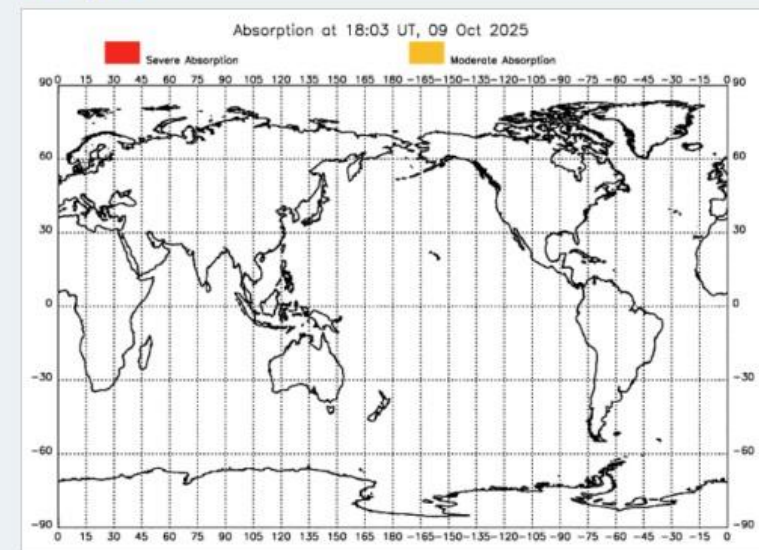


HF absorption (Short-Wave Fadeout) latest conditions. Spatial resolution and thresholds as per ICAO specifications

Shortwave Fadeout Viewer

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

#### PCA/AA



HF absorption (Polar Cap Absorption/Auroral Absorption) latest conditions. Spatial resolution and thresholds as per ICAO specifications.

PCA/AA Viewer

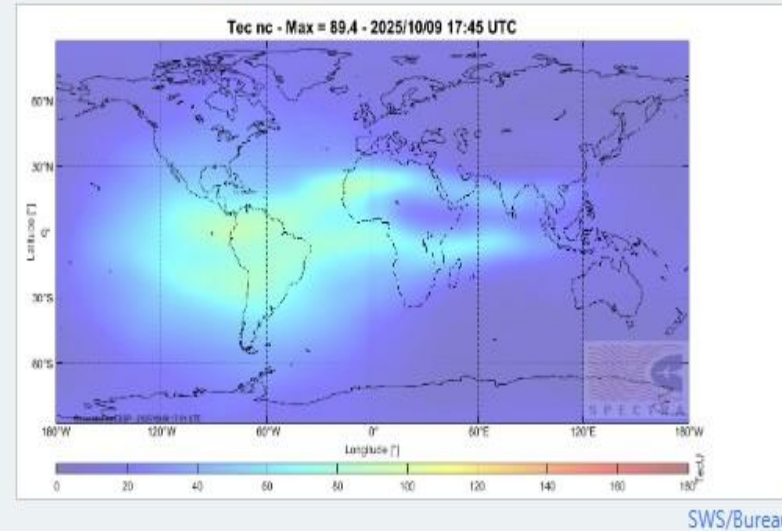




## GNSS Conditions

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

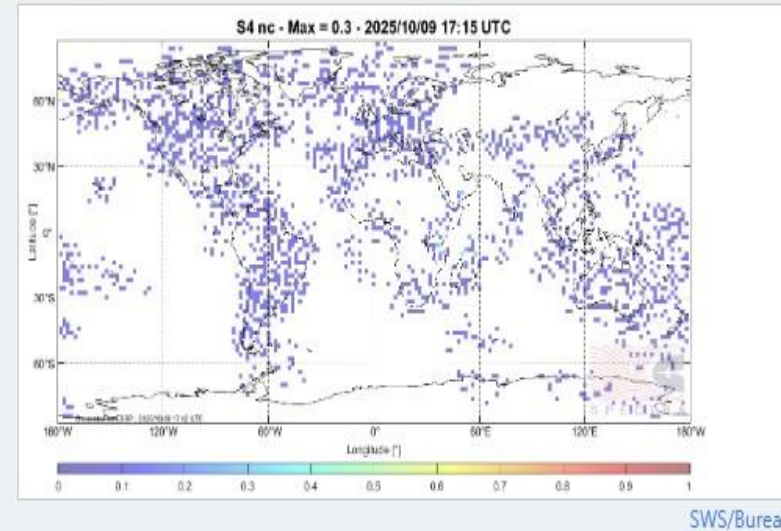
### GNSS Delay (TEC)



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

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

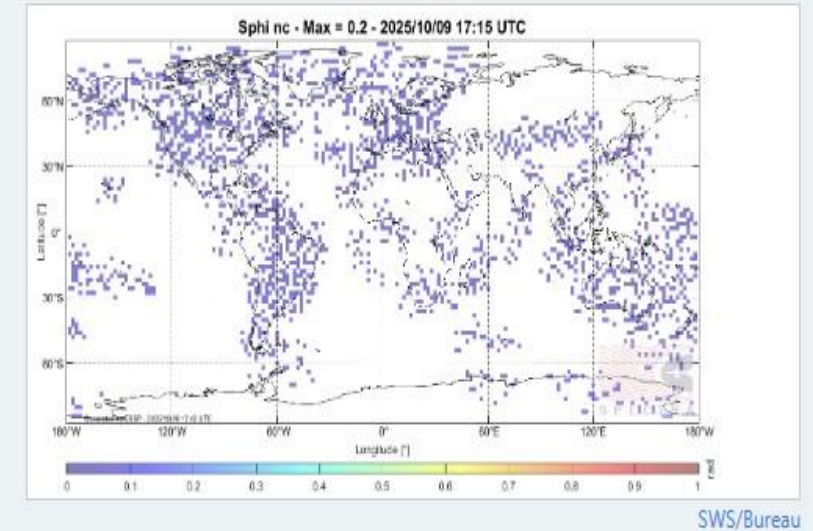
### Amplitude Scintillation (S4)



GNSS ionospheric amplitude scintillation latest conditions, expressed in terms of S4 index

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

### Phase Scintillation (SPHI)



GNSS ionospheric phase scintillation latest conditions, expressed in terms of Sigma\_phi index

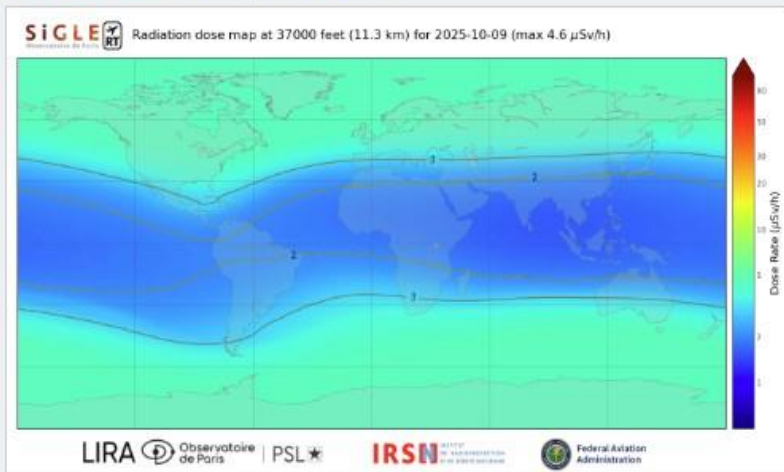




## Radiation Conditions

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

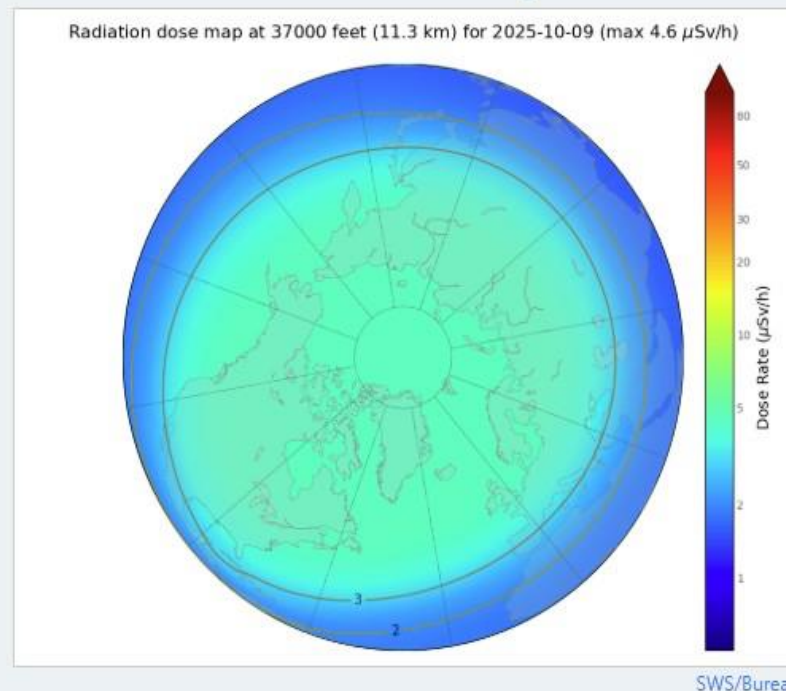
### Dose Rate Map FL370



SWS/Bureau

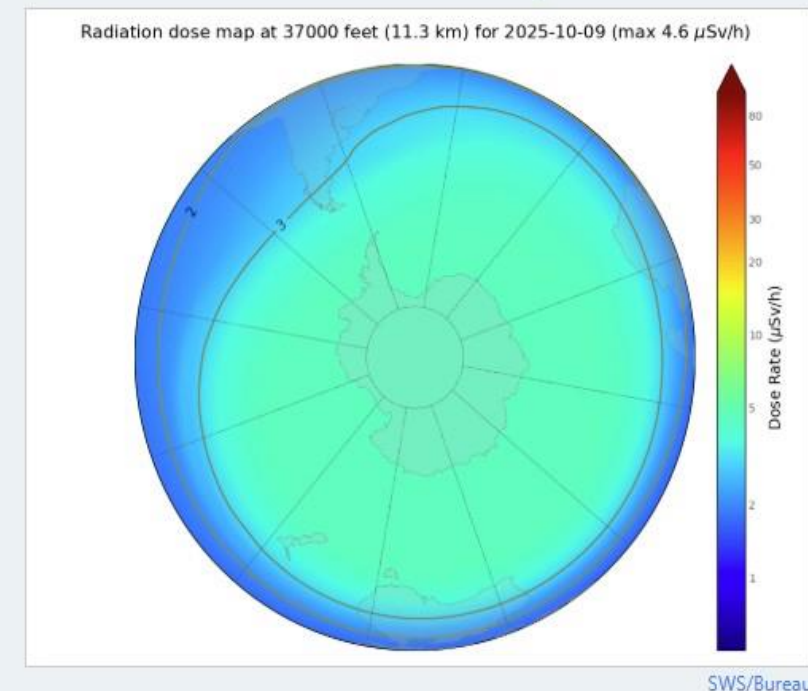
Modelled radiation dose rate at FL370, latest conditions. Image provided by Paris Observatory.

### Northern Polar Dose Rate Map FL370



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

### Southern Polar Dose Rate Map FL370



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



METEOROLOGY PANEL



METP SWX User Workshop, 20 October 2025, Rome, Italy

# Training and Educational Materials

[https://www.stce.be/PECASUS\\_guide4pilots](https://www.stce.be/PECASUS_guide4pilots)

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





METEOROLOGY PANEL



METP SWX User Workshop, 20 October 2025, Rome, Italy

# Thank You!

