



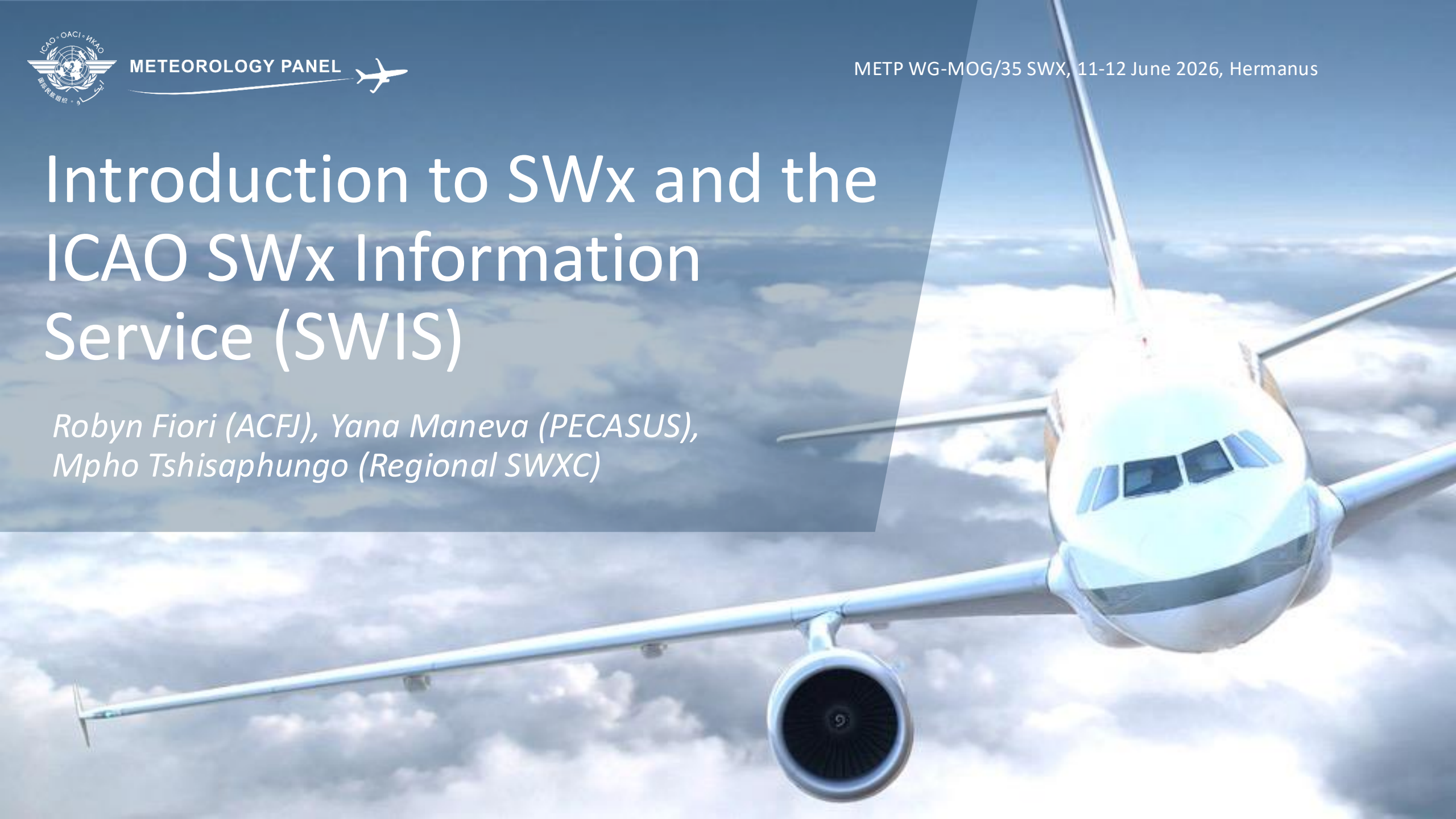
METEOROLOGY PANEL



METP WG-MOG/35 SWX, 11-12 June 2026, Hermanus

Introduction to SWx and the ICAO SWx Information Service (SWIS)

*Robyn Fiori (ACFJ), Yana Maneva (PECASUS),
Mpho Tshisaphungo (Regional SWXC)*





METEOROLOGY PANEL



Space Weather vs Terrestrial Weather

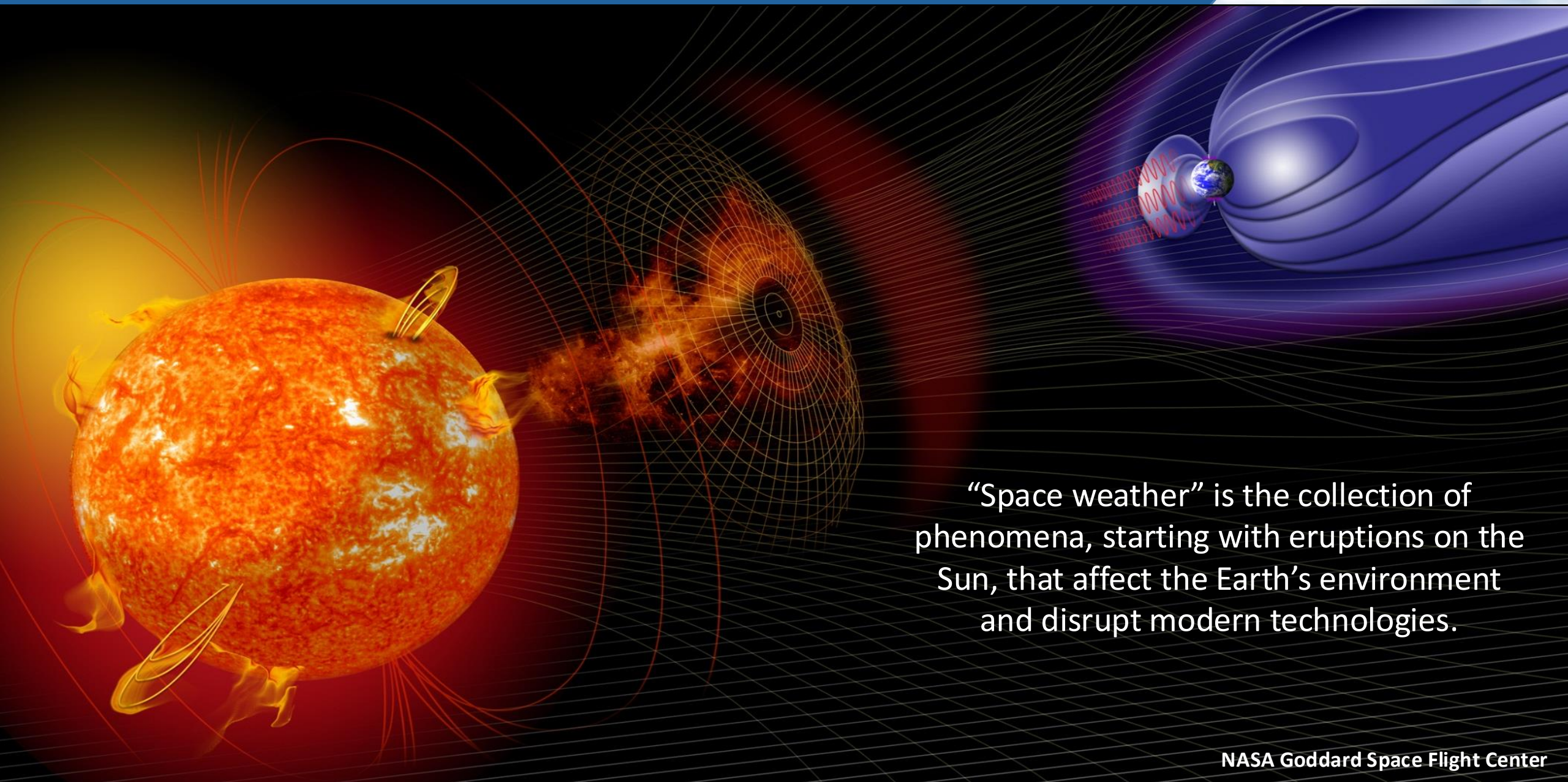




METEOROLOGY PANEL



Space Weather Introduction



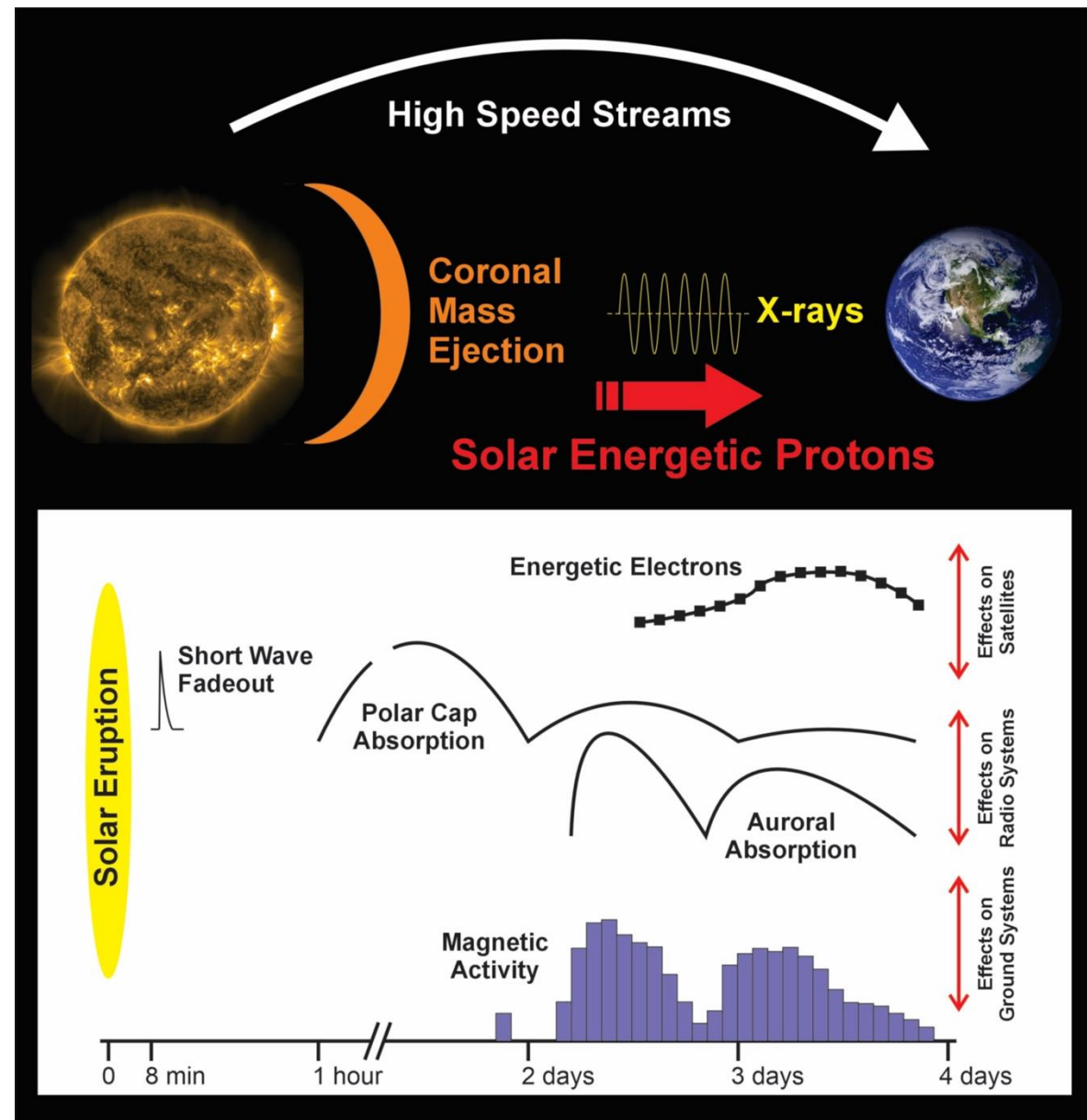
“Space weather” is the collection of phenomena, starting with eruptions on the Sun, that affect the Earth’s environment and disrupt modern technologies.



Space Weather Introduction

Solar phenomena impact technologies and infrastructure on a variety of time scales.

Solar Phenomena	Arrival Time	Duration of effect
solar X-ray flares	~8 minutes	minutes to hours
energetic particles	10's of minutes	hours to days
CMEs	1-4 days	hours to days
coronal holes	1-4 days	hours to days



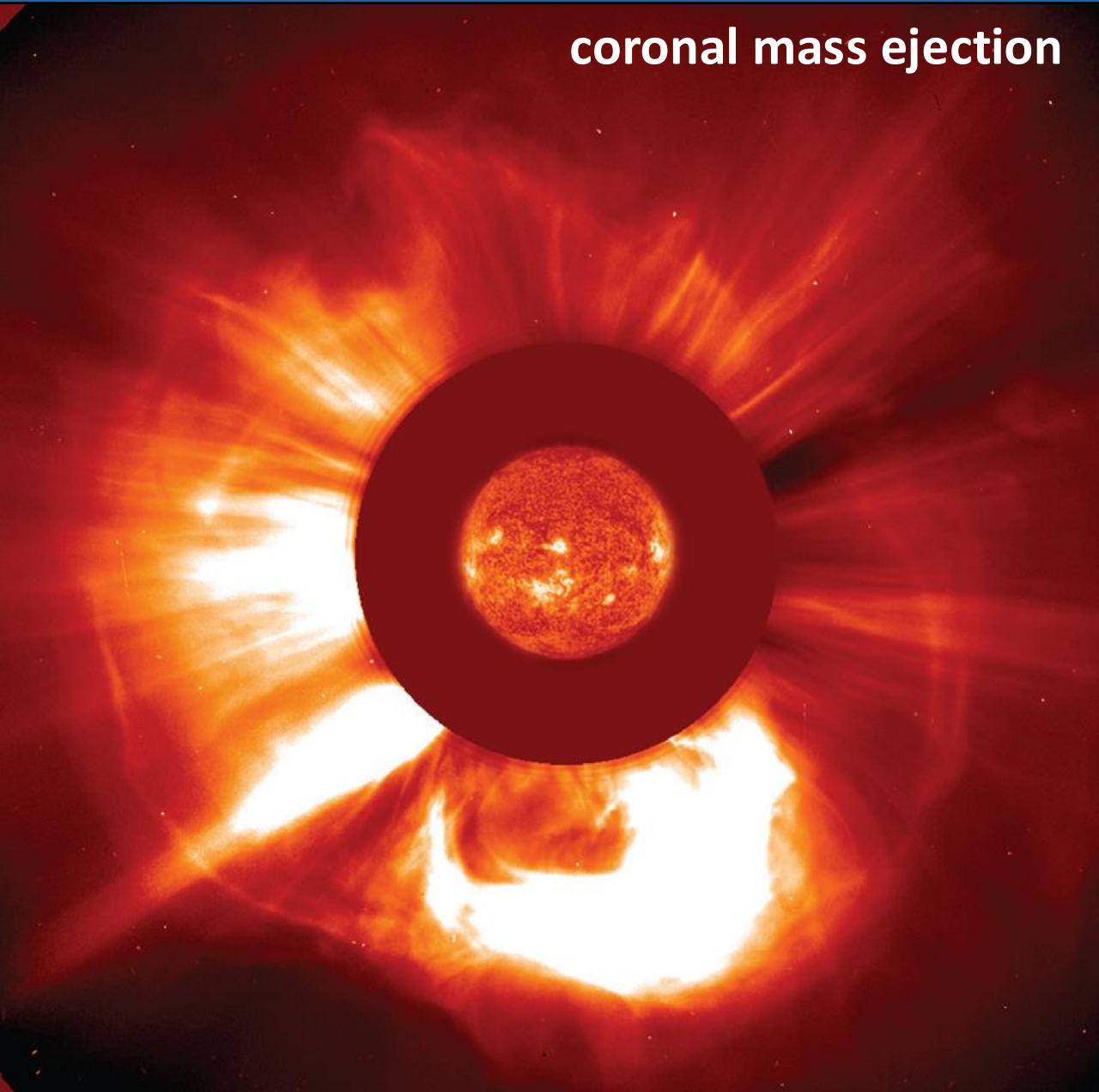


METEOROLOGY PANEL

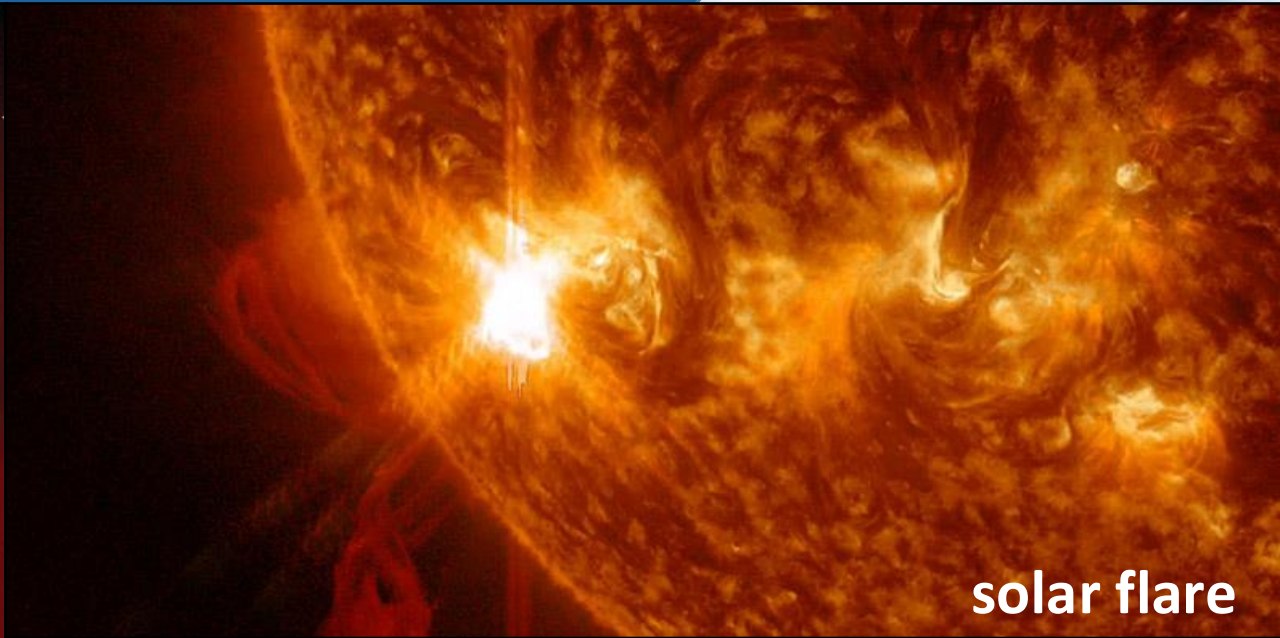


Space Weather Introduction

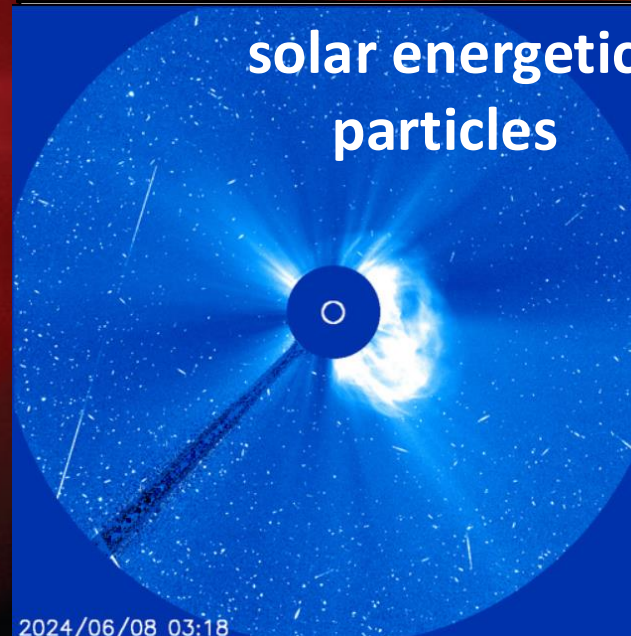
coronal mass ejection



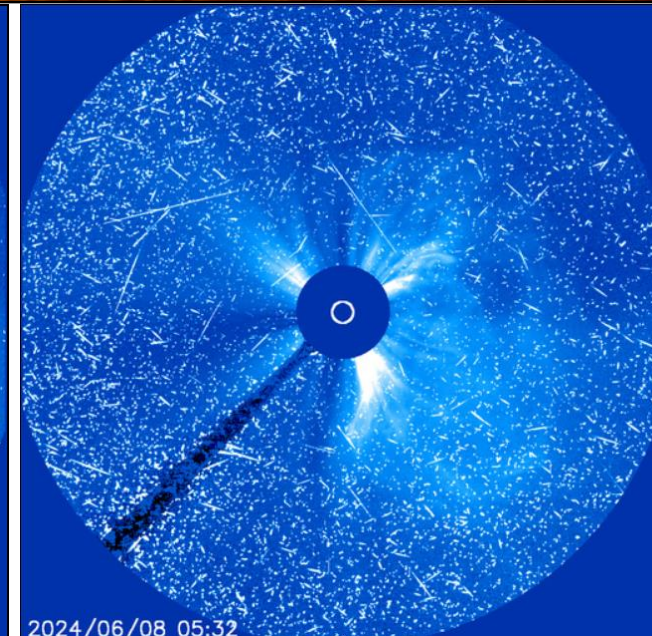
solar flare



solar energetic
particles



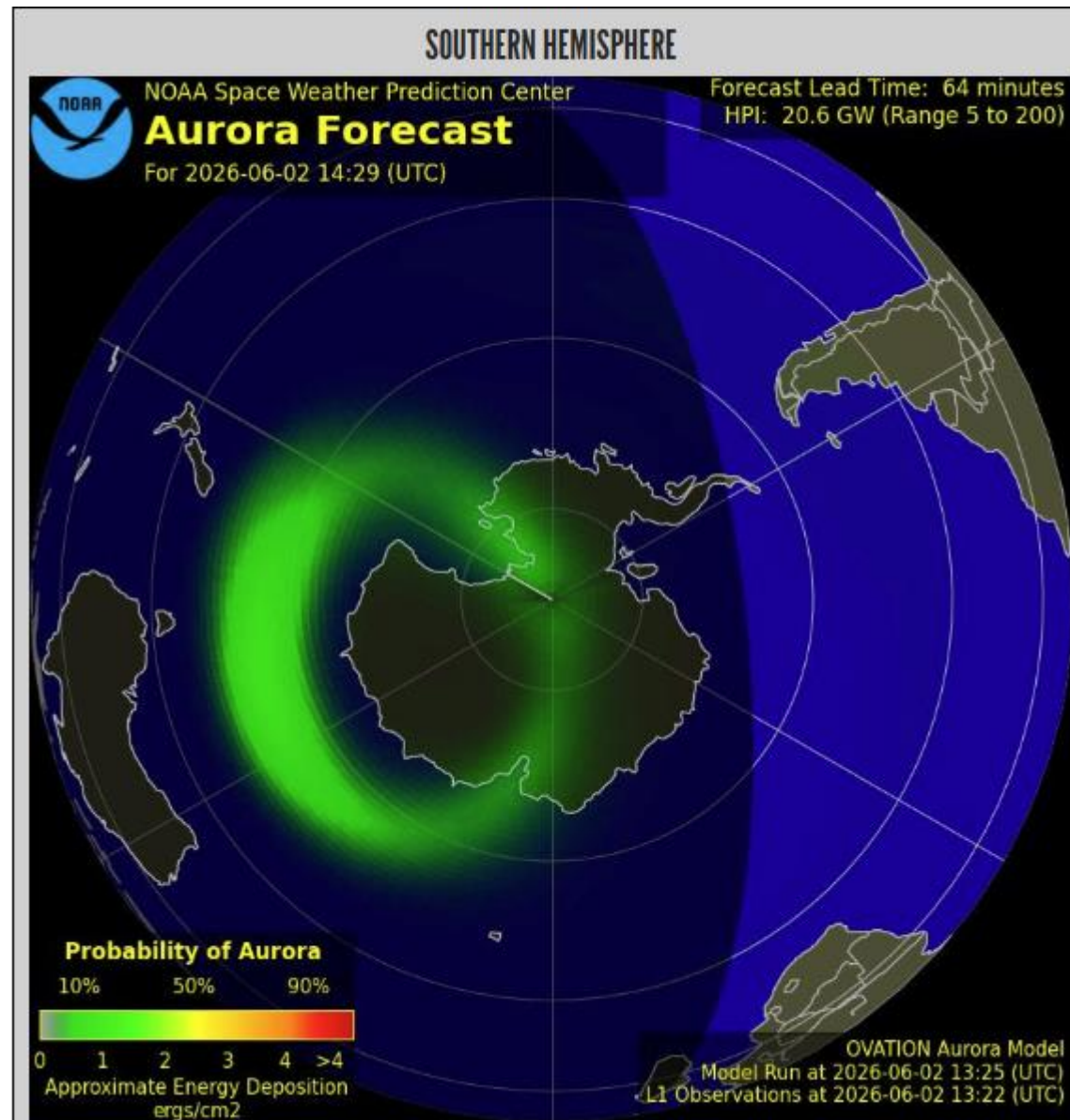
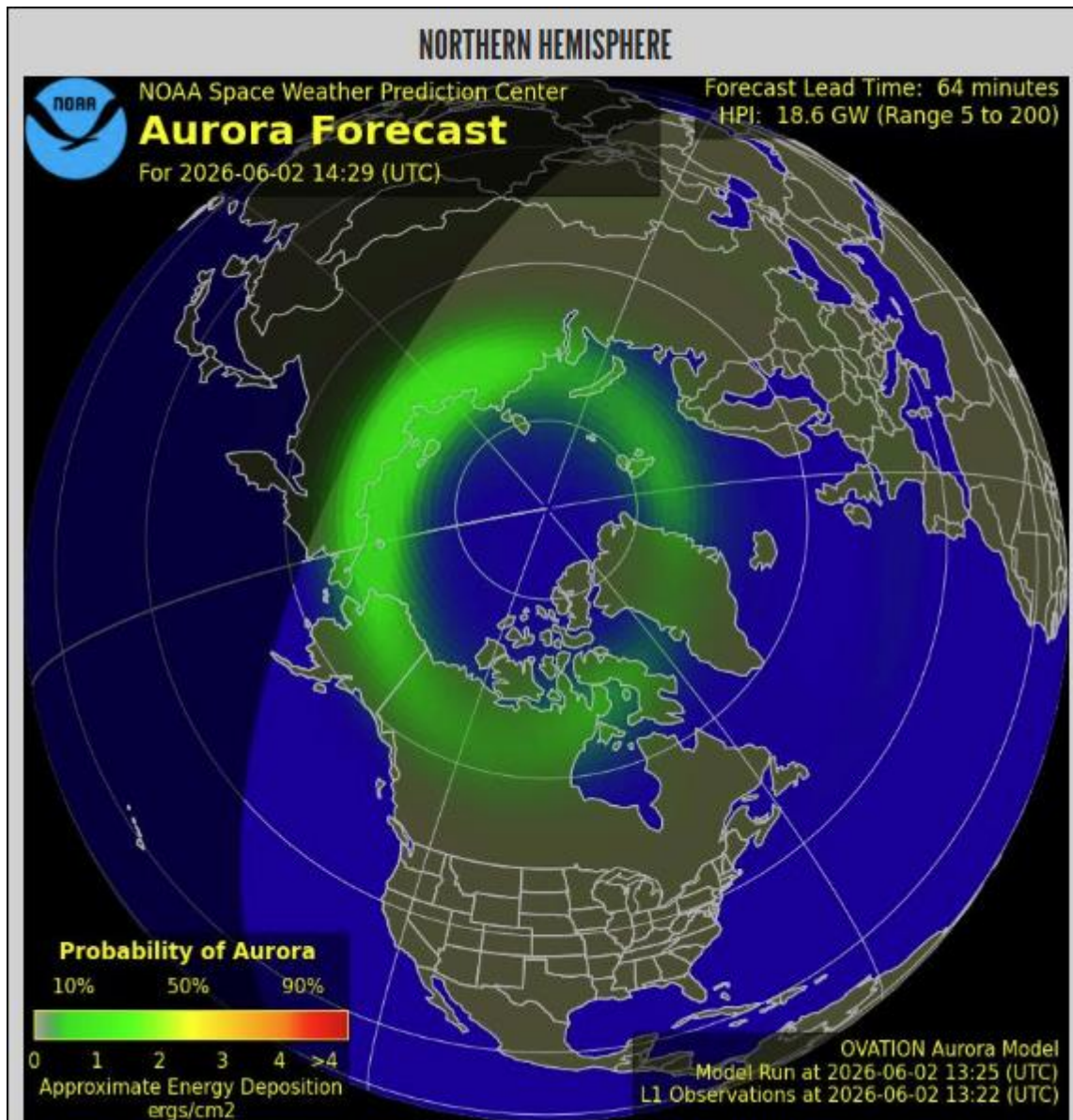
2024/06/08 03:18



2024/06/08 05:32



Space Weather Introduction





Challenges

GEOGRAPHIC VS. GEOMAGNETIC COORDINATES: KEY DIFFERENCES FOR CANADIAN AVIATION

GEOGRAPHIC (TRUE) COORDINATES



KEY DIFFERENCE



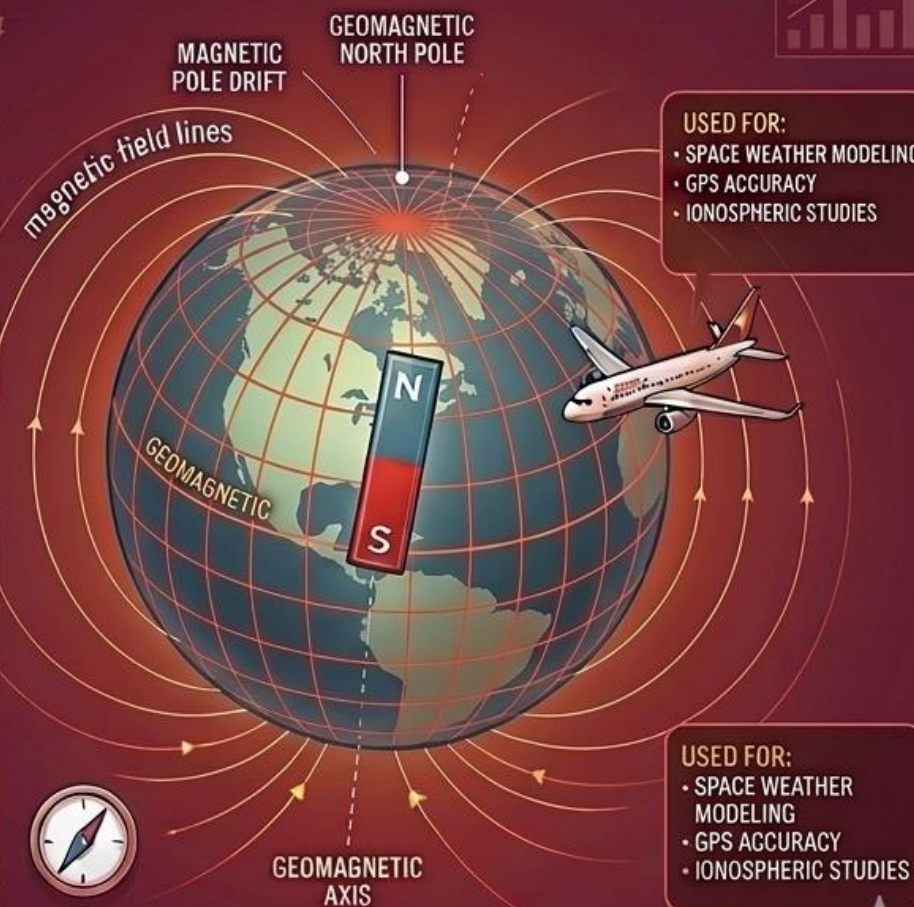
AVIATION IMPACT IN CANADA

CRITICAL FOR POLAR & HIGH-LATITUDE NAVIGATION

COMPASS ERRORS IN THE NORTH

GNSS VULNERABILITY TO GEOMAGNETIC STORMS

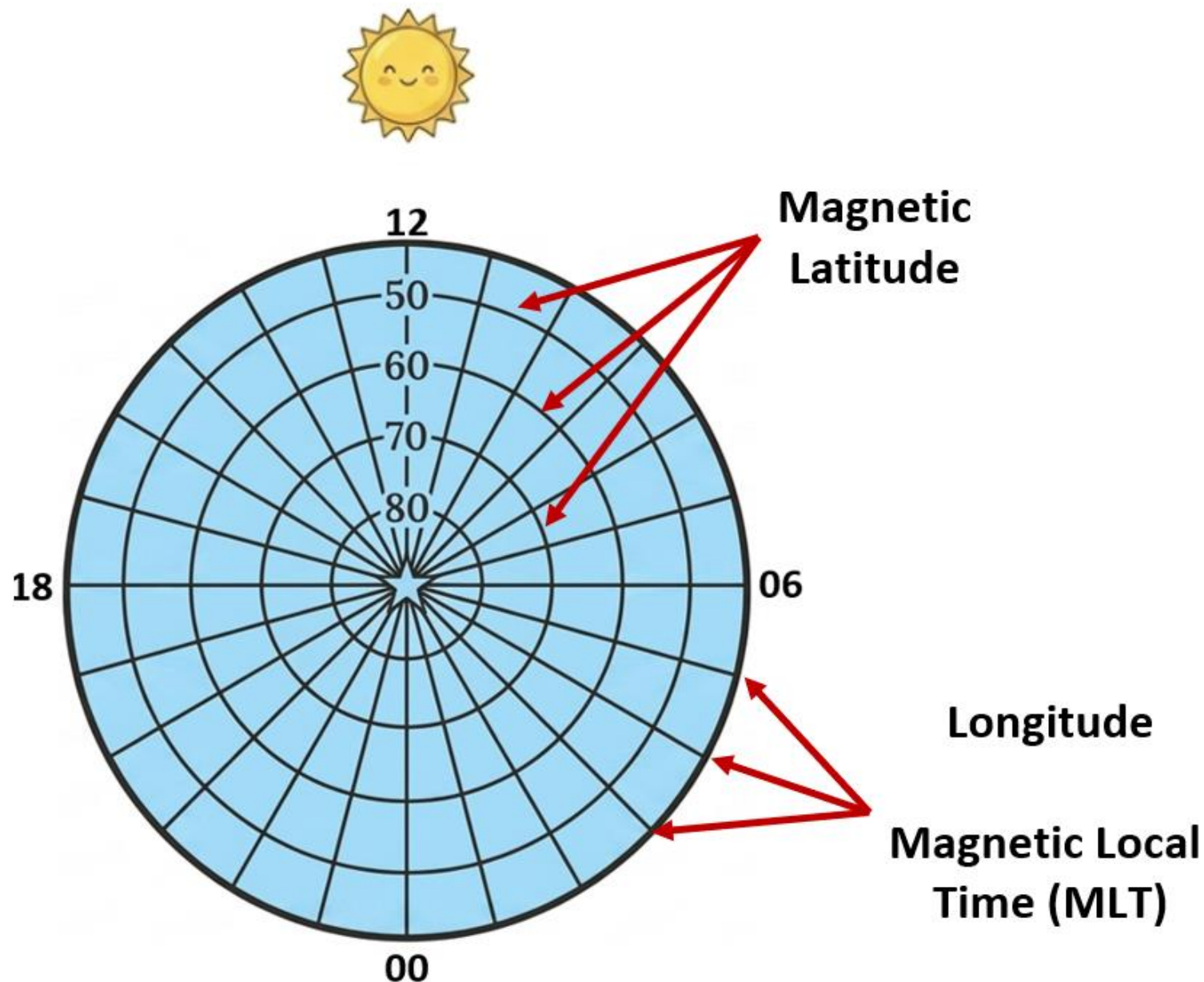
GEOMAGNETIC COORDINATES





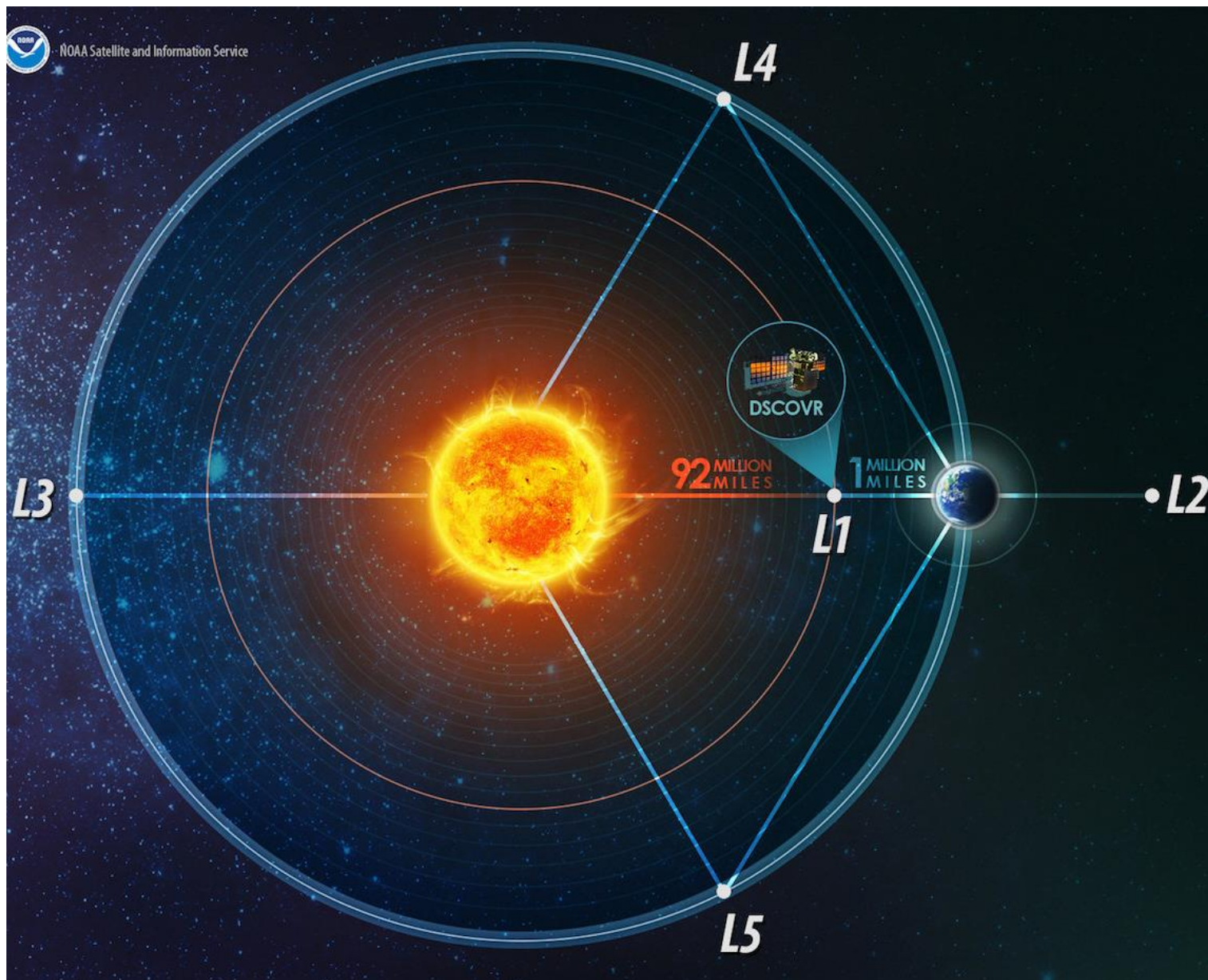
Challenges

Many space weather impacts are dependent on the location of the Sun with respect to the Earth.





Challenges



Impacts from solar activity are challenging to forecast until the solar wind reaches the L1 point.



SWx Impacts Aviation

HF COMMUNICATION



GNSS

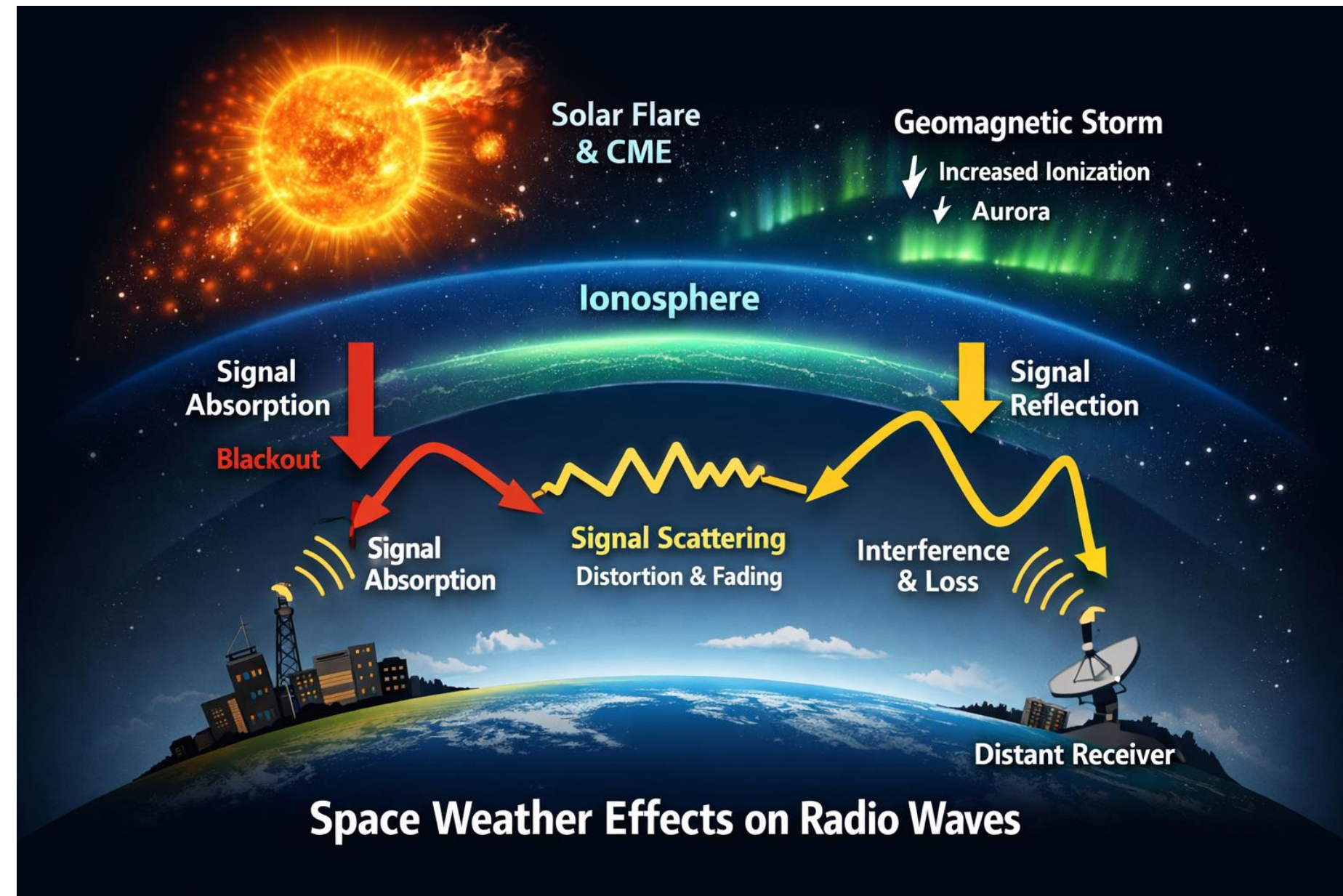


RADIATION EXPOSURE





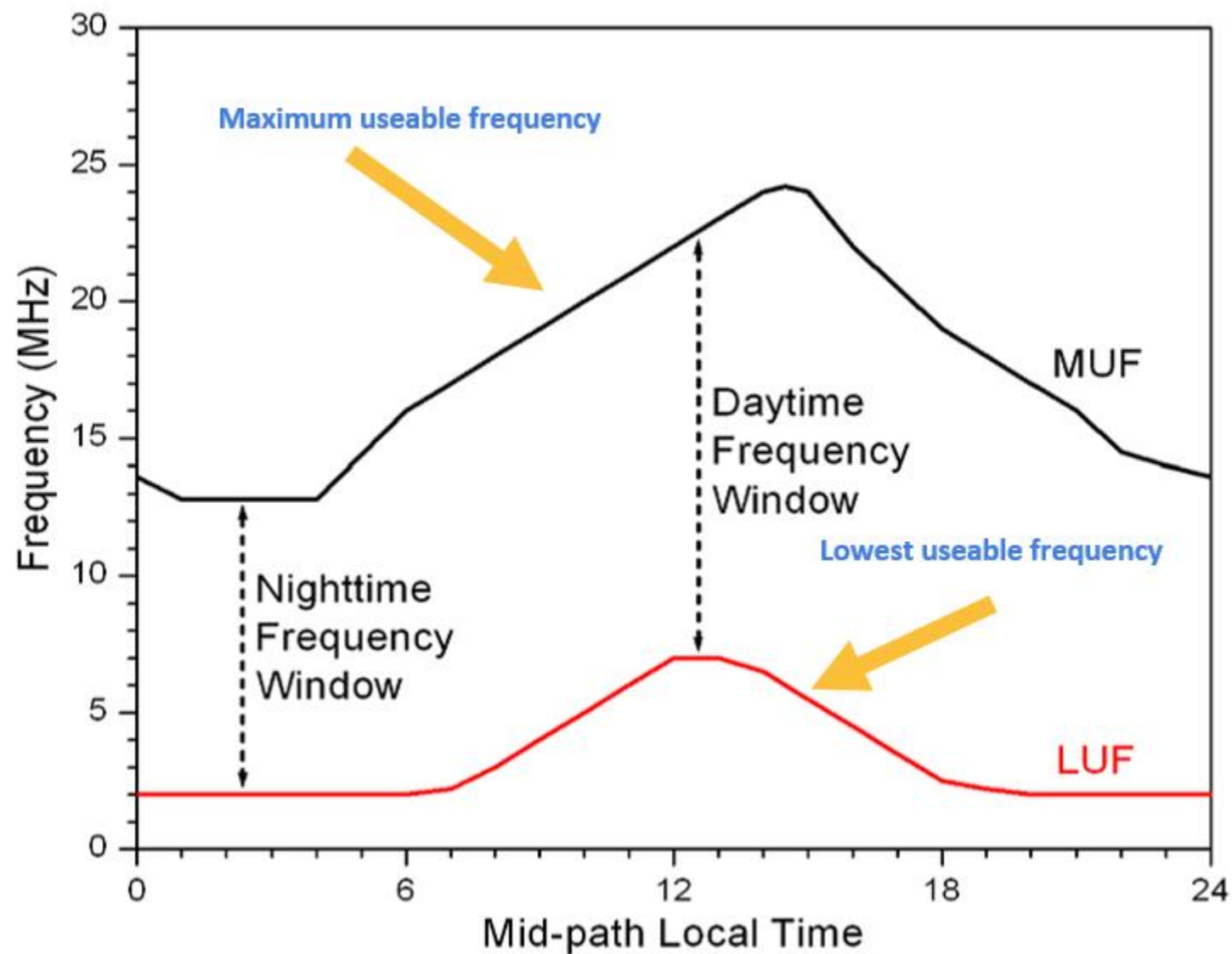
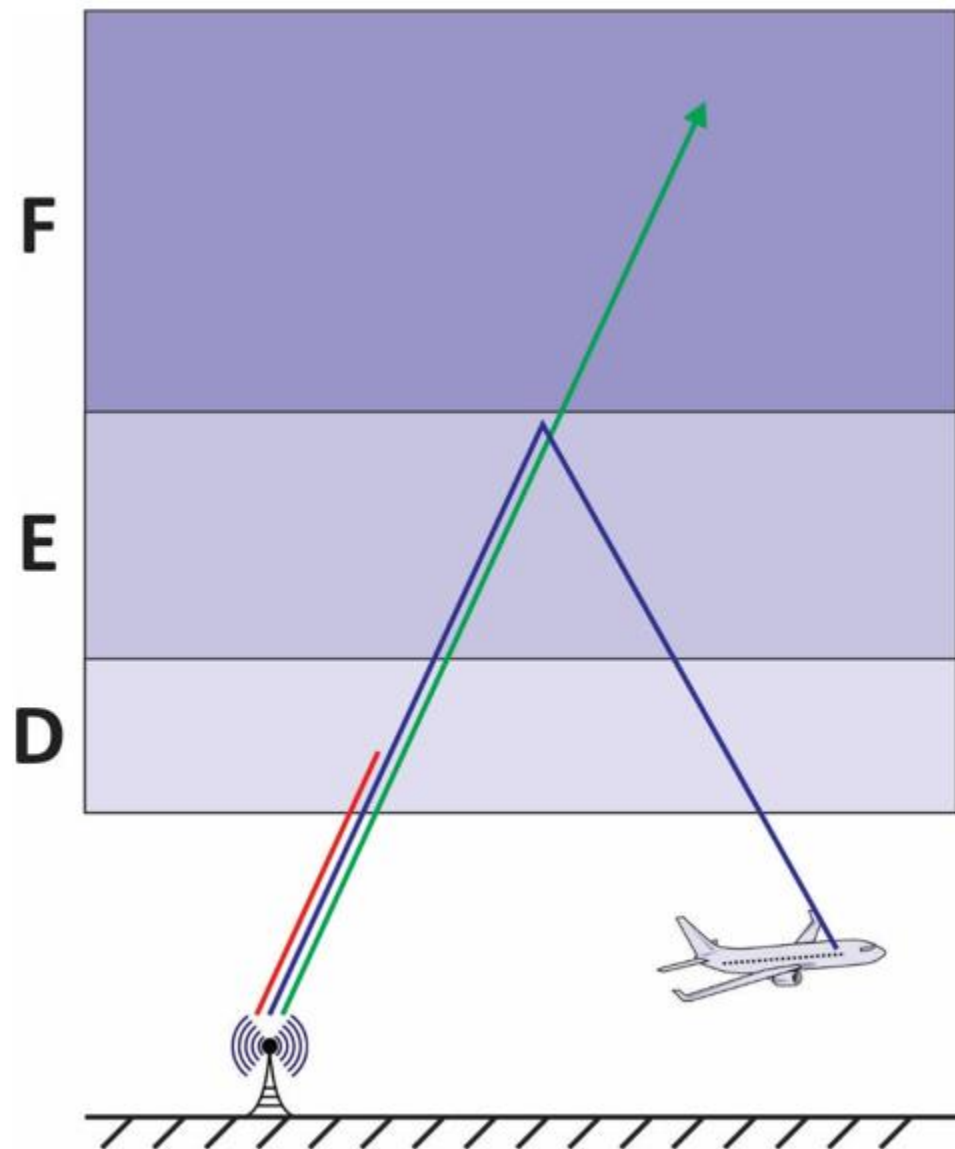
SWx Impacts - HF COM



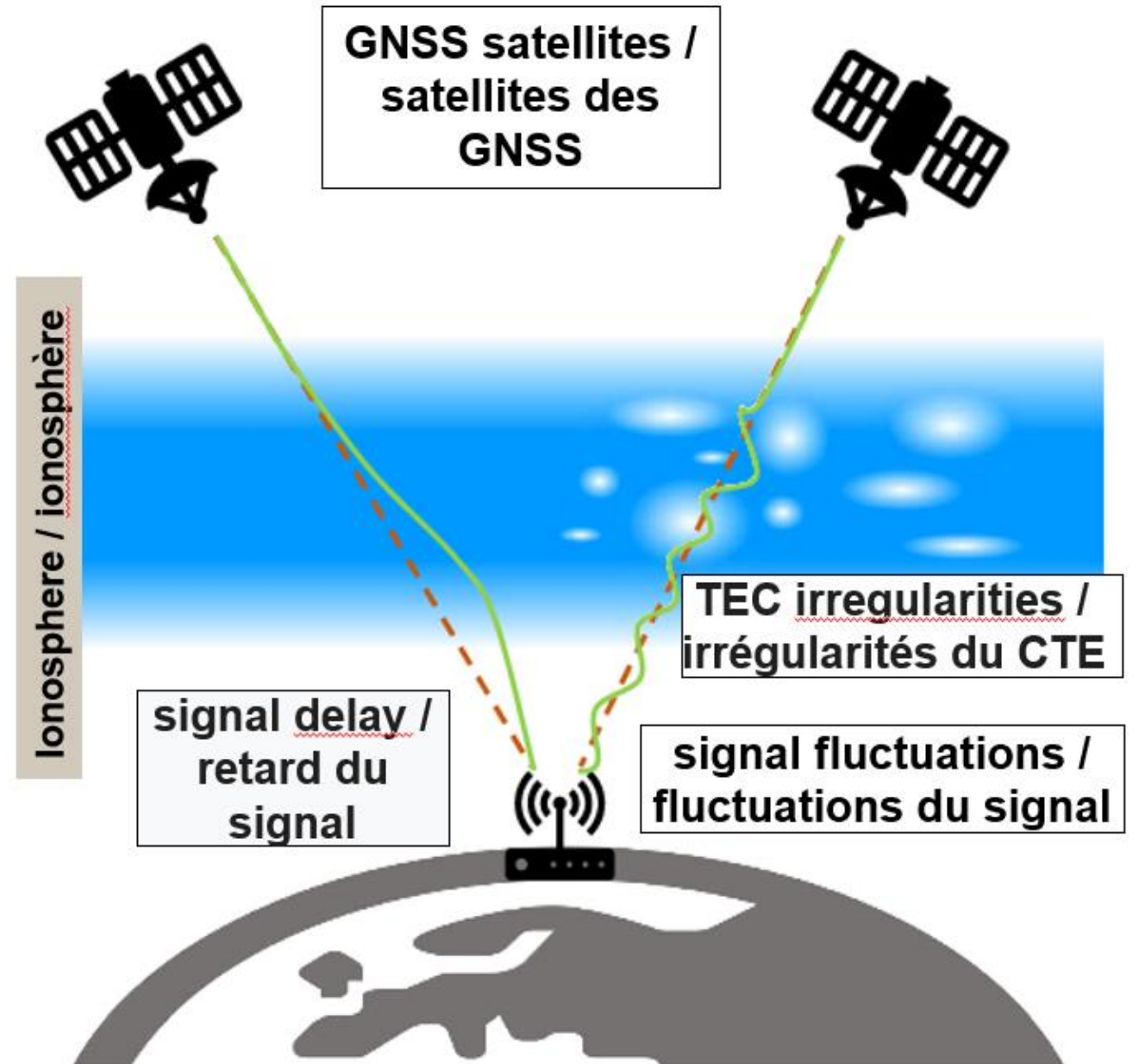
**degradation of high
frequency
(HF; 3-30 MHz)
radio systems**



SW Impacts – HF COM



**reduced accuracy
of GNSS
positioning and /
or timing**



IONOSPHERIC SCINTILLATION: AN ANALOGY

Like trying to see a coin on the bottom of a pool.

CALM WATER

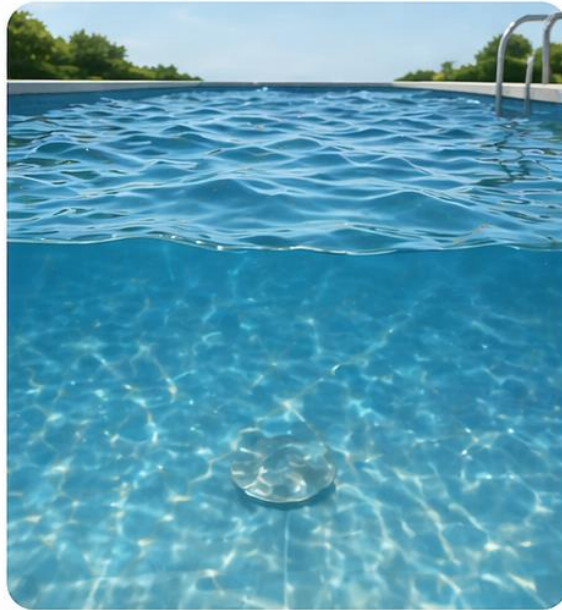
Signal is clear and steady



You can easily see the coin's position.

WAVY WATER

Signal is fluctuating



It's harder to see the coin's position.

VERY WAVY WATER

Signal is severely degraded



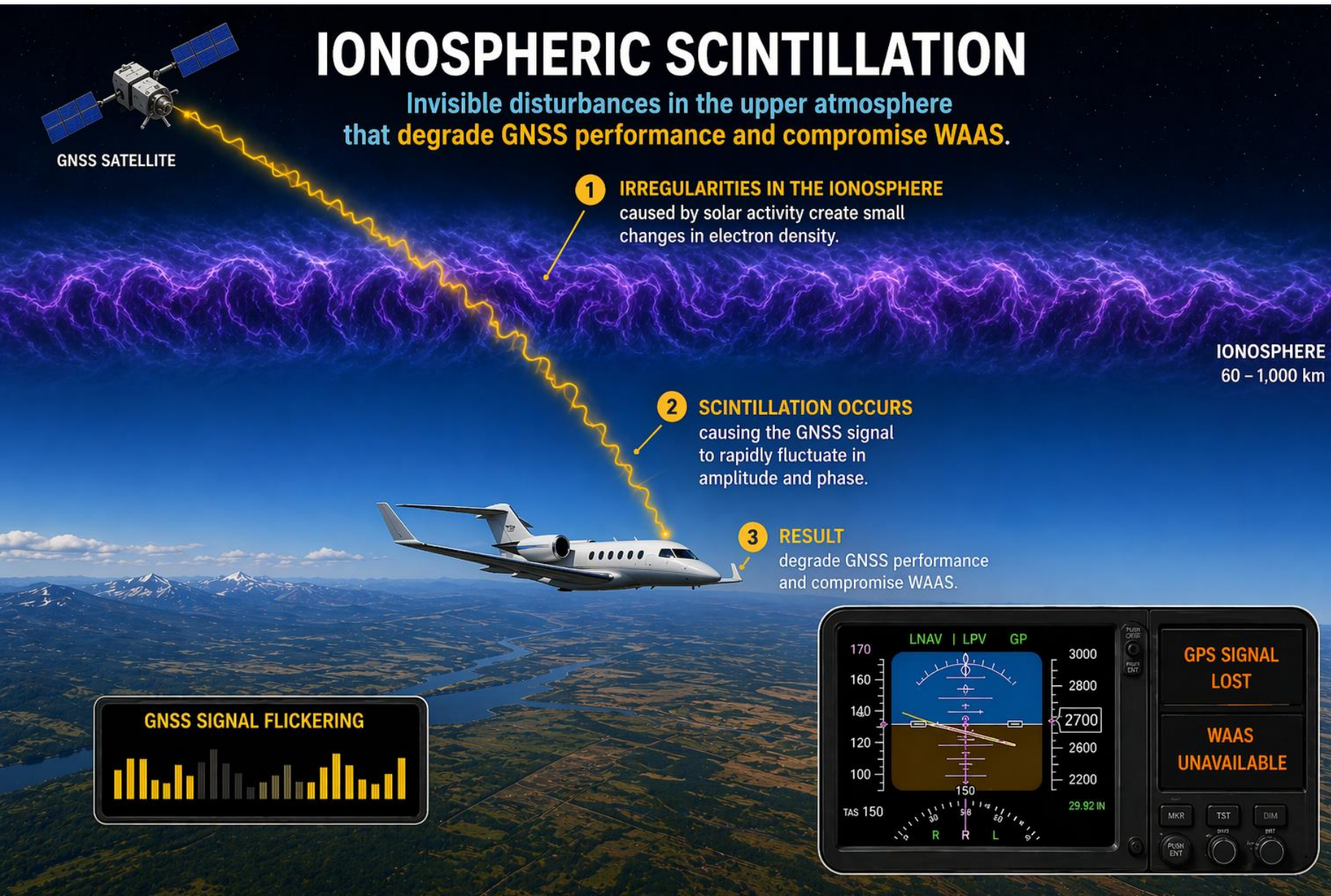
Sometimes you can't even see the coin.



Scintillation causes rapid changes in GNSS signals, making position and accuracy harder to determine.

IONOSPHERIC SCINTILLATION

Invisible disturbances in the upper atmosphere that **degrade GNSS performance and compromise WAAS.**



GNSS SATELLITE

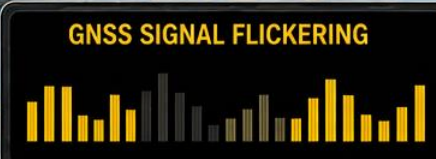
1 IRREGULARITIES IN THE IONOSPHERE
caused by solar activity create small changes in electron density.

2 SCINTILLATION OCCURS
causing the GNSS signal to rapidly fluctuate in amplitude and phase.

3 RESULT
degrade GNSS performance and compromise WAAS.

IONOSPHERE
60 – 1,000 km

GNSS SIGNAL FLICKERING



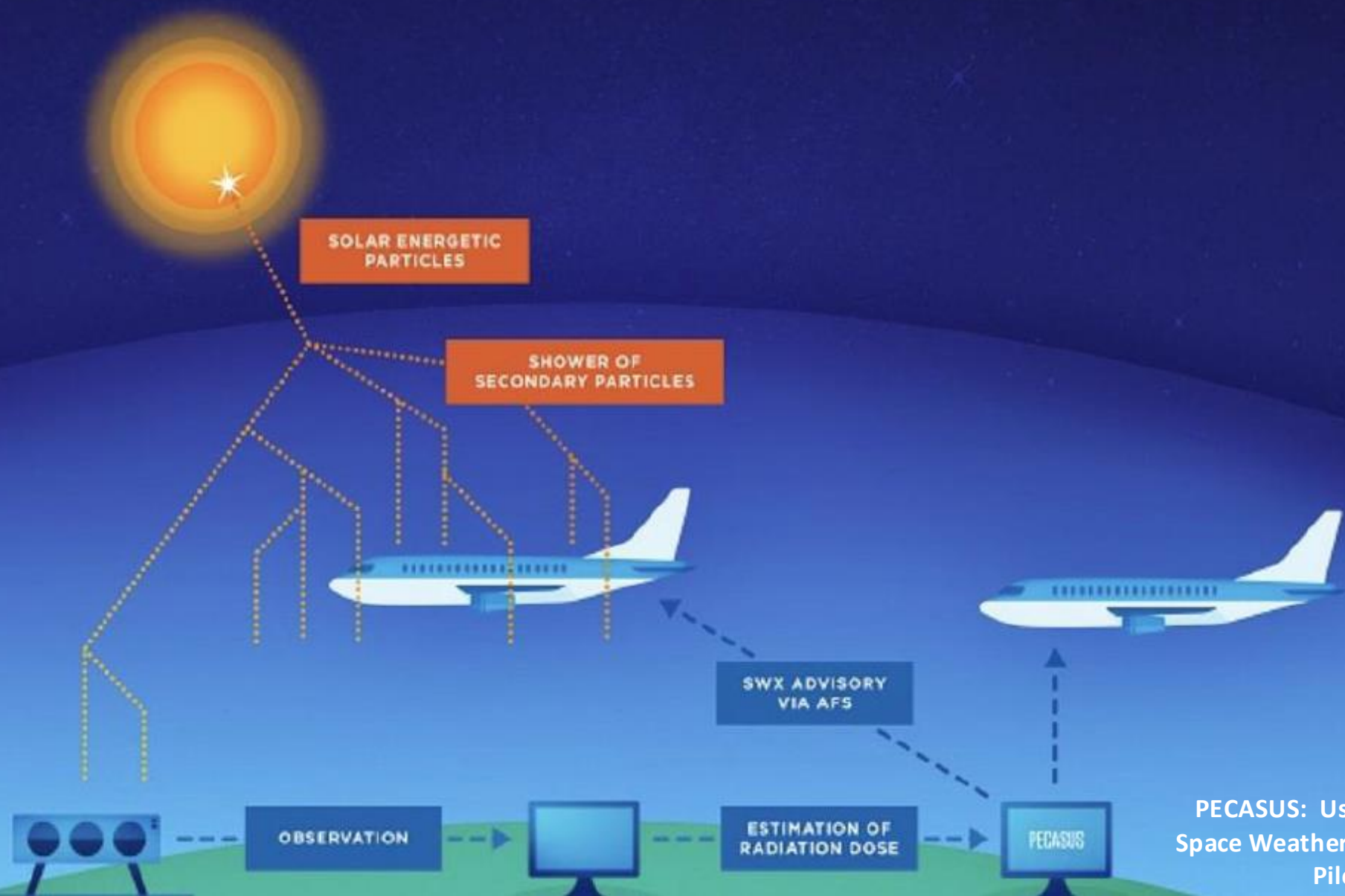
GPS SIGNAL LOST

WAAS UNAVAILABLE





SWx Impacts - Radiation Exposure



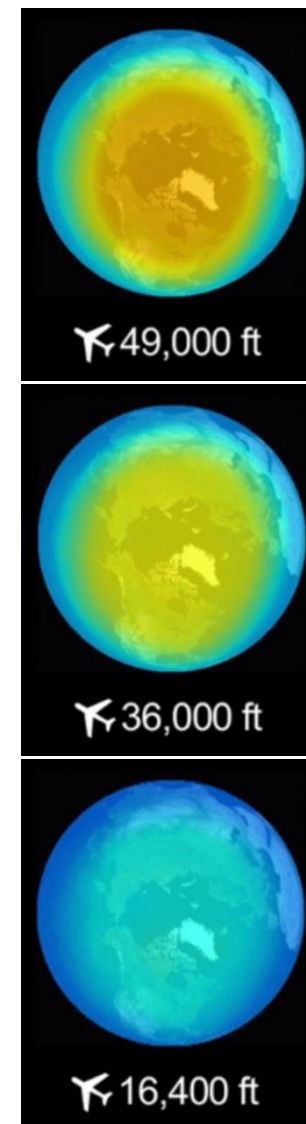
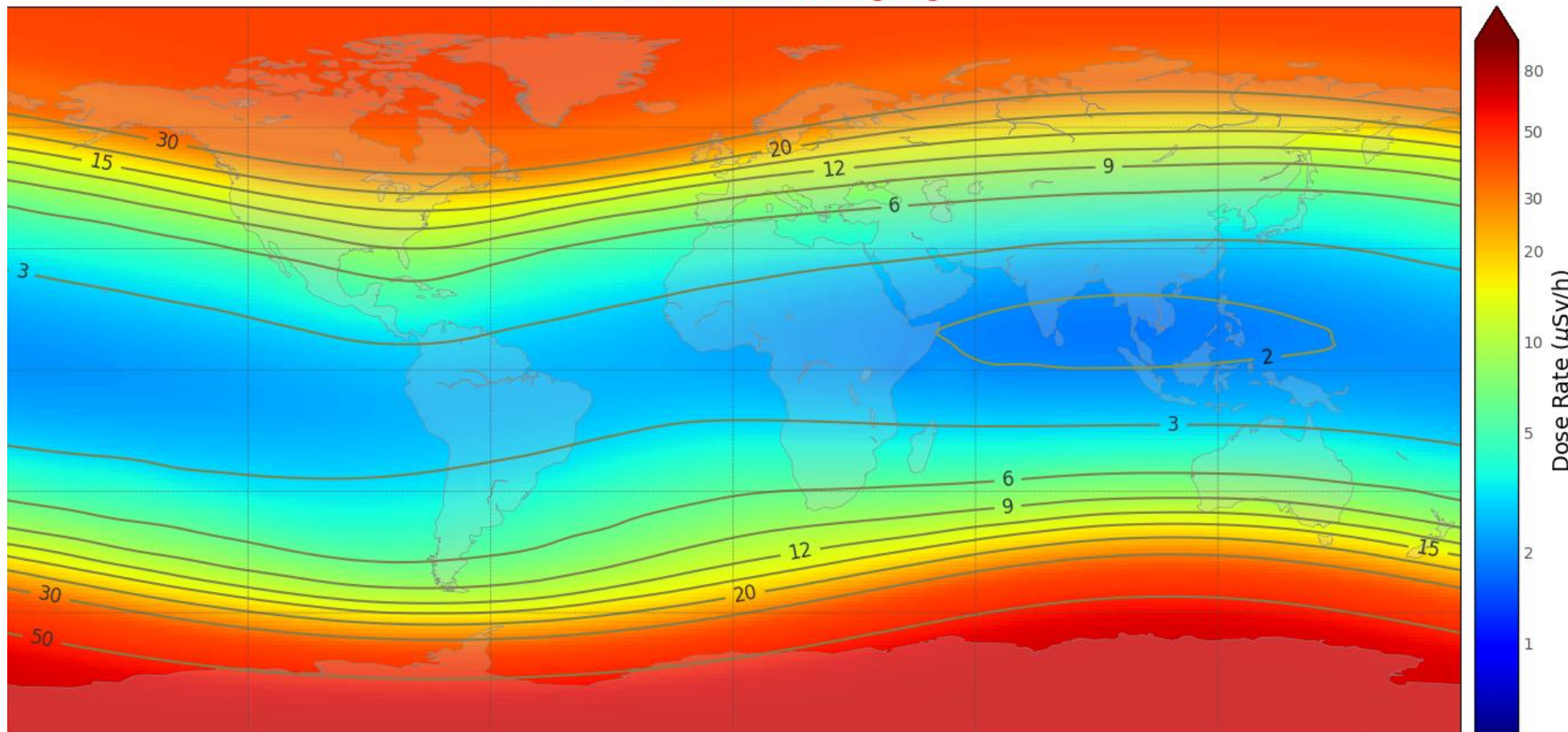


SWx Impacts - Radiation Exposure

SiGLe
 Observatoire de Paris

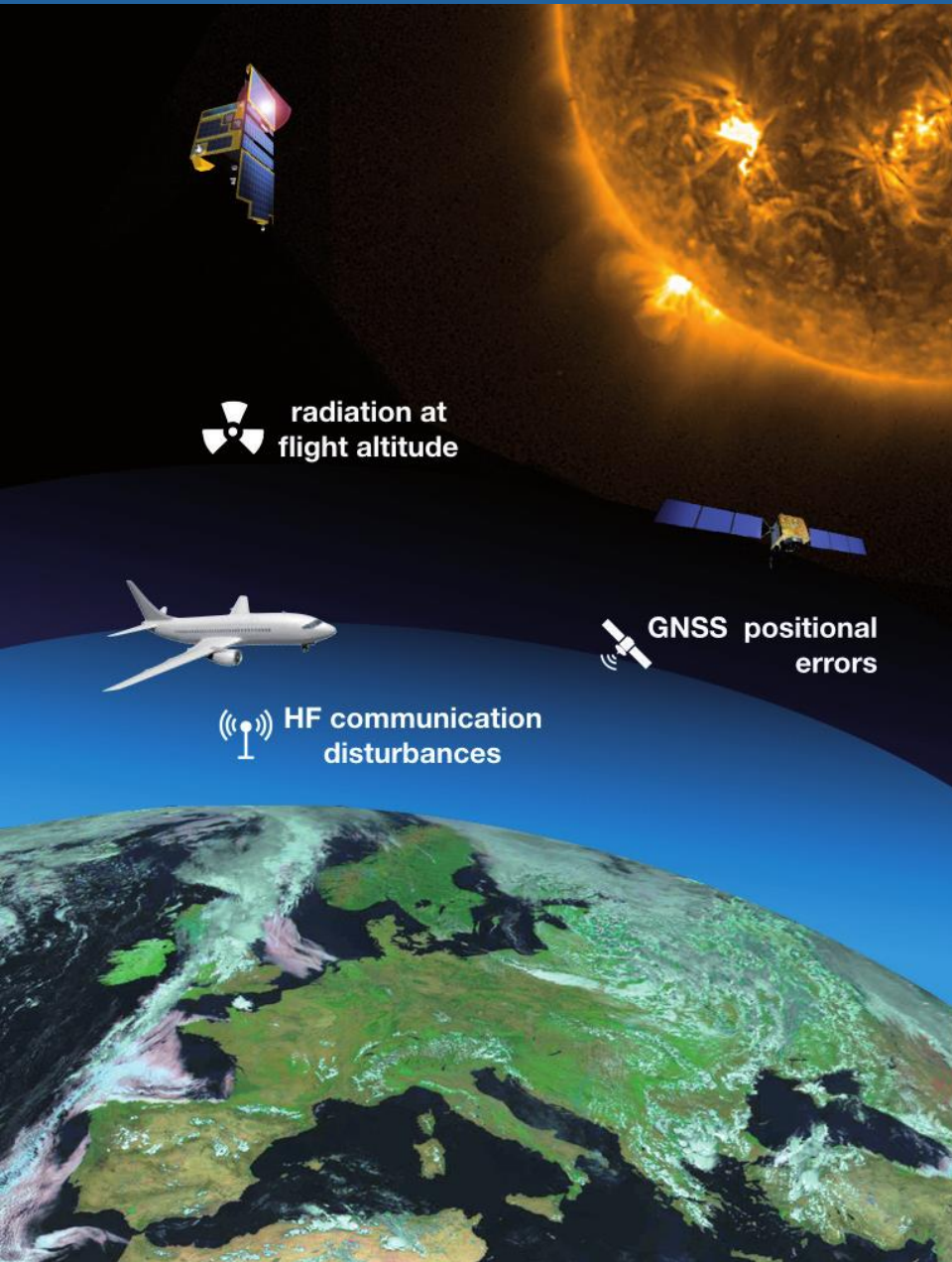
Radiation dose map at 37000 feet (11.3 km) for 2005-01-20T07:30:00 (max 68.3 $\mu\text{Sv/h}$)

A Ground Level Event is ongoing





ICAO SWx Information Service



- International Civil Aviation Organisation (ICAO) has organised a 24/7 global space weather advisory service for international aviation.
- GNSS
 - vertical total electron content (vTEC)
 - scintillations
- HF COM
 - shortwave fadeout
 - auroral absorption
 - polar cap absorption (PCA)
 - post storm depression (PSD)
- Radiation Exposure
 - human health
 - avionics



ICAO SWx Information Service

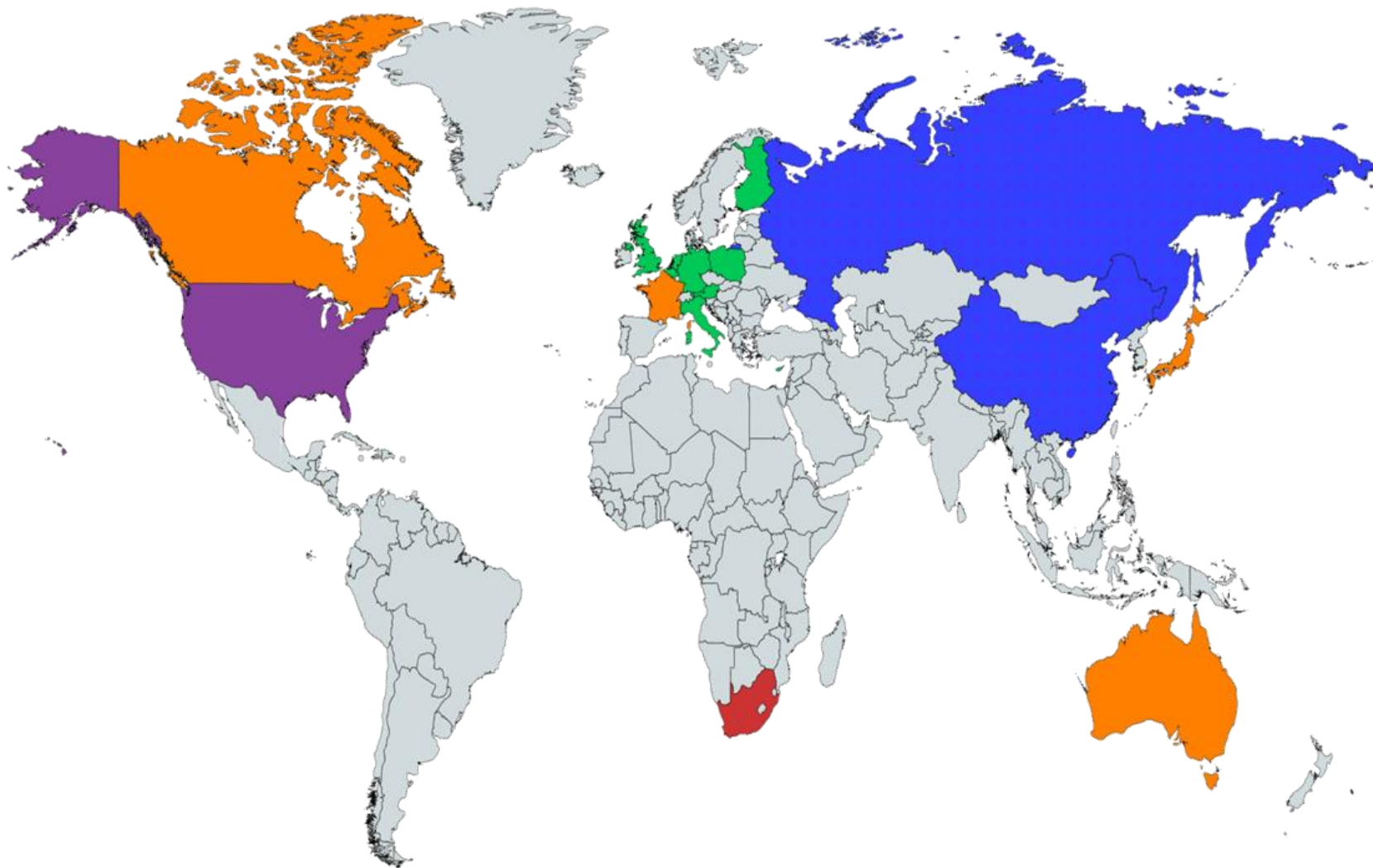


- Objective: To provide situational awareness and advise aviation users when SWx events are expected to cause a moderate or severe impact
 - Deterioration or loss of satellite navigation
 - Deterioration or loss of HF communications (HF COM)
 - Enhanced radiation exposure at specific flight levels
- Actionable information
 - Inform pre-flight planning (e.g. route selection, altitude selection, fuel loading)
 - Real-time warning of space weather events
 - In-flight route or altitude deviations
- Disseminated through ICAO's standard communication channels.
 - TAC and IWXXM formats with different WMO headers



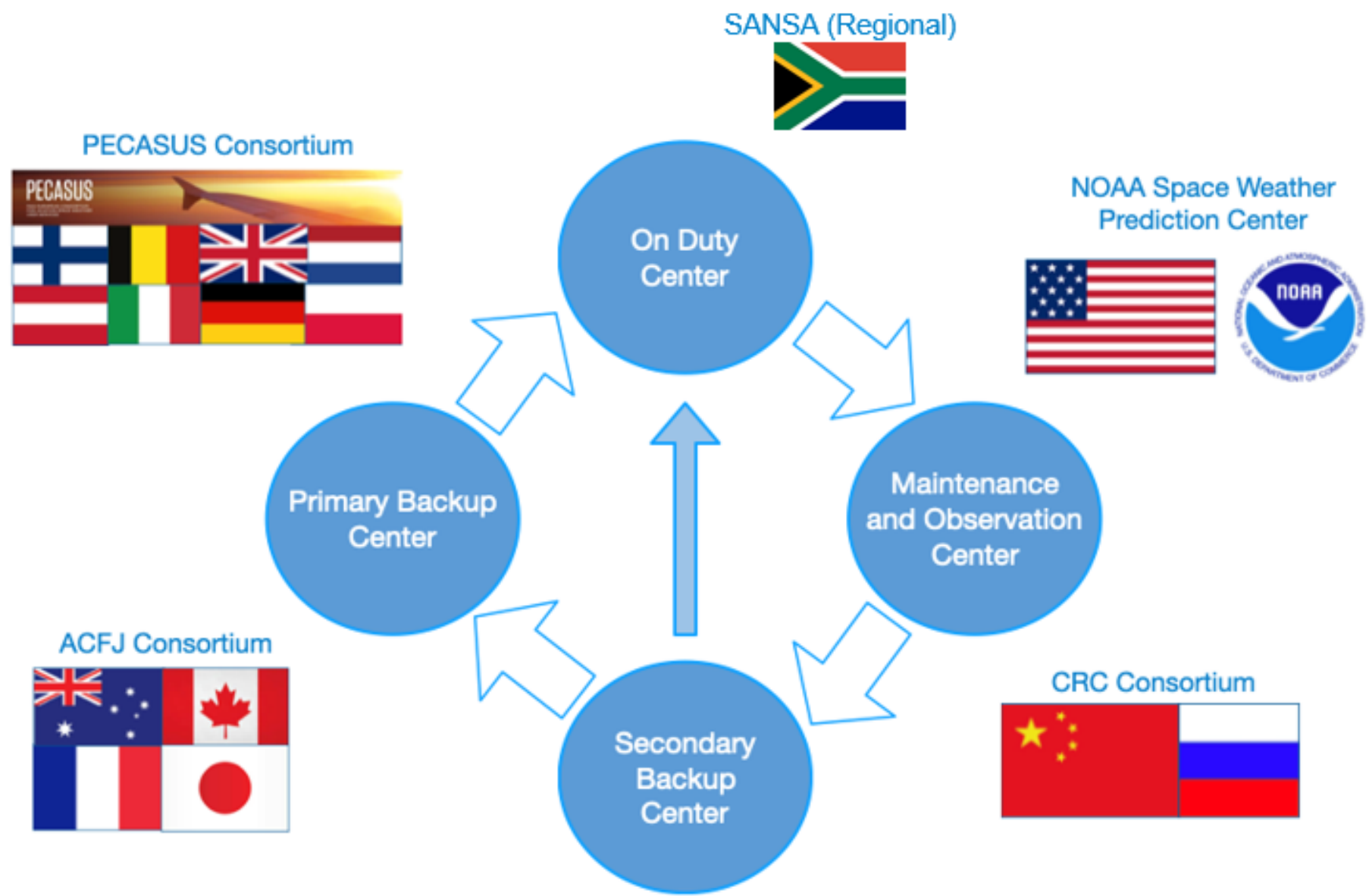
SWIS Providers

- ICAO-designated centres
 - Four global warning centres
 - **PECASUS:** Austria, Belgium, Cyprus, Finland, Germany, Italy, Netherlands, Poland, United Kingdom
 - **ACFJ:** Australia, Canada, France, Japan
 - **SWPC:** United States
 - **CRC:** China, Russia
 - One regional center
 - **South Africa**





SWIS Providers





SWx Advisory

FNXX01 LFPW 150043

SWX ADVISORY

DTG: 20240115/0043Z

issuing centre

SWXC: ACFJ

ADVISORY NR: 2024/23

type, magnitude

SWX EFFECT: GNSS MOD

latitude bands

OBS SWX: 15/0015Z EQN EQS W105 – 2000

FST SWX +6 HR: 15/0700Z NOT AVBL

FCST SWX +12 HR: 15/1300Z NOT AVBL

FCST SWX +18 HR: 15/1900Z NOT AVBL

FCST SWX +24 HR: 16/0100Z NOT AVBL

longitude extent

RMK: SWX EVENT (SCINTILLATION) INPR POSSIBLY IMPACTING GNSS PER. COULD LEAD TO DEGRADATION OF TIMING AND POSITIOINING PER. INTST GENERALLY STRONGER ON THE NIGHTSIDE.

NXT ADVISORY: 20240115/0700Z=

remarks

observed
conditions

forecast
conditions



SWx Advisory

FNXX02 EFKL 251127

SWX ADVISORY

DTG: 20251127/1210Z

SWXC: DONLON

ADVISORY NR: 2025/313

NR RPLC: 2025/311 2025/312

SWX EFFECT: GNSS

OBS SWX: 27/1200Z SEV N80E000-N80E090-N60E090-N60E000-N80E000 MOD S60E000-S60E090-S80E090-S80E000-S60E000

FCST SWX +6 HR: 27/1800Z MOD N80E000-N80E090-N60E090-N60E000-N80E000 SEV S60E000-S60E090-S80E090-S80E000-S60E000

FCST SWX +12 HR: 28/0000Z NO SWX EXP

FCST SWX +18 HR: 28/0600Z NO SWX EXP

FCST SWX +24 HR: 28/1200Z NO SWX EXP

RMK: THIS IS A SAMPLE GNSS SPACE WEATHER ADVISORY BASED ON POLYGONS. PLEASE DISREGARD

NXT ADVISORY: WILL BE ISSUED BY 20251127/1800Z=

3 possible entries

affected region

NO SWX EXP

NOT AVBL

issuing centre

type

polygons (with magnitude)

remarks

observed
conditions

forecast
conditions



SWx – region impacted

- Latitude bands

- 30° resolution in latitude
- 5° resolution in longitude

HNH 60° to 90°

MNH 30° to 60°

EQN 00° to 30°

HSH -60° to -90°

MSH -30° to -60°

EQS -00° to -30°

- DAYLIGHT SIDE (extent of the planet in daylight)

- Polygon

- multiple vertices
- 5° x 5° resolution in latitude and longitude for the corner points

- For radiation

- MOD issued for FL250 to FL460
- SEV issued above FL250



SWx – region impacted



HNH

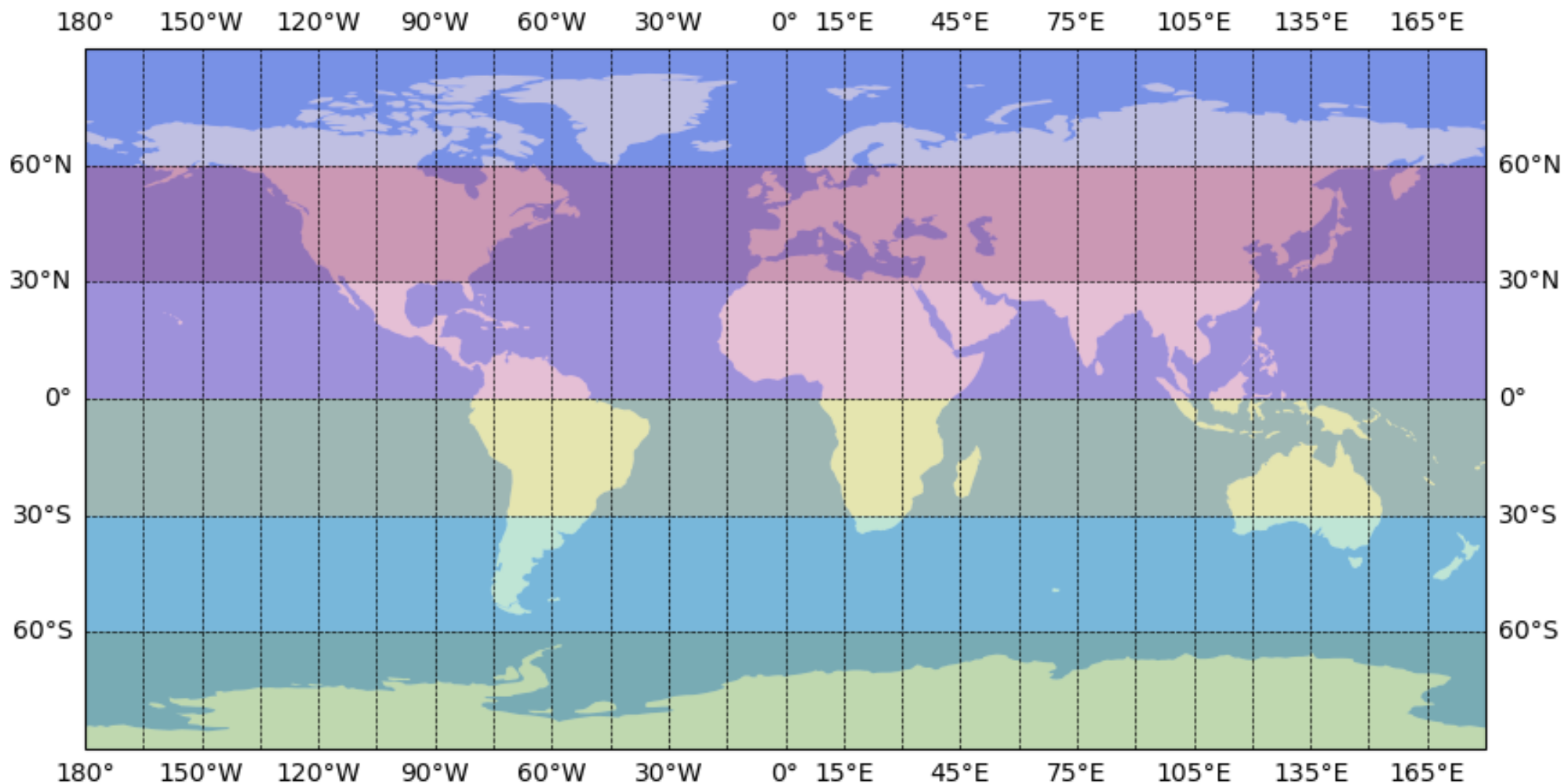
MNH

EQN

EQS

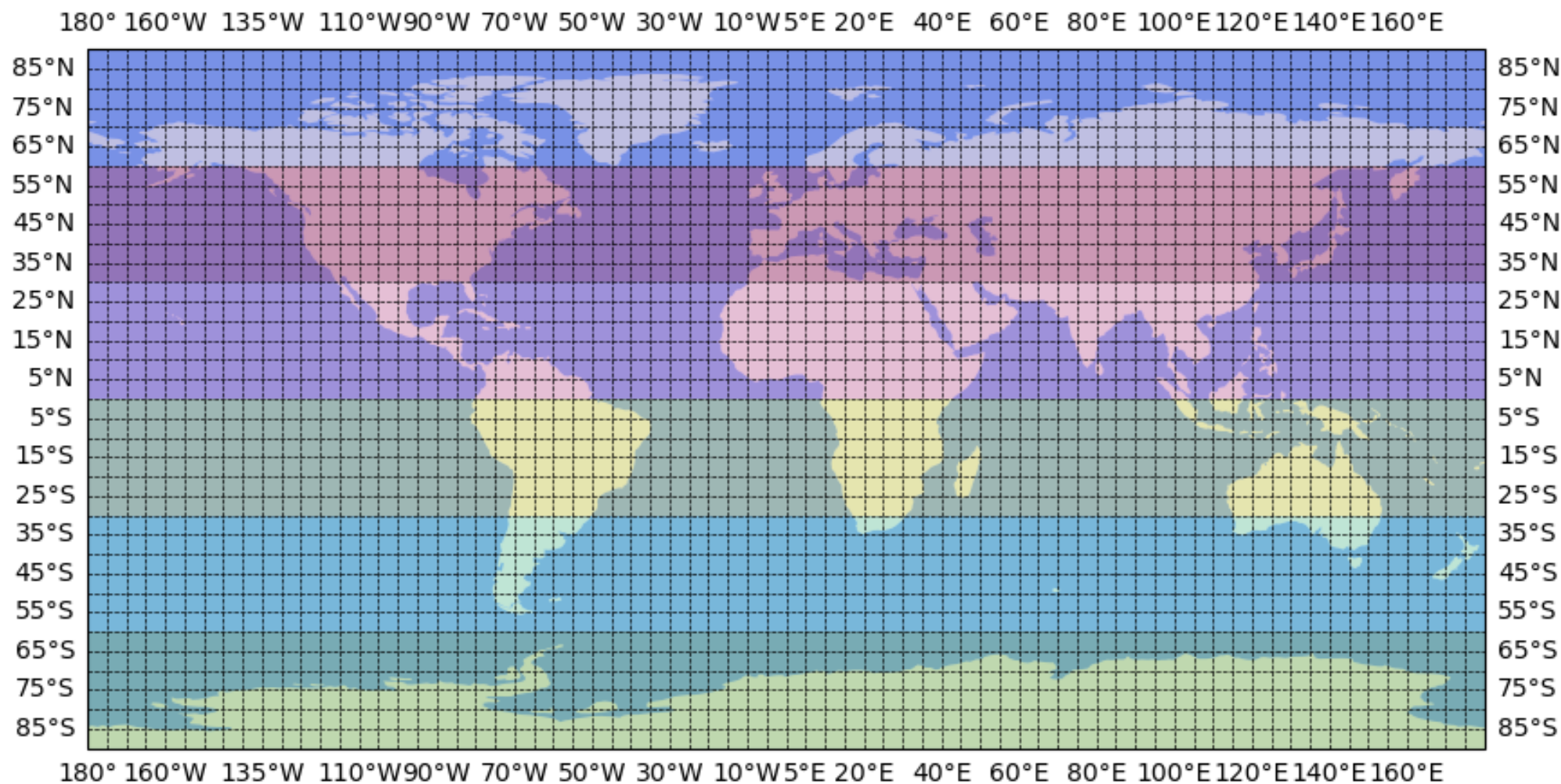
MSH

HSH





SWx – region impacted

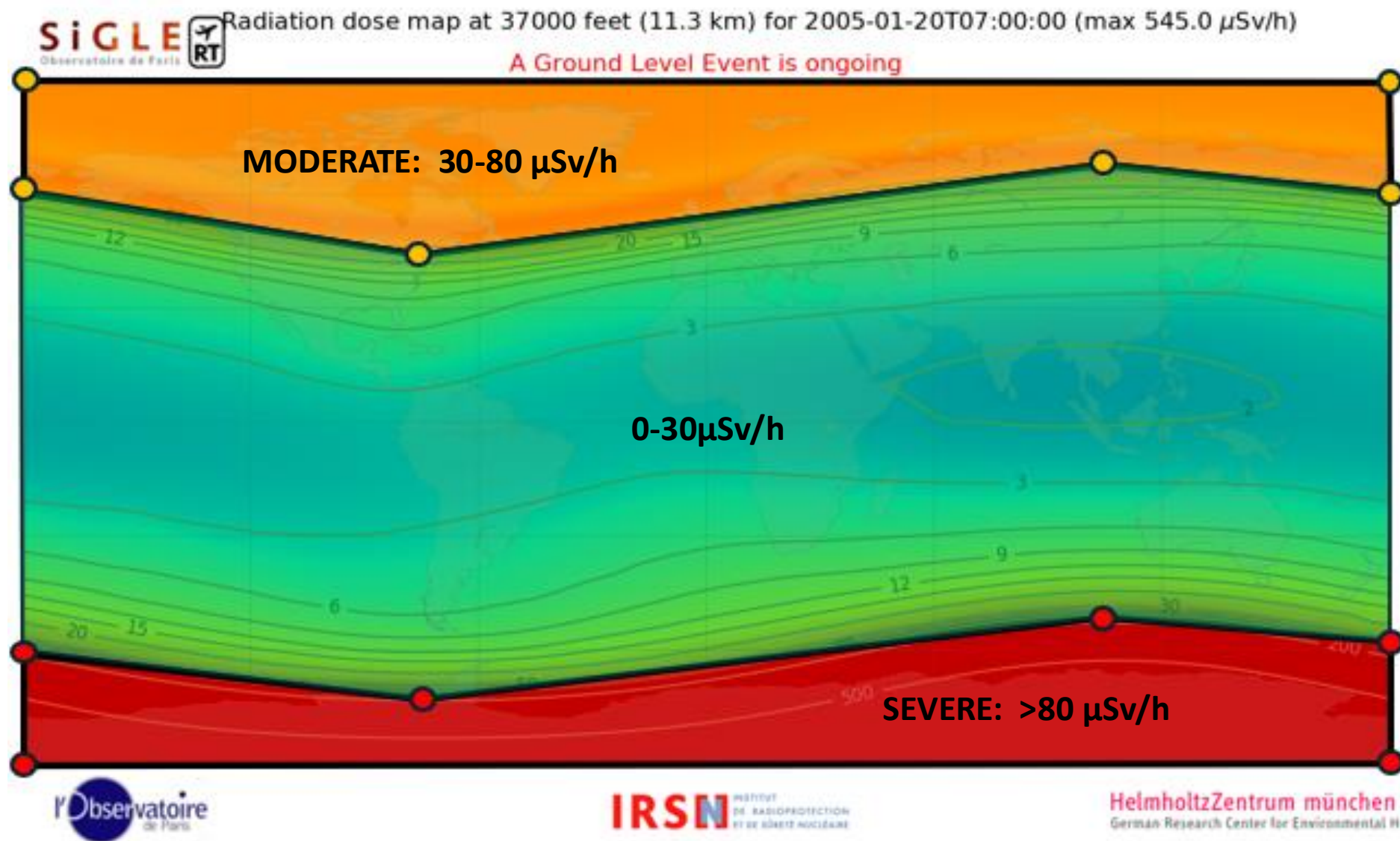


5° resolution



SWx – region impacted

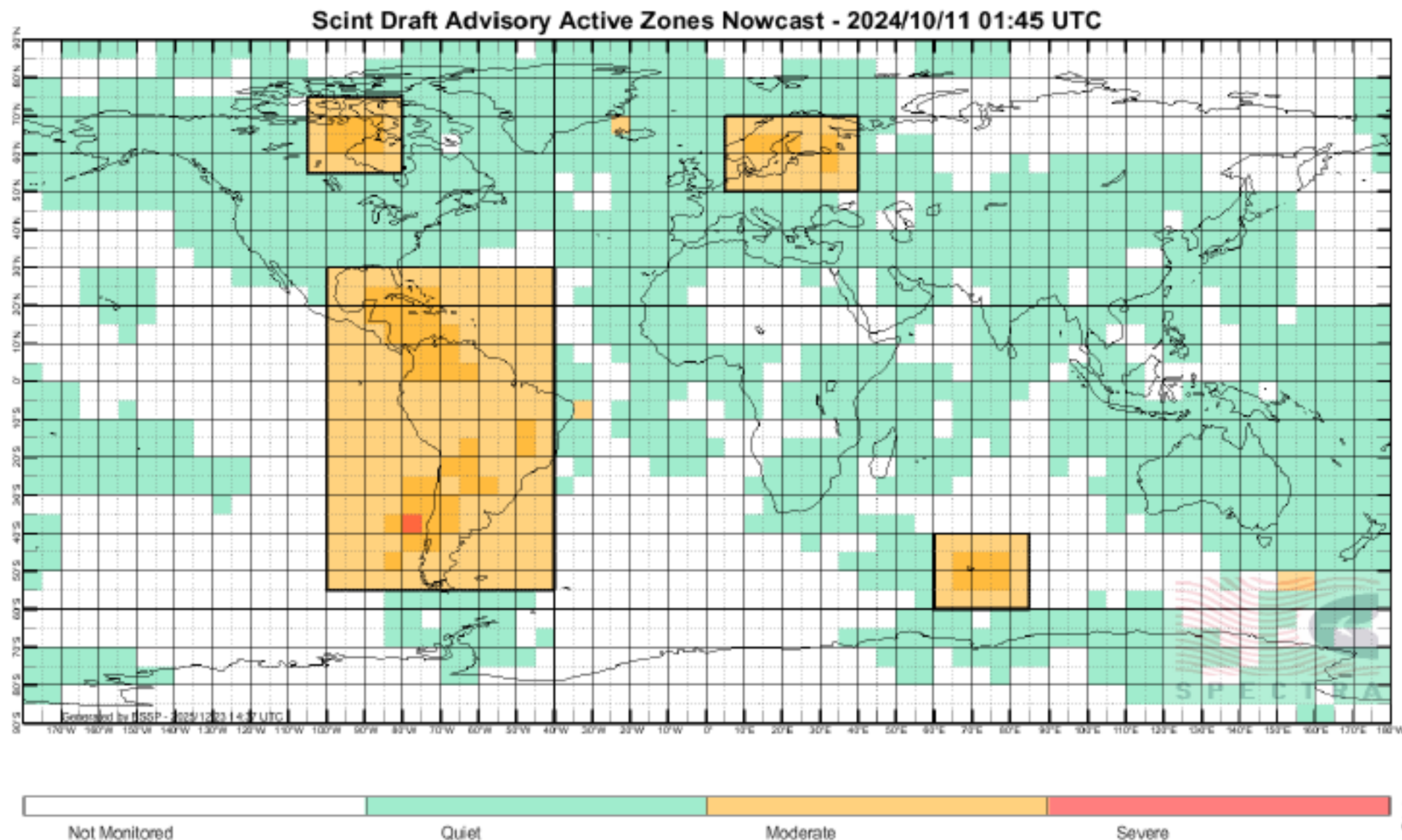
- Example of a 7-point polygon (6 vertices)
- Radiation exposure (with altitude)
- HF COM (polar cap absorption)





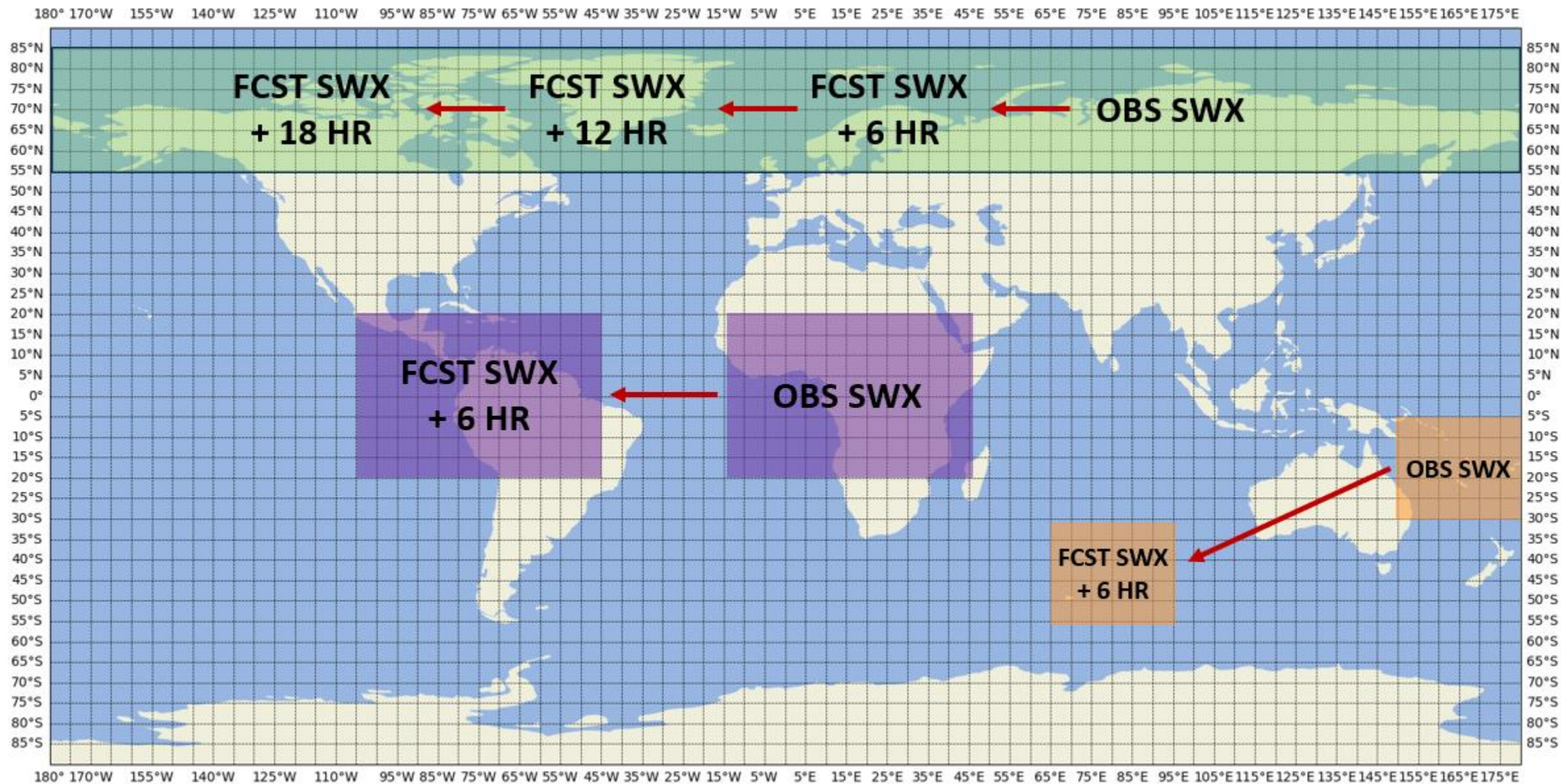
SWx – region impacted

- Example of multiple polygons
- GNSS
- HF COM (post storm depression)





SWx - forecast





Testing and start of the service

GNSS		4		4		2	2	2	2	4	2
HF			4		4		3	2	2	2	2
RADIATION											
			Oct			Nov			Dec		Jan 2020
	2019										

GNSS 2019 1

SWX ADVISORY

STATUS: **TEST**

DTG: 20190924/1303Z

SWXC: PECASUS

ADVISORY NR: 2019/1

SWX EFFECT: GNSS MOD

OBS SWX: 24/1200Z HNH HSH W180-E180

FCST SWX +6 HR: 24/1800Z NO SWX EXP

FCST SWX +12 HR: 25/0000Z NO SWX EXP

FCST SWX +18 HR: 25/0600Z NO SWX EXP

FCST SWX +24 HR: 25/1200Z NO SWX EXP

RMK: TEST TEST TEST. THIS IS A TEST SPACE WEATHER ADVISORY,
PLEASE DISREGARD.

NXT ADVISORY: NO FURTHER ADVISORIES

24 Sept 2019

HF 2019 1

SWX ADVISORY

STATUS: **TEST**

DTG: 20191001/1210Z

SWXC: PECASUS

ADVISORY NR: 2019/1

SWX EFFECT: HF COM SEV

OBS SWX: 01/1200Z DAYLIGHT SIDE

FCST SWX + 6 HR: 01/1800Z NO SWX EXP

FCST SWX + 12 HR: 02/0000Z NO SWX EXP

FCST SWX + 18 HR: 02/0600Z NO SWX EXP

FCST SWX + 24 HR: 02/1200Z NO SWX EXP

RMK: TEST TEST TEST. THIS IS A TEST SPACE WEATHER
ADVISORY, PLEASE DISREGARD.

NXT ADVISORY: NO FURTHER ADVISORIES

01 Oct 2019



Testing and start of the service

GNSS		4		4		2	2	2	2	4	2
HF			4		4	3	2	2	2	2	2
RADIATION											
	2019									Jan	2020

GNSS 2019 1

SWX ADVISORY

STATUS: **TEST**

DTG: 20190924/1303Z

SWXC: PECASUS

ADVISORY NR: 2019/1

SWX EFFECT: GNSS MOD

OBS SWX: 24/1200Z HNH HSH W180-E180

FCST SWX +6 HR: 24/1800Z NO SWX EXP

FCST SWX +12 HR: 25/0000Z NO SWX EXP

FCST SWX +18 HR: 25/0600Z NO SWX EXP

FCST SWX +24 HR: 25/1200Z NO SWX EXP

RMK: TEST TEST TEST. THIS IS A TEST SPACE WEATHER ADVISORY, PLEASE DISREGARD.

NXT ADVISORY: NO FURTHER ADVISORIES

RAD 2019 1

SWX ADVISORY

STATUS: **TEST**

DTG: 20191029/1100Z

SWXC: PECASUS

ADVISORY NR: 2019/1

SWX EFFECT: RADIATION MOD

OBS SWX: 29/1200Z HNH HSH W180 - E180

FCST SWX + 6 HR: 29/1800Z NO SWX EXP

FCST SWX + 12 HR: 30/0000Z NOT AVBL

FCST SWX + 18 HR: 30/0600Z NOT AVBL

FCST SWX + 24 HR: 30/1200Z NOT AVBL

RMK: TEST TEST TEST. THIS IS A TEST SPACE WEATHER

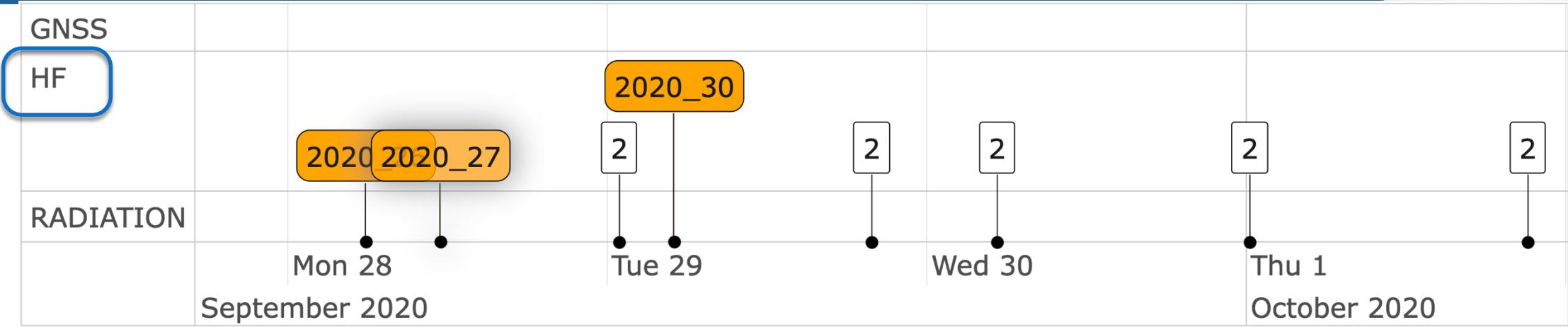
ADVISORY, PLEASE DISREGARD.

NXT ADVISORY: NO FURTHER ADVISORIES

29 Oct 2019

RMK: TEST TEST TEST. THIS IS A TEST SPACE WEATHER ADVISORY, PLEASE DISREGARD.

NXT ADVISORY: NO FURTHER ADVISORIES



HF 2020 26

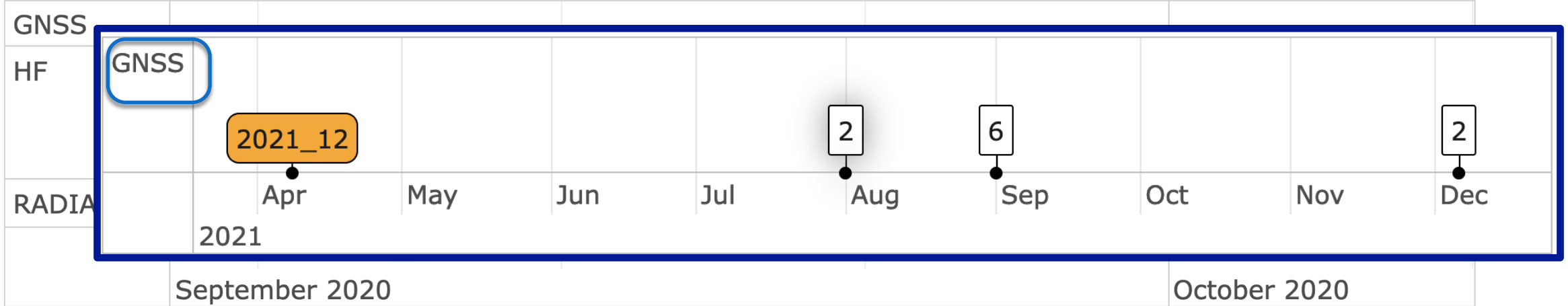
0000071901
FNXX01 YMMC 280555
SWX ADVISORY
DTG: 20200928/0555Z
SWXC: ACFJ
ADVISORY NR: 2020/26
SWX EFFECT: HF COM MOD
OBS SWX: 28/0532Z HNH MNH E000 - E060
FCST SWX +6 HR: 28/1200Z NO SWX EXP
FCST SWX +12 HR: 28/1800Z NO SWX EXP
FCST SWX +18 HR: 29/0000Z NO SWX EXP
FCST SWX +24 HR: 29/0600Z NO SWX EXP
RMK: SPACE WEATHER EVENT (MAXIMUM USABLE FREQUENCY DEPRESSION) IN PROGRESS IMPACTING HIGHER HF COM FREQUENCY BAND. LOWER FREQUENCIES MAY BE LESS IMPACTED. ISOLATED AREAS OF SEV HF COM DEGRADATION POSSIBLE.
NXT ADVISORY: WILL BE ISSUED BY 20200928/1140Z=

28 Sept 2020

GNSS 2021 37

0000060501
FNXX01 EFKL 312134
SWX ADVISORY
DTG: 20210731/2132Z
SWXC: PECASUS
ADVISORY NR: 2021/37
SWX EFFECT: GNSS SEV
OBS SWX: 31/2025Z HNH W005 - E035
FCST SWX +6 HR: 01/0300Z NOT AVBL
FCST SWX +12 HR: 01/0900Z NOT AVBL
FCST SWX +18 HR: 01/1500Z NOT AVBL
FCST SWX +24 HR: 01/2100Z NOT AVBL
RMK: SPACE WEATHER EVENT (IONOSPHERIC DISTURBANCE) IN PROGRESS. IMPACT ON GNSS PERFORMANCE POSSIBLY LEADING TO LOSS OF GNSS SIGNALS AND/OR DEGRADATION OF TIMING AND POSITIONING PERFORMANCE.
NXT ADVISORY: WILL BE ISSUED BY 20210801/0252Z=

31 July 2021



HF 2020 26

0000071901
 FNXX01 YMMC 280555
 SWX ADVISORY
 DTG: 20200928/0555Z
 SWXC: **ACFJ**
 ADVISORY NR: 2020/26
 SWX EFFECT: HF COM MOD
 OBS SWX: 28/0532Z HNH MNH E000 - E060
 FCST SWX +6 HR: 28/1200Z NO SWX EXP
 FCST SWX +12 HR: 28/1800Z NO SWX EXP
 FCST SWX +18 HR: 29/0000Z NO SWX EXP
 FCST SWX +24 HR: 29/0600Z NO SWX EXP
 RMK: SPACE WEATHER EVENT (MAXIMUM USABLE FREQUENCY DEPRESSION) IN PROGRESS IMPACTING HIGHER HF COM FREQUENCY BAND. LOWER FREQUENCIES MAY BE LESS IMPACTED. ISOLATED AREAS OF SEV HF COM DEGRADATION POSSIBLE.
 NXT ADVISORY: WILL BE ISSUED BY 20200928/1140Z=

28 Sept 2020

GNSS 2021 37

0000060501
 FNXX01 EFKL 312134
 SWX ADVISORY
 DTG: 20210731/2132Z
 SWXC: **PECASUS**
 ADVISORY NR: 2021/37
 SWX EFFECT: GNSS SEV
 OBS SWX: 31/2025Z HNH W005 - E035
 FCST SWX +6 HR: 01/0300Z NOT AVBL
 FCST SWX +12 HR: 01/0900Z NOT AVBL
 FCST SWX +18 HR: 01/1500Z NOT AVBL
 FCST SWX +24 HR: 01/2100Z NOT AVBL
 RMK: SPACE WEATHER EVENT (IONOSPHERIC DISTURBANCE) IN PROGRESS. IMPACT ON GNSS PERFORMANCE POSSIBLY LEADING TO LOSS OF GNSS SIGNALS AND/OR DEGRADATION OF TIMING AND POSITIONING PERFORMANCE.
 NXT ADVISORY: WILL BE ISSUED BY 20210801/0252Z=

31 July 2021

GNSS	50	81	350	715	451	108
HF COM	45	97	230	248	304	159
RADIATION	45	14	14	12	8	6
	2021	2022	2023	2024	2025	2026

NB: data includes official + TEST advisories; last checked June 2 2026

GNSS	May 2024			12	5	3	2			
HF	4		3	10	5	6	6	6		4
RADIATION										
	May 2024	Fri 10	Sat 11	Sun 12	Mon 13	Tue 14				

GNSS: 22 advisories (scintillation, VTEC)

HF-COM: 33 advisories (geo storms (AA + PSD), X-class flaring (SWF), high proton flux (PCA))



Summary

- Space weather directly affects aviation, influencing HF communications, GNSS performance, and radiation exposure at flight levels.
- ICAO SWx Information service provides situational awareness and advises aviation users when SWx events are expected to cause moderate or severe impacts.
- Timely detection, forecasting, and clear thresholds support flight planning, dispatch decisions, and ICAO Annex 3 compliance.

