METEOROLOGY PANEL

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

Case Study – May 2024 Event Part 2 – SWX Impacts

User Feedback Workshop

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Case Study – May 2024 Event

- Largest geomagnetic storm in 20 years (Since Halloween 2003 event)
- 1 in 12.5 years – intensity*
- 1 in 41 years – duration*
- Weak/moderate Solar Energetic Proton (SEP) event
- Benign compared with reasonable worst-case scenario

* Source: Elvidge & Themens, 2025; https://doi.org/10.1029/2024SW004113

May 8-9 HF COM Impacts from X-Class Flares

Official MOD HF-COM Advisories issued for each X-class flare by ACFJ

2024/87 HF COM (8.5.2024 01:48,)
2024/88 HF COM (8.5.2024 01:54)

2024/89 HF COM (8.5.2024 05:16)
2024/90 HF COM (8.5.2024 05:52)

2024/91 HF COM (8.5.2024 21:46)
2024/92 HF COM (8.5.2024 21:55)

2024/93 HF COM (9.5.2024 09:06)
2024/94 HF COM (9.5.2024 10:06)

2024/95 HF COM (9.5.2024 17:44)
2024/96 HF COM (9.5.2024 18:03)

2024/93 HF COM (9.5.2024 09:06, YMMC)

Message

STATUS	
DTG	20240509/0906Z
SWXC	ACFJ
ADVISORY NR.	2024/93
SWX Effect	HF COM MOD
OBS SWX	09/0900Z DAYLIGHT SIDE
FCST SWX + 6 HR	09/1500Z NOT AVBL
FCST SWX + 12 HR	09/2100Z NOT AVBL
FCST SWX + 18 HR	10/0300Z NOT AVBL
FCST SWX + 24 HR	10/0900Z NOT AVBL
RMK	SWX EVENT (SOLAR FLARE) INPR IMPACTING LOWER HF COM FREQ BAND ON THE DAYLIGHT SIDE. FURTHER PERIODIC LOSS OF HF COM ON THE DAYSIDE EXPECTED. HIGHER FREQ MAY BE LESS IMPACTED.
NXT ADVISORY	WILL BE ISSUED BY 20240509/1505Z=

Most of the X-class flares were while Canada was on the nightside, so minimal shortwave fadeout reported
Shortwave band (HF) disrupted in Japan due to short-wave fadeout

Sources: ROB/SIDC, NICT

Questions

- Did you notice HF COM impacts (shortwave fadeouts) during the short-lived daytime X-class flares?
- Were you aware of the potential for CMEs, solar protons, and geomagnetic storms that could impact HF COM and GNSS?
- Would you take any pre-emptive actions based on a forecasted CME arrival?
- If so, how much information would you want?

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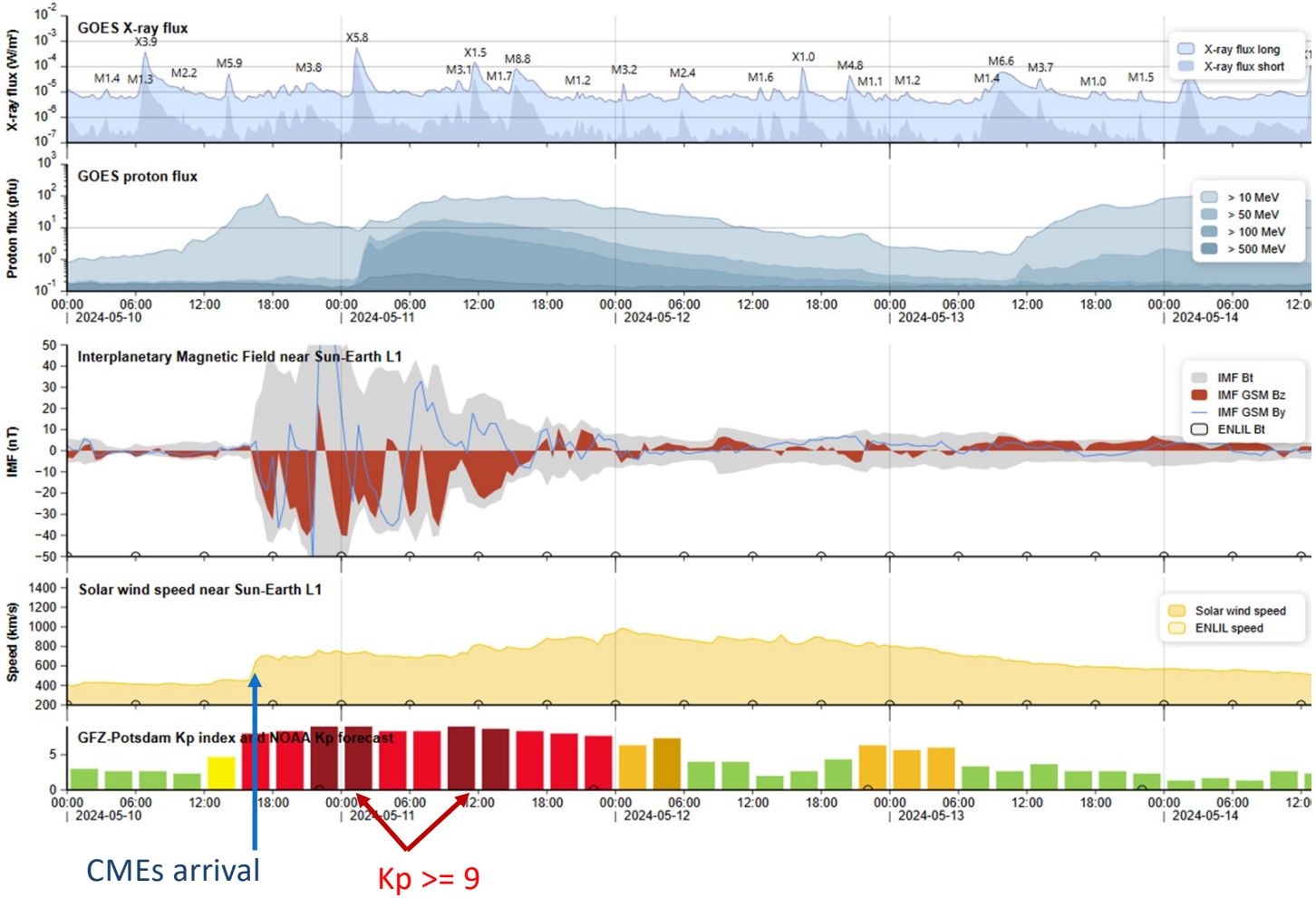
May 10-12: CMEs, solar protons, geomagnetic storm

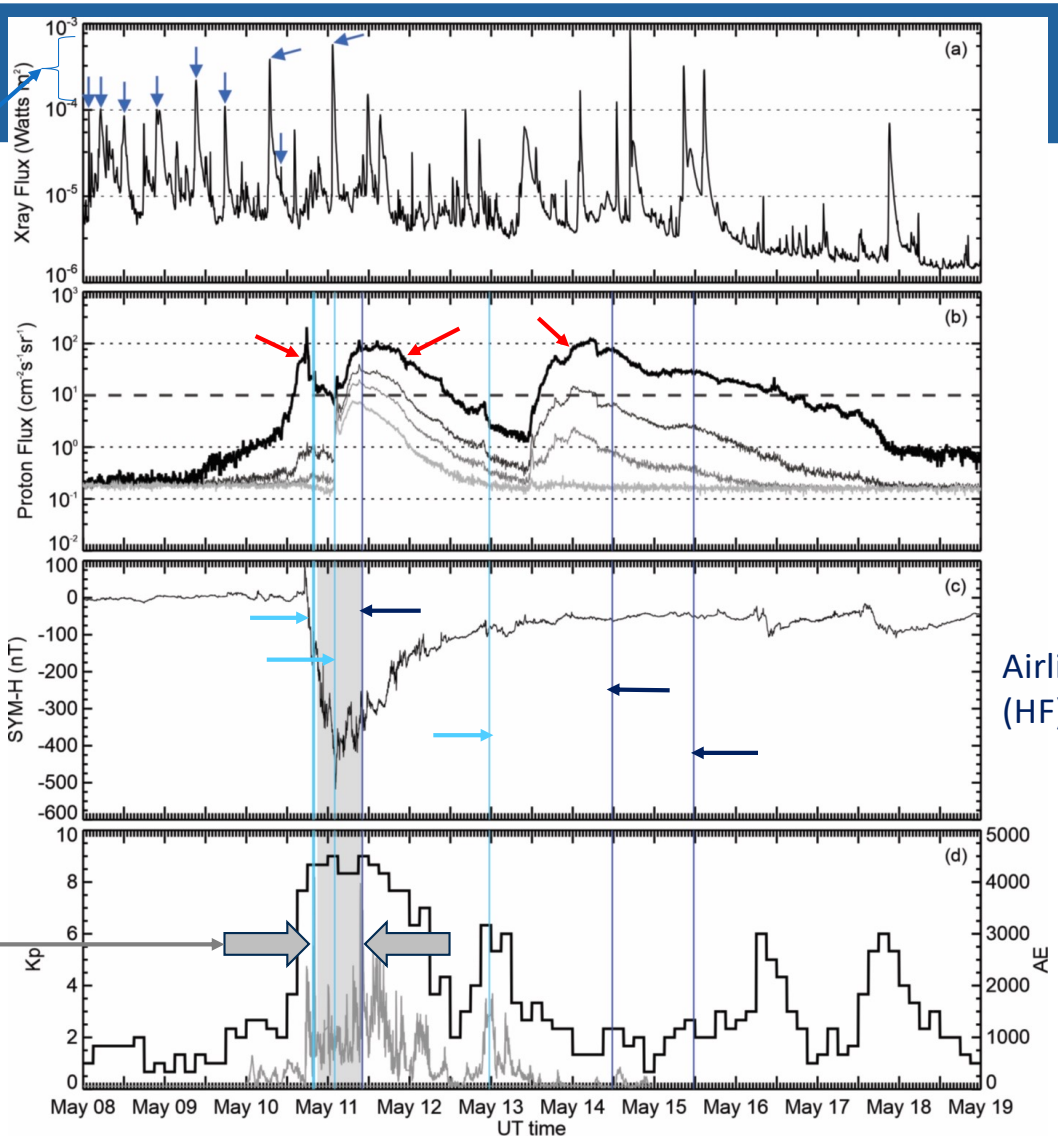


Flares associated with potentially geoeffective CMEs

Solar Proton Enhancements

Airline reports GNSS degradation

WAAS unavailable



Airline reports (HF) COMMS issues

Note: Missing AE data after May 15

HF COMM and GNSS Impacts

May 10-12: Generally disturbed Ionosphere and Geomagnetic field conditions.

HF COM advisories issued due to:

- Post Storm Depression (DEP)
  - MUF depression
- Auroral Absorption (AA)
  - Kp > 8, 9 – Mostly nighttime
- Polar Cap Absorption (PCA)
  - Proton flux increase in polar regions – Mostly daytime
- Short Wave Fadeout (SWF)
  - X class flares – Daylight)

GNSS advisories issued due to:

- Total Electron Content (TEC)
- Scintillation (Phase or Amplitude)

Impacts to aviation reported

Notes

- Japan: reports temporary disruptions in shortwave comms, but no flight suspensions (source: NICT).
- Australia: flights re-routed where HF expected to be impacted. Flights had to seek other comms means. Trans-Tasman HF COMs interrupted but operations continued safely (source: BOM).
- Iceland HF radio circuits impacted May 10-15 (source: SIDC).
- Also intermittent HF impacts reported in New Zealand, Antarctica, China, Canada

Polar Cap and Auroral Absorption (PAA) includes AA and PCA

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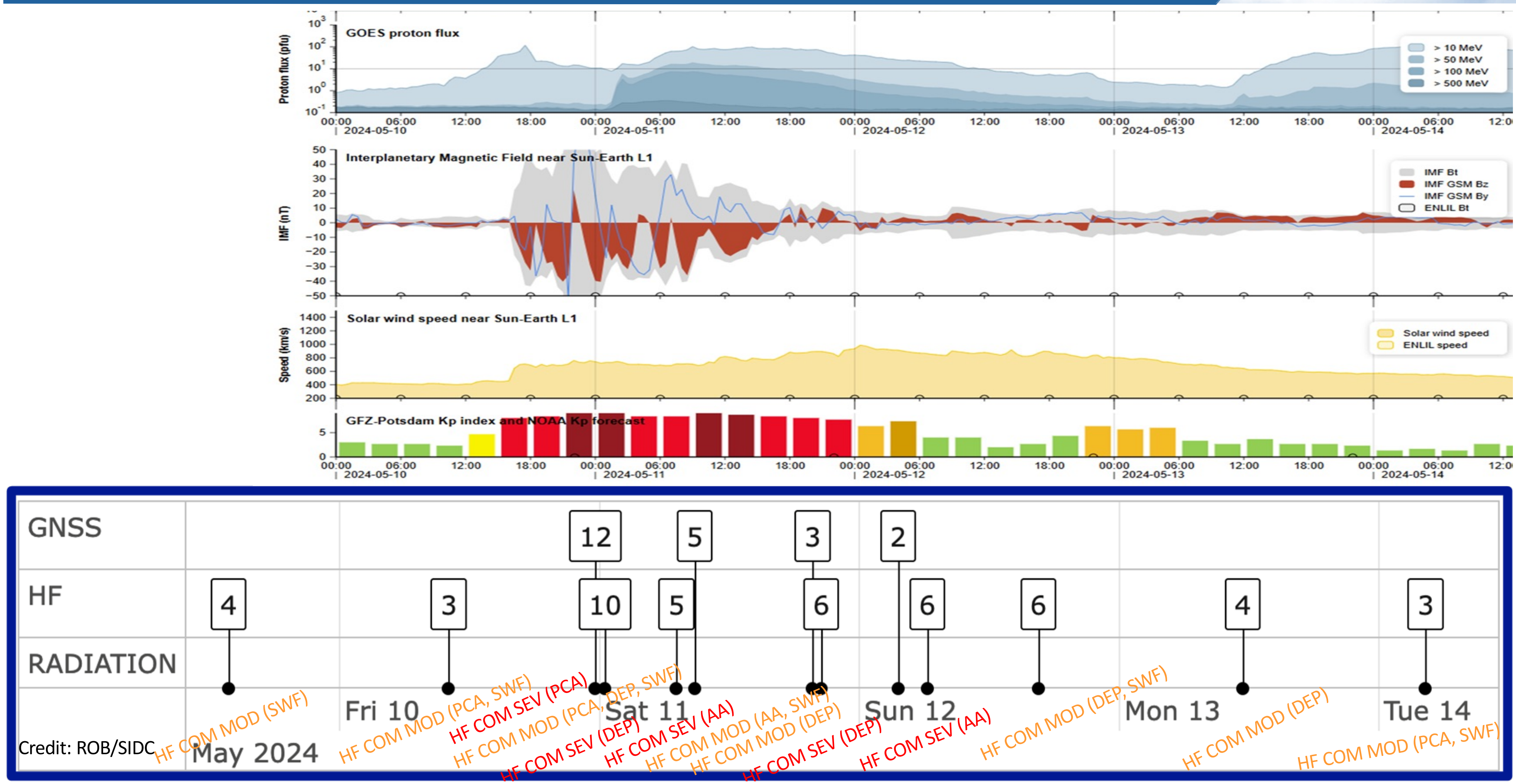
May 10-14: ICAO SWX advisories issued

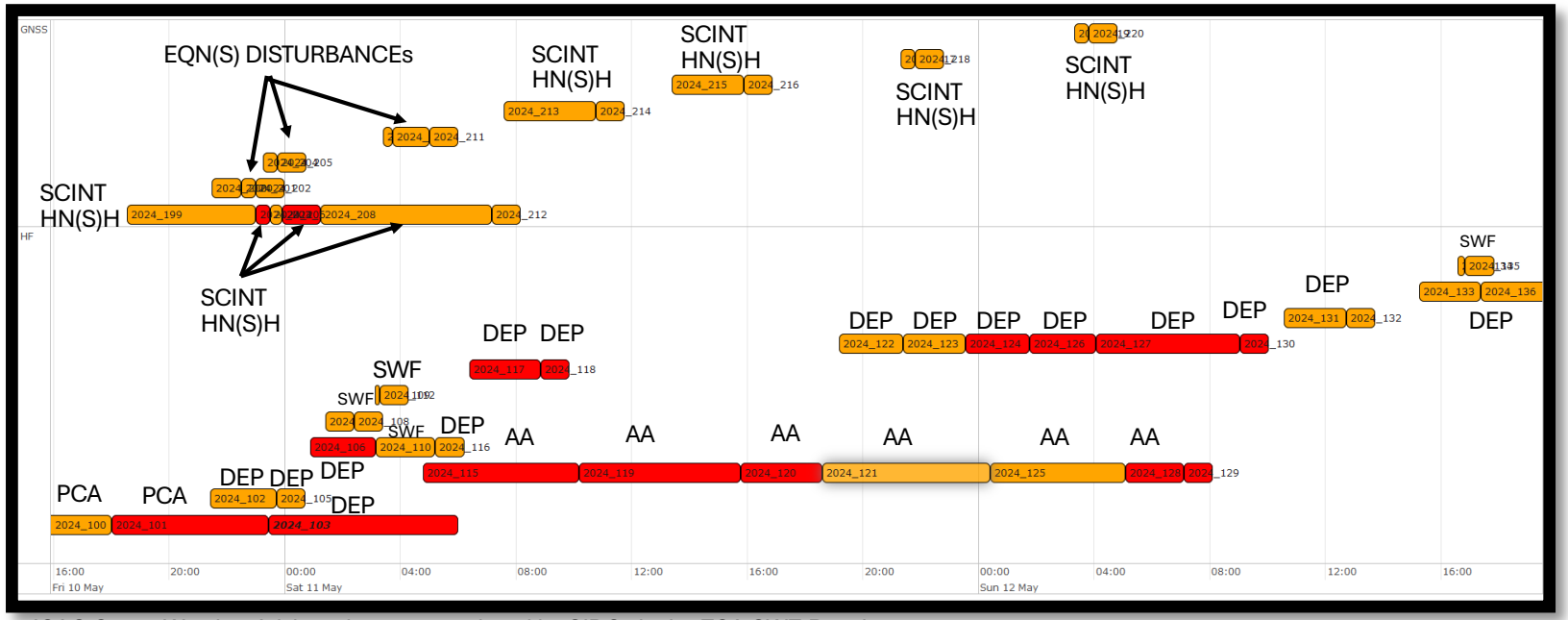


May 10-12 – HF COM and GNSS Advisories

GNSS: 22 advisories

HF-COM: 32 advisories

} issued between 10 May 18:30 and 13 May 00:00



ICAO Space Weather Advisory browser, produced by SIDC via the ESA SWE Portal

Royal Observatory of Belgium

Solar Influences Data analysis Centre
www.sidc.be

Question?

- Did you notice HF COM MUF depressions during or after the geomagnetic storm?
- If so, what operational mitigations did you or would you take?

May 10-13: HF COM and GNSS

HF COM advisories issued for AA and PCA

Date	Time (UTC)	Comments	Kind
20240510	1515	MOD, start of event	PCA
20240510	1755	SEV	PCA
20240510	2115	MOD	PCA
20240510	2330	SEV	AA
20240511	0430	SEV (update)	AA
20240511	1000	SEV (update)	AA
20240511	1530	SEV (update)	AA
20240511	1830	MOD	AA
20240512	0015	MOD (update)	AA
20240512	0500	SEV	AA
20240512	0700	End of event	

Effect and Kind	MOD	SEV	Total
GNSS	**20**	**2**	**22**
Scintillation	14	2	16
TEC	6	0	6
HF COM	**22**	**14**	**36**
DEP	11	7	18
PAA	3	7	10
SWF	8	0	8
RADIATION	0	0	0
Grand Total	**42**	**16**	**58**

ICAO advisories disseminated over 10-13 May 2024

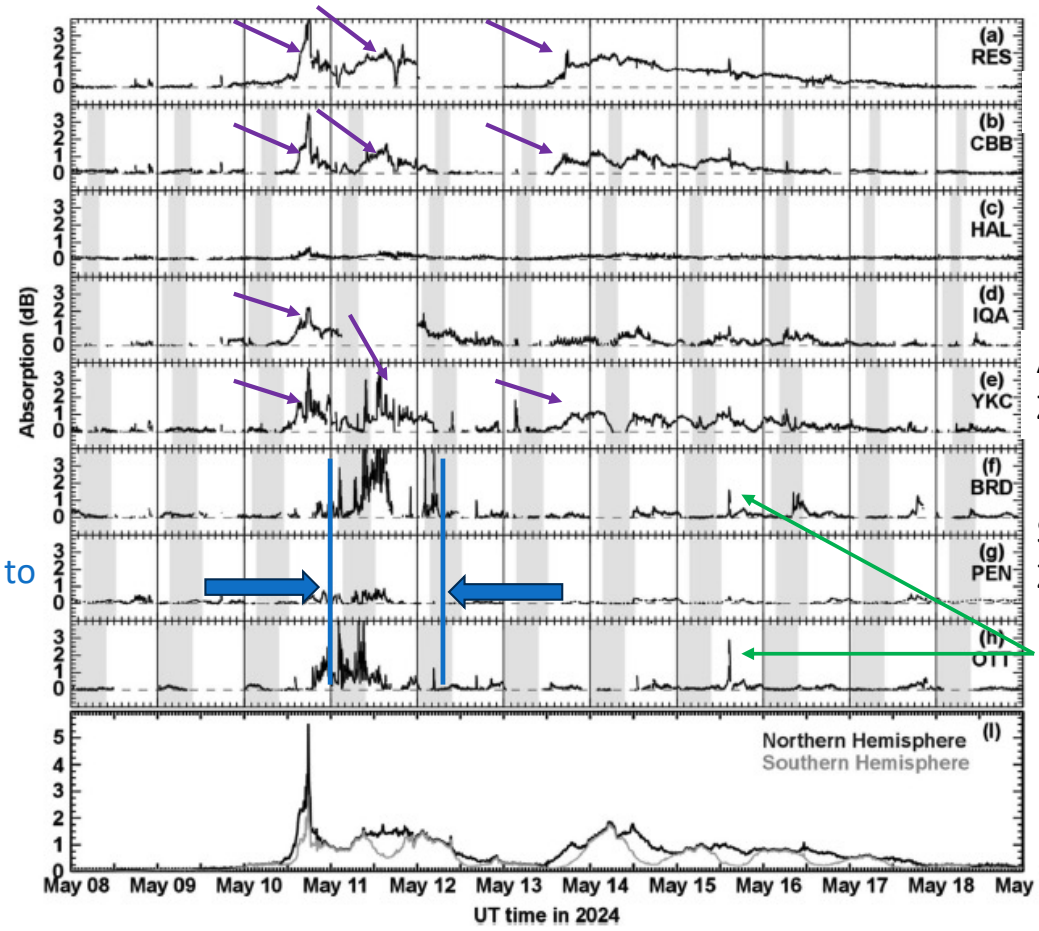
Credit: Australia BOM

HF COM - Polar Cap & Auroral Absorption

HF COM:
Polar Cap Absorption (PCA) due to Solar Protons

HF COM:
Auroral Absorption (AA) due to geomagnetic storm

R.A.D. Fiori et al.: J. Space Weather Space Clim. 2025, 15, 43



Polar Zone

Auroral Zone

Sub-Auroral Zone

Dayside X-class flare signatures

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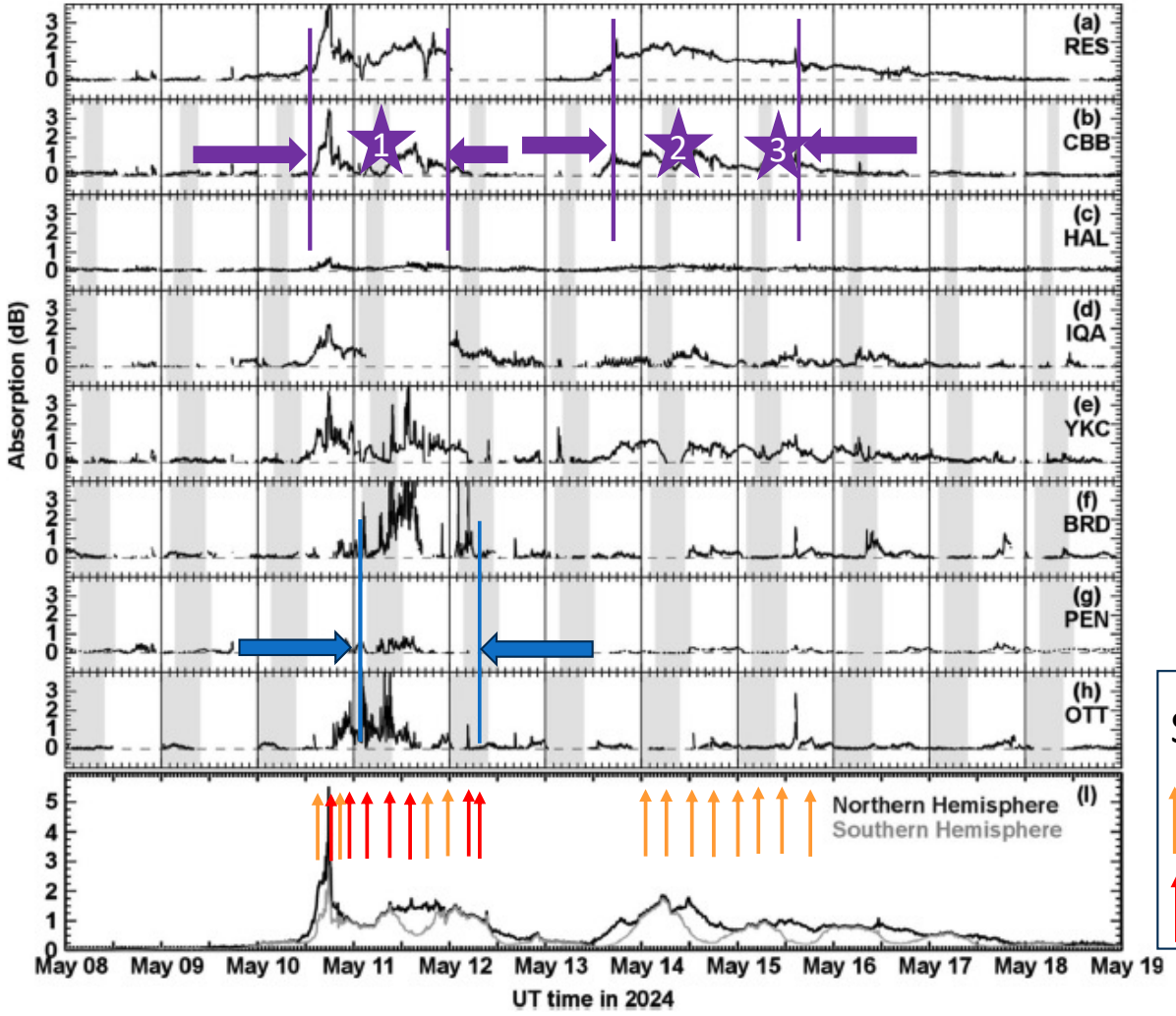
HF COM – PCA and AA Impacts

HF COM:
Polar Cap Absorption

HF COM:
Auroral Absorption



★ Reported impacts

SWX advisories

↑ HF COM MOD (PAA)

↑ HF COM SEV (PAA)

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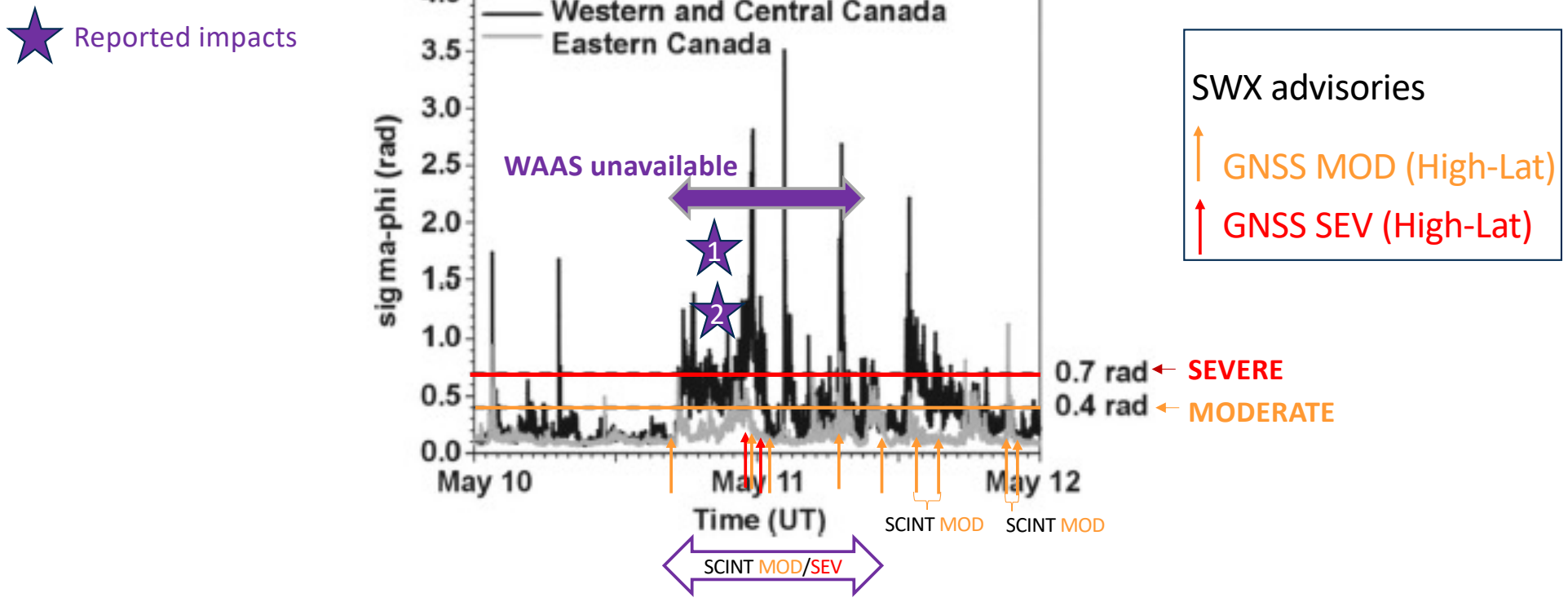
HF COM – PCA and AA Impacts

CADORS Number	Date	Time (UT)	City, Province OR Province	Narrative
2024C2966 1	20240511	10:07	Nunavut (1 aircraft)	A Societe Air France Boeing 777-300 (FGZNU/AFR163) from Tokyo/Haneda, Japan (RJTT) to Paris/Charles de Gaulle, France (LFPG) showed radio failure on automatic dependent surveillance - broadcast (ADS-B) and then climbed without a clearance.
2024C4190 2	20240514	11:38	Nunavut (1 aircraft)	A Lufthansa German Airlines Boeing (DLH717) from RJTT to EDDF was observed on surveillance display climbing from FL330 to FL350 without a clearance from air traffic control (ATC), and in close proximity to a boundary between Edmonton Area Control Center and Reykjavik Control Center. The event occurred when the flight was approximately 70 miles from entering Reykjavik Control Area. High Frequency (HF) conditions were very poor or blackout during this period. The flight may not have had any contact with ATC for several hours during this period. No data link connection was present, too far North. The aircraft may have been following North Atlantic Traffic (NAT) communication failure procedures.
2024C4189 3	20240515	11:35	Nunavut (1 aircraft)	A Societe Air France Boeing (AFR291) from RJBB to LFPG was observed on surveillance display climbing from FL350 to FL370 without a clearance from air traffic control (ATC), and in close proximity to a boundary between Edmonton Area Control Center and Reykjavik Control Center. The event occurred when the flight was approximately 70 miles from entering Reykjavik Control Area. High Frequency (HF) conditions were very poor or blackout during this period. The flight had previously had positive data link connection with Edmonton area control centre (ACC). The aircraft may have been following North Atlantic Traffic (NAT) communication failure procedures. The obtained positive HF contact with Iceland Radio at the boundary or shortly after, with Reykjavik Control Center. (Second entry, 2024C4188, 20240515, 11:37 UT)

Questions

- Was the number of HF COM advisories issued adequate? Frequency of updates?
- Would a duration forecast be useful vs end of event advisory?
- How do airline operators react to loss of HF comms?
- Polar and oceanic regions are most susceptible due to the need for long-range communications (SATCOM-based/ Controller-Pilot Data Link Communications (CPDLC) or Automatic Dependent Surveillance Broadcast (ADS-B) systems) or HF communications.
- Is SATCOM or HF primary during trans-oceanic operations?
- Are there any backup communications (other than HF) for polar flights above 82 degrees latitude?

GNSS: Ionospheric Scintillation



GNSS – Scintillation/ WAAS impacts

CADORS Number	Date	Time (UT)	City, Province OR Province	Narrative
2024C3562 ★1	20240510	1933	La Ronge, Saskatchewan (1 aircraft)	A Rise Air de Havilland (C-FDGV/RS630T) from CYVC to CYVC and a Government Of Canada, Royal Canadian Mounted Police Pilatus (C-GMPA) from CZWL to CYVC reported global navigation satellite system (GNSS) issues, loss of localizer performance with vertical guidance (LPV). Area Control Centre Shift Manager (CSM) advised.
2024C3141 ★2	20240510	2000	Rankin Inlet, Nunavut (multiple flights)	A Canadian North Boeing 737-737-406 (C-FFNF/AKT118) from Yellowknife, NT (CYZF) to Rankin Inlet, NU (CYRT) and a Nolinor Aviation Boeing 737-2B6C (C-GNLN/NRL947) from Meadowbank, NU (CMB2) to Rankin Inlet, NU (CYRT) reported a global navigation satellite system (GNSS) downgrade from localizer performance with vertical guidance (LPV) to lateral navigation (LNAV) on the area navigation (RNAV) Runway 31 and Runway 13 approaches respectively. The beginning was at 30NM northwest of ONDOS on the latter approach. A Calm Air Aerospatiale ATR 42-320 (CAV234) from Yellowknife, NT (CYZF) to Rankin Inlet, NU (CYRT) and a Calm Air Aerospatiale ATR 42-320 (C-FMAK/CAV235) from Rankin Inlet, NU (CYRT) to Naujaat, NU (CYUT) reported similar occurrences at CYUT and a Nolinor Aviation Boeing 737-200 (NRL946) from Rankin Inlet, NU (CYRT) to Meadowbank, NU (CMB2) at CMB2, between 1851Z and 2041Z. A Canadian North Boeing 737-400 (AKT152) from Winnipeg/James Armstrong Richardson, MB (CYWG) to Rankin Inlet, NU (CYRT) reported the same issue at 2325Z and stated they heard multiple aircraft with same issue at other airports on other frequencies.

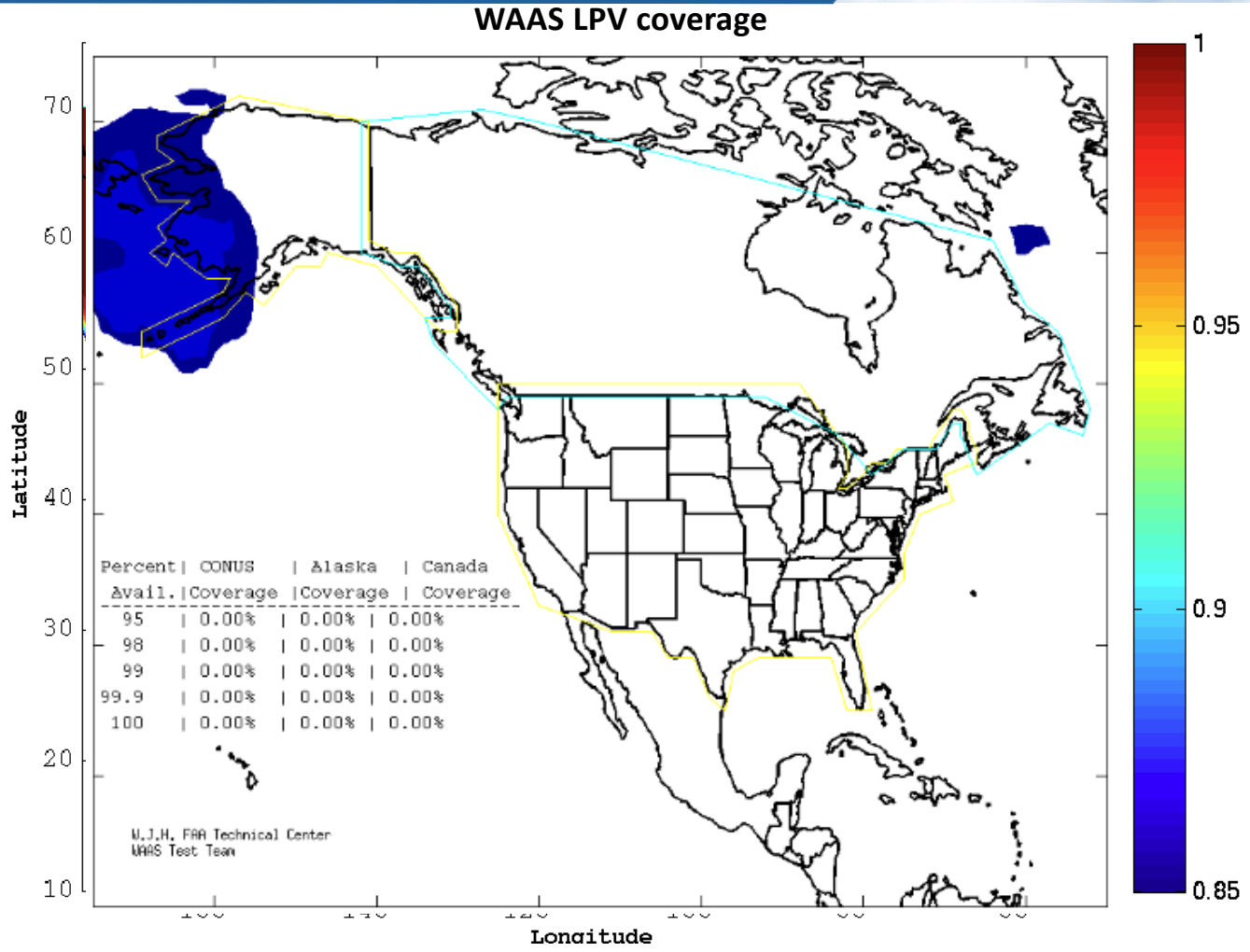
May 10-11: GNSS Impacts

WAAS was degraded in Canada, Alaska, and CONUS for **> 16 hours** (LPV, LPV200)

Table 4. Onset and end of periods of significant degradation to WAAS LPV and LPV 200 services over the continental US (CONUS), Alaska, and Canada during the May 2024 space weather event as reported by WAAS report #89.

Region	Service	Onset, 10 May 2024 (UT)	End, 11 May 2024 (UT)
CONUS	LPV	18:45	10:45
CONUS	LPV200	18:35	10:40
Alaska	LPV	18:35	10:35
Alaska	LPV200	18:25	10:40
Canada	LPV	18:30	10:30
Canada	LPV200	18:10	10:30

Fiori et al., 2025



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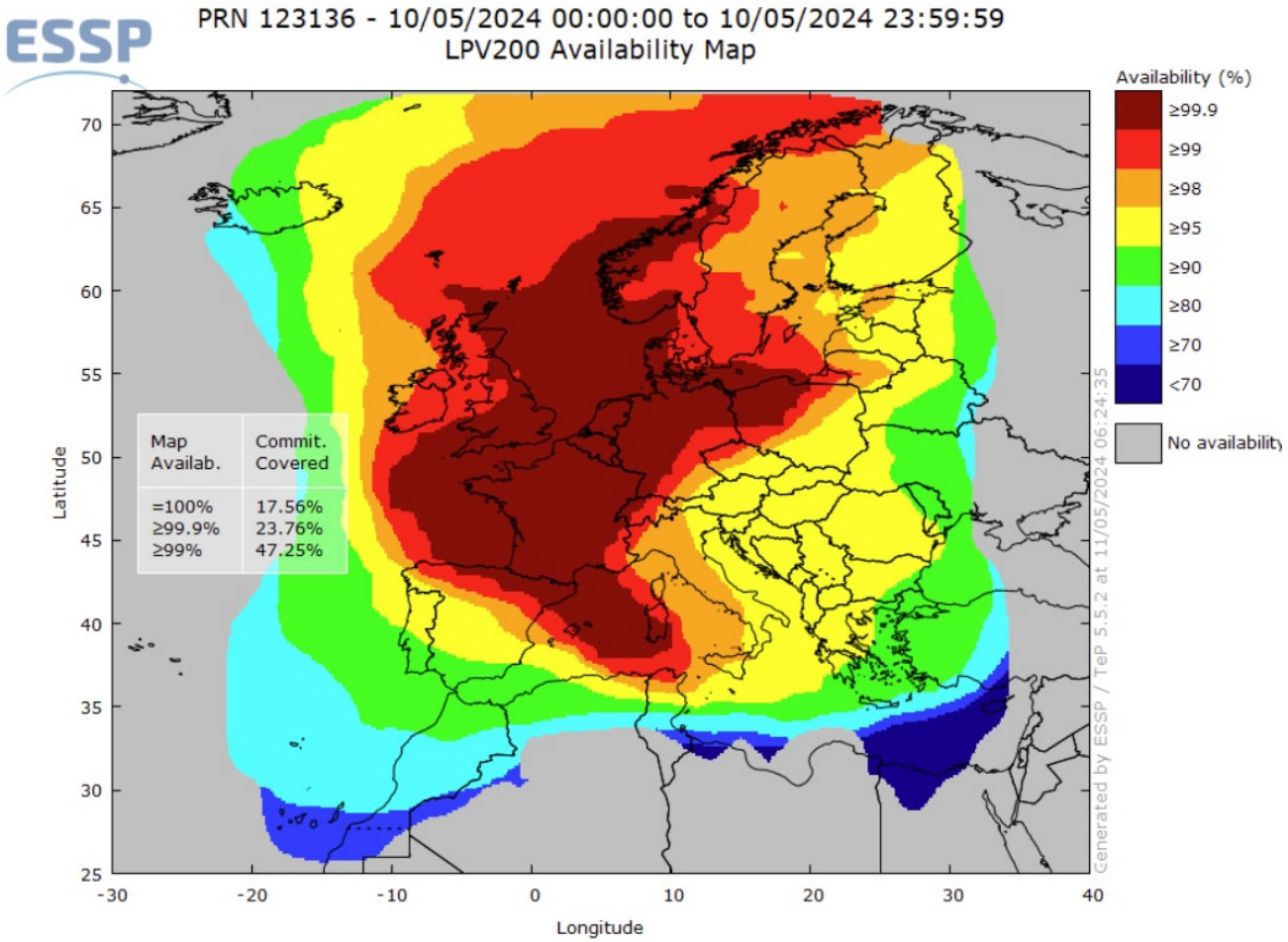
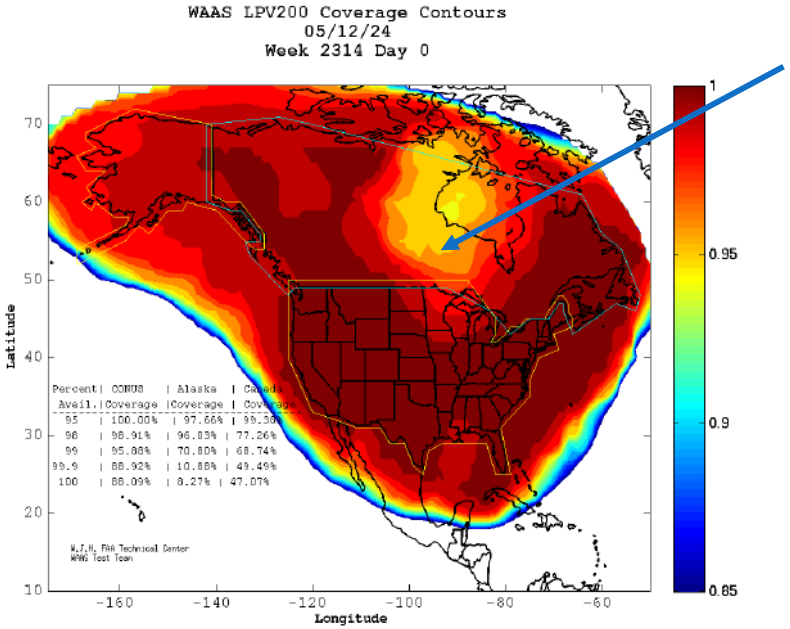
May 10 – EGNOS Degradation



May 11: GNSS Impacts

LPV-200 Coverage Plot for May 12, 2024



CADORS # 2024C3097

20240512 23:28 Thompson, Manitoba

A Keewatin Air Beech B200 (C-FSAO/KEW214) from The Pas, MB (CYQD) to Thompson, MB (CYTH) reported a GNSS downgrade of localizer performance with vertical guidance (LPV) to lateral navigation (LNAV) after commencing the area navigation (RNAV) Runway 06 approach. Two subsequent aircraft reported similar experiences from 2328Z to 2343Z, including a Missinippi Air-Care Beech 200 (C-FICU/MA04) from Gods River, MB (CZGI) to Thompson, MB (CYTH) and a North Star Air Ltd. ATR-GIE ATR 72-212A (C-FNSN/BF502) from Rankin Inlet, NU (CYRT) to Thompson, MB (CYTH). All aircraft completed their approaches without incident.

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Questions

- Was the number of GNSS advisories issued adequate? Frequency of updates?
- Are GNSS Scintillation (or TEC) advisories useful pre-flight, in-flight, before landing?
- GNSS scintillation with severe intensity seems to be a good proxy of degradation of SBAS services, or sustained GNSS scintillation with moderate intensity during major storms with Kp ≥ 8-9.
- Would separate advisories on the status of GNSS space-based augmentation system (SBAS) services be useful? NOTAMS?

Additional questions

- How do the mitigation or operational responses differ between ANSPs, air traffic control centers, and airline operators?
- Any reported impacts to INMARSAT (GEO) or IRIDIUM (LEO) SATCOM Voice?
- Did you experienced SATCOM degradation (from GEO or LEO) that could have been caused by scintillation?
- Any reported impacts to space-based ADS-B (~800 km altitude)?

Thank you

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Back Up Slides

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ICAO SWX Thresholds

Effect	Sub-effect	Parameter used	Thresholds		Impact within advisory area	
			MOD	SEV	MOD	SEV
GNSS	Amplitude Scintillation	S4 (dimensionless)	0.5	0.8	Possible degraded service	Possible unreliable service
GNSS	Phase Scintillation	Sigma-phi (radians)	0.4	0.7		
GNSS	Vertical Total Electron Content (TEC)	TEC units	125	175		
RADIATION		Effective dose rate (micro-Sieverts/hour)	30	80	Possible increased dose rates above normal levels.	
HF COM	Auroral Absorption (AA)	Kp index	8	9	Possible degraded service	Possible unreliable service
HF COM	Polar Cap Absorption (PCA)	dB from 30MHz riometer data	2	5		
HF COM	Shortwave Fadeout (SWF)	Solar X-rays (0.0-0.8 nm) ($W-m^{-2}$)	$1x10^{-4}$ (X1)	$1x10^{-3}$ (X10)		
HF COM	Post-Storm Depression	Maximum usable frequency (MUF)	30%	50%		
SATCOM	No threshold has been set for this effect				Possible degraded service	Possible unreliable service

May 7-9 Events

- Majority of activity due to Active Region (AR) 3664 – a complex region near the center disk.
- Crossed central solar disk on 7 May
- Multiple CMEs were predicted to have an Earth directed component on May 8-9.
- Produced numerous M and X class flares with associated Coronal Mass Ejections (CMEs) on May 8-9.