



ICAO BANGKOK

UNITING AVIATION

# Space Weather Advisory Service for Aviation

*Ashwin Naidu*  
*Australian Bureau of Meteorology*



**MET/ATM Seminar – 1 May 2023**

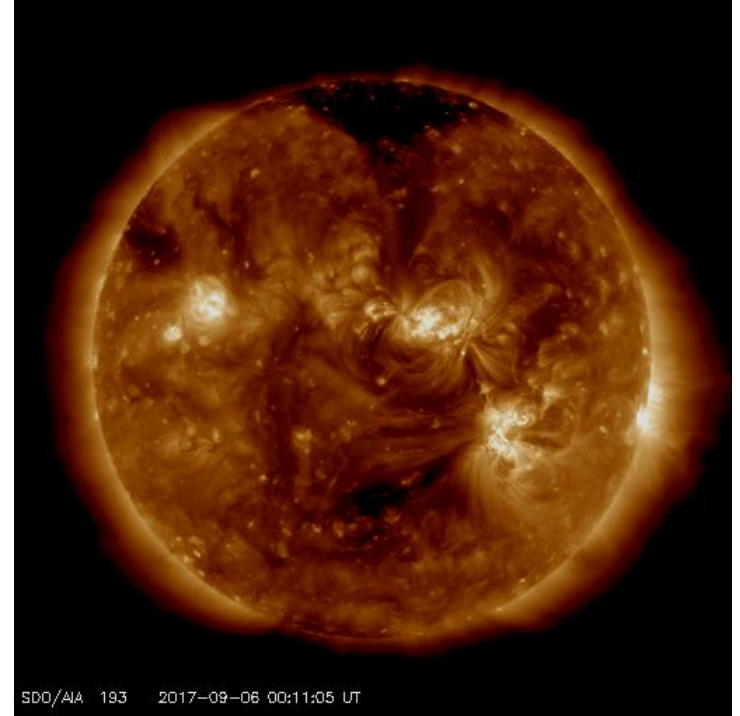
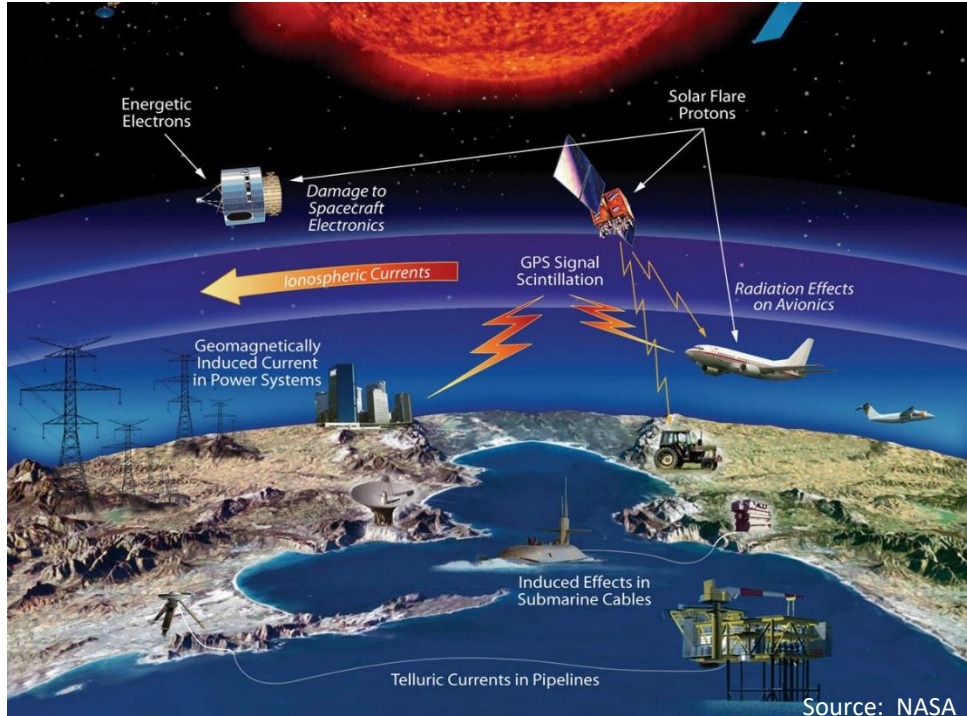




## Outline

- What is space weather?
- Impacts on aviation (HF COM, GNSS, RADIATION and SATCOM)
- ICAO development of space weather information Standards for aviation
- The Global Space Weather Advisory Service
- Space Weather Advisories
- Advisory Dissemination
- Operational Considerations

## What is space weather?





## Space Weather impacts on aviation



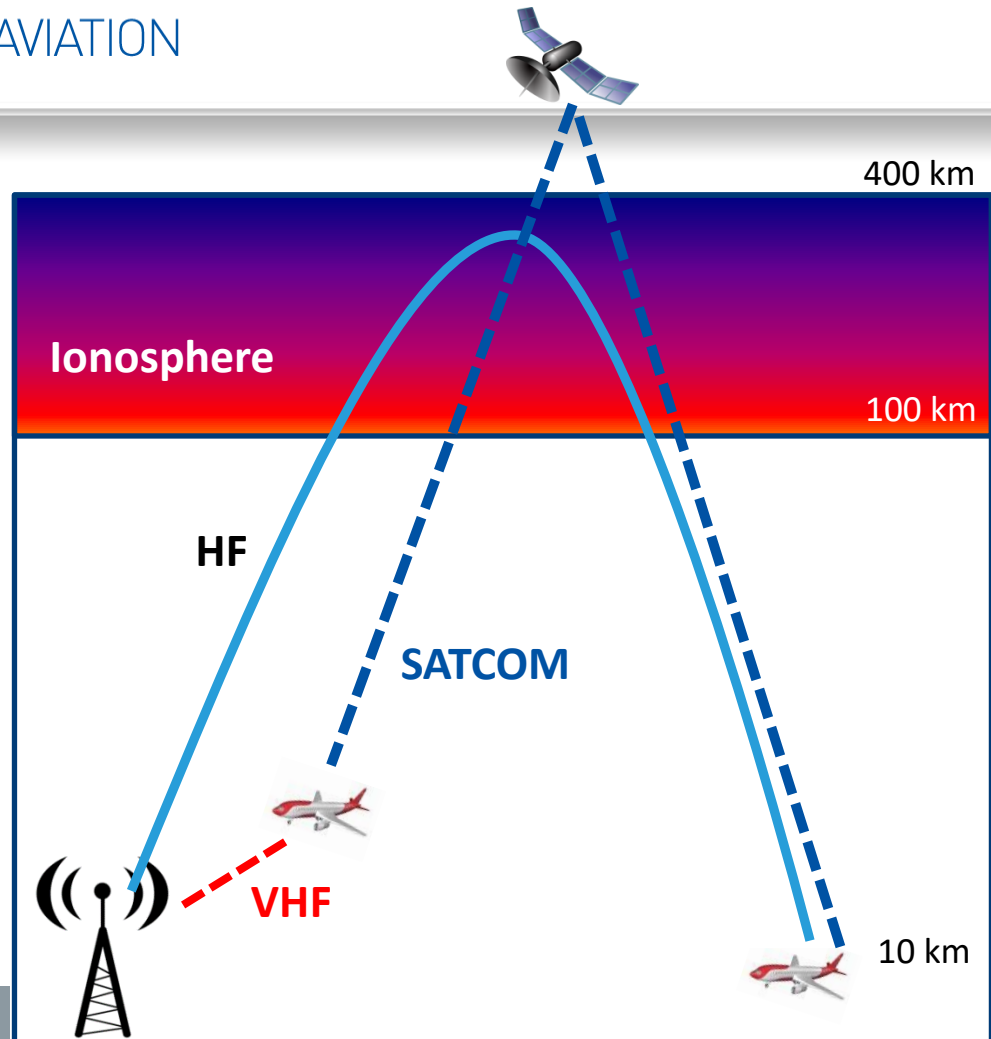
- HF communications
  - HF radio blackout (absorption)
    - X-ray flares → dayside
    - Solar Protons → Polar Cap
  - Compressed HF bandwidth (depression)
    - Geomagnetic storms
- Satellite communications
  - Ionospheric scintillation
- GNSS-based navigation and surveillance
  - Positioning errors (ionospheric delay)
  - GNSS loss of lock (scintillation)
- Elevated radiation dose rates on polar flights

## Impact of space weather on HF Communications (HF COM) and SATCOM

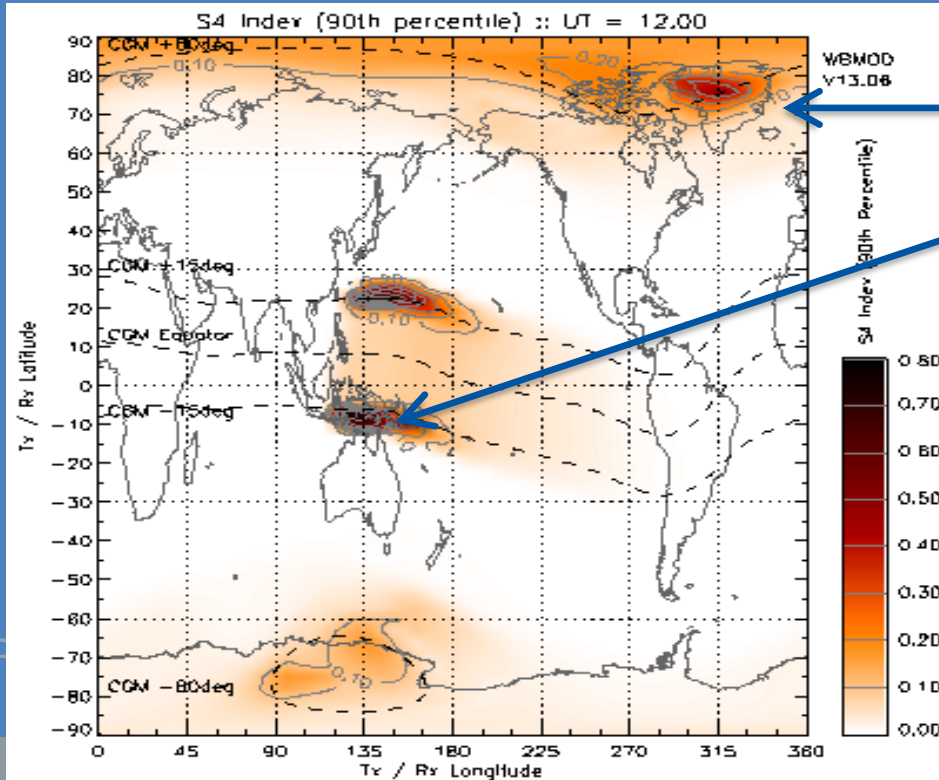
Space weather modifies the ionosphere, blocking or degrading HF communications

Space Weather Impacts:

- Complete loss of HF COM on dayside (solar flares)
- Complete loss of HF COM across polar caps (energetic protons)
- Reduced HF COM frequency set (ionospheric storms)



## Impact of space weather on GNSS (GPS) performance



### Ionospheric irregularities

- Geomagnetic storms and substorms
- Equatorial Plasma Bubbles

### Ionospheric disturbance

### Space Weather Impacts:

- Lower positioning accuracy
- Loss of satellite tracking
- Poor Quality / Availability of SATCOM

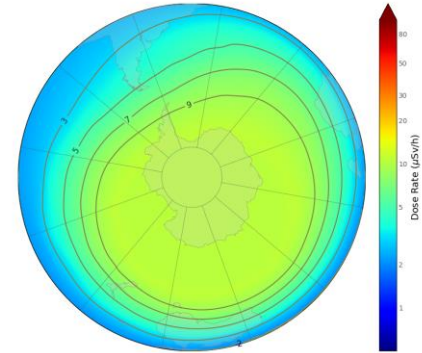
## Impact of space weather on radiation levels

Radiation bursts from the sun increase the ionising radiation environment in the Polar Regions

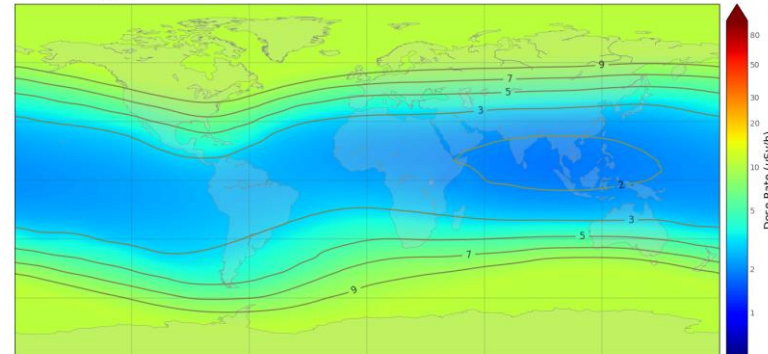
### Space Weather Impacts:

- Increased radiation dose rates at flight altitude in Polar Regions
- Poorly understood impacts on avionics
- Impacts stronger at higher altitude and higher latitude

Radiation dose map at 37000 feet (11.3 km) for 2021-05-18 (max 10.8  $\mu\text{Sv/h}$ )

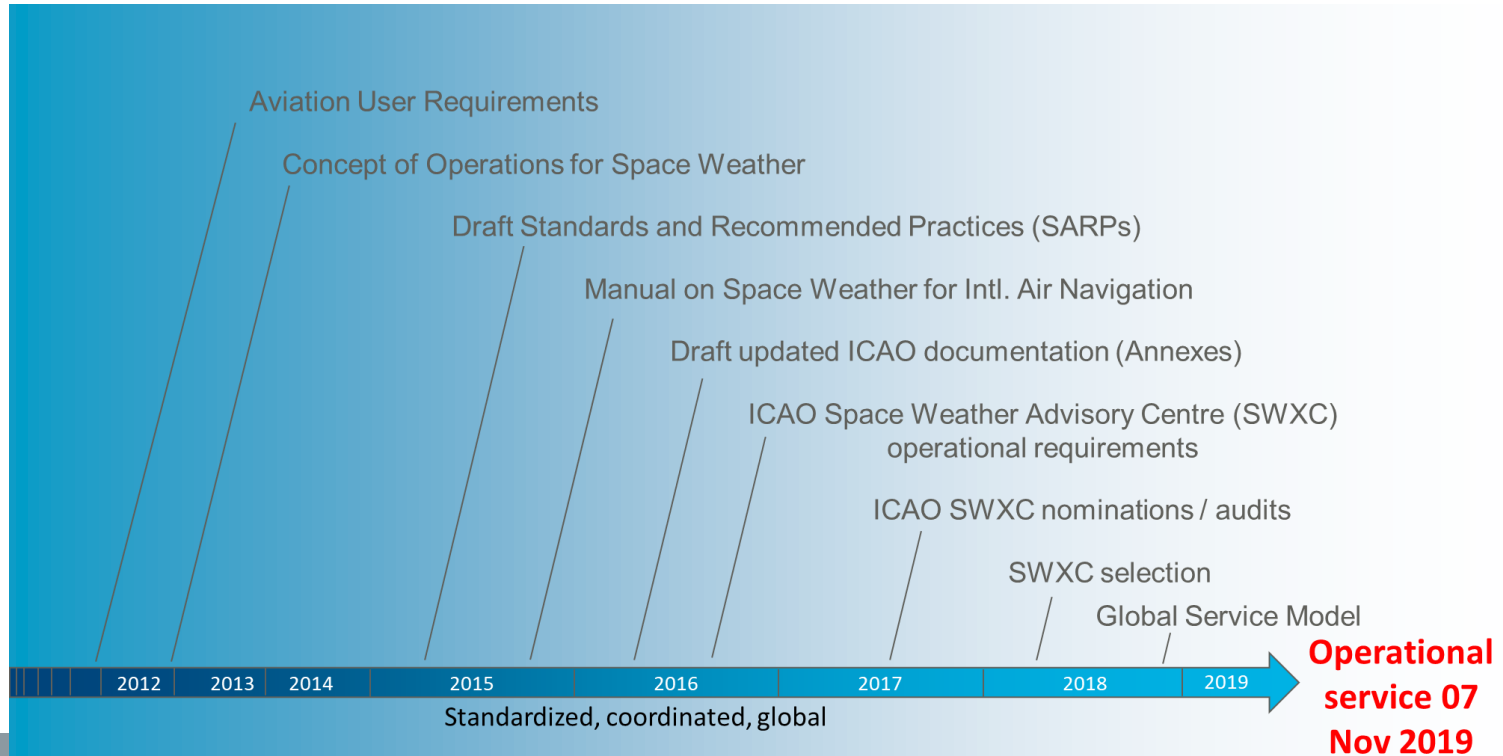


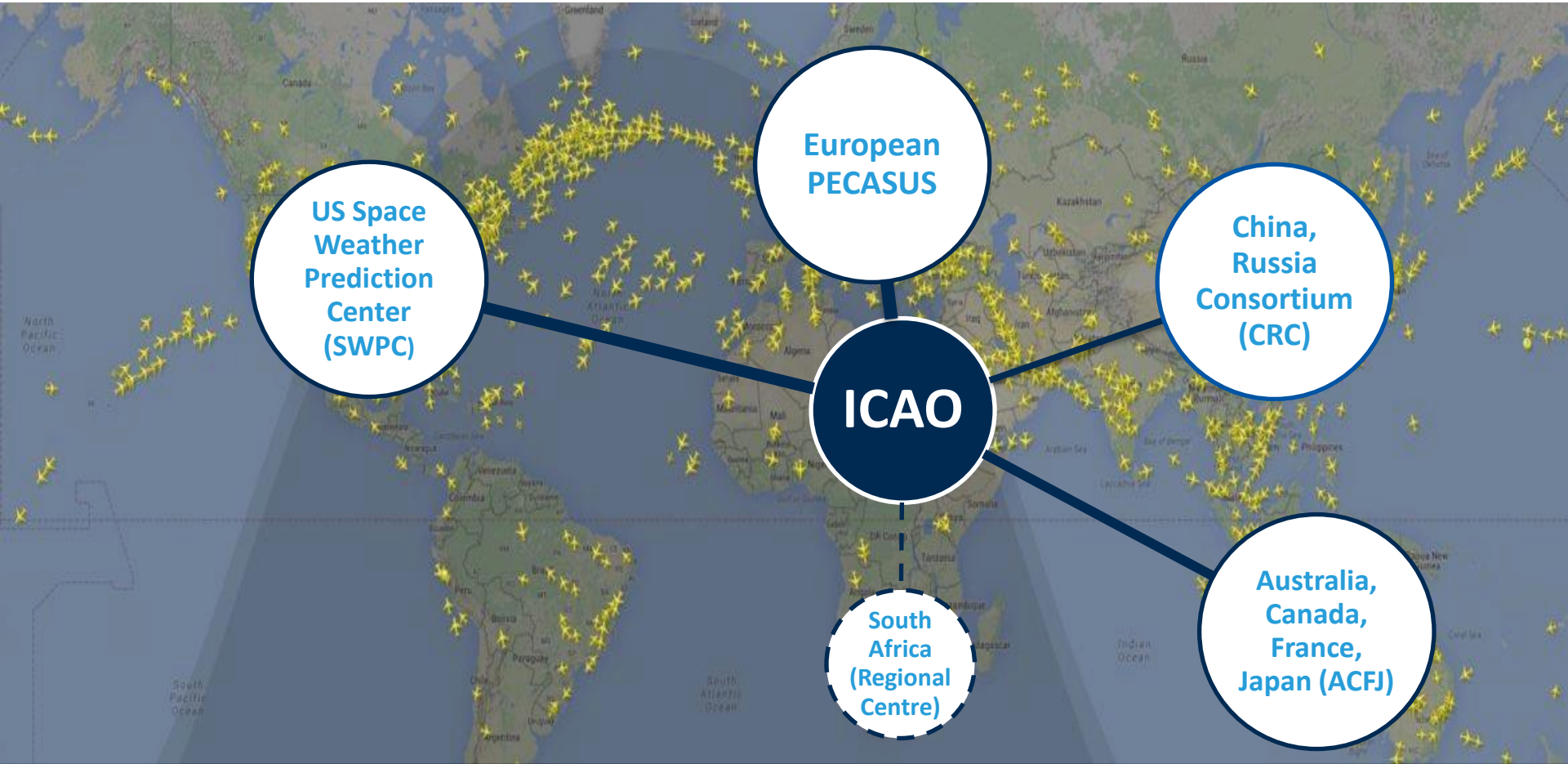
**SIGLE**  RT Observatoire de Paris Radiation dose map at 37000 feet (11.3 km) for 2021-05-18 (max 10.8  $\mu\text{Sv/h}$ )





## Towards an ICAO standardized global space weather service for aviation





**US Space  
Weather  
Prediction  
Center  
(SWPC)**

**European  
PECASUS**

**China,  
Russia  
Consortium  
(CRC)**

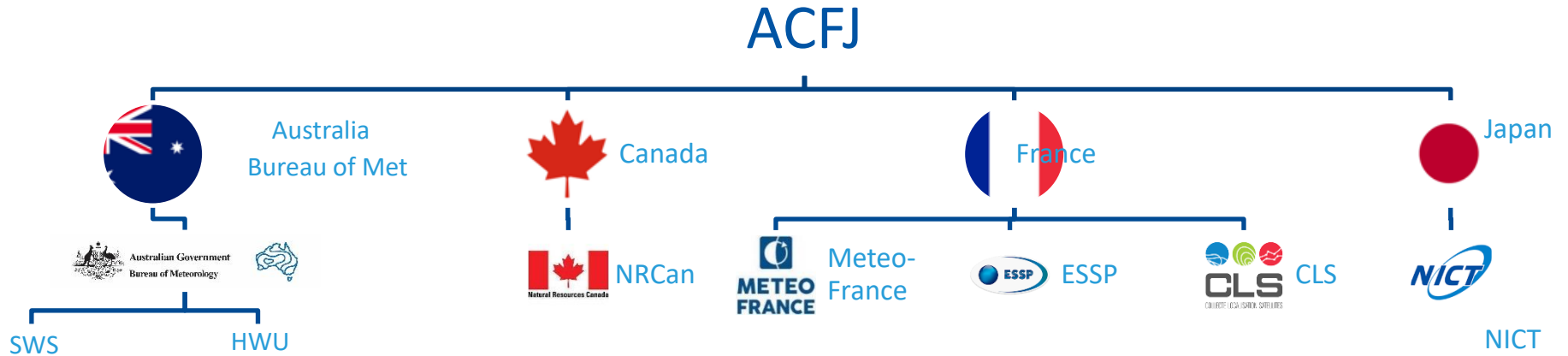
**ICAO**

**South  
Africa  
(Regional  
Centre)**

**Australia,  
Canada,  
France,  
Japan (ACFJ)**



## The Australia-Canada-France-Japan (ACFJ) Consortium



24 / 7 global space weather advisory service for aviation



## A global space weather advisory service

### Coordination model

- **Global centres active all the time** and rotate through the following roles:  
On Duty Centre → Primary Backup Centre →  
Secondary Backup Centre → Maintenance and Observation Centre
- **The On Duty Centre is solely responsible for the creation and dissemination** of all defined SWX products
- The Primary and Secondary Backup Centres are on standby
- The fourth global centre acts as Maintenance and Observation Centre added

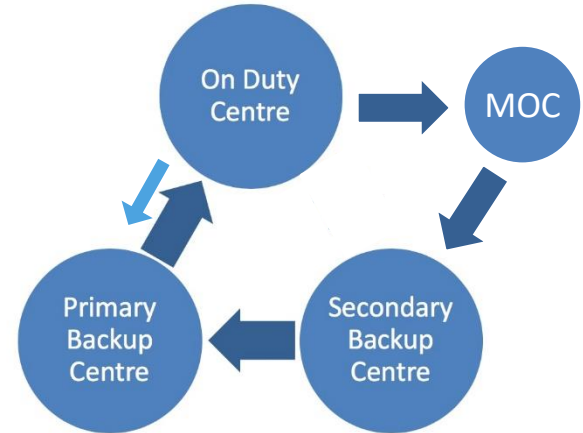
### Rotation cycle

- Rotation cycle is **2 weeks**, per the rotation model →

### Handover between global centres

- **Routine handover is at 08UTC on every second Tuesday**
- Detailed handover procedures have been developed to ensure the handover is seamless and transparent to external users

### 4-centre model



# Meteorological Service for International Air Navigation (Annex 3)

Standards and Recommended Practices (SARPs) for Space Weather, addressing four distinct categories:

- HF radio communications advisories (**HF COM**)
- GNSS navigation and surveillance advisories (**GNSS**)
- Advisories for elevated radiation dose rates (**RADIATION**)
- Satellite communications advisories (**SATCOM**)

*Note: Advisories for SATCOM not issued*



Specifies template for space weather advisory

Annex 3 — Meteorological Service for International Air Navigation Appendix 2

Element	Detailed content	Template(s)	Examples
5 Advisory number (M)	Year in full and unique message number	ADVISORY NR: nnnn[nn][nn]	ADVISORY NR: 2016/1
6 Number of advisory being replaced (C)	Number of the previously issued advisory being replaced	NR RPLC: nnnn[nn][nn]	NR RPLC: 2016/1
7 Space weather effect and intensity (M)	Effect and intensity of the space weather phenomena	SWX EFFECT: HF COM MOD or SEV or SATCOM MOD or SEV or GNSS MOD or SEV or HF COM MOD or SEV AND GNSS MOD or SEV or RADIATION MOD or SEV	SWX EFFECT: HF COM MOD SATCOM SEV GNSS SEV HF COM MOD AND GNSS MOD

**Details: Manual on Space Weather Information in Support of International Air Navigation (Doc 10100)**

## Space Weather Advisory Example – Moderate HF Communications disturbance

FNXX02 EFKL 150645

SWX ADVISORY

DTG: 20210515/0645Z

SWXC: PECASUS

ADVISORY NR: 2021/18

NR RPLC: 2021/17

SWX EFFECT: HF COM SEV

OBS SWX: 23/0535Z EQS W045 - E045

FCST SWX +6 HR: 23/1800Z NOT AVBL

FCST SWX +12 HR: 23/0000Z NOT AVBL

FCST SWX +18 HR: 23/0600Z NOT AVBL

FCST SWX +24 HR: 23/0600Z 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 20210515/1222Z

Space Weather Centre

PECASUS

Time and Location

UNIT / UCL

Details

Next update

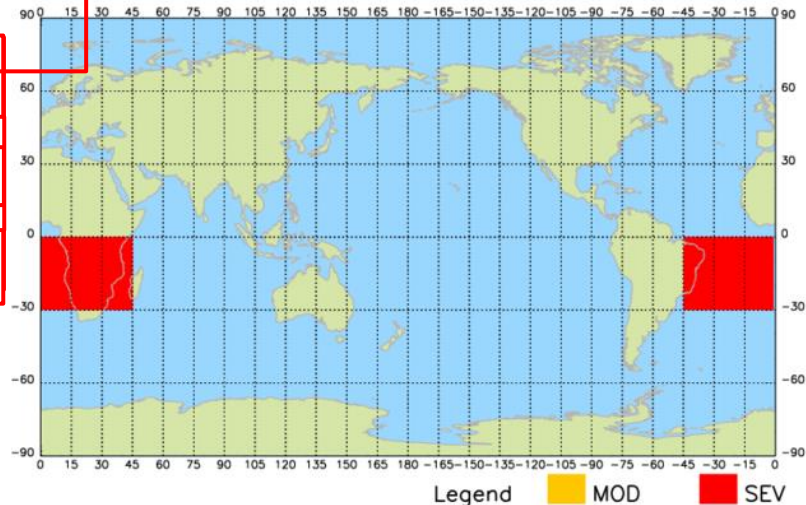
[FREE TEXT]

DAYSIDE

[ABV FLxx]

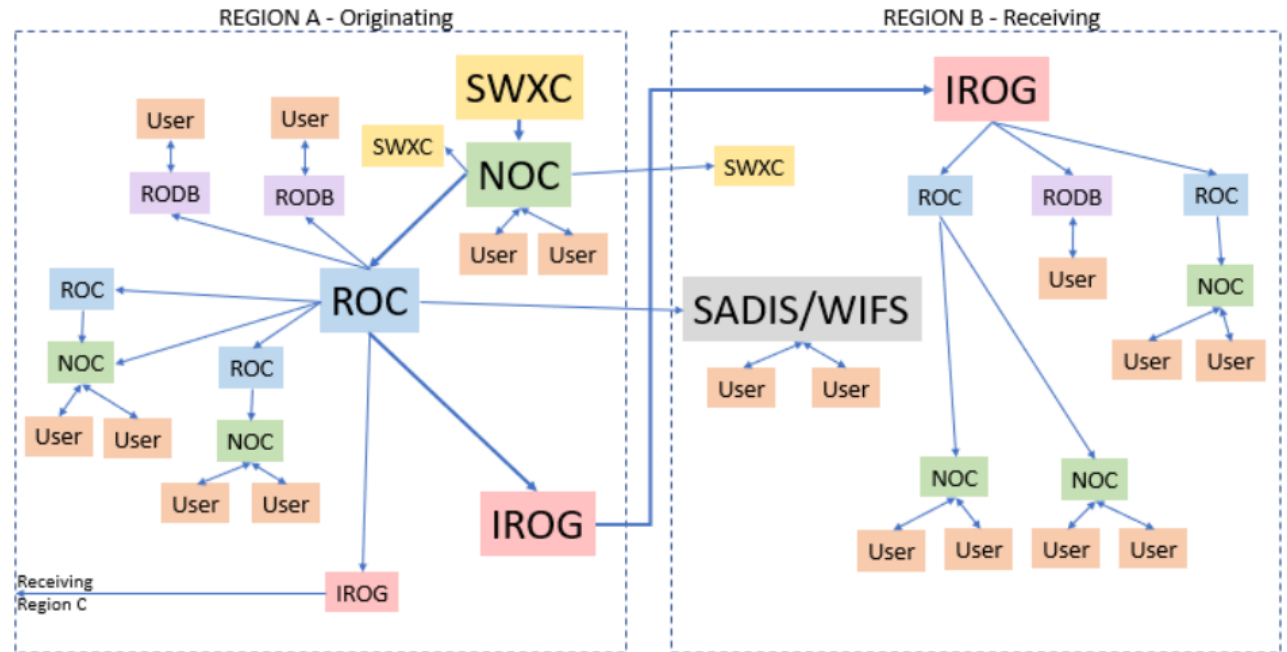
### GLOBAL HF COM ADVISORIES

Graphic issued at 0645UTC 15 May 2021, by Bureau of Meteorology



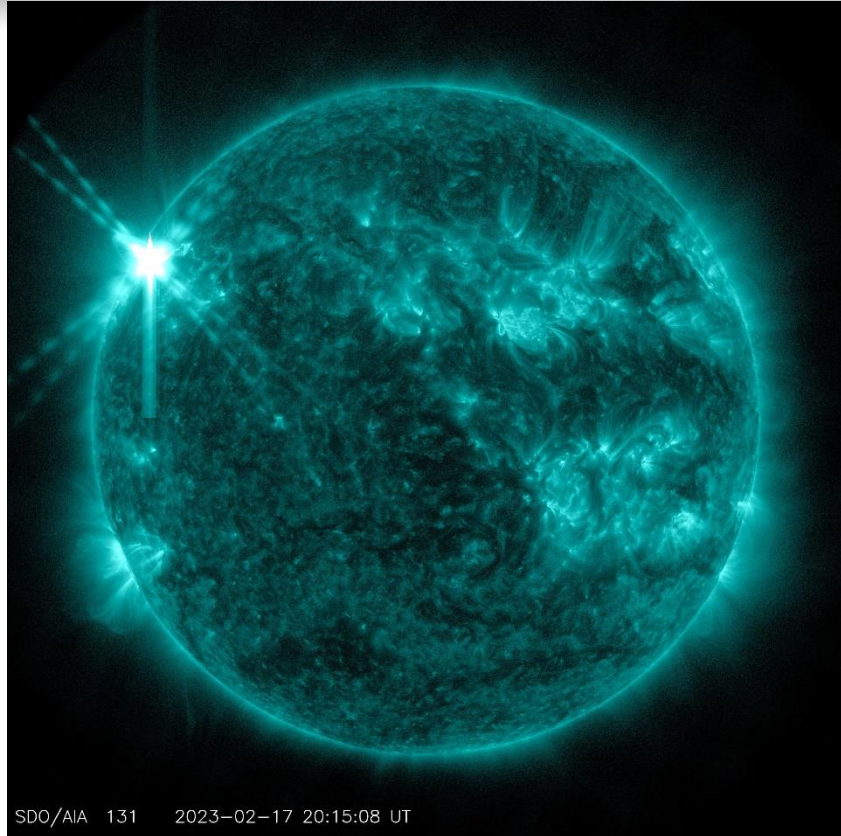
## Space Weather Advisory (SWXA) dissemination

Regular testing of the dissemination system (using SWXAs with STATUS: TEST) has been conducted since 2019 (1 test advisory every 2 weeks)



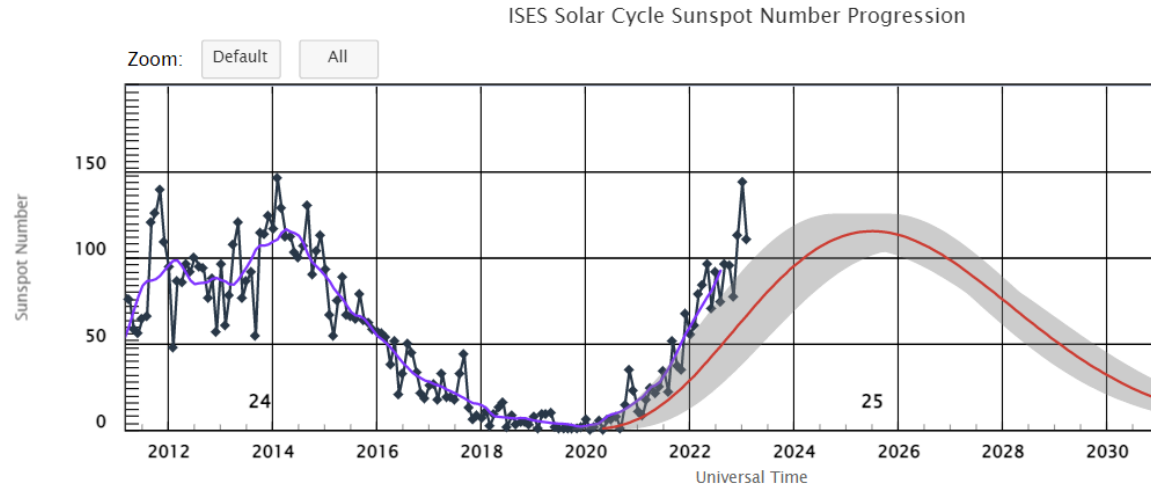


# Space Weather Update

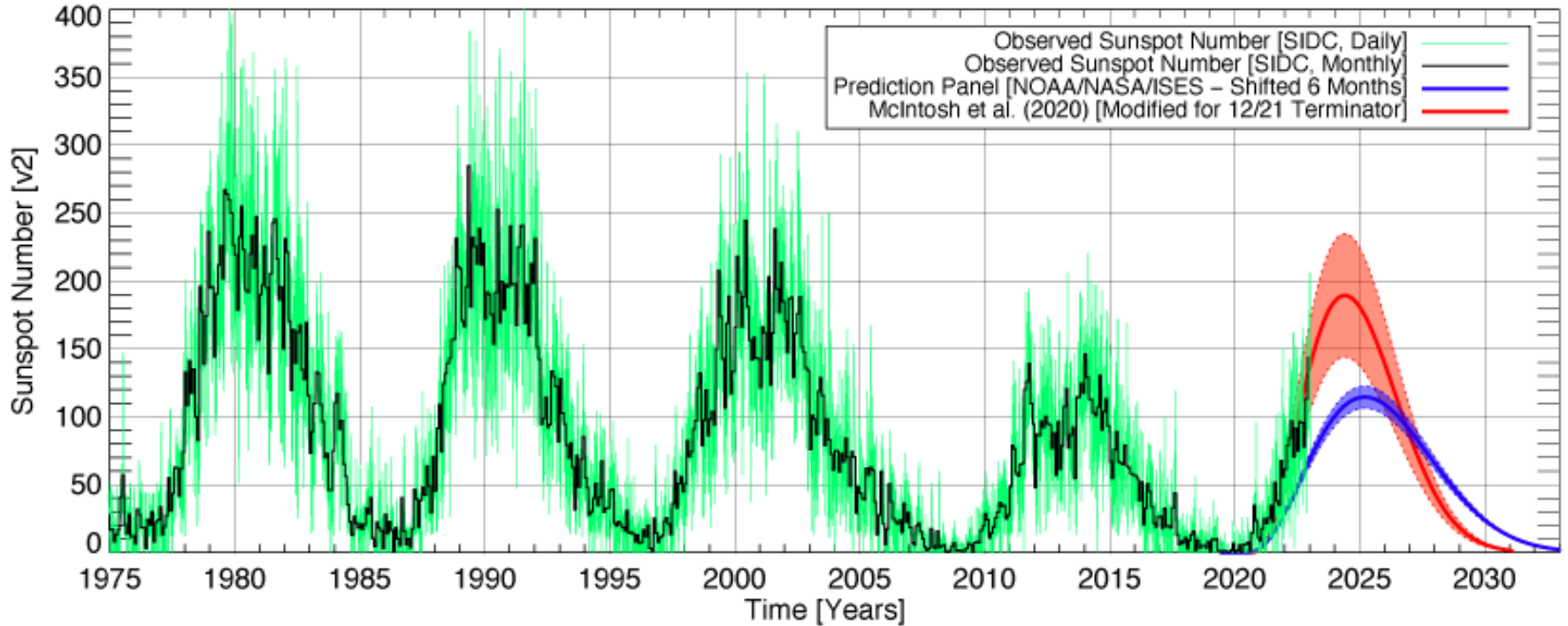




- Solar activity has increased as we progress toward solar maximum of solar cycle 25
- Increased solar activity especially observed in April, May, August and December of 2022
- January 2023 – largest sunspot number since 2014
- Majority of flare activity below MOD ICAO threshold (X1)

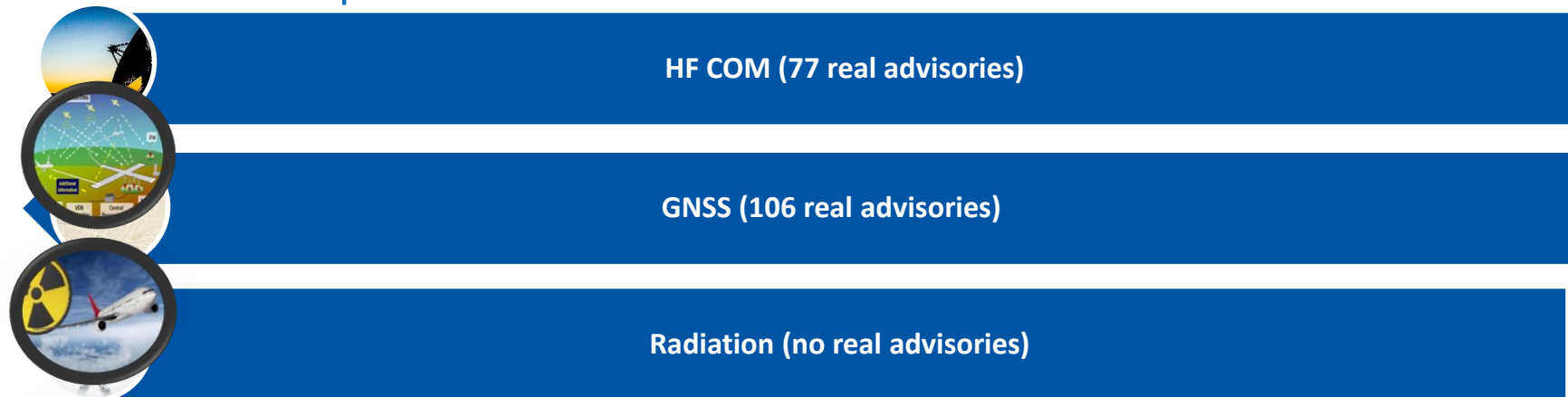


Source: NOAA/SWPC



McIntosh et al. (2020)

## How often will space weather advisories be issued?

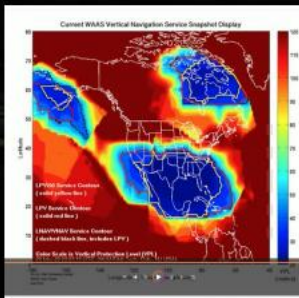
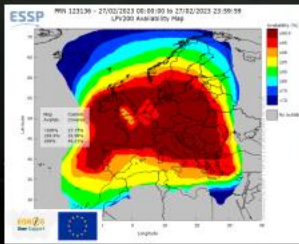


A summary of all Space Weather Advisories issued by the ICAO centres from 1 March 2022 to 20 February 2023

# Space Weather Impacts

## Which impacts do SBAS (WAAS & EGNOS) degradations have in real life?

Verification of ICAO SWX advisories in real airplanes needs to begin - NOW!  
Start your test program!



MODERATE CONFIRMED?

```

FNXXX01 LFR 200053
SWX ADVISORY SIMULATED
DTG: 2022/220/0049Z
SWXC: ACF3
ADVISORY NR: 2023/45
SWX EFFECT: RADMOD
OBS SWX: 20/0015Z EQN EQS W105 - W000
FCST SWX +6 HR: 20/0700Z NOT AVBL
FCST SWX +12 HR: 20/1300Z NOT AVBL
FCST SWX +18 HR: 20/1900Z NOT AVBL
FCST SWX +24 HR: 21/0100Z NOT AVBL
RMK: SWX EVENT GENERALLY STRONGER ON THE NIGHTSIDE.
NXT ADVISORY: WILL BE ISSUED BY 20230220/0649Z=
No warnings
    
```

SEVERE CONFIRMED?

```

©2022-11-07 18:47:00
FNXXX01 EFLX 071851
SWX ADVISORY
DTG: 20221107/1847Z
SWXC: PECASUS
ADVISORY NR: 2022/58
NR RPLC: 2022/57
SWX EFFECT: GNSS SELV
OBS SWX: 07/1844Z HNH HSH W105 - E180
FCST SWX +6 HR: 08/0100Z NOT AVBL
FCST SWX +12 HR: 08/0700Z NOT AVBL
FCST SWX +18 HR: 08/1300Z NOT AVBL
FCST SWX +24 HR: 08/1900Z NOT AVBL
RMK: SPACE WE
DISTURBANCE) IN PROGRESS.
SWX ADVISORY
DTG: 20220819/0043Z
SWXC: GRC
ADVISORY NR: 2022/52
SWX EFFECT: HF COM MOD
OBS SWX: 18/2300Z HNH MNH W090-E045
FCST SWX +6 HR: 19/0500Z NOT AVBL
FCST SWX +12 HR: 19/1100Z NOT AVBL
FCST SWX +18 HR: 19/1700Z NOT AVBL
FCST SWX +24 HR: 19/2300Z NOT AVBL
RMK: SWX EVENT (MAX USABLE FREQ DEPRESSION) INPR IMPACTING HYR HF
COM FREQ BAND
NXT ADVISORY: WILL BE ISSUED BY 20220819/0500Z=
No warnings
    
```

MODERATE CONFIRMED?

**Report Impacts - Help Aviation!**

# Space Weather Impacts

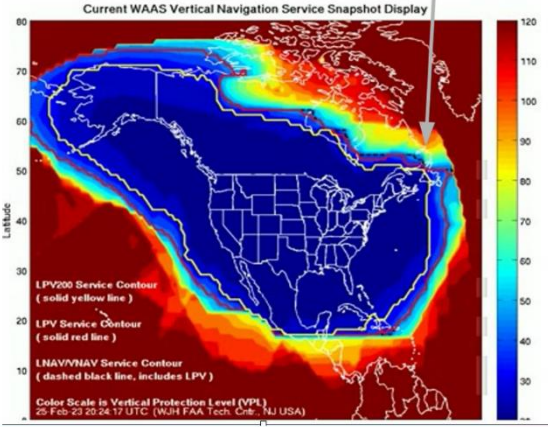
**SPACE WEATHER: IT IS REAL !!!**  
**4 AIRCRAFT, 2 AIRPORTS >**  
**NEAR SIMULTANEOUS LPV FAILURE !**



Report from Canadian CADORS system. Occurrence: 25 Feb 2023

Report: 202300875  
 Date Entered: 2023-03-07  
 Narrative: On approach for Runway 25 at Kuujuaq, QC (CYVP), an Exact Air Inc. Beech A100 (C-FTS/ETR23) from Tasiqaj, QC (CYTD) to Kuujuaq, QC (CYVP) mentioned having lost the localizer performance with vertical guidance (LPV) in lateral navigation (LNAV) and during the previous approach for CYTD. Following this, an Air Inuit Ltd. de Havilland DHC-8-314 (C-FHA/AIE827) from Kangiqsuajuaq, QC (Georges River) (CJLJ) to Kuujuaq, QC (CYVP) mentioned having the same problem when on approach for Runway 25. An Air Inuit Ltd. de Havilland DHC-8-300 (C-GTYS/AIE599) from Kangiqsuajuaq, QC (Wakeham Bay) (CYGK) to Kuujuaq, QC (CYVP) that was following C-AIE827 had the same problem on approach for Runway 25 at CYVP and for its previous approach at CYGK.

ICAO SWx ADVISORY ? None known  
 NOTAM ? None issued  
 Consequences ? To be discussed at the Met Panel and other venues.



blue = good, red = bad

*Credit: Klaus Sievers –German Airline Pilot Association*



## Further Information



ICAO Annex 3 (Meteorological Service for International Air Navigation) including the new SARPs for Space Weather

ICAO Manual on Space Weather Information in Support of International Air Navigation (ICAO Doc #10100)

BoM Information Brochures:

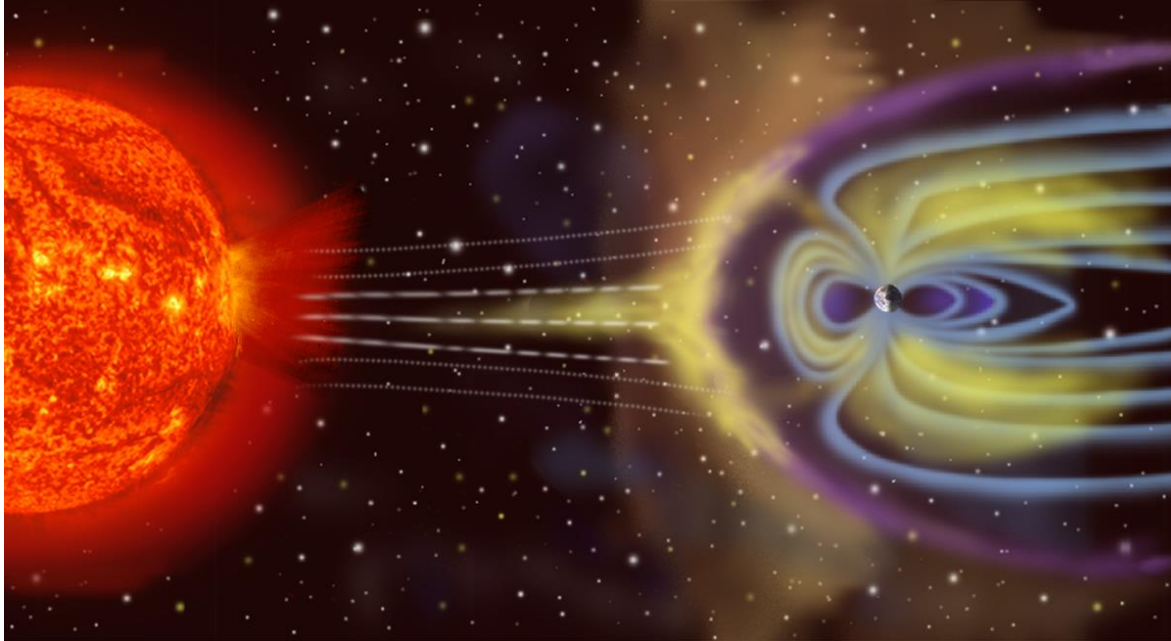
Space Weather Advisories

<http://www.bom.gov.au/aviation/data/education/space-weather-advisories.pdf>

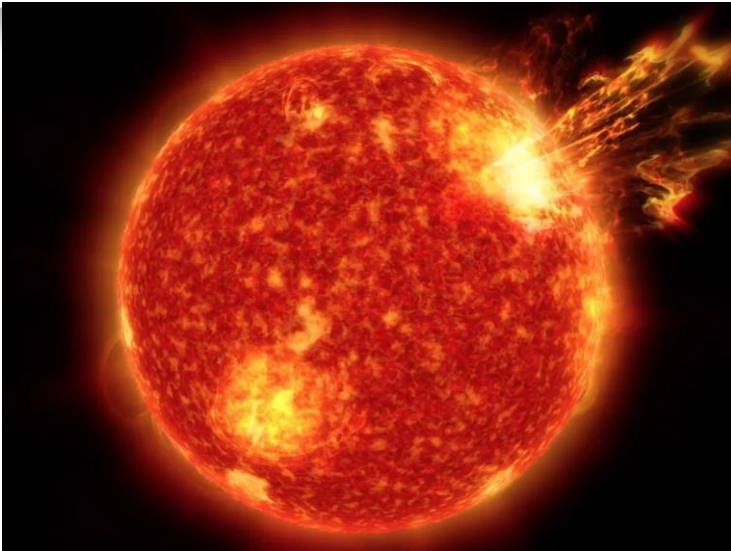
Space Weather Hazard

<http://www.bom.gov.au/aviation/data/education/space-weather.pdf>

## Recent Geomagnetic Storm SWX Event



- Geomagnetic Storm space weather event occurred between Sat, 22 April to Monday, 24 April 2023
- On Sat, it was G3 strong and escalated to G4 event, severe event.



### Possible impacts:

- GNSS positioning accuracy and availability degraded, availability of location information with vertical guidance through LPV-200 and position data through ADS may be affected. Impacts more severe in the equatorial and high latitude regions but they may also extend to middle latitudes.
- Ground-based augmentation systems (GBAS) for GPS may be compromised.
- HF communications may be severely degraded or unavailable in some regions.
- Strongest effects are likely over the polar regions where both GNSS-based positioning and HF communications may be completely unavailable.



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Headquarters  
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Central African  
(WACAF) Office  
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North Atlantic  
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Southern African  
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THANK YOU