ICAO BANGKOK UNITING AVIATION

Space Weather Advisory Service for Aviation

Ashwin Naidu
Australian Bureau of Meteorology

Australian Government
Bureau of Meteorology

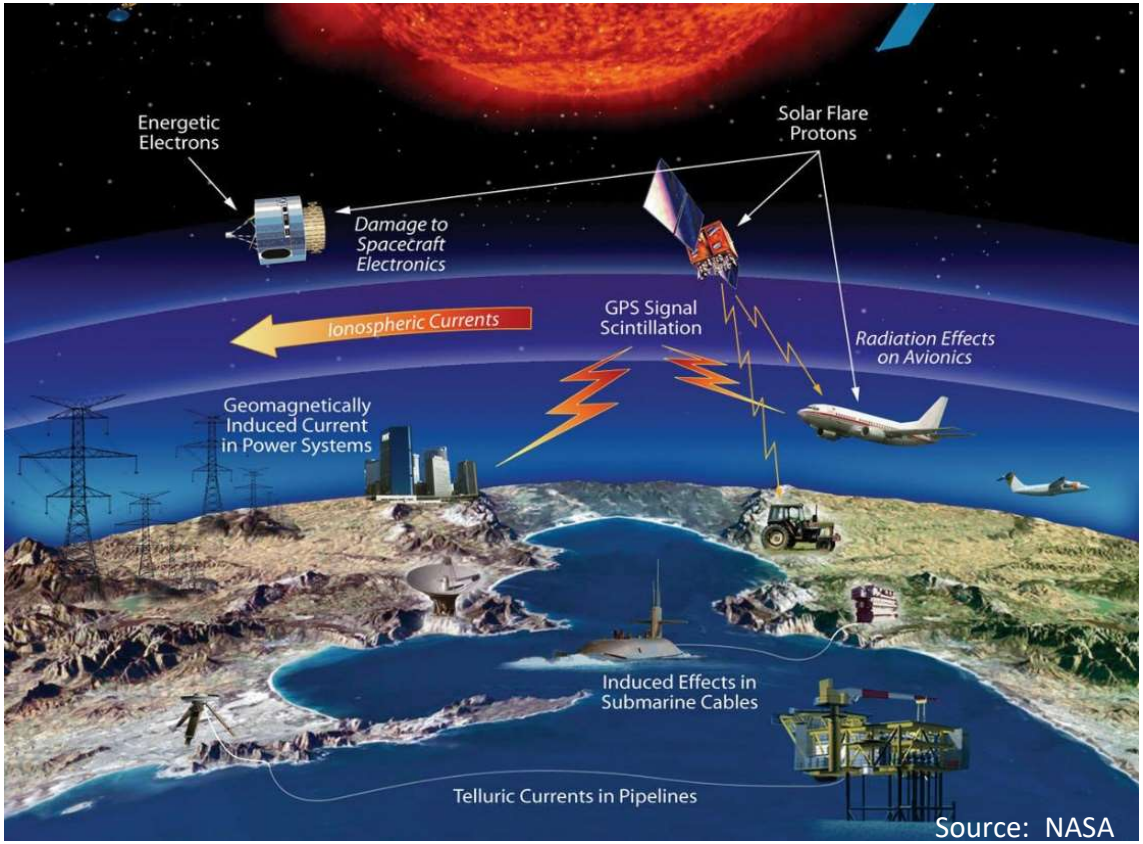
ICAO APAC_MID ATM Contingency Workshop

27 June 2024

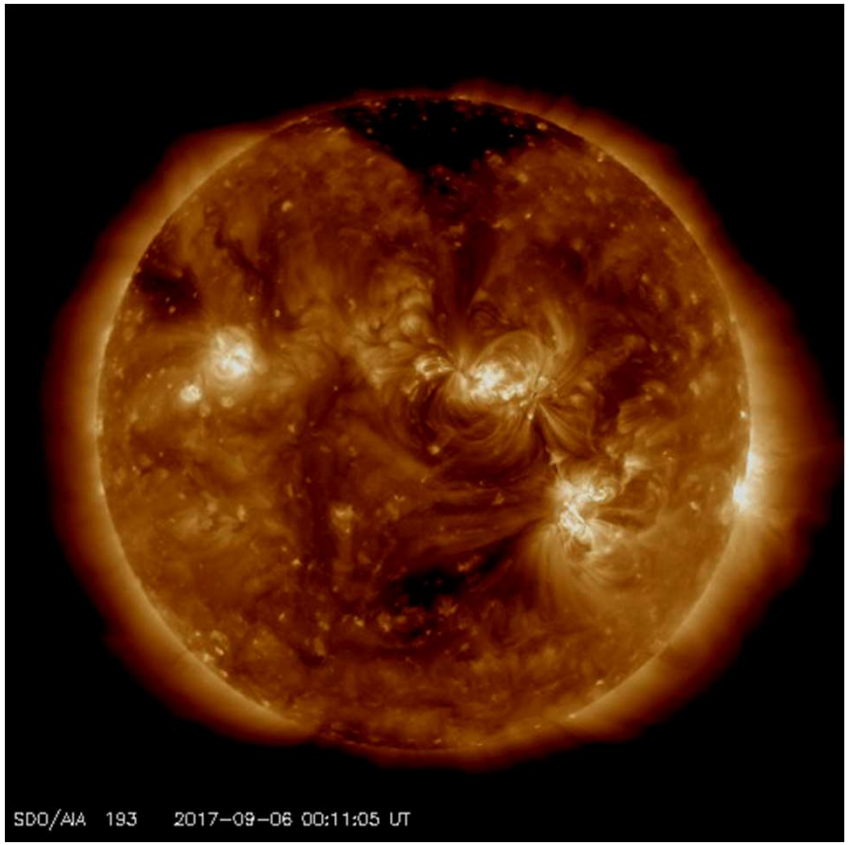
Outline

- What is space weather?
- Impacts on aviation
- ICAO development of space weather information
- The global space weather advisory service
- Space weather advisories
- Advisory dissemination
- Space weather updates and reports
- Space weather reference documents

What is space weather?



Source: NASA



Space Weather impacts on aviation

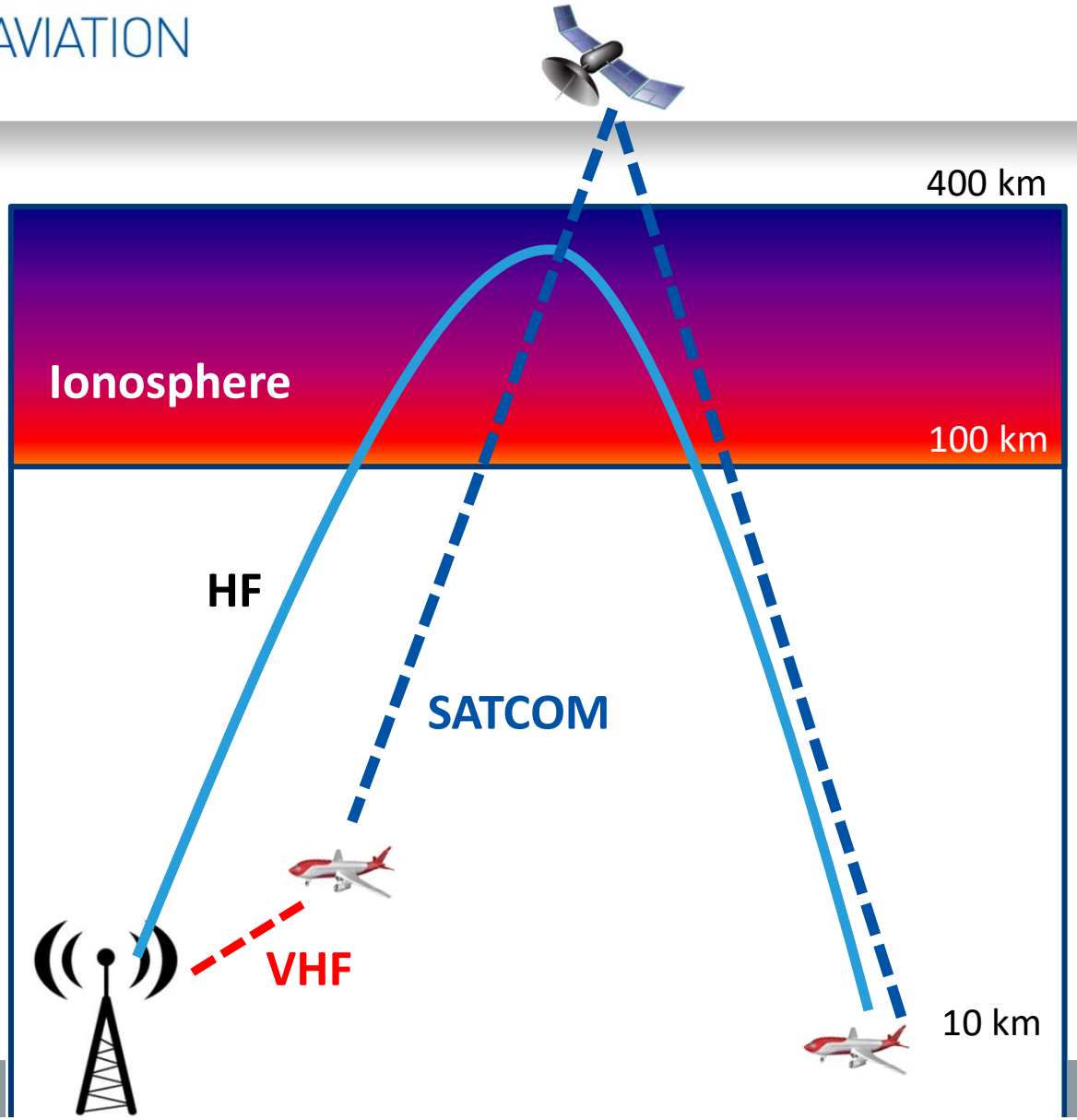
- HF communications
  - HF radio blackout (absorption)
    - X-ray flares -> dayside
    - Solar Protons -> Polar Cap
  - Compressed HF bandwidth (depression)
    - Geomagnetic storms
- Satellite communications
  - Ionospheric scintillation
- GNSS-based navigation and surveillance
  - Positioning errors (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

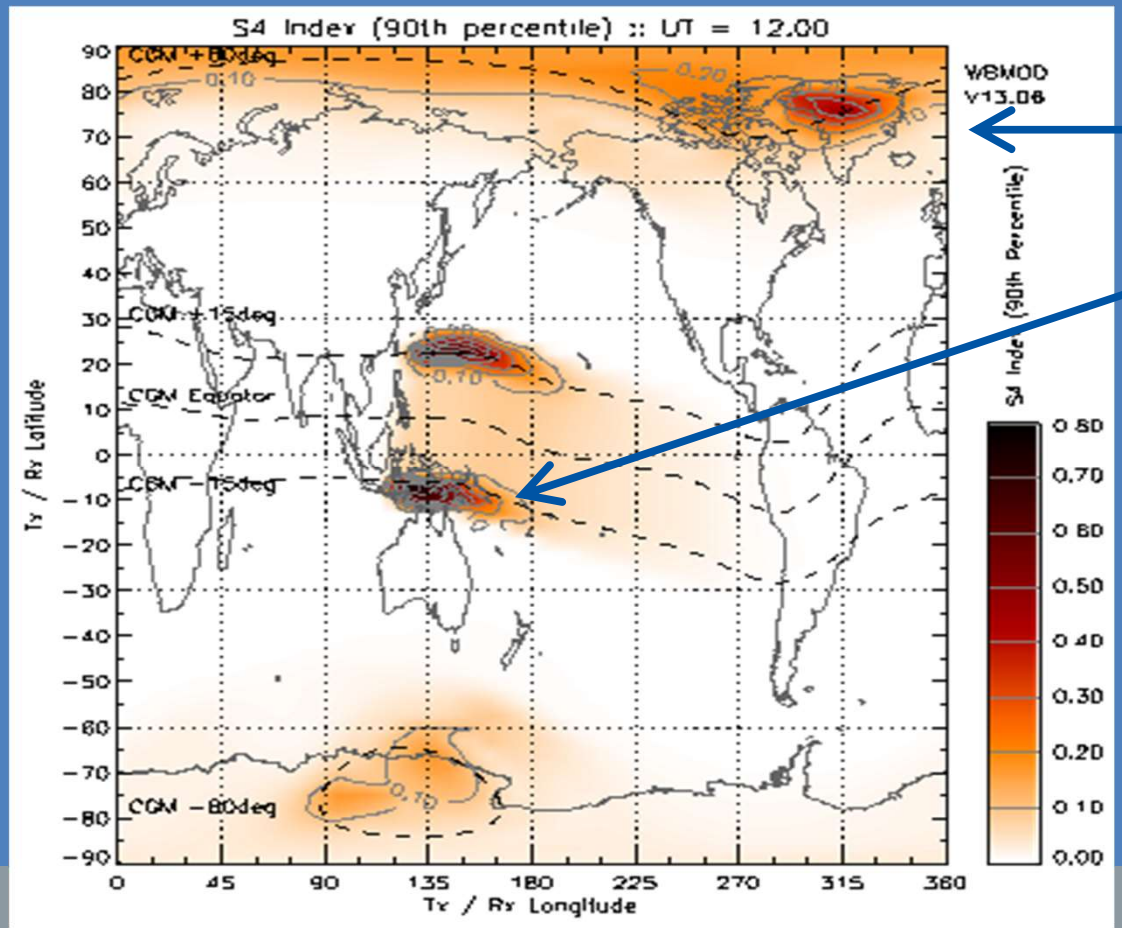
Space weather modifies the ionosphere, blocking or degrading HF communications

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

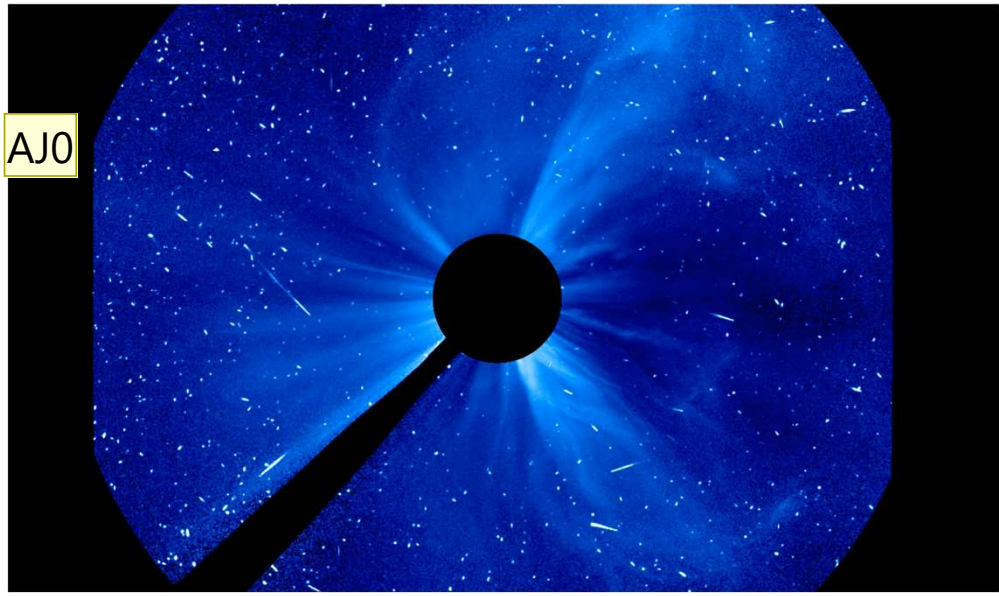
- Geomagnetic storms and substorms
- Equatorial Plasma Bubbles

Space Weather Impacts:

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

Impact of space weather on passenger and crew safety

- Large solar flares can release an associated burst of solar energetic particles (SEPs)
- SEPs follow Earth's magnetic field lines – penetrating more easily at the poles
- SEPs can penetrate aircraft interior and human tissue/cells
- Increased exposure of passengers and crew to high-energy atomic particles – particularly impacting polar flights



Slide 7

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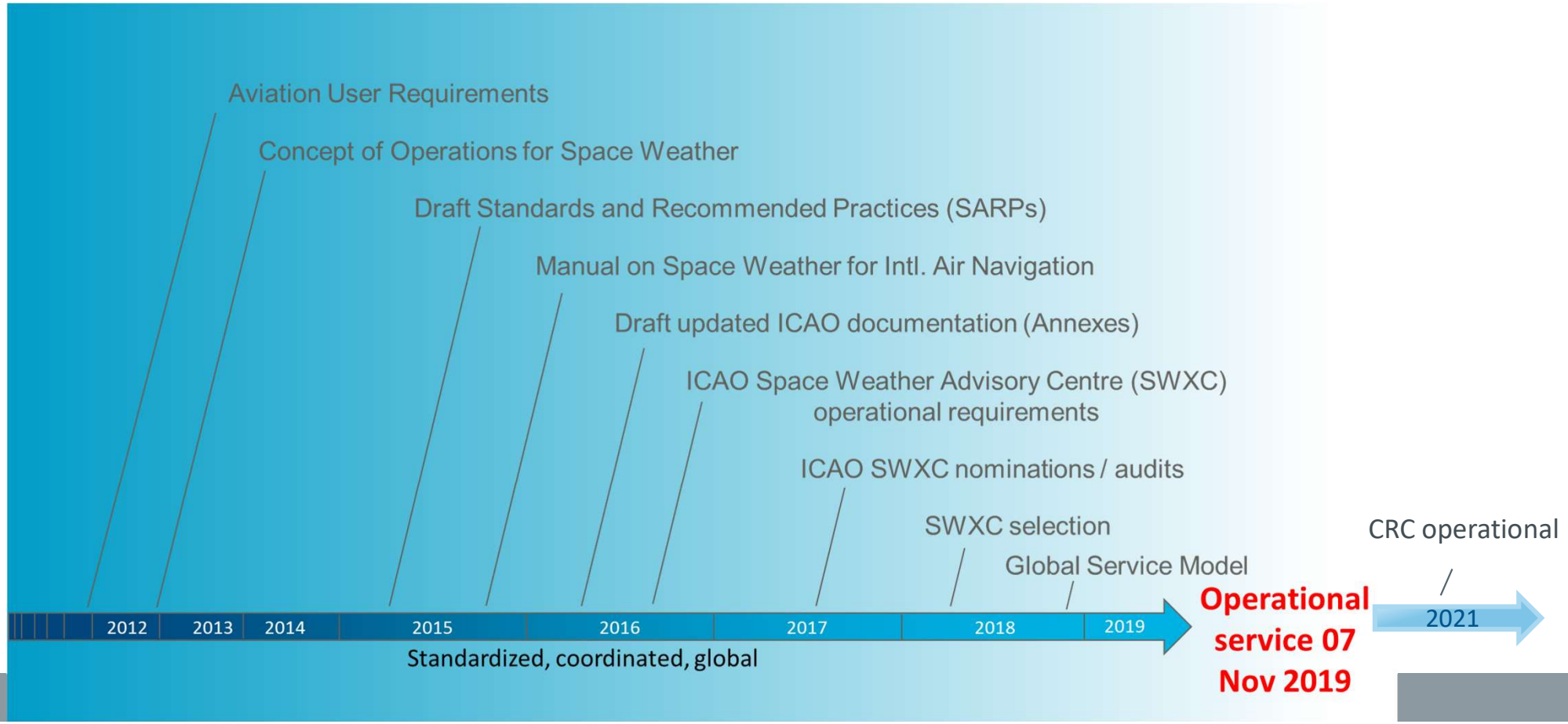
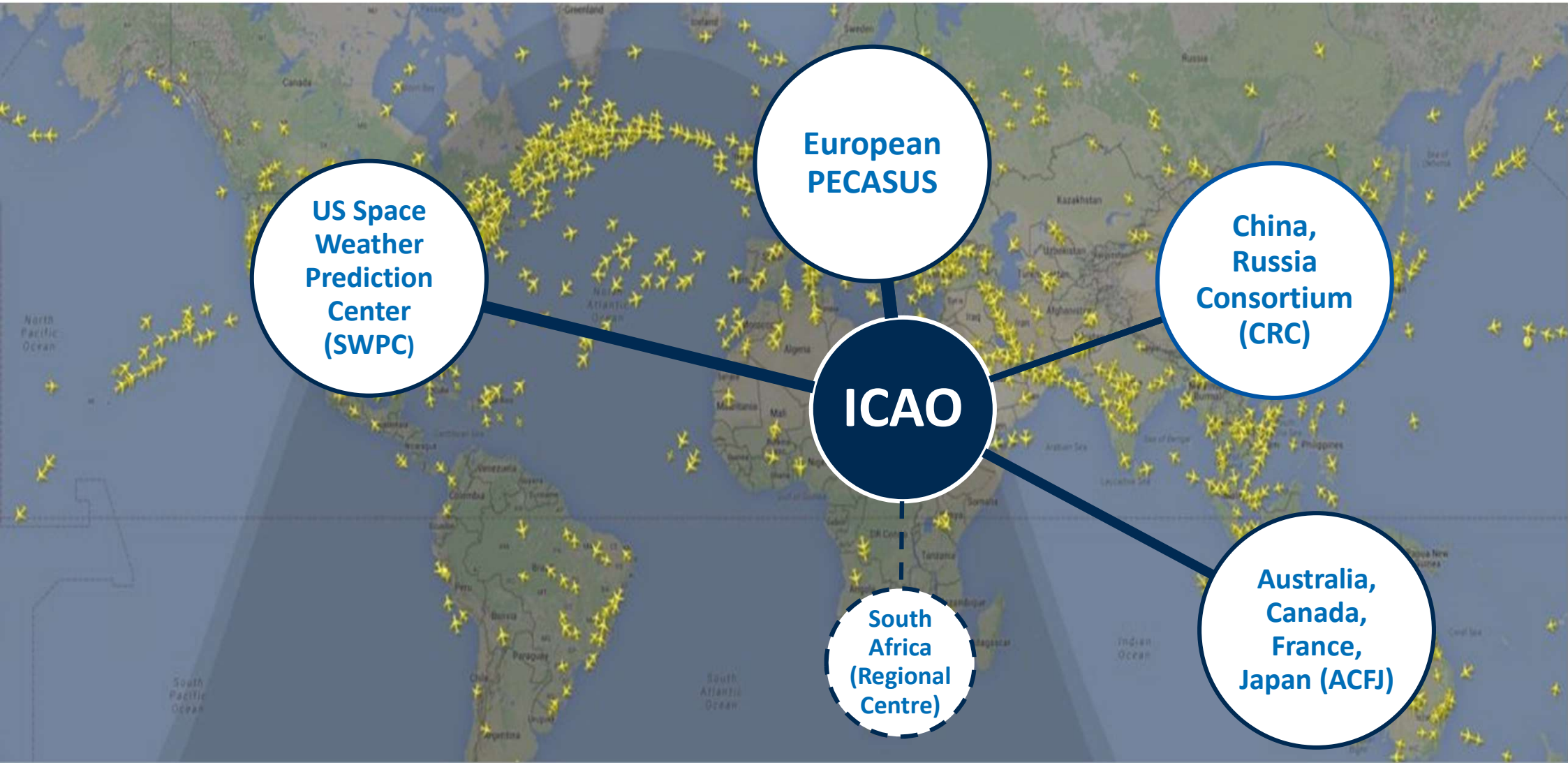
Towards an ICAO standardized global space weather service for aviation




European PECASUS
US Space Weather Prediction Center (SWPC)
China, Russia Consortium (CRC)
ICAO
South Africa (Regional Centre)
Australia, Canada, France, Japan (ACFJ)

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

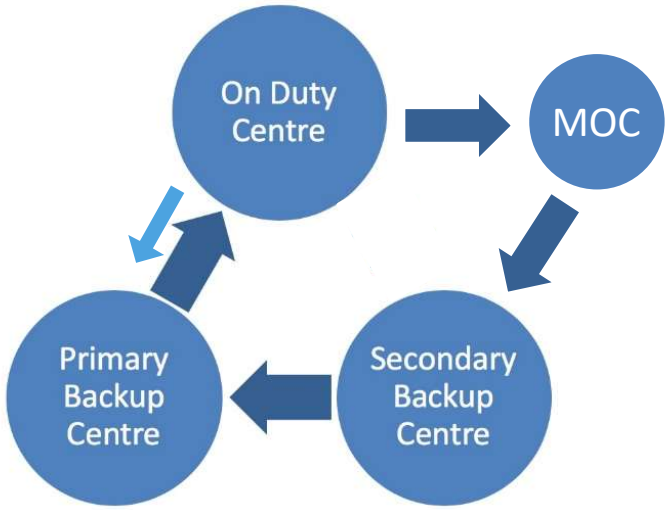
Rotation cycle

- 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)


International Standards and Recommended Practices

Annex 3 to the Convention on International Civil Aviation

Meteorological Service for International Air Navigation

Part I Core SARPs

Part II Appendices and Attachments

International Civil Aviation Organization

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/[n][n][n]n	ADVISORY NR:	2016/1
6	Number of advisory being replaced (C)	Number of the previously issued advisory being replaced	NR RPLC:	nnnn/[n][n][n]n	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[2] 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

UNKL / USKL

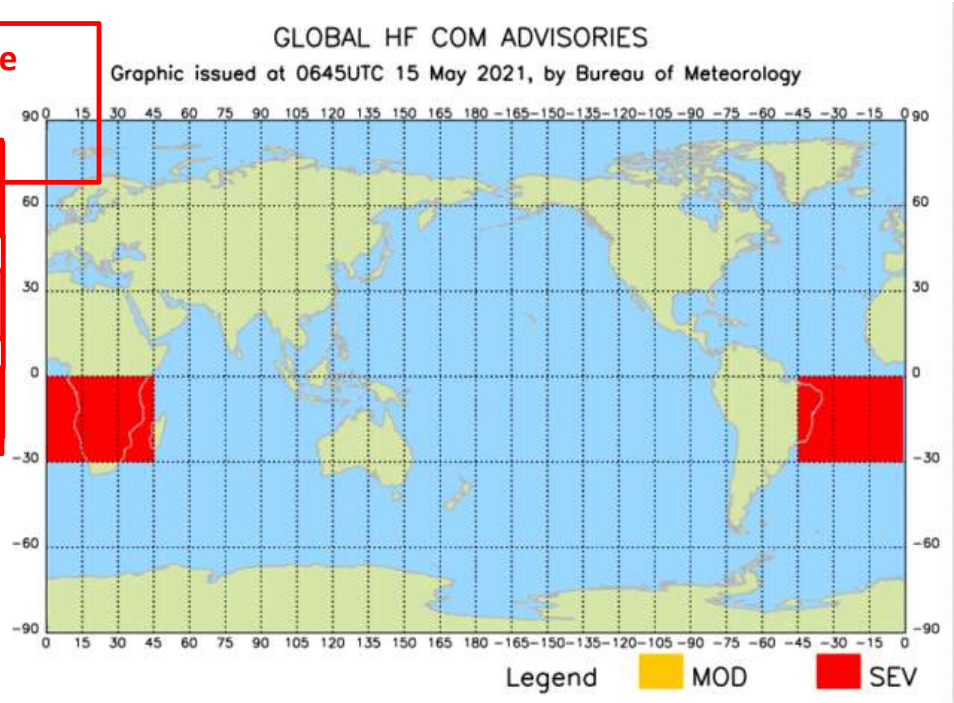
Details

Next update

[Free text]

DAYSIDE

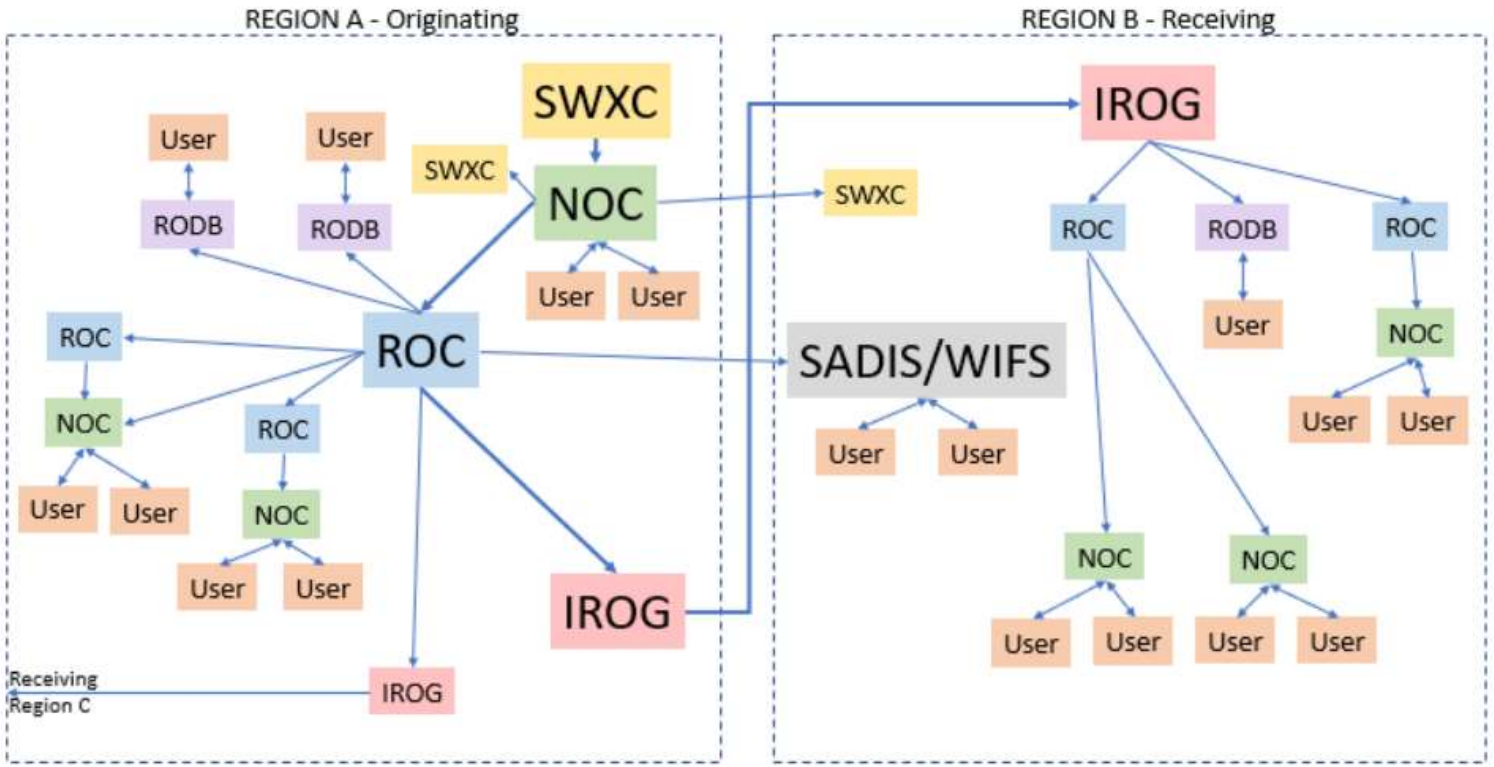
[ABV FLxx]



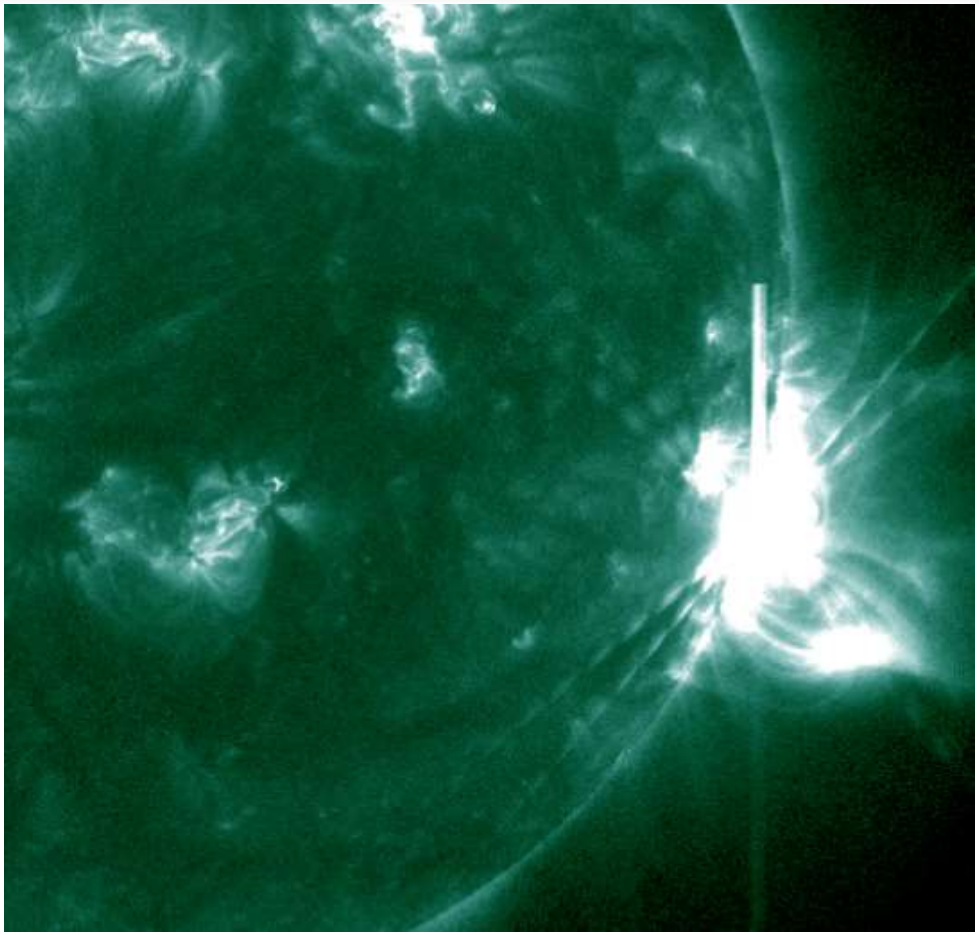
http://www.bom.gov.au/aviation/space-weather-advisories/

Space Weather Advisory (SWXA) dissemination

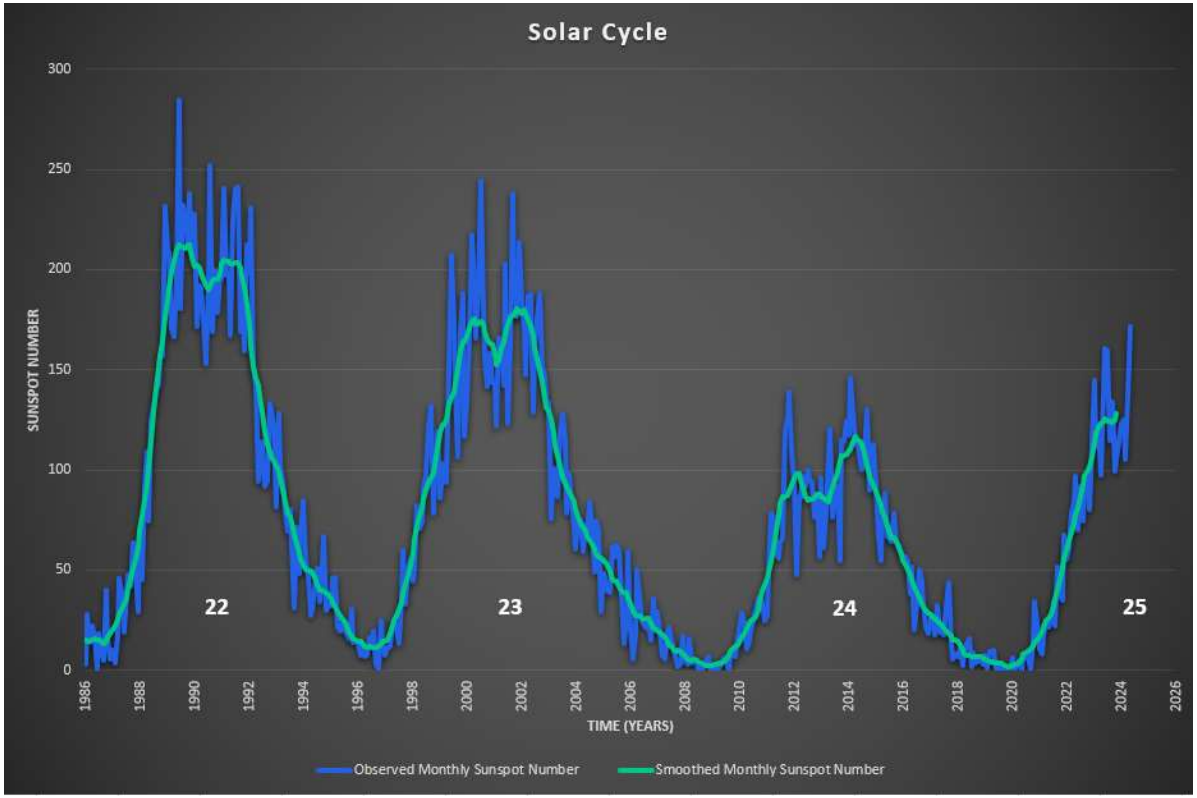
Ad hoc testing of the dissemination system (using SWXAs with STATUS: TEST) is conducted.



Space weather updates



- Solar activity has increased as we progress toward solar maximum of solar cycle 25
- Increased solar activity especially observed in September and December 2023, and February, March and May 2024.
- May 2024 was the largest monthly sunspot number since September 2002
- Solar maximum expected in 2024
- Solar cycle 25 is so far considered a weak to moderate strength cycle



How often will space weather advisories be issued?

HF COM (101 real advisories)

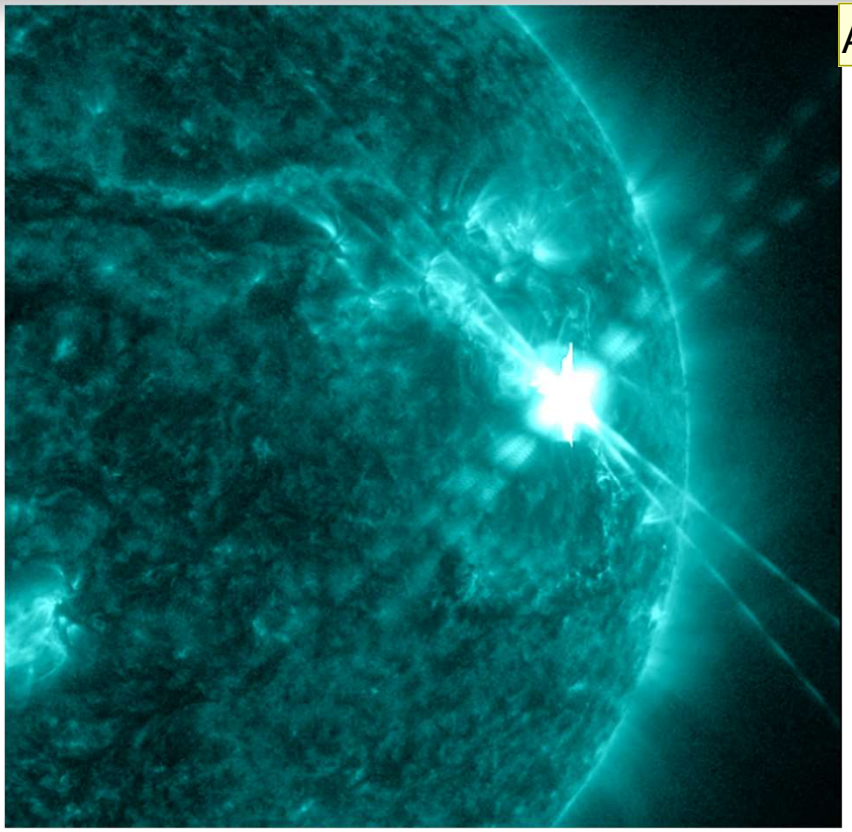
GNSS (293 real advisories)

Radiation (no real advisories)

A summary of all Space Weather Advisories issued by the ICAO centres from 8 August 2023 to 24 February 2024

Space Weather Impacts

- X2.8 flare on 14 December occurred during American daylight hours
- HF COM MOD advisory issued (shortwave fadeout)
- Radio comms interference with aircraft reported
- Several pilots reported communication disruptions "across the US"



X2.8 flare on 14 December 2023
Credit: NASA/SDO

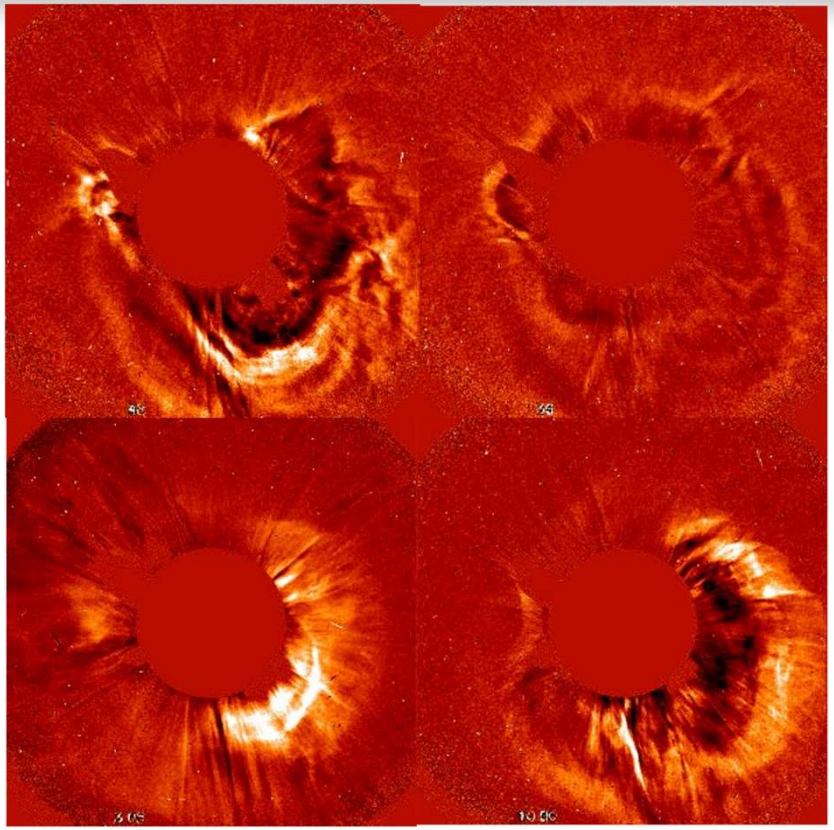
Slide 17

AJ0 Replace with image of the x2.8 flare

Andrew Jackling, 2024-04-16T04:13:16.359

G5 Geomagnetic Storm – May 2024

- Four coronal mass ejections (CMEs) were observed over 8th and 9th of May
- These CMEs arrived at Earth on 11th May
- G5 geomagnetic conditions were observed
- Geomagnetic storm lasted for approximately 37 hours
- Largest geomagnetic storm since the Halloween storms in 2003



Four halo coronal mass ejections (CMEs) observed over 8-9 May 2024.
Source: SOHO/ESA/NASA

G5 Geomagnetic Storm – Impacts

- Southern polar flights rerouted to avoid HF areas most impacted by storm
- Widespread HF communication issues reported, some flights unable to use HF and had to seek alternatives
- All trans-Tasman flights continued to operate safely but HF comms were interrupted at times

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

G5 Geomagnetic Storm – How does this event compare?

- Not all G5 geomagnetic storms are equal

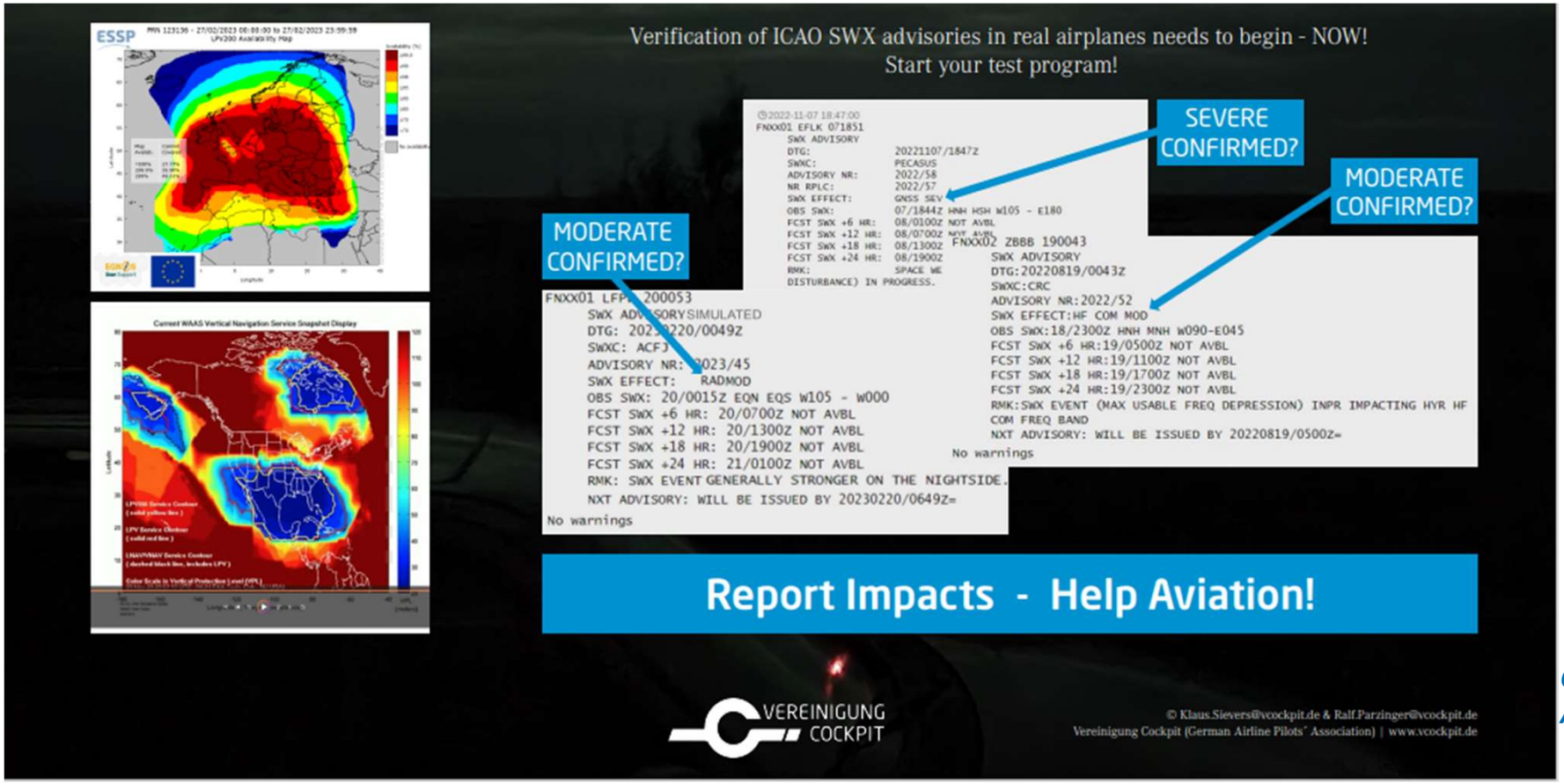
Storm	G-scale	Dst-Index (global)
2001 March	G5	-350 nT
2003 Halloween	G5	-383 nT
2024 May	**G5**	**-412 nT**
1989 Quebec	G5	-589 nT
1921 May	G5	-907 nT*
1859 Carrington Event	G5	-800 to -1750 nT*

* estimated

Provision of SWXA by ANSP

- Are SWXA is shared currently?
- How?
- SWX should be shared via FIS to aircraft in flight similar to SIGMETS

Space Weather Reports



Credit: Klaus Sievers –German Airline Pilot Association

Space Weather Reports

SPACE WEATHER: IT IS REAL !!!

4 AIRCRAFT, 2 AIRPORTS >

NEAR SIMULTANEOUS LPV FAILURE !

Report from Canadian CADORS system. Occurrance: 25 Feb 2023

Report:

2023Q0875

Date Entered: 2023-03-07

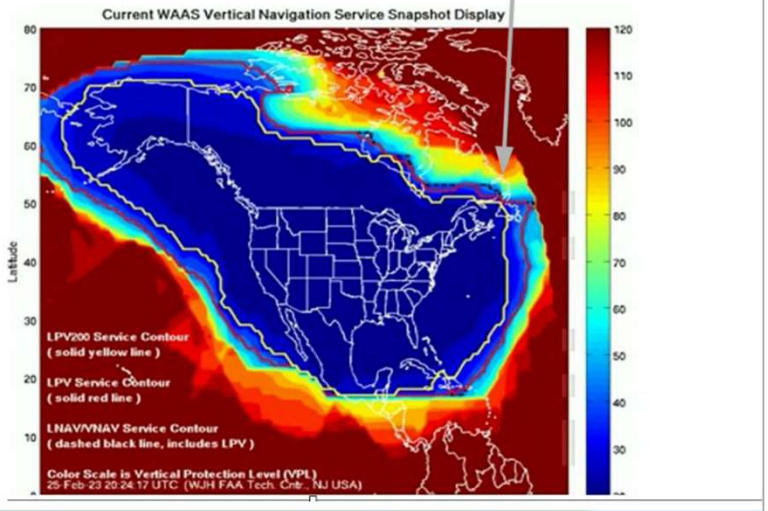
Narrative:

On approach for Runway 25 at Kuujjuaq, QC (CYVP), an Exact Air Inc. Beech A100 (C-FLTS/ET823) from Tasiujaq, QC (CYTQ) to Kuujjuaq, QC (CYVP) mentioned having lost the localizer performance with vertical guidance (LPV) in lateral navigation (LNAV) and during the previous approach for CYTQ. Following this, an Air Inuit Ltd. de Havilland DHC-8-314 (C-FIAI/AIE827) from Kangiqsualujjuaq, QC (Georges River) (CYLU) to Kuujjuaq, QC (CYVP) mentioned having the same problem when on approach for Runway 25. An Air Inuit Ltd. de Havilland DHC-6-300 (C-GTYX/AIE659) from Kangiqsujuaq, QC (Wakeham Bay) (CYKG) to Kuujjuaq, QC (CYVP) that was following C-AIE827 had the same problem on approach for Runway 25 at CYVP and for its previous approach at CYKG.

ICAO SWx ADVISORY ? None known

NOTAM ? None issued

Consequences ? To be discussed at the Met Panel and other venues.

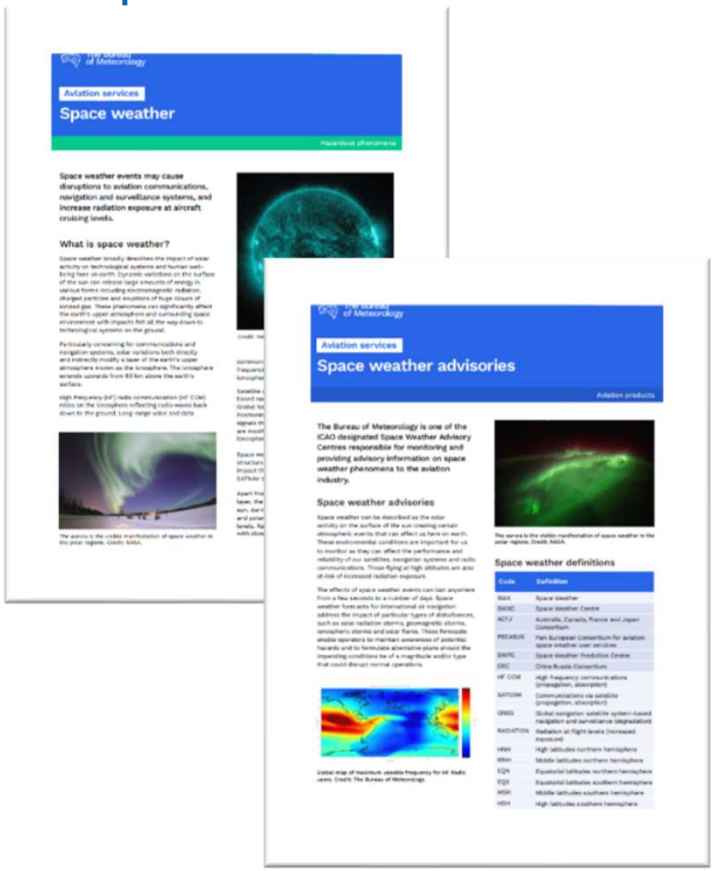


VEREINIGUNG COCKPIT

blue = good, red = bad

Credit: Klaus Sievers –German Airline Pilot Association

Space Weather Reference Documents



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

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THANK YOU