ICAO BANGKOK UNITING AVIATION

Space Weather Advisory Service for Aviation

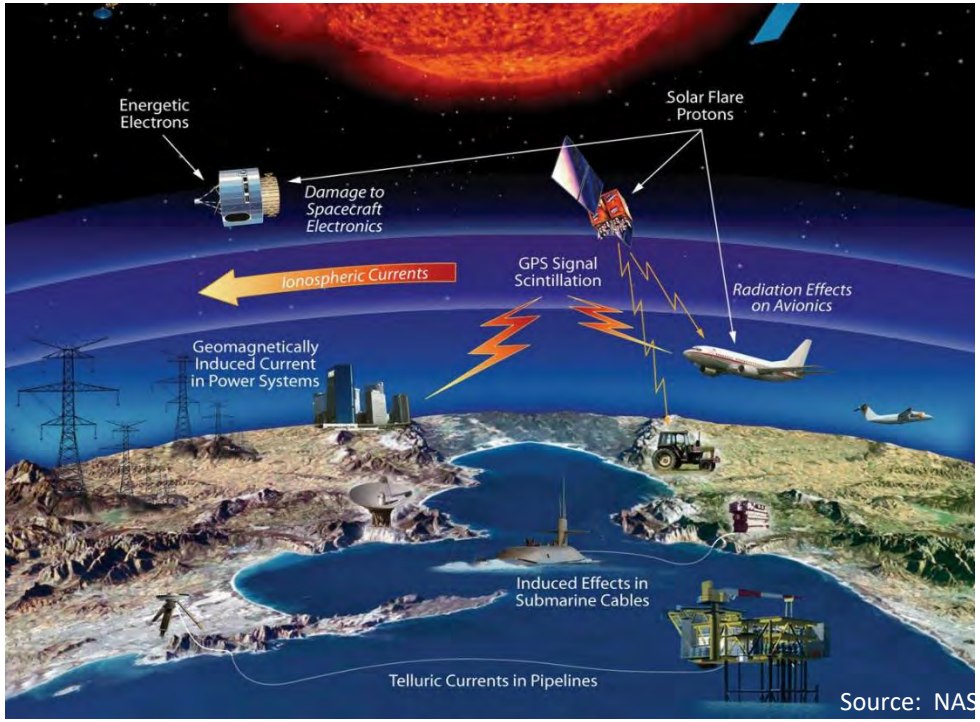
Ashwin Naidu
Australian Bureau of Meteorology

MET/R WG/10 – May 24-28 2021

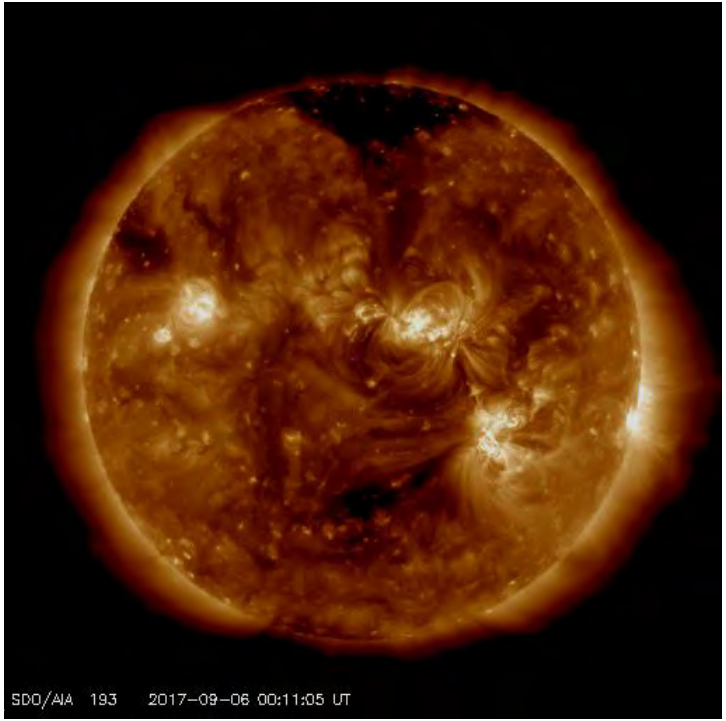
Outline

- What is space weather?
- Impacts on aviation (HF COM, GNSS, RADIATION)
- 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?



Source: NAS



Space Weather impacts on aviation

IMAGE: CORBIS, RUSS ROHDE

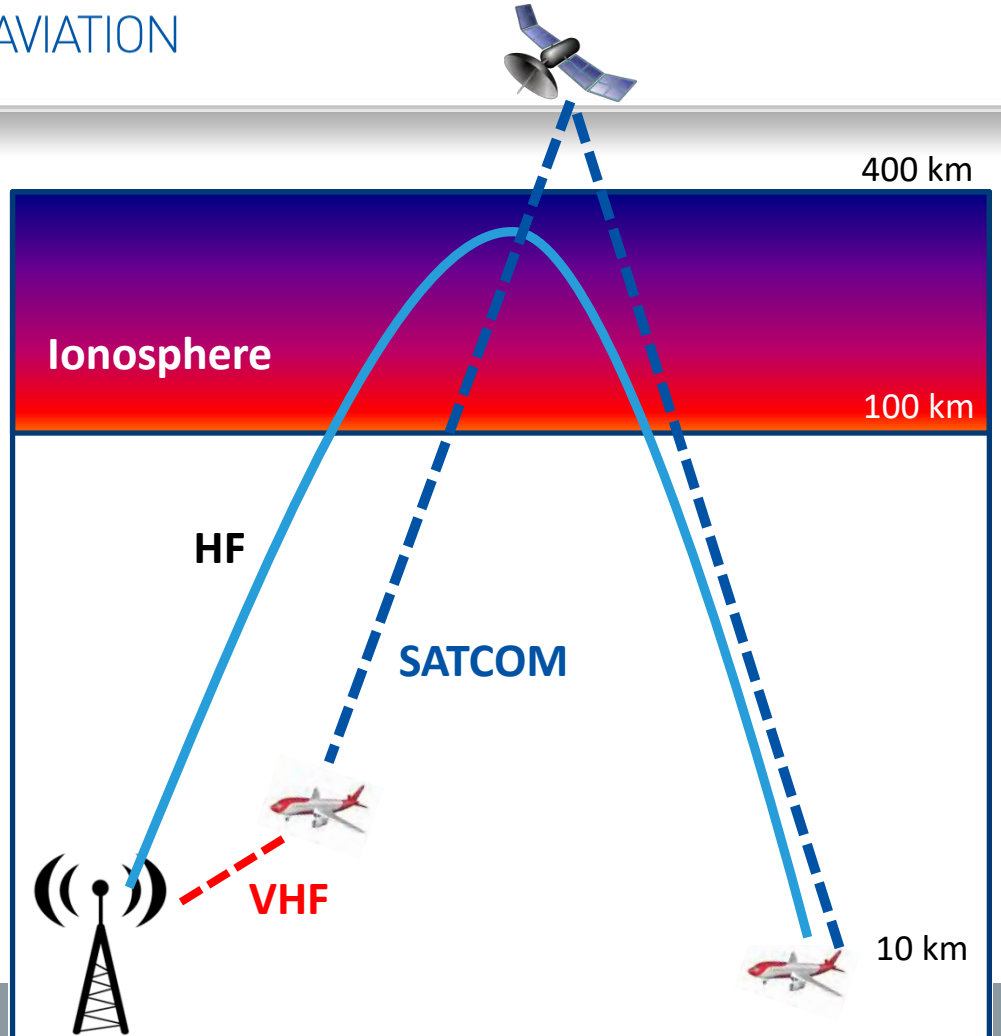
- HF communications
  - HF radio blackout (absorption)
    - X-ray flares → dayside
    - Solar Protons → Polar Cap
  - Compressed HF bandwidth (depression)
    - Geomagnetic storms
- Satellite communications
  - Ionospheric scintillation
- GNSS-based navigation and surveillance
  - Positioning errors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

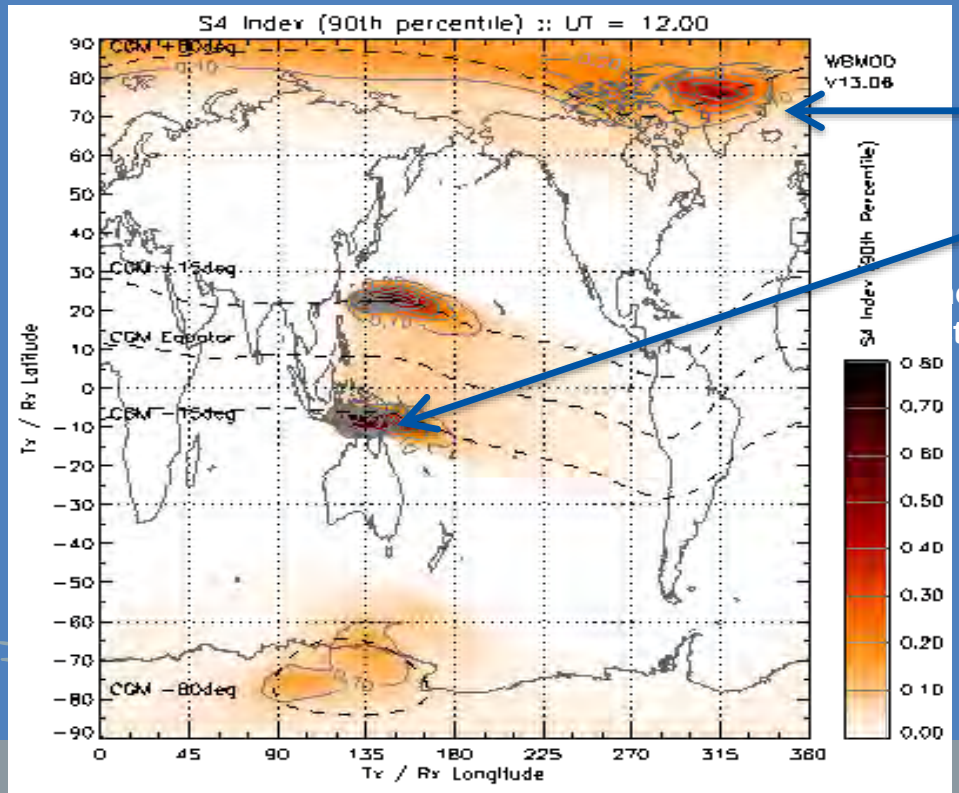
Space weather modifies the ionosphere, blocking or degrading HF communications

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

ospheric
turbance

Space Weather Impacts:

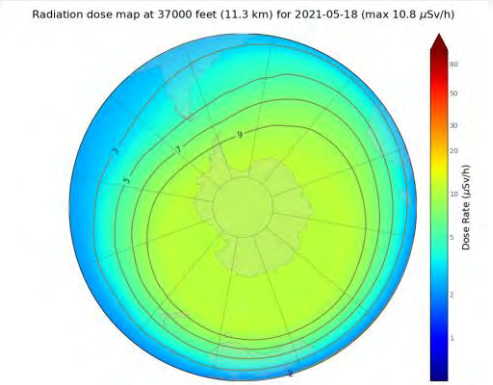
- Lower positioning accuracy
- Loss of satellite tracking
- Poor Quality / Availability of SATCOM

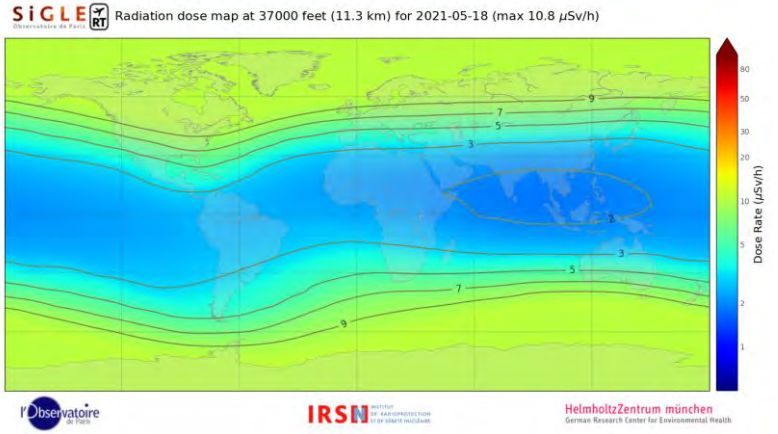
Impact of space weather on radiation levels

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

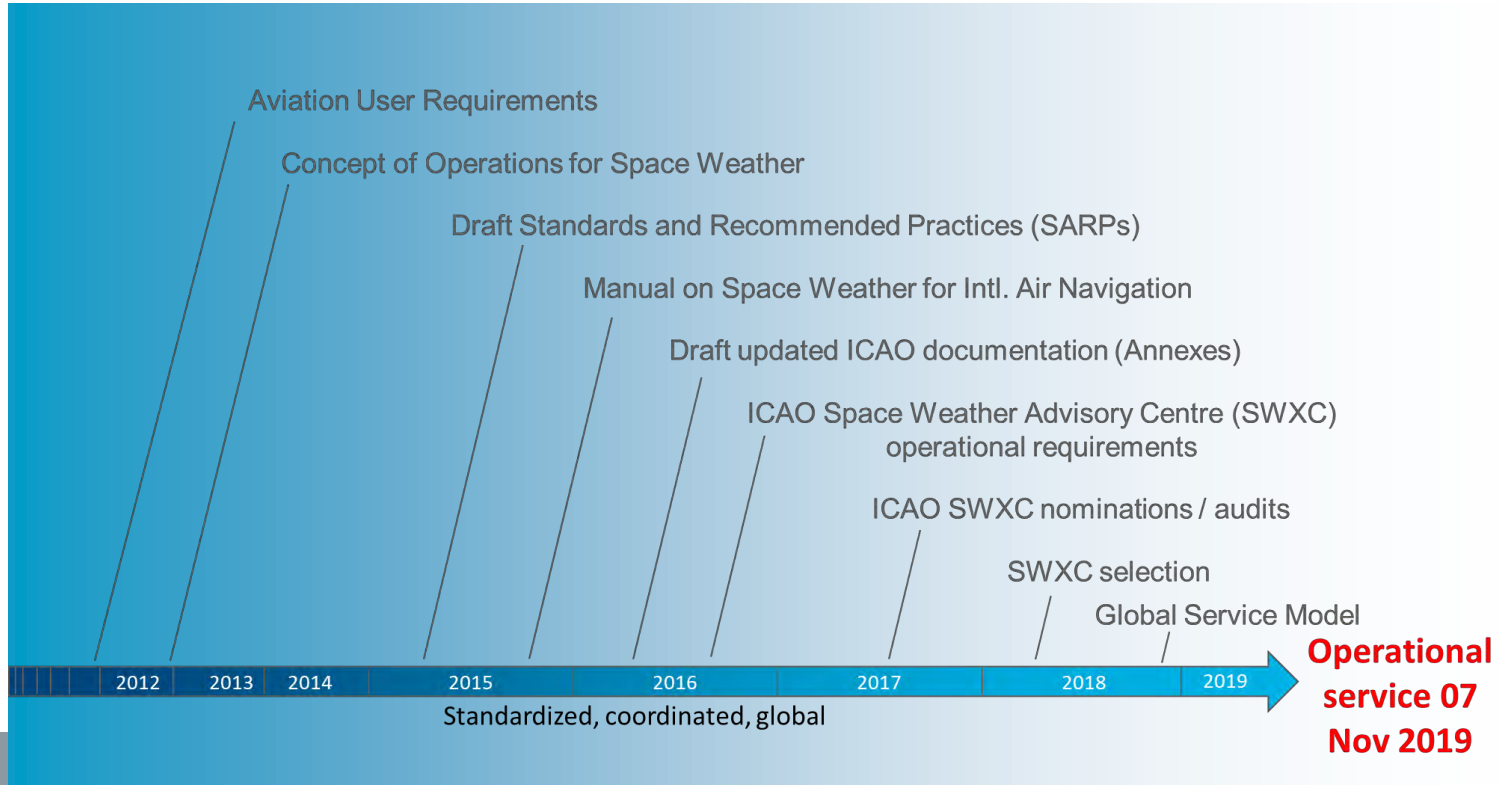
Space Weather Impacts:

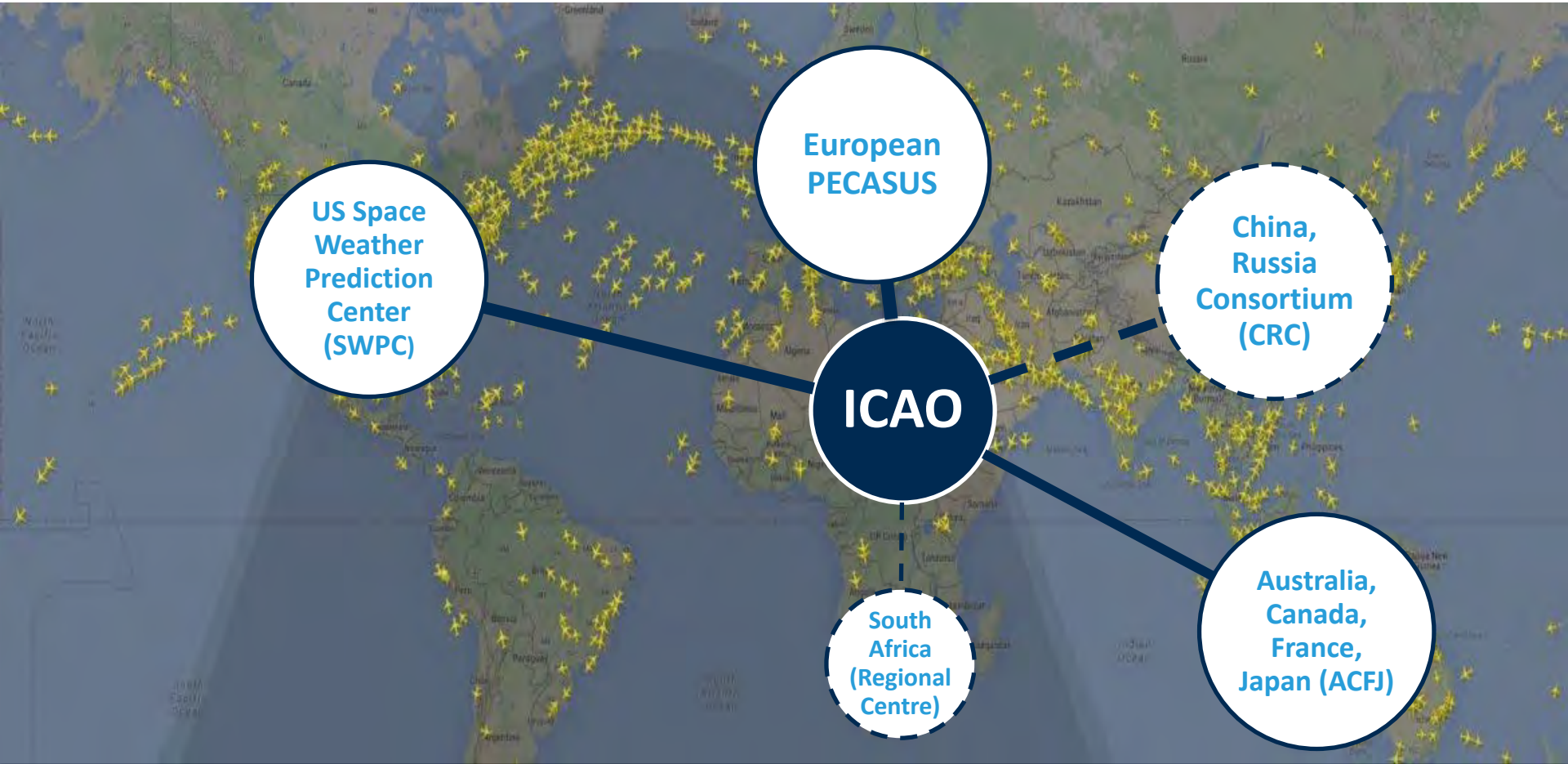
- Increased radiation dose rates at flight altitude in Polar Regions
- Poorly understood impacts on avionics
- Impacts stronger at higher altitude and higher latitude



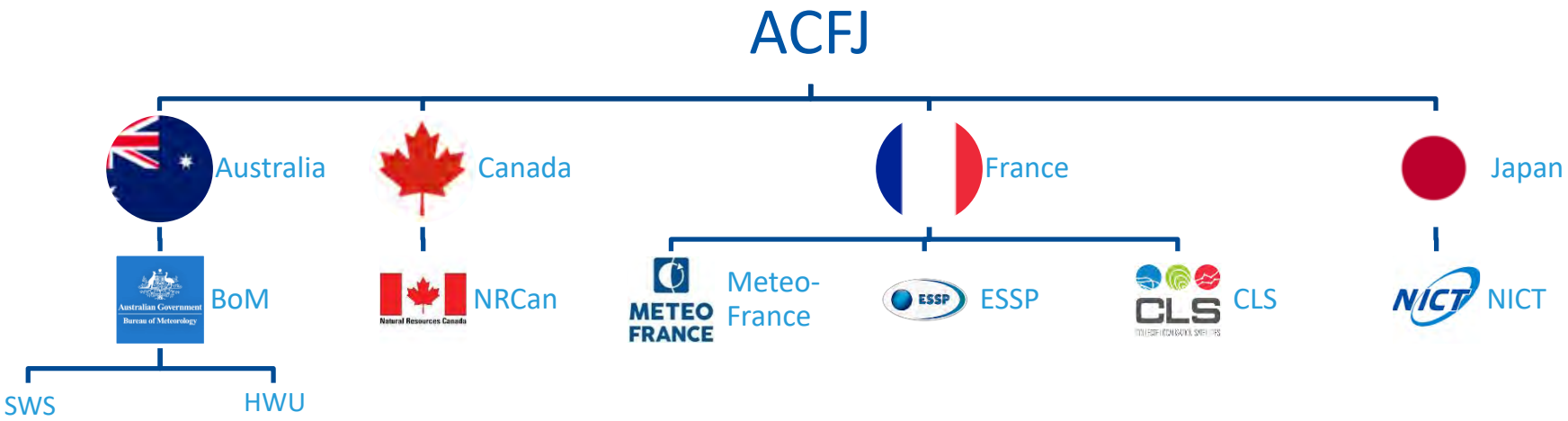


Towards an ICAO standardized global space weather service for aviation




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

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



24 / 7 global space weather advisory service for aviation

A global space weather advisory service

Coordination model

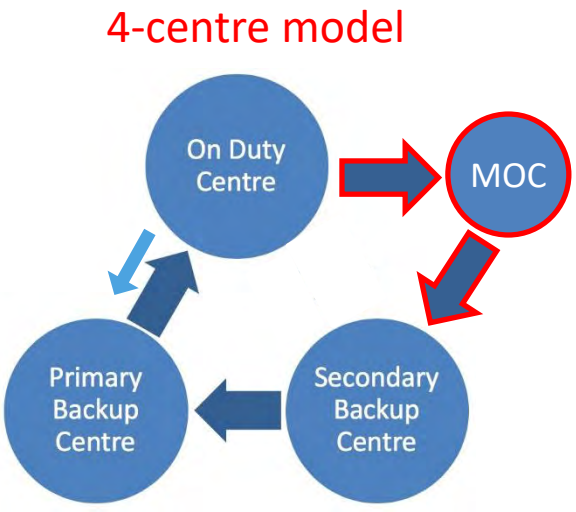
- Global centers active all the time and currently rotate through the following roles:
  On Duty Center → Primary Backup Center → Secondary Backup Center
- The On Duty Center is solely responsible for the creation and dissemination of all defined SWX products
- The Primary and Secondary Backup Centers are on standby
- From 2021, a fourth global centre (China-Russia Consortium) will be added to the service, and a fourth role (Maintenance and Observation Centre, MOC) 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



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

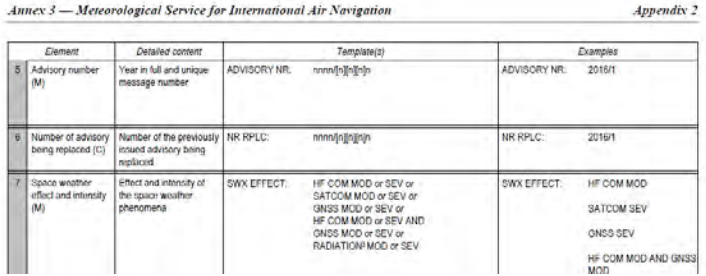
Part II
Appendices and Attachments

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**)

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 MOD or SEV	SWX EFFECT:	HF COM MOD SATCOM SEV GNSS SEV HF COM MOD AND GNSS MOD

Two formats:

- Simple text
- XML (https://schemas.wmo.int/iwxxm/3.0/spaceWxAdvisory.xsd)

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=

Time and Location

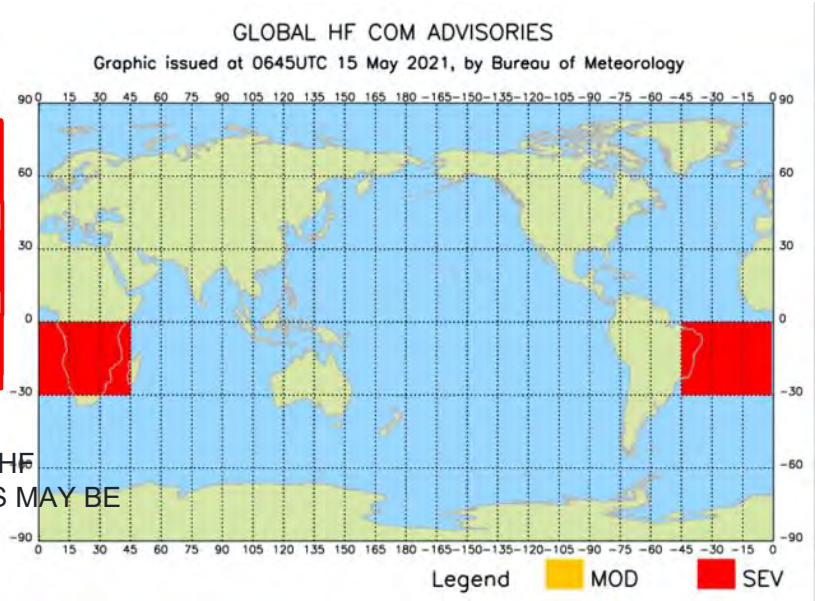
Details

Next update

[Free text]

DAYSIDE

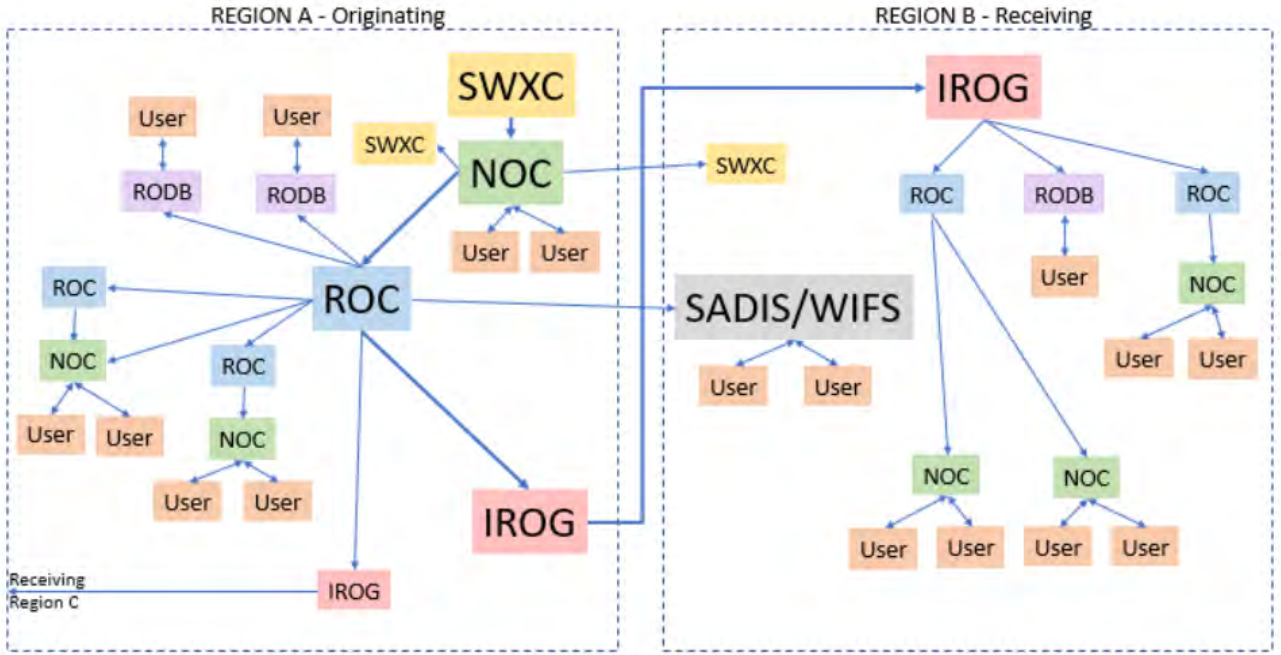
[ABV FLxx]



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

Space Weather Advisory (SWXA) dissemination

Regular testing of the dissemination system (using SWXAs with STATUS: TEST) has been conducted since 2019 and will continue through 2021
(1 test advisory every 2 weeks)

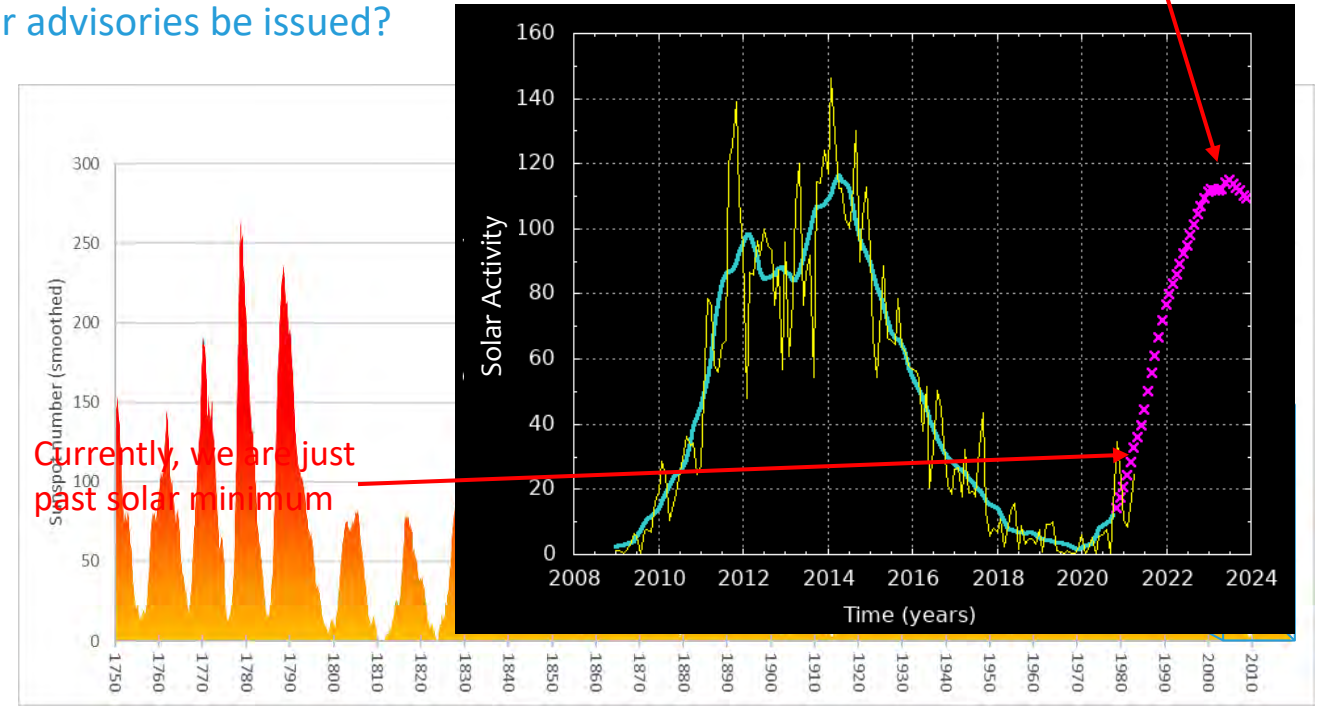


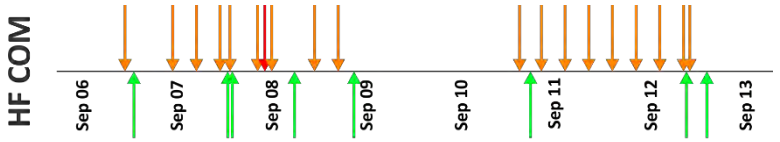
Operational Considerations

How often will space weather advisories be issued?

Space weather events closely follow the 11-year solar activity cycle.

More intense events are expected to occur near **solar maximum**





How often will space weather advisories be issued?

Rarely during solar minimum

Since the commencement of the service in Nov 2019, only one space weather event has reached ICAO advisory thresholds:

In September 2020, 13 space weather advisories were issued by ACFJ over a four-day period relating to a MODerate HF COM disturbance across Europe →

More commonly near solar max

SWX Effect	Advisory number	Replaced	Issuance time	OBS SWX
HF COM MOD	2020/26	-	28-Sep-2020, 05:55:00 UTC	28/0532Z HNH MNH E000 - E060
	2020/27	2020/26	28-Sep-2020, 11:31:00 UTC	28/1124Z NO SWX EXP (end of event)
HF COM MOD	2020/28	-	28-Sep-2020, 23:19:00 UTC	28/2302Z HNH MNH E000 - E120
HF COM MOD	2020/29	2020/28	29-Sep-2020, 02:33:00 UTC	29/0228Z HNH MNH W120 - E020 (update)
	2020/30	2020/29	29-Sep-2020, 05:04:00 UTC	29/0500Z NO SWX EXP (end of event)
HF COM MOD	2020/31	-	29-Sep-2020, 19:24:00 UTC	29/1912Z HNH MNH EQN E015 - E060
	2020/32	2020/31	29-Sep-2020, 20:23:00 UTC	29/2012Z NO SWX EXP (end of event)
HF COM MOD	2020/33	-	30-Sep-2020, 04:15:00 UTC	30/0352Z HNH E000 - E075
	2020/34	2020/33	30-Sep-2020, 06:23:00 UTC	30/0612Z NO SWX EXP (end of event)
HF COM MOD	2020/35	-	30-Sep-2020, 23:12:00 UTC	30/2252Z HNH E000 - E045
	2020/36	2020/35	1-Oct-2020, 01:23:00 UTC	01/0112Z NO SWX EXP (end of event)
HF COM MOD	2020/37	-	1-Oct-2020, 20:08:00 UTC	01/1952Z HNH MNH EQN E000 - E060
	2020/38	2020/37	1-Oct-2020, 22:13:00 UTC	01/2202Z NO SWX EXP (end of event)

Space weather mitigation

To mitigate the immediate effects of severe space weather, operators might take the following actions.

High-frequency radio communications

- Switch to lower HF radio frequencies during ionospheric storms and higher HF radio frequencies during solar flares/HF absorption events (per ICAO recommendations).
- Use alternate forms of communication, where available, such as satellite or very high frequency (VHF) radio.
- Delay or re-route flights where alternative communication technology is inadequate, particularly in polar regions

Satellite-based navigation and surveillance

- Increase spacing between aircraft on the ground or in-flight to mitigate increased GNSS position uncertainties.
- Use alternative navigation technology in impacted locations. Impacts are strongest in high latitudes, and near the equator after dusk.
- Ground-based and space-based GNSS augmentation system operators should monitor service performance and execute risk mitigation plans.

Radiation exposure on polar routes

- Reduce altitude of polar flights. A 2100 m decrease in altitude lowers the radiation dose by approximately 50%.
- Re-route polar flights to lower latitudes. The Earth's magnetic field provides greater shielding against dangerous radiation at latitudes less than about 60°.

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-wx-advisories.pdf

Space Weather Hazard
http://www.bom.gov.au/aviation/data/education/space-weather.pdf

ICAO

THANK YOU