



ICAO BANGKOK

UNITING AVIATION

Space Weather Advisory Service for Aviation

Ashwin Naidu

Australian Bureau of Meteorology

MET/R WG/10 – May 24-28 2021

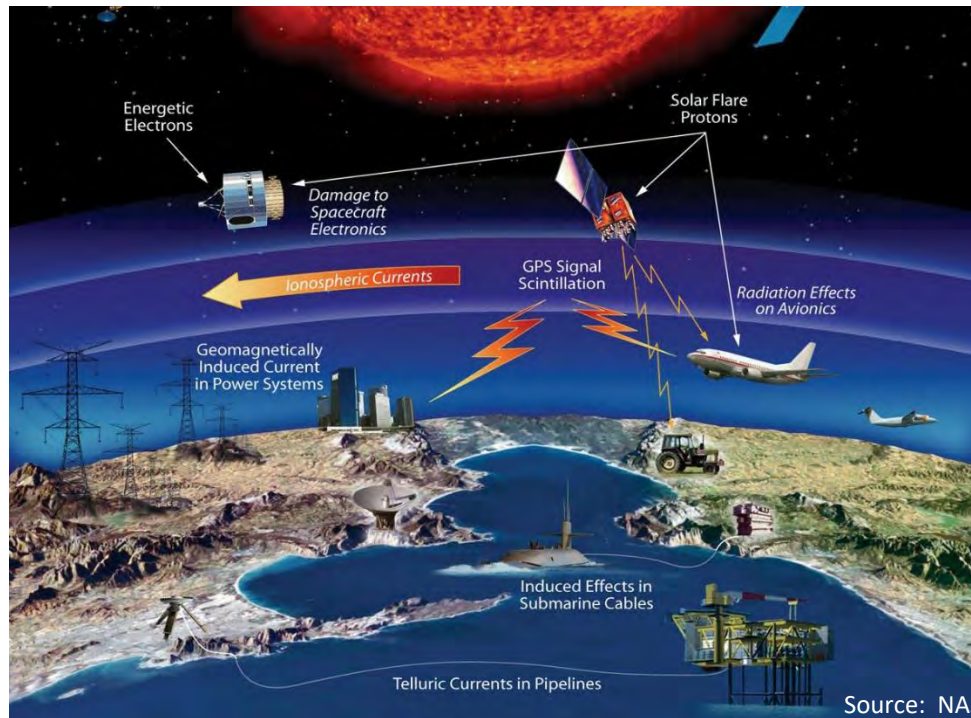




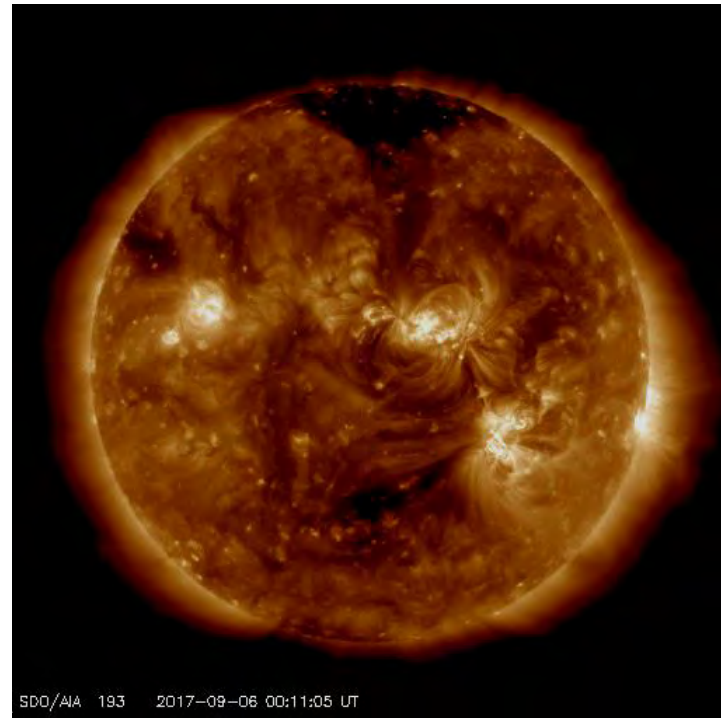
Outline

- 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: NASA



SDO/AIA 193 2017-09-06 00:11:05 UT

Space Weather impacts on aviation



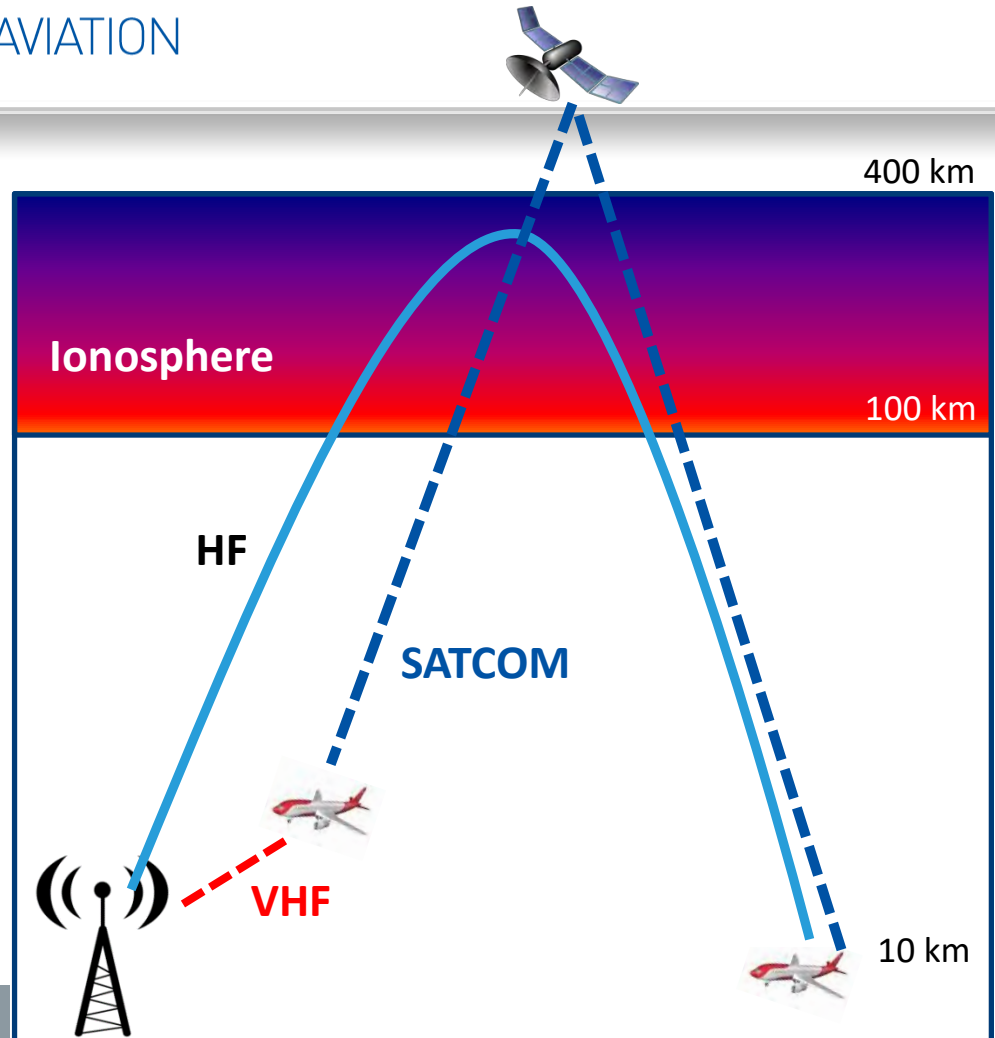
- **HF communications**
 - HF radio blackout (absorption)
 - X-ray flares → dayside
 - Solar Protons → Polar Cap
 - Compressed HF bandwidth (depression)
 - Geomagnetic storms
- **Satellite communications**
 - Ionospheric scintillation
- **GNSS-based navigation and surveillance**
 - Positioning errors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

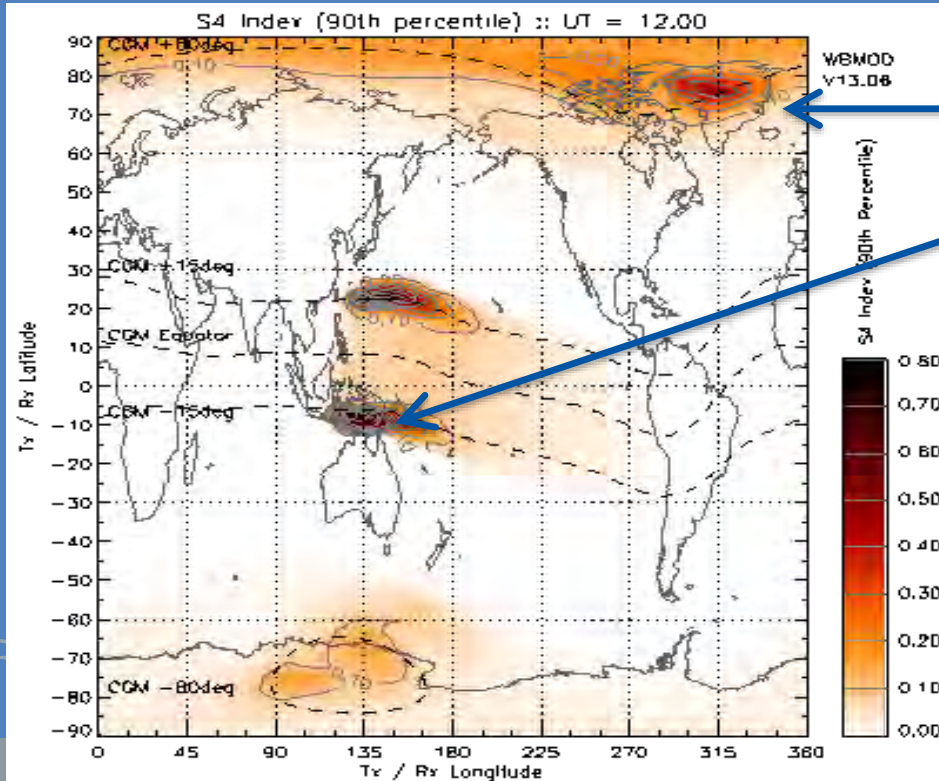
Space weather modifies the ionosphere,
blocking or degrading HF communications

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
turbulence

Space Weather Impacts:

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

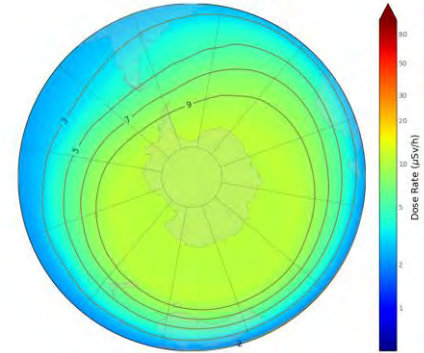
Impact of space weather on radiation levels

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

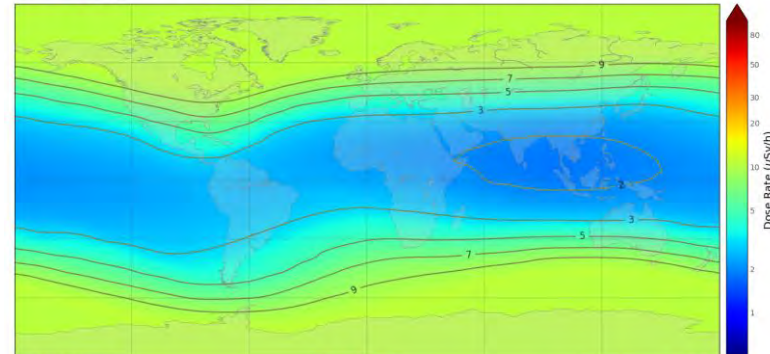
Space Weather Impacts:

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

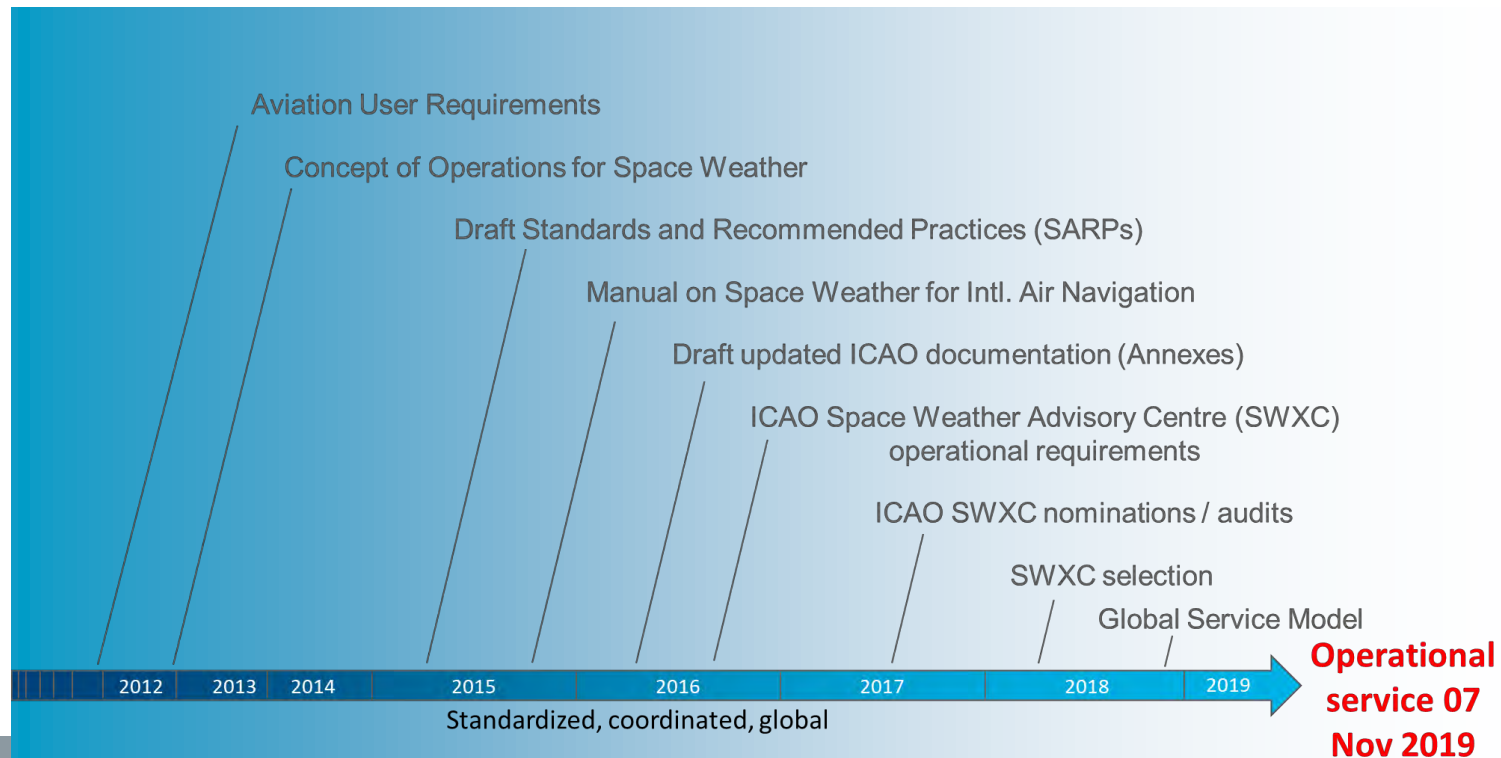
Radiation dose map at 37000 feet (11.3 km) for 2021-05-18 (max 10.8 $\mu\text{Sv/h}$)



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



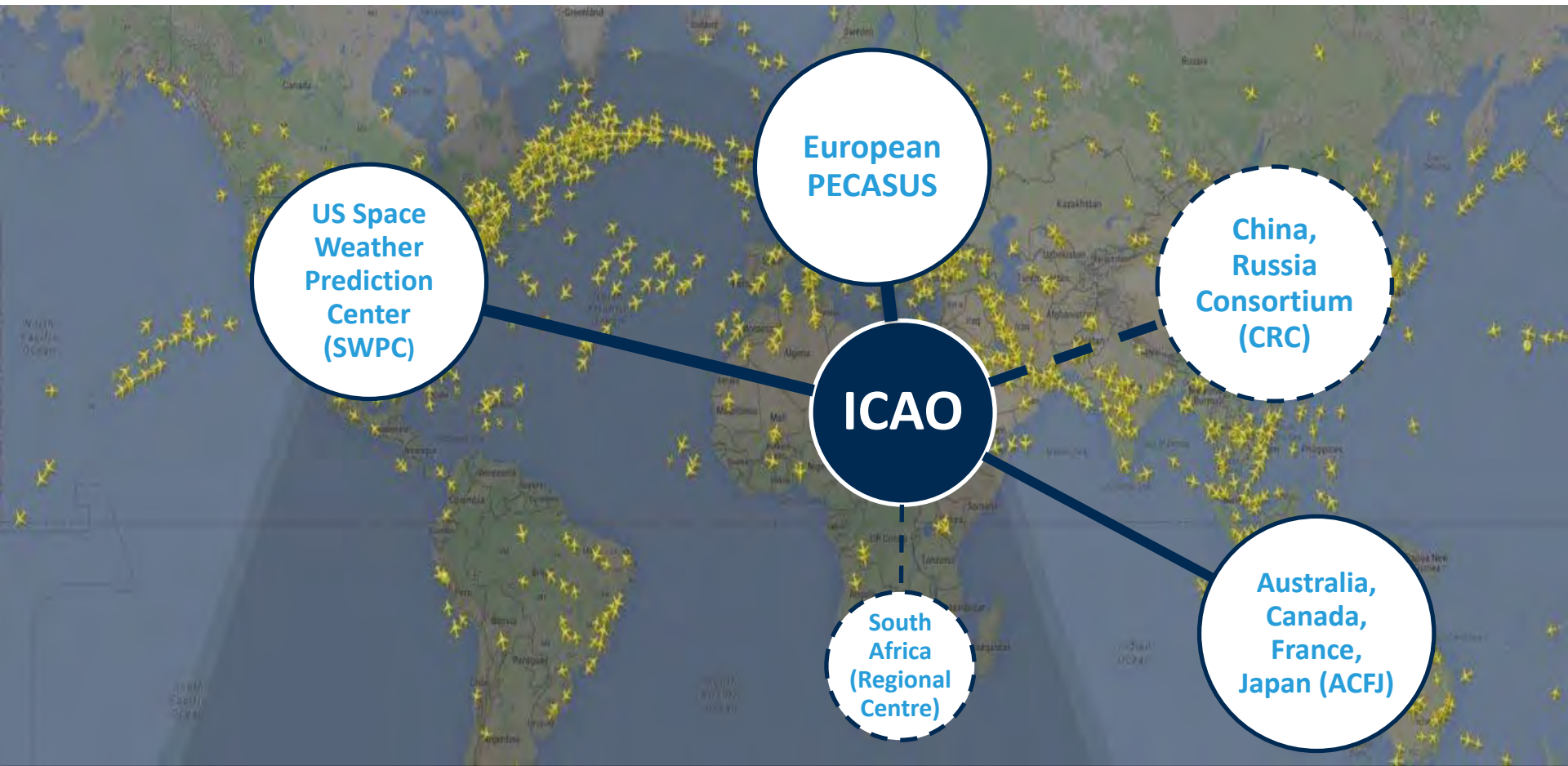
Towards an ICAO standardized global space weather service for aviation



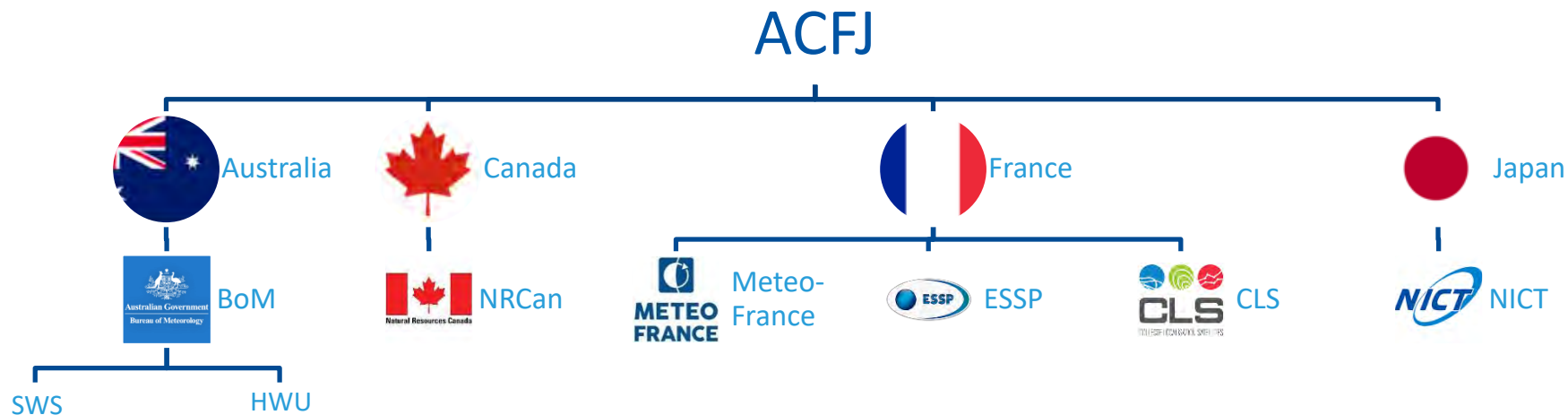


ICAO BANGKOK

UNITING AVIATION



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

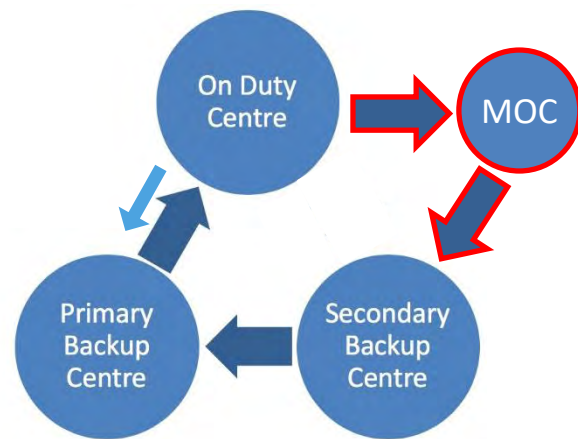
Rotation cycle

- 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

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**)



Specifies template for space weather advisory

Two formats:

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

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[0-9][0-9]	ADVISORY NR: 2015/1
6 Number of advisory being replaced (C)	Number of the previously issued advisory being replaced	NR REPL: nnnn[0-9][0-9]	NR REPL: 2015/1
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

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

UNIT / HIGH

Details

Next update

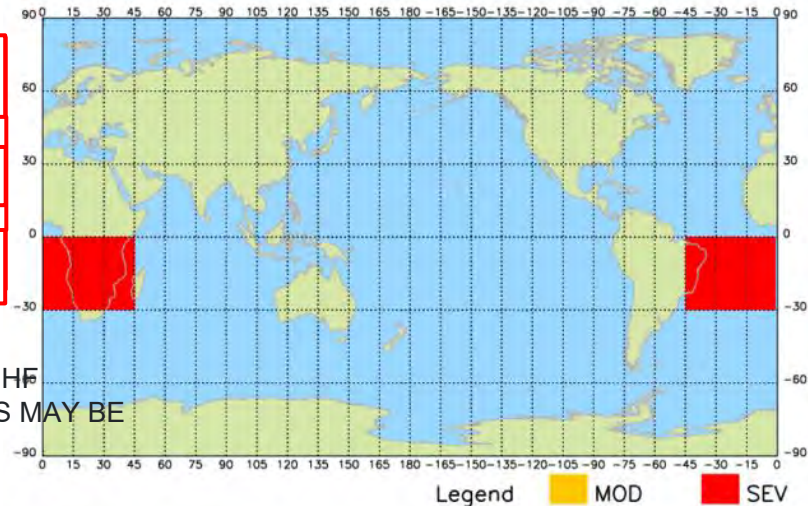
FREE TEXT

DAYSIDE

[ABV FLxx]

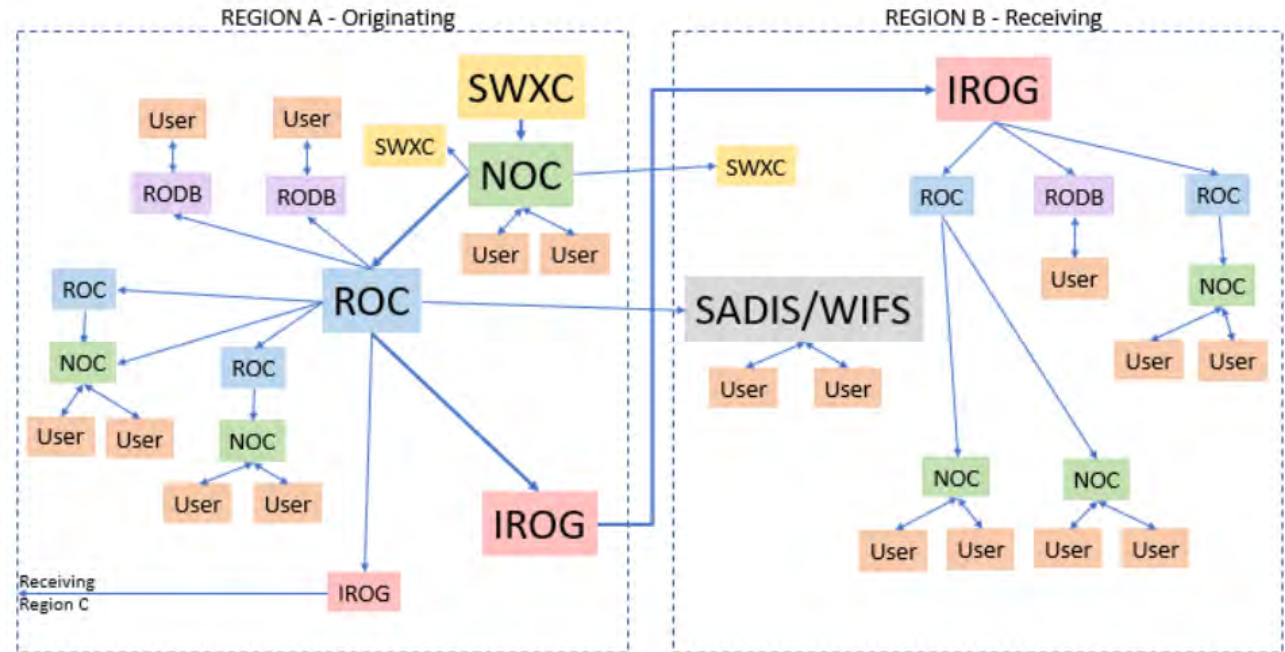
GLOBAL HF COM ADVISORIES

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 and will continue through 2021 (1 test advisory every 2 weeks)

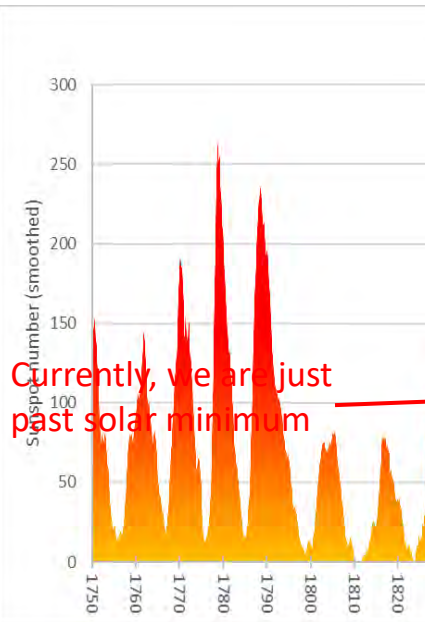


Operational Considerations

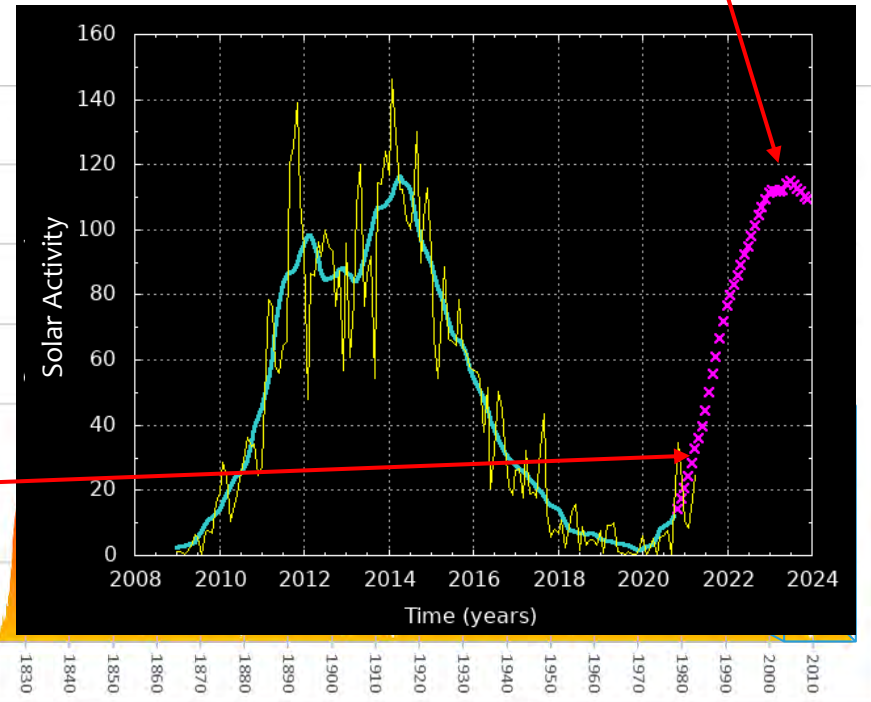
How often will space weather advisories be issued?

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

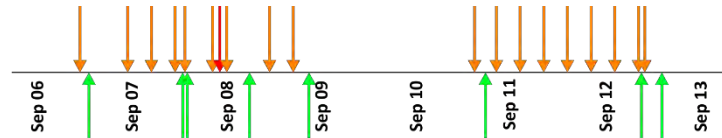
More intense events are expected to occur near **solar maximum**



Currently, we are just past solar minimum



The next solar maximum is expected around 2024



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 BANGKOK

UNITING AVIATION



ICAO

North American
Central American
and Caribbean
(NACC) Office
Mexico City

South American
(SAM) Office
Lima

ICAO
Headquarters
Montréal

Western and
Central African
(WACAF) Office
Dakar

European and
North Atlantic
(EUR/NAT) Office
Paris

Middle East
(MID) Office
Cairo

Eastern and
Southern African
(ESAF) Office
Nairobi

Asia and Pacific
(APAC) Sub-office
Beijing

Asia and Pacific
(APAC) Office
Bangkok



THANK YOU