



ICAO BANGKOK | UNITING AVIATION

Space Weather Advisory Service for Aviation

Ashwin Naidu
Australian Bureau of Meteorology

MET/ATM Seminar– May 30, 2022



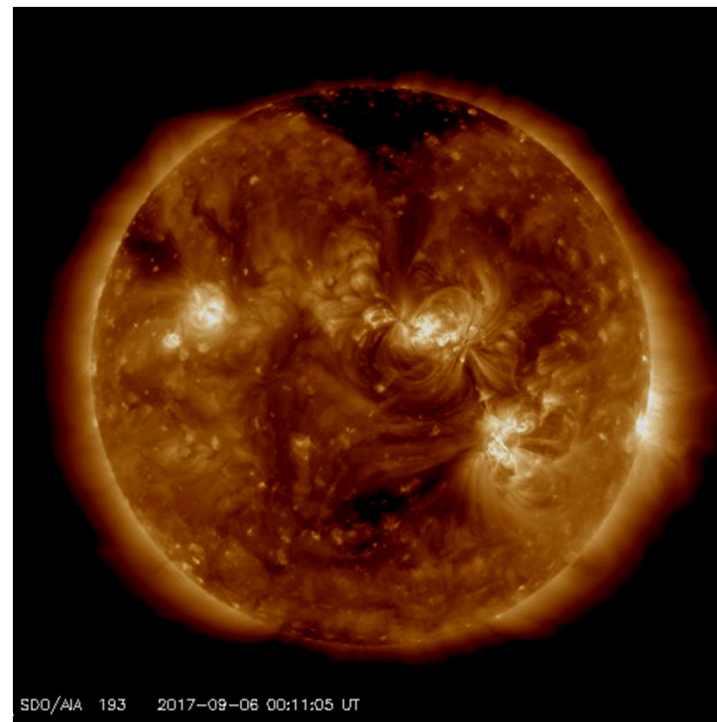
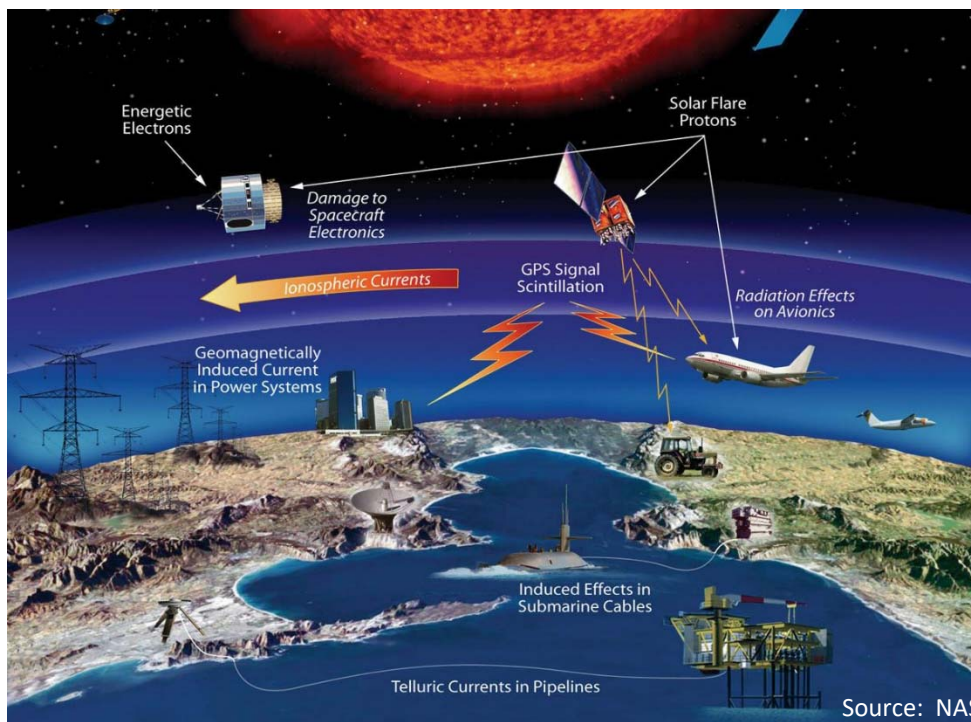


Outline

- 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?





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

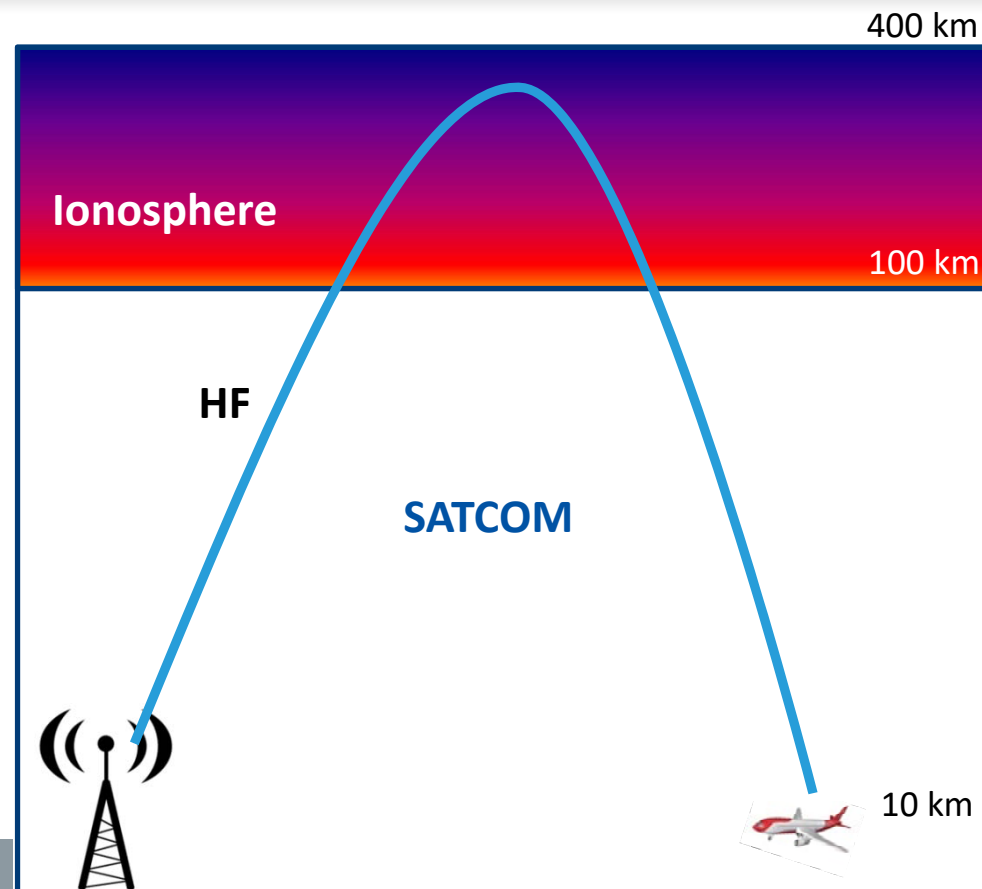


Impact of space weather on HF Communications (HF COM) and SATCOM

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)



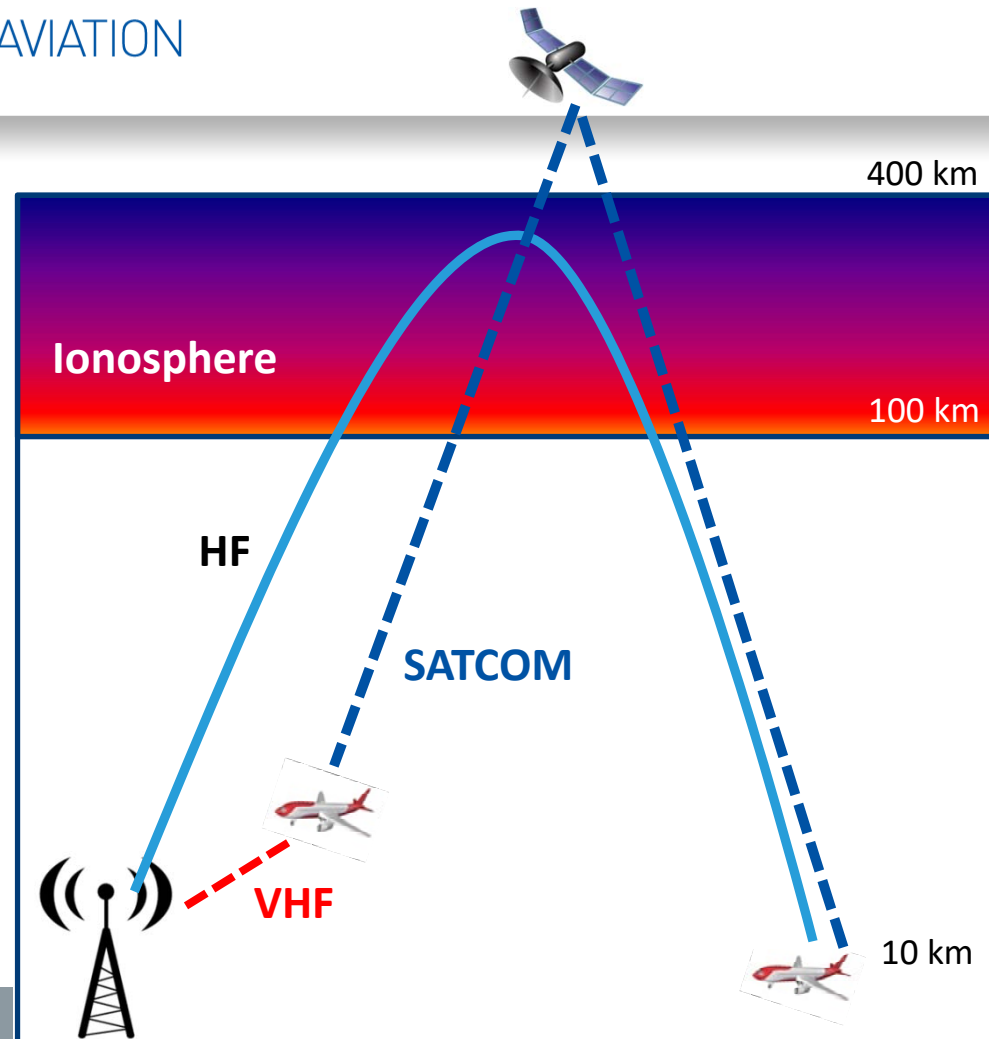


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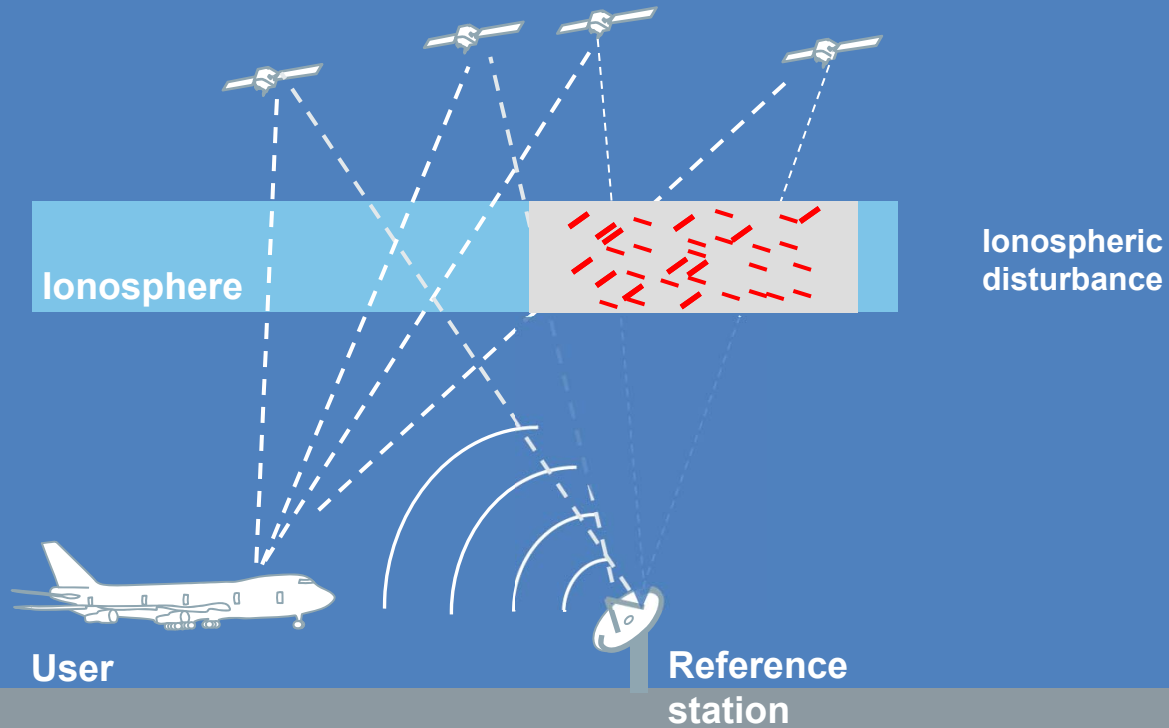
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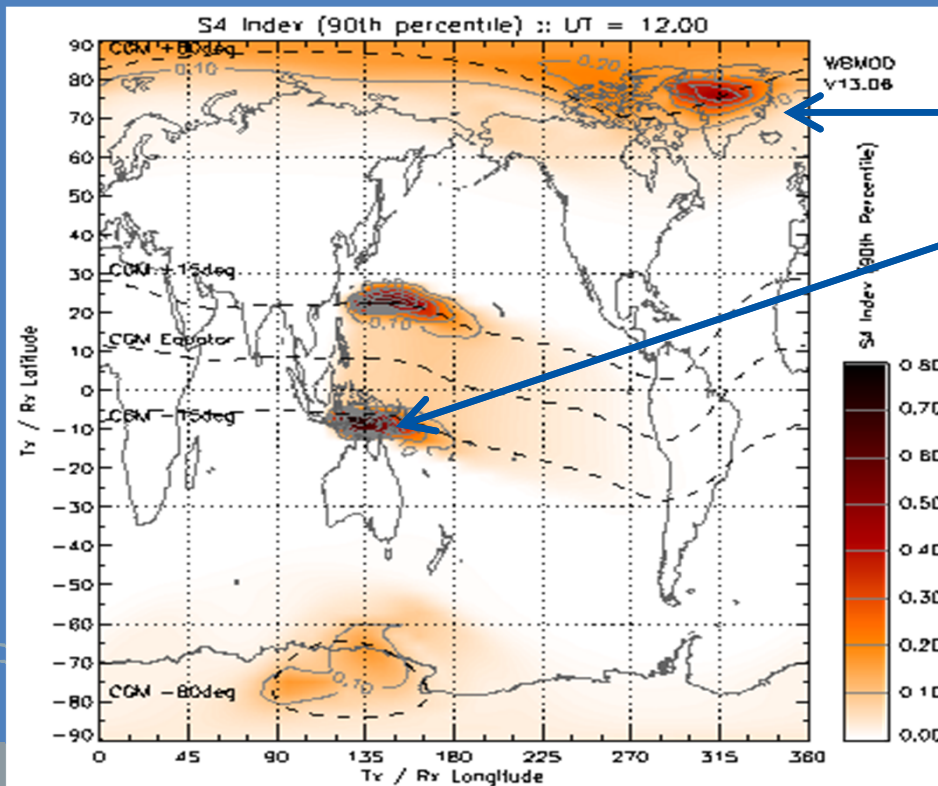


Impact of space weather on GNSS (GPS) performance





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



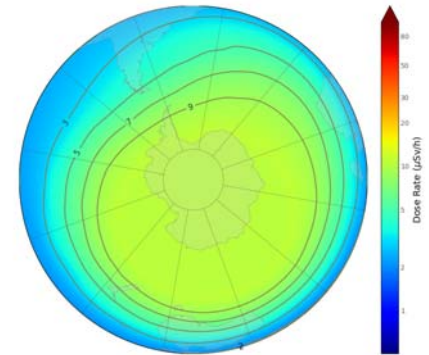
Impact of space weather on radiation levels

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

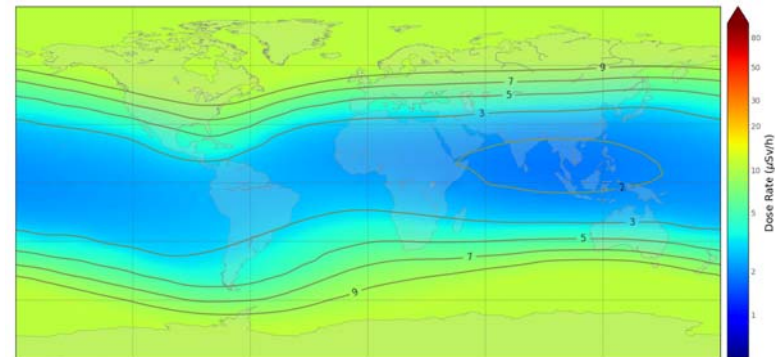
Space Weather Impacts:

- 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 μ Sv/h)

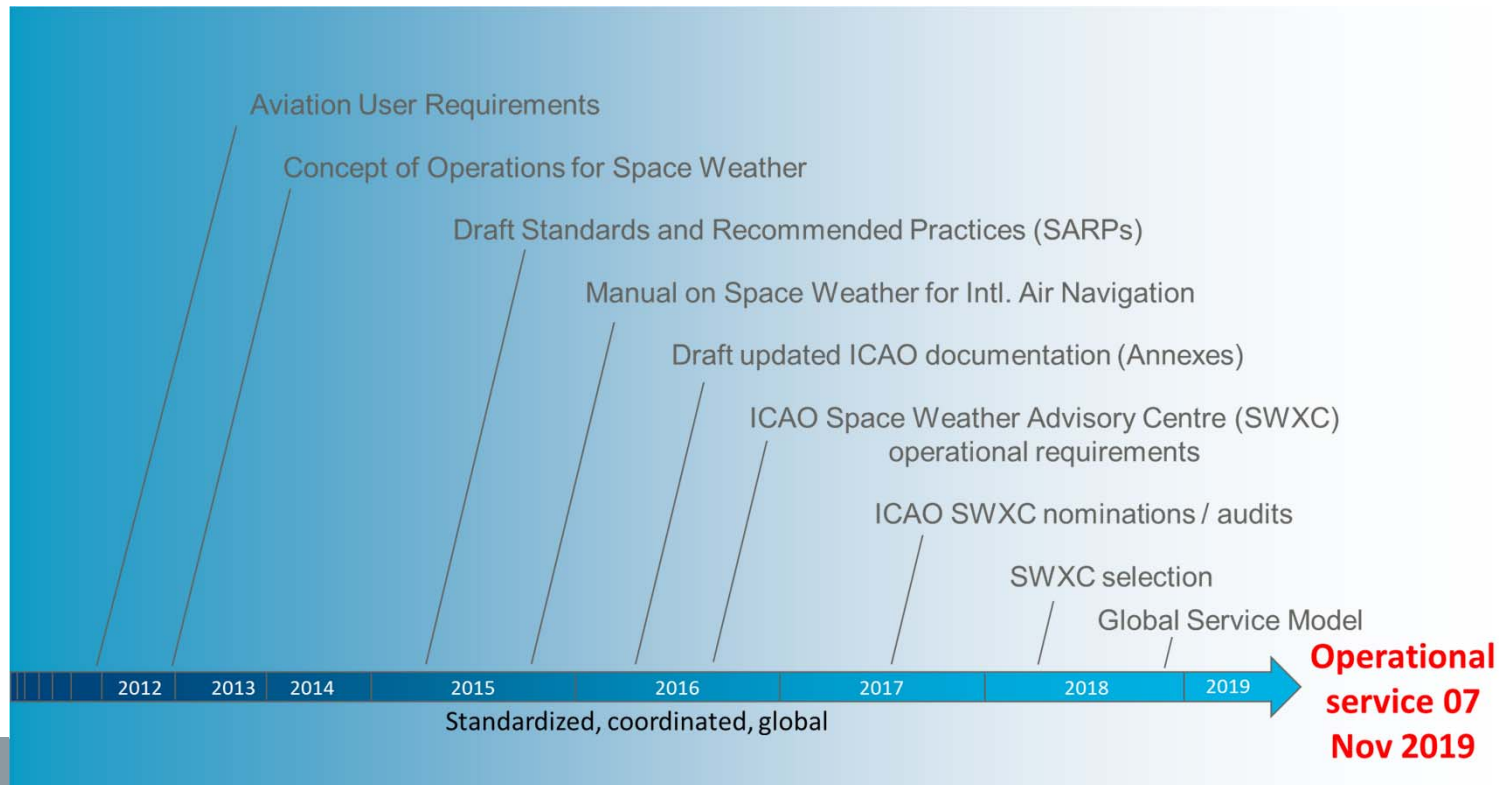


SIGLE  Radiation dose map at 37000 feet (11.3 km) for 2021-05-18 (max 10.8 μ Sv/h)





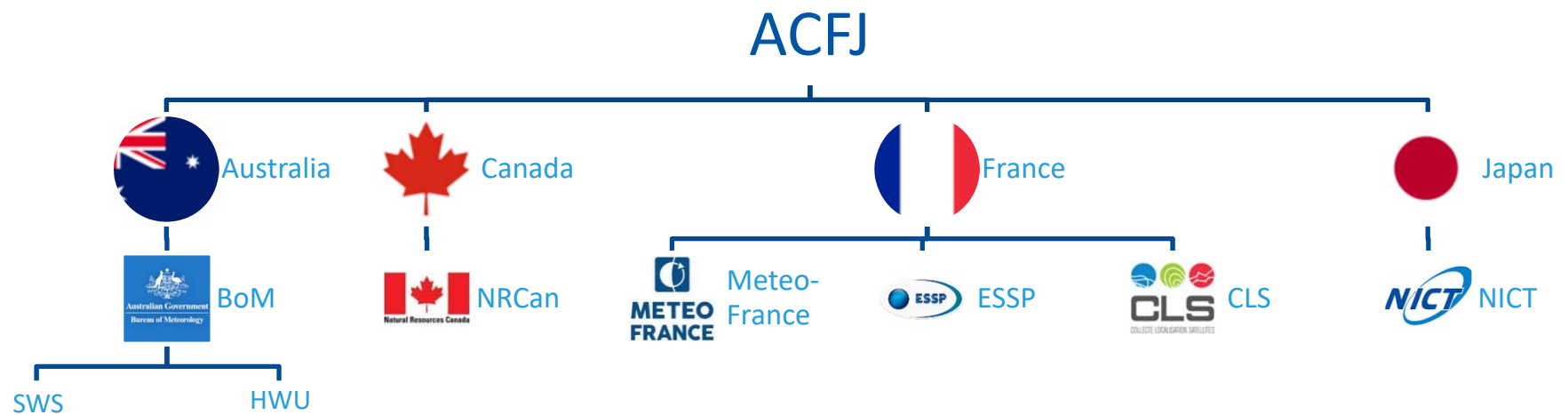
Towards an ICAO standardized global space weather service for aviation







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 rotate through the following roles:
On Duty Center → Primary Backup Center →
Secondary Backup Center → Maintenance and Observation Centre
- 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
- The fourth global centre acts as Maintenance and Observation Centre added

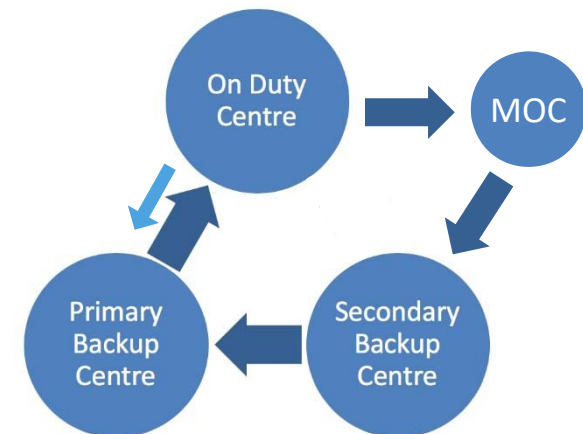
Rotation cycle

- 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**)



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

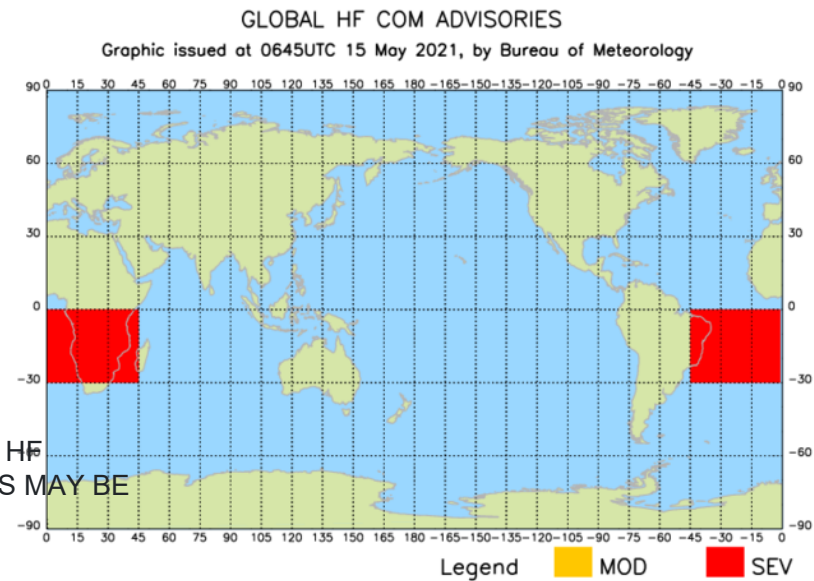
Appendix 2

Element	Detailed content	Template(s)	Examples
5 Advisory number (M)	Year in full and unique message number	ADVISORY NR: nnnn[<i>n</i>][<i>n</i>][<i>n</i>]	ADVISORY NR: 2016/1
6 Number of advisory being replaced (C)	Number of the previously issued advisory being replaced	NR RPLC: nnnn[<i>n</i>][<i>n</i>][<i>n</i>]	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



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=



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

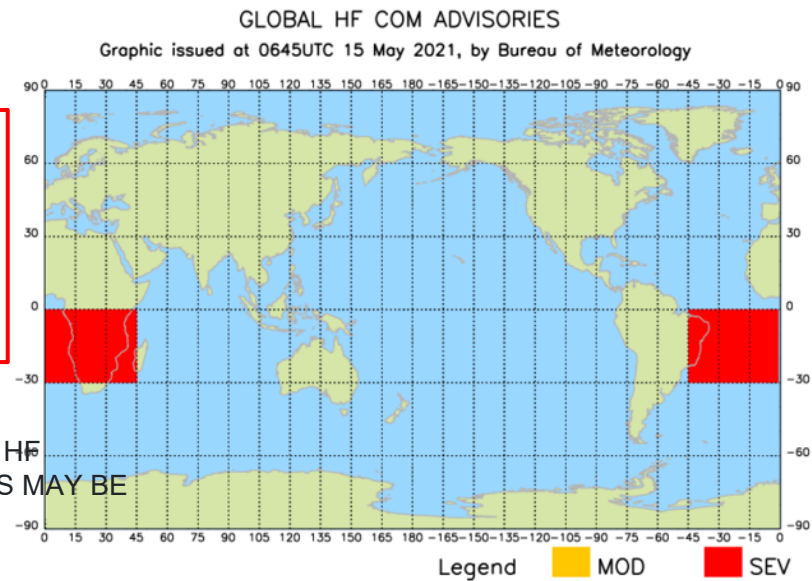


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**Space Weather Effect +
Severity**

HF COM
GNSS
RADIATION } MOD / SEV



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

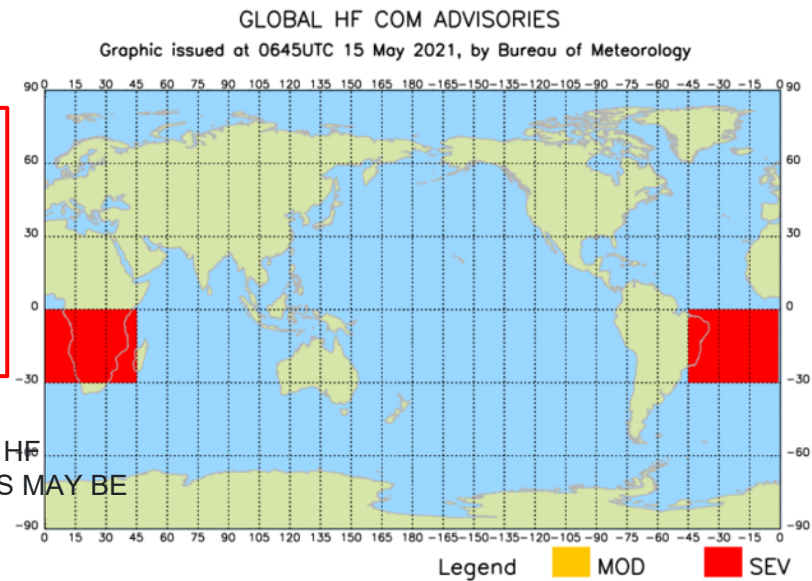


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Time and Location

HNH / HSH
MNH / MSH } [lon range]
EQN / EQS
DAYSIDE
[ABV FLxx]



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

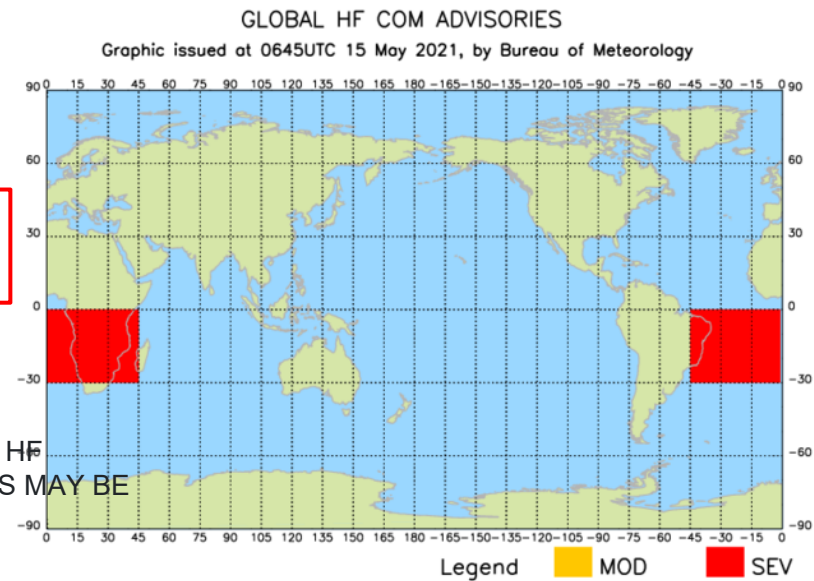


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Details

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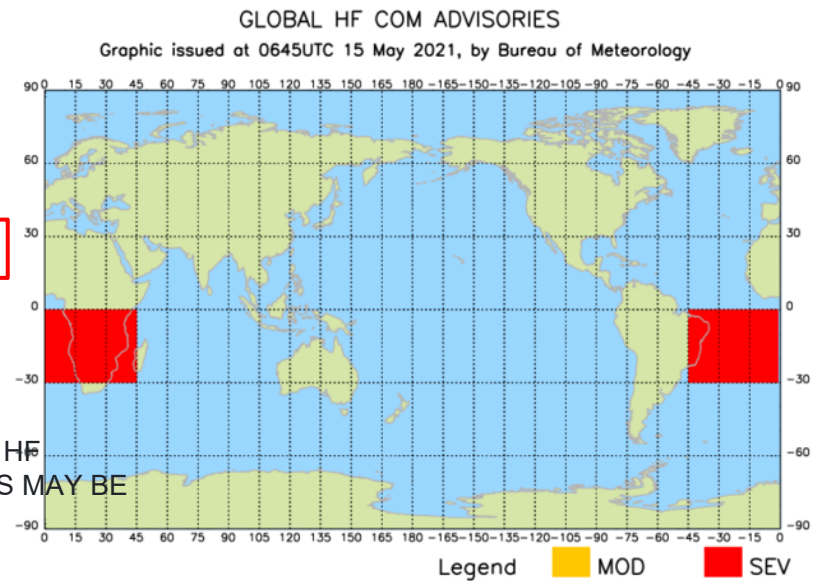
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Next update

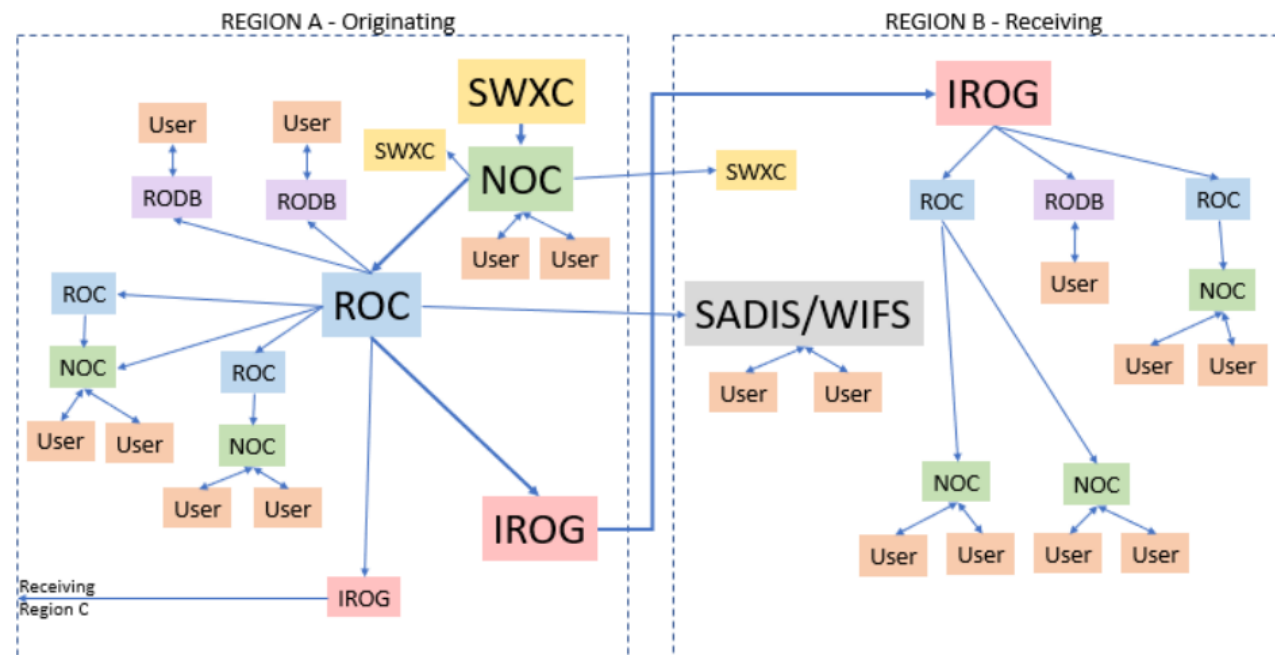


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Space Weather Advisory (SWXA) dissemination

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



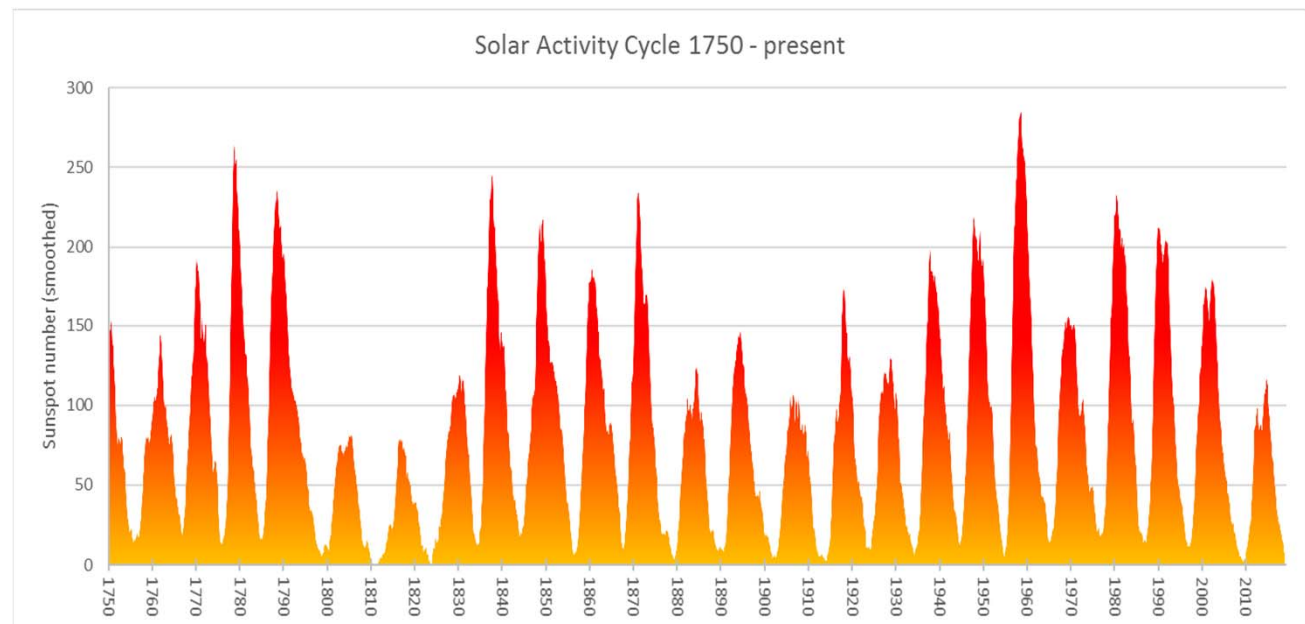


Operational Considerations

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**





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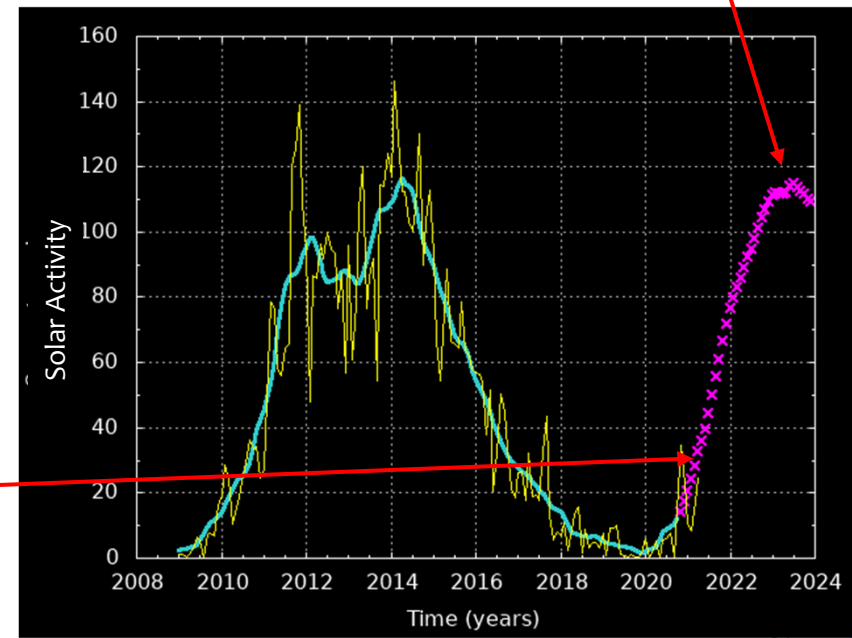
How often will space weather advisories be issued?

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?



HF – BOM Responsibility (30 real advisories)
With input from Canada



GNSS – France responsibility (4 real advisories)
QC checks by BOM, Canada, backup by Japan



Radiation – France responsibility (no real advisories)
QC checks by Japan, backup by BOM and Canada



ICAO space weather daily briefs – BOM
With inputs from France, Canada, Japan

24-7 Admin watch (BOM, France, Japan)
24-7 Scientific watch (shared between BOM, France, Canada)



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°.



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Mexico City
- South American (SAM) Office
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Dakar
- European and North Atlantic (EUR/NAT) Office
Paris
- Middle East (MID) Office
Cairo
- Eastern and Southern African (ESAF) Office
Nairobi
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Beijing
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THANK YOU