

# ICAO Space Weather Center Provisions

Presented to: ICAO MID SWX Advisory Information Dissemination Webinar

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**Federal Aviation  
Administration**

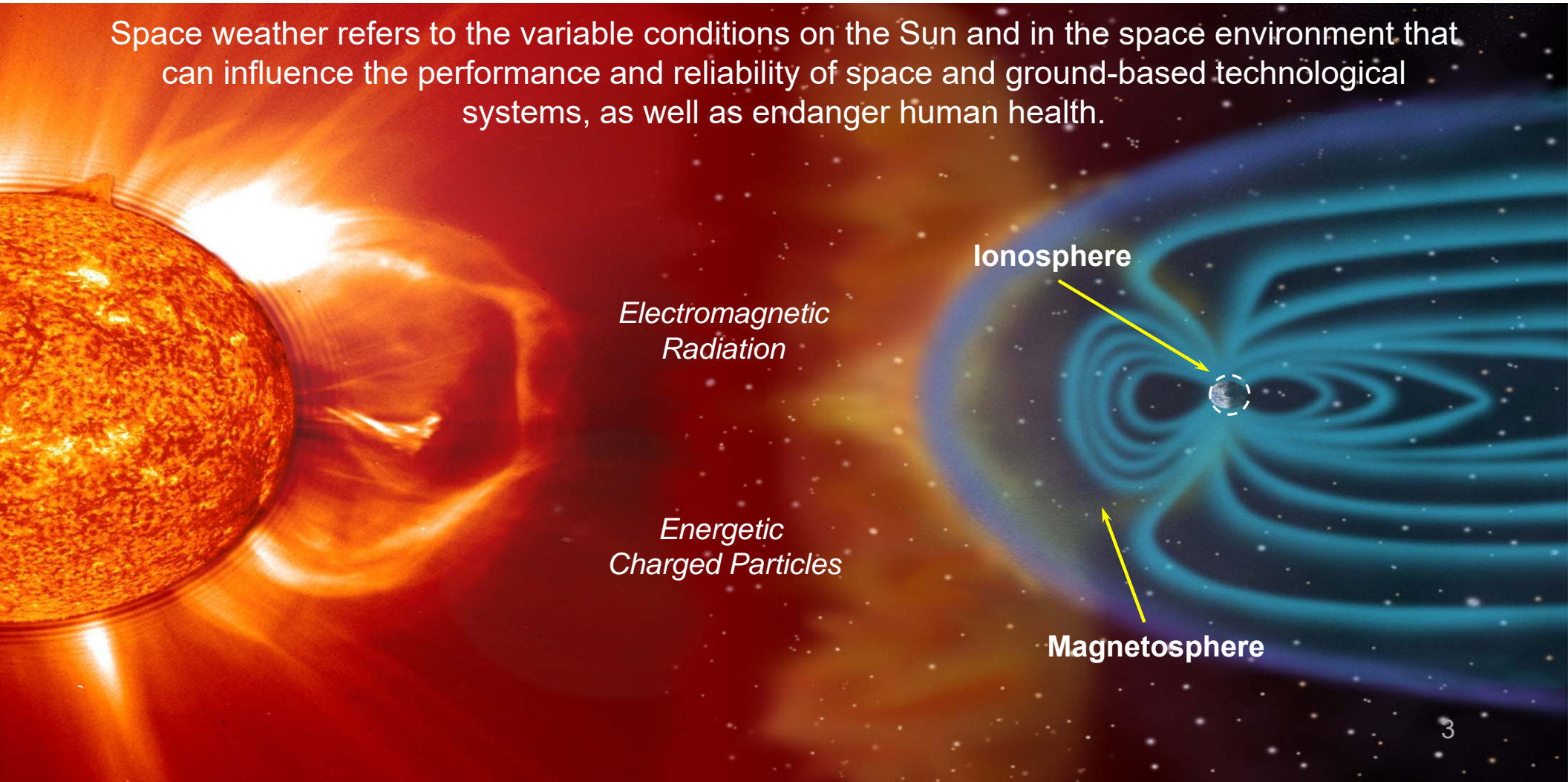
# Overview

- What is “Space Weather”
- Space Weather Phenomena
  - Solar Flares
  - Radiation Storms
  - Geomagnetic Storms
- Impacts to Aviation
- Services in ICAO



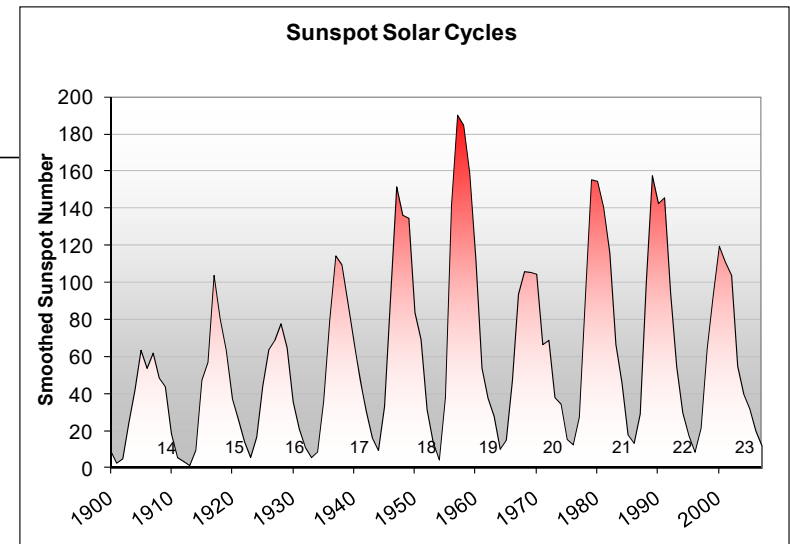
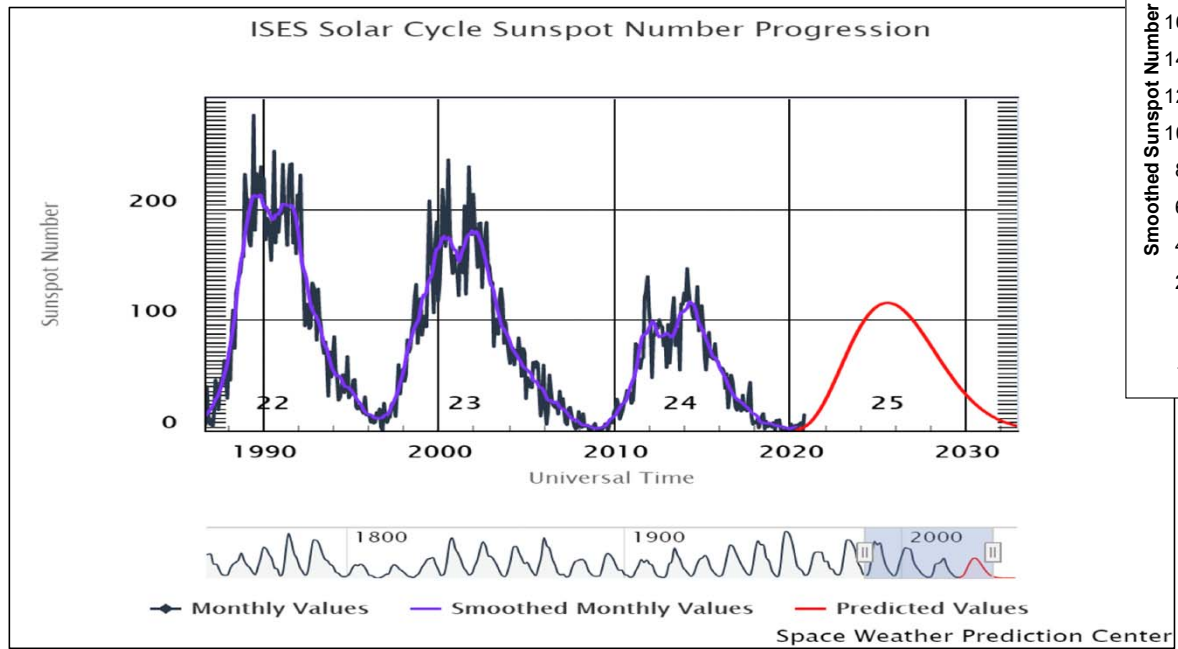
# What is Space Weather?

Space weather refers to the variable conditions on the Sun and in the space environment that can influence the performance and reliability of space and ground-based technological systems, as well as endanger human health.

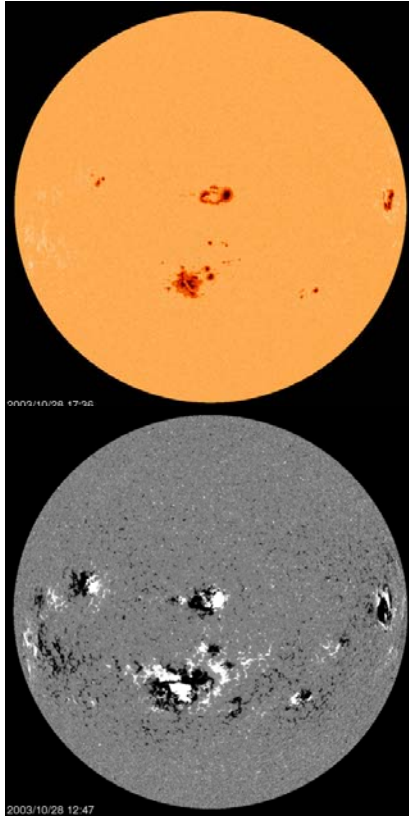


# Solar Cycle Update

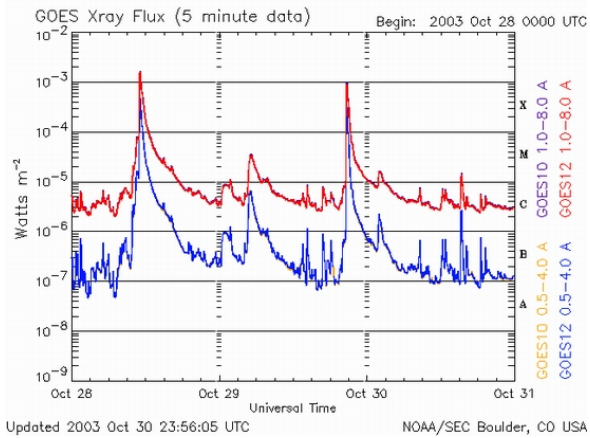
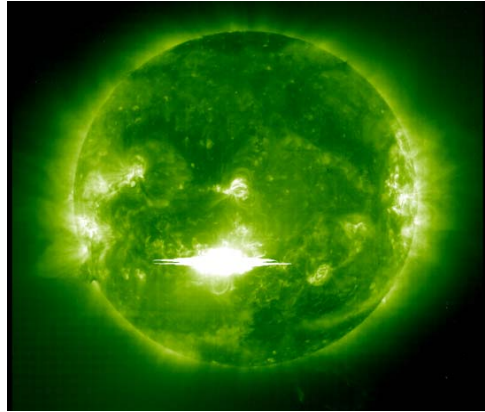
- Space weather impacts more prominent during high points of cycle
- New Cycle 25 in its early phase
- Severity of impact loosely correlated with cycle size



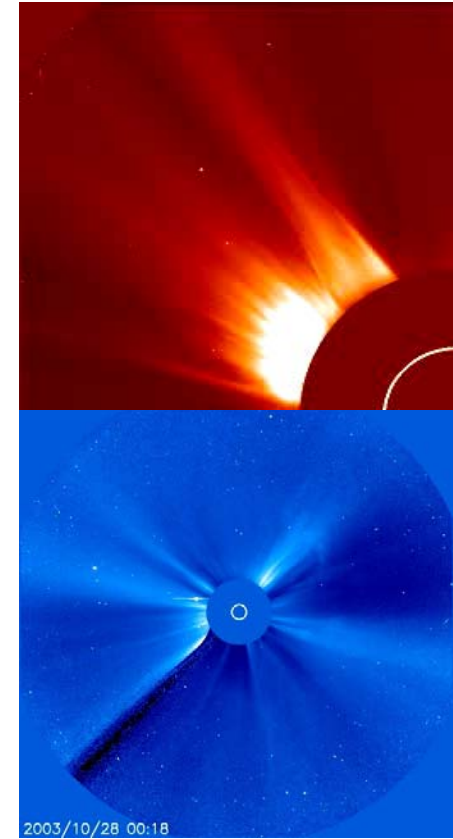
# Sequence of Events



Conditions are Favorable for Activity  
(Probabilistic Forecasts)



Event Occurs



Coronal Observations



# Aviation Space Weather / Impacts

- **High Frequency (HF) Communications:**
  - No advance warning
  - Effects lasts for 10's of minutes to several hours
  - Impacts HF communication on the sunlit side of the Earth
  - First indication significant radiation and Performance Based Communication and Surveillance (PBCS) activity may be possible
- **Radiation:**
  - Warnings possible on the minutes to hours time scale
  - Elevated levels can persist for several days
  - Impacts High Frequency communication in the polar regions, affecting commercial airline operations
- **Global Navigation Satellite System (GNSS):**
  - Advance notice possible given coronal mass ejection (CME) transit times from Sun to Earth range from just under a day to several days (CMEs being the main driver of significant storms)
  - In extreme storms, impacts to power grid operations and stability
  - Driver of aurora; severe to extreme storms may cause aurora to be visible over most of the mid-latitudes



# Current Capability

- **Communications**

- HF blackout can be nowcast and forecast probabilistically
- Limited skill in satellite communications, both in nowcast and forecast phases
- Longer range forecasts remain challenging, both pre-eruption and when awaiting commencement of a storm as well

- **GNSS**

- Nowcasting fairly mature where observational data is available
- Skill improving in short-term forecasting (10's of minutes)
- Longer range forecasts remain challenging, both pre-eruption and when awaiting commencement of a storm



# Evolution of Services and Future Needs

- **Radiation**

- As aircraft fly farther and longer, exposures will increase
- In situ observations will help with model validation, data assimilation, and operational decision making

- **GNSS**

- Additional GNSS frequency adoption can largely eliminate ionospheric-induced position errors
- Engineers with time and money can engineer around some challenges, but some will remain
- Scintillation will likely remain the primary issue

- **Communications**

- Application of HF is changing. HF datalink use still increasing...
- Geosynchronous and low Earth orbit (LEO)-based satellite communications evolving

- Short-term forecasting gains are coming in the 3-5-year timeframe. However, no paradigm shifts in longer-term forecasting are likely in the foreseeable future.

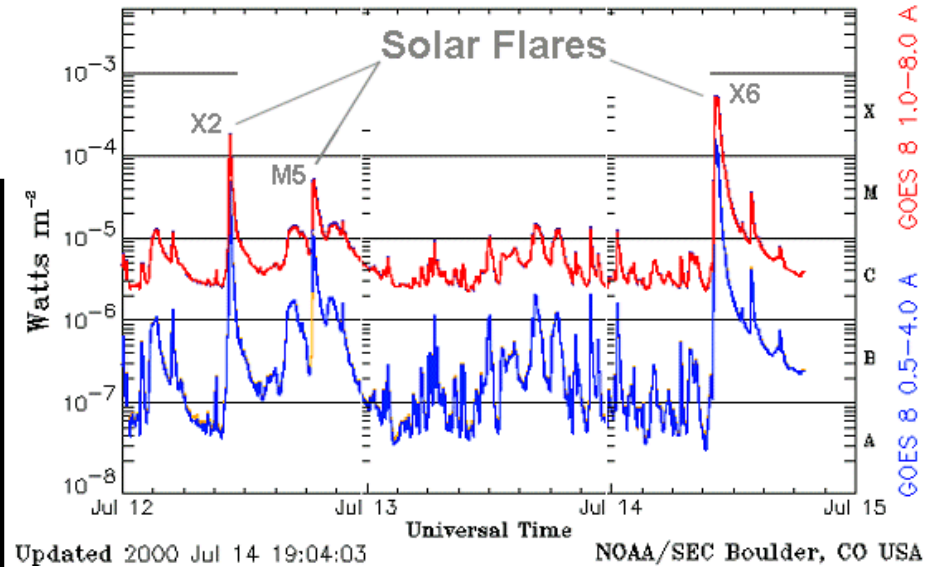
- Given the chaotic, eruptive nature of the phenomena, space weather may never be like weather, but we can try...



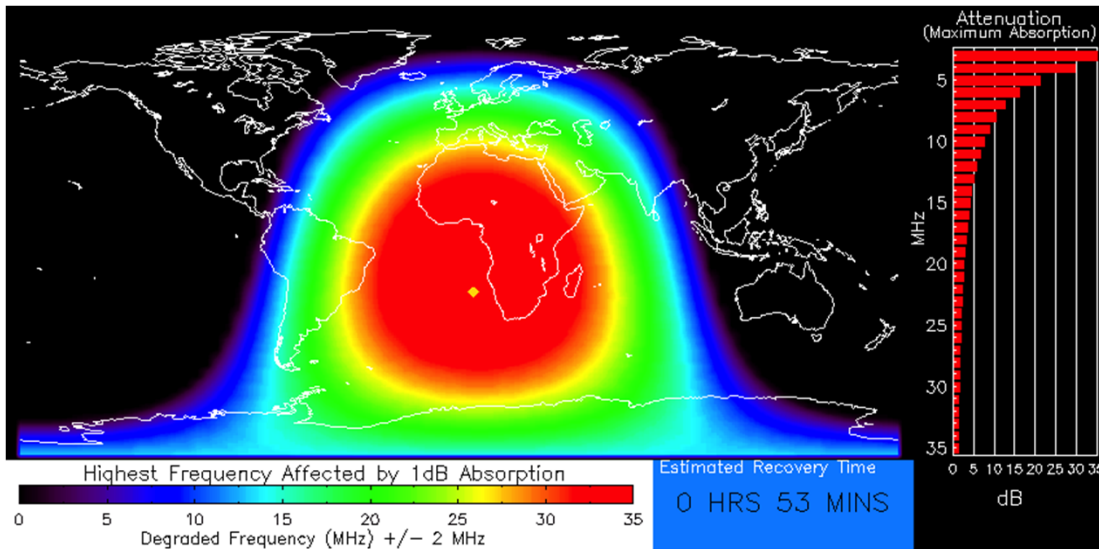


# HF Impacts Caused by Solar Flares

GOES Xray Flux (5 minute data)



- Duration: Minutes to 3 hours
- Daylight-side impacts



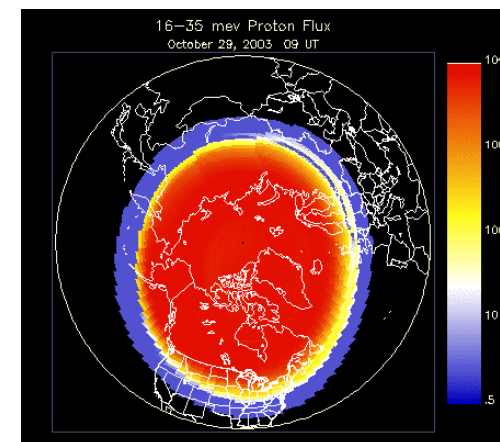
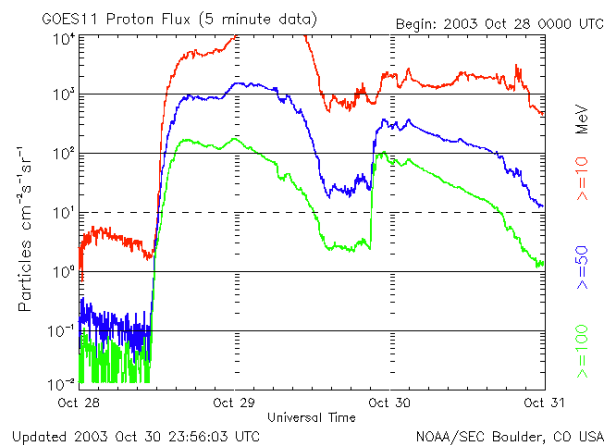
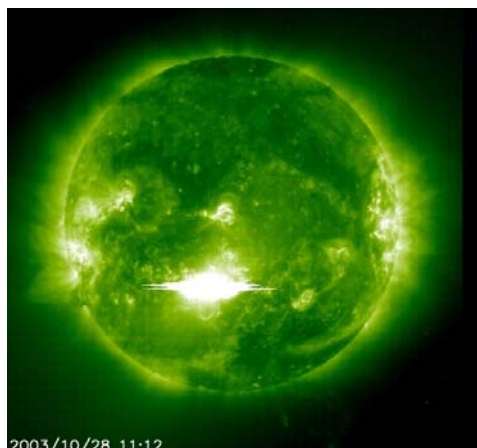
Moderate X-ray flux  
Product Valid At : 2010-02-12 11:27 UTC

Normal Proton Background  
NOAA/SWPC Boulder, CO USA



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# Radiation

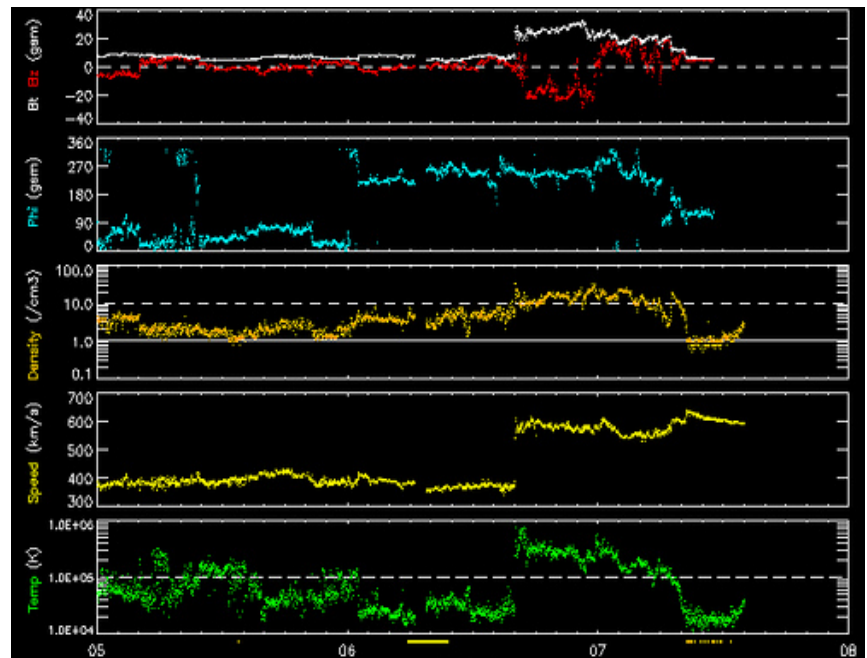
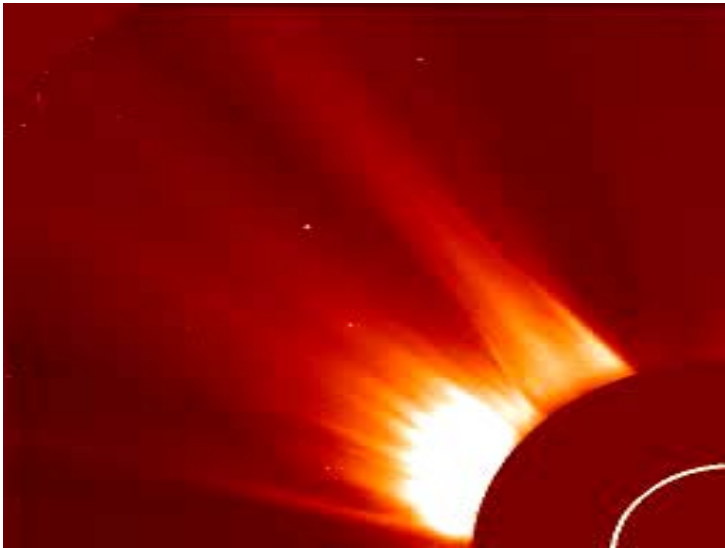


- Arrival: 10's of minutes to several hours
- Duration: hours to days
- Short-term warning



# PBCS Affected by Geomagnetic Storms

- CMEs create geomagnetic storms
- Arrival: ~18 – 96 hours
- Duration: Hours to a day or two
- Creates ionospheric storms, geomagnetically induced currents, aurora

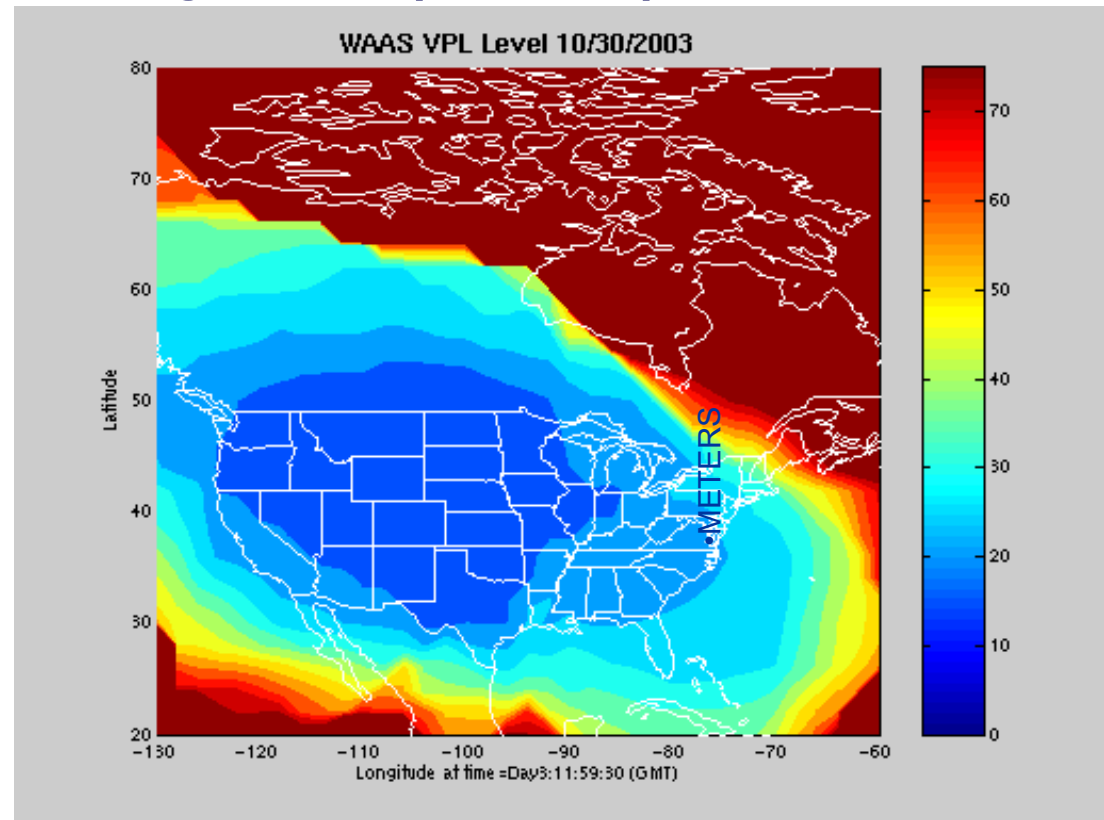


- 1-2 Day watch products based on coronagraph observations and modeling (Highest Expected K)
- Short-term (15-60 min) warnings based on measurement between Sun/Earth



# GPS IMPACT – U.S. Federal Aviation Administration (FAA) Wide Area Augmentation System (WAAS)

- Intense geomagnetic and ionosphere storms occurred on 29 and 30 October 2003
- Acceptable vertical error limits were exceeded for 15 and 11-hour periods



## Polar Region: Space Weather Above

- The geomagnetic field converges at the poles, creating a focal point for solar energetic particles
- As geomagnetic activity increases, the Aurora gets brighter, more active, and moves equatorward

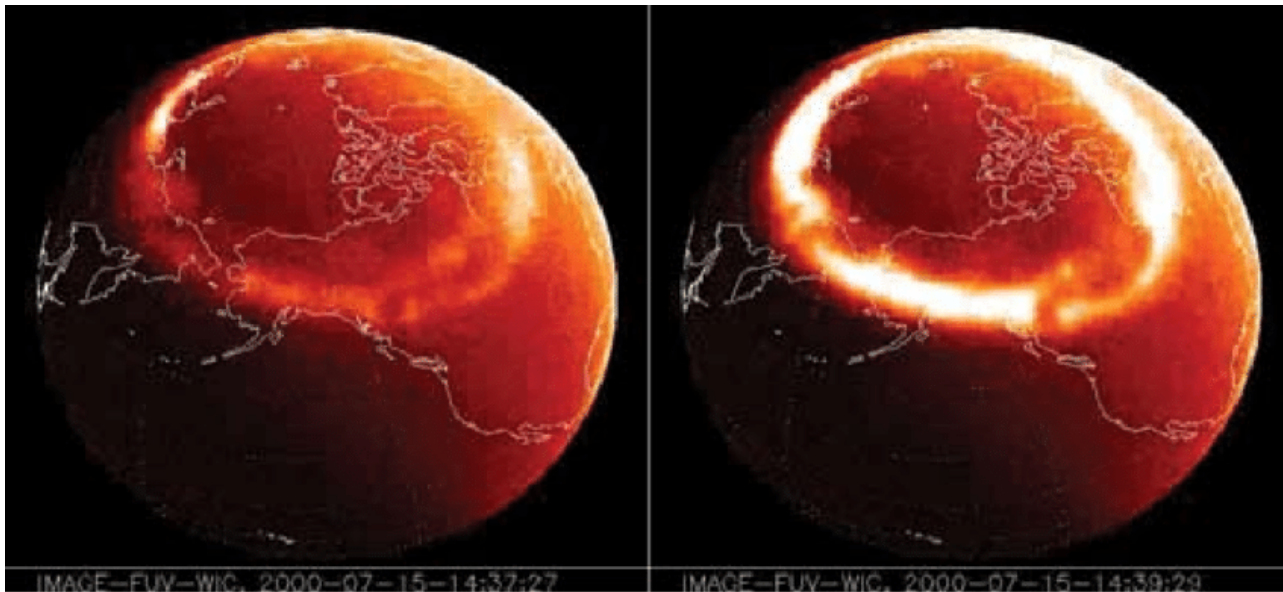
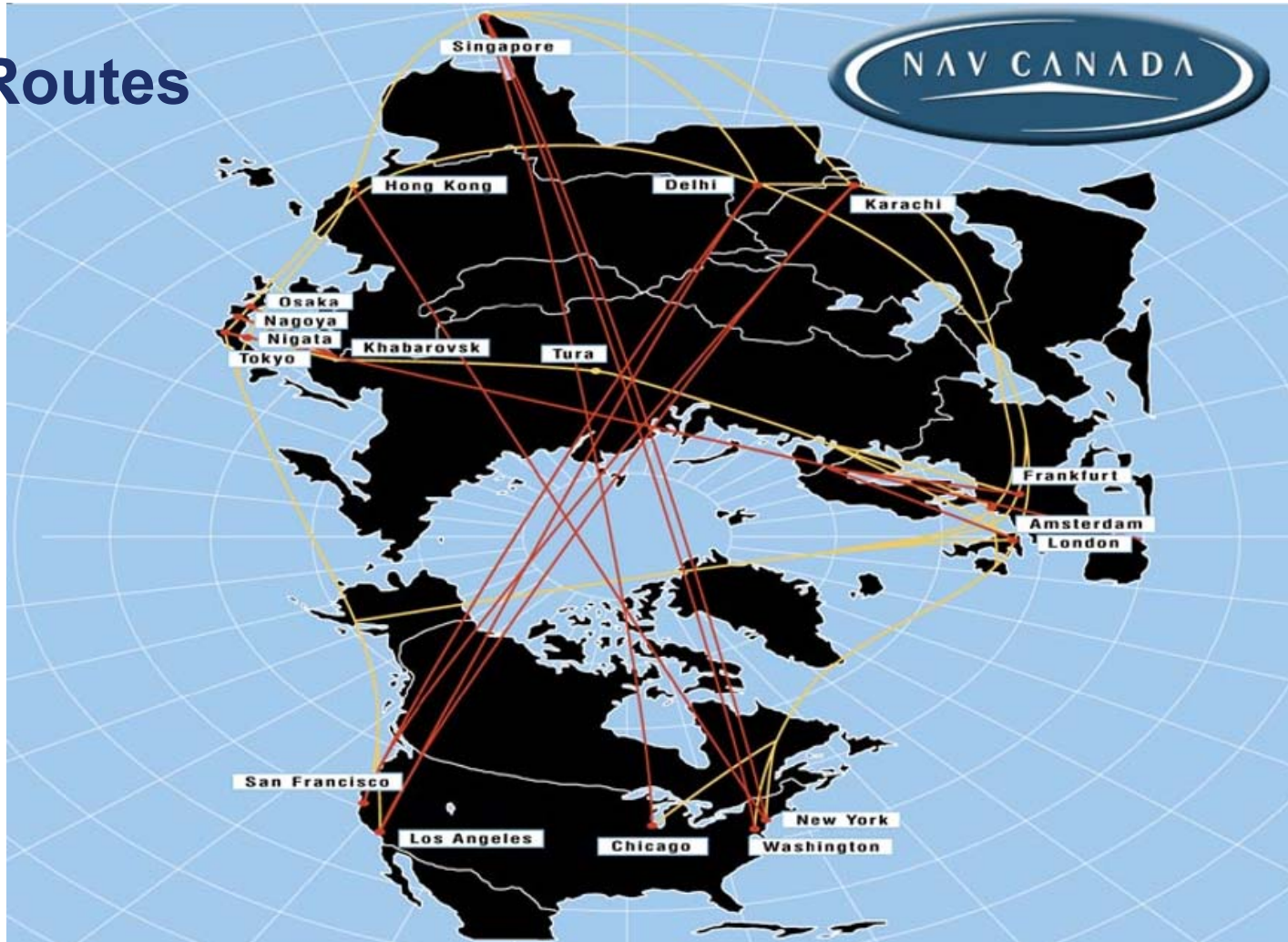


Image from NASA IMAGE Satellite



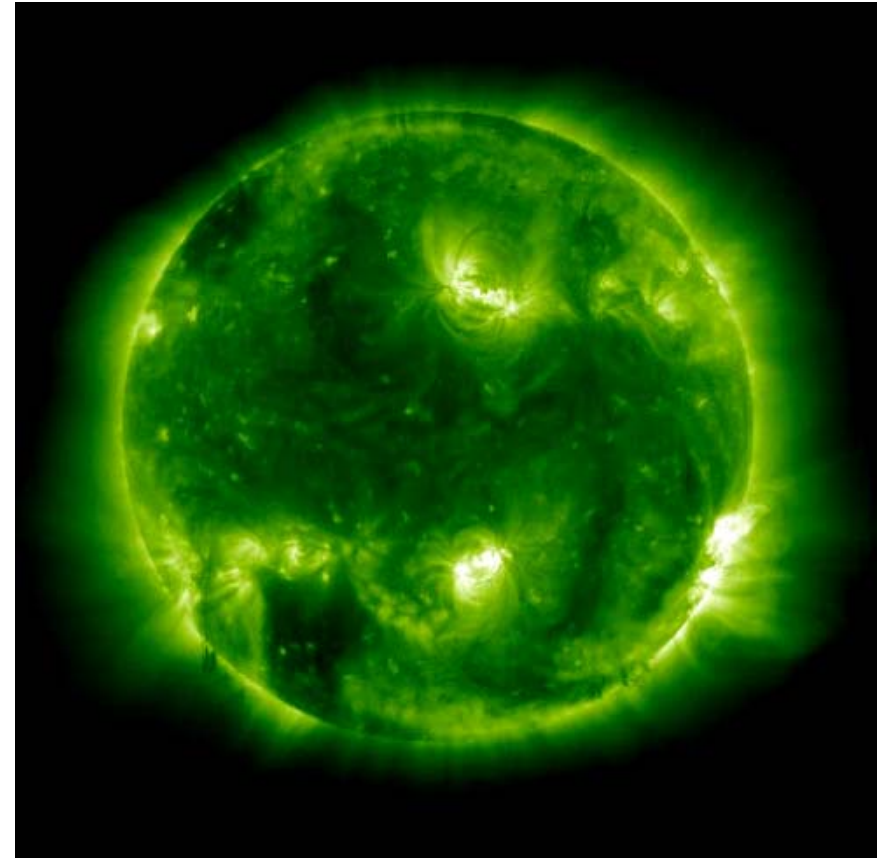
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# Polar Routes



# Space Weather Storms – Timing and Consequences

- A Flare and/or CME erupts from the Sun
- 8 minutes later: First blast of extreme ultraviolet (EUV) and X-ray light increases the ionospheric electron density
  - Radio (HF) communications are lost
- 30 to 1000 minutes later: Energetic Particles arrive
  - Astronauts are impacted
  - Satellites are impacted
  - Polar flights are impacted
- 1 to 4 days later: CME passes and energizes the magnetosphere and ionosphere
  - Electric Power is affected
  - Navigation Systems are affected
  - Radio Communications are affected

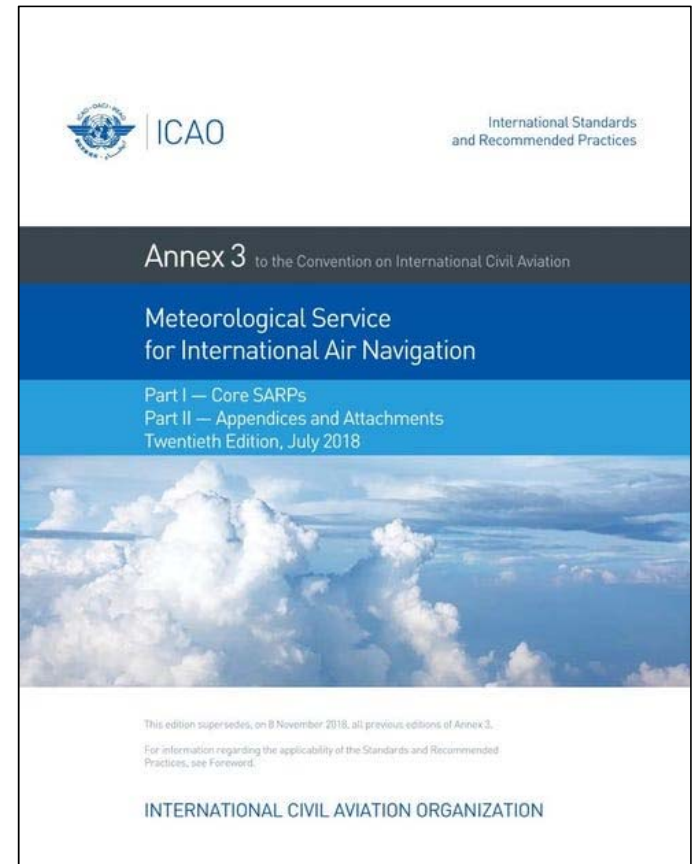


From NASA SOHO Satellite



# ICAO Annex 3 – *Meteorological Service for International Air Navigation*

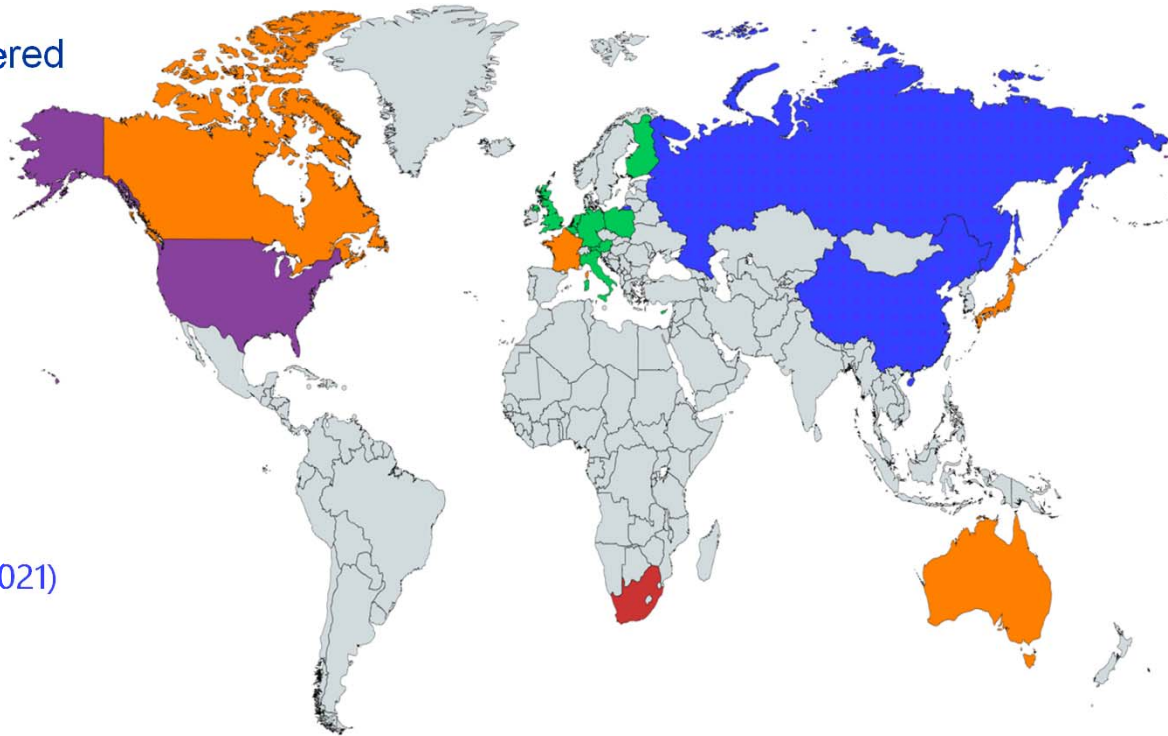
- Space weather introduced in Amendment 78 (2018)
  - Advisories issued for
    - HF Voice/Data & Satellite Communications
    - Radiation Exposure to Crew & Passengers
    - GNSS Based Navigation & Surveillance
- Minor changes made to the content of the advisory in Amendment 79 (2020)
- Additional changes to the format and content planned for Amendment 81 (2023)





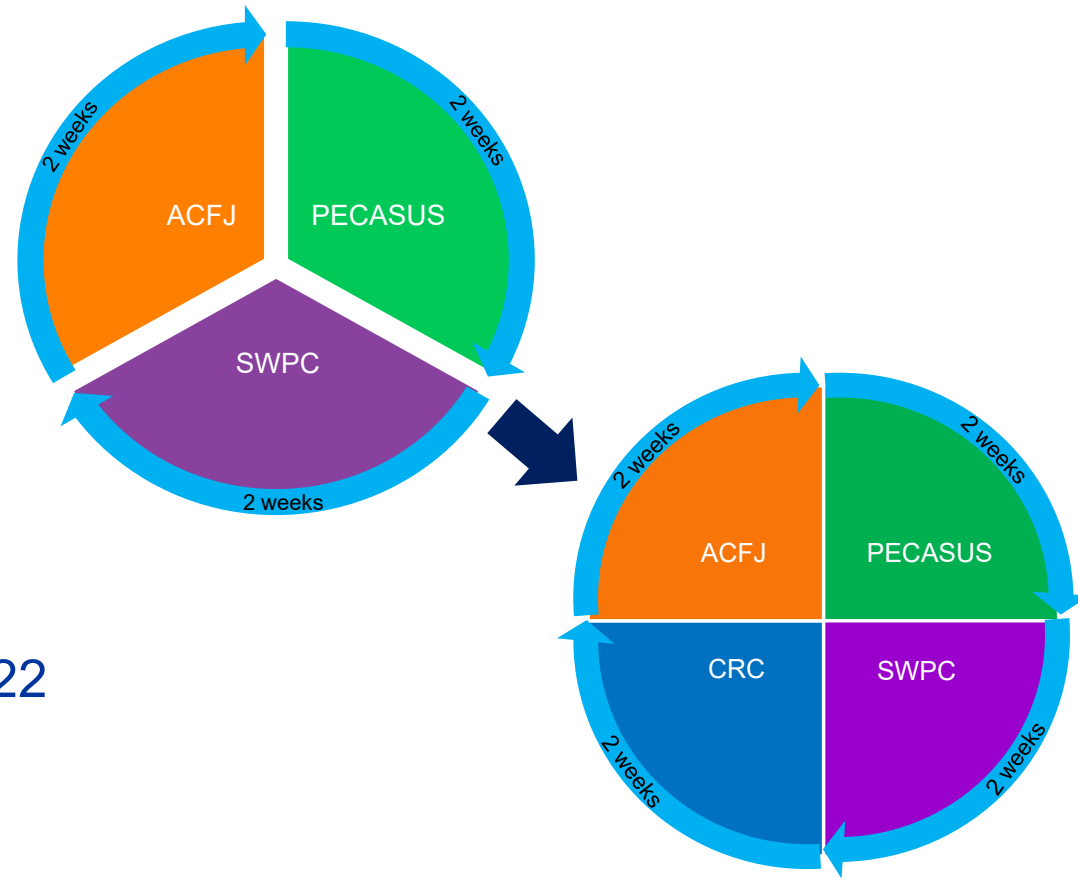
# ICAO Space Weather Centers

- Designated ICAO Centers
  - Four Global – Consortiums are considered one center
    - PECASUS (European consortium lead by Finland)
      - Finland, United Kingdom
      - Germany, Austria
      - Poland, Italy
      - Netherlands, Belgium
      - Cyprus
    - ACFJ (Australia, Canada, France, Japan)
    - NOAA SWPC (United States)
    - China/Russia Consortium (Beginning 10/2021)
  - One Regional
    - South Africa



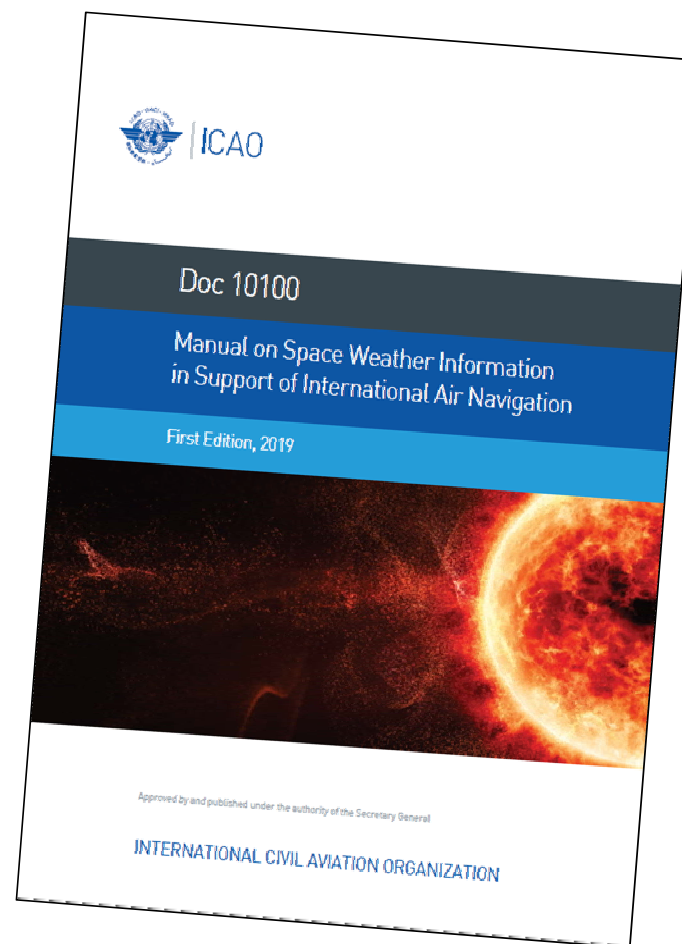
# ICAO Space Weather Centers – cont.

- Global Centers working to meet Annex 3 Global provision → operational **7 November 2019**
- One ‘On Duty’ Center at any given time
  - Two-week rotation
  - ‘On Duty’ Center issues all advisories
  - Centers coordinate and collaborate continually
  - China-Russia Consortium joins later 2021
- Regional Center operational by 2022
  - Sooner if feasible



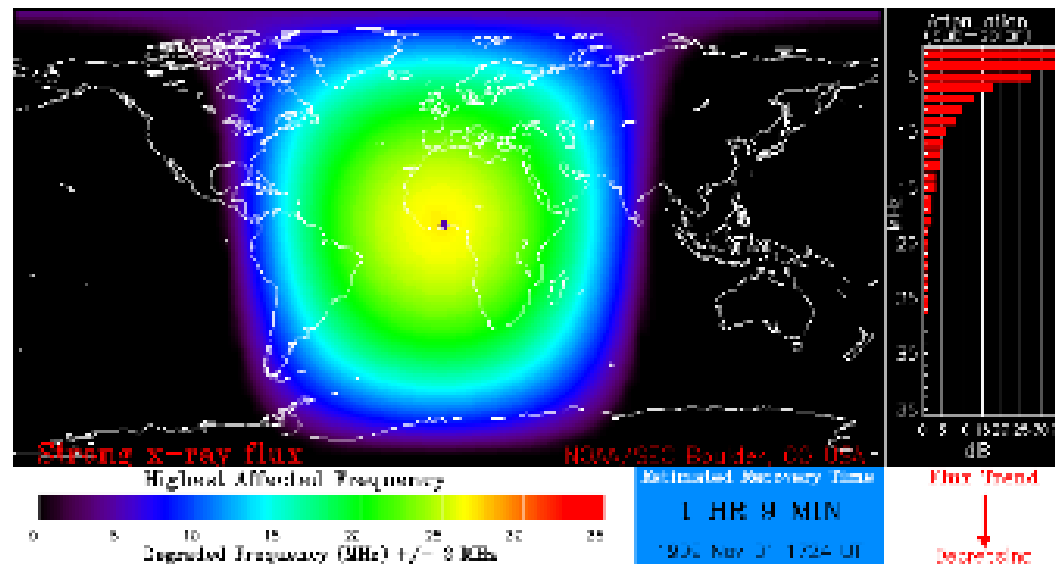
# ICAO Space Weather Manual

- Published October 2019
  - Manual on Space Weather Information in Support of International Air Navigation
- Other Guidance Material
  - Center Rotation & Operations
  - Advisory Interpretation and Use



# Description of Advisories

- Issue advisories for:
  - HF Voice/Data & Satellite Communications (HF *most mature*, SATCOM *tbd*)
  - Radiation Exposure to systems, crew & passengers
  - GNSS Based Navigation & Surveillance (newest addition)



# ICAO Space Weather Advisory

- **Issued for moderate (MOD) and severe (SEV) events**
  - For radiation events,
    - MOD is issued for radiation between FL 250 and FL 460
    - SEV is issued above FL 250.
- **The advisory depicts the affected region in one of three ways:**
  - one or more pre-defined latitude bands of width 30° shown in the table, followed by a longitude range in 15° increments;
  - the term DAYLIGHT SIDE, meaning the extent of the planet that is in daylight; or
  - a polygon using latitude and longitude coordinates

Title of the latitude bands	Ranges of the latitude bands
High latitudes northern hemisphere (HNH)	N90 to N60
Middle latitudes northern hemisphere (MNH)	N60 to N30
Equatorial latitudes northern hemisphere (EQN)	N30 to equator
Equatorial latitudes southern hemisphere (EQS)	Equator to S30
Middle latitudes southern hemisphere (MSH)	S30 to S60
High latitudes southern hemisphere (HSH)	S60 to S90



# Sample ICAO SWX Advisory

FNXX01 YMMC 020100

SWX ADVISORY

DTG: 20190202/0100Z

SWXC: ACFJ

ADVISORY NR: 2019/10

SWX EFFECT: HF COM MOD

OBS SWX: 02/0100Z DAYLIGHT SIDE

FCST SWX + 6 HR: 02/0700Z DAYLIGHT SIDE

FCST SWX + 12 HR: 02/1300Z DAYLIGHT SIDE

FCST SWX + 18 HR: 02/1900Z NO SWX EXP

FCST SWX + 24 HR: 03/0100Z NO SWX EXP

RMK: LOW END OF BAND HF COM DEGRADED  
ON SUNLIT ROUTES. NEXT 12 HOURS  
MOST POSSIBLE, DECLINING THEREAFTER.

NXT ADVISORY: 20190202/0700Z=



# ICAO Space Weather Advisory Thresholds

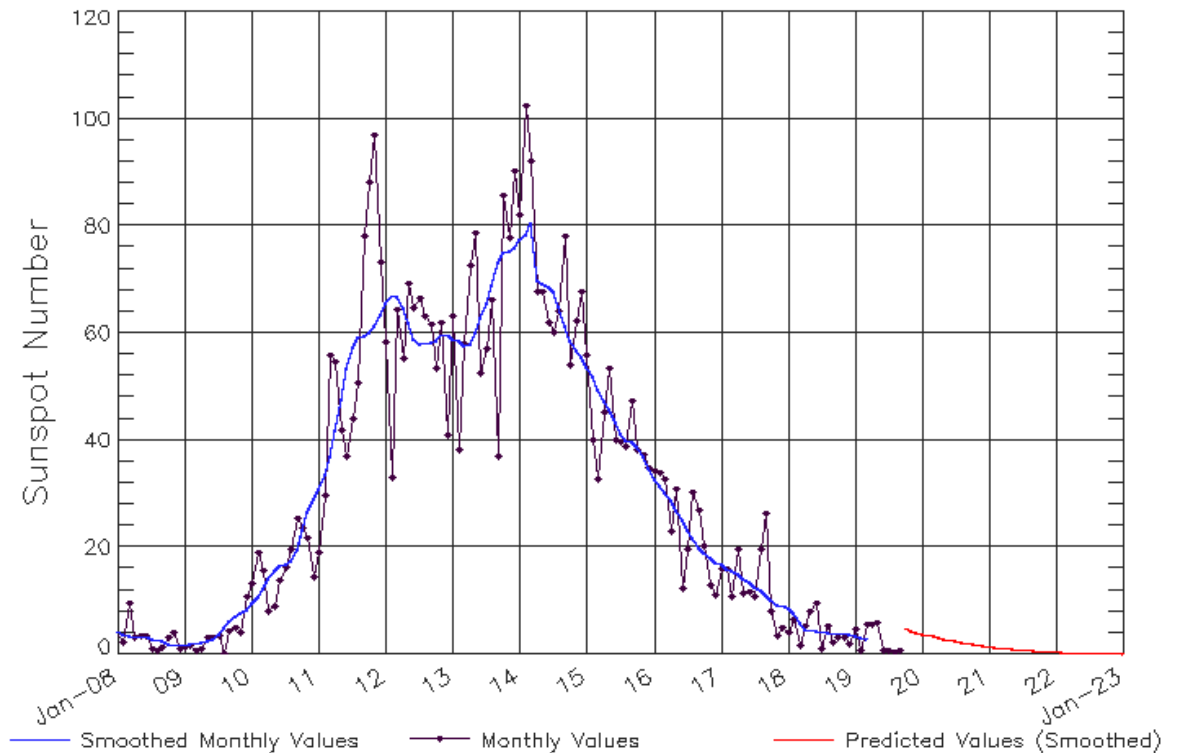
		Moderate	Severe
<b>GNSS</b>			
	Amplitude Scintillation (S4)(dimensionless)	0.5	0.8
	Phase Scintillation (Sigma-Phi)(radians)	0.4	0.7
	Vertical TEC (TEC Units)	125	175
<b>RADIATION</b>			
	Effective Dose Rate (micro-Sieverts/hour)*	30	80
<b>HF</b>			
	Auroral Absorption (Kp)	8	9
	PCA (dB from 30MHz Riometer data)	2	5
	Solar X-rays (0.1 - 0.8 nm)(W-m <sup>-2</sup> )	1X10 <sup>-4</sup> (X1)	1X10 <sup>-3</sup> (X10)
	Post-Storm Depression (MUF)**	30%	50%



# Operational Considerations

- Near solar minimum – few advisories
  - Only 1 advisory issued
- Expect additional advisories over next 6 months as move into solar maximum
  - Adjustments may be made to advisories

ISES Solar Cycle Sunspot Number Progression  
Observed data through Sep 2019



Updated 2019 Oct 7

NOAA/SWPC Boulder, CO USA



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# Dissemination

- User's can obtain the Space Weather Advisory (SWXA) through their National (Operational Meteorological) OPMET Centre (NOC), their State Aeronautical Information Service (AIS) or the secure internet services: The Secure Aviation Data Information Service (SADIS) and the World Area Forecast (WAFS) Internet File Service (WIFS)
- The World Meteorological Organization (WMO) message headers (TTAAii CCCC) for the text and IWXXM Advisories and Administration messages are given in the table below
  - *Note: ACJF Consortium will issue advisories from two locations*



## Dissemination – cont.

WMO Headers		
	TAC Advisory	IWXXM Advisory
ACFJ – Australia	FNXX01 YMMC	LNXX01 YMMC
ACFJ – France	FNXX01 LFPW	LNXX01 LFPW
PECASUS – Finland	FNXX01 EFKL	LNXX01 EFKL
PECASUS – UK	FNXX01 EGRR	LNXX01 EGRR
CRC – China	FNXX01 ZBBB	LNXX01 ZBBB
CRC – Russia	FNXX01 UUAG	LNXX01 UUAG
SPWC – USA	FNXX01 KWNP	LNXX01 KWNP

01 = GNSS  
 02 = HF COM  
 03 = RADIATION  
 04 = SATCOM



# Use of Advisory

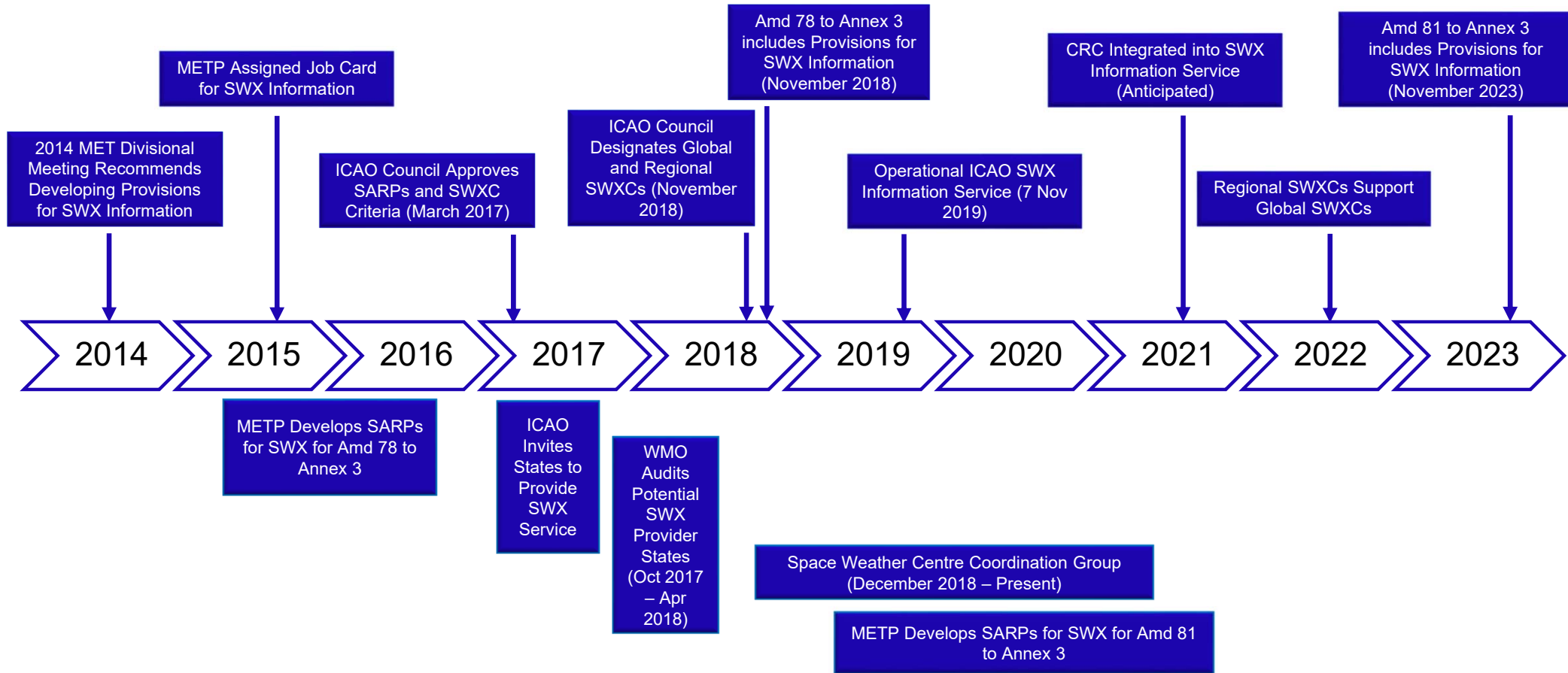
- ICAO service of real-time warnings
- Allow users to be situationally aware
- Follow company's operating procedures to account for prudent actions



# Backup Slides



# Space Weather Information Service





## Background – cont.

- ICAO Council selects/designates States to provide Space Weather Annex 3 products in Nov 2018
  - Considered ‘optimum number’ recommended by METP
  - Based on WMO audit results
  - Based on ‘other’ considerations

