The Bureau of Meteorology

Space Weather Advisory Service for Aviation

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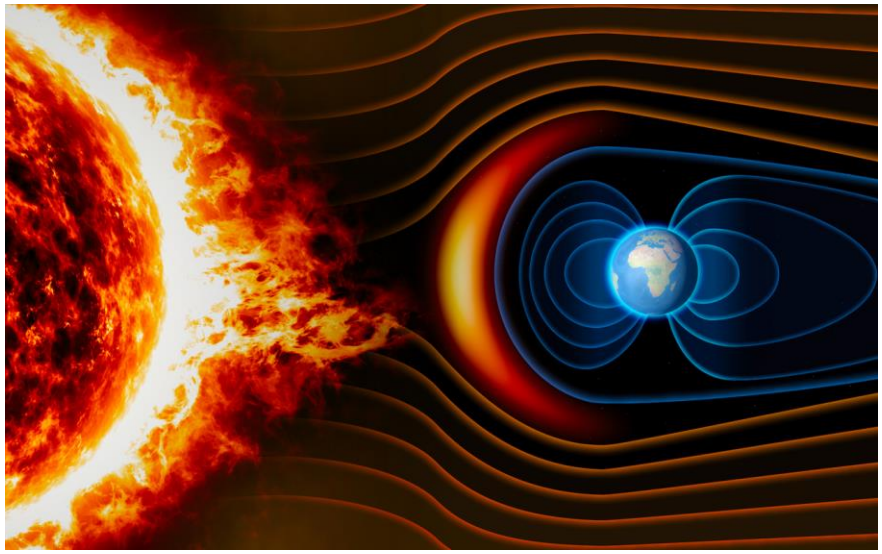
Outline

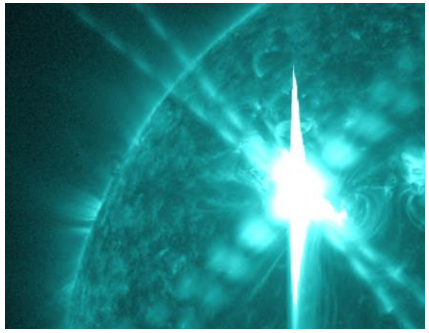
- What is space weather?
- Impacts of Space Weather on International Civil Aviation
- ICAO space weather advisory information
- Dissemination of advisories
- Reference Documents / educational brochures

What is space weather?

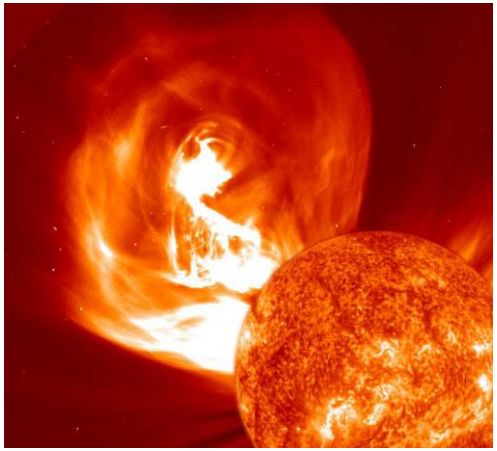
- Events in space that can impact on our technology and the near-Earth environment
- Primary source of space weather is eruptions on the Sun
- These eruptions can produce a wide range of effects on technological systems at Earth
- Satellites, power networks, GPS, communications
- Aviation impacted in various ways



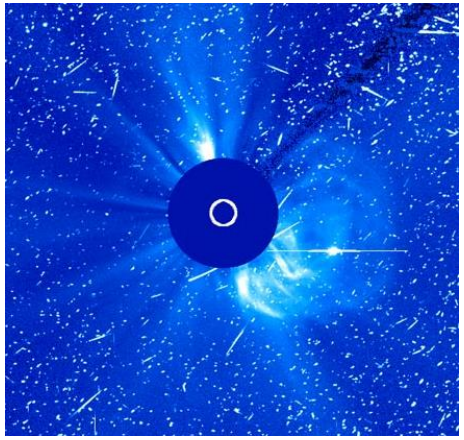
What is space weather?



- **Solar flares** are intense bursts of electromagnetic (EM) radiation. Travelling at the speed of light, impacts are immediate and they usually last from minutes to hours. MAIN IMPACT AREA: HF



- **Coronal mass ejections (CMEs)** are intense eruptions of plasma. Impacts not observed until the plasma reaches Earth, usually 2-3 days from the time of eruption. IMPACT MAIN AREA: HF, GNSS



- **Radiation storms** are showers of protons with extremely high energies. Impacts not observed until protons reach Earth, usually within hours from the time of eruption. MAIN IMPACT AREA: HF, RADIATION

Impacts of Space Weather on International Civil Aviation

There are three main impacts of space weather on aviation

HF Communications

- *Radio Blackouts (absorption)*
- *Compressed HF bandwidth (HF depression)*

Satellite Communications/GNSS

- *Aircraft positioning*
- *Communications*

Radiation

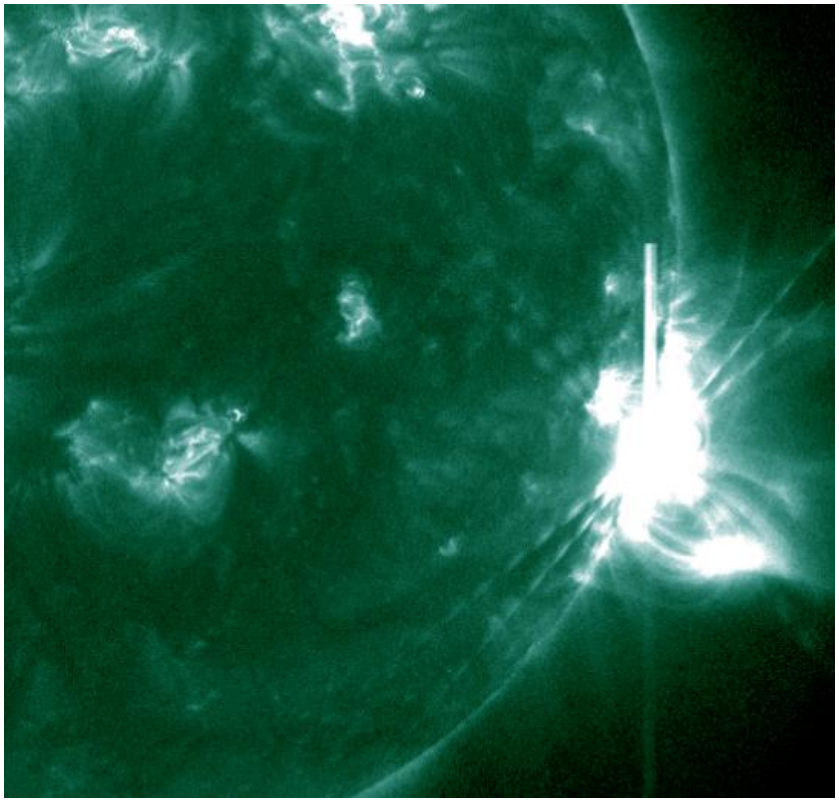
- *Impact on health and safety of passengers and crew*

HF Communications

- Space weather regularly modifies the content of the ionosphere, blocking or degrading HF communications

Space weather impacts aviation in the following ways:

- Complete loss of HF COM on the day side of Earth (solar flares)
- Complete loss of HF COM across polar caps (energetic protons)
- Reduced HF COM frequency set globally (ionospheric storms)



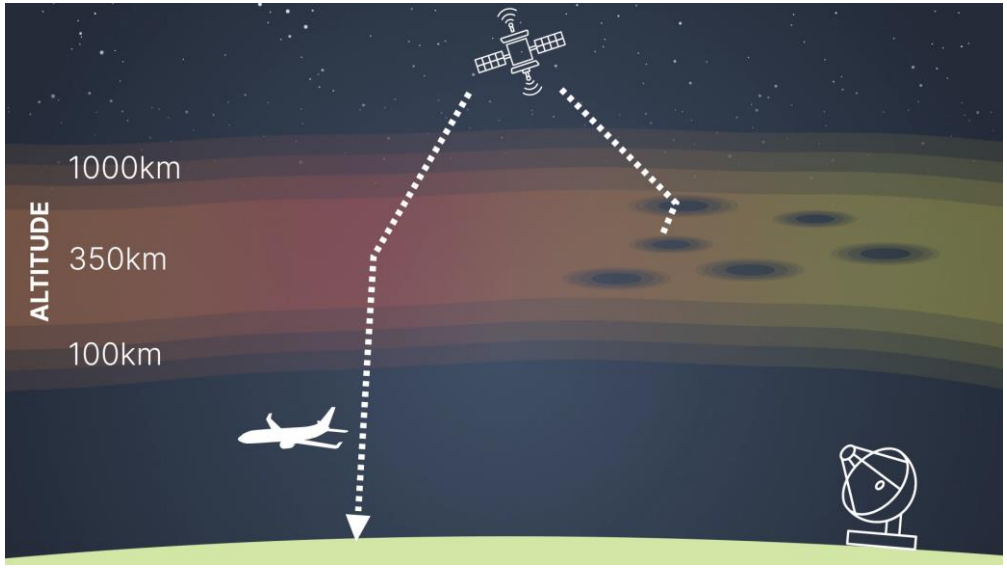
X8.7 solar flare observed on 14th May 2024, the largest of this solar cycle so far. Source: NASA/SDO

GNSS/Satellite Communications

- SATCOM relies on the transmission of signals through the ionosphere
- Ionospheric storms, geomagnetic storms and/or scintillation can lead to aircraft positioning errors

Space weather impacts aviation in the following ways:

- Lower positioning accuracy
- Loss of satellite tracking
- Poor quality / availability of SATCOM



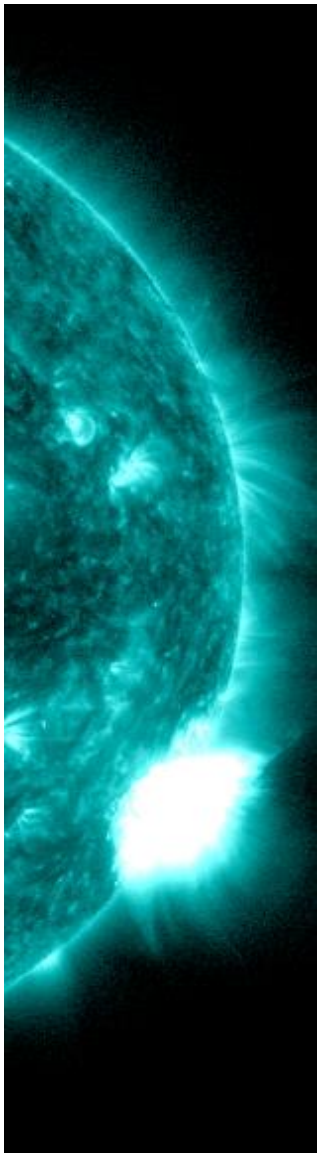
Left: An ionospheric storm causes incorrect positioning information of aircraft below.
Right: Plasma bubbles causes signal disruption in Earth's ionosphere.

Radiation

- Large, long-duration solar flares can release an associated burst of solar energetic particles (SEPs)
- SEPs can penetrate aircraft interior and human tissue/cells

Space weather impacts aviation in the following ways:

- Increased radiation exposure to passengers and crew
- Main impact to flights on polar routes



Large solar flares can produce associated energetic proton events. Source: NASA/SDO

ICAO SWX Service

- Provided by 4 global centres
  - Australia, Canada, France and Japan (ACFJ) Consortium
  - China and Russia Consortium (CRC)
  - European (PEGASUS) Consortium
  - USA
- Global centres are active all the time and rotate through the following roles:
  - On Duty Centre - responsible for the creation and dissemination of all defined SWX products
  - Primary Backup Centre
  - Secondary Backup Centre
  - Maintenance and Observation Centre
- The roles change every 2 weeks
- SWXA are sent to national OPMET Centres

Space Weather Advisory Example – Severe 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

Details

Next update

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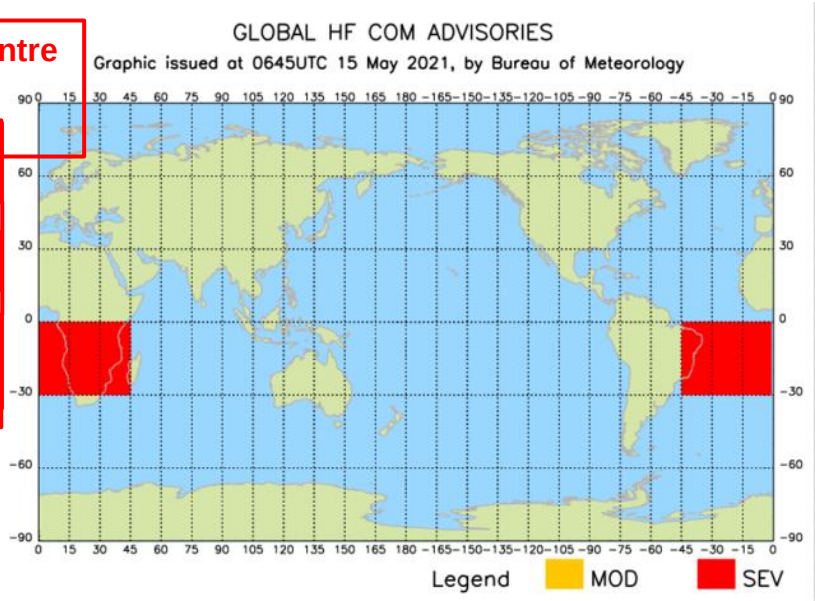
EQN/ EQS
DAYSIDE
[ABV FLxx]



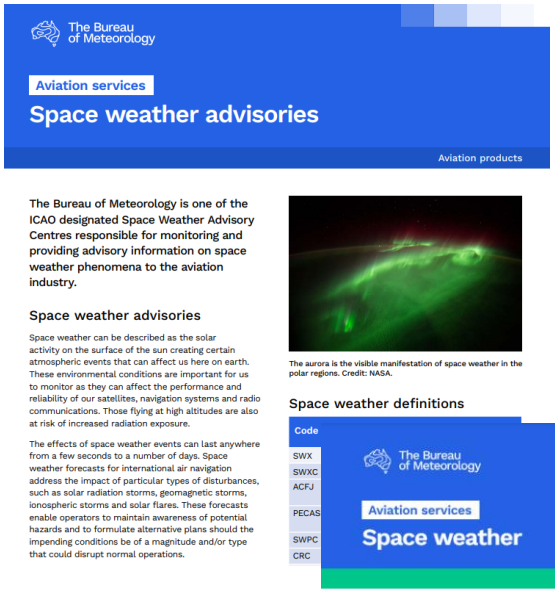
http://www.bom.gov.au/aviation/space-weather-advisories/

Reference Documents

- ICAO Annex 3 (Meteorological Service for International Air Navigation) defines the 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
  http://www.bom.gov.au/aviation/data/education/space-weather.pdf


The Bureau of Meteorology

Aviation services

Space weather advisories

Aviation products

The Bureau of Meteorology is one of the ICAO designated Space Weather Advisory Centres responsible for monitoring and providing advisory information on space weather phenomena to the aviation industry.

Space weather advisories

Space weather can be described as the solar activity on the surface of the sun creating certain atmospheric events that can affect us here on earth. These environmental conditions are important for us to monitor as they can affect the performance and reliability of our satellites, navigation systems and radio communications. Those flying at high altitudes are also at risk of increased radiation exposure.

The effects of space weather events can last anywhere from a few seconds to a number of days. Space weather forecasts for international air navigation address the impact of particular types of disturbances, such as solar radiation storms, geomagnetic storms, ionospheric storms and solar flares. These forecasts enable operators to maintain awareness of potential hazards and to formulate alternative plans should the impending conditions be of a magnitude and/or type that could disrupt normal operations.

The aurora is the visible manifestation of space weather in the polar regions. Credit: NASA.

Space weather definitions

Code
SWX
SWXC
ACFJ
PECAS
SWPC
CRC

The Bureau of Meteorology

Aviation services

Space weather

Hazardous phenomena

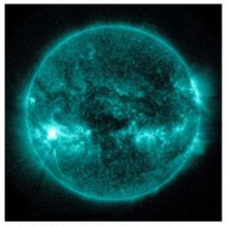
Space weather events may cause disruptions to aviation communications, navigation and surveillance systems, and increase radiation exposure at aircraft cruising levels.

What is space weather?

Space weather broadly describes the impact of solar activity on technological systems and human well-being here on earth. Dynamic variations on the surface of the sun can release large amounts of energy in various forms including electromagnetic radiation, charged particles and eruptions of huge clouds of ionised gas. These phenomena can significantly affect the earth's upper atmosphere and surrounding space environment with impacts felt all the way down to technological systems on the ground.

Particularly concerning for communications and navigation systems, solar variations both directly and indirectly modify a layer of the earth's upper atmosphere known as the ionosphere. The ionosphere extends upwards from 90 km above the earth's surface.

High frequency (HF) radio communication (HF COM) relies on the ionosphere reflecting radio waves back down to the ground. Long-range voice and data


Credit: NASA/GSFC/Solar Dynamics Observatory

communication, including the range of usable HF frequencies, can vary according to the state of the ionosphere.

Satellite communication (SATCOM) and satellite-based navigation and surveillance (SATNAV) that use Global Navigation Satellite Systems (GNSS) (e.g. Global Positioning System (GPS)), rely on the transmission of signals through the ionospheric layer. These signals are modified in various ways as they travel through the ionosphere, depending on its density and structure.

Space weather events that modify the density and/or structure of the ionosphere can therefore significantly impact the performance of HF COM, SATCOM and SATNAV systems.

Apart from effects associated with the ionospheric layer, the release of highly energetic particles from the sun, during solar disturbances, can result in increased and potentially dangerous radiation at aircraft cruising levels. Radiation exposure increases with altitude and