Space Weather and its Impact on ATM

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Introduction

The Earth is constantly subjected to electromagnetic and high energy particle radiation from both galactic sources and the Sun. Most of the variability is of solar origin and is collectively known as space weather. Like terrestrial weather, minor events are more common than major events. Generally the day-to-day variation in space weather has a negligible impact on technology and humans but on average several times in each solar cycle of 11 years space weather can have operational impact.
What is Space weather

Generally:

the term Space Weather refers to “the conditions of the sun and in the solar wind magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health”

Short term variations in space weather originate on the Sun.

From ICAO Perspective:

space weather events occur when the Sun causes disruptions to aviation communications, navigation and surveillance systems, and elevates radiation dose levels at flight altitudes.

Space weather events may occur on short time scales, with the effects occurring from almost instantaneously to over a few days.
2003 Halloween solar storms

During the declining phase of the solar cycle the Sun unexpectedly burst into activity. A number of CMEs and flares resulted from a very large and complex group of sunspots. These resulted in geomagnetic storms that caused outages in high frequency (HF) communication systems, fluctuations in power systems and minor to severe impacts on satellite systems. This included two Inmarsat satellites (used by the aviation industry) of which one required manual intervention to correct its orbit and the other went offline due to central processor unit (CPU) failures. These were just two of forty-seven satellites reported to have service interruptions lasting from hours to days.
The Sweden Case: Airplanes disappear from radars due to "solar storm"

Posted by Teo Blašković on November 5, 2015 at 00:01 UTC (4 years ago)

Categories: Featured articles, Geomagnetic storms, Solar activity

Swedish media is reporting air traffic problems due to 'solar storm' interfering with air traffic control.
Space weather phenomena are:

- Geomagnetic storms
- Ionospheric storms
- Solar flare radio blackouts
- Solar radiation storms
- Galactic cosmic rays
Geomagnetic storms are strong disturbances in the Earth’s (geo)magnetic field. These are the response to a heightened energy flux carried by the solar wind.

The solar wind is the continuous outflow from the Sun of magnetic field and its charged particles.
Ionospheric storms are the result of adding energy to the weakly ionized plasma which is the ionosphere, which extends upward from about 60 km.
Solar flare radio blackouts are strictly a dayside impact. Solar flares are rapid releases of energy stored in strong and localized magnetic fields on the Sun.

These solar flare blackouts can eliminate or degrade HF, both voice and data link, for periods ranging from a few minutes to a few hours. The duration of the impact is much shorter than it is during geomagnetic storms. The affected range of HF frequencies is also quite different.
Solar radiation storms occur when charged particles, primarily protons, are energized and accelerated in processes occurring near the Sun or beyond. These particles are guided by the interplanetary magnetic field and, under the right conditions, engulf the Earth with additional radiation.
Galactic cosmic rays are the slowest changing element in the suite of variables. Originating in distant supernovae, they are kept to a minimum near the Earth when the Sun is eruptive and producing flares and coronal mass ejections, due to the turbulence that activity spawns in the inner heliosphere.
International recognition on Space weather

- In 2002 the ICAO Meteorology Divisional Meeting requested the evaluation of the need to provide information for international air navigation, inter alia, on solar radiation storms.

- ICAO and the World Meteorological Organization (WMO) worked closely together over many years to mature a proposal for space weather requirements (through the International Airways Volcano Watch Operations Group (IAVWOPSG)).

- In 2011 the International Air Transport Association (IATA) confirmed a high-level user requirement for information on space weather.

- In 2014 the Meteorology (MET) Divisional Meeting recommended: That an appropriate ICAO expert group, in close coordination with WMO, be tasked to develop provisions for information on space weather to international air navigation consistent with the Global Air Navigation Plan (Doc 9750), including the integration of the information produced into the future system-wide information management (SWIM) environment underpinning the future globally interoperable air traffic management system.
International recognition on Space weather

- The ICAO Air Navigation Commission (ANC) has tasked the Meteorology Panel (METP) to develop international SARPs and guidelines for space weather that may present a hazard to aviation operations.
- The METP was established in 2015 and has met as a full Panel in April 2015 and October 2016.
- Space Weather is one of the Work Streams associated with the METP Working Group on Meteorological Information & Service Development (WG-MISD).
The hazards and Effect of Space weather

Space weather impacts occur in communications, navigation, surveillance, radiation-sensitive electronics, and human exposure (flight Crews and Passengers).
The impact of space weather

- unexpected loss of communications; HF voice and data link, i.e. controller pilot data link communications (CPDLC), on routes where that manner of communications is used
- poor or unusable performance in satellite communications;
- Degraded performance of navigation and surveillance that rely on GNSS and Automatic dependent surveillance – broadcast (ADS-B) and/or automatic dependent surveillance – contract (ADS-C) anomalies;
- Sporadic loss-of-lock of GNSS, especially near the equator and post-sunset;
- unanticipated non-standard performance of on-board electronics resulting in reboots and anomalies;
- Issues related to radiation exposure by aircrew and passengers.
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Space weather mitigation aspects

- **Satellite failure and GNSS-based applications:** A back-up to satellite communication and navigation should remain available. Depending on the flight phase, area and aircraft equipment, this back-up could be HF/VHF/SATCOM voice communication, ground based navigation, radar vectoring, inertial navigation, etc.

- **Power failure:** Air traffic control centers have alternate power generation in case of power failure to ensure the safety of air navigation.

- **Increase in the radiation level:** As the radiation dose is higher at higher altitude and latitude, a possible solution is to decrease the aircraft altitude and latitude. However, the geographic and altitude limit are difficult to determine. Currently, airlines are not flying polar routes when a radiation storm is in progress.
**Forecasting of Space Weather** The timely availability of reliable and consistent space weather information (observations and forecasts) is essential to mitigate the safety risk of aircraft losing key in-flight functionality.

The designated Space Weather Centers (SWXC) have at their disposal information from satellite and ground-based sensors, enabling both prompt event detection as well as providing input for predictive models.

Physics-based models are now available to operations centers to predict the trajectory of CMEs and there now exists an ability to predict the onset of a geomagnetic storm to about $\pm 8$ hours. Ionospheric storms can be predicted in a similar way.
The information and services required for safe and efficient aircraft operations will be provided by designated global centers assisted by regional centers passing relevant information to the global centers for dissemination. The working principle for the centers is to provide space weather advisory information that users can employ for decision-making.

Aviation products must have a high priority in the formulation and distribution of the required space weather advisory information due to the almost immediate effects on aircraft navigation and communication systems as well as radiation impacts to passengers and aircrew.

All centers must develop coordination protocols and procedures to enable clear and unambiguous information disseminated to the aviation industry.
SWXC issue the space weather advisory information when there are impacts to HF communications, communications via satellite, GNSS-based navigation and surveillance systems, or when heightened radiation occurs.

The advisory message informs the user of:

a) the type of impact;
b) the expected onset, or that the event is already in progress;
c) the duration of the event;
d) a generalized description of the spatial extent affected for the next 24 hours; and
e) a description of the severity of the impact in moderate (MOD) or severe (SEV) categories.