EASA Safety Information Bulletin

SIB No.: **2012-09**
Issued: **23 May 2012**

Subject: **Effects of Space Weather on Aviation**

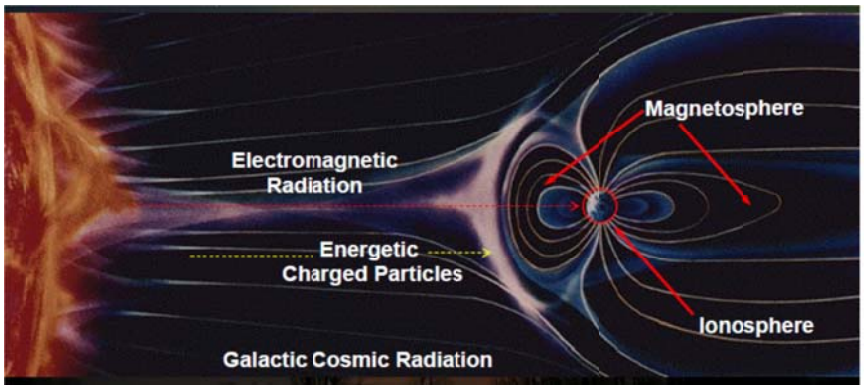
Ref. Publication:
1. EU OPS 1.390 Cosmic Radiation;
2. SIB 2012-10 Single Event Effects (SEE) on Aircraft Systems Caused By Cosmic Rays;
3. Appendix 1 contains a list of useful web-site and identify those that provide information or prediction on actual space weather.

Applicability: All aircraft and their operations, all ATM/ANS (Air Traffic Management/Air Navigation Services) systems and their operations, all aerodromes and their operations.

Description: This SIB informs aircraft operators, aircraft manufacturers, avionics systems designers, electronic equipment and component manufacturers, ATM/ANS service providers, aerodrome operators and competent authorities of the effects of space weather on electronic devices, communication, navigation and surveillance services and human beings and should be read in conjunction with SIB 2012-10 for on-board systems.

Space weather is a generic term which refers to the environmental conditions in the space around the Earth extended up to the Sun. The major drivers for the space weather are flows of energetic charged particles and electromagnetic radiation. Both of which penetrate and interact with the Earth's atmosphere and magnetic field. The main contributors to space weather can be further separated into Solar and Galactic radiation.

The figure below is a graphical, not to scale, representation of solar and galactic radiation and their interaction with the Earth magnetosphere and ionosphere (from NOAA: National Oceanic and Atmospheric Administration (USA)). The sun activity is the main contributor.



The solar activity follows an eleven year cycle. The last peak was in 2001/2002 and the next one is forecast for 2013 (Also refer to paragraph on Solar Radiation timeline in this SIB)

Classification:

There are several classifications possible. The following list of phenomena is not exhaustive (from ICAO manual on space weather):

1. Geomagnetic storm:
   Geomagnetic storms, strong disturbances to Earth's magnetic field in the solar wind, pose problems for many activities, technological systems and critical infrastructure. The topology of Earth's magnetic field changes in the course of a storm, as the near-Earth system attempts to adjust to the jolt of energy from the Sun carried in the solar wind. CMEs (Coronal Mass Ejections) and the shocks they drive are often the causative agent, and can send the geomagnetic field into a disturbed state for days at a time.

2. Solar radiation storms:
   Solar radiation storms occur when large quantities of charged particles, primarily protons, are accelerated by processes at or near the Sun and then the near-Earth environment is bathed with these charged particles. These particles cause an increase in the radiation dose to humans, and create an increased possibility of single event upsets in electronics. Earth's magnetic field and atmosphere offer some protection from this radiation, but that shielding decreases with altitude, latitude, and magnetic field strength and direction. The polar regions on Earth are most open to these charged particles, because the magnetic field lines at the poles extend vertically downwards intersecting Earth's surface, which allows the particles to spiral down the field lines and penetrate into the atmosphere increasing the ionization.

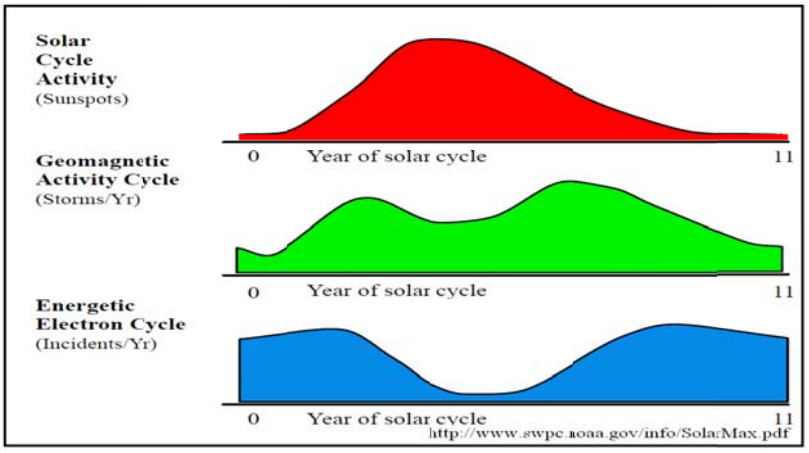
3. Radio black out:
   Radio blackouts primarily affect HF (3-30 MHz) although detrimental effects may spill over to VHF (30-300 MHz) and beyond in fading and diminished ability for reception. The blackouts are a consequence of enhanced electron densities caused by the emissions from solar flares that ionize the

sunlit side of Earth. For example, the powerful solar flare of Nov. 4, 2003 resulted in lost or degraded HF communications for several hours.

4. Ionospheric storms
   Ionospheric storms arise from large influxes of solar particle and electromagnetic radiation, which give rise to the occurrence of geomagnetic storms. There is a strong coupling between the ionosphere and the magnetosphere, which results in both regimes being disturbed concurrently.

   Note 1: Scales have been established by NOAA for each of the first three categories that associate the magnitude of the phenomena (from minor to extreme) and its effects on systems or operations.

   Note 2: It should be highlighted that the events described above are not occurring simultaneously as presented by the picture below.



Potential Effects on the Aviation system: The effects on the Aviation system can be varied. These effects can be separated into two broad categories: effects on people on board and effects on systems and services

People on board aircraft: Solar radiation storms, occurring under particular circumstances, cause an increase in radiation dose to flight crews and passengers. As high polar latitudes and high altitudes have the least shielding from the particles, the threat is the greatest for executive jet and higher altitude commercial polar flights. Operators are already required to monitor the occupational exposure of aircrew to cosmic radiation (refer to EU-OPS 1.390 or Directive 96/29/Euratom on ionising radiation).

a. Systems and Services Affected:

- Avionics
- HF communication
- Low frequency communications
- GPS/GLONASS/WAAS/EGNOS/MSAS
- Communication Satellites
- Weather Satellites
- Potentially any on-board system containing electronic devices
- ATC facilities/services
- CNS facilities/services

Each of the above systems or services may experience degraded operation or loss of function during periods of high Solar and/or Galactic radiation levels.

b. Summary for People, Systems and Services :

The following matrix provides an overview of the effects on people, services and systems (based on a table established by George Washington University-Space policy Institute):

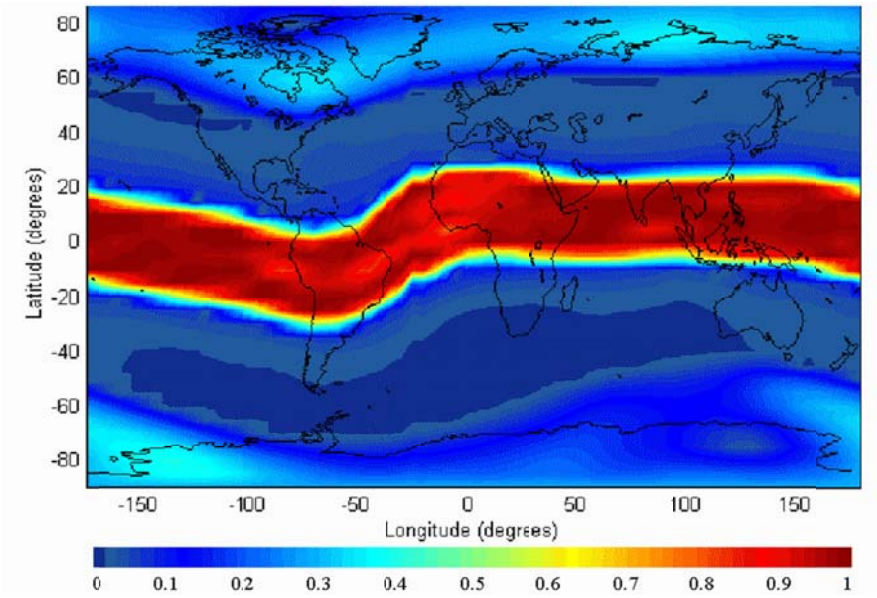
	Solar Event	Solar Flare				Coronal mass ejection		Solar wind	Galactic cosmic rays	
	Secondary Effect	X-ray emission	Ultraviolet emissions	Radio bursts	Solar Energetic Protons (SEPs)	Plasma	Solar Energetic Protons (SEPs)	Enhances radiation belts		
	Effect on Earth system	Increase ionosphere density	Ionospheric disturbances			Geomagnetic storm		Aurora	Radiation	Ionospheric scintillations
Aviation related systems	Occupants of aircraft				X	X	X		X	
	Avionics				X		X		X	
	HF Communication	X	X		X	X	X			X
	GPS/Glonass/Galileo/WAAS/EGNOS/MSAS	X	X	X	X	X	X	X		X
	Satellites (Navigation/Communication)	X	X	X	X	X	X	X	X	X
	Low Frequency Communicattion	X		X		X				
	ATC facilities		X			X				
	NextGen/SESAR	X	X	X	X	X	X	X	X	X

Effects of Solar and Galactic Radiation on Society

Solar and galactic radiation affects the whole of society and not only aviation: satellites systems, electric power grids, communication and navigation systems may be affected. Some of these systems (e.g. power grids) are outside the control of aviation authorities but it is important to highlight they can be affected too.

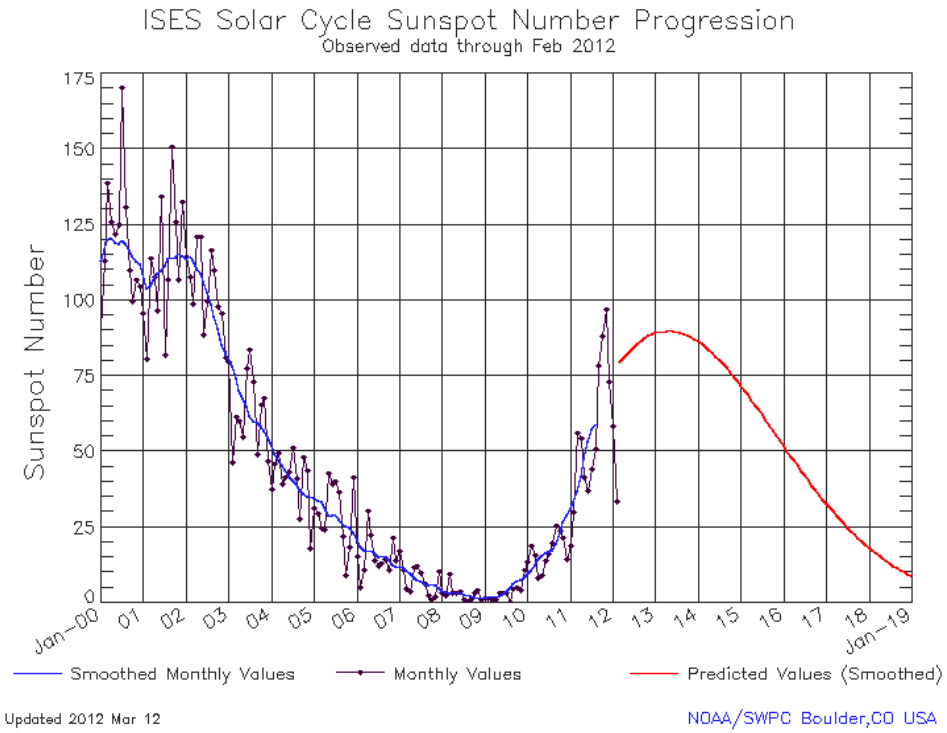
The following risk considerations are relevant:

a. There is an increased reliance on GNSS as the main source for navigation and time.
b. In a similar manner, there is an increased reliance on satellite based communications.
c. The Aviation system is becoming a network
d. The use of polar routes for aircraft trajectory is increasing as it provides reduction in travel times. Especially on such routes, airlines also need to consider the effects of solar activity on HF communication: poorer quality, a shift to lower usable frequency bands, and more noise or fading. During extreme solar activity, HF communications may not be available in the polar region.
e. A peak of solar radiation is approaching
f. The availability, continuity, integrity and accuracy of un-augmented GNSS in the region close to the magnetic equator can rapidly change in time during the event. (see image below from ESA (European Space Agency), where the scintillation index is depicted. In areas where the scintillation index is larger than 0.7 sudden signal losses are quite likely.)



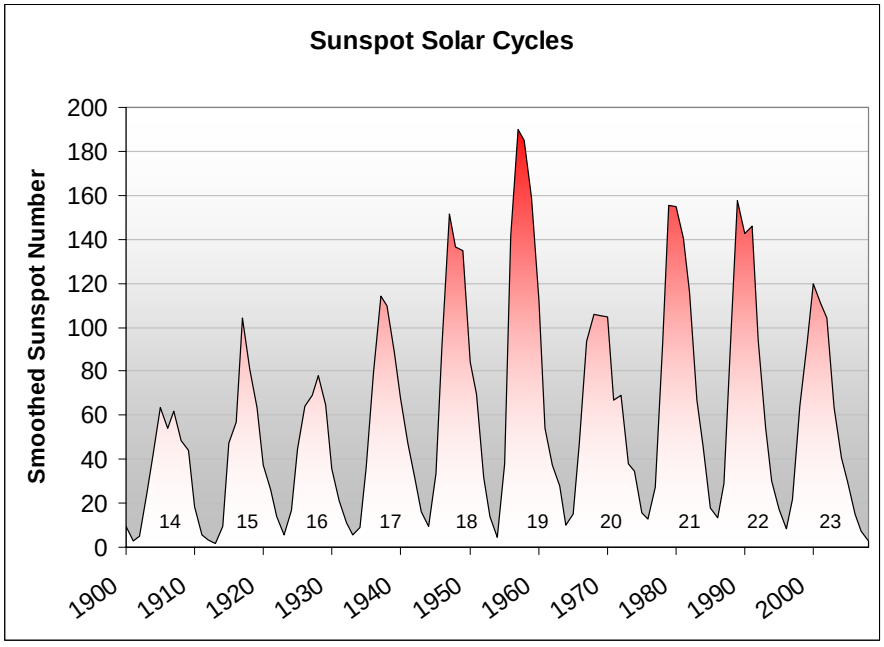
Solar Radiation Timeline:

NOAA (National Oceanic and Atmospheric Administration) have released data indicating that the solar radiation effects on the earth are cyclic. The predicted solar radiation effects are presented in the diagram below:



The diagram gives an indication of when the earth will be subjected to increased solar radiation.

The picture below presents the cycles since the beginning of the 20th century (From ICAO manual on space weather):



Recommendations: Aircraft Operators should continue to make their crews aware of this phenomenon and its potential effects. Operators should also monitor the predicted solar weather information websites

This is information only. Recommendations are not mandatory.

to ensure awareness of when high levels of Solar and Galactic radiation are present or are expected.

Aircraft manufacturers, avionics systems designers, electronic equipment and component manufacturers should continue to work together via the existing industry groups to assess the potential effects of Solar and Galactic radiation at component, systems and aircraft level and provide fault tolerant systems.

ATM/ANS service providers, aerodrome operators and competent authorities should continue to make their relevant personnel aware of the phenomenon and the potential effects.

Contacts:

For further information contact the Safety Information Section, Executive Directorate, EASA. E-mail: ADs@easa.europa.eu .

Appendix 1:
Useful web sites

a. ICAO: concept of operations, high level requirements and manual available at:
    i. http://www.icao.int/safety/meteorology/iavwopsg/Space%20Weather/Forms/AllItems.aspx
    ii.
b. EU OPS:
    i. http://eur-lex.europa.eu/Notice.do?val=479580:cs&lang=en&list=479580:cs,&pos=1&page=1&nbl=1&pgs=10&hwords=(EC)%20No%20859/2008~
    ii. Paragraph 1.390 addresses Cosmic radiation

c. WMO:
    i. http://www.wmo.int/pages/prog/sat/spaceweather-intro_en.php
    ii. This site contains a space weather portal that provide links to several other organisations dealing with space weather

d. ESA
    i. http://www.esa-spaceweather.net/
    ii. This site provides information on “today’s space weather” and a link to the prediction centre of NOAA

e. NOAA:
    i. http://www.swpc.noaa.gov/
    ii. This is the site of the space weather prediction centre of NOAA; A subscription service is available to receive alerts.

f. SKYBRARY:
    i. http://www.skybrary.aero/index.php/Cosmic_Radiation