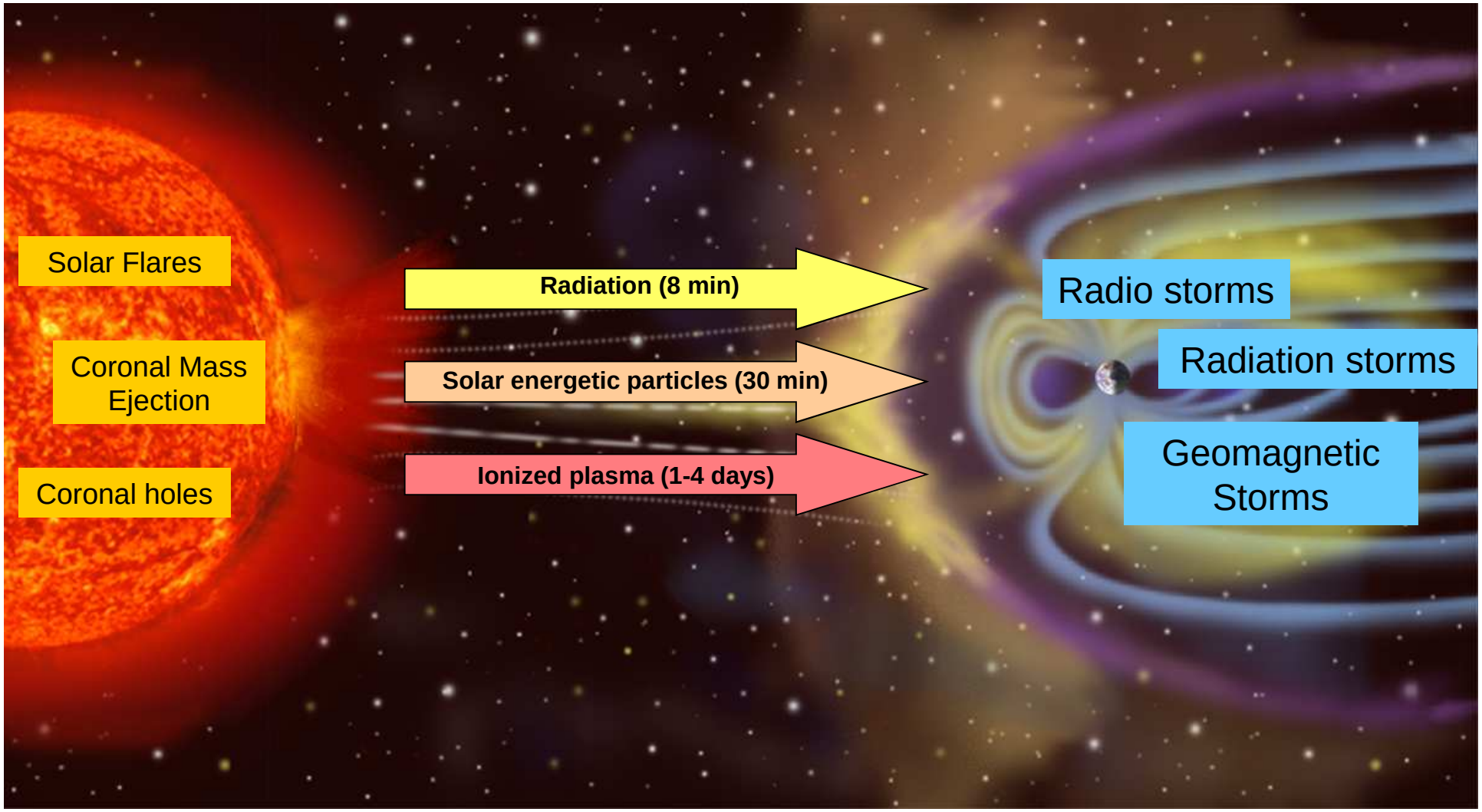
Space Weather and its impact on the infrastructure / aviation

Space weather workshop – Köln, March 20th, 2013

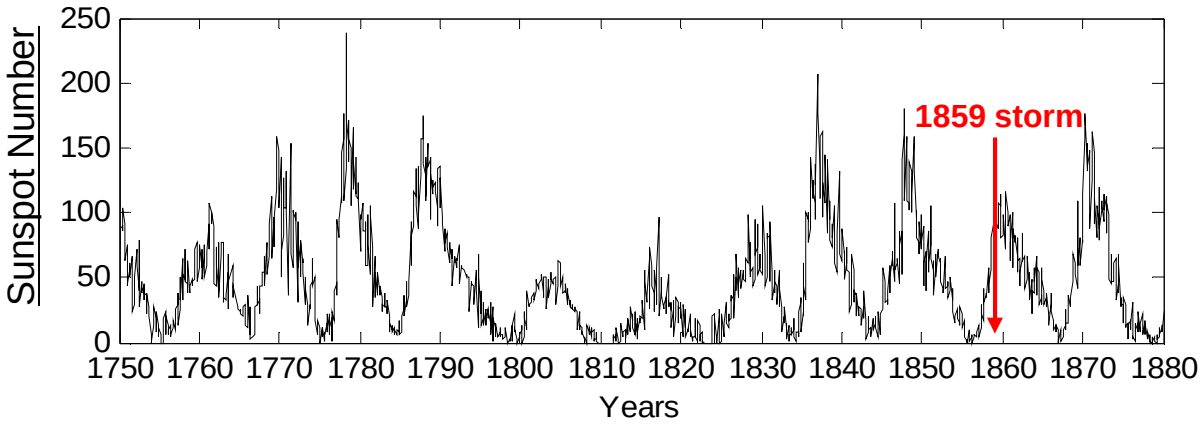
Emilien ROBERT

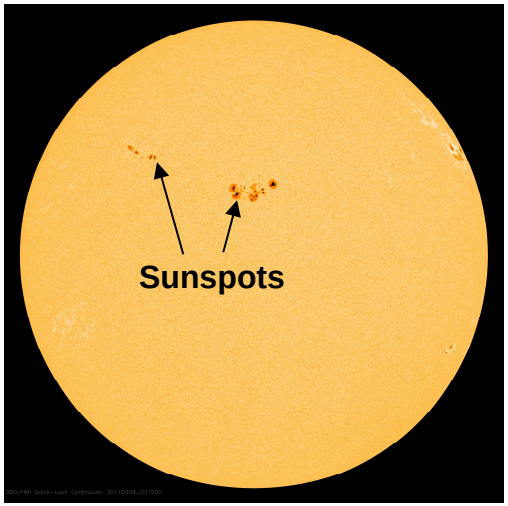
EUROCONTROL

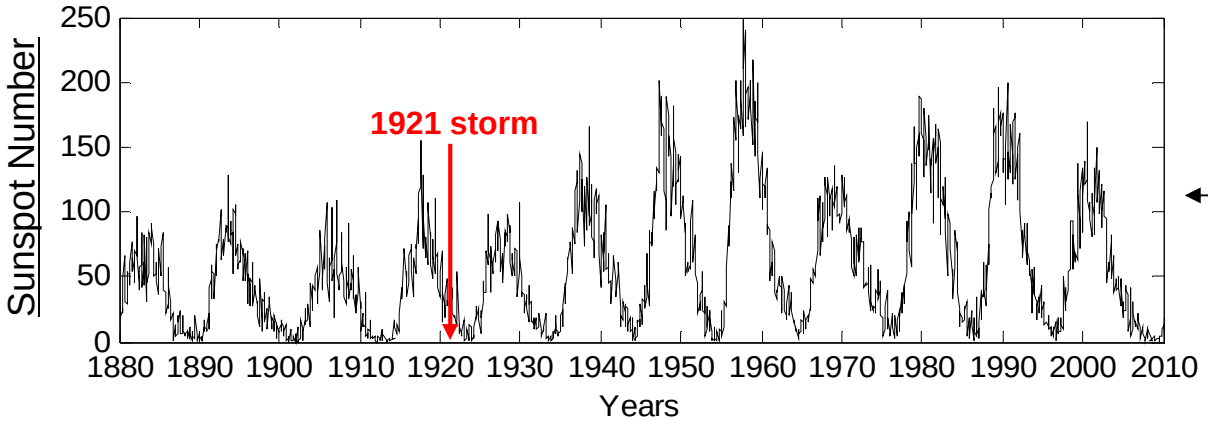
Introduction to Space Weather



Sunspot and the Solar Cycle



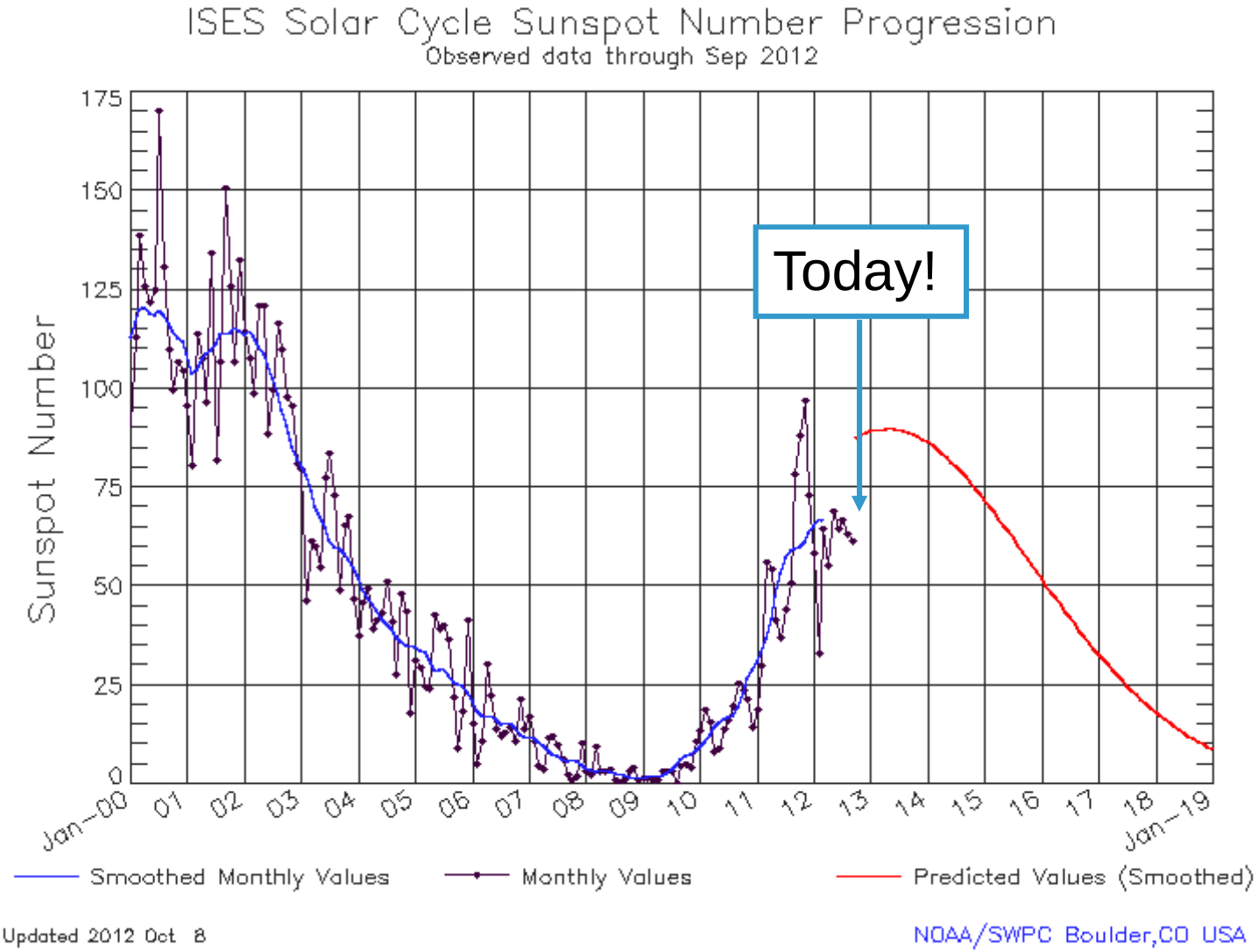




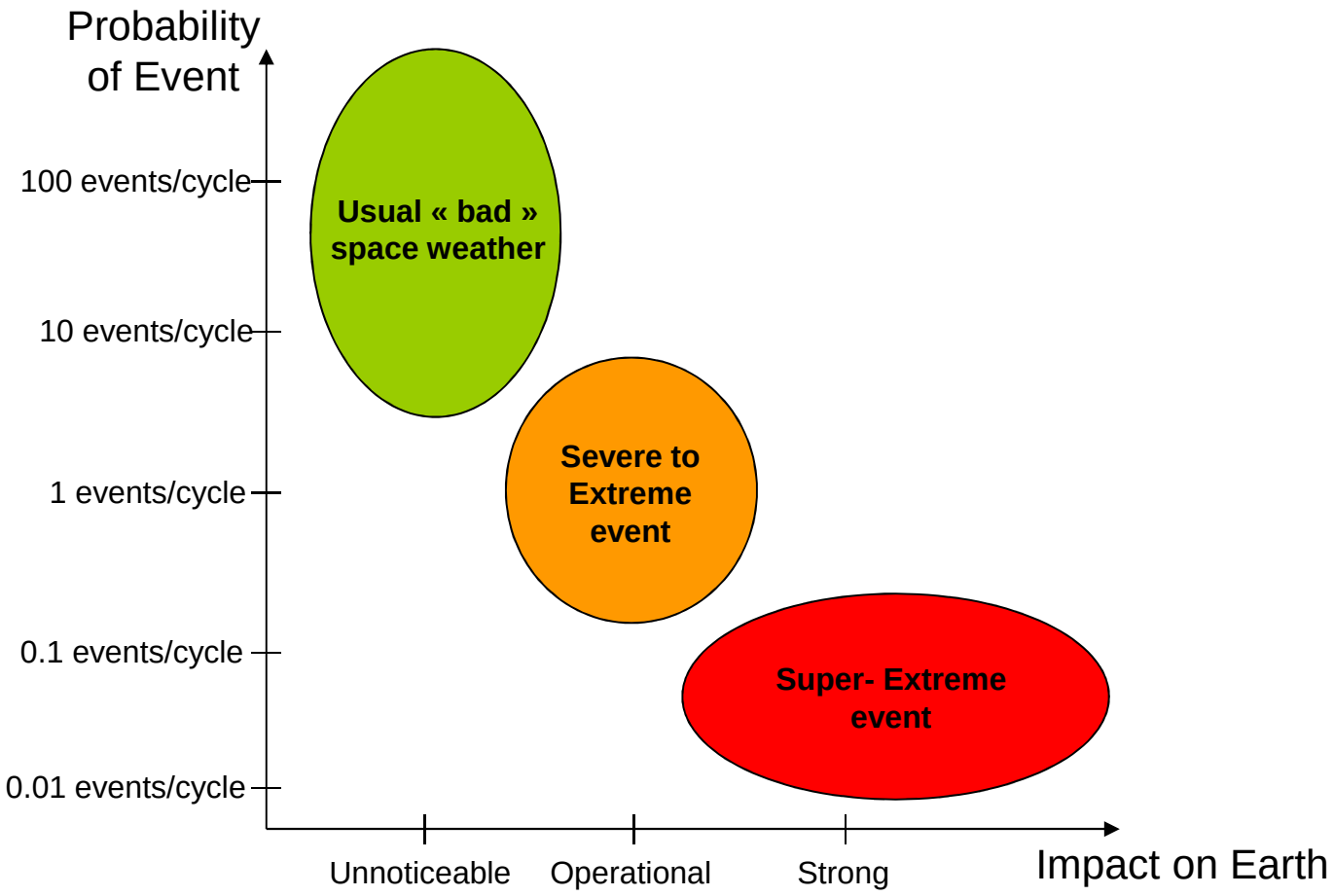
Solar cycle~11 years

- Solar eruptions are most likely to occurs during high solar activity or during the solar activity decrease
- Severity of solar eruptions are not linked to the magnitude of the solar cycle

Next period of high solar activity

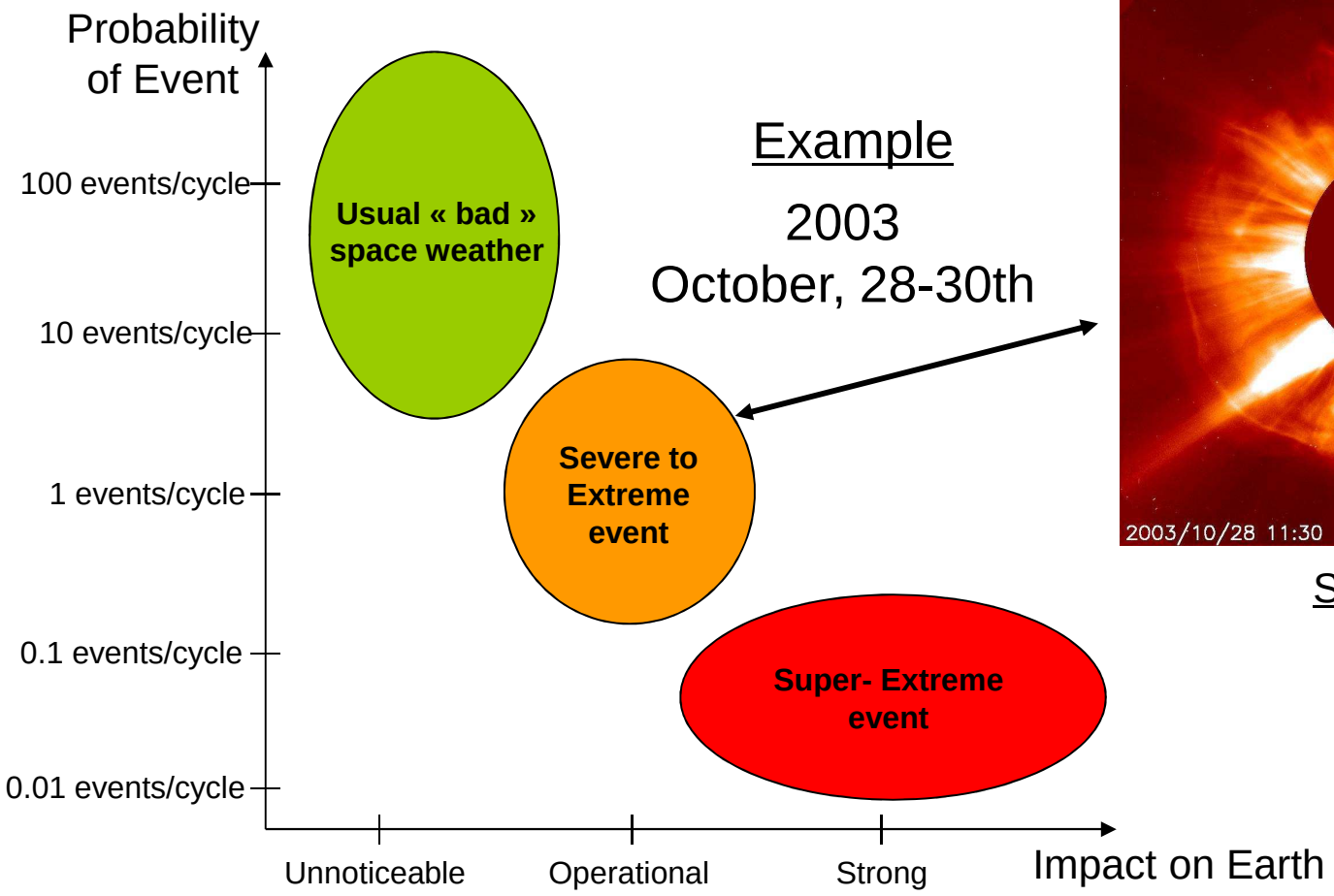


Magnitude/Probability of Solar Event



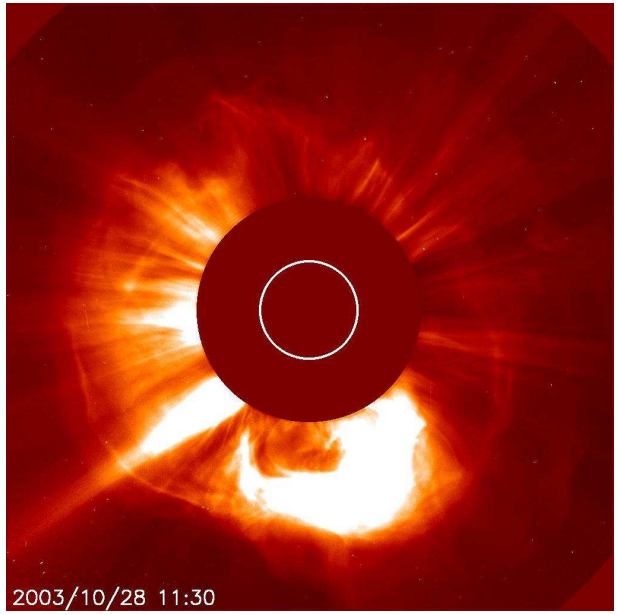
Nota: Solar cycle~11 years

Magnitude/Probability of Solar Event



Example

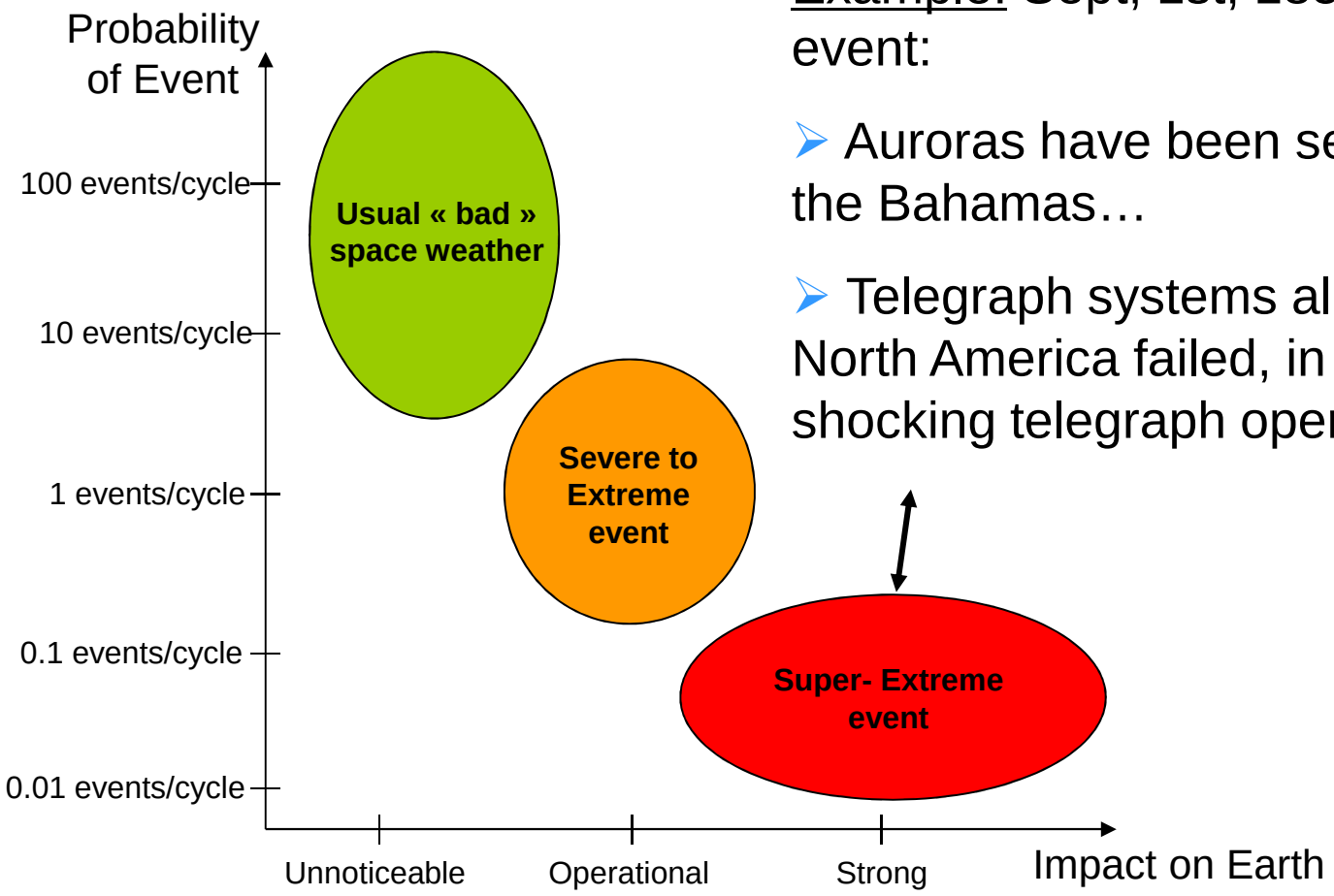
2003
October, 28-30th



Solar eruption

Nota: Solar cycle~11 years

Magnitude/Probability of Solar Event

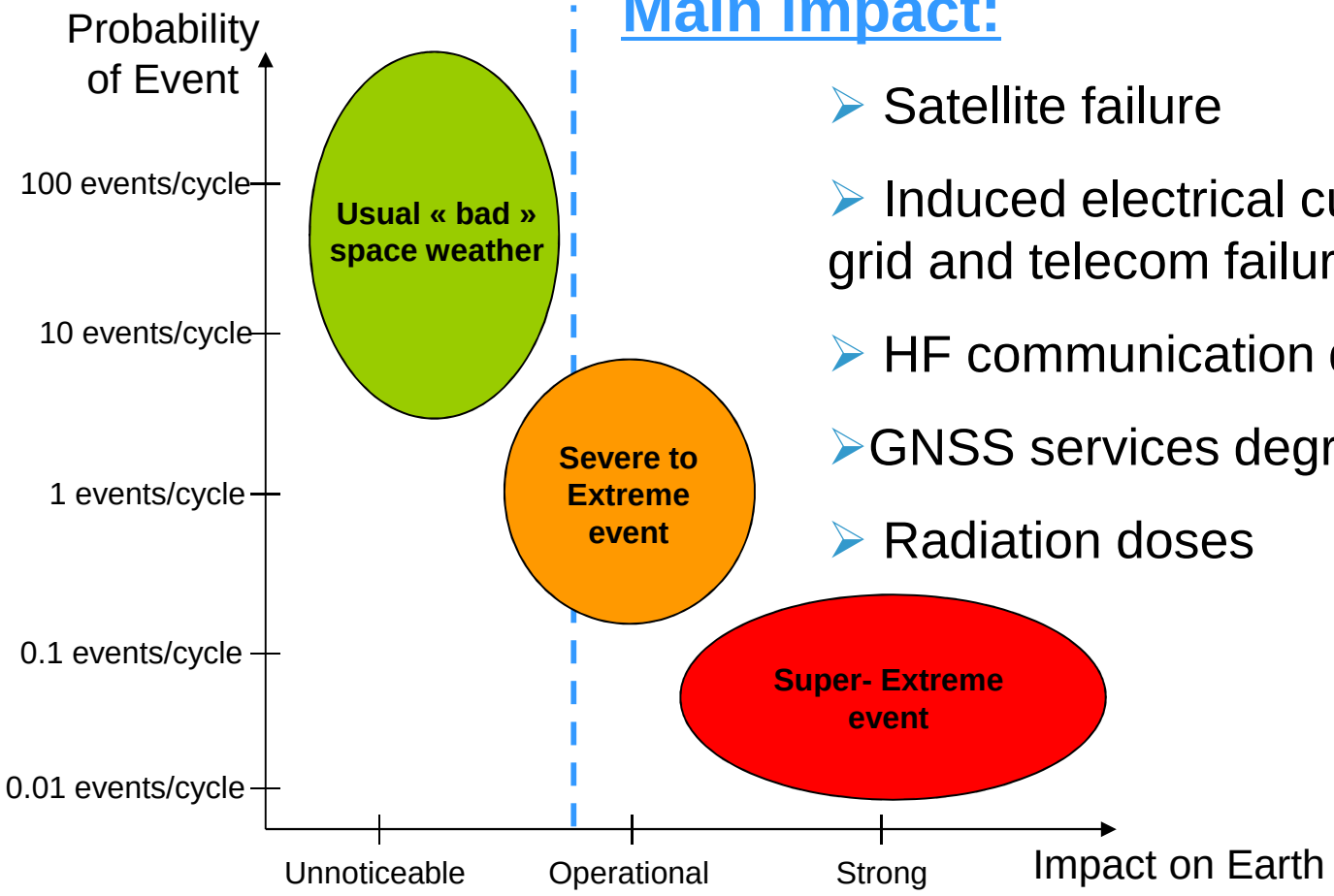


Example: Sept, 1st, 1859 «Carrington» event:

- Auroras have been seen down to Cuba, the Bahamas…
- Telegraph systems all over Europe and North America failed, in some cases even shocking telegraph operators.

Nota: Solar cycle~11 years

Magnitude/Probability of Solar Event



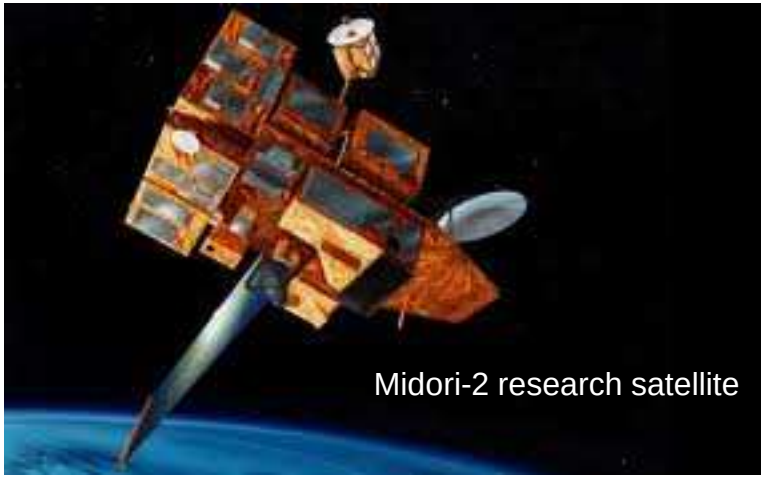
Main impact:

- Satellite failure
- Induced electrical currents (power grid and telecom failure)
- HF communication disturbances
- GNSS services degradation
- Radiation doses

Nota: Solar cycle~11 years

Space Weather impact on satellites

- Solar Energetic Particles and geomagnetic storm may cause failure on satellite


Midori-2 research satellite

- <u>Example:</u>
  - 4 US Navy navigational satellites lost on March 1989.
  - $450 million Midori-2 research satellite lost on October 2003 “Halloween storm”

- <u>Possible impact:</u>
  - Severe to extreme event: a couple of space vehicles may be lost
  - Super-extreme event: up to 50% of the space vehicles may be lost

- <u>Mitigations:</u>
  - Back up to satellite navigation and communication (HF/VHF, ground based navigation, radar vectoring, inertial navigation…)

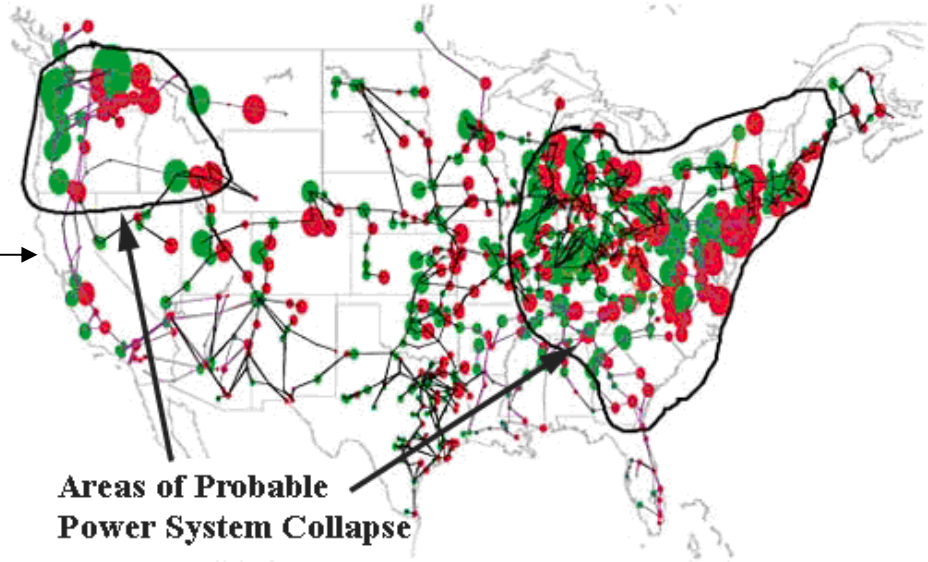
Space Weather impact on power supply

- Geomagnetic storm may create failure in power and ground telecommunication grid

- Example: On March 13th, 1989, at 2:45 AM, the entire Quebec power grid collapsed and 6 million people were affected for 9 hours

Image courtesy of Public Service Electric and Gas and Peter Balma

- Possible impact:
  - Severe to extreme event: power failure overt part of a country for tens of hours
  - Super-extreme event: power failure over part of a continent



- Mitigations:
  - Alternate power generation

Space Weather impact on communication

- Geomagnetic storm may create failure in the ground communication network and in air HF communication

- Example: On September 7th, 2005, solar activity severely impacted all HF communications over US.

- Possible impact:
  - HF and, potentially, satellite communication may be degraded

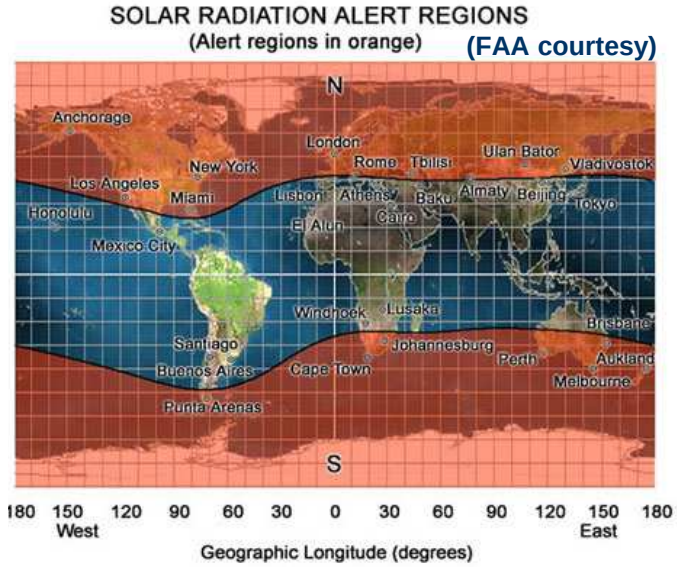
- Mitigations:
  - VHF, SATCOM voice communication
  - Operational mitigations based on space weather nowcast / forecast: flights can be re-routed

Radiation dose impact on health and system

- Radiation storm may cause unusually high levels of ionizing radiation

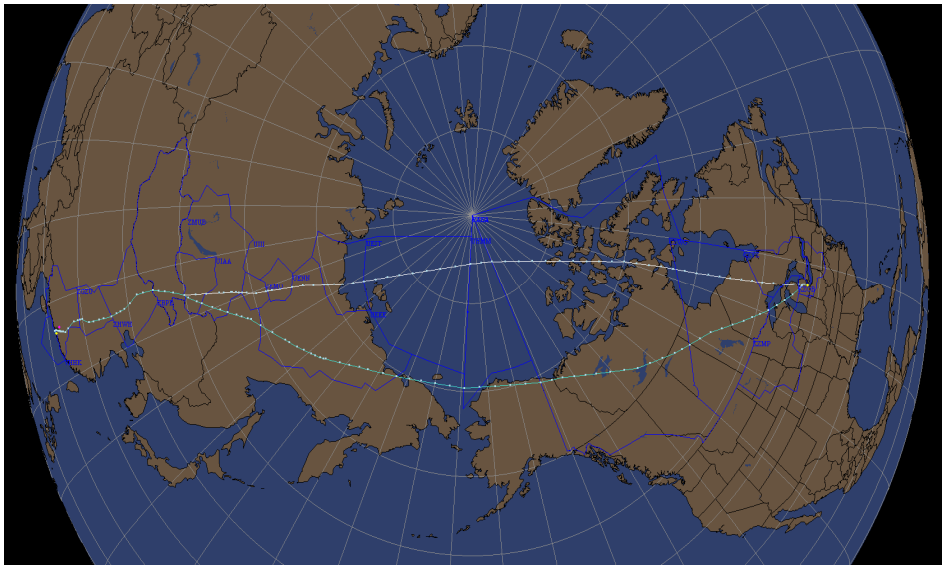
- Radiation storm may also cause failure into electronic devices

- Example:
  - on October, 28th, 2003, FAA Civil Aerospace Medical Institute issued a Solar Radiation Alert



- Possible impact :
  - Higher exposure dose than usual
  - Potential onboard system failure

- Mitigations :
  - Decrease the aircraft altitude and latitude
  - Polar routes may be avoided



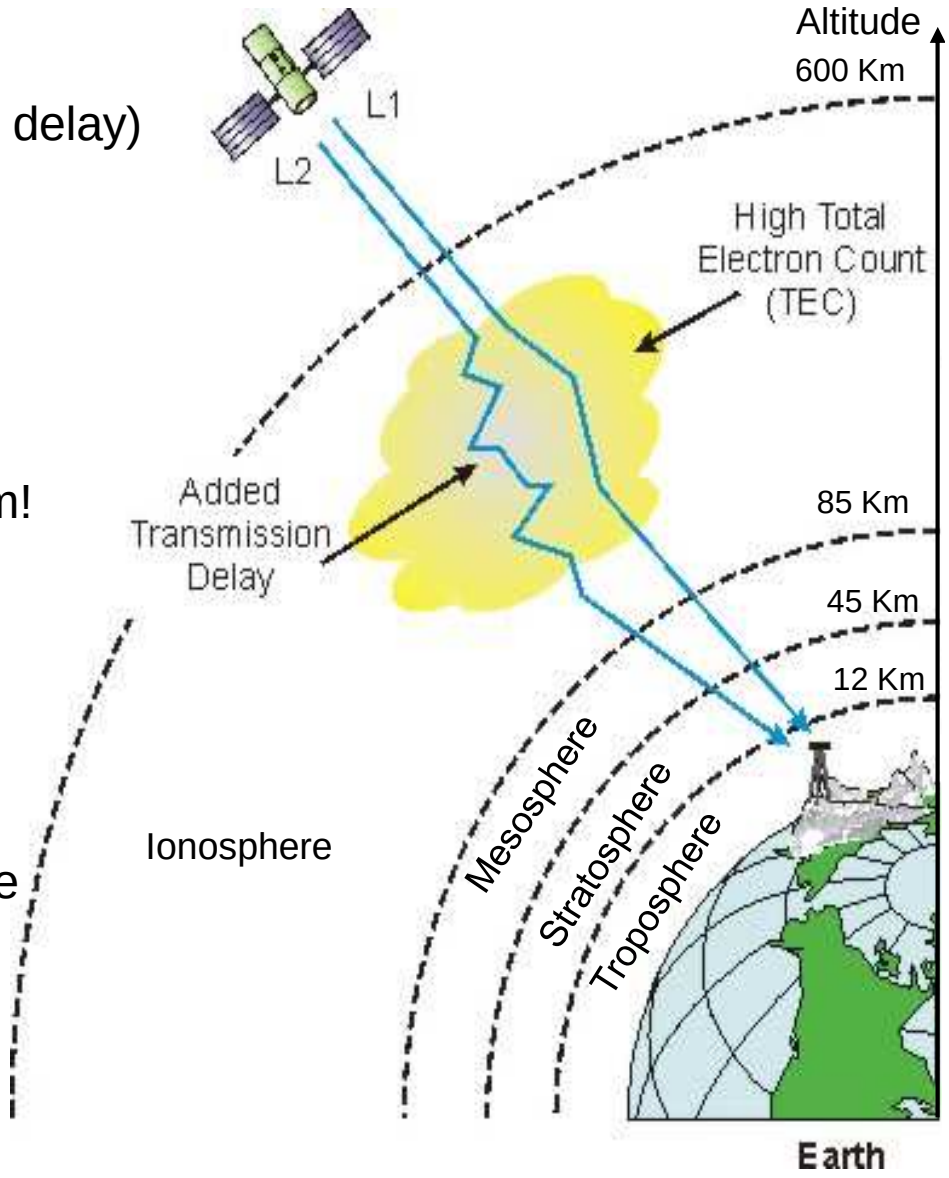
Space Weather impact on GNSS

- Geomagnetic storm may cause:
  - error in the GNSS position (ionosphere delay)
  - loss of lock of the satellite (scintillation)

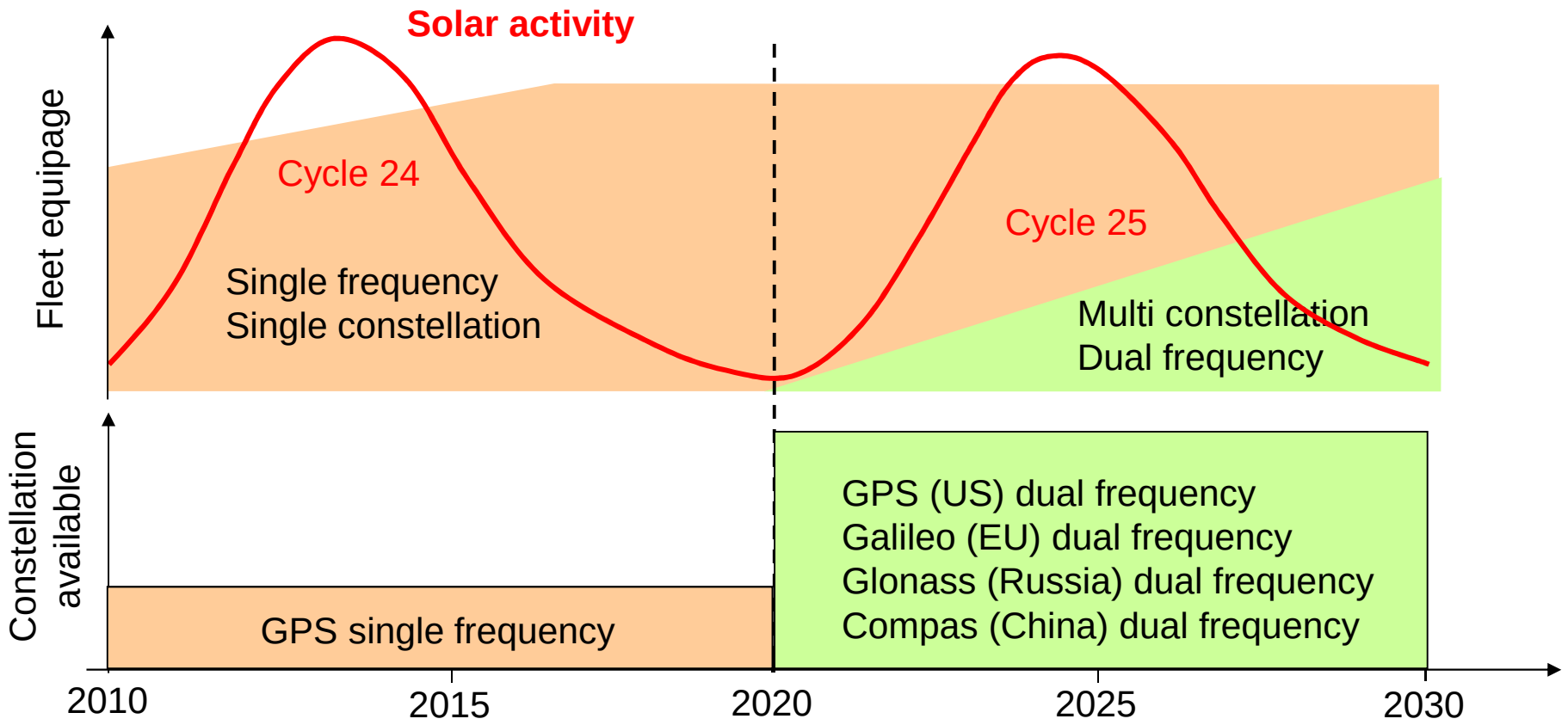
- Possible impact:
  - Accuracy decrease
  - Disruption of services

But it depends on the augmentation system!

- Mitigations :
  - Use of dual frequency constellation: next GPS (US), Galileo (EU), Glonass (Russia), Compas (China)
  - Use of multi-constellation to have more satellites



GNSS roadmap and fleet equipment



⇒ Dual constellation (or more), dual frequency will be operational from 2020 but the A/C fleet will not be significantly equipped for the 25th solar cycle (2022-2027)

Space Weather Impact on GNSS operations

GNSS

GPS
Galileo*
Compas*
Glonass*

\+

* When available: 2020+

Airborne Based Augmentation System

Coverage: Worldwide

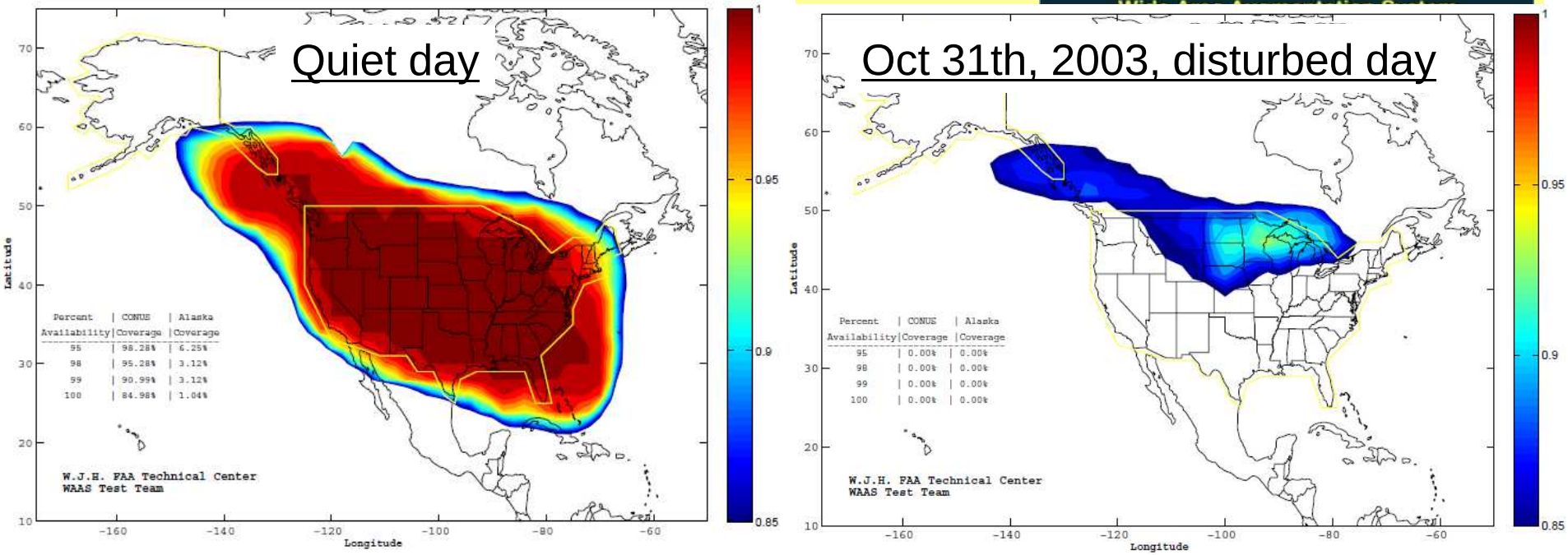
Operations:
- En route and terminal navigation
- Non precision approach (LNAV / VNAV)
- GNSS based surveillance applications (ADSB)

Possible impact:
- Accuracy decrease (100s meters)
- Loss of services over a contained (extreme) or worldwide (super-extreme) area (TBC)

Mitigations:
- Back up to satellite navigation & surveillance
- Long term future: multi-constellation & dual-frequency receivers

Space Weather Impact on GNSS operations

Satelite Based Augmentation System



Mitigations:

- Non GNSS based landing system (ILS, MLS…)
- Short/Mid term future: system improvement
- Long term future: dual frequency constellation (TBC)

Space Weather Impact on GNSS operations

GNSS

GPS
Galileo*
Compas*
Glonass*

+

* When available: 2020+

Ground Based Augmentation System

Coverage: Local (airport)

Operations:
•Precision approach (CAT I – II/III)

Possible impact:
• Positioning error higher than usual
• Regional loss of services

Mitigations:
• Non GNSS based landing system (ILS, MLS)
• Use of space weather nowcast/forecast (Australia)
• Long term future: dual frequency constellation (TBC)

Eurocontrol involvement in space weather

- Directorate SESAR and Research
  - SESAR WP 15.03.04 task 6: GNSS vulnerability
    - Task 6.a: Ionosphere assessment impact

- Directorate Network Management
  - European Aviation Crisis Coordination Cell (EACCC) has identified the space weather as a possible hazard for aviation.

- FAA-EUROCONTROL Memorandum of Cooperation
  - includes space weather as an area of mutual interest and coordination. ICAO space weather activities are followed up under this working arrangement.

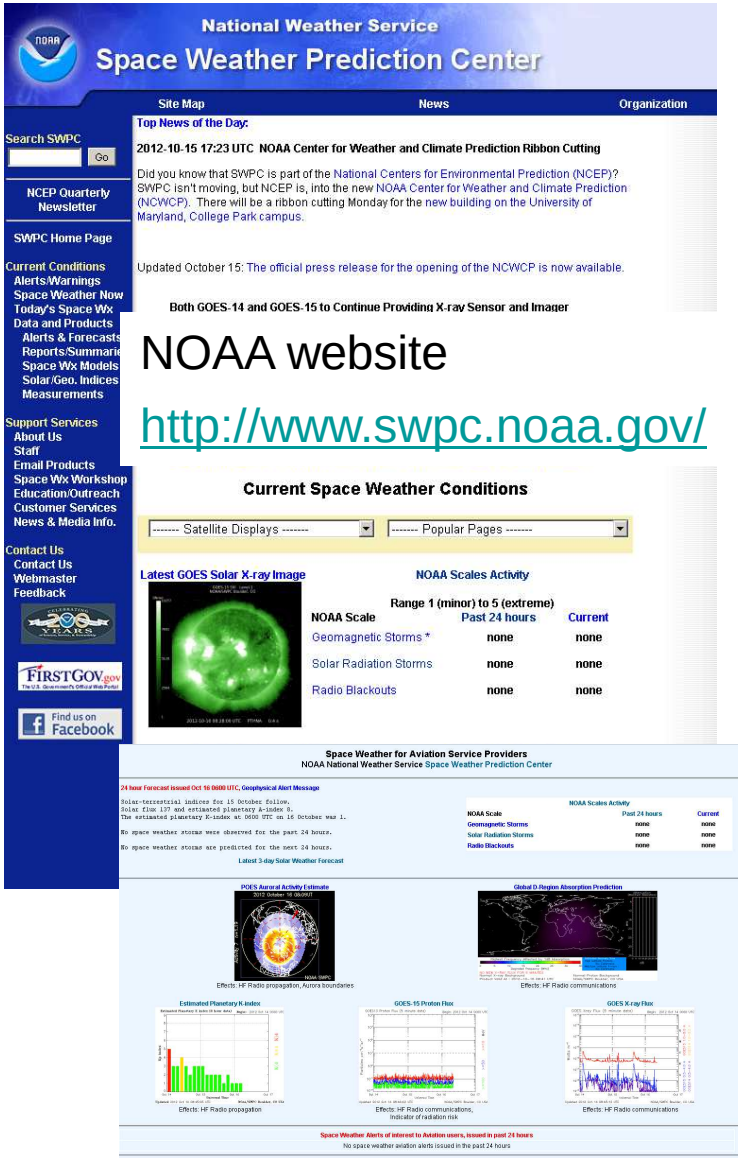
More information?

ESA website

http://www.esa-spaceweather.net/

General public website

http://spaceweather.com

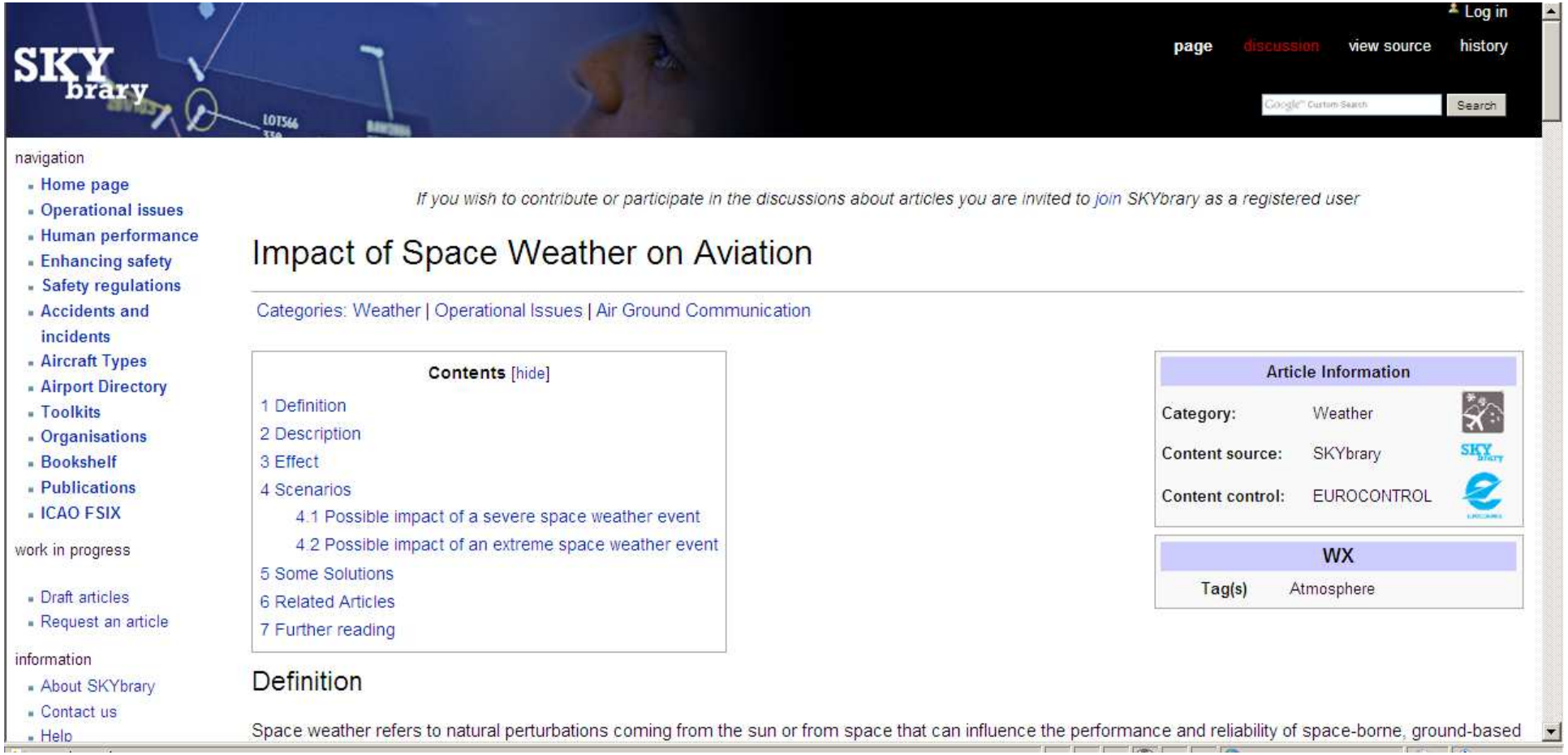


NOAA website

http://www.swpc.noaa.gov/

http://www.swpc.noaa.gov/aviation/

More information? SKYBRARY!!



http://www.skybrary.aero/index.php/Impact_of_Space_Weather_on_Aviation