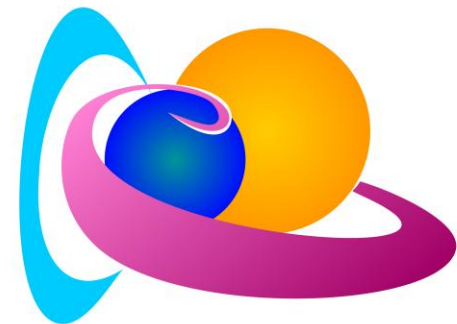


Space Weather impacts on Aviation

Course by the
Solar-Terrestrial Centre of Excellence



Space Weather impacts on Aviation

Disturbances seen in GNSS, HF Com and Radiation at FL

Jan Janssens



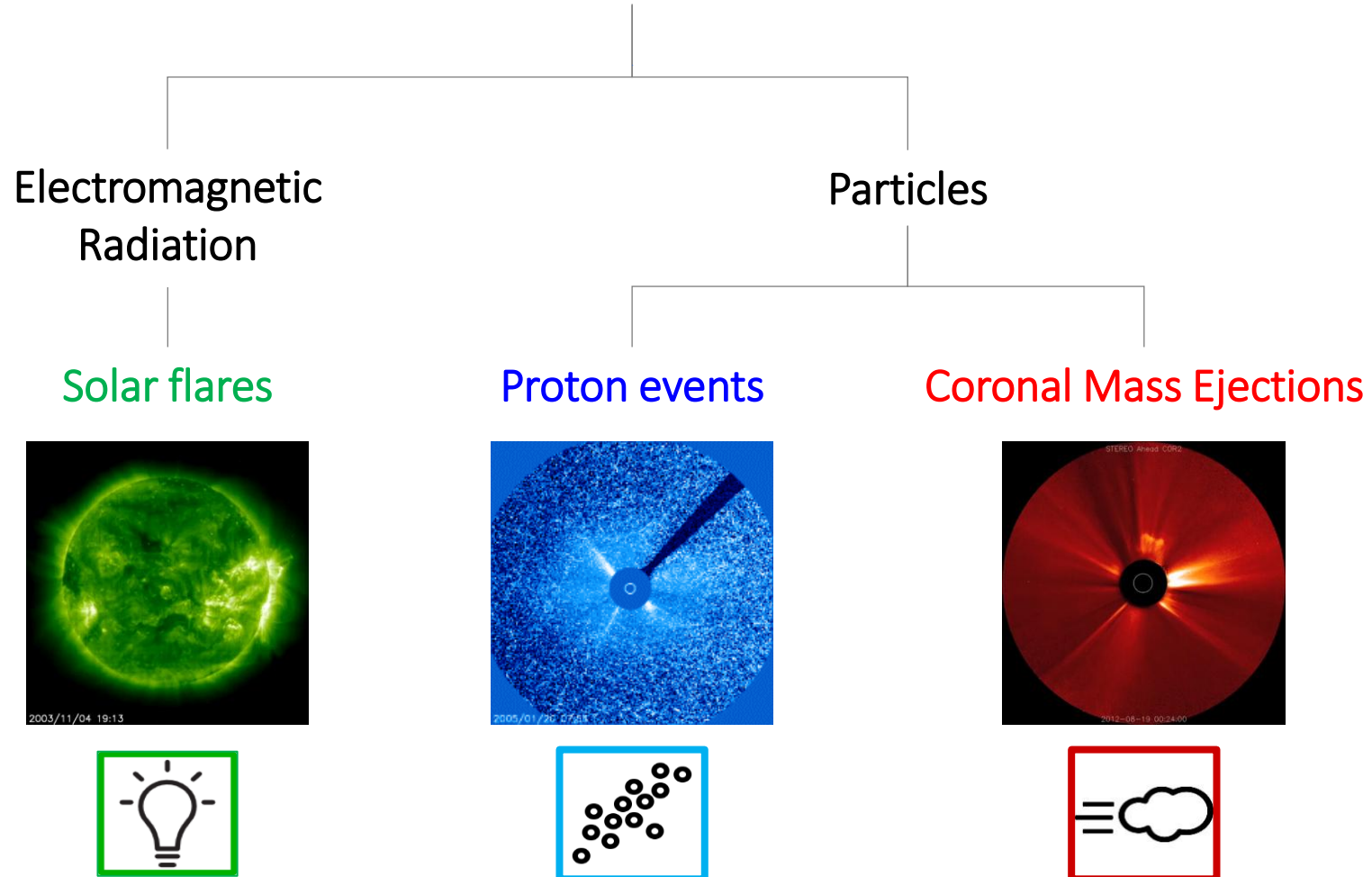
Contents

- Drivers of disturbed SWx
- SWx impacts on aviation
 - Diagram
 - Historical events
 - HF Com
 - Radiation
 - GNSS

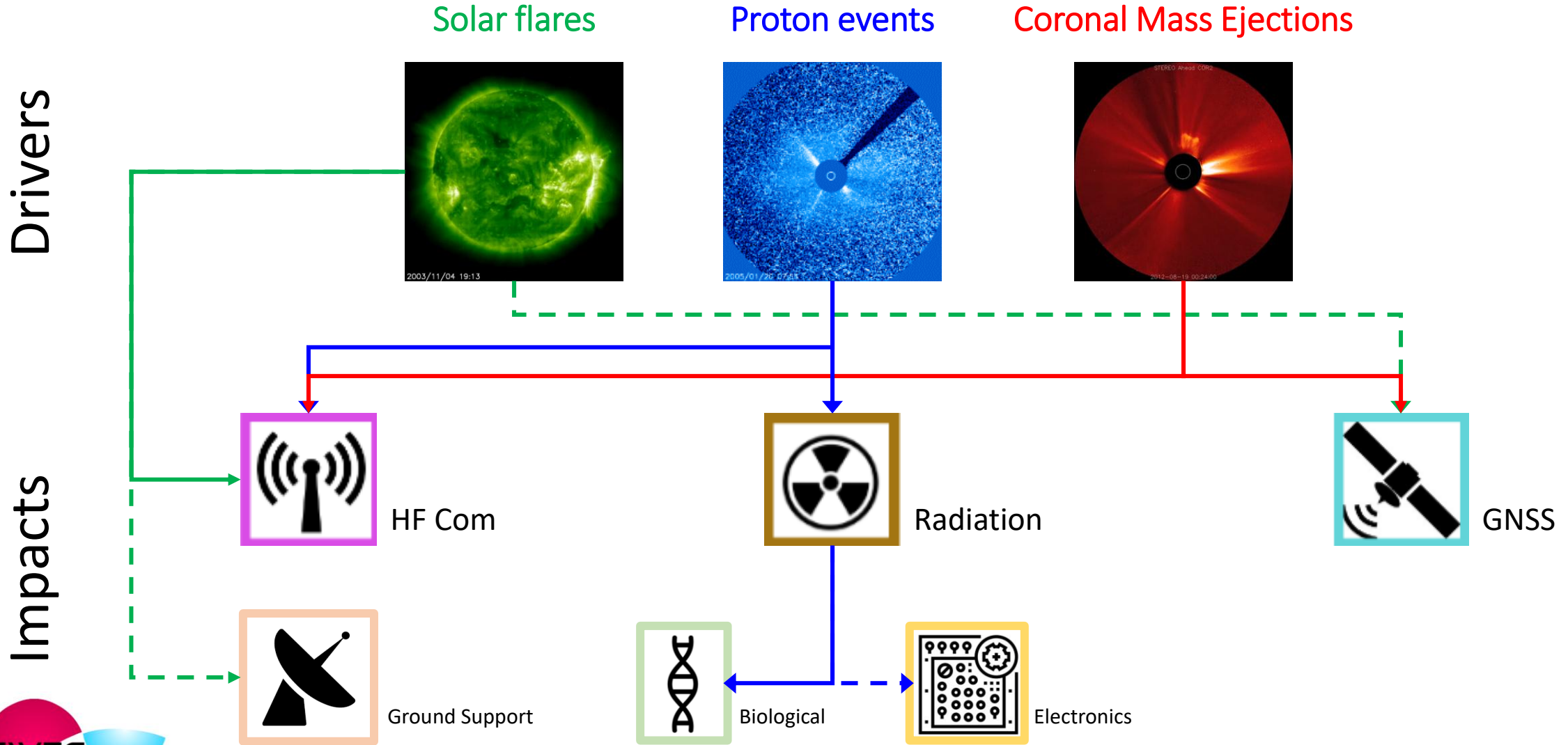


Drivers of disturbed SWx

Solar eruptions



SWx impacts on aviation

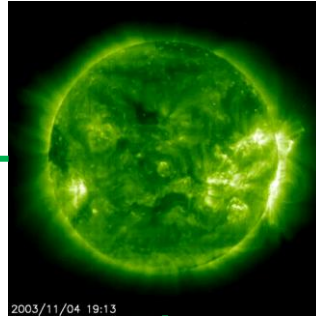


HF Com: High Frequency Communications (3-30 MHz) ; GNSS: Global Navigation Satellite Systems (GPS, Galileo,,...) - - - Currently NOT covered by SWx advisories for ICAO

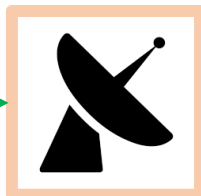


SWx impacts from solar flares on aviation

Solar flares



HF Com

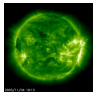


Ground Support



GNSS

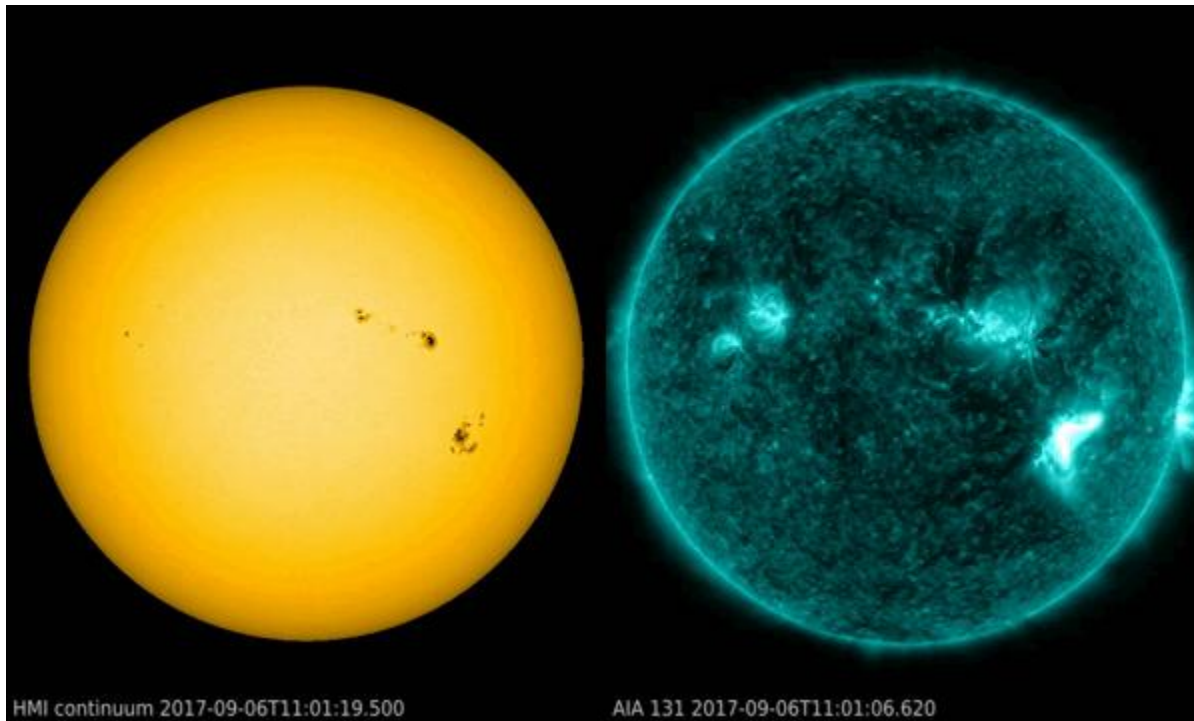




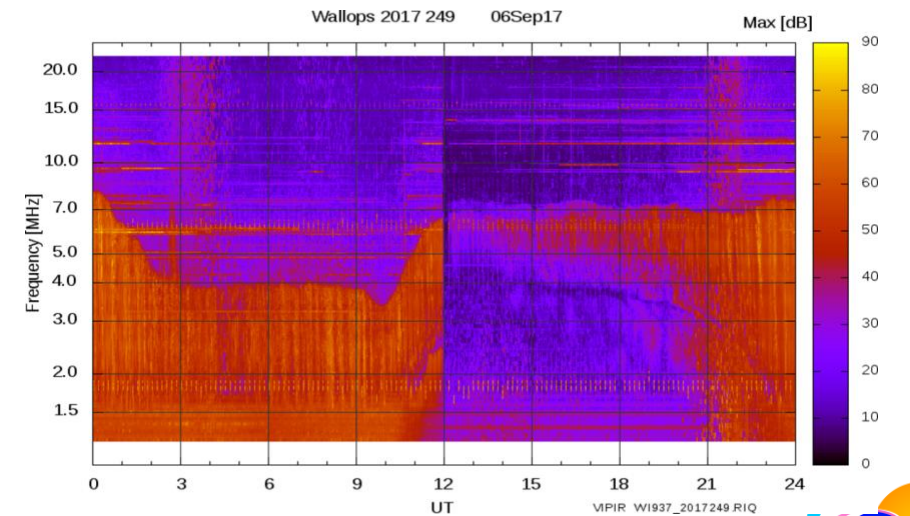
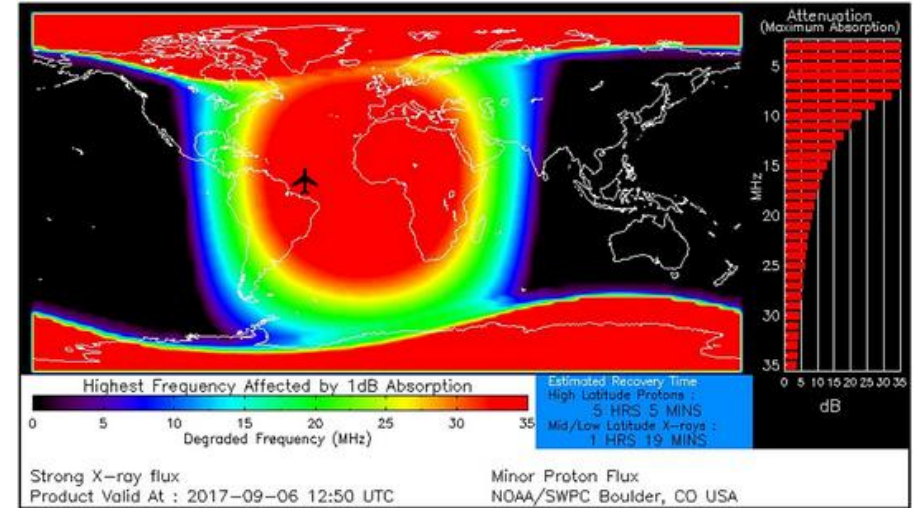
SWx impacts from solar flares on HF Com



- From EUV and x-rays
 - Short-wave fadeout (SWF)



Solar Flares Impacted Radio Communications

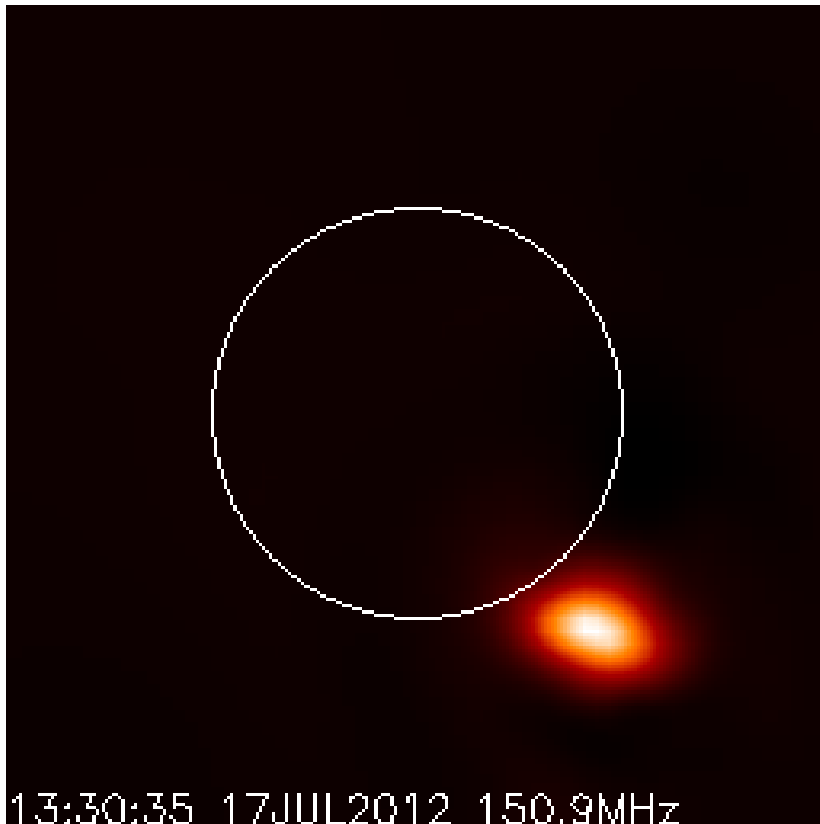


Courtesy of CIRES, Terry Bullett

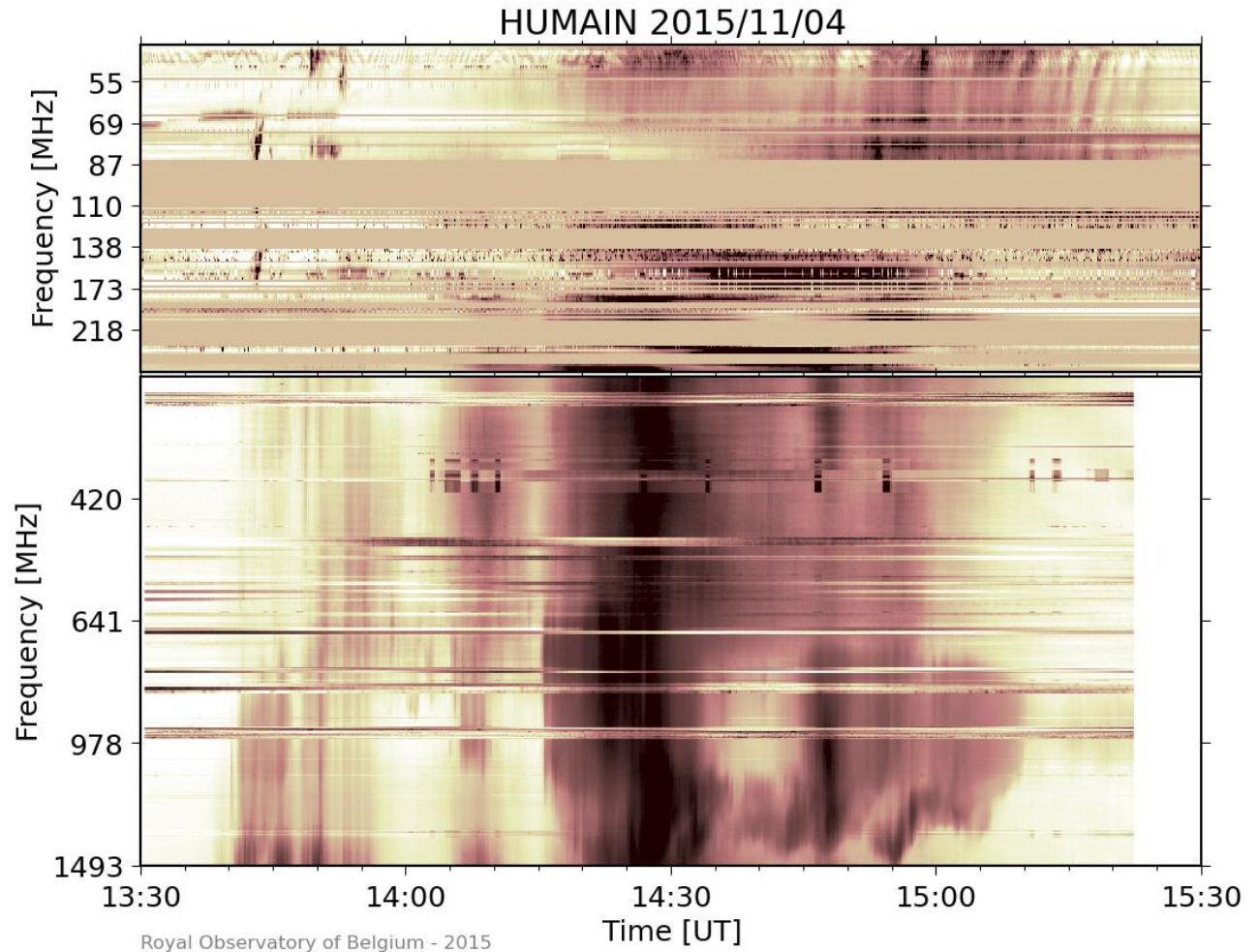


SWx impacts from solar flares on Ground Support

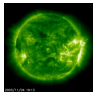
- From radio emission
 - Solar Radio Burst (SRB)



Nançay Radioheliograph



--- Currently NOT covered by SWx advisories for ICAO



SWx impacts from solar flares on GNSS



- From radio emission @ GNSS frequencies
 - Solar radio burst (SRB)
- 6 December 2006

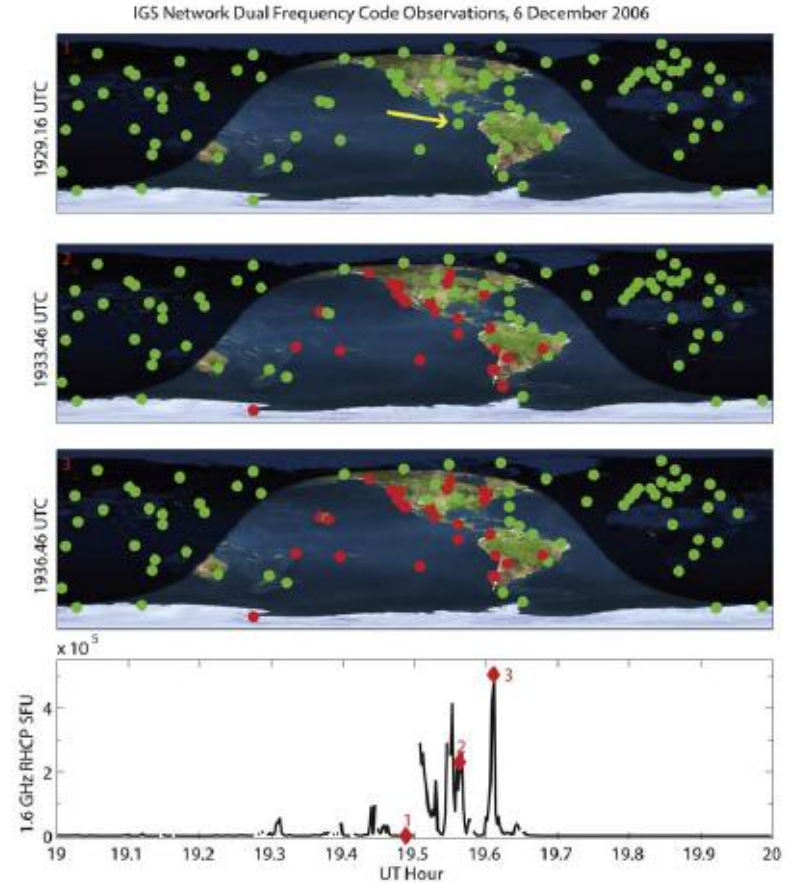
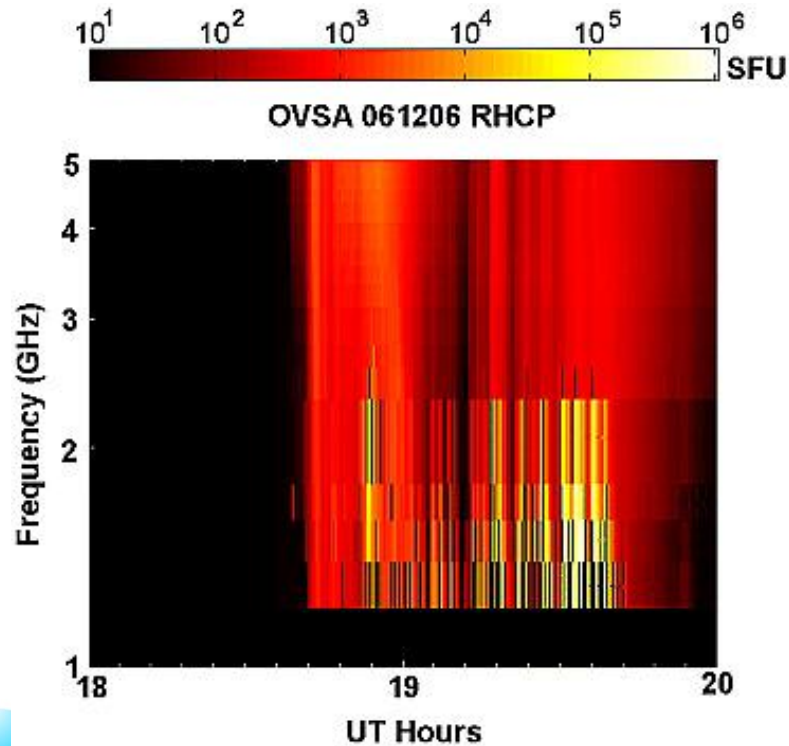
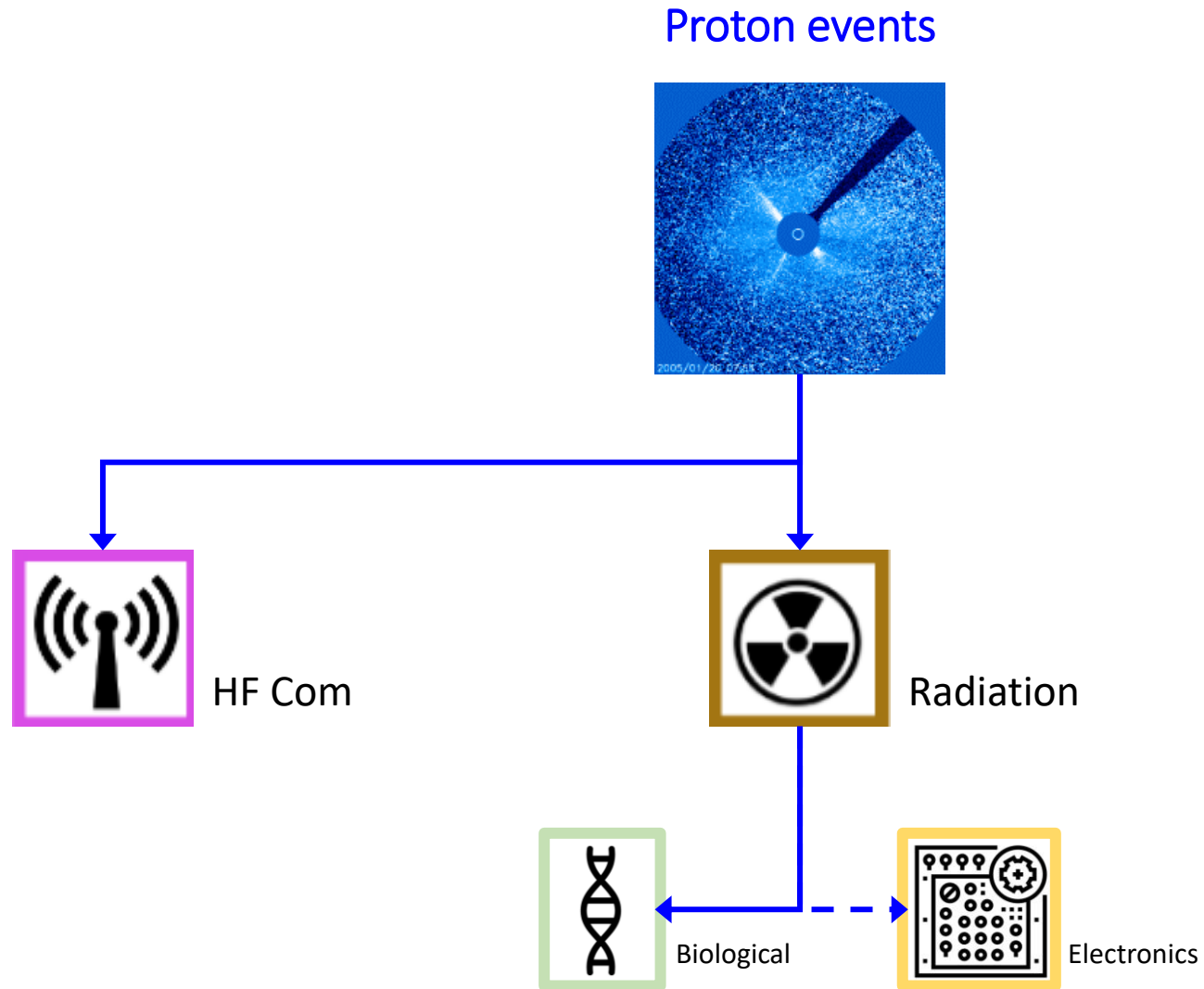


Figure 6. Receivers in the Global GPS Network that were analyzed during the solar radio burst. Green indicates the normal number of satellites being tracked (fourth panel) During the burst (power at 1.6 GHz), several sunlit receivers tracked fewer than the four satellites needed for a full positioning solution (marked in red). (Image of Earth from the The Living Earth, 1996 and is used here by permission of the publisher. Day/night overlay created using Earth Viewer by J. Walker.)

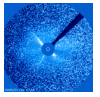
Credits: Cerruti et al. (2008)



SWx impacts from proton events on aviation



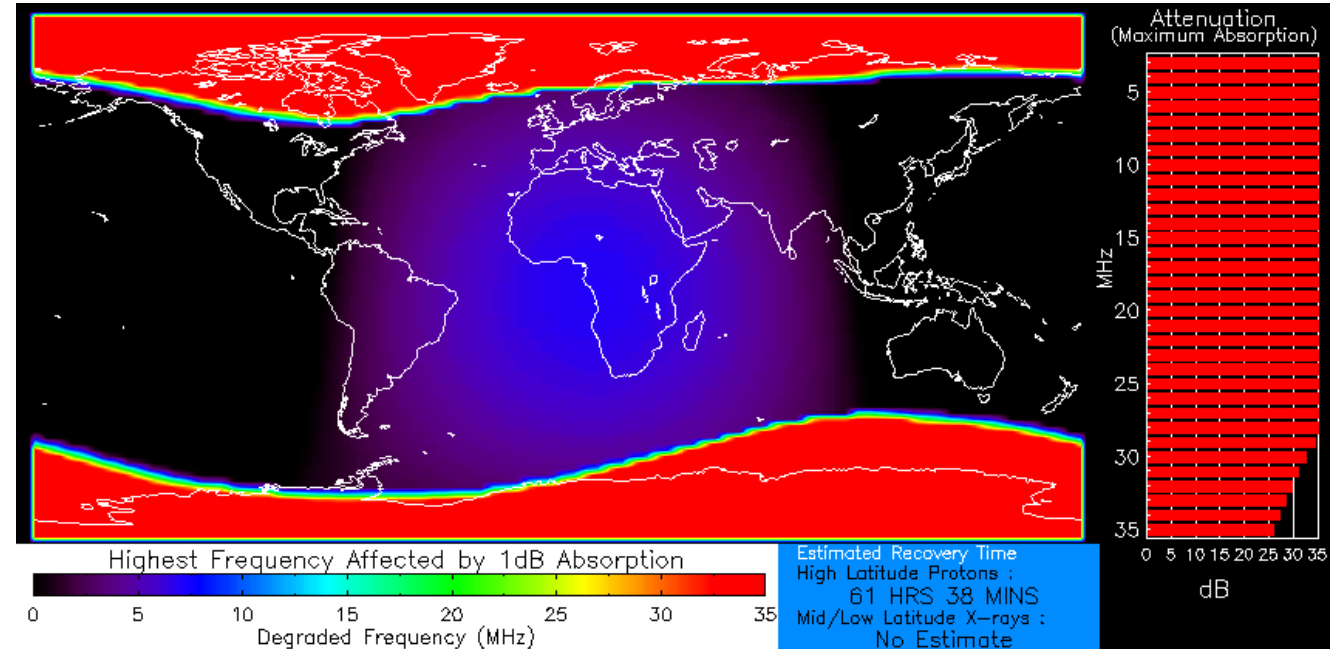
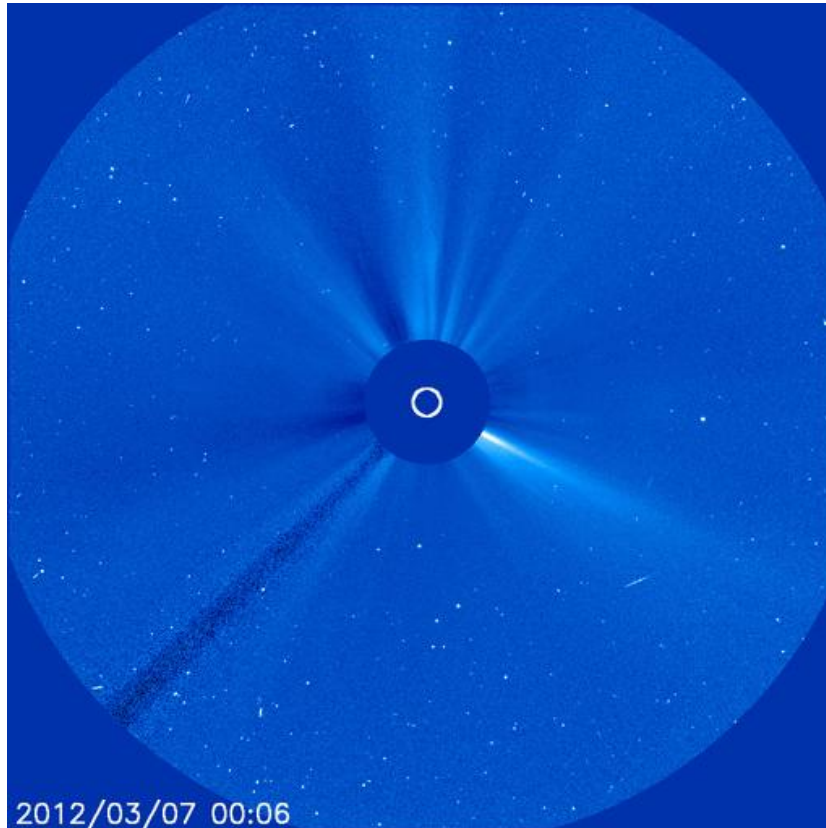
HF Com: High Frequency Communications (3-30 MHz) - - - - Currently NOT covered by SWx advisories for ICAO



SWx impacts from proton events on HF Com



- Polar Cap Absorption (PCA)
 - From 10 MeV proton flux
 - 7-8 March 2012



Normal X-ray Background
Product Valid At : 2012-03-08 11:15 UTC

Strong Proton Flux
NOAA/SWPC Boulder, CO USA

MeV: megaelectronvolt ; MF: magnetic field ; HF Com: High Frequency Communications (3-30 MHz) ; pfu: proton flux units ; dB: decibel

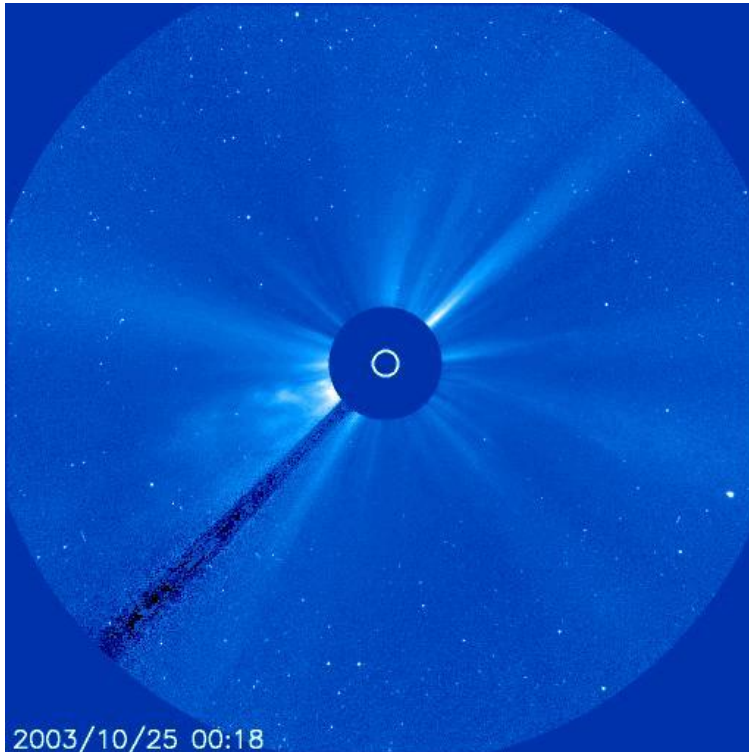
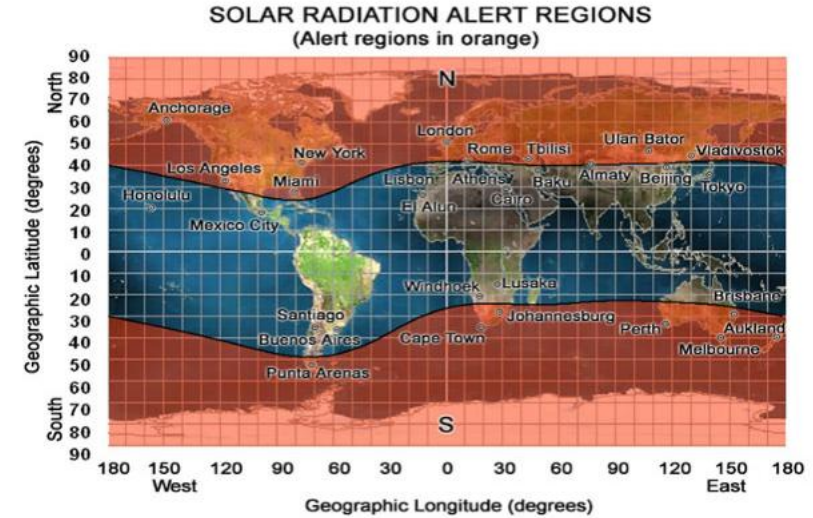




SWx impacts from proton events : Biological



- Energetic particles (GCR ; SEP)
 - Can damage DNA and cause cancer & reproductive problems
- Halloween storms October 2003



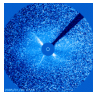
Space Weather Message Code: ALTPAV Issue Time: 2003 Oct 28 2123 UTC
 ALERT: Solar Radiation Alert at Flight Altitudes
 Conditions Began: 2003 Oct 28 2113 UTC

Comment:
 Satellite measurements indicate unusually high levels of ionizing radiation, coming from the sun. This may lead to excessive radiation doses to air travelers at Corrected Geomagnetic (CGM) Latitudes above 35 degrees north, or south.

Avoiding excessive radiation exposure during pregnancy is particularly important.

Reducing flight altitude may significantly reduce flight doses. Available data indicates that lowering flight altitude from 40,000 feet to 36,000 feet should result in about a 30 percent reduction in dose rate. A lowering of latitude may also reduce flight doses but the degree is uncertain. Any changes in flight plan should be preceded by appropriate clearance.

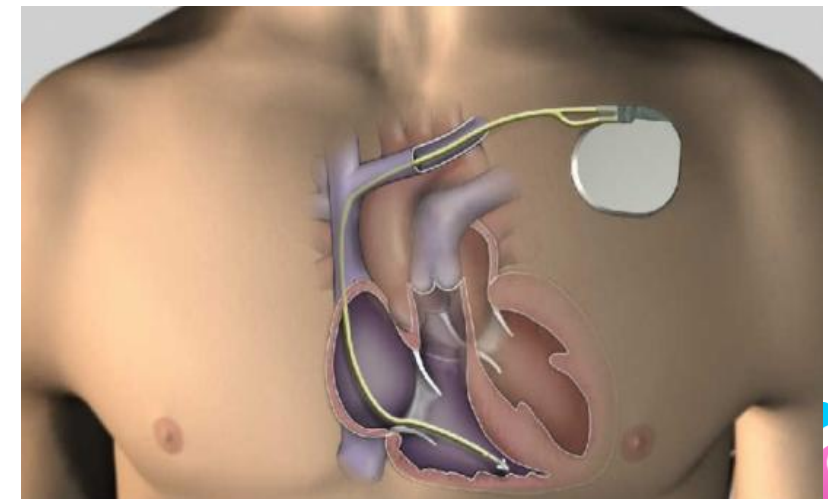




SWx impacts from proton events : Electronics

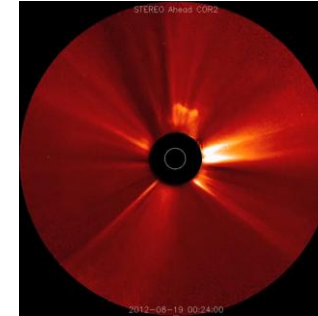


- Single Event Effects (SEE)
 - Direct hit of an electronic component by an energetic particle (GCR, SEP) resulting in an anomaly
 - Phantom commands, attitude control systems, satellite failure,...
- Ground Level Enhancement (GLE)
 - Sharp increase #neutrons @ ground
 - Main source
 - Strong SEPs ~500 MeV per nucleon
 - => RARE!! (about 1 per year)
 - Impacts
 - Computer glitches, servers,...
 - Pacemakers, defibrillators, and other medical devices,...
 - Difficult to prove connection!



SWx impacts on aviation

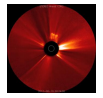
Coronal Mass Ejections



HF Com



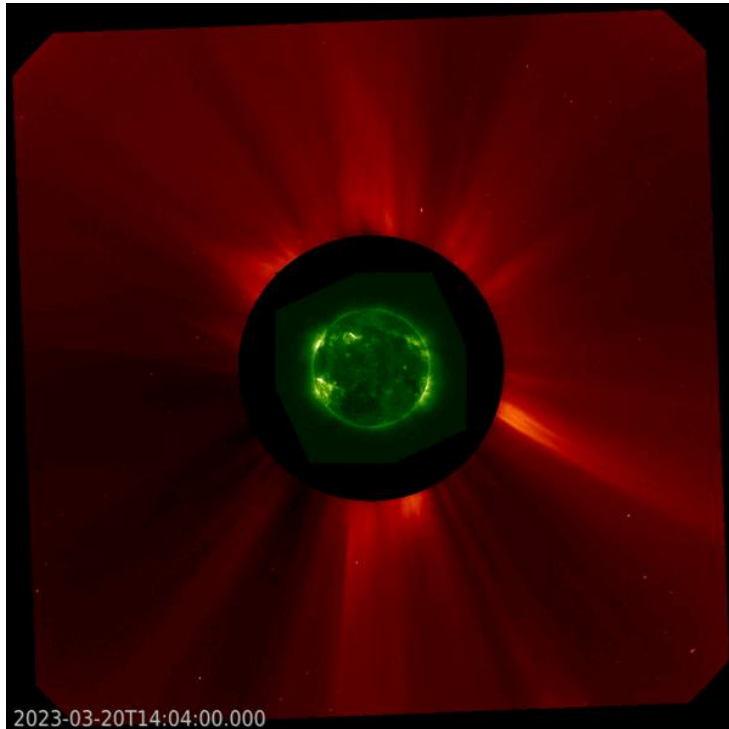
GNSS



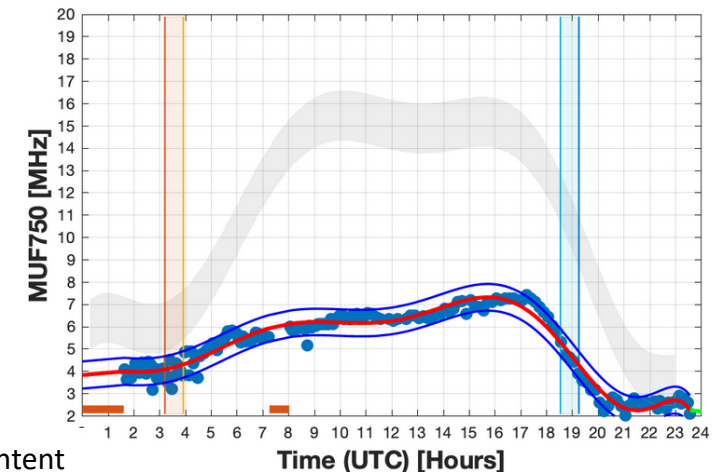
SWx impacts from ICMEs on HF Com

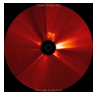


- Auroral Absorption (AA)
 - Aurora affecting lower ionosphere
- Post-Storm Depression (PSD)
 - Negative phase ionospheric storm



Ionosphere Maximum Usable Frequency (MUF750)
 Date : 2023-03-24 Day Number : 083
 Time : 23:33:16 [UTC]

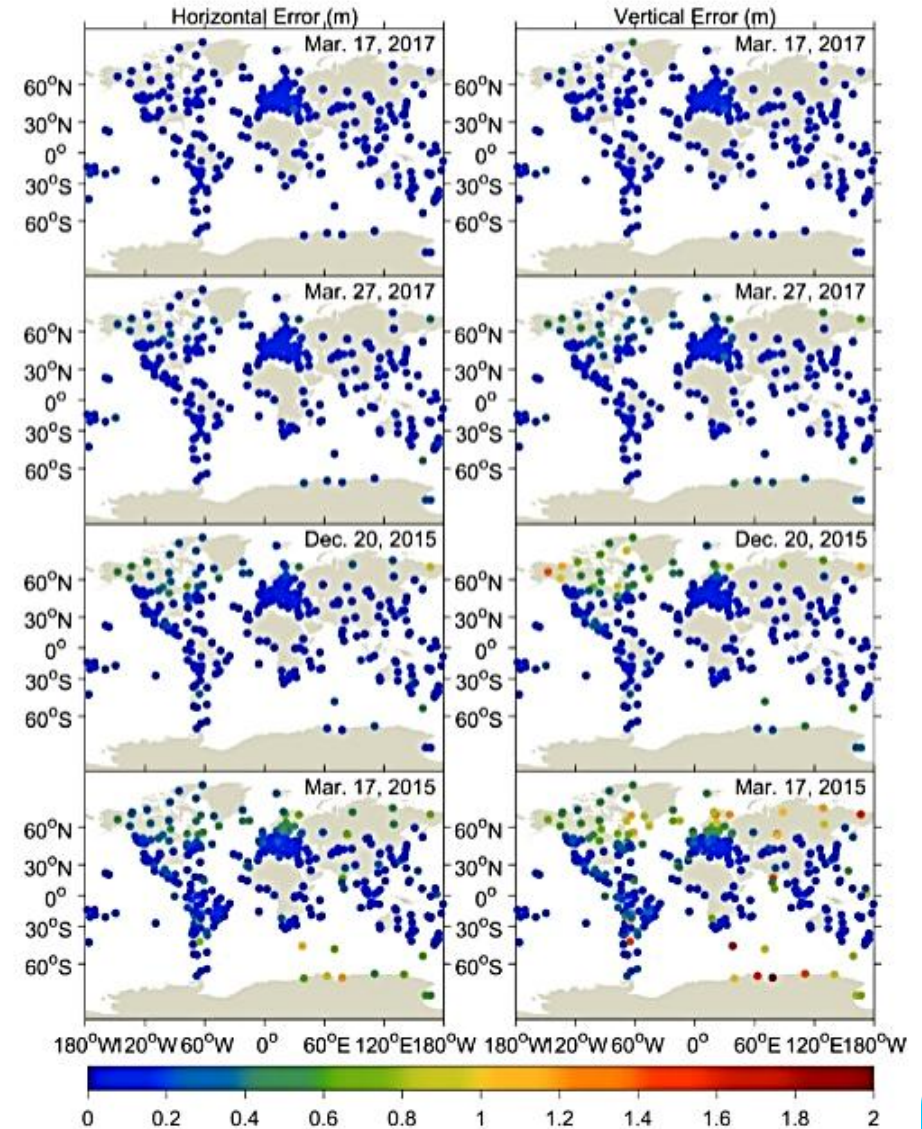
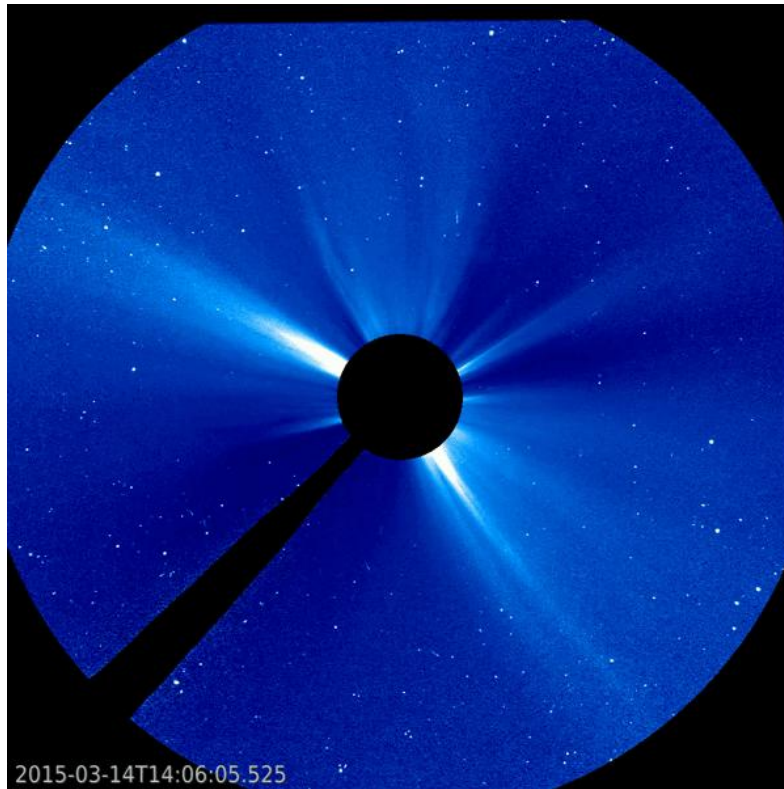




SWx impacts from ICMEs on GNSS

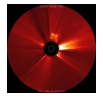


- Ionospheric storm
 - VTEC based



Credits: Luo et al. (2018)

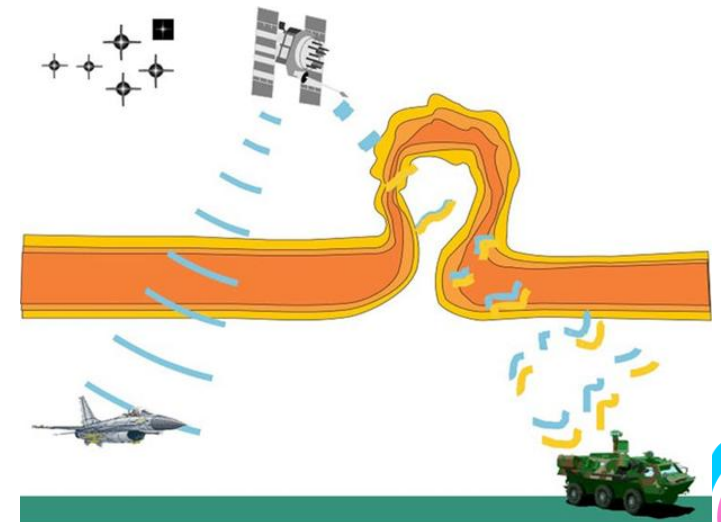
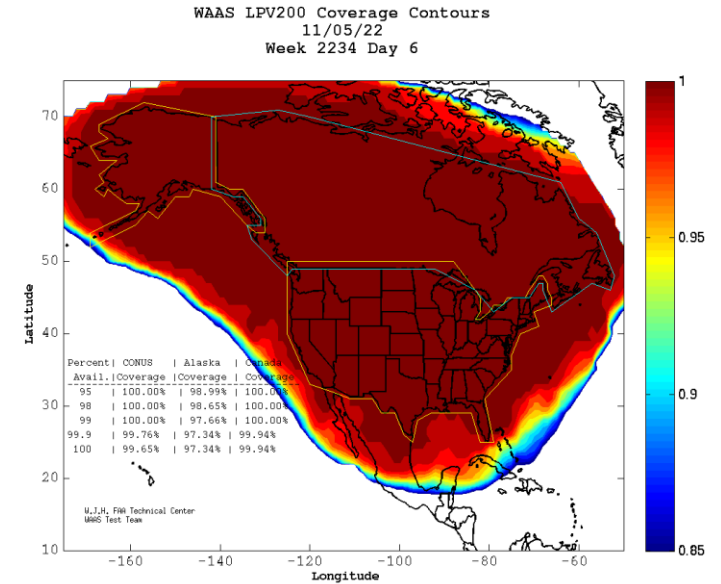




SWx impacts from ICMEs on GNSS



- Ionospheric scintillations
 - Small-scale density variations in ionosphere
 - Affect GNSS signals
 - 7 November 2022
 - Kp = 5o ; Dst = -89 nT
 - Also in February, March, April and November 2023, and May and October 2024
 - Reminder
 - Also when geomagnetic activity is quite low
 - Battle of Takur Ghar! (2002)



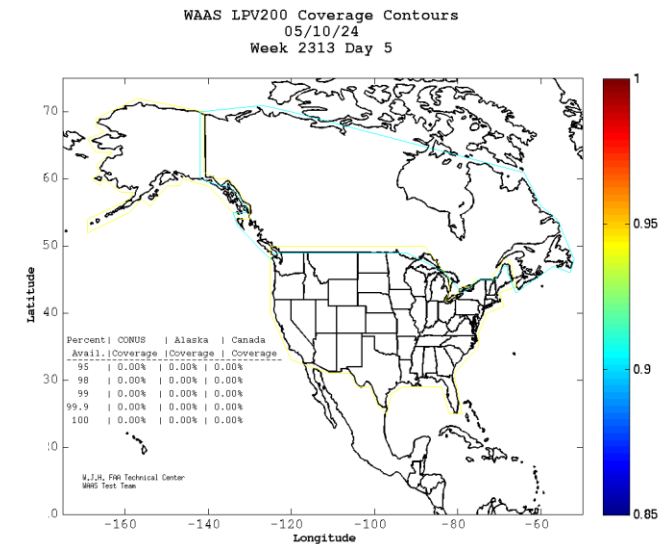
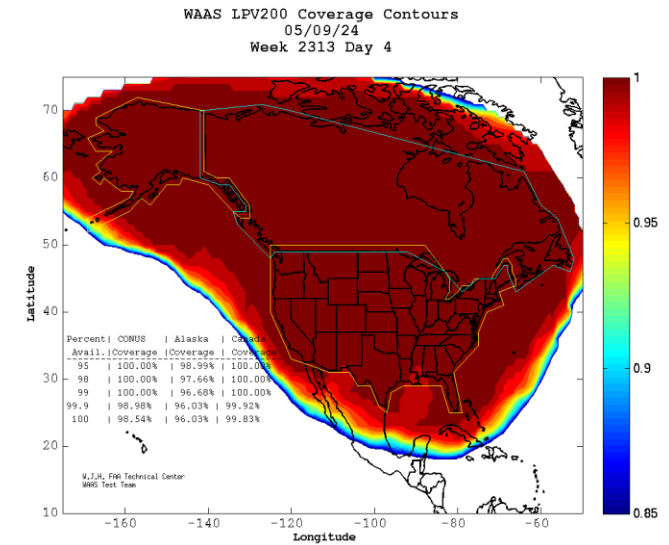
Credits: US Air Force Research Laboratory



SWx impacts from the 10-11 May 2024 storm

Strongest geomagnetic storm in 20 years

- Federal Aviation Administration:
 - Frequency issues on overseas flight
 - Brief radio transmission/equipment blips
 - Transoceanic flight rerouted due to HF radio comms loss
 - WAAS Extreme storm detector (ESD) tripped for the first time since its inception in 2007 causing an extended loss of LPV/LPV200 over entire WAAS coverage volume
 - NOTAMs issued advising on navigational disruptions
 - EGNOS limited over Europe



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 - NOTAMs issued advising on navigational disruptions
 - EGNOS limited over Europe
 - ESD tripped again during the 10-11 Oct 2024 storm...
- PECASUS
 - 9 reports of HF Com loss (8-14 May)
 - Few ; Difficult to link to source (location)
 - Iceland Radio (HF Com Tower)
 - Black out on 11-12 May (above 70N)

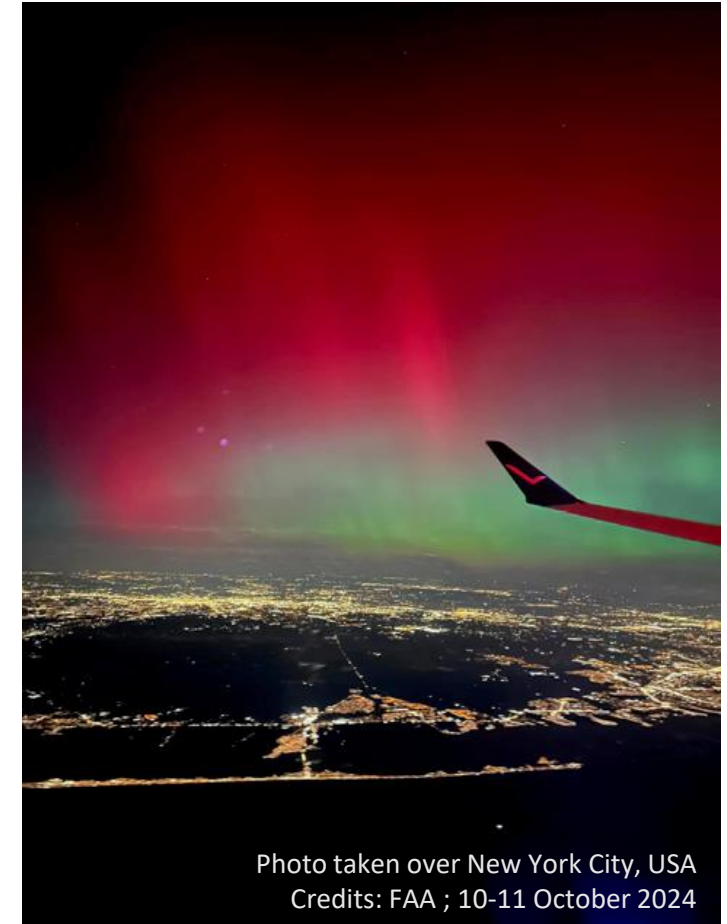
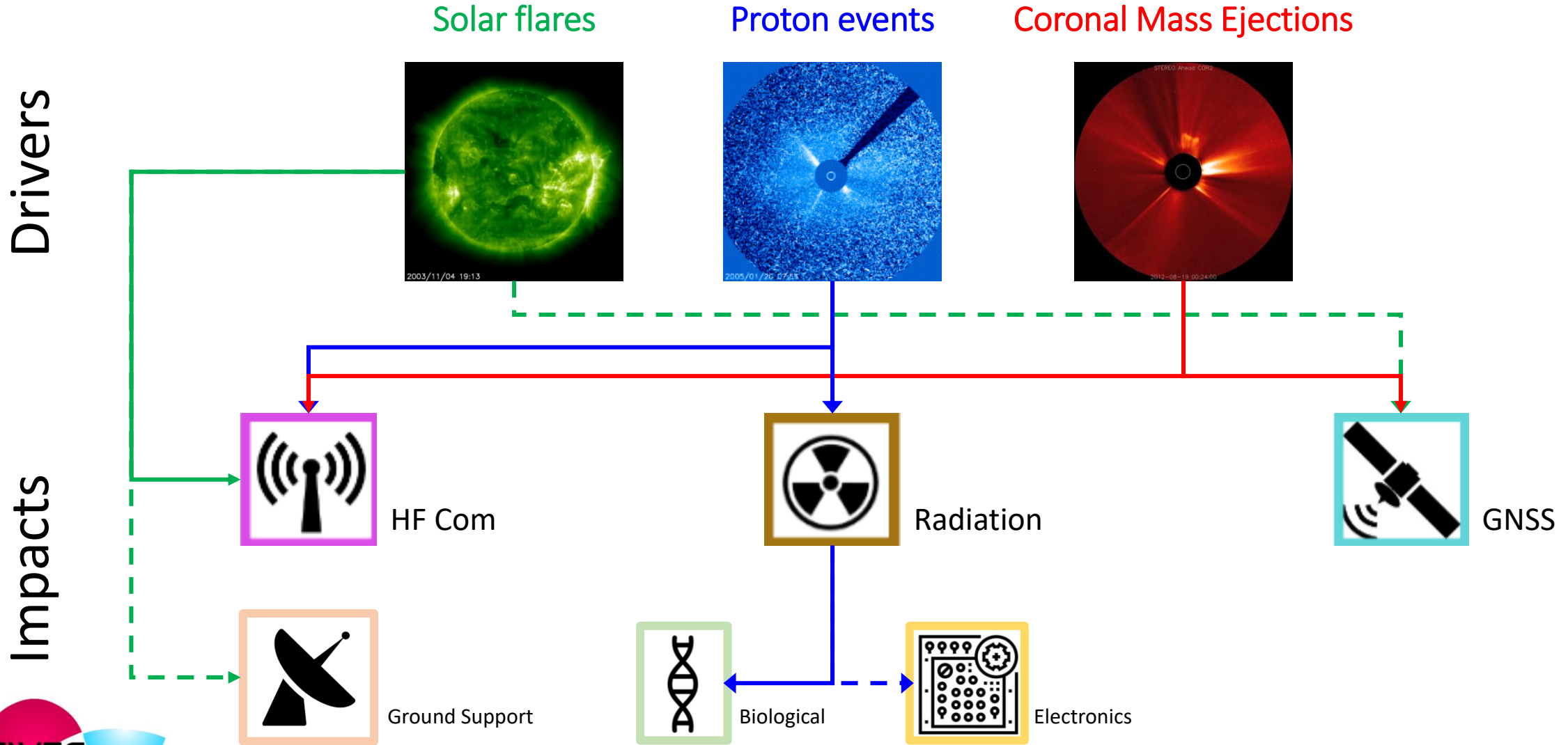


Photo taken over New York City, USA
Credits: FAA ; 10-11 October 2024



SWx impacts on aviation



HF Com: High Frequency Communications (3-30 MHz) ; GNSS: Global Navigation Satellite Systems (GPS, Galileo,,...) - - - Currently NOT covered by SWx advisories for ICAO



Questions?

