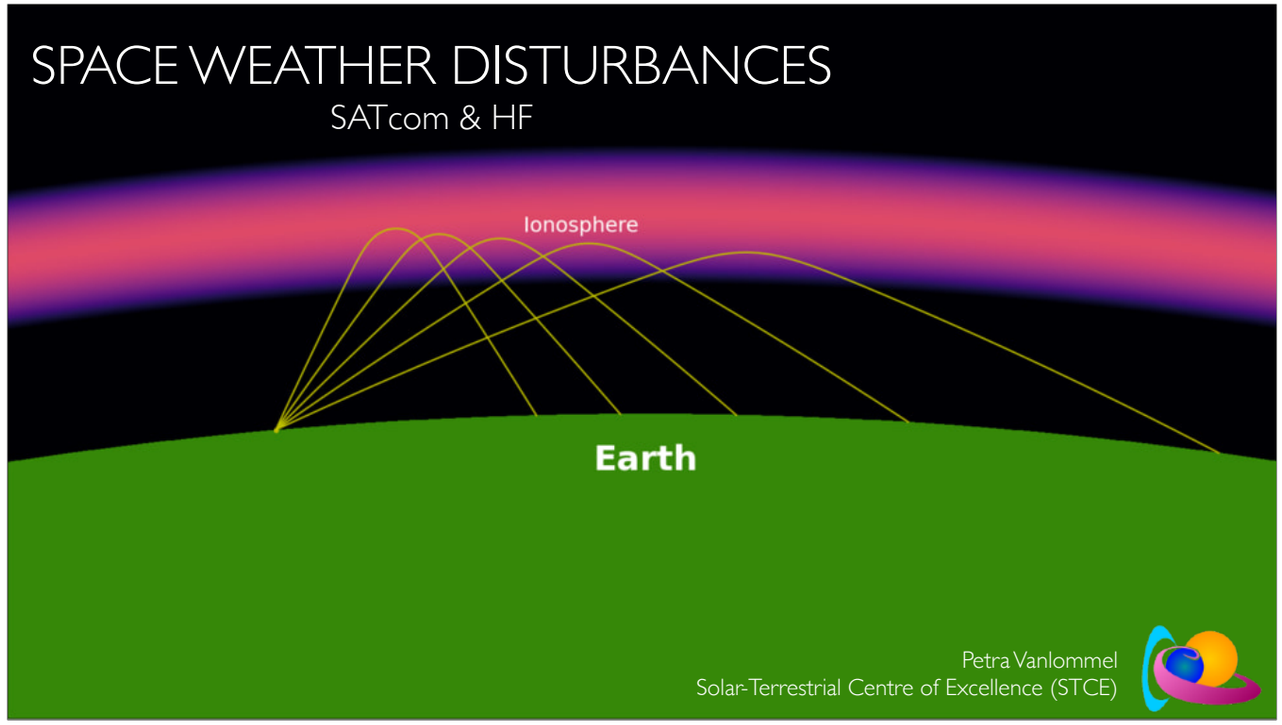
Role of the Ionosphere & SPWx in Military Communications

SWEC
Space Weather Education Center

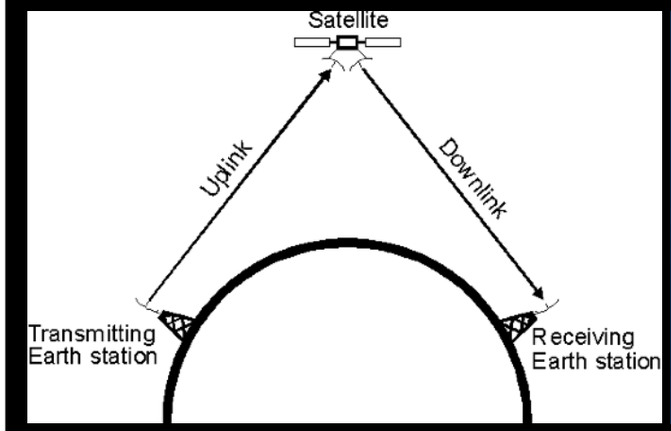
Solar-Terrestrial
Centre of Excellence


SPACE WEATHER DISTURBANCES
SATcom & HF
Petra Vanlommel
Solar-Terrestrial Centre of Excellence (STCE)



https://svs.gsfc.nasa.gov/5240

SATcom

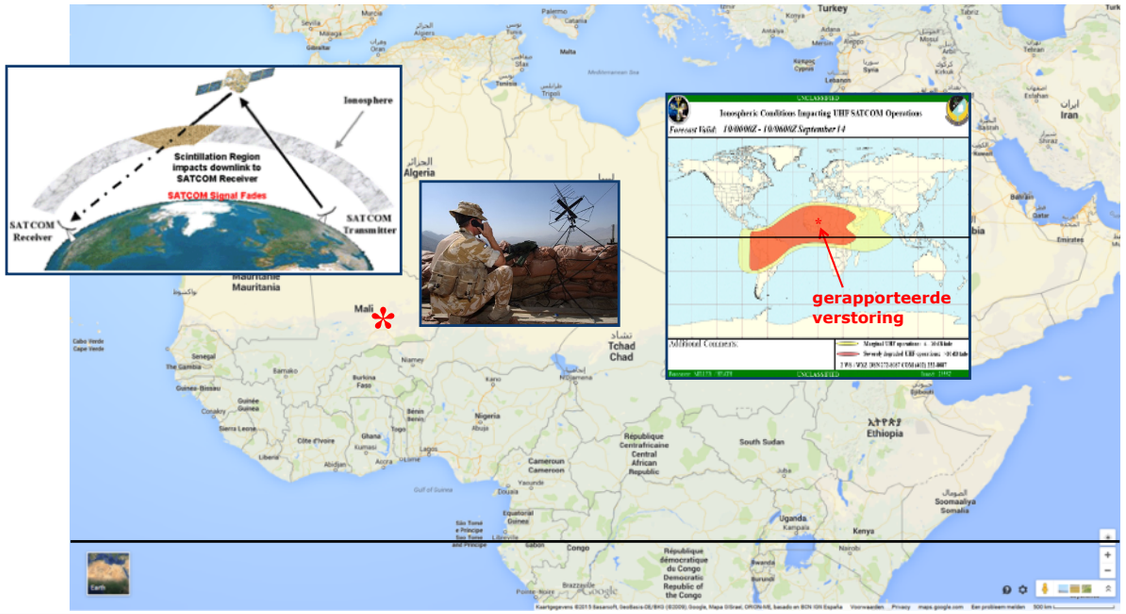


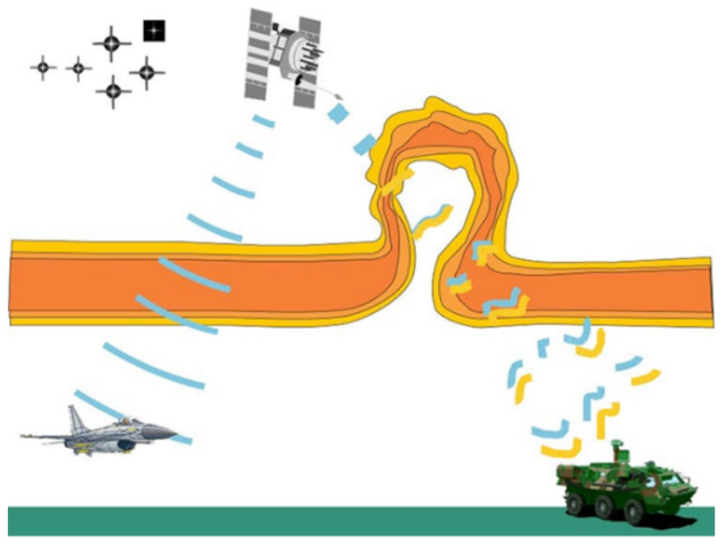
https://en.wikipedia.org/wiki/Communications_satellite

A communications satellite is an artificial satellite that relays and amplifies radio telecommunication signals via a transponder; it creates a communication channel between a source transmitter and a receiver at different locations on Earth. Communications satellites are used for **television, telephone, radio, internet, and military applications**.

- Many communications satellites are in **geostationary orbit 35,900 km above the equator**, so that the satellite appears stationary at the same point in the sky; **therefore the satellite dish antennas of ground stations can be aimed permanently at that spot and do not have to move to track the satellite**.
- Others form satellite constellations in **low Earth orbit**, where **antennas on the ground have to follow the position of the satellites and switch between satellites frequently.**

Outage due to Ionospheric scintillation





Source: U.S. Air Force Research Laboratory (AFRL)

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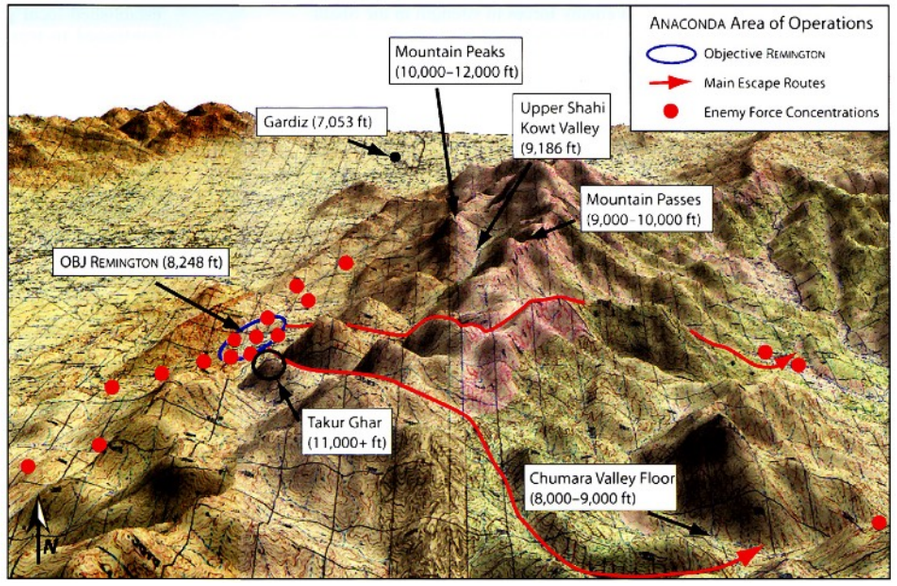
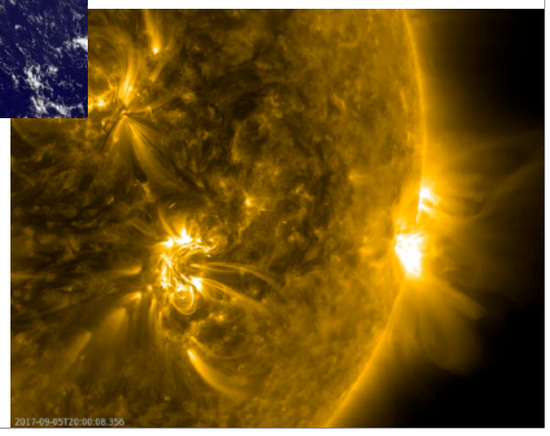


Battle of Takur GHar - Afghanistan
Tactical impact of SWx
Navy seals were under fire in montainous region. A chinook heli was sent to rescue them. To avoid hot landing a UHF message was sent but never received by the chinook.
The radio was blamed but after investigation, this wasn't the only reason. Ionospheric perturbation led to the loss of the signal due to plasma bubbles in the ionosphere.

Sept 2017 - Earth and Space weather aligned



https://news.agu.org/press-release/solar-flares-disrupted-radio-communications-during-september-2017-atlantic-hurricane-relief-effort/

X2.2 and X9.3 flare on Sept 6 —> Magnetic Storm on Sept 7
X8.2 flare on Sept 10 —>Magnetic Storm on Sept 12

Ham radio hobbyists routinely volunteer to disseminate hazard information from the National Weather Service to island communities and ships during major storms, report real-time ground conditions and damages back to the National Hurricane Center, and assist the Red Cross with communications.

Hurricane train: Irma and Jose

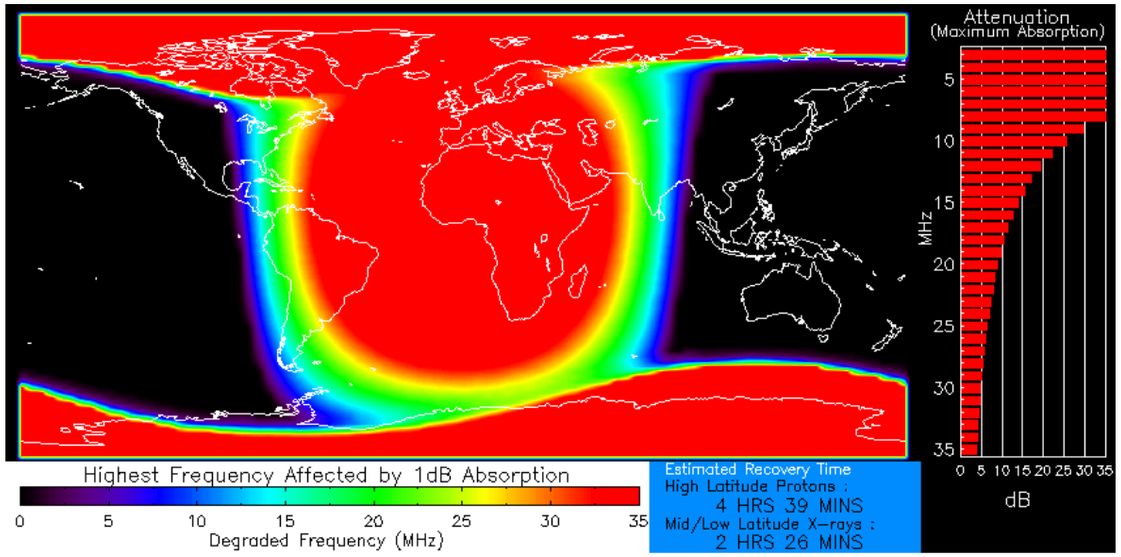
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018SW001897

https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018SW002008
During September 2017, a significant number of solar flares and geomagnetic activity occurred. Simultaneously, major hurricanes, including Hurricane Irma and Hurricane Jose, caused situations in the Caribbean region requiring the use of emergency HF communications, often provided by ham (amateur) radio operators.

Even in the modern age of space-borne relays and widely distributed Internet availability, HF radio remains a key technology for long-distance communications.

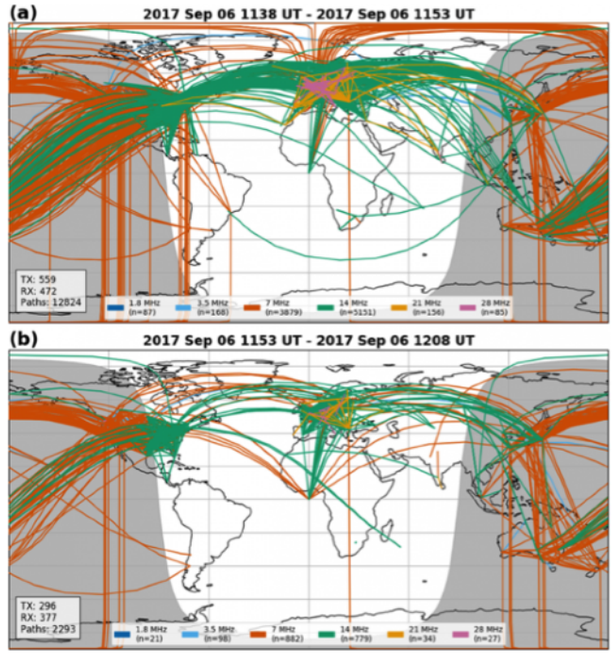
It is actively used by aircraft, by ships at sea, in military operations, for disaster relief efforts, and by amateur radio operators. HF radio is particularly attractive in a backup or emergency communications role because of its ad hoc and agile nature, relatively low cost, and ability to communicate across large distances. In September 2017, HF amateur radio was called upon to provide emergency communications to the Caribbean Region in response to the devastation caused by Hurricanes Irma and Jose (American Radio Relay League, 2018).

Numerous solar flares and CME-induced interplanetary shocks associated with solar active region AR12673
caused disturbances to terrestrial HF (3–30 MHz) radio communications from 4–14 September 2017. Simultaneously,
Hurricanes Irma and Jose caused significant damage to the Caribbean Islands and parts of Florida. The coincidental timing of both the space weather activity and hurricanes was unfortunate, as HF radio was needed for emergency communications. This paper presented the response of HF amateur radio propagation as observed by the RBN and the WSPRNet to space weather events of that period. Distributed data coverage from these dense sources provided a unique mix of global and regional coverage of ionospheric response and recovery that revealed several features of storm time HF propagation dynamics. Specifically, X-class flares on 6, 7, and 10 September caused acute radio blackouts during the day in the Caribbean with recovery times of tens of minutes to hours, based on the decay time of the flare. A severe geomagnetic storm with Kpmax = 8+ and SYM-Hmin = −146 nT occurring 7–10 September wiped out ionospheric communications first on 14 MHz and then on 7 MHz starting at ~1200 UT 8 September. This storm, combined with effects from additional flare and geomagnetic activity, contributed to a significant suppression of effective HF propagation bands both globally and in the Caribbean for a period of 12 to 15 days.



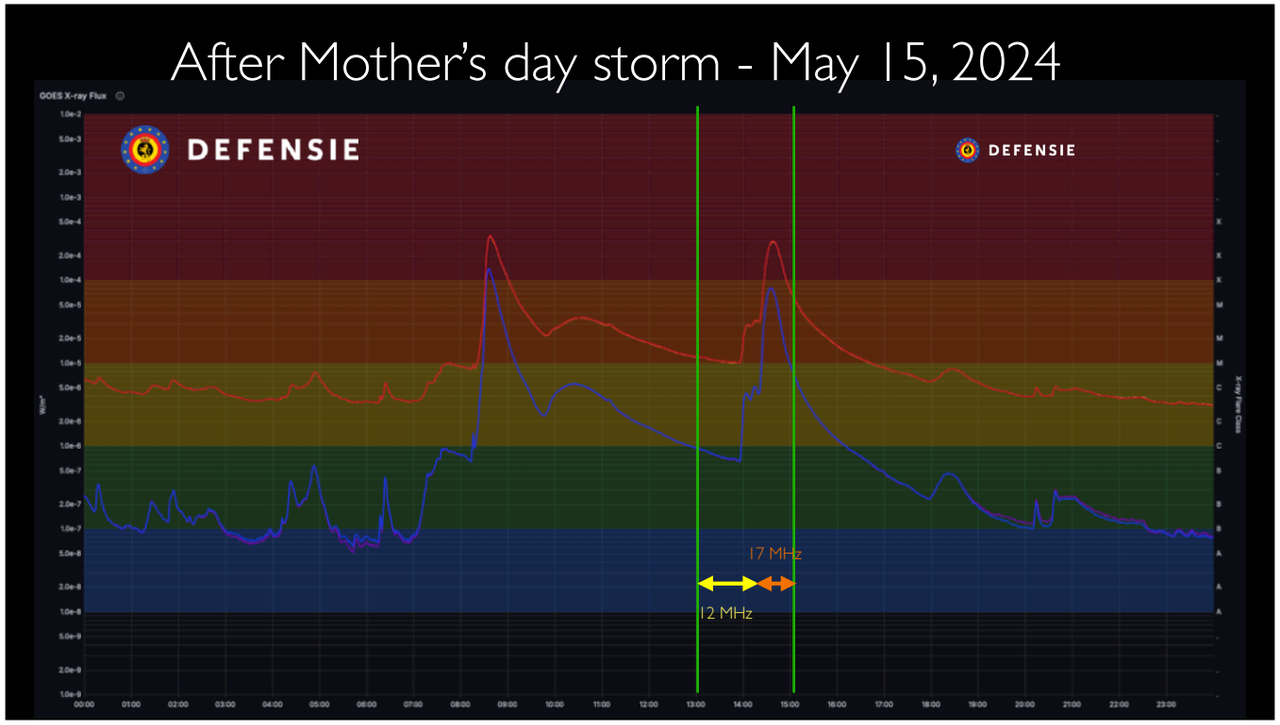
Strong X-ray flux
Product Valid At : 2017-09-06 12:03 UTC

Minor Proton Flux
NOAA/SWPC Boulder, CO USA



Amateur radio reporting network results for the (a) 15 min prior to and (b) 15 min following the X9.3 solar flare on 6 September 2017 1153 UT. The propagation paths are color-coded based on the amateur radio frequency on which the report occurred. The gray and white background shows the diurnal boundary. A reduction in reports can be seen across all frequencies with 7 MHz (dark orange), 14 MHz (bluish green), and 21 MHz (light orange) being the most affected across Europe. (Figure from Frissell et al. 2019)

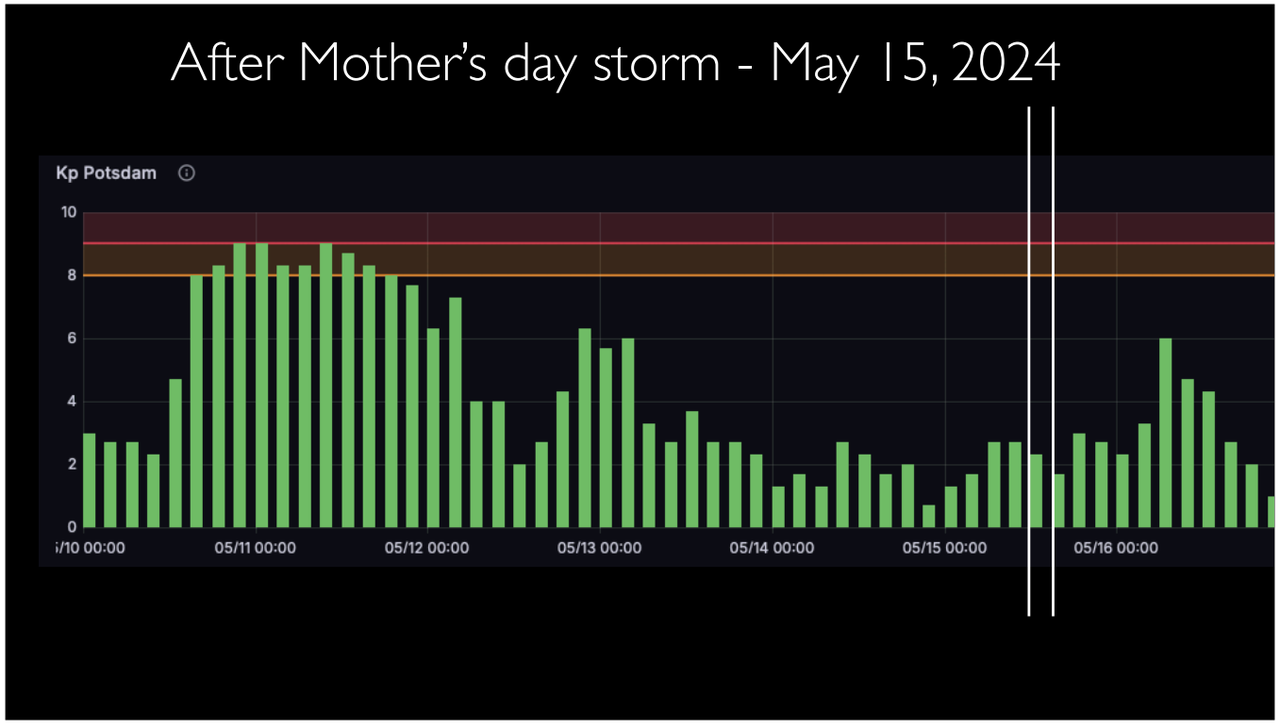
After Mother's day storm - May 15, 2024



15 mei was een test tussen België en Canada.

We hebben toen getest van 13u tot laat in de avond en niets heeft gewerkt. Dat heeft een aantal redenen, maar ik ben ervan overtuigd dat SWx er een belangrijke rol in heeft gespeeld.
13u-14u: Gestart op 12 MHz, mogelijks niet een ideale frequentie, maar ik denk het eigenlijk wel. Ik denk dat er hier niets gelukt was wegens andere verkeerde instellingen. Rond 14u zijn ze dan overgeschakeld naar 17 MHz, maar het is net op dat moment dat er een M class flare begon, gevolgd door een X class flare! Spreekt voor zich dat er met die ionosfeer niet te veel meer aan te vangen viel.
Men is dan blijven testen op 17 MHz, maar dat is waarschijnlijk al te hoogfrequent, en zeker naar de avond toe.

De volgende dag heeft men de testen hervat in de namiddag, toen was er een Kp van 4, ook toen kwam er niets door.



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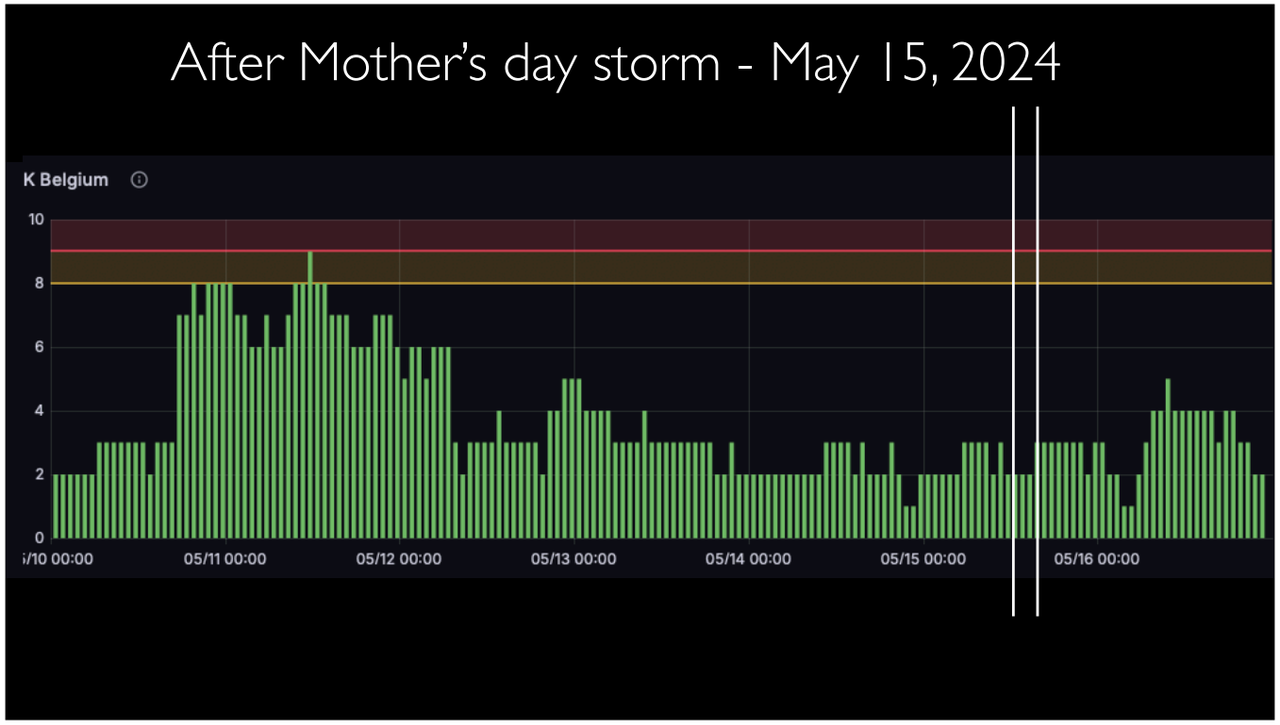

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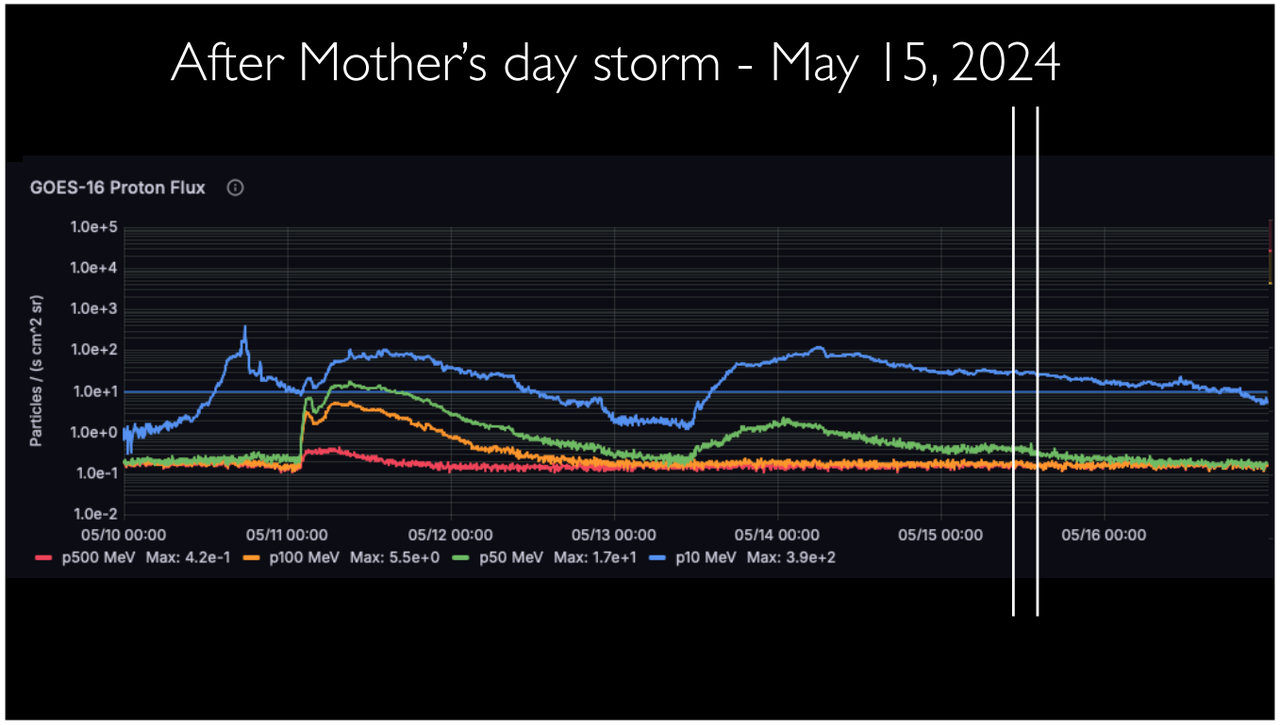

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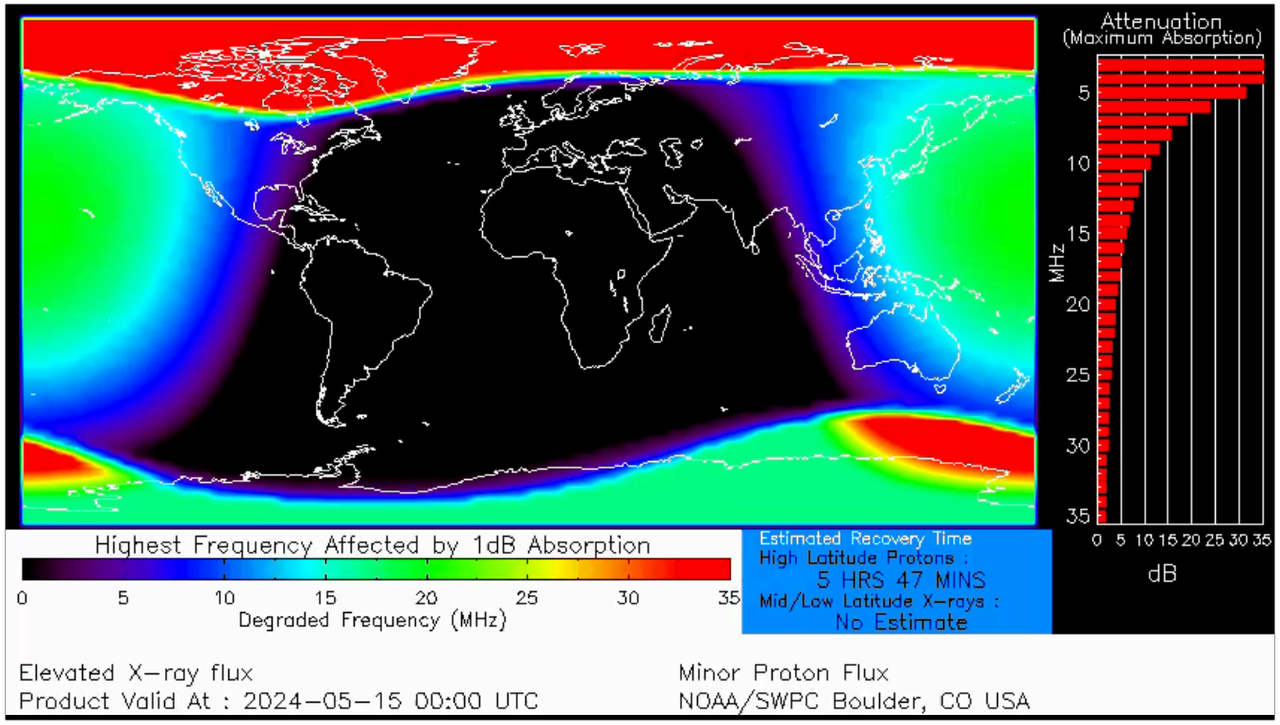
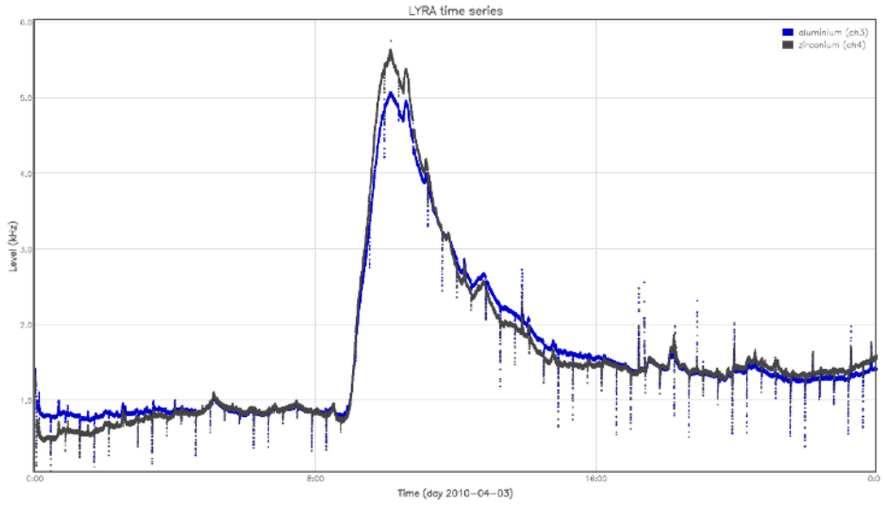

Attenuation
(Maximum Absorption)
MHz
5
10
15
20
25
30
35
0 5 10 15 20 25 30 35
dB
Highest Frequency Affected by 1dB Absorption
0 5 10 15 20 25 30 35
Degraded Frequency (MHz)
Estimated Recovery Time
High Latitude Protons :
5 HRS 47 MINS
Mid/Low Latitude X-rays :
No Estimate
Elevated X-ray flux
Product Valid At : 2024-05-15 00:00 UTC
Minor Proton Flux
NOAA/SWPC Boulder, CO USA

April 3, 2010



On April 03, 2010, the SIDC sent out a PRESTO message alerting about the halo CME heading for Earth. PROBA2 witnesses the radiation flare associated with the plasma eruption.

A B7.4 flare peaking at 09:54 UT was detected today in the Catania sunspot group 56 (NOAA AR 1059) located around S25W05. It was accompanied by a post-eruption arcade, coronal dimmings, possibly an EIT wave and a partial halo CME (angular width around 210 degrees). The CME was first detected at 10:33 UT (by LASCO) and at 09:54 UT (by SECCHI/COR2 on STEREO A). The CME was moving at a projected plane-of-the-sky speed of around 250 km/s (according to the LASCO data). Using some reasonable assumptions on the CME geometry, the true radial CME speed can be estimated to be around 600 km/s. The arrival of the corresponding ICME (possibly an interplanetary flux rope) at the Earth is thus expected in the morning of April 6. The flux rope orientation as inferred from the SOHO/EIT and SOHO/MDI data is ESW, although it may change during propagation. STEREO A and B data indicate that the bulk of the CME was propagating to the south of the ecliptic (according to the COR2 data). If the flux rope will arrive at the Earth, we expect a strong geomagnetic disturbance. Currently, the Earth is inside a slow solar wind flow (460 km/s) with average (5 nT) interplanetary magnetic field magnitude. Geomagnetic conditions are expected to remain quiet in the coming hours.

As you are aware there was a very interesting geomagnetic storm period over the Easter period this year, this period was particularly significant as the disturbed space environment caused a number of spacecraft anomalies, including the well publicised Galaxy 15 failure suffered by our competitor Intelsat. The Presto Alerts and Daily Bulletins ('URSIGRAM') issued by SIDC at the time were superior to alternative products issued by NOAA SWPC, both in terms of timeliness and content.

In general I find that the level of technical content and commentary included in your Daily Bulletins and other products are exactly what we need as a spacecraft operator, and I find that these products compare very favourably with the alternative products issued by NOAA SWPC. You are tending to include greater detail in your commentary regarding events observed on the sun and the effects likely to be experience at earth, we value this additional detail.

I hope these comments are of use and trust that your team will keep up the good work!

Email from a satellite operator to Ronald
Subject SIDC URSIGRAMS / GEOALERTS & PRESTO ALERTS - SOME FEEDBACK

Galaxy is owned by Intelsat
Geostationary satellite

SES (Société Européenne des Satellites) company Satellite Communications Service Provider

Aug 01, 2010 - Satellite Operator's interest

Aug 01, 2010

Nr	Time	Instrument	description
1.	02:59UT	SDO/AIA-193	a coronal dimming of small extent in NOAA AR 1092
2.	03:39UT	STEREOA/COR2	CME front coming from behind the occulted area directed to the upper left of the COR2 field of view (FOV). This CME is associated with event 1.
3.	05:29UT	STEREOA/HI1	CME front coming from behind the occulted area on the right directed to the left of the HI1 FOV. This is the same faint CME as in 2
4.	05:29UT	SDO/AIA-193	Start of rise of filament in the western hemisphere, near the North Pole, stretched from N60W0 to N30W50
5.	05:30UT	SDO/AIA-304	Start of rise of filament in the western hemisphere, near the North Pole, same as event 4.
6.	07:55UT	GOES-X-rays	Start of long duration C3.2 flare
7.	07:59UT	SDO/AIA-193	EUV-wave, seen as a running EUV intensity disturbance, and a coronal dimming, i.e. the evacuated plasma leaves a black gap in EUV-images, around NOAA AR 1092
8.	08:24UT	STEREO/COR2	CME front coming from behind the occulted area in the upper left of the COR2 FOV, associated with 6. **This is a halo CME**.
9.	08:26UT	GOES-X-rays	peak of C3.2 flare
10.	09:30UT	SDO/AIA-304	Polar filament, mentioned in event 5 lift off
11.	09:54UT	STEREOA/COR2	CME front coming from behind the occulted area directed to the upper left of the COR2 FOV, this CME has a smaller angular extent compared to the CME mentioned in 7. **This is a halo CME** associated with the polar filament mentioned in 10.
12.	09:59UT	SDO/AIA-193	Start of rise of post-flare loops in NOAA AR 1092
13.	10:09UT	STEREOA/HI1	CME front coming from behind the occulted area on the right directed to the left of the HI1 FOV. This is the same CME as in 8
14.	10:14UT	SDO/AIA-193	Start of rise of magnetic arcade at the position of the filament mentioned in 4.
15.	10:30UT	SDO/AIA-304	Start of rise of a filament at the same position of the filament mentioned in 5.
16.	11:15UT	SDO/AIA-304	Last SDO/AIA-304 image of the filament mentioned in 15.
17.	13:29UT	STEREOA/HI1	CME front coming from behind the occulted area on the right directed to the left of the HI1 FOV. This is the same CME as in 11
18.	13:59UT	SDO/AIA-193	Start of the slow rise of the filament at the lower base of the filament arcade mentioned in 12. This filament is situated at +/- the same latitude as NOAA AR 1092: N35W0.
19.	14:45UT	SDO/AIA-304	Start of the slow rise of the filament, same as in 18.
20.	16:29UT	SDO/AIA-193	Coronal dimming at N20W50
21.	17:09UT	STEREOA/COR2	CME front coming from behind the occulted area in the upper left of the COR2 FOV, possibly linked with 20
22.	20:09UT	STEREOA/HI1	CME front coming from behind the occulted area on the right directed to the left of the HI1 FOV. This is the same CME as in 21
23.	20:44UT	SDO/AIA-193	Last SDO/AIA-193 image of the filament mentioned in 18.
24.	22:00UT	SDO/AIA-304	Filament mentioned in 16, large on disk arcade, ready to lift off.
25.	22:24UT	STEREOA/COR2	CME front coming from behind the occulted area directed to the upper right of the COR2 FOV. This CME is ejected backwards seen from the Earth, which is located to the left of the COR2 images. This is the filament mentioned in 23 and 24
26.	22:09UT	STEREOA/HI2	CME front coming from behind the occulted area on the right directed to the left of the HI2 FOV. This is the same CME as in 13. The CME front 17 cannot be clearly distinguished.

Op 1 augustus 2010 nam de GOES satelliet een C-zonnevlam waar. Dit is niet uitzonderlijk. Deze zonnevlam was een 'long duration event' en duidt op de aanwezigheid van een plasmawolk die weggekatapulteerd wordt. Die dag was er een reeks van plasmawolken die hun energie hebben gebundeld. Ze kwamen aan op 3 en 4 augustus Eén satelliet alleszins (Galaxy) ondervond zware hinder.
http://www.sidc.be/news/129/welcome.html

August 10, 2022

Broadcasting

Intelsat Loses Command of Galaxy 15 Satellite

By Rachel Jewett | August 22, 2022

Rendering of the Galaxy 15 satellite. Photo: Intelsat

Intelsat has lost the ability to command its Galaxy 15 satellite after an anomaly caused by a space weather event. The anomaly caused the loss of commanding links, which is the signal used to fly the satellite and to receive telemetry data, an Intelsat spokeswoman told *Via Satelite*.

"Intelsat, working with the satellite manufacturer, has concluded that the anomaly is likely due to a lock up of both baseband electronics units triggered by space weather, i.e., solar eruptions of plasma and magnetic fields that can disrupt electronics," the spokeswoman said.

On 10 August 2022, Intelsat again lost control of Galaxy 15 attributing this to a space weather event.