

radiation at
flight altitude



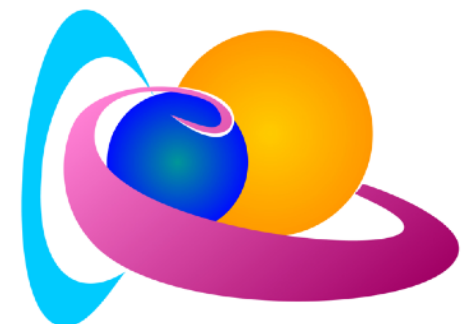
HF communication
disturbances



GNSS positional
errors

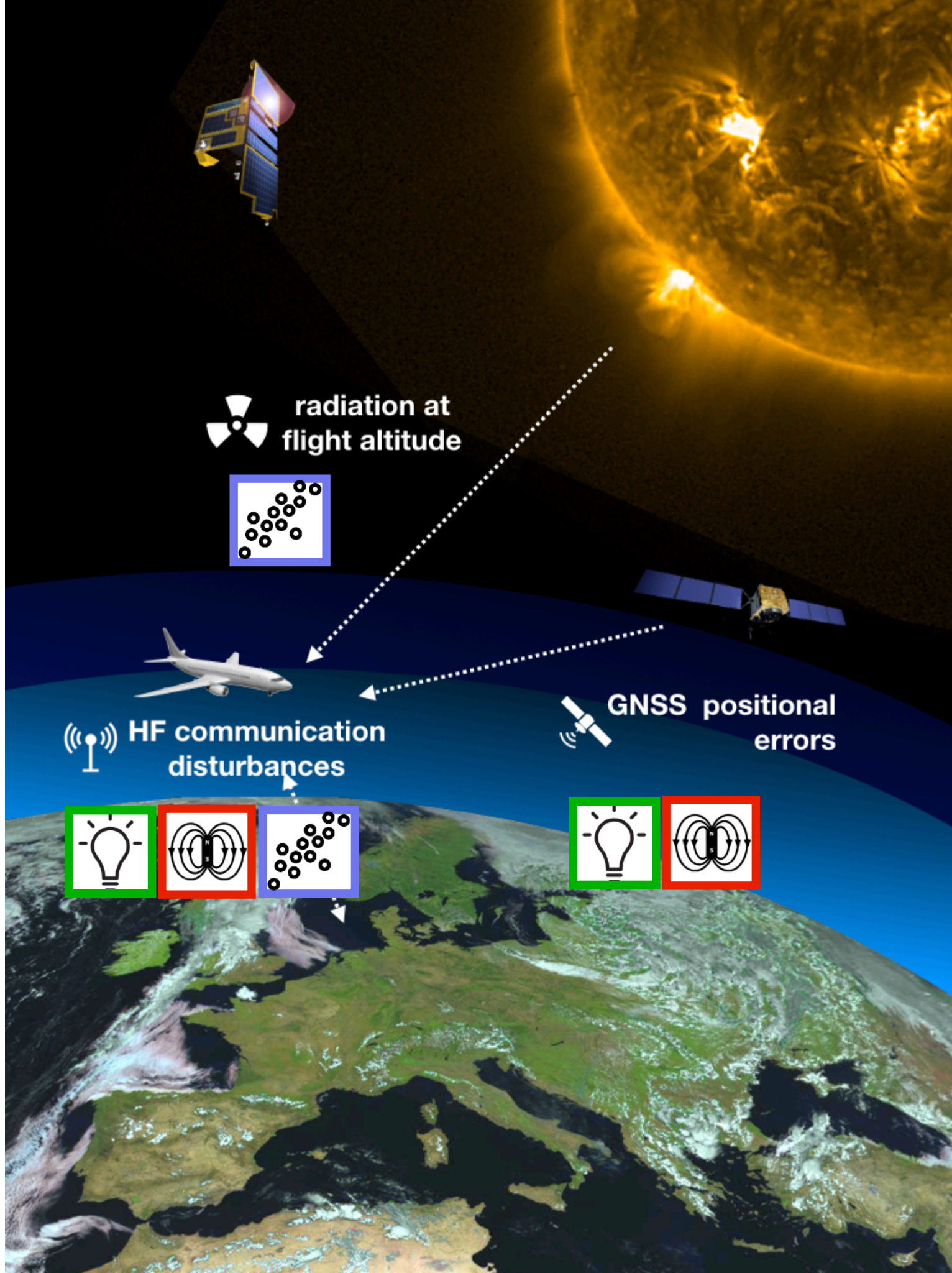
SWx for aviation

Petra.Vanlommel@oma.be



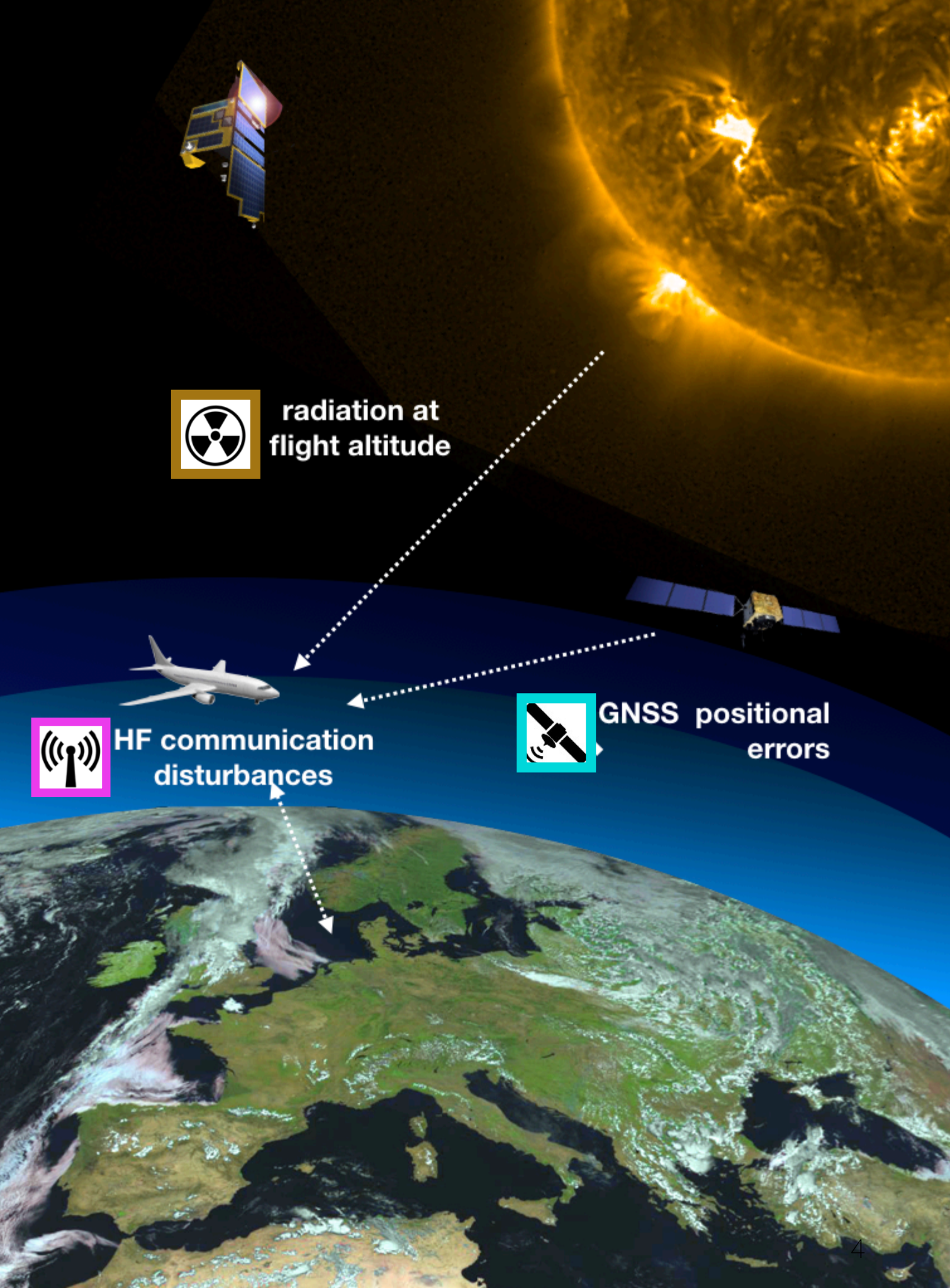
SOLAR STORMS IMPACTING AVIATION

A solar storm initiates space weather processes which impact our navigation and radio communication systems and can cause an increase of radiation levels at flight altitude.



PEGASUS FOR ICAO

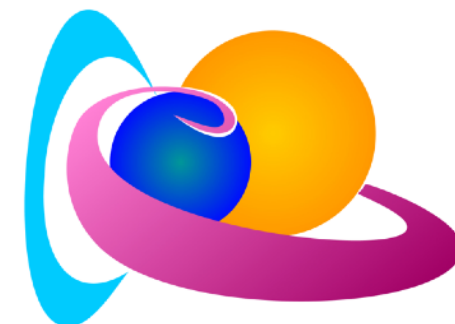


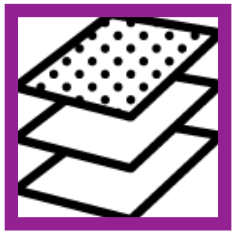


Storm parameters

Thresholds

Petra.Vanlommel@oma.be





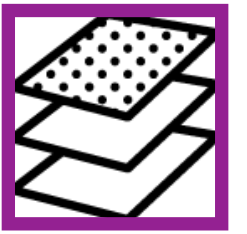
IONOSPHERE

Atmospheric layer with free electrons.

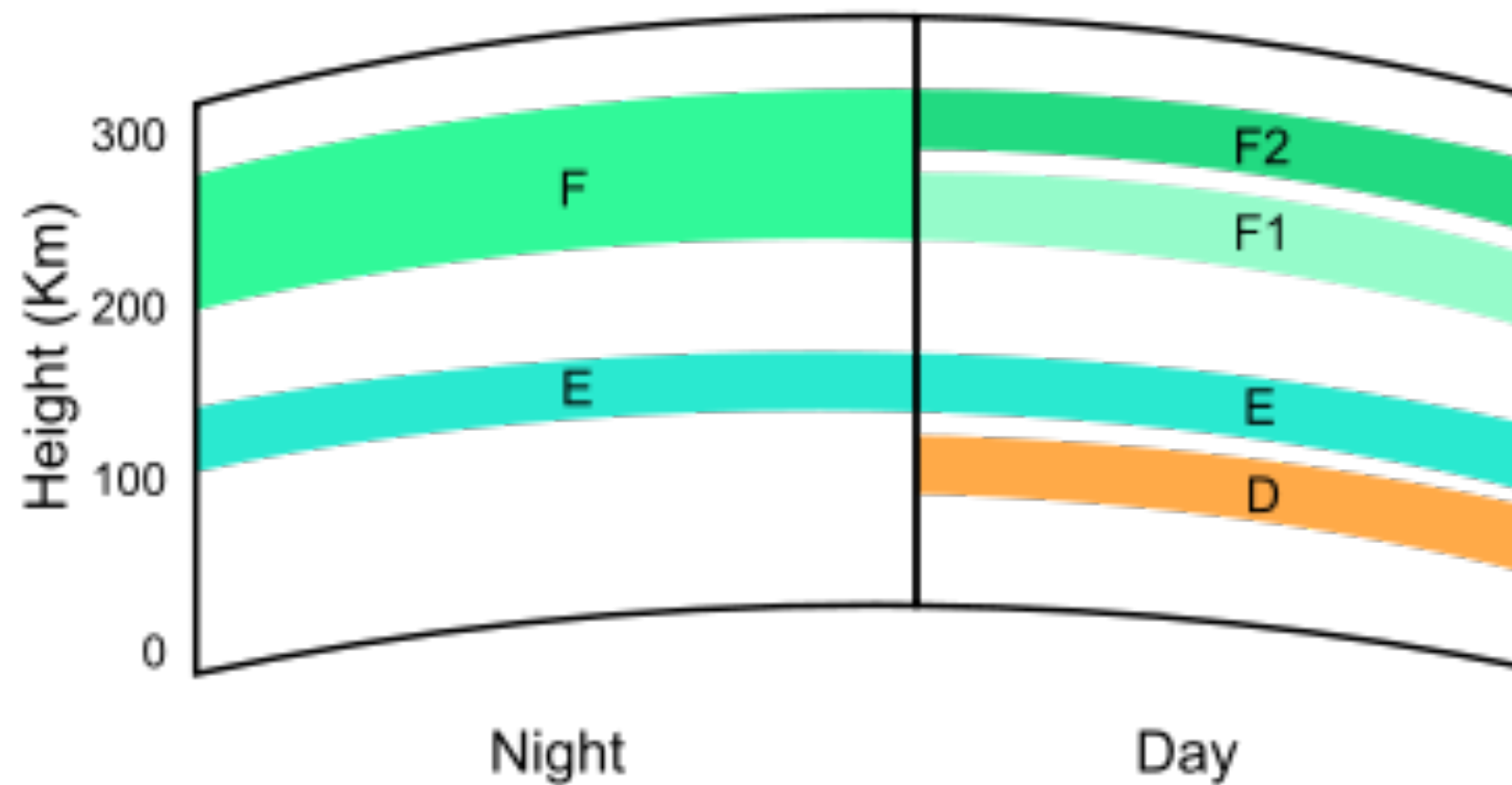
Ionization by solar x-ray, extreme ultraviolet radiation and particle radiation.



RADIO WAVES AND IONOSPHERE



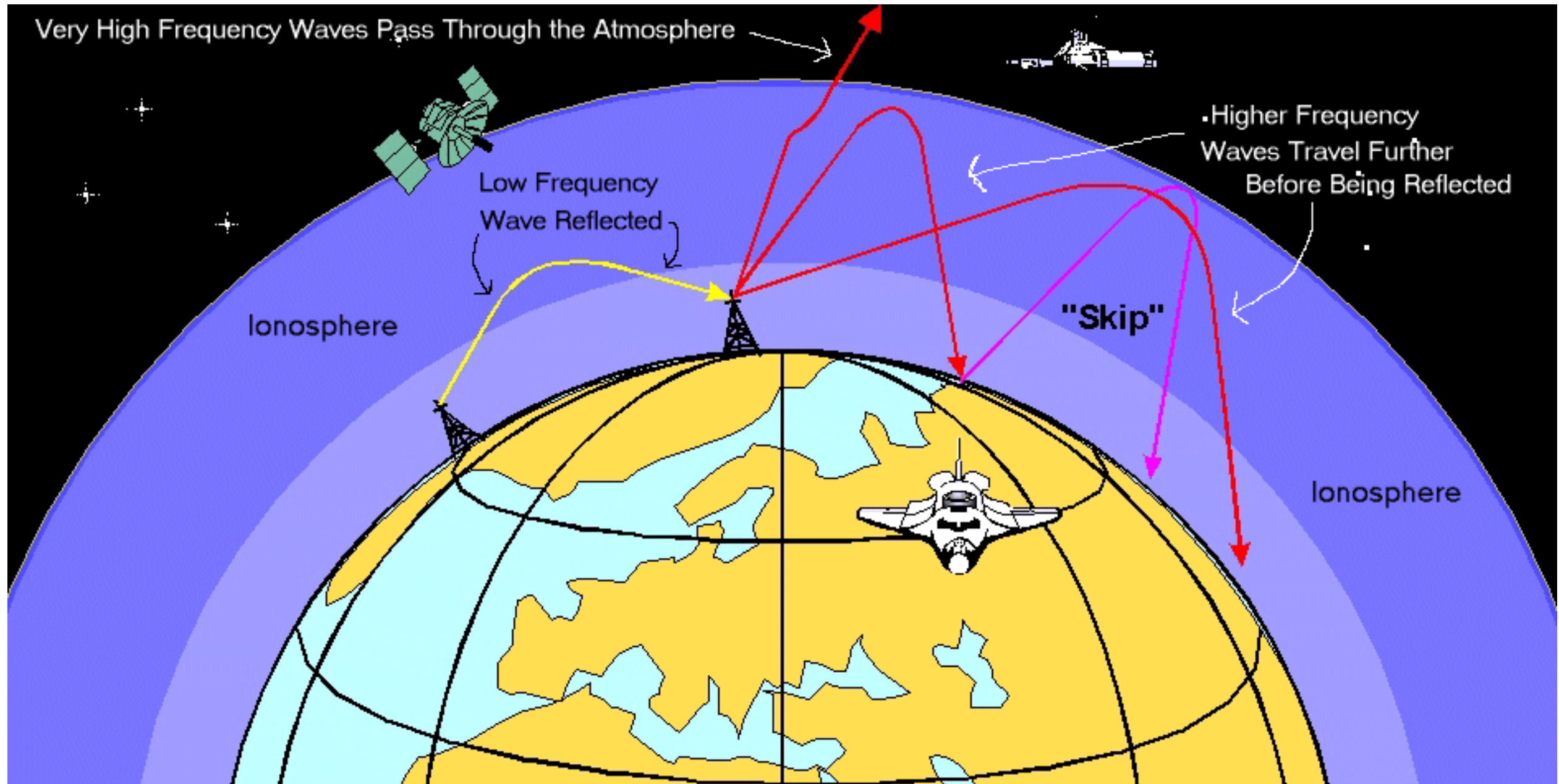
The electron content of each layer defines a characteristic frequency which in turn affects the refractive index of the medium. Each layer will **reflect** or **absorb** radio waves depending on their frequencies. The reflection is used for long distance communications.



RADIO WAVES & IONOSPHERE



The ionosphere seems to be the key-layer for HF communication and GNSS performance: or radio waves are reflected at, or pass through the ionosphere.



PECASUS DASHBOARDS



GNSS - GLOBAL NAVIGATION SATELLITE SYSTEM



GNSS	Moderate	Severe	Time UTC	Values	Status	Alert	Max-3h values	Max-3h status
<u>Amplitude Scintillation</u>	0.5	0.8	2020-10-12 14:15	0.25	QUIET		0.35	QUIET
<u>Phase Scintillation</u>	0.4	0.7	2020-10-12 14:15	0.13	QUIET		0.14	QUIET
<u>Vertical TEC</u>	125	175	2020-10-12 14:15	61.92	QUIET		61.93	QUIET

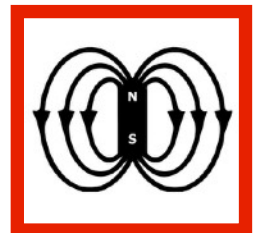
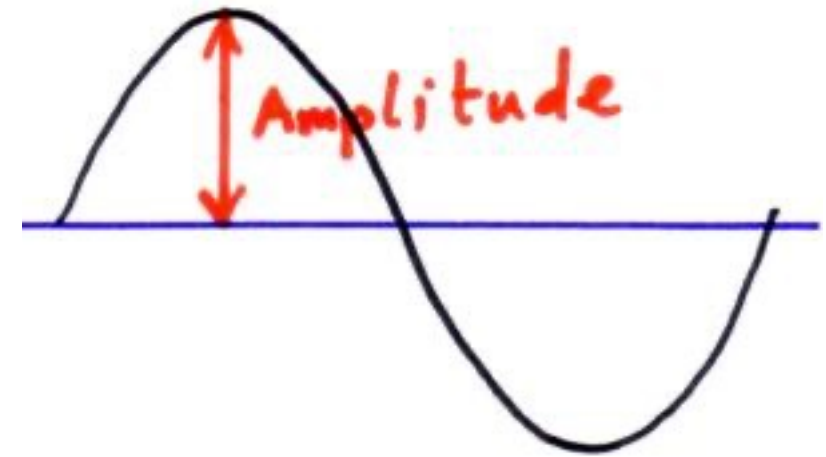
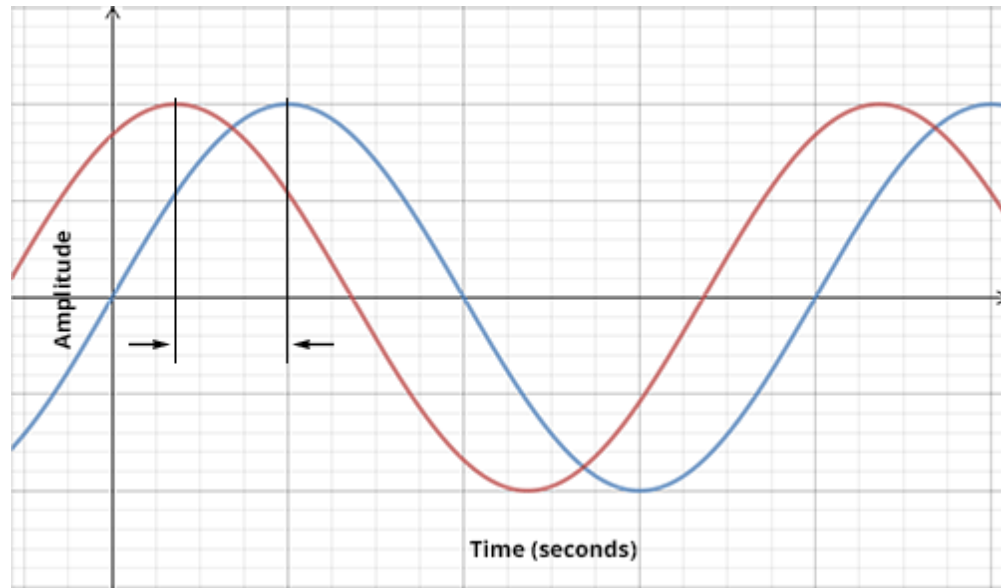


RADIATION	Moderate	Severe	Time UTC	Flags	Status	Alert	Max-3h flags	Max-3h status
<u>Effective Dose FL_{≤460}</u>	30	80	2020-10-12 14:20	0	QUIET		0	QUIET
<u>Effective Dose FL > 460</u>	/	80	2020-10-12 14:20	0	QUIET		0	QUIET

HF COM	Moderate	Severe	Time UTC	Values/Flags	Status	Alert	Max-3h values	Max-3h status
<u>Auroral Absorption (AA)</u>	8	9	2020-10-12 14:16	3.0	QUIET		3.0	QUIET
<u>Polar Cap Absorption (PCA)</u>	2	5	2020-10-12 14:20	0.00	QUIET		0.00	QUIET
<u>Shortwave Fadeout (SWF)</u>	x1.0	x10.0	2020-10-12 14:17	< M.5-flare	QUIET		< M.5-flare	QUIET
<u>Post-Storm Depression (PSD)</u>	30%	50%	2020-10-12 14:15	0	QUIET		0	QUIET



IONOSPHERIC SCINTILLATION



A Station connects with many satellites.

IPP are concentrated in the area of the station.

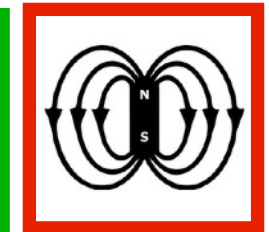
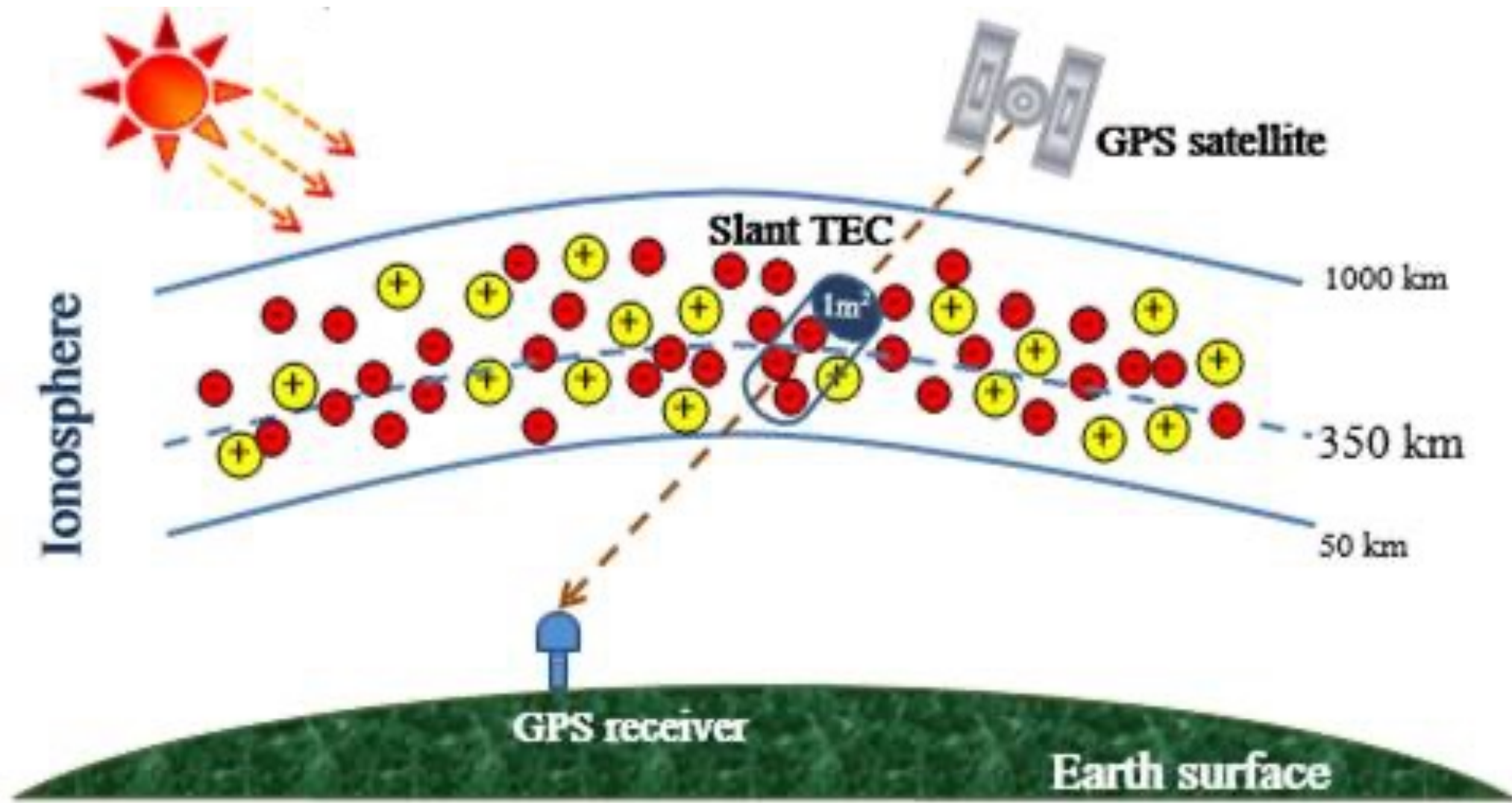
Scintillation is a localised phenomenon.

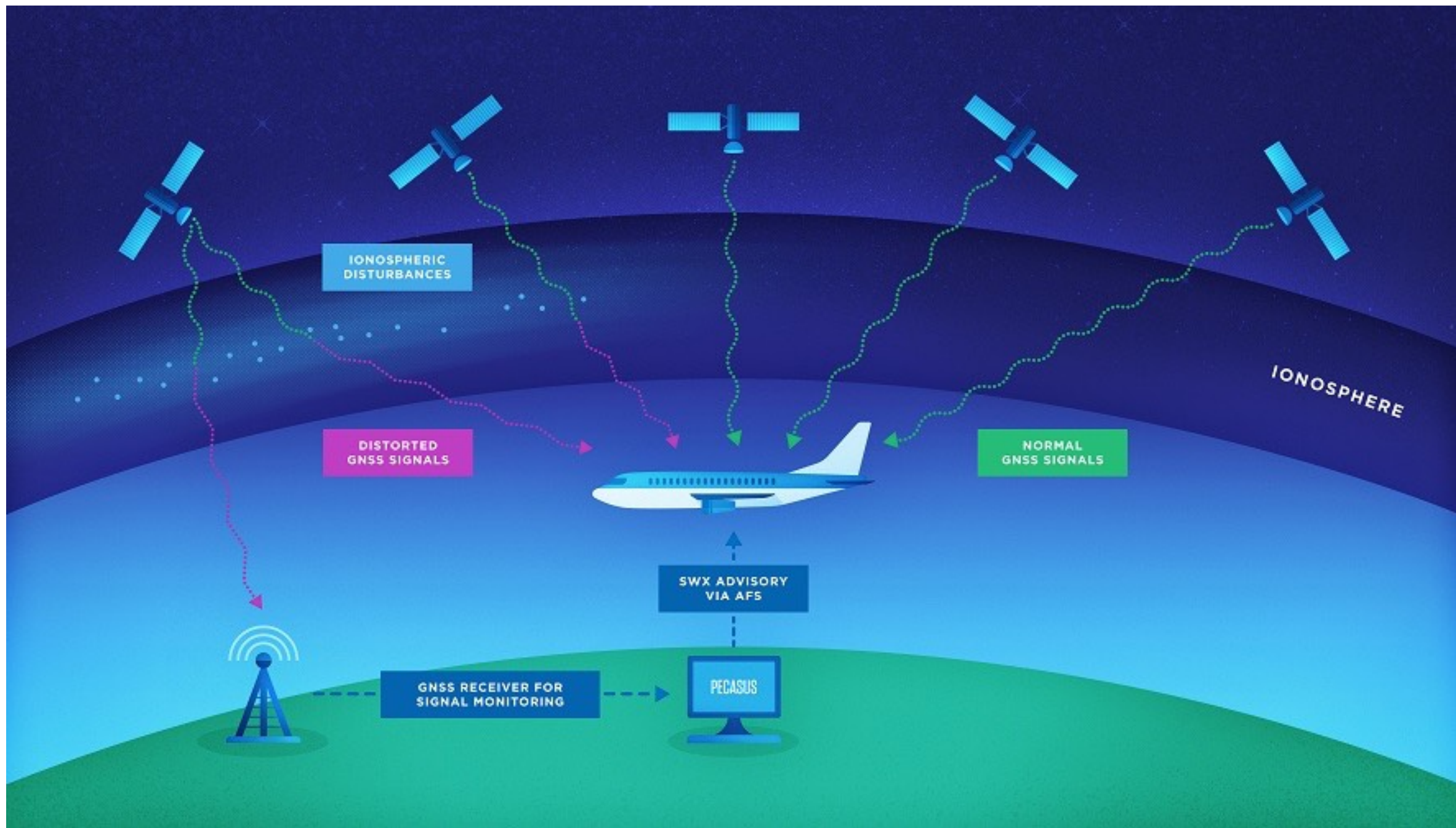
A green/orange/red dot are 15 dots on top of each other: last 15 min data, the max is the top dot.

Stations without green dots: station doesn't provide data - data outage.



VERTICAL TEC





RADIATION



GNSS	Moderate	Severe	Time UTC	Values	Status	Alert	Max-3h values	Max-3h status
<u>Amplitude Scintillation</u>	0.5	0.8	2020-10-12 14:15	0.25	QUIET		0.35	QUIET
<u>Phase Scintillation</u>	0.4	0.7	2020-10-12 14:15	0.13	QUIET		0.14	QUIET
<u>Vertical TEC</u>	125	175	2020-10-12 14:15	61.92	QUIET		61.93	QUIET

RADIATION	Moderate	Severe	Time UTC	Flags	Status	Alert	Max-3h flags	Max-3h status
<u>Effective Dose FL_{≤460}</u>	30	80	2020-10-12 14:20	0	QUIET		0	QUIET
<u>Effective Dose FL > 460</u>	/	80	2020-10-12 14:20	0	QUIET		0	QUIET



HF COM	Moderate	Severe	Time UTC	Values/Flags	Status	Alert	Max-3h values	Max-3h status
<u>Auroral Absorption (AA)</u>	8	9	2020-10-12 14:16	3.0	QUIET		3.0	QUIET
<u>Polar Cap Absorption (PCA)</u>	2	5	2020-10-12 14:20	0.00	QUIET		0.00	QUIET
<u>Shortwave Fadeout (SWF)</u>	x1.0	x10.0	2020-10-12 14:17	< M.5-flare	QUIET		< M.5-flare	QUIET
<u>Post-Storm Depression (PSD)</u>	30%	50%	2020-10-12 14:15	0	QUIET		0	QUIET

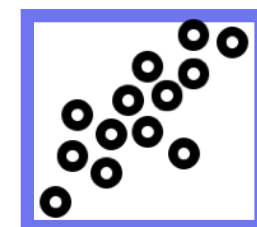
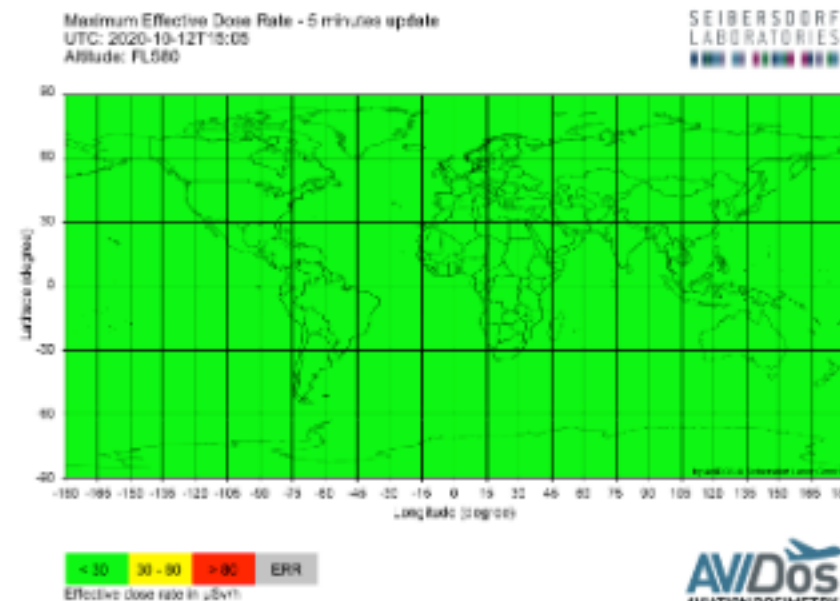


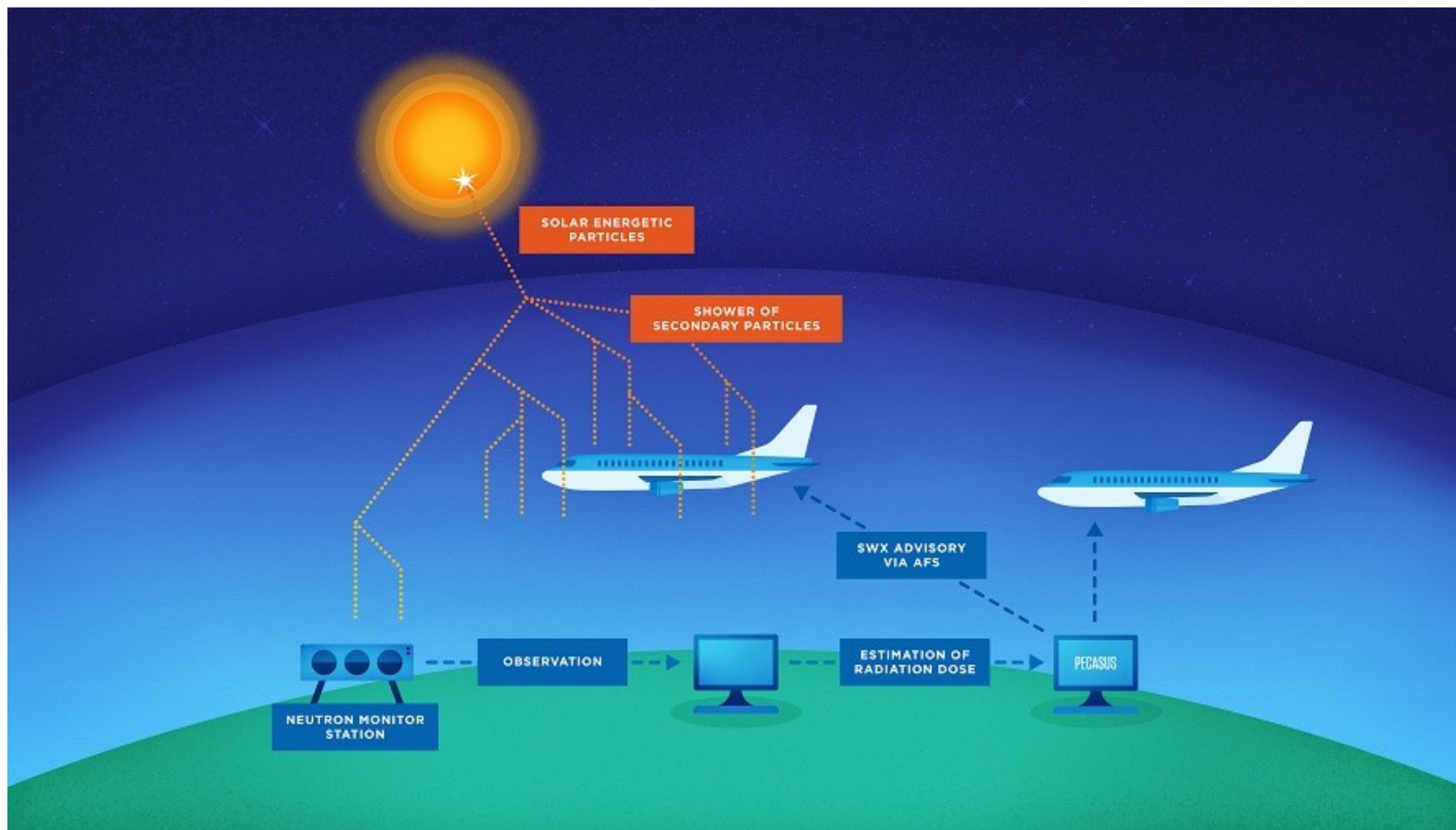
RADIATION $-\mu Sv/h$



During a strong Solar Radiation Storm, a Ground Level Enhancement (GLEs) may occur. A GLE is sudden increase in the cosmic ray intensity recorded by ground based detectors. Radiation at FLV in particular latitude bands will increase.

What?	Strong Solar Radiation Storm
Consequences	Increased radiation
What to monitor	micro-Sieverts/hour



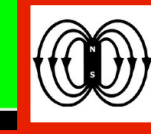
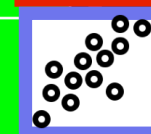


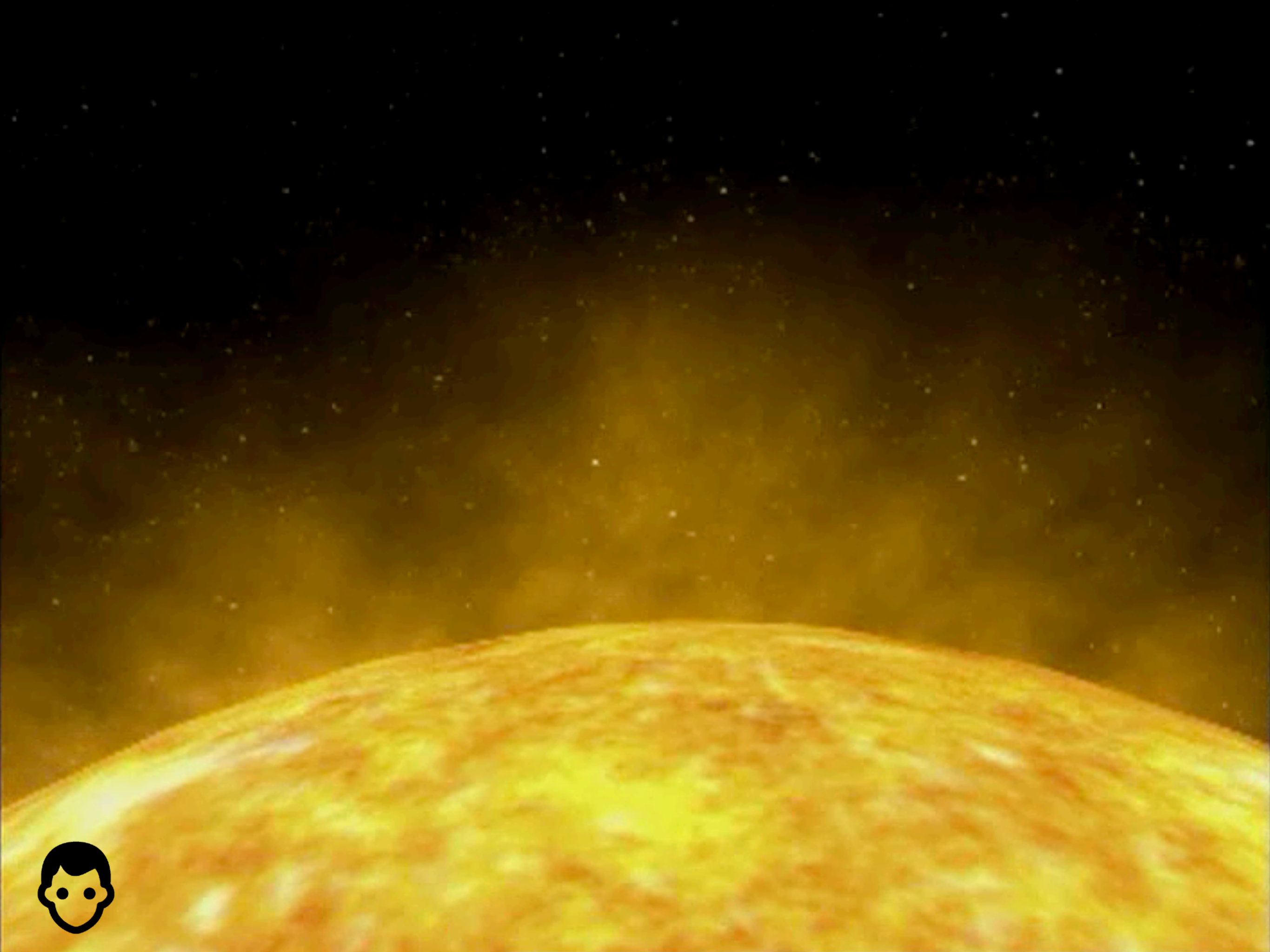


GNSS	Moderate	Severe	Time UTC	Values	Status	Alert	Max-3h values	Max-3h status
<u>Amplitude Scintillation</u>	0.5	0.8	2020-10-12 14:15	0.25	QUIET		0.35	QUIET
<u>Phase Scintillation</u>	0.4	0.7	2020-10-12 14:15	0.13	QUIET		0.14	QUIET
<u>Vertical TEC</u>	125	175	2020-10-12 14:15	61.92	QUIET		61.93	QUIET

RADIATION	Moderate	Severe	Time UTC	Flags	Status	Alert	Max-3h flags	Max-3h status
<u>Effective Dose FL_{≤460}</u>	30	80	2020-10-12 14:20	0	QUIET		0	QUIET
<u>Effective Dose FL > 460</u>	/	80	2020-10-12 14:20	0	QUIET		0	QUIET

HF COM	Moderate	Severe	Time UTC	Values/Flags	Status	Alert	Max-3h values	Max-3h status
<u>Auroral Absorption (AA)</u>	8	9	2020-10-12 14:16	3.0	QUIET		3.0	QUIET
<u>Polar Cap Absorption (PCA)</u>	2	5	2020-10-12 14:20	0.00	QUIET		0.00	QUIET
<u>Shortwave Fadeout (SWF)</u>	x1.0	x10.0	2020-10-12 14:17	< M.5-flare	QUIET		< M.5-flare	QUIET
<u>Post-Storm Depression (PSD)</u>	30%	50%	2020-10-12 14:15	0	QUIET		0	QUIET



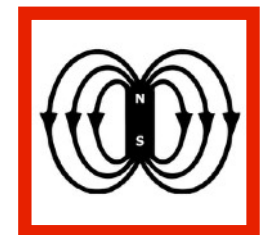


AURORAL ABSORPTION - KP



During geomagnetic storms, energetic particles will enter the polar regions of the ionosphere and trigger excess ionisation, triggering radio absorption, called an **auroral absorption**.

What?	Strong geomagnetic storms Kp>8
Consequences	radio fade out in both polar region
What to monitor	Kp indices



<https://www.swpc.noaa.gov/products/planetary-k-index>

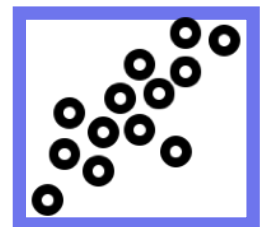


POLAR CAP ABSORPTION

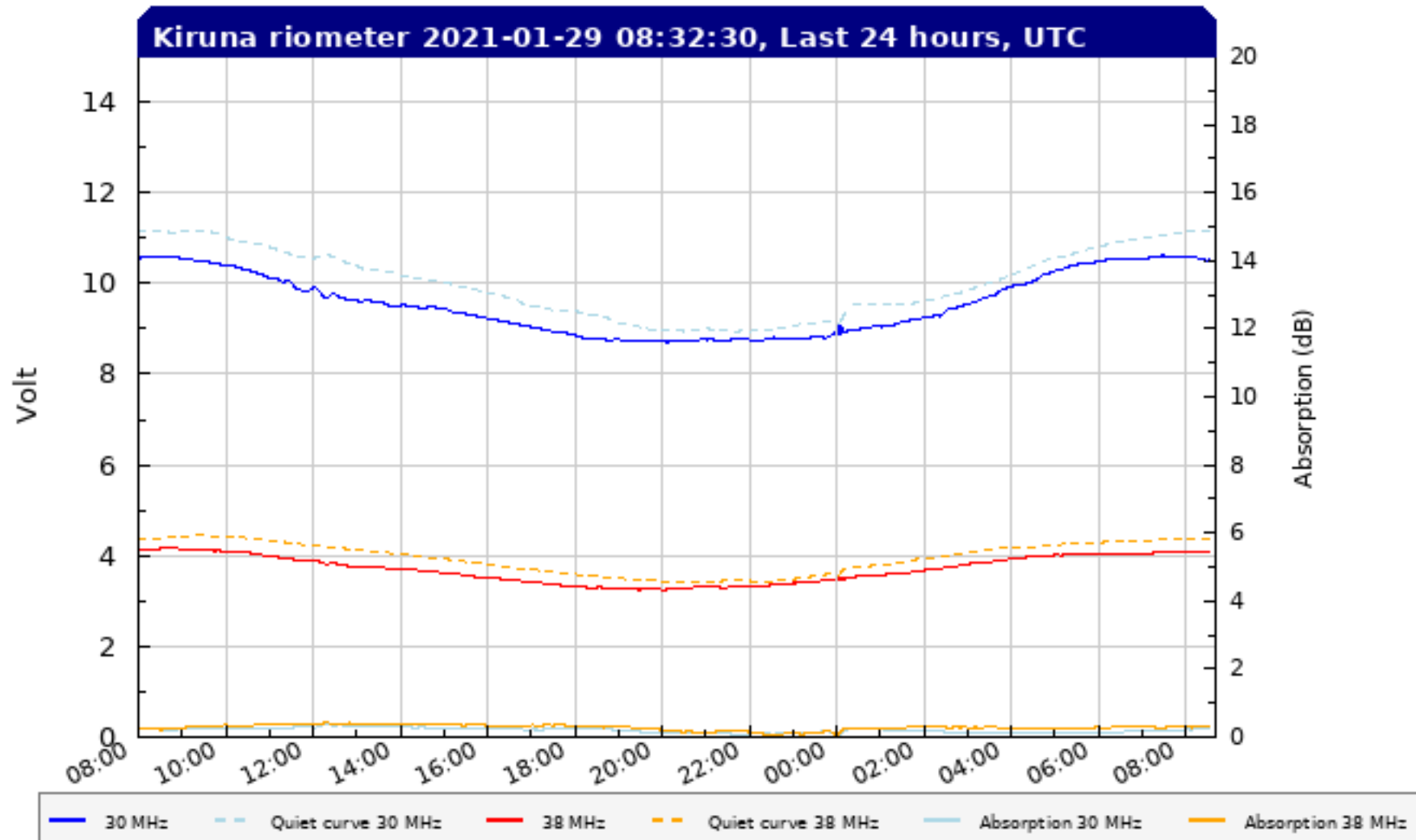


During proton events or solar radiation storms, energetic particles from the Sun will trigger extra ionisation of the D-layer in the polar regions inducing a radio fade out, called a **Polar Cap Absorption**.

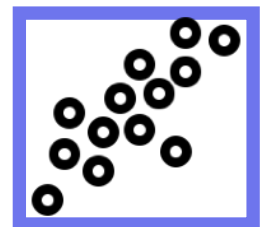
What?	Solar radiation storm
Consequences	radio fade out in both polar regions
What to monitor	Absorption >2 dB



PCA - RIOMETERS



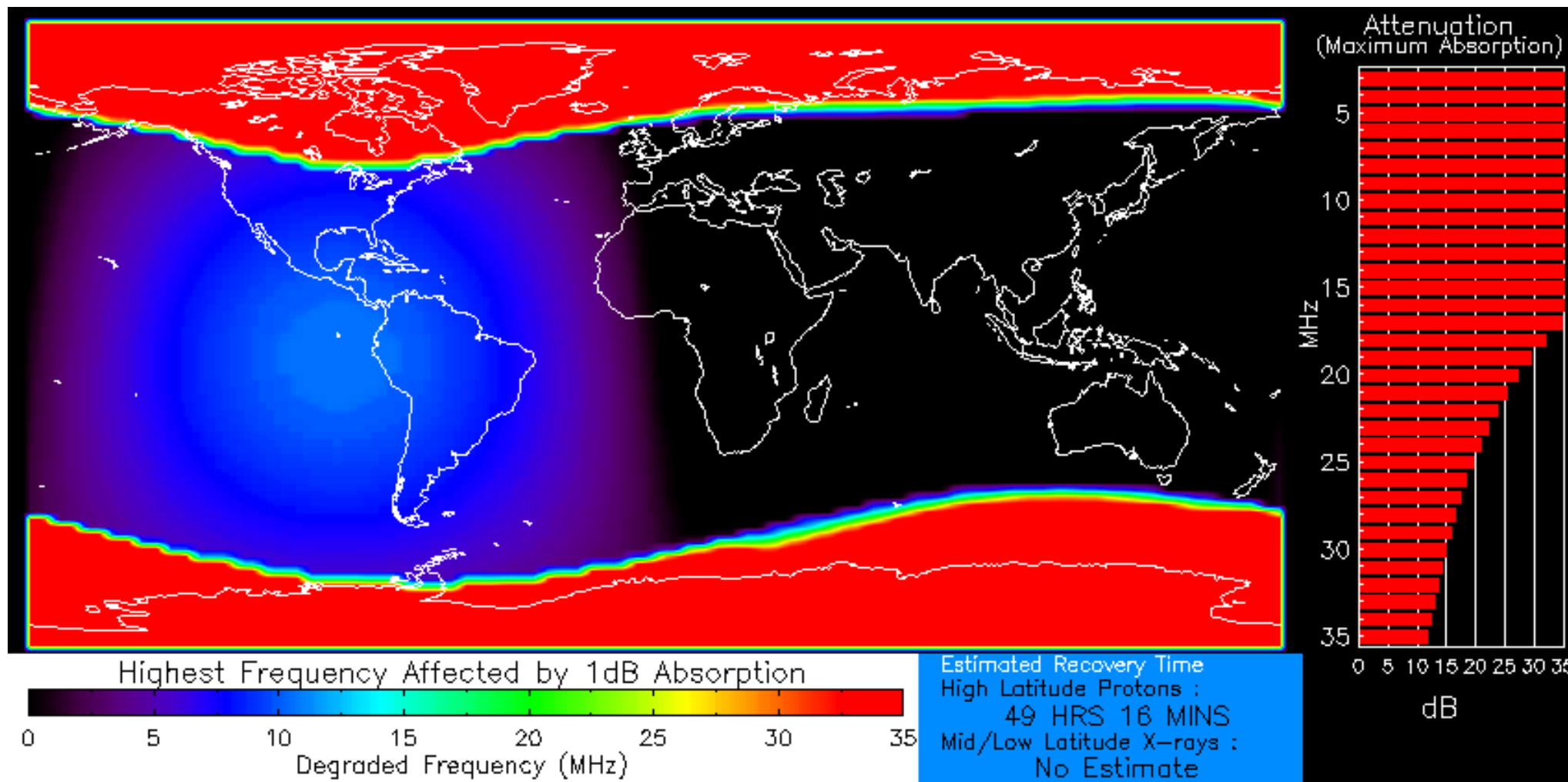
[http://pecasus.stce.be/dashboards/pecaDashboard_HF_PCA.php?
&time=2020-10-12+15:06](http://pecasus.stce.be/dashboards/pecaDashboard_HF_PCA.php?&time=2020-10-12+15:06)



PCA - D-RAP MODEL



Conditions in the D-region of the ionosphere have a dramatic effect on HF communications. The global D-Region Absorption Predictions (D-RAP) depicts the D-region at high latitudes where it is driven by particles as well as low latitudes, where photons cause the prompt changes.



Normal X-ray Background
Product Valid At : 2012-03-07 18:00 UTC

Strong Proton Flux
NOAA/SWPC Boulder, CO USA

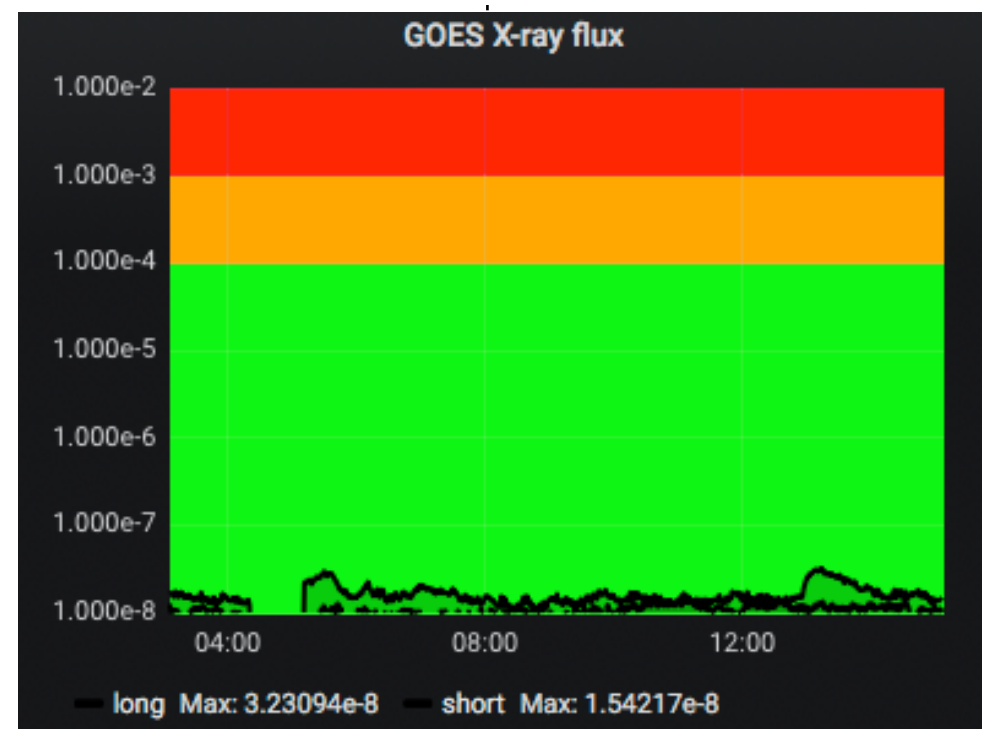


SHORT WAVE FADE OUT



The soft Xray flux increase will induce an excess ionisation of the D layer triggering an absorption of low HF frequencies (fade out).

What?	Strong flares (>X1)
Consequences	radio fade out in the Sun-lit hemisphere
What to monitor	GOES soft Xray flux



<https://www.swpc.noaa.gov/products/goes-x-ray-flux>



POST STORM DEPRESSIONS



The maximum usable frequency (MUF) for a given communication path is the highest HF radio frequency that can be used for communication via reflection. In the late phases of ionospheric storms, the ionosphere remains in an unsettled state, triggering disturbances in long range radio communications. The MUF varies with respect to their undisturbed values.

What?	ionospheric disturbances
Consequences	Global radio communication troubles
What to monitor	$\frac{MUF}{median_{30days}(f_oF_2)}$ % decrease

$$f_oF_2 \equiv f_p \propto \sqrt{n_o}$$

$$MUF \equiv \frac{f_oF_2}{\cos \theta}$$



