

# GNSS: A USEFUL TOOL TO STUDY THE IMPACT OF SOLAR ACTIVITY AT EARTH.

*Bergeot Nicolas, Chevalier Jean-Marie, Marqué Christophe, de Patoul Judith, Maneva Yana, Vanlommel Petra, Janssens Jan*

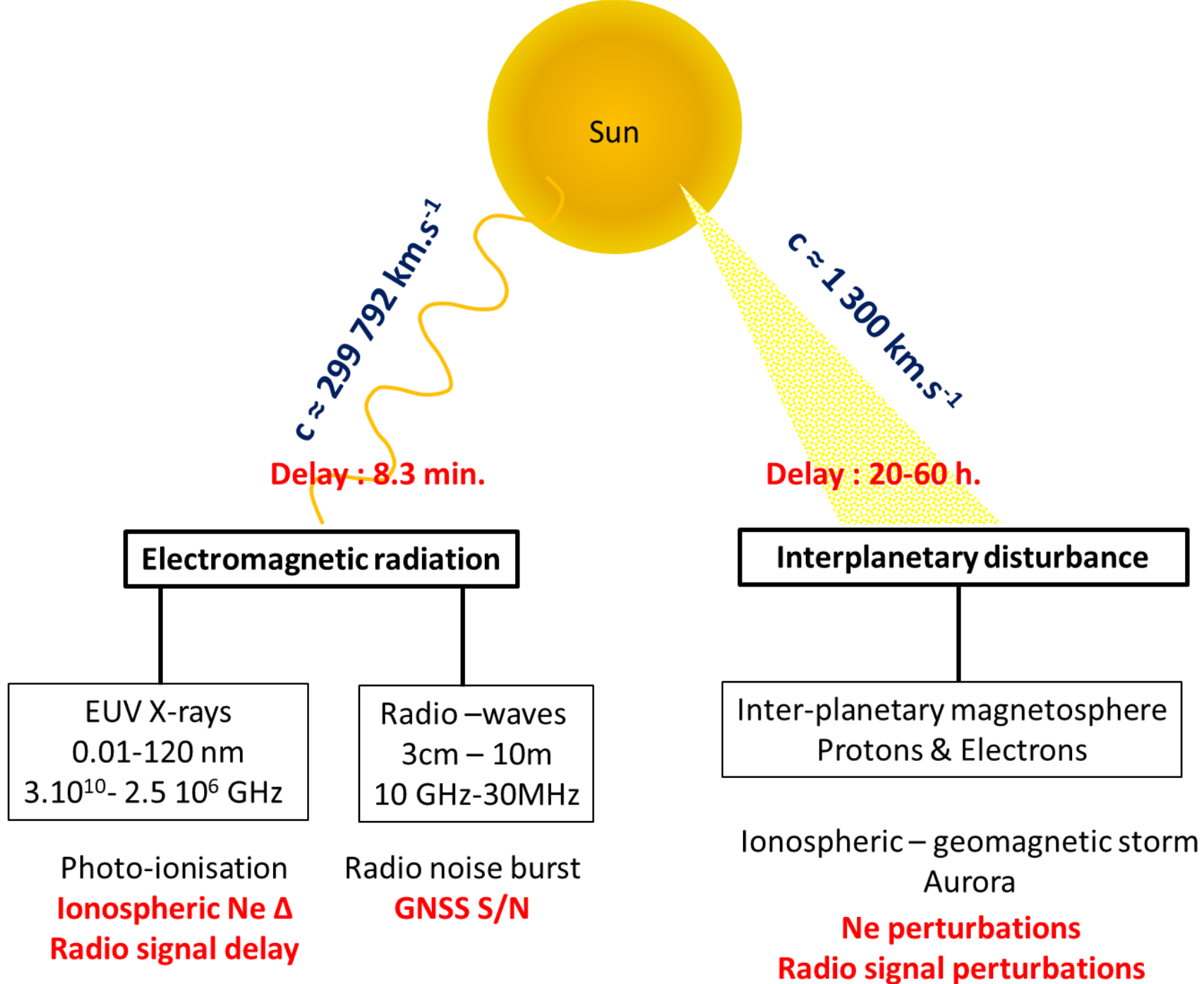
Royal Observatory of Belgium  
Solar-Terrestrial Centre of Excellence

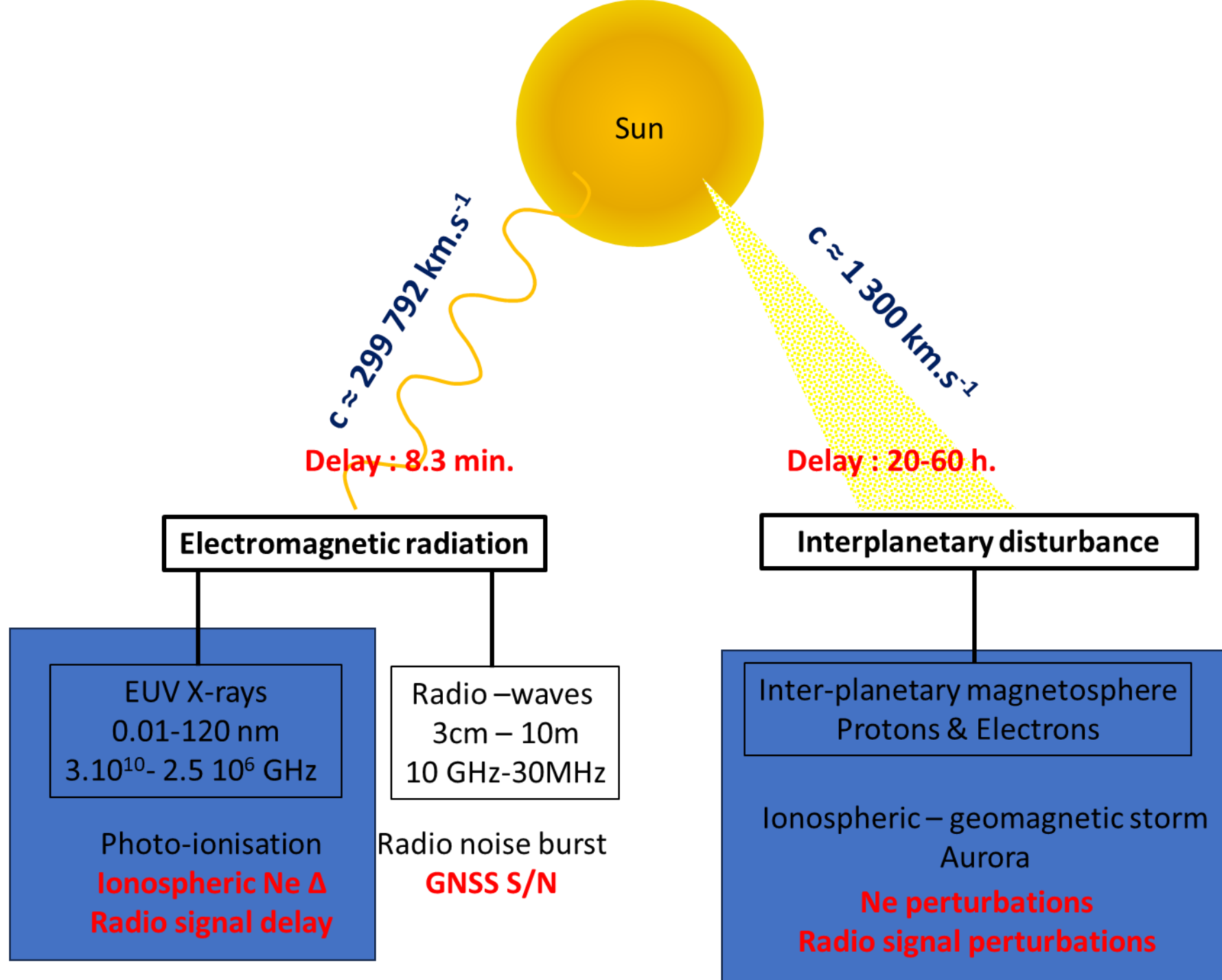


Royal Observatory of Belgium



Solar-Terrestrial Centre of Excellence





# 1. TEC maps

## Near Real Time European TEC Maps

*Grid resolution:  $0.5^\circ \times 0.5^\circ$*

*Every 5-min (15-min before 2022)*

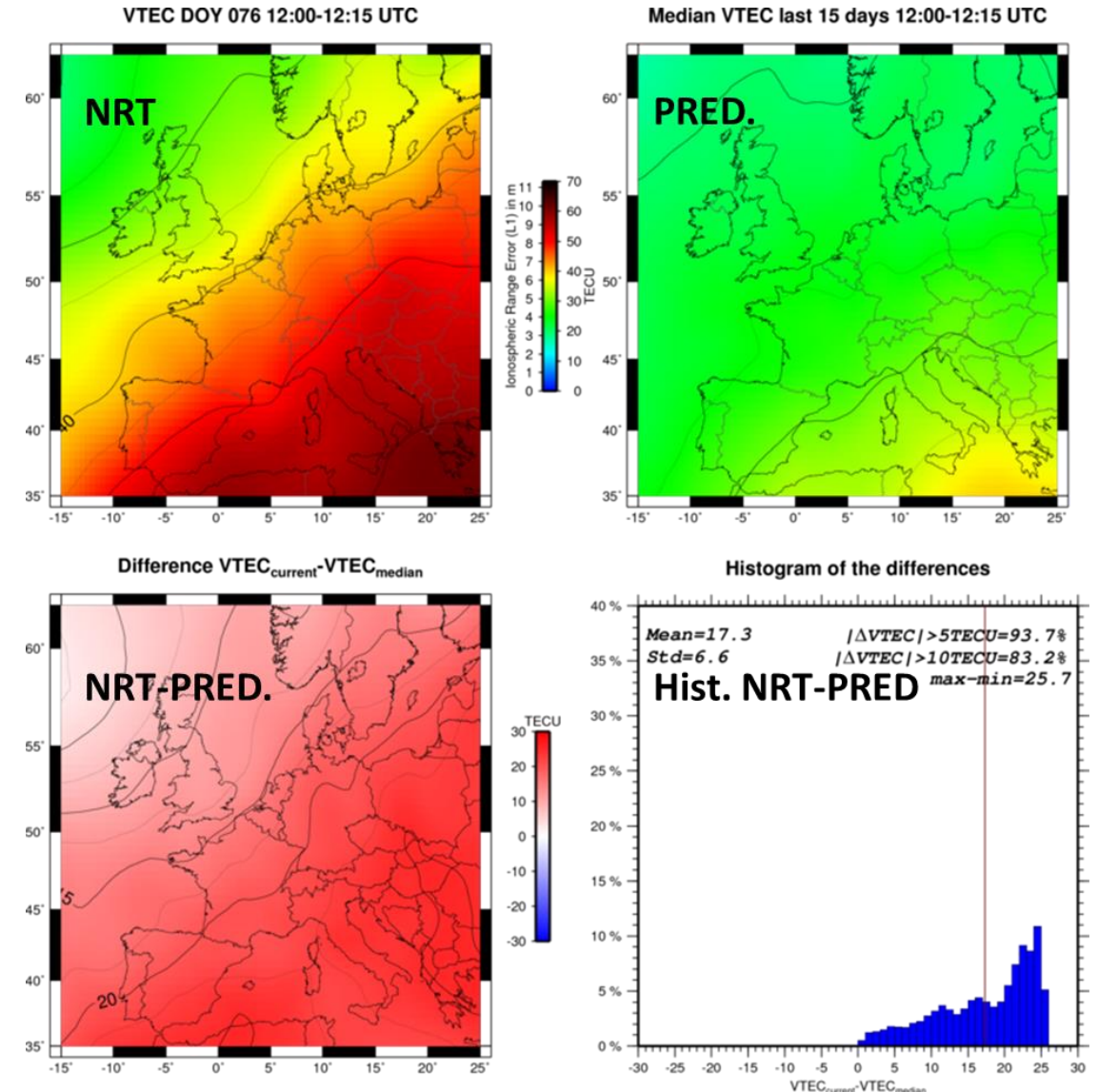
*GPS+GLONASS+Galileo*

*Input ~180 EPN stations*

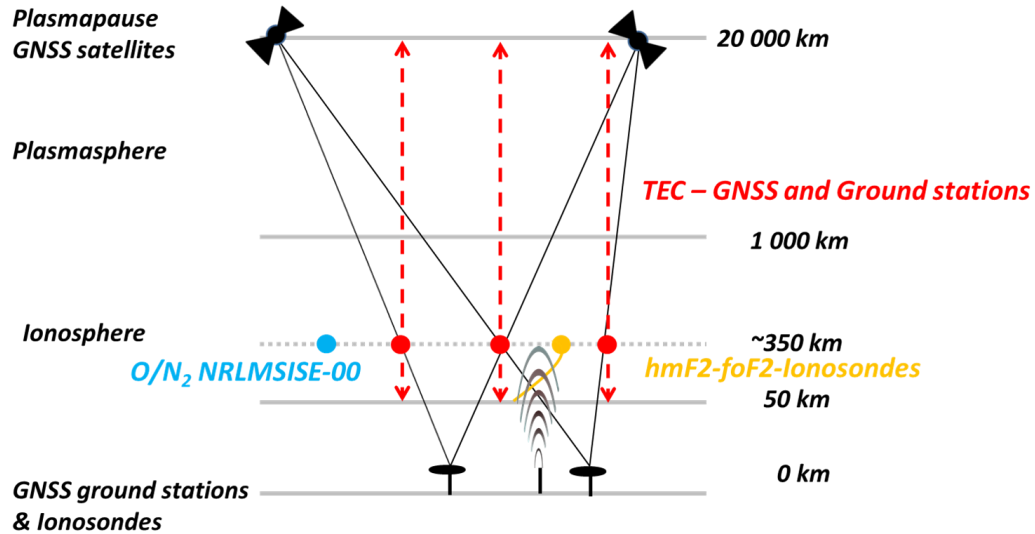
*No background model, IONEX Files*

<ftp://gnss.oma.be/gnss/products/IONEX/>

[Visualization: gnss.be](http://gnss.be)



# 1. TEC maps



## TEC data (15-20 years)

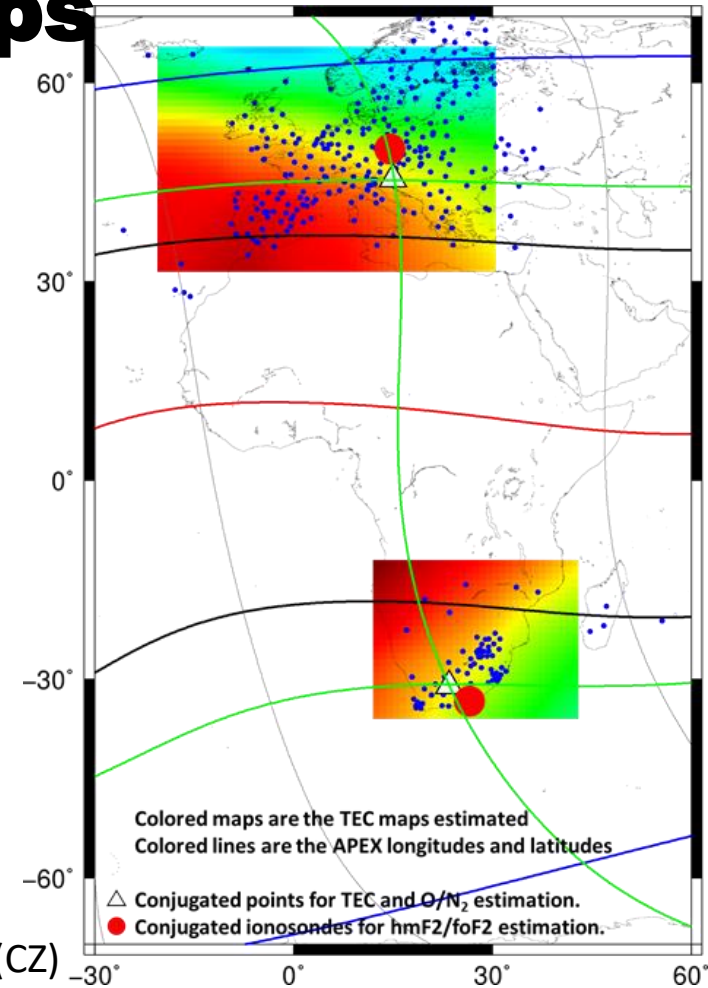
IONEX maps. 2003-2018 for South Africa, 1998-2019 for Europe.  
Sampling rate 15 min. Grid resolution 0.5°x0.5°

## Ionosondes data (hmF2 and foF2, 15-23 years)

Grahamstown (SA) 1996-2019. Sampling rate : hourly to 15 min. Průhonice (CZ) 2004-2019. Sampling rate : hourly.

## O/N<sub>2</sub> data (18 years)

2000-2019 data from NRLMSISE-00 model (Picone et al. 2002) output of O/N<sub>2</sub> at 350 km altitude. Sampling rate : 1 minute.

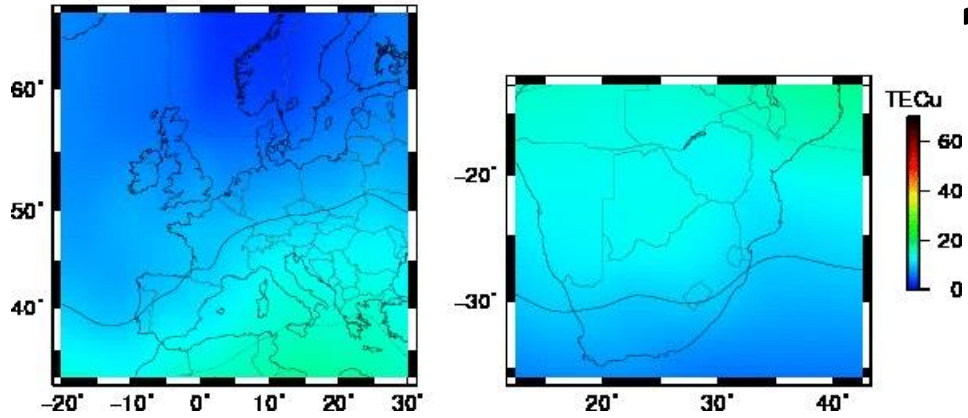


## Data extraction

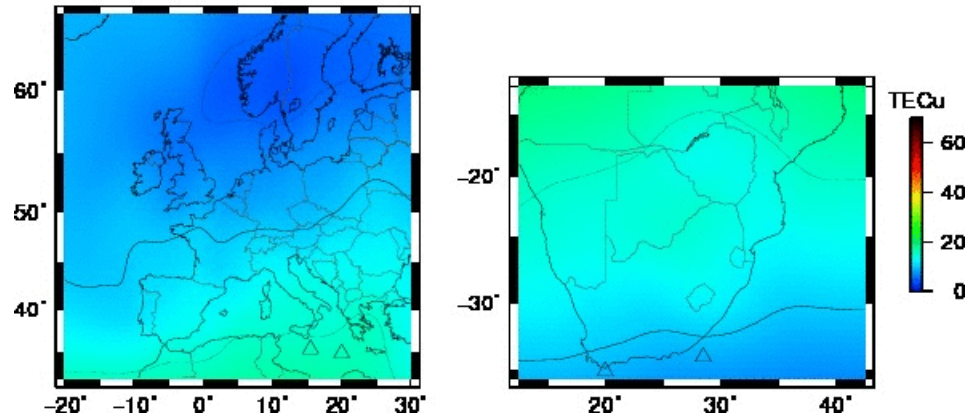
E90° N-S 40° in Geomag.  
Coord. (APEX, Richmond 1995)

00:00 UTC

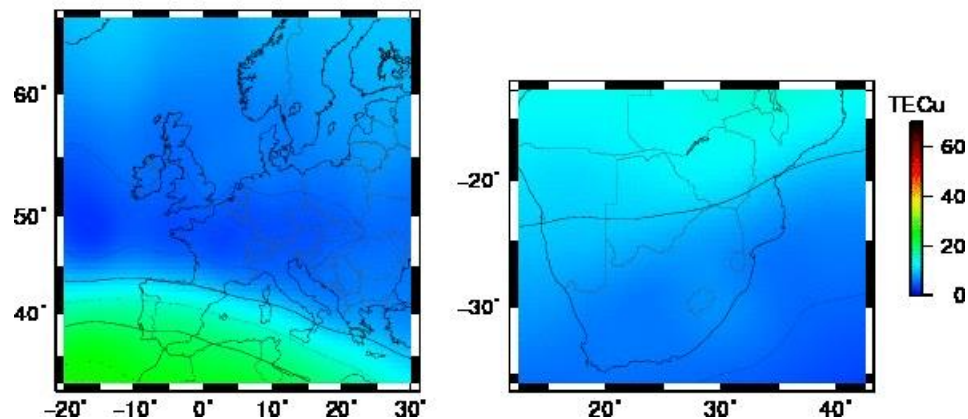
# 1. TEC maps



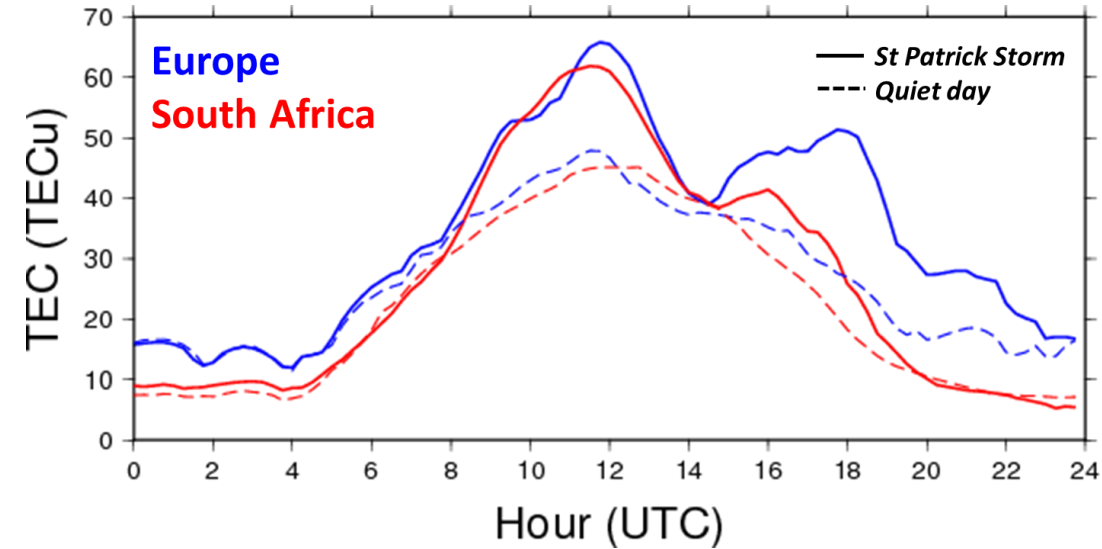
16th March 2015



17th March 2015



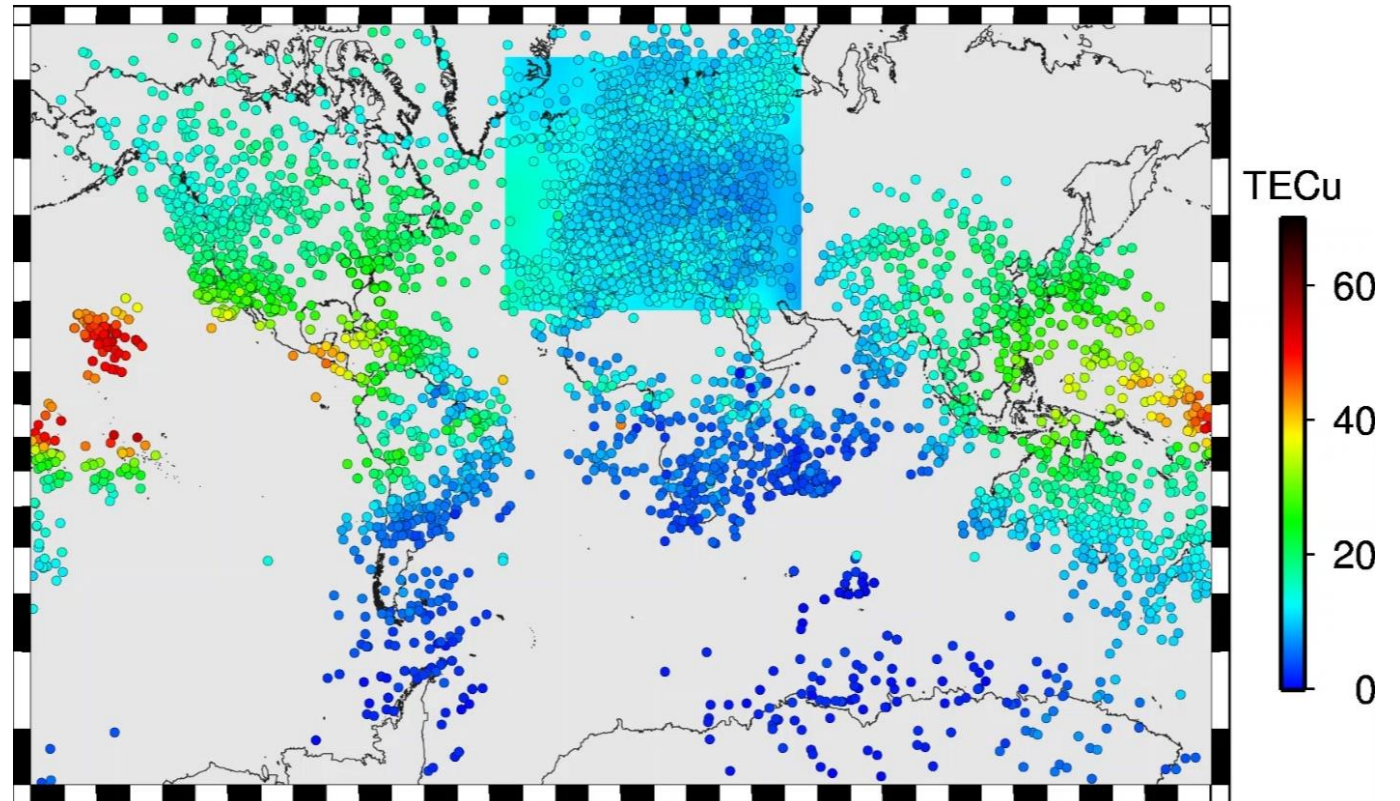
18th March 2015



March 17, 2015 - Onset 03:30 UTC  
Dst = -223 nT – Geom. Storm (Kp=7)

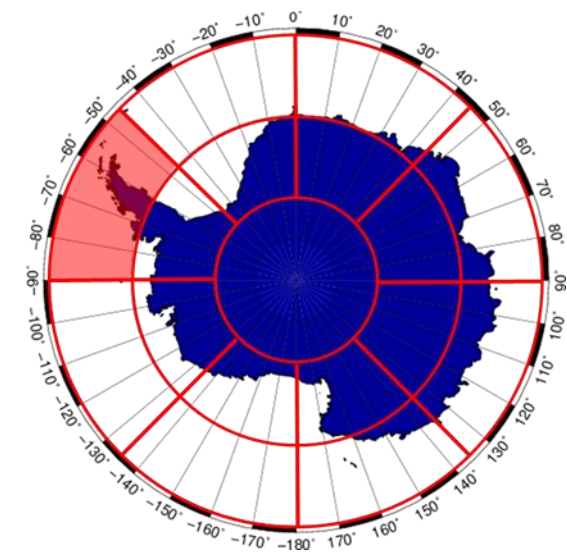
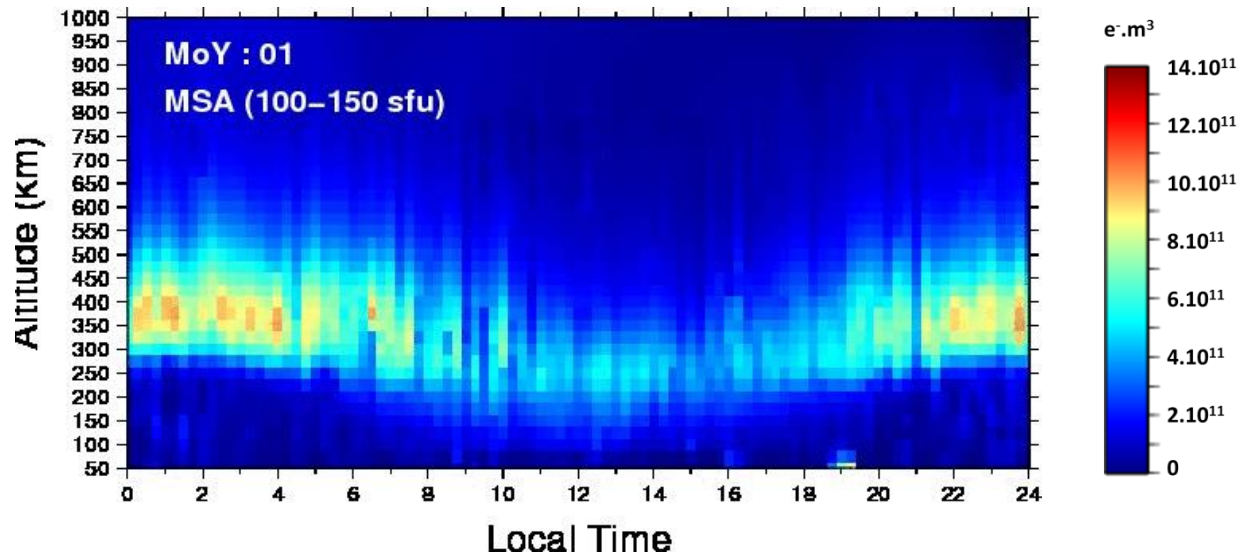
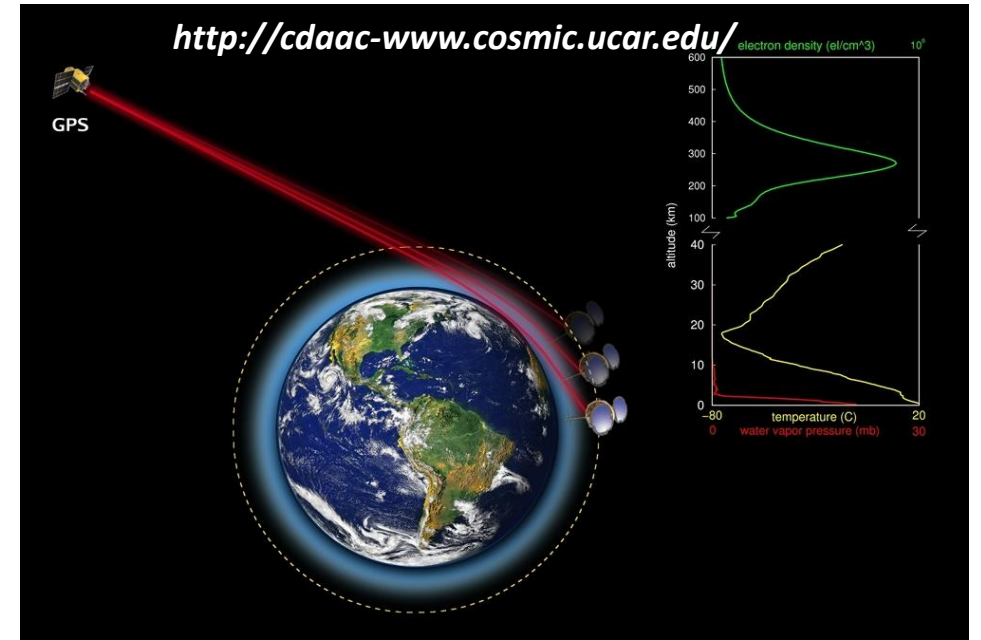
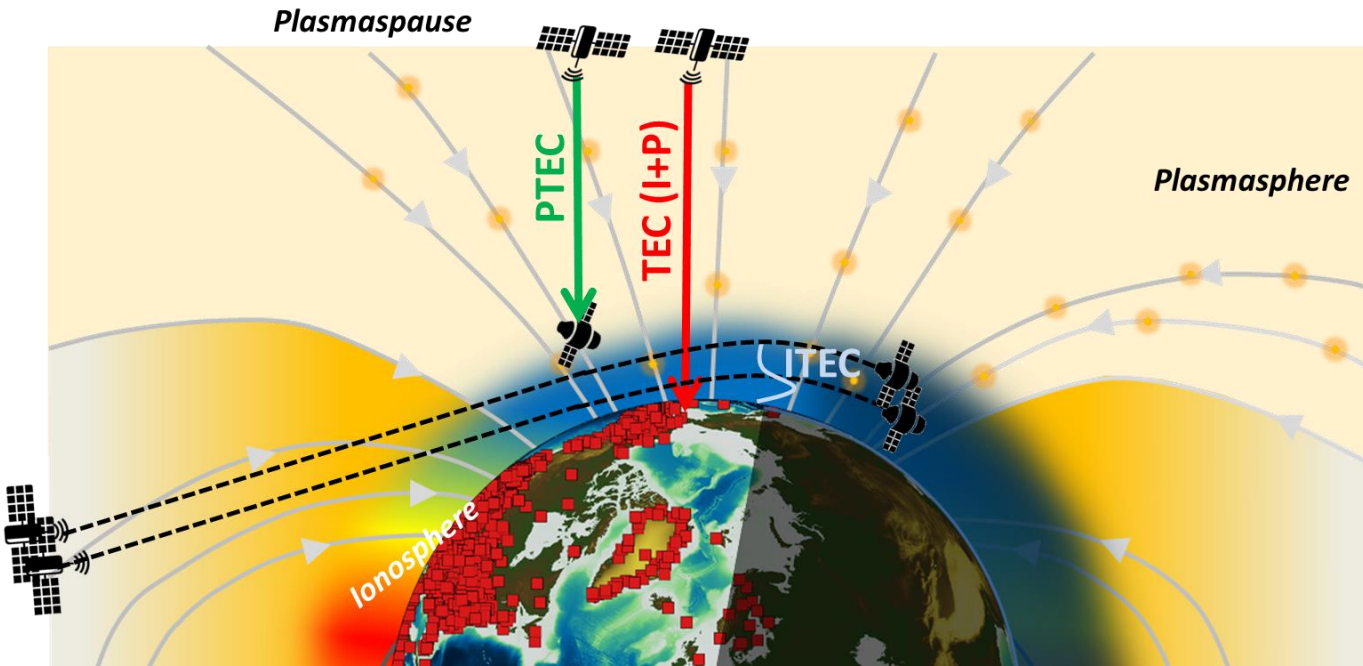
## 2. TEC at IPPs

- **Daily European TEC Maps**  
*enlarged zone, 5min, M-GNSS based, ~380 EPN stations, (on-going, archives up to 2022 available)*
- **Global Daily TEC at IPP**  
*~650 stations IGS+EPN networks  
GPS+Galileo+GLONASS,*



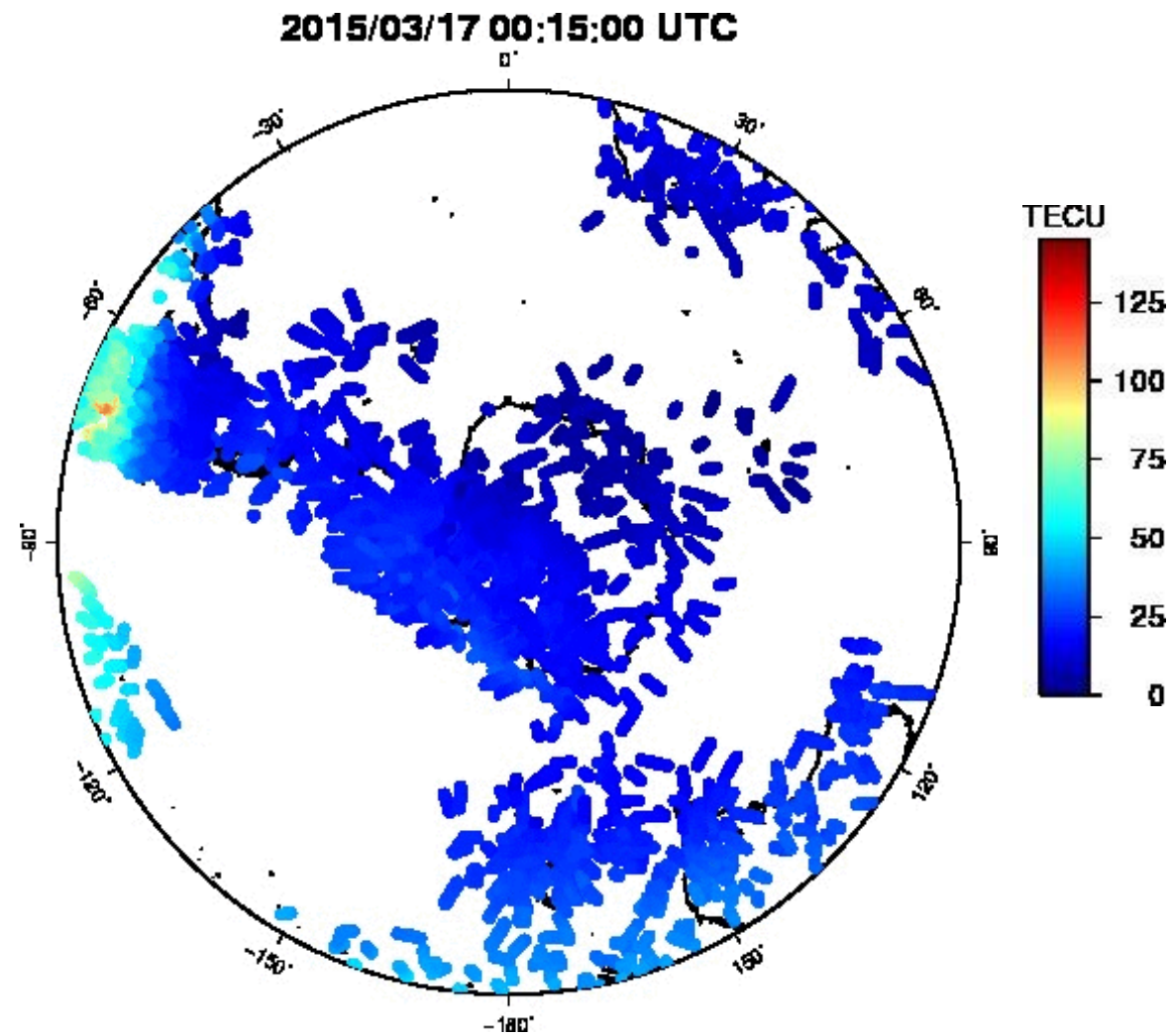
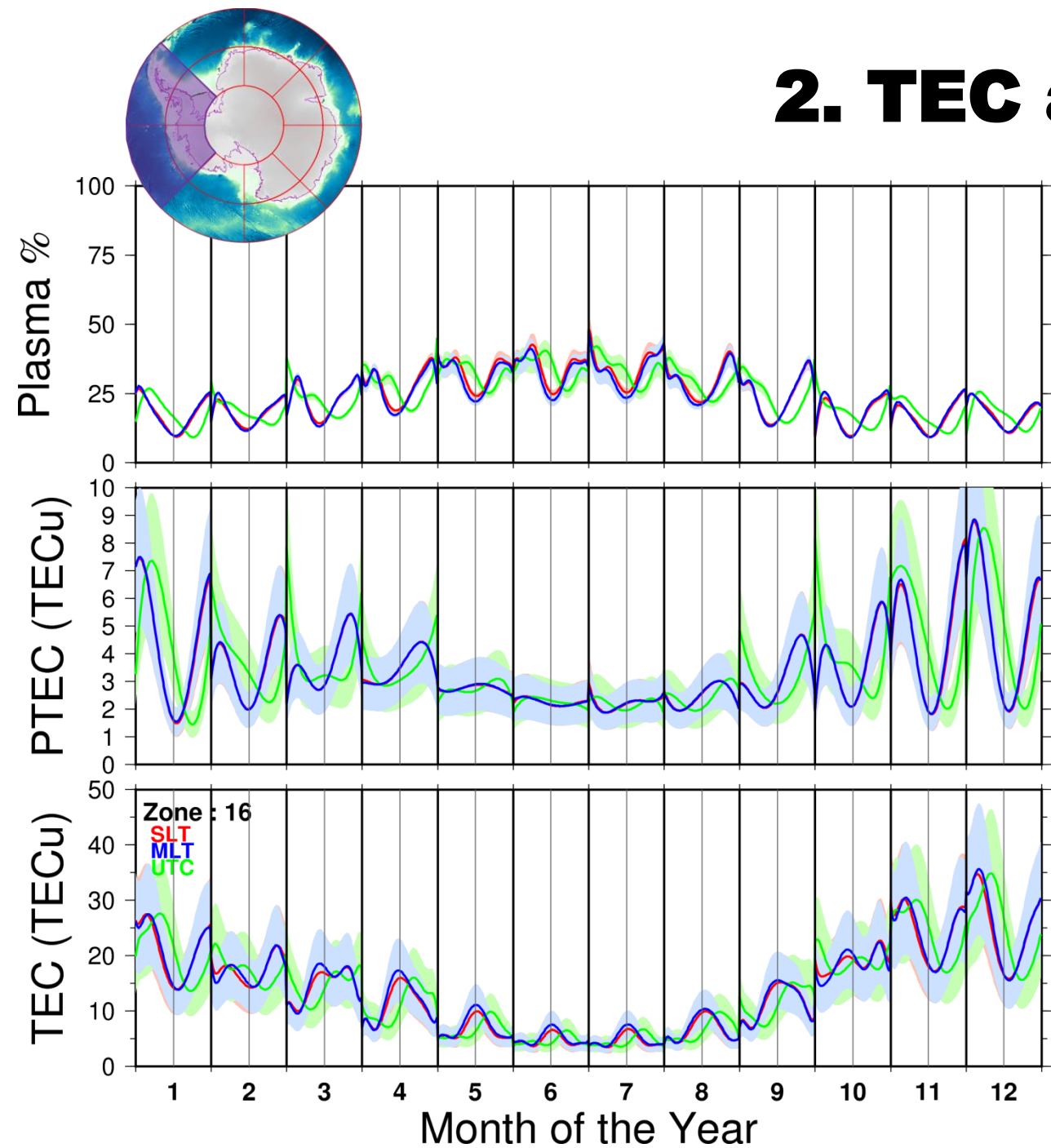
Ipp Total : 9172 Ipp Interp : 5781

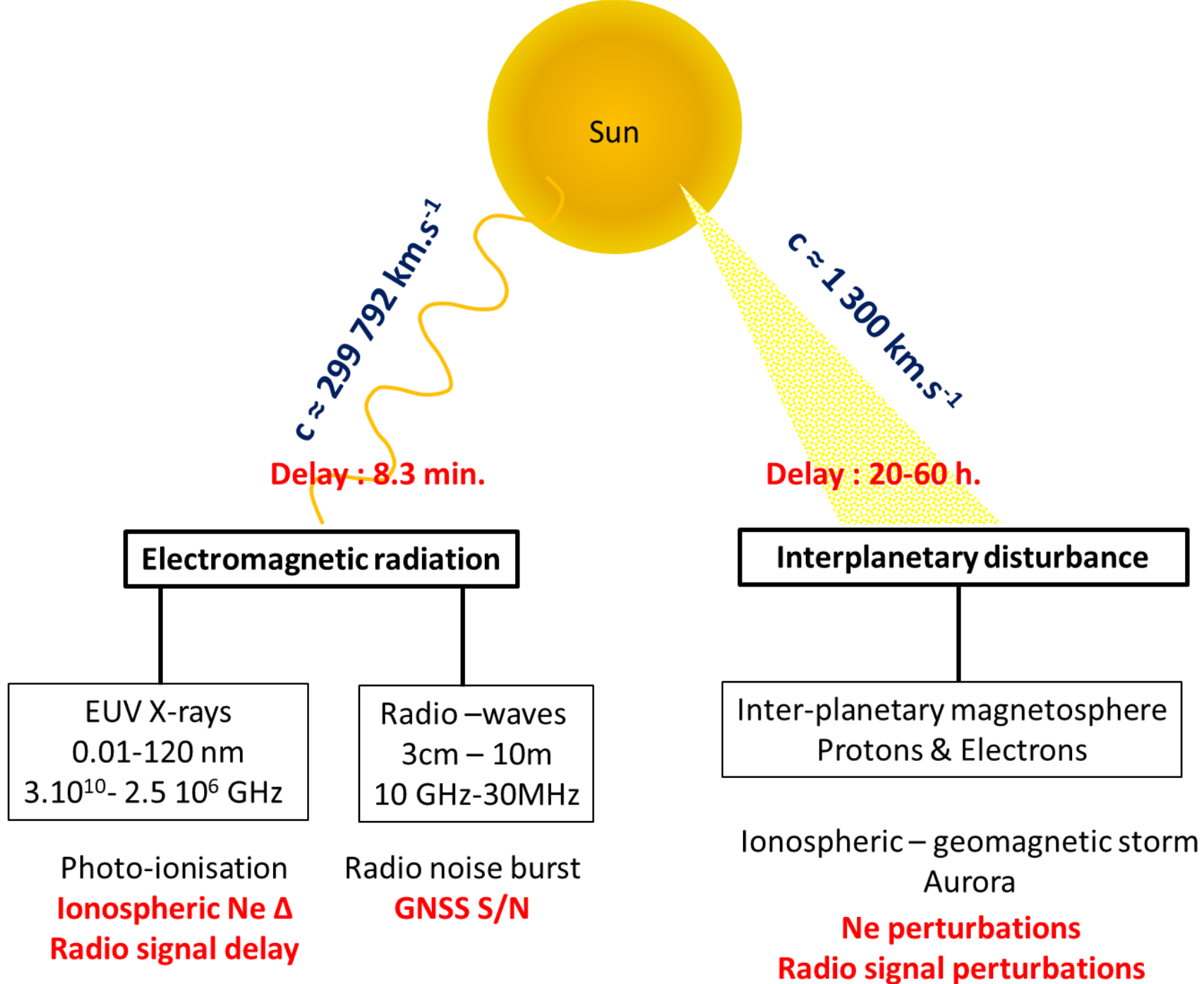
## 2. TEC at IPPs

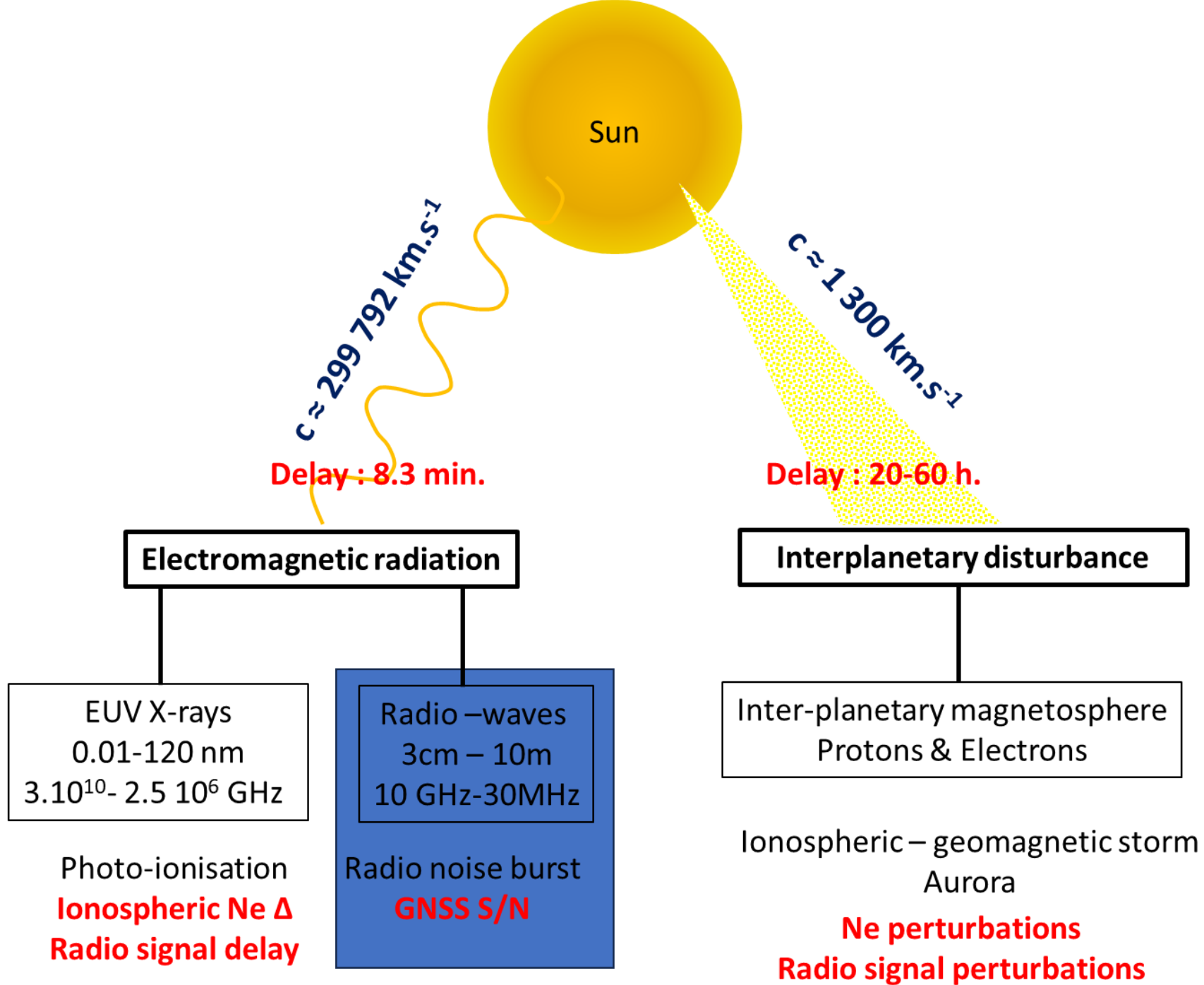




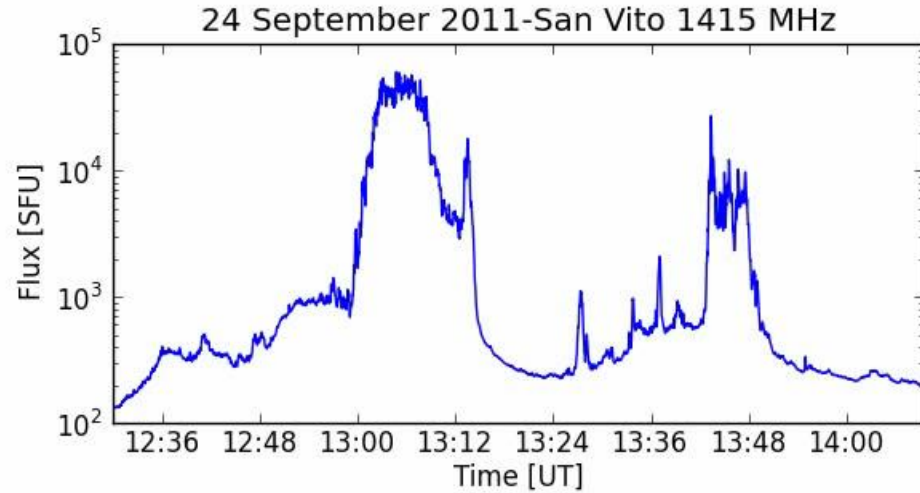
## 2. TEC at IPPs





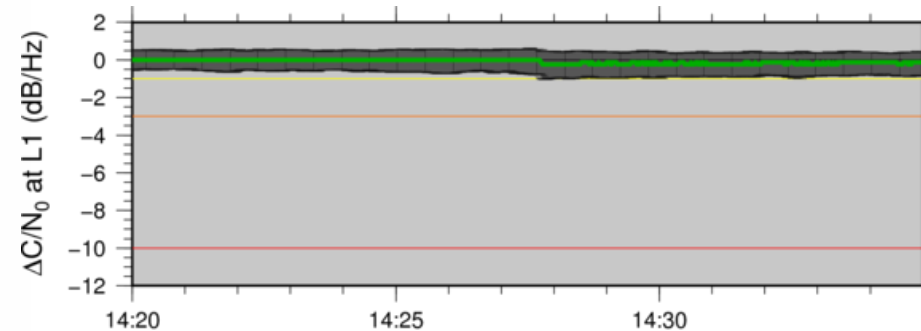
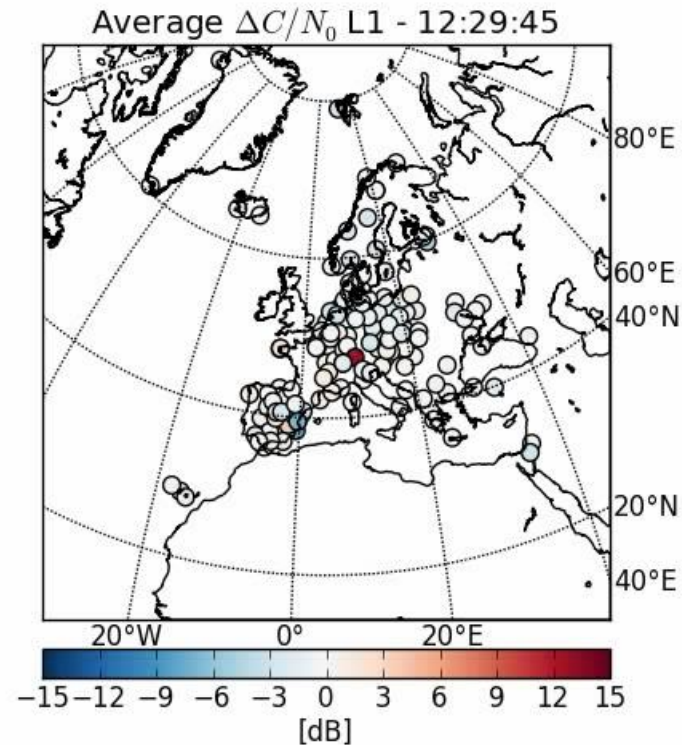


# 3. Solar Radio Burst and GNSS

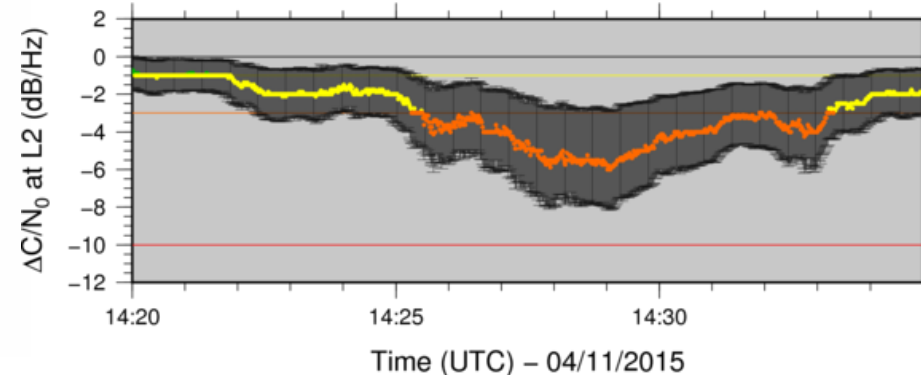


Nowcast SRB impacting the GNSS applications.

The warning system presented here is **operational since 2015 in near-real time** to detect SRB at the GNSS frequency bands over Europe.

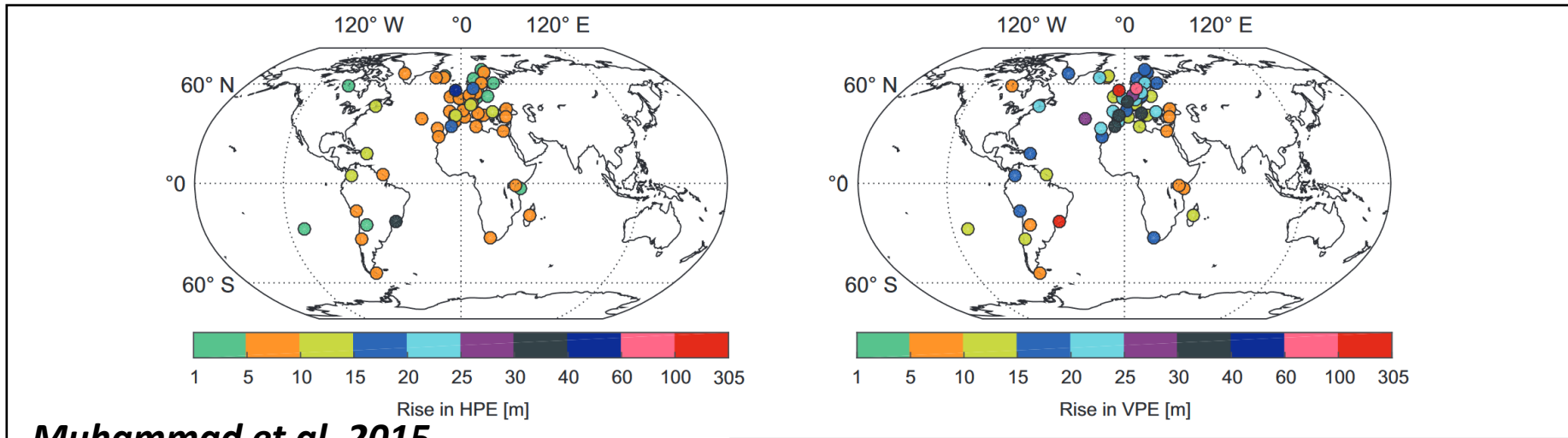


- *quiet*
- *moderate* : SRB detected but should not impact GNSS applications,
- *strong* : potential impact on GNSS applications,
- *severe* : potential failure of the GNSS receivers.



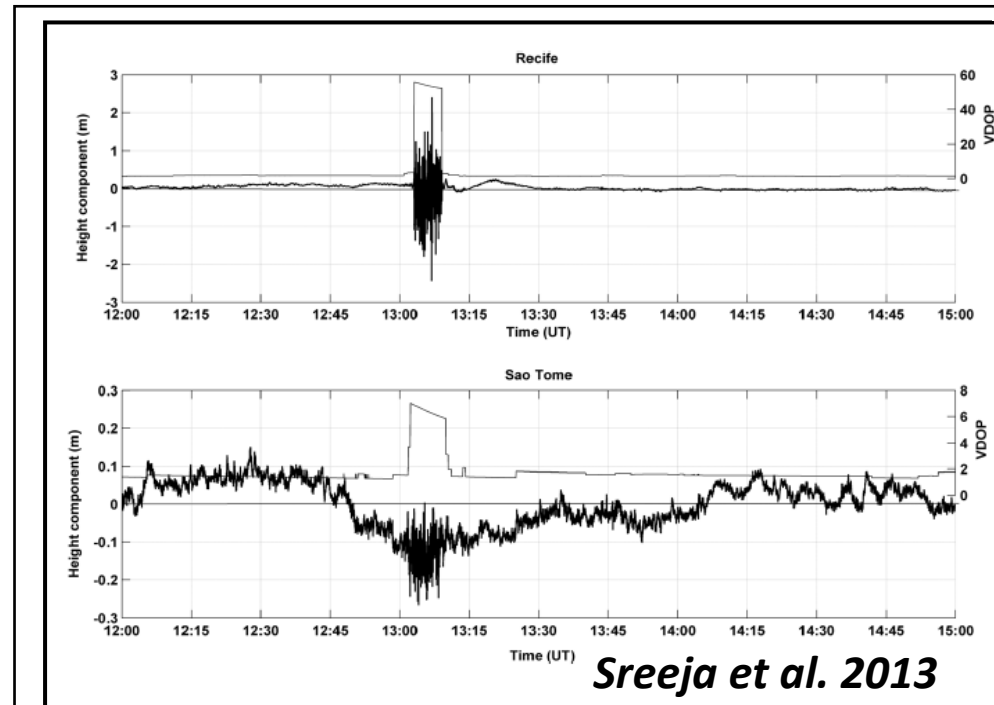
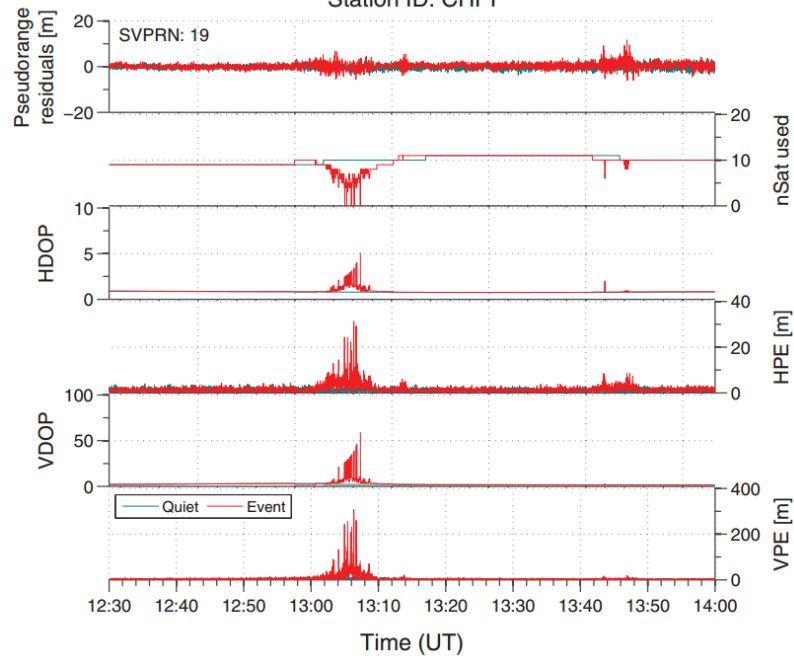
[iono@gnss.be](mailto:iono@gnss.be)

# 3.SRB impact on GNSS applications



**Muhammad et al. 2015**

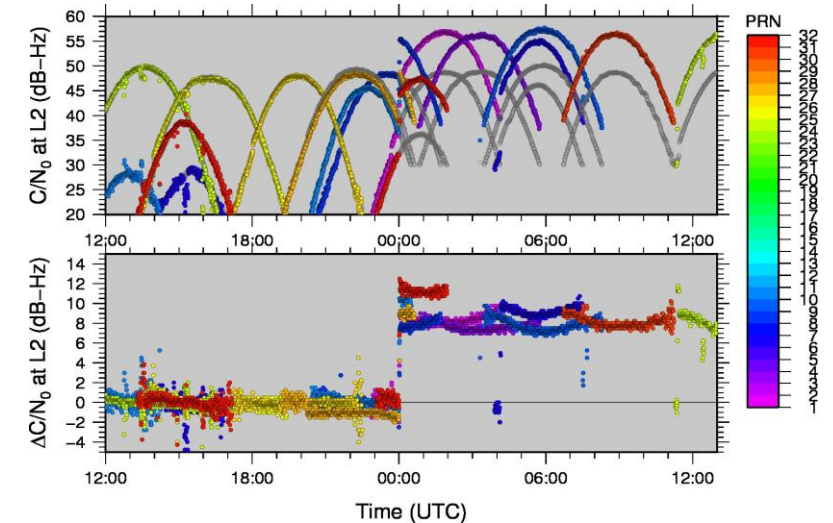
Station ID: CHPI



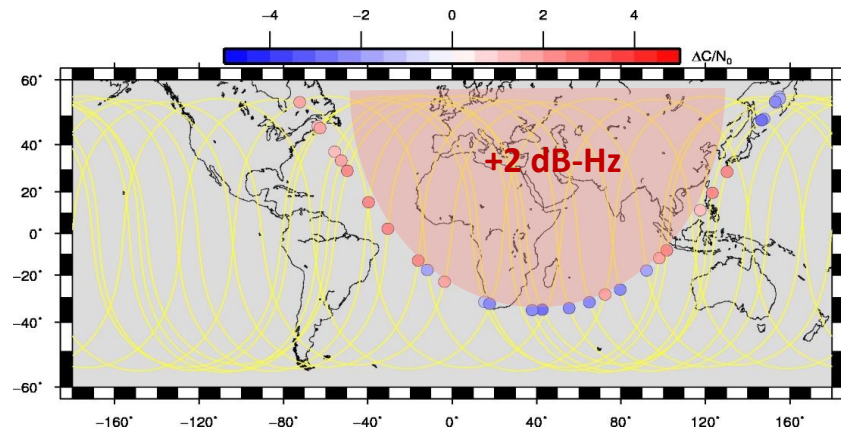
# 4. GPS Flex Power Campaigns

Since 2017, we identified several flex power campaigns:

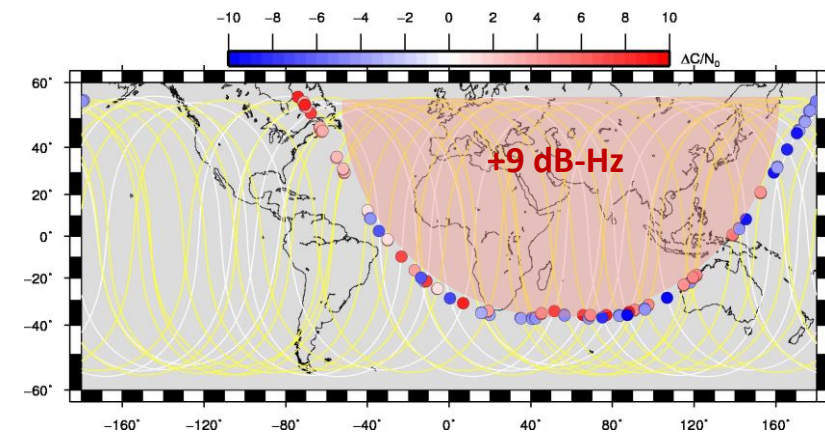
Starting Date	Ending Date	Zone	Satellites	Signal	$\Delta C/N_0$
Long-Term Campaigns					
27 <sup>th</sup> Jan. 2017 (Figure 12)	14 <sup>th</sup> Feb. 2020	Eu-Afr-As	Block IIF (G10 and G32 excluded)	L1 C/A (S1) L2 P(Y) (S2)	+2 dB-Hz +1 dB-Hz
<a href="#">14<sup>th</sup> Feb. 2020</a> (Figure 11, 13)	On-going	Eu-Afr-As	IIR-M and IIF	L1 C/A (S1) L2 P(Y) (S2)	-2 dB-Hz +9 dB-Hz
Short-Term Campaigns					
<a href="#">13<sup>th</sup> Apr. 2018</a> (Figure 10) <a href="#">20<sup>th</sup> Jun. 2019</a>	17 <sup>th</sup> Apr. 2018 21 <sup>st</sup> Jun. 2019	Global	Block IIF and IIR-M	L1 C/A (S1) L2 P(Y) (S2)	-1.5 dB-Hz +6 dB-Hz
<a href="#">6<sup>th</sup> Apr. 2020</a>	7 <sup>th</sup> Apr. 2020		G17, G31 (IIR-M)	L2 P(Y) (S2)	-10 dB-Hz



Flex power of the 14<sup>th</sup> Feb. 2020. Top plot:  $C/N_0$  observations from BRUX of the block IIF and IIR-M satellites (one colour per satellite) and their expected behaviour (in grey). Bottom plot: estimated  $\Delta C/N_0$  w.r.t. to the previous days



$C/N_0$  variations of L1 C/A signals along the orbit of the Block IIF satellites using the IGS. It highlights the satellite locations of the flex power activation and deactivation on a typical day between the 27<sup>th</sup> Jan. 2017 and 14<sup>th</sup> of Feb. 2020



$C/N_0$  variations of L2 P(Y) signals along the orbit of the Block IIF and IIR-M satellites using the IGS on a typical day since the 14<sup>th</sup> of Feb. 2020.

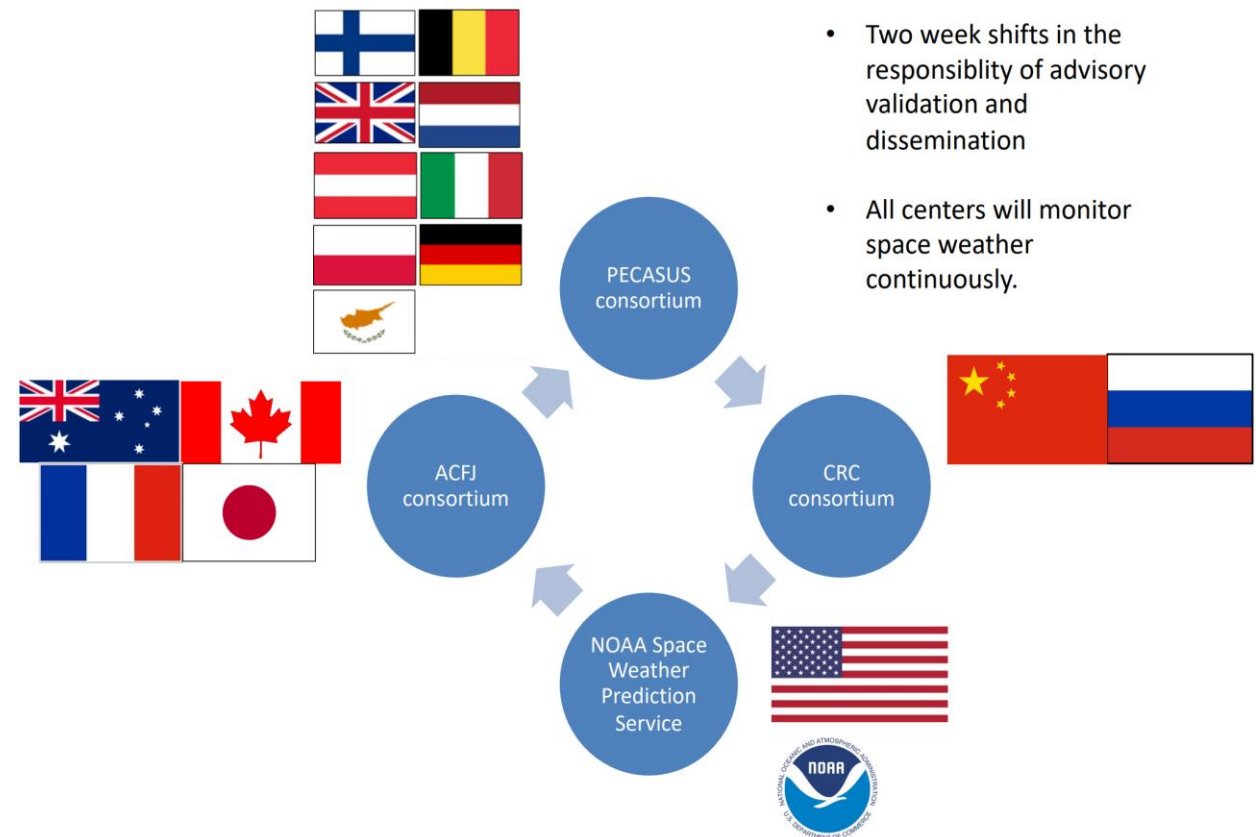
# SWX serviced for Aviation STCE as part of PECASUS consortium



- global aviation space weather network, operations **launched Nov 7th 2019**
- a new 24/7 service launched to provide real-time and worldwide space weather updates for commercial and general aviation



## Four global space weather centers












- Two week shifts in the responsibility of advisory validation and dissemination
- All centers will monitor space weather continuously.

# NRT Event Monitoring and Alerting

## PECASUS DASHBOARD

PECASUS DUTY STATUS: On Duty Centre

GNSS	Moderate	Severe	Time UTC	Values	Status	Alert	Max-3h values	Max-3h status
<u>Amplitude Scintillation</u>	0.5	0.8	2022-09-08 07:10	0.25	QUIET		0.38	QUIET
<u>Phase Scintillation</u>	0.4	0.7	2022-09-08 07:10	0.13	QUIET		0.21	QUIET
<u>Vertical TEC</u>	125	175	2022-09-08 07:15	59.32	QUIET		75.35	QUIET
RADIATION	Moderate	Severe	Time UTC	Flags	Status	Alert	Max-3h flags	Max-3h status
<u>Effective Dose FL ≤ 460</u>	30	80	2022-09-08 07:10	0	QUIET		0	QUIET
<u>Effective Dose FL &gt; 460</u>	/	80	2022-09-08 07:10	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	2022-09-08 07:12	4.0	QUIET		4.0	QUIET
<u>Polar Cap Absorption (PCA)</u>	2	5	2022-09-08 07:15	0.15	QUIET		0.15	QUIET
<u>Shortwave Fadeout (SWF)</u>	x1.0	x10.0	2022-09-08 07:12	< M5 flare	QUIET		< M5 flare	QUIET
<u>Post-Storm Depression (PSD)</u>	30%	50%	2022-09-08 07:15	1	MODERATE		2	SEVERE





Available in the e-science centre:

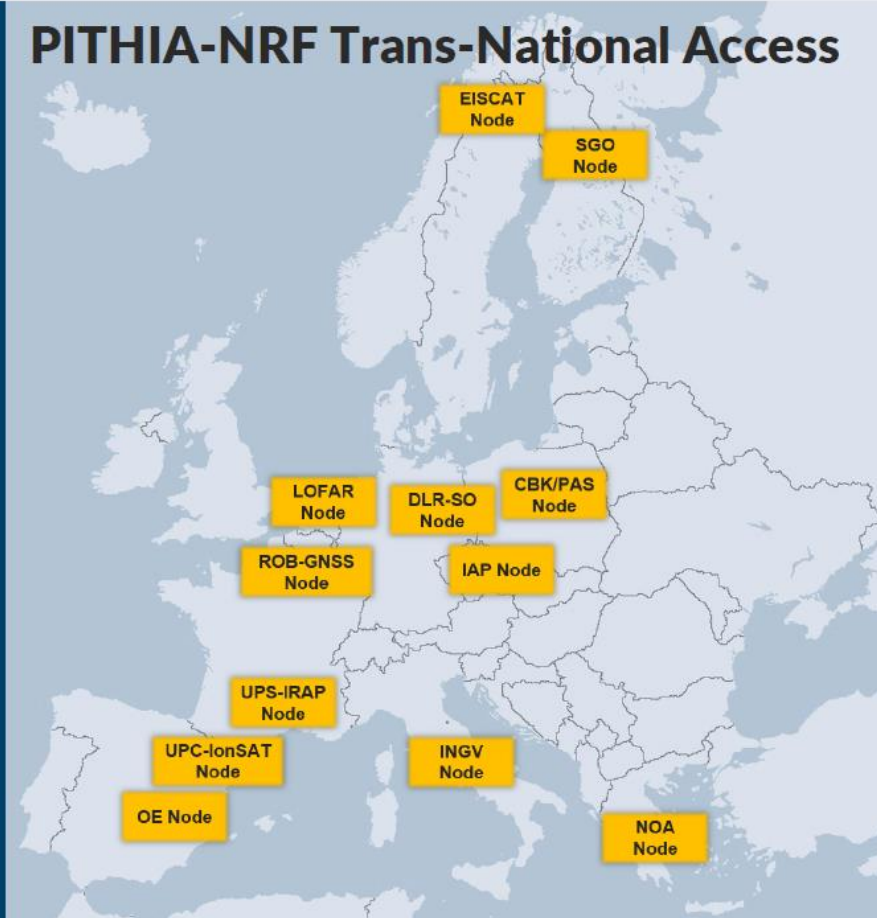
[ROB-IONO Near-Real Time European Ionospheric Maps](http://pithia.eu)

[\(pithia.eu\)](http://pithia.eu)

## A NETWORK OF RESEARCH FACILITIES

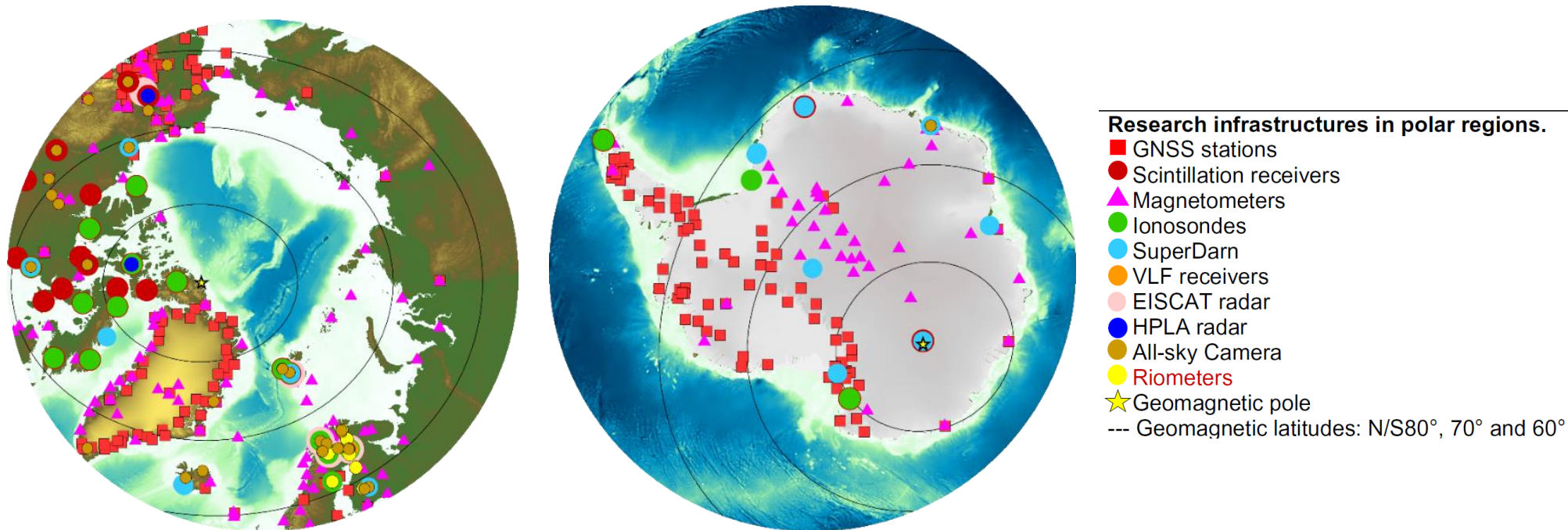
PITHIA-NRF has the ambition to become the European hub that will act as facilitator for coordinated observations, for data processing tools and modelling advances, and for software and data-products standardization; the project will advise on the transitioning of models from research to operations – R2O, providing e-Science supporting tools so that models can reach the desired accuracy and standards.

### PITHIA-NRF Trans-National Access



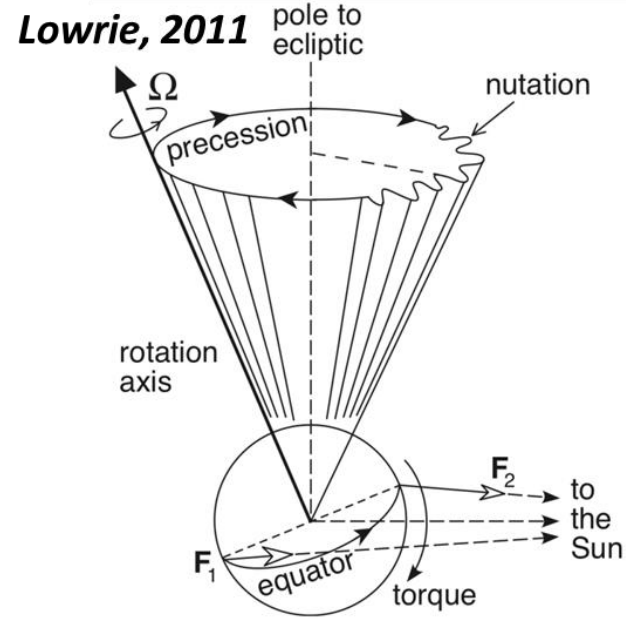
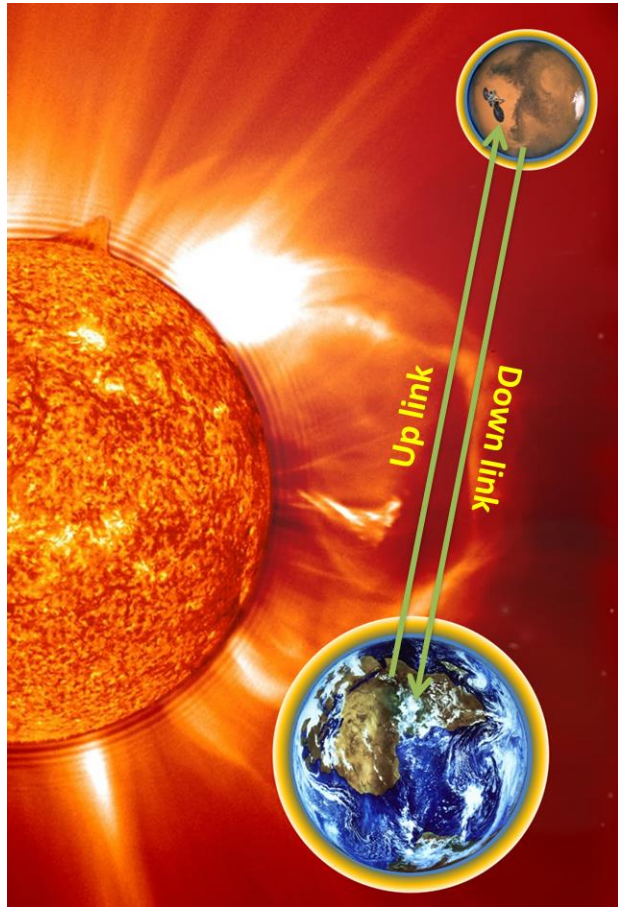
Lucilla Alfonsi (INGV, Italy), Wojciech Miloch ( University of Oslo, Norway), Nicolas Bergeot (ROB, Belgium) on behalf of the AGATA Planning Group Core Membership (30 international teams)

Website <https://www.scar.org/science/agata/home/>



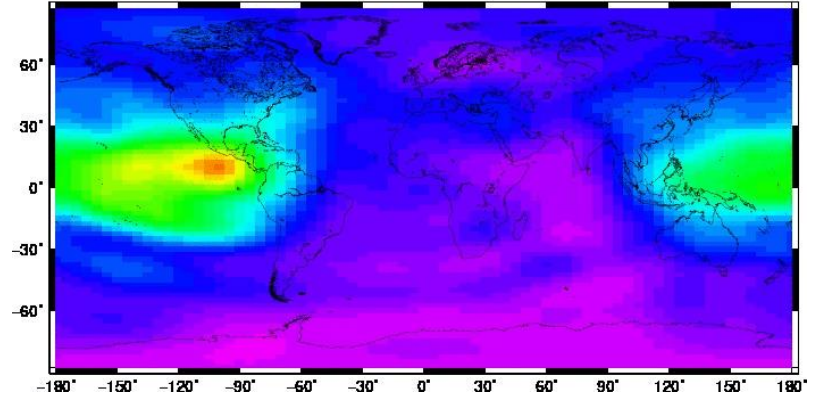
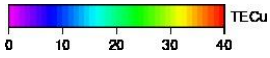
Alfonsi, L., Bergeot, N., Cilliers, P. et al., Review of Environmental Monitoring by Means of Radio Waves in the Polar Regions: From Atmosphere to Geospace, *Surv Geophys.* <https://doi.org/10.1007/s10712-022-09734-z>, 2022

# RISE: Rotation and Interior Structure Experiment.



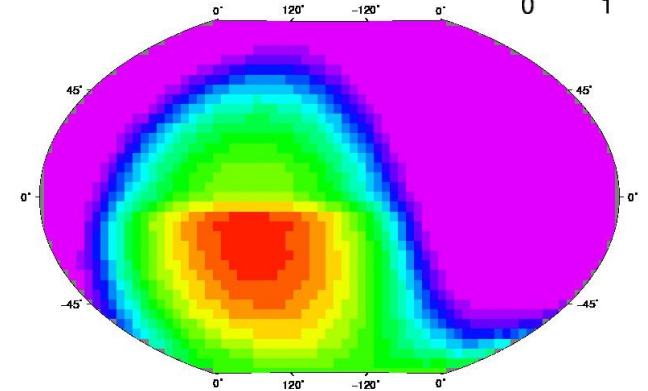
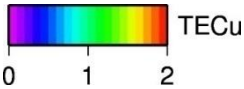
Earth vTEC

2019 Doy 126 00:00:00 UTC



Mars vTEC

2014 Doy 344 00:00:00 UTC



# JOB OFFER 2-years post-doc position in ionospheric research in Brussels (Royal Observatory of Belgium)



Detailed CV together with a motivation letter  
[p.defraigne@oma.be](mailto:p.defraigne@oma.be) with a copy to [n.bergeot@oma.be](mailto:n.bergeot@oma.be)  
at the latest on **November 5, 2023**