Identification and monitoring techniques of TIDs in the H2020 TechTIDE project

Anna Belehaki, David Altadill, Antoni Segarra, Estefania Blanch, José Miguel Juan, Dalia Buresova, Ivan Galkin, Haris Haralambous, Claudia Borries and **TechTIDE** consortium

- Traveling Ionospheric Disturbances (TIDs) are wave-like propagating irregularities that alter the electron density environment and play an important role spreading radio signals propagating through the ionosphere.
- TechTIDE project, funded by the European Commission Horizon 2020 research and innovation program, is establishing a pre-operational system to issue warnings of the occurrence of TIDs over the region extended from Europe to South Africa based on the reliability of a set of TID detection methodologies.
- This contribution aims at presenting the different methods and techniques of identification and tracking the activity of TIDs and their respective performance, that serve to feed the warning system of TechTIDE.

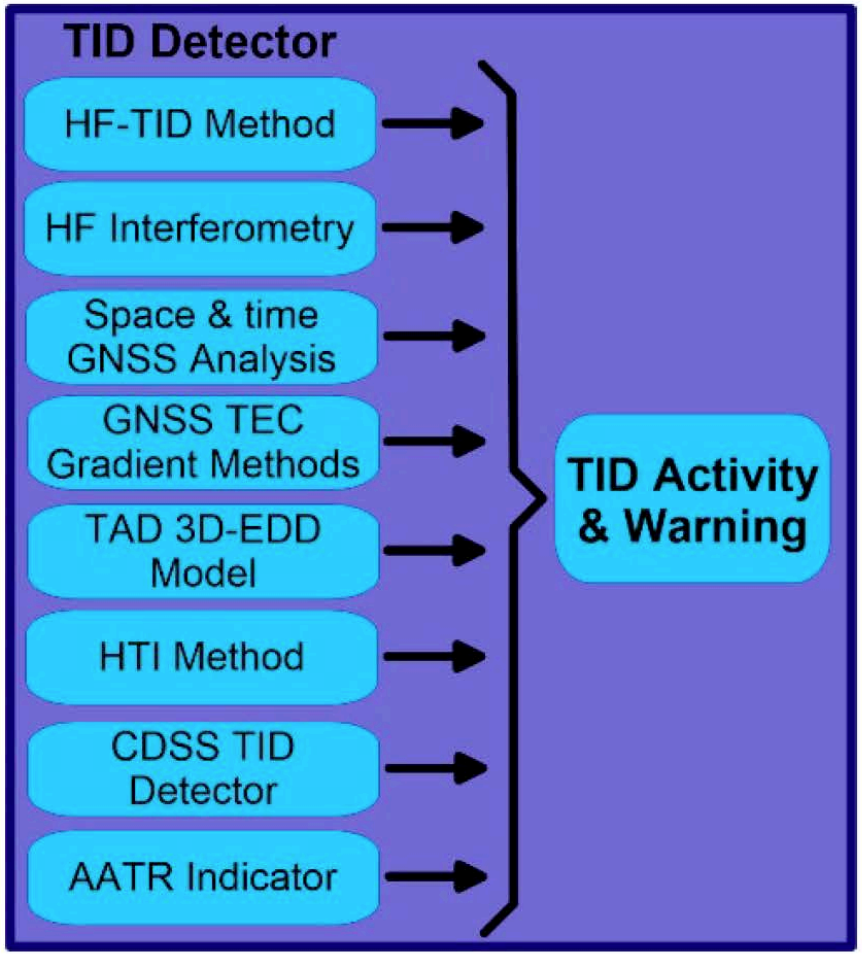
SUMMARY

- The main objective of the TechTIDE project (Warning and mitigation Technologies for Travelling Ionospheric Disturbances Effects) is the development of an identification and tracking system for Travelling Ionospheric Disturbances (TIDs) which will issue warnings of electron density perturbations over large world regions.
- The TechTIDE project has put in operation a real-time warning system that provides the results of complementary TID detection methodologies. The TechTIDE methodologies are able to detect in real time activity caused by both large-scale and medium-scale TIDs and to provide indicators of TID activity.
- TechTIDE methodologies are based on the exploitation of data collected in real time from Digisondes, Global Navigation Satellite System (GNSS) receivers and Continuous Doppler Sounding System (CDSS) networks.

Real-Time detection of TIDs

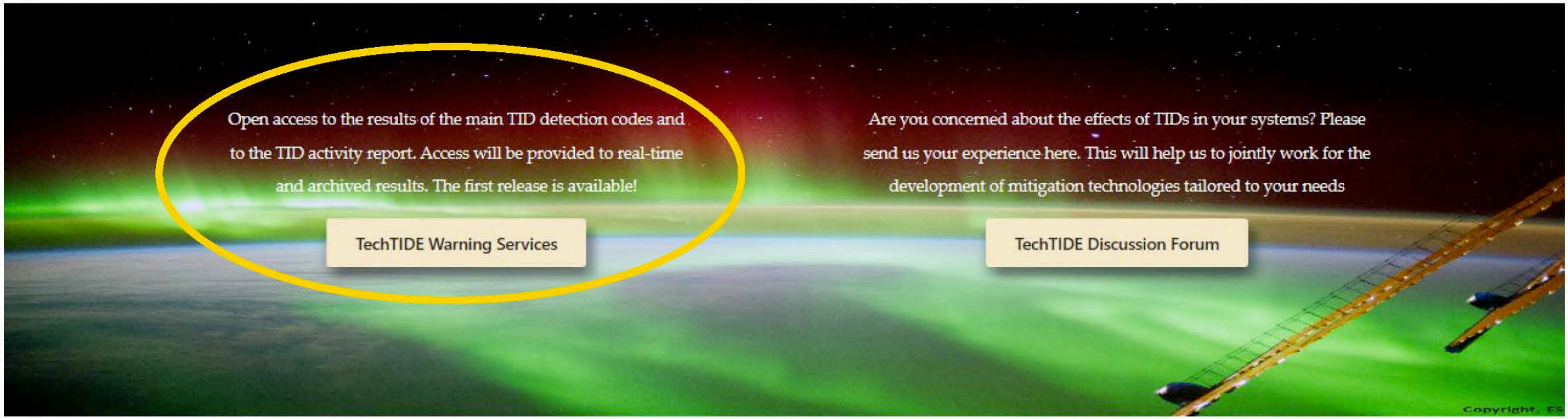
TID detection methods in TechTIDE

- HF-TID model.
- HF-INT method.
- Space & Time GNSS analysis.
- GNSS TEC Gradient method.
- TAD 3D-EDD method.
- HTI algorithm.
- CDSS method.
- AATR indicator.



TechTIDE Project

HOME | COMMUNITY | TID DETECTION | DISSEMINATION & COMMUNICATION | WIKI | USER LOGIN



Warning and Mitigation Technologies for Travelling Ionospheric Disturbances Effects — TechTIDE

Travelling Ionospheric Disturbances (TIDs) are plasma density fluctuations that propagate as waves through the ionosphere at a wide range of velocities and frequencies. TIDs constitute a threat for operational systems using predictable ionospheric characteristics as they can impose significant disturbances in the ambient

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TechTIDE Follow Project

TID detection methodologies

- **Detectors of LSTIDs:**
  - HF-TID (No TID / Uncertain / TID)
  - HF-INT (No TID / Uncertain / TID)
  - HTI (No TID / Uncertain / TID)
  - LSTID index: 1-D version TAD 3D-EDD (No TID / Uncertain / TID)
- **Detectors of MSTIDs**
  - CDSS MSTID (No TID / Uncertain / TID)
  - MSTID index: Space & Time GNSS Analysis (No TID / Uncertain / TID)
- **Ionospheric disturbance indicators**
  - AATR indicator (Low / Medium / Strong)
  - GNSS TEC Gradient (Low / Medium / Strong)
  - Background Ionospheric Activity (Negative / Median / Positive)

Detectors of LSTIDs

HF-TID method

- Detects perturbations in space from all possible sources (solar and lower atmosphere origin) and it is suitable for identification of both **MS** and **LS TIDs**.

INPUT	OUTPUT	PRODUCTS
Signal properties from Digisonde synchronized operation	TID velocity, amplitude, propagation direction at the signal reflection point between the stations	• European map indicating the velocity, amplitude and propagation direction at the reflection points between Digisondes operated in bistatic mode. • Report of TID characteristics extracted from the analysis of the raw data from the D2D operations, i.e TID propagation Doppler frequency, angle of arrival, and time-of-flight from Tx to Rx, both OI and VI sounding • Plots of amplitude, Doppler, azimuth within the last 45 minutes from the TID detection

Detectors of LSTIDs

HF-TID method

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```
# Traveling Ionospheric Disturbance TID Detection
#
#-id---- ReferenceTime---------- Ref.Loc(N,E,km)--- Amp,%- Period,min Prop.Azim(CW) Wavlen,km Confid Uncert.% Rx/Tx,distance,bearingCW-- RayPath,km OELCutoff,km An.win,min
  488987 2019-10-03T19:22:35.000Z  52.30  14.03  184   28.3       72.5         272.6      1281      0    100.0 JR055<--PQ052    517  170.5        687          628        145
  488984 2019-10-03T19:22:35.000Z  48.82  15.69  228   36.2      145.0         200.9      4192      0    100.0 SO148<--PQ052    305  -29.7        546          423        145
  488990 2019-10-03T19:27:35.000Z  52.30  14.03  409   12.7       67.5         122.7      1414    100      0.0 JR055<--PQ052    517  170.5       1065          628        135
  488989 2019-10-03T19:27:35.000Z  48.82  15.69  449    7.8       65.0         269.5       144    100      0.0 SO148<--PQ052    305  -29.7        987          423         65
  488995 2019-10-03T19:32:35.000Z  52.30  14.03  182   61.0      155.0         278.0      1661      0    100.0 JR055<--PQ052    517  170.5        686          628        155
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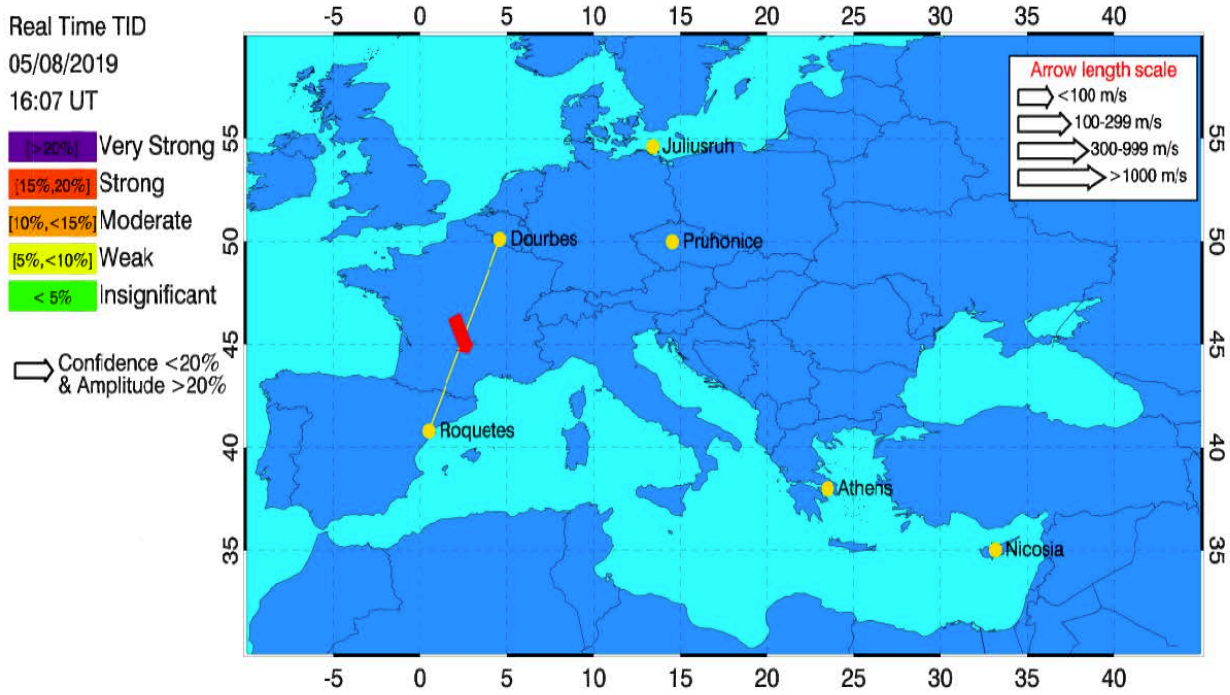

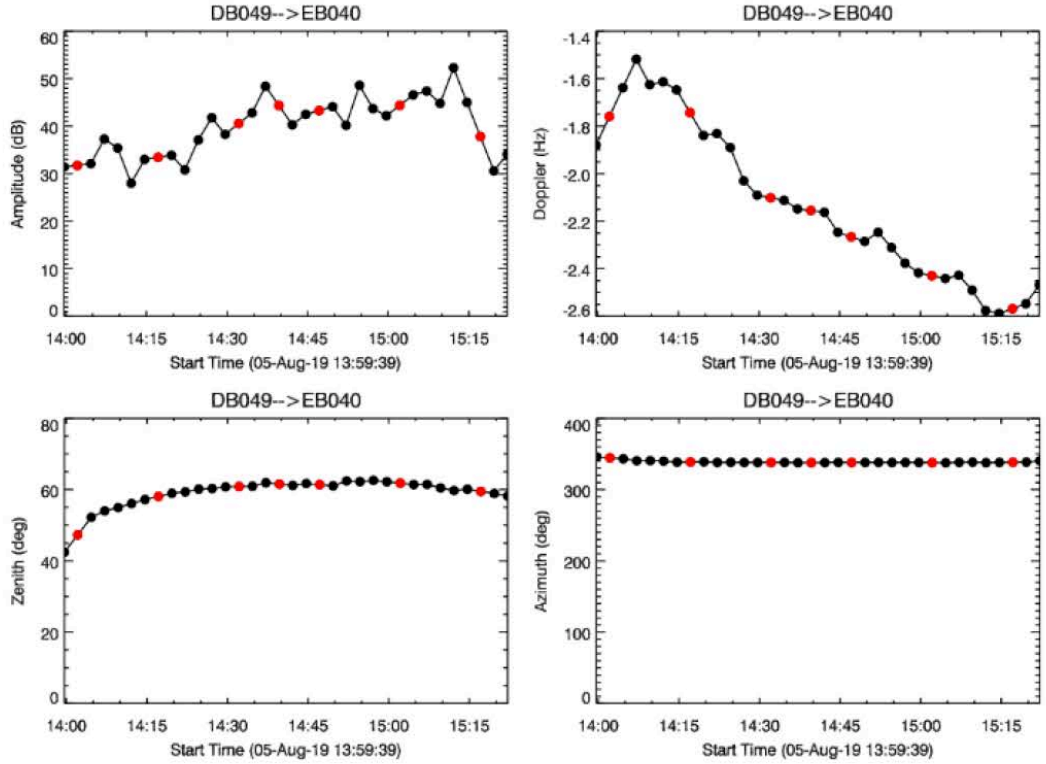

Detectors of LSTIDs

HF-INT method

- Identifies **LSTIDs** for the monostatic measurements of a given network of HF sensors (i.e. ionosondes) dense enough, separated less that 1000 km.

INPUT	OUTPUT	PRODUCTS
Ionospheric characteristics from VI and OI soundings	2D TID vector velocity, amplitude and period	• TID log files with characteristics extracted from the analysis of the raw data. • Map indicating the velocity and propagation direction of TIDs over measuring sites. • Dominant period, Amplitude and Horizontal Vector velocity of detected LSTID over the region of interest and over each Digisonde location • Daily plots of TID variability, Period and Azimuth

Detectors of LSTIDs

HF-INT method

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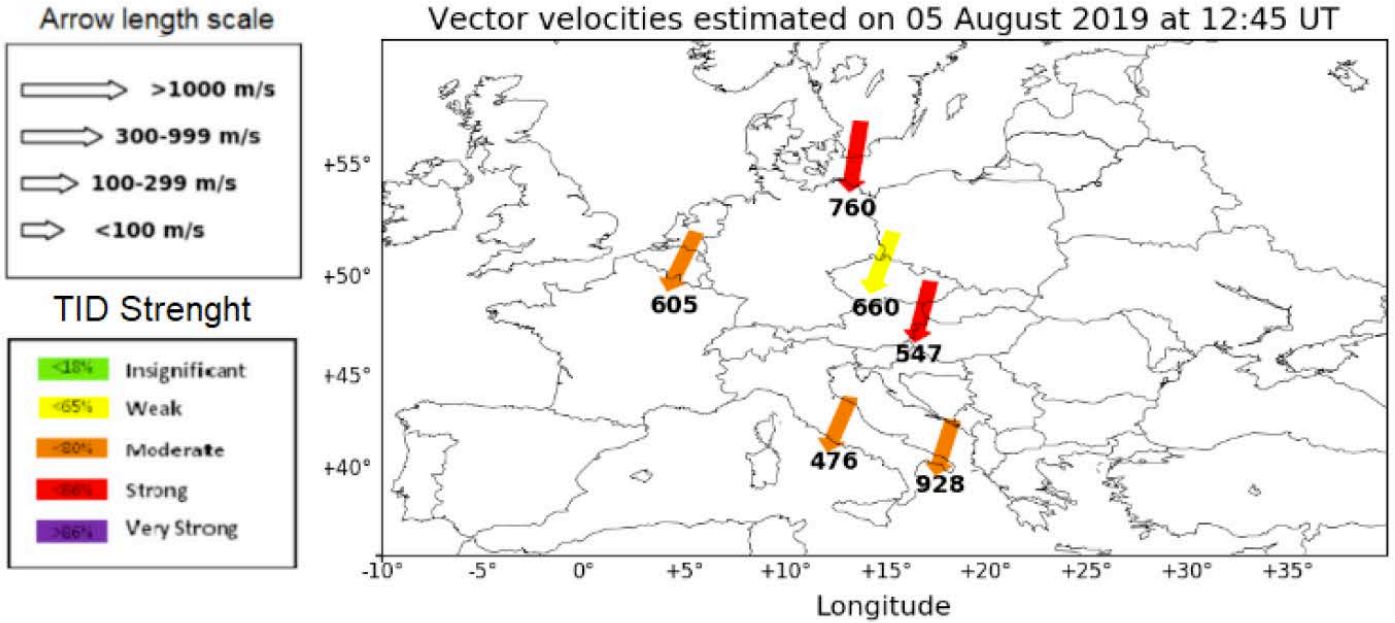
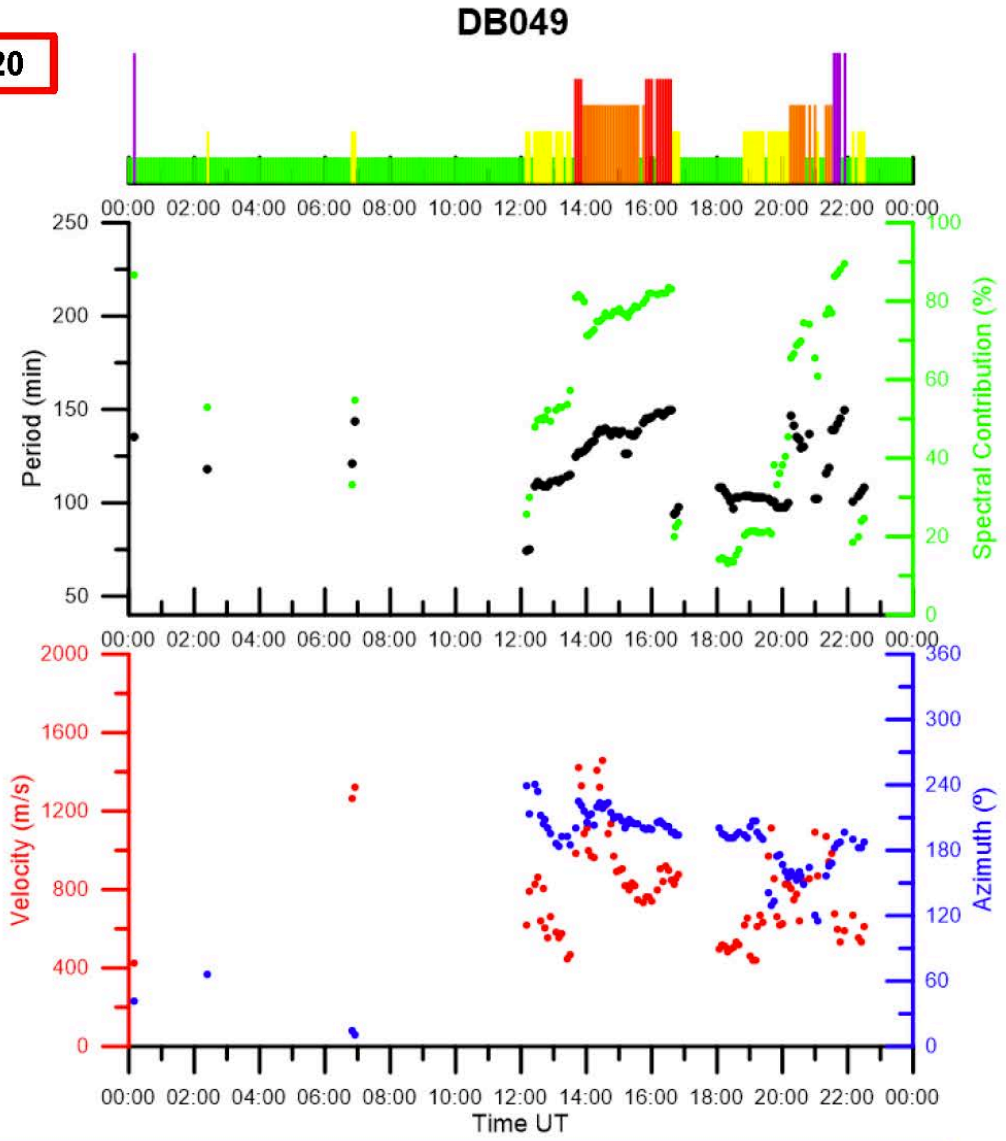
OE_HFI_201910020910.log

TechTIDE project Ebre Observatory HF-Interferometry

NT	ST	FL	STA	DATE&TIME	ALATI	ALONG	NW	IW	PERIO	POWER	AMPLI	SPCONT	VEL	AZI	TrL	IQ	IR
1	2	1	DB049	201910020910	50.10	4.60	2	1	145	76.8	0.29	81.8	271	246	4	80	50
1	7	1	RL052	201910020910	51.50	-0.60	2	1	122	58.4	0.83	73.1	396	270	3	80	50
1	9	1	SO148	201910020910	47.63	16.72	2	1	145	92.5	0.33	77.3	399	257	3	80	50





Detectors of LSTIDs

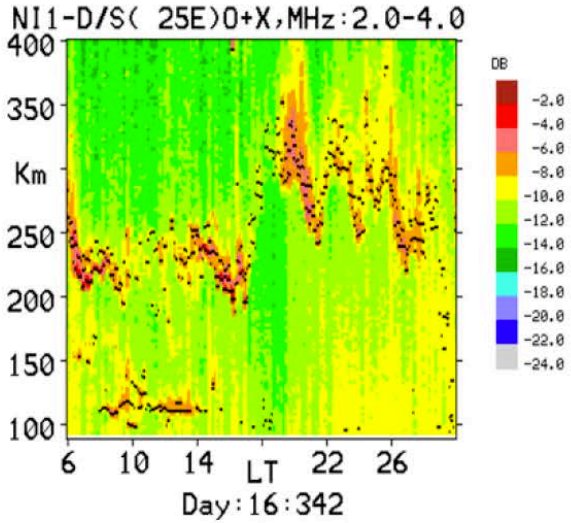
HTI method

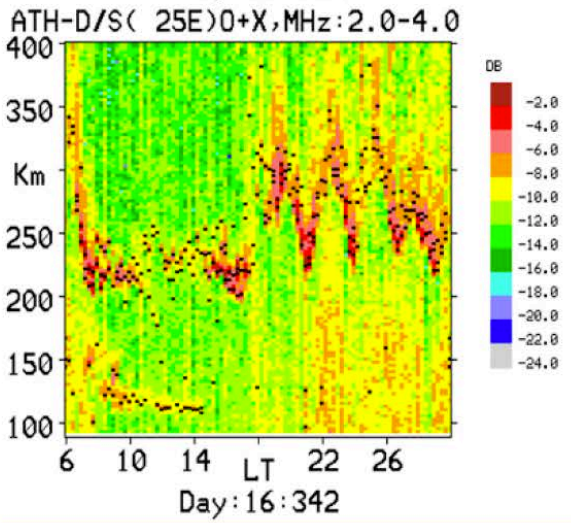
- Reconstructs daily plots of the **vertical movement** of the ionospheric layers over measuring sites and detect oscillations from all possible sources.

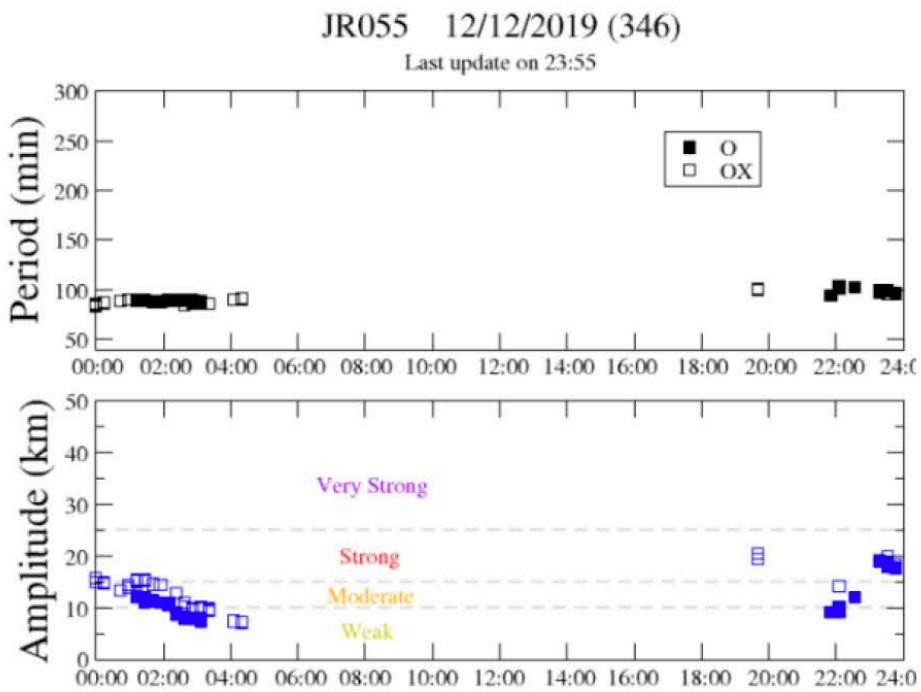
INPUT	OUTPUT	PRODUCTS
Raw vertical ionogram binary data from single station	Reconstructed daily variability of F region virtual height	• F region virtual height variation above a given Digisonde station. • Dominant period, Amplitude and Strength of TID. • Daily plots F region virtual height variability.

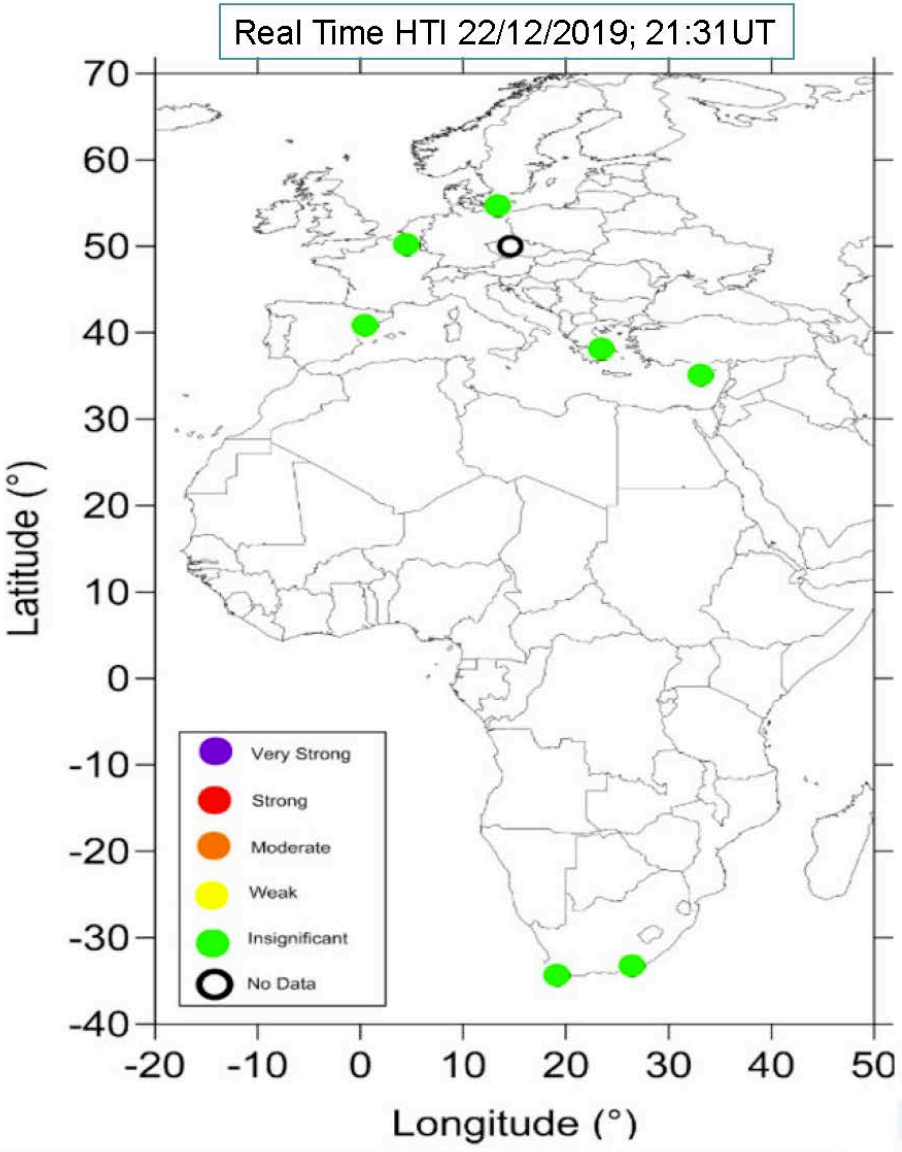
Detectors of LSTIDs

HTI method









Detectors of LSTIDs

LSTIDx: 1-D version TAD 3D-EDD

- Provides **LSTIDx index** as the absolute values of the residuals of the electron density at given altitude after detrending the 30-day running median.

INPUT	OUTPUT	PRODUCTS
Ionospheric characteristics at the hmF2 altitude and TEC maps	Analytical function of the electron density distribution with altitude from 90 km to 22000 km	• Residuals of the detrended electron density from the median values, calculated with the TaD model for heights ranging from 150 up to 900 km with 50km step. • The results are provided over specific European Digisondes performing VI sounding at least every 5min. • Map of the height of the maximum electron density disturbance.

Detectors of LSTIDs

LSTIDx: 1-D version TAD 3D-EDD

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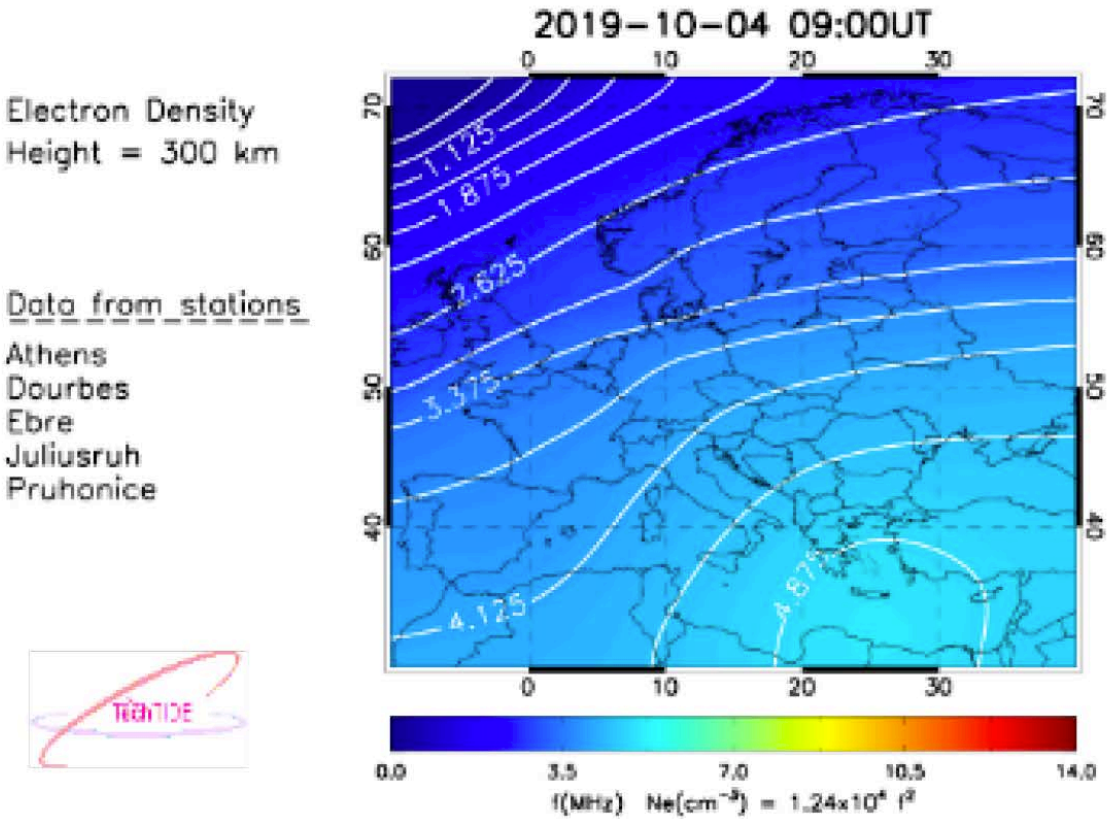

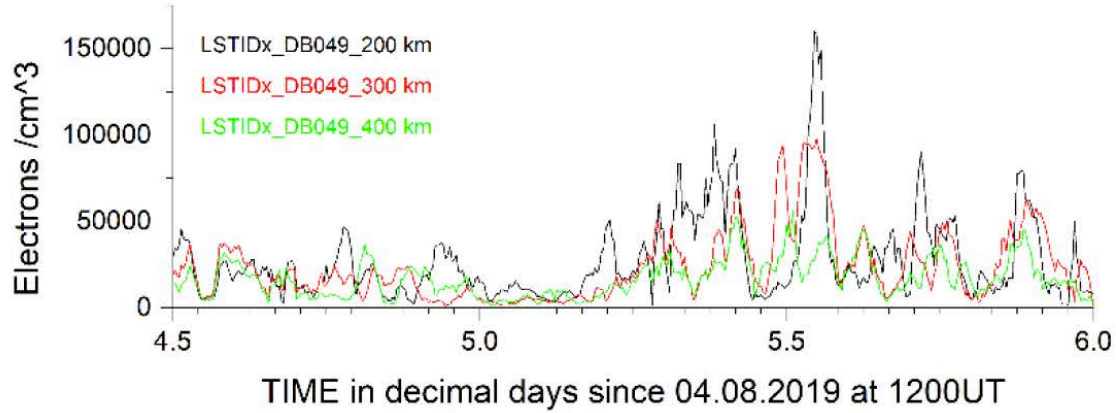

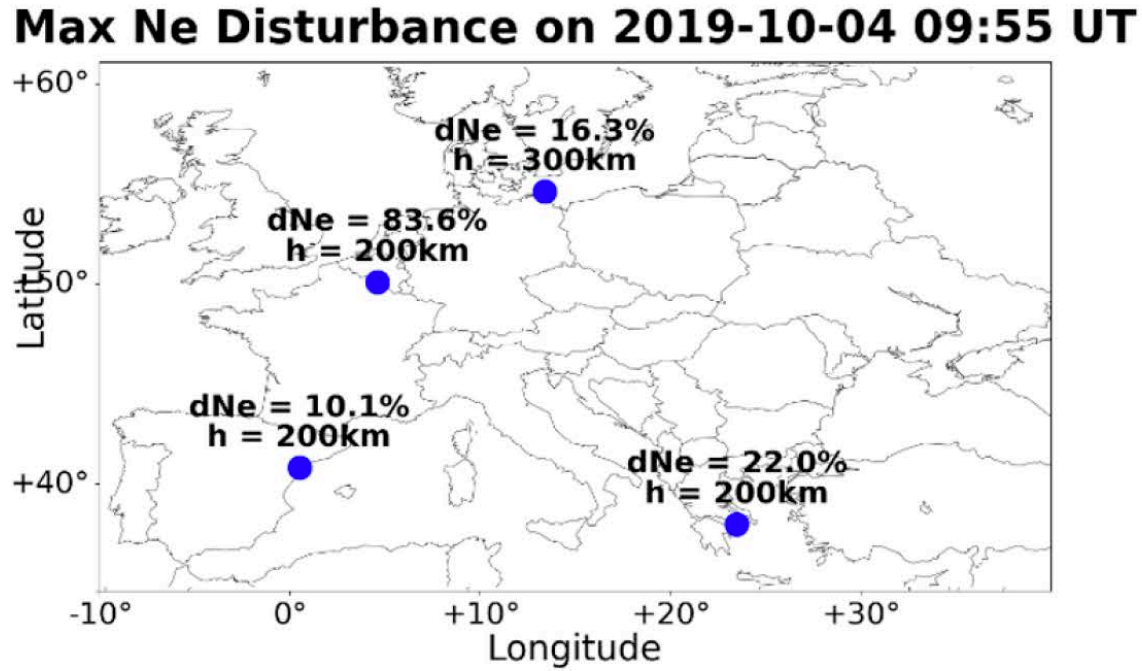

Detectors of MSTIDs

CDSS MSTID

- Provides **multipoint CDSS** of different frequencies in regions with at least three sounding paths (transmitter – receiver pairs).

INPUT	OUTPUT	PRODUCTS
CDSS reflected signals, ionospheric characteristics and irregularities	Doppler shift. Fluctuations associated to the TIDs and estimation of the propagation parameters (direction, velocity and amplitude)	• Period, Amplitude of Doppler measurements. • Observed horizontal velocities and azimuths of MSTIDs.

Detectors of MSTIDs

CDSS MSTID

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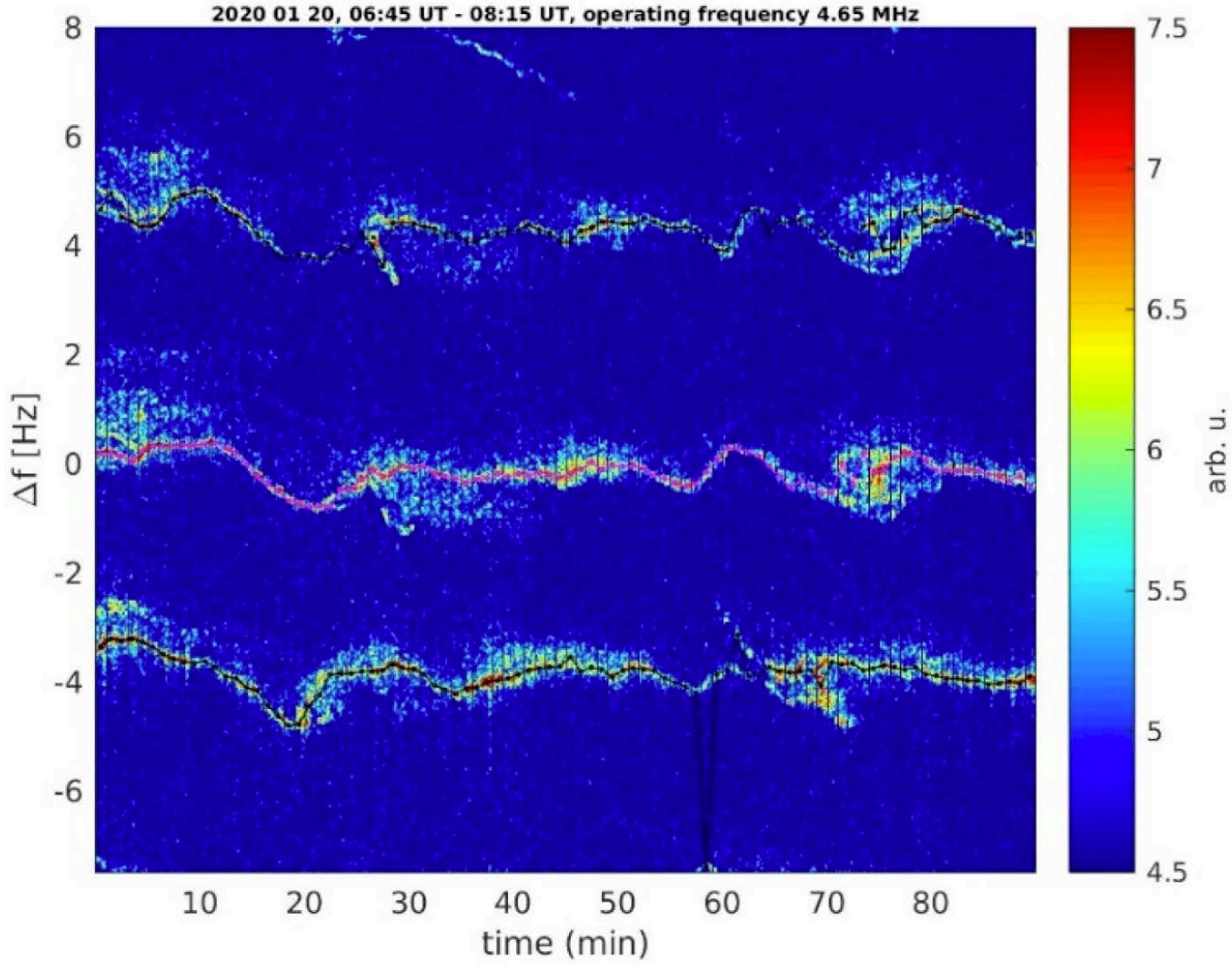


Detectors of MSTIDs

Space & Time GNSS Analysis

- Provides **MSTID index** detrending GNSS data of a single receiver and estimates the propagation parameters for a network of receivers.

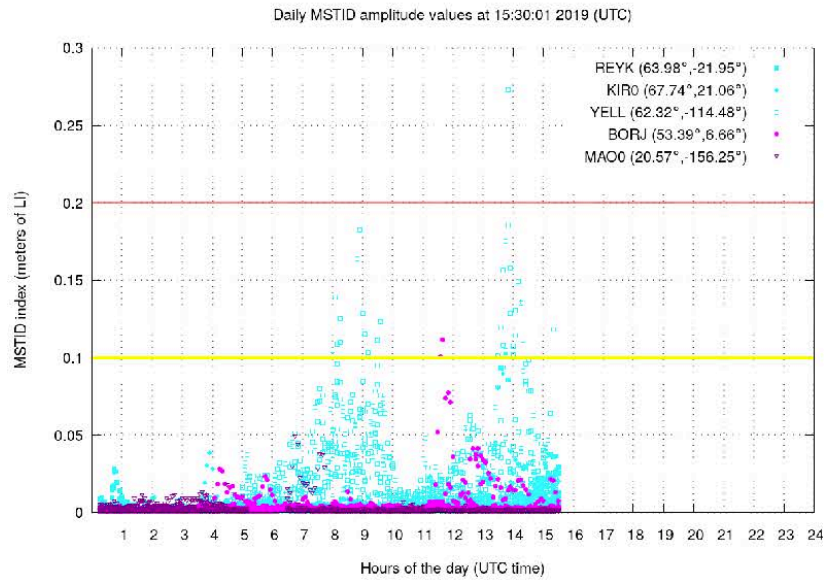
INPUT	OUTPUT	PRODUCTS
GNSS TEC from single receivers over a region	Fluctuations associated to the MSTIDs and estimation of the propagation parameters (direction, velocity and amplitude).	• MSTID index calculated at each GNSS contributing receiver. • Daily plots of MSTIDx • Maps of MSTIDx • Estimated horizontal velocities and azimuths of MSTIDs.

Detectors of MSTIDs

Space & Time GNSS Analysis

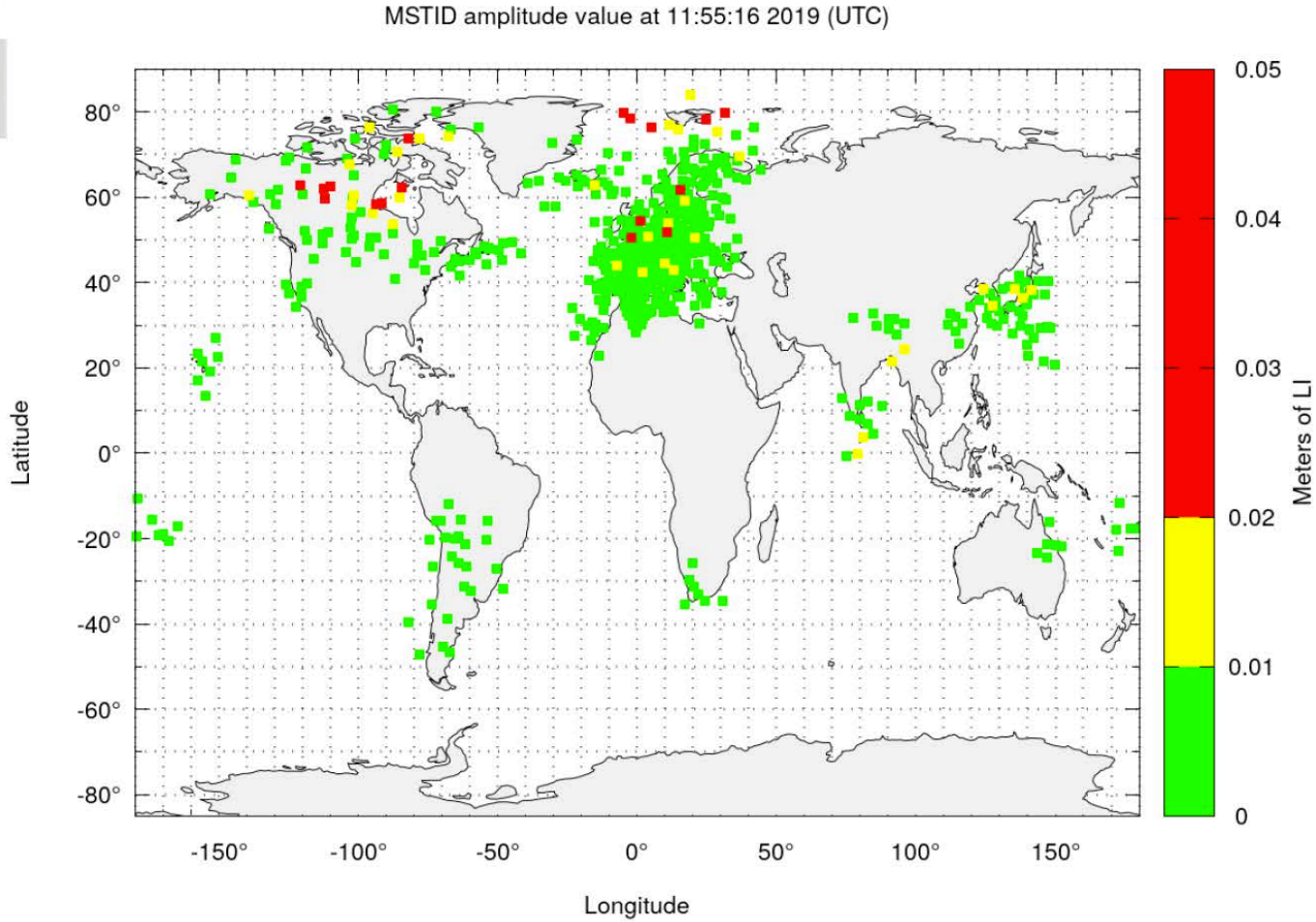
sec	Station	Satellite	Arcs	MSTID Amplitude (LI m)	IPP Long (degrees)	IPP Lat (degrees)	LoS X	LoS y	LoS Z	Mapping	Flag
31260	ACOR	8	1	0.0007922	-134.57	21.74	0.89781367	0.20360564	0.39048093	1.1	0
31260	ACOR	10	1	0.0019113	37.53	53.29	-0.16989459	0.70930844	0.68411794	3.6	0
31260	ACOR	18	1	0.0035796	-116.67	-41.10	0.52651575	-0.06824271	0.84742203	1.0	0
31260	ACOR	22	1	0.0025992	-98.69	54.93	0.90779889	-0.39979784	0.12673937	1.2	0
31260	ACOR	28	1	0.0018164	-3.82	-2.84	-0.06495647	-0.69163617	0.71931917	1.9	0

mstid_idx.YEAR.day **Ex: mstid_idx.19.270**



MSTID.YEAR.day_day.png **Ex: MSTID.19.270_day.png**

Figure Credits to Belehaki et al., 2020



MSTID.YEAR.day_5m.png **Ex: MSTID.19.270_5m.png**

Ionospheric disturbance indicators

AATR indicator

- Provides a **metric for ionospheric activity** at high latitudes, based on the rate of the slant TEC, which causes performance degradation of the EGNOS network.

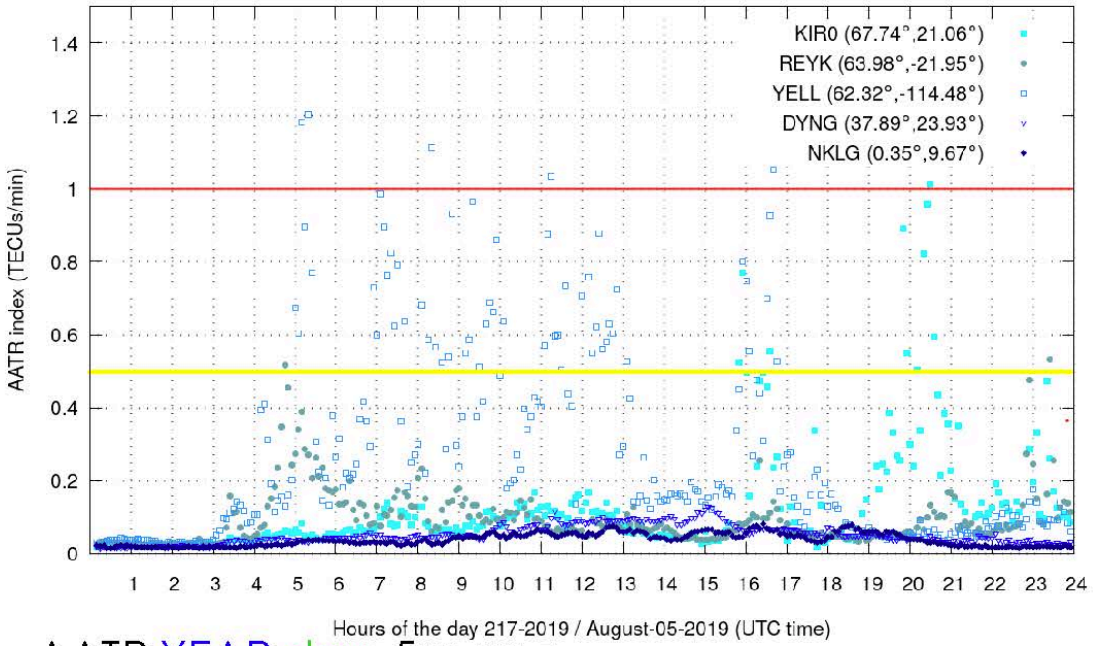
INPUT	OUTPUT	PRODUCTS
Slant TEC parameters	Along Arc STEC Rate, metric to characterize the ionosphere operational conditions of EGNOS	• AATR indicator calculated at each GNSS contributing receiver. • Daily plots of AATR indicator • Maps of AATR indicator

Ionospheric disturbance indicators

AATR indicator

Year	Day of Year	Seconds of the day	Station	AAR Index (cm/s LI)
17	304	31260	ACOR	0.00416
17	304	31260	ACRB	0.01353
17	304	31260	ADIS	0.00447
17	304	31260	AGAB	0.01249
17	304	31260	AJAC	0.00413
17	304	31260	ALBB	0.01006

aatr.YEAR.day **Ex: aatr.19.250**



AATR.YEAR.day_5m.png **Ex: AATR.19.217_5m.png**

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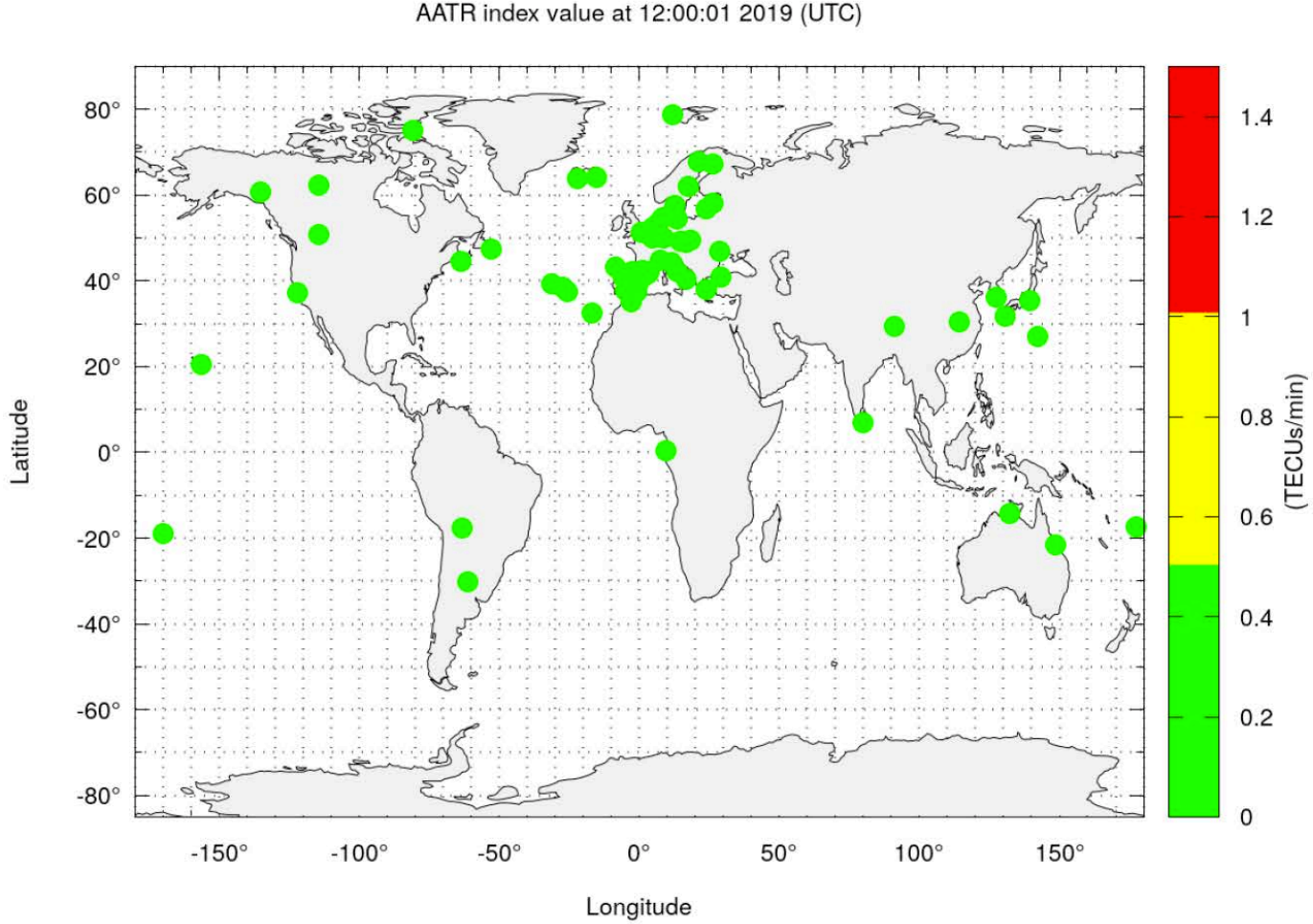

AATR.YEAR.day_5m.png **Ex: AATR.19.270_5m.png**

Ionospheric disturbance indicators

GNSS TEC Gradient

- Provides temporal and spatial **TEC gradients** which are indicative of strong ionosphere-thermosphere perturbations and precursors of LSTID activity.

INPUT	OUTPUT	PRODUCTS
Grids of TEC maps over a region	**Latitude-time maps of TEC gradients and indication of significant gradients**	• **Maps of TEC gradients for the European region.**

Ionospheric disturbance indicators

GNSS TEC Gradient

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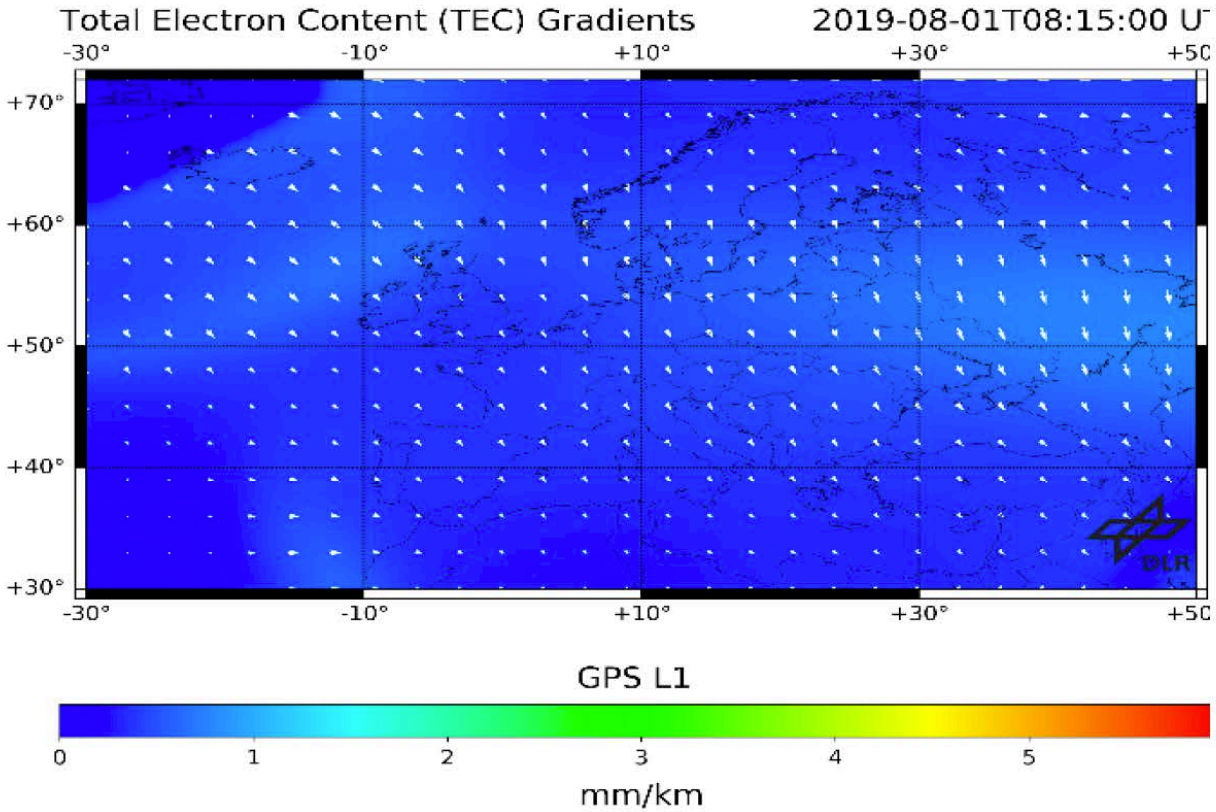

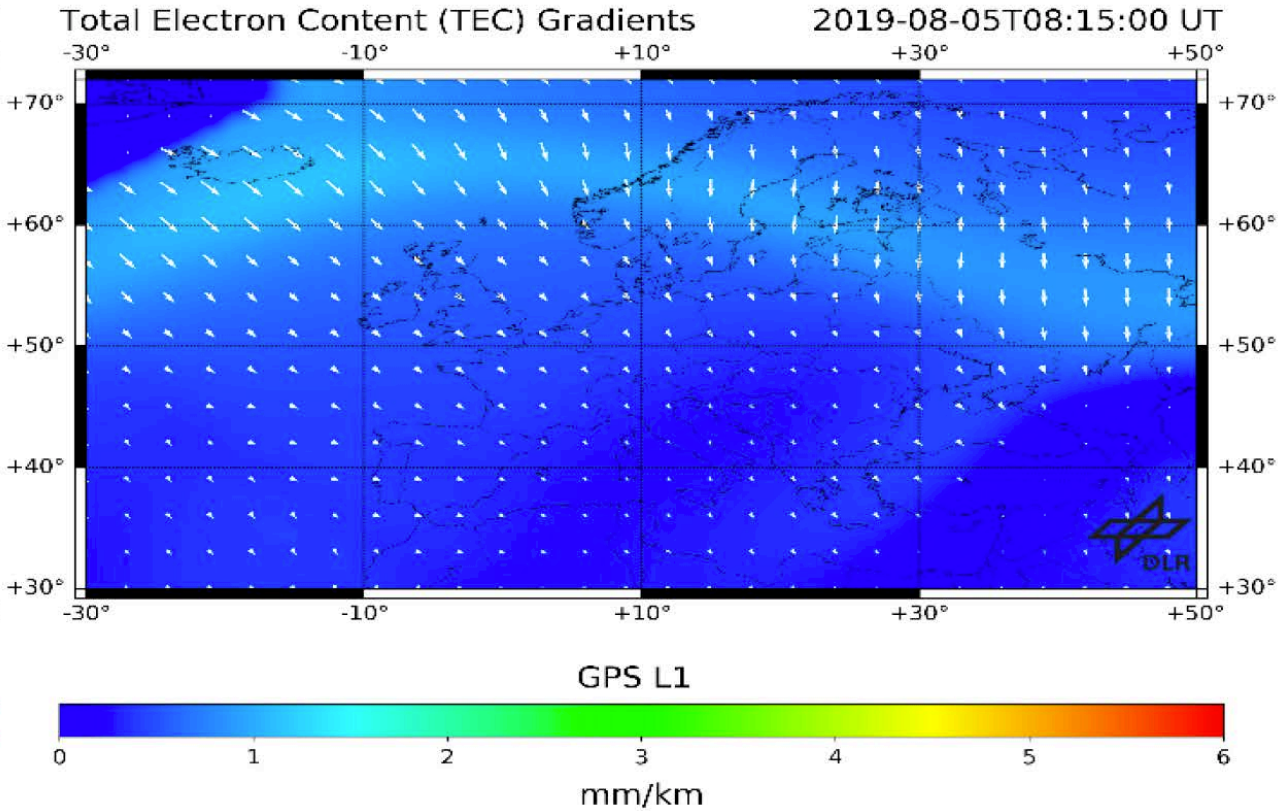

Ionospheric disturbance indicators

Background Ionospheric Activity

- Provide **indication of ionospheric disturbances** for a region of interest and probability of detection of TIDs produced by Gravity Waves.

INPUT	OUTPUT	PRODUCTS
Ionogram derived characteristics in the F2 layer from ionosondes **GNSS TEC at the ionosonde location** **Geomagnetic and solar flux indices**	**Maps of the electron density at any height in the bottomside and topside ionosphere**	• **Maps of relative standard deviation of the electron density at each ionospheric altitude with an indication of the probability for LSTIDs detection**

Ionospheric disturbance indicators

Background Ionospheric Activity

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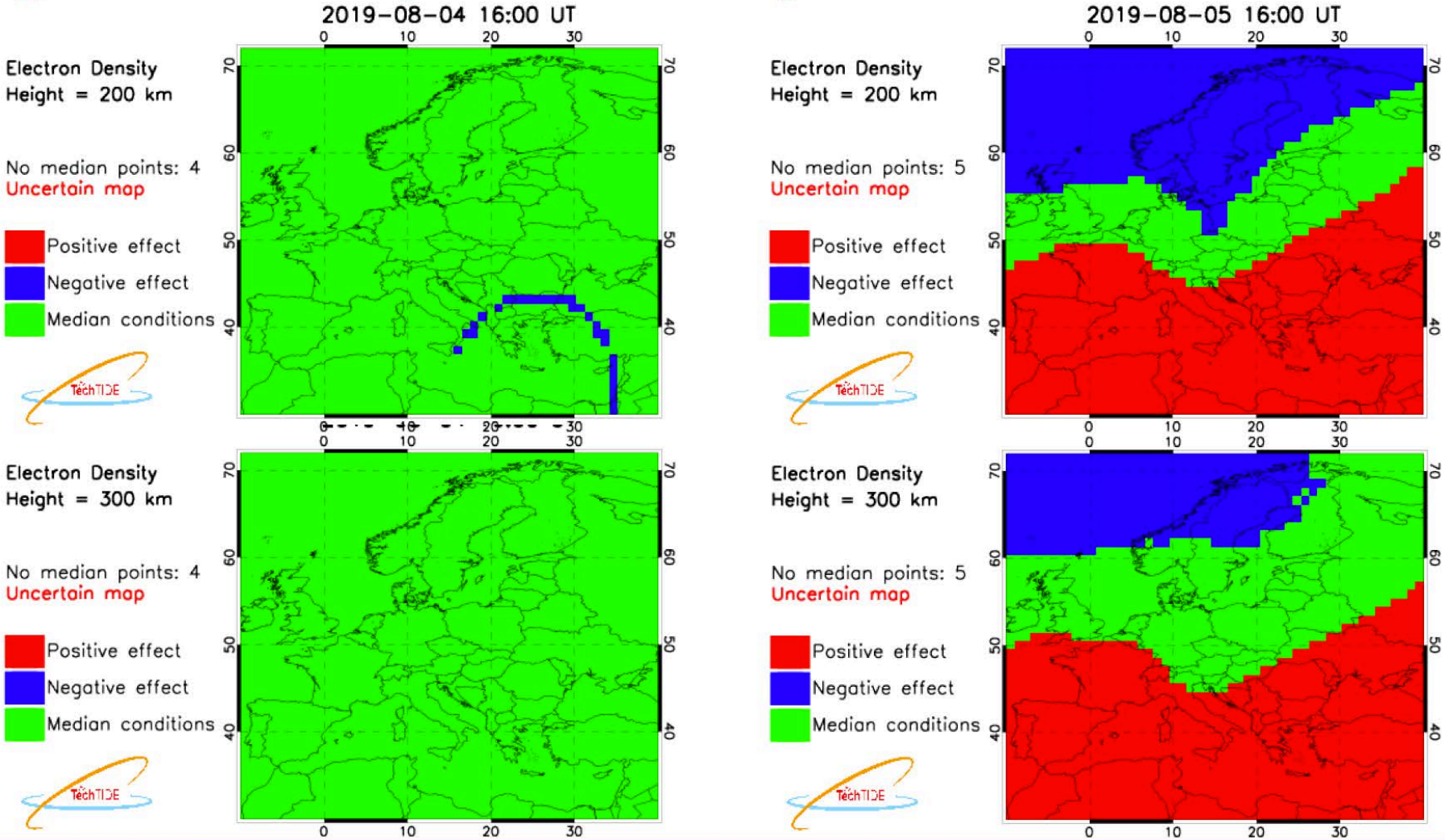

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Keep safe and see you at #EGU2021!