



An ionospheric activity index for the identification of large scale travelling ionospheric disturbances (LSTIDx)



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User requirements

SWE-CRD-TIO-1636	Service: TIO	Priority: Essential	SWE
The system shall provide monitoring and detection of ionospheric phenomena causing local disturbances of electron density. These shall explicitly include: trough, Travelling Ionospheric Disturbances (TIDs), patches, depletions and D-region absorption			
Justification:	Local and narrow disturbances in the ionosphere (trough, TIDs, patches, depletions, D-region absorption) affect system performance in localised regions which are difficult to detect and mitigate by the system.		
Comments:			
Source Requirements:	MR-SSA-SWE-360 MR-SSA-SWE-400		
Related Requirements:	SWE-CRD-TIO-1639 SWE-CRD-TIO-1641 SWE-CRD-TIO-1642 SWE-CRD-TIO-1643 SWE-CRD-TIO-1644 SWE-CRD-TIO-1645 SWE-CRD-TIO-1646 SWE-CRD-TIO-1647 SWE-CRD-TIO-1648	Verification Method:	Design Review Test

Source: SSA-SWE-RS-CRD-1001

TIDs severely affect all operational systems using predictable ionospheric characteristics as they can impose disturbances with amplitudes of up to ~20% of the ambient electron density, and Doppler frequency shifts of the order of 0.5 Hz on HF signals (Reinisch et al., 2018).



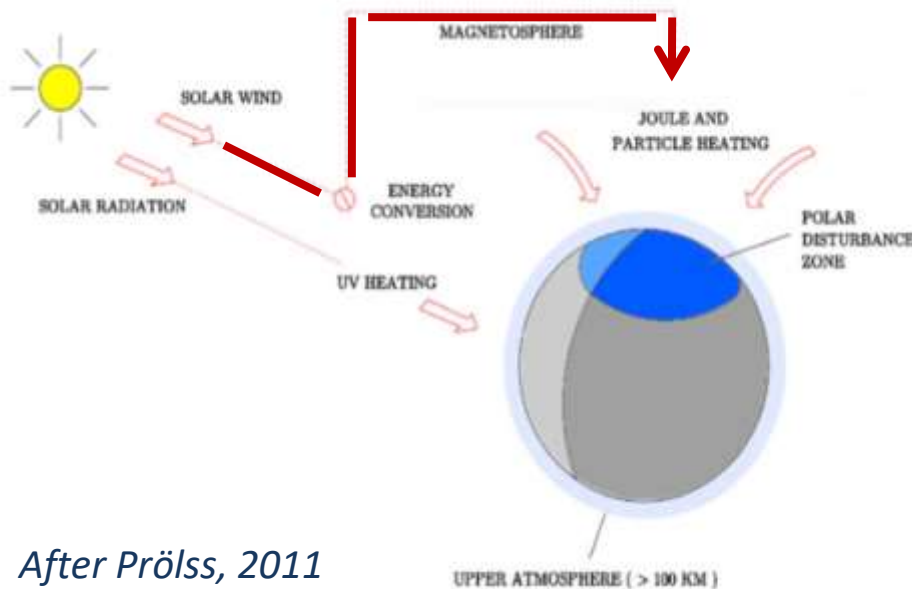
Specification of TIDs activity over large world regions is a key requirement from the operators of systems using or affected by ionospheric conditions (Belehaki et al. 2020)



COMPET – Space Weather 2017
Grant Agreement 776011

Large Scale Travelling Ionospheric Disturbances (TIDs)

Large-scale traveling ionospheric disturbances (LSTIDs):



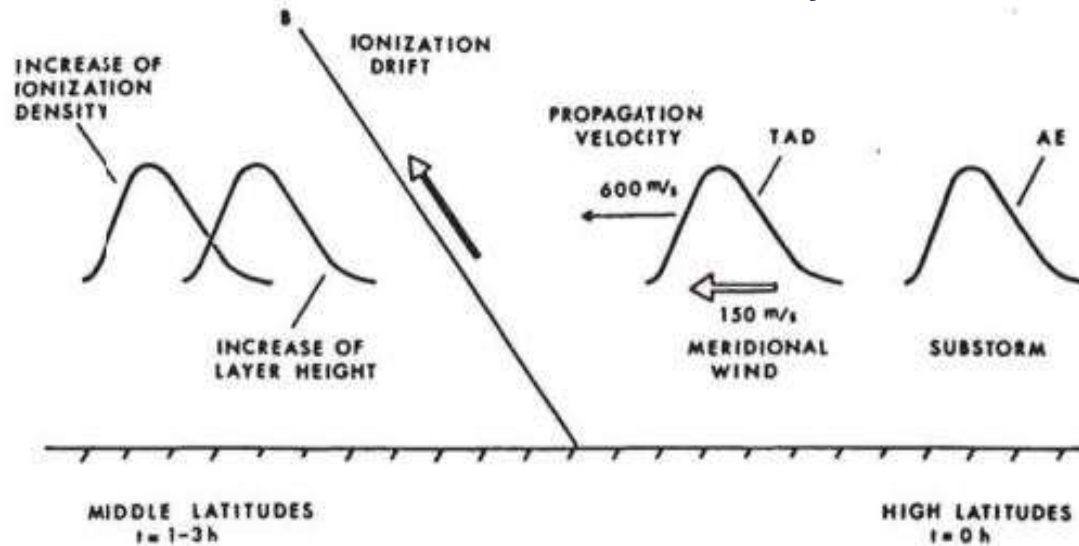
After Prölss, 2011

- Manifestation of the atmospheric gravity waves in the ionosphere /usually observed during geomagnetic storms and substorms.
- Joule heating or intense particle precipitation are the main excitation sources of the LSTIDs.

LSTIDs have horizontal propagation velocities between 300 m/s and 1000 m/s, horizontal wavelengths greater than 1000 km and periods in the range of 30 min to 3 h.

Large Scale Travelling Ionospheric Disturbances (TIDs)

After Prölss, 1995



The injection of solar wind energy to the polar upper atmosphere (indicated by **AE index increase**) launches a **wide spectrum of atmospheric gravity waves** that are superimposed to form impulse-like travelling disturbances. These disturbances propagate with high velocity towards lower latitudes carrying along equatorward-directed winds of moderate magnitude that cause an **F2 layer uplifting** due to vertical drifts (**increase in $h_m F_2$**) in higher heights when the ionisation loss rates are lower (**increase in $f_o F_2$**).

LSTIDx specifications

The proposed index (LSTIDx) is designed to monitor the wave-like LSTIDs disturbances (associated with enhancements in geomagnetic / magnetospheric activity)

Ionospheric characteristic: foF2

Running window: 1 hour

LSTIDx = $\text{std_foF2} / \text{std_foF2median}$

Std_foF2: standard deviation of the foF2 actual observations within the last 1 hour

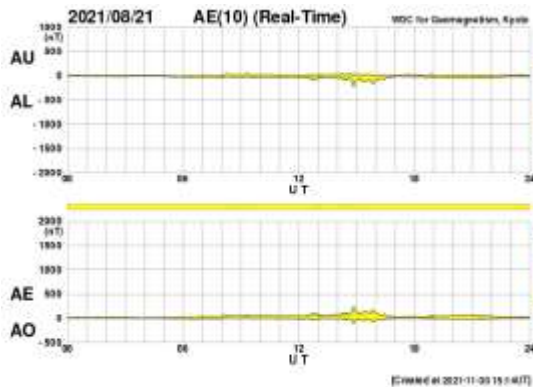
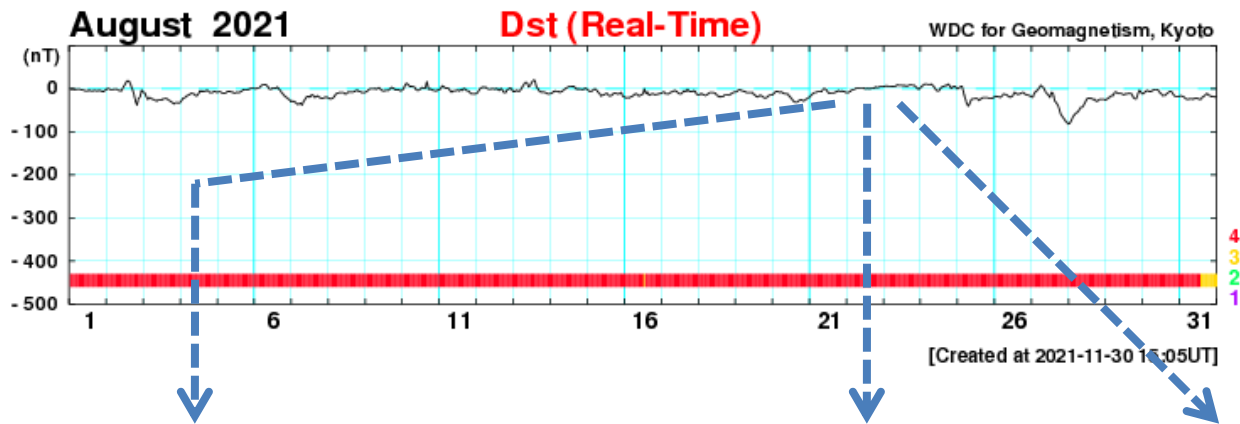
Std_foF2median: standard deviation of the foF2 median estimates within the last 1 hour

Spatial resolution: Local

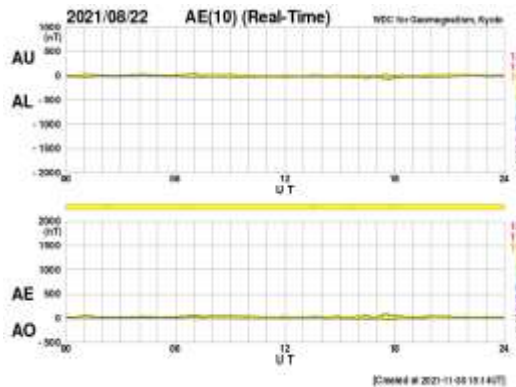
Temporal resolution: 5 min

Quiet conditions

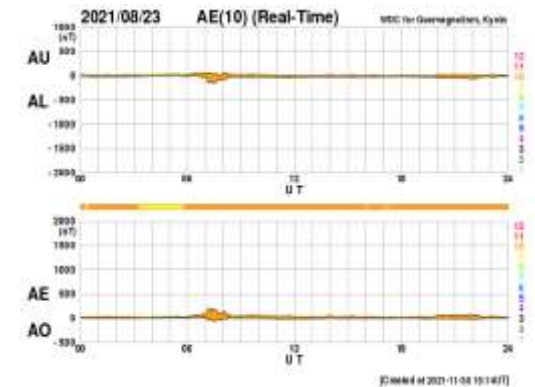
21 – 23 August 2021



21 August 2021



22 August 2021



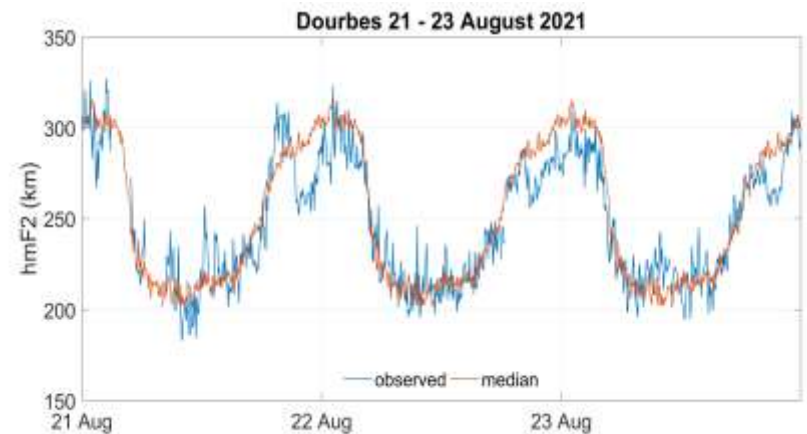
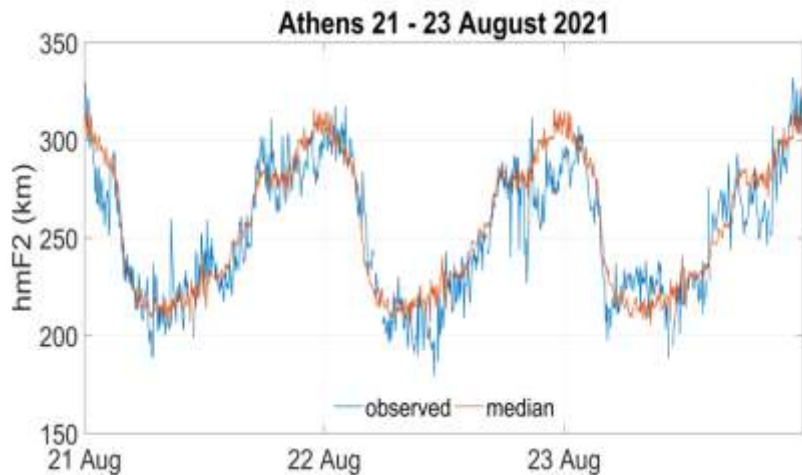
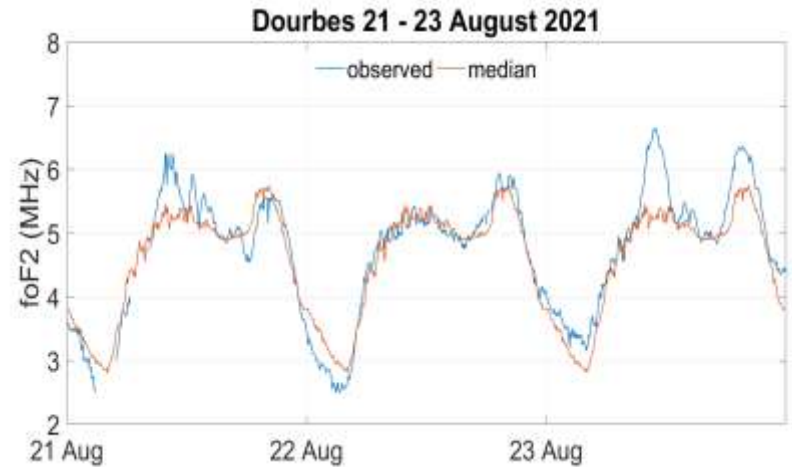
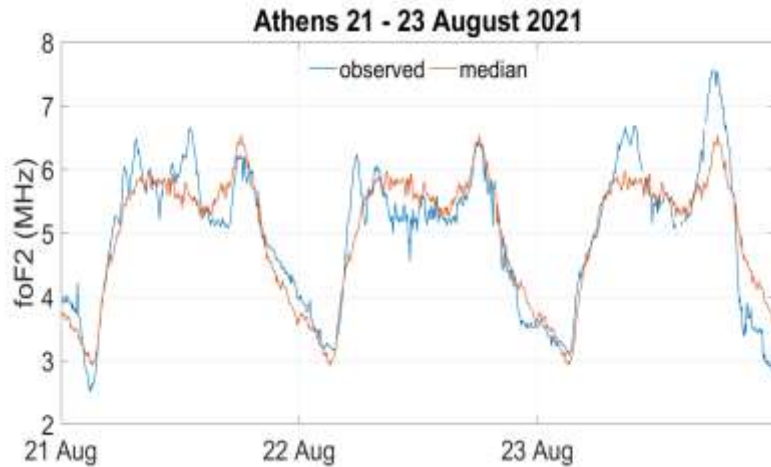
23 August 2021

Quiet conditions

21 – 23 August 2021

Manually scaled

Weak wave-like foF2 disturbances



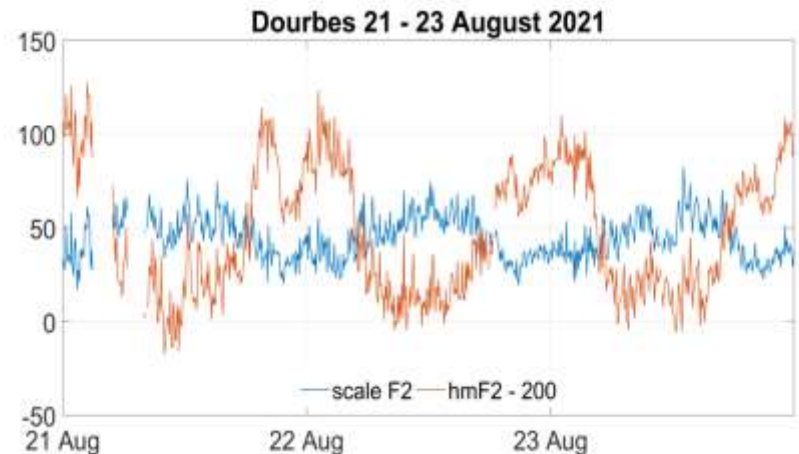
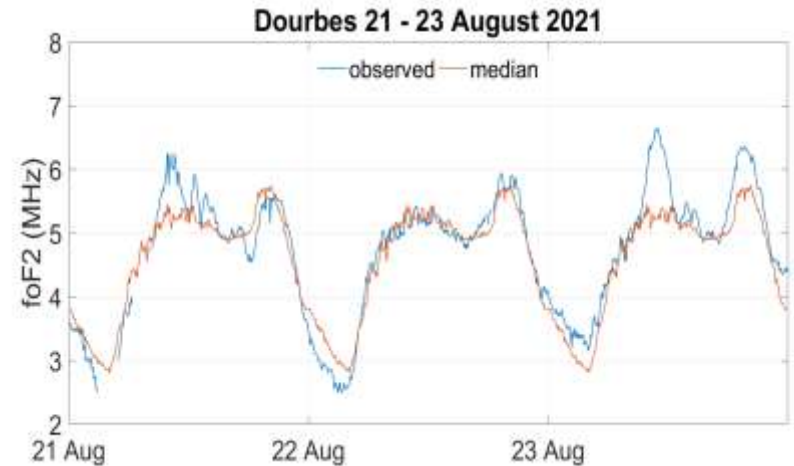
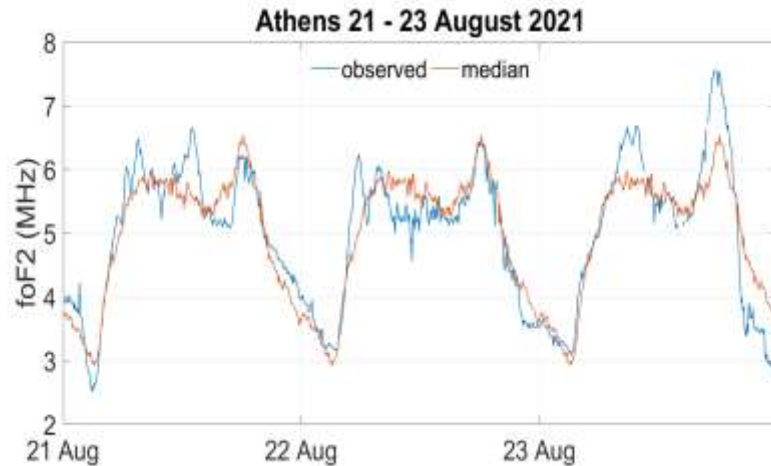
No significant hmF2 signatures

Quiet conditions

21 – 23 August 2021

Manually scaled

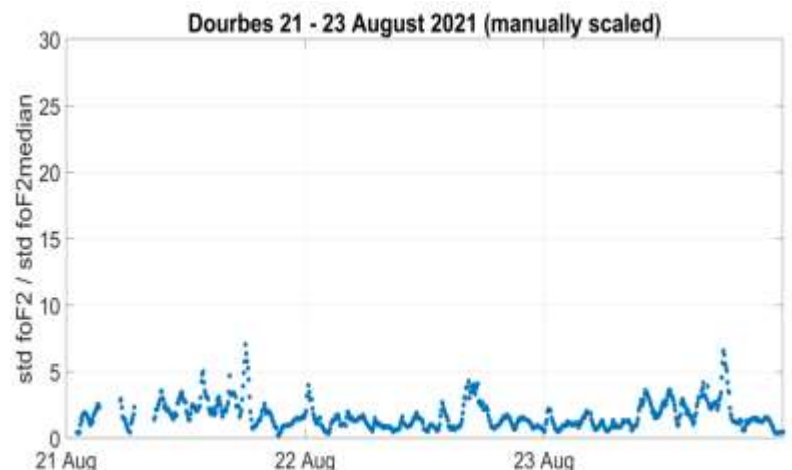
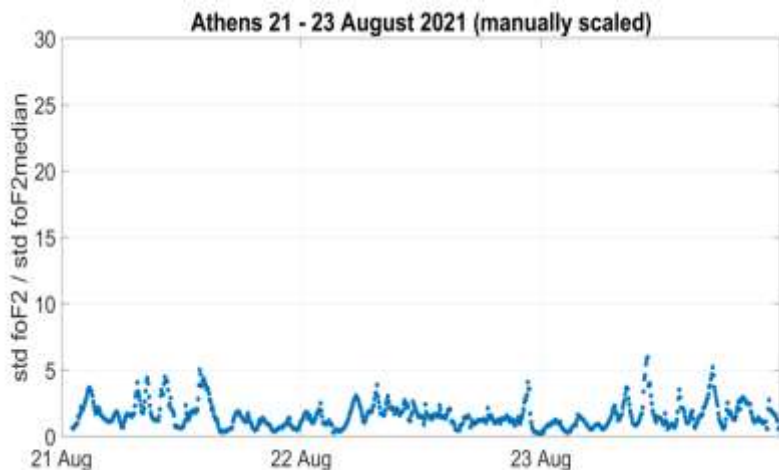
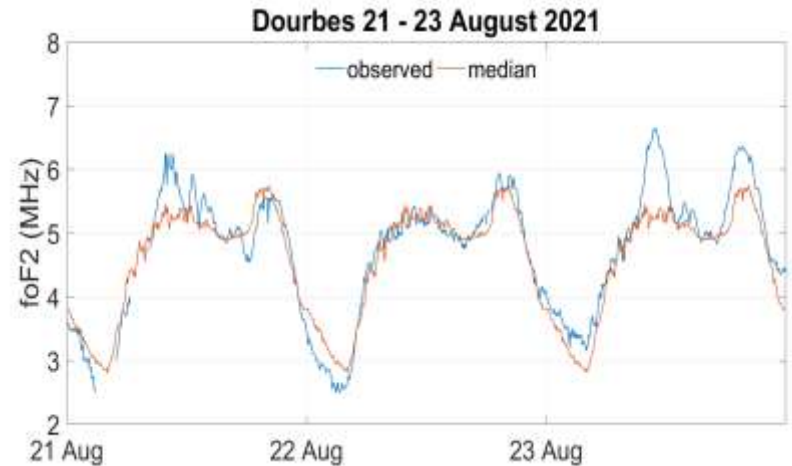
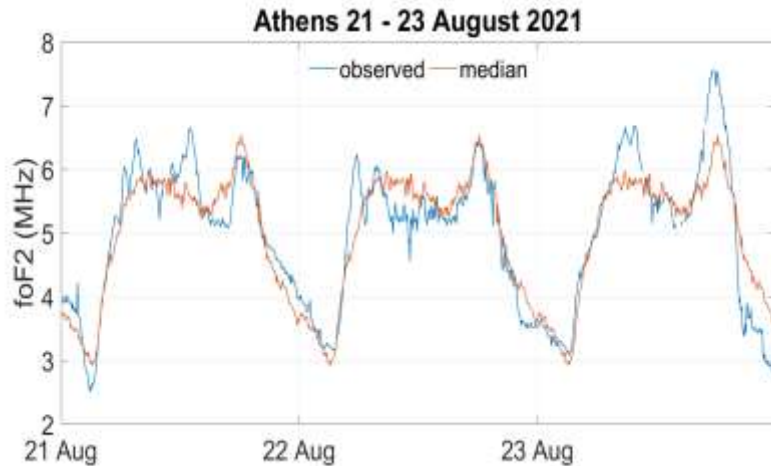
Weak wave-like foF2 disturbances



No significant scale F2 signatures

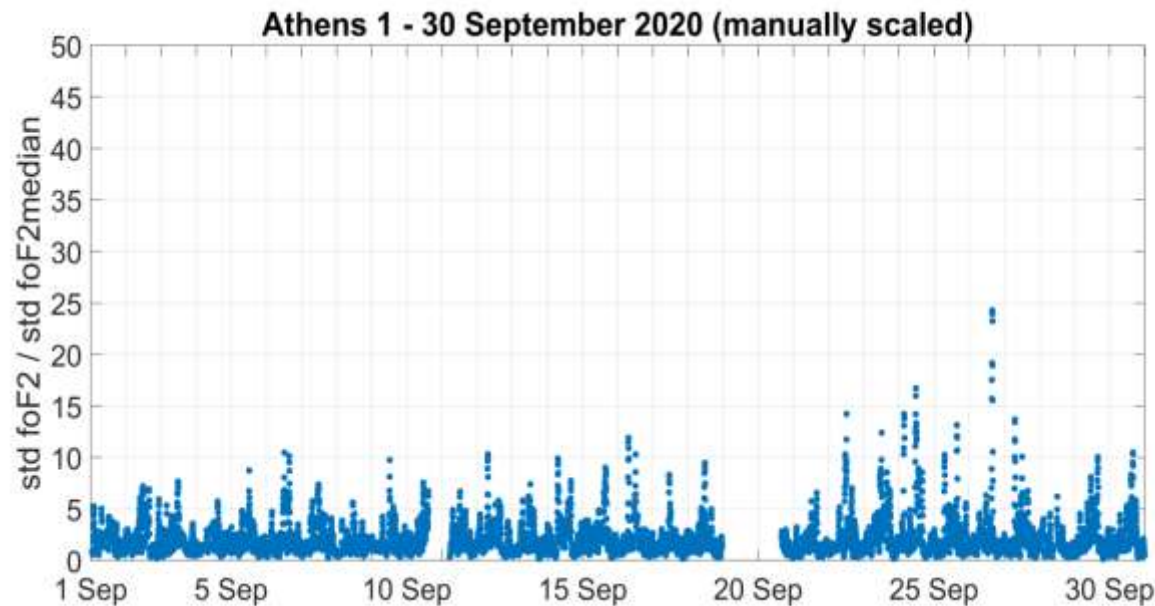
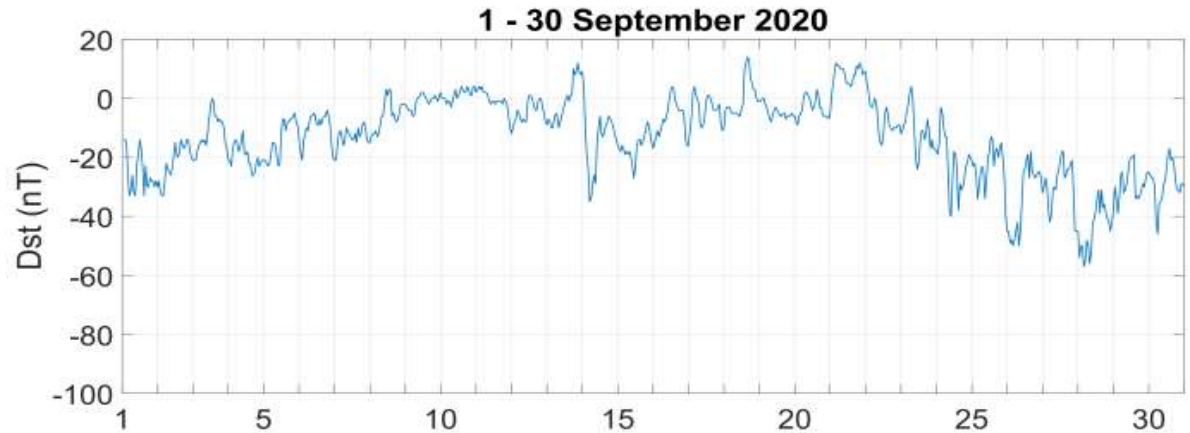
Quiet conditions

21 – 23 August 2021



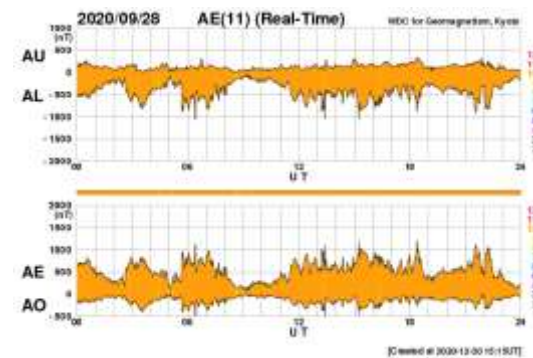
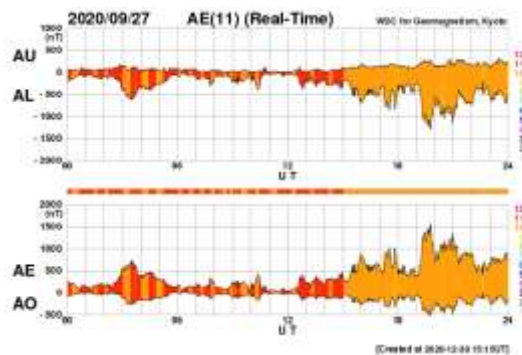
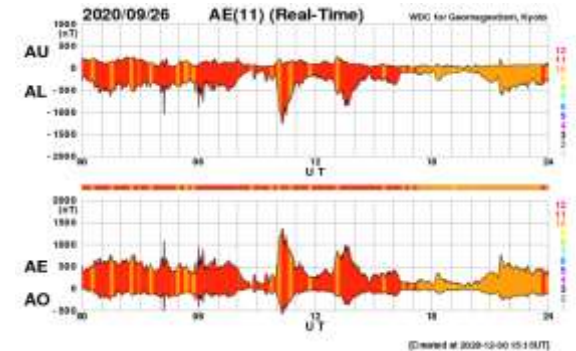
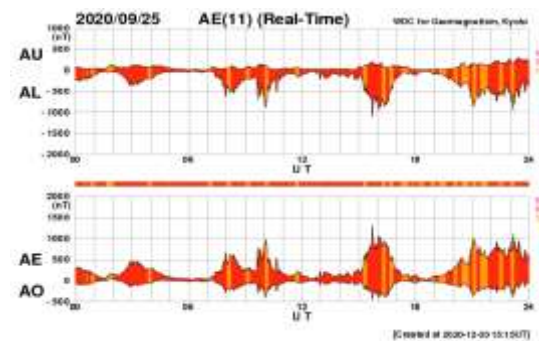
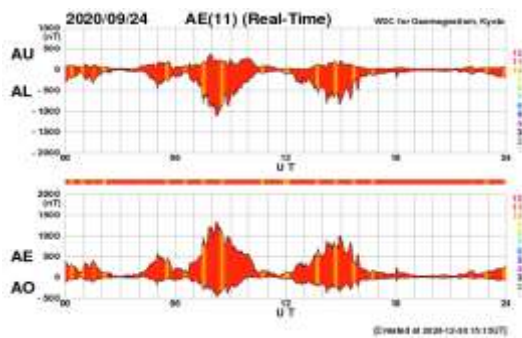
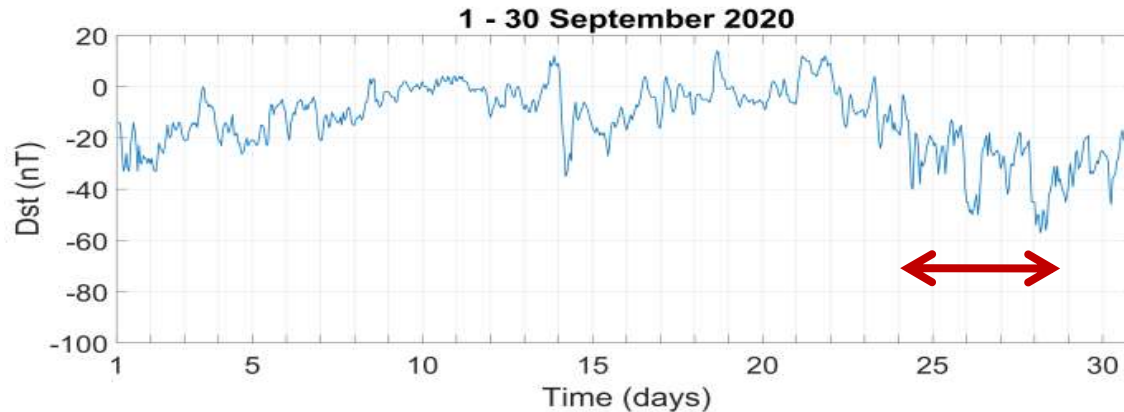
LSTIDx values remain rather low in both ionospheric locations

Disturbed conditions 1 – 30 September 2020



LSTIDx tends to
follow the
geomagnetic activity
level

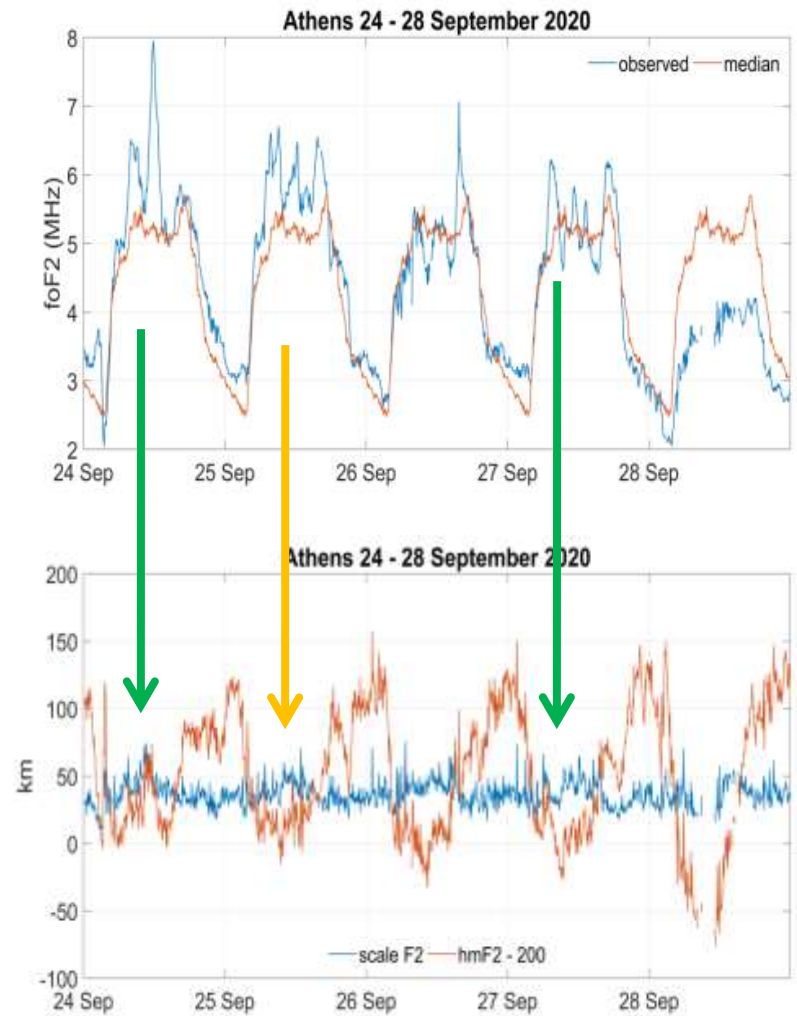
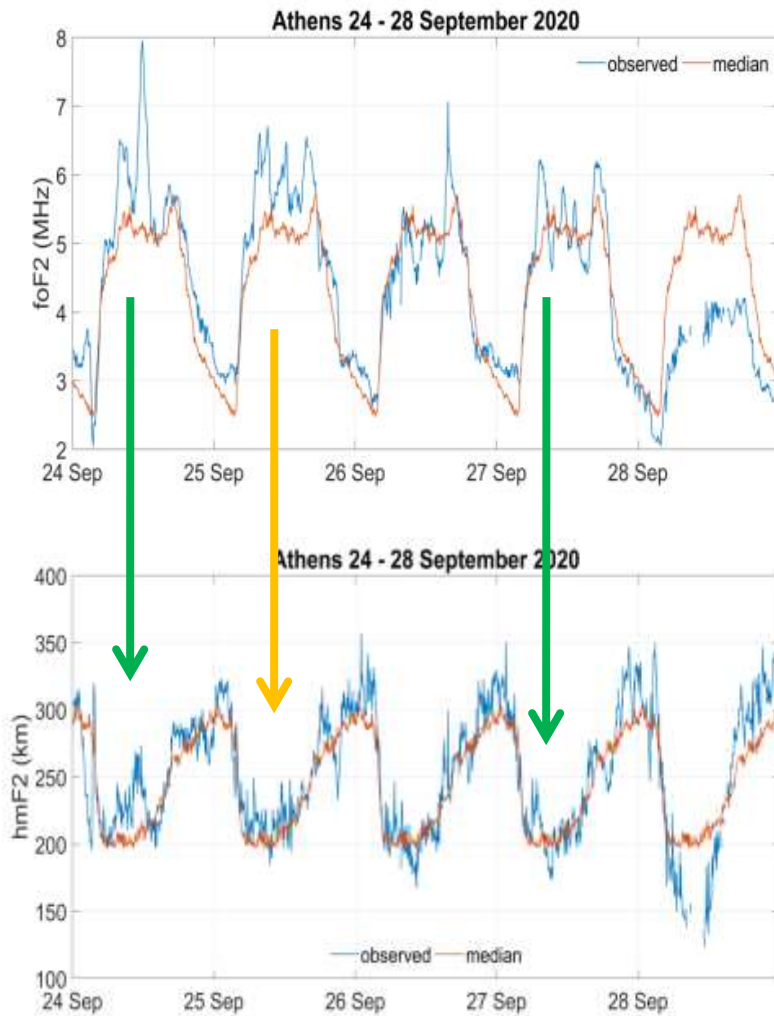
Disturbed conditions 24 – 28 September 2020



Disturbed conditions

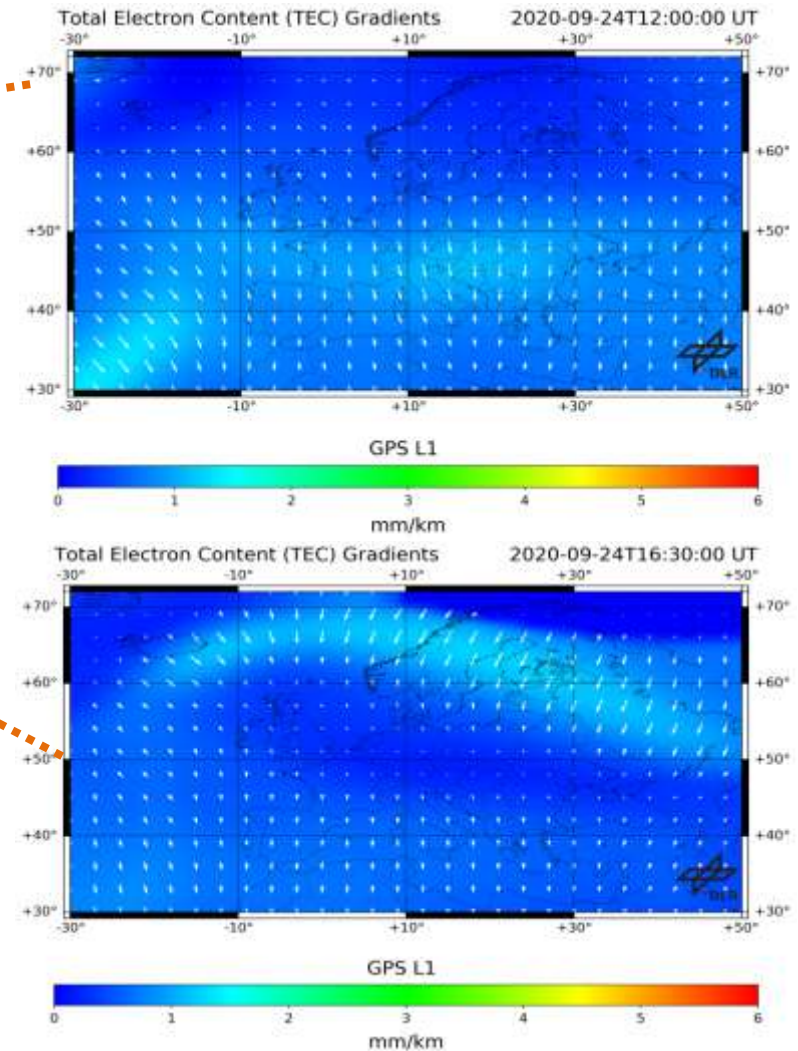
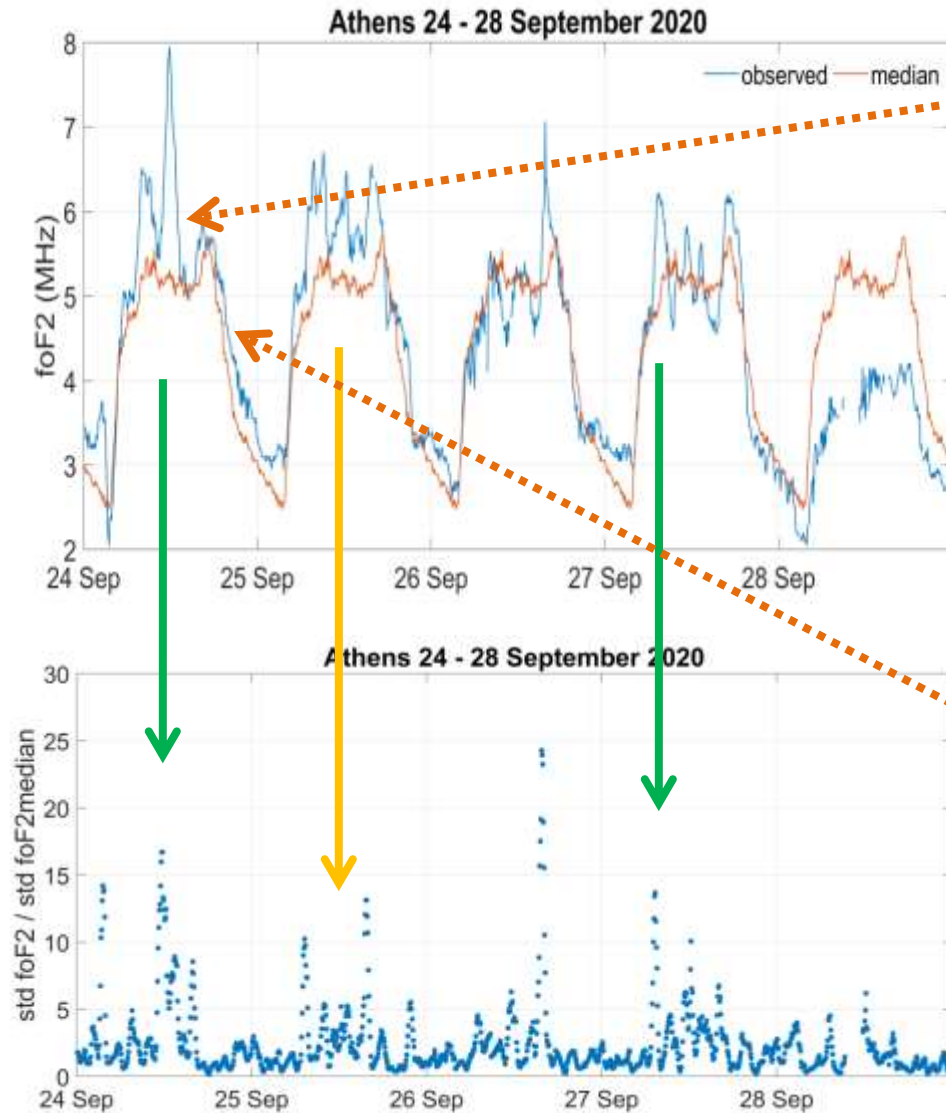
24 – 28 September 2020

Manually scaled



Disturbed conditions 24 – 28 September 2020

Manually scaled

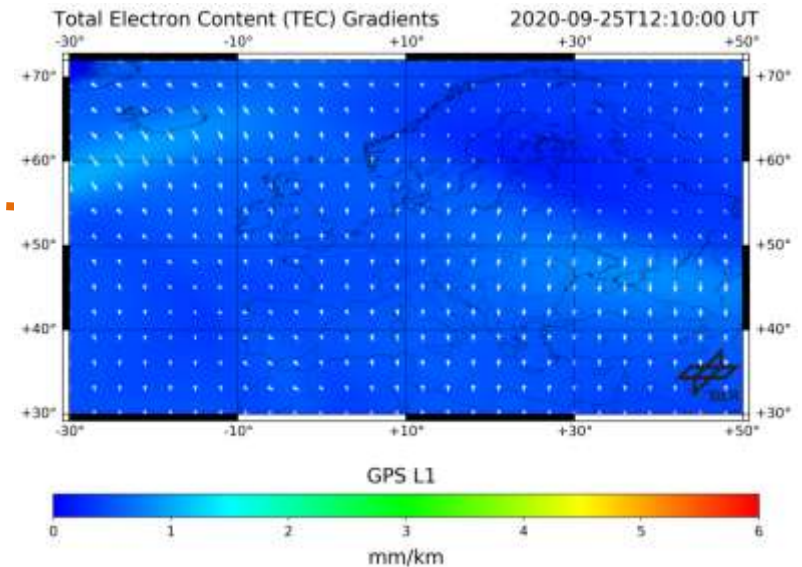
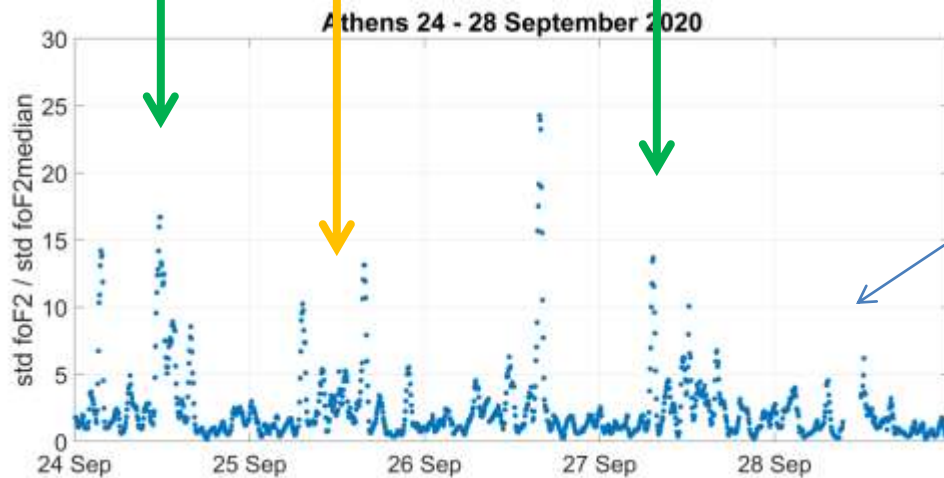
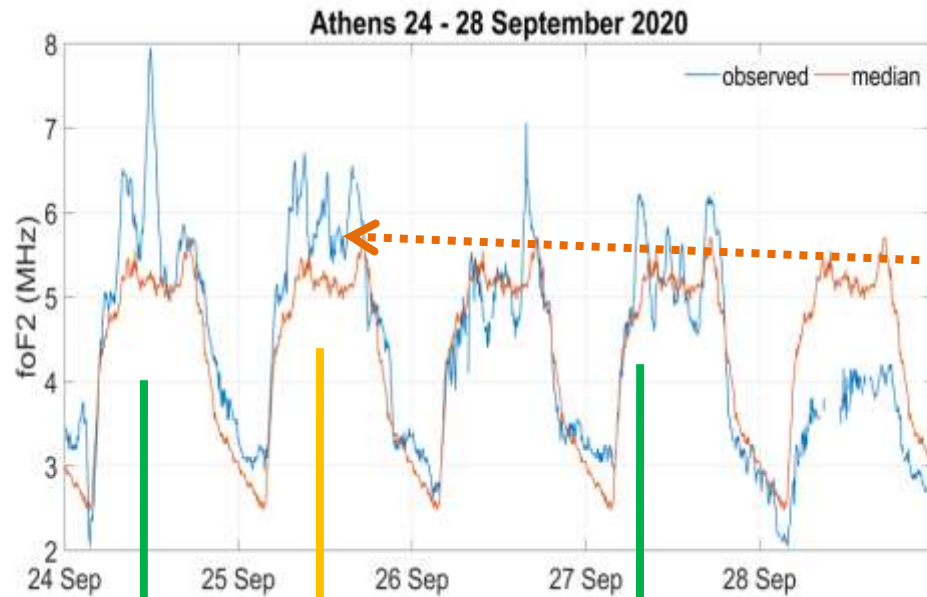


Available by TechTIDE warning services

Disturbed conditions

24 – 28 September 2020

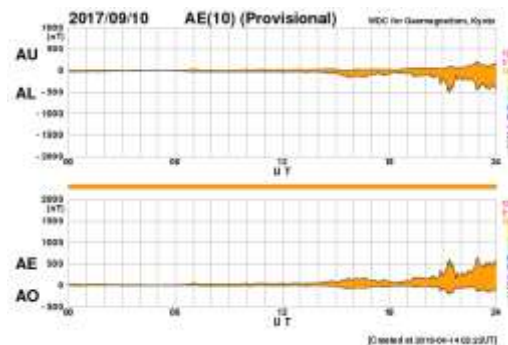
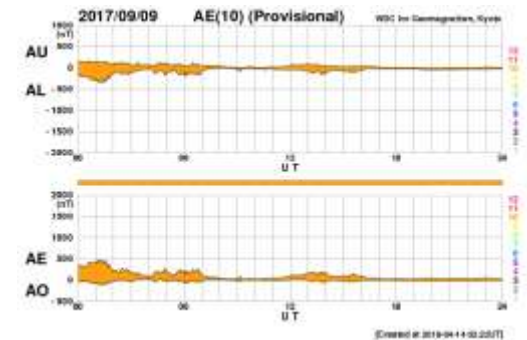
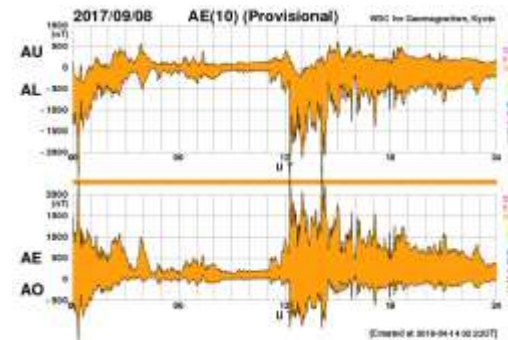
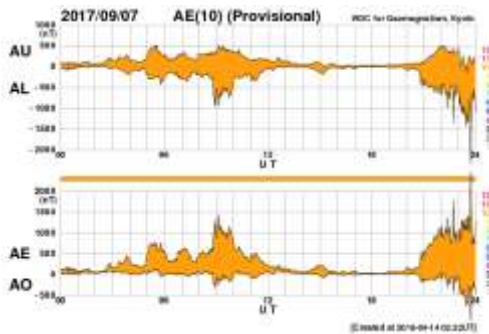
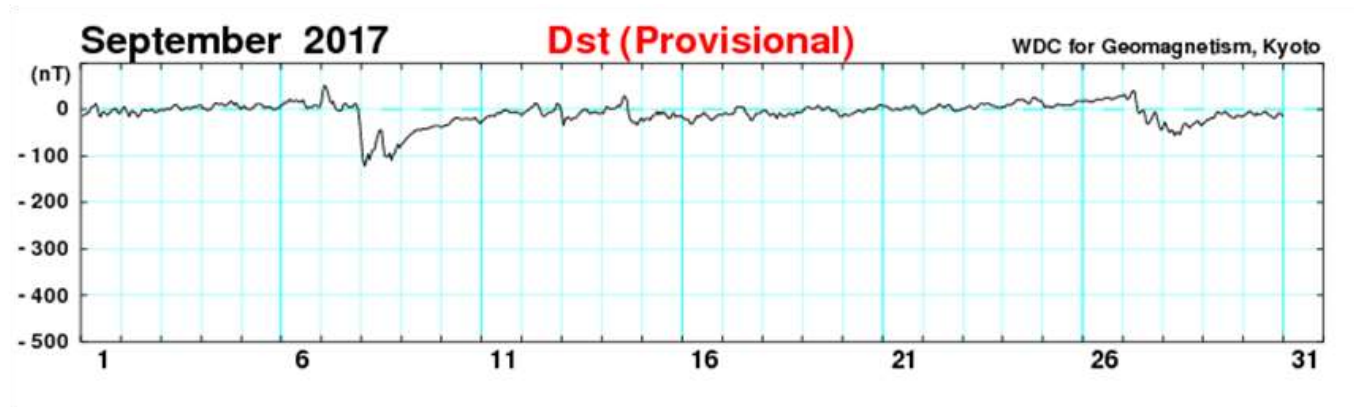
Manually scaled



Available by TechTIDE warning services

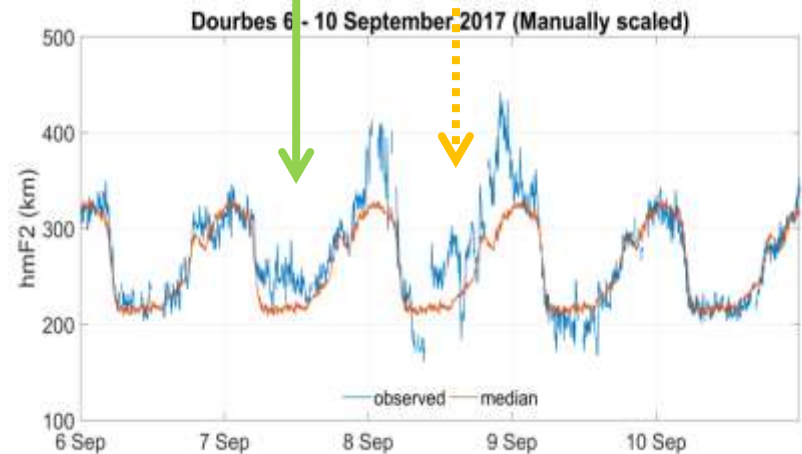
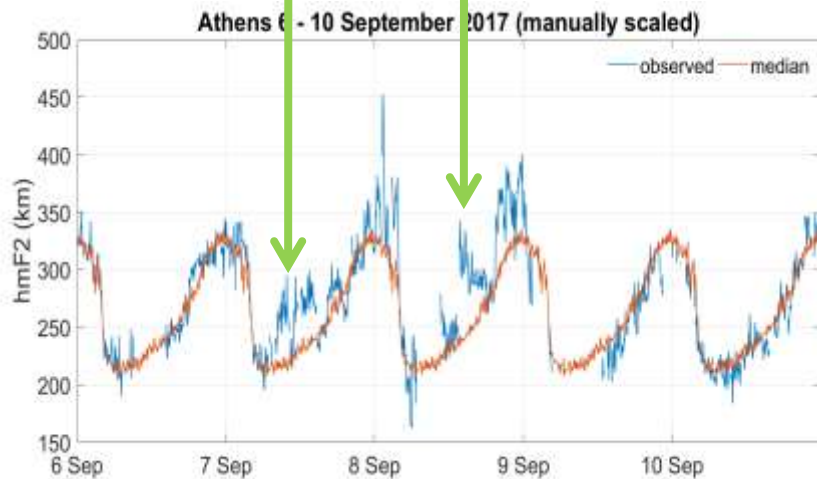
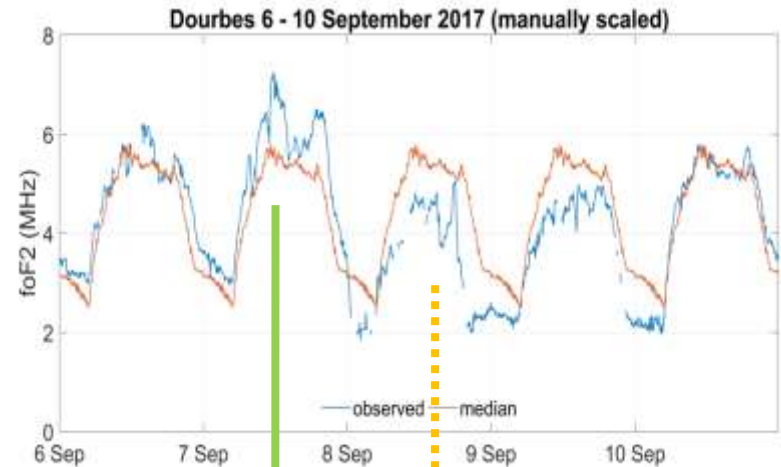
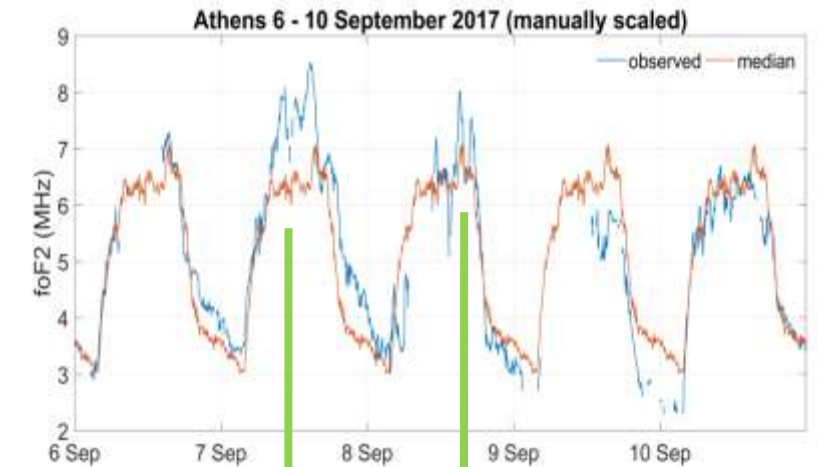
No TIDs activity under the occurrence of negative storm effects

Disturbed conditions 6 – 10 September 2017



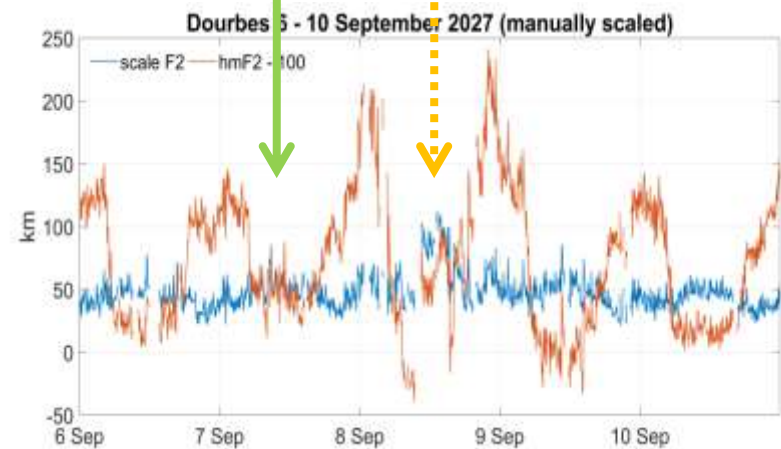
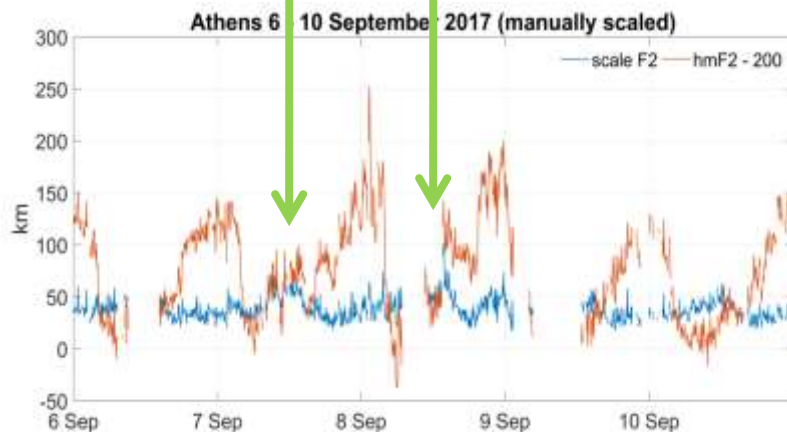
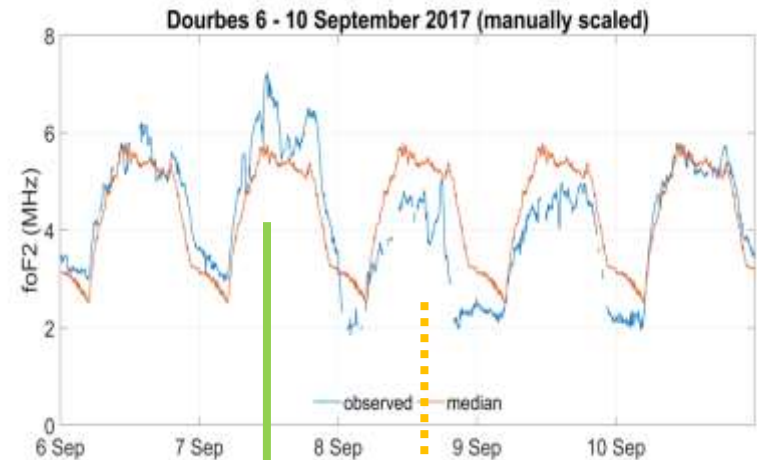
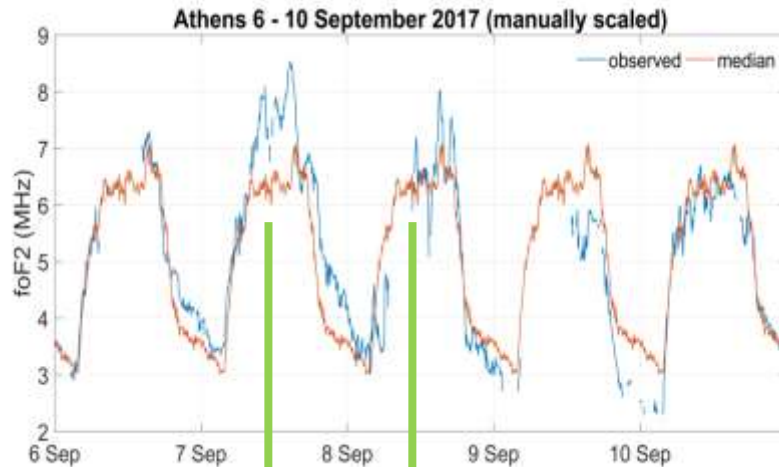
Disturbed conditions

6 – 10 September 2017



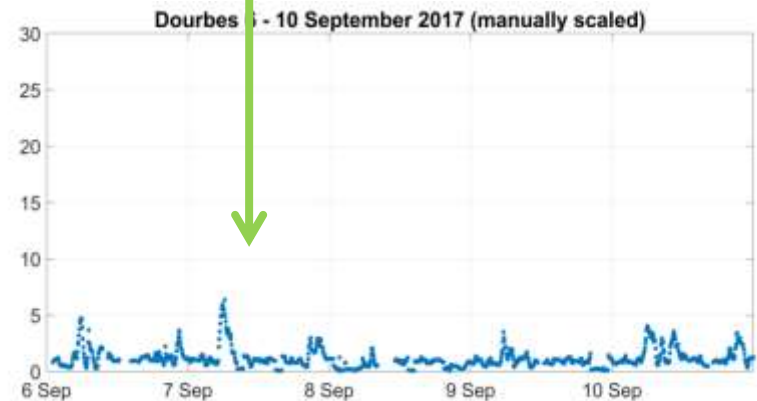
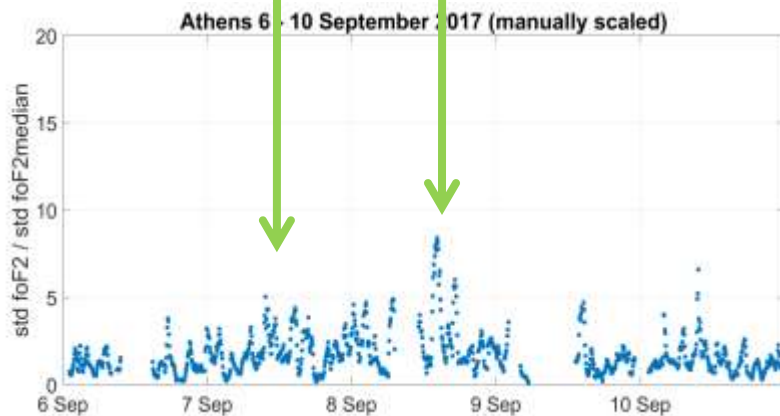
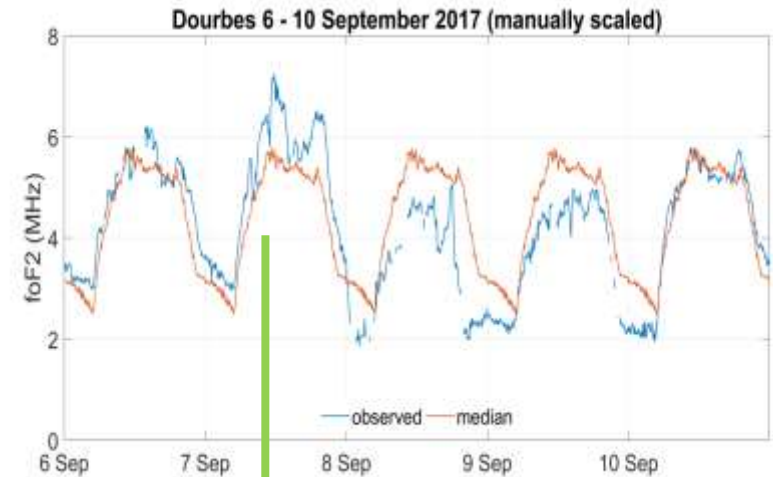
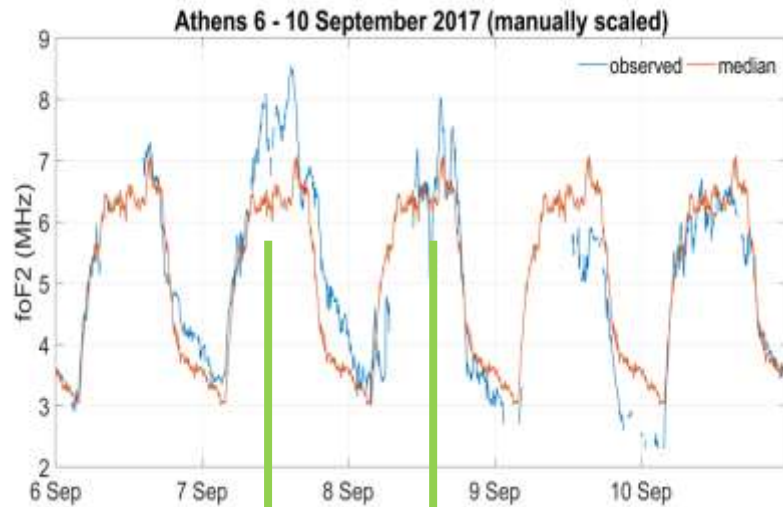
Disturbed conditions

6 – 10 September 2017



Disturbed conditions

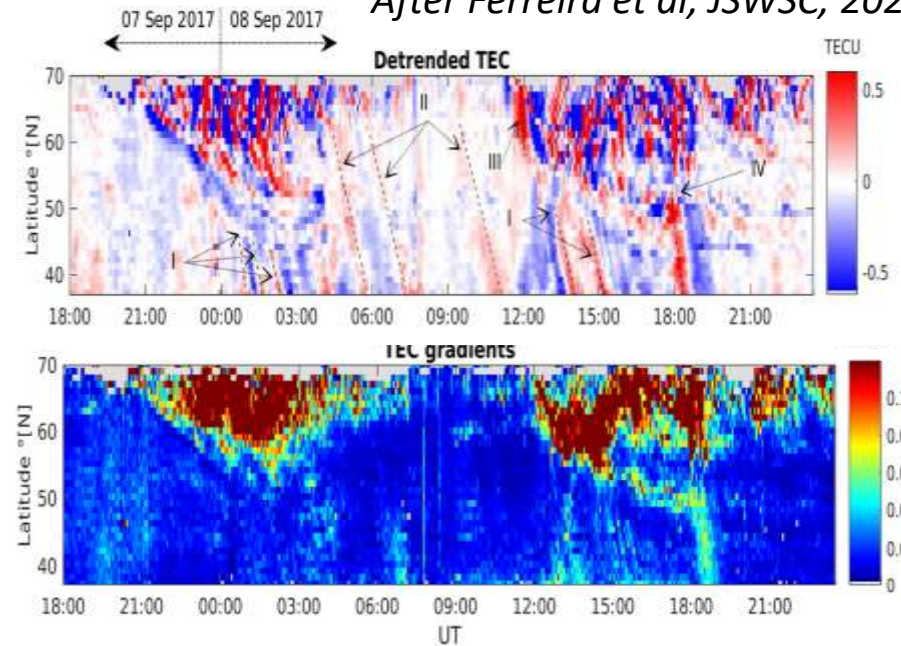
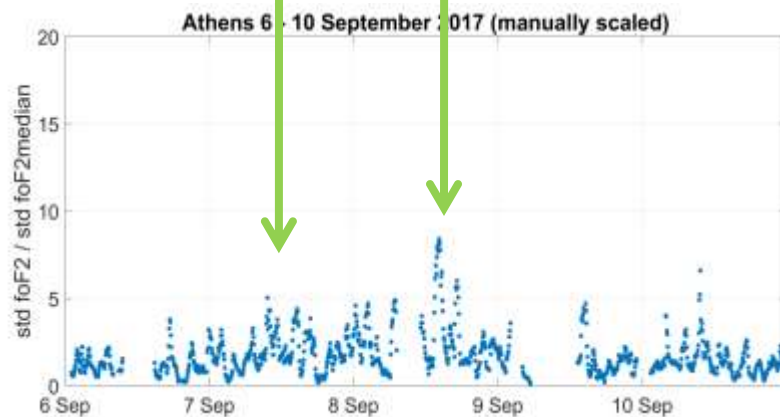
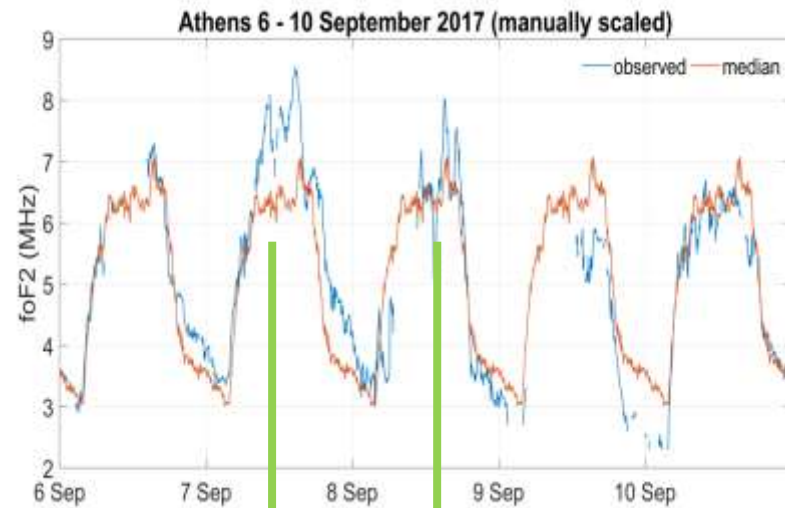
6 – 10 September 2017



Disturbed conditions

6 – 10 September 2017

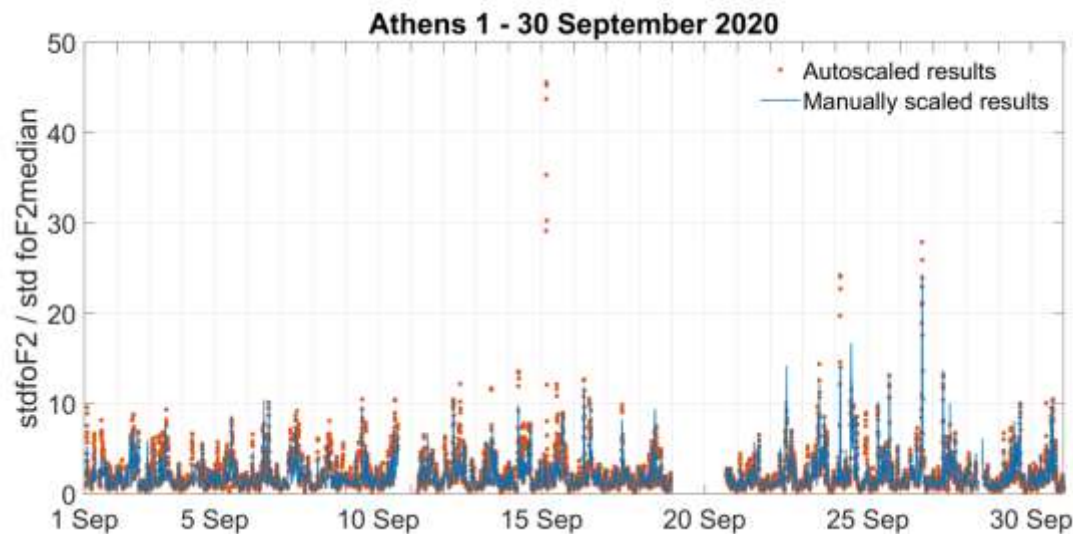
After Ferreira et al, JSWSC, 2020



Ferreira et al. (2020) report LSTIDs signatures observed during 8th September 2017 (around 15° in longitude): fast LSTIDs in midlatitudes between 0–3 UT and 13–16 UT

Discussion

1. The proposed index (LSTIDx) appears sensitive to LSTIDs local signatures in the F2 layer, i.e.: wave-like disturbances in the foF2 that follow AE index excursions and are accompanied by increases in peak F2 layer ionisation density and height



2. Possible limitations in LSTIDx validity may be considered in terms of:
 - data quality (i.e. autoscaling errors affect the LSTIDx values), and
 - Data gaps: they tend to underestimate the LSTIDx values. In the presented results only LSTIDx values estimated by the availability of 7 out of 12 values within an hour are considered.
3. The fair evaluation of the results require cross-comparison with other TIDs activity metrics provided by TechTIDE methodologies