TEC maps released by the European Ionosonde Service

Anna Belehaki and the EIS group

ESA SWESNET WORKSHOP 2022

11 May 2022

Data providers: NOA IAP RAL INGV OE UFA INTA IZMIRAN ROB NOAA

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- Ionospheric Alerts
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Near Real-time TEC Maps (I.117)

EIS Home / Near Real-time TEC Maps

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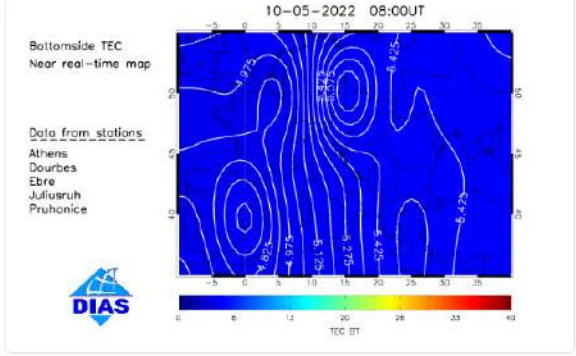
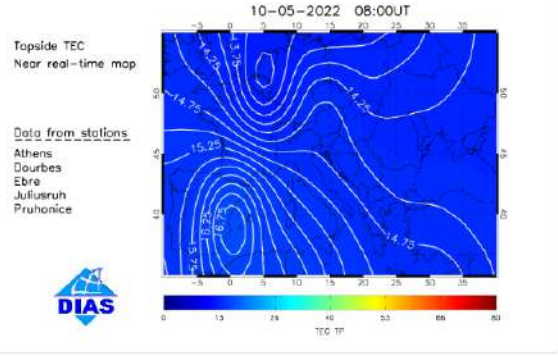
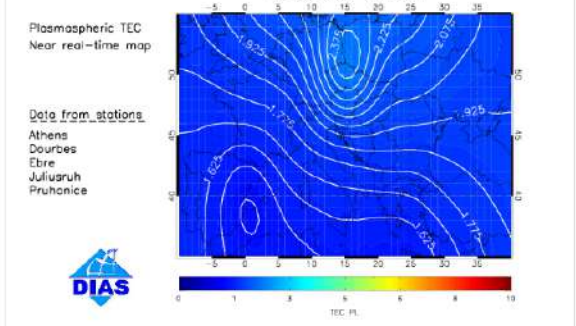
TEC Bottomside — View Data File



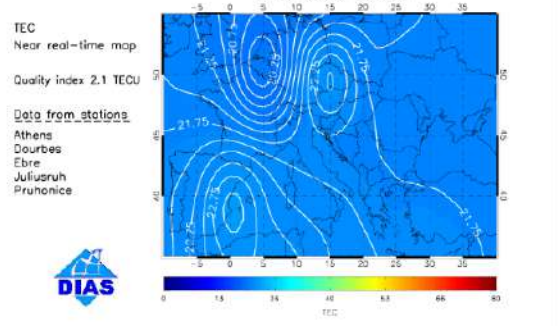
TEC Topside — View Data File



TEC Plasmaspheric — View Data File



TEC Total — View Data File



Real-time TEC maps from DIAS/EIS based on the TaD model

Refresh rate:
15 min

Resolution:
1x1 degree

TEC maps in EIS are based on the TaD electron density reconstruction model

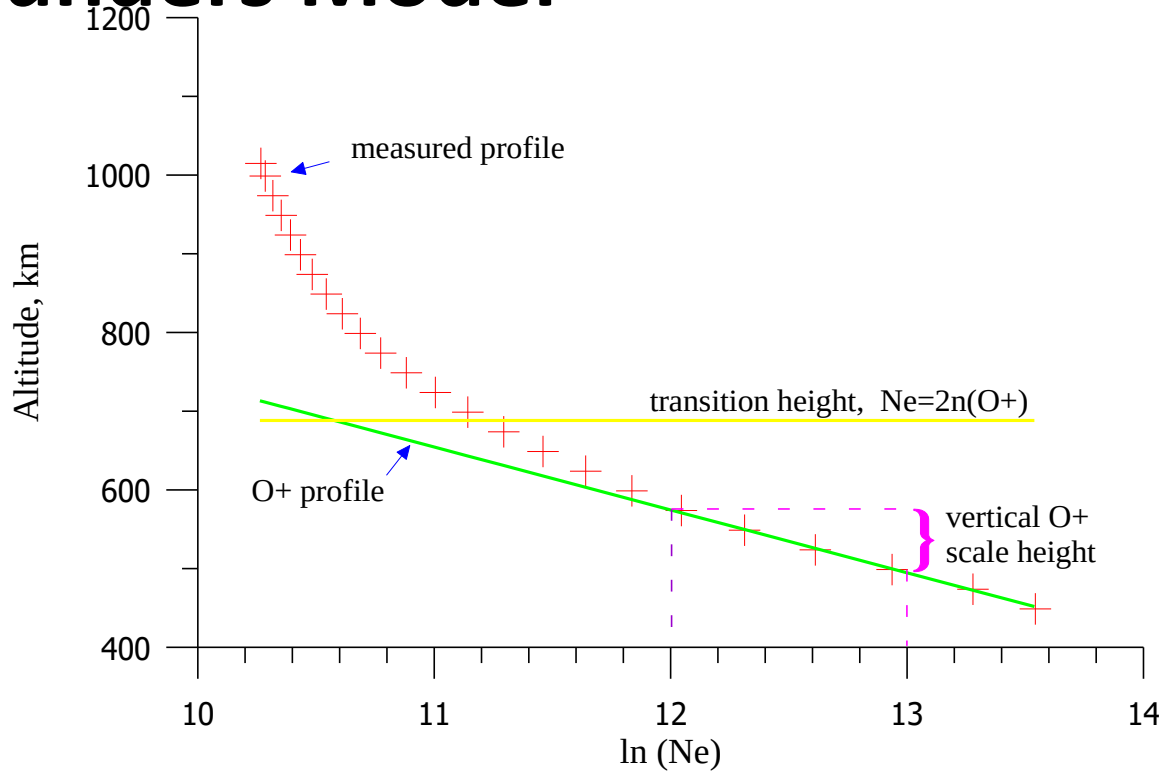
How TaD works:

The TaD profiling technique combines:

- **a core empirical model (TSM)** providing the topside scale height and upper transition (O^+- H^+) height,
- **a profiler (TSMP)** providing the shape of the vertical electron density profile in the topside and plasmasphere as a sum of O^+, H^+, and He^+ partial distributions,
- **a TSM-assisted Digisonde (TaD) profiler** ingesting Digisonde-derived parameters peak altitude, density, and topside scale height into TSMP, allowing real-time update of TSMP.

The basic concept behind the Topside Sounders Model

The database, archived at the National Space Science Data Center (NSSDC), Greenbelt, MA, includes 176,622 topside electron density (Ne) profiles from the Alouette-1a, -1b, -1c and -2 and ISIS-1 and -2 topside sounders, covering the period 1962-1979. A detailed description of the database is given by *Bilitza (2001).*



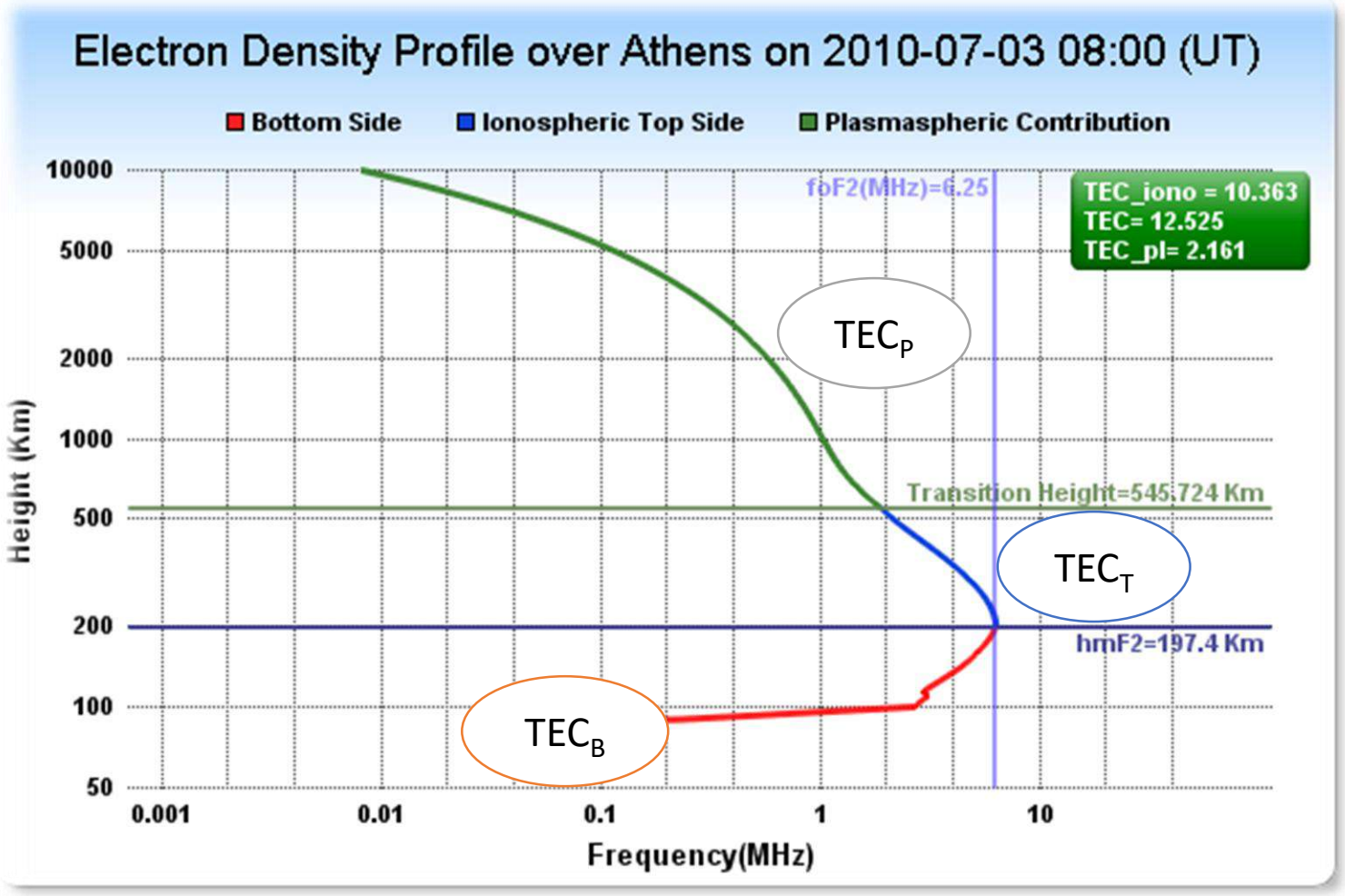
Two parameters are extracted from each individual Ne profile: the vertical O^+ scale height (H_T) and the O^+-H^+ transition height (h_T).

- H_T is defined as the lowest gradient of the measured Ne profiles
- h_T is defined as the height at which the extrapolated to higher altitudes lowest Ne gradient yields a density which is one half of the measured Ne.

Input Parameters	Code	Output
Month, LT, glat, f10.7, Kp	TSM: Topside Sounders Model Analysis of Alouette, ISIS-1,-2 topside profiles (Bilitza, 2001)	Empirical functions of H_T: topside scale height h_T : transition height R_T: ratio H_T/h_T
H_T ($\equiv H_{O+}$), h_T, H_m, N_m and *glat*	TSMP: Topside Sounders Model Profiler Analysis of ISIS-1 topside profiles to model plasmaspheric scale height	Empirical functions of H_P: plasmaspheric scale height ($\equiv H_{H+}$) $H_P=H_T(9cos^2 glat+4)$ *Ne*: electron density profile in the topside ionosphere and plasmasphere $Ne = N_O(h) + gN_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{Hp}\right) + (1-g)N_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{4H_T}\right)$ and $N_O(h) = Nm\exp\left\{-\frac{1}{2}\left[\frac{h-hm}{Hm}+1-\exp\left(\frac{h-hm}{Hm}\right)\right]\right\}$ g is the ratio N_H+ / N_O+ at h_T
Digisonde parameters at the height of maximum density (*hmF2*, *foF2*, H_m) and vTEC (GNSS) at the Digisonde location	TaD: TSM-assisted Digisonde Profiler Calculation of the actual profile over each Digisonde location to update TSMP with current Digisonde and TEC (GNSS) parameters	$Ne = N_O(h) + gN_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{Hp}\right) + (1-g)N_O(h_T)\exp\left(-\frac{\lvert h-h_T\rvert}{skH_m}\right)$ where $s=H_{He+}/kH_m$ k is the correction parameter that converts H_m (the neutral scale height) to make it compliant with H_T The integral of the Ne profile is adjusted to the measured vTEC by varying solely the correction parameter k

TEC maps from ROB GNSS group

TEC - TaD based products in EIS



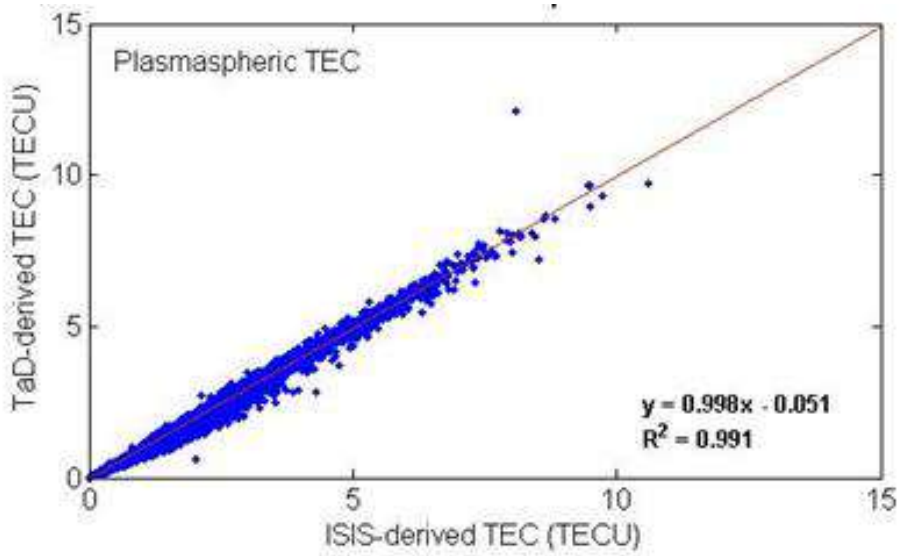
Validation of TaD model

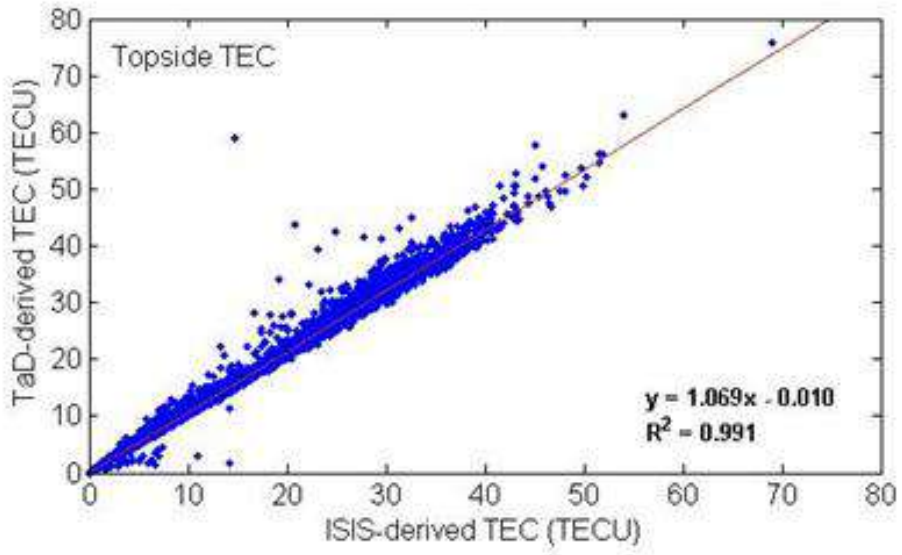
TaD is extensively tested and validated using independent observations:

- CHAMP TEC and profiling;
- ground-based GPS-TEC;
- Malvern Incoherent Scatter Radar (ISR);
- RPI sounder on IMAGE

Latest improvement, allows adjustment of TaD integral with GPS-derived TEC, increasing the accuracy of the method.

TaD validation results

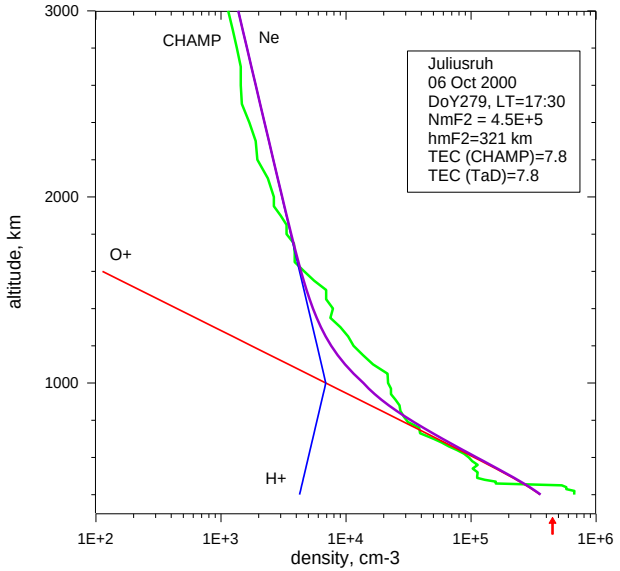


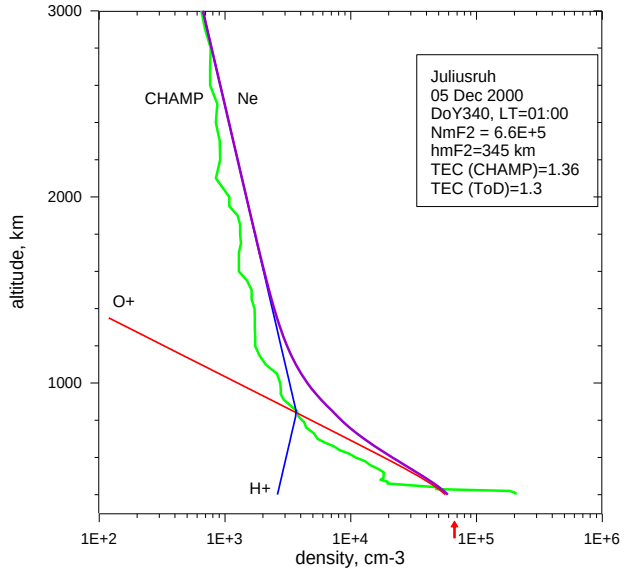


Internal consistency check: how well the model can reproduce ISIS-2 derived TEC

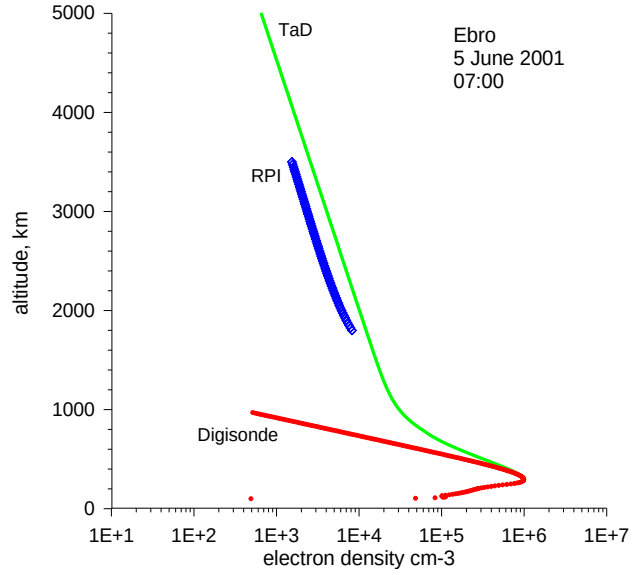
TaD validation results
Comparison with CHAMP and IMAGE/RPI derived profiles

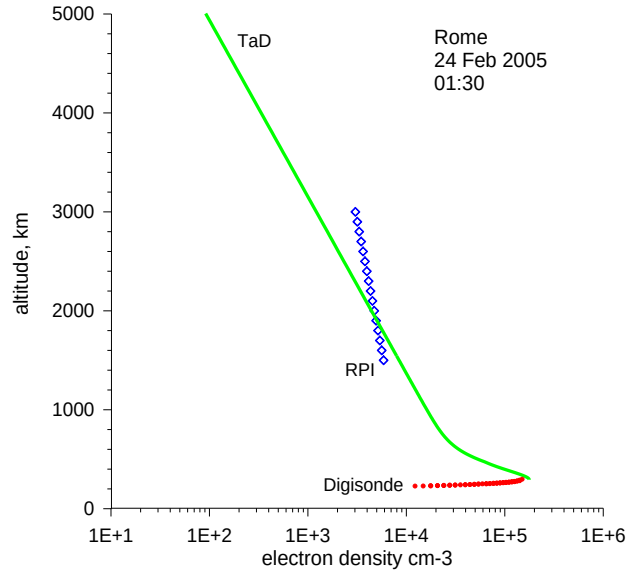
CHAMP



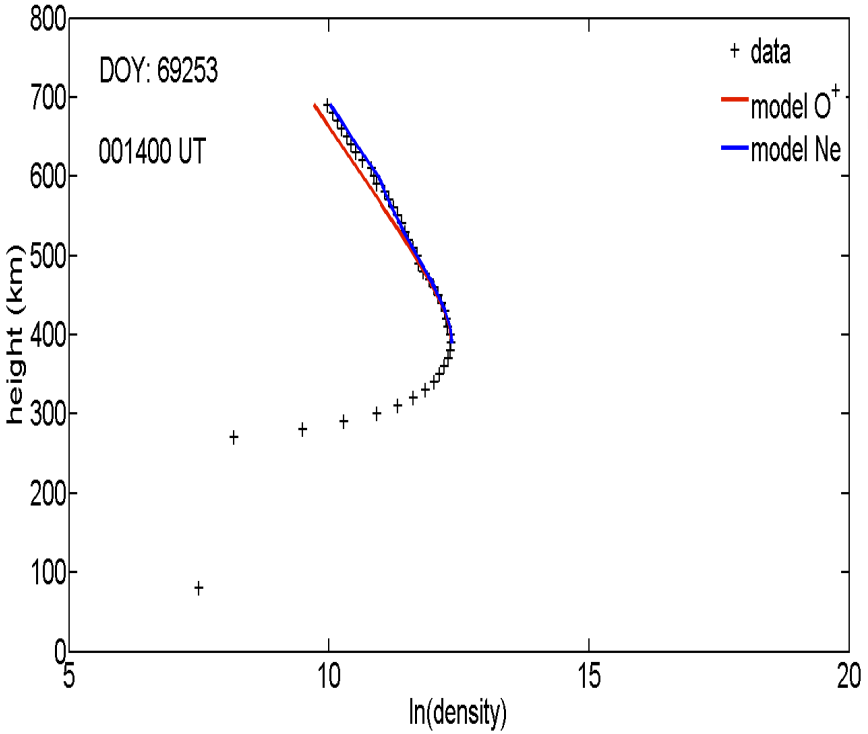


IMAGE

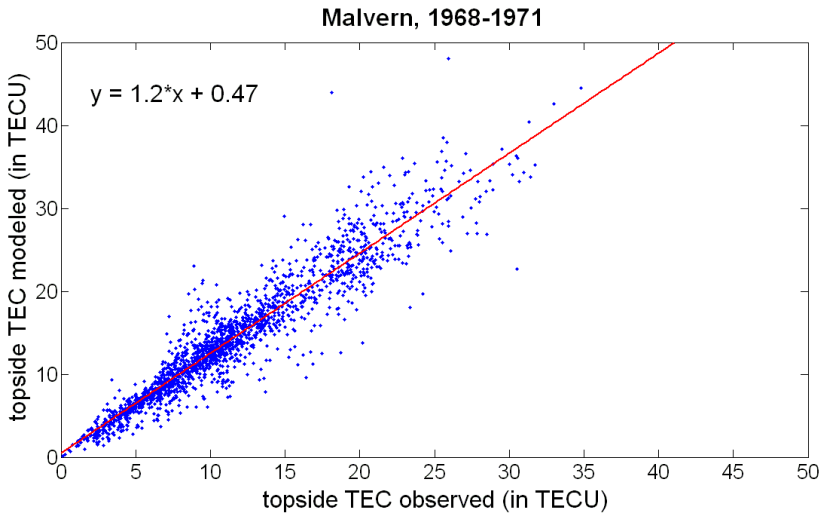


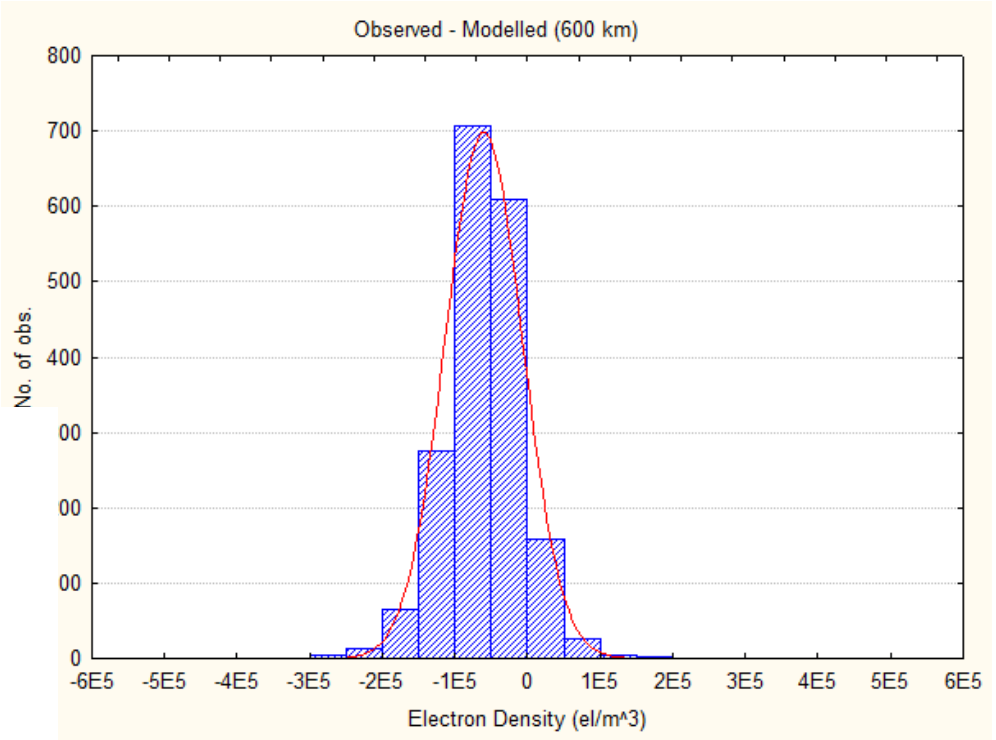


TaD validation results
Topside ED: comparison with Malvern ISR



Example for TaD derived profiles based at Malvern site

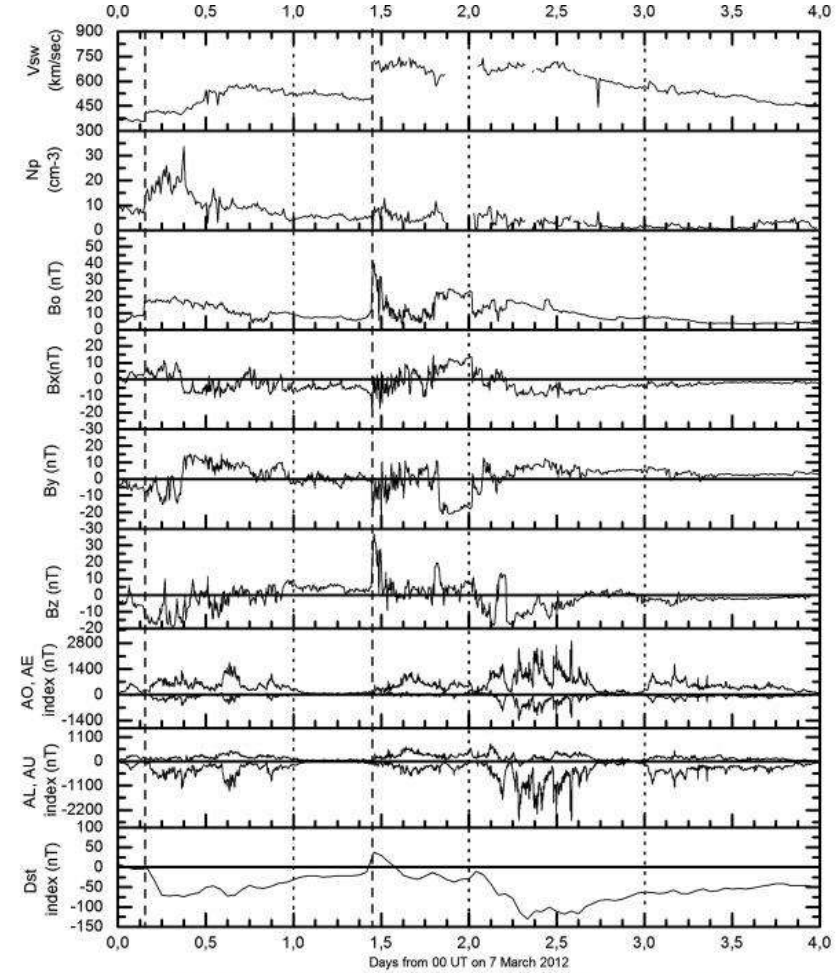


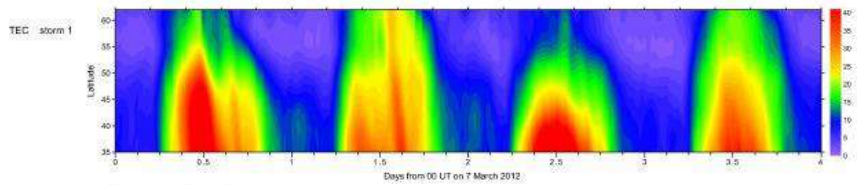


The distribution of the simple difference between the observed ISR and the modeled electron densities at 600 km

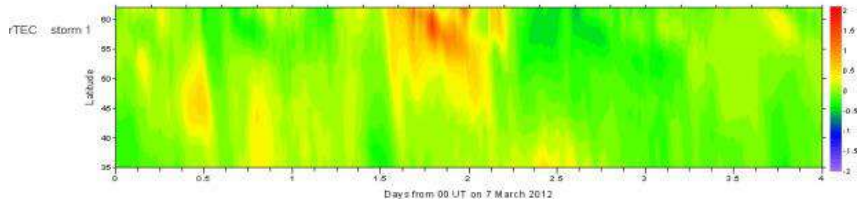
The TaD performance under ionospheric storms

Disturbed period 7-10 March 2012 selected to test TaD extensive capabilities



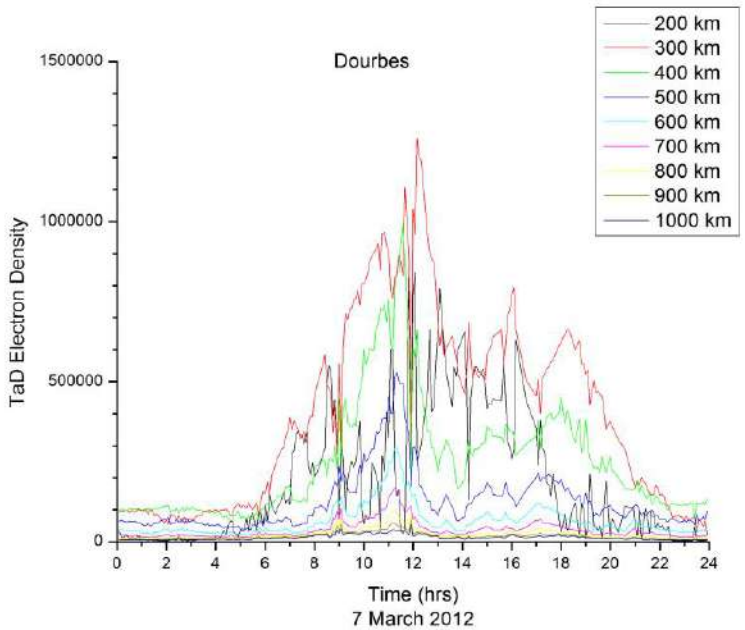


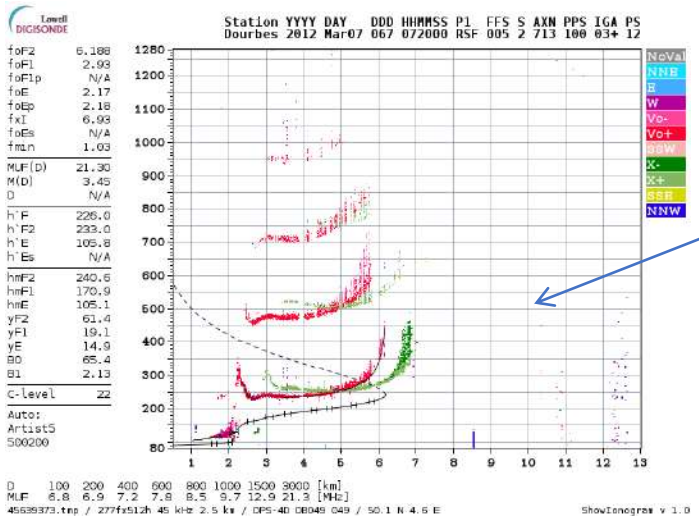
TEC calculated with the TaD model: absolute values

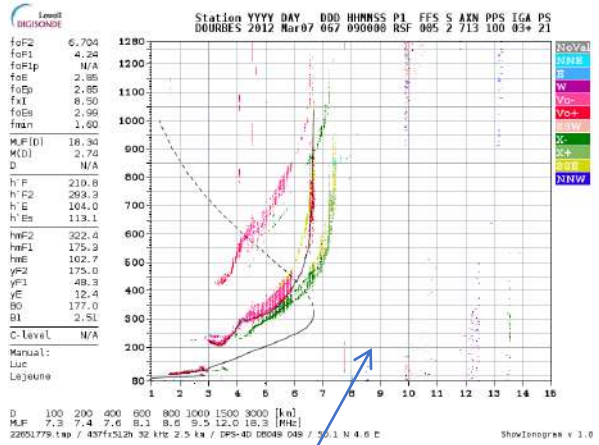


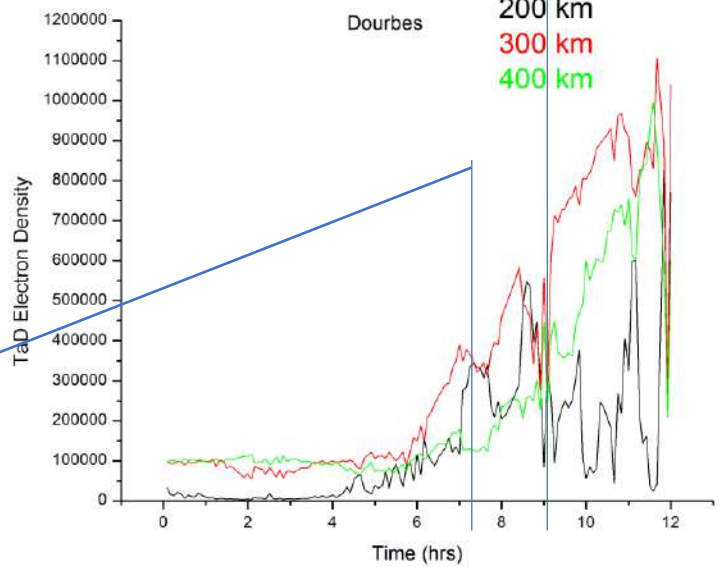
TEC calculated with the TaD model: Relative deviation from median values

The TaD performance under ionospheric irregularities (TIDs)

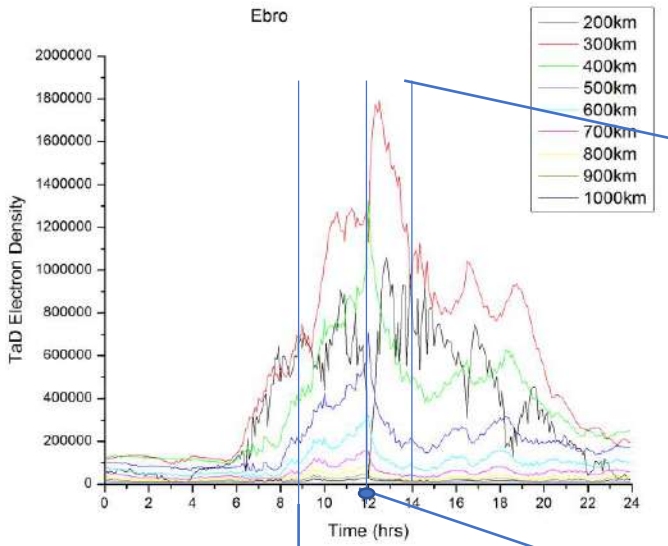


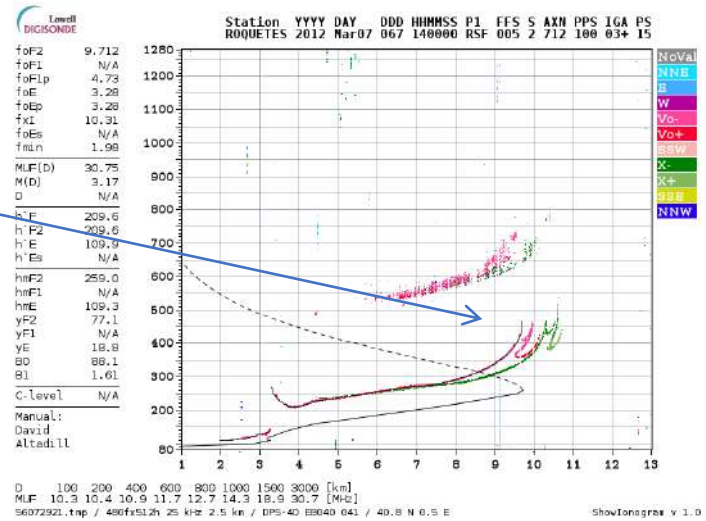


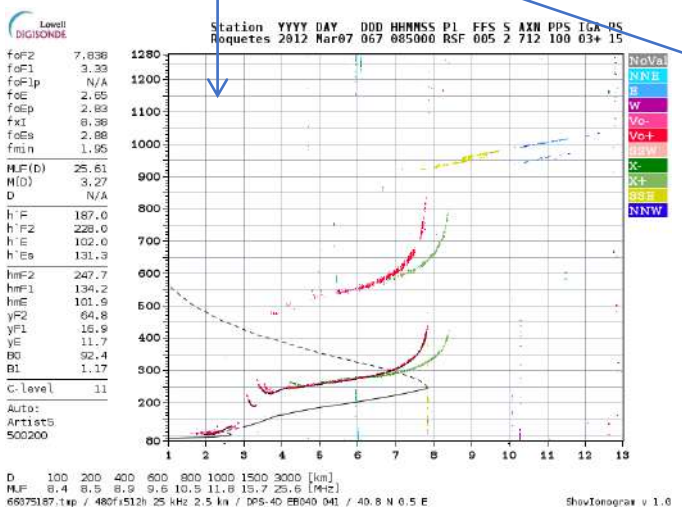


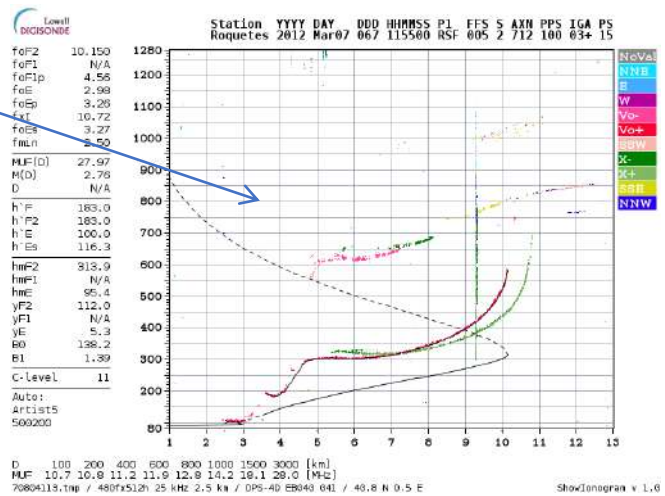


The TaD performance under ionospheric irregularities (TIDs)









Archived Quality Indicators of the EIS products

Year	Month	Day	Hour	Minute	(UTC)
2022	05	10	08	00	VIEW

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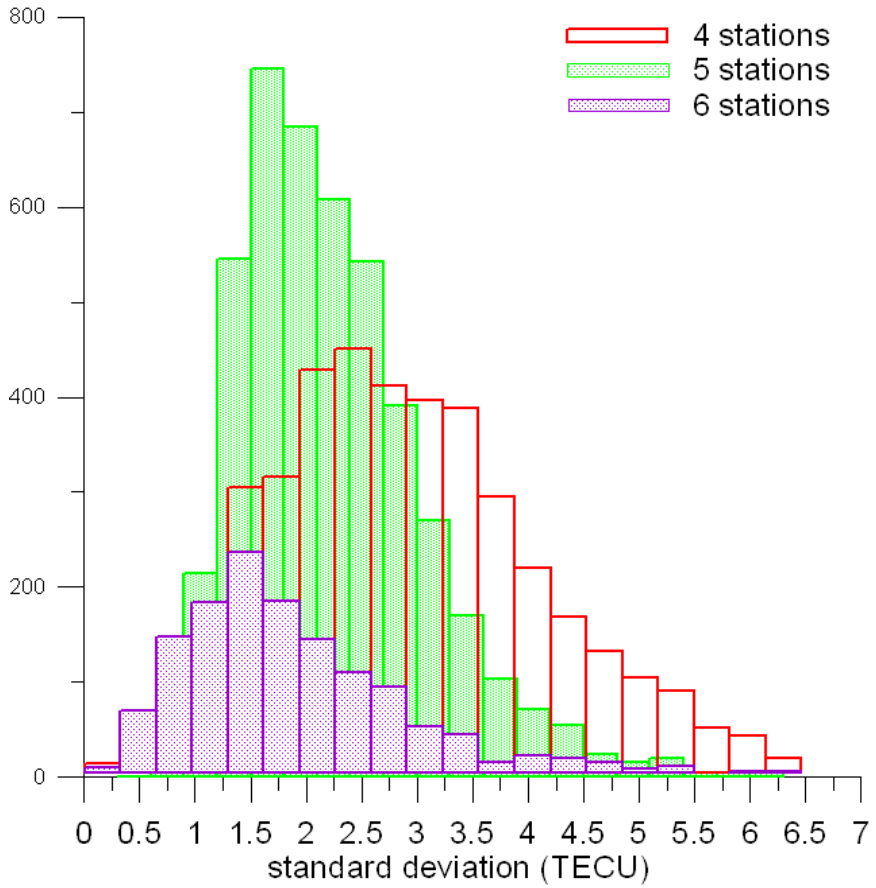
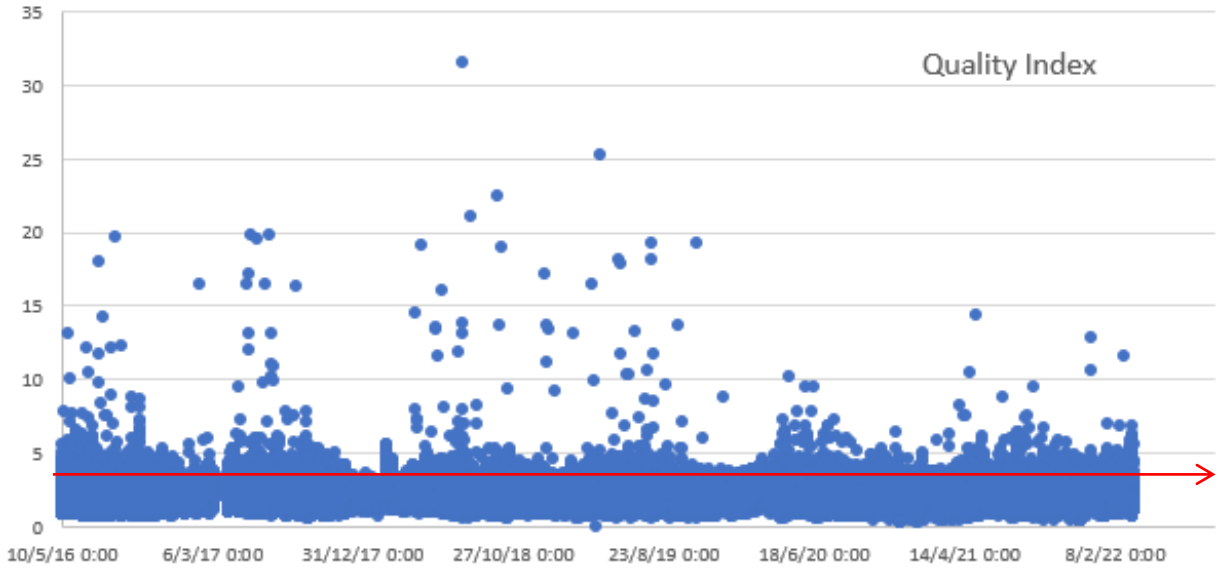
Product	Timestamp	# Stations	Available Stations	Deviation Metric
TEC Map	2022-05-10 08:00:00	5	Athens, Dourbes, Ebre, Juliusruh, Pruhonice	Deviation (TECU) 2.09

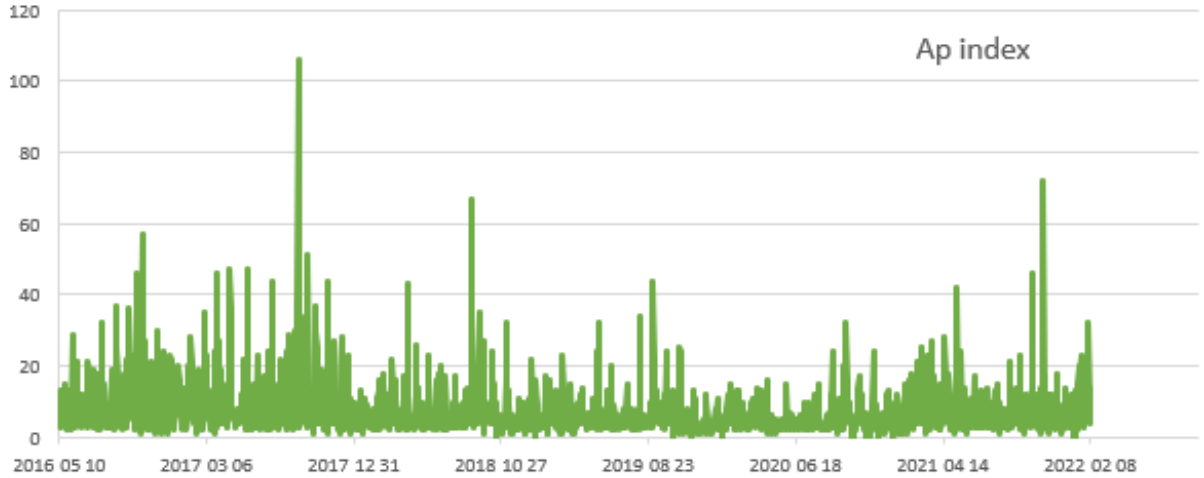
- The number of contributing Digisonde stations
- The deviation between the modelled TEC and the GNSS derived TEC parameters computed over the whole grid

The number of contributing Digisonde stations affect the accuracy of the TEC-TaD based maps





3TECU is the RMSE vs ROB maps



Geophysical conditions affect in general the quality of the TEC maps because of the occurrence of:

- Negative storm effects
- Strong scintillation
- Sporadic E layers
- Autoscaling errors in the ionograms

Thank you for your attention!