

# Recent upgrades in the Topside Sounders Model codes and possible links with IRI-2012

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# TSM set of codes

Present 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.

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 ( $\equiv H_{H^+}$ ) $H_p = H_T(9\cos^2 glat + 4)$ $N_e$ : electron density profile in the topside ionosphere and plasmasphere $N_e = N_{O^+}(h) + gN_{O^+}(h_T) \exp\left(-\frac{ h-h_T }{H_p}\right) + (1-g)N_{O^+}(h_T) \exp\left(-\frac{ h-h_T }{4H_T}\right)$  and $N_{O^+}(h) = Nm \exp\left\{-\frac{1}{2}\left[\frac{h-h_m}{H_m} + 1 - \exp\left(\frac{h-h_m}{H_m}\right)\right]\right\}$  $g$ 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	$N_e = N_{O^+}(h) + gN_{O^+}(h_T) \exp\left(-\frac{ h-h_T }{H_p}\right) + (1-g)N_{O^+}(h_T) \exp\left(-\frac{ h-h_T }{skH_m}\right)$  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 $N_e$ profile can be adjusted to the measured vTEC by varying solely the correction parameter $k$

# TSM-TSMP-TaD basic references

- Kutiev, I., and P. Marinov, Topside sounder model of scale height and transition height characteristics of the ionosphere, *Adv. Space Res.*, **39**, 759–766, 2007
- Kutiev, I., P. Marinov, A. Belehaki, N. Jakowski, B. Reinisch, C. Mayer, and I. Tsagouri, Plasmaspheric electron density reconstruction based on the Topside Sounder Model Profiler, *Acta Geophys.*, **58 (3)**, 420–431, 2009
- Belehaki, A., I. Kutiev, B. Reinisch, N. Jakowski, P. Marinov, I. Galkin, C. Mayer, I. Tsagouri, and T. Herekakis, Verification of the TSMP-assisted Digisonde (TaD) topside profiling technique, *Acta Geophys.*, **58 (3)**, 432–452, 2009
- Kutiev, I., P. Marinov, S. Fidanova, A. Belehaki, and I. Tsagouri, Adjustments of the TaD electron density reconstruction model with GNSS TEC parameters for operational application purposes, *J. Space Weather Space Clim.*, **2**, A21, 2012
- Belehaki, A., I. Tsagouri, I. Kutiev, P. Marinov, and S. Fidanova, Upgrades to the Topside Sounders Model assisted by Digisonde (TaD) and its validation at the topside ionosphere, *J. Space Weather Space Clim.*, **2**, A20, 2012

# Verification of TaD at a single site location

TaD is extensively tested and verified using independent observations:

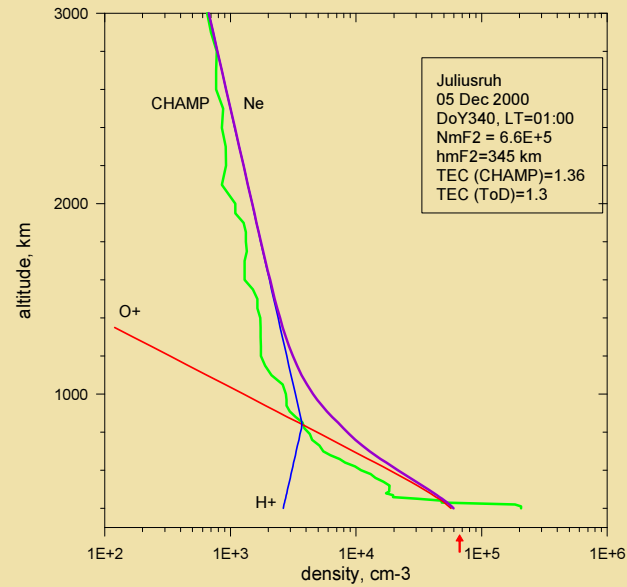
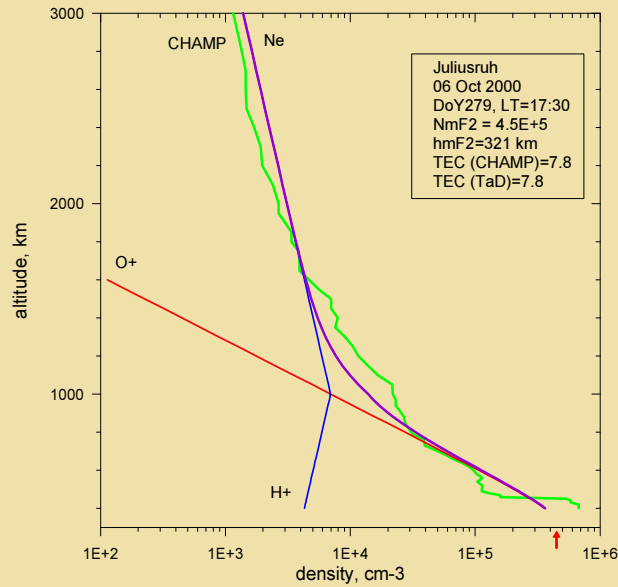
- CHAMP TEC and profiling;
- ground-based GPS-TEC;
- Malvern Incoherent Scatter Radar (ISR);
- RPI sounder on IMAGE

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

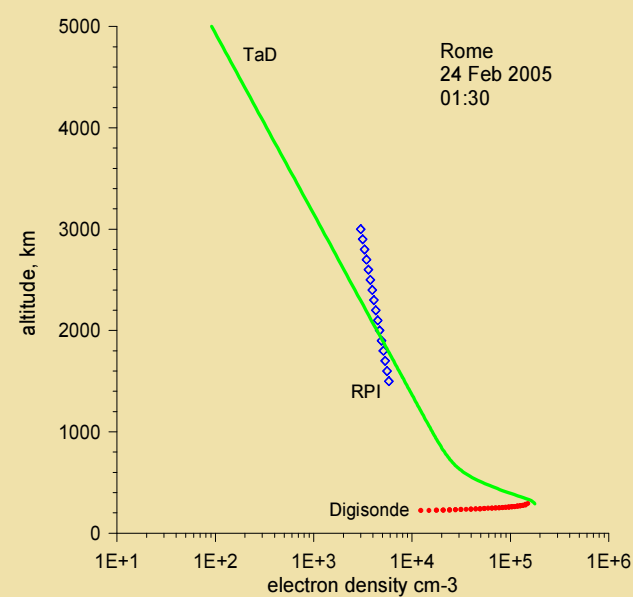
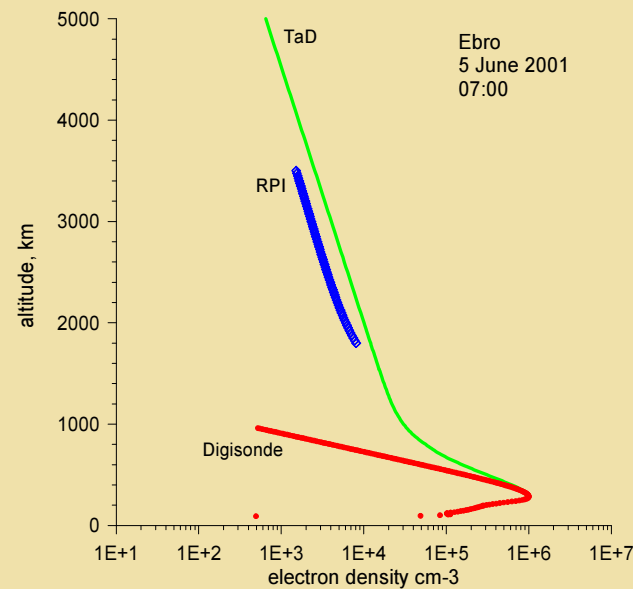
# TaD verification results

## Comparison with CHAMP and IMAGE/RPI derived profiles

CHAMP

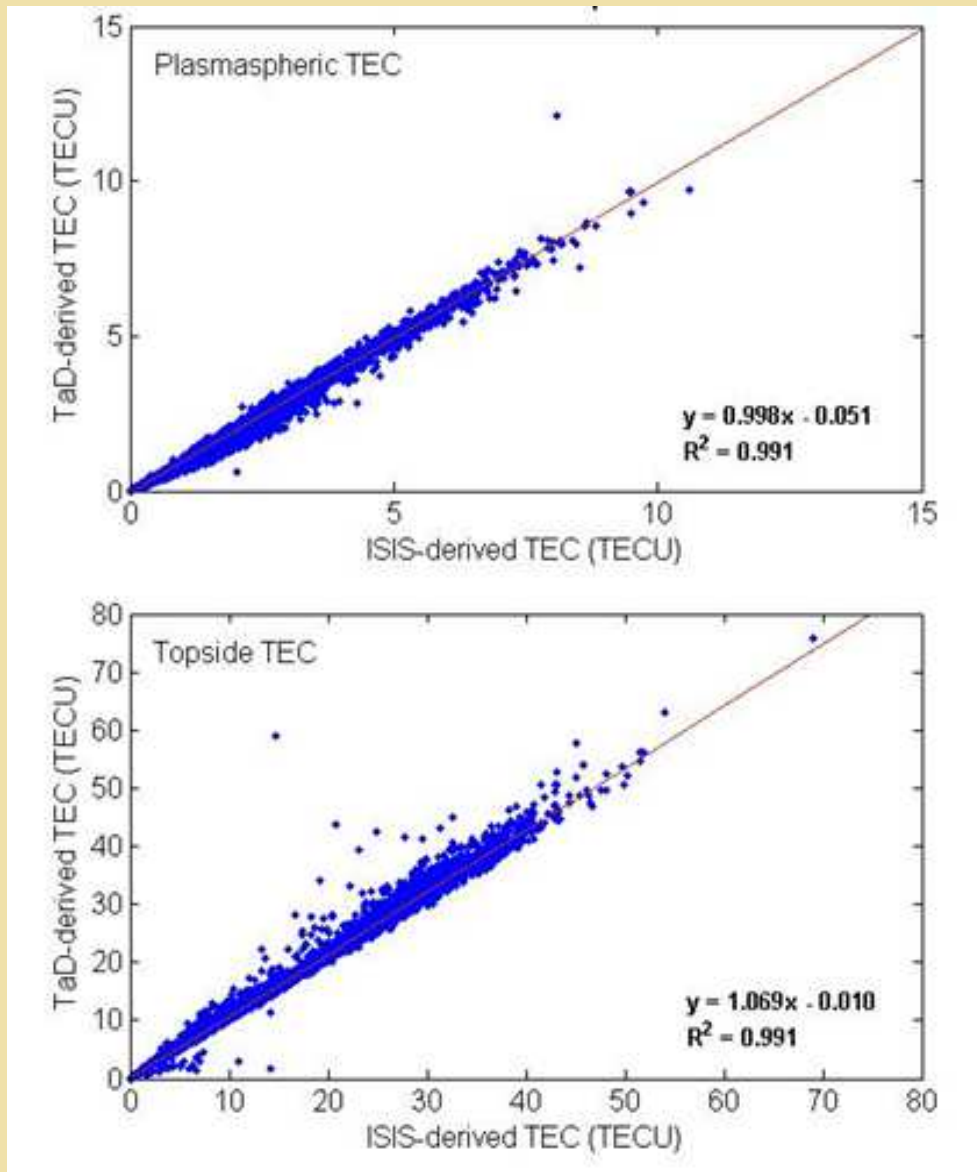


IMAGE



Belehaki et al.,  
Acta Geo., 2009

# TaD verification results

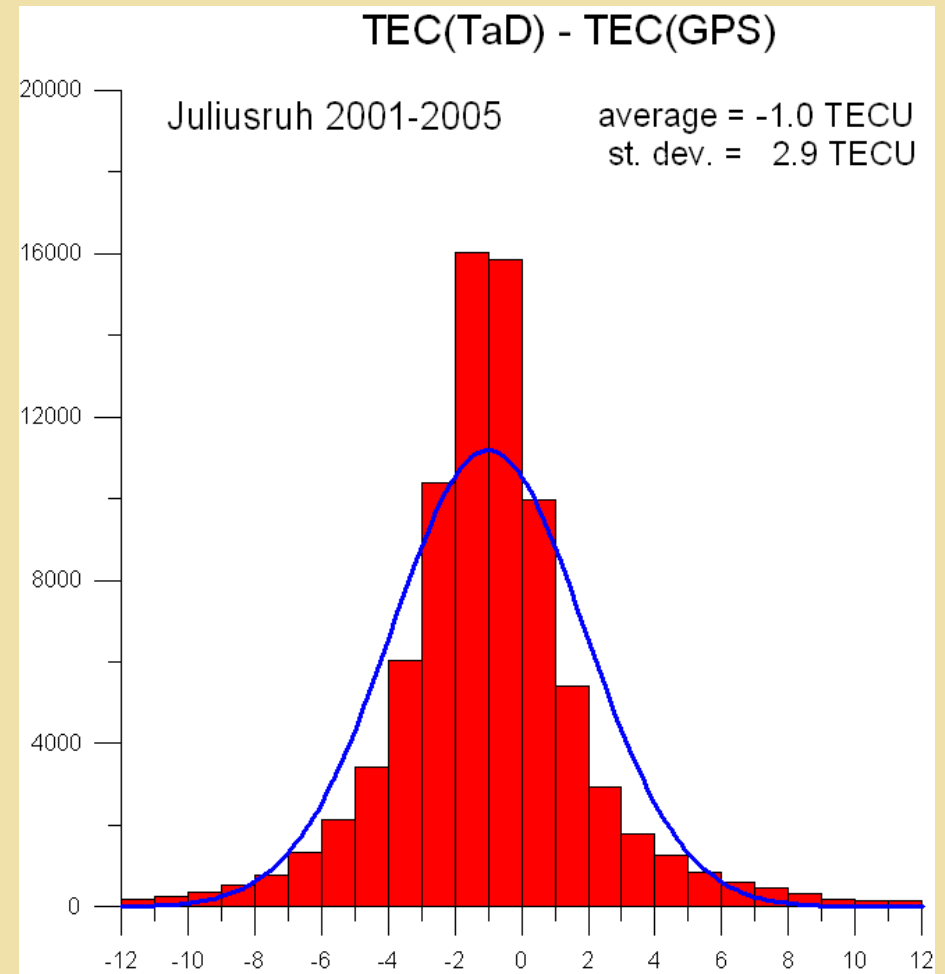
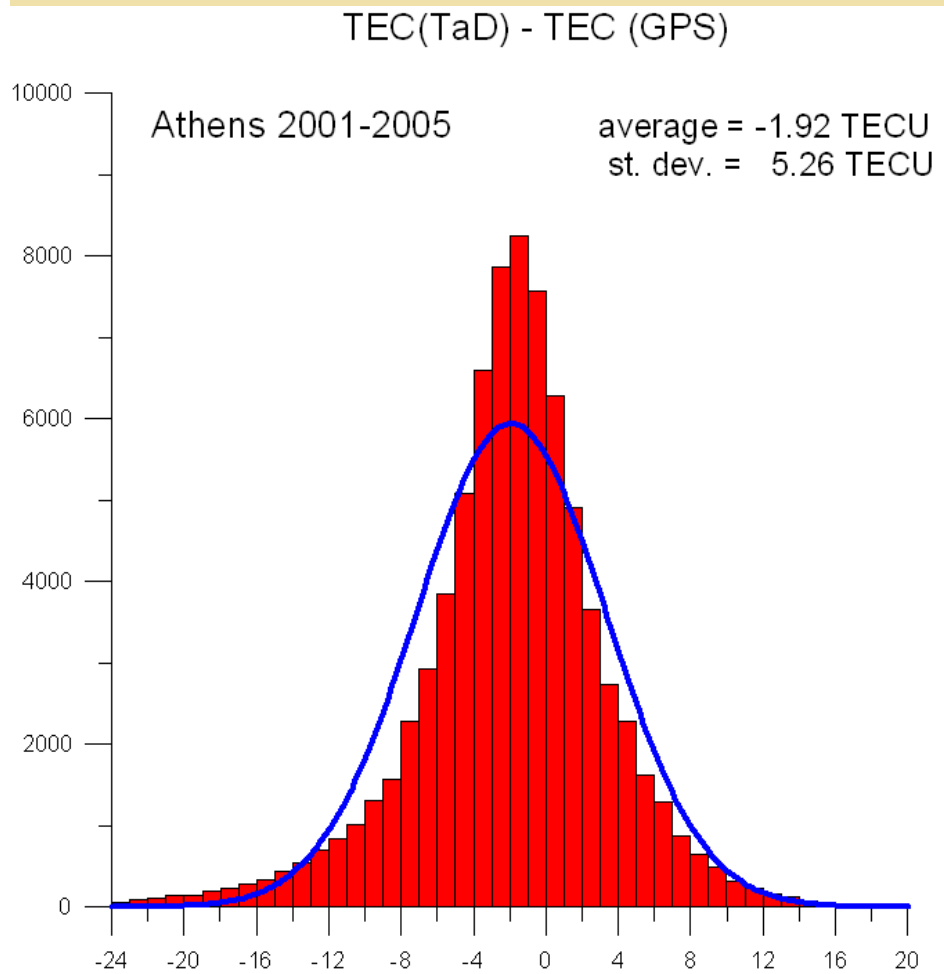


Internal consistency check:  
how well the model can  
reproduce ISIS-2 derived  
TEC

From  
Belehaki et al., SWSC,  
2012

# TaD verification results

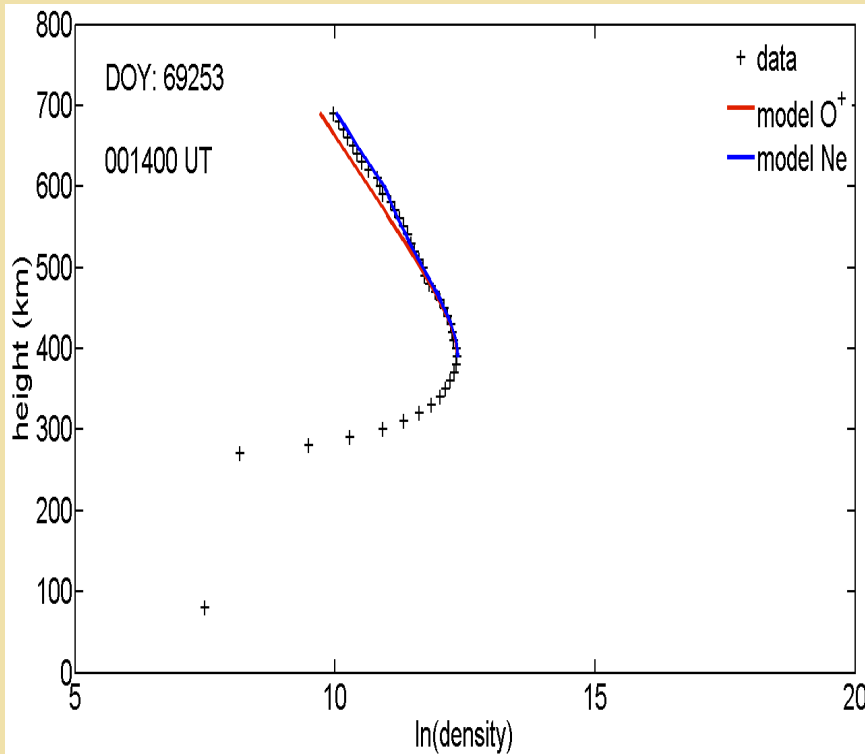
## Comparison with TEC-GNSS ground based receivers





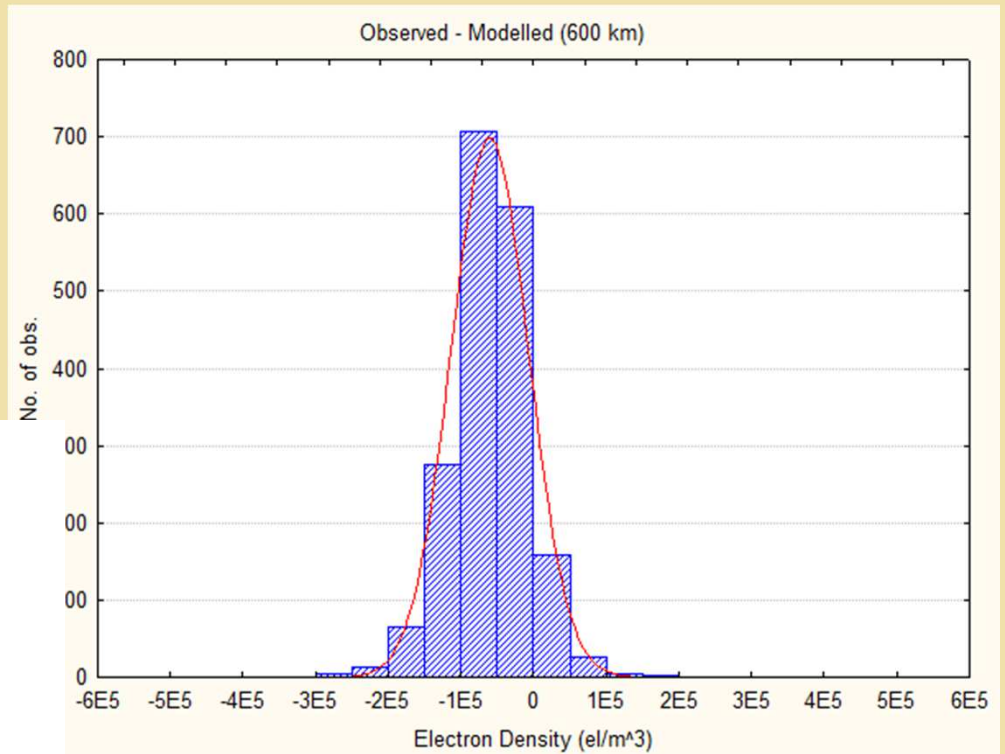
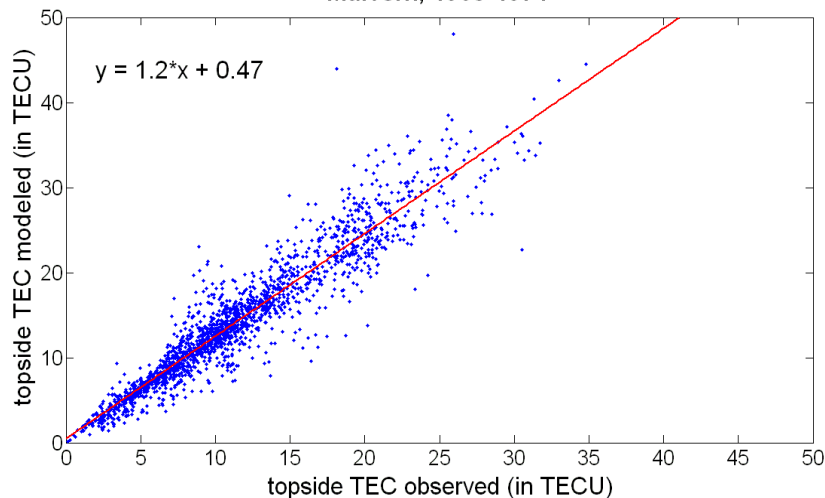
# TaD verification results

## Topside ED: comparison with Malvern ISR



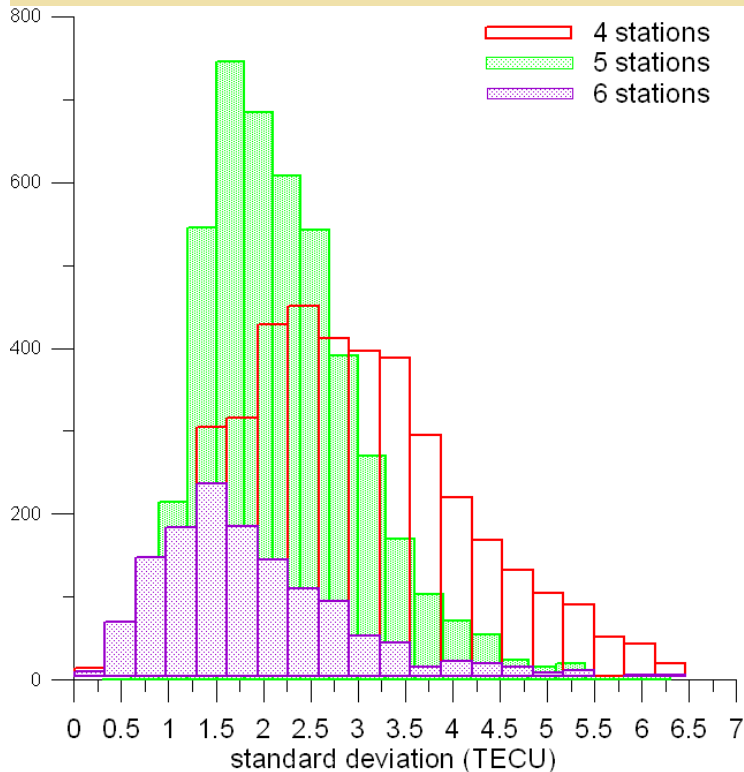
Example for TaD derived profiles based at Malvern site

Malvern, 1968-1971

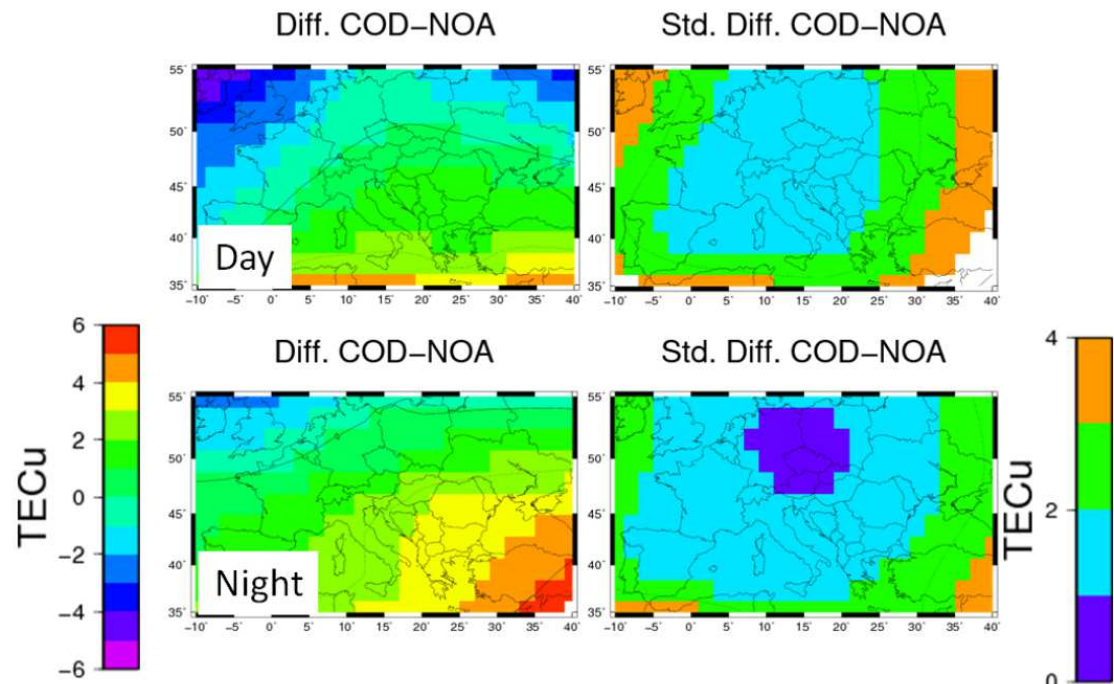


The distribution of the simple difference between the observed ISR and the modeled electron densities at 600 km

# Validation of TaD maps



Comparison of TaD-TEC maps with EUREF-ROB and CODE maps for a period of 12 months (November 2012 – October 2013). Reasonable agreement with a maximum discrepancy of 3 TECU for the 96% of the cases, depending on the latitude of the geographic location under consideration.



# TaD operational implementation

## DIAS: EDD at predefined heights



DIAS Project is co-funded by the *eContent* programme of the European Union 

Home Page

NOA IAP CCLRC DIDBASE INGV SGO Ebre UFA INTA IZMIRAN

Home Page

Information

Ionograms

f-plots

SSN plot

HF propagation maps

Electron Density

TEC maps

ED Bottomside maps

ED Topside maps

Profile over station

Ionospheric Activity

Alerts

Historical Data

Subscription

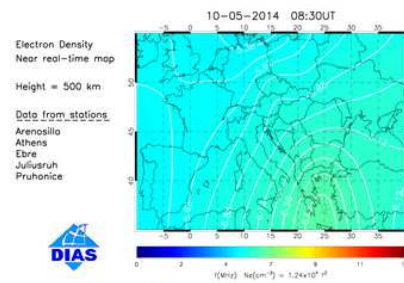
Near real-time of the topside electron density over Europe

Help Year 2014 Month 05 Day 10 Hour 08 Minute 30 UT VIEW

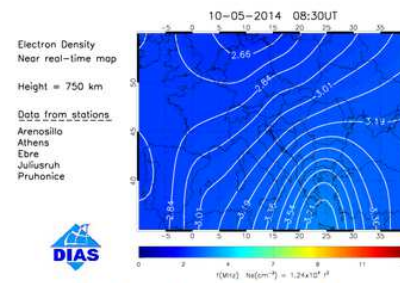
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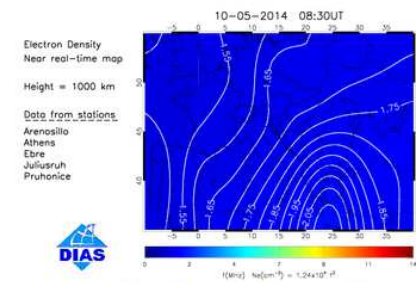
Latest available maps



Electron Density at 500km



Electron Density at 750km



Electron Density at 1000km



# TaD operational implemmentation

DIA



Mozilla Firefox

hertz2.space.noa.gr:8080/LatestDias2/TEC\_maps.jsp

View data file

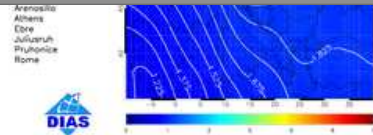
10-05-2014 09:15UT

TEC

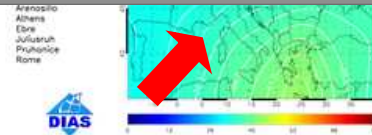
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DIAS TEC map @ 10-05-2014 09:15UT
Longitudes: -10E to 40W (left to right column)
Latitudes: 35N to 55N (top to bottom row)
Considered stations: Arenosillo Athens Ebre Juliusruh Pruhonice Rome
0.33228E+02 0.33117E+02 0.33034E+02 0.33219E+02 0.33273E+02 0.33435E+02 0.33724E+02 0.33895E+02 0.3
0.37533E+02 0.37945E+02 0.38111E+02 0.38509E+02 0.38892E+02 0.39266E+02 0.39389E+02 0.39773E+02 0.4017
0.43398E+02 0.43091E+02 0.42852E+02 0.42218E+02 0.41532E+02 0.40863E+02 0.40524E+02 0.39995E+02 0.3951
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0.37317E+02 0.37514E+02 0.37948E+02 0.38367E+02 0.38758E+02 0.39128E+02 0.39237E+02 0.39596E+02 0.3996
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0.37095E+02 0.37315E+02 0.37773E+02 0.38208E+02 0.38606E+02 0.38971E+02 0.39064E+02 0.39398E+02 0.3973
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```

User logout




TEC Plasmaspheric



TEC Total

# TaD operational implementation

## ESA-SSA SWE: TEC and partial TEC


space situational awareness

ESA
SSA
SWE
NEO
SST

**About SWE**

- What is Space Weather
- SSA Space Weather Activities
- User Domains
- Current Space Weather
- Contact

**Expert Service Centres**

- Solar Weather
- Space Radiation
- Ionospheric Weather
- Geomagnetic Conditions

**SWE Applications**

- SWENET
- SPENVIS
- SEISOP
- SEDAT
- IONMON
- EDID
- Applications Preferences


**Other Resources**

- DOCUMENTS
- SWWT
- SWEN NEWSLETTER
- UPCOMING EVENTS

**Sign-In**

- Kostas Themelis is signed in
- Sign Out

Federated products from the Ionospheric Group of the National Observatory of Athens (NOA)



DIAS Project is co-funded by the *eContent* programme of the European

**TEC Maps**

- EIS Home
- Current Ionospheric Conditions
- Ionospheric Alerts
- foF2 nowcasting maps
- foF2 long term prediction maps
- foF2 forecasts
- Integrated Electron Density Maps
- Rules of the Road
- The EIS team
- ESA SSA-SWE Portal

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

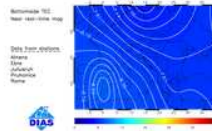
Near real-time maps of partial TEC over Europe

Year: 2014
Month: 05
Day: 10
Hour: 14
Minute: 45
UT
VIEW

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Latest available

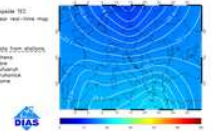
Latest available maps

Bottomside TEC  
Near real-time map



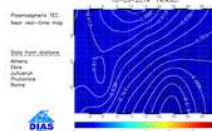
DIAS

Topside TEC  
Near real-time map



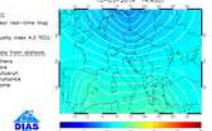
DIAS

TEC Bottomside  
10-05-2014 14:45UT



DIAS

TEC Topside  
10-05-2014 14:45UT



DIAS

TEC Plasmaspheric
TEC Total

TEC maps are generated with the Tsd model using data from European Digisondes participating in DIAS project and TEC parameters provided by the Royal Observatory of Belgium

# Conclusions

- TSMP provides the **electron density profile in the topside ionosphere and plasmasphere**, based on the modeling of Alouette, ISIS-1 and ISIS-2 data
- TSMP depends on TSM parameters  $H_T$  and  $h_T$  and on the independent parameters month, LT, glat, Kp and F10.7
- TSMP offers the basic empirical functions based on which TaD calculates 3D electron density profiles and TEC maps over the area of the DIAS network. The service is running for more than a year, demonstrating **operational reliability even with autoscaled F2 parameters**.
- Through IRI-2012, TSMP can be provided as an additional option, to allow **further validation** by the community of IRI users