Ionospheric specification services delivered by the National Observatory of Athens for the European Space Agency

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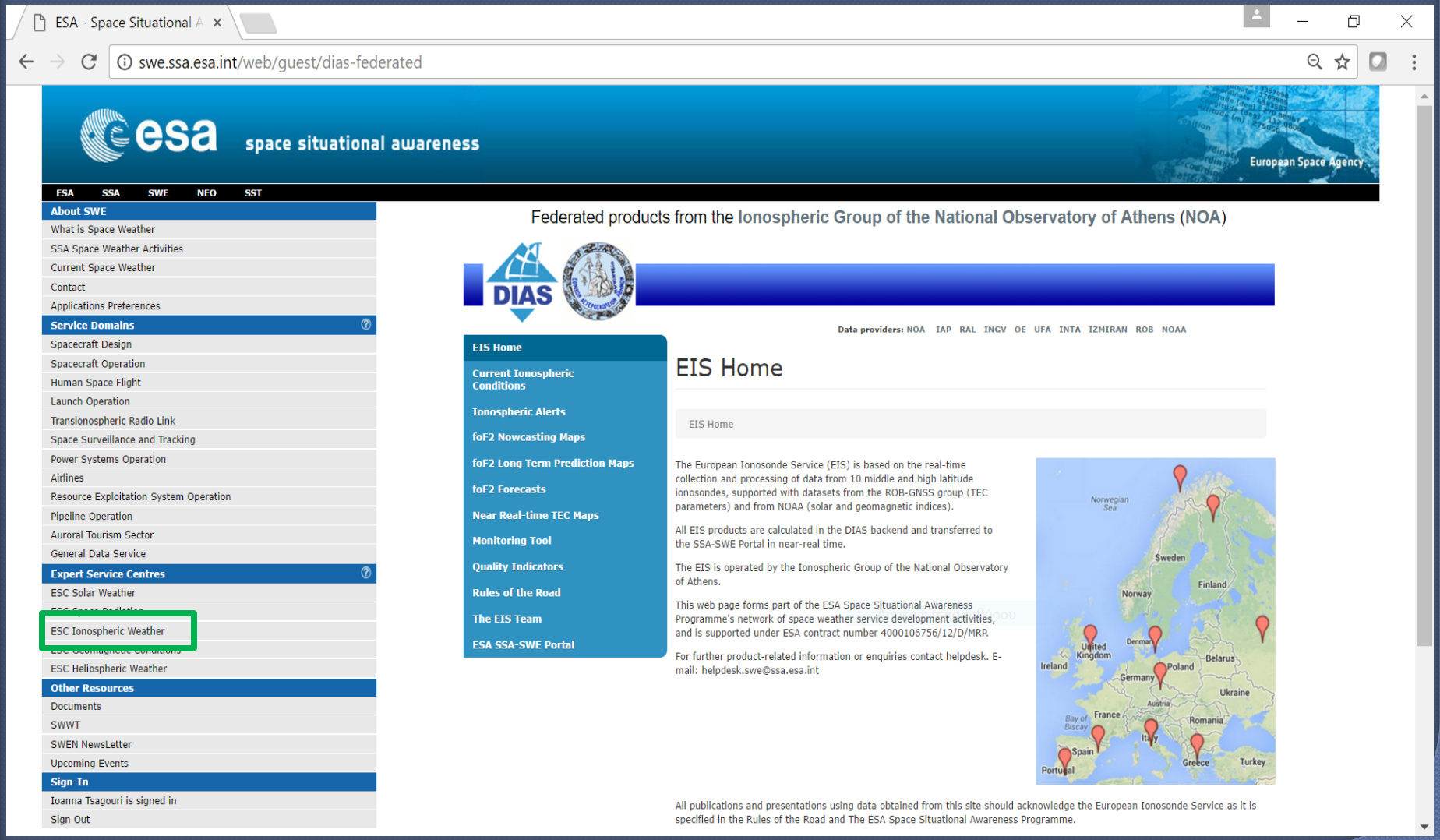
European Ionosonde Service (EIS)

ESA Space Situational Awareness Programme / Space Weather Service Network: available at http:\\swe. ssa.esa.int after registration



European Ionosonde Service (EIS): exploitation of the DIAS network (http:\\dias.space.noa.gr)

DIAS Ionosonde Network

- IMF observations from ACE
- Solar and geomagnetic indices from NOAA
- TEC maps from ROB

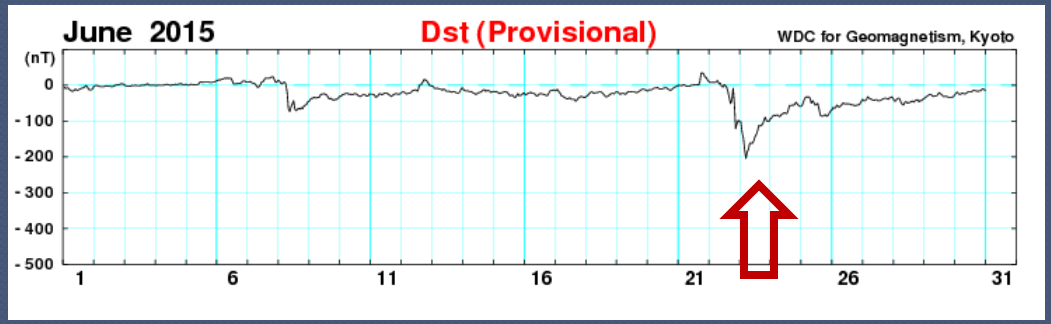
- Nowcasting and forecasting products
- Validation studies
- Quality indicators

DIAS Models

Background model	Related products
Combination of the **Simplified Ionospheric Regional Model (SIRM)** and the Comité Consultatif International pour la Radio (**CCIR**) model [*Zolesi et al.*, 1993; *Belehaki et al.*, 2015].	• Long-term predictions of the foF2
The enhanced version of the **Simplified Ionospheric Regional Model Updated in Real-Time (SIRMUP)** [*Zolesi et al.*, 2004; *Belehaki et al.*, 2015]	• Nowcasting regional maps of the foF2 critical frequency
The enhanced version of the **Solar Wind Driven Autoregression Model for Ionospheric Short-term forecast (SWIF)** [*Tsagouri et al.*, 2009; *Tsagouri and Belehaki*, 2015; *Belehaki et al.*, 2015].	• Maps of the forecasted foF2 over Europe for the next 24 hours • Alerts for the forthcoming ionospheric disturbances in the European sector • Forecasted foF2 values for the next 24 hours over each station.
The **Topside Sounders Model – assisted by Digisondes (TaD)** [*Kutiev et al.*, 2012; *Belehaki et al.*, 2015].	• Near real-time TEC maps for the European region
Real time activity index	• Maps of current ionospheric conditions at each station location

EIS monitoring and prediction capabilities

Strom event: 21 – 25 June 2015

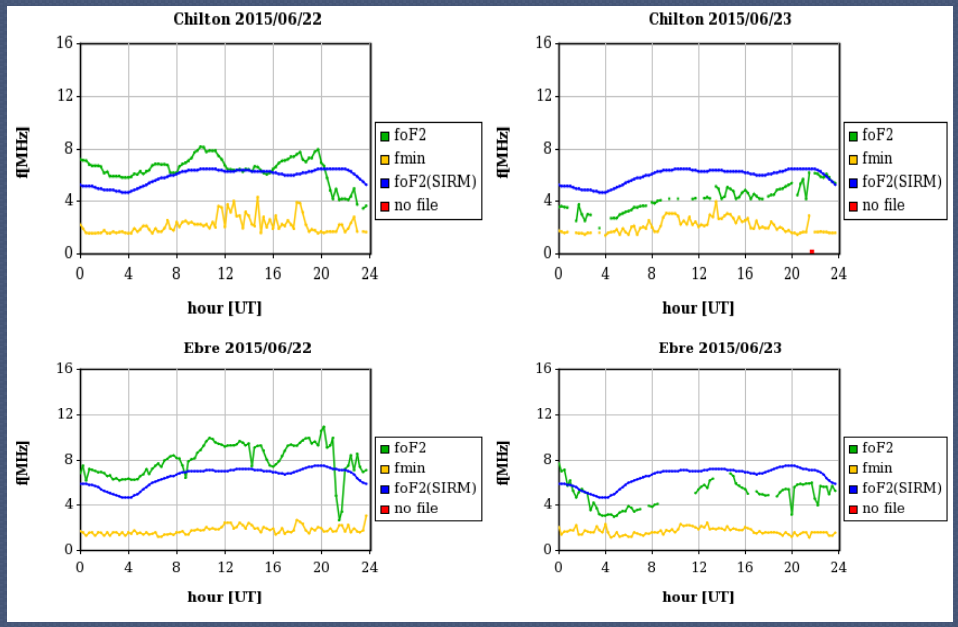


Storm characteristics:

- Intense storm event with multiple onsets
- Min Dst: -204 nT
- CME-driven event (http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm)

Ionospheric response

Ionization increases (positive storm effects) and decreases (negative storm effects) are apparent over Europe during the June 22 and June 23, respectively. The predictions of the SIRM model are also provided as representative of the ionospheric reference level.



EIS Alerts (based on the SWIF model, Tsagouri et al 2009; Tsagouri and Belehaki, 2015)

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EIS Product I.110: Alerts for ionospheric disturbances in the European sector (based on the Alert Algorithm of the SWIF model)
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EIS Ionospheric Storm Alert for Europe powered by the DIAS backend

Issue Time: 2015-06-22 18:00 UT
Updated on: 2015 06 22 23:00 UT
Updated on: 2015-06-23 04:00 UT
Updated on: 2015-06-23 06:00 UT
foF2 storm time disturbances are expected over Europe from 22-06-2015 to 24-06-2015

Expected storm effects
Positive: Possible at middle to low latitudes
Negative: Possible up to 46% (locally)
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National Observatory of Athens
Ionospheric Physics Group, IAASARS
DIAS - European Digital Upper Atmosphere Server
For more information, see http://dias.space.noa.gr
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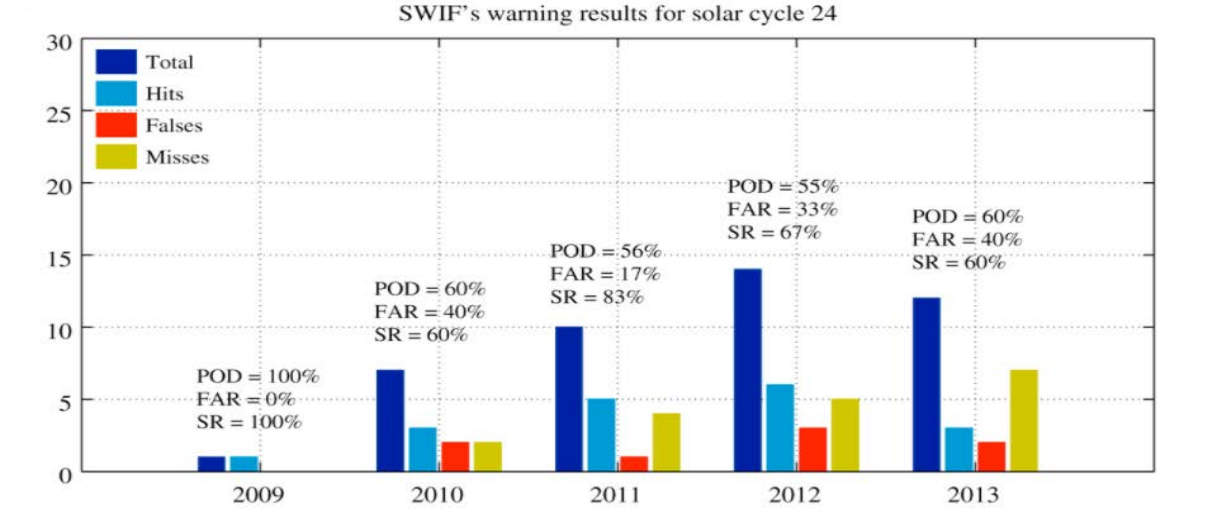
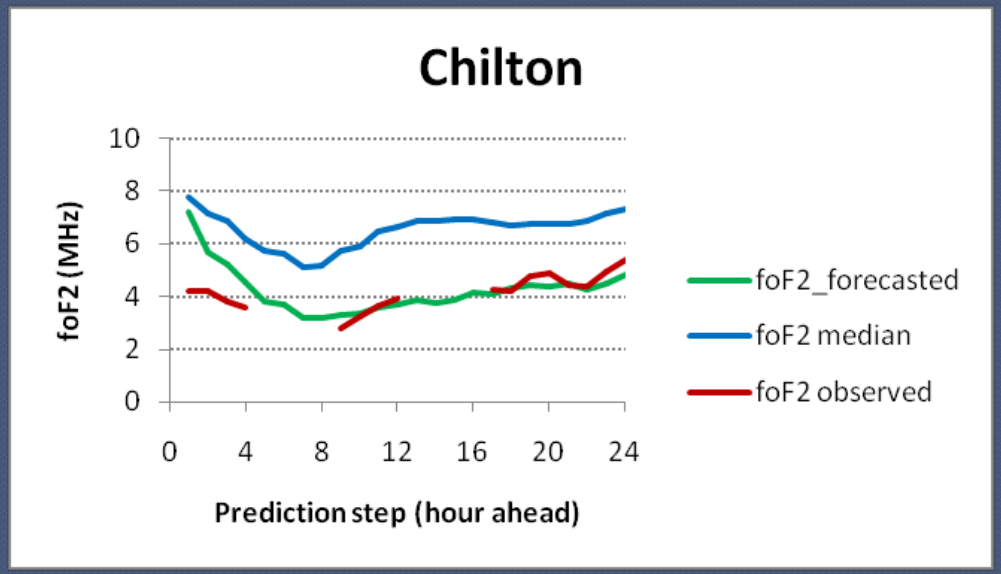


The EIS alert issued on 23 June 2015 at 06:00 UT. This was the last one of a series of alerts that were issued by the system during the specific storm event and summarizes all previous alert activity (see the list of updates in the report).

The alerts are provided with an average probability of detection 80% (*Tsagouri and Belehaki*, 2015).

EIS Forecasts (based on the SWIF model, Tsagouri et al 2009; Tsagouri and Belehaki, 2015)



The single site 24-hour forecasts of the foF2 issued by EIS for Chilton location on 22 June 2015, 20:00 UT. The plot was reproduced here to include actual measurements of the foF2 for comparison purposes.

EIS Product I.120: Forecast foF2 values for the next 24 hours over each DIAS station (based on the SWIF and on the GCAM models)
foF2 forecast (SWIF model) for Chilton at 2015/06/22 20:00 UT

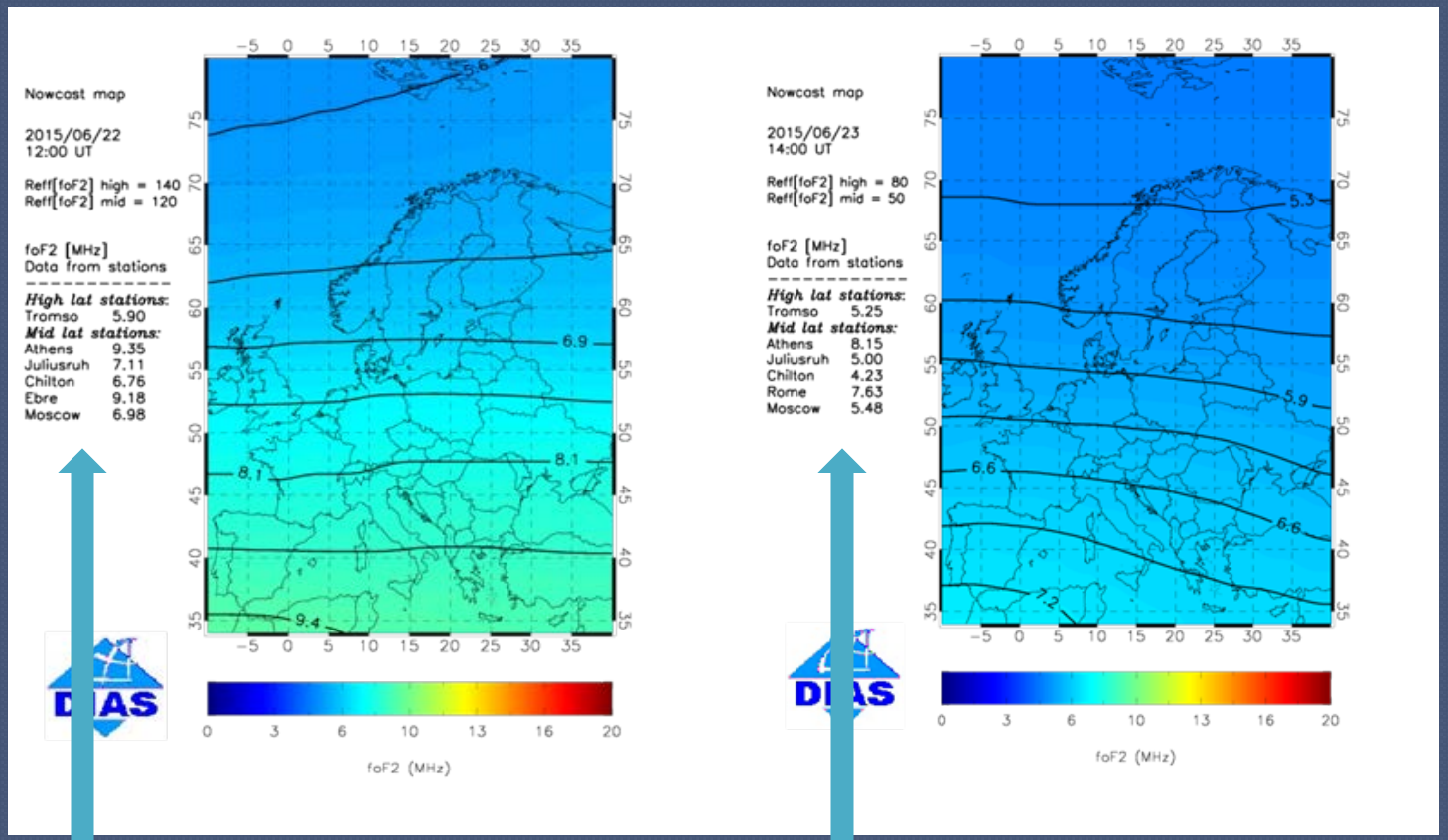
Hour	Forecasted foF2 (SWIF) (MHz)	Running Median (25-days) (MHz)	Swif mean relative Error (%)
21:00	7.190	7.800	6.580
22:00	5.680	7.150	9.060
23:00	5.210	6.850	10.030
00:00	4.530	6.200	10.570
01:00	3.790	5.750	10.840
02:00	3.690	5.600	10.890
03:00	3.210	5.100	10.960
04:00	3.180	5.160	10.850
05:00	3.280	5.750	11.020
06:00	3.340	5.930	10.890
07:00	3.600	6.460	10.670
08:00	3.690	6.650	10.570
09:00	3.880	6.880	10.600
10:00	3.760	6.850	10.560
11:00	3.850	6.930	10.610
12:00	4.130	6.920	10.530
13:00	4.080	6.790	10.460
14:00	4.300	6.710	10.340
15:00	4.420	6.780	10.400
16:00	4.400	6.770	10.400
17:00	4.470	6.780	10.360
18:00	4.290	6.850	10.410
19:00	4.500	7.160	10.390
20:00	4.810	7.330	10.510

Quality indicators

- Mean Relative Error (%)
- Running Medians

Available at the main nodes of the network (*Tsagouri and Belehaki*, 2015).

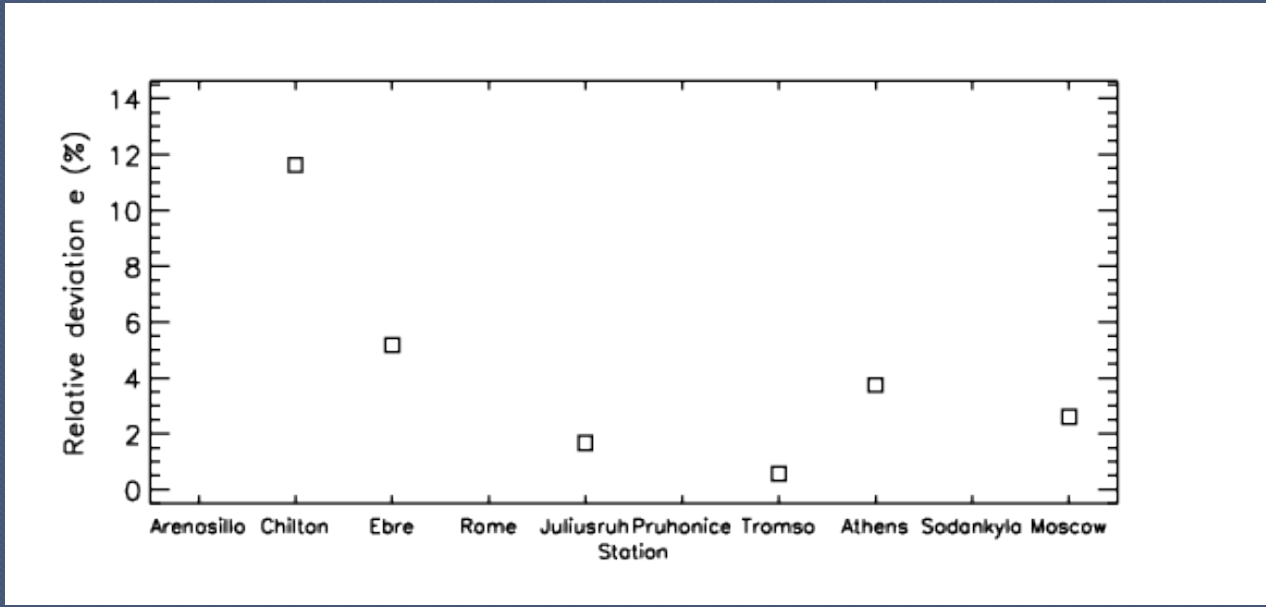
EIS Nowcasting products: foF2 (based on the SIRMUP model, Zolesi et al. 2004; Belehaki et al., 2015)



EIS nowcasting maps of the foF2 critical frequency: 22 June 2015, 12:00 UT (left: positive storm effects) and 23 June 2015, 14:00 UT (right, negative storm effects).

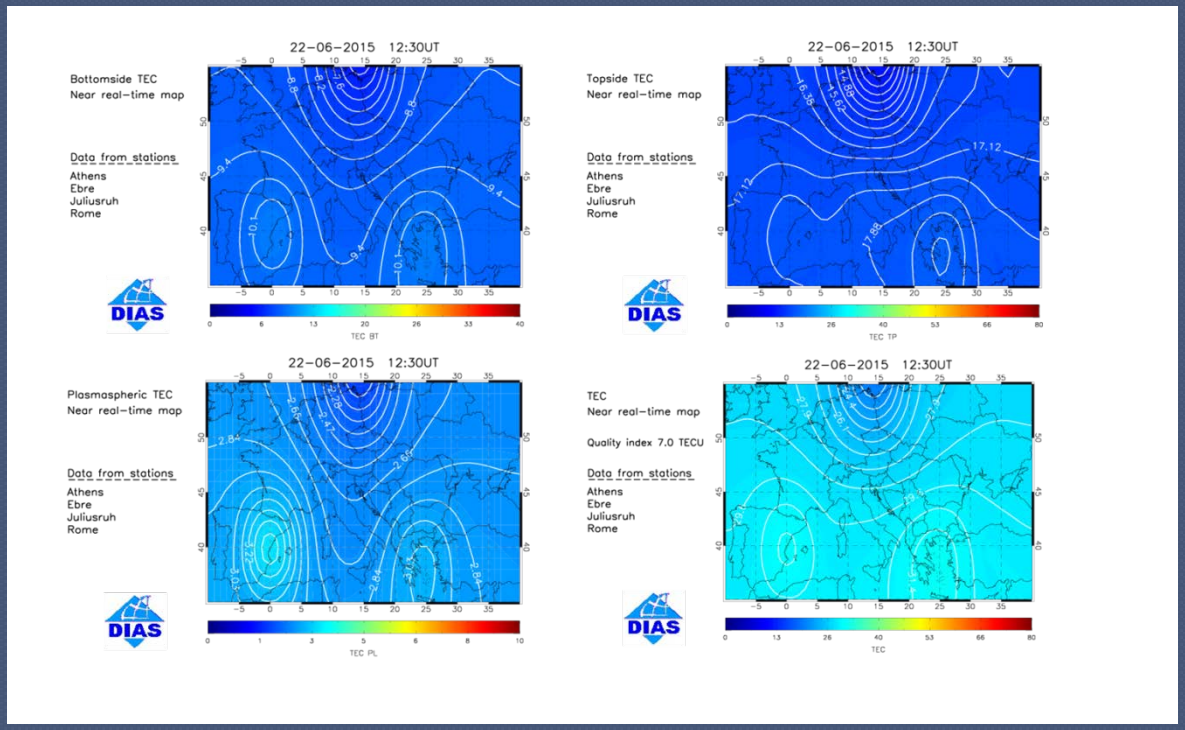
Quality indicators: number of stations used for the generation of the maps.
Example: 5 stations in the mid-latitudes and one station in the high latitudes: nowcasting estimates of significant reliability *(Belehaki et al., 2015).*

EIS Nowcasting products: foF2 (based on the SIRMUP model, Zolesi et al. 2004; Belehaki et al., 2015)



Quality indicators: The relative deviation of the nowcasted from observed foF2 values over the reference stations is given as a quality indicator for EIS nowcasting services. *(Belehaki et al., 2015).*

EIS Nowcasting products: Near real time TEC maps (based on the TaD model: *Kutiev et al.*, 2012; *Belehaki et al.*, 2015)

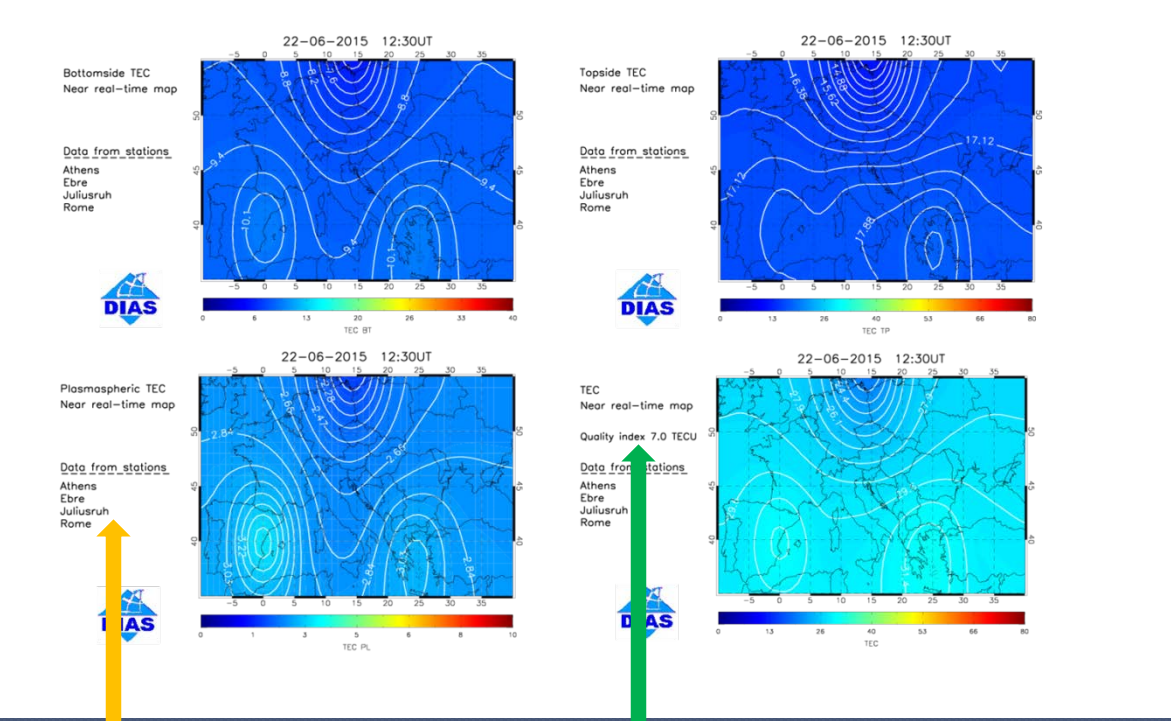


Positive storm effects are apparent in the TEC parameter.

Near real-time TEC maps for the European region generated on 22 June 2015, 12:30 UT:

- Bottomside TEC: The integrated electron density from 90 km to the hmF2 altitude
- Topside TEC: The integrated electron density from the hmF2 altitude up to the O+/H+ transition height
- Plasmaspheric TEC is the integrated electron density from the O+/H+ transition height up to 20,000 km
- Total TEC is the integrated electron density from 90 km up to 20,000 km.

EIS Nowcasting products: Near real time TEC maps (based on the TaD model: *Kutiev et al.*, 2012; *Belehaki et al.*, 2015)

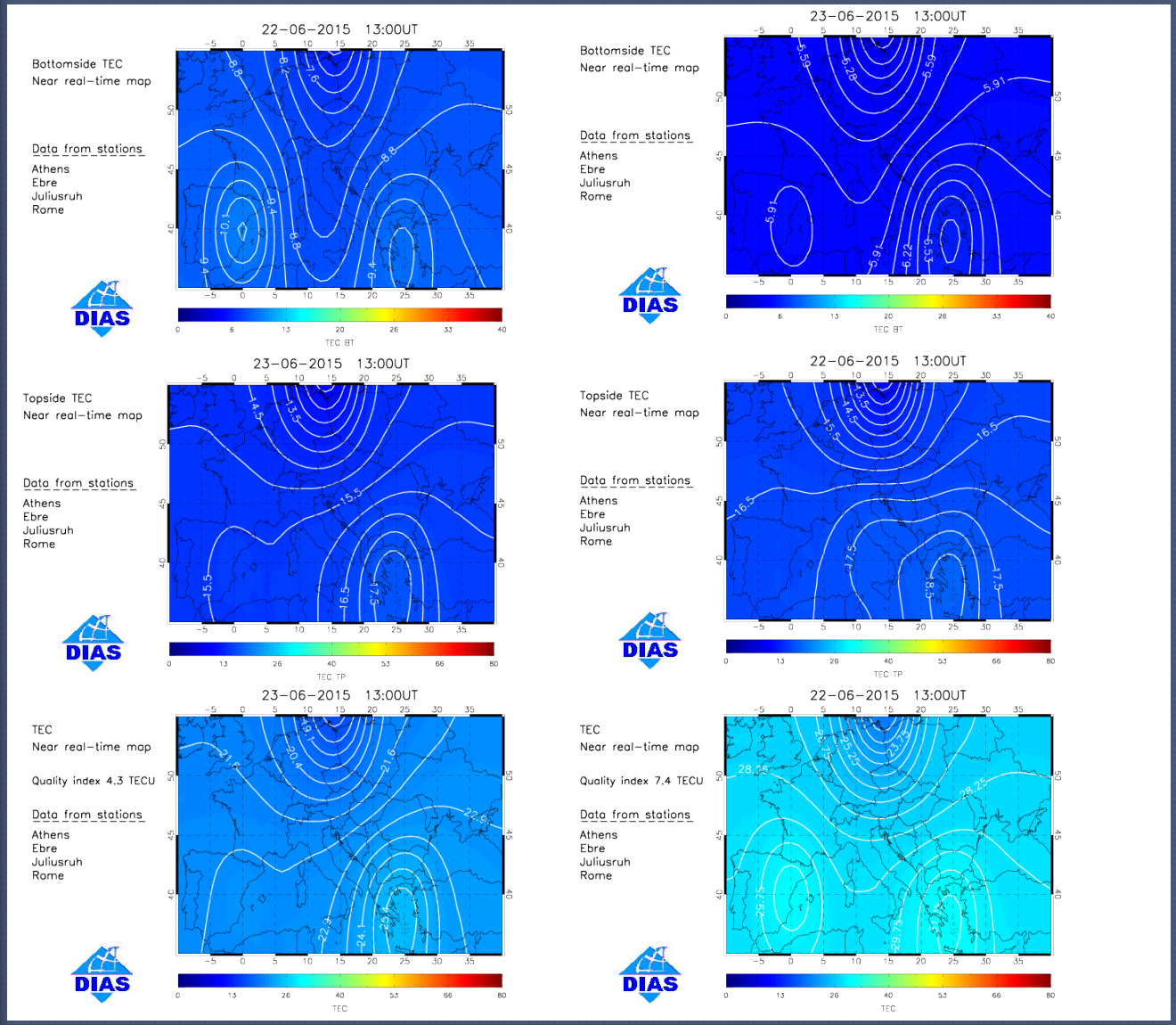


Quality indicators

- Number of stations: 4 stations is the minimum number of stations required for the generation of the map.

- Quality index, which is a measure of the deviation between the model and the GNSS-derived TEC parameters. The smallest the quality index is, the best is the fit between the model-derived maps and the GNSS-derived TEC maps.

EIS Nowcasting products: Near real time TEC maps (based on the TaD model: *Kutiev et al.*, 2012; *Belehaki et al.*, 2015)



While the TEC over Europe mapped at 13:00 UT on 23 June 2015 shows clear signs of ionization decrease over the area in respect to the same representation taken the previous day, inspecting the maps of the partial TEC along the bottomside and topside parts of the electron density profile, we conclude that the decrease is mainly due to ionization changes in the bottomside ionosphere.

Future Improvements

- Improved forecasting algorithms for ionospheric disturbances: in its present form, the SWIF model predicts mainly ionospheric foF2 disturbances driven by CME-associated structures at L1 point. Improvements include the consideration of the effects of solar flares [*Kontogiannis et al.*, 2016] and high-speed solar wind streams [*Tsagouri and Belehaki,* 2015], but also the expansion of the models' capabilities in forecasting the TEC storm-time response [*Tsagouri et al.,* 2017 this meeting].

- New algorithms for the identification of travelling ionospheric disturbances based on the measurement of angle-of-arrival, Doppler frequency, and time-of-flight of ionospherically reflected high-frequency (HF) radio pulses exploiting the capabilities of modern ionosondes DPS4D [*Reinisch et al.,* 2017].

- Improved 3D electron density distribution models to trace the variation of the electron density along any arbitrary orbit in space which is a specific request of satellite operators [*Kutiev et al.*, 2016].