Ground-based techniques and networks for monitoring the Earth's ionosphere: Latest developments in Europe

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Features of digital ionosondes

Common features of digital ionosondes:

Integration with a PC for programmable scheduling

Observing-mode parameter settings

System control and data management

Differences: They differ considerably in ideology, ranging from analog-ionosonde emulation to highly specialized or highly generalized data acquisition concepts.

- CADI
- IPS-71
- BIZON
- PARUS
- KOS
- Digisonde
- Dynasonde

Ionospheric Observatories in Europe

Rome (Italy)	http://dps-roma.ingrm.it/
Chilton (UK)	http://www.wdc.rl.ac.uk/ionosondes/view_latest.html
Juliusruh (Germany)	http://www.ionosonde.iap-kborn.de/ionogram.htm
Tromso (Norway)	http://digisonde.phys.uit.no/cgi-bin/latest.exe?
Tromso (Norway)	http://www.eiscat.no/updating_dynasonde.html
Norilsk, Irkutsk, Yakutsk, Zhigansk (Russia)	http://ds.iszf.irk.ru/
Dourbes (Belgium)	http://digisonde.oma.be/
Kiruna, Uppsala, Lycksele (Sweden)	http://www.irf.se/~ionogram/
Roquetes/Tortosa (Spain)	http://www.obsebre.es/w3/ionosfer.php
Athens (Greece)	http://www.iono.noa.gr
El Arenosillo (Spain)	http://www.inta.es/iono/
Pruhonice (Czech Republic)	http://147.231.47.3

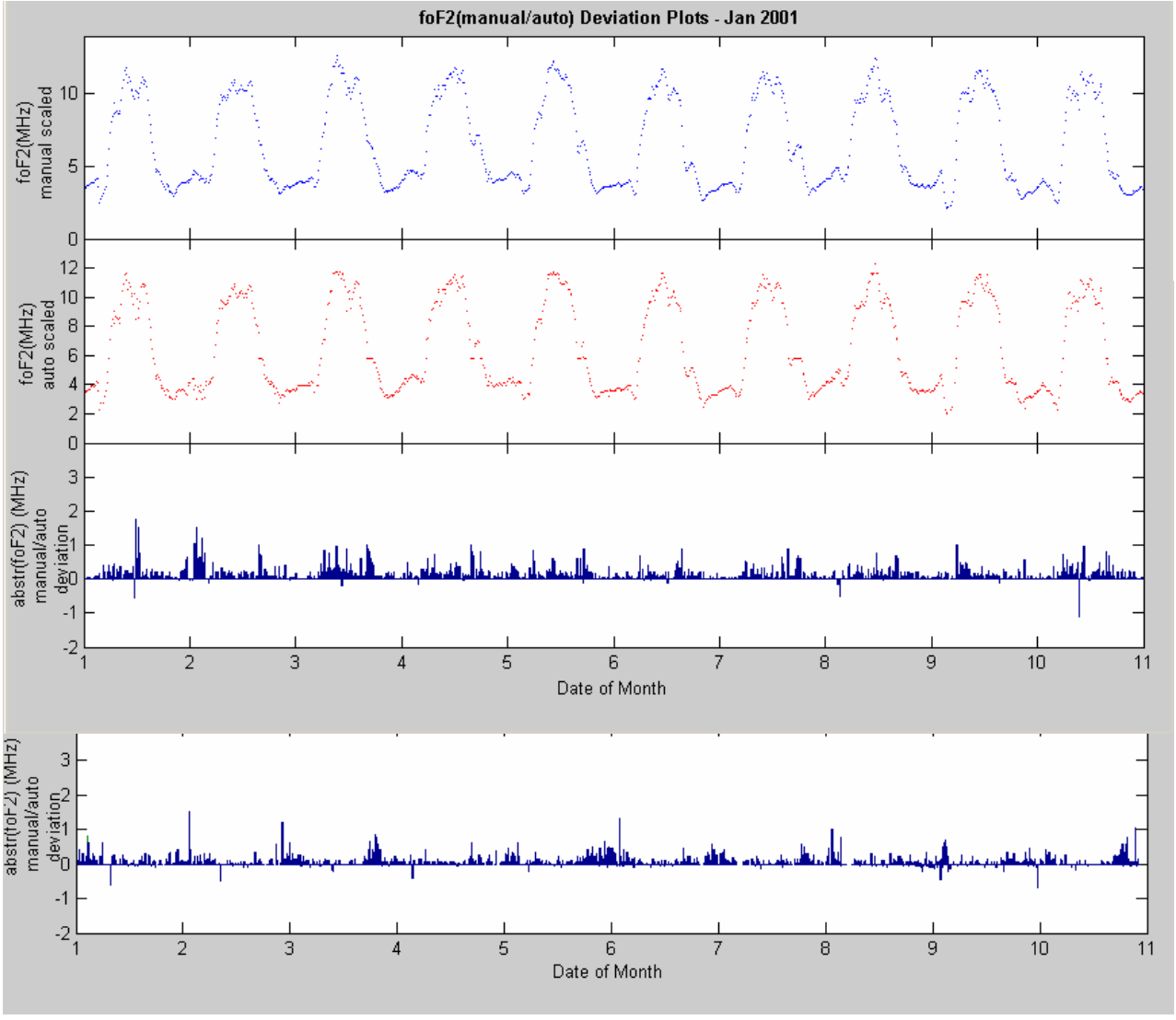
Advanced specifications of modern ionosondes

- automatic scaling of ionograms
- determination of the ionospheric structure in real-time
- reconstruction of electron density profile in real-time
- calculation of the Ionospheric Total Electron Content (ITEC)
- determination of ionospheric motions for the calculation of drift velocities

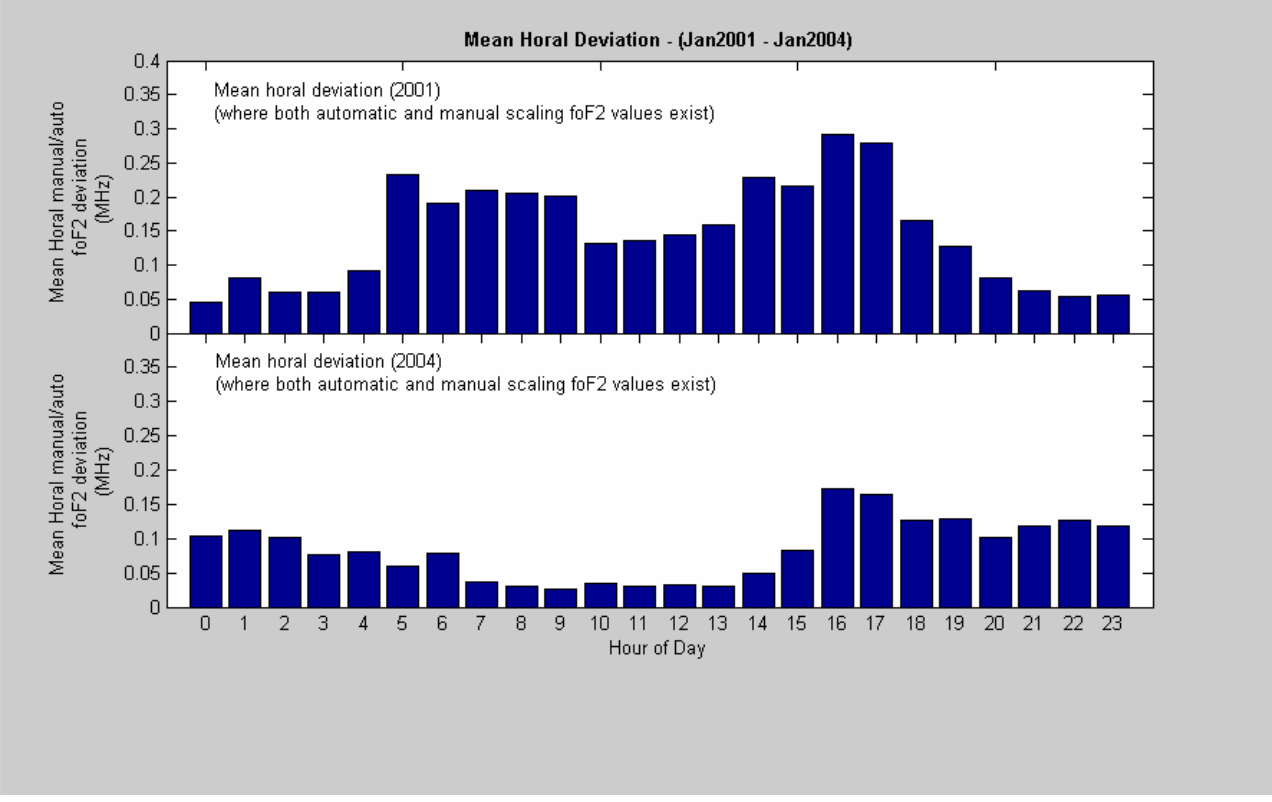
Automatic scaling of ionograms – New ARTIST

Artist 4.0599

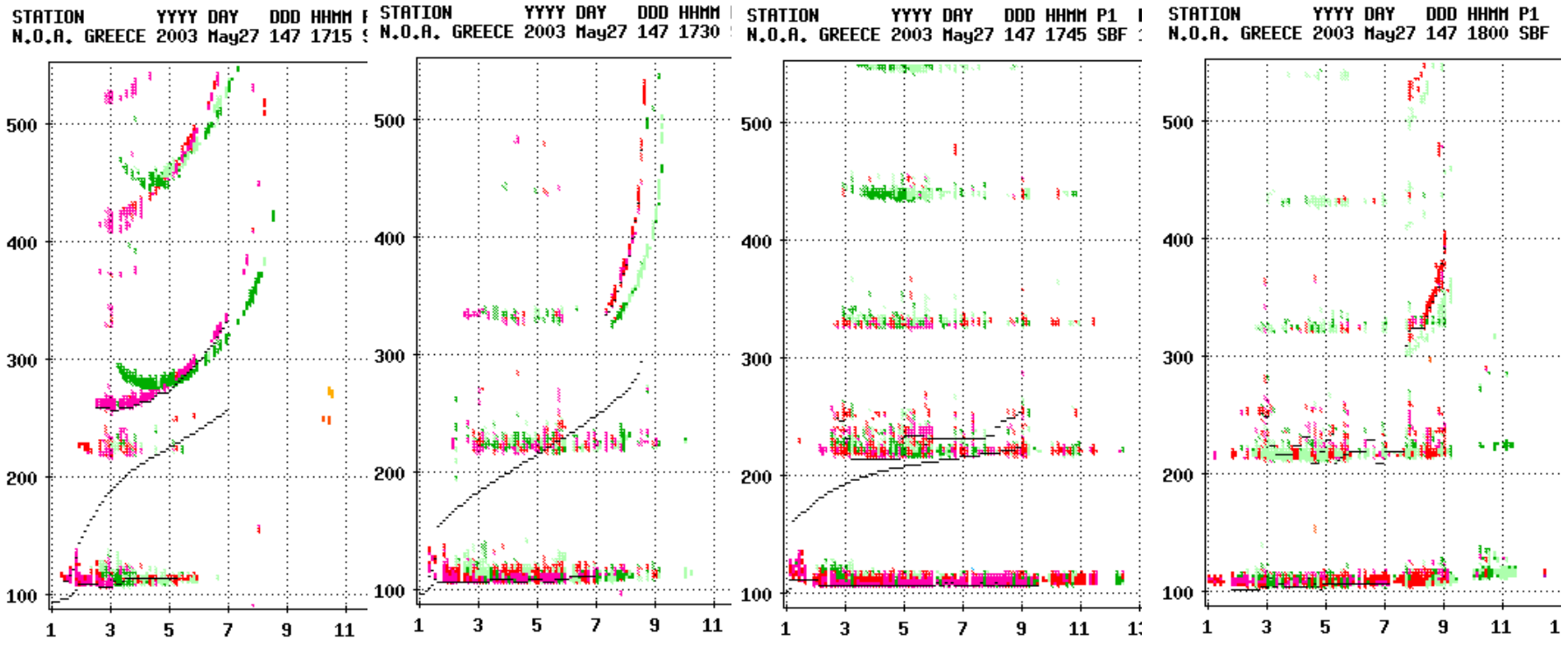
Artist 4.0702



Evaluation of ARTIST performance



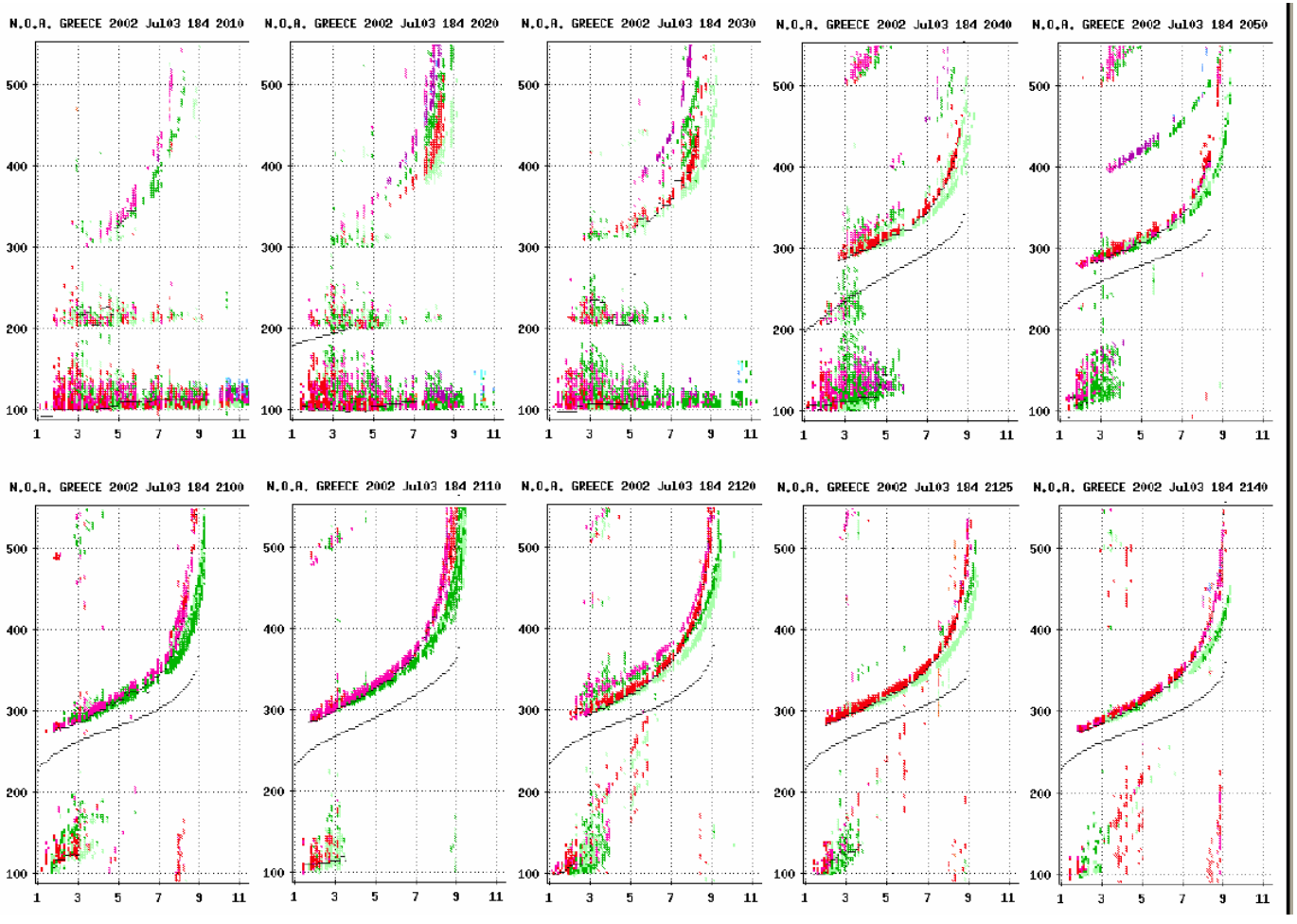
Real-time determination of ionospheric structure



17:15UT **17:30UT** **17:45UT** **18:00UT**

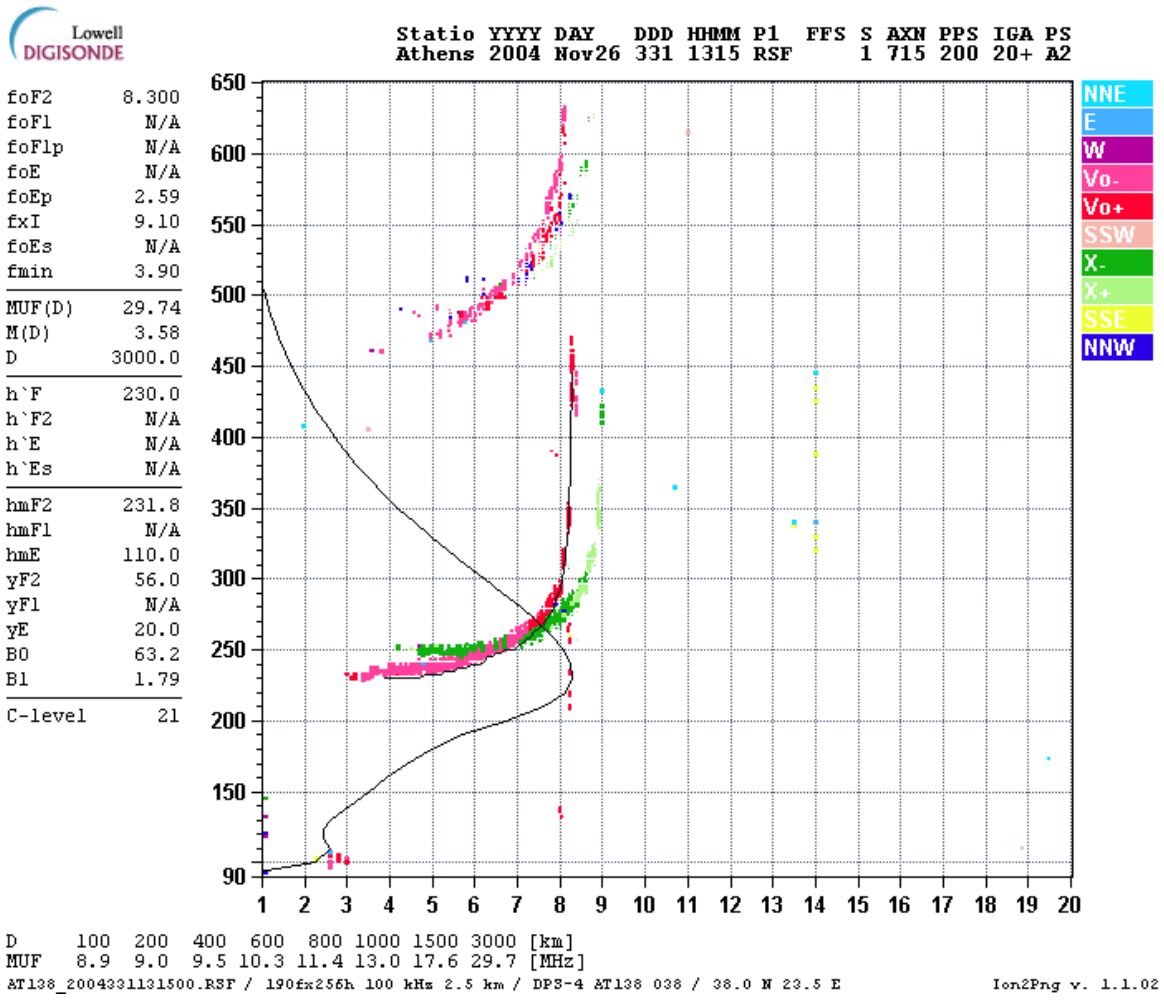
Patchy sporadic E layers cause total F-layer blanketing

Real-time determination of ionospheric structure



Patchy sporadic E-layers accompanied by mid-latitude spread F. These events give strong evidence that polarization electric fields are built up in the E region and are mapped upward to the F region, creating rising and falling regions in the bottomside plasma (Kelley et al., 2003)

Real-time electron density profiles calculation



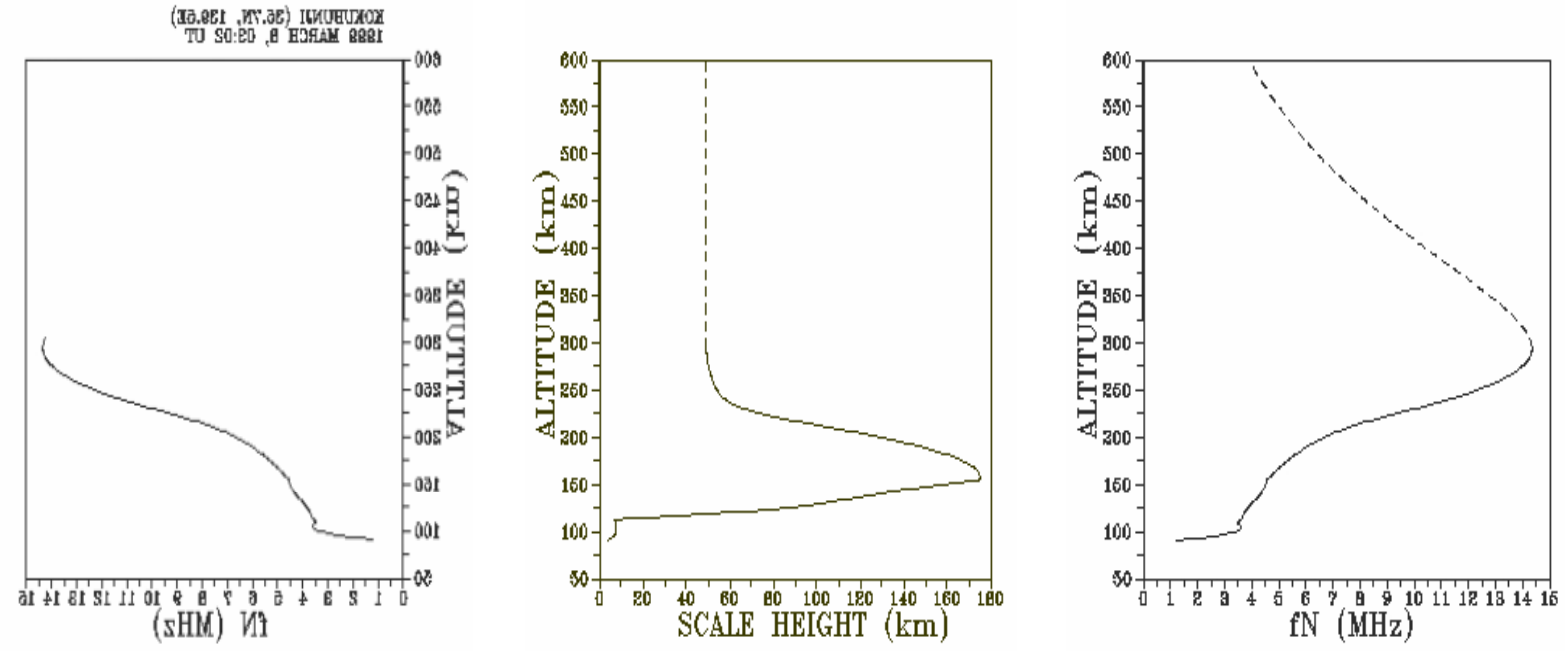
The Reinisch and Huang method for the topside extrapolation of ground ionograms

The topside profile is modeled as an a-Chapman function, making a simplifying assumption that it has a constant scale height H_T (Huang and Reinisch, Radio Science, 2001)

$$N(h) = N_m \exp[\tfrac{1}{2}(1 - z - e^{-z})]; \qquad z = \frac{h - hmF2}{H_T}$$

H_T=H_m at the F2 layer peak.

H_m can be calculated from the known bottomside function N(h)



(Reinisch et al., ASR 2004, submitted)

ITEC calculation

The Ionospheric Total Electron Content (ITEC) is currently computed in real-time with the built-in software of Reinisch and Huang running in the Digisondes.

ITEC represents the electron content up to 1,000 km.

$$ITEC = \int_{h_E}^{h_mF2} N_B(h)dh + \int_{h_mF2}^{1000} N_T(h)dh$$

Validation studies:

1. Statistical study for the qualitative validation (Belehaki et al., 2003)
2. Statistical study for the quantitative validation (Belehaki and Kersley, 2004)

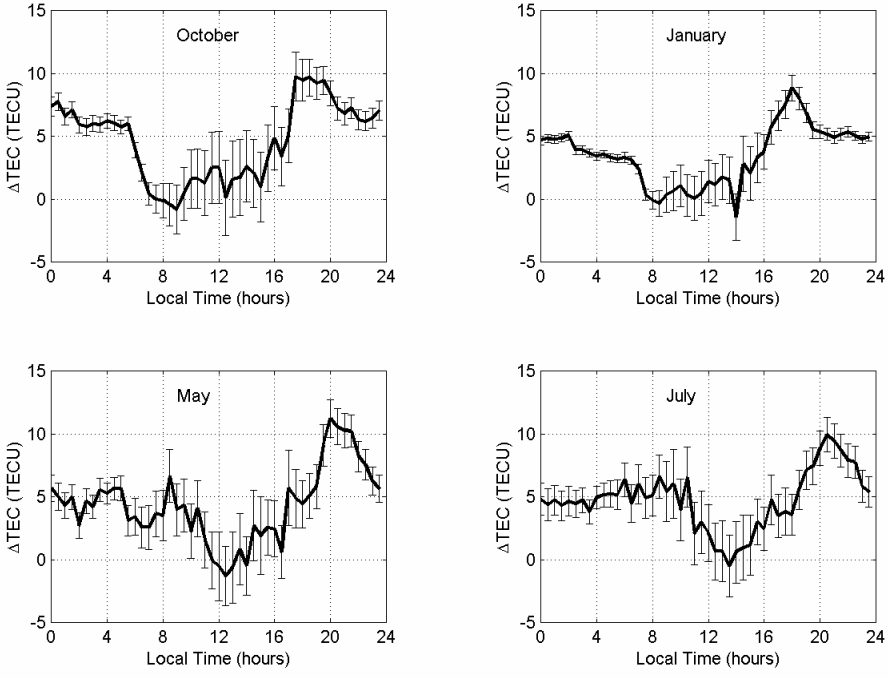
ITEC: qualitative validation

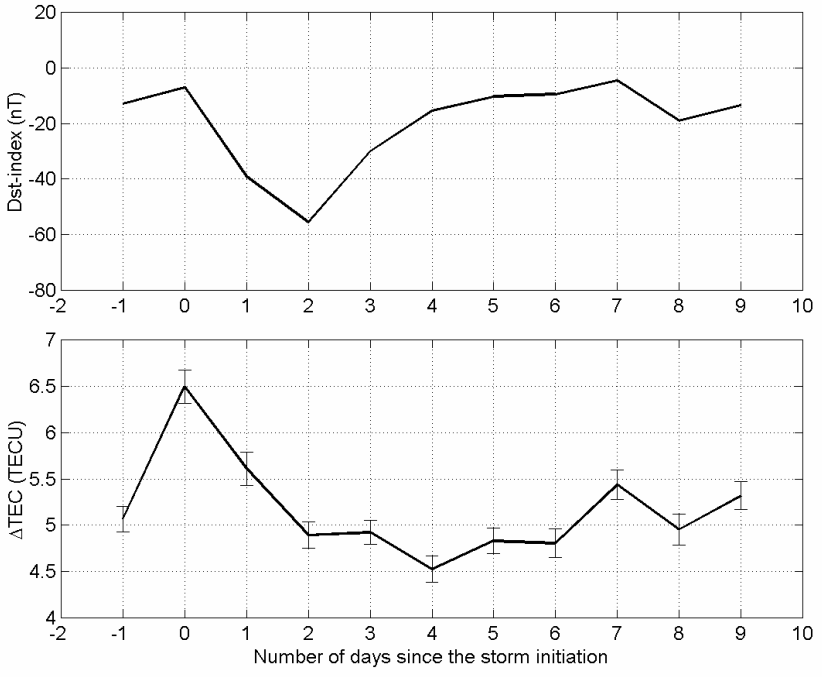
Data samples:

ITEC from Athens Digisonde (up to 1,000 km)

GPS derived TEC from DLR maps – extracted values for Athens coordinates (up to 20,000 km)

Period of analysis: October 200 – September 2001



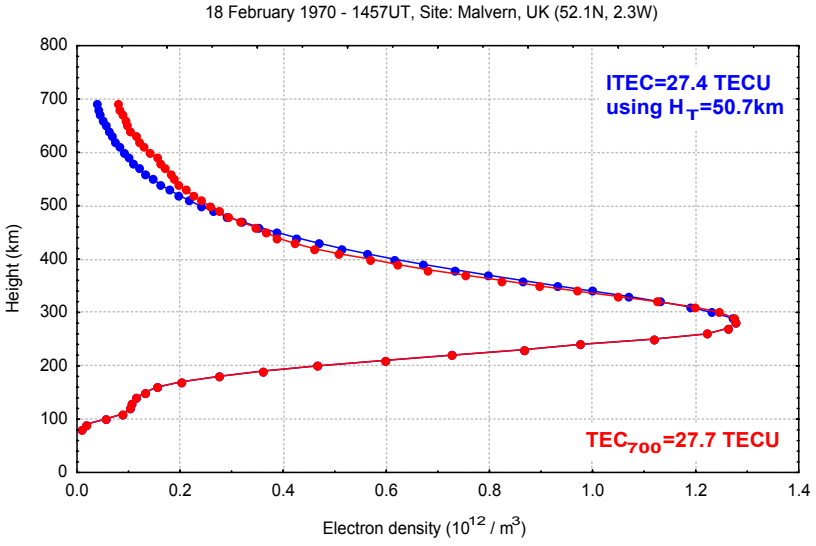


Result: The residual differences (GPSTEC-ITEC) has same qualitative characteristics with the plasmaspheric electron content, as deduced from the diurnal and seasonal behaviour and the variation during geomagnetic storms (*Belehaki, Jakowski and Reinisch, Radio Science 2003*).

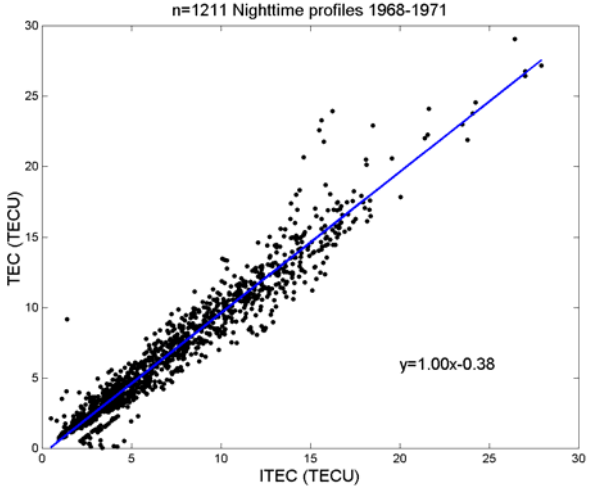
ITEC quantitative validation

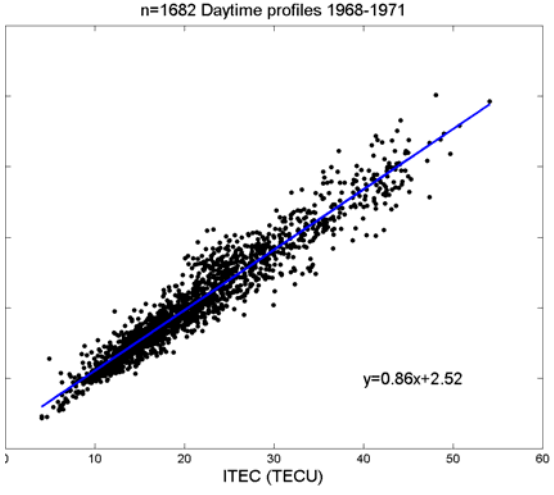
Data source: 4,000 ISR profiles from Malvern in UK (1968-1972) – up to 700 km

Method: Each ISR bottomside profile was extrapolated to the topside using the Reinisch and Huang method (2001). The computed ITEC has been compared with the TEC computed from the original ISR profile.



Results: Very reliable ITEC estimations especially during nighttime, while in daytime hours an average deviation of 2.5 TECU was obtained. The agreement between the modeled and the observed total electron content is better as we approaching from summer to winter months.





Ionospheric Drift Measurements

Three main processes are creating ionospheric drifts.

a) Gradient drift $$u_{gd} = \frac{\varepsilon_{\perp} + 2\varepsilon_{\parallel}}{qB^3}(\overline{B} \times \nabla_{\perp}|B|)$$

b) Electric field drift $$u_{ed} = \frac{1}{B^2}(\overline{E} \times \overline{B})$$

c) Drift due to gravity $$u_{ed} = \frac{q}{mB^2}(\overline{g} \times \overline{B})$$

Two more mechanisms cause movement of ionospheric plasma:
a) neutral winds
b) traveling ionospheric disturbances (TID's)

Digisonde Drift Analysis

The Digisondes measures the Apparent Velocity "Va", which is a complicated function of a number of time varying properties of the radio wave propagation medium.

The Doppler frequency shift is affected by:

a) the motion of the reflecting surface and

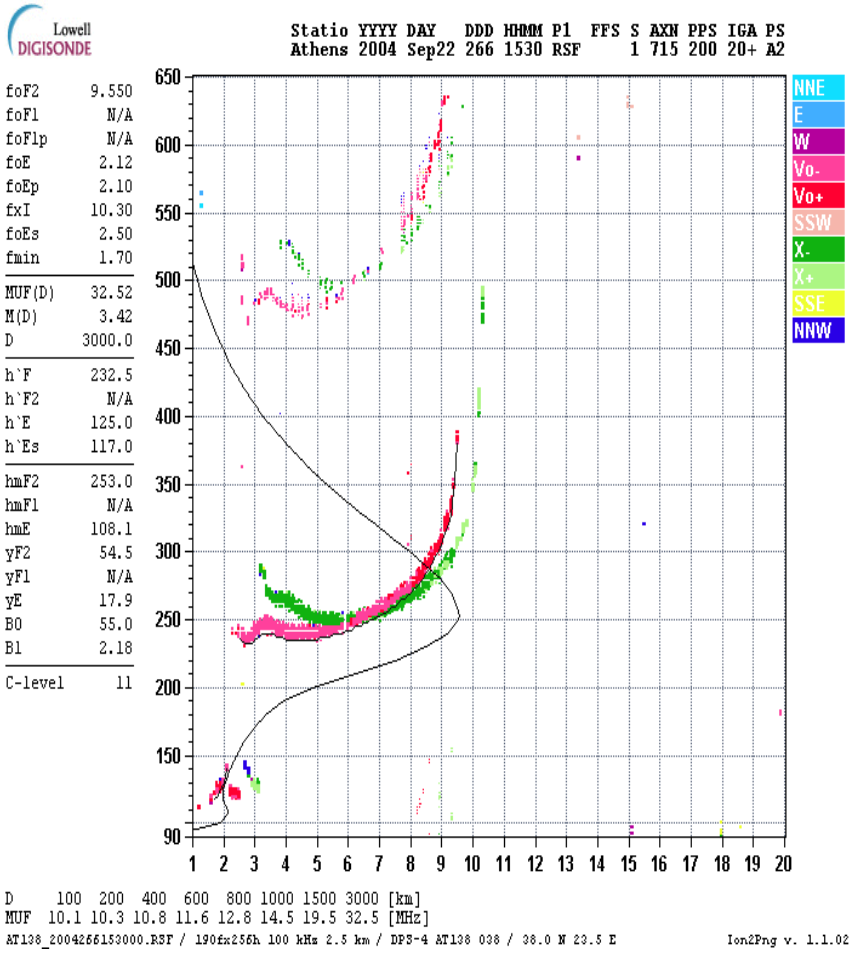
b) the time variation of the refractive index along the ray.

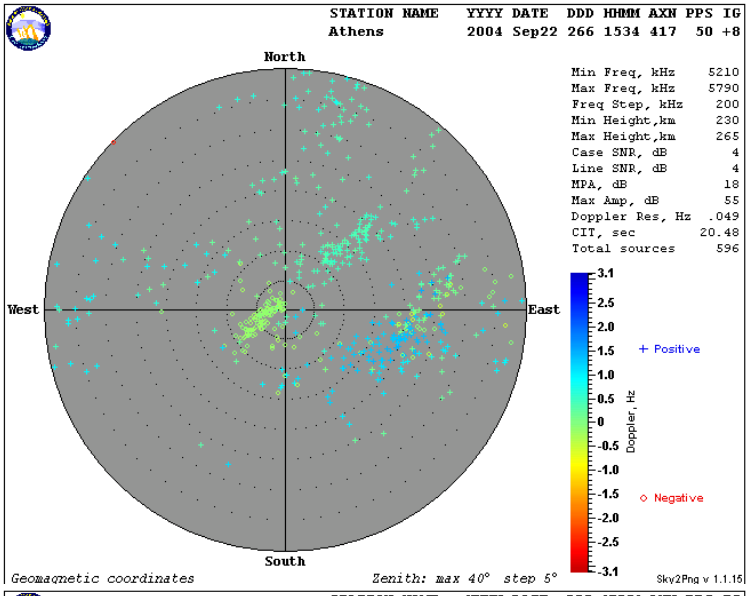
The ionospheric refractive index is influenced by:

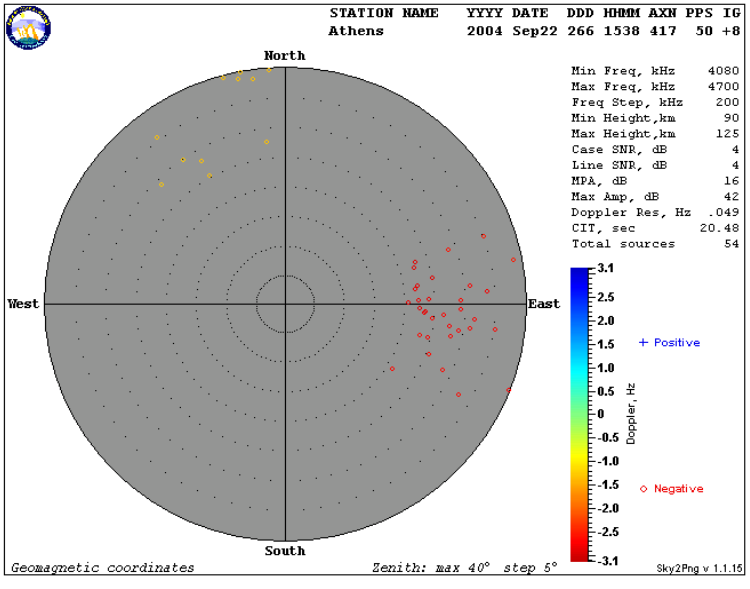
- ionospheric motions
- production and loss of ionization

Velocity measurements from HF radars could be related to the effects of photoionization, recombination, gravity waves (TIDs) and plasma motion.

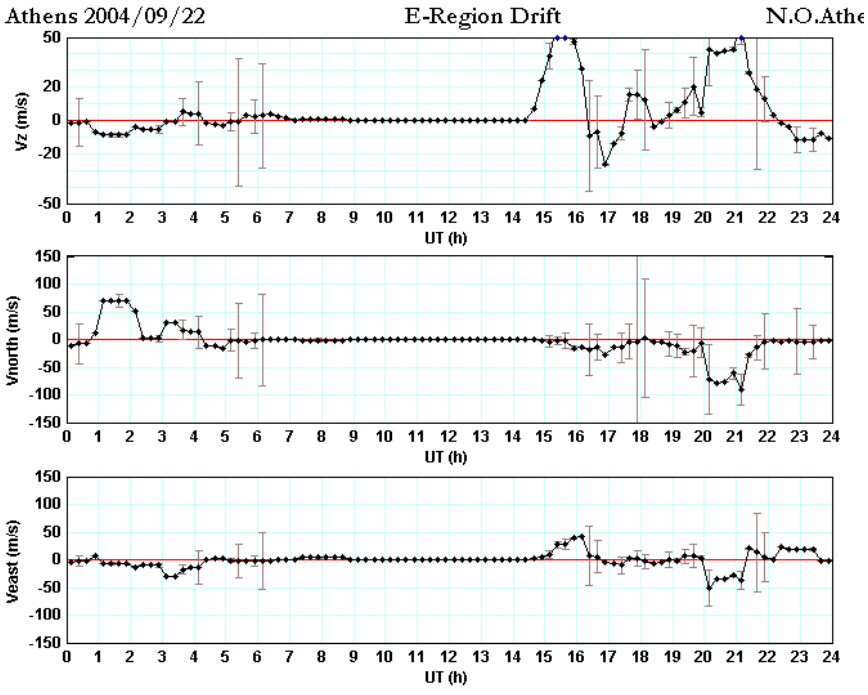
Ground-based techniques and networks for monitoring the Earth's ionosphere

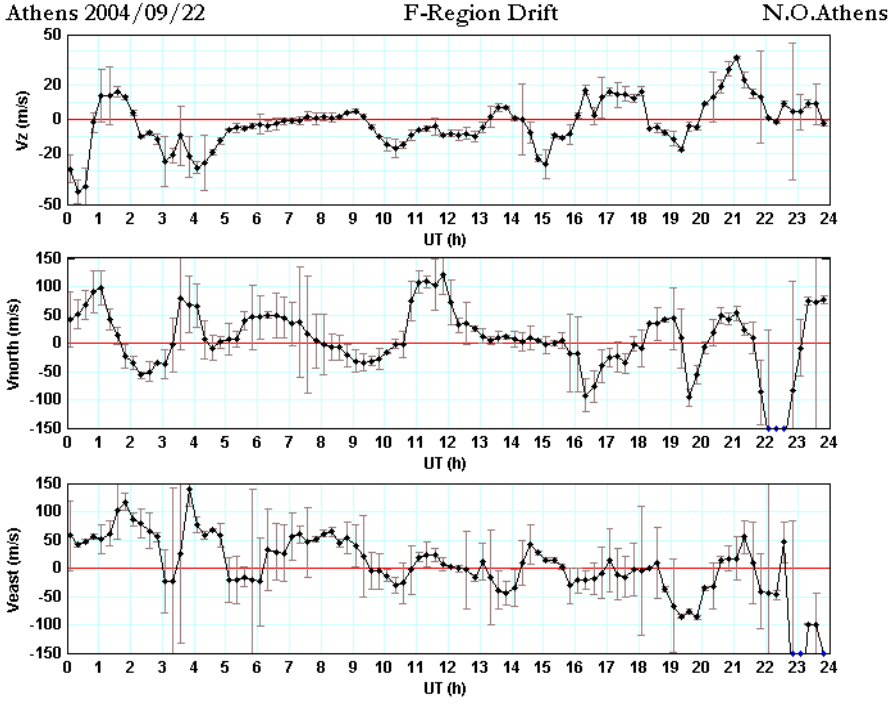






Independent monitoring of E and F region drift motions: Operated in Athens Digisonde since September 2004

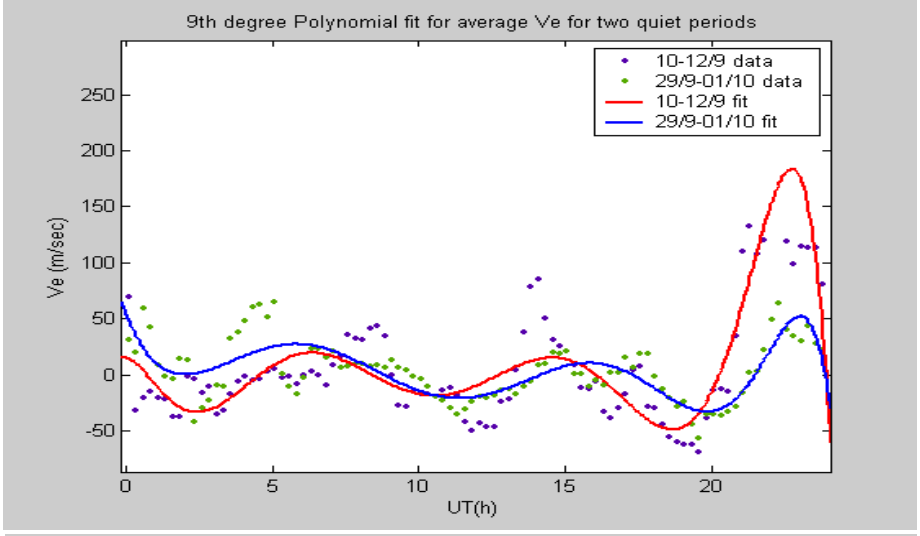




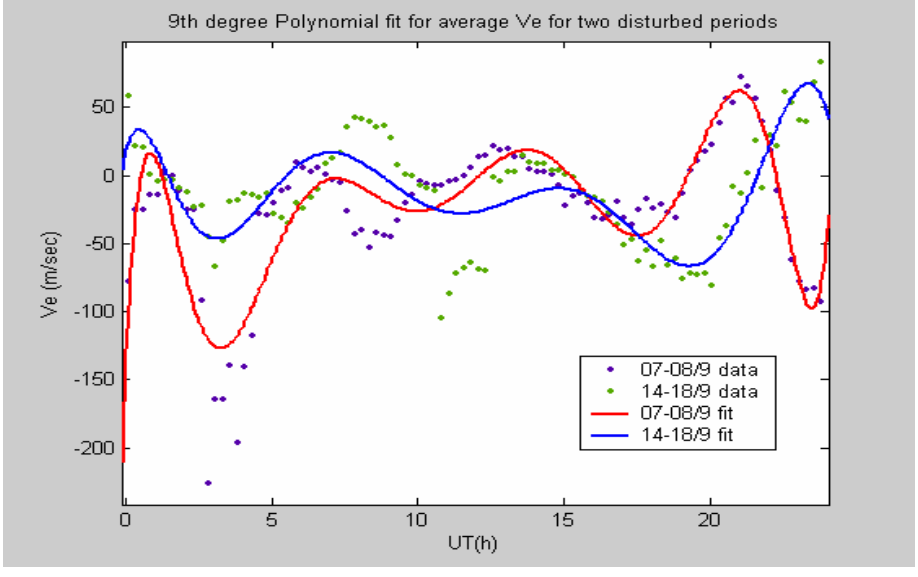
http://www.iono.noa.gr

Daily drift pattern – Eastward component

Quiet →

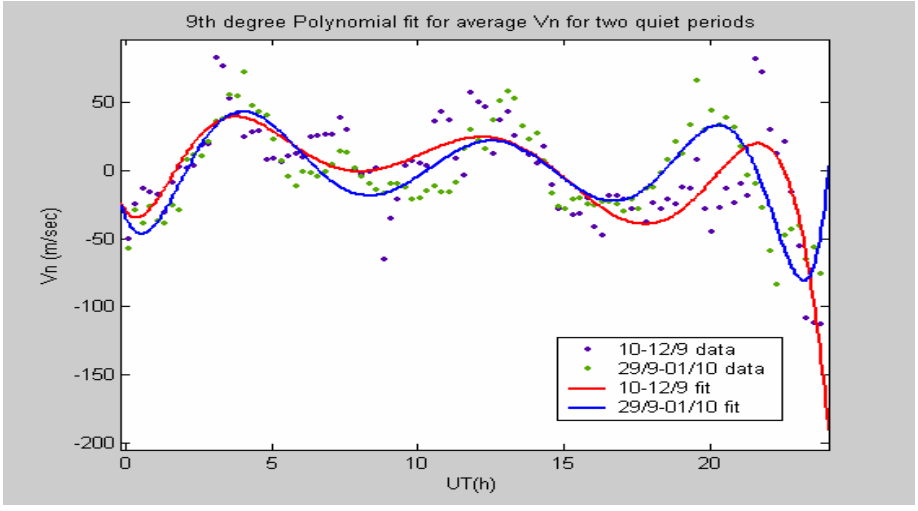


Disturbed →

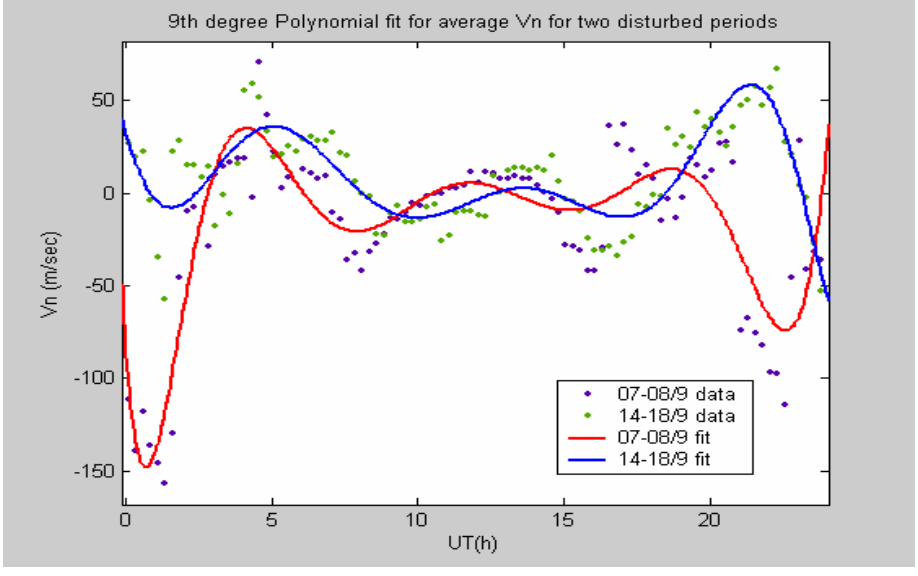


Daily drift pattern – Northward component

Quiet →

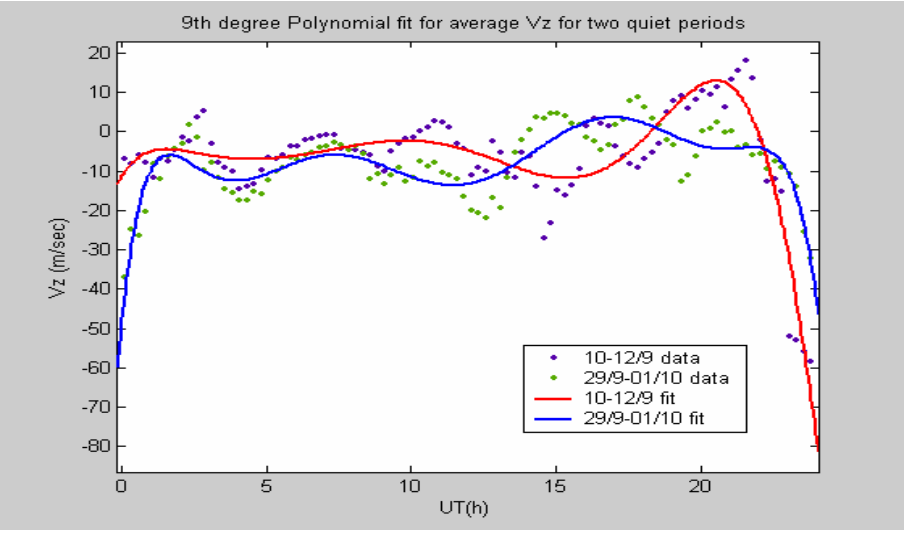


Disturbed →

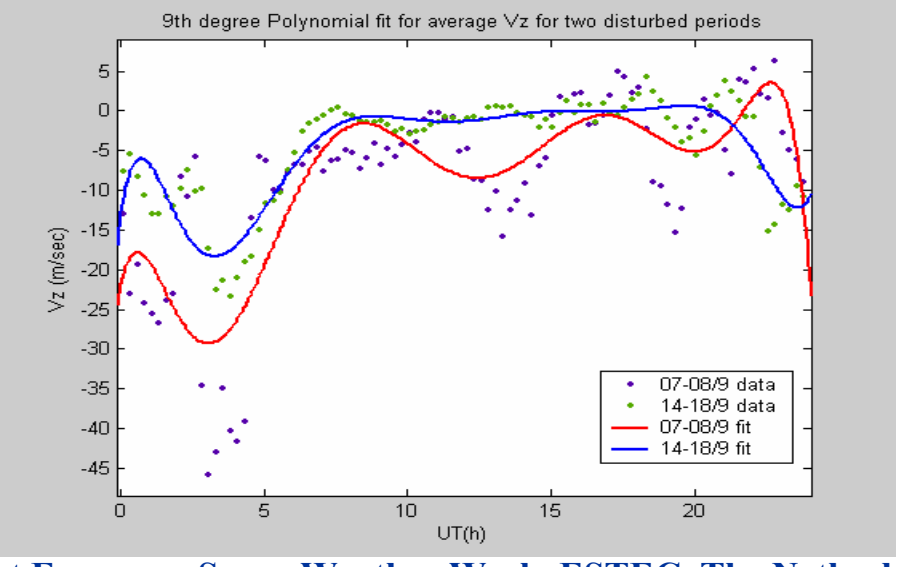


Daily drift pattern: vertical component

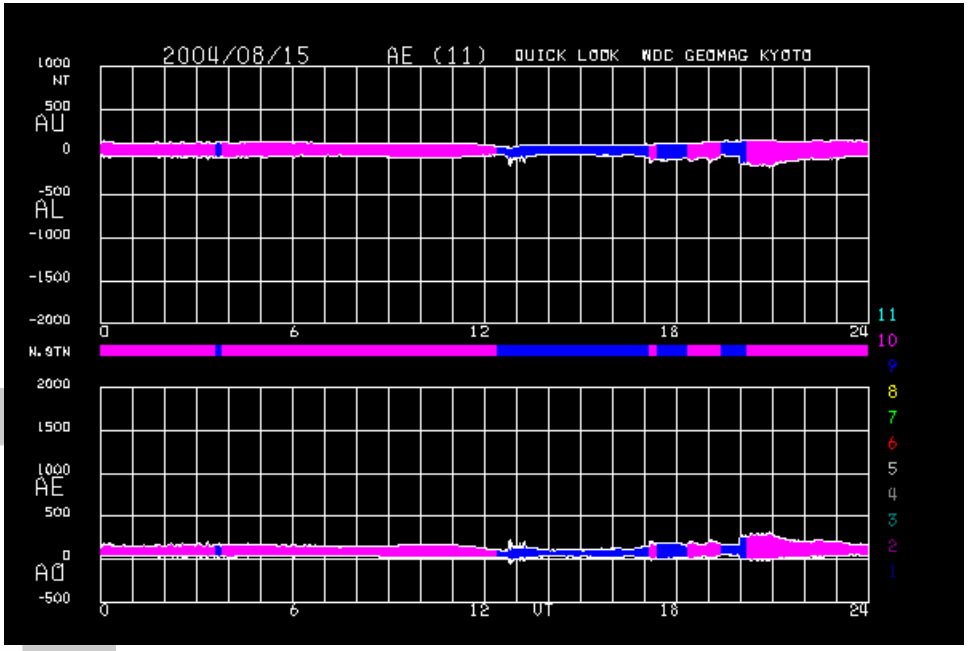
Quiet →

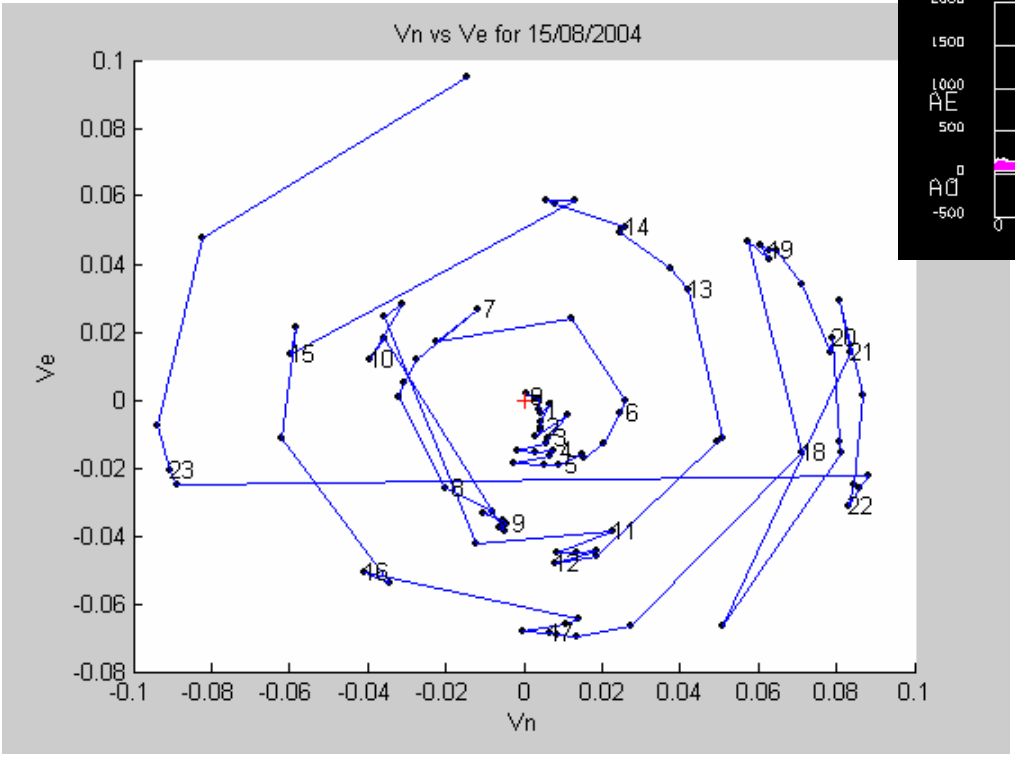


Disturbed →

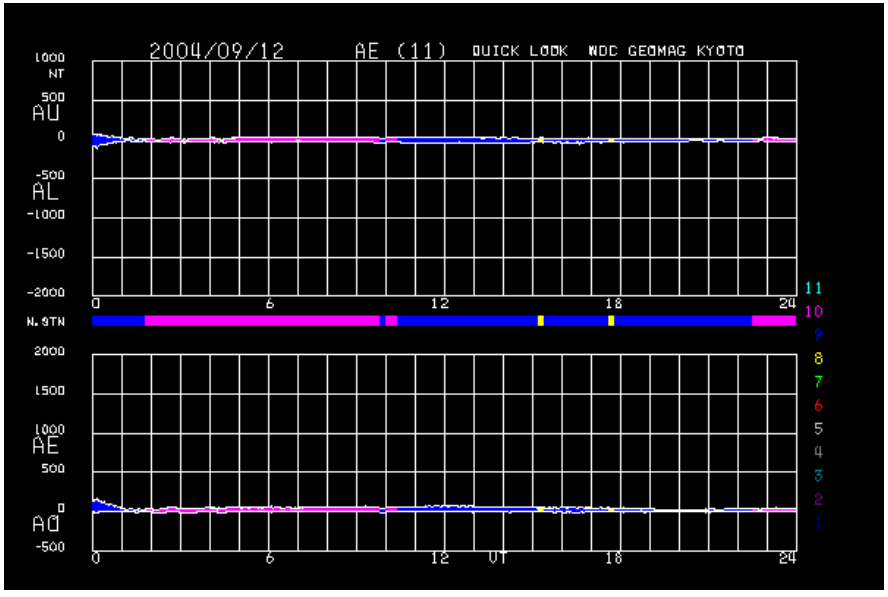


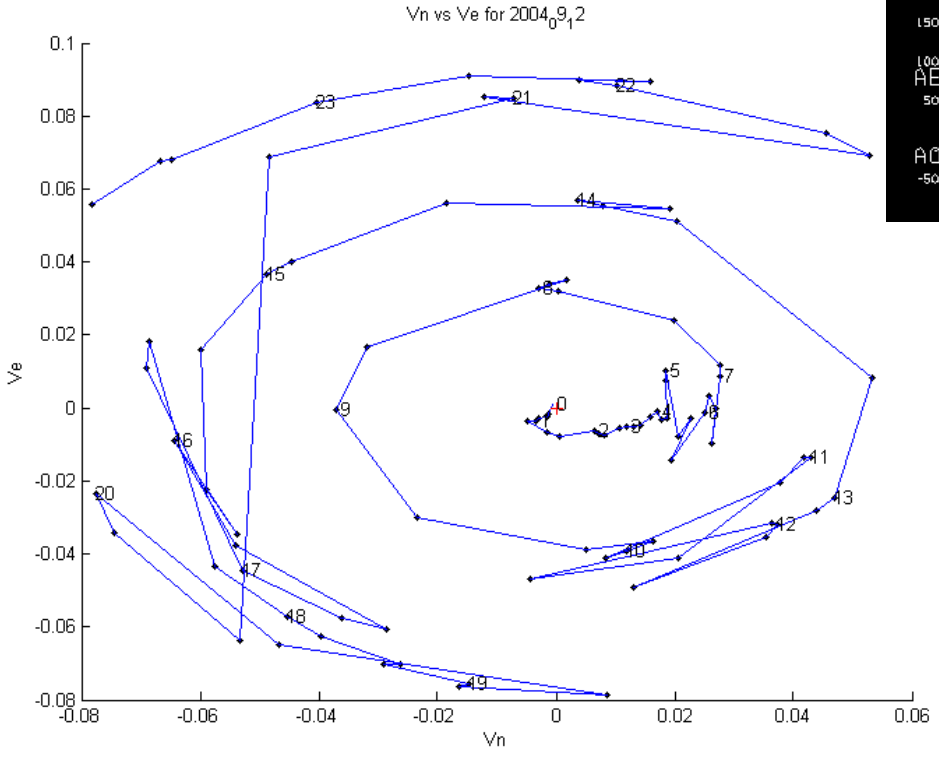
Quiet Conditions



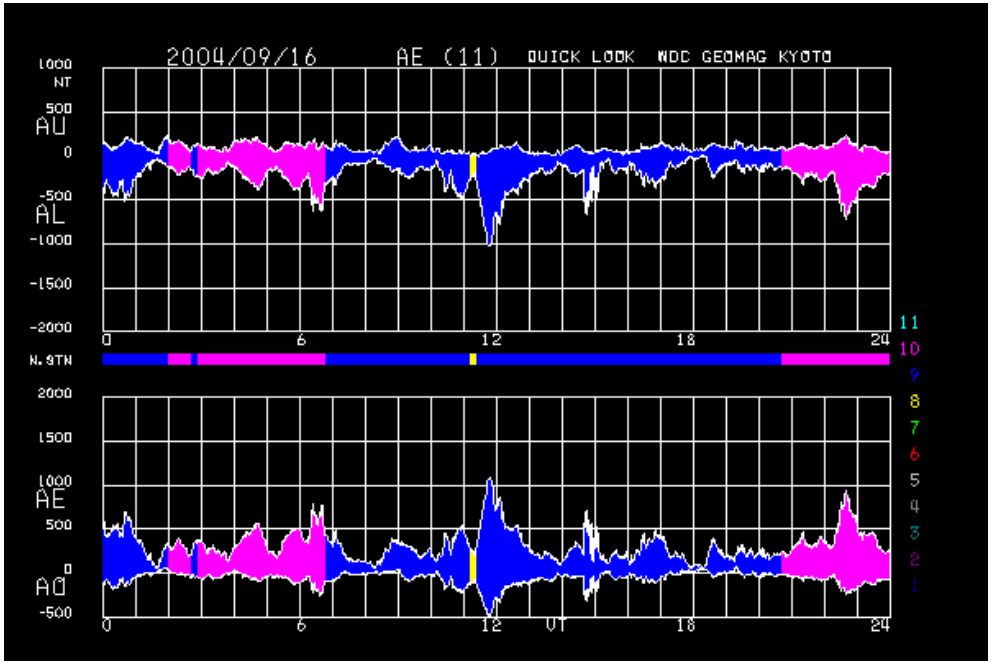


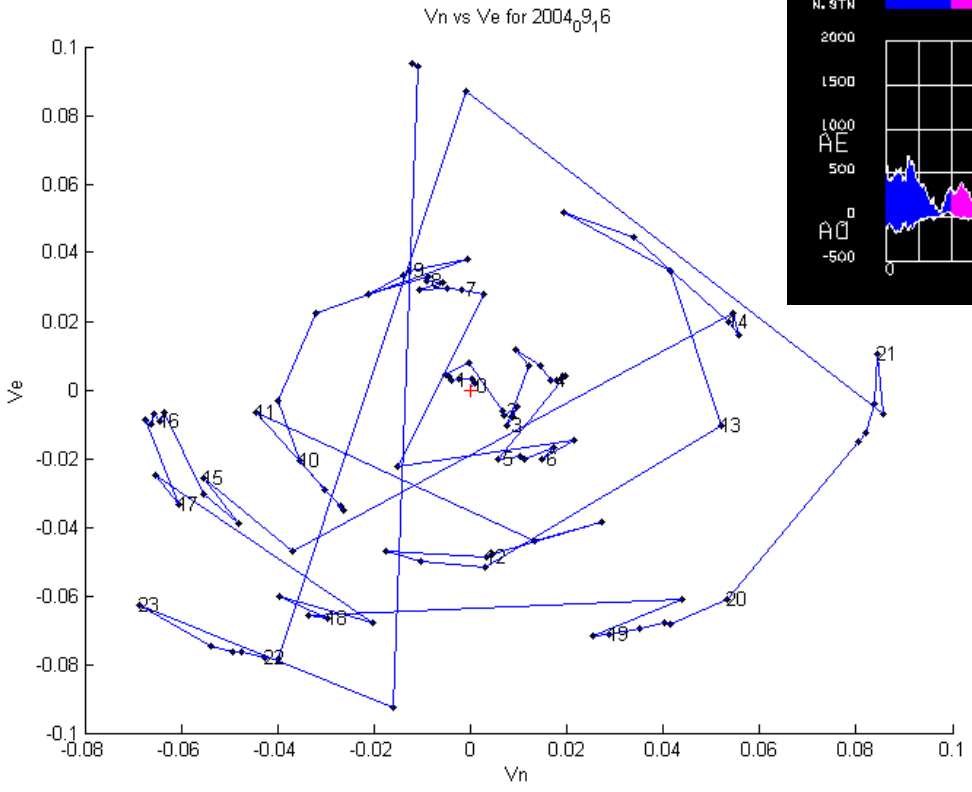
Quiet Conditions





Disturbed Conditions





European networks and research programs for monitoring, modeling and forecasting the ionosphere

- COST271
- DIAS
- ESA Space Weather Pilot Projects
- COST296 (MIERS)

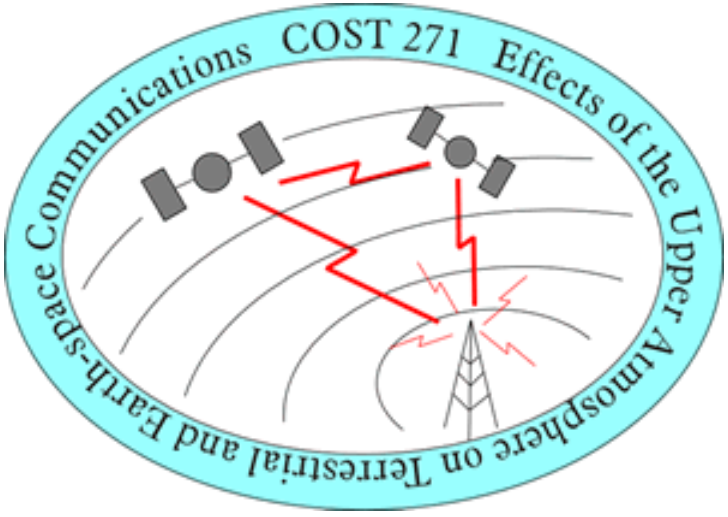
COST Action 271

Effects of the Upper Atmosphere on Terrestrial and Earth-Space Communications

http://www.cost271.rl.ac.uk/

Objectives

The objectives of the COST 271 project (European Co-operation in the field of Scientific and Technical Research) are to stimulate international co-operation in predicting and forecasting the ionosphere and plasmasphere; to develop and implement new communication services; to minimise the effects ionospheric perturbations have on communications systems; and to collect new data for now-casting and forecasting.

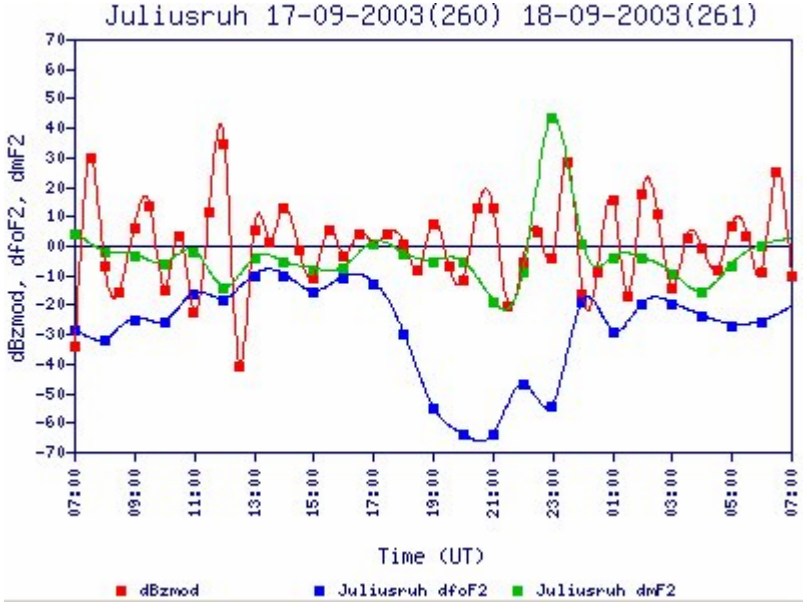


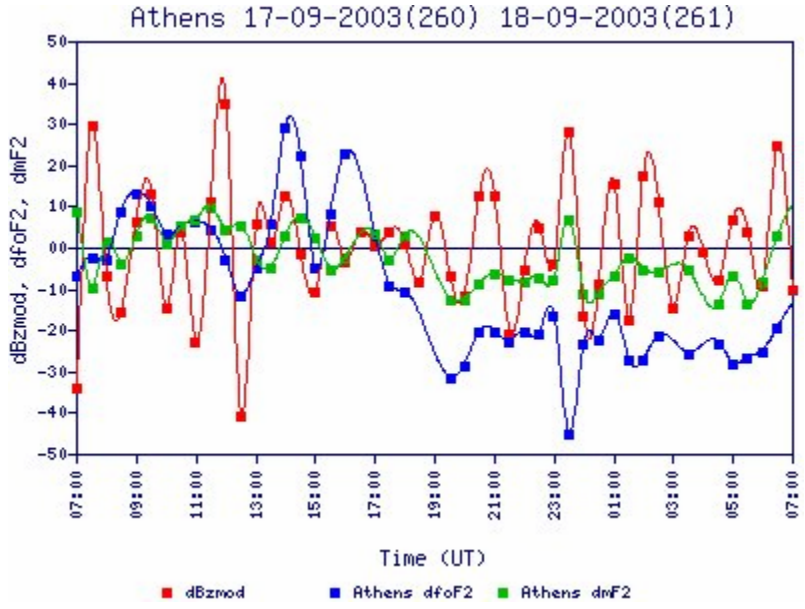
Action Lifetime: 16/08/2000 to 15/08/2004

Chair and Vice-Chair persons: Bruno Zolesi, Ljiljana Cander

A real-time dynamic system to specify ionospheric storm effects in middle latitudes

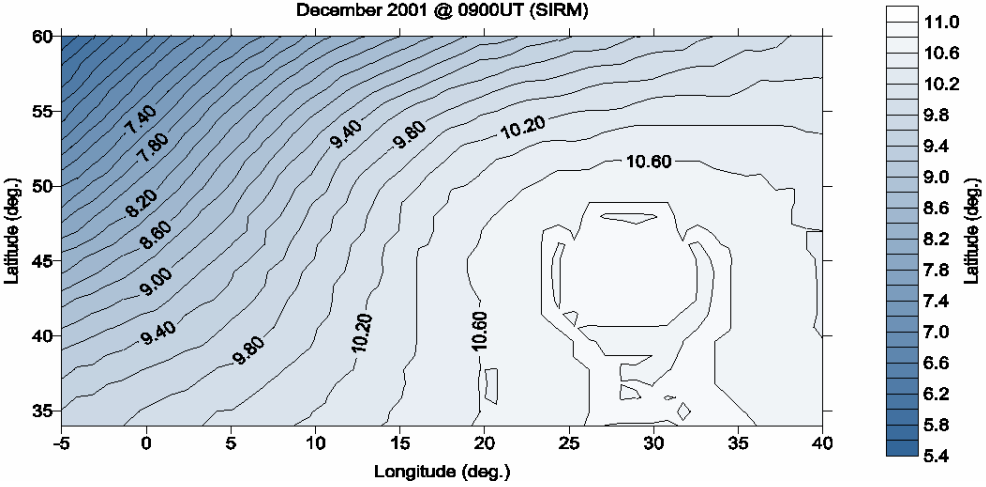
Operational tool developed at RAL (http://ionosphere.rcru.rl.ac.uk) in collaboration with NOA, to study how the IMF parameters are related to subsequent ionospheric disturbances detected at Juliusruh, Chilton, Athens, Rome, Tortosa stations (*Cander, Hickford, Tsagouri and Belehaki, Electronics Letters, 2004*)

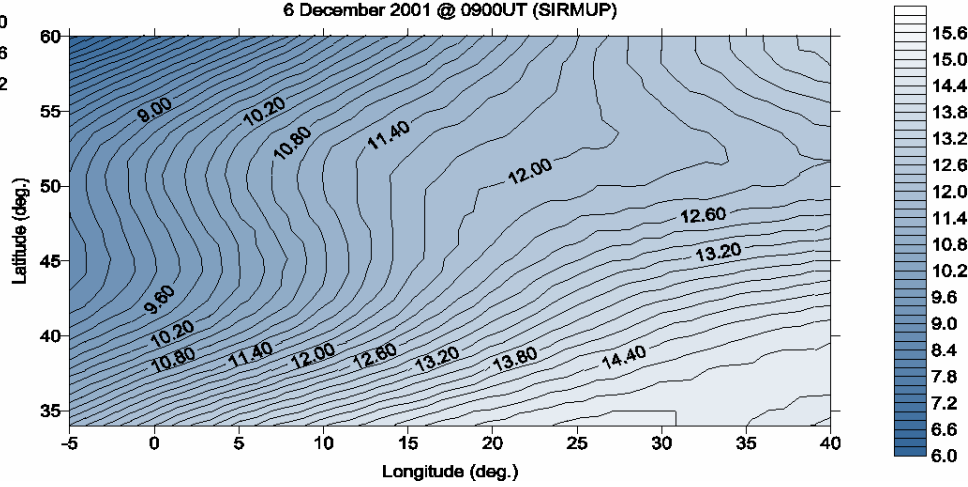




Real-time SIRM updating for operational applications

The method is based on SIRM, updated with real-time (automatic scaled) ionospheric observations from Athens, Chilton, Rome and Juliusruh, to produce nowcasting maps over Europe (*Zolesi, Belehaki, Tsagouri and Cander, Radio Science, 2004*).

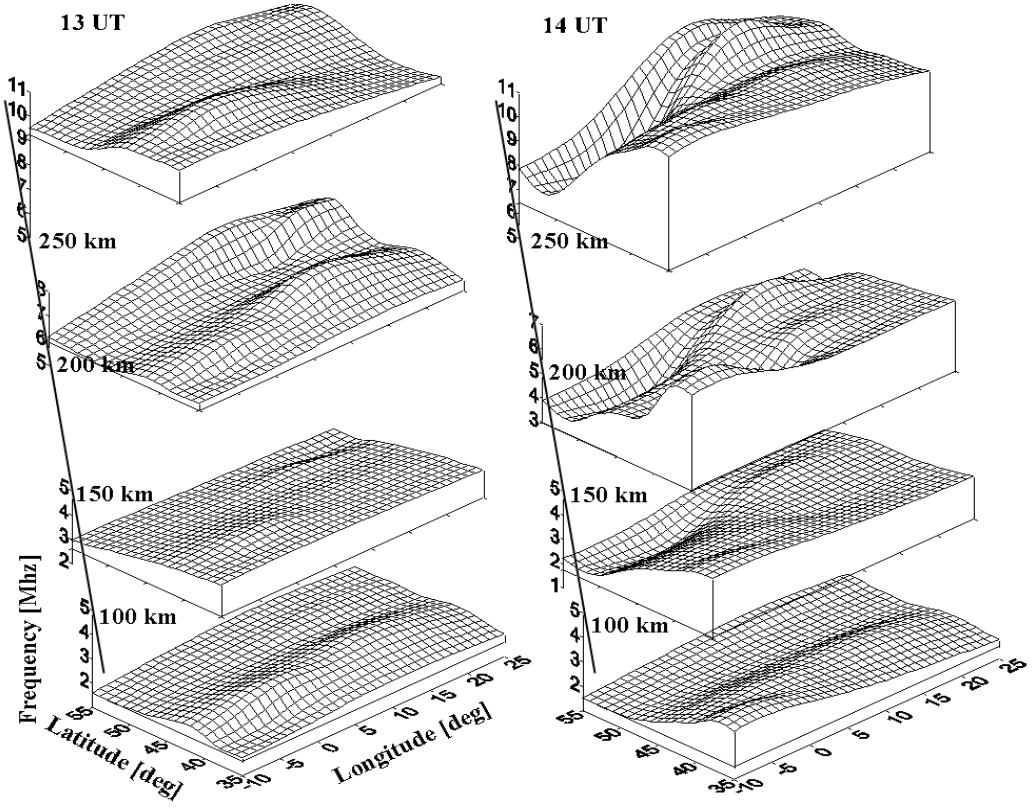




Modeling electron density profiles updating the NeQuITUR and IRI model

Quasi-empirical 3-D maps of Ne in the bottom side ionosphere for quiet and disturbed conditions. As background one of two empirical models can be used: IRI 2000 or NeQuITUR. Preliminary tests show a fair agreement of measurements and mapping results.

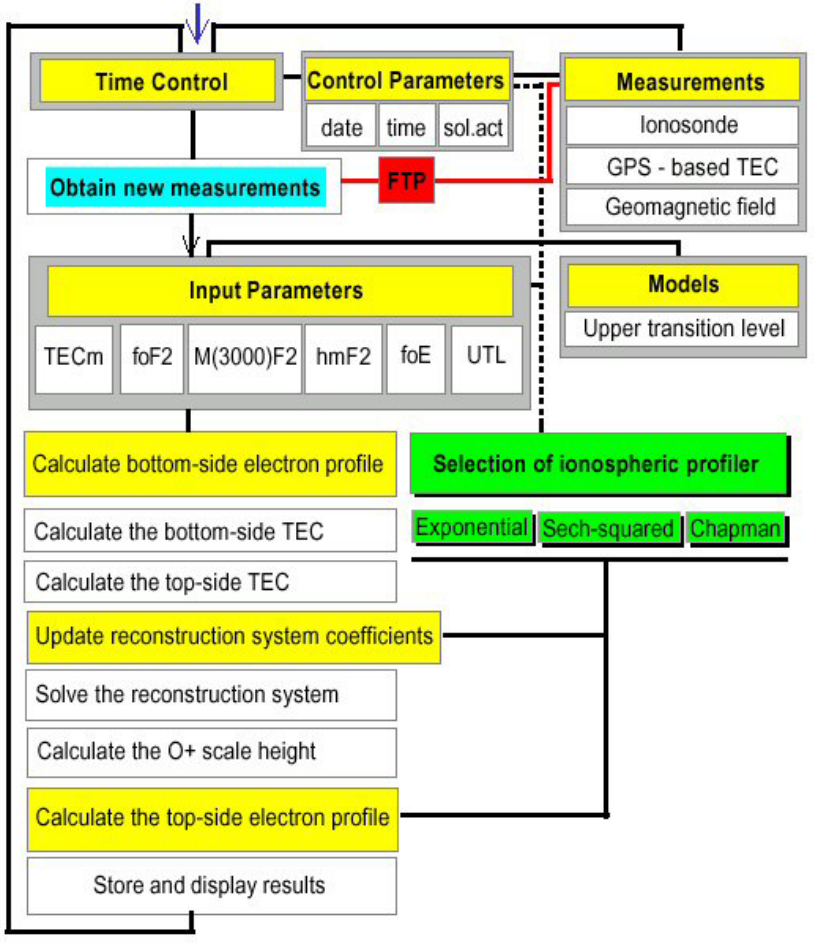
(Stanislawska et al., 2nd COST271 Workshop, 2002 and Adv. Space Res. 2003)



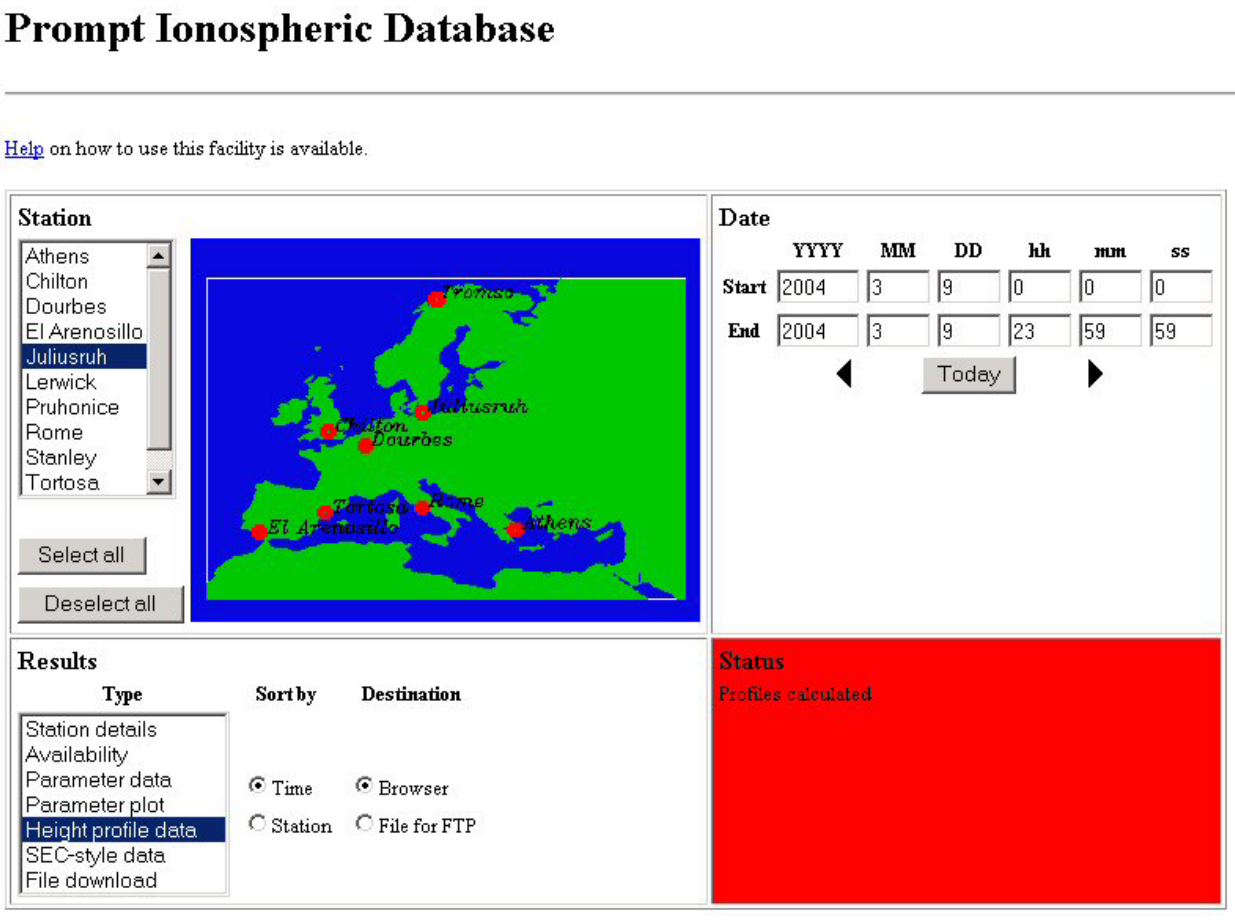
Real time reconstruction of the electron density profile at a single ionosonde location

The reconstruction is based on concurrent GPS-based total electron content and ionosonde measurements, assuming Exponential, Epstein or Chapman type of vertical density distribution. The method works at middle latitudes.

(*Stankov et al., 2004, JGR)*



Ionospheric Database (RAL)



Public DB

Allows users to:

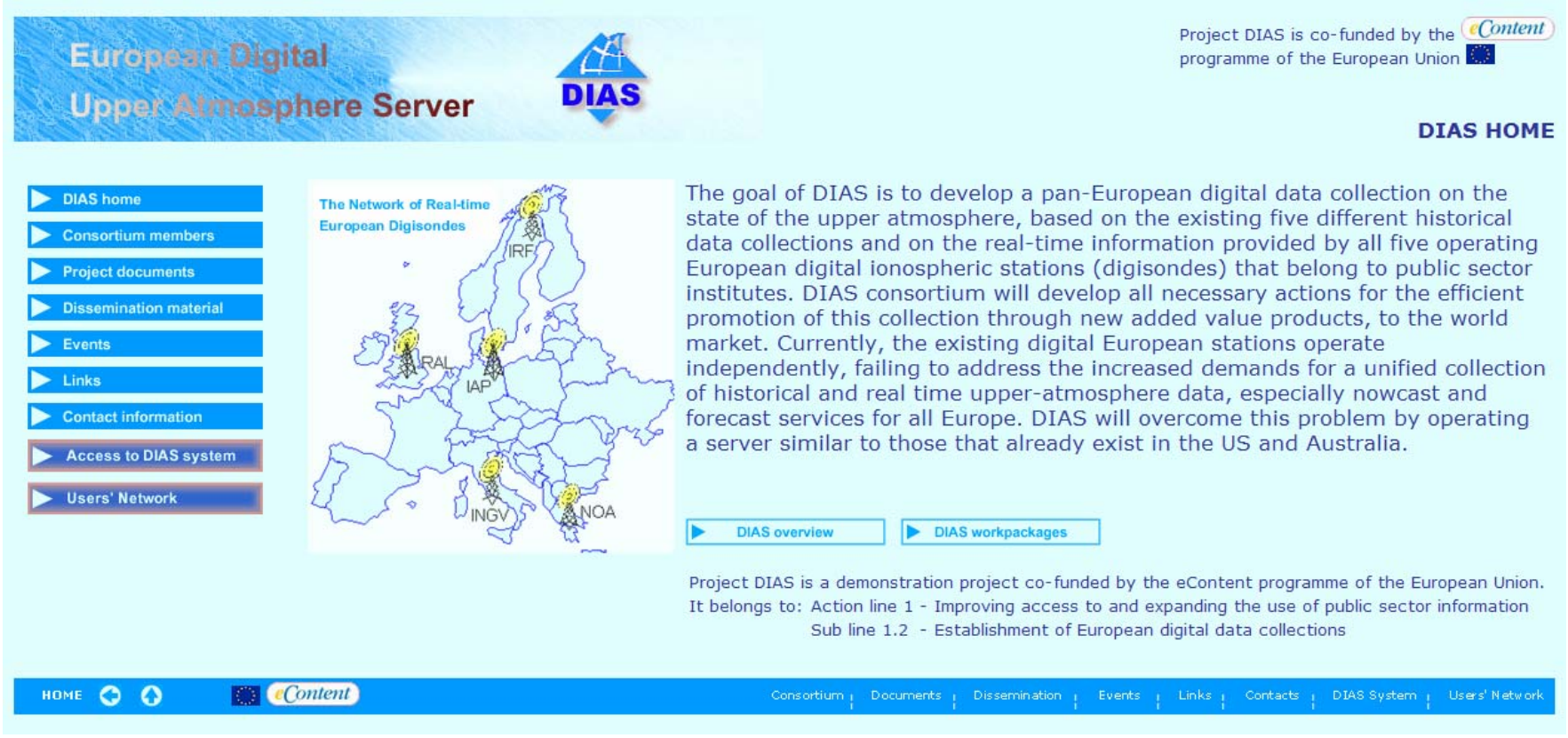
Select data by station and by arbitrary time intervals

http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl

DIAS

European Digital Upper Atmosphere Server

http://www.iono.noa.gr/DIAS



DIAS info

- Co-Funded by the eContent Programme of the European Commission
- Project life time: 2 years
  March 2004 – February 2006
- Project Co-ordinator: Anna Belehaki, NOA

DIAS consortium

National Observatory of Athens, Greece (NOA) - Co-ordinator

University of Athens, Greece (UOA)

Rutherford Appleton Laboratory, UK (CCLRC)

National Institute of Geophysics and Volcanology, Italy (INGV)

Swedish Institute of Space Physics (IRF)

Leibniz Institute of Atmospheric Physics, Germany (IAP)

Space Research Center, Polish Academy of Sciences (SRC-WARSAW)

01 Pliroforiki, Greece (01P)

Blustaff, Italy (BLS)

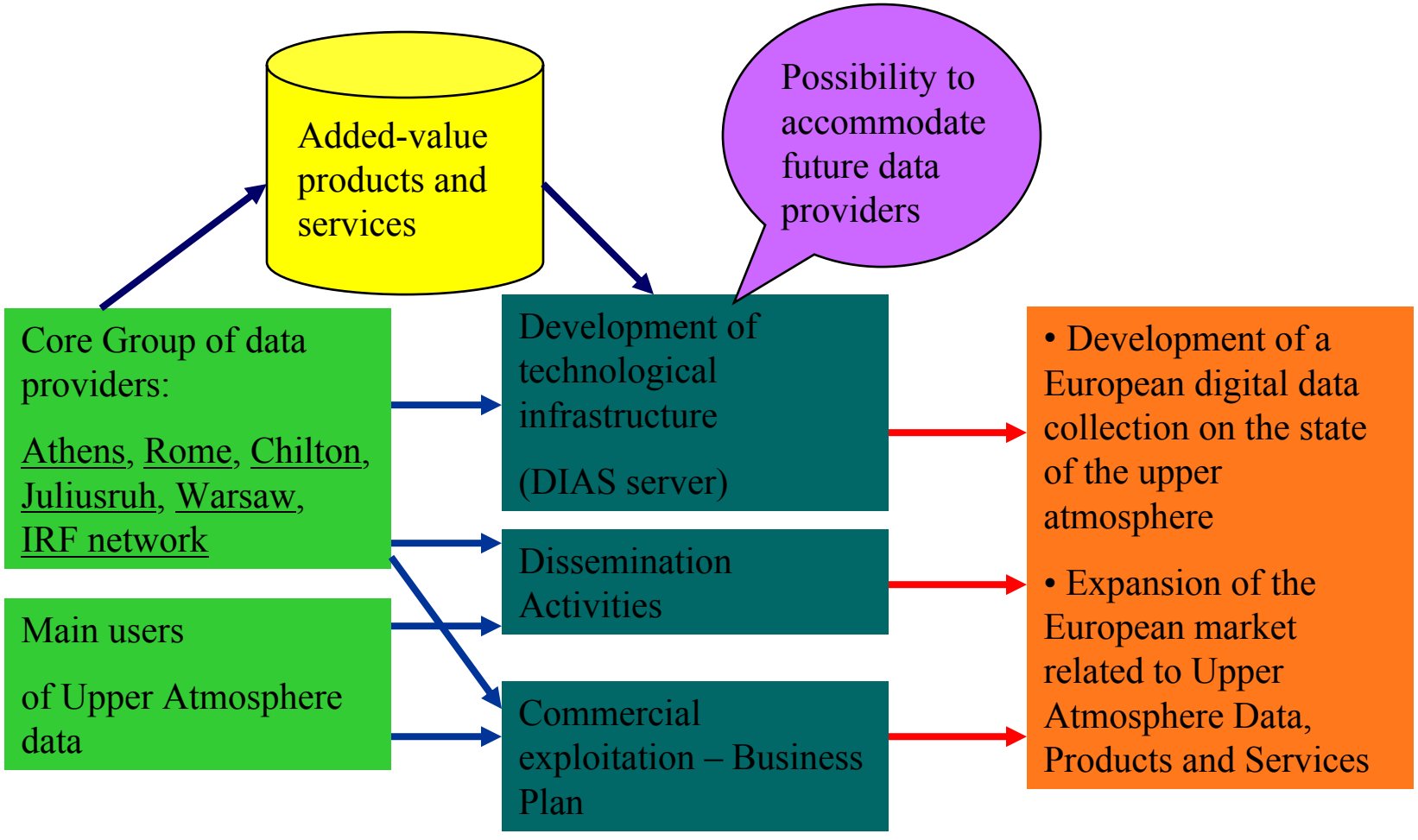
Why Europe needs DIAS?

- Currently, the existing digital European stations operate independently
- This independent operation does not meet the increased market demands for a unified collection of historical and real time upper-atmosphere data, especially nowcast and forecast services for the European region.

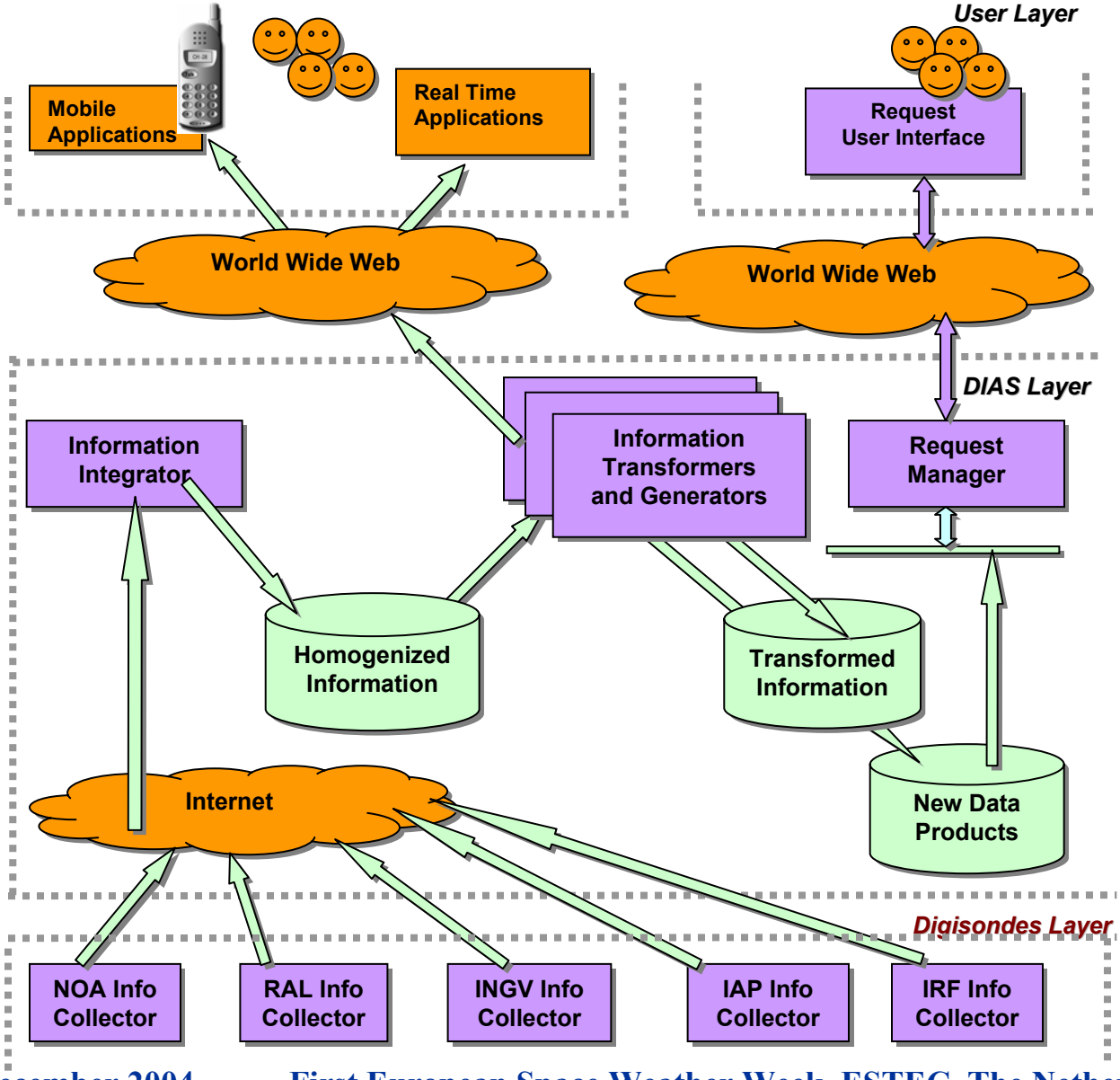
Groups of potential users of DIAS products and services

- ✓ Aviation industry (civil and military)
- ✓ Defense
- ✓ Satellite operators
- ✓ Commercial satellite designers
- ✓ Positioning and Navigation Systems
- ✓ Ground-based systems managers and operators
- ✓ Upper atmosphere researchers
- ✓ Seismic hazards researchers

Workflow
http://www.iono.noa.gr/DIAS

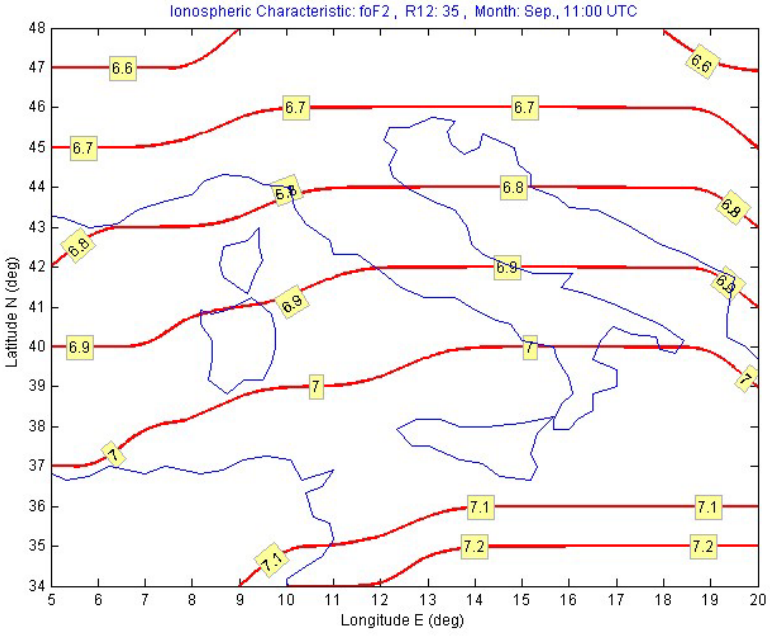


Architecture of DIAS system

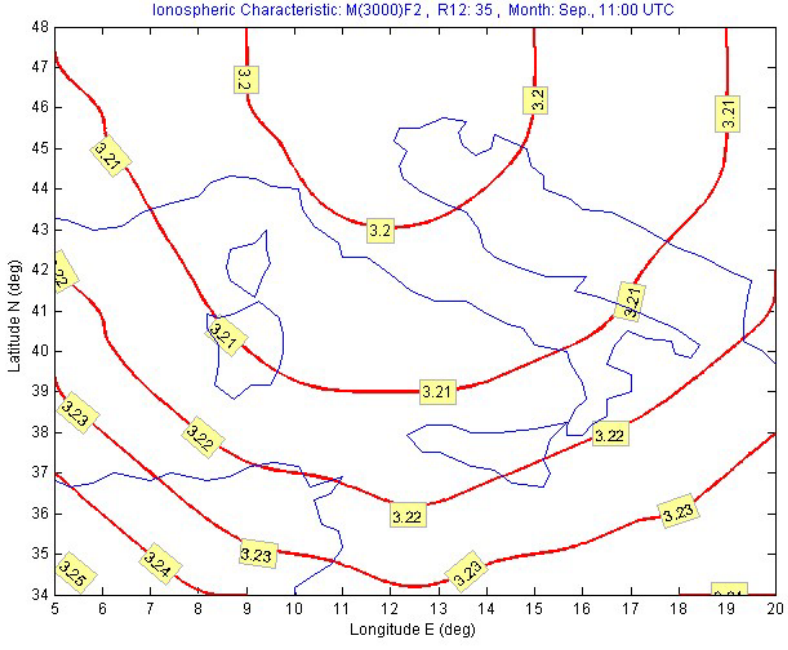


DIAS data, products and services

- Real-time ionograms with the results of the automatic scaling from DIAS network stations
- Historical and real-time radio wave propagation characteristics and trans-ionospheric propagation data in ASCII and graphical output
- Maps of ionospheric and trans-ionospheric parameters over Europe produced and released on the web and/or in mobile platforms in real-time
- Regular forecasts for the conditions of the ionosphere over Europe based on interplanetary data and ground sounders observations released on the web
- Alerts and warnings on forthcoming ionospheric disturbances released on the web and sent to subscribed users in mobile platforms (SMS, PDA, etc)



ESA/ESTEC Space Weather Pilot Project
GIFINT (Geomagnetic Indices Forecasting and Ionospheric Nowcasting Tools)
WP200: **I**onosphere **N**owcasting **T**ool
(INGV, NOA, RAL)



Maps of foF2 and M(3000)F2 over Central Mediterranean area derived from the Simplified Ionospheric Regional Model (SIRM) updated by real-time autoscaled measured values at Rome ionospheric station.

http://eskimo.ingv.it/spaceweather/start.htm

MIERS: The new COST Action 296

Mitigation of Ionospheric Effects on Radio Systems

Objectives

The main objective of the Action is to develop an increased knowledge of the effects imposed by the ionosphere on practical radio systems, and for the development and implementation of techniques to mitigate the deleterious effects of the ionosphere on such systems.

Expected inauguration: February 2005

Coordinators: Ljiljana Cander, Bruno Zolesi

Summary

Advantages:

- ✓ Important infrastructure and dense network of ionosondes
- ✓ Advanced skills in monitoring and interpreting observations
- ✓ Rich scientific and technical know-how
- ✓ Long tradition in ionospheric observations
- ✓ Several very good databases

Conclusion:

The establishment of a European operational network for monitoring the ionosphere will bring added-value to the existing investment and will support operational applications with reliable services.