Overview on the EU COST271Action: Effects of the Upper Atmosphere on Terrestrial and Earth Space Communications (EACOS) Aiakos

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

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A **COST** (**Co**-operation in the Field of **S**cientific and **T**echnical Research) 271 Action was inaugurated by the European Union in October 2000.

It follows the successful Actions **COST** 238 on **PRIME** (**P**rediction **R**egional **I**onospheric **M**odelling over **E**urope) and **COST** 251 on **IITS** (**I**mproved Quality of Service in **I**onospheric **T**elecommunication **S**ystems Planning and Operation).

This is a four-year Action and its primary objectives, the work programme and the main results are here shortly presented.

COST Action 271 : Effects of the Upper Atmosphere on Terrestrial and Earth-Space Communications (EACOS)

Number of signatories: 17

- Austria 7 June 2000
- Greece 31 May 2000
- Poland 10 May 2000
- Hungary 23 May 2000
- Bulgaria 16 August 2000
- Italy 3 July 2000
- Czech Rep. 26 June 2000
- Spain 10 May 2000
- Portugal 26 October 2000
- Latvia 9 June 2000
- Finland 6 September 2000
- Turkey 26 May 2000
- France 10 May 2000
- United Kingdom 29 June 2000
- Germany 17 May 2000
- Belgium 1 September 2002
- Serbia Montenegro 1 March 2002

Main objectives of the COST 271 Action

- to perform studies to influence the technical development and the implementation of new communication services, particularly for the GNSS and other advanced Earth-space and satellite to satellite applications,
- to develop methods and algorithms to predict and to minimise the effects of ionospheric perturbations and variations on communications and to ensure that the best models over Europe are made available to the ITU-R,

Main objectives of the COST 271 Action

- to collect additional and new ionospheric and plasmaspheric data for now-casting and forecasting purposes,
- to stimulate further co-operation in the domain of ionospheric and plasmaspheric prediction and forecasting for terrestrial and Earth-space communications, including interactive repercussions on the corresponding standards in this field, taking into account the present and future needs of users.

The work is arranged under four topics as follows:

1. **Impact of variability of space environment on communications**
2. **Assessment of space plasma effects for satellites applications**
3. **Ionospheric effects on terrestrial communications**
4. **Space plasma effects on Earth-space and satellite to satellite communications**

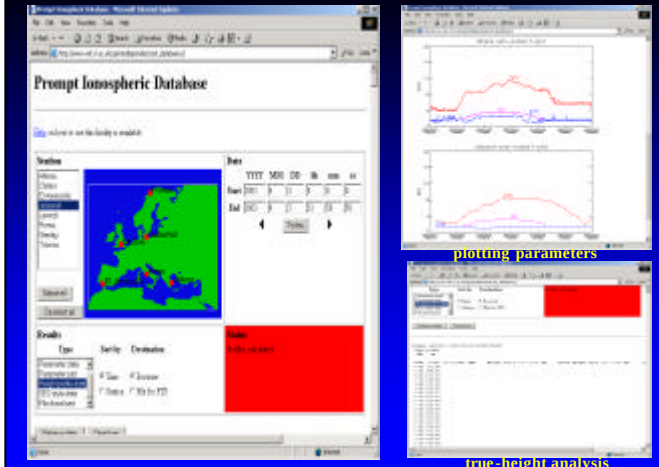
MAIN RESULTS

Working Group 1: Impact of variability of space environment on communications

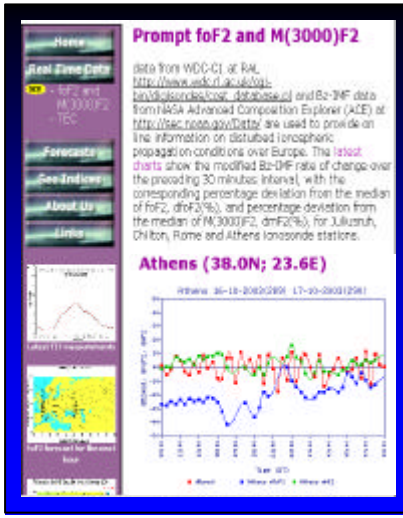
WP1.1 "*Impact of space weather on communication*" has been studying propagation phenomena, which are under certain circumstances related to the space weather events.

WP1.2 "*Database and tools for nowcasting, forecasting and warning*"

The Ionospheric component of the **Space Weather Database** has been developed. Data are catalogued and archived typically within minutes of the soundings being taken and data are then immediately available to users through the web interface. The database is available to all at http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl.



The web interface of RAL-Ionospheric Space Weather Database

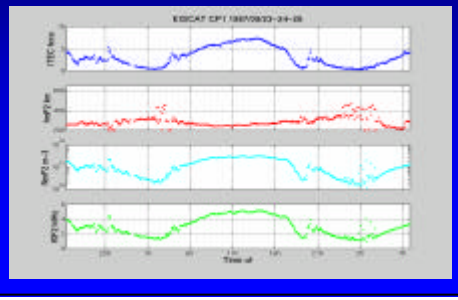


Real-time measurements of foF2 and M(3000)F2 from European Digisondes operating in Athens, Rome, Chilton and Juliusruh and the Bz component of the interplanetary magnetic field, Bz-IMF, from NASA Advanced Composition Explorer (ACE) spacecraft mission are combined for the development of a real-time dynamic system, oriented to monitor the ionospheric propagation conditions over Europe:

http://ionosphere.rcru.rl.ac.uk/

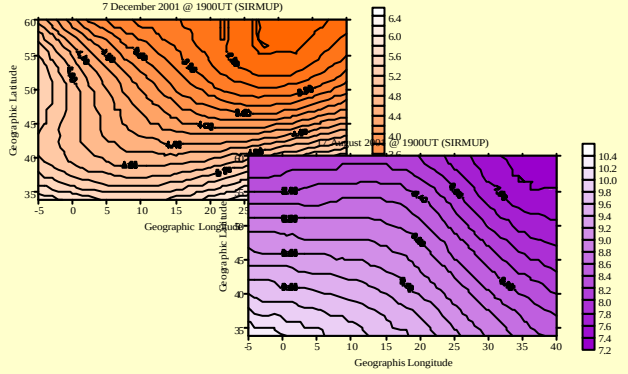
by RAL and NOA

The Grenoble EISCAT database has been extended to include values of Integrated TEC, hmF2, NmF2 and f_OF2. These have been calculated from EISCAT data taken with the common programme CP1, with the data covering intervals in the period 1986-1999. The data is freely available from http://eiscat.obs.ujf-grenoble.fr/, and there are plans to extend the data coverage up to the present.



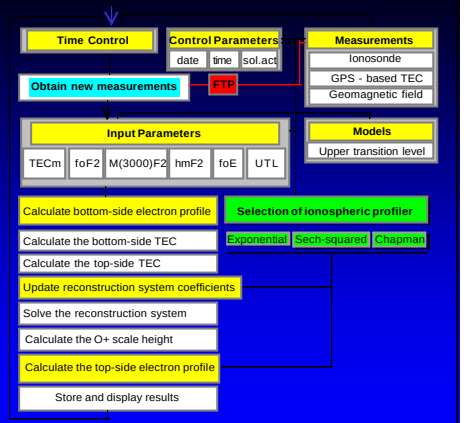
In the frames of developing space weather now-casting and forecasting procedures and software tools, different software tools of real-time mapping of the ionosphere over Europe are under development.

One of the mapping technique is based on the Simplified Ionospheric Regional Model (SIRM), updated using autoscaled ionospheric parameters from four real-time European digisondes operated in Rome, Athens, Chilton and Juliusruh. According to the preliminary results, the method of real-time updating SIRM is successful in improving ionospheric mapping over Europe, especially during storm periods.



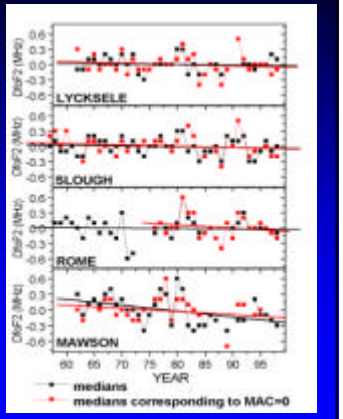
Maps of the foF2 parameter obtained with the method of updating SIRM with real time automatic scaled digisonde data, for a quiet period (7 December 2001) and for a storm period causing positive storm effect over Europe (17 August 2001), at 1900UT (Zolesi et al., 2002).

Concerning the topside ionosphere, Stankov et al. (2003) developed an operational model for topside electron density profile reconstruction on a real-time basis, using combined ground-based GPS TEC and ionosonde measurements.



WP1.3 "*Long term trends in the ionosphere and upper atmosphere parameters*"

Regarding the potential effect of long-term trends on prediction models the trends in foF2 and hmF2 are very small and have a not significant practical meaning (Bremer and Lastovicka, 2002; Lastovicka, 2003; Mikhailov et al., 2002). The scientific origin needs to be investigated. The possible role of other causes, as the consequences of the greenhouse gasses emission enhancement, are still under investigation.



Working Group 2: Assessment of space plasma effects for satellites applications

In the frame of **WP2.1** "*Plasma effects on GNSS applications*" validation studies were carried out with "Ionospheric Radio Occultation (IRO)" data gained by the German CHAMP (CHAllenging Minisatellite Payload) satellite.

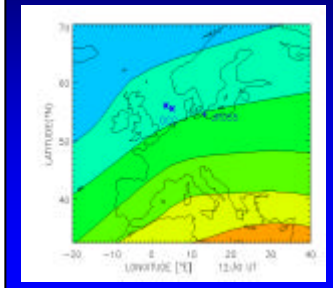
The data were subjected to a model assisted retrieval technique to provide vertical electron density profiles on a global scale. Validation studies revealed RMS deviations of the F2 layer parameters foF2 and hmF2 of about 1.3 MHz and 47 km, respectively.

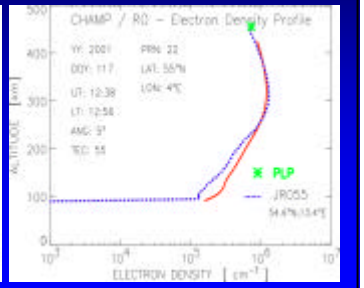
DLR Neutrality

IRO Validation - Vertical sounding / TEC

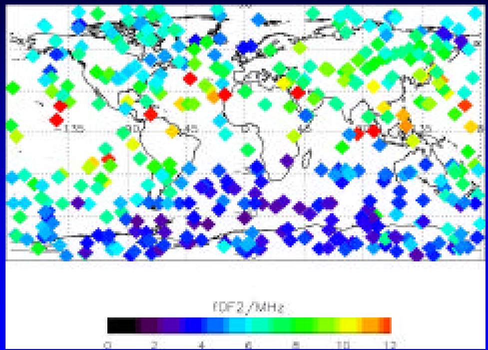
Day-time profile retrieved from GPS IRO measurements onboard CHAMP during the HIRAC/SolarMax of IGS on 27 April 2001, supported by COST 271

Comparison with ionosonde vertical profile measured in Juliusruh/IAP Kühlungsborn,





Night-time f0F2 values for days 101-224 /2002



Global distribution of the typical vertical sounding parameters f0F2 and hmF2 on night-time between 11 April and 12 August 2001

Possibility to complete the global ionosonde network by IRO data

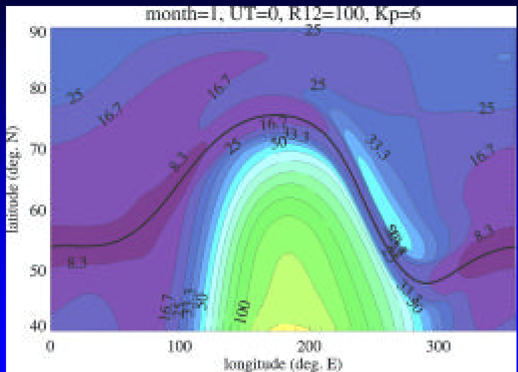
Working Group 2: Assessment of space plasma effects for satellites applications

The main results concerning **WP 2 and 3** "*Assessment of plasma propagation errors in navigation systems and merits and shortcomings of novel data sources*" are three dimensional and time dependent electron density models for assessment studies.

Family of COSTprof models provide a larger scale background ionosphere which can be "modulated" to incorporate smaller scale structures like troughs and ridges.

The most important structures ready to use are the main trough of the F regions which is found at the border between mid latitudes and high latitudes and Traveling Ionospheric Disturbances (TIDs).

ITU-R peak density modulated by the main trough



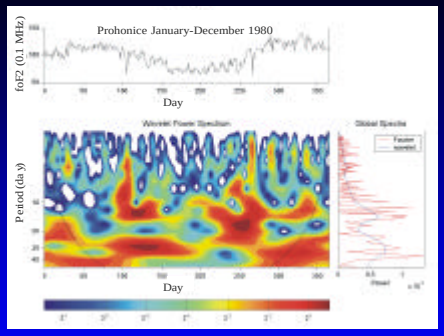
Contours of peak density in units of 10^9 m^{-3}

Working Group 3: Ionospheric effects on terrestrial communications

WP3.1 "*Effects of large-scale fluctuations on terrestrial communications*"

Planetary waves

The persistence of the planetary wave type oscillations in the lower ionosphere (radio wave absorption) and foF2 was investigated and compared.The typical planetary wave type oscillation persistence in foF2 for Europe is 4 cycles for ~5-day waves, rather 3.5 cycles for ~10 day waves and rather 3 cycles for ~16-day waves , whereas in the lower ionosphere it appears to be by a 0.5 cycle longer , but this difference is not statistically significant. The oscillation activity in the geomagnetic activit y plays an important role in the percentage of existence of such oscillations in the F region.



Planetary wave activity inferred from foF2 for Pruhonice, January – December 1980, Morlet wavelet transform. Top panel – time series of raw foF2 data. Bottom left panel –wavelet transform power spectrum of the planetary wave activity changing by colour from white and black blue (minimum values) through green to red and black red (maximum values). Power spectrum is normalized to 1. Bottom right panel – global (over 365 days) Morlet wavelet and Fourier spectrum; horizontal axis – power; vertical axis - period of oscillations in days.

WP3.1 "Effects of large-scale fluctuations on terrestrial communications"

Gravity waves

Study of the variations of GW using Continuous Wavelet Transform applied on the data measured during campaigns of rapid ionospheric sounding (variations of electron concentration) shows the diurnal changes in intensity and presence of the GW in the F-region ionosphere.

The large family of the GW of the wide range periods exists in the ionosphere. There are several groups of waves (groups of specific periods) that do not change too much their onset time during the day (sunrise, sunset waves).

The corresponding variations were detected on the Total Electron Content measurements over the same area as well.

WP3.2 ***"****Mid-latitude ionospheric features in radio propagation models****"***

• F1 region (160-200 km) behaviour during intense geomagnetic storms in Europe displays summer/winter asymmetry with much stronger effects in the winter half of the year (maximum during autumn).

• At European high-middle and high latitudes, the daytime effect at F1 region heights was found to be negative and independent on the F2 region (foF2) response to intense geomagnetic storm for all 18 newly analysed cases.

• *Spread F*. The origin of mid-latitude spread F has been studied considering plasma instabilities and TIDs producing spread F and a closer relation to Es layer occurrence .

WP3.4 *"Development of methods and algorithms to minimize the effects of small and large scale fluctuations on terrestrial communications"*

TRILION project

Its goal is to build a modem to transmit images via the ionospheric HF channel.

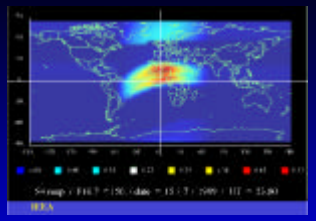
A first system has been developed to evaluate the feasibility of the system. The algorithm has been optimized. A new multi channel HF receiver is developed for angle of arrival measurements of long distance propagation mode via the ionospheric channel, using co-localized antennas and high-resolution algorithms.

Very encouraging results have been obtained with direction of arrival changes and simulated ionograms being reminiscent of the experimental measurements.

Working Group 4: Space plasma effects on Earth-space and satellite to satellite communications

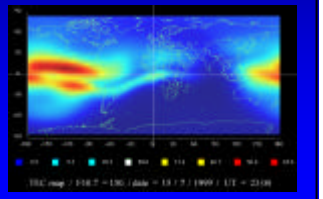
Within the **WP4.1** "*Effect of space plasma variability and irregularities on Earth-space and satellite to satellite communication channels*" it has been studied the scintillation probability distribution functions and frequency correlation.

The results obtained will be used to build up a scintillation effect model which could be used for system specification. Comparisons have been made between experimental data from low latitudes and theoretical models (WBMOD and GISM). The results show advantages and limitations of such models.

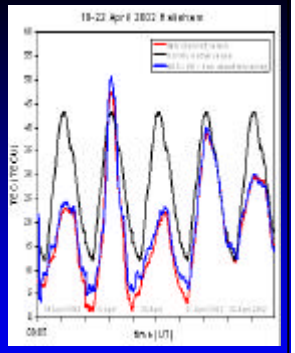


The S4 map obtained with GIM gives the expected values and geographical dependencies for S4 for both equatorial and polar regions. From "A Review of Scintillations Events and Probabilities" by Y. Béniguel, (Presented at the 1st COST271 Symposium at Sopron)

S4 and TEC maps for vertical links with a GPS satellite. The grid points correspond to the sub satellite points coordinates.



Concerning the **WP2.2** *Development of algorithms and software to treat disturbances in Earth-space and satellite to satellite communications*", the neural networks based model of the Middle East Technical University Group was used to forecast the 10 minutes values of the Total Electron Content, 1 hour ahead, during high solar activity in the current solar cycle. The network is designed to forecast TEC data evaluated from GPS measurements from 2000 to 2001 at Chilbolton (51.8 N, 1.26 W). An additional validation has been performed on an independent data set by producing the forecast TEC values at Hailsham (50.9 N, 0.3 E) receiving station for selected months in 2002.



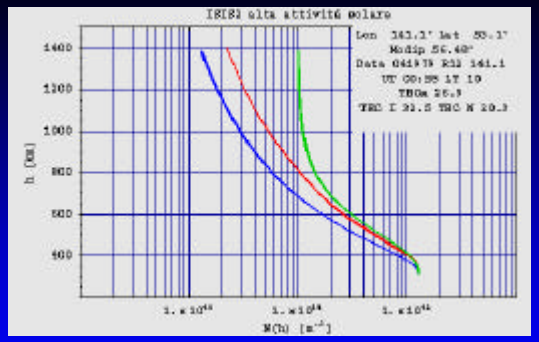
Observed GPS TEC results for disturbed solar-terrestrial conditions (red), 1 hour ahead forecast (blue), and monthly median (black) TEC values for Halisham, 18-22 April 2002.

Concerning the **WP4.3** "*Application of theoretical considerations to the study of space plasma effects*" the study of the mechanism of natural electromagnetic and electrostatic plasma emissions generated in the near space has been continued together with the investigation of radio broad band electromagnetic emission particularly over the ionospheric trough.

The study of the electromagnetic emissions and modifications of plasma ionosphere density and electron temperature profile over seismo-active and those generated during the injection of electron beam into the ionospheric plasma have been carried out.

Within **WP4.4** " *Effects of the vertical and horizontal gradients of the electron density on Earth-space and satellite to satellite communication* " an investigation of the slant to vertical TEC conversion errors introduced by the thin shell approximation for the ionosphere and the use of a simple mapping function to obtain vertical delay starting from slant values has been continued.

Results based on experimental data indicates a strong dependence of the errors with respect to geomagnetic activity as given by the Dst index. An extensive work of validation of IRI and NeQuick topside electron concentration models using 20000 satellite topside profiles from available databases that cover different seasons and solar activity level have been carried out.



Comparison of vertical electron density profiles for high solar activity. Red: experimental ISIS 2 profile. Blue: NeQuick profile. Green: IRI profile.

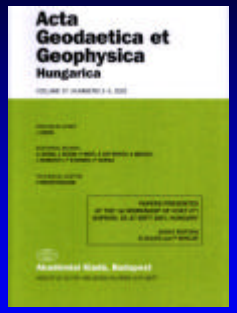
Publications and Reports

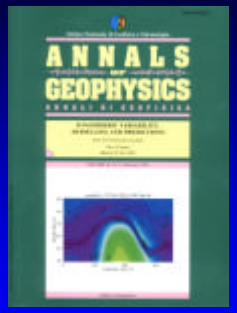
Most of the papers concerning the activities of the COST271 Action have been published in the following special issues:

1st COST271 Workshop Proceedings CD "Ionospheric Modelling and Variability studies for Telecommunication Applications", 25-27 September 2001, Sopron, Hungary.

2nd COST271 Workshop Proceedings CD "Products for ITU-R and other Radio communication application", 1-6 October 2002, Faro, Portugal.

Special volume of Acta Geophysica Hungarica on the COST271 Workshop "Ionospheric Modelling and Variability studies for Telecommunication Applications", Volume 37, N. 2-3,2002





Special volume of Annals of Geophysics dedicated to the XXVI EGS General Assembly Session on Solar-Terrestrial Sciences:'' Ionospheric variability and modelling", Vol. 45, N.1, February 2002. The next Special volume Annals of Geophysics dedicated to EGS-AGU 2003 is in preparation.

Scientific and Technical Cooperation

Most part of the scientific studies performed during last years has been obtained as result of co-operations among different countries in Europe.

A pilot project involving Italian, Greek and UK partners , named GIFINT, Geomagnetic Indices Forecasting and Ionospheric Nowcasting Tools, has been recently approved and financially supported by the European Space Agency. Participants of this action are active in international projects as the HIRAC campaign or are promoting new international projects that are involving other COST271 members as the European FP6 or the " ROSE" a project to establish in "Gaudos" the southernmost land in Europe an international geophysical observatory .

A new COST Action proposal – *after the successful end of the COST271 Action*

for the research to be addressed in the COST Telecommunications and Information Science and Technology (TIST) on:

- **three particular systems operating via the ionosphere : (i) radio wave communications, (ii) navigation, and (iii) surveillance**
- **Ionospheric propagation data networking**
- **Ionospheric monitoring and modelling data networking.**

ROAD MAP:

1. **Possible objectives of the new COST Action -** ***National Representatives to the COST271 Chair by 31 December 2003 ;***
2. **Summary of proposals to be considered -** ***COST271 MC meeting in Spain, March 2004;***
3. **Establishment of the Working Group for MoU preparation -** ***MC meeting in Spain, March 2004;***
4. **Working Group meeting to prepare draft MoU -** ***EGU meeting in Nice, April 2004;***
5. **Draft MoU to National Representative -** ***1 June 2004;***
6. **Final version of MoU to be considered and approved -** ***COST271 Final meeting, RAL, August/September 2004***

ESA PARTICIPATION WELCOME

Web site

The Web site of the COST271 action is active on the following address: http://www.cost271.rl.ac.uk/