



COST 296 Action: **Mitigation of Ionospheric Effects on Radio Systems (MIERS)**

Approved Minutes of the 8th Management Committee Meeting
13-15 March 2008
Mediterranean Beach Hotel, Limassol, Cyprus

1. **Welcome**

AB (COST 296 Chairperson) welcomed all participants (Annex II – List of attendees) and thanked HH and LE for hosting this meeting, everyone for coming and wished us all a good meeting.

2. **Approval of the Agenda**

The Draft Agenda for the meeting was approved see ANNEX I

3. **Adoption of the Minutes of the seventh MC meeting**

The minutes of the seventh MC meeting held at Hotel Globus, Prague, Czech Republic were approved with no requested changes.

4. **Official status of the COST 296 Action by 10 July 2007**

AB reported that there are 18 signed countries with Croatia, Sweden, The Russian Federation and possibly Latvia intending to sign and 7 signatories from non-COST countries. The MC was asked to approve an application from Radio Research Laboratory, Korea and this was accepted.

5. **COST296 Budget 1 July 2007 to 30 June 2008**

AB reported that the COST 296 budget (Annex III) arrived to RAL the budget administrators. AB proposed the following repartition and the MC accepted this proposal:

Travel costs 83,200€

Workshop organisation: 5,300€

STSM: 8,000€

L'Aquila Training School: 1,000€

Secretariat 7,500 €

Total : 105,000€

AB also mentioned that there is a new ruling from Brussels that each COST Action must nominate 2 people willing to examine and sign the Final Financial Report before it is sent to Brussels. From COST296 AB proposed to nominate L Cander and B Zolesi. Both nominees and the MC accepted this proposal.

6. **Short Term Scientific Missions (STSM) Reports**

VR presented the STSM report for Inigo Blanco who visited INGV to discuss work on the installation of a GISTM in El Arenosillo, Spain.

Benoit Bidaine presented the STSM report from his visit to ICTP, Trieste, Italy where BB, who is starting his Ph D thesis dedicated to the improvement of the ionospheric correction derived from the NeQuik model for Galileo users, had discussions on this subject.

7. **Workshop in Nottingham**

AB gave a report (full report at Annex IV) from the Ionospheric Scintillation Workshop held at Nottingham University, UK 20-22 February 2008. This was a very successful workshop with around 48 participants and 29 presentations these can be seen at www.nottingham.ac.uk/iessg. COST296 funded some of the participants travel and awarded a grant for incidental costs.

8. **Collaboration with IC 0603**

AC reported that he had attended IC0603 an Antenna Action lead by J Mosig, AC identified the topics under which potential collaboration would be possible. He will also participate in the next IC0603 meeting scheduled to take place later in 2008.

9. **COST activities related to IHY**

VR presented a verbal report from L Alfonsi who was unable to attend the MC meeting.

10. **The PGHM campaign**

DA reported on the forthcoming PGHM campaign The Whole Heliosphere Interval targeted campaigns from March 20 to April 16 (http://ihy2007.org/WHI/targeted_plans.shtml).

The COST 296 campaign may fit supporting the first one of the Geospace Targeted Observing Campaigns (<http://ihy2007.org/WHI/teccampaign.shtml>). This will deal on Day-to-day variability of total electron content (TEC) and scintillations and being coordinated by Ayman Marhous and Keith Groves. The proposed campaign request that stations operating GPS receivers should make continuous 24-hour calibrated measurements of TEC during this entire period. Those stations belonging to SCINDA or other networks should similarly make calibrated measurements of scintillations every night. Ionosonde measurements of F-region heights and densities would be very helpful as additional inputs for modeling electron density profiles. It is believed that regular VS measurements will fit in this as well as TEC measurements we may perform.

11. **Receipt and adoption of the progress reports of Working Group Leaders**

WG 1: Ionospheric monitoring and modelling (ANNEX V)

WG 2: Advanced terrestrial systems (ANNEX VI)

WG 3: Space based systems (ANNEX VII)

Six further STSM were proposed and accepted by MC: Greece to Italy; Germany to UK; Greece to Poland; Poland to UK; two Turkey to Italy.

12. Preparation of Annual Report

Working Group leaders were asked to send to AB contributions from their WG's by 1 April 2008. AB has to then prepare and send his Chairman's report to Brussels ready for the ARM (Annual Review Meeting) being held in Larnaca, Cyprus, June 2008.

13. Preparation for the COST296 Action Final Report

It was decided after much discussion to have the COST296 Final Report as a publication in Annals of Geophysics book. To enable a draft form to be ready for the Final meeting in February 2009 the WP leaders were asked to send contribution to WG leaders and Chairman by the end of August 2008. These contributions will be discussed during the October MCM being held in Rome. INGV will print drafts for January 2009 before sending to Annals of Geophysics.

14. Discussion of a possible follow-on Action

The MC decided that it would be happy to have a new Action.

15. Next meeting of the COST296 Action

The proposal from BZ to have the next MCM and Workshop at INGV in Rome in October 2008 was adopted by the MCM. BZ also proposed that in 2008 COST296 should organise a special meeting to celebrate 20 years of participation in a COST Action. Two invitations were received to host the Final meeting of COST296 from both Slovenia and Poland further discussions will take place at the next MC meeting to decide when and where.

16. International meetings relevant for the COST296 Action

There are several international meetings relating to COST296 activities:

International School of Space Science in L'Aquila Italy, 7-12 April 2008

EGU 2008, Vienna

IES Ionospheric Effects Symposium 13-15 May 2008, Washington DC, USA

ISEA12 Crete, Greece, May 2008

URSI GA 2008, August, Chicago, USA

NAVITEC 2008, 12 December 2008, Noordwijck, Netherlands

IAGA 2009, 23-30 August, Sopron, Hungary

17. **Discussion on FP7**

After the Nottingham meeting a discussion was organized on an FP7 proposal for IPDM. The meeting concluded that it would be preferable to start with a training network before going into the preparation of a proposal.

18. **The IES 2008 meeting**

For the COST session during the IES2008 being held in Alexandria, USA where 11 COST296 participants will have presentations, the MC decided that there will be limited funding of €2000 per person to help towards expenses for this conference.

19. **Report on the JASTP special session**

The JASTP special issue have accepted 6 papers and a 8 further papers after revisions, all papers should be ready for August 2008.

20. **Report on the task force for the improvement of COST296 web site**

There was no report or activity from this task force. IS offered to provide a template for WG leaders to use to improve their WG pages.

21. **Any other Business**

LC explained that she hasn't received any information from IRI/COST group that had been set up in Prague to work on mapping and modelling. AB to send an official request to D Bilitza and B Reinisch (LC to provide draft).

AB thanked HH and LE for their hospitality and all others for coming to the meeting.

ANNEX I



Eighth Management Committee meeting of the COST 296 Action

Mitigation of Ionospheric Effects on Radio Systems (MIERS)

*Cyprus
13 - 15 March, 2008*

Agenda

1. Welcome
2. Approval of the Agenda
3. Adoption of the Minutes of the seventh MC meeting
4. Official status of the COST296 Action
5. Status of COST296 Budget from 1 July 2007 to 30 June 2008.
6. Short Term Scientific Missions (STSMs). Report on those already done
7. Report on the Nottingham workshop
8. Collaboration with Action IC 0803 on antennas (A. Casimiro)
9. COST296 activities related to the IHY
10. The PGHM campaign (D. Altadill)
11. Receipt and adoption of the progress reports of Working Group Leaders
 - Report on WG1
 - Report on WG2
 - Report on WG3
- General discussion
12. Preparation of the annual report
13. Discussions on the preparation of the final report
14. Discussion on a possible following action
15. Next meetings of the COST296 Action
16. International meetings relevant for the COST296 Action
17. FP7 application
18. The IES 2008 meeting
19. Report on the JASTP special session
20. Report of the task force for the improvement of COST296 web site
21. Any other business

ANNEX II

COST 296 Action MC meeting 13-15 March 2008 List of Attendees

D Altadill	(DA) Observatory de l'Ebre, Roquetes, Spain (NR)
J Azevedo	(JA) University of Madeira, Madeira, Portugal (NR)
A Belehaki	(AB) NOA , Athens, Greece (NR)
P Benzce	(PB) Hungarian Academy of Sciences, Sopron, Hungary (NR)
Y Beniguel	(YB) IEEA, France (NR)
B Bidaine	(BB) University of Liège, Belgium
A Bourdillon	(AB) University Rennes 1, France (Chairman, NR)
J Boška	(JBO) Academy of Sciences of Czech Republic, Prague, Czech Republic (NR)
Lj R Cander	(LC) Rutherford Appleton Laboratory, Chilton, Didcot, UK
A Casimiro	(AC) University of Algarve, Faro, Portugal (NR)
L Ecomomou	(LE) Intercollege, Limassol, Cyprus (NR)
H Haralambous	(HH) Fredrick Institute of Technology, Nicosia, Cyprus (NR)
S S Kouris	(SK) Aristotelian University of Thessaloniki, Thessaloniki, Greece (NR)
J Laštovička	(JL) Academy of Sciences of Czech Republic, Prague, Czech Republic (Co-Leader WG-1, NR)
J-P Luntama	(J-PL) Finnish Meteorological Institute, Helsinki, Finland (NR)
V Romano	(VR) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy (NR)
H Rothkaehl	(HR) Space Research Centre, Warsaw, Poland (NR)
H Strangeways	(HS) University of Leeds, Leeds, UK (NR)
I Stanislawska	(IS) Space Research Centre, Warsaw, Poland (Co-Leader WG-1, NR)
I Tsagouri	(IT) NOA, Athens, Greece
A Vernon	(AV) Rutherford Appleton Laboratory, Chilton, Didcot, UK (COST296 Secretary)
EM Warrington	(MW) University of Leicester, Leicester, UK (Co-Leader WG-2, NR)
B Zolesi	(BZ) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy (Vice-Chairman, NR)

NR: National Representative

ANNEX III

COST ACTION 296

PROPOSED BUDGET FOR THE PERIOD JULY 1ST 2007 TO JUNE 30TH 2008

(1)	TRAVEL COSTS	€ 83,200
(2)	WORKSHOP ORGANISATION SUPPORT	€ 5,300
(4)	SHORT-TERM SCIENTIFIC MISSIONS	€ 8.000
(5)	TRAINING SCHOOLS	€ 1,000
(6)	SECRETARIAT	€ 7.500
	TOTAL	€ 105,000

Ionospheric Scintillation: Scientific Aspects, Space Weather Application and Services

Workshop hosted by the IESSG, University of Nottingham, UK

Sponsored by COST 296 and The University of Nottingham

Co-sponsors: Leica Geosystems and Spirent Communications

The Ionospheric Scintillation Workshop was hosted by the IESSG between 20 and 22 February 2008. It was an opportunity for the European scientific community within the COST296 action MIERS (Mitigation of Ionospheric Effects on Radio Systems) to discuss the scientific and practical aspects of this action, with potential for setting up an ionospheric scintillation monitoring network in the Northern Hemisphere. This initiative would build on existing and planned infrastructures and instrumentation and would contribute to the knowledge of the ionospheric plasma density irregularities, potentially responsible for degrading in particular positioning and navigation systems and services. The workshop was a forum for discussion on the integration of existing and future tools (such as ionospheric imaging, structured data bases, mitigation techniques, scintillation modeling, irregularities modelling, etc.), with the specific aim to pursue funding opportunities in Europe, in particular within FP7. Its main scientific focus was on ionospheric effects, scintillation in particular, on GNSS signals and receivers and on the integration of services and corresponding scientific basis that will be of interest to the GNSS user community. It is an aspiration of all European countries to reduce the impact of this phenomenon, especially due to its impairing effect on safety critical applications of GNSS. Ionospheric monitoring services already exist or are planned to be established at national level in some countries. However further research is needed to better understand and model the data from such networks to allow their integration with the aim to provide warning and/or mitigation information in a timely (near real-time) and reliable manner.

There were 4 scientific sessions covering the entire spectrum of current research and system advances in the proposed field, with a total of over 40 leading experts representing 16 countries and several institutions, including Universities, Observatories and National Space Centers, alongside organisations such as the European Space Agency (ESA), Rutherford Appleton Laboratory and the international defence and security technology company Qinetiq. The University of Nottingham contributed to the organization of the event with a grant of approximately £5,000 awarded by its Research Committee, while sponsorship from COST296 was over € 20,000, to cover travel and expenses of designated national representatives of member countries in Europe as well as overseas participants, such as colleagues from as far afield as Brazil. Also, a contribution of € 2,500 from COST296 was made directly to the University of Nottingham to aid in the organization, with additional contributions kindly coming from Leica Geosystems and Spirent Communications. The workshop took place at the East Midlands Conference Centre, in Nottingham.

On the last day of the workshop, Session 4 was dedicated to ‘European Synergy for Integrated Ionospheric Services and Funding Opportunities’, with presentations highlighting the impact of ionospheric scintillation and current efforts to address the problem in a concerted manner. A proposal to form a consortium to establish an ‘Ionospheric Perturbation and Detection Monitoring (IPDM)’ network in Europe was introduced, which could be the foundation of a research initiative and potentially a service that would meet the expectations raised at the workshop. Session 4 also saw a presentation by Dr Martin Pickard of GrantCraft, a consultancy company hired by the University of Nottingham to provide insight and support applications to FP7 related calls. The workshop helped fulfil the objectives of the COST296 action.

Links to the available workshop presentations can be found at the IESSG website:
www.nottingham.ac.uk/iessg.

Working Group 1 - Ionospheric monitoring and modelling

Report August 2007 – February 2008

Jan Laštovička (CZ) and Iwona Stanisławska (PL)

WP1.1 Near Earth space plasma monitoring
Leader: D. Altadill (ES)

WP1.2 Data ingestion and assimilation in ionospheric models
Leaders: D. Burešova (CZ) and B. Nava (I)

WP1.3 Near Earth space plasma modelling and forecasting *Leaders: I. Kutiev (BG) and H. Strangeways (UK)*

WP1.4 Climate of the upper atmosphere
Leaders: J. Bremer (D) and E. Turunen (FIN)

WP1.1 Near Earth space plasma monitoring

1. Developing monitoring techniques and parameters describing the state of the ionospheric plasma, to include ground-based and space based techniques.

Planetary and zonal ionospheric indices were designed on the basis of foF2 characteristics observations for the years 1999-2006 according to the procedure developed for TEC parameter. Analysis for scientific and operational assessments for global as well as regional monitoring and modeling was provided.

Planetary index of the ionospheric changes did not exist so far because it can be difficult to immediately deduce it from a mixture of increases and decreases of plasma density and electron content on the globe. This task is resolved using the numerical GPS-IONEX maps of the vertical total electron content, TEC, available daily since 1998. TEC values are extracted at 600 grid points of the map at latitudes 60°N to 60°S with a step of 5° and longitudes 0° to 345°E with a step of 15° providing hourly values for 0 to 23 hrs of local time for a representative set of conditions during a period 1999-2006. The local effects of solar radiative energy are filtered out. The derivation of the planetary perturbation index is a two-step process. In step 1, degree of perturbation is computed as logarithm of TEC relative to quiet reference taken as daily-hourly median for 27 days prior the day of observation. The W-index map is generated. In step 2, the planetary Wp index is obtained from W-index map as latitudinal average of ranges between maximum positive index and minimum negative index weighted by the latitude/longitude extent of the extreme index values on the map. The single-sign Wp index varies from 2 to 16 units growing towards the solar minimum. Equinoctial maximum of Wp index is observed, correlated with the Dst index. The planetary Wp index discloses the disturbances which may belong either to magnetosphere or the ionosphere-plasmasphere system or both providing broader proxy index driving the space weather than the geomagnetic indices alone.

A study has been carried out on ionosphere vertical TEC observations at solar minimum from a chain of European GPS stations. A preliminary investigation of all available 5 minutes vTEC data over the period 2006-2007 reveal a total of 15 “clean” events, all of which exhibited some form of vTEC increase focus exclusively on NON large-magnitude solar-terrestrial events.

A digisonde phase-difference technique measures precise radar ranges of echoes reflected from the ionosphere. The technique, which analyzes the phase differences between signals at slightly different frequencies, allows measuring the reflection range, i.e., the virtual height $h'(f)$ for vertical sounding, with accuracies of better than one kilometer. First results of measurements carried out at Millstone Hill demonstrate the robustness and reliability of the developed technique, and show the potential of the method for routine application. Preliminary results were obtained using the above HF technique for COST296/IHY Campaign in support to 3rd CAWSES tidal campaign.

A new method of evaluation of drift measurements in the ionosphere was developed for the Pruhonice station. This method excludes multiple and/or too oblique reflections and enables to separate E-region and F-region drifts (this is not routinely done by any other ionospheric sounding station), characteristics of which are substantially different.

2. Maintaining and extending the flow of real-time and retrospective ionospheric monitoring data to databases.

This activity has been made continuously at all COST296 ionospheric vertical sounding stations. Ionosondes of the COST296 network continue contributing with real-time VI data to WDC for STP, Chilton (RAL), DIDBase (UMLCAR), and DIAS (NOA) databases. The UMLCAR continued to archive in DIDBase all digisonde data available in real time via Internet, these include the European COST296 stations.

Besides automatic scaling of ionograms at some stations like El Arenosillo, Ebro and Pruhonice a routine handy control and corrections of ionogram scaling are made, which provides data in quality suitable not only for service but also for accurate scientific analyses.

The El Arenosillo observatory took part in the E Layer Precision Group Height Measurement (PGHM) campaign to contribute to the objectives of the Third CAWSES Global Tidal campaign scheduled from 1 June to 14 August 2007.

INGV continued to carry out the eSWua project. It is based on measurements performed by all the instruments installed by upper atmosphere group of INGV. The aim is the realization of a hardware-software system for a Data Base to standardize historical and real time observations for different instruments. After completing the two DBs related to the Rome DPS digisonde and the 4 GISTM (GPS Ionospheric Scintillation and TEC Monitor) measurements, in the last period the system has been enhanced with data of Gibilmanna Ionospheric Observatory. The system is able now to allow the user to explore and download validated vertical sounding data since 1976, view the ionograms and access to the automatic scaled data. Specific tools in order to survey the ionospheric behaviour both for real and historic time has been developed, they are already accessible by web.

3. Validating the quality and consistency of monitoring data, particularly those collected in real time.

The performance of the ARTIST algorithm (Automatic Real Time Ionogram Scaler with True height algorithm) used in digisondes with the use of N(h)-profiles calculated from Pruhonice ionosonde and Doppler system measurements (common volume measurements) was tested. We found that the

results of automatic scaling with ARTIST are essentially of good quality and reliable under quiet geomagnetic conditions and absence of the sporadic-E layer, but rather unreliable during moderate and strong geomagnetic storms.

A comparison of evaluation of the same ionograms by POLAN and ARTIST algorithms/computer codes revealed significant systematic differences between these two methods. The true reflection height is systematically higher at night for ARTIST, during daytime for POLAN. The best agreement of two inversion techniques is seen for two-layer profiles; in relation to that the largest difference between two inversion technique results occurs at F1 region heights and in F1-F2 transition region.

Recent results from RAL on a comparison between the hourly auto scaled and manual scaled characteristics from the Chilton ionosonde from 1996 to 2004 can be found in Bamford et al. (2008).

The UMLCAR archives all edited ionogram data together with the autoscaled values in DIDBase. The edited data files include the name of the scaler, and the DIDBase user can select the files with the “most trusted” editor. UMLCAR encourages all other digisonde users that perform hand-scaling routinely or for special campaigns to archive the edited data in DIDBase (DIDBase manager: Grigori_khmyrov@uml.edu).

4. Supporting and developing INTERNET sites and protocols for disseminating data products.

RAL has continued to maintain, support and improve the Prompt Ionospheric Database at http://www.wdc.rl.ac.uk/cgi-bin/digisondes/cost_database.pl. This is 24/7 on-line service that is based on the contributions of a number of COST296 participating institutions indicated at the above web site. Recent results on a comparison between the hourly auto scaled and manual scaled characteristics from the Chilton ionosonde

The RWC-Warsaw/IDCE (The Ionospheric Despatch Centre in Europe) web service (<http://www.cbk.waw.pl/rwc/idce> and <ftp://www.cbk.waw.pl/idce>) provides on line access to data base of the critical frequency of F2 ionospheric layer and M(3000)F2 forecast for all available sites. Ionosonda data from 1983 up to last measurements from all over the world in IIWG format are available. Daily plots of foF2 and M(3000)F2 for 30 stations from all over the world are presented along with their digital version. 24-hours ahead forecast for every station in digital and graphical form is supplied. GPS measurements and ionograms from Warsaw station are offered also. Continuous now-casting of regional ionospheric conditions (foF2 and M(3000)F2) over Europe, East Asia and Australia area are presented. A catalogue of the quiet and disturbed days and a catalogue of ionospheric disturbed periods with duration of 3h or longer is compiled for European stations and presented and also at IZMIR AN web. The Webpage addresses of Cost 296 related topics are presenting on the web navigator <http://rwc.cbk.waw.pl/cost296/>.

A dynamic web site www.eswua.ingv.it has been opened to the community for a real time access to raw and processed data. The user access is monitored and managed by using new developed tools: “General stats” and “Manage users”.

The Ionospheric Weather page at IZMIRAN website is maintained at <http://www.izmiran.ru/services/iweather/>. Technique for producing a proxy for foF2 critical frequency which improves correlation between the data of different stations was developed. It is applied for reconstruction of missed observations of foF2 at 30 stations worldwide. The complete daily-hourly-monthly data of foF2, hmF2 and the ionospheric variability indices for the past 2 years are kept at Archive of the IZMIRAN web page.

WP1.2 Data ingestion and assimilation in ionospheric models

- 1. Determine additional data products for inclusion in the COST271 Action Space Weather Database to improve support for ionospheric modelling; promote the generation of such products, to include manually corrected ionospheric parameters and N(h) profiles covering the entire European region.**

El Arenosillo maintains TEC and electron density profiles databases; the latter is maintained also by some other stations like Pruhonice. Besides automatic scaling of ionograms at some stations like El Arenosillo, Ebro and Pruhonice a routine handy control and corrections of ionogram scaling are made.

- 2. Promote and coordinate the creation of a suitable set of very high quality experimental data (like TEC and ionospheric parameters) for model validation and data ingestion studies.**
- 3. Promote and coordinate the creation of a set of “synthetic” data (produced with a model) for assessment of retrieval techniques.**
- 4. Select and validate appropriate models and data ingestion and assimilation techniques.**

The NeQuick ionosphere electron density model, version 2.0, has been published. Major changes have been introduced in the model topside formulation and important modifications have also been introduced in the bottomside description. Specific revisions have also been applied to the computer package associated to NeQuick in order to improve its computational efficiency.

The model assisted ionosphere electron density retrieval technique already developed using the NeQuick 1 has been tested with NeQuick 2. The tests confirmed the improvement of the new version of the model when it is adapted to GPS derived TEC data and ionosonde measured peak parameters.

The IRI 2007 options for computing the electron density in the topside have been analysed, focusing on the use of NeQuick topside formulation. An attempt to make this representation of the topside more coherent with the full IRI profile has been carried out, showing that it is possible to change the formulation of the B2top parameter in terms of IRI parameters only (B0). The empirical relation that describes B2top has been reformulated and tested on the ISIS-2 topside profiles using the two options for IRI B0. In this way the topside is directly connected to the bottom-side and there is no need to use M(3000)F2 value to compute NeQuick topside parameters.

A comparative analysis of the observed ionospheric peak parameters with IRI-2001 and a neural network based global foF2 model during strong-to-severe ionospheric storms continues. We used data from a few ionospheric stations (e.g., Pruhonice, El Arenosillo, Athens), which were not included in the development or the previous validation of the STORM and the global foF2 models. Hourly values of foF2 and hmF2 were compared with those generated by IRI-2001, and foF2 was also compared with the global foF2 model. Medians and model-generated values of the correlation coefficient, the normalized root-mean-square error (NRMSE), and the percentage improvement were calculated. The analysis shows that the improved IRI-2001 model with the activated STORM option provides better description of the ionisation distribution under geomagnetic storm conditions. The STORM model captures more effectively the negative phases of the summer ionospheric storms (an improvement is about 25-35 %); nevertheless, electron density enhancement during winter storms and changeover of

the different storm phases is reproduced with lower accuracy (for some storms the STORM option was disserviceable or an improvement was very low – about 2-8%). The model corrections are less efficient for lower-middle latitudes and severe geomagnetic storms. As STORM model makes no storm-time corrections of hmF2, the correlation coefficient during storm main phase ranges between 0.3-0.7. Results for the prediction of foF2 during storm-time periods by the global foF2 model were also generated.

A new global numerical model of the peak height of the F2 layer, hmF2_top, was developed using the topside sounding database of 90,000 electron density profiles for a representative set of conditions, provided by ISIS1, ISIS2, IK19 and Cosmos-1809 satellites for the period of 1969-1987. The model of regular hmF2 variations is produced in terms of local time, season, geomagnetic latitude, geodetic latitude and solar radio flux. The hmF2 given by IRI exceeds hmF2-top at the low solar activity. The developed model differs from hmF2 given by IRI based on M(3000)F2 to hmF2 conversion by empirical relationships in terms of foF2, foE and R12 with these quantities mapped globally by ITU-R from ground based ionosonde data.

In Prague-Ebro collaboration, an LM (Local Model) model was developed and tested. Its aim is to improve predictions of the bottomside F-region parameters B0, B1 and D1 by IRI 2001 during quiet geomagnetic conditions. The simple LM model simulates annual, seasonal and diurnal variation of the above parameters. The model was developed based on Ebro database and tested with data from Juliusruh, El Arenosillo and Pruhonice. The LM model simulates variations of the bottomside F region much more accurately than tabular method in IRI 2001; it eliminates artificial appearance of the F1 layer and predicts B0, B1 and D1 values 2-3 times better than IRI 2001.

5. Improve/develop real-time or near-real-time electron density reconstruction techniques.

Additional studies about the thickness of the NeQuick 2 F2 layer bottomside have been performed. The attention has been focused on the model behaviour at low latitudes compared to modeled profiles parameter with the ones extracted from experimental data, mostly related to the African and the Indian sector. Different levels of solar activity, seasons and local times have been considered.

6. Identify criteria to be used to validate the data ingestion and assimilation techniques.

7. To carry out specific studies on the use of the selected data ingestion techniques in order to improve the models formulation (structure) and applicability under different degrees of disturbance of the ionosphere.

The RWC-Warsaw/IDCE web service (<http://www.cbk.waw.pl/rwc/idce> and <ftp://www.cbk.waw.pl/idce>) provides on line access to the 24-hours ahead forecast of foF2 and M(3000)F2 for quiet as well as disturbed conditions based on data of continuous monitoring of regional ionospheric conditions from all available sites.

WP1.3 - Near-Earth space plasma modelling and forecasting

1. List the available forecasting models and classify them by lead-time: warning, nowcasting and forecasting.

The list of available classified forecasting models is completed, see Table at the end of report. More detailed description of models is available at the COST296 Web page. This term of reference is completed and finished.

2. Develop common rules for error estimates and testing procedures.

3. Develop techniques for real-time forecasting (data adjustment).

The revised version of the METU-NN neural-network based model is presented in a case study on the ELF Characterization of the Earth-Ionosphere cavity. The process parameters of interest are forecast in high accuracy generalizing the system modeling capability of the METU-NN. Figure 1 shows the variation of the observed and 2-hour in advance forecast 1st SR mode powers for April 2005 for Sarkoy, Turkey (40.50⁰N 27.08⁰E).

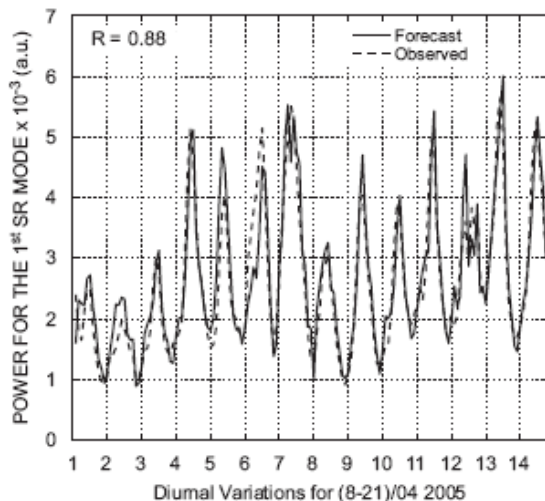


Fig. 1. The variation of the observed and 2-hour in advance forecast 1st SR mode powers for April 2005.

The METU-NN-C Model has NN (neural network) module which estimates interior variables of the Cascade Model. It shows higher accuracy when compared with NN and IRI-2001. It also has advantages related with its architecture. Since the interior variables can be observed it is not a black-box model. This fact supports the non-linear system designers and operators. The modular structure of it allows the designer to have different forms of non-linearity representations including polynomials, Bezier curves and B-Spline curves.

4. Improve the existing and develop new space plasma models.

The NeQuick ionosphere electron density model, version 2.0, has been published. Major changes have been introduced in the model topside formulation and important modifications have also been introduced in the bottomside description. Specific revisions have also been applied to the computer package associated to NeQuick in order to improve its computational efficiency.

The IRI 2007 options for computing the electron density in the topside have been analysed, focusing on the use of NeQuick topside formulation. An attempt to make this representation of the topside more coherent with the full IRI profile has been carried out, showing that it is possible to change the formulation of the B2top parameter in terms of IRI parameters only (B0). The empirical relation that describes B2top has been reformulated and tested on the ISIS-2 topside profiles using the two options for IRI B0. In this way the topside is directly connected to the bottom-side and there is no need to use M(3000)F2 value to compute NeQuick topside parameters.

5. Forecasting of foF2 and TEC and unifying geomagnetic drivers.

A prediction procedure of the hourly values of foF2, based on the utilisation of a time-weighted accumulation magnetic index $ap(\tau)$ based on recent past history of the geomagnetic planetary index ap , was developed. An empirical relationship between the ratio $\log(NmF2(t)/NmF2M)$, where $NmF2(t)$ is the hourly maximum electron density at the F2 peak layer and $NmF2M$ is its 'quiet' value, and $ap(\tau)$ was applied. Geomagnetic storms with a maximum of $ap \geq 132$, classified as strong events, were selected between 1986 to 2003. The prediction of foF2 is calculated during periods of severe geomagnetic activity in the solar cycle 23 in Rome. The r.m.s. obtained utilising the $ap(\tau)$ model, for the cases analysed, is 1.23 MHz.

After a first oblique-incidence ionospheric sounding campaign over Central Europe performed during the period 2003-2004 over the radio links between Inskip (UK, 53.5° N, 2.5° W) and Rome (Italy, 41.8 N, 12.5E) and between Inskip and Chania (Crete, 35.7° N, 24.0° E), new and more extensive analysis of systematic MUF measurements from January 2005 to December 2006 have been performed. MUF measurements collected during moderately disturbed days ($17 \leq Ap \leq 32$), disturbed days ($32 < Ap \leq 50$) and very disturbed days ($Ap > 50$), have been used to test the long term prediction models (ASAPS, ICEPAC and SIRM&LKW), and the now casting models (SIRMUP&LKW and ISWIRM&LKW). The performances of the different prediction methods in terms of r.m.s were obtained for selected range of geomagnetic activity and for each season.

An ionospheric forecasting empirical local model over Rome (IFELMOR) has been developed to predict the state of foF2 during geomagnetic storms and disturbed ionospheric conditions. Hourly measurements of foF2 obtained at the Rome observatory, hourly quiet-time values of foF2 ($foF2_{QT}$), and the hourly time-weighted accumulation series derived from the geomagnetic planetary index ap ($ap(\tau)$), were considered during the period January 1976 - December 2003. Statistically significant regression coefficients were obtained for the relation between the ionospheric disturbance index $\log(foF2/foF2_{QT})$ and the integrated geomagnetic index $ap(\tau)$, for different months and for different ranges of $ap(\tau)$ and used as input to calculate the short-term ionospheric forecasting of foF2. The empirical STORM model was compared with the IFELMOR model. The results provided by IFELMOR are satisfactory, in particular, for periods characterized by high geomagnetic activity and very disturbed ionospheric conditions.

6. Modelling and predicting different scale ionospheric perturbations.

Plasma enhancements drifting into the nightside ionosphere from the polar region are of interest. The ionisation is believed to originate on the dayside in the sunlit ionosphere, from where it is carried antisunward through the polar cap and into the nightside sector by the convective flow under conditions of Interplanetary Magnetic Field (IMF) $B_z < 0$. Modelling work has shown that the transport of plasma across the polar cap is expected to maximise when Europe is on the nightside because of the offset between the geomagnetic and geographic reference frames.

7. Tomographic imaging for model validation.

Multi instrument observations using the Aberystwyth University radio tomography chain in northern Scandinavia, the EISCAT incoherent scatter facility and the SuperDARN radar network have recently provided experimental evidence for the reconfiguration of a polar patch into a boundary blob. They have also revealed ionisation of dayside origin forming the poleward wall of the main ionisation trough in the post-magnetic midnight sector under IMF $B_z < 0$. Further studies have revealed cold, long-lived plasma in the winter nightside ionosphere under conditions of IMF B_z positive and attributed it to the transport of dayside photoionisation across the polar cap. Supporting modelling studies are underway using the Coupled Thermosphere-Ionosphere-Plasmasphere (CTIP) model where the electric potential patterns generally available to the model have been replaced by patterns derived from SuperDARN plasma flow observations. Preliminary investigations under conditions of IMF B_z negative have shown better agreement between the model and observations when the SuperDARN patterns are used. They have also indicated the potential of the method for modelling under different IMF orientations, in particular when IMF B_z is positive, which could not be simulated by the previous electric potential patterns in the model.

8. Channel modeling by neurofuzzy and other novel techniques.

9. Modelling of irregularities for propagation predictions and from inversion of propagation data.

WP 1.4 Climate of the upper atmosphere

1. Derivation of long-term trends in different ionospheric/atmospheric parameters and different height regions to get hints about their origin (greenhouse effect, geomagnetic influence, or other sources)

Some discrepancies between the results of various authors on trends in foF2 were removed and/or explained via comparison on a test data set from Juliusruh. The artificial neural network-based trends are very close to trends derived by simple linear regression. Wavelet-based analysis results by Chilean team were proved to be wrong. Therefore only the foF2 trends derived by Mikhailov's method, which uses a special way of eliminating geomagnetic activity effects, are substantially different from other results. At present trends in foF2 seem to be still dominated rather by geomagnetic activity long-term changes, whereas trends in hmF2 appear to be dominantly of anthropogenic origin (greenhouse gas

effect). In the past, the influence of geomagnetic activity was more important than it is now; for future we expect increasing role of anthropogenic control of trends in F2 region.

Investigations of possible connection between the possible excursion (or inversion) of the geomagnetic field and the foF2 trends, with special focus over Antarctica where the geomagnetic field weakening seems to be faster than over the rest of the globe.

As predicted by model calculations long-term changes in the stratospheric ozone content should influence also trends in the meso- and thermosphere. These predictions have been tested by means of ionospheric reflection height data in the LF range and critical frequency data series of the ionospheric E-layer, foE, observed at different stations around the world. It could be shown that an essential part of the derived trends in the mesosphere and in the lower thermosphere is correlated with long-term changes of the atmospheric ozone content. During the sub-interval with the strongest ozone decrease (1979 until 1995) the detected ionospheric trends are most pronounced. Additionally it could be demonstrated that also the longitudinally dependent ozone trends are related to similar variations in the foE trends.

Analysis of winds and signatures of planetary waves shows significant non-linear trends during the last 2 decades.

The investigation of the geographical distribution of hmF2 trends has been continued. Considering the world wide hmF2 trend sign distribution it has been found that nonmigrating tidal winds may be responsible for this geographical distribution. Comparing geographical distribution of trend signs with geographical distribution of nonmigrating tidal winds (meridional component) observed by the UARS satellite (by HRDÍ), a good agreement has been found.

2. Detection of signatures of different atmospheric waves (e.g. gravity, planetary and infrasonic), the investigation of their propagation through the atmosphere/ionosphere, and the search for possible predictability of their effects on the ionosphere

A computer code for the 2-D analysis of oscillations of electron density and determination of parameters of acoustic-gravity waves propagating through ionospheric plasma is now available at the IAP Prague Web site at: <http://www.ufa.cas.cz/html/climaero/sauli.html>.

Currently its 3-D version has been developed, which could utilize future high-quality Galileo-LEO RO electron density profiles for determining the 3-D structure of medium- and smaller-scale TIDs and/or gravity waves.

An analysis of generation of acoustic-gravity waves during solar eclipses reveals remarkable differences between total and partial eclipses both in characteristics of gravity waves propagating through the ionosphere and in formation and location of their source. Acoustic mode waves (long-period infrasound) generated by an eclipse has been detected for the first time.

The results of our investigations show that infrasonic waves of tropospheric origin are not a typical ionospheric phenomenon in Central Europe, which would accompany (strong) tropospheric convective storms. Infrasound has been observed in the ionosphere only during two events of extreme tropospheric activity.

Waves of periods of about 1-3 min, if observed simultaneously on all five measuring paths of the Czech Doppler system, correlate with geomagnetic Pi2 pulsations, particularly with fluctuations of horizontal components of the geomagnetic field as one of space weather phenomena. Such waves are not infrasound.

During the final stratosphere warming, 6–11-day oscillations arising from the planetary wave activity in the lower atmospheric regions were observed over Ebro and Alma-Ata stations. Such oscillations indicate the timing of the transition from the winter to the summer circulation

Long-period (3-20 days) oscillations have been measured simultaneously by meteor radar temperatures, and scale height estimates using the diurnal cycle of LF refraction heights, indicating that neutral atmosphere planetary waves influence the lower E region ionisation.

3. Investigation of ionospheric variability at middle as well as high latitudes (influence of precipitating high energy electrons on the ionised and neutral part of the atmosphere)

The investigations of the variations of TEC, foF2 and slab thickness in dependence on solar activity, location and season have continued. The correlations between the three parameters TEC, foF2 and slab thickness (s.t.) show that TEC and foF2 are highly correlated with correlation coefficients greater than 0.95 always, but TEC and s.t., as well as foF2 and s.t. are not correlated. They have also a different behaviour with the season and latitude.

The mid-latitude electron density trough observed in the topside ionosphere has been shown to be the near-Earth signature of the plasmopause. To present the evolution of ionospheric trough in time and space domain we need some multipoint measurements and different type of measurements techniques. To develop a quantitative model of evolution ionospheric trough features during geomagnetic disturbances the analysis of particle and wave in situ measurements and TEC data was carried out. The high resolution plasma particle diagnostics and wave diagnostics located on board of satellite DEMETER gives a precise description of trough signatures and instabilities at defined point in space. On the other hand, GPS permanent networks provide regular monitoring of the ionosphere in a global scale. Recently, TEC maps have been produced with 5 min intervals and with spatial resolution of 150 – 200 km. In order to better understanding the physical process occurred in plasmopause region during strong geomagnetic disturbances we present the data gathered by help the ground-based ULF “Hylaty” station located in Bieszczady mountains.

The results of improved drift data of Pruhonice digisonde show that drift speeds in the F region display (particularly in winter) a strong diurnal variation with the highest speeds (~ 200 m/s) after midnight. The average F-region drift speed substantially changes from about 50 m/s under quiet conditions to up to 400 m/s during geomagnetic storms, partly in relation to increasing TID activity.

In the E region, at Pruhonice we are able in some cases to determine even detailed height profile of drift speeds and demonstrate wind shear in this region.

4. Incoherent radar observations and model calculations for investigations of the coupling between ionized and neutral part of the atmosphere for quiet and disturbed conditions

The problem of positive F2-layer disturbances (unlike negative ones) is still unsolved what concerns their formation mechanism. Additional efforts are needed in this direction both in morphological physical analyses. There are two types of positive disturbances. The disturbances of Type I mostly are quiet time ones, while the Type II is related to the increased magnetic activity. The disturbances of Type I are more prolonged and the active period may repeat in 24 hours (this takes place in ~ 15% of all cases). The disturbances of Type II mostly are short-term: ~50-60 % of them have the duration of 1-2 h, 23-26 % with a 3-4 h duration. The disturbances of this type practically do not exhibit the repetition effect in 24 hours. The disturbances of Type II just present the first (positive) phase of a two-phase ionospheric disturbance. The duration of disturbances decreases at lower latitudes. The Type I is

the most frequent in the equinoxes, while the Type II – in winter, both types of disturbances being rare in summer. The dusk (16-20 LT) sector is the most preferable for the commencements of both types of disturbances at middle (Slough) and lower (Alma-Ata) latitudes.

The daytime mid-latitude F2-layer positive disturbance mechanisms are related mainly to either an increase of atomic oxygen concentration or/and an enhanced equatorward thermospheric winds resulted from an enhanced auroral heating. The percentage of both processes is different from case to case and depends on conditions. Anyway it is obvious that long-duration N_mF2 -layer positive effects (Type I) may be totally due to an increase in atomic oxygen concentration like in case of April 11, 2000 event. However, the atomic oxygen contribution may be essential also during normal geomagnetic disturbances (Type II). In both cases a competition between increased [O] and β takes place and positive [O] effect is strongly compensated by an enhanced loss process. On the other hand, in daytime sunlit conditions the wind mechanism can strongly contribute to the observed positive N_mF2 effect or even fully explain the effect like on Aug 22, 1995. Therefore, the quantitative contribution of neutral composition and temperature, on one hand, and thermospheric winds, on the other hand, may be different in each particular event and a careful analysis is required in each case.

5. Space weather impacts on the midlatitude ionosphere

The sufficiently strong ($\Delta f_oF2 > 20\%$) pre-storm enhancements of electron density in the ionosphere have been further studied, mainly for European region. They occur before 20-25% of strong geomagnetic storms. They were observed both day and night, more often in summer than in winter half of the year, they do not display a systematic dependence on latitude in Europe and they are not accompanied by respective changes in hmF2. They have not been observed in the E and F1 regions; the pre-storm enhancements are confined to the F2 region. Comparison of European, Japanese and U.S. measurements revealed a typical longitudinal size of this phenomenon to be 120-240°. We established several constraints for the mechanism of the pre-storm enhancements, several potential sources of the pre-storm enhancements were excluded, but their mechanism remains to be uncovered.

A study has been carried out on ionosphere vertical total electron content observations at solar minimum from a chain of European GPS stations. A preliminary investigation of all available 5 minutes vTEC data over the period 2006-2007 reveal a total of 15 “clean” events, all of which exhibited some form of vTEC increase focus exclusively on NON large-magnitude solar-terrestrial events.

Published Papers

- Bamford, R.A., R. Stamper, Lj.R. Cander (2008): A comparison between the hourly autoscaled and manual scaled characteristics from the Chilton ionosonde from 1996 to 2004, *Radio Sci.*, 43, RS1001, doi:10.1029/2005RS003401.
- Bencze, P. (2007): What do we know of the long-term change of the Earth's ionosphere? *Adv. Space Res.*, 40, 1121-1125.
- Burešová, D., V.M. Krasnov, Ya.V. Drobzheva, J. Laštovička, J. Chum, F. Hruška (2007): A method for ionogram interpretation quality using the HF Doppler technique, *Ann. Geophysicae*, 25, 895-204.
- Gordienko, G.I., I.N. Fedulina, D. Altadill, M.G. Shepherd (2007): The upper ionosphere variability over Alma-Ata and Observatorio del Ebro using the foF2 data obtained during the winter/spring period of 2003-2004, *J. Atmos. Solar-Terr. Phys.*, 69, 2452-2464, doi: 101016/j.jastp.2007.05.008.

- Gulyaeva, T.L., I. Stanislawska, M. Tomasik (2008). Ionospheric weather: Cloning missed foF2 observations for derivation of variability index, *Ann. Geophysicae*, 26, 315-321.
- Jacobi, Ch., D. Kürschner (2007): Possible climate change response of the mesosphere/lower thermosphere region. *Proc. Int. Symp. "Atmospheric Physics: Science and Education"*, St. Petersburg, pp. 33-37.
- Keuer, D., P. Hoffmann, W. Singer, J. Bremer (2007): Long-term variations of the mesospheric wind field at mid-latitudes, *Ann. Geophysicae*, 25, 1779-1790.
- Kouba, D., J. Boška, I. A. Galkin, O. Santolík, P. Šauli (2008): Ionospheric drift measurements: Skymap points selection, *Radio Sci.*, 43, RS1S90, doi: 10.1029/2007RS003633.
- Krankowski A., Shagimuratov I.I., Baran L.W., Yakimova G.A. (2007): The structure of the mid- and high-latitude ionosphere during the November 2004 storm event obtained from GPS observations, *Acta Geophysica*, 55 (4), 490-508, doi: 10.2478/s11600-007-0033-3.
- Krankowski A., Shagimuratov I.I., Baran L.W., Yakimova G.A. (2008): The occurrence of total solar eclipse on October 3, 2005 in TEC over Europe, *Adv. Space Res.*, 41, 628-638, doi: 10.1016/j.asr.2007.11.002
- Krasnov, V., Ya. Drobzheva, J. Laštovička (2007): Acoustic energy transfer to the upper atmosphere from sinusoidal sources and a role of non-linear processes, *J. Atmos. Solar-Terr. Phys.*, 69, 1357-1365.
- Middleton, H.R., S.E. Pryse, A.G. Wood, R.L. Balthazor (2008): The role of the tongue-of-ionisation in the formation of the poleward wall of the main trough in the European post-midnight sector, *J. Geophys. Res.*, 113, A02306, doi:10.1029/2007JA012631.
- Oleynikov, A.N., D.M. Sosnovchik, V.D. Kukush, Ch. Jacobi, K. Fröhlich (2007): Seasonal variation of space-time parameters of internal gravity waves at Kharkiv (49°30'N, 36°51'E), *J. Atmos. Solar-Terr. Phys.* 69, 2257–2264.
- Perrone, L., M. Pietrella, B. Zolesi (2007): A prediction model of foF2 over periods of severe geomagnetic activity, *Adv. Space Res.*, 39, 674-680.
- Pietrella, M., L. Perrone (2008): A local ionospheric model for forecasting the critical frequency of the F2 layer during disturbed geomagnetic and ionospheric conditions, *Ann. Geophysicae*, 26, 323-334.
- Romano V., Pau S., Pezzopane M., Zuccheretti E., Zolesi B., De Franceschi G., Locatelli S. (2008): The electronic Space Weather upper atmosphere (eSWua) project at INGV: advancements and state of the art, *Ann. Geophysicae*, 26, 345–351.
- Šauli, P., Z. Mošna, J. Boška, D. Kouba, J. Laštovička, D. Altadill (2007): Comparison of true-height electron density profiles derived by POLAN and NHPC methods, *Studia geoph. geod.*, 51, 449-459.
- Šauli, P., S.G. Roux, O. Abry, J. Boška (2007): Acoustic-gravity waves during solar eclipse: Detection and characterization using wavelet transforms. *J. Atmos. Solar.-Terr. Phys.*, 69, 2465-2484, 2007.
- Tulunay, Y., E. Altuntas, E. Tulunay, C. Price, T. Ciloglu, Y. Bahadirlar, E.T. Senalp (2008): A Case Study on the ELF Characterization of the Earth-Ionosphere Cavity: Forecasting the Schumann Resonance Intensities, *J. Atmos. Solar-Terr. Phys.*, 70, 669-674.
- Zakharenkova I.E., Shagimuratov I.I., Krankowski A. (2007): Features of the ionosphere behavior before the Kythira 2006 earthquake, *Acta Geophysica*, 55 (4), 524-534, doi: 10.2478/s11600-007-0031-5.

Accepted/in-press Papers

- Alfonsi, L., G. De Franceschi, A. De Santis (2007): Geomagnetic and ionospheric data analysis over Antarctica: A contribution to the long term trends investigation, *Ann. Geophysicae*.
- Altadill, D., D. Arrazola, E. Blanch, D. Burešová (2008): Solar activity variations of ionospheric parameters, experimental and modelling results, *Adv. Space Res.*
- Boška, J., P. Šauli, F. Hruška, L. Cander (2008): Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005. *J. Atmos. Solar-Terr. Phys.*
- Burešová, D., J. Laštovička (2008): Pre-storm electron density enhancements at middle latitudes. *J. Atmos. Solar-Terr. Phys.*
- Cander, Lj.R., B. Zolesi (2008): Science rationale for MIERS/IRI colabration, *Adv. Space Res.*
- Chum, J., J. Laštovička, T. Šindelářová, D. Burešová, F. Hruška (2008): Peculiar transient phenomena observed in the infrasound range *J. Atmos. Solar-Terr. Phys.*
- Gulyaeva, T.L., Bradley, P.A., Stanislawski, I., Juchnikowski, G. (2008): Towards a new reference model of hmF2 for IRI. *Adv. Space Res.*, doi:10.1016/j.asr.2008.02.021.
- Jakowski, N., Stankov, S. M., Wilken, V., Borries, C., Altadill, D., Chum, J., Burešová, D., Boška, J., Šauli, P., Hruška, F., Cander, L. (2008): Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005, *J. Atmos. Solar-Terr. Phys.*
- Laštovička, J., R.A. Akmaev, G. Beig, J. Bremer, J.T. Emmert, C. Jacobi, M.J. Jarvis, G. Nedoluha, Yu.I. Portnyagin, T. Ulich (2007): Emerging pattern of global change in the upper atmosphere and ionosphere, *Ann. Geophysicae*.
- Laštovička, J., X. Yue, W. Wan (2008): Long-term trends in foF2: Their estimating and origin. *Ann. Geophysicae*.
- Nava, B., P. Coisson, S.M. Radicella (2008): A new version of the NeQuick ionosphere electron density model. *J. Atmos. Solar-Terr. Phys.*, doi:10.1016/j.jastp.2008.01.015
- Pietrella, M., L. Perrone, G. Fontana, V. Romano, A. Malagnini, G. Tutone, B. Zolesi, Lj.R. Cander, A. Belehaki, I. Tsagouri, S.S. Kouris, F. Vallianatos, J. Makris, M. Angling (2008): Oblique-incidence ionospheric soundings over Central Europe and their application for testing now casting and long term prediction models, *Adv. Space Res.*
- Rothkaehl H., Krakowski A., Stanislawski I., Błęcki J., Parrot M., Berthelier J-J., Lebreton J-P. (2007): HF wave measurements and GPS diagnostic of main ionospheric trough as a hybrid method used for Space Weather purposes, *Ann. Geophysicae*.

Submitted Papers

- Bremer, J., D. Peters: Influence of stratospheric ozone changes on long-term trends in the meso- and lower thermosphere, *J. Atmos. Solar-Terr. Phys.*
- Coisson, P., B. Nava, S.M. Radicella, J.O. Adeniyi, S. Gopi Krishna, O.A. Oladipo, Sudha Ravindran, P.V.S. Rama Rao: NeQuick bottomside analysis at low latitudes. *J. Atmos. Solar-Terr. Phys.*
- Gulyaeva, T.L.: Proxy for the ionospheric peak plasma density reduced by the solar zenith angle. *Earth, Plan. Space*.
- Gulyaeva, T.L., I. Stanislawski: Differential planetary index of ionospheric activity deduced from GPS-TEC IONEX Maps, *Geophys. Res. Lett.*
- Kouris, S.S., K. V. Polimeris, Lj. R. Cander, L. Ciraolo: Solar and seasonal dependence of TEC and slab thickness, *J. Atmos. Solar-Terr. Phys.*

- Kouris, S. S., K. V. Polimeris, L. Ciruolo, D. N. Fotiadis: Seasonal dependence of TEC and slab thickness, *Adv. Space Res.*
- Senalp E.T., Y. Tulunay, E. Tulunay, Total electron content (TEC) forecasting by cascade modeling: A possible alternative to the IRI-2001, *Radio Science*.
- Wood, A.G., S.E. Pryse, H.R. Middleton, V.S.C. Howells: Multi-instrument observations of nightside plasma patches under conditions of IMF Bz positive, *Ann. Geophysicae*.

Presentations

- J. Boška, Burešová, D.: Changes of electron density profiles during extreme manifestation of solar activity. 4th ESWW, Brussels, November 2007.
- D. Burešová, J. Laštovička: Pre-storm enhancements of electron density at middle latitudes. Paper P1-052, *Int. CAWSES Symp.*, Kyoto, October 2007.
- Lj. R. Cander and L. Ciruolo, Total electron content over Europe at solar minimum: Storm case, invited presentation at COST296 Workshop on Ionospheric Scintillation: Scientific aspects, *Space Weather Application and Services*, Nottingham, February 2008.
- Lj.R. Cander, A. Bourdillon, B. Zolesi, “COST296 Action’s main results and their relevance for European space weather”, 4th European Space Weather Week, November 2007, Brussels.
- Z. Klos, I. Stanislawska, A. Kiraga: Evaluation of GPS signal ionospheric and tropospheric corrections in the effective dielectric permittivity concept, 1st Colloquium on Scientific and Fundamental Aspects of the Galileo Programme, Toulouse, October 2007.
- Krankowski A., Rothkaehl H., Shagimuratov I.I., Sieradzki R., Zakharenkova I.E., Tepenitzyna N.Yu., 2007, Solar flare effect in GPS TEC variations and in situ waves measurements at high latitude ionosphere, 4th European Space Weather Week, Brussels, November 2007.
- Krankowski A., Shagimuratov I.I., Rothkaehl H., Krypiak-Gregorczyk A., Zakharenkova I.E., Tepenitzyna N.Yu.: Response of TEC to solar flare: latitude and longitude features, AGU 2007 Fall Meeting, San Francisco, December 2007.
- J. Laštovička: Meteorological impacts on space weather. 4th European Space Weather Week, Brusel, November 2007 (invited).
- J. Laštovička: Long-term trends in the ionosphere: Overall pattern and open problems. Paper P3-104, *Int. CAWSES Symp.*, Kyoto, October 2007.
- S.E. Pryse: Space Weather and its effects at Earth, Institute of Physics (Wales) 6th Annual Physics Teachers Conference, Christ College, Brecon, October 2007.
- Tulunay Y., E.T. Senalp, E. Tulunay, TEC forecasting during disturbed Space Weather conditions: A Possible Alternative to the IRI-2001, 4th European Space Weather Week, Brussels, November 2007.
- Tulunay Y., E. Tulunay, E.T. Senalp, Forecast of total electron content variations to model irregularities, *Ionospheric Scintillation: Scientific Aspects, Space Weather Application and Services*, Nottingham, February 2008.
- Wielgosz P., Krankowski A., Baran L.W., Grejner-Brzezinska D., 2007, Application of Predicted Ionosphere Model to Medium Range RTK Positioning: Performance Assessment, *ION GNSS 2007*, September 25–28, Fort Worth, Texas.
- A.G. Wood, S.E. Pryse, H.R. Middleton, V.S.C. Howells: Large-scale structuring of polar cap plasma in the nightside ionosphere: the influence of the orientation of the interplanetary magnetic field, 13th *Int. EISCAT workshop*, Mariehamn, August 2007.

E.L. Whittick, S.E. Pryse, H.R. Middleton, A.R. Loting, A.D. Aylward: The CTIP model with SuperDARN electric potential input: comparison with radiotomography observations, UK MIST Meeting, London, November 2007.

Papers presented at the IRI/COST 296 Workshop & COST 296 Management Committee meeting, Prague, Czech Republic, 10-14 July 2007, are not included in the list, they are available via meeting Web site and Abstract Book. Papers presented before the IRI/COST workshop, like those from IUGG 2007, are not included, as well.

Annex VI

WORKING GROUP 2 - ADVANCED TERRESTRIAL SYSTEMS

PROGRESS REPORT FOR THE PERIOD JULY 2007 TO MARCH 2008

E. Tulunay (ersintul@metu.edu.tr) and E.M. Warrington (emw@le.ac.uk)

WP2.1 Radar and radiolocation

Leader: E.M. Warrington (emw@le.ac.uk)

- 2.1.1. Frequency management of sky-wave radars
- 2.1.2. Angle of arrival measurements for sky-wave signals
- 2.1.3. Propagation effects that influence radar and radiolocation systems

WP2.2 HF/MF communications

Leaders: J.M. Andujar (andujar@uhu.es) and Y. Erhel (yvonerhel@aol.com)

- 2.2.1. Digital radio systems – predictions, methods of estimating reliability: experimental studies concerning channel reliability (using ITU standard).
- 2.2.2. Wideband propagation modelling and development of a hardware simulator
- 2.2.3. High data transfer rate system of radio communications through the ionospheric channel
- 2.2.4. Extension of existing wideband HF simulators to the MF band

WP2.3 Spectrum management

Leaders: L.W. Barclay (lesbarclay@iee.org) and A.M. Casimiro (acasimi@ualg.pt)

- 2.3.1. Use of GPS to improve HF communications management
- 2.3.2. Adaptive waveform management
- 2.3.3. The effects of environmental noise on HF radar systems and occupancy determination of HF band
- 2.3.4. Supporting research and application in antenna systems to increase their efficiency and mitigate the propagation errors
- 2.3.5. Developing new techniques to analyse the radiation path in the propagation channel

LIST OF PARTICIPANTS:

N. Abbasi, D. Altadill, E. Altuntas, J.M. Andujar, M.J. Angling, J.A.R. Azevedo, Y. Bahadirlar, L.W. Barclay, E. Benito, P. Bencze, L. Bertel, D. Boteler, C. Bianchi, A. Bourdillon, P. Bradley, S.O. Buyukpabusecu, Lj.R. Cander, R. Caputcu, A.M. Casimiro, T. Ciloglu, P. Clency, N. Melida, B.A. de la Morena, L. Economou, Y. Erhel, S.M. Feeney, J.E.N. Field, I.A. Galkin, V. Gherm, S.D. Gunashekar, H. Haralambous, F. Honary, X. Huang, F. Jangal, J. Kalmár, Z. Kocabas, P. Lassudrie Duchesne, G. Le Bouter, D. Lemur, J.P. Luntama, F. Marie, D. Marin, J.M. McElroy, H. Nazli, M. Oger, V.V. Paznukhov, C. Perrine, M. Pietrella, B.W. Reinisch, V. Romano, S. Saillant, S. Salous, M.O. Sari, E.T. Senalp, D.R. Siddle, A.J. Stocker, H.J. Strangeways, E. Tulunay, Y. Tulunay, A.S. Turk, E.M. Warrington, T. Yapici, N.Y. Zaalov, N. Zernov, H. Zhang

The above list is based on the list given in the minutes of the Prague meeting, with the addition of anyone named on work reported here. Please advise of any omissions and erroneous entries.

WP2.1 RADAR AND RADIOLOCATION

Off great circle propagation along the trough

The nature of azimuthal deviations from the great circle direction that occur over the Uppsala to Leicester path in a period of low solar activity (2006-2007) and high solar activity (2001-2002) differ significantly. It appears that the main factor is the change in the background ionospheric parameters. In the weak ionosphere at solar minimum, the rays do not refract sufficiently in the wall of the trough and the radiowaves do not reach the auroral oval zone at the appropriate angle relative to the magnetic field for scattering on auroral irregularities to occur and consequently do not reach the receiver.

In order to take into account this situation, a new model of the background ionosphere has been developed. The model is based on vertical sounding data collected at a number of worldwide stations available from the internet (we used <http://spidr.ngdc.noaa.gov/>). The main parameters of the ionosphere taken into account are: longitudinal and latitudinal dependence of foF2, height of the maxima of foF2 and altitude scale of the layer. The model of this kind is able to reflect day to day variation of the receiving signal.

A new type of off-great circle signal (compared with the 2001 measurements) has been observed in 2007. This takes the form of a smooth gradual northward deviation in azimuth, and to a large extent is the main type of the off-great circle propagation observed in the 2006-2007 measurements. This type of the signal possibly arises due to scattering on small horizontal scale field aligned irregularities within the trough region. These irregularities are possibly caused by some kind of ionospheric instability. The scale of these irregularities in the direction transverse to magnetic field is very small and requires very small angular step for simulation. The ray-tracing model previously developed was not able to reproduce this type of signal behaviour properly, therefore additional modifications to the ionospheric model and calculation algorithm are currently being undertaken. Example simulations are shown in Figures 1 and 2.

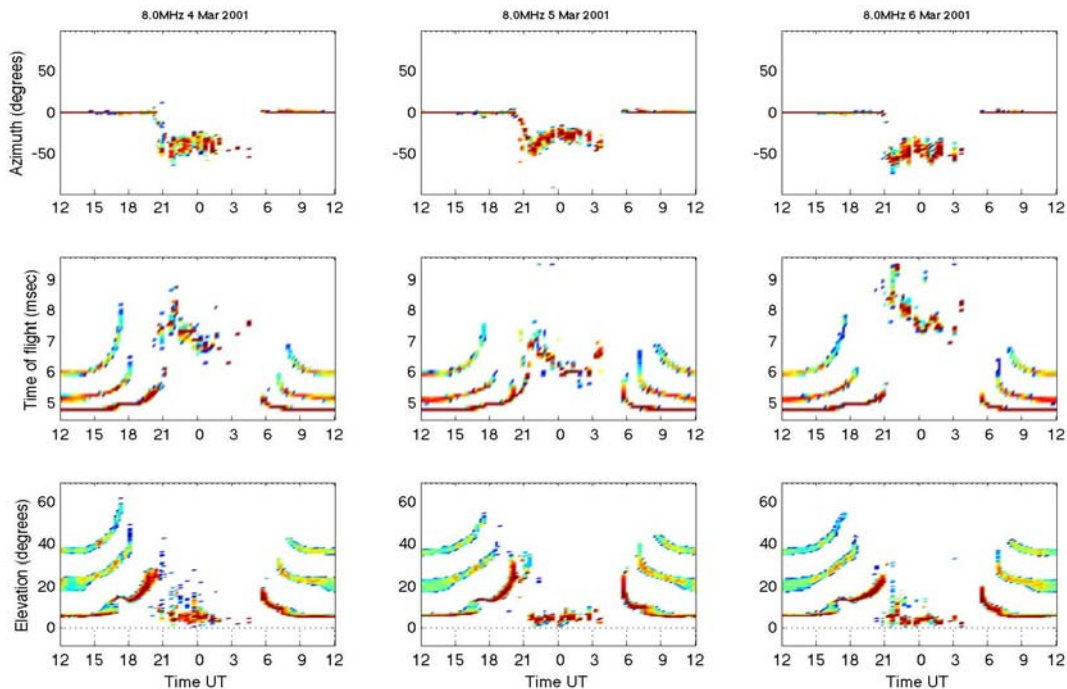


Figure 1. Simulated signal for the Uppsala-Leicester path, three days in March 2001.

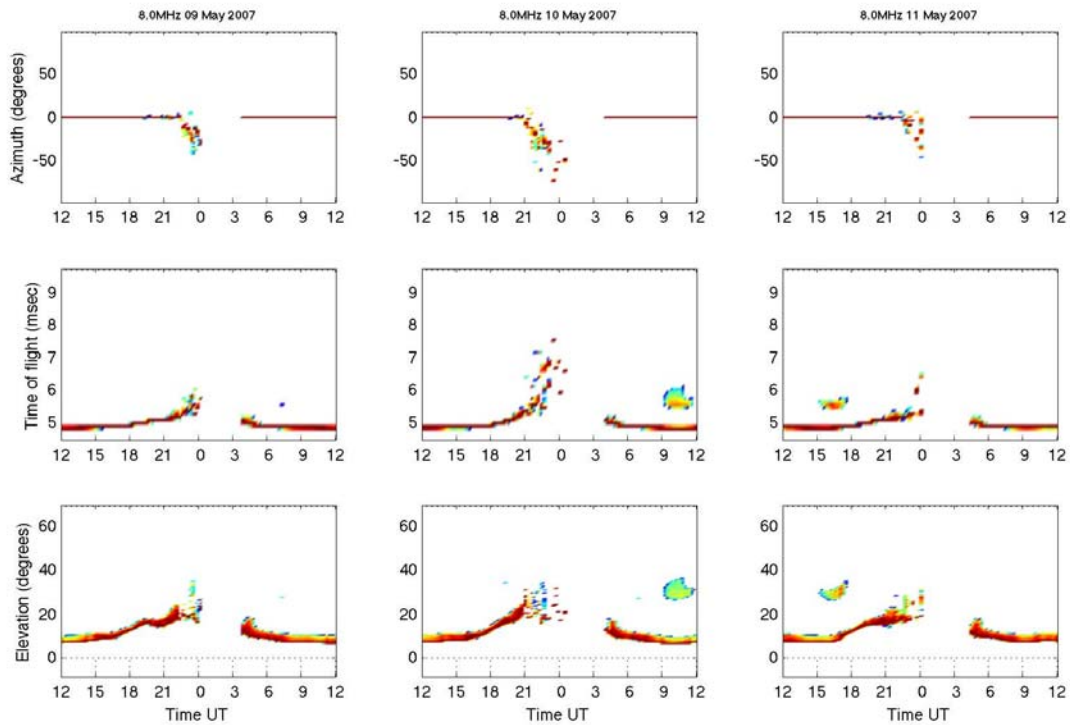


Figure 2. Simulated signal for the Uppsala-Leicester path, three days in May 2007.

HF Radar

Research and preliminary achievements on HF Radar studies were presented before.

The Middle East Technical University Neural Network (METU-NN) model proved the power of forecasting the parameters of a non-linear process in our previous WG Reports. Then, the METU Neural Networks and Cascade Model (METU-NN-C) was developed leading significant improvements in non-linear system identification. The theory behind the Cascade Models based on Hammerstein system modeling and some case studies were given in the Ph-D Thesis of E.T. Senalp supervised by E. Tulunay [Senalp, 2007].

The details of the METU-NN-C model have been reported to the COST 296 WP.1.3 (Near Earth space plasma modelling and forecasting). It forecasts ionospheric process parameters as well. Demonstration of the learning capability and demonstration of the nonlinear system modeling and identification by using METU-NN-C in several case studies have been presented [Senalp, 2007] [Tulunay et al., 2008].

In future, with some adaptations and with some new contributions, METU-NN-C can be used as a module of an international reference model of interest. It can also be used for HF radar studies.

Analysis of ambiguities on a heterogeneous array

The structure of a heterogeneous array has been proposed by the I.E.T.R. laboratory for HF direction finding purpose with advantages resulting from its sensibility to the incident polarization.

Taking part in a global project of electronic warfare, the laboratory is currently working on the analysis of ambiguities of such an array (first, second, third and fourth order ambiguities). A criterion has been defined based on the projection of the array manifold in the signal subspace. It is computed after a Gram-Schmidt orthogonalization of the steering-vectors related to the incident signals.

In the case of third order ambiguities, the 3 steering-vectors associated to the incident signals are denoted

SV1, SV2 and SV3.

The Gram-Schmidt procedure yields an orthonormal basis (u1o , u2o, u3o) which spans the same subspace than (SV1, SV2 ,SV3).

$$\underline{u1o} = \frac{\underline{SV1}}{|\underline{SV1}|}$$

$$\underline{u2i} = \underline{SV2} - \langle \underline{SV2}, \underline{u1o} \rangle \underline{u1o}$$

$$\text{Then } \underline{u2o} = \frac{\underline{u2i}}{|\underline{u2i}|}$$

$$\underline{u3i} = \underline{SV3} - \langle \underline{SV3}, \underline{u1o} \rangle \underline{u1o} - \langle \underline{SV3}, \underline{u2o} \rangle \underline{u2o}$$

$$\text{and finally } \underline{u3o} = \frac{\underline{u3i}}{|\underline{u3i}|}$$

Denoting A the matrix [u1o u2o u3o], the matrix of projection in the signal subspace is $PR = A * A^H$.

1. AMBIGUITY CRITERION

For a variable steering-vector SV, its projection in the signal subspace is $PR * \underline{SV}$.

SV is an ambiguous vector if it is element of the signal subspace : SV is equal to its own projection.

A smart criterion, with real positive values, that can be used to detect the existence of possible ambiguities is then :

$$\text{crit}_{amb} = \frac{\underline{SV}^H * PR * \underline{SV}}{\underline{SV}^H * \underline{SV}}$$

Based on this cost function, electromagnetic simulations search to optimise the structure of array in order to limit the level of ambiguities. For each case under test, a comparison is made with the corresponding homogeneous (classical) array.

WP2.2 HF/MF COMMUNICATIONS

HF MIMO

The concept of multiple input multiple output (MIMO) has become a productive area of research in the field of wireless communications with the aim of delivering increased data throughput. However, to date, MIMO research has focussed primarily on short-range communications within the VHF, UHF and SHF bands. Our research has been directed at exploiting MIMO techniques for long-range communications within the HF band.

Between September and December 2007, several HF-MIMO measurement campaigns were performed over a 255 km path between Durham and Bruntingthorpe in the UK. A variety of different antenna array configurations were employed at both the transmitter and receiver ends of the link (e.g. homogeneous and heterogeneous spaced arrays). In order to realise increased channel capacity by means of a MIMO system, it is essential that there is sufficient de-correlation between the signals received at each of the antenna elements of the receiver array from each of the elements of the transmitter array. Our investigations have confirmed that at HF wavelengths, the use of homogeneous spaced-antenna arrays may require significant spacing to achieve acceptable levels of de-correlation. However, marked orientation-dependent fading effects have also been observed with respect to spaced antenna arrays. For example, at times the two orthogonal arms of an L-shaped antenna array of spaced vertical monopoles exhibit significantly different levels of de-correlation as a function of antenna spacing (as illustrated in Figure 3). Furthermore, the prevailing modal structure of the ionosphere expectedly has a major influence on the MIMO performance of the system. Finally, in addition to conventional spaced homogeneous arrays, configurations employing heterogeneous antennas at both the transmitter and receiver sites are also being employed in the investigation, which would enable the compact implementation of an HF-MIMO system.

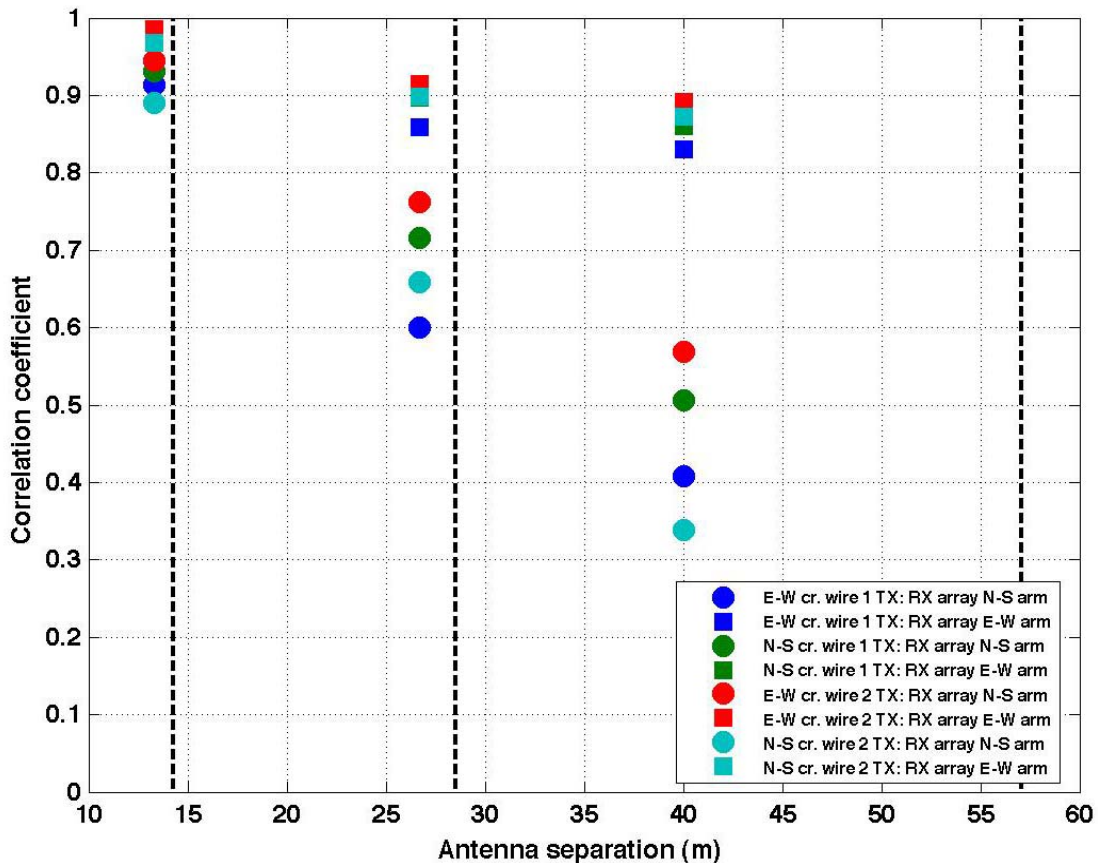


Figure 3. The amplitude correlation coefficients computed for various antenna pair spacings of an L-shaped receiver array comprised of 5 vertical monopoles. [Transmitter configuration: two pairs of crossed wire antennas spaced approximately 22 m apart were employed with the following specifications: E-W arm of crossed wire 1: 5.255010 MHz, N-S arm of crossed wire 1: 5.255020 MHz, E-W arm of crossed wire 2: 5.255030 MHz and N-S arm of crossed wire 2: 5.255040 MHz]. Note: the data from each transmitter (indicated by the different colours) have been divided into two parts (indicated by the different symbols) depending on the orientation of the particular receive antenna arm: N-S arm of L-shaped array (solid circles); E-W arm of L-shaped array (solid squares).

HF noise

The Atmospheric Sounding Station “El Arenosillo” (INTA - National Institute for Aerospace Technology), together with the University of Rennes, carried out an HF noise measurement campaign in January 2008. The aim of this experiment is to characterize HF loss in the D region of the ionosphere. The experiment will permit to characterize this HF loss every 15 minutes, during night and day. And, as the ionosphere changes every season, there will be repetition of the experiments in El Arenosillo in spring, summer, and autumn. Some results of HF loss will be obtain at the end of the planned campaigns.

Short Term Scientific Mission

Iñigo Blanco Alegre (El Arenosillo, INTA) carried out a Short-Term mission (STM) at the INGV, Istituto Nazionale di Geofisica e Vulcanologia in Rome in September 10-17, 2007. The STM of Iñigo Blanco has been devoted to prepare the installation of a GPS receiver in the INTA laboratories, at El Arenosillo Sounding Station. The inclusion of this equipment is extremely important for its location in the western part of the Mediterranean sea and will complete the cooperation among the following European Scientific Institutions: INGV and CNR from Italy, NOA and University of Chania from Greece, INTA from Spain and University of Bath from UK.

Propagation along the trough

Systematic time of flight measurements (TOF) over the radio link between Uppsala (Tx: 59.9° N, 17.6° E, Sweden) and Bruntingthorpe (Rx: 52.5° N, 1.1° W, U.K.) have been performed every 2 minutes at 6 frequencies (4.637 MHz, 6.954 MHz, 8.008 MHz, 10.391 MHz, 11.118 MHz, and 14.364 MHz). Such measurements have been compared with the TOF provided by the long term prediction models SIRM (Simplified Ionospheric Regional Model) in conjunction with Bradley - Dudeney model and ICEPAC (Ionospheric Communications Enhanced Profile Analysis and Circuit) (see Figure 4).

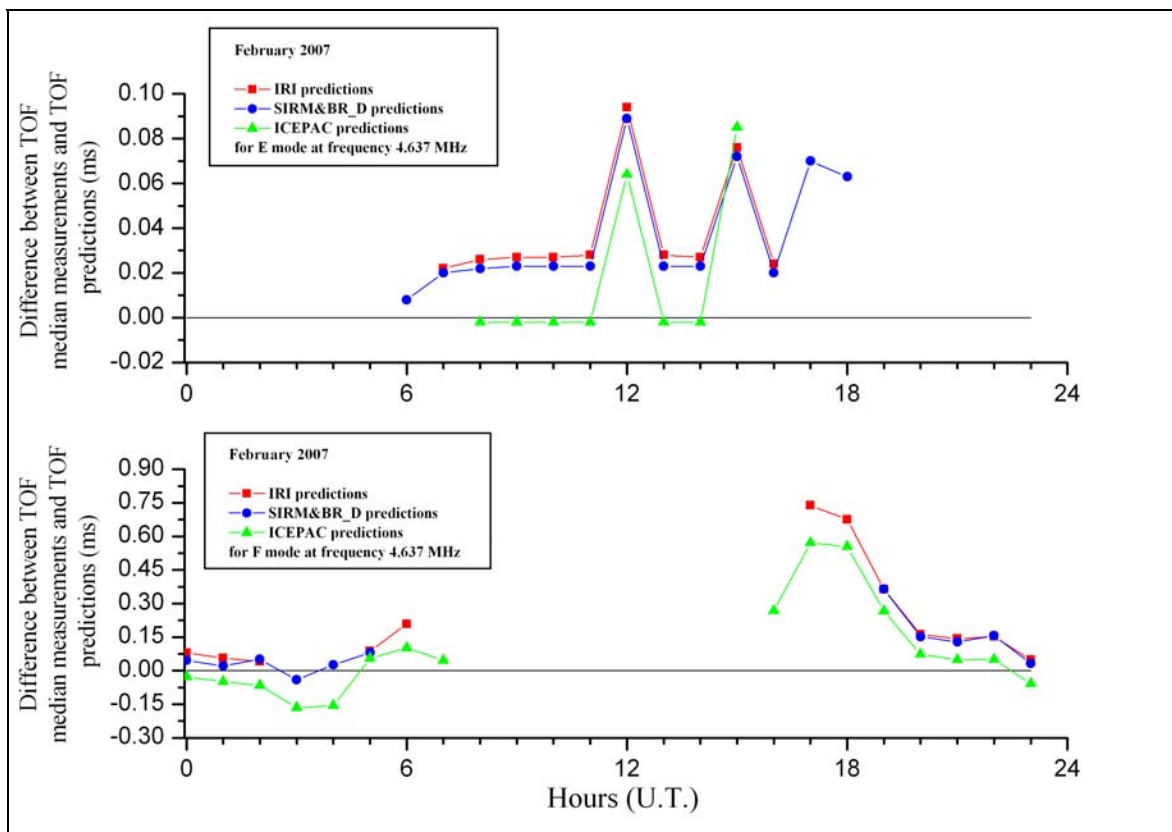


Figure 4. The red plots show the TOF (time of flight) predictions obtained when the median electronic density profile, derived by means of IRI model, is considered at the middle point of the link; the blue plots show the TOF predictions obtained when at the middle point of the link is used the median electronic density profile derived applying the SIRM model in conjunction with the Bradley-Dudeney model; the green plots show the TOF predictions obtained by ICEPAC. The horizontal line marks the 0 ms level (no difference observed).

As expected, both the models are able to predict TOF belonging to E normal propagation modes during daylight hours (upper panel). IRI, SIRM&BR_D and ICEPAC give better TOF predictions when E propagation modes are considered in place of F propagation modes (lower panel).

Polar cap propagation simulation and coverage modelling

Commercial aircraft, for safe operations, have to be able to communicate with air traffic control centres at all times. This communication is possible by VHF links whilst within range of the widespread network of ground stations and by HF links in remote areas such as the North Atlantic, Pacific, polar regions and areas of South Africa and Philippines. At high latitudes, and especially on polar routing, VHF ground infrastructure does not exist and the aircraft rely on HF radio for communications. However, at high latitudes, disturbances in the ionosphere can severely disrupt the ability for aircraft to stay in contact with air traffic control. At times when HF communication fails, or is anticipated to fail, the aircraft are routed over more southerly paths with a consequent increase in flight time and fuel usage. In addition to the financial impact, the latter point is highly relevant to current concerns over global warming.

The number of commercial airline flights over the northern polar region is rapidly increasing, producing a high demand for HF radio communications. Consequently there is a requirement for improved knowledge about the propagation characteristics of the polar ionosphere to facilitate accurate predictions, forecasts and nowcasts of

the propagation conditions, and hence communications quality. As one of the important steps of the development of the prediction code for HF propagation in northern ionosphere, the simulation of area coverage maps has begun (see, for example Figure 5).

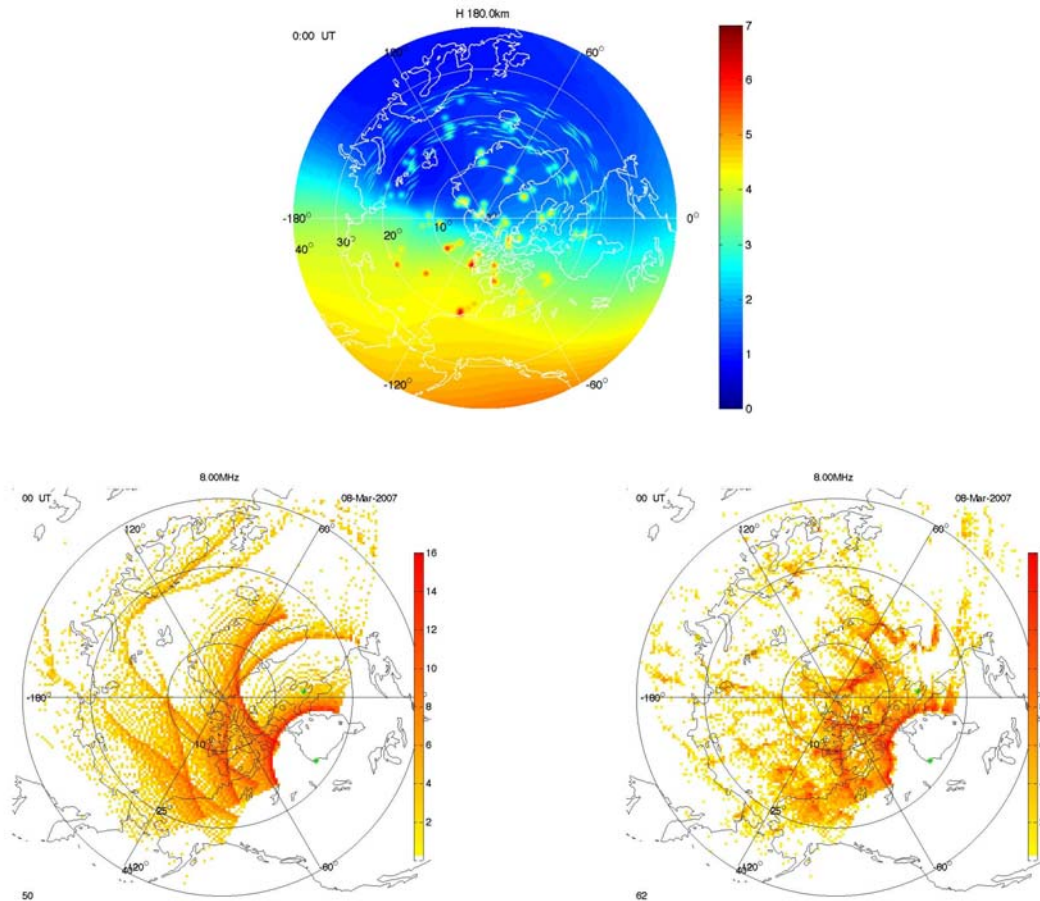


Figure 5. Example coverage map (8 MHz) for two transmitters in polar cap area. The upper frame shows the ionospheric model including the presence of patches, the lower left frame the coverage ignoring the presence of the patches and the lower right frame the coverage taking the patches into account.

WP2.3 SPECTRUM MANAGEMENT

Spectral occupancy

Recent work deals with the application of Neural Networks as a means of optimizing the reliability of HF communication systems by predicting the detrimental effect of interference from other users and its variability due to the ionosphere. In particular, the development of a long-term interference prediction model for the HF spectrum is described. This model can be used in the absence of system capability to assess interference background in real time or near real time, to advise operators on typical interference occupancy levels and therefore assist in the planning of frequency usage and management. The dataset of diurnal occupancy measurements used for the model development was taken over a period of seven years (April 1994 to January 2000) at Linköping and Kiruna (Sweden) in the frames of a long-term project being undertaken jointly by the

University of Manchester and by the Swedish Defense Research Establishment to measure systematically and to analyze the occupancy of the entire HF spectrum.

COST IC 0603

António Casimiro participated in the COST IC 0603 meeting that was held in Bonn last October for collaboration among COST Actions. It was presented there an overview of COST 296. Now is under preparation a paper, also related with COST 296 work, for presentation of next COST IC 0603 meeting that will be on April this year, again taking in account the collaboration principle. The research in the radiation, antennas and propagation field is going on.

PUBLICATIONS:

Papers

Gunashekar, S.D., E.M. Warrington, S. Salous, W. Kassem, L. Bertel, D. Lemur, H. Zhang and N. Abbasi, An Experimental Investigation into the Feasibility of MIMO Techniques Within the HF Band, *Proceedings of the European Conference on Antennas and Propagation 2007 (EuCAP 2007)*, Edinburgh, UK, November 2007.

Reinisch, B.W., V.V. Paznukhov, I.A. Galkin, D. Altadill, J.M. McElroy, Precise Radar Range Measurements with Digisondes, AIP Conference Proc. #974, Radio Sounding and Plasma Physics, Editors P. Song, J. Foster, M. Mendillo, D. Bilitza, Melville, New York, pp. 144-149, 2008.

Tulunay Y., E. Tulunay, E.T. Senalp, Forecast of Total Electron Content Variations to Model Irregularities, *Ionospheric Scintillation: Scientific Aspects, Space Weather Application and Services*, Nottingham, UK, 20-22 February 2008

Accepted/in-press papers

Gunashekar, S.D., E.M. Warrington, S. Salous, S.M. Feeney, H. Zhang, N. Abbasi, L. Bertel, D. Lemur and M. Oger, Early Results of Experiments to Investigate the Feasibility of Employing MIMO Techniques in the HF Band, *Proceedings of the Loughborough Antennas and Propagation Conference 2008 (LAPC 2008)*, Loughborough, United Kingdom, March 2008.

Pietrella, M., E.M. Warrington, A.J. Stocker and C. Bianchi, Time of flight measurements over the radio-link Uppsala - Bruntingthorpe and their application for testing the long term prediction models. URSI General Assembly, August 2008.

Warrington, E.M., F. Honary, A.J. Stocker, D.R. Siddle, N.Y. Zaalov and D.H. Boteler, Propagation modelling and prediction for trans-polar airline routes, *12th International Ionospheric Effects Symposium (IES 2008)*, Virginia, U.S.A., May 2008.

Warrington, E.M., S.D. Gunashekar, S. Salous, S.M. Feeney, H. Zhang, N. Abbasi, L. Bertel, D. Lemur and M. Oger, Investigations into the Feasibility of MIMO Techniques Within the HF Band: Preliminary Results, *12th International Ionospheric Effects Symposium (IES 2008)*, Virginia, U.S.A., May 2008.

Warrington, N.Y. Zaalov and A.J. Stocker, Off-great circle HF propagation over sub-auroral and polar paths: New measurements and coverage considerations, *The Seventh Symposium on Radiolocation and Direction Finding*, Southwest Research Institute, San Antonio, May 2008.

Submitted papers

Azevedo, J.A.R., Antenna pattern control of planar arrays for long distance communications, *Advances in Space Research*.

Zaalov, N.Y., E.M. Warrington, A.J. Stocker and D.R. Siddle, Experimental observations of HF propagation on two paths aligned along the mid-latitude trough, *Advances in Space Research*.

Presented at meetings (no printed paper in a proceedings)

None reported

Theses

Senalp E.T., Cascade Modeling of Nonlinear Systems, Ph-D Thesis, Supervisor: E. Tulunay, Dept. of Electrical and Electronics Eng., Middle East Technical University, Ankara, Turkey, August 2007.

ANNEX VII

WG 3 Report - Space based systems – July 07-March 08

N Jakowski (norbert.jakowski@dlr.de) ; R Warnant (r.warnant@oma.be);

R Leitinger (reinhard.leitinger@uni-graz.at)

Report presented by B Bidaine:

WP 3.1 Space plasma effects

Space plasma effects have been investigated according to the terms of reference by several groups in Europe which have reported their activity at various international conferences.

The German Aerospace Center (DLR) has further developed the operational service for space-plasma and space-weather monitoring via the project SWACI - Space Weather Applications Center Ionosphere (<http://w3swaci.dlr.de/>).

Besides the retrieval of vertical electron density from GPS radio occultation measurements onboard the Geo-Research satellite CHAMP, retrieval algorithms were applied also to GPS radio occultation measurements performed onboard one of the two US-German satellites GRACE.

The tests were successful, indicating their potential for doubling the number of electron density profiles per day within the SWACI service.

Studies of the E-layer dominated ionosphere (ELDI) in the aurora zone have been continued and compared with EISCAT measurements. It is assumed that ELDI is due to electron precipitation. Ionospheric storms were studied by including both ground and space based GPS measurements. The observations show ELDI phenomena as well as strong ion outflow in the polar ionosphere.

The group of the University of St. Petersburg has continued its work on modelling the transionospheric propagation effects caused by the mid-scale in-homogeneities of the ionosphere (e.g. bubbles in the equatorial ionosphere, or patches in the high-latitude ionosphere). It was done by introducing effective models of such mid-scale in-homogeneities embedding them into a model of the background ionosphere. In a sense, one can consider this as modelling the mid-scale ionospheric inhomogeneities for low- and high-latitude ionosphere.

T. Gulyaeva in Moscow has continued her work on ionospheric perturbations during geomagnetic storms and the group of the ICTP in Trieste has advanced in analyzing slant TEC rate of change under different geophysical conditions.

WP 3.2 Mitigation techniques

The University of Liège – Department of Geomatics is performing a study dedicated to the improvement of the NeQuick model for Galileo users. In a first step, the different weaknesses of the model at mid-latitudes are being identified. This study assesses NeQuick predictions using GPS-TEC and Digisonde data from Dourbes Observatory. First results have been presented during IRI/COST workshop in Prague and 1st Galileo Colloquium in Toulouse. They include mainly the highlight of the improvement from the second version of NeQuick and the remaining problems in the topside formulation. These investigations were the occasion of an STSM in Trieste (ICTP, December 2007) and a visit at ESTEC (February 2008). (B. Bidaine and RMI, R. Warnant)

Development of special mitigation techniques in the frame of GNSS radio occultation experiments aiming at retrieving neutral atmosphere parameters. The University of Graz is currently performing a "climate observing system simulation experiment", where one major aspect is the influence of uncorrected ionospheric errors in radio occultation (RO) climatologies over two solar cycles. It involves quasi-realistic modeling of the neutral atmosphere and the ionosphere and subsequent modeling of RO observables. The Univ. of Graz started

analyzing RO data from the GRAS instrument onboard MetOp. First results indicate that the receiver noise of the GRAS instrument is about a factor of two smaller than the noise of the receivers of the COSMIC constellation. Comparisons between data from MetOp and COSMIC should therefore allow for a better separation of ionospheric and receiver errors at altitudes above 30 km (University of Graz, U. Foelsche).

Development of special mitigation techniques in the frame of GNSS radio occultation experiments. FMI has started in February 2008 a study for EUMETSAT to assess the benefits of using three observation frequencies to perform ionospheric correction in Radio Occultation (RO) soundings of the neutral atmosphere. This study will also look at how space borne ionospheric soundings could be used for new types of space weather observations. (Finnish Meteorological Institute, J.-P. Luntama).

The bending of the ray path of GNSS signals caused by the ionospheric refractivity has been investigated for ground and space based GNSS measurements. Empirical formulas for correcting the second order effect in GNSS applications have been developed. The validity of such a formula is restricted to a certain area such as mid-Europe. Ray path computations for radio occultation measurements indicate ray path bending effects leading to a deviation of up to more than 1 km from the line of sight for L1 frequency (DLR, Neustrelitz, Germany, M. Hoque and N. Jakowski).

In collaboration with the University of Bath, FMI has used the MIDAS ionospheric tomography algorithm to produce high resolution regional electron density maps over Scandinavia. The first results showing detailed 3D structures of the plasma during a geomagnetic storm on 14-15 December 2006 are very promising. Validation of the retrieved electron density maps is one of the next challenges to be addressed. At the moment FMI has access only to archived GNSS observations from December 2006. (Finnish Meteorological Institute, J.-P. Luntama).

The University of Leeds University of St Petersburg program for determining higher order ionosphere errors (the term in f-3 due to the effect of the geomagnetic field; the three f-4 terms (i) due to the curvature of the path in the plane of incidence, (ii) curvature perpendicular to the plane of incidence and (iii) due to the actual distribution of electron density along the path) has been extended to determine these errors for satellite to satellite paths. The program also shows how these errors change with time as both satellites move on their respective orbits giving also occultation effects. The program is also being applied to determine these errors at P-band for satellite borne SAR (H. Strangeways, University of Leeds, UK)

WP 3.3 Scintillation Monitoring and Modelling

Work has been made at different topics according to the terms of reference as follows:

3.3.1 Climatology of irregularities and scintillations

The original model to simulate ionospheric scintillations is under test applying spectral analysis to the Raw Data acquired by ISACCO (Ionospheric Scintillation Arctic-Antarctic Coordinated Campaign Observations) GISTMs located in Ny Alesund and in Longyearbyen (Svalbard, Norway). The test is performed sorting the data according to different helio-geophysical conditions in order to verify the modeled scintillation scenario.

A new GISTM receiver has been recently installed at Concordia Station (75.1S, 123.4E). The participants continue to maintain the polar GISTM stations located at Ny Alesund (79.9N, 11.9E) and Longyearbyen (78.2N, 16.0E) at Svalbard (Norway), and at the Italian Antarctic Station "Mario Zucchelli" at Terra Nova Bay (74.7S, 164.1E). All the data from the station are accessible in real time to the electronic Space Weather upper atmosphere web site (www.eswua.ingv.it).

3.3.2 Scintillation studies at University of St. Petersburg and at University of Leeds

The transionospheric simulator has been updated to model also the effect on transionospheric paths of plasma bubbles at low latitudes and polar patches at high latitudes giving the time evolution of sigma-phi and S4 indices.

3.3.3 Scintillation monitoring at Nottingham University

The IESSG have two GISTMs currently being installed in Norway, with support from Fugro (in Trondheim) and Subsea7 (in Bodo) respectively. These receivers will collect 50Hz amplitude and phase scintillation data, as well as 1 minute range data, and will augment the IESSG network, which comprises another two units currently operating in Nottingham and Dourbes (in collaboration with RMI). These four units add to the existing network of GISTMs operating in Europe and help form a long term data base for scintillation monitoring and modeling.

3.3.4 Scintillation monitoring and studies at DLR

The monitoring of ionospheric scintillation activity in the vicinity of Bandung, Indonesia (6.9° N; 107.6°E), Puerto Cruz, Spain (28.9°N; 16.3°E) and Kiruna, Sweden (67.8°N; 20.4°E) has been continued. The scintillation index S4 and $\sigma\phi$ are derived from 50/25 Hz GPS observations at the three sites on a regular basis. Near real time access to these data is established at the Kiruna and Puerto de La Cruz station. Multipath impact on scintillation measurements is reduced by a code-carrier divergence algorithm. The scintillation occurrence was at the minimum level due to the low solar activity in 2006/07. Nevertheless, scintillations have been observed at the low latitude station in Bandung (occurrence probability of severe scintillations with $S4 \geq 0.8$ is about 6×10^{-3} in 2006). Comparing the scintillation strength in 2006 and 2007, it is concluded that there is a strong correlation with the solar activity level.

3.3.5 Investigation of ionospheric irregularities by means of scintillation and TEC observations.

The measurements performed by a chain of similar GISTM receivers located in a latitudinal band between 53° and 78° N, have been analysed to investigate the formation and the dynamics of the Ionospheric irregularities causing scintillations and TEC enhancement over mid and high latitude European area. A multi instrument approach based on the use of an original tomographic technique (MIDAS, Bath University) and on the use of polar cap ionospheric potential simulation (Weimer model), has allowed the study of the ionospheric plasma dynamics under disturbed condition. The INGV group continued to investigate spatial and temporal correlations between GPS scintillations and SuperDARN echo characteristics.

3.3.6 Wavelet analysis of ionospheric scintillation

A characterisation of the wavelet coefficient statistics of time intervals before, during and after a scintillation event has been continued. Comparisons are under study between the scalogram of scintillation on a satellite-to-ground radio link and the same plot for the ionization density measured in situ of a region compatible with the radio link. The results seem to give interesting information on the typical time scales that characterise the irregularities causing scintillations.

3.3.7 GPS observations of polar and equatorial scintillations

The INGV and University of Rennes IETR manage the same kind of GPS receivers specially modified for recording the phase and amplitude of the L1 signals and Total Electron Content (TEC) from L1 and L2. The receivers are located at northern polar latitudes (NyAlesund 78.9°N, 11.9°E) and at equatorial latitudes (Hanoi 21.04739° N, 105.79972° E and Hocmon 10.86° N, 106.56° E). Some analyses have been addressed to the investigation of differences and similarities of high and low latitude scintillations during some selected space weather events. The use of the same receivers allows the scientific groups to concentrate their attention to the different physical mechanisms causing scintillations at equatorial and polar regions.

3.3.8 Ionospheric Scintillation Monitoring and Forecasting in Northern Europe, Royal Society project

The IESSG (Nottingham, UK) continues to collaborate with INGV under the International Joint Project grant of the Royal Society titled *Ionospheric Scintillation Monitoring and Forecasting in Northern Europe*. Two main aspects related to the effects of scintillation on GNSS are addressed in the frame of this collaboration: warning users of its occurrence (scintillation forecast) and potential near real-time mitigation of effects.

3.3.9 Scintillation studies at CRIRP (China Research Institute of Radiowave Propagation)

In January 2008 another GPS scintillation receiver has been installed in Svalbard.

3.3.10 Scintillation studies at IEEA

The monitoring of ionospheric scintillation activity in N'Djamena (Chad) has been continued within the ESA PRIS project which is now finished. The data base analysis has been performed. The IGS data has been studied for comparison. The development of forecasting models have been initiated

Recent Publications and talks related to WG3 activities

(Update July 2007 - March 2008)

Bidaine, B., Warnant, R. (2007), *Assessment of the NeQuick Model at Mid-latitudes using GPS TEC and Ionosonde Data*, Proceedings of the First Colloquium Scientific and Fundamental Aspects of the Galileo Programme [CD-Rom], Toulouse, France, 1- 4 October 2007.

De Franceschi, G., L. Alfonsi, V. Romano, M. Aquino, A. Dodson, C.N. Mitchell, P. Spencer, A.W. Wernik, Dynamics of high-latitude patches and associated small-scale irregularities during the October and November 2003 storms. *Journal of Atmospheric and Solar-Terrestrial Physics* (2008), doi:10.1016/j.jastp.2007.05.018

Foelsche, U., G. Kirchengast, A. K. Steiner, L. Kornbluh, E. Manzini, and L. Bengtsson (2008), An observing system simulation experiment for climate monitoring with GNSS radio occultation data: setup and testbed study, *J. Geophys. Res.*, in press, 2008

Gherm, V.E., N. N. Zernov and H.J. Strangeways, Modelling of the effect of strong scintillation on GPS Signals due to plasma bubbles in the low-latitude ionosphere, presented at COST 296/IRI Meeting in Prague, Czech Republic, 10 -14 July, 2007. Published on the conference website.

Gulyaeva, T.L. Assessments of ionospheric perturbations during geomagnetic storms from GPS observations. *Solar - Terrestrial Phys.*, 2008 (submitted in Russian).

Hoque, M.M., N. Jakowski, "Mitigation of higher order ionospheric effects on GNSS users in Europe", *GPS Solutions*, DOI 10.1007/s10291-007-0069-5

Jakowski, N., S. M. Stankov, V. Wilken, C. Borries, D. Altadill, J. Chum, D. Buresova, J. Boska, P. Sauli, H. Hruska, L. Cander, Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005, *J. Atmos. Solar-Terr. Phys.*, (in press), 2008

Jakowski, N., C. Mayer, J. Wickert, S.Heise, W. Köhler, Retrieval of electron density profiles from GRACE radio occultation data, Joint International GRACE Science Team Meeting and DFG SPP 1257 Symposium, 15-17 Oct. 2007, GFZ Potsdam Jakowski, N., V. Wilken, and C. Mayer (2007), Space weather monitoring by GPS measurements on board CHAMP, *AGU Space Weather*, 5, S08006, doi:10.1029/2006SW000271.

Materassi, M., L. Alfonsi, G. De Franceschi, V. Romano, C.N. Mitchell, P. Spalla, Detrend effect on the scalograms of GPS amplitude scintillation, *Advances in Space Research*, in press, 2008.

Maurits, S.A., V.E. Gherm, N.N. Zernov, and H.J. Strangeways, "Modeling of Scintillation Effects on High-Latitude Transionospheric Paths Using Ionospheric Model (UAF EPPIM) for Background Electron Density Specifications, Radio Science, paper #2006RS003539R, accepted in December, 2007.

Spits J., Warnant R. (2007), Real time TEC monitoring using triple frequency GNSS data: a three step approach. Proceedings of the First Colloquium Scientific and Fundamental Aspects of the Galileo Programme [CD-Rom], Toulouse, France, 1- 4 October 2007.

Strangeways, H.J., V.E. Gherm and N.N. Zernov, Modeling and mitigation of the effect of scintillations on GPS, invited paper at 49th International Symposium ELMAR-2007, 12-14 September 2007, Zadar, Croatia, published in Proceedings - ELMAR 2007, pp69-73, 2007.

Presentations

Zernov, N.N. V.E Gherm, and H.J. Strangeways, "The scintillation propagation model for the effects of scintillation on transionospheric paths traversing mid-scale ionospheric inhomogeneities". Presented at the Workshop "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services". Nottingham, UK, 20 -22 February, 2008.

Mayer, C., N. Jakowski, Observation of Ionospheric Effects in the Aurora Zone using CHAMP and COSMIC/Formosat-3 Data, 13th International EISCAT Workshop and Radar School 6-10 August 2007, Mariehamn, Åland Islands, Finland

Luntama, J-P., and Kauristie, K., Regional ionospheric monitoring in Scandinavia. In: Ionospheric Scintillation: Scientific aspects, Space Weather applications and Services Workshop. Invited oral presentation, 2008

Jakowski, N., Aquino, M., Beniquez, Y., Bourdillon, A., De Franceschi, G., and Luntama, J-P., On establishing an □ Ionospheric Perturbation Detection and Monitoring Network. Fourth European Space Weather Week, 5-9 November, 2007, Brussels, Belgium. Poster presentation, 2007

Luntama, J-P., Radio Occultation Soundings in Ionosphere and Space Weather Applications: Achievements and Prospects. 3rd International Workshop on Occultations for Probing Atmosphere and Climate. Invited oral presentation, 2007

Luntama, J-P., What is space weather?. Royal Meteorological Society National Meeting. Invited oral presentation, 2007

Luntama, J-P., Mitchell, C. and Spencer, P., Mesoscale Ionospheric Tomography Over Finland, Fourth European Space Weather Week, 5-9 November, 2007, Brussels, Belgium. Oral presentation. 2007

Luntama, J-P., Mitchell, C. and Spencer, P., Tomography based ionosphere correction for mobile GNSS applications. Sähkömagnetiikka 2007, Riihimäki 28.8.2007. Oral presentation. 2007.

Alfonsi, L., M. Materassi, M. Pozoga, V. Romano, A. W. Wernik, High-latitude ionospheric scintillation modelling based on satellite in situ data, presented during the IUGG XXIV General Assembly, Perugia, July 2007.

Materassi, M., The WAM scintillation model: overview and applications to ionospheric studies, Invited paper at the Workshop on "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services", in Nottingham, 20-22 February 2008

Gherm, V.E., N. N. Zernov and H.J. Strangeways, Modelling of the effect of strong scintillation on GPS Signals due to plasma bubbles in the low-latitude ionosphere, presented at COST 296/IRI Meeting in Prague, Czech Republic, 10 -14 July, 2007. Published on the conference website.

Strangeways, H.J., V.E. Gherm and N.N. Zernov, Modeling and mitigation of the effect of ionospheric scintillations on GPS due to time-varying electron density irregularities and plasma bubbles, invited paper at the workshop on Global Navigation Satellite Systems (GNSS): problems, vulnerabilities and solutions, Baska, Krk Island, Croatia, 12-14 September 2007.

Zernov , N.N., V.E. Gherm and H.J. Strangeways, The scintillation propagation model for the effects of scintillation on transionospheric paths traversing mid-scale ionospheric inhomogeneities, Invited paper at the Workshop on "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services", in Nottingham, 20-22 February 2008

Romano V., Pau S., Pezzopane M., Zuccheretti E., Zolesi B., De Franceschi G., and Locatelli S. "The electronic Space Weather upper atmosphere (eSWua) project at INGV: advancements and state of the art", *Annales Geophysicae*, 26, 345–351, 2008.

Romano, V., M. Aquino, B. Arbesser-Rastburg, Y. Béniguel, A. Bourdillon, C. Mitchell, A. Wernik "The European "GPS Ionospheric Scintillation and TEC Monitor" network: monitoring and databases". Invited paper at the Workshop on "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services", in Nottingham, 20-22 February 2008

Valette, J.J., P. Lassudrie-Duchesne, N. Jakowski, Y. Beniguel, V. Wilken, M. Cueto, A. Bourdillon, C. Pollara-Brevart, P. Yaya, J.P. Adam, R. Fleury, Observations of ionospheric perturbations on GPS signals at 50 Hz, 1 Hz and 0.03 Hz in South America and Indonesia, ", the 4th European Space Weather Week, 5 – 9 November 2007, Brussels, Belgium

Béniguel Y., J-P Adam, N. Jakowski, T. Noack, V. Wilken, M. Cueto, A. Bourdillon, J.-J. Valette, P. Lassudrie Duchesne, B. Arbesser-Rastburg, Ionospheric Scintillations recorded at low and high latitudes during the PRIS measurement campaign : Summary of results, COST 296 Ionospheric Scintillation Workshop: Scientific aspects, Space Weather application and Services, 20 – 22 February 2008, Nottingham, UK

Coco, E. Amata, L. Alfonsi, G. De Franceschi, M.F. Marcucci, V. Romano, M. Lester, P. Dyson, Statistical correlations between GPS scintillations and SuperDARN HF backscatter, presented during the IUGG XXIV General Assembly, Perugia, July 2007.

De Franceschi G., Alfonsi L., Romano V., GPS ionospheric scintillations monitoring at INGV: scientific aims and space weather applications, 1st colloquium scientific and fundamental aspects of the Galileo programme Toulouse, 1-4 october 2007.

Amata, E., G. De Franceschi, L. Alfonsi, I. Coco, M.F. Marcucci, S. Milan, V. Romano "Statistical comparison of GPS and SuperDARN observations during ionospheric scintillations". Paper at the Workshop on "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services", in Nottingham, 20-22 February 2008

Materassi, M., L. Alfonsi, G. De Franceschi, V. Romano, A.W. Wernik, Wavelet Analysis of Raw Data from Ionospheric Scintillation GPS Receivers, IRI/COST296 Workshop, Prague 2007.

Alfonsi L., G. De Franceschi, V. Romano, A. Bourdillon, Minh Le Huy “Ionospheric scintillation at polar and equatorial latitudes: recent advances“. Paper at the Workshop on "Ionospheric Scintillation: Scientific aspects, Space Weather application and Services", in Nottingham, 20-22 February 2008.

Zhen Weimin “The scintillation forecasting study”. The 6th Space Weather symposium, 7 - 13, Aug. 2007, Guiyang.

Zhen Weimin “The characteristics of scintillation in low latitude”. The 9th meeting of Radiowave Propagation, 18 - 22 Sep. 2007, Xi’an.

Zhen Weimin “The scintillation effects on the space communication system”. Invited paper at the 23rd Geophysics symposium, 19 - 23, Oct. 2007, Qingdao.

Zhen Weimin “The method study of monitoring scintillation based on the satellite sensors”. The 12th Symposium of Solar-Terrestrial Space Physics”, 9 - 16, Nov. 2007, Sanya.

Béniguel, Y., J-P Adam, N. Jakowski, T. Noack, V. Wilken, M. Cueto, A. Bourdillon, J.-J. Valette, P. Lassudrie Duchesne, B. Arbesser-Rastburg, Ionospheric Scintillations recorded at low and high latitudes during the PRIS measurement campaign: Summary of results, Nottingham Scintillation workshop, February 2008

Adam, J.-P., Y. Béniguel, GISM model in the case of strong scintillations, Nottingham Scintillation workshop, February 2008