COST 296 Action: **M**itigation of **I**onospheric **E**ffects on **R**adio **S**ystems (MIERS)

Approved Minutes of the 6th Management Committee Meeting
15-17 March 2007
INGV, Rome, Italy

1. **Welcome**

BZ, the local host, welcomed the participants, and explained the logistical arrangements. AB (COST 296 Chairperson) thanked BZ 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 with small changes, see ANNEX I

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

The minutes of the fifth MC meeting held at IETR, University Rennes 1, France were approved.

4. **Official status of the COST 296 Action by 3 October 2006**

AB reported that there are 17 signed countries and 8 signatories from non-COST countries. There are 2 more non-COST countries in process of signing, Geomagnetic Laboratory, Ottawa, Canada and Universiti Kebangsaan (UKM), Malaysia. The Department of the Royal Air Force, AFRL, USA is considering joining COST 296 but there is a question about the military use of the results to be resolved.

5. **COST296 Budget 1 July 2006 to 30 June 2007**

AB reported the status of the COST 296 Budget. The MC approved an advance payment to JL who is hosting the joint COST296/IRI Workshop being held in Prague, Czech Republic in July 2007.

6. **Short Term Scientific Missions (STSMs) on the budget (July 06-June 07)**

There was 1 STSM to report at this MC: Ioanna Tsagouri had a STSM in Prague, 26 February to 2 March 2007. Five more STSM are planned before the end of the COST296 financial year.

7. **Annual Report**

AB suggested that WG leaders produce 2 versions of the Annual Report, a short version for him to present at the Annual COST review and an extended report for the minutes then these can be collected together to form the Final Report at the end of the project. There was also a discussion of the Appraisal Report from COST296 Rapporteur http://www.cost296.rl.ac.uk/pdf/Yearly_Evaluation_of_rapporteur_COST296_2006.pdf who remarked that there were too many papers listed with very few collaborative papers.

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

WG 1: Ionospheric monitoring and modelling (ANNEX IV)
WG 2: Advanced terrestrial systems (ANNEX V)
WG 3: Space based systems (ANNEX VI)

9. **Collaboration between COST296 and COST274 actions**

BZ led the discussion on COST296 contribution to the final report of COST724. BZ asked for a list of models that were ready and could be introduced in 724 final report. BZ gave a deadline of early April 2007 for contributions to be sent to him for inclusion in this report. Discussing the issue of collaboration between COST 296 and 724, LC made a remark that these COST296 models should also be included in the COST296 final report.

10. **Short Term Scientific Missions (STSM) Proposals from WG Leaders for next budget period**

Working Group 1 proposed 3 STSM for the next financial period. Working Groups 2 and 3 had no written proposals but plan to discuss and present something at the next MC meeting.

11. **Preparation of the Annual Report**

The Annual Progress Report must be sent to Brussels in June. AB asked for a short report (maximum 3 pages) for the period July 2006 to June 2007 this must be sent by the WG Leaders to AB by 15 April deadline. AB also stressed the importance that these reports show collaborative work.

12. COST296 activities related to the IHY

GD presented an IHY calendar initiative asking all participants to take part by publicising in their countries a competition for school children. Part of the prize would be having the winning entries as months in the IHY 50th anniversary 2007/08 calendar. LC offered to use the opportunity of the Chilbolton 40th Anniversary open day as venue for the UK.

13. Proposals for a workshop

GD Proposed holding a workshop on Ionospheric Scintillations, Measurements and Modelling. The decision will be taken when will have information about the next year budget.

14. COST296 Workplan and Budget for 2007-08

AB presented the proposed COST296 budget and workplan for 2007-08 see Annex III. There was a request from an expert participant for reimbursement there was no opposition to this request. AB pointed out that in future all experts will be formally invited by the chairman and offered reimbursement.

15. Next meetings of the COST296 Action

JL presented the arrangements for the joint COST296 IRI workshop and COST296 MC meeting to be held in Prague 10-14 July 2007. JL stated that location of workshop will be the Hotel Globus and he suggested booking through the web site http://www.ufa.cas.cz/htm/conferences/iricost2007 JL will also send out a global COST296 message giving booking and registration details on his return to Czech Republic.

A Working Group Leaders meeting is to be held during the Vienna EGU on Thursday 19 April 2007 – reimbursement will be given to those Working Group leaders attending.

LE and HH – our Cyprus colleagues offered to host the next COST296 meeting in March 2008. Turkish MCM members made the following remarks:

Cyprus is an area under dispute. Therefore holding an MCM in Cyprus will not make sense and also creates unnecessary problems concerning visa and travel for the Turkish group. Because the requirements of Cyprus for Turkish citizens for obtaining visa, traveling freely and making hotel reservations freely are unacceptable. Therefore, most probably, Turkish group can not be able to attend the COST 296 activity to be held in Cyprus.
There are alternative offers made by Huelva and Trieste who have been in the project for a long time. Therefore there is no necessity to insist on having MCM in Cyprus under presently existing conditions.
This point will be discussed further at the next MC meeting.

BZ also proposed that in 2008 COST296 should organise a special meeting to celebrate 20 years of participation in a COST Action. Further discussions at the next MC meeting.

16. International meetings relevant for the COST296 Action

There are several international meetings relating to COST296 activities:

Lowell Symposium to celebrate Bodo Reinisch 70th birthday
EGU Vienna April 2007 COST296 poster session.
AGU Acapulco, Mexico, 22-25 May 2007
Beacon meeting Boston, USA, June 2007
CAWES Campaign, Canada, August 2007
Series of Schools in L'Aquila Italy, March 2006-Fall 2008
EUCAP 2007, Edinburgh, UK, 11-16 November 2007
IUGG Perugia – Poster session in Cattacombs.
URSI 2008, Chicago, USA

17. Discussion on FP7

A meeting to discuss FP7 was held in Paris on 23 January 2007 and it is still not clear if it is possible that COST296 could take part in this initiative. SR offered to read FP7 to see if there is any relevance to COST296, AC will also participate in ERC: European Research Council whose objectives are to help in the development of very high quality research teams.

18. Participation of Croatia

AB received a message of Pr. Tomislav Kos from Croatia. University of Zagreb, Faculty of Electrical Engineering and Computing expresses his willingness to join COST296. The MC approved the participation of Croatia.

19. Election of the chairman, vive-chairman and secretary

AB, BZ and AV were unanimously re-elected.

20. Any other business

AC asked for financial help to attend COST ICO603, two participants were not in agreement with this proposal, others preferred the money to be used to invite Russian colleagues to COST296 meetings. Decision to be made during WG leaders meeting in Vienna and/or during the next MC meeting in Prague.

ANNEX I

Sixth Management Committee meeting of the COST 296 Action

Mitigation of Ionospheric Effects on Radio Systems (MIERS)

INGV, Rome, Italy
15-17 March, 2007

Approved Agenda

Thursday 15/3 14.30 – 17.30
1. Welcome
2. Approval of the Agenda
3. Adoption of the Minutes of the fifth MC meeting
4. Official status of the COST296 Action
5. Status of COST296 Budget from 1 July 2006 to 30 June 2007.
6. Short Term Scientific Missions (STSMs). Report on those already done
7. Report on the Helsinki meeting

Friday 16/3 0900 – 1230
8. Receipt and adoption of the progress reports of Working Group Leaders
Report on WG1
Report on WG2
Coffee break
Report on WG3
General discussion – Terms of Reference
9. Collaboration between COST296 and COST724
9(a). ITU-R Discussion

Lunch break

Friday 16/3 14 00 – 1530
10. Short Term Scientific Missions (STSM). Proposals of WG leaders for the next budget period
11. Preparation of the COST296 Annual Report
12. COST296 activities related to the IHY (G. De Franceschi)
13. Proposal of a workshop on ionospheric scintillations, measurements and modelling (G. De Franceschi)

Reception on the roof of the Capitolium

Saturday 17/3 0930 – 1230

14. Presentation of the workplan and budget requested for 2007-2008
15. Next meetings of the COST296 Action (B. Zolesi and J. Lastovicka)
16. International meetings relevant for the COST296 Action
17. Discussion on FP7
18. Participation of Croatia
19. Election of the chairman, vive-chairman and secretary
20. Any other business

Alain Bourdillon

ANNEX II

COST 296 Action MC meeting 15-17 March 2007
List of Attendees

B Abesser-Rastburg	(BA) ESA, Noordwijk, Netherlands
L Alfonsi	(LA) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
D Altadill	(DA) Observatory de l'Ebre, Roquetes, Spain **(NR)**
M Aquino	(MA) University of Nottingham, Nottingham, UK
J Azevedo	(JA) University of Madeira, Madeira, Partugal **(NR)**
A Belehaki	(ABE) NOA, Athens, Greece **(COST724 Representative)**
Y Beniguel	(YB) IEEA, France **(NR)**
A Bourdillon	(AB) University Rennes 1, France **(Chairman, Co-Leader WG-2, NR)**
J Boška	(JBO) Academy of Sciences of Czech Republic, Prague, Czech Republic **(NR)**
J Bremer	(JB) Leibniz-Institute of Atmospheric Physics, Kühlungsborn, Geremany (**NR**)
D Buresova	(DB) Academy of Sciences of Czech Republic, Prague, Czech Republic
Lj R Cander	(LC) Rutherford Appleton Laboratory, Chilton, Didcot, UK
A Casimiro	(AC) University of Algarve, Faro, Portugal **(NR)**
G De Franceschi	(GD) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy
L Ecomomou	(LE) (Cyprus) **(NR)**
U Foelsche	(UF) Karl-Franzens-Universität, Graz, Austria **(NR)**
H Haralambous	(HH) Fredrick Institute of Technology, Nicosia, Cyprus **(NR)**
N Jakowski	(NJ) DLR/DFD, Neustrelitz, Germany **(Co-Leader WG-3, 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)**
B A de la Morena	(BM) INTA, El Arenosillo, Spain **(NR)**
B Nava	(BN) Abdus Salam ICTP, Trieste, Italy
L Perrone	(LP) INGV, Rome, Italy
B Reinisch	(BR) ULM, Lowell, Massachussetts, USA
V Romano	(VR) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy **(NR)**
H Rothkaehl	(HR) Space Research Centre, Warsaw, Poland **(NR)**
P Sauli	(PS) Academy of Sciences of Czech Republic, Prague, Czech Republic
H Strangeways	(HS) University of Leeds, Leeds, UK **(NR)**
I Stanislawska	(IS) Space Research Centre, Warsaw, Poland **(NR)**
I Tsagouri	(IT) NOA, Athens, Greece **(NR)**
E Tulunay	(ET) The Middle East Technical University, Ankara, Turkey + TUBITAK-Marmara Research Center, Kocaeli, Turkey **(Co-Leader WG-2, NR)**
Y Tulunay	(YT) Istanbul Technical University, Istanbul, Turkey **(NR)**
E Turunen	(ETU) Sodankyla Geophysical Observatory, Finland **(NR)**
A Vernon	(AV) Rutherford Appleton Laboratory, Chilton, Didcot, UK **(COST296 Secretary)**
B Zolesi	(BZ) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy **(Vice-Chairman, NR)**

NR: National Representative IR: Institute Representative

ANNEX III

COST ACTION 296

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

(1)	TRAVEL COSTS	€ 84.000
(2)	TRAVEL COSTS FOR 2 PARTICIPANTS OF COST NEAR NEIGHBOURS (Russia)	€ 2.000
(3)	WORKSHOP ORGANISATION SUPPORT	€ 7.000
(4)	SHORT-TERM SCIENTIFIC MISSIONS	€ 10.000
(5)	TRAINING SCHOOLS	€ 0
(6)	PUBLICATIONS	€ 1.000
(7)	SECRETARIAT	€ 7.500
(8)	IHY Calendar initiative	€ 5.000
(9)	**TOTAL**	**€ 116.500**

ANNEX IV

Working Group 1 - Ionospheric monitoring and modelling

Leaders : J. Laštovička (CZ) and I. Stanislawska (PL)

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

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

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 (GER) and E. Turunen (FIN)

REPORT ON ACTIVITIES OVER THE PERIOD OCTOBER 2006 – FEBRUARY 2007.

ARRANGED ACCORDING TO THE WORKING PACKAGES AND TERMS OF REFERENCE.

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.

The Germany and UK teams have proposed new ionospheric activity indices derived from automatically scaled online data from several European ionosonde stations. These indices are used to distinguish between normal ionospheric conditions expected from prevailing solar activity and ionospheric disturbances caused by specific solar and atmospheric events (flares, coronal mass ejections, atmospheric waves, etc.). The most reliable indices are derived from the maximum electron density of the ionospheric F2-layer expressed by the maximum critical frequency foF2. Similar indices derived from ionospheric M(3000)F2 values show a markedly lower variability indicating that the changes of the altitude of the F2-layer maximum are proportionally smaller than those estimated from the maximum electron density in the F2-layer. By using the ionospheric activity indices for several stations the ionospheric disturbance level over a substantial part of Europe (34°N–60°N; 5°W–40°E) can now be displayed online.

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

Ionosondes of the COST296 network continue contributing with real-time VI data to WDC for STP, Chilton (RAL), DIDBase, and DIAS prototype databases.

The Ebro and El Arenosillo real-time data are also shown at http://www.inta.es/iono/ and http://www.obsebre.es/php/ionosfera.php (real time data). Ebro revised VI data are shown in graphical form at http://www.obsebre.es/php/ionosfera.php (revised data) and are available in digital form on request.

The University of Massachusetts Lowell continued to archive in DIDBase all digisonde data available in real time via Internet, these include the European COST296 stations.

The team of the SRC, Poland, have constructed an IIWG data base for VI data which is being distributed via ISES network. The data base has been constructed with the data coming daily at SRC by the URSIGRAMs. The last two months of these data are availbale also at SRC ftp site and archieves data distributed worldwide (http://rwc.cbk.waw.pl/iiwg).

IZMIRAN has received the Reinisch's digisonde and it will be (I hope soon) included to the European ionosonde network for mutual use.

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

The UMLCAR team 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).

For a COSMIC (Constellation Observing System for Meteorology, Ionosphere, and Climate) campaign in December 2006, 41 digisondes around the globe collected electron density profiles at a 5-min cadence, including many European COST stations: Tromso, Chilton, Juliusruh, Dourbes, Tortosa, Pruhonice, El Arenosillo, Rome, and Athens. Data were archived in UMLCAR's DIDBase for comparison with Ne profiles derived from COSMIC radio occultation measurements. UMLCAR has recently received the first COSMIC profiles.

To compare digisonde DPS-4 measurements with the Doppler data, a phase path was calculated from both Doppler and digisonde records for 21 selected days of 2004. Under geomagnetically disturbed conditions, in the case where a sporadic E layer was present, and when the sounding frequency is close to the critical frequency of ionospheric layer a significant disagreement between both measurements has been found. The discrepancies could be related to the uncertainties of the observational inputs and to the interpretation of the digisonde data. The comparison of the phase paths shows that during geomagnetically quiet days, in the absence of the sporadic E layer, and when high quality ionograms are available and correctly scaled, the electron density (Nh) profiles, calculated by the Automatic Real Time Ionogram Scaler with True height algorithm (ARTIST), can be considered reliable.

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

The team of the SRC, Poland, have enriched more links to addresses (sites) related with ionospheric weather (http://www.cbk.waw.pl/cost296).

The COST Prompt Ionospheric Database at RAL (http://www.ukssdc.ac.uk/prompt_database.html) continues to receive, catalogue and archive auto-scaled data on a real time basis from ionospheric sounders across Europe. The full set of contributing instruments now numbers 10 in Europe, at Athens, Chilton, Dourbes, El Arenosillo, Juliusruh, Lycksele, Pruhonice, Rome, Tortosa, and Tromsø.

The IZMIRAN team has created a web site on ionospheric weather (http://www.izmiran.ru/ionosphere/weather/). Data of 19 ionospheric stations (foF2, hmF2 and their deliverables) are presented therein for the current month. The past data are available in the archive since December 2006. Missed data are reconstructed by cloning data of other stations so the data sets are complete for the daily-hourly grids. The ionospheric disturbances are being indexed in comparison with the running median of the preceding 27 days calibrated with ITU-R prediction of the seasonal trend.

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.**

Manually corrected hourly ionograms from Pruhonice ionospheric station for the period from July 2004 to July 2006 are prepared for sending to COST database in Chilton.

The Ebro observatory promotes the availability of real-time and revised VI data for comparison validating studies. The data are visible in graphical form at http://www.obsebre.es/php/ionosfera.php, and in digital form under request.

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.**

40 days of GPS-derived slant TEC data at 30 seconds time interval for about 50 stations in Europe have been prepared. It has to be noted that the data have been produced using a filter on slant TEC rate of change of 2 TEC unit per minute.

3. **Promote and coordinate the creation of a set of "synthetic" data (produced with model) for assessment of retrieval techniques.**

4. **Select and validate appropriate models and data ingestion and assimilation techniques.**

The Ebro and Czech teams have continued testing the Local Model (LM) of IRI parameters for a 12-years-long data set (1993-2004) of El Arenosillo (37.1°N, 353.2°E) station and for one-year-long data sets of Juliusruh (54.6°N, 13.4°E), Chilton (51.5°N, 358.7°E), Pruhonice (50.0°N, 14.6°E), Athens (38.0°N, 23.6°E), and Grahamstown (33.3°S, 26.5°E) ionospheric stations. The linear regression coefficient between the IRI2001-predicted and observed (MARP) values was low ($R2 \sim 0.3$, 0.22, and 0.1 for B0, B1, and D1, respectively). We obtained better results for B0 parameter, when the Gulyaeva option has been used for middle and lower-middle latitude stations (about $R2 \sim 0.55$). However, the use of the LM presents a significant improvement for all these stations compared with the IRI2001 predictions. The LM improves by 30% for all parameters from El Arenosillo and Pruhonice, by 50% for B0 and D1 and by 20% for B1 from Juliusruh, by 35% for B1 and by 50% for B0 and D1 from Athens, and about 30% for Grahamstown parameters.

The development of the Electron Density Assimilative Model (EDAM) has been continued. EDAM provides a means to assimilate measurements into a background ionospheric model. The assimilation is based on a weighted, damped least mean squares estimation. This is a form of minimum variance optimal estimation (also referred to as Best Linear Unbiased Estimation, BLUE) that provides an expression for an updated estimation of the state (known as the analysis) that is dependent upon an initial estimate of the state (the background model), and the differences between the background model and the observations. The error covariance matrices of the background model and the observations are also included to control the relative contributions of the background and the observations to the analysis.

EDAM testing has shown that, whilst the RMS errors in foF2 may be reduced by the assimilative model (Fig. 1), it is difficult to modify the vertical structure of the electron density grid using ground based TEC data alone – this is a problem common to all assimilative approaches (Angling and Khattatov, 2006). It is anticipated that the introduction of RO data will provide much better vertical information and, therefore, improve the vertical representation of the ionosphere.

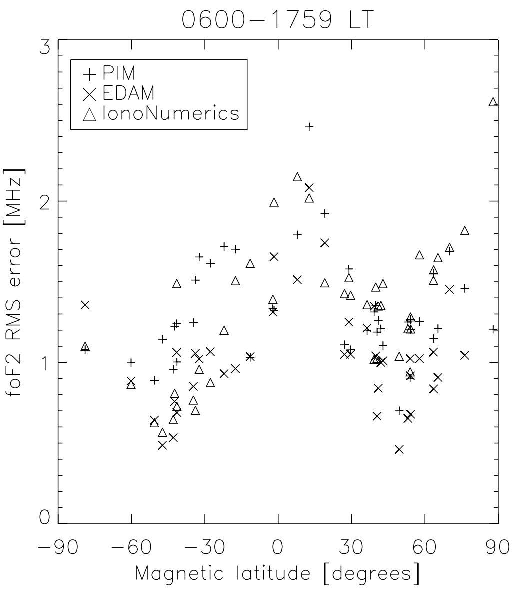

Fig. 1. Daytime *foF2* RMS error as a function of magnetic latitude. From Angling and Khattatov, 2006.

Further testing has been undertaken using both ground based IGS data and space-based data from COSMIC. For moderate and also disturbed conditions (19-20/8/2006, Fig.), EDAM generally performs better than PIM. As expected, the assimilation of the RO slant TEC data has the greatest impact on the assimilation results, though the improved RMS exhibited by EDAM ingesting just ground based IGS data does demonstrate that it is possible to reduce errors in the vertical structure of the ionospheric model using this data.

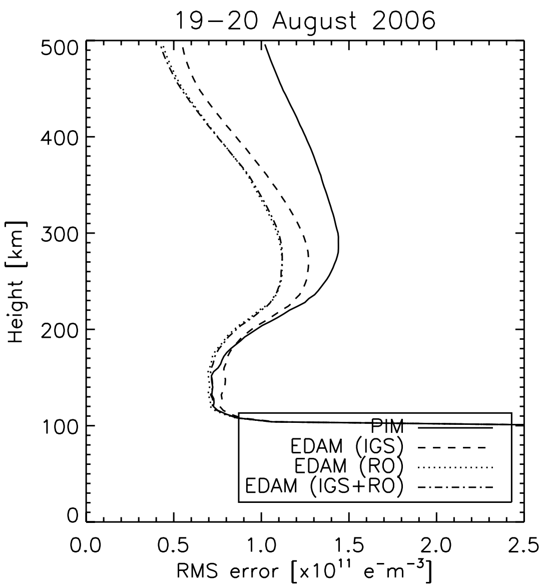

Fig. 2. RMS error between ionospheric models and Abel transform vertical profiles at 5 km height steps on 19-20 August 2006. The models are: PIM (solid line); EDAM assimilating IGS data only (dashed line); EDAM assimilating COSMIC RO data only (dotted line); and EDAM assimilating IGS and COSMIC RO data (dot-dash line). From Angling, 2007.

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

The same technique to retrieve the electron density of the ionosphere starting from total electron content values has also been used to analyse both the standard and the NeQuick option for the IRI topside. The preliminary results indicate that with a single topside option it is not possible to reproduce with the same accuracy the foF2 experimental values for all given locations and epochs.

Variations of the upper boundary of the ionosphere (UBI) were investigated using three sources of information: (i) ionosonde-derived parameters: critical frequency foF2, propagation factor M3000F2 and sub-peak thickness of the bottomside electron density profile; (ii) total electron content TEC observations from signals of the Global Positioning System (GPS) satellites; (iii) IRI model-generated electron densities. the ionospheric slab thickness τ was calculated as ratio of TEC to the F2 layer peak electron density NmF2 representing a measure of thickness of electron density profile in the bottomside and topside ionosphere eliminating the plasmaspheric slab thickness of GPS-TEC with IRI code. The ratio of slab thickness to the real thickness in the topside ionosphere was deduced making use of the similar ratio in the bottomside ionosphere with a weight Rw. Model weight Rw was expressed as a superposition of the base-functions of local time, geomagnetic latitude, solar and magnetic activity. Results show that the time-space variations of domain of convergence of the ionosphere and plasmasphere differ from an average value of UBI at ~1000 km over the earth. Analysis for quiet monthly average conditions and during the storms (September 2002, October-November 2003, November 2004) has shown shrinking UBI altitude at daytime to 400 km. The upper ionosphere height is increased by night with an 'ionospheric tail' which expands from 1000 km to more than 2000 km over the Earth under quiet and disturbed space weather. These effects are interposed on a trend of increasing UBI height with solar activity when both the critical frequency foF2 and the peak height hmF2 are growing during the solar cycle.

The analysis of IRI model behaviour at low latitudes, using different formulation for the topside profile has been done. The model shows a tendency to underestimate the total electron content, which is stronger using NeQuick topside option. The causes of these underestimations were analysed comparing IRI and NeQuick profiles for the bottomside with experimental electron density profiles for low latitudes for both low and high solar activity conditions. The behaviour of the bottomside was reflected in the NeQuick topside and appears as one of the causes of the observed underestimations in TEC and topside electron density profiles. In addition, the NeQuick ionosphere electron density model, version 2.0, has been finalized, but still not presented. Major changes have been introduced in the model formulation and specific revisions have been applied to the computer package associated to model, in order to improve its computational efficiency.

To give better description of the three-dimensional electron density of the ionosphere for actual conditions, different techniques based on vertical or slant total electron content (TEC) data ingestion into NeQuick model have already been developed. Recently, a near real-time ionosphere electron density retrieval technique has been elaborated and has been implemented both using the IRI and the NeQuick models. The technique is based on the models adaptation to GPS-derived TEC data obtained from a single ground station. This technique has been used to evaluate the performance of the two models to reproduce the electron density of the ionosphere at a given time and location. In particular the data analysis has been focused on the capabilities of the models to reconstruct the experimental foF2 values obtained from 6 ionosondes located in the vicinity of the GPS receivers providing the TEC values. The day 5 April 2000 has been chosen for the test, being a geomagnetic undisturbed period of high solar activity. The data analysed indicate that both models are able to reproduce reasonably well the foF2 experimental values. Nevertheless in some cases the NeQuick model achieves better performance when it is used to reproduce the diurnal behaviour of the critical frequency of the F2 layer of the ionosphere.

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.

A new assimilation procedure of ground-based and occultation GPS TEC data into combined IRI/GCPM model has been developed. The accuracy of the resulting electron density fields is markedly better through the assimilation of the GPS data as shown by comparison with soundings of seven European ionosonde stations (Stolle et al., 2006).

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
2. Develop common rules for error estimates and testing procedures
3. Develop techniques for real-time forecasting (data adjustment)
4. Improve the existing and develop new space plasma models

The Ebro, Czech, and UMLCAR teams have investigated the behavior of the neutral scale height Hm at hmF2 (the F2 peak) deduced from electron density profiles N(h). Hm is deduced by fitting a vary-Chap function to the bottomside N(h) profiles obtained after operator scaling of the ionogram traces. One solar cycle of data were analyzed, 1995 to 2006. The temporal behavior of Hm shows systematic daily and yearly patterns that can easily be fitted to diurnal and annual harmonic functions. Moreover, the spectral characteristics of the above functions are sunspot activity dependent, and the solar activity dependence can easily be described by analytical functions. The model for Hm at the F2 peak can be used as the lower limit for construction of the topside N(h) model in terms of a vary-Chap function.

IRI-2001 model has still large discrepancies for ionospheric F region bottomside parameters B0, B1 and D1, probably due to the present tabular form of IRI for these parameters. In 2005 a Local Model (LM) has been developed to improve model predictions of the above parameters based on a least-square fitting to a harmonic function that simulates the diurnal, semidiurnal and seasonal variations according to different levels of solar activity under quiet conditions. The LM was created using the retrospective data set of European mid-latitude station Ebro (40.8°N, 0.5°E), which covers more than one solar cycle. The Monthly Averaged Representative Profile (MARP) has been used to obtain the parameters B0, B1 and D1 for quiet ionospheric conditions. Recently the LM is been tested using manually scaled data from European middle latitude ionospheric stations (Arenosillo, Pruhonice, Juliusruh,). Model validation results show that the proposed LM provides more reliable variation of the analysed bottomside parameters comparing with those IRI-2001-generated. At mid-latitudes and under quiet ionospheric conditions LM allows an improvement of the IRI-2001-predicted coefficients B0 and B1 at an average by factor of two and improvement of the parameter D1 predictions by factor of three (Fig. 3).

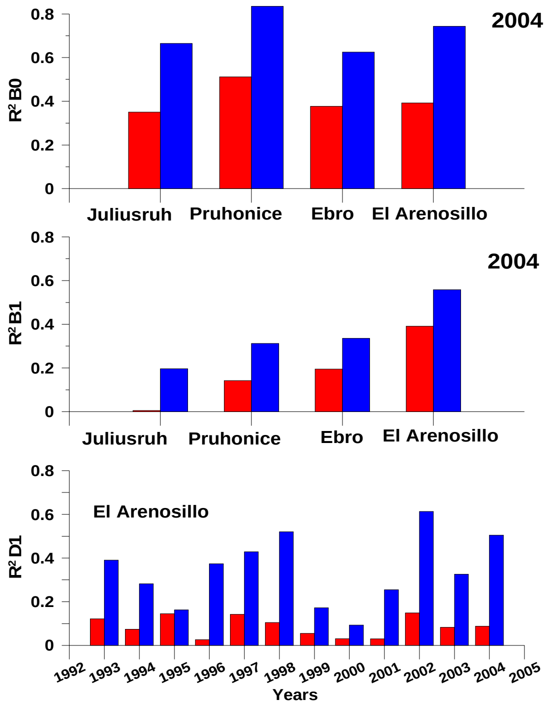

Fig. 5. Comparison of the linear coefficient of determination R^2 for IRI2001 model-predicted (red bars) and LM-calculated (blue bars) parameters B0 and B1 for four European stations (upper and middle panels) for 2004. Bottom panel represents R^2 obtained for D1 El Arenosillo for different solar activity.

The proposed technique including mathematical formulation could be considered to integrate into further updates of the IRI model. The presented LM has a simple formulation where the coefficients depend on a single parameter, the annual average of Rz12. This makes the model easy to update and to extend to larger geographical region.

5. Forecasting of foF2 and TEC and unifying geomagnetic drivers

The German Aerospace Center (DLR) established a novel space weather monitoring service (SWACI) focused on high precision GNSS positioning applications (Jakowski et al., 2006). Part of this service includes the use of the regional TEC model (NTCM) for TEC forecasting purposes. TEC forecast maps are generated based on prediction of the TEC geomagnetically quite time behaviour by using the latest SWACI TEC maps, the TEC gradient estimated by the regional NTCM model, and the sub-sequent correction for geomagnetic / ionospheric storm influence (Stankov and Jakowski, 2006). The storm correction assumes that the GPS TEC storm-time fluctuations depend solely on the level of geomagnetic activity; therefore it was necessary to analyze the relation between the relative TEC value, TECrel (= TECmeas-TECmed)/TECmed) and the Kp index of geomagnetic activity. Since this relation depends on geographic location, most strongly on latitude, a preliminary latitude-dependent model of the average TECrel value as a function of Kp has been developed. The model allows if the quite-time TEC value is available for a given location, this TEC value to be multiplied by a coefficient provided by the model and thus the TEC value to be corrected for geomagnetic storm influence. Hence, if predicted TEC for non-storm (median) conditions and predicted Kp values are both available, a new (more reliable) TEC forecast value can be produced. The forecast based on this method is realised for 1-hour ahead, considering the availability of Kp prediction from solar wind estimations and user requirements. The NTCM coefficients are regularly updated by the use of former TEC measurements.

An ionospheric forecasting empirical local model over Rome (IFELMOR) to predict the state of the critical frequency of the F2 layer (foF2) during strong geomagnetic storms and disturbed ionospheric conditions has been developed as a part of the prediction and retrospective ionospheric modelling over a given area.

Hourly measurements of foF2 in Rome observatory, hourly quiet-time values of foF2 ($foF2_{QT}$) calculated following Wrenn's pocedure and the time weighted accumulation hourly series derived from the geomagnetic planetary index ap (ap(τ)), were considered during the period January 1976 – December 2003. Under the assumption that the ionospheric disturbance index log(foF2/ $foF2_{QT}$) is correlated to the integrated geomagnetic index ap(τ), statistically significant regression coefficients are obtained for different months and for different ranges of ap(τ) and used as input in a linear equation to calculate the short-term ionospheric forecasting of foF2. The empirical storm-time ionospheric correction model (STORM) has been considered to make comparisons with IFELMOR model. A few comparisons among STORM's performance, IFELMOR's performance, were made for significant geomagnetic storm events (ap > 150) occurred from 2000 to 2003. The results provided by IFELMOR are satisfactory and encourage in the development of other short - term forecasting empirical local models to a number N of stations to produce a short – term forecasting map of foF2 over the area including the N stations under consideration.

A prediction procedure of the hourly values of the critical frequency of the F2 ionospheric layer, foF2, based on the utilisation of a geomagnetic index, is presented. A time-weighted accumulation magnetic index ap(τ) based on recent past history of the geomagnetic planetary index ap is used.

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(τ) is applied. Geomagnetic storms with a maximum of ap ≥ 132, classified as strong events, are selected between 1996 to 2003. The prediction of foF2 is calculated during periods of severe magnetic activity in 2001 in Rome (41.9° N; 12.5° E) observatory. The results are satisfactory.

IZMIRAN has accomplished a system of ionospheric short-term (1-24 hours in advance) foF2 forecast. It is completely automatic and works in real time. The information (hourly foF2 values) comes from 6 European digisonde stations (Chilton, Juliusruh, Athens, Rome, Pruhonice, El Arenosillo). The prediction method used provides better accuracy compared to the IRI-2000 model for severe ionospheric storm conditions (the IRI-2000 model now takes into account disturbed conditions).

Using the predicted as well as foF2 model values, hourly maps for the whole Eurasian (-10E - 200E; 30-80N) area are calculated. The model by Karpachev for the Main Ionospheric Trough is included to the mapping. This very interesting and important ionospheric feature is absent in other prediction models, as far as we know.

6. Modelling and predicting different scale ionospheric perturbations

7. Tomographic imaging for model validation

8. Channel modelling 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 (April – September 2006)

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)

The global pattern of long-term changes and trends in the upper atmosphere-ionosphere system (Fig. 4) has further been improved and related papers published or submitted (Laštovička et al., 2006a, 2006b). Most parameters in the upper atmosphere-ionosphere system, including thermospheric density and E- and F1-region ionosphere (Bremer et al., 2006) behave at least qualitatively as expected from the increasing greenhouse gas concentration and related upper atmospheric cooling and contraction.

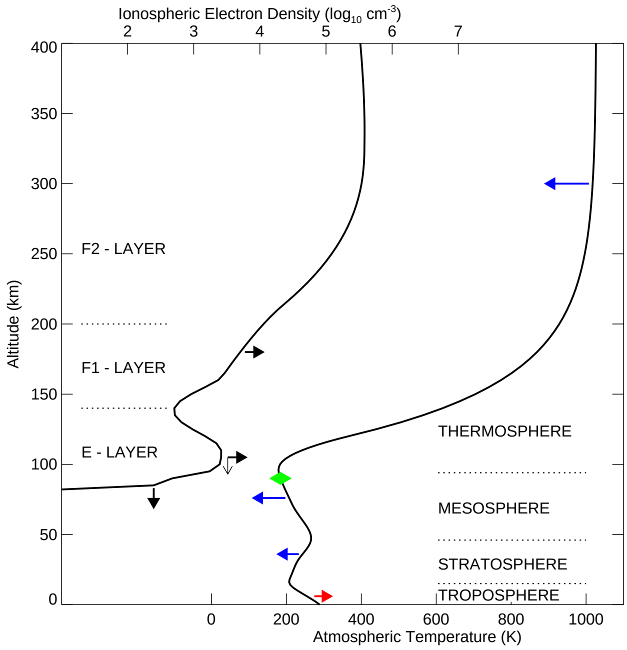

Fig. 4. Overall pattern of global change in the atmosphere-ionosphere system. Red arrow – heating, blue arrows – cooling, green – no change of temperature. Ionosphere – vertical arrows – change of height; horizontal arrows – change of electron density (Laštovička et al., 2006b).

There are still large discrepancies between the results of different authors and different methods as for trends in the F2 region parameters (foF2, hmF2) (Laštovička et al., 2006c), and it is possible that long-term changes of geomagnetic activity play more important role in the observed trends than the greenhouse effect. However, all these changes are relatively weak, long-term and slow and, therefore, do not play a role in ionospheric forecasting. They can affect to some extent only long-term predictions and planning.

The study of the spatial distribution of hmF2 trends has been continued. It has been assumed that the spatial differences of the hmF2 trends are related to the sea-land transitions similar to the existence of non-migrating tides at these discontinuities (Bencze, 2006).

Analysis of mesospheric wind measurements at different stations on the Northern Hemisphere shows non-linear trends during the last 4 decades in the prevailing zonal and meridional wind components as well as in the amplitude of the semidiurnal tidal component (Portnyagin et al., 2006).

Gravity wave analyses (0.7-3 h period interval) have been performed using mesospheric LF wind observations at Central Europe. No long-term trend was detected, but a possible impact of the solar cycle was found, which could be supported by model results (Jacobi et al., 2006).

The investigations of a possible link between geomagnetic field reversal (or excursion) and ionospheric trends in foF2 have been continued mainly using observations in Antarctica (Alfonsi et al., 2006).

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

Effects of the annular solar eclipse of 3 October 2005 on the ionospheric plasma at F layer height were further analyzed. While electron density decreased, the slab thickness somewhat increased. The supersonic motion of Moon's cool shadow through the atmosphere generated atmospheric gravity waves, observed by ionospheric methods. According to the Ebro digisonde data analysis, the source region was the lower thermosphere below about 180 km altitude; however, the gravity waves were not detected in TEC (Jakowski et al., accepted). The height interval of gravity wave excitation does not differ much from heights where the solar terminator excites gravity waves.

Long-period oscillations (3-20 days) have been measured simultaneously by meteor radar temperatures, and scale height estimates using the diurnal cycle of LF reflection heights, indicating that neutral atmospheric planetary waves influence the lower E region ionisation (Jacobi and Kürschner, 2006).

GPS satellite measurements have been used to analyse waves in the ionosphere (Pavelyev et al., 2006).

Infrasound investigations dealt with two topics, transient peculiar phenomena occurring in the infrasound period range (Chum et al., submitted), and response of ionospheric infrasound to tropospheric storms (Šindelářová et al., submitted):

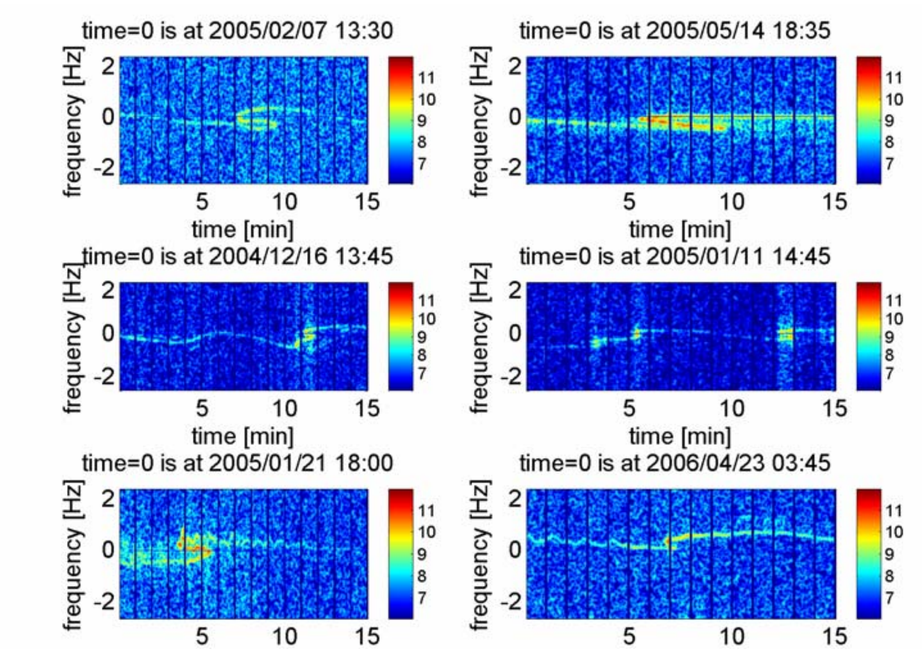

Fig. 5. Examples of various S-shape phenomena (Chum et al., submitted).

(a) S-shapes and oblique quasi-linear shape (QLS) traces (Fig. 5). S-shapes occur predominantly near sunrise and sunset, therefore are mostly related to solar terminator, but some of them may likely be excited by several other potential mechanisms. As for QLS events, a typical QLS has a frequency span around 10 Hz, duration of about 20 s and a slope about 0.4-0.5 Hz/s. We discussed the possible origin of QLSs. We excluded/discarded several potential sources of QLSs such as aircrafts, satellites, bolides, meteors, meteorites, thunderstorms, or geomagnetic storms. We speculate that QLS events are formed by radio waves that propagate in the Z-mode in the ionosphere and reflect in the region of negative density gradient along the up-going part of their ray trajectory at $\omega \sim \omega_{UHR}$ (Upper Hybrid Resonance frequency), but their origin remains unconfirmed.

(b) Response of the ionospheric infrasound to strong meteorological tropospheric events. A case study of analysis of three days of convective storm activity, including one day of severe tropospheric storm, revealed dominance of Doppler spectra by infrasonic waves of periods of 3-4 min for severe storms and by somewhat longer periods for weaker storms. Our analysis revealed that infrasound generated by strong tropospheric events is well detectable at ionospheric heights when the top of the clouds are higher than 14 km. The infrasonic waves are detected more than 2 hours before the storm passage over the measurement points. Sporadic-E layer occurred during some parts of storm intervals, which made a detailed study of these events difficult (Šindelářová et al., submitted).

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

A feature-guided pattern recognition method has been developed to describe the dominant morphology of long-duration negative foF2 disturbances. Using hourly foF2 values from 75 stations during three solar cycles mean characteristic disturbance profiles have been derived and fitted by simple mathematic functions. The model may help, during an ionospheric disturbance at a certain location, to predict its further development (Fotiadis and Kouris, 2006).

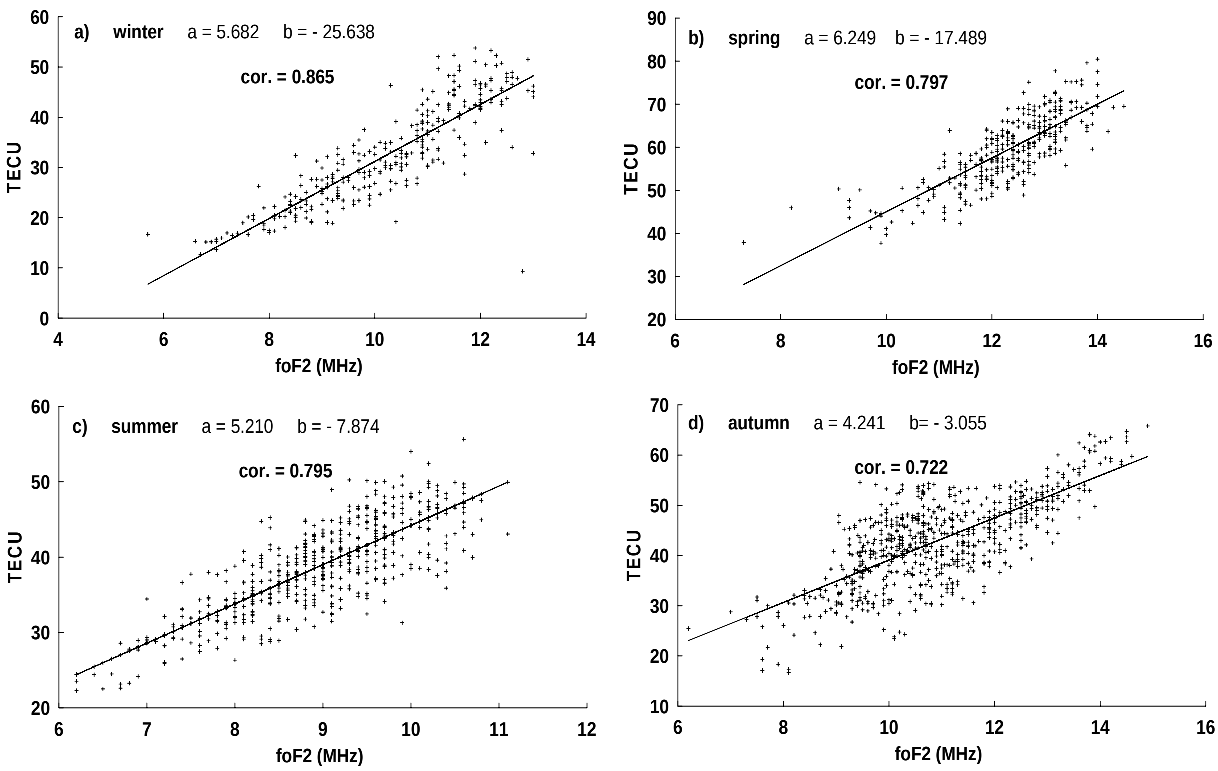

Fig. 6. The scatterplot of TEC against the corresponding foF2 over Rome for different seasons: winter (a), spring (b), summer (c) and autumn (d) 2000. The line drawn corresponds to the best fit line. Krankowsky et al. (accepted).

The results of correlation analysis for daytime variations of TEC and hourly values of foF2 at Rome during different seasons are presented in Fig. 6. A very good correlation between TEC and foF2 took place.

TEC and slab thickness data from different European stations are statistically analysed to study their annual response to changes in solar activity and their dependence on latitude. Moreover a study on their dependence on season and their daily variation as a function of solar zenith angle is in progress. Furthermore a classification of TEC variability which consists of four classes, i.e. (1) "quiet" or undisturbed state with relative deviation of TEC less or equal 0.20, (2) "disturbed" state with relative deviation between 0.20 and 0.50, (3) "very disturbed" state with relative deviation between 0.50 and 0.80, and (4) "extreme or storming" state with relative deviation greater than 0.80, is attempted.

Three polar cap absorption (PCA) events recorded during January, July and September 2005 have been investigated using observations of ionospheric absorption, obtained by a 30 MHz riometer at the Italian observatory of Mario Zucchelli Station (Antarctica), and by solar proton fluxes, monitored by the NOAA-GOES11 satellite. The January event was the most energetic proton event of solar cycle 23 with a maximum of the integral solar proton flux > 100 MeV equal to 652 pfu. Good agreement was obtained between observed and calculated absorption by an empirical flux-absorption relationship (Perrone et al., 2006a; 2006b).

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

NmF2 and NmE variations were analyzed for the periods of positive and negative quiet-time F2-layer disturbances (Q-disturbances: disturbances which are not related with geomagnetic disturbances) observed in the midlatitude daytime F2-layer. The noontime δNmF2 and δNmE deviations demonstrate a synchronous type of variations what can be explained by vertical gas motion in the thermosphere. This neutral gas motion should result in atomic abundance variations, the latter being confirmed by the Millstone Hill ISR observations for periods of positive and negative Q-disturbance events. The analysis of the ISR data has shown that atomic oxygen concentration variations are the main cause of the daytime F2-layer Q-disturbances. The auroral heating controlling the poleward thermospheric wind is considered as the basic mechanism for the Q-disturbances, however the specific mechanisms of positive and negative Q-disturbances are different. Some morphological features of the Q-disturbances revealed earlier are explained in the scope of the proposed concept (Mikhailov et al., 2007).

5. Space weather impacts on the midlatitude ionosphere

Burešová et al. (2007) summarized manifestations of strong geomagnetic storms in ionospheric F2 and F1 layers above Europe.

The UMLCAR and Ebro teams have investigated geomagnetic storms effects on the ionosphere. Two longitudinal chains at American and European sectors were used and it was showed that ionosondes provides an advantage of looking into the altitude distribution of the ionospheric reaction to the geomagnetic storms. Moreover the Digisonde network is a useful tool for studying spatial effects of the magnetic storms.

A catalogue of the ionospheric disturbed periods with duration of 3h or longer is compiled for each station and presented at two web sites, at the IZMIRAN and IDCE (http://www.cbk.waw.pl/).

Investigations of pre-storm enhancements of foF2 continued (Burešová and Laštovička, 2006). The pre-storm enhancements (Fig. 7) do not exhibit a systematic latitudinal dependence and are not accompanied by a corresponding change of hmF2. Several constraints for their mechanism were established. Several potential sources of pre-storm enhancements were excluded: solar flares (they can only occasionally strengthen the pre-storm enhancements), soft particle precipitation in dayside cusp, magnetospheric electric field penetration, auroral region activity expressed via the AE index, and Mikhailov's quiet-time F2-layer disturbances. However, the origin of pre-storm enhancements remains to be uncovered.

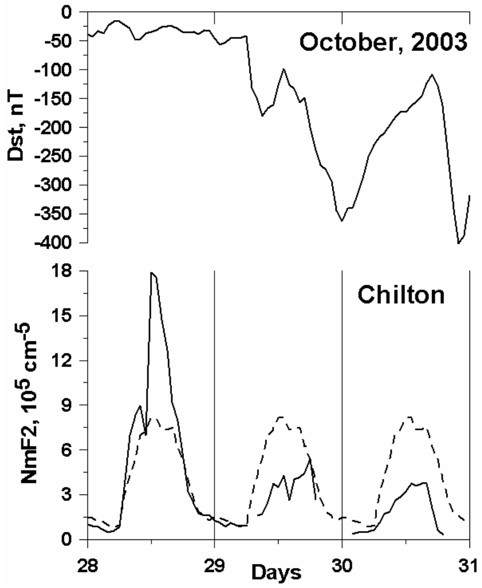

Fig. 7. Effects of the late October 2003 geomagnetic super-storms on NmF2 for Chilton, England. Top plot - hourly D_{st} variation, October 28-30. Bottom plot - NmF2 (hourly values) response; full line – measured values, dashed line – monthly median values. A large pre-storm enhancement (amplified by solar flare) occurs in the middle of the day before the storm. After Burešová and Laštovička (2006).

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ANNEX V

COST 296 WG2 Report

Covering the period October 2006 – March 2007

Submitted to the 6th MC

(15-17 March 2007, Rome)

12 March 2007

WG2 Co-leaders: Ersin Tulunay, Patrick Lassudrie Duchesne

1. WP Terms of Reference Number[1] 2.1

2. **List of Participants**

Contributing to this report are: Eulàlia Benito, Stéphane Saillant, Alain Bourdillon E.M. Warrington, N.Y. Zaalov, A.J. Stocker, D.R. Siddle, J.P. Luntama Ersin Tulunay, Olcay Büyükpapuşçu, Tolga Çiloğlu, Yurdanur Tulunay M.J. Angling and J.E.N. Field

3. **Main Results**

PERFORMING INVERSION OF HF RADAR BACKSCATTER IONOGRAMS

The inversion technique validation on real data is in progress. Our purpose is to recover the initial ionospheric parameters (f_c, h_m, y_m) from a backscatter ionogram.

An elevation-scan backscatter sounding was realized on the Ebre ionosonde direction (Figure 1). This ionosonde, which is situated below the ionosphere's area sounded by the radar, will be used to validate the inversion technique results.

The data contains many outliers which are difficult to eliminate. For this reason, we have changed the data acquisition process. Now, we take five acquisitions and make its incoherent average (Figure 2). Now, we have:

- A lower dispersion of the points,
- More points to use;
- A wider curve.

Nevertheless, more points imply doing more operations. We will take more different acquisitions in order to choice the most performing.

On the other hand, we start applying the ionogram inversion on different frequencies.

1 See Appendix A for information

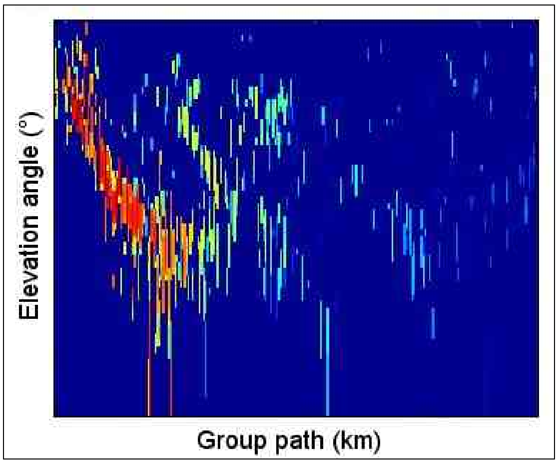

Figure 1 Elevation-scan backscatter ionogram on 10 January 2007 at 13.00UT

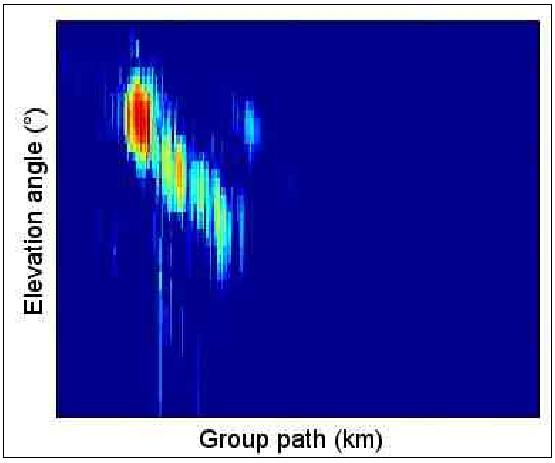

Figure 2 Elevation-scan backscatter ionogram on 29 January 2007 at 13.30UT

HF PROPAGATION ALONG THE TROUGH

Experimental observations of HF propagation made at solar maximum along a 1400 km path (Uppsala–Leicester) aligned roughly parallel to the mid-latitude trough were reported to the COST 271 programme. A variety of propagation characteristics were observed, the most striking of which was the sudden increase in the TOF accompanied by a direction of arrival deviated northwards from the great circle by up to about 40° that occurred on 60% of winter nights. This off great-circle propagation was consistent with the signal scattering from irregularities embedded in the poleward trough wall or in the auroral oval. The deviation in direction was usually to the north rather than to the south in marked contrast to the observations made on a similar path (but in Canada) near sunspot minimum where deviations in either (or sometimes both) directions were found.

Further measurements have now commenced to investigate the effect of the solar cycle on the behaviour of the trough on HF propagation. The link from Uppsala to Leicester has been re-established (from Autumn 2006), and a second transmitter installed at the Nurmijärvi Geophysical Observatory near Helsinki (from December 2006). It is intended that measurements will be made over these paths throughout 2007.

Initial analysis of these new data indicate that the propagation characteristics at solar minimum are markedly different from those that were observed at solar maximum. A detailed report on these results will be made at the next COST-296 workshop.

HF RADAR

Sky-Wave HF radar only is considered because of the lack of data on surface-wave HF Radar.

The ionospheric effects can be investigated efficiently by working with sky-wave HF radar. Following the "proposal for future work" reported in 5th MCM in Rennes 3-7 October 2006, Effects of space weather conditions on the variation of group range and line-of-sight Doppler velocity of the HF Radar echo signal are investigated.

Since there are no data made open, semi-synthetic data are generated by using Tasman International Geospace Environment Radar (TIGER) image plots available on internet as it was hinted during 5th MCM.

HF radar system under ionospheric disturbances has been identified globally and some operational suggestions have been presented. The use of HF radar system is considered from the identification of ionospheric propagation medium point of view. Doppler velocity is considered as the characteristic parameter of the propagation medium. ap index is chosen as the parameter for disturbance characterization due to geomagnetic storms in the ionosphere.

ap index is grouped with two levels of magnetic activity; ap ≤ 9 and ap > 9. Former level will be used for undisturbed ionosphere and the letter will be used for disturbed ionosphere. Table-1 shows the single hop group ranges calculated from TIGER image plots.

Frequency (MHz)	Group Ranges Calculated From Summary Plots (km)	
	ap ≤ 9	**ap > 9**
11	1090-1950	640-2550
14	1390-2550	700-2250

Table-1 Single Hop Group Ranges Calculated from Summary Plots

Considering the results obtained from the TIGER image plots and solar cycle and seasonal variation of the ap index, it is possible to give some suggestions to HF radar planner and operator for the radar operating at the frequencies 11MHz and 14 MHz:

I. When ap index is greater than 9, it seems that it is not possible to communicate with the station located within the group range of 640 km at 11MHz and 14 MHz. (Figure 1)

II. When ap index smaller than 9, it seems that it is not possible to communicate with the station located within the group range of 1950 km at 11MHz and 2550 km at 14 MHz. (Figure 2)

III. It seems that the maximum group range of the HF signal for the single hop propagation does not change significantly with respect to the operating frequencies for 11 MHz and 14 MHz. Therefore, there is no constraint about the maximum group ranges for the given frequencies. Actually HF signal can propagate to group ranges of up to 4000 km via second hops.

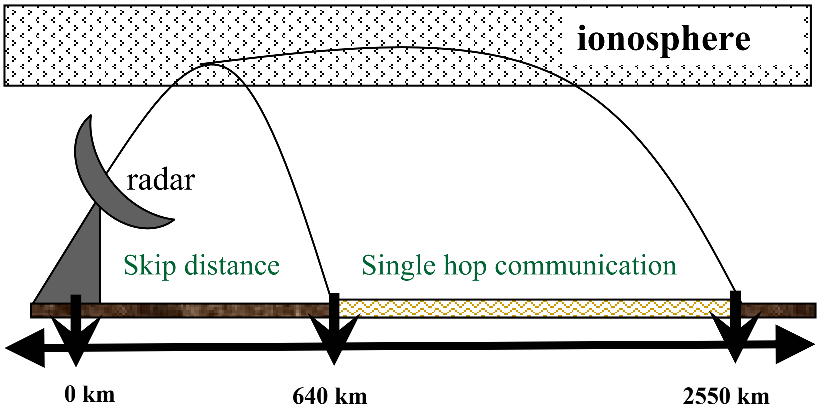

Figure 1 Possible Skip Distance when ap > 9

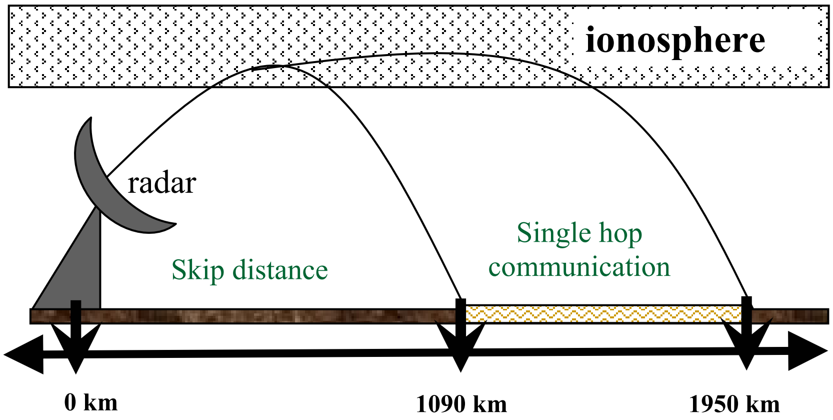

Figure 2 Possible Skip Distance when ap ≤ 9

ap forecasting models and organizations make it possible to forecast the ap index one to four hours ahead, therefore it is possible for the HF radar operator to estimate the possible skip distance and possible single hop group ranges for the given frequencies of 11 MHz and 14 MHz.

SINGLE SITE LOCATION (SSL)

A collaboration between QinetiQ and the University of Leicester has been initiated (via an ICASE studentship). One aspect of the work will be to investigate the use of the Electron Density Assimilative Model (EDAM) to improve the performance of HF single site location systems.

4. Dissemination of Results

   a) Journal Papers
      i. Published

      ii. Submitted

N.Y. Zaalov, E.M. Warrington and A.J. Stocker. The effect of geomagnetic activity on the channel scattering functions of HF signals propagating in the region of the mid-latitude trough and auroral zone. *Radio Science.*

b) Conference Publications

i. Presentation Proceedings

N.Y. Zaalov, E.M. Warrington, A.J. Stocker and D.R. Siddle. Experimental observations of HF propagation on two paths aligned along the mid-latitude trough. To be presented at Nordic HF07.

N.Y. Zaalov, E.M. Warrington and A.J. Stocker. Effect of geomagnetic activity on HF channel scattering functions for signals propagating in the northerly ionosphere. To be presented at Nordic HF07.

ii. Abstract Proceedings

iii. Presentation CD only

iv. Abstract CD only

c) Reports

MS Thesis:

System Identification with Particular Interest On The High Frequency Radar Under Ionospheric Disturbances

Advisor : Ersin Tulunay
Co-advisor: Yurdanur Tulunay

A thesis submitted to the Graduate School of Natural and Applied Sciences of METU by Süleyman Olcay Büyükpapusçu, in partial fulfillment of the requirements for the degree of master of science in Electrical and Electronics Eng., February 2007

5. Short Term Missions Completed

6. Outreach Activities

7. Other Contributions

1. WP Terms of Reference Number[2] 2.2

2. **List of Participants**

Contributing to this report are: E.M. Warrington, S. Salous, S.D. Gunashekar, W.I. Kassem, L. Bertel H. Strangeways

3. **Main Results**

EXPERIMENTAL STUDIES OF THE APPLICABILITY OF MIMO TECHNIQUES IN THE HF BAND

Preparations are now underway to undertake an extensive experimental investigation related to the use of MIMO techniques within the HF band. We envisage that the experimental programme will shortly commence. Currently the necessary equipment (receivers, transmitter, antennas, etc) is being assembled

HF LINKS, HF MIMO SYSTEMS

Determination of the correlation distance for spaced antennas on multipath HF links taking account of time-varying electron density irregularities.

Determination of the capacity of ionospheric HF MIMO systems employing linear or planar arrays or co-located antennas.

The significant multipath and diffraction by small-scale irregularities that exists for HF links would seem to be very suitable for MIMO (Multiple Input Multiple Output) techniques which employ antenna arrays at both transmitter and receiver locations and use space-time coding methods to utilize the increased capacity inherent in having a number of uncorrelated (or at least partially uncorrelated) paths. The capacity improvement which MIMO systems permit at UHF would be very desirable for HF links, potentially permitting much higher data rates. However, it is not clear whether MIMO systems could be used to advantage for HF ionospherically reflected signals and there are significant differences between the UHF and HF scenarios. Further the wavelength is much greater at HF implying much greater distances for given antenna separations in terms of the carrier frequency wavelength Thus important questions are (i) whether the differences between UHF and HF channels are so significant as to preclude the capacity increases found to be possible at UHF (ii) how large a separation between antennas would be required for sufficient channel decorrelation (iii) the possibility of the employment of co-located rather than spaced antennas to reduce the size of transmitting and receiving arrays (iv) what length of path or latitude region would be most ideal for MIMO links. These questions have all been addressed in the recent works.

4. Dissemination of Results

   d) Journal Papers
      i. Published

      ii. Submitted

2 See Appendix A for information

e) Conference Publications

i. Presentation Proceedings

ii. Abstract Proceedings

iii. Presentation CD only

H.J. Strangeways, Determination of the capacity of ionospheric HF MIMO systems employing linear or planar arrays or co-located antennas, Paper presented at COST 296 workshop, Rennes, France 4-6 October 2006 and published on workshop CDROM

V.Gherm, R.Novitsky, N.Zernov, H.J. Strangeways, R.T.Ioannides, On the Limiting Accuracy of Range Measurements for the Three Frequency Mode of Operation of a Satellite Navigation System, Paper presented at COST 296 workshop, Rennes, France 4-6 October 2006 and published on workshop CDROM.

H.J. Strangeways, Investigation of Signal Correlation for Spaced and Co-located Antennas on Multipath HF links and Implications for the Design of SIMO and MIMO Systems, Presented at the 1st European Conference on Antennas and Propagation (EuCAP) . Nice, France, 6-10 November 2006. Published on conference CDROM.

iv. Abstract CD only

f) Reports

5. Short Term Missions Completed

6. Outreach Activities

7. Other Contributions

1. WP Terms of Reference Number[3] 2.3

2. **List of Participants**

Contributing to this report are: A. Casimiro, L. Economou, H. Haralambous

3. **Main Results**

WP 2.3.4 OCCUPANCY DETERMINATION OF HF BAND

The research is focused on the occupancy of the HF Spectrum over Northern Europe. In cooperation with the University of Manchester HF spectral occupancy research group, they have developed mathematical models that fit the experimental measurements of congestion (The statistical measure of the occupancy of an ITU frequency allocation) extremely well.

Congestion is defined as the probability of placing at random a band pass filter of a given bandwidth at any ITU frequency allocation so that the 30kHz IF output of the receiver exceeding a predefined threshold .

The aim of the work was to provide experimental data and mathematical models, showing how occupancy varies with frequency, time, threshold level, bandwidth, type of user allocation, antenna, geographical location, and azimuth.

The most recent models are for single user azimuthal measurements made at Cobbett Hill Radio station UK over the period July 1995 to December 2000.

WP 2.3.5 ANTENNA SYSTEMS
Research is continuing on antenna systems.

WP 2.3.6 PROPAGATION CHANNEL
Research is continuing on new propagation models.

8. Dissemination of Results

g) Journal Papers
i. Published

ii. Submitted

h) Conference Publications
i. Presentation Proceedings

1. H. Haralambous, H. Papadopoulos, Neural network prediction of HF spectral occupancy accepted to the Nordic HF 07 conference

3 See Appendix A for information

2. A. Casimiro, F. Emidio, Analysis and Design of Field Patterns of Multidimensional Structures, EUCAP, November 2006, Nice, France.

ii. Abstract Proceedings

iii. Presentation CD only

iv. Abstract CD only

i) Reports

9. Short Term Missions Completed

10. Outreach Activities

The Cyprus Research Promotion Foundation approved a fund for the installation and operation of a Lowell DPS-4D ionospheric monitoring station.

11. Other Contributions

APPENDIX A. LIST OF WORK PACKETS AND TERMS OF REFERENCE

(Ref: http://www.ukssdc.ac.uk/twiki/bin/view/COST296/WorkingGroup2)

WP2.1 Radar and radiolocation (Leaders: C. Bianchi (bianchi@INGV.IT) and E.M. Warrington (emwarrington@mac.com))

2.1.1. Hot clutter modelling for surface wave radar. Existing hot clutter models will be evaluated and a new model may be proposed. Models will be validated with measurements from a basic surface wave set-up. An experimental set-up will be designed and implemented

2.1.2. Frequency management of ground-wave and sky-wave radars

2.1.3. Angle of arrival measurements for sky-wave signals

2.1.4. Propagation effects that influence radar and radiolocation systems

2.1.5. The effects of environmental noise on HF radar systems

WP2.2 HF/MF communications (Leaders: J.M. Andujar (andujar@UHU.ES) and Y. Erhel (yvon.erhel@st-cyr.terre.defense.gouv.fr)

2.2.1. Digital radio systems – predictions, methods of estimating reliability: experimental studies concerning channel reliability by using existing experimental set-up complied with ITU standards will be conducted in cooperation with University of Leicester UK

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. Effects of gravity, planetary and infrasonic wave effects on propagation

2.2.5. 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. Effects of infrasound on radio propagation

2.3.4. Occupancy determination of HF band for the East Mediterranean conducted using calibrated HF spectrum measurements and HF receiver array

2.3.5. Supporting research and application in antenna systems to increase their efficiency and mitigate the propagation errors

2.3.6. Developing new techniques to analyse the radiation path in the propagation channel

Work Packet : WP2.i
Work Packet Activity : WP2.i.ii

ANNEX VI

WG 3 Report - Space based systems activities within the period October 2006 - March 2007
WG Leaders N Jakowski and R Leitinger

WP 3.1 Space plasma effects (WP Leaders S Radicella and P Sauli)

Large scale effects during severe ionospheric perturbations and their relationships to space weather
During last two years 2004-2006 plasma motion has been monitored in the observatory Pruhonice. In the E region during storm events, both horizontal drift velocity components strongly increase, from typical value of 10 -20 m/s up to 50 m/s during medium events and 100m/s (during severe storm). The vertical component is less affected, it increases from quiet value 5m/s till 10-15 m/s during medium events up to 20 m/s during strong event. SSC events are directly reflected in drift velocity observations. In the F region, all components of the ionospheric F region drift velocity, measured during medium and strong geomagnetic events are strongly disturbed by storm conditions. Observed drift velocity components reach during strong storm values 100- 150 m/s.

Strong weather system influence on the ionosphere
Strong active weather systems, particularly in the troposphere, influence the ionosphere mainly through the upward propagating waves. First results of observation of waves emitted by convective storms at the ionospheric bottomside F-region above Czech Republic have been obtained. To monitor the propagation of the waves generated by strong meteorological events to ionospheric heights the continuous HF Doppler sounding system has been used. During convective storms of lower intensity oscillations of larger periods (over 5 minutes) were observed, whereas during severe convective storms passage, the waves of periods 3 to 4 minutes dominated.
Ionospheric/thermospheric effects of the solar eclipse 3 October 2005 were subject of wide scientific investigation. In the study, ionosonde data, Doppler shift measurements, dual frequency GPS observations were involved. Atmospheric waves related to the eclipse event were identified within data, however the ionospheric response was weaker than expected (compare to solar eclipse event 1999).

Modelling efforts
Comparisons of two IRI plasmasphere extensions with GCPM (Gallagher et al. 2000) and IZMIRAN-IRI* plasmasphere models has revealed that IZMIRAN model shows 1 to 2 orders of magnitude greater plasma density than GCPM model at altitude of 20,000 km above the Earth.

Continuation of monitoring service
The German Aerospace Center (DLR) have further developed the operational service for space-plasma and space-weather monitoring for high precision GNSS positioning applications which is part of the comprehensive project SWACI - Space Weather Applications Center Ionosphere (http://w3swaci.dlr.de/). The efforts in this direction, apart from developing an ionosphere/space weather monitoring service, include the development of a new index which in addition to capturing the local ionospheric response can also enable the prediction of the ionospheric effects on GNSS based applications.

Solar flare Effect on TEC and TEC rate
Global Navigation Satellite Systems operations can be seriously affected in their range accuracy in regions or conditions where large gradients of TEC are found.
TEC data from stations, mostly from the IGS, located in different regions of the world have been analyzed in the ICTP to determine the characteristics of the frequency distribution of the absolute rate of change of TEC. The results show also that during disturbed conditions the slant TEC rate of change values is larger over the American sector than over the European-African sector. Sudden Increase of TEC associated to solar flares can give rise to slant TEC rate of change of 9 TECu/min and jumps of up 20 TECu in 3 minutes

Ionospheric depletions
The Group on Ionosphere and Global Positioning of the University Complutense of Madrid was created in 2003 and deals with the detection of ionospheric depletions and the influence of Ionosphere on satellite positioning.

With reference to the study of ionospheric depletions, a technique has been developed to identify and characterize the depletions.

WP 3.2 Mitigation techniques (WP Leaders U Foelsche and R Warnant)

3.2.1 Basic mitigation techniques which are based on models and operational measurements for real-time corrections The University of Liège – Department of Geomatics has started a study (Ph. D. Thesis) dedicated to the improvement of the NeQuick model for Galileo users. In a first step, the different weaknesses of the model are being identified (University of Liège, B. Bidaine and Royal Meteorological Institute of Belgium, R. Warnant)**.**

DLR has continued operating the ionosphere data service SWACI (http://w3swaci.de) funded by the state government of Mecklenburg-Vorpommern . The service provides near-real-time ionospheric information derived from ground and space based GPS measurements for mitigating first and second order ionospheric propagation errors. (DLR, N. Jakowski).

3.2.2 Mitigation techniques for specific GNSS applications

The University of Graz (UoG) has processed over 5 years of CHAMP Radio Occultation Data (RO) leading to high quality climatology's of the upper troposphere and lower stratosphere Recently, SAC-C RO data were added to this database. Our results suggest that standard ionospheric correction techniques (linear combination of bending angles) are sufficient for CHAMP and SAC-C climatology's up to 35 km altitude, where the RO data are of sufficient quality. Higher order ionospheric effects are, however, expected to become important for data from the recently launched Taiwan/US COSMIC constellation and from the European MetOp satellite (UoG, U. Foelsche).

Development of a TID forecasting technique for GNSS applications based on a dense network of GNSS stations in Belgium. TID propagation parameters are studied using a cross correlation technique. Then, the idea is to use (to extrapolate) these propagation parameters to forecast the TID trajectory (Royal Meteorological Institute of Belgium, M. Bavier, R. Warnant).

The first study by a consortium led by Finnish Meteorological Institute (FMI) to investigate the mitigation of the ionospheric errors in mobile satellite applications has been completed at the end of 2006. We have developed software tools to generate off-line TEC maps from ground based GPS observations and compare the maps to Klobuchar, IRI and NeQuick models. Our results indicate that new techniques are needed in order to take full advantage of the near future GNSS including GPS and GALILEO. (FMI, J.-P. Luntama)

Study aiming at using the third frequency which will be available with Galileo and with modernized GPS for a better mitigation of ionospheric effects on precise positioning, in particular, for a more efficient ambiguity resolution. A method allowing solving ambiguities in real time using un-differenced data is being developed. When ambiguities have been solved, TEC can be reconstructed with a much better accuracy than with the classical dual frequency technique. The method has been successfully tested on Galileo simulated data.

3.2.3 Higher order ionospheric influences in dual frequency systems with emphasis on long-term applications.

Research work is being performed at DLR in order to estimate higher order refraction effects in GNSS systems which can easily be applied in operational measurements. Solutions were found to correct second order ionospheric effects for GNSS users in Germany and Europe without knowing the geomagnetic field structure and the exact shape of the electron density profile. (DLR, N. Jakowski)

3.2.4 Capabilities and remaining weakness of mitigation techniques for GNSS under quiet and perturbed ionospheric conditions

Assessment of the effect of TID's on high accuracy real time positioning techniques like the so-called Real Time Kinematic (RTK) technique: origin of TID's and of their impact in terms of local TEC variability; their effects in the different steps of the data processing algorithms, in particular on ambiguity resolution. It has been demonstrated that strong TIDs can affect ambiguity resolution even on distances as short as 4 km under quiet

background ionospheric conditions: due to these TID's, positioning errors up to 2 meters have been observed on RTK technique (Royal Meteorological Institute of Belgium, S. Lejeune, R. Warnant and the Geophysical Institute of the Bulgarian Academy of Science, I. Kutiev).
IESSG has been working with colleagues from UNESP (Sao Paulo State University, Brazil), namely JFG Monico and H Marques, on the use of receiver tracking models and scintillation indices to mitigate GPS positioning errors. This work is continuing, now also with the participation of Giorgiana deFranceschi and her team at INGV. (IESSG Nottingham, Marcio Aquino).

WP 3.3 Scintillation Monitoring and Modelling (WP Leaders Y Beniguel and V Romano)

GPS scintillation monitoring and analysis by INGV Rome and partners
Measurements were continued in the frame of the ISACCO (Ionospheric Scintillation Arctic Coordinated Campaign Observations) project
The participants continue to maintain the polar GISTM station located at Ny Alesund (79.9N, 11.9E, Svalbard, Norway) and at the Italian Antarctic Station "Mario Zucchelli" at Terra Nova Bay (74.7S, 164.1E). In November 2006 other two GISTM stations have been installed in Svalbard, one kindly hosted by the Statens Kartverk at Ny Alesund and the second one in Longyearbean (78.2N, 16.0E). All the data from the station are accessible in real time to the electronic Space Weather upper atmosphere web site (www.eswua.ingv.it). Furthermore, a model for simulating ionospheric scintillations is now under test applying spectral analysis to the Raw Data acquired by ISACCO GISTM located in Ny Alesund. A one year amount of data has been selected in order to obtain a significant outcome of the test. The test is performed sorting the data according to different helio-geophysical conditions in order to verify the modeled scintillation scenario.
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. Signatures of different responses of the perturbed ionosphere due to different external conditions are visible in the regions of enhanced TEC as revealed by the scintillation data.

The IESSG (Nottingham, UK) was awarded an International Joint Project grant by the Royal Society to foster collaborative research with INGV (Rome, Italy), under the title '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. The 2-year grant provides travel and subsistence funds to cover for exchange visits between the two groups.
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 first preliminary results seem to give interesting information on the typical time scales that characterise the irregularities causing 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 21.047° N, 105.799° 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 allow the scientific groups to concentrate their attention to the different physical mechanisms causing scintillations at equatorial and polar regions and make this collaboration a promising contribution to the general comprehension of these phenomena.

Scintillation monitoring at Nottingham University and at Royal Observatory of Belgium

The IESSG and the ROB/RMI have installed a GPS Ionospheric Scintillation and TEC monitor receiver at the RMI observatory in Dourbes, which has been continuously collecting 50Hz phase and amplitude scintillation data since March 2006. Current plans include comparing the results obtained by the scintillation receiver with the output of ROB/RMI's detection method applied to the Dourbes ROB receiver.

Scintillation monitoring and studies at DLR and IEEA

The monitoring of ionospheric scintillation activity in the vicinity of Bandung/Indonesia (6.9° N; 107.6°E) and Kiruna (67.8°N; 20.4°E) has been continued. A third station has been installed together with GMV at Puerto Cruz /Spain. This station is in the commissioning phase, preliminary results have been obtained.

The scintillation index S_4 and σ_φ were derived from 50/25 Hz GPS observations on a regular base.

The major focus of the work over the past month has been to increase the level of automation of the processing and analysis software.

Due to the low solar activity the number of scintillation events is not very big. Typical post-sunset effects have been observed in Bandung.

Related studies have shown that S4 is a function of elevation and azimuth. Therefore these parameters have to be considered simultaneously. Left panel shows an increase of S4 in the crest region.

The monitoring of ionospheric scintillation activity in N'Djamena has been continued. Correlatively additional features have been included in the GISM model in particular regarding the time series generation.

WG 3 PAPERS

WP1

Alfaro, P., Estevez, A., Blázquez, B. , Borque, M. J., Garrido, M. S., Gil, A. J., de Lacy, C., Ruiz, A., Jiménez, J., Molina, S., Rodríguez-Caderot, G., Ruiz Morales, M., Sanz de Galdeano, C., 2006, "Geodetic Control of the Present Tectonics Deformation of the Betic Cordillers (Spain)", International Association of Geodesy Symposia, 131, 209-216.

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Herraiz, M., E. Kazimirovski, 2006, "En torno a las influencias externas sobre el sistema ionosfera-atmósfera" in Física de la Tierra, 18, 97-118, Universidad Complutense de Madrid, ISSN 0214-4557.

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Rodríguez-Caderot, G., de Lacy, M. C, Gil, A. J., Blázquez, B., 2006, "Comparing Recent Geopotential Models in Andalusia (Southern Spain)", Studia Geophysica & Geodaetica, 50, 619-631.

WP2

Hoque M.M., and Jakowski N. (2006) Higher Order Effects in Precise GNSS Positioning, *Journal of Geodesy*, 10.1007/s00190-006-0106-0

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Warnant R., Kutiev I., Marinov P., Bavier M., Lejeune S. (2007) Ionospheric and geomagnetic conditions during periods of degraded GPS position accuracy : 2. RTK events during disturbed and quiet geomagnetic conditions. *Adv. Space Res.*, in press.

WP 3

Alfonsi, L., G. De Franceschi, V. Romano. ISACCO: an Italian project to monitor the high latitudes ionospheric scintillations. Presented during the 3rd European Space Weather Week, Bruxelles Nov. 2007.

Alfonsi L., De Franceschi G., Romano V., Aquino M., Dodson A., GPS positioning errors during the space weather event of October 2003, in press on Location, 2006

Béniguel Y. and J-P Adam, “Effects of scintillations in GNSS operation”, chapter 3.5 in Space Weather, research towards Applications in Europe, J. Lilenstein Editor.

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