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

Approved Minutes of the 5th Management Committee Meeting
3-7 October 2006
University of Rennes 1, France

1. **Welcome**

The participants were welcomed by Alain Bourdillon (COST 296 Chairperson) and local host who thanked everyone for coming.

2. **Approval of the Agenda**

The Draft Agenda for the meeting was approved without any amendments, see ANNEX I

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

The minutes of the fourth MC meeting held at Park Hotel, Neustrelitz, Germany 27-29 November 2006 was approved.

4. **Official status of the COST 296 Action**

AB reported that there were no changes in the official status of COST296 since the last MC meeting.

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

AB reported the status of the COST 296 Budget (ANNEX III)

6. **Short Term Scientific Missions (STSMs) on the previous budget (July 05-June 06)**

There were 3 STSM reported at this MC: D Kouba from UFA, Pargue, Czech Republic to NOA, Athens, Greece in March 2006; V Romano from INGV, Rome, Italy to University of Rennes, France in May 2006; A Krankowski from Krakow, Poland visiting UCP, Barcelona, Spain in July 2006.

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.

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)

During the discussion it has been proposed and accepted to change some names for WG and WP leaders. They are now:

- WG1 Dr J. Lastovicka and Dr I. Stanislawska
  - WP1.1 Dr. D. Altadill
  - WP1.2 Dr. D. Buresova and B. Nava
  - WP1.3 Dr. I. Kutiev and H. Strangeways
  - WP1.4 Dr. J. Bremer and E. Turunen
- WG2 Pr. E. Tulunay and Pr. P. Lassudrie-Duchesne
  - WP2.1 Dr. C. Bianchi and M. Warrington
  - WP2.2 Pr. J. M. Andujar and Y. Erhel
  - WP2.3 Pr. L. W. Barclay and Pr. A. M. Casimiro
- WG3 Dr. N. Jakowski, R. Leitinger and R. Warnant
  - WP3.1 Pr. S. Radicella and Dr. P. Sauli
  - WP3.2 Dr. U. Foelsche and Dr. R. Warnant
  - WP3.3 Dr. Y. Beniguel and Dr. V. Romano

9. Collaboration between COST296 and COST274 actions

(a) Report on SWW III – BZ gave a short report on what is happening during the next SWW being held in Brussels in November 2006.
(b) BZ reported that the he has a disk with the proofs of the SW School presentations to be published shortly.
(c) BZ reported that the ICTP Advanced School on Space Weather was very successful and as previously stated the presentations will be published soon.

10. Special issues of the international journals related to the COST271/296 actions activities

BZ asked that all presented papers be sent to him for preparation of a CD. AB to send to all details of formatting and deadlines.

11. COST296 activities related to the IHY

BZ presented the latest activities relating to COST 296 outlining a proposal from Dr Giorgiana De Franceschi who is the coordinator between IHY and COST296. This was given full approval by the MC.

12. Short Term Scientific Missions (STSMs) July 06-June 07

AB reported that there is enough funding for 9 STSMs during the F/Y 1 July 2006 to 30 June 2007. It was decided that the maximum reimbursement for each STSM would be 1000 Euro per mission. Three proposals were introduced from WG1 a) Czech Republic to Finland; b) Italy to Austria; c) Greece to Czech Republic and accepted. A further three proposal from WG2 a) University of Liecester, UK to University of Rennes, France; b) to GET-ENST, Brest, France; c) Middle East Technical University, Ankara, Turkey to University of Rennes, France. WG3 presented two proposals: a) NOA Athens to IAP Prague, Czech Republic and b) from DLR, Nuestrelitz, Germany to Leeds University, UK.

13. Preparation of the Annual Report

The suggestion of AB to have 2 versions of the Annual report (see § 7) was accepted by all participants present.

14. COST296 Budget

The budget for this financial year was accepted see Annex III Also approval was given to reimburse AC part of his expenses incurred attending a recent related COST MC.

15. Next meeting of the COST296 Action

BZ offered to host the next MC in15-17 March in Italy – more details to be circulated.

JL presented suggestions for the joint COST296 IRI workshop to be held in Prague 10-14 July 2007. JL stated that location of workshop would depend on how many people registered to attend. More details to be circulated.

16. TIST Annual Review – Helsinki

AB announced that the COST296 report had already been sent to the COST office in Brussels ready for the next annual review being held in Helsinki 21-22 November 2007.

17. International meetings relevant for the COST296 Action

There are several international meetings relating to COST296 activities:

IEE – EUCAP, Nice, France - 6-10 November 2006
EGU Vienna April 2007 COST296 poster session.
Series of Schools in L'Aquila Italy, March 2006- Fall 2008.
IAGA Perugia – Poster session in Cattacombs.

18. Status of UK ionosondes

AB has sent a letter to Pr. Keith Mason on the necessity to maintain UK ionosondes but he didn't get any answer. AB read a message form Richard Stamper (UK) explaining that the sounders will keep running until March 2007. Hopefully sufficient funds will be found to continue after that date.

19. Discussion on eventual participation in FP7

YT report on the FP7 procedure see ANNEX VII for full report.

20. Any other business

AB reported that Slovenia has signed the COST296 MoU and that Biagio Forte will be the National Representative. The MC accepted the participation of Solvenia.

ANNEX I

COST296
Mitigation of Ionospheric Effects on Radio Systems (MIERS)

Fifth Management Committee meeting of the COST 296 Action

Mitigation of Ionospheric Effects on Radio Systems (MIERS)

University of Rennes 1, France
3-7 October, 2006

MC meeting Agenda

1. Welcome
2. Approval of the Agenda
3. Adoption of the minutes of the fourth MC meeting
4. Official status of the COST296 Action
5. COST296 Budget from 1 July 2006 to 30 June 2007
6. Short Term Scientific Missions on the previous budget (STSM)
7. Discussion on the annual report
8. Receipt and adoption of the progress reports of Working Group Leaders
    - WG 1: Ionospheric monitoring and modelling
    - WG 2: Advanced terrestrial systems
    - WG 3: Space based systems
9. Collaboration between COST296 and COST724 actions (general discussion):
    - a - Report on European Space weather Week III (B. Zolesi)
    - b - Report on SW book (B. Zolesi)
    - c - Report on the ICTP Advanced School on Space Weather (B. Zolesi)
10. Special issues of the international journals related to the COST251/296 actions activities (B. Zolesi)
11. COST296 activities related to the IHY (G. De Franceschi)
12. Short Term Scientific Missions (STSM)
13. Preparation of the fourth COST296 Annual Report
14. COST 296 budget
15. Next meetings of the COST296 Action (B. Zolesi and J. Lastovicka)
16. Information on the TIST meeting
17. International meetings relevant for the COST296 Action
18. Status of UK ionosondes
19. Discussion on eventual participation in FP7
20. Any other business

Prof. Alain Bourdillon
Chairman COST296

ANNEX II

COST 296 Action MC meeting 3-7 October 2006
List of Attendees

Y Beniguel	(YB) IEEA, France **(NR)**
P Benzce	(PBE) Hungarian Academy of Sciences, Sopron, Hungary **(NR)**
E Blanch	(EB) Observatory de l'Ebre, Roquetes, Spain **(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)**
P A Bradley	(PB) Consultant, UK
Lj R Cander	(LC) Rutherford Appleton Laboratory, Chilton, Didcot, UK
A Casimiro	(AC) University of Algarve, Faro, Portugal **(NR)**
L Ecomomou	(LE) (Cyprus) **(NR)**
V Gherm	(VG) St Petersburg University, St Petersburg, Russia
H Haralambous	(HH) (Cyprus) **(NR)**
N Jakowski	(NJ) DLR/DFD, Neustrelitz, Germany **(Co-Leader WG-3, NR)**
A Krankowski	(AK) Institute of Geodesy, University of Warmia and Mazury in Olsztyn, Poland
L Kersley	(LK) University of Wales, Aberystwyth, UK
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)**
A Mikhailov	(AM) IZMIRAN, Moscow, Russia
B Nava	(BN) Abdus Salam ICTP, Trieste, Italy
L Perrone	(LP) INGV, Rome, Italy
V Romano	(VR) Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy **(NR)**
P Sauli	(PS) Academy of Sciences of Czech Republic, Prague, Czech Republic
H Strangeways	(HR) University of Leeds, Leeds, UK **(NR)**
M Tomasik	(MT) Space Research Centre, Warsaw, Poland
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)**
R Warnant	(RW) Royal Meteorological Institute of Belgium, Belgium **(NR)**
M Warrington	(MW) University of Leicester, Leicester, UK **(NR)**
N Zaalov	(NZA) University of Leicester, Leicester, UK
N Zernov	(NZ) University of Leeds, Leeds, UK
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

BUDGET FOR THE PERIOD JULY 1ST 2006 TO JUNE 30TH 2007

(1)	SECRETARIAT	**7,500€**
(2)	WORKSHOP and MC MEETINGS	**61,000€**
(3)	WORKSHOP ORGANISATION SUPPORT	**7,000€**
(4)	SHORT-TERM SCIENTIFIC MISSIONS	**9,000€**
TOTAL		**84,500€**

PUBLICATIONS SEPARATE BUDGET	**0**

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 MAY-SEPTEMBER 2006 - 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.

(a) Riometer installations in Canada to assist in evaluation of HF radio propagation by RWC (Regional Warning Centre) Canada, Ottawa. Two riometers were installed in late 2005 and 15 additional riometer systems were purchased for installation at geomagnetic observatories and other key locations in Canada, as indicated by the red diamond in the following figure. The black diamonds are the former CANOPUS riometers.
Further improvements made include a new data acquisition and internet capability. Now 1 s sampled data from the riometers as well as the collocated magnetometers will be able to be retrieved each minute. In 2006 due to being in solar minimum conditions, there have been almost no D-region absorption events due to auroral precipitation near Ottawa. However there have been a few events on the dayside related to solar activity. Firm plans are set to install IQA, RES, CBB, YKC, INUV in September 2006 quickly followed by installations at MEA, SANI, SASK, BRN, PRIN and DRAO in October. EUA and ALE will be installed in Jul 2007.

(b) The Ebro team, in collaboration with Czech team, validated the technique of Local Climatological Model for ionospheric bottomside parameters developed for Ebro station at other ionospheric stations. All stations show improvements by factor of two as compared with IRI2001 prediction.

(c) The Czech team improved the Standard DDA method of drift velocity evaluation by skymap-points selection: (i) height range selection, (ii) Doppler frequency shift value limitation, and (iii) choice of the maximum incidence angle. Raw drift data from Pruhonice observatory for period Jan-May 2006 were recalculated using this method. Preliminary results show behavior of F-region drift: velocity components diurnal variability during quiet geomagnetic conditions and seasonal trends of daily characteristics. Significant decrease in the daily-maximal horizontal component from winter to summer 2006 was found within the analyzed data.

(d) The Ebro team investigated the typical time/altitude variability of the ionospheric electron density at mid-latitude over Europe on monthly basis. This variability reflects the contribution from different sources at periods lower than 30 days. The largest variability occurs at the base of the F region during night-time, and it shows different long-term (solar cycle) and seasonal pattern depending on time in night-time sector. Particularly, the largest variability at the base of the F region occurs from sunset to midnight, when upward F region drifts dominate; it displays a clear summer half-year maximum pattern and it does not show solar cycle dependence. The lack of photochemical control during night-time indicates more important role of dynamics as variability contributor. The coupling from below by the wave activity in the mesosphere/lower thermosphere is discussed as potential driver of the observed time/altitude pattern of the ionospheric variability. Moreover, the challenges of modelling of the above described systematic pattern of variability have been discussed and proposed model of the expected deviations from typical electron density profiles.

(e) A cooperating team among the COST community evaluated the response of the ionosphere/thermosphere caused by solar radiation changes during solar eclipse of October 2005 over Europe. The ionospheric plasma redistribution processes significantly affect the shape of the electron density profile. These processes were discussed based on a comparison of vertical sounding and vertical total electron content (TEC) data above selected ionosonde stations in Europe. The equivalent slab thickness, derived with a time resolution of 10 minutes, provides relatively good information on the variation of the electron density profile shape during the eclipse. The computations reveal an increased width of the ionosphere before the maximum phase. Moreover, the photo production is significantly reduced during the event leading to a slower increase of the total ionization in comparison with the neighbouring days, as indicated by the available measurements over Spain. The supersonic motion of the Moon's cool shadow through the atmosphere may generate atmospheric gravity waves that propagate upward and are detectable as travelling ionospheric disturbances in ionospheric heights. High frequency (HF) Doppler shift spectrograms were recorded during the eclipse showing a distinct disturbance in the band of maximum eclipse. However, it is almost not distinguishable outside this band, which is a different result obtained from previous eclipses. Whereas ionosonde and HF Doppler measurements show enhanced wave activity, the TEC data analysis doesn't, indicating that the wave amplitudes are too small for detecting. The total ionization reduces up to about 30%. Comparisons with similar observations from the solar eclipse of 11 August 1999 revealed quite different horizontal distribution of the depletion which is assumed to be related to differences in the meridional thermospheric wind system.

(f) The UMLCAR team in cooperation with the Czech team has developed a tentative topside electron density model in terms of vary-Chap functions. The modeling is based on data from four satellites, Hinotori, ISS-B, ISIS-1, and ISIS-2. This new topside presentation avoids the "kinks" in the profiles resulting from applying the Booker formulism.

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

(g) Stations from COST ionosonde network continued to measure and send data to COST database in RAL, WDC-A in Boulder and other data bases and data exchange systems.

(h) The University of Massachusetts Lowell continued to archive in DIDBase all digisonde data available in real time via Internet, these includes the European COST network digisondes Tromsø. By cooperation between UMASS Lowell and INGV in Rome, the data gaps in the Rome data set have been filled.

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

(i) The Czech team analysed the consistency of two different methods of obtaining electron density profiles from inversion of ionograms. 10361 ionograms from two midlatiude ionospheric stations Ebro (40.8N, 0.5E) and Pruhonice (49.9N, 14.5E) were inverted into true height N(h) profiles using POLAN and NHPC methods. Curves of electron concentration are smoother with the NHPC inversion technique for both station data. POLAN systematically underestimates true height compared to NHPC at lower frequencies and overestimates at frequencies close to critical frequency foF2. However, the standard deviation reaches large values in the whole studied frequency range, especially at low frequencies. When two or three layers are present, true-height derived by NHPC is systematically lower than that computed by POLAN. Maximum differences are located around 5-6 MHz and exceed values of 10 km in case of three-layer profiles. Results for two stations are in agreement. During high geomagnetic activity the character of the result remains the same except for Pruhonice night-profiles, where the difference is positive and very close to zero. Standard deviation significantly increases in case of one-layer profiles. Maximum difference is larger in Pruhonice data. Larger differences at nighttime occur on the base of the F region, and at the transition regions between layers during daytime. This is probably caused by different connection techniques between layers on both algorithms POLAN and NHPC. Largest difference in one-layer profiles occurs slightly below 200 km. The difference has positive values, it means, at fixed height POLAN computes larger frequency than NHPC. In all other cases (presence of two or three layers), we see that maximum difference is systematically shifted about 30 km upward and reaches negative values. Under presence of more than one layer, POLAN computes lower frequency than NHPC at a given height. In general, mean standard deviation is larger in stormy data sets compared to quiet days except for two-layer profiles. During night-time, when only F-layer is present, mean standard deviation reaches maximum values up to 1 MHz (during storm-time exceeds 1 MHz). That means, we cannot simply conclude, that POLAN systematically computes higher frequency at given height. Location of the maximum difference is close to 200 km independently on the geomagnetic condition. Large differences in the profile bottom parts are caused by model application as described in the previous part.

(j) 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. Some other COST observatories also provide such data.

(k) 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)

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

(l) Several COST network observatories maintain internet accessibility to their revised VI data.

(m) 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.

(n) RAL has continued to maintain, support and improve the Space Weather Web Facilities for Radio Communications Users at http://ionosphere.rcru. rl.ac.uk/. This service is based on the contributions of a number of COST296 participating institutions indicated at the above web site. This is 24/7 on-line service that includes the following products:
(1) Interactive forecast maps of foF2, MUF(3000)F2 and ITU-R NeQuick modelled TEC values over Europe based on ionosonde measurements;
(2) Near real-time dynamic system for monitoring ionospheric propagation conditions over Europe;
(3) Near real-time TEC maps over Europe and 24 hours single station plots based on TEC evaluation from IGS GPS measurements;
(4) Near real-time solar-terrestrial and ionospheric indices and warning messages so that ionospheric and trans-ionospheric propagation conditions are known to world-wide users; and
(5) Archive of all data and images.

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.**

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 German Aerospace Center (DLR) continues to operate a system for regularly processing space based measurement data and for reconstructing the electron density distribution in the Earth's ionosphere/plasmasphere system utilizing the ionospheric radio occultation (IRO) technique. One of the current applications of this technique is the deduction and modelling of the ionospheric scale height. The ionospheric scale height deduced from CHAMP satellite data has been compared with the scale height obtained from topside sounders and digital ionosonde measurements. The results will help further developing the empirical models of the topside ionospheric scale height. Collaboration with ICTP Trieste and University of Graz.

(b) 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. The speed of EDAM's operation has been increased. This has been achieved by speeding up the generation of the background error covariance matrices and relies on assumptions about the ordering of voxels within the background model. The speed increase allows more voxels to be included in the assimilation of each measurement and consequently allows the data to have influence over a wider area. The scale lengths used in generating the co-variances have also been enhanced and now allow for a full 3D specification of scale length in latitude, longitude and altitude. Testing will now be undertaken to investigate the impact on performance that these changes have made. Tests have been conducted to investigate the forecasting performance of EDAM. These tests have compared measured vertical ionosonde foF2 data with foF2 estimates from EDAM. Two test periods have been considered: December 2003 (Figure 1) and March 2004 (Figure 2), which have used ~60 and ~300 input stations respectively. Forecasts have been run from zero to twelve hours for a range of scale times. Results support the view that EDAM forecasts are only likely to be effective up to a few hours in the future.

Fig. 1

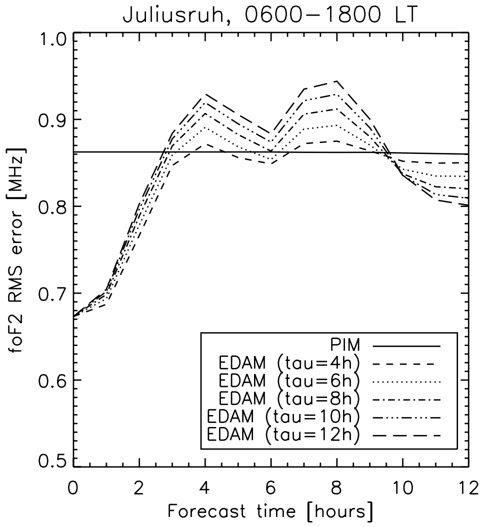
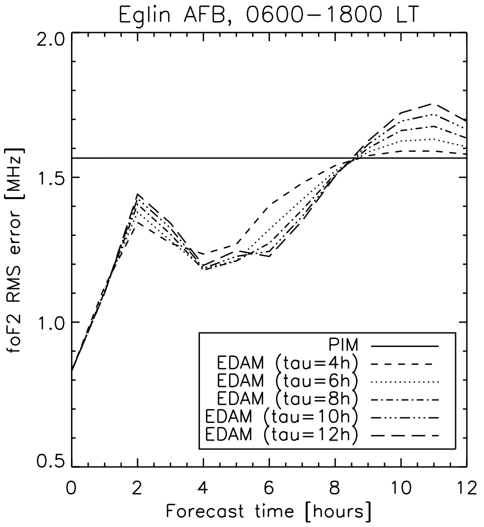

Juliusruh, 0600−1800 LT

Fig. 2


Eglin AFB, 0600−1800 LT

COSMIC radio occultation data is now available and the required assimilation code has been developed. Initial testing has shown the positive effect of including RO data within the assimilation. However, the satellite constellation has not yet been spread to its operational configuration, so the full impact of the system cannot yet be determined.

The comparative test with IonoNumerics has been rerun with identical input data sets. This removes some of the difficulty with interpreting the results. The analysis has also been expanded to include many more ionosondes (~40) and the results have been examined as a function of magnetic latitude and distance to the nearest input data point. The *foF2* RMS errors for all the test ionosondes are shown in Figure 4 as a function of magnetic latitude. The data has been split into two groups by local time (0600-1759 and 1800-0559) at each ionosonde site. As might be expected the errors are worst at low and high latitudes where ionospheric variability is likely to be greatest. Conversely, the data does not show a clear dependence on the distance of each ionosonde to the nearest IGS station. Nineteen of the ionosondes also reported values for *hmF2*. It should be noted that *hmF2* is not a quantity measured by the ionosondes, but rather it is derived from a true height inversion of the ionogram. Consequently, *hmF2* is sensitive to errors in the (often automatic) scaling of the ionograms and tends to be a rather noisy parameter. RMS results have been split into local day and night. The results have a limited distribution in magnetic latitude and it is not possible to discern any trends. The most prominent feature is the generally high RMS errors shown by IonoNumerics during the day. This can be attributed to a positive bias in the IonoNumerics *hmF2* that is present during the day, but not at night.

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

(c) After specific adaptations, the NeQuick model has been used to implement different near-real-time non-tomographic electron density retrieval techniques able to provide the electron density of the ionosphere above the geographic areas of interest. The technique relies on knowledge of the model driving parameter Az (ionization level) for the locations considered. The necessary Az values have been obtained through direct ingestion of GPS-derived slant TEC data in two different ways: using data from a single GPS receiver and using data from multiple ground stations. The statistical comparisons between experimental and reconstructed slant TEC values and between experimental and retrieved maximum electron concentration values clearly show the effectiveness of the model assisted electron density reconstruction techniques when they are used to describe the electron density of the ionosphere for actual conditions.

(d) The necessary Az values have been computed through NeQuick model adaptation to GPS-derived vertical TEC maps and the ingestion technique has been used to reconstruct median map of foF2 all over the Globe. The results of the comparisons between reconstructed median values of foF2 and median values obtained from ionosonde experimental data confirm the validity of the model assisted electron density reconstruction technique. Moreover the analysis of TEC, experimental and reconstructed foF2 data indicates a way to use the slab thickness concept to improve the analytical formulation of both the topside and bottomside of the NeQuick model.

(e) A new formulation of NeQuick topside profile has been developed on the basis of ISIS 2 topside sounder data. This formulation has been adopted by IRI for inclusion in IRI 2006 version, as one of the options for calculation of electron density profile and TEC.

(f) The topside profiles from IK 19, a satellite operating during high solar activity and providing a good coverage of low latitude region, have been used for model validation. In the analysis of low latitude NeQuick topside it has been found that during night time the new topside can reproduce the experimental profile, but during day time thicker electron density profiles are underestimated. This fact could be explained considering that ISIS2 satellite collected more data during medium and low solar activity than for high solar activity.

(g) Global validation of IRI TEC for high and medium solar activity conditions. A massive test has been performed: 30 IGS stations worldwide distributed have been selected and data for the years 2000 and 2004 have been analyzed to verify model performances during high and medium solar activity conditions. Slant TEC data for each station and each day of both years have been evaluated and compared with slant TEC values computed using the two options of the IRI model. The IRI validation demonstrates that using NeQuick topside the values of slant TEC computed by IRI are generally smaller and they avoid unrealistic increase of TEC at high latitudes during high solar activity. However at low latitudes, where IRI model generally underestimates TEC, the use of NeQuick model topside produce still lower values of TEC. Therefore it appears that deeper study to investigate also the link between bottomside and topside profile is needed.

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.**

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

5. Forecasting of foF2 and TEC and unifying geomagnetic drivers

(a) The group of Thessaloniki in collaboration with the INGV group and also with L. Cander and G. Ciraolo investigate the variability in TEC and in slab thickness, and their dependence on latitude, solar activity and season. Furthermore, an investigation of the within - the -hour variability in TEC has been completed and levels and probabilities are reported in a paper submitted to Annals Geophys. (Kouris et al.).

(b) The German Aerospace Center (DLR) established an operational space-plasma and space-weather monitoring service within the comprehensive project SWACI - Space Weather Applications Center Ionosphere (http://w3swaci.dlr.de/). Within this project, several nowcast and forecast products are being developed: Total Electron Content (TEC) maps, spatial and temporal TEC gradient maps, etc. A recent development, currently being tested, is the TEC short-term forecast based on the empirical model NTCM (Neustrelitz Total electron Content Model) providing the median / quiet-time forecast and another model providing the TEC storm-time deviation from the median. Work continues on improving the forecast by further analyzing the TEC storm-time behaviour with the help of recent SWACI data.

(c) The METU-NN-C technique based on the Hammerstein Model has been employed to forecast TEC grid values. The use of the Bezier surfaces in mapping the forecast grid values is also included. The results of the METU NN TEC model are compared with those of the METU-NN-C model. In particular, for this task we have chosen the space weather events in November 2003. The overall absolute TEC error map is plotted in Fig. 3. The occurrence of the neighbour grids increases the learning performance of the model for forecasting.

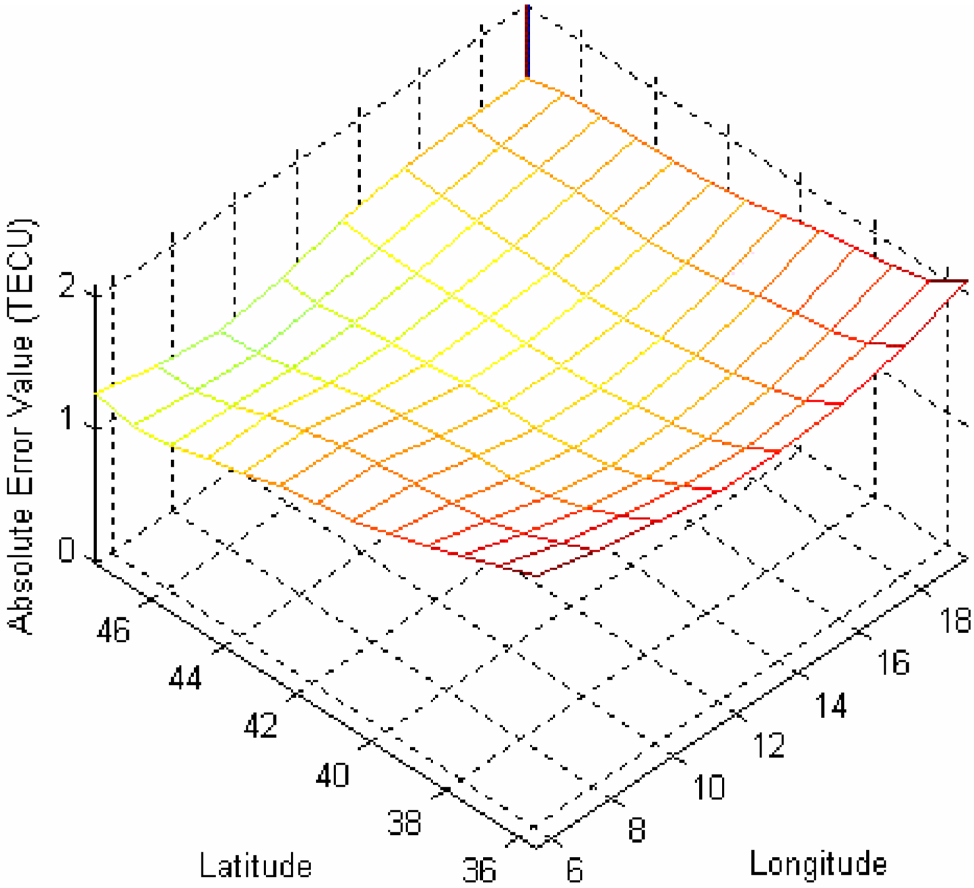


Fig. 3. Absolute error map for observed and 1 h. ahead forecast TEC during 16-29 Nov. 2003.

The model gave accurate forecast maps before, during and after the disturbed conditions. The average absolute error in "1 hour forecast" mapping of the TEC values is found to be 1.50 TEC units (TECU). When compared with the METU-NN Model this error value is about 10% smaller. In addition, there are some structural advantages in the design and operation of the METU NN-C.

(d) An analysis of the F2-layer short-term forecast problem has been done. Both objective and methodological problems prevent us from a deliberate F2-layer forecast issuing at present. An empirical approach based on statistical methods may be recommended for practical use. A forecast method based on a new aeronomic index (a proxy) AI has been proposed and tested over selected 64 severe storm events. The method provides acceptable prediction accuracy both for strongly disturbed and quiet conditions. The problem with the prediction of the F2-layer quiet-time disturbances as well as some other unsolved problems is discussed (Mikhailov). Among the problems with the foF2 short-term forecast quiet time F2-layer disturbances occurring under quiet geomagnetic conditions should be considered as a serious one. Presumably such disturbances are due to an impact from below but no precursor for their occurrence has been revealed yet. Any prediction method will be inefficient in such cases unless a precursor is found.

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)

(a) The global pattern of consistent long-term changes and trends in the atmosphere-ionosphere system has been established; it consists from trends in neutral mesospheric and mesopause region temperature, neutral thermospheric density, and ionospheric D, E and F1 regions. In other areas and parameters the situation with trends is not clear enough.

(b) Trends in F2 region remain controversial. Some recent results: The long-term behavior of the F2 plasma frequency observed by some ionospheric observatories at mid and high latitudes reveals a negative trend. The trend rate is variable and it is higher over Antarctica. By selecting data under quiet magnetic conditions, the trends in the Antarctica are still negative and comparable with those at middle latitudes supporting the geomagnetic influence on the F2 layer.
The ionospheric F2-layer parameter long-term trends are considered from the geomagnetic control concept and the greenhouse hypothesis points of view. It is stressed that long-term geomagnetic activity variations are crucial for ionosphere long-term trends as they determine the basic natural pattern of foF2 and hmF2 long-term variations. Just a thermosphere cooling which is accepted as an explanation for the neutral density decrease cannot be reconciled with negative foF2 trends revealed for the same period. Thermospheric cooling practically cannot be seen in foF2 trends due to a weak NmF2 dependence on neutral temperature; therefore foF2 trends are mainly controlled by geomagnetic activity long-term variations. Long-term hmF2 variations are also controlled by geomagnetic activity variations as both parameters NmF2 and hmF2 are related by the F2-layer formation mechanism. But hmF2 is very sensitive to neutral temperature changes, so strongly damped hmF2 long-term variations observed at Slough after 1972 may be considered as a direct manifestation of the thermosphere cooling.
Further methodical problems of trend estimation in the ionospheric F2 region and their validity have been discussed at a workshop in Sodankylä in early September 2006.

(c) Ionospheric trends in the E- and F1-regions have been derived from different, globally distributed ionosonde stations. The estimated mean global trends show some general behaviour (positive trends in foE and foF1, negative trend in h'E) which can at least qualitatively be explained by an increasing atmospheric greenhouse effect and decreasing ozone values. First indications could be found that the changing ozone trend (before about 1979, between 1979 until 1995, and after about 1995) can modify the estimated mean trend at least in foE.

(d) At Collm Observatory (51.3N, 13.0E) long-term measurements of lower E region drifts and LF reflection heights at oblique incidence are carried out using LF passive measurements and VHF meteor radar measurements. Analysis of winds, also together with other data from the Northern Hemisphere, indicates a change of sign of wind trends in the late 1980s-early 1990s, therefore the results on trends in winds remain inconclusive.

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

(e) Gravity wave analyses (0.7-3 h period interval) have been performed using LF winds from observations at the Collm Observatory. No long-term trend was detected, but a possible impact of the solar cycle was found, which is supported by model results. Long-period (3-20 days) oscillations have been measured simultaneously by meteor radar temperatures, and scale height estimates using the diurnal cycle of LF reflection heights, indicating that neutral atmosphere planetary waves influence the lower E region ionisation.

(f) Main focus of infrasound investigations was on two transient peculiar phenomena occurring in infrasound range – S-shapes and oblique linear traces called unidentified moving objects (UMOs). S-shapes occur predominantly near sunrise and sunset and may likely be excited by several different mechanisms. All most distinct UMOs have been observed during late evening or early night-time hours, none during high geomagnetic activity.
One of the most common and thus one of the most important sources of tropospheric infrasound are passages of cold fronts. In the ionosphere the Doppler shifts can be caused not only by the vertical motion of the reflecting height, but also by variations of the refractive index (electron density) below reflection point. Some results of the observations of infrasonic and gravity wave activity caused by strong thunderstorms connected with passage of distinct cold fronts was compared with wave activity caused by geomagnetic storms. The effects of the strong convective storms on the ionosphere appear to depend on storm intensity and on the state of ionosphere.

(g) Effects of the annular solar eclipse on the ionospheric plasma at F layer height are less pronounced compare to total eclipse effects, only signatures of bow shock wave are detected within plasma. Also spectral analysis shows lower energy in oscillations during annular eclipse event (2005) compare to total eclipse events (1999, 2006). Annular solar eclipse does not seem to generate acoustic waves. Within ionospheric plasma we have found only wave-like oscillations of the gravity domain that could be attributed to the propagating bow shock.

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)

(h) Linear regression analyzes show clearly the annual response of TEC to changes in solar activity and its dependence on latitude whereas the Slab Thickness is independent of solar activity and of latitude. That means that the dependence on solar activity and location of TEC and Nmax is very similar.

(i) Using riometer observations at the Italian Antarctic station (Mario Zucchelli station) as well as other magnetospheric and solar parameters two large PCA events in September 2005 have been analysed in detail.

(j) A special investigation was made on atmospheric implications of a proposed radiation belt remediation system, which should reduce the high-energy population of the radiation belt electrons, by controlled precipitation into the atmosphere. Excess high-energy electron populations would be expected for extreme solar activity events or man-made nuclear detonations in upper atmosphere. It turned out that when using such a system, radio blackout effects would be severe and long lasting, while neutral atmospheric effects would correspond to those expected for large solar proton events.

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

(k) Coupling of ionised and neutral atmosphere during high ionisation events was studied during selected solar proton events using the coupled ion-neutral chemistry model SIC (Sodankyla Ion Chemistry model). Model approach was validated and compared with experimental data from EISCAT incoherent scatter radar, VLF propagation experiments and satellite observations of the neutral minor constituents by the GOMOS instrument. Quantifications of production of odd nitrogen and odd hydrogen, as well as consequent reduction of ozone were presented.

5. Space weather impacts on the midlatitude ionosphere

(l) Investigations of the effects of strong geomagnetic storms induced by solar wind on ionosphere over Europe continued. Changes in the electron density distribution at the ionospheric F region heights above Europe during 65 strong-to-severe geomagnetic storms, which occurred over present solar cycle, have been analysed. As for the seasonal preference, during storm main phase only negative effects dominate in summer above higher-middle latitude stations (for the lower-middle latitude station El Arenosillo the probability of appearance of only negative phases and both negative and positive effects is approximately the same), while during winter events with both negative and positive phases are more probable, except the El Arenosillo station where the appearance of such events is more distinct also in summer. Enhancements of electron density have been observed for 15 storms out of 65 several hours before the onset of geomagnetic storm. They occur both day and night and are not caused (only occasionally strengthen) by solar flares. They tend to appear more often in summer half of the year. Also the existence of few-hours-long periods during storm main phase, when the deviation of the electron density from median was insignificant, has been observed.

Published Papers

Angling, M.J., B. Khattatov (2006), Comparative study of two assimilative models of the ionosphere, *Radio Science, 41*, RS5S20, doi: 10.1029/2005RS003372.
Belehaki, A., P. Marinov, I. Kutiev, N. Jakowski, S. M. Stankov (2006): Comparison of the topside ionosphere scale height determined by topside sounders model and bottomside digisonde profiles. Adv. Space Res., 37 (5), 963-966.
Bianchi, C., D. Altadill (2005); Ionospheric Doppler measurements by means of HF-Radars techniques; Annals Geophys., 48 (6), 989-993 (delayed publication).
Clilverd, M. A., A. Seppälä, C. J. Rodger, N. R. Thomson, P. T. Verronen, E. Turunen, Th.Ulich , J. Lichtenberger, P. Steinbach: Modelling polar ionospheric effects during the October-November 2003 solar proton events, Radio Sci., 41 , RS2001, doi:10.1029/2005RS003290, 2006a.
Clilverd, M. A., C. J. Rodger, Th.Ulich: The importance of atmospheric precipitation in storm-time relativistic electron flux drop outs, Geophys. Res. Lett., 33, L01102, doi:10.1029/2005GL024661, 2006b.
Fotiadis; D.N., S.S. Kouris: A functional dependence of f_oF2 variability on latitude, Adv. Space Res., 37, 1023-1028, 2006.
Jacobi, Ch., D. Kürschner: Long-term trends of MLT region winds over Central Europe. Phys. Chem. Earth 31, 16-21, 2006.
Kouris, S.S., K. Polimeris, Lj. Cander: Specifications of TEC variability, Adv. Space Res., 37, 983 – 1004, 2006.
Krankowski A., Shagimuratov I.I., Baran L.W., Yakimova G.A. (2004), Storm-time changes of ionospheric TEC during the November 5, 2001 disturbances, Bulg. Geophys. J., 30, 10-22.
Krasnov, V.M., Ya.V. Drobzheva, J. Laštovička: Recent advances and difficulties of infrasonic wave investigation in the ionosphere. Surv. Geophys., 27, 169-209, 2006.
Nava, B., S. M. Radicella, R. Leitinger, P. Coisson (2006), A near-real-time model-assisted ionosphere electron density retrieval method, Radio Sci., 41, RS6S16, doi:10.1029/2005RS003386.
Pryse, S.E., L Kersley, D Malan, G J Bishop (2006), Parameterization of the main ionospheric trough in the European sector, Radio Sci., 41, RS5S14, doi:10.1029/2005RS003364.
Rodger, C.J., M.A. Clilverd, Th.Ulich , P.T. Verronen, E. Turunen, N.R. Thomson: The atmospheric implications of radiation belt remediation, Ann. Geophys., 24 , 2025-2041, 2006a.

Rodger, C.J., M.A. Clilverd, P.T. Verronen, Th.Ulich , M.J. Jarvis, and E. Turunen, Dynamic geomagnetic rigidity cutoff variations during a solar proton event ,J. Geophys.Res., 111 , A04222, doi:10.1029/2005JA011395, 2006b.

Šauli, P., P. Abry, D. Altadill, J. Boška (2006); Detection of the wave-like structures in the F-region electron density: Two station measurements; Studia Geoph. Geod., 50 (1), 131-146. doi: 10.1007/s11200-006-0007-y.

Senalp E.T., Tulunay E., Tulunay Y., Neural Networks and Cascade Modeling Technique in System Identification, Artificial Intelligence and Neural Networks, 14th Turkish Symposium, TAINN 2005, Izmir, Turkey, June 16-17, 2005, Revised Selected Papers, Series: Lecture Notes in Computer Science, Subseries: Lecture Notes in Artificial Intelligence , Vol. 3949 / 2006, pp.84-91, Savaci, F. Acar (Ed.), Publisher: Springer Berlin / Heidelberg, 2006.

Seppala, A. , P.T. Verronen, V.F. Sofieva, J. Tamminen, E. Kyrola, C. J. Rodger, and M.A. Clilverd: Destruction of the Tertiary Ozone Maximum During a Solar Proton Event, Geoph. Res. Lett., 33, L07804, 2006.

Tulunay E., Senalp E.T., Radicella S.M., Tulunay Y. (2006), Forecasting TEC Maps by Neural Network technique, Radio Science, 41 (4), RS4016.

Verronen, P. T., Th.Ulich , E. Turunen, and C. J. Rodger: Sunset transition of negative charge in the D-region ionosphere during high-ionization conditions, Ann. Geophys., 24, 187-202, 2006.

Accepted/in-press Papers

D. Buresova, J. Lastoviska, G. de Franceschi: Manifestation of strong geomagnetic storms in the ionosphere above Europe, The 2nd ESWW Book, ESA, Nordwijk, November, 2006.

Fotiadis, D.N., S.S. Kouris: Capturing the morphology of long-duration negative ionospheric disturbances using an empirical pattern recognition method, Radio Science, 2005RS003395.

Jacobi, Ch., D. Kürschner: Long-period upper mesosphere temperature and plasma scale height variations derived from VHF meteor radar and LF absolute reflection height measurements. Adv. Radio Sci.

Jacobi, Ch., N.M. Gavrilov, D. Kürschner, K. Fröhlich: Gravity wave climatology and trends in the mesosphere/lower thermosphere region deduced from low-frequency drift measurements 1984-2003 (52.1°N, 13.2°E). J. Atmos. Solar-Terr. Phys.

Krankowski A., Kosek W., Hobiger Th., Schuh H., Popinski W., Wavelet analysis in TEC measurements obtained using dual-frequency space and satellite techniques, Proceedings of the Journées 2005 - Systèmes de Référence Spatio-Temporels “Earth dynamics and reference systems: five years after the adoption of the IAU 2000 Resolutions”.

Krankowski A., Shagimuratov I.I., Mapping of foF2 over Europe based on GPS-derived TEC data, Adv. Space Res.

Krankowski A., Shagimuratov I.I., L.W. Baran, I.I. Epishov, N.J. Tepenitzyna, The Occurrence of Polar Cap Patches in TEC Fluctuation Using GPS Measurements, Adv. Space Res., doi: 10.1016/j.asr.2005.12.006.

Laštovička, J., P. Šauli, P. Križan: Persistence of the planetary wave type oscillations in the midlatitude ionosphere. Annals Geophys.

Laštovička, J., A. V. Mikhailov, Th. Ulich , J. Bremer, A. G. Elias, N. Ortiz de Adler, V. Jara, R. Abarca del Rio, A. J. Foppiano, E. Ovalle, A.D. Danilov: Long-term trends in foF2: A comparison of various methods ,J. Atmos. Sol.-Terr. Phys.

Mikhailov, A.V., Ionospheric long-term trends: Can the geomagnetic control and the greenhouse hypotheses be reconciled?, Annals Geophys.

Perrone, L., M. Pietrella, B. Zolesi , "A Prediction of fof2 during periods of severe geomagnetic activity in Rome observatory" Adv. Space Res.

Portnyagin, Yu.I., E.G. Merzlyakov, T.V. Solovjova, Ch. Jacobi, D. Kürschner, A. Manson, C. Meek: Long-term trends and year-to-year variability of mid-latitude mesosphere/lower thermosphere winds. J. Atmos. Solar-Terr. Phys.
Pryse, S.E., A.G. Wood, H.R. Middleton, I.W. McCrea M. Lester,
Reconfiguration of polar-cap plasma in the magnetic midnight sector, Ann. Geophysicae.
Zakharenkova I.E., Krankowski A., Shagimuratov I.I., Modification of the low-latitude ionosphere before the 26 December 2004 Indonesian earthquake, Nat. Hazards Earth Syst. Sci., 6.

Submitted Papers

Chum, J., J. Laštovička, T. Šindelářová, D. Burešová, and F. Hruška: Peculiar transient phenomena observed in the infrasound range. J. Atmos. Solar-Terr. Phys.
Coisson, P., S.M. Radicella, B. Nava, R. Leitinger, Low Latitudes topside in NeQuick, J. Atmos. Solar-Terr. Phys.
Jakowski, N., S. M. Stankov, V. Wilken, C. Borries, D. Altadill, J. Chum, D. Buresova, J. Boska, P. Sauli, H. Hruska, and L. Cander; Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005; J. Atmos. Solar-Terr. Phys.
Krankowski A., Shagimuratov I.I., Baran L.W., Yakimova G., The structure of the mid- and high-latitude ionosphere during the November 2004 storm event obtained from GPS observations, J. Atmos. Solar-Terr. Phys.
Nava, B., S.M. Radicella, R. Leitinger, P. Coisson, A possible way to update ITU-R maps of foF2, J. Atmos. Solar-Terr. Phys.
Šauli, P., Z. Nechutný, J. Boška, D. Kouba, J. Laštovička, D. Altadill: Comparison of true-height electron density profiles derived by POLAN and NHPC methods; Studia Geophysica & Geodetica.
Triskova L., I. Galkin, V. Truhlik, and B. W. Reinisch, Application of Seamless Vertical Profiles for Use in the Topside Electron Density Modelling, Adv. Space Res., 2006

Solicited papers presented at meetings

Altadill, D.; Solar activity variations of ionosonde measurements, experimental and modeling results; Solicited; 36 COSPAR Scientific Assembly, Session C4.2, Paper-ID: C4.2-0006-06; Beijing, China; 16-23 July 2006.
Bremer, J.: Long-term trends in the ionospheric E and F1 regions, 4th Workshop on Long-Term Changes and Trends in the Atmosphere, Sodankylä, September 2006.
Bremer, J.: Long-term trends in the ionospheric E and F1 regions, 4th Workshop on Long-Term Changes and Trends in the Atmosphere, Sodankylä, September 2006.
Laštovička, J., R.A. Akmaev, G. Beig, J. Bremer, J.T. Emmert, C. Jacobi, M. J. Jarvis, G. Nedoluha, Y. I. Portnyagin, Th. Ulich: Emerging pattern of global change in the upper atmosphere, 4th IAGA/ICMA/CAWSES Workshop "Long-Term Changes and Trends in the Atmosphere", Sodankylä, September 2006.
Laštovička, J., D. Burešová, V.M. Krasnov, Ya.V. Drobzheva, J. Chum, F. Hruška, T. Šindelářová: Recent progress in investigation of effects of infrasound on the ionosphere and upper atmosphere, 3rd IAGA/ICMA Workshop "Vertical coupling in the ionosphere/atmosphere system", Varna, September 2006.
Laštovička, J., A. V. Mikhailov, Th. Ulich, J. Bremer, A. D. Danilov, A. G. Elias, N. Ortiz de Adler, R. Abarca del Rio, A. J. Foppiano, E. Ovalle: Long-term trends in foF2: result of a comparison of various methods, 4th IAGA/ICMA/CAWSES Workshop "Long-Term Changes and Trends in the Atmosphere", Sodankylä, September 2006.

Laštovička, J., T. Šindelářová, D. Burešová, J. Chum, Ya.V. Drobzheva, V.M. Krasnov: Impact of (almost forgotten) infrasound on the upper atmosphere and ionosphere, 36th COSPAR, Beijing, July 2006.
Mikhailov, A.V., Ionospheric long-term trends: If the geomagnetic control concept and the greenhouse hypothesis can be reconciled, 4th IAGA/ICMA/CAWSES Workshop on Long-Term Trends, Sodankylä, September 2006b.
Ulich, Th., M. A. Clilverd, M. J. Jarvis, H. Rishbeth: Chasing trends in noisy ionospheric data: the Sodankylä Ionosonde, 4th IAGA/ICMA/CAWSES Workshop on Long-Term Trends, Sodankylä, September 2006.

Other papers presented at meetings

Alfonsi, L., A. De Santis, G. De Franceschi: Geomagnetic and ionospheric data analysis over Antarctica: a contribution to the long term trends investigation, 4th IAGA/ICMA/CAWSES Workshop on Long-Term Changes and Trends in the Atmosphere, Sodankylä, September 2006.
Boška, J., D. Kouba, P. Šauli: Ionospheric E and F region drifts during high and low geomagnetic activity, 3rd IAGA/ICMA Workshop "Vertical coupling in the ionosphere/atmosphere system", Varna, September 2006.
Burešová, D., J. Laštovička: Pre-storm enhancements of foF2 above Europe, 36th COSPAR, Beijing, July 2006a.
Burešová, D., J. Laštovička: Enhancements of foF2 above Europe before strong geomagnetic storms, 3rd AOGS, Singapore, July 2006b.
Coisson, P., S.M. Radicella, L. Ciraolo, R. Leitinger and B. Nava, Global validation of IRI TEC for high and medium solar activity conditions, 36th COSPAR, Beijing, July 2006.
Kouba, D., P. Šauli, J. Boška, J. Santolík; Ionospheric F-region Drift Measurements, First Results for Winter 2006; WDS06 – Physics of Plasmas and Ionized Media, Prague, 2006. Accepted for publication in Proceedings.
Kouba, D., P. Šauli, J. Boška, and O. Santolík: Ionospheric F-region drift measurements at observatory Pruhonice: Seasonal quiet day patterns, 3rd IAGA/ICMA Workshop "Vertical coupling in the ionosphere/atmosphere system", Varna, September 2006.
Krankowski A., Shagimuratov I.I., Baran L.W., Yakimova G.A., The occurrence of total solar eclipse on October 3, 2005 in TEC over Europe, 36th COSPAR, Beijing, July 2006.
Laštovička, J.: Global change in the upper atmosphere, Western Pacific Geophysics Meeting, Beijing, July 2006.
Pryse, S.E., H.R. Middleton, K L Dewis, A.G. Wood, E.L. Whittick, R.L. Balthazor, Large-scale plasma structure in the polar and auroral ionosphere: experimental observations and modelling, NATO/URSI Specialists' Meeting/Symposium on "Characterising the Ionosphere", University of Alaska, Fairbanks, pp10, June 2006.
Rothkaehl H., Krankowski A., Stanislawska I., Blecki J., Parrot M., Berthelier J-J., Lebreton J-P., Signature of main ionospheric trough diagnosed by in situ waves measurements and GPS diagnostic during strong geomagnetic disturbances, 36th COSPAR, Beijing, July 2006.
Senalp E.T., Tulunay E., Tulunay Y., System Identification by Cascade Modeling Technique with Bezier Curve Nonlinearity Representations,15th Turkish Symposium on Artificial Intelligence and Neural Networks, TAINN 2006, pp.75-82, June 2006, Akyaka, Mugla, Turkey.
Šauli, P., P. Abry, S. Roux, J. Boška, D. Kouba, Z. Nechutný: Effects of solar eclipse events in the ionospheric plasma – acoustic-gravity waves generation and detection, 3rd IAGA/ICMA Workshop "Vertical coupling in the ionosphere/atmosphere system", Varna, September 2006.
Šindelářová, T., D. Burešová, J. Chum, F. Hruška: Doppler observations of infrasonic and gravity waves of different origin at ionospheric heights, 3rd IAGA/ICMA Workshop "Vertical coupling in the ionosphere/atmosphere system", Varna, September 2006.

Turunen, E., Th. Ulich, C-F. Enell, A. Kero, S. Hyvarinen, P. Verronen, A. Seppala, C. Rodger, M. Clilverd, R. Steiner: Chemical Effect of Excess Ionisation Events in Mesosphere, ASIM meeting, ESTEC, June 2006.

Other contributions

Blanch E. and others; Space Weather Observation, Research and Distribution 2006, Student team project final report, Master Program 2006, International Space University,
Strasbourg.

ANNEX V

Progress report presented at the 5th MCM Rennes October 2006

Working Group 2 – Advanced terrestrial systems

Leaders: Alain Bourdillon, Ersin Tulunay

WP2.1 Radar and radiolocation (Leaders: Dr C. Bianchi and Dr E.M. Warrington)

Activities **(Ref: COST 296, Progress Report, Period: from February 2005 to May 2006,** Annex 3 to Doc.WGCEM/1/00):

WP2.1.1.Ionospheric effects on surface-wave radar

WP2.1.2.Frequency management of ground-wave and sky-wave radars

WP2.1.3.Angle of arrival measurements for sky-wave signals

1. List of Participants

Contributing to this report are:

E. Benito, A. Bourdillon, O. Buyukpabuscu, S. Saillant, A.J. Stocker, E. Tulunay, Y. Tulunay, E.M. Warrington, N.Y. Zaalov

2. WP Activity Number 2.1.x

3. Main Results

INVERSION OF HF RADAR BACKSCATTER IONOGRAMS

The purpose of the inversion technique is to recover the initial ionospheric parameters (f_c, h_m, y_m) from three points of the backscatter ionogram.
The inversion technique is being tested on real data. Some elevation-scan backscatter soundings were realized with the HF radar NOSTRADAMUS (Figure 1). After filtering data, we obtain n points in the elevation-group path plane (Figure 2).

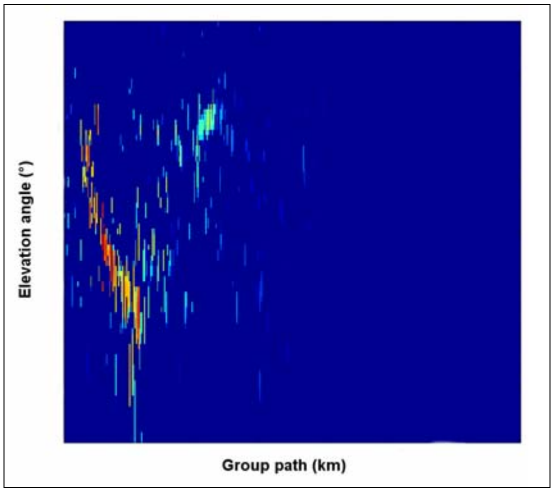


Figure 1: Elevation-scan backscatter ionogram on 15 April 2006 at 1655 UT

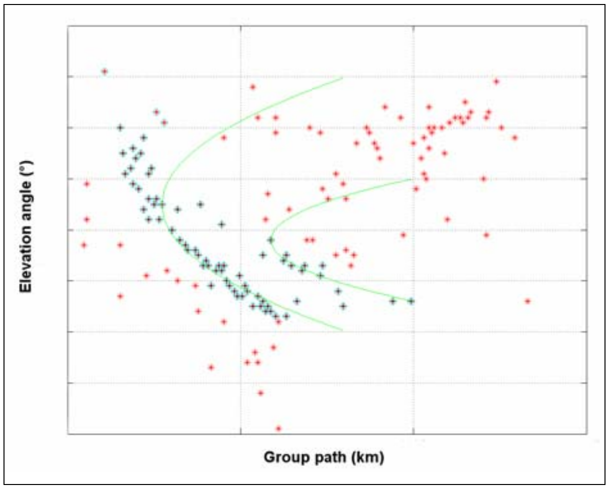


Figure 2: Backscatter ionogram after filtering data

The data contain the outliers which are difficult to eliminate. Accordingly we can't select only three points in the elevation-group path plane. So we will use all the points obtained after filtering data.

But a single outlier in a data set can lead to unacceptable inverse results if the errors are supposed to be Gaussian. In fact, the errors supposed to be Gaussian lead to an *a posteriori* probability density equal to zero.

The solution is to use long-tailed density function to represent uncertainties (Figure 3). We will use the Cauchy function, which has the nice particularity of having infinite standard deviation.

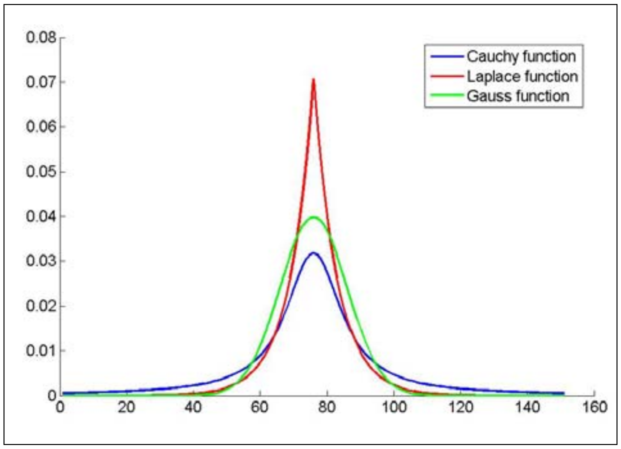


Figure 3: Cauchy, Laplace and Gauss probability density functions

So the inversion technique was modified, as follows:

1) The first step is to record the coordinates of *n* points in the elevation-group path plane (T_{exp1}, …, T_{expn}) at *n* fixed elevation angles (E_{ref1}, …, E_{refn}). The number of points, *n*, is variable.

2) The second step is to make a model of the ionosphere (MQP) by using:

   - The ionospheric forecasts to obtain the parameters (f_c, h_m, y_m) of the lowest layers.
   - A space of parameters for the upper layers (F layer).

   And to simulate the elevation-group path curve using this model, in order to obtain the

coordinates of the *n* group paths (T_{ref1}, …, T_{ref3}) corresponding to the *n* fixed elevation angles.

3) **The third step is to compute the *a posteriori* probability density σ_p over a grid of points sampling the parameter space (f_c, h_m, y_m), for *n* given pairs of experimental values, using:**

$$\sigma_p(f_c,h_m,y_m)=\left[\frac{1}{\pi\delta T_{\exp 1}}\frac{1}{1+\left(\frac{T_{ref1}(f_c,h_m,y_m)-T_{\exp 1}}{\delta T_{\exp 1}}\right)^2}\right]\cdot\ldots\cdot\left[\frac{1}{\pi\delta T_{\exp n}}\frac{1}{1+\left(\frac{T_{refn}(f_c,h_m,y_m)-T_{\exp n}}{\delta T_{\exp n}}\right)^2}\right]$$

where δT_{exp1}, …, et δT_{expn} represent the variances of the measurement errors over T_{exp1}, …, T_{expn}. These errors are presumed to be Cauchy distribution and independent with each other.

The variances of the measurement errors, δT_{exp1}, …, δT_{expn}, are obtained from the signal to noise ratio as follows:

$$\delta T_{\exp i}=\frac{\Delta D}{\sqrt{S/N}}$$

where ΔD is the distance resolution and *S/N* is the signal to noise ratio.

4) **The last step is to identify the maximum value of σ_p and record (f_c, h_m, y_m) as the solution of the inverse problem.**

First results on real data:

An elevation-scan backscatter sounding was realised on 04 July 2006 at 0700 UT. After filtering data, we obtain *n* points in the elevation-group path plane (Figure 4).

The ionospheric forecast program COST 251 is also used to get the forecast of the same day. The points obtained by the sounding don't match very well with these forecasts.

Finally, the Arenosillo and Ebre ionosondes are used to validate the results of the inversion technique (Figure 4 and Figure 5). But these ionosondes are far (+300km) from the point of the ionosphere sounded by the radar. The Ebre ionosonde have one E sporadic layer and the Arenosillo ionosonde is closest to the points obtained by the sounding.

The backscatter ionogram obtained by the inversion technique go through the data but the ionospheric profile is higher in frequency than the forecasts and the ionosondes profiles. The reason is the absence of data after the focalisation point.

These first results aren't ideal because the propagation conditions weren't perfect. We expect to get some data without E sporadic layer and closer to one ionosonde for validation.

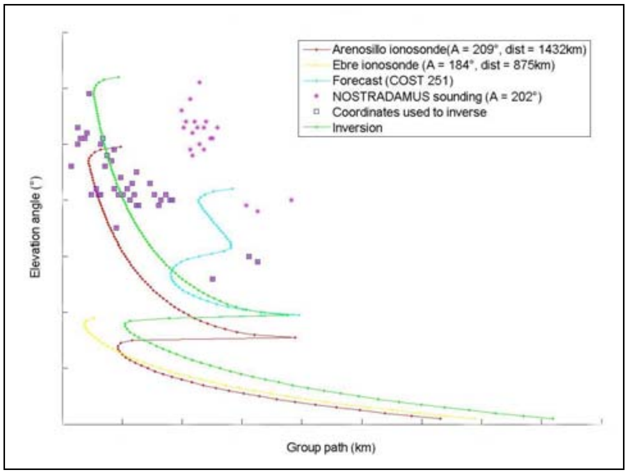


Figure 4: Backscatter ionogram on 4 July 2006 at 0700 UT

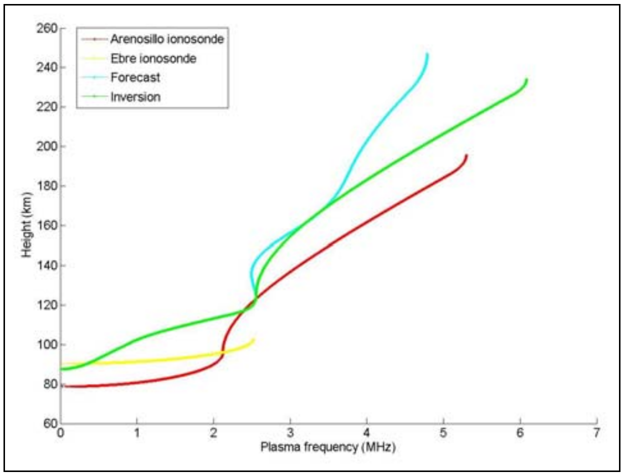


Figure 5: Electron density profile on 4 July 2006 at 0700 UT

THE INFLUENCE OF THE PARTICLES PRECIPITATION LEVELS AND GEOMAGNETIC ACTIVITY ON THE CHANNEL SCATTERING FUNCTIONS OF HF SIGNALS PROPAGATING AT NORTHERLY LATITUDES

The morphology of the auroral and sub-auroral ionosphere is strongly dependent on the interplanetary magnetic field and the level of particle precipitation. For example, as the geomagnetic activity increases the size of the polar cap tends to increase and the auroral oval moves equatorwards. This change in the morphology of the ionosphere can impact on the characteristics of signals received after propagation through these ionospheric regions. An understanding of the correlation of the HF channel scattering function with geomagnetic activity and particle precipitation is a necessary component in the development of the prediction techniques required for new systems. A number of experiments have recently been undertaken by the University of Leicester in order to develop a better understanding of these effects. In these experiments, the time of flight, Doppler frequency, and azimuth and elevation angles of arrival have been measured over several northerly paths. Measurements from Kirkenes, Norway to Kiruna, Sweden and from Uppsala, Sweden to Leicester, U.K. are reported in this paper (see Figure 1).

The signals were received with a large sampled aperture antenna array, each element of which was connected to a separate receiver and sampled simultaneously. A superresolution direction finding algorithm was then applied to each signal component in order to estimate the directional characteristics of the received signal. Projection of the multi-dimensional scattering function onto four planes produced four scattering functions: Doppler-delay, azimuth-delay, elevation-delay and azimuth-frequency.

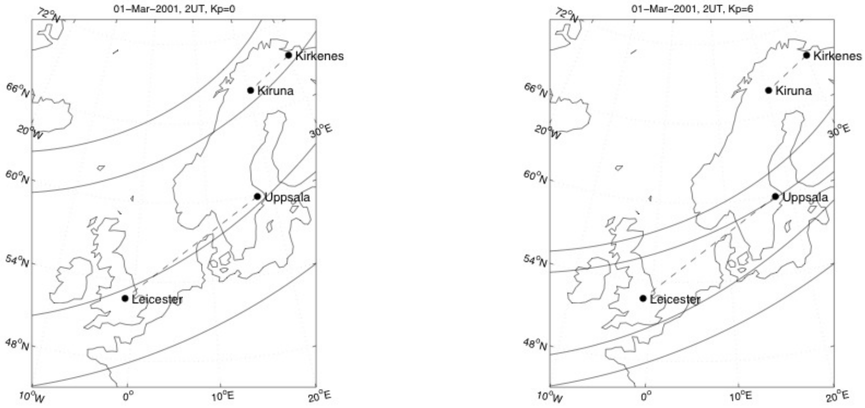


Figure 1. Maps showing various propagation paths subject to investigation and a typical position for the trough, as estimated by the model of Halcrow and Nisbet [1977].

An example of the scattering function parameters measured over the Uppsala - Leicester path during two winter months is shown in Figure 2. Distributions of azimuth and elevation angles of arrival and propagation delay of each mode have been plotted as function of time of day (left column). Several interesting features are apparent: off great circle propagation is observed predominantly at night with azimuthal deviations of about 40° to the north, (top left frame) and maximum propagation delay of around of 10 ms (middle left frame), i.e. twice the great circle delay of about of 5ms; the statistics of the scattering function parameters are different during the dawn and dusk periods, especially in elevation angle (bottom left frame). More intriguing features are found in correlations of the scattering function parameters with the Kp index, shown in right column.

The azimuthal deviations (middle right frame) exhibit a pronounced correlation with geomagnetic activity (Kp). Three different regions corresponding to Kp values 0.2-1.0, 1.2-2.8 and 2.8-5.0 are evident: maximum azimuth deviations (middle right frame) and delays (top right frame) are observed when Kp is about 0.3. The trends in azimuthal deviation are also slightly different for different Kp values. Elevation angle of arrival (bottom right frame) did not exhibit a correlation with Kp. This behaviour is related to changes with Kp in the position of the auroral oval and mid latitude trough relative to the propagation path.

The scattering function statistics are very different over the Kirkenes – Kiruna path. In this case, the delay, azimuth and elevation angle deviations do not exhibit a pronounced correlation with Kp. This effect can be related to the geometry of the propagation path in relation to the auroral oval, which covers the path beginning from Kp values of about 1 (see Figure 1). The main propagation mechanism is forward (side) scattering from auroral irregularities. The oval is centred on the geomagnetic pole and consequently Kp is not the best parameter to describe the scattering function statistics.

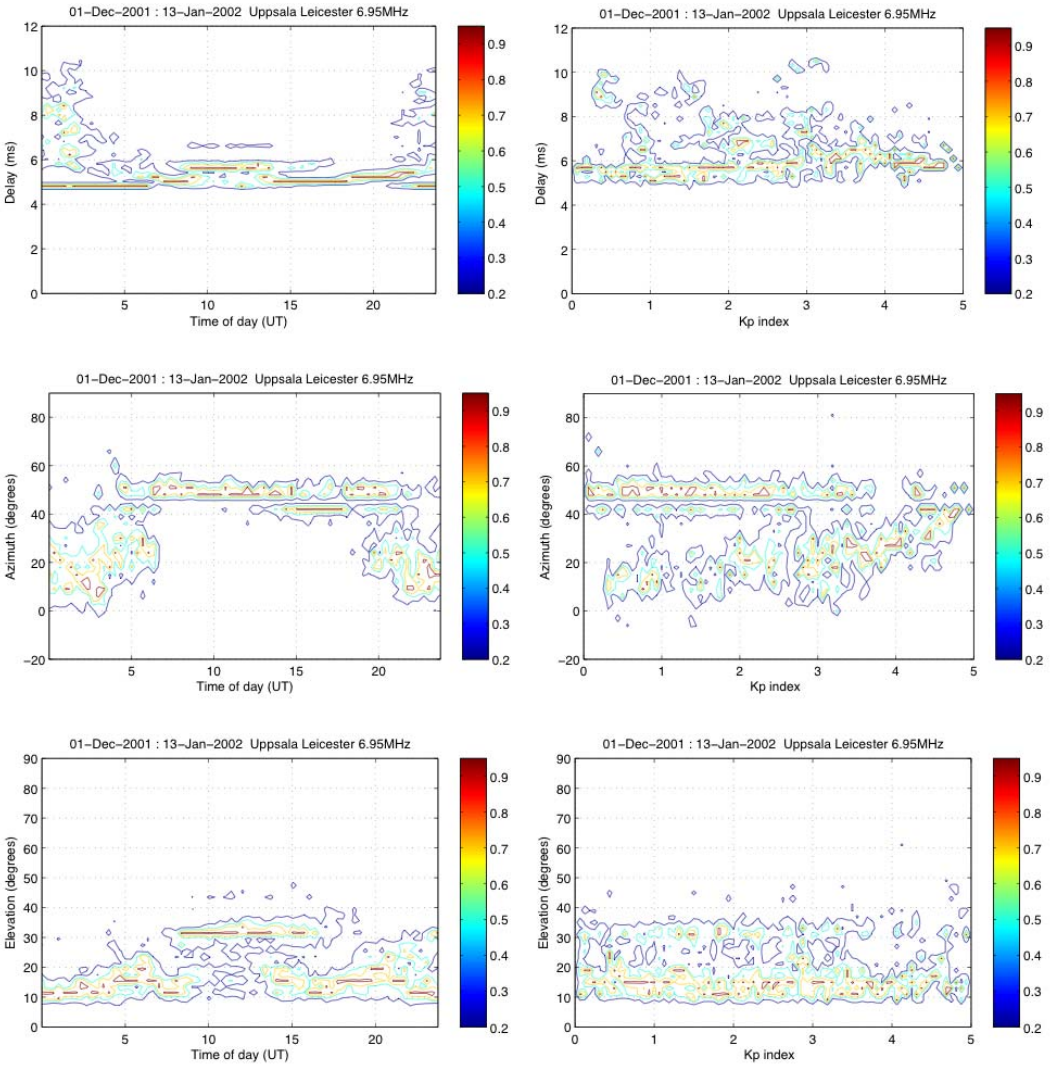


Figure 2 Observations made over Uppsala – Leicester path at 6.95MHz between 1 December 2001 and 13 January 2002.

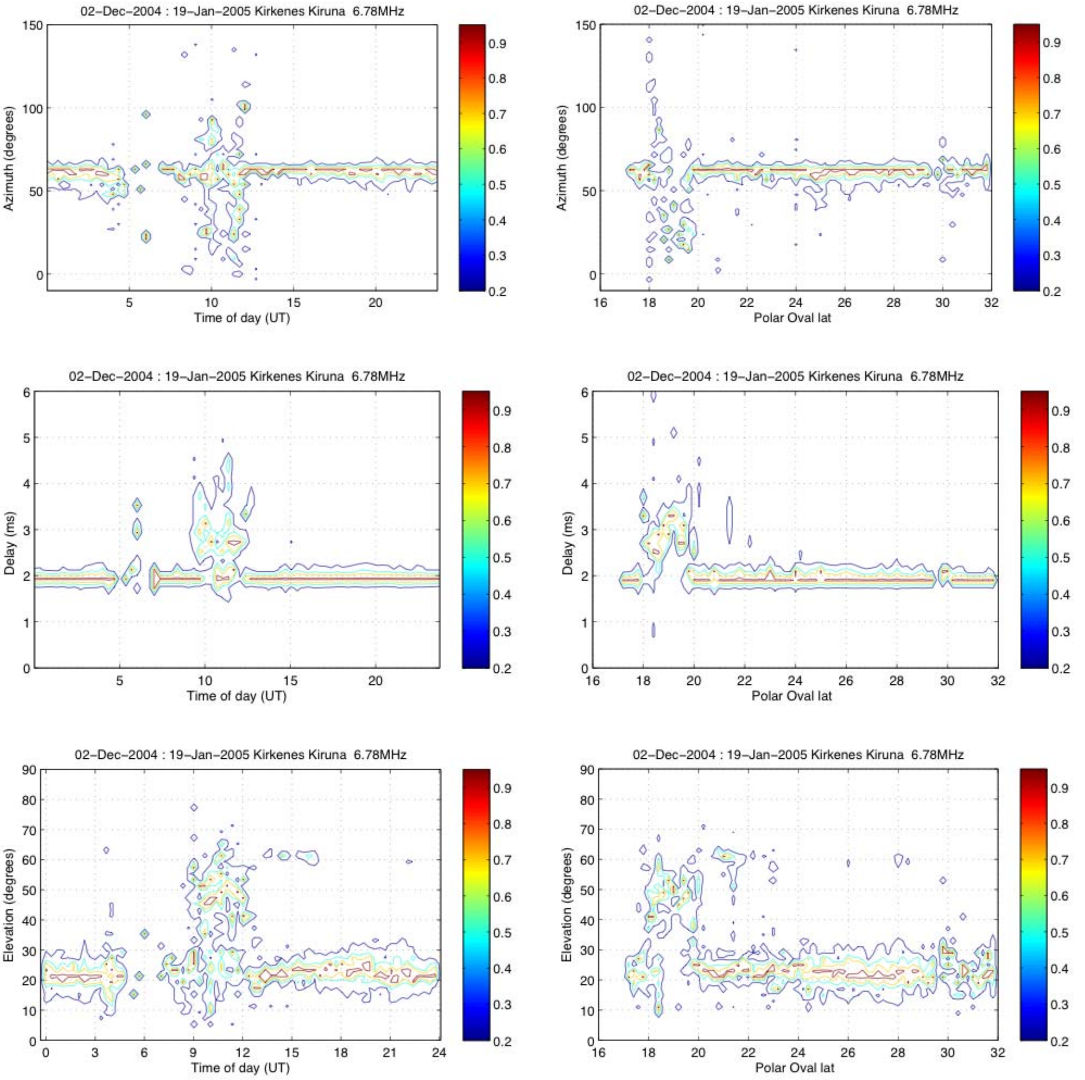


Figure 3 Observations made over Kirkenes– Kiruna path at 6.78MHz between 1 December 2004 and 20 January 2005.

It is relevant to determine the correlation between the scattering function parameters and the auroral oval location, in particular the latitude of the southward border of the oval region at the mid point between the receiver and the transmitter (about 20°E for Kirkenes – Kiruna path).

The scattering function parameter distributions corresponding to observations made on the Kirkenes – Kiruna path at 6.78MHz between 1 December 2004 and 20 January 2005 are presented in Figure 3. Distributions of delay, azimuth and elevation angles during the day are shown in left column of this figure. Azimuth deviations of about 40° to the south and up to 50° to the north in day time between 0800 and 1200 UT can be seen in top left frame. These modes are accompanied by delay of about 3-4 ms (middle left frame) and elevation angles of 40°-60° (bottom left frame). Correlation between these parameters and the auroral oval position are shown in right column. The southward trace with a maximum azimuth deviation of about 60° occurs at a latitude between 18° and 19° accompanied by a loop-shaped northward trace between 18.5° and 20° (right top frame). The southward trace can be related to refraction in the southern wall of the mid-latitude trough whilst the northward trace is due to scattering from irregularities in the auroral oval (and also by refraction in the northern wall of the trough).

WP Activitiy 2.1.1 IONOSPHERIC EFFECTS ON SURFACE-WAVE RADAR

A survey has been carried out. Clutter seems to be a major factor in investigating the ionospheric effects on surface-wave and sky-wave radars. To keep following definitions in mind will be useful.

Noise: Unwanted uncorrelated signal.

Clutter: Unwanted but correlated echoes from unintentional targets. These include radar background, echo, or group of echoes from Ionosphere, ground, sea, rain, birds, chaffs, etc. which are operationally unwanted.

Sea clutter: Unwanted echoes due to electromagnetic wave, ocean wave interaction.

Ionospheric clutter: Unwanted echoes due to the affect of ionosphere and self generated interface.

Characteristic quantities to be considered:

Variations of echo power, elevation angle, echo velocity, spectral width versus HF frequency range 3-30 MHz.

A typical example: Tasman International Geospace Environment Radar (TIGER)

Super DARN: Super Dual Auroral Radar Network.

Typical ionograms are shown in Figure 1.

Proposal for future work:

Investigations of the Effects of Space Weather conditions on the variations of the above mentioned quantities will contribute to the understanding of ionospheric effects on HF surface-wave and sky-wave radar.

Important condition:

Relevant natural or at least artificial data are needed. At the moment, to the best of our knowledge, no such data are available for us.

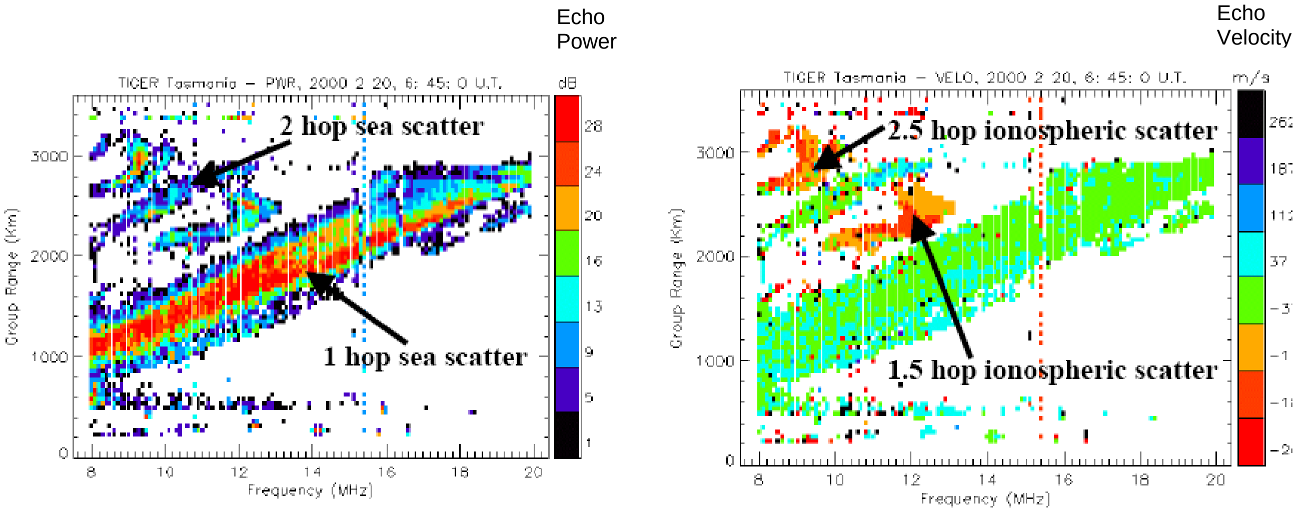


Fig. 1. Backscatter ionogram showing one and two hop sea scatter and 1.5 and 2.5 hop ionospheric scatter. Ionogram on left displays echo power, one on right displays echo velocity.

Dissemination of Results

a) Journal Papers

i. Submitted

A.J. Stocker, E.M. Warrington and D.R. Siddle. A comparison between measured and predicted parameters of HF signals propagating along the mid-latitude trough and within the polar cap. *Radio Science*, 2006RS003557 (submitted).

b) Conference Publications

i. Presentation Proceedings

A.J. Stocker and E.M. Warrington. Comparison Between the Measured and Predicted Parameters of HF Radio Signals Propagating in the Polar Cap. IRST2006

E.M. Warrington, A.J. Stocker and D.R. Siddle. Directional spread characteristics of HF signals received over paths within the auroral zone. IRST2006

N.Y. Zaalov, E.M. Warrington and A.J. Stocker. The Effect of the Interplanetary Magnetic Field and Kp on the Channel Scattering Functions of HF Signals Propagating at Northerly Latitudes. IRST2006

E.M. Warrington, A.J. Stocker and D.R. Siddle. Directional spread characteristics of HF signals received over paths within the auroral zone. *In:* Proceedings of the Sixth Symposium on Radiolocation and Direction Finding, Southwest Research Institute, San Antonio, Texas, 2-4 May 2006.

WP2.2 HF/MF communications (Leaders: Prof J.M. Andujar and Dr P. Lassudrie-Duchesne)

Activities ***(Ref: COST 296, Progress Report, Period: from February 2005 to May 2006,*** Annex 3 to Doc.WGCEM/1/00):

WP2.2.1.Digital radio systems – predictions, methods of estimating reliability

WP2.2.2.Wideband propagation modelling and development of a hardware simulator

WP2.2.3.Increased capacity of HF links through MIMO techniques

WP2.2.4.Gravity and planetary wave effects on propagation

WP2.2.5.Extension of existing wideband HF simulators to the MF band

1. List of Participants

Contributing to this report are:

Y. Bahadirlar, P. Bencze, T. Ciloglu, M.O. Sari, E.T. Senalp, H.J. Strangeways, E. Tulunay, Y. Tulunay, A.S. Turk, E.M. Warrington, T. Yapici

2. WP Activity Number 2.2.1

Digital radio systems – predictions, methods of estimating reliability

3. Main Results

ASSESSMENT OF HF CHANNEL AVAILABILITY UNDER IONOSPHERIC DISTURBANCES

A new approach has been proposed for the assessment of HF Channel Availability under Ionospheric Disturbances. Channel availability is considered as a fundamental component of HF Communication Channel reliability.

Modem availability is related to the magnetic indices. HF channel is characterized as shown in Fig. 1 from the modem availability point of view.

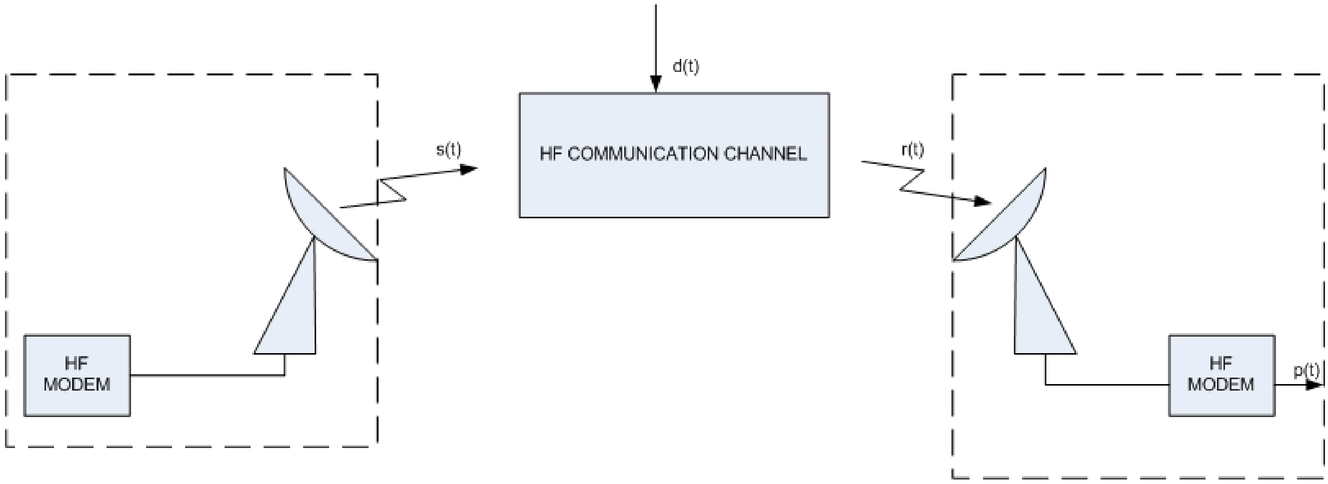


Fig 1. Proposed block diagram for the channel. (s(t) : transmitted signal; d(t): ionospheric disturbances; r(t) : the signal output of the HF channel; p(t): the signal output of the HF modem)

As examples of modem characterizations Military Standards are considered. In these stanags HF modems are specified in terms of Effective Mutipath Spread, Frequency (Doppler) Spread, Signal to Noise Ratio (SNR), Bit Error Rate (BER), Modulation Type, and Data Conversion (Long-Short Interleaver)

Modem availability is quantified as a fraction or percentage of time that the modem will function satisfactorily.

$$\text{modem}\, availability = 100 \times \frac{(\text{number of available points})}{(\text{total number of points})}$$

The availability of a modem can be estimated by placing each composite-channel measurement on the modem characterization to determine the difference between the measured SNR and the SNR of the surface (the SNR difference). A positive SNR difference indicates that the channel would support the specified BER.

Ionospheric disturbances are characterized by Disturbance Storm Type (DST) index. Throughout the study the data from two different sources are used.
i) the experiment made between Leicester, UK (52.63_ N, 1.08_ W) and Uppsala, Sweden (59.92_ N, 17.63_ E). The experiment was held in the year 2001, for Effective Mutipath Spread, Composite Doppler Spread, and SNR.

ii) the National Geophysical Data Center for DST index.

First joint probability density functions (pdf) of SNR, Doppler, and Multipath Spread versus DST are considered. By using Bayes' Theorem their dependencies are observed. Therefore it is concluded that the availability of the HF channel is also a function of DST.

An availability example is shown in Fig. 2 by using STANAG 4539 as a typical case.

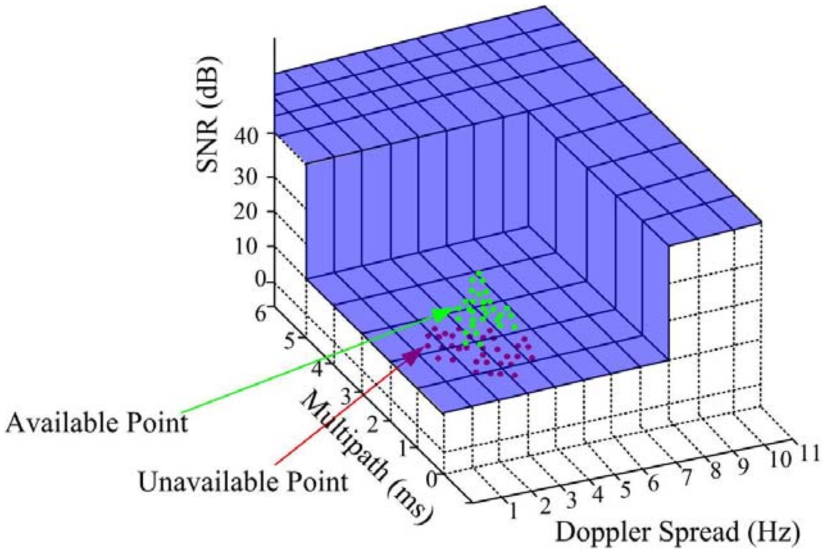


Fig 2. Approximated availability surface according to STANAG 4539

If a point is above the Modem Surface, then it corresponds to an unavailable channel.

The proposed method is general and can include other Space Weather parameters which may be thought of being effective on HF communication channel reliability.

1. **WP Activity Number 2.2.2**

Wideband propagation modelling and development of a hardware simulator

2. **Main Results**

MAPS OF THE SPORADIC E-LAYER PARAMETERS

During the period considered, maps of the sporadic E layer parameters have been studied. Maps showing diurnal and seasonal variations of the spatial distribution have been analized, first of all that of the difference foEs-fbEs regarding it as a parameter proportional to transparency of Es-layers for HF radio propagation. Thus, Es layers may be considered as thin diffration screens, patches of increased electron density within Es layers due to wind shear producing eddies at mid-latitudes. It has been demonstrated, namely that at mid-latitudes Es layers are formed by wind shear as it is described by the wind sear theory. The validity of the wind shear theory has been shown by comparison of wind shear profile based on wind measurements with the profile deduced from Es parameters. Good agreement has been found. For determination of the characteristic of the above mentioned thin diffraction screen, the screen constant temporal variation of foEs have been determind by vertical incidence sounding frequently carried out (5 min). Thus, it was possible to establish the most frequently occuring interval between foEs maxima. Multiplying this period with the wind speed at Es layer altitude, the mean dislance between Es patches could be determined (<3 km).

1. **WP Activity Number 2.2.3**

Increased capacity of HF links through MIMO techniques

2. **Main Results**

RESEARCH ON MIMO FOR HF IONOSPHERICALLY PROPAGATED SIGNALS

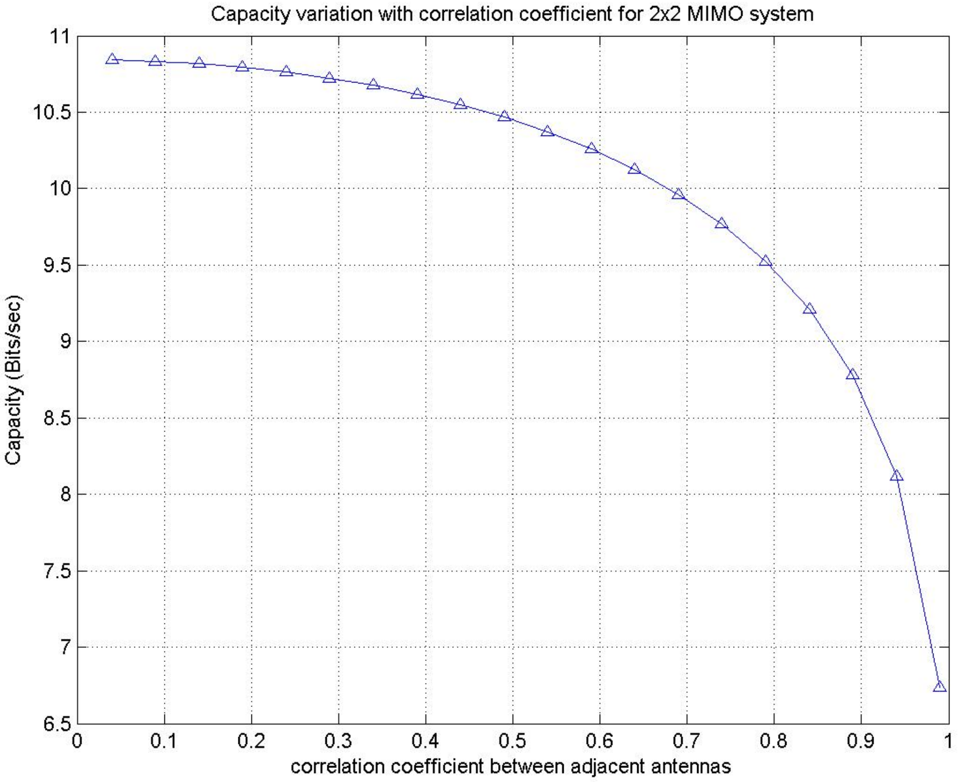
Research on the following items has been conducted.

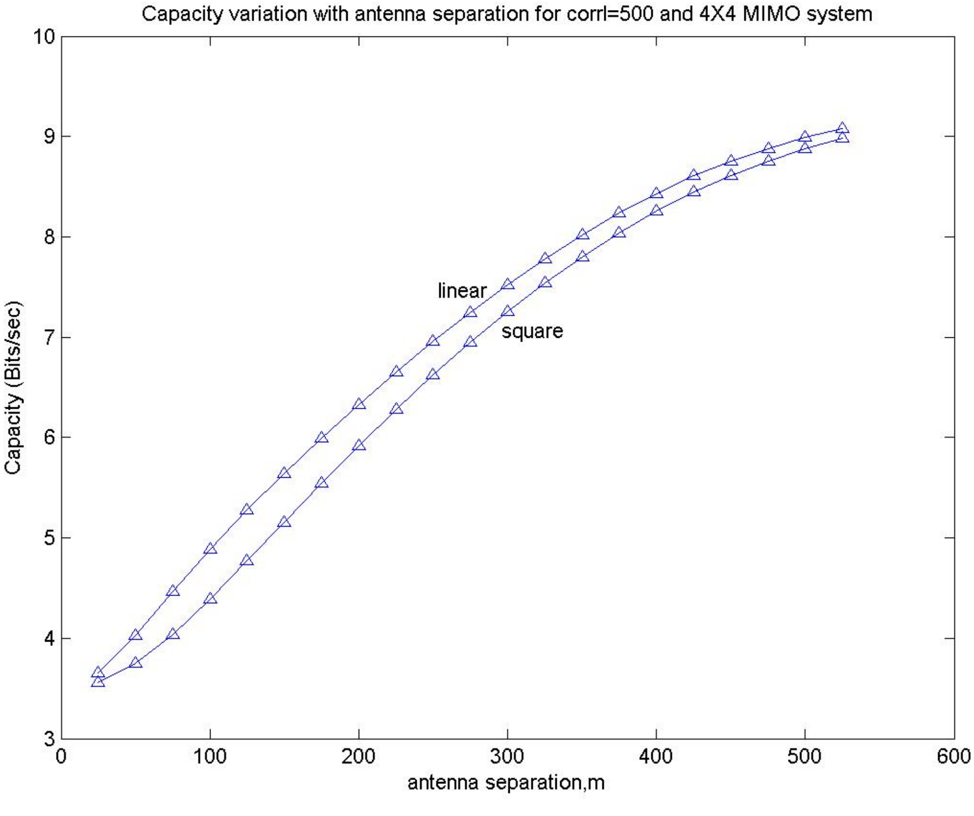
(i) determining correlation distances between spaced antennas in terms of the physical properties of the background ionosphere and ionospheric irregularities, propagation geometry and hence also different multipath.
(ii) considering also polarisation diversity
(iii) determining expected capacity and its variation with antenna separation, array length, array type (linear or planar) , SNR, correlation length etc.

Also, work has been carried out on the "Determination of the capacity of ionospheric HF MIMO Systems employing linear or planar arrays or co-located antennas"

MIMO (Multiple Output Multiple Input) systems have been shown to be capable of providing significant capacity improvement in a multipath environment (e.g. 20-40 bits/s/Hz for SNRs of 24-34 dB for 8 transmit and 12 receive antennas). Such spectral efficiencies would be very desirable at HF where data rates tend to be significantly limited by a variety of factors including delay and Doppler spread. MIMO systems utilize antenna arrays at both transmitting and receiving locations and rely on there being limited correlation between the different propagation paths from any one transmit antenna to any one receiving antenna, a condition which can arise in a rich multipath propagation environment. This would seem possible at HF as there are a number of propagating modes (E, F, low/high angle o/x etc) and de-correlation is also provided by diffraction on time-varying small-scale irregularities in the ionosphere.

To achieve the potential MIMO capacity, it is important that the receiving (or transmitting) antennas are sufficiently far apart that the fading is relatively independent for each transmitter receiver path. Experimental measurements have shown that separations of 10-15 λ are required to achieve a spacing corresponding to the correlation length. However for a 6 element linear array this would require an array length of 500-750m at the top of the HF band and 5 to 7.5 km at the bottom of the band. Since these array lengths are rather unrealistically long, it is important to investigate whether reasonable capacity improvements are possible for HF MIMO systems for antenna separations rather smaller than the correlation length and planar rather than linear arrays which for the same number of antenna elements would require a significantly smaller array length. Thus, in this paper, MIMO capacity has been investigated for HF links of ionospherically reflected signals for different numbers of array elements and antenna separations for both linear and planar arrays and different correlation lengths for the received fading signal at the receiving array as well as varying SNR. Arrays containing co-located antennas using different polarisations have also been investigated as these will also considerably reduce the size of the receiving array. Correlation lengths have been estimated from both experimental measurements and from calculations using an HF simulator in which the effect of time-varying irregularities is included (1). The latter enables the correlation length to be related to the geometry of the propagation path and the propagating modes as well as the parameters of the small scale ionospheric irregularities such as their drift direction, the variance of their electron density, their outer scale, aspect ratio and the exponent index p of their anisotropic spatial spectrum. It is found, in particular, that capacities are not significantly reduced even for correlation coefficients between antennas as large as 0.8 and there is also little difference in capacity between planar as opposed to linear arrays containing the same number of elements and with the same inter-element spacing. Some specimen results are shown:.





(1) V. Gherm, N. N. Zernov and H.J. Strangeways, HF propagation in a wideband ionospheric fluctuating reflection channel: Physically based software simulator of the channel, Radio Science, Vol. 40, No. 1, doi 10.1029/2004RS003093, January 2005.

Dissemination of Results

a) Journal Papers

i. Submitted

Spatial and temporal variations of the transparency of Es layers above Europe

b) Conference Publications

i. Presentation Proceedings

Tulunay E., Warrington E. M., Tulunay Y., Bahadırlar Y., Türk A.S., Çaputçu R., Yapıcı T. , Şenalp E.T., Propagation Related Measurements during Three Solar Eclipses in Turkey, IET 10th International Conference on Ionospheric Radio Systems & Techniques, IRST 2006, 18-21 July 2006, London, UK.

H.J. Strangeways, "Estimation of signal correlation at spaced antennas for multi-moded ionospherically reflected signals and its effect on the capacity of SIMO and MIMO HF links", Proceedings of the 10th International Conference on Ionospheric Radio Systems, and Techniques, London, 18-21 July 2006.

c) Reports

i. Thesis: Sari M.O.: A New Approach For The Assessment Of Hf Channel Availability Under Ionospheric Disturbances, (Supervisor: E. Tulunay), MS Thesis, EEE Dept., Middle East Technical University, Ankara, Turkey, September 2006.

Short Term Missions Completed

M. Ozgur Sari (METU) to M. Warrington (Univ. of Leicester). Already reported in Neustrelitz (27-29 April 2006)

WP2.3 Spectrum management *(Leaders: Prof L.W. Barclay and Prof A. M. Casimiro)*

Activities ***(Ref: COST 296, Progress Report, Period: from February 2005 to May 2006,*** Annex 3 to Doc.WGCEM/1/00):

WP2.3.1.Use of GPS to improve HF communications management

WP2.3.2.Adaptive waveform management

WP2.3.3.Effects of infrasound on radio propagation

1. **List of Participants**

Contributing to this report are:

A. Azevedo, L. Barclay, A. Casimiro, Charalambous, L. Economou

2. **WP Activity Number 2.3.x**

3. Main Results

OCCUPANCY OF HF SPECTRUM

Occupancy of HF Spectrum over Northern Europe has been studied.

In cooperation with the University of Manchester HF spectral occupancy research group, we 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*
Measurement systems are currently installed at Baldock (UK). Linkoping (Sweden), Kiruna (Sweden), and Munich (Germany). These sites provide effective measurement of spectral occupancy over northern Europe.
Analysis was undertaken to derive an appropriate model index function for the Laycock Gott model for spectral occupancy.

ANTENNA ARRAY ANALYSIS AND SYNTHESIS

Research has been conducted concerned with the application of antenna procedures for array analysis and synthesis, and for propagation studies.

4. Dissemination of Results

   d) Journal Papers

      i. Submitted

Azevedo, Joaquim A.R., Casimiro, António M.E.S.
"Non-Uniformly Sampling and Polynomial Interpolation for Array Synthesis",
Submitted to IEE Proc. Microwaves, Antennas & Propagation

   e) Conference Publications

      i. Abstract Proceedings

Casimiro, António M.E.S.
"An Antenna Array Approach for Propagation of Electromagnetic Waves in Different Media"
PIERS2006, 2-5 August 2006 in Tokyo, Japan.

ANNEX VI

WG 3 Report - Space based systems

WG Leaders N Jakowski and R Leitinger

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

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) continued operating a space-plasma and space-weather monitoring service within the project SWACI - Space Weather Applications Center Ionosphere. One of the key issues to be addressed in this project is the GNSS reference Network Model Integrity (NMI) under perturbed ionosphere/space weather conditions.

To define proper indices for describing ionospheric perturbations, a COST 296 task force group has been established. The first action is focussed on determining temporal and spatial gradients of peak electron density and total electron content during the storm period on October 2003. TEC and peak density gradients shall be computed following the same rules and under equivalent geometrical conditions. A comparative study shall provide new information about different types of ionospheric perturbation descriptors.

The effect of plasma on signal propagation in remote sensing applications using the L-band has been discussed. Vice versa, the measurable effects in signal travel time and phases can be used for ionospheric sounding by Synthetic Apertur Radar techniques.

A joint study describing ionospheric effects during the solar eclipse on October 3, 2005 have been finished (DLR, Observatorio del Ebro, Spain, Institute of Atmospheric Physics - IAP, Czech Republic, Rutherford Appleton Laboratory, UK).

Effects of total solar eclipse events in the ionosphere are significantly different from those observed during an annular eclipse. During the annular eclipse event less AGW activity has been observed, no signatures of acoustic waves have been found. The propagation direction close to the horizontal plane of the detected waves (event 2005) indicates the distant source / likely bow shock (IAP).

The standard DDA method of drift velocity evaluation was improved. Raw drift data from the Pruhonice observatory for the period Jan-May 2006 were recalculated using an improved method. The preliminary analysis reveals results on the diurnal variability of the velocity components at quiet geomagnetic conditions and seasonal trends of daily characteristics. Significant decrease in the daily maximal horizontal component from winter to summer 2006 was found within the analyzed data (IAP).

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

1. Basic mitigation techniques based on separate models and operational measurements

DLR has continued operating the ionosphere data service SWACI funded by the state government Mecklenburg-Vorpommern. The service, which provides near-real-time ionospheric information derived from ground and space based GPS measurements, has been further consolidated and is now available under http://w3swaci.de. The 5 minutes updated TEC data may be used for correcting first and second order ionospheric propagation effects. Besides TEC maps also TEC rates and latitudinal and latitudinal gradients are provided.

Research work is focused on improving temporal and spatial resolution of the TEC maps and on developing forecast tools. (DLR)

2. Mitigation techniques for specific GNSS applications

a) GNSS radio occultation

During the last months, the University of Graz has processed almost 5 years of CHAMP Radio Occultation Data (RO) with the aim of producing high quality climatology of the upper troposphere and lower stratosphere (5 km to 35 km altitude). Recently, SAC-C RO data were added to this database. All these data have been processed using standard ionospheric correction techniques (linear combination of bending angles). Based on the knowledge obtained so far, it can be concluded that higher order ionospheric effects are not a major problem for CHAMP and SAC-C climatology's up to 35 km altitude, where the RO data are of sufficient quality. In April 2006, six satellites of the Taiwan/US COSMIC constellation have been successfully launched. All these satellites are equipped with high quality radio occultation receivers. These measurements will form a rich basis for error studies with focus on the influence of higher-order ionospheric errors and the development of mitigation techniques. The University of Graz has started to process COSMIC data (for the neutral atmosphere) and hope to be able to use these data up to at least 40 km altitude.

b) GNSS reference networks

IGS and EUREF data were processed to produce real-time corrections by several groups in Europe (e.g. DLR, FMI). The FMI has recently investigated TEC data interpolation and mapping functions for ground based GPS observations and has also started to look at the use of ionospheric measurement data from the COSMIC satellites to complement the ground based observations.

The use of 1 Hz data collected in a network of 86 permanent stations in Finland (with inter-distances < 100 km) is planned to be started later this year in order to produce higher resolution TEC maps. Finally, a prototype single channel GPS receiver (intended for future mobile navigation applications) has been installed at the FMI roof top next to a two frequency GPS receiver (the two frequency receiver is the UNAVCO SuomiNet station SG40). The collocation of the single and two frequency receivers can be used to validate ionosphere correction algorithms with real observation data.

Development of mitigation techniques in the frame of the Wide Array Real Time Kinematic (WARTK) GNSS positioning technique has been continued at the Technical University of Catalonia.

At the Royal Observatory of Belgium a TID forecasting technique for GNSS applications based on a dense network of GNSS stations is under development.

c) Triple frequency methods (Galileo, modernized GPS)

This topic is related to studies 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 using TCAR method.

First results based on simulated data show that ambiguities can be solved in real-time using un-differenced data. This method which uses different combinations of the 3 frequencies solves ambiguities in 3 steps. When ambiguities have been solved, TEC can be reconstructed with a much better accuracy than with the classical dual frequency method. Results are presented at the COST 296 workshop in Rennes (Royal Observatory of Belgium).

d) Higher order ionospheric influences in dual frequency systems

A technique has been developed at the Technical University of Catalonia allowing assessing higher order ionospheric effects on dual frequency high accuracy GNSS applications using IGS global TEC maps.

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 without knowing the geomagnetic field structure and the exact shape of the electron density profile. The correction formulas need only TEC which may be derived by the GNSS user or may be provided by a service as mentioned above. Results are presented at the workshop (DLR)

Two new quasi-analytical methods for higher order corrections have been developed at the University of St. Petersburg and University of Leeds. The computations reach mm-accuracy and show excellent agreement with corresponding numerical ray-tracing results.

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

Work has been made at different topics according to the terms of reference. Topics are highlighted in the following:

1. **Climatology of irregularities and scintillations under different helio-geophysical conditions from scintillation modelling (SRC, Warsaw, INGV, Rome)**
After a first phase devoted to the production of a model able to reproduce weak scattering scintillation conditions, the authors are now working on a new release to simulate the strong scattering scintillation scenario. The weak scattering model 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.

2. **GPS scintillation monitoring in the frame of ISACCO (Ionospheric Scintillation Arctic Coordinated Campaign Observations) project (INGV, Rome)**
   The participants continue to maintain the polar GISTM stations 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). Thanks to the new network wideband facility it is now possible to have a complete control of the station and a not limited data flow from the Arctic Base. The development of the scintillation data base is still in progress and it is now able to host Arctic and Antarctic data. Efforts have been addressed to upgrade manual and automatic procedures dedicated to the data acquisition, processing, transfer, archive and analysis.

3. **Investigation of ionospheric irregularities by means of scintillation and TEC observations. (INGV, Rome, SRC, Warsaw, University of Nottingham, Royal Observatory of Belgium)**
   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 Nottingham University group continue to log high rate scintillation data in Nottingham and has installed a GISTM receiver in Dourbes, Belgium, fully operational and logging 50Hz data. The main objective is the co-location with a dual-frequency EUREF receiver and an ionosonde that will allow correlation studies in collaboration with ROB.

4. **GPS observations of polar and equatorial scintillations (INGV, IETR, DLR, IEEA)**
   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. The receivers are located at northern polar latitudes (Ny Alesund 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. In particular the attention is focused on the detection of patches and bubbles, typical signatures of the ionospheric irregularities at some selected receiver-satellite path. The monitoring of ionospheric scintillation activity in the vicinity of Bandung/Indonesia and Kiruna (20.4°E, 67.8°N) has been continued by DLR.

5. **Prediction of Ionospheric Scintillations – ESA project (IEEA, DLR, IETR, ENSTB, GMV, CLS)** In the frame of an ESA project 'PRIS' it is intended to perform studies and measurements campaigns. Installation of the receivers and collection of data has been started.

Recent Publications and talks related to WG3 activities

(Update October 2006)

Aquino, M., A. Dodson, J. Souter and T. Moore: Ionospheric Scintillation Effects on GPS Carrier Phase Positioning Accuracy at Auroral and Sub-auroral Latitudes, accepted by Springer.

Arbesser-Rastburg, B. and N. Jakowski, Effects on Satellite Navigation, chapter 13, in Space Weather – Physics and Effects (Eds. V. Bothmer and I. Daglis), ISBN: 3-540-23907-3, 2006

De Franceschi G. Alfonsi L., Romano V. "ISACCO: an Italian project to monitor the high latitudes ionosphere by means of GPS receivers", GPS Solution, DOI 10.1007/s10291-006-0036-6, 2006

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. Submitted to JASTP, Sep 2006.

Foelsche, U., M. Borsche, A.K. Steiner, A. Gobiet, B. Pirscher, G. Kirchengast, J. Wickert, and T. Schmidt (2006), Observing Upper Troposphere–Lower Stratosphere Climate with Radio Occultation Data from the CHAMP Satellite (2006), Submitted to Climate Dynamics.

Foelsche, U., G. Kirchengast, and A.K. Steiner (Eds.) (2006), Atmosphere and Climate: Studies by occultation Methods, Springer, Berlin, Heidelberg, New York.

Hanuise, C., J.C. Cerisier, F. Auchère, K. Bocchialini, S. Bruinsma, N. Cornilleau-Wehrlin, N. Jakowski, C. Lathuillère, M. Menvielle, J.J. Valette8, N. Vilmer, J. Watermann, P. Yaya , From the Sun to the Earth: impact of the 27-28 May 2003 solar events on the magnetosphere, ionosphere and thermosphere, JASTP, 2006 (submitted)

Hernandez-Pajares M., Juan J. M., Sanz J. (2006), Medium-scale Travelling Ionospheric Disturbances affecting GPS measurements : spatial and temporal analysis. J. of Geoph. Res., Vol. 111, A07S11, doi:1029/2005JA011474.

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

Jakowski, N., S. Heise, S.M. Stankov, K. Tsybulia, Remote sensing of the ionosphere by space-based GNSS observations, Advances in Space Research, in press

Jakowski, N., V. Wilken, K. Tsybulya , S. Heise, Search of earthquake signatures from ground and space based GPS measurements, in Flury, J., Rummel, R., Reigber, C., Rothacher, M., Boedecker, G., Schreiber, U. (Eds., 2006) Observation of the Earth System from Space, Springer, Berlin, Heidelberg, New York, ISBN: 3-540-29520-8, pp 43-53

Laštovička, J., Forcing of the ionosphere by waves from below. J. Atmos. Solar-Terr. Phys., 68, 479-497, 2006.

Lejeune S., Warnant R. (2006), A novel method for the quantitative assessment of the ionosphere effect on high accuracy GNSS applications which require ambiguity resolution.
J. of Atmospheric and Solar-Terrestrial Physics, submitted.

Materassi, M., C. N. Mitchell, "Wavelet analysis of GPS amplitude scintillation, a case study", in press, Radio Science (2005RS003415RR)

Meyer, F., R. Bamler, N. Jakowski, and Th. Fritz, The Potential of Low-Frequency SAR Systems for Mapping Ionospheric TEC Distributions, IEEE Geoscience and Remote Sensing Letters, 3, Nr. 4, 560-564, 2006

Stankov, S.M., N. Jakowski, Topside ionospheric scale height analysis and modeling based on radio occultation measurements, J. Atmos. Solar-Terr. Phys. 68, 134-162, 2006

Stankov, S.M., N. Jakowski, K. Tsybulya, and V. Wilken, Monitoring the generation and propagation of ionospheric disturbances and effects on GNSS positioning, Radio Science, 41, RS6S09, doi:10.1029/2005RS003327, 2006

Stankov, S.M., N. Jakowski, Topside plasma scale height retrieved from radio occultation measurements, Adv. Space Res. 37, 958-962, 2006

Warnant R., Kutiev I., Marinov P., Bavier M., Lejeune S. (2006), Ionospheric and geomagnetic conditions during periods of degraded GPS position accuracy : 1. Monitoring variability in TEC which degrades the accuracy of Real Time Kinematic GPS applications. Adv. Space Res., in press.

Warnant R., Kutiev I., Marinov P., Bavier M., Lejeune S. (2006), 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.

Warnant R., Lejeune S., Bavier M. (2006), Space Weather influence on satellite based navigation and precise positioning. In : Space Weather - Research towards Applications in Europe, Astrophysics and Space Science Library series, Vol. 344, Ed. J. Lilensten, Springer, in press.

Wernik, A.W., L. Alfonsi, M. Materassi, Scintillation modelling using in-situ data, Radio Science, 2006, in press

Presentations:

Jakowski, N., S.M. Stankov, D. Klähn, C. Becker, SWACI - a near-real time ionosphere service based on Ntrip technology, CD-ROM, Proc. Ntrip Symposium & Workshop “Streaming GNSS Data via Internet” BKG, 6-7 February, Frankfurt am Main, Germany

Warnant R., Bavier M., Lejeune S., Kutiev I., Marinov P., Andonov B. (2006), Impact of geomagnetic activity on high precision GNSS positioning. Galileo GALOCAD project. Presented at the COST724 Management Committee Meeting, Antalya, Turkey, March 26-31 2006.

Lejeune S., Warnant R. (2006), Near real time assessment of the ionosphere effect on high accuracy GNSS applications which require ambiguity resolution. Presented at the European Geosciences Union General Assembly 2006, Vienna, Austria, April 02-07 2006.

Bavier M., R. Warnant R., Lejeune S. (2006), Detecting and forecasting ionospheric irregularities using a cross-correlation method applied to the Belgian dense GNSS network, presented at the European Geosciences Union General Assembly 2006, Vienna, Austria, April 02-07 2006.

L. Alfonsi, M. Materassi, A. W. Wernik, Properties of the high-latitude irregularites of importance in the scintillation modelling, Session ST5.7 “Measurements of ionospheric parameters influencing radio systems”, EGU 2006, Vienna (Austria), 2-7 April, 2006.
Boška, Kouba, Šauli: Ionospheric drift measurements during high and low geomagnetic activity. Symp. ST5.7, EGU Ass. 2006, Vienna, 2006.

Chum, J.Laštovička, D. Burešová, Ya.V. Drobzheva, V.M. Krasnov: Impact of infrasonic waves on the ionosphere and radio wave propagation (solicited). Symp. ST5.7, EGU Ass. 2006, Vienna, 2006.

De Franceschi, Alfonsi, V. Romano, M. Aquino, A. Dodson, Mitchell, Wernik: GPS TEC and scintillations as signatures of the ionospheric plasma movement. Symp. ST5.7, EGU Ass. 2006, Vienna, 2006.

De Franceschi, G., L. Alfonsi, V. Romano, Polar upper atmosphere monitoring by ground based stations, Session ST3 “Open session on the ionosphere and thermosphere including connections to regions above and below” , EGU 2006, Vienna (Austria), 2-7 April, 2006.

De Franceschi, G., L. Alfonsi, V. Romano, M. Aquino, A. Dodson, C. N. Mitchell, A. W. Wernik, GPS TEC and scintillations as signatures of the ionospheric plasma movement, Session ST5.7 “Measurements of ionospheric parameters influencing radio systems” EGU 2006, Vienna (Austria), 2-7 April, 2006.

Romano, V., L. Alfonsi, G. De Franceschi, GPS scintillation monitoring in Antarctica: first campaign at the Italian station “Mario Zucchelli”, Session GI7 “Instrumentation related to the International Polar Year” , EGU 2006, Vienna (Austria), 2-7 April, 2006.

Jakowski, N., S. M. Stankov, V. Wilken, D. Altadill, J. Chum, D. Buresova, J. Boska, P. Sauli, R. Bamford, L. Cander, R. Stamper, Ionospheric behaviour over Europe during the solar eclipse of 3 October 2005, EGU 2006, Vienna (Austria), 2-7 April, 2006 (solicited paper).

Hoque, M. Mainul and N. Jakowski (2006), Second order propagation delay effects in regional precise positioning , Oral presentation, EGU General Assembly 2006, Vienna, Austria, 02 – 07 April 2006

Hoque M., Jakowski N. (2006), Possibilities of Higher Order Range Error Correction in Real-time Precise Positioning, presented at the IGS Workshop, 8-11 Mai 2006, Darmstadt, Germany

Jakowski, N., C. Mayer, V. Wilken, GPS Sounding onboard CHAMP, Proc. NATO IST 051 RTG 023 Symposium, 12 – 16 June 2006, Fairbanks, Alaska, USA

J.J. Valette1, N. Suard2, P. Lassudrie-Duchesne3, R. Fleury3, C. Hanuise4, P. Yaya1, G. De Franceschi5, L. Alfonsi5, V. Romano5, C. Mitchell, B. Meggs ”Analysis of local ionospheric effects on GNSS signals in Scandinavia” presented at Earth-Space Propagation - 3nd CNES workshop – Toulouse, 25-27 September 2006

Bavier M., Warnant R. (2006), Detection and characterization of ionospheric irregularities using the Belgian dense GNSS network. Presented at the COST296 2nd Workshop, Rennes, 3-7 October 2006.

Spits J., Warnant R. (2006), Real time TEC monitoring using triple frequency GNSS data: a three step approach. Presented at the COST296 2nd Workshop, Rennes, 3-7 October 2006.

Lejeune S., Warnant R. (2006), Near real time assessment of the ionosphere effect on high accuracy GNSS applications which require ambiguity resolution. Presented at the COST296 2nd Workshop, Rennes, 3-7 October 2006.

Hoque, M. M., Jakowski, N. (2006), Second-order Propagation Delay Correction in Real-time Precise Positioning. Presented at the COST296 2nd Workshop, Rennes, 3-7 October 2006.

V. Romano, A. Bourdillon, L. Alfonsi, G. De Franceschi, Le Huy Minh, GPS observations of polar and equatorial scintillations. presented at 2nd COST296 Workshop 3-7 October 2006.

ANNEX VII

The notes of the impromptu talk on the FP7 SAG meetings delivered by Yurdanur Tulunay:

During the COST 296 Rennes MCM, YT was asked to give an informal overview, on the spot, about the highlights of the EU FP7 Space Program by the co-chairs of the Actions.

The 'Highlights' of the program may be summarized as:

(i) EU is to play a global role in Space

(ii) EU aims to achieve an operational and autonomous European Capability.

(iii) EC's intention is to move from concept to reality

(iv) 1 out of the 9 themes of the Specific Program of the FP7 'Cooperation' is on 'Space and Security'

(v) Under the 'space' sub theme the following sets of activity are foreseen:

- Space Based Applications at the service of the European Society; the GMES, the next EU flagship for the space after the GALILEO, is identified as the flagship applications.
- RTD for strengthening the space foundations.
- Cross-cutting issues.

(vi) The 'Space' and the 'Security' dimensions of the specific program 'Cooperation' are allocated equal amounts of the budget i.e. approximately €1.4 each. (total about €2.8)

About 85% of €1.4 is allocated to the GMES; 15% for the RTD for strengthening the space foundations and cross-cutting issues.

(vii) The user driven development of the GMES services represents the priority actions. To fulfill this objective there will be operational collaborative projects as referred the 'Fast Track Services' in marine environment; land cover and change monitoring (including water management); information on natural and technological risks and emergency situations, in 2008.

Summarizing, the EU needs services in the fields of transport, environment, agriculture, fisheries, telecommunications and security. The space is considered as a tool.

The EU will 'define' the priorities and requirements, aggregate the political will, user demand, ensure the availability and continuity of services.

The ESA will support and define the technical specifications of the GMES space component; implement it; give advice to the EU on the future requirements.

The EC has setup a GMES bureau since June 2006 to manage the GMES which replaced the former GMES Programme Office.

References:

1. Dr. M. Malacarne's talk at the 1st FP7 SAG, 2006
2. http://ec.europa.eu/research /fp7/advisory_en.html