# IRI/COST 296 Workshop

## Ionosphere - Modelling, Forcing and Telecommunications

## Workshop program

**Hotel Globus, Prague**
**Czech Republic**
**10–14 July, 2007**

## Program commitee

Bodo Reinisch, Dieter Bilitza, Alain Bourdillon, Bruno Zolesi, Jan Lastovička

## Local organizing committee

Jan Laštovička, Ludmila Třísková, Daniel Kouba, Zbyšek Mošna, Petra Šauli, Tereza Šindelářová, Vladimír Truhlík
(Institute of Atmospheric Physics, ASCR, v.v.i., Prague)

## Workshop Schedule

| DATE | MORNING | AFTERNOON | EVENING |
|---|---|---|---|
| **Tue, July 10** | 8:30–10:30 COST 296 MC meeting/ Registration. 11:00–12:00 Opening | 14:00–16:00 Scientific session | |
| **Wed, July 11** | 8:30–12:00 Scientific session | 14:00–15:30 Scientific session 16:00–18:00 Poster session | 19:30 Gala Dinner |
| **Thu, July 12** | 8:30–12:00 Scientific session | Excursion to the Konopiste castle | |
| **Fri, July 13** | 8:30–12:00 Scientific session | 14:00–15:30 Scientific session 16:00–18:00 Poster session | |
| **Sat, July 14** | 9:30–10:00 COST 296 MC meeting + parallel Scientific session 10:30–12:30 IRI final discussions. Closing of the Workshop | | |

# List of Participants

## List of Participants


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# Oral sessions

**TUESDAY-Beginning of the Workshop**

**8:30 MC COST / Registration**

**10:30 Coffee break**

**11:00 Opening**

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**12:00 Lunch**

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**Ionospheric Effects on Radio Systems (12)**

**Chair: Bruno Zolesi**

**14:00 Alain Bourdillon, IETR University of Rennes 1, France**

MIERS MITIGATION OF IONOSPHERIC EFFECTS ON RADIO SYSTEMS

**14:20 Cander Ljiljana, Rutherford Appleton Laboratory, United Kingdom**

SCIENCE RATIONAL FOR MIERS/IRI COLLABORATION

**14:40 Laštovička Jan, Institute of Atmospheric Physics, ASCR, Czech Republic**

COST 296 WORKING GROUP 1 "IONOSPHERIC MONITORING AND MODELLING" ACTIVITIES AND RESULTS

**15:00 Cannon Paul, QinetiQ, United Kingdom**

EQUATORIAL STUDIES OF SCINTILLATION IN SUPPORT OF LOW FREQUENCY SPACE RADAR

**15:15 Tulunay Ersin, Dept. of Electrical and Electronics Eng. Middle East Technical University, Turkey**

HF RADAR

**15:30 Coffee break**

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**Chair: Ljiljana Cander**

**16:00 Warnant René, Royal Meteorological Institute of Belgium, Belgium**

COST 296 WORKING GROUP 3 "SPACE-BASED SYSTEMS" ACTIVITIES AND RESULTS

**16:20 Arikan Feza, HACETTEPE UNIVERSITY, Turkey**

MULTIPATH SEPARATION-DIRECTION OF ARRIVAL (MS-DOA) WITH GENETIC SEARCH ALGORITHM FOR HF CHANNELS

**16:35 Arikan Orhan, BILKENT UNIVERSITY, Turkey**

A NEW TECHNIQUE FOR DIRECTION-OF-ARRIVAL ESTIMATION FOR IONOSPHERIC MULTIPATH CHANNELS

**16:50 Zaalov Nikolay, University of Leicester, United Kingdom**

OBSERVATIONS OF HF PROPAGATION ON A PATH ALIGNED ALONG THE MID-LATITUDE TROUGH

**17:05 Sherstyukov Oleg, Kazan State University, Russia**

STATISTICAL MODELLING OF RADIOWAVE PROPAGATION UNDER ES-LAYER INFLUENCE

**17:20 Rodrigues Azevedo Joaquim Amândio, University of Madeira, Portugal**

ANTENNA PATTERN CONTROL OF PLANAR ARRAYS FOR LONG-RANGE COMMUNICATIONS

**17:35 McKinnell Lee-Anne, Hermanus Magnetic Observatory, South Africa**

THE VARIABILITY AND PREDICTIBILITY OF THE IRI SHAPE PARAMETERS OVER GRAHAMSTOWN, SOUTH AFRICA

**17:50 Adjourn**

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**WEDNESDAY**

**GPS and TEC (10)**

**Chair: Sandro Radicella**

**8:30 Rich Frederick, Air Force Research Laboratory (VSBXP), United States**

SPECIFYING THE IONOSPHERE BY ASSIMILATING DATA FROM GROUND-BASED IONOSONDES AND GPS SENSORS ON THE COSMIC SPACECRAFT: VALIDITY AND PROBLEMS WITH ASSIMILATION

**8:45 Hernández-Pajares Manuel, gAGE/UPC, Spain**

OBTAINING ACCURATE WORLDWIDE DISTRIBUTED ELECTRON DENSITY PROFILES FROM GPS OCCULTATION DATA: COSMIC/FORMOSAT-3 CONSTELLATION

**9:00 Spits Justine, Royal Meteorological Institute of Belgium, Belgium**

REAL TIME TEC MONITORING USING TRIPLE FREQUENCY GNSS DATA: A THREE STEP APPROACH

**9:15 Lejeune Sandrine, Royal Meteorological Institute of Belgium, Belgium**

EFFECT OF SMALL-SCALE VARIABILITY IN TEC ON HIGH ACCURACY GNSS APPLICATIONS WHICH REQUIRE AMBIGUITY RESOLUTION

**9:30 Wautelet Gilles, Royal Meteorological Institute of Belgium, Belgium**

STATISTICAL STUDY OF IONOSPHERIC SMALL-SCALE IRREGULARITIES AT MID-LATITUDES USING GPS MEASUREMENTS

**9:45 Gherm Vadim, School of Electronic and Electrical Engineering, University of Leeds, United Kingdom**

MODELING OF SCINTILLATION ON GPS SIGNALS DUE TO PATHS TRAVERSING EQUATORIAL PLASMA BUBBLES

**10:00 Coffee break (Wednesday)**

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**Chair: Jan Laštovička**

**10:30 Krankowski Andrzej, University of Warmia and Mazury in Olsztyn, Institute of Geodesy, Poland**

THE OCCURRENCE OF THE MID-LATITUDE IONOSPHERIC TROUGH IN GPS-TEC MEASUREMENTS

**10:45 Zhang Man-Lian, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

VARIABILITY STUDY ON THE EQUATORIAL IONIZATION ANOMALY USING GPS OBSERVATIONS AROUND 120E LONGITUDE

**11:00 Shi Jiankui Center for Space Science and Applied Research, Chinese Academy of Sciences, China**

A COMPARISON STUDY ON PERFORMANCES OF DIFFERENCE TEC MODELS IN EAST ASIAN REGION

**11:15 Zeilhofer Claudia, DGFI, Germany**

REGIONAL 4-D MODELLING OF THE IONOSPHERIC ELECTRON DENSITY FROM SATELLITE DATA AND IRI

**Topside (8)**

**11:30 Sibanda Patrick, Hermanus Magnetic Observatory, South Africa**

EVALUATING TOPSIDE IONOSPHERE MODELS: A REVIEW OF THE MODELLING TECHNIQUES AND THE CURRENT STATUS OF TOPSIDE MODELLING

**11:45 Bhuyan Pradip, Dibrugarh University, India**

THE EQUATORIAL IONIZATION ANOMALY AT THE TOPSIDE F REGION OF THE IONOSPHERE ALONG 75OE MERIDIAN

**12:00 Lunch**

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**Chair: Bodo Reinisch**

**14:00 Bilitza Dieter, SPDF, Goddard Space Flight Center, United States**

AN EVALUATION OF THE NEW MODEL OPTIONS FOR THE IRI TOPSIDE ELECTRON DENSITY WITH TOPSIDE SOUNDER DATA

**14:15 Coïsson Pierdavide, ICTP, Italy**

ON THE USE OF NEQUICK TOPSIDE OPTION IN IRI 2007

**14:30 Bidaine Benoît, University of Liège, Belgium**

ASSESSMENT OF THE NEQUICK MODEL AT MID-LATITUDES USING GPS TEC AND IONOSONDE DATA

**14:45 Jakowski Norbert, Institute of Communications and Navigation, Germany**

LARGE SCALE IONOSPHERIC GRADIENTS OVER EUROPE OBSERVED IN OCTOBER 2003

**15:00 Kutiev Ivan, Geophysical Institute, BAS, Bulgaria**

RECONSTRUCTION OF TOPSIDE DENSITY PROFILE BY USING THE TOPSIDE SOUNDER MODEL PROFILER AND IONOSONDE DATA

**15:15 Liu Libo, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

THE IONOSPHERIC SCALE HEIGHTS DERIVED FROM THE INCOHERENT SCATTER RADAR MEASUREMENTS OVER ARECIBO AND MILLSTONE HILL

**15:30 Coffee break**

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**16:00 POSTER I**

**Chair: Manuel Hernández-Pajares**

**18:00 Adjourn**

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**THURSDAY**

**Ionospheric Storm Effects (7)**

**Chair: Bilitza**

**8:30 Reinisch Bodo, Univ. of Massachusetts, United States**

STUDY OF GEOMAGNETIC STORM EFFECTS USING DIGISONDE NETWORK DATA

**8:45 Boška Josef, Institute of Atmospheric Physics, ASCR, Czech Republic**

EFFECTS OF GEOMAGNETIC ACTIVITY ON THE E AND F REGION IONOSPHERIC DRIFTS DURING 2004–2007 YEARS

**9:00 Klimenko Maxim, Kaliningrad State Technical University, Russia**

EFFECTS OF SUBSTORM WITH CURRENT WEDGE IN THE NE AND ION COMPOSITION OF THE OUTER IONOSPHERE

**9:15 Kouris Stamatis, Aristotle University of Thessaloniki, Electrical and Computer Eng. Dept.**

MORPHOLOGY (AND CLIMATOLOGY) OF UPPER ATMOSPHERE DISTURBANCES

**9:30 Fuller-Rowell Tim, Space Environment Center, United States**

TOWARDS CHARACTERIZING TERRESTRIAL WEATHER IMPACTS IN IRI

**9:45 Depueva Anna, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russia**

DAYTIME F2-LAYER NEGATIVE USUAL AND Q-DISTURBANCE EVENTS: WHAT IS THE DIFFERENCE

**10:00 Coffee break (Thursday)**

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**Ionospheric Sounding (6)**

**Chair: Dalia Burešová**

**10:30 Latteck Ralph, Leibniz-Institut für Atmosphärenphysik, Germany**

D-REGION ELECTRON DENSITIES AT 69°N AFTER 3-MHZ DOPPLER RADAR OBSERVATIONS

**10:45 Al-Ubaidi Najat M. Rashid, Baghdad University/College of Science/ Astronomy & Space Department, Iraq**

THE ACCURACY OF IONOSPHERIC MODELS WITH IRAQI IONOSONDE OBSERVATIONS subsection 11:00 Chum Jaroslav, Institute of Atmospheric Physics, Czech Republic

MULTIPOINT CONTINUOUS DOPPLER SOUNDING IN THE CZECH REPUBLIC; FIRST RESULTS

**11:15 Scotto Carlo, Istituto Nazionale di Geofisica e Vulcanologia, Italy**

HIGHLY ADAPTIVE ELECTRON DENSITY PROFILE MODEL APPLIED TO IONOGRAMS FOR REAL TIME MONITORING

**11:30 Ruslan Latipov, Kazan State University, Russia**

IONOSPHERIC RESEARCH WITH HELP OF DOPPLER GONIOMETRIC COMPLEX “SPEKTR”

**11:45 Petrova Inna, Kazan State University, Russia**

RESEARCH OF WAVE PROCESSES IN IONOSPHERE ON THE BASIS OF DOPPLER EXPERIMENTAL DATA

**12:00 Lunch**

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**Excursion**

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**FRIDAY**

**F Peak Mapping (12)**

**Chair: Tim Fuller-Rowell**

**8:30 Bradley Peter A., Expert, United Kingdom**

OPTIONS FOR MAPPING FOF2

**8:45 McKinnell Lee-Anne, Hermanus Magnetic Observatory, South Africa**

PROGRESS TOWARDS A NEW GLOBAL FOF2 MODEL FOR THE INTERNATIONAL REFERENCE IONOSPHERE (IRI)

**9:00 Tomasik Michal, Space Research Centre, Polish Academy of Sciences, Poland**

MODELLING IONOSPHERE WITH NEURAL NETWORK OVER THE EUROPE REGION

**9:15 Tulunay Yurdanur, Middle East Technical University Aerospace Eng. Dept., Turkey**

FOF2 FORECAST 1-H IN ADVANCE DURING DISTURBED CONDITIONS BY USING A RECURRENT FUZZY NN

**9:30 Wan Weixing, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

EIGEN MODE ANALYSIS OF IONOSPHERIC IONIZATION PARAMETERS

**9:45 Tamara Gulyaeva, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Russia**

ALTERNATIVE MODEL OF THE IONOSPHERIC CRITICAL FREQUENCY REDUCED BY THE SOLAR ZENITH ANGLE

**10:00 Coffee break (Friday)**

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**Chair: Alain Bourdillon**

**10:30 Mikhailov Andrei, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russia**

THE MECHANISM OF QUIET-TIME DISTURBANCES IN THE MID-LATITUDE DAYTIME F2-LAYER

**10:45 Pulinets Sergey, Institute of Geophysics, UNAM, Mexico**

CRITICAL FREQUENCY FOF2 VARIABILITY OVER MEXICO

**11:00 Mosert Marta, CASLEO-CONICET, Argentina**

BEHAVIOR OF THE F2 REGION OVER THE ARGENTINE ANTARCTIC SECTOR

**11:15 Wang Xiao, Center for Space Science and Applied Research, China**

COMPARISON OF IONOSPHERIC F2 PEAK PARAMETERS FOF2 AND HMF2 WITH IRI2001 IN HAINAN

**11:30 Danilov Alexey, Institute of Applied Geophysics, Russia**

TIME AND SPATIAL VARIATIONS OF THE FOF2(NIGHT)/FOF2(DAY) VALUES

**11:45 Rothkaehl Hanna, Space Research Centre PAS, Poland**

FINE STRUCTURE OF MAIN IONOSPHERIC TROUGH

**12:00 Lunch**

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**Bottomside and E-Region (5)**

**Chair: Ludmila Třísková**

**14:00 Blanch Estefania, Ebre Observatory, Spain**

GLOBAL IMPROVEMENT OF THE IRI2001 PREDICTION OF BOTOMSIDE PARAMETERS BASED ON SPHERICAL HARMONIC ANALYSIS

**14:15 Mertens Christopher, NASA Langley Research Center, United States**

PROGRESS ON DEVELOPING AN EMPIRICAL IONOSPHERIC E-REGION SOLAR-GEOMAGNETIC STORM CORRECTION TO THE IRI MODEL USING TIMED/SABER DATA

**14:30 Ryabchenko Evgeny, Kazan State University, Russia**

GENERAL FEATURES OF 4–24-DAY WAVES IN SPORADIC E-LAYER VARIATIONS AND THEIR CONNECTION WITH EQUATORIAL STRATOSPHERIC QBO

**14:45 Depuev Victor, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russia**

SYNCHRONOUS NMF2 AND NME DAYTIME VARIATIONS DURING THE PERIODS OF QUIET-TIME F-2 LAYER DISTURBANCES

**15:00 Akchurin Adel, Kazan State University, Russia**

SHORT-PERIOD VARIATIONS OF VIRTUAL HEIGHTS OF THE MIDDLE IONOSPHERE BY VERTICAL SOUNDING WITH ENHANCED PRECISION

**15:15 Ratovsky Konstantin, Institute of Solar-Terrestrial Physics, Russia**

DIURNAL AND SEASONAL VARIATIONS OF THE ELECTRON DENSITY OVER IRKUTSK DURING THE DECREASE IN SOLAR ACTIVITY IN 2003-2006. OBSERVATIONS AND IRI-2001 MODEL PREDICTIONS

**15:30 Coffee break**

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**16:00 POSTER II**

**Chair: Lee-Anne McKinnell**

**18:00 Adjourn**

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**SATURDAY 8:30–10:00**

**MC COST Parallel session: New Developments (3)**

**Chair: Shigeto Watanabe**

**8:30 Moeketsi Daniel Mojalefa, Hartebeesthoek Radio Astronomy Observatory, South Africa**

VALIDATION OF UNB-IMT WITH IONOSONDE TEC MEASUREMENTS OVER SOUTH AFRICA

**8:45 Watanabe Shigeto, Hokkaido University, Japan**

IONOSPHERE-THERMOSPHERE COUPLING IN MIDDLE AND LOW LATITUDE REGIONS

**9:00 Talaat Elsayed, The Johns Hopkins University Applied Physics Laboratory, United States**

SOLAR AND LOWER ATMOSPHERE FORCING OF THE IONOSPHERE AS OBSERVED BY SATELLITES

**Temperatures and Drifts (3)**

**9:15 Truhlík Vladimír, Institute of Atmospheric Physics, ASCR, Czech Republic**

A DATA-MODEL STUDY OF THE SOLAR ACTIVITY DEPENDENCE OF THE TOPSIDE IONOSPHERE ELECTRON TEMPERATURE AT EQUATORIAL AND MID-LATITUDES

**9:30 Su Shin-Yi, Institute of Space Science, National Central University, Taiwan**

PREDICTING EQUATORIAL DENSITY IRREGULARITY OCCURRENCES FROM RESULTS OF STATISTICAL STUDY OF IRREGULARITY OCCURRENCES WITH VERTICAL DRIFT VELOCITIES

**9:45 Souza Jonas, INPE, Brazil**

AN EQUATORIAL ZONAL ION DRIFT MODEL FOR JICAMARCA

**10:00 Coffee break**

**Chairs: Dieter Bilitza, Bodo Reinisch**

**10:30–12:30 IRI - FINAL DISCUSSIONS, END OF WORKSHOP**

# Poster sessions

**Wednesday (16:00-18:00)**

**1. Alkar Ali Ziya, HACETTEPE UNIVERSITY, Turkey**

WEB BASED AUTOMATED TEC ESTIMATION WITH IONOLAB

**2. Yilmaz Atila, HACETTEPE UNIVERSITY, Turkey**

COMPARISON OF NEURAL NETWORK STRUCTURES IN TEC BASED REGIONAL IONOSPHERE MAPPING

**3. Sayin Isiltan, HACETTEPE UNIVERSITY , Turkey**

REGIONAL SPACE-TIME INTERPOLATION OF GPS-TEC WITH KRIGING

**4. Arikan Feza, HACETTEPE UNIVERSITY, Turkey**

INSTRUMENTAL BIAS ESTIMATION USING SINGLE STATION GPS/TEC

**5. Arikan Feza, HACETTEPE UNIVERSITY, Turkey**

CORRELOGRAM AND PDF ESTIMATION FOR TOTAL ELECTRON CONTENT

**6. Arikan Orhan, BILKENT UNIVERSITY, Turkey**

TOMOGRAPHIC RECONSTRUCTION OF THE IONOSPHERIC ELECTRON DENSITY AS A FUNCTION OF SPACE AND TIME

**7. Kutiev Ivan, Geophysical Institute, BAS, Bulgaria**

MODELING THE MEDIUM-SCALE TEC STRUCTURES, OBSERVED BY BELGIAN GPS RECEIVERS NETWORK

**8. Kouris Stamatis, Aristotle University of Thessaloniki, Electrical and Computer Eng. Dept., Greece**

ON THE SEASONAL DEPENDENCE OF TEC AND SLAB THICKNESS

**9. Bhuyan Pradip, Dibrugarh University, India**

ASSESSMENT OF IRI PREDICTABILITY FROM COMPARISON WITH MEASURED TEC OVER INDIAN LOW LATITUDES

**10. Mosert Marta, CASLEO-CONICET, Argentina**

IRI 2001/90 TEC PREDICTIONS OVER A LOW LATITUDE STATION

**11. Mosert Marta, CASLEO-CONICET, Argentina**

BEHAVIOR OF GPS TEC, ITEC AND IRI TEC PREDICTIONS OVER PRUHONICE

**12. McKinnell Lee-Anne, Hermanus Magnetic Observatory, South Africa**

PREDICTION OF GLOBAL POSITIONING SYSTEM TOTAL ELECTRON CONTENT USING NEURAL NETWORKS

**13. Romano Vincenzo, INGV, Italy**

WAVELET ANALYSIS OF RAW DATA FROM IONOSPHERIC SCINTILLATION GPS RECEIVERS

**14. Romano Vincenzo, INGV, Italy**

WWW.ESWUA.INGV.IT: THE WEB ACCESS TO THE "ELECTRONIC SPACE WEATHER UPPER ATMOSPHERE" SYSTEM.

**15. Todorova Sonya, Institute of Geodesy and Geophysics, Vienna University of Technology, Austria**

INTEGRATION OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) AND SATELLITE ALTIMETRY MEASUREMENTS TOWARDS COMBINED GLOBAL IONOSPHERE MAPS

**16. Zakharenkova Irina, West Department of IZMIRAN, Russia**

FEATURES OF IONOSPHERIC TOTAL ELECTRON CONTENT BEHAVIOR RELATED WITH EQUATORIAL REGION EARTHQUAKES

**17. Klimenko Maxim, Kaliningrad State Technical University, Russia**

HEAT BALANCE OF THE OUTER IONOSPHERE DURING SUBSTORM WITH CURRENT WEDGE

**18. Klimenko Maxim, Kaliningrad State Technical University, Russia**

HEAT BALANCE OF THE F-REGION IONOSPHERE DURING APRIL 8, 2005 SOLAR ECLIPSE

**19. Wan Weixing, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

STATISTICAL ANALYSIS ON SPATIAL CORRELATION OF IONOSPHERIC DAY-TO-DAY VARIABILITY BY USING GPS AND INCOHERENT SCATTER RADAR OBSERVATIONS

**20. Wan Weixing, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

ANNUAL AND SEMIANNUAL VARIATIONS OF THE IONOSPHERIC VERTICAL PLASMA DRIFTS OVER JICAMARCA: EMPIRICAL ORTHOGONAL FUNCTION ANAL YSIS

**21. Korenkov Yurij, West Departmen of IZMIRAN, Russia**

CALCULATION OF THE GLOBAL CLIMATOLOGY OF THE IONOSPHERIC PARAMETERS IN GSM TIP AND IRI MODELS

**22. Korenkov Yurij, West Departmen of IZMIRAN, Russia**

GLOBAL COMPARISON OF THE MODEL RESULTS OF GSM TIP WITH IRI FOR EQUINOX CONDITIONS

**23. Perrone Loredana, Istituto Nazionale di Geofisica e Vulcanologia, Italy**

FOF2 FORECAST DURING SEVERE GEOMAGNETIC ACTIVITY IN ROME OBSERVATORY

**24. Perrone Loredana, Istituto Nazionale di Geofisica e Vulcanologia, Italy**

STUDY ON SOLAR SOURCES AND POLAR CAP ABSORPTION EVENTS RECORDED AT MARIO ZUCCHELLI STATION, ANTARCTICA

**25. Pietrella Marco, Istituto Nazionale di Geofisica e Vulcanologia, Italy**

FURTHER OBLIQUE-INCIDENCE IONOSPHERIC SOUNDINGS OVER CENTRAL EUROPE TO TEST NOWCASTING AND LONG TERM PREDICTION MODELS

**26. Mayer C., DLR Neustrelitz, Germany**

COMPARISON OF THE IRI-2007 TOPSIDE ELECTRON DENSITY WITH CHAMP AND COSMIC/FORMOSAT 3 DATA

**27. Obrou Olivier, University of Cocody, Abidjan, Cote d'Ivoire**

TOTAL ELECTRON CONTENT (TEC) MODELING AT EQUATORIAL LATITUDES

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**Friday (16:00-18:00)**

**1. Benito Eulalia, Onera - Universit de Rennes 1, France**

IONOGRAM INVERSION BY SCANING IN ELEVATION WITH 2D HF RADAR. COMPARISON AT DIFFERENT FREQUENCIES.

**2. Astafyeva Elvira, Institute of Solar-Terrestrial Physics, Russia**

IONOSPHERE REDISTRIBUTION DURING STRONG GEOMAGNETIC STORMS AS SEEN BY THE CHAMP, TOPEX AND JASON-1

**3. Astafyeva Elvira, Institute of Solar-Terrestrial Physics, Russia**

IRI MODELING OF IONOSPHERE TRANSFER CHARACTERISTIC FOR RADIO AS TRONOMICAL SIGNALS AND SPACE WEATHER

**4. Kurkin Vladimir, Solar-Terrestrial Physics, Russia**

THE USE OF IRI-2001 MODEL FOR HF PROPAGATION FORECAST ON SUPERLONG PATHS

**5. Krasheninnikov Igor, IZMIRAN, Russia**

IRI-2001 MODEL EFFICIENCY IN THE PROBLEM OF IONOSPHERIC RADIOWAVE PROPAGATION FORECAST

**6. Bencze Pál, Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences, Hungary**

COMPLEX STUDY OF PROCESSES IN THE EARTH'S ENVIRONMENT BY GROUND BASED OBSERVATIONS

**7. Bhuyan Pradip, Dibrugarh University, India**

CIT RECONSTRUCTION OF THE EFFECT OF NOVEMBER 2004 GEOMAGNETIC STORM IN THE INDIAN IONOSPHERE

**8. Coïsson Pierdavide, ICTP, Italy**

STUDY ON THE NEQUICK BOTTOM-SIDE F2 LAYER THICKNESS PARAMETER

**9. Burešová Dalia, Institute of Atmospheric Physics of the Academy of Sciences of the Czech Republic, Czech Republic**

EVALUATION OF THE STORM MODEL STORM-TIME CORRECTIONS FOR EUROPEAN MIDDLE LATITUDES

**10. Kouba Daniel, Institute of Atmospheric Physics, ASCR, Czech Republic**

BASIC CHARACTERISTICS OF E-REGION PLASMA MOTION OVER PRUHONICE OBSERVATORY AND THEIR SEASONAL TRENDS

**11. Klimenko Maxim, Kaliningrad State Technical University, Russia**

EFFECTS OF APRIL 8, 2005 SOLAR ECLIPSE IN THE GLOBAL DISTRIBUTION OF THE FOF2

**12. Zhang Man-Lian, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

A SINGLE STATION EMPIRICAL MODEL OF M(3000)F2 FOR WUHAN BASED ON EIGEN MODE ANALYSIS

**13. Zernov Nikolay, Department of Radiophysics, the University of St.Petersburg, Russia**

CORRELATION OF DIFFERENT FREQUENCY L-BAND SATELLITE NAVIGATION SIGNALS ON THE SAME TRANSIONOSPHERIC LINK FOR SCINTILLATION CONDITIONS

**14. Yu Tao, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

USING THE RADIAL BASIS FUNCTION NEURAL NETWORK TO PREDICT IONOSPHERIC CRITICAL FREQUENCY OF F2-LAYER OVER WUHAN

**15. Wan Weixing, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

DATA ASSIMILATION OF INCOHERENT SCATTER RADAR OBSERVATION INTO A 1-DIMENSIONAL MID-LATITUDE IONOSPHERIC MODEL BY APPLYING ENSEMBLE KALMAN FILTER

**16. Wan Weixing, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

DATA ASSIMILATION IONOSPHERIC MODEL OF MIDDLE AND LOW LATITUDE BASED ON LEAST-SQUARE FIT METHOD AND TIME-IGGCAS MODEL

**17. Liu Libo, Institute of Geology and Geophysics, Chinese Academy of Sciences, China**

THE RESPONSE OF THE MIDLATITUDE IONOSPHERE TO SOLAR ECLIPSE: THE MEASUREMENTS AND MODELING

**18. Lomidze Levan, Georgian National Astrophysical Observatory (former Abastumani Astrophysical Observatory), Georgia**

MULTILAYER STRUCTURE IN THE IONOSPHERE F2 LAYER AND ITS SHORT-PERIOD OSCILLATION CAUSED BY SHEAR EXCITED ATMOSPHERIC VORTICAL PERTURBATION

**19. Tulunay Yurdanur, Middle East Technical University Aerospace Eng.**

MODELING IONOSPHERIC AND SOLAR PARAMETERS USING GENETIC PROGRAMMING APPROACH

**20. Terzuoli Andrew, DAYTON GRAD STUDY INST, United States**

NON-GAUSSIAN OTH RADAR CLUTTER CHARACTERIZATION USING A MIXTURE OF TWO RAYLEIGH PROBABILITY DENSITIES

**21. Maltseva Olga, Institute of Physics, Russia**

APPLICATIONS OF THE IRI MODEL IN EUROPE

**22. Mosert Marta, CASLEO-CONICET, Argentina**

ANALYSIS OF THE TOTAL ELECTRON CONTENT OVER AN ANTARCTIC STATION USING GPS MEASUREMENTS

**23. Mosert Marta, CASLEO-CONICET, Argentina**

VALIDATION OF THE STORM MODEL IN IRI2000 AT A HIGH LATITUDE STATION

**24. Šindelářova Tereza, Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Czech Republic**

IONOSPHERIC EFFECTS OF CONVECTIVE STORMS IN HF DOPPLER SHIFT MEASUREMENTS UNDER GEOMAGNETIC QUIET OR SLIGHTLY DISTURBED CONDITIONS

**25. Warrington Michael, University of Leicester, United Kingdom**

AN EXPERIMENTAL INVESTIGATION INTO THE FEASIBILITY OF MIMO TECHNIQUES WITHIN THE HF BAND

**26. Šauli Petra, Institute of Atmospheric Physics ASCR , Czech Republic**

WAVELET-BASED ANALYSIS OF SPORADIC E LAYER

# Abstracts

## IRI MODELING OF IONOSPHERE TRANSFER CHARACTERISTIC FOR RADIO ASTRONOMICAL SIGNALS AND SPACE WEATHER

**Afraimovich, E.L., Yasukevich, Y.V., Astafyeva, E.I., Tatarinov, P.V.**

Institute of Solar-Terrestrial Physics SB RAS, P.O.Box 291, Irkutsk 33, 664033

Continuous improvements of VHF radio telescopes have been made due to growing scientific and applied importance to radio astronomy. VHF signals are widely used for observations of the sun and pulsars. Nowadays huge low-frequency radio astronomical arrays (LOFAR, 30-240 MHz; MIRA, 80-300 MHz) are being constructed to record pulsar radiation at maximum possible distance. Registration of solar radio emission intensity at fixed frequencies and in spectral VHF band is very important along with other methods of monitoring of coronal mass ejection. In order to extend the dimension of observable solar radio corona they endeavor to use maximum permissible low frequencies of VHF band. At the interpretation of the ground based radio telescopes data it is necessary take into account the possible distortions of radio astronomical signals at the Earth ionosphere. However in contrast to modern radar and navigation systems (GPS, GLONASS, GALILEO), where very accurate reconstruction of ionosphere parameters is a built-in function, in present-day radio astronomy a retrieve of ionosphere transfer characteristics has not been appropriately worked out yet. We have developed a method and software for calculation of the ionosphere measure of rotation RM, and the measure of dispersion DM for specific experimental and space weather conditions. We used the ionosphere model IRI-2001, magnetic field model IGRF-10 and values of ionosphere total electron content as deduced from GPS measurements. The obtained values of the ionosphere DM and RM were recalculated into characteristics of phase delay, Faraday amplitude modulation, spectrum distortion and polarization changes (Afraimovich, Astron. Astrophys., 1981, V.97, N2, 366-372). We proposed the relevant method of ionosphere corrections permitting to reconstruct the initial parameters of radio astronomical signals ("before ionosphere"). In the report we made calculations for different levels of geomagnetic and solar activity. On the examples of radio telescopes LOFAR and MIRA we examined dependence on location of radio telescope and on angular position of radio sources as well.

## GLOBAL IMPROVEMENT OF THE IRI2001 PREDICTION OF BOTOMSIDE PARAMETERS BASED ON SPHERICAL HARMONIC ANALYSIS

**Altadill, D.[1], Torta, M.[2], Blanch, E.[2]**

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The time series of hourly electron density profiles N(h) obtained from over twenty stations distributed world-wide have been used to obtain N(h) average profiles on a monthly basis and to extract the expected bottomside parameters that define the IRI profile under quiet conditions. The time series embrace the time interval from 1998 to 2006, which practically contains the entire solar cycle 23. The Spherical Harmonic Analysis (SHA) has been used as an analytical technique for modeling globally, initially, the B0 parameter as a general function on a spherical surface.

Due to the irregular longitudinal distribution of the stations over the globe, it has been assumed that the ionosphere remains approximately constant in form for a given day under quiet conditions for a particular coordinate system. Since the Earth rotates under that fixed system, the time differences have been considered to be equivalent to longitude differences. The magnetic dip coordinates have been tested to be the best choice to define the parallels that pass over the location of the original stations to distribute the 24 hourly values in longitude. Colatitudinal variations have been allowed till n=6 by the SHA model while longitudinal variations (equivalent to diurnal) till m=4. The time dependence has been represented by a two-degree Fourier expansion to model the annual and semiannual variations and the year-by-year analyses of the B0 has furnished nine sets of spherical harmonic coefficients. The spatial-temporal yearly coefficients have been further expressed as linear functions of Rz12 to model the solar cycle dependence. The resultant analytical model provides a tool to predict B0 at any location distributed among the used range of magnetic dip latitudes (70.6°N - 52.1°S) and at any time that improves the fit to the observed data with respect to IRI prediction. Results over the different station data and global contour maps of B0 at particular times and epochs are presented along with the envisaged new developments.

## OBTAINING ACCURATE WORLDWIDE DISTRIBUTED ELECTRON DENSITY PROFILES FROM GPS OCCULTATION DATA: COSMIC/FORMOSAT-3 CONSTELLATION

**Aragon-Angel, A., Hernandez-Pajares, M., Miguel Juan, J., Sanz, J.**

Research group of Astronomy and Geomatics, Technical University of Catalonia, gAGE/UPC, Mod. C3 Campus Nord UPC, E08034-Barcelona, Spain

Since 1995, with the first GPS occultation mission on board Low Earth Orbiter (LEO) GPS/MET, it has been shown that the inversion techniques applied to GPS occultation data, constitutes a powerful tool to retrieve accurate worldwide distributed refractivity profiles, i.e. electron density profiles in the case of Ionosphere. Important points to guarantee the accuracy is to take into account horizontal gradients and topside electron content above the LEO orbit (see Improved Abel inversion in Hernández-Pajares et al. 2000, García-Fernández et al. 2003). This allows improving the accuracy from 20 to 50%, depending on the conditions, latitude and epoch regarding to Solar cycle. More recently, the COSMIC/FORMOSAT-3 satellite constellation, formed by 6 micro-satellites, is being deployed since April 2006 in circular orbit around the Earth, with a final altitude of about 700-800 kilometers. Its global and almost uniform coverage will overcome one of the main limitations of this technique which is the sparcity of data, related to lack of GPS receivers in some regions. This new amount of incoming data can significantly stimulate the development of radio occultation techniques with the use of the huge volume of data provided by the COSMIC constellation to be processed and analysed updating the current knowledge of the Ionosphere. In this context, a summary of the Improved Abel transform inversion technique and the first results based on COSMIC constellation data will be presented. Moreover, comparison of different approaches and strategies in the occultation data inversion will be compared and discussed, taking advantage of the COSMIC datasets. References: M. Hern'andez-Pajares, J. M. Juan and J. Sanz, Improving the Abel inversion by adding ground GPS data to LEO radio occultations in ionospheric sounding, GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 16, PAGES 2473-2476, AUGUST 15, 2000. M. Garcia-Fern'andez,

M. Hern'andez-Pajares, M. Juan, and J. Sanz, Improvement of ionospheric electron density estimation with GPSMET occultations using Abel inversion and VTEC Information, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. A9, 1338, doi:10.1029/2003JA009952, 2003.

## MULTIPATH SEPARATION-DIRECTION OF ARRIVAL (MS-DOA) WITH GENETIC SEARCH ALGORITHM FOR HF CHANNELS

**Arikan, F.[1], Koroglu, O.[1], Fidan, S.[1], Arikan, O.[2], Guldogan, B. [2], Yilmaz, N.[3].**

[1]Hacettepe University, Department of Electrical and Electronics Engineering, Ankara, Turkey, [2]Bilkent University, Department of Electrical and Electronics Engineering, Ankara, Turkey, [3]Turkish General Staff, Ankara, Turkey

Ionospheric channels exhibit random space, time and frequency variations which cause various degrading effects on the transmitted signals. For proper recovery of the transmitted signals, the modes and multipath components need to be successfully separated at the receiver. There have been various efforts to separate the modes and overcome the degrading effects of fading. One major direction is to apply diversity techniques including angle of arrival, polarization, frequency and time diversity. In spite of the advantages, due to variation of HF channel in time, space and frequency, none of the above listed diversity techniques is a universal solution. Although the RAKE receiver has been in use for some time, the performance for channels with even moderate ISI is unacceptable. The Faraday Rotation principle, which is used to separate O and X modes, requires the knowledge of the polarization properties of the waves at the exit of the ionosphere and directions of the earth's magnetic field components at the receiver with very high accuracy. Eigenstructure methods such as MUSIC, CLOSEST and ESPRIT are advantageous over the classical DF methods with typical homogeneous array apertures. Yet, these algorithms fail to distinguish highly correlated multipath signals. Algebraic methods for deterministic source separation and DOA estimation have certain advantages over the adaptive techniques. The sources impinging on the antenna array are determined as a collection of eigenvalues and eigenvectors utilizing the subspace properties of the antenna array response matrix. In this study, the basic algebraic subspace methods for blind source estimation are adopted to develop an algorithm for separation of the multipath modes successfully and find their arrival angles with high accuracy. Multipath Separation-Direction-Of-Arrival (MS-DOA) method allows the user to recover the multipath signals with very high accuracy. For homogeneous arrays, the number of antennas that are required in the array has to be one more than the number of incoming signals. In MS-DOA, both the array output vector and incoming signal vector are expanded in terms of a basis vector set. A linear system of equations equation is formed using the coefficients of the basis vector for the array output vector, the incoming signal vector and the array manifold. The angles of arrival in elevation and azimuth are obtained as the maximizers of the sum of the magnitude squares of the projection of the signal coefficients on the column space of the array manifold. Once the array manifold is estimated then the incoming signals can also be determined using the basis vectors and signal coefficients. For certain array configurations, the search for maximizing angles can be eliminated by using closed form solutions of the constructed linear system. In this study, alternative Genetic Search (GS) algorithms for the maximizers of the projection sum are investigated using ionospheric channel simulations and experimental data. GS algorithms provide promising results for forming the search space especially for large arrays and multiple incoming signals. Studies are continuing in this area for the optimization of the search routines for various ionospheric conditions, SNRs, array manifold formation and antenna choice.

## TOMOGRAPHIC RECONSTRUCTION OF THE IONOSPHERIC ELECTRON DENSITY AS A FUNCTION OF SPACE AND TIME

**Arikan, O.[1], Erturk, O.[1], Feza Arikan, F.[2]**

[1]Bilkent University, Department of Electrical and Electronics Engineering, Ankara, Turkey,[2]Hacettepe University, Department of Electrical and Electronics Engineering, Ankara, Turkey

Estimation of electron density distribution in the ionosphere as a function of space and time is a problem with important application areas. GPS satellites and receivers provide Total Electron Content (TEC) measurements along a network of lines connecting satellites to the receivers. Therefore a line-projection relates the electron density distribution to the available measurements resulting in a tomographic set up for the estimation problem. However the classical tomographic reconstruction techniques fail to provide reliable results with the limited number of available line-projections. In addition, the time varying nature of the electron density distribution creates further complications. In this work, to improve the reliability of the obtained 3-D estimates, we propose an SVD based tomographic reconstruction technique, where the IRI-2001 model is used as an a priori source of information. To improve the performance of the estimation, we form the SVD basis by using IRI-2001 model results for the location and the time of interest. Also, to account for variation as a function solar activity, we consider IRI-2001 model results with similar sun-spot number index. We investigated variations in the obtained SVD basis as a function of spatial and temporal location in detail showing that there is significant change with respect to both variables. Therefore a reconstruction based on a fixed basis would have limited applicability around the earth. We also investigated reconstruction quality of the proposed technique both on synthetic and real measurements showing that robust estimation of the ionospheric electron density distribution that fits to the observed data as well as the IRI-2001 model is possible.

## IONOSPHERE REDISTRIBUTION DURING STRONG GEOMAGNETIC STORMS AS SEEN BY THE CHAMP, TOPEX AND JASON-1

**Astafyeva, E.I., Tatarinov, P.V.**

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The interconnection between southward interplanetary magnetic field and the Earth's magnetic field leads to strong dawn-to-dusk electric fields which can have dramatic effects on the ionosphere. The interplanetary electric fields can penetrate to the low-latitude ionosphere, producing significant alteration in the equatorial ionospheric electrodynamics; they play very important role in the storm-time redistribution of the global ionosphere plasma. Here we analyzed ionosphere effects of several strongest geomagnetic storms occurred in the 2001-2005. For this purpose we used observational data from the CHAMP and SAC-C satellites and from satellite

altimeters TOPEX and Jason-1. This allowed us to study in detail the ionosphere redistribution due to geomagnetic storms, dayside ionospheric uplift and ionosphere plasma accumulation within the crests of the EIA. Besides, use of global ionosphere maps of vertical total electron content (TEC) together with the method of calculation of TEC equal lines seeming displacements allowed us to obtain quantitative characteristics of the ionosphere plasma redistribution during the main phase of geomagnetic storms.

## ANTENNA PATTERN CONTROL OF PLANAR ARRAYS FOR LONG-RANGE COMMUNICATIONS

**Azevedo, J. A. R.**

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As an alternative to standard antennas and due to the advent of low-cost digital processors and materials, adaptive antenna arrays are increasingly considered for applications in long-range communications. The beam control potentialities provide the improvement of the performance of the communication systems. In this context, this work presents a technique that permits to synthesize the antenna pattern of a planar array. Considering that the relationship between the array factor and the array excitations for the far field region is a Fourier transform in the appropriate variables, the non-uniform sampling procedure is extended for planar arrays. These arrays permit a further control of the antenna pattern since two dimensions of space are used. The technique considers a number of array factor points equal to the array size, which is used to impose appropriated positions and values in the pattern. The produced array factor passes through those points with the desired values, which allows synthesize antenna patterns with appropriated characteristics. The theory is presented in order to develop the necessary direct expressions to calculate the array excitation. The array factor can be obtained using the inverse Fourier transform. As application examples, it is possible with this technique to define the level of each side lobe in the antenna pattern, to control the main beam and to impose nulls in prescribed directions of the pattern.

## COMPLEX STUDY OF PROCESSES IN THE EARTH'S ENVIRONMENT BY GROUND BASED OBSERVATIONS

**Bencze, P., Wesztergom, V.**

Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences, H-9401 Sopron

Mitigation of ionospheric effects on radio systems is only possible, if processes in the Earth's environment are known in the required degree. In case of radio systems ionospheric effects are related to radio wave propagation. However, radio wave propagation depends on the state of plasma in the ionosphere and magnetosphere. Processes responsible for state of plasma and its variations there are connected with solar activity and phenomena in the interplanetary space. These processes are reflected in variations of the geomagnetic field and ioospheric parameters. Geomagnetic variations are due partly to currents generated by flux of changed particles (auroral electrojet, ring current) originating in the plasmasheet, partly related to plasma waves of interplanetary and terrestrial origin (geomagnetic pulsations, traveling ionospheric disturbances). Coupling between the state of the interplanetary

space (solar activity) and static, as well as electromagnetic fields of terrestrial ongin may indicate effect of solar activity on weather. For study of these processes recording of geomagnetic variations are used in sevealing of changes in the magnetosphere and plasmasphere. Parameters of geomagnetic pulsations (period, amplitude, polarisation) depend on plasma density in the inner magnetosphere (plasmasphere). Plasma density in the plasmasphere is determined by the F region of the ionosphere implemented by plasma transport and shown by vertical sounding of the ionosphere. Study of the ionosphere issupplemented by GPS measurements. Phenomene, as whistlers are responsive to plasma density variations indicating its variations. Variations of static electric field (atmosphere electric field) maintuned by the global thunderstorm activity and resonances of the Earth-ionosphere cavity resonator (indicators of changes of the global thunderstorm activity may show influence of processes induced by extraterrestrial sources. These processes are studied in the "Széchenyi István" Geophysical Observatory Nagycenk of the Hungarian Academy of Sciences (47°38'N, 16°43'E). GPS measurements are carried out by the permanent GPS station from building of the Institute in Sopron.

## IONOGRAM INVERSION BY SCANING IN ELEVATION WITH 2D HF RADAR. COMPARISON AT DIFFERENT FREQUENCIES.

**Benito, E.[1], Saillant, S.[1], Rannou, V.[1], Bourdillon, A.[2]**

[1]ONERA, [2]Université de Rennes

A backscatter radar system is an oblique HF radar where the transmitted wave is reflected from the ionosphere, scattered from the ground and returned via the ionosphere to the receiver. The distance covered by the radar's wave is a three parameters function: the ionospheric characteristics, the transmitted frequency and the elevation angle. Our purpose is to determine the ionospheric characteristics from radar backscatter ionograms. In order to fit the frequencies on the focus area and to localize the targets accurately, we will use an inversion method. Most of the inversion methods use the backscatter ionogram obtained with a frequency scan backscatter sounding. These methods are unstable. Our radar is capable to make an elevation-scan backscatter sounding, so we will use that information to realise the inversion. The model of the ionosphere used for the inversion method is the Multi Quasi-Parabolic layer model. This model has been used because it allows a simple analytical solution for the propagation equations. The purpose is to recover the initial model parameters (fc, hm, ym) from n points of the ionogram. We use a Bayesian approach for that. We will compare the initial model parameters obtained after inversion of backscatter ionograms at different frequencies. Normally, we must obtain the same parameters at different frequencies because the ionosphere is unchanged.

## THE EQUATORIAL IONIZATION ANOMALY AT THE TOPSIDE F REGION OF THE IONOSPHERE ALONG 75OE MERIDIAN

**Bhuyan, P.K., Bhuyan, K., Mahanta, P.**

Department of Physics, Dibrugarh University, Dibrugarh 786 004, Assam, India

The electron density measured by the Indian satellite SROSS C2 from 1995 to 2000 are used to study the seasonal variation of the equatorial ionization anomaly

(EIA) at the altitude of ∼500 km in the 75°E longitude sector. Results show that the latitudinal position, peak electron density and crest to trough ratios of the anomaly crests vary with season and from one year to another. They are also asymmetric about the geomagnetic equator. The latitudinal position and peak density of the crests of the anomaly has been found to bear a good positive correlation with the equatorial electrojet (EEJ) as well as sunspot activity.The EIA as obtained from the IRI during this period is compared with the SROSS C2 measurenents to assess the predictability of the model in the Indian zone.

## ASSESSMENT OF IRI PREDICTABILITY FROM COMPARISON WITH MEASURED TEC OVER INDIAN LOW LATITUDES

**Bhuyan, P.K., Borah, R.R., Bora, S., Bhuyan, K.**

Department of Physics, Dibrugarh University, Dibrugarh 786004 Assam India

Total electron content (TEC) measured simultaneously using Global Positioning System (GPS) satellites at 18 locations in North-South and East-West directions across the Indian subcontinent during 2004 and 2005 are used to assess the predictability of the International Reference Ionosphere along 75°E meridian. Results show that the measured TEC are in general lower than those predicted by the IRI in all seasons and across all latitudes. The equatorial ionization anomaly for observed TEC is sharp while that predicted by the model tends to spread over a range of latitudes centering 20° N. The time of occurrence of the anomaly crest also varies between observed and predicted TEC. A comparison of the TEC predicted by the IRI storm model during magnetically disturbed days of July 2004 and November 2004 reveal the inadequacy of the storm model at low latitudes. For example, during the July 2004 storm, EIA predicted by the IRI gradually decreases in strength from July 23 to July 25 whereas observed anomaly in TEC is found to be strong on July 23 and July 25 i.e. the days of storm. Similarly, the IRI has not been able to predict the measured variations around the equatorial anomaly latitudes during the November 2004 storm period.

## CIT RECONSTRUCTION OF THE EFFECT OF NOVEMBER 2004 GEOMAGNETIC STORM IN THE INDIAN IONOSPHERE

**Bhuyan, P.K., Bhuyan, K., Mahanta, P.**

Department of Physics, Dibrugarh University, Dibrugarh 786004 Assam India

In recent years, radio ray tomography of the ionosphere has developed in to a very useful technique for the study of the ionosphere. Compact generalized singular value decomposition (CGSVD) is used to study the response of the Indian equatorial and low latitude ionosphere to changes in the sun earth space weather during a period of intense geomagnetic activity in November 2004. Data recorded at four GPS receiving cites along 73oE longitude in India has been used to reconstruct the ionospheric electron density distribution during this period of intense geomagnetic activity. The IRI is used as a regularization profile for constructing the tomograms. The reconstruction study reveals the storm-induced effect on the growth and decay of the Equatorial Ionization Anomaly (EIA). Independent foF2 and h'F data collected from an equatorial ionosonde station has also been used to study the behavior of the ionosphere during the storm period. The results have shown that the foF2 is reduced by a large value from the mean as the Dst index fell to very low values.

A comparison of the results from the reconstructions and independent ionosonde observations is presented in the paper.

## ASSESSMENT OF THE NEQUICK MODEL AT MID-LATITUDES USING GPS TEC AND IONOSONDE DATA

**Bidaine, B.**[1]**, Warnant, R.,** [2]

[1]Unit of Geomatics, University of Liège, Belgium, [2]Royal Meteorological Institute of Belgium

The ionosphere plays a crucial role in GNSS accuracy. In extreme cases, this electrically charged part of the atmosphere can lead to errors in positioning exceeding 100m. At first approximation, the ionospheric effect depends on the frequency of the incident signal and on the total content in free electrons of the ionosphere ("total electron content" TEC) which is the integral of the electron density on the path between the satellite and the receiver. The modelling of this parameter reveals then itself to be critical in particular for single-frequency receivers, the most common ones constituting the mass market, but also for multiple-frequency devices which will comprise a fallback mode in single frequency within the framework of critical applications such as civil aviation where the level of precision must be guaranteed in all circumstances. The NeQuick model, which has been chosen for correcting the ionospheric error contribution in GALILEO single frequency users, calculates the electron density at a given point of the ionosphere according to the time conditions and the solar activity. This electron density can be integrated along the path from the receiver to the considered satellite to provide the TEC. The NeQuick model depends on a parameter Az ("effective ionization level") which will be daily updated by the GALILEO ground stations to give the solar activity information to the model. In order to reach the ionosphere error correction level objective (70% or 20 TECu whichever is larger), the model itself as well as its use for GALILEO are investigated. Different situations have to be considered: different latitude regions (space conditions), different hours, seasons and years (time conditions) and specific phenomena appearance (magnetic storms, Travelling Ionospheric Disturbances – TIDs). In addition the results can be compared to different data sets among which GPS slant or vertical TEC measurements, Global Ionospheric Maps, ionosonde profiles, topside soundings but also other ionosphere models results such as IRI. As a first step in a thorough comparison process, we take benefit of various ionosphere data from the Dourbes Observatory (Belgium) where ionosonde and GPS TEC data are available on a period of more than one solar cycle, to study the mid-latitudes. We first investigate the difference between GPS-derived vTEC for Dourbes station and vTEC values from NeQuick for the latest years (between solar maximum in 2000 and minimum in 2006) in order to observe the temporal dependencies towards Universal Time, season and solar activity. The paper analyses the different situations when NeQuick fails to represent TEC in an adequate way to provide an efficient correction for navigation. Ionosonde measurements will help in the interpretation of these situations.

## AN EVALUATION OF THE NEW MODEL OPTIONS FOR THE IRI TOPSIDE ELECTRON DENSITY WITH TOPSIDE SOUNDER DATA

**Bilitza, D.**

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IRI-2007 provides two new options for the topside electron density profile: (a) an correction of the IRI-2001 model, and (b) the NeQuick topside formula. We use the large volume of Alouette 1, 2 and ISIS 1, 2 topside sounder data to evaluate these two new options with special emphasis on the uppermost topside where IRI-2001 showed the largest discrepancies. We will also study the accurate representation of profiles in the equatorial anomaly region where the profile function has to accommodate two latitudinal maxima (crests) at lower altitudes but only a single maximum (at the equator) higher up. In addition to the two new options we will also include the old IRI-2001 model and the Intercosmos-based topside model of Triskova, Truhlik, and Smilauer (2006) in our analysis.

## SHORT-PERIOD VARIATIONS OF VIRTUAL HEIGHTS OF THE MIDDLE IONOSPHERE BY VERTICAL SOUNDING WITH ENHANCED PRECISION

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A technique of height resolution enhancement ($\sim$300 m) for coherent pulse sounding of an ionosphere is used by the pulse vertical sounding of an ionosphere. The method of maximum likelihood in spectral domain is used as the basis for calculation of group delay. The main field of our research is the study of the irregular ionosphere structure and the variations of ionospheric parameters under the impact of neutral atmosphere. The first experiment was conducted on 27 May, 2006, when sounding had been conducting from 10:00 till 19:00 LT on two frequencies 4.7 and 4.9 MHz with sounding period of 1 minutes. In this case the sample rate is magnified to one sounding per minute, which allows to investigate oscillations close to Brunt-Väisälä frequency. Further, a spectral analysis of virtual height variations registered with enhanced resolution was performed to study a F layer irregular structure. Estimations of spectral power density, made on the basis of the MUSIC enhanced resolution method are performed. The second experiment was conducted on 18 March, 2007. The MUSIC method was chosen because it lets us to derive a high spectral resolution in case of relatively small length of an analysed series. It also gives the possibility to detect the presence of narrow-band spectral component and to estimate their frequencies. MUSIC method is supposed to give a pseudo-spectrum estimation, because a PSD Fourier image may not be in coincidence with correlation function. To conceive the values of different spectral components of virtual height variations, the correspondence of spectral estimations obtained by MUSIC algorithm and Welch's averaged modified periodogram method is investigated. The spectral analysis with enhanced frequency resolution, applied to the measurements of virtual reflection height with enhanced altitude resolution, allows us to reveal clearly the spectral features such as slope, cut-off frequency and specific frequencies with periods of 4-60 min. Thus, the offered technique is applicable for more detail investigation of parameters of traveling ionospheric disturbances in the middle ionosphere. Acknowledgments This work was supported by the Russian Foundation for Basic Research, projects No.06-05-65150, 05-05-64651.

## EFFECTS OF GEOMAGNETIC ACTIVITY ON THE E AND F REGION IONOSPHERIC DRIFTS DURING 2004 – 2007 YEARS.

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The digisonde DPS-4, which is in operation at the Pruhonice observatory of the Institute of Atmospheric Physics, Prague (IAP) from 2004, enables us to carry out ionospheric drift measurements. Using standard mode of autodrift measurements the velocity of the F region drifts is usually determined in the vicinity of the peak of the electron density profile (N(h) profile). Since 2005 we are also measuring ionospheric drifts at the heights of the ionospheric E region (within the altitudinal interval of 95-145 km). Here we present the analysis of the plasma drifts of two different ionospheric regions observed under moderate-to-intense ionospheric storm conditions. Storm effects on the electron density distribution are also presented.

## MIERS : MITIGATION OF IONOSPHERIC EFFECTS ON RADIO SYSTEMS

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The objectives of the COST 296 Action MIERS are presented describing also the organisation in working groups and working packages, the participants, the progress made recently and the plan for the next year.

## OPTIONS FOR MAPPING FOF2

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In 1969 the CCIR produced and recommended for international use global numerical maps of monthly median values of the ionospheric characteristic foF2. Dissatisfied with some aspects of these maps, in 1984 an URSI Working Party developed alternate maps. The current version of the IRI computer code includes both these CCIR and URSI maps as an option, and although from time to time dissatisfaction with both sets of maps has been expressed, hitherto IRI efforts have largely been confined to specifying the relative form of the height distribution of electron density parametric in terms of the peak density or foF2. It is noted that the ITU-R, successor organisation to the CCIR, has now proposed replacing its numerical coefficients version with direct digital values on a uniform latitude-longitude grid, thereby making it possible for updates to be introduced over limited areas where ionospheric information becomes available from other sources. The present Workshop offers the opportunity for a review of the best way forward in mapping and this paper considers some aspects that may be followed. Particularly there is concern that the ionosphere has changed since the maps were first produced and there is intense interest to determine if use may be made of GPS or other satellite data in conjunction with an ionospheric model to give additional foF2 information over the large ocean areas not otherwise sampled. This paper will address these aspects, paying particular attention to the purposes for which the maps are wanted. Hitherto the CCIR and URSI maps have been seen as standards against which other maps have been compared, but here it is suggested that it is preferable to allow

external requirements to determine what maps are best for a particular application. It may well be that the IRI should introduce a number of agreed sets of maps for different purposes. Features that will be touched upon include the relative options of grid-point value versus functional forms of representation, spatial and temporal scale sizes of changes, allowances for solar-cycle variations, the need for regional as well as global maps, and the desirability of having a real-time mapping capability within the IRI.

## EVALUATION OF THE STORM MODEL STORM-TIME CORRECTIONS FOR EUROPEAN MIDDLE LATITUDES

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Modeling and forecasting of the ionospheric parameters is very useful for different radio communication purposes. As long as variations in the ionosphere are related in regular patterns, empirical models, such as IRI model, estimate sufficiently corrections for the ionosphere effects on radio wave propagations. During geomagnetic storms variability of the ionospheric parameters increases substantially and makes forecasting more complicated. Recently the IRI2001 model contains a geomagnetic activity dependence based on an empirical Storm-Time Ionospheric Correction Model (STORM), which is driven by an index derived from the previous thirty hours of geomagnetic activity. Here we present results of the storm-time corrections quality evaluation for European middle latitudes. The created database incorporates 65 strong-to-severe geomagnetic storms which occurred within the period 1995-2007. We studied ionospheric F region response to geomagnetic storms analyzing changes in the state of ionization at the peak of electron density (NmF2). As for the seasonal preference, during storm main phase over European middle latitude only negative phases dominate in summer (May-August), while during winter (October-February) occurrence of both negative and positive phases is more probable. To evaluate the quality of the STORM model output we compared it with observed ionospheric response above at least 4 European middle latitude stations during strong-to-severe winter and summer geomagnetic storms. To perform a detailed comparison between observed and model-generated NmF2 values the correlation coefficient, mean root-square error (RMS error), skewness and a confidence interval are evaluated. The STORM model more effectively captures the negative phases of the summer ionospheric storms, while electron density ehancement during winter storms is reproduced with lower accuracy.

## SCIENCE RATIONAL FOR MIERS/IRI COLLABORATION

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The Action 296 on Mitigation of Ionospheric Effects on Radio Systems (MIERS) is a comprehensive grass-roots European effort under the COST (European Cooperation in the Field of Scientific and Technical Research) umbrella to be conducted over the period 2005-2009. MIERS builds on the experience of COST's several successful actions on ionospheric research and application. This action aims to develop an increased knowledge of the effects imposed by the ionosphere on practical radio systems, and for the development and implementation of techniques to mitigate the deleterious effects of the ionosphere on such systems. The main functions of MIERS are: (a) to provide continues ionospheric monitoring and modelling; (b) to significantly enhance our understanding of ionospheric influence on both advanced terrestrial and space based systems; and (c) to mitigate ionospheric effects on these systems. MIERS would also help the science communities in many similar on-going individual, national and international activities. In this paper, we will highlight some of the aspects of MIERS science and attempt to discus how IRI (International Reference Ionosphere) and MIERS expertise can be brought together with a well-defined purpose of understanding the ionospheric environment and its impact on radio communications.

## EQUATORIAL STUDIES OF SCINTILLATION IN SUPPORT OF LOW FREQUENCY SPACE RADARS

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Measurements of V/UHF radio signal characteristics are being undertaken in both the Pacific and the Atlantic sectors. Together with a series of theoretical studies these measurements are being used to support the development of low frequency space based radars. Measurements have been undertaken using the ALTAIR V/UHF radar on Kwajalein atoll in the Pacific Ocean of the wideband trans-ionospheric channel impulse response. These are being related to theoretical studies using the Trans-Ionospheric Radio Propagation Simulator (TIRPS) which embodies a multi-screen parabolic equation model of the propagation path. The data are also being compared with incoherent scatter radar measurements made using the same radar. In addition measurements are also being made on Ascension Island in the Atlantic, using a single GPS receiver. The one second resolution TEC variations are being analyzed in the context of baseline design for a low frequency radar. This paper will review and report on the progress being made within these studies.

## THE VARIABILITY AND PREDICTIBILITY OF THE IRI SHAPE PARAMETERS OVER GRAHAMSTOWN, SOUTH AFRICA

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The International Reference Ionosphere (IRI) shape parameters, B0, B1 and D1 provide a representation of the shape of the F2 layer, the thickness of the F2 layer and the shape of the F1 layer of the ionosphere respectively. This parameter can be determined from electron density profiles that are inverted from ionograms recorded with an ionosonde. Data representing the B0, B1 and D1 parameters with a half hourly or hourly interval, were scaled and deduced from the digital pulse sounder ionosonde at the Grahamstown, South Africa (33.3°S, 26.5°E) station for the period April 1996 to December 2006. An analysis of the diurnal, seasonal, and solar variations of the behaviour of these parameters using monthly medians was undertaken for the years 2000, 2004 and 2005. Comparisons between the observational results and that of the IRI model (IRI 2001 version) were made. The study showed that

the IRI 2001 model is deficient in the prediction of the IRI shape parameters as determined by ionosonde measurements. The variations of the B0 and B1 parameters for this mid latitude station were then modelled using the technique of Neural Networks (NNs). This paper will present the results of prediction from the NN model compared with observations and predictions from the IRI 2001 model.

## MULTIPOINT CONTINUOUS DOPPLER SOUNDING IN THE CZECH REPUBLIC; FIRST RESULTS

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In 2004, we started operating continuous Doppler Sounding of the ionosphere to investigate infrasonic and short period gravity waves that cannot be detected by ionosondes because of their relatively high frequencies. Since January 2007, the Institute of Atmospheric Physics (IAP), Prague has been operating four stable transmitters, distributed in the western part of the Czech Republic and working at a frequency of ∼3.59 MHz. Their frequencies are mutually shifted to 4 Hz. One receiver, located at the main building of the IAP, receives signals from all these transmitters. After primary processing, the data are visualised by means of Doppler shift spectrograms and further analysed. Multipoint measurements enable us to investigate the horizontal propagation of ionospheric disturbances (waves) and to estimate the horizontal distances at which these disturbances (waves) are correlated. We present first results of these observations and analysis. We also focus on the cross-correlations between Doppler shift records and the variations of geomagnetic field measured at the observatory of Budkov in the south of the Czech Republic. We have found distinct cross-correlations for oscillations of a period ∼1 minute. These oscillations usually occur practically simultaneously on all sounding signals and are observed in advance of the pulsations of geomagnetic field. We also analyse wave activity under moderate-to-intense geomagnetic storm conditions.

## CRITICAL FREQUENCY FOF2 VARIABILITY OVER MEXICO

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Analysis of the ionospheric variability based on data of the ionospheric station El Cerrillo (Toluca, Mexico), 19.3N, 260E, Modip 40.13N, is presented for the whole 11 years solar cycle. The data have been divided by years of LOW (1973 to 1977), MODERATE (1972, 1978,1982) and HIGH (1979 to 1981) solar activity. We analyzed the F2 layer critical frequency foF2 variability, measured hourly. The number of days analyzed for every month oscillates between 20 and 30 days because of ionosonde schedule (for some years no measurements during weekends). The variability description of the ionospheric parameters is necessary to improve the ionospheric models. For applications like HF communication, global satellite positioning, space and terrestrial navigation, etc., the users of the ionospheric models need to know not only the average monthly conditions but also the expected deviations from the mean or median values. Since the statistical distribution of foF2 in Mexico, is not like a normal one, the parameters of variability used in the analysis have been: the monthly median m, the upper Qup and lower Qlo quartile, the inter-quartile range $Q_r = Q_{up} - Q_{lo}$ and the indices of variability $C_{up} = Q_{up}/m$,

$C_{lo} = Q_{lo}/m$ and $C_r = C_{up} - C_{lo}$. Following the recommendations of the IRI Task Force Activity (Bilitza 2001), the measurements obtained for the Toluca station have been grouped according to (i) Four groups of representative periods of local time 22-02 LT; 05-07 LT; 10-14 LT and 18-20 LT. (ii) By seasons: Winter, Spring, Summer and Autumn. (iii) In levels of solar activity: LOW, MODERATE and HIGH. In general, the results show that: a) the greater solar activity leads to greater mean value of the frequency foF2, that means the greater electronic density in this region of the ionosphere. b) For the three conditions of solar activity, the effect of seasonal anomaly between the 7 LT and the 12 LT can be observed, when the mean value of the frequency foF2 is greater in winter than in summer. c) The variability is greater during the LOW solar activity than during HIGH solar activity.

## ON THE USE OF NEQUICK TOPSIDE OPTION IN IRI 2007

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The latest version of IRI includes various options for the computation of the topside electron density profile. One of the possible choices is based on NeQuick model. Its inclusion in IRI has been made transferring all the formulations used in NeQuick model. In details, an Epstein layer function is used to describe the electron density profile and the topside shape is controlled by an empirical parameter, connected to the NeQuick F2 bottomside thickness parameter, B2bot. It is computed also in this IRI topside option in order to maintain self-consistency with itd original formulation. This paper analyses the possibility of using the IRI bottomside parameters for this option and its impact on the profile and TEC. The case of experimental peak values given as input is also analysed.

## STUDY ON THE NEQUICK BOTTOM-SIDE F2 LAYER THICKNESS PARAMETER

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NeQuick electron density and total electron content (TEC) model, adopted by ITU-R in Recommendation 531-7 as a suitable method for TEC modeling, has been recently improved. In the topside part of the profile the thickness parameter formulation has been modified using topside sounder data. The bottom-side of the model has been modified in terms of the F1 layer in such a way to eliminate unrealistic peculiarities of the height profile which occasionally occurred in that region. This paper describes new attempts to modify the bottom-side F2 thickness parameter of the model to better reproduce experimentally derived TEC particularly in the low magnetic dip latitudes. Both total electron content data from global maps derived from GPS and TOPEX satellite are used. Equinoctial conditions at low and high solar activity have been considered.

## TIME AND SPATIAL VARIATIONS OF THE FOF2(NIGHT)/FOF2(DAY) VALUES

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The ratio of daytime and nighttime values of the foF2 critical frequency is analyzed on the basis of the data of 28 ionospheric stations of the Eastern Hemisphere. It is found that after about 1980, three types of the behavior of this ratio with time are observed: an increase with time (a positive trend), a decrease with time (a negative trend) and the absence of pronounced changes (a zero trend). The sign of this trend is shown to be governed by the signs of the magnetic declination D and magnetic inclination I at the given ionospheric station. This fact makes it possible to assume that the above indicated trend is caused by long-term variations in the zonal component Vny of the horizontal wind in the thermosphere, the latter component contributing into the vertical drift velocity W. The causes of the systematic changes in the thermospheric circulation regime after 1980 are not yet known, however with sufficient probability they are related to anthropogenic changes in the atmosphere.

## SYNCHRONOUS NMF2 AND NME DAYTIME VARIATIONS DURING THE PERIODS OF QUIET-TIME F-2 LAYER DISTURBANCES

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The analysis of the daytime (11-14 LT) observations of NmF2 and NmE at subauroral and midlatitude stations for the periods of positive and negative F2-layer Q-disturbances has shown a synchronous type of the ΔNmF2 and ΔNmE variations. The ΔNmE difference from the unity (i.e., the median) is significant at any confidence level for both, negative and positive Q-disturbances. Therefore, under the negative Q-disturbances in the F2-layer we have negative deviations in the E-layer and the positive F2-layer disturbances are accompanied by positive deviations in NmE. Thus, ΔNmF2 and ΔNmE exhibit in-phase variations in a statistical sense. In the case of the positive Q-disturbances, the in-phase variations take place not only on the average, but also at the point-to-point level. The only mechanism capable to explain the observed ΔNmE variations is the vertical gas motion which changes the effective scale height $H(O^2)$ of the molecule oxygen distribution at E-region heights. The neutral gas downwelling enriches the thermosphere with atomic oxygen at F2-layer heights and decreases $H(O^2)$ in the E-region to result in a synchronous NmF2 and NmE increases. The upwelling of the neutral gas should result in the opposite effect. The expected variations of atomic oxygen during F2-layer Q-disturbance events were confirmed by the Millstone Hill ISR observations for the periods of positive and negative Q-disturbances. Different formation mechanisms of the daytime positive and negative Q-disturbances explain the different level of the synchronism in the ΔNmF2 and ΔNmE variations. For the negative Q-disturbances, we have in-phase ΔNmF2 and ΔNmE changes only on the average (i.e., in a statistical sense) as no physical processes relating ΔNmF2 and ΔNmE are involved in this case. On the contrary, in the case of the positive Q-disturbances, the downward gas motion in the thermosphere produces the in-phase ΔNmF2 and ΔNmE changes not only on the average, but at the point-to-point level as well.

## DAYTIME F2-LAYER NEGATIVE USUAL AND Q-DISTURBANCE EVENTS: WHAT IS THE DIFFERENCE

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The morphological analysis of the F2-layer negative Q-disturbances using the worldwide ionosonde observations has shown that hmF2 usually do not exhibit any pronounced variations during such events being close or even below monthly median values. Such hmF2 behavior is different from usual negative storm hmF2 variations when the F2-layer maximum height always increases. Millstone Hill ISR observations for the Apr 15-18, 2002 period were used for the analysis. The selected period comprises a quiet (control) day Apr 15 which coincides with the monthly median, a well-pronounced negative Q-disturbance event on Apr 16, followed by a severe geomagnetic storm on Apr 17-18 resulted in a strong negative F2-layer storm effect. The ISR data provide the required difference in hmF2 variations with hmF2 being higher the median on Apr 18, and lower the median values on Apr 16. Basic thermospheric parameters: neutral composition ([O], [$O^2$], [$N^2$]), temperature Tn(h), vertical plasma drift W related mainly to the neutral thermospheric winds were found from the ISR data and used for physical interpretation. In the case of negative Q-disturbance on Apr 16 three controlling parameters – [O], Tex, and $\beta = \gamma_1[N_2] + \gamma_2[O_2]$ work in one direction decreasing hmF2 with respect to the monthly median values. The increased hmF2 on the disturbed day of Apr 18 are due to larger (beta) and vertical drift W resulted from the disturbed thermospheric circulation in accordance with the contemporary understanding of the negative F2-layer storm mechanism. Vertical Ne(h) profiles are also different for the two types of disturbances. In the case of Q-disturbance the effective plasma scale height is close the median (quiet) one, therefore the negative disturbance effect takes place in the whole topside ionosphere. In the case of usual negative storms the negative effect takes place only in the vicinity of the F2-layer maximum changing for the positive one in the topside (above 600 km) ionosphere due to different effective scale heights. Therefore, negative F2-layer Q-disturbances belong to a separate class of events with there own formation mechanism.

## MORPHOLOGY (AND CLIMATOLOGY) OF UPPER ATMOSPHERE DISTURBANCES

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Based on the methodology developed by Fotiadis and Kouris (Radio Science, 41(6), RS6012, doi: 10.1029/2005RS003395, 2006) and using foF2 data from 3 solar cycles 1964-1995 and European ionosonde stations other than in the above work, the most dominant patterns of large scale negative disturbances -presented with the upper and lower variability bounds from the monthly median- are recalculated and their distribution in time and space for the COST 296 region is provided. A twofold validation of the aforementioned work by Fotiadis and Kouris (2006) is achieved: (a) by comparing the space/time distribution between the hereby calculated dominant

patterns and the results obtained previously and (b) by identifying some foF2 disturbances in another period (1996-2005) and comparing them with the final calculated patterns within the expanded space/time distribution framework. The developed model could improve existing ionospheric models (e.g. the STORM model in IRI) and form potentially a comprehensive correction disturbance model, directly operational by radio users.

## TOWARDS CHARACTERIZING TERRESTRIAL WEATHER IMPACTS IN IRI

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The response of the upper atmosphere to space weather events from the sun has been studied for decades. The impact of terrestrial weather on the upper atmosphere has received less attention. However, the upper atmosphere and ionosphere clearly exhibit variability on global scales with periods from several hours to several days, characteristic of lower-atmospheric planetary waves and tides. To study the origin, vertical propagation, and possible effects of these planetary-scale perturbations on the coupled thermosphere-ionosphere-electrodynamics system, a new model of Integrated Dynamics through Earth Atmosphere (IDEA) has been developed under a NASA sponsored collaborative project between the University of Colorado and National Weather Service's (NWS) Environmental Modeling and Space Environment Centers. The IDEA model interactively couples a Whole Atmosphere Model (WAM) with Global Ionosphere-Plasmasphere (GIP) and electrodynamics models. WAM is a 150-layer general circulation model based on NWS's operational weather prediction Global Forecast System (GFS), extended from its nominal top altitude of about 60 km to over 600 km. It incorporates relevant physical processes in the extended domain, ranging from the hydrological cycle, cloud physics, and atmosphere-surface exchanges in the troposphere, to solar and Joule heating and mutual diffusion of major species in the thermosphere. IDEA is ideally suited to understanding and forecasting terrestrial weather impacts on the near-Earth space environment, including day-to-day tidal forcing of electrodynamics, the redistribution of plasma at mid and low latitudes impacting communications and navigation, and the modulation of neutral density affecting satellite drag. This understanding will enable the next generation empirical reference ionosphere to be developed that include terrestrial weather indices.

## MODELING OF SCINTILLATION ON GPS SIGNALS DUE TO PATHS TRAVERSING EQUATORIAL PLASMA BUBBLES

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A scintillation propagation model for L-band signals on transionospheric paths of propagation developed at the Universities of St. Petersburg and Leeds Universities (see Radio Science, vol. 40, RS1003, doi: 10.1029/2004RS003097, 2005) is further

extended to describe the effects caused by the localized structure of plasma bubbles in the low-latitude ionosphere. The extended model takes into account quasi-regular (quasi-deterministic) and random structures typical of the bubbles. The model is capable of producing the statistical moments of the signal (power spectra, correlation functions, scintillation index, etc.) and generating its random time series including the case of through-bubble propagation. In particular, the results of modeling demonstrate that strong enhancements of the scintillation index (S4) can occur depending on the parameters of the bubble and the path. The results of modeling L-band signals will be presented for the case of the line of sight path from the satellite traversing across the bubble. The characteristics of the field before, during and after the propagation path passes through the bubble will be shown and compared. These results will also be qualitatively compared with typical observed data of GPS signal scintillation during bubble traversals

## CORRELATION OF DIFFERENT FREQUENCY L-BAND SATELLITE NAVIGATION SIGNALS ON THE SAME TRANSIONOSPHERIC LINK FOR SCINTILLATION CONDITIONS

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Ionospheric correction schemes, such as dual frequency GPS, make use of 2 different frequency transmissions from the same navigation satellite. Some future schemes for Galileo or GPS-M will use 3 frequencies. For GPS, L1 can also be used in decoding L2, enabling decoding without access to the encryption algorithm. State-of–the-art semi-codeless techniques rely on cross-correlation of the signals received at L1 and L2 to improve the likelihood of acquiring and maintaining lock on the L2 signal. For all the above-mentioned schemes, it is important to determine how well the 2 frequency signals are correlated. Lack of correlation will introduce range error in dual frequency correction using L1 and L2 even in the case of perfect decoding. A possibly significant factor in reducing this correlation would be scintillation of the signals resulting from propagation through time-varying small-scale irregularities in the ionosphere. In order to model scintillation effects on transionospheric propagation of GPS and other GNSS signals from a navigational satellite to a ground-based receiver, a method that is valid for strong scintillation conditions is required. Such a propagation model and simulator has been constructed by the Leeds/St.Petersburg team. The propagation model can treat scintillations for the case of very strong fluctuations of the electron density (up to 100% of the background) at GPS frequencies. Further, to treat the problem of signal correlation at spaced frequencies, the simulator program has been modified to generate two random screens below the ionosphere, corresponding to the two GPS (or other GNSS) frequencies. These random fields on the screens are generated taking into account the auto- and cross-correlation functions of phase and log-amplitude at the two frequencies. Then the fields of the both frequencies are simulated on the ground. This thus provides a method of simulating the stochastic fields at different frequencies, which are properly correlated. Then any required correlations and cross correlations of these fields and of their phases and amplitudes can be calculated. This also enables extraction of the phases and determination of the

## A NEW TECHNIQUE FOR DIRECTION-OF-ARRIVAL ESTIMATION FOR IONOSPHERIC MULTIPATH CHANNELS

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A new array signal processing technique called Cross Ambiguity Function – Finding (CAF-DF) is proposed to estimate direction of arrival (DOA), time delay, Doppler shift and amplitude corresponding to each impinging signal onto a sensor array. The proposed technique iteratively estimates the path parameters and their direction of arrivals. Iterations start with CAF computation at the output of each sensor element. Using incoherent integration of the computed CAFs, the strongest signal in the delay-Doppler domain is detected and based on the observed phases of the obtained peak across all the sensors, the DOA of the strongest signal is estimated. Having found the DOA, CAF of the coherently integrated sensor outputs is computed to find more accurate delay and Doppler estimates for the strongest signal. Then to start the next iteration, the contribution of the detected signal is eliminated from each sensor and on the residuals the next stronger signal parameters are estimated. Iterations continue until there is no detectable peak on the incoherently integrated CAFs. Performances of the proposed technique and multiple-signal-classification (MUSIC) are compared using synthetic signals in terms of root mean squared error for different signal-to-noise ratio values. Moreover success of the CAF-DF is investigated on the recorded multipath ionosphere data. The signals processed in the simulations were transmitted by a Doppler and multipath sounding network (DAMSON) transmitter located in Uppsala/Sweden. The transmitted signals consist of Barker-13 coded binary phase shift keyed (BPSK) pulses modulated at 1667 baud with a repetition rate of 55 coded pulses per second. Reflected signals are received on a circular six-element antenna array located in Kiruna/Sweden. Based on a wide range of comparisons, it is found that the proposed CAF-DF technique is highly accurate and robust technique that has the potential to be the new standard in ionospheric applications.

## ALTERNATIVE MODEL OF THE IONOSPHERIC CRITICAL FREQUENCY REDUCED BY THE SOLAR ZENITH ANGLE

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The effects of changes in the Sun's zenith angle can be removed by multiplying the critical frequency foF2 by a factor related with the solar zenith angle XHI at a particular time and the local noon value XHIo (Gulyaeva and Gulyaev, 2007). So inverted critical frequency fnF2 coincides with observed foF2 at noon but it is gradually reduced towards the midnight during a year. Correlation between fnF2 values at different locations and between the data of the same station at different seasons is improved compared with the source foF2 data. This paper addresses modeling of fnF2 based on the long-term topside sounder measurements onboard of ISIS1, ISIS2, IK19 and Cosmos-1809 satellites during 1969-1987. The solar zenith angle is calculated with IRI standard subroutine SOCO (McNamara, 1986; Bilitza, 2001). Using the criterion of the lowest rms error between modeled and measured fnF2 we have found the optimum proxy index for solar activity Fsp=(Fs+F10.7)/2 where Fs

is deduced from the solar radio flux F10.7, averaged for the past 81 days (3 solar rotations) and F10.7 is value for one day prior the day of observation (Lei et al., 2005). The solar cycle changes of both fnF2 and foF2 have proved to vary with the local time. Variation in the solar activity have been allowed for by reduction of the data base to the solar minimum at Fsp=70 flux units. The model of regular fnF2 variations is produced in terms of local time, season, modified dip latitude and solar activity. Impact of geomagnetic activity has been ignored due to mixed positive and negative storm-time effects in the topside sounding data. Modip latitudes parameterization has been used so that in the neighborhood of the dip equator they follow constant dip while at higher latitudes they depend on a combination of dip and geodetic latitude (Rawer, 1963) similar to foF2 mapped globally by the ITU-R (former CCIR). The proposed model produces output of foF2, transformed back from fnF2, for the user-specified conditions including standard procedures for converting of geodetic coordinates to/from geomagnetic coordinates and modip latitudes, local time to/from universal time, season/month/day-of-year and solar activity proxy index.

## AN EXPERIMENTAL INVESTIGATION INTO THE FEASIBILITY OF MIMO TECHNIQUES WITHIN THE HF BAND

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To date, the majority of MIMO research has focussed primarily on communications within the UHF band (and above). Environments such as those associated with indoor wireless systems are ideal for the implementation of MIMO systems because of the rich multi-path environment. Moreover, the small wavelengths involved permit the use of physically small antenna arrays. So far, however, very little experimental research has been conducted in the area of exploiting MIMO techniques within the HF band. Some limited modelling work in this area has been reported. The authors have recently embarked on an experimental investigation into the applicability of MIMO techniques within the HF band. State of the art digital frequency techniques will be employed to set up radio links both in the UK and the UK and France to estimate the MIMO channel capacity from measurements. The investigation will include consideration of operational frequencies (including the effect of different mode content), antenna configurations (e.g. spaced arrays and heterogeneous co-located arrays), and geographical effects (e.g. the different nature of the ionosphere between the mid and high latitudes). Some preliminary analysis has been undertaken using data from an earlier (unrelated) study, and this will be presented.

## NON-GAUSSIAN RADAR CLUTTER CHARACTERIZATION USING A MIXTURE OF TWO RAYLEIGH PROBABILITY DENSITIES

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A practical technique for characterizing non-Gaussian radar clutter is specified and demonstrated using, as an example, Over The Horizon Radar (OTHR) data.

The technique employs maximum likelihood to fit the probability density of the clutter amplitude returns to a mixture of two Rayleigh probability densities instead of the single Rayleigh density typically used for Gaussian clutter. This model for non-Gaussian clutter is fully specified for any set of clutter amplitudes by a log likelihood, two Rayleigh parameters, and a mixing coefficient. A 3D plot of these values yields an easily-visualized clutter characterization, as is illustrated using OTHR data.

## PREDICTION OF GLOBAL POSITIONING SYSTEM TOTAL ELECTRON CONTENT USING NEURAL NETWORKS

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Global Positioning System (GPS) networks have provided an opportunity to study the dynamics and continuous changes in the ionosphere by supplementing ionospheric studies carried out using various techniques including ionosondes, incoherent scatter radars and satellites. Total electron content (TEC) is one of the physical quantities that can be derived from GPS data, and provides an indication of ionospheric variability. This paper presents a feasibility study for the development of a Neural Network (NN) based model for the prediction of South African GPS derived TEC. Three South African locations were identified and used in the development of an input space and NN architecture for the model. The input space included the day number (seasonal variation), hour (diurnal variation), Sunspot Number (measure of the solar activity), and magnetic index (measure of the magnetic activity). An analysis was done by comparing predicted NN TEC with TEC values from the IRI2001 version of the International Reference Ionosphere (IRI), validating GPS TEC with ionosonde TEC (ITEC) and assessing the performance of the NN model during equinoxes and solstices. Results show that NNs predict GPS TEC more accurately than the IRI at South African GPS locations, but that more good quality GPS data is required before a truly representative empirical GPS TEC model can be released.

## LARGE SCALE IONOSPHERIC GRADIENTS OVER EUROPE OBSERVED IN OCTOBER 2003

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It is well known that ionospheric perturbations are characterized by strong horizontal gradients and rapid changes of the ionization. Thus, space weather induced severe ionosphere perturbations can cause serious technological problems in Global Navigation Satellite Systems (GNSS) such as GPS. During the severe ionosphere storm period of 29-31 October 2003, reported were several significant malfunctions due to the adverse effects of the ionosphere perturbations such as interruption of the WAAS service and degradation of mid-latitudes GPS reference services. To warn users of such services in a proper way, a quick evaluation of the current signal propagation conditions effectively expressed in a suitable ionospheric perturbation index would be of great benefit. To investigate possibilities of describing ionospheric perturbations by such an index, a task force group was established in the COST 296 activity. Preliminary results of a comparative study of ionospheric gradients including vertical sounding and TEC data are presented. Strong enhancements of latitudinal gradients and temporal changes of the ionization are observed over Europe during the 29-30 October storm period. The potential use of spatial and temporal gradients for characterizing the actual perturbation degree of the ionosphere is discussed.

## EFFECTS OF SUBSTORM WITH CURRENT WEDGE IN THE NE AND ION COMPOSITION OF THE OUTER IONOSPHERE

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In the given work the results of numerical calculations of the global distribution of the electron concentration, Ne, and concentration of atomic ions, $n(O^+)$ and $n(H^+)$ in the outer ionosphere during modeling substorm are presented. Substorm has begun in 18 UT. Calculations are executed on the basis of Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere, developed in WD IZMIRAN, added by the new block of calculation of electric fields in the ionosphere. In the calculations we considered the superposition of magnetospheric convection electric field (at set of field aligned currents of the first and second zones and substorm current wedge with taking into account particle precipitation) and dynamo field generated by thermospheric winds. It is shown that during substorm at 18:30 UT the displacement of the bottom of the trough in Ne to the equator in the northern hemisphere is observed. Thus the trough from morning sector is stretched on the dayside. In a southern hemisphere during a substorm the longitudinal extent of the trough in Ne at height 1500 km increases. In quiet conditions in the global distribution of Ne in post-midnight sector of local time one minimum is formed. During substorm two minima are formed – in near-midnight sector and in pre-sunrise hours at geomagnetic latitudes -75° and -70°, accordingly. At low latitudes during substorm in distribution of $n(O^+)$ the decreasing of O+ concentration relative to background values is formed. In high latitudes the trough in $n(O^+)$ increases its longitudinal extent in both hemispheres. In both polar caps $n(H^+)$ grows up. Longitudinal extent of the light ion trough increases. In quiet conditions in a southern hemisphere the midnight trough in $n(H^+)$ is formed. During substorm two additional minima in pre-midnight and pre-sunrise hours are formed. In the period from 19:00 UT till 20:00 UT in the morning hours in the southern hemisphere the latitudinal stratification of the trough in Ne is observed in the calculations with taking into account the Substorm Current Wedge (SCW) according to G.Rostoker. The substorm leads to the increase in longitudinal extent of the trough in Ne in both hemispheres. In quiet conditions at this time in northern hemisphere the night trough is formed. And during substorm two additional troughs, the afternoon and pre-midday, are formed. In the southern hemisphere at the same time the evening minimum is formed. In the distribution of $n(O^+)$ in both hemispheres the longitudinal extent of the troughs increases. Thus in the northern hemisphere, as well as in Ne, the additional minima are formed. In both hemispheres the longitudinal extent of the light ion troughs increases. Since 21:00 UT the process of the recovery of the outer ionosphere after a substorm begins.

## HEAT BALANCE OF THE OUTER IONOSPHERE DURING SUBSTORM WITH CURRENT WEDGE

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In the given work the results of numerical calculations of the global distribution of the ion and electron temperatures in the outer ionosphere during modeling substorm are presented. Substorm has begun in 18 UT. Calculations are executed on the basis of Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere, developed in WD IZMIRAN, added by the new block of calculation of electric fields in the ionosphere. In the calculations we considered the superposition of magnetospheric convection electric field (at set of field aligned currents of the first and second zones and substorm current wedge with taking into account particle precipitation) and dynamo field generated by thermospheric winds. It is shown, that in the quiet conditions in the post-sunset hours the "hot spots" in the global distribution of ion temperature, Ti, at height of 1500 km are formed. In the "hot spots" in the southern hemisphere Ti is much higher, than in the northern hemisphere. The substorm leads to the splitting up of these spots on two. At 18:30 UT during substorm the "hot spots" in Ti in pre-sunrise hours in the southern hemisphere are formed. At the nighttime the area of the lowered values of electron temperature, Te, in the outer high-latitudinal ionosphere of the southern hemisphere extends on a longitude, and in the northern hemisphere it is narrowed. At 19:00 UT in quiet conditions Ti in the "hot spots" in the post-sunset hours increases up to ~6000 K. Maximal value of Ti in the "hot spots" during substorm with taking into account the Substorm Current Wedge (SCW) according to G. Rostoker is equal ~4500 K, without taking into account SCW it is equal ~4200 K and with taking into account the SCW according to A. Namgaladze and M. Volkov it is equal ~3000 K. In the northern hemisphere during substorm Ti in the "hot spots" increases from ~2800 K in quiet conditions up to ~3500 K. During substorm the "hot spot" in the southern hemisphere, generated at 18:30 UT in the pre-sunrise hours vanishes. In the global distribution of Te the small growth is observed in the area of the "hot spots" of ions which in the course of time disappears. The substorm leads to the heating of the electrons in the southern hemisphere in the vicinity of geomagnetic latitude -70°. At 20:00 UT in both hemispheres two "hot spots" are formed in the global distribution of Ti. In the southern hemisphere these spots settle down on small distance from each other in the morning sector of local time at geomagnetic latitudes -60° and -55°. In the northern hemisphere they are on the significant distance from each other at geomagnetic latitudes 50° and 65° in the morning and afternoon sectors, accordingly. The substorm leads to small heating of electrons nearby the geomagnetic equator.

## EFFECTS OF APRIL 8, 2005 SOLAR ECLIPSE IN THE GLOBAL DISTRIBUTION OF THE FOF2

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In the given work the results of numerical calculations of global distribution of critical frequency of the F2-layer, foF2 in MHz, during a solar eclipse are presented. Calculations have been executed on the basis of Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP), developed in WD

IZMIRAN, added by the new block of calculation of electric fields in the ionosphere of the Earth. In calculations we considered superposition of magnetospheric convection electric field and dynamo field generated by thermospheric winds without taking into account the tides. The solar eclipse of hybrid type viewed in the given work has occurred on April, 8, 2005. The hybrid eclipse was visible from within a thin corridor, which traverses the Southern Hemisphere. The path of the shadow of the Moon has begun southeast of New Zealand and stretched across the Pacific Ocean to Panama, Columbia, and Venezuela. The eclipse has begun at 18.54 UT and has ended at 22.15 UT. From 20.30 UT till 21.10 UT the shadow of an eclipse transited in a neighborhood of geomagnetic equator. It is shown that at the passing of the solar eclipse spot through the area of the middle latitudes the delay of the negative effects of solar eclipse in global distribution of the foF2 is observed. In the subequatorial latitudes this delay disappears. The negative effects of the eclipse in the foF2 are equal ∼1.5 MHz relative to the quiet values. At 19:40 UT the crest of equatorial anomaly in the southern hemisphere is divided on two parts along the longitude. At approach to the equator the depth and the sizes of the spot of the lowered values of the foF2 decrease. At 20:30 UT the crest of equatorial anomaly in the northern hemisphere is divided on two parts along the longitude. During eclipse the depth of a trough of equatorial anomaly increases. This trough is the deepest in the period from 20:40 UT till 21:10 UT. At 20:50 UT the spot in the foF2 appears in the northern hemisphere. At this time the solar eclipse spot passes the geomagnetic equator. At 21:30 UT the spot in the foF2 in the southern hemisphere disappears.

## HEAT BALANCE OF THE F-REGION IONOSPHERE DURING APRIL 8, 2005 SOLAR ECLIPSE

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In the given work the results of numerical calculations of global distribution of ion and electron temperatures at heights of 300 km during a solar eclipse are presented. Calculations have been executed on the basis of Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP), developed in WD IZMIRAN, added by the new block of calculation of electric fields in the ionosphere of the Earth. In calculations we considered superposition of magnetospheric convection electric field and dynamo field generated by thermospheric winds without taking into account the tides. The solar eclipse of hybrid type viewed in the given work has occurred on April, 8, 2005. The hybrid eclipse was visible from within a thin corridor, which traverses the Southern Hemisphere. The path of the shadow of the Moon has begun southeast of New Zealand and stretched across the Pacific Ocean to Panama, Columbia, and Venezuela. The eclipse has begun at 18.54 UT and has ended at 22.15 UT. From 20.30 UT till 21.10 UT the shadow of an eclipse transited in a neighborhood of geomagnetic equator. It is shown, that the maximal negative effects in the ion temperature, Ti, and in the temperature of electrons, Te, are late relative to the solar eclipse spot when it is at the middle latitudes. In the subequatorial latitudes this delay disappears. At 19:00 UT in the global distribution of Ti the effect of the solar eclipse is very weak. At this time in the distribution of Te the precise spot of the lowered values of electron temperature is formed. The values of Te in this spot fall on ∼600-700 K. Later on in the global distribution of Ti there are small negative effects (∼20 K) in the vicinity of the solar eclipse spot. In the distribution of Te the local areas of the reduced values of the electron temperatures on ∼500-700 K relative to the quiet values are formed. At 20:40 UT the local minimum in the distribution of Ti is formed at geomagnetic equator. The values in this minimum are less than quiet values on 50 K. At the same time the local minimum in Te is formed at geomagnetic equator. The values in this minimum are less than quiet values on 500 K. In the further these local minima are displaced into the northern hemisphere. The effects of solar eclipse in Ti and Te are visible in an hour after the termination of the eclipse. Especially for a long time the effects of the solar eclipse are kept in the electron temperature.

## GLOBAL COMPARISON OF THE MODEL RESULTS OF GSM TIP WITH IRI FOR EQUINOX CONDITIONS

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This paper presents the results of the numerical calculations thermosphere/ionosphere parameters which were executed with using of the Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP)and comparison of these results with empirically-based model IRI-2001. Model GSM TIP was developed in West Department of IZMIRAN and solves self-consistently the time-dependent, 3-D coupled equations of the momentum, energy and continuity for neutral particles ($O^2$, $N^2$, O), ions ($M^+$, $O^+$, $H^+$) and electrons and largescale eletric field of the dynamo and magnetospheric origin in the range of height from 80 km to 15 Earth's radii. The empirically derived IRI model describes the E and F regions of the ionosphere in terms of location, time, solar activity and season. Its output provides a global specifiation not only of Ne but also on the ion and electron temperatures and the ion composition. The IRI is an evolutionary model and has continued in improving its specification of the topside ionosphere, total electron content (TEC), more accurate definition at high latitudes etc. In this investigation we concentrate on the IRI and GSM TIP models. These two models represent a unique set of capabilites that reflect major differences in along with a substantional approaches of the first-principles model and global database model for the mapping ionosphere parameters. We focus on global distribution of the Ne, Ti, Te and TEC for the one moment UT and three fixed altitudes: 110 km, hmF2 and 1000 km. The calculations were executed with using of GSM TIP and IRI models for equinox, moderate solar activity and quiet geomagnetic conditions. Results present as the global percent differences between the IRI and GSM TIP models predictions. The discrepancies between model results are discussed.

## CALCULATION OF THE GLOBAL CLIMATOLOGY OF THE IONOSPHERIC PARAMETERS IN GSM TIP AND IRI MODELS

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In this study we present the global numerical results of the foF2 and TEC obtained with using the theoretical Global Self-consistent Model of Thermosphere, Ionosphere and Protonosphere of the Earth (GSM TIP). Model GSM TIP was developed in West Department of IZMIRAN and solves self-consistently the time dependent, 3-D coupled equations of momentum, energy and continuity for neutral particles ($O^2$,$N^2$,O) and ions ($M^+$,$O^+$,$H^+$) and large-scale electric field of the dynamo and magnetospheric origin in the range of height from 80 km to 15 Earth‘s radii. Simulations have been performed for all seasons, in low (F10.7=76) and high (F10.7=200) solar activity and quiet geomagnetic conditions. The calculation results are presented as a global distrbutions of the foF2 and TEC in the geographic coordinate system for 12.00 UT. The similar calculations were executed with using database IRI model and comparison between two models was completed. The emphasis of this paper is not only to compare two models results but also to make an estimate of the effects of the large-scale dynamo fields on the foF2 distribution in the low-latitude regin. In the first version of the GSM TIP model the 3-D equation for the dynamo electric field was solved by integrating this equation in the sperical geomagnetic coordinate system. These results presented in another report on this conference. In the latest version of the GSM TIP model presented here, the integration of the dynamo electric field equation carried out in the magnetic dipole coordinate system. This method leads to more adequate description of the foF2 in equatorial region. Differences between caculaion results of the two models, which can be associated with uncertainty of the input parameters for theoretical model and because the IRI model disregarded some physical phenomenon in the ionosphere, are discussed.

## IONOSPHERIC E-REGION DRIFT MEASUREMENTS IN OBSERVATORY PRUHONICE

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Regular measurement of plasma motion brings new important information about the state of the ionosphere. We present here analysis of ionospheric plasma motion in the E region ionosphere during period of low solar activity. In the study we concentrate on the plasma motion at height range 90 km - 150 km that corresponds to E-region. Data were collected during year 2006, period of “exceptionally” low geomagnetic and solar activity, which allows us to study plasma drifts in the quiet ionosphere. Our study involves measurements of DPS4 from ionospheric station Pruhonice (50N, 14.6E). Raw data are manually checked and controlled using method described in Kouba et al. (2007). Our preliminary results show behavior of E-region drift during the year 2006. We discuss new results observed in parts of measurements: height variation of E-region drift velocity and different results for “E” and “Es” drift sounding.

## ON THE SEASONAL DEPENDENCE OF TEC AND SLAB THICKNESS

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Studies of the total electron content (TEC) variations in time and space are very important to assess and monitor ionosspheric and plasmaspheric effects which may have significant impacts on satellite navigation and communication systems .Besides,similar studies on the space and time variations of the slab thickness ($\tau$) are useful for the planning and operation of such communication systems. In a previous work (Kouris et al., 2006)the response to changes in solar activity and location of TEC and $\tau$ has be investigated using several years of data measured at different European locations. The analysis has pointed out that the total electron content is highly correlated with the solar activity, and also with the latitude. On the contrary, the slab thickness seems to be independent of the solar activity and of the latitude (Kouris et al., 2006) . In this work the seasonal dependence of the equivalent slab thickness t and of the vertical total electron content is investigated. An average daytime value of TEC and of slab thickness for each month/year/location is calculated and similarly a corresponding average nighttime value for each month/year/location. Thus, the day is divided into two parts; that is we are dealing with two sets of data representing day and nighttime conditions. Then, the daytime TEC values for each month/location at the quiet Sun level are calculated and correlated with the $cos\kappa$ at noon ($\kappa$ being the solar zenith angle) values of the corresponding month /location. The same procedure is followed when the nighttime values of TEC and slab thickness are considered . The regression analyses show that in each of the cases considered the two corresponding variables are highly correlated ; useful analytical expressions are obtained, expressing the seasonal dependence of TEC and slab thickness as a fuction of cos $\kappa$ at noon.

## THE OCCURRENCE OF THE MID-LATITUDE IONOSPHERIC TROUGH IN GPS-TEC MEASUREMENTS

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Simultaneous GPS observations from about 150 stations of European Permanent Network (EPN) have been used for studying dynamics of latitudinal profiles and structure of mid-latitude ionospheric trough (MIT). For the analyses, the TEC maps over Europe were created with high spatial and temporal resolution. The latitudinal profiles from TEC maps with a one-hour interval were produced for geographic latitude range from 35N to 75N. The structure of latitudinal profiles relates to occurrence of the ionospheric trough and its location depends on geophysical conditions. The trough structure in GPS TEC demonstrates the smooth shape. The trough occurrence as a distinguished structure is more distinct during winter. The relation of TEC in trough minimum to equator and polar walls amounted to a factor of 2-4. The diurnal, seasonal as well as storm-time dynamics of the latitudinal profiles and trough-like structure during different geomagnetic conditions are also presented. Day by day snapshots demonstrate great variability of TEC profiles and MIT, essential changes of the structure took place during a storm. Similarly to the F2 region trough, the position of the TEC trough shifts towards lower latitudes during disturbances. In the storm-time, the TEC trough was recognized in day-time at latitudes lower than 70N. In this paper, the detailed statistics about the location of the trough in the latitude are presented. The occurrence of the trough in TEC derived using GPS measurements was also compared to the measurements provided by other techniques.

## IRI-2001 MODEL EFFICIENCY IN THE PROBLEM OF IONOSPHERIC RADIOWAVE PROPAGATION FORECAST

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This paper presents the results of experimental chirp-sounding data analysis for two mutually-perpendicular paths: Inskip(GB)-IZMIRAN (∼2500 km) and Cyprus-Troitsk (∼2300 km) and vertical ionosonde data obtained at IZMIRAN in the vernal equinox periods of 2002-2007. The whole period of observation was characterized by a wide range of solar activity values.For instance, March solar spot numbers vary from 112.0 at the maximum (2002) to 4.6 at the minimum (2007). We have made an attempt to consider this combined set of experimental data from the point of view of their description by IRI-2001 model supplemented with the electron collision frequency calculations together with the electron concentration. Our goal was to estimate the root-mean-square error of the model description as monthly average so separate diurnal realizations MUF F2 on the basis of IRI-2001 model with taking into consideration solar radio flux F10.7 and current position of main ionospheric maximum from ionosonde data: FoF2 and HmF2. It has been shown that in the long-term forecast the averaged difference between experimental monthly average and model MUF F2 is about 12%, when using only Rz as input parameter. It reduces to ∼ 9% when both monthly solar data parameters Rz and F10.7 are combined together. In the short-term forecast (diurnal realization) the average deviation can be reduced to similar value ∼ 8% only by taking into account the entire set of current data: F10.7, FoF2 and HmF2. This value is a definite lower limit, at least for March in middle latitudes. The reason is a significant discrepancy between the true electron density profile in the F1 layer and the lower part of F2 layer from its model representation.

## THE USE OF IRI-2001 MODEL FOR HF PROPAGATION FORECAST ON SUPERLONG PATHS

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For investigation of global distribution of electron concentration in the upper ionosphere we carried out a unique experiment series by multi-frequency Doppler sounding on superlong radio paths system. The radiation in pulse and continuous regimes is carried out from Russia territory. For this goal we modernized transmitting facilities of Russian chirpsounders network in Irkutsk, Norilsk and Magadan. The receive of signal has been conducted in Kharkov and Ukraine Antarctic station "Vernadsky" The experiments were carried out on radio paths with extent from 18 to 35,4 thousands km. We researched the peculiarities of HF propagation on superlong radio paths for summer, winter and spring periods. The transmitting points were on distance near 1500 km from antipode point of "Vernadsky" receiving facility in different longitude sectors. The modeling of amplitude-frequency and time characteristics of radio signals by IRI-2001 model enables us to reveal the peculiarities of electron concentration spatial distribution in different parts of Earth which essentially influence on superlong HF propagation for different seasons. The work is done in framework of integration project SB RAS No.3-24 and Agreement No.1.18.22 Ukraine NAS - Ukraine NAS Presidium.

## RECONSTRUCTION OF TOPSIDE DENSITY PROFILE BY USING THE TOPSIDE SOUNDER MODEL PROFILER AND IONOSONDE DATA

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Topside Sounder Model (TSM) provides the plasma scale height (hs), O+ -H+ transition height, and their ratio Rt=hs/ht, derived from topside sounder data of Alouette and ISIS satellites. The Topside Sounder Model Profiler (TSMP) incorporates TSM and uses the model quantities as anchor points in reconstruction of topside density (Ne) profile. TSMP provides Ne profiles for three different analytical shapes: sech-squared, a-Chapman, and exponential. For any particular location, TSMP provides Ne by using measured ionosonde values of F2 layer critical frequency foF2 and peak height hmF2. Results are obtained for ionosonde stations Athens and Juliusruh. TSMP is also used in combination with Digisonde ITEC technique. The topside scale height, instead of TSM, is obtained from ionograms at the height of hmF2. Ne profiles obtained from TSM and ITEC technique are compared for different diurnal, seasonal and geomagnetic conditions and the proper analytical shape is outlined. Applicability of the combined TSMP and ITEC techniques for reconstruction of the topside Ne profiles is discussed. TSMP results are compared with profiles obtained by the Radio Plasma Imager (RPI) onboard IMAGE satellite. The plasmasphere extension and plasmapause cutoff of Ne profiles for different geomagnetic latitudes are discussed.

## MODELING THE MEDIUM-SCALE TEC STRUCTURES, OBSERVED BY BELGIAN GPS RECEIVERS NETWORK

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GALOCAD project “Development of a Galileo Local Component for the nowcasting and forecasting of atmospheric disturbances affecting the integrity of high precision Galileo applications” aims to perform a detailed study on ionospheric small- and medium-scale structures and to assess the influence of these structures on the reliability of Galileo precise positioning applications. GPS-derived TEC (total electron content) is obtained from the Belgium Dense Network (BDN), consisting of 67 permanent GPS stations. An empirical 3-D model is developed for studying these ionospheric structures. The model, named LLT model, described temporal variations of TEC in latitude/longitude frame (46° 52°)N and ( -1° 11°)E. The special variations of TEC are modeled by Tchebishev base functions, while the temporal variations are described by a trigonometric basis. To fit the model to the data, the observed area is divided into bins with (1° x 1°) geographic scale and 6 min on time axis. LLT model is made flexible, with varying number of coefficients along each axis. This allows different degree of smoothing, which is the key element of the present approach. Model runs with higher number of coefficients describing in details medium-scale TEC structures are subtracted from results obtained with smaller number of coefficients; the latter represent the background ionosphere. The

residual structures are localized and followed as they travel across the observed area. In this way, the size, velocity, and direction of the irregular structures are obtained.

## COST296 WORKING GROUP 1 "IONOSPHERIC MONITORING AND MODELLING" ACTIVITIES AND RESULTS

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We briefly summarize activities and results of the COST296 Working Group 1 "Ionospheric monitoring and modelling" These activities cover both measurements/monitoring of the ionosphere and research towards modelling and understanding ionospheric behaviour to make better ionospheric predictions possible. WG-1 monitoring of the state of the ionosphere by the European ionosonde network and with the use of European GPS station network, including data dissemination and archiving, development of new methods, and data quality checking and analysis. Important part of WG-1 activities is data ingestion and assimilation in ionospheric models including development of techniques of quasi real-time reconstruction of electron density profiles. Another area of WG-1 activities covers development of near Earth space plasma modelling and forecasting, particularly forecasting of foF2 and TEC. Last but not least, WG-1 deals with the climate of the upper atmosphere and ionospheric variability, including the impact of space weather and atmospheric waves on the ionosphere, long-term trends in the ionosphere and utilization of incoherent scatter radar observations.

## IONOSPHERIC RESEARCH WITH HELP OF DOPPLER GONIOMETRIC COMPLEX "SPEKTR".

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Different radio sounding methods are used to research various ionospheric dynamic processes. Usually we need to build multi channel receiving systems, if we use interference methods of ionosphere radiosounding in SW band. One of the instruments used to research parameters of ionosphere in Kazan State University is multi channel Doppler goniometric complex (DGC) "Spektr". DGC "Spektr" current hardware and software modernization is shown in this report. In hardware part we use new ADCs to sample signals after second frequency transformation, also we use digital filter and decimator. In software we use GPRS channel to control complex and to examine complex parameters.

## THE RESPONSE OF THE MIDLATITUDE IONOSPHERE TO SOLAR ECLIPSE: THE MEASUREMENTS AND MODELING

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The total eclipse of August 11, 1999 occurred with its path of totality passing over center of Europe at the latitude range 40 − 50N. The eclipse coincided with a relatively long geomagnetic quiet period. So the eclipse provides us a unique opportunity to study the mid-latitude ionospheric response to the variation of solar EUV radiation. The ionospheric responses to this eclipse were measured by a wide ionosonde network. In this paper, on the basis of the measurements of foE, foF1, and foF2 from sixteen ionosondes in Europe, we statistically analyze the variations of these parameters with eclipse function (0 for none eclipse and 1for totality). Results show that the maximum response of the mid-latitude ionosphere to the eclipse is in the F1-region. The variations of foF1 depend on the eclipse function linearly. The variations of foF2 have obvious delay effect compared to the eclipse function. And then we also simulate the effect of the total eclipse of August 11, 1999 with a midlatitude ionosphere theoretical model. Comparison of model results with data of the measurements showed a good qualitative and quantitative agreement.

## EFFECT OF SMALL-SCALE VARIABILITY IN TEC ON HIGH ACCURACY GNSS APPLICATIONS WHICH REQUIRE AMBIGUITY RESOLUTION.

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The main subject of our research is to estimate the effect of the ionospheric activity on relative GNSS positioning techniques based on carrier phase measurements. In practice, we want to evaluate the residual ionospheric error which affects positions obtained in real time using the Real Time Kinematic (RTK) technique. Former studies carried out by Wanninger (Wanninger L. Ionospheric Disturbance Indices for RTK and Network RTK positioning, Proc. ION GNSS 2004, Long Beach, CA, 2849-2854.) ana-lysed this problem : this work led to the creation of two ionospheric variability index, named I95 and I95L. These index are computed based on data collected in reference stations separated by a distance of about 50 km. These indices allow to monitor the impact of the ionospheric activity on RTK positioning accuracy. The goal of the present study is to propose an other complementary approach tested on the Bel-gian dense network (where the distances between reference stations ranges from 4 to about 20 km) which assesses the ionospheric influence in terms of positioning error and more precisely in percentages of correctly resolved ambiguities. This paper addresses thus the impact of a given ionospheric variability in terms of ambiguity resolution. In a first step, we evaluate the correct proportion of ambiguity correctly resolved in function of the geometry and of the distance be-tween the stations (length of the baseline) during quiet ionospheric days (low variability in TEC). After that, the impact of the presence of a strong ionospheric disturbance (i.e. a strong Traveling Ionospheric Disturbance) or of a geomagnetic storm has been tested in terms of percentage of ambiguity correctly solved. The paper demonstrates that even on short distances small-scale variability in TEC can strongly affect the ambiguity resolution and degrade the accuracy of real time positions at a few decimeter level. The final goal of the work is to improve the I95 index in cases where very localized ionospheric variability is observed.

## A SINGLE STATION EMPIRICAL MODEL OF M(3000)F2 FOR WUHAN BASED ON EIGEN MODE ANALYSIS

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The eigen mode analysis method, combined with regression analysis, is used to construct a single station empirical model for the ionospheric propagation factor

M(3000)F2. Data used to construct the model are monthly median hourly values of M(3000)F2 observed at Wuhan Ionospheric Observatory (geographic 114.4°E, 30.6°N; 45.2°dip) during the years of 1957-1991. The constructed climatological model incorporates the diurnal, seasonal as well as solar-cycle variations of M(3000)F2. Comparisons between the observational results and the modeled ones showed good agreement. A comparison between our model result and that of the International Reference Ionosphere (IRI) model is also made. In general, the root mean squared error (RMSE) of our model is smaller than that of the IRI. We suggest that it would be worthy to further investigate developing regional or global models of ionospheric parameters based on the modelling technique used in this paper.

## USING THE RADIAL BASIS FUNCTION NEURAL NETWORK TO PREDICT IONOSPHERIC CRITICAL FREQUENCY OF F2-LAYER OVER WUHAN

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Abstract. In this paper, using nonlinear radial basis function RBF) neural networks (NNs) forecasting methods to predict the critical frequency (foF2) of middle-low latitude (WuHan) is presented. Principal component analysis is adopted for the purposes of noise and dimension reduction. The whole study is based on a sample of about 6000 observations of foF2 with 1-hour time resolution. Embedding dimension of the dynamical system that generates above sample is estimated using the nearest neighbor method. This information is then utilized for the training of the predictors employed in this study.

## THE IONOSPHERIC SCALE HEIGHTS DERIVED FROM THE INCOHERENT SCATTER RADAR MEASUREMENTS OVER ARECIBO AND MILLSTONE HILL

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We statistically analyze the ionospheric scale heights in the lower topside ionosphere on the basis of the electron density (Ne) and temperature profiles observed from the incoherent scatter radar (ISR) at Arecibo and Millstone Hill. In this study, we report the diurnal and seasonal variations and solar activity dependences of the vertical scale height (VSH), which is deduced from the electron concentration profiles defined as the value of -dh/d(ln(Ne)), and the effective scale height (Hm), which is defined as the scale height in the Chapman-a function to approximate the Ne profiles. As a measure of the slope of the height profiles of the topside electron density, the derived VSH and Hm show marked diurnal and seasonal variations and solar activity dependences. Their features are discussed in terms of thermal structures in the lower topside ionosphere. We also investigate the quantitative relationships between Hm, VSH, and plasma scale height (Hp) over Arecibo. The similarities and differences in these scale heights are discussed. Results suggest that both the

contributions from topside temperature structure and diffusion processes can also greatly control VSH and Hm through changing the profile shape.

## MULTILAYER STRUCTURE IN THE IONOSPHERE F2 LAYER AND ITS SHORT-PERIOD OSCILLATION CAUSED BY SHEAR EXCITED ATMOSPHERIC VORTICAL PERTURBATION

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It is found that the mid-latitude nighttime ionosphere F2 region electron density height distribution under the influence of shear excited vortical perturbations is characterised by multilayer structures. The atmospheric shear wave patterns of its transform into short-period atmospheric gravity waves (AGWs) are reflected in the oscillations of the peak heights of the ionosphere F2 region electron density. The analytic approach for the height distribution of the ionosphere F2 region electron density was obtained by solution of ambipolar diffusion equation taking into account in the meridional wind with zonal shear evolving atmospheric shear waves. The peak heights and the corresponding values of the multilayer F2 region electron density depend on the values of the meridional wind zonal shear and the shear wave vertical wavenumber. The oscillation of the ionosphere F2 layer peak density NmF2 close to the Brunt-Väisälä periods, observed mostly on magnetically disturbed days, is considered as a possible result of atmospheric shear waves and its transform into short-period AGWs.

## APPLICATIONS OF THE IRI MODEL IN EUROPE

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Empirical models are widespread tools to describe ionospheric conditions. They possess some advantages over the other types of models, in particular, for the prediction of the HF radio coverage zone. Nowadays these models are used not only for the long-term prediction but for the real-time description of ionospheric conditions. The European region is very attractive to test models because of existing “on-line” databases from networks of ionosondes and GPS stations up to DIAS system provided characteristics of HF propagation. The purpose of this report is to estimate: 1) the correspondence between the foF2 values delivered by the IRI model (initial and updated) and the experimental values of foF2, 2) the correspondence between the MOF values on Inskip-Rostov path (D$\sim$3050 km) and MUF values calculated by means of the IRI model, 3) a possibility to use the observational values of the plasma frequency fne on the low orbiting satellite or the empirical TTS model to update the IRI model because the frequency fne is proportional to foF2. Short results concerning these 3 points are: 1) the mean values of the standard deviation s(off, foF2) for foF2 were 0.87 MHz for daytime and 0.72 MHz for night for some months of 2005, the ST-factor and the TEC updating provide values of 0.61 and 0.52 MHz although the disturbed conditions need an additional statistics, 2) the mean values of s(off, MUF) lie in range 1.0–3.0 MHz; using parameters of current diagnostics decreases these values up to 0.65–1.85 MHz, 3) it is shown that only value of fne(hsat) could not be successful used to update the IRI model but in addition to the TEC value it can allow to precise values of updating coefficients.

## VALIDATION OF THE STORM MODEL IN IRI2000 AT A HIGH LATITUDE STATION

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The latest version of the International Reference Ionosphere IRI contains geomagnetic activity dependence based on an empirical storm time ionospheric correction (STORM model). An extensive validation of the STORM model for the middle latitude region has been performed. Also, in previous papers it was demonstrated an improvement of IRI with STORM model at low latitudes. In this paper the ability of the STORM model to predict foF2 values at high latitudes is analyzed. For this, ionosonde data obtained at Base Gral. San Martin (68.10S, 2930E) are compared with those obtained by the IRI model with or without storm correction during four geomagnetic storms occurred in 2000 (Rz12= 117) and 2001 (Rz12=111). The results show that predicted values with the STORM model follow the behaviour of foF2 data better than without the STORM model. The relative deviation between measured and predicted foF2 reaches values of up to 24% and 43% with and without the STORM model in IRI, during the main phase of the storms. In addition, possible physical mechanisms to explain increases of electron density observed prior to the storm onset and decreases of electron density observed during the first part of the recovery of the storm are discussed. (POSTER PRESENTATION)

## WAVELET ANALYSIS OF RAW DATA FROM IONOSPHERIC SCINTILLATION GPS RECEIVERS

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Scintillation produced on radio links by the irregularities in the ionospheric refraction index are a non-stationary phenomenon, showing interesting scale properties. This reflects the scale properties of the ionospheric turbulence and its space-time variability. Wavelet analysis is a mathematical tool widely used to process non stationary signals in many fields of physics, engineering and life sciences. In this work the use of wavelets to process and study ionospheric scintillation raw data is illustrated. The usefulness of this technique is shown, in particular in the raw data detrending, in the detection of non-stationary events and in the study of statistical properties depending on the resolution used.

## COMPARISON OF THE IRI-2007 TOPSIDE ELECTRON DENSITY WITH CHAMP AND COSMIC/FORMOSAT-3 DATA

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Reported are results of a comparison of the topside electron density of the IRI-2007 model with data obtained from the CHAMP and the COSMIC/Formosat-3 satellite missions. Starting from 2001 we have collected on average 15 tomographic reconstructions of the topside electron density every day using GPS data of the

zenith-viewing antenna onboard CHAMP. These data sets form the basis of a comparative study with IRI-2007 topside data. While this long-term data basis enables us to study solar cycle dependent effects in the upper ionosphere/plasmasphere, the electron density profiles derived from COSMIC/Formosat-3 offer an up to now unprecedented temporal and spatial resolution with up to 2500 profiles per day. As more and more of the COSMIC satellites approach their design orbits in about 800km height, the upper part of the electron density profiles can provide valuable information about the transition region between the ionosphere and the plasmasphere. Starting from F2-layer height we fit a combination of a Chapman layer function and a topside approximation with a linearly variable scale height to the COSMIC profiles and compare the results with the IRI-2007 model.

## PROGRESS TOWARDS A NEW GLOBAL FOF2 MODEL FOR THE INTERNATIONAL REFERENCE IONOSPHERE (IRI)

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A new neural network (NN) based global empirical model for the foF2 parameter, which represents the peak electron density has been developed using extended temporal and spatial geophysical relevant inputs. The first results from this new model were presented at the International Reference Ionosphere (IRI) 2006 workshop in Buenos Aires, Argentina, and showed that this new model would be a suitable replacement for the URSI and CCIR maps currently used within the IRI model for the purpose of F2 peak electron density predictions. Measured ground based ionosonde data, from 80 global stations, spanning the period 1995 to 2005 and, for a few stations from 1976 to 1986, obtained from various resources of the World Data Centre (WDC) archives (Space Physics Interactive Data Resource SPIDR, the Digital Ionogram Database, DIDBase, and IPS Radio and Space Services) have been used for training a NN. This paper will demonstrate the significance of the inputs chosen for the input space and their ability to be suitable predictors for foF2. In addition, this paper presents a progress report on the status of the global foF2 model, the search for additional data to ingest into the model to complete the global representation of foF2, the readiness of the model for incorporation into the IRI and its expandability to the other peak parameters.

## PROGRESS ON DEVELOPING AN EMPIRICAL IONOSPHERIC E-REGION SOLAR-GEOMAGNETIC STORM CORRECTION TO THE IRI MODEL USING TIMED/SABER DATA

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Nighttime thermospheric infrared emission at 4.3 um can be enhanced by several orders of magnitude during strong solar-geomagnetic storms, as observed by the TIMED/SABER instrument. Auroral electron dosing followed by ion-neutral chemical reactions leads to vibrationally excited $NO^+$ (i.e., $NO^+(v)$) and emission at 4.3 um in the ionospheric E-region. Since $NO^+$ is the terminal E-region ion, emission by $NO^+(v)$ is a suitable proxy to characterize both the electron and ion density response to solar-geomagnetic forcing. Consequently, nighttime measurements from the SABER 4.3 um radiometer channel provide an excellent dataset to: (1) monitor the global E-region response to solar-geomagnetic disturbances, and (2) to develop a parameterization of the E-region electron and ion density enhancements during solar-geomagnetic storms. Thus, it is our aim to develop an empirical storm-time correction to the E-region IRI $NO^+$ and electron densities for solar-geomagnetic activity. Specifically, we derive $NO^+$(v) 4.3 um volume emission rates (VER) from SABER 4.3 um limb emission measurements during all magnetically disturbed periods contained in the SABER database from 2002-2006. SABER-derived $NO^+$(v) VER is an observation-based proxy to characterize the storm-induced E-region electron and ion density enhancements. The $NO^+$(v) VER will be used to develop the storm model parameterization using linear impulse-response theory, as a function of integral ap-index. The $NO^+$(v) VER is derived by (1) removing the background contribution from CO2 infrared emission ,and (2) by performing a standard Abel inversion on the residual radiance. An accurate removal of the background CO2 infrared emission is an essential step to develop a reliable storm-time correction that is independent of electron and ion density profile shapes, and independent of chemistry, kinetics, or spectroscopic parameters. Much effort has been put into this step and we report our progress in deriving $NO^+$(v) VER during magnetically disturbed periods. Finally, we present our approach and preliminary results on using SABER-derived $NO^+$(v) VER to derive an empirical storm-time correction to the IRI E-region ion and electron densities.

## THE MECHANISM OF QUIET-TIME DISTURBANCES IN THE MID-LATITUDE DAYTIME F2-LAYER

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There is a large class of F2-layer disturbances which are not related to geomagnetic activity - so called Q-disturbances. Their morphology is different from the morphology of usual F2-layer storms implying other mechanisms of their formation. Mid-latitude daytime positive and negative Q-disturbances were considered. It was shown that both, the positive and negative Q-disturbances in the F2-region are mainly due to the atomic oxygen concentration variations. An idea of the ground state of the thermosphere has been proposed. The ground state of the thermosphere corresponds to very low geomagnetic activity with an unconstrained solar-driven thermospheric circulation characterized by relatively strong daytime poleward wind and relatively low atomic oxygen concentrations at middle and sub-auroral latitudes. The negative Q-disturbances occur under the ground state of the thermosphere. Their occurrence is not related to any physical process, but depends on the NmF2 median level they are counted from. The positive Q-disturbances appear under slightly enhanced auroral activity when the high-latitude heating increases and damps the solar-driven poleward thermospheric circulation. This damping produces a downwelling of the neutral gas with the corresponding enrichment of the thermosphere with atomic oxygen at F2-region heights. The positive Q-disturbances belong to the same class of events as the positive long-duration F2-layer disturbances. The mechanism of both disturbances is the same: the damped poleward circulation and neutral gas downwelling resulting in the [O] abundance increase. The proposed concept allows one to explain the observed morphological features of the positive and negative Q-disturbances in the mid-latitude daytime F2-region.

## VALIDATION OF UNB-IMT WITH IONOSONDE TEC MEASUREMENTS OVER SOUTH AFRICA

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For more than a decade, ionospheric research over South Africa have been carried out using data from ionosondes located at Madimbo (28.38°S, 30.88°E), Grahamstown (33.32°S, 26.50°E) and Louisvale (28.51°S, 21.24°E). The area of interest has been modelling the bottomside ionospheric parameters using Neural Networks. Most recently, efforts have been undertaken to use Global Navigation Satellite System (GNSS) data as a new technique to monitor the dynamics and variations of the ionosphere over South Africa, with possible future application in high frequency radio communication. For this task, the University of New Brunswick Ionospheric Modelling Technique (UNB-IMT) was applied to compute midday (10:00 UT) GNSS-derived total electron content (GTEC). We computed GTEC using GNSS data for stations located near the ionosondes for periods 2002 near solar maximum, and 2005 near solar minimum. The GTEC was compared with the midday ionogram-derived TEC (ITEC) measurements to validate the UNB-IMT results. It was found that the variation trends of GTEC and ITEC over all stations are in good agreement and show a pronounced seasonal variation for the period near solar maximum, with maximum values (∼ 80 TECU) around autumn and spring equinoxes, and minimum values (∼22 TECU) around winter and summer. Short-time variations (∼27 day) of TEC, presumably due to solar rotation, are evident from both techniques. Signature TEC depletions and enhanced spikes occur more frequently around equinoxes particularly near solar maximum conditions. These observations were investigated and further discussed with an analysis of midday Disturbance Time Storm index of geomagnetic activities. The residual GTEC-ITEC was computed. It was evident that GTEC-ITEC which is believed to correspond to plasmaspheric electron content, showed a pronounced seasonal variation with maximum values (∼ 20 TECU) around equinoxes and minimum (∼ 5 TECU) around winter near solar maximum. These results verified the use of UNB-IMT as one of the tools for future ionospheric TEC research over South Africa.

## BEHAVIOR OF THE F2 REGION OVER THE ARGENTINE ANTARCTIC SECTOR

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The ionospheric parameters, strongly dependent on the solar conditions and on the complex behaviour of the magnetosphere, are very interesting for studying the complex phenomena and high degree of space/time variability of the ionosphere occurring at the high latitude regions. In the Argentine Antarctic Sector there are two ionospheric stations: San Martín (68.1°S; 293.0°E geographic; 53° S magnetic) and Belgrano (77.9°S; 321.4°E geographic, 67.5° magnetic). Vertical ionospheric soundings have been done for more than 4 decades in the Antarctic region. However

only some few studies can be found in the literature using the Antarctic ionospheric data base. The objective of this paper is to present a preliminary analysis of the behaviour of the critical frequency of the F2 region (foF2) using data recorded at the two Argentine Antarctic stations. The data base includes ionograms obtained during the representative months of summer (January), winter (July), fall (April) and spring (October) during years of low solar activity (LSA) and high solar activity (HSA). The diurnal, seasonal and solar activity variations are analyzed using the monthly medians for all the hours of the day. In all the cases the median values have bee obtained using at least 15 days of the month. The experimental values of foF2 are also compared with those predicted by the International Reference Ionosphere Model, IRI-2000. The results for San Martin show that the daily peak occurs around the local noon in winter and fall. In summer and spring a secondary maximum appears in the morning. This behaviour is observed at low and high solar activity. The winter anomaly is not observed at LSA. At HSA it appears around noon. The semi-annual anomaly appears also at hours near noon. The influence of the solar activity on foF2 is also shown. The behaviour of foF2 over Belgrano is similar to that observed for San Martín. From the analysis of the comparisons between the experimental values of foF2 and the IRI-2000 predictions can be seen that there are cases in which the model predicts reasonably well the experimental values. Cases are observed in which the model underestimates the observations. An analysis of the performance of the model is done using the two IRI options (URSI and CCIR) to predict foF2. Although modelling of the high-latitude ionosphere has improved in recent years with the advent of modern digital ionosondes, additional efforts are needed. The observational database in the Argentine Antarctic Sector can help to describe better the morphology of the high latitude ionosphere particularly in the South hemisphere.

## BEHAVIOR OF GPS TEC, ITEC AND IRI TEC PREDICTIONS OVER PRUHONICE

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In this paper we investigate the behavior of the total electron content derived from ionograms (ITEC) recorded by a DGS 256 at Pruhonice (50.0°N;15.0°E) and the vertical electron content derived from GPS signals (GPSTEC). The study is done for two years of low solar activity and for different seasonal conditions. We also compare the ITEC values with the corresponding IRI-2000 predictions (IRITEC). The differences between the GPS TEC and ITEC values (representing an estimate of the plasmaspheric electron content) are also analyzed. It is found that the diurnal and seasonal variations of GPSTEC and ITEC are in good agreement. The daily peak of the two TEC estimates is observed around noon and a clear seasonal behaviour is observed with minimum values in winter and maximum values in summer. The diurnal and seasonal variations of the differences between GPSTEC and ITEC are analyzed. The plasmaspheric contribution range between 20 and 35% during daytime and 40-60% during nighttime and is maximum during the winter months. The results are compared with those obtained in previous studies.

## ANALYSIS OF THE TOTAL ELECTRON CONTENT OVER AN ANTARCTIC STATION USING GPS MEASUREMENTS

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The objective of this paper is to analyze the behavior of the vertical electron content obtained from GPS signals (GPSTEC) during the high solar activity years: 2000 (Rz=117) and 2001 (Rz=111) at the station O'Higgins (63.3°S, 302.5°E geographic; 49° S magnetic ) located in the Argentine Antarctic Sector. The vertical electron content is derived from oblique GPS signals using La Plata Ionospheric Model, LPIM. The diurnal and seasonal variations of the GPSTEC values are analyzed. The daily peak is observed around the local noon in winter, fall and spring. In summer the maximum values are observed in the morning hours. This summer behaviour is similar to that observed in foF2 analyzing data from the Antarctic station San Martin (68.1°S; 293.0°E geographic; 53° S magnetic). The winter anomaly is not observed and the semi-annual anomaly is generally presented during daytime. An analysis of the variability is also done using the variability indexes Cup =upper quartile/median, Clo=lower quartile/median, and V%= (standard deviation/mean) x100.

## THE ACCURACY OF IONOSPHERIC MODELS WITH IRAQI IONOSONDE OBSERVATIONS

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The purpose of this research work is to validate the ionospheric models (IRI and CHIU) to assess its suitability and usefulness as an operational tool for Iraq. The ionospheric model is a computer model designed to predict the state of the global ionosphere for 24 hours. The scope was limited to conduct comparisons between the predicted F2 layer critical frequency (f0F2) and height of peak electron density (hmF2) against observed ionosonde data. The ionospheric prediction model (IPM) was designed to predict by using monthly median sunspot number, while the observation data are taken from digital ionospheric sounding (DIS) stations (Al-Battani, Iraq 33.34 N, 44.45 E) which lies within the mid latitude region of the globe. Analysis of the f0F2 data for Al-Battani station showed that the IRI model output, on average, was within approximately 2 MHz above observed data values, but for CHIU model was within approximately 2 MHz below observed data values. Correlation between predictions and observations was, in February about 0.103 for CHIU model, 0.844 for IRIC model and 0.858 for IRIU model. In March it was 0.566 for CHIU model, 0.749 for IRIC model and 0.764 for IRIU model. In December it was 0.872 for CHIU model, 0.971 for IRIC model and 0.966 for IRIU model. Analysis of the hmF2 data showed that there is poor correlation between the predicted and observed values, this analysis was approximately same for the three months (February, March and December) and it was chosen with high solar activity (for 1989) based primarily on data availability. From these results the empirical formula for applying correction factors were determined, these formula can be used to correct the error occurred in predicted f0F2 value.

## INSTRUMENTAL BIAS ESTIMATION USING SINGLE STATION GPS/TEC

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Variation of the ionospheric refractive index with frequency is a major source of error in computation of group delay and phase advance for Global Positioning System (GPS) signal measurements. Earth-based dual frequency GPS receivers present a plausible and cost-effective way of computing Total Electron Content (TEC) through the recorded pseudo-range and carrier phase observables. In order to estimate TEC values, frequency dependent satellite and receiver instrumental biases should be removed from GPS measurements properly. Satellite biases are computed by various analysis centers and they are available via the internet. However, receiver biases are computed for a small set of GPS receiver stations. In this study, three different methods are developed and implemented to estimate the single station receiver biases. First method models TEC by a second order polynomial and computes receiver biases in least squares sense. Second method computes VTEC data for each satellite, compares standard deviation of Vertical TEC (VTEC) values for different receiver biases and selects the receiver bias which minimizes the standard deviation with respect to the mean. Third approach is a process of leveling computed VTEC values with those from IGS analysis centers. Each of these TEC computation processes is applied to various mid-latitude, high latitude and equatorial receiver stations and for both quiet and disturbed days of the ionosphere. Estimated receiver biases are compared with the results from the IGS analysis centers. It is observed that the receiver biases estimated from first two methods are in agreement with each other and with the receiver biases estimated by CODE and JPL for high latitude and mid-latitude stations. These two methods can be used off-line and for equatorial regions, the estimates from the first two methods do not match the estimates from CODE or JPL. The third method can be used on-line and provides a fast estimate for the receiver biases. It also provides a very good agreement for all regions with the estimates of CODE and JPL.

## TOTAL ELECTRON CONTENT (TEC) MODELING AT EQUATORIAL LATITUDES

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Total Electron Content derived from ionosonde data recorded at Korhogo (Lat=9.33 N, Long =5.43 W, Dip = 0.67 S) an equatorial station, are compared to the International Reference Ionosphere (IRI) model predicted TEC for high and low solar activity conditions. The technique used to compute the TEC in this study was developed by Huang et al., (2001). The vertical columnar electron content is defined by the integral over the vertical electron density profile N(h) as follow $TEC = \int_0^{hmF2} N_B(h)dh + \int_{hmF2}^{\infty} N_T(h)dh$ where $N_B$ and $N_T$ are respectively the bottomside and topside electron density profiles. $N_B$ is computed from the recorded ionograms with accuracy by the inversion technique of Hang et al.,(1996). Since the ionograms do not provide direct information on the ionosphere above the F2 peak height, the topside profile, $N_T$ is approximated by exponential functions with

suitable scale heights (Bent et al., 1972) The result shows that the TEC has a solar activity and seasonal dependence. The IRI predicted values are closer to the observed TEC at high solar activity. However, at low solar activity the IRI overestimates the observed TEC. The deviation is more prominent in equinox during the time range 0900 to 2300 local time. The deviation is estimated to 60% of the observed TEC References X. Huang and B. W. Reinish,Vertical electron content from ionograms in real time, Radio Sci. 36,2,335-342,2001 X. Huang and B. W. Reinish, Vertical electron density profiles from the Digisonde network, Radio Sci.,18,121-129, 1996 R. B. Bent and S. K. Llewellyn,Documentation and description of the Bent ionospheric model,Air Force Geophysics Lab., AFCRL-TR-73-0657,Hanscom AFB, Mass.,1972

## STUDY ON SOLAR SOURCES AND POLAR CAP ABSORPTION EVENTS RECORDED AT MARIO ZUCCHELLI STATION, ANTARCTICA

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Particularly intense events on the Sun occurred in a period around minimum of solar activity during cycle 23. We investigated the characteristics of these events and the properties of the correlated observations of ionospheric absorption, obtained by a 30 MHz riometer installed at the Italian observatory of Mario Zucchelli Station (MZS-Antarctica), and of geomagnetic activity recorded at Scott Base and MZS (Antarctica). Solar events are studied using the characteristics of CMEs measured with SOHO/LASCO coronagraphs and the temporal evolution of solar energetic particles in different energy ranges measured by GOES 11 and ACE spacecrafts. Analysing these data, we have tried to determine possible clues that could allow a forecast evaluation of the effects produced at the Earth's orbit by the interplanetary perturbations. Moreover we have tried to determine as these effects are finally observed on the Earth's surface not only in the ionospheric absorption of radio waves and in the intense geomagnetic activity, but also in the significant variations of the cosmic ray modulation, even at high energies.

## FOF2 FORECAST DURING SEVERE GEOMAGNETIC ACTIVITY IN ROME OBSERVATORY

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A prediction procedure of the hourly values of the critical frequency of the F2 ionospheric layer, foF2, based on the geomagnetic index, is presented. The geomagnetic index used in this study is the time-weighted accumulation magnetic index ap(tau) based on the recent past history of the planetary index ap. The procedure is based on an empirical relationship between the ratio log(NmF2(t)/NmF2M(t)) and ap(tau), where NmF2(t) is the hourly maximum electron density at the F2 peak layer and NmF2M(t) is its "quiet" value. The prediction of foF2 has been calculated during periods of severe magnetic activity in the current solar cycle 23 using data processed at the Rome ionospheric observatory.

## RESEARCH OF WAVE PROCESSES IN IONOSPHERE ON THE BASIS OF DOPPLER EXPERIMENTAL DATA

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In this paper the analysis results of the spectral characteristics for ionospheric HF-signal on middle-latitude radio lines are presented. For the analysis Doppler experimental data have been used. Experiment was carried out on Doppler measuring equipment of the Kazan state university in 2005-2006. During this experiment continuous time series of ionospheric signal parameters have been obtained. Ionospheric signal parameters were measured on each radio line continuously within some months. Simultaneous measurements on two lines also were carried out. As a result of processing of experimental data the time series of Doppler frequency shift and half-width of spectrum for ionospheric signal have been obtained. The spectral analysis of these time series with use of wavelet transform has been carried out. Quasi-periodic variations with the periods of internal gravity waves (from 10 till 80 minutes), tidal waves (6 - 7 hours) and planetary waves (16 - 18 day) have been found out. Features of these quasi-periodic variations for different time of day, seasons and radio lines have been analyzed. Significant differences in range and spectral structure of variations for various seasons and radio lines have been found out. The fact of increase in range of Doppler frequency shift variations on radio line directed on longitude has been established. The fact of increase in range of Doppler frequency shift variations during autumn and winter seasons has been established.

## FURTHER OBLIQUE-INCIDENCE IONOSPHERIC SOUNDINGS OVER CENTRAL EUROPE TO TEST NOWCASTING AND LONG TERM PREDICTION MODELS

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

## DIURNAL AND SEASONAL VARIATIONS OF THE ELECTRON DENSITY OVER IRKUTSK DURING THE DECREASE IN SOLAR ACTIVITY IN 2003-2006. OBSERVATIONS AND IRI-2001 MODEL PREDICTIONS

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Climatic features of the electron density (Ne) variations over Irkutsk, Russia (52.5N, 104.3E) are studied using the method of running medians. The median values for each day of year are calculated by averaging over 31-day period. As a result the electron density can be considered as a function of height, LT and day of year. It is assumed that this function properly represents diurnal and seasonal regularities, because the influence of other factors is significantly decreased by 31-day averaging. Such form of ionospheric data representation is suitable for investigations of regular variations of the electron density, and for comparison with the ionosphere model predictions in particular. The comparison of the IRI-2001 predictions to the observational data collected at Irkutsk during the decrease in solar activity in 2003-2006 is presented in the report. Systematic differences between the predicted and observed diurnal behavior of Ne are discussed. Most likely these differences are associated with longitudal variation of critical frequency. In the report we also discuss the distinctions between regular variations of Ne at different heights.

## STUDY OF GEOMAGNETIC STORM EFFECTS USING DIGISONDE NETWORK DATA

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We present an analysis of the mid-latitude ionospheric response to geomagnetic storms using digisonde observations in the European and American sectors. For the strongest storms of 2001-2005 we analyzed the evolution of the ionosphere making use of the electron density profiles and main characteristics foF2 and hmF2. For the majority of the storms the observed pattern suggests that the main driver of the ionospheric response is neutral wind and composition change bulge. The local time dependence of the ionospheric effects supports a possibility of this mechanism as well. There is also experimental evidence that the Traveling Atmospheric Disturbances (TADs) play significant role in the daytime effects. Digisonde measurements demonstrate a strong uplifting of the ionosphere near the electron density maximum observed at all stations. The delay between the sudden storm commencement and the beginning of the ionospheric uplifting is consistent with the effect of ionospheric disturbances originating in the auroral oval and propagating equatorward with the speed of a few hundred meters per second. The observed longer delay in the start of the uplifting for the stations located at lower latitudes is in agreement with such picture. We also present data showing that at the equator very strong geomagnetic disturbance can lead to additional stratification in the equatorial F region, and to the appearance of an F3 layer.

## ANNUAL AND SEMIANNUAL VARIATIONS OF THE IONOSPHERIC VERTICAL PLASMA DRIFTS OVER JICAMARCA: EMPIRICAL ORTHOGONAL FUNCTION ANALYSIS

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By means of the empirical orthogonal functions analysis, we develop an experiential model to study the annual and semiannual variations of the equatorial ionospheric vertical plasma drifts from the incoherent scatter radar observations at Jicamarca. It is found that the annual and semiannual variations of vertical plasma drifts exist almost at all the local time. Under most of local time, the annual and semiannual variations are comparable, but semiannual variation is the main component of vertical plasma drifts at sunset. Although the amplitudes of annual and semiannual variations increase when F10.7 increases, they mainly change greatly with local time. The daytime vertical plasma drifts' annual and semiannual variations are smaller than that at night, and the annual and semiannual variation both minimize at the periods of from 0600LT to 1000LT. The phases of annual and semiannual variation change with local time, but nearly don't change with F10.7. The phase of annual variation is mainly in the neighborhood of two solstices and the phase of semiannual variation is mainly in the neighborhood of equinoxes and solstices. The annual variation of the vertical plasma drifts at Jicamarca is mainly caused by the variations of local background parameters, and the semiannual variation is mainly caused by the coupling of both hemispheres.

## SPECIFYING THE IONOSPHERE BY ASSIMILATING DATA FROM GROUND-BASED IONOSONDES AND GPS SENSORS ON THE COSMIC SPACECRAFT: VALIDITY AND PROBLEMS WITH ASSIMILATION

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Because there are plans to create a version of the International Reference Ionosphere IRI which assimilates data, the recent experience at AFRL with an assimilative algorithm for specifying the ionosphere is presented to show the potential gains and potential shortfalls of an assimilative algorithm. At AFRL, the Global Assimilative Ionospheric Model algorithm developed by the NASA Jet Propulsion Lab. and University of Southern California (JPL/USC GAIM) has been utilized to determine the accuracy of the output. While this assimilative model does not use IRI as its initial climatology, the results of this study can be useful as a guide for the development of an assimilative algorithm based on IRI. The AFRL study has been done by ingesting into GAIM data from the world-wide network of GPS stations and from the GPS occultation sensors on the COSMIC spacecraft. These sensors measure slant total electron content (TEC). The output of the assimilation algorithm is a set of electron density vs. altitude profiles at all low and mid-latitude

locations. From these profiles, various ionospheric parameters can be derived. The quality of the algorithm's results are determined by comparing the values from the algorithm with measurements of the ionosphere made almost simultaneously by the Jicamarca incoherent scatter radar, by the ionosonde stations at a few locations and by DMSP spacecraft at 850 km altitude. The study shows that assimilated ionospheric profiles yield TEC values which are significantly better than the climatology if the comparison is made within a few hundred kilometers distant of the TEC station(s) used as input. Although we have not compared the assimilated TEC values at many hundreds to over a thousand kilometers of the input locations, we expect a decrease in improvement with distance. A cursory comparison of the density vs. altitude profiles from the climatology, from the assimilation and from the ISR and ionosonde measurements indicates a significant improvement, but we have not yet quantified the improvement. The deficiency of the assimilation is that it degrades some ionospheric parameters such as the height of F2 peak (hmF2), the ion density at the F2 peak (nmF2). This degradation is due to an inadequate change in the half-width of the F2 peak between the climatology and the assimilated density profile.

## WWW.ESWUA.INGV.IT: THE WEB ACCESS TO THE "ELECTRONIC SPACE WEATHER UPPER ATMOSPHERE" SYSTEM.

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The INGV manages different kind of observations of the upper atmosphere and has been collecting digital data since several decades from middle and high latitudes. This big amount of information is now organized in a proper database, able to contribute to scientific and technological improvements at national as well as at international level in the field of telecommunications and space weather. The eSWua system is capable of supporting the acquisition, elaboration, evaluation, sharing and archiving of multi-instruments observations of the ionized atmosphere. A dynamic Web site has been recently opened for a real-time access to these data (www.eSWua.ingv.it). The COST296 Action (http://www.cost296.rl.ac.uk) offers the possibility to share the expertise of excellence in Europe in order to test the potentialities of the system, which can be, in turn, extended to host other data and scientific tools provided and suggested by the partners of the same Action. In the frame of international collaborations the eSWua is contributing to the projects where the interoperability of the system and effective data access are necessary requirements, such as Virtual Observatories (www.egy.org), ICESTAR (Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research, http://www.scar-icestar.org) and SIRIA (Information System for the Italian Research in Antarctica) (Piervitali et al 2004). The eSWua is the outcome of a big effort of manpower, time and funds motivated by the awareness that geoscience has to rely on structured digital data and on appropriate scientific procedures developed ad hoc by experts open and shared among the international community. This paper describes the technical features, software and hardware, of the system as well as the future tasks and potentiality. Moreover details on Web tools concerning ionospheric and scintillations data treatment, and user policy management are presented.

## FINE STRUCTURE OF MAIN IONOSPHERIC TROUGH

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The mid-latitude electron density trough observed in the topside ionosphere has been shown to be the near-Earth signature of the plasmapause and can provide useful information about the magnetosphere-ionosphere dynamics and morphology. Thus for present the evolution of ionosheric trough in time and space domain we need some multipoint measurements and different type of measurements techniques. To develop a quantitative model of evolution ionospheric trough features during geomagnetic disturbances the analyse of particle and waves in situ measurements and TEC data was carried out. The high resolutions plasma particle diagnostics and wave diagnostics located on board of currently operated satellite DEMETER can give us precisely description of trough signatures and instabilities at define point in space . On the other hand GPS permanent networks such as IGS and EPN provide regular monitoring of the ionosphere in a global scale. Recently, TEC maps have been produced with 5 min intervals and with spatial resolution of 150 – 200 km. In order to better understanding the physical process occurred in plasmapause region during strong geomagnetic disturbances we present the data gathered by help the ground-based ULF “Hylaty” station located in Bieszczady mountains. The aim of this paper is to present some general behaviour of trough dynamics as well as the fine structures of ionospheric trough and discuss the different type of instability generated inside the trough region from ULF frequency range thru VLF up to HF frequency range. As a consequence of different time scales of physical processes occurred in the near Earth environment during geomagnetic disturbances we discusses the different fine structures of main ionospheric trough both in particle as well as in waves presentation. . In order to better understand the physical conditions and evolution of ionosphere trough region and describe the coupling between ionosphere and inner magnetosphere the global map of TEC parameters was constructed

## GENERAL FEATURES OF 4–24-DAY WAVES IN SPORADIC E-LAYER VARIATIONS AND THEIR CONNECTION WITH EQUATORIAL STRATOSPHERIC QBO

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This paper summarizes the results of our research in sporadic E-layer (Es) dynamics with planetary wave periods (2–32 days) in the Northern hemisphere and its connection with equatorial stratospheric quasi-biennial oscillation (QBO). The interpolation of averaged daily values of Es highest frequency (foEs), amplitudes of 2–32-day foEs oscillations and filtered 16-day foEs oscillations is conducted on the basis of foEs measurement data for 1965–1989 from the world ionosonde network. Averaged monthly values of the zonal wind ¡u¿ in the equatorial stratosphere at the 19–31 km height interval are used as the index of quasi-biennial oscillation of atmospheric circulation. A correlation analysis between the annual averaged values of

¡u¿ index and the interpolated values of foEs and 4–24-day foEs oscillations showed significant correlation in the sector of longitude from 30° to 270° (to the East of Greenwich) and latitude from 15°N to 75°N. We have developed an original algorithm for detecting a spatial motion in scalar field of any interpolated geophysical parameter in a specific local area. The algorithm is used to obtain zonal and meridional projections of local displacement of the 4–24-day foEs wave perturbation field in the Northern hemisphere. A connection between the annual prevailing directions of 4–24-day foEs wave perturbations and the QBO phase (eastern or western) of atmospheric circulation is revealed on the basis of correlation analysis. The strongest correlation is discovered in the area around 60°N, 120°E in the case of filtered 16-day foEs oscillation field.

## WAVELET-BASED ANALYSIS OF SPORADIC E LAYER

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Two high sampling rate campaigns were performed in midlatitude station Pruhonice (50N, 14.6E) in order to analyse variability of sporadic E layer. Regular vertical sounding was accompanied by E region drift measurement. Our study concerns measurements recorded during period of low solar activity during summer 2004 and 2006. Our data sets consist of time series of critical frequencies foEs, corresponding maxima hEs and particle drifts at two frequencies in the height range 90 km–150 km. Dominant oscillation modes, their persistence and prevailing plasma motion are analysed using wavelet transform and further discussed. Besides periodicities in tidal and planetary range that are known to occur within time series of critical frequencies foEs, we evidence the existence of planetary wave type oscillations in the time series of the height of Sporadic E layer. Detail analysis of the central-period of the diurnal tide (time series of foEs and hEs) shows that it is not exactly 24 hours but it varies with planetary wave period.

## REGIONAL SPACE-TIME INTERPOLATION OF GPS-TEC WITH KRIGING

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Spatiotemporal variations in the ionosphere affects the HF and satellite communications and navigation systems. Total Electron Content (TEC) is an important parameter for analyzing the spatial and temporal variability of the ionosphere. Due to the high variability of the ionosphere in space and time, the electron density distribution and TEC can be regarded as spatiotemporal random functions similar to their counterparts in geostatistics, hydrology, meteorology and environmental sciences. The Global Positioning System (GPS), due to its availability for civilian use in the last 10 years, provides a cost-effective means for estimating TEC. Since GPS-TEC can be estimated only for a limited and mostly sparsely distributed number of receiving stations, a suitable interpolation both in space and time representing the nature of ionosphere is necessary. Kriging is a widely used interpolation technique in geostatistics. Kriging linearly estimates the process by minimizing the error variance

with respect to an unbiasedness condition. It is also known as the Best Linear Unbiased Estimator (BLUE). Kriging first preprocesses the data to infer the structure of variability of the random function and joined with the Kalman Filter, it presents an important alternative for space-time interpolation. Due to the inherent errors in the TEC measurement and computation, it is better to observe the performance of Kriging over synthetic TEC surfaces generated in space and combine them with model TEC like IRI. Synthetic TEC data is simulated by using geostatistical data simulation algorithms, for different variance and correlation range parameters and a trend model is added onto the data set. Parameters of the trend models, variance and correlation range values are chosen to represent various ionospheric variability states. The synthetic TEC data is reconstructed from the taken samples at various numbers and sampling patterns by Ordinary and Universal Kriging algorithms and compared over sampling patterns, sample numbers, variance and range parameters. Secondly, spatiotemporal interpolation techniques implemented on TEC estimates computed from GPS observations both in space and time by using mean and covariance functions derived from IRI-2001 and GIM. Regional TEC maps are generated by space-time Kriged-Kalman technique, using both the TEC computations at the ionospheric piercing points and the regulated TEC above the receiver stations. Appropriate sampling pattern and number of stations, the optimum Kriging algorithm with the covariance function that best represents various ionospheric distributions are determined. The estimated GPS-TEC data is used in the selected Kriging algorithm to generate regional TEC maps with increased accuracy, reliability and space-time resolution.

## IRI 2001/90 TEC PREDICTIONS OVER A LOW LATITUDE STATION.

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Total electron content (TEC) over Tucumán (26.9°S,. 294.6°W) measured with Faraday technique during the high solar activity year 1982, is used to check IRI 2001 TEC predictions at the southern crest of the equatorial anomaly region. Comparison with IRI 90 are also made. The results show that in general IRI overestimates TEC values around the daily minimum and underestimates it the remaining hours. Better predictions are obtained using ground ionosonde measurements as input coefficients in the IRI model. The results suggest that for hours of maximum TEC values the electron density profile is broader than that assumed by the model. The main reason for the disagreement would be the IRI shape of the electron density profile. In a previous work using TEC measurements over Tucumán, obtained from GPS satellite signals during the high solar activity year 1999, a better agreement between IRI predictions and measurements has been observed. That better agreement was produced by the fact that 1999 GPS TEC measurements are 50% lower than those obtained by Faraday rotation technique on 1982. The results suggest that southern peak of the equatorial anomaly could have moved equator ward during 1999. Moreover, it can be seen that in most of cases IRI TEC values around daily minimum show an hour displacement with respect to the experimental data. (POSTER PRESENTATION)

## HIGHLY ADAPTIVE ELECTRON DENSITY PROFILE MODEL APPLIED TO IONOGRAMS FOR REAL TIME MONITORING

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An electron density profile model with free parameters is introduced. Initially the parameters are calculated on the basis of the ionospheric characteristics automatically obtained from the ionograms by Autoscala and considering the heliogeophysical conditions. The technique used for adjust the free parameters to the particular ionograms recorded is presented. The real time application to the ionospheric stations equipped by the AIS-INGV ionosonde (Rome and Gibilmanna) is shown.

## STATISTICAL MODELLING OF RADIOWAVE PROPAGATION UNDER ES-LAYER INFLUENCE

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The Es-layer greatly affects the radiowave propagation. There are several methods for evaluation of the Es-signal probability characteristics on the fixed radioline frequencies. A less amount of papers are dedicated to investigation of the Es-layer influence on the mode structure of received signal and its energy characteristics. However, there are no methods for the statistical modelling and the forecasting of radiowave propagation in circumstances of the Es-layer existence. In this paper we present a method of modelling of radiowave propagation at the midlatitude tracks in circumstances of the Es-layer existence, aimed to the commercial long-time forecast of the maximum usable frequency (MUF) band and to the increase of radiocommunication reliability. A frequency band with the high signal energy and the absence of miscellaneous mode multi-beaming is determined. The input parameters of the method are the heliophysical and the geomagnetic data, as well as the technical characteristics of the track. The geometric track parameters and the M coefficients (coefficients of recalculation of the vertical sounding critical frequencies to the maximum virtual height) are calculated. The track energetics and the threshold value of reflection coefficient are determined. The NGDC database of the worldwide vertical incidence parameters is used in this research. The hourly values of ionospheric parameters with the similar geophysical and geomagnetic conditions are used. A method of evaluation of the maximum observed frequency (MOF-Es), reflected from the Es-layer is considered, that is conditioned by the dependence of this frequency on the threshold value of reflection coefficient. The probabilities of miscellaneous propagation mode appearance are obtained. The examples of modeling of radiowave propagation conditions for midlatitude 1000 km track are shown. Several frequency bands of miscellaneous influence of the Es-layer on the radiowave propagation conditions are pointed out: the increase of MUF-band from 12 to 14.5 MHz; the screening of upper reflection layers and disappearing of multi-beaming from 4 to 5 MHz. The frequency band of the stable radiolink and the multi-beaming absence varies during the day from 1–7 MHz at night to 5–13 MHz at daytime. This band may be extended if we disregard of multi-beaming caused by Es-layer: at night–up to 10 MHz, at daytime–up to 18 MHz. Contribution of the Es-layer reflections in working frequency band increases with the distance increase approximately on 30%, i.e. 2–4 MHz for 500–2000 km range. This work was supported by the Russian Foundation for Basic Research, project 06-05-65150.

## A COMPARISON STUDY ON PERFORMANCES OF DIFFERENCE TEC MODELS IN EAST ASIAN REGION

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Performances of TEC models are validated by the GPS-TEC data in 2000 and 2004. The validation data cover the area from north to south, especially at the low latitude. The factors, such as solar activity, diurnal and seasonal variations, elevation and azimuth angles, which affect the performances of the two models, are considered respectively. NeQuick model provides considerably better results in the middle latitude than at low latitude, in solar minimum than in solar maximum, at daytime than at nighttime, and in summer and winter than in equinox. Klobuchar model has lower model slant TEC values than the experiment data in 2000 and higher ones in 2004 except for a low latitude station which always has lower model values. NeQuick model has higher slant TEC values than the experiment data in 2000 and 2004 except for the low latitude station which has lower model values in 2004. Both these two models show bigger errors in 2000 than in 2004, and higher mean errors in the low latitude than in the middle latitude, which increase with the latitude decreasing generally. Both Klobuchar and NeQuick models have higher biases in the daytime and lower ones in the nighttime. The difference of both models' biases is smaller when azimuth angle is in -45°∼45°. And biases of the two models decrease with the elevation angle increase.

## EVALUATING TOPSIDE IONOSPHERE MODELS: A REVIEW OF THE MODELLING TECHNIQUES AND THE CURRENT STATUS OF TOPSIDE MODELLING

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Representation of the topside ionosphere (region above the F2 peak) is very critical because of the limited experimental data available. Over the years, a wide range of models have been developed in an effort to represent the behaviour and the shape of the density profile of the topside ionosphere. The topside ionosphere modelling efforts will be reviewed with emphasis on their performance in the South African region. Various studies have used different techniques that include: Using a unique method to calculate the Vertical Scale Height (VSH) such as: obtaining VSH from GPS derived TEC, calculating VSH from groundbased ionosonde measurements, using topside ionosonde vertical electron density profiles to obtain VSH and then use one or a combination of the topside profilers (Chapman layer, Exponential layer, Sech-Squared(Epstein) layer and/or Parabolic layer) to reconstruct the topside density profile. The different approaches and techniques are evaluated in terms of their abilities to reproduce measured topside profiles and the current status of topside modelling efforts are reviewed. This review is a first step in the process of developing a South African topside ionosphere model.

## IONOSPHERIC EFFECTS OF CONVECTIVE STORMS IN HF DOPPLER SHIFT MEASUREMENTS UNDER GEOMAGNETIC QUIET OR SLIGHTLY DISTURBED CONDITIONS

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Many kinds of waves originating from various natural and artificial sources have been observed in the upper atmosphere including infrasonic (acoustic) waves, gravity waves, planetary waves and tides. Periods of the waves extend in the range from seconds to days. Here we focus on a study of short period waves of tropospheric origin observed using HF Doppler shift measurements. As there are no specific characteristics to identify infrasonic waves generated by severe tropospheric weather, it is difficult to distinguish such an emission from the waves originated from another sources. The only way to distinguish waves emitted by severe meteorological events is to recognize and eliminate atmospheric waves emitted by other sources. Here, we compare atmospheric wave activity during severe convective storms, which occurred under both geomagnetically quiet and disturbed conditions. We also discuss possible ways to distinguish between short period oscillations of tropospheric origin and geomagnetic origin.

## D-REGION ELECTRON DENSITIES AT 69°N AFTER 3-MHZ DOPPLER RADAR OBSERVATIONS

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Electron number densities of the lower ionosphere are estimated with the Saura MF radar which is located near Andenes, Norway (69.3°N, 16.0°E) and is operated at 3.17 MHz with a peak power of 116 kW. The narrow beam transmitting/receiving antenna consists of 29 crossed half-wave dipoles arranged as a Mills Cross resulting in a beam width of about 7°. Antenna and transceiver system provide high flexibility in beam forming as well as the capability forming beams with left and right circular polarization. The experiment utilizes partial reflections of ordinary and extraordinary component waves from scatterers in the altitude range 50-90 km to estimate electron number densities from differential absorption (DAE) and differential phase (DPE) measurements. Height profiles are obtained between about 55 km and 90 km with a time resolution of 9 minutes and a height resolution of 1 km. The electron number density profiles derived with the DAE and DPE measurements are in remarkable good agreement and electron number densities are given if the results of the DAE and DPE experiments are in agreement within a factor of two. We discuss the diurnal and seasonal variability of electron densities obtained at Andenes since July 2004, the response of D-region electron densities to geomagnetic disturbances and solar proton events. The results are compared with previous rocket-borne radio wave propagation measurements at Andenes as well as with co-located simultaneous insitu observations using radio wave propagation experiments in December 2004 and September 2006. In addition, the electron densities obtained with the MF Doppler radar are compared with the recent IRI model.

## AN EQUATORIAL ZONAL ION DRIFT MODEL FOR JICAMARCA

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We have published a regional empirical model for the disturbed- and quiet-time equatorial zonal plasma drift near the F region peak. Incoherent scatter radar database from Jicamarca Radio Observatory registered between 1970 and 2003 and Bernstein polynomials as base functions were used to construct this model which will be incorporated into the IRI. The model also includes dependences with solar activity and season. Our quiet-time model results confirm that the daytime drifts are westward and are nearly season and solar cycle independent. The nighttime drifts are eastward, have larger magnitudes, and increase strongly with solar flux, particularly near equinox and December solstice. Enhanced geomagnetic activity drives small eastward perturbation drifts during the day and much larger westward disturbance drifts at night. The nighttime drift perturbations are largest near midnight and increase strongly with solar flux near equinox and December solstice but are essentially absent near June solstice.

## REAL TIME TEC MONITORING USING TRIPLE FREQUENCY GNSS DATA: A THREE STEP APPROACH

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In the near future, triple frequency GNSS (Galileo, modernized GPS) will be operational. In fact, the first Galileo satellite (GIOVE-A) was launched in December 2005, and its validation phase is nearly achieved. The availability of a third frequency will not only allow to improve the positioning accuracy but also to develop improved real time TEC monitoring techniques. The paper describes our first attempts to develop such an improved TEC monitoring technique, and explains which tests we intend to make on the first available triple frequency Galileo data. Firstly, we have developed a software allowing to simulate precise and realistic code and phase measurements that will be made on the signals which will be emitted by the Galileo system and by the modernized GPS constellation. Those simulated data can be used to test a triple frequency technique for TEC monitoring. We applied a method which is divided in three steps. GPS frequencies are L1, L2 and L5 which corresponds to L1, E5b, E5a for Galileo. The goal of the first step is to resolve the so-called extra widelane (EWL) ambiguities ( = 5.861m for GPS cw–9.768m for Galileo) by differencing the code and phase combinations of L2 and L5. In the second step, we use the EWL fixed ambiguities to resolve the widelane (WL) ambiguities, which is a combination of L1 and L2 ambiguities ( = 0.862m for GPS–0.814m for Galileo In the third step, we solve the one-epoch system of 2 dual frequency Geometric Free (GF) phase combinations (2 equations–4 unknowns) by using the information we have from EWL and WL ambiguities, so we obtain a system of 2 equations with two unknowns: the TEC and the ambiguities on L2. The main advantage of our method is that we have to resolve integer ambiguities (EWL and WL) in place of non-integer ambiguities coming from the GF combination, what is easier and more efficient. The second is that even if code measurements are used in the first step of the method, code biases do not affect the accuracy of the final reconstructed TEC. Secondly, we can explain several tests to make with the first available GIOVE-A triple frequency data. All those tests will mainly help to validate our TEC monitoring technique, but also in the same time to validate our Galileo simulation software. In a first step, we will form the EWL combination, to see whether the influence of code noise and code multipath effects on this combination is coherent with our simulations results. In other words, we will see whether it is possible to resolve the EWL ambiguities with real data in the same way as with simulated data. Then, we will form the WL combination and see whether its characteristics are similar to the simulated WL combination. Finally, we will try to solve the GF phase combinations systems in order to monitor the TEC. We will then be able to say whether the accuracy of the final reconstructed TEC is improved (at least one order of magnitude) with respect to the double frequency technique.

## PREDICTING EQUATORIAL DENSITY IRREGULARITY OCCURRENCES FROM RESULTS OF STATISTICAL STUDY OF IRREGULARITY OCCURRENCES WITH VERTICAL DRIFT VELOCITIES

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Global monthly/seasonal/longitudinal variations of equatorial density irregularities have been obtained from the ROCSAT data taken at the 600 km topside ionosphere from March 1999 to June 2004 during high to moderate solar activity periods. Seasonal/longitudinal (s/l) variations of quiettime post-sunset vertical drift velocities are found to track closely with the s/l variations of irregularity occurrences except during the September equinox. Linear regression analyses between the vertical drift velocities and the irregularity occurrences are carried out for four seasons as well as at various longitude regions to examine the effectiveness of vertical drift velocity in causing the irregularity occurrences. The results indicate that although the effectiveness varies, the vertical drift velocity at any longitude regions has a good correlation with the irregularity occurrences for all seasons. This implies that the vertical drift velocity alone can proportionally drive the occurrences of equatorial density irregularities even though its effectiveness has some longitudinal variations. Since the ion density variation measured at a constant height can be related to the vertical drift velocity, we use the variation of measured ion density above a reference background level to predict the subsequent irregularity occurrences along the ROCSAT orbit as a test to develop a prediction scheme. The test result indicates that the prediction outcome, though only about 80% accurate, is still well above the random guess result.

# SOLAR AND LOWER ATMOSPHERE FORCING OF THE IONOSPHERE AS OBSERVED BY SATELLITES

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The Ionosphere-Thermosphere-Mesosphere (ITM) region is highly variable and has a complex system of drivers including variable solar radiation, geomagnetic activity, and forcing from the lower atmosphere. Waves that originate in the troposphere grow in amplitude as they travel upwards into decreasing density at higher altitudes where they become the most prominent dynamical features of the ITM. Planetary and gravity waves modify the zonal mean temperature and winds through dissipation and momentum deposition. The effects of these waves on the ITM are expected to depend on the level of solar activity. For all types of waves, how high they penetrate into the thermosphere depends on the temperature, wind, and viscosity profiles. Current observations have shown signatures of both gravity waves and planetary waves in upper atmospheric measurements of winds, temperature, and ion density. Momentum deposition by the diurnal tide at low latitudes in the lower thermosphere produces indirect circulations that will transport neutral and ionized constituents both vertically and horizontally to higher latitudes. While magnetospheric forcing dominates the variability at high latitudes in the ionosphere and thermosphere, photochemistry and neutral dynamics play dominant roles in the ITM structure and variability at mid and low latitudes. The wind-driven E-region dynamo generates large-scale electric fields, causing upward plasma drifts that combine with pressure forces and gravity to form the equatorial ionization anomaly in electron density. As a result, variability in E-region winds could translate upwards into the low-latitude ionosphere. The dominant dynamical feature in the E-region is the diurnal tide, and its seasonal, interannual, and daily variability are important factors in understanding the behavior of the ionosphere. Recent global observations of the low latitude neutral atmospheric and ionospheric structure revealed by TIMED/SABER, TIMED/GUVI, TOPEX, JASON, and DMSP allow us to investigate the interplay between the neutral, plasma, and background fields. Specifically, this rich dataset allows us to examine the solar activity effects on the low-latitude ionosphere on different timescales–including solar flare, rotational, and 11-year solar cycle effects. In this paper we describe the effects of solar activity on the low-latitude ionosphere as observed by three different sets of measurements, including the maximum electron number density, the peak height, the latitudinal separation of the equatorial arcs, the asymmetry of the peak densities. In addition, we examine the relationship between the variability observed in and mesospheric and lower thermospheric dynamical fields to variations observed in the low latitude ionosphere. We also compare these results with those from the IRI model and a first-principles general circulation model, the TIE-GCM. The characterization and analysis of the observed effects are essential for understanding low-latitude electrodynamics.

## INTEGRATION OF GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) AND SATELLITE ALTIMETRY MEASUREMENTS TOWARDS COMBINED GLOBAL IONOSPHERE MAPS

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Several space geodetic techniques - such as the Global Navigation Satellite System (GNSS), the satellite altimetry missions Topex/Poseidon and Jason-1, and Low Earth Orbit Satellites (LEOs) like CHAMP, SAC-C, COSMIC - can be utilized for observation and modelling of the ionosphere in terms of Total Electron Content (TEC) values. The different observation principles of these techniques result in specific features of the ionosphere parameters derived by each of them. A combined model of the ionosphere should make best use of the advantages of each particular space geodetic technique, having a more homogeneous global coverage, and being more accurate and reliable than the single results. As a first step towards a sound combination procedure for computation of integrated Global Ionosphere Maps (GIM) using data from the various observation techniques, the integration from GNSS and altimetry measurements is investigated. The classical input data for estimation of GIM is the "geometry-free" linear combination, derived from dual-frequency GNSS observations. The precision of these maps is particularly associated with the network density and homogeneity and thus lowers over the oceans. Dual-frequency satellite altimetry missions provide information about the ionosphere parameters above the sea surface but due to the limited spread of the measurements and some open questions related to the systematic errors, they are mainly used for cross-validation so far. In this study we create two-hourly GIM from GNSS data and additionally introduce satellite altimetry observations. The combination allows also the independent estimation of systematic instrumental errors, affecting the two techniques.

## MODELLING IONOSPHERE WITH NEURAL NETWORK OVER THE EUROPE REGION

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The ionospheric critical frequency and M(3000) of the F2 layer is highly variable on time- and space-scales. The state of the ionosphere depends on the intensity of solar activity, magnetic activity, local time, season, and other space weather factors. Therefore it is important the ionospheric variability to forecast. The paper presents the neural network method modification in space weather applications and the use of this method for the forecast of the ionosphere characteristics, as foF2, M(3000)F2. The neural network modified algorithm was used for data gaps correction, as well as the characteristics' forecast. The proposed algorithm is demonstrating for European area. The accuracy of the obtained maps is enclosed.

## A DATA-MODEL STUDY OF THE SOLAR ACTIVITY DEPENDENCE OF THE TOPSIDE IONOSPHERE ELECTRON TEMPERATURE AT EQUATORIAL AND MID-LATITUDES

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Electron temperature (Te) in the topside ionosphere and plasmasphere is an important parameter because thermal electrons play a key role in the energy balance of these regions. The IRI model includes an empirical representation of Te in the topside ionosphere depending on altitude, latitude, local time, and season. But due to a lack of data and sometimes conflicting measurements, the solar activity variation of Te has not been reliably modeled so far. Using a large electron temperature (Te) satellite database of almost all available satellite measurements in conjunction with the theoretical FLIP and GSM TIP models, we discuss prevailing cooling and heating terms and their influence on the Te balance and its change with solar activity in the topside ionosphere (from 400 to 2000km). For the equator we have found very good agreement between calculations of the GSM TIP model and Te data. The FLIP model represents Te data very well in the mid-latitudes. Specifically we note the following results: (1) During nighttime at equatorial latitudes Te is close to the temperature of neutrals (Tn) and always increases with increasing solar activity. (2) This is also valid for daytime at low altitudes (below ∼650km) and high solar activity (F107¿150) but a self-consistent modeling (included in the GSM TIP model) of Tn is required for explanation of a steep increase of Te with increasing solar activity. (3) the influence of ExB drift on the solar activity dependence of Te above the equator is marginal. (4) Possible nonlinear dependence of Te on F107 at low solar activity at daytime is also pointed out. (5) At mid-latitudes the Te variation with solar activity is very complicated and it is dependent on seasons and altitude (as discussed by Bilitza et al., 2007). With help of these results and using the Te satellite database we propose an empirical representation of dependence of Te on solar activity. This representation is in the form of a term depending on latitude, altitude, local time, and solar activity. This term is additive to the overall average pattern of Te obtained from the Te database. D. Bilitza, V. Truhlik, P. Richards, T. Abe, and L. Triskova, Solar cycle variations of mid-latitude electron density and temperature: Satellite measurements and model calculations, Advances in Space Research 39, 779–789, doi:10.1016/j.asr.2006.11.022, 2007

## FOF2 FORECAST 1-H IN ADVANCE DURING DISTURBED CONDITIONS BY USING A RECURRENT FUZZY NN

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In this paper the scientific activities related to one of the effects of the Near Earth Space on Ionospheric Radio Propagation will be introduced. HF radio communication requires forecasting the ionospheric critical frequencies (Tulunay Y., 2004).

Ionospheric F layer critical frequency, foF2, is a parameter designating the maximum usable frequency. In addition to diurnal, seasonal and solar variability of foF2, during geomagnetically disturbed conditions induced by Solar Storms, the physics of ionosphere become more complex and non-linear, therefore the response of ionosphere to such disturbances need to be qualified and quantified for the system designers, operators and users. There are various models constructed for the forecasting of foF2 using different methods, for example, mathematical modeling using first physical principles, statistical models, data driven models. In this work a hybrid data-driven modeling approach is employed. In this paper, a Recurrent Fuzzy Neural Network (RFNN) approach is employed for forecasting of foF2 during the geomagnetically disturbed conditions. A new optimization algorithm, D-FUNCOM (Dynamic Fuzzy Neural Optimization Method) is used in the training of the Neural Network (Mastorocostas and Theocharis, 2000). To demonstrate the performance of the approach, the major storms of 2003 are chosen as case studies. That is, the Halloween and the Superstorm of 2003.

## HF RADAR

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Sky-Wave HF radar only is considered because of the lack of data on surface-wave HF Radar. The ionospheric effects can be investigated efficiently by working with sky-wave HF radar. Following the "proposal for future work" reported in 5th MCM in Rennes 3-7 October 2006, Effects of space weather conditions on the variation of group range and line-of-sight Doppler velocity of the HF Radar echo signal are investigated. Since there are no data made open, semi-synthetic data are generated by using Tasman International Geospace Environment Radar (TIGER) image plots available on internet as it was hinted during 5th MCM. HF radar system under ionospheric disturbances has been identified globally and some operational suggestions have been presented. The use of HF radar system is considered from the identification of ionospheric propagation medium point of view. Doppler velocity is considered as the characteristic parameter of the propagation medium. ap index is chosen as the parameter for disturbance characterization due to geomagnetic storms in the ionosphere. ap index is grouped with two levels of magnetic activity; ap = 9 and ap ¿ 9. Former level will be used for undisturbed ionosphere and the letter will be used for disturbed ionosphere. Considering the results obtained from the TIGER image plots and solar cycle and seasonal variation of the ap index, it is possible to give some suggestions to HF radar planner and operator for the radar operating at the frequencies 11MHz and 14 MHz: I. When ap index is greater than 9, it seems that it is not possible to communicate with the station located within the group range of 640 km at 11MHz and 14 MHz. II. When ap index smaller than 9, it seems that it is not possible to communicate with the station located within the group range of 1950 km at 11MHz and 2550 km at 14 MHz. III. It seems that the maximum group range of the HF signal for the single hop propagation does not change significantly with respect to the operating frequencies for 11 MHz and 14 MHz. Therefore, there is no constraint about the maximum group ranges for the given frequencies. Actually HF signal can propagate to group ranges of up to 4000 km via second hops. ap forecasting models and organizations make it possible to forecast the ap index one to four hours ahead, therefore it is possible for the HF radar operator to estimate the possible skip distance and possible single hop group ranges for the given frequencies of 11 MHz and 14 MHz.

## MODELING IONOSPHERIC AND SOLAR PARAMETERS USING GENETIC PROGRAMMING APPROACH

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In this paper, the modelling capabilities with the use of Genetic Programming approach are introduced. For particular cases, some of the Near Earth Space parameters and their effects on Geospace are investigated. One of the parameters is the Ionospheric F layer critical frequency, foF2, which is a parameter designating the maximum usable frequency. In addition to diurnal, seasonal and solar variability of foF2, during disturbed conditions induced by Solar Storms, the physics of Ionosphere become more complex and non-linear. Despite the fact that foF2 is a crucial parameter of telecommunication there are limited number of ionosondes over the world. Moreover, during disturbed conditions, for some of the ionosondes, the quality of measurements decrease and missing number of data increases. Thus, there have been attempts to generate foF2 instantaneous maps of Europe (Bradley et al., 1998; Lazo et al., 2004; Stanislawska et al., 2001 and Stanislawska et al., 2004). Different than the previous works, genetic programming approach is used and an algebraic mapping function is constructed. Other case study is an attempt to construct whole TIMED Solar EUV Flux data with the use of only six measured flux values of six wavelengths. Several solar EUV irradiance models have been developed since the 1970s to compensate the lack of observations (Kretzschmar et al., 2006). Importance of the study comes from the fact that the Solar EUV data is necessary for most of the Ionospheric and Thermospheric models. Similarly, for this particular case, Genetic Programming approach was employed to construct a model for achieving the task.

## CORRELOGRAM AND PDF ESTIMATION FOR TOTAL ELECTRON CONTENT

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Total Electron Content (TEC) is the total number of free electrons inside the cylinder with 1 m2 cross-section. TEC is an important parameter which is used in the ionospheric variability research. Observing the ionospheric variability by statistical methods gives information about the characteristics of ionospheric variability. The power spectral density (PSD) is a key tool to determine the frequency of variability and its distribution. In the literature, the ionospheric variability has been investigated usually with distribution of the deviation from the mean. With the computation of PSD over the long term TEC data and the deviations from the mean TEC, a general trend statistics of the variation and the deviation from the mean can be obtained. PSD can be computed with various algorithms including periodograms and correlograms. In this study, correlogram method is prefered over periodograms due to the incomplete or missing data sets. Correlogram uses autocovariance and discrete fourier transform (DFT) to estimate PSD. The data sets for analysis are obtained from both IONOLAB and from IRI-2001. The International Reference Ionosphere (IRI) is a widely used standard for the specification of ionospheric parameters and it is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI). The correlogram analysis provides the variance periodicities that cannot be observed with other statistical analysis techniques. The comparison of the correlograms with GPS-based IONOLAB TEC and IRI-TEC is an important indicator of the performance of IRI-TEC in estimating the general trends. Another important parameter of space-time statistics of ionospheric variability is estimation of the probability density function (PDF). Although various interpolation and mapping algorithms have been used in the literature, a complete statistical description of the regional space-time statistics of the ionosphere with PDFs have not been investigated. The experimental PDFs are formed using histograms of the IONOLAB data both in space and time. The statistical distribution of TEC over a region, represented by a random function model in space and time, is very important for the performance of many mapping algorithms. In this study, both space-time correlograms and PDFs will be derived for the first time for certain regions of ionosphere.

## WEB BASED AUTOMATED TEC ESTIMATION WITH IONOLAB

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Dispersion and phase delay is a major concern for the propagation of radio waves used for communication, navigation and observation systems due to the increased ionization in the Earth's ionosphere. The ionosphere can be monitored by estimating Total Electron Content (TEC). TEC is expressed as the amount of free electrons within 1 m2 cross-sectional area of the region between ground and ionosphere. TEC estimations can be obtained either based on model and/or measurement. International Reference Ionosphere (IRI) is the most well-known among model based estimations. Global Positioning System (GPS) provides a cost effective way for estimating TEC. Reg-Est algorithm, developed by F.Arikan, C.B. Erol and O. Arikan is a new alternative for estimating high resolution, robust TEC values combining GPS measurements of 30 s resolution obtained from the satellites which are above the 10° elevation limit. With Reg-Est, TEC can be estimated for a whole day or for a desired time period, both for quiet and disturbed days of the ionosphere. Reg-Est provides robust TEC estimates for high-latitude, mid-latitude and equatorial stations. After investigating some important parameters of Reg-Est and incorporating the changes, Reg-Est is developed into the IONOLAB algorithm. IONOLAB provides reliable and robust TEC estimates independent of the choice of the maximum ionization height. The optimum weighting function is implemented in IONOLAB, for minimizing the non-ionospheric noise effects and distortion due to multipath. IONOLAB can input both absolute TEC and phase-corrected low-noise TEC. IONOLAB includes the hardware biases obtained from the web for TEC estimates that are consistent with the results from the IGS analysis centers. In order to expand the usage of the IONOLAB algorithm, a userfriendly easily accessible web application is developed in JAVA. Developed application estimates TEC values for the given GPS station and time period requiring minimal user input. Observation data needed for estimation is retrieved from IGS data centers in Receiver

Independent Exchange (RINEX) format. Bias values for receivers and satellites are automatically downloaded from Center of Orbit Determination Europe (CODE). Developed application is the first one in the world that provides TEC estimations with a temporal resolution of 30 s and requires no installation on the client side. The application has a layered design. These layers are the browser, the data source and the server, consisting of the server layer, process layer and data access layers. The layers are designed modularly using an object-oriented approach, so that possible changes regarding the estimation method can be easily adapted. Same flexibility is also provided for the data access. Previously calculated TEC estimations are stored in a database providing a cache mechanism eliminating the recalculation of the results. The application provides both a graphical output and a text file output in the Comma Separated Values (CSV) format. The automated web-based computation software can be accessed from www.ionolab.org.

## EIGEN MODE ANALYSIS OF IONOSPHERIC IONIZATION PARAMETERS

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In the present work we use a statistical eigen mode method to analyze both the ionospheric total electron content (TEC, from GPS and TOPEX observation) and NmF2 (from a world wide ionosonde network). The obtained eigen vectors display the principle patterns of TEC and NmF2 distributed with both climate parameters (solar activity F107 and days of a year DoY) and mapping parameters (magnetic latitudes MLAT and magnetic local time MLT). It is found that the statistical eigen model analysis can separate the TEC and NmF2 distribution into chief process and the first three eigen modes illustrate the main ionospheric climate properties. The first mode depicts the linear solar activity dependence, the semiannual ionospheric variation which shows the semiannual anomaly, and the annual ionospheric variation which shows the non-seasonal anomaly of the ionospheric ionization. The second mode presents the solar activity saturation, and the annual variation which shows the ionospheric seasonal anomaly. The third mode shows mainly the equinoctial anomaly. The map distribution of the ionospheric climatology is detail analyzed. It is concluded that the statistical eigen mode method is resultful in analyzing the ionospheric climatology hence can be used to construct the empirical climatological model of ionospheric parameters.

## SHORT TERM VARIATIONS OF LF/MF SKY-WAVE FIELD STRENGTHS

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Predicting annual median values of sky-wave field strengths is a reasonably well-understood topic. See, for example, the latest version of ITU-R Recommendation P.1147. Short-term variation is a different story. This paper attempts to fill this vacuum by studying 3 different topics: Seasonal variation of field strengths, variation of field strengths with sunspots, and the impact of magnetic storms. The latest and largest LF/MF sky-wave data bank maintained by ITU-R Working Party 3L (Ionospheric Propagation) has been revisited and reorganized by this author for the purpose of studying short-term variations. To study seasonal variation, measured monthly median field strengths of about 100 propagation paths from different regions

of the world have been tabulated and studied. Conventional wisdom suggests that field strengths are the strongest during spring and autumn and are the weakest during summer. The current study, which is based on a much larger data bank, suggests that the conventional wisdom is only true under certain conditions and only true in certain areas of the world. This paper attempts to discuss seasonal variation in more detail, both qualitatively and quantitatively. A number of representative examples will be given. Impact of other factors affecting seasonal variation will also be pointed out and discussed. The effect of sunspots is a very complicated matter. It involves four factors: sunspot number, geomagnetic latitude, distance, and, to a lesser degree, frequency. These factors will be discussed in this paper. In Recommendation ITU-R P.1147, a formula is given for predicting attenuation of field strengths due to sunspots (Lr). This formula works well except in the high-latitude areas such as Alaska. Furthermore, there is a discontinuity between North America and Europe. These shortcomings can be greatly minimized by simply using the corrected geomagnetic latitudes instead of the dipole latitudes. Furthermore, Lr has a built-in diurnal variation. Lr is the greatest at about two hours after sunset and gradually reaches its minimum at about midnight. The effects of magnetic storms have a frequency variation. The storm-enhanced absorption, particularly during the first few days immediately after the storm, increases with increasing frequency. Furthermore, unlike VLF and LF, where the immediate and post storm effects are most pronounced during twilight periods and are virtually nonexistent during noon, at MF the effects have no diurnal variation to speak of.

## COMPARISON OF IONOSPHERIC F2 PEAK PARAMETERS FOF2 AND HMF2 WITH IRI2001 IN HAINAN

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In this study, monthly median values of foF2, hmF2 and M(3000)F2 parameters, with quarter-hourly time interval resolution for the diurnal variation, obtained with DPS4 digisonde at Hainan(19.5ON, 109.1OE; Geomagnetic ordinates: 178.95OE, 8.1ON) are used to investigate the low latitude ionospheric variation behaviors and their comparison with the International Reference Ionosphere model predictions are investigated. The time period of the data used for the present study is from Feb 2002 to April 2007, which was characterized by a wide range of solar activity, from solar maximum (2002) to solar minimum (2007). Results show that (1) Generally IRI predictions follow well the diurnal and seasonal variation patterns of the experimental values of foF2, especially in summer in 2002. However, there are systematical deviation between experimental values and IRI predictions with either CCIR or URSI coefficients. Generally IRI model greatly underestimate the values of foF2 from about noon to sunrise of next day, especially in the afternoon, and slightly overestimate them from sunrise to about noon. And also the time of foF2 peak in one day of the IRI predictions is earlier than that of observations. It seems that there are bigger deviations between IRI Model predictions and experimental observations for the solar median. (2) Generally the IRI predicted hmF2 values using CCIR M(3000)F2 option shows a poor agreement with the experimental results, but there is a relatively good agreement in summer. The deviation between the IRI predicted hmF2 with CCIR M(3000)F2 and observational hmF2 is bigger from noon to sunset and around sunrise. The occurrence time of hmF2 peak (about 1200LT) of the IRI model predictions is earlier than that (about 1500LT) of observations. When using the measured M(3000)F2 as input, the agreement between the IRI predicted hmF2

values with the measured M(3000)F2 and the experimental hmF2 is very well in the daytime and bad in the nighttime, and IRI model underestimate the hmF2 values in the nighttime.

## COST 296 WORKING GROUP 3 "SPACE-BASED SYSTEMS" ACTIVITIES AND RESULTS

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Complex temporal and spatial changes within the Earth's ionosphere can limit and degrade the performance of terrestrial, Earth to satellite and satellite to satellite radio systems in many different ways. The main objective of COST 296 is to develop an increased knowledge of the effects imposed by the ionosphere on practical radio systems and to develop techniques for the mitigation of these ionospheric effects. COST 296 Working Group 3 deals with ionospheric effects on Space-based systems; it is divided in 3 Work Packages which address the following topics: WP3.1: Ionospheric medium and large scale structures, their impact on GNSS signals; gravity wave effects on GNSS signals; ionospheric disturbances effects on GNSS signals. WP3.2: Mitigation techniques with emphasis on ionospheric structures, their physical nature and impact on GNSS signals; improved accuracy of GNSS by better ionospheric correction and errors due to ionospheric perturbations. WP3.3: Scintillation monitoring and modeling with emphasis on scintillation effects, their physical nature and impact on ionospheric radio systems (GNSS signals in particular); high-latitude and equatorial scintillation effects (experimental work and modeling). The paper briefly summarizes COST 296 WG3 activities and results and focuses on one topic: the mitigation of TID effects on GNSS high precision applications.

## IONOSPHERE-THERMOSPHERE COUPLING IN MIDDLE AND LOW LATITUDE REGIONS

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Though the ionization rate is less than 1% in the region of low latitude thermosphere, the dynamics of neutral atmosphere is strongly controlled by the plasma. The coupling process between the neutral atmosphere and the plasma has been investigated by satellites such as DE-1, AE, CHAMP, etc. The observations showed similar local time variation of plasma drift velocity and neutral wind (Rishbeth, 1971; Heelis et al., 1974), super rotations of thermosphere and ionosphere (Coley and Heelis, 1989), and equatorial temperature and wind anomaly (ETWA; Raghavarao et al. 1991). From ground observations of 630nm airglow by Otsuka et al. (2005), mesoscale structure generated by gravity wave was found at the same time in conjugate points of northern and southern hemispheres. The result suggests that the electromagnetic coupling along magnetic field lines is important in the thermosphere and ionosphere. NCAR TIE-GCM indicated the coupling between ionospheric plasma and strong eastward wind in the evening at magnetic equator (Richmond et al. 1992). Fuller-Rowell et al. (1997) suggested the importance of chemical heating in the ETWA. Maruyama et al. (2003) indicated the effect of ion drag on the ETWA. Coupling between neutral atmosphere and plasma is a key process to understand the dynamics and the structure, but the direct observation and the comparison with modeling are not yet performed in detail. Rocket experiment is carried out to investigate a coupling process between neutral atmosphere and plasma of thermosphere and ionosphere, such as momentum transfer through collisional process of the neutral atmosphere and the plasma, atmospheric circulation and super rotation in the low latitude thermosphere and a medium scale traveling ionospheric disturbance (MS-TID) occurring in the mid-latitude ionosphere, at Kagoshima Space Center (KSC) of JAXA. The rocket will be launched in the evening of July 31, 2007. In the rocket experiment, we observe plasma drift velocity, plasma density and temperature and its fluctuations, electric field, magnetic field and neutral wind. The neutral winds are estimated from the movements of Lithium clouds, which are released at altitudes between 150km and 300km and scatter sunlights by resonance scattering with wavelength of 670 nm. The Lithium clouds are observed by CCD imagers on ground. In this paper, we present the coupling process from some observation results and our modeling of thermosphere and ionosphere

## STATISTICAL STUDY OF IONOSPHERIC SMALL-SCALE IRREGULARITIES AT MID-LATITUDES USING GPS MEASUREMENTS

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At the present time, Global Navigation Satellite Systems (GNSS) allow to obtain a precision of a few centimeters in real time using positioning techniques like the so-called Real Time Kinematics (RTK) technique. Nowadays, the ionosphere remains the most important error source affecting such GNSS applications. Indeed, the presence of small-scale irregular structures in the Total Electron Content (TEC) can strongly affect the reliability and the precision of high precision real time positioning applications. Those small-scale structures can have several origins: Traveling Ionospheric Disturbances, “noise-like” variability in TEC, scintillations. The Royal Meteorological Institute of Belgium (RMI) has developed a software which allows to monitor the TEC using GPS measurements (at one station). The software can also be used to detect small-scale irregularities in TEC by monitoring TEC temporal gradients (i.e. rate of TEC changes). The RMI has applied this software to the GPS data collected at Brussels from April 1993 up to now what represents a period of more than one Solar Cycle. The results obtained from this GPS-TEC software will be presented. First, the paper analyzes the different types of small-scale structures which have been observed in TEC. Then, a statistical study of those ionospheric irregularities is presented; we shall analyze their probability of occurrence and their amplitude (in TECU/min) depending on daytime, season, solar activity, geomagnetic activity... The results of our study which is financed by the GNSS Supervising Authority will allow to have a better understanding of the usual case/worst case conditions encountered in high precision positioning applications based on GNSS.

## COMPARISON OF NEURAL NETWORK STRUCTURES IN TEC BASED REGIONAL IONOSPHERE MAPPING

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Ionosphere has an important affect on communication systems. Due to long term and short term variations caused by the sun, ionosphere causes errors on com-

munication systems. For this reason it is important to understand the variations occurred in ionosphere in time. Regional ionosphere mapping is a useful tool to observe the ionosphere and to analyze its underlying properties. Ionosphere is a dispersive medium and it causes delays during the transmission of GPS (Global Positioning Systems) signals. TEC values are computed from the transmission delays of GPS signals by using dual frequency receivers resided in GPS stations on earth. Note that TEC is defined as the number of free electrons along the ray path above one square meter on the ionosphere and its unit is represented as TECU (1 TECU = 1016 el/m2). There is a limited number of stations on earth and in order to form a map for a region and obtained real data from those stations must be interpolated by a proper method. Most frequently used methods for interpolation are Kriging, Multiquadratic, Spherical Harmonics, Thin Plate Spline Interpolation. Performances of these methods are studied and reported in the literature in many respects comprehensively. In addition to these methods, one other promising technique is Neural Networks (NN) approach. Due to fact that NN is well known universal function approximator, it is frequently used in estimation and prediction for the cases where the nature of the given data is not well defined. By using this fact and nonlinear function approximation capability of NN, random and nonlinear structure of the ionosphere are being considered under the frame of NN models. In this study two different methods of NN, Multilayer Perceptron (MLP) and Radial Basis Networks (RBN) are modified to show the ionosphere mapping potential of these non-linear structures. In the first stage, performances of these methods are tested by using artificial surfaces which are chosen to represent probable ionosphere distributions and an IRI surface for a predetermined time interval. These surfaces are sampled by using various sampling schemes under various sampling rates. MLP and RBN learning networks are then used to reconstruct more realistic TEC distributions and resulting maps decided after a set of tests are compared with different surfaces. Besides analyzing MLP and RBN capabilities over ionosphere mapping, we also use these simulations to investigate an optimum neural network structures as well as an optimum number of positions of GPS stations. In the last stage of the report, surfaces provided by IRI maps are sampled and reconstructed by MLP and RBN modeling structures in order to assess the performances of discussed methods in comparison with the highly rated and commonly used IRI based TEC maps.

## STATISTICAL ANALYSIS ON SPATIAL CORRELATION OF IONOSPHERIC DAY-TO-DAY VARIABILITY BY USING GPS AND INCOHERENT SCATTER RADAR OBSERVATIONS

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In this paper, the spatial correlations of ionospheric day-to-day variability are investigated by statistical analysis on GPS and Incoherent Scatter Radar observations. Strong correlations of TEC's day-to-day variabilities can be found between magnetic conjugate points, which may be due to the geomagnetic conjugacy of several factors for the ionospheric day-to-day variability. The correlation coefficients between geomagnetic conjugate points have obvious decrease around sunrise and sunset time at upper latitude (60o) and their values are bigger between winter and summer hemisphere than between spring and autumn hemisphere. The time delay of sunrise (sunset) between magnetic conjugate points with high dip latitude is a probable reason. Obvious latitude, local time variations of meridional correlation distance, latitude variations of zonal correlation distance, and altitude and local

time variations of vertical correlation distance are detected. Further more, there are evident seasonal variations of meridional correlation distance at higher latitudes of northern hemisphere and local time variations of zonal correlation distance at higher latitudes of southern hemisphere. These variations can generally be interpreted by the variations of controlling factors, which may have different spatial scales. Further modeling and data analysis are needed to address this problem. We suggest that our results are useful in the specific modeling/forecasting of ionospheric variability and the constructing of background covariance matrix in ionospheric data assimilation.

## DATA ASSIMILATION OF INCOHERENT SCATTER RADAR OBSERVATION INTO A 1-DIMENSIONAL MID-LATITUDE IONOSPHERIC MODEL BY APPLYING ENSEMBLE KALMAN FILTER

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In this paper electron densities during September 25-28, 2000 observed by the Millstone Hill incoherent scatter radar (ISR) are assimilated into a one-dimensional mid-latitude ionospheric theoretical model by using an ensemble Kalman filter (EnKF) technique. It is found that (1) the derived vertical correlation coefficients of electron density show obvious altitude dependence. These variations are consistent with those from ISR observations. (2) The EnKF technique has a better performance than the 3DVAR technique especially in the data-gap regions, which indicates that the EnKF technique can extend the influences of observations from data-rich region to data-gap region more effectively. (3) Both the altitude and local time variations of the root mean square error (RMSE) of electron densities for the ensemble spread and ensemble mean from observation behaves similarly. It is shown that the spread of the ensemble members can represent the deviations of ensemble mean from observations. (4) To achieve a better prediction performance, the external driving forces should also be adjusted simultaneously to the real weather conditions. For example, the performance of prediction can be improved by adjusting neutral meridional wind using equivalent wind method. (5) In the EnKF, there are often errorless correlations over large distance because of the sampling error. This problem can be avoided by using a relative larger ensemble size.

## DATA ASSIMILATION IONOSPHERIC MODEL OF MIDDLE AND LOW LATITUDE BASED ON LEAST-SQUARE FIT METHOD AND TIME-IGGCAS MODEL

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TIME-IGGCAS(Theoretical Ionospheric Model of the Earth in Institute of Geology and Geophysics, Chinese Academy of Sciences) model solves the equations of mass continuity, motion and energy of electron and ions self-consistently and uses an eccentric dipole field approximation to the Earth's magnetic field. We combine the Eulerian and Lagrangian approaches in the model and take into account the plasma $E \times B$ drift velocity. Calculation results reveal that the model is steady and credible and can reproduce most large-scale features of ionosphere. Based on TIME-IGGCAS model, we construct a data assimilation model by using non-linear Least-Square Fit method. This data assimilation model can estimate ionospheric

drivers such as E cross B drift, neutral wind,and neutral compositions simultaneously by ingesting multi-ionospheric observations including GPS-TEC, ionosondes observations. We modeled the ionospheric response to the geomagnetic storm during November 6–8, 2004 in Asia/Pacific sector by this assimilation model. The modeled results show that the enhanced O/N2 in the northhemisphere and the turnaround of neutral wind should be responsible for the intense variations of ionosphere during this geomagnetic storm.

## OBSERVATIONS OF HF PROPAGATION ON A PATH ALIGNED ALONG THE MID-LATITUDE TROUGH

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The mid-latitude trough is an area of depleted electron density in the nighttime F-region ionosphere in which the critical frequencies drop by a factor of at least two and the altitude of the electron density peak rises by 100 km or more. During the winter and equinoctial months, the trough takes the form of a band a few degrees wide in latitude to the equatorward side of the auroral oval, stretching in local time from dusk to dawn. In summer, the trough is much less pronounced and is confined to the hours around midnight. The location of the trough also depends on geomagnetic activity; the trough region moving equatorwards and the evening sector tending to move to earlier local times as activity increases. For HF systems, the electron density depletion in the trough region reduces the maximum frequency that can be reflected by the ionosphere along the great circle path (GCP). For long paths, the signal is often received via a ground / sea-scatter mechanism to the side of the great circle direction. For shorter paths, gradients in electron density associated with the trough walls and embedded ionospheric irregularities often result in propagation in which the signal path is well displaced from the great circle direction, with directions of arrival at the receiver offset by up to 100°. The establishment of multi-frequency HF circuits between Uppsala and Helsinki to Leicester at two different points in the solar cycle has allowed us to observe simultaneously the direction of arrival, time of flight, Doppler shift and Doppler spread of signals reflected from the ionosphere. During the day, the measurements usually show propagation via the F-region along the great circle path with little Doppler spread. At night, however, off-great circle propagation often occurs with characteristics that may fall into a number of types. At this stage of the investigation (which is on going at the time of writing) we are not in a position to firmly propose the propagation mechanisms involved, however a number of preliminary suggestions are made.

## FEATURES OF IONOSPHERIC TOTAL ELECTRON CONTENT BEHAVIOR RELATED WITH EQUATORIAL REGION EARTHQUAKES

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In this report the analysis of the ionosphere behavior at low latitudes associated with seismic activity in the regions of Southeast Asia and South America is presented. GPS-derived Total Electron Content variations over IGS stations located in the vicinity of the earthquake epicenters were used to detect temporal changes of

the equatorial ionosphere. Global Ionospheric Maps produced by IGS community were used to clearly identify the spatial modification of the ionosphere related with seismic activity. It was found out that distinguishing feature of pre-seismic effect occurrence is related with alteration of the main low-latitude ionosphere peculiarity – equatorial anomaly. Analysis of the IONEX TEC maps has shown that modification of the equatorial anomaly occurred a few days before strong earthquakes. For 3-5 days before seismic event the daytime amplification of equatorial anomaly was observed. Maximal enhancement in crests reached 50-70% relative to the non-disturbed state. At the same time, in previous days in evening and night hours of local time the specific transformation of spatial TEC distribution was detected over equator. This modification took the shape of a double-crest structure with a trough near the epicenter, though usually in this time the restored normal latitudinal distribution with a maximum near the magnetic equator is observed. It is assumed that anomalous electric field generated in the earthquake preparation zone can be associated with like-natural "effect" phenomenon and might be a possible cause of the observed ionospheric effect. It is necessary to note that main features of pre-seismic ionospheric effects were rather similar for different longitudinal sectors and different seasons.

## REGIONAL 4-D MODELLING OF THE IONOSPHERIC ELECTRON DENSITY FROM SATELLITE DATA AND IRI

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The accurate knowledge of the electron density is the key point in correcting ionospheric delays of electromagnetic measurements and in studying ionosphere physics. During the last decade satellite missions have become a promising tool for monitoring ionospheric parameters such as the total electron content (TEC). In this contribution we present a four-dimensional (4-D) model of the electron density consisting of a given reference part, i.e., the International Reference Ionosphere (IRI), and an unknown correction term expanded in terms of multi-dimensional base functions. The corresponding series coefficients are calculable from the satellite measurements by applying parameter estimation procedures. Since satellite data are usually sampled irregularly, finer structures of the electron density are modelable just in regions with a sufficient number of observation sites. Applying our approach GNSS (GPS, GLONASS) observations can be combined with COSMIC measurements and other available data including observations from dual-frequency radar altimetry (T/P, JASON, ENVISAT). The proposed method is applied to simulated slant total electron content measurements from GPS. The procedure can be used, e.g., to study the Equatorial Anomaly.

## VARIABILITY STUDY ON THE EQUATORIAL IONIZATION ANOMALY USING GPS OBSERVATIONS AROUND 120E LONGITUDE

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The equatorial and low latitude ionosphere is one of the most important regions of the ionosphere which has a unique structure with two crests of ionization at about $\pm 17^{\circ}$ dip latitude on each side of the magnetic equator and a trough in between. This equatorial ionization anomaly (EIA) phenomenon is formed as a consequence of the so called "fountain" effect, which is produced by the upward ExB drift of the plasma followed by a downward diffusion along the magnetic field line to a higher latitude under the influence of the gravity and the pressure gradient forces. The location of the crests and the strength of the equatorial ionization anomaly are two important parameters that were shown by previous studies to be closely related to the generation and development of the equatorial spread F irregularities that has important impact on the telecommunication systems. In this paper, total electron content (TEC) deduced from the dual-frequency GPS measurements around 120E longitude were used to study the variability of the equatorial anomaly. Results on the variation behavior of the equatorial anomaly with local time, season, solar activity level and day-to-day variation will be presented.