Workshop
on Assessment and Validation of Space Weather Models

Alcalá de Henares, Spain, 16-17 March 2011
COST ES0803 workshop on Assessment and Validation of Space Weather Models

Universidad de Alcalá, Spain, 16-17 March 2011
COMMITTEES

Programme Committee

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PROGRAMME

Wednesday 16 March 2011

09.00 - 09.20 opening remarks
  J. Watermann and C. Cid

Session 1 - Interdisciplinary Activities and Validation Approaches

09.20 - 09.50 Overview of the scope and methods of meteorological forecast verification
  (Invited)
  P. Nurmi, Finnish Meteorological Institute, Finland

09.50 - 10.20 Validation of atmospheric models in an operational setting
  (Invited)
  J. Borneman, MetOffice, UK

10.20 - 10.50 Improving confidence in forecasts via data assimilation and ensemble methods
  (Invited)
  N. Smith, University of Bath, UK

10.50 - 11.20 Coffee Break

11.20 - 11.50 Space Weather Prediction Testbed (SWPT): Activities, Priorities, Challenges
  (Invited)
  E.A. Araujo-Pradere, T.G. Onsager, R. Viereck, NOAA/SWPC, USA

Session 2 - Space Weather Prediction and Validation Concepts

11.50 - 12.20 Recent Advances in Flares Prediction and Validation
  (Invited)
  R. Qahwaji (1), O. Ahmed (1), T. Colak (1), P.A. Higgins (2), P.T. Gallagher (2)
  (1) Space Weather Research Group, University of Bradford, UK
  (2) Solar Physics Research Group, Trinity College Dublin, Ireland

12.20 - 12.40 Solar wind forecasting: a method based on data assimilation with Kalman filters
  M.E. Innocenti (1), G. Lapenta (1), B. Vrsnak (2), M. Temmer (3), A. Veronig (3),
  L. Bettarini (1), S. Markidis (1), F. Crespon (4), C. Skandrani (4), Soteria Space-
  Weather Forecast & Data Assimilation Team
  (1) Centre for Plasma Astrophysics, Katholieke Universiteit Leuven, Belgium
  (2) Hvar Observatory, Faculty of Geodesy, Croatia
  (3) Institute of Physics, University of Graz, Austria
  (4) Noveltis, France

12.40 - 13.00 On the Assessment of the Quality of Hazardous Event Forecasts
  M. Núñez, D. Núñez
  Department of Computer Science, Universidad de Malaga, Spain
13.00 - 14.30 Lunch Break

14.30 - 16.30 Poster Session and Coffee

Session 2 cont. - Space Weather Prediction and Validation Concepts

16.30 - 17.00 Model Validation and Verification as input to ESA Space Weather Activities (Invited)
   A. Glover (1), J.P. Luntama (1), P. Jiggens (2), A. Hilgers (2)
   (1) ESAC, Spain
   (2) ESTEC, The Netherlands

17.00 - 17.20 Validation of the TaD electron density reconstruction model
   A. Belehaki (1), I. Tsagouri (1), I. Kutiev (2), P. Marinov (2), S. Fidanova (2)
   (1) National Observatory of Athens, Greece
   (2) Bulgarian Academy of Sciences, Bulgaria

17.20 - 18.00 Advances in the N(t) model – Assessment of the model's output
   V. Zigman (1), D. Grubor (2), D. Sulic (3)
   (1) University of Nova Gorica, Slovenia
   (2) Milutina Milankovica, Serbia
   (3) Institute of Physics, Belgrade, Serbia

Thursday 17 March 2011

Session 3 - Space Weather Research – Models and Model Support Activities

09.30 - 09.50 The Space Weather Service at UAH: a description of the models and outputs
   C. Cid, Y. Cerrato, E. Saiz, J. Aguado, A. Guerrero
   Space Research Group – Space Weather, Universidad de Alcala, Spain

09.50 - 10.10 Thermosphere monitoring based on routine ionospheric observations: method and validation plan
   A. Mikhailov (1), A. Belehaki (2), B. Zolesi (3), L. Perrone (3), I. Tsagouri (2)
   (1) Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russia
   (2) National Observatory of Athens, Greece
   (3) Istituto Nazionale di Geofisica e Vulcanologia, Italy

10.10 - 10.30 GPS-TEC data improve accuracy of TaD electron density reconstruction model
   I. Kutiev (1), P. Marinov (1), S. Fidanova (1), A. Belehaki (2), I. Tsagouri (2)
   (1) Bulgarian Academy of Sciences, Bulgaria
   (2) National Observatory of Athens, Greece
10.30 - 10.50  The model for forecasting of radiation hazard from great SEP events in space, in magnetosphere, and in atmosphere on the basis of one-minute data of several neutron monitors

Lev Dorman (1,2), Lev Pustil’nik (1)
(1) Israel Cosmic Ray and Space Weather Center, Israel
(2) Cosmic Ray Department of IZMIRAN, Russian Academy of Science, Russia

10.50 - 11.20  Coffee Break

11.20 - 11.40  Model and visualization software for the nowcasting of the middle atmosphere

T. Egorova (1), E. Rozanov (1,2), N. Hochmuth (3), A.V. Shapiro (1,2), A.I. Shapiro (1,2)
(1) Physical-Meteorological Observatory/World Radiation Center, Switzerland
(2) Institute for Atmospheric and Climate Science ETH, Zurich, Switzerland
(3) Institut fuer 4D-Technologien, Fachhochschule Nordwestschweiz, Switzerland

11.40 - 12.00  An empirical model for calculation of the absorbed dose rates on ISS

Ts.P. Dachev, N.G. Bankov, B.T. Tomov, Pl.G. Dimitrov, Yu.N. Matviichuk
Space and Solar-Terrestrial Research Institute, Bulgarian Academy of Sciences, Bulgaria

12.00 - 12.20  Relations between magnetic indices used for Space Weather applications

Peter Stauning (1,2)
(1) Danish Meteorological Institute, Denmark
(2) DCGA Consult, Denmark

12.20 - 12.40  Solar energetic events and solar energetic particles as precursors of geomagnetic storms: assessment by neural network models

P. Hejda (1), J. Bochnicek (1), F. Valach (2), M. Revallo (3)
(1) Institute of Geophysics, Academy of Sciences, Czech Republic
(2) Geomagnetic Observatory, Geophysical Institute, Slovak Academy of Sciences, Slovakia
(3) Geophysical Institute, Slovak Academy of Sciences, Slovakia

12.40 - 13.00  Description of high latitude ionospheric plasma structures for Space Weather services

H. Rothkaehl (1), A. Krankowski (2), R. Sieradzki (2), E. Slominska (1)
(1) Space Research Center, Polish Academy of Sciences, Poland
(2) University of Warmia and Mazury in Olsztyn, Geodynamics Research Lab., Poland

13.00 - 14.30  Lunch Break

Discussion – Next steps for model validation within COST Action ES0803

14.30 - 16.30  Verification and validation plans for models discussed at the workshop.
Strategies for model validation to be adopted by COST ES0803.
Lead: J. Watermann
Poster Session

Model of the Solar Activity cycle 24 dynamics based on the method of precursors and singular spectral analysis
T.K. Breus (1), V.A. Ozheredov (1), V.N. Obridko (2)
(1) Space Research Institute of the Russian Academy of Sciences, Russia
(2) Institute of the Earth Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russian Academy of Sciences, Russia

The model of using satellite data for forecasting of radiation hazard from great SEP events in space, in magnetosphere, and in atmosphere
L. Dorman (1,2), L. Pustil'nik (1)
(1) Israel Cosmic Ray and Space Weather Center, Israel
(2) Cosmic Ray Department of IZMIRAN, Russian Academy of Science, Russia

Assessment of a neural network model for high energetic protons > 10 MeV forecast
F. Valach (1), M. Revallo (2), P. Hejda (3), J. Bochnicek (3)
(1) Geomagnetic Observatory, Geophysical Institute, Slovak Academy of Sciences, Slovakia
(2) Geophysical Institute, Slovak Academy of Sciences, Slovakia
(3) Institute of Geophysics, Academy of Sciences of the Czech Republic, Czech Republic

Improved Operational Cosmic Ray Ionization Model for the Atmosphere (CRIMA)
P. Velinov, L. Mateev, S. Asenovski
Space and Solar-Terrestrial Research Institute, Bulgarian Academy of Sciences, Bulgaria

Model Prediction of the Influence of Solar Activity to Global Atmospheric Electric Circuit through Trans-Polar Ionospheric Potential
P. Tonev, P. Velinov
Space and Solar-Terrestrial Research Institute, Bulgarian Academy of Sciences, Bulgaria

Two types of positive disturbances in the daytime mid-latitude F2-layer: impact on the performance of space weather prediction models
A. Mikhailov (1), L. Perrone (2)
(1) Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), Russia
(2) Istituto Nazionale di Geofisica e Vulcanologia, Italy

Study of Earth-directed Halo Coronal Mass Ejections observed between 1996 and 2008
O. Chiricuta (1,2), I. Chifu (3,4), M. Mierla (1,2), G. Maris (1)
(1) Institute of Geodynamics of the Romanian Academy, Romania
(2) Research Center for Atomic Physics and Astrophysics, University of Bucharest, Romania
(3) Max Planck Institute for Solar System Research, Germany
(4) Astronomical Institute of the Romanian Academy, Romania

Solar Wind Forecast in practice
P. Vanlommel (1), C. Marque (2), A. Zhukov (2)
(1) Solar-Terrestrial Centre of Excellence, Belgium
(2) SIDC, Royal Observatory of Belgium, Belgium
Development of Central Europe Regional Ionospheric Model (CERIM IION) based on Kharkov incoherent scatter data
M. Lyashenko (1), I. Domnin (1), L. Chernogor (1,2)
(1) Institute of Ionosphere, Kharkov, Ukraine
(2) Kharkiv V. N. Karazin National University, Ukraine

Overview of the Ionosonde measurement campaign in Hornsund.
L. Tomasik (1), I. Stanislawska (1), B. Dziak-Jankowska (1), M. Pezzopane (2), A. Rokicki (1), M. Pozoga (1), M. Milodrowska (1)
(1) Space Research Centre, Polish Academy of Sciences, Poland
(2) Istituto Nazionale di Geofisica e Vulcanologia, Italy

Improvement of ionosphere coverage area for EGNOS
I. Stanislawska, Z. Zbyszynski, A. Swiatek, B. Dziak-Jankowska
Space Research Centre, Polish Academy of Sciences, Poland

Ionospheric W index maps in the operational use for telecommunication and navigation systems
I. Stanislawska (1), T.L. Gulyaeva (2), L. Tomasik (1), L.V. Poustovalova (2), A. Swiatek (1)
(1) Space Research Center, Polish Academy of Sciences, Poland
(2) IZMIRAN, 142190 Troitsk, Moscow Region, Russia

Ionospheric response to Solar activity during the 23rd solar cycle
N. Bergeot (1), J. Legrand (1), R. Burston (1), C. Bruyninx (1), P. Defraigne (1), J.-M. Chevalier (1), F. Clette (2), C. Marque (2), L. Lefevre (2)
(1) Reference Systems and Planetology, Royal Observatory of Belgium, Belgium
(2) Solar Physics and Space Weather, Royal Observatory of Belgium, Belgium
Abstracts

Oral presentations

Overview of the scope and methods of meteorological forecast verification

Pertti Nurmi

Finnish Meteorological Institute, Finland

Forecast verification is an essential and integral component in both meteorological research and operational activities. After having defined and designed the scope and methodologies properly, verification results will answer various questions addressed by different target groups like modelers, forecasters and end users of forecast information. Therefore, verification can be considered as an efficient tool to direct research, to aid operational forecasting and modeling centres to decide upon model upgrades, to monitor if forecasting quality is generally improving with time, or to assist weather dependent businesses to manage and control their decision-making.

The meteorological verification history has customary constituted of computing a number of verification measures over comprehensive datasets of forecast-observation pairs. The observations are typically upper air or surface point observations of meteorological variables or grid analyses based on such observations. This presentation will first give a broad overview of such “traditional” verification methods. Thereafter, some more recent spatial verification techniques as well as probabilistic and ensemble verification approaches are demonstrated with an emphasis on the verification of rare and/or extreme weather events. The presentation will end with a discussion of verification scores which the ECMWF (European Centre for Medium-range Weather Forecasts) has recently adopted as headline measures to follow up long-term progress in the medium-range forecasting capabilities of the Centre’s deterministic and probabilistic models.

Validation of atmospheric models in an operational setting

Jorge Bornemann

Met Office, UK

Atmospheric Numerical Weather Prediction (NWP) models have been providing guidance to forecasting centres since the 1960s. During this time, the evolution of the observing systems, the advent of remote sensing, the developments in computing technology and the advances in weather, climate and numerical modelling sciences have brought remarkable improvements to our forecasting capability, but also a substantial increase in the complexity of the systems. Nowadays many activities, from aviation to engineering, from disaster prevention to rescue and recovery operations, depend critically of reliable weather forecasts and climate advice; thus monitoring the quality of the numerical models in order to identify and address shortcomings, and assessing changes to assure increasing quality of the NWP products, is necessary. This need, compounded with the intricate nature of the current modelling systems, makes model evaluation a very important activity on any operational centre.

The Met Office is a world leading weather and climate institution, integrating several configurations of its model (Met UM) for timescales from hours to centuries, and has established robust procedures to assess model changes prior to operational implementation. This presentation will follow the typical life cycle of an upgrade to the Met Office operational NWP system, focusing in the evaluation and monitoring aspects.
Improving confidence in forecasts via data assimilation and ensemble methods

Nathan Smith
University of Bath, UK

It is important to assess confidence in space weather models, especially when they are used for forecasting. However, space weather processes are highly complicated, and it is unlikely that any single model can sufficiently replicate real-world phenomena at all times and in all locations, especially during extreme events such as geomagnetic storms. Two methods which can be used to increase confidence in our models are (i) data assimilation and (ii) ensemble methods. In data assimilation, data is used to push/pull models and steer them in the correct direction. In ensemble methods, a variety of models are run simultaneously and their outputs combined. However, the models must be combined intelligently, for example using posterior weighting. The talk will briefly introduce these two methods in the context of improving model confidence (the work originates from collaborative research with colleagues at the University of Bath).

Space Weather Prediction Testbed (SWPT): Activities, Priorities, Challenges

Eduardo A. Araujo-Pradere, Terrance G Onsager, and Rodney Viercke
NOAA/SWPC, USA

The main goal of the recently implemented Space Weather Prediction Testbed (SWPT) is to infuse the benefits of new research and technology developments into operational space weather products to improve the value and capabilities of the Space Weather Prediction Center’s (SWPC). Among SWPT’s priority goals are the long lead-time warning of Coronal Mass Ejection arrival, spatially resolved forecasts of geomagnetic activity, and the prediction of ionospheric scintillations and TEC gradients. The initial task assumed by SWPT, in collaboration with several other agencies, is the transition of a solar wind and CME model (ENLIL–Cone) to operations. This effort involves a detailed Verification and Validation study, a sensitivity evaluation, and the transportation of the codes to operational computers. Although significant research challenges exist in all of these areas, SWPT is confident that through cooperation with our national and international partners on data exchange, model development and validation, and operational service delivery, our main priorities, and the need of our customers, will be satisfied.

Recent Advances in Flares Prediction and Validation

Rami Qahwaji(1); Omar Ahmed(1); Tufan Colak(1); Paul A. Higgins (2); Peter T. Gallagher (2)

(1) Space Weather Research Group, University of Bradford, UK;
(2) Solar Physics Research Group, Trinity College Dublin, Ireland

In this presentation we introduce our recent work on the enhanced prediction of solar flares by integrating state-of-the-art feature extraction of the magnetic properties of Active regions from magnetogram images with advanced data associations, feature selection and machine learning techniques. A new pilot system is developed to provide flares predictions and the prediction performance is assessed using various evaluation measures. The new system is also compared against existing prediction systems, such as ASAP. Very promising results are obtained and we believe this new technology could be the cornerstone for the development of the next-generation of efficient operational prediction tools.
Solar wind forecasting: a method based on data assimilation with Kalman filters


(1) Centre for Plasma Astrophysics, Katholieke Universiteit Leuven, Leuven, Belgium
(2) Hvar Observatory, Faculty of Geodesy, Zagreb, Croatia
(3) Institute of Physics, University of Graz, Graz, Austria
(4) Noveltis, Ramonville Saint-Agne, France

Data Assimilation through Kalman filtering [1,2] is a powerful statistical tool which combines modeling and observations to increase the degree of knowledge of a system. We apply this technique to the forecast of solar wind parameters (proton speed, proton temperature, absolute value of the magnetic field) at 1 AU, using the model described in [3] and ACE data as observations. The model, which relies on GOES 12 observations of the percentage of the meridional slice of the sun covered by coronal holes, grants 1-day resolution forecasts of the aforementioned quantities in quiet times (CMEs are not taken into account) during the declining phase of the solar cycle and is tailored for specific time intervals. We show that the application of data assimilation generally improves the quality of the forecasts during quiet times and, more notably, extends the periods of applicability of the model. Our model validation activities [4] include the analysis of the Mean Absolute Error, of the Skill Score, of the distribution of the Signed Differences and of the Innovations in the filtering procedure.

Acknowledgement: The research leading to these results has received funding from the European Commissions Seventh Framework Programme (FP7/2007–2013) under the grant agreement N. 218816 (SOTERIA project: http://www.soteria-space.eu).

References:
[1] R. Kalman, J. Basic Eng. 82, 35 (1960);

On the Assessment of the Quality of Hazardous Event Forecasts

M. Núñez and D. Núñez

Department of Computer Science, Universidad de Málaga, Spain

Space weather predictors need to anticipate hazardous events early and reliably. In particular, they should neither miss major events nor issue false warnings at an unacceptably high rate that might be disruptive for space activities. Predictors should enable users to take precautions until the potential damages have ceased. The more anticipation there is, the lower are the risk to health and risk of damage to equipment. Nonprobabilistic (yes/no) forecasts are an appropriate way to communicate the expected harmful space weather conditions to the users with no ambiguity, so they could take decisions with more confidence to avoid or mitigate their effects. These forecasts may inform the user that a hazardous event is either expected or not expected, so the verification is relatively simple: a forecast may be either right or wrong. These forecasts may also be issued by numerical and probabilistic forecasters using a threshold. For this reason, it is very important to the space weather community to assess the quality of nonprobabilistic (yes/no) forecasts. NOAA/SWPC has identified three types of storms. Each storm has five specific categories: minor, moderate, strong, and extreme. Each category describes space weather conditions and the possible effects on people and systems, and provides the physical measure associated to the identified physical events. The three types of storms are caused by the following hazardous events: >M1 flares, which produce radio blackouts; SEPs with integral proton flux J (E>10 MeV) >= 10 pfu, which indicate the occurrence of solar radiation storms; and, Kp-indices of 5 or greater, which indicate the occurrence of geomagnetic storms. The most well-known performance measures for assessing the quality of nonprobabilistic (yes/no) forecasters are the probability of detection (POD), the false alarm rate (FAR), and the
prediction lead time, also known as warning time. Other important aspects that need to be forecasted are the duration of the hazardous event, its peak intensity, and the expected time interval of occurrence of this peak; therefore, the estimation of the forecast errors while forecasting these quantities are also important. There is a need to assess the performance of forecasters with historical data, because the most hazardous space weather events do not occur frequently. It is recommendable to use a large evaluation time interval (e.g., a solar cycle) so the performance measures could be calculated for several solar activity conditions.

**Model Validation and Verification as input to ESA Space Weather Activities**

A. Glover (1), J.P. Luntama (1), P. Jiggens (2), A. Hilgers (2)

(1) ESAC, Spain  
(2) ESTEC, The Netherlands

The development of robust space weather models is a key aspect underpinning services for the prediction and mitigation of space weather effects on vulnerable infrastructure. A comprehensive validation and verification plan provides an important element in assessing the suitability of a model for implementation in an operational context. It will also provide crucial information on model performance under a range of conditions and a means by which to make comparisons with other models. This supports both operational model implementation and future development.

The Space Weather segment of the ESA SSA programme is currently establishing a network of service prototypes, laying the groundwork for a future operational system. This builds on earlier work carried out within the framework of the Space Weather Applications Pilot Project including the results of associated validation and verification activities. This paper will describe upcoming activities where validation and verification techniques will be applied within the framework of the SSA preparatory programme Space Weather segment, in addition to ongoing and upcoming R&D studies.

**Validation of the TaD electron density reconstruction model**

A. Belehaki (1), I. Tsagouri (1), I. Kutiev (2), P. Marinov (2), and S. Fidanova (2)

(1) National Observatory of Athens, Greece  
(2) Bulgarian Academy of Sciences, Bulgaria

The safety and security of space operations requires that spacecraft operators know and understand the environment around their spacecraft. A measure of the ionospheric element of that environment is given by the precise values of the partial total electron content (TEC), i.e. the integral of the electron density between the spacecraft and some location on the surface of the Earth - and in some cases between two spacecrafts. Therefore knowledge of the analytical function of the electron density up to GNSS heights is required. While the bottomside part of the ionospheric electron density can be determined, at least over specific locations, from ionogram inversion, in the topside ionosphere direct observations of electron density are sparse. Electron density models of high accuracy are required to fill in the gap. The Topside Sounder Model – assisted Digisonde profiler (TaD) reconstructs the electron density profile (EDP) to plasmaspheric heights, proven able to follow the general trends of plasmaspheric observations derived from multiple experiments as CHAMP satellite (TEC derived parameters and reconstructed profiles), TEC derived parameters from ground-based GNSS receivers and profiles reconstructed from RPI/IMAGE plasograms (Kutiev et al., 2009; Belehaki et al., 2009). Here we present further improvements of the TaD model and a systematic validation of the upgraded version. TaD is based on the Topside Sounder Model whose empirical functions for the transition height, the topside O+ scale height and their ratio have been derived from the analysis of the Alouette/ISIS profiles. Based on these functions, the corresponding profiler (TSMP) expresses the shape of the EDP above the F-layer peak as the sum of O+ and H+ density profiles, while the H+ scale height is determined statistically from ISIS-1 topside profiles. To specify lower boundary conditions, TSMP is using as input the characteristics of the F-layer peak determined by Digisondes. Improvements consist on a new scaling technique for the analysis of the EDPs from ISIS-1 topside profiles. To allow the calculation of O+, H+, and He+ density distributions in transition region between topside F region and plasmasphere, yielding to a
more reliable determination of important scale height parameters (O+, H+, and He+) and transition height. In addition improvements of the TSMP formulation resulted to the optimization of the TaD algorithm. The main model expressions were revised to include He+ distribution as a function of geomagnetic latitude and local time. The improved TaD is validated using Topside EDPs from ISIS-1, EDPs from Malvern Incoherent Scatter Radar, and TEC parameters from ground-based GNSS receivers. The results show reduction of the model error 2.25 times in comparison to the previous version of the TaD model. Validation of the model results based on comparison with ISIS1 EDP shows clearly the model's ability to reproduce with impressive accuracy the ISIS1 EDP (98.8%). Systematic comparison between the O+ distribution of TaD and measured EDP from the Malvern ISR gave a mean RMSE of 12% while this error increased slightly when compared between the TaD derived TEC and the ISR-derived TEC values. This analysis gives an overall mean error of 3TECU which is comparable to the GNSS measurements error. A demonstrator of the optimized TaD performance with real-time autoscaled data from Athens Digisonde is available at “http://www.iono.noa.gr/ElectronDensity/EDProfile.php”. Based on the results of this assessment, further improvements on the TaD accuracy are attempted and presented in a separate contribution in this workshop.

References

Advances in the N(t) model – Assessment of the model’s output

V. Zigman (1), D. Grubor (2) and D. Sulic (3)

(1) University of Nova Gorica, Slovenia
(2) Milutina Milankovica 130, Belgrade, Serbia
(3) Institute of Physics, Belgrade, Serbia

In the course of the Cost space weather Actions a model for predicting D-region electron density enhancements during Solar X-ray flares has been set up, from conceptual description to implementation, its further development and improvement being an ongoing task. The proposed model, we call N(t), relates ground measurements of amplitude and phase perturbations of Very Low Frequency (VLF<30 kHz) signals to the Solar X-ray (0.1-0.8 nm) irradiance measured by the geostationary GOES satellites. The principal VLF data base is provided by the Belgrade VLF Observatory, with two independent receivers that log simultaneously signals from a worldwide net of transmitters, including sites in Europe, USA and Australia. While the recorded VLF signals show typical diurnal and seasonal variations under quiet ionospheric conditions, abrupt amplitude and phase disturbances are observed in distinct coincidence with X-ray bursts from Solar flares. >From continuously available ground- and space-based data sources, the key parameters (e.g. time delay, effective recombination coefficient, etc...) are evolved and used as input to the model that solves the time-dependent electron continuity equation, with the X-ray flare irradiance driving the ionization rate. The output is the time profile of the electron density, continuous throughout flare duration, at a given height. The N(t) model has been successfully applied to around 150 Solar X-ray flare events in the period May to August 2004-2007 and several from the beginning of Solar cycle 24; good agreement with the results of Long Wavelength Propagation Capability (LWPC) programme of NOSC and with the rather sparse and scarce measurements has been evidenced. Unfortunately, compiled and extant data for the D-region (~60-90 km above Earth) remain scarce and not free from large uncertainties. Presently we aim at assessing the model output through comparison with up to date observations. We validate the model by using the empirical standard model IRI 2007 as a baseline and the measurements of EISCAT Tromso VHF IS radar, as observational data. The IRI model, presently does not use wavelength selective indices so it is not likely to be applicable to ionospheric conditions under severe X-ray radiation, therefore the focus is on lower class flares. We deal with the validation as a case study analysis, however, some initial efforts in the statistical approach will be addressed as well.
Assessment of the DIAS ionospheric forecasting models performance

I. Tsagouri

National Observatory of Athens, Institute for Space Applications and Remote Sensing, Greece

Following up the COST ES0803 request for the assessment of existing ionospheric forecasting models, this paper attempts the evaluation of the performance of two ionospheric models that are designed to forecast the foF2 critical frequency over single locations in the middle latitude ionosphere up to 24 hours ahead: i) the Solar Wind driven autoregression model for Ionospheric short-term Forecast - SWIF (Tsagouri et al., 2009), which combines historical and real-time ionospheric observations with solar-wind parameters obtained in real time at the L1 point from NASA ACE spacecraft, and ii) the Geomagnetically Correlated Autoregression Model - GCAM (Muhtarov et al., 2002), which is a time series forecasting method driven by a synthetic geomagnetic index. Both models are implemented on line in the European Digital upper Atmosphere Server – DIAS (Belehaki et al., 2006) to provide ionospheric forecasting products and services for the European region (http://dias.space.noa.gr). Following current trends in the assessment of ionospheric forecasting models for operational use established worldwide, quantitative tests were designed to drive a metrics-based evaluation of the two models’ performance under all possible ionospheric conditions. The tests were based on the systematic comparison between models’ predictions with: i) actual observations, ii) simple prediction strategies, such as the median and the persistence based predictions and iii) IRI2000 predictions during selected storm events. For this purpose, ionospheric observations obtained over almost one solar cycle (1998-2007) at four European ionospheric locations (Athens, Chilton, Juliusruh and Rome) were analysed. The results verify consistent operation of both models and quantify their prediction accuracy under all possible conditions in support of operational applications. In addition, the systematic evaluation of two ionospheric forecasting models through a well established methodology may provide a useful basis for the European COST ES0803 community in building assessment standards and methods for ionospheric forecasting models.

References

Assessment and validation of physics based codes: the exemple of Trans family code

Jean Lilensten

Institut de Planétologie et d’Astrophysique de Grenoble, France

The Trans family code is a set of codes describing the kinetic and fluid transports of electrons and protons both from solar wind origin and due to photoabsorption in the upper atmosphere. It has been widely used for research projects. It has also been made operational for space weather uses. In some extend, its operationnability is a failure. I now believe that research codes should be used for what they are, i.e. research. This code, as all their equivalents that I know, is complicated, gives many different results on a very large set of parameters, some being not even measureable. It necessitates an expert to check its good use. However, it is still useable for space weather purposes. The first way is to degrade it. This is what I did for red line modeling. It is not that satisfying intellectually and in order to be fully useable, this effort requests the help of an engineer: someone able to understand the science on one side, and the users requirement on the other, and able to link the two. One other way physics based codes are useful for space weather is to calibrate or intercalibrate space weather instruments and space weather operational codes. Every time I compared the outputs of the code to instruments resulted in a better understanding and often calibration of the instrument. I will show such comparisons with space measurements of electron distributions and thermospheric emissions, with
positioning measurements, with ground based instruments (optical and radars). Physics based codes are also useful in order to predict (and not forecast) mechanisms. This code requests too many inputs to be really used for producing future values of physical parameters but it can for example evaluate the range of emissions in different planetary atmospheres. This in turn is used by space-research teams to design their future instruments. Finally of course, such codes are used for science : interpretation and understanding. But this is very trivial. In a future organization of space weather, research codes certainly have a niche with important implications. This example will serve as a basis for this discussion.

**The Space Weather Service at UAH: a description of the models and outputs**

C. Cid, Y. Cerrato, E. Saiz, J. Aguado and A. Guerrero

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Dst index is used extensively to quantify the geoeffectiveness of a solar disturbance. Several models relating solar wind parameters and the magnetosphere response, as seen by Dst index, have been developed at the University of Alcalá in the framework of COST Action ES0803. The predictions, which are available through the web site www.spaceweather.es and by e-mail, include alerts of large variations of Dst only from Bz component of IMF and an estimation of the duration of the disturbance once it has taken place. Improvements on the outputs are under development in order to provide, not only a warning when a threshold value is exceeded, but also the value of the variation of Dst which will take place as an output.

**Thermosphere monitoring based on routine ionospheric observations: method and validation plan**

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Despite obvious progress in generating both theoretical and empirical ionospheric models for researchers and applications the main part of the Earth’s atmosphere presented by neutral species is still ‘terra incognito”. Direct observations of thermospheric neutral composition, temperature and winds technically are very complicated and expensive. Therefore one hardly may hope to have any thermosphere monitoring system in the nearest future. On the other hand a necessity in such a system is obvious keeping in mind thousands of satellites (communication, military, navigation) orbiting around the Earth, their orbiting characteristics being dependent on neutral density. The use of world-wide routine ionospheric observations at F2-region heights to retrieve thermospheric parameters may be considered as a solution. In this workshop we will discuss how it will be possible to implement this approach. The following steps should be considered: (1). To develop such a method which is based on ISR observations as the most complete and reliable. The list of ISR routine observations include Ne(h), Te(h), Ti(h), Vl(h) profiles. This is enough to solve an inverse problem of aeronomy and find a consistent set of main aeronomic parameters: neutral composition (O, O2, N2), temperature Tn(h), total EUV solar ionizing flux, equivalent meridional thermospheric wind Vnx. (2). To compare retrieved thermospheric parameters with available empirical models (MSIS series) and direct optical TIMED observations of column O/N2 ratio. (3). To develop a method to retrieve thermospheric parameters using only bottom side Ne(h) profiles as we will have in reality dealing with digisonde Ne(h). (4). To compare ISR bottom side Ne(h) profiles with routine digisonde profiles and estimate errors in the retrieved parameters resulted from the difference in the observed Ne(h) profiles. (5). In the case of routine digisonde observations such parameters as Te(h), Ti(h), vertical plasma drift Vl(h) are absent, but they are used in the continuity equations for ionospheric ions which are used in the
method. Therefore methods to parameterize these parameters should be developed. This is a special and not a simple problem. (6). A basic validation of the developed method can be achieved through comparison with the full initial method based on ISR observations. In the case of a successful solution of the problem listed, it will be possible to organize a thermosphere monitoring over Europe where 8 Digisondes participating in the DIAS e-infrastructure, provide ionospheric observations in real time.

GPS-TEC data improve accuracy of TaD electron density reconstruction model

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TaD (TSM-assisted Digisonde) reconstruction model improve the accuracy of the topside ionosphere and plasmasphere electron density (Ne) profiles produced by Digisonde software as a complement to the measured bottomside profile. TaD uses the TSM Profiler (TSMP), developed on the base of TSM (Topside Sounder Model). TSM model obtains topside scale height (HT), transition height (hT), and their ratio (RT), being functions of the day-of-the-year, geomagnetic latitude, local time, solar flux (F10.7), and Kp. TSMP expresses the shape of the Ne profile above the F layer peak as a sum of O+ and H+ profiles, as the O+ scale height and O+ H+ transition height are taken from TSM, while the H+ scale height is statistically determined from ISIS-1 topside sounder profiles. When electron density NmF2 and height hmF2 are specified at the lower boundary, TSMP provides Ne profile up to GPS orbit heights. To reconstruct the topside Ne profile, TaD uses the actual (measured) NmF2 and hmF2 from Digisonde, as well as the scale height Hm determined by fitting the around maximum profile with a-Chapman formula. TaD multiplies Hm with a predefined factor (approximately 2.5) and uses the modified scale height (2.5Hm) to run TSMP. In this way, the measured F peak parameters and the modified scale height represent the actual (instant) state of ionosphere, comparing to the average TSM parameters. A systematic validation of the TaD model is presented in this workshop in a separate contribution. Based on these results, further improvements on the model accuracy are proposed here. In TaD profiler, transition height hT and the plasmasphere scale height Hp are statistically connected to the O+ (topside) scale height HT. In this paper we explore the idea to change the integral of TaD Ne profile by varying HT or the magnitude of the scale factor that multiplies Hm. We developed a procedure which changes the Ne integral by varying the scale height factor in order to equalize it with the corresponding measured GPS-TEC value. We estimated the error that the statistical relations of HT with hT and Hp introduce. We demonstrate that this procedure, which improve significantly the reconstructed Ne profile, can be implemented in the operational GNSS practice. In addition the implementation of this improved version of TaD in Digisondes participating in the DIAS network will provide a whole set of new products for the specification of the electron density around a spacecraft and along its orbit.

The model for forecasting of radiation hazard from great SEP events in space, in magnetosphere, and in atmosphere on the basis of one-minute data of several neutron monitors

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In case of great solar flares with generation big fluxes of solar CR (or as it frequently called in scientific literature, solar energetic particles — SEP), the radiation hazard during this short periods may be also important. In this paper we consider probabilities of great SEP events in dependence of the level of solar activity and how to forecast expected SEP fluxes on the basis of on-line one minute data in real time-scale from ground observations during the first 20-40 min by several neutron monitors by solving inverse problem of SEP generation and propagation and then forecasting for about two days ahead. The solution of inverse problem (based on observations of the beginning of SEP event) give a possibility to determine the SEP source function on the Sun, time of ejection of SEP into solar wind, and diffusion
coefficient in dependence of particles rigidity and distance from the Sun. On the basis of this information we can then
determine expected time variation of SEP fluxes on the Earth (at satellite altitude and on the ground), as well as in
interplanetary space in dependence from the distance to the Sun. We check the model by data of historical event by
comparison of forecasting SEP fluxes and observed. We show that the model starts to work well after 10-15 minutes
from the beginning of SEP observations (what corresponds for relativistic SEP to one-two scatterings in space before
arriving to the Earth). After solving of the inverse problem of SEP generation and propagation in space, and determining
expected time variation of SEP fluxes on the Earth as well as in interplanetary space, we can determine expected
differential and integral radiation doses inside spacecrafts, inside satellites in magnetosphere, and inside airplanes in
atmosphere by using method of coupling functions. We consider here in details following problems. 1. On the
probability of solar CR fluency during SEP event, based on three solar cycles observations. 2. Statistical properties of the
radiation hazard probabilities derived from GOES 7-11 for 1994-2004 data on daily fluencies. 3. Data from the past and
classification of space weather radiation hazard (NOAA classification and its modernization). 4. The first step of
forecasting: Automatically search of the start of great SEP events. 5. The second step of forecasting: Determination of
SEP energy spectrum out of atmosphere. 6. The third step: On-line simultaneously determination of time of ejection,
diffusion coefficient, and SEP energy spectrum at the source by neutron monitor data. 7. The fourth step: Forecasting of
SEP event development. 8. The fifth step: Forecasting of expected differential and integral radiation doses during great
SEP events inside different objects in dependence of shielding: in space, in magnetosphere, and in atmosphere.

Model and visualization software for the nowcasting of the middle atmosphere

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We have developed climate-chemistry-ionosphere model SOCOL which is based on a general circulation model and
includes complete representation of the chemistry of neutral and ionized species in the atmosphere from the ground
up to the mesopause. To validate the model we have simulated the response of the neutral and charged species in the
middle atmosphere to the short-term increase of the solar UV irradiance in January 2004 and severe solar proton
events in October-November 2003 and January 2005. The results of the simulations were compared with the available
measurements with satellite and ground based instruments. Reasonable agreement of the simulated results with
observations confirms the applicability of the model for the nowcasting of the neutral and charged species in the
middle atmosphere using the near-real time solar spectral irradiance data. The model functioning in the nowcasting
mode will be illustrated using specially designed visualization software. For the demonstration purposes the model will
be driven by the near-real time solar spectral irradiance calculated with a solar radiation code using the sun surface
magnetic field observed in February-March 2011.

An empirical model for calculation of the absorbed dose rates on ISS

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The ionizing radiation has been recognized as a one of the main health concern to the International Space Station (ISS)
crew. Estimating the effects of radiation on humans in ISS requires at first order accurate knowledge of the global
distribution of absorbed dose rates. The R3DE (Radiation Risks Radiometer-Dosimeter (R3D) for the EXPOSE-E facility on
the European Technological Exposure Facility (EuTEF) outside of the European Columbus module of ISS is a Liulin type
Bulgarian build miniature spectrometer-dosimeter. R3DE worked successfully between February 2008 and September 2009 accumulating about 4 million measurements of the flux and absorbed dose rate with 10 seconds resolution behind less than 0.4 g cm-2 shielding. This large data base was used for development of an empirical model for calculation of the absorbed dose rates on the ISS at 359 km altitude. The model approximate the averaged in a grid empirical dose rate values to predict values at required from the user point, line or area in geographic coordinate system. The model is under development and the next planned steps are to be divided in 3 levels of altitude and to be considered mechanism for transformation of the calculated values for larger shielding. The data from another Bulgarian build Liulin-5 instrument (Liulin-5) inside of ISS is planned to be used. Another problem with very small solar activity of the existing model is going to be solved after the analysis and incorporation of new data base obtained with the analogical R3DR instrument on ISS in period with larger solar activity till August 2010. Very preliminary comparisons with the existing AP-8 MIN model shows that the South Atlantic Anomaly (SAA) maximum is moved westward with at least 12° for the period after 1970. This very simple mathematical model could be used by medicals and other not specialized in the radio physics support staff for first approach to the problem of modeling of radiation effects of the humans in ISS. Demonstration of the model during the presentation is foreseen.

**Relations between magnetic indices used for Space Weather applications.**

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A host of magnetic indices are used in various Space Weather applications. Most commonly used are the ring current indices, Dst (1-hour), SYM (1-min), and ASY (1-min), the mid-latitude planetary Kp index (3-hours), the auroral electrojet indices, AL, AU, AE, and AO (1-min), and the polar cap indices, PCN, PCS, and PCC (1-min). These indices are all related to disturbances in the solar wind, hence they are mutually related although they aim to describe widely different geophysical features. Thus the PC indices, for instance, can be used to predict occurrences of substorms and thereby predict events of high levels of the auroral electrojet indices. Furthermore, the PC indices can be used to predict the asymmetrical ring current index ASY as well as the development in the symmetrical ring current indices, Dst and SYM. In a fair approximation the ring current indices could be calculated solely from the single-station PC index values. The levels of the above indices, except Kp, are mainly controlled by the large-scale electric fields generated by the interaction of the solar wind with the magnetosphere. It is more difficult to relate the Kp indices to the other indices since cases of high Kp index values also rely on the occurrence of strong solar wind dynamic pressure. The presentation shall briefly discuss the relations between the solar wind parameters and the above-mentioned magnetic indices. Furthermore, the mutual relations between the indices shall be outlined with special emphasis on the timing relations, which could be exceedingly important for Space Weather applications. Examples based on major magnetic storms in solar cycle 23 shall be presented.

**Solar energetic events and solar energetic particles as precursors of geomagnetic storms: assessment by neural network models**

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Coronal mass ejections (CMEs) are believed to be the principal cause of increased geomagnetic activity. They are regarded as being in context of a series of related solar energetic events, such as X-ray flares (XRAs) accompanied by solar radio bursts (RSPs) and also by solar energetic particle (SEP) flux. Our research started with the analysis of geoeffectiveness of solar energetic events, observed in the years 1996 – 2004. It was shown that the degree of their
geoeffectiveness depends on their size and on their solar disc location. The analysis also revealed that disappearance of solar filament (DSF) data cannot be used in forecasting geomagnetic disturbances as the geoeffective and nongeoeffective DSFs are too disproportional. In the second stage a neural network was used to construct a forecasting scheme enabling us to determine the probability, with which flares will be followed by a geomagnetic response of a particular intensity. The successfulness of forecasts produced after the fact depended on the flare class and on the combination of radio-burst types. In the case of RSP IV, 58% of the geomagnetic responses of X-ray flares of at least B class were successfully forecast. If only RSP II was observed, the forecast was successful only for flares of the X class (67% of successful forecasts). In the second step, a strong geomagnetic response was correctly forecast after geoeffective flares in 58% of the cases. The forecast scheme was tested using the data in the time interval 2005 – 2006. In the next stage we tested if the successfulness of the neural network prediction scheme can be improved by additional information concerning the SEP flux. To resolve this problem, we chose the SEP events possessing significant enhancement in the 10-h window, commencing 12 h after the generation of XRAs. In particular, we consider the flux of high-energy protons with energies over 10 MeV. A chi-square test has been used to demonstrate that supplying such extra input data improves the neural network prediction scheme.

**Description of high latitude ionospheric plasma structures for Space Weather services**

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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. The details description of the structure and dynamic can be very important in order to build the proper physical models and for applications purposes and services. The aim of this presentation is to show manifestation of ionospheric trough structures and dynamic diagnosed by various measuring techniques as: in situ wave and plasma diagnostics registered on board of DEMETER satellite, GPS observations collected at IGS/EPN network employed to reconstruct diurnal variations of TEC using all satellite passes over individual GPS stations, GPS observation carried out at the Antarctic and Arctic IGS (International GNSS Service) stations used to study TEC fluctuations in the high latitude ionosphere and the data retrieved from FORMOSAT-3/COSMIC radio occultation measurements. These analyses also give new data on understanding of the ionosphere-magnetosphere coupling processes. The hybrid method based on wave diagnostics across the whole frequency band, was elaborated using electron density and temperature measurements. We would like also to discuss the limitations for presented diagnose techniques with respect to different geomagnetic condition and localisation in space and discuss the physical limitations on modelling large scales ionospheric structures.
Poster presentations

Model of the Solar Activity cycle 24 dynamics based on the method of precursors and singular spectral analysis
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The main goal of solar-terrestrial physics is the study of the Sun-Earth coupling and processes controlled by the latter. The given work dedicated to solar sunspot number prediction for Solar Cycle 24 using one of the methods of precursors. As the assumptions used for construction of SA prediction, it uses an idea on dynamics of the solar magnetic fields forming solar spots, being basic for an estimation of Wn. We attempt to expand the horizons of the Wn forecast for 24 cycle by adding a predictor correlating with Wn with a positive shift $\Delta t$. As such predictor we are going to use quadratically transformed solar polar field module, $q(pf)$. If the autoregressive prediction horizon of Wn is equal to $T$, then when the predictor $q(pf)$ is strongly correlated with Wn, autoregressive prediction horizon is also equal to $T$, and taking into account the presence of shift between both time series, an effective prediction horizon of Wn becomes equal to $T+\Delta t$. The Solar Cycle 24 maximum is predicted to happen in April, 2012, and its average value can be as low as 50.

The model of using satellite data for forecasting of radiation hazard from great SEP events in space, in magnetosphere, and in atmosphere
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The model based on available through Internet satellite one minute data (e.g., of series GOES) in different energy ranges (from 4 MeV up to 500 MeV). In the first we developed a program, which automatically determined on the continuously analyzing of satellite data the beginning of SEP. After the start of SEP, by using data in four biggest energy ranges we determine SEP energy spectrum. After few (as minimum 4 minutes) we try to solve the inverse problem of SEP generation and propagation and estimate on the basis of determined changes of SEP energy spectrum in time the following main parameters: time of ejection into solar wind, energy spectrum of SEP generation, two-parametric diffusion coefficient in dependence of energy and distance from the Sun. With each new minute of observation obtained results of the inverse problem solution became more and more exactly. For each new minute of observation we then solve direct problem (by using estimated values of time of ejection into solar wind, energy spectrum of SEP generation, two-parametric diffusion coefficient) and determine expected SEP fluxes in different energy ranges not only during observed time (for checking solution of inverse problem), but also expected SEP fluxes in near future for forecasting of expected total radiation hazard in space, in magnetosphere, and in atmosphere for spacecrafts, satellites, and airplanes.
Assessment of a neural network model for high energetic protons > 10 MeV forecast

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Assessment of the use of a model in practice is the crucial part of papers dealing with space weather forecasts. In our presentation we deal with this problem imagining a point of view of an operator of a manned space flight who has to decide whether to do or not to do put into operation some safety measure against SEP event. The spirit of the method is simple, however, we believe that such a treatment can be instructive and it demonstrates clearly that the procedure of the forecast assessment has to be respectful of the purpose for which the forecast is intended to be employed. Some acceptable compromise has to be achieved between jeopardizing a human crew of the space ship and the wasted time due to the safety measure. Establishing level of acceptable risk is beyond the scope of physicists alone, who are merely restricted to provide the forecasts together with some statistical estimates. Broader discussion with experts from other branches as well as with the users is desirable, too. The assessment of the neural-network-based model, which was built up for forecast of high energetic solar protons exceeding 10 MeV, is demonstrated in our presentation. A linear filter and a recurrent neural network were combined to the dynamic model in order to study the time structures of space weather parameters’ time series. Coronal mass ejection’s characteristics together with the data of X-ray flares and type II/IV radio bursts were taken as inputs to the model. Daily values of the parameters were processed. The model was built upon almost continual data in the period of 1998 to 2005. In dependence on four fixed critical levels of proton fluxes (100, 200, 500, 1000 pfu, respectively), some statistics of the successful/failed alarms were calculated for 758 test days.

Improved Operational Cosmic Ray Ionization Model for the Atmosphere (CRIMA)

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The presented Cosmic Ray Ionization Model for the Atmosphere (CRIMA) is physical space weather model with fully operational implementations. CRIMA is able to produce values of electron production by CR ionization in the Earth atmosphere for different altitudes (30 – 120 km), solar activities (low, moderate and high), geomagnetic and atmospheric cut offs. Besides, CRIMA can determine the energy intervals contributions for all groups of CR nuclei. The effects of galactic and solar cosmic rays (CR) in the middle atmosphere can be computed with our model. We take into account the CR modulation by solar wind and the anomalous CR component also. In fact, CRs determine the electric conductivity in the middle atmosphere and influence the electric processes in it in this way. CR introduce solar variability in the terrestrial atmosphere and ozonosphere. A new analytical approach for CR ionization by protons and nuclei with charge Z in the lower ionosphere and the middle atmosphere is developed. For this purpose, the ionization losses (dE/dh) for the energetic charged particles according to the Bohr-Bethe-Bloch formula are approximated in different energy intervals (two ionization losses intervals, one charge Z decrease interval and intermediate coupling intervals). Electron production rate profiles q(h) is determined by the numerical evaluation of a 3D integral with account of cut-off rigidities. The integrand in q(h) gives the possibility for application of adequate numerical methods - in this case Wolfram Mathematica 7 and Maple 14 interactive procedures, for the solution of the mathematical problem. The contributions of the different approximation energy intervals can be presented in graphical mode. In this way the process of interaction of CR particles with the upper and middle atmosphere are described much more realistically. The full CR composition is taken into account. The COSPAR International Reference Atmosphere CIRA’86 is applied in the computer program for the neutral air density and scale height values. The proposed improved CR ionization model (CRIMA) will contribute to the quantitative understanding of solar-atmosphere relationships. Our
improved ionization rate model is important for investigation of the different space weather effects. The cosmic rays and XUV radiations determine to a great extent the chemistry and electrical parameters in the middle and upper atmosphere, where are situated strato-mesosphere and thermosphere. They create ozonosphere and influence actively the stratosphere ozone O3 processes. But the ozonosphere controls the meteorological solar constant and the thermal regime and dynamics of the lower atmosphere, i.e. the weather and climate processes. CR influence dominates during the night and sunrise-sunset periods, because galactic CR are always bombarding the Earth atmosphere. The CR flux varies during the solar cycle in an opposite face to that of sunspots. This hypothesis of the solar-terrestrial relationships shows the way to a non-contradictory solution of the key problems of the solar-terrestrial physics. The structure of the proposed model allows its decomposition in several submodels. In this case we take into account the physical meaning of the independent variables subintervals. The ionization losses function is calculated taking into account the energetic particles charge decrease interval. The energy intervals investigation takes place according to the goal of the user of the model with respect to accuracy and interval types.

REFERENCES

Model Prediction of the Influence of Solar Activity to Global Atmospheric Electric Circuit through Trans-Polar Ionospheric Potential

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The action of the global atmospheric electrical circuit (GAEC) is maintained, according to the Wilson’s hypothesis, by tropospheric electric generators (thunderstorms and electrified shower clouds), and depends on different factors, the space weather parameters among them. GAEC is considered by many scientists as a possible link between solar activity and terrestrial processes, including the climate formation. That is why, it is important to predict how GAEC’s characteristics are influenced by space weather. One important way of such influence is realized through the ‘solar wind - magnetosphere - ionosphere’ coupling which leads to formation of convection patterns and determines large trans-polar (dawn-dusk) difference V of the electric potential in both polar caps of magnitude ~40-140 kV depending on the parameters of the solar wind and IMF. The high latitudinal potential distributions, thus formed, is superimposed on the uniform ionospheric potential maintained by tropospheric electric generators of 250-300 kV at geomagnetic latitudes below ~60 degree where it is not affected by magnetospheric factors. Because of the large horizontal scale of the trans-polar potential difference (~3000 km), the fair-weather electric current flowing from the ionosphere to the surface can be substantially modified (by 20% and more for the air-earth current, according to previous models) by current j superimposed to GAEC, which is caused by the distribution of the potential V. We propose a physical computational 3D steady-state model which serves to predict quantitatively the modification of GAEC characteristics caused by the potential V distributions in each polar cap which are linked to the solar wind and IMF characteristics. The input to our model consists of the solar wind and IMF characteristics. The output includes the superimposed electric current j (and related electric potential U and field E) at arbitrary coordinates and altitude in the model domain. The model is based on the continuity equation for the current density j presented as a partial differential equation for the spatial distribution of the superimposed electric potential U in spherical coordinates. For an initial estimation of the influence of the solar wind on GAEC the model is limited to a single gm hemisphere (northern or southern). The model comprises different ranges by altitude: from 1 to 1.1 earth’s radiuses (0 - 640 km) at latitudes above 60 degree, and from 0 to 80 km at lower latitudes. The potential distribution V at latitudes above 60 degree at the upper model boundary is obtained for the input characteristics specified from the Weimer’s model. The profiles of the components of anisotropic conductivity in the ionosphere (above 80 km) for specified conditions are obtained from the conductivity model IRI2007. For the conductivity below 80 km a representation used is with respect to the total columnar resistance
(as a function of geographical coordinates), to the tropospheric conductivity profile, and to possible modifications of the stratospheric conductivity (e.g. by fine aerosols). It has to be noted that our model can be easily adapted to another (possibly, more precise) models for the polar cap potential distribution and the ionospheric conductivity, than those of Weimer and IRI2007. The finite volume method is applied to solve the source equation. Because of the enormous increase of the conductivity and of its anisotropy with altitude, a decomposition of the model domain into sub-domains by altitude is used, together with an iteration scheme for the distribution of U and j in each sub-domain. The uppermost sub-domain comprises altitudes where the closure (horizontally oriented) currents are small compared to the vertical currents, and the problem is reduced to a 2D problem. The solution is used to determine the boundary where the closure currents become significant. At lower sub-domains a fully 3D representation is needed, in order to evaluate the redistribution of currents due to the closure currents. An irregular numerical model grid is used (in order to reflect the fine details, and yet to limit the large computational complexity). Our model allows obtaining quantitatively the modifications of the electric characteristics of GAEC caused by the coupling of the solar wind with the magnetosphere and the polar ionosphere. Thus, the behavior of GAEC by different levels of solar activity can be predicted. The results obtained for the air-earth current under different levels of solar activity by the model can be compared with the results obtained experimentally at ground. By now, the model is used by us as a pre-operational model. Further it will be developed as a fully operational model.

Two types of positive disturbances in the daytime mid-latitude F2-layer: impact on the performance of space weather prediction models

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The performance of ionospheric prediction models is usually limited under the occurrence of positive ionospheric disturbances in the F2 layer. Ionospheric modeling and therefore ionospheric prediction efficiency can take substantial advantage by the comprehensive understanding of the physical aspects underlying such disturbances. The mechanisms of F2-layer positive disturbances are still under discussion. Even in the simplest daytime mid-latitude case there is no any final conclusion – TADs, electric fields, neutral composition. An attempt is undertaken to clarify at least some aspects of this problem that can affect the performance of prediction models. There are two types of daytime positive F2-layer disturbances at middle latitudes with different formation mechanisms and morphological characteristics. Type I of disturbances is referred to those followed by quiet ionospheric conditions. Positive disturbances of type II are followed by negative storms. The duration of disturbances of type II is shorter than of type I, but their amplitude is larger. Disturbances of type II are accompanied by larger hmF2 increase. After the active period of the disturbances of type I enhanced foF2 are observed for the whole day and the active period may be repeated in 24 hours with a decreased dfoF2. These morphological features follow from analysis of ionospheric data on three stations located in the sub-auroral zone (St. Petersburg), at middle latitudes (Slough), and at middle-low latitudes (Alma-Ata). Millstone Hill ISR along with ground-based ionosonde observations were used to understand the formation mechanisms. It was shown that positive disturbances of type II at middle latitudes are mainly explained by TADs launched by the auroral heating while relative variations of thermospheric neutral composition are small at the initial storm phase. At lower latitudes penetrating electric fields may contribute to positive storm effect. Positive disturbances of type I are related with low/moderate auroral activity damping the background poleward thermospheric circulation. The latter results in a decrease of the downward plasma drift and in an increase of the atomic oxygen abundance in the thermosphere – both processes lead to NmF2 increase. The thermospheric parameters used in our analysis are extracted from ISR observations solving an inverse problem of aeronomy. The different formation mechanisms could help towards the determination of appropriate drivers to be used in prediction models. Also the quantitative specification of the different morphological characteristics could support the development of realistic empirical models as well as their validation and verification.
Study of Earth-directed Halo Coronal Mass Ejections observed between 1996 and 2008

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In the period 1996 - 2008, 558 Earth-directed coronal mass ejections (CMEs) with clear signatures on the visible disk of the Sun and with projected speeds higher than 300 km/s were observed. We analysed the correlations between the parameters characterising these CMEs, their interplanetary counterpart (ICMEs) and the related geomagnetic storms. Using a simple spherical model which expands in a self-similar manner we calculated the real propagation speed of the CME and we have correlated this value with the Dst index. Most of the events were decelerated and only few events were accelerated in their way from the Sun to the Earth. It is observed a tendency of CMEs to decelerate more during the sunspot maximum. This can be due to the fact that at the maximum of solar activity, the slow solar wind dominates the interplanetary space. The results derived from this study can be used as input for space weather models in order to predict the occurrence of geomagnetic storms based on the CME parameters only.

Solar Wind Forecast in practice

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At the Regional Warning Center Belgium at the Space Pole in Brussels, we review on a daily basis the space weather status: of the solar activity, the solar wind and geomagnetic conditions. We provide a forecast of the flaring activity, the F10.7 cm flux and the geomagnetic conditions for the next 3 days. We focus here on the STEREO data and the forecast of the geomagnetic conditions. We will review a few practical space weather examples showing how a forecaster can easily and very fast interpret these data in order to predict the solar wind conditions near Earth.

Development of Central Europe Regional Ionospheric Model (CERIM IION) based on Kharkov incoherent scatter data

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Central Europe Regional Ionospheric Model (CERIM IION) based on the Kharkov incoherent scatter radar (ISR) database consists of two parts. Empirical part of the CERIM IION based on experimental data obtained with the Kharkov ISR during period 1997 – 2006 that is corresponding to the 23-nd solar activity cycle. This part of the model allows calculating the main geospace parameters – electron density, electron and ion temperatures, and vertical component of plasma drift velocity. Theoretical part of the CERIM IION includes well-know theoretical relations and served for calculation of medium and dynamic process parameters. Parameters of neutral atmosphere calculated using the NRLMSISE-00 model. Results of theoretical modelling are values of heat and particle flux densities, input energy to electron gas as well as values of thermospheric winds, ion-electron and ion-neutral collision frequencies, heat conductivity and ambipolar diffusion tensors, plasma scale height. Modelling results of the ionospheric plasma parameters are presented in the tabular form. Each of the tables includes the diurnal ionospheric parameters variations for vernal and autumnal equinoxes, winter and summer solstices in the range height of 200 – 750 km. Dependence of ionospheric parameters on solar activity (SA) is determined by phase of SA cycle – minimum, maximum, descending and
CERIM ION is used for accurate definition of global models of ionosphere and for more accurate calculation of radio wave propagation conditions over the Central Europe region that allows decreasing transmission system power, improving noise immunity of radio communication, radiolocation and radio navigation facilities. Reduction of power inputs allows improving electromagnetic and ecological situation over the Central Europe.

**Overview of the Ionosonde measurement campaign in Hornsund.**

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The Hornsund digital low power pulse ionosonde, built at Space Research Centre PAS was installed at Polish Polar Station at Hornsund, Spitsbergen, Norway. Location of the PPS (77N 15.55E invariant latitude 73.4) enable to observe ionosphere in the auroral zone as well as in the day side cusp. The main goal of this paper is to present software solutions designed for this type of ionosonde, integrated whit Autoscala Software developed at the Istituto Nazionale di Geofisica e Vulcanologia to automatically scale ionospheric characteristics from an ionogram, and also to present collected data useful to study the dynamics of the polar ionosphere. This paper gives an overview of the ionosonde measurements made during the Hornsund campaign, which was held between the 1.09.2009 and 11.01.2011.

**Improvement of ionosphere coverage area for EGNOS**

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Ionosphere coverage is likely to be the driver for EGNOS coverage area. Hence, a study considering a dedicated ionosphere algorithm to improve the ionosphere coverage area has been conducted. The logic of the study is following: The accuracy of the GPS signal depends mainly on the TEC (Total Electron Content). TEC at two close points change in time in a very similar way, these are region dependent variables. This correlation decreases with a distance between the observation points and is anisotropic. Based on TEC variogram analysis the specific algorithm has been elaborated. This a specific algorithm is presented and discussed.

**Ionospheric W index maps in the operational use for telecommunication and navigation systems**

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An increased knowledge of effects imposed by the ionosphere on operational radio systems could be earned by the new service providing online estimate of the degree of TEC perturbation at each grid point of the map expressed by the ionospheric W index. The W index reveals TEC behaviour providing an useful proxy index driving space weather than geomagnetic indices alone. The W index maps characterizing quiet and stormy conditions of the ionosphere-plasmasphere plasma are provided online. Analysis for operational assessments for regional service under different scenarios is provided.
The beginning of the 23rd solar cycle (May 1996 to December 2008) coincided with the start of the catalogue of global ionospheric modeling based on Global Position System (GPS) data. Comparison between solar activity parameters and GPS-derived Vertical Total Electron Content (VTEC) is now possible for the whole of solar cycle 23. In this study, we compared the daily sunspot number, the 10.7 cm radio flux $F_{10.7}$ and derived $F_{10.7P}$ with the daily mean global VTEC values during the entire last solar cycle. In order to better quantify the ionospheric response to solar activity, we show correlations between the daily $F_{10.7cm}$ delivered by NGDC-NOAA (National Geophysical Data Center - National Oceanic and Atmospheric Administration) and the daily sunspot number from SIDC (Solar Influences Data Analysis Center) with the daily mean latitudinal VTEC values extracted from CODE (Center for Orbit Determination in Europe) for the period 1995-2009. The correlations were investigated for different daily mean latitudinal ionospheric VTEC: (1) expressed in geographic and geomagnetic coordinates; (2) with respect to the seasons and; (3) with respect to the different phases of the solar cycle. In general, results show a better correlation, up to 0.97, between $F_{10.7P}$ and ionospheric VTEC. Moreover, a clear dichotomy in the correlations is observed between the southern compared to the northern hemisphere. The switch from geographic to geomagnetic coordinates does not change significantly the estimated correlations between VTEC and solar parameters excepted close to $\pm 30^\circ$ of latitude. Finally, a larger correlation is observed at N$20^\circ$-$30^\circ$ during the transition phase in the solar cycle.