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Office for Outer Space Affairs

# United Nations/United States of America
# Workshop on the International Space Weather Initiative: The Decade after the International Heliophysical Year 2007

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## ABSTRACTS

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*Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)*

*National Aeronautics and Space Administration (NASA)*

*International Committee on Global Navigation Satellite Systems (ICG)*

*National Science Foundation (NSF)*

*Boston College*

*Universities Space Research Association (USRA)*

CONTENTS

# Argentina

## National Space Weather Activities of Argentina

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Taking a look back, among the first space research institutions in Argentina is the Institute of Astronomy and Space Physics (IAFE) created in 1969 by the University of Buenos Aires (UBA) and the National Council of Scientific and Technical Research (CONICET), with the main purpose of doing scientific research in the field of Space Physics and Astronomy. Towards mid 1970s several institutions in Argentina began with upper atmosphere research under the coordination of a National Project called "Programa Nacional de Radio-Propagación" formed from several institutions such as the Physics and Electrical Engineering Institutes from the National University of Tucuman. In 1991 CONAE, the Argentine Space Agency was created to coordinate the country's space activities, and to propose and implement a National Space Plan. CONAE also cooperates with foreign space agencies, like European Space Agency (ESA), National Center for Space Studies (CNES), and NASA on space weather and climate related missions. Among its space weather related activities are three of the Scientific Applications Satellite (SAC) series, SAC-B, SAC-C and SAC-D, which have carried space-borne instrumentation to measure solar X-rays and energetic particle distributions reaching low Earth orbit. Currently, in addition to the mentioned institutions that are actively involved in space weather research and data gathering, several researchers and laboratories in Argentina carry on space weather related studies and measurements jointly under RAPEAS project (an Argentina net of CONICET, formed by several institutions, focused on academic activities linked with the upper atmosphere). They are also actively working on the creation of Argentina's own Space Weather Regional Warning Center, while being part of the International Space Weather Initiative (ISWI) and the Interprogramme Coordination Team on Space Weather (ICTSW) from the WMO. In this presentation, a detailed enumeration of institutions, instruments and senior scientists in Argentina involved in space weather activities is done together with its evolution in a historical perspective.

# Armenia

## Worldwide Network of Particle Detectors SEVAN: 10 Years of Operation

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In 1957, in a display of unprecedented international cooperation, more than 66.000 scientists and engineers from 67 nations participated in the International Geophysical Year (IGY1957). Fifty years on, the International Heliophysical Year (IHY 2007) again drew scientists and engineers from around the globe in a coordinated observation campaign of the heliosphere and its effects on planet Earth. The United Nations Office for Outer Space Affairs, through the United Nations Basic Space Science Initiative (UNBSSI), assists scientists and engineers from all over the world in participating in the International Heliophysical Year (IHY). A most successful IHY 2007 program is to deploy arrays of small, inexpensive instruments around the world to provide global measurements of ionospheric and heliospheric phenomena. The small instrument program is a partnership between instrument providers and instrument hosts in developing countries. The lead scientist provides the instruments and helps to install and run it; the host country place facilities provides manpower for instrument maintenance and operation to obtain data with the instrument. The lead scientists institution developed joint databases, provide tools for user-friendly access to data from the network, assisted in staff training and paper writing to promote space science activities in developing countries.

"Space Environment Viewing and Analysis Network" (SEVAN) aim to improve the fundamental research on particle acceleration in the vicinity of sun and - space environment conditions. The new type of particle detectors simultaneously measures changing fluxes of most species of secondary cosmic rays, thus turning into a powerful integrated device for exploration of solar modulation effects. The SEVAN modules are operating at the Aragats Space Environmental Center (ASEC) in Armenia, in Croatia, Bulgaria, Slovakia and India.

The network of hybrid particle detectors, measuring neutral and charged fluxes provide the following advantages over existing detector networks measuring single species of secondary cosmic rays (Neutron Monitors and Muon detectors):

- Measure count rates of the 3 species of the Secondary cosmic rays (SCR): charged particles with energy threshold 7 MeV, neutral particles (gamma rays and neutrons) and high-energy muons (above 250 MeV);
- Significantly enlarge statistical accuracy of measurements;
- Probe different populations of primary cosmic rays with rigidities from 7 GV up to 20 GV;

- Reconstruct SCR spectra and determine position of the spectral “knees”;
- Classify GLEs in “neutron” or “proton” initiated events;
- Estimate and analyze correlation matrices among different fluxes;
- Significantly enlarge the reliability of Space Weather alerts due to detection of 3 particle fluxes instead of only one in existing neutron monitor and muon telescope worldwide networks;
- Perform research on runaway electron acceleration during thunderstorms; research the enigma of lightning.

In the paper we present the most interesting results of SEVAN network operation last decade devoted to 10-th anniversary of the IHY-2007.

# Austria

## International Committee on Global Navigation Satellite Systems and Its Programme on Global Navigation Satellite Systems Applications

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The International Committee on Global Navigation Satellite Systems (ICG), established in 2005, promotes cooperation on matters related to civil satellite-based positioning, navigation, timing, and value-added services. The ICG works to enhance coordination among providers of global navigation satellite systems (GNSS), regional systems, and augmentations in order to ensure greater compatibility, interoperability, and transparency, and to promote the introduction and utilization of these services and their future enhancements with the integration into their infrastructures.

Within the framework of the ICG workplan, GNSS applications in low-cost worldwide ground-based instrument arrays for exploring atmospheric phenomena related to space weather have been considered in the ICG working group information dissemination and capacity-building. As the body leading the working group, the United Nations Office for Outer Space Affairs, through its programme on GNSS applications, each year co-organizes and co-sponsors a wide range of seminars, training courses and workshops. Those activities usually bring together a large number of experts, including specialists from developing countries, to discuss the GNSS applications in various fields of the world economy.

Additionally, a series of activities are undertaken at the regional centres for space science and technology education, affiliated to the United Nations, also acting as the ICG information centres. The regional centres are located in India and China for Asia and the Pacific, in Morocco and Nigeria for Africa, in Brazil and Mexico for Latin America and the Caribbean and in Jordan for West Asia. The main objective of the ICG information centres is to enhance the capabilities of member States to use GNSS and related applications at the regional and international levels so as to advance their scientific, economic and social development. The centres coordinate their activities closely with ICG and its Providers' Forum through the ICG executive secretariat. These activities emphasize the development and enhancement of the knowledge and skills of university educators and research and application scientists in both the physical and natural sciences as well as in analytical disciplines.

# Austria

## Space Weather Activities in Austria

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Space Weather is an important issue of global matter, but needs coordinated efforts - first of all on a national level. The University of Graz coordinates in Austria the different institutions dealing with research and forecasting services on Space Weather. This includes the University of Graz itself with its Institute of Physics that gives a real-time solar wind forecasting and provides CME forecasting tools, and the Kanzelhöhe Observatory which gives real-time warnings of solar flares. Together with the Seibersdorf Laboratories they are part of ESA's Space Situational Awareness program for Heliospheric and Solar Weather as well as Space Radiation. The Conrad Observatory is specialized on ground-induced currents and local magnetic field variations as consequences of solar activity and part of the national weather service ZAMG. The Space Research Institute in Graz is involved in satellite missions dedicated to Space Weather.

# Brazil

## The South America VLF Network - SAVNET: Last Results and New Research Perspectives

Jean-Pierre RAULIN
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In this paper we present the latest developments of SAVNET, both on the instrumental (OS, phase and amplitude digitalizing etc.) as well as on the divulgation and outreach points of view (website, data access etc.). As for the latest research activities, SAVNET data allows to determine the height Hn of the nighttime ionosphere by using a genuine method. Hn is an important parameter, directly and only accessible by the VLF technique, which time variability can inform on the Quasi Biennial Oscillation (QBO), the regime of atmospheric lightning activity, and other disturbances initiated by natural phenomena, like seismic activity. More recently, it was possible to estimate the minimum energy deposit necessary to disturb the ionospheric plasma of the lower ionosphere under daylight conditions. This quantitative value can then be used to estimate an occurrence detection rate of bursting remote cosmic sources which are of great astrophysical importance. Numerical simulations are also being performed to separate the causes of ionospheric disturbances from outside perturbations, namely the changes of the electrical conductivity due to photo-ionization and/or particle-ionization processes. In a near future, this technique can be helpful to infer low-energy X-ray solar flare spectra, and estimate if Solar Energetic Particle events can be detected in the low ionosphere. Finally, we will report on the first evidence of the presence of the South Atlantic Magnetic Anomaly using VLF data. This was possible by comparing ionospheric disturbances produced by solar flares, and recorded on different VLF propagation paths.

# Brazil

## The AFINSA Network: Presentation, Scientific Objectives, First Results

Jean-Pierre RAULIN
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The Atmospheric electric Field in South America network (AFINSA) has recently been added to the Instrumental network list of the ISWI program. It is now composed of seven sensors operating in Brasil, Argentina and Peru. Details of the AFINSA network, including data access is now available at https://theafinsa.wordpress.com/. The main objective of AFINSA network is to study the dynamics of the Global Electric Field Circuit (GAEC). To do this we monitor the atmospheric electric field and study its time variability in response to solar, geophysical and atmospheric disturbances, and during natural phenomena like seismic activity. Any change in the atmospheric electric field is defined by a time variation with respect to the fair weather electric field, and, therefore, the latter needs to be estimated first. The monitoring of the atmospheric electric field under fair weather conditions is presented elsewhere at this conference. We will present observations of the atmospheric electric field during solar flares, Solar Energetic Particle (SEP) events, and geomagnetic storms. In principle, all these phenomena are potential candidates to produce changes in the electrical conductivity of the Earth's atmosphere, and therefore to cause electric field changes. In order to enhance possible small effects, we use a super-imposed epoch method. The main conclusion is that, while geomagnetic storms and SEP events do produce significant changes of the atmospheric electric field, solar flares do not. We will discuss these results in term of the atmospheric electrical conductivity.

## Brazil

### Brazilian Space Weather Program with New Developments

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Ionospheric weather maps using the total electron content (TEC) monitored by ground based GNSS receivers over South American continent, TECMAP, have been operationally produced by INPE's Space Weather Study and Monitoring Program (Estudo e Monitoramento Brasileiro de Clima Especial, Embrace) since 2013. In order to cover the whole continent, 4 GNSS receiver networks, RBMC/IBGE, LISN, IGS and RAMSAC, in total ~140 sites, have been used. Also, additional effort is being done to enlarge it to cover up to Mexico. Besides the GNSS network, the Embrace Magnetometer Network is gradually being expanded, in cooperation with several institutions from Argentina, Mexico and Chile, to monitor most of the Latin America in the composition of the KSA magnetic index developed by Embrace. Moreover, Embrace is participating in a small satellite project called SPORT to observe the ionosphere irregularities to be launched in 2018 inside the NASA ITA-INPE cooperation. Recently, the Brazilian space weather program has endeavored efforts to study the space weather phenomena analyzing the observables in their variation scales. The Embrace Team defined the ranges as indices typically with five levels of occurrence or intensity. The indices are being defined in four areas: solar, interplanetary medium-magnetosphere, magnetism and atmosphere. The indices establish ranges of observable characteristics of a space weather event. They provide a reference to improve the understanding of the phenomena through the frequency of occurrence by magnitudes. The use of the indices for the daily analysis of the space weather is becoming a common practice in Embrace program. Some of them are predictive of the phenomena development being useful for taking decisions on the weather evolution. We will show some of the well-established interplanetary medium indices for the solar wind and the interplanetary magnetic field being implemented in the Embrace Web Portal. Also, we will present discussions on ionospheric indices for South America with some preliminary results. For the Embrace Team the description of the observables through their indices (levels) is a way to discuss the analyses of the weather monitoring among the international cooperation.

**Brazil**

## On the Temporal Variation of Atmospheric Electric Field in South America

José TACZA, Jean-Pierre RAULIN
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Continuous measurements of atmospheric electric field are being recorded by the Atmospheric Electric Field Network in South America (AFINSA). The main objective from this network is to obtain a diurnal curve of atmospheric electric field variations under fair weather conditions, which we will consider as a reference curve. To accomplish this, we made daily, monthly, seasonal and annual averages; the shape of this curves are maintained from year to year showing the reliability of them. For all sensor location, the results show significant similarities with the Carnegie curve. The Carnegie curve is the characteristic curve in universal time of atmospheric electric field in fair weather and one thinks it is related to the currents flowing in the global atmospheric electric circuit. We will discuss this similarities (global representation of the electrical circuit) and the differences (local effects) between our reference curves and the Carnegie curve for all our stations. In addition, we will discuss the long-term temporal variations of electric field in comparison with the distribution of thunderstorms and variations in the aerosol optical thickness (on the sites where we have these measures).

# Bulgaria

Katya GEORGIEVA
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Bulgaria is an active participant in IHY and ISWI. We were the initiator of the Balkan, Black sea and Caspian Sea Regional Network for Space Weather Studies, organized the Fourth UN/ESA/NASA/JAXA Workshop on the International Heliophysical Year and Basic Space Science in 2007 and coordinated the participation of the country of the region in ISWI. Here I will present the current activities in Bulgaria in the framework of ISWI: the instrumental program, the web-page management, the related meetings, and the international cooperation.

# Bulgaria

## Balkan, Black Sea, and Caspian Sea Network for Space Weather Studies

Katya GEORGIEVA and the BBC Network
Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia

In June 2005, in the eve of the International Heliophysical Year, scientists from 11 countries (Armenia, Azerbaijan, Bulgaria, Croatia, Georgia, Greece, Romania, Russia, Serbia and Montenegro, Turkey, and Ukraine), gathered in Bulgaria for a kick-off meeting organized by the former Solar-Terrestrial Influences Laboratory at the Bulgarian Academy of Sciences (later Bosnia and Herzegovina joined for some time). The initial idea was to coordinate the IHY activities in the region, and to this end, a regional network was created. However, even during this first meeting it was decided that the collaboration among our countries in the area of heliophysics would continue well beyond the duration of the IHY program, and in order to emphasize this, the network was named “Balkan, Black Sea and Caspian Sea Regional Network for Space Weather Studies” (widely known as the “BBC Network”). The Network was very instrumental in strengthening the observational, scientific and educational activities and the collaboration in the region related to the IHY, and after the completion of IHY it naturally became a part of the International Space Weather Initiative. Several joint projects were initiated, a number of regional meeting were organized, and the Network publishes its own journal “Sun and Geosphere” with an international editorial board and already 12 volumes. In this talk we will present the activity of the BBC Network in the framework of IHY and ISWI.

# Cameroon

## The first results on Sq Solar variation at Yaoundé-Cameroon AMBER station

Messanga Etoundi HONORÉ, César Mbane BIOUELE
Department of Physics, University of Yaounde, Yaounde

The geomagnetic data used for this study are obtained from magnetic station of Yaoundé, (AMBER Network) located at University of Yaoundé 1 in Cameroon (3.87°N, 11.52°E), provide continuous recordings of geomagnetic field since 2009. The variability of H component of geomagnetic field has been examined by using the north component (X) and east component (Y) of the earth's magnetic field, recorded from 2011 to 2014. The H component was used to calculate and analyze the diurnal and seasonal Solar quiet variations Sq(H) observed at Yaoundé-Cameroon during quiet magnetic days. The results obtained show that, Sq(H) shows a seasonal variation. The Sq(H) amplitude of 2014's campaign is the greatest one (~ 80 *nT*) while the Sq(H) amplitude of 2011's campaign is the smallest one during all the seasons. The Sq(H) amplitudes in Spring and Autumn are comparable (~ 80 *nT*). The Sq(H) exhibits the reversal of H component of geomagnetic field around morning and evening during all the seasons. This significant negative excursion of Sq(H) in Yaoundé during the night time might be due to other physical processes such as storms or thunderclouds or to the existence of a strong induced current in Yaoundé which can affect the ground-based instruments. The aim of this work is analyze the diurnal and seasonal variations of Sq(H) at Yaoundé-Cameroon using the data recorded from 2011 to 2014 during the quiet days, we also compare these ground magnetic observations with the solar Cycle 24 which shows that the Sq(H) amplitudes depends strongly on Solar Activity and that explains the greatest amplitude of Sq(H) observed on 2014's campaign and that corresponds to peak maximum of Solar Cycle 24.

# China

## Ionospheric TEC Assimilation and Now-casting System over China

Ercha A, Wengeng HUANG, Siqing LIU
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Ionospheric data assimilation is a now-casting technique to incorporate irregular ionospheric measurements into certain background model, which is an effective and efficient way to overcome the limitation of the unbalanced data distribution and to improve the accuracy of the model, so that the model and the data can be optimally combined with each other to produce a more reliable and reasonable system specification. In this study, a regional total electron content (TEC) now-casting system over China and adjacent areas (70oE-140oE and 15oN-55oN) is developed on the basis of data assimilation technique. The International Reference Ionosphere (IRI) is used here as background model, and the GNSS data are derived from both the Space Environment Monitoring Network of Chinese Academy of Sciences (SEMnet) and International GNSS Service (IGS) data. A three-dimensional variation algorithm is used to implement the data assimilation. The regional gridded TEC maps and the position errors of single-frequency GPS receivers can be generated and publicized online in quasi-real time with the spatial resolution being 1o×1o in longitude and latitude, and updated every 15 min. It is the first ionospheric now-casting system in China based on data assimilation algorithm, which can be used not only for real-time monitoring of ionosphere environment over China and adjacent areas, but also in providing accurate and effective specification of regional ionospheric TEC and error correction for satellite navigation, radar imaging, shortwave communication, and other relevant applications.

# China

## The Requirement Analysis for User-Oriented Space Weather Products and Services

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National Space Science Center, Chinese Academy of Sciences, Beijing

Routine space weather predictions, such as the indices of solar activity, geomagnetic activity, the occurrence probability of space weather events, are common products from space weather operational departments. Obviously, these products are not sufficient to meet the needs of various users, whose requirements for space weather (or space environment) information is substantially different. In the future, the space weather products and services should be more focused on user's specific needs, and should be designed and developed accordingly. For such kind of tailored services, identification of user requirements is needed at first for different fields and different technical systems. Typical users include aviation, GNSS systems, ground infrastructures, space craft design and operations, etc. For each kind of users, space weather operational departments should analyze the impacts of the space weather on the instruments or systems through communication with space weather experts, system managements and users, and identify the user needs for space weather forecast information. Feasibility analysis is also needed to illustrate how to satisfy the user needs, and give the prioritization of the requirements. And then, products and services should be developed and verified to be valid through some demonstrations. These processes for tailored products and services are now best practiced in aviation and spacecraft tasks.

Here, space weather services for China manned space missions are introduced to give an example of practice for how to apply space weather information to serve a specific space task. The purpose and needs of space information are different on different stages. Space weather products are also different for different spacecrafts, according to the specific activities that were carried out during the mission. For the ShenZhou-7 task, solar proton events predictions were needed before the astronaut extravehicular activity. Period of geomagnetic quiet time after the launch of ShenZhou-7 was requested to be provided for the following micro-satellite releasing experiment. In China's Tiangong-1 and Tiangong-2 tasks, the most important requirement for space weather forecast is the information of neutral density. To satisfy this requirement, short-term and mid-term forecasts of indices representing solar activities and geomagnetic activities were served. Also, information of the density disturbances was provided in time using the in-orbit measurements from Tiangongs' instruments.

We recommend that experiences and achievements in other practices around the globe be shared in this workshop. It will be useful for establishing an international framework for space weather services.

# China

## Future Solar and Interplanetary Radio Instrumentation for Space Weather Studies in China

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Solar eruptive phenomena have great impact to solar–terrestrial system and may cause severe space weather. Radio bursts are prompt indicators of those various solar activities including flares and coronal mass ejections (CMEs). It is an unique technique that can detect radio emissions tracking solar eruptive processes all the way from the Sun through interplanetary space to the Earth environment. To address the fundamental processes such as energy release, particle acceleration and transportations in the solar eruptive phenomena, it is important to have imaging - spectroscopy over centimetric - decimetric wave range. The Mingantu Spectral Radioheliograph (MUSER) with high spatial resolution, high time resolution, and high frequency resolution has been established in recent years dedicated for solar observations that will play an important role in space weather. To address the processes how solar eruptive events generate and propagate into interplanetary space, it is important to have imaging-spectroscopy observations covering metric to decametric frequency range. Future solar and interplanetary radio instrumentation including IPS observations for space weather studies in China is introduced in this presentation.

# Republic of the Congo

## Estimated Impacts Induced by The Magnetic Activity Index (Dst) on the Local Total Electronic Content (TEC) in Equatorial Area

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Institut National de Recherche en Sciences Exactes et Naturelles(IRSEN), Université Marien Ngouabi, Brazzaville

Abstract: The state of equatorial ionosphere has been studied from the determination of the TEC based on the correction of errors propagation of GPS signals due to ionospheric disturbances using the dual frequency method. In our study, we considered tree stations of the equatorial area (adis, bjco and nklg) in January 2012. Firstly, the monthly survey of the TEC has revealed that the magnetic storm days coincide with the days that the TEC Rinex around 70 UCET. Secondly, the daily survey of the TEC reveals two TEC (TEC/RINEX and the TEC/CODG) has revealed that during magnetics storms days, the interval between curves of TEC observed between 10: 00PM to 16:00PM (UT) is more important (around 10 UCET) when the Dst is strongly negative whatever the nature of the magnetic storm, and the interval between curves of TEC observed between 17:00 to 20:00PM (UT) is function of the nature of the magnetic storm.

Keywords: Total Electron Content, magnetic storm, Ionosphere and equatorial.

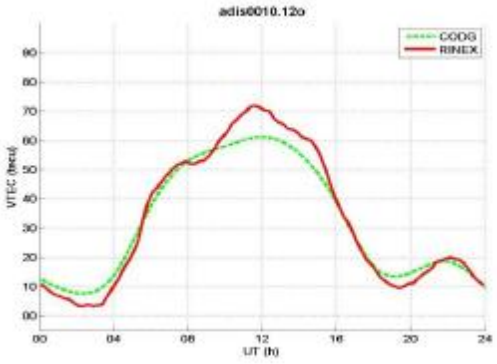


Fig. 24: TEC du 01 Janvier 2012

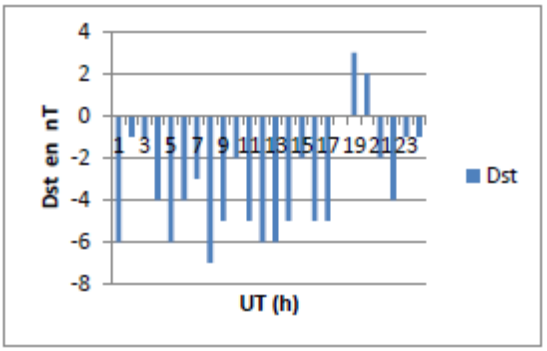


Fig. 25: Dst du 01 Janvier 2012

2. Journée du 03 janvier 2012

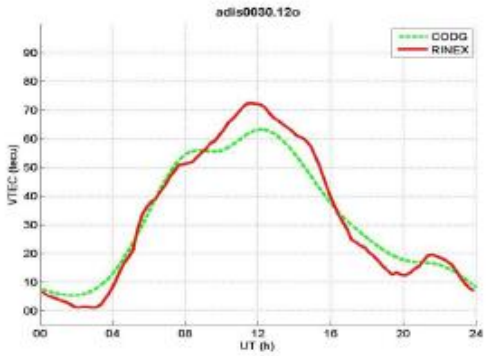


Fig. 26: TEC du 03 Janvier 2012

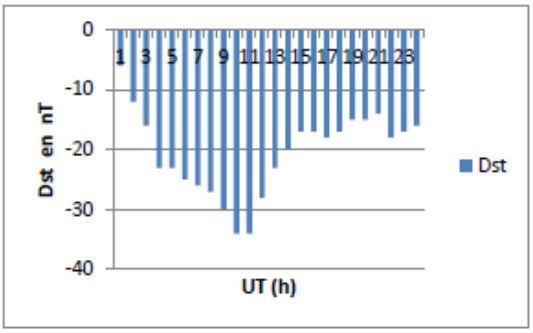


Fig. 27: Dst du 03 Janvier 2012

3. Journée du 04 janvier 2012

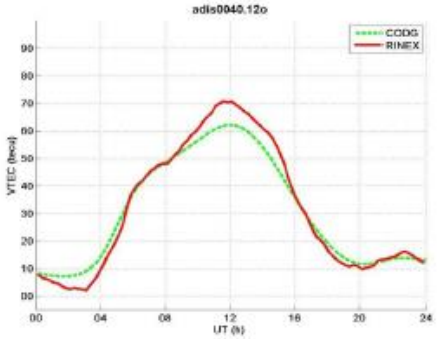


Fig. 28: TEC du 04 Janvier 2012

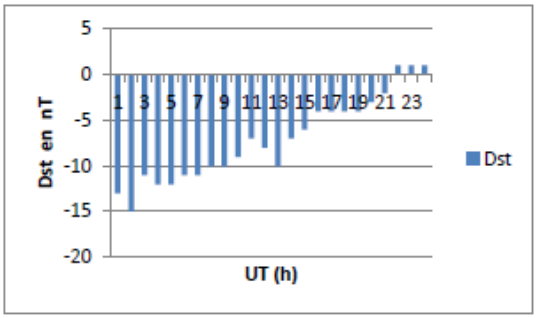


Fig. 29: Dst du 04 Janvier 2012

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# Cote d'Ivoire

## Geomagnetically Induction Effects Related to Impulsive Space Weather Events at Low Latitudes

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In this study we examine the influences of geomagnetic activity on the Earth surface electric field variations at low latitude. The induced effects of space weather related geomagnetic disturbances in the EEJ influence area in West Africa are examined. In that purpose, variations of the North-South (Ex) and East-West (Ey) components of geo-electric field are analyzed, along with that of the three components (H, D and Z) of geomagnetic field during geomagnetic storms and the solar flares. In addition, we estimate the Geomagnetically induced current (GIC) from the magnetic variations and compare with the GIC inferred from geo-electric field variations observed during the considered geomagnetic disturbances.

# Croatia

## An IGS-Based Simulator of Ionospheric Conditions for GNSS Positioning Quality Assessment

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Abstract: The analysis of space weather and ionospheric disturbance effects on satellite navigation, its performance and operation relies upon either the identification of the deteriorating conditions and setting up the GNSS equipment for data collection, or the utilisation of model-based simulators that hopefully resemble the natural conditions of a space weather or an ionospheric event. Here we present an alternative approach, based on the experimentally collected GNSS observations using the International GNSS Service global network of reference stations. In recent development, we have developed an IGS-based statistical learning-driven simulator of ionospheric conditions for GNSS positioning, that examines the requirements given by its user (description of a class of a space weather event with the choice of geographical region and GNSS systems/pseudoranges to be used), finds out the appropriate storm-case through the search of the internet-based archive of space weather indicators, and returns the most suitable IGS RINEX record of GNSS pseudorange observations with which a GNSS (SDR) receiver is to be fed for the space weather/ionospheric effects assessment. Currently in its first development phase, this simulator allows for a rather accurate simulation of the space weather conditions at minimum costs. Future research will be aimed at refining the algorithms for identification of the suitable space weather storm-case by expansion of the related space weather descriptive parameters and deployment of advanced artificial intelligence storm-case selection algorithm.

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# Croatia

## A Comparative Study of Forecasting Methods for Space Weather-Caused GNSS Positioning Performance Deterioration

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Space weather and ionospheric dynamics have a profound effect on the positioning performance of Global Satellite Navigation System (GNSS). However, the quantification of tat effect is still the subject of scientific activities around the world. In the latest contribution to the understanding of the space weather and ionospheric effects on GNSS positioning performance, we conducted a comparative study of several candidates for forecasting method for space weather-induced GNSS positioning performance deterioration. First, a moderately large set of experimentally collected data was established, encompassing space weather and ionospheric activity indices (including: the readings of the Sudden Ionospheric Disturbance (SID) monitors, components of geomagnetic field strength, global Kp index, TEC, and sunspot number) and observations of GPS positioning error components (northing, easting and height) derived from the IGS reference stations' RINEX files in quiet space weather periods. This data set was split into the training and test sub-sets. Then, a selected set of supervised machine learning methods (Decision Tree Model - DTM, Generalised Linear Model – GLM, and Artificial Neural Network - ANN) was applied to the experimentally collected data set in order to establish the appropriate forecasting models for space weather-induced GNSS positioning performance deterioration. The forecasting models were developed in R/rattle statistical programming environment. The forecasting quality of the examined forecasting models was assessed and the conclusions drawn on the advantages and shortcomings of the proposed forecasting models for space weather-caused GNSS positioning performance deterioration.

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# Ecuador

## Ecuadorian Geomagnetic Station (MAGDAS equipment): Equatorial Electrojet Study

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The study of variations of the geomagnetic field, since 2012, using the magnetometer of the MAGDAS network installed in Ecuador at the Jerusalem station located on the Equinoctial line, is presented in the current work.

Interesting results have been obtained from the geomagnetic data, such as the occurrence of seasonal variation of the magnetic field peaks and their temporal displacement, as well as valuable information for mapping the magnetic field in our geographic region. In the present talk these results are presented, as well as our current understanding of occurrence of the equatorial jet phenomenon.

# Egypt

## IHY-ISWI achievements in Egypt: Ten years of success

Ayman MAHROUS
Space Weather Monitoring Center, Helwan University, Ain Helwan

This paper highlights the achievements made over the past ten years in the field of space weather research in Egypt with the support of IHY-ISWI.

As part of the ISWI strategy to increase the space weather applications and instrumentation in Africa, Helwan University has established the Space Weather Monitoring Centre (SWMC) in Helwan, Egypt. The Center was founded to sustain the Egyptian Space Programme through monitoring and forecasting space weather. SWMC includes twenty-five researchers working in four research groups in the fields of the ionosphere, geomagnetism, solar physics and cosmic rays. The center comprises several instruments and monitoring stations through many joint international projects with USA (SCINDA, SID and three CIDRs), Japan (two MAGDAS stations), Switzerland (CALLISTO). We present here survey of remarkable results of several instruments obtained through IHY-ISWI and discuss the future prospects. The presence of the previously mentioned projects sustained us to establish a space division in the faculty of science of Helwan University, three batches have been graduated from the space division with high quality of space education.

# Egypt

## Space Weather Center Activities in Egypt (Space Weather Monitoring Center)

Nada M. ELLAHOUNY, Ayman MAHROUS, Ola Abu ELEZZ, Aliaa ABDELNASSER
Space Weather Monitoring Center, Helwan University, Ain Helwan

Here we will introduce 2 topics, Firstly, the Space Weather Monitoring Center research groups and their current activities in Space Weather field (Geomagnetism- Ionosphere- Cosmic Rays- Solar physics), what are the instrumentations and tools we are using, the Space Weather Application, what is the past, current and future research work in our center, what is the challenges, ideas for collaboration. Secondly, We will introduce International Space Weather Week ”ISWW” proposal, It is to Set up an international annually event to distribute the knowledge of Space Weather elements, the current status of its evolution and hazards for public, and attract the kids and students to this field earlier as they would be the Space Weather researchers of the future. There are 3 target groups: Kids, Elementary, junior, and high school students (special needs student are encouraged to be targeted), and Youth.

# Ethiopia

## Space Science (Space weather) Activities in Ethiopia

Melessew NIGUSSIE
Washera Geospace and Radar Science Research Laboratory, Bahir Dar University

The International Heliophysical Year (IHY) was aiming to advance our understanding of the fundamental Heliophysical processes that govern the Sun, Earth, and Heliosphere. Through this initiative different ionospheric monitoring devices such as SCINDA GPS receivers have been installed in African, for example, in Ethiopia. Following on activities of IHY, the International Space Weather Initiatives (ISWI) has been lunched since 2009. Through ISWI program activities, related to space science, have been conducted. In this presentation space science activities related to education and research and also ionospheric monitoring instruments status in Ethiopia are presented. Moreover, organization establishment in Ethiopia related to space science is presented.

# Finland

## New Findings Using VLF Data from SAVNET and Kannuslehto Radio Receivers

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The Very Low Frequency (VLF) technique is an important tool that is used to study changes in the ionospheric conductivity (using transmitting signals from navigation systems) by means of the propagation of radio waves inside the Earth-ionosphere waveguide. The VLF technique is also a very suitable tool to study changes in the properties of the magnetospheric plasma (using natural emissions). For this case, the waves generated in the magnetosphere first propagate along the geomagnetic field lines and then reach the Earth-ionosphere waveguide. The changes in the ionosphere and magnetosphere are caused by a diversity of transient or long term physical phenomena (e.g. lightning, atmospheric waves, solar flares, solar eclipses and gamma ray bursts). The present work aims at making use of VLF data obtained by the narrowband SAVNET network which receivers are spread over Latin America and the broadband VLF receiver at Kannuslehto station (in northern Finland), to characterize and determine the response of the lower ionosphere and inner magnetosphere to solar phenomena. In this paper are presented results on the sensitivity of the lower ionosphere to solar flares and its variation during the solar cycle 24. The findings show that the ionospheric sensitivity depends on the solar activity, being more sensitive during solar minimum. In this work are also presented observations of unusual natural emissions in broadband above 16 kHz that have not been reported before in the VLF literature. The period of analysis for unusual natural emission was between the years 2013 and 2015. As a final point, a classification is depicted of the types of VLF natural emission observed, the total power and polarization of the emissions, their time of occurrence, their duration and the angle of arrival to the receiver.

# France

## The Need for Training Integrating Knowledge from the Sun to the Earth

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Sorbonne Universités UPMC Paris 06, LPP, Polytechnique, Paris
T/ICT4D Abdus Salam ICTP, Trieste, Italy

The International Heliophysical Year (IHY) project brought together researchers from different disciplines from the sun to the earth. This project allowed a better understanding of recent advances in sun physics and showed the need for ionosphere physicists to integrate new knowledge of the sun in their studies. This has become essential in the new field of space weather: it is clear that the solar source must be identified in order to predict its effects on technologies like GNSS. In this presentation we will show how only certain events have been selected by the physicists of the ionosphere and the limitations that these choices have imposed in the development of the research of the ionosphere. It thus seems important in the new training of the students to envisage in the university curricula to integrate the knowledge from the Sun to the Earth.

# France

## ESA Heliophysics Archives: A Key Asset for The ISWI

A. MASSON, B. MARTINEZ, H. PEREZ, J. COOK, C. ARVISET
European Space Agency

ESA has launched, operates and is planning several heliophysics missions relevant to the International Space Weather Initiative. Among them, are the well-known ESA/NASA Solar and Heliospheric Observatory (SOHO), and the first multi-spacecraft magnetospheric Cluster missions, operated since 1995 and 2000 respectively. It also includes data from the dual spacecraft magnetospheric Double Star (2003-2007), the solar Proba-2 (2010-), the heliosperic Ulysses (1990-2007) missions and the SOLACES EUV solar experiment on the International Space Station (2007-2017). In parallel, geo-referencing of Northern images taken by astronauts from the ISS have been made available. Preparatory work is on-going for future heliophysics missions like Solar Orbiter and SMILE (magnetospheric imaging mission in soft X-ray). Eventually, the ESA heliophysics archives will also welcome data from the Proba-3 (coronograph with two satellites) and possibly the THOR (solar wind turbulence) missions and the ISS-SOLSPEC instrument (solar UV to Infrared).

# Georgia

## On the Development of Thermosphere-Ionosphere Coupling Study in Georgia under Various Helio-Geophysical Condition by TEC Data Obtained with GNSS Receivers

Goderdzi DIDEBULIDZE, Maya TODUA
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The TEC data observed by the GNSS receivers installed on the territory of Georgia gives possibility to develop a study of temporal and spatial characteristics of the thermosphere-ionosphere coupling phenomena under various helio-geophysical conditions on global and regional scales.

The increase of interest for such close to real-time monitoring and theoretical research of TEC is caused by the results obtained from the long-term dataset of the lower and upper atmosphere-ionosphere parameters. The measurements of the ionosphere F2 layer parameters from the Tbilisi ionosphere station (41.65o N, 44.75o E), the variations of the nightglow intensities of the oxygen red 630.0 nm line (emitted from the ionosphere F2 region) and green 557.7 nm line (emitted from the lower thermosphere and ionosphere F2 regions) observed from Abastumani Astrophysical Observatory (AAO - 41.75oN; 42.82oE) demonstrate their coupling with space weather. Such coupling is manifested in the formation of the irregular (e.g., various scales of the ionosphere disturbances, including TIDs, multilayered structures in the F2 region, sporadic E, etc.) ionospheric structures during strong geomagnetic disturbances which influences the TEC and thus can affect the red and green line intensity variations. Some thermosphere-ionosphere coupling phenomena observed in mid-latitudes also reveal their coupling with the polar and equatorial regions, most of which cannot be described by global circulation models. To investigate such and other regional scale phenomena characteristic for thermosphere-ionosphere coupling in Caucasus, it is important to develop the close to real-time monitoring of TEC and its oscillations by the local GNSS receivers network. The TEC and thermosphere red and green line intensities data allow us to investigate new properties of the thermosphere-ionosphere coupling, caused by space weather and climate changes, and to predict their temporal development in space.

We will present the preliminary results of sensitivity of the TEC and ionospheric scinitillation observed from AAO by high-frequency GNSS receiver to the geomagnetic disturbances.

# Germany

## Impact and Modeling of the Solar Eclipse Effects of 20 March 2015 on VLF Measurements

Daniela WENZEL, Jens BERDERMANN, Norbert JAKOWSKI
German Aerospace Center (DLR), Institute of Communications and Navigation

On 20 March 2015, a solar eclipse occurred over Northern Europe providing an excellent opportunity for studying the ionospheric response to well-defined changes of solar irradiation. Due to the obscuration of the Sun by the Moon, X-ray and EUV radiation were reduced affecting the plasma production. Thus, the ionization of the whole ionosphere decreased in close relation to the obscuration function. The study focusses on the response of the ionospheric D region by means of VLF measurements.

Germany maintains two VLF instruments that are part of the International Space Weather Initiative (ISWI): the educational project named SOFIE (SOlar Flares detected by Ionospheric Effects) and the global, near real-time network named GIFDS (Global Ionospheric Flare Detection System). We analyzed the behavior of diverse VLF signals demonstrating different steps of solar obscuration. The observation results of VLF amplitude measurements varied in strength and time showing a strong relation to the obscuration function.

VLF signal propagation was simulated according to the waveguide mode theory with the help of the Long Wavelength Propagation Capability Code (LWPC). By changing the boundary conditions of the waveguide, modelled VLF amplitudes were calculated for three exemplary paths. Therefore, an exponential electron density profile was used depending on the reflection height and the sharpness. A linear relation between the ionospheric reflection height / sharpness and the solar X-ray flux has been found. Though, a comparison with observations from the upcoming solar eclipse on 11 August 2017 over the United States may reveal quite different ionospheric behavior since different latitudes will be affected. This needs further investigation.

# Germany

## Space Weather Activities in Germany

Daniela WENZEL, Jens BERDERMANN, Norbert JAKOWSKI
German Aerospace Center (DLR), Institute of Communications and Navigation

Germany participates in ESA's Space Situational Awareness (SSA) Programme supporting Europe's independent utilization of space through the provision of space weather information, in particular with respect to hazards to the infrastructure. The delivery of space weather services is gathered under five European expert groups and centres of excellence, among which the German Aerospace Center (DLR) coordinates the Ionospheric Weather Expert Service Center (I-ESC). Furthermore, DLR operates the Ionosphere Monitoring and Prediction Center (IMPC). The service center offers nowcast and forecast information on the ionospheric state as well as warnings on issues related to space weather.

Moreover, in 2015 the DLR Neustrelitz invited scientists and experts of scientific institutions, commerce and industry as well as government agencies to participate in a joint national space weather workshop and continues previous activities organized in 2000, 2005, and 2008. Those events have contributed to establishing the topic of space weather in Germany in order to raise the awareness of possible influences on the highly technological society. Within the framework of the last workshop, a position paper was prepared which is currently in iteration. The document shall help national decision makers to consider the current aspects of space weather issues for their policy and to use existing national resources accordingly.

DLR holds two projects that are part of the International Space Weather Initiative (ISWI): The world-spanning, near real-time network named GIFDS (Global Ionospheric Flare Detection System) and the educational project named SOFIE (SOlar Flares detected by Ionospheric Effects). Both projects deal with the monitoring of the lower ionosphere by means of VLF measurements in order to provide information on solar flare effects. The SOFIE project is a prominent part of the annual Joint Space Weather Summer Camp. In collaboration with the University of Alabama in Huntsville (UAH), the South African National Space Agency (SANSA) and the DLR, the Summer Camp has become a trilateral workshop in which always two of the partners take over the role of the hosts.

Of course, Germany has a variety of scientists and experts in diverse institutions dealing with the topic space weather. Amongst others, the working group on extraterrestrial research (AEF: Arbeitsgemeinschaft Extraterrestrische Forschung) promotes space weather activities including various subdisciplines ranging from the Sun to the geospace. Therefore, regular meetings and symposia are arranged at national level.

# Germany

## The German ISWI instruments SOFIE and GIFDS

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SOFIE (SOlar Flares detected by Ionospheric Effects) is an educational venture established by the DLR_Project_Lab in Neustrelitz, Germany. Its objective is a robust ground-based detection of solar radiation bursts, i.e. solar flares, via measureable changes in the lower ionosphere. In order to accomplish this, continuous signals of powerful VLF Navy transmitters are received and stored. SOFIE offers a professional insight into topics of space weather, the ionosphere and the radio wave propagation. During the project interested students may construct the antenna on their own. Moreover, they are given the opportunity to assemble and operate the receiver following the provided construction kit and the included installation manual. The German Aerospace Center (DLR) offers the students professional support and guidance. The recorded VLF data is transferred over the Internet directly to a server in the DLR_Project_Lab.

SOFIE was started as a German educational project, however, a collaboration with schools in other countries is intended and welcome. Currently, there are six active SOFIE receivers operating in Germany and additional four abroad.

The Global Ionospheric Flare Detection System (GIFDS), operated by the German Aerospace Center (DLR), consists of a ground-based network of Perseus SDR (Software Defined Radio) receivers which provide concurrent measurements of VLF signal strength and phase at multiple frequency channels ranging from 10 kHz to 100 kHz. One of the main objectives of GIFDS is the immediate and continuous detection of solar flares affecting the bottomside ionosphere and consequently inducing sudden interferences of VLF signals. In general, these measurements are determined by solar irradiation and geophysical conditions. The influence of diurnal variations on VLF amplitudes can be corrected by applying time series analysis followed by detrending. The VLF data is regularly adjusted by various transformation techniques to ensure a stabilized output. Finally, the results are compared with the X-ray flux obtained from GOES satellites to validate the magnitude and shape of flares recorded by GIFDS. As solar events can only be detected during daytime, DLR has been installing a uniform array of receivers at selected locations around the globe. Measurements carried out at the dayside part of the Earth will be provided 24/7 in the near future.

# Greece

## Geospace Driver Effects on Electron Acceleration and Loss in the Outer Van Allen Belt

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Understanding the response of relativistic electrons to interplanetary and geospace drivers is of utmost importance for the best possible specification and prediction of their fluxes in the outer Van Allen belt. In this work we investigate the response of the outer Van Allen belt electrons to various types of solar wind and internal magnetospheric forcing – in particular to Interplanetary Coronal Mass Ejections (ICMEs), to High Speed Streams (HSS), to geospace magnetic storms of different intensities and to intense magnetospheric substorms. We have employed multi-point particle and field observations in the inner magnetosphere (both *in situ* and through ground-based remote sensing), including the Cluster, THEMIS, Van Allen Probes and POES constellations, the XMM and INTEGRAL spacecraft, and the CARISMA and IMAGE ground magnetometer arrays. The data provide a broad range of particle energies and a wide radial and azimuthal spatial coverage. Observations show that losses of equatorially mirroring electrons are primarily caused by magnetopause shadowing which in turn is achieved by outward diffusion driven by Pc5 ULF waves. Substorm-driven chorus wave activity, on the other hand, seems to be responsible for electron enhancements in the outer radiation belt even in the presence of pronounced outward diffusion.

# Hungary

## Impact of the solar hemispheric asymmetry on the variations of the interplanetary current sheet

Judit MURAKÖZY
Debrecen Heliophysical Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences

The solar activity has specific hemispheric asymmetries. The levels of activity are different on the two hemispheres on middle and longer time scales. During four Schwabe cycles the progress of the northern hemispheric activity precedes that the southern one, while in the next four cycles the southern cycle takes over the preceding role (Muraközy&Ludmány, 2012, MNRAS; Muraközy, 2016, ApJ). The interplanetary magnetic field is formed by the distribution of the solar magnetic fields and the outward streaming solar wind. The mentioned solar hemispheric predominance causes a predominance of one half-space, the northern predominance pushes the mean current sheet toward the southern half-space. My study intends to show the variation of the impact of the hemispheric predominance on the current sheet. The geophysical datasets will be chosen from various sources such as Bx and By components of the interplanetary magnetic field, cosmic ray data, aa-index and its hemispheric components, while the solar hemispheric asymmetry will be examined by using the historical sunspot observations, Greenwich Photoheliographic Results as well as the Debrecen Photoheliographic Data. My research tries to find those quantities and combinations of data which are the most indicative about the targeted dynamics of the current layer affected by varying solar north/south asymmetry.

# Hungary

## Space weather activities in Hungary

Judit MURAKÖZY
Debrecen Heliophysical Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences

In spite of the small size of country, the space weather reasearch is well-represented in Hungary. The following five institutes or groups are doing research in this field: Geodetic and Geophysical Institute, as well as Debrecen Heliophysical Observatory of Research Centre for Astronomy and Earth Sciences, Department of Space Physics of Wigner Research Centre for Physics, and the Department of Geophysics and Space Science as well as Department of Astronomy of Eötvös Loránd University.

From the Sun to the Earth there are a lot of research topics such as solar physics (solar cycles, solar flares, solar high-energy ions and solar wind), physics of heliosphere and the magnetosphere of Earth or other planets.

Besides the above mentioned theoretical and observational research topics, space weather related databases are also available from this country. There are several sunspot databases as well as an online tool for studying solar flares by Debrecen Heliophysical Observatory, and a Cluster Hungarian Data Center by the Dept. of Space Physics of Wigner Research Centre.

# India

## Halo Coronal Mass Ejections and Type II Radio Bursts During the Two Peaks of Solar Cycle 24

V. M. ASHNA, N. GOPALSWAMY, S. YASHIRO, P. MAKELA, S. AKIYAMA

Most solar cycles have double peaks in the sunspot number (SSN). In cycle 24, the peaks were well separated with the second peak more pronounced. Gopalswamy et al. (2015) found that there were more space weather events during the first peak, even though the SSN peak was smaller than the second. In this paper, we focus on coronal mass ejections (CMEs) that are observed as halos in the SOHO/LASCO field of view. We take a one-year period centered on the two SSN peaks and compare the space weather consequences of the halo CMEs in the two intervals. We consider the numbers of large solar energetic particle events, major geomagnetic storms, and coronal/interplanetary type II bursts. We find that the milder space weather during the second SSN peak is primarily due to the lack of energetic CMEs during that peak. We discuss the results in comparison with the space weather events during the two SSN peaks of solar cycle 23.

# India

## Control of Gravity Waves on Equatorial Spread F Day-to-Day Variability: an Empirical Approach

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The gravity wave control on the daily variation in night time ionization irregularity incidence is studied using ionosonde data for the period 2002 - 2007 at magnetic equatorial location Trivandrum, India. Here we present the novel result that the amplitude of the seed perturbations is a very critical parameter which decides whether or not Equatorial Spread F (ESF) would occur on a given day and that this threshold level of seed perturbation amplitude required on a given day decreases as the post sunset height of the F layer increases. The requisite seed perturbation at a particular altitude also shows solar activity dependence with progressively lower requisite seeds being observed at lower levels of solar activity. Further, the requisite seed is also found to be showing unique altitudinal dependence for each season. These results underline the need to evolve a new ESF prediction parameter, which takes into account the amplitude of the seed perturbation along with the layer height.

Having established the above unique altitude dependence of the seed perturbation for a given season and solar activity, the next logical step is to use the same to develop a model which can predict the requisite seed at any given altitude and solar activity for a given season. Therefore we also present an empirical model which is capable of incorporating the electro dynamical effects and the gravity wave effects to delineate a threshold curve for the autumnal equinox season of any year if the Solar Flux Index (F10.7) is known. The empirical model is validated using sample data. This model has the potential to be used to eventually forecast ESF occurrence if the base height of ionosphere is in the electrodynamically controlled region. This study is thus an important step in the efforts to predict communication and navigation outages.

# India

## Current State of Reduced Solar Activity: Space Weather Events in the Inner Heliosphere

P. K. MANOHARAN
Radio Astronomy Centre, National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, Udhagamandalam

In this talk, I will review the signatures of solar eruptions (e.g., coronal mass ejections (CMEs)) and of associated phenomenon in the near-Sun region as well as effects of their propagation in the interplanetary medium. The radio interplanetary-scintillation data, along with the white-light images, are useful in understanding the radial evolution of speed and expansion of CMEs in the inner heliosphere. I present the detail investigations of three-dimensional distribution of solar wind density turbulence and speed in the inner heliosphere, based on interplanetary scintillation (IPS) measurements obtained from the Ooty Radio Telescope, which is operated by National Centre for Radio Astrophysics, Tata Institute of Fundamental Research. Ooty measurements provide estimates of solar wind at most of heliospheric latitudes and in the distance range of ~10-250 solar radii. Such estimates along a large number of lines of sight through the heliosphere allow the reconstruction of 3-D structures of quiet (i.e., ambient) solar wind as well as propagating transients in the inner heliosphere. The results on IPS images of solar wind density and speed reveal the propagation characteristics of CME events, and the 3-D evolution of quiet solar wind at various levels of solar activity between solar cycles 22 and 24. The geoeffectiveness of CMEs is discussed based on both CME and solar wind conditions encountered by the CME on its way from Sun to 1AU.

# India

## Space Weather Activities in India

P. K. MANOHARAN
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The solar astronomy in India has a significant long history. Over the years the Indian research and developmental activities in the area of solar physics and space weather sciences have grown and excellent facilities are now available to monitor the sun and its processes from the interior of the sun to the interplanetary space as well as to study the impacts of solar processes on the magnetosphereionospherethermosphere system of the Earth. These facilities form the main chain of the nation's space weather programme and are supported by a large number of observatories, research institutions and university departments. This presentation discusses and provides an overview of existing infrastructure for space weather related activities in India. Some of the ongoing international collaborative researches related to the ISWI programme and their results are also highlighted.

# India

## Study of Space Weather Events of Solar Cycle 23 And 24 and Their Geoeffectiveness

B. VEENADHARI, Selva KUMARAN, Sandeep KUMAR, Megha PANDYA, S. MUKHERJEE
Indian Institute of Geomagnetism, Navi Mumbai

Space weather disturbances caused by enhanced stream of solar plasma during solar flares and Coronal Mass ejections(CMEs) are known to disrupt communications, endanger satellite payloads and introduce severe errors in a variety of tracking and positioning systems. The phenomena known as geomagnetic storms are the most obvious features of space weather disturbances. Magnetic storms are characterized by a sudden enhancement in the ring current circulating around the earth. When the interplanetary magnetic field which encounters Earth's bow shock points southward, a reconnection process can take place. During the solar cycle of 23 and solar cycle 24, several solar flares and CMEs which give rise to intense geomagnetic storms due to highly active solar environment. Solar flares and CMEs are the most prominent and violent manifestation of the solar activity. Some of the intense and moderate events of solar cycle 23 and 24 are selected to investigate using ground based geomagnetic data, multi satellite data of solar wind and interplanetary parameters spacing distances from the L1 point to the spherical location of plasmasphere are made use to find the role of interplanetary drivers. The solar and interplanetary characteristics of the moderate storms driven by CME are compared for solar cycle 23 and 24 in order to see reduction in geoeffectiveness has anything to do with the occurrence of moderate storm. We will discuss the importance of super intense space weather events are investigated using old preserved historical records of Colaba, India which will provide important insights into plausible interplanetary conditions for intense geomagnetic storms and probable frequency of their occurrence. This study will strengthen the coupling processes of solar-magnetosphere through space weather events.

# Indonesia

## Space Weather Program in Indonesia

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In the equatorial archipelago of Indonesia, solar physical activities and space weather monitoring have been mainly established by two institutions at Bosscha Observatory, Bandung Institute of Technology (ITB) and Indonesian National Institute of Aeronautics and Space (LAPAN). The former is a national university which provides, the only one, undergraduate and graduate programs in astronomy and astrophysics, since October 18, 1951. LAPAN is a research government institution, established on November 27, 1963. We pointed some activities for both institutions as reaching significant progresses in the last decade. In ITB, courses in Space Weather, Solar Physics, and Astrophysical Plasma have been conducted since 2003 for advanced undergraduate and graduate students with more than 160 participants or about 10 participants/course/semester on average. Mobility programs for undergraduate and graduate students and international conferences were routinely offered. Solar activities have been monitored simultaneously with Coronado 60mm telescopes of H-alpha (0.5A) and Ca II K, in conjunction with 80mm white-light telescope, also sunspot sketch. JOVE radio telescope and Callisto radio spectrometer have been installed at Bosscha Observatory, Sumedang (West Java), Tomohon (North Sulawesi), and Biak (Northern West Irian). We need more Callisto instruments at different islands in Indonesia. Solar radiospectrograh SN4000 has also been operated by LAPAN at Sumedang station. Several types of ionosonda, HF antenna, magnetometer, and GPS for TEC works together to derive ionosphere, radio, and geomagnetic fluctuations. Space Weather Information and Forecast Services (SWIFtS) is a web-based services made by LAPAN to accommodate results from all related space weather instruments. LAPAN and ITB involve in microsatellite missions and a new national observatory. Distinguished guests and instrumentations are needed to give more insight and collaborations for space weather impacts, especially in the equatorial region.

# Italy

## The Software Defined Radio Technology for GNSS Ionosphere Monitoring

Nicola LINTY, Fabio DOVIS, Vincenzo ROMANO, Lucilla ALFONSI

Professional hardware Ionospheric Scintillation Monitoring Receivers (ISMR) are commercial devices specifically designed for monitoring ionospheric events affecting GNSS signals. ISMRs have been successfully exploited for ionosphere monitoring for years; nevertheless, recent works and projects proved that complementary monitoring installations based on Components Off-The-Shelf (COTS) and on Software Defined Radio (SDR) technology can provide valuable alternative to professional receivers.

The most common architecture of a GNSS SDR receiver consists of:

A GNSS data grabber. It includes a GNSS multi-frequency antenna and a Radio Frequency (RF) front-end; the GNSS signal is received, amplified, band-pass filtered, down converted to Intermediate Frequency (IF), represented into a stream of digital samples exploiting an Analog-to-Digital Converted (ADC), and finally raw GNSS IF samples are stored on mass memories for further processing.

A SDR-based GNSS receiver. SDR refers to an ensemble of hardware and software technologies that enable reconfigurable radio communication architectures. All the receivers typical signal processing operations, such as acquisition (signal correlation), tracking (phase and delay lock loops), data demodulation and position computation, are entirely realized in software exploiting programmable platforms, such high-performance general purpose processors (PC). The SDR receiver processes directly the stored raw IF data, either in real time or in a post-processing phase, to produce standard GNSS observables and scintillation indices.

The implementation by means of the SDR approach adds flexibility and configurability to the implementation of the whole monitoring station.

On one side, the software approach enables the possibility to design and implement innovative algorithms (e.g. different acquisition or tracking loops structures) and advanced signal processing techniques, for example for multipath and interference removal or for ionosphere monitoring.

On the other side, having access to the full receiver chain, SDR receivers offer to the user a larger subset of observables. When using commercial GNSS receivers, only the storage of post-processed data is possible, such as ionospheric data and outputs of the correlation stages. On the contrary, SDR-based receivers allow the access to intermediate and low level receivers signal processing stages. In addition, the two different blocks of Figure 1 can operate independently during monitoring operations. Raw IF signal samples collected on site can be

transferred exploiting external memories and then post-processed, by using different configurations and architectures of the receivers. Disposing of raw IF data also allows to replay GNSS signals back to RF, thus recreating in the lab the original data collection scenario. This signal can be fed to different commercial receivers, for instance to test and compare their performance. This feature makes the approach equivalent to a plethora of receivers.

Last but not least, even considering the hardware costs for the front-end section, the solution is cost effective, especially when considering the possibility to mimic the behavior of different receiver architectures and the possibility to replay scenarios for significant atmospheric events.

The effectiveness of the architecture has been proved in several installations at equatorial regions, and lately by the installation of two data collection systems designed and realized for the purposes of the DemoGRAPE project in two Antarctica research stations: the Brazilian station Estação Antártica Comandante Ferraz (EACF), and the South African Antarctic base SANAE IV. During the first months of operation, significant events have been observed, and the software processing has been able to provide values for the scintillation indexes S4 and $\sigma_{\varphi}$ with the quality and reliability of a Septentrio PolaRxS PRO ISMR.

# Italy

## Italian Contributions to SW Studies: Recent Progress

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The poster reviews the current state of the ongoing initiatives in Italy in relation to Space Weather (SW) studies. According to different objectives, the review is presented in 3 sections: SW Services and Tools; SW recent scientific results and Education & Training. The first section presents the space and ground based instruments and services that operate and or have been developed in Italy. The section "SW recent scientific results" focuses on research and related solar physics, solar-earth interaction, geomagnetism and ionospheric studies. Third section, "Education and Training" presents some of the last activities carried out in Italy in order to promote and enhance SW research in students and among the scientific community.

It is worth mentioning that since October 2014 the Italian scientific and industrial community involved in Space Weather created a national group named "Space Weather Italian Community" (SWICO) with the primary objective of the exploitation of the Italian knowledge in the field. The community includes expertise in observational, theoretical studies and modelling, as well as application in industrial sectors.

All these national efforts have been strengthened in the last years and have offered new insights in the complex field of Space Weather. At the same time, they contributed to the participation of the different institutions in international projects and to support global collaboration.

# Italy

## From The IGY to the ISWI: A Perspective View of the Importance of International Cooperation in Geo-Heliophysics

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After a brief history of international programs from the International Geophysical Year (1957-1958) to today International Space Weather Initiative the relevance of international collaboration in the development of Geo-Heliophysics and Space Weather research is analyzed. It is shown how such collaboration in science in general and in these specific fields has increased rapidly in recent decades. Paper coauthorship relations are recognized as a very good indicator of international collaboration. The importance of the means of communications grow in the increase of international relationships is pointed out.

# Italy

## Ionospheric Prediction Tools in IPS EU-Project

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Ionosphere Prediction Service (IPS) is an ongoing EU project leaded by TELESPAZIO (IT) and include the collaboration of Istituto Nazionale di Geofisica e Vulcanolgia (INGV-IT), the University of Nottingham (UNOTT-UK), the University of Tor Vergata (UTOV-IT), the Nottingham Scientific Ltd (NSL, UK) and TELESPAZIO VEGA (DE). The goal of the project is to improve ionospheric nowcasting and forecasting capabilities, beyond the state of the art, to realize a service prototype to feed different GNSS user's needs. The outcomes of the project will contribute to the mitigation of the impact of significant ionospheric-related geophysical events on our technology-based society. In this view, the project becomes an important contribution to space weather. In the framework of IPS, INGV developed a set of nowcasting and forecasting ionospheric tools at global and regional (Europe and Italy) level. Such tools, based on integration of several kind of real-time data from different sources, models and "ad hoc" developed algorithms, are able to provide nowcasting, short-term (30 minutes) and long-term forecasting of TEC and scintillations related quantities. Nowcasting and forecasting tools are now at prototype level and validation of their performance is ongoing. In this paper, tools are described and results for selected case studies are presented.

# Japan

## Latest Scientific Results of MAGDAS Project

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MAGDAS project is the global ground-based magnetic field observation network and allows to understand the energy transfer and propagation process from the poles to the equator, in the terms of the coupling the solar-magnetosphere-ionosphere-atmosphere. In 2008, International Center for Space Weather Science and Education, Kyushu University (ICSWSE) proposed the EE-index (Uozumi et al., 2008; Fujimoto et al., 2016), which is an index to monitor quantitatively various equatorial geomagnetic phenomena in real time. EE-index separates the magnetic disturbances in the equatorial region into the global (EDst) and local (EUEL) magnetic variations. Especially, the detail analysis of EUEL index provides the quantitative and visible information in order to reveal the electromagnetic phenomena affecting the fundamental structure of Equatorial Electrojet (EEJ). This paper will show some examples applying EE-index to the equatorial magnetic variation: solar cycle variation of EEJ peak, semiannual EEJ variation and semidiurnal EUEL variation. The amplitude of semidiurnal EUEL variations increased in January and decreased around July. The seasonal dependence of semidiurnal variation agrees with the seasonal profile of atmospheric neutral wind (2.2) mode. The semiannual EEJ variation has two peaks in March and September. In other words, the amplitude of EEJ is weaker during solstices (January and July). We demonstrated these characteristics with time series analysis of EE-index. We are trying to understand the sources affecting the total current intensity flowing the equatorial ionosphere by separating the different contributing factors from the magnetic field variations.

# Japan

## JAXA's Contribution to Space Weather; Arase and Other Satellites

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Japan Aerospace Exploration Agency (JAXA)

The ARASE (ISAS/JAXA) satellite was launched on December 20, 2016 from the Uchinoura Space Center in Japan. It has a mission to clarify the mechanism responsible for the decrease and increase in the Van Allen radiation belts. It has 9 instruments and three of them, MGF, HEP and XEP, can provide quasi-real-time data for space weather. We started to provide space weather data from the Space Environment and Effects System (SEES)/JAXA web site on March 20, 2017. The MGF is a fluxgate magnetometer to measure magnetic field. The HEP has Solid-State Silicon Detectors to measure electron from 70keV to 2MeV. The XEP has 5 Solid-State Silicon Detectors and a Scintillator (GSO) to measure electron from 400keV to 20MeV.

On the other hand, the Research and Development Directorate of JAXA has measured the space radiation environment since 1987 and provided real time and quasi-real-time data on the SEES. The ETS-V (Kiku-V) was our first satellite in geostationary Earth orbit (GEO) to measure electrons, protons and heavy ions. JAXA provides space environment data obtained by these instruments on the Space Environment & Effects System (SEES) web site. The SEES is a database system for space environment data. It has developed many instruments to measure the space environment and study the effect of radiation on instruments called TEDA and SEDA. TEDA and SEDA are provided on sixteen spacecraft and seven spacecraft, respectively, that are now in operation. In addition, the Japanese GPS satellites QZS-2 and QZS-4 are to be launched in the future (into quasi-zenith satellite orbit) and will be equipped with SEDA (LPT/MAM) to provide us with more details of the space environment.

These data are uncalibrated, so users can not use them for science, but we expect them to be used for space weather studies.

# Japan

## Transportation, Acceleration and Loss of Electrons in the Slot Region Responsible for The Formation of New Radiation Belt During Big Magnetic Storm

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It was reported that relativistic electrons in the outer radiation belt have been transported into the slot region during big magnetic storms (Obara and Matsumoto, 2016 and references therein). Baker et al. (2013) further reported a new radiation belt has been made in very near Earth region; i.e. L~3.

We have examined electron data in the radiation belt during magnetic storms paying a particular attention to the formation of new radiation belt. Issues, we like to clarify, will be following questions; i.e. 1) electrons injected into the slot region will be additionally accelerated there? 2) what is the cause of electron acceleration? 3) how long electrons will be accelerated? and 4) what mechanism will be adequate for the formation of new radiation belt?

We have analyzed two events; one is March 24, 1991 event, and the other is July 14, 2000 event. In both cases, new radiation belt has been made at round L～3 in both and it persisted for almost two weeks. We have confirmed in both cases that local acceleration was evident and intense very low frequency (VLF) plasma waves have been observed. Additional acceleration has been likely accomplished by these waves.

New point of our study will be an identification of local acceleration of electrons in the new radiation belt in very near Earth region; i.e. L~3. We will report our results in detail in the presentation.

# Japan

## The Recent Progress of CHAIN Project and the Method for Utilizing Its Data for Space Weather Prediction

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Continuous H-Alpha Imaging Network(CHAIN) project is to create a world-wide observational network with ground-based solar telescopes for the purpose of 24-hour continuous observation of the three-dimensional velocity fields of filament eruptions and shockwave structures on the whole solar surface [1]. As its progress from 2007 to now, 2 countries(Peru and Saudi Arabia) have joined, 10 papers related to CHAIN project have been published(2 of them are written based on the data obtained in Peru[2][3]), and 7 lectures(4 in Peru, 1 in Algeria, and 2 in Saudi Arabia), 3 technical trainings(1 in Japan and 2 in Peru), 4 scientific trainings(3 in Peru in June, October, and November of 2010, and 1 in Saudi Arabia in October of 2015), and 5 data-analysis workshops(1 in Peru and 4 in Japan) have been held. In the former part of this presentation, I will show the details of these progresses and mention about the future plan of this project. In its latter part, I show a recent scientific result we obtained as an example of our progresses. Filaments, the dense cooler plasmas in the solar corona, often become unstable and erupt into the interplanetary space as coronal mass ejections (CMEs). The CMEs may cause geomagnetic storms that result in various societal and economic impacts such as blackouts and satellite anomalies, so that it is important to predict when filament eruptions will occur. For the purpose of investigating the characteristics of eruptive filaments that can be used as the precursor of filament eruptions, we analyzed the solar full disk images captured by Solar Dynamics Doppler Imager(SDDI) installed on Solar Magnetic Activity Research Telescope(SMART) at Hida Observatory, Kyoto University. SDDI can obtain solar full disk images in 73 wavelengths between (Hα center - 9°A) and (Hα center+9°A) per 0.25°Awith the time resolution of about 15 seconds. Therefore, this instrument can observe unprecedented detailed line-of-sight velocities of filaments. As a result, we observed an increase in the amplitude of line-of-sight velocity of the small scale motions in the filament before the onset of the eruption. This result can possibly be used as the precursor of filament eruptions and create a new alerting method for CMEs combined with CHAIN.

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# Japan

## Establishing the IHY Asia-Pacific Program

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The International Heliophysical Year Asia-Pacific region began activities in 2004, starting with a planning meetings in India and Japan. Many of the Asia-Pacific countries had individual national programs. Additionally, Asia-Pacific scientists participated in and provided leadership for many of the IHY instrumentation programs and educational activities. The region hosted IHY summer schools and supported schools in other regions. The MAGDAS (Magnetic Data Acquisition System), led by SERC at Kyushu University, was established to study of dynamics of geospace plasma changes during magnetic storms and auroral substorms, the electromagnetic response of iono-magnetosphere to various solar wind changes, and the penetration and propagation mechanisms of DP2-ULF range disturbances from the solar wind region into the equatorial ionosphere. These programs became the basis for the ISWI Asia-Pacific activities that continue today.

# Japan

## The MAGDAS Project the Past and Next 10 Years

Akimasa YOSHIKAWA
ICSWSE, Kyushu University

For study of coupling processes in the Solar-Terrestrial System, International Center for Space Weather Science and Education (ICSWSE), Kyushu University has developed a real time magnetic data acquisition system (the MAGDAS project) around the world. The number of observational sites is increasing every year with the collaboration of host countries. Now at this time, the MAGDAS Project has installed 77 real time magnetometers –so it is the largest magnetometer array in the world. The history of global observation at Kyushu Univ is over 30 years and number of developed observational sites is over 140. The MAGDAS project has been contributed to IHY and ISWI. I will introduce our international MAGDAS activity the past and next 10 years.

# Kazakhstan

## Kazakhstan's Center for Diagnostics of Near-Earth Space and Forecast of Space Weather

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Monitoring of key parameters for space weather on the basis of Kazakhstan's multi-level system measurements with a database update and diagnostics of a state of the near-Earth space is carried out. Results of space environment monitoring are accessible via Internet on the web-site of the Institute of Ionosphere (http://www.ionos.kz/?q=en/node/21) in real time. Kazakhstan's multi-level system measurements includes an experimental setup for records of cosmic ray intensity by using a neutron monitor (high mountain cosmic ray station AATB), a magnetic observatory “Alma-Ata”, an optical interferometer called the Spectral Airgrow Temperature Image (SATI) instrument for observing the emission of night sky, an ionospheric sounder, a solar radio telescope for the measurements of the solar radio flux at frequencies of 1.078 GHz (27.8 cm) and 2.8 GHz (10.7 cm) with 1-second time resolution, and a Callisto radio spectrometer (type eC37). Kazakhstan Space Weather Prediction Center works daily (http://ionos.kz/?q=en/node/21). We issue the short-term and long-term forecasts of the magnetic activities (Ap-indexes) and solar activity (F10.7) for 55 days, the forecast of probability of a large proton enhancement for 28 days and the forecast of fluence of magnetospheric electrons with energy> 2 MeV in a geostationary orbit for 28 days and provide this information to all interested organizations in Kazakhstan. An off-optimum situation with the Kazakhstan geostationary satellite KazSat-2 was analyzed.

# Kenya

## Space Weather Research and Development in Kenya:2008- 2017

Paul BAKI

Technical University of Kenya, Nairobi

An account is given of the status of Space weather science in Kenya, detailing out infrastructural development, starting with SCINDA-GPS to Digisonde and the concomitant Human capital development including research capability, research themes and opportunities for collaborations.

# Malaysia

## Equatorial Plasma Bubble for Space Weather Monitoring in Malaysia

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The equatorial ionosphere most often shows a nighttime plasma irregularity that is commonly referred as equatorial plasma bubble (EPB). The occurrence of EPB could cause rapid fluctuations in the amplitude and phase of the propagation radio signals and crucial to communication and navigation systems. The EPBs normally occur successively where one structure rising after another during the sunset time. However, the onset time and location of the EPBs are ubiquitous because the seed of the initial perturbation is not completely understood. Although various observation systems have been developed to capture the EPB, each of the measurement is limited with space and time resolution.

The high-density GPS receivers in Malaysia are capable of monitoring the onset location and the evolution of the EPB structures with high temporal and spatial resolutions. Statistical results from 2008 to 2013 showed that the EPB structures tend to occur successively in one night during equinoxes in high solar activity years. The horizontal modulation in a form of wavelike structures along the observed longitudes might be responsible for the development of successive EPBs. The wavelike structures at the bottom-side of ionospheric layer could be easily amplified into successive EPBs due to high growth rate of Rayleigh-Taylor instability (RTI) during high solar activity. The wavelike structures in the zonal direction could be present in the late evening plays an important role in the development of successive EPBs during sunset time.

The wavelike structures that appear at the bottom-side of the ionospheric layer could not be detected from GPS data, where the signal is integrated from the satellites at 22,200 km altitude. In this study, the existence of the wavelike structures prior to the development of the EPBs will be investigated using radio beacon data from low earth orbit satellite (LEOS) such as Communications/Navigation Outage Forecasting System (C/NOFS) which orbits at 400 - 800 km altitude. The GRBR installed at Kuala Lumpur and Georgetown receives beacon data from LEOS at 150 and 400 MHz frequencies. The total electron content (TEC) at the bottom-side of the F layer can be derived from phase different between both frequencies. The LSWS can be determined from the perturbation inside the TEC by subtracting a 2.5 minutes running average.

The zonal properties of the wavelike structures or so-called large scale wave structures (LSWS) will be derived from GRBR in Kuala Lumpur and Georgetown. At the same time, the onset locations of the EPBs will be captured by high-density GPS receivers in Malaysia. Properties such as zonal wavelength, onset time, duration and location of the LSWS and the EPBs will be examined. The spatial relationship between the modulation of the wavelike structures and the development of the EPB structures will be discussed. An actual perspective of the modulation of the wavelike structures that responsible for the development of the successive EPBs will be revealed. The properties of the LSWS prior to the development of the EPB is useful for early warning system in operational of Malaysian space weather service such as ISKANDARnet Ionospheric Outburst MOnitoring and alert System (IOMOS).

# Mexico

## Instrumentation for Space Weather Activities: The Mexican Experience

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Worldwide efforts have been made in the last decade, after the International Heliophysical Year (IHY) in 2007, to bring the space weather into the agenda of developing nations. In the case of Mexico, this process started recently, in 2014, with legislative changes to the national civil protection law, which now includes space weather phenomena as potential hazards for our country. In this contribution we show how different scientific groups in Mexico have developed instrumentation devoted to scientific and space weather activities, and the first attempts to create coordination mechanisms, through the Mexican Space Weather Service (SCiESMEX), in order to collect, to create, and to offer space weather data, products, and services, respectively. We also show the nationwide efforts to encourage students to pursue a career in space physics through their involvement in educational activities organized by institutions and government agencies. The mexican experience may provide useful lessons to other developing nations that are planning to be involved in space weather activities.

# Mexico

## Interplanetary Scintillation Observations at 140mhz: Toward Near Real-Time Monitoring of Solar Wind Properties

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Observations of interplanetary scintillation (IPS) are currently carry on by the Mexican Array Radio Telescope (MEXART), which is a ground-based instrument that operates at 140 MHz and is devoted to study solar wind properties such as density and speed through the IPS technique. These observations of IPS can be used to provide, in real time, the solar wind conditions of the inner heliosphere that can be useful for space weather forecasting purposes. In this contribution we report on the implementation of a procedure for the MEXART data in order to provide near real-time values of solar wind speed and density. These values are planned to have a specific format that fits with a defined format given by other IPS instruments in order to unify a worldwide IPS stations network. An immediate application is to use these solar wind values as an input to the UCSD tomography 3-D code to image the interplanetary medium. We show preliminary results of solar wind sky projections of density and velocity produced on a daily basis with MEXART.

# Mexico

## Mexican Space Weather Strategy

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In 2013, the Mexican Parliament approved the initiative to reform the General Law of Civil Protection, specifically Articles 2º and 82º, which for the first time included in the national legislation the concept of "astronomical phenomena" (AP), defined as disturbing agents generated by the constant activity of outer space and its interaction with the Earth that causes destructive phenomena, putting human life at risk, causing death or alteration to the natural order and social life on Earth. The AP includes space weather and Near Earth Objects (NEOs).

These two phenomena are already defined in the classification recognized by the National Center for Disaster Prevention (CENAPRED) in the National Atlas of Risks. In addition, this law defines the classification of "astronomical phenomena": solar storms, solar eruptions, meteorites and bolides.

It is these phenomena that must have preventive and contingency plans in the event of disasters, considering that these could lead as predicted by NASA, a solar storm that could leave the northern hemisphere without power supply, if the solar activity is severe.

In July 2015, the National Center for Disaster Prevention (CENAPRED), the Mexican Space Agency (AEM) and the Mexican Space Weather Service (SCiESMEX) started a working group involving different government bodies, research institutes and industries which activities could be affected by disturbing phenomena from outer space. Following the amendments of the General Law on Civil Protection there is a mandate to stablish public policies regarding the preparedness, response, recovery and mitigation of disasters caused by phenomena from outer space.

Following with the actions undertaken and the creation of the Working Group on Space Weather in Mexico, this group is working on the development of an action protocol for civil protection, as a risk management strategy for space weather disasters.

This protocol establishes the types of risks, as well as the levels of warning in relation to the risks, in the same way establishes the procedure by means of which these warnings will be carried out for a greater and better coverage of the incidents caused by astronomical phenomena, as well as the responsibilities of each institution during such events.

Therefore, today there are joint efforts in the interior of Mexico to advance in the field of prevention and integration for a greater understanding of this type of phenomena, the new strategy against space climate is about to reach its final draft, which will create a public policy, positioning Mexico as one of the first countries in the world with an initiative like this.

Once the Space Weather National strategy is concluded, the next steps of the Group of Experts will be the creation of the new group to generate the strategy to counteract the effects of the Near-Earth Objects that affect the national territory.

# Mexico

## Space Weather Activities in Mexico

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Space weather hazards were recognized by the legislative modifications of the General Civil Protection Law in Mexico in 2014. The Mexican Space Weather Service (SCIESMEX) (www.sciesmex.unam.mx) initiated in October 2014 and it is operated by the Geophysics Institute at the National Autonomous University of Mexico (UNAM). The SCIESMEX observational capabilities combines a network of different ground instruments covering solar, interplanetary, geomagnetic, and ionospheric observations. The service became a Regional Warning Center (RWC) of the International Space Environment Services (ISES) in June 2015 and participates representing Mexico in the Interprogamme Coordination Team on Space Weather (ICTSW) of the Word Meteorological Organization (WMO) and the Space Weather expert group of the UNCOUPUOS. We report the progress in developing a space weather strategy in Mexico. The plan includes: (1) to strengthen regional observational capabilities to monitor ionospheric and geomagnetic disturbances; (2) to develop of an early warning alert within the national civil protection system; (3) to study the vulnerability of critical technological systems in the country towards intense or extreme space weather events; and (4) to design national policies to prepare the reaction of the government to space weather hazards.

# Morocco

## Local Ionosphere Modelling Using GNSS Reference Stations Network

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In the last years, the interest of the GNSS community in precise positioning has widely increased. Taking into account all error sources and combining the precise satellite orbit and clock data with dual frequency data, GNSS performs well and can provide centimeter or millimeter level solutions. However, in many applications, single frequency receivers are used. In this case, one of the critical error source is related to the ionosphere and has to be mitigated. The mitigation of ionospheric effects on GNSS is an important component of the national strategy aiming the implementation of new GNSS Infrastructure, the dissemination of local products and algorithms to support the use of precise GNSS positioning.

In this presentation, we will describe the approach to develop a Local Ionospheric Model (LIM) based on the determination of total electronic content (TEC). The model will be derived from data of the National GNSS Reference Stations Network (Morocco) and will be used to improve the quality of positioning and navigation. We will also present the proposed scheme for the assessment of this LIM. The results will be compared to Gridded Global Ionospheric Maps (GIM) and by analyzing their impact on positioning.

# Nepal

## Space Weather Initiative and Its Application in Nepal

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New scientific discipline 'Space Weather' is based on the integration of the physical processes between the Sun and the Earth. It has the application on Global Navigation Satellite System (GNSS). The interest of this global approach is to unify different disciplines of the past to connect fundamental research to the applications in GNSS. Nepal has very limited research studies yet government, INGOs and Universities are working on the GNSS in limited area and proposed to extend the study of the GNSS. There have been some initiatives of its application data collection and in use disaster management, mining as well as teaching in University. Kathmandu university initiated the study of Geomatics and it was followed by the Tribhuvan University. The governmental organization such as the department of mining, Geodetric survey branch, Survey department of Land reform ministry and International Centre for Integrated Mountain Development (ICIMOD) as an INGO is using the GPS stations for the research and disaster management. There are 29 GPS station and it is monitored by the UVAC for data collection. Nepal has affiliated to ISWI and at present coordinator is working on gathering information and disseminating knowledge to the study of space weather. Tribhuvan University has proposed for its study in master level research for the space weather and project work on Bachelor level of Geomatics engineering has promoted the study in space weather.

# Nigeria

## Variability of TEC and ionospheric irregularities with phases of solar cycle over East and West African Regions

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In this study we investigated the variability of total electron content TEC and ionospheric irregularities with phases of solar cycle over East and West African regions. We considered GPS measurements taken during the solar cycle # 24 (2009 – 2016) from three stations in the West (Ykro, dip latitude 2.59°; Nklg, dip latitude 3.08°; Bjco, dip latitude 8.05°) and three in the East Africa (Moiu, dip latitude 9.22°; Mal2, dip latitude 10.25°; Mbar, dip latitude 10.8°). We compared the TEC and ionospheric irregularities obtained at the two regions along the African longitudes. Disparity in the observed TEC and ionospheric irregularities in the two regions were further investigated and probable mechanisms responsible of the disparity discussed. The ascending and declining phases of the solar cycle was considered separately and the effect of the change in phase of solar cycle was also investigated on the observed ionospheric irregularities. Longitudinal variability and sunspot cycle dependence of TECHNOLOGY and ionospheric irregularities were ascertained within African region.

# Nigeria

## Advances in Space Weather Research and Operations in Nigeria During IHY and ISWI (2007 – 2017)

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Nigeria participated actively in the United Nations endorsed International Heliophysical Year IHY and ongoing International Space Weather Initiative ISWI programs. Today, 4 magnetometers (1 AMBER, 3 MAGDAS), 23 GNSS receivers, 1 All-sky Optical Imager, 1 Fabry Perot Interferometers, 1 digisonde and a couple SID monitors are some of the space weather observational facilities that have been installed in Nigeria during since the inception of IHY/ISWI. Masters and PhD graduates have been produced locally using the data obtained from the facilities. Other benefits derived from national participation in these programs include control of brain drain, local training of graduate students, topical academic conferences/workshops, establishment of international cooperation and linkages. Education and Public Outreach activities were organised nationally during solar eclipse events. This poster also presents some activities of the Centre for atmospheric Research established in January 2013 by the Federal Government f Nigeria with a specific mandate to focus on Space Weather. Ionospheric maps and other results obtained from installed space weather facilities are also presented.

# Nigeria

## Africa and Space Weather Research: Review of Deployed Instrumentation and Scientific Results from IHY to ISWI (2007 – 2017)

A.B. RABIU
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International Heliophysical Year IHY and International Space Weather Initiative ISWI programs facilitated deployment to Africa of instruments capable of monitoring space weather from 2006 to date. The list of these multiple equipment includes magnetometers, GNSS receivers, Interferometers, among others. This paper presented the chronology of the deployment of Space Weather observational facilities to Africa during IHY and ISWI, highlighting the benefits of such programs. Great number of papers have been published by Africans during the period under review using data obtained from IHY'ISWI equipment. A precise review of works done using some data obtained from these facilities is presented in this present work. Results from ground observations have been used to validate and improve existing ionospheric models. Temporal and continental-spatial variation of Solar quiet daily Sq variation in the three geomagnetic field components H, D and Z have been investigated. There is clear indication that equatorial ionosphere exhibits longitudinal variability over Africa as the equatorial electrojet EEJ appears stronger in East than West Africa. Flow gradient do not follow a definite diurnal pattern. On a global scale, the EEJ undergoes variability from one longitudinal representative station to another with strongest EEJ of about 192.5 nT in the South American axis at Huancayo and a minimum peak of 40.7 nT at Ilorin in West Africa. Obtained longitudinal inequality in EEJ was explicable in terms of the effects of local winds, dynamics of migratory tides, propagating diurnal tide and meridional winds. In Africa, most frequent simultaneous occurrence of CEJ at western and eastern equatorial stations was in the morning (77%). The longitudinal variability in the local time of occurrence of CEJ along African longitudes is attributed to the differences in meridional currents and some other phenomena. African stations of Ilorin and Addis Ababa registered the greatest % of occurrence of CEJ than elsewhere. More results on the ionosphere over Africa obtained from GPS-derived TEC, Fabry Perot interferomoters and optical imager are further reviewed.

# Nigeria

## African Participation in IHY and ISWI (2007 – 2017): Benefits and Implications for Space Weather Research

A.B. RABIU
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The participation of African countries in the United Nations endorsed International Heliophysical Year IHY and International Space Weather Initiative ISWI programs has changed the landscape of space weather related research in the region. This poster presents some of the benefits accrued to African continents and her researchers in the course of the twin programs. Several instruments capable of monitoring space weather were deployed to a number of countries. More than one-third of African 54 nations actively participated in the twin programs. Today, space weather data streams from multiple equipment installed on African soil during the IHY/ISWI programs. This list includes magnetometers (MAGDAS, AMBER), GNSS receivers (SCINDA and others), Fabry Perot Interferometers, all-sky optical imagers, digisonde, SID, CALLISTO, among others. The poster shall among other things showcase the statistics of regional development during the years 2007 – 2017 in terms of capacity building seminars/workshops/conferences held in Africa, graduate degrees produced in Africa, chronology of increase in research publications and development of skills in space weather research in the region.

# Norway

## Space Weather Effects on Critical Operations and Activity in the High North

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Norwegian Space Centre

There is a growing interest for the understanding of space weather in Norway, and preparation for possible impacts related to more extreme space weather in the years to come are ongoing. The need for a reliable space weather forecast of high quality is necessary and highly wanted among Norwegian users. The most relevant user groups in Norway are transport, navigation, oil and gas industry and the power industry.

The expected increasing activity level in the Arctic will require a good understanding of space weather effects on critical system to ensure safe operations in these areas. Radio communication can be degraded or disrupted which can be crucial during rescue operations. This can also lead to diversion of polar flights. Space weather will also affect navigation systems like GPS and Galileo. Furthermore, disturbances in the Earth's magnetic field can disrupt oil-drilling operations.

Norway is uniquely located for space weather studies and have access to excellent installations for monitoring space weather. We have good coverage of geomagnetism data, and real time monitoring of the ionosphere. We have also developed space weather instruments for small satellites. The Norwegian satellite NORSAT-1 will be launched this summer and will carry a space weather instruments and a solar irradiance detector.

Northern lights tourism has become a big industry in Norway and improved space weather forecasting will be of great help in planning tours and activities.

Norway is contributing to the ESAs Space Situational Awareness program where space weather is one of the three elements. Tromsø Geophysical Observatory and The Norwegian Mapping Authority have important roles in ESAs space weather program.

# Norway

## Kristian Birkeland - The Almost Forgotten Scientist and Father of the Sun-Earth Connection

P. BREKKE
Norwegian Space Centre

In 2017, physicist Kristian Birkeland's legacy still stands strong - 150 years after his birth and 100 years after his death. He is regarded as the leading scientist and inventor in Norwegian history. Kristian Birkeland was the first scientist to explain that the sun was the source of the northern lights and founded much of today's modern space research. He was also the man behind the fantastic invention that enabled the making of artificial fertiliser by harvesting nitrogen from the air. The discovery was the basis for the foundation of Hydro and turned out to be extremely important for the food production around the world at that time. Hydro (today called Yara) is still the world's largest fertiliser company operating production in more than 50 countries. Birkeland's theories about the northern lights and electrical currents in the atmosphere met great opposition among internationally renowned scholars such as Lord Kelvin and Sydney Chapman. It took over 60 years before one could confirm Birkeland's theories when satellites became available and observed solar wind particles and detected electrical currents which we today call Birkeland currents. However, in 1994, Birkeland was deservedly honoured. His portrait was chosen for the front side of the Norwegian 200-kroner banknote and he now also features on the tail of a Norwegian Airlines plane. This lecture is a tribute to one of the greatest scientists in space research.

# Norway

## Norwegian Contributions to the ISWI Program

K.M. LAUNDAL and N. OSTGAARD
Birkeland Centre for Space Science, University in Bergen

In this talk we will give an overview of main Norwegian space research activities and then focus on one important research result from the Birkeland Centre for Space Science. As part of an effort to understand the asymmetric geospace we have developed a new empirical model of global ionospheric currents and magnetic perturbations. This model is based on magnetic field measurements at low Earth orbit. The model is the first of its kind to be truly global: It includes low-latitude solar quiet currents as well as the two polar current systems. The polar current systems are treated independently, made possible by meticulously taking into account asymmetries in Earth's main magnetic field. The model is also the first of its kind to include the effect of both the field-aligned and horizontal solenoidal currents. That property enables us to predict magnetic field perturbations on ground. It may therefore be useful in space weather applications, such as directional drilling, and potentially predictions of geomagnetic induced currents. We demonstrate the model's ability to predict the AL index, and address a main challenge for all models that aim to characterize global geospace parameters: A lack of routinely available measurements of nightside reconnection rates.

# Pakistan

## Particle-In-Cell Modeling of CubeSat and Ionospheric Plasma Interaction

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We numerically investigate the interaction between the nano-satellite 'CubeSat' and surrounding plasma. The Dynamic Ionosphere CubeSat Experiment (DICE) is an exploratory space weather mission which aims to understand the impact of the solar flares on the Earth's environment. The DICE mission consists of the two identical 1.5 U CubeSats. Each CubeSat's payload carry multiple instruments including, a double probe electric field instrument, plasma and magnetic probes. The measurements made by these instruments provide deep insight into the way solar flare particles interact with the Earth's upper atmosphere. Therefore, the purpose of the present study is to elucidate the particular issues related to the nanosatellite-plasma interaction which affect the on-board instruments.

The goal is achieved by simulating the interaction between CubeSat and ionospheric plasma with the three dimensional particle-in-cell code, PTetra. It is an electrostatic code which accounts for the presence of a static background magnetic field. The model also accounts for a number of physical processes which play important roles in the spacecraft charging. These include, the photo-emission and secondary electron emission. The study focuses on particular physical effects including, the presence of magnetic field, ionic composition and the photo-emission on the spacecraft charging and on the floating potential and plasma density spatial profiles in the vicinity of the CubeSat.

In the first part of this study, we investigate the effects of different physical conditions on the current collection of the spherical Langmuir probes mounted on the CubeSat. The computed current characteristics are then used to estimate the plasma parameters; i.e., the floating potential, the plasma density and temperature. In the second part of our study, PTetra is used to model a double probe electric field (EFP) instrument. The sheath potential profiles obtained from PTetra simulations can be used to estimate the values of the electric field under specific conditions. These potential profiles are also used to compute the particle velocity distribution functions near the EFP instrument.

The simulation results illustrate the sensitivity of the current characteristics, electric field and the particle velocity distribution functions to certain physical effects. This study will be helpful to understand the detailed interaction between the nanosatellites and the mesothermal plasma environment.

# Peru

## Space Weather Program in Peru: Preliminary Results

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In this work we present results from 2008 to 2015 obtained by two stations, SAVNET (South American VLF Network in Peru) and CALLISTO-BPL (Compound Astronomical Low cost, Low frequency, Instrument for Spectroscopy and Transportable Observatory in Punta Lobos Base-Peru). These VLF and radio receivers are part of a Space Weather Program which we are developing in CONIDA (National Commission for Aerospace Research and Development), with the main objective to study the variability of the solar activity. SAVNET purpose is to monitor ionospheric parameters during quiet and active solar phenomena, SAVNET is a network composed of several VLF receivers located in South America. On the other hand, CALLISTO uses a radio telescope to monitoring and observing radio solar emissions from the solar corona in the frequency band of 45 to 870 MHz. The stations we use to collect the data and analyze it, are located in Punta Lobos Scientific Base (Peru). We will also report about the CRIRP (China Research Institute of Radiowave Propagation) cooperation for the Ionospheric modeling and the APOSOS/APSCO (Asia-Pacific Ground-Based Optical Satellite Observation System/Asia Pacific Space Cooperation Organization) project for monitoring DEBRIS phenomena, satellite orbits and asteroids warning alerts from the COE (Space Observation Center) located in Huancayo city, Peru.

# Philippines

## Space Weather Activities in the Philippines (2007-2017)

Quirino SUGON JR[1,3], Christine CHAN[1], Clint BENNETT[1,3], Alex ALGABA[2], Randell TEODORO[1], Felix MUGA II[3], James Bernard B. SIMPAS[1,3], Daniel J. MCNAMARA[4], Sergio SU[1], Roland OTADOY5, Grace ROLUSTA6, Akiko FUJIMOTO7, Teiji UOZUMI7, and Akimasa YOSHIKAWA7

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Ten years after the celebration of the International Heliophysical Year (IHY), the Philippines has progressed in space weather research and instrumentation development. Manila Observatory, designated in 2011 as the Subcenter of ICSWSE (International Center for Space Weather Science and Education) of Kyushu University, now manages 6 MAGDAS stations, 1 FMCW, 2 SCINDA receivers, and 2 SAMBA magnetometers. University of San Carlos has one SEALION GNSS receiver. The Philippine National Mapping and Resource Information Authority (NAMRIA) continues to make magnetic maps for the Philippines, while expanding its GNSS network to 30 GPS stations. And in 2016, the Philippines launched Diwata-1, its first microsatellite, from the International Space Station. All these new instrumentation arrays are important contributions in studying space weather and its impact on the magnetosphere, ionosphere, troposphere, and lithosphere, not only in the Philippines, but also in the rest of the world.

# Poland

## Geant4 Simulations of STIX Instrument Response to the Solar Particle Events and Cosmic Rays

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Spectrometer/Telescope for Imaging X-rays (STIX) is a part of Solar Orbiter (SO) science payload. SO is scheduled to be launched in 2018 into orbit with the perihelion only 0.3 a.u. distant from the Sun. STIX is a Fourier imager equipped with pairs of grids that comprise the hard X-ray tomograph. Similar imager types were already used in the past (eq. RHESSI, Yohkoh/HXT), but STIX will incorporate Moiré modulation and a new type of pixelated detectors. Therefore, accurate modeling of the registered background is curtail to obtain proper image reconstruction. We developed a method of modeling the instrument response using the Geant4 simulations of energetic particles interactions with the instrument body and the CdTe detector crystals. Taking into account known instrument design and detector effects we modeled the instrument response.

# Poland

## Space Weather Activities in Poland

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Poland has a variety of scientists and experts in diverse institutions dealing with the topic space weather. It is an important issue of global matter, and needs coordinated efforts on a national level. The Space Research Centre Polish Academy of Sciences together with Astronomical Institute of Wrocław University coordinates in Poland different institutions researching and forecasting of Space Weather. The Białków Observatory is specialized on ground based observation of the solar activity and its impact on the interplanetary space. The Space Research Centre in Wrocław is involved in number of satellite missions dedicated to Space Weather.

# Rwanda

## Characterization of CMEs from Associated Solar Radio Bursts Detected with CALLISTO Spectrometers

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Solar radio bursts (SRBs) are electromagnetic radiations originating from solar active regions by plasma emissions. Type II SRBs are of particular interest for space weather as they often occur in association with geo-effective CMEs. This paper presents the main results outcomes of a research study conducted to characterize solar CMEs using physical parameters of associated SRBs. This study analyzed type II SRBs events that occurred between January 2012 and December 2015. Bursts data considered are dynamic spectra corresponding to 32 bursts events that were detectable by a ground network of CALLISTO solar spectrometers.

Part of this research consisted in deriving the type II bursts drift rate (df/dt) from Callisto-observed dynamic spectra and further, which were further used in a model to estimate the speed of associated CMEs. For the period of study considered, this analysis could only clearly identify a few (13%) Callisto dynamic spectra corresponding to 32 type II bursts events as compared to the total number of events provided by the NOAA list. For all events analyzed, the average type II burst rate calculated was found to be -0.13 +/- 0.09 / MHz. The burst drift rate was further used to estimate the speed of related CME. Obtained values of CME speed were compared with CME speed as indicated on the SOHO list of CMEs and the comparison shows that the model used perform well with a correlation coefficient of 98%. The results from this research work show consistent with similar investigations conducted using SRBs data observed from space using Wind / WAVES data. Investigating the geo-effectiveness of CMEs from associated SRBs signatures detected from ground is an important contribution towards improved space weather modeling and prediction.

# Slovakia

## Space Weather Research in Slovakia and Related ISWI Activities in The Last Decade

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Space weather research in Slovakia is performed at 4 leading institutions: (1) Astronomical Institute, Slovak Academy of Sciences, Tatranská Lomnica (Department of Solar Physics) - coronal station at Lomnický Štít Observatory, systematic spectropolarimetric observations of the solar corona, fine structure of the solar chromosphere, investigation of solar activity cycles, differential rotation of the solar corona, observation of the corona during total solar eclipses, co-organiser of the 2011 ISWI Summer School in Space Science; (2) Institute of Experimental Physics, Košice (Department of Space Research) - neutron monitor and muon detector system SEVAN at Lomnický Štít Observatory for cosmic radiation research, participation in various space instrument programs; (3) Earth Science Institute, Slovak Academy of Sciences, Bratislava (Division of Geophysics) - Study of the Sun – Earth relations, geomagnetic response to solar activity: modeling of CME and CIR driven geomagnetic storms by means of artificial neural networks; (4) Slovak Central Observatory Hurbanovo (Scientific and Observational Department) - observation of sunspots, solar flares and prominences, investigation of solar activity cycles, differential rotation of the solar atmosphere, space weather research, SID monitoring, CALLISTO spectrometer, observation of the corona during total solar eclipses, co-organiser of the 2011 ISWI Summer School in Space Science. Next to these institutes, Rimavská Sobota Astronomical Observatory has the following observational program - photographic observations of the solar photosphere (the sunspot details – white light and CaIIK filter) and prominences. In addition, basic daily patrol observations of sunspots are currently carried out in a network of 14 observatories and individual observers. The national centre for sunspot observations is at the Astronomical Observatory and Planetarium Prešov. This contribution presents the main research fields and related ISWI projects and activities performed in Slovakia in the last decade. Details about the ISWI activities in Slovakia can be found at http://stara.suh.sk/id/iswi/iswi_SK-en.htm.

# Slovakia

## Solar differential rotation profile estimation using coronal bright points data derived from the SDO/AIA images

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Coronal bright points (CBPs) are small and bright structures observed in the extreme ultraviolet (EUV) part of the solar spectrum.While sunspots are known to be found concentrated in two bands, migrating from mid-latitudes to the equator, the CBPs, on the other hand, can be found all over the Sun, even appearing at the poles and in coronal holes. This unique feature allows researchers, after detecting and tracking them over a sequence of images, to understand the Sun's rotational speed, whichis known to be differential. The AIA instrument,onboard the SDO satellite,provides high-resolution and high-cadence solar images since 2010. This hugeamount of available high-resolution images require efficient automatic software tools to detect and/or track the CBPs. In the last decades, several research teams have been developingsuch tools,for obtaining more precise estimationsof the solar rotation profile (e.g. Zharkova 2005, Martens 2012, Sudar et al. 2016, among others).

The CTS/UNINOVA-CA3 (Caparica, Portugal) research team applied a segmentation algorithm, used in medical retinalimages (Mora 2010),called Gradient Path Labeling (GPL), to detect and track CBPs using SDO/AIA images. The obtained coordinates of the automatic process that uses GPL segmentation algorithm are then converted into heliographic coordinates. Our test results show that this algorithm is a promising tool that can help to refine Sun's rotational profile. The CBPs have a tendency to change shape and sizealong time, yielding great difficulty totrack them. Therefore, asuitable solution might beusing decision treesto supportinferring recognizingCBPs, based ona given set of parameters.

This research workis being performed in the frame of a mobility project Slovakia-Portugal, SRDA (APVV) Bratislava (SK-PT-2015-0004), FCT Lisbon (COOP_PT/ESLOV/441).

# Spain

## Space Weather Activities of Spain

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Large efforts have been done in the field of Space Weather in Spain in the last years, including the awareness about the economic and societal effects of extreme events and the development of a National Space Weather Service, SeNMEs. Important advances have also been done in scientific research. Educational activities with university students involve ISWI instruments and outreach activities have reached from general public to children. This presentation summarizes all these activities.

# Sri Lanka

## Type II Solar Radio Bursts Detected by CALLISTO at ACCIMT

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As a result of IHY/UNBSSI and ISWI instrument deployment program a CALLISTO solar radio spectrometer was established at the Arthur C Clarke Institute for Modern Technologies (ACCIMT) in Sri Lanka. The system consists of CALLISTO spectrometer which was donated by Institute of Astronomy of ETH Zurich in Switzerland and a locally designed and constructed logarithmic periodic antenna. The system is connected to the e-CALLISTO global network and observes solar radio bursts in 24 hours.

The system has detected both type II and type III solar radio bursts in the frequency range of 110 MHz to 460 MHz. We report the first data analysis of type II solar radio burst detected on 4th November 2015 from the system along with the same event recorded on CALLISTO instruments at three other stations, ALMATY, GAURI and OOTY. The all four spectra were image processed to eliminate the artificial noise and trimmed. Drift rates were calculated from the frequencies of the maximum intensities along the bursts. Using the drift rates and with the assumption of Newkirk's coronal density model, full range of radial velocities of the radio source were determined for all the type II solar radio burst observed at four stations.

# Switzerland

## The e-CALLISTO Network

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A low cost solar radio spectrometer, CALLISTO and the network e-Callisto, are presented. CALLISTO is a frequency-agile receiver based on cheap, commercially available consumer electronics. Its major characteristic is the low price for hardware and software, and the short assembly time, two or more orders of magnitude below existing spectrometers. The instrument is sensitive at the physical limit and extremely stable. The native frequency range is 45 MHz up to 870 MHz, and the width of individual channels is 300 kHz. A total of up to 800 measurements can be made per second. The output of the spectrometer is stored in FIT-files, one per 15 minutes of observation. All files from all observatory sites are archived at a central data-server a FHNW in Switzerland and everyone has full access to all data back to 2002. The spectrometer is well suited for solar low-frequency radio observations pertinent for space weather research, radio monitoring and outreach. More than 120 instruments of the type were constructed until now and put into operation at 67 sites, distributed over the whole planet. Several copies of CALLISTO were put into operation in view of IHY and ISWI. A few representative antenna setups and recent observations, made at different locations are presented.

Detailed information and data access here: http://e-callisto.org/

# Tunisia

## AWESOME and SuperSID Space Weather Monitoring Instruments: Outreach and Research Activities Developed in Tunisia

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Tunisia is a member of the worldwide network of the United Nations: International Space Weather Initiative (ISWI) since 2007. AWESOME and SuperSID are two classes of receivers installed in Tunisia since 2005 and adjusted in the ELF/VLF range to carry out quantitative investigations of ionospheric perturbations. In terms of outreach program, since 2012, we have created a local SuperSID network composed of seven groups made up of students and teachers that we helped to set up their systems. We show in this presentation how this local network is organized around a simple and cheap 'SID and superSID' receivers and what is done in order to simplify the understanding on how to monitor solar activity, for instance day/night variation or solar flares, through its impact on VLF waves propagating in the Earth-Ionosphere waveguide. On the other hand, and in terms of research activities carried out in the LSAMA Laboratory at the Faculty of Science of Tunis, we present some results based on the analyzes of signals recorded by a more sophisticated receiver 'AWESOME'. These observations are broadband spectrograph in the ELF/VLF frequency range, showing tweeks generated during thunderstorm activity and also results based on narrowband VLF signals describing the effect of the total solar eclipse (March, 20, 2015) on the ionospheric D-region.

# Ukraine

## Operational Space Weather Services in Ukraine

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Ukraine has profound expertise and capabilities in the field of space weather. A lot of space weather related research is conducted both in the mainland territory and at the Academician Vernadsky base in the Antarctic peninsula. The excellence of both basic and applied research of Ukrainian scientists in the field of space weather is exhibited in many successful international projects they were involved in. Ukrainian space weather community aims to integrate deeper into the international space weather community and to transit from research to operations. Ukraine is represented in most major international space weather working groups and pursues collaboration with other nations, most importantly with the U.S. and the E.U.

Work is underway to create a fully functional space weather warning center in Ukraine on the basis of the Main Center of Special Monitoring – a division of the National Space Facilities Control and Test Center. This center is envisaged to combine best practices of the NOAA/NWS Space Weather Prediction Center, Boulder CO, U.S.A. and the Solar Influences Data Center in Brussels, Belgium. A preliminary agreement was reached with ISES that this center will be nominated a formal status upon achievement of operational readiness.

# United Kingdom

## Report on the "L5 in Tandem with L1: Future Space-Weather Missions Workshop" – Working Towards a L5 Operational SWx Mission

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As an era of dedicated operational space-weather (SWx) monitoring missions comes nearer, the "L5 in Tandem with L1: Future Space Weather Missions Workshop" was a key step to fortifying notions on how two such missions might work in tandem. The workshop also sketched out the major steps already taken, and currently underway, towards the definition of a truly operational L5 SWx Mission. The organisation of the workshop was led by the Science & Technology Facilities Council's Space Department (STFC RAL Space) along with the Met Office – both in the UK, and the National Oceanic and Atmospheric Administration's National Weather Service Space Weather Prediction Center (NOAA NWS SWPC) – in the USA. Additional Committee Members also came from STFC RAL Space, Predictive Science, Inc. (USA), and the European Space Agency's Space Situational Awareness (ESA SSA) Programme at the European Space Operations Centre (ESOC – Germany). The workshop was hosted by the UK's Government Office for Science (GO Science) and co-sponsored by STFC RAL Space and MOSWOC while being held at the Department of Business, Education, and Innovation Strategy (BEIS) Conference Centre in central London, UK, 06-09 March 2017 (https://www.ukssdc.ac.uk/meetings /L5InTandemWithL1/). The workshop explored how we can move towards a future operational system that exploits the potential of solar and heliospheric observations from away from the Sun-Earth line in a more-cohesive, international effort, collectively with those more-traditionally undertaken from orbit around L1 near the Sun-Earth line. Several strategic areas were presented and discussed, from constructing the case for a L5 operational mission, through several socio-economic studies, to full-blown pre-phase-A mission studies, and everything in between (including ground-based support, ground-segment requirements, and modelling). Here we will provide a high-level synopsis of the workshop, with some brief conclusions incorporating what a L5 mission would look like, the main observation/measurement requirements, as well as summarising how these missions might work together in tandem in the near future to continue the much-needed enhancement of the provision of SWx forecast services worldwide.

# United Kingdom

## The Worldwide Interplanetary Scintillation (IPS) Stations (WIPSS) Network as a Potential Future ISWI Instrument

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Interplanetary Scintillation (IPS) allows for the determination of velocity and a proxy for plasma density to be made throughout the corona and inner heliosphere. Where sufficient observations are undertaken, the results can be used as input to the University of California, San Diego (UCSD) three-dimensional (3-D) time-dependent tomography suite to allow for the full 3-D reconstruction of both velocity and density throughout the inner heliosphere. In addition, source-surface magnetic fields can also be propagated out to the Earth (and elsewhere in the inner heliosphere) as well as the incorporation of in-situ data into the 3-D reconstructions. By combining IPS results from multiple observing locations around the globe, we can increase both the temporal and spatial coverage across the whole of the inner heliosphere. IPS also provides an excellent opportunity to enhance collaborations between developed and developing countries thanks to the locations of many of the IPS-capable systems used. The WIPSS Network aims to bring together the worldwide real-time-capable IPS observatories, as well as those used on a more-campaign-only basis, with well-developed and tested analyses techniques being unified across the majority of the IPS-capable systems. A WIPSS website is currently under development. During October 2016, a distinctive opportunity arose whereby the European-based LOw Frequency ARray (LOFAR) radio telescope was used to make nearly four weeks of continuous observations of IPS as a heliospheric space-weather pilot campaign. This was expanded into a global effort to include observations of IPS from the Murchison Widefield Array (MWA) in Western Australia, as well as many more standard analyses from various IPS-dedicated WIPSS Network systems. IPS data from LOFAR, ISEE, the MEXican Array Radio Telescope (MEXART), and where possible other WIPSS Network systems (such as LPI-BSA and Ooty), will be used in this study where we present some initial findings for these data sets and their combination. We also undertake an initial demonstration analysis of some of these WIPSS data incorporated into the UCSD

tomography, and highlight the prospects of the WIPSS Network going forward as a future potential ISWI Instrument.

# United States

## Girls InSpace Project: A New Space Physics Outreach Initiative

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We present here the concept and state-of-art of the new space physics youth education and outreach initiative called “Girls InSpace project”. The project goal is to spread quality scientific information to underrepresented groups, motivate girls in STEM and promote gender equality in the Space Physics area. Initially, the “Girls InSpace project” will be available in two languages (Portuguese and English) aiming to reach out to the youth of Brazil, United States, Nigeria, South Africa, Ethiopia and Angola. Eventually, the material will be translated to French, focusing on French-speaking countries in Africa.

The project spans a collection of four books about a group of young girls and their adventures (always related to the sky and simultaneously introducing earth and space science concepts). Ancillary content such as a webpage, mobile applications and lesson plans are also in development. The book topics and titles are as follows:

- 1st book: about Astronomy (title: A luneta e Isabelle, or "Isabelle and the telescope");
- 2nd book: about Space Weather (title: Hélio: o primeiro amor de Cecília, or "Helio: Cecilia's first love");
- 3rd book: about Cosmic Rays (title: O bisavô cósmico de Lélis e Lola, or "Lelis and Lola cosmic great-grandpa");
- 4th book: about Auroras (title: A não-princesa Aurora, of “The non-princess Aurora”).

The books were written by a Latin space physicist PhD woman, illustrated by a Brazilian young artist and commented by senior female scientists, creating positive role models for the next generation of girls in STEM. The story lines were drawn around the selected topics of astronomy and space physics, introducing scientific information to the target readers (girls from 8-13 years old) and enhancing their curiosity and critical thinking. The books instill the readers to explore the available extra web-content (with images, videos, interviews with scientists and deeper scientific information) and game apps (with Virtual Reality components

and real space images). Moreover, for teachers from grades 8-12, a collection of lesson plans will be made available, aiming to facilitate scientific content discussed in the books and inside classroom environments.

Gender bias in STEM reported earlier this year in Nature and based on a study of the American Geophysical Union's member database showed a competitive disadvantage for women in the Earth and Space Sciences. The AGU has since challenged the scientific community to act and support gender balance initiatives as crucial path to progress. This project aligns well with AGU's mission and similar thinking organizations, and aims to educate and promote development of young girls in underrepresented communities.

# United States

## The National Space Weather Program: Two Decades of Interagency Partnership and Accomplishments

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This paper describes the development of the United States National Space Weather Program (NSWP) from early interests in space environmental phenomena and their impact through the culmination of the program in 2015. Over its 21 year run, the NSWP facilitated substantial improvements in the capabilities of Federal Space Weather services and fostered broad and enduring partnerships with industry and the academic community within the U.S. and internationally. Under the management of the Office of the Federal Coordinator for Meteorological Services and Supporting Research a coalition of 10 federal agencies worked together from 1994 to 2015 to advance the national space weather enterprise. The paper describes key events and accomplishments of the NSWP interagency partnership while recognizing the great achievements made by the individual agencies. In order to provide context, the paper also discusses several important events outside the NSWP purview. Some of these external events influenced the course of the NSWP, while others were encouraged by the NSWP partnership. Following the establishment of the Space Weather Operations, Research, and Mitigation Task Force of the National Science and Technology Council in the White House and the deactivation of the NSWP Council, the agencies now play a supporting role in the national effort as the federal engagement in the National Space Weather Partnership graduates to a higher level.

# United States

## On the Energetics of Large Geomagnetic Storms

William T. BURKE
Boston College Institute for Scientific Research

The great magnetic storm of 13 March 1989 was a watershed event for raising awareness of space weather impacts on Earth and its environment. The loss of about 3400 tracked objects from the US Space Surveillance Catalog ranks among the storm's more severe impacts. The causal interplanetary event that that drove the storm was not seen coming. For now, satellites in halo orbits around the L1, L4 and L5 points have reduced the element of surprise. However, exact predictions of stormtime redistributions of thermospheric mass and consequent satellite drag effects remain work in progress.

This presentation describes recent developments of empirically based models for quantifying the energy extracted from the solar wind and deposited into the stormtime thermosphere. Two independent lines of attack are described. First, we use input data that include solar wind dynamic pressure and interplanetary magnetic field enhancements as observed by satellites near L1, for comparison with orbit-averaged accelerometer measurements from polar-orbiting satellites such as GRACE or CHAMP. This comparison shows that the stormtime thermosphere behaves like large circuit whose total thermal energy is largely driven by the inter-planetary electric field and dissipated via radiative cooling. The second method uses Poynting fluxes into the high-latitude ionosphere inferred from measurements by magnetic and electric field sensors on polar-orbiting spacecraft. The presentation will include a direct comparison prediction by the two methods using satellite data acquired during the magnetic superstorm of 10 November 2004.

# United States

## The AWESOME Program: VLF/LF Remote Sensing of the Ionosphere and Magnetosphere: From IHY, to ISWI and Beyond

Morris COHEN
Georgia Tech, Atlanta, Georgia

We review VLF/LF radio remote sensing (0.3-300 kHz) of lightning activity, the D-region ionosphere (60-90 km altitude), and the magnetosphere. VLF/LF waves are guided to global distances in the Earth-ionosphere waveguide, and the small amount of energy that does escape this waveguide interacts with energetic radiation belt electrons and impacts space weather. Sources of VLF/LF waves are predominantly lightning-generated radio atmospherics, and a small number of VLF/LF radio stations. There are also naturally-generated emissions due to the magnetosphere, including chorus, hiss, and whistlers. VLF/LF waves are also useful for global ionospheric remote sensing since they are highly sensitive to D-region electron density changes, and to global lightning geolocation with a network of receivers.

The AWESOME receiver (in its current form) detects the two horizontal components of the magnetic field, and provides high sensitivity (0.03 fT/rt-Hz) broadband detection of the VLF/LF range (0.5-470 kHz), with 15-20 ns time resolution, 16 bits of dynamic range, and direction finding ability. The original AWESOME was built at Stanford University and became part of the IHY/ISWI program. This activity included deployment of ~25 receivers mainly in developing countries, establishment of a full set of tutorials and a series of international workshops. Now, the AWESOME receiver has been migrated to Georgia Tech, redesigned and revamped, and a new global network of VLF/LF receivers is being established. Previously collected VLF data is being opened to the public for internet access, and new data is supplementing the original collection. We are preparing for the 2017 solar eclipse across the USA, and planning for new educational outreach activities to support ISWI.

In this presentation, we will review the scientific applications for VLF/LF remote sensing, the history of the AWESOME program under IHY/ISWI, the current receiver and program status, and future plans for both science and educational outreach.

# United States

## Space Weather Resources Available Through MIT Haystack's Madrigal Database

Anthea J. COSTER, William E. RIDEOUT, and Philip J. ERICKSON
MIT Haystack Observatory

The Madrigal database is an open source, web-based distributed system created and maintained at MIT Haystack Observatory under support from NSF's Geospace Facilities program. Madrigal provides storage, access, and visualization needs for both historic and emerging geospace science data. The majority of data within Madrigal is of high impact to the space weather community, and the focus here is to highlight Madrigal's capabilities for data analysis and retrieval of space weather events. A summary of useful space weather data sets within Madrigal will be provided and different data retrieval techniques will be discussed. Specific examples of useful space weather data sets include: measurements of electron density, and electron and ion temperature from incoherent scatter; measurements of total electron content (TEC) from the global network of GNSS receivers; and the recently added measurements from the Defense Meteorological Satellite System (DMSP). Madrigal also provides access to summary plots for a large segment of its data. Pre-defined survey plots exist for DMSP flights, ISR products, and GPS TEC Global maps. Additionally, in some instances, Madrigal allows direct access to plotting tools that can provide overlays of different data sets. For example, SuperDARN southern hemisphere radar observations and convection maps can be overlaid onto background GPS TEC data. To illustrate these, and other Madrigal tools, a space weather case study of a single event will be shown illustrating the majority of the Madrigal tools.

# United States

## A Collaborative Approach at Building Capacity in Space Weather at the Undergraduate Student Level

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[2] NASA Goddard Spaceflight Center & The Catholic Univ. of America

As a discipline, space science is mostly taught at the graduate level, and at relatively few colleges and universities in the United States. Thus, undergraduate students are not exposed to space science and related-fields as potential careers. For the past two years, the City University of New York (CUNY) in partnership with the NASA Goddard Space Flight Center have been successful at engaging undergraduate students in applied research and educational activities in solar, geospace, and atmospheric physics, under the umbrella discipline of space weather. Through use of space- and ground-based data, students are engaged in applied research that contribute to the fundamental understanding of space weather's impact on Earth's space environment, life and society. Engaging undergraduate students in space weather research and education activities has the following broader impacts: 1) long term integration of space weather into the undergraduate curricula, thus exposing them early to research in their academic careers; 2) increasing students' interests in and motivation to study STEM, as well as preparing them for choosing a career path in space science and related fields; 3) training a new generation of students that can look at a problem from an interdisciplinary approach—physics, engineering and policy; and 4) collaborating with both research scientists and student peers globally to contribute toward improving the understanding, monitoring, prediction, and mitigation of space weather in an era of increased technological use and dependence, and increased human space exploration. To fulfil these goals, CUNY partnered with NASA to develop a year-long space weather curriculum which consists of two parts: 1) during the academic year, students are enrolled in two course-based introductory research (CURE) courses where they are introduced to space weather research; and 2) summer internship program where students are placed at NASA and partner institutions to engage in research for 10-weeks. This talk will describe these approaches, as well as present best strategies that are used to both attract and retain students in space science and related-fields.

# United States

## Beginnings of the International Heliophysical Year and the International Space Weather Initiative

Joseph DAVILA, Barbara THOMPSON, and Nat GOPALSWAMY

The International Heliophysical Year (IHY) 2007-8 was an international program of scientific collaboration involving thousands of scientists from nearly 90 nations. The IHY began as an idea in 1999 as a commemoration of the International Geophysical Year 1957 to mark its fiftieth anniversary. Over the next few years a series of community workshops were organized, and the IHY began to take shape. In those workshops, the concept of Universal Processes was introduced, and the concept of "heliophysics," coined to imply a parallelism with geophysics, began to take shape. Four main thrusts of the IHY activity were identified: scientific research, observatory development, history, and outreach. With support from the United Nations Office for Outer Space Affairs a series of yearly international workshops were begun to plan the IHY activities. One of the major accomplishments of the IHY was the establishment of international arrays of small instruments, placed around the globe in advantageous locations. At the conclusion of the IHY, the ISWI was initiated as a 2-year continuation of the IHY activities. Eventually the scientific community found the ISWI to be useful for the international coordination of space weather related science and requested that the ISWI to be a permanent agenda item. Accordingly, ISWI is now part of the permanent space weather agenda of UN Committee for the Peaceful Uses of Outer Space (COPUOS).

# The Boston College and Abdus Salam International Centre for Theoretical Research Collaboration for Outreach and Capacity Building

Patricia DOHERTY[1], Sandro RADICELLA[2]

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[2] Abdus Salam International Centre for Theoretical Physics, Trieste, Italy

This presentation will describe the purpose and success of a long term collaboration between Boston College (BC) and the Abdus Salam International Centre for Theoretical Physics (ICTP) that addresses outreach and capacity building for space weather research in the developing world.

The collaboration between BC and ICTP was initiated in 2009 in a formal Memorandum of Agreement (MOA) to host a series of schools and workshops with the prime purpose of training students, young scientists, and professors on the benefits of using Global Navigation Satellite Systems (GNSS) for applications with societal benefits and as a tool for scientific investigations of the space environment. Initially, the collaboration was focused on the African region in response to the Africa Science and Technology Plan of Action that clearly presented Africa's commitment to develop and use science and technology for socio-economic transformation and full integration into the world economy. The BC/ICTP collaboration supported this plan by providing training at the university level in GNSS science and technology that has led to increased awareness, capability and capacity building in the region for the use and benefits of GNSS.

In this presentation, we will describe the details of the workshop series and the success that is apparent in the number of papers published in peer reviewed journals and in the number of young scientists in Africa now teaching and performing space science and space weather research in the developing world.

The workshops have primarily been co-sponsored by ICTP, Boston College, the International Committee on GNSS and the Institute of Navigation. There have been 9 workshops to date held on a near annual schedule. Although our original MOA was to focus on the African region, our more recent workshops include participants from around the world. As we plan our 10th workshop in 2018, it is time to reflect on the purpose and success of the workshop and to assess our future plans.

# United States

## Evidence of Madden-Julian Oscillation Effects in the Mesosphere and Lower Thermosphere from GOCE and MERRA/TIME-GCM

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[2] University of Colorado, Boulder, CO

As space-borne technology assumes a greater role in fulfilling the daily needs of society, the understanding of the environment in which they operate becomes more important. In the last decade evidence has demonstrated that terrestrial weather significantly impacts the ionosphere-thermosphere (IT). Periodic absorption of solar radiation in local time and longitude by tropospheric water vapor and stratospheric ozone as well as latent heat release in clouds generate a spatially- and temporally evolving spectrum of global-scale atmospheric waves. A subset of these waves propagates vertically, evolving with height due to wave-mean flow, wave-wave, and wave-plasma interactions, and driving electric fields of tidal origin in the dynamo region. One of the largest waves that is known to greatly affect the IT is the diurnal eastward propagating wave with zonal wavenumber 3 (DE3). In this work, using neutral density and cross-wind measurements from the Gravity field and steady-state Ocean Circulation Explorer (GOCE) satellite, we present evidence of a new and persistent global-scale quasi-90-day oscillation in the thermosphere connected to DE3 originating in the tropical troposphere. We investigate the origin and nature of this oscillation and its link to the Madden-Julian oscillation (MJO) taking advantage of a high-resolution numerical simulation from the National Center for Atmospheric Research (NCAR) Thermosphere Ionosphere Mesosphere Electrodynamics General Circulation Model (TIME-GCM) with the lower boundary based on Modern Era Retrospective-Analysis for Research and Applications (MERRA) re-analysis data.

# United States

## Early Results and Ionospheric Observations from LITES on the ISS

Susanna FINN[1], Supriya CHAKRABARTI[1], Andrew STEPHAN[2]
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The Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet Spectrograph (LITES) is an imaging spectrograph designed to measure extreme- and far-ultraviolet airglow emissions that originate from photochemicial processes in the ionosphere and thermosphere. LITES was launched and installed on the International Space Station (ISS) in late February 2017 and has begun operations along with the highly complementary GPS Radio Occultation and Ultraviolet Photometery – Colocated (GROUP-C) experiment. LITES is limb-viewing (~150 – 350 km tangent altitude) and measures airglow emissions from 60 – 140 nm with 0.25° angular and 0.4 nm spectral resolutions. During the daytime, LITES observes the bright O+ 83.4 nm emission from which the ionospheric profile can be inferred. At night, LITES observes recombination emissions at 91.1 and 135.6 nm which provide a direct measure of the electron content along the line of sight. We will present an overview of the LITES experiment and some early results from the first few months of operations, the challenges and opportunities presented by making ionospheric measurements from the ISS, and the advantages in calibration and validation that are possible through a combination of LITES measurements, GROUP-C measurements, and ground-based optical and radar systems.

# United States

## Los Alamos National Laboratory: Space Weather Research and Data

Reinhard FRIEDEL, Greg CUNNINGHAM, Geoff REEVES, Vania JORDANOVA, Steve MORLEY, Mike HENDERSON
Space Science and Applications Group (ISR-1), Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) has been one of the pioneers of the early space age with over 50 years of flying missions in space, both in support of the Nation's Space Nuclear Detonation Detection (SNDD) Program and in support of NASA for basic research. The space environment energetic particle and plasma detectors fielded by LANL at geosynchronous orbit since the 1970s and the energetic particle detectors on the GPS constellations since the 19880s have yielded an unprecedented space weather dataset which have now been made public in the wake of the October 2016 Executive order. We will here present an overview of these datasets and their utility for Space Weather.

Space Weather Research efforts at LANL have made use of these and other NASA mission data to build research programs for various aspects of Magnetospheric, Ring Current and Radiation Belt modeling, collaborating strongly with existing modeling frameworks such as the Univeristy of Michigan's Space Weather Modeling Framework (SWMF). In this talk we will present an overview of three such efforts: Modeling natural and artificial radiation belts with DREAM3D; the LANL/SWMF SHIELDS program to model the spacecraft charging environment; and a recent new project start on modeling ground induced current (GIC) impacts.

# United States

## Space Hazards Induced near Earth by Large Dynamic Storms (SHIELDS)

Reinhard FRIEDEL, Vania JORDANOVA
Los Alamos National Laboratory, Los Alamos, NM

We present a recently funded project through the Los Alamos National Laboratory (LANL) Directed Research and Development (LDRD-DR) program that aims at developing a new space weather capability to understand, model, and predict Space Hazards Induced near Earth by Large Dynamic Storms, the SHIELDS framework. SHIELDS is an end-to-end model of the magnetosphere driven by the dynamic solar wind, designed to predict one of the most harmful space-weather hazards: the spacecraft surface-charging environment (SCE). A thorough understanding of SCE, the hot (keV) electrons representing the source and seed populations for the radiation belts, is needed to strengthen spacecraft design when it comes to hazard mitigation. The SHIELDS project goals are to understand the dynamics of the SCE on both macro- and micro-scale including important physics related to rapid particle injection and acceleration associated with magnetospheric storms/substorms, as well as plasma waves. These challenging problems are addressed using a team of world class experts in the fields of space science and computational plasma physics, and state-of-the-art models and computational facilities. In addition to physics-based models (like RAM-SCB, BATS-R-US, and iPIC3D), new data assimilation techniques employing data from LANL instruments on the Van Allen Probes and geosynchronous satellites are developed. SHIELDS simulations demonstrate that the data assimilation can capture storm phenomena and improve by an order of magnitude the characterization of the SCE in near-Earth regions where operational satellites reside.

# United States

## From Discovery to Operations: Whole Atmosphere-Ionosphere Physical Models for Space Weather Applications

Tim FULLER-ROWELL
University of Colorado

Ten years ago, at the first IHY-Africa Space Weather Science and Education workshop in Addis Ababa, Ethiopia in 2007, some of the early ideas connecting terrestrial and space weather were presented and discussed. At the time, whole atmosphere models were just beginning to be developed. Five years later, at the AGU Chapman Conference in the same city, these ideas were further developed, and were documented in an AGU Monograph. We have known for a long time that waves from the lower atmosphere are a source of variability in the thermosphere and ionosphere, but it was very hard to quantify the impact and understand the physical processes. With the advent of whole atmosphere models we are able to probe the connection, begin to understand the physical processes, quantify the impact, and potentially be able to forecast the consequences on operational systems. Of course, when there is a big solar storm, and a coronal mass ejection strikes Earth, it dominates space weather in the near-Earth environment. Upper atmosphere models have to be able to deal with these extreme but relatively infrequent geomagnetically disturbed conditions; but space weather doesn't just occur during big geomagnetic storms. For instance, ionospheric irregularities can disrupt satellite navigation and communication on any day. Whole atmosphere models can explore the day-to-day variability and the longitude dependence of lower atmosphere wave sources driving the sporadic ionospheric space weather. Whole atmosphere models, coupled to the ionospheric plasma domain, have shown that the three drivers – solar radiation, geomagnetic activity, and the lower atmosphere – all contribute to space weather in the upper atmosphere. In just ten years, the discovery phase of exploring the connection between terrestrial and space weather has evolved to evaluating in a real-time operational setting at NOAA.

# United States

## ISWI Open Data Policy: An Instrument of International Collaborations

Shing FUNG
NASA Goddard Space Flight Center, Greenbelt, MD

The International Space Weather Initiative (ISWI) is “a program of international cooperation to advance the space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students.” To enable the ISWI to achieve its goal to develop the scientific insight necessary to understand the science, and to reconstruct and forecast near Earth space weather, the ISWI has established an open data policy and the associated rules of the road to govern the availability and access of all ISWI instrument data. In this presentation, we provide a status report on the ISWI data policy and discuss how it will support international collaborations.

# United States

## Multi-Nation Coordinated Monitoring of Ionospheric Weather by Means of High Frequency Sounding

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Eighty-five years after the inaugural sounding of the ionosphere at Slough in the UK, ionosondes have remained the main provider of continuous "ground-truth" observations of the sub-peak ionosphere, available with only a few minutes latency. A "quiet revolution in sensor networks", as data visionaries called it in 2003, has played its enabling role in transforming the disjointed ionosonde observatories into a real-time, automatic, collaborative space weather resource. Over 60 ionosondes in 23 countries currently contribute their data in real-time to the Global Ionosphere Radio Observatory (GIRO) [1]. GIRO is more than a multi-nation coordinated data sharing repository for ionosonde experts; it is a wide-audience, high performance data center that synthesizes a live "Realistic Ionosphere" view, and provides tools for its exploration and practical use. Every 15 minutes, the Ionosphere Real-Time Assimilative Model (IRTAM) [2] software at the Lowell GIRO Data Center (LGDC) updates its computation of the global 3D sub-peak ionospheric plasma distribution. IRTAM belongs to a novel class of assimilative models, complementary to the first-principle theoretical formulations based on the Kalman filter approach: The Realistic Ionosphere is generated by a smooth transformation of the underlying empirical International Reference Ionosphere (IRI) climatology [3] into the best agreement with the latest 24-hour history of observations at GIRO sites. This transformation treats the ionosphere in terms of its inherent "eigen" basis functions that capture the essential variability in time and space to morph these model constituents, elastically and iteratively, so that the updated model representation of the ionosphere closely follows its "weather" variability as reported by the GIRO sensors. An additional input from GIRO is its novel characterization of traveling ionospheric disturbances (TIDs), currently undergoing initial testing in a pilot network of Digisonde sounders in Europe [4]. TID events have been identified as a major operational nuisance upsetting the accuracy of GNSS navigation and HF geolocation. The timelines of oblique Digisonde signal parameters are processed at LGDC using the Doppler-Frequency-Angular-Sounding (FAS) technique [5] to derive the TID wave characteristics: amplitude, wavelength, phase velocity, and direction of propagation. A new RayTRIX algorithm suite (Ray-Tracing through Realistic Ionosphere eXplorer) uses the HR2006 technique [6] to ray-

trace through the IRTAM-3D electron density model with added TID specifications, using the high performance computing means of the LGDC infrastructure.

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# United States

## Modeling and Forecasting the Geospace Environment

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Climate and Space Sciences and Engineering, University of Michigan

There are three main routes along which the Sun affects the Earth's space environment: the electromagnetic connection, the plasma chain mediated by the solar wind, and the energetic particle chain consisting of high-energy charged particles accelerated in the solar corona and along their way to the Earth. Fast and large coronal mass ejections (CMEs), in particular when its magnetic field has a strong southward component, is the most efficient driver of magnetospheric activity and such a structure lies behind all the strongest space weather events.

Most technological systems sensitive to space weather operate inside the magnetosphere, including those in the atmosphere or on the surface of the Earth. Over the last decade physics-based models of the space environment progressed considerably. Today, there is growing recognition that large- scale numerical models contribute considerably to space physics research by putting spatially and temporally limited observations in global context. This talk will use the experience of the space plasma modeling group at the University of Michigan to show the progress, successes, failures and challenges of the geospace modeling effort.

# United States

## ISWI Outreach and Capacity Building Activities

Nat GOPALSWAMY
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One of the three primary activities of the International Space Weather Initiative (ISWI) is capacity building and outreach. The capacity building involves running an advanced school for graduate students and young scientists as a recurring activity in many parts of the world with the aim of developing space-weather literate communities. The schools consist of lectures and hands-on activities provided by well-known experts in the field of solar terrestrial physics. The lectures cover all topics from the solar interior, solar atmosphere, interplanetary medium, and the geospace with a pervading theme of space weather. ISWI instrument sessions are included that provide opportunities for initiating collaborations between scientists from developing countries and developed countries in deploying new instruments for space weather science. Lectures are arranged in local high schools and colleges given by the ISWI school lecturers. Other capacity building activities such as enabling science teachers to become space weather topics are also conducted in the vicinity of the ISWI schools. The ISWI school activity is a direct descendent of the IHY school activities started in 2007. Since 2012, the schools are conducted in cooperation with the Scientific Committee on Solar Terrestrial Physics (SCOSTEP), which is an interdisciplinary body of ICSU, the international council for science. Typically, the travel of the lecturers is supported by funds from ISWI and SCOSTEP, while the local expenses are borne by the institution that hosts the school. The lectures are all archived at the ISWI secretariat web site (iswi-secretariat.org) and are available free for the scientific community.

# United States

## Studies of Solar Eruptions Using Type II bursts from Ground and CMEs from Space

N. GOPALSWAMY, S. YASHIRO, P. Makela, C. MONSTEIN

Type II radio bursts observed from the ground using radio telescopes such as ISWI's CALLISTO provide important information on shocks driven by coronal mass ejections (CMEs). The frequency at which the type II radio emission starts indicates the distance from the Sun at which the associated CME starts driving shocks. The shock formation distance is an important indicator of the spectral hardness of solar energetic particle (SEP) events. The SEP spectrum is important in deciding the type of space weather impact they produce. In this paper, we show that important information on the life time of shocks can be derived by combining ground and space based observations. We use data from the ground based radio telescopes, the Solar and Heliospheric Observatory (SOHO) and the Solar Terrestrial Relations Observatory (STEREO). We also illustrate the hierarchical relationship between CME kinetic and type II radio bursts.

# United States

## SCINDA Scintillation Sensor Network: Sites, Systems and Science

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The SCINDA (Scintillation Network Decision Aid) is a real-time, data driven communication outage forecast and alert system that was originally developed for the United States Air Force by the Air Force Research Laboratory (AFRL). Its primary purpose was to aid in the specification and prediction of satellite communication degradation due to ionospheric scintillation in the equatorial region. Ionospheric disturbances can cause rapid phase and amplitude fluctuations of satellite signals observed at or near the earth's surface; these fluctuations are known as scintillation. The most intense natural scintillation events occur during the nighttime hours within 20o of the earth's magnetic equator. Scintillation affects radio signals up to a few GHz frequency and seriously degrades and disrupts satellite-based navigation and communication systems. SCINDA was designed to provide regional specification and short-term forecasts of scintillation activity to operational users in real-time. With increasing interests in worldwide specification of scintillation, under the IHY/ISWI program the SCINDA network expanded its coverage to include the African region. The global network grew to more than 50 ground-based scintillation monitors worldwide before a decision by USAF to acquire operational sensors in 2014 left the research network unfunded. The historical data have been used for numerous scientific investigations related to equatorial dynamics, irregularity formation and systems impacts, and data collection continues at many sites. The presentation will include a review of the network development, scientific results, current and future measurement opportunities and a strategy for reinvigorating the network with renewed support in the near future.

# United States

## A Report on Cube- and Small-Sats and the System Science of NASA's Living with a Star Program

Madhulika GUHATHAKURTA
Program Scientist, New Initiatives, NASA Ames Research Center

The NASA Heliophysics/LWS program studies the interaction between the variable sun, the Earth and the solar system. This program, by necessity, deals with the complexity of a connected system that requires multiple, distributed measurement perspectives to provide the necessary scientific data in order to understand and model the diversity of physical couplings involved.

The LWS program charts an exciting and challenging research plan, with overarching goals to understand the solar outputs that drive the solar system and earth environment, and the responses of those environments (e.g. radiation environments and the planetary response via magnetospheric/ionospheric coupling). The goals of the program are outtined in multiple documents, including the Heliophysics Decadal Survey, the Heliophysics Roadmap, the 2015 COSPAR/ILWS roadmap, and the Living With a Star Program 10-Year Vision Beyond 2015. Multiple spacecraft currently contribute to this system study, including many in their extended mission phase. This understanding should enable us to forecast space weather and to map its impacts on technological infrastructure in space and on earth.

In this talk, I will summarize the findings of the NASA Ames Research Center Small-Sat/Nano-Sat Working Group report which was chartered to develop a strategy to exploit the growing capabilities of small satellites and nano-satellites to address Living with a Star (LWS) system science goals. The working group identified knowledge and measurement gaps in the study of the LWS system that could be filled using small-sat and nano-sat missions, outlined example missions with the potential to address these gaps, and identified relevant technologies.

# United States

## Contributions of the International Space Weather Initiative (ISWI) to Space Weather Monitoring and Research in Africa: Decadal Achievements and Future Outlooks

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[2] Institute for scientific research, Boston College, United States

Space weather monitoring, prediction and research have become essential pillars of the global response to advance space weather science. The International Space Weather Initiative (ISWI) is a program of international cooperation to advance space weather science and to communicate results to the public. As a follow up, a decade after the International Heliophysical Year 2007, this paper reviews the developments in space science instruments in Africa in the last decade, other activities which includes training workshops and international scientific collaborations are discussed. Several international collaborators were identified for their different roles in the advancement of space weather science on the continent in the last decade, this includes the ICTP, UNOOSA, Boston college, NASA to mention but a few. Contributions from the different collaborating institutions have helped in knowledge and technological transfer, and also in making available research facilities for internationally competitive research; thus promoting stronger partnership amongst African scientists and with scientists in other parts of the world. Finally, the paper identifies the need to increase awareness for space weather studies in Africa and also to develop a comprehensive space weather science road map for Africa.

Keywords: International space weather initiative (ISWI), international heliophysical year (IHY), space weather science

# United States

## A Comparison of In-Situ and Ground-Based Observations of Equatorial Ionospheric Irregularities and Implications for Spread F Dynamics

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Equatorial Spread F is an important problem in space-aeronomy characterized by large-scale instabilities in the post-sunset low-latitude ionosphere and the subsequent formation of medium to small scale irregularities over large regions. These irregularities can cause critical space weather impacts in the form of deleterious radio wave scintillation effects on man-made technologies such as satellite communications and global navigation satellite systems (GNSS). The responsible mechanism for Spread F, formally identified as the gravitational Rayleigh-Taylor Instability, is commonly described as depletions or low density plasma "bubbles" that originate at the magnetic equator and expand poleward as the perturbation electric fields map along magnetic field lines. In this paradigm the meridional extent of the disturbances is wholly determined by the height of the bubbles at the equator. Here we present an investigation of the occurrence and altitudes of bubbles as a function of solar flux from in situ observations in the context of ground based scintillation measurements. We analyze ion density data as measured by the PLP sensor onboard the Communication/Navigation Outage Forecasting System (C/NOFS) satellite developed by the Air Force Research Laboratory and launched into an elliptical low earth orbit at an inclination of 13o, a perigee of 400 km and an apogee of 850 km. While the altitude variation of the spacecraft complicates the statistical comparisons of parameters for purposes that require height-normalized values, it readily supports investigations of altitude variability, specifically electron density irregularities. The investigation presented here will identify the regions affected by low-latitude scintillation, enhance our ability to model radio occultation results and provide insight into the growth mechanism and longitudinal variability of equatorial spread F. We present the first ever extensive comparison between ground station scintillation observations and satellite observations of the ion density irregularities. This may provide new insight into the flux-tube expansion mechanism of equatorial plasma bubbles. Moreover, the space-based platform supports an analysis of longitudinal variations in spread F occurrence.

# United States

## Challenges and Opportunities in Solar-Heliospheric Modeling for Space Weather Prediction

Judy KARPEN
NASA Goddard Space Flight Center, Greenbelt, MD

The ultimate practical goal of space weather modeling is to predict its effects throughout the heliosphere, especially on and near our home planet. To accomplish this goal, however, requires both fundamental understanding of the physical processes involved and models that accurately reproduce these processes. Much progress has been made in theory and modeling of space weather, from solar eruptions to geomagnetically induced currents at Earth's surface, but formidable obstacles still prevent us from reliable daily forecasting. I will give an overview of the major gaps in our understanding and modeling that must be filled in order to provide accurate advance warning of potentially destructive space weather, focusing specifically on the key solar and heliospheric phenomena.

# United States

## The Low-Latitude Ionospheric Electrodynamics and its Importance in Space Weather Prediction

Sovit KHADKA[1, 2], Cesar VALLADARES[3], and Patricia DOHERTY[2]
[1] Physics Department, [2] Institute for Scientific Research, Boston College, Massachusetts
[3] William B. Hanson Center for Space Sciences, University of Texas at Dallas, Richardson

The dynamic sun is the main source of space weather activity on Earth. The energy transfer from the Sun to the Earth's environment produces a large variability that is known as space weather. Several space weather processes can cause deleterious effects on the operation of space-borne as well as ground-based technological systems. Although ionospheric irregularities have been studied for several decades, the ability to forecast their occurrence and variability is still not fully feasible and remains a potential threat to the space weather dependent technologies. At low latitudes, most of the post sunset plasma behaviors depend on the zonal electric field and its neutral wind driver. These processes are an excellent illustration of the possible connection between pre- and post-sunset space weather events. In this study, we present results that show the mutual relationship between noon (electrojet), afternoon (GPS-TEC) and nighttime ionospheric phenomena (Scintillation, S4 index). We will discuss the drivers of ionospheric scintillation and disturbance events through statistical, and case study analyses using different databases observed in the American low-latitude sector. The role played by various input parameters of the equatorial and low-latitude ionosphere and their electrodynamic processes in the development of irregularities and influence of solar activity on space weather variations will also be discussed. These investigations can provide significant advances to improve the predictability efforts of low-latitude space weather events and mitigate their effects on communication and navigation system.

# United States

## NASA Data Resources and the International Space Weather Initiative

Robert McGUIRE
NASA Goddard Space Flight Center, Greenbelt, MD

A major strategic interest of NASA and the NASA heliophysics science research program is improved physical understanding and prediction capabilities for space weather. Significant real-time and processed research data under NASA's open data policy from many operating solar, near-earth heliospheric, magnetospheric and ionospheric-thermospheric-mesospheric (ITM) missions and instruments are available or planned and relevant. In this presentation, I will briefly summarize the major sources, access methods and nature of currently-important and anticipated NASA data resources relevant to the ISWI.

# United States

## Imaging Science Contributions to Space Weather Research Using Geomagnetic Conjugate Point Observations: Latitude Coupling - North & South America / Europe & Africa

Michael MENDILLO, Jeffrey BAUMGARDNER, Joei WROTEN, Carlos MARTINIS
Center for Space Physics, Boston University

The Imaging Science Laboratory at Boston University has established a global network of all-sky-imagers (ASIs) that records emissions from the upper atmosphere and ionosphere under quiet and disturbed conditions.

The unique aspect of this observing method is that the sites selected are at the opposite ends of geomagnetic field lines in multiple latitude domains: equatorial, mid-latitude, sub-auroral. The ASI observations obtained enable the study of how single sources of space weather disturbance affect the ionosphere due to seasonally-different "receptor conditions" in each hemispheres. In this presentation, results will include the similarities and differences found during three types of ionospheric perturbations: stable auroral red (SAR) arcs, medium scale traveling ionospheric disturbances (MSTIDs) and equatorial spread-F (ESF). In each case, emphasis is placed on the degree of success found in mapping patterns from one hemisphere to the other. While coherence of the largest-scale patterns is frequent, smaller-scale structuring effects appear to result from the seasonally-different receptor conditions.

# United States

## Space-Based Sentinels and Improved Modeling of Infrared Cooling for Extreme Space Weather Forecasting

Martin MLYNCZAK[1], Delores KNIPP[2], Linda HUNT[3]
[1] NASA Langley Research Center
[2] University of Colorado
[3] SSAI

Infrared radiative cooling of by nitric oxide and carbon dioxide modulates the thermosphere's density response to geomagnetic storms. Over the past several years, failed density forecasts have been tied to onset of rapid and significant cooling due to production of nitric oxide and its associated radiative cooling via emission of infrared radiation at 5.3 um. These results have been diagnosed, after the fact, through analyses of infrared cooling made by the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument now in orbit over 15 years on the NASA TIMED spacecraft. In this talk we present the concept for a set of Earth-orbiting sentinels measuring nitric oxide radiative cooling in real-time for input to short-term "nowcasts" of thermospheric density. We also present the concept of principal component or neural network models of infrared cooling based on SABER observations. Recent research has shown that different geomagnetic storm types generate substantially different infrared radiative response, and hence, substantially different thermospheric density response. The ability to identify these storms, and to measure and predict the Earth's nascent response to them, should enable substantial improvement in thermospheric density forecasts. We will also discuss methods to assess the economic value of these observations and models, using similar recent studies in the field of climate science as a guide.

# United States

## Long Term and Short Term Forecasts of the Radiation and Plasma Environment Near Earth: Identifying Needs and Delivering Value

T. Paul O'BRIEN, Seth G. CLAUDEPIERRE
Space Sciences Department, The Aerospace Corporation, El Segundo, CA

We discuss two distinct types of forecasts of the radiation and plasma environment near Earth: long term forecasts for space and launch system design, and short term forecasts for space and launch system operation.

Long term forecasts typically arise in the form of climatology models that specify the mean cumulative environment and worst case transient environments many years in advance. These forecasts are often mostly empirical, and are not predicting a specific future, but the range of possible futures. Essentially every launch and space system utilizes some kind of long-term forecast model to set requirements. Therefore, multiple, intentional interactions between scientists who develop these models and the engineers who utilize them have led to a relatively clear set of user priorities and requirements.

By contrast, short term forecasts of the radiation and plasma environment near Earth serve a narrow set of users: launch system operators and a very small minority of space system operators. For the most part, space system operators do not take preventive action in response to a space weather watch or warning – they may ignore such events entirely, or simply raise their level of readiness in case of an anomaly. Launch system operators, however, have strict go/no-go criteria based on radiation and plasma conditions, and therefore they are dependent on forecasts for launch campaign planning and execution. Finally, a very small minority of space system operators have a known space radiation or plasma susceptibility with an established preventive action, and therefore might incorporate a short-term forecast into their operations. Because of the sensitive nature of operational vulnerabilities, it is difficult to obtain firm requirements for short term radiation and plasma environment forecasts. As a result, much of the forecasting research is motivated by a more fundamental scientific objective: demonstrating quantitative understanding through forecast modeling.

In the past year, however, there have been multiple workshops to determine user requirements for space weather, including short term radiation and plasma forecasting. Based on our experience with long term forecast models, these user outreach efforts will likely lead to a reshaping of the forecast research portfolio to include more investment in empirical models, which value quantitative performance over scientific understanding.

# United States

## On the Magnetic Connection Between Solar Active Regions and Interplanetary Coronal Mass Ejections

S. PAL[1], D. NANDY[1], N. GOPALSWAMY[2], S. YASHIRO[2], and S. AKIYAMA[2]
[1] Indian Institute of Science Education and Research (IISER), Kokata, India
[2] NASA Goddard Space Flight Center, Greenbelt, Maryland

We report on a study of the relation between magnetic parameters of a set of solar active regions (ARs) and those of interplanetary coronal mass ejections (ICMEs) from the ARs observed during solar cycle 24. Using horizontal, vertical and line-of-sight magnetic field components of the ARs, we calculate seven integrated magnetic parameters (total magnetic flux, flare reconnection flux (RC flux), and four different non-potential parameters). We then examine the relationship of CME speeds and their co-produced peak flare intensities with the AR magnetic parameters. We find that the helicity of the source AR can determine the upper-speed limit of CME speed better than any of the other AR measures considered here. We also observe a good correlation between two of the AR magnetic parameters, i.e., the RC flux and the total AR flux. We also find that the correlation between the RC flux and the total magnetic field intensity of the ICMEs observed at 1 AU is significant.

# United States

## Synergic Combination of Ionosonde Data and GNSS-based TEC Data for Monitoring Ionospheric Disturbances and Turbulent Structures

Rezy PRADIPTA
Institute for Scientific Research, Boston College, Chestnut Hill, MA

We present a particular framework for utilizing the combination of ionosonde data and total electron content (TEC) data from wide-area GNSS receiver network, along with a set of practical examples from real observations. The proposed framework primarily revolves around (1) how to effectively summarize the daily data from routine ionosonde measurements, and (2) how to detrend and map the TEC data from wide-area GNSS receiver network so that wave disturbances or other turbulent structures in the ionosphere can be clearly revealed. We found that the daily ionosonde data can often be summarized effectively by presenting them in frequency-time-intensity (FTI) and range-time-intensity (RTI) plots, which would provide a comprehensive picture on how the ionospheric state had been in a 24-hour window. Such FTI/RTI plot format generally can be used for visualizing various types of observables that had been recorded by the ionosonde, including the total amount of return echoes as well as the Doppler velocities. Most of the time, characteristic signatures of traveling ionospheric disturbances (TID), the presence of spread echoes associated with equatorial plasma bubbles (EPB), as well as the distribution of sporadic-E layers are quite easily recognizable by examining the FTI/RTI summary plots of the ionosonde data as prescribed above. In the meantime, we found that the process of detrending absolute TEC data typically needs to be able to capture two types of features: wavelike behaviour in TEC signal associated with TID (for any latitude regions of the Earth) and TEC depletions associated with EPB (for equatorial/low-latitude regions). Following those principles, we have recently developed a special TEC data detrending technique that can inherently distinguish between wavelike perturbations and depletions in the TEC data [Pradipta et al., 2015]. By applying this type of procedure on TEC data from multiple GNSS receivers in an extended area, mapping the resulting TEC perturbation (TECP) values in latitude/longitude would enable us to produce a 2-D map of the TID or EPB at any times of the day. Such 2-D maps of TID and/or EPB would also provide a certain level of geospatial awareness on how such turbulent structures/disturbances in the ionosphere evolve and migrate over a certain region. The ionosonde data (in FTI/RTI plot representation) and the detrended TEC data (in 2-D geospatial representation) are almost certainly a powerful combination, which could be potentially useful for regional space weather monitoring applications.

# United States

## NASA and International Open Standards and the Future of Space Weather Studies

D. Aaron ROBERTS
NASA Goddard Space Flight Center, Heliophysics Division, Greenbelt, MD

NASA Heliophysics has been unifying its approach to the archiving and dissemination of data, based largely on its HP Data Management Policy, initially released in 2007. The main keys to success are an open data policy that guarantees all community members access to the same data, and standards that relieve scientists (and others) of many basic data access and analysis chores. This approach has led to the de facto adoption of data format standards (FITS for solar data, CDF for most space physics data, and NetCDF for a number of near-Earth datasets), as well as a metadata standard (Space Physics Archive and Extract: SPASE) that facilitates the formation of readily searchable registries of data products. A recent addition to the standards is the Heliophysics Application Program Interface (HAPI) that is intended to make data from any repository accessible by any application that uses the protocol. The use of standards makes it possible to quickly bring together the disparate datasets needed in many current Space Weather studies. It also makes it possible for new data providers (e.g., ISWI participants) to add their data to the mix of existing datasets. This talk will give an overview of existing standards and tools, and will illustrate how they can be used to advantage.

# United States

## The IHY/ISWI Education and Public Outreach Programs and the SID Space Weather Monitors – A Retrospective

Deborah SCHERRER
Stanford University Solar Center

The International Heliophysical Year (IHY) aimed to advance our understanding of the fundamental processes that govern the Sun, Earth, and heliosphere. The IHY Education and Outreach Program was specifically dedicated to "inspiring the next generation of space and Earth scientists as well as spreading the knowledge, beauty, and relevance of our solar system to the people of the world." The continuing ISWI extended the instrument distribution programs to "develop the scientific insight necessary to understand the science…including instrumentation, data analysis, modeling, education, training, and public outreach."

In our SID Space Weather Monitor project, a part of both the IHY and ISWI education programs, we deployed a network of instruments to high schools and universities around the world. These sensor monitors provided quantitative diagnostics of solar-induced ionospheric disturbances in a manner designed to give students hands-on access to real scientific data. To support the program, we instituted a series of educator training workshops to provide scientific background and to supply educators with resources to support their own programs. Workshops were given at the various IHY and ISWI summer schools and conferences.

My talk will highlight the progress of this educational program through the IHY and ISWI, the roadblocks we faced, what partnerships we developed, the outcomes of the educator workshops, and what made the project successful.

# United States

## The SID Space Weather Monitors - Educational Instruments of the ISWI

Deborah SCHERRER
Stanford University Solar Center

The International Heliophysical Year (IHY) aimed to advance our understanding of the fundamental processes that govern the Sun, Earth, and heliosphere. The IHY Education and Outreach Program was specifically dedicated to "inspiring the next generation of space and Earth scientists as well as spreading the knowledge, beauty, and relevance of our solar system to the people of the world."

In our SID Space Weather Monitor project, a part of the IHY Education Program, we deployed a global network of sensors to high schools and universities around the world. These instruments provided quantitative diagnostics of solar-induced ionospheric disturbances in a manner designed to give students hands-on access to real scientific data. The result was a world-wide network of instruments and shared data that have supported collaborations of scientists, teachers, and students in investigating the variability of the ionosphere and inspiring the next generation of students. All data has been made publically available. Our SID instruments, along with their big brother, the research-quality AWESOME (Atmospheric Weather Electromagnetic System of Observation, Modeling, and Education) instruments were then selected as a participating program in the United Nations International Space Weather Initiative (ISWI).

The poster will describe the SID project as it moved from the IHY to the ISWI, partnerships we formed, provide technical details of the instruments themselves, and give an overview of the centralized data repository. It will also include educational aspects of being incorporated into the ISWI.

# United States

## Predictability of Extreme Space Weather

A. Surjalal SHARMA
University of Maryland, Department of Astronomy, College Park, Maryland

Modeling of space weather using numerical simulation codes based on the plasma processes provides a comprehensive view and has been widely used in the analysis of the key phenomena such as geomagnetic storms and substorms. The predictability of extreme events using these and other approaches are however limited, as is the case in the prediction of all natural hazards. Data-driven modeling based on complexity science is a framework for modeling and prediction of extreme events and for quantifying the associated predictability. The dynamical features derived from the time series data of space weather, from ground-based and spacecraft-borne instruments, yield predictions of the typical behavior and the large deviations are the extreme events. A key feature of extreme events is the long range correlation in the system and is characterized by scaling exponents, such as Hurst exponents, usually computed after removing trends in the data to avoid spurious correlations. The scaling exponents provide a measure of the long-range correlation in space weather and thus a means to quantify the predictability. The data-driven modeling of space weather, based on the dynamical systems theory, thus yields predictions based on the inherent dynamical features and the likelihood of extreme events based on the intrinsic nature of the fluctuations.

# United States

## ULF Waves in the Ionospheric Alfven Resonator: Observations and Simulations

Beket TULEGENOV, Anatoly V. STRELTSOV
Physical Sciences department, Embry Riddle Aeronautical University, Daytona Beach

We present results from a numerical study of physical processes responsible for the generation of small-scale, intense electromagnetic structures in the ultra-low-frequency range frequently observed in the close vicinity of bright discrete auroral arcs. In particular, our research is focused on the role of the ionosphere in generating these structures. A significant body of observations demonstrate that small-scale electromagnetic waves with frequencies below 1 Hz are detected at high latitudes where the large-scale, downward magnetic field-aligned current (FAC) interact with the ionosphere. Some theoretical studies suggest that these waves can be generated by the ionospheric feedback instability (IFI) inside the ionospheric Alfven resonator (IAR). The ionospheric feedback instability occurs when the magnetic field-aligned currents change the conductivity in the ionosphere by precipitating and removing electrons from it and the variations in the conductivity positively “feed back” on the structure and amplitude of the FACs increasing their magnitude. The ionospheric Alfven resonator is the region in the low-altitude magnetosphere bounded by the strong gradient in the Alfven speed at high altitude and the conducting bottom of the ionosphere (ionospheric E-region) at low altitude.

To study ULF waves in this region we use a numerical model developed from reduced two-fluid MHD equations describing shear Alfven waves in the ionosphere and magnetosphere of the earth. The active ionospheric feedback on structure and amplitude of magnetic FACs that interact with the ionosphere is implemented through the ionospheric boundary conditions that link the parallel current density with the plasma density and the perpendicular electric field in the ionosphere. Our numerical results are compared with the in situ measurements performed by the Magnetosphere-Ionosphere Coupling in the Alfven Resonator (MICA) sounding rocket, launched on February 19, 2012 from Poker Flat Research Range in Alaska to measure fields and particles during a passage through a discreet auroral arc. Parameters of the simulations are chosen to match actual MICA parameters, allowing the comparison in the most precise and rigorous way. . Waves generated in the numerical model have frequencies between 0.30 and 0.45 Hz, while MICA measured similar waves in the range from 0.18 to 0.50 Hz. These results prove that the ionospheric feedback instability driven inside the IAR by a system of large-scale upward-downward currents is the main mechanism responsible for the generation of small-scale intense ULF waves in the vicinity of discrete auroral arcs.

# United States

## The Low-Latitude Ionospheric Sensor: Recent Scientific Results

Cesar E. VALLADARES
William B. Hanson Center for Space Sciences, University of Texas at Dallas, Richardson

The low-latitude ionospheric sensor network (LISN) consists of an array of small instruments that operates continuously as a real-time distributed observatory. LISN was designed and built to understand the complex day-to-day variability and the extreme state of disturbance that occurs in the South American low-latitude ionosphere. This presentation will show the latest scientific results procured by the LISN instrumentation, an extended network of GPS receivers that exist in South and Central America, the implementation of new processing algorithms, and the complementary usage of satellite data.

LISN observables have allowed us to study the association of primary and secondary gravity waves with tropical storms. TEC values from the American continent have also been used to characterize the conjugacy of MSTIDs. It was found that mid-latitude nighttime MSTIDs, also named electro-buoyancy waves, map into the opposite hemisphere but the amplitude of the TEC disturbance in the southern hemisphere is between 8 and 13% of the amplitude in the original hemisphere. During two large magnetic storms that occurred during the northern hemisphere summer solstice, a pronounced TEC enhancement was observed in addition to the storm enhanced density (SED). This second TEC enhancement was observed equatorward of the SED and apparently moving northward. A careful analysis of the TEC values indicated that this second TEC enhancement had a local origin and was driven by a southward directed meridional wind that moved plasma up the tilted magnetic field lines. The LISN network provided new insights on the occurrence of near-midnight TEC enhancements that develop after sunset at low latitudes on 30% of the days. These TEC enhancements last for several hours and can have amplitudes between 1 and 50 TEC units. It was suggested that a combination of zonal electric fields and meridional neutral winds are able to redistribute the plasma along the field lines and create the regions of enhanced TEC. Ionosonde and GPS LISN measurements have been used in conjunction with SWARM, CNOFS and DMSP passes to understand the onset of a variety of bubble and blob forms that exist over South America.

# United States

## Do Countries Under the Equatorial Electrojet Belt Should Worry About Geomagnetically Induced Currents?

Endawoke YIZENGAW[1], Brett CARTER[2]
[1] Institute for Scientific Research, Boston College, Chestnut Hill, MA
[2] SPACE Research Centre, RMIT, Melbourne, Australia

The arrival of interplanetary shocks drives magnetosphere and ionosphere current systems, which then can cause magnetic field variability at ground. The strength of these currents can be detected by the time derivation of the magnetometer observation (dB/dt) on the ground. The stronger dB/dt magnetic spikes at the arrival of interplanetary shocks may be able to cause significant geomagnetically induced currents (GIC) and electric fields that may have damaging effects on modern ground based technological infrastructures. Although significant attention has been given to the impact of GICs at high-latitude regions, mainly in the auroral region where it gets amplified by the auroral electroject (AE), its impact at the geomagnetic equator has been largely overlooked until recently. It is well known that the interplanetary shocks-driven magnetopause current penetrates into the inner-magnetosphere and almost instantaneously extends down to the equatorial ionosphere through the TM0 (zero order transverse magnetic) mode waves in the Earth-ionosphere waveguide. These currents, which get amplified by the equatorial electroject (EEJ) in the same way the AE does to it, can cause bursts of GIC onto the power lines that are located in the vicinity of geomagnetic equator. At the same time, modern infrastructures in the vicinity of EEJ region is booming, and the GIC could be a concern for countries under the EEJ belt. In this paper, using ground- and space-based observations, we demonstrate that the interplanetary shocks driven GIC bursts have potential effects at the equatorial region both during geomagnetically quiet and storm periods.

# United States

## USA-sponsored Space Instruments Deployed under the ISWI Umbrella

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One of the main objectives of the United Nations Office for Outer Space Affairs (UNOOSA) and other space science funding agencies is to understand the behavior of ionosphere-thermosphere-magnetosphere (ITM) coupling phenomena and its impact on our technological systems, such as navigation and communication systems, on regional and global scales. To achieve this objective, it is essential to have in place well-coordinated data sets and international collaboration in their analyses. Thus, through a cooperative program with the UNOOSA, the International Heliophysical Year (IHY) and its successor International Space Weather Initiative (ISWI) program have facilitated the deployment of a number of arrays of instruments around the world. Today significant a number of instruments, ranging from a new network of radio dishes (to observe solar transients), to networks of radars (UHF, VHF, ionosondes), GNSS receivers, magnetometers, to optical instruments (Fabry-Perot interferometers and all-sky imagers) are either installed or in process. The ISWI program also serves as a vehicle to draw scientists and engineers from around the globe into a coordinated observation campaign for better understanding of space weather, particularly ITM coupling and its impact to our technological systems. In this paper, the scientific and societal contributions of the USA-sponsored instruments which have been deployed around the world under the ISWI umbrella will be discussed.

# United States

## Inner-Magnetospheric Array for Geospace Science: iMAGS

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The Inner-Magnetospheric Array for Geospace Science (iMAGS) is the chain of magnetometer arrays that merged the three individual arrays (AMBER, SAMBA and MEASURE) and created common data processing and storage system. Recently, in order to get complete understanding of solarwind-magnetosphere-ionosphere coupling phenomenon and its impact at the geomagnetic equator, iMAGS team proposed to expand the chain to higher-latitudes. Detections of magnetic field perturbations using such latitudinal and longitudinal chain of ground-based magnetometers provide valuable information about different space weather topics, such as about electric currents and waves in the magnetosphere and ionosphere, equatorial ionospheric electrodynamics, subsurface electrical conductivity, bursts of damaging GIC onto the power grids, and possibly signals prior to and during major earthquakes. Therefore, the expansion of iMAGS array not only provides good opportunity to monitor the solar wind-magnetosphere-ionosphere coupling phenomena and its impact on the ground on a regular bases but also serve as an exemplary path forward towards the effort of creating the Distributed Array of Small Instrumentation (DASI) concept that enhances observational capabilities for space weather and other disciplinary enterprises. In this paper, we will address the important space weather related sciences that can be addressed with iMAGS ground-based observations, augmented with observations by instruments on board discovery missions (e.g., ACE, WIND, THEMIS, MMS, etc). The importance of iMAGS chain for the advancement of cross-disciplinary knowledge of ground magnetic perturbations will be discussed, because understanding the cause of ground magnetic perturbations is more critical to properly predict or forecast the natural hazards on the ground that may be associated with different conditions of geospace phenomenon.

# United States

## Impulsive Energy Transfer Via Joule Heating from the Magnetosphere to the Ionosphere During Geomagnetic Storms

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Data from the Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE) have been used to study electric fields, currents, precipitating energy flux, and Joule heat for 24 magnetic storms. The calculation uses a high latitude conductivity model based on the field-aligned currents measured by AMPERE. The derivation of conductivities from field-aligned currents ensures spatial and temporal consistency in the calculated electrodynamic parameters. For all of the magnetic storms studied, the combined energy input from precipitating particles and Joule heating exhibits sharply-peaked maxima at the times of local minima in Dst, suggesting a close coupling between ring current energy content and the high latitude currents driven by field-aligned currents. Within these enhancements, the Joule heating rate typically exceeds the energy flux from precipitating particles by a factor of two to six. These relatively rapid increases and decreases of the high latitude energy deposition are a result of the variation of ionospheric conductance with field-aligned current strength, leading to a nonlinear relation between current and voltage, and impulsive transfer of energy from the magnetosphere to the ionosphere.

# United States

## Monitoring and Investigation of Geospace Disturbances Along the 120E/60W Longitudes: International Meridian Circle Project

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Dynamics and coupling processes in the geospace system of the magnetosphere, ionosphere and thermosphere (M-I-T) often exhibit complex temporal and spatial characteristics. The meridian circle of 120E/60W longitude spans across America and Asian/Oceanic longitude sectors that are of particular geophysical interests arising primarily from their distinctive and opposite offsets associated with geomagnetic field configuration. Space weather and climate along the circle have demonstrated various important aspects of the M-I-T system science nature. An international effort has been initialized and implemented in recent years to conduct coordinated observations and scientific analysis based on a very extensive set of ground-based facilities along the circle. They include those from China as part of a Chinese major infrastructure project for the space weather science, from the US funded by the NSF geospace facility program (e.g., the chain of incoherent scatter radars), as well as from other partners around the world. This cooperative effort has a general goal to enhance our understanding of the essential geospace behavior during space weather events, and eventually improve the space weather prediction capability. One of the most highlighted event studies was carried out for the 2015 St Patrick's Day solar and geomagnetic storm where an observational campaign was successfully planned and launched, resulting in very comprehensive observational datasets. Analyses of these and other relevant observations have yielded a series of presentations, reports and papers, including publications that form a dedicated special collection on the St Patrick's Day storm for Journal Geophysical Research (Space Physics). The international Meridian Circle project will be continuing to provide a critical mass to the community with a feasible approach to foster efficient space weather collaboration.

# Uruguay

## Geophysics Using Hubble Space Telescope

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We exploit Hubble Space Telescope (HST) as a cosmic ray detector to probe the interaction between the Earth's magnetic field with the interplanetary environment. We have got access to 100 000+ dark images obtained during 26 years of HST operation from several instruments onboard. From the analysis of the dark images, we applied numerical algorithms to extract the cosmic rays and we calculate the flux of cosmic rays at an altitude of ~500 km above the surface. Our analysis will combine HST results with measurements of solar activity, cosmic ray flux on Earth's surface, and geomagnetic data to tease out external field variations.

A two-phases workflow is needed to process the images: first, extracting the read-out noise contribution from the images (the bias); and second, processing the subtracted image to detect the cosmic ray impacts. For the first phase, we use the python version IRAF (Image Reduction and Facility), pyraf. For the detection of the cosmic rays, we compare the performance of two available algorithms: LACOSMIC based on a Laplacian edge detection method and the IRAF XZAP task. We conclude that LACOSMIC is better but slower than XZAP. For each dark frame, a cosmic-ray-free image is created and subtracted from the original dark frame to produce a zero background image. The latter is then processed with an algorithm to find connected components among the pixels with non-zero values. Every identified cosmic ray track's pixel length, width and total flux are recorded. Sub-observer latitude and longitude are calculated from the geocentric X, Y, and Z coordinates written in the image header.

The problem of detecting cosmic rays from 100 000+ HST dark images requires a lot of computing effort. Thus, applying a parallel model either on data or instructions domain is required to complete the processing in reasonable execution times. We follow a data-parallel approach for distributed memory system using containers. All the images are supposed to be available at the same time on an external database. The processing is performed by a set of worker processes running as Docker containers, managed by Apache Mesos.

The MatLab version of HEALPix was used to look at the distribution of detected cosmic rays over Earth's surface. Finally, we analyze the temporal variation of cosmic ray number and total flux in the 26-year period, and compute the median CR count rate and CR flux (ADU/sec).

These results correlate with increasing solar activity, but are opposite to the cosmic rays detected on the ground by the neutron monitor stations.

# Viet Nam

## NAVINET: An Experimental Portal for Low-Latitude Ionosphere Study in South East Asia

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The ionosphere monitoring based on the Global Navigation Satellite Systems (GNSS) signals is important not only to understand the space weather but also to realize its impacts on the operation and the performance of GNSS receivers. It is well-known that the performance of GNSS receivers is influenced by the propagation of broadcast signals through ionosphere. The ionospheric delay is one of the main error sources in GNSS positioning, also the ionospheric scintillation typically has adverse effects at the synchronization process of a GNSS receiver and, therefore, is a threat to all navigation receivers incorporating GNSS technology. This is particularly true in low latitude regions, where the ionospheric activity related to space weather events and their interaction with the geomagnetic field is stronger than in mid latitude regions. In particular, South East Asia (SEA) is a very interesting and critical area, since its ionosphere is characterized by the presence of the Equatorial Ionospheric Anomaly (EIA) and by a strong amplitude magnetic signature of the equatorial electrojet (EEJ), observed especially over Vietnam. However, the research community is difficult to access to the GNSS data collected due to lack of the GNSS infrastructure in the region, e.g. stations, data sharing systems.

As a R&D hub on satellite navigation in SEA, the International Centre on Research and Development of Satellite Navigation (NAVIS Centre) has focused on improving that situation for years. As a result, an experimental portal named NAVINET is established to provide to the research community data, and data analysis tools for the ionosphere research. Currently, the NAVINET is composed of 3 monitoring stations, each of which has a precise GNSS receiver and an ionospheric scintillation monitoring receiver (ISMR); and a data server center, which continuously download data from the stations, as well as provide services to users. We have used a low-cost approach in setting up the systems. Precise GNSS chipsets and RF frontends are utilized, while the data and signal processing parts are developed by the Centre. In particular, the ISMR receivers are developed by the software defined radio (SDR) approach, which leverages the low cost RF frontend and advanced signal processing algorithms running realtime in a PC-based platform. Moreover, the ISMRs also record the IF samples (frontend's raw outputs) whenever a scintillation event is detected for the purposes of testing and validating GNSS receivers in harsh space weather conditions. Also based on the station outputs, a query tool is developed to provide users with a graph-based data analysis tool, with

which users can generate plots of the parameters such as: CN0, S4, sigma-phi, satellite scintillation events, daily scintillation events, scintillation map, TEC, dTEC… from any station of the network in anytime. In summary, the NAVINET can provide to the research community: (i) RINEX data; (ii) GNSS IF Raw Samples in harsh conditions from its stations on a daily basis; and (iii) a web-based tool to analyse the ISMR parameters.

In this presentation, we aim at introducing the NAVINET portal including the designs and implementations of the precise and ISMR receivers, the ISMR analysis tool, the data server center, and the communication between the stations and the data center; as well as some research results based on the NAVINET. Furthermore, we take this opportunity to introduce the international projects between NAVIS and EU institutions, which focus on promoting the collaborations on ionosphere study in the SEA region.