The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)

Annual Report (January 1 – December 31, 2012)

Prepared by Marianna G. Shepherd, SCOSTEP Scientific Secretary

The report that follows covers the period from January 1 to December 31, 2012. It reflects the activities carried out by the organization and its current scientific program, Climate and Weather of the Sun-Earth System (CAWSES). During the reported period SCOSTEP became a permanent observed at the UN COPUOS (Committee on the Peaceful Use of Outer Space), SCOSTEP&CAWSES supported 8 scientific conferences and workshops, developed closer collaboration with the ISWI (International Space Weather Initiative), through the support of ISWI meetings. These events were communicated to the SCOSTEP scientific community via 3 Newsletters.

SCOSTEP Sponsored Scientific Meetings and Workshops (in chronological order)

- ***The 13th International Symposium on Equatorial Aeronomy, March 12-16, 2012***

The 13th International Symposium on Equatorial Aeronomy (ISEA13) was held on March 12-16, 2012, in Paracas, Peru. The ISEA is held every three to four years. The meeting is a major gathering of scientists around the world interested in the low-latitude atmosphere and ionosphere and their coupling to other latitudes and altitudes. Each ISEA meeting represents an opportunity for researchers to share their most recent results and discuss possibilities for future campaigns and experiments. The objective of the symposium is to bring together the leaders in the field of equatorial, low-latitude and mid-latitude aeronomy to advance our knowledge of these regions of the Earth's atmosphere. Topics for the workshops cover a wide range of research areas, reflecting the need to study the Earth's ionosphere/atmosphere system in a coupled sense.

Figure 1: *Group-photo of the participants in the ISEA13 and the celebration of the JRO 50th anniversary.*

The ISEA13 participants joined in the celebration of two important events: the 50th Anniversary of the Jicamarca Radio Observatory (JRO) and the 1st ISEA meeting, ISEA1, which took place in Huaychulo, Peru, in 1962. The celebration day for JRO's 50th anniversary was held on March 17th, 2012 on the observatory grounds and was attended by about 150 guests and participants in the ISEA13 conference.

The participants in ISEA13 included 25 students and representatives from 23 countries. 120 oral presentations were given, as well as 95 posters displayed during two poster sessions. The oral and poster presentations were given in eight topical sessions: 1) Irregularity Physics, 2) E and F region coupling (low and mid latitude coupling; 3) Wave propagation between low/middle atmosphere and ionosphere; 4) Plasma- neutral coupling; 5) Low and mid latitude Aeronomy and Electrodynamics; 6) Ionospheric storms and Space weather effects at low and mid latitudes; 7) New techniques, experiments, campaigns and results, and 8) Future trends and challenges. More information about the meeting, including access to the program and the abstract book can be found at http://jro.igp.gob.pe/isea13. The results from the workshop will be published in a special issue of the *Journal of Atmospheric and Solar-Terrestrial Physics*. Ethiopia was chosen as the site of the next ISEA meeting to be held in 2015/2016 time window.

- ***The MST13 Workshop, Kühlungsborn, March 19-23, 2012***

The 13th International Workshop on Scientific and Technical Aspects of MST Radar (MST13) was held in Kühlungsborn, Germany on March 19 – 23, 2012. The MST radar workshop debuted in Germany after its first meeting in May 1983 at the University of Illinois, USA.

The MST workshop series is special in that it encompasses scientist, engineers, technical experts, theoreticians, and students. These all are united in one forum for radar studies of the troposphere, stratosphere, and mesosphere. The contributions to these workshops address the comprehensive development of the technical, scientific, operational, and educational directions of the MST radar community throughout the years. The scientific program was developed by the International Steering Committee (ISC) in close cooperation with the Local Organizing Committee of the MST13 workshop formed by Prof. Markus Rapp, Dr. Ralph Latteck, and Dr. Gunter Stober. The ISC consists of Prof. Philipp Chilson (USA), Prof. Wayne Hocking (Canada), Dr. David Hooper (UK), Prof. Erhan Kudeki (USA) , Prof. Iain Reid (Australia), Prof. Toshitaka Tsuda (Japan), and Dr. Werner Singer (Germany). More than 160 contributions were received from 17 countries which encompassed 98 oral presentations and 51 posters. 89 scientists and 29 students participated in the meeting.

Figure 2: *Participants in the MST13Workshop, held in Kühlungsborn, Germany on March 19 – 23, 2012.*

The contributions to the workshop were grouped into six sessions: 1) Scattering and calibration, 2) New instruments and signal processing, 3) Meteors studied with MST radar, 4) Plasma irregularities, 5) Meteorology and forecasting, and 6) Middle Atmosphere Dynamics and Structure. 24 invited talks encompassing in all six sessions were presented along with two tutorial lectures which dealt with "Radar Atmospheric Imaging Techniques" by Philipp Chilson and "Atmospheric processes and variability up to the lower thermosphere – numerical studies with HAMMONIA" given by Hauke Schmidt.

MST13 was supported by the Leibniz-Institute of Atmospheric Physics (IAP) at the Rostock University, the German Research Foundation (DFG), and the Scientific Committee On Solar-Terrestrial Physics (SCOSTEP). The funding provided travel support for eleven scientists and twelve students. The SCOSTEP contribution allowed us to support three of the twelve students.

- ***Second CAWSES II, Task 2 Workshop: Modeling Polar Mesospheric Cloud Trends Laboratory for Atmospheric and Space Physics, University of Colorado, May 3-4, 2012.***

This was the 7th workshop sponsored by IAGA/ICMA/CAWSES and focused on global change in the upper mesosphere, specifically decadal-scale trends in Polar Mesospheric Clouds, PMC (or Noctilucent Clouds, NLC, as they are traditionally called when observed from the ground at twilight).

The issue of long-term changes in PMC was addressed in the first workshop held in Boulder, Colorado, 10-11 December, 2009. Thirty-five scientists and students from 6 countries attended the workshop at LASP (Laboratory for Atmospheric and Space Physics), with two full days of presentations and discussions. The total number of papers was twenty six. There was a final wrap-up with a panel discussion, consisting of six scientists, both modelers and observers.

Figure 3: *Group Photo of the participants in the Second CAWSES II, Task 2Workshop.*

All presentations, in PDF and audio (mp3) formats have been made available to the community at large at a dedicated website. Both, the presentations and the questions, answers and discussion are included in the audio files. We have also recorded the panel discussion, which provides an overall view of the scientific results, and opinions of the panel on the outstanding questions.

Materials on the workshop can be found at
http://www.cawses.org/wiki/index.php/Project_3_PMC/NLC_altitude,_frequency_and_brightness_changes_related_to_changes_in_dynamics_and_chemical_composition

- ***Whole Atmosphere Wave Coupling and Interaction Processes (C22), 39th COSPAR, Mysore, India***

This well attended symposium brought together over 80 researchers from 13 countries to focus on new measurements, modeling and theoretical studies of dynamical, electrodynamical and chemical coupling processes throughout the neutral and ionized atmosphere, emphasizing planetary waves, gravity waves and tides. It was also an open forum supporting CAWSES-II/TG4 and other coordinated project activities. The meeting comprised six half-day oral and one poster session and took place over four days with 16 solicited presentations, 39 contributed talks and 21 poster papers. Presentations, including solicited talks, were about equally divided between junior (PhD students, post-docs), middle and senior level scientists, proving that atmospheric wave phenomena and their coupling is a lively field. Solicited speakers were given 30 minutes with 15 minutes for contributed papers.

Figure 4: *The venue of the 39th COSPAR Scientific Assembly, Infosys Campus, Mysore, India*

The five main topics covered in C22 were: 1) Global structure, variability and sources of GW, PW and tides; 2) Secondary wave generation, propagation and their effects on the neutral and ionized atmosphere; 3) Neutral-ionosphere coupling processes; 4) Ionosphere-Thermosphere-Mesosphere response to lower and middle atmosphere variability; 5) Polar dynamics and coupling to lower latitudes. Five half-day sessions were organized according to these physical problems, to allow for different views from the neutral and ionized atmosphere communities and to bring lower, middle, and upper atmosphere scientists closer together.

The first half-day was devoted to a comprehensive overview of coordinated projects, including CAWSES, new measurement capabilities and science challenges. During the second half-day, the focus was on "Global structure and variability of GWs" which provided the global observational perspective from ground-based optical, radar, and balloon and satellite measurements at various altitudes from the troposphere to the MLT region, and the corresponding modeling perspective.

During the third half-day, the emphasis was on "Gravity wave coupling to the ionosphere and thermosphere" that highlighted the profound effects of these waves on the IT system. The fourth half-day then focused on larger scale waves: PWs and tides including their structure and variability.

Similar to GWs, PWs and tides also significantly influence the IT system, and this was the main point of the fifth half-day, including wave-wave interaction effects and processes. The sixth half-day was then devoted to stratospheric warmings and their effect on the IT, including presentations addressing the potential importance of lunar tides for the coupling between stratospheric polar dynamics and the low-latitude ionosphere-thermosphere.

The presentations given were of high quality as indicated by the extensive discussions after almost every talk. There was significant progress in a number of fields, e.g., in polar region neutral dynamics and planetary-scale wave coupling into the ionosphere, to name just a few. Financial support from SCOSTEP was provided (through COSPAR) for travel support for five participants including three students.

- ***7th IAGA/ICMA/CAWSES Workshop on Long-Term Changes and Trends in the Atmosphere, Buenos Aires, Argentine, September 11-14, 2012*** http://www1.herrera.unt.edu.ar/faceyt/trends2012/

The 7th IAGA/ICMA/CAWSES workshop on Long-term changes and trends in the atmosphere, attended by 54 participants, took place during September 11-14, 2012 in Buenos Aires, Argentina. Altogether 46 oral presentations (including 12 invited) and 14 posters were given with sufficient time for lively discussions. The workshop included also a general discussion on open problems concerning the long-term atmospheric changes and trends to identify outstanding topics in preparation of a new SCOSTEP project in the area of climate change in the upper atmosphere. The analysis of trends covered a large range of atmospheric parameters and from the stratosphere to the thermosphere expressed through variations of neutral, ion and electron temperatures, TEC , trace gases (NO, O_3, CO_2), polar mesospheric clouds, airglow emissions and atmospheric dynamics of gravity and planetary waves.

Photo 5: *Participants in the Trends-2012 Workshop*

For example, it was reported that the regular negative trend in thermospheric density has been perturbed in the years 2008-2009 (the last deep extraordinary solar minimum) by a deep gap – the 2008-2009 thermospheric density at 400 km was lower by about 36% than in the previous solar minimum in 1996-1997. Most of this decrease (but not all) was explained by extraordinary low solar and geomagnetic activity.

The Working Group decided to prepare a white paper highlighting key scientific question which need be addressed in coming years and which is anticipated to form the basis of a new program of SCOSTEP following the end of CAWSES II in 2013.

A special issue of Journal of Geophysical Research will publish with selected papers from this 7th Trend Workshop 2012. The next workshop will be organized in Cambridge, U.K. in late July 2014.

- ***HEPPA/SOLARIS-2012 Workshop, Boulder, Colorado, September 9-12, 2012***
  http://www2.acd.ucar.edu/heppasolaris.

In recent years it has become increasingly apparent that there are many common mechanisms by which variations in solar irradiance and energetic particle precipitation (EPP) affect the atmosphere. The HEPPA/ SOLARIS 2012 meeting brought together the High Energy Particle Precipitation in the Atmosphere (HEPPA) and SOLARIS (Solar Influences for SPARC (Stratosphere/Troposphere Processes and their Role in Climate)) communities for the first joint meeting. This workshop, which was held 9-12 October 2012, followed three previous HEPPA workshops in Helsinki, Finland (2008), Boulder, Colorado, USA (2009), and Granada, Spain (2011).

HEPPA/SOLARIS 2012 brought together 80 participants from ten countries. The workshop consisted of invited tutorials that were targeted at a level appropriate for scientists and students from various disciplines, as well as contributed posters. A total of 14 tutorials and 56 poster presentations were given during the 4-day meeting. In addition, on the fourth day of the meeting parallel HEPPA and SOLARIS model/measurement inter-comparison working group sessions were held. Presentations were grouped according to five broad topics that included: (1) Solar and particle variability; (2) Solar and particle effects on the stratosphere and above; (3) Solar and particle effects on the troposphere; (4) Atmosphere and ocean/atmosphere coupling; (5) Tools for assessing solar and particle influences.

Significant advances have been made recently in our understanding of solar irradiance and particle influences on the atmosphere and climate. Global models increasingly include solar cycle variations in both total solar irradiance and spectral solar irradiance. There is more recognition of the importance of not only the "top-down" solar mechanism but also the "bottom-up", or ocean-atmosphere coupling mechanism. A new value of the solar constant, based on NASA satellite observations, is now accepted. There have been improvements in calculations of EPP ionization rates and of both simulations and measurements of the chemical effects that follow atmospheric ionization. Some recent data analysis and modeling studies suggest that EPP induces coupling of different atmospheric regions, and might affect even surface temperatures by triggering wave-mean flow interactions. Ionization from galactic cosmic rays (GCR) has been included in global models, and measurements at CERN show that it is possible for GCR to stimulate aerosol nucleation at tropospheric temperatures.

Photo 7: *Participants at the HEPPA/SOLARIS-2012 Workshop in Boulder, CO, 9-12 October 2012.*

There was also substantial discussion about future work and the outstanding questions. Predictions of solar cycle and longer effects on climate are problematic. Much of our knowledge is based on the last three solar cycles, but it is not known how representative these cycles are. There are disagreements in the measurements of spectral solar irradiance variations over the solar cycle. Measurements of the sources of EPP at different energies are severely lacking. Substantially more work must be done to understand the precise coupling mechanisms that are triggered by either solar irradiance or EPP forcing. With the demise of ENVISAT the community lacks global measurements of the most important atmospheric trace constituents for unraveling the effects of EPP. The investigations of GCR effects are really just in their infancy.

The HEPPA organizers received financial support from SCOSTEP/CAWSES. The next HEPPA workshop is scheduled for May, 2014, in Karlsruhe, Germany. The next joint HEPPA/ SOLARIS workshop will be held in 2015 at a location TBD.

- ***International Conference on Solar and Heliospheric Influences on the Geospace, Bucharest, Romania, October 1-5, 2012***

The Conference was the fourth one organized in the frame of the *Balkans, Black Sea and Caspian Sea Regional Network on Space Weather Studies (BBC SWS*). Its main goals were to bring together experts in different areas of solar-terrestrial physics and to give a more complete picture of the origin of heliospheric phenomena influencing the geospace. The conference included aspects on theory, models and observations of the solar eruptive events; solar drivers of geo-effective events; solar wind and heliosphere; ionosphere and magnetosphere physics; physics of the middle and lower atmosphere.

The Conference was organized by the Institute of Geodynamics of the Romanian Academy (IGAR) in collaboration with the Romanian Space Agency (ROSA). The program was structured in eight sessions: (1) Solar magnetism as driver of the short- and long-term solar variability; (2) Solar wind: sources and structures; (3) High-energetic solar events (Flares, CMEs, SEPs); (4) Heliosphere: its magnetic structure, ICMEs, Cosmic Rays; (5) Magnetosphere variability under the solar & heliospheric forcing; (6) Ionosphere and its induced disturbances; (7) Middle and lower atmosphere long-term variability / Climate change, and (8) Education, Dissemination, and Outreach in the Space Weather Field.

There were 33 participants from: Europe (12), USA (2) and Romania (19); among them there were 13 young scientists (MSc and PhD students).

The program consisted of 8 invited talks, 9 contributed oral presentations and 10 poster presentations. The invited talks summarized recent advances in our understanding in those fields whereas the contributed and posters papers presented the authors' relevant research. The section dedicated to "Education, Dissemination, and Outreach in the Space Weather Field" included eight invited lectures about the main aspects of space weather in the Sun-Earth system dedicated to the young researchers as well as some aspects relating to education and public outreach.

The program and abstracts, as well as all relevant information could be found at http://www.geodin.ro/CONFERENCE2012/second%20announcement.htm.

The Proceedings of the Conference (invited talks, contributed oral and poster presentations) will be published, after peer-review, in a special issue (no. 1/2013) of SUN and GEOSPHERE (ISSN: 1819 – 0839) – the journal of the Balkan, Black Sea, and Caspian Sea Network for Space Weather Studies (new webpage: http://sungeosphere.org).

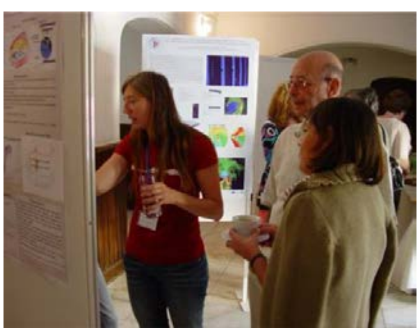


Photo 8: *Poster session and participants in the workshop*

The invited lectures will be published in a review book entitled "Solar and Heliospheric Influences on the Geospace**"** (Eds. G. Maris Muntean and C. Demetrescu), that will be distributed to the participants as well as to other young interested scientists.

Support for the conference was provided by SCOSTEP and the ANCS.

- ***International Symposium on Solar-Terrestrial Physics (ISSTP 2012) – November 6-9, 2012, Pune, India***
http://www.iiap.res.in/meet/ISTP/index.php

The International Symposium on Solar-Terrestrial Physics (ISSTP 2012) was successfully conducted during November 6 – 9, 2012 at the Indian Institute of Science Education and Research, (IISER) Pune, India. About 130 participants attended the meeting, including 30 graduate students. In addition, several local students from IISER Pune attended the sessions. International participants for the symposium came from Nigeria, Kazakhstan, Russia, Italy, France, UK, Japan, China, Canada, USA and Mexico.

Photo 9: *Dr N Gopalswamy, SCOSTEP president and co-chair, SOC, ISSTP 2012, addressing the audience.*

The symposium was preceded by a one day tutorial session on November 5, 2012 for graduate students, where subject experts gave tutorial lectures on areas ranging from magnetic field generation on the Sun to the physics of the Earth's magnetosphere and ionosphere. The 3 subsequent days (November 6 - 8) were packed with a mix of invited and contributed lectures from distinguished speakers reporting on a wide variety of research topics related to solar and solar-terrestrial physics. The meeting also featured 80 posters that were displayed throughout the duration of the event.

The evening of Nov 7 saw a public talk on the Faint young Sun paradox by Petrus Martens followed by the conference banquet, and the participants were treated to a visit to the Giant Metre-wave Radio Telescope (GMRT) on Nov 8, followed by a dinner hosted by the director of the National Centre for Radio Astrophysics.

Photo 10: *Group photograph of the participants in the ISSTP 2012, Pune.*

The final day (Nov 9) featured panel discussions on the SCOSTEP/ CAWSES program and SCOSTEP's future scientific directions. The full program is available on the conference website http://www.iiserpune.ac.in/~isstp2012 and proceedings of the meeting will be published with the conference series of the Astronomical Society of India. The ISSTP 2012 conference was supported by SCOSTEP.

- ***Chapman Conference on longitudinal and hemispheric dependence of space weather, November 12-16, 2012, Addis Ababa, Ethiopia*** www.agu.org/meetings/Chapman/

The AGU Chapman conference on longitudinal and hemispheric dependence of space weather, which was the first space weather Chapman conference in the African continent, was held successfully in Addis Ababa, Ethiopia during November 12-16, 2012. The conference organized primarily by the Colorado State University and Boston College was well attended by a large number of participants from more than 27 nations. Of these delegates about 45% came from 12 African countries, about 35% were from USA and Canada, and the remaining 20% were from other countries around the globe (see Figure 1). The Chapman conference was held at United Nation for Economic Commission of Africa (UN-ECA) meeting hall in Addis Ababa.

There were two prime objectives for the conference: (1) to assemble an international group of heliophysics scientists to plan and discuss current and needed observations at middle and low latitudes in the African longitude sector, a region that has never been explored in detail using ground-based instruments, and (2) to enhance the space science education and research interest in Africa.

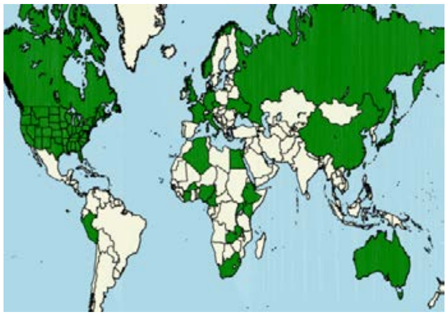


Figure 1: Geographic distribution of countries (shaded in green) that were represented at the Chapman Conference in Addis Ababa

There were six main scientific themes of the conference: (1) Hemispherical Dependence of Magnetospheric Energy Injection and the Thermosphere-Ionosphere Response, (2) Longitude and Hemispheric Dependence of Storm-Enhanced Densities (SED), (3) Response of the Thermosphere and Ionosphere to X-Ray and EUV Time-History During Flares, (4) Quiet-Time Longitude Spatial Structure in Total Electron Content and Electrodynamics, (5) Temporal Response to Lower-Atmosphere Disturbances, and (6) Ionospheric Irregularities and Scintillations.

High-quality oral and poster papers were presented at the conference. Finally, the conference concluded by formally establishing the African Geophysical Society (AGS), which was officially inaugurated at the closing ceremony of the AGU Chapman Conference. Photo 9 shows the group pictures taken outside the meeting venue.

***Photo 11:** Group photo of the participants in the Chapman Conference in Addis Ababa*

SCOSTEP Bureau Meetings

SCOSTEP organizes and conducts international solar-terrestrial physics (STP) programs of finite duration in cooperation with other International Council for Science (ICSU) bodies. Results from these programs are shared with the community of SCOSTEP scientists by joining in conducting meetings, conferences, and workshops and by publishing newsletters, handbooks and special journal issues.

The relevant ICSU bodies are represented in SCOSTEP by the Bureau members (IAU, IAGA, IAMAS, IUPAP, COSPAR, URSI, SCAR; IUGG has a liaison).

SCOSTEP is one of the 17 interdisciplinary bodies of ICSU, along with COSPAR and SCAR.

The general requirement for conducting a scientific program is that it be approved by at least two of the participating bodies. The current scientific programme supported by SCOSTEP is the Climate and Weather of the Sun-Earth System (CAWSES - Phase II) and will end in 2013. The work under CAWSES II will culminate with a scientific symposium to be held in Nagoya, in November 2013.

In 2012 a new IAU (International Astronomical Union) representative, Prof. Mei Zhang, joint the SCOSTEP Bureau, replacing the previous IAU representative, Dr. Nat Gopalswamy. Prof. Zhang is a professor at the National Astronomical Observatory of China, Chinese Academy of Sciences, in Beijing, and chief scientist at the Huairou Solar Observing Station. Mei Zhang has made several fundamental contributions to the understanding of the formation of long-lived coronal structures and their two forms of eruption, solar flares and coronal mass ejections (CMEs). (For more information on the SCOSTEP Bureau please see the SCOSTEP Website, http://www.yorku.ca/scostep/).

1. SCOSTEP Bureau Meeting - Vienna, April 22, 2012

The SCOSTEP Bureau meeting for 2012 took place on April 22, 2012 in Vienna, prior to the EGU meeting. The Bureua meeting was chaired by SCOSTEP's President, Nat Goplaswamy. The annual report on SCOSTEP activities for 2011 and up to that meeting, together with SCOSTEP's Financial Audit were presented by the SCOSTEP Scientific Secretary, M. Shepherd, and approved by the Bureau. A report was presented on the possible updating of the SCOSTEP constitution with recommendation from a 3-member panel led by Vladimir Obridko. A decision on these recommendations was deferred to a later date. A report on SCOSTEP recognitions - honors and awards was also presented by Mark Lester also by a 3-member panel. Great part of the discussion was focused on the end of the current SCOSTEP scientific program, CAWSES II in 2013 and the selection of a panel of scientific advisors for the new scientific programs for the period 2014-2018. For the results from the Bureau meeting, please see the Minutes, given in Appendix.

2. SCOSTEP at UN COPUOS

At its 64th meeting in June 2012, the UN COPUOS (United Nations Committee on the Peaceful Uses of Outer Space) invited, at their request, the observers for the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), President Dr. Natchimuthuk Gopalswamy and Scientific Secretary, Prof. Marianna Shepherd, to attend its 55th session and to address it, as appropriate, on the understanding that it would be without prejudice to further requests of that nature and that it would not involve any decision of the Committee concerning status. The 55th session of UN COPUOS was held in Vienna, Austria from June 6th to June 15th, 2012. This invitation followed SCOSTEP's application to UN Office for Outer Space Affairs (OOSA) in October 2011 for becoming an Observer to UNCOPUOS and its Subcommittees.

In his address to the Committee on June 7, 2012 Dr. N. Gopalswamy pointed out that SCOSTEP provides guidance to the Solar-Terrestrial Physics (STP) discipline centers of ICSU's World Data System and seeks opportunities for interaction with national and international programs involving STP elements. It attempts to develop and sustain student interest in Sun-Earth connections, to promote efficient exchange of data and information between solar and terrestrial scientists in all countries, and to seek projects and programs that cross over traditional boundaries of physical regions and focused scientific disciplines. Thus SCOSTEP objectives are in accord with the United Nations Committee on the Peaceful Uses of Outer Space mission and we would like to develop a stronger relationship, participate in United Nations activities and implement UN OOSA principles and goals into SCOSTEP's mission. This is particularly relevant in view of the fact that at the 49th session of the Scientific and Technical Subcommittee of COPUOS, the Working Group on the Long-term Sustainability of Outer Space Activities established an expert group on Space Weather. SCOSTEP is striving to clarify the science behind the Space Weather phenomenon and hence it is highly beneficial to have a closer relationship between COPUOS and SCOSTEP. Granting SCOSTEP a permanent observer status with COPUOUS will provide an opportunity for a close collaboration in Space Weather issues.

The SCOSTEP President's address to the Committee was followed by a technical presentation on SCOSTEP's activities, given by the Scientific Secretary, Prof. Marianna Shepherd, on June 12, 2012.

Both these presentations at the 55th session of UN COPUOS can be found at http://www.yorku.ca/scostep/?page_id=46 .

COPUOS decided to recommend the granting of SCOSTEP's observer status. The General Assembly (GA), in its resolution on international cooperation in the peaceful uses of outer space, endorsed the decision of the Committee to grant permanent observer status to SCOSTEP. The final deliberation on the matter was at the GA plenary session in December 2012, when SCOSTEP status as a Permanent Observer to UN COPUOS was approved.

SCOSTEP first participation in the work of the COPUOS as a Permanent Observer was in the 50th session of the STSC (Scientific and Technical Subcommittee) held from February 11-22, 2013 in Vienna. SCOSTEP activities were featured by the display 9 posters on SCOSTEP – related activities in SCOSTEP National adherent members, namely Bulgaria, Canada, India, Japan, New Zealand, Norway, Russia, Slovakia, USA and SCOSTEP.

A SCOSTEP poster was also presented at the symposium dedicated to the 10th anniversary of the International Living With a Star (ILWS) program. All posters can be found on the SCOSTEP website.

On February 14 SCOSTEP's President Dr. Nat Gopalswamy made a technical presentation at the 50th STSC session and announced the MiniMax24 Campaign, which is SCOSTEPs' focus on the Weakness of the Current Solar Cycle. In his address N. Gopalswamy stated that SCOSTEP seeks focus on the peculiar state of the Sun by declaring the year 2013 as the year of "MiniMax24" to note that the even though the Sun is going through activity maximum conditions, the activity is rather low. SCOSTEP will conduct year-long scientific and outreach activities to understand and explain the current behavior of the Sun and its potential impact on human society and Earth's space environment. The scientific activity will include a comprehensive "MiniMax24 Campaign" to observe and record the subdued activity of the Sun and compare it with that of previous cycles. In particular, events on the Sun will be recorded and tracked all the way to Earth's atmosphere along paths of mass and electromagnetic flows from the Sun. Outreach activities explaining the implications of the weak solar activity on space weather and Earth's climate. SCOSTEP encourages year-long activities to be led by national SCOSTEP committees and by task group leaders of the current SCOSTEP scientific program CAWSES (Climate and Weather of the Sun-Earth System).

A wiki page has been established to record all the MiniMax24 campaign activities: https://igam02ws.uni-graz.at/mediawiki/index.php?title=Main_Page . Members of the scientific community have been encouraged to participate in the MiniMax24 campaign by registering in the wiki page and edit the community portal in this wiki page to include information on daily variability in the solar terrestrial space. Dr. Manuela Temmer (University of Graz, Austria, manuela.temmer@uni-graz.at) is the coordinator for the MiniMax24 Campaign. Further information can also be obtained from the SCOSTEP secretariat (www.yorku.ca/scostep).

Updates on CAWSES II Activities

1. Appointment of New CAWSES TG Leaders

The SCOSTEP/CAWSES II (Climate and Weather of the Sun-Earth System) program which began in 2009 as a continuation of the original CAWSES (2004 – 2008) has been dedicated to addressing fundamental questions of how the coupled sun-Earth system operates on timescales of minutes to millennia while encompassing a coordinated inter-disciplinary international effort organized into four theme groups (TG), namely:

1) What are the solar influences on the Earth's climate? (TG1 Leaders: Katja Matthes, Annika Seppälä), (2009-2011: Joanna Haigh, Ilya Usoskin);
2) How will geospace respond to an altered climate? (TG2 Leaders: Dan Marsh, Jan Lastovička)
3) How does short-term solar variability affect the geospace environment? (TG3 Leaders: Kazunary Shibata, Joe Borovsky)
4) What is the geospace response to variable inputs from the lower atmosphere? (TG4 Leaders: Jens Oberheide, Kazuo Shiokawa)

In order to strengthen the activity of these four theme groups in May 2012 the CAWSES Co-chairs, Dr. Joseph Davila and Prof. Toshitaka Tsuda appointed the following additional TG leaders: Prof. Cora Randall, University of Colorado, Department of Atmospheric and Oceanic Sciences, Boulder, Colorado. (US), for TG1; Prof. Gufran Beig, Indian Institute of Tropical Meteorology, Pune (India), for TG2; Prof. Yihua Yan, Key Laboratory of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences (China), for TG3, and Prof. S. Gurubaran, Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism, Tirunelveli (India), for TG4.

Active CAWSES and SCOSTEP related projects

SCOSTEP Secretariat

The SCOSTEP Secretariat continued its work in coordinating and managing all SCOSTEP related activities, as well as providing logistic and technical support for the CAWSES program. The Scientific Secretary, Prof. M. Shepherd organized the annual SCOSTEP Bureau meeting, prepared the application for SCOSTEP's status as a permanent observer to the UN COPUOS (Committee on the Peaceful Use of Outer Space) and ECOSOC and gave a technical presentation on SCOSTEP to the UN COPUOS session in June 2013. Prof. Shepherd also administered the SCOSTEP finances. SCOSTEP provided support for 7 CAWSES workshops, and 5 SCOSTEP Capacity Building Science Schools. M. Shepherd prepared 4 SCOSTEP Newsletters and prepared the template for and edited 12 posters on SCOSTEP/CAWSES National activities, as well as designed the SCOSTEP Brochure for Public outreach and looked after general day-to-day SCOSTEP business.

Education/Training/Outreach

1. **SCOSTEP Capacity Building Activities**

1.1. **Comic Books in Tamil**

During the Space Festival 2012 in Coimbatore, India (July 9 – 14, 2012) organized by the Bharathiar University, SCOSTEP Comic Books translated into Tamil, a classical language from Southern India, were released by the former President of India, Dr. APJ Abdul Kalam. Ten thousand copies were printed and distributed to the students. The Space Festival had several outreach activities organized by NASA scientists including Nat Gopalswamy (SCOSTEP President), Joseph Davila (CAWSES co-chair), S. Gurubaran (CAWSES TG4 co-chair), and P. K. Manoharan (CAWSES – India). The Festival was attended by more than 100,000 students (elementary school to high school) and general public. The activities included solar scale modeling, radio and optical telescopes to view the Sun, balloon launches, sounding rocket exhibit, planetarium show by the Periyaar Science Center, Chennai, and launching of many types of model rockets.

Figure 12: *The release of the COMIC Books in Tamil at the Space Festival 2012 in Coimbatore, India (July 9-14, 2012). The former president of India, Dr. APJ Abdul Kalam (inset).*

Comic books in Tamil were received by several dignitaries during the inauguration of Space Festival 2012 from the former President of India, Dr. APJ Abdul Kalam, who encouraged children to take to science and become achievers (inset) (http://www.yorku.ca/scostep/?page_id=1342).

The comic books were also translated into Czech (http://www.yorku.ca/scostep/?page_id=1332).

1.2. SCOSTEP Capacity Building and Teacher Workshop in Bandung Indonesia

SCOSTEP has become a major partner in running the Space Science Schools organized by the International Space Weather Initiative, thanks to a grant from SCOSTEP's parent body, the International Council for Science (ICSU). The most recent school was hosted by the National Space Agency of Indonesia (LAPAN) in Ciloto, near Bandung during September 17-26, 2012. The school was cosponsored by the MAGDAS group from Kyushu University, Kyoto University, IPS Australia, KASI (Korea), and Alcala University, Spain. The school was directed by Nat Gopalswamy (SCOSTEP & ISWI), Clara Yatini (LAPAN), and Kiyohumi Yumoto (Kyushu University, MAGDAS PI). The school lectures covered all aspects of solar terrestrial physics, starting from solar interior and magnetism, interplanetary disturbances, geospace disturbances, and ionospheric precursors of earthquakes. The school was accompanied by two additional capacity building activities: (1) a one-day teacher workshop run by Deborah Scherrer and David Rodrigues from Stanford Solar Center, Stanford University with SCOSTEP support, and (2) an ISWI instrument workshop, featuring low-cost instruments such as MAGDAS (Kyushu University), CALLISTO (ETH Zentrum, Switzerland), and GPS receivers (Ecole Polytechnique, Paris, France). Sixty eight students from 10 countries attended the School. Twenty four lecturers from 12 countries gave 44 lectures in all in the school. Several lecturers included hands-on activities as part of their lectures. There was also a one-day field trip to the historical Bosscha Observatory in Bandung (started 90 years ago).

Figure 14: *Photo of the participants in the Science Teacher Workshop on September 24, 2012, Bandung, Indonesia*

Future Plans

1. Request for input to the planning of the next SCOSTEP Scientific Programs for the period 2014-2018

The current SCOSTEP scientific program CAWSES (the Climate and Weather of the Sun-Earth System) started in 2005 and will complete 2 consecutive 4-year terms at the end of 2013. SCOSTEP began discussing potential scientific programs that are timely for the 2014-2018 period. In September 2012 a call for white papers on the future scientific program(s) was released by SCOSTEP's President soliciting input from scientific bodies engaged in solar terrestrial physics issues and from the scientific community in general. These white papers were required to define the scientific program including the scientific question to be addressed, an objective that can be achieved over a period of four years, data sets to be used, modeling collaborations, and a team of scientists (international steering committee) to coordinate the project. The programs need to be interdisciplinary and international.

Nine white papers were submitted covering a number of issues of solar physics, effect of space weather on climate and atmospheric coupling. A Forum of 30 scientists was created to review the white papers submitted and make recommendations to the SCOSTEP Bureau for the new scientific program(s) to succeed CAWSES. The Forum was organized and hosted by the International Space Science Institute in collaboration with SCOSTEP. May 7-8, 2013 were set for the ISSI/SCOSTEP Forum to be held in Bern, Switzerland.

Publications

A number of scientific reports were published in all fields of solar-terrestrial physics. Some of those have been listed in the respective National Annual Reports. The National reports submitted by the time of this report are given in Appendix and can also be found at the SCOSTEP Website.

APPENDIX: NATIONAL REPORTS *(in alphabetical order of country)****:***

BRAZIL:

Solar, solar-terrestrial and space weather researches are extensively developed in Brazil, since the early sixties. In this report we summarize the principal institutions carrying out these activities, and the respective areas in which relevant progress were obtained in the past two years (2011-2012). Many of these works were done in joint collaboration of several institutions, national and international. In this period, Brazil actively participated of the organization of scientific events related to SCOSTEP; VERSIM, IV SBGEA and COLAGE.

Brazil institutions active on SCOSTEP-related disciplines:

- Escola Politécnica da Universidade de São Paulo (EPUSP), Universidade de São Paulo, São Paulo, SP - EPUSP
- Centro Regional Sul em Pesquisa Espaciais, Laboratório de Ciências Espaciais da UniversidadeFederal de Santa Maria, Santa Maria, RS - CRS/LACESM/INPE
- Instituto Nacional de Pesquisas Espaciais (INPE), Ministério de Ciência e Tecnologia, São José dos Campos, SP - INPE
- Instituto Tecnológico de Aeronáutica (ITA), São José dos Campos, SP - ITA
- Observatório Nacional (ON), Conselho Nacional para Desenvolvimento Científico e Tecnológico, Rio de Janeiro, RJ - ON
- Universidade Estadual Paulista (UNESP), Faculdade de Ciência e Tecnologia (FCT/UNESP) Presidente Prudente, SP - UNESP
- Universidade Federal da Paraíba, João Pessoa, PB - UFP
- Universidade Estadual do Rio de Janeiro (UERJ), Laboratório de Radioecologia e Mudanças Globais (LARAMG), Rio de Janeiro, RJ - UERJ
- Universidade Federal de Campina Grande, Campina Grande, PB - UFCG
- Universidade Federal do Rio Grande do Norte (UFRN), Natal, RN – UFRN
- Universidade Luterana do Brasil (ULBRA), Palmas, TO - ULBRA
- Universidade Presbiteriana Mackenzie, Escola de Engenharia, Centro de Rádio Astronomia e Astrofísica Mackenzie (CRAAM), São Paulo, SP - UPM/EE/CRAAM
- Universidade de Taubaté (UNITAU), Taubaté, SP - UNITAU
- Universidade do Vale do Paraíba (UNIVAP), São José dos Campos, SP – UNIVAP
- Principal areas of research and the respective institutions involved inside (brackets):

- Atmospheric airglow investigations (UFCG, INPE);
- Atmospheric gravity waves, propagation over Brazil, Atmospheric tides (INPE, UFCG, UNIVAP);
- Climatology from tree growing rings and solar activity (CRS/LACESM/INPE, INPE);
- Development of nanosat for magnetospheric studies (CRS/LACESM/INPE);
- Dusty plasma and the interplanetary medium (UPM/EE/CRAAM);
- Earth hydrology cycle and solar activity; Climatology and solar activity (UERJ, UNIVAP, INPE);
- Geomagnetic activity, Geomagnetic storms, solar activity and solar wind anomalies (INPE, CRS/LACESM/INPE);
- High energy cosmic rays; Solar Cosmic Rays; Cosmic rays and solar cycle relationships (CRS/LACESM/INPE, INPE, UPM/EE/CRAAM);
- High atmosphere studies by means of meteor radar and photometry (UFCG);
- Imaging riometer and satellite studies, riometer operation (INPE, CRS/LACESM/INPE, ULBRA, UPM/EE/CRAAM);
- Ionospheric researches in Antarctica (EPUSP, CRS/LACESM/INPE, INPE, UNESP, UFRN, UPM/EE/CRAAM);
- Ionosphere E-region mechanisms. Sporadic E-region events (INPE);
- Ionosonde operations and related researches, Equatorial Spread-F investigation (INPE, CRS/LACESM/INPE, UNIVAP);
- Ionospheric irregularities. Trans-equatorial ionosphere bubbles (INPE, UNIVAP);
- Ionospheric scintillations, GNSS observations (INPE, UNESP);
- Lightning-induced electron precipitation events (UFRN);
- Long term solar activity analysis (CRS/LACESM/INPE, INPE);
- Magneto-hydrodynamic processes in quiescent and active space weather conditions (INPE);
- Magnetometer network operation and related researches, Terrestrial magnetic activity. Long-term activity and transient pulsation monitoring (INPE, UNITAU, UNIVAP, ON);
- Mesospheric studies (INPE, UPM/EE/CRAAM, UFCG);
- Meteor radar studies (CRS/LACESM/INPE, INPE, UFP, UFCG);
- Mm- and sub mm-waves solar radio astronomy, Mid-IR and visible solar physics (UPM/EE/CRAAM);
- Non-ionization radiation artificial effect on the lower atmosphere, Environment gamma radiation (UNITAU, ITA);
- Planetary waves and long scale ionosphere irregularities (INPE, UFCG, UNIVAP);
- Solar Coronal Mass Ejections (CRS/LACESM/INPE, INPE, UPM/EE/CRAAM);
- Solar diameter accurate measurements in the visible, long term and transient monitoring (ON);
- Solar Physics, Solar flare radio emission (INPE, UPM/EE/CRAAM);
- Solar sub-THz and THz instrumentation, sensors, materials, and systems to observe from stratospheric balloons (UPM/EE/CRAAM);
- Space geodesy, geodetic VLBI, GPS signal propagation (UPM/EE/CRAAM);
- Space weather effects on high voltage transmission power lines (UPM/EE/CRAAM);
- Transient tropospheric electrical discharges and physics of thunderstorms (INPE);
- Very low frequency (VLF) signals, propagation in the lower terrestrial ionosphere. Response to solar activity, cosmic events, and association to terrestrial disturbance in gravity and seismology, Coordination of Latin American VLF Network (UPM/EE/CRAAM).

BULGARIA:
Name of the National Adherent Representative: Prof. Dora Pancheva
Institution: National Institute of Geophysics, Geodesy and Geography (NIGGG) – Bulgarian Academy of Sciences (BAS)
Country: Bulgaria
Reported Period: 2012

1. Approximately how large is the National STP community – not more than 50-55
2. Which institutions participate in this STP activity - only the activities of the Space Research and Technology Institute (SRTI) and the National Institute of Geophysics, Geodesy and Geography (NIGGG); both organizations belong to the Bulgarian Academy of Sciences (BAS). There is also a Center for Space Research and Technologies at the Sofia University "St. K. Okhridski" but it is mainly an educational organization.

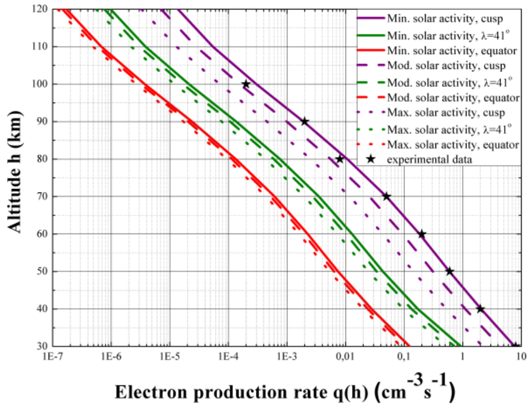
3. Main topics of the STP research carried out nationally
· Solar-Terrestrial relationships and solar forcing of the climate
· Cosmic rays impact on the climate
· Coupling processes in the atmosphere-ionosphere system
· Space weather; global empirical TEC models for long- and short-term prediction
· Technology for measurements of the space radiation

4. A summary of STP research carried out during the reported period, with highlights of the results obtained (could include references of seminal papers, if available)

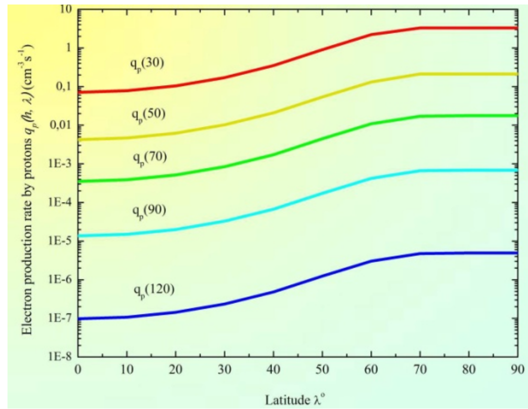
A. Space Research and Technology Institute (SRTI) - Bulgarian Academy of Science (BAS)
Cosmic ray and solar radiation impact on the ionization, electrical and chemical parameters of the ionosphere, ozonosphere and Earth's atmosphere
Two new numerical operational models have been elaborated:

- Operational model CORIMIA (COsmic Ray Ionization Model for Ionosphere and Atmosphere) for calculating the electron production rate during galactic, solar and anomalous cosmic ray fluxes penetration through the Earth's atmosphere. New results for the ionization profiles at altitudes 30 - 100 km are obtained. The geomagnetic and atmospheric differential spectrum cut-off influence, also the penetrating cosmic ray flux composition influence is taken into account. A precise agreement with experimental data from rocket and balloon measurements is established.
- The model CORIAEC (COsmic Radiation Influence on Atmospheric Electric Circuit) investigates the transpolar potential influence on the global atmospheric electrical circuit; a software program for its computer realization is implemented. This model has been developed as an operational model.

Coordination for obtaining a common solution for models CORIMIA and CORSIKA/GEANT4 in the height interval 30 - 35 km is future task. Above that region and up to altitude of 120 km the cosmic ray ionization is determined by the electromagnetic interactions and by model CORIMIA. Below that region the nuclear interactions have been included and the model CORSIKA/GEANT4 is applied for solution of the problem. In this way the whole profiles of the electron production rate from cosmic rays in the height interval 0-120 km will be obtained with the models CORIMIA and CORSIKA/GEANT4.



Electron production rate q(h) profiles due to galactic cosmic rays for polar cusps, middle latitudes (λ=41o) and equator (λ=0o) at minimal, moderate and maximal solar activity. The results are obtained by the operational model CORIMIA and they are compared with. experimental data (*) (Brasseur & Solomon, 2005)



Electron production rates due to cosmic ray protons qp(h,λ), (cm-3s-1) depending on geomagnetic latitude λ. This planetary distribution of GCR ionization for different altitudes h = 30, 50, 70, 90 and 120 km is shown. The results are obtained by the operational model CORIMIA.

Publications related to the above topic:

Gronoff G., C.J. Mertens, J. Lilensten, L. Desorgher, R. Modolo, E. Flueckiger, & P.I.Y. Velinov. 2012, Ionization Processes in the Atmosphere of Titan: from Electron Precipitation along Magnetic Field Lines to High-Z Cosmic Rays Ionization. Report on Second Workshop on "Titan Through Time", April 3-5th 2012, Building 34, Goddard Space Flight Center, Greenbelt, Maryland, USA.

Dimitrova M., S. Asenovski, P.I.Y. Velinov, M. Zaharinova, L. Mateev, R. Nedkov, Y. Tassev, P. Tonev, P. Trenchev, P. Hristov. Analysis of the information, published in the Web page of the Space weather and space climate prediction center at ISRT – BAS and its future development. Report on 8-th Scientific Conference with International Participation 'Space, Ecology, Safety' (SES 2012), December 4 - 6 2012, Sofia.

Mishev A., P.I.Y. Velinov, L. Mateev, & Y. Tassev. 2012, Ionization Effect of Nuclei with Solar and Galactic Origin in the Atmosphere During GLE 69 on 20 January 2005, J. Atmos. Sol.-Terr. Phys., **89**, 1 - 7.

Mishev A., & P.I.Y. Velinov. 2012, Contribution of Cosmic Ray Nuclei of Solar and Galactic Origin to Atmospheric Ionization During SEP Event on 20 January 2005, C.R. Acad. bulg. Sci., **65**, 3, 373 - 380.

Tassev Y., A. Abunin, M. Abunina, S. Gaidash, S. Asenovski, P.I.Y. Velinov, M. Dimitrova,M. Zakharinova, L. Mateev, P. Tonev , Comparative analysis of forecasts in the period 2011 - 2012 by the Center for space weather and space climate predictions at ISRTBAS. Report on 8-th Scientific Conference with International Participation 'Space, Ecology, Safety' (SES 2012), December 4 - 6 2012, Sofia.

Tonev, P., & P.I.Y. Velinov. 2012, Solar Wind Influence to Global Atmospheric Electric Circuit through Trans-Polar Ionospheric Potential. Prediction by Developing Operational Model CORIAEC. Report on COST Action ESO803: 7-th MCM and Spring Workshop on Final Results, Prague, 12-14 March 2012.

Tonev P. & P.I.Y. Velinov. Electric Currents and Fields above Meso-scale Convective Structures at Equatorial Latitudes and Their Ionospheric Effects - Model Results, Report on the XXXIX-th General Scientific Assembly of COSPAR, Mysore, India, 14-22 July 2012.

Tonev P., A. Abunin, M. Abunina, S. Asenovski, A. Belov, P.I.Y. Velinov, S. Gaidash, M. Dimitrova, E. Eroshenko, L. Mateev, Y. Tassev. Analysis of the development of geomagnetic storms on 8 and 9 October 2012 and of their forecasting. Report on 8th Scientific Conference with International Participation 'Space, Ecology, Safety' (SES 2012), December 4 - 6 2012, Sofia.

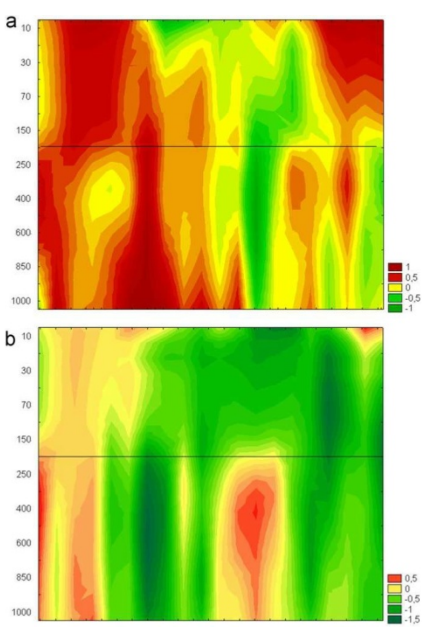
Velinov P.I.Y., S. Asenovski, & L. Mateev. 2012, Improved COsmic Ray Ionization Model for Ionosphere and Atmosphere (CORIMIA) with Account of 6 Characteristic Intervals. C.R. Acad. bulg. Sci., **65**, 8, 1137 - 1144.

Velinov P.I.Y., S. Asenovski, & L. Mateev. 2012, Ionization of Anomalous Cosmic Rays in Ionosphere and Middle Atmosphere Simulated by CORIMIA Code, C.R. Acad. bulg. Sci., **65**, 9, 1261 - 1268.

Velinov P.I.Y., S. Asenovski, & L. Mateev. 2012**,** Improved Operational COsmic Ray Ionization Model for Ionosphere and Atmosphere (CORIMIA) with Account of 6 Characteristic Intervals. Report on COST Action ESO803: 7-th MCM and Spring Workshop on Final Results, Prague, 12-14 March 2012

Effects of the solar activity on the atmospheric circulation

Solar activity has different manifestations related to the two types of solar magnetic fields poloidal and toroidal, which have different effects on the geomagnetic field disturbances. It is shown that the geoeffective solar agents related to these two types of solar magnetic fields have opposite effects on atmospheric circulation in the Northern hemisphere as characterized by the Northern Annular Mode index: high speed solar wind streams, manifestation of the solar poloidal field, enhance the zonal atmospheric circulation and lead to positive NAM indices, while in periods of increased solar irradiance, solar flares and coronal mass ejections, manifestation of the solar toroidal field, meridional forms of circulations prevail with negative values of the NAM index. These two types of solar magnetic fields are generated in different solar regions governed by different factors. Based on geomagnetic data, it is shown that the long-term evolution of these two types of solar magnetic fields differs, with periods in which the one or the other has greater influence on the terrestrial system. The different effects of these two types of solar activity on the Earth and their different long-term evolution can explain the instability of the solar-climatic correlations.



Composites of time-height development of the northern annular mode for the 11winters of high aa-index and low sunspot number and F10.7 (a), and the 9 winters of high sunspot number and F10.7 and low aa-index (b).The horizontal line denotes the approximate altitude of the tropopause (after Georgieva et al., J. Atmos, Sol-Terr. Phys., 2012).

Publications related to the above topic:

Georgieva, K., Space Weather and Space Climate—What the Look from the Earth Tells Us About the Sun, In: Jean-Pierre Rozelot, Coralie Neiner (Eds.), The Environments of the Sun and the Stars, Lecture Notes in Physics, Volume 857. ISBN 978-3-642-30647-1. Springer-Verlag Berlin Heidelberg, 2013, p. 53-107

Georgieva, K. B. Kirov, P. Koucká Knížová, Z. Mošna, D. Kouba, Y. Asenovska, Solar influences on atmospheric circulation, J. Atm. Solar-Terr. Phys., 90,15-25, 2012. doi: 10.1016/j.jastp.2012.05.010

Gousheva M., D. Danov, P. Hristov, Statistical Study of the Quasi-Static Electric Field Anomalies in the Upper Ionosphere Related to Seismic Activity above Different Tectonic Structures of the Earth, C. R. Acad. Bulg. Sci. 64 (5), 729-736, 2012

Obridko, V. N., Yu.A. Nagovitsyn, K. Georgieva, The Unusual Sunspot Minimum: Challenge to the Solar Dynamo Theory, In: V.Obridko, K.Georgieva, Yu.Nagovitsyn (Eds), The Sun: New Challenges, Astrophysics and Space Science Proceedings, V. 30, Springer-Verlag Berlin Heidelberg, 1-17, 2012, ISBN 978-3-642-29416-7.

B.Kirov, V.Obridko, K.Georgieva, E.Nepomnyashtaya, Secular variations of the solar magnetic field and geomagnetic activity, Proceedings of the XVI conference "Solar and Solar-Terrestrial Physics", Pulkovo 2012, 447-452, 2012.

Georgieva K., B. Kirov, Yu.A. Nagovitsyn, Long-term variations of solar magnetic fields from geomagnetic data, Proceedings of the XVI conference "Solar and Solar-Terrestrial Physics", Pulkovo 2012, 431-436, 2012.

B. National Institute of Geophysics, Geodesy and Geography (NIGGG) – Bulgarian Academy of Science (BAS)

Additional Ozone source found in the Lower Stratosphere

The only source of stratospheric ozone is thought to be the dissociation of molecular oxygen O_2 by solar ultra violet (UV) radiation with wavelengths 175-242 nm, and the consequent three body reaction: $O+O_2+M \rightarrow O_3+M$. In the far 1930, however, Chapman has pointed out that besides from solar UV radiation, the dissociation of molecular oxygen O_2 may be brought about by corpuscular radiation as well. He ignored the latter, because the intensity of corpuscular radiation has been unknown at that time, but noted that some of the ignored factors in his theory may be quite important for the ozone chemistry.

Presently, the impact of energetic particles in the ozone balance is mainly linked to the O_3 destruction by solar protons, while the effect of Galactic cosmic rays (GCR) is assumed small, because of their less intensity. Penetrating deeper into the atmosphere, GCR initiate ion molecular reactions in the lower stratosphere and troposphere. Reassessment of the efficiency of these reactions (Kilifarska, 2012, 2013) reveals existence of an autocatalytic cycle – continuously producing ozone near the maximum of ionization produced by GCR (known as Pfotzer maximum). The spatial distribution of so derived O_3 depends on the GCR intensity, being modulated by solar and geomagnetic fields.

Comparison of total ozone and world geomagnetic field gives an initial idea for such a relation between columnar ozone and geomagnetic field (Fig.1). The mediator of this relation is GCR, producing ozone. Note that the areas with highest O_3 values practically coincides with that of the highest magnetic field intensity.

Moreover, analysis of O_3 deviations from its decadal means (i.e. anomalies), illustrates that areas of ozone enhancements correspond very well to the regions with positive correlations between mean ozone values and GCR, calculated for the period 1957-2012 (see Fig.2). The negative correlations coincide with the negative O_3 anomalies.

The discovery of this additional source of O_3, which impacts the lower part of the ozone profile, could have a substantial impact in the climate variability, altering its radiation balance.

Publications related to the above topic:

Kilifarska N.A. Mechanism of lower stratospheric ozone influence on climate, *Int. Rev. Phys*. **2012,** 6(3), 279-290.

Kilifarska N.A. An autocatalytic cycle for ozone production in the lower stratosphere initiated by Galactic Cosmic rays, **2013**, *Compt. rend. Acad. bulg. Sci.*, 66(2), 243-252.

Response of the ionosphere to forcing from below: Comparison between COSMIC measurements and simulations by the Atmosphere-Ionosphere Coupled Model GAIA.

(Note: The figures pertinent to this section of the report could not be exported from the original document and therefore are not shown here. The full report and list of publications can be found at the SCOSTEP Website.)

The last 3-4 years a group from the NIGGG-BAS has worked on the response of the ionosphere to the wave forcing from the lower atmosphere. The research is done by using global satellite measurements: temperature data from SABER/TIMED and electron density data from FORMOSAT-3/COSMIC. The next step in this research is a detailed comparison between simulated and observed global electron density responses that gives credit to the used for the comparison model but supports also the data analysis method used by the group particularly for satellite measurements. The recently developed Earth's whole atmospheric model from the troposphere to the ionosphere, called GAIA, has been used for the simulation of the electron density tidal responses. They have been compared with the extracted from the COSMIC electron density data tidal responses for both quite and disturbed, i.e. period of major stratospheric warmings. It was found that the GAIA model reproduced quite well the COSMIC tidal responses and particularly the revealed by the COSMIC data analysis three altitude regions of enhanced electron density responses. For the first time the GAIA model simulations supported the observational evidence found in the COSMIC measurements that the ionospheric WN4 (WN3) longitude structure is not generated only by the DE3 (DE2) tide as it has been often assumed. As regards the comparison of the migrating DW1, SW2 and TW3 responses the obtained results clearly demonstrate that the GAIA model reproduce very well of the SW2 and TW3 COSMIC electron density responses, but the observation does not support the splitting of the simulated DW1 response at both sides of the equator. This is due to the difference between the SABER and GAIA SW2 tide in the lower thermosphere as it turned out that the DW1 electron density response strongly depends on the mean features of the lower thermospheric SW2 tide. These investigations present valuable and strong experimental and model evidence that confirms the new paradigm in upper atmospheric and ionospheric physics that the entire ionosphere regularly responds to the troposphere and stratosphere. These results highlight the importance of understanding the variability of the lower atmospheric weather systems and the predictability of the ionospheric response to them.

The major stratospheric sudden warming (SSW) during the northern winter of 2008/2009 was investigated by the GAIA model and the SABER and COSMIC satellite data. The GAIA model has assimilated meteorological reanalysis data by a nudging method. The comparison shows general agreement in the major features from the stratosphere to the ionosphere including the growth and decay of the major SSW event in January 2009. During this period, a pronounced semidiurnal variation in the F region electron density and its local-time phase shift similar to the previous observations are reproduced by the model and COSMIC observation. The model suggests that the electron density variation is caused by an enhanced semidiurnal variation in the ExB drift, which is related to an amplified semidiurnal migrating tide (SW2) in the lower thermosphere. The model and SABER observations show that the SW2 tide amplifies at low latitudes from the stratosphere to the thermosphere as well as the phase variation. Possible mechanisms for the SW2 variability in the low latitude stratosphere could be the change of its propagation condition, especially the (2, 2) mode, due to changing zonal background wind and meridional temperature gradient, and/or an enhancement of its source due to redistribution of stratospheric ozone.

Publications related to the above topic:

Pancheva, D., Y. Miyoshi, P. Mukhtarov, H. Jin, H. Shinagawa, and H. Fujiwara, Global responseof the ionosphere to atmospheric tides forced from below: Comparison between COSMIC measurements and simulations by Atmosphere-Ionosphere Coupled Model GAIA, *J. Geophys. Res. – Space Physics*, v. 117, A07319, doi:10.1029/2011JA017452, 2012

Jin, H., Y. Miyoshi, D. Pancheva, P. Mukhtarov, H. Fujiwara, and H. Shinagawa, Response of migrating tides to the stratospheric sudden warming in 2009 and their effects on the ionosphere studied by a whole atmosphere-ionosphere model GAIA with COSMIC and TIMED/SABER observations, *J. Geophys. Res.- Space Physics*, v. 117, A10323, doi:10.1029/2012JA017650

3. Outreach Activities

A Space Weather and Space Climate Prediction Center (SWSCPC) in the SRTI-BAS – it secures daily 3-day predictions of the state of the solar and geomagnetic activity: solar flares, coronal mass ejections, geomagnetic disturbances and storms etc. The SWSCPC elaborates and issues warnings and detailed analysis of the space conditions. The analyses and predictions are operationally secured with data from ground based measurements, satellite observations, data from mathematical models for numerical forecast of processes on the Sun, in the interplanetary space and Earth's environment (http://www.space.bas.bg/SpaceWeather/index.html)

Services in the NIGGG-BAS (http://www.geophys.bas.bg/) – (i) ***ionospheric predictions*** offered mainly to the Ministry of Defense; (ii) ***nowcast of geomagnetic Kp-index***, i.e. 6 hours ahead, based on an empirical model for prediction (**MAK Model)** through the parameters of solar winds which are received online from the ACE satellite, and (iii) two ***global empirical TEC models for longand short-term prediction*** have been recently implemented; the models offer TEC maps which depend on geographic coordinates (5°x5° in latitude and longitude) and UT at given solar activity/geomagnetic activity and day of the year.

5. Capacity Building Activities

6. Participation in National/International conferences (which ones, how many scientists?)

International Conference „Solar and heliospheric influences on the geospace", 1-5 October, Bucharest, Romania

Joint WG2 and Nordforsk workshop on "Complexity and climates", 26-29 March 2012, Tromso, Norway

39th COSPAR Scientic Assembly, 14-22 July 2012, Mysore, India

United Nations/Austria Symposium on Data Analysis and Image Processing for Space Applications and Sustainable Development: Space Weather, 18 - 21 September 2012, Graz, Austria

XVI conference "Solar and Solar-Terrestrial Physics", 24-28 September 2012, St. Petersburg, Russia

Third UN/Ecuador Workshop on ISWI, 8-12 October 2012, Qito, Equador Ninth European Space Weather Week, 5-9 November 2012, Brussels, Belgium

International conference on "From the stratosphere to the ionosphere: coupling, boundary conditions and assumptions", Paris, 26-28 November 2012.

SPACE, ECOLOGY, SAFETY SES 2012, 4-6 December 2012, Sofia, Bulgaria

Fourth Workshop "Solar influences on the magnetosphere, ionosphere and atmosphere", 4-8 June 2012, Sozopol, Bulgaria

7. How many have been supported by SCOSTEP/CAWSES

International Conference „Solar and heliospheric influences on the geospace", 1-5 October,Bucharest, Romania – the participation of Prof. K. Georgieva was supported by SCOSTEP

8. International Collaborations and Initiatives

International Space Weather Initiative (http://www.iswi-secretariat.org)

Regional Network of the Balkan, Black Sea and Caspian Sea Countries on Space Weather Studies (http://www.stil.bas.bg/IHY/); the international journal "Sun and Geosphere" is published (http://sungeosphere.org)

FP7 – People, "Marie Curie" program: Complex Research of Earthquake's Forecasting Possibilities, Seismicity and Climate Change Correlations (PIRSES-GA-2009-246874)

COST ES1005: "Towards a more complete assessment of the impact of solar variability on the Earth's climate (TOSCA)"

COST Action ES0803: Developing space weather products and services in Europe ISSI, Bern, Switzerland Project: Atmosphere-Ionosphere Coupling during Stratospheric Sudden Warmings

FA8655-12-1-2057 EOARD, London project: Regional empirical model of the TEC response to geomagnetic activity and forcing from below Bilateral collaborations with Czech Republic, Romania, Russia

NOTE: Further detail description of the STP activities in Bulgaria can be found in the original report on the SCOSTEP Website. The full list of publications can also be found in the original report, on the SCOSTEP Website.

GERMANY:

by Franz-Josef Lübken (chair), Sami Solanki, and Karin Labitzke (National German SCOSTEP board)

1. SCOSTEP in Germany

Approximately how large is the National STP community? ~ 300

Which institutions participate in this STP activity? see below

Main topics of the STP research carried out nationally? see below

A summary of STP research carried out during the reported period, with high-lights of the results obtained (could include references of seminal papers, if available). see below

1.1. Relevant science organizations in Germany:

- *German Science Foundation (Deutsche Forschungsgemeinschaft, DFG)*
  - *Member of SCOSTEP; provides financial support.*
  - *Nominates chair and members of the national SCOSTEP board.*
  - *Runs scientific programs relevant to SCOSTEP.*
  - *Self-governing organization for science and research in Germany.*
  - *Serves all branches of science and the humanities.*
  - *Members: German research universities, non-university research institutions,*
  - *Scientific associations and the Academies of Science and the Humanities.*
  - *Receives funds from the states and the Federal Government.*
  - *Selection of scientific projects is science-driven.*

- <u>*Universities*</u>
  - *Approximately 100 general Universities*
  - *and 200 Universities of Applied Science (Fachhochschulen)*
  - *Some universities are active in SCOSTEP related science topics (see below).*
  - *Mainly funded by the federal states*
  - *Main institution for the education of students, including PhD programs.*
- <u>*Research organizations*</u>
  - *Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF)*
  - *Max-Planck Society*
  - *Leibniz Society*
  - *Helmholtz Society*
  - *German Aerospace Center (DLR, part of Helmholtz)*
    - *Germany's national research center for aeronautics and space. 16 sites in Germany*
    - *Organizes German space programs, performs research, operates large research facilities.*
  - *German Physical Society (DPG)*
    - *Union `Extraterrestrial physics'*
    - *Consortium on Extraterrestrial research (AEF)*

1.2. German research institutes involved in science relevant for SCOSTEP (Alphabetical order; only the most important topics are noted here)

1. Solar and heliospheric physics

- *Kiepenheuer-Institute for solar Physics, Freiburg (www.kis.uni-freiburg.de)*
- *Leibniz Institute for Astrophysics Potsdam (www.aip.de)*
- *Max Planck Institute for Solar System Research, Lindau (www.mps.mpg.de)*

Ruhr-University Bochum, Institute for Theoretical Physics IV (www.tp4.rub.de)

- *University Kiel, Institute for Experimental and Applied Physics (www.ieap.unikiel.de)*

2. Space Weather and Magnetospheric Physics

- *German Aerospace Center, Institute of Communications and Navigation, Departement Neustrelitz (www.dlr.de)*
- *German Research Centre for Geosciences, Potsdam (www.gfz-potsdam.de)*
- *Technical University Braunschweig, Institute for Geophysics and extraterrestrial Physics (www.geophys.tu-bs.de)*
- *University Göttingen, Institute for Astrophysics (www.astro.physik.uni-goettingen.de)*

3. Atmospheric Physics and Climate

- *Free University Berlin, Institute for Meteorology (www.met.fu-berlin.de)*
- *German Aerospace Center, Institute of Atmospheric Physics, Oberpfaffenhofen (www.dlr.de)*
- *German Aerospace Center, Earth Observation Center, Oberpfaffenhofen (www.dlr.de)*
- *Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research (www.imk-tro.kit.edu)*
- *Leibniz Institute of Atmospheric Physics, Kühlungsborn (www.iap-kborn.de)*
- *Max Planck Institute for Chemistry, Mainz (www.mpic.de)*
- *Max Planck Institute for Meteorology, Hamburg (www.mpimet.mpg.de)*
- *Research Center Jülich, Institute of Bio- and Geosciences (www.fz-juelich.de)*

- *University Bremen, Institute of Environmental Physics (www.iup.uni-bremen.de)*
- *University Frankfurt, Institute for Atmospheric and Environmental Sciences (www.iau.unifrankfurt.de)*
- *University Greifswald, Institute of Physics (www.physik.uni-greifswald.de)*
- *University Heidelberg, Institute of Environmental Physics (www.iup.uni-heidelberg.de)*
- *University Leipzig, Institute for Meteorology (www.uni-leipzig.de)*
- *University Osnabrück (www.uni-osnabrueck.de)*
- *University Wuppertal (www.physik.uni-wuppertal.de)*

2 Science

2.1 CAWSES in Germany (Climate And Weather of the Sun Earth System)

- *CAWSES is the current scientific program of SCOSTEP (www.cawses.org).*
- *German members in international task groups:*

Prof. Ulrich Achatz (Frankfurt), Dr. Christina Arras (Potsdam), Dr. Andreas, Baumgärtner (Bonn), Prof. Erich Becker (Kühlungsborn), Dr. Uwe Berger (Kühlungsborn), PD Dr. Michael Bittner (Oberpfaffenhofen), Dr. Manfred Ern (Jülich), Dr. Peter Hoffmann (Kühlungsborn), PD Dr. Michael Höpfner (Karlsruhe), Prof. Christoph Jacobi (Leipzig), Prof. Hermann Lühr (Potsdam), Prof. Katja Matthes (Kiel), PD Dr. Jens Oberheide (Clemson), Dr. Peter Preusse (Jülich), Prof. Markus Rapp (Oberpfaffenhofen), Dr. Hauke Schmidt (Hamburg), Dr. Werner Singer (Kühlungsborn), Prof. Christian von Savigny (Greifswald)

- *CAWSES priority program of DFG from 2005 to 2011*
  - *Appr. 10 Mio Euro, 25-30 institutes, 98 individual grants*
  - *Funding for PhD students and postdocs*
  - *International cooperation strongly encouraged*
  - *International review and steering panel*
  - *Science topics:*
    - *Influence of the Sun on the terrestrial atmosphere*
    - *Coupling by physical/chemical processes*
    - *Climate: anthropogenic versus natural forcing*
  - *Several hundred papers in international peer reviewed journals*
  - *{Scientific summary published in a Springer book (600 pages, 31 chapters)*

Major topics in the book are:

- *Solar radiation, heliosphere, and galactic cosmic rays*
- *Solar influence on trace gases*
- *Thermosphere, energetic particles, and ionization*
- *Mesospheric ice clouds*
- *Gravity waves, planetary waves, and tides*
- *Large-scale coupling*

3 Conferences and collaborations

Q.: Participation in National/International conferences (which ones, how many scientists?). How many have been supported by SCOSTEP/CAWSES?

– Arbeitsgemeinschaft Extraterrestrische Forschung, 12-16 March 2012, Stuttgart (part of the annual meeting of the German Physical Society with 2500 participants)
– MST radar workshop in Kühlungsborn, 19-23 March 2012, ~ 150 participants, supported by SCOSTEP!

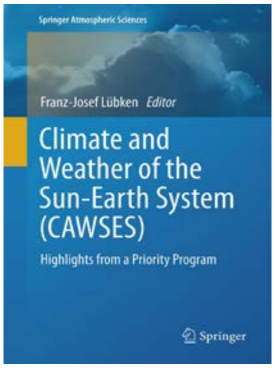


Figure 1: Cover page of a Springer book published in October 2012 on science results from the German CAWSES priority program.

– Dedicated session on CAWSES at EGU symposium in Vienna (22-27, April 2012)
– Participation in major international conferences: COSPAR, IAGA, AGU, etc.
– General Assembly of the IAU 2012 in Beijing (~ 4000-5000 participants).
– Several presentations and sessions related to Sun-Earth and Star-Planet interactions.

Q.: *International Collaborations and Initiatives?*

The German institutes mentioned above are actively involved in many international programs, collaborations, and initiatives. It is beyond the scope of this report to list all these cooperations.

4. Outreach and capacity building

Capacity Building Activities:

Several research schools and graduate schools exist in Germany where physical processes relevant for SCOSTEP are studied and education of PhD and graduate students takes place.

Examples:

- *Physical Processes in the Solar System and Beyond (MPS research school)*
- *ILWAO: International Leibniz Graduate School for Waves and Turbulence in the Atmosphere and Ocean*
- *(Graduate School at IAP, Kühlungsborn)*

5. Missions, campaigns, future plans

Q.: Current and upcoming missions and campaigns, in which the respective National STP community participates?

Q.: Future plans?

5.1 German participation in satellite missions relevant for SCOSTEP

- *CLUSTER: four satellites to study the magnetosphere http://clusterlaunch.esa.int/*
- *SolACES: self-calibrating EUV/UV-spectrophotometer on the international space station ISS http://www.dlr.de/rd/desktopdefault.aspx/tabid-2448/3635 read-5422/*
- *SDO: Solar Dynamics Observatory http://sdo.gsfc.nasa.gov/*
- *STEREO: The Sun and its energetic eruptions in three dimensions http://www.nasa.gov/stereo/*
- *Several projects from the Earth observation program of DLR http://www.dlr.de/rd/desktopdefault.aspx/tabid-2440/ (MERLIN, EnMAP, TanDEM-X, TerraSAR-X, RapidEye, METimage, GRACE,CHAMP, ENVISAT, SCIAMACHY, BIRD)*
- *SOHO: from the Sun's interior, its visible surface and stormy atmosphere, to the solar wind http://www.esa.int/science/soho*
- *SWARM: three satellites to study Earth's magnetic field http://www.swarm-projektbuero.de/*
- *Space Situational Awareness (SSA) program of ESA including space weather studies*

- *Solar Orbiter: coupling the solar atmosphere to the Heliosphere and probing the poles of the Sun. http://sci.esa.int/solarorbiter/*

5.2 Some other activities in Germany relevant for SCOSTEP

- *German scientists are involved in ILWS (International Living With a Star) which is a mission to coordinate space research to understand the Sun-Earth System http://ilwsonline.org/ilws organization.htm*
- *Ionospheric Space Weather Service via SWACI at DLR in Neustrelitz http://swaciweb.dlr.de*
- *International Network for the Detection of Mesopause Change (NDMC) at DLR (Earth Observation Center) http://wdc.dlr.de/ndmc*

5.3 Future plan: ROMIC: Role Of the MIddle atmosphere in Climate

- *New program of the German Federal Ministry for Education and Research (BMBF)*
- *Important part of BMBF's hightech strategy (better scientific understanding and prediction of climate change)*
- *Science topics:*
  - *Influence of anthropogenic activities on the middle atmosphere.*
  - *Solar influence on middle atmosphere (composition, circulation, physical processes)*
  - *Physical/chemical coupling mechanisms of Earth's middle atmosphere to the troposphere with relevance to climate*
  - *Observed trends in the entire atmosphere: anthropogenic versus natural forcing*
- *Start in spring 2013, 3 years, several million Euro*

HUNGARY:

Name of the National Adherent Representative: András Ludmány
Institution: Research Centre for Astronomy and Earth Sciences, Hungarian Acad. Sci.
Country: Hungary
Reported Period: 2012

1. Size of the Hungarian National STP community: 6 institutes, 30 members

2. Institutions participating in this STP activity (with the number of involved active members)

Eötvös University (ELTE),
member institutes: Department of Astronomy (2)
Space Research Group (4)

Hungarian Geological and Geophysical Institute
member institute: Eötvös Loránd Geophysical Institute (ELGI) (3)

Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences,
Member Institutes: Konkoly Observatory, Budapest (KO) (3)
Heliophysical Observatory, Debrecen (6)
Geodetic and Geophysical Research Insitute (GGKI), Sopron (6)

Wigner Research Centre for Physics, Hungarian Academy of Sciences
member institute: Department of Space Physics (6)

3. Main topics of the STP research carried out nationally

- Solar physics: sunspot activity, fast tachocline model, magnetic flux emergence, magnetic topologies, cycle analysis and prediction, forecast of flares and CMEs, slow and fast solar

winds, solar irradiance, detailed sunspot catalogues,
- Space physics: propagation of electromagnetic waves, VLF waves, automatic detection of whistlers, interplanetary magnetic fluxes,
- Geophysics: ionospheric research, Schumann resonances, telluric currents, geomagnetic activity, pulsations,

4. A summary of STP research carried out during the reported period

ELTE Dept.Astronomy
- It has been cofirmed that the flux transport dynamo and the fast tachocline scenario can be compatible (Karak, B.B., Petrovay, K. 2013, Solar Phys. 282, 321)
- Structure of the heat transport in sunspot umbrae has been described by small-scale convection, narrow convective columns (Tian, C., Petrovay, K., 2013, A&A, 551, 92T)

ELTE Space Research Group
- An exact full-wave modeling is presented for the electromagnetic signals propagating through curved space-time. (Ferencz, Cs., 2012, Radio Science, doi:10.1029/2011RS004905)
- Two VLF phenomena 'hiss' and 'chorus' have been observed simultaneously during a moderate geomagnetic storm and their possible connection has been investigated (Delport et al. with Lichtenberger, J, 2012, JGRA, 117, 12218)
- The international effort, PLASMON, provides plasmaspheric electron and mass densities for models describing the relativistic electron precipitation (Lichtenberger et al., 2012 EGUGA, 8106)

ELGI
- The temporal and spatial intermittency of the plasma fluctuations has been investigated statistically in the foreshock region by using Cluster data (Kovács et al, 2012 EGUGA, 13231)
- Reversed interhemispheric asymmetries of geomagnetic Pc3 (Pc4) pulsations have been observed near solar maximum probably due to the anomalously high F2 region electron density (Heilig et al. 2012, EGUGA, 10341)

KO
- Conncetions are identified between solar- space- and geophysical appearances of Gleissberg, Schwabe and 5.5 year signals (Kolláth et al., 2012 IAUS286, 423)
- Detailed description of a twisted emerging magnetic field is given by using nonlinear force-free extrapolation and multi-wavelength observations (Valori et al., 2012 So.Ph. 278, 73)
- High temporal and spatial resolution multi-wavelength observations are used for a new method for the determination of mass of prominence material (Williams, D., 2013, ApJ, 764, 165)

Heliophys.Obs.
- Detailed descriptions of the properties of sunspot group development became possible by using the new SDD sunspot database: leading-following asymmetries, distances, time profiles and tilts (Muraközy J. et al, 2012, CEAB, 36, 1)
- The behaviour of solar active longitudes is proven to be independent of the cyclic variations (Gyenge,N. et al, 2012, CEAB, 36, 9)
- Evidences were found about the impact of active region properties on the irradiance variations (Baranyi, T., Pap, J., 2012, Ad.Spa.Res. 50, 676)

Wigner Dept.Space Phys.
- The magnetic flux density at 1 AU has been found to be independent of location and solar wind type after removing the fluctuating component (Erdős, G., Balogh, A., 2012, ApJ, 753, 130)

- The distribution of directional discontinuities in the heliospheric magnetic fields are found to be independent of latitude but decreasing with radial distance, this may indicate that they are formed close to the Sun (Lukács, K., Erdős, G., 2012, 9480)
- Three different particle populations and acceleration processes have been distinguished in the solar wind during quiet periods of cycle 23 (Ishkov et al. with Kecskeméty, K., 2012, Ad.Spa.Res. 50, 757)

5. Outreach Activities

- Long Night of the Sciences, 28 Sept, 2012
  Debrecen University - Space programs with participants from Debrecen
- Living with a Star, Cervantes Inst. Budapest 24 Feb, 2012 (H. Socas Navarro - IAC Tenerife, Lichtenberger J., Petrovay K. ELTE, Farkas Bertalan)

6. Capacity Building Activities

Numbers of current studentships:

Solar physics: 3 PhD students (sunspot activity; flare forecast), 2 undergraduate students (oscillator models of solar cycle; relationships of solar activity indicators)

Space physics: 1 PhD student (relativistic particles in the plasmasphere)

Participations in the ESA student program, BEXUS (Balloon EXperiments for University Students): TECHDOSE project for dosimetric measurements in the polar stratosphere (8 participating university students with a background of two universities and two research institutes)

7. Participation in National/International conferences in 2012:

- 26th NSO Workshop, "Solar Origin of Space Weather and Climate" Sacramento Peak, NM, May, (two scientists, four presentations)
- Hvar Astrophysical Colloquium, Sept., Hvar, Croatia (four scientists, three presentations)
- eHEROES, FP7 project, kickoff meeting (three scientists, two presentations), Rome, Italy, March,
- IAU General Assembly and Symposium 294 (one scientist, SOC member, 2 presentations), Aug 2012
- ISSI Forum on Solar Activity, Bern, Nov 2012
- PLASMON, FP7 project, ann. meeting (2 scientists, 5 presentations) Hermanus, South Africa, Jan.

8. How many have been supported by SCOSTEP/CAWSES

No participations have been supported by SCOSTEP/CAWSES.

9. International Collaborations and Initiatives

- eHEROES, "Environment for Human Exploration and RObotic Experimentation in Space", FP7 project (European Seventh Framework Program) with 15 European institutes, among them one Hungarian institute, 7 participants.
- PLASMON, a FP7 project coordinated by the ELTE Space Research Group. A new, ground based data-assimilative model of the Earth's Plasmasphere - a critical contribution to Radiation Belt modeling for Space Weather purposes. 11 participating institutes, including two Hungarian institutes.

10. Current and upcoming missions and campaigns, in which the respective National STP community

participates

11. Future plans (besides the continuation of the current programs)

- Participation in the revision of the International Sunspot Number (ISSN), a series of workshops, an international effort.
- Establishing as long datasets as possible from the existing separate datasets and historical observations in solar, geophysical and space physics.

INDIA:

National Report on STP-related activities

Name of the National Adherent Representative: Prof. A. Bhattacharyya

Country: India

Reported Period: 2012

1. Introduction

The STP community in India is actively involved in the investigation of various facets of the complex connected Sun-Earth system, using a variety of ground- and space-based observations, and theoretical modeling. The unusual extended solar minimum between solar cycles 23 and 24, its influence on the state of the heliosphere, and on geospace, in particular, continued to be major topics of research for solar physicists and scientists who study solar-terrestrial relations. The extended quietness of the Sun also turned the attention of the ionopsheric and atmospheric scientists to forcing of the ionosphere-thermosphere system from below and the coupling of different regions of the atmosphere. Understanding the 'quiet time' variability of the ionosphere-thermosphere system is an important component of space weather, as it is required for delineating effects of transient events on the Sun.

The national component of the second phase of the SCOSTEP program on 'Climate and Weather of Sun-Earth System (CAWSES)', supported by the Indian Space Research Organization (ISRO), has around 40 on-going projects related to three science themes: (1) Solar influence on climate (0-100 km); (2) Space weather and climate: Science and applications; (3) Atmospheric coupling processes. Under Theme 1, solar cycle effects on surface temperature, tropopause temperature and monsoon circulation, and also the solar influence on Indian Summer Monsoon rainfall have been studied. Prediction of magnetic substorms using a state space model, a prediction model for ionospheric parameters and precursors for the development of equatorial plasma bubbles have been the focus of several studies under Theme 2. Influence of polar winter disturbances on tropical atmosphere-ionosphere system has been studied for several sudden stratospheric warming (SSW) events under Theme 3, as also the differences between the tropical tropopause in the Indian region and other tropical stations.

2. Organizations involved in STP activities in India

Major centres for STP activities in India include several national institutions and universities some of which are listed here.

Physical Research Laboratory (PRL), Ahmedabad & Udaipur Solar Observatory (USO)
Space Physics Laboratory (SPL), Vikram Sarabhai Space Centre, Trivandrum
Radio Astronomy Centre, National Centre for Radio Astrophysics (NCRA), Pune
National Atmospheric Research Laboratory (NARL), Gadanki
Indian Institute for Science Engineering and Research, (IISER), Pune
Indian Institute for Science Engineering and Research, (IISER), Kolkata

Indian Institute of Geomagnetism (IIG), Mumbai
Indian Institute of Astrophysics (IIA), Bangalore
National Physical Laboratory (NPL), New Delhi
Indian Institute of Tropical Meteorology (IITM), Pune
Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital
Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune
Andhra University (AU), Waltair
Barkatullah University (BU), Bhopal
Banaras Hindu University (BHU), Varanasi
Dibrugarh University (DU), Dibrugarh
Saurashtra University (SU), Rajkot
S.K. Mitra Centre for Research in Space Environment, University of Calcutta (CU)
University of Kerala (KU), Thiruvanathapuram
University of Lucknow, (UL) Lucknow

3. Research areas covered

The main topics of STP research in India are in the following areas:

(1) Solar physics (solar dynamo studies, modeling & simulations, instabilities related to eruptive activity, helio-seismology, radio, optical and magnetic observations of sunspots, solar flares, etc.).

(2) Interplanetary medium (Interplanetary radio scintillations, propagation of coronal mass ejecta (CMEs), magnetic clouds and their interaction with Earth's magnetosphere).

(3) Magnetosphere-Ionosphere coupling (Optical, radio, and magnetic measurements of the effects of magnetic storms and substorms; prompt penetration and disturbance dynamo effects on equatorial and low-latitude ionospheres).

(4) Ionospheric / thermospheric studies (electrodynamics of the equatorial and low latitude ionosphere, generation of plasma irregularities in the equatorial ionosphere, etc.)

(5) Atmospheric coupling processes with emphasis on forcing from below.

4. Summary of STP research carried out in India

4.1 Sun, solar wind and interplanetary medium

A major effort is underway to understand the dynamo origin of solar magnetic fields and in developing computational algorithms for constraining the mechanisms of solar eruptions. This year, the implications of the unusual minimum of solar cycle 23 for the heliospheric environment were explored. The results highlighted that even small adjustments in the plasma flows in the solar interior can profoundly impact solar activity and consequently the state of the heliosphere (**IISER - Kolkata**).

The interplay of diverse magnetic flux transport processes in the solar interior is known to govern the memory of the solar cycle. This memory eventually leads to the possibility of solar cycle predictions. A stochastically forced solar dynamo model was used to demonstrate that the inclusion of turbulent pumping -- a hitherto ignored process in predictive dynamo models, reduces the memory of the solar dynamo to only one-half cycle. This implies that reliable predictions of the strength of the solar maximum can only be possible at the preceding minimum and that accurate, long-term solar cycle forecasts are implausible (**IISER - Kolkata**).

Techniques for quantifying the magnetic properties of solar active regions that lead to magnetic instabilities and eruptive activity are being developed. Specifically, a technique, which can observationally constrain the twist in the magnetic field lines of solar active regions and assess whether they are kink unstable or not, has been devised. This technique does not rely on the questionable force-free assumption (of sunspot magnetic structures) and is thus an improvement over previous algorithms. Kink instability is thought to be behind large-scale magnetic flux rope ejections in the form of coronal mass ejections (CMEs). This technique is currently being tested on solar data using the Hinode SOT and XRT instruments through studies of sunspot structures and eruptive X-ray sigmoids (**IISER - Kolkata**).

The primary objective of the 2-m National Large Solar Telescope (NLST) proposed by the Indian Institute of Astrophysics is to study the solar atmosphere with high spatial and spectral resolution. With an innovative optical design, NLST is an on-axis Gregorian telescope with a low number of optical elements to reduce the number of reflections and yield a high throughput with low polarization. In addition, it is equipped with a high order adaptive optics that works with a modest Fried's parameter of 7-cm to produce close to diffraction limited performance. To control atmospheric and thermal perturbations of the observations, the telescope will function with a fully open dome, taking advantage of the natural air flush to achieve its full potential atop a 25 m tower. Given its design NLST can also operate at night, without compromising its solar performance. The post-focus instruments include broad band and tunable Fabry-Perot narrow band imaging instruments; a high resolution spectro-polarimeter and an Echelle spectrograph for night time astronomy. The main science goals of NLST include: a) Magnetic field generation and the solar cycle; b) Dynamics of magnetized regions; c) Helioseismology; d) Long term variability; e) Energetic phenomena and Activity; and f) Night time astronomy. Critical to the successful implementation of NLST is the selection of a site with optimum atmospheric properties, such as the number of sunshine hours and good "seeing" over long periods. A site characterization programme carried over several years has established the existence of suitable sites in the Ladakh region. After its completion, currently planned for 2016, NLST will fill a gap in longitude between the major solar facilities in the world and will be for some years the largest solar telescope in the world **(IIA).**

Systematic observations at 327 and 236 MHz, coordinated with the Nancay Radio-heliograph (NRH), France, have been carried out on several occasions at the Giant Meter-wave Radio Telescope (GMRT) located near Pune, India, to observe the quiet sun with an aim to produce composite synthesis maps from NRH and GMRT, with both wide field of view and high spatial resolution. After several years of efforts, a method has been developed, in collaboration with scientists at the NRH, to combine the two sets of visibilities and obtain a spectacular increase in the quality and dynamic range of solar images at several frequencies. In principle, imaging noise storms in order to describe both their structure and their relation with photospheric or coronal structures would require a) a field of view wider than the sun (it is usual that two or more widely separated and intense sources are simultaneously present, b) a resolution better than their typical apparent size and c) simultaneous observations at several frequencies over their bandpass. Until now these conditions were never fulfilled simultaneously: the field of view of the NRH is larger than the sun but their resolutions are ~1 arcmin at best. Conversely, the resolutions for the VLA in its extended (A) configuration and for the GMRT can be 5-10 times better but they lack short baselines, which results in aliasing of noise storms sources. The VLA in its compact (C) configuration has short baselines, but its resolution is not much better than ~1arcmin. This explains why the structure of noise storms is still poorly known: in most studies, images have resolutions ~1 arcmin or larger, comparable to the size of the sources, and were not simultaneously produced at several close frequencies. Results from this study are: (i) storms are produced in regions much denser than the ambient corona; (ii) the structure of source at one frequency is now resolved and can be as small as ~15 arcsec at 327 MHz. The observations also show that the size of noise storm sources may significantly change from one case to another. Such changes cannot be explained by propagation effects and indicate that the resolution of the observations allows identification of the intrinsic features of the structure of storm sources; (iii) these multi-frequency observations have provided values for the scale height of the electron density distribution in noise storm sources that are significantly less than in the ambient corona (which corresponds approximately to a hydrostatic equilibrium at temperature ~1.5 MK). This implies that the source regions emitting at different frequencies *are not magnetically connected*. This contradicts the classical columnar model and questions the currently used theories for emission mechanisms, which imply magnetic trapping of supra-thermal electrons (**PRL, IISER - Pune**).

An international campaign on 'Whole Heliosphere Interval (WHI)' has been made to study the three-dimensional 'solar-heliospheric-planetary' connected system near the solar minimum of cycle 23. The observation and model correspond to the solar Carrington rotation 2068, which covered the period 20 March – 16 April 2008, extending from below the solar photosphere, through interplanetary space, and down to earth's mesosphere. Nearly 200 people participated in different aspects of WHI studies, analyzing and interpreting data from nearly 100 instruments (Ooty Radio Telescope also participated in this study) and modeling in order to elucidate the physics of fundamental heliophysical processes. The solar and inner heliospheric data showed structure consistent with the declining phase of the solar cycle. A closely spaced cluster of low- latitude active regions was responsible for an increased level of magnetic activity, while a highly warped current sheet dominated heliospheric structure. The geospace data revealed an unusually high level of activity, driven primarily by the periodic impingement of high-speed streams. The WHI studies traced the solar activity and structure into the heliosphere and geospace, and provided new insight into the nature of the interconnected heliophysical system near solar minimum **(NCRA).**

The 3-D evolution of solar wind density turbulence and speed has been investigated at various levels of solar activity between solar cycles 22 and 24. The solar wind data used in this study has been obtained from interplanetary scintillation (IPS) measurements made at the Ooty Radio Telescope, operating at 327 MHz. Results show that on the average, there was a downward trend in density turbulence from the maximum of cycle 22 to the deep minimum phase of cycle 23. The latitudinal distribution of solar wind speed was significantly different at the minimum phase of cycles 22 and 23. At the transition phase between cycles 23 and 24, the high levels of density and density turbulence were observed close to the heliospheric equator and the low-speed speed wind extended from equatorial- to mid-latitude regions. The above results in comparison with Ulysses and other in-situ measurements suggest that the source of solar wind has changed globally in the prolonged period of low level of solar activity during cycle 23, with an important implication that the supply of mass and energy from the Sun to the interplanetary space has significantly reduced. The IPS results are consistent with the onset and growth of the current solar cycle 24, starting from middle of 2009. However, recent IPS measurements show that the width of the high-speed wind at the north polar region has almost disappeared, indicating that the ascending phase of the current cycle has almost reached close to the maximum phase in the northern hemisphere of the Sun. But, in the southern part of the hemisphere, the solar activity has yet to develop and/or increase **(NCRA).**

The characteristics of 46 radio-loud (RL) CMEs, that occurred during 1997-2006, have been investigated. These radio-loud events were associated with intense x-ray flares of M and X classifications. Nearly 57% of them (26 out of 46 events) had good connectivity to the near-earth space and solar energetic particles (SEPs) caused by them were observed at 1 AU. The link between flare accelerated electrons (i.e., integrated radio flux density) and observed proton flux at 1 AU shows a positive, but small correlation of ~ 30%. It suggests a possible connection between the injection sites of both electrons and protons, which are most likely accelerated at the turbulent/high temperature flare current sheet. However, the relationship between the CME speed and peak proton flux (>10 MeV) at 1 AU shows a correlation of ~ 60%, which indicates the acceleration of protons by the shock moving in front of the CME. Moreover, when the CME speed is compared with the proton flux, two distinct groups of SEP events, showing significant differences in characteristics, are evident. For instance, the SEP events of relatively high flux with low-speed CME show impulsive rise and larger peak of proton flux, whereas the other group is associated with gradual rise and lesser peak proton flux. Results suggest that in the first group, initial flare and CME energies are involved in the acceleration of particles. However, in the case of gradual SEP events, CME-generated shock seems to play an essential role in the particle acceleration **(NCRA).**

A comprehensive understanding of the so-called Sun-Earth connection and of the impact of CME-driven geomagnetic storms in particular, is of great practical importance. The physical issues underlying this so-called Sun-Earth connection, even when viewed from the restrictive vantage point of geomagnetic disturbances, are quite complex. In a recent work carried out in collaboration with Mexican scientists, an important breakthrough has been made in understanding the manner in which CMEs propagate through the interplanetary medium between the Sun and the Earth. Physical processes responsible for the drag force acting on fast CMEs, which slows them down after they leave the Sun, have been analyzed to obtain a drag prescription that can be used profitably in sophisticated numerical simulations of CME propagation to obtain accurate predictions of Sun-Earth travel times. This will be a vital component in a reliable warning system for geomagnetic storms (**IISER - Pune**).

The kinematics and dynamics of CMEs in interplanetary medium particularly along the Sun-Earth line is a topic of significant interest to solar terrestrial physics community. Previous work on kinematics of CMEs includes development of statistical and empirical models to derive the propagation profiles of CMEs between the sun and earth. However, these models are based on comparison of data taken at two points - near the sun as CME and near the earth as Interplanetary Coronal Mass Ejections (ICME). Furthermore, the identification of ICMEs near the earth is not straightforward because there is no single or a combination of clear signatures. Therefore, for a better understanding, an attempt was made to track some of the observed CMEs from near the sun to beyond 1 AU along a suitable position angle, particularly in the sun-earth line for geo- effective events. For this purpose, images from coronagraph COR2 and Heliospheric Imagers HI1 & HI2 instruments onboard STEREO were used. These instruments provide coverage over solar elongation angle from 0.7 to 88.7 degrees at the viewpoints of two spacecrafts. Present work at USO is focused on combining the remote sensing observations by STEREO/COR and STEREO/HI with in-situ data from near earth spacecraft (ACE, WIND and STEREO) to derive kinematics and true propagation direction of ICMEs. For this purpose, the CMEs were tracked in the inner heliosphere, by constructing time elongation map (J-map). The purpose of this study is to understand the propagation of CMEs, their arrival time, testing and also refining the existing models of CME propagation profiles. This study is aimed at estimation of the arrival time of Earth-directed CMEs and its comparison with the estimated value from *Drag Based Model* **(USO).**

CMEs associated with solar filaments cause gigantic clouds of solar plasma to escape from the Sun into the heliosphere, causing intense geomagnetic storms. In interplanetary medium, these structures maintain their three part similarity to CMEs and are termed as ICMEs. In rare cases, when sampled in-situ by spacecraft, the presence of dense, cold ejecta is observed in ICMEs which is believed to be associated with erupting filaments. This filament plasma retains its “frozen-in” compositional, magnetic and thermal properties and provides a unique way to investigate the environment of their origin. Two cases of observed filament plasma embedded in ICMEs were studied: one related to a flare-associated eruptive filament (18 November, 2003) and other a quiescent filament eruption (1 August, 2010) at different phases of solar cycle by using plasma, magnetic and compositional parameters. Plasma properties such as low temperature, high proton and electron densities coincided with pressure balanced regions in magnetic clouds, along with compositional signatures such as depressed ion charge states, high ion and helium densities, and presence of He+ ions. These were used to locate filament plasma. In interplanetary medium, the magnetic cloud is identified by its high magnetic field strength, low plasma beta and changing elevation and azimuth angles. Depression in the magnitude of D_{st} index gives the measure of associated geomagnetic storm. High proton and electron densities with low corresponding temperatures indicate embedded filament plasma, within and outside magnetic cloud. The decreasing trend in bulk velocity indicates the expansion of magnetic cloud. The studied ICMEs appear to have a mixture of cold and hot plasma with presence of He+ ions. The rarity of finding cold, low charge state ions at 1 AU as filament plasma suggests partial ionization of elements during transit through corona. The fact is that filament material is regularly observed in ICMEs at 1 AU but is not recognized as such because it is no longer distinguished as ionizationally cold **(USO).**

During the period of this report, the upgrade of the Ooty Radio Telescope (ORT) has been completed. In particular, all the required RF subsystems (264 numbers of stage-1 amplifiers, stage-2 amplifiers, as well filters for each of the amplifiers) were fabricated. Installation of these RF systems for Phase 2 of the ORT upgrade has been done on the telescope feed as well as at the bottom of the telescope in record time. Optical fiber connectivity has been established among the newly installed systems and signals are brought into the ORT receiver room. The new system is stable and working well with the existing analog chain. Development of software to correlate signals from the 264 elements (each of 2-m section of ORT) is in progress. The sensitivity of the telescope is tracking well. Now the ORT system has a new lease of life, with the wide field of view as well as a much improved sensitivity. The new capacity of the ORT provides impetus to initiate various studies, such as pulsar observations, cosmological studies, spectral-line studies, in addition to solar and space weather observations **(NCRA).**

Cosmic ray data from the GRAPES-3 muon telescope at Ooty has been used to investigate the tructure of CMEs and their associated shocks near the Earth. For the first time, multi-rigidity data from a single instrument has been used to investigate the origin of high rigidity cosmic ray Forbush decreases observed at the Earth. It has been conclusively established that such Forbush decreases occur primarily due to the cumulative diffusion of cosmic rays into the CME as it travels from the Sun to the Earth (**IISER - Pune**).

4.2 Solar flare effects, Solar wind-magnetosphere-ionosphere interactions, interplanetary drivers, magnetic storms and substorms.

Interplanetary shocks (IP) are mainly responsible for the sudden compression of magnetosphere causing storm sudden commencement (SC) and sudden impulses (SI) which are detected by ground based magnetometers. Based on the list of 222 IP shocks compiled by *Gopalswamy et al.* [2010], the dependence of SC/SIs amplitudes on the speed of the CMEs that drive the shocks near the Sun as well as in the interplanetary medium has been investigated. For each SC event, the onset time is determined from the H component geomagnetic variation in the rapid sampling records (with the time resolution of 1 min) obtained at Alibag (ABG) (geographic latitude 18.62°; geographic longitude 72.87°; geomagnetic latitude 10.32°) magnetic observatory of Indian Institute of Geomagnetism (IIG). Only those SC/SIs events that temporally correspond with the IP shock timings have been selected. The SC events have been taken from the available geomagnetic data yearly bulletins which are published by IIG. It is found that about 91% of the IP shocks were associated with SC/SIs. The average speed of the SC/SI associated CMEs is 1015km/s, which is almost a factor of 2 higher than the general CME speed. When the shocks were grouped according to their ability to produce type II radio burst in the interplanetary medium, it was found that the radio-loud (RL) shocks produce a much larger SC/SI amplitude (average ~32 nT) compared to the radio-quiet (RQ) shocks (average ~ 19 nT). Clearly, RL shocks are more effective in producing SC/SIs than the RQ shocks. The IP shocks were also divided according to the type of IP counterpart of CMEs (ICMEs): magnetic clouds (MCs) and non-magnetic clouds. It was found that the MC- associated shock speeds are better correlated with SC/SI amplitudes than those associated with non-MC ejecta. The SC/SI amplitudes are also higher for MCs than Ejectas (EJs) **(IIG).**

Co-rotating interaction region (CIR) induced magnetic storms, which occurred during solar minimum, are investigated to study their effects on equatorial and low latitude ionosphere and geomagnetic field in the Indian sector. This work was a part of Indian CAWSES campaign for the period of March – April 2006. The penetration electric fields play a crucial role in modifying equatorial electric fields during severe magnetic storms and these effects are not studied in detail for moderate magnetic storm originated by CIRs. Effects of CIR related moderate storms were investigated and it was found that during moderate magnetic storms, the short lived (duration of 2 - 3 h) penetration of high latitude electric fields to equatorial ionosphere exists during local morning and noon hours during main phase as inferred from changes in the equatorial electrojet (EEJ) in response to interplanetary electric field (IEF) variations. The variations of EEJ are linearly correlated with the sudden changes in IEFY around morning to noon hours, which confirms existence of the penetration of electric fields **(IIG).**

A case of drastic effects of an eastward prompt penetration and a westward over-shielding electric field successively affecting the daytime equatorial ionosphere during a space weather event showed that under the influence of the strong eastward prompt penetration electric field, the EEJ strength reached a value of 225 nT, almost 7 times greater than the monthly quiet time mean at the same time. This peak EEJ value exceeds the maximum observed values during the month for the entire solar cycle, by more than 100 nT. Further, owing to an ensuing over- shielding event that occurred during the main phase of the storm rather than the end of the main phase, this unusually large EEJ showed an equally strong polarity reversal along with a weakening of the sporadic E-layer over equator. The EEJ strength got reduced from +225 nT to -120 nT resulting in a strong counter electrojet (CEJ) condition. The latitudinal variation of the F- region electron density data from the CHAMP satellite also revealed an ill-developed equatorial ionization anomaly over Indian sector due to this significant weakening of the zonal electric field. These observations showcase the significant degree to which the low latitude ionosphere can get affected by the IEF. (**PRL, IIG, SPL, University of Kerala**).

During daytime, the primary zonal electric field generated by the E region dynamo is the key for several equatorial electro-dynamical processes such as the EEJ, equatorial ionization anomaly (EIA), pre-reversal enhancement of electric field (PRE) and formation of additional F3 layer, etc. It is well known that the primary zonal electric fields undergo severe modifications during geomagnetic storm periods due to processes such as overshielding/undershielding prompt penetration electric fields and ionospheric disturbance dynamo. A number of earlier studies during geomagnetic storm periods also demonstrated the intensification/inhibition of EIA at F- region altitudes due to eastward/westward zonal electric field perturbations as inferred from EEJ observations at E-region altitudes. Hence, it is fairly believed that the induced electric field perturbations would be similar, at least in their polarity, at both E and F region altitudes. Present results show first observational evidence for simultaneous existence of daytime westward and eastward zonal electric fields at equatorial E- and F-region altitudes, respectively, in a wide longitude sector during the geomagnetic storm on 15 December 2006. While the westward electric fields at E region altitudes cause westward electrojet, at the same time, the eastward zonal electric fields at F-region altitudes reinforce the EIA even in the topside ionosphere (~660 km). Reversal of the electric fields is found to occur at ~280 km height. A clear bifurcation of F region plasma at ~280 km is evident in the iso-electron density contours due to these oppositely polarized zonal electric fields, which manifests as an unusually deep cusp between F1 and F2 layers on equatorial ionograms (**IIG, SPL, Andhra University**).

An impact of a magnetic cloud on the Earth's magnetosphere occurred at 1636 UT on 25 June 1998 associated with the sudden increase of the solar wind density, velocity and southward component of interplanetary magnetic field (IMF-Bz), which subsequently turned northward. During the positive phase of IMF-Bz, both the Auroral index (AE) and ring current index SYM- H remained steadily low indicating complete isolation of the Earth's magnetosphere from the solar wind and no significant changes were observed in the equatorial ionosphere. Subsequently, the southward turning permitted solar wind energy to penetrate the magnetosphere which caused a magnetic storm associated with strong auroral electrojet activity. Strong southward IMF-Bz corresponds to the dawn-dusk interplanetary electric field (eastward on the dayside and westward on the night side). The ionograms at Jicamarca (night side) showed strong spread-F and at Thumba (dayside) showed absence of equatorial type of sporadic-E, indicating dusk to dawn electric field. Thus, the observations point to electric field which is opposite in direction than what is expected by the prompt penetration of interplanetary electric field **(PRL, SPL).**

Geomagnetic storms give rise to latitudinal and longitudinal gradients in temperatures and electron densities which result in the redistribution of energy and momentum across various latitudes. During one such event (D_{st} = -300 nT) ground-based optical daytime thermospheric measurements over a wide field-of-view indicated a steady propagation in the emission brightness from high- to low-latitudes. Latitudinal total electron content on that day showed an inter-hemispheric asymmetry, indicating a strong equatorward wind. However, no enhancement in electron density was observed. Forward modeling carried out using inputs by varying composition and temperature to the physics based photochemical model indicate that O/N_2 values of around 0.6 – 0.8 and a 30% enhancement in the neutral temperature are required to match with the observations. These values agree reasonably well with the Thermosphere Ionosphere Mesosphere Electrodynamical Coupled Model (TIMEGCM) calculations. Results such as these provide insights into the energy distribution in the upper atmosphere during space weather events **(PRL).**

Magnetospheric substorm is primarily a night-side phenomenon. However, based on a case study, it was shown that the eastward electric field associated with the onset of the expansion phase of a magnetospheric substorm caused positive bay disturbances in the deviations of the northward component of magnetic field (ΔH) over Indian low latitude stations in the noon sector and also at the stations in the 210° magnetic meridian (MM) magnetometer network in the afternoon sector. The onset of the susbtorm caused characteristic signatures in the global storm/substorm indices as well as in the energetic particle fluxes measured by the Los Alamos National Laboratory 1991–080 satellite at geosynchronous altitude. The OI 630.0 nm dayglow intensities over two low latitude stations also registered enhancements during this period (1124–1205 Indian Standard Time (IST); IST = UT + 5.5 h). The investigation adduced the response of 630.0 nm dayglow intensities over low latitudes corresponding to the onset of the expansion phase of an auroral/magnetospheric substorm. Modeling work is now underway to understand V the causative mechanism for the enhancement in the 630.0 nm dayglow intensity under the influence of eastward electric field perturbation. Further, the mechanism through which the susbtorm phenomenon affects the dayside low latitude ionosphere is also being investigated **(PRL, IIG).**

The impact of the transient changes in the solar EUV flux (0.1-50 nm) associated with a few lesser rank (M, C and B classes) X-class solar flares on the E-region of the low latitude ionosphere is investigated. The lesser rank X-class solar flare events occurring under magnetically quiescent conditions during 2005-2010 are selected for this investigation. The solar flare events left their imprints in the form of enhancements in the EEJ strength irrespective of normal or counter electrojet (CEJ) conditions and high precision magnetic measurements facilitated this detection. This investigation suggested that these enhancements in the EEJ strength are primarily due to the enhancements in the E region ionization density. However, the plausible role of the solar quiet time ionospheric electric field in defining the magnetometer signatures corresponding to solar flares is being investigated **(PRL, IIG)**.

In addition to the transient changes, the changes in the mean level of the EUV flux (0.1-50 nm) on the low latitude ionosphere during the deep minimum between solar cycles 23 and 24, is also investigated. It is observed that the rate of decrease of the mean level of solar EUV flux during the declining phase of solar cycle 23 is comparable with the corresponding rate of increase during the ascending phase of solar cycle 24. However, the rate of increase of the mean TEC level over Rajkot (22.29°N, 70.74°E, 31.6°N dip angle) is found to be greater at the beginning of the solar cycle 24 compared to the rate of decrease during the declining phase of the solar cycle 23. This anomalous behavior in TEC is attributed to the important roles played possibly by the residual (difference between annual averages) effects of the trans-equatorial wind and compositional changes over this time scale. It is verified that the inherent solar periodicity of around six months has no consistent causal connection with the semi-annual variation in TEC. A few spectral differences are also observed between the EUV flux and F10.7 cm (2800 MHz) flux. The annually averaged peak TEC value over Rajkot is found to be well-correlated (R = 0.98) with the corresponding annually-averaged F10.7 cm flux during 2005-2009. Statistical analyses also indicate that the time of occurrence of maximum TEC over Rajkot changes randomly during 2005-2009 indicating the possible role played by the processes related to the residual trans-equatorial wind over the years **(PRL, Saurashtra University).**

GPSTEC data at 4 stations over Indian longitudes are used to investigate ionospheric F region response to the X ray and UV flux changes during flare events of different classes. The study reveals that : (1) UV flux enhancement depends on both intensity of flare and its position on the solar disk while X-ray flux enhancement depends only on the intensity of the flare irrespective of its position on the solar disk; (2) The E region response to flare events for X and M class flares as seen in geomagnetic field is directly related to the X ray flux enhancement and it does not show any relationship with UV flux; (3) The geomagnetic field response does not show any limb effect confirming that it is being controlled by the X-ray flux which does not exhibit limb effect; (4) F region response to flares as seen in TEC shows limb effect indicating the UV flux control on the same; (5) The TEC response to flares is greater at equatorial regions during winter and equinox than at low latitude stations towards the north, whereas during summer it is greater at northern low latitude regions compared to equatorial regions. This is an effect of the variation of solar zenith angle and consequent modulation of production rate **(SPL).**

Modulation of the seasonal pattern of the threshold height and the seasonal mean O/N_2 values are investigated using Ionosonde data from a magnetic equatorial and off equatorial location in the Indian longitude sector, during winter and equinox seasons of 2002 (solar maximum) and 2005 (low solar activity). The O/N_2 data obtained through TIMED/GUVI during summer, equinox and winter seasons of low solar activity period and solar maximum have been used for the study. The study reveals that during solar minimum, the disturbed period threshold height ($h'F_C$) is least for summer, with comparable values for winter and equinox, while during solar maximum, the above threshold height is higher for equinox than for winter. The O/N_2 values also show similar variation. Another important aspect that has emerged from this study is the substantial increase of threshold height with magnetic activity for all the seasons examined. The modulation of h'F_C by neutral density changes is found to be valid irrespective of season, solar or magnetic activity **(SPL).**

Obliquely propagating ion-acoustic solitary waves are examined in a magnetized plasma composed of kappa distributed electrons and fluid ions with finite temperature. Using a quasi-neutrality condition it is possible to reduce the set of equations to a single equation (energy integral equation) which describes the evolution of ion-acoustic solitary waves in magnetized plasmas. The temperature of warm ions affects the speed, amplitude, width, and pulse duration of solitons. Both the critical and the upper Mach numbers are increased by an increase in the ion temperature. The ion-acoustic soliton amplitude increases with the increase in super-thermality of electrons. For auroral plasma parameters, theoretical predictions of soliton speed, amplitude, width, and pulse duration are in good agreement with Viking observations **(IIG).**

The ion temperature anisotropy instabilities in planetary magnetosheaths are studied. The fully kinetic electromagnetic dispersion relation is solved numerically using the WHAMP (Waves in Homogeneous Anisotropic Multi-component/Magnetized Plasma) code to study the growth rates and dispersion properties of the two major low frequency temperature anisotropy instabilities, mirror and ion cyclotron anisotropy instability, in planetary magnetosheath regions. The role of plasma electron temperature anisotropy on the ion cyclotron and mirror mode instabilities is studied and it is shown that inclusion of anisotropic electrons reduces the ion cyclotron growth rate substantially and increases the mirror mode growth rate even for a low beta plasma and could possibly explain the mirror structures found in low beta magnetopause regions **(IIG).**

Cluster spacecrafts have revealed bipolar electrostatic solitary waves (ESWs) at different magnetospheric boundary layers, including the magnetosheath and the cusp. The wave amplitudes are typically of 0.04-1 mV/m and the pulse durations are 0.05 to 1.3 ms. The origin and the generation mechanisms of these waves are yet to be understood. It was previously shown that, the presence of minority components of He^+ ions prohibits the formation of regularly shaped smooth electron acoustic solitary waves and a singularity occurs for the relevant parameter regime. It is now shown that inclusion of ion inertia eliminates the singularity and may offer an workable model for the observed ESWs **(IIG).**

4.3 Ionosphere-thermosphere-mesosphere coupling and dynamics at low latitudes

Evidence is obtained for a shear in the zonal plasma flow and for a tilted plume structure simultaneously, using collocated optical and radar measurements. A multi-wavelength photometer with a narrow band-width (0.3 nm) and a narrow field-of-view (3°) was operated to measure airglow emissions from two different altitude regions in a bi-directional mode along the zonal direction. The identifiable features in the 630.0 nm airglow emission that originate from the base of the F region, moved westward while the similar features in the 777.4 nm airglow emission, that originate from around the peak height of the F layer, moved eastward. This indicates a shear in the zonal plasma flow. Simultaneous measurements of equatorial plasma irregularity structures using a VHF radar reveal the presence of C-shaped plume structure during the period of the sheared flow. This investigation provides experimental evidence for the existing theories **(PRL).**

Many a times, using the Radio Beacon (RaBIT) onboard Indian satellite YOUTHSAT, measurements of Total Electron Content (TEC) during nighttime show large modulations therein. As is known, the electron density depletions also known by the generic name 'ESF', are usually present in the equatorial ionosphere during nighttime, and indeed produce these modulations in the observed TEC. Therefore, a simulation study was carried out to understand the extent of modulations these density depletions can produce in the TEC. For the simulations, an overhead RaBIT path was simulated and the night time electron densities were obtained from the IRI model. Further in this model ionosphere, plasma density depletions were introduced suitably to mimic the presence of a plasma bubble. The TEC was estimated and the manifestations of the plasma bubble on TEC were clearly seen. The TEC thus estimated when compared with actual night time TEC measured using RaBIT revealed striking similarities. Likewise more simulations were done to understand how the variation in the spatial extent i.e. along latitude and altitude of these plasma bubbles manifests in the reconstructed TEC. In the real ESF scenario a large number of bubbles would be present at different locations modulating the TEC, making the ionospheric reconstruction really difficult. A tomogram was generated for the night pass of RaBIT at 22:00 IST on October 20, 2011. The digisonde derived ionograms around 22:00 IST revealed the presence of Equatorial Spread-F (ESF) on this night. This tomogram is, perhaps, the first representing the ESF conditions. The tomogram reveals very significant modulations in the top-side ionosphere. Many small scale fluctuations are seen to be present on the topside ionosphere indicating the presence of ESF instabilities. The peak electron density around the 250-350 km altitude range also exhibits several small scale modulations present therein **(SPL).**

Power spectral characteristics of ESF irregularities during quiet and disturbed days has been investigated using spaced receiver scintillations on a 251 MHz signal recorded at Tirunelveli (dip lat. 0.6°N). This study reveals that at higher heights ESF irregularities are more likely to have small scale lengths **(IIG).**

The evolution of large scale (few kilometers)**,** medium scale (few hundreds of meters), and small scale (meters) size plasma density irregularities in the post-sunset equatorial F region have been investigated from Indian longitudes using GPS total electron content (GTEC) variations. The ionograms and GTEC from a GPS receiver installed as a part of the GPS Aided Geo Augmentation Network (GAGAN) project for satellite based navigation are obtained from an equatorial station at Trivandrum (8.5°N, 76.91°E, 0.5°N Mag. Lat.). The residuals in GTEC obtained by subtracting the variations with the running mean in the GTEC are considered to represent the seed perturbations (P) for the plasma instability that results in the equatorial spread F (ESF) irregularities. The VHF radar at Gadanki (13.5° N, 79.17° E, 6.4° N Mag. Lat) provided the small scale structures of ESF. The background thermospheric conditions that affect the growth of the plasma instability through ion-neutral collision frequency (ν_{in}) are inferred using the F region base height (h′F). This (h′F) and the scale height for the neutral species at this altitude are used to estimate a growth factor (G). The present case-study reveals a close coupling between the background ionospheric conditions and the baseline perturbations in deciding the evolutionary phases of the ESF. It has been shown that although large scale size irregularities are formed without any constraints when the background ionospheric-thermospheric conditions are favorable, (in the presence of fluctuations in GTEC), the medium scale and small-scale irregularities show a remarkable similarity with the variations in the product of the perturbation (P) and growth (G) factors. Such clarity in the evolutionary pattern of different scale size irregularities are expected to pave the way for a realistic forecasting of the phenomenon of ESF **(PRL, NARL).**

Ionospheric scintillations, whether they are in the VHF, UHF or L-band, are a hindrance to uninterrupted ground-satellite-ground communication links. Forecasting the occurrence of L- band scintillations has been a challenging task and this challenge has been tackled by evolving a simple/novel method using GPS-TEC data. A network of ground based GPS receivers has been established in India that provides round the clock data on TEC and scintillations in the L-band. For given background conditions, it has been shown that the fluctuations in the GPS-TEC truly represent the characteristic features of the perturbations that are responsible for the initiation of the plasma instability that finally culminates into the observed irregularities. The close linkage between the perturbation features and the evolutionary pattern of the scintillations enable us to forecast '*when*', and '*for how* *long*' the L-band scintillations would occur, in addition to their 'occurrence pattern'. The first of their kind of results take us a step closer towards operational forecasting of the L-band scintillations for real time navigational purposes **(PRL).**

To investigate the gravity wave seeding hypothesis of equatorial plasma bubble (EPB), simultaneous lidar observations of middle atmospheric temperature and VHF radar observations of E and F region FAI from Gadanki were scrutinized. Temperature observations provided clear evidence of upward propagation of gravity waves, having wave period of 20 min^{-2} h. Simultaneous observations of E region FAI drifts showed similar variations to prevail. The cross correlation analysis of temperature and E-region FAI drift variations showed remarkably high correlation indicating the imprint of gravity waves in the E-region electric fields. On such nights, periodic plume activities were observed and interestingly a remarkable correlation is found among the gravity wave periods in the middle atmosphere, E region FAI drifts, and temporal separation of plume occurrence. Further, investigations on the nights when no EPB occurred on nearby nights reveal a close link between the occurrences of plume structures and the amplitudes of the short period gravity waves in the mesospheric temperature variability. It is emphasized that such waves have a crucial role in seeding the Rayleigh-Taylor (RT) instability manifesting EPB **(NARL, IIG).**

The quantification of the role of gravity wave seed perturbations on ESF occurrence has not been attempted so far, although some case studies are there which highlight the importance of seed perturbations in controlling ESF day-to-day variability. In this study for the first time, the role of seed perturbations in day to day ESF variability is addressed in a quantitative manner. Ionosonde data for autumnal and vernal equinoxes, summer and winter of low solar activity year 2005 from Trivandrum is used for this study. An interesting outcome of this investigation is the unraveling of the role of altitude dependence of threshold level of seed perturbation in producing the observed equinoctial asymmetry in equatorial spread F. That is, during autumnal equinox the seed amplitude required for ESF occurrence at a particular altitude is much higher than for vernal equinox. The study shows that the amplitude of the seed perturbations is a very critical parameter which decides whether or not ESF would occur on a given day **(SPL).**

Since long, the atmospheric gravity waves (AGW) were believed to provide the required initial seed for the equatorial plasma bubble (EPBs), however, the coupling processes that lead to the transfer of energy from AGWs to the plasma at the base of F-layer where the EPBs initiate is not yet understood. Recent studies suggest that the modulation by AGW manifest as zonal large scale wave structure (LSWS) at the bottom side F-layer and the (EPB) irregularities are observed to be developing at the upwellings of these zonal LSWS. Though the observations on LSWS and EPBs are quite promising on a day-to-day basis, general consensus is not yet emerged primarily due to the inability to detect and characterize LSWS with the currently available instruments, except by steerable incoherent scatter radar such as ALTAIR radar. A novel method is introduced to detect the zonal LSWS in ionospheric total electron content (TEC) using space- borne beacon transmissions from the low-inclination orbiting satellites (such as C/NOFS). Since the radio beacon signal reception from the low-inclination orbiting satellite provides a wide zonal (~30 – 35° longitudes) coverage, this method provides an excellent opportunity to derive, instantaneously, the ionospheric total electron content (TEC) and observe zonal LSWS over a wide longitudinal region. The salient features of LSWS are identified and are (i) The upwellings of LSWS manifest as depletions in the residual TEC variations (ii) These zonal structures are found to be aligned with geomagnetic field lines in north-south direction for several hundreds of kilometers (iii) EPBs are found to initiate at the westward walls of LSWS and (iv) The zonal wavelengths of LSWS typically varies between 200 – 650 km **(IIG, PRL).**

Coordinated observations of equatorial plasma bubbles (EPBs) have been made with an all-sky airglow imager, narrow bandwidth photometer, VHF radar, and ionosonde over the Indian sector on the night of 23 March 2009. Ionograms showed satellite traces while, the airglow structures revealed large amplitude small scale wave structures (SSWS) together with a medium scale wave structure. Results are compared with the ionosonde and imager observations made on the night of 21 February 2008, when, the PRE and the maximum height attained by the F layer were very similar to that of 23 March 2009. The ionograms showed the presence of satellite traces but, no subsequent evolution of spread F. These observations imply that though the presence of LSWS may be important for the triggering of EPBs, they alone are not sufficient. However, the coexistence of both LSWS and SSWS may have the potential to trigger EPBs **(NARL, IIG).**

Near simultaneous airglow imaging observations of mesospheric airglow emissions were used to study the phase propagation of the high frequency gravity waves in the upper mesospheric region. The study has provided insights in to the different types of phase propagation and their implications to the nature of the waves. In addition, imaging observations of thermospheric atomic oxygen nightglow were used to study the characteristics of plasma bubbles associated with nighttime F-region instabilities and equatorward movement of ionization anomaly associated with the reverse plasma fountain. Detailed investigation of thermospheric atomic oxygen airglow has revealed occurrence of very intense depletions on two of the nights on which sub-storms had occurred around sunset. However, those depletions do not appear to be typical plasma bubbles generated by Rayleigh-Taylor mechanism and they are different from earlier reports of MSTIDs as well. A new hypothesis is proposed to explain the observations **(IIG).**

Solar and Seasonal dependence of post sunset vertical plasma drift at equatorial F-region is investigated using long-term (1990-2003) ionosonde measurements from Trivandrum (77° E, 8.5°N, dip 0.5°N). The present work is in general agreement with the previous reports of seasonal and solar flux dependence of peak vertical drift in post sunset hours. This study indicates that pre-reversal enhancement is absent or rather weak for May-Aug (Jun-Jul) solstice during low to moderate (high) solar flux. The downward movement of F-layer during NDJF solstice is slower compared to equinoxes and found to be weakly controlled by solar flux **(IIG, SPL).**

An attempt has been made to bring out the relationship between post noon E-region electric field and post sunset F-region vertical plasma drift during Counter Electrojet days (CEJ). Study carried out using the data recorded during moderate solar activity years 2004 and 2006, using multi frequency HF Doppler Radar and Ionosonde located over the geomagnetic dip equator revealed some new and interesting aspects of the daytime CEJ related electric field variations and the post sunset F-region electrodynamics. It shows, as compared to the normal electrojet days, the pre reversal enhancement is inhibited on counter electrojet days and the field reversal is happening much earlier than usual. This suggests the persistence of a westward electric field during the post sunset hours even though westward electric field during CEJ time is reversed to eastward around 04:00 IST **(SPL).**

Behavior of the equatorial ionosphere using observations from a Digital Ionosonde at Trivandrum, India has been investigated. Of particular interest was an undulation in the F region peak altitude shortly after sunrise. Although the oscillation was reminiscent of the well-known `pre-reversal enhancement' observed at sunset, a study using a 1-dimensional model shows that, contrary to previous explanations, the apparent undulating motion of the equatorial ionosphere F region peak height at sunrise can be produced by chemistry rather than dynamics **(SPL).**

Recently the University of Michigan's Global Ionosphere- Thermosphere Model (GITM) has been equipped with new potential dynamo solver. GITM explicitly solves the full three- dimensional dynamo equations of the thermosphere and ionosphere self-consistently with realistic forcing. Unlike the other coupled global ionospheric models, GITM relaxes the hydrostatic assumption. It includes the IGRF magnetic field with the modified APEX coordinate system, set for the date of the simulation. The model runs are initiated with MSIS model for the neutral atmosphere and with IRI model values for the ionospheric charged particles, but eventually computes these quantities self-consistently. The model is also updated to include lower boundary tidal forcing. During geomagnetic quiet conditions, the poleward boundary of the ionospheric dynamo in the model is fixed at ±70 deg geomagnetic latitude. Two-dimensional electrostatic potential patterns are constructed assuming the equipotential field lines. The model is run for 10 days to ensure quasi-equilibrium state. The GITM simulations reproduce the stronger dynamo processes near dusk during solar maximum. The seasonal dependence is investigated during spring equinox, June and December solstices. GITM results indicate a weaker evening pre-reversal enhancement (PRE) during winter and a stronger PRE during equinoctial months. It is found that the time of PRE occurrence in the Philippine sector is independent of the solar activity and season. Also the seasonal effects are prominent near dawn and dusk sectors. The morning reversal of the vertical drifts occurs late during March and the evening reversals are late during month of December. The effects of different lower boundary tidal inputs have been studied, which reveal the significance of E-region wind dynamo in determining F-region plasma drifts. The model is capable of capturing the salient features of the low to mid-latitude ionosphere, and should be a helpful tool for the investigation of the upper atmosphere and ionosphere **(IIG).**

A dual-frequency software-based GPS receiver is operational at Calcutta providing high resolution (~50Hz) amplitude and phase data from virtually underneath the northern crest of the Equatorial Ionization Anomaly (EIA) in the Indian longitude sector. After the abnormally prolonged bottom of the solar cycle spanning 2006 to early-2010, scintillation activity has dramatically been enhanced in 2011 and 2012. Depletions in TEC in excess of 40TECU and associated peak-to-peak fluctuations greater than 20dB-Hz in CNO-L1 were noted in a number of cases. Patches of GPS phase scintillations were identified in the records associated with cycle slips of maximum duration ~ 210s and rapid fluctuations in the pseudo range rate. Characterization and modeling of such events in geophysically sensitive Indian longitude sector will provide valuable inputs for SBAS system designers. Applicability of commonly used ionospheric models like PIM and IRI to the low latitudes is severely restricted. For reliable operation of navigation system and prediction of range error accurately in the low latitude equatorial region, a model based on real time local TEC data is required. A TEC model, IRPE-TEC is developed using Neural Network (NN) taking the TEC data from dual frequency GPS receivers located at Calcuta, Baharampore and Siliguri. The chain of stations cover a sub-ionospheric area of 20°−28°N and 85°−91°E. Comparison of the model output with standard ionospheric models like PIM and IRI for October 2011 and April 2012 showed that the maximum error of TEC prediction of IRPE-TEC model always lies below 40 TEC units. For the same geophysical conditions, the errors from PIM and IRI are more than 60 TEC units. It is expected that augmentation of the existing TEC database for IRPE-TEC with more data from Farakka and Siliguri will result in improved prediction capability at locations beyond the northern crest of the EIA where the gradient of ionization is sharper than towards the magnetic equator **(CU).**

An attempt has been made to study the seasonal, altitudinal, diurnal and latitudinal variation of low latitude electron density using COSMIC radio occultation (RO) measurements over Indian longitudes during the deep solar minimum year 2008. The seasonal variation shows enhanced electron densities at vernal and autumn equinoxes compared to winter and summer seasons. The observations also suggest a shift in the time and altitude at which the peak of the electron density occurs in different seasons. An important finding is that there exists an equinoctial asymmetry in the electron density with respect to altitude and latitude, where the electron density is higher at vernal equinox compared to autumn equinox. The latitudinal and seasonal variation of peak electron density (N_mF_2) during 10:00-14:00 hrs LT indicate enhanced EIA on either side of the magnetic equator at both vernal and autumn equinoxes compared to the other seasons. Seasonal variation of EEJ strength obtained from geomagnetic H-field variations also shows strong EEJ at vernal and autumn equinoxes indicating that EEJ strength indeed partly controls the EIA development. Further, the results indicate that N_mF2 over the northern EIA crest region is correlated well with solar flux **(IIG).**

The quiet-time ($\Sigma Kp \leq 3$) daily variations of the geomagnetic field at the Indian Antarctic station, Maitri during two consecutive years of solar minimum are utilized to investigate the characteristics of the solar quiet (Sq) current system. It is observed that seasonal variation of the Sq current strength over Maitri is strongest during summer months and weakest during winter months. In spite of the total darkness during winter months, Sq pattern is identified at Maitri. The range of horizontal field variation in the daily Sq pattern during summer is one order higher than that during winter. An interesting feature regarding the phase of local time variation in the seasonal pattern is found here. A sharp shift in the time of peak Sq current to later local times (> 1 hour per month) is observed during January-February and July-August, which may correspond to the transitions from complete presence or absence of sunlight to partial sunlight. The differences in the incoming solar UV radiation during such transitions can cause a sudden change in the local ionospheric conductivity pattern, and can also trigger some unusual thermo-tidal activity, that might be responsible for modifying the global Sq pattern **(IIG).**

A quasi-two dimensional ionospheric model has been developed that numerically solves the continuity equation. It estimates the electron density profile of the ionosphere up to 500 km altitude by computing O_2^+, NO^+, N_2^+ and O^+ densities. The chemistry includes the photo- ionization of O, O_2, and N_2, the conversion of O^+ to molecular ions via charge exchange reactions, and the subsequent dissociative recombination reactions of molecular ions. The EUV flux is taken from the EUVAC model employing all the relevant photo ionization and photo absorption rates. Other important parameters such as the neutral density and neutral temperature are taken from the MSIS model while the electron temperature is estimated using the IRI model. An additional ionization source, which is significant at lower altitudes, is secondary electrons. This production term is included by incorporating the procedure given by Richards et al. [1988]. The model also incorporates the effects on the composition and electron density profile of uniform upward or downward drifts resulting from zonal electric fields **(SPL).**

In order to understand the effect of conductivity changes associated with solar eclipse on the E region plasma waves a rocket flight campaign was planned and conducted during the annular solar eclipse. Two RH 300 Mark II rockets were successfully launched at 1220 IST on 15 and 16 January 2010 to obtain plasma parameters on the eclipse and control days. The rocket payloads were Langmuir and electric field probes to measure the electron densities, electron temperature, amplitude of plasma waves, and fluctuations in electric fields. The result reveals that the ionization on the eclipse day reduced by 50 to 30% at different altitude regions. Further, the streaming plasma waves were found to be absent over Thumba due to the movement of the magnetic dip equator. In addition, the signatures of gradient drift waves were observed at the base of the E-region where sharp electron density gradients exist, indicating the ambient electric field is directed upward. Based on the amplitudes of fluctuations in plasma density and scale length measurements, it is inferred that the electric field strength is less on the eclipse day **(PRL, SPL).**

Evidence for an enhanced gravity wave activity of 1-2 hour periodicity in the equatorial mesopause temperature during the Counter Electrojet (CEJ) events has been presented. The analysis based on the data from a Dayglow photometer and Proton Precession Magnetometer over a dip equatorial station Trivandrum clearly indicates that, in general the wave activity is high during CEJ events compared to a normal day. This study further shows that the wave activity as seen from the wavelet periodogram at mesopause region fades out during the period of the occurrence of CEJ when the mesospheric zonal wind shows a reversal from west to east. This vindicates a possible upward penetration of the gravity waves from mesosphere to lower thermosphere during such events, thereby reversing the vertical polarization field and hence the generation of CEJ. This study presents first direct evidence for such an enhancement in the wave activity in the upper mesospheric region during CEJ events **(SPL).**

An airglow imager which monitors mesospheric OH and $O(^1S)$ emissions together with thermospheric $O(^1D)$ emission with a capability to map the sky at 150° field of view has been installed at Gadanki (13.5°N, 79.2°E). First measurements have been made using 90° field of view. First results revealed large amplitudes of mesospheric waves traveling from South to North direction with horizontal wavelengths 10-50 km and simultaneous occurrence of North-South aligned plasma depletions moving to the East. Simultaneous measurements of Rayleigh lidar, MST radar and GPS –TEC are expected to provide new insight into the mesosphere- thermosphere-ionosphere system processes **(NARL).**

The three VLF stations setup in India at Allahabad (Geomag lat. ~16° N), Nainital (Geomag lat. ~20° N) and Varanasi (Geomag lat. ~15° N) by Indian Institute of Geomagnetism under scientific collaboration with Stanford VLF Group, Stanford University are among the lowest latitude VLF stations. All the three stations are generating good quality VLF data for studies of VLF phenomena in low latitudes. Recent studies have concentrated on understanding 'Tweek' radio atmospherics morphology and behavior of the D-region of the ionosphere using these lightning generated signals in low latitudes. During the last two years, there have been a good number of observations of low latitude 'Whistlers' on various nights. Determination of the locations of the causative lightning strikes around the conjugate region of recording station in Indian Ocean have resulted in the establishment for the first time in Indian low latitude sector, that "ducted" propagation of low latitude whistlers was taking place. Dependence of whistler occurrence on peak current radiated by causative lightning discharge was also studied. During 2012, two stations have been established in India in collaboration with DTU Space, Denmark, for the observation of 'Transient Luminous Events' (TLE's). The TLE experiment is the first in the Indian region for observation of "Sprites" and Sprites were observed on five nights during the monsoon season in 2012 **(IIG).**

4.4 Atmospheric Coupling Processes

Solar radiation is a major component driving the atmospheric circulation and affecting the cloud liquid water content (LWC), integrated water vapour (IWV) as well as summer monsoon rainfall (SMR) activity. Both positive and negative correlations between SSN and SMR are observed in the tropical region, which are due to the two competitive processes that are active in determining the nature of the relationship. The increased heating of the earth's atmosphere during high solar activity period has a role to play in determining the relationship of SSN with IWV and, therefore also with SMR activity. The sun can also influence the cloud forming process and the rainfall activity by intervening through galactic cosmic rays (GCR) which control nucleation of water droplets in the atmosphere. With the increase in SSN, the suppression of GCR occurs and, consequently, the formation of cloud is reduced. Hence during the maximum solar activity period, a reduced GCR activity will affect the rainfall as well as LWC. The prominent positive correlation between IWV and LWC, related to solar activities, indicates that their interrelationship is more direct and strong to overcome the dynamic and orographic effects **(CU).**

Quiet time variabilities of the ionospheric total electron content (TEC) derived from GPS signals recorded at several stations in India along with simultaneous observations of equatorial electrojet (EEJ) strength obtained from geomagnetic field variations during January–March 2006 when sudden stratospheric warming (SSW) events occurred, are studied. Analysis of the observations confirmed that strong correlation exists among the variabilities in EEJ strength and GPS TEC observations. Investigations suggest that there exist large-scale wave like structures with periodicity of quasi 16-day in the TEC observations near the equatorial ionization anomaly (EIA) crest similar to that of EEJ strength. Observations also indicate the existence of morning enhancement and evening reduction of TEC and EEJ strength and vice versa during SSW events. Presence of similar periods in the EEJ strength and TEC observations near the EIA crest region, supports the view that the large-scale wave like structures seen in TEC near the EIA crest are associated with planetary waves that are modifying the primary eastward electric field in the equatorial E region and hence the EEJ strength through non linear interactions with atmospheric tides **(IIG).**

Signature of a major Sudden Stratospheric Warming (SSW) is observed during late February of 2007 over Gadanki, the tropical station. Although SSW is a polar region phenomenon, our study has revealed significant latitudinal coupling in terms of wave dynamical features preceding and following the dramatic event. Significant air mass travels from low to high latitude before and during the warming episode which is supposed to carry enough heat for the sustenance of the event. Enhancement of the planetary wave amplitude starts well ahead at high latitude and reaches low latitude at the time of warming. The Planetary wave progresses towards high latitude after the event. Increase in the amplitude of GWs is found at the final stage of the warming period at high latitude **(NARL, PRL).**

The semi diurnal tide in zonal wind at 90 km and EEJ strength over Tirunelveli shows enhancement during SSW event. Though there is enhancement in the lunar tidal amplitude also during SSW 2009, it is much less than that of solar semi diurnal tide. The main observation of the present study is that the large semi-diurnal tide observed during the SSW 2009 is mostly solar driven and only partly lunar driven, though tidal planetary wave interaction also may play a vital role **(IIG).**

High-spectral resolution daytime optical emission measurements at multiple wavelengths over a large (140°) field-of-view were obtained simultaneously using the multi-wavelength high- resolution E c h e l l e spectrograph from a low-latitude location, Hyderabad. The three oxygen emission lines measured are 557.7 nm, 630.0 nm and 777.4 nm that emanate from around 130 km, 230 km and peak altitude of the F-region, respectively during daytime. Analysis of around 60 days of data obtained during January – April 2011 shows different wave features in different emissions (different altitudes), different diurnal patterns in consonance with the dynamics at that altitude, and latitudinal variations that reflect the effect of neutral- and electro-dynamics of the low-latitude region. Further, wave periodicities were obtained for all these emission variations. Larger periods (of > 2 hrs.) seem to be present on more number of days at higher heights (in 777.4 and 630.0 nm) as compared to those of the lower altitudes (in 557.7 nm). At all the heights, periodicities of smaller timescales (< 20 minutes) are found to be predominant away from the equator when compared to other directions. Also, 13 – 20 minute periods are seem to be present on almost all the days. Such simultaneous multiple wavelength emission measurements provide us with a means of comprehensive investigations of vertical coupling in the upper atmosphere **(PRL).**

Systematic measurements using sodium (Na) airglow photometers were carried out from Mt. Abu (24.6°N, 72.7°E) and Gadanki (13.5°N, 79.2°E) during cloudless and moonless nights of winter and spring equinoctial months during 2006-2009. The fluctuations of 5 minutes to 3 hours are analyzed to determine the impact of mesospheric gravity waves on Na airglow intensity. The power spectra derived from Na airglow intensity variation over both Mt. Abu and Gadanki indicate the occurrence of 15-30 min periods. Further, a few case studies were performed using mesospheric temperature and horizontal wind obtained from Sounding of Atmosphere using Broadband

Emission Radiometry (SABER) and TIMED Doppler Interferometer (TIDI) onboard Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite nearly simultaneously over both the places. This investigation revealed that whenever convective and dynamical instabilities occur within Na airglow layer, wave periodicities are found to be shorter. Larger periodicities are observed when the instabilities occurred above the Na airglow layer or did not occur within the emission layer. It is suggested that the gravity wave breaking

Systematic measurements of zonal wind have been carried out with radiosonde over Gadanki (13.5°N, 79.2°E) during April 2006 to December 2009. These measurements are combined with the results obtained from TIMED Doppler Interferometer, European Center for medium Range Weather Forecasting (ECMWF) zonal wind data and Outgoing Longwave Radiation (OLR) data from tropics to address Intra-Seasonal Oscillation (ISO). There is an emphatic signature of ISO modulation by dominant annual oscillation in the lower troposphere and upper stratosphere. Periodogram analysis has revealed dominant oscillations in the periodicity range 20-100 days. ISO amplitudes are significantly higher in Mesosphere and Lower Thermosphere (MLT) in comparison with the Troposphere and Stratosphere. ISO activity is found to be intermittent in the troposphere and consistent in MLT. Signature of the ISO is found to be insignificant in the stratosphere. Normally, there is good correlation between convection and zonal wind during all seasons within ISO scale of variability. Also mean latitudinal and longitudinal ISO amplitudes in OLR show common pattern of variability with higher activity during winter over summer during certain times, which is affirmed by ECMWF filtered wind results. These findings indicate presence of some complex mechanisms which alter the direct impact of convection on the tropical ISO during certain times **(NARL, PRL).**

It is well known that gravity waves and planetary waves accelerate the mean flow through wave mean flow interactions thus generating the stratospheric and mesospheric Semi-Annual and Quasi-Biennial oscillations (SSAO, MSAO, SQBO, MQBO) and several qualitative and theoretical studies are already reported. After quantifying the contribution from gravity waves towards the generation of these oscillations over tropical stations, like Thumba and Gadanki, an attempt has been made to quantify the forcing from a wide range of planetary waves viz., 2-16 day period waves towards these oscillations over Thumba making use of horizontal winds/vertical winds/temperature measurements from balloon, RH 200 rocket Meteor Wind Radar and TIMED SABER satellite data. As first step towards these, the momentum flux of 2-16 day waves were estimated and it is found that for 16 day waves, the maximum vertical flux of zonal momentum is 6 m^2s^{-2} with an uncertainty of ±1.3 m^2s^{-2}, that of 2-8 day period planetary wave, it is ~18 m^2s^{-2}. The forcing from 2-16 day period planetary waves towards the mean flow acceleration producing maximum phase of SQBO/MQBO is found to be 80 -90 %, while during minimum phase of SQBO/MQBO the contribution is 30-35% **(SPL).**

Making use of the temperature profiles with fine horizontal and vertical resolution of ~75-100 km and ~ 1 km respectively (at 5° x 10° grids over the globe) from the limb viewing atmospheric sounder HIRDLS (High Resolution Dynamic Limb Sounder), the momentum fluxes and potential accelerations of global scale gravity waves in the stratospheric and mesospheric regions are estimated. It was observed that though the potential energy increases with height, the momentum fluxes are greater in lower stratosphere than in the upper stratosphere/lower mesosphere owing to the exponential decrease of atmospheric density. Unlike the momentum fluxes, it is seen that the potential acceleration has larger latitudinal variability than altitudinal **(SPL).**

To investigate cloud dynamics and particle microphysics in the UTLS region and its association with Tropical Tropopause Layer a coordinated experimental campaign is being conducted by SPL, Trivandrum and NARL, Gadanki since December 2010 as part of Tropical Tropopause Dynamics (TTD) Experiment, under CAWSES-India (Phase-II) program. Preliminary results from this campaign conducted during the dry months (December-February) of 2010-11 show that, when ITCZ is in the southern hemisphere, the Indian sub-continent is almost free from cirrus clouds. The satellite images show that the Indian peninsula lies in the northern fringe of a large scale cirrus cover associated with the ITCZ which is in the southern hemisphere during this season. A close association is observed between the regional scale convection and cirrus manifestation at Trivandrum and Gadanki, with regional distinctiveness. The altitudes at which cirrus occurs differ at these two locations. Altitude structure of turbulent kinetic energy estimated from the altitude profiles of temperature obtained from the Radiosonde measurement indicate that occurrence of sharp and thin turbulent layers are very frequent in this region. Strong stratified turbulent layers are also observed in the altitude region 3-7 km with significant short- term temporal variations associated with low level clouds. Altitude profiles of wind and temperature data obtained from Radiosonde measurements at these two locations showed wave like disturbances near the tropopause. The vertical wavelength spectra of temperature, zonal wind and meridional wind clearly showed prominent amplitudes corresponding to 1.7 km, 3.4 km and 7 km. These features indicate that these undulations are due to the vertically propagating short-period waves. Altitude profiles of temperature and zonal wind from Gadanki also shows almost similar features during this period **(SPL).**

In recent years, the mesosphere (50 to 85–100 km) has evoked great scientific interest as long- term changes due to global warming can be clearly captured due to the large perturbation amplitudes at these altitudes. In the present study, zonal wind observations between 70 and 80 km over the Indian region provided by rocket sonde (19777-1991), HRDI/UARS (1991-1999) and MST radar (1995–2010) are used to construct a long-term data set from 1977 to 2010. Using this unprecedented data set, a decreasing trend of 2 m/s/yr is found, changing from strong eastward winds during the 1970s to weak westward winds in recent years. On the other hand, between 80 and 98 km using medium frequency radar observations during 1993-2009, no perceptible trend is found. Simulations of NCAR TIME-GCM also showed a similar change in the circulation when CO_2 in the atmosphere is doubled, suggesting role of anthropogenic changes in the dynamics of the mesosphere **(NARL).**

5. Outreach Activities

Space Festival 2012 held at Bharathiar University, Coimbatore

Scientists from National Aeronautics and Space Administration (NASA) chose the Bharathiar University, Coimbatore, to conduct a ‘Space Festival’ in its campus during 9-14 July 2012. The NASA delegation organized an exhibition of their activities and arranged lectures on topics like space exploration, robotics, astronomy, solar system, etc. Indian Space Research Organization (ISRO) and Defence Research and Development Organization (DRDO) also participated in this event. Other research organizations like RAC (NCRA-TIFR), IIA, ARIES, and IIG also put up posters and model instruments for display.

IIG scientists launched five sounding balloons carrying GPS sondes during this event that gathered considerable attention from the participating student and teacher communities. The live demonstrations of balloon soundings involved on-the-spot lectures by IIG scientists on basic atmospheric phenomena, explanation about the balloon experiment and the scientific information retrieved from this experiment. The GPS tracking of the balloons shown on a big LCD screen, as they drifted with the easterlies and westerlies at various heights and finally disappeared, when the GPS antenna could no longer detect the balloon, was a great attraction. Each of the balloon flights lasted about two hours and yielded scientific data on relative humidity, temperature, wind speed and wind direction up to altitudes ranging between 32 and 36 km.

6. Participation in National/International conferences

6.1 National conferences/symposia/workshops on STP related activities

17th National Space Science Symposium (NSSS – 2012) held at Sri Venkateswara University, Tirupati during February 14-17, 2012.

NSSS-2012 was sponsored by the Indian Space Research Organization (ISRO) in association with the Astronomical Society of India. Six hundred delegates from different parts of India participated in the symposium. The scientific program had several parallel sessions, special plenary sessions and special invited talks. Amongst the Inter-disciplinary Lectures there was one on "CAWSES". The technical sessions covered the areas of i) Space - based Meteorology, Oceanography and Geosphere-Biosphere Interactions; ii) Middle atmosphere, coupling dynamics and climate change; iii) Ionosphere, magnetosphere, Thermosphere, Space weather and sun earth relationships; iv) Astronomy and Astrophysics; v) The Solar system bodies including Planetary system. There were discussions on the new dimensions and future perspectives in space science research. A special session was organized on the research being carried out by Indian space scientists in Antarctica and the Arctic. The conference was held for four days with oral and poster sessions and an ISRO exhibition was also arranged for the benefit of College / School students. Best Oral and Poster Prize Awards were given during the concluding session.

6.2 International conferences/workshops organized in India

39th COSPAR Scientific Assembly, July 14 -22, 2012, Mysore, India.

The hosts for COSPAR 2012 were ISRO and the Department of Space, Government of India. The venue for the Assembly was the N.R. Narayanamurthy Centre of Excellence on the campus of the Indian IT company Infosys. For the 114 events comprising the core scientific program,

3504 abstracts were submitted by 2620 authors. Of the 2129 participants in COSPAR 2012, 346 were students. The program included six interdisciplinary scientific lectures, a presentation of the 'Global Road Map for the Next Decades' formulated by the COSPAR Working Group on the Future of Space Astronomy, and a space agency round table organized by ISRO. There was also a public lecture on 'Exoplanets' organized at the University of Mysore. There were several sessions related to STP science under Commission C dealing with 'Space studies of the upper atmospheres of the Earth and Planets including reference atmospheres' and Commission D dealing with 'Space plasmas in the solar system, including planetary magnetospheres'.

International Symposium on Solar-Terrestrial Physics (ISSTP 2012) – November 6-9, 2012, Pune, India

The International Symposium on Solar-Terrestrial Physics (ISSTP 2012) was successfully conducted from Nov 6 - 9 2012 at the Indian Institute of Science Education and Research, (IISER) Pune, India. Around 130 people attended the meeting, which included 30 graduate students. In addition, several local students from IISER Pune attended some sessions. International participants for this symposium came from Nigeria, Kazhaksthan, Russia, Italy, France, UK, Japan, China, Canada, USA and Mexico. The symposium was preceded by a one day tutorial session on Nov 5 2012 for graduate students, where subject experts gave tutorial lectures on areas ranging from magnetic field generation on the Sun to the physics of the Earth's magnetosphere and ionosphere. The 3 subsequent days (Nov 6 - 8) were packed with a mix of invited and contributed lectures from distinguished speakers reporting cutting edge research on a wide variety of topics related to solar and solar-terrestrial physics. The meeting also featured around 80 posters that were displayed throughout the duration of the event. The final day (Nov 9) featured panel discussions on the SCOSTEP and CAWSES programs and their future directions.

The full program is available on the conference website http://www.iiserpune.ac.in/~isstp2012 and proceedings of the meeting will be published with the conference series of the Astronomical Society of India.

7. International collaborations and initiatives

Indian scientists have collaborations with scientists from various parts of globe. Some of the institutions and countries are mentioned below.

Harvard-Smithsonian Centre for Astrophysics, USA.

Montana State University, Bozeman, USA. Universidad Nacional Autónoma de Mexico, Mexico.

STAR Lab, Stanford University, Stanford, California, USA. Boston University, Boston, USA.

University of Massachusetts, Lowell, USA.

Institute for Scientific Research, Boston College, Boston, USA. US Air Force (SCINDA program), USA.

RISH / Kyoto University, Japan. University of Saskatoon, Canada. University of Adelaide Australia. University of Michigan, Ann Arbor, USA. SRI International, USA.

INDO-RUSSIAN collaboration in YOUTHSAT.

ISRO-CNES (Indo-French collaboration that resulted in Megha-Tropiques mission). DTU Space, Technical University of Denmark.

Space Research Group, Etvos University, Budapest, Hungary. High Altitude Observatory, Colorado, USA.

8. Current and upcoming missions and campaigns

ADITYA is a project to take images of the solar corona in the two emission lines, namely, the green and red, the strongest lines in the visible part of the solar corona at a relatively high frequency of 3-4 Hz. There will be provision to take the images of the solar corona through three different orientations of the Polaroids to study the linear polarization and generate maps. Recently, a proposal has been made to make Doppler images of the solar corona by taking the images in the blue and red wavelength regions around red emission line. The scientific objectives of the experiment are to study the heating of coronal plasma, dynamics of coronal loops, and CMEs (**IIA**).

The 2-m National Large Solar Telescope (NLST) proposed by IIA, the 50 cm Multi Aperture Solar Telescope (MAST) at the Udaipur Solar Observatory, and establishment of a new high- latitude station, Bharati (Larsemann Hills), in Antarctica are other major missions. The Indian STP community is actively participating in the international CAWSES Task Group 4 campaigns. A national campaign was carried out in December 2012 for Theme 3 of the CAWSES- India Phase II program focusing on Stratosphere-Troposphere Exchange (STE) processes. Another such campaign is planned for July 2013 during the Indian Summer Monsoon period.

9. Future plans

Satellites for Earth's Near Space Environment (SENSE) mission

The SENSE mission was proposed by the upper atmospheric science community in India in response to the ISRO Announcement of Opportunity for Small Satellites. The aim of the mission is to focus on studies of Earth's near-space electrodynamical environment, with emphasis on understanding how key aeronomical processes drive the ionosphere-thermosphere (IT) system and determine the space weather at low latitudes. Initially, it was envisaged that two satellites could be launched, one (SENSE-P) in a polar orbit and the other (SENSE-E) in a near-equatorial or low inclination LEO (in the range 450-500 km) orbit that would enable sampling of important neutral and plasma parameters over a wide range of latitudes and local time. Considering that such a scenario may not be possible, the payload team would participate in a polar mission if an opportunity arises in the coming years, though compromising a few of a host of scientific objectives.

The SENSE science payload will comprise of four instrument packages: (1) plasma diagnostic probes (electron RPA, ion RPA and Ion-Drift meter) (PDP), (2) Neutral Mass Spectrometer for upper atmospheric composition experiment (UACE), (3) Electric and Magnetic Field probes (Double Probe for electric field and Search Coil Magnetometer for magnetic field measurements) for large scale electric field and plasma wave diagnostics (LEF-PWD) and (4) Visible Airglow Photometer (VAP).

Balloon Experiment on Electrodynamics of Near Space Environment (BEENS)

IIG scientists have proposed to conduct a series of high altitude balloon experiments from Hyderabad aiming at probing the near space electrodynamics, especially at stratospheric altitudes, using a variety of probes during the next five years. The first of these experiments will be launched during March-April 2013. Though the chemistry and dynamics of this height region have been explored quite extensively from a number of space platforms and using several ground based experiments in the recent past, the electrodynamics of this region has not been receiving the attention it deserves in view of recent reports, which have highlighted that the middle atmosphere is not a passive element in the global electric circuit as has been envisaged till recently. It is thus important to monitor the electrical structure at these intermediate altitudes and understand how this region plays an active role in the global electric circuit and couples electro-dynamically to the mesosphere above wherein some spectacular displays of optical discharge phenomena were discovered in recent years. It has been reported in the past that large- scale (>100 km) ionospheric electric fields appear at stratospheric altitudes with small attenuation. The planned balloon experiments from the low latitude site, Hyderabad, are expected to capture the post-sunset electrodynamics operative over the magnetic equator, that are responsible for several of the fascinating equatorial ionospheric phenomena.

NEW ZEALAND:

Report prepared by Associate Professor Craig J. Rodger.

Overview Comments

New Zealand has a long history of scientific research in interdisciplinary solar-terrestrial physics. Due to our unique location in the world New Zealand researchers are both a user of international datasets, and a contributor to them. This continues to this day, involving both "local" and "hosted" instrumentation, both in New Zealand and in the Ross Sea region of Antarctica. In addition New Z researchers often work with international collaborators to increase the impact of our work in the wider international field. Our SCOSTEP-related science involves strong links to researchers in countries such the United Kingdom, United States, Canada, Finland, Hungary, and South Africa.

Institutions Involved

University of Otago
University of Canterbury
University of Waikato
Institute of Geological and Nuclear Sciences Limited

Antarctica New Zealand

Main topics of the STP research carried out nationally
New Zealand researchers have multiple SCOSTEP-related interests. Examples are given below:
Detection and importance of electron precipitation from the radiation belts
Remote sensing of the ionosphere and plasmasphere
Coupling of space processes to the neutral atmosphere and climate
Solar Flares

Highlights

Detection and importance of electron precipitation from the radiation belts

There has been a strong research thrust by New Zealand researchers into the detection of electron precipitation from the radiation belts. The detection work has made use of both satellites (e.g., the French DEMETER, NOAA's POES) and ground based instruments. Of particular importance is the joint NZ-UK led Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium (AARDDVARK) network of subionospheric precipitation monitors. A core focus of current activities is to extend these observations, and to validate using other tools, led by the academics and students at the University of Otago. In the last year 4 papers were published investigating the detection and importance of electron precipitation from the radiation belts. These papers are listed below.

Geophys. Monogr. Ser., vol. 199, edited by D. Summers et al., 213–223, AGU, Washington, D. C., doi:10.1029/2012GM001299, 2012.
J. Geophys. Res., 117, A12213, doi:10.1029/2012JA018175, 2012.
Radio Sci., 47(2), RS2021, doi:10.1029/2011RS004971, 2012.
J. Geophys. Res., 117, A02313, doi:10.1029/2011ja016933, 2012.

Remote sensing of the ionosphere and plasmasphere

There is particular focus on researching the natural variation of the lower-most section of the ionosphere, the D-region. Research campaigns undertaken by Assoc. Prof. Neil Thomson (University of Otago) conducted in New Zealand, Australia, and Hawaii have focused on describing the "typical" electron density profiles of the D-region for both night and day conditions. Continuous D-region monitoring is undertaken from Dunedin and Scott Base. New Zealand researchers operate several different experiments for probing the plasmasphere from the ground, primarily from Dunedin. This includes an instrument hosted in collaboration with the Eötvös Loránd University (Hungary). In addition, ionosondes are operated and maintained in Eyrewell and Scott Base (Antarctica) by the Department of Physics and Astronomy of the University of Canterbury.

Other relevant experimental instruments operated in New Zealand include the University of Canterbury radars at Birdlings Flat (which includes the AMOR Meteor RADAR) and also Scott Base. Magnetometers are operated in New Zealand by the Institute of Geological and Nuclear Sciences Limited (providing data to the INTERMAGNET programme), Newcastle University (Australia), and Osaka Electro-Communication University (Japan).

In 2012 Assoc. Prof. Neil Thomson (University of Otago) published a study on the dependence of ionospheric D-region electron density upon sunspot number, using campaign observations he made in Western Australia (J. Geophys. Res., 117(A10), A10306, doi:10.1029/2012JA018077, 2012). Working with collaborators in South Africa, Europe and the USA we were part of a study looking at the motion of the plasmapause during a fairly large magnetic storm. This study combined satellite and ground-based observations, including Marion Island (South Africa) and Dunedin (New Zealand), and showed very strong inwards movement of the plasmapause (J. Geophys. Res., 117, A12218, doi:10.1029/2012JA017609, 2012).

Coupling of space processes to the neutral atmosphere and climate

The Otago researchers have been collaborating with European researchers to establish the atmospheric chemical changes driven by energetic particle precipitation striking the atmosphere from space, and in particular quantifying the production of ozone-destroying species like NOx and HOx. Recently, a paper was produced with our Finnish colleagues showing that one-third of the variation observed in satellite HOx observations was due to energetic electron precipitation, with significant atmospheric changes detected to altitudes as low as 52 km (i.e., from ~3 MeV relativistic electrons) (J. Geophys. Res., 117(D9), D09304, doi:10.1029/2011JD01724, 2012).

New Zealand researchers have also been active in examining the overall importance of these changes to the polar climate. A very recently accepted study examined geomagnetic activity signatures in wintertime stratosphere wind, temperature, and wave response. We found that for high geomagnetic activity levels the stratospheric polar vortex becomes stronger in late winter, with more planetary waves being refracted equatorward. Our results also indicated that the geomagnetic effect on planetary wave propagation has a tendency to take place when the stratosphere background flow is relatively stable, or when the polar vortex is stronger and less disturbed in early winter. These conditions typically occur during high solar irradiance cycle conditions, or westerly Quasi- Biennial Oscillation conditions. This work is part of efforts to better describe the importance of atmospheric chemical changes driven by energetic particle precipitation to the polar climate (J. Geophys. Res., (in press), doi:10.1029/2012JD018946, 2012).

Solar Physics

The space physics group at the University of Waikato includes Professor Ian Craig, Associate Professor Sean Oughton, and Dr Yuri Litvinenko. Topics of focus centre on understanding processes active in the solar corona and solar wind. These include, magnetic reconnection, solar flares, particle acceleration and cosmic rays, coronal heating, evolution of solar wind fluctuations, and MHD turbulence. These are investigated using theory, numerical simulations, and modelling, and are of course constrained by matching with observational data.

Outreach Activities

New Zealand STP researchers participated in multiple public talks, including during the New Zealand "Icefest" (14 September – 14 October 2012). In 2012 Assoc. Prof. Rodger (Otago University) was twice interviewed on life public radio describing recent STP activities.

International Collaborations and Initiatives

SCOSTEP-related research in New Zealand has been funded by multiple sources. An important source is Vote Education money from the New Zealand Government through the Universities. Antarctic-focused programmes have received indirect (logistical) finding from Antarctica New Zealand and the Australian Antarctic Division. Direct funding for research undertaken in 2012 includes the New Zealand Marsden fund, and the European Union Framework Project 7. New Zealand's SCOSTEP-related science involves strong links to researchers in countries such the United Kingdom, United States, Canada, Finland, Hungary, and South Africa with shared experiments and multiple active collaborations.

The New Zealand delegate to SCOSTEP is currently Assoc. Prof. Craig J. Rodger (Department of Physics, University of Otago, Dunedin, New Zealand). He has held the position since 2006, acting on behalf of the Royal Society of New Zealand. Craig Rodger would like to thank Adrian McDonald (Department of Physics and Astronomy, University of Canterbury) and Sean Oughton (University of Waikato) for input.

NORWAY:

Name of the National Adherent Representative: Nikolai Østgaard

Institution: Birkeland Centre for Space Science and Department of Physics and Technology, University of Bergen

Country: Norway

Reported Period: 2012

1. ***Approximately how large is the National STP community -*** *About 60 people.*

In 2012 the Norwegian Research Council decided to fund the first Centre of Excellence in Space Physics: the Birkeland Centre for Space Centre, located in Bergen. The centre will have funding for 10 years and will support about 55 people involved in space science and instrument development at UiB (40), UNIS (12) and NTNU (4).

2. ***Which institutions participate in this STP activity***

The following institutions have space physics activity: University of Bergen, University of Oslo, University of Tromsø, NTNU, NGO and UNIS

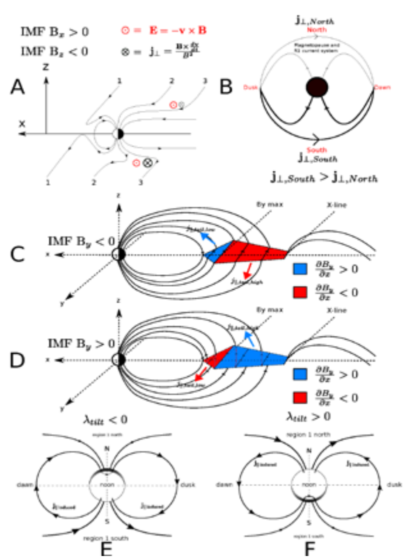
3. ***Main topics of the STP research carried out nationally***

See highlights below:

4. ***A summary of STP research carried out during the reported period, with highlights of the results obtained***

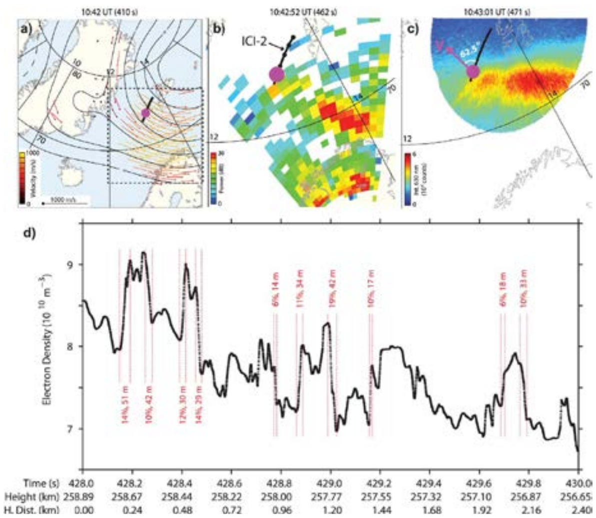
Below are listed some of the highlights, which were also presented at the CAWSES II workshop in Australia, fall 2012.

Conjugate imaging of aurora in both hemispheres and inter-hemispheric currents*:* In 2009, Laundal and Østgaard published a study, that was featured on the front page of *Nature Lett (Vol. 480, 2009)*, showing how completely asymmetric the aurora can be in the two hemispheres. They suggested that this is evidence of interhemispheric currents, and in a paper in AGU monograph 'Relationship between Auroral Phenomenology and Magnetospheric Processes', #2011BK001190, 2012, by Østgaard and Laundal, they pursue this by suggesting three causes for such asymmetric/ interhemispheric currents (to the right)



Non-conjugate aurora (left) and three mechanisms that can produce interhemispheric currents (right)

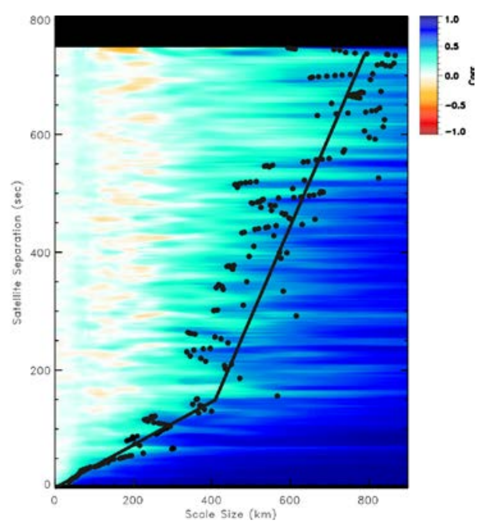
Turbulence and instabilities at work in the cusp. The group in Oslo is deploying an ambitious rocket program to investigate turbulence and instabilities in the region where the solar wind has direct access to the upper atmosphere, the CUSP. From the successful ICI-2 campaign several papers have been published *(e.g., Moen et al., Geophys. Res. Lett. 2012; Oksavik et al. J. Geophys. Res., 2012)*



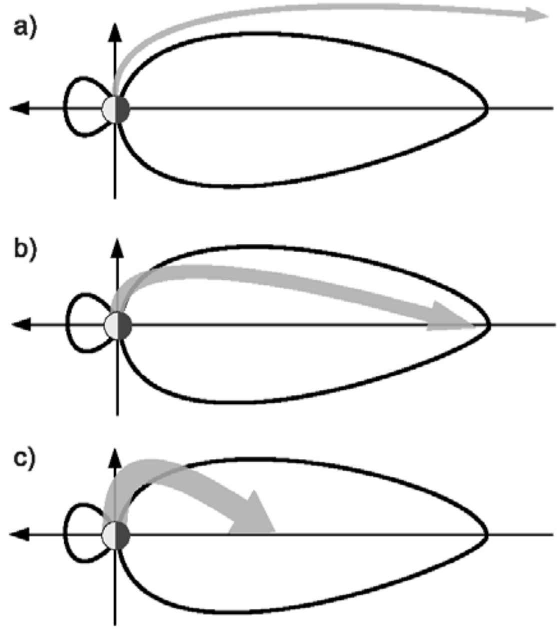
To the left: From Moen et al., Geophys. Res. Lett. 39, L07104, 2012. (a) SuperDARN convection map (b) HF backscatter power recorded by the SuperDARN and(c) A 630.0 nm all-sky image during the ICI-2 rocket campaign. (d)Shows the 2 s high-resolution electron density data, measured by ICI-s as it flu through the arc. They showed that the steep gradients in electron densities were consistent with a Gradient Drift Instability at work

The spatio-temporal characteristics of field aligned currents. The group in Bergen is examining the dynamic and fine structure of field-aligned currents

To the right: From Gjerloev et al., Ann. Geophys., 29, 1713–1729, 2011. Based on the three STM 5 satellites flying through and measure the field align current structure the figure shows the correlation between scale size and satellite separation - time. To the left are signatures that correlate well, meaning that small scale structures only correlate on short timescales, while large scale structure correlate on longer time scales. The figure also shows a very distinct transition in time and space when the correlates disappears

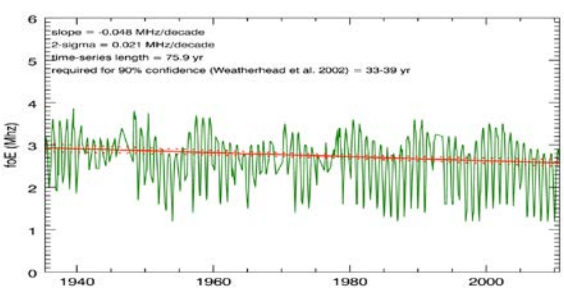


Ion outflow*:* The Norwegian Cluster team that involves UiB and UiO has published several papers the last year about the loss of mass from the Earth´s upper atmosphere through ion outflow.-



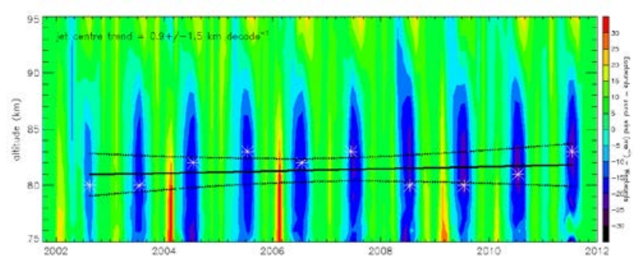
In two papers Haland et al., J. Geophys. Res., Vol. 117, A07311, 2012 and AGU monograph, 2012 have shown that the rate of loss through ion outflow is dependent on the ion outflow velocity and convection speed, as shown to the right, for three different convection speed. With slow convection speed (upper panel) the ions will be lost into the solar wind, while with moderate to high convection speed the ions will re-circulate back to the closed magnetosphere through the reconnection process in the tail. They found that about 10% of the out-flowing cold ions detected by Cluster at 6–20 RE altitude (i.e., about 10^{25} ions/s) were directly lost into the solar wind.
During northward IMF almost all the ions are lost. During disturbed times both ion outflow and convection speed increase, but the net results is recirculation.

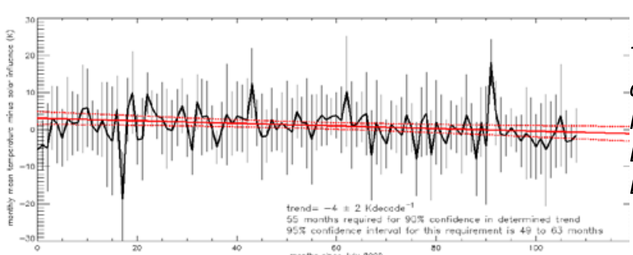
In a series of paper the group at UiT and UNIS with others have examined ***the trend of temperature, mesospheric jets and electron density in the E-region*** over the last decades.



To the left the trend of decreasing electron density in the E-region over Svalbard during the last 40 years

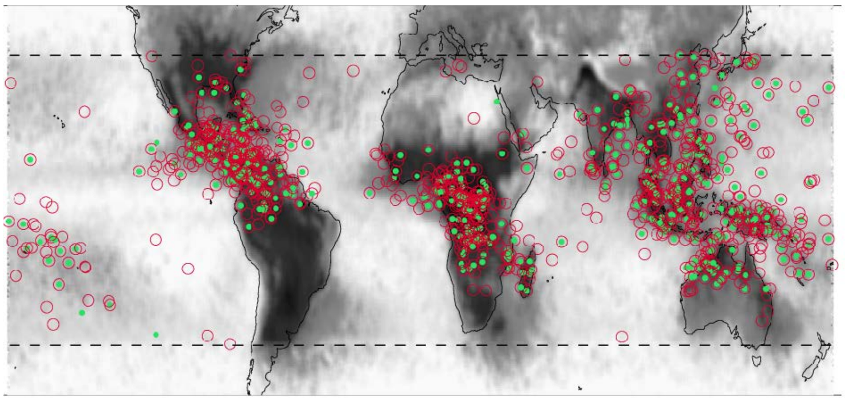
To the right, the trend of mesospheric jets over Svalbard he last decade





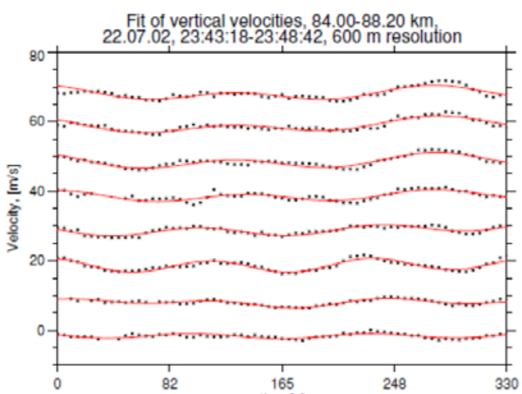
To the left, the trend of winds over Svalbard the last decade:
Hall et al, J. Geophys. Res., 117, D08104, 2012
Dyrland et al, Radio Science, 45, RS4006, 2010
Dyrland et al, J. Geophys. Res., D07103, 2010

Terrestrial Gamma Flashes (TGF) are the most energetic photon phenomenon naturally occurring on Earth. TGF are related to thunderstorms and emit gamma rays, relativistic electrons and antimatter through the mesosphere and into space. The group at UiB has published several papers on this hot topic the last year.



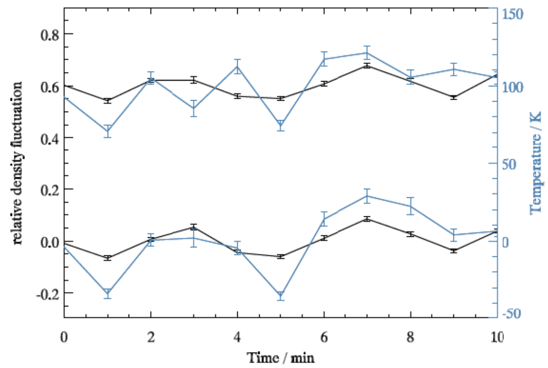
The group in Bergen developed a new search algorithm to search for TGFs in the RHESSI data base and discovered twice as many TGFs that have recently been reported (see the new map of TGFs as reported by Gjesteland et al., Geophys. Res. Lett. 39, L05102, 2012, above). This may imply that TGFs are much more common than previously believed, and Østgaard et al., (J. Geophys. Res., 117, A03327, 2012), showed that we cannot rule out that all lightning produce TGFs.

Gravity waves and accoustic waves studied with the EISCAT VHF radar and the Na Lidar at ALOMAR by the groups in Tromsø and Oslo.



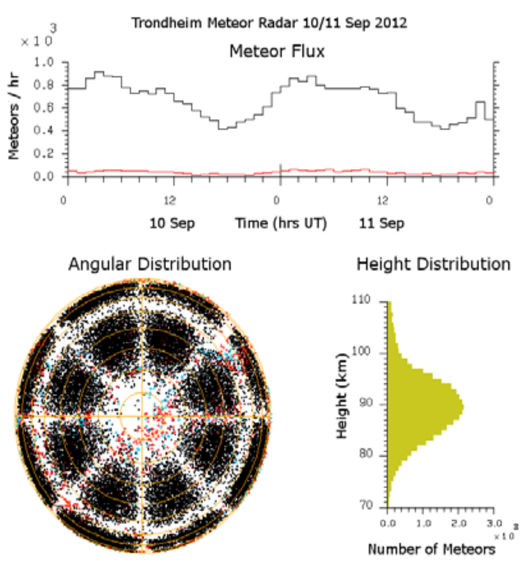
To the left: Acoustic wave in vertical velocity observed independently in several range gates. The phase velocity is in agreement with the speed of sound for a wave propagating at approximately 41 degrees through the radar beam. The traces for the higher range gates are displaced by 10 m/s each for clarity.

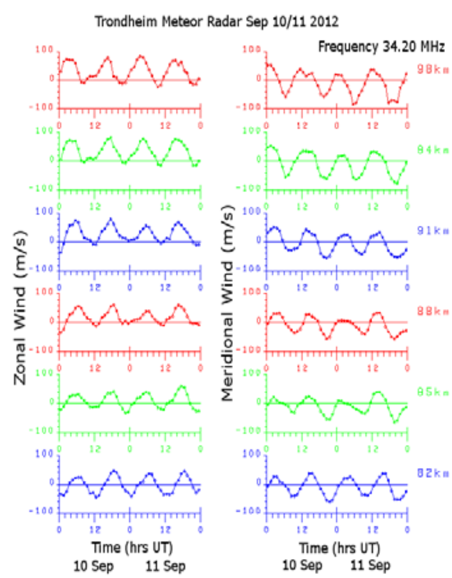
To the right: The temperature and Na-density variation in two adjacent range gates (92 km and 93.2 km) on 2 March 2010, 23:52 - 0:02 UT. The upper traces are displaced by 100 K respectively 0.6 for clarity. Density and temperature vary in phase as we expect in an acoustic wave. In a gravity wave, these two perturbations would be in quadrature. (Courtesy: Ulf-Peter Hoppe, UiT and UiO)



Gravity waves measured at NTNU

The Momentum-Flux radar at the NTNU (Trondheim) campus provides direct measurements of the vertical flux of horizontal momentum by gravity waves. Combined with the radars at Andenes, Norway and Kiruna, Sweden, it will quantify the wave-momentum flux over the full range of wave scales from typical propagating gravity waves (~20km), mountain waves (~100km) and mesoscale waves associated with aurora and the polar vortex shear zones in the altitude range 82 to 98 km. The radar provides the wave forcing of the mesospheric circulation and the flux of horizontal momentum into the ionosphere. Left panel shows the flux of meteors vs time (top), azimuth angle (lower left) and altitude (lower right). The zonal and meridional winds for these days are shown in the right panel at 6 different altitudes. A clear semi-diurnal tide with amplitude of ~50 m/s is evident in the raw data. (Roos de Wit (PhD student), Robert Hibbins, and Patrick Espy, NTNU).





5. Outreach Activities

Space Physics in Norway are often features in news papers, radio and TV. One highlight was the group at NTNU in Schrødinger Katt, where they showed the new radar facilities in Tronheim to probe the atmosphere by measuring meteor trails (see below)

The Birkeland Centre for Space Science will have a dedicated group for education and public outreach activity.

Capacity Building Activities

University of Oslo runs a rocket program. NTNU and University of Oslo is both involved in student Cube Sat projects. University of Bergen and the Birkeland Centre for Space Science is building X- and gamma-ray detector for the International Space Station, as well as gamma-ray detectors for balloon and aircraft campaigns. UNIS and the University of Tromsø run large ground-based facilities: EISCAT, Alomar and KHO.

7. Participation in National/International conferences

The Norwegian space physics community participates in all the big international meetings, such as AGU, EGU, COSPAR and IAGA, as well as workshops like CEDAR and GEM. We also organize sessions in these big conferences.

8. How many have been supported by SCOSTEP/CAWSES

The activity in Norway has been funded by other sources

9. International Collaborations and Initiatives

The University of Oslo has signed agreements with both Japan and Canada for supporting the rocket program. EISCAT is a large international collaboration. Birkeland Centre of Space Science has a large number of international collaborators both for data analysis and instrument development. Norway is also active in both Cluster and ASIM (University of Bergen).

11. Future plans

As the creation of the Birkeland Centre for Space Science marks a real emphasis and support for the Norwegian Space Science we give a brief outline of the main activity as well as deliverables by this centre:

The Birkeland Centre for Space Science (BCSS) will combine theoretical understanding, data analysis and instrument development to attack the primary and secondary objectives listed above. The centre will have world leading scientists in global auroral imaging, ground-based magnetic/radar/optical techniques, theoretical understanding/modeling of plasma, and in designing/constructing space and ground-based instrumentation. Main deliverables are:

1) Determination of the degree and importance of asymmetries in the two polar regions to understand the complexity of the Sun-Earth system
2) A comprehensive data set of ground based measurements of current systems
3) Parameterization of the Birkeland currents on fine spatial and temporal scales, to be used in MI coupling models
4) Parameterization of the temperature and chemical effects of energetic particles (from above and below) in the stratosphere and mesosphere, to be used in atmospheric and climate models
5) The most comprehensive set of TGF observations from new experiments
6) A model and a theory for the production mechanism of TGFs

BCSS will:

1) Maximize the utilization of existing Norwegian infrastructure at Svalbard, Northern Norway as well as large investments in Cluster and ASIM.
2) Strengthen the international position of the Norwegian space physics community by making significant progress on compelling science questions
3) Bridge the historical gap between scientists focusing on the atmosphere, ionosphere and magnetosphere thereby enabling the cross disciplinary science that is known to provide breakthrough discoveries.
4) Initiate a unique collaboration between space physicists (BCSS) and climate researchers (Bjerknes Centre for Climate Research).
5) Strengthen and further expand our capability to develop and build state-of-the-art instrumentation for space.
6) Educate and position the next generation of Norwegian space physics scientists through ambitious educational and public outreach components

There are two important initiatives, EISCAT 3D (University of Tromsø) and SIOS (UNIS) , which are awaiting for funding. If successful, these initiatives will play an important role in Norwegian Space Physics.

SLOVAKIA:

Name of the National Adherent Representative: Miloš Revallo
Institution: Geophysical Institute of the Slovak Academy of Sciences (**GPISAS**), Bratislava
Country: Slovakia
Reported Period: 2012

The National STP community and participating institutions

Research activities in the field of Solar Terrestrial Physics in Slovakia are mainly performed in scientific institutions of the Slovak Academy of Sciences (SAS) and the Faculty of Mathematics, Physics and Informatics of the Comenius University (CU).

Ivan Dorotovič – Slovak Central Observatory – Solar Section (**SCOSS**), Hurbanovo, http://www.suh.sk
Adriena Ondrášková – Department of Astronomy, Physics of the Earth, and Meteorology, Faculty of Mathematics, Physics and Informatics of the Comenius University (**DAPEMCU**), Bratislava http://www.fmph.uniba.sk
Miloš Revallo – Geophysical Institute of SAS (**GPISAS**), Bratislava http://gpi.savba.sk
Ján Rybák – Astronomical Institute of SAS (**AISAS**), Tatranská Lomnica http://www.ta3.sk
Marián Slivka – Institute of Experimental Physics of SAS (**IEPSAS**), Košice http://space.saske.sk/?lang=1
Fridrich Valach – Geomagnetic Observatory, Geophysical Institute of SAS (**GO GPISAS**), Hurbanovo http://www.geomag.sk

Main topics of the STP research carried out nationally

– *cosmic rays (**IEPSAS, SCOSS**)*
– *ground-based geomagnetic observations (**GO GPISAS**)*
– *magnetospheric physics (**GPISAS**)*
– *research of the magnetosphere-ionosphere-atmosphere system (**DAPEMCU**)*
– *solar photosphere, chromosphere and solar activity (**AISAS**)*

A summary of STP research carried out during the reported period 2012

Theoretical models aimed at space weather forecast are being developed at GPISAS, in cooperation with colleagues from Institute of Geophysics, Academy of Sciences of the Czech Republic (P. Hejda and J.Bochníček). In previous models, solar energetic particles (SEPs) fluxes and interplanetary magnetic field (IMF) orientation were considered in relation with the geomagnetic activity. The method of artificial neural networks (ANN) was used to produce synthetic geomagnetic response in terms of geomagnetic indices. New approach is underway, combining the method of ANN together with the empirical models of solar wind-magnetosphere interaction. Preliminary results indicate, that such effort can help to improve accuracy of geomagnetic forecasts.

At AISAS, a new instrument Coronal Multi-channel Polarimeter for Slovakia (CoMP-S) was used successfully within the frame of international program „Mass loading of quiescent prominences from multi-wavelength observations"(HOP186). Instrument CoMP-S was designed and constructed by the team of specialists from the High Altitude Observatory, National Center for Atmospheric Research, Boulder, USA (HAO/NCAR) and was installed at the coronagraph at the Lomnický Štıt Observatory of the Astronomical Institute of the Slovak Academy of Sciences (AISAS) at the beginning of the year 2011. The tests and first observations were performed in April 2011. A cooperation with the High Altitude Observatory, National Center for Atmospheric Research, Boulder, USA, was established to utilize advantage of two instruments (CoMP, CoMP-S), to measure velocities and magnetic fields in the solar corona. The older CoMP is placed at the Mauna Loa Solar Observatory at Hawaii, USA, (MSLO). The longitude distance between LSO and MSLO is 175.80◦ which offers the possibility of coordinated observations with these two instruments. More details about the facility CoMP-S can be found at (www.astro.sk/LSO/COMP-S/). Besides of that, preparatory works were initiated for installation of new post-focal devices CHROMAG-S a SCD.

Researchers at AISAS took part in project COST Action MP1104 „Polarization as a Tool to Study the Solar System and beyond" (www.polarization.eu). Within the 7th Framework Programme FP7-SPACE-2013-1, the application was developed at AISAS entitled PINDAROS (Project to INcrease the exploitation of DAtabases for Research Of Space). This project proposal is directly related to SCOSTEP activities.

Outreach activities

Slovak Astronomy Seminar for Teachers 2012, Tatranská Lomnica, 26 – 28 April, 2012
(J.Rybák)

Participation in selected conferences

- *International workshop – COST Action ES0803 "Developing space weather products and services in Europe" Prague, March 2012 (M.Revallo, F.Valach)*
- *21th National Solar Physics Meeting, Stara Tura, Slovakia, June 2012 (I.Dorotovič, J.Rybák, F.Valach, M.Revallo)*
- *International Symposium on Solar-Terrestrial Physics, Pune, India, November 2012 poster session CAWSES II – Towards Solar Maximum - TG3 "How does short term solar variability affect the geospace environment?" (M.Revallo, F.Valach, I.Dorotovič)*

Current and upcoming missions and campaigns, in which the respective National STP community participates

Participation in International Space Weather Initiative (ISWI) 2010 - 2012. Details can be found at http://stara.suh.sk/id/iswi/iswi_SK-en.htm

Future plans

Focusing observational as well as outreach activities within „SCOSTEP/CAWSES MiniMax24 Campaign".