The Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)
(Affiliated to the United Nations)

Memoirs

TENTH SPACE AND ATMOSPHERIC SCIENCE COURSE
(AUGUST 1, 2016 TO APRIL 30, 2017)

Hosted by

Physical Research Laboratory
Ahmedabad, India

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Bangalore - 560 094

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New Delhi-110024

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New Delhi - 110 057

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Prof. AbdykalykovAkymbekAbdykalykovich
President,
International University for Innovation Technologies
720048, Bishkek 1/17, Gorky Street
Kyrgyz Republic 720048

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Malaysia High Commission
50M Satya Marg, Chankyapuri
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President of Mongolian Academy of Sciences,
Mongolian Academy of Sciences (MAS)
Floor 6th ,bldg. SoyolTuvUrguu
A.Amargudamj,Sukhbaatarsq.3,
Ulaanbaatar -210620A,Mongolia

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Myanmar

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New Delhi - 110 048

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BarhaKhamba Road
New Delhi - 110 001

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Embassy of Republic of Philippines
50N, Nyaya Marg,
Chanakyapuri
New Delhi -110021

REPUBLIC of KOREA
Mr. Ok-Kyu Lee
Principal Engineer
International Relations Team,
Korea Aerospace Research Institute
45, Eoeun-Dong, You Seong-Gu
Daejeon - 305 333, Republic of Korea

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Arthur C Clarke Institute for Modern Technologies
Katubedda, Moratuwa, Sri Lanka

THAILAND
The Executive Director,
Geo-Informatics and Space Technology Development Agency (GISTDA)
Government Complex, Building B,6-7th Floor
120 MOO 3 Chaeng Wattana Road
Lakshi, Bangkok 10210
Bangkok 10900, Thailand

UZBEKISTAN
Dr.Kamol M. Muminov
GB CSSTEAP Member
Ulugh Beg Astronomical Institute of the Uzbekistan Academy of Sciences
33, Astronomicheskaya Street
Tashkent 100052, Uzbekistan

UN-OOSA
Dr. Simonetta Di Pippo (Observer)
Director
UN Office for Outer Space Affairs (OOSA)
Vienna International Centre
PO Box 500, A-1400
Vienna, AUSTRIA

ITC, The Netherlands
Prof Dr.Ir A. (Tom) Veldkamp
(Observer)
Rector, ITC
Faculty of Geo-information Science and Earth Observation of the University of Twente
PO Box 217, 7500 AE Enschede
The Netherlands

Dr. A. Senthil Kumar (Secretary) (INDIA)
Director, CSSTEAP
Indian Institute of Remote Sensing Campus
PB No 222, No. 4, Kalidas Road,
Dehradun 248001

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अन्तरिक्ष भवन
न्यू बी ई एल रोड, बेंगलूर – 560 231, भारत
दूरभाष : +91-80-2341 5241 / 2217 2333
फैक्स : +91-80-2341 5328

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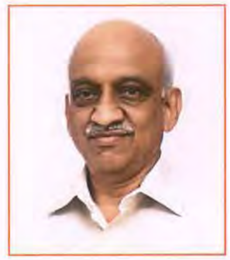
Indian Space Research Organisation
Department of Space
Government of India
Antariksh Bhavan
New BEL Road, Bangalore - 560 231, India
Telphone: +91-80-2341 5241 / 2217 2333
Fax : +91-80-2341 5328
e-mail : chairman@isro.gov.in

आ. सी. किरण कुमार / **A. S. Kiran Kumar**
अध्यक्ष / Chairman



MESSAGE

I am delighted to note that the 10th Post Graduate Course on Space and Atmospheric Science organized by the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) and conducted by Physical Research Laboratory (PRL), Ahmedabad is concluding on April 30, 2017. I congratulate all the 12 course participants from 2 Asia-Pacific countries for choosing the programme and completing it successfully.

The course has been designed to enable the participants to get in-depth understanding of the intricacies of space and atmospheric science such as, planetary atmosphere, ionosphere, ground-based techniques, space instrumentation and exploration, magnetosphere, solar physics, astronomy and astrophysics. Exposure to this course, I am sure, will encourage the participants to pursue career/research in areas like exploration of earth's environment, outer space and deep space.

I hope that the students will be able to utilize the knowledge and experience gained from this course in related areas back in their home countries.

I once again congratulate all the course participants and wish them the very best in their future endeavours. I also compliment the faculty and staff members of CSSTEAP and PRL for their sincere efforts in the successful conduct of the programme.

(आ. सी. किरण कुमार)
(A. S. Kiran Kumar)

Bangalore
April 09, 2017

ANDHRA UNIVERSITY

(NAAC - CGPA of 3.60 on four point scale at "A" grade)
"ISO 9001 - 2008 Certified"
5 - Star University by Careers 360 Magazine

Prof. G. NAGESWARA RAO Ph.D.
VICE-CHANCELLOR

Off. : 0891-2755547, 2844333
Res. : 0891-2755516, 2844194
Fax : +91-891-2525611
e-mail : auvicechancellor@gmail.com
VISAKHAPATNAM - 530 003, (A.P.) INDIA

13th April, 2017

MESSAGE

I am glad to know that the tenth batch of PG course in Atmospheric and Space Physics will successfully conclude by 30th April 2017. Department of Physics, Andhra University is one of the pioneering centers for research in atmospheric and Space physics and it is heartening that Andhra University is the focal point for the Diploma and M.Tech., programmes in Atmospheric and Space Physics being offered by the Centre for Space Science and Technology Education in the Asia and Pacific from its inception. It is a matter of immense pride and satisfaction that the Andhra University is associated in this programme and we look forward to a more fruitful interaction in future.

I convey my hearty congratulations to the participants and the faculty, particularly to Dr. J. Banerjee of Physical Research Laboratory, Ahmedabad, the Course Co-coordinator on a very successful course tenure of the 10th batch and I wish the all the very best to the participants for their future success.

(G.NAGESWARA RAO)

Centre for Space Science and Technology Education in Asia and the Pacific

Dr. A. Senthil Kumar
Director, CSSTEAP

Introduction

Space science and technology have contributed significantly to the socio-economic development of many developed and developing countries. Knowledge about time and space has economic and social benefits that contribute in meeting several societal needs, from human security to sustainable development. Continuous development of human resources is crucial to ensure the scientific & technological as well as economic, social and cultural development in any country. Strategies for developing human resources should be based on broad and long-term perspectives of the regional needs and resources through awareness, training and education. In order to develop these capabilities, nations or regions should be able to share their expertise and should also evolve opportunities to encourage awareness and train the manpower. In recognition of such a pre-requisite, a consensus has emerged within the international community that if effective assimilation and appropriate application of Space Science & Technology are to succeed in developing countries, devoted efforts must be made for the development of the necessary human and infrastructural capacity in all fields. A comprehensive training and education in Remote Sensing & Geographic Information System (RS & GIS) would enable developing countries to build a capability in the field, and to educate and stimulate students in other disciplines as well.

Considering the importance and use of space science, technology and applications in promoting social and economic development, the United Nations, through its Office for Outer Space Affairs (UN-OOSA), facilitated the establishment and operation of the Regional Centres for Space Science and Technology Education. In its resolution 45/72 of December 11, 1990, the United Nations General Assembly (UN-GA) endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space (COPUOS) to establish Regional Centres for Space Science and Technology in developing countries. Under the auspices of the United Nations, through its Office for Outer Space Affairs (UN-OOSA), six Regional Centres for Space Science and Technology Education have been established in the regions that correspond to the United Nations Economic Commissions for Asia and the Pacific (India and China), Africa (Morocco, Nigeria) and Latin America and the Caribbean (with offices in Brazil and Mexico) and Jordan for the West Asia region. The Centres are affiliated to the United Nations through UN-OOSA. Centre for Space Science & Technology Education in Asia and the Pacific (CSSTEAP) is the first Centre and was established on November 1, 1995 in India and has been Centre for Space Science and Technology Education in Asia and the Pacific imparting education/training in the areas of RS&GIS, Satellite

Communications, Satellite Meteorology and Global Climate, Space and Atmospheric Science, Navigation and Satellite Positioning System and Small Satellite Missions using modern infrastructure, technology and training tools and practices. The Centre has a announced a new Post Graduate course on Global Navigation Satellite Systems (GNSS) from 2015 and is hosted by Space Applications Centre, ISRO Ahmedabad.

The Centre's headquarter is located in Dehradun, India, and its programmes are executed by faculty of the Department of Space (DOS) at campuses in Dehradun, Ahmedabad and Bengaluru. The Centre has arrangements with Indian Institute of Remote Sensing (IIRS), Dehradun for RS & GIS course; with Space Applications Centre (SAC), Ahmedabad for Satellite Communication (SATCOM), Satellite Meteorology and Global Climate (SATMET) and Global Navigation Satellite System (GNSS) and Navigation and Satellite Positioning Systems (NAVSAT) short courses; with Physical Research Laboratory (PRL), Ahmedabad for Space & Atmospheric Science course and ISRO Satellite Centre (ISAC), Bengaluru for short course on Small Satellite Missions. The Centre also has agreement with the Government of India by which it has been accorded specific privileges and international status to the centre, similar to the privileges enjoyed by UN specialized agencies. Under the agreement the Centre also has access to facilities, infrastructure and expertise of DOS/ISRO institutions, including IIRS, SAC, PRL, NRSC and ISAC. The Centre has a Governing Board consisting of signatories from 16 countries from Asia-Pacific region and two observers, (UN-OOSA & ITC, The Netherlands). The Centre has formal UN affiliation with UN-OOSA for developing the CSSTEAP model and extending support in terms of expert advice, technical assistance, relevant documentation and future directions. The countries have agreed to the goals and objectives of the Centre by endorsing a cooperation agreement through which the Centre was established. The technical activities of the Centre are guided by an International Advisory Committee (AC) consisting of subject experts that critically reviews the curricula, technical facilities, expertise in terms of faculty, etc.

The course curricula developed by the Centre and endorsed by the United Nations are adapted for the educational programmes. The educational programmes of the centre are oriented towards the dissemination of knowledge in relevant aspects of space science and technology. The centre offers Post Graduate level courses in these five areas. The model of the PG courses is designed as to emphasize university educators, researchers and application scientists on the development and enhancement of knowledge and skills coupled with a

Shri A.S Kiran Kumar, Chairman, ISRO/Secretary Department of Space and present Chairman CSSTEAP Governing Board during the 21st GB meeting at Delhi

Governing Board members during 21st GB meeting chaired by Shri A.S Kiran Kumar, Chairman, CSSTEAP GB

application project with a small component (3 months) in India and major one (one year) in their home country with a view to transfer the technology in their home organization. This gives an opportunity to the scholar to apply their knowledge and training received to deal with a 'real life' problem, where inputs from space technology can be used. Besides the Post Graduate level courses, the Centre also conducts short courses, workshops, awareness programmes on specific themes in the four areas, highlighting how space-based information can be used for national development. These educational programmes have benefited many scientists/engineers who will be the future policy & decision makers in several countries.

CSSTEAP conducts all of its educational programmes in close collaboration with one of the DOS institutions and thus has direct access to their physical facilities and intellectual capabilities. In addition to providing facilities,infrastructure and skilled manpower, the Government of India, through the Department of Space provides most of the funding. Funding grants for international travel of participants, subject experts, tuition fees and scholarships of students and the management of the centre are mainly provided by Department of Space on behalf of Host country. UN-OOSA also provides funding for travel of the participants. Other agencies financially contribute include are UNAgencies like UNSPIDER, Beijing, China; UN-ESCAP in Bangkok, Thailand, UNESCO and UNDP.

Educational Programmes

The Centre offers post-graduate (PG) level training in five areas of specialization namely:

1) Remote Sensing and Geographic Information Systems (RS & GIS),
2) Satellite Communication (SATCOM),
3) Satellite Meteorology and Global Climate (SATMET)
4) Space and Atmospheric Science (SAS), and
5) Global Navigation Satellite Systems (GNSS)

Apart from these, Centre conducts short courses on different themes of Remote Sensing and GIS, Small Satellite Missions and Navigation and Satellite Positioning system on regular basis. The Centre also organizes workshops & awareness programmes from time to time (Fig. 1 & 2).

The educational programmes are conducted in English and for students who need help to improve their English language skills, facilities are made available upon their arrival in campus. The courses are taught in smart

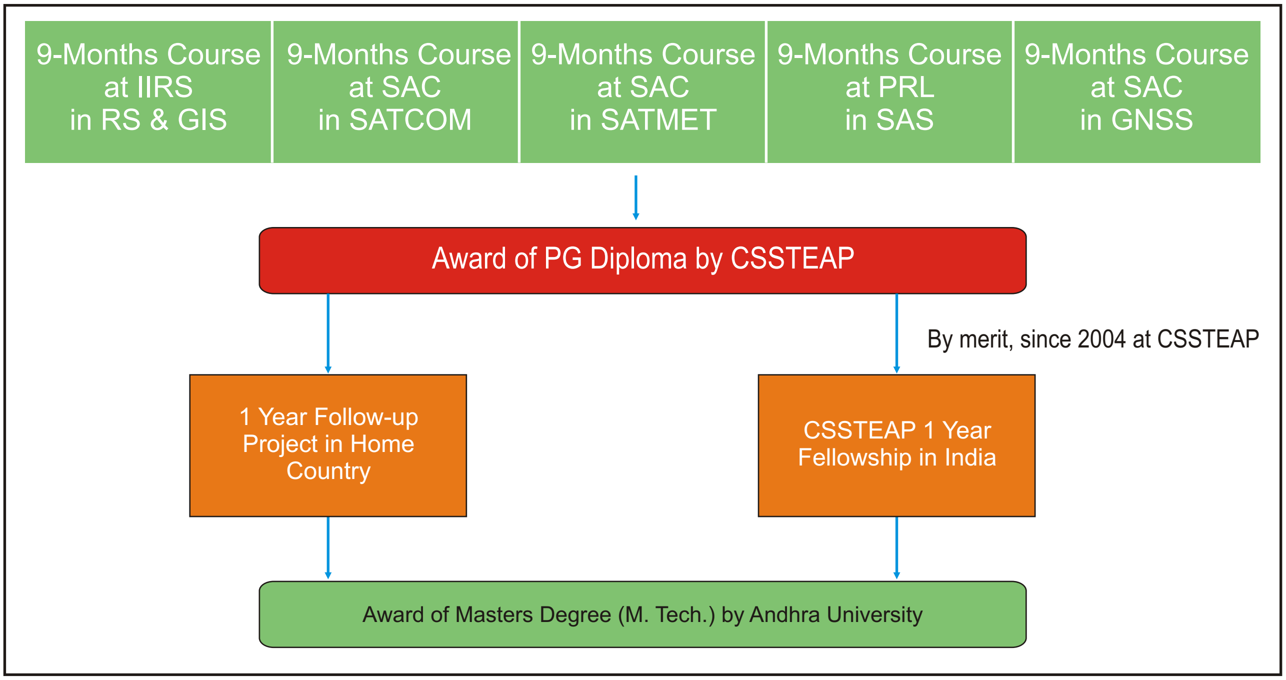


Fig. 1: Structure of PG diploma educational programmes at CSSTEAP

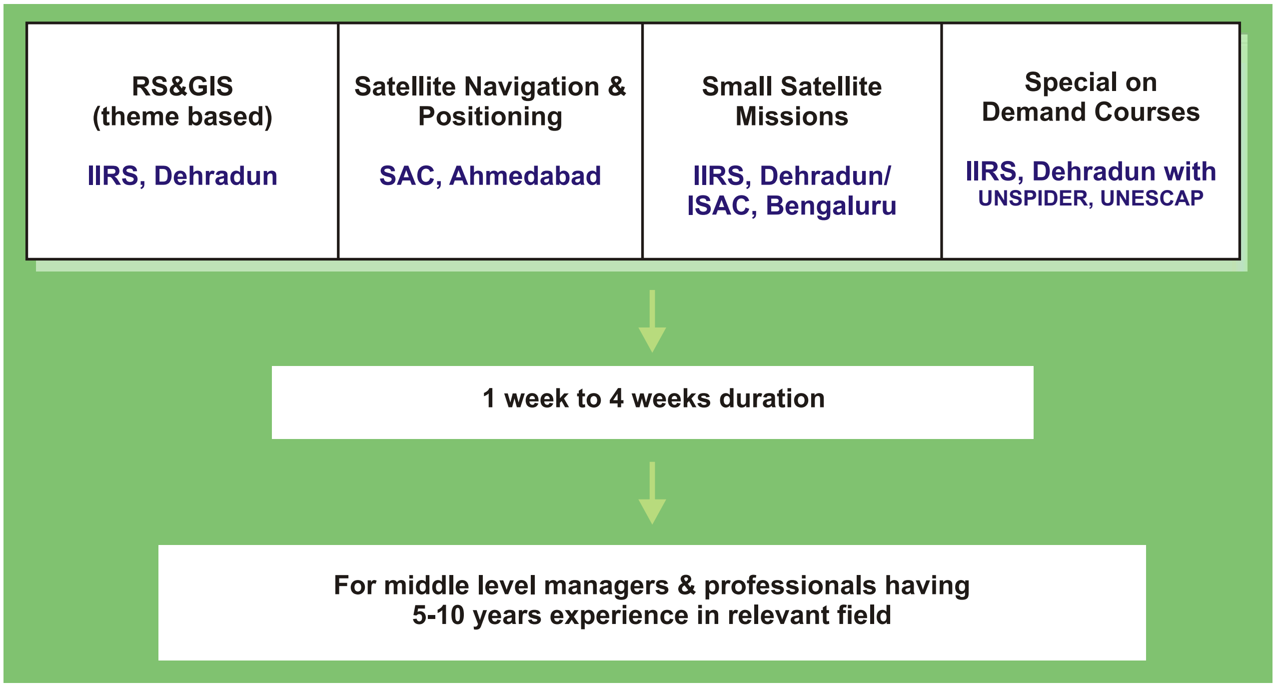


Fig. 2: Short-term training programmes at CSSTEAP

classroom environments with the use of modern teaching methods and tools, and also include multimedia tutorials for self-study. Practical excercises are given in the laboratories and skill development environments of the DOS institutions. In each of the host institutions, most of the faculty are drawn from the host institution (about 80% of the teaching time). Whenever desirable or needed, faculty is drawn from other DOS/ISRO institutions, or professional, scientific or academic institutions in India (~10%) or from institutions or organizations outside India, from the Asia-Pacific Region as well as globally (~ 5%). In order to provide wider exposure to the students in their respective fields, the centre provides opportunities for technical visits to scientific institutions, laboratories and national symposia in India. The successful completion of the 9-month PG-Phase of the programme leads to the award of a Post Graduate diploma by the Centre. For the students who successfully complete their PG course and are interested in continuing for a Master of Technology (M.Tech.) degree, the Centre offers the opportunity to do so, in collaboration with Andhra University (AU) in Visakhapatnam, India. To this end, the student has to complete a 1-year research project in an application of space science or technology. This project has to be approved by CSSTEAP and AU, and the research is supervised by designated academic staff of CSSTEAP, AU and the institution where the research is carried out. In most cases the 1-year project is carried out at the home institution of the student concerned. Since 2004 onwards every year selected meritorious PG students in RS & GIS are being given fellowships to complete their M.Tech. thesis work at CSSTEAP. In year 2004 four PG students (one each from Azerbaijan, Bangladesh, Kyrgyzstan and Nepal), in year 2005 one student from Nepal, in 2007 one student from Mongolia, in 2008 one student from Indonesia, in 2009 one student from Myanmar were given M.Tech. fellowships to complete their M.Tech. research work at CSSTEAP and all have completed and degree has been awarded M.Tech. degree. In 2011 one student from Sri Lanka, in 2012 three PG students (one from each India, Nepal and Vietnam) have been awarded fellowship, in 2013 four students (one each from Bangladesh, Nepal and two from India), in 2014 two students (India & Nepal), in 2015 two participants from India and in 2016 two participants from India have been awarded scholarship.

Till date 143 PG students (69 in RS & GIS; 37 in SATCOM; 18 in SATMET and 19 in SAS) from 16 different countries have been awarded M.Tech. degree. The country-wise distribution of M.Tech. degree awarded in RS &GIS course is shown below: (Fig. 3).

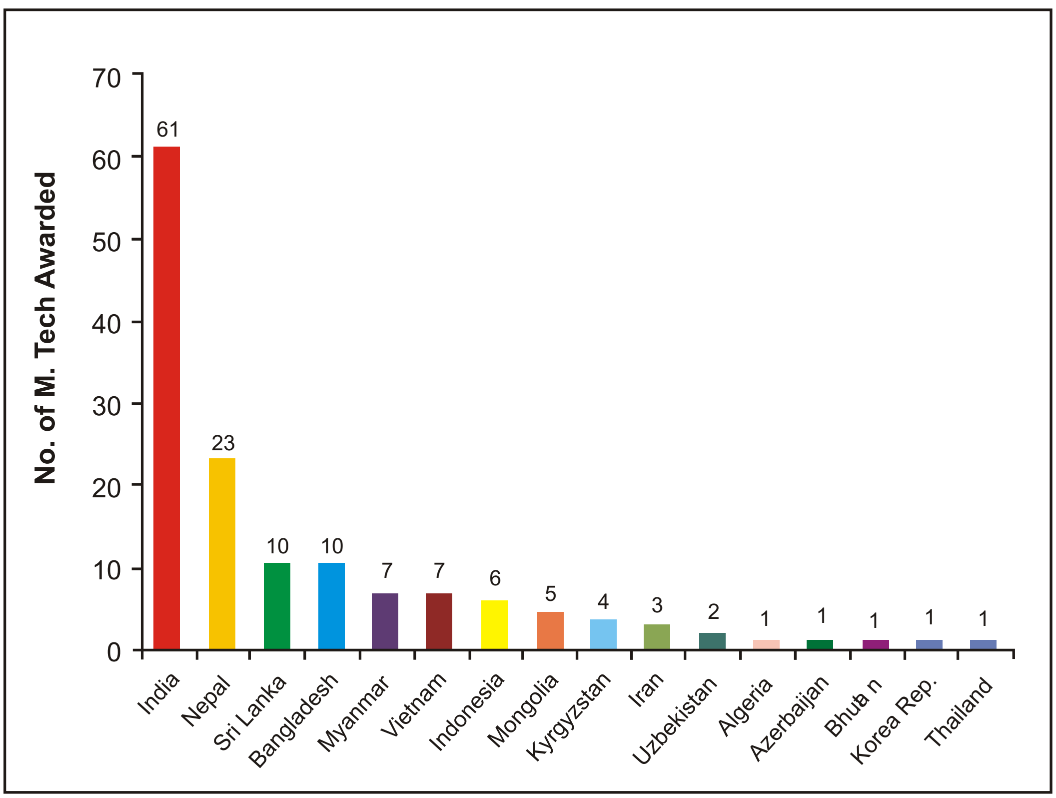


Fig. 3. Status of M. Tech. degree awarded

Remote Sensing and GIS course

The RS & GIS course is directed towards university educators and researchers, natural resources managers and professional in environmental management and to support disaster management. The Post Graduate course is divided into two semesters (semester-I of four months and semester-II of five months including three months pilot project work). Semester-I covers principles of RS, photogrammetry, image analysis, GIS and GPS, recent trends in RS & GIS technology, satellite meteorology, earth processes, natural disaster and environmental monitoring and analysis. Each of the course participants chooses one optional thematic application discipline in semester-II based on his/her academic qualification, professional experience and requirement of his/her parent organization. The thematic optional streams cover RS & GIS applications to (i) Agriculture and Soils, (ii) Forestry Ecosystem Assessment & Management, (iii) Geosciences & Geo-hazards, (iv) Water Resources, (v) Urban & Regional Studies (vi) Marine & Atmospheric Science, (vii) Satellite Image Analysis & Photogrammetry and (viii) Geoinformatics. This also consists of a pilot project which forms the basis for a one year project to be carried out in their home country of the course participant. The discipline-wise distribution of the students in the RS & GIS PG course is indicated below (Fig. 4). A new thematic area in technology Satellite Image Analysis & Photogrammetry was added from theyear 2012.

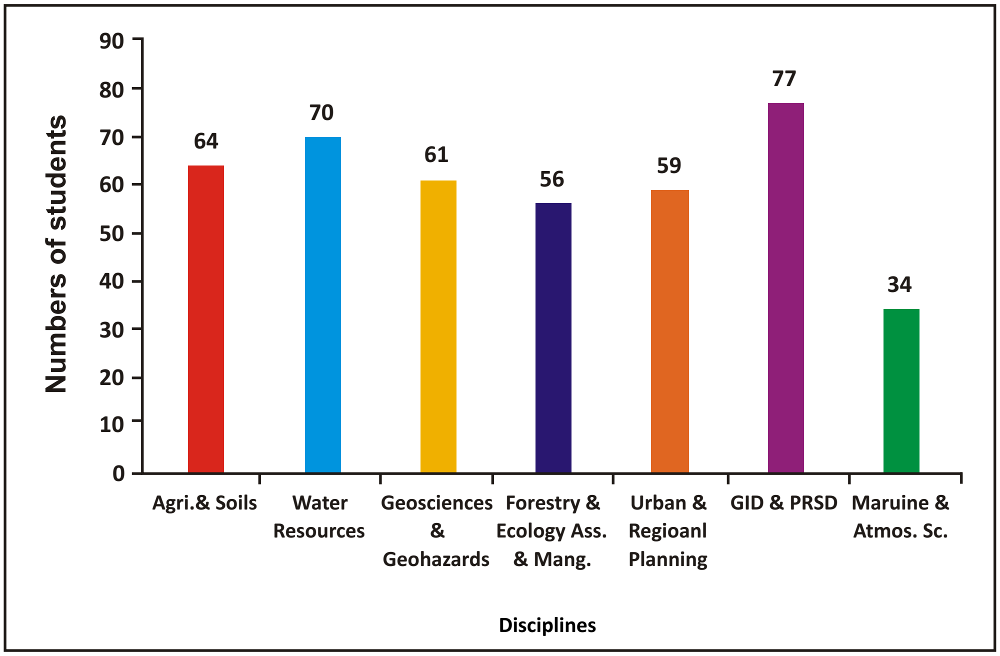


Fig. 4. Status of students in different disciplines

Achievements

Till date the Centre has been conducted 49 PG Courses: 20 in RS&GIS, 10 in SATCOM, 09 in each SATMET and SAS and 01 in Global Navigation Satellite System. Three courses are presently ongoing namely, RS&GIS, SATMET and SAS. In addition, the Centre has conducted 48 short courses and workshops in the past 21 years. These programmes have benefited some 1726 participants from a total of 35 countries in the Asia-Pacific region and 29 participants from 18 countries outside Asia Pacific region have also benefited from these educational programmes.

The centre has played a major role in the development of curricula of four courses which are currently being followed by all the CSSTE's. All course materials are published by the Centre in the form of hard-copy lecture volumes and CDs. The Centre further publishes conference proceedings and other outreach documents, such as general information brochures, course announcement brochures, newsletters and memoirs- marking the end of every PG course. A newsletter is published regularly and sent to all alumni and to persons and institutions associated with the Centre. CSSTEAP has scientific and research collaborations with University of Illinois, USA; TWAS-UNESCO; ITC Twente University for cooperation and mutual assistance in the areas of education and research.

PHYSICAL RESEARCH LABORATORY

Host Institute for Space and Atmospheric Science Course

Dr. Anil Bhardwaj, Director

Physical Research Laboratory (PRL) is a premier, national research institution, under the aegis of the Department of Space, Government of India. Founded in 1947 by Dr. Vikram Sarabhai, PRL has served as the "**cradle of space sciences**". The laboratory is engaged in basic research in Theoretical Physics, Atomic, Molecular & Optical Physics, Astronomy, Astrophysics, Solar Physics and in Earth-, Planetary-, Atmospheric-, and Space- sciences. Presently, the laboratory has about sixty accomplished academic faculty members, over hundred highly skilled technical faculty, assistants, and qualified engineers, and over hundred research scholars and post-doctoral fellows. PRL also hosts short term visitors from other institutions and university departments. Several major experimental programmes in Astronomy, Solar Physics, Space Sciences, Planetary Sciences, and Geosciences are being carried out. Some of these programmes are serving as national facilities. PRL also conducts research on scientific issues of societal relevance.

PRL main campus

The Laboratory has four campuses, located at Ahmedabad, Mt. Abu and Udaipur. The main campus in Navrangpura, Ahmedabad houses most scientific activities of research except programmes in

Astronomy, Astrophysics and Planetary Science and Exploration. These activities are located in Thaltej campus, Ahmedabad. The other two campuses at Mt. Abu and Udaipur, house the Infrared (IR) and the Solar Observatory, respectively.

SCIENCE AT PRL

Astronomy & Astrophysics

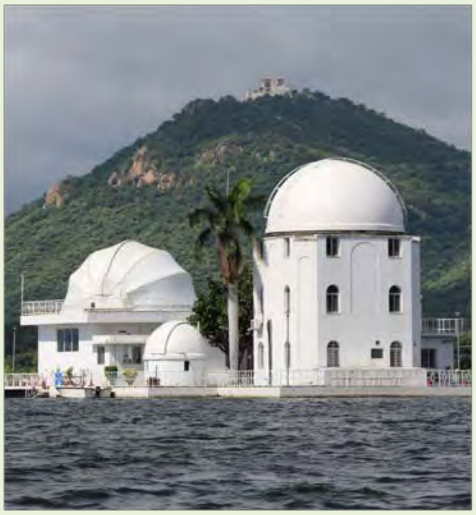
Sight of a dark night with millions of twinkling stars is fascinating and intriguing to human being since time immemorial. The stars are forming even today in large molecular clouds that exist in space. With time, stars evolve and die when their fuel, mainly hydrogen, is exhausted. Each phase of their lives is interesting – the old stars become cooler, redder and bloat up in size, reaching a stage called super-giant. Some of them throw away their outer shell, forming spectacular planetary nebulae while some others end their lives with a violent explosion, shining brilliantly, called novae and supernovae. More massive stars turn into neutron stars and black holes in their end phase and vanish from sight but make their mysterious presence felt through strong gravity.

IR Observatory, Gurushikhar, Mt. Abu

Electromagnetic radiation in radio, IR, optical, X-ray and Gamma-ray plays role of a messenger telling us about these astronomical sources and events happening in the universe. The scientists in the Astronomy & Astrophysics Division are engaged in seeking answers to a host of questions on the birth, life and death of stars, comets and many exotic astronomical sources and events by analyzing radiation emanated by them. It requires light collecting telescopes and sophisticated instruments and basic techniques to decode the messages coming from sources millions and billions of light years away. The main work-horse of the Astronomy & Astrophysics division is Mt. Abu Infrared Observatory (MIRO) housing 1.2m IR and 0.50m telescopes. Over the years scientists have developed and acquired sophisticated back-end instruments, which include Near Infrared Camera and Spectrometer (NICS), Optical Imaging Polarimeter (PIPOL), NICMOS-3 IR array, Fiber fed Echelle spectrograph for radial velocity measurements (PARAS) to detect exoplanets. Apart from the above, scientists at the A&A division are involved in studies of the Sun and its magnetic activity, the solar wind which fills the heliosphere and is important in understanding space-weather on the effects of solar emissions on the near-earth environment. Such studies have indicated that the sun is going through an extremely quiet phase with very low levels of magnetic activity similar to what occurred 400 years ago during the so called Maunder minimum. The observations in optical and IR wavelengths are enriched by the observational data across the electromagnetic spectrum from other facilities, including space observatories which help unfold the mysteries of the universe.

The main scientific programs pursued by the division members are: Infrared photometric and spectroscopic studies of novae, study of star forming regions, infrared study of X-ray binaries, emission processes responsible for high emission from active galactic nuclei, hunt for extra-solar planetary systems, studies of the sun and comets. In addition to these, studies of the astronomical sources are also conducted in radio and X-ray energy regimes. The division is also actively involved in developing instruments for ground and space missions.

Udaipur Solar Observatory



Udaipur Solar Observatory on an island of Lake Fatehsagar

The Sun is closely associated with life on Earth. The modern space based communication systems are vulnerable to emission of high-energy particles and radiation from the Sun. It is necessary to watch the Sun continuously to find out the intensity and timings of these emissions. It is also necessary to do basic scientific research on the physical causes of these emissions to provide warning for such events. The location of the observatory must be at a site mostly free of clouds.

Udaipur is one such place providing more than 270 days of clear skies every year. In addition, this city of lakes has also provided a convenient spot in the middle of Lake Fatehsagar for observing the Sun. The water body reduces the turbulence arising from ground heating during the day. This enables us to observe the details of the various solar features more easily throughout the day. Thus, the Udaipur solar observatory was established on September 20, 1975 under the aegis of the Vedshala Trust, Ahmedabad with financial support from the Department of Science and Technology, Government of India. In 1981, the Department of Space, Government of India, took over the Udaipur Solar Observatory. Since then, it is being managed by PRL.

Solar phenomena become clearer with better spatial, temporal, and spectral resolution. Thus, one is always looking for collecting more light. This means one is looking for telescopes with large apertures. To fully exploit the atmospheric conditions at the island site, Udaipur Solar observatory initiated a project to install a new 50 cm telescope named the Multiple Application Solar Telescope (MAST). This telescope has 10 times more light gathering power compared to the earlier 15 cm Spar telescope. It also is equipped with a modern adaptive optics system for online correction of the image distortion produced by atmospheric turbulence. MAST has been installed and is functional on the island.

Space and Atmospheric Sciences

The Earth's atmosphere is characterized as troposphere, stratosphere, mesosphere, thermosphere, and exosphere with height depending on vertical temperature structure. The interaction of solar ejecta with the neutral atmosphere essentially gives rise to charged species. Based on charged species the upper atmosphere is classified further as ionosphere, plasmasphere, and magnetosphere. The activities of the

Space and Atmospheric Sciences Division aim to understand radiative, chemical, ionization, and dynamical processes in the Earth's atmosphere by employing state-of-the-art and in-house built rocket-, balloon-, and ground-based experiments, radio probing techniques, laboratory experiments along with theoretical simulation and numerical modeling of atmospheres of Earth and other planets.

Lower atmospheric (0-50 km) studies include characterization of aerosols and their impact on the Earth’s radiation budget, their seasonal and diurnal variations, trace gases and volatile organic compounds and their effects on atmospheric chemistry and pollution, middle atmospheric (30-80 km) temperature, etc. These studies are aimed to understand climate change and implications on environment which include radiative forcing of man-made aerosols and rare atmospheric trace gases.

As the ionosphere is embedded in the thermosphere, plasma-neutral interaction in the presence of geomagnetic field helps in the generation of electric fields which control several phenomena that are unique to low-latitudes including formation of spatio-temporally varying structures. Such structures are also formed during *Space Weather* events, wherein geomagnetic storms occur as a consequence of solar disturbances. Our scientists have been making fundamental contributions in understanding these phenomena.

In addition, modelling studies on the processes influencing the Martian ionosphere, effect of space weather events on Mars, and the influence of dust storm on Martian lower atmosphere are being carried out.

Planetary Sciences and Exploration

Studies on the origin and evolution of the solar system, with focus on inner planets are the primary research objectives of the Planetary Sciences Division. Several key questions are addressed by investigating the chemical and isotopic records contained in various terrestrial and extraterrestrial samples. These questions include the following: When and how did the solar system form? How have the solar system objects evolved through time? What are the processes that determined their evolution?

The information on the origin and evolution of the solar system is stored in some minerals formed during its inception. These minerals are found in some select groups of primitive meteorites. Isotopic records derived from these minerals have allowed us to infer that the death of a massive star triggered the collapse of an interstellar gas and cloud that led to the formation of the solar system. Studies on a meteorite which fell in Piplia Kalan village of Rajasthan led to the identification that the radioactive decay of ^{26}Al was the heat source for the melting of asteroids during the very early stages of the solar system evolution. Records of noble gas and nitrogen isotopes in Martin meteorites have led to the characterization of the ancient Martian atmosphere, and inferences on the chemical composition of the source materials which accreted to form Earth and Mars.

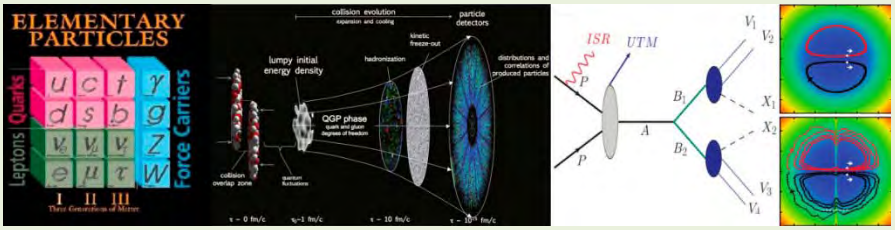
In 2001, a National Programme in Planetary Sciences was envisaged to explore the inner solar system objects beginning with the first Indian moon mission (Chandrayaan-1). PRL's is pursuing planetary exploration as one of the major directions of future space science activities in India made it necessary to initiate a Planetary Science Exploration Programme (PLANEX). The PLANEX Programme envisaged the following components: (a) identification and financial support of research projects related to planetary science research at different national institutions, (b) organization of special workshops for training of young students in planetary science for human resource development, (c) establishment of national facilities for analysis of planetary materials and research in planetary sciences. With the aim of creating awareness amongst students and research scholars in the universities, research laboratories and academic institutions and to attract bright talented young scholars to take up research in the challenging area of Planetary Science and Exploration, the PLANEX programme has been organizing periodic workshops and training programmes. Besides the core group at PRL, twenty other groups at various places across India have been supported for conducting research in planetary sciences and allied fields, and PLANEX Programme has supported more than fifty research proposals on various aspects of planetary science research. An X-ray Fluorescence Spectrometer, Electron Probe Micro Analyser, Inductively Coupled Plasma Mass Spectrometer and a Noble Gas Mass Spectrometer have been procured and are part of the National Facilities for analysis of astromaterials at PRL. Results from the Moon Mineralogy Mapper payload on Chandrayaan-1 for the first time revealed that the lunar surface (particularly Polar Regions) hosts hydroxyl (OH) and water molecules.

Geosciences

Research in Geosciences Division (GSDN) is aimed at understanding origin and evolution of planet Earth and its various reservoirs, with special emphasis on timescales and processes. The major areas of research in this division include studies on ancient and modern volcanoes, chemical evolution of Earth's interior with time, changes in surface morphologies, causes and effects of changing ocean chemistry and sediments deposited in them, nitrogen and carbon cycling in marine and terrestrial environment, history of global climate and Indian monsoon in geological and historical records, surface, sub-surface and atmospheric components of hydrological processes, impact of biological processes on evolution of water bodies, aerosol chemistry and characterization, climate change etc. The methodologies followed are centred on measurements of abundances and ratios of elements, radioactive isotopes, radiogenic isotopes, stable isotopes, and luminescence properties of materials using modern analytical tools. Some of the modern instruments used for carrying out various analyses are: Multi-collector Inductively Coupled Plasma Mass-Spectrometer (MC-ICPMS); Thermal Ionization Mass Spectrometer (TIMS); Liquid Scintillation Counter (LSC); Alpha, Beta and Gamma detectors; Isotope Ratio Mass Spectrometer (IRMS), Thermo luminescence (TL) and Optically Stimulated Luminescence (OSL) dating systems etc.

Scientists from this Division are participating in an international programme named GEOTRACES which aims to improve the understanding of biogeochemical cycles and large-scale distribution of trace elements and their isotopes in the marine environment. A multi-institutional collaborative national programme for Isotope Fingerprinting of Waters of India (IWIN) has been conceived and is being implemented by researchers from this division with a view to understand subtle hydrological processes which cannot be observed by measurement of volumes and fluxes of water. Another important research programme of the division deals with volcanological, chronological, geochemical and petrogenetic evolution of the Barren Island Volcano, India.

Theoretical Physics



Each one of us, starting from childhood, is fascinated by various physical phenomena that we witness, and yearn to understand the principle(s) and basic laws that govern them. The study of fundamental principles, eventually yielding mathematical structures and equations that describe the physical phenomena that we observe constitutes the main activities of any theoretical physics group/department in any institute/university. The Theoretical Physics Division at PRL studies the fundamental principles in diverse fields such as Particle Physics, Nuclear Physics, Atomic Physics, Complex systems and Cosmology, covering a wide spectrum ranging from micro to macro.

The question about our own existence and the existence of the universe that we observe and infer via direct and indirect experimental measurements has always intrigued the human mind. These issues have multiple facets, from philosophical to understanding them from first principles. The Theoretical Physics Division studies the fundamental laws of physics which relate such diverse experimental results. The Higgs particle was discovered by the Large Hadron Collider at CERN, Geneva. This particle is supposed to endow everything else with their mass, and is therefore central to our understanding of the universe. The division has been involved in studying different aspects of this particle and its interactions with other fundamental particles. Any attempt to understand the present universe necessarily requires us to have good understanding of the early phase of the universe and how it has evolved to the present form. Observations show that the early universe should have been much hotter and denser, and the matter at that epoch of time would have been in the form of plasma. The very early phase of the universe is expected to produce gravitational waves. The Background Imaging of Cosmic Extragalactic

Polarization (BICEP2) collaboration announced the observation of such gravitational waves in an experiment at the South pole. The division is engaged in studies that relate the present and early phases of the universe. Studies of the Theoretical Physics Division contributed towards the experimental design of the Indian Neutrino Observatory (INO) which is being built at Pottipuram in Theni District of Tamil Nadu to study cosmic ray neutrinos and detect dark matter.

Atomic clocks are known to be the most precise clocks we have, and are routinely used as primary standards for services like GPS, to control the wave frequency of television broadcasts etc. To be able to use them and improve upon them, detailed atomic calculations are required. Studies of atomic systems pursued at PRL not only help in this direction but also aid in deciphering the fundamental principles from precision measurements with atoms and condensates of atoms. The studies on large nuclei have paved way for new avenues in nuclear physics and mathematics.

Any real and practical system, that we may wish to make and work with typically, turns out to be a complex system, i.e. it is not possible to describe it in terms of a small number of components and the overall behaviour of the system cannot be approximated to be the sum of the behaviour of the individual components. Complex systems describe phenomena as wide and disparate as photosynthesis, traffic on roads and in air, internet connectivity, social networking. Studies along these directions have led to better understanding of the basic features. Members of the group are also studying high temperature superconductors with the aim to discern the principles governing their properties, in order to harness them to the optimum.

Atomic, Molecular and Optical Physics

Research in this division is interdisciplinary and covers a wide spectrum of themes ranging from foundations of quantum mechanics to quantum information and from Astrochemistry to Geosciences. This division investigates atoms, molecules, molecular clusters and condensed matter systems using wide range of electromagnetic spectrum and other sources like high energy electrons and charged ions to understand various optical and spectroscopic properties of matter.

The division undertakes experimental and theoretical studies on both classical and quantum aspects of light. Its laboratories are equipped with state of the art instruments and the group combines calculations with experimental work which have yielded several new results such as violation of Bell's inequality for phase singular beams, high power tunable Airy beam generation, spontaneous parametric down conversion of perfect vortex beams and recovering the vorticity of a scattered optical vortex. Experimental facilities in the Molecular Physics laboratories include Recoil Ion Momentum Spectrometer, Laser Plasma Spectrometer, Time of Flight Mass Spectrometer, Fourier Transform Infrared Spectrometer, System for Low Temperature (10K) Astrochemistry, Electron Guns and other sophisticated equipment to understand molecular synthesis and molecular fragmentation under varied temperature and pressure environments.

The luminescence dating lab is amongst the more advanced laboratories in the world and has a large suite of systems for thermo luminescence (TL) and optically stimulated luminescence (OSL) dosimetry and dating, and an indigenously developed system for surface imaging of luminescence. It has extensively studied past climate and seismological events using geological sediments. It has also investigated thermal and radiation history of meteorites using their luminescence signals.

National and International acclaim

Research work carried out by PRL scientists is published in prestigious scientific journals and are referred to by scientists all over the world. The average number of publications in peer reviewed journals exceeds 150 per year.

Numerous books on contemporary topics have been authored and edited by PRL scientists. PRL scientists have been recognized at national and international levels. Scientific research conducted at PRL received high acclaim in a recently conducted international review.

Facilities at PRL

The **Computational services** at PRL employ two IBM e-Server X-365 (Dual Processor, IBM POWER-5 with 4 Processors that offers high performance parallel computing environment for numerically intensive computational tasks. This, together with 4HP Proliant DL385, dual core AMD Opteron processors with 5 terra bytes of usable disk space provides a platform for sophisticated computations and meets the requirements of data storage for image processing and other scientific applications. A cluster based enhancement in computation capability is being implemented.

The VIKRAM-100 is a High Performance Computing (HPC) Cluster with 100 teraflops sustained performance. This is a centrally-run service to support scientists, researchers and research scholars at PRL who require high performance computing. This includes workloads with requirements that can't be met by desktop PCs. Currently, Vikram-100 is the 15th fastest supercomputer in India.

The 97 computing nodes of the HPC facility offers 2,328 CPU cores, 1,15,200 GPU Cores, 25 TB of RAM and 300 TB of high performance parallel files system.

The cluster operating system is Red Hat Enterprise Linux 6.5, with job submission handled by IBM Platform Computing. The service supports a wide variety of third-party software including numerical packages, libraries and C and FORTRAN compilers.

PRL has a state of art **library** with excellent collection of books, print- and e-journals. Processing in the library is computerized and links to other libraries ensure easy access to any desired information/publications. PRL also has well equipped machine shop, a glass-blowing section and in house liquid nitrogen facility.

Distinguished Professorships

PRL hosts prestigious **Vikram Sarabhai Professorship and K. R. Ramanathan Professorship**, under which eminent scientists are invited for lectures, popular talks and academic stays for extended duration. Several Nobel Laureates have graced these professorships. PRL also offers visiting positions under various national and international exchange programmes.

CAPACITY BUILDING INITIATIVES

Doctoral and Post doctoral Programmes

PRL has contributed significantly to the scientific manpower development in the country through Doctoral (Ph.D.) and Post-Doctoral programmes. PRL attracts highly motivated students to pursue doctoral research in several branches of Theoretical Physics, Space and Atmospheric Sciences, Astronomy, Astrophysics, and Solar Physics, Atomic, Molecular & Optical Physics, Planetary Sciences, and Geosciences. The students are trained through a rigorous course work followed by a research programme leading to a Ph.D degree. The post doctoral programme at PRL also attracts young researchers, to work on research themes of complementary interests.

The fellowships at PRL compare with the best in the country, and are supplemented by an annual book grant, International travel support and Ph.D. registration fee. Details of these programmes can be had on PRL website or from the Head, Academic Services, PRL.

PRL alumni have played a key role in the development of institutions and programmes in India and abroad. The Indian Space Research Organization (ISRO) was nucleated in PRL in the early seventies and two of the past ISRO Chairmen Prof. U.R. Rao and Prof. K. Kasturirangan - are distinguished alumni of PRL. The Institute of Plasma Research (IPR) was nucleated by the erstwhile Plasma Physics group at PRL.

UN course on Space Sciences

Under the auspices of the Center for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) of United Nations, PRL has been organizing a **UN - sponsored Post-Graduate Course in Space Science** every alternate year since 1998. Participants from the Asia-Pacific region have been attending this course. PRL regularly organizes National and International conferences/ seminars/ symposia/ workshops on problems of topical interest. Advance schools are also organized on specific themes to train young researchers in the country.

Programmes for Students and Teachers

A summer programme for students at BSc (final) / MSc – I year levels and college/university teachers is organized to provide them with hands on experiences in research methodologies in various areas.

This programme is organized during May-July every year. The programme for students is meant for BSc (final) / MSc I-year students in Physics/Chemistry/Geosciences. The programme for teachers is meant for those involved in teaching Physics and Geosciences at graduate and post-graduate level and having interest in pursuing research.

PRL Associateship

PRL Associateship programme facilitates university teachers to visit PRL and work in collaboration with PRL scientists. This provides them with an opportunity to use experimental, computing and library facilities at PRL to further their research initiatives.

RESPOND programme

On behalf of the ISRO, PRL administers the RESPOND (Sponsored Research). The main objectives of the RESPOND Programme is to establish strong links with academic institutions in the country to carry out research and developmental projects which are of relevance to space and derive useful outputs of such R&D to support ISRO programmes. RESPOND programme aims to enhance academic base, generate human resources and infrastructure at the academic institutes to support the space programme. The major activity of RESPOND is to provide support to research projects in wide range of topics in space technology, space science and applications areas to universities/ institutions. In addition conferences, workshops and publications, which are of relevance to space research, are also being supported.

Project Training Programmes

PRL offers project training for Engineering students in Electronics and Communication, Computer Engineering, Information Technology, and Master of Computer Applications (MCA). In addition, trainees are also taken in the Computer Centre, Workshop, Library, and Engineering Services and at Mt. Abu and Udaipur observatories.

Interactions with the Society

PRL values its interaction with the society and organizes science exhibitions and open houses, to inform the society about its programmes, contributions and the excitement of science. In additions it welcomes visits by school and college students. Special arrangements are made from time to time for observing astronomical events, popular / public lectures by distinguished visitors and by PRL scientists are arranged on topical events such as, the appearance of comets, solar eclipses, meteor showers, earthquakes etc.

PRL celebrates the National Science day by holding a series of programmes that include a science quiz and lectures for high school students and teachers.

Joint Inaugural Function

The Tenth Post Graduate Courses on Satellite Meteorology and Global Climate and Space and Atmospheric Science, under the aegis of the UN affiliated CSSTEAP, is being conducted at Space Applications Centre (Bopal Campus), Ahmedabad during August 1, 2016 to April 30, 2017. Twenty-five participants representing seven countries of the Asia Pacific region are attending the Courses.

A joint inaugural function of the two courses i.e. the Satellite Meteorology and Global climate conducted by Space Applications Centre and the Space and Atmospheric Sciences conducted by Physical Research Laboratory was held at K.R. Ramanathan Auditorium, PRL on 4th August 2016. Shri Tapan Misra, Director SAC & PRL, Dr. Senthil Kumar, Director CSSTEAP & IIRS, Dr P Janardhan, Dean PRL and. senior officers from SAC and PRL graced the function.

Dr Janardhan welcomed the participants, presented a brief overview of PRL and gave the students an idea of what to expect from this course. The participants from distant countries and varied cultures gave a brief introduction about themselves, their professional background and their aspirations from the course. Dr. Senthil Kumar gave an overview of the CSSTEAP Programs. Shri Tapan Misra gave the inaugural address and observed that this is not only a golden opportunity to learn advanced subjects like Satellite Meteorology and Space science, but also to learn about India and her diverse cultures.

The common orientation module of both the courses began in the afternoon.


Dimensions of Indian Space Program
Ground Segment
Data Acquisition, Processing, Cal-Val
AWS Ground stations, DSN
TTC Network
Space Infrastructure
Capacity Building
Formal education through IIRS, CSSTE-AP
Hands on training @SAC, NRSC
Indian Institute of Space Science & Technology
Applications
Institutionalization
International Cooperation
Bilateral and multilateral cooperation with various countries and international Organisations

SAS-10 Academic Activities: An Overview

J. Banerji, *Course Director*

The Tenth PG course in Space and Atmospheric Science (SAS-10) was conducted by Physical Research Laboratory (PRL), Ahmedabad at its Bopal Campus from August 1, 2016, under a programme by The Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), affiliated to the United Nations. The course has a nine-month duration spread over two semesters. A brief semester-wise description of the academic activities is as follows.

First Semester

The course started with introductory lectures common and useful to both SAS and SATMET participants. In this common module very interesting talks were given by the faculty members from PRL, SAC and IIRS. Regular course began immediately after the common module was over. The course was spead over two semesters. Faculty members included eminent Scientists/Engineers from PRL and other Institutions in India. Each subject was taught in 40 one-hour lectures during the morning hours. Relevant practicals were conducted in the afternoon sessions. For each of these subjects, there were tests, assignments and short seminars which were graded and used for internal assessment of the students. There were 2 assignments, 6 tests, 4 seminars and 6 practicals in the first semester.Subjects covered in the 1st semester were Atmosphere, Ionosphere, Ground Based Techniques, Space Instrumentation and Space Exploration. Lectures for the first semester ended on November 7. Final examinations for the first semester were conducted during the period 13-27 November, 2016. As a part of the programme, the students were taken on a scientific tour to Udaipur Solar Observatory and the infra-red observatory at Mt Abu during the period 28 November- 2 Decemeber, 2016.

Second Semester

Classes for the second semester began on Dec. 5 and ended on Jan 13, 2017. There were 3 theory papers covering topics on Magnetosphere, Solar and Radio Astronomy, and Stellar Astronomy. In the second semester, there were 7 tests, 2 seminars and 6 practicals. Final examinations were conducted during the period 20-27 January.

From February 1, pilot projects started. Each student chooses a topic of her/his research interest and pursues the research under the guidance of a faculty of PRL. The project counts as equivalent to two elective papers. The pilot project topics are as follows:

1. Temperature and soil moisture change over Ulaanbaatar, Mongolia
2. Ozone and its precursors in ahmedabad : Features of diurnal and day-to-day variations
3. Study of waves and oscillations in the Earth's atmosphere
4. Investigation of Atmospheric Greenhouse gases over India
5. Determination of aerosol optical depth by using sun photometer
6. Study of Aerosol Black Carbon
7. Enhancing spectropolarimetry of CZT Imager, AstroSAT
8. CCD Photometry of AGNs
9. Study of stealth CME and ICME
10. Study of halo CME in interplanetary medium during 2011
11. Study of Proton Flare Characteristics and Their Relation to CME Dynamics
12. Looking at the coronal loop dynamics using numerical simulations

At the end of February, the students were taken on educational tour to selected national centres of excellence in Space and Atmospheric Science. We visited NRSC and TIFR baloon facilty at Hyderabad, IIA and CREST at Bangalore, RAC and Cosmic Ray Laboratory at Ooty and Andhra University, Vishakhapatnam for the mandatory document verification. The tour lasted till March 10,2017.

There were two examinations in the pilot project in which students gave presentations in front of an evaluating committee. These examinations took place on March 15 and April 12, 2017.

Common Module

The following topics were covered:

1. **EM Spectrum** by Dr. Shashi Kiran Ganesh,
2. **Data Collection Platforms** by Ms. Pushapalata Shah,
3. **Computer Orientation-1 Visit to MOSDAC Data reception system**, by Mr. Mahesh/Ms. Shivani/Ms. Ruchi,
4. **Ionosphere** by Prof. Harish Chandra,
5. **Radio Antenna** by Dr. S.Sankararaman,
6. **Remote Sensing** by Dr. Senthil Kumar,
7. **Universe** by Dr. U.C.Joshi,
8. **Atmosphere** by Prof. Shyamlal,
9. **Solar Activity** by Prof. Rajmal Jain,
10. **Introduction to Satellite Communications** by Dr. Raghunath Bhattar,
11. **LIDAR** by Dr. Som Kumar Sharma,
12. **About Library and Documentation** by Ms. Rachana,
13. **Global Climate and Climate Change** by Dr. Abhijit Sarkar,
14. **Satellite Meteorology** by Dr. B. Simon,

Course Contents

Details of the individual theory papers

Semester 1

Paper 1: Atmosphere (40)

1.1 Concepts of Earth's Atmosphere (10): Basic Structure of Atmosphere - Hydrostatic Equilibrium - Scale Height - Geopotential Height Thermodynamic Considerations – Elementary Chemical Kinetics – Composition and Chemistry of Lower, Middle and Upper Atmosphere - Thermal Balance in Thermosphere .

1.2 Effects of Solar Radiation on Atmosphere (5): Solar Radiation at the Top of the Atmosphere – Attenuation of Solar Radiation in the Atmosphere – Radiative Transfer – Thermal Effects of Radiation – Photochemical Effects of Radiation

1.3 Aerosols, Greenhouse Gases and their effects on Radiation Budget (15): Aerosols & Radiation Budget - Long Term Climate Impact - Black Carbon & Dust- Greenhouse Gases - Carbon monoxide - Carbon dioxide - Oxides of Nitrogen - Methane – Atmospheric Ozone – Ozone Chemistry – Ozone Hole .

1.4 Dynamics of Earth's Atmosphere (10): Equation of Motion of Neutral Atmosphere – Thermal Wind Equation – Elements of Planetary Waves – Internal Gravity Waves and Atmospheric Tides – Fundamental Description of Atmospheric Dynamics and Effects of Dynamics on Chemical Species

Paper 2: Ionosphere (40)

2.1 Structure and Variability of Earth's Ionosphere (13): Introduction - Chapman's Theory of photo-ionization – Continuity equation and photo-chemical equilibrium – Loss processes - α and β Chapman layers - Chemistry of E and F1 regions - D region chemistry – Water cluster ions and their significance - Electron attachment and negative ions in the D region - F region processes – F layer splitting - Vertical transport - Ambipolar diffusion and F2 peak - Topside ionosphere – Diffusion between ionosphere and protonosphere - Morphology – diurnal, seasonal and solar cycle variations of ionospheric regions - F- region anomalies - SIDs

2.2 Ionospheric Plasma Dynamics (13): Properties of magneto plasma – Gyro frequency - Plasma frequency - Debye length and Frozen in field - Basic fluid equation - Steady state plasma motions due to applied forces - Electrical conductivity of the ionosphere - Generation of electric field and electric field mapping - Ionospheric dynamo - Ionospheric irregularities – Equatorial Spread F and Equatorial Electrojet (linear theories) - Mid-latitude ionospheric irregularities – Sporadic E

2.3 Electromagnetic Wave Propagation in Ionosphere (14): Theory of Wave propagation - Properties of plane waves in isotropic and anisotropic media - Group propagation - Ray and group velocities - Radio waves in ionized media – Propagation in isotropic plasma and refractive index - Concepts of critical frequency and virtual height - Magnetoionic theory – Appleton-Hartree formula for refractive index - Ordinary and extraordinary waves - Reflection conditions - Deviative and nondeviative absorption formulas - Oblique incidence propagation – MUF and skip distance.

Paper 3: Ground Based Techniques (40)

3.1 Radio Antenna (12): EM radiation - Small dipoles and Loops - Half wave dipole - Antenna Arrays - Reflector Antenna –Applications for Radio Astronomy - Transmission lines and Impedance Matching Techniques - Receivers and Transmitters

3.2 Radio sounding (12): Ionospheric Absorption Techniques - Ionosonde - HF and VHF Radars – Coherent and Incoherent Scatter Radars (HF, VHF and MST) - Radio Beacon Techniques - Global Positioning System (GPS),

3.3 Optical Techniques (10) : Photomultipliers Tubes - Image Intensifiers – Lasers - Semiconductor Photonic Devices - Photo diodes - Avalanche diodes - Laser diodes & CMOS imaging detectors -– Imagers - Interference Filters and Etalons – Fabry Perot Interferometer - Filter Photometers – Lidar, - Aerosols, Trace Gases and Ozone measuring devices.

3.4 Airglow (6): Airglow – Oxygen green and red line emission - Nightglow – Dayglow – Twilight Glow –– Applications of Airglow Measurements for Ionospheric Dynamics

Paper 4: Space Instrumentation (40)

4.1 Launch Vehicles, Satellites and their Orbits (5): Principles of Rocketry - Rocket Motors - Solid and Liquid Fuel Rockets - Sounding Rockets - Cryogenic engines - Multistage Rockets - Satellite Launch Vehicles - Basics of Satellite orbits- Kepler’s Laws – Sub-satellite Point – Orbital Parameters – Sun-synchronous and geosynchronous Orbits – Low-Earth Orbits

4.2 Attitude Control, Power and Thermal systems of Spacecrafts (10): Attitude Sensors – Sun Sensors – Star Sensors – Earth Sensors – Magnetic Aspect Sensors- Accuracy – Spin Stabilization and Gyros – Control of Flight-path – Close-loop Guidance, Spacecraft Power System –Solar Cells and Panels – Primary and Secondary Batteries— Special Power Sources – Radioactive Thermoelectric Generators (RTG) , Spacecraft thermal control techniques

4.3 Selection of Materials for Space –borne payloads (5): Behavior of Materials in Space (Temperature, Pressure and Radiation) – Outgassing —Corona Discharge— Coating and Coating-compounds – Radiation Damage –,Mounting of Subsystems – Structural and Mass Limitations – Carbon Fiber Reinforced Plastic (CFRP) - Honeycomb Structures —Effects of Vibrations and Shocks on Spacecraft Structures – Spacecraft Thermal Environments – Thermal Paints and Surface Finish

4.4 Reliability, Tests and Qualification of Payloads for Space Experiments (5): Fabrication of Electronics – Subassemblies- Electromagnetic Compatibility—Checkout, Reliability Considerations and derating - Test and Evaluation - Thermovac tests - Vibration and shock tests

4.5 Telemetry, Tracking , Command (TTC) and Data Handling System (5): Telemetry System – Signal Conditioner, Onboard Data Recorder, Telecommand – Encoder—Decoder—Pulse and Data Commands - RF Systems – Receivers, Transmitters and Antenna— Ground Segments – Real-time and Off-line — Tracking

4.6 In Situ Techniques on Space Platforms (10): Langmuir Probe – Electric Field Probe – Ion Drift Meter – Retarding Potential Analyzers – Mass Spectrometers and Magnetometers – Satellite based temperature measurement - Satellite Drag for Neutral Densities

Paper 5: Space Exploration (40)

5.1 Atmospheres of other Planets and Satellites (10): Inner and outer planets - Structure and Composition of atmospheres planets (e.g. Jupiter, Mars, Venus and Saturn) - their important Satellites

5.2 Ionospheres of Planets and their Satellites (10): Ionospheres and magnetospheres of solar planets (Mars, Venus, Jupiter, Saturn etc.) and those of natural satellites (e.g. Titan), Extra-solar planets and their search procedures

5.3 Data Analysis Techniques (10): Data resources, Data processing, Error analysis - Time series – Fourier Transform – DFT – FFT –Least Square Method – Linear Fitting – Statistical test of Significance – Correlation – Chi Square Test.

5.4 Examples of science and application satellites (10): Indian and foreign operating remote sensing satellites and their instruments - Vital instrument parameters and sensitivity of instruments - Examples of communication satellites and their instruments - limitations and sensitivity of instruments; Instruments and their capabilities on Atmospheric Science satellites like ENVISAT, Megha-Tropique - Instruments and sensitivities of Astronomy satellites – Hubble Space Telescope, Spitzer Observatory - Chandra X-ray Observatory, Rossi X-ray Timing explorer - Astrosat and Swift mission

Semester 2

Paper 6: Magnetosphere (40)

6.1 Origin of Magnetic Field of Earth (10): Dipole Description of Geomagnetic Field –Local elements and their determination - Secular and Diurnal Variation of Geomagnetic Field – Determination of Geomagnetic Coordinates of Station

6.2 Magnetosphere of Earth (10): Effects of Solar Wind on Planetary Magnetic Fields – Formation of Geomagnetic Cavity – Magnetopause – Magnetosheath and Bow Shock – Polar Cusp and magnetotail

6.3 Phenomena in Magnetosphere (10): Plasmasphere and Van Allen Radiation Belts – Magnetotail Dynamics - Substorms , Aurorae and Storms - Magnetosphere of Other Planets

6.4 Space Weather and its Effects (10): Geomagnetic Storms – Sub-storms and Current Systems – Aurora

Paper 7: Solar and Radio Astronomy (40)

7.1 Elements of Solar Physics (10): Sun and its Atmosphere – Solar Magnetic field - Sunspots and Solar Cycles – Solar Flares , Coronal Mass Ejections (CME) and Solar Wind Effect of Magnetic Disturbance on Ionosphere and Thermosphere System - Effects on Space and Ground Based Systems

7.2 Solar System Objects and their Exploration (10): Planets and satellites of the planets and their orbits - Structure and topography of planets and their satellites - Physical and chemical characteristics - Space imagery of planets and their environment - Comets, asteroids and other minor bodied in the solar system - Their orbits, surface and composition - Comet and asteroid collisions

7.3 Basics of Radio Astronomy (10): Different type of Radio Telescopes - Aperture Synthesis - Very Long Base Interferometers (VLBI)

7.4 Radio Sources (10): Radiation Mechanisms, Radio Galaxies, Pulsars, Radio Catalogues

Paper 8: Stellar Astronomy (40)

8.1 Introduction to Astronomy (8): Celestial Sphere; Coordinate systems; Measurement of Time; Observable quantities; Continuum radiation from Stars; Terminology - Brightness, Luminosity, Magnitude scale, colour; Size and Distance; Stellar spectra - formation of spectral lines - line broadening - curve of growth; Local Thermodynamic Equilibrium - Saha's equation; Spectral classification of stars; HR diagram; Binary stars and determination of stellar parameters.

8.2 Introduction to Astrophysics (12): Main sequence phase of stars - Energy sources; Equations for Stellar interiors - stability; Atmospheres of stars; Post-main sequence evolution of stars; Fate of stars at the late stages of evolution - Mass loss -Planetary nebulae - supernovae; Chandrasekhar limit - Degenerate core remnants - White Dwarfs - Neutron stars - Black Holes; Interstellar medium and Star formation; Galaxies and their classification; Hubble's law; Introduction to Active Galactic Nuclei and Gamma Ray Bursts

8.3 High Energy Astrophysical Processes and Phenomenology (10): Radiation processes - Cosmic Rays – Composition, energy and origin - X-ray Sources - X Ray Binaries - Supernova Remnants – Pulsars – Galaxies - Active Galactic Nuclei - Solar X-rays - Gamma –ray astronomy-Gamma-rays from Pulsars - Supernova Remnants and Active Galactic Nuclei - Neutrino astronomy

8.4 Astronomical Instruments and Observing Techniques (10): Telescopes - Different types of telescopes - Angular resolution and Diffraction Limited Resolution - Image formation in a camera - Plate Scale - Observatories (Ground Based & Space Based) - Focal Plane Instruments—Imagers - Photometers -

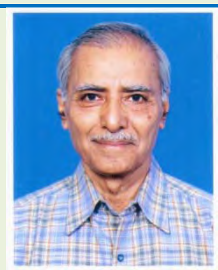
Teaching Faculty

The lectures were delivered by experienced scientists from both PRL and other institutes. In what follows, we give a paper-wiselist of faculty members, the sections they have taught and the number (given in the bracket) of one-hour lectures they have delivered.

Sr. No.	Paper 1	Paper2	Paper3	Paper 4
1	Shyamlal 1.1 & 1.2 (15)	K N Iyer 2.1 & part of 2.2 (19)	R N Misra 3.1 (12)	R N Misra 4.1, 4.3-4.6 (30)
2	Harish Gadhavi 1.3 (15)	Harish Chandra 2.3 & part of 2.2 (21)	Harish Chandra 3.2 & 3.4 (12)	Y B Acharya 4.2 (10)
3	P. C. Joshi 1.4 (10)		Y B Acharya 3.3 & 3.4 (16)	
4				
5				
6				
Total	**3**	**2**	**3**	**2**
Lectures	**40**	**40**	**40**	**40**

Sr. No.	Paper 5	Paper6	Paper7	Paper 8
1	S Seth 5.1 & 5.2 (20)	A. C. Das 6.1-6.4 (40)	A. Ambastha 7.1 (10)	U C Joshi 8.1 & 8.2 (20)
2	Y B Acharya (10)		Dipen & Vijayan 7.2 (10)	R. K. Manchanda 8.3 (10)
3	R Ramesh 5.3 (02)		Sankararaman 7.3 (12)	T Chandrasekhar 8.4 (10)
4	K K Shukla 5.3 (04)		P K Manoharan 7.4 (8)	
5	Utkarsh 5.3 (04)			
6	Som kumar 5.3 (03)			
Total	**6**	**1**	**5**	**3**
Lectures	**43**	**40**	**40**	**40**

Faculty from PRL


A. C. Das


Harish Chandra


R. N. Mishra

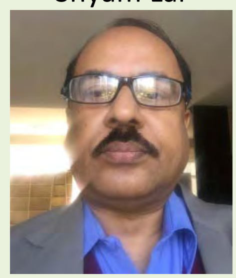

U. C. Joshi


Y. B. Acharya


Shyam Lal


A. Ambastha


T. Chandrasekhar


R. Ramesh


S. K. Sharma


H. Gadhavi


U. Deva


K. K. Shukla


S. Vijayan


D. Sahu

Guest Faculty

R. K. Manchanda

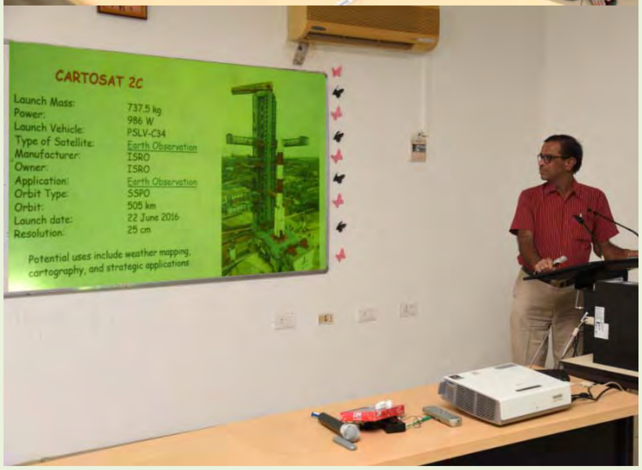
P. C. Joshi

K. N. Iyer

M. Sankararaman

P. K. Manoharan

S. Seth



Practicals

There were six practicals in each semester as listed below:

First Semester:

1. **Study of Clouds over Ahmedabad using Ceilometers,**
   guided by Dr. Somkumar Sharma (PRL).
2. **Inospheric sounding using an INOSONDE/DIGISONDE,**
   guided by Prof. Harish Chandra.
3. **Radiation properties of Radio Antenna,**
   guided by Mr. N. M. Vadher and Mr. Rohit Dadhania.
4. **Measurement of Geomagnetic field,**
   guided by Dr.Y. B. Acharya and Mr.M. B. Dadhania.
5. **Study of Plank's constant,**
   guided by Mr.N. M. Vadher and Mr. Rohit Dadhania.
6. **Study of Ultrasound Velocity,**
   guided by Mr.N. M. Vadher and Mr. Rohit Dadhania.

Second Semester:

1. **Study of Antenna Gain, Polarization , Inverse Square law,**
   guided by Mr.N. M. Vadher and Mr. Rohit Dadhania.
2. **Study of CCD detector as a astronomical imaging,**
   guided by Dr. Shashi K Ganesh.
3. **Study of Atmospheric density over Mt. Abu using Rayleigh LIDAR,**
   guided by Dr. Somkumar Sharma.
4. **Measurement of Sun's Temperature,**
   guided by Mr.N. M. Vadher and Mr.M. B. Dadhania.
5. **Measurement of electron density/weak current using Langmuir probe,**
   guided by Mr.N. M. Vadher and Mr.M. B. Dadhania.
6. **Measurement of O_3,H_2O and Aerosol optical thickness over PRL(Main Campus) using Microtop-II,**
   guided by Dr. Somkumar Sharma.

Academic Activities at Bopal Campus

Pilot Projects

Sr. No	Name	Guide	Title
1	Ms. Jinee Gogoi	Dr. Som Kumar Sharma	Study of the middle and upper atmosphere during Sudden Stratospheric Warming (SSW) episodes
2	Ms. Manpreet Kaur	Dr. Harish Gadhavi	Remote sensing of aerosol properties by using sun-photometer
3	Ms. Parminder Kaur	Dr. Harish Gadhavi	Source apportionment of black carbon aerosols using Aethalometer
4	Ms. Shirsh Lata Soni	Dr. Shashikiran Ganesh	CCD Photometry of AGNs
5	Ms. Veena Choithani	Prof. Rajmal Jain	Study of Proton Flair characteristics and their relation to CME Dyanamics
6	Ms. Mitali Damle	Dr. S Vadawale	Enhancing spectropolarimetry of CZT Imager, AstroSAT
7	Ms. Vrunda Maniya	Dr. Aveek Sarkar	Looking at the coronal loop dynamics using numerical simulation
8	Mrs. Kunjal Dave	Dr. Nandita Srivastava	Study of halo CME in interplanetary medium during 2011
9	Ms. Miral Bhatt	Dr. Nandita Srivastava	Study of Stealth CME and ICME
10	Mrs. Badamkhand Tserennadmid	Dr. Lokesh Kumar Sahu	Ozone and its precursors in Ahmedabad: Features of diurnal and day-by-day variations
11	Ms. Baljinnyam Shagdarsuren	Prof. S Ramachandran	Temperature and Soil moisture change over Ulaanbaatar, Mongolia
12	Mr. Mallikarjun K.	Dr. Som Kumar Sharma	Investigation of Atmospheric Greenhouse gases over India

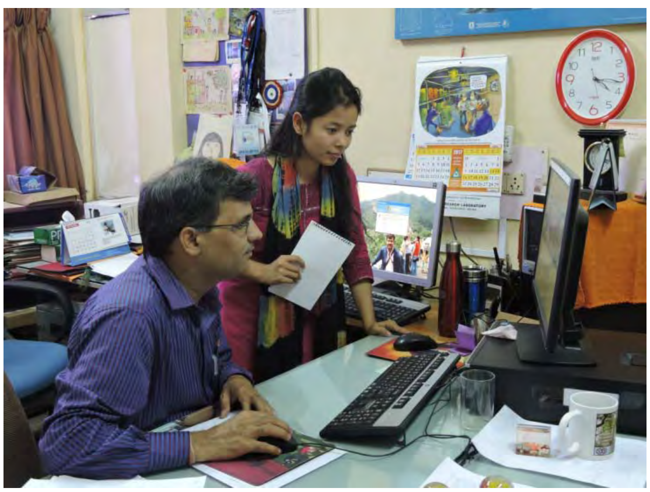
Study of the middle and upper atmosphere during Sudden Stratospheric Warming (SSW) episodes

Jinee Gogoi[1] and Dr. Som Kumar Sharma (Project Guide)[2]

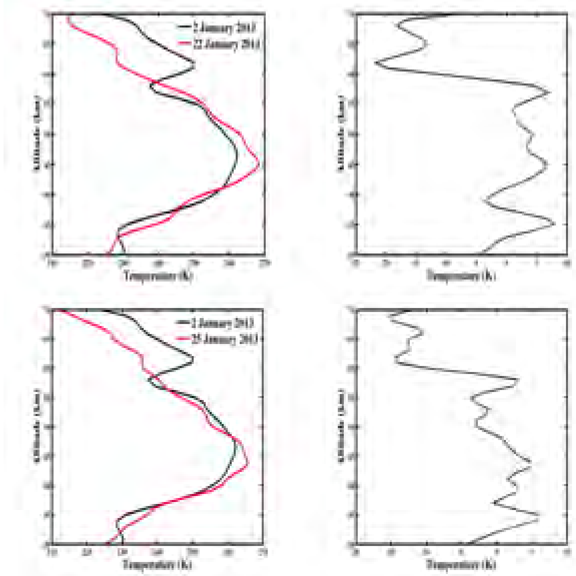
[1]*Department of Physics, Dibrugarh University, Dibrugarh-786004, Assam, India*

[2]*Physical Research Laboratory, Navrangpura, Ahmedabad-380009, Gujarat*

The Earth's atmosphere is variable in nature due to various dynamical processes in the different layers (i.e. Troposphere, Stratosphere, Mesosphere and Thermosphere) of the atmosphere. These layers are coupled to each other with the different dynamical, electrical, radiative and



chemical processes . A large scale thermodynamical phenomenon in winter polar regions which affects the middle atmosphere vigorously is Sudden Stratospheric Warming (SSW). Such kind of event development can be ascribed to the growth of PWs propagating upward and their non linear interaction with zonal mean flow.[1] These SSW events have significant impact on the middle and upper atmospheric dynamics over different region such as polar region, high, mid and low latitude region. Dynamical coupling through latitude is due to various types of waves and oscillations in the atmosphere. Such interaction causes deceleration and/or reversal of the eastward winter winds, and induces a downward circulation in the stratosphere causing adiabatic heating and an upward circulation in the mesosphere resulting in adiabatic cooling.The vertically propagating waves from lower atmosphere can cause remarkable variations in the ionosphere. Some of the recent observations show that there is a effective connection between SSWs and distinct changes in the ionosphere. But the process responsible for generating variations in the ionosphere in connection with SSW have still been poorly understood. Two major SSW events are occurred during 1998-1999; one in December 1998 which is associated with vortex displacement and another in February- March 1999 associated with vortex splitting. Lidar study of these two major events from Mt. Abu (24.36^{0}N, 72.45^{0}E, ~1670 m amsl) have showed that though SSWs are mostly observed over high and mid latitudes, their effects can also be seen over India also. We have studied ionospheric variations (primarily f_oF_2, h'F and hpF_2) over Ahmedabad (23.1^{0}N, 72.58^{0}E) during these events. Ionospheric disturbances have been found after four-five days of peak temperature. An increase (decrease) in foF2 during morning (afternoon) has been noticed which may be in response to the updrift (down drift). h'F and hpF2 are also noticed to be increased with fluctuations having clear peak during early morning. Effects are stronger during Displacement event (1998) than during the Splitting event (1999). Since growth of Planetary waves are responsible for occurrence of stratospheric warming event, they may have role in the ionospheric disturbances. In some plots we have noticed semi-diurnal patterns, so we can say that atmospheric tides may also have some role in ionospheric disturbances. We have also studied some recent events occurred during 2006 (January), 2009 (January) and 2013 (January) using temperature data from Sounding of Atmosphere using Broadband Emission Radiometry (SABER) satellite. Though some modeling work supports the hypothesis that Planetary waves are responsible for Atmosphere-ionosphere coupling, there is still more significant works to do to understand how exactly the coupling can take place. For understanding properly we will consider more major and minor SSWs episodes covering different solar epochs along with more stations in different latitudes to see the global picture. Later we will extend this work by studying the role of different type of waves and oscillations which are responsible for coupling between middle and upper atmosphere.



Temperature from SABER: SSW (Jananuary 2013)

during event day (red line) and control day (black line)

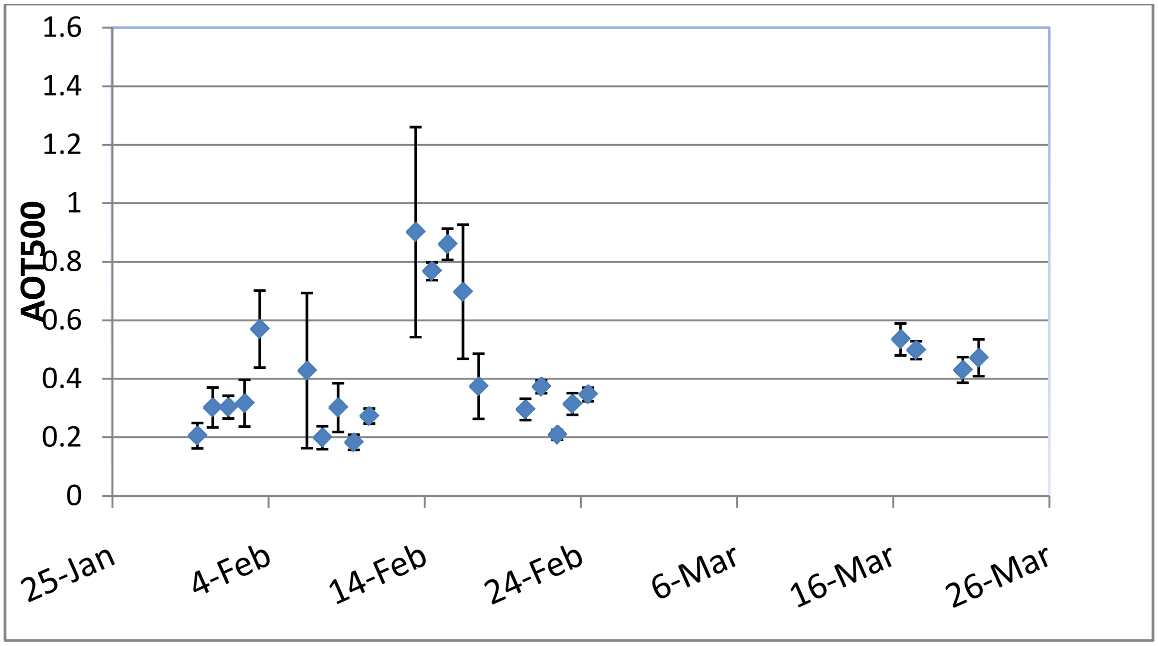
Remote sensing of aerosol properties by using sun-photometer.

Manpreet Kaur[1] and Dr. Harish S. Gadhavi (Project Guide)[2]

[1]*Department of Physics, Punjabi University, Patiala, 147002, Punjab, India*

[1]*Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, Gujarat, India*

Atmospheric aerosol plays an important role in global and regional climate. Aerosols affect our weather and climate because they change the amount of sunlight reaching earth's surface. Aerosol Optical Depth (AOD) is a measurement of transparency (or lack of it) of the atmosphere due to aerosol. Larger the AOD at given wavelength, less the light of that wavelength reaches earth's surface. Spectral variation of AOD is important for estimating the concentration, size distribution and other aerosol properties in the atmosphere. AOD is measured at five optical channels by Microtops II sunphotometer at Physical Research Laboratory, Ahmedabad from 30 January to 21 March 2017. The angstrom exponent 'α' is calculated from AOD measurements. The variation of AOD and α is analysed on daily basis. Records with 'α' less than 0.5 are removed from further processing as this could be due to cloud in field of view of sun-photometer. For remaining data, It is observed that the minimum and maximum of daily average values of α are 0.535 and 1.314 in 17march 2017 and 15 Feb.2017. Likewise the value of AOD at 500 nm is 0.183 on 9 Feb. 2017 and 0.902 on 13 Feb. 2017. The value of α shows that the different types of aerosols are present over Ahmedabad in beginning of the measurement period and in the ending of measurement period.



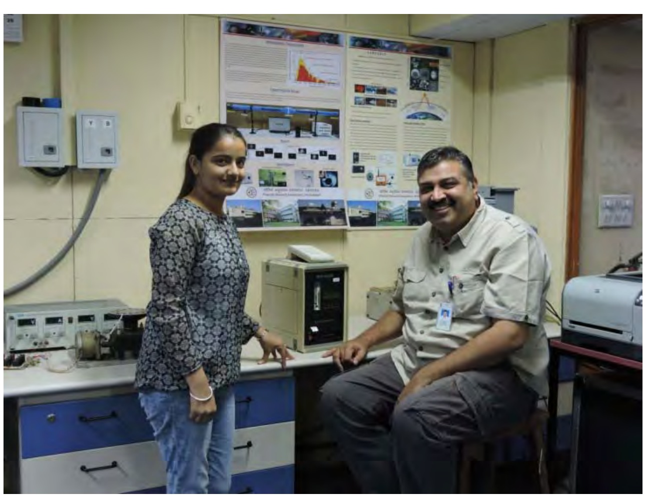
Source apportionment of black carbon aerosols using Aethalometer

Parminder Kaur[1] and Dr. Harish S. Gadhavi (Project Guide)[2]

[1]*Department of Physics, Punjabi University, Patiala, 147002, Punjab, India*

[2]*Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, Gujarat, India*

Black carbon (BC) particles impact Earth's climate and air quality. Black carbon is a graphitic form of carbon particles with unique physical properties. They also have many negative impacts on human health. Two main sources of black carbon particles in the atmosphere are combustion process involving fossil fuel and biomass burning. Understanding relative contribution of biomass vs. Fossil fuel in atmospheric load of black carbon particles is important for designing effective control policy. During biomass burning several other organic materials are emitted which condense over black carbon particles and change their optical properties. In this pilot



study we explore difference in optical properties of black carbon particles as a mean to source apportion black carbon particles.

Aethalometer is one of the popular instruments world wide for measuring black carbon particles. Aethalometer measures absorption coefficient at seven discrete wavelengths. Spectral variation of absorption coefficient depends on sources of black carbon particles. Black carbon data is collected using Aethalometer from two different locations : Patiala (30.2° N;76.3° E) an urban location in northern India and Gadanki (13.5° N;79.2° E) a rural location in southern India.

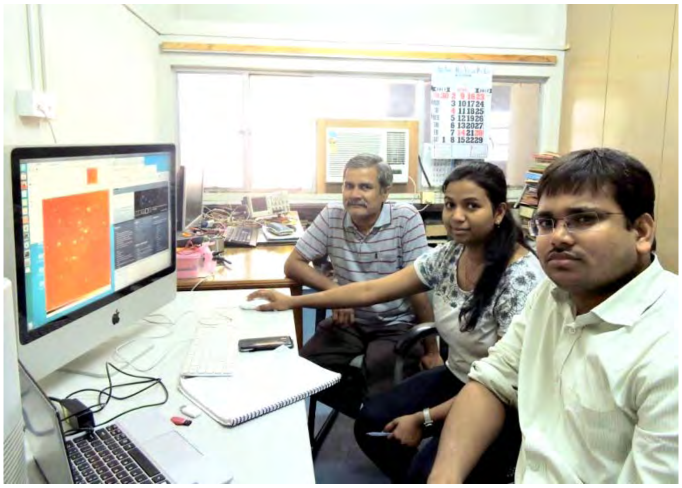
The diurnal and daily mean values of BC mass concentration during March 2016 and November 2016 have been determined. Diurnal variation in BC is marked with two peaks, one in the morning hours and other in the late evening hours. The contribution of fossil fuel and biomass burning in absorption coefficient have been determined by assuming exponent value 2.0 and 1.0 of wavelength for biomass aerosol and fossil fuel black carbon respectively. It was noticed that biomass burning activity contributes more black carbon particles over Patiala than over Gadanki.

CCD photometry of Active Galactic Nuclei (AGN)

Shirsh Lata Soni[1] and Dr. Shashikiran Ganesh (Project Guide)[2]

[1]*Department of Physics, Awadhesh pratap Singh (APS) University Rewa (MP)*
[2]*Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, Gujarat, India*

Active Galactic Nuclei (AGNs) are the most energetic sources in the Universe. These are the central regions of the host galaxy. Many of them have nearly a stellar shape on photographic plates but can not be explained by stellar theories. They emit huge amount of radiation, which is variable, thousand times more than the host galaxy at all the frequencies. Their continuum and emission-line properties manifest one extreme form of Seyfert activity. NLS1 galaxies may hold important clues to the key parameters that drive nuclear activity. Their high accretion rates, close to the Eddington rate, provide new insight into accretion physics, their low black hole masses and perhaps young ages allow us to address issues of black hole growth, their

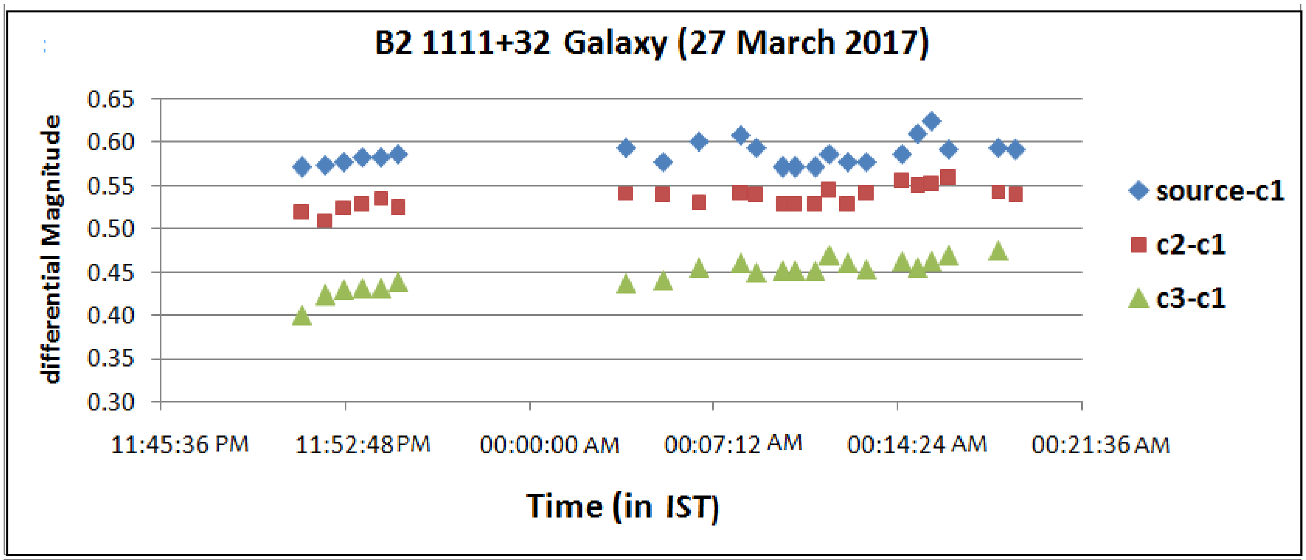


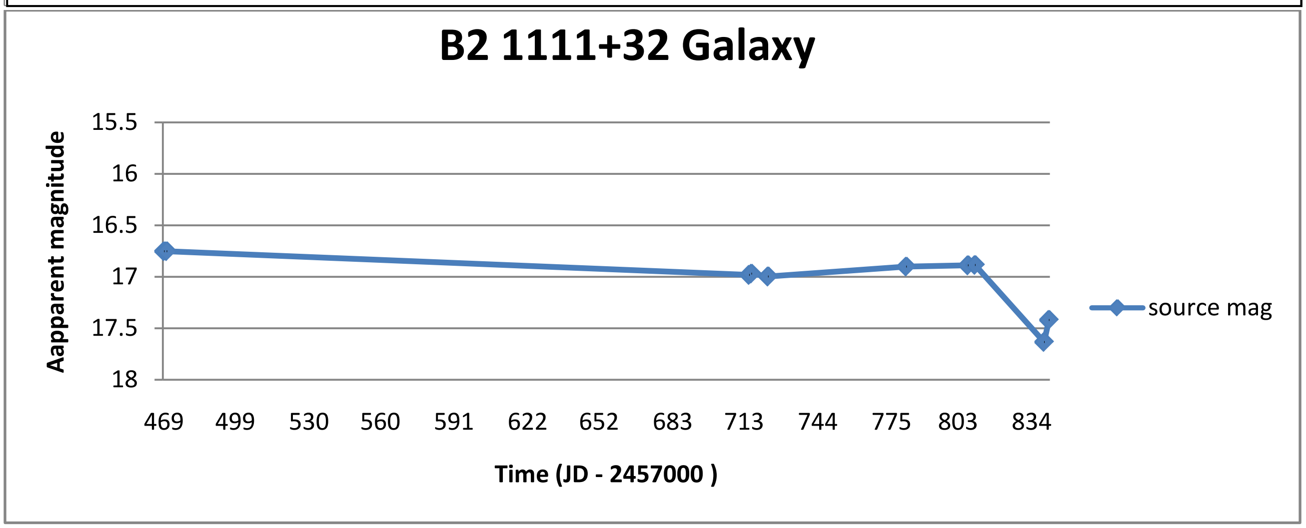
optical Fe II emission places strong constraints on Fe II and perhaps metal formation models and physical conditions in these emission-line clouds.

In this present work, I have provide a short review of the properties of Narrow line Seyfert-1 (NLS1) galaxies in the long-term and short-term variability across the electromagnetic spectrum to explain them. Variability studies have been essential in understanding the physics of Active Galactic Nuclei. AGN emit a continuum radiation coming from the vicinity of the black hole. They also emit intense and broad emission lines originating in fast moving gas clouds located in a small region around the continuum source, known as the broad line region or BLR. The flux level of the continuum and the intensity of the spectral emission lines emitted by AGN undergo variations on time scales ranging from hours to years depending on the energy range and on the intrinsic luminosity of the AGN. When the flux emitted by a source of energy varies significantly with a time scale t this flux variation sets a limit to the size R of the emitting region such that R <=ct.

To study the properties of Narrow line Seyfert1 {Observations of one particular object (B2 1111+32)} galaxies in the long-term and short-term (optical variability) we are using CCD observations from Mount Abu IR Observatory (MIRO) with 1.2 meter telescope. Three stars in the same images are used as comparison or reference stars to study the nature of variability of the source. As this field is not studied in detail before, more stars are taken as reference to study the stability of the reference stars also. Their brightness is similar to that of the source. The small variability (scatter in the light curves) seen in the comparison stars is due to photon noise in these rather faint sources.

Marginal variability is inferred in one night data. We are processing data of the other nights to estimate the degree of variability present (or not) in the source. There is a indication of a trend in long term observation (for several months), but we need denser sampling to confirm it. Variability study is also expected to provide us insight on the nature of radio-loudness of this source.





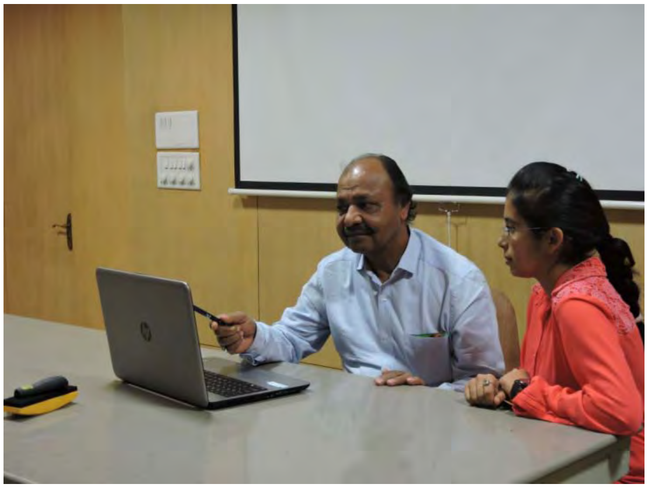
Study of Characteristics of Proton Flares associated with CME's

Veena Choithani and Prof. Rajmal Jain (Project Guide)

Kadi SarvaVishwavidyalaya, Gandhinagar, Gujarat 382016

We study 13 flare associated CME and SEP events. Our investigation is two-fold objectives: first we probe the temporal relationship between flares and CMEs within cadence of observations, and next we focus on the CME dynamics and associated SEP. We employ observations from GOES for X-ray emission from flares as well as protons emitted in association to the flare-CME event. The CME data has been considered from LASCO/ SOHO mission.. We study the temporal characteristics of the flare in 0.5 to 4 Å and 1 to 8 Å. The data is of 3s cadence.

Employing this data and CME data we attempt to find temporal correlationship. The cadence of CME observations is 12 min and thus correlation is restricted to this time limit. Nevertheless we



find correlation ~0.95 in all 13 events. We have also studied the proton flare characteristic start time, peak time, end time and proton flux in differentseven channelsviz 0.8-4.0 MeV, 4.0-9.0 MeV, 9.0-15.0 MeV, 15.0-40.0 MeV, 40.0-80.0 MeV, 80.0-165 MeV and 165.0-500.0 MeVWe made spectra from temporal observations in each energy band. We consider 3-hour interval to form the spectra in view of count statistics. The spectra for each proton flare event are fitted with least chi-square method. The spectral index (negative power-law index) is derived at every 3-hour interval for a given event. We then study growth of spectral index over time of the proton flare event to understand the acceleration process. We found that acceleration process continue for about 20 hours. On the other hand the CME velocityas a function of integrated proton flux over the rise time enables as to conclude that CME produces the shock and the shock further accelerates the particles with a correlation coefficient of ~0.77. The shock speed depends on the CME dynamics.

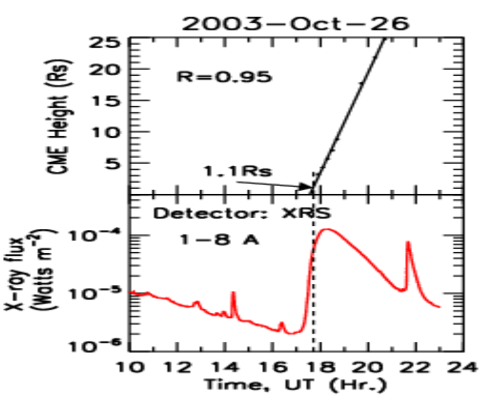


Fig. 1

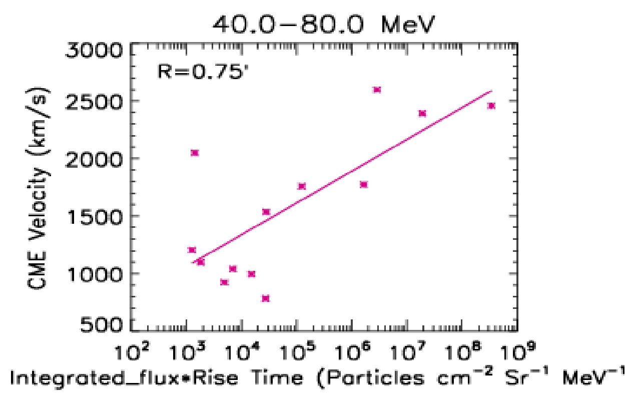


Fig. 2

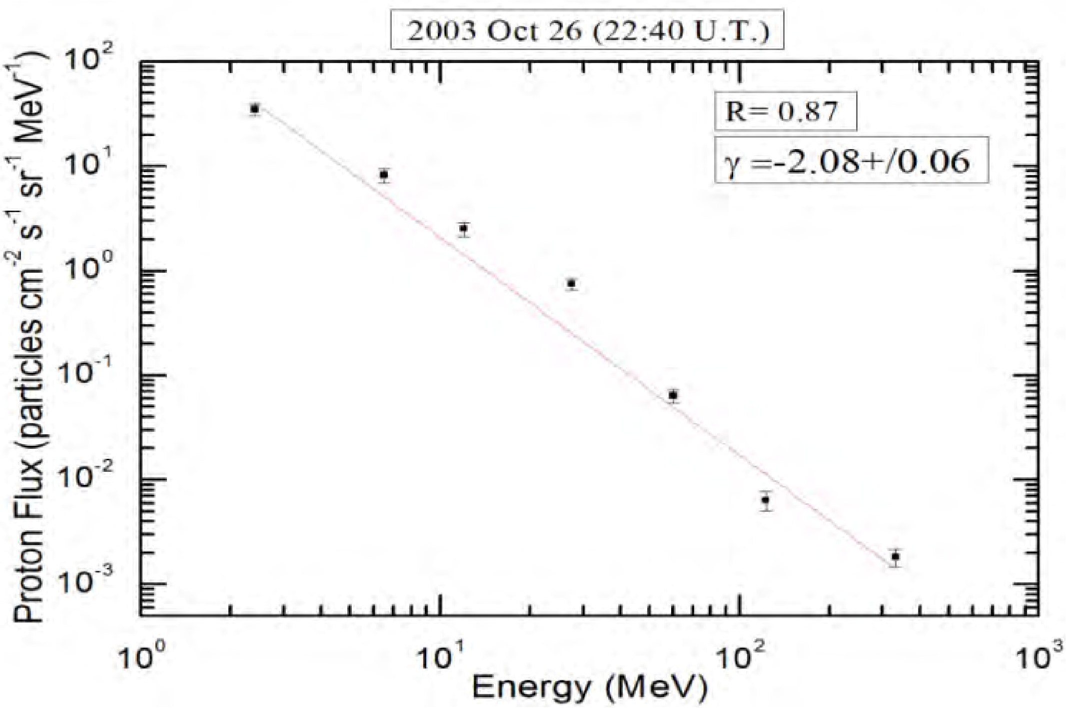


Fig. 3

Figure Captions:

Fig. 1:

Schematic representation of CME-Flare association on a temporal scale for event, 2003 Oct 26. The height of the CME observed by LASCO instruments C2 and C3 (top panel) and X-ray flux of the associated flare in 1-8 A band (bottom panel) are plotted as a function of time. The observed CME heights are fitted with linear and extrapolated to 1.1 Rs from the centre of the Sun to determine the CME onset time.

Fig. 2:

Association of CME dynamics and energetics of SEP for channel 40.0-80.0 MeV for 13 events.

Fig. 3:

Spectra of 2003 Oct 26 solar flare at 22:40 U.T. Slop of the spectra gives the spectral index. It provides information on the hardness of the energy acceleration.

Enhancing spectroscopic sensitivity of the CZT Imager onboard AstroSat

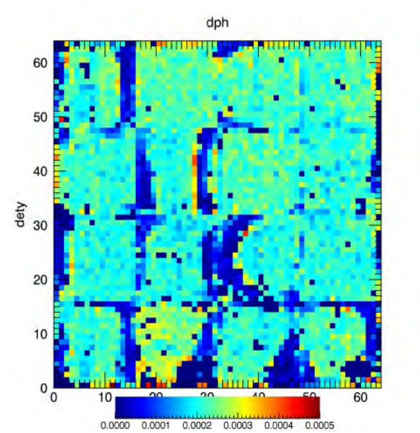
Mitali Damle[1] and Dr. Santosh Vadawale (Project Guide)[2]

[1]*Department of Physics, University of Mumbai, Kalina, 400098, Maharashtra, India*

[2]*Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, Gujarat, India*

The CZT (Cadmium Zinc Telluride) Imager onboard India's first dedicated Astronomy satellite, AstroSat, is a Hard X-ray imaging & spectroscopic instrument, operating in the energy range of 20-200 KeV. Coded Aperture Mask (CAM) technique is employed here. CZTI count rate is background dominated. Also, the individual pixel response varies over a range of energies. This inherent quality of the detector pixels is always reflected in any observations. The Detector Plane Histogram (DPH) is the plot that gives us information about the pixel-by-pixel distribution of counts over a range of energies. Hence, to credibly extract the signal (especially in case of fainter sources);it is necessary to have proper calibration of background. The modulations in DPH for all quadrants over different energy ranges for different observations have been studied.

A code was written in IDL for reading the files and computing DPH's. Each of these DPH's was saved to a 4-dimensional array comprising of 4 quadrants and 25 energy bins (each of 10 keV energy). To facilitate direct comparison of DPH's between multiple observations, all the DPH's were divided (quadrant-wise, energy bin-wise) by the total counts respectively. DPH's obtained have been compared with those obtained from the CZTI pipeline and they are in good agreement. The modulations in DPH's over a period of time, for all quadrants, were studied. We will study the distribution of background events in the detector plane in different energy ranges and make modifications in the mask-weighting technique, as required.



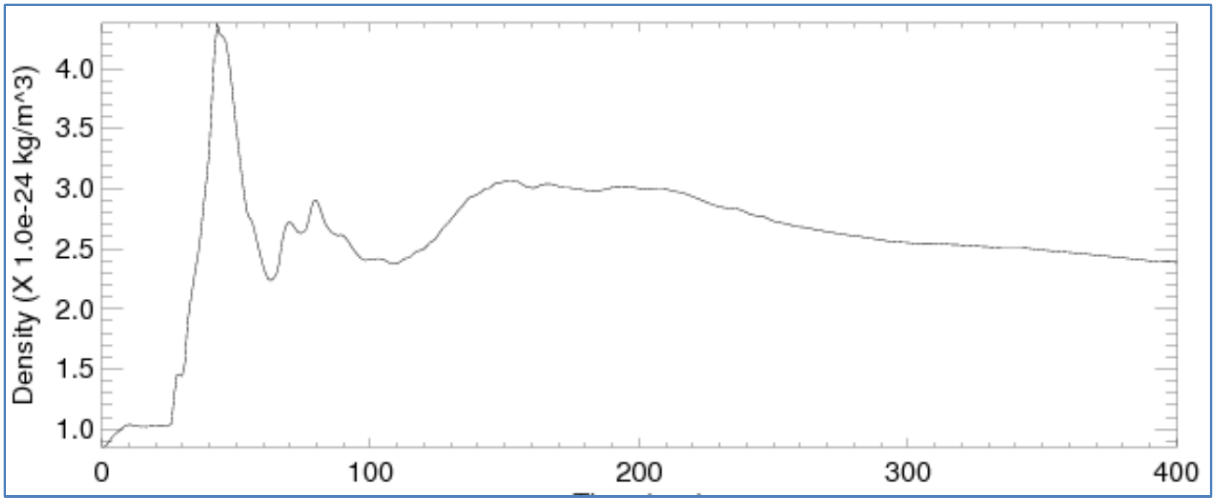
Further studies are in process to obtain variations in DPH's with longitude and that due to shielding effect due to neighboring payloads. CZTI is a very promising candidate for carrying out Hard X-ray polarimetry above 200 keV. Efforts are on to include polarimetric studies within this project. Thus, with proper knowledge of background, the overall spectroscopic sensitivity of the instrument can be improved upon considerably.

Looking at the coronal loops dynamics using 1-D numerical simulations

Vrunda Maniya[1] and Dr. Aveek Sarkar (Project Guide)[2]

[1] Sardar Vallbhbhai National Institute of Technology, SVNIT, Surat, India
[2]Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, India

Million degree solar atmosphere above relatively cooler (~6000K) surface is an astrophysical enigma. It is understood that the magnetic field is responsible to carry energy from within the sun to its atmosphere, but understanding the mechanism is one of the prominent research in solar physics. Solar active regions get most importance in this regard as they show various complicated magnetic behaviour. The main ingredients of these active regions are coronal loops. Plasma in these loops is hot and dynamic. Due to high magnetic field plasma is bound to follow the magnetic field lines. We model a coronal loop using one dimensional hydrodynamic equations. We see the evolution of the loop in space and time when is hit by a nanoflare like heating event. Our result shows, heat of nanoflare quickly gets conducted to the chromosphere beneath and evaporate plasma in the corona, this mechanism is known as chromospheric evaporation. Such evaporation makes the loop overdense which is seen in the associated figure where we show density evolution at the looptop region. Such phenomenon is consistently observed in coronal loop systems.Such modelled coronal loop data can be folded through the instrument response function to produce intensity like observables and can be compared with the direct observation.



Study of interplanetary and geomagnetic signatures of halo CMEs observed during 2011

Kunjal Dave[1] **and** Prof. **Nandita Srivastava (Project Guide)**[2]

[1] *C. U. Shah University, Wadhwan City, Surendranagar 363030, Gujarat, India*

[2] *Udaipur Solar Observatory, Udaipur 313001, Rajasthan, India*

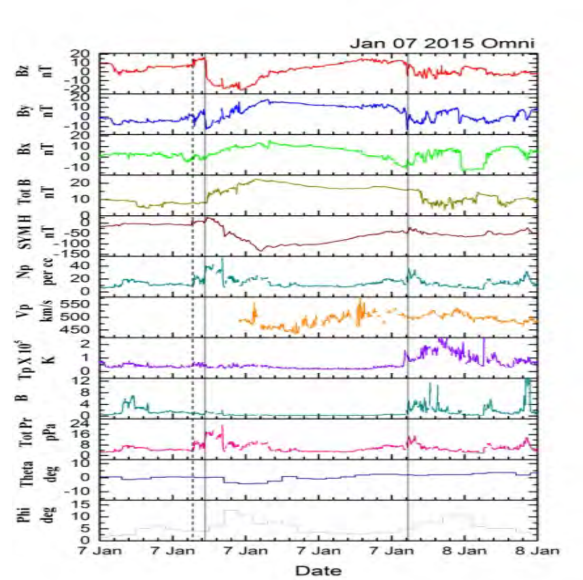
The effects of solar storms like solar flare, coronal mass ejection (CME), solar bursts etc. have been found to have major effects on terrestrial magnetic field. We report on the properties of halo coronal mass ejections observed during 2011 using LASCO coronagraphs aboard SOHO spacecraft. Their interplanetary signature recorded by in-situ spacecraft viz, Wind/ACE and STEREO have been examined using measurements at L1, STA and STB (from 3 different view points) and their impact in producing moderate & strong geomagnetic activity have been studied. We have chosen 7 events which are full halo (angular width 360°) except one which is partial halo (angular width 120°≤W<360°) to study the ICME properties of halo CMEs. ICMEs on 11th March, 6th August, 10th September, 17th September, 24th September, 26th September and 25th October have been studied using the in-situ plasma and magnetic parameters to investigate whether it is Earth directed and produced strong geomagnetic activity or not. Among all 7 ICMEs, 6 were Earth directed observed at L1 and either in STA or ST. Out of 7 events, 1 was not Earth directed (ICME on 24th September) but it was observed in STA and STB. Our analysis shows that in situ properties measured at L1, STA and STB for the same ICME are distinctly different which implies that ICME plasma is inhomogeneous. The measured ICME speeds

are different in different directions, therefore arrival time of ICME should be estimated using propagation speed in the direction of the spacecraft.

A study of Stealth CMEs and associated ICMEs

Miral Bhatt[1] and Prof. Nandita Srivastava (Project Guide)[2]
[1] C. U. Shah University, Wadhwan City, Surendranagar 363030, Gujarat, India
[2] Udaipur Solar Observatory, Udaipur 313001, Rajasthan, India

Coronal Mass Ejection (CME) is a large eruption of plasma and magnetic field from the sun into interplanetary space. CMEs are most frequently associated with a variety of phenomena occurring in the lower corona before, during the and after onset of eruption. CMEs are visible in coronagraph observation, so- called Stealth CMEs do not obviously exhibit any of the low-coronal signatures like solar flares, flows, jets, coronal dimmings or brightenings, filament eruptions or the formation of flare loop arcades like Low Coronal Signatures (LCS). ICME is heliospheric counterpart of a CME. In this study, Stealth CMEs and associated ICMEs events selected using LASCO/SOHO CME catalogue and CACTus catalogue are studied. STEREO, ACE, WIND data are selected for selected Stealth CME events. In particular, five events of ICMEs associated with the Stealth CMEs are studied here.



ICME plasma and magnetic parameters plotted for the 7th January 2015 ICME.

Among which 3 of the events arrived at L1 point and produced strong geomagnetic storm of ~100 nT or more. None of these events showed any Low Coronal Signatures (LCS). The remaining two events were not Earth directed, and were observed at STEREO S/C. From the analysis of in-situ parameters, we also found that 3rd June 2008 CME arrived at the STEREO B spacecraft however, if it would have arrived at the Earth, then it would have led to a moderate to strong geomagnetic storm. Solar eruption without any LCS can lead to unexpected space weather impacts, since many early warning signs for the same activity are not present in these events. Our study also shows that although ICMEs associated with

Stealth events are associated with minor shocks they can sometimes lead to strong geomagnetic storms. The present study will improve our understanding of Stealth CMEs and the associated ICMEs.

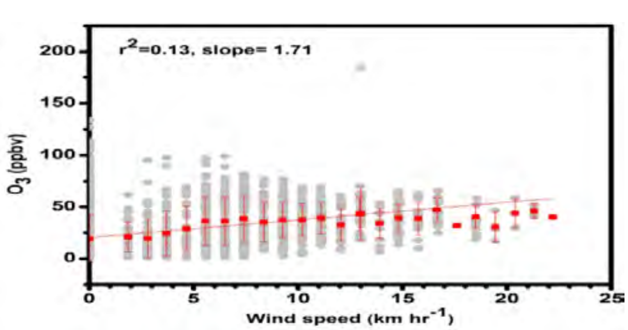
Ozone and its precursors in Ahmedabad: Features of diurnal and day-to-day variations

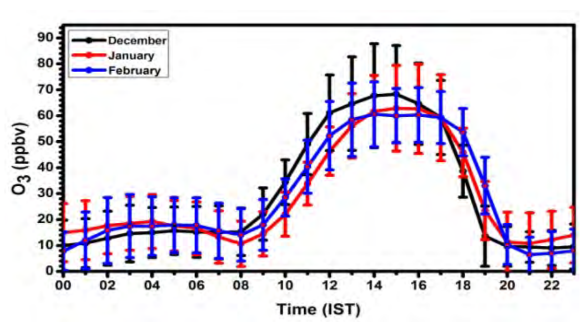
BadamkhandTserennadmid[1] and Dr. Lokesh Kumar Sahu (Project Guide)[2]

[1]Aviation meteorological center of Mongolia, Chinggis khan international airport, Ulaanbaatar, Mongolia

[2]Physical Research Laboratory, Navrangpura, Ahmedabad, 380009, Gujarat, India

Air quality and climate change are very challenging problem for all over the world mainly due to increasing emissions from anthropogenic sources.The increased levels of trace gases (for example O_3, CO and NO_X) is a major cause of concern and from local to global scale.The large emissions of trace gases from a variety of anthropogenic sources are one of the major environmental issues in urban and industrial regions. Tropospheric O_3 is the third most important greenhouse gas after CO_2 and CH_4due to the global positive radiative forcing of about 0.39 W m^{-2}as it absorbs earth's outgoing radiation at 9.6 µm wavelength (IPCC, 2007).Surface/ground level O_3 has two main sources, namely, stratosphere intrusion (Lefohn et al., 2011) and in-situ production via photochemical oxidation of precursor's gases such as CO, CH_4 and volatile organic compounds (VOCs) in the presence of NOx (Sahu et al., 2016).In addition to greenhouse effect, the higher levels of O_3 at surface adversely effects human health, ecosystem and crop productivity. Ozone is a precursor of hydroxyl radical (OH) which controls the oxidizing capacity of the troposphere. However, depending on region to region, local emission, meteorological condition and long-range transport play important roles in the variation of O_3 and its precursors.





We were interested to investigate the very recent measurements of O3 and other trace gases. The major goal of my study is to investigate the detailed features of variations and role of key factors controlling the variations of trace gases at this site.

We studied the relation between trace gases and including meteorological parameters during a winter month (December 2016 – February 2017) at an urban site of Ahmedabad.The high levels of O_3 during the afternoon hours could be due to enhanced photochemical production and instrusion of air from the free troposphere. In the winter month, the ozone concentration begins to increase after sunrise.The primary peak (evening) and secondary peak (morning) coincide with rush hour traffic in the city. Winter month, the lowest mixing ratios of CO (NO_x) were observed during the afternoon hours. The mixing ratios of CO and NOx decreased with the increase in wind speed due to dispersion of pollutants emitted from local sources. The mixing ratio of O_3 increased with the increasing wind speed, suggesting higher levels of O_3 in the upwind region. The rapid decline of O_3 with increase in relative humidity is due to the chemical loss ofO_3.

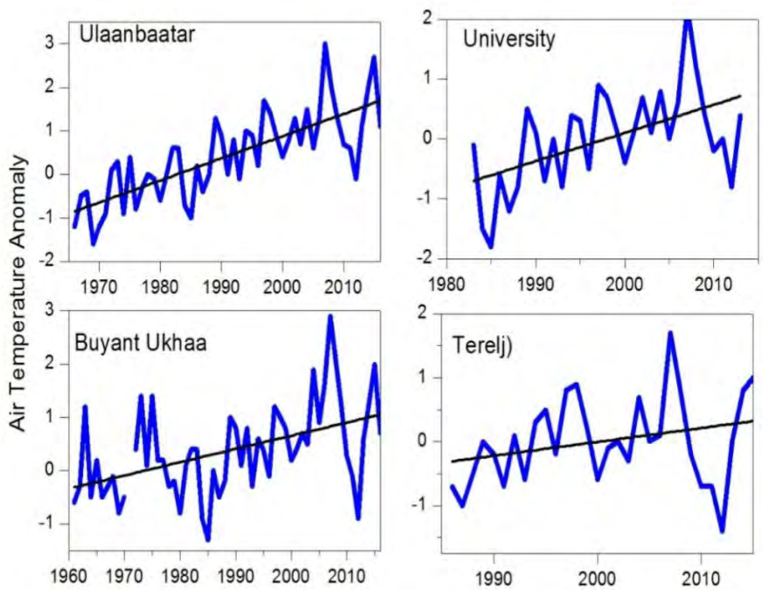
Temperature and soil moisture change over Ulaanbaatar,Mongolia

Baljinnyam Shagdarsuren[1] and Prof. S.Ramachandran (Project Guide)[2]

[1]Aviation meteorological center of Mongolia, Chinggis khan international airport, Ulaanbaatar, Mongolia
[2]Physical Research Laboratory, Navrangpura, Ahmedabad-380 009, India

Research indicates that natural causes do not explain most observed warming, especially warming since the mid-20th century. Rather, it is extremely likely that human activities have been the dominant cause of that changing. Global air temperatures increased by 0.99°C per century over the past 150 years.

Global climate change is already affecting Mongolia and the annual air temperature has increased by approximately 1.6°C (2.6°C/century) in the past 60 years (1940-2000) with warming starting in the 1970s and intensifying at the end of the 1980s (Batima, P. & Dagvadorj, D. (eds) (2000) Climate Change and Its Impacts in Mongolia).



Objective is to determine the effect of global warming in Mongolia including Ulaanbaatar.

This change can be seen in changes in the atmospheric parameters such as temperature, and geophysical parameters such as soil moisture.

In this study, the data collected in the last 50 years in 4 stations in Ulaanbaatar, Mongolia, namely Ulaanbaatar, Buyant-ukhaa, Mongolia national university and Terelj, which are governed by different environmental conditions, will be used. In this project, these data will be analyzed to document the changes in air temperature, soil temperature over Ulaanbaatar, Mongolia. Air temperature and soil temperature are increased respectively 0.6-2.4 ^{0}C and 0.9-2.3 ^{0}C in the Ulaanbaatar, Mongolia. More warming obserbed month is in July. The temperature increase is attributed to global warming.In recent years, human activities including construction and increased population migration and traffic also big causes of increasing temperature. These changes have affected environment, water supply, and natural disasters leading to financial, environmental and human loss.

	Changed air temperature (^{0}C)				Changed Soil Temperature (^{0}C)		
	Ulaanbaatar (51 Year)	**University (31 Year)**	**Buyant Ukhaa (56 Year)**	**Terelj (31 Year)**	**Ulaanbaatar (48 Year)**	**University (19 Year)**	**Terelj (31 Year)**
Year	2,6	1,5	1,4	0,6	2,3	-0,3	0,9
Jan	0,6	-1,4	-1,1	-1,6	-1,9	-2,1	-1,4
Feb	2,7	-0,1	0,8	-1,8	0,4	-6,1	-0,4
Mar	3,1	1,4	1,0	1,0	3,1	-2,5	1,3
Apr	3,8	2,7	3,0	2,2	4,4	0,2	2,4
May	1,6	0,4	1,1	0,0	2,3	2,0	0,1
Jun	2,8	3,9	2,3	2,3	2,9	1,3	1,3
Jul	4,0	4,0	3,6	2,8	4,3	-0,4	2,9
Aug	3,7	2,7	2,5	1,9	4,0	1,0	2,9
Sep	3,4	3,0	2,6	1,9	4,4	1,1	2,7
Oct	2,2	0,8	1,7	1,2	2,8	0,8	1,1
Nov	1,4	1,4	-0,2	-0,3	0,9	1,8	0,6
Dec	1,7	-1,4	-0,5	-1,8	0,1	-0,6	-2,0

Investigation of Atmospheric Greenhouse GasesOver India

K Mallikarjun[1] and Dr. Som Kumar Sharma (Project Guide)[2]
[1]National Remote Sensing Centre-NRSC, ISRO/DOS, Hyderabad
[2]Physical Research Laboratory, Navrangpura, Ahmedabad, Gujarat, India

The atmosphere of Earth is composed of several different gases in different concentrations. The major gases whose percentages do not change from day to day are nitrogen, oxygen and argon. Nitrogen accounts for 78% of the atmosphere, oxygen 20.8% and argon 0.9%. Minor gases like carbon dioxide (CO_2), methane (CH_4), water vapour(H_2O), nitrous oxide (N_2O) and ozone (O_3) etc are trace gases that account for about a one tenth percent of the atmosphere. Water vapour is unique in that its concentration varies from 0-4% of the atmosphere depending on location and time of the day it is. Ozone is a pollutant and also responsible for greenhouse effect.Greenhouse gases (GHGs) and other trace gases play a vital role in controlling the climate system of the lower atmosphere (Stocker et al. 2013). Climate change arising due to the increase inGHG's such as CO_2, CH_4,O_3, N_2O and H_2O etc.in the atmosphere since the pre-industrial times has emerged as a serious global environmental issue and poses a threat and challenge to all of us. The 40% increase in the CO2 from 280 ppm in 1750 to 400 ppm in 2015. Atmospheric CH4 was at 1803.20 ppb in 2011, an increase of 150% from the ambient concentrations prior to 1750.CO2 and CH4 are the most influential anthropogenic GHGs, which together contribute to 80% of the total anthropogenic radiative forcing, leading to global warming (Forster et al. 2007). Without greenhouse gases, theaverage temperature of Earth's surface would be about −18 °Crather than the present average of about 15 °C.

In the present project we haveinvestigated the behaviour and visibilities of CO2 & CH4 overPunjab, Hyderabad, Assam & Ahmedabad regions from North, South, East& Western regions of India respectively usingSCIAMACHY(SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) satellite data. SCIAMACHY was one of ten instruments aboard of ESA's ENVIronmental SATellite(ENVISAT). ENVISAT's mission started on March 2002 and was ended in May 2012. CO2 (ppm) -The Carbon dioxide column-averaged dry air mole fraction

(XCO2)and CH4 (ppb) -Methane column-averaged dry air mole fraction (XCH4) has been selected from the satellite.

Temporal, annual and seasonal climatology variations of CO2 &CH4 has been analysed from the year 2003 to 2011 and results are found satisfactory (Ref: Sreenivas et. Al. 2016). Examination of CO2 & CH4 data with climate indicators LULC demonstrated an inverse &direct relationship between the LULC w.r.t CO2& CH4 (Ref: Sreenivas et. Al. 2016).

The final observations from the present project are as follows:

1. CO2& CH4has increased 1.9ppm& 5ppb per annum respectively. The increased concentrations are 375 to 390 ppm& 1760 to 1800 ppb during the year 2003 to 2011 respectively over India.
2. The high CO2 concentrations are observed in Hyderabad and Punjab regions during Pre-moon & Post-monsoon respectively. Whereas comparatively less concentrations observed in North East. And Indian average is falling in between Hyderabad and North East.
3. Punjab and North East regions have been observed high concentration's during post monsoon.
4. The results are shown in below two plots:

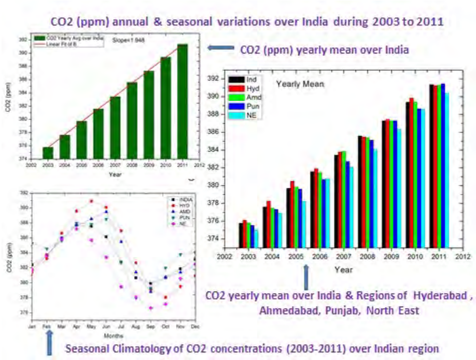


Fig. 1: CO2 (ppm) concentrations of Annual and Seasonal variations over Indian regions during 2003-2011.

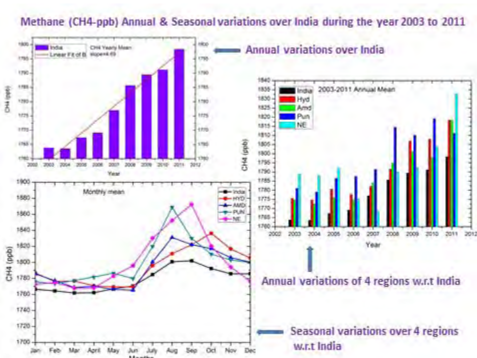


Fig. 2:CH4 (ppb) concentrations of Annual and Seasonal variations over Indian regions during 2003-2011.

Project Presentation

Lab Visits







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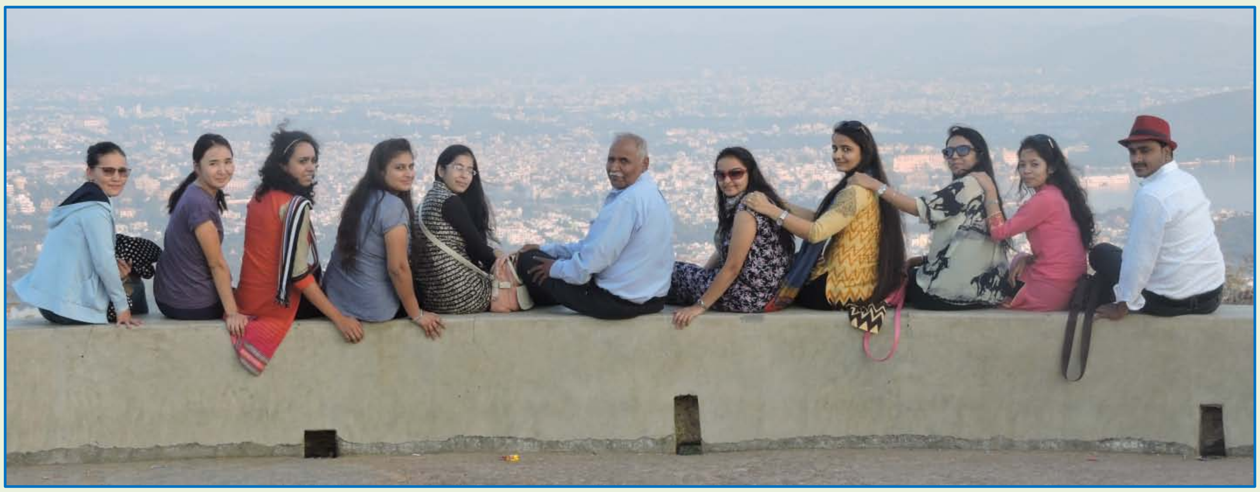
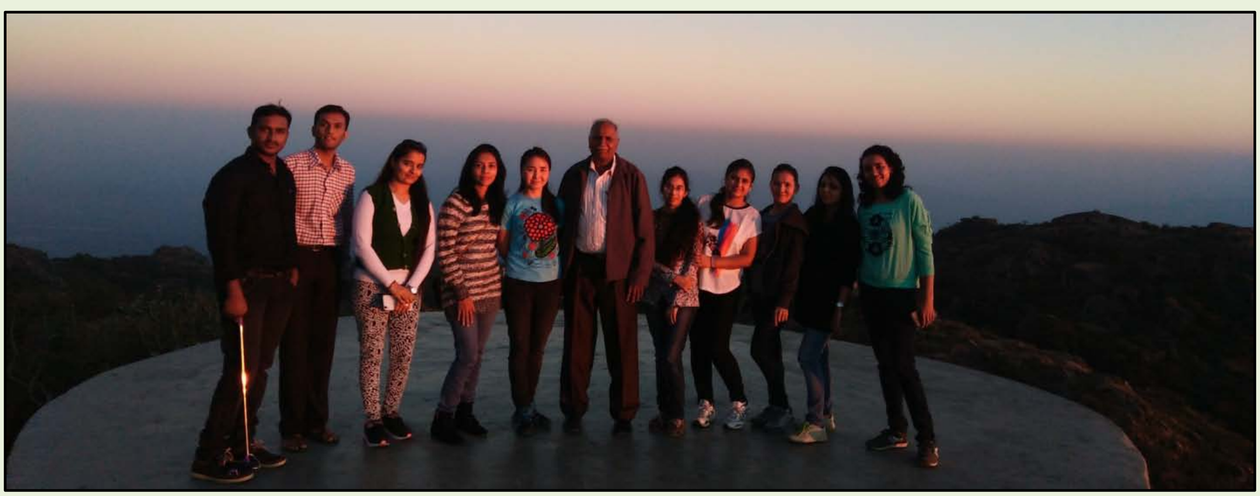
Photo Gallery



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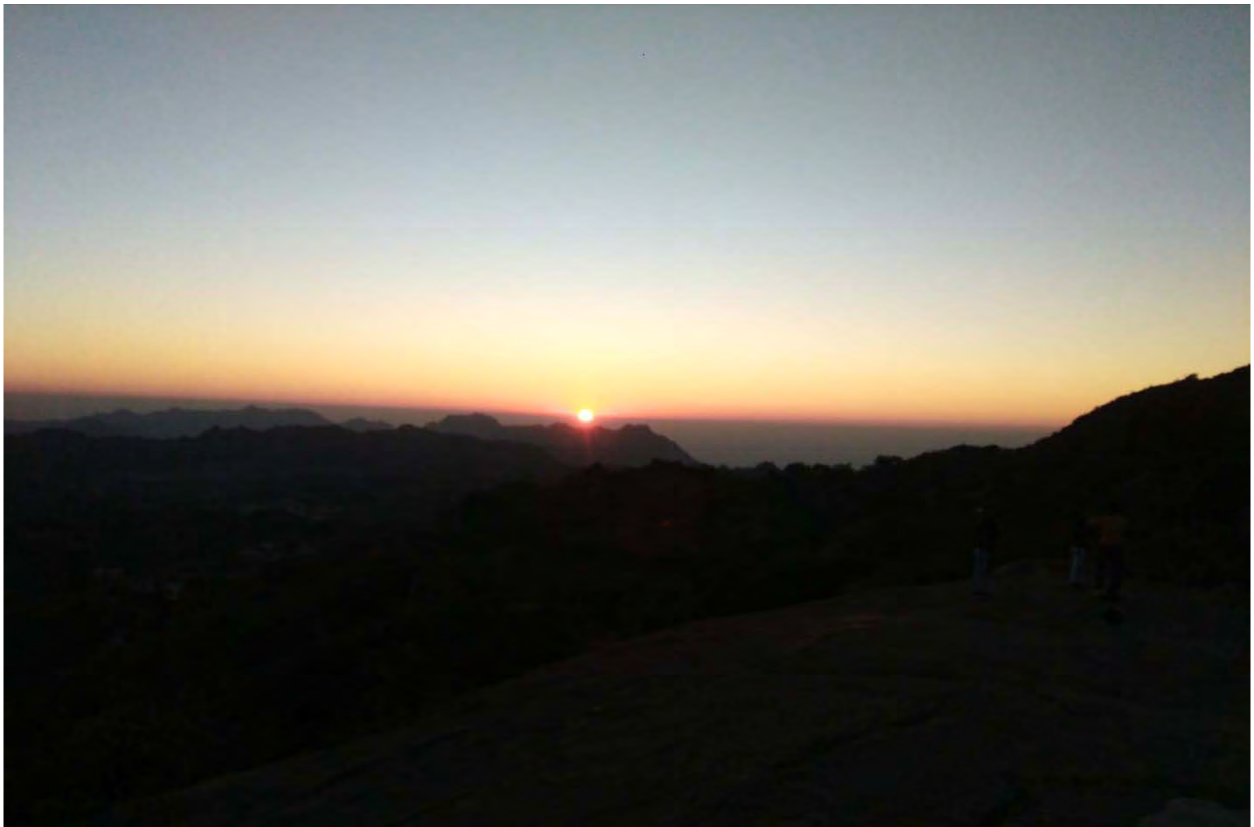

Host Institute:

Physical Research Laboratory

Ahmedabad 380009, India

Email: uncsc@prl.res.in

Head Quarters:

IIRS

Dehradun 248001, India

Email: cssteap@iirs.gov.in