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Earth's Environment and Solar-terrestrial Science

(K. R. Ramanathan Memorial Lecture)

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Chairman, ISRO

I. Indian Geophysical Union and Prof Ramanathan's contributions:

I consider it a proud privilege to deliver the Prof. K. R. Ramanathan Memorial Lecture-2005 and am grateful to the Indian Geophysical Union (IGU) for giving me the opportunity.

The scientific community is well aware of the unique contributions made by Prof. Ramanathan in the fields of meteorology and atmospheric phenomena particularly related to water vapour and ozone. He had studied various aspects of interactive processes of ionised region of the upper atmosphere due to cosmic rays and galactic x-rays, effect of solar electromagnetic and charged particle eruptions in the lower and upper ionosphere.

Prof. Ramanathan carried out extensive research on the ozone layer and used ozone as tracer for understanding the dynamics of the middle atmosphere (10-100 km). He derived the quasi-biennial oscillation of ozone concentration using the Dobson spectrophotometer and balloon ozonesonde data. He also found depletion of ozone due to intrusion of water vapour to higher altitudes due to strong convection. Thematically, similar depletion of ozone due mainly to the reaction with CFCs has been termed as the "ozone hole" discovered over the Antarctic region.

Prof. Ramanathan had strong interest in the ionisation phenomena taking place in the upper atmosphere from D-region ionosphere to the F-region and particularly the ionospheric response to solar flares and geomagnetic storms. He classified different types of lower ionospheric solar flare effects based on hardening of the solar x-ray spectrum observed by satellite sensors. Many of the pioneering studies pursued by him are very relevant even today and a large number of his students pursued these further.

In this lecture I would like to highlight some of the recent trends in research in the areas of earth's atmosphere, aeronomy and solar interactions with space environment, as these were very dear to Prof. Ramanathan.

II. Overview of Space Research and Science programmes of ISRO

First I would like to provide a broad introduction to ISRO's research activities particularly in atmospheric and space science areas.

Indian Space Programme

The Indian space programme is driven by the vision of Dr. Sarabhai to utilise space technology for the benefit of common man. The primary objective of the space programme has been to establish operational space systems in a self-reliant manner to cater to the thrust areas of satellite communications, satellite remote sensing based information to assist in survey/ management of natural resources and satellite based synoptic meteorological data for weather prediction. The indigenous development of satellites, launch vehicles and associated ground segment for providing these services is integral to these objectives. Over the years ISRO has established two indigenously built fully operational satellite systems, i.e., (i) Indian Remote Sensing Satellites (IRS) and (ii) Indian National Satellite System (INSAT). Indigenous launch vehicle capability has also been achieved for launching these satellites for space applications and so far 43 satellites and 20 launch vehicle missions have been accomplished. Based on these achievements ISRO has projected a plan for further space science, technology and applications programmes in the coming two decades. Apart from providing enhanced communication services in new frequency bands with higher transmitted power, better spatial, temporal and spectral resolution data for remote sensing and meteorological applications, ISRO would develop new technologies for planetary probes, space astronomy, atmospheric research, launch vehicle technology using advanced cryogenic stages, Two Stage to Orbit (TSTO) and reusable systems. A road map depicting highlights of ISRO's future missions and programmes is shown in Fig-1.

Figure 1. Indian Space Programme in the next two decades

Figure 2. Details of Chandrayaan-1 mission showing different payloads to be launched for scientific investigations of lunar terrain, mineral deposits and trapped volatiles etc.

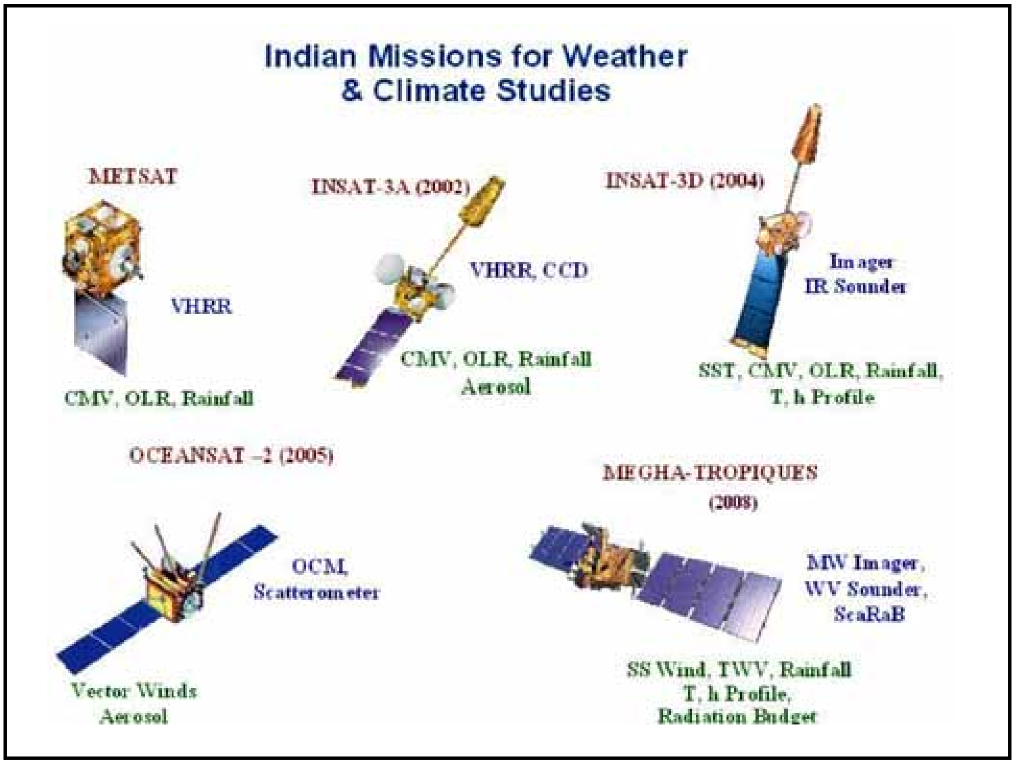

Figure 3. Weather and climate satellites launched and planned by ISRO

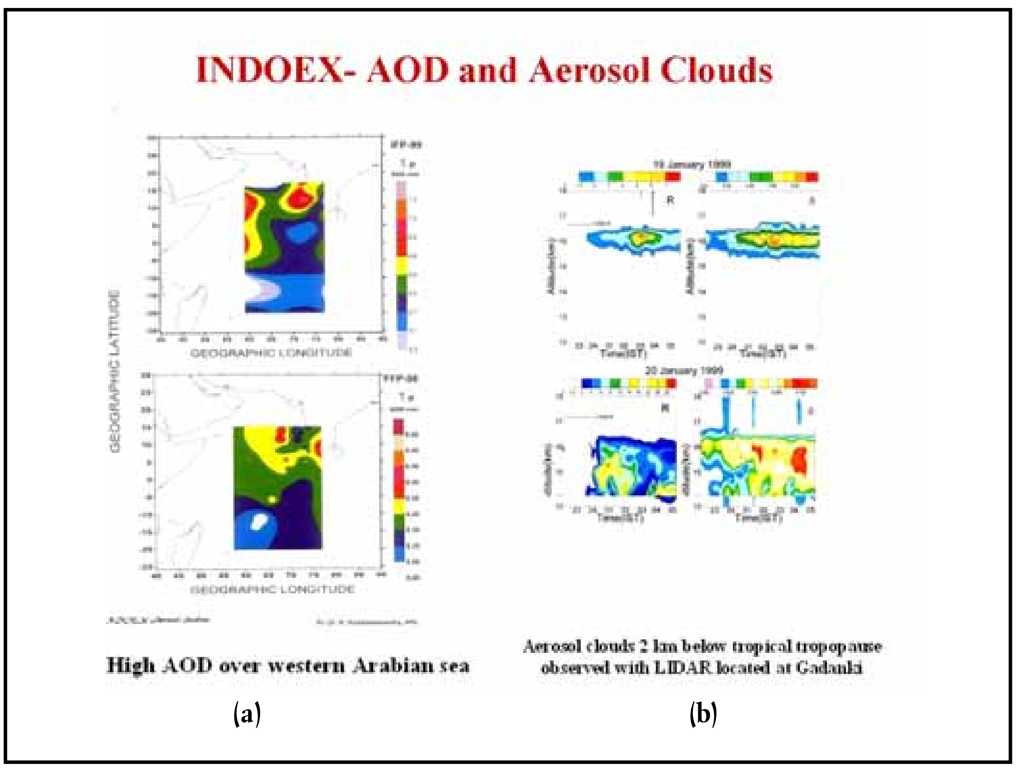

Figure 4. Some results from INDOEX: (a) High Aerosol Optical Depth (AOD) over western Arabian sea, (b) aerosol clouds near tropopause over Gadanki

Atmospheric and Space Science Research Programmes

The atmospheric and space science research activities within ISRO/DOS are mainly carried out at the Physical Research Laboratory (PRL), Ahmedabad, Space Physics Laboratory (SPL), Thiruvananthapuram, Space Astronomy and Instrumentation Division (SAID) of ISRO Satellite Centre (ISAC), Bangalore and the National Atmospheric Research Laboratory (NARL), Gadanki.

ISRO has undertaken several research projects at national level with the participation of atmospheric and space scientists/astronomers from various national laboratories and universities. Recently a number of such research activities have been initiated by ISRO based on recommendations of ADCOS (ISRO's Advisory Committee for Space Science). The major ones include ASTROSAT, Chandrayaan-1 and Megha-Tropiques satellite Missions, Planetary Science and Exploration (PLANEX) programme, National Microgravity Research Programme including microgravity experiments on-board Space Recovery-capsule Experiment (SRE-1) etc., piggy back satellite experiments such as TAUVEX (Tel Aviv Ultra Violet Experiment) onboard GSAT-4 and RT-2 (X-ray spectrometer) on-board Russian Coronas-Photon Mission etc. The Chandrayaan-1 mission's main objective is to place a lunar spacecraft at 100 km polar circular orbit around moon to carry out high resolution imaging of surface topography, elemental/ mineral distribution, exploring signatures of presence of water-ice etc. Fig-2 shows the mission details and various Indian and foreign scientific payloads to be flown on-board Chandrayaan-1 mission.

In the field of atmospheric and solar terrestrial science ISRO has taken up specific programmes on Regional Atmospheric Modelling, MIDAS/CRABEX campaigns and CAWSES-India (Climate and Weather of Sun Earth System) programme with the participation of Indian scientific community. In addition, high altitude balloons and sounding rocket experiments are periodically carried out with very focussed objectives requiring in-situ data on vertical profiles of key atmospheric/ionospheric parameters etc.

Atmosphere is the life-line for all living objects on the planet earth. Understanding the atmospheric phenomena and how each activity on earth affects our environment through such phenomena is vital to scientific understanding of planet earth. The coupling between land, ocean, radiations from space especially from sun is quite important. ISRO has encouraged studies in this vital area right from its inception and some examples are highlighted in following sections.

Satellite data from INSAT meteorological payloads (VHRR), Modular Opto-electronic Scanner (MOS) experiment on board IRS-P3, MSMR and OCM payloads on Ocansat-1 (IRS-P4) are already being used by the science community for ocean-atmosphere-weather-climate research. Besides, the remote sensing applications are now covering several new areas; i.e., to assess damage due to floods, earthquakes etc., and for helping in relief operations. Fig-3 shows some of the satellites launched and planned by ISRO for weather and climate research.

Apart from the data obtained from space platforms, ground based measurement of atmospheric parameters provides vital information enabling studies requiring continuous data possible. One such example is the versatile and state of the art MST radar with collocated LIDAR and other facilities established at the National Atmospheric Research Laboratory (NARL). This national facility is available to atmospheric and ionospheric scientists in the country from any research laboratory/university. Already the facility has been utilised by a large number of scientists from these institutions.

III. Atmospheric, Climate and Weather Science

There is a concern that depletion of stratospheric ozone would let harmful UV-B radiation from the sun to reach earth's surface. To study its global nature and related aspects, the International Middle Atmosphere Programme (MAP) was undertaken (1982-86). Indian scientists participated in MAP with large number of balloon and rocket experiments and new ground based monitoring instruments for solar UV-B radiation fluxes (BUV photometer) and atmospheric aerosols (Multi Wavelength Radiometer, MWR) deployed in a network of observing stations. The successful implementation of IMAP (Indian MAP) paved the way for intensive studies on the complex ozone hole/ depletion related phenomena, role of tropospheric ozone, trace gases/pollutants and aerosols in influencing the variability of the environment, climate and weather patterns.

These studies brought out many gaps in the observation system related to the dynamics and chemistry of the troposphere and middle atmosphere which led to the establishment of the versatile and world class MST radar facility at Gadanki and setting up of the Geosphere Biosphere Programme of ISRO (ISRO-GBP). In addition the INDOEX-India campaign was also sponsored by ISRO to study the aerosol-radiation-cloud interactive processes over the Indian ocean during the highly convective period of pre-SW Monsoon period. INDOEX-India programme primarily involved observational campaigns during 1998 and

1999 using ship cruise, instrumented aircraft and ground based instrument in coastal areas. A large number of scientists from national laboratories and universities participated in INDOEX campaigns.

Some major results of INDOEX include (i) the role of black carbon in producing a haze layer ~3 km thick over Indian ocean, (ii) spatial anomalies of ozone and other pollutants in Indian and Arabian seas, (iii) decrease of aerosol loading from Indian coastal stations to interior sea. Results led to further modelling studies to identify the possible source regions of aerosols/pollutants and their transport/ diffusion. Fig-4 shows some results on aerosol distribution over ocean and continental regions.

Further, IRS-P4 OCM data has been used to retrieve AOD and its spatial, spectral and temporal variations over the oceans. The Bay of Bengal experiences much more aerosol loading (dominated by finer particles) compared to the Arabian Sea. A zone has been found over the Bay of Bengal, which shows low values of AOD (< 0.25) for all the months. An aerosol plume is found in the north western Arabian Sea during February to March.

NIMBUS satellite measured Total Ozone Content (TOC) and balloon ozonesonde profiles have been studied for determining long term ozone trend in many Indian cities. A slowly decreasing ozone trend has been observed during 1980-2004 like in many other cities of the world. However the uncertainties due to inter-relationship between El-Nino, SST and TOC needs further investigation. The UV-B fluxes did not show significant trend of enhancement over the Indian stations

Under ISRO-GBP Phase I (1990-2000) several pilot projects have been carried out; some of them are (i) High altitude cryogenic balloon experiments over Hyderabad showed declining concentrations of tropospheric and stratospheric halons over a period of few years. This is the only quantitative measurement providing a scientific basis on the phasing out trend of ozone depleting compounds from India and (ii) The long-term observations on aerosol optical depths at locations over Thiruvananthapuram and Visakhapatnam showed the seasonality and intra-annual variability of aerosol optical depths, (iii) LIDAR data showed volcanic eruption related growth and decay in stratospheric aerosols concentration. Fig-5 shows the results of the growth and decay of Mt. Pinatubo related stratospheric aerosol layer from LIDAR observations over Mt. Abu and the increasing concentrations of halons (SF_6) during 1987-98 due to anthropogenic emissions.

During the second phase, ISRO-GBP has undertaken a mobile pilot land aerosol campaign during 1st -28th Feb 2004 covering 15,000 km road length in southern India through participation of 10 national institutions. As a follow up of this pilot land campaign ISRO-GBP has also completed another land campaign covering west to east of India including entire Indo-Gangetic plains through continuous measurements of aerosols during 1-30 December, 2004. The primary objectives of this Land Aerosol Campaign was to characterize the atmospheric aerosols during the winter period and to identify the possibilities of transport and transformation across west to eastern Indian region. This would also give opportunity to understand the dynamics of fog formation during the winter period and the possible role of atmospheric aerosols. This campaign was complemented through vertical measurements of atmospheric boundary layer using Micro Pulse Lidar (MPL) and tethered balloon. In addition NRSA aircraft was used for making observations with various instruments up to 10 km in the troposphere. About 28 national institutions participated in this endeavour involving nearly 70 scientists specialized in the areas of atmospheric sciences.

Monsoon as revealed by the transition of ITCZ (Inter Tropical Convergence Zone) and cyclone track dynamics have been studied extensively using INSAT and IRS wide swath optical/IR sensors. Impact of clouds perhaps forms the greatest unknown parameter in the evolution and variability of global climate. Indian monsoon variability has been viewed as a manifestation of the vagaries of the deep cloud systems embedded within ITCZ. The performance of global models for monsoon simulation depends critically on the model initial conditions and model physics such as boundary layer, cloud processes, and cloud-radiation interactions.

Model initial conditions (at model grid points) are derived by statistical assimilation of global observations measured at different time and spatial scales. These initial conditions are representative of observations in measurement rich regions, whereas in data void regions such as oceans, which cover ~70% on the tropics, they are more governed by model evolutions. It is the INSAT series of satellites that has provided extensive observations over oceans by making measurements in Visible, Infrared and Water vapour channels on various cloud and surface parameters such as Cloud Albedo, Outgoing Longwave Radiation (OLR), Cloud Height, Cloud Motion Vectors (CMV), Precipitation and Sea Surface Temperature (SST). These INSAT measurements of cloud and surface parameters are utilized in the data assimilation processes for producing the model initial conditions. In order to have automated ground based observational

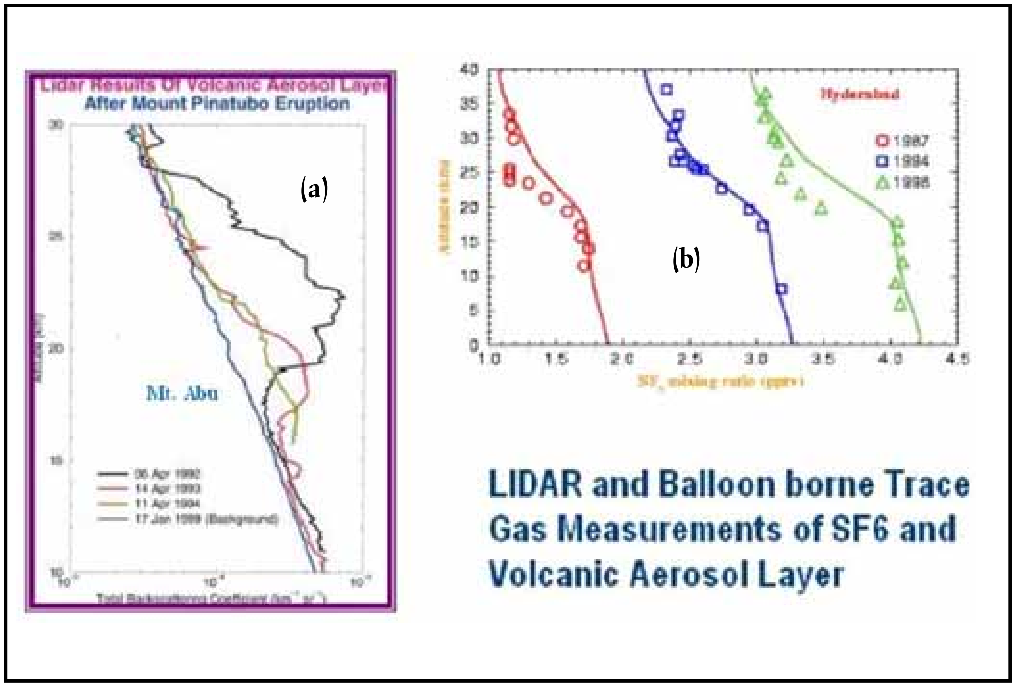

Figure 5. (a) LIDAR results of stratospheric enhancement of aerosol concentration following Mt. Pinatubo volcanic eruption and slow return to ambient values, (b) Balloon measurement over Hyderabad showing increase of SF_6 (sulphur hexafluoride from high voltage power units) having long resident time in stratosphere.

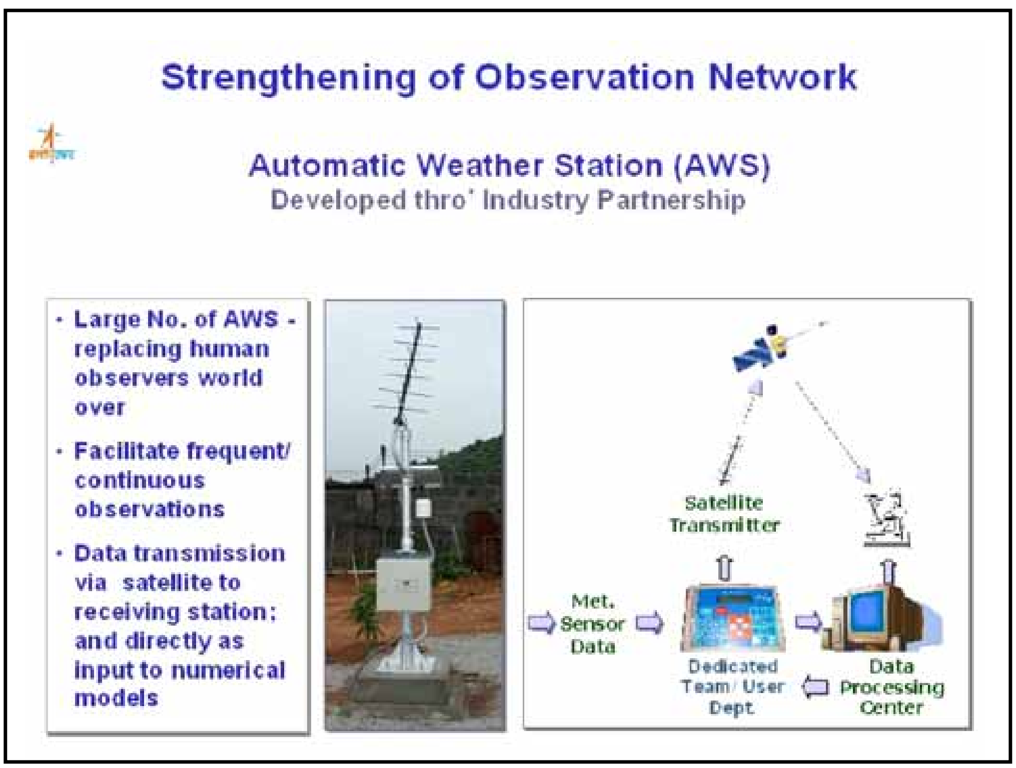

Figure 6. Automatic Weather Station (AWS) developed by ISRO through Industry partnership.

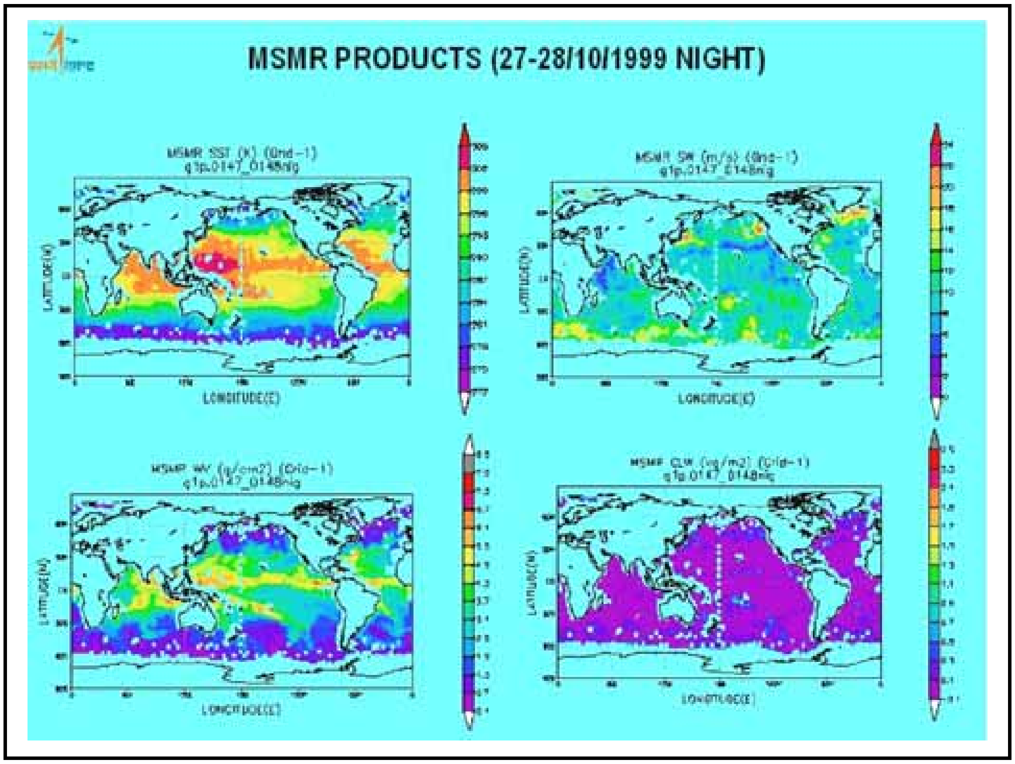

Figure 7. Typical global products of sea surface and atmospheric parameters derived from MSMR data

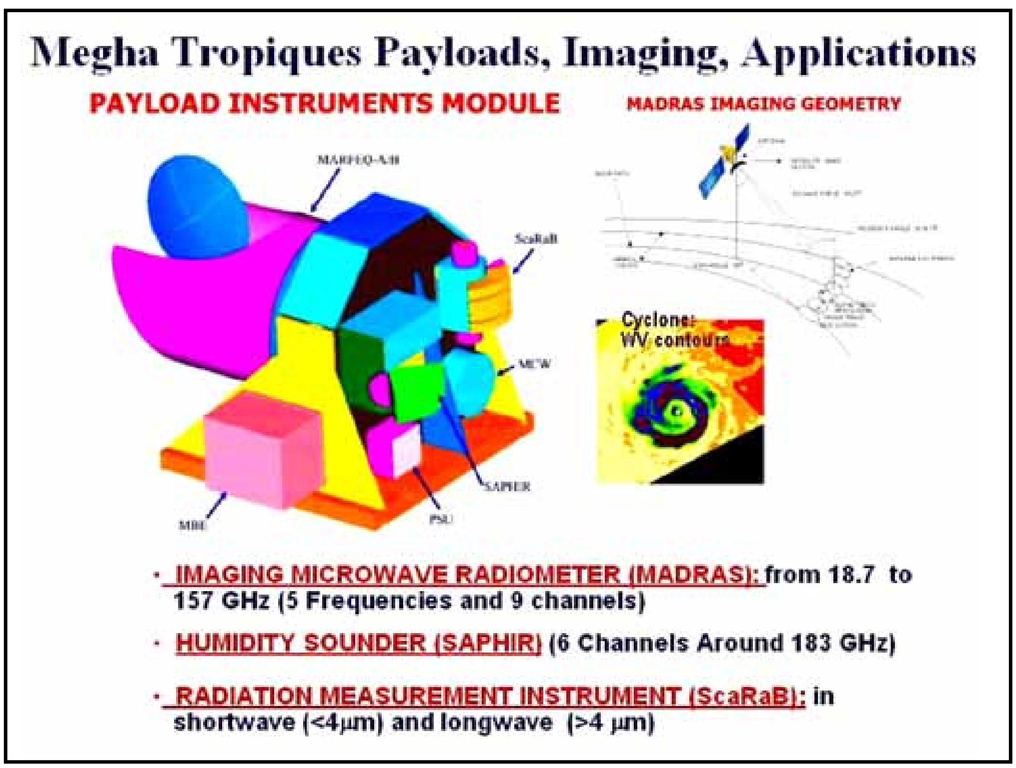

Figure 8. Megha Tropiques mission showing the payload configuration, imaging strategy and science objectives

programme of primary meteorological parameters for a denser network of stations, ISRO has plans to deploy hundreds of Automatic Weather Stations (AWS) with satellite data relay system. The accurate observational data with ground based AWS, Doppler weather radars and satellite sensors would improve the initial conditions for accurate regional weather forecast. Fig-6 shows a standard AWS system.

Movement and landfall predictions of cyclones have improved considerably by using INSAT/IRS data. The influence of local coastal geomorphology on the deviation of cyclone track just before crossing the coast is important for accurately predicting the landfall. A powerful tool used is remote sensing to map the regional geomorphology of the terrain. The database generated can be updated regularly whenever a new cyclone develops and crosses the coast. The study has revealed that accurate prediction can be made on the landfall of cyclone when the eye of the cyclone is within the range of 100 km from the coast. Due to inherent limitations of Vis/IR sensors, it is not possible to determine the vertical cloud structure and profiles of thermodynamic parameters.

Hence ISRO has initiated a series of remote sensing satellites known as IRS-P series (launched by PSLV), which carry microwave channels. For example, OCEANSAT-I carried Multi-frequency Scanning Microwave Radiometer (MSMR) operating in four channels 6.6, 10.5, 18 and 21 GHz measuring SST, wind speed, precipitable water vapour and cloud Liquid Water Content. Typical global maps of SST, SSW, WV and CLW obtained from MSMR data are shown in Fig-7.

Megha-Tropiques is an exclusive and unique mission planned with high repetitive measurements (orbit inclination: 20 deg, orbit: 867 km) and aims to make simultaneous measurements of radiative fluxes, humidity profiles and cloud properties, a rare combination of parameters, using radiometers, microwave sounders and microwave imagers at spatial resolutions of 10-50 km. Megha-Tropiques (MT) mission, slated for launch during 2008 is devoted to study energy and water exchanges in the tropical atmosphere with a special emphasis on clouds and precipitation and cyclone track prediction. The microwave imager (MADRAS) will operate at nearly 18, 23, 37, 89 and 159 GHz for observing rain above oceans, integrated water vapour, liquid water in clouds, rain above sea, convective areas over land and sea, ice at cloud tops. ScaRaB is a wide band radiometer measuring radiative fluxes at the top of the atmosphere in Visible (0.5 to 0.7 ìm), Solar (0.2 to 4 ìm), and IR window channels. SAPHIR is a microwave sounder operating in five channels around the absorbing line of water vapour at ~183 GHz measuring water vapour vertical profile. Fig-8 shows the Megha Tropiques configuration and mission details.

Atmospheric Dynamics

The meteorological rocket soundings were initiated in 1970 from Thumba using M-100 rockets to measure temperature and wind and ionisation profiles up to mesospheric altitudes ~85km. Similarly indigenous RH-200 meteorological rocket launchings from Balasore (21.5°N, 86.9 °E) and Sriharikota (13.7°N, 80.2°E) are carried out. The RH 200 rocket launchings have been continued to study equatorial wave characteristics and recently in MIDAS (Middle Atmosphere Dynamics) programme as part of campaign studies of break monsoon and stratospheric warming related phenomena along with numerous ground based LIDAR and radar observations**.** Some of the main results obtained refer to the gravity and equatorial waves, semi-annual, annual and quasi-biennial oscillations.

The MST Radar facility set up at Gadanki (13.5N,79.2E) near Tirupati, has been in operation for a decade now. It is the second largest MST Radar System in the world measuring atmospheric dynamical parameters with very high height and time resolutions on a continuous basis. Vertical profiles of prevailing winds, waves, turbulence, atmospheric stability & mesoscale phenomena between 5-100 km (with a gap region between 30-60 km) are obtained from this facility. The radar has an Yagi antenna array of 1024 elements with an aperture of 130m x 130m with a peak transmitter power of 2.5 MW. It has a 3Ú beam which can be electronically switched between 0-20Ú and directed towards zenith, E-W and N-S directions. The Facility also has collocated systems like Lower Atmospheric Wind Profiler (LAWP), LIDARs, Optical Rain Gauge, Disdrometer, AWS etc., which are used in conjunction with radar, to study lower, middle and upper atmospheric structure and dynamics. The facility has been recently renamed as National Atmospheric Research Laboratory (NARL) to further strengthen the atmospheric research activities in the country. Fig-9 shows the existing MST radar system and new experiments planned to augment the NARL facilities.

IV. Space Weather

Ionospheric and related Studies

Indigenously developed different types of sounding rockets and associated facilities have been widely used by the Indian scientific community for studies of middle atmosphere, aeronomy and thermosphere/ ionosphere processes. In recent times major scientific campaigns with high altitude RH-300 MK-II and RH-560 MK-II rockets carrying RPA, LP, electric field probe, chemical vapour release (Ba/Sr), ion/neutral mass spectrometer experiments have been conducted to investigate Leonid meteor shower related ionisation, F-region ionisation depletions, electrodynamics of E and F regions and mesospheric ionisation irregularities etc.

Indian scientists had the unique opportunity to carry out space science experiments using dedicated small scientific satellite system called Stretched Rohini Satellite System (SROSS). Two satellites weighing ~100 kg each in this series namely, SROSS-C and SROSS-C2 were launched during 1992 & 1994 using indigenous ASLV-3 carrying the Retarding Potential Analyses (RPA) payload for in-situ observations of the ionospheric parameters. SROSS-C2 was initially put into an orbit of 430 x 900 km which was brought down to an orbit of 450 x 650 km, the latitude coverage being –40°S to + 40°N. Studies with RPA and other related data have produced new results on variability of electron/ion temperatures, ionisation bubbles and occurrence of spread F/ionospheric scintillation, etc. Intense electron density bite outs have been detected coupled with deep fading of different radio links from GPS and geo-stationary satellite transmissions. Eight university groups reduced, analysed and studied the RPA data after they were trained under ISRO initiative. Fig-10 shows the SROSS-C2 satellite and the top instrument deck, blown up RPA payload and results of mass plots of electron and ion temperatures with local time.

The Coherent Radio Beacon Experiment (CRABEX) is an ongoing project consisting of geostationary satellite based coherent radio beacon transmissions at 150/400 MHz and a ground chain of receivers located at various universities and research institutions to receive radio beacon transmissions from low earth orbiting satellites for ray tomography. The main purpose is to develop a two-dimensional low latitude ionospheric model including the characterisation and morphology of the ionospheric irregularities. The satellite payload on-board GSAT-2 and the chain of ground stations both for geostationary and low orbiting satellites have been realised and preliminary results obtained under CRABEX.

A piggy back experiment on-board GSAT-2 was launched during May 2003 carrying a Solar X-ray Spectrometer (SOXS) payload to study the solar flares phenomenon. SOXS is composed of two independent components viz. SOXS Low Energy Detector (SLD) and SOXS High Energy Detector (SHD) payload. SLD covers the energy range 4-60 keV, while SHD from 25 keV-10 MeV. SLD employs the state-of-the-art solid state devices namely Si and CZT detectors that is exploited for the first time for solar astronomy research. These detectors provide high spectral (sub-keV) and temporal (100 ms) resolution capabilities required for such studies. A number of solar flare spectra are observed and their characteristics being studied.

The main stress in space weather studies is the proper understanding of solar energetic radiation and CMEs (Coronal Mass Ejections) driven magnetic storm/sub-storm phenomena and their impacts on magnetosphere-ionosphere coupled systems and modelling of the solar terrestrial phenomena. Such models are needed for reliable and effective communication and navigation systems.

Small satellite missions weighing ~ 100 kg are contemplated for measurements of critical parameters needed to understand the phenomena of earth's weather as well as space weather. Small satellite proposals on e.g. (i) space borne LIDAR system for spatial and temporal variation of aerosol profiles and (ii) ionisation/electric field probes to study the high latitude-low latitude magnetosphere-ionosphere coupling processes are being examined by ISRO for possible implementation.

Magnetosphere and Solar-Terrestrial Phenomena

The variability of the radiation environment of the earth within its magnetosphere boundary is what constitutes the space weather. The Sun is the main driver of space weather. Variable EUV radiation, energetic particle fluxes and solar wind conditions cause significant changes in the distribution of energetic particles, electric fields, currents and temperatures of the space environment at time scales of few seconds to days. These solar radiation components are modulated by heliomagnetic and geomagnetic field orientations. Fig-11 shows the overall phenomena of solar wind plasma interacting with the earth's magnetic field and creating the magnetosphere with electron and proton Van Allen radiation belts.

At polar regions intense fluxes of energetic electrons, known as precipitating electrons, propagate down along magnetic field lines. As altitude increases, the exposure to these particles gradually increases.

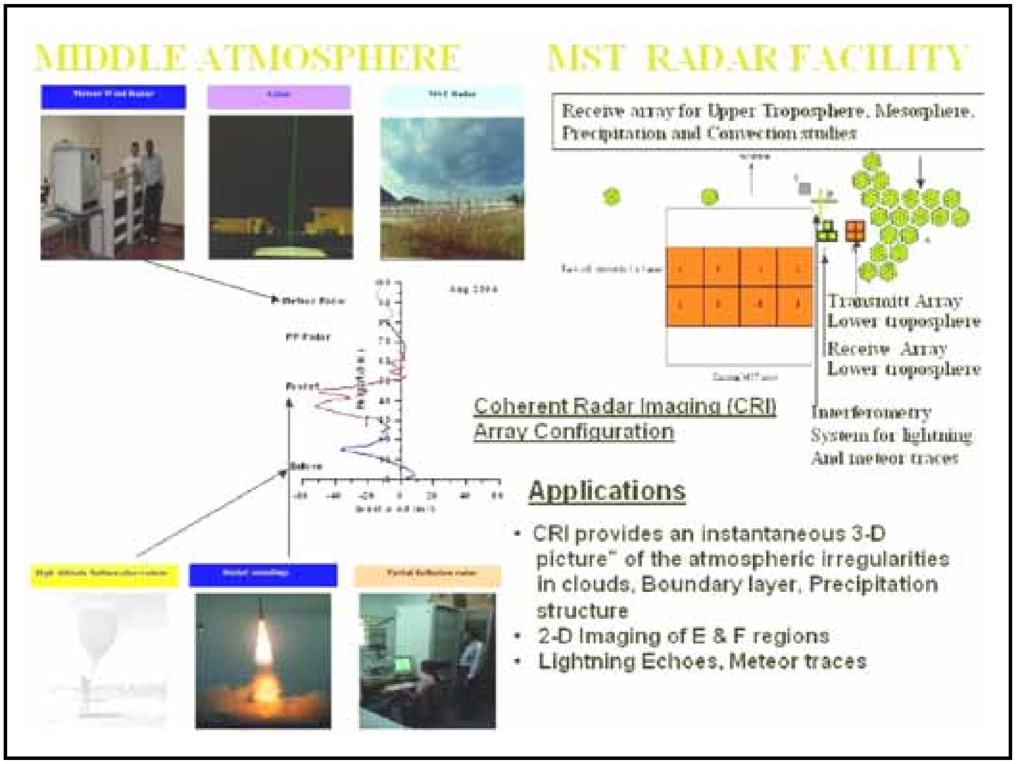

Figure 9. Existing and planned facilities at NARL. Major up gradation includes coherent radar imaging, GPS sonde launches, cloud radar, new LAWP

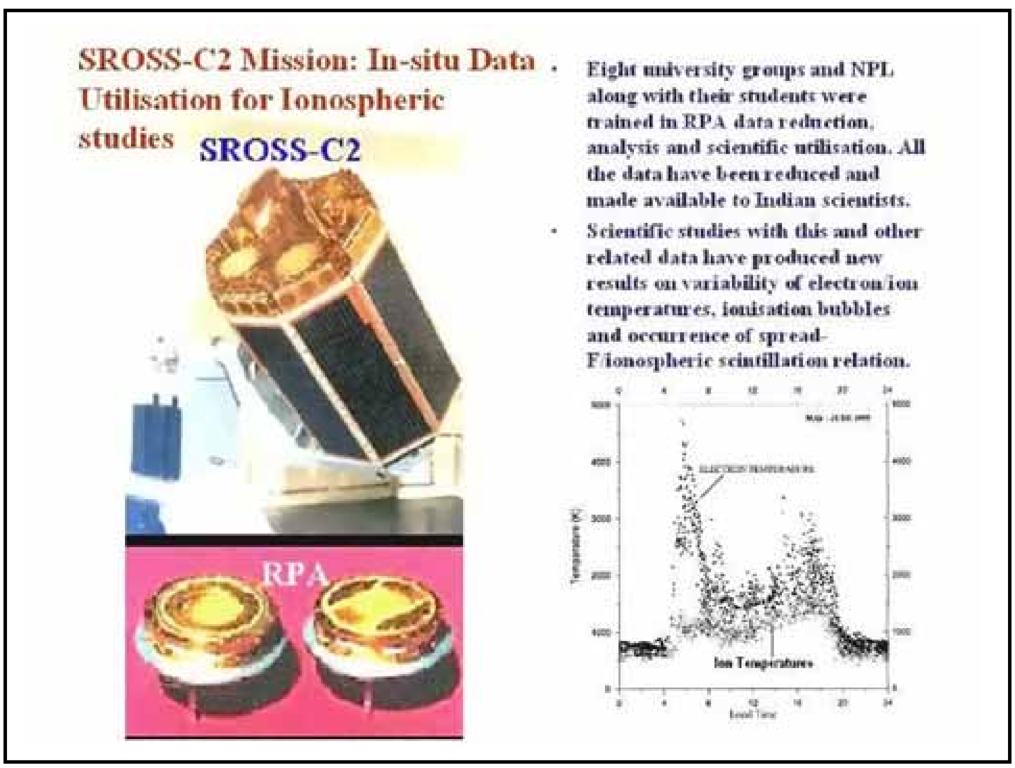

Figure 10. SROSS-C2 satellite with RPA payload (also carried a gamma ray burst experiment) and scatter plot of electron and ion temperatures

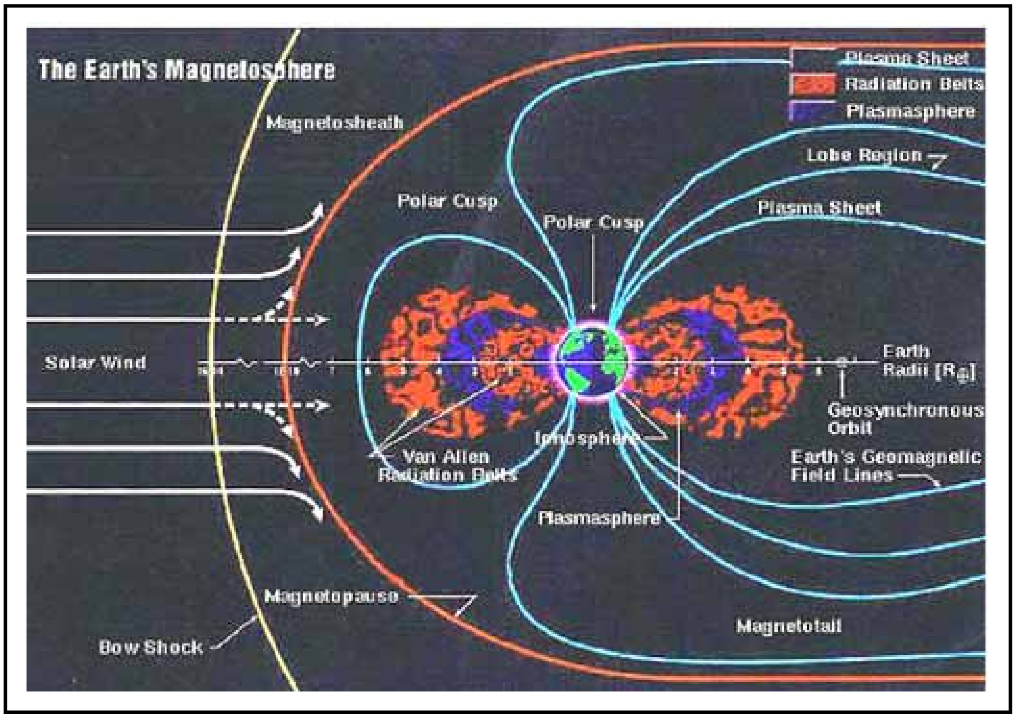

Figure 11. The geomagnetic field deflects cosmic ray charged particle motions in the Earth's orbit, acting as a barrier. The geomagnetic field traps solar wind plasma, mostly electrons and protons, into the Van Allen radiation belts. The energetic charged particles can descent to lower heights of <1000 km during periods of solar eruption events like flares, coronal mass ejections (CME)

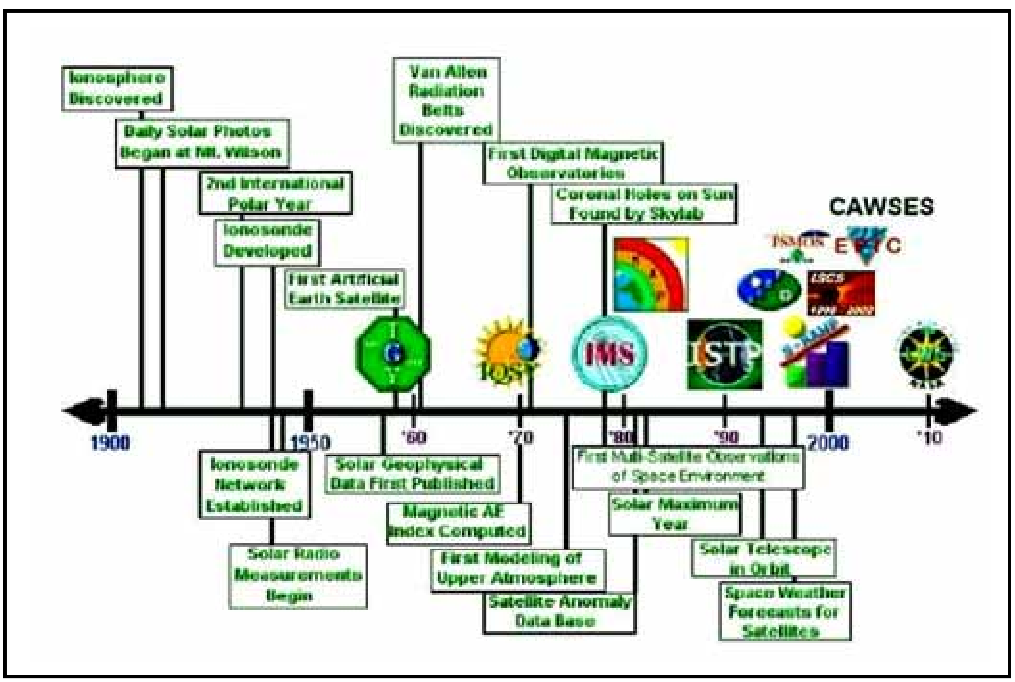

Figure 12. International coordinated programmes in a chronological sequence to study the solar-terrestrial phenomena from International Geophysical Year, IGY (1957) to International Magnetosphere Studies, IMS (1978) to International Solar-Terrestrial Energy Programme ISTEP, 1990 to Climate and Weather of Sun Earth System (CAWSES)

Trapped charged particles oscillate between the poles forming the radiation belts. The charged particle population increases considerably during magnetic storms.

Prediction of space weather conditions is vital so that effective measures can be taken to safeguard the space technological systems working in earth orbits, estimate changes in ionospheric electron density content due to changing current systems during magnetic storm events as well as provide adequate warning for any possible impending danger to systems working at or near the earth surface.

A daily measure of geomagnetic disturbance, the Ap index, is available from 1932 to the present. The numbers of days each year having Ap $\geq$ 40 (when there is a significant magnetic storm in progress) are well correlated with smoothed annual sunspot numbers. The distribution of magnetic storms at Earth is more complex than the pattern of high and low sunspots. Large magnetic storms disrupt telecommunications, cause power system failures, and may cause a variety of satellite anomalies

Disturbances on the Sun can produce dramatic effects in the space environment surrounding the Earth. Energetic particle effects pose a serious hazard to astronauts and damage spacecraft electronics. Satellite lifetimes are shortened by increased atmospheric drag, and communications/navigation are disrupted by the changing plasma environment.

Recently a number of satellites such as ACE, SOHO, GOES, YOHKOH are providing vital in-situ data on solar terrestrial linkage parameters. In spite of efforts at international level to coordinate scientific programmes like IGY, IQSY, IMS, IMAP, STEP etc., models are yet to be evolved for prediction of even the solar disturbances, let alone its effect on earth's magnetosphere, ionosphere, tropospheric weather etc. Recently an International Programme called the Climate and Weather of Sun-Earth System (CAWSES) has been initiated to address the outstanding problems in this field and come out with predictive models. Fig-12 shows the chronological sequence of international coordinated programmes in solar-terrestrial science starting from International Polar Year (IPY), International Geophysical Year (IGY) to the recently concluded International Solar Terrestrial Energy Programme (STEP). The outcome from these programmes and recent development in space techniques led to the formulation of CAWSES programme.

The main aims of CAWSES are to (i) mobilize the international solar-terrestrial science community to fully utilize the past, present, and future data; (ii) improve space weather forecasting to produce better design of space and Earth-based technological systems and (iii) improve our understanding of the effects of solar-terrestrial influences on Global Change. The CAWSES program would foster a scientific approach to understanding the short term (Space Weather) and long term (Space Climate) variability of the integrated Solar-Terrestrial environment, and its effects on society.

Four themes of CAWSES are: (a) Solar influence on terrestrial weather, (b) Space Weather: science and applications, (c) Atmospheric coupling processes, (d) Space Climatology

Conclusions

Prof. Ramanathan's pioneering contributions to the phenomena in the atmosphere, ionosphere and solar-terrestrial science have led many Indian scientists to pursue these very engrossing fields of space science research. Today the field of space research poses many challenges both in terms of intriguing scientific problems that remain unresolved and many facets of the impact of solar radiations on distant as well as near earth environment. Intensive observations through space techniques as well as ground based monitoring of various parameters along with evolving physical modelling and analysis efforts are vital to pursue these areas of research. ISRO has taken up a number of initiatives with space missions and has plans to strengthen these further. The planned activities of Metsat, Oceansat, Megha-Tropiques missions and the nation wide ISRO-GBP and CAWSES programmes provide excellent opportunity to the scientific community to participate. The young students and the academia may find the subject matter of the research on atmosphere and outer space very interesting. Networking such research and knowledge centres is important to tackle the multi-disciplinary complex task.

G. Madhavan Nair

Chairman, Space Commission & Secretary to Government of India, Department of Space, Bangalore

Chairman, Indian Space Research Organization, Bangalore.

Chairman, Governing Body, National Remote Sensing Agency, Hyderabad.

Chairman, Antrix Corporation Limited, Bangalore.

Major Contributions :

Shri Madhavan Nair is currently the Chairman of Indian Space Research Organization entrusted with the responsibility of development of space technology and its applications to solve problems of man & society in India. During the past two years, 9 successful missions were accomplished i.e., INSAT-3E, Resourcesat-1, Edusat, Cartosat-1, Hamsat-1, INSAT-4A, PSLV-C5, GSLV-F1 and PSLV-C6. Major thrust is given in evolving application programme such as tele-education and telemedicine meeting the needs of society at large.

Shri Madhavan Nair is a leading technologist in the field of rocket systems and has made significant contributions to the development of multi-stage satellite launch vehicles, achieving self-reliance in independent access to space using indigenous technologies.

Shri G.Madhavan Nair as Chairman, Space Commission is responsible for chalking out the future plan for space research in the country. Major thrust are in scientific exploration of outer space using the Astrosat and Chadrayaan (moon) missions apart from implementing schemes for telemedicine, tele-education and disaster management support systems. He is also providing guidance and leadership in undertaking new technology developments related to launch vehicle, spacecrafts for communication, remote sensing and applications programmes to meet societal needs.

His main focus has always been to achieve self-reliance in the high technology areas and to bring the benefits of space technology to the national development, specially targeting the needs of the rural and poor sections of the society.

National Recognition

Padma Bhushan (1998)

Honours:

D.Philosophy (Honoris Causa) conferred by Punjab Technical University, Jalandhar (2003).

D.Sc (Honoris Causa) conferred by Sri Venkateswara University, Tirupati (2004).

Honoris Causa Doctor of Science conferred by Indian Institute of Technology, Delhi (2004).

Honoris Causa Degree of Doctor of Science Award by Rani Durgavati Vishwavidyalaya, Jabalpur (2005).

Honorary Doctorate Degree (D.Sc.) conferred by Cochin University of Science and Technology, Kochi (2006).

Honoris Causa degree conferred by University of Mysore at the 86th Convocation in Mysore (2006)

Honoris Causa from GJ University, Hissar (2006)

Fellowships/ Memberships:

Fellow, Indian National Academy of Engineering.

Fellow, Astronautical Society of India.

Fellow, National Academy of Sciences, India.

Honorary Fellow, Indian Society for Non-Destruction Testing (ISNT).

Member, System Society of India.

Member, Working committee of the Current Science Association (2004-06)

Member, International Academy of Astronautics (2004).

Senior Associate, National Institute of Advanced Studies (2004-2007).

President, Intersputnik Board (2005)

Awards:

National Aeronautical Award (1994)

FIE Foundation's Award (1994)

Shri Om Prakash Bhasin Award (1995)

Swadeshi Sastra Puraskar Award (1995)

Vikram Sarabhai Memorial Gold Medal of the Indian Science Congress Association (2003)

Personality of the Decade Award from KG Foundation, Coimbatore (2004)

Melpadom Attumail Georgekutty Award from Mar Thoma Syrian Church of Malabar, Thiruvalla (2004)

Raja Sir Muthiah Chettiar Endowment Award from Crescent Engineering College, Chennai (2004)

10th Science & Technology Award for Excellence for the year 2003-2004 from Sathyabama Deemed University, Chennai (2005)

Benedict Mar Gregorios Award from The Association of Mar Ivanios College Old Students, Trivandrum (2005)

Dr. Yelavarthy Nahudamma Memorial Award - 2004 from Dr. Y.Nayudamma Memorial Trust, Tenali, Andhra Pradesh (2005)

H.K. Firodia Award-2005 from HK Firodia Foundation, Pune.

"Best R&D Man of the Year" Corporate Excellence Award – 2005 from Foundation of Indian Industry & Economists at ND (2006)

Best College of Engineering Trivandrum Alumni Association (CETAA) Alumni Award 2005 at Trivandrum (2006)

Fifth "Shri Balvantbhai Parekh Award" from The Indian Planetary Society, Mumbai (2006)