Satellite Meteorology and Global Climate

Education Curriculum

Space Applications Centre
Ahmedabad

December 2007

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*** Report of the Committee set up by Director, CSSTEAP to review the Curriculum of CSSTEAP 9-months P G Course on Satellite Meteorology and Global Climate (SATMET).**

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Chairman Curriculum Committee

Preface

The CSSTEAP Post Graduate course in Satellite Meteorology and Global Climate (SATMET) is being conducted at the Space Applications Centre (SAC), Ahmedabad. So far five courses (once in two years) have been conducted and more than 90 participants from 18 countries in Asia-Pacific region have benefited by these education programmes. Based on the guidelines of the United Nations, the education curriculum for the nine-months course has been prepared. The syllabus attempts to cover a broad perspective in satellite meteorology for the operational weather forecasters as well as research scientists. The main idea is to expose the course participants to the fundamentals of the subject to enable them to enter the field of research in specific areas, carry out the operational day to day forecasting duties with a broad comprehension of the total field.

Curriculum development is a continuous process that should take into account, among other things, various technological developments, new emerging application scenarios and feed back received from participants and faculty. A mechanism for in-depth review of the syllabus at the end of each course, based on the above considerations exists.

An expert committee was constituted by Director, CSSTEAP to review the current syllabus of the SATMET Course and make recommendations on changes needed, based on the advancements in the field. The expert committee met on October 17, 2007 at SAC and critically reviewed the existing syllabus (theory and practicals) and recommended modifications considering the present operational/research satellites for Meteorological observations and planned future missions, emerging application scenario; and feedback of the students. Efforts have been made to improve the total syllabus, so as to meet the requirements and aspirations of the participating organizations for a period of coming five years. The recommended revised curriculum shall be implemented during the SATMET-6 (2008) course.

Contents

Curriculum Development for CSSTEAP Post Graduate Course on 'Satellite Meteorology and Global Climate'(1995-2006)

1. Introduction

The benefits of space technology, both direct and indirect have introduced new dimensions into the study and understanding of earth's processes and in improving the quality of life for the people living on it. All countries should have access to space technology and must share the benefits. An essential pre-requisite to partaking in these opportunities is the building of various indigenous capabilities for the development and utilization of space science and technology. In recognition of such a pre-requisite, a consensus has emerged within the international community that if effective assimilation and appropriate application of space technology are to succeed in the developing countries, devoted efforts must be made at the local level, for the development of necessary high level knowledge and expertise in space technology fields. Towards this end, the United Nations General Assembly has called for the establishment of Centres of Space Science and Technology Education at the regional level in the developing countries.

The Centre for Space Science and Technology Education for Asia and the Pacific (CSSTEAP), affiliated to the United Nations, was established in India in November 1995. Satellite Meteorology and Global Climate is one of the four post graduate courses run by the Centre.

The importance of conducting training course in Satellite Meteorology has been realized by many national meteorological agencies for their operational needs. Their regular training courses include Satellite Meteorology as a small portion, covering primarily the synoptic studies of the weather system with imageries.

The issues related to global warming, ozone depletion, ENSO and Ocean atmosphere interaction, global climate change, once academic, have now become extremely relevant. The Course, besides imparting knowledge in basics of satellite meteorology and above issues, caters primarily to education in this field. Handling of satellite digital data, working with dynamical models, problem solving, and executing projects of relevance to the home country have been the prime focus of attention.

Meteorological satellites have been operating almost continuously since the beginning of the space age. Their continuing presence in space for decades to come is virtually assured because of the importance that society at large places on the observations and forecasting of weather phenomena. Spacecraft have been launched by some countries specifically to meet the needs of professional government meteorologists in those countries who are responsible for providing weather forecasts for civil and military interests. However, most countries that launch weather satellites have designed the satellites to operate in such a manner that anyone who is within radio receiving range of the satellites can acquire the data free and use the data for any purpose. Thus, it is feasible to use real-time, direct readout observations from the satellites as an educational resource in schools. Such observations can also be used as a tool for managing and forecasting weather, detecting forest fires, supporting air, sea and land transportation, supporting agricultural and fishing interests, and for a wide range of other

non-meteorological purposes. In addition to operational satellites, a few research and development satellites, giving more information about the atmosphere and oceans, are now available. The inclusion of satellite data in numerical weather prediction is possible and found to be invaluable in generating the initial conditions for the models. Information from geographic information systems (GIS) in meteorological and climatological studies is gaining importance.

In the context of Asia Pacific region, the information generated from meteorological satellites and their timely and real time distribution assumes great importance. This region covers countries many of which experience the typical tropical weather systems – especially tropical cyclones and monsoons and a few other mid-latitude weather phenomenon.

Global access to meteorological satellite data was initiated by the World Meteorological Organization (WMO) to help ensure that knowledge of aerospace sciences and technologies that have evolved as a result of the free access to meteorological satellite observations can and will be utilized by individuals, organizations and countries, especially developing countries.

The establishment of CSSTEAP is a significant step in the development and transmission of knowledge in the fields of space science and technology. The principal goal of the centre is the development of skills and knowledge of university educators and research and application scientists, through rigorous theory, research, applications, field exercises and pilot projects in those aspects of space science and technology that can enhance social and economic development in each country.

2. Review of the Existing curriculum and experience gained (Grenada Guidelines)

The United Nations has developed model curricula in Satellite Meteorological Applications for the Centre. The initial work on these curricula was accomplished at a workshop that was organized and hosted by the Government of Spain in Grenada in February / March 1995. In order to attain international recognition and certification, this finished model curricula was prepared to provide the Centre with a benchmark of the academic level necessary to maintain the international standard and character of the course as well as the Centre.

The course consists of nine-months study at a regional Centre, followed by the implementation and completion of a one-year research project in the scholar's home country.

The objectives of the course on Satellite Meteorology include the following:

(a) To educate specialists from developing countries in Satellite Meteorological Applications in support of their development and social-economic well-being; and

(b) To promote the utilization of meteorological satellite data techniques for the monitoring and assessment of the environment, and severe meteorological phenomena.

It is anticipated that at the end of the course, participating scholars will be able to:

(a) Serve as points for furthering the skills and knowledge of other professionals in their countries;
(b) Contribute to policy-making, planning, development and management of operational Meteorological satellite data and applications in their countries; and
(c) Enhance and increase the self-reliance of their countries so as to lessen dependence on external experts.

Grenada meeting envisaged that participants will participate in a course of instruction designed to increase their scientific knowledge in the application of meteorological satellite-derived data and develop and extend their computational and analytical experience in order to allow them to initiate and implement the benefits of this science and technology in their home countries.

The experts at the Grenada meeting suggested that the following topics should be covered by the course :

- Atmospheric Compositions, radiation laws, General Circulation of atmosphere and oceans
- Basic radiometry, interaction of electro magnetic radiation and matter
- Thermodynamics, dynamics, tropical and extra-tropical motion systems, meso-scale and synoptic scale systems
- Weather forecasting, combined use of satellite, radar and conventional data, numerical weather prediction.
- Essentials of satellite types, orbits, and sensors, vertical sounding systems onboard satellites, as well as in-situ data collection platforms, retrieval of meteorological products.
- Specialized treatment and application of satellite data, acquired by polar orbiting and geostationary satellites, in several areas of human endeavors, e.g. agriculture, determination of shelter temperature, estimation of soil skin temperature; estimation of amount and distribution of precipitation, crop inventory, livestock management, fisheries, etc.

Five courses have been held so far beginning 1998 (organized every alternate year). The country wise output (as on December, 2007) of SATMET courses is given in **Table 1**. The details of the curricula implemented during these courses are presented below.

3. First Course (SATMET - 1998):

Based on the broad guidelines given in the Grenada document, it was decided to prepare a detailed syllabus for the first 9 months PG Course in Satellite Meteorology and Global Climate (SATMET) which was held in 1998. A national committee comprising of members from India Meteorological Department (IMD), Andhra University, Indian Institute of Science, Indian Institute of Tropical Meteorology, Indian Space Research Organisation (ISRO) was constituted for this purpose. This syllabus as per Grenada meeting recommendations was executed during the first 1998 SATMET course. The various modules

covered in the course are given in **Annex.I, Table-2.** The breakup of the course curriculum in terms of classroom lectures, laboratory work, tutorial, Library, Technical visits etc is provided in **Fig. 1**. This helped a great deal in the preparation of the schedules during the course.

The following comments were received from the participants / faculty as feedback :

- Too much emphasis was placed on tropical meteorology. More topics related to mid-latitude systems to be included.
- More case studies (e.g. satellite data application in NWP models) and sample numerical problems would be desirable.
- An introductory course on basic physics, mathematics and computer programming was suggested.
- More time to be allotted to topics such as climate change, radiative transfer etc
- Number of tutorials to be increased

4. Modifications for the Second Course (SATMET - 2000):

Based on the feedback received from the participants of the first SATMET-1998 Course and the faculty, a few modifications were made in the course curricula to be followed during the Second SATMET(2000) course :

- An orientation module covering basics of mathematics, statistical methods and computers was included
- Emphasis on tropical meteorology, including monsoons/tropical severe weather systems was significantly reduced
- New lecture topics covering mid latitude and extra tropical systems were introduced

The modules covered during the SATMET-2000 course are given in **Table 3** and the corresponding break up of time schedule is given **Fig 2.** The inclusion of the orientation module covering the basics of mathematics, statistics and computers was welcomed by participants and helped them in improving their knowledge.

Prior to the course, it was decided to introduce three elective papers in specialized fields providing in-depth information (covering 20 lectures) during the second course, namely :
(a) parameter retrieval using satellite data (b) data assimilation and numerical models and (c) climate change

Based on discussions with and background of participants, the elective option was dropped. The important aspects of each were included in the respective general modules.

In addition, a number of changes in the curriculum were implemented (e.g. the inclusion of lectures in Dynamic Meteorology and Physical Oceanography in the Orientation Module).

5. Modification for third Course (SATMET -2002)

The third CSSTEAP course in Satellite Meteorology and Global Climate was held during August 1, 2002 to April 30, 2003. Following an in-depth review of the second course, the following changes were made in the curriculum for the third course :

(i) Physical Oceanography topics were introduced in the introduction sub-module.
(ii) Emphasis on advanced topics like Radiative transfer and parameter retrieval was reduced.
(iii) More stress was put on applications of satellite data.
(iv) The lectures on Global Climate were increased. Lectures on short term climate variability and long term climate changes were introduced.

The modules covered during the third course are given in **Table 4.**

6. Modification for fourth and fifth courses (2004 and 2006)

During the Board of Studies meeting held at the end of the third course, it was felt by the members and faculty that the present course curricula has more or less met the requirements / expectations of the participants. It was decided that the present curricula shall be implemented for at least two courses to get meaningful feedback from the participants.

The Fourth and Fifth courses in Satellite Meteorology & Global Climate were held in 2004 and 2006 respectively. Excepting for a few minor changes, the course curricula followed the syllabus set up for the third course. Some of the changes that were made included introduction of new topics like GPS in Meteorology, Hyper-spectral sounding, AIRS data and their applications etc.

7. Curriculum for Practicals of SATMET Course:

In addition to morning theory classes, participants spend considerable time in the afternoon sessions in carrying out various practicals involving image analysis and interpretation, retrieval of met and ocean parameters, and interpretation of numerical model outputs. The main workhorse for these hands-on-exercises is the operational (Geostationary) INSAT-VHRR data and (polar) NOAA-AVHRR data. A ground facility for receiving these satellite data in real time exists. In addition, data from experimental satellites like TRMM, ERS and IRS P4 MSMR are also used to demonstrate potential useful applications. With recent developments in dynamic models and computer technology, it has now become possible to run these models (e.g. GCM, Mesoscale models) for weather forecasting at various scales. Participants are exposed to the requirements of the resources (computing, satellite data etc), capabilities/limitations of the models through the analysis of the model outputs. Important applications like rainfall estimation, tropical cyclone intensity/track studies, monsoon monitoring, retrieval of temperature/moisture profile, retrieval of atmospheric (OLR, CMV), oceanic (SST, SSH, SSW) and land (LST, LAI, Evapo-transpiration) parameters are covered. The assimilation of some of these satellite derived parameters in Mesoscale (MM5) models to study the impact on forecasts is also part of the course.

The detailed list of practicals of Module 1 and 2 of the SATMET Course are provided below:

(a) 1998 Course - **Table 5**
(b) 2000 Course - **Table 6**
(c) 2002 Course - **Table 7**
(d) 2006 Course - **Table 8**

8. Pilot Project of SATMET Course

The Satellite Meteorology and Global Climate Course (SATMET) of 9 months duration has three modules, each of three months duration. The first two modules covering various aspects of Satellite Meteorology and Global climate are conducted through rigorous theory (class room lectures) and practicals - as discussed above. The Module III deals with the Pilot Project. In this module, each scholar formulates and executes a Pilot Project under the guidance of the faculty. The topics of the projects are of relevance to participant's region involving extensive use of satellite data and application. It is supposed to be precursor to the one-year project undertaken by the participant in their home country.

The broad themes of the pilot projects could be classified in retrieval and validation of satellite products, applications to weather phenomena, analysis of model outputs, climate analysis etc.

The details of the pilot projects carried out by the participants during 1998 - 2006 are provided in **Table 9.**

9. Revised Curriculum for the Course on Satellite Meteorology & Global Climate (2008)

As discussed earlier, the present course curricula designed in 1998 is almost ten years old. The Board of Studies (BOS), meets at the end of each course to review the academic programme, including the course content, relative time allotted to each topic etc. While the overall curriculum remains as established by UN, fine tuning of sub topic contents are carried out on the recommendations of the BOS.

The UN-OOSA organized a meeting of experts from all regional centres during September 2001 at Frascati, Italy to review and update curricula at the university level and across cultures in four areas : Remote Sensing, Satellite Meteorology, Satellite Communications and Space Science.

Curriculum development is a continuous process. It takes into account, among other things, various technological developments, new emerging application scenario and feedback received from the students and the faculty.

Director, CSSTEAP constituted a specialized committee to review the current syllabus and make recommendations on changes needed, based on the advancements in the field. (Ref : No.CSSTEAP/Revision/SATMET/07 dated July 25, 2007). **Annex. II** gives the terms of reference of the Committee. The Committee met on October 17, 2007 and reviewed the existing syllabus.

Committee members felt that the recommended syllabus should serve for at least five years and urged to take into account new sources of data (new satellites and sensors), new retrieval techniques, novel applications etc into consideration. Accordingly, emphasis on soundings (temperature/moisture profile estimation using sounders on Geostationary platform), GPS Occultation, hyper-spectral data, scatterometer (sea surface winds) and Megha Tropiques applications have been increased. The high-temporal (3 hr) sounder data providing temperature and moisture profiles would help in characterizing the stratification of the atmosphere, through stability indices and help in observing mesoscale thunderstorm development, thus improving the nowcasting capabilities (forecasts out to a few hours). In addition these would also be very useful as initial conditions for the dynamical models. Similarly the emerging GPS radio occultation technology providing information on atmospheric conditions (temperature, moisture, refractivity, pressure etc) will have a large impact on daily weather forecasting (including tropical cyclone track forecasting), besides helping scientists studying long-term climate trends–occultation measurements don't require calibration.

Scatterometer wind vector observations over the oceans would help in the monsoon onset monitoring (through wind reversals, computation of moisture flux and kinetic energy over the Arabian sea), cyclogenesis (low level vorticity patterns) and tropical cyclone intensification. Incorporation of these wind vectors in numerical models are known to have a positive impact on operational analysis and forecasts. The assimilation of these wind vectors in Ocean circulation models will result in significant improvement of the ocean state forecasts.

In view of the large number of participants from land locked countries attending the course, three elective topics, namely satellite parameter estimations over land and oceans have been added. The third elective topic deals with the advanced techniques for parameter estimations over atmosphere. It has been noticed that more participating countries are looking forward to exposure/training in Mesoscale models (e.g. MM5 and WRF) for initiating dynamic predictions of weather. Accordingly, a number of lectures dealing with the specific requirements have been suggested.

Recommended text books and internet based reading materials have also been included at each (sub) module.

The evolution of the curriculum (SATMET 1-1998 to SATMET 6-2008) is shown in **Table 10.**

The final curriculum, taking into account all the recommendations of the members, to be implemented from August 2008 (SATMET-6) is provided below :

Course at a Glance : SATMET (Revised : 2007)

Module 1 : Fundamentals of Satellite Meteorology, Global Climate and Relevant Techniques (Three Months)

Sub-Module 1.1	Concepts in Meteorology and Climatology	No. of Lectures *
Section 1-1 MET	Basic concepts of Meteorology, Climatology and Oceanography	35
Section 1-1 MATH	Mathematical and Statistical, Computational Techniques for Satellite Meteorology	15
Sub Module 1.2	Concepts in Satellite Meteorology	
Section 1-2-SM	Principles of Meteorological Remote Sensing	25
Section 1-2-MSI	Overview of Meteorological Satellites / Orbits	15
Sub Module 1.3	Image Processing , Interpretation and GIS	
Section 1-3-DIP	Image Processing Techniques and Geographic Information System (GIS)	15
Section 1-3-WF	Image Interpretation in Meteorology and Weather Forecasting	25

* ***Lecture duration : 1.5 hrs***

Total : 130 Lectures (195 hrs)

Module 2 : Advanced Concepts and Techniques in Satellite Meteorology and Global Climate (Three Months)

Sub Module 2.1	Geophysical Parameter Retrieval	
Section 2-1 AP	R T Theory, Atmospheric Parameters	30
Section 2-1 LOP	Land and Oceanic Parameters	10
Sub Module 2.2	Applications of Satellite Derived Parameters	
Section 2-2-AWF	Applications in Meteorology and Weather Forecasting	25
Section 2-2-NM	Satellite Data Assimilation in Numerical Models	15
Sub Module 2.3	Global Climate and Environment	
Section 2-3-SC	Short Term Climate Variability	20
Section 2-3-LC	Long Term Climate Change	20
Section 2-3-ESI	Environment Issues and Societal Impacts	10

Total : 130 Lectures (195 hrs)

Module 3: PILOT PROJECTS (Three Months)

Revised Curriculum (2007)

The revised curriculum for the Post Graduate Course in Satellite Meteorology and Global Climate is presented below:

Module 1: Fundamentals of Satellite Meteorology, Global Climate and Relevant Techniques (Three months) – 130 hours

Sub Module 1.1 : Basic Concepts (50 hours)

1. Atmospheric Physics (5 hrs)

   Composition of the atmosphere (Vertical structure, trace gases)
   Thermodynamics (Laws, Lapse rates and stability, Inversion)
   Basic Radiation laws
   Electromagnetic spectrum (Wavelength regions)

2. Atmospheric Dynamics (5 hrs)

   Atmospheric dynamics (Fundamental atmospheric forces, Equations of Motion Scale analysis, divergence / Vorticity)
   Balanced flows, Vertical motions

3. Meteorology (10 hrs)

   General circulation of the atmosphere (Surface winds and pressure, Upper air winds, Jet streams, Long waves - Rossby)
   Tropical weather systems (Easterly waves, ITCZ, Thunderstorms, Mesoscale systems, Tropical Cyclone, Monsoons)
   Extra tropical weather systems (Fronts-Characteristics, Extra tropical cyclones)

4. Oceanography (5 hrs)

   Role of oceans in weather and climate
   Oceanographic parameters (Measurements, accuracies)
   Ocean circulation
   Air-sea interactions (Heat momentum fluxes)

5. Climatology (10 hrs)

   Components of the Earth's climate (Classification, climatic time scales)
   Annual and semi-annual cycles (Stratosphere / troposphere, Mean winds Temperature, QBO)
   Climate variability and climate change
   Overview of world climate (A-P region, Tropical / Extra - tropical)

6. Mathematical Methods (7 hrs)

   Matrices
   Partial and total differential equations
   Integrals and derivatives
   FFTs

7. Statistical Analysis (8 hrs)

   Data analysis (Time series analysis, correlation & regression analysis)
   Advanced Techniques: Artificial Neural Networks, Chaos Theory
   Principal Component Analysis

Suggested Books :

1) Climatology (1989) - B. Haurwitz and J.M. Austin, Mc Graw Hill Book Co., N Y
2) Climate and Circulation of the Tropics (1985) - S. Hastenrath, D. Reidal Publishing Co., Tokyo, 455 p.
3) The Global Climate (1985) - J.T.Houghton, Cambridge University Press
4) Climatology of the Asia Pacific Region (1996) - G B Pant and Roop Kumar, John Wiley
5) An Introduction to Atmospheric Physics–Andrews David, 2000, Cambr. Univ. Press.
6) Southwest Monsoon – Rao Y P, (1976), Met Monograph, IMD, New Delhi
7) Exercises in Meteorology – Paul, Robert A, 1996, Upper Saddle River, New Jersy.
8) Atmospheric dynamics. - Green, John Cambridge University Press, 1999. 213 p.
9) Dynamics of the atmosphere: a course in theoretical meteorology - Wilford Zdunkowski and Andreas Bott , Cambridge Univ. Pr., 2003. 719 p.
10) Meteorology for Scientists and Engineers. - Stull, Roland--2nd ed., Pacific Grove: Brooks/Cole Pub., 2000. 502 p
11) The Physics of Atmospheres - Houghton, John, Cambridge Uni. Pr., 2002. 320 p.
12) Tropical Meteorology - Asnani, G. C.-- 2006. 3 Volumes.
13) An introduction to Dynamic Meteorology – Fourth Ed, James R Holton (2004) Elsevier Academic Press, 531 p
14) Tropical cyclones, their evolution, structure and effects – R A Anthes (1982), Ame. Met. Soc., 208 p
15) Atmosoheric Sciences – An Introductory Survey, John Wallace and Peter Hobbs, 2nd Ed. (2006), Elsevier Academic Press, 504 p
16) The Asian Monsoon – Ed. Bin Wang (2006), Springer Pub. 787 p

Sub Module 1.2 : Concepts in Satellite Meteorology (40 hours)

1. Principles of Meteorological Remote Sensing (25 hrs)

Interaction of EM radiation with matter (absorption, reflection, scattering etc)
Passive and active sensors : Principles of Observations
- Passive : Imaging radiometer/Sounder/MW radiometer
- Active : Scatterometer/Altimeter/Laser/SAR

Sensor technology: optical/infrared/water vapour and microwave
Charged Coupled Devices
Concept of resolution: spatial, temporal
Spectral signatures
Spectrometers
Radiation balance of the earth

2. Overview of Meteorological Satellites / Orbits. (15 hrs)

Orbital dynamics (Orbital elements, laws)
Types of Orbits (Polar, geostationary, tropical and equatorial satellites, coverage, advantages, applications)
Operational meteorological satellite (Sensors – imagers and sounders, instrumentation and applications, INSAT/GMS/Meteosat/GOES, DMSP, NOAA, etc)
Experimental Met/Ocean satellites (TRMM, Oceansat-1&2, Megha Tropiques, ERS etc)

Suggested Books :

1) Satellite Meteorology-An Introduction (1995) - S.Q. Kidder and T.H. Vonder Haar Academic Press, N York, 340 p.
2) Weather Satellites: Systems, Analysis and Environmental Applications (1990)- P.K.Rao, et al, American Met Society, Boston
3) Fundamentals of Remote Sensing – Joseph, George, 2005, Universities Press (India) Ltd.
4) Manual of Remote Sensing Vol.1, Ed. Colwell RN, 1983, American Society of Photogrammetry, Chapter 6, 10,11, 12,13 and 16
5) W M O Notes on Satellite Meteorology (1991): P Menzel, NOAA/CIMSS
6) Satellite Meteorology, R R Kelkar, 2007, B S Publications, Hyderabad – 95
7) Observation of the earth system from space, Eds. Jacob Flury., et al.—Berlin, Springer, 2006. 494 p.
8) Microwave Remote Sensing - Active and Passive, Vol.1, 2. Ulaby Fawaaz, Richard K Moore and Adrian K Fung, 1981, Addison – Wesley publishers.
9) Measuring the oceans from Space : The Principles and methods of Satellite Oceanography – Robinson, Ian Stuart, 2004, Springer.
10) Remote Sensing : Principles and Interpretation, Sabins F.F., 2nd Ed. Freeman and Company, Chapter 1.

Sub Module 1.3 : Image processing, Interpretation and GIS (40 hours)

1. Image Processing Techniques (8 hrs)

   Projection software
   Image registration/navigation, radiometric and geometric correction
   Atmospheric correction
   Image classification, clustering etc.

2. Image interpretation (5 hrs)

   Characteristics of satellite imagery (Brightness, texture, etc)
   Brightness temperature
   Gray Scale
   Calibration

3. Applications to Weather Forecsting (20 hrs)

   Synoptic and Meso-scale systems (cloud systems, vortices, thunderstorms, squall lines, Monsoon weather systems)
   Tropical cyclones (Monitoring, Dvorak's technique, motion analysis)
   Air masses, fronts, extra-tropical cyclones, Jet streams, Long waves
   Atmospheric pollutants (dust, haze, smoke, forest fires etc.)
   Ocean monitoring (Sea surface features, temperature gradients, eddies)

4. GIS (7 hrs)

   Basic concepts (Components of GIS, organizational aspects)
   Data management (Spatial data structure, raster Vs. Vector, non spatial data)
   Data manipulation (Coordinate transformation / manipulation, 2D, 3D data)
   Implementation of GIS
   Multi-layer map production
   Applications in Meteorology and Climatology

Suggested Books :

1) Introductory Digital Image Processing, Jensen JR, Prentice-Hall, NJ, 1986
2) Remote Sensing Digital Image Analysis : An Introduction , Springer Richards, JA and Jia Xiuping, Chapters 2,4,5 and 6
3) Manual of Remote Sensing, Vol. 1, Ed. Colwell RN, ASPRS, Chapter 24.
4) Remote Sensing for the Earth Sciences – Manual of Remote Sensing, Ed., Renz A N, 1999, Vol.3, ASPRS and John Wiley & Sons Inc. USA, 707 p
5) www.epa.state.oh.us/dsw/gis/learngis/home.html
6) The Use of Satellite Data in Rainfall Monitoring (1981): Barret E. C and D.W.Martin Academic Press, New York, 340 p
7) W M O Notes on Satellite Meteorology (1991): P Menzel, NOAA/CIMSS
8) Weather Satellites: Systems, Analysis and Environmental Applications (1990)- P.K.Rao, et al, American Met Society, Boston

9) Satellite Meteorology-An Introduction (1995) - S.Q. Kidder and T.H. Vonder Haar Academic Press, N York, 340 p.
10) Images in weather forecasting: A practical guide for interpreting satellite and radar imagery – Bader, M.J. ed:, 1995, Cambridge Univ. Press.
11) Satellite Meteorology, R R Kelkar, 2007, B S Publications, Hyderabad – 95
12) Fundamentals of Remote Sensing–Joseph, George, 2005, Universities Press (India) Ltd.

Afternoon sessions : (Operational Meteorological Satellite Data Handling and Applications) (Three Months)

Computer techniques : Different computational environments, Computer language (Fortran Programming)
Meteorological software (Visualisation tools), Graphic tools, Multimedia
Image Processing s/w familiarization,
Weather related World Wide Web sites

Laboratory exercises :

Geostationary & Polar orbiting satellite data – channels and characterisitcs
Cloud characteristics & feature extraction (INSAT/GMS/Meteosat/MTSAT -VHRR, NOAA-AVHRR), Rainfall estimation, Applications to Tropical & Extra-tropical weather systems, Tropical cyclone intensity, Eddies

Module 2 : Advanced Concepts and Techniques in Satellite Meteorology and Global Climate (Three Months) – 130 hours

Sub Module 2.1: Geophysical Parameter Retrieval (40 hrs)

1. Theory of Radiative Transfer (10 hrs)

   Radiative Transfer concepts, Absorption bands, Emission, Scattering, Extinction Coefficient, LT Equilibrium,

2. Techniques for Retrieval of Atmospheric parameters (20 hrs)

   Winds (Surface and upper air)
   Atmospheric vertical profiles (Temperature & Moisture)
   Statistical and Physical inversion methods, Weighting functions
   Precipitation (IR & MW methods, validation)
   Outgoing longwave radiation (OLR)
   Radiation budget
   Aerosol concentration and characteristics (Dust and Volcanic Ash outbreaks)
   Cloud information (Cloud clearance, cloud fraction, cloud properties)

3. Techniques for Retrieval of Land and ocean parameters (5 hrs)

   Sea-surface temperature, Land Surface Temperature, Vegetation Index, Snow cover

4. Advanced Elective Topics : (5 hrs)

Value added Land / Ocean / Atmosphere Parameters

(a) Land:
Evapotranspiration, Insolation, albedo, Soil moisture, LAI, Fluxes etc.
(b) Ocean:
Sea-surface salinity, Height (and Geostrophic circulation there from, eddies)
(c) Atmosphere:
Hyperspectral Sounding
GPS Radio Occultation Techniques
Lightning Detection

Suggested Books :

1) W M O Notes on Satellite Meteorology (1991): P Menzel, NOAA/CIMSS
2) Applications with Meteorological Satellites (2004) : P Menzel, NOAA/NESDIS
3) Satellite Meteorology-An Introduction (1995) - S.Q. Kidder and T.H. Vonder Haar Academic Press, N York, 340 p.
4) Satellite Oceanography: An Introduction for Oceanographers and Remote Sensing Scientists (1985): John Wiley, 455p.
5) Microwave Remote Sensing - Active and Passive, V.1, 2, 3. Ulaby Fawaaz, Richard K Moore and Adrian K Fung, 1981, Addison – Wesley publishers.
6) Satellite Remote Sensing of clouds and the atmosphere – III – Jaqueline E., Russell (Editor), 1998, Spie – U.S.A. Spain.
7) An Introduction to Ocean Remote Sensing. / by Martin, Seelye, Cambridge Univ. Press, 2004. 426 p.
8) Inverse methods for atmospheric sounding; theory and practice / Rodgers, Clive D., Singapore: World Scientific, 2000. 238 p. (Series on Atmospheric, Oceanic and Planetary Physics, Vol. 2).

Sub Module 2.2 : Applications of Satellite Data (40 hrs)

1. Application of Satellite - derived Parameters in Meteorology & Weather forecasting (25 hrs)

   Intra-seasonal and inter-annual variability, Madden Julian Oscillations
   Tropical/ extra-tropical systems
   Drought monitoring
   Rainfall variability
   Air-sea interaction (including El-Nino, La-Nina, ENSO, NAO, IOD, Storm Surge)
   Regional/local weather systems –
   Especially: Monsoon – Onset, Active/Break cycles, Monsoon depressions, Mid-tropospheric cyclone (MTC)
   Asian Monsoon and Tibetan Energy Budget
   Tropical Cyclones (Genesis, Intensity, Energetics, Track)
   Western Disturbances
   Severe Local Storms
   Floods (Rain – induced, ice melt)
   Fronts (Temp/Humidity)
   ITCZ, Mid -latitude cyclones, Long Waves
   (Case studies highlighting utilization of satellite data sets)

2. Numerical Models and Satellite Data Assimilation (15 hrs)

Simple models and zero-, one-, two- and three-dimensional models
Basic model structure**,** Scaling of Models (Mesoscale, Regional, Global)
Role of satellite data for parameterization
Ranges of Models (Short, Medium, Extended, Seasonal, Long, Climate)

Data Assimilation

Basics of data assimilation
Observing systems, Subjective and objective analysis
3-D and 4-D-Var Concepts
Adjoint Equations
Assimilation cycle
Assimilation of Satellite derived - Humidity, wind, temperature, Rainfall and Radiance
Impact Studies
Model output & Analysis

Suggested Books :

1) W M O Notes on Satellite Meteorology (1991): P Menzel, NOAA/CIMSS
2) Applications with Meteorological Satellites (2004) : P Menzel, NOAA/NESDIS
3) Satellite Meteorology-An Introduction (1995) - S.Q. Kidder and T.H. Vonder Haar, Academic Press, N York, 340 p.
4) The Asian Monsoon – Ed. Bin Wang (2006), Springer Pub. 787 p
5) Severe Convective Storms – Ed. Charles A Doswell, (2001) Ame. Met. Soc., 561 p

6) Microwave Remote Sensing - Active and Passive, V.1, 2, 3. Ulaby Fawaaz, Richard K Moore and Adrian K Fung, 1981, Addison – Wesley publishers.
7) Satellite Remote Sensing of clouds and the atmosphere – III – Jaqueline E., Russell (Editor), 1998, Spie – U.S.A. Spain.
8) Satellite Meteorology, R R Kelkar, 2007, B S Publications, Hyderabad – 95
9) Weather Satellites: Systems, Analysis and Environmental Applications (1990)- P.K.Rao, et al, American Met Society, Boston
10) Climate System Modelling (1992): K.E. Trenberth, Cambridge University Press
11) A Climate Modelling Primer (1987): Handerson Sellers A and K Mc Guffic, John Wiley, 217p.
12) Numerical prediction and dynamic meteorology. / by George J. Haltiner and Roger Terry Williams , 2nd ed.—N.Y.: John Wiley, 1980. 477 p.
13) Recent advances in atmospheric physics. / ed. by P.K. Das.—New Delhi: Indian National Science Academy, 1994. 438 p.
14) Radar Meteorology – S Raghavan. S, 2003, Kluwer Academic Publications.
15) Atmospheric and Oceanic Fluid Dynamics – Fundamentals and large scale circulation – Geoffrey k Vallis (2006), Cambridge Uni Press, 745 p
16) Atmospheric modeling – Chock David P. ed: Carmichaels, Gregory R J., 2002, Springer – Verlag.
17) Dynamic meteorology; data assimilation methods / ed. by Lennart Bengtsson, Michael Ghil and Erland Kallen Springer-Verlag, 1981. 330 p. (Applied Mathematical Sciences, V.36).
18) Frontiers of climate modeling. / ed. by J.T. Kiehl and V. Ramanathan : Cambridge Univ. Pr., 2006. 367 p.
19) Meso scale Atmospheric Circulations – B W Atkinson (1981), Academic Press, 495 p
20) Mid-latitude weather systems. / by Carlson, Toby N.-- Boston: Ame. Meteor. Soc. (AMS), 1998. 507 p .
21) Ocean-atmosphere interaction and climate modeling, Mikhail Hazin Cambridge Univ. Pr., 1995. 377 p.

Sub Module 2.3: Global Climate and Environment (50 hrs)

1. Short term Climate Variability (15 hrs)

   ENSO , IOD, NAO and their tele-connections
   Cloud climatology
   Land surface changes
   Ozone and other trace gases
   Atmospheric chemistry
   Radiation budget
   Satellite studies

2. Long term Climate Change (15 hrs)

   Climate change
   Green House Effect and Global warming
   Cryosphere studies (Polar, Mountains)
   Model studies
   Coupled models and future climate scenario

3. Climatology Programmes (based on satellite data) (10 hrs)

   Cloud climatology (International Satellite Cloud Climatology Project (ISCCP))
   Land surface climatology (International Satellite Land Surface Climatology Project (ISLSCP)
   Global Precipitation (Global Precipitation Climatology Project (GPCP))
   ERBE

4. Environmental Issues (5 hrs)

   Pollution of air and water
   Coastal zone environment
   Oceanic biological productivity

   Global climate change and policy implications
   Agenda 21: integrated sustainable development
   Kyoto Protocol to the United Nations Framework Convention on Climate Change

5. Disaster Management (5 hrs)

   Monitoring techniques
   Dissemination of information
   Satellite –based warning systems
   Post Disaster Management

Suggested Books :

1) Climate Change: Science, Impacts and Policy (1991): J.E. Harris, E. Harwood
2) Atmospheric Data Analysis (1991): R.Daley, Cambridge Univ Press
3) Earth watch : The climate from Space – Harries, Johne, 1990, Ellis Horwood, NY.
4) Climate changes 1992; the supplementary report to the IPCC Scientific assessment – Houghton, J.T. ed. Callender B.A, Varney, S.K. J, 1992, Cambridge, Univ. Press
5) Long-term climate monitoring by the Global climate of serving system – Thomas, R. Karl (Editor), 1996, Kluwer – Academic Publishers
6) El Nino Southern oscillation and climatic variability / by Rob Allan, Janette Lindesay and David Parker / CSIRO Publishing, 1996. 405 p
7) Global warming - myth or reality?; the erring ways of climatology. / by Leroux, Marcel-- Chichester: Springer, 2005. 509 p.
8) Satellites, Oceanography and Society – Ed David Halpern (2000) Elsevier, 367 p
9) El Nino, La Nina and the Southern Oscillation – S George Philander (1990), Academic Press, 293 p

Afternoon sessions: (Remote Sensing of Geophysical Parameters & Numerical Modelling Aplications)

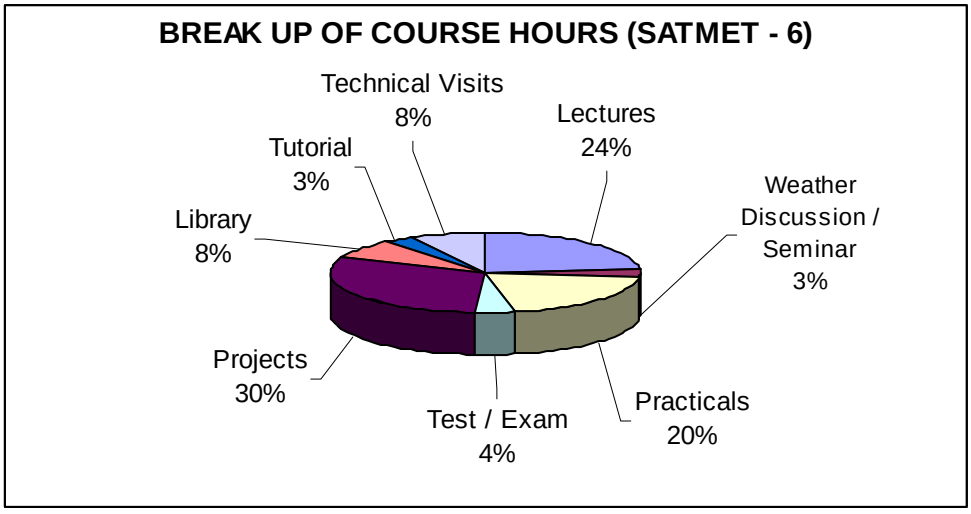
Temperature and Moisture Profile from INSAT – 3D, NOAA-ATOVS data and Validation, SST from MODIS/NOAA-AVHRR data and Ocean thermal features,

Assimilation of Satellite data (Scatterometer / Temperature profiles) in Meso scale models, Geophysical parameter retrievals from MW radiometer / Scatterometer data.
Cloud Motion Vectors using INSAT Triplet image data
Geostationary Multi-channel imager applications (METEOSAT / INSAT-3D)
(Radiation Budget)
Convective/subsidence zones., Dust storms.
Future : MT Applications :
Rainfall/Precipitation, Cloud Properties

Pilot Project (Three months): (Indicative only)

Broad Topics

Tropical Cyclone and Storm surge studies using TRMM data and Model
Ozone / CO studies using satellite data sets and validation
Meso scale studies using MM5 and WRF models (Heavy rainfall, cyclone studies)
MODIS data applications
TRMM-TMI data analysis and applications
SST Estimation and validation
Tropical cyclone track prediction
Temperature / Moisture profiles using AIRS data
Cloud motion vectors using advanced techniques and their validation
Water vapour winds
Land applications – Crop and pest disease / drought monitoring using RS data
Validation of merged rainfall products
Validation of Model outputs / products
INSAT-3D data applications (VHRR, Sounder)
Oceansat-2 (Scatterometer, Ocean colour monitor) applications



Summary:

The Centre for Space Science and Technology Education for Asia and the Pacific (CSSTEAP), set up in 1995 has so far organized five courses in Satellite Meteorology and Global Climate beginning 1998. 90 participants from 20 countries in Asia and the Pacific region have so far attended these courses. The Workshop conducted in 1995 at Granada, prepared broad guidelines for the curriculum development for the Satellite Meteorological Applications. Based on these guidelines, a detailed syllabus for both theory and practicals was prepared; considering the expertise / facilities available in the host Center, requirements of the participating organizations in the Asia Pacific region etc.

The curriculum development is a continuous process. It takes into account various technological developments, new emerging application scenario, feedback received from the outgoing candidates, from the faculty etc. The expert committee set up by Director, CSSTEAP has critically reviewed the existing curricula of the SATMET course and gave many suggestions for the improvement. The details of the modifications evolved have been provided and efforts have been made to improve the total syllabus, so as to realize the goals of the Centre.

The revised syllabus recommended by the Expert committee will be implemented during SATMET-6 (2008) course.

Table 1

SATMET - PG Course Country wise Output (as on December, 2007)

S. N.	*COUNTRY*	SATMET 1998	SATMET 2000-01	SATMET 2002-03	SATMET 2004-05	SATMET 2006-2007	Total
1	**Bangladesh**	2	1	2	**2**	**2**	**9**
2	**China**				**1**		**1**
3	**India**	2	3	3	**1**	**4**	**13**
4	**Indonesia**	1	2		**2**	**1**	**6**
5	**Iran**	1	1	1			**3**
6	**Kazakhstan**	1	2	2	**2**	**2**	**9**
7	**Korea DPR**		2	2			**4**
8	**Korea, Rep.**			1			**1**
9	**Kyrgyzstan**		1		**1**	**2**	**4**
10	**Maldives**				**1**		**1**
11	**Malaysia**			1			**1**
12	**Mongolia**	3	2	1	**3**	**1**	**10**
13	**Myanmar**					**1**	**1**
14	**Nepal**	2	2	1	**1**		**6**
15	**Philippines**	2	2	1	**1**		**6**
16	**Sri Lanka**	1	1	1			**3**
17	**Tajikistan**					**1**	**1**
18	**Thailand**			1		**2**	**3**
19	**Uzbekistan**	2	1			**1**	**4**
20	**Vietnam**		1	2		**1**	**4**
Total Participants		**17**	**21**	**19**	**15**	**18**	**90**
Total Countries		**10**	**13**	**13**	**10**	**11**	**20**

Annex I

Curriculum for the five courses

Modules

Table 2

First course (1998) at a glance

Module/ submodule	*Topic*	*Number of Lectures*
1	Fundamentals of meteorology, climatology and remote sensing	
1.1	Concepts in meteorology and climatology	
	Basic concepts of Meteorology	25
	Basic concepts of climatology	20
1.2	Concepts in satellite meteorology	
	Introduction to satellite meteorology	23
	Meteorological satellite orbits, instrumentation and data products	26
1.3	Applications of satellite imagery and digital image processing	
	Use of satellite imagery in meteorology and weather forecasting	15
	Statistics, digital image processing techniques and GIS	17
2	Advanced concepts in satellite meteorology, parameter retrieval and applications	
2.1	Radiative transfer and parameter retrieval	
	Concepts of radiative transfer	25
	Meteorological and oceanographic parameter retrieval	38
2.2	Applications using digital satellite data	
	Applications of digital satellite data in meteorology and weather forecasting	29
	Applications in oceanography	23
	Applications in climate studies	15
2.3	Environmental problems and numerical models	
	Environment issues and societal impacts	17
	Satellite data assimilation and modelling	28
3	Pilot projects (Three months)	

Figure I

Percentage of time spent on each activity during the first course

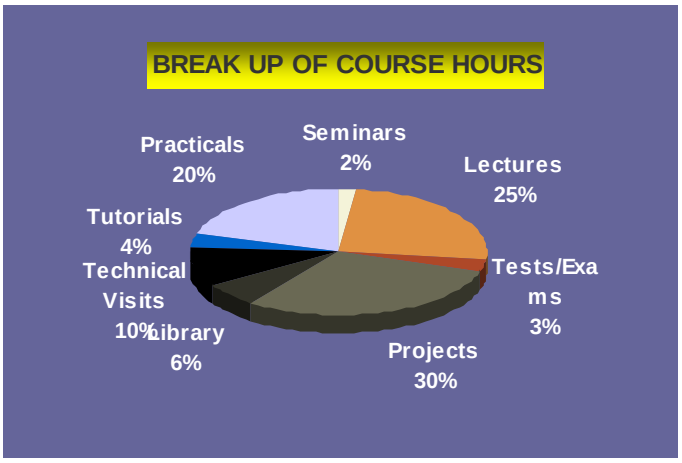


Table 3

Second course (2000) at a glance

Module/ submodule	*Topic*	*Number of Lectures*
1	Fundamentals of meteorology, climatology and remote sensing	
1.1	Concepts in meteorology and climatology	
	Basic concepts of Meteorology	20
	Basic concepts of climatology	10
1.2	Concepts in satellite meteorology	
	Mathematical and computational techniques for satellite meteorology	20
	Introduction to satellite meteorology	25
	Meteorological satellite orbits, instrumentation	20
1.3	Applications of satellite imagery and digital image processing	
	Use of satellite imagery in meteorology and weather forecasting	20
	Statistics, digital image processing techniques and GIS	15
2	Advanced concepts in satellite meteorology, parameter retrieval and applications (Three months)	
2.1	Radiative transfer and parameter retrieval	
	Concepts of radiative transfer	30
	Meteorological and oceanographic parameter retrieval	30
2.2	Applications using digital satellite data	
	Applications of digital satellite data in meteorology and weather forecasting	25
	Applications in oceanography	15
	Satellite data assimilation and numerical models	10
2.3	Applications in climate and environmental studies	
	Climate studies	15
	Environment issues and societal impacts	15
2.4	Advanced applications (electives)	
	Advanced meteorological and oceanographic parameter retrieval	20
	Advanced applications in climate studies	20
	Advanced satellite data assimilation and modeling	20
3	Pilot projects (Three months)	

Figure II

Percentage of time spent on each activity during the second course

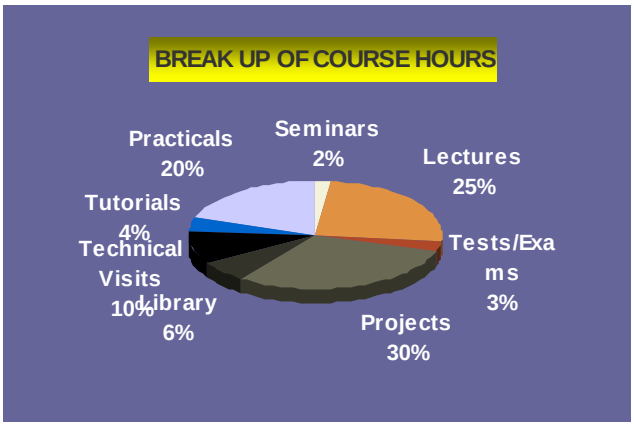


Table 4

Third (2002 / Fourth (2004) / Fifth (2006) course at a glance

Module/ submodule	*Topic*	*Number of Lectures*
1	Fundamentals of meteorology, climatology and remote sensing	
1.1- MET	Concepts in meteorology and climatology	
	Basic concepts of Meteorology, Climatology and Oceanography	30
1.2- MATH	Mathematical and computational techniques for satellite meteorology	20
1.2	Concepts in satellite meteorology	
1-2- SM	Radiative Transfer in Satellite Meteorology	25
1-2- MSI	Meteorological satellite orbits, instrumentation	15
1.3	Image Processing & Interpretation	
1.3-DIP	Image Processing Techniques and Geographic Information System (GIS)	15
1.3-WF	Image Interpretation in Meteorology and Weather Forecasting	30
2	Advanced concepts in satellite meteorology and Global Climate	
2.1-AP	Geophysical Parameter Retrieval	
	Atmospheric Parameters	15
2.1-LOP	Land and Oceanic Parameters	10
2.2	Applications of Satellite Derived Parameters	
2.2-AWF	Applications in Meteorology and Weather Forecasting	30
2.2-NM	Satellite Data Assimilation and Numerical Models	15
2.3	Global Climate and Environment	
2.3-SC	Short Term Climate Variability	25
2.3-LS	Long Term Climate Change	25
2.3-ESI	Environment issues and societal impacts	10
3	**Pilot projects (Three months)**	

Figure III

Percentage of time spent on each activity during the course

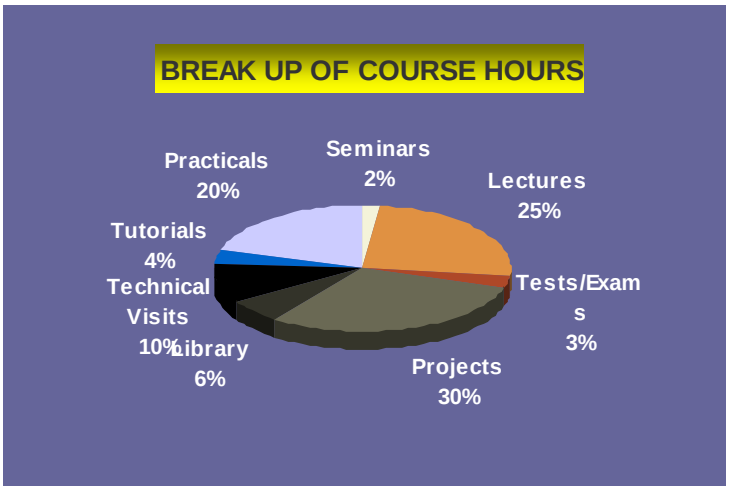


Table 5

LIST OF PRACTICALS FOR SATMET – 1998 COURSE

Module 1: Operational Meteorological Satellite Data Handling and Applications

1. Computer Facilities and Familiarisation
2. INSAT – VHRR Data Applications
3. NOAA – AVHRR Data Applications
4. GMS Data Handling
5. Cloud Motion Vectors from INSAT and its Applications
6. Applications of Satellite Data in Cyclone Intensity Estimation
7. Applications of Satellite Data in Cyclone Track Prediction
8. Multi Media Demonstration for METEOSAT/ GOES/ Cyclone data
9. Visualisation Packages

Module 2: Parameter Retrieval and Numerical Modelling

1. Estimation of Outgoing Long Wave radiation (OLR) using INSAT VHRR data / GMS data
2. Estimation daily and weekly rainfall using INSAT – VHRR data
3. Sea Surface Temperature estimation from NOAA – AVHRR data and application in oceanic circulation studies
4. Study of average layer humidity and temperature over different regions using NOAA TOVS finished product.
5. Estimation of temperature / moisture profiles using NOAA/TOVS data
6. Interpretation of General circulation model results
7. Study of model simulation results from CO_2 – doubling using General Circulation Models.
8. Snow cover estimation from NOAA – AVHRR Data
9. Normalised vegetation index from NOAA – AVHRR Data
10. Use of satellite meteorological data in GIS
11. Surface winds from Scatterometer Data
12. Sea level from altimeter data
13. Familiarisation with LOWTRAN Package

Table 6

LIST OF PRACTICALS FOR SATMET – 2000 COURSE

Module 1: Operational Meteorological Satellite Data Handling and Applications

1. Computer Facilities and Familiarisation
2. INSAT – VHRR Data Applications
3. NOAA – AVHRR Data Applications
4. Visualisation Techniques
5. INSAT – CCD Data Applications
6. Cloud Motion Vectors from INSAT and its Applications
7. Applications of Satellite Data in Cyclone Intensity Estimation
8. Applications of Satellite Data in Cyclone Track Prediction
9. Multi Media Demonstration for METEOSAT/ GOES/ Cyclone data & Visualisation Packages
10. Estimation of Outgoing Long Wave radiation (OLR) using INSAT VHRR data / GMS, Meteosat and Applications

Module 2: Parameter Retrieval and Numerical Modelling

1. Estimation daily and weekly rainfall using INSAT – VHRR data
2. Sea Surface Temperature estimation from NOAA – AVHRR data and application in oceanic circulation studies
3. Estimation of temperature / moisture profiles using NOAA/TOVS data
4. Interpretation of General circulation model results
5. Snow cover, Normalised Vegetation Index. Sea Ice, Forest fire From NOAA-AVHRR Data
6. GIS and satellite meteorological data
7. Surface winds from Scatterometer Data
8. Familiarisation with LOWTRAN package (Demo)
9. IRS–P4-MSMR Retrievals
10. Aerosol Applications

Table 7

LIST OF PRACTICALS FOR SATMET – 2002 and 2004 COURSE

Module 1: Operational Meteorological Satellite Data Handling and Applications

1. Computer Facilities and Familiarisation
2. INSAT – VHRR Data Applications
3. NOAA – AVHRR Data Applications
4. Visualisation Techniques
5. Cloud Motion Vectors from Geostationary Satellite and its Applications
6. Applications of Satellite Data in Cyclone Intensity Estimation
7. Applications of Satellite Data in Cyclone Track Prediction
8. Multi Media Demonstration for METEOSAT/ GOES/ Cyclone data & Visualisation Packages
9. Estimation of Outgoing Long Wave radiation (OLR) using VHRR data and Applications

Module 2: Parameter Retrieval and Numerical Modelling

1. Estimation daily and weekly rainfall using VHRR data
2. Sea Surface Temperature estimation from NOAA – AVHRR data and application in Oceanic circulation studies
3. Estimation of temperature and humidity profile using NOAA/TOVS data
4. Interpretation of General circulation model results
5. Snow cover, Normalised Vegetation Index. Sea Ice, Forest Fire from NOAA-AVHRR Data (demo)
6. Use of satellite meteorological data in GIS (demo)
7. Surface winds from Scatterometer Data (demo)
8. Familiarisation with LOWTRAN package (demo)
9. Geophysical Parameter Retrievals from Microwave Radiometers
10. Objective analysis of wind
11. Objective analysis of temperature

Table 8

LIST OF PRACTICALS FOR SATMET – 2006 COURSE

Module 1 : Operational Meteorological Satellite Data Handling & Applications

1 Computer & Internet Facilities and Familiarisation including Visualisation tools, MOSDAC, LINUX and FORTRAN
2 ERDAS Familiarisation
3 Geo location / Calibration / Registration of INSAT VHRR Data
4 INSAT-VHRR cloud characteristics - Feature extractions and Applications
5 NOAA-AVHRR Data Processing – Feature extractions and Applications
6 Estimation of Daily & weekly Rainfall using INSAT-VHRR data – Arkin's Technique
7 Cloud Motion Vectors using INSAT-VHRR data and computation of Divergence & Vorticity
8 Agromet Applications
9 Application of satellite data in Tropical cyclone intensity estimation – Dvorak Technique

Module 2 : Remote Sensing of Geophysical Parameters & Numerical Modelling Applications

1 Advance tools for Meteorological Satellite Data Analysis
2 Temperature and Moisture profile from NOAA-ATOVS data and validation
3 Geophysical Parameter Retrievals from MW Radiometer data
4 SST from MODIS/NOAA-AVHRR data and study of Ocean Thermal features
5 Temperature / Humidity Profile from GPS Occultation
6 Application of Scatterometer Vector Winds for study of Ocean surface features
7 Objective Analysis of Satellite derived Meteorological fields
8 Assimilation of Satellite Data (Scatterometer /Temperature Profiles) in Meso- scale Models
9 Demonstration Laboratory Exercises – Snow, NDVI, Forest Fire etc
10 Application of Satellite data in Meteorological Disaster Management

Table 9

SATMET-1 Pilot Project (March 1998- November 1998)

Sr. No.	Pilot Project Title
1	Vegetation and Soil Moisture Tendency Estimation Using Normalized difference Vegetation Index (NDVI) From NOAA/AVHRR Data over Mongolia.
2	Retrieval, Validation and Applications of Sea Surface Temperatures around Sri-Lanka Using NOAA-AVHRR and ERS-ATSR Data
3	Rainfall Estimation Using Cloud Indexing
4	Cloud Analysis Of Western Disturbances
5	Wildfire Danger Estimation, Detection And Monitoring Using NOAA-AVHRR, IRS And GIS Techniques
6	Normalized Differential Vegetation Index (NDVI) And Estimation Of Soil Moisture Over Bangladesh Using NOAA-AVHRR Data.
7	Retrieval, Validation And Application Of Atmospheric Temperature And Humidity Profiles From NOAA/TOVS Satellite Sounding Data Over Mongolia
8	Tropical Cyclone Track Prediction Using Cloud Top Temperature Analysis And Chaos Theory Approach
9	Onset Of Monsoon Over Nepal Using Satellite Data
10	Rainfall Estimation Over Bangladesh And Adjoining Bay Of Bengal By Arkin's Method
11	Temperature And Humidity Profile Over Uzbekistan Using NOAA/TOVS Sounding Data
12	Study Of Coastal Upwelling In Persian Gulf And Oman Sea
13	Rainfall Estimation Over Indonesian Region
14	Validation Of NWP Model Output With The Satellite Derived Products Vis-À-Vis Conventional Meteorological Observations
15	Rainfall Estimation Over A Cyclone Using Cloud Indexing Technique
16	Break And Active Monsoon Over Nepal
17	Ocean Circulation Modelling Using Satellite Data

Table 9 (Contd)

SATMET-II Pilot Project (July 2000- March 2001)

Sr. No.	Pilot Project Title
1	Movement of Tropical Cyclones near Philippines Using GMS Water Vapor Imagery
2	Tropical Cyclone Track Prediction By Using INSAT-VHRR Data
3	Satellite Cloud Top Temperature Method for Cyclone Track Prediction Over Vietnam.
4	Identification Of The Oceanic Features Using NOAA/AVHRR Data
5	A Study Of Sea Surface Temperatures And Sea Surface Winds Over The Indian Seas During Monsoon Using TRMM Microwave Imager And IRS-P4 MSMR
6	Humidity Profiles over the Arabian Sea and the Bay of Bengal Using MSMR Total Precipitable Water
7	Study of MSMR Brightness Temperature Data over India and Kazakhstan And Its Potential For Large Area Soil Moisture Estimation
8	Retrieval of Temperature and Humidity Profiles from NOAA/TOVS Satellite Data and Its Comparison with Radiosonde and NCEP Data
9	Humidity and Temperature Profile from NOAA/TOVS Package and the Comparison with NCEP and Meteosat Data
10	Climatology Of Mongolia Using NCEP/NCAR Data
11	Rainfall Estimation Over Indian Region Derived From DMSP-SSM/I And IRS P-4 MSMR
12	The Diurnal Cycle Of Rainfall During Asian Summer Monsoon Using TRMM Observations
13	Qualitative Rainfall Estimation Using VIRS And TMI Observations Using Artificial Neural Network (ANN) Approach
14	Study Of Western Disturbances Using Satellite Data
15	Verification Of Different Model Forecasts Over Kazakhstan With Analysis And Satellite Data
16	Verification Of Extended Range Model Outputs With Oceansat 1 Data
17	A Comparative Study Of Sea State Estimated By Satellite Data And Conventional Fleet Forecast Over Arabian Sea
18	SST Monitoring In El Nino Region From Satellite And Linkage With Rainfall Over Indonesia
19	Snow Cover Monitoring Over Western Himalayas
20	Vegetation Monitoring Using Multi-Temporal Coarse Resolution satellite (and weather) Data Over Korean Peninsula
21	Monitoring Of Crops In DPR Korea Using Muti-Date NOAA-AVHRR Satellite Data

Table 9 (Contd).

SATMET–III Pilot Project (August 2002- April 2003)

Sr. No.	Pilot Project Title
1	MODIS Atmospheric Data Validation and Application For Meso-Scale Processes Studies
2	Cloud Radiative Forcing Over the Indian Region During 1987 El Nino Event
3	Movement of Tropical Cyclone Using GMS Water Vapour And NCEP Data
4	Assimilation of Quickscat Data into A Mesoscale Modeling System
5	Intra And Inter Season Variation In Vegetation Index Over Mongolia
6	Use Of Vegetation Index And Thermal Channels For Assessing Soil Moisture Availability
7	Study Of Variations In Thermal Structure Of Indian Ocean Using A Limited Area Ocean Model
8	Analysis Of SSM/I Derived Meteorological Parameters For Southwest Monsoon Studies Over Sri Lanka
9	Climatic Variability Of Mountain Valley Glacier: A Case Study Of Parbati Glacier, Himachal Pradesh
10	Wave Modeling Over The South China Sea
11	Rainfall Features Of Bay Of Bengal Cyclones Observed By Satellite Data And Their Comparison With Surface Observations
12	Validation Of NOAA-AVHRR Pathfinder SST Over Malaysian Waters
13	Inter annual Variability Of Boundary Layer Heat Fluxes And Related Parameters Over Caspian Sea Using SSM/I And AVHRR
14	Study Of IRS-P4 MSMR Brightness Temperature Data Over Iran And Its Potential For Drought Monitoring Through Soil Moisture Estimation
15	Studying The Variability Of The 1990's El Nino Using Satellite derived Parameters
16	Temporal And Spatial Variation Of Aerosol Optical Depth Over Indian Ocean Using Satellite Data
17	Rainfall From TRMM-Radar And Radiometer
18	Exploration Of Linkage Between The Kazakhstan Climate And The Polar Sea Ice
19	Re-Estimation Of Surface Winds In The Neighborhood Of Cyclones In The Bay Of Bengal Using TOPEX/Poseidon Altimeter Data

Table 9 (Contd).

SATMET–IV Pilot Project (August 2004 – April 2005)

Sr. No.	Pilot Project Title
1	Validation Of TRMM-Meteosat Merged Daily Rainfall Over Bangladesh
2	Storm Surge Prediction And Inundation Along Bangladesh Coast Using Satellite Data And Model
3	Analysis Of The Impact Of Ground Surface Reflectance On The Aerosol Optical Depth Using Terra And Aqua MODIS And Ground-Truth Data Over Ahmedabad
4	Determination Of The Height Of Atmospheric Motion Vector Winds Using Geostationary Satellite Images
5	Detection And Dynamical Modeling Of Forest Fire Spread
6	Rainfall Climatology Over Indonesia Using TRMM Data
7	Analysis And Verification Of T-80 Model Temperature Forecast And NCEP Data Over Kazakhstan Region With MODIS And In Situ Data
8	Temperature And Moisture Profiles With Radiosonde And NCEP Analysis Over Kazakhstan
9	Estimation of Global Insolation at Surface Using Meteosat I.0. Coverage
10	Climatology Of Sea Surface Temperature, Surface Winds, Significant Wave Height And Sea Surface Height Anomaly (SSHA) Using Satellite And Island-Station Data Over And Around Maldives Islands
11	Verification of Extended Range Forecast over Mongolia
12	Drought Assessment Using Remote Sensing and Meteorological Data
13	Large Area Characterization of Dust Aerosols From Satellite Remote Sensing Data
14	Oceanic Thermal Response to Tropical Cyclones around The Philippines Using Satellite Data
15	Impact of MODIS Data in Meso-Scale Model (MM5) To Predict Rainfall over Nepal

Table 9 (Contd).

SATMET–V Pilot Project (August 2006 – April 2007)

Sr. No.	Pilot Project Title
1	Study of heavy Rainfall cases over Tajikistan using TRMM-Data.
2	Rainfall studies using SSM/I Data over Kyrgyzstan.
3	Validation of TRMM – Rainfall Variability with ground based Rainfall observation over Bangladesh.
4	Retrieval of temperature / humidity profile using NOAA-ATOVS data and their Validation.
5	Retrieval of Temperature and Humidity Profile using AIRS Data
6	Changes in columnar ozone over Uzbekistan
7	Varibility in surface ozone of two high altitude stations in Kyrgyzstan.
8	Detecting mustard rot disease using EO-1 Hyperion Hyper spectral Data
9	Crop Monitoring using Remote Sensing Data.
10	Study of carbon monoxide – ozone relationship over Kazakhstan.
11	Mesoscale system study over Thailand
12	The Impact of Satellite data on the initialization and prediction of weather systems over Indian region.
13	Simulation of very heavy rainfall events over Ahmedabad during August 2006 using WRF Model.
14	Study of Tropical Cyclone using WRF Model
15	Storm surge studies over Thailand
16	Analysis of oceanic parameters (With special emphasis on mixed layer depth) in the tropical Indian Ocean: Model – Data Comparison.
17	Impact of MODIS Data on heavy rainfall simulation over Vietnam using MM5
18	Development of empirical Track prediction for land-falling Tropical cyclones over Bangladesh and east Indian coastline.

Evolution of SATMET Course Curriculum

Table 10

SATMET – 1 (1998)			SATMET – 6 (2008)		
Module/ submodule	***Topic***	***No. of Lectures***	***Module/ submodule***	***Topic***	***No. of Lectures***
1	**Fundamentals of Meteorology, Climatology and Remote Sensing**		**1.**	**Fundamentals of Satellite Meteorology, Global Climate and Relevant Techniques (Three Months)**	
1.1	Concepts in Meteorology and Climatology		1.1	Concepts in Meteorology and Climatology	
	Basic concepts of Meteorology	25	1-1 MET	Basic concepts of Meteorology, Climatology and Oceanography	35
	Basic concepts of Climatology	20	1-1 MATH	Mathematical and Statistical, Computational Techniques for Satellite Meteorology	15
1.2	Concepts in satellite Meteorology		1.2	Concepts in Satellite Meteorology	
	Introduction to Satellite Meteorology	23	1-2-SM	Principles of Meteorological Remote Sensing	25
	Meteorological satellite orbits, instrumentation and data products	26	1-2-MSI	Overview of Meteorological Satellites / Orbits	15
1.3	Applications of satellite imagery and digital image processing		1.3	Image Processing , Interpretation and GIS	
	Use of satellite imagery in meteorology and weather forecasting	15	1-3-DIP	Image Processing Techniques and Geographic Information System (GIS)	15
	Statistics, digital image processing techniques and GIS	17	1-3-WF	Image Interpretation in Meteorology and Weather Forecasting	25
		Total : 126 hrs			**Total : 130 hrs**
2.	**Advanced concepts in Satellite Meteorology, Parameter Retrieval and Applications**		**2.**	**Advanced Concepts and Techniques in Satellite Meteorology and Global Climate (Three Months)**	
2.1	Radiative transfer and parameter retrieval		2.1	Geophysical Parameter Retrieval	
	Concepts of radiative transfer	25	2-1 AP	R T Theory, Atmospheric Parameters	30
	Meteorological and oceanographic parameter retrieval	38	2-1 LOP	Land and Oceanic Parameters	10
2.2	Applications using digital satellite data		2.2	Applications of Satellite Derived Parameters	
	Applications of digital satellite data in meteorology and weather forecasting	29	2-2-AWF	Applications in Meteorology and Weather Forecasting	25
	Applications in oceanography	23	2-2-NM	Satellite Data Assimilation in Numerical Models	15
	Applications in climate studies	15	2.3	Global Climate and Environment	
2.3	Environmental problems and numerical models		2-3-SC	Short Term Climate Variability	20
	Environment issues and societal impacts	17	2-3-LC	Long Term Climate Change	20
	Satellite data assimilation and modelling	28	2-3-ESI	Environment Issues and Societal Impacts	10
		Total : 175 hrs			**Total : 130 hrs**
3.	**Pilot projects (Three months)**		**3.**	**Pilot Projects (Three Months)**	
		Total : 301 hrs			**Total* : 260 hrs**

* excluding Seminars, Lead Paper Presentations of Pilot Projects and Guest Faculty lectures.

ANNEX. II

No.CSSTEAP/Revision/SATMET/07 Dated July 25, 2007

Sub: Revision of course curriculum of Satellite Meteorology and Global Climate under CSSTEAP 9 month PG Diploma Course

Sir,

At the initiative of the UN office of Outer Space Affairs (UN-OOSA), regional centres are established for space science and technology education in the developing countries. The Centre for Asia and the Pacific region is established in India - Centre for Space Science & Technology Education in Asia and the Pacific (CSSTEAP) in 1995. The principal goal of the Centre is the development of the skills and knowledge of university educators, and research and application scientists, through rigorous theory, research, applications, field exercises and pilot projects in those aspects of space science and technology that can contribute to sustainable development of each country. Towards this, the Centre primarily organizes post graduate level courses of 9-month duration in Remote Sensing and Geographic Information System, Satellite Communications, Satellite Meteorology and Global Climate and Space and Atmospheric Science. The successful candidates are awarded post graduate diploma. Those who further, carry out 12 month research are awarded M.Tech. degree by Andhra University, India.

The Satellite Meteorology and Global Climate course is organized every alternate year at the space Applications Centre (SAC), Ahmedabad. So far 5 courses have been conducted at SAC since 1998 benefiting more than eighty students in the Asia-Pacific region. The emphasis of the educational programme of the Centre is to concentrate on in-depth education, research and applications programmes, linkages to the global programmes/databases, execution of pilot projects etc. The practicals involving use of meteorological satellite data sets (Geostationary and polar orbiting) for geophysical parameter retrievals and applications in weather and climate is a special feature of the course.

The curriculum of the course has been developed by a panel of international experts convened by the UN. Since the students come from different academic standards, a "Board of Studies" (BOS) has been constituted by CSSTEAP Director to review the academic programme, including the course content and relative time

allotted for each topic. The BOS meets once in a year towards the end of each course. While the overall course curriculum remains as established by UN, fine tuning of sub topic contents have been carried out based on the recommendations of the BOS. Based on this, the current syllabus being followed with details of number of lectures in each module is attached.

Curriculum development is a continuous process that should take into account, among other things, various technological developments, new emerging application scenario and feedback received from the faculty and students. The following specialized committee is hereby constituted to review the current syllabus and make recommendation on changes needed, based on the advancements in the field :

1. Dr. P S Desai, Ex Chief Scientist (RS), SAC - Chairman
2. Dr. R R Kelkar, ISRO Chair, Pune University - Member
3. Prof. P V Joseph, CUSAT, Cochin - Member
4. Dr. R C Bhatia, DGM, IMD, New Delhi - Member
5. Prof. D V Bhaskar Rao, Andhra University - Member
6. Dr. P C Joshi, Head, ASD/MOG, SAC - Member
7. Mr. B M Rao, Course Director, SATMET-5 - Member Secretary

Among other things, the Committee shall look into the following aspects

i) Review the syllabus followed till now
ii) Suggest changes/modification in the existing curricula, based on the latest advances in the field. Detailed sub topics under each module to be identified.
iii) Suggest time allotment for each topic
iv) Suggest mark allotment for each module
v) Review the existing practicals and recommend addition/deletion as deemed necessary.
vi) Suggest text books to be followed. Internet links also may be suggested for self study.
vii) Any other suggestions that make the course more effective to enhance the knowledge and skills of the students.

The recommendations of the Satellite Meteorology & Global Climate Syllabus Committee will be submitted to Director, CSSTEAP by 30th October 2007.

I request you to spare your valuable time and actively participate in the deliberations. With your vast experience in the field, I am sure CSSTEAP will get the best advice.

Non DOS/ISRO members shall be paid TA/DA/Honorarium as per existing rules.

With kind regards,

Yours sincerely,

(George Joseph)

To

All the members of the Committee

Copy to: Director, SAC
Associate Director, SAC
Dy. Director, RESA
Group Director, MOG
Copy for Information: Chairman, CSSTEAP, GB