भारतीय उष्णदेशीय मौसम विज्ञान संस्थान

INDIAN INSTITUTE OF TROPICAL METEOROLOGY

IITM

Annual Report
2013 - 14

Meetings

Research Advisory Committee
15 & 16 January 2014

Finance Committee
21 August 2013 & 16 January 2014

Governing Council
22 August 2013 & 17 January 2014

Annual Report
2013-14

Indian Institute of Tropical Meteorology

(An Autonomous Institute of the Ministry of Earth Sciences, Govt. of India)

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(attended 87th meeting)

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(attended 87th meeting)

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Scientist 'E'
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Director
Indian Institute of Tropical Meteorology
Pune – 411 008
(Member Secretary)

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Joint Manager
LACD-Manager
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Ministry of Earth Sciences
Prithvi Bhavan
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Prof. B.N. Goswami
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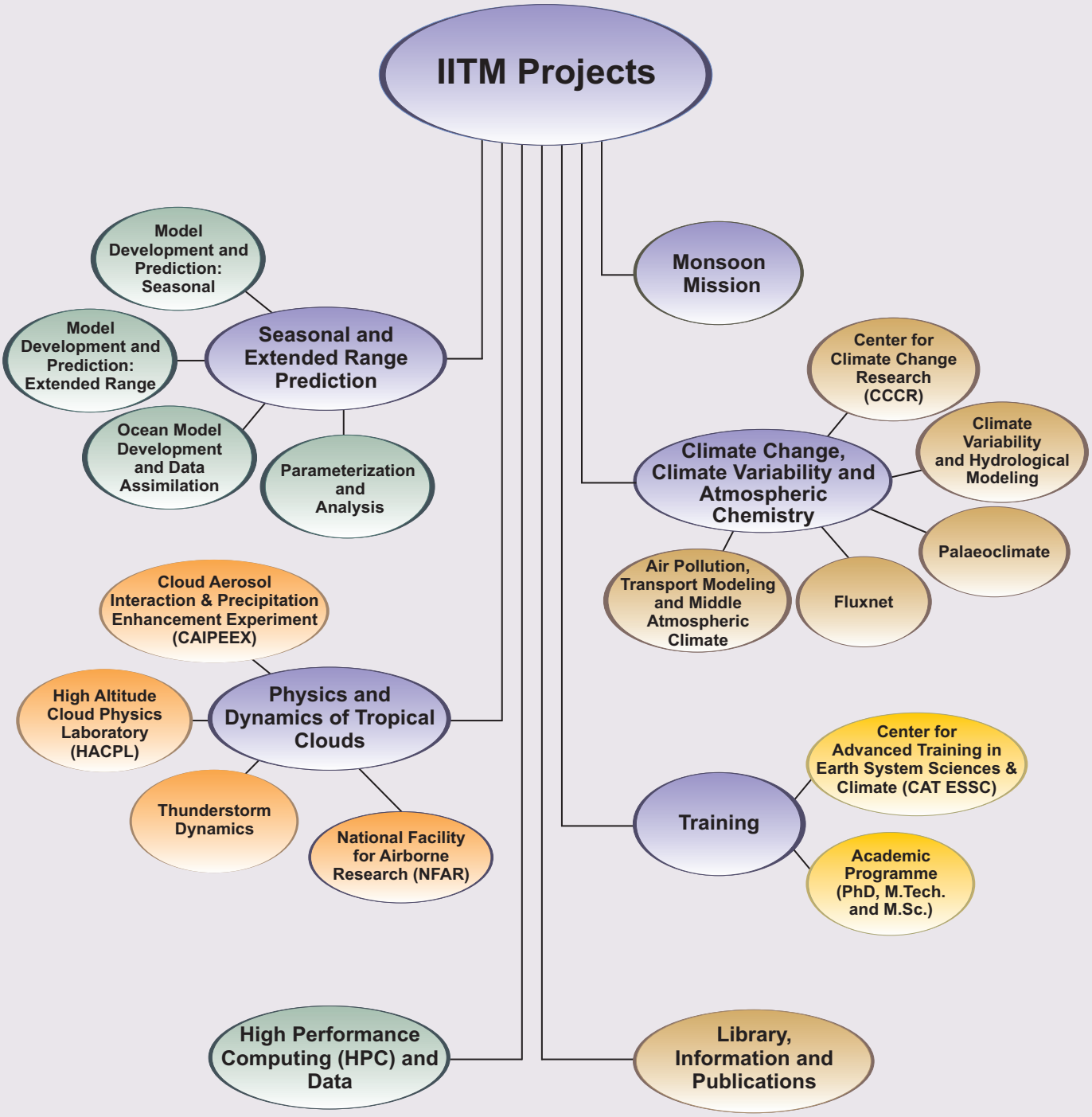


Organizational Flow Chart of R&D Activities

Contents

Overview of R&D Activities

Seasonal and Extended Range Prediction

- Model Development and prediction: Seasonal
- Model Development and prediction: Extended Range
- Ocean Model Development and Data Assimilation
- Parameterization and Analysis

Monsoon Mission

Climate Change, Climate Variability and Atmospheric Chemistry

- Centre for Climate Change Research (CCCR)
- Climate Variability and Hydrological Modeling
- Air Pollution, Transport Modeling and Middle Atmospheric Climate
- Palaeoclimate
- Fluxnet

Physics and Dynamics of Tropical Clouds

- Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX)
- High Altitude Cloud Physics Laboratory (HACPL)
- Thunderstorm Dynamics
- National Facility for Airborne Research (NFAR)

Training

- Centre for Advanced Training in Earth System Sciences and Climate (CAT ESSC)
- Academic Programme (PhD, M.Tech. and M.Sc.)

Other Activities

Important Events and Activities
Awards and Honours
Publications
Visitors
Seminars
Deputations Abroad
Staff
Audited Statement of Accounts

Foreword

It is my great pleasure to present the annual progress of the Indian Institute of Tropical Meteorology (IITM), Pune in all its mission mode programmes and activities during the financial year 2013-14. The Institute has consistently grown up to an international stature through its continuous efforts for achieving the vision of making IITM a World Centre of Excellence in Climate Science. The Institute has achieved new milestones in understanding the coupled land-atmosphere-ocean climate system and in developing monsoon prediction systems with improved skills.

I am also pleased with the growth achieved during the year in all the leadership initiatives of IITM. The report presents glimpses of the major research results, activities and achievements of the Institute during the year.

Keeping the high and ever growing computational needs in mind, IITM has achieved yet another milestone by acquiring a new high performance computing (HPC) system named as 'AADITYA' with a computing capability of 790 Tera Flops in addition to the existing PRITHVI HPC with a computing capability of 72 Tera Flops. Therefore, the AADITYA has empowered the IITM research community by increasing the computing power more than ten times. This increased computing power will help in running complex climate models at relatively faster speed and do more R&D experiments with the models in a reasonable time frame thereby helping to accelerate the process of improving weather and climate forecasts over India.

With an objective of prevention of lightning related disasters, the Institute has also taken the initiative to study the characteristics of lightning. I am pleased that IITM has established a Lightning Location Network (LLN) at its premises in this regard. The LLN enables the researchers to accurately detect the location of occurrence of lightning and forewarn the public at least 1-2 hours before the occurrence of thunderstorm.

Keeping pace with the quality and quantity of research papers published in reputed peer-reviewed journals, it is my pleasure to report that this year too, we published a record number of 153 papers in peer-reviewed journals with a Cumulative Impact Factor of 364.796 and the Average Impact Factor of 2.384.

The Institute has carried out various focused scientific studies during the year. The experimental forecast for the 2013 monsoon based on CFSv2 dynamical seasonal prediction system was correct and was matching well with the observed value. Also, the accuracy of spatial distribution of predicted rainfall was good. IITM's real-time experimental extended range forecasts issued using CFSv2 and GFSv2 were provided to IMD and were also made public on the Institute's website for scientific use. These were generally correct and were useful to different stake holders resulting in appreciation for the same. The rapid advancement of the monsoon and Uttarakhand heavy rainfall events were also well predicted by the system. Efforts made for an experimental super-parameterization in CFS have yielded relatively good results.

Scientists at the Centre for Climate Change Research (CCCR) are continuously working towards the development of the Indian Earth System Model. In this direction, they have noted in the 100-year run that the model successfully captures the observed ENSO-Monsoon lead-lag cycle and simulates the observed pacific decadal oscillation structure and its variability.

More publications in peer reviewed journals are coming out of the analysis of the data obtained from the Cloud-Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX). Preparations for the CAIPEEX Phase-III experiments and the related ground observations campaign over the Ganga basin during the 2014 monsoon are underway. The path breaking initiative 'Monsoon Mission' is attracting research proposals from eminent persons from prestigious R&D institutions of national and international repute for contributing in the development of an enhanced Indian Dynamical Prediction System within the next few years.

Several high end instruments/equipments were acquired during the year to strengthen the Institute's infrastructure. I would specially like to mention the newly acquired Ka-band Scanning Polarimetric Radar (KASPR) which was used along with the existing X-band radar during the 2013 Monsoon observational campaign at Mandhardev in Maharashtra.

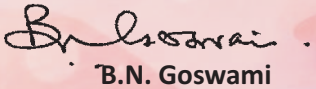
Academic and research support is continued to the M.Tech. and PhD programmes in Atmospheric Science of the University of Pune under the Institute's manpower development activities. In addition to this, IITM has joined hands with the University of Pune to run a new collaborative academic programme of M.Sc. (Atmospheric Science) Partly by Paper and Partly by Research (PPPR). The programme started successfully with the first batch of 10 students in August 2013 through the Department of Atmospheric and Space Sciences of the University. We are committed to the tradition of sharing and exchanging knowledge and expertise with the centres of excellence around the world and collaborating with the global community. Institute's human resources are strengthened by recruiting young scientists and other professionals at different levels. The Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC) under the auspices of MoES is running smoothly at IITM. The second batch has successfully completed the training and has been absorbed at Scientist-B/C level at IITM and NCAOR under the Ministry. The induction training of the third batch is being run successfully.

IITM received several opportunities to organize and host trainings, meetings, seminars, conferences and workshops. A few such events to mention were international workshop on 'Changing Chemistry in Changing Climate: Monsoon (C4)' and the Ocean Society of India's 3rd National Conference (OSICON). During the C4 workshop, SAFAR-Pune with all its facilities was inaugurated to offer its services about air quality and weather information. I am proud that many IITM scientists have received different awards, honours, memberships and fellowships in recognition of their outstanding performance in research.

Over the last few years, IITM has constantly grown and has shown its relevance and presence in the global arena. Such growth would have been hard to achieve without the resourcefulness, commitment, constructive cooperation, devotion to work and innovative thinking of my colleagues at IITM. I appreciate their concerted and collective efforts in this direction.

I take this opportunity to express my sincere gratitude to the Ministry of Earth Sciences for advisory and funding support, and the Governing Council, the Finance Committee and the Research Advisory Committee for their support and guidance. I also thank the Ministry of Science & Technology, the Ministry of Environment & Forests and the ISRO for their continuing support and for sponsoring some important scientific projects. IITM owes a lot to organizations such as IMD, NCMRWF, NCAOR, INCOIS, IISc, IITs and universities for their continued and strong collaboration and cooperation.

This is going to be my parting foreword for the Annual Report of IITM. So taking this opportunity, I reiterate my wish that IITM will ever continue to take up leadership initiatives to transform itself as a World Centre of Excellence in Atmospheric and Oceanic Sciences and to deliver high standard research useful to the nation and the world. May IITM ever continue growing and serving the nation and the world at large.

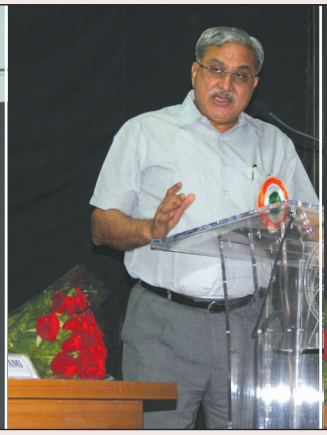


B.N. Goswami
Director

International Workshop on
'Changing Chemistry in Changing Climate: Monsoon (C4)

Dignitaries on Dias (L-R) Dr. Manish Naja, Dr. G. Beig, Dr. Shailesh Nayak, Dr. Liisa Jalkanen, Prof. John Burrows and Prof. B.N. Goswami

Welcome Address by
Prof. B.N. Goswami



Inaugural Address by
Dr. Shailesh Nayak

Address by
Dr. Liisa Jalkanen

Address by
Prof. John Burrows

Inauguration of High Tech Safar Air Quality and Weather Monitory Station and
AWADHI Facility: Master Control Room by Dr. Shailesh Nayak

Inauguration of digital LED display board
of SAFAR-Pune at IITM

National Conference of Ocean Society of India - 2013 (OSICON - 2013)

Dignitaries on Dias (L-R) Dr. C. Gnanaseelan, Shri V. Chander, Dr. Shailesh Naik, Prof. B.N. Goswami, Prof. P.V. Joseph and Dr. C. Revichandran

Welcome Address by
Prof. B.N. Goswami

Address by
Prof. P.V. Joseph

Inaugural Address by
Dr. Shailesh Naik

Inauguration of Pune Chapter of OSI by
Shri V. Chander

Releasing of Proceeding by
Dr. Shailesh Naik

Vote of Thanks by
Dr. C. Revichandran

52nd Foundation Day Celebrations

Dignitaries on Dias (L-R) Prof. B.N. Goswami, Prof. K.N. Ganesh, Prof. Wojciech Grabowski and Dr. A. Suryachandra Rao

Welcome Address by Prof. B.N. Goswami

Lamp Lightening

Address by Prof. K. N. Ganesh

Presentation of IITM Annual 25th Silver Jubilee Award to (R-L) Dr. H.S. Chaudhari, Dr. S.K. Saha, Shri A.R. Dhakate, Dr. R.K. Yadav, Shri K.D. Salunke, Shri S. Mahapatra and Dr. A. Suryachandra Rao

Presentation of IITM Excellent Performance Award (R-L) Shri R.T. Waghmare, Shri Y.J. Pawar, Shri R.A. Paradkar and Shri G.E. Dhongade

Presentation of Best Student Paper Award to (R-L) Shri C.T. Sabeerali and Dr. A. Suryachandra Rao

Foundation Day Lecture by Prof. Wojciech Grabowski

25th Silver Jubilee Award Lecture by Dr. Samir Pokhrel

Best Student Paper Award Lecture by Shri C.T. Sabeerali

Cultural activities on the occasion of 52nd Foundation Day Celebrations

Inaugurations


Inauguration of CCCR Building by Dr. Shailesh Nayak


Inauguration of HPC 'AADITYA' Building by Dr. Shailesh Nayak


Inauguration of HPC 'AADITYA' by Dr. Shailesh Nayak and Prof. B.N. Goswami


Inauguration of Lightning Location Network by Dr. Shailesh Nayak

Visitors

Dr. Sandip Dhomse, UK

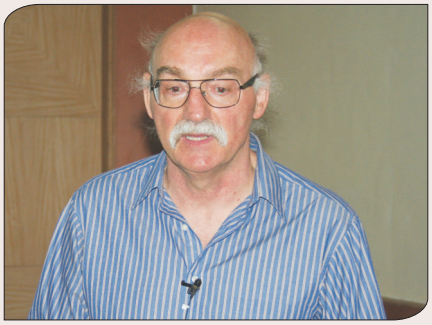
Dr. Radhakrishna Basivi, Canada

Prof. T. Yamagata, Japan

Dr. S.Y. Wang, USA

Prof. John Michael Wallace, USA

Dr. V. Chandrashekhar, USA



Prof. Andrew Mazda, USA

Prof. Sir Brian Hoskins, UK

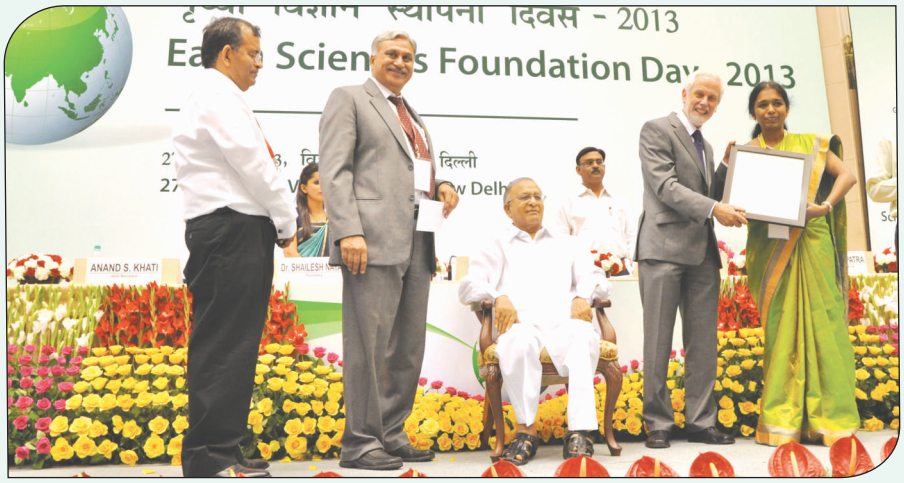
Prof. S. Harshavardhan, USA

Dr. Amala Mahadevan, USA

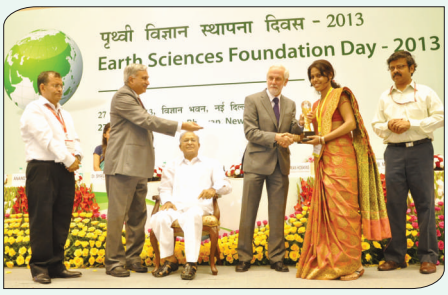
Prof. Wojciech Grabowski, USA

Dr. Robert Gillies, USA

MoES Awards



Dr. (Smt.) Thara Prabhakaran receiving 'Certificate of Merit 2013' of Ministry of Earth Sciences, Govt. of India



Shri P.W. Dixit, Kum. A.P. Bhujbal and Shri S.V. Raut receiving 'Best Employees Award 2013' of Ministry of Earth Sciences, Govt. of India for Group B, C and Multi Tasking Staff Category respectively

Hindi Week Celebrations

Dignitaries on Dias on the Inaugural Function of Hindi Week Celebrations

Address by Dr. Ramshankar Vyas

Welcome Address by Dr. G. Beig

Dignitaries on Dias on the Concluding Function of Hindi Week Celebrations

Inaugural Speech by *Padmashree* Dr. G.C. Mishra

Project

Seasonal and Extended Range Prediction

Chief Project Scientists: **Dr. A. Suryachandra Rao** and **Dr. A.K. Sahai**

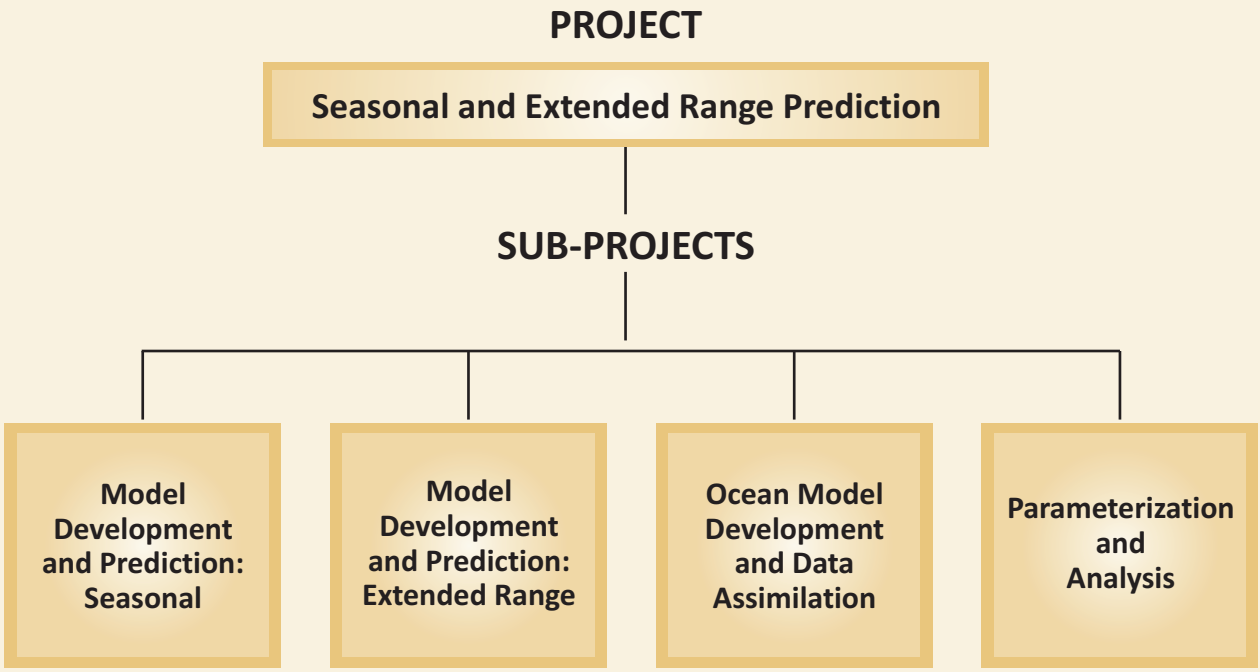
The Indian summer monsoon rainfall (ISMR) is the lifeline of the Indian agriculture-based economy. Anomalies and extreme events in monsoon cost us dearly in terms of agriculture, water management, life and property. So, here, seasonal and extended-range prediction of ISMR is very important for India, especially for planning strategies for management of agricultural production and water resources, and disaster (like flood, drought, etc.) management. The seasonal prediction of the monsoon by dynamical models is based on the fact that the slowly varying boundary conditions like sea surface temperature (SST), soil moisture, snow cover, etc. exert significant influence on atmospheric development on seasonal time-scales in the tropics. Although the seasonal mean monsoon seems to be potentially predictable, atmospheric GCM simulations have not shown enough skill in capturing the inter-annual variations in the monsoon rainfall. Indian Summer Monsoon has limited potential predictability. Even when the seasonal mean of rainfall is close to normal, the spatio-temporal distribution of rainfall is very inhomogeneous. Therefore, the prediction of intra-seasonal variability of monsoon over spatio-temporal scale requires special attention. Even 2-3 weeks in advance, extended-range prediction of active and break spells in monsoon can be very useful in sowing, harvesting, water resources management, etc.

For determining the potential predictability of monsoon, a fully coupled ocean-atmosphere-land modeling system for dynamical prediction of seasonal mean as well as active/break spells of ISMR is required to be developed and improvised. Once fully functional, the same will be transferred to the India Meteorological Department (IMD). Development of such a model, based on CFS coupled model, is also a part of the Monsoon Mission.

The development and improvisation of the model will require certain modifications like better physical parameterizations and better representation of air-sea interaction processes, higher resolution, etc. that can enhance model skill of simulating ISMR.

For successful and speedy execution, Seasonal and Extended Range Prediction project is divided into four sub-projects: 1) Model Development and Prediction: Seasonal, 2) Model Development and Prediction: Extended Range, 3) Ocean Model Development and Data Assimilation, and 4) Parameterization and Analysis.

The main objectives of this project include: development of an Indian model based on CFS coupled model, experimental assimilation of ocean and atmospheric data, to better understand monsoon coupled ocean-land-atmosphere interactions using observational datasets and diagnostics of coupled ocean-atmosphere model, improving the parameterization schemes of the model for better prediction skill for both summer (SW) and winter (NE) monsoon over the Indian region, developing Multi-Model Ensemble (MME) system for monsoon prediction, developing new empirical techniques and improving the existing empirical models for improving the prediction skills of active and break phases of monsoon, incorporating the cloud super parameterization concept in model, to carry out basic research to understand complex atmospheric/oceanic processes, model parameterization schemes to improve the forecast skills using global and regional dynamical models, disseminating forecast in real time using both empirical and dynamical models, etc.


PROJECT
Seasonal and Extended Range Prediction
SUB-PROJECTS
Model Development and Prediction: Seasonal
Model Development and Prediction: Extended Range
Ocean Model Development and Data Assimilation
Parameterization and Analysis

Model Development and Prediction: Seasonal

Chief Project Scientist: **Dr. A. Suryachandra Rao**, Scientist-F

Objectives

- To develop a fully coupled ocean-atmosphere-land modeling system for dynamical prediction of the seasonal mean monsoon rainfall.
- To study the monsoon variability over different spatio-temporal scales.
- To study Indian Ocean dynamics and variability.

Developmental Activities

Seasonal prediction and seasonal hindcast experiments using fully coupled General Circulation Model

The resolution of the CFSv2 model has been increased from original T126 spectral resolution (equivalent to about 110 km resolution) to T382 spectral resolution (equivalent to about 38 km resolution). Retrospective forecast (hindcast) experiments were carried out using the coupled model CFSv2 with this higher spectral resolution of T382. Ensemble runs of these forecast experiments have also been carried out. CFSv2 forecast runs were performed using initial conditions of February (36 members ensemble), March (20 members ensemble), April (24 members ensemble), May (28 members ensemble) and June (24 members ensemble). CFSv2 T382 hindcast runs using June initial conditions with 00 UTC data were performed and the same with 12 UTC data are underway.

The latest high resolution research version of the coupled model (CFSv2) is used to generate the experimental forecast for the 2014 SW Monsoon season rainfall (over the Indian region) using the February initial conditions with 56 ensembles.

Dynamical seasonal prediction for 2013 Summer Monsoon rainfall using CFSv2

CFSv2 was used to generate the experimental dynamical seasonal forecast for the 2013 SW Monsoon season rainfall (over the Indian region) using the April initial conditions. The forecast was provided to IMD.

The experimental dynamical forecast (using Monsoon Mission experimental CFSv2) issued on 14 June 2013 is given below:

"The experimental forecast based on the monsoon mission dynamical prediction system using the April initial conditions indicates that the rainfall during the 2013 monsoon season (June to September) averaged over the country as a whole is likely to be **108% ± 4%** of long period model average (LPMA)". This prediction was correct and was matching well with the observed value (all India area weighted rainfall in 2013 SW monsoon was about **106%** of its Long Period Average value). Also, the accuracy of spatial distribution of predicted rainfall was reasonably good.

Impact of increased resolution (T382) in CFSv2 (in comparison to T126 version):

- Better annual cycle of Indian summer monsoon rainfall (ISMR)
- Reduction in SST bias (reduced by about 25%)
- Reduction in radiation biases
- Improvement in inter-annual variability
- Big improvement in ISO variance in T382 version (as compared to T126 version)
- Space-time spectra is better

Model performance: Sensitivity to initial conditions

- The model skill is better for ISMR (JJAS) when February initial conditions are used (*i.e.*, with sufficient lead time) as compared to March/April/May initial conditions. Possibly, the better skill is coming mainly from ENSO-Monsoon tele-connection. Spring barrier of predictability may be a reason of less skill when March/April initial conditions are used.

Sensitivity experiments with CFSv2 cloud microphysics and convection

- At present, Zhao & Carr warm microphysics as well ice microphysics is being used.

? Sensitivity to change in critical relative humidity has been explored. It is found that variable critical relative humidity (85-95%) works better than the model assigned value of 85%.

? The present study attributes to improve the representation of clouds in CFSv2 over the Indian monsoon region. The sensitivity experiments are performed by the adjustment of critical relative humidity (RHcrit) and cloud microphysics for the better climatological representation of clouds. It has been explored that the improvement in clouds may lead to correct representation of large scale circulations through the enhanced radiation properties and consequently, modulate tropospheric temperature (TT) which plays a major role in the establishment of monsoon. Dry bias over the Indian subcontinent also gets improved. In addition to this, modification of microphysics is also being carried out and it exhibits promising results. Improvement in model bias is being explored.

Implementation of super-parameterization in CFSv2 (SP-CFS)

? An experimental super-parameterization in CFS (SP-CFS) has been explored with relatively good results.

Basic Research

Improved simulation of Indian summer monsoon in the latest version of NCEP Climate Forecast System free run

Simulation of Indian summer monsoon features by the latest coupled model of National Centers for Environmental Prediction (NCEP) Climate Forecast System version 2 (CFSv2) is attempted in its long run. Improvements in the simulation of Indian summer monsoon as compared with previous version (CFSv1) is accessed and the areas which still require considerable refinements are introduced. It is found that spatial pattern of seasonal mean rainfall and wind circulations are more realistic in CFSv2 as compared with CFSv1 (**Fig. 1**). Variance and northward propagation of intra-seasonal oscillation (**Fig. 2**), which also contribute to the seasonal mean rainfall, are remarkably improved. However, the central Indian dry bias still persists and is amplified. Pervasive cold bias in surface (2 m air temperature) as well as in the whole troposphere is further increased in CFSv2. These cold biases may be partly attributed to the lack of model's ability to realistically simulate the ratio of convective and stratiform rainfall. Sea-surface temperature (SST) over the Indian Ocean is underestimated in CFSv2. However, CFSv1 shows east-west dipole structure in the bias. The tele-connection of El-Niño Southern Oscillation (ENSO) and Indian summer monsoon rainfall (ISMR) in terms of Niño3 SST and monsoon rainfall correlation is more realistic in the latest version of the model. Overall, there are substantial improvements in CFSv2 as compared with CFSv1, but it has to evolve further to realistically simulate the mean and variability of ISMR. *[**Saha S.K., Pokhrel S., Chaudhari H.S., Dhakate A.R., Shewale S., Sabeerali C.T., Salunke K.D., Hazra A., Mahapatra S., Suryachandra A. Rao,** Improved simulation of Indian summer monsoon in latest NCEP climate forecast system free run, **International Journal of Climatology**, online, July 2013, DOI:10.1002/joc.3791, 1-14]*

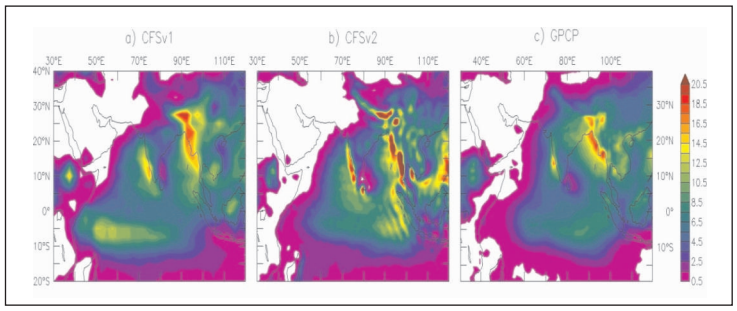


***Fig. 1:** Seasonal (JJAS) averaged climatological mean rainfall (in mm/d) from **(a)** CFSv1, **(b)** CFSv2 and **(c)** GPCP.*

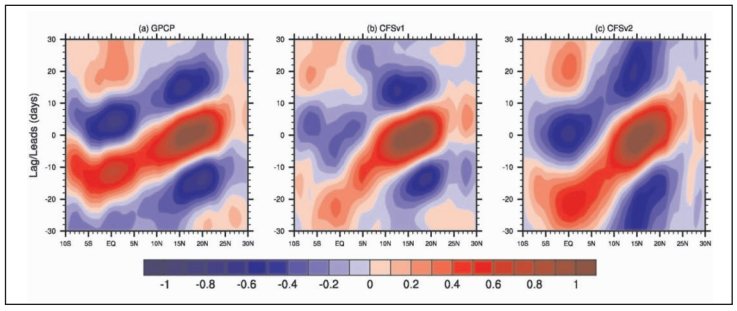


***Fig. 2:** Northward propagation of ISOs using lead/lag regressed 20-100 days filtered rainfall anomaly during JJAS: **(a)** GPCP, **(b)** CFSv1 and **(c)** CFSv2.*

Simulation of boreal summer intra-seasonal oscillations in the latest CMIP5 coupled GCMs

The simulation of the boreal summer intra-seasonal oscillation (BSISO) has been analyzed in the historical run of the 32 models, which participated in the Coupled Model Inter-comparison Project phase-5 (CMIP5), and it is shown that the current state-of-the-art general circulation models (GCMs) still have difficulties to properly simulate the BSISO. Compared to CMIP3 models, more CMIP5 models simulated the northward propagation of BSISO. The majority of the models could not simulate the spatial pattern of BSISO variance over the Asian summer monsoon (ASM) region. Except very few models (CMCC-CM, MPI-ESM-LR, MPI-ESM-MR, MPI-ESM-P, MIROC5 and BNU-ESM), all other models failed to capture the three peak centers of BSISO variance over the Indian summer monsoon region. Although MIROC5 capture all three peak centers of BSISO variance over the Indian summer monsoon domain, it failed to simulate a reasonable pattern correlation with observation **(Fig. 3)**, due to its failure over the northwest Pacific. Out of 32 models analyzed, only seven (CMCC-CM, MPI-ESM-LR, MPI-ESM-MR, MPI-ESM-P, CSIRO-Mk3.6.0, GFDL-CM3, BNU-ESM) models give the pattern correlation of BSISO variance greater than 0.6 **(Fig.3)**. Even though CSIRO-Mk3.6.0 and GFDL-CM3 have better correlations, these models failed to simulate all the three major centers of BSISO variance over the Indian summer monsoon domain. The two models MPI-ESM-LR and MPI-ESM-P show the maximum correlations and better variance compared to other models and these two models are the best to represent the BSISO variance over the ASM domain **(Fig. 3)**. Many of the models underestimated the BSISO variance over the equatorial Indian Ocean, and it is associated with the seasonal mean dry biases over this region. A reasonable representation of the intra-seasonal sea surface temperature and its coupling to the convection over the equatorial Indian Ocean and an equatorial eastward propagation of convective anomalies beyond 100ºE assure realistic simulation of BSISO over the ASM domain. It is found that the models MIROC5, IPSL-CM5A-LR, GFDL-CM3, CMCC-CM, and MPI-ESM-LR are able to represent reasonable BSISO characteristics and can be used to unravel the modulation of BSISO characteristics due to various projected climate changes.

The authors have also analyzed the performance of BSISO in the CFSv2 model (which is the model chosen for Monsoon Mission by the Government of India to improve prediction skills of Indian summer monsoon rainfall on different time scales). It was found that CFSv2 is good at simulating the characteristics of the BSISO, and it is comparable to the best CMIP5 models. *[**Sabeerali C.T., Dandi A.R., Dhakate A., Salunke K., Mahapatra S., Rao Suryachandra A.,** Simulation of boreal summer intraseasonal oscillations in the latest CMIP5 coupled GCMs, **Journal of Geophysical Research**, 118, May 2013, DOI:10.1002/jgrd.50403, 4401-4420]*

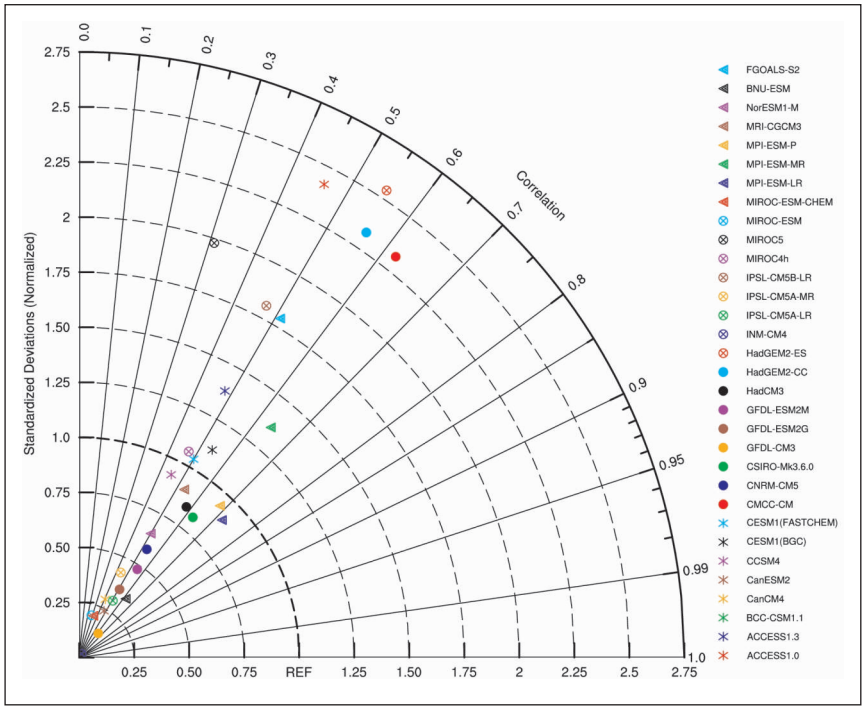


***Fig. 3** : The Taylor diagram for spatial pattern of mean variance of 20-100-day band pass filtered June-September (JJAS) precipitation anomalies (for 32 CMIP5 models). The domain 20^0 S - 30^0 N and 40^0 E - 140^0 E has been used to compute the Taylor metric.*

Model Development and Prediction: Extended Range

Chief Project Scientist : **Dr. A.K. Sahai**, Scientist-F

Objectives:

- To develop a fully coupled ocean-atmosphere-land modeling system for dynamical prediction of the monsoon rainfall on extended range.
- To develop a technique for prediction of active and break spells of sub-seasonal monsoon, 2-3 weeks in advance. This will involve the existing empirical techniques and development of dynamical ocean atmosphere coupled models.
- To evaluate simulation of global climate and monsoon climate by the coupled model and diagnosis of systematic bias.
- To attempt the use of an Atmospheric General Circulation Model (GCM) to predict the phases of intra-seasonal oscillations.
- To study the air-sea interaction associated with monsoon intra-seasonal oscillations.

Developmental Activities:

Experimental real-time prediction of MISO during 2013 monsoon

Real-time experimental extended range forecasts were issued using CFSv2 and GFSv2. Both GFSv2 and CFSv2 were integrated for 25 days in ensemble mode. Here, both GFS and CFS model setups share the same set of 11 atmospheric initial conditions and the AGCM GFS is forced with bias corrected SST forecasted from corresponding unperturbed CFS forecast. The large-scale monsoon intra-seasonal oscillations have been monitored using MISO index method proposed by Suhas *et al.* (2012). This MISO index monitors the temporal evolution and amplitude of ISO as it evolves from the Equatorial Indian Ocean to the foothills of the Himalayas.

- The forecast of Monsoon Onset over Kerala was issued based on 16 May initial condition using CFS T126. The forecasted onset date (29 May 2013) was very much close to the observed onset (01 June 2013).
- The rapid advancement of the monsoon and Uttarakhand heavy rainfall events were well predicted.
- The delayed withdrawal of monsoon was well predicted 10-15 days in advance.
- The forecast skill of both CFS and GFS with bias corrected SST is shown in **Table-1** for the year 2013. It is clear that the rainfall prediction skill over the monsoon zone for GFS is improved in the 4th pentad lead as compared to CFS.
- The GFS skill is very much improved in the 3rd and 4th pentads when forced with bias corrected SST.
- Though the phases of large scale MISOs are better predicted in both the models, amplitude prediction skill during 2013 is slightly improved in GFS.
- The categorical probabilistic prediction skill shows that the break and active category is forecasted with better fidelity at 4th pentad lead (**Fig. 1 & 2**).

[***A. K. Sahai, S. Abhilash, S. Joseph, R. Chattopadhyay]***

2013		
	CFS	**GFS**
P1-Lead	0.78	0.86
P2-Lead	0.61	0.62
P3-Lead	0.54	0.70
P4-Lead	0.39	0.51

Table 1: Correlation coefficients (CC) for the monsoon zone rainfall for 24 pentads during the year 2013. The CC values are shown upto 4 pentad lead for GFS and CFS.

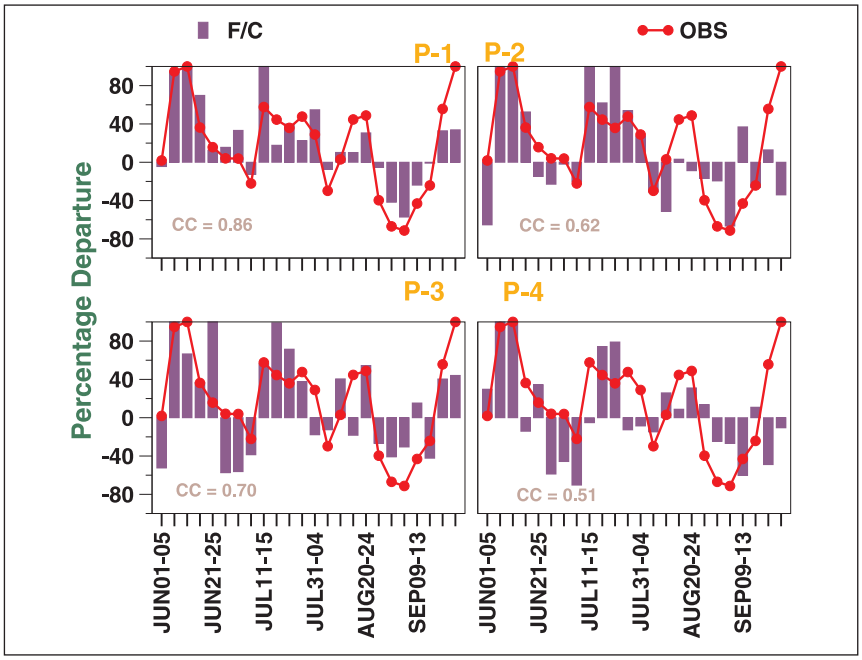


Fig. 1: Observed pentad mean percentage rainfall departures over monsoon zone and predicted (for 1 to 4 pentads) with GFSbc.

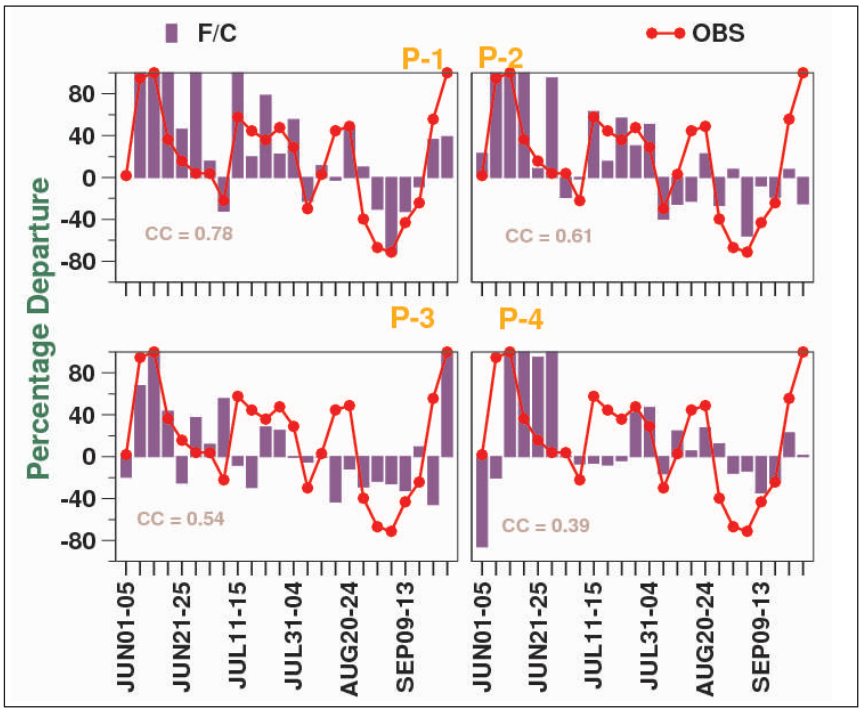


Fig. 2: Observed pentad mean percentage rainfall departures over monsoon zone and predicted (for 1 to 4 pentad lead) with CFS.

Basic Research

Does bias correction in the forecasted SST improve the extended range prediction skill of active-break spells of Indian summer monsoon rainfall?

The large bias in SST and associated dry bias over the Indian land mass is reported in CFS model. In order to address this issue, bias correction in daily forecasted SST from CFSv2 for each lead time was done by removing the daily mean bias for corresponding lead time (model climatology – observed climatology) from forecasted daily SST and is provided as the boundary forcing for the GFSv2 (hereafter known as GFSv2bc, with 'bc' indicating bias correction). In GFSbc, the biases in precipitation are considerably reduced compared to CFSv2. The pentad lead prediction skill of ensemble mean deterministic and probabilistic forecasts from GFSv2bc is significantly higher than CFSv2 for all lead pentads. At pentad 3 and 4 lead, GFSv2bc has higher relative operating characteristic (ROC) score than CFSv2 for predicting break and active categories (**Fig. 3**). It is also found that GFSv2bc is superior to CFSv2 in predicting large-scale low-frequency components of MISO. *[**Abhilash S., Sahai A.K., Borah N., Chattopadhyay R., Joseph S., Sharmila S., De S.** and **Goswami B.N.**, Does bias correction in the forecasted SST improve the extended range prediction skill of active-break spells of Indian summer monsoon rainfall? **Atmospheric Science Letters,** online, December 2013, DOI:10.1002/asl2.477, 1-6]*

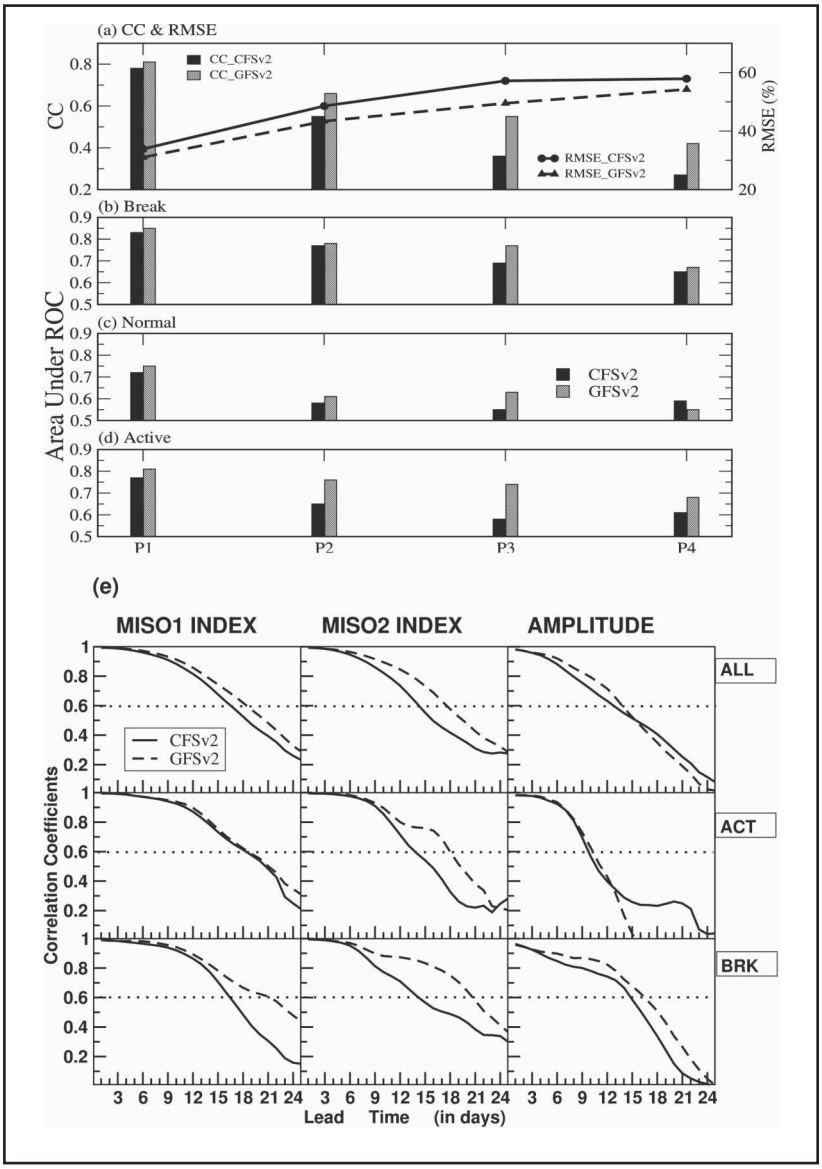


Fig. 3: *Pentad lead (**a**) correlation coefficients and RMSE and area under ROC for (**b**) break, (**c**) normal and (**d**) active categories of rainfall over MZI region. (**e**) Prediction skill of large scale MISO1 index (left panel), MISO2 index (middle panel) and Amplitude (right panel) from all start dates (top panel), active start dates (middle panel) and break start dates (bottom panel).*

A self-organizing map-based ensemble forecast system for extended range prediction of active/break cycles of Indian summer monsoon

A probabilistic prediction scheme of the intra-seasonal oscillation of Indian summer monsoon (ISM) in the extended range (ER, ~3-4weeks) using a self-organizing map (SOM) based technique is described. SOM is used to derive a set of patterns through empirical model reduction. An ensemble method of forecast is then developed for these reduced modes based on the principle of analogue prediction. A total of 900 ensembles is created based on the variations of one of the parameters like length of the observation sample, number of patterns, number of lags and number of input variables while keeping the others constant. Deterministic correlation skill at fourth pentad lead (15-20 days) from the current model is 0.47 (for development period, 1951-99) and 0.43 (for hindcast period, 2000-11) over the monsoon zone of India. It is found that the probabilistic forecast is also skillful up to 4 pentads (**Fig. 4**). This method effectively takes care of the stochastic uncertainties associated with a deterministic prediction scheme and provides better guidance to the user community. A large part of the uncertainty in the model's prediction skill is related to the inter-annual variability of the prediction skill of the active/break spells. The model has problems in forecasting the unusually long active/break spells during the monsoon season, especially during September. Forecasts from certain initial conditions are less predictable than those from others. An effort is made to describe some probable mechanisms from the literature for such problems in the model. This study will provide a benchmark to evaluate dynamical models' skills in predicting the ISM in ER time scale in future. *[**Borah. N., Sahai A.K., Chattopadhyay, R., Joseph S., Abhilash S.** and **Goswami, B.N.,** Self-organizing map-based ensemble forecast system for extended range prediction of active/break cycles of Indian summer monsoon, **Journal of Geophysical Research**, 118, August 2013, DOI:10.1002/jgrd.50688, 1-13]*

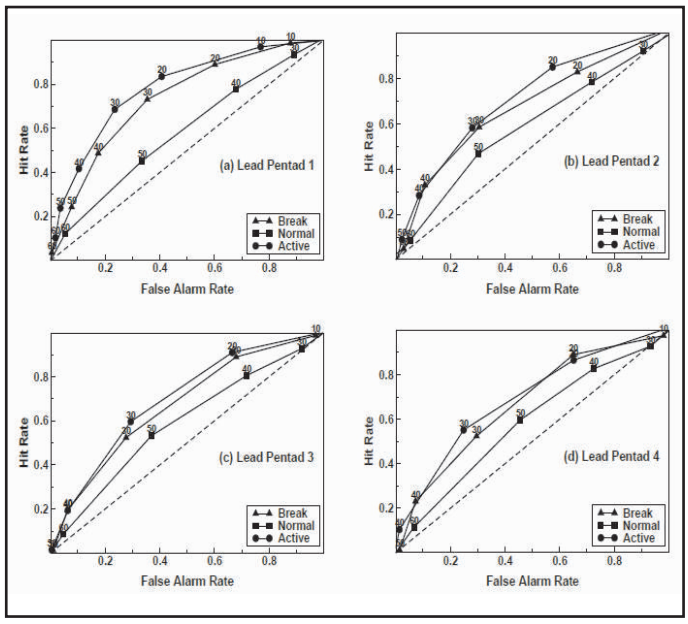


Fig. 4: *shows the Relative Operating Characteristics (ROC) curve prepared for three categories break, active, and normal considering 900 independent forecast for each pentad and for 1st to 4th pentad lead prediction. Figure shows that the probabilistic forecasts are skillful up to 4 pentads. The forecasts are more skillful for the active and break category both in all the four pentad lead compared to the normal category forecast.*

A new method to compute the principal component time series of self organizing maps: An application to monsoon intra-seasonal oscillations

A self-organizing map (SOM) based local principal component analysis (PCA) is developed to obtain the linearly decorrelated principal components (PCs) of monsoon intra-seasonal oscillations (MISOs) (**Fig. 5**). The SOM-based local PCA is seen also to be statistically equivalent to extended empirical orthogonal function (EOF) analysis when applied to MISO analysis. The life cycle and phase evolution of MISO through SOM-based PCA is robust and conforms to the results based on extended EOFs besides having potential to give new information. The remarkable similarity of results with the symmetric SOM configurations shows the effectiveness of these methods for use as empirical reduction models for climate patterns. The asymmetric SOM lattice configurations derive similar phase evolution as compared to a symmetric lattice, but asymmetric temporal evolution in the PC-defined phase space. *[**Sahai A.K., Chattopadhyay R., Joseph S., Borah N.** and **Goswami B.N.,** New method to compute the principal components from self-organizing maps: an application to monsoon intra-seasonal oscillations, **International Journal of Climatology**, online, December 2013, DOI:10.1002/joc.3885, 1-15]*

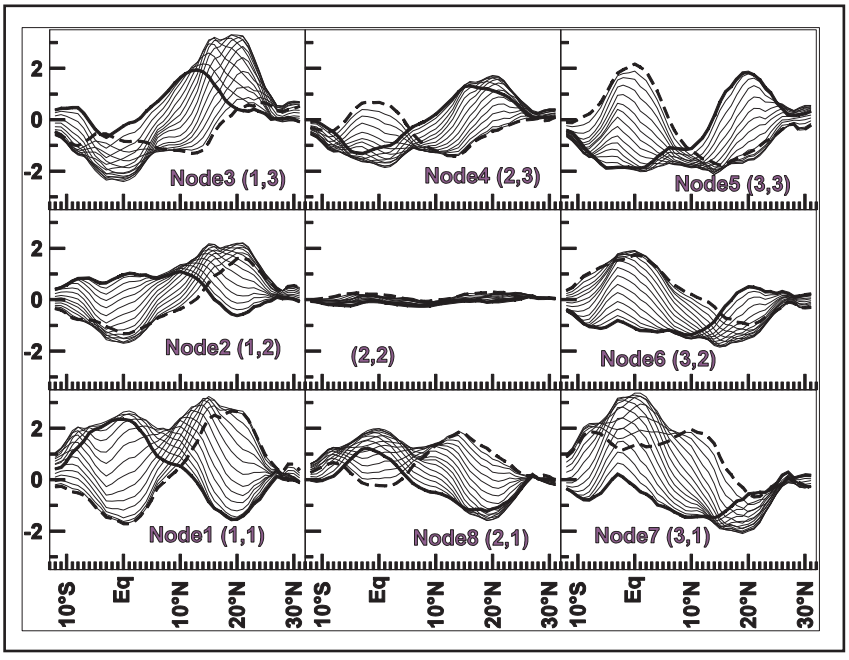


Fig. 5: *Feature maps associated with each of 3×3 node (node coordinate is mentioned in each panel). Each node has 16 curves (the day itself and 15 lags associated with it). The latitudinal variations of SOFs for each lag day are plotted as separate curves in each node. Lag 0 is shown as solid curve while lag 15 is shown as dashed curve. The curves with different colours represent different lag days. This arrangement clearly shows that every feature map in each node has a time history of evolution associated with it.*

Ocean Model Development and Data Assimilation

Deputy Chief Project Scientist : **Dr. C. Gnanaseelan**, Scientist-E

Objectives:

- Development of data assimilation system for CFS.
- Ocean model development for CFS.
- Understanding the ocean processes and air sea coupling in CFS.

Developmental Activities

Ocean data assimilation for coupled forecast

Estimating the state of the ocean with assimilation techniques that meld numerical general circulation model information with observations is a primary target both in the context of climate variability assessment and for forecasting purposes such as the initialization of coupled ocean-atmosphere predictions. It is a well established fact that accurate representation of ocean state is very essential for better seasonal as well as short term weather forecast. The recent advent of several oceanic observation networks like ARGO (Array for Real-time Geostrophic Oceanography) and the radical improvement in the methods of data assimilation has a promising revolutionary role in operational forecast as well as climate studies. With a primary intention to improve the ocean initial state for CFS. The NCEP Global Ocean Data Assimilation System (GODAS) is based on a three-dimensional variational data assimilation scheme (3DVAR). The NCEP GODAS as well as the improved version of GODAS at INCOIS assimilates synthetic salinity profiles which are derived from temperature. However, assimilation of actual salinity has the potential to enhance the quality of ocean analysis. The GODAS assimilation system has been improved at IITM by implementing assimilation of actual salinity observations for preparing ocean initial state. The ARGO salinity and temperature profiles from different platforms and different ocean basins are extracted, quality controlled and assimilated to 3DVAR based IITM-GODAS system. New ocean reanalysis has been prepared using GODAS-MOM4 for the period 2005 to 2013 by assimilating ARGO observations. The quality of ocean analyses obtained from the IITM-GODAS is assessed by examining the role of actual ARGO salinity assimilation. The analysis indicates improved salinity and temperature in all the ocean basins. The assimilation of actual salinity profiles resulted in reasonable analysis of ocean state and interannual variability over the central Bay of Bengal which is a region highly influenced by freshwater influx. Ocean initialization has a significant impact on the skill of coupled forecast at the seasonal time scale.

Any inaccuracy in the upper ocean thermal structure, particularly in the sea surface temperature (SST) strongly influences the atmospheric circulation in the coupled model. To examine the role of improved ocean state in the CFSv2 seasonal forecast, CFSv2 hindcast experiments with and without ocean data assimilation were performed. CFS forecast runs indicate that the ocean initial conditions with assimilation (GODAS) are playing significant role in improving rainfall prediction (**Fig. 1**) by improving the SST (compared to non assimilated runs).

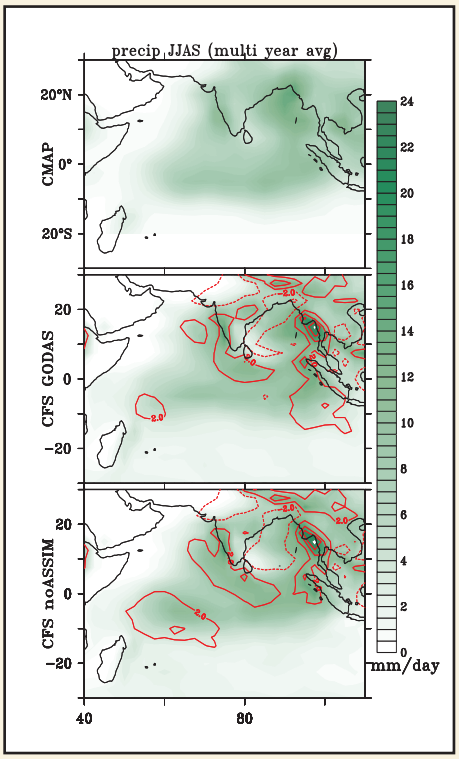


Fig. 1: *Climatological precipitation (mm/day, shaded) from CMAP data (upper panel); forecasted precipitation (shaded) from CFS for JJAS season overlaid by bias (contours), where CFS ocean initial state is prepared using GODAS-IITM by assimilating ARGO profiles (middle panel); forecasted precipitation from CFS overlaid by bias (contours), where CFS ocean initial state is taken from MOM4 (lower panel) noASSIM (without assimilating observations). All the panels represent JJAS average for the period 2005 to 2009.*

Basic Research

Summer monsoon circulation and precipitation over the tropical Indian Ocean during ENSO in the NCEP climate forecast system

The importance of SST evolution in the coupled model in ISMR is better demonstrated in **Fig. 2**, which shows ISMR (India land points only) for JJAS from CFSv1 hindcast initialized on 01 May and IMD precipitation for the period 1981-2007. Correlation coefficient between model and observed rainfall is 0.4, which is significant at 95% confidence level for 27 years. This demonstrates that model has some skill in predicting ISMR when initialized from May. However, the model fails to predict the observed rainfall in many years. For example, during 1983, 1985, 1990 and 1999, the model rainfall anomaly is in opposite phase with the observations. It is essential to know how the SST pattern during these years in the model differs from the observations. The out of phase (in phase) years are selected based on rainfall anomalies being more than half standard deviation in both model and observations and the phases are opposite (same). The SST difference (between model predictions and observations in JJAS) during out of phase years is shown in **Fig. 2b**. Large SST bias is apparent over the central tropical Pacific Ocean and some parts of the Indo-western Pacific region, indicating that model has strong warm bias during these years. It is identified that warm SST over the central Pacific is not only related to the developing phase of El-Niño but also to the decay phase. The late onset and late decay of El-Niño could be responsible for warm bias in the model. *[**Chowdary J.S., Chaudhari H.S., Gnanaseelan C., Parekh A., Rao A.S., Sreenivas P., Pokhrel S.** and **Singh P.**, Summer monsoon circulation and precipitation over the tropical Indian Ocean during ENSO in the NCEP climate forecast system, **Climate Dynamics**, Online, June 2013, DOI:10.1007/s00382-013-1826-5]*

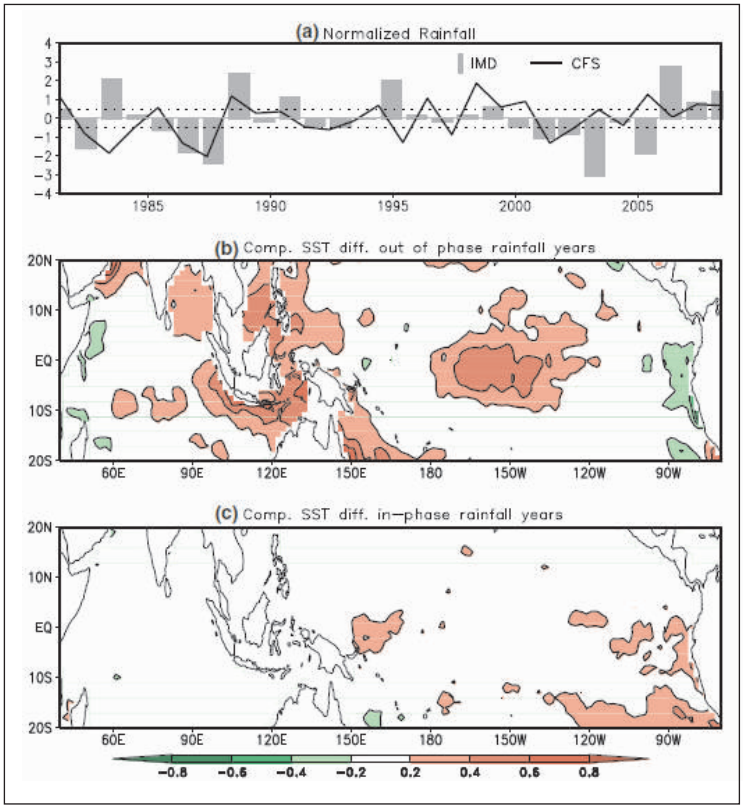


*Fig. 2: (**a**) Time-series (1981-2007) of all India summer (JJAS) monsoon rainfall (mm/day) anomalies (only land points; normalized with standard deviation) for CFSv1 hindcast (line) and observations (IMD rainfall; bars). Composite of JJAS SST anomaly (°C) difference between model prediction (initialized in May) and observations for (**b**) the years in which rainfall is out-of-phase (1983, 1985, 1990 and 1999) and (**c**) is similar to (**b**) but for the years in which rainfall is in phase (1986, 1987, 1988, 2001, 2006, 2007).*

Role of thermocline-SST coupling in the evolution of IOD events and their regional impacts

New indices are developed to understand and classify strong and weak Indian Ocean Dipole (IOD) events. The anomalous Walker circulation in June, July and August (JJA) and in September, October and November (SON) is characterised by a double cell pattern (convection over the western equatorial Indian Ocean and subsidence over the east equatorial Indian Ocean and the African landmass) during the strong IOD years **(Fig. 3)**. It is found that the evolution of strong IOD events is driven by ocean dynamics in the form of thermocline-SST coupling and is strongly interactive with the atmosphere, whereas the weak IOD events are mere response to surface winds without such dynamical coupling. The easterly wind anomalies extend up to the western equatorial Indian Ocean (WIO) during strong IOD years and support enhanced EIO air-sea interactions. On the other hand, the evolution of

zonal wind anomalies is weak during the weak IOD years. Thermocline-SST coupling is robust in both EIO and WIO during strong IOD years, which is primarily responsible for the enhanced SST gradient, strong enough to establish anomalous Walker circulation within the Indian Ocean. The strong convection over the WIO associated with the Indian Ocean Walker cell triggers a secondary cell with subsidence over the African landmass. Strong subsidence over the large region is an indicative of changes in the Walker circulation over the Indian Ocean. They have strong impact on the regional rainfall pattern and the climate variability. *[**Deshpande A., Chowdary J.S.** and **Gnanaseelan C.,** Role of thermocline-SST coupling in the evolution of IOD events and their regional impacts, **Climate Dynamics**, online, July 2013, DOI:10.1007/s00382-013-1879-5, 1-12]*

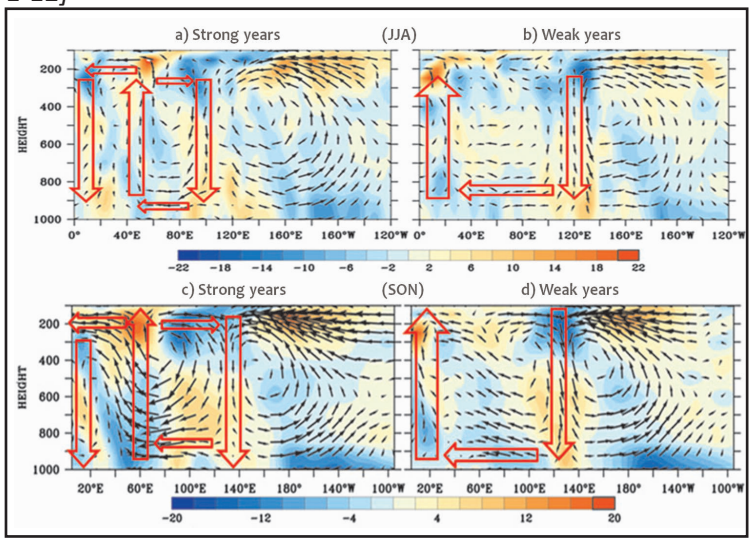


Fig. 3: *Depth-longitude plot of wind divergence anomalies (shaded, x10^{-7}, s^{-1}) overlaid with anomalous zonal (ms^{-1}) vertical (in -10^{-2} Pa s^{-1}) JJA circulation averaged over 5^{0}S-5^{0}N during a strong IOD years (**a**) and weak IOD years (**b**). (**c**) and (**d**) are same as (**a**) and (**b**) but for SON.*

Role of the Arabian Sea on IOD formation

An Indian Ocean Dipole (IOD) event often evolves without any forcing from the Pacific. The Arabian Sea spring warming and associated summer barrier layer play an important role in the evolution of such IODs. An alternate mechanism for IOD evolution is provided. Anomalous Walker circulation over the Indian Ocean during IOD years forced by the Arabian Sea warming in spring and summer plays a crucial role in initiating the easterly wind anomalies in the eastern equatorial Indian Ocean. It is clear from **Fig. 4** that the central equatorial Indian Ocean easterlies are initiated by the western warming and the associated convection and surface convergence. The resultant upper level divergence induces subsidence over the eastern basin from May onwards through Walker circulation, *i.e.,* about a month prior to the initiation of eastern cooling (surface). The Walker circulation (averaged over 5^{0}S-10^{0}N) clearly reveals that the subsidence in the east is induced by convection over the west. This drives surface easterlies in the eastern Indian Ocean. This clearly supports the role of the Arabian Sea warming in the initiation of the easterlies. The western warming and the associated convection induce easterly wind anomalies much before the significant eastern cooling during IOD years, which strongly supports the role of western warming in the IOD evolution. The processes responsible for the anomalous Arabian Sea warming during IOD years are also studied. Special emphasis is given to understand the formation of barrier layer in the Arabian Sea and its interannual variability. The role of oceanic processes in the deep Arabian Sea warming is also discussed. [***Ojha S., Gnanaseelan C., Chowdary J.S.**, Role of Arabian Sea in the evolution of Indian Ocean Dipole, **International Journal of Climatology**, Online, August 2013, DOI:10.1002/joc.3805*]

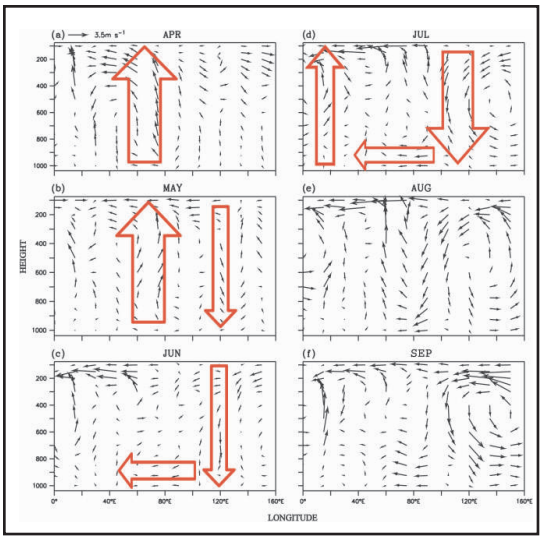


Fig. 4: *Composite of Walker circulation [zonal (ms^{-1}) and vertical (- 10^{-2} Pa s^{-1}) wind] anomalies averaged over (5^{0}S-10^{0}N) for pure IOD years during (**a**) April, (**b**) May, (**c**) June, (**d**) July, (**e**) August and (**f**) September.*

Parameterization and Analysis

Deputy Chief Project Scientist : **Dr. P. Mukhopadhyay**, Scientist-D

Objectives:

- To design, develop, employ and test different convective parameterization concepts in the CFS model.
- To develop new hypotheses based on observations to modify model grid scale cloud processes in CFS.
- Analyzing and evaluating CFS fidelity for different spatio-temporal scales of Indian monsoon.

Developmental Activites

Development of Super-parameterized CFSv2 (SP-CFS)

The Climate Forecast System Version 2 (CFSv2) is being identified as the operational model for issuing seasonal and extended range forecast of Indian summer monsoon. Even though the model has a reasonable skill in capturing the intra-seasonal variabilities, it shows some prominent bias such as lesser rainfall over Indian landmass, colder tropospheric temperature and colder sea surface temperature, etc. On analyzing CFSv2 free run of 20 years, it is noted that the model rainfall probability distribution is not realistic as shown in **Fig. 1**. Further, on analyzing rainfall and outgoing longwave radiation (OLR), it is found that stratiform rain rates and deep clouds are significantly low. Keeping in mind the possible role of high frequency modes into the overall rainfall variability, the ratio of synoptic variance and intra-seasonal variance was analysed. The ratio clearly shows that CFSv2 has lesser contribution from synoptic scale as compared to the observation. All these analyses suggest that the organization of cloud and associated cloud/convective processes possibly needs improvement to get the realistic simulation of rainfall and its variabilities and also to reduce the biases.

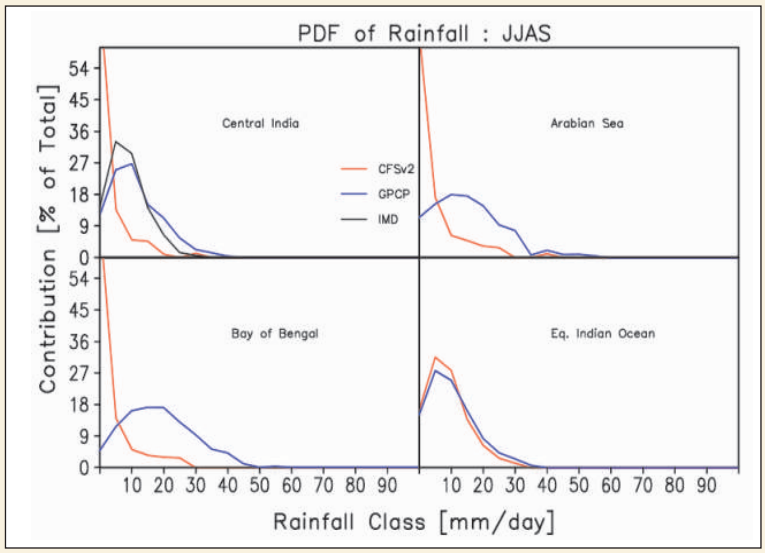


Fig. 1: *Probability distribution function (PDF) for different rain rate categories, based on daily JJAS rainfall over (**a**) central India, (**b**) Bay of Bengal, (**c**) Arabian Sea and (**d**) equatorial Indian Ocean (EIO).*

To accomplish the mentioned objective of improving the rainfall simulation by improving the cloud parameterization in the existing CFSv2, an attempt was made for developing superparameterized CFSv2 (SP-CFS) to improve different features of monsoon. SP-CFS has been developed and implemented in CFSv2 T62. Initially, an attempt was made to implement SP framework in CFSv2 T126 but it being too much expensive, T62 resolution was chosen to implement the SP framework. There are 32 Cloud Resolving Models (CRMs) in each GCM grid box with 64 vertical levels. Presently, SP-CFS takes around four days to run a season. A 3-year free run of the SP-CFS is made where the cold tropospheric temperature bias has reduced significantly **(Fig. 2)**. The annual cycle of rainfall has improved with a significant increase of rainfall over Indian landmass **(Fig. 3)**. SP-CFS has simulated a realistic upper and lower level wind fields. The synoptic (2-10 day) variance and the ratio of synoptic to intra-seasonal oscillation (ISO) scale are found to be much realistic in SP-CFS than CFS as compared to TRMM. Finally, the SP-CFS has simulated realistically major tropical waves namely MJO, Kelvin

waves, Rossby-Gravity waves, etc. as shown in **Fig. 4** (as per the methodology adopted by *Wheeler and Kiladis*, 1999). This work, therefore, demonstrates that representation of cloud and convection play a key role in determining the model simulated cloud, outgoing longwave radiation (OLR), precipitation distribution and finally, the heating.

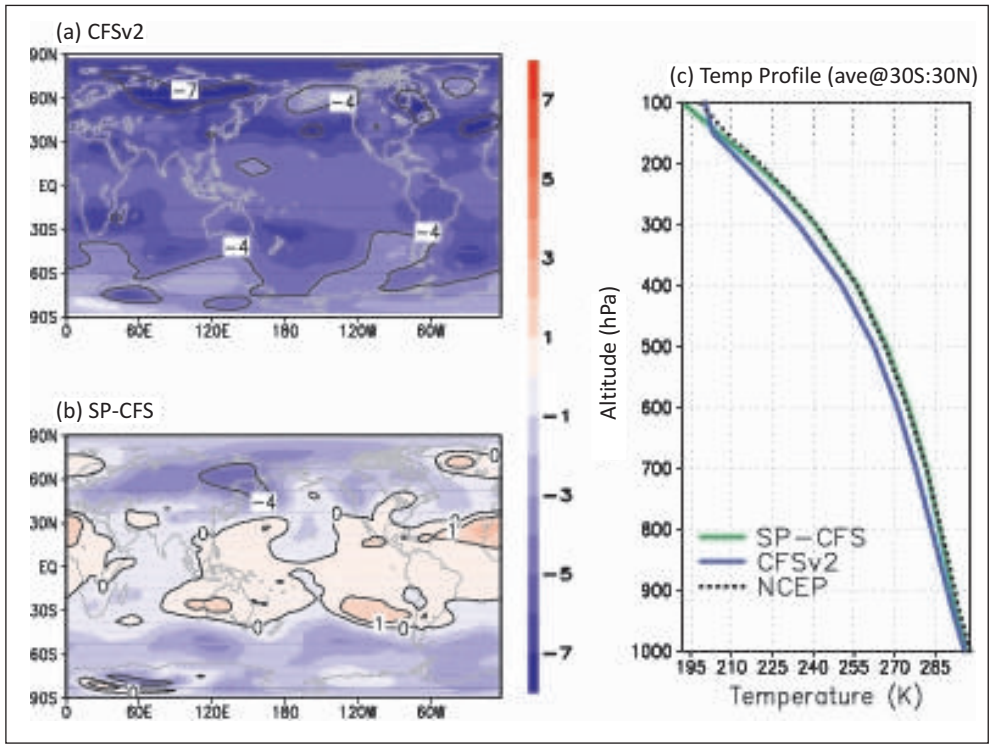


Fig. 2: *Boreal summer (JJAS) Tropospheric temperature bias of (**a**) CFSv2 and (**b**) SP-CFS, relative to NCEP. [The boreal summer tropospheric temperature is computed as the JJAS mean of climatological temperature averaged between 300-600 hPa]. (**c**) Vertical profile of JJAS mean climatological temperature for tropics (30°S to 30°N for all longitudes).*

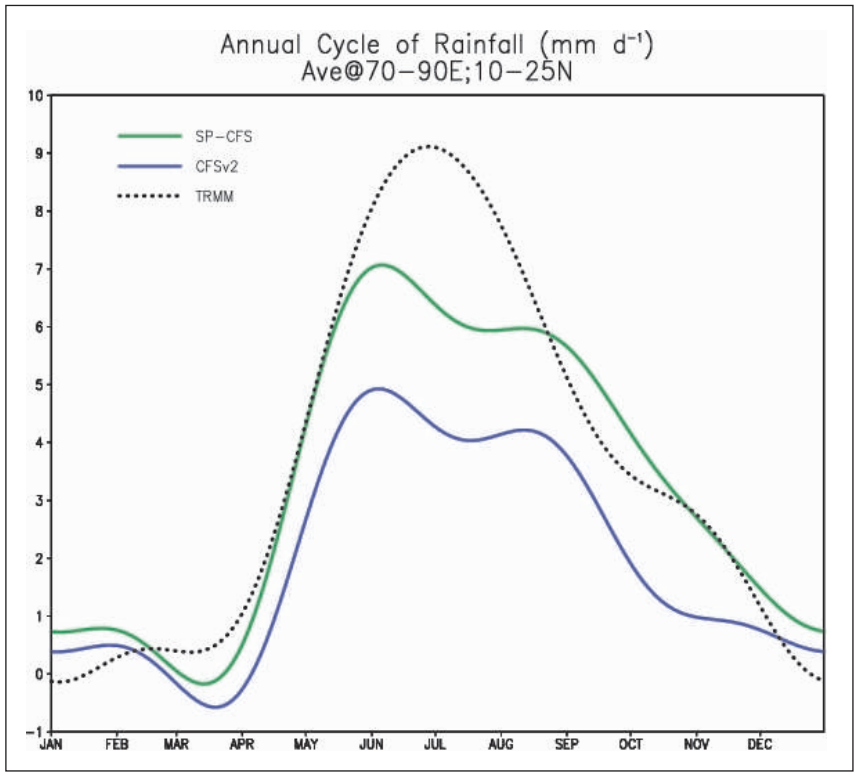


Fig. 3*: Annual cycle of the climatological mean rainfall (mm/day) for SP-CFS (Green line), CFSv2 (Blue line) and TRMM (Black dotted line) averaged over the area: 70°E-90°E; 10°N-25°N.*

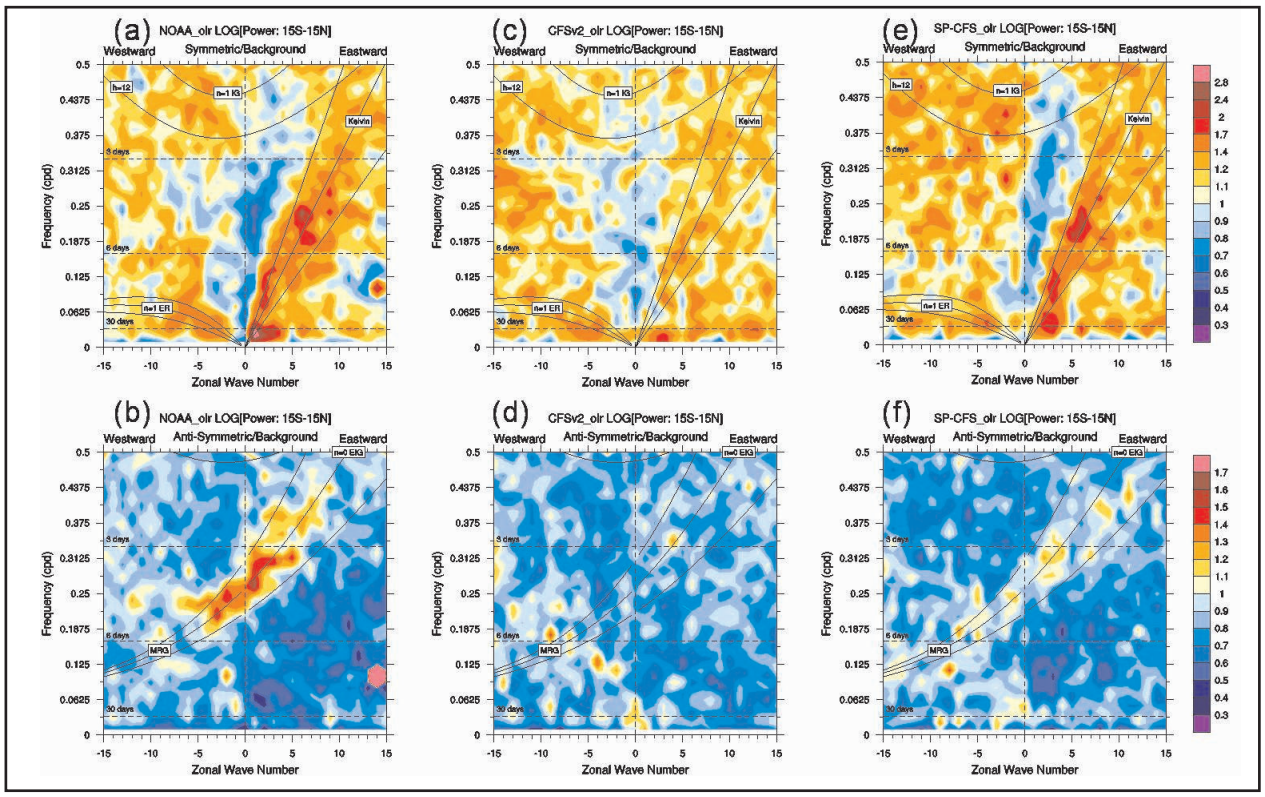


Fig. 4: *Space-Time spectra of OLR showing the symmetric component for (**a**) NOAA OLR, (**b**) CFSv2 and (**c**) SP-CFS and the anti-symmetric component for (**d**) NOAA OLR, (**e**) CFSv2 and (**f**) SP-CFS.*

Basic Research

Impact of aerosols on tropical cyclones: An investigation using convection-permitting model simulation

The role of aerosols' effect on two tropical cyclones over the Bay of Bengal is investigated using a convection-permitting model with a two-moment mixed-phase bulk cloud microphysics scheme. The simulation results show that aerosols play a role in the microphysical and the dynamical properties of clouds and bring out the change in efficiency of clouds in producing precipitation. The tracks of tropical cyclones (TCs) are hardly affected by the changing aerosol concentrations, but the intensity exhibits significant sensitivity due to the change in aerosol concentration. It is also clearly seen from the analyses that higher heating in the middle troposphere within the cyclone center is in response to latent heat release as a consequence of greater graupel formation. Greater heating in the middle level is particularly noticeable for the clean aerosol regime which causes enhanced divergence in the upper level, which, in turn, forces lower level convergence. As a result, the cleaner aerosol perturbation is more unstable within the cyclone core and produces a more intense cyclone as compared to the other two aerosol perturbations. This study brings out that continuous increase in aerosol concentration does not enhance the TC intensity rather shows a tipping point where the intensity actually reduces (**Fig. 5**). This study, along with previous simulations, shows the robustness of the concept of TC weakening by storm ingestion of high concentrations of cloud condensation nuclei (CCN). The consistency of these model results gives us confidence in stating that there is a high probability that ingestion of high CCN concentrations in a TC will lead to weakening of the storm but has little impact on storm direction. Moreover, as pollution is increasing over the Indian subcontinent, it suggests that pollution may be weakening TCs over the Bay of Bengal. *[**Hazra A., Mukhopadhyay P., Taraphdar S.,** Chen J-P., Cotton W.R., Impact of aerosols on tropical cyclones: An investigation using convection-permitting model simulation, **Journal of Geophysical Research**, 118, July 2013, DOI:10.1002/jgrd.50546, 7157-7168]*

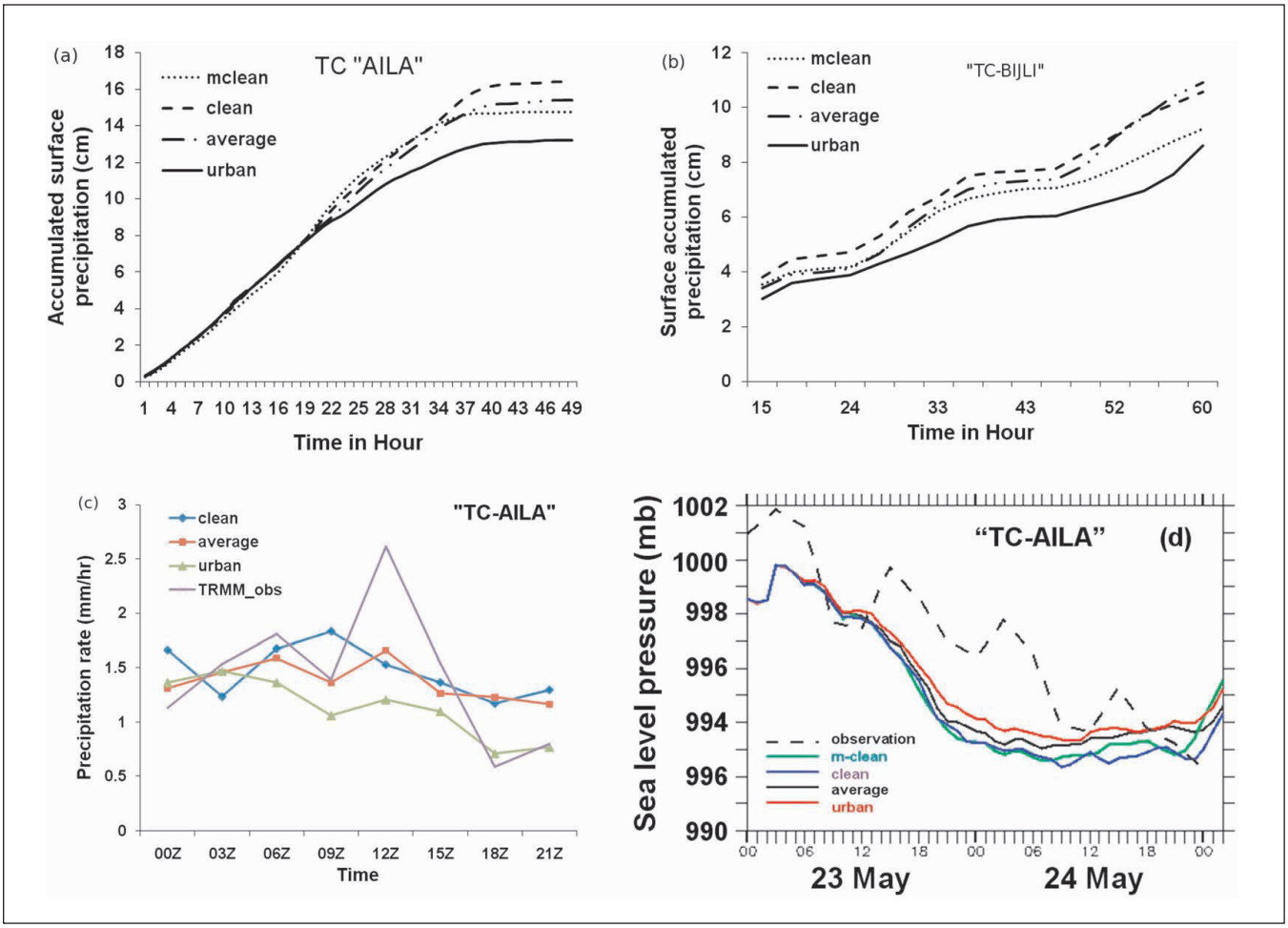


Fig. 5: *Total surface rainfall accumulation for two tropical cyclone (TC) cases (a) Aila and (b) Bijli under four types of background aerosol environments (maritime clean, clean, average, and urban). (c) Rain rates are compared with the TRMM3B42 observation for TC Aila. (d) Time evaluation minimum surface pressure as compared with the IMD observation.*

Simulation of monsoon intra-seasonal variability in NCEP CFSv2 and its role on systematic bias

The simulation of Indian summer monsoon and its intra-seasonal oscillations in the National Centers for Environmental Prediction (NCEP) climate forecast system model version 2 (CFSv2) is evaluated. The dry bias over the Indian landmass in the mean monsoon rainfall is one of the major concerns. In spite of this dry bias, CFSv2 shows a reasonable northward propagation of convection at intra-seasonal (30-60 day) time scale. In order to document and understand this dry bias over the Indian landmass in CFSv2 simulations, a two pronged investigation is carried out on the two major facets of Indian summer monsoon: one, the air-sea interactions and two, the large scale vertical heating structure in the model. Analysis shows a possible bias in the co-evolution of convection and sea surface temperature in CFSv2 over the equatorial Indian Ocean. It is also found that the simulated large scale vertical heat source (Q1) and moisture sink (Q2) over the Indian region are biased relative to observational estimates. Finally, this study provides a possible explanation for the dry precipitation bias over the Indian landmass in the simulated mean monsoon on the basis of the biases associated with the simulated ocean-atmospheric processes and the vertical heating structure. This study also throws some light on the puzzle of CFSv2 exhibiting a reasonable northward propagation at the intra-seasonal time scale (30-60 day) despite a drier monsoon over the Indian landmass by showing that the contribution of synoptic variance to the total variance is

underestimated by the CFSv2 (**Fig. 6**) as compared to observation. The lack of synoptic scale variance may be crucial in resolving the dry bias of CFSv2 over land. *[**Goswami B.B., Deshpande M.S., Mukhopadhyay P., Saha S.K., Rao A.S.,** Murthugudde R. and **Goswami B.N.**, Simulation of monsoon intraseasonal variability in NCEP CFSv2 and its role on systematic bias, **Climate Dynamics**, online, February 2014, DOI:10.1007/s00382-014-2089-5, 1-21]*

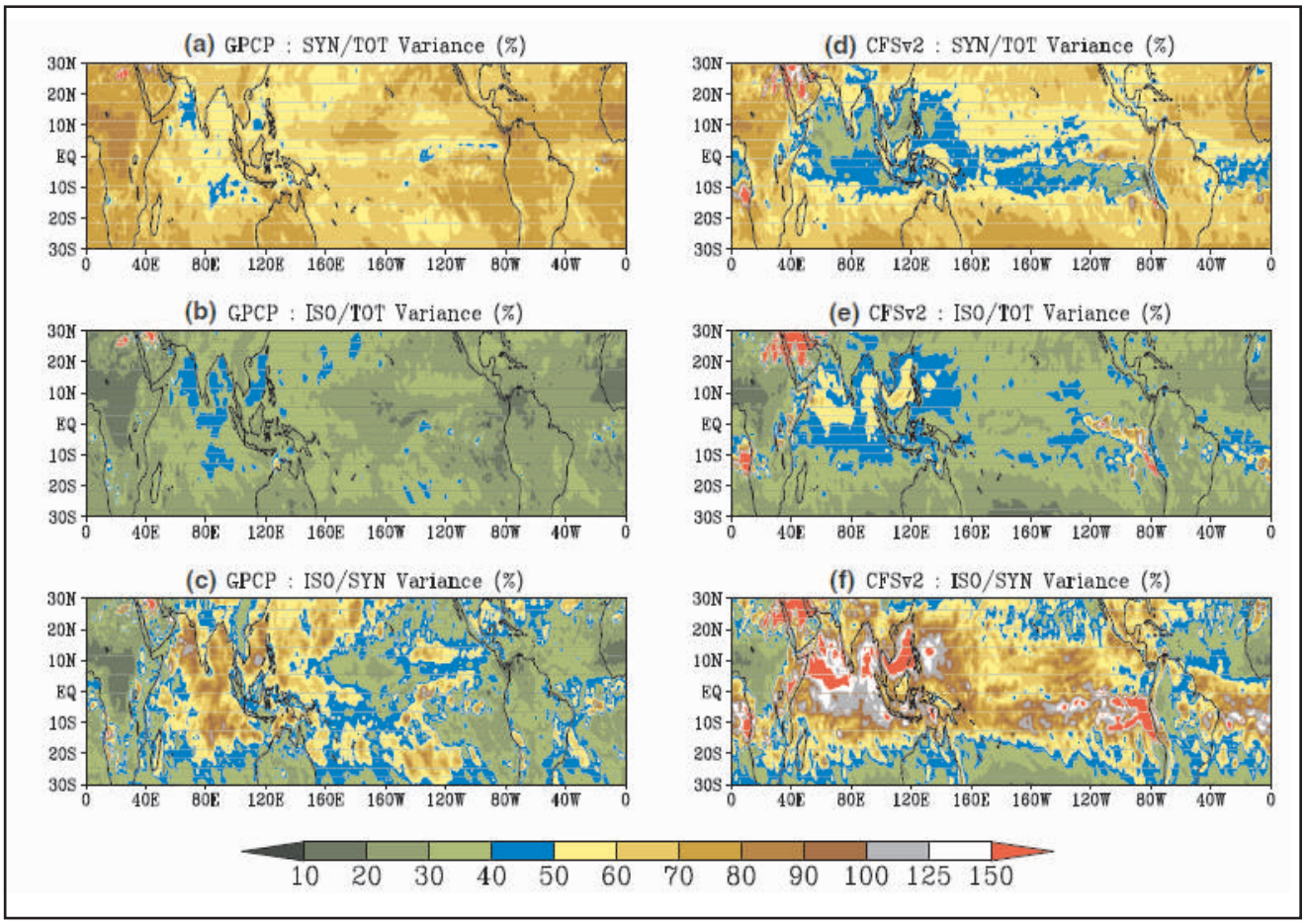


***Fig. 6**: (**a**) ratio of synoptic scale (2-10 day bandpassed) variance to total variance in GPCP, (**b**) ratio of ISO scale (10-90 day bandpassed) variance to total variance in GPCP, (**c**) ratio of ISO scale variance to synoptic scale variance in GPCP, (**d**) ratio of synoptic scale variance to total variance inCFSv2, (**e**) ratio of ISO scale variance to total variance in CFSv2, and (**f**) ratio of ISO scale variance to synoptic scale variance in CFSv2. (the values are given in percentage)*

Project

Monsoon Mission

Mission Director : **Prof. B.N. Goswami,** Director, IITM

Indian summer monsoon is the lifeline of the Indian subcontinent, especially India. Any variability in its onset, withdrawal or quantum of rainfall affects the country dearly. Knowledge of variability in advance would reduce the adverse impacts related to excess or deficient rainfall. Unfortunately, the prediction of Indian Summer Monsoon rainfall has remained a challenge over the decades. Empirical models have not shown any improvement in prediction skill over the years. Dynamical models show some hope in improving skill in monsoon prediction. Many centres in the world are routinely using dynamical models to predict seasonal mean climate. Here, NCEP CFS model is used as one of such reliable models.

However, there are some intrinsic problems in predicting the Indian monsoon rainfall through such dynamical models. Hence, to improve the assimilation and forecasting system especially for the monsoon region, the Ministry of Earth Sciences (MoES), Government of India has formulated a focused mission mode programme 'Monsoon Mission' with a vision to develop a state-of-the-art dynamical prediction system for monsoon rainfall on all the different time scales with concerted efforts by various research and academic institutes in India and abroad. The mission is being executed under the leadership of IITM for designing a prediction model to improve Indian Monsoon weather and climate forecasts.

To make the mission a success, the MoES has signed a Memorandum of Understanding (MoU) with the National Oceanic and Atmospheric Administration (NOAA), USA under the agreement 'Technical Cooperation for the Study of Dynamical Seasonal Prediction of Indian Monsoon Rainfall'. The Mission is working on developing an Indian model based on NCEP CFSv2 model by improvising on its strengths and weaknesses and by incorporating new physics/ parameterization schemes for improving its simulations/prediction skill of the monsoon rainfall. Further, Unified Model (UM) developed by the United Kingdom Meteorological Office (UKMO) will also be utilized for short to medium range prediction.

Seasonal prediction component of the mission is being coordinated by IITM, and short to medium range prediction by NCMRWF. While INCOIS is providing ocean observations, and IMD is implementing the research results in operational model and evaluating the verification of forecasts. Academic institutions from national and international organizations are participating through extra mural funding to improve the modeling framework adopted by India.

To oversee the overall functioning of the mission, a Mission Directorate is set up at IITM. The overall execution of the mission is bestowed on Mission Director, who is advised by a High Level National Scientific Steering Committee. An International Advisory Panel constituted by the MoES provides guidance to the Mission Director and also reviews the progress of the projects. Further, a standing Scientific Review and Monitoring Committee reviews various research proposals from national and international partners and recommends the proposals that have direct relevance to the mission objectives.

The main objectives of the mission are to build a working partnership between the academic R&D organizations and the operational agency to improve the monsoon forecast skill, and to set up a state-of-the-art dynamical modeling frame work for improving prediction skill of (i) seasonal and extended range prediction system and (ii) short and medium range prediction system.

Committees for Monsoon Mission

1. Scientific Steering Committee (SSC)

Dr. Shailesh Nayak (Secretary, MoES), Chairman
Prof. J. Srinivasan (Professor, IISC, Bangalore), Co-Chairman
Dr. M. Rajeevan (Scientist-G, MoES), Member Secretary
Prof. D.R. Sikka (Ex-Director, IITM), Member
Prof. B.N. Goswami (Director, IITM), Member
Dr. (Smt.) Swati Basu (Director, NCMRWF, Noida), Member

2. Scientific Review and Monitoring Committee (SRMC)

Shri D.R. Sikka (Ex-Director, IITM), Chairman
Prof. B.N. Goswami (Mission Director and Director, IITM), Member
Dr. P.K. Pal (SAC, Ahmedabad), Member
Prof. B. Jayaraman (Professor, IIT Delhi), Member
Dr. S.R. Shetye (VC, Goa University), Member
Dr. V.K. Dadhwal (Director, NRSC, Hyderabad), Member
Dr. (Smt.) Swati Basu (Director, NCMRWF, Noida), Member
Prof. U.C. Mohanty (Professor, CAS, IIT Delhi), Member
Prof. G.S. Bhat (Chairman, CAOS, IISc, Bangalore), Member
Prof. D. Sengupta (Professor, CAOS, IISc, Bangalore), Member
Dr. L.S. Rathore (DG, IMD), Member
Dr. K. Krishnamoorty (Director, SPL, VSSC, Tiruvanantapuram), Member
Dr. S.S.C. Shenoi (Director, INCOIS, Hyderabad) Member
Dr. M. Rajeevan (Scientist-G, MoES), Member
Dr. R. Krishnan (Executive Director, CCCR, IITM), Member
Dr. E.N. Rajagopal (NCMRWF, Noida), Project Director (SMRP)
Dr. S.K. Roy Bhowmik (IMD, New Delhi), Project Director (Op. Ver. Model F/c)
Dr. M. Ravichandran (INCOIS, Hyderabad), Project Director (Ocean Obs.)
Dr. A. Suryachandra Rao (IITM), Member Convener and Project Director (SERP)

Monsoon Mission Science and Implementation Plan: Monsoon Mission Directorate has finalized the compilation of the draft 'Science and Implementation Plan' of Monsoon Mission.

Installation of a new HPC at IITM: A new HPC installation at IITM was inaugurated by Dr. Shailesh Nayak, Secretary of the Ministry of Earth Sciences (MoES), Govt. of India on 28 February 2014. This new HPC is named as 'AADITYA' (in Hindi, meaning 'SUN') to signify the major source of energy that drives our climate system. It is a highly parallel supercomputing system built on IBM System X technology. Its computing performance is more than 790 Tera Flops with Intel Sandy bridge Processors. There are 2384 compute Nodes with each node having two 8-core processors (Intel Xeon E5-2670 2.6GHz cache 20MB) and the memory is 4 GB per core and 64 GB per node. The total RAM of the cluster is more than 150 TB. The system is having six peta bytes disk storage capacity. The HPC system will boost research in weather and climate forecasting as well as monitoring air pollutions and forecasting air quality.

Human Resource Development Activities: Monsoon Mission Directorate at IITM coordinated the visit of research students and organized various training activities for research students of University of Calcutta, Andhra University, etc. IITM Scientists gave training on the CFSv2 model and shared the model output data.

Research proposals for Funding: Research proposals were invited and were reviewed by the Scientific Review and Monitoring Committee (SRMC) of the Monsoon Mission. On the recommendations of SRMC, Scientific Steering Committee (SSC) approved 10 (eight International and two National) proposals for funding.

Following is the list of research proposals approved by the SSC for funding under the monsoon mission:

S. No.	Principle Investigator Affiliation	Title of the proposal	Duration (in years)	Budget
1.	**Dr. Dale Barker** UK Met Office, UK	Indian Monsoon Data Assimilation and Analysis	4	UK Pounds 9,85,000
2.	**Prof. Terray Pascal,** LOCEAN-IPSL, Paris, France	Impacts of ocean-atmosphere coupling and SST high frequency variability on the coupled simulation of the mean state and variability of the Indian Summer Monsoon	3	US $ 2,91,600
3.	**Dr. Arun Kumar** University of Maryland & NCEP, USA	Understanding the role of sea surface temperatures in the simulation and prediction of the monsoon intra-seasonal oscillation	3	US $ 3,14,595
4.	**Dr. H. Annamalai** IPRC, University of Hawaii, USA	Extended Monsoon Episodes: Understanding Processes and Pathways for Improved Prediction in CFSv2	3	US $ 3,10,333
5.	**Dr. Andrew Turner** University of Reading, Reading, UK	Improved Indo - UK capability for seamless forecasting of monsoon rainfall: from days to the season	3	US $ 2,98,285
6.	**Dr. Suneet Dwivedi** University of Allahabad, Allahabad, India	Improved Ocean Initialization for Coupled Modeling for week-2 Monsoon forecast	3	INR 91,59,200
7.	**Dr. Boualem Khouider** University of Victoria, Canada	An approach of Multi-scale multi-cloud parameterization to improve the CFS model fidelity of monsoon weather and climate through better organized tropical convection	3	US $ 3,00,000
8.	**Dr. Duane Waliser** JIFRESSE/UCLA	Advancing Monsoon Weather-Climate Fidelity in the NCEP CFS through Improved Cloud Radiation-Dynamical Representation	3	US $ 3,18,309
9.	**Prof. Raghu Murtugudde** ESSIC, University of Maryland, USA	Role of the Atmosphere and the Indian Ocean in the Evolution of Monsoon-ENSO Tele-connections in CFS	3	US $ 3,60,000
10.	**Dr. Debasis Sengupta** Indian Institute of Science, Bangalore, India	Coupled physical processes in the Bay of Bengal and monsoon air-sea interaction	4	INR 38,56,20,000

Project

Climate Change, Climate Variability and Atmospheric Chemistry

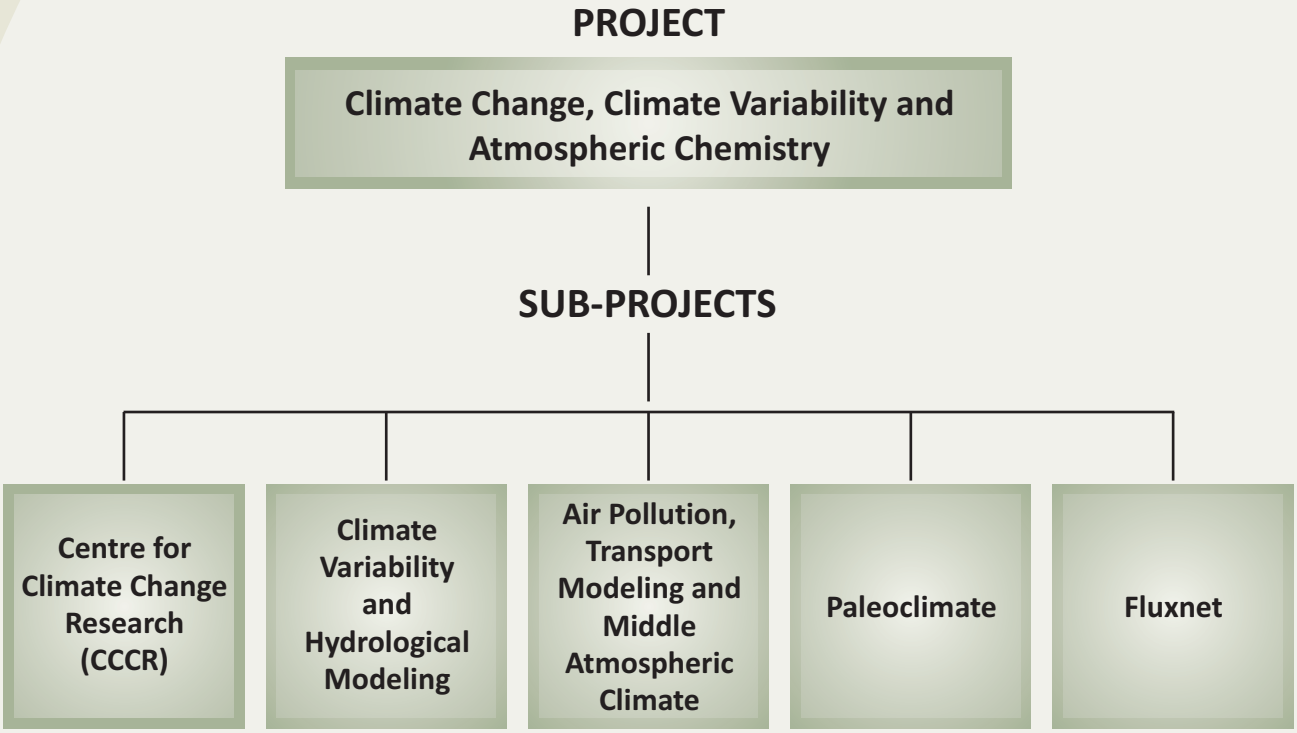
Chief Project Scientists : **Dr. R. Krishnan** and **Dr. G. Beig**

Climate shows a wide range of spatio-temporal variability and such variability is closely associated with atmospheric chemistry. Understanding such climate variability and achieving its potential predictability is already a complex problem. Now, climate change has altogether added another higher level of complexity to the problem. Therefore, understanding the nature of climate change on regional time scales is a strong and widely felt need. Climate change scenarios are necessary for the various impact assessment groups and for reducing the uncertainty in the future projections.

An understanding of how the increasing trend of global temperature in the recent decades is affecting global climate, especially monsoon variability and atmospheric chemistry, is required urgently for improving prediction skills. For improving any prediction capability, it is also essential to strengthen basic research in weather forecasting, climate diagnostics, dendro-climatology, climate modelling, climate dynamics, ocean dynamics, energetics of monsoon systems, atmospheric chemistry, air pollution, atmospheric aerosols and trace gas monitoring, atmospheric electricity, weather modification, etc. Such research is also crucial for the development of systems and techniques for long-range model simulation and capacity building for air quality and weather forecasting. In this direction, project SAFAR has been launched with an aim to develop a system for air quality and weather forecasting over metropolitan cities through integrated air quality and weather monitoring network, micro-level emission inventory and high resolution coupled atmospheric chemistry transport modeling. It also aims to understand the microclimate of mega city and to study the processes responsible for extreme pollution events. The data generated for air quality is also used to study impact on human health and crop yield. Another important national network MAPAN (Modeling Atmospheric Pollution And Network) is set-up along with 3-D global chemistry transport modeling framework to study the impact of chemical emissions on the distribution of trace gases regionally as well as globally. The carbon explorations study involves research on carboneous aerosols (black carbon and organic carbon) in different environments in India including some parts of glaciers.

For the ease of execution, the activities under this project are categorised into five sub-projects: 1) Centre for Climate Change Research (CCCR), 2) Climate Variability and Hydrological Modeling, 3) Air Pollution, Transport Modeling and Middle Atmospheric Climate, 4) Palaeoclimate, and 5) Fluxnet.

The main objectives of this project include: development of a high resolution Earth System Model (ESM) incorporating various interactions among the different earth system components (viz., atmosphere, ocean, biosphere, hydrosphere, cryosphere, etc.), studying monsoon variability and predictability by identifying regional and global climate drivers and to identify useful predictors, establishing expertise in air quality forecasting using interactive meteorology-atmospheric chemistry transport model, climate reconstructions through high resolution proxies for understanding long-term monsoon climate variability over the Asian region, capacity building in global and regional climate modeling, generating reliable climate inputs for impact assessments, understanding the impact of aerosol chemistry on the Indian Monsoon, measuring GHG fluxes, studying CO_2 flux in tropical ecosystems, establishing a Multi-parameter Dendroclimatological Network over India (MDNI) for reconstructing the spatio-temporal variability of pre-monsoon and monsoon climate signals, to establish base line network of monitoring atmospheric pollutants, to monitor tropospheric vertical distribution and seasonal variability in Black carbon/OC and air pollutants over India with special reference to Indo-Gangetic plane to study radiative forcing over Indian region and climatic impact assessment, etc.


PROJECT
Climate Change, Climate Variability and Atmospheric Chemistry
SUB-PROJECTS
Centre for Climate Change Research (CCCR)
Climate Variability and Hydrological Modeling
Air Pollution, Transport Modeling and Middle Atmospheric Climate
Paleoclimate
Fluxnet

Centre for Climate Change Research (CCCR)

Deputy Chief Project Scientist : **Dr. K. Ashok**, Scientist-E

Objectives:

- To identify and explore new areas of research that will contribute to the fundamental understanding of the Earth's climate system.
- Enhancement of knowledge on regional climate change over the Indian subcontinent.
- To understand the nature of biogeochemical interactions and their response to environmental change.
- To understand the impacts of global warming on planetary scale phenomena like monsoons and El-Niño.
- To create and update information reservoirs for better assessment of changes and impacts.
- To generate technology based knowledge products based on climate studies.
- Building linkages with national and international research groups to optimally leverage scientific capabilities for climate change research.

Developmental Activities

Towards the development of the Indian Earth System Model: achievements and initial results

This year, the main efforts in this direction include: (i) extending the available 50-year IITM-CCCR Earth System Model version 1 (ESMv1) simulation through the 100-year simulations, (ii) verification of the sustained improvement in reduction of cooling bias relative to the predecessor and diagnosing the reason for improvement, and (iii) to initiate development of a low resolution model.

So far, several 100-year climate simulations with the CFSv2, a fully coupled GCM, were successful. Maintaining the lead, a 100-year simulation with the ESMv1 was successfully completed, as mentioned in the 2012-13 annual report of the Institute, the model is the first of its kind to be developed in India. The model has an atmosphere@T106, ocean@360X200X40 and contains a state-of-the-art biogeochemistry and ecosystem module, named TOPAZ. Note that the TOPAZ module has been switched off in order to objectively compare the results from this run with the available comparable simulations of the CFSv2, which does not have such a module.

The results from the 100-year simulation confirm that the cold bias present in the long-term simulations by the CFSv2, the base model, have indeed substantially decreased in ESMv1 (**Fig. 1**).

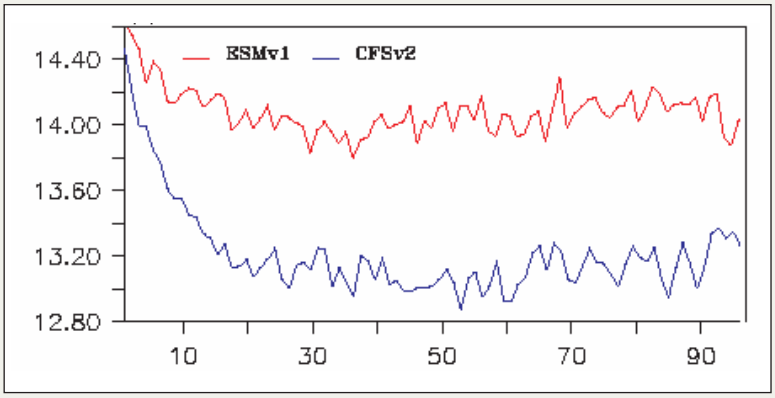


***Fig. 1**: The time evolution of simulated global mean temperature from the IITM-CCCR ESM-v1 (red), and CFSv2 (blue). The X-axis and Y-axis represent the years elapsed from the initial conditions and temperature in ^{0}C respectively. The model integrations start with initial conditions of December 2009. The observed global mean temperature for the 2000-2010 period, computed from the Hansen's data, stands at 14.5^{0}C for reference.*

The model also simulates the ENSO variance (**Fig. 2**) and its observed inter-annual variability reasonably well. It is known that many current generation models fail to reproduce the ENSO-Monsoon lead-lag relationships. However, the results from the 100-year run show that the model is successful in capturing the observed ENSO-Monsoon lead-lag cycle. Further, for a model slated to study the climate change issues, it is imperative that it captures the natural decadal variations. From this context, it is noticeable that the model successfully simulates the observed pacific decadal oscillation (PDO) structure and its variability.

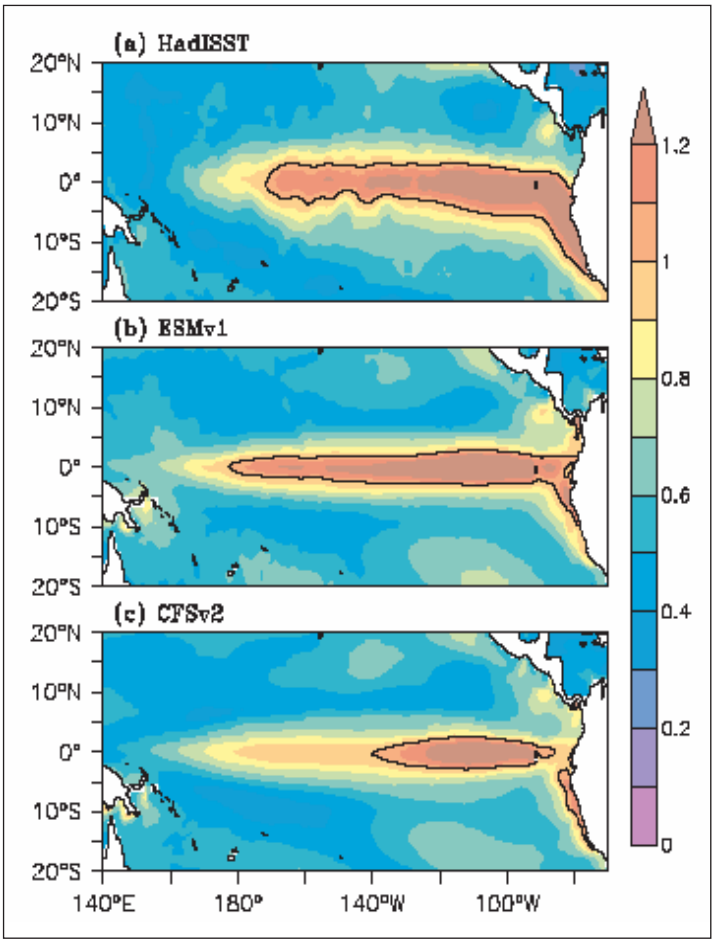


Fig. 2: *Standard deviation of interannual SST anomalies (°C) for (**a**) HadISST (**b**) ESMv1 and (**c**) CFSv2.*

A critical issue in CFSv2 that apparently manifested in various missed layers, SST and atmospheric temperature bias is that warmer-than-observed temperatures extend deeper in CFSv2 as shown by the position of the 4°C isotherm in the zonally-averaged vertical profiles of temperature (**Fig. 3**). This implies that pumping of heat away from the surface into deeper layers of the ocean takes place in CFSv2 resulting in cooling of the surface and warming the ocean below. The ESMv1 simulation, on the other hand, indicates a significantly improved fidelity. This improvement, among other things, apparently resulted in the reduction in mixed layer depth bias, reduced cold bias in SST in the tropics and in the region of northern subtropical gyres in ESMv1 and eventually, the global atmospheric temperature (**Fig. 1**). The improved vertical distribution of the global ocean zonal mean temperature (°C) by ESMv1 relative to that of the CFSv2 may be due to the effect of mixing and transport by sub-mesoscale eddies included in ESMv1 by incorporating the *Fox* and *Kemper* (2011) sub-mesoscale parameterization, which allows the lateral transport by mesoscale eddies and prevents the pumping of heat away from the surface to the deeper layers.

The ESMv2 framework envisages a fully functional aerosol module implemented into the ESMv1. The implementation strategy involves two stages of development. The recently completed first stage addresses development of an interface for sub-model registrations, initialization, introduction of anthropogenic emission files and inventory updates in the ESMv2 framework. The next stage involves incorporating aerosol transport modules to allow interactions between aerosol and radiation. The same has already started and is expected to be completed by the early 2015.

CORDEX Regional Climate Model's Performance in the present day climate for South Asia

Under the Coordinated Regional Climate Downscaling Experiment (CORDEX), efforts were made for collecting, collating and distributing downscaled CMIP5 future projections, at about 50 km scale, from five regional models. In addition, a comparison study of the downscaled historical projections for 1990-2004 with the corresponding coarser resolution CMIP5 model products was carried out for 10 selected sub-regions of South Asia. Analysis indicates that the dynamically downscaled products provide relatively more realistic information such as an improved mean seasonal precipitation cycle in regions having complex topography (*e.g.*, Nepal, Bangladesh, Bhutan and Myanmar) as compared to the coarser CMIP5 outputs.

The fidelity of regional climate models (RCMs) in reproducing the observed regional climate is important for providing reliable information of regional climate change. CORDEX, initiated by WCRP, provides a framework to understand model uncertainties through the use of multiple RCMs which are

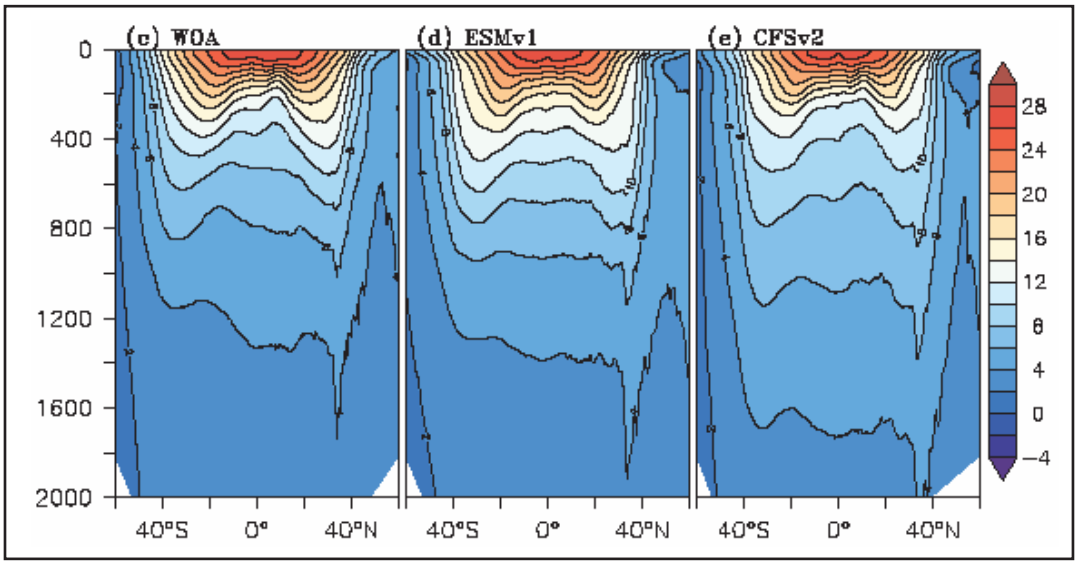
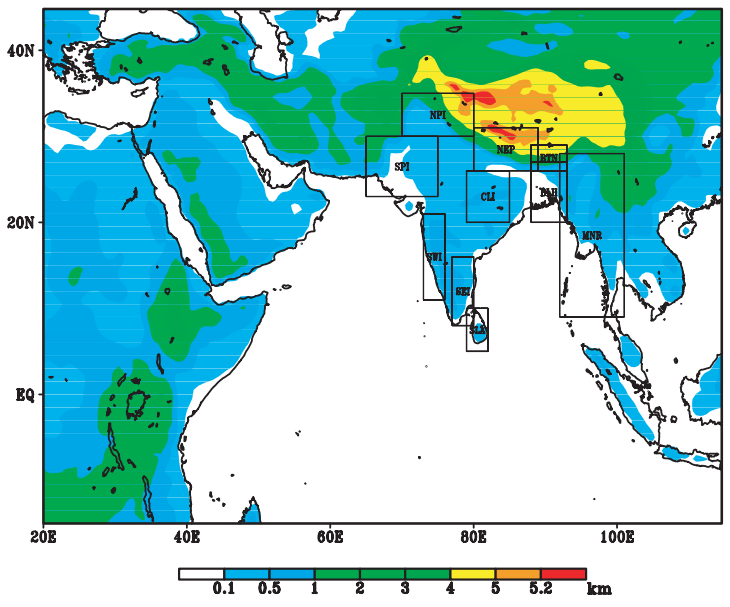


Fig. 3: *Left panel shows vertical distribution of the global ocean zonal mean temperature (^{0}C) from WOA. The middle and right panels present the corresponding distributions simulated by the ESMv1 and CFSv2 respectively.*

driven by boundary conditions from the state-of-the-art coupled atmosphere ocean general circulation models (AOGCMs). An evaluation of RCMs participating in the CORDEX South Asia evaluation and historical experiments in comparison with AOGCMs participating in the fifth phase of the Coupled Models Inter-comparison Project (CMIP5) was carried out. The simulated precipitation annual cycle for 1990-2004 in the selected ten sub-regions over South Asia (**Fig. 4**) suggests that the dynamical downscaling of CMIP5 AOGCM outputs using RCMs to the scale more suited to end-users for understanding local monthly precipitation climate in regions that have complex topography such as Nepal, Bangladesh, Bhutan and Myanmar (**Fig. 5**).

About 200 active users have registered this year with the CORDEX data distribution server for using the CORDEX outputs.



Label	Sub-regions as shown in boxes
R1	Central India (CLI)
R2	South West India (SWI)
R3	South East India (SEI)
R4	North Pakistan & India (NPI)
R5	South Pakistan & India (SPI)
R6	Nepal (NEP)
R7	Bangladesh (BLH)
R8	Bhutan (BTN)
R9	Srilanka (SLA)
R10	Myanmar (MNR)

Fig. 4: *The topography (in km) over the domain used for the CORDEX South Asia RCM simulations with 0.44^0 horizontal resolution.*

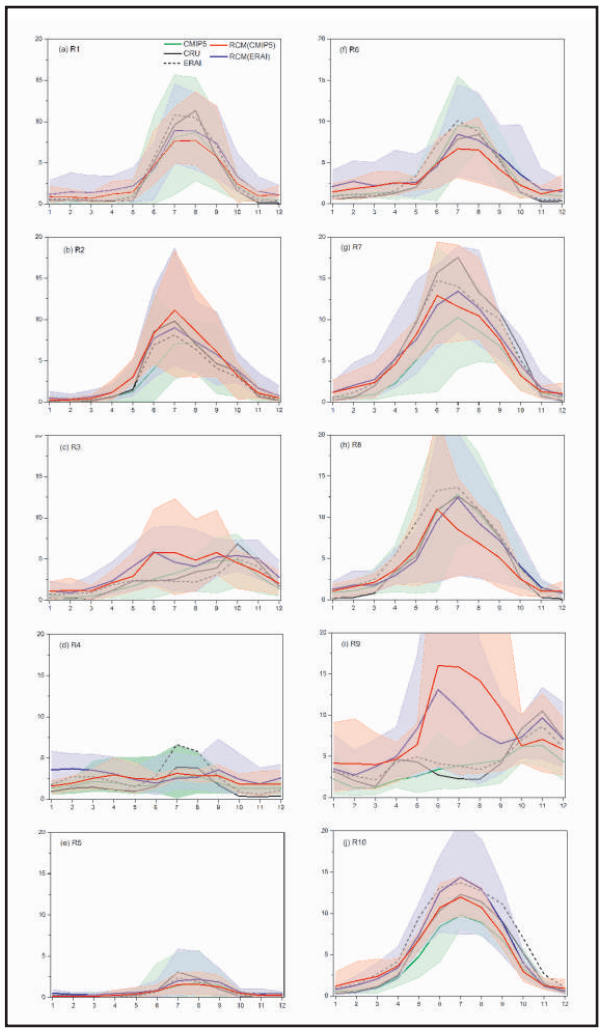


Fig. 5: *The simulated precipitation annual cycle for 1990-2004 in 10 selected sub-regions over South Asia. The ensemble mean (thick lines) and the range (shading) for CMIP5 AOGCMs (green), RCMs driven with ERA interim (blue) and RCMs driven with AOGCMs (red) are shown. The CRU observations (black line) and ERA interim (black dashed line) are also plotted.*

Chemistry Monsoon Interactions in a Changing Climate (CMICC)

A new project, Chemistry Monsoon Interactions in a Changing Climate (CMICC), which focuses on the various aspects of interaction of monsoon dynamics with atmospheric chemistry in a changing climate has been initiated with setup of instruments for measuring oxidative species and atmospheric chemistry focused model studies. Past studies have suggested that observed increasing trends in anthropogenic emissions (CO, CH_4, CO_2, H_2O, volatile organic compounds, ozone precursors, aerosol, etc.) could show circuitous linkages with monsoon precipitation and also, affect global atmospheric chemistry. Monsoon circulation perturbs the distribution of atmospheric constituents which may feedback on monsoon circulation through changes in radiative balance, temperature, cloud microphysical processes, etc. The complex feedback loop involving coupled chemistry-dynamics linkages is to be studied under this project. The first study which has been conducted under this project is on the convective transport of peroxyacetyl nitrate (PAN), which is a source of NO_x and hence, ozone in the remote environment. Satellite based PAN retrievals from the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) were analyzed in the altitude range 08-23 km over the Asian summer monsoon (ASM) region during 2002-2011. The largest enhancements of PAN mixing ratios in the upper troposphere and lower stratosphere (UTLS) are seen during the ASM season from June to September (**Fig. 6**). During the monsoon season, PAN concentration in the UTLS increases by 2.75 ± 1.87 to 7.88 ± 4.50% per year which is higher than annual mean (1.88 ± 1.74 to 7.1 ± 2.8% per year) over the ASM region. This increased concentration points to increasing NO_x (= NO + NO_2) and volatile organic compound (VOC) emissions from developing nations in Asia, notably India and China. Influence of monsoon convection on the distribution of PAN in UTLS was also analyzed by using global chemistry-climate model ECHAM5-HAMMOZ simulations. The model results show that transport over the Asian region primarily occurs from two convective zones, one extending from the Bay of Bengal to the South China Sea and the other over the southern flank of the Himalayas. The contributions from enhanced NO_x emission to change in PAN, HNO_3 and O_3 concentrations in the UTLS due to emissions from India and China were also evaluated using sensitivity based model simulations. The model results show that Chinese emissions are fed into the monsoon anti-cyclone more effectively than from India. In the convective zone south of the Himalayas, NO_x is locked up as HNO_3 and removed by wet scavenging. There appears to be a higher degree of intermittency of NO_x injection into the UTLS from Indian emissions compared to Chinese emissions. These preliminary results show a relatively smaller role of Indian emissions to global contaminants such as PAN and a need to investigate in further detail to

quantify the effect of emissions from India on the global oxidizing budget.

This is planned to be studied through model simulations and observations of critical trace gases, which have not been observed to date. Under the CMICC project, the building of instruments for measurement of the main oxidizing agent, the hydroxyl radical, has been started. Observations of other key chemical species such as halogens and green house gases have also been initiated at key locations in the Indian subcontinent and in high climate sensitivity regions such as the Southern Ocean and Antarctica (through a collaborative project with the National Centre for Antarctic and Oceanic Research (NCAOR)) to quantify the impact of atmospheric chemistry on local and global climate.

Basic Research

Indian Ocean and monsoon coupled interactions in a warming environment

Several studies have drawn attention to the steady warming of the equatorial and tropical Indian Ocean (IO) sea surface temperature (SST) observed during recent decades. An intriguing aspect of the IO SST warming trend is that it has been accompanied by a pronounced weakening of the large-scale boreal summer monsoon circulation. Based on a detailed diagnostic analysis of observed datasets and reanalysis products, this study examines how the observed changes in the summer monsoon circulation could have contributed to this SST warming trend. The results reveal that the weakening trend of the summer monsoon cross-equatorial flow has favoured a re-orientation of surface westerlies towards the equatorial IO during recent decades, relative to summer monsoons of earlier decades, which were dominated by stronger cross-equatorial flow (**Fig. 7**). The findings suggest that the weakening of the summer monsoon cross-equatorial flow has in turn significantly accelerated the SST warming in the central equatorial IO. While the trend in the equatorial westerlies has promoted downwelling and thermocline deepening in the eastern equatorial IO, the central equatorial IO warming is attributed to reduced upwelling in response to a weakening trend of the wind-stress curl. The observed trends in Indian monsoon rainfall and the near-equatorial SST warming are shown to be closely related to variations in the meridional gradient of the monsoon zonal winds. *[**Swapna P., Krishnan R.** and Wallace J.M., Indian Ocean and monsoon coupled interactions in a warming environment, **Climate Dynamics**, online, May 2013, DOI:10.1007/s00382-013-1787-8, 1-16]*

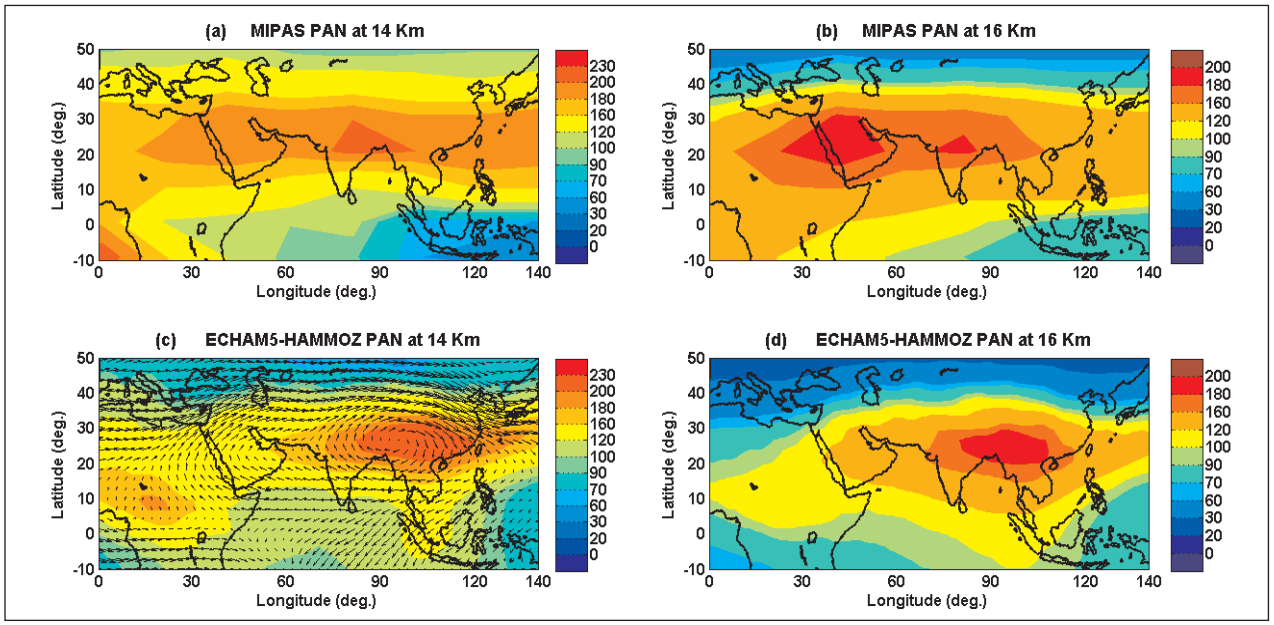


Fig. 6: *Distribution of seasonal mean (monsoon: JJAS) PAN concentration (ppt) as observed by MIPAS (climatology for the period 2002-2011) at (**a**) 14 km (**b**) 16 km and ECHAM5-HAMMOZ baseline simulations for the period 1995-2004 at (**c**) 14 km (**d**) 16 km.*

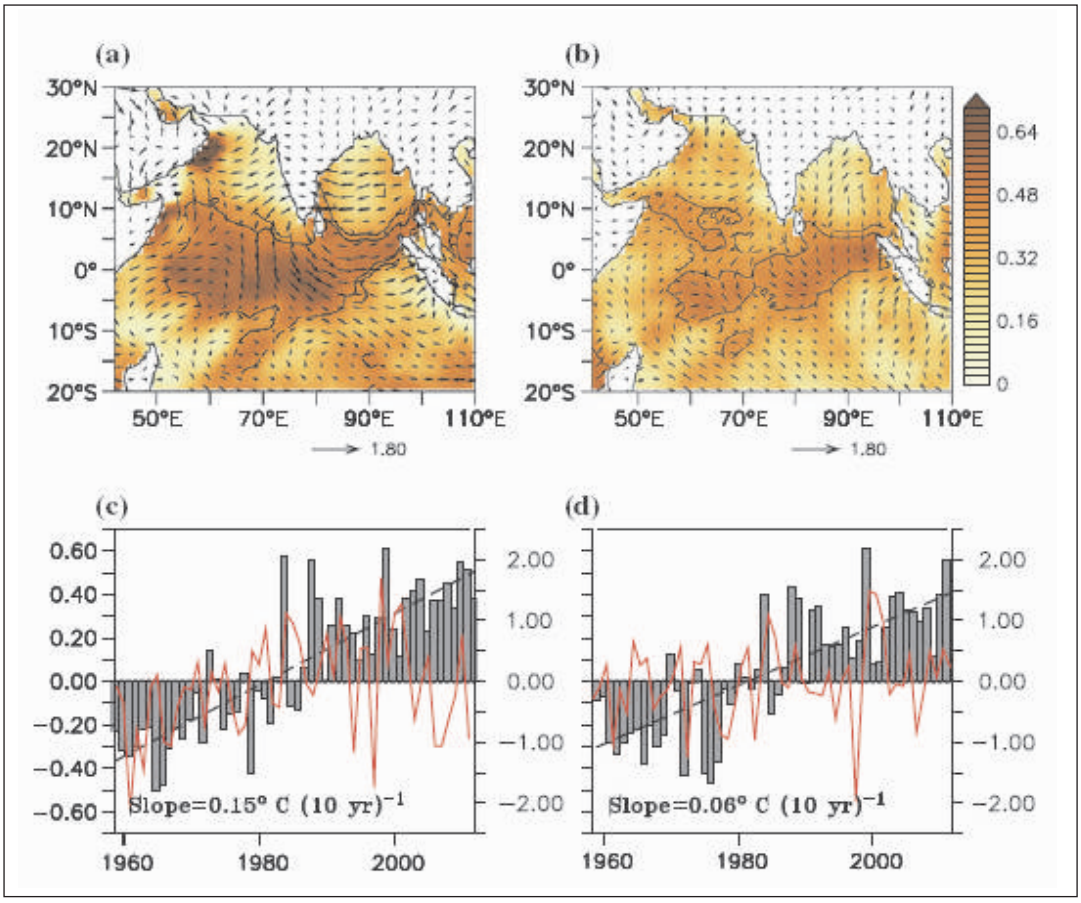


Fig. 7: *Upper panels show spatial map of linear trends in SST (^{o}C per 62 years, the departure from the global mean SST) and ERA surface winds (ms^{-1} per 54 years) in the tropical Indian Ocean for (**a**) June-September monsoon season and (**b**) Remaining calendar months. Color shading indicates the magnitude of SST trends and the contour corresponds to 99% confidence level based on the Student's t-test. The lower panels show time-series of SST (^{o}C) in bars and zonal wind anomalies (ms^{-1}, red lines) averaged over the equatorial Indian Ocean (50^{o}E-100^{o}E; 5^{o}S-5^{o}N) for (**c**) June-September monsoon season and (**d**) Remaining calendar months. The trends of the linear regression best-fit lines exceed the 95% confidence level.*

Transport of aerosols into the UTLS and their impact on the Asian monsoon region as seen in a global model simulation

An eight member ensemble of ECHAM5-HAMMOZ simulations for a boreal summer season was analyzed to study the transport of aerosols in the Upper Troposphere and Lower Stratosphere (UTLS) during the Asian Summer Monsoon (ASM). The simulations showed persistent maxima in black carbon, organic carbon, sulfate, and mineral dust aerosols within the anticyclone in the UTLS throughout the ASM period (July to September) when convective activity over the Indian subcontinent is highest, indicating that boundary layer aerosol pollution is the source of this UTLS aerosol layer. The longitude-pressure cross-section (averaged over 15-35^{o}N) and latitude-pressure cross-section (60-120^{o}E) of aerosols fields are shown in **Fig. 8a** and **8b** respectively. They indicate that the increased vertical transport between 15-30^{o}N and around 100^{o}E reaches into the tropical lower stratosphere. This is the primary transport pathway into the tropical tropopause layer (TTL) and tropical lower stratosphere and it agrees with the observational findings that the southern slopes of the Himalayas are the region with the deepest penetrating convection. However, the convective region from the Bay of Bengal to the South China Sea is also a source of aerosols. Evidence of ASM transport of aerosols into the stratosphere is also found in agreement with aerosol extinction

measurements from the HALogen Occultation Experiment (HALOE) and the Stratospheric Aerosol and Gas Experiment (SAGE) II.

Comparison of model simulations with and without aerosols indicates that anthropogenic aerosols are central to the formation of this transport pathway. The horizontal distribution of aerosol-induced cloud ice (μg/m^3) anomalies at 181 hPa averaged during the ASM season is shown in **Fig. 9a**. It shows a prominent feature where the positive cloud ice anomaly has a maximum (~15mg/m^3) at the eastern end of the anti-cyclone region. **Fig. 9b** shows the seasonal and zonal average (60^{o}E-120^{o}E) latitude versus pressure cross section of aerosol-induced cloud ice anomalies (μg/m^3). It can be seen that cloud ice increase up to 10 μg/m^3 near the tropical tropopause is due to aerosol loading. Thus, aerosols act to increase cloud ice in the model UTLS. Aerosol induced circulation changes include a weakening of the main branch of the Hadley circulation and a reduction of monsoon precipitation over India as noted in previous studies. *[**Fadnavis S.S.**, Semeniuk K., Pozzoli L., Schultz M.G., **Ghude S.D.,** Das S. and **Kakatkar R.**, Transport of aerosols into the UTLS and their impact on the Asian monsoon region as seen in a global model simulation, **Atmospheric Chemistry and Physics**, 13, September 2013, DOI:10.5194/acp-13-8771-2013, 8771-8786]*

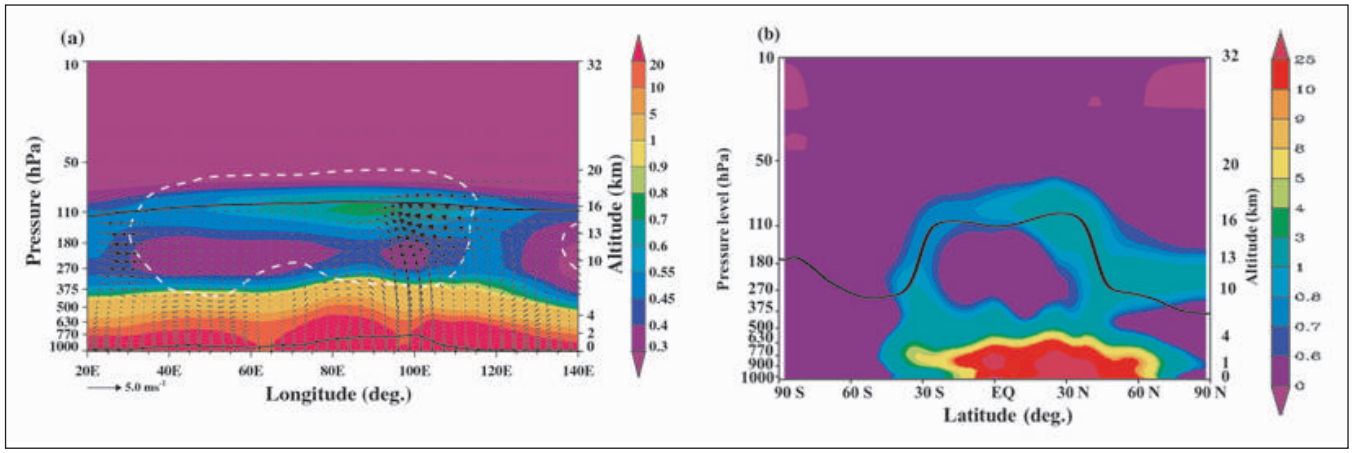


Fig. 8: *(**a**) Longitude-pressure section (averaged for June-September and 15-35^{o}N) of BC aerosols (ng/m^3); (**b**) Latitude-pressure section (averaged for June-September and 60-120^{o}E) of OC aerosols concentrations (ng/m^3).*

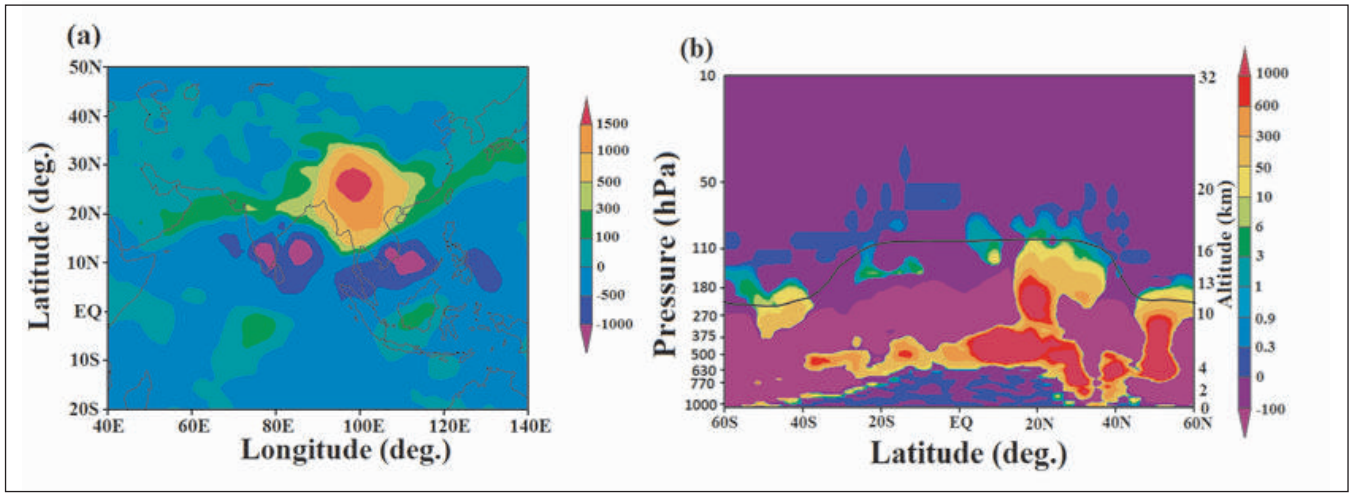


Fig. 9: *Spatial structure of mean cloud ice (μg/m^3) anomalies as obtained from ECHAM5-HAMMOZ CTRL - NOAER runs during ASM. (**a**) Pressure level slice at 181 hPa. (**b**) Latitude-pressure distribution averaged over 60-120^{o}E.*

Enhanced production of oxidized mercury over the tropical Pacific Ocean: A key missing oxidation pathway

Mercury is a contaminant of global concern. It is transported in the atmosphere primarily as gaseous elemental mercury, but its reactivity and deposition to the surface environment, through which it enters the aquatic food chain, is greatly enhanced following oxidation. Measurements and modeling studies of oxidized mercury in the polar to sub-tropical marine boundary layer (MBL) have suggested that photolytically produced bromine atoms are the primary oxidant of mercury. Year-round measurements of elemental and oxidized mercury along with ozone, halogen oxides (IO and BrO) and nitrogen oxides (NO_2) were carried out in the MBL over the Galápagos Islands in the equatorial Pacific. Elemental mercury concentration remained low throughout the year, while higher than expected levels of oxidized mercury occurred around midday. Results show that the production of oxidized mercury in the tropical MBL cannot be accounted for by bromine oxidation only or by the inclusion of ozone and hydroxyl. As a two-step oxidation mechanism, where the HgBr intermediate is further oxidized to Hg(II), depends critically on the stability of HgBr. An additional oxidant is needed to react with HgBr to explain more than 50% of the observed oxidized mercury (**Fig. 10**). Based on the best available thermodynamic data, it is shown that atomic iodine, NO_2, or HO_2 could all play the potential role of the missing oxidant, though their relative importance cannot be determined explicitly at this time due to the uncertainties associated with mercury oxidation kinetics. It can be concluded that the key pathway that significantly enhances atmospheric mercury oxidation and deposition to the tropical oceans is missing from the current understanding of atmospheric mercury oxidation. *[Wang F., Saiz-Lopez A., **Mahajan A.S.**, Gómez Martín J.C., Armstrong D., Lemes M., Hay T., Prados-Roman C., Enhanced production of oxidized mercury over the tropical Pacific Ocean: a key missing oxidation pathway, **Atmospheric Chemistry and Physics**, 14, February 2014, doi:10.5194/acp-14-1323-2014, 1323-1335]*

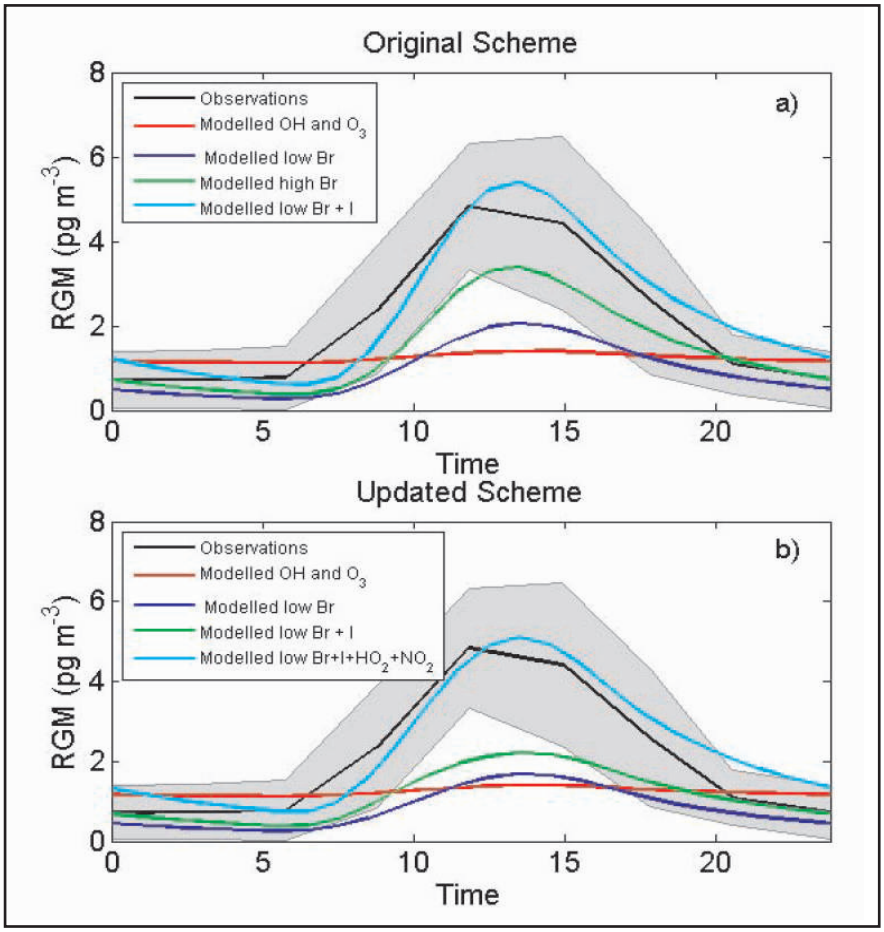


Fig. 10: *Comparison of the average daily profile of reactive gaseous mercury (RGM) during October (grey area indicates the standard deviation of the data) with simulated profiles obtained by two different modeling approaches. (**a**) Modeled results from the commonly used chemistry scheme under four different scenarios. Scenario 1: oxidation is assumed to result only from OH and O_3 (red line). Scenario 2 adds bromine oxidation using a peak BrO of 0.2 pptv (blue). Scenario 3 (green) assumes BrO to be at the detection limit of the DOAS instrument (0.5 pptv). Scenario 4 (cyan) shows a simulation with 0.2 pptv of BrO and the observed levels of IO, an average of 1 pptv during the daytime. (**b**) Modeled results using an updated chemistry scheme.*

Climate Variability and Hydrological Modeling

Deputy Chief Project Scientist : **Dr. R. Krishanan,** Scientist-G

Objectives:

- To understand the science of hydrological response to climate change using high-resolution climate models.
- Development of hydrological models for assessing the impacts of climate change on the river basins of South Asia.

Basic research

Falling monsoon depression frequency

The annual monsoon depression frequency making landfall on the east coast of India shows a statistically significant decreasing trend for the period 1979-2010. Importantly, about 80% of this fall is confined to the south of 20°N. Seasonal mean *in-situ* parameters important for tropical cyclogenesis are examined to understand the plausible reason(s) for this decreasing trend. Various observational data from IMD and three atmospheric climate reanalysis datasets were used to account for the possible quality constraints in them. The study suggests that the observed weakening of monsoon depression frequency south of 20°N in the Bay of Bengal is likely due to the declining trend in the mid-tropospheric relative humidity over the Indian region (**Fig. 1**). Numerical sensitivity experiments carried out using an axis-symmetric tropical cyclone model strongly support the hypothesis that weakened mid-tropospheric humidity results in inhibition of the amplification of the initial cyclonic perturbations. *[**Prajeesh A.G., Ashok K.**, Bhaskar Rao D.V., Falling monsoon depression frequency: A Gray-Sikka conditions perspective, **Scientific Reports**, 3:2989, October 2013, DOI: 10.1038/srep02989, 1-8]*

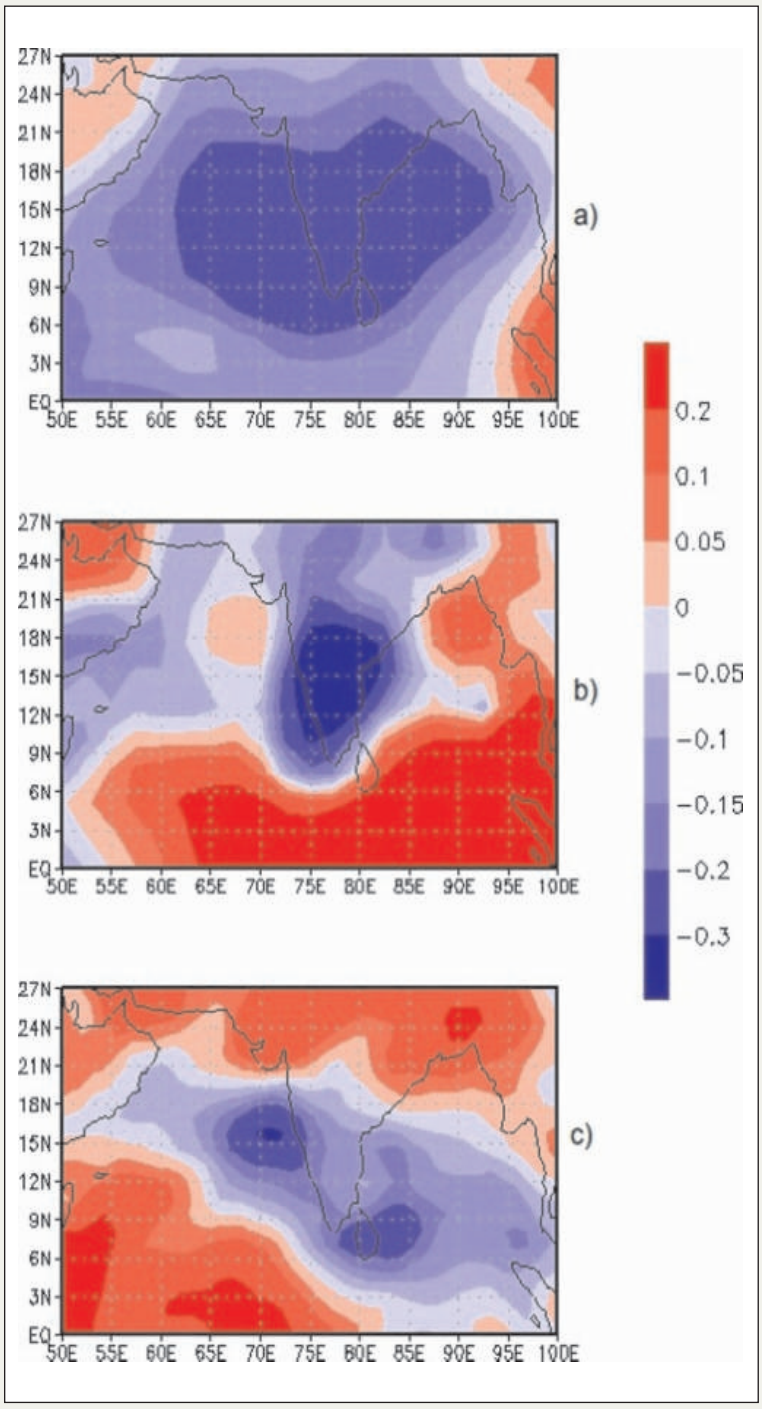


Fig. 1: *Spatial map of trends in mid-tropospheric relative humidity in different re-analysis products. (**a**) NCEP reanalysis (1950-2010), (**b**) ERA-40(1958-2002), and (**c**) MERRA (1979-2010).*

Anomalous precipitation enhancement over the Himalayan foothills during monsoon breaks

The spatio-temporal variability of rainfall over the Himalayas is poorly known as compared with many other mountains of the world. This may be due to a sparse network of gauge observations and the topographical complexity. Further, an intriguing feature associated with 'breaks' in the Indian summer monsoon is the occurrence of flood-producing precipitation confined to the central-eastern parts of the Himalayan (CEH) foothills and the north-eastern parts of India. Past studies have documented various large-scale circulation aspects associated with monsoon-breaks. However, the dynamical mechanisms responsible for anomalous precipitation enhancement over CEH foothills remain unclear. This problem is investigated using diagnostic analyses of observed and reanalysis products and high-resolution Weather Research and Forecasting (WRF) model simulations. This study shows that the anomalous precipitation enhancement over the CEH foothills during monsoon-breaks emerges as a consequence of interactions between southward intruding mid-latitude westerly troughs and the South Asian monsoon circulation in its weak phase. These interactions facilitate intensification of mid-tropospheric cyclonic vorticity and strong ascending motion over the CEH foothills, so as to promote deep convection and concentrated rainfall activity over the region during monsoon-breaks. Mesoscale orographic effects additionally tend to amplify the vertical motions and precipitation over the CEH foothills as evidenced from the high-resolution model simulations. It is further noted from the model simulations that the coupling between precipitation and circulation during monsoon-breaks can produce nearly a 3-fold increase of total precipitation over the CEH foothills and the neighborhood as opposed to active-monsoon conditions (**Fig. 2**). As persistent monsoon-break situations generally result in all-India drought and flash flooding in the CEH foothills, changes in the frequency of break monsoon conditions is a serious concern that can have profound impact on the water resources. *[**Vellore R.K., Krishnan R., Pendharkar J., Choudhury A.D.** and **Sabin T.P.,** On the anomalous precipitation enhancement over the Himalayan foothills during monsoon breaks, **Climate Dynamics**, online, January 2014, DOI:10.1007/s00382-013-2024-1, 1-22]*

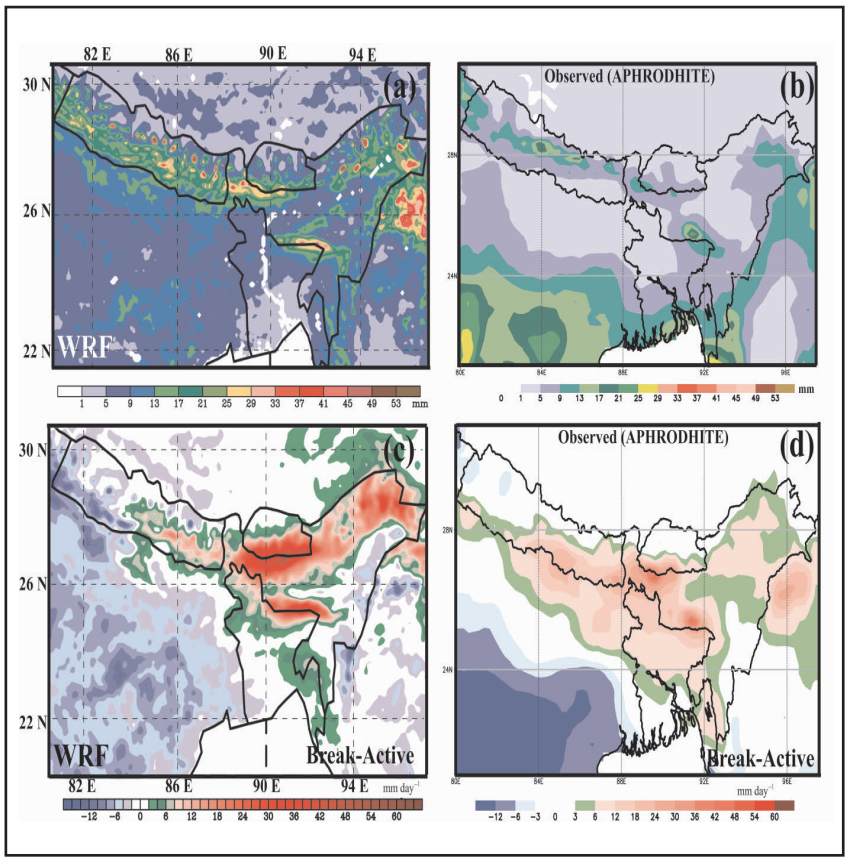


Fig. 2: *(**a**) WRF-simulated and (**b**) observed rainfall rate (mm day^{-1}) during active monsoon periods, and the rainfall difference (mm day^{-1}) between break and active periods from (**c**) simulations and (**d**) observations in north-eastern parts of India. Observations are from the APHRODITE (0.25^{o} × 0.25^{o}) rainfall dataset.*

Air pollution, Transport Modeling and Middle Atmospheric Climate

Deputy Chief Project Scientists : **Dr. D.M. Chate**, Scientist-E and **Dr. K. Ali**, Scientist-E

Objectives:

- Development of a state-of-the-art air quality forecasting and extreme air pollution warning system for Indian Metropolitan cities called SAFAR (System of Air quality Forecasting And Research) and to quantify impact on human health and food security**.**
- Modeling Air Pollution And Networking (MAPAN) for Indian domain to validate the regional model and to further investigate the role of anthropogenic versus long range transport of chemical and dynamical parameters.
- 3-D atmospheric chemistry transport modeling to investigate the intercontinental transport of pollutants.
- To study the behaviour of carboneous aerosols in different environments in India and glaciers and their role in climate change.

Developmental Activities

- **SAFAR-Pune:** IITM has successfully developed a system which gives the information on current as well as 24-72 hour advance forecast for air quality and weather parameters for Pune Metropolitan Region (PMR) including Pune and Pimpri Chinchwad cities and is named as 'SAFAR-Pune'. SAFAR-Pune will help the citizens to understand the quality of Puneri-Air. The system works on four different components simultaneously, viz. establishing dense network of air quality and weather monitoring stations, development of emission inventory, developing forecasting model and representing air quality in terms of air quality index, combined results of which give air quality and weather forecast which is then translated into information for the citizens of Pune so only colours and codes will speak. Information and advisories about the ultraviolet radiation dose also will be provided. The term 'UV-Index' is a measure of the amount of skin damaging UV-radiation expected to reach the Earth surface at the time when the sun is highest in the sky (mid-day). The UV-Index for India is developed and proposed by the scientists of the Ministry of Earth Sciences after extensive research work based on the analysis of the time series of long term stratospheric ozone data and carrying forward from the guidelines of WHO. The UV-Index provides the expected risk of over exposure to the sun.

Under the project, 10 Air Quality Monitoring Stations have been established (**Fig. 1**) at Bhosari (Growth lab, PCMC), Nigdi Pradhikaran (Jal shudhikaran Kendra, PCMC), Alandi (MIT), Pashan (IITM), Shivajinagar (Shimla Office), Dhanakawadi (Bharati Vidyapeeth), Hadapsar (Lohiya Udyan, PMC), Manjari (VSI), Lohegaon (Pune Airport) and Girinagar (DIAT) spread across Pune Metropolitan Region (PMR) representing different environmental conditions in the city. The parameters selected for monitoring includes PM_{10}, $PM_{2.5}$, CO, NO_x, VOCs, O_3 and BC which have direct link with the health of individuals along with the weather parameters: temperature, humidity, wind speed, wind direction, rainfall and solar radiation. For the first time under SAFAR-Pune, levels of mercury are also being monitored. All this information will be received at SAFAR-Control room where after rigorous quality control and quality check, information will be disseminated in very simple and user friendly format for the public through 12 digital display boards, SAFAR website, e-mail alerts, SMS alerts and interactive voice response service (IVRS). Interactive voice response service (IVRS) is presently available for two cities, Pune and Delhi, where citizens can get the current and 24 hour advance forecast information on air quality and weather by dialling a toll free number. The 12 digital display boards are established at locations having maximum visibility including Swargate, Mandai, Katraj Snake Park, Alaka Talkies Chowk, Hadapsar Gadital, PMC office, IITM Pashan, Shimla Office Shivajinagar, Pune airport, Chafekar Chowk Chinchwad, Pimpri Chowk and Alandi.

Fig. 1: *Inner and outer view of SAFAR Air Quality Monitoring Station (AQMS) and Automatic Weather Station (AWS).*

Under the project, a new concept has been developed 'Air Quality and Weather-Assessment and Data on Hi-Tech-Digital India (AWADHI)' which one can say is a One-Stop-Shop for metro air quality and weather information for all SAFAR stations at Master Control Room of SAFAR. Often a need is felt that the scientific research work or the product which is generated should be translated in a simplistic language which could be understood by a common man. Effort has been made by a team of scientists and research students in this direction and a report on SAFAR-Pune is prepared in three languages namely, Hindi, English and Marathi.

- **SAFAR-Mumbai:** In an effort to initiate the development of SAFAR-Mumbai, survey by IITM team with officials from Mumbai Municipal Corporation was conducted to identify strategic locations for the establishment of monitoring stations under SAFAR (AQMS and AWS) covering all kinds of micro-environments as per the WMO guidelines which should include background, coastal, industrial, traffic insertions and residential sites within Mumbai Metropolitan Region. The scientific basis of selection to capture pollutants from upwind direction and oceanic site has also been considered. Also, locations are identified for installations of public display boards where maximum public viewing is available.

- **Development of Emission Inventory for Mumbai-SAFAR:** Pollutants are added to the environment through emissions of various natural as well as anthropogenic sources. One of the most crucial parts of SAFAR is to generate primary data and to validate the secondary data for the development of micro-level emission inventory for Mumbai. This effort for Mumbai SAFAR has been initiated with a one day oriental workshop organized on 03 December 2013 at the International Institute of Population Sciences, Mumbai by involving 250 students from various educational institutes of Mumbai for collecting series of primary and activity data for developing the emission inventory. The emission inventory campaign was successfully completed with more than 50,000 samples collected. Detailed analysis for quality control and quality check for the same are under progress. Then, such data will be used along with secondary data collected from different departments of BMC, MPCB, Mumbai RTO, etc. for developing high resolution emission inventory for Greater Mumbai region which will provide an important input to air quality forecasting model being set-up for predicting Mumbai air quality. The generation of primary and activity data related to industrial, transport, residential and other sectors is going on. Emission inventories are being prepared for NO_x, CO, $PM_{2.5}$, PM_{10}, VOCs, SO_2, BC and OC in a region of 60x60 km centered around Mumbai with 1km x 1km resolution using GIS based statistical model.

Basic Research

Quantifying the effect of air quality control measures during the 2010 Commonwealth Games at Delhi, India

In order to understand the effects of policy induced control measures, a network of air quality and weather monitoring stations was set-up across different areas in Delhi under the Government of India's System of Air quality Forecasting And Research (SAFAR) project. The measurements of aerosols, reactive trace gases (*e.g.,* NO_x, O_3, CO) and meteorological parameters were made before, during and after the Commonwealth Games (CWG-2010). **Fig. 2** shows a comparison of one day forecast provided using WRF-Chem simulations along with the 24 hour mean PM_{10} and $PM_{2.5}$ observations at the MDNS site. During the CWG-2010 period, the model does not greatly over predict the concentrations, keeping in mind that the 'weekend effect' is not captured even after the games. It is thus likely that the air quality control measures during CWG-2010 did not result in large reductions in emissions because of the fairly good match between the model and observations. The results indicate that any future air quality control measures need to be well planned and strictly imposed in order to improve the air quality in Delhi, which affects a large population. Thus, the state-of-art integrated SAFAR system that of systematic high resolution data and emission inventories along with WRF-Chem will be directly useful for the future.

*[**Beig G., Chate D.M., Ghude S.D., Mahajan A.S., Srivinas R., Ali K., Sahu S.K., Parkhi N.S., Surendran D.E., Trimbake H.K.,** Quantifying the effect of air quality control measures during the 2010 Commonwealth Games at Delhi, India, **Atmospheric Environment**, 80, December 2013, DOI:10.1016/j.atmosenv.2013.08.012, 455-463]*

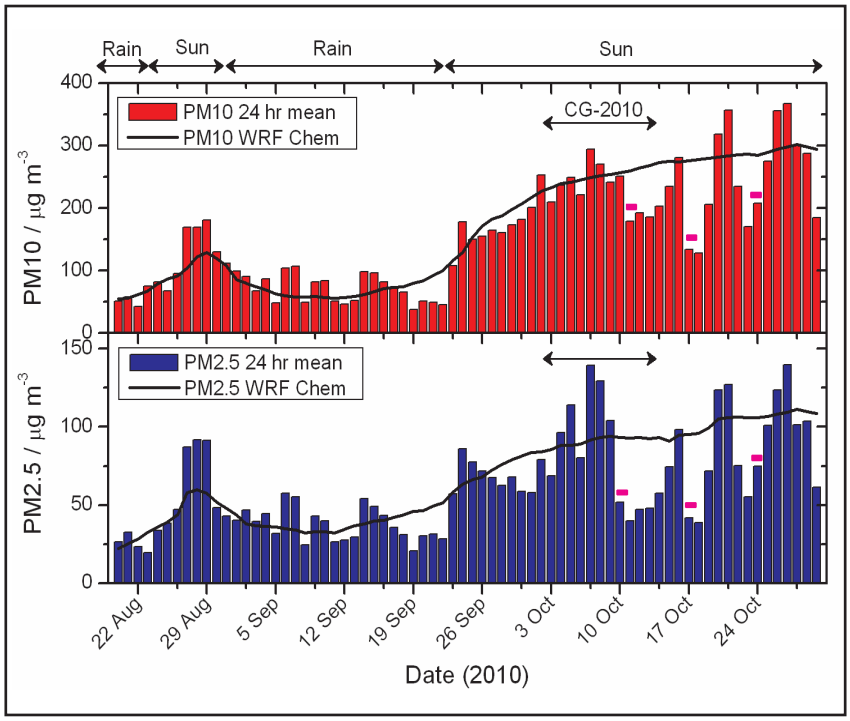


Fig. 2: *A comparison of one day forecast provided using WRF-Chem simulations along with the 24 hour mean PM_{10} and $PM_{2.5}$ observations at the MDNS site.*

Radiative forcing of black carbon over Delhi

The radiative effects of black carbon (BC) aerosols over New Delhi for the period August 2010 to July 2011 have been investigated using Santa Barbara DISTORT Atmospheric Radiative Transfer (SBDART) model. **Fig. 3** shows the average variation in BC radiative forcing obtained over Delhi at the surface, at the top of the atmosphere (TOA), and in the atmosphere every month. It has been observed that the monthly mean BC forcing is the highest in the month of November (66 ± 6.86 Wm^{-2}) and December (65.43 ± 6.9 Wm^{-2}). The forcing solely due to BC during winter was found to be - 45.31 Wm^{-2} at the surface and +20.45 Wm^{-2} at TOA, indicating strong radiative absorption by BC. The lowest forcing is found to be in the month of July (23 ± 3.89 Wm^{-2}). This could be due to the fact that, in normal conditions, the amount of atmospheric aerosols is minimum during the monsoon months (JJAS) because of the scavenging due to wet removal processes. During the XIX Commonwealth Games (CWG-2010) in Delhi, the Government of Delhi set up a plan to reduce emissions of air pollutants during the Games from 03 October to 14 October 2010. But opposite to the

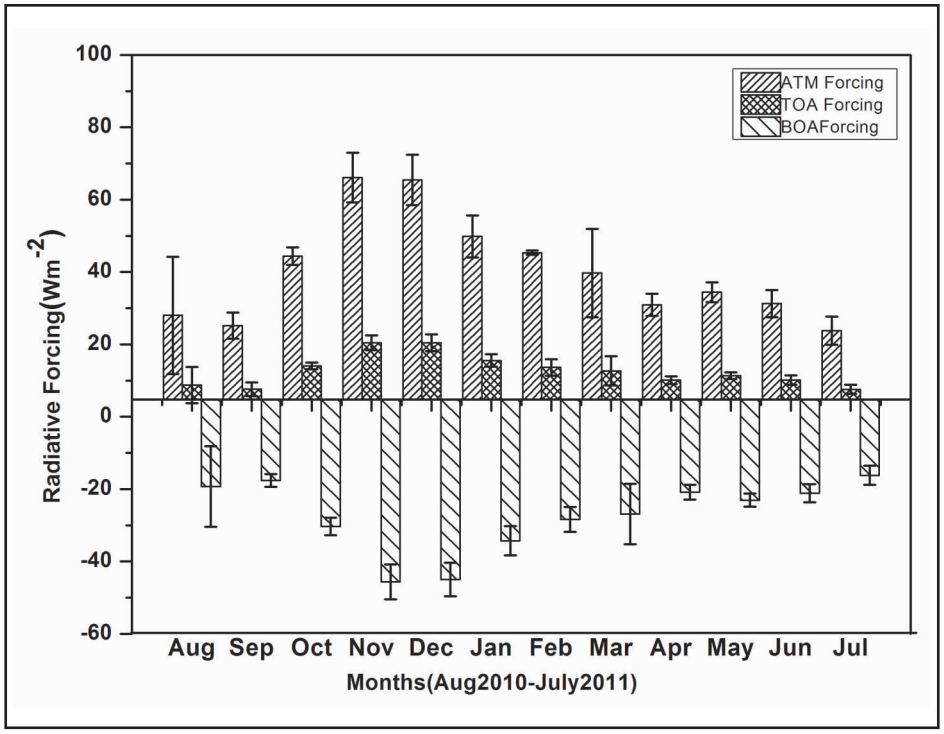


Fig. 3: *Variation of monthly averages of clear sky BC radiative forcing over top of the atmosphere (TOA), bottom of atmosphere (BOA) and in the atmosphere from August 2010 to July 2011.*

expectations, the emission controls implemented were not sufficient to reduce the pollutants like black carbon (BC), and therefore, relatively a high value of BC radiative forcing (44.36 ± 2.4) was observed during the month of October 2010. *[**Surendran D.E., Beig G., Ghude S.D., Panicker A.S., Manoj M.G., Chate D.M., Ali K.,** Radiative forcing of black carbon over Delhi, **International Journal of Photoenergy**, 2013, November 2013, DOI:/10.1155/2013/313652, ID 313652, 1-7]*

Estimated crop yield losses due to surface ozone exposure and economic damage in India

Yield losses and economic damage of two major crops (winter wheat and rabi rice) due to surface ozone (O_3) exposure using hourly O_3 concentrations for the period 2002-2007 in India were estimated. This study estimates crop yield losses according to two indices of O_3 exposure: 7-hour seasonal daytime (0900-1600 hours) mean measured O_3 concentration (M7) and AOT40 (accumulation exposure of O_3 concentration over a threshold of 40 parts per billion by volume during daylight hours (0700-1800 hours), established by field studies. Results indicate that a relative yield loss of 5-11% (6-30%) for winter wheat and 3-6% (9-16%) for rabi rice using M7 (AOT40) index of the mean total winter wheat 81 million metric tons (Mt) and rabi rice 12 Mt production per year for the period 2002-2007. The estimated mean crop production loss (CPL) for winter wheat are from 9 to 29 Mt accounts for an economic cost loss from 1,222 to 4,091 million US$ annually. Similarly, the mean CPL for rabi rice is from 0.64 to 2.1 Mt, worth 86 to 276 million US$. These calculated winter wheat and rabi rice losses agree well with previous results, providing the further evidence that large crop yield losses occurring in India due to current O_3 concentration and further elevated O_3 concentration in future may pose threat to food security (**Fig. 3 and 4**). *[**Debaje S.B.,** Estimated crop yield losses due to surface ozone exposure and economic damage in India, **Environmental Science and Pollution Research**, online, February 2014, DOI:10.1007/s11356-014-2657-6, 1-10]*

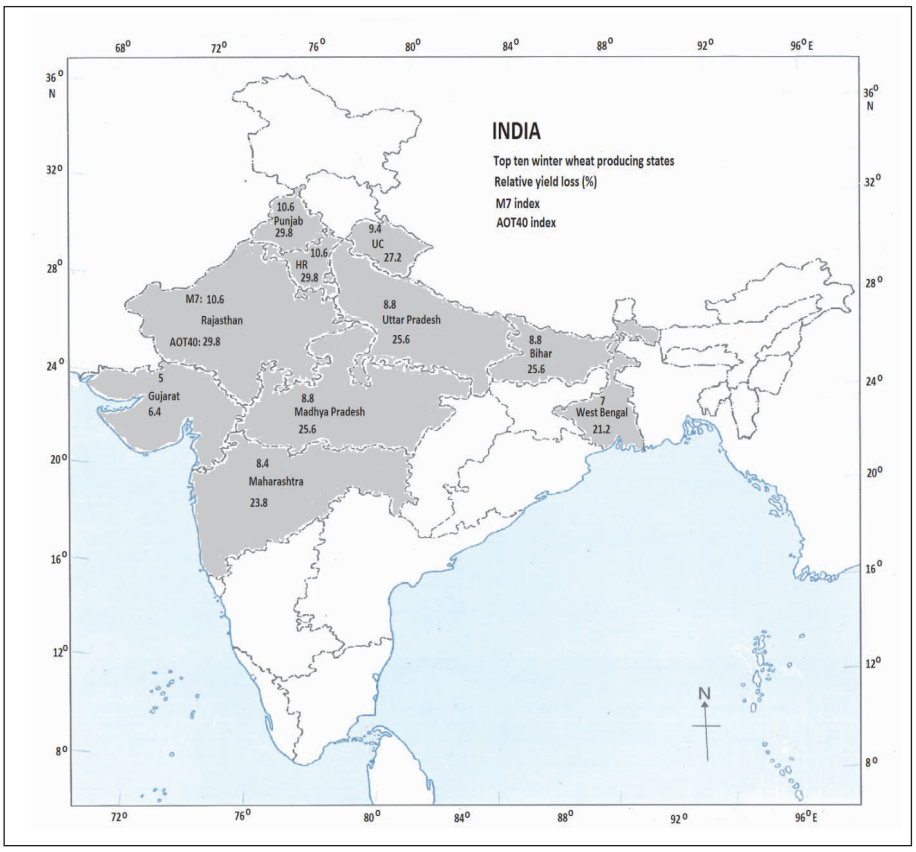


Fig. 3: *Map of India shows the winter wheat relative yield loss (%) per year in top ten states producing winter wheat for the period 2002-2007 due to O_3 exposure according to the M7 and AOT40 indices. HR is Haryana state. Top numbers on the States name is RYL using M7 index and bottom number RYL using AOT40 index. Star mark shows the location of O_3 measurements site.*

Fig. 4: *Map of India shows the rabi rice relative yield loss (%) per year in top ten states producing rabi rice for the period 2002-2007 due to O_3 exposure according to the M7 and AOT40 indices. Star mark shows the location of O_3 measurements site.*

Palaeoclimate

Deputy Chief Project Scientist : **Dr. H.P. Borgaonkar**, Scientist-E

Objectives:

- To develop a wide network of high resolution proxies such as tree-ring, historical records, speleothems, corals, etc. over different parts of India and Asian Monsoon region.
- To develop models to understand the relationship between climate and high resolution proxies such as tree-ring, speleothem, varves, etc. in order to reconstruct the responsive climate parameters of the Indian monsoon going back to a few thousand years.
- To document chief features of climate change based on reconstructed long climate data derived from high resolution proxies and to understand the long-term monsoon climate variability over the Asian region in relation to El Niño/SO, global warming and episodes of prolonged droughts.
- To investigate the isotopic properties of precipitation in wider spatio-temporal scales in order to better use the monsoon proxies such as tree ring and speleothem.

Developmental Activities

Tree Ring width Index Chronology Development from the Himalayas in Sikkim

One of the major difficulties in studying climate change over the Himalayan region is that very few instrumental climate records extend back to 100 years. Particularly over the Himalayas in Sikkim, there is hardly any climate record available. Therefore, the main constraint on making any conclusive remarks towards the climate change scenario over the region is the very sparse network of meteorological data. Information on climate variability over the region on annual to decadal scale for periods longer than the available instrumental records is important for understanding the nature of long-term climate change. In view of this, a couple of field expeditions were carried out recently in the forests in Sikkim to collect tree-ring data for dendroclimatic reconstruction.

More than 100 samples were analyzed in the laboratory for accurate dating using dendrochronological methods. The ring width of the samples was measured and detrended using negative exponential or cubic spline smoothing with the wave length equal to 2/3 of the length of the series. These two detrending methods were found to be appropriate to get optimum common climatic signal. Tree-ring index chronology from Yumthang, North Sikkim indicates moderately high values of lag-1 auto-correlation (persistence), mean sensitivity, common variance (which is mostly due to climate) and signal to noise ratio (SNR). These statistics indicate high dendroclimatic potential of tree-ring chronologies. **Fig. 1** shows the master tree-ring chronology from Yumthang prepared from *Abies Spectabilis* samples.

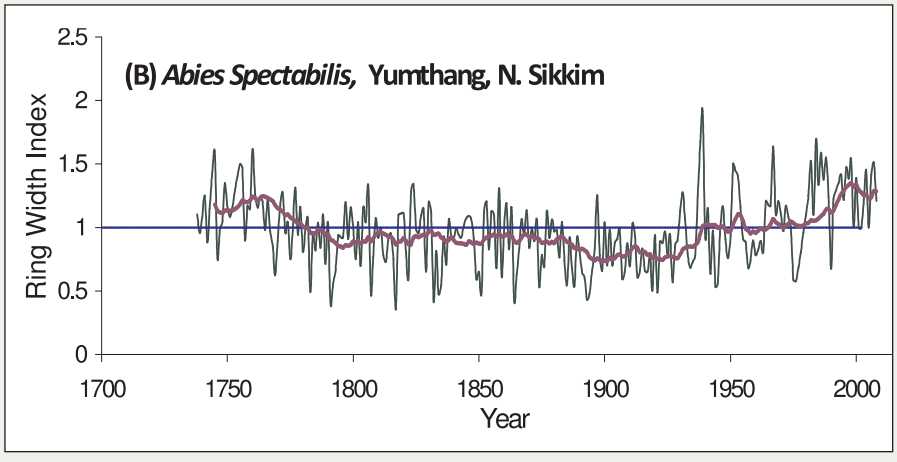


Fig. 1: *Tree-ring chronology of Abies Spectabilis from Yumthang (3200 M amsl), North Sikkim. (A.D. 1738-2008; 270 years)*

A noticeable feature observed in the tree-ring chronology is the unprecedented surge in tree growth after around A.D. 1930. Such anomalous behaviour is not observed prior to A.D. 1930 and can be attributed to the effect of winter warmth. To understand the relationship between climate and tree growth more clearly, analysis of additional tree-ring chronologies from different locations in Sikkim is in progress.

Basic Research

Oxygen isotopic analysis of the Bay of Bengal waters to constrain the ocean circulation

A study was undertaken to constrain the circulation parameters in the Bay of Bengal (BoB) using the oxygen isotope and salinity. Water samples were collected along the depths (surface to 1800 m depth) from 22 locations in the Bay of Bengal during July-August 2009 and December-January 2012-2013. Four water masses were identified based on the temperature-salinity relationship: (a) Bay of Bengal water (0-50 m), (b) Mixed zone (60-120 m), (c) Indonesian through flow (200-500 m), and (d) Indian Ocean deep water (600-1800 m). The study revealed that the $\partial^{18}O$-salinity relation for the BoB water was consistent with surface BoB water reported earlier. Mixing of various water masses was observed underneath the mixed zone. Low salinity water, with depleted isotopic signature from southern hemisphere, spreads up to $18^{0}N$, and the vertical profiles at various sampling locations showed a continuous enrichment of $\partial^{18}O$ within the top 60-100 metres irrespective of their proximity to coastline. It was observed that the sub-surface water $\partial^{18}O$ reached its peak in a zone of mixing between the younger BoB waters and the relatively older Indonesian through flow. This result was also supported by the low radiocarbon activity reported by other investigators. This preliminary study indicates oxygen isotope and salinity together can be used to identify different water masses in the BoB. *[**Sengupta S., Parekh A., Chakraborty S., Ravi Kumar K.** and **Bose T.,** Vertical variation of oxygen isotope in Bay of Bengal and its relationships with water masses, **Journal of Geophysical Research**, 118, December 2013, DOI:10.1002/2013JC008973, 6411-6424]*

Analysis of Kashmir tree-ring chronologies in relation to Palmer Drought Severity Index (PDSI)

Tree-ring width index chronologies of *Abies pindrow* and *Picea smithiana* of Kashmir Himalaya are sensitive to the moisture availability and the amount of soil moisture in the region. The first principal component (PC1) among the site chronologies explaining 61.2% of the common variance is strongly correlated with Palmer Drought Severity Index (PDSI) during summer season (May to July). Whereas increased temperature of the region had significant adverse effect on tree growth over the region. The moisture availability, especially during the growing season, is found more conducive in developing the annual tree-ring width as compared to rainfall during the season. PC1 is more stable with PDSI from 1901 to 1962 (**Fig. 2**), which is significant at 5% level. It shows that soil moisture availability of the region has a significant role in developing of annual ring width patterns. Moreover, the increasing temperature and vapour pressure during November and December of the previous year might play an important role for early snow melt over the region, which maintains enough soil moisture favouring physiological processes and trees' growth during the subsequent growing season. A wide network of such moisture sensitive tree-ring data would be useful in reconstructing a long history of PDSI. *[**Somaru Ram** and **Borgaonkar H.P.**, Growth response of conifer trees from high-altitude region of Western Himalaya, **Current Science**, 105, July 2013, 225-231]*

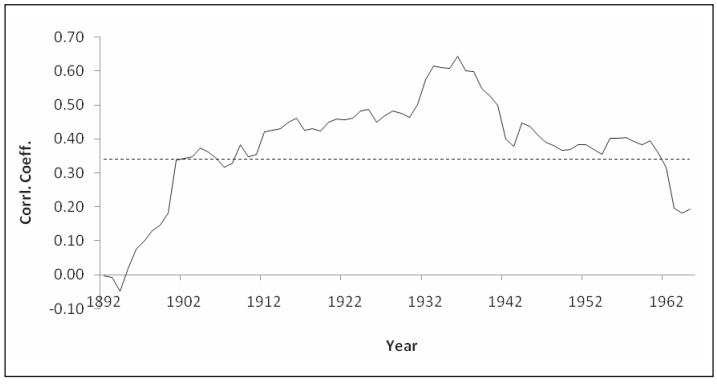


Fig. 2: *31-year sliding correlation between PC1 and summer PDSI for the common period 1877-1980. Correlation coefficients are plotted against the central year of 31 years period. Dashed lines are significant at 5% level.*

A multi-proxy study to infer the mid-late Holocene monsoon variations in mainland Gujarat

A multi-proxy study involving palynology, phytoliths, sedimentology, clay mineralogy, carbon isotopes and magnetic mineralogy was carried out on Wadhwana lake sediments from sub-humid zone of mainland Gujarat to determine the mid-Holocene climatic fluctuations and its possible impact on the Harappan culture. Five paleoclimatic phases are identified (**Fig. 3**). The study reveals high lake stand during Phase-I (~7500-5560 calibrated years before the present). Considerably cool and moist climatic conditions during Phase-I can be inferred due to the presence of pollen belonging to wet evergreen taxa and high phytolith climatic index. Later parts of the Phase-I show a gradual replacement of evergreen to deciduous pollen taxa, decrease in climatic index value and dominance of smectite over kaolinite, indicating a reduction in wet climatic condition due to a decline in the precipitation and prevalence of seasonally dry climate. However, a large variety of pollen taxa, abundant fresh-water algae in this period provide evidence of intensified arboriculture and agricultural activity. Low lake level and dry climate has been documented during Phase-II (5560-~4255 calibrated years before the present) and is synchronous with the lake records of the western Indian region. High values of phytolith aridity index, high primary minerals and increase in the $\delta^{13}C$ values provide an evidence for excessive dry climatic conditions at ~4255 calibrated years before the present. Phase-III shows a gradual strengthening of SW monsoon after ~3500 calibrated years before the present. Phase-IV is a short pulse of dry climatic conditions (~3238-~2709 calibrated years before the present) followed by somewhat similar to present day climate for Phase-V. The study concludes that onset of dry climate after 5500 calibrated years before the present is a regionally spread synchronous event that has been documented in several lake records of the western India. It is surmised that urbanization in the Harappan civilization in the North West India was coincident with the initial phase of declining rainfall of the mid-Holocene. The emergence of cultural complexity of the Harappan civilization should be seen as an initial adaptation to the earliest phase of environmental deterioration and its subsequent decline is probably linked with the changing seasonality pattern and excessive dry climate in the later phase (~4200-4255 calibrated years before the present) of the mid-Holocene. *[Prasad V., Farooqui A., Sharma A., Phartiyal B., **Chakraborty S.**, Bhandari S., Raj R., Singh A., Mid-late Holocene monsoonal variations from mainland Gujarat, India: A multi-proxy study for evaluating climate culture relationship, **Palaeogeography, Palaeoclimatology, Palaeoecology**, 397, March 2014, 38-51]*

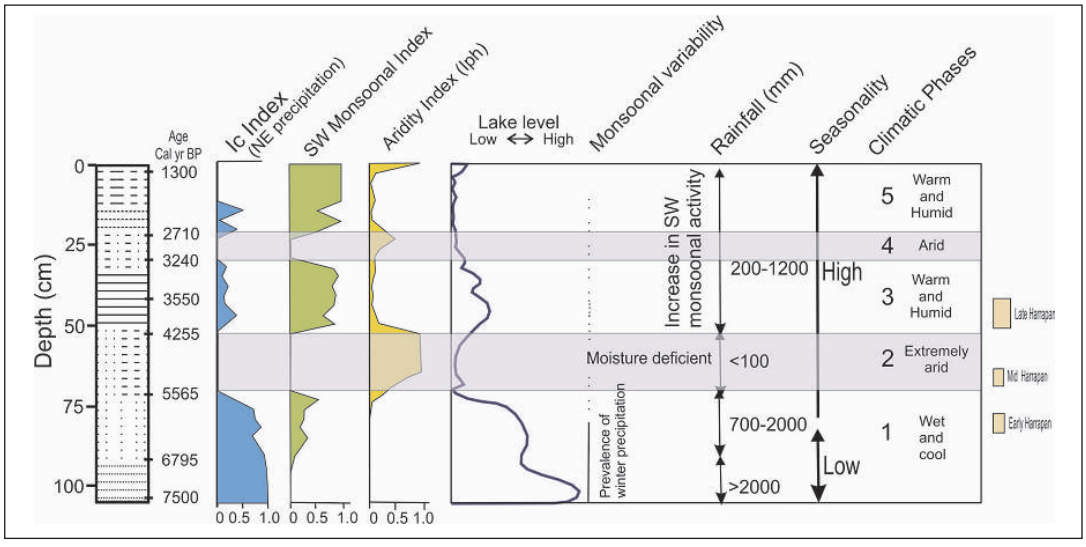


Fig. 3: *Compilation of various indices showing the seasonality and paleoclimatic phases along with the archaeological phases of the Harappan culture.*

Fluxnet

Deputy Chief Project Scientist : **Dr. S. Chakraborty**, Scientist-E

Objectives:

- Establishment of Eddy Covariance (EC) flux towers (Kaziranga National Park, Darjeeling, Mahabaleswar and Pichavaram) for measuring the net eco-system exchange (NEE) of CO_2, energy, water vapour and quantification of these fluxes at different time scales and understanding the processes that control their variations.
- To generate long-term quality assured water vapour and energy flux data along with other meteorological and ecological data for developing land-surface parameterization schemes for use in weather and climate models.
- To investigate the relationship of CO_2 exchange with plant, soil and atmospheric factors.
- To determine the flux of CO_2 in sediment-air interface and to understand the influence of sedimentary parameters such as sediment moisture, water and air temperature, pH and tidal & current patterns prevailing in the coral reef ecosystem (Port Bliar and Agatti).
- To examine whether the reef ecosystems act as source or sink of CO_2 and to understand the regional climate change and its impact on the coral reef ecosystem.

Developmental Activities

The Fluxnet aims in gathering valuable data on spatio-temporal variability of eco-system CO_2 flux across widely varied environmental domains, and measuring regional carbon, energy and water vapour exchange between terrestrial vegetation and the atmosphere.

Work has been initiated at the coastal sites of Agatti in Lakshadweep Island, Port Blair in Andaman Island and Pichavaram in Tamil Nadu. The installation of towers for observing the micro-meteorological parameters at forest ecosystems is underway at the Kaziranga Forest in Assam (**Photo 1**) and at the Selembong Forest, Darjeeling in West Bengal (**Photo 2**).

To make preliminary observations in an urban environment, several sensors such as Multi-Component Weather Sensor, PAR Sensor, Soil Heat Flux Plate, etc. have been installed on a tower at the IITM campus.

A training programme on Eddy Covariance was arranged at IITM during 11-13 November 2013. It was sponsored by M/s. Licor Biosciences, USA. About 35 scientists, JRFs from different national research organizations involved in eddy flux study participated in this programme.

Photo 1: *Erection of the meteorological tower at the Kaziranga National Park, Assam.*

Photo 2: *Erection of the meteorological tower at the Selembong Forest, Darjeeling, West Bengal.*

Basic Research

On understanding the land-ocean CO_2 contrast over the Bay of Bengal: A case study during 2009 summer monsoon.

Atmospheric CO_2 concentrations were observed over the Bay of Bengal (BoB) during the summer of 2009, a drought over the Indian subcontinent. The scientific cruise enabled sampling close to land or in the open ocean at various times. This meandering of the cruise captured a high (low) level of atmospheric CO_2 when the ship was close to (away from) the land. Detailed investigation reveals that this is directly related to the contrast in intensity of land and oceanic CO_2 fluxes. This spatio-temporal variability is also captured in an atmospheric CO_2 inversion model. **Fig. 1a** shows the observations of CO_2 measured along the cruise track (black dots and the line) and CO_2 concentration from AIRS satellite retrievals at the same intervals when the ship-based observations were made. **Fig. 1b** shows atmospheric CO_2 from Carbon Tracker and TM3 simulations. **Fig. 1a** shows a remarkable similarity between AIRS retrieved and ship-observed CO_2 (R^2=0.8), which indicates somewhat uniform concentration in the atmospheric column over the BoB. During the summer monsoon season, deep convection over the south Asian region can carry the surface CO_2 vertically and is detected by AIRS data. **Fig. 1b** also suggests that such land-ocean contrast in CO_2 values is also represented in the Carbon Tracker and TM3 simulated data. Both the observations and the models display similar CO_2 variability, which is a clear indication that models track atmospheric CO_2 fairly well over the BoB. Observations not only offer a

validation of model simulations but indicate strongly that the vertical transport paradigm for surface CO_2 is supported by AIRS data. This study highlights the need for more high-resolution observations to unravel important aspects of CO_2 variability over the BoB. *[**Ravi Kumar K., Tiwari Y.K., Valsala V.,** Murtugudde R., On understanding the land-ocean CO_2 contrast over the Bay of Bengal: A case study during 2009 summer monsoon, **Environmental Science and Pollution Research**, online, December 2013, DOI:10.1007/s11356-013-2386-2]*

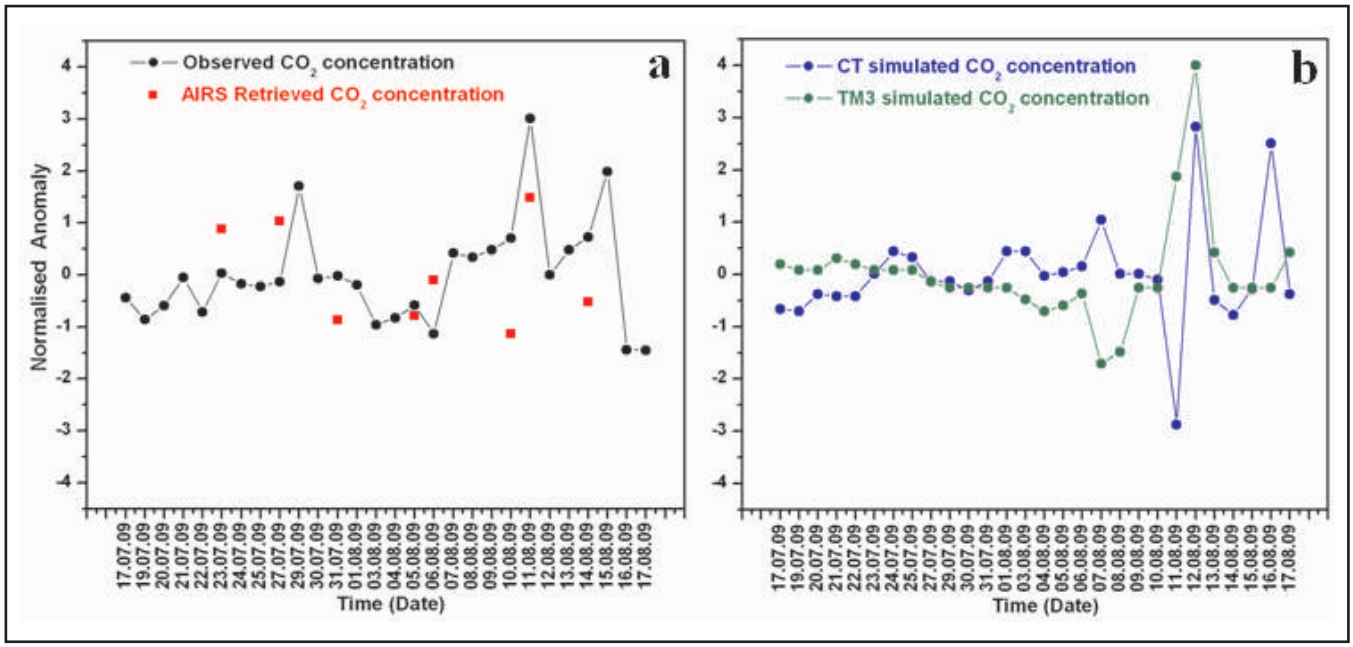


***Fig. 1:** Comparison of (**a**) CO_2 observations with the satellite retrievals and (**b**) CO_2 model simulations during the cruise period.*

Project

Physics and Dynamics of Tropical Clouds

Chief Project Scientist: **Dr. (Smt.) Thara Prabhakaran**

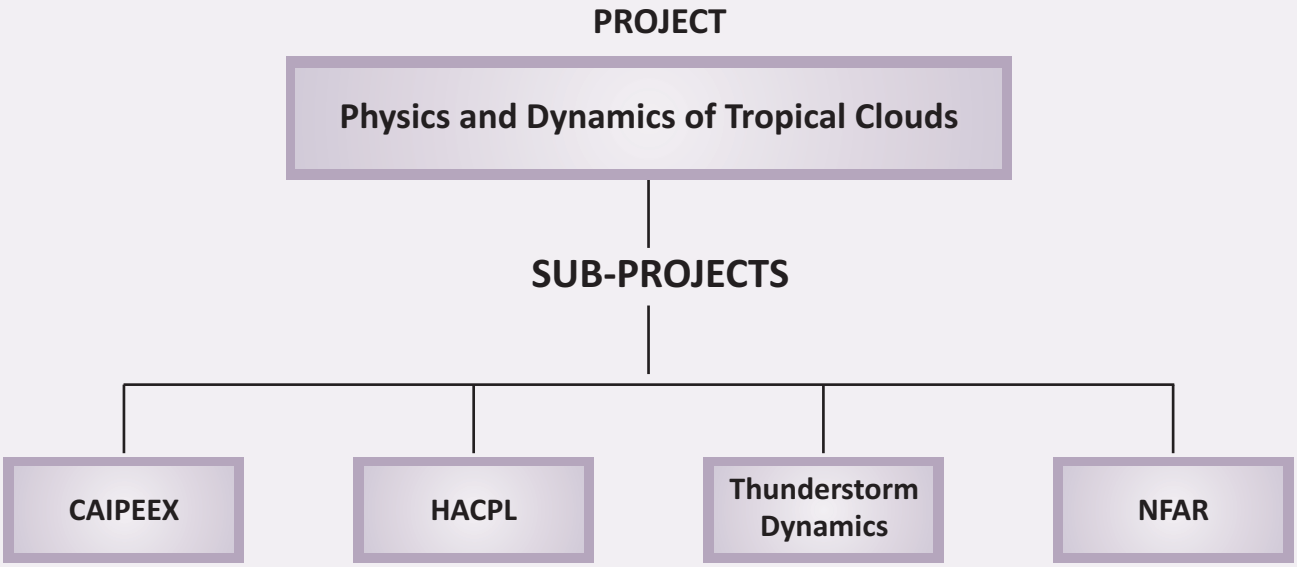
Basic research is required for improving models for weather and climate forecast. It requires to be strengthened through observations.

Better prediction of monsoon requires better understanding of tropical clouds and their interaction with the environment. Here, dynamics and microphysics play a crucial role in cloud formation and in precipitation. Getting a clear understanding of how these dynamical and microphysical processes influence cloud formation is the main goal of this project. The main objective of the project is to formulate an understanding on the direct and indirect effect of aerosols in monsoon environment and to understand the interaction with dynamics and realize these in improving the convective and microphysical parameterization schemes in numerical models used for monsoon forecasting. Process level studies of tropical clouds addressed with state-of-the-art ground based and airborne observations and with laboratory facilities.

Aerosols have impact on rainfall processes and play an important role in weather and climate systems. How aerosol interacts with clouds needs to be thoroughly studied by taking simultaneous and *in situ* measurements of aerosols and cloud microphysics. Such measurements can be taken by using airborne platforms (instrumented aircrafts). However, an airborne platform may not give continuous data throughout the monsoon season or the year. To address this need, a ground based cloud physics laboratory at a high altitude station where clouds touch the ground is established for cloud-microphysics measurements together with aerosol and meteorological measurements. The project also addresses the spatio-temporal distributions of thunderstorms over India and their relation to thermodynamic conditions, aerosols, etc. and has established a Lightning Location Network for the study of charge distribution of thunderstorms. The thrust area of this project is in collecting valuable data relating to various atmospheric processes. To enhance the cloud physics studies and address the national need for such studies, National Facility for Airborne Research (NFAR) is also being established by procuring a research aircraft.

During weak monsoon conditions, there are demands for cloud seeding to enhance rainfall. Whether cloud seeding can be a feasible and fruitful technique in the country (keeping the local conditions in view) needs to be investigated scientifically. IITM conducted cloud seeding experiments which are planned to be continued for gaining deeper insights of this research area.

This project has four sub-projects: 1) Cloud and Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX), 2) High Altitude Cloud Physics Laboratory (HACPL), 3) Thunderstorm Dynamics, and 4) National Facility for Airborne Research (NFAR).


PROJECT
Physics and Dynamics of Tropical Clouds
SUB-PROJECTS
CAIPEEX
HACPL
Thunderstorm Dynamics
NFAR

Cloud Aerosol Ineraction and Precipitation Enhancement Experiment (CAIPEEX)

Deputy Chief Project Scientist : **Dr. (Smt.) B. Padma Kumari**, Scientist-D

Objectives:

- To address the cloud-aerosol interactions.
- To formulate a scientific basis to enhance rain formation and rain enhancement using the recent cloud seeding technologies and the state-of-the-art instrumentation.
- To carry out airborne and integrated ground based observations to understand a) the microphysical changes in the clouds as a result of changes in aerosol particles, b) microphysical and dynamical controls on the rain formation, c) how physical and chemical properties of aerosols may impact radiative forcing and cloud formation, d) how direct and indirect effect of aerosols may be quantified, and e) utilization of observations in formulating parameterization for monsoon clouds.

Developmental Activities

- **CAIPEEX Phase-III**: Third phase of CAIPEEX is underway with state-of-the-art cloud physics observations with aircraft and integrated ground based observations in the central Indian region with Varanasi as a base station. CAIPEEX Phase-III has established an integrated ground observational site at Banaras Hindu University (BHU), Rajiv Gandhi south campus, Barkachha, Mirzapur, Uttar Pradesh to monitor the cloud properties and associated thermodynamics, aerosol and radiation measurements.
- CAIPEEX data is used in the development and testing of different parameterizations of microphysical processes (autoconversion, ice nucleation, etc.), calibration of bulk microphysical models, etc.
- Preliminary efforts were made in exploring the possibility of using Unmanned Aerial Vehicle (UAV) for studying the atmospheric process studies in collaboration with Vehicle Research Development and Establishment (VRDE), Ahmednagar.
- IITM is exploring a collaborative project concept with NCAR's Earth Observing Laboratory (EOL) on the development of portable wind profilers. Initial discussions and communications with the MoES' Technical Research Board (TRB) were conducted.

Basic Research

The mechanism responsible for high rainfall over the Indian West Coast region

Dynamical, thermodynamical and microphysical processes over the Indian West Coast (IWC) region for the monsoon season are investiagted. The lower troposphere over the IWC region remains convectively unstable during the study period. High SSTs and low level convergence favour in realization of the convective instability. The high latent heat fluxes, high equivalent potential temperature (θ_e), low lifting condensation level (LCL) heights, high convective available potential energy (CAPE) and low convective inhibition energy (CINE) were found to co-exist throughout the study period over the IWC region. During such favourable conditions, the moist adiabatic stratification is developed to its full potential. It is associated with low updraft rates. The low updraft rates get sufficient time to complete the warm rain process before reaching to freezing level. The low updrafts above the freezing level provide sufficient time for conversion of liquid water into ice particles. The diabatic heat released in the rainfall also causes warming in the upper layers. This type of stratiform heating intensifies the circulation with positive feedback. Thus, the circulation sustains for longer duration generating high rainfall spell. The IWC region is also under the influence of advection of dry warm air in the low and the middle layers from the nearby desert regions which suppresses convection. The rainfall is reduced, so the heat source at upper level is cut off. The monsoon circulation weakens which causes reduction in rainfall. Thus, the system goes into

negative feedback cycle resulting in a long low rainfall spell. A schematic for the rainfall mechanism is given in **Fig. 1**. *[**Maheskumar R.S., Narkhedkar S.G., Morwal S.B., Padmakumari B., Kothawale D.R., Joshi R.R., Deshpande C.G., Bhalwankar R.V.** and **Kulkarni J.R.**, Mechanism of high rainfall over the Indian west coast region during the monsoon season, **Climate Dynamics,** online, October 2013, DOI:10.1007/s00382-013-1972-9, 1-17]*

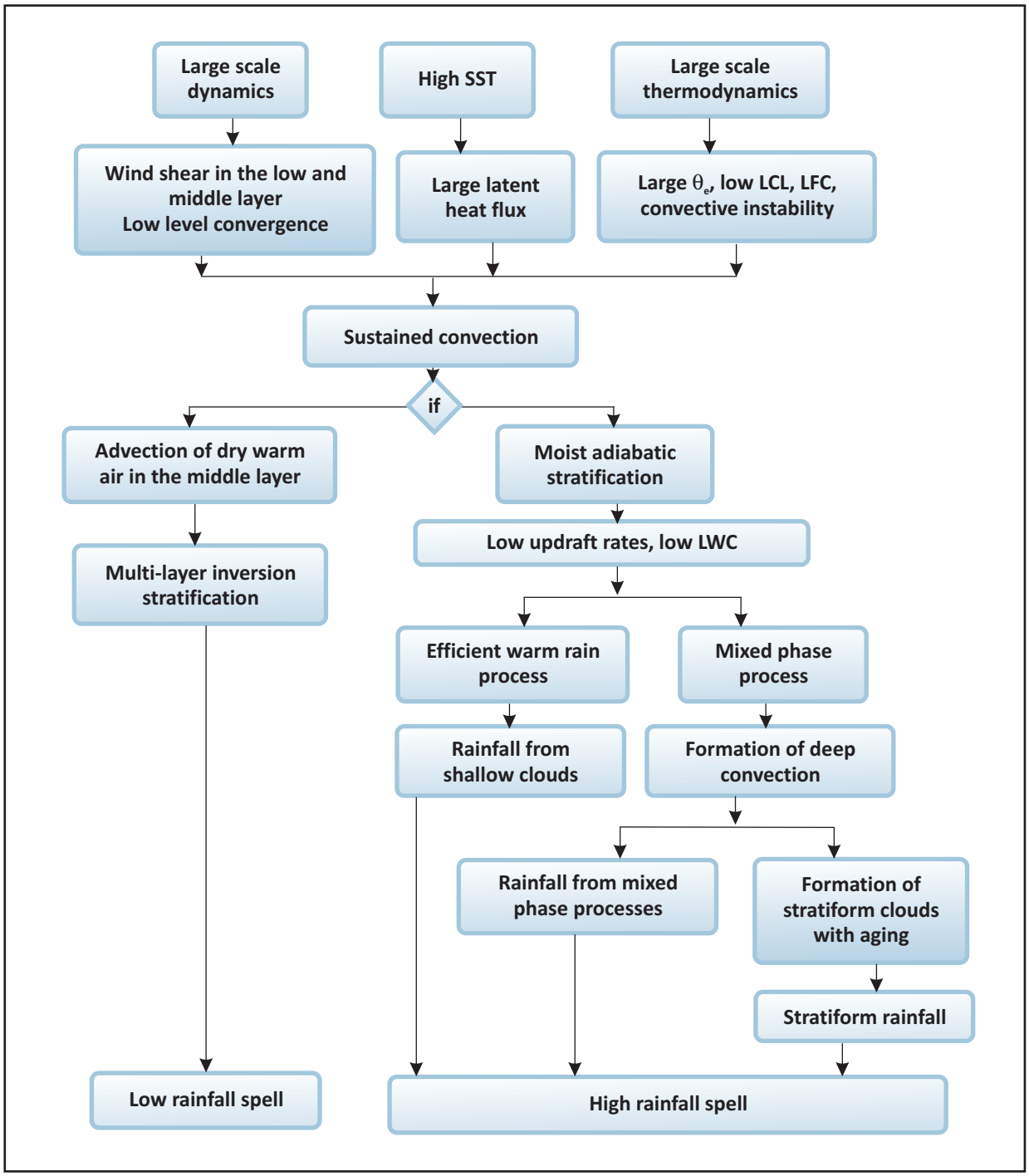


Fig. 1: *Schematic of the rainfall mechanism over the Indian West Coast Region.*

Raindrop formation in monsoon clouds

A combination of CAIPEEX observational data and 2D & 3D numerical cloud microphysical model simulations (**Fig. 2**) suggest that the first raindrops form at the top of undiluted or slightly diluted cores in the monsoon clouds. The initial raindrop formation is determined by the basic microphysical processes within ascending adiabatic volumes. The study indicates that the role of mixing and entrainment in the formation of the first raindrops is not of crucial importance. These results allow one to predict the height of the formation of first raindrops considering the processes of cloud condensation nuclei activation, droplet diffusion growth and coalescence growth. The results obtained in the study explain observational results through which the in-cloud height of first raindrop formation depends linearly on the droplet number concentration at cloud base. The present study provides a physical basis for retrieval algorithms of cloud microphysical properties and aerosol properties using satellites as well as in the formulation of an autoconversion parameterization in numerical models. *[Khain A., **Prabha T.V.**, Benmoshe N., **Pandithurai G.**, Ovchinnikov M., Mechanism of first raindrops formation in deep convective clouds, **Journal of Geophysical Research**, 118, August 2013, DOI:10.1002/jgrd.50641, 9123-9140]*

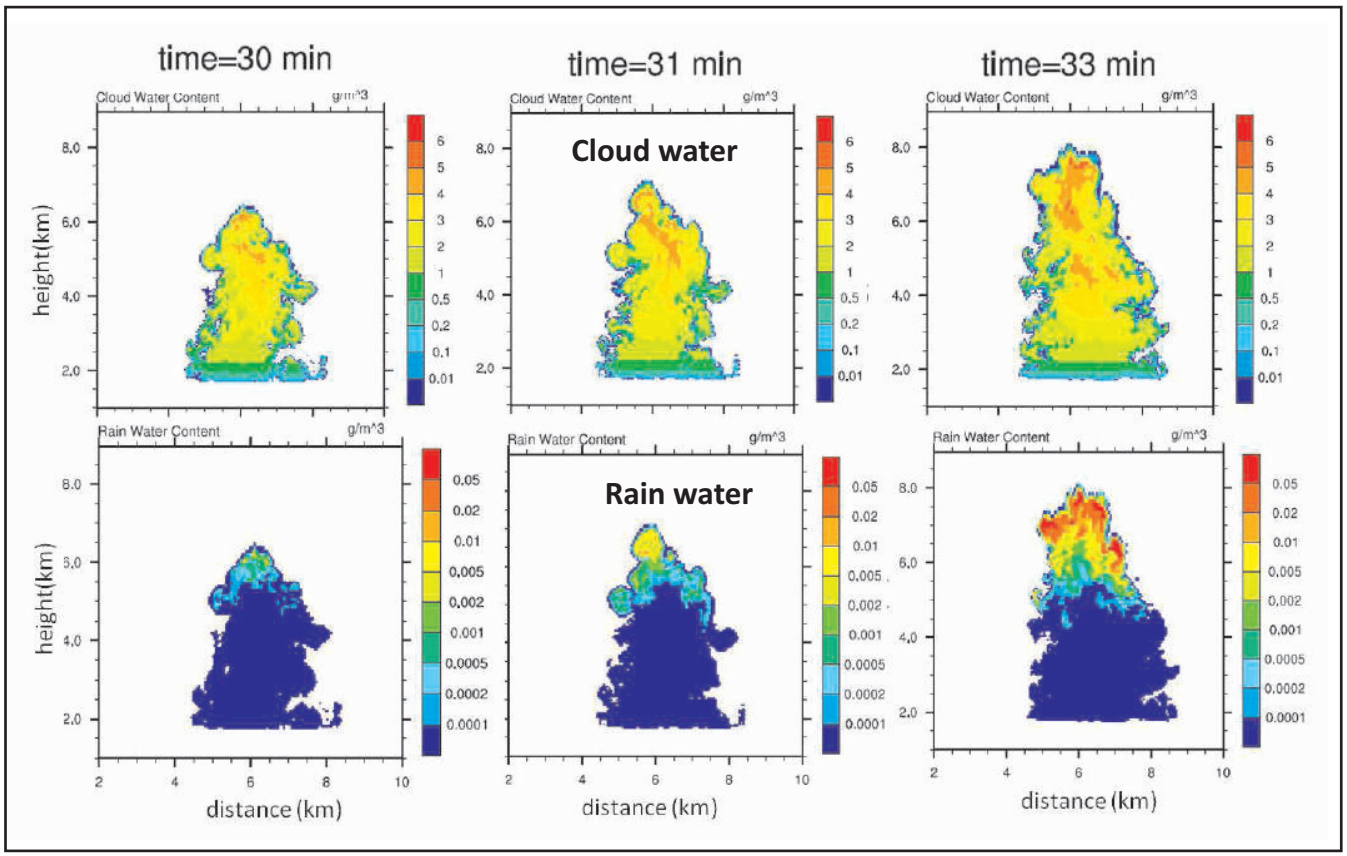


Fig. 2: *Large eddy simulation of CAIPEEX cloud with bin microphysics: Top panel is cloud liquid water and bottom panel is rain water from model simulations, indicating that raindrops form in the slightly diluted/undiluted bubble cores that are not determined by turbulence.*

Observational evidence of strong decrease in evaporation and wind speed over the Indian monsoon region: Implication on regional hydrological cycle

Pan evaporation (E_{pan}) measurements over 58 stations in India showed a highly significant decreasing trend of 9.24 mm a^{-2} for the last four decades (1971-2010). Surface wind speed, RH, R_s and T_{air} showed significant trends of –0.02 $ms^{-1}a^{-1}$, +0.07% a^{-1}, –0.47 $Wm^{-2}a^{-1}$ and +0.013ºC a^{-1} respectively (**Fig. 3**). Wind speed and R_s are highly correlated with E_{pan} followed by RH, while T_{air} is poorly correlated. PenPan model, forced with surface observations, shows that E_{pan} trends are attributed to changes in both aerodynamic (in terms of wind speed and humidity) and radiative (in terms of R_{net}) components, with aerodynamic being dominant over radiative component at some stations and vice-versa. The results also showed that annually and during dry season, India is water-limited ($E_p > P$), while energy-limited ($P > E_p$) in wet season. Long term trends of E_p-P showed that annually E_p-P (moisture divergence) is decreasing significantly with time. The scatter plots of E_p-P *versus* E_p also indicate that decrease in E_p leads to increase in convergence in wet season and decrease in divergence in dry season (**Fig. 4**). Long term observations showed that decreasing E_{pan} is contributing to increasing moisture convergence and India is tending towards energy-limited. Apart from E and P being important components of hydrological cycle, convection and condensation might also play an important role. The same dynamical factors which control E may also affect P in terms of convection and condensation in a positive feedback mode thereby maintaining P. *[**Padmakumari B.**, Jaswal A.K., **Goswami B.N.**, Decrease in evaporation over the Indian monsoon region: Implication on regional hydrological cycle, **Climatic Change**, 121, December 2013, DOI:10.1007/s10584-013-0957-3, 787-799]*

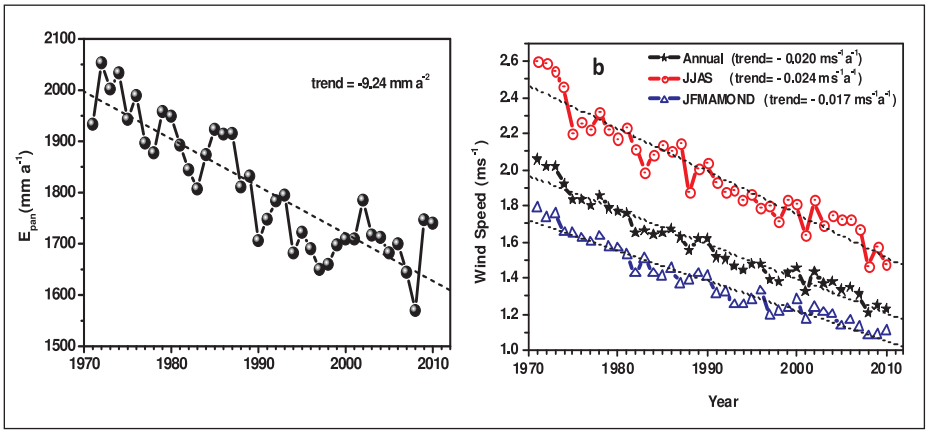


*Fig. 3: **(a)** Annual variation of pan evaporation (E_{pan}) and **(b)** annual and seasonal variation of surface wind speed over the Indian monsoon region.*

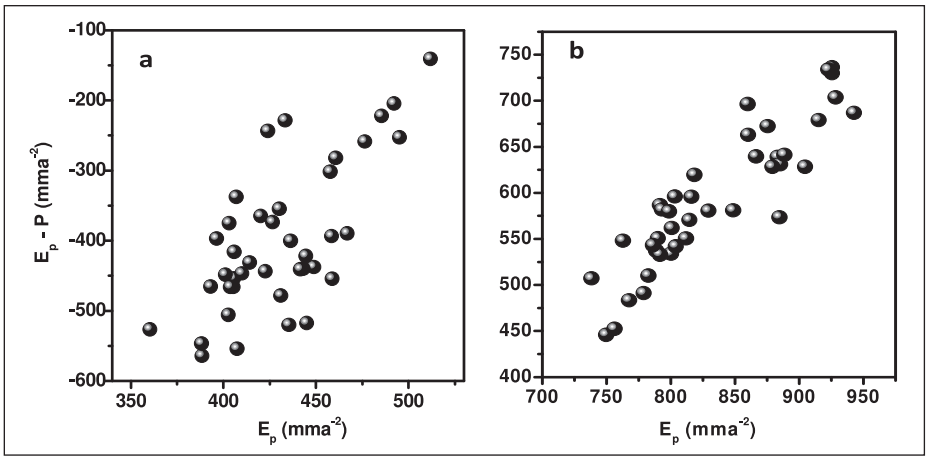


*Fig. 4: E_p-P versus E_p for **(a)** wet and **(b)** dry seasons.*

High Altitude Cloud Physics Laboratory (HACPL)

Deputy Chief Project Scientist : **Dr. G. Pandithurai**, Scientist-E

Objectives:

- To understand the fundamental properties and microphysical aspects of monsoon clouds and their interactions with aerosol and environment through continuous *in situ* observations.
- To use both precipitation and cloud radars to understand the cloud and rain formation, vertical structure of clouds, their organization and interaction with environment.
- To facilitate integrated observational data for their use in research for development of improved parameterization schemes for cloud microphysics in climate models.

Developmental Activities

- Efforts are underway in establishing Z-R relationships, deriving wind/divergence fields, calibration against disdrometers/rainguages/etc., validation against satellite products, deriving usable matrix for modifying model parameterizations for convective and startiform clouds, etc. This ongoing process will benefit the user community and eventually for the model developments and data assimilations. Most of the developed products are under peer review.
- Observational data repository now includes two years of monsoon observations, which is presently shared with the IITM research community.
- Accurate estimate of aerosol indirect effect (AIE) is important in the climate models, which are beginning to incorporate AIE. HACPL will be augmented with special drying units for accurate measurements of aerosol and CCN during high humid monsoon conditions to decrease the uncertainty under high humidity conditions. It has been noted in the CAIPEEX observations that interstitial particles could activate at higher levels in the cloud under polluted conditions. To evaluate the importance of interstitial aerosol particles in their physical and chemical characteristics, a whole air inlet and an interstitial inlet will be implemented. Aerosol chemical composition and hygroscopicity measurement facilities will be implemented. To establish such a facility, a long-term and sustainable collaboration with the Leibniz Institute for Tropospheric Research (TROPOS), Leipzig, Germany is sought. A proposal in this regard is submitted to MoES.
- Outgoing Longwave Radiations (OLR) is estimated by utilizing infrared (10.5-12.5 µm) and water vapour (5.7-7.1 µm) radiances of Very High Resolution Radiometer (VHRR) instrument onboard Kalpana-1 satellite. These data up to December 2013 are updated and are available in classic NetCDF format at the URL http://www.tropmet.res.in/static_page.php?page_id=144 for academic usage. A file listing the missing hours of data can be found in the README folder. Along with the three-hourly data (3Hrly); daily (DlyAvg) and monthly (MonAvg) averages are also provided in separate folders.

Basic Research

Vertical structure of clouds during active and break phases of monsoon

Cloud characteristics during the active and the break periods of Indian summer monsoon using Cloudsat and Calipso data sets show that low-level clouds and optically thick cirrus are dominant and occur more frequently during the active period. In contrast, high-level clouds and optically thin cirrus are more frequent during the break phase of monsoon. The integrated depolarization ratio of high-level cloud exhibits bimodal distribution. *[**Das S.K.,** Uma K.N., **Konwar M., Raj P.E., Deshpande S.M., Kalapureddy M.C.R.,** CloudSat-CALIPSO characterizations of cloud during the active and the break periods of Indian summer monsoon, **Journal of Atmospheric and Solar Terrestrial Physics**, 97, May 2013, DOI:10.1016/j.jastp.2013.02.016, 106-114]*

Time evolution of monsoon low-level jet observed over an Indian tropical station during the peak monsoon period from high-resolution Doppler wind lidar measurements

Time evolution of the monsoon low-level jet (MLLJ) during the southwest monsoon season has been investigated using high-resolution Doppler wind lidar measurements of horizontal winds over Mahbubnagar (16.73^{0}N, 77.98^{0}E, 445 m above mean sea level). Vertical profiles of zonal wind in the altitude range of 100 to 3000 m above surface (at every 50 m height interval and 5 min time averaged) obtained during July-August 2011 have shown that winds are predominantly westerly throughout the period. On almost all the days, during nighttime, there exists a westerly wind speed maximum around 500 m above ground. Soon after local sunrise, the core of this wind speed maximum (jet) gets lifted up and by afternoon, the westerly wind maximum is shifted to a higher altitude of 2000 m to 2500 m (*an example is given in* **Fig. 1**). Analysis of the high-resolution wind lidar data strongly suggests that the same nocturnal low-level jet seems to be moving up and evolving into daytime westerly MLLJ reported in several previous studies. Results further show that the time-height evolution of the jet core is closely associated with daytime convection and boundary layer growth. Therefore, observational evidence of the diurnal evolution of low-level jet in the monsoon environment is reported for the first time. *[**Ruchith R.D., Raj P.E., Kalapureddy M.C.R., Deshpande S.M.** and **Dani K.K.**, Time evolution of monsoon low-level jet observed over an Indian tropical station during the peak monsoon period from high-resolution Doppler wind lidar measurements, **Journal of Geophysical Research**, 119, February 2014, DOI:10.1002/2013JD020752, 1786-1795]*

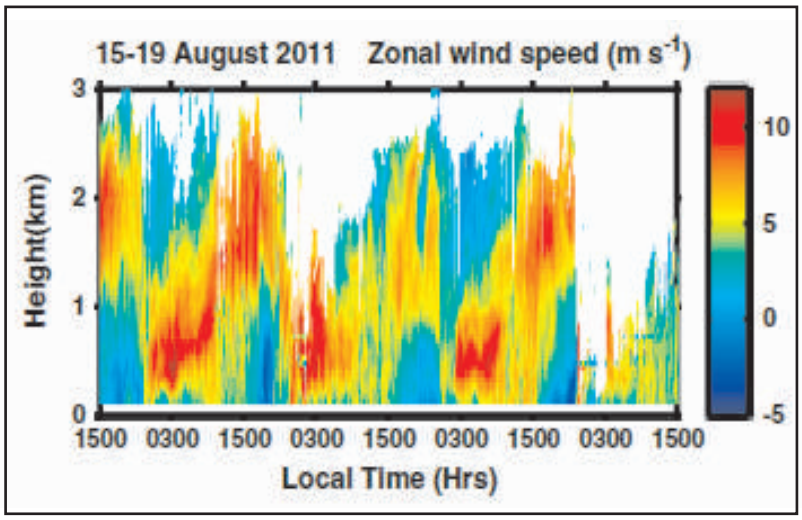


Fig. 1: *Time-height variations of zonal wind in the altitude range up to 3 km during 15-19 August at Mahbubnagar.*

Assessment of the aerosol distribution over Indian subcontinent using CMIP5 models

The capability of various global models participating in CMIP5 project, in capturing the realistic spatial and temporal distribution of aerosol species over the Indian subcontinent is assessed. Model simulations compared with MODIS satellite observations show that a majority of the CMIP5 models (except HADGEM2-ES and HADGEM2-CC) seriously underestimates the spatio-temporal variability of aerosol species over the Indian subcontinent, in particular over the Indo-Gangetic Plains (IGP). The simulated dust loading was found to be significantly low in the majority of the models. There is presence of pronounced dust activity over northern India. The biases in this dust loading have a great impact on the AOD of IGP. It was also found that considerable biases in simulation of 850 hPa wind field (which plays an important role in the transport of dust from adjacent deserts) would be the possible reason for poor representation of dust AOD and in turn total AOD over the Indian region in CMIP5 models. This analysis emphasizes the fundamental need to improve the representation of aerosol species in the current state-of-the-art climate models. *[**Sanap S.D., Ayantika D.C., Pandithurai G.** and Niranjan K., Assessment of the aerosol distribution over Indian subcontinent using CMIP5 models, **Atmospheric Environment**, 87, February 2014, DOI:10.1016/j.atmosenv.2014.01.017, 123-137]*

High resolution outgoing longwave radiation dataset from Kalpana-1 satellite for research use

Outgoing longwave radiation (OLR) is estimated by utilizing infrared (10.5-12.5 µm) and water vapour (5.7-7.1 µm) radiances of Very High Resolution Radiometer (VHRR) instrument onboard Kalpana-1 satellite stationed at 74^{0}E. This research quality product of three hourly outgoing longwave radiations for the period from May 2004 to June 2012 is produced over the Indian region (40^{0}S-40^{0}N, 25^{0}E-125^{0}E) in a regular grid of 0.25×0.25 degrees. The VHRR images were obtained from the archival of National Satellite Data Centre of the India Meteorological Department, New Delhi. Narrow band to broad band conversion was performed through empirical relations developed using Genetic algorithm. Although this data is available for a relatively shorter period, it is shown that this will be potentially more useful than the widely used OLR from NOAA satellites in representing the annual cycles particularly over the desert and the humid oceans, due to its frequent sampling and quality. The active-break periods in the Indian summer monsoon picked up by both the OLRs match well. This three hourly outgoing longwave radiation estimated from Kalpana-1 VHRR was able to describe the fine scale structure of the diurnal variation over the region. **Fig. 2** shows amplitude and phase of the diurnal harmonics obtained from the data during various seasons. It shows that the variation is largest over the land surfaces, especially over the arid regions, approaching as high as 55 Wm^{-2} during monsoon season (JJAS) *i.e.,* almost equal to the variability due to seasonal change (**Fig. 2c**). The diurnal signal is always high over the deserts. The seasonal change in diurnal variation is due to fluctuations in cloud cover associated with migration of inter tropical convergence zone over the region, with the largest change over the Indian mainland. Over the ocean, the amplitude of the diurnal cycle is small, generally less than 5 Wm^{-2} with little seasonal change, except over the Bay of Bengal where the amplitude of the variations is slightly high (around 8 Wm^{-2}) during the wet seasons. The values are also slightly high over southern Indian Ocean during summer. The oceanic region surrounding the maritime continents has large amplitude of diurnal change similar to the nearby continents. It can be observed that the diurnal variation in OLR over the eastern parts of China is maritime in nature during the boreal summer (**Fig. 2b-c**). *[**Mahakur M., Prabhu A.A.**, Sharma A.K., Rao V.R., Senroy S., Singh R., **Goswami B.N.**, A high-resolution outgoing longwave radiation dataset from Kalpana-1 satellite during 2004-2012, **Current Science**, 105, October 2013, 1124-1133]*

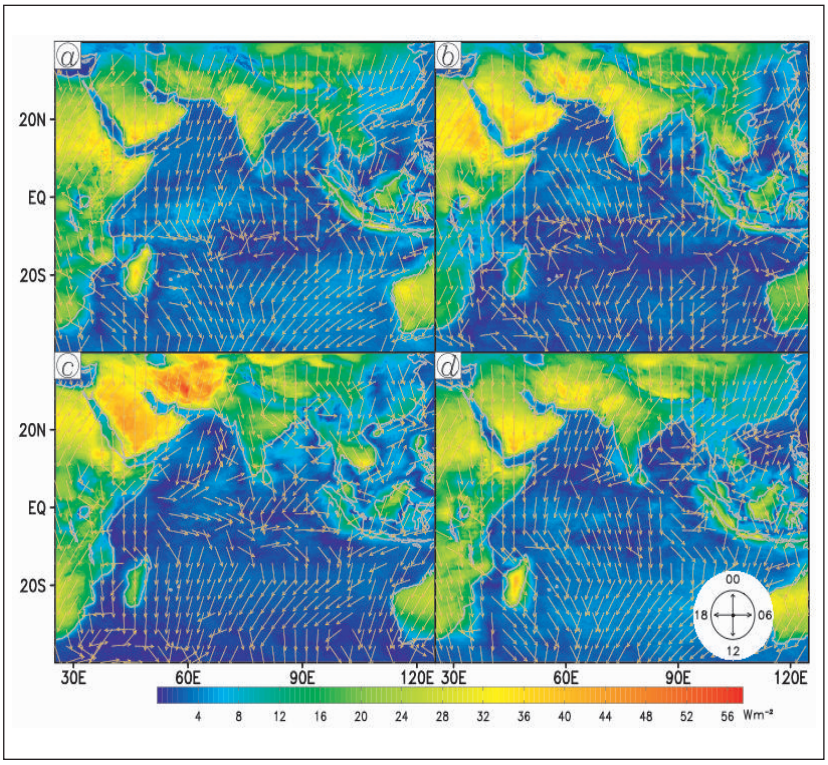


Fig. 2: *Diurnal variations observed in Kalpana-1 three hourly OLR during various seasons; (**a**) winter (January-February), (**b**) pre-monsoon (Mar-May), (**c**) monsoon (June-September) and (**d**) post-monsoon (October-December). Amplitude (Wm^{-2}) is shaded and the phase (in LST) is shown in 24-hour clock dial, i.e., arrow pointing northward is for 00 LST peak and southward for 12 LST.*

Thunderstorm Dynamics

Deputy Chief Project Scientist : **Dr. S.D. Pawar**, Scientist-E

Objectives:

- To study the interaction between thermodynamical, microphysical and electrical properties of thunderstorm.
- To establish the Lightning Location Network to study the fine structure of lightning.
- To study the effect of electrical forces on microphysical processes of chemically polluted water drops suspended in a vertical wind tunnel.
- To measure atmospheric electrical, meteorological parameters and aerosols over different environments to study the global electrical circuit.
- To quantify the relative role of boundary layer fluxes and synoptic scale forces in thunderstorm dynamics.
- To improve the parameterization of surface fluxes of momentum and heat.
- To study the role of land surface processes on atmospheric boundary layer evolution using meteorological tower observations.

Developmental Activities

A Lightning Location Network (LLN) is being implemented in the state of Maharashtra for a detailed study of thunder clouds, the processes responsible for various types of lightning, factors responsible for initiation and possible aspects for nowcasting. Dr. Shailesh Nayak, honorable Secretary of the Ministry of Earth Science (MoES), Chairman, Earth System Science Organization (ESSO) inaugurated the facility at IITM, Pune on 28 February 2014.

LLN Sensors are installed at 17 locations (please refer **Fig. 1**) spread all over Maharashtra as per the plan. The sensors send data through internet (TCP/IP connection) and the data is being processed and archived in the Lightning Information and Prediction System (LIPS) server at IITM.

The system is fully operational since its installation. Internet link for viewing online lightning information is being given to the Disaster Management Department, Govt. of Maharashtra through which the active and warning regions of lightning activity can be immediately informed to the general public.

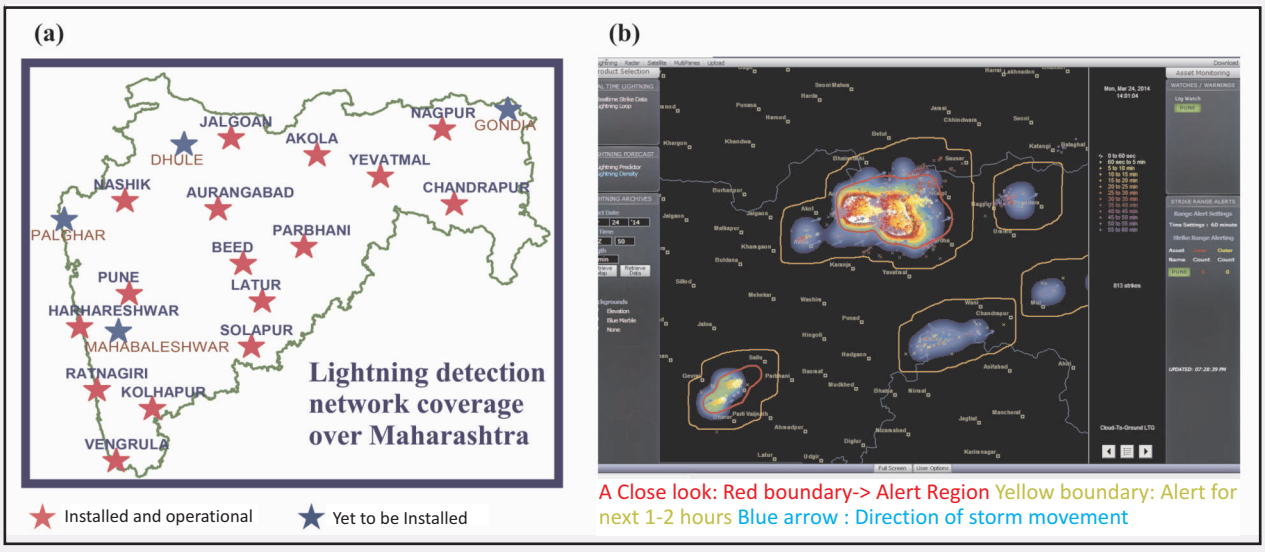


Fig. 1: *(**a**) Lightning location network stations over Maharashtra and (**b**) the LLN display showing the direction of storm movement, which could be used to alert public about the severe weather conditions.*

Observations suggest that in the dissipating stage of the thunderstorm, the charge generating mechanisms in cloud have ceased to operate

Observations of atmospheric electric field made below two thunderstorms at Pune suggest that in the dissipation stage of thunderstorm, the charging generating mechanisms have ceased to operate. Charge being transported from the upper to lower regions of cloud by downdrafts is the only in-cloud process affecting the surface electric field and/or enhancing the electric field stress in and below the cloud base to cause yet another lightning discharge (**Fig. 2**). *[**Pawar S.D.** and **Kamra A.K.,** Recovery curves of the lightning discharges occurring in the dissipation stage of thunderstorms, **Journal of Earth System Sciences,** 122, April 2013, 531-536]*

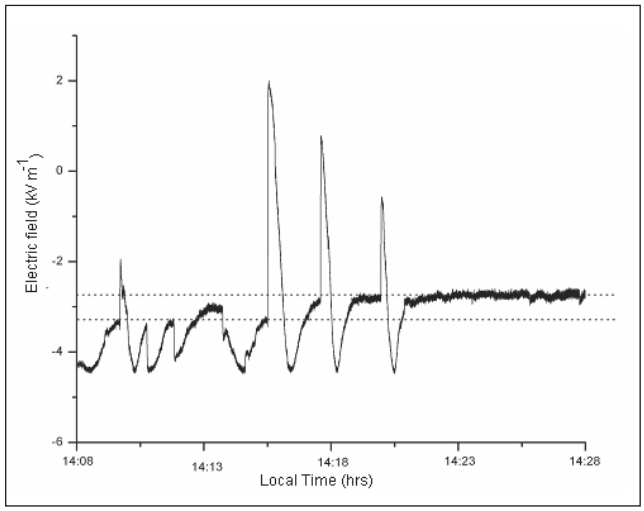


***Fig. 2:** The surface electric field record in the dissipating stage of a thunderstorm on 12 November 1997.*

Climatology of lightning over the Indian region and its relationship with convective available potential energy

As prevailing meteorological conditions and orography over the northern and central India, north-east Pakistan and Bangladesh provide a favourable condition for the formation of thunderstorms. The lightning activity is higher in spite of lower value of CAPE over these regions compared to other parts of the Indian region. During the monsoon season, lightning activity and CAPE are found to be better correlated with each other compared to other seasons over the central and northern India (**Fig. 3**). High mountains of the Himalayas not only generate strong updrafts necessary for the deep convective events by interacting with prevailing winds but the diabetic heating and radiative cooling of mountain tops creates conditions favourable for convections. The diurnal variation of lightning activity at stations over the foothills of the Himalayas showing a strong peak in lighting activity after midnight supports the idea that radiative cooling at mountain tops can create a moisture convergence at the foothills and can trigger convections. *[**Murugavel P., Pawar S.D., Gopalakrishan V.,** Climatology of lightning over Indian region and its relationship with convective available potential energy, **International Journal of Climatology**, online, January 2014, DOI:10.1002/joc.3901, 1-9]*

New particle formation by ion nucleation

Simultaneous measurements of atmospheric ions in the mobility range of 3.16 to 0.00133 $cm^2v^{-1}s^{-1}$ (diameter range 0.46 to 50 nm) made with a Neutral Cluster and Air Ion Spectrometer (NAIS) in Pune revealed nucleation events for the formation of ions. These events generally occurred between 0800-1000 LST and enhanced concentrations of Aitken particles continued to be observed up to 1700-1800 LST (**Fig. 4**). During these events, particles grew at rates of 3.1 ± 0.8 to 11.2 ± 3.5 nm h^{-1} for different particle size ranges. Characteristics and contributions of opposite polarity of ions for increasing total ion concentration were examined. The ratio of positive to negative ions decreased during the period of this unique event as compared to before and after the event. Sulphur dioxide (SO_2) concentration is positively correlated with the concentrations of intermediate, light large and heavy large ions but negatively correlated with the concentration of cluster ions. *[**Siingh D., Gautam A.S., Kamra A.K.,** Komsaare K., Nucleation events for the formation of charged aerosol particles at a tropical station - Preliminary results, **Atmospheric Research**, 132-133, October 2013, DOI:10.1016/j.atmosres. 2013.05.024, 239-252]*

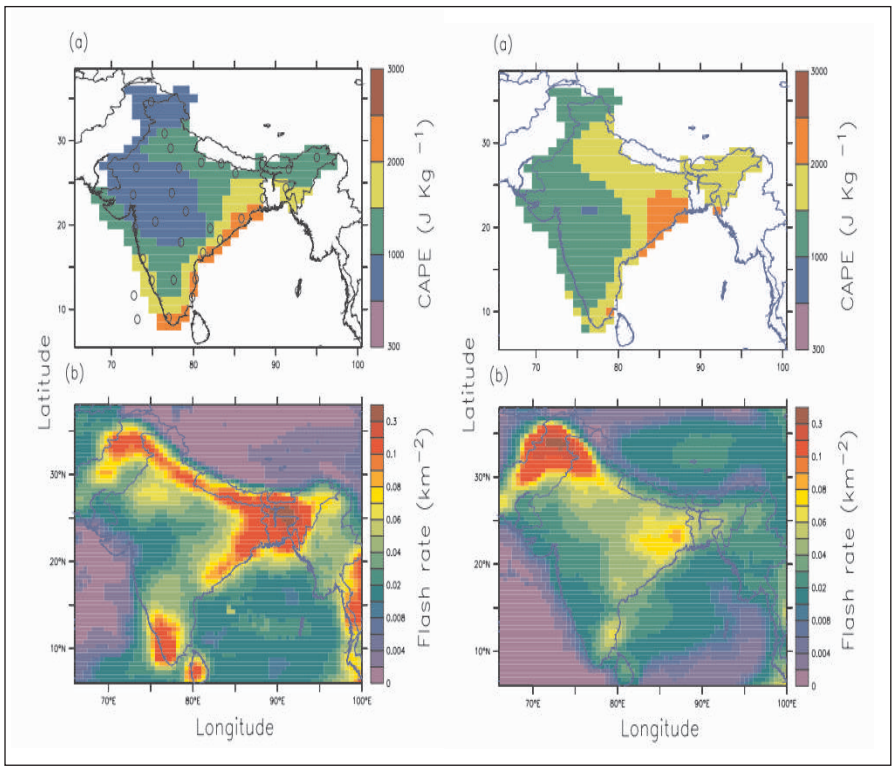


Fig. 3: ***Top:*** *Distribution of CAPE during pre-monsoon (Left) and monsoon (Right) season averaged for 17 years (i.e., from 1995 to 2011). Circles indicate the location of radiosonde stations.* ***Below****: Distribution of lightning flash density over Indian region during the same season averaged for the same period.*

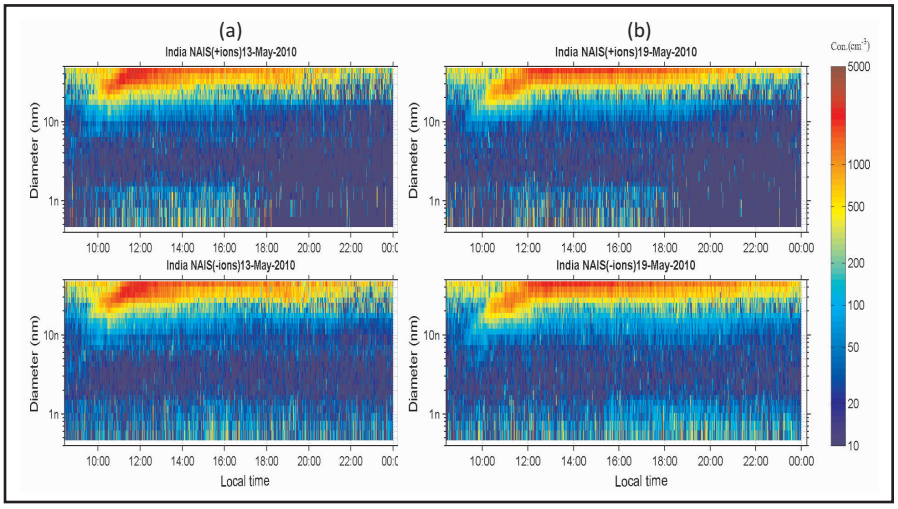


Fig. 4: *Ion Mobility spectra of particle formation events on (**a**) 13 May and (**b**) 19 May.*

Sodar-measured boundary layer jet on the lee side of the Western Ghats

Observations on boundary layer low level jet over lee side of the Western Ghats during south west monsoon (June-August) during 2009, 2010 and 2011 and a possible inter-connection to Somali jet are presented during this period. Baroclinicity due to east-west temperature gradient on the lee side to induce thermal wind and the other mechanism, inertial oscillation appear to have a little role in low level jet formation. The Somali jet seems to govern the boundary layer jet on the lee side through its dynamical interaction with the Western Ghats causing flow reversal and wave breaking above the Western Ghats and inducing acceleration of down slope winds. *[**Murthy B.S., Latha R.** and **Sreeja P.**, Boundary layer jet on the lee side of Western Ghats during southwest monsoon as revealed by high resolution sodar winds, **Journal of Atmospheric and Solar-Terrestrial Physics**, 105-106, December 2013, DOI:0.1016/j.jastp. 2013.09.002, 101-109]*

National Facility for Airborne Research (NFAR)

Deputy Chief Project Scientists : **Dr. C.G. Deshpande**, Scientist-D and **Dr. R.S. MaheshKumar**, Scientist-D

Objectives:

- Procurement of an instrumented aircraft as national facility for airborne research.
- To facilitate cloud microphysics and aerosol observations during different seasons using the instrumented airborne platform for studying cloud aerosol interactions over different parts of country.
- To facilitate observations for understanding the interactions between clouds and large-scale environment, which may be used in developing physical parameterization schemes useful in numerical models used for monsoon prediction.

Developmental Activities

With the experience of CAIPEEX programme, it was realized that in order to meet the challenges of the expanding subject of cloud physics and the role of aerosols and pollution, and to be at par with other atmospheric research communities in the world, India should have its own airborne platform. With this motivation, IITM has undertaken the initiative to establish the National Facility for Airborne Research (NFAR).

The Ministry of Earth Sciences (MoES), Govt. of India has issued an Administrative Order for the Implementation of the National Facility for Airborne Research (NFAR) vide Letter No. MoES/Airborne Platforms-NFAR/XII-Plan/2012 dated 25 September 2013 under the 12th Five Year Plan.

Preparatory work is underway for procuring an Instrumented Aircraft System (IAS) and for acquiring space for hangar at Pune airport.

Project

Training

Chief Project Scientists: **Dr. R.H. Kripalani** and **Dr. H.P. Borgaonkar**

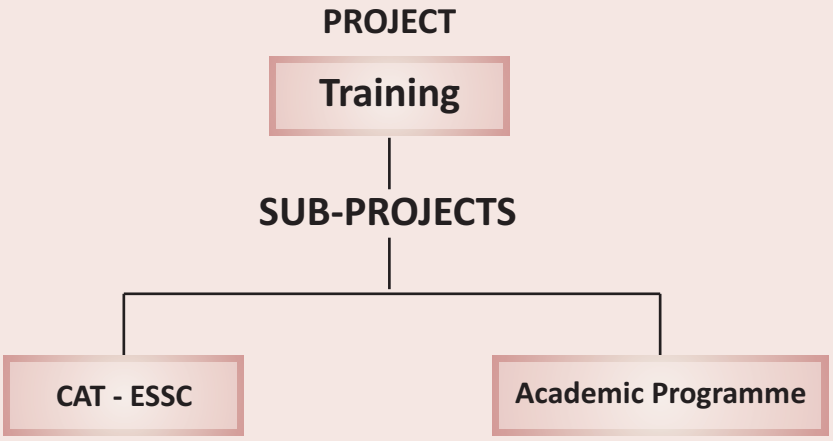
Great strides have been made in weather forecasting in the recent years. While India has made a beginning in dynamical weather forecasting some time ago, our skill remains far below the state-of-the-art. This is partly due to the lack of adequate number of skilled scientists required for improving weather forecasts. Dynamical seasonal prediction and its improvement require specialist climate scientists and modelers, and they are currently lacking in the country (may be as few as 20). A large pool of trained and dedicated climate and earth system scientists (~400-500) is required urgently to catch up with the best practices in the world of weather and climate prediction/forecast in a limited time frame.

In order to improve the quality of weather and climate forecasts in the country, the Ministry of Earth Sciences (MoES), Govt. of India has recognized the need of inducting well trained scientists into the country's R&D and operational organizations.

There is demand for well trained manpower in different areas of Earth System Sciences and Climate Studies in all the institutions of MoES. Such manpower is also in demand by some organizations outside the MoES umbrella as well.

IITM, in collaboration with the University of Pune, is already running PhD and M.Tech. courses in Atmospheric Sciences since 1988. Therefore, the responsibility of developing human resources in Earth System Sciences and Climate to meet the demand of modeling and forecasting scientists in MoES institutions was entrusted to IITM. Recently, a new collaborative academic programme M.Sc. (Atmospheric Science) Partly by Paper and Partly by Research (PPPR) was started through the Department of Atmospheric and Space Sciences (DASS) of the University of Pune. The training project is, therefore, divided into two sub-projects: 1) Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC), and 2) Academic Programme (PhD, M.Tech. and M.Sc.)

The main objectives of the project include: to continue the existing PhD, M.Tech. and M.Sc. courses in Atmospheric Sciences, to conduct and continue the advanced training programme in Earth System Sciences and Climate which includes a robust recruitment process, to establish a state-of-the-art advanced training centre in Earth System Sciences and Climate, to equip the training centre with the best possible infrastructure and facilities, to utilize the high end computational facilities for providing hands-on training of global numerical models to the trainees, to prepare and encourage the development of early career scientists in the fields related to Earth System Sciences involving ocean, land, atmosphere and sea ice and their interactions, to offer M.Tech. and PhD through the centre, etc.



Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC)

Deputy Chief Project Scientist : **Dr. Vinu Valsala,** Scientist-D

Objectives

- To establish a state-of-the-art advanced training centre in earth system sciences and climate.
- To create a large pool of trained and dedicated multi-disciplinary climate and earth system scientists.

Internal Faculty

- Prof. B.N. Goswami
- Dr. R.H. Kripalani
- Dr. R. Krishnan
- Dr. A.K. Sahai
- Dr. Gufran Beig
- Dr. A. Suryachandra Rao
- Dr. P.S.P. Rao
- Dr. C. Gnanaseelan
- Dr.(Smt.) Thara Prabhakaran
- Dr. G. Pandithurai
- Dr. S. Chakraborty
- Dr. K. Ashok
- Dr. Kausar Ali
- Dr. Vinu Valsala
- Dr. Anupam Hazra
- Dr. Ramesh Vellore
- Dr. Subodh K. Saha
- Shri S. Mahapatra
- Dr. P. Mukhopadhyay
- Dr. Shivsai Dixit
- Dr. K.M.C. Reddy
- Dr. Anoop Mahajan
- Dr. Anant B. Parekh
- Shri M. Mahakur
- Dr. Subrata K. Das

External Faculty

- Dr. Somnath Dutta (IMD)
- Dr. Prakash Khare (IMD)
- Shri M.K. Tandon (Rtd. from IITM)
- Dr. S. Rajan (NCOAR)
- Dr. Thampan Meloth (NCAOR)
- Dr. M. Ravichandran (INCOIS)
- Dr. K. Anand (Pune University)
- Dr. P. Srinivasulu (NARL)

National and International Faculty (Special Courses)

- Dr. Raghu Murtugudde
  University of Maryland, USA (Earth System Sciences & Introductory Oceanography).
- Prof. V. Krishnsmurthy
  University of Maryland, USA (Predictability of monsoons).
- Prof. V.K. Gaur
  Distinguished Professor, Indian Institute of Astrophysics, Bangalore (Inverse modeling).
- Prof. Mike John Wallace
  University of Washington, USA (Physics of the Atmosphere).
- Prof. Venkata Bhaskar Rao Dodla
  Jackson State University, USA (Atmosphere-Ocean-Modelling)
- Dr. Oliver Talagrand
  Laboratoire de Météorologie Dynamique, France (Data Assimilation).
- Prof. T. Yamagata
  Director, Application Laboratory, JAMSTEC Japan (Sub-tropical Dipole Modes).

Project work of Batch-II Trainee Scientists

For the partial fulfillment of the induction training programme, the trainee scientists underwent a six months project/dissertation work during July-December 2013 either at IITM or at other institutes of MoES. The projects were assigned to trainees. The trainee scientists did their project work at different MoES institutions as per the details given in the following table:

No.	Project Title	Project Mentor(s)	Institute	Trainee Scientist
1.	Indian Ocean Dipole in CFS & ESMv1: Role of ocean biases.	Dr. Vinu Valsala Dr.(Smt.) P. Swapna Dr. (Smt.) A. Krishnamurty Dr. Roxy Mathew Koll	IITM, Pune	Kum. Shikha Singh
2.	Scale Interaction in CFS coupled model.	Dr. A.S. Rao	IITM, Pune	Shri Ankur Srivastava
3.	Possible mechanism behind organized convection associated with BSISO in observation.	Dr. P. Mukhopadhyay Dr. A.S. Rao Prof. B.N. Goswami	IITM, Pune	Shri Sahadat Sarkar
4.	Quantifying the effect of $HCHO/NO_2$ ratio changes on O_3 production in the Indian subcontinent.	Dr. Anoop S. Mahajan	IITM, Pune	Shri Mriganka Biswas
5.	Evaluating the short range ensemble forecast for tropical cyclones over India using TIGGE EPS.	Dr. P. Mukhopadhyay Dr. A.S. Rao Prof. B.N. Goswami	IITM, Pune	Kum. Deepa J.S.
6.	Evaluating the short range ensemble forecast of weather associated with eastward propagating Tropical Intra-seasonal Oscillations (TISO) using ECMWF TIGGE EPS data.	Dr. P. Mukhopadhyay Dr. A.S. Rao Prof. B.N. Goswami	IITM, Pune	Kum. Shilpa Malviya
7.	Evaluating the short range ensemble forecast of monsoon weather associated with Indian Summer Monsoon ISOs using NCEP TIGGE EPS data.	Dr. P. Mukhopadhyay Dr. A.S. Rao Prof. B.N. Goswami	IITM, Pune	Kum. Snehlata Tirkey
8.	Assimilation of Sea Level Anomaly Data in 1½ layer Linear Reduced gravity model for the Indian Ocean Region.	Dr. Francis P.A. Dr. Arya Paul	INCOIS, Hyderabad.	Shri Pavan Kumar Nadiminti
9.	Satellite detection and monitoring of high biomass algal bloom: Preparedness for an ecological disaster.	Dr. Aneesh Lotlikar	INCOIS, Hyderabad	Shri Sandeep NarayansSetti
10.	Environmental forcing on phytoplankton biomass distribution in Bay of Bengal using Satellite and in-situ ARGO float data.	Dr. T. Srinivasa Kumar Dr. Aneesh Lotliker	INCOIS, Hyderabad	Shri Bhupendra Bahadur Singh

No.	Project Title	Project Mentor(s)	Institute	Trainee Scientist
11.	Identifying the sources of dust in Antarctica using Lagrangian Transport Model.	Dr. K. Satheesan	NCAOR, Goa	Shri Sourav e Chatterje
12.	Chemical signatures of phytoplankton-bacterial interaction in the Kongsfjorden.	Dr. K.P. Krishnan	NCAOR, Goa	Kum. Chaitri Roy
13.	Study of Intra-seasonal variations in the Bay of Bengal using OMNI buoydata.	Dr. R. Venkatesan Dr. Anant Parekh	NIOT, Chennai IITM, Pune	Shri Maheswar Pradhan
14.	Storm surge Modeling for Tamil Nadu Coast.	Smt. V. Ravichandran Dr. R.H. Kripalani	NIOT, Chennai IITM, Pune	Kum. Varghese Mercy
15.	Motion Response Control and Measurement of Interconnection System Response using LabVIEW Programme.	Dr. Purnima Jalihal	NIOT, Chennai	Shri B. Balaji
16.	Generation of Probabilistic forecast of Maximum and Minimum Temperature based on Global Ensemble Forecast System (GEFS).	Dr. Gopal R. Iyengar Dr. R. Ashrit	NCMRWF, New Delhi	Shri Avijit Dey
17.	Calibration of SAPHIR radiance towards Data Assimilation.	Dr. V.S. Prasad	NCMRWF, New Delhi	Shri Raju Mandal
18.	Study of progress of Monsoon Isochrones from south to north from coupled model outputs and observational data.	Dr. Ashis K. Mitra	NCMRWF, New Delhi	Kum. Sadhana Singh

Review of Project Work

The second batch trainee scientists submitted their project reports in the form of dissertations. A 2-day workshop was held during 16-17 December 2013 at IITM to evaluate these project works with the following review committee:

1. Prof. B.N. Goswami, Director, IITM, Chairman
2. Dr. R.H. Kripalani, Advisor & Head, CAT-ESSC, Member
3. Dr. Vinu Valsala, Faculty, CAT-ESSC, Member
4. Dr. R. Krishnan, Scientist-G, IITM, Member
5. Dr. G. Beig, Scientist-F, IITM, Member
6. Dr. A.K. Sahai, Scientist-F, IITM, Member
7. Dr. A.S. Rao, Scientist-F, IITM, Member
8. Dr. C. Gnanaseelan, Scientist-E, IITM, Member
9. Dr. (Smt.) Thara Prabhakaran, Scientist-E, IITM, Member
10. Dr. P. Mukhopadhyay, Scientist-D, IITM, Member
11. Dr. Somenath Dutta, Head, IMD Training Centre, Member
12. Dr. E.N. Rajgopal, Scientist-G, NCMRWF, Member
13. Dr. M. Ravichandran, Scientist-G, INCOIS, Member

Eighteen trainee scientists of Batch-II successfully completed the training programme by qualifying all the semester examinations and the project work in December 2013. Out of the 18 successful trainee scientists, 16 were issued office orders to join IITM as either Scientist-B or Scientist-C (according to their background qualification) in January 2014 and one trainee scientist joined NCAOR, Goa. One trainee scientist Kum. Sadhana Singh resigned w.e.f. 31 December 2013.

Recruitment of Batch-III Trainee Scientists

For the third batch of trainees, a detailed advertisement was issued in January 2013 and was re-advertised in March 2013. Advertisement brochures were sent to different institutions across the country during January-March 2013. A total of 7046 applications were received, out of which 420 were shortlisted for the two-stage interview process held in June 2013. Finally, 25 candidates were selected out of which the following 23 candidates joined on 16 August 2013:

No.	Trainee Scientist	Qualifications	University/Institute/etc.
1.	Kum. Aditi Modi	B.Tech. (Civil Engg.)	GBTU, Lucknow
2.	Shri Alakes Samanta	M.Sc. (Physics)	Banaras Hindu University, Varanasi
3.	Shri Ambuj Jha	B.Tech. (Mechanical Engg.)	Vinoba Bhave University Hazaribag (Jharkhand)
4.	Shri Anand Kishor	B.Tech. (Mechanical Engg.)	Guru Ghasidas Vishwavidyalaya, Bilaspur (Chhattisgarh)
5.	Shri Aruj Pant	M.Tech. (Geophysical Tech)	IIT-Roorkee, Roorkee
6.	Kum. Anulekha Majumdar	B.Tech. (Mechanical Engg.)	Guru Gobind Singh Indraprastha University, New Delhi
7.	Kum. Archana Singh	M.Sc. (Chemistry)	University of Delhi, New Delhi
8.	Shri Arka Roy	M.Sc. (Physics)	IIT-Bombay, Mumbai
9.	Shri Badimela Upendra	M.Sc. (Chemistry)	IIT-Madras, Chennai
10.	Shri Biswajit Haldar	B.Tech. (Instrumentation)	Haldia Institute of Technology, Midnapore (W.B.)
11.	Shri Biswamoy Paul	M.Sc. (Mathematics)	Jadavpur University, Kolkata
12.	Shri Dharmadas Jash	M.Sc. (Physics)	Homi Bhabha National Institute, Mumbai
13.	Shri Manmeet Singh	B.E. (Civil Engg.)	Thapar University, Patiala
14.	Shri Ningthoujam Singh	M.Sc. (Geophysics)	Osmania University, Hyderabad
15.	Shri Pramit Debburman	M.Sc. (Physics)	IIT-Delhi, New Delhi
16.	Shri Prasenjit Das	M.Sc. (Chemistry)	University of Calcutta, Kolkata
17.	Kum. Prerna Singh	M.Sc.(Tech.)(Geophysics)	Banaras Hindu University, Varanasi
18.	Shri Rajat Sharma	B.Tech. (Civil Engg.)	MMMUT, Gorakhpur
19.	Kum. Smrati Gupta	B.E. (Instrumentation Engg.)	Rajiv Gandhi Technical University, Bhopal
20.	Shri Subrata Mukherjee	M.Sc. (Chemistry)	University of Calcutta, Kolkata
21.	Shri Sujit Maji	M.Sc. (Chemistry)	IIT-Kanpur, Kanpur
22.	Shri Suresh Thatikonda	M.Sc.(Tech.)(Applied Geophysics)	Indian School of Mines, Dhanbad
23.	Shri Vikash Kumar	BS-MS dual degree, (Geo. Sci.)	IISER, Kolkata

Courses

The 18 months training programme consists of two semesters of academic study and one semester for project work. The courses for the two semesters are given below:

FIRST SEMESTER

No.	Subject	Faculty
1.	**Core courses**	
C1	Introduction to Earth Systems and Climate	Dr. Vinu Valsala, Dr. S. Chakraborty
C2	Physics and Chemistry of the Atmosphere	Dr. G. Pandithurai, Dr. Anoop Mahajan Dr. A. Hazra
C3	General Circulation and Climate	Prof. B.N. Goswami
C4	Geophysical Fluid Dynamics-I	Dr. Ramesh Vellore
C5	Statistical-Numerical Methods and Computer Programming	Dr. R.H. Kripalani, Dr. C. Gnanaseelan Shri M.K. Tandon
2. Elective courses (**one of the following**)		
E1	Mathematics for Atmospheric and Oceanic Sciences	Dr. C. Gnanaseelan, Dr. S. K. Saha
E2	Synoptic Meteorology	Dr. Somenath Dutta, IMD Dr. Prakash Khare, IMD

SECOND SEMESTER

No.	Subject	Faculty
1.	**Core courses**	
C1	Large-Scale Air-Sea Interaction	Prof. B.N. Goswami
C2	Atmosphere-Ocean Modelling, & Data Assimilation	Dr. A.S. Rao, Dr. C. Gnanaseelan Prof. Bhaskar Rao
C3	GFD-II & Parameterization	Dr. A.S. Rao, Dr. P. Mukhopadhyay Dr. Ramesh Vellore
C4	Observational Techniques	Dr. G. Pandithurai Dr. M. Ravichandran (INCOIS)
2. Elective courses (Two of the following)		
E1	Physical and Dynamic Oceanography	Dr. C. Gnanaseelan, Dr. Anant Parekh
E2	Boundary Layer and Micrometeorology	Dr. (Smt.) Thara Prabhakaran Dr. K. Anand (Pune University)
E3	Tropical Meteorology, Monsoon Dynamics, Climate Variability & Change	Dr. R. Krishnan, Dr. K. Ashok Dr. S. Chakraborty, Dr. Ramesh Vellore
E4	Environmental Chemistry (including Air Water/Pollution)	Dr. G. Beig, Dr. P.S.P. Rao
E5	Satellite Meteorology, Radar Meteorology and Applications	Dr. K.M.C. Reddy, Dr. M. Mahakur Dr. P. Mukhopadhyay, Dr. S. K. Das
E6	Advanced Statistical Techniques using Fortran 90	Dr. R.H. Kripalani, Dr. A.K. Sahai Shri M.K. Tandon

Academic Programme (PhD, M.Tech. and M.Sc.)

Deputy Chief Project Scientist: **Dr. P. Mukhopadhyay**, Scientist-D

Objectives:

- To conduct and continue PhD, M.Tech. and M.Sc. courses in Atmospheric Sciences in collaboration with the University of Pune and other Academic Institutions.
- To generate a trained pool of human resources in the field by attracting young talent and by encouraging IITM scientists to opt for higher studies.

M.Tech. (Atmospheric Science) Programme

M.Tech. (Atmospheric Science) is a joint academic programme of IITM and the Department of Atmospheric and Space Sciences (DASS), University of Pune. Classes of the first year of the 26th batch (10 students) of this programme started in August 2013. While six students of the second year of the 25th batch are doing their project works – four at IITM and two at DASS.

M.Sc. (Atmospheric Science) Programme

As per the Memorandum of Understanding (MoU) between IITM and the University of Pune signed on 13 March 2013, a new collaborative academic programme of M.Sc. (Atmospheric Science) Partly by Paper and Partly by Research (PPPR) was to be started through the Department of Atmospheric and Space Sciences (DASS) of the University of Pune. The first batch (10 students) of this programme was successfully started in August 2013. Under the programme, following courses have been conducted at IITM: Physical Meteorology, Numerical Methods, Mathematical Methods, Statistical Methods, Fundamentals of Ocean Science, Dynamic Meteorology and Climate Science.

Faculty for M.Tech. and M.Sc. Programmes

Following scientists of IITM were awarded Adjunct Professorship by the University of Pune. They worked as a faculty for the above mentioned M.Tech. and M.Sc. courses:

Name, Designation	Professorship Awarded
Dr. H.P. Borgaonkar, Scientist-E	Adjunct Professor
Dr. C. Gnanaseelan, Scientist-E	Adjunct Professor
Dr. S. Chakraborty, Scientist-E	Adjunct Professor
Dr. (Smt.) A.A. Kulkarni, Scientist-E	Adjunct Professor
Dr. P. Mukhopadhyay, Scientist-D	Adjunct Associate Professor
Dr. Milind Mujumdar, Scientist-D	Adjunct Assistant Professor
Dr. (Smt.) A.A. Deo, Scientist-D	Adjunct Assistant Professor
Dr. S.A. Dixit, Scientist-D	Adjunct Assistant Professor
Dr. S.M. Deshpande, Scientist-C	Adjunct Assistant Professor
Dr. R.M. Koll, Scientist-C	Adjunct Assistant Professor
Dr. A.B. Parekh, Scientist-C	Adjunct Assistant Professor
Dr. S. De, Scientist-C	Adjunct Assistant Professor
Dr. J.S. Choudary, Scientist-C	Adjunct Assistant Professor

Special Lectures for M.Sc. and M.Tech. (Atmospheric Science) Programmes

To acquaint the students of M.Sc. and M.Tech. (Atmospheric Science) programmes with various R&D activities at IITM, following special lectures were arranged:

Speaker	Lecture Topic
Dr. K. Ashok	Modeling for climate change predictions in India
Dr. (Smt.) Thara Prabhakaran	Linking aerosol-clouds and precipitation: Challenges and efforts from IITM
Dr. D.M. Chate	SAFAR and MAPAN systems: Impact of air pollution on environment, vegetation and population
Dr. Kaushar Ali	Understanding physico-chemical characteristics of atmospheric aerosols and the chemistry of trace gases and precipitation particles

Award of PhD by the University of Pune, Pune

Student	Thesis	Guide(s)
Shri Subhadeep Halder	Role of land surface processes in the variability of Indian summer monsoon	Prof. B.N. Goswami Dr. S.K. Saha Dr. K. Krishna Kumar
Shri H.N. Singh	Observed climatic changes in olr, cloud cover and rainfall across India: Linking hydroclimatic variation to large scale atmospheric circulations	Dr. N. Singh
Smt. S.K. Patwardhan	Study of the impact of climate change on the characteristics of Indian summer monsoon using Regional Climate Model	Dr. K. KrishnaKumar Dr.(Smt.) A.A. Kulkarni
Shri Dipu Sudhakar	Effect of aerosols on cloud microphysical properties: Measurements and implications to aerosol indirect effect estimates	Dr. G. Pandithurai
Shri M.I.R. Tinmaker	Space-time variations of lightning activity over Indian region	Dr. K. Ali

Thesis submitted to the University of Pune, Pune for the Award of PhD

Student	Thesis	Guide
Shri C.T. Sabeerali	Modulation of monsoon intraseasonal oscillations by global warming	Dr. A.S. Rao Prof. B.N. Goswami
Shri Bidyut B. Goswami	Study of Indian summer monsoon intraseasonal oscillation in multiscale modelling framework	Dr. P. Mukhopadhyay Prof. B. N. Goswami
Smt. Madhuparna Halder	Study of cloud microphysics and lightning activity using observations and numerical modeling	Dr. Devendraa Siingh Dr. A.K. Kamra Dr. P. Mukhopadhyay
Shri K. Ravi Kumar	A study of atmospheric carbon dioxide (CO_2) transport over India using observations and modeling techniques	Dr. Y.K. Tiwari Dr. (Smt.) A. Krishnamurthy
Shri Vijayakumar Soni	Multi-decadal solar radiation trends and direct tropospheric aerosol forcing in India	Dr. D.S. Pai (IMD, Pune) Dr. G. Pandithurai

Research Guidance to Students for Project Work

Guide(S)	Student(S)	Internship/Project Title	Degree, University
Dr. R. Krishnan	Kum. Luisa Knobloch	Comparison of high resolution gridded daily precipitation data of APHRO_MA_V1101 with satellite rainfall estimates of TRMM_3B42 over South Asia	B.Sc. (Geography), Georg August-University of Gottingen
Dr. G. Beig and Dr. D.M. Chate	Kum. Zenat Fatima	Atmospheric pollutants and its impact on different environements in India	IAS's Summer Research Fellow
Dr. A.K. Sahai and Dr. Abhilash S.	Kum. Remya R.	Prediction of the genesis and propagation of monsoon depressions: A comparative assesment using a coupled model and atmosphere model forced with bias corrected forecasted SST	M.Tech. (Atmos. Sciences), Cochin University of Science & Technology, Cochin
Dr. A.S. Rao and Shri S. Mahapatra	Shri A.K. Akshay Krishna	Some aspects of climate modelling	Integrated BS-MS, IISER, Pune
Dr. P.S.P. Rao	Shri Nikunj Pathak	Chemical analysis of $PM_{2.5}$ and PM_{10} aerosols at Sinhagad - a high altitude station	M.Sc. (Env. Science), University of Pune, Pune
Dr. P.S.P. Rao	Kum. Vidhi Singh	Chemical composition of rain water at Pune - an urban station	M.Sc. (Env. Science), University of Pune, Pune
Dr. P.S.P. Rao	Shri Hashavardhan Patil	Physical and chemical characterization of aerosols	PG B.Sc. (Applied Chem.), University of Pune, Pune
Dr. P.S.P. Rao	Shri Rahul Sonawane	Chemical analysis of rain water	PG B.Sc. (Applied Chem.), University of Pune, Pune
Dr. C. Gnanaseelan	Kum. Saee Peshave	Indian ocean dipole in the coupled model NCEP CFSv2	M.Tech.(Atmos. Science), University of Pune, Pune
Dr. C. Gnanaseelan and Dr. J.S. Chowdary	Shri G. Srinivas	Understanding the impact of shortwave penetration on air-sea interaction processes in climate forecasting system (CFSv2) coupled model	M.Tech.(Oceanic Science), Andhra University, Visakhapatnam
Dr. S.D. Pawar and Shri P. Murugvel	Shri P.S. Vishnu and Kum. A. Manayath	Lightning disaster over India	M.Sc. (Disaster Mang.), Mahatma Gandhi University, Kottayam, Kerala
Dr.(Smt.) Thara Prabhakaran	Shri V. Murugan	Aerosol-cloud interaction during monsoon onset	M.Tech. (Atmos. Science), Cochin University of Science & Technology, Cochin

Guide(S)	Student(S)	Internship/Project Title	Degree, University
Dr.(Smt.) Thara Prabhakaran	Kum. Smitha Joshi	Cloud classification over Indian region	M.Tech. (Earth System Sci. and Tech.), IIT Kharagpur
Dr.(Smt.) Thara Prabhakaran	Shri Swanand Khalagar	Effects of boundary layer humidity changes on atmospheric boundary layer entrainment: Inference from large eddy simulation	M.Tech. (Modeling and Simulation), University of Pune, Pune
Dr.(Smt.) Thara Prabhakaran	Shri Shrishail Dhaware	The role of free troposphere shear on the deep and shallow convection in monsoon environment: a large eddy simulation experiment	M.Tech. (Modeling and Simulation), University of Pune, Pune
Dr. S. Chakraborty	Shri Shubhadeep Rakshit	The isotopic analysis of tree ring from the high altitude locations in the Himalayas	Integrated BS-MS, IISER, Kolkata
Dr. S. Chakraborty	Shri Sandeep Mohan	Studying the past ENSO activities using proxy records	M.Sc. (App. Geology), Pondicherry University, Pondicherry
Dr. S. Chakraborty	Shri Rohit Otekar	Chemical processing of wood samples for isotopic analysis purposes	PG B.Sc. (Applied Chem.), University of Pune, Pune
Dr. S. Chakraborty and Dr. Y. K. Tiwari	Shri R.K. Gupta	Carbon cycle study around Pune	Integrated BS-MS, IISER, Kolkata
Dr. D.M. Chate	Kum. Namita Singh	Environmental health indices for population exposure to air pollutants at Delhi during the year 2001 to 2011	M.Tech. (Climate Change and Sustainable Development), CEPT University, Ahmedabad
Dr. G. Pandithurai	Kum. Saloni Saxena	On the relationship between aerosol and cloud condensation nuclei	M.Sc. (Physics), University of Mumbai, IASc-INSA-NASI Summer Research Fellowship
Dr. (Smt.) N.R. Deshpande	Shri Pravin Nimbalkar and Shri Dhiraj Raut	Hydrometeorological analysis of observed and future rainstorms in the Indus basin of India using GIS & RS techniques with SWAT model	PG B.Sc. (Applied GIS & RS), University of Pune, Pune
Dr. (Smt.) N.R. Deshpande	Kum. Harshada Wagh, Kum. Kalyani Patil and Shri Jitendra Misar	GIS & RS based extreme rainfall maps and trend analysis of climate parameters over the Krishna Basin in India	PG B.Sc. (Applied GIS & RS), University of Pune, Pune
Shri V. Gopalkrishnan	Shri Shailesh Kumar	Study of size distribution of raindrops by using optical disdrometer	M.Sc (Tech.) Geophysics, Banaras Hindu University, Varanasi

Guide(S)	Student(S)	Internship/Project Title	Degree, University
Dr. (Smt.) S.B. Morwal	Shri Pawan M. Surwase	Variability of intra-cloud parameters revealed from CAIPEEX	M.Sc. (Physics), H.V. Desai College, Pune
Dr. M.N. Patil	Shri Mangesh Nivruti Hande	Variability of fluxes in atmospheric boundary layer by using micro-meteorological tower	M.Sc. (Physics), Nowrosjee Wadia College, Pune
Dr. Ramesh Vellore	Shri Manish Manjhi	Understanding the role of water vapor feedback in tropics	B.Tech. (Physical Science), Indian Institute of Space Science & Technology (IIST), Trivandrum
Dr. P.D. Safai	Shri Prithviraj Mali	Day night variation of organic carbon and elememtal carbon aerosols over Pune during monsoon and post monsoon seasons of 2013	M.Sc. (Physics), H.V. Desai College, Pune
Dr. (Smt.) B. Padma Kumari	Kum. Vrinda Anand	Aerosol-cloud interactions over two contrasting regions from in situ observations	M.Sc. (Physics), University of Pune, Pune
Dr. H.S. Chaudhari and Dr. Anupam Hazra	Shri Bharat R. Bade	Study of ice-nucleation using AGCM for ISMR	M.Sc. (Physics), Fergusson College, Pune
Dr. D.R. Kothawale	Shri Santosh Ugale and Shri Rahul Ovhal	Spatial and temporal distribution of monsoon rainfall over Maharashtra: Using GIS technique	PG B.Sc. (Applied GIS & RS), University of Pune, Pune
Dr. Devendraa Siingh and Kum. P.S. Buchunde	Shri Himanshu Gandhi	Study of lightning and convective rain over Indian peninsula and Indo-China Peninsula	M.Sc. (Tech.), Geophysics, Banaras Hindu University, Varanasi
Dr. (Kum) S.S. Nandargi	Smt. Bhanupriya Pawar-Karki	Spatio-Temporal Rainfall Variability of the Mandovi River Basin, Goa, India	M.Sc. (Env. Science), Fergusson College, Pune
Dr. (Kum) S.S. Nandargi	Shri Tushar Patekar and Shri Bhagwat Kurve	To study rainfall and ground-water relationship in all the talukas of Pune district	M.Sc. (Geoinformatics), University of Pune, Pune
Dr. (Kum) S.S. Nandargi	Kum. Poorva Hendra and kum. Sapna Ugale	To study rainfall and cropping pattern, their average yield in different talukas of Pune district	M.Sc. (Geoinformatics), University of Pune, Pune
Dr. (Kum) S.S. Nandargi	Shri Abhijeet Kamble, Shri Vivek Kharate and Shri Manoj Bankar	To study rainfall variation in Pune district during 1971 to 2012 and its comparison with the past data	PG B.Sc. (Applied GIS & RS), University of Pune, Pune

Guide(S)	Student(S)	Internship/Project Title	Degree, University
Dr. K.M.C. Reddy	Kum. Manisha M. Tupsoundare	Understanding the precipitation and cloud radar interaction with the tropical cloud systems: Theoretical approach	M.Tech.(Atmos. Science), University of Pune, Pune
Dr. Abhilash S. and Dr. A.K. Sahai	Kum. Saranya G.	Impact of model resolution on intensity and track prediction of monsoon depressions using an ensemble prediction system	M.Tech. (Atmos. Sciences), Cochin Univ. of Science and Technology, Cochin
Shir S.S. Sabade and Dr. K. Ashok	Kum. Katru Nagalakshmi	Simulation of intraseasonal oscillations of the indian summer monsoon in the CMIP5 models	M.Tech. (Atmos. Science), Andhra University, Vishakhapatnam
Dr. (Smt.) P. Swapna and Dr. K. Ashok.	Kum. Jyoti Jadhav	Understanding the evolution and withdrawal of different El Niño flavours	M.Tech. (Atmos. Science), University of Pune, Pune
Dr. Sachin M. Deshpande	Shri Buddhisagar Kharat	Storm structure analysis using X-band doppler weather radar observations	M.Tech. (Atmos. Sciences), University of Pune, Pune
Dr. Roxy Mathew Koll	Kum. Ritika Kapoor	Indian Ocean Warming and its effect on the southwest Monsoon	M.Sc. (Env. Sciences), Fergusson College, Pune
Dr. Y. K. Tiwari	Kum. Ritugandha Chaugule	Carbon cycle, atmospheric CO_2 modeling and monitoring techniques: An overview	B.E. (Env. Engg.), KIT's College of Engg., Kolhapur
Dr. Y. K. Tiwari and Dr. Sachin Ghude	Kum. Deepali Rautela	A study of transport patterns of tracer emitted from thermal power plants in India	M.Sc. (Env. Sciences), Fergusson College, Pune
Dr. Saikat Sengupta	Shri Shivanand Mandraha	Dendrocronology from teak samples of the Western Ghats	Integrated BS-MS, IISER, Kolkata
Dr. Saikat Sengupta	Shri Anuraag Kumar	Dendrocronology and carbon/ oxygen isotope study of teak samples from the Eastern Ghats	Integrated BS-MS, IISER, Kolkata
Dr. Mahen Konwar	Shri Arun K. Dubey	Recent relative humidity variability during Indian summer monsoon season	M.Sc. (Tech.), Geophysics, Banaras Hindu University, Varanasi

Important Events and Activities

- **IITM-WMO (World Meteorological Organization) Seminar** was organized on 'Metropolitan Air Quality Forecasting and Services (SAFAR)' at IITM on 30 April 2013. The seminar aimed at bringing together scientists, experts, practitioners and decision-makers involved in real-time data generation, modelling and short term predictions in the field of air quality and weather to share evidence-based knowledge and experiences in order to discuss the current state and challenges in air quality and weather forecasting and to set the future agenda in the field.
- **C4 Workshop**: An international workshop on 'Changing Chemistry in Changing Climate: Monsoon (C4)' was organised during 01-03 May 2013 at IITM. This workshop provided a platform for exchange of knowledge amongst the developed and developing world, specifically in the field of Atmospheric Chemistry and health impact of air pollution. During the inaugural function held on 01 May 2013, all the facilities of SAFAR-Pune were made available and were dedicated to the nation by Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Govt. of India. These facilities include (i) Puneri-AIR: A booklet for common citizens about SAFAR-Pune prepared in three languages namely, Hindi, English and Marathi, (ii) High-Tech SAFAR Air Quality and Weather Monitoring Station, AWADHI facility (air quality and weather assessment and data on hi-tech-digital India) at the Master Control Room, (iii) Interactive Voice Response (IVR) Service where citizens of Pune can get the current and 24 hour advance forecast information on air quality and weather of Pune and Delhi by a toll free number, (iv) Dynamic SAFAR-Pune website (http://pune.safar.tropmet.res.in) with detailed SAFAR data and advisories, and (v) Digital LED Screens (10'x6') at 12 different locations, having maximum visibility, across Pune and PCMC. In addition to these, a report on 'Pune specific Emission Inventory of Pollutants: 2012' was also released.
- IITM in association with the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia organized a meeting of the forum on **'Seasonal Climate Forecasting in India and Sri Lanka (SCFIS) and its Application to Food Security'** at the Institute during 23-24 May 2013. National and international delegates attended the meeting. Director and scientists of the Institute provided expertise to the scientists of the above forum and discussed about the existing consensus forecast activities in India (by IITM and IMD with support from NCMRWF and INCOIS) for preparation of the seasonal climate forecasting in India.
- **Ka-band Scanning Polarimetric Radar (KASPR)** was installed and tested at IITM during 05-10 May 2013 by the suppliers M/s ProSensing Inc., USA. A team of three members (Prof. Andrew Pazamany along with two engineers, *viz*., Shri Brian Sima and Shri Joe Harney) visited IITM during this period and demonstrated operational procedures on 10 May 2013. Since then, the KASPR system was under test for almost continuous operation and collected important data. CAIPEEX-HACPL TEC radar expert Prof. G. Viswanathan, Ex-Head of Radar Development Cell (RDC), Indian Space Research Organization (ISRO), Bangalore visited the Institute during 16-17 May 2013 to review the proper installation and functioning of KASPR. Most of his concerns/ questions have been discussed with M/s Prosensing via online Skype and based on his report and recommendations, the Site Acceptance Test (SAT) was approved. Marking the first anniversary of the HACPL, Mahabaleshwar, the Ka-band radar was deployed at Mandhardev in collocation with existing X-band radar on 06 June 2013 for the Monsoon-2013 observational campaign. Prof. B.N. Goswami, Director, IITM flagged-off the campaign on 07 June 2013 at Mandhardev, in the presence of Satara District Collector Dr. N. Ramaswami, who was the Chief Guest on the occasion. Data from these radars and the HACPL instruments were collected.

- **Fifth Prof. P.R. Pisharoty Distinguished Lecture** by Prof. Sir Brian Hoskins, FRS, Director of Grantham Institute for Climate Change, Imperial College London; and Department of Meteorology, University of Reading, UK was arranged jointly by IITM and the Pune Chapter of the Indian Meteorological Society on 31 July 2013 at the Institute. The topic of the lecture was 'The potential for skill across the range of the seamless-weather climate prediction problem – a stimulus for our science'.
- **3rd Batch of the Advanced Training Course in Earth System Sciences and Climate (CAT-ESSC)** was inaugurated on 16 August 2013 at the Institute by Prof. B.N. Goswami, Director, IITM. The batch consists of twenty three (23) Trainee Scientists. The classes for the first semester started on 19 August 2013.
- **2nd WCRP CORDEX South Asia Science and Technology Workshop** was held in Kathmandu, Nepal during 27-30 August 2013. The event was jointly organized by the International Centre for Integrated Mountain Development (ICIMOD), World Climate Research Programme (WCRP), Centre for Climate Change Research of Indian Institute of Tropical Meteorology (CCCR-IITM), Chinese Academy of Sciences (CAS) and Monsoon Asia Integrated Regional Study (MAIRS). CCCR scientists played a key role in organizing the workshop and provided (a) expertise by delivering scientific lectures, (b) training lectures on regional climate downscaling over South Asia and (c) hands-on training on analysis and applications of CORDEX South Asia regional climate data for sectorial assessments.
- **CAIPEEX Phase-III Planning Meeting** involving Ganga Valley Ground Observational groups was conducted on 30 August 2013 at IITM. Shri D.R. Sikka, (Ex-Director IITM) was the Chairman of the meeting and was also attended by Dr. M. Rajeevan, Sc-G and Advisor, Ministry of Earth Sciences (MoES). Seventeen Indian scientists participated and made presentations on their facilities for conducting the experiments for the Ganga Valley.
- **Fifth MoES-CCCR National Workshop** on Climate Change with the theme 'Climate Science: Recent Research' was jointly organized by IITM and MoES in New Delhi during 04-05 October 2013.
- **CAIPEEX Science Meeting** was organized at IITM during 17-18 October 2013. Scientists from other institutions such as Space Physics Laboratory (SPL), Trivendrum; Physical Research Laboratory (PRL), Ahmedabad; Jawaharlal Nehru Technological University (JNTU), Hyderabad; Tata Institute of Fundamental Research (TIFR), Hyderabad; and Indian Institute of Technology, Kanpur (IIT-K); and Indian Institute of Technology, Bombay (IIT-B) also participated in the meeting. There were 22 oral and 25 poster presentations on various themes *viz*., (i) Aerosol and radiation, (ii) Aerosol-cloud interactions, (iii) Cloud microphysics and Precipitation, and (iv) Cloud dynamical interactions.
- **Three-day Eddy Co-variance Training Workshop** was organized at IITM during 11-13 November 2013. The Training was provided by the scientists of Licor Biosciences, USA. Theoretical and observational aspects of various atmospheric sensors related to green house gas flux measurements were taught. About 40 scientists and junior research fellows from various institutions including IITM participated in the workshop.
- **IITM-NIO Workshop:** IITM and the National Institute of Oceanography (NIO), Goa jointly organized a workshop on 19 November 2013 at IITM to identify the potential areas of mutual interests for possible collaborations in R&D. Dr. S.W.A. Naqvi, Director, NIO and Prof. B.N. Goswami, Director, IITM along with several scientists from both the institutes participated in the workshop.
- **OSICON 2013:** The Ocean Society of India (OSI), Kochi in collaboration with IITM organised its 3rd National Conference, popularly known as OSICON, on the theme 'Role of Oceans in Earth System' at IITM during 26-28 November 2013. Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Govt. of India inaugurated the

conference. The conference was well attended by over 200 scientists/experts from across the country working in the areas of ocean studies, earth system sciences, climate change, ocean-land-atmosphere interactions, etc. with about 130 presentations/talks on various subjects. A special press conference by Dr. Shailesh Nayak along with Prof. B.N. Goswami, Director, IITM and Dr. C. Gnanaseelan, President, OSI, Pune Chapter was held on 26 November 2013 after the inaugural function. On the concluding day of the conference, a panel discussion on the theme 'The Role of Oceans in Monsoon' was held. OSI, Pune Chapter and scientists of IITM contributed significantly for organizing the workshop.

- **AGU Fall Meeting 2013:** A new initiative on science and technology in India has spurred the expansion of education and research with new institutions and funding, which have provided career opportunities for bright young scientists. To represent India's contribution in Earth System Sciences, and to attract young talented faculty to different Earth Science Programmes in India, a special Town Hall Meeting with young investigators and senior scientists was arranged at the American Geophysical Union Fall Meeting 2013 to discuss strategies for scientific success. A follow-up meeting will be held to take full advantage of the contacts made in the first meeting. Prof. B.N. Goswami, Director attended the Town Hall Meeting held in San Francisco, USA during 9-11 December 2013.

- **Inauguration of new HPC and Lightning Location Network:** IITM has acquired a new High Performance Computing (HPC) system with a computing speed of 790 Tera Flops and a storage of 06 Petabytes. This newly augmented HPC is named as 'AADITYA' (meaning SUN in Hindi) to signify the major source of energy that drives our climate system. The AADITYA is a highly parallel supercomputing system built on IBM System X technology. There are 2384 compute nodes with each node having two 8-core processors (Intel Xeon E5-2670 2.6 GHz cache 20 MB) and the memory is 4 GB per core and 64 GB per node. The new installation will accelerate the process of improving weather and climate forecasts over India. The Institute has also taken the initiative to study the characteristics of lightning by a using Lightning Location Network (LLN). The LLN has been established at IITM. This network will be able to detect accurately the location of occurrence of lightning and forewarn the public at least 1-2 hours before the occurrence of thunderstorm. Both the AADITYA and the LLN were inaugurated by Dr. Shailesh Nayak, Secretary of the Ministry of Earth Sciences (MoES), Govt. of India on 28 February 2014 at IITM. In addition to this, he also laid the foundation stone for the construction of a new students' hostel at IMD Campus, Pashan, Pune. This upcoming hostel will be jointly utilized by IITM and IMD.

- **National Workshop on Monsoon 2013:** The Pune Chapter of the Indian Meteorological Society in association with IITM organized a one day National Workshop on Monsoon 2013 at IITM on 26 March 2014. IITM scientists contributed significantly for organizating the workshop.

- **52nd Foundation Day Celebration:** IITM celebrated its 52nd Foundation Day on 17 November 2013 at its premises. Prof. K.N. Ganesh, Director, Indian Institute of Science Education and Research (IISER), Pune was the Chief Guest and Prof. Wojciech Grabowski, Senior Scientist, National Centre for Atmospheric Research (NCAR), USA was the Guest of Honour at the function. In addition to the main function, the celebration included the presentation of various IITM awards *viz*. the Annual Silver Jubilee Award for the best research paper published in peer reviewed journal, the Best Student Research Paper Award and the Excellent Performance Award for the Scientific Support, Administrative, Technical and Multi-Tasking Staff, Dr. Anandu Vernekar Award for a daughter of an economically backward employee of the Institute, the Foundation Day Lecture, the Silver Jubilee Award Lecture and the Best Student Paper Award Lecture by the respective award winners. The celebrations concluded in the evening with a cultural programme by the employees and their family members. Several ex-employees and special invitees, in addition to the existing employees and their families, attended the function.

- Presentation of the IITM Annual 25th Silver Jubilee Awards for the year 2012 to a paper entitled 'ENSO, IOD and Indian summer monsoon in NCEP climate forecast system' by S. Pokhrel, H.S. Chaudhari, S.K. Saha, A.R. Dhakate, R.K. Yadav, K.D. Salunke, S. Mahapatra and S.A. Rao, published in the international journal Climate Dynamics, 39, November 2012, 2143-2165.
- Presentation of the Annual Excellent Performance Award for the year 2012 to Shri Ravindra Waghmare, Shri Yogesh Pawar, Shri R.A. Paradkar and Shri G.E. Dhongade for the Scientific Support, Administrative, Technical and Multi-Tasking Staff category respectively.
- Presentation of the Best Student Paper Award for the year 2012 to a paper 'On the relationship between Indian summer monsoon withdrawal and Indo-Pacific SST anomalies before and after 1976/1977 climate shift' by C.T. Sabeerali, S.A. Rao, R.S. Ajayamohan and R. Murtugudde published in the international journal Climate Dynamics, 39, August 2012, 841-859.
- Presentation of the Anandu Vernekar Scholarship for the Girl Students of Economically Backward Employees of IITM to Kum. Sukanya Sambhaji Ghanwat daughter of Shri S.B. Ghanwat (a Multi-Tasking Staff) for the academic year 2013-14. Scholarship cheque of Rs. 5000/- was presented to the recipient.
- A special Foundation Day lecture on the topic 'Clouds, Climate and Climate Change' by Prof. Wojciech Grabowski, Senior Scientist, NCAR, USA.

Collaborative Programmes

- **Assessment of Air Quality at Lumbini Protected Zone, Nepal:** Under this collaborative programme of WHO Nepal and IITM, online observations were carried out under two different phases (Phase- II & III). The period of observation for the Phase-II was 19 December 2012 - 24 January 2013 and for the phase-III, it was 14 May - 22 June 2013. Online Particulate Monitoring System ($PM_{2.5}$, PM_{10}), Ozone Analyzer and AWS (all of Environmental SA France Make) were taken to Lumbini for measurements of $PM_{2.5}$, PM_{10}, Ozone and weather parameters. During Phase-III, additional sampling for OC/EC was carried out. Four sites were selected, each one representing Monastic Zone, Industrial Zone, Exposed Zone and Control Site. Therefore, Panditrama Lumbini International Vipasana Meditation Centre - Monastic Zone, Parsahawa - an industrial site, Bhairahawa – an urban location, Tilaurakot Police Station – a control site were considered. Continuous measurements and sampling work during the two phases at all the four locations were successfully completed. Broad conclusions from the observations carried out at Panditrama Meditation Centre indicate that both the PM_{10} and $PM_{2.5}$ concentration levels are very high. Fine particles normally remained above the NAAQS level but the PM_{10} occasionally went above the NAAQS. Weather data support the formation of accumulation mode particles under highly humid, low temperature and foggy atmospheric condition. Ozone concentration was low mainly due to weak photochemistry caused by non-appearance of the sun.
- IITM has signed a Memorandum of Understanding (MoU) with the Society for Applied Microwave Electronics Engineering & Research (SAMEER), Mumbai for collaborative research on atmospheric remote sensing instrumentation and facilities on 15 July 2013. This collaboration is beneficial in the use of microwave radiometer. Ka-band radars are presently under development at SAMEER.
- As a part of the CAIPEEX Phase-III campaign, an MoU is signed with Banaras Hindu Univeristy for using its Rajiv Gandhi south campus, Barkachha, Mirzapur, U.P. as a base station for the ground observational campaign.
- An Memorandum of Understanding (MoU) is signed with Mahatma Gandhi University, Kottayam for a specific interest in using the facilities at the International and Inter-University Centre for Nanoscience and Nanotechnology.

- **Establishing collaborations with NCAR in radar data corrections and management:** Radar data quality and corrections is a forefront issue and efforts are being made in that regard for capacity building for radar through collaborations with National Centre for Atmospheric Research (NCAR), USA. The main goal of such collaborations is to develop usable data quality for radar and its derivable products. Efforts are underway so that IITM scientists could visit NCAR for short periods to learn various aspects of signal processing and algorithms used in data corrections and product developments.
- Under the Indo-Russian collaborative Programme [Department of Science & Technology (DST), India and Russian Foundation for Basic Research (RFBR), Russia], a project is undertaken with a Russian research and instrumentation group led by Dr. Andrei of A.I. Voeikov Main Gophysical Observatory, St. Petersburg to investigate the effect of high aerosol concentration on microphysical and electrical characteristics of cumulus clouds using a state-of-the-art cloud model and the ice nucleus properties of dust and soot particles using cloud chamber.

Observational Programmes/Field Campaigns

- A field trip to remote places of Andhra Pradesh during 02-06 May 2013 was arranged for exploring new caves containing stalagmites and stalactite deposits. A few pieces of cave deposits and drip waters were collected for examining their potential for rainfall reconstruction on millennial time scales.
- A field observational campaign for the measurement of optical properties of aerosols, SW radiation, black carbon aerosols, PM_{10}/$PM_{2.5}$ and size separated aerosols and meteorological parameters was conducted at the Microwave Tower, Sinhagad during summer (10 to 20 May 2013) and winter (27 January - 07 February 2014).
- Rain water samples were collected from Paud and Bhira, Pune on 06 June 2013 and from Bhor, Shirwal, Khandala, Wai and Washiwali Niuhar during 12-13 June 2013.
- **Monsoon-2013 Campaign:** The state-of-the-art Mobile Ka-Band Radar, which was recently procured by IITM, was colocated with the existing Mobile X-Band Radar at Mandhardev on 07 June 2013 for the Monsoon-2013 Campaign. Continuous measurements of the following were carried out: (i) Cloud liquid water content, cloud drop size distributions, cloud drop number concentrations, (ii) rain intensity, rain drop size distribution, fall velocity, oblateness of rain drops, (iii) aerosol number concentration, aerosol number size distributions, (iv) CCN number concentration, supersaturation spectra, (v) vertical profiles of temperature, humidity, water vapour, liquid water content through microwave radiometric profiler, (vi) vertical sounding of temperature, humidity and winds using radiosonde balloon borne measurements, (vii) aerosol scattering coefficient at three different wavelengths, (viii) short and longwave radiation components, (ix) vertical profiles of rain drop size distributions, (x) whole sky images, cloud fraction, (xi) X-Band Radar precipitation spatial/temporal distributions and (xii) Ka-Band Radar cloud spatial/temporal distributions. Level-0 data from HACPL instruments (CCP, CCN, SMPS/APS, Aethalometer, Optical/impact/video disdrometers, Nephelometer, Radiosonde, Radiometric profiler, AWS, FRRG) till November 2013 after initial quality check have been released to the IITM research community. Observational data of aerosol, clouds and thermodynamics over the Western Ghats at HACPL over two monsoon seasons and radar data with Ka-Band Radar (Cloud) and X-Band Radar (precipitation) have also been collected. Radiosonde data from May 2013 onward for both the stations (IITM Pune and HACPL) were supplied to SAC Ahmedabad for calibration of INSAT 3D Satellite of ISRO. Radiosonde data collected at IITM Pune were provided to Air Force Station for now casting by the Air Force Met Office during Monsoon 2013.

Infrastructure Development

- **Inauguration of CCCR Building at IITM**: The newly constructed office building for the Centre for Climate Change Research (CCCR) at IITM was inaugurated at the hands of Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences (MoES), Govt. of India on 23 August 2013. The CCCR office building has a green design with energy efficient techniques leading to reduction in energy consumption.
- Day Care Centre for kids of IITM employees was inaugurated at the IITM Colony on 17 November 2013 at the hands of the Director, IITM.
- A Car Parking Facility at IITM for its employees was inaugurated on 17 November 2013.
- Renovation work of two blocks of Type-III quarters, Room Nos. 101 & 102 of C&H Division, Room No. 324 of I&OT Division, Room Nos. 205 to 207 of PM&A Division, landscaping of the Meghdoot Complex and toilets near the canteen is completed.
- An Memorandum of Understanding (MoU) between IITM and IMD is signed for the construction of a student hostel at the premises of IMD, Pune. Its foundation stone was laid and *bhoomi poojan* was done on 28 February 2014. The construction work is in process.
- Construction of High Altitude Cloud Physics Laboratory (HACPL) at Mahabaleshwar is under progress.
- The civil work of the renovation work of the Guest House and Laboratory Building of IITM Branch Office in New Delhi is completed and the interior work is in progress.

Computer and IT Services

- Preparation of SRS document for office Automation System is in progress.
- Preparation of the e-school software for CAT-ESSC is completed. Training and demonstrations were arranged for the faculty members and other users. It is working satisfactorily.

Special Days/Weeks Observed

- **Anti-Terrorism Day** was observed on 21 May 2013. On this day, a pledge was administered to the Institute's employees.
- **Sadbhavana Diwas** was observed at IITM on 20 August 2013. On this occasion, a pledge was administered to the Institute's employees to eschew violence and to promote goodwill among people.
- **Vigilance Awareness Week** was observed during 28 October - 02 November 2013 as per the guidelines of the Central Vigilance Commission (CVC), Govt. of India. A pledge on anti-corruption was administered to the employees of the Institute on 28 October 2013. An essay competition was arranged on the theme 'Your Positive Contribution of Vigilance to IITM' on 31 October 2013. The concluding function of the Vigilance Awareness Week was organised on 01 November 2013. Shri B.C. Joshi, Indian Ordnance Factories Service (IOFS), Director, Vigilance, Ammunition Factory, Pune was the Chief Guest at the concluding function. Shri Joshi also delivered a lecture on this occasion. Prizes to the winners of the essay competition were presented at the hands of the Chief Guest.
- **Quami Ekata week** was observed and a pledge was taken by the employees on 23 November 2013.

Science Popularization Programmes

- **Earth Day:** IITM celebrated the Earth Day on 22 April 2013. This year's theme announced by the Ministry of Earth Sciences, Govt. of India was 'Future Earth'. On this occasion, a special film about climate scientists and climate change entitled 'Thin Ice', released worldwide on 22 April 2013, was screened at IITM.
- **Indian Science Congress 2014:** IITM participated in the common exhibition stall of the Ministry of Earth Sciences (MoES) in the 101st Indian Science Congress held at the University of Jammu, Jammu during 03-07 February 2014. Shri Abhay S.D. Rajput and Shri Vijay H. Sasane represented IITM in the exhibition and gave demonstrations and presentations about the various R&D activities of the Institute to the visitors. Publicity material was also distributed.

- **INTROMET-2014**: The Institute participated in the ESSO exhibition at the International Tropical Meteorology Symposium (INTROMET) on 'Monsoons – Observations, Prediction and Sustainability (MOPS)' jointly organized by the Indian Meteorological Society and the SRM University, Chennai at the latter's campus in Chennai during 21-24 February 2014. Shri Abhay S.D. Rajput and Shri Vijay H. Sasane represented IITM in the exhibition.
- **National Science Day:** The Institute celebrated the National Science Day on 28 February 2014 at its premises in a befitting manner. On this occasion, an open day for students, general public and the media persons was observed. Students and other visitors were taken round the Institute, in groups, to see the working of scientific instruments and experimental activities at the various laboratories and to have interactions with scientists. The visitors showed great curiosity to know and explore more and more about weather, atmospheric sciences, global warming, climate change, etc. An introductory presentation about the Institute was also given. Students were also guided about the various career opportunities available in the field. Refreshments were distributed among the visitors. An open on-the-spot quiz competition was organized for students who visited the Institute and token gift prizes were given to students who gave the right answer first.
- **National Science Day Celebrations at GMRT, Narayangaon:** On invitation, IITM participated in the National Science Day Celebrations of the Giant Metrewave Radio Telescope (GMRT) at Narayangaon during 28 February - 01 March 2014. During this period, a big science exhibition is organized by GMRT where IITM participates regularly. The exhibition attracts huge crowd of inquisitive visitors, especially from the rural areas. Four persons from IITM *viz*. Shri T. Dharmaraj, Dr. Shivsai Dixit, Shri S.S. Sabade and Smt. V.V. Sapre participated in the exhibition. A big stall was set up where IITM's popular scientific exhibits were displayed for the general public and students. The visitors to the stall were apprised about the various research activities and projects being carried out by IITM and their relevance to the society. Many school and college students and faculty and the general public visited the exhibition stall. Availing this opportunity, an effort was made to popularize Atmospheric Sciences and to sensitize students for opting a career in the same. For this, Institute's information and career flyers and posters were distributed among the interested students and faculty. The visitors were explained science through exhibits and demonstrations.
- **World Meteorological Day:** As 23 March 2014 was a closed holiday, the World Meteorological Day was celebrated in the Institute on 25 March 2014. As a part of the celebration, an interactive programme on 'WATER' (Research and Development, and Adaptation and Conserving the Good Practices) was organised.
- **School, College and Public Visits throughout the Year:** IITM receives a lot of requests from the different walks of life to visit the Institute and to see the science in action in the laboratories and to interact with scientists. Many groups visited the Institute thoughout the year. Such visits were coordinated by late Dr. T. Venugopal and Dr. M.D. Chipade. The visitors are shown the laboratories, equipments, etc. used for the research purpose. They are given presentations about the R&D activities going at the Institute. They are also allowed to interact with scientists and researchers.

Library Information and Publication Services

The Library, Information and Publication Division serves as the National Information System in Meteorology and Atmospheric Sciences. The information resources have been strengthened by adding a good number of international scientific journals in Meteorology and Oceanography with online access and purchasing latest books. IITM subscribed to 77 journals (68 foreign and 09 Indian) with online access to 67 foreign and 4 Indian journals for the year 2013 (costing approx. Rs. 65.97 lakhs). Subscription to 76 journals (68 foreign and 08 Indian) with online access to 68 foreign and 3 Indian journals for the year 2014 (costing approx. Rs. 70.57 lakhs) has

been processed. In addition to this, access to 19 foreign journals and the SCOPUS database, which were earlier subscribed to individually by IITM, is available under the MoES Consortium from the Science Direct. The remaining journals (21 total: 11 Indian and 10 foreign) are either complimentary/ free online or against life membership. Online IP based institutional access to the Earth and Environment Sciences Package of the E-book resources of Springer for the copy right years 2005-13 is working satisfactorily. Online IP based institutional access to 55 titles of Cambridge e-books was purchased (costing approx. Rs. 4.53 lakhs). Eighty one (81) books covering majority of the Institute's research areas (costing approx. Rs. 4.04 lakhs) were purchased. Payments for paper publications/perpetual access/excess length fee charges for four papers of the Institute scientists were approx. Rs. 1.91 lakhs. A good number of scientific and technical reports of leading institutions from various countries have also been received on exchange and gratis basis.

The division has maintained liaison with institutions, universities and ministries. A number of reports on the research activities of the Institute were compiled and sent to the Ministry of Earth Sciences, India Meteorological Department, universities and research institutes. English and Hindi Version of the Institute's Annual Report for 2012-13, Director's Reports for the Meetings of the Governing Council and the Research Advisory Committee, Institute's input for Annual Report of the Ministry of Earth Sciences, etc. were compiled. Various reports in respect of 11th and 12th Five Year Plan schemes were compiled and provided to the MoES.

Institute's website is being regularly updated. Latest information on various activities, achievements, tenders, jobs, etc. is being uploaded from time to time. Access to library catalogue, subscribed to and open access journals, papers and research reports of the Institute's scientists, Annual Reports, Meteorological Data, scientists' profiles, etc. has been made available on Institute's website.

Notifications of awards, seminars, symposia, conferences, etc. received from other organizations were provided to the scientists of the Institute. Centralized Technical Services like photocopying, photography, video recording, printing and binding are also being provided to the Institute.

The division arranges programmes for popularization of Meteorology among students and the public by organizing open days, scientific exhibition depicting research activities of the Institute, scientific film shows and popular science lectures by experts on the occasion of important events such as National Science Day, Earth Day and World Meteorological Day. Organized tours are arranged for the students and trainees visiting the Institute under their study tour. The visitors are taken round the Institute and shown the laboratories, library and various instruments. The Division also arranged Institute's participation in scientific exhibitions of other organizations. Institute participated in National Science Day Celebration of the GMRT at Narayangaon, INTROMET-2014 and Indian Science Congress 2014.

Management

As per the Notification No. O.M. No. 25/10/2006 dated 19 July 2006 from the President of India, the Indian Institute of Tropical Meteorology (IITM), Pune has been transferred from the Department of Science and Technology (Ministry of Science and Technology) to the Ministry of Earth Sciences, Government of India with effect from 12 July 2006. The management of the Institute vests with its Governing Council at the apex level comprising of a Chairman and twelve Members, consisting seven outside senior scientists, Director General of Meteorology, three Senior Representatives of the Ministry of Earth Sciences including Financial Advisor, and Director, IITM as the Member Secretary. Administrative Officer, IITM is the Non-Member Secretary. Prof. U.R. Rao, Former Chairman, ISRO is the Chairman of the IITM Governing Council with effect from 28 April 2006. The Governing Council meets twice a year. During the year 2013-14, the Governing Council had its 87th and 88th on 22 August 2013 and 17 January 2014, respectively. The executive responsibility of the Institute's management is vested in the Director who manages the research, administrative, financial and technical aspects of the Institute's functioning. Research work in IITM, which is its core function, is organized in two major areas viz.,

Theory and Modelling, and Observations and Diagnosis, through various research programmes supported by the Technical and Administration Divisions. The organizational structure is evolved from time to time to meet the needs and demands of the day. Today, the IITM has flexible intermeshing structure with typical divisions/sections as well as multifaceted research teams of scientists from different programmes.

The Institute has been maintaining close collaboration and interaction with other organizations working in the field of Meteorology, particularly with the India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Space Research Organization (ISRO), Indian Institutes of Technology, Universities and other scientific organizations associated with academic and research work in Atmospheric and Oceanic Sciences.

Research Advisory Committee

The Governing Council at its 69th meeting held on 26 December 2003 formed a Research Advisory Committee for the Institute which consists of four scientists from various disciplines of meteorology and atmospheric sciences, one of whom will be one of the scientist members of the Governing Council. The Chairman is nominated by the Governing Council. The senior most scientist of the Institute is the Member Secretary. The roles and functions of the Research Advisory Committee are (i) to advice and recommend thrust areas and research programmes of the Institute and to monitor and evaluate its programmes from time to time, (ii) to recommend in general the allocation of funds to various activities of the Institute to enable it to achieve academic excellence, (iii) to recommend new areas of research to be undertaken by the Institute, and (iv) to advice upon and recommend the creation of posts for priority areas of research. The seventh meeting of the Research Advisory Committee was held during 16 January 2014 under the Chairmanship of Prof. V.K. Gaur, Distinguished Professor, Indian Institute of Astrophysics, Bangalore. Director and all the Chief Project Scientists made presentations on the achievements and the future plans of their respective research and development projects.

Administration

The Administration provides support for the personnel management, finance, purchase, stores, capital works and maintenance of buildings and campus.

Personnel Profile as on 31 March 2014

Category	No. of Posts
Research	131
Scientific Support Staff	41
Technical Support Staff	7
Isolated Staff	2
Admin. Support Staff	44
MTS	29
Total	**254**

Staff Changes

Appointments

Research Staff

- Shri Bhupendra Bahadur Singh, Scientist-C, 17 January 2014
- Kum. Mercy Varghese, Scientist -C, 17 January 2014
- Shri Sandeep Narayanasetti, Scientist-B, 17 January 2014
- Shri Maheswar Pradhan, Scientist-B, 17 January 2014
- Shri Ankur Srivastava, Scientist -B, 17 January 2014
- Shri Raju Mandal, Scientist -B, 17 January 2014
- Shri Avijit Dey, Scientist - B, 17 January 2014
- Shri Mriganka Sekhar Biswas, Scientist-B, 17 January 2014
- Kum. Chaitri Roy, Scientist -B, 17 January 2014
- Shri Nadiminti Pavan Kumar, Scientist-B, 17 January 2014
- Kum. Shikha Singh, Scientist-B, 17 January 2014
- Shri Sahadat Sarkar, Scientist -B, 17 January 2014
- Kum. Shilpa Malviya, Scientist -B, 17 January 2014
- Kum. Deepa J.S., Scientist -B, 17 January 2014
- Kum. Snehlata Tirkey, Scientist -B, 17 January 2014
- Shri Balaji B., Scientist -C, 20 January 2014

Administrative Support Staff

- Shri Amit Kumar Trivedi, Senior Executive (Hindi), 17 June 2013

Separation from the Institute

- Shri S.D. Patil, Scientist-D, by superannuation on 30 June 2013
- Shri Suyash Bire, Scientist-C, by resignation on 20 July 2013
- Smt. N.V. Panchawagh, Scientist-B, by superannuation on 31 July 2013
- Dr. Nityanand Singh, Scientist-F, by superannuation on 31 August 2013
- Dr.(Smt.) R.R. Joshi, Scientist-C, by superannuation on 31 August 2013
- Dr. K. Krishna Kumar, Scientist-F, by voluntary retirement on18 March 2014
- Dr. T. Venugopal, Scientist-C, by untimely demise on 26 December 2013

Status of SC/ST/OBC reservations as on 31 March 2014

Category	SC	ST	OBC	Total
Research	15	4	12	**31**
Scientific Support Staff	5	5	1	**11**
Technical Support Staff	3	—	—	**3**
Isolated Staff	—	—	—	**—**
Admin. Support Staff	4	5	5	**14**
MTS	7	3	2	**12**
Total	**34**	**17**	**20**	**71**

Employment of Ex-servicemen

Reservation for Ex-servicemen is made at 10% in Group C & MTS posts of the Institute. The percentage of Ex-servicemen at the Institute vis-à-vis total number of employees in the group of 'A', 'B', 'C' and MTS is: Nil, Nil, 3.70% and 3.44% respectively.

Finance

Finance Committee

Finance Committee constituted by the Governing Council meets twice in a year and reviews the financial performance of the Institute and provides guidance for improvement of the performance. The Finance Committee held its 25th and 26th meetings at IITM, Pune on 21 August 2013 and 16 January 2014 respectively.

Budget

The grant received and the actual expenditure incurred for the period 2013-2014 are as follows: (₹ in crores)

Schemes	Opening Balance	Funds Received	Other Receipts	Total Funds	Total Expenditure
A - Plan Schemes					
Advanced Training in Earth System Science & Climate	5.72	22.687	0.36	28.77	8.28
Centre for Climate Change Research	-1.73	16.17	0.59	15.03	13.41
High Performance Computer System (Monsoon Mission 66.23 + BIMSTEC 7.36 + HOOFS 29.43)	2.64	103.02	5.31	110.97	101.13
IITM Operations & Maintenance	0.00	12.00	0.04	12.04	11.05
Metropolitan Air Quality & Weather Services	3.29	1.00	0.22	4.51	4.53
Monsoon Mission	-3.01	16.00	0.21	13.20	11.65
Physics and Dynamics of Tropical Cloud * CAIPEEX - 0.26 * HACPL - 3.11	3.37	3.00	0.06	6.43	3.31
Short Term Climate Prediction & Variability	12.58	1.505	0.67	14.76	18.93
Total of - A	**22.86**	**175.38**	**7.46**	**205.70**	**172.29**
B - Non-Plan	**5.71**	**17.55**	**1.39**	**24.65**	**21.47**
C - Sponsored Projects	**36.65**	**1.91**	**0.00**	**38.56**	**38.24**
Total (A+B+C)	**65.22**	**194.84**	**8.85**	**268.91**	**232.00**

Figures are regrouped as per audit report.

The Auditors appointed by the Governing Council M/s Sulakhe & Co., Pune conducted the audit for the F.Y. 2013-14. The abstract of the report is enclosed at the end of this report.

PURCHASE AND STORES

The Institute acquired scientific equipments and accessories, data acquisition and storage systems, personal computers, work stations, enhancing systems and accessories to the existing computer systems and office furniture items.

During the period the following purchases were made:

	Institute Funds (in Rs.)	Project Funds (in Rs.)	Total (in Rs.)
Equipment	**2,32,27,39,303.67**	**4,83,706.90**	**2,32,32,23,010.57**
Consumable	**30,26,085.98**	**36,773.00**	**30,62,858.98**
Dead Stock	**20,04,004.65**	**0.00**	**20,04,004.65**
Total	**2,32,77,69,394.30**	**5,20,479.90**	**2,32,82,89,874.20**

Official Language Implementation

- Continuous efforts are being made for compliance of the Official Language Policy of the Union.
- Quarterly Report on Progressive use of Hindi in the Institute for the quarters ending on 30 June 2013, 30 September 2013 and 31 December 2013 were prepared and sent to the Ministry of Earth Sciences, the Department of Official Language and the Town Official Language Implementation Committee, Pune.
- The ninth edition of the in-house Hindi magazine 'Indradhanush' is published.
- Four meetings of the Official Language Implementation Committee were held on 06 May 2013, 29 August 2013, 23 December 2013 and 05 March 2014.
- Half yearly meeting of the Town Official Language Implementation Committee was held at the Institute on 10 May 2013.
- A one day Hindi Scientific Workshop was organized on 25 July 2013 for the Institute's employees. About 100 employees participated in the said workshop. Some scientists gave presentations on their respective scientific work in Hindi.
- Translation of Institute's Annual Report is being carried out.
- The roaster of Hindi knowledge in respect of all the employees of the Institute is being updated from time to time.
- Hindi Website is updated regularly.
- Maintenance of Hindi Library, issue and receipt of books.
- Day-to-day translation and correspondence work is being carried out.
- A one day Hindi workshop on the 'Use of Hindi on computer (Unicode)' was organized for the Institute's employees on 16 December 2013. About seventeen employees participated in the workshop. The workshop was conducted by Shri R.P. Verma, Hindi Teaching Scheme, Department of official Language, Pune. Dr. O.N. Shukla, the Institute's Hindi Officer, also spoke about the various forms of correspondence on the occasion.
- IITM celebrated 'Hindi week' during 10-17 September 2013 by organizing various competitions such as Quiz, Poem Recitation, Antakshari, Essay Writing, Translation of Administrative Terminology, Solo Song, etc. Many IITM employees participated in various competitions. Hindi Week Concluding Function was organized on 17 September 2013. *Padmashree* Dr. Gyan Chandra Mishra, Retired Director and Eminent Scientist, National Centre for Cell Science (NCCS), Pune was the Chief Guest of the function. On this occasion, prizes were distributed to the winners of the various competitions at the hands of the Chief Guest.
- A one day Hindi workshop on the subjects of 'Scientific Terminology and Grammar' and the 'Official Language Policy' was organized on 04 March 2014. About 15 employees participated in the workshop.

Awards and Honours

Dr. R. Krishnan

- Member, Scientific Steering Group, WCRP-CLIVAR Asian-Australian Monsoon Panel.
- National Expert in the Belmont Forum Scoping Workshop on Seasonal to Decadal Predictability of Regional Climate for Decision Making: Bridging the Gap between Users' Needs and the State of Climate Knowledge, emphasizing on predictability of monsoon systems and their interactions and tele-connections with the polar regions, jointly organized by the Ministry of Earth Sciences and the French National Research Agency, NCAOR, Goa, 23-25 October 2013.

Dr. G. Beig

- Selected as Chairman of the Scientific Programme Committee, the 8th International Workshop on Long-Term Changes and Trends in the Atmosphere (TREND-2014) to be held during 28-31 July 2014, Cambridge, United Kingdom.
- Member, Advisory Committee for the selection of CSIR-Young Scientist Award in Earth, Atmosphere, Ocean & Planetary Science, Council of Scientific and Industrial Research (CSIR), New Delhi, 2013-14.

Dr. A.K. Sahai

- Chaired a session on 'SASCOF: Scientific and Operational Setting' in the Fourth Session of South Asian Climate Outlook Forum (SASCOF-4), Kathmandu, Nepal, 18-19 April 2013.
- Chaired a session on 'Global Warming, Climate Change and Adaptation' in the National Conference of Ocean Society of India (OSICON 2013), IITM, Pune, 26-28 November 2013.

Dr. A. Suryachandra Rao

- Member, WGNE WMO-MJO (Working Group on Numerical Experimentation-World Meteorological Organization-Madden Julian Oscillation) Task Force, Geneva, Switzerland.
- Member, Editorial Board, Weather and Climate Extremes journal.

Dr. C. Gnanaseelan

- Chairman, Local Organising Committee, National Conference of Ocean Society of India 2013 (OSICON 2013), IITM, Pune, 26-28 November 2013.

Dr. (Smt.) Thara Prabhakaran

- Received the MoES Certificate of Merit for the year 2013 from the Ministry of Earth Sciences, Govt. of India for her outstanding contribution in the field of Atmospheric Science and Technology.

Dr. G. Pandithurai

- Vice Co-Chair, International SKYNET Committee, Japan for organizing and coordinating the SKYNET activities; and their interfacing with the GAW/WMO for four years from July 2013.

Dr. (Smt.) Ashwini A. Kulkarni

- Expert at the Regional Consultation on State Action Plan on Climate Change, Ministry of Environment and Forests, Govt. of India.
- Contributory Author of Chapter 14 of IPCC AR5 'Climate Phenomena and their Relevance for Future Regional Climate Change'.

Dr. Milind Mujumdar

- Chaired a session on 'Impact of the climate change on biodiversity and water resources' at the International Conference on the Asian Monsoon and Climate Change, Islamabad, Pakistan, 20-21 January 2014.

Dr. (Smt.) J.V. Revadekar

- Member, Editorial Board, Studies in Atmospheric Sciences journal.

Dr. Roxy M. Koll

- Convened and chaired a scientific session on 'Ocean-Atmospheric Processes in the Dynamics of the Asian Monsoon' at the Asia Oceania Geosciences (AOGS) 2013 Conference, Brisbane, Australia, 23-29 June 2013.

Dr. Yogesh K. Tiwari

- Member, Asian GAW Greenhouse Gases Working Group.
- Member, Editorial Board, Studies in Atmospheric Sciences journal.

Dr. H.N. Singh

- Chairman, Local Organizing Committee and a Session on 'Climate Change', Third National Conference on Environment and Biodiversity of India (EBI-2013) organized by the North East Centre for Environmental Education and Research (NECEER), Imphal in association with the PE Society's Modern College of Arts, Science and Commerce, Pune, 6 October 2013.
- Chaired a session on 'Environment, Globalization and People's Movement' at the two days National Seminar on 'Environmental Protection Drives: Politics and Unseen Challenges' jointly organized by MB College, Imphal and Indian Council of Social Sciences Research, New Delhi at MB College, Imphal during 28-29 March, 2014.

Dr. Sachin D. Ghude, Dr. D.M. Chate and **Dr. Samir Pokhrel**

- Guest Editors, special issue on 'Air Pollution, Air Quality, and Climate Change' (AIRPOL), Advances in Meteorology journal.

Dr. O.N. Shukla

- Received a certificate of appreciation from the Town Official Language Implimentation Committee (TOLIC) for his contributions as a member of a sub-committee of TOLIC during 2010-13.

Dr. P.C.S. Devara (Advisor, IITM)

- Chaired a session on 'Aerosol and Rainfall' at the 8th Asian Aerosol Conference (AAC 2013), Sydney, Australia, 02-05 December 2013.
- Honorable Member, International SKYNET Committee, Japan
- Member, National Advisory Committee, National Symposium on 'Emerging Trends in Physics for Ionizing Radiations, Aerosols and Material Science (ETPRAM-13)', Physics Department, Punjabi University, Patiala, 13-14 December 2013.
- Member, Asian Young Aerosol Scientist Award (AYASA) Selection Committee, participated in the evaluation process for the AYAS Awards to be presented at the Asian Aerosol Conference (AAC 2013), Sydney, Australia, 02-05 December 2013.

Dr. R.H. Kripalani, (Advisor, IITM)

- Member, Academic Expert Committee for Curriculum Development to frame the curriculum of M.Sc. in GIS Remote Sensing and Satellite Oceanography, Kerala University of Fisheries and Ocean Studies (KUFOS) and to develop syllabus for the course on Statistics in Atmospheric and Oceanic Sciences.
- Expert Reviewer, first draft of the Working Group-I Contribution to the IPCC Fifth Assessment Report: Climate Change 2013: The Physical Science Basis.

Shri P.W. Dixit, Shri Ashish R. Dhakate, Kum. Ashwini P. Bhujbal and **Shri Sunil V. Raut**

- Received the MoES Annual Award for Best Employees for the year 2013 under category 'Group B', 'Group B', 'Group C' and 'Multi Tasking Staff' respectively.

Smt. Madhura Kane (Research Fellow)

- Best Poster Award for the poster 'Changes in Western Disturbances over Western Himalayas in a warming environment' at the Fourth National Research Conference on Climate Change, IIT-Madras, Chennai, 26-27 October 2013.

Kum. Saumi Chakravorty (Research Fellow)

- Best Presentation Award for the paper 'Role of El Nino and IOD forcing on the southern tropical Indian Ocean Rossby waves' co-authored by C. Gnanaseelan, J.S. Chowdary and J.J. Luo at the National Conference of Ocean Society of India (OSICON 2013), IITM, Pune, 26-28 November 2013.

Kum. Aditi Deshpande (Research Fellow)

- Best Presentation Award for the paper 'Role of thermocline-SST coupling in the evolution of IOD events and their regional impacts' co-authored by J.S. Chowdary and C. Gnanaseelan at the National Conference of Ocean Society of India (OSICON 2013), IITM, Pune, 26-28 November 2013.

Kum. Sayantini Ojha (Research Fellow)

- Best Presentation Award for the paper 'The role of Arabian Sea in the evolution of Indian Ocean Dipole' co-authored by C. Gnanaseelan and J.S. Chowdary at the National Conference of Ocean Society of India (OSICON 2013), IITM, Pune, 26-28 November 2013.

Kum. Shamal S. Date (Research Fellow)

- Best Presentation Paper Award for the paper 'Tropical Indian Ocean SST variability in different CMIP5 scenarios' co-authored by K. Ashok, Swapna P., T. Pascal and J.V. Revadekar at the National Conference of Ocean Society of India (OSICON 2013), IITM, Pune, 26-28 November 2013.

INTROMET-2014 Best Poster Award (Gold Medal)

- In the session 'Aerosols and Monsoons' at INTROMET-2014 held at SRM University, Chennai during 21-24 February 2014 for the poster 'Observed cloud microphysical changes due to elevated pollution layers near the foothills of the Himalayas' by **B. Padma Kumari, G. Harikishan, Anupam Hazra, R.S. Maheskumar** and **S.B. Morwal.**
- In the session 'Extreme Events and Monsoons and their Applications' at INTROMET-2014 held at SRM University, Chennai during 21-24 February 2014 for the poster 'On the high rainfall mechanism over the West Coast and the adjoining Arabian Sea during the monsoon season' by **R.S. Maheskumar, S.G. Narkhedkar, S.B. Morwal, B. Padmakumari, D.R. Kothawale, R.R. Joshi, C.G. Deshpande, R.V. Bhalwankar** and **J.R. Kulkarni.**

INTROMET-2014 Second Best Paper Award

- INTROMET-2014 held at SRM University, Chennai during 21-24 February 2014 for the paper 'Premonsoon thunderstorm triggered over Pune: inferences from observations and mesoscale model' by **P.P. Leena, G. Pandithurai, K.K. Dani, P. Murugavel, R.D. Ruchith, S. Sakharam** and **Thara Prabhakaran.**

INTROMET 2014 Best Paper Award (Oral Presentation)

- **Dr. (Smt.) Amita Prabhu** received the Best Paper Award including a gold medal and a certificate for the oral presentation of the paper 'Role of Southern Annular Mode variability on Indian Summer Monsoon in the recent decades' by Amita Prabhu, R.H. Kripalani and A. Suryachandra Rao at INTROMET 2014 during 21-24 February 2014 at SRM University, Chennai.

IMS Biennial Award for the Best Paper Published on Monsoon Research (formerly B.N. Desai Award) during 2011-2012

- For the paper 'A dynamical comparison of two recent drought southwest monsoon seasons 2002 and 2009 over India' by Somenath Dutta, **Dr. S.G. Narkhedkar,** D.R. Sikka and Sunitha Devi published in the journal Mausam in 2011.

First IMS Young Scientist Award for the Best Paper on Tropical Meteorology

- For the paper 'Model biases in long coupled runs of NCEP CFS in the context of Indian summer monsoon' by **H.S. Chaudhari, S. Pokhrel, S.K. Saha, A.R. Dhakate, R.K. Yadav, K.D. Salunke, S. Mahapatra, C.T. Sabeerali** and **A.S. Rao** published in the International Journal of Climatology, 33, April 2013, 1057-1069.

IMS Award for Best Paper Published on Modelling Study on Atmospheric and Oceanic Sciences (Formerly A.D. Vernekar Award)

- For the paper 'Experimental real-time multi-model ensemble (MME) prediction of rainfall during monsoon 2008: Large-scale medium-range aspects' by A.K. Mitra, G.R. Iyengar, V.R. Durai, **J. Sanjay**, T.N. Krishnamurti, A. Mishra, D.R. Sikka published in the Journal of Earth System Science, 120, February 2011, 27-52.

Publications

Papers Published in Peer Reviewed Journals

1. **Abhik S., Mukhopadhyay P., Goswami B.N.,** Evaluation of mean and intraseasonal variability of Indian summer monsoon simulation in ECHAM5: identification of possible source of bias, **Climate Dynamics**, online, June 2013, DOI:10.1007/s00382-013-1824-7, 1-18 **(Impact Factor 4.231)**
2. **Abhilash S., Sahai A.K., Borah N., Chattopadhyay R., Joseph S., Sharmila S., De S., Goswami B.N.,** Does bias correction in the forecasted SST improve the extended range prediction skill of active-break spells of Indian summer monsoon rainfall?, **Atmospheric Science Letters**, online, December 2013, DOI:10.1002/asl2.477, 1-6 **(Impact Factor 1.932)**
3. **Abhilash S., Sahai A.K., Borah N., Chattopadhyay R., Joseph S., Sharmila S., De S., Goswami B.N.,** Arun Kumar, Prediction and monitoring of monsoon intraseasonal oscillations over Indian monsoon region in an ensemble prediction system using CFSv2, **Climate Dynamics**, online, January 2014, DOI:10.1007/s00382-013-2045-9, 1-15 **(Impact Factor 4.231)**
4. **Abhilash S., Sahai A.K.,** Pattnaik S., **De S.,** Predictability during active break phases of Indian summer monsoon in an ensemble prediction system using climate forecast system, **Journal of Atmospheric and Solar Terrestrial Physics**, 100-101, August 2013, DOI:10.1016/j.jastp.2013.03.017, 13-23 **(Impact Factor 1.596)**
5. Aher G.R., Pawar G.V., Gupta P., **Devara P.C.S.,** Effect of major dust storm on optical, physical, and radiative properties of aerosols over coastal and urban environments in Western India, **International Journal of Remote Sensing**, 35, January 2014, DOI:10.1080/01431161.2013.873153, 871-903 **(Impact Factor 1.138)**
6. Ahmed M., Anchukaitis K.J., Asrat A., **Borgaonkar H.P**., Braida M., *et. al*, Continental-scale temperature variability during the past two millennia (PAGES 2k Consortium), **Nature Geoscience**, 6, May 2013, DOI:10.1038/NGE01797, 339-346 **(Impact Factor 11.754)**
7. Annamalai H., Hafner J., **Sooraj K.P.**, **Pillai P.,** Global warming shifts the monsoon circulation, drying South Asia, **Journal of Climate**, 26, May 2013, DOI:10.1175/JCLI-D-12-00208.1, 2701-2718 **(Impact Factor 4.097)**
8. Anoop A., Prasad S., **Krishnan R.,** Naumann R., Dulski P., Intensified monsoon and spatiotemporal changes in precipitation patterns in the NW Himalaya during the early-mid Holocene, **Quaternary International**, 313-314, November 2013, DOI:10.1016/j.quaint.2013.08.014, 74-84 **(Impact Factor 1.874)**
9. Bandgar A.B., **Chowdary J.S., Gnanaseelan C.,** Indian summer monsoon rainfall predictability and variability associated with Northwest Pacific circulation in a suit of coupled model hindcasts, **Theoretical and Applied Climatology**, online, November 2013, DOI:10.1007/s00704-013-1051-5, 1-11 **(Impact Factor 1.942)**
10. **Beig G., Chate D.M., Ghude S.D., Ali K., Sahu S.K., Parkhi N., Trimbake H.K.,** Evaluating population exposure to environmental pollutants during Deepavali fireworks displays using air quality measurements of the SAFAR network, **Chemosphere**, 92, June 2013, DOI:10.1016/j.chemosphere.2013.02.043, 116-124 **(Impact Factor 3.206)**
11. **Beig G., Chate D.M., Ghude S.D., Mahajan A.S., Srinivas R., Ali K., Sahu S.K., Parkhi N.S., Surendran D., Trimbake H.K.,** Quantifying the effect of air quality control measures during the 2010 Commonwealth Games at Delhi, India, **Atmospheric Environment**, 80, December 2013, DOI:10.1016/j.atmosenv.2013.08.012, 455-463 **(Impact Factor 3.465)**
12. Bhawar R.L., **Rahul P.R.C.,** Aerosol-cloud-interaction variability induced by atmospheric brown clouds during the 2009 Indian summer monsoon drought, **Aerosol and Air Quality Research**, 13, August 2013, DOI:10.4209/aaqr.2012.11.0329, 1384-1391 **(Impact Factor 2.827)**

13. **Borah N., Sahai A.K., Chattopadhyay R., Joseph S., Abhilash S., Goswami B.N.,** Self-organizing map-based ensemble forecast system for extended range prediction of active/break cycles of Indian summer monsoon, **Journal of Geophysical Research**, 118, August 2013, DOI:10.1002/jgrd.50688, 1-13 **(Impact Factor 3.021)**

14. **Bose T.,** Misra S., **Chakraborty S.,** Reddy K., Gamma Ray Activity as a Tool for Identification of Hidden Ejecta Deposits Around Impact Crater on Basaltic Target: Example from Lonal Crater, India, **Earth, Moon and Planets**, 111, November 2013, DOI: 10.1007/s11038-013-9422-6, 31-46 **(Impact Factor 0.667)**

15. **Chate D.M., Beig G., Satpute T., Sahu S.K., Parkhi N.S., Ghude S.D.,** Assessments of population exposure to environmental pollutants using air quality measurements during Commonwealth Games-2010, **Inhalation Toxicology**, 25, May 2013, DOI:10.3109/08958378.2013.788103, 333-340 **(Impact Factor 1.919)**

16. Chattopadhyay T., Vadawale S.V., **Pendharkar J.,** Compton polarimeter as a focal plane detector for hard X-ray telescope: sensitivity estimation with Geant4 simulations, **Experimental Astronomy**, 35, April 2013, DOI:10.1007/s10686-012-9312-3, 391-412 **(Impact Factor 1.818)**

17. **Chowdary J.S., Attada R.,** Lee J-Y, Kosaka Y., Ha K-J, Luo J-J, **Gnanaseelan C., Parekh A**.B., Lee D-Y., Seasonal prediction of distinct climate anomalies in summer 2010 over the tropical Indian Ocean and South Asia, **Journal of Meteorological Society of Japan**, 92, March 2014, DOI:10.2151/jmsj.2014-101, 1-16 **(Impact Factor 0.800)**

18. **Chowdary J.S., Chaudhari H.S., Gnanaseelan C., Parekh A.B., Rao Suryachandra A., Sreenivas P., Pokhrel S., Singh P.,** Summer monsoon circulation and precipitation over the tropical Indian Ocean during ENSO in the NCEP climate forecast system, **Climate Dynamics**, Online, June 2013, DOI:10.1007/s00382-013-1826-5, 1-23 **(Impact Factor 4.231)**

19. **Chowdary J.S., Parekh A.B., Gnanaseelan C., Sreenivas P.,** Inter-decadal modulation of ENSO teleconnections to the Indian Ocean in a coupled model: Special emphasis on decay phase of El Niño, **Global and Planetary Change**, 112, January 2014, DOI:10.1016/j.gloplacha.2013.11.003, 33-40 **(Impact Factor 3.155)**

20. Collins M., Achuta Rao K., **Ashok K**., Bhandari S., Mitra A.K., Prakash S., Srivastava R., Turner A., Observational challenges in evaluating climate models, **Nature Climate Change**, 3, November 2013, 940-941 **(Impact Factor 14.472)**

21. **Das S.K.,** Das S.S., Chiang C-W, Nee J-B, Descending cirrus associated with planetary scale disturbance: An observational study from lidar, radiosonde and reanalysis data, **Journal of Atmospheric and Solar Terrestrial Physics**, 104, November 2013, DOI:10.1016/j.jastp.2013.08.019, 137-147 **(Impact Factor 1.596)**

22. **Das S.K.,** Uma K.N., **Konwar M., Raj P.E., Deshpande S.M., Kalapureddy M.C.R.**, CloudSat–CALIPSO characterizations of cloud during the active and the break periods of Indian summer monsoon, **Journal of Atmospheric and Solar Terrestrial Physics**, 97, May 2013, DOI:10.1016/j.jastp.2013.02.016, 106-114 **(Impact Factor 1.596)**

23. **Debaje S.B.,** Estimated crop yield losses due to surface ozone exposure and economic damage in India, **Environmental Science and Pollution Research**, online, February 2014, DOI:10.1007/s11356-014-2657-6, 1-10 **(Impact Factor 2.618)**

24. **Deshpande A., Chowdary J.S., Gnanaseelan C.,** Role of thermocline–SST coupling in the evolution of IOD events and their regional impacts, **Climate Dynamics**, online, July 2013, DOI:10.1007/s00382-013-1879-5, 1-12 **(Impact Factor 4.231)**

25. **Deshpande C.G., Bhalwankar R.V., Padmakumari B., Maheskumar R.S.,** Axisa D., **Kulkarni J.R.,** Possible evidence of new particle formation and its impact on cloud microphysics from airborne measurements over Bay of Bengal, **Atmospheric Research**, 140-141, February 2014, DOI:10.1016/j.atmosres.2014.01.014,1-13 **(Impact Factor 2.200)**

26. **Deshpande C.G., Kamra A.K.,** Physical properties of the arctic summer aerosol particles in relation to sources at Ny-Alesund, Svalbard, **Journal of Earth System Science**, 123, February 2014, 201-212 **(Impact Factor 0.695)**
27. **Deshpande N.R., Goswami B.N.,** Modulation of the diurnal cycle of rainfall over India by intraseasonal variations of Indian summer monsoon, **International Journal of Climatology**, Online, May 2013, DOI:10.1002/joc.3719 **(Impact Factor 2.886)**
28. **Devara P.C.S., Jaya Rao Y., Sonbawne S.M., Dani K.K., Saha S.K.,** First results of compact coherent Doppler wind lidar and its validation at IITM, Pune, India, **Meteorological Applications**, online, August 2013, DOI:10.1002/met.1428, 1-9 **(Impact Factor 1.411)**
29. **Devara P.C.S., Sumit Kumar, Vijaykumar K., Pandithurai G.,** Sun-Sky radiometer synthesis of interplay between aerosols and monsoon activity over Pune, India, **Pure and Applied Geophysics**, online, March 2014, DOI:10.1007/s00024-014-0828-5, 1-17 **(Impact Factor 1.617)**
30. Dhorde A.G., Zarenistanak M., **Kripalani R.H., Preethi B.,** Precipitation analysis over southwest Iran: trends and projections, **Meteorology and Atmospheric Physics**, online, March 2014, DOI:10.1007/s00703-014-0313-9, **(Impact Factor 1.327)**
31. **Dipu S., Pandithurai G., Panicker A.S.,** Takamura T., Lee D-I, Kim D., Assessment and validation of i-skyradiometer retrievals using broadband flux and MODIS Data, **Advances in Meteorology**, 2014, February 2014, Article ID 849279, 1-8 **(Impact Factor 1.239)**
32. **Dipu S., Prabha T.V., Pandithurai G.,** Dudhia J., Pfister G., Rajesh K., **Goswami B.N.,** Impact of elevated aerosol layer on the cloud macrophysical properties prior to monsoon onset, **Atmospheric Environment**, 70, May 2013, DOI:10.1016/j.atmosenv.2012.12.036, 454-467 **(Impact Factor 3.465)**
33. **Dixit S.A.,** Ramesh O.N., On the k -1 1 scaling in sink-flow turbulent boundary layers, **Journal of Fluid Mechanics**, 737, December 2013, DOI:10.1017/jfm.2013.566, 329-348 **(Impact Factor 2.459)**
34. Elampari E., **Debaje S.B**., Jeyakumar S.J., Chithambarathanu T., Measurements of ozone and its precursor nitrogen dioxide and crop yield losses due to cumulative ozone exposures over 40 ppb (AOT40) in rural coastal southern India, **Journal of Atmospheric Chemistry**, 70, December 2013, DOI:10.1007/s10874-013-9272-7, 357-371 **(Impact Factor 0.985)**
35. **Fadnavis S.S.,** Dhomse S., **Ghude S.D., Iyer U.S., Buchunde P.S., Sonbawne S.M., Raj P.E.,** Ozone trends in the vertical structure of Upper Troposphere and Lower stratosphere over the Indian monsoon region, **International Journal of Environmental Science and Technology**, 11, March 2014, DOI:10.1007/s13762-013-0258-4, 529-542 **(Impact Factor 1.844)**
36. **Fadnavis S.S., Iyer U.S., Raj P.E.,** Long-term trends and decadal solar variability in ozone near the tropopause over the Indian region, **International Journal of Remote Sensing**, 34, October 2013, DOI:10.1080/01431161.2013.798054, 6749-6763 **(Impact Factor 1.117)**
37. **Fadnavis S.S., Raj P.E., Buchunde P.S., Goswami B.N.,** In search of influence of stratospheric Quasi-Biennial Oscillation on tropical cyclones tracks over the Bay of Bengal region, **International Journal of Climatology**, 34, March 2014, DOI:10.1002/joc.3706, 567-580 **(Impact Factor 2.886)**
38. **Fadnavis S.S.,** Semeniuk K., Pozzoli L., Schultz M.G., **Ghude S.D.,** Das S., **Kakatkar R.,** Transport of aerosols into the UTLS and their impact on the Asian monsoon region as seen in a global model simulation, **Atmospheric Chemistry and Physics**, 13, September 2013, DOI:10.5194/acp-13-8771-2013, 8771-8786 **(Impact Factor 5.520)**
39. **Fadnavis S.S., Deshpande M.S., Ghude S.D., Raj P.E.,** Simulation of severe thunder storm event: a case study over Pune, India, **Natural Hazards**, Online, January 2014, DOI:10.1007/s11069-014-1047-1 **(Impact Factor 1.639)**

40. Ghosh R., Paruva D.K., Khan M.A., **Chakraborty S.,** Sarkar A., Bera S.K., Late Quaternary climate variability and vegetation response in Ziro Lake Basin, Eastern Himalaya: A multiproxy approach, **Quaternary International**, 324, February 2014, DOI:10.1002/2013JD020752, 1786-1795 **(Impact Factor 1.962)**

41. **Goswami B.B., Deshpande M.S., Mukhopadhyay P., Saha S.K., Rao A.S.,** Murthugudde R., **Goswami B.N.,** Simulation of monsoon intraseasonal variability in NCEP CFSv2 and its role on systematic bias, **Climate Dynamics**, online, February 2014, DOI:10.1007/s00382-014-2089-5, 1-21 **(Impact Factor 4.231)**

42. **Goswami B.N., Krishnan R.,** Opportunities and challenges in monsoon prediction in a changing climate - Editorial of Special OCHAMP issue, **Climate Dynamics**, 41, July 2013, DOI:10.1007/s00382-013-1835-4, 1 **(Impact Factor 4.231)**

43. **Hazra A., Goswami B.N.,** Chen J-P, Role of interactions between aerosol radiative effect, dynamics, and cloud microphysics on transitions of monsoon intraseasonal oscillations, **Journal of Atmospheric Sciences**, 70, July 2013, DOI:10.1175/JAS-D-12-0179.1, 2073-2087 **(Impact Factor 2.555)**

44. **Hazra A., Mukhopadhyay P., Taraphdar S**., Chen J-P., Cotton W.R., Impact of aerosols on tropical cyclones: An investigation using convection-permitting model simulation, **Journal of Geophysical Research**, 118, July 2013, DOI:10.1002/jgrd.50546, 7157-7168 **(Impact Factor 3.021)**

45. **Hazra A., Taraphdar S., Halder M., Pokhrel S., Chaudhari H.S., Salunke K.D., Mukhopadhyay P., Rao A.S.,** Indian summer monsoon drought 2009: role of aerosol and cloud microphysics, **Atmospheric Science Letters**, 14, July 2013, DOI:10.1002/asl2.437,181-186 **(Impact Factor 1.932)**

46. Ishii M., Feely R.A., Rodgers K.B., Park G-H, Wanninkhof R., Sasano D., Sugimoto H., Cosca C.E., Nakaoka S., Telszewski M., Nojiri Y., Fletcher M.S.E., Niwa Y., Patra P.K., **Valsala V.,** Nakano H., Lima I., Doney S.C., Buitenhuis E.T., Aumont O., Dunne J.P., Lenton A., Takahashi T, Air-sea CO2 flux in the Pacific Ocean for the period 1990-2009, **Biogeosciences Discussions**, 10, July 2013, DOI:10.5194/bgd-10-12155-2013, 12155-12216 **(Impact Factor 0.000)**

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48. **Jena Chinmay, Ghude S.D.,** Blond N., **Beig G., Chate D.M., Fadnavis S.S.,** Van der A.R.J., Estimation of nitrogen oxides lifetime over India using SCIAMACHY observations, **International Journal of Remote Sensing**, 35, February 2014, DOI:10.1080/01431161.2013.873146, 1244-1252 **(Impact Factor 1.138)**

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144. **Valsala V., Tiwari Y.K., Pillai P., Roxy M.,** Maksyutov M., Murtugudde R., Intraseasonal variability of terrestrial biospheric CO2 fluxes over India during summer monsoons, **Journal of Geophysical Research**, 118, June 2013, DOI:10.1002/jgrg.20037, 752-769 **(Impact Factor 3.021)**

145. **Varikoden H., Krishna Kumar K.,** Babu C.A., Long term trends of seasonal and monthly rainfall in different intensity ranges over Indian subcontinent, **Mausam**, 64, July 2013, 481-488 **(Impact Factor 0.170)**

146. **Varikoden H.,** Ramesh Kumar M.R., Babu C.A., Indian Summer Monsoon Rainfall Characteristics During Contrasting Monsoon Years, **Pure and Applied Geophysics**, online, July 2013, DOI:10.1007/s00024-013-0691-9, 1-12 **(Impact Factor 1.787)**

147. **Vellore R.K., Krishnan R., Pendharkar J., Choudhury A.D., Sabin T.P.,** On the anomalous precipitation enhancement over the Himalayan foothills during monsoon breaks, **Climate Dynamics**, online, January 2014, DOI:10.1007/s00382-013-2024-1, 1-22 **(Impact Factor 4.231)**

148. Vishnu R., **Anil Kumar V., Varikoden H.,** Krishnan K.S., Sreekanth T.S., Symon V.N.S., Das S.M., Kumar G.M., Convective thundercloud development over the Western Ghats mountain slope in Kerala, **Current Science**, 104, June 2013, 1506-1514 **(Impact Factor 0.935)**

149. Wang F., Saiz-Lopez A., **Mahajan A.S.,** Gómez Martín J. C., Enhanced production of oxidised mercury over the tropical Pacific Ocean: a key missing oxidation pathway, **Atmospheric Chemistry and Physics**, 14, February 2014, DOI:10.5194/acp-14-1323-2014, 1323-1335 **(Impact Factor 5.510)**

150. Yadav R., **Beig G.,** Jaaffrey S.N.A., Linkages of anthropogenic emissions and meteorology in the rapid increase of particulate matter at a foothill city in the Arawali range of India, **Atmospheric Environment**, 85, March 2014, DOI:10.1016/j.atmosenv.2013.09.007, 147-151 **(Impact Factor 3.110)**

151. **Yadav R.K., Ramu D.A.,** Dimri A.P., On the relationship between ENSO patterns and winter precipitation over North and Central India, **Global and Planetary Change**, 107, August 2013, DOI:10.1016/j.gloplacha.2013.04.006, 50-58 **(Impact Factor 2.930)**

152. Zarenistanak M., Dhorde A.G., **Kripalani R.H.,** Temperature analysis over southwest Iran: trends and projections, **Theoretical and Applied Climatology**, online, June 2013, DOI:10.1007/s00704-013-0913-1, 1-15 **(Impact Factor 1.942)**

153. Zarenistanak M., Dhorde A.G., **Kripalani R.H.,** Trend analysis and change point detection of annual and seasonal precipitation and temperature series over southwest Iran, **Journal of Earth System Science**, 123, March 2014, 281-295 **(Impact Factor 0.695)**

Publications in books, reports, proceedings, newsletters, etc.

1. **CAIPEEX Group**, Report on CAIPEEX Data Workshop, **IITM Scientific Report,** SR-15, July 2013.
2. **Borah N., Abhilash S., Joseph S., Chattopadhyay R., Sharmila S.** and **Sahai A.K.,** Development of Extended Range Prediction System Using CFSv2 and Its verification, **IITM Research Report,** RR-130, July 2013.
3. **Joseph S., Sahai A.K., Sharmila S., Abhilash S., Borah N., Pillai P.A., Chattopadhyay R.** and **Kumar A.,** Extended Range Prediction of Uttarakhand Heavy Rainfall Event by an Ensemble Prediction System based on CFSv2, **IITM Research Report,** RR 131, November 2013.
4. **Beig G., Chate D.M., Parkhi N.S., Karandikar M., Ali K., Satpute T.S., Srinivas R., Trimbake H.K.** and **Shinde R.K.,** Metropolitan Advisories for Cities for Sports and Tourism, SAFAR-PUNE-2013 (Puneri-Air, Marathi and Hindi versions), **Special Scientific Report 1-3**, ESSO, MoES, May 2013.
5. **Parkhi N.S., Beig G.** and **Sahu S.K.**, High Resolution Emission Inventory of Pune Metropolitan Region, **Special Scientific Report-4**, ESSO, MoES, 2013.
6. Shigeo Yoden, Masato Shiotani, Negar Banan, **Das S.K.**, Young-Ha Kim and Vinay Kumar, Report on the WCRP Regional Workshop on Stratosphere-Troposphere Processes And their Role in Climate, 1-3 April 2013, Kyoto, Japan, **SPARC Newsletter**, 41, July, 2013, Pp. 35-39.
7. **Deo A.A.** and **Ganer D.W.**, Cyclone Activity over the Indian Ocean in the Warmer Climate, in the book '**Monitoring and Prediction of Tropical Cyclones over Indian Ocean and Climate Change**' edited by U.C. Mohanty, M. Mohapatra, O.P. Singh, B.K. Bandyopadhyay and L.S. Rathore, ISBN: 978-94-007-7719-4 (Print), 978-94-007-7720-0 (Online), published by Capital Publishing Co. & Springer Publications Ltd., pp 72-80.
8. Thorne P.W., Lawrimore J.H., Willett K.M., Allan R., Chandler R.E., Mhanda A., Podesta M. de, Possolo A., **Revadekar J.V**., Rusticucci M., et al., The international surface temperature initiative, Temperature: its measurement and control in science and industry, volume 8: Proceedings of the **Ninth International Temperature Symposium**, AIP Conference Proceedings, Vol. 1552, pp. 1020-1029, September 2013, DOI:http://dx.doi.org/ 10.1063/1.4821418.
9. **Tiwari Y.K., Vellore R., Ravi Kumar K.,** and Marcel V. van der Schoot, Groung-based monitoring of greenhouse gases (CO_2, CH_4) along the west coast of India: Role of Indian summer monsoon, **Asian GAW Greenhouse Gases Newsletter**, Vol.4, pp. 10-15, ISSN 2093-9590, Korea Meteoroslogical Administration, South Korea, December 2013.
10. Sue GRIMMOND, **Gufran BEIG**, Barbara BROWN, Greg CARMICHAEL, CHEN Baode, FANG Zheqing, Gerald FLEMING, Agustin GARCIA, Liisa JALKANEN, Haleh KOOTVAL, LI Hong, Karla LONGO, MU Haizen, PENG Li, SHI Jianping, TAN Jianguo, TANG Xu, Deon TERBLANCHE, WOO Wang-Chun and ZHANG Jianle, Technical Report: '**Establishing Integrated Weather, Climate, Water and Related Environmental Services for Megacities and Large Urban Complexes – Initial Guidance**', Global Framework for Climate Services (GFCS), World Meteorological Organization (United Nations), 2014.

Publications

Papers Published in Journals	:	**153**
Cumulative Impact Factor	:	**364.796**
Average Impact Factor	:	**2.384**
Papers Published in Books, Reports, Proceedings, etc.	:	**10**

Visitors

International

- **Prof. Mercedes Pascual** and **Prof. Menno Bouma,** University of Michigan, **USA,** 04-07 April 2013.
- **Prof. Andrew Pazmany**, M/s ProSensing, **USA**, 10 May 2013.
- **Prof. Raghu Murtugudde**, Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, **USA** and member of Research Advisory Committee of the Institute, 30 May 2013.
- **Dr. Anand S. Mudaliar**, Post-Doctoral Fellow, CCSR, University of Tokyo, **Japan,** 13 June 2013.
- **Dr. Sandip Dhomse**, Research Fellow, School of Earth and Environment, University of Leeds, **UK**, 20 June 2013.
- **Dr. Nicolas Poussielgue,** Science and Technology attaché, **French** Embassy in India, Mumbai, 11 July 2013.
- **Dr. Radhakrishna Basivi,** Post-doctoral Fellow, McGill University, **Canada**, 29 July 2013.
- **Dr. Prof. Sir Brian Hoskins,** FRS, Director of Grantham Institute for Climate Change, Imperial College London, and Department of Meteorology, University of Reading, **UK,** 31 July - 02 August 2013.
- **Dr. V. Chandrashekhar,** Colorado State University, **USA,** 07 August 2013.
- **Dr. V. Balaji** and **Ms. Jasmin John,** Geophysical Fluid Dynamics Laboratory (GFDL), Princeton University, **USA,** 16 August 2013.
- **Prof. S.K. Bhattacharya**, Visiting Research Fellow, Research Center for Environmental Changes, Academia Sinica, **Taiwan,** 17 September 2013.
- **Dr. J. Vivekanandan,** National Center for Atmospheric Research (NCAR), **USA,** 30 September - 07 October 2013
- **Prof. John McGregor**, Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Aspendale, Victoria, **Australia,** 13-16 October 2013.
- **Prof. S. Harshvardhan**, Department of Earth, Atmospheric and Planetary Sciences, Purdue University, **USA,** 23-28 October 2013.
- **Shri Colin Stuart Cookes**, Director, Enterprise Electronics Corporation (EEC), **USA,** 24 October 2013.
- **Prof. John Michael Wallace,** University of Washington**,** Seattle, WA, **USA**, 01-15 November 2013.
- **Prof. Kirk Bryan,** AOS Program of Princeton University, GFDL, **USA,** 04-06 November 2013.
- **Prof. Wojciech W. Grabowski,** Senior Scientist, Mesoscale and Microscale Meteorology Division (MMM), National Center for Atmospheric Research (NCAR), **USA,** 07-19 November 2013.
- **Dr. Alexei Korolev,** Research Scientist, Cloud Physics and Severe Weather Research Section, Environment Canada, **Canada,** 19-28 November 2013.
- **Dr. Robert R. Gillies,** Director/State Climatologist, Utah State University, **USA,** 20-23 November 2013.
- **Dr. S.Y. Simon Wang,** Assistant Professor, Climate Program, Utah State University, **USA,** 20-23 November 2013.
- **Prof. Andrew Majda,** Morse Professor of Arts and Science, Department of Mathematics and Climate, Atmosphere, Ocean Sciences (CAOS), Courant Institute of Mathematical Science, New York University, New York, **USA,** 09-13 December 2013.
- **Prof. Jürgen Kurths,** Potsdam Institute for Climate Impact Research and Humboldt University, Berlin & King's College, University of Aberdeen, **UK,** 16 December 2013.

- **Dr. Terray Pascal**, Universite Pierre et Marie Curie, **France** is on a visit to the Institute for two years with effect from 16 December 2013 in order to strengthen the Indo-French collaboration on the monsoon and its modeling.
- **Dr. Amala Mahadevan**, Senior Scientist, Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA, **USA,** 20 December 2013.
- **Dr. Arunchandra S. Chandra**, Post-doctoral scholar, Meteorology and Physical Oceanographic Division, Rosentiel School of Marine and Atmospheric Sciences, University of Miami, **USA,** 12 March 2014.
- **Prof. T. Yamagata**, Director, Application Laboratory, JAMSTEC, Chief Editor of Ocean Newsletter, Ocean Policy Research Foundation, Emeritus Professor,The University of Tokyo, **Japan**, 09-15 March 2014.

National

- **Dr. Arvind Agarwal** and his associates, Society for Applied Microwave Electronics Engineering and Research (SAMEER), Mumbai to participate in KASPR installation and demonstration, 06-08 May 2013.
- **Prof. Amit Agrawal, Dr. Amitabh Bhattacharya and Shri C.S. Pant,** Department of Mechanical Engineering, Indian Institute of Technology, Mumbai, 29 May 2013.
- **Prof. G. Viswanathan,** Former Head of RDC, ISRO, for inspection of the installation and functioning of KASPR, 16-17 May 2013.
- **Dr. Subimal Ghosh,** Department of Civil Engineering, Indian Institute of Technology, Mumbai, 07 August 2013.
- **Prof. S. Ramachandran**, Associate Professor, Physical Research Laboratory, Ahmadabad, 29 August 2013.
- **Dr. S. Ram Babu**, Scientist, Society for Applied Microwave Electronics Engineering and Research (SAMEER) visited IITM during 26-30 September 2013.
- **Dr. Rajiv Kumar Chaturvedi,** National Environmental Sciences Fellow, Centre for Sustainable Technologies, Indian Institute of Science, Bangalore, 19-20 November 2013.
- **Dr. Prasad Perlekar**, Centre for Interdisciplinary Sciences, Tata Institute of Fundamental Research (TIFR), Hyderabad, 02 December 2013.
- **Dr. Ajit Srivastava**, Executive Director, Madhya Pradesh Council of Science and Technology, 13 December 2013.

Seminars

By Visitors

Prof. Andrew Pazmany, M/s ProSensing, USA

- IITM Ka-band cloud radar: Capability and research opportunity, 10 May 2013.

Prof. Amit Agrawal, Department of Mechanical Engineering, Indian Institute of Technology, Mumbai

- Effect of latent heat release on entrainment in a turbulent jet with application to cumulus cloud, 29 May 2013.

Prof. Raghu Murtugudde, Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, USA

- Do we really understand ENSO? 30 May 2013.

Dr. Sandip Dhomse, Research Fellow, School of Earth and Environment, University of Leeds, UK

- Development of a microphysical aerosol model to study the impact of stratospheric geo-engineering aerosols on climate, 20 June 2013.

Dr. Radhakrishna Basivi, Post-doctoral Fellow, McGill University, Canada

- Radar in rainfall nowcasting, 29 July 2013.

Prof. Sir Brian Hoskins, Grantham Institute for Climate change, Imperial, Imperial College, London, University of Reading, UK

- Vorticity, potential vorticity and the monsoon, 02 August 2013.

Dr. Subimal Ghosh, Department of Civil Engineering, Indian Institute of Technology, Mumbai

- Data driven models to understand and project Indian Summer Monsoon rainfall, 07 August 2013.

Dr. V. Chandrashekhar, Colorado State University, USA

- Small Radar Network for mitigating urban flash flood, 07 August 2013.

Dr. V. Balaji and **Ms. Jasmin John,** Geophysical Fluid Dynamics Laboratory (GFDL), Princeton University, USA

- (i) The GFDL flexible modeling system: Towards the million-core era (ii) Climate, Carbon, and Ecosystem Interactions, 16 August 2013.

Prof. S. Ramachandran, Associate Professor, Physical Research Laboratory, Ahmadabad

- Aerosols and Biogeochemical Coupling, 29 August 2013.

Prof. S.K. Bhattacharya, Visiting Research Fellow, Research Center for Environmental Changes, Academia Sinica, Taiwan

- The development of a new technique of the isotopic analysis of tropospheric ozone, 17 September 2013.

Prof. S. Harshvardhan, Department of Earth, Atmospheric and Planetary Sciences, Purdue University, USA

- Semi direct effect and emission from biomass burning, 24 October 2013.
- Air Quality in the late twenty first century 25 October 2013.

Prof. John Michael Wallace, University of Washington**,** Seattle, WA, USA

- Series of Lectures for Trainee Scientists of the Centre for Advance Training in Earth System Science and Climate (CAT ESSC), 01-13 November 2013.
- Structure of Madden-Julian Oscillation (MJO), 08 November 2013.

Prof. Wojciech W. Grabowski, Senior Scientist, Mesoscale and Microscale Meteorology Division (MMM), National Center for Atmospheric Research (NCAR), USA

- Modeling of cloud microphysics: from simple concepts to sophisticated parameterizations: ice microphysics Part I & part II), 08 & 11 November 2013.
- Growth of cloud droplets in turbulent clouds, 12 November 2013.
- (i) Atmospheric aerosols, cloud microphysics and climate (ii) Effects of cloud turbulence on collision-coalescence in maritime shallow convection, 13 November 2013.

- (i) Super-parameterization: what it is and what is super about it? An review of the super-parameterization approach to large-scale atmospheric modeling (ii) Organized convection and its representation in climate models, 14 November 2013.

Dr. Rajiv Kumar Chaturvedi, National Environmental Sciences Fellow, Centre for Sustainable Technologies, Indian Institute of Science, Bangalore

- CMIP5 based climate change projections for South Asia and its application for Impact assessment studies: challenges and opportunities, 20 November 2013

Dr. Robert R. Gillies, Director/State Climatologist, Utah State University, USA

- Climate change impact in Nepal and its society, 21 November 2013.

Dr. S.Y. Simon Wang, Assistant Professor, Climate Program, Utah State University, USA

- Intensification of pre-monsoon tropical cyclones in the Bay of Bengal, 21 November 2013.

Dr. Alexei Korolev, Research Scientist, Cloud Physics and Severe Weather Research Section, Environment Canada, Canada

- (i) Warm clouds: Supersaturation in liquid clouds (ii) Broadening of droplet size distribution at the diffusional stage, 20 November 2013.
- (i) Supersaturation in mixed phase clouds (ii) Effect of dynamics on mixed phase, 21 November 2013.
- (i) Experimental studies of mixed phase clouds (instrumentation) (ii) Experimental studies of mixed phase clouds (results) 22 November 2013.
- (i) Effect of shattering on airborne microphysical measurements (ii) Analysis and processing of measurements of 2D probes, 25 November 2013.
- Calibration techniques of cloud microphysical probes, 26 November 2013.

Dr. Prasad Perlekar, Tata Institute of Fundamental Research (TIFR), Centre for Interdisciplinary Sciences, Hyderabad

- Droplet break-up in turbulence, 02 December 2013.

Prof. Andrew Majda, Morse Professor of Arts and Science, Department of Mathematics and Climate, Atmosphere, Ocean Sciences (CAOS), Courant Institute of Mathematical Science, New York University, New York, USA

- Multi-scale multi-cloud models for the tropics, 09 December 2013.
- Multi-cloud models: Basic features and GCM parameterization, 11 December 2013.
- Improving parameterization through stochastic multi-cloud models, 13 December 2013.

Prof. Jürgen Kurths, Potsdam Institute for Climate Impact Research and Humboldt University, Berlin & King's College, University of Aberdeen, UK

- Are modern concepts of complex systems science useful for Earth Sciences? 16 December 2013.

Dr. Arunchandra S. Chandra, Post-doctoral scholar, Meteorology and Physical Oceanographic Division, Rosentiel School of Marine and Atmospheric Sciences, University of Miami, USA

- Application of millimeter wavelength radars for boundary layer, cloud and precipitation research, 12 March 2014.

Prof. T. Yamagata, Director, Application Laboratory, JAMSTEC, Chief Editor of Ocean Newsletter, Ocean Policy Research Foundation, Emeritus Professor, The University of Tokyo, Japan

- Predictability of the subtropical dipole modes in the Atlantic and Indian Oceans, 11 March 2014.
- New faces of climate variations in the Indo-Pacific sector, 12 March 2014.
- Tsunami catastrophe, 14 March 2014.

Internal Discussions Seminars

Dr. Subodh K. Saha

- Towards improving the Indian summer monsoon simulation by NCEP CFS, 04 April 2013.

Dr. Saikat Sengupta

- Role of recycled moisture in monsoonal precipitation across Western Ghat and its implication to palaeo-monsoon study: an Isotope based approach, 04 April 2013.

Dr. K. Ashok

- Decadal changes in the relationship between Indian and Australian monsoons, 18 April 2013.

Dr. (Smt.) A.A. Deo

- Upper ocean response to Indian Ocean cyclones using simple ocean models, 18 April 2013.

Dr. P.D. Safai

- Atmospheric abundances of carbonaceous aerosols over Pune, 25 April 2013.

Dr. A. K. Sahai

- How important is the coupled model resolution in the operational extended range forecast of monsoon precipitation over Indian region, 09 May 2013.

Dr. (Smt.) Medha Deshpande

- Impact of cloud parameterization on the numerical simulation of a super cyclone, 23 May 2013.

Dr. S. Abhilash

- Real time extended range prediction of monsoon 2013, 23 May 2013.

Dr. Milind Mujumdar

- Large-scale and synoptic-scale features, 31 May 2013.

Dr. (Smt.) P. Swapna

- Indian Ocean and monsoon coupled interactions in a warming environment, 06 June 2013.

Dr. Samir Pokhrel

- SST bias in CFSv2: Limit to seasonal prediction (surface heat perspective), 06 June 2013.

Kum. Trina Bose

- Modelling net carbon isotopic fractionation during tree-ring cellulose deposition in C3 plants, 13 June 2013.

Shri Sachin Patade

- Droplet dispersion in pre-monsoon and monsoon clouds over Indo-Gangetic valley during CAIPEEX, 27 Jun 2013.

Group Working on Extended Range Prediction of Monsoon

- Interesting features of the current monsoon, 11 July 2013.

Dr. Rajib Chattopadhyay

- The updates of 2013 monsoon conditions, 08 August 2013.

Dr. D.R. Kothawale

- Performance of all-India southwest monsoon seasonal rainfall when monthly rainfall reported as deficit/excess, 14 August 2013.

Dr. J.R. Kulkarni

- Where the monsoon 2013 will go from here?, 14 August 2013.

Seminar on Ph.D. Proposal

Kum. Shamal S. Date

- A study on the linear and non-linear evolution of the tropical Pacific events, 16 April 2013.

Shri Sakharam Sanap

- Study on aerosol-monsoon interactions over Indian subcontinent using satellite data and CMIP-5 simulations, 02 September 2013.

Seminar on Ph. D. Synopsis

Shri C.T. Sabeerali

- Modulation of monsoon intra-seasonal oscillations by global warming, 21 June 2013.

Shri Ravi Kumar Kunchala

- A study of atmospheric carbon dioxide (CO_2) transport over India using observations and modeling techniques, 02 August 2013.

Smt. Madhuparna Halder

- Study of cloud microphysics and lightning activity using observations and model, 02 August 2013.

Shri Bidyut B. Goswami

- Study of Indian summer monsoon intraseasonal oscillation in multiscale modelling framework, 08 October 2013.

Lectures Delivered Outside

Prof. B.N. Goswami

- Scaling the potential predictability barrier for Indian monsoon: An Indian initiative, Physical Research Laboratory, **Ahmedabad**, 17 July 2013.
- Aerosol invigoration of monsoon clouds: CAIPEEX Experience, Seminar on Fluids Day- 2013, Indian Institute of Science, **Bangalore**, 18 July 2013.

Dr. R. Krishnan

- Climate modeling, SERB School on Science of Climate Change, Doon University, Dehradun, 07 August 2013.
- CORDEX South Asia - A framework for addressing regional monsoon issues in a changing climate, Jamia Millia Islamia University, New Delhi, 19 February 2014.

Dr. Nityanand Singh

- Characteristics of wet and dry spells and their extremes across India, training programme on agrometeorological aspects of extreme weather events, Central Research Institute for Dryland Agriculture (CRIDA), **Hyderabad**, 13 May 2013.

Dr. G. Beig

- A Journey from air to polluted air, SERB School on Science of Climate Change, Doon University, **Dehradun**, 16 August 2013.
- Overview and advances in anthropogenic and solar trends in MLT-Region: Thermal structure, Doon University, **Dehradun**, 17 August 2013.

Dr. A.K. Sahai

- Use of IITM extended range forecast for generation of multimodel ensemble monthly forecast, Indian Institute of Technology, **Bhubaneswar**, 11, 12 and 13 December 2013 (Three lectures).

Dr. K. Ashok

- (i) Tropical Indo-Pacific variability and relevance for global climate and (ii) Modeling the Climate change signals in the Indian summer monsoon: Progress, scope, and challenges, SERB School on Science of Climate Change, **Dehradun**, 12 August 2013.
- Global climate change scenarios and modeling for climate change predictions in India, DST training programme on 'Climate Change and Carbon mitigation', Indian Council of Forestry Research and Education (ICFRI, MoEF), **Dehradun**, 21 October 2013.

Dr. H.P. Borgaonkar

- (i) Introduction to Dendrochronology as climate proxy and (ii) Dendroclimatology: Methods, Case studies and Indian Scenario, SERB School on Quaternary Geology and Climate Change, Department of Geology, University of Pune, **Pune**, 08-09 January 2014.

Dr. C. Gnanaseelan

- Spring asymmetric mode in the tropical Indian Ocean: Role of El Niño and IOD, Research Scholar Day, Centre for Oceans Rivers Atmosphere and Land, Indian Institute of Technology, **Kharagpur**, 25 April 2013.
- Data assimilation in coupled ocean atmosphere model, Department of Mathematics, Indian Institute of Technology, **Kharagpur**, 26 April 2013.
- Series of lectures on physical oceanography and air-sea interaction, Forecasters' Training, India Meteorological Department, **Pune**, April-July 2013 and October-December 2013.
- (i) Indian Ocean warming and its climatic impacts and (ii) The role of ocean in climate change: a modelling perspective, SERB school on Science of Climate Change, Doon University, **Dehradun**, 12-13 August 2013.

Dr. S. Chakraborty

- Palaeoclimate, to Advance Meteorological Training Course Batch No. 173, India Meteorological Department, **Pune**, 06-07 June 2013 (Three lectures).

Dr. D.M. Chate

- Atmospheric new particle formation, air quality and its impact on environment and health, Department of Physics, Punjabi University, **Patiala**, 13 December 2013.

- Lectures on introduction to climate change, winter school on Quaternary Geology and Climate Change, Department of Geology, University of Pune, **Pune**, 07, 08 and 14 January 2014.

Dr. G. Pandithurai

- Aerosol-cloud interactions: the uncertain component of climate system, PRL colloquium, Physical Research Laboratory (PRL), **Ahmedabad**, 18 December 2013.
- Aerosol indirect effect, dispersion offset, Dept. of Atmospheric and Space Sciences, Physical Research Laboratory (PRL), **Ahmedabad**, 16 December, 2013.

Dr. (Smt.) Ashwini Kulkarni

- Science of climate change, IMD Advance Training Batch No.173, India Meteorological Department, **Pune**, 31 May 2013 (Two lectures).

Dr. (Smt.) S.K. Patwardhan

- Basic ideas on applied climatology and bio-climatology, Meteorologist Grade-II Training Course, India Meteorological Department, **Pune**, 03 July 2013 and 20 December 2013.

Dr. (Smt.) N.R. Deshpande

- Rainstorm analysis in India: Hydrometeorological approach, training programme on hydrology for engineers, National Water Academy, **Pune**, 19 December 2013.

Dr. (Smt.) B. Padma Kumari

- The overview of CAIPEEX, Vehicle Research and Development Establishment (VRDE), **Ahmednagar**, 23 October 2013.

Dr. Vinu Valsala

- Ocean dynamics and ocean modeling, TERI-BCCR Climate Research School-II, **New Delhi**, 02 October 2012 (02 lectures).

Dr. Devendraa Siingh

- Coordinated study of very low frequency (VLF) waves at low latitude, Climate and Weather of Sun-Earth System, National Atmospheric Research Laboratory, Gadanki, **Tirupati**, 01 May 2013.

Dr. (Smt) J.V. Revadekar

- (i) Analysis on daily weather extremes, (ii) Changes in temperature and precipitation extremes over India, SERB School on Science of Climate Change, Doon University, **Dehradun**, 13 August 2013.

Smt. R. Latha

- Effect of aerosols on evapo-transpiration: observations and model evaluation, Birla Institute of Technology, Mesra, **Ranchi**, 20 July 2013.

Dr. Roxy Mathew Koll

- Climate model database and their use, Training Programme on 'Climate Modeling: Simulations and Analysis', Indian Institute of Technology, **New Delhi**, 17 December 2013.

Dr. Yogesh K. Tiwari

- The atmospheric CO_2 and other GHG's monitoring activities by the IITM, Pune, Institute of Environment and Sustainable Development, Banaras Hindu University (BHU), **Varanasi**, 14 February 2014.

Dr. S.D. Ghude

- Satellite remote sensing and its application in air pollution monitoring and modeling, winter school on Quaternary Geology and Climate Change, Department of Geology, Pune University, **Pune**, 16 January 2014.

Dr. H.N. Singh

- Why is the summer monsoon rainfall weaker on the face of global warming? - A climate change research for science and society, D.M. College of Science, **Imphal**, 26 April 2013 and Central Agriculture University, **Imphal**, 27 April 2013.

Dr. R.H. Kripalani (Advisor)

- Series of lectures on application of statistics in atmospheric and oceanic sciences, Advanced Meteorological Training, India Meteorological Department, **Pune**, September-october 2013.

Kum. Trina Bose

- Modeling net carbon isotopic fractionation during tree-ring cellulose deposition in C3 plants, GFZ Laboratory, Potsdam, Leipzig, **Germany**, 19 April 2013.

Deputations Abroad

Prof. B.N. Goswami

- 34th Annual Meeting of the Joint Scientific Committee of the World Climate Research Program, Brasilla, **Brazil,** 27-31 May 2013.
- Town Hall Meeting of the American Geophysical Union (AGU) Fall Meeting, San Francisco, **USA,** 07-11 December 2013.

Dr. R. Krishnan

- International India-Brazil-South Africa (IBSA) Oceans Workshop and India-Brazil-South Africa (IBSA) Oceans Executive Committee Meeting, Cape Town, **South Africa**, 08-14 April 2013.
- Asian Development Bank (ADB), Inception Workshop for the Technical Assistance (RETA 8359), Bangkok, **Thailand,** 27-28 June 2013.
- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.
- First International Joint Symposium for ABC (Atmospheric Brown Cloud), SLCP (Short-Lived Climate Pollutant) and CCAC (Climate and Clean Air Coalition), Seoul, **South Korea,** 08-10 September 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.

Dr. G. Beig

- WHO Sponsored Air Quality Sampling and Testing Programme under the Collaborative Project of IITM and WMO entitled 'Assessment of Air Quality in Lumbini Protected Zone', Lumbini, **Nepal,** 13-17 May 2013.
- Workshop on Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia, NCAR, Boulder, **USA,** 09-12 July 2013.
- Workshop on Whole Atmosphere Coupling during Solar Cycle 24 of CAWSES-II/TG-4, National Central University, Jhongli City, **Taiwan**, 15-17 July 2013.
- WHO Megacity Implementation Plan and Shanghai and MHEWS (Multi Hazard Early Warning Systems) Project Expert Meetings, Shanghai, **China,** 19-22 August 2013.
- Twelfth Session of the IPCC WG I, and 36th Session of IPCC, Stockholm, **Sweden,** 23-26 September 2013.
- SCOSTEP/CAWSES-II (Climate And Weather of the Sun-Earth System II) International Symposium, Nagoya, **Japan,** 18-22 November 2013.
- 2013 Global and Regional Modeling Workshop organized by the Task Force on Hemispheric Transport of Air Pollutants (TF HTAP) under the Convention of Long-range Transboundary Air Pollution and Meeting of the Task Force on Hemispheric Transport of Air Pollution San Francisco, **USA,** 05-06 December 2013.

Dr. A.K. Sahai

- Fourth Session of South Asian Climate Outlook Forum (SASCOF), Kathmandu, **Nepal,** 15-19 April 2013.
- 'WMO International Conference on Subseasonal to Seasonal Prediction', Maryland, **USA**, 08-20 February, 2014.

Dr. A. Suryachandra Rao

- Fourth session of South Asian Climate Outlook Forum (SASCOF), Kathmandu, **Nepal**, 15-19 April 2013.
- (i) Asian Australian Monsoon Panel Meeting (ii) WGNE MJO Task Force Meeting 2013 and (iii) Fifth WMO International Workshop on Monsoons (IWM-V), Macao, **China**, 26 October - 01 November 2013.
- SAARC Monsoon Initiative Programme: First Meeting of SAARC Working Group on Monsoon (SWGM), SAARC Meteorological Research Center (SMRC), Colombo, **Sri Lanka,** 16-18 December 2013.

Dr. P.S.P. Rao

- International Workshop on Atmospheric Chemistry and Asian Monsoon (ACAM), Kathmandu, **Nepal**, 09-12 June, 2013.

Dr. K. Ashok

- Global Symposium on Climate Variability Predictions and Services (GSCVPS), Istanbul, **Turkey**, 24-28 June 2013.
- Twelfth East Asian Climate (EAC) Workshop and visit to Pusan National University (PNU), Busan, **Korea,** 01-04 July 2013.
- Twelfth Session of the IPCC WGI 12 and 36th Session of IPCC, Stockholm, **Sweden,** 23-26 September 2013.
- International Symposium on 'New Faces of Climate Variability', Yakohama, **Japan,** 30-31 October 2013.

Dr. H.P. Borgaonkar

- Eighteenth Inter Governmental Meeting (IGM)/Scientific Planning Group (SPG) Meeting, Kobe, **Japan**, 08-12 April 2013.
- Asia Pacific Network for Global Change Research (APN) activities (i) 5th South Asia Sub-Regional Cooperation Meeting (SA-SRC) (ii) Project Development Training Workshop (PDTW), Colombo, **Sri Lanka,** 01-05 October 2013.
- 19th Inter-Governmental Meeting (IGM)/ Scientific Planning Group (SPG) Meeting, Siem Reap, **Cambodia**, 16-23 March 3014.

Dr. S.D. Pawar

- Training Programme on 'Lightning Location Network', Germantown. Maryland and to Visit 3-D Lightning Mapping Array Facility for Familiarization and Discussion with Scientist at NASA, Washington, **USA**, 13-26 January 2014.
- Indo-Russian Joint Collaborative Programme DST-RFBR scheme, St. Petersburg, **Russia**, 15-31 March 2014.

Dr. (Smt.) Thara Prabhakaran

- Asian Monsoon Years (AMY) Open Science Conference (OSC), Zhuhai, **China,** 26-27 October 2013.
- Workshop on 'Clouds, Convection and Data', Abu Dhabi, **UAE**, 03-07 March 2014.

Dr. Supriyo Chakraborty

- First Research Coordination Meeting on Stable Isotopes in Precipitation and Paleoclimatic Archives in Tropical Areas to Improve Regional Hydrological and Climatic Impact Models, IAEA Headquarters, Vienna, **Austria,** 30 November - 13 December 2013.

Dr. D.M. Chate

- Workshop on Risks Associated with Air Quality and Climate in Asia, NCAR, Boulder, **USA,** during 09-12 July, 2013.
- Fifth Annual International Workshop for Air Quality Forecasting and Research, Santiago, **Chile,** 07-09 October 2013.
- GlobEmission User Workshop: Emission Estimates from Satellite Observations, Franscati, **Italy,** 02-07 December 2013.

Dr. Kaushar Ali

- WHO Sponsored Air Quality Sampling and Testing Programme under the Collaborative Project of IITM and WMO entitled 'Assessment of Air Quality in Lumbini Protected Zone', Lumbini, **Nepal,** 17-22 June and 24-29 October 2013.

Dr. (Smt.) Indira S. Joshi

- Sixth International Congress of Chemistry and Environment (ICCR-2013) Conference, Antwerp University, Antwerp, **Belgium,** 08-10 July 2013**.**

Dr. B.D. Kulkarni

- 2013 International SWAT (Soil and Assessment Tool) Conference and Workshops, Paul Sabatier University, Toulouse, **France,** 17-19 July 2013.

Shri V. Gopalkrishnan

- Training Programme on 'Lightning Location Network', Germantown. Maryland and to Visit 3-D Lightning Mapping Array Facility for Familiarization and Discussion with Scientist at NASA, Washington, **USA**, 13-26 January 2014.
- Indo-Russian Joint Collaborative Programme DST-RFBR scheme, St. Petersburg, **Russia**, 15-31 March 2014.
- Davos Atmosphere and Cryosphere Assembly 2013 (DACA-13), WSL Institute for Snow and Avalanche Research SLF, Davos, **Switzerland,** 06-14, July 2013.

Dr. J. Sanjay

- Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) Proposal development Workshop, University of Cape Town, Cape Town, **South Africa**, 29-31 July 2013.
- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.

Dr. Anupam Hazra

- Workshop on 'NTU Cloud and Aerosol Microphysical Parameterization', National Taiwan University, Taipei, **Taiwan**, 12-17 March 2014.

Shri A.B. Sikder

- Third International Conference of Asian Dendrochronology Association on Climate Change and Tree-Rings, University of Tehran, Tehran, **Iran,** 11-14 April 2013.
- 9th International Conference on Dendrochronology, Melbourne, **Australia**, 10-19 January 2014.

Dr. C.G. Deshpande

- Facility for Airborne Atmospheric Measurements (FAAM) and Data Centres, Cranefield, **UK,** 26 June - 03 July 2013.

Dr. S. Tiwari

- Sixth International Conference on Fog, Fog Collection and Dew, Kanagawa University, Yokohama, **Japan**, 19-24 May 2013.
- Workshop on Atmospheric Composition and the Asian Summer Monsoon (ACAM), Kathmandu, **Nepa**l, 09-12 June 2013.

Dr. (Smt.) S.S. Fadnavis

- First SPARC Stratospheric Sulfur and its Role in Climate (SSiRC) Workshop, Atlanta, **USA,** 28-30 October 2013.

Dr. P. Mukhopadhyay

- Fifth WMO International Conference on Monsoon (IWM-V), Macao, **China,** 28-31 October 2013.
- Workshop on 'Clouds, Convection and Data', Abu Dhabi, **UAE**, 03-07 March 2014.

Dr. Vinu Valsala

- Ninth International Carbon Dioxide Conference (ICDC-9), Beijing, **China,** 03-07 June 2013.
- Discussion on 'Overviewing the Continued Update of Air-sea CO_2 Fluxes for the Inversion of Global Sources and Sinks of Carbondioxide Based on GOSAT Data, National Institute for Environmental Studies (NIES), Tsukuba, **Japan**, 02-08 March 2014.

Dr. D.R. Kothawale

- Conference on Advances in Extreme Value Analysis and Application to Natural Hazards, University of Siegen, **Germany,** 18-20 September 2013.

Dr. Devendraa Siingh

- Davos Atmosphere and Cryosphere Assembly 2013 (DACA-13), WSL Institute for Snow and Avalanche Research SLF, Davos, **Switzerland,** 06-14, July 2013.

Dr. Subodh Kumar Saha

- 94th American Meteorological Society Annual Meeting, Atlanta, GA, **USA**, 31 January - 08 February 2014.

Dr. Milind Mujumdar

- Asian Development Bank (ADB) Inception Workshop for the Technical Assistance (RETA 8359), Bangkok, **Thailand,** 27-28 June 2013.
- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.
- International Conference on 'Asian Monsoon and Climate Change', Islamabad, **Pakistan**, 19-23 January 2014.

Shri P. Murugavel

- Training Programme on 'Lightning Location Network', Germantown. Maryland and to Visit 3-D Lightning Mapping Array Facility for Familiarization and Discussion with Scientist at NASA, Washington, **USA**, 13-26 January 2014.

Dr. (Smt.) J.V. Revadekar

- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.

Dr. Anoop Mahajan

- Junior Scientist's Workshop to Brainstorm on Future of the Surface Ocean Lower Atmosphere Study (SOLAS), Plymouth, **UK,** 02-07 December 2013.

Dr. S.D. Ghude

- Workshop on Atmospheric Composition and the Asian Monsoon (ACAM) and ICIMOD's First Annual Regional Atmospheric Science Workshop (FARAS), Kathmandu, **Nepal,** 09-14 June 2013.
- Workshop on Health, Agricultural and Water Risks Associated with Air Quality and Climate in Asia, NCAR, Boulder, **USA,** 09-12 July 2013.
- 2013 Global and Regional Modeling Workshop organized by the Task Force on Hemispheric Transport of Air Pollutants (TF HTAP) under the Convention of Long-range Transboundary Air Pollution, San Francisco, **USA,** 05-06 December 2013.
- Meeting on Tracer Experiments, Fog Simulations and Development of Emission Estimates for $PM_{2.5}$ using Satellite Data Assimilation, NCAR, Boulder, **USA,** 07-14 December 2013.

Dr. S. Abhilash

- Fifth WMO International Workshop on Monsoon (IWM-V), Macao, **China,** 28-31 October 2013 and Hong Kong, **China,** 01 November 2013.

Dr. Kaustav Chakravarty

- American Geophysical Union (AGU) Fall Meeting-2013, San Francisco, **USA,** 09-13 December 2013.
- Visit to Colorado State University, **USA**, 25 March - 03 May 2014

Dr. Roxy Mathew Koll

- Asia Oceania Geosciences (AOGS) 2013 Conference, Brisbane, **Australia**, 23-29 June 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.

Smt. Preethi Bhaskar

- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.

Dr. Y.K. Tiwari

- WMO conference on CO_2, other Greenhouse Gases, and Related Measurement Techniques (GGMT-2013), Beijing, **China**, 10-14 June 2013.
- Advanced Study Programme (ASP) Summer Workshop on 'Key Uncertainties in the Global Carbon Cycle: Perspectives Across Terrestrial and Ocean Ecosystems', National Centre for Atmospheric Research (NCAR), Boulder, **USA**, 06-10 August 2013.
- Conference on 'Towards a Global Carbon Observing System: Progresses and Challenges', Geneva, **Switzerland**, 01-02 October 2013.
- Fifth Asia-Pacific GAW Workshop on Greenhouse Gases, Jeju Island, **South Korea**, 24-25 October 2013.

Dr. Subrata Kumar Das

- WCRP Regional Workshop on Stratosphere-Troposphere Processes and their Role in Climate, Kyoto, **Japan**, 01-03 April 2013.

Dr. Rajib Chattopadhyay

- School and Workshop on 'Weather Regimes and Weather Types in the Tropics and Extra-Tropics: Theory and Application to Prediction of Weather and Climate', Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, **Italy**, 21-30 October 2013.

Dr. Abhilash Panicker

- Workshop on ACCENT Plus Symposium on Air Pollution *viz,* Bringing together the European Research in Atmospheric Composition Change Challenges for the Next Decade, Urbino, **Italy,** 17-20 September 2013.

Dr. T.P. Sabin

- International Workshop on Downscaling 2013 organized by Meteorological Research Institute (MRI) and University of Tsukuba and Scientific Discussions in MRI towards the utilization of MRI-NHRCM for the CORDEX South Asia Programme in IITM, Tsukuba, **Japan,** 01-12 October 2013.
- Workshop on 'Clouds, Convection and Data', Abu Dhabi, **UAE**, 03-09 March 2014.

Dr. A.K. Srivastava

- SPARC/IGAC Chemistry-Climate Model Initiative Workshop, NCAR, Boulder, **USA,** 14-16 May 2013.
- International SKYNET Workshop 2013, Chiba University, Chiba, **Japan,** 04-05 July 2013.

Dr. K.P. Sooraj

- Fifth WMO International Conference on Monsoon (IWM-V), Macao, **China,** 28-31 October 2013.

Shri Sunil Sonbawne

- Ninth Summer School on Atmospheric Aerosol Physics, Measurement of Atmospheric Aerosols Course, Hyytiala, **Finland,** 04-10 May 2013.
- Observations and Field Work at Indian Arctic Station under the Arctic Project, Ny-Alesund, **Norway,** Arctic Circle, 14 October - 21 November 2013.

Dr. (Smt.) Ayantika Dey Choudhury

- Facilitation of the incorporation of HAM in CFSv2 as part of the ESM development through scientific interaction with the INPE ESM Group, Instituto Nacional de Pesquisas Espaciais (INPE), San Paulo, **Brazil,** 19 November 2013 - 13 August 2014.

Shri Deewan Singh Bisht

- International Conference on First Iberian Meeting on Aerosol Science and Technology, Evora, **Portugal,** 01-03 July 2013.

Shri H.K. Trimbake

- WHO Sponsored Air Quality Sampling and Testing Program under the Collaborative Project of IITM and WMO, entitled 'Assessment of Air Quality in Lumbini Protected Zone', Lumbini, **Nepal,** 17-22 June 2013, 24-29 October 2013 and 21-25 November 2013.

Dr P.C.S. Devara (Advisor)

- International SKYNET Workshop 2013, Chiba University, Chiba, **Japan,** 04-05 July 2013.
- International Conference on Regional Climate-CORDEX 2013, Brussels, **Belgium,** 04-07 November 2013.
- Eighth Asian Aerosol Conference 2013, Sydney, **Australia,** 30 November - 05 December 2013.

Dr. J.R. Kulkarni (Advisor)

- Invited Talk, Bahrain International Exhibition and Convention Center, **Bahrain**, 17-20 March 2014

Smt. Radhika Kanase (IITM Senior Research Fellow)

- Fourth WGNE Workshop on Systematic Errors in Weather and Climate Models, UK Met Office, Exeter, **UK,** 15-19 April 2013.
- Davos Atmosphere and Cryosphere Assembly 2013 (DACA-13), WSL Institute for Snow and Avalanche Research SLF, Davos, **Switzerland,** 08-13, July 2013.

Kum. Trina Bose (IITM Senior Research Fellow)

- EGU General Assembly 2013, Vienna, **Austria**, 07-12 April 2013.
- Visit to GFZ Laboratory, Potsdam, Leipzig, **Germany**, 13-20 April 2013.

Kum. P. Priya (IITM Senior Research Fellow)

- Two Day Workshop, Uni Climate and Bjerknes Centre for Climate Research (BCCR), Bergen, **Norway,** 21-24 April 2013.

Shri Reka Srinivas (IITM Senior Research Fellow)

- Advance Training for Working on High Resolution Interactive Atmospheric Chemistry Transport Model (WRF-Chem), University of Iowa, **USA**, 12 February - 22 March 2014

Shri Chinmay Kumar Jena (IITM Senior Research Fellow)

- Workshop on Atmospheric Composition and the Asian Monsoon (ACAM) and ICIMOD's First Annual Regional Atmospheric Science Workshop (FARAS), Kathmandu, **Nepal,** 09-14 June 2013.
- GlobEmission User Workshop: Emission Estimates from Satellite Observations, Franscati, **Italy**, 05 December 2013.

Shri K. Ravi Kumar (IITM Research Fellow)

- FLEXPART Training Course, Vienna, **Austria,** 15-17 April 2013.

Shri Abhik Santra (CSIR-SRF)

- School and Workshop on 'Weather Regimes and Weather Types in the Tropics and Extra-Tropics: Theory and Application to Prediction of Weather and Climate', Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, **Italy**, 21-30 October 2013.

Kum. Sharmila Sur (CSIR-SRF)

- School and Workshop on 'Weather Regimes and Weather Types in the Tropics and Extra-Tropics: Theory and Application to Prediction of Weather and Climate', Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, **Italy**, 21-30 October 2013.
- American Geophysical Union (AGU) Fall Meeting-2013, San Francisco, **USA,** 09-12 December 2013.

Smt. Madhura Kane (Research Fellow)

- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.

Kum. Sayantini Ojha (Research Fellow)

- EOROMECH Colloquium 552 on 'Modelling Atmospheric and Oceanic Flows: Insights from Laboratory Experiments and Numerical Simulations', Berlin, **Germany,** 24-26 September 2013.

Shri Pushpa Raju Made (Research Fellow)

- Eighth Asian Aerosol Conference (AAC-2013), Sydney, **Australia,** 02-05 December 2013.

Kum. Neha S. Parkhi (Prog. Officer)

- WHO Sponsored Air Quality Sampling and Testing Programme under the Collaborative Project of IITM and WMO entitled 'Assessment of Air Quality in Lumbini Protected Zone', Lumbini, **Nepal,** 13-17 May 2013 and 21-25 November 2013.

Shri Sandip Ingle (Software Engineer)

- Second WCRP CORDEX South Asia Science and Technology Workshop, Kathmandu, **Nepal,** 27-30 August 2013.

Regular Staff (as on 01 April 2014)

StaffName	Project/Div./Sec./ Unit (core team)
Research Staff	
Director	
Prof. B.N. Goswami	
Scientist-G	
Dr. R. Krishnan	CCCVAC
Scientist-F	
Dr. Gufran Beig	CCCVAC
Dr. A.K. Sahai	SERP
Dr. A. Suryachandra Rao	SERP
Scientist-E	
Dr. P.S.P. Rao	PDTC
Dr. K. Ashok	CCCVAC
Dr. H.P. Borgaonkar	CCCVAC, Training
Dr. C. Gnanaseelan	SERP
Dr. S.D. Pawar	PDTC
Dr. (Smt.) Thara Prabhakaran	PDTC
Dr. S. Chakraborty	CCCVAC
Dr. D.M. Chate	CCCVAC
Dr. G. Pandithurai	CCCVAC, PDTC
Dr. (Smt.) A.A. Kulkarni	CCCVAC
Dr. Kaushar Ali	CCCVAC
Scientist-D	
Dr. (Smt) I.S. Joshi	PDTC
Dr. (Smt.) S.K. Patwardhan	CCCVAC
Dr. (Smt.) N.R. Deshpande	CCCVAC
Dr. B.D. Kulkarni	CCCVAC
Dr. B.S. Murthy	PDTC
Shri V. Gopalkrishnan	CCCVAC, PDTC
Dr. Sanjay J.	CCCVAC
Shri T. Dharmaraj	PDTC
Dr. (Smt) S.B. Morwal	PDTC
Dr. Anupam Hazra	SERP
Dr. Y. Jaya Rao	PDTC
Dr. M.N. Patil	PDTC
Shri A.B. Sikder	CCCVAC
Dr. S.B. Debaje	CCCVAC, PDTC
Dr. C.G. Deshpande	PDTC
Dr. P.D. Safai	PDTC
Dr. (Smt). S.K. Mandke	SERP
Shri S. Mahapatra	SERP
Dr. Suresh Tiwari	PDTC
Dr. Ramesh Vellore	CCCVAC
Dr. (Smt.) S.S. Fadnavis	CCCVAC
Dr. P. Mukhopadhyay	SERP, Training
Shri S.D. Bansod	CCCVAC
Dr.Vinu Valsala	Training
Dr. (Smt.) B. Padma Kumari	PDTC
Dr. H.S. Chaudhari	SERP
Dr. D.R. Kothawale	CCCVAC
Dr. G.S. Meena	PDTC
Dr. Devendraa Siingh	PDTC
Dr. Subodh Kumar Saha	SERP
Dr. Milind Mujumdar	CCCVAC
Dr. (Kum) S.S. Nandargi	CCCVAC
Shri P. Murugvel	PDTC
Dr. (Smt.) J.V. Revadekar	CCCVAC
Shri S.M.D. Jeelani (Comp. Engg.)	HPC, CDD
Dr. Anoop Mahajan	CCCVAC
Smt. Shompa Das	LIP
Dr. (Smt.) A.A. Deo	SERP
Dr. Shivsai Dixit	PDTC
Shri K.K. Dani	PDTC
Dr. R.S. Maheskumar	PDTC
Dr. S.D. Ghude	CCCVAC
Dr. S.G. Narkhedkar	SERP, PDTC
Dr. (Smt). Susmitha Joseph	SERP
Dr. Srinivas Pentakota	SERP
Dr. K.M.C. Reddy	PDTC
Dr. Abhilash S.	SERP
Scientist-C	
Shri Prem Singh	SERP
Shri N.K. Agarwal	SERP
Shri S.S. Mulye	CCCVAC
Shri D.K. Trivedi	CCCVAC
Smt. M.K. Kulkarni	PDTC
Shri S.S. Sabade	CCCVAC
Dr. (Smt.) Swapna P.	CCCVAC
Dr. Hamza Varikoden	CCCVAC

Shri S.B. Kakade	SERP
Smt. Sompriti Deb Roy	CCCVAC
Smt. R. Latha	PDTC
Dr. K. Chakravarty	PDTC
Dr. (Smt.) A. Krishnamurthy	CCCVAC
Shri Abhay S.D. Rajput	LIP
Dr. S.M. Deshpande	PDTC
Dr. Roxy Mathew Koll	CCCVAC
Shri Mata Mahakur	SERP
Smt. M.N. Kulkarni	PDTC
Shri Deen Mani Lal	PDTC
Dr. (Smt.) Amita Ajay Prabhu	SERP
Dr. Ramesh K. Yadav	SERP
Dr. Samir Pokhrel	SERP
Dr. A.B. Parekh	SERP
Smt. Preethi Bhaskar	CCCVAC
Shri S. De	SERP
Dr. P.R.C. Reddy	PDTC
Dr. Y.K. Tiwari	CCCVAC
Smt. R.V. Bhalvankar	PDTC
Dr. S. Sengupta	CCCVAC
Dr. S.K. Das	PDTC
Dr. J.S. Chowdhary	SERP
Dr. Prashant A. Pillai	SERP
Dr. (Smt.) M.S. Deshpande	SERP
Dr. Navin Gandhi	CCCVAC
Dr. Rajib Chattopadhyay	SERP
Dr. Abhilash S. Panicker	CCCVAC
Shri Jnanesh S.P (Elec. Engg.)	HPC, EMU
Shri R.M. Bankar (Mech. Engg.)	PDTC
Shri A.K. Saxena (Civil Engg.)	SERP, CW
Dr. Sabin T.P	CCCVAC
Dr. A.K. Srivastava	PDTC
Dr. M.I.R. Tinmaker	PDTC
Shri Mahesh Dharua (Mech. Engg.)	HPC, WS
Dr. Phani Murali Krishna	SERP
Dr. K.P. Suraj	CCCVAC
Dr. H.N. Singh	CCCVAC
Dr Mahen Konwar	PDTC
Smt. Anika Arora	SERP
Shri Siddharth Kumar	SERP
Shri S.P. Ghanekar	SERP
Shri S.M. Sonbawane	PDTC
Dr. (Smt.) A.D. Choudhury	CCCVAC
Shri G.R. Chintalu	PDTC
Shri Somaru Ram	CCCVAC
Shri Bhupendra Bahadur Singh	CCCVAC
Shri Balaji B.	PDTC
Kum. Mercy Varghese	PDTC
Scientist B	
Shri Appala Ramu Dandi	SERP
Kum. Leena P.P.	PDTC
Kum. Renu Siddharth	SERP
Dr. (Smt.) Resmi E.A	PDTC
Smt. Sathy Nair	PDTC
Smt. U.S. Iyer	PDTC
Smt. Asha Nath	PDTC
Shri M.D. Chipade	SERP
Shri S.K. Saha	PDTC
Shri Tanmay Goswami	SERP
Shri Malay Ganai	SERP
Shri Sudarsan Bera	PDTC
Kum. Archana Rai	SERP
Shri Prajeesh A.G.	CCCVAC
Shri Subharthi Chouduri	PDTC
Shri Vivek Singh	Deputed to
Shri Amit Kumar Verma	NCMRWF
Kum. Rashmi Kakatkar	SERP
Shri Sandeep Narayanasetti	CCCVAC
Shri Maheswar Pradhan	SERP
Shri Ankur Srivastava	SERP
Shri Raju Mandal	SERP
Shri Avijit Dey	SERP
Shri Mriganka Sekhar Biswas	CCCVAC
Kum. Chaitri Roy	CCCVAC
Shri Nadiminti Pavan Kumar	SERP
Kum. Shikha Singh	Training
Shri Sahadat Sarkar	SERP
Kum. Shilpa Malviya	SERP
Kum. Deepa J.S.	SERP
Kum. Snehlata Tirkey	SERP
Scientific Support Staff	
Scientific Officer Grade-II	
Smt. S.U. Athale	HPC, CDD
Shri Oommen Abraham	WS

Scientific Officer Grade-I	
Smt. S.R. Inamdar	CCCVAC
Smt. S.S. Naik	SERP
Shri D.W. Ganer	SERP
Smt. A.R. Seshagiri	HPC, CDD
Shri V.R. Mali	PSU
Smt. V.V. Sapre	LIP, PDTC
Shri V.H. Sasane	LIP
Smt. S.B. Patankar	HPC, EMU
Scientific Assistant Grade-C	
Shri A.R. Dhakate	SERP
Scientific Assistant Grade-B	
Shri V. Vasudevan	SERP
Shri R.S.K. Singh	HS
Shri M.A. Shinde	SERP
Shri Deewan Singh Bisht	PDTC
Shri A.L. Sagar	PSU
Scientific Assistant Grade-A	
Shri R.T. Waghmare	PDTC
Shri K.D. Salunke	SERP
Shri A.S. Gautam	PDTC
Kum. P.S. Buchunde	PDTC
Technical Support Staff	
Technician Grade-F	
Shri P.W. Dixit	HPC, CDD
Technician Grade-E	
Shri B.C. Morwal	Security
Shri H.K. Trimbake	CCCVAC
Shri S.M. Thorat	WS
Technician Grade-D	
Shri S.G. Purandare	LIP
Shri R.A. Paradkar	EMU
Technician Grade-C	
Shri S.P. Hasnale	TS
Isolated Staff (Driver Isolated Staff)	
Shri P.S. Jagtap	TS
Shri S.A. Sayyed	TS
Administrative Staff	
Senior Manager	
Vacant	

Joint Manager	
Shri S.M. Hendre	AS
Deputy Manager	
Vacant	
Assistant Manager	
Shri S.N. Prasad	SBU
Smt. Y.V. Kad	AS
Shri S.J. Khade	GA
Smt. R.S. Ovhal	LIP
Smt. R.S. Salunke	CDD, Est
Kum. M.M. Lakra	LIP
Shri Y.S. Belgude	PSU
Assistant Manager (Hindi)	
Dr. Omkar Nath Shukla	**HS**
Senior Executive (Hindi)	
Shri Amit Kumar Trivedi	HS
Senior Executive	
Smt. Y.K. Bhonde	Est
Smt. A.A. Desai	AS
Smt. A.A. Ursekar	PSU
Executive	
Smt. V.P. Amale	PSU
Shri V.R. Khare	AS
Smt. S.S. Devale	PDTC
Shri G.M. Limaye	CW
Shri G.M. Jambhale	AS
Shri R.N. Kulkarni	TS
Shri M.V. Kale	AS
Smt. S.S. Kharbanda	Est
Shri Y.J. Pawar	PSU
Kum. A.P. Bhujbal	AS
Smt. B.N. Naik	AS
Junior Executive	
Shri I.A. Pathan	AS
Smt. L.R. Shinde	LIP
Smt. M.V. Deshpande	AS
Shri Niraj Kumar Jha	NDB
Shri R.P. Dhanak	Est
Smt. Kavita Bharati	Est
Shri S.B. Ghoman	GA
Shri S.B. Gaikwad	GA
Shri D.E. Shinde	DS

Smt. S.H. Otari	HS
Shri S.S. Kulkarni	Est
Shri Amitkumar S. Giri	GA
Shri Shafi S. Sayyed	AS
Shri B.T. Pawar	GA
Shri G.R. Handrale	SBU
Coordinating Staff	
Coordinator Grade-IV	
Kum. S.R. Kamble	CCCVAC, Training
Shri K.D. Barne	Training
Smt. S.P. Iyer	SERP
Coordinator Grade-III	
Shri R.D. Nair	CCCVAC
Shri R.K. Nandanwar	SERP
Multi Tasking Staff	
Shri Birendra Singh Bhandari	NDB
Shri S.G. Kawade	SERP
Shri S.B. Ghanwat	CCCVAC
Shri S.S. Shewale	WS
Shri U.R. Kashid	Est
Shri C.R. Joshi	AS
Shri N.G. Upasani	PDTC
Shri S.M. Jadhav	Training
Shri C.C. Rathod	HPC, CDD
Shri V.V. Bamble	PSU
Shri S.N. Dandekar	CCCVAC
Shri D.L. Rawade	Training
Shri S.V. Raut	AS
Shri P.P. Vyawahare	GH
Shri M.T. Badhe	SERP
Shri D.D. Takawale	EMU
Shri G.E. Dhongade	Est
Shri Rakesh Bhandari	NDB
Shri T.L. Mundhe	GA
Shri S.M. Thorve	CW
Shri K.M. Kamble	CCCVAC
Smt. D.J. Titkare	LIP
Smt. K.Y. Chavan	PDTC
Shri E.M. Botla	CCCVAC
Shri M.S. Waghela	WS
Shri H.E. Nindhane	PDTC
Shri I.O. Dulguch	Est
Shri I.R. Mehetre	SERP

**This list is not as per the seniority*

Legend

AS	:	Accounts Section
CCCVAC	:	Climate Change, Climate Variability and Atmospheric Chemistry
CDD	:	Computer and Data Division
CW	:	Civil Works
DS	:	Director's Secretariat
EMU	:	Electrical Maintenance Unit
Est	:	Establishment Section
GA	:	General Administration
GH	:	Guest House
HPC	:	High Performance Computing
HS	:	Hindi Section
LIP	:	Library, Information and Publication Division
NDB	:	New Delhi Branch
PDTC	:	Physics and Dynamics of Tropical Clouds
PSU	:	Purchase and Stores Unit
SBU	:	Service Benefit Unit
SERP	:	Seasonal and Extended Range Prediction
WS	:	Workshop

Other Than Regular Staff (as on 01 April 2014)

INSA - Senior Scientist : Dr. A.K. Kamra

Under Short-Term Contract Basis

Dr. P.C.S. Devara, Advisor	Shri Akshay Joshi, Junior Engineer
Dr. R.H. Kripalani, Faculty & Head, CAT-ESSC	Shri Dinesh Gurnule, Junior Engineer
Dr. (Smt.) C. Bardhan, Advisor and LACD Manager	Shri Ganesh M. Kalkutki, Junior Engineer (Civil)
AVM Dr. Ajit Tyagi, Koteswaram Professor	Shri Anil K. Pandey, Junior Computer Scientist/Engineer
Dr. J.R. Kulkarni, Advisor, NFAR	Shri Kunal S. Dhadse, Junior Engineer (I.T.)
Smt. A.A. Shiralkar, Advisor, LIP (resigned on 12.03.2014)	Kum. Kiran Panwar, Part-time Data Entry Operator to Koteswaram Professor
Dr. Manish K. Joshi, Scientist-C (contract)	Shri Manas K. De, Coordinator to Koteswaram Professor
Shri Sandip P. Ingle, Associate Scientist Grade-I (CCCR)	Shri Mayuresh S. Narkar, Junior Engineer (Civil)
Shri Yogesh K. Kolte, Assistant Engineer (RADAR)	Shri Vinayak V. Waghmare, Laboratory Assistant
Shri Rohit D. Patil, Assistant Engineer (HACPL)	Shri Amey M. Datye, Laboratory Assistant
Shri Ravindra U. Waghmare, Assistant Engineer	Shri Krunal Kamble, UDC
Shri Anil Kumar V., Junior Scientist	Smt. Rupali Mangaldas Tupe, UDC
Shri Mangesh M. Goswami, Jr. Engineer (Electrical)	Kum. Trupti M. Bhingarkar, UDC
Shri Padmakar D. Domutwar, Jr. Engineer (A & V)	Smt. Shabana I. Patel, UDC

IITM Research Associates

Dr. Jayant Pendharkar	Smt. Madhuparna Halder	Shri Ravikumar Kunchala
Shri Sabeerali C.T.	Shri Bidyut B. Goswami	

IITM Research Fellows

Smt. Radhika Kanase	Kum. Priya P	Kum. Sukanya Patra
Kum. Trina Bose	Shri Sachin Patade	Shri Sreeush M.G.
Kum. Nabanita Borah	Kum. Aditi H. Deshpande	Shri Dipjyoti Mudiar
Smt. Madhura H. Kane	Shri Chinmaya K. Jena	Shri Shambu Ravindren
Shri M.V.S. Rama Rao	Shri Raju Attada	Shri Prodip Acharja
Kum. Tanushri Chakraborty	Smt. Gayatri S. Kulkarni	Kum. Jyoti Jadhav
Shri Sakharam Sanap	Kum. Shamal S. Date	Shri Rahul S.
Shri Harikishan Gandham	Shri Nitesh Sinha	

INSPIRE Fellows	Shri Utsav Bhowmik	Kum. Rohini P.

Working under SAFAR Project

Shri Reka Srinivas, SRF	Shri Karumuri LNBR Krishna, JRF	Shri Bhaveshkumar Vagadiya, JRF
Kum. Divya E. Surendran, SRF	Shri Anurag Sarathi, JRF	Smt. Manasi Karandikar, JRF
Shri Yesobu Yarragunta, JRF	Shri Shaik Darga Saheb, JRF	Shri Rajanikant Shinde, Tech. Asstt.
Shri M.Y. Aslam, JRF		

Working under ENVIS Project	Kum. Neha S. Parkhi, Sr. Prog. Officer	Shri Gaurav P. Shinde, IT Asst.

Research Fellows under ISRO-GBP Project	Shri Pushpa Raju Made	Shri K. Vijaya Kumar

Research Fellow under ISRO-SAC Project : Shri G. Srinivas

CSIR Research Fellows

Shri Abhik Santra	Shri Nagarjuna Rao	Kum. Fousiya T.S.
Kum Sharmila Sur	Kum. Soumi Chakravorty	Shri Sujith K.
Shri Gibies George	Shri Ruchith R.D.	Kum. Sayantani Ojha

A. R. SULAKHE & COMPANY

CHARTERED ACCOUNTANTS

Anand Apartment, 1180/2, Shivajinagar, Pune - 411 005.
Phone : 020 - 30281845 / 46 / 47 Fax : 020 - 30281847 E-mail : sulakhe@vsnl.com
Website : www.arsandco.com / www.charteredaccountantfromindia.com

INDEPENDENT AUDITORS' REPORT

To,

The Director
Indian Institute of Tropical Meteorology,
Dr. Homi Bhabha Road,
Pashan,
Pune 411008.

Report on the Financial Statements

We have audited the accompanying financial statements of Indian Institute of Tropical Meteorology ("the Institute"), which comprises the Balance Sheet as at March 31st, 2014 and the Statement of Income & Expenditure account for the year then ended, and a summary of significant accounting policies and other explanatory information.

Management's responsibility for the Financial Statements

The Institute's management is responsible for the preparation of these financial statements that give a true and fair view of the financial position and financial performance of the Institute. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the Standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments; the auditor considers internal control relevant to the institute's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by the management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Basis for Qualified Opinions

1. Fixed Asset Register was found not updated on regular basis.
2. Fixed assets were not physically verified during the year under audit.

3. In case of closed projects, transfer of funds and closure of funds accounting was pending. Further interest on earmarked investments was not credited to respective funds.
4. Delays were observed in payment of service tax, professional tax & works contract tax. Amount of interest on delays was not accounted.
5. Interest accrued on Fixed Deposits for Gratuity & Leave encashment has not been accounted for. The amount of interest receivable could not be quantified.
6. Leave encashed by & gratuity paid to the employees in earlier years were not routed through & reduced from head 'Provision for Leave Encashment & Gratuity' hence this provision is not showing correct balance.

Cumulative impact of all these on income/ expenditure and assets and liabilities could not be ascertained.

Qualified Opinion

In our opinion, except for the effects of the matter described in the **Basis for Qualified Opinion** paragraph, the financial statements of Indian Institute of Tropical Meteorology give a true and fair view in conformity with the accounting principles generally accepted in India

(a) in the case of the Balance Sheet, of the state of affairs of the Company as at March 31, 2014;

(b) In the case of the Statement of Income & Expenditure for the year ended on that date.

FOR **A. R. SULAKHE & CO.**
CHARTERED ACCOUNTANTS
FRN : 110540W

Sd/-
(PRAJAKTA DURAGKAR)
PARTNER
M. NO. 122542

Date : 7th July , 2014
Place : Pune

ANNEXURE TO AUDITOR'S REPORT

Following is the observation based on books, record and documents produced before us and information & explanation given by the officials of the institute:

1. Land Dispute with National Chemical Laboratory (NCL), Pune:

We have been informed that a high level discussion with NCL officials had taken place regarding encroaching of land belonging to llTM. It has been explained that NCL is getting the land surveyed. Efforts are in progress to get the land in question from NCL as per the demarcation of the land shown by the city survey office. However, there has been no progress on this front since last year and same needs follow up with NCL authority.

FOR **A. R. SULAKHE & CO.**
CHARTERED ACCOUNTANTS
FRN : 110540W

Sd/-
(PRAJAKTA DURAGKAR)
PARTNER
M. NO. 122542

Date : 7th July , 2014
Place : Pune

COMPLIANCE TO AUDIT OBSERVATIONS

OBSERVATIONS	COMPLIANCE
1. Maintenance of Fixed Assets Register:	
To have proper control over the assets, it is recommended that the entries in the said register should be made as soon as the entries are made in the stores records.	The Assets acquired fully (Equipments) are entered in Dead Stock Register maintained by the Purchase and Stores Unit. Also, the same is reflected in the balance sheet of the books of accounts maintained by the Institute. In addition, the fixed assets register is being maintained by the concerned division. As soon as assets are acquired, entry would be made in the asset register.
2. Physical Verification of Dead Stock:	
Physical verification report for the year ended 31st March, 2014 is on record.	A committee has been constituted for physical verification for the financial year 2013-14. The physical verification work completed for the period concerned. A copy of physical verification report is ready to produce to auditors.
3. Funds for Earmarked Investments and Projects.	
In respect of funds received for earmarked investments / projects, no separate investment / bank accounts are maintained. As informed to us by the management, this is due to a large number of projects. Hence, interest income earned on these funds are not credited to the respective projects but is shown as a consolidated figure in Income & Expenditure account.	This Institute has 62 sponsored projects by various organization / Ministry. A separate bank account for the above projects has been maintained by the Institute. It is not practicable to open separate bank account for each project and make its investment and credit interest to those account. Hence the unutilized funds are kept in C.L.T.D. of SBI. The interest earned on the same are transferred to the Institute overhead funds account and are utilized for enhancing the infrastructure for the projects. In case of closed projects, Utilization Certificates were already been sent to concerned funding agency. On receipt of reply from funding agency appropriate action on funds accounting will be taken as suggested by statutory auditor.

COMPLIANCE TO AUDIT OBSERVATIONS

OBSERVATIONS	COMPLIANCE
4. Payment of Statutory dues:	
Payment of statutory dues (Service Tax, Professional Tax, TDS & Works Contract Tax) is made within the stipulated time frame of the concerned tax law.	Service Tax challan was remitted through Punjab National Bank. December 2013 onward bank denied to accept the challan manually as directed by the Service Tax Authority. Enquiry was made at several banks but nobody is ready to accept the challan manually & hence delay was happened. From the month of March 2014, it is decided by the management, service tax challan is to be remitted through statutory auditor & same has been in practice henceforth. Monthly challan of Works Contract Tax is remitted though CA Gokhale & Co., Pune by making payment in the form of Demand Draft & it is handover to CA in every month on or before 5th of the preceding month for which the challan is concerned. No notice has been received from the Sales Tax Department till date. Professional Tax also remitted regularly & no notice of delay has been received till date.
5. Fixed Deposit for Gratuity & Leave Encashment	
Provision for payment of Gratuity & Encashment is made in the form of Fixed Deposit worth Rs.5.50 Crores fromNon-Plan Grant.	Fixed Deposit kept in the bank in three different term up to Rs.5.50 Crores. Provision of accrued interest was made in the F.Y. 2012-13 & actual interest received on F.D. has been re-invested in the concerned F.D.'s. In addition to this, provision for accrued interest for the F.Y. 2013-14 is also been made. As suggested by Statutory Auditor, payment for gratuity & leave encashment will be made through provision made for it, as & when transaction takes place.
6. Land dispute with National Chemical Laboratory (NCL), Pune.	
We have been informed that a high level discussion with NCL officials had taken place regarding encroachment of the land belonging to IITM. It has been explained that NCL is getting the land surveyed. Efforts are in progress to get the land in question from NCL as per the demarcation of the land shown by the city survey office. However, there has been no progress on this front since the last year and the same needs follows up with NCL authorities.	The matter regarding transfer of IITM land to lIT M by NCL was further discussed with NCL authorities and they have informed IITM that since Director General CSIR has not been appointed so far decision on this issue cannot be taken.

BALANCE SHEET AS AT 31-3-2014

Amount in ₹

1 CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	4486276133.21	2797606467.77
RESERVES AND SURPLUS	2	11072225.87	7884072.23
EARMARKED/ ENDOWMENT FUNDS	3	3184532.68	366520792.09
SECURED LOANS AND BORROWINGS			
UNSECURED LOANS AND BORROWINGS			
DEFERRED CREDIT LIABILITIES			
CURRENT LIABILITIES AND PROVISIONS	4	299918997.64	127075989.85
INTEREST TO BE ADJUSTED AGAINST FUTURE GRANTS (PLAN)	15	74660780.00	64106640.00
INTEREST TO BE ADJUSTED AGAINST FUTURE GRANTS (NON-PLAN)	15	11831703.00	15696605.00
2. TOTAL		**4886944372.40**	**3378890566.94**
1. ASSETS			
FIXED ASSETS	5	3740685703.65	1974665071.27
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUNDS			
INVESTMENTS - OTHERS			
CURRENT ASSETS LOANS ADVANCES ETC.	6	1146258668.75	1404225495.67
MISCELLANEOUS EXPENDITURE (to the extent not written off or adjusted)			
3. TOTAL		**4886944372.40**	**3378890566.94**
SIGNIFICANT ACCOUNTING POLICIES CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS		0.00	0.00

FOR **A.R. SULAKHE & CO.**
CHARTERED ACCOUNTANTS
FRN : 110540W

Sd/-
LACD Jt. Manager
Indian Institute of Tropical Meteorology
Pune - 411 008

Sd/-
Director
Indian Institute of Tropical Meteorology
Pune - 411 008

Sd/-
(PRAJAKTA DURAGKAR)
PARTNER
MEMBERSHIP NO. 122542

INCOME & EXPENDITURE ACCOUNT
FOR THE PERIOD/YEAR ENDED 31-3-2014

Amount in ₹

INCOME	Schedule	Current Year	Previous Year
Income from Sales/Services Grants/Subsidiser	7	650250000.00	509600000.00
Fees/Subscriptions	-		
Income from Investments (Income on Invest from earmarked/endow. Funds transferred to Funds) Income from Royalty Publication etc.	-		
Interest Earned	-		
Other Income	10	2844406.00	3013128.99
Increase/(decrease) in stock of Finished goods and works-in-progress			
TOTAL (A)		**653094406.00**	**512613128.99**
EXPENDITURE			
Establishment Expenses	11	260520386.59	254125513.67
Other Administrative Expenses etc.			
Expenditure on Schemes Interest	13 A	314303375.51	244649337.75
Depreciation during the year	14	107349943.01	88872109.00
TOTAL (B)		**682173705.11**	**587646960.42**
TOTAL (C) - Prior Period Expenses (Exp. Incurred before 01.04.2014, but payment made in the F.Y. 2013-14	**13 B**	**1124280.45**	**0.00**
Balance being excess of Income over Expenditure (A-[B+C]))			
Transfer to Special Reserve (Specify each) Transfer to / from General Reserve Previous years depreciation			
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS / CAPITAL FUND		**-30203579.56**	**-75033831.43**
SIGNIFICANT ACCOUNTING POLICIES CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS			

FOR **A.R. SULAKHE & CO.**
CHARTERED ACCOUNTANTS
FRN : 110540W

Sd/-
LACD Jt. Manager
Indian Institute of Tropical Meteorology
Pune - 411 008

Sd/-
Director
Indian Institute of Tropical Meteorology
Pune - 411 008

Sd/-
(PRAJAKTA DURAGKAR)
PARTNER
MEMBERSHIP NO. 122542

RECEIPTS AND PAYMENTS FOR THE PERIOD/YEAR ENDED 31-3-2014

Amount in ₹

RECEIPTS		Current Year	PAYMENTS		Current Year
I. Opening Balances			**I. Establishment expenses**		**214689881.14**
a) Cash in hand		191000.00	**II. Payment made against various project funds**		**382373589.47**
b) Bank Balances			**III. Advances to Others than project**		**4101230.00**
i) In current accounts - SRI - Main Nc		272327418.63	**IV. Advances to staff**		**5843807.00**
ii) In current accounts - PNB Main Nc		114005844.57	**V. Deposits with**		**8503835.00**
iii) In current accounts - SBI - Project Nc		12530348.08	**VI. Overheads**		**19650.00**
iv) In deposit accounts		10576233.00	**VII. Funds Retained from suppliers**		**13060746.87**
v) In deposit accounts (Gratuity & Leave Encashment)		55000000.00	**VIII. Statutory Liability**		**194231669.76**
			Short Term Climate Prediction		**189345528.45**
II. Grants Received		**2289320000.00**	Recurring	51045672.98	
Advanced Training in Earth System Science and Climate	226870000.00		Non-Recurring	170247940.47	
Centre for Climate Change Research	161700000.00		Advance	90922140.32	
HPC -2	1030200000.00		Total	312215753.77	
IITM - Operations & Maint.	120000000.00		Less: Advance adjusted	122870225.32	
Metropolitan Air Quality and Weather Services	10000000.00		**Centre for Climate Change Research**		**134124851.72**
Monsoon Mission	160000000.00		Recurring	23143555.36	
Physics & Dynamics of Tropical Clouds	30000000.00		Salary	15517976.00	
Short Term, Climate Prediction and Variability	15050000.00		Non-Recurring	133403629.36	
Non-Plan	175500000.00		Advance	53373403.06	
Prior Period Grant :			Total	22543856378	
HPC NCMRWF, NOIDA	360000000.00		Less: Advance adjusted	91313712.06	
			Advance Training in Earth System Science & Climate		**82834186.94**
III. Interest Received			Recurring	37977679.32	
a) Non-Plan Interest (to be adjusted against future grants)		**11831703.00**	Salary	9857259.00	
a) On Bank deposits	11764240.00		Non-Recurring	34571996.76	
b) Penal Interest	990.00		Advance	17629451.00	
c) Penal Interest (Project)	393.00		Total	100036386.08	
d) Interest on House Building Advance	66080.00		Less: Advance adjusted	17202199.14	
e) Interest on Scooter Advance	0.00		**IITM Operations & Maintenance**		**110483464.41**
b) Plan Interest - On Schemes (to be adjusted against future grants)		**74660780.00**	Recurring	82201263.97	
Advance Training in Earth System Science & Climate	3600000.00		Salary	20129489.45	
CAIPEEX	0.00		Non-Recurring	8024569.99	
Centre for Climate Change Research	5929713.00		Advance	156036.00	
			Total	110511359.41	
			Less; Advance adjusted	27895.00	
			Monsoon Mission		**116469306.63**
			Recurring	116469306.63	
			Salary	0.00	
			Non-Recurring	0.00	
			Advance	55500.00	
			Less: Advance adjusted	55500.00	

RECEIPTS AND PAYMENTS FOR THE PERIOD/YEAR ENDED 31-3-2014

Amount in ₹

RECEIPTS		Current Year	PAYMENTS		Current Year
Climate Variability & Dynamics	160583.00		**Metropolitan Air Quality and Weather Services**		**45348217.12**
High Altitude Laboratory	572580.00		Recurring	3957090.20	
HPC -2	53086556.00		Salary	325781.00	
HPC NCMRWF NOIDA	0.00		Advance	44267386.00	
IITM - Operations & Maint.	400000.00		Total	89565776.12	
Metropolitan Air Quality and Weather Services	2222150.00		Less: Advance adjusted	44217559.00	
Monsoon Mission	2100000.00		**HPC -2**		**1011328076.14**
Short Term Climate Prediction	6589198.00		Recurring	0.00	
IV. Other Income (Specify)		**2844406.00**	Non-Recurring	1480291214.14	
1) Licence Fee	1275380.00		Advance	1093696307.00	
2) Guest House	417695.00		Total	2573987521.14	
3) Fees from Student	97345.00		Less: Advance adjusted	1562659445.00	
4) Misc. Receipts	476245.00		**Physcis & Dynamics of Tropical Clouds**		**33088793.25**
5) Cont. to Pensioners medical scheme	342900.00		Recurring	633087.50	
6) Water charges	40091.00		Non-Recurring	5815705.75	
7) Maint. Of Colony Welfare	55865.00		Advance	26640000.00	
8) Maint. of Office Vehicle	5400.00		Total	33088793.25	
9) Profit on Sale / Disposal of Assets	133485.00		Less: Advance adjusted	0.00	
V. Any other receipts (give details)		**457601371.92**	**X. Claims Receivable**		**31194015.00**
a) Receipts from various project	19037330.06		**Xl. Deposits From Creditors**		**27513122.80**
b) Funds Retained from suppliers	100269562.02		**XII. Accrued Interest**		**922853.00**
c) Claims Receivable	14427942.00		**XIII. Closing Balance**		
d) Statutory liabilities	295056146.19		a) Cash in hand		240454.00
e) Deposits with	0.00		b) Bank Balances		
f) Advance to others than project	7636457.00		i) In current accounts - SBI - Main A/c	563258663.15	
g) Overheads	3207803.64		ii) In current accounts - PNB Main A/c	53534068.55	
h) Deposits from creditors	12322839.01		iii) In current accounts - SBI - Project A/c	8108009.80	
i) Adv. to staff	5643292.00		iv) In deposit accounts	10576233.00	
VI. Accrued Interest		**3841473.00**	v) In deposit accounts (Gratuity & Leave Encashment)	63536425.00	
TOTAL		**3304730578.20**	**TOTAL**		**3304730578.20**

SCHEDULE NO. 14 - NOTES TO ACCOUNTS

SIGNIFICANT ACCOUNTING POLICIES

1) BASIS OF ACCOUNTING -

The Financial statements are prepared by the Institute on the basis of historical cost convention, unless otherwise stated and on accrual method of accounting.

2) FIXED ASSETS -

Fixed Assets stated in the Balance Sheet are at their cost of acquisition inclusive of freight, octroi and other direct and indirect cost in respect thereof less depreciation. Assets acquired for sponsored projects are written off as project cost.

3) DEPRECIATION -

Depreciation is provided on Straight Line method at the following rates -

Sr. No.	Particulars	Rate of Depreciation
1	Building, Tube Wells and Overhead Water Tank	1.63 %
2	Furniture & Fixtures	6.33 %
3	Plant & Machinery, Scientific Equipments and Office Equipment	4.75%
4	Computers and Workstations	16.21 %
5	Vehicle	9.50%
6	Books	100.00 %

Date: 7th July, 2014

Place: Pune

4) GOVERNMENT GRANTS -

a) Government Grants of the nature of contributions towards capital cost are shown as capital grants in the Balance Sheet.

b) Grants in respect of specific fixed assets acquired are shown as a deduction from the cost of related asset.

c) Government grants are accounted for on realization basis.

5) RETIREMENT BENEFITS -

Retirement Benefits to the employees comprise of payment of gratuity, superannuation and provident fund under the approved schemes of the society. Contribution to pension fund is made on monthly basis and provision for payment of gratuity and leave encashment is made on ad hoc basis.

6) Previous year figures have been regrouped wherever necessary.

FOR **A. R. SULAKHE & CO.**
CHARTERED ACCOUNTANTS
FRN : 110540W

Sd/-
(PRAJAKTA DURAGKAR)
PARTNER
M. NO. 122542

Science Popularization

Institute's Participation in National Science Day Celebration at GMRT, Narayangaon and Indian Science Congress, Jammu

Visitors at IITM on Open Days

भारतीय उष्णदेशीय मौसम विज्ञान संस्थान

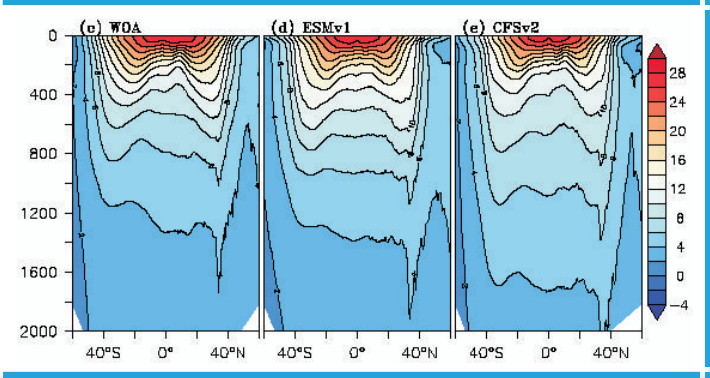
(पृथ्वी विज्ञान मंत्रालय, भारत सरकार का एक स्वायत्त संस्थान)

डॉ. होमी भाभा मार्ग, पाषाण, पुणे–411 008, भारत

INDIAN INSTITUTE OF TROPICAL METEOROLOGY

(An Autonomous Institute of the Ministry of Earth Sciences, Government of India)

Dr. Homi Bhabha Road, Pashan, Pune - 411 008, India



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