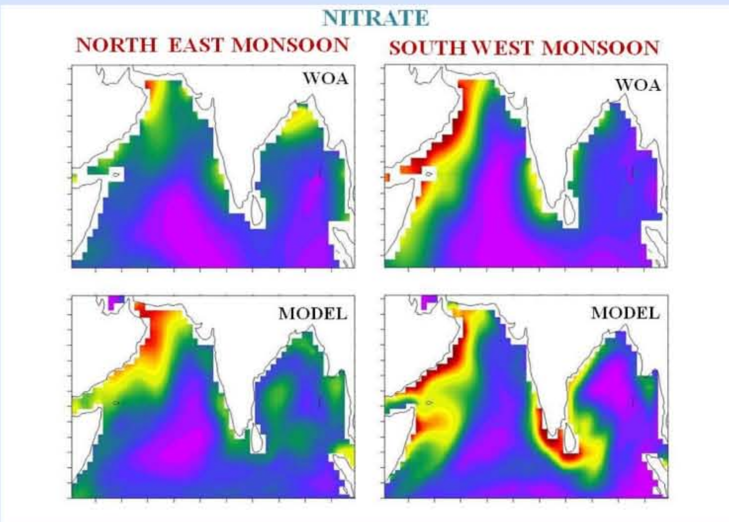
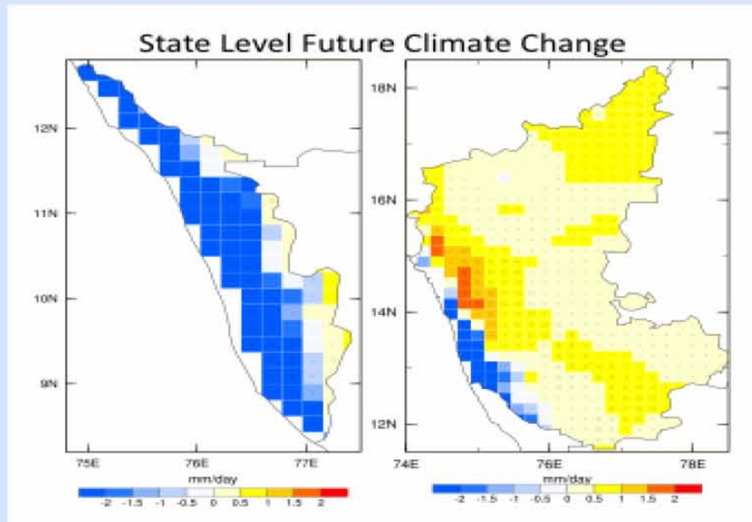
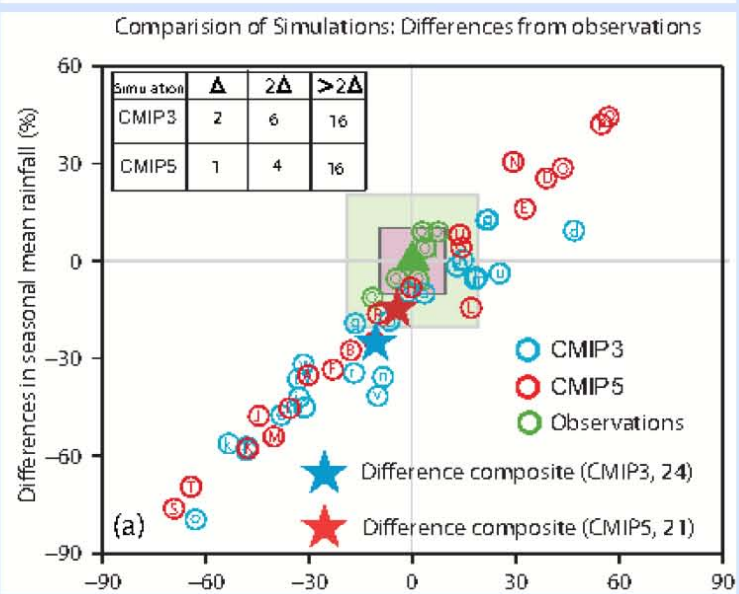
CSIR-4PI (erstwhile C-MMACS)

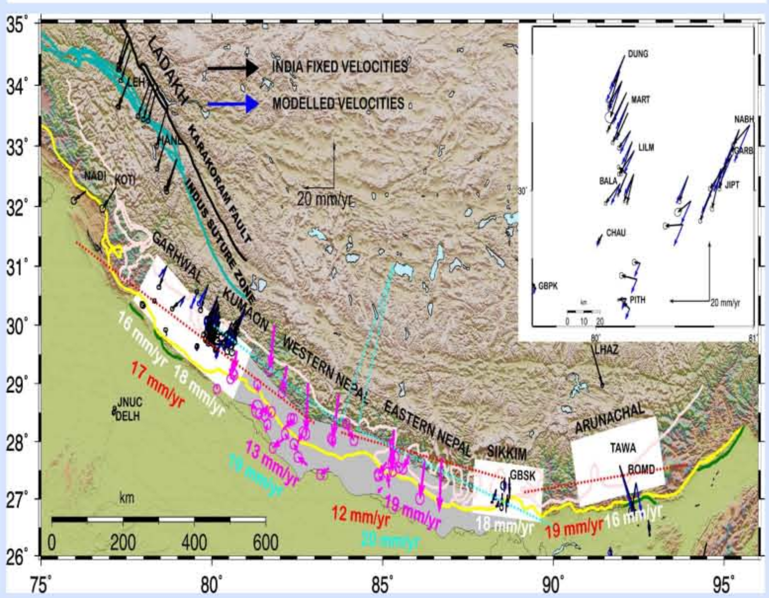
Computing Insights

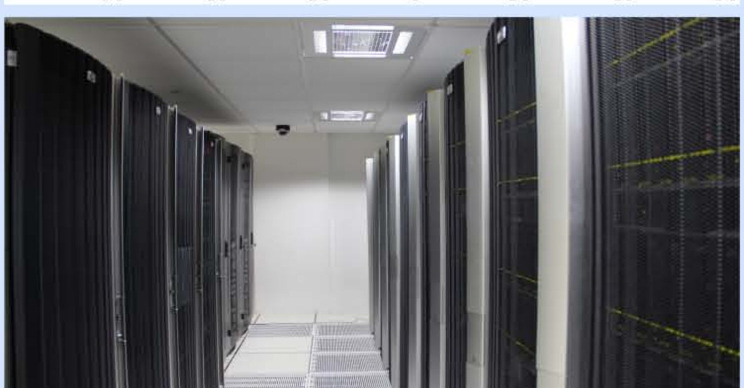
Annual Report 2013-2014

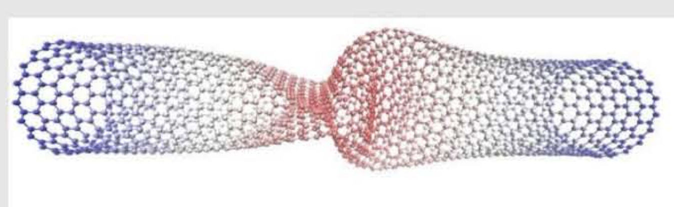




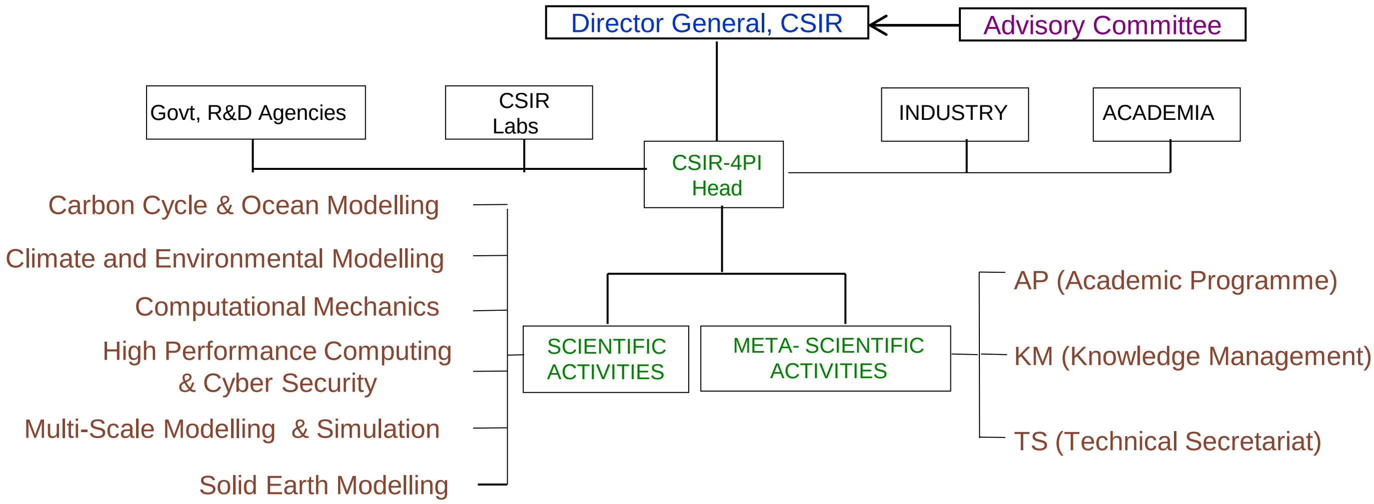








ORGANISATIONAL STRUCTURE OF CSIR-4PI (erstwhile C-MMACS)



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Head, CSIR-4PI **(erstwhile C-MMACS)** Bangalore

CSIR-4PI (erstwhile C-MMACS) , Wind Tunnel Road, Bangalore 560 037, India

Fax: +91 80 25220392
E-mail: head@csir4pi.in

Tel: +91 80 2522 4667, 25051920
Website: http://www.csir4pi.in

CSIR-4PI (erstwhile C-MMACS)

Annual Report 2013-2014

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Front Cover (clockwise from top right): *Projected change in future rainfall over the states of Kerala and Karnataka, Observed surface GPS velocities and Modelled velocities in Kashmir-Himachal, Garhwal, Kumaon, Sikkim and Arunachal Himalaya, Shell Buckling of Carbon Nanotube, CSIR centralized 360TF High Performance Computing Facility, Distribution of historical (1951-2005) simulations in seasonal and annual rainfall over continental India, Spatial Variation of Nitrate from the Model compared with World Ocean Atlas for two seasons*

Back Cover (clockwise from top): *Data Enriched SACK Enabled Stream Control Transmission Protocol, Projected Malaria Vulnerability due to rise in temperature, Piccarro and LGR instruments measuring* CO_2/CH_4 *and* N_2O/CO*, Spatial distribution of the estimated design ground acceleration in g.*

Editorial Team
Ramamohan T R
Rameshan K
Suchanda Ray

Published by
Head
CSIR Fourth Paradigm Institute (erstwhile C-MMACS)
NAL Belur Campus
Wind Tunnel Road
Bangalore 560037
Ph No: 080-25051920, 25224667
Fax: 080-25220392
E mail: head@csir4pi.in

Acknowledgements
To all staff members of the CSIR-4PI (erstwhile C-MMACS) for inputs to the report.

Foreword

It is a great pleasure and privilege to present the CSIR-4PI (erstwhile C-MMACS) Annual Report 2013-14. The celebration of its Silver Jubilee Year (2012-13) continued with organizing workshops, training programmes, and finally concluded with an International Conference in August 2013. It was CSIR-4PI (erstwhile C-MMACS)'s great honor to receive the Former President of India and one of the India's well known scientists Dr Abdul Kalam to inaugurate the International Conference. On the occasion of Silver Jubilee Year (1988-2013) CSIR-4PI (erstwhile C-MMACS) has brought out a publication "Compendium of Publications: Silver Jubilee Issue" with a collection of abstracts of all CSIR-4PI (erstwhile C-MMACS) publications since its inception. A "Coffee Table Book" has also been prepared to cover the events organised by CSIR-4PI (erstwhile C-MMACS) for the last 25 years with glimpses of the ongoing activities in CSIR-4PI (erstwhile C-MMACS). It will be released on the CSIR-4PI (erstwhile C-MMACS) Foundation Day 2014.

CSIR-4PI (erstwhile C-MMACS) continued its journey through XII Five Year Plan in cutting edge scientific research in multidisciplinary areas by publications in journals, research collaborations with national & international institute/organizations.

The main activities of CCOM were modelling and measurements of the carbon cycle. We performed extensive simulations of the ocean carbon model to illuminate several aspects of the oceanic carbon cycle: role of iron in photosynthesis and consequent effects on ocean fertilization, simulation of oxygen minimum zones, and climate change effects of increased sea surface temperatures on primary production. With the help of accurate carbon dioxide measurements at Hanle and an inverse transport model we showed the presence of a robust sink of 1.5 gigatonnes of carbon in Temperate Asia. A new forward transport model with increased resolution over Asia has been developed for future work.

The primary strength of CEMP is its multi-disciplinary research and outreach. The year 2013-14 has seen this potential and efforts of CEMP realized through several high-impact multi-disciplinary SCI publications. While novel methodology for assessing climate projections was formulated and developed (Nature: Scientific Reports), a mathematical model for pro-active malaria mitigation was validated (PLOS One); similarly model of air pollution forecasting was validated over Delhi. These models are developed completely in-house from computer coding to validation. Along with these applicable products, three students and scientists also received Ph D from CEMP. A number of international (UKIERI, CSRIO,..) and national (NDMA, ICRI, ICAR,..) agencies have approached us for collaborative R&D with CEMP. The year also marks the fifth consecutive year of successful operation of CSIR (COMoN), with two new installations over Siachen (in collaboration with SASE, DRDO) and Leh (in collaboration with Kashmir University). The experimental advance dynamical forecasting of Date of Onset of Monsoon saw the 12th successful year in 2013.

Computational Mechanics Group that continued their work on development and application of novel Homotopy Analysis Methods also demonstrated the advantage of using the modification of the Homotopy Analysis Method with a non homogeneous term for a system of equations for the first time. Computational nanomechanics focuses on nonlocal continuum modelling and molecular dynamics simulations in nanomaterials. Studies have been carried out on a nonlocal continuum theory for modeling the buckling of Carbon Nanotubes.

Multiscale Modeling and Simulation Group is involved in setting up a multiscale, earth system model to address climate and climate change issues specific to India. Studies of tropical climate and monsoon variability, and climate projections under different global warming scenarios are carried out using an unprecedentedly high resolution global climate model. Climate change projections for the state of Kerala are provided to the Directorate of Environment and Climate Change, Government of Kerala since 2012.

During the year, the 360 TFLOPS Supercomputing facility was thrown open to the CSIR scientific community to promote computational science based research in CSIR. The facility is operational on round-the-clock basis and it is being accessed by CSIR Scientists over the high speed National Knowledge Network. The supercomputer has been under high utilization since its release to users. The group is also actively involved in research in Cyber Security under the 12th Five Year Plan of CSIR. This effort has produced innovative results, including an international patent filing, in important areas like, security aspects of next generation communication protocol, algorithms for processing in encrypted domain and unsolicited network traffic analysis.

Solid Earth modelling group's major initiative on data intensive research for earthquake hazard assessment by modelling the solid-earth has been sanctioned as a part of a new CSIR XII Five year plan project, ARiEES (Advanced Data intensive Research in Engineering and Earth Sciences) with CSIR-4PI (erstwhile C-MMACS) as the nodal Lab. For first time in the country we have developed comprehensive buried dislocation models from Ladakh Himalaya in the west to Arunachal Himalaya in the east using surface deformation derived from a decade of GPS observations. We have developed neo-deterministic seismic hazard map of India as well as seismic hazard and risk estimates for Himalaya and surrounding regions. During this year we have established seismic broad band experiments in the Kashmir Himalayas and also set up real time data telemetry for the Andaman GPS network.

The academic programme of CSIR-4PI (erstwhile C-MMACS) is progressing very well with increasing number of students enrolling for the SPARK programme. The year saw a good number of students from premier institutions in India joining for their project work under the guidance of scientists in different areas. In this year, K C Gouda secured his Ph.D. degree.

My sincere thanks to all the concerned Departments and Organizations, both national and international, for supporting the research efforts of CSIR-4PI (erstwhile C-MMACS). It is my privilege to express my gratitude to DG, CSIR and members of our Advisory Committee for their support & guidance. I would like to thank Mr. Shyam Chetty, who despite his busy schedule as Director CSIR-NAL, took keen interest in nurturing CSIR-4PI (erstwhile C-MMACS) programmes. Our special thanks to all the divisions of CSIR NAL for their unstinted support. Thanks are also due to Prof V K Gaur, Dr K S Yajnik, Dr U N Sinha, Dr Ehrlich Desa and Dr T S Balganesh for continuing to be involved with the activities of CSIR-4PI (erstwhile C-MMACS) and providing advice and guidance to the scientists. I take this opportunity to thank all scientists and other staff members of CSIR-4PI (erstwhile C-MMACS) for their commitment to this unique organization.

Head, CSIR-4PI (erstwhile C-MMACS)

Highlights

- Extensive computations with TOPAZ and Modular Ocean Model to simulate seasonal and interannual variability of marine ecosystems and biogeochemical cycles in the Indian Ocean.
- Investigated the effect of a crucial parameter in the iron uptake process in the nutrient limitation and consequent effect on primary production.
- Simulated the presence and extent of oxygen minimum zones in the Arabian Sea well.
- Illustrated the inverse correlation between sea surface temperature and chlorophyll in data and model.
- Established the presence of a sink of 1.5 gigatonnes of carbon in temperate Eurasia by inversion of accurate greenhouse gas (GHG) measurements.
- Set up a new forward model for the transport of GHG from source regions specifically for the Asian region.
- 12th Successful year of Advance forecasting of Date of Onset of Monsoon
- 3rd Successful year of Hobli (Village Cluster) Level forecasting over Karnataka
- Fifth year of uninterrupted operation of CSIR Climate Observation and Modelling Network (COMoN)
- K C Gouda awarded Ph Ds from Mangalore University
- IPCC Assessment Report 5 Lead Authorship (Working Group I, Chapter 14)
- Multi-disciplinary SCI Publications: Climate Projection, Malaria Model, Air Pollution Model, etc
- Workshop on Harnessing Improved Weather and Climate Information for Renewable Energy Generation under Public Sector Linkages Program
- Establishment of GIS Lab
- Establishment of COMoN profiler at Leh, Siachen and Bhubaneshwar
- A 360 TFLOP supercomputer and a state-of-the-art data center
- Filed the first International patent from CSIR-4PI (erstwhile C-MMACS) for security enhancement of Stream Control Transmission Protocol
- Three publications in the field of security assurance and homomorphic encryption
- Calibrated the small scale parameter for buckling analysis of carbon nanotube using Molecular Dynamic Simulation
- Symbolic computation was carried out using open source software Sage-Maxima and its reliability was validated for the continuum modeling
- GNSS based deformation modelling along the 2500 Km Himalayan arc from Ladakh Himalaya in the west to Arunachal Himalaya in the east

- 2004 M 9.3 Sumatra-Andaman Rupture Extent and Slip Distribution, and its Implications on the Regional Tectonics.
- Establishment of real-time data telemetry VSAT's for Andaman GNSS Network
- GPS measurements for landslide deformation monitoring,
- Seasonal perturbations in Inter-seismic deformation of North-East India.
- Absence of Intermontane valleys in the Nahan Salient of Western Indian Sub-Himalaya
- Seismic hazard and risks estimates for Himalayas and surrounding regions based on the Unified Scaling Law for Earthquakes
- Probabilistic seismic hazard assessment for Gujarat region of western India: An Application of a Bayesian extreme-value model of the Results
- Neo-Deterministic Seismic Hazard Map of India
- Crustal imaging of Dharwar Region across E-W Corridor
- Seismic Broadband Experiment in Kashmir Himalayas
- Finite Element Method to study deformation in porous thermoelastic material, wave Propagation in thermoelastic saturated porous medium, transient wave problem in thermoelastic saturated poro-viscoelastic medium
- 2004 M 9.3 Sumatra-Andaman rupture extent and slip distribution, and its implications on the regional tectonics.
- Source Process of the Sikkim Earthquake 18th September, 2011, Inferred from Tele-seismic Body-wave Inversion.
- Setting-up of coupled ocean-atmosphere General Circulation Model (CGCM) for climate and climate change studies
- Estimation of aerosol radiative forcing over India under various scenarios
- Physically based assessment of wind changes over Indian region under different scenarios of anthropogenic aerosol emissions
- Understanding of aerosol influence on interannual variability of monsoon rainfall
- Climate change impact on Indian monsoon extreme events
- Comparative study of IPCC AR5 climate model simulations of Indian Summer Monsoon Rainfall with respect to those of IPCC AR4
- Ultra high resolution global model climate change projection for India
- Downscaling of Indian summer monsoon rainfall using statistical models
- Delineating characteristics of rainfall and cloud over the tropics using high frequency satellite datasets
- Identification of dominant modes of the vertical profiles of atmospheric latent heating

1

CARBON CYCLE AND OCEAN MODELLING

Measurement and modelling of the carbon cycle are key components in understanding the science and mitigation options of global warming. At CSIR-4PI (erstwhile C-MMACS) we have been involved in a comprehensive study of the carbon cycle which covers atmospheric, terrestrial and oceanic components. The key processes involved in the oceanic carbon cycle, especially the role of iron in photosynthesis has been studied by embedding a complex biogeochemical model in an ocean general circulation model. The presence and extent of oxygen minimum zones in the ocean have also been modelled. The modelling of atmospheric transport of green house gases combined with accurate measurements of green house gases has provided robust fluxes from basin-scale regions to complete the budgets of carbon. Temperate Eurasia was shown to be a robust sink to the tune of 1.5 gigatonnes of carbon. A new transport model based on LMDZORINCA was developed for future use in inversion.

Inside

- *Seasonal and Interannual Variability of Marine Ecosystem in the North Indian Ocean*
- *Forward Modelling of Carbon Dioxide Transport with LMDZORINCA*

1.1 Seasonal and Interannual Variability of Marine Ecosystem in the North Indian Ocean

We have investigated the climatological and interannual variability of biogeochemical cycles in the north Indian Ocean with simulations of TOPAZ (Tracers of Phytoplankton with Allometric Zooplankton) during 1949-2009. This model has twenty five tracers and incorporates several processes like multinutrient limitations including the micronutrient iron, nitrification-denitrification, regeneration of nutrients, dynamic elemental ratios etc. and is embedded in an ocean General Circulation Model (Modular Ocean Model MOM4). Model simulations have been carried out with climatological and interannual fluxes forcings and the results have been evaluated by using the available data from different sources in the Arabian Sea (AS) and the Bay of Bengal (BOB).

Initially, the model (TOPAZ) simulation results are evaluated for seasonal, interannual and spatial variations of SST and surface chlorophyll (Chl) during 1998-2007 in the AS and the BOB using the satellite data. Monthly variations of SST are compared with satellite data from TMI, MODIS-A and ERSST (Extended Reconstructed Sea Surface Temperature) data during 1997 to 2009 at seven stations in the AS and nine stations along the 88º E and coastal transects made by NIO during BOBPS Cruise carried out in the Bay of Bengal. Comparison of model results with the data at two stations in the BOB and at two stations in AS are shown in Figure 1.1. It can be seen that the model is able to capture the trend seen in the observed data but SST is underestimated during June to November at all locations during most of the years in the BOB and SST is underestimated during SIM (Spring Inter Monsoon-April, May, June) and FIM (Fall Inter Monsoon – September, October, November) and overestimated during SWM (South West Monsoon – June, July, August) sometimes at all locations during most of the years in the AS. In general, SST from TMI is higher than ERSST and SST from the model is close to the MODIS data at many locations during many months.

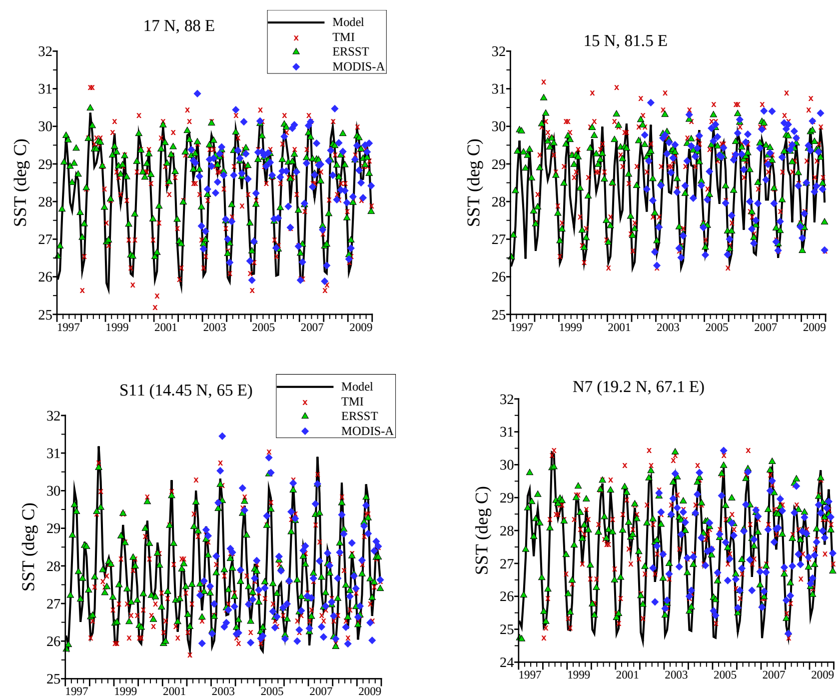

Figure 1.1 Monthly variations for SST for the period 1997-2009 at 2 stations in the Bay of Bengal and 2 stations in the Arabian Sea

Monthly variations of surface Chl are compared with satellite data from SeaWiFS and MODIS-A during 1997 to 2009. Comparison of model results with the data at two stations in the AS and

BOB are shown in Figure 1.2. It can be seen Chl values from the model are always higher than the satellite data at all locations during all the years in the BOB. The model is able to capture the trend seen in the observed data, whereas it is unable to capture high values of Chl during SWM and NEM (North East Monsoon – December, January, February) during most of the years in the AS.

Model simulations are able to capture most of the features that are observed in the satellite data in the North Indian Ocean for both SST and surface Chl. This kind of model validation studies are required to identify and understand in detail the significant marine ecosystem processes in the north Indian Ocean for estimation of primary productivity and carbon flux.

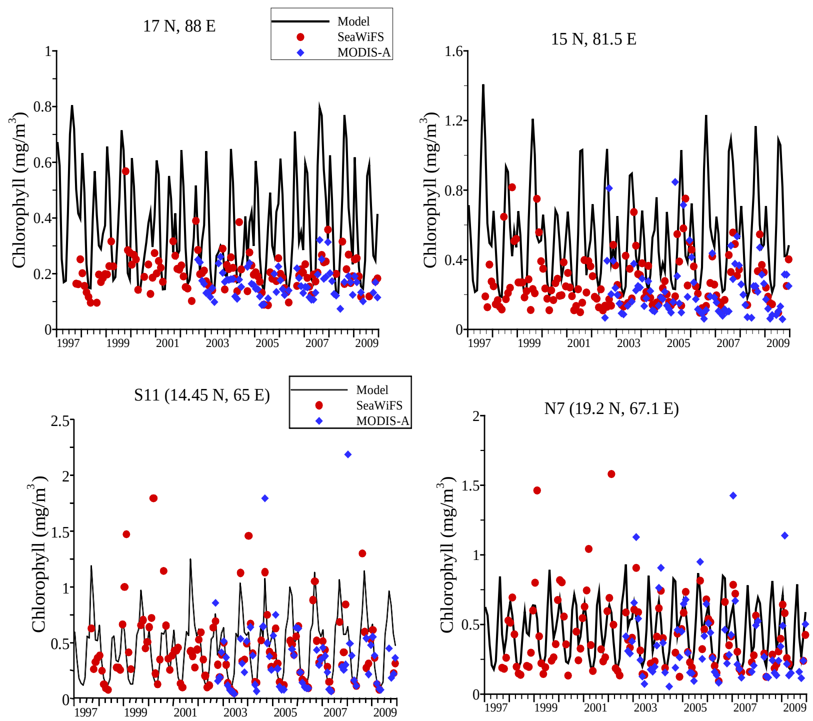

Figure 1.2 Monthly variation of chlorophyll for the period 1997-2009 at 2 stations in the Bay of Bengal and 2 stations in the Arabian Sea

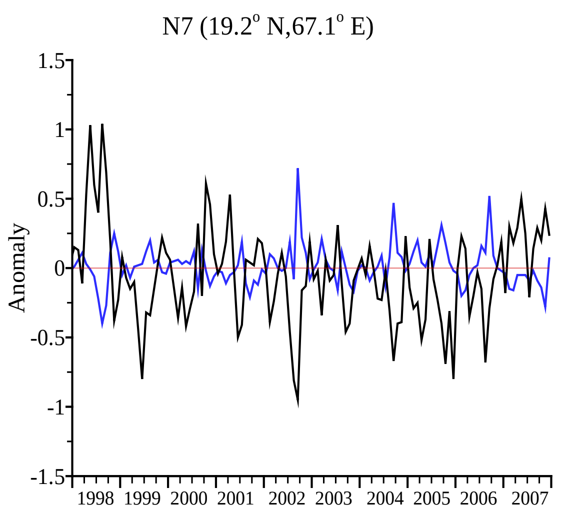

Figure 1.3 Surface Chl anomaly (mg/m3) scaled by 2 and SST (⁰C) anomaly in the interannual simulations (1998-2007)

Anomalies of surface Chl from model simulation results and SeaWiFS for the period 1998-2007, surface Chl and SST anomalies with MODIS-A for the period 2003-2007 are studied. It is seen that there is a negative surface Chl anomaly during a positive SST anomaly i.e., when there is an increase in SST, surface Chl decreases. To emphasize this trend a few locations in the AS and BOB are studied in detail using model simulations. Figure 1.3 illustrates the two anomalies from the model for a location in the AS (Blue –Chl Anomaly*2, Black- SST Anomaly). Studies on anomalies of SST and surface Chl from model and satellite data will help in analysing the impact of climate change on ecosystem and carbon cycle.

Parameter Sensitivity Study

Numerical simulations of TOPAZ are carried out for three different values of a parameter related to iron limitation namely, $(Fe:N)_{irr}$. Initially the model results are evaluated for some of the biogeochemical components using data from World Ocean Atlas-05 (WOA-05). Then, the results of the simulations are examined in detail at 3 Stations in AS, namely S4 (59.8°E, 17.2°N), S7 (62° E, 16° N) and N7 (19.2º N, 67.1º E) for monthly variations with depth. It is noticed that at 2 stations S4 and S7, PP and Chl increase, NO_3 and pCO_2 decrease during January-March and September-December, when $(Fe:N)_{irr}$ is reduced. However at N7, PP, Chl, NO_3 and pCO_2 did not show any change when $(Fe:N)_{irr}$ is varied. Model results show that iron limitation has significant influence on PP, Chl as well as pCO_2 at some of the regions in the AS (Figure 1.4).

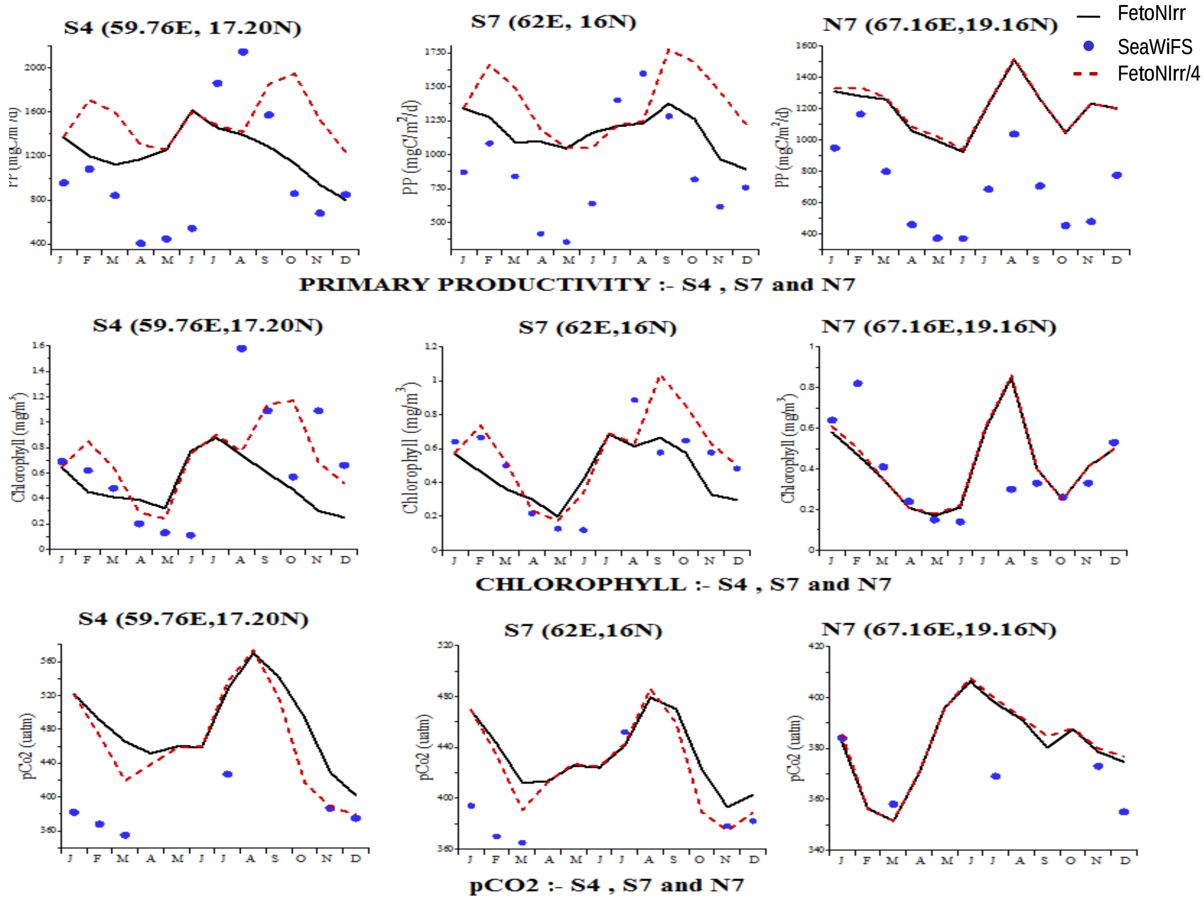

Figure 1.4 Monthly variations of Primary Productivity (mgC /m² /d) over the euphotic zone, surface Chlorophyll (mg /m³) and sea surface pCO_2 (uatm) for the locations S4 (59.76E,17.20N), S7 (62E,16N) and N7(67.16E,19.16N)

Modelling and Simulation of Subsurface Oxygen Distribution in the North Indian Ocean

The focus of this study is to understand the processes related to nitrogen and carbon cycles in the oxygen-depleted environments from literature, data and numerical simulations of the existing biogeochemical models. The biogeochemical model TOPAZ developed at GFDL coupled with MOM4p1 has been used to carry out the numerical simulations for

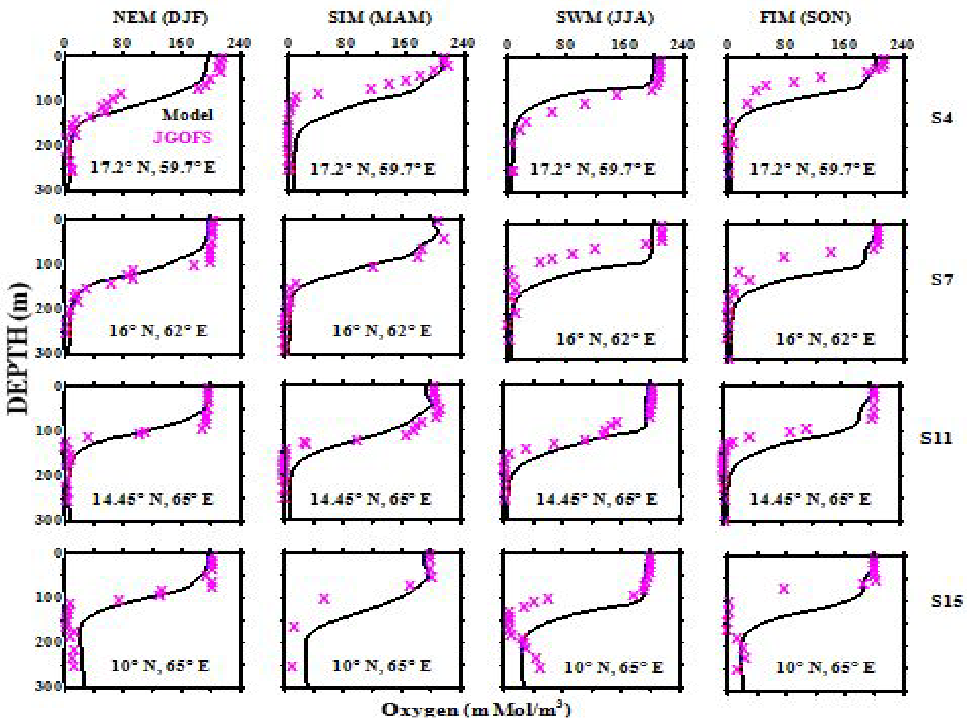

Figure 1.5 (a) Comparison of Oxygen (mMol/m^3) from Model with USJGOFS observations during four seasons at 4 stations in the Arabian Sea

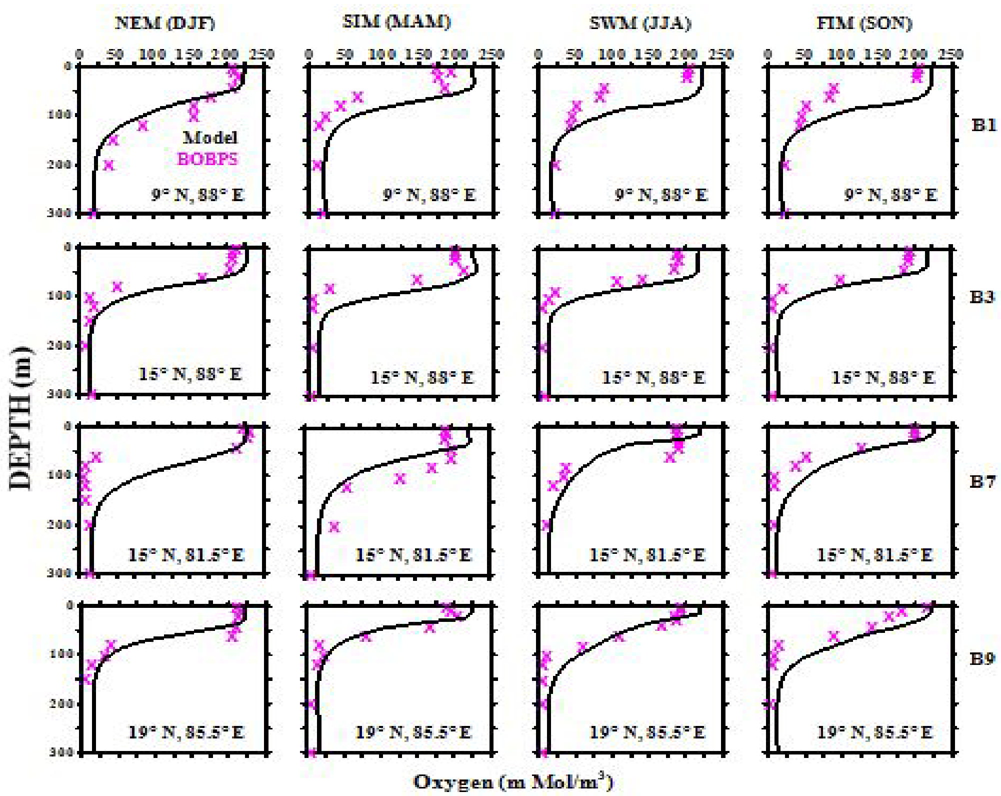

Figure 1.5 (b) Comparison of Oxygen (mMol/m^3) from Model with BOBPS observations during four seasons at 4 stations in the Bay of Bengal

climatological and interannual variability in the global domain. Initially, model results on the annual average value of oxygen concentration at deeper depths are compared with the World Ocean Atlas. It is noticed that model is able to capture all the Oxygen Minimum zones well (not shown). Variation of oxygen with respect to depth from the model is compared with the data from US JGOFS Cruises at four stations in the AS and with BOBPS data at four stations in the BOB (Figure 1.5). It can be noticed that there is a considerable decrease in oxygen below 100m. Model simulations are able to capture the oxygen minimum zone well both in the AS and BOB, but the oxygen concentration from the model is more than the observed by 5 to 10 units.

Results of the model simulations for climatological and interannual variability are being analysed and evaluated using data, for different biogeochemical components to get a better understanding of the processes and model parameters in the oxygen minimum zone in the north Indian Ocean.

Swathi P S, Sharada M K, Kalyani Devasena C, Sundara Deepthi M V, Shelava Srinivasan M K, Sharanya and Yajnik K S

2.2 Forward Modelling of Carbon Dioxide Transport with LMDZORINCA

We have setup a model for global atmospheric transport of carbon dioxide (CO_2) using LSCE's LMDZORINCA model with the following features: a zoom over India and China of 0.5^0 resolution centered over India and China and a total grid count of 144*142*19. The model couples LMDZ for transport with ORCHIDEE, a biosphere model and INCA a chemistry and aerosol model.

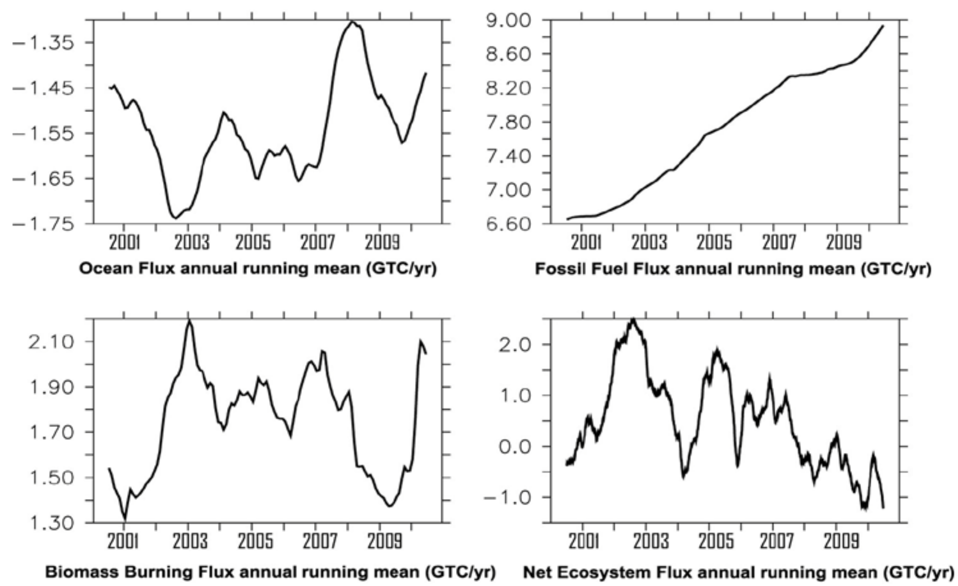

Figure 1.6 Global totals of surface fluxes forcing the transport model

The surface fluxes of CO_2 from (i) anthropogenic emissions (monthly) are taken from the CARBONES programme (www.carbones.eu), (ii) biomass burning (monthly) from Global Fire Emission Data base (GFEDV3.1) ,(iii) land biosphere (daily) from ORCHIDEE, CARBONES and (iv) ocean fluxes (monthly) from NOAA/AOML product. The model is integrated from 2000-

2011. Figure 1.6 shows the global totals (1 year running mean) of all the surface fluxes. Note that anthropogenic emissions have steadily increased from 6.6 GTC in 2000 to nearly 9.0 GTC in 2011 while other components show large interannual variability. The land biospheric component shows both positive emissions as well as uptake after 2008.

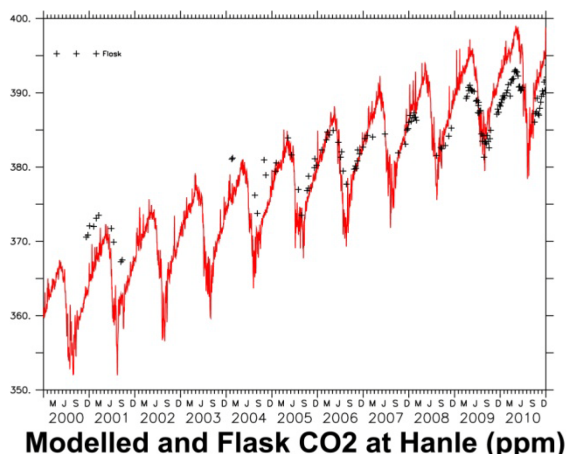

Figure 1.7 Model-data comparison at Hanle

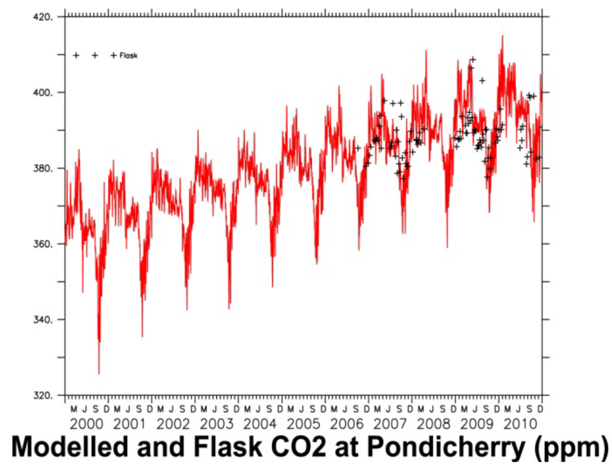

Figure 1.8 Model-data comparison at Pondicherry

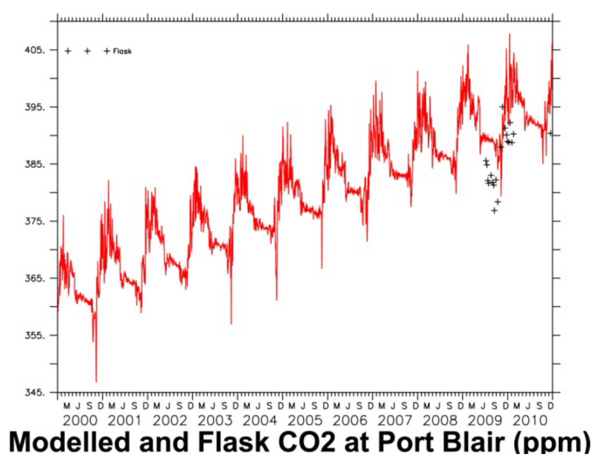

Figure 1.9 Model-data comparison at Port Blair

CSIR-4PI (erstwhile C-MMACS) has been running a detailed measurement programme of greenhouse gases at 3 sites, Hanle, Pondicherry and Port Blair for the past few years. The measurements conform to WMO standards and are the best available in the country. The output from the above model is compared with discrete flask data, collected at uniform intervals (weekly to bimonthly) at each site. Figure 1.7 shows the comparison at Hanle and it can be seen that both the model and data have a very pronounced seasonal cycle and a marked annual trend which are both higher in the model than in the data. The results at Pondicherry (Figure 1.8) and Port Blair (Figure 1.9) show similar features though there are structural differences among the three sites which reflect the combined effects of prevailing winds and surface emissions.

Swathi P S, Indira N K, Prashant Meti, Xin Lin[1], Ramonet M[1], Bhatt B C[2], Balakrishnan S[3] and Kirubagakaran R[4]

[1] LSCE, Gif-sur-Yvette, France, [2] IIA, Bangalore, [3] Pondicherry University, [4] NIOT, Chennai

2

CLIMATE AND ENVIRONMENTAL MODELLING PROGRAMME (CEMP)

The basic approach of CEMP is a fusion of innovation and sound mathematical modeling that can fill critical knowledge gaps and also enable real-life applications. The emphasis continues to be on understanding of the climate system and applications through multi-disciplinary modelling combining climate science with water, agriculture, health energy and sustainability in general.

CEMP uses a hierarchical modelling platform along with a spectrum of analysis and visualization tools. Most of the process models, with associated computer codes, are developed in-house. The CSIR climate observation and modelling network (COMoN) is a comprehensive data infrastructure. COMoN has been designed and developed by CEMP as a multi-application sustained network in a resource and effort sharing participation by multiple agencies.

CEMP has often adopted approaches that are unconventional but scientifically sound. After its cognitive network for monsoon forecasting, CEMP pioneered long-range, high-resolution forecasting of monsoon with novel methodology, such as a conceptual framework and methodology for advance dynamical forecasting of the date of onset of monsoon. CEMP has been communicating its experimental forecasts of monsoon to various agencies since 2003 for post-forecast evaluation.

Advance weather informatics, like forecasts of fog, can aid many sections of the society as well as strategic and industrial sectors. The dynamical fog forecasting model developed by CEMP was transferred to IMD for integration to the national weather services.

To complete the cycle from development to application, CEMP integrates effective outreach to its activities. An important outreach programme in weather informatics is in collaboration with Karnataka State Natural Disaster Monitoring Centre (KSNDMC). Forecasts generated using the novel methodology developed at CSIR-4PI (erstwhile C-MMACS) are disseminated by KSNDMC for the benefit of the farmers. CEMP had been the first to develop an industrial interface in weather informatics.

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A. Climate Analysis, Modelling and Projections

2.1 Assessment of Reliability of Regional Climate Projections

Projections of climate change are emerging to play major roles in many applications. However, assessing reliability of climate change projections, especially at regional scales, remains a major challenge. An important question is the degree of progress made since the earlier IPCC simulations (CMIP3) to the latest, recently completed CMIP5. We consider the continental Indian monsoon as an example and apply a hierarchical approach for assessing reliability, using the accuracy in simulating the historical trend as the primary criterion. While the scope has increased in CMIP5, there is essentially no improvement in skill in projections since CMIP3 in terms of reliability (confidence). Thus, it may be necessary to consider acceptable models for specific assessment rather than simple ensemble. Analysis of climate indices shows that in both CMIP5 and CMIP3 certain common processes at large and regional scales as well as slow timescales are associated with successful simulation of trend and mean.

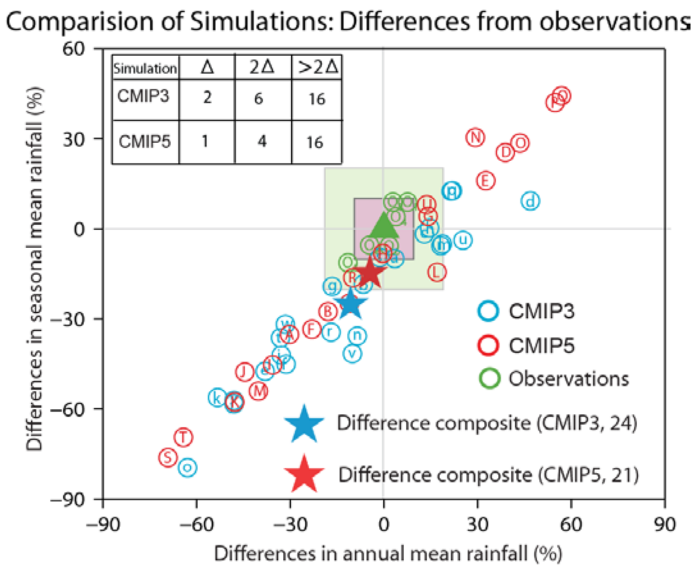

Figure 2.1 Distribution of historical (1951-2005) simulations in seasonal and annual rainfall over continental India for CMIP5 (red, uppercase) and CMIP3 (blue, lower case) in terms of the difference (simulation – observed composite) as percentage of the corresponding observed composite. The dispersion in the observations (green) is shown in terms of the difference (observation – observed composite) as percentage of the observed composite. The adopted acceptable uncertainty is defined by the difference (Δ) between the maximum and the minimum in the observed values, centered at the observed composite; the inner shaded box (pink) is defined by 1Δ, while the outer square (green) is defined by 2Δ. The inset table shows the number of simulations that fall in each category.

However, these regional (continental) trends may not represent global trends, and the oceanic trends, due to increased evaporation, are likely to be markedly different.

Ramesh K V, Goswami P
Nature Scientific Reports, 2014.

2.2 Monsoon in a Changing Climate

A revised scenario of global and regional monsoonal rainfall, and their changes in the 21st century under RCP4.5 and RCP8.5 scenarios was examined based on projections by 29 climate models that participated in the Coupled Model Intercomparison Project phase 5. The projections show that the global monsoon area defined by the annual range in precipitation is likely to expand mainly over the central to eastern tropical Pacific, the southern Indian Ocean, and eastern Asia. Over the Asian monsoon domain, projected changes in extreme precipitation indices are larger than those over the other monsoon domains, indicating the strong sensitivity of the Asian monsoon to global warming. The projections also indicate a delay in the retreat of the monsoon, while the onset will either advance or show no change, resulting in lengthening of the monsoon season. However, the models' limited ability to reproduce the present monsoon climate and the large scatter among the model projections limit confidence in the results. The projected increase of the global monsoon precipitation can be attributed to an increase of moisture convergence due to increased surface evaporation and water vapor in the air column although offset to a certain extent by the weakening of the monsoon circulation.

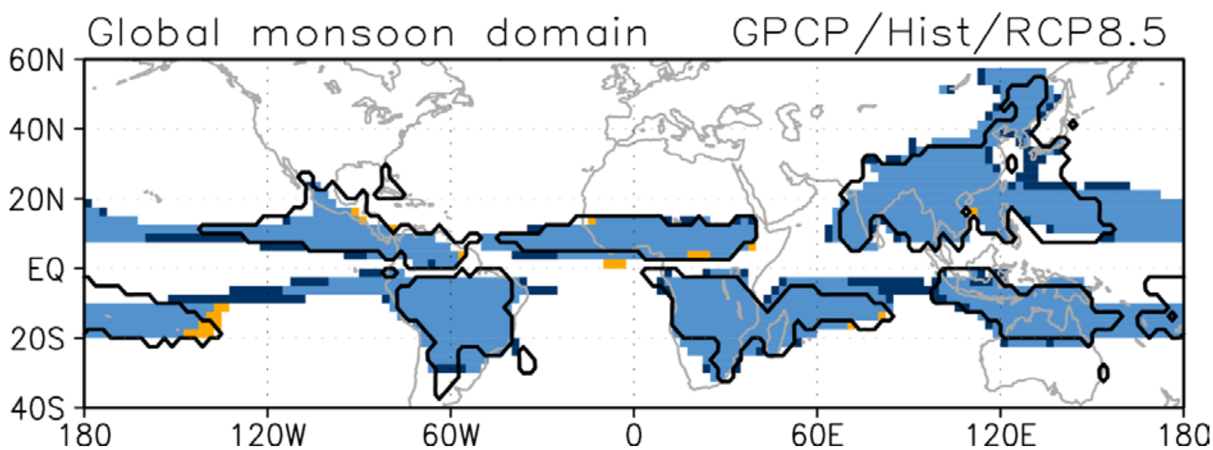

Figure 2.2 Observed GPCP; (thick contour) and simulated (shading) global monsoon domain, based on the definition by Wang et al. (2011). The simulations are based on 29 CMIP5 multi-model mean precipitation with a common 2.5 by 2.5 degree grid in the present-day (1986-2005) and the future (2080-2099; RCP8.5 scenario). Warm yellow (dark blue) shading: monsoon domain only in the present-day (future). Blue shading: monsoon domain in the both periods.

This study in the global context complements our earlier study on continental India monsoon. Thus while there may be an increase in in oceanic and hence global monsoon, the continental Indian monsoon may continue to decrease.

Akio Kitoh[1], Endo H[1], Krishna Kumar K[2], Iracema F A Cavalcanti[3], Goswami P and Tianjun ZhoJ[4], Geophys. Res. Atmos., 2013
[1]Meteorological Research Institute, Japan. [2]Indian Institute of Tropical Meteorology, India.
[3]Center for Weather Forecasting and Climate Studies (CPTEC), Brazil.
[4]LASG, Institute of Atmospheric Physics, China.

B. Long-range Forecasting of Monsoon Rainfall and Date of Onset

2.3 Long-range, High-Resolution Forecasting of Monsoon Rainfall

Given the tremendous socio-economic impacts of monsoon rainfall essentially on all socio-economic sectors of India, accurate forecasts of monsoon rainfall can be a critical input. However, for effectiveness such forecasts should have the scope, lead and reliability required by the users. As long-range forecasting of monsoon is still a evolving science with many challenges, CSIR-4PI (erstwhile C-MMACS) had initiated a sustained effort to develop and improve methodologies for long-range forecasting of monsoon.

The forecasts of monthly anomalies are made by computing the anomalies with respect to 25 year model mean for each ensemble. The ensemble average is then determined as an average over the ensembles with equal weight for different scenarios. The monthly and seasonal anomalies are expressed as percentage of the model mean.

Spatial distribution seasonal rainfall anomaly (% of mean) for June-August, 2013 from IMD observation (left panel) and CSIR-4PI (erstwhile C-MMACS) long range forecasting (right panel) are represented in Figure 2.3.

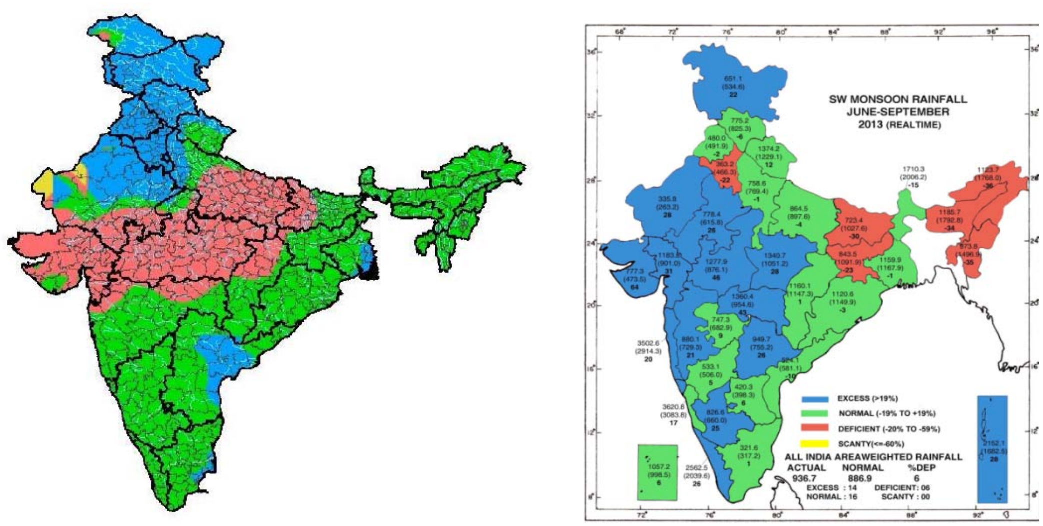

Figure 2.3 Comparison of CSIR-4PI (erstwhile C-MMACS) 2nd outlook forecast for the period June-August 2013 rainfall anomaly with IMD observation. The simulation is an ensemble average of five initial conditions between April 01 and May 15, 2013 from NCEP Reanalysis.

Since 2003, CSIR-4PI (erstwhile C-MMACS) has been generating and communicating its long-range experimental forecasts (issued in march-April) for objective post-forecast validation. These experimental forecasts, pioneered by CSIR-4PI (erstwhile C-MMACS) have created new approaches and benchmarks for long-range forecasting of monsoon.

Gouda K C and Goswami P

2.4 Advance Forecasting of Date of Onset of Monsoon

The onset of summer monsoon over Kerala heralds the rainy (and hence agricultural) season for India; thus advance and accurate forecast of the date of onset can have many applications, especially in agricultural planning. However, advance dynamical forecasting of the date of monsoon has been rarely attempted anywhere in the world due to poor skill in forecasting daily rainfall. Although forecasting of day to day variability of rainfall beyond a few days remains a major challenge, we have argued that large transitions like the onset of monsoon should have a high signal-to-noise ratio, and should be predictable. Along with this hypothesis, a dynamical framework with a general circulation model (GCM) optimized over India (variable-resolution GCM adopted from LMD, France) was advanced (Goswami and Gouda, 2010); further, objective criteria and algorithm for identifying the date of onset from the GCM simulations were developed (Goswami and Gouda, 2010).

Although the date of onset shows a standard deviation of only seven days, many years are known to show large deviations; besides, many years are also characterized by false onsets. Thus accurate forecasting of date of onset is non-trivial. The methodology was first tested in hindcast mode (forecasts of past events) and the skill was found to be useful, with an average error of 2 days.

These methodologies have been followed to generate advance (> 15 days) forecast of the date of onset of monsoon. The CSIR-4PI (erstwhile C-MMACS) Forecasts of date of onset, announced in April, 2013, matched with the date of onset announced by IMD (May 31, 2013).

Table 2.1 Performance of CSIR-4PI (erstwhile C-MMACS) Experimental Forecasts of Monsoon Onset

Year	Actual Onset Date	CSIR-4PI (erstwhile C-MMACS) Forecast Onset Date	Error (Days)
2007	May 28	May 26	2
2008	May 31	May 28	3
2009	May 23	May 23	0
2010	May 31	May 29	2
2011	May 29	June 03	5
2012	June 04	June 04	0
2013	**May 31**	**May 31**	**0**
Average error in prediction of date of onset			2 Days

CSIR-4PI (erstwhile C-MMACS) began its experimental forecast of the Date of Monsoon in 2007. The 7 year performance of dynamical prediction of DOM using CSIR-4PI (erstwhile C-MMACS) methodology shows (table 2.1) the average error to be essentially same as that for the hindcast skill, with only one forecast with large (but smaller than standard deviation) error of five days. As the post-forecast evaluation of CSIR-4PI (erstwhile C-MMACS) forecasts begin to present robust skill, other agencies are beginning to come forward with advance forecasts of date of onset.

Gouda K C and Goswami P

C Forecast Methodology, Applications and Outreach

2.5 High-resolution (Village Cluster) Rainfall Forecast for Real Time Applications

Evaluation of real-time rainfall forecast at the *hobli* (village cluster ~ 10 km2) level from an atmospheric mesoscale model over Karnataka (located at southwest India, with nearly 56% of the workforce engaged in agricultural activities) for the southwest (June–September) and northeast (October–December) monsoon seasons of 2011 is presented in this study. The forecast system has been operationally implemented through data assimilation from a number of local observatories for effective applications as well as for proof of concept. A highlight of the study is the validation of the rainfall forecasts against observations at comparable resolution established by Karnataka State Natural Disaster Monitoring Centre, Government of Karnataka (KSNDMC). An evaluation of the forecast skill against daily observed rainfall is presented. A number of statistical evaluations show that the forecasts have enough skill to be useful for end users (Figure 1). A few areas of systematic bias (Figure 2) and relatively higher forecast error were identified for further improvement in forecast skill.

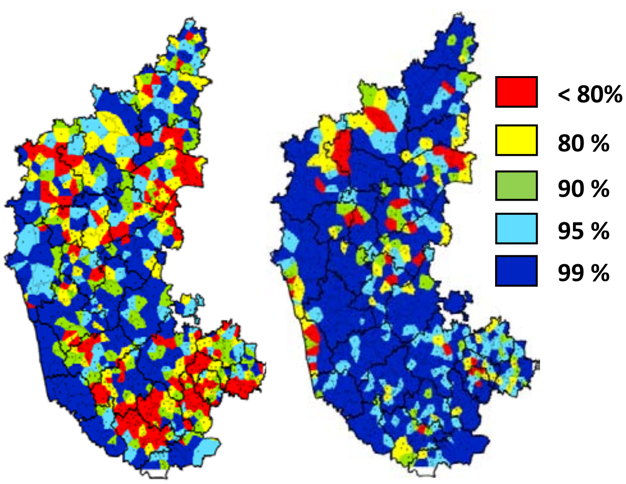

Figure 2.4 Significance of Correlation between the observed and forecasted daily rainfall for SWM (left panel) and NEM (right panel) season for 2011.

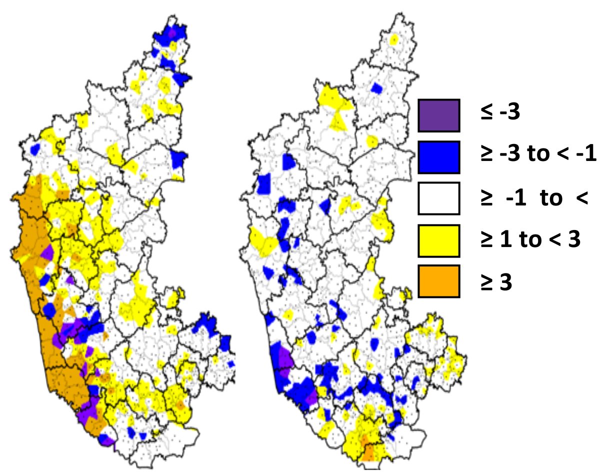

Figure 2.5 The average bias in daily rainfall (mm/day) for SWM (left panel) and NEM (right panel) season 2011.

Efforts are now on to increase the accuracy of the forecasts further through assimilation of data from CSIR COMoN as well as from the KSNDMC observation network. An initiative to generate forecasts at Panchayat level (a few Km scale) has also begun.

***Rakesh V, Goswami P and Prakash V S*[1]**
Meteorological Applications, 2013
[1]Director, KSNDMC, Bangalore

2.6 Dynamical Model for Air Pollution: Interfacing with GCM

Species like suspended particulate matter (SPM), respirable suspended particulate matter (RSPM), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) not only act as atmospheric pollutants but also affect long-term climate through radiative and chemical forcing. Earlier work has shown that the daily variations in these species over a location could be simulated quite well by considering daily meteorological fields from NCEP–NCAR reanalysis data in combination with models for natural and anthropogenic sources over Delhi, India. In the present work this possibility is explored by simulating the pollutant concentrations by using forecast fields from an atmospheric general circulation model (AGCM); this takes the model closer to a forecast model. Because of the coarse resolution, however, the present work considers an air basin rather than a detailed spatiotemporal distribution.

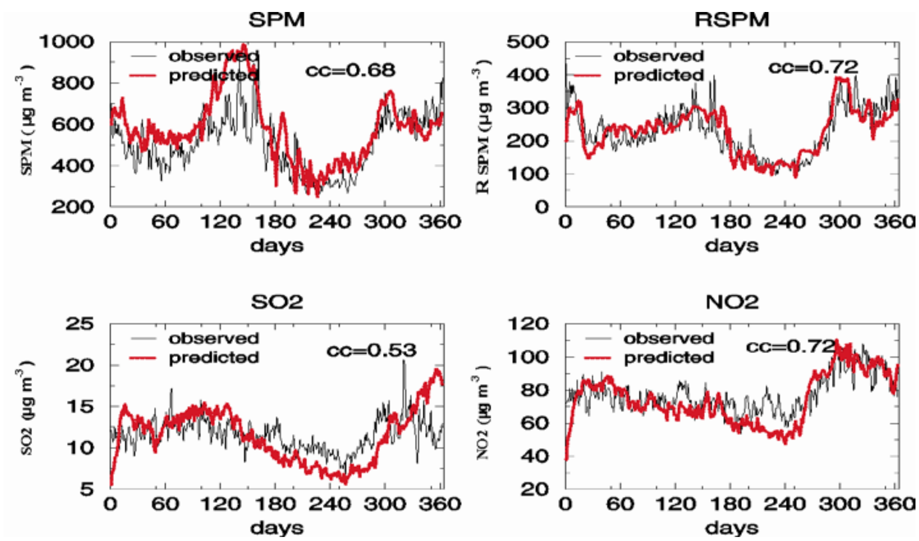

Figure 2.6 Climatology (2000-2005) of observed (black line) and simulated (red line) values for different pollutants over Delhi as indicated. The meteorological variables have been taken from debiased prediction of gridded model output with the centre of zoom at 77° E and 28° N (Delhi). The observed data is from Central Pollution Control Board.

One of the objectives of the present work has been to compare and assess the impacts of a GCM-generated field with reference to NCEP–NCAR reanalysis data used in earlier work. In the present work the interaction is one way, and active chemistry for the species is not considered; thus the work should be regarded as a minimal forecast model, especially for SO_2 and NO_2. It is shown that the GCM-driven model has skill comparable to skill obtained when using NCEP–NCAR reanalysis data. However, much higher skill can be expected with incorporation of techniques like data assimilation and objective debiasing.

Goswami P and Barua J
J Meteor. Climatol., 2013

2.7 Impact of Domain Size and Parameterization Scheme on Simulation of Tropical Cyclones

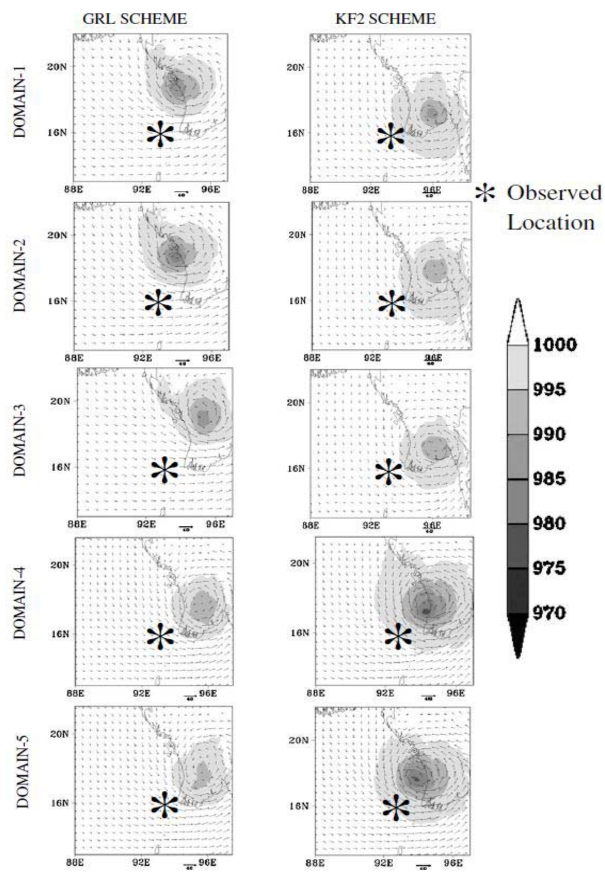

Figure 2.7 Surface pressure (hPa) and vector wind for cyclone Mala at 18 h on 28 April 2006 for different domains and parameterization schemes. All the simulations were carried out with initial condition extracted from NCEP FNL (1° × 1°) 06 h data on 25 April 2006. The observed minimum surface pressure is 954 hPa.

Accuracy of forecasts of tropical cyclones is still below the user requirement, especially over the north Indian Ocean. In case of dynamical forecasting, a large number of processes and factors control the quality of simulations with a numerical weather prediction model and especially with mesoscale models; identification and optimization of these processes are critical for improving forecast skill. The importance of cumulus parameterization schemes in simulation of tropical cyclones was recognized early, and a large number of studies have addressed this issue. However, certain other aspects have received relatively less attention. In particular, unlike simulation with a global circulation model, a mesoscale simulation is characterized by a limited domain and hence inhomogeneous lateral boundary conditions that strongly affect the quality of the simulation. In this work, we investigate the relative impact of size of the model domain and the cumulus parameterization scheme on simulation of 10 cyclones over the Bay of Bengal during the period 1999–2009. For five domains with different spatial extents, simulations were carried out for three different cumulus parameterization schemes (Anthes-Kuo, Grell, and Kain-Fritsch2) for each of the 10 events (using the mesoscale model MM5). Our results show that the size of the domain also plays an equally critical role as the parameterization scheme in simulation of maximum intensity, track, and spatial structure of the cyclones. The impact of domain size is not linear; while each domain chosen is large enough, neither the largest nor the smallest domain provides the best simulation. However, there is consistency in the sense that a single domain emerges as best for intensity and track among the five considered. While the specific conclusions may depend on the ocean basin, the methodology is generic and can be applied to any ocean basin of cyclogenesis. The result provides a basis and methodology for improving skill in forecasting tropical cyclones over the north Indian Sea.

Goswami P and Mohapatra G N
Journal of Geophysical Research: Atmospheres, 2014

D. Climate Change Assessment, Impact and Mitigation

2.8 Efficient, Non-disruptive and Sustainable C Sequestration with Vetiver

The increase of atmospheric CO2 concentration is a major cause of global warming. This issue may be effectively addressed through sequestration of carbon in plants and soils. Here we studied the potential of vetiver, Vetiveria zizanioides L., to sequester carbon in field plots in Bangalore, India. Vetiver is a perennial and economically viable crop growing in tropical and subtropical regions. Vetiver has medicinal and aromatic properties. Vetiver shoot and root C amounts were measured. Results show that vetiver sequesters 15.24 Mg C ha−1 year−1 in shoot and roots, much higher than that for lemongrass with 5.38, palmarosa with 6.14, and trees with 2.92. In addition the benefit/cost ratio of vetiver, 2.3, is higher than that of rice, 1.97.We estimate that vetiver cropping could sequester 150 Tg per year in India, which is nearly 46 % of C emissions in India.

Table 2.2 Comparative economics of production of three aromatic plants and rice

Crop	Fresh biomass (mega grams ha^{-1} $year^{-1}$)	Essential oil (%)	Benefit cost ratio
Vetiver	4.25 (roots)	0.8	2.3
Lemongrass	27.7	0.8	1.97
Palmarosa	30	0.5	2.75
Rice	-	-	1.97

India has approximately 6.63m ha salt effected soils, 17.9 m ha acid soils and 83.3 m ha land affected by soil erosion. Even if 10% of the degraded soils affected by erosion, acidity, salinity and sodicity in India (which comes to nearly 10 m ha) is employed for a vetiver-based carbon sequestration system (vetiver and vetiver based agro-forestry systems), a potential exists to sequester more than 50 Tg C year $^{-1}$ in soil and 150 Tg C year $^{-1}$ in the biomass over a 5- year period. This potential is much higher than some earlier estimates for restoration of degraded soils in India. The potential C-sequestration by vetiver could be nearly 46% of the C emissions of 434 Tg year $^{-1}$ in India. It should be noted that as only a small fraction (~10%) of potential area is considered in the estimate. the plantations of vetiver can be rotated, allowing SOC to decline below saturation value, so that the cycle can be repeated. Thus vetiver can provide a sustainable, non-disruptive solution to sequester carbon in soil along with societal benefits.

Munnu Singh[1], Neha Guleria[1], Prakasa Rao E V S and Goswami P
Agron. Sustain. Dev, 2013.
[1]CIMAP, Bangalore

2.9 Modeling of Vulnerability of an Urban Groundwater System under Combined Impacts of Climate Change and Management

Climate change impact on a groundwater-dependent small urban town has been investigated in the semiarid hard rock aquifer in southern India. A distributed groundwater model was used to simulate the groundwater levels in the study region for the projected future rainfall (2012–32) obtained from a general circulation model (GCM) to estimate the impacts of climate change and management practices on the groundwater system. Management practices were based on the human-induced changes in the urban infrastructure such as reduced recharge from the lakes, reduced recharge from water and waste water utility due to an operational and functioning underground drainage system, and additional water extracted by the water utility for domestic purposes. An assessment of impacts on the groundwater levels was carried out by calibrating a groundwater model using comprehensive data gathered during the period 2008–11 and then simulating the future groundwater level changes using rainfall from six GCMs [Institute of Numerical Mathematics Coupled Model, version 3.0 (INM-CM.3.0); L'Institut Pierre-Simon Laplace Coupled Model, version 4 (IPSL-CM4); Model for Interdisciplinary Research on Climate, version 3.2 (MIROC3.2); ECHAM and the global Hamburg Ocean Primitive Equation (ECHO-G); Hadley Centre Coupled Model, version 3 (HadCM3); and Hadley Centre Global Environment Model, version 1 (HadGEM1)] that were found to show good correlation to the historical rainfall in the study area. The model results for the present condition indicate that the annual average discharge (sum of pumping and natural groundwater outflow) was marginally or moderately higher at various locations than the recharge and further the recharge is aided from the recharge from the lakes. Model simulations showed that groundwater levels were vulnerable to the GCM rainfall and a scenario of moderate reduction in recharge from lakes. Hence, it is important to sustain the induced recharge from lakes by ensuring that sufficient runoff water flows to these lakes.

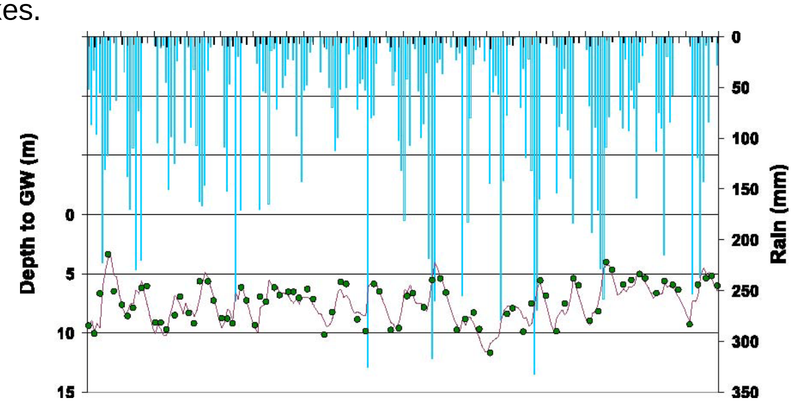

Figure 2.8 Comparison of observed and simulated groundwater levels monitor data station during 1978–97. The line represents simulated and circle represents observations.

Efforts are now on to develop a comprehensive simulation platform for ground water demand and availability in different socio-economic scenario.

Sekhar M[1], Shindekar M[1], Tomer Sat K [1]and Goswami P, Earth Interactions, 2013
[1] Indian Institute of Science, Bangalore, India

E. Sustainability Policy Analysis and Modelling

2.10 Quantitative Assessment of Agricultural Sustainability over India

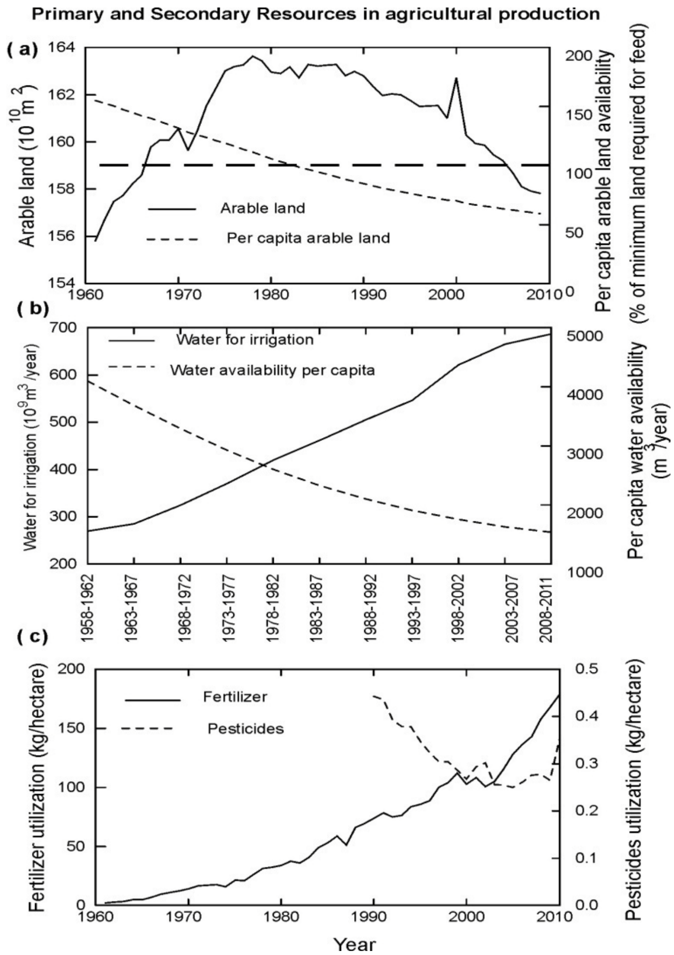

Figure 2.9 Availability and status of the primary resources for India. Top panel: Total arable land (left y axis, solid line) and per capita land availability (right y axis, dash line); expressed as the % of minimum land needed to produce food for one person (0.22 hectares: http://www.gdrc.org/sustdev/fao-100.pdf). Middle panel: Water use for irrigation (solid line, left y axis) and the per capita water availability (dash line, right y axis) for different epochs. Bottom panel: Fertilizer utilization per hectare (left y axis, solid line) and pesticides utilization per hectare (right y axis, dash line). The observed data for fertilizer utilization and arable land is taken from FAOSTAT; the data on pesticides is adopted from Dept. of Agricultural and Corporation http://agricoop.nic.in/Agristatistics.htm).

Agricultural sustainability is an important parameter for policy design. Sustainability is a complex function of many variables and has to follow a constrained dynamics due to limited resources, increase in demand and factors like climate change; thus quantitative estimation and projection of sustainability pose significant scientific challenge. With respect to food sustainability, saturation and even decline of agricultural land along with growing consumption in many parts of the world can make surpluses unavailable for redistribution through trades. Thus agricultural self-sustainability, defined as the ratio of the total food producible to the total food demand of a people, is going to be increasingly relevant. However, a quantitative, dynamical framework for regional agricultural self-sustainability is often missing. We present an assessment of agricultural self-sustainability in terms of primary resources like arable land and water for India with its changing population and consumption for a case study. It is shown that India is at the threshold of losing sustainability in the primary resources, with extreme vulnerability to any adverse change in climate.

These results can provide important inputs for long-term policy planning in areas like food sustainability, water sustainability and export.

Goswami P and Shiv Narayan Nishad,
Current Science, 2014

F. Climate Observation and Modelling Network (COMoN)

2.11 Soil Moisture Analysis with COMoN Data

Accurate soil moisture data is critical for many applications like agriculture and estimate of ground water. However, reliable climatology of soil moisture is limited by the absence of high-frequency, multi-site observations, especially over India. A long term sustained soil moisture observation at four vertical levels (5cm, 15cm, 50cm and 100cm) is now available at several locations over India under a multi-institutional program Climate Observations and Modelling Network (COMoN) led by CSIR, India. At the same time, a high resolution (0.1°x0.1°) daily (moving 5-day mean) surface relative soil moisture data set has now become available from the Advanced Scatterometer (ASCAT). However, there is a need to compare remotely sensed data and in situ observations to ensure consistency and quantify uncertainties. This is particularly true for India characterized by diverse climatic zones. We present a comparative analysis of gridded ASCAT soil moisture data and in situ COMoN station data over six locations in India during the period 2010-2013. The comparisons are carried out at daily, weekly, monthly and seasonal time scales at each location. Analyses in terms of a number of statistical parameters show that the two data sets are generally consistent, although there are seasonalities in the agreement. In general, the correlation coefficient is higher for the wet season (summer, autumn), and moderate for dry season (winter, spring). Our results show consistency between the remotely sensed and in situ soil moisture in spite of the inherent differences in their methodology, resolution etc.; however, the results also show certain differences that introduce uncertainties in the climatology of soil moisture.

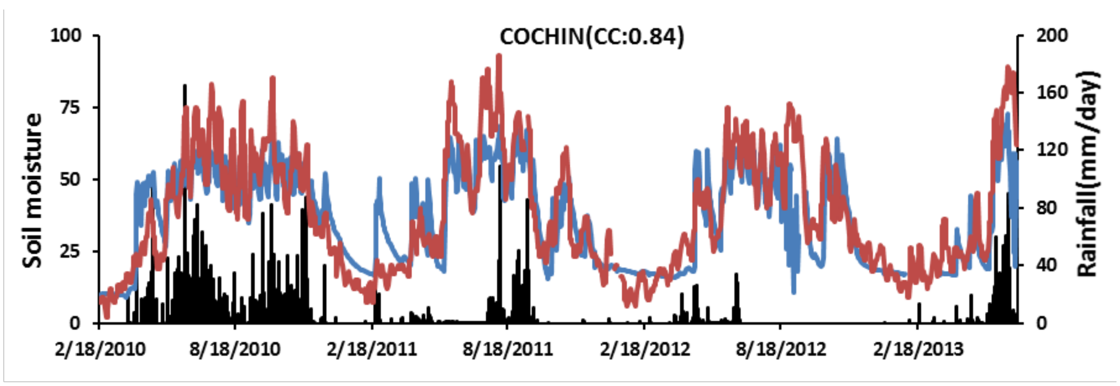

Figure 2.10 Daily time series plot of soil saturation from ASCAT and COMoN observations associated with concurrent rainfall episodes. The primary y-axis represents the soil saturation and secondary y-axis represents the Rainfall values.

Trends in soil moisture also provide important and quantitative measure of change in aridity; thus accurate spatial distributions of soil moisture are critical inputs for many applications. Our study provides the first quantitative multi-scale comparison of in situ and remotely measured soil moisture over India.

Bhimala K R and Goswami P

2.12 Validation of the Simulation of Heavy Rainfall Event over Delhi using WRF model and data assimilation system with CSIR COMoN observations

Hourly data from three MONUS profilers were used for the comparison and analysis of simulations. In addition, horizontal wind and temperature from MONUS were also examined. Simulated rain (both control and test experiments) was compared with station and TRMM data.

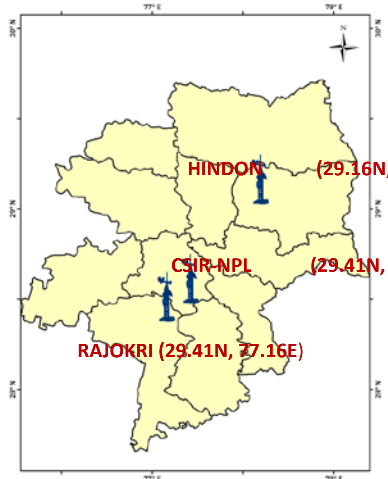

Figure 2.11 Location of 32-meter meteorological profilers under Mesoscale Observation Network for Urban System (MONUS) over the study area of Delhi.

Figure 2.12 shows the comparison of the time evolution of the simulated rain at each station with the observation (TRMM and COMoN data) and also the comparison of the time evolution of the simulated rain averaged over the three stations with the observation averaged over the same grid points or stations. Looking at each station it may be said that there was a high degree of rainfall variability (onset, intensity and duration) amongst the neighboring stations that are a few kilometers apart.

The simulated rain, despite some discrepancies, when compared to observations (with regards to time-lag, intensity and onset of the event) could have been useful in issuing an alert. Another important observation was that TRMM data showed excess rain before the event at all the stations that is not reflected in the observed rain (COMoN) at these stations. Thus our results indicate that satellite-based quantitative precipitation estimates might not be reliable during heavy rainfall events because of their limitations in resolution.

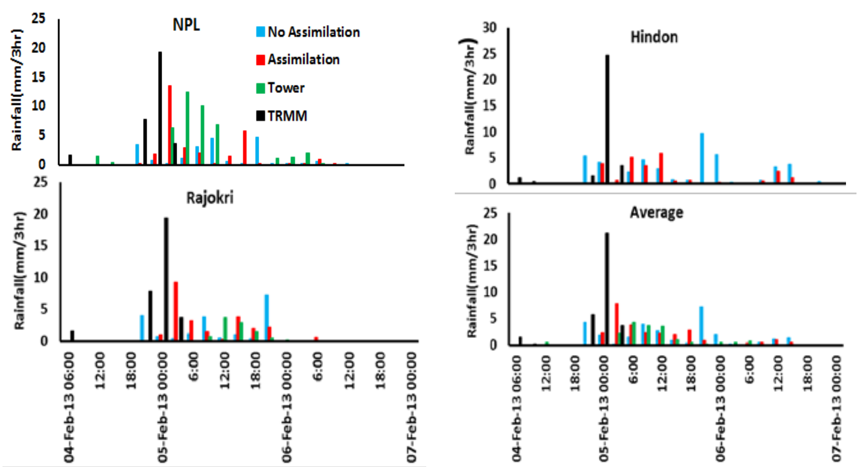

Figure 2.12 Comparison of the time evolution of simulated and observed (COMoN) rain in Delhi during the heavy rainfall event. The peak of the event was on 5th Feb 2013, 00.30 hour. Large variation in neighboring stations just few km away is evident from tower observation but is not reflected in TRMM data. It is also evident that assimilation improved the simulation in terms of intensity which is in phase with tower observation, except at Hindon.

These results are being used to calibrate and validate a disaster forecast platform over the National Capital Region.

Himesh S, Rakesh V, Ramesh K V, Mohapatra G N, Bimala K R, Gouda K C and Goswami

3

COMPUTATIONAL MECHANICS

We have continued our work on development and application of novel Homotopy Analysis Methods. We have demonstrated the advantage of using the modification of the Homotopy Analysis Method with a non homogeneous term for a system of equations for the first time. We have also developed a Homotopy Analysis Method with an optimal distribution of the initial conditions in a shooting method to solve two point boundary value problems.

Computational nanomechanics focuses on nonlocal continuum modelling and molecular dynamics simulations in nanomaterials. Parallel Super Computers are used to analyse and simulate the properties of new materials (nanomaterials) from the nano to macroscale. This reduces the cost of expensive experimental analysis. Studies have been carried out on a nonlocal continuum theory for modeling the buckling of Carbon Nanotubes. We have calibrated the nonlocal small scale parameter from Molecular Dynamics simulations and we have shown that the approach currently used in the literature may lead to inaccurate results. We have demonstrated the efficiency of some open source software for solving these problems.

Inside

- *Influence of Thermal Radiation on Unsteady Flow Over a Contracting Cylinder with Thermal-Diffusion and Diffusion-Thermo Effects by HAM with Non-Homogeneous Term*
- *Homotopy Solutions for Nonlinear Problems with Two-point Neumann Boundary Conditions*
- *Small Scale Parameter Calibration for Buckling Analysis of Carbon Nanotube using Molecular Dynamic Simulation*
- *Symbolic Computation Analysis of One-Dimensional Nanostructures Using Open Source Software*

3.1 Influence of Thermal Radiation on Unsteady Flow over a Contracting Cylinder with Thermal-Diffusion and Diffusion-Thermo Effects by HAM with Non-Homogeneous Term

An analytical study is carried out to present the thermal radiation, Dufour and Soret effects on unsteady viscous flow over a contracting cylinder. The coupled nonlinear partial differential equations are transformed into a system of coupled nonlinear ordinary differential equations by using a suitable similarity transformation. The homotopy analysis method (HAM) and HAM with a non-homogeneous term are employed to obtain analytical solutions for the system of coupled nonlinear ordinary differential equations through the minimization of the averaged square residual error. The inclusion of the non-homogeneous term is presented to further minimize the average square residual error (Δ). We observe a better convergence in comparison to HAM solutions. To the best of our knowledge this is the first application to a system of coupled nonlinear differential equations where the idea of the inclusion of the non-homogeneous term is used. We present the convergence analysis for the solutions obtained by HAM and HAM with a non-homogeneous technique in Tables [3.1] and [3.2]. It is clear from these tables that with the latter approach HAM with a non-homogeneous term gives better convergence and minimum square residual error in comparison to standard HAM approach.

Table 3.1 The averaged square residual error with varying at 10th order of approximation with standard HAM (without non-homogeneous term) technique $\Pr = 1$, $S = -1$, $Sc = 0.65$, $Sr = 1$, $Du = 0.06$, $R_d = 10$.

h	Δ
-0.25	0.002751320
-0.26	0.002231060
-0.27	0.001805630
-0.28	0.001459880
-0.29	0.001184700
-0.30	0.000982196
-0.31	0.000879418
-0.32	0.000963043
-0.33	0.001463140
-0.34	0.002952130
-0.35	0.006827180

Table 3.2 The averaged square residual error with varying at 10th order of approximation with non-homogeneous term $F(\eta) = c_1 e^{-\eta}$ and for optimal $h = -0.31$, $\Pr = 1$, $S = -1$, $Sc = 0.65$, $Sr = 1$, $Du = 0.06$, $R_d = 10$.

c_1	Δ
0.5	0.000716046
0.6	0.000694628
0.7	0.000676962
0.8	0.000663048
0.9	0.000652887
1.0	0.000646477
1.1	0.000643820
1.2	0.000644914
1.3	0.000649761
1.4	0.000658360
1.5	0.000670711

Anant Kant Shukla, Ramamohan T R, Srinivas S and Reddy A S**

* VIT University, Vellore

3.2 Homotopy Solutions for Nonlinear Problems with Two-Point Neumann Boundary Conditions

We study a comparison of modified versions of Rational Homotopy Perturbation Method (RHPM) and homotopy analysis method (HAM) to solve two-point nonlinear problems with Neumann boundary conditions which very often arises in physical systems. The modification of RHPM relies on the strategic distribution of the Neumann boundary conditions among the different iterations. RHPM gives solutions assuming the form of solution to be a rational polynomial and then using the distribution of boundary conditions throughout the different orders. HAM coupled with a shooting technique gives good results in a very simple and straightforward way with fewer assumptions. The results of both methods are accurate with respect to the exact solution of the problems considered. Nonetheless, RHPM requires only a second order approximation to obtain similar results in comparison to the seventh order HAM approximation. To check the efficiency of the proposed modifications we solve two nonlinear problems with given Neumann boundary conditions one is Bratu's problem and other is Burger's equation. The comparative results for the Bratu's and the Burger's equation are shown in Table [3.3] and [3.4].

Table 3.3 The comparative study for the solution of Bratu's problem with the proposed second order RHPM and the proposed seventh order HAM with the exact solution.

X	RHPM solution	HAM solution	Exact solution
0	0	0	0
0.1	0.00987156	0.0100167	0.0100167
0.2	0.04000446	0.040271	0.040270
0.3	0.09119138	0.0914016	0.091383
0.4	0.16446022	0.164556	0.164458
0.5	0.26133364	0.261514	0.261168
0.6	0.38410832	0.384852	0.383930
0.7	0.53620148	0.538116	0.536172
0.8	0.72263494	0.725982	0.722781
0.9	0.95077066	0.954324	0.950885
1.0	1.23125000	1.230100	1.231250

Table 3.4 The comparative study for the solution of Burger's problem with the proposed second order RHPM and the proposed seventh order HAM up to fifth terms of sin (2x) with the exact solution.

x	RHPM solution	HAM solution	Exact solution
0	0	0	0
0.1	0.09988958	0.0998334	0.0998334
0.2	0.19879931	0.198668	0.198669
0.3	0.29566654	0.295511	0.295520
0.4	0.38951433	0.389379	0.389418
0.5	0.47943371	0.479311	0.479426
0.6	0.56456849	0.564369	0.564642
0.7	0.64410435	0.64366	0.644218
0.8	0.7172632	0.716345	0.717356
0.9	0.78330427	0.781668	0.783327
1.1	0.89131935	0.887798	0.891207
1.2	0.93212389	0.927808	0.932039
1.3	0.96353598	0.958955	0.963558
1.4	0.98531969	0.981452	0.98545
1.5	0.99746956	0.995789	0.997495
$\pi/2$	1.00039043	1.00138	1.000000

Hector Vazquez-Leal, Anant Kant Shukla, Ramamohan T R and Antonio Marin-Hernandez**
* University of Veracruz, Mexico

3.3 Small Scale Parameter Calibration for Buckling Analysis of Carbon Nanotube using Molecular Dynamic Simulation

The aim of the present study is to improve nonlocal continuum elasticity theory for Carbon Nanotubes (CNT) by calibrating its small scale parameter. In this work, the small scale parameter of the Nonlocal Timoshenko beam model and the Nonlocal shell model has been calibrated. Despite the high number of studies conducted on the buckling of CNTs, there are still several issues that are not addressed sufficiently like change of properties with chirality and aspect ratio of CNTs since most of the studies conducted on buckling of CNT are based on continuum mechanics which is used conveniently to analyze large-scale problems. However continuum theory cannot address small size effect problems. Hence to overcome this drawback, nonlocal continuum theory was developed.

Nonlocal continuum theory uses a small scaling parameter (e_o) to address this nanoscale problem and can also be used to address the chirality effect of CNTs but some arbitrary value is taken on the basis of trial and error and leads to inaccurate results. In this work Molecular Dynamics Simulation (MDS) is used to calibrate this small scale parameter value and an empirical relation has been developed which can be directly be used in the nonlocal continuum theory to study the mechanical properties of CNT.

In this work Molecular Dynamic Simulation (MDS) has been used to calculate the critical buckling load and the critical buckling strain. The Figure 3.1 shows compressive load vs strain diagram for a (16, 0) zigzag Carbon Nanotube with 1.25 nm diameter and 10 nm length.

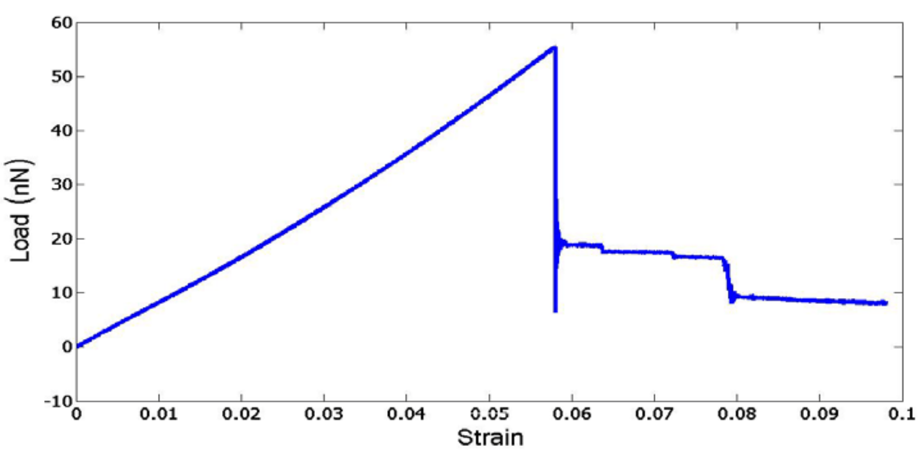

Figure 3.1 Critical buckling load vs Critical Strain

As is seen in the Figure 3.1, the load increases with strain but at a point it fails and there is a sudden drop in load, the strain at this point where it loses its load carrying capacity is called its critical strain and maximum load at this point is called Critical Buckling load. The Carbon Nanotube under goes two modes of buckling, namely column and shell buckling. Critical Buckling load analysis has been carried out for CNT for various diameters ranging from 0.5 nm to 2 nm for various chiral angles of the Carbon Nanotube (0°, 5° & 30°). It is found that the buckling mode depends on its diameter. A transition diameter is 1nm. Carbon nanotubes below 1nm show column buckling and above 1nm show shell buckling which is also shown in Figures 3.2 and 3.3.

In the shell buckling diagram a (16,0) a zigzag Carbon Nanotube, with a diameter of 1.25 nm shows shell buckling at strain of 0.05783 whereas the (7,7) Carbon Nanotube where the diameter is 0.949 shows column buckling at strain of 0.04305.

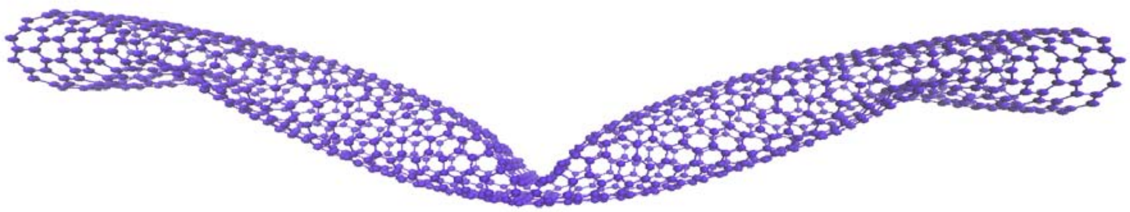

Figure 3.2 Column Buckling of (7,7) Carbon Nanotube

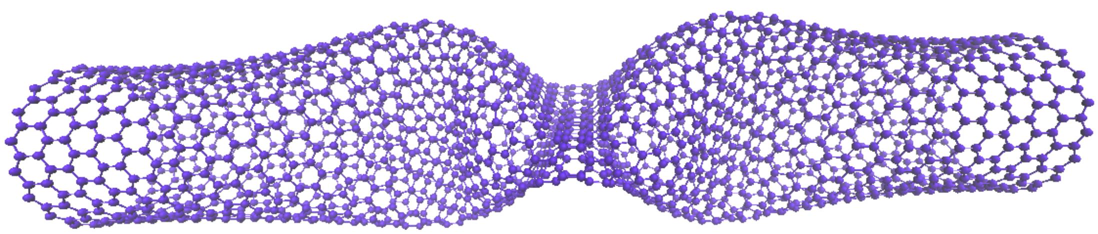

Figure 3.3 Shell Buckling of (16,0) Carbon Nanotube

From this Molecular Dynamic Simulation Study Critical data, it is shown that a single fixed small scaling parameter cannot be used in every condition (chirality and aspect ratio) as it will yield inaccurate results. This MDS data is used to generate the small scaling parameter data for nonlocal continuum theory for nonlocal the Timoshenko Beam model and the Nonlocal Shell model and small scaling parameter data is used to develop empirical relations for nonlocal continuum theory which can be directly used in without selecting any particular small scaling parameter value.

Senthilkumar V and Agrawal A[*]
[*]NIT Calicut

3.4 Symbolic Computation Analysis of One-Dimensional Nanostructures using Open Source Software

There are many commercial computer algebra system software like Mathematica, Matlab, and Maple which are available at high cost. Many non commercial software like Maxima, GiNaC, SymPy, Sage, Axiom are available as open source packages. Here, the structural behaviour of carbon nanostructures are investigated using symbolic computation with open source software Sage-Maxima. This symbolic computing packages gives quick solutions compared with numerical analysis. For larger computations, parallel computation is required to study the mathematical model.

Mathematical models of carbon nanorods and nanotubes are studied by using the open source computer algebra system (CAS) software Maxima. Vibration analysis of nanorods and buckling behaviour of carbon nanotubes are carried out using continuum elasticity modeling. It has been observed that the open source software Maxima is comparable with proprietary software in giving reliable results and the execution time is very small for linear problems. It is difficult to simplify and solve more complex equations by using Maxima. SymPy can be used to solve complex equations but the excecution time has to be compromised with the simple implementation methodology. This can be achieved through the Super Computer facility available in the institute. SAGE and SymPy have been installed in the Super Computer “Cluster Platform 3000 BL460c with 1084 nodes Gen8”. It can be used to solve complex equations and higher order polynomials (order > 200) using SAGE parallel programming.

Senthilkumar V and Penmatsa R[*]
[*]MVJCE Bangalore

4

HIGH PERFORMANCE COMPUTING & CYBER SECURTY

The importance of computation in science is well known. In contemporary research, the capability of a scientific organization is judged by the computational facility it has access to. CSIR-4PI (erstwhile C-MMACS) has been given the responsibility to provide world-class computational facility to the computational scientists and researchers of CSIR to address Grand Challenge problems in their frontier areas of science and engineering. The facility at CSIR-4PI (erstwhile C-MMACS) is one of the fastest in the country and is aimed at providing multiple architectures suitable for domain specific applications. The HPC group at CSIR-4PI (erstwhile C-MMACS) is also involved in research on cyber security, the importance of which can be only realized when computing infrastructure is provided as a centralized service over Internet. Under the 12th five year plan CSIR has sponsored a sub-project "CySeRO" to carryout research in the field of Cryptography and Cyber Security.

Inside

- *Cyber Security Inference through Unsolicited Traffic Analysis*
- *Automation of Security Assurance Process based on PCI-DSS for Cloud Computing*
- *Fully Homomorphic Encryption*
- *Cloud based High Performance Computing and its Security*
- *Method and Device for Categorizing a Stream Control Transmission Protocol (SCTP) Receiver Terminal as a Malicious SCTP Receiver (International Patent, filed on 27.03.2014)*
- *High Performance Computing*

4.1 Cyber Security Inference through Unsolicited Traffic Analysis

Unsolicited traffic continues to occupy a portion of the overall Internet traffic. It was found that during November 2010, about 5.5 Gigabits of unsolicited traffic was generated every second on the Internet. Also, a modem user would lose about 20 bits per second of his bandwidth to the unsolicited traffic. These are typically TCP/IP (Transmission Control Protocol/Internet Protocol) packets addressed to globally routable IP addresses, which are not assigned to any network devices.

Unsolicited network traffic can be used for remote inference of cyber security incidents. For example, one of the major sources of unsolicited traffic is Internet worm propagation. A worm-infected machine, in the process of spreading the worm to other hosts on the Internet, generates unsolicited packets. Likewise, Internet Botnets or Zombies, trigger unsolicited networks as part of network scanning to identify vulnerable hosts on the Internet. Misconfigured hardware, reflections from IP spoofed Denial-of-Service attacks and leaks from private networks are other potential sources of unsolicited traffic. By capturing, analyzing and actively responding to unsolicited traffic, significant insight can be gained to the nature and prevalence of various malicious incidents.

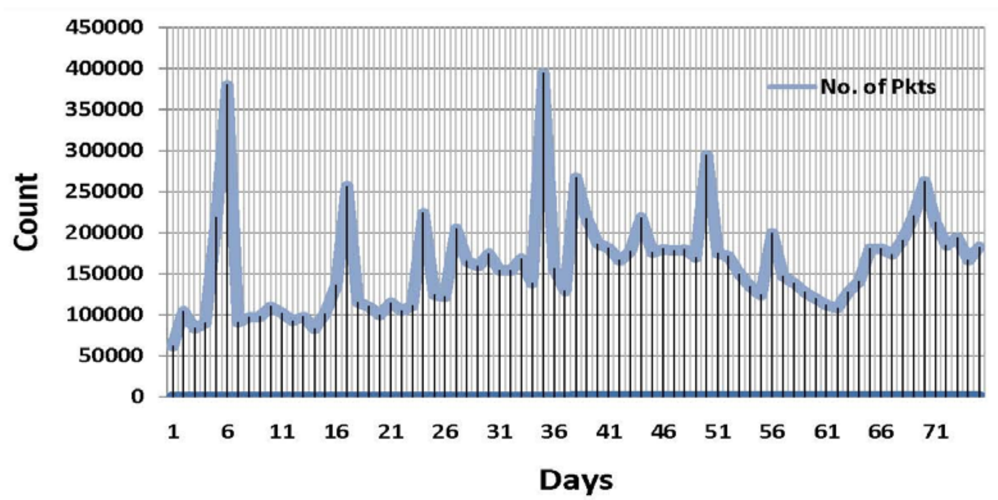

Figure 4.1 Number of unsolicited packets collected at CSIR-4PI (erstwhile C-MMACS) network.

CSIR-4PI (erstwhile C-MMACS) has been focusing on unsolicited network traffic analysis for past several years. In order to strengthen this activity, a comprehensive software framework is being designed and developed to capture and analyze such traffic. Our broad objective is to gain better understanding of the security dynamics on the Internet as whole and regional networks of particular interest to us. The tool is being implemented in python with several modules for various analyses.

The software is capable of identifying different type of network packets and accordingly parsing the packet headers at different layers such as Ethernet, ARP, IP, TCP, UDP, SCTP and other application protocols. Figure 4.1 shows the number of unsolicited packets collected at CSIR-4PI (erstwhile C-MMACS) network during a time span of about 75 days.

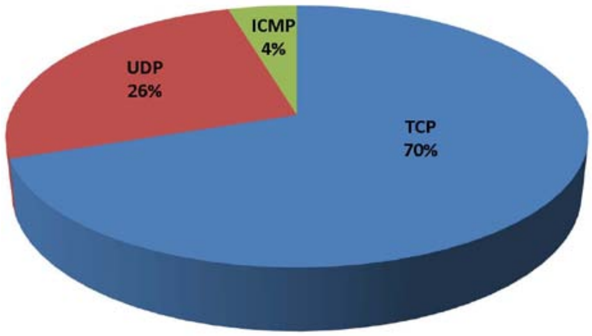

Figure 4.2 Protocol level break-up of unsolicited traffic.

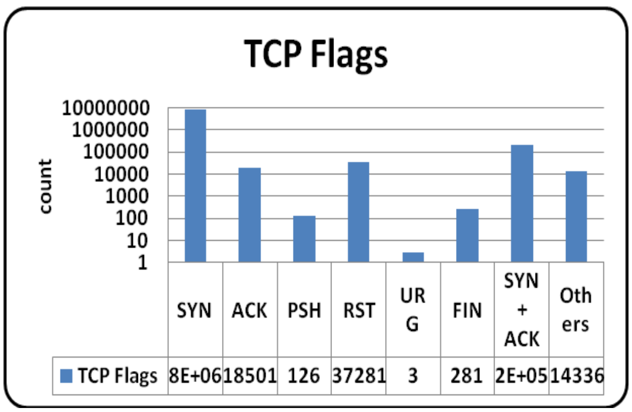

Figure 4.3 Flag-level break-up of TCP packets.

Figure 4.2 provides a protocol level break-up of unsolicited packets. As expected TCP, being the most popular transport layer protocol, accounts for the maximum portion of the unsolicited traffic.

The tool can further penetrate into the minute protocol details. For example, Figure 4.3 provides a flag level break-up of all unsolicited TCP packets received. Majority of them are connection initiation request (SYN packets). This could be either a active port scan or worm propagation attempt over TCP protocol.

Other features are being designed and integrated into the tool. Our immediate focus is on a trend analysis module to automatically generate trends from short and long-term data. Other feature enhancements include parallelizing the code with MPI for faster execution on supercomputer class of machines and development of GUI for data visualization.

*Anil Kumar V, Sudeep Nesakumar S * and Patra G K*
* SPARK (VIT University, Chennai Campus)

4.2 Automation of Security Assurance Process Based on PCI-DSS for Cloud Computing

Security and privacy have always been a challenge and are of primary concern with computing resources, and with the invention of cloud computing the need to secure the data stored in the cloud becomes much more challenging. As the cloud appears to be a black box, the user of the cloud is completely unaware of the security of the data residing in the cloud servers. To address such security concerns, standard organizations have devised a number of guidelines that are needed to be followed by the Cloud Service Providers to ensure secured and reliable services to the users. There are a number of standard security compliance guidelines available and a vendor is expected to comply with at least one of them to assure security if their services need to gain user trust. Some of the standard compliance guidelines are ISO 270001/2, PCI DSS, HIPAA, FedRAMP, SOC 1/ SOC 2/ SOC 3 etc. In this work, we have focused primarily on PCI DSS which is the mostly followed standard for security assurance. PCI DSS stands for Payment Card Interface - Data Security Standard and it was originally developed to enhance and ensure data security for the cardholder users. It is comprised of twelve requirements and any organization that needs to be PCI DSS certified must follow all the twelve guidelines. The certification is obtained by a rigorous auditing process that is carried out by PCI Qualified Security Assessors (QSA). Since the audit process is being carried out manually, there is a huge gap between security requirements and the actual measurements taken to provide the security. Moreover, the audit needs to be carried out after every three months to ensure the service is still according to the guidelines and incorporate any update to the original guidelines. To ease the process, it is best if the whole process can be automated which will reduce the requirement of human intervention making the audit process much faster. In this work we have proposed an automated system for the audit process of PCI DSS. Instead of performing it manually, we install a newly designed dedicated software agent authenticated by PCI Approved Scanning Vendor (ASV). This software agent monitors the CSP's services and notifies the security manager of the CSP if there is some mismatch in their service from the compliance guideline. The software can also be programmed to notify the manager about any changes or modifications made in the original guideline such that the CSP incorporates those changes in their operations.

*Tejas N Rao, Patra G K and Nilotpal Chakraborty**
* Devi Ahilya Vishwavidyalaya, Indore

4.3 Fully Homomorphic Encryption

Computing in an encrypted domain has been an intense area of research for cryptographers and computer scientists for quite a long time now and the scheme that supports such operations is fully homomorphic encryption (FHE). Fully homomorphic encryption provides a third party with the ability to perform simple computations on encrypted data. Typically, a third party can calculate one of the encrypted sums or the encrypted product of two encrypted messages. It can be pictorially represented with the help of figure 4.4.

The concept was originally devised by Rivest et al in 1978 and since then rigorous efforts have been rendered to devise a practical FHE. In 2009, Craig Gentry, an IBM researcher, showed the first plausible construction of fully homomorphic encryption based on the hardness problems of ideal lattices. But eventually, the scheme remained purely theoretical due to its inefficiency, and it cannot be implemented for real life applications.

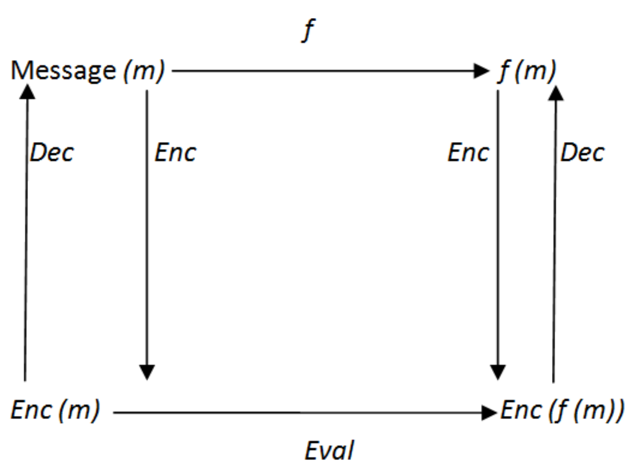

Figure 4.4 Fully Homomorphic Encryption

In this work, our primary focus has been to devise an efficient FHE scheme that would be practical for implementing in the real life scenario. The existing FHE schemes work only bit by bit and due to this they have been inefficient. Our motivation have been to develop the FHE scheme that can take decimal inputs directly, process it, and produce ciphertexts that can be homomorphically evaluated. We started with analyzing the FHE construction as proposed by Van Dijk et. al. and implemented it in C programming language. The scheme at first constructs a somewhat homomorphic encryption that can evaluate polynomials up to a certain limit, after which the decryption does not result in obtaining the actual plain text. To make it fully homomorphic, they followed Gentry's blueprint and suggested to apply the squashing technique. However eventually, we have observed a number of applications where the operations on the ciphertexts are limited and hence we can work with the somewhat homomorphic encryption only. Applications such as image processing, video processing, ASCII character encoding etc. have limited operations, with limited ciphertext space. Thus we can efficiently implement somewhat homomorphic encryption scheme for these applications. We have modified the DGHV scheme to process decimal inputs directly without converting them to their corresponding binary equivalents, thus increasing the efficiency up to a lot of extent as compared to the original scheme. The construction of the modified scheme is shown as follows—

KeyGen: The key is a large prime integer *'p'*.

Encrypt (p,m): Takes an input as a bit m={0,n-1}, and produces the cipher text as $c:=m+nr+pq$, where integers q and r are chosen at random and r is essentially very small than p such that $r<p/2$ in absolute value.

Decrypt (p,c): Takes cipher text c as input and produces the original pain text $m:= (c \bmod p) \bmod n$.

The above scheme works perfectly fine because by removing the p from the ciphertext, we remain with the noise part and the original message. By removing the mask of n, we obtain the original message. This scheme supports homomorphic additions and multiplications till the limit for the noise r is not crossed.

Here, the data can either be decrypted by administration or by Students and Faculty taken together. It cannot be the case that the same data is being accessed both by students/faculty and by the administration section. Functional encryption promises to provide such delegate cryptographic security to the systems using it.

Nilotpal Chakraborty, Patra G K and Anil Kumar V*
* Devi Ahilya Vishwavidyalaya, Indore

4.4 Cloud based High Performance Computing and its Security

In cloud computing, almost all the resources are delivered as a service. It would have been valuable if the same can be incorporated for High Performance Computing (HPC) services. As an HPC system incurs a lot of financial investment as well as manpower needed to run and maintain such systems, it would be very helpful for medium scale enterprises to leverage the benefits of HPC for various scientific and engineering problems in a very cost effective manner if the same can be provided as a service model of cloud computing. In general, supercomputers and HPC systems are used by the scientists for their researches and some limited number of organizations for gaining an upper hand against their competitors and maximizing their profits. By implementing such HPC services through cloud environment, if at all possible, such services can be provisioned for the general public and HPC can be made accessible to a large class of users. As general users, would use it like just another cloud service models, it would free them from the pain of huge investment and tedious maintenance job, as the same would be taken care of by the HPC Cloud Service Provider. The vendors, on the other hand would gain a lot, as now cloud services would not only be used for storage and simple compute operations, it would now be used to perform various important scientific and engineering modeling and simulations including data analytics and data processing in an HPC infrastructure.

It would both be beneficial and challenging for the service providers, as it would increase the number of customers in one hand as well as increase the concerns of security on the other hand. Though various security measurements have been proposed and introduced, only a limited number of techniques have actually succeeded in mitigating all the issues and security challenges. We in our work have proposed to use an advanced cryptographic scheme, called Functional Encryption, which not only allows users to perform computations on encrypted data, but also to provide user specific credentials for encryption/ decryption and operations on the data. The decryption operation in Functional encryption happens as depicted in Figure 4.5.

Functional encryption basically is a public key cryptosystem that provides fine grained access control to the encrypted data. The scheme is based on Fully Homomorphic Encryption which is ultimately the reason behind the possibility of computations on the encrypted information and over to that restricts the user to perform operations based on the public key issued to him.

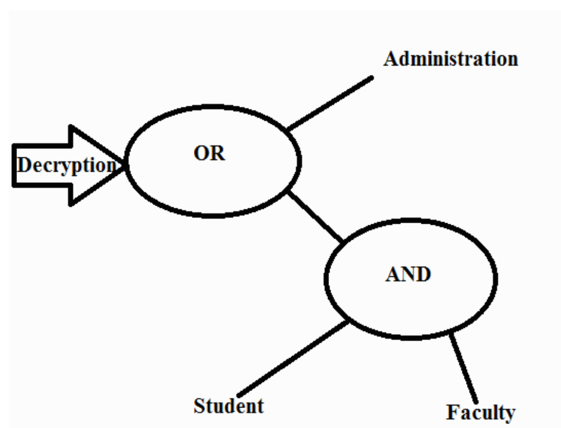

Figure 4.5 Functional Encryption

Functional encryption is a new way towards public key cryptography, where data is not only encrypted and decrypted, we can specify what can be decrypted by whom and what operations can be performed based on the user credential. Such a scheme, if possible to implement, would certainly mitigate, if not all, most of the security problems of cloud computing, high performance computing and big data analytics. As now the owner of the data can decide who can do what and provide specific keys to the users. We have already implemented and tested the use of fully homomorphic encryption for specific applications and further work is being carried out to implement functional encryption. We believe that, such a scheme would be possible to implement in the HPC systems of CSIR Fourth Paradigm Institute and thus the same infrastructure can be provisioned to provide services to greater number of organizations and individuals through the use of cloud computing.

Patra G K, Nilotpal Chakraborty*, Anil Kumar V

* Devi Ahilya Vishwavidyalaya, Indore

4.5 Method and Device for Categorizing a Stream Control Transmission Protocol (SCTP) Receiver Terminal as a Malicious SCTP Receiver (International Patent, filed on 27.03.2014)

The invention provides a novel method and a system to detect and eliminate optimistic Selective Acknowledgement (SACK) spoofing in a Stream Control Transmission Protocol (SCTP) based communication consisting of a SCTP data sender and a SCTP data receiver with an established association. The said optimistic SACK spoofing can be remotely performed either by a malicious SCTP receiver for exploiting a SCTP sender as a flood source for Denial-of-Service (DoS) attacks or by a greedy SCTP receiver for downloading data from a SCTP data sender faster than normal SCTP receivers. The invention consists of a ***data enriched SACK generation** at* the SCTP data receiver side and a ***data enriched SACK validation*** at the SCTP data sender side. The SCTP data sender generates and sends SCTP data packets in the standard header format. The SCTP data receiver generates data enriched SACK packet, which contain a fixed size ***Cumulative Payload Essence*** of application data. Upon receiving a data enriched SACK, the SCTP data sender performs a data enriched SACK validation in which it locally computes the Cumulative Payload Essence using the data packets stored in its retransmission buffer, and compares the locally computed value with the Cumulative Payload Essence received through the data enriched SACK. SACKs whose Cumulative Payload Essences do not match with the locally computed value are marked maliciously spoofed optimistic SACKs even if the Cumulative TSN Ack of SACKs pretends to acknowledge data packets sent by the SCTP data sender. The SCTP data sender discards maliciously spoofed optimistic SACKs and an early termination of SCTP association is performed through SCTP ABORT packet to rescue the data sender from the exploitation.

*Anil Kumar V and Debabrata Das**
* International Institute of Information Technology (IIIT), Bangalore

4.6 High Performance Computing

Computational Scientists of CSIR have been provided with access to one of the largest supercomputing facilities of the country. The supercomputer with a peak computing power of 360TF and a sustained computing capability of 334 TF on a High Performance LINPACK (HPL) is currently the 3rd fastest system in the country and 99th fastest in the world. The supercomputer was released to the CSIR community on 6th September 2013, after extensive testing and optimization to maximize the capability of the system.

Figure 4.6 CSIR centralized 360TF High Performance Computing Facility.

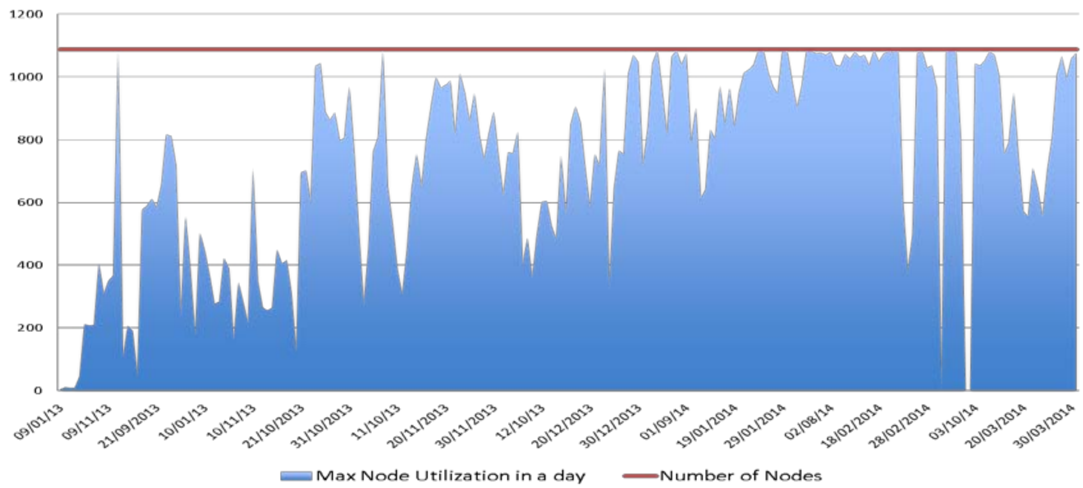

Figure 4.7 Intra-day maximum node used since the 1st September 2013 till 31st March 2014

The system is a cluster of 1088 computing nodes distributed over 17 numbers of 42U 600mm width racks. Each node is a HP Blade server, with two Intel Xeon E-5 2670 (8 cores, Sandy bridge) processors each. Hence, the system has 2176 physical processors and 17408 processing cores. The nodes are connected to each other using high speed FDR infiniband interconnect from Mellenox in a FAT tree topology, which is capable of providing a dedicated 56 Gbps interconnect bandwidth. The high throughput is achieved through a number of 16 port leaf switches in the computing racks connected with two 648-port core switch in a well designed redundancy with respect to availability of all the nodes. The memory per core is one of the important aspects of the system. The memory of about 68TB is distributed across the nodes, and the memory inside a node (48 GB) can be used in a shared memory architecture.

Online Storage, where jobs are run plays an important role in the performance of the system. The system has a high performance parallel file system. The size of the storage is about 2.1 Peta Byte (3 Peta Byte unformatted) capable of providing more than 20 Gbps read and write throughput. This storage is designed using the popular open source LUSTRE file system, with optimized performance tuning. It provides hardware RAID in a RAID6 configuration. The parallel I/O is achieved through 8 numbers of object servers and is controlled through two numbers of redundant meta-data servers.

Figure 4.8 Altix ICE system with 2304 processing cores distributed over 192 nodes and 30 TB of parallel file system along with all associated hardware and software.

The users with large computational requirements have been shifted to this new supercomputer. The maximum nodes used in a day from the date of releasing the computational facility is presented in the Figure 4.7. It is worth noting that, the usage has touched the maximum in many days during the period, indicating the need of scientists for such computational capability. The distribution of computing usage by different CSIR Laboratories is shown in Figure 4.9. This indicates the usage of the system in different fields of computational sciences, such as Biological, Chemical, Engineering, Earth and Atmosphere, Physical and Information Sciences. The system has been used in both capacity and capability mode of computing.

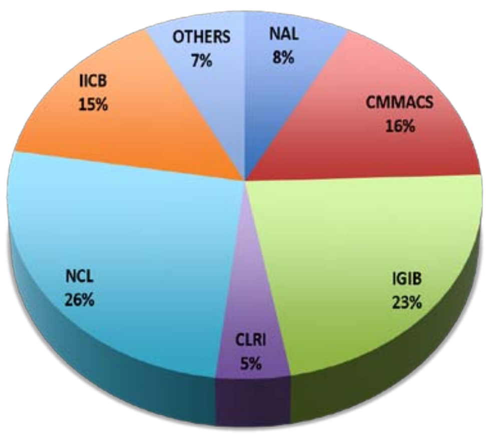

Figure 4.9 Distribution of usage of 360TF system in percentage by Major CSIR labs from 1st September 2013 till 31st March 2014

The computational scientists, who do not have large computational needs still use the Altix ICE cluster (Figure 4.8). The system with 2304 numbers of processing cores distributed over 192 nodes interconnected in the form of an enhanced hypercube using the QDR (32Gbps) infiniband interconnect. The system is equipped with Intel Westmere-EP Hex core processors running at 2.93/3.06 GHz frequencies. Each node has 12 processing cores with 24 GB of memory in a shared memory form, while the system as a whole has 4608 GB of memory across the 192 nodes in a distributed architecture. The peak performance the system is 27 TFLOPS. A lustre parallel file system of 30TB handles the storage requirements for the computing system.

All the computing systems use PBSPro, workload manager, compilers and other essential software to manage smooth transition from one to other. The workload manager ensures the efficient usage of the system and also provides an easy user interaction and submission process.

High Performance archival Storage

While, the working area to run jobs are provided through either a high performance parallel file system or a direct attached scratch file system for better read/write performance, the final storage is done on as archival system using a high performance SAN (Storage Area Network). The archival system is upgraded regularly to support the growing need of data storage. The SAN archival system has four numbers of LTO Gen 5 drives. Currently the virtualized 3-tired storage solution has 6 TB online (FC), 20TB of near-line (SATA) and 520 TB of offline storage. The home areas of all the users are centralized on a Network Attached Storage (NAS) of 200TB. Procurements of additional Tapes and archival facility are under process and likely to be installed by June end.

Data Center

The Tier-3 equivalent state-of-the-art data center along with the associated energy farm has been a constant support for the HPC system. The cooling infrastructure is the highlight of the complete setup. The cooling through water-cooling mechanism using Rear Door Heat Exchangers (RDHX) makes the datacenter, one of the high density datacenters in the country. This cooling infrastructure ensures highly efficient cooling with less power consumption..

The Power Usage Efficiency (PUE) of less that 1.5 is one of the best achieved PUEs. The energy farm consists of two numbers of compact substations of 1.25MVA each and backup power by using three numbers of diesel generators, an underground diesel yard of capacity more than 15000 liters, three numbers of UPS with battery backup etc.

The datacenter is monitored through the building management service. The system, the electrical infrastructure, fire detection and suppression system, very early smoke detection system, water leakage system, CCTV, rodent repellant system is monitored continuously through an integrated building management services. .

Network Facilities

Thanks to the National Knowledge Network (NKN), the accessibility to the centralized computing facility from other CSIR laboratories has been through a reliable and high speed communication medium. Currently the communication speed is 1 Gbps with a backup connectivity of 8 Mbps through ERNET. Scientists and researchers of CSIR-4PI (erstwhile C-MMACS) and CSIR-NAL (all the three campuses) use the facility from their desktops through a high speed local network interconnected using a 10 Gbps backbone. All network services namely DNS (Domain Name Server), NIS (Network Information Services), WWW (World Wide Web), institutional repository, webmail, mail services, Intranet and Internet gateways (both for ERNET and NKN connections) have been provided for efficient communication and data dissemination.

Software Enhancements

Application software were maintained and upgraded to keep pace with hardware enhancements. The heavily used software are ABAQUS, CFD-ACE+, IDL, GAMIT/GLOBK, Tecplot, S-Plus, Hyperworks, Fluent, ANSYS, OpenFOAM etc. However, CSIR 4PI supports the open source movement and most of the open source software generally required for modelling and simulation are made available in the HPC systems. The systems are used extensively for running complex models in the field of ocean, atmosphere, earth and aerospace.

Technical support was provided to a large number of users from CSIR-4PI (erstwhile C-MMACS) & NAL. The team also provided web-hosting facilities for organizing different workshops and conferences during this period. In addition, several students from academic institutions across the country have availed the computing services as part of their academic work at CSIR-4PI (erstwhile C-MMACS) under the SPARK program. Technical advices and consultancies were provided to various institutions within and outside CSIR.

Thangavelu R P, Patra G K, Anil Kumar V, Ashapurna Marndi, Prabhu N, Nagaraju, Mudkavi V Y, Premalatha*,* *National Aerospace Laboratories

5

MULTISCALE MODELING AND SIMULATION

To advance the simulation of weather and climate and climate change projection, General Circulation Models (GCMs) we need to represent atmospheric processes such as multiscale organization of organized convection and aerosol-cloud-radiation feedback.

Under CSIR-4PI (erstwhile C-MMACS) Multiscale Modeling and Simulation Group (MMSG) we seek to develop an ultra-high resolution climate modeling framework to address multiscale processes of the atmosphere and analyze the data from observations and simulations in a data intensive paradigm of research.

Inside

- *Coupled Ocean-Atmosphere General Circulation Model for Climate and Climate Change Studies: Installation, Optimization and Benchmarking*
- *Clouds and Aerosol Radiative Forcing*
- *Physically Based Assessment of Wind Changes over Indian Region under Different Scenarios of Anthropogenic Aerosol Emissions*
- *Aerosol Influence on Interannual Variability of Monsoon Rainfall*
- *Climate Change Impact on Seasonal Cycle and Indian Monsoons in CMIP5 Coupled Model Simulations*
- *Characteristics of Rainfall and Cloud Over the Tropics*
- *Dominant Modes of Vertical Profiles of Atmospheric Latent Heating*
- *Do CMIP5 Simulations of Indian Summer Monsoon Rainfall Differ from those of CMIP3?*
- *Fine Scale Projections of Indian Monsoon Rainfall using Statistical Models*
- *High Resolution Global Climate Change Projection for India: A Data Intensive Paradigm*

5.1 Coupled Ocean-Atmosphere General Circulation Model for Climate and Climate Change Studies: Installation, Optimization and Benchmarking

Ocean-atmosphere interaction and dynamical changes play a crucial role in natural climate variability on a broad range of time scales and in anthropogenic climate change. Thus, the development and continuous improvement of global coupled ocean-atmosphere general circulation model (CGCM) is essential for simulating, understanding, and predicting the global climate system. For example, the essence of Bjerknes (1969)'s postulate still stands as the basis of present day work, that ENSO arises as a self-sustained cycle in which anomalies of SST in the Pacific cause the trade winds to strengthen or slacken, and that this in turn drives the changes in ocean circulation that produce anomalous SST. At the same time, over the Indian domain, local SST-convection relationship is rather poor. These characteristics need to be represented well by a model in order to be useful for climate and climate change studies.

In a typical coupling scheme for an ocean-atmosphere model, the ocean model passes SST to the atmosphere, while the atmosphere passes back heat flux components, freshwater flux, and horizontal momentum fluxes. The numerical coupling interval (over which variables are averaged before being passed) is chosen for computational convenience or to satisfy assumptions of physical parameterizations. The atmospheric response to SST is rapidly redistributed vertically, especially in convective regions, and is nonlocal horizontally on time scales longer than dynamical adjustment times, of the order of a few days to a month. For most purposes, the atmosphere can be assumed to be in statistical equilibrium with given SST boundary conditions on time scales longer than a season. The ocean responds on a wide range of time scales, from days (for some features of the mixed layer) to millenia (for the deep-ocean thermal adjustment). Thus, it is common to characterize the ocean as having the *memory* of the system.

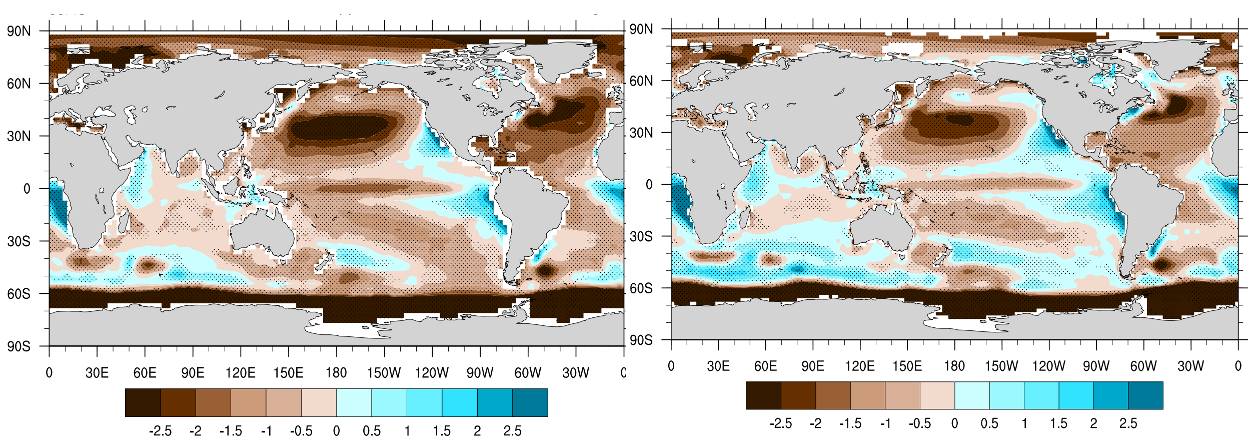

Figure 5.1 Difference between simulated and observed summer mean (June to September, JJAS) SST from multimodel ensemble of IPCC AR4 (left) and AR5 (right) climate models.

Climate bias in models, i.e, departure of the model climatology from the observed, is a common problem in coupled models. For example, the state-of-the-art coupled models participated in 4th and 5th Assessment Reports (AR4 & AR5) of Intergovernmental Panel for Climate Change

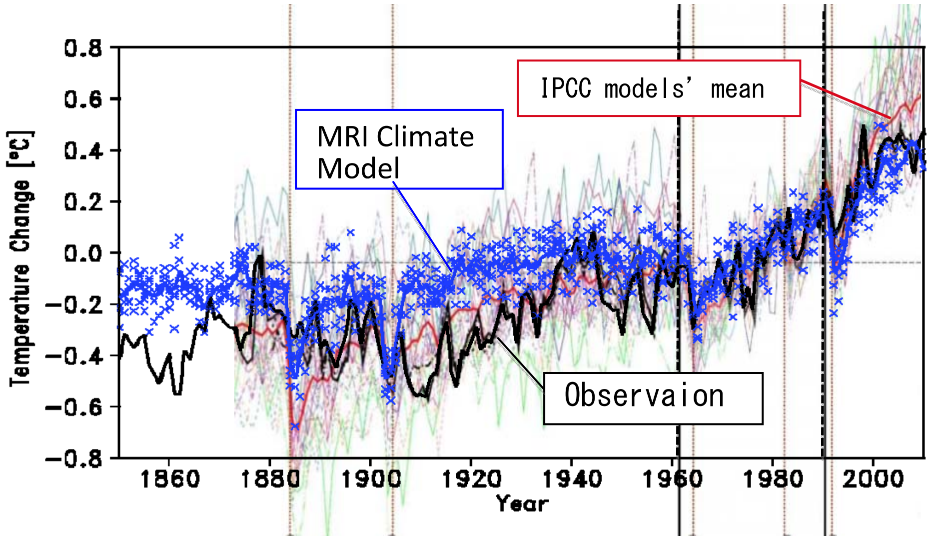

Figure 5.2 Time series of observed and simulated global mean surface air temperature from IPCC AR5 models and MRI climate model ensembles.

(IPCC) show large bias in simulating seasonal mean sea surface temperature (SST) with substantial cold bias evident over a large part of the ocean (Figure 5.1). Most of the models show significant cold bias over northern Pacific and significant warm bias over East Pacific. Further, it was found that the models that show a tendency for warm bias over the Indian Ocean tend to simulate the nonlinear SST-rainfall relationship slightly better. Similarly the time series of global mean surface air temperature change (Figure 5.2) manifests the systematic bias in its simulation from an ensemble simulation of a single climate model as well as from the multimodel mean of all the IPCC AR5 coupled models. The cold bias for a coupled version compared to its atmospheric-alone version results in shifting the mean SST-rainfall relationship to the colder SSTs, as seen in the IPCC AR4 version of a model (Figure 5.3).

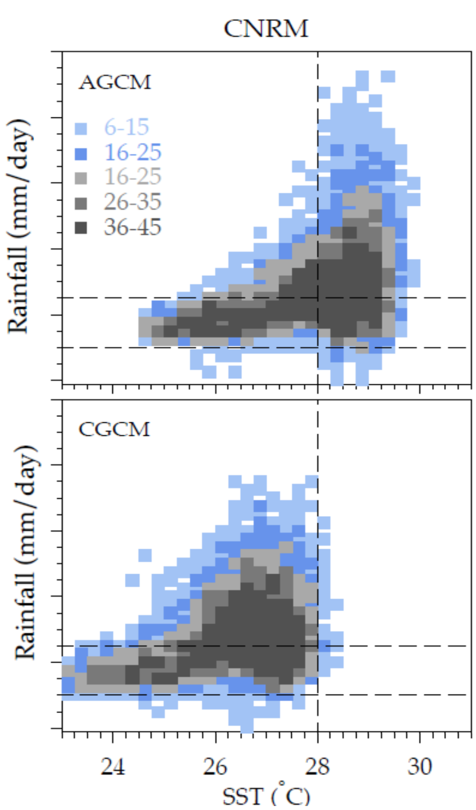

Figure 5.3 SST rainfall relationship simulated by IPCC AR4 CNRM atmosphere-alone (top) and coupled (bottom) GCMs.

Although numerics contribute, climate bias arises primarily from the cumulative effects of errors in the sub-grid parameterizations; as such the process of correcting it based on careful physical arguments can be slow and painstaking. Design specifications in the coupled models for the tropical problem include the use of moderate resolution ocean components to resolve equatorial wave dynamics with characteristic meridional scales of order 0.1°-0.5° latitude. For the global problem, the ocean models typically are used with coarser resolution because of the necessity of very long integrations for equilibration.

For climate applications over tropical regions, the common way to improve the bias is 1) enhanced resolution of individual components, 2) Improved subgrid-scale parameterizations and 3) Increased coupling frequency. We have initiated an in-house collaborative project involving CSIR-4PI (erstwhile C-MMACS), Meteorological Research Institute (MRI), Japan and Divecha Centre for Climate Change (DCCC), Indian Institute of Science (Project R-8-118) to develop a skillful coupled model for climate studies of Indian region. As part of the project a CGCM is installed and test integrations are performed at CSIR-4PI (erstwhile C-MMACS).

Rajendran K, Sajani Surendran
Adachi Y*, Akio Kitoh*, *MRI, Japan
Ravi S Nanjundiah# and Srinivasan J#, #DCCC, IISc

5.2 Clouds and Aerosol Radiative Forcing

The degree to which the aerosol impacts the radiative forcing depends on many factors including non-aerosol properties, e.g., presence of cloud, surface albedo and aerosol single scattering albedo. Aerosol forcing is also influenced notably by the surface albedo and low-level cloudiness. The aerosol radiative forcing is highly impacted by the low level cloud which affects the aerosol direct radiative forcing at the TOA level. For example, previous study of Aerosol simulations show that changes in cloud amount associated with changes in rainfall can strongly limit temperature changes. To examine the perturbations caused by aerosols in the radiative forcing, a set of climate simulations were performed; the control simulation without any aerosol forcing (henceforth referred to as \`NO_AERO') and simulations with three different representations of aerosol direct radiative forcing (1. different species of sulphate, carbonaceous, dust and sea salt, \`ALL_AERO', 2. constant global aerosol simulation, \`BKG_AERO' and 3. constant aerosols over the extended Indian region, prescribed from ISRO's ACE aerosol observations, \`ACE_AERO').

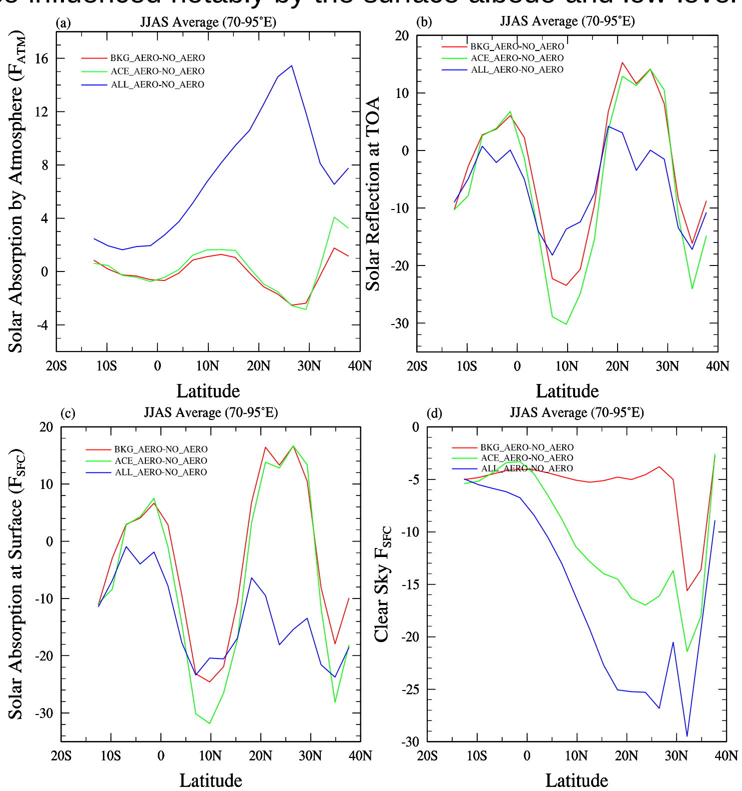

Figure 5.4 Simulated changes in JJAS mean aerosol solar radiative forcing (in Wm^{-2}) over India for BKG_AERO, ACE_AERO and ALL_AERO with respect to NO_AERO; a) solar absorption by the atmosphere, b) solar reflection at top of the Atmosphere (TOA), c) net solar absorption at the surface and d) net solar absorption by the surface under clear-sky condition.

Figure 5.4 shows the boreal summer (JJAS) aerosol solar radiative forcing averaged over Indian longitudes from BKG_AERO, ACE_AERO, and ALL_AERO simulations. Similarly, Figure 5.5 shows the distribution of corresponding changes in JJAS mean total cloud amount due to aerosols. We examine the absorption of shortwave radiation by the atmosphere (F_{ATM}) in Figure 5.4a. We notice that while there is a warming vis-a-vis the control in the ALL_AERO simulation, the other two simulations (BKG_AERO and ACE_AERO) show cooling. The impact of aerosols is seen to be the highest over the northern parts of the subcontinent between 20°N-30°N, a region where the aerosol concentration is the highest. When absorbing aerosols are absent (for example in BKG_AERO and ACE_AERO), this depletion is much less (opposite to that in ALL_AERO) and mainly due to scattering aerosols. F_{ATM} is reduced (gets negative) over regions where there are strong reductions in convection and cloud cover due to scattering aerosols (Figure 5.5). On the contrary, atmospheric absorption is increased over areas where scattering aerosol impact results in increased convection and cloud cover. Expectedly, in ALL_AERO in which absorbing species such as dust and carbonaceous aerosols are prescribed, there are wide spread increases in atmospheric absorption over the whole monsoonal region. In ALL_AERO, atmospheric absorption by aerosols such as carbonaceous and dust particles dominant than that by clouds. However, still the cloudiness is reduced over continental monsoon region.

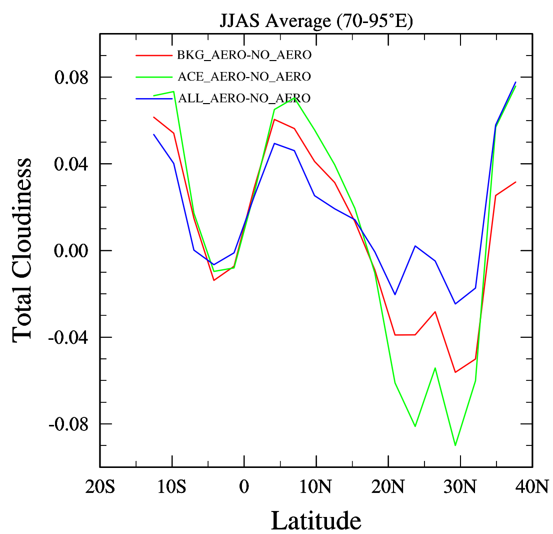

Figure 5.5: Simulated changes in JJAS mean total cloud amount (fraction) over India for BKG_AERO, ACE_AERO and ALL_AERO with respect to NO_AERO.

Summer mean solar reflection at the top of the atmosphere (TOA, F_{TOA}, Figure 5.4b), is mainly controlled by non-absorbing aerosols such as sulphate particles, and cloud-radiation interaction. The distribution of the aerosol reflection differs from that of the absorption, but both aerosol absorption and reflection reduce downward solar insolation, so the net solar absorption by the surface (F_{SFC}, Figure 5.4c) is reduced more than F_{TOA} (Figure 5.4b), especially in ALL_AERO simulation (in which atmospheric absorption is high). But, F_{SFC} under clear sky condition (Figure 5.4d) shows that both absorption of shortwave radiation by the atmosphere and reflection at the top of the atmosphere reduces the solar absorption by the surface uniformly. This also suggests that, in the absence of clouds, the total effect of aerosol radiative forcing is to reduce the incoming solar radiation at the surface. However, in the presence of clouds, the spatial distribution of radiative forcing (Figures 5.4a, b and c) is much more complex with some pockets where the incoming solar radiation is increased. For example, both F_{TOA} and F_{SFC} are increased over the regions such as northern India (north of ~17°N) where there is strong reduction in cloudiness due to aerosols (Figure 5.5). Thus, the aerosol forcing, which includes reflection and absorption, is considerably augmented by the internal climate feedbacks to result in a much more complex spatial distribution than the forcing associated with greenhouse gases which is fairly uniform in space. With all three ways of prescribing aerosols, the simulations tend to reduce the total cloud amount over the continental convective regions. The region with maximum reduction in cloudiness (e.g., north of ~17°N) experiences increased surface solar absorption (Figure 5.4c) associated with weakened atmospheric solar depletion (Figure 5.4a) due to reduced cloudiness. This suggests that the aerosol-climate direct effect itself is highly non-linear because of aerosols feedback into cloud-radiation interaction, particularly over continental monsoon regions.

Low-level clouds reflect solar radiation effectively, and so absorbing aerosols above low cloud have more absorption. Thus, absorbing aerosols above low cloud enhance aerosol forcing, just like absorbing aerosols over reflective surfaces. The difference between low cloud and highly reflective surface is that aerosols can be located below or above low cloud. Our study of absorbing aerosol forcing with respect to low cloud is focused on the contributions of BC aerosols above low clouds to the global burden and to the forcing.

Sajani Surendran

5.3 Physically Based Assessment of Wind Changes over Indian Region under Different Scenarios of Anthropogenic Aerosol Emissions

The climatological response of summer circulation to the direct radiative effects of natural and anthropogenic aerosols is investigated using the Community Atmosphere Model (CAM3) that has comprehensive treatment of the aerosol-radiation interaction, coupled to two different ocean boundary conditions: (1) prescribed climatological sea surface temperatures (SSTs) and (2) an ocean model (CCSM3). As atmospheric general circulation models (GCMs) cannot simulate aerosol loadings directly, we coupled the GCM to a chemical transport model driven by meteorological analysis fields to simulate different species of aerosols. We studied the changes in wind and associated circulation parameters' climatology under different aerosol scenarios (with respect to the control simulation without aerosols (CNTL or NO_AERO)) by analyzing a set of climate simulations with mainly three types of aerosol direct radiative forcing viz. due to (i) total aerosols (ALL_AERO), (ii) scattering aerosols and (iii) absorbing aerosols and doubled amount of anthropogenic absorbing aerosols (DABS_AERO).

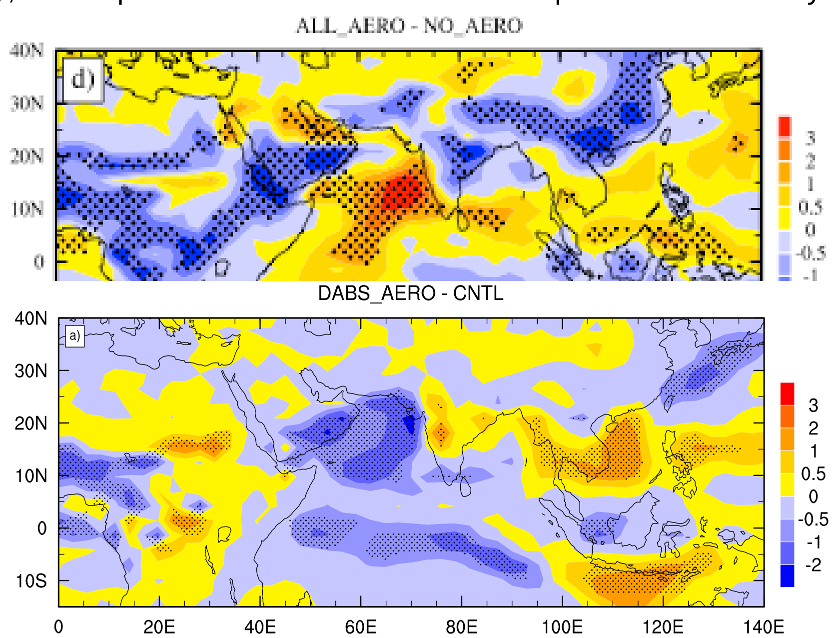

Figure 5.6: JJAS mean precipitation differences (mm day^{-1}) for A) ALL_AERO with respect to that from NO_AERO and B) DABS_AERO with respect to CNTL/NO_AERO. Differences significant at 95% level are stippled.

Aerosol forcing reduces surface solar absorption over the primary convective region of India and reduces the surface and lower tropospheric temperatures. Concurrent warming of the lower atmosphere over the warm oceanic region in the south reduces the land-ocean temperature contrast and thereby weakens the monsoon overturning circulation and the advection of moisture into the landmass. This increases atmospheric convective stability, decreases convection, clouds, precipitation, and associated latent heat release. Our analysis reveals a defining negative moisture-advection feedback that acts as an internal damping mechanism spinning down the regional hydrological cycle and leading to significant circulation changes in response to external radiative forcing perturbations of both scattering aerosols and total aerosols (mixture of scattering and absorbing aerosols).

When total aerosol loading (both absorbing and scattering aerosols) is prescribed, though dust and black carbon aerosols are found to cause significant atmospheric heating over the monsoon region, the aerosol-induced weakening of meridional lower tropospheric temperature gradient (leading to weaker summer monsoon rainfall) more than offsets the atmospheric heating effect of absorbing aerosols, leading to a net decrease of circulation and summer monsoon rainfall (Figure 5.6). Analysis of simulation with doubled anthropogenic aerosols suggests that anthropogenic and natural aerosols significantly affect the circulation but in nearly opposite ways; anthropogenic aerosols tend to have a net local warming effect and strengthening of the circulation and natural aerosols tend to result in net cooling and weakening of cross equatorial monsoon circulation.

*Sajani Surendran and Ravi S Nanjundiah**
*DCCC, IISc

5.4 Aerosol Influence on Interannual Variability of Monsoon Rainfall

The Asian monsoon region is known to have high concentrations of aerosols, which can significantly affect monsoon rainfall through direct and indirect shortwave radiative forcing. Additionally, rainfall variability is also governed by cloud occurrence and microphysics that play important roles in the radiative energy and water cycle balance. Studies suggest that aerosols may influence regional climate and the monsoon water cycle via the interplay of different factors relating shortwave radiative forcing by aerosols through direct and indirect pathways to changes in monsoon rainfall. Previous studies investigated the influence of enhanced anthropogenic aerosol on convective precipitation due to indirect radiative forcing from GCM simulations with a focus on the differences between the experiments with the present-day aerosol emissions (PD) and the pre-industrial aerosol emissions (PI). The model was found to simulate a wide-spread and substantial change in column aerosol concentration due to anthropogenic emissions, which leads to a wide-spread and strong surface cooling. This cooling is mainly due to aerosol absorption. Significant cloud changes via indirect effects are confined to a smaller region in central India, where a strong further surface forcing is exerted in the South West (SW) monsoon season. A signal in precipitation is observed only over central India in the SW monsoon season. This reduction in precipitation mainly stem from convective precipitation. The large surface cooling by the aerosol indirect radiative forcing is responsible for a reduction in precipitation over the central India (Figure 5.7).

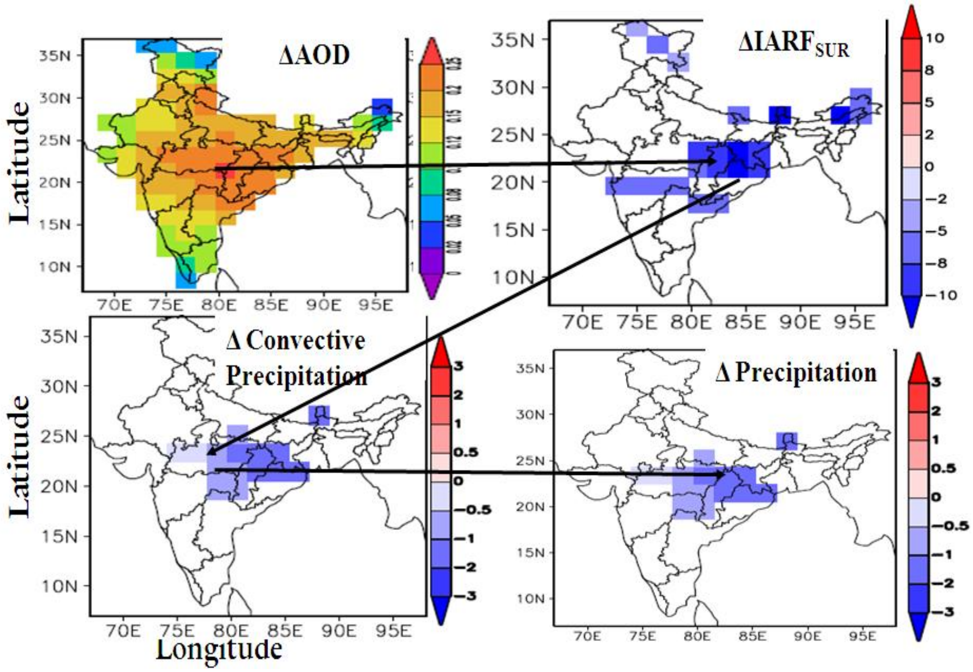

Figure 5.7: Spatial distribution of model simulated seasonal mean changes (Δ=PI–PD) in aerosol optical depth (AOD), convective precipitation (mm/day), indirect aerosol radiative forcing and precipitation due to anthropogenic aerosol emissions over the Indian subcontinent during the monsoon season.

In view of this, an attempt has been made to investigate the interannual variability in aerosol radiative effects over Central India (CI) and Gangetic Plain (GP) regions in monsoon season (June-September, JJAS). This work investigates the contrast between two years with normal and drought monsoon years. The more recent monsoon drought of 2002 caused the lowest rainfall in the historical records during the last 130 years. Much of the rainfall decrease occurred in the core rainy month of July 2002, when the rainfall distribution over the country was nearly 50% below the long-term normal. Similarly 2004 was also a significant drought year with 15% below the long-term normal rainfall.

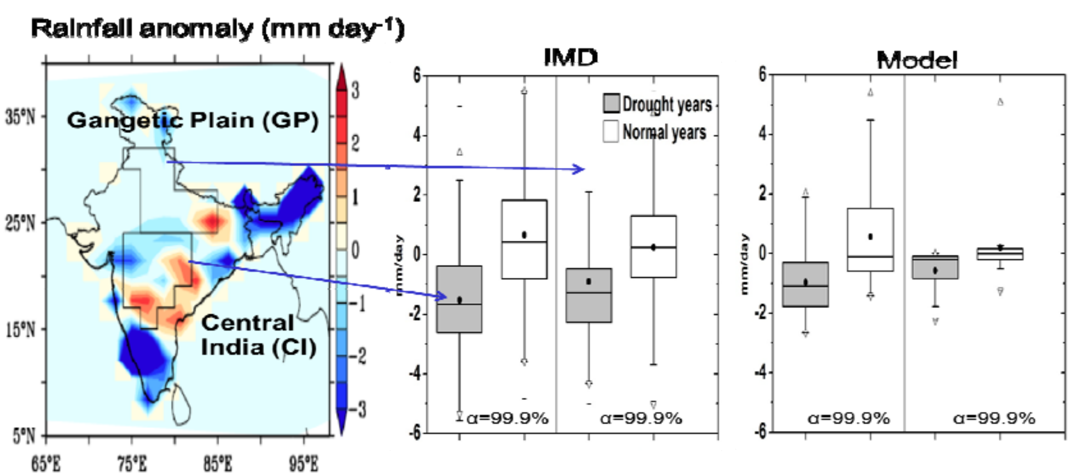

Figure 5.8 Drought-normal monsoon season rainfall over India from simulation (left) and the validation against observation (IMD) of rainfall difference over Central Indian region and Gangetic Plain.

In this study, we performed nudged simulations of a GCM combined with a comprehensive aerosol module. The spatial distribution of seasonal rainfall anomaly in JJAS is calculated for the normal and drought years of Indian summer monsoon to relate the modeled rainfall to atmospheric aerosol parameters, to understand the mechanism behind the impact of aerosol perturbation on rainfall in drought and normal monsoon years and to validate simulated aerosol variables against the observations. The model captures the sign and magnitude of observed rainfall anomalies i.e. negative in drought years and positive in normal monsoon years, over CI and GP regions (Figure 5.8). Behind aerosol influence on monsoon rainfall, two main pathways have been proposed which are the radiation-pathway and the aerosol-cloud-microphysics pathway because these pathways are important in affecting rainfall variability.

Nitin Patil, Chandra Venkataraman* and Sajani Surendran*
*IIT-Bombay

5.5 Climate Change Impact on Seasonal Cycle and Indian Monsoon in CMIP5 Coupled Model Simulations

Future climate change projections for Indian summer monsoon variability and the basic seasonal cycle have been studied using a suite of coupled ocean-atmosphere general circulation models (CGCMs), which had participated in the Coupled Model Intercomparison Project-Phase 5 (CMIP5, IPCC AR5).

Most of the state of the art models project wide spread increase in seasonal and annual rainfall over the Indian region. However, the projected rainfall variability of Indian monsoon rainfall differs among models. Analysis of present-day climatological rainfall simulations over the Indian region shows that while a group of models compare well with observation, another group of models simulate less than 2 mm/day over the core monsoon region of Indian subcontinent. Unlike rainfall, all the models project an increase in surface temperature over the Indian region. Further, the biases in the mean monsoon simulation are found to be related to those in simulating mean seasonal variation of rainfall over the Indian region and mean SST over the Indo-Pacific region.

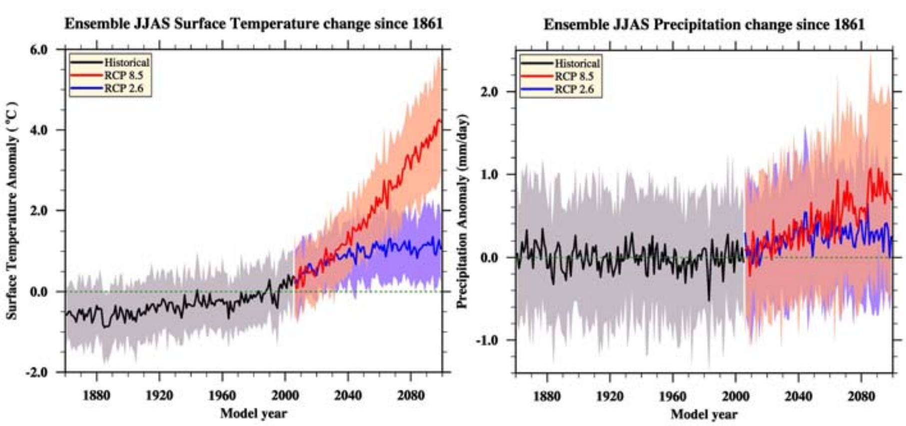

Figure 5.9: Time series of CMIP5 ensemble simulation and projection of JJAS surface temperature and precipitation anomalies.

The disparity among the CMIP5 models in projecting increased change in annual mean rainfall is evident from the large inter-model standard deviation (Figure 5.9). So, as per the projections, in the end of the 21st century there is a clear increase in annual surface temperature with a highly probable tendency for increased mean rainfall.

Indian summer monsoon rainfall exhibits large natural variability, which is strongly related to El Niño. In observation, the variation of summer rainfall with Pacific SST shows strong positive correlation in equatorial Pacific Ocean and negative correlation in the central Indian region. Future projections under different scenarios predict intensification of Indian summer monsoon rainfall over the interior parts of India and weakening of rainfall over parts of the equatorial Indian Ocean, towards the end of the 21st century. The dominant causative mechanisms and the significance of projected changes in Indian summer monsoon rainfall, in the light of SST bias in the present-day simulation, are also addressed.

Jayasankar C B, Rajendran K and Sajani Surendran

5.6 Characteristics of Rainfall and Cloud over the Tropics

Using TRMM 3G68 and infrared data of geostationary satellite, we study the characteristics of rainfall and cloud over the tropics. Many studies have shown that diurnal variation of rainfall is significant over the tropics especially land area. Our analysis demonstrates the semi-diurnal variation of rainfall over the tropics. The semi-diurnal variation was studied in relation to deep convective cloud (DC) defined by infrared data. We construct mean hourly rainfall from 14 years of TRMM 3G68 over the tropics. The data shows both diurnal and semi-diurnal variation of rainfall depending on the location. Semi-diurnal variation is seen over the southern Africa and Amazon region during DJF both in PR and TMI data. Further, the data indicates that afternoon primary peak is dominated by convective rain, while the morning secondary peak is consists of a larger percentage of strati-form rain than convective rain. Brightness temperature (TBB) threshold has been conventionally used to identify (estimate) rainfall. We have employed several TBBs for rainfall that show the existence of only diurnal modes with no semi-diurnal mode over southern Africa and the Amazon region. Here, we inspected mean size and number of DC defined by a TBB of 213K within the area (Figure 5.10). While, mean size of DC indicates clear semi-diurnal mode, the number of DC within the area shows weak semi-diurnal mode. Afternoon primary peak of rainfall coincides with the time when the mean size of

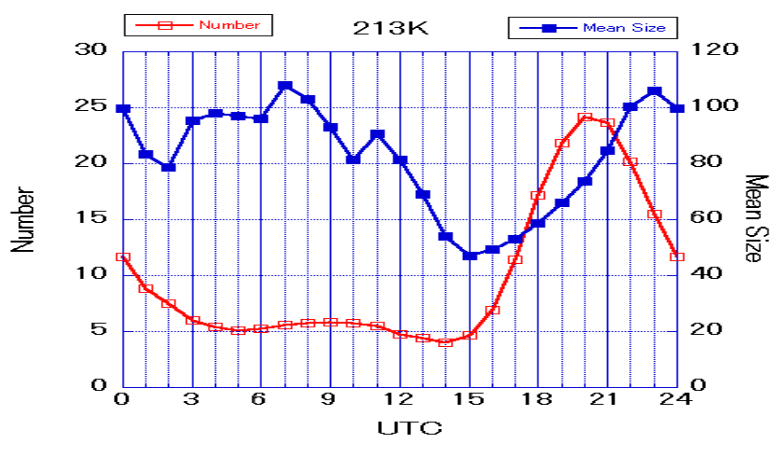

Figure 5.10: Daily variation of number and mean size of OLR from a global cloud resolving model (GCRM) simulation for the Amazon basin.

DC is rapidly increasing with the largest number of DC over the area. This suggests that convective rain is associated with the developing stage of DC. These characteristics of mean size and number of DC are seen over both southern Africa and the Amazon.

Over southern Africa, the morning secondary peak of rainfall coincides with the time of the secondary peak of mean size (almost comparable with primary peak) and number of DC. While the morning secondary peak over the Amazon coincides with the primary peak of mean size of DC with the secondary peak of number of DC. These suggest that the morning peak is associated with larger size of DC that is typical for stratiform rain. Semi-diurnal variation of rainfall is also found over the ocean area along the ITCZ.

Inoue T and Rajendran K*
*University of Tokyo

5.7 Dominant Modes of Vertical Profiles of Atmospheric Latent Heating

The analysis of the basic seasonal and annual mean pattern over different tropical domain clearly suggests that the vertical diabatic heating structure is seasonally dependent and varies from one geographical region to another. To figure out the dominant mode of the vertical profile for modeling application, Empirical Orthogonal Function (EOF) analysis is done for seasonal area averaged heating data over different tropical land and ocean regions (Figure 5.11). The reconstructed profiles show that the first three modes effectively represent mean profile over the tropical domains.

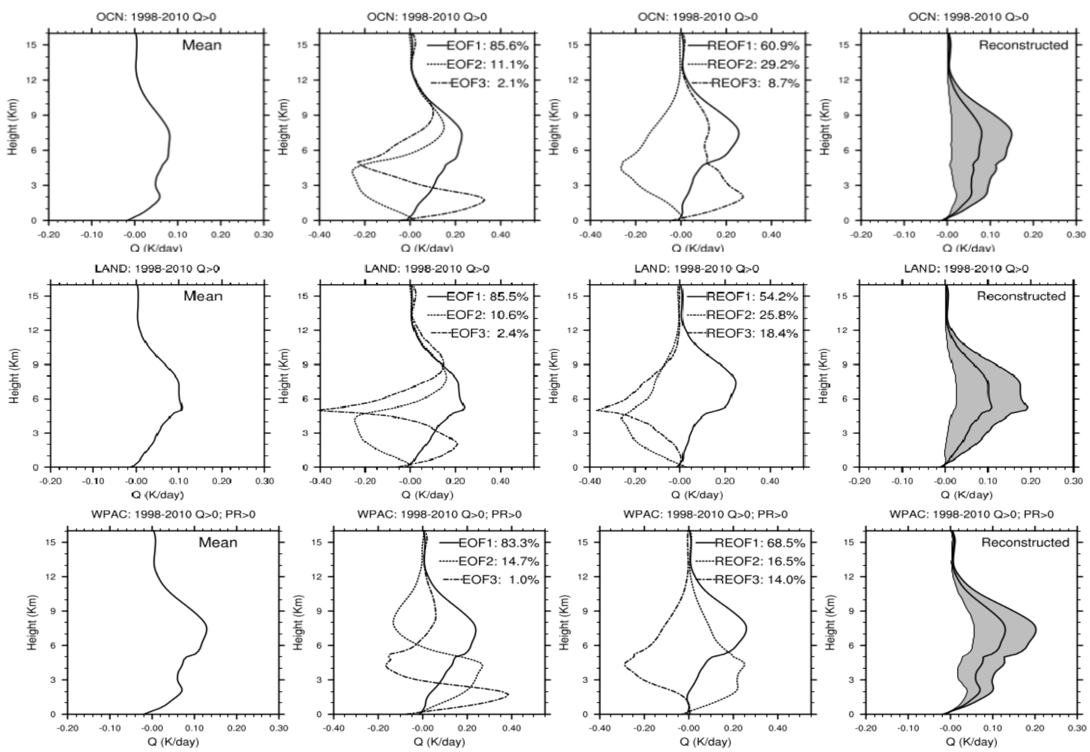

Figure 5.11: The panels (from left) are showing mean, EOF, REOF and reconstructed profile with standard deviation for latent heating for the entire tropical ocean (top), entire tropical land (middle) and for west pacific region (bottom).

To derive the basic moisture profile over the tropics, 15 years of annual mean profiles for total Q_2, convective Q_2, stratiform Q_2, and shallow Q_2 have been analyzed over selected tropical land and ocean domains.

Ipsita Putatunda and Rajendran K

5.8 Do CMIP5 Simulations of Indian Summer Monsoon Rainfall Differ from those of CMIP3?

To understand the improvements in the simulations of Indian Summer Monsoon Rainfall (ISMR) by CMIP5 over CMIP3, a comparative study is performed with the original and statistically downscaled outputs of Five General Circulation Models (GCMs). Original GCM simulations are not bias corrected, while statistical downscaling is performed with bias correction and kernel regression (Figure 5.12).

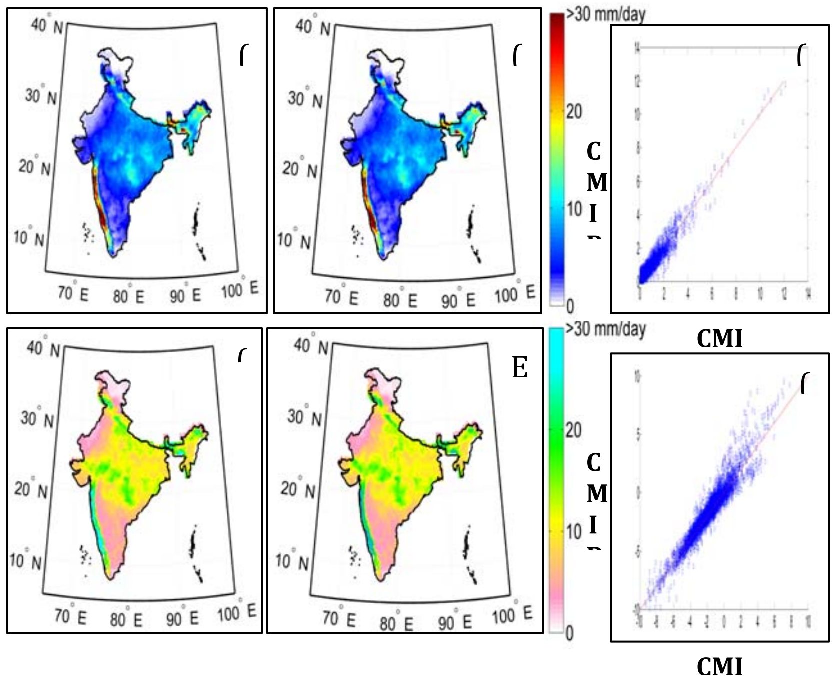

Figure 5.12: Multi-model average of downscaled Indian summer monsoon rainfall. Both CMIP3 and CMIP5 statistically downscaled simulations capture the orographic impacts on the spatial variability of ISMR in mean (a, b) and standard (deviation (d, e) respectively. The scatter plots of errors in mean (c) and standard deviation (f) for CMIP3 vs CMIP5 show no improvements in terms of bias in CMIP5 simulations over CMIP3. However, downscaling reduces the error in the rainfall simulations because of bias correction and kernel regression-based training method with observed data. The predictors used in kernel regression-based statistical downscaling are U wind, V wind, temperature both at surface and 500 hPa, specific humidity at 500 hPa and MSLP.

We observe that multi-model average of original CMIP5 simulations do not show visible improvements in bias, over CMIP3. We also observe that CMIP5 original simulations have more multi-model uncertainty than those of CMIP3. The statistically downscaled simulations show similar results in terms of bias; however, the uncertainty in CMIP5 downscaled rainfall projections is lower than that of CMIP3. Both the downscaled projections show spatially heterogeneous changes, which are not visible in original simulations.

Shashikanth K, Kaustubh Salvi*, Subimal Ghosh* and Rajendran K*
*IIT-Bombay

5.9 Fine Scale Projections of Indian Monsoon Rainfall using Statistical Models

General Circulation models (GCMs) simulate climate variables globally accounting for the effects of green house emission; however, they mostly work in coarse resolutions and hence their performances for simulations of precipitation are not always reliable. To overcome this limitation we are using statistical techniques as downscaling methods for projecting precipitation as finer resolution (25 km grid approximately, 0.22° latitude x 0.22° longitude). Here we use conventional statistical downscaling where the relationship between predictor climate variables (other than precipitation) and precipitation are determined and then applied to GCM output for projections of precipitation. Kernel regression is used for developing the statistical relationship. The results are compared with interpolated, quantile based bias corrected GCM simulated precipitation output. Both the methodologies are applied to CMIP3 and CMIP5 simulations and the multi-model averaged (MMA) results are compared.

We first evaluate the 20C3M simulations with the observed data, and we find that conventionally downscaled MMA simulations of CMIP5 do not show significant improvements over those of CMIP3, which suggests that there is no significant change in predictor simulations by the CMIP5 GCMs over those of CMIP3. However, when we do the same exercise with bias correction, we find bias corrected CMIP5 simulations are significantly improved. This shows that simulation of precipitation in Indian region for observed period has been improved with CMIP5 models.

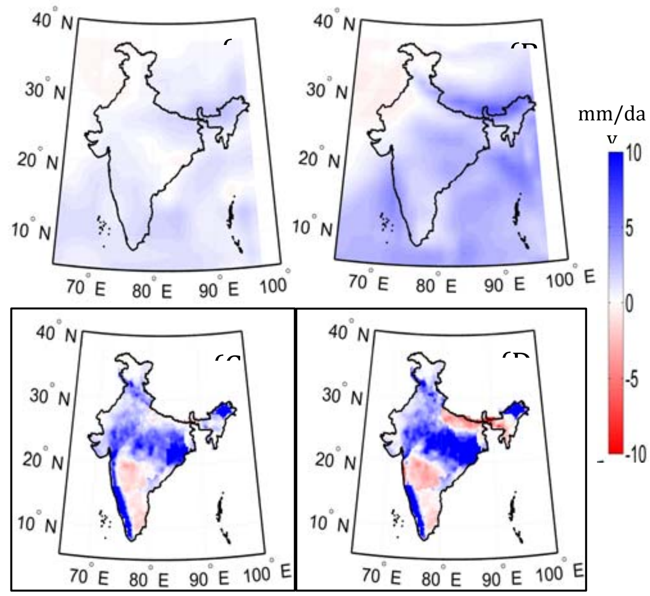

Figure 5.13: A) Raw difference between future–present from CMIP3 mean B) raw difference between future–present from CMIP5 mean C) downscaled difference between future–present from CMIP3 mean D) downscaled difference between future–present from CMIP5 mean.

After validation, both the models are applied for future projections. It is observed that, though bias corrected models perform well for observed period, they simulate spatially uniform changes of precipitation in the entire country (Figure 5.13). The conventional downscaling method, involving predictors other than precipitation, simulates non-uniform changes for future, which is similar to the trend of last 50 years of Indian precipitation pattern. The reason behind the failure of bias corrected model in projecting spatially non-uniform precipitation is the inability of the GCMs in modeling finer scale geophysical processes in changed conditions. The results highlight the need to revisit the bias correction methods for future projections and to incorporate finer scale processes.

Shashikanth K, Subimal Ghosh* and Rajendran K*

*IIT Bombay

5.10 High Resolution Global Climate Change Projection for India: A Data Intensive Paradigm

Global warming will precariously affect agricultural production and the livelihood of farmers by unpredictably changing the abundance of rainfall and extreme events, which exhibits strong variation of rainfall. Hydro-power generation and water availability are some of the other concerns that depend on rainfall variation. Thus, identification of recent climate trends and projection of future climate change are crucial for agro-economic states. As we build strong observational networks and monitor climate indicators, parallel efforts in dynamical modeling should also be practiced. Since, the special nature of the geographical orientation of the country with low altitude coast lines and highly elevated mountains at the north, numerical models employed for projections should have sufficiently high spatial resolution to resolve these details. An ultra-high resolution global general circulation model (GCM) at 20-km resolution is used to investigate the future projection of climate change patterns for India. Deriving inferences by analyzing 4-dimensional multivariable global dataset at ultra-high resolution of 20-km and century time scale for climate change projections is highly data intensive and requires high performance computing with huge memory, visualization and storage. The results of high-resolution projections aim to fill the current knowledge gap about future climate change effects by a large extent.

The projections are determined through time-slice integrations of the model, which has shown marked fidelity in representing the present-day climate of India in all seasons especially the mean summer monsoon rainfall over India. Projected future scenarios show coherent and significant enhancement in summer rainfall over most parts of India along with significant reduction in rainfall along the southern parts of the Western Ghats (Figure 5.14). For example, the model predicts wide spread but spatially varying increase in rainfall which are significant compared to the seasonal mean rainfall over many states, in particular over the interior regions of Peninsular, West Central, Central Northeast and Northeast India (~5-20% of seasonal mean). However, over the southern west coast of India (~10-15%), and some parts of Northwest India and Jammu-Kashmir (~5-10%), future reduction in rainfall is projected by the model. Over the Western Ghats, the drastic reduction of wind by steep orography predominates over the moisture build-up effect (that causes enhanced rainfall under a warmer environment), in reducing the rainfall over the southern west coast. Over this region, faster rate of increase of temperature at higher levels as compared to lower levels (upper-tropospheric warming effect)

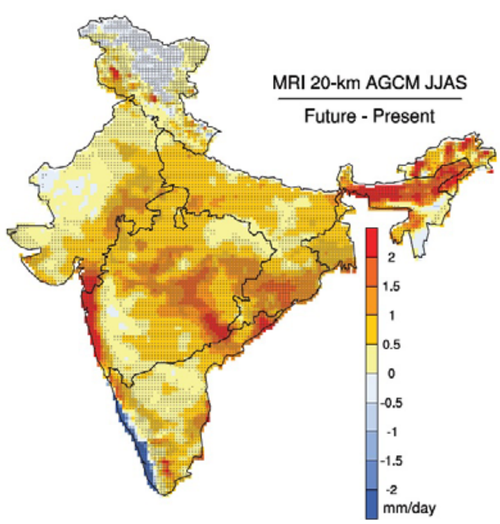

Figure 5.14: JJAS mean difference in rainfall between future projection and present-day simulation of the 20-km model over India. Within each colour the gradient in hue corresponds to changes as percentage of mean summer monsoon rainfall (< 5%: no symbol, 5-15%: dots, 15-25%: open circle and >25%: plus)

leads to increased dry static energy and vertical gross moist static stability which in turn weakens the vertical ascent, large-scale monsoon circulation and thereby rainfall.

The projections for the states of Kerala and Karnataka (Figure 5.15a) show reduction in future monsoon rainfall especially over the western coast. In addition, there is large spatial heterogeneity within state-level. For example, for the state of Maharashtra, there is significant quantitative variation in the projected climate change (Figure 5.15b). So far, IPCC future scenarios for the Indian summer monsoon rainfall even using high-resolution regional climate models have projected relatively uniform climate change over the whole country. Over the windward side of the west coast, the projected changes indicate significant weakening of rainfall in future. In the leeward side, marked increase in future rainfall is predicted by the model. These projected changes are qualitatively similar to the recent trends observed over this region. Another notable aspect is the opposite future change projected by the model in the northern parts of the Western Ghats along the west coast of Maharashtra compared to the coasts of Kerala and Karnataka (Figure 5.15).

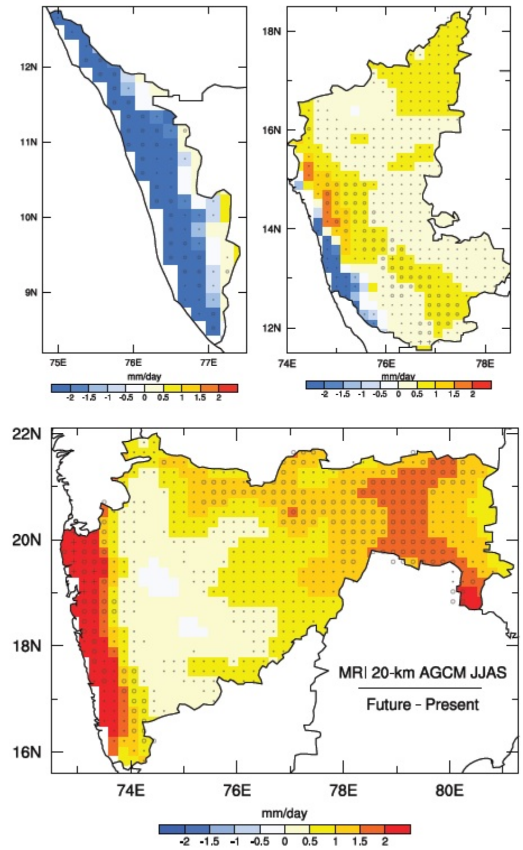

Figure 5.15: a) Projected change in future rainfall over the states of Kerala and Karnataka (upper panels) and b) for the state of Maharashtra (lower panel).

The pattern of changes in the frequency of intense precipitation events in monsoon season is similar to those of seasonal mean precipitation. Further, the model projects increased (decreased) occurrence of extreme rainfall events over interior parts of India (the southern Western Ghats). Over the southern west coast, the number of extreme rainfall events will be reduced due to climate change. The pattern of future precipitation change for summer monsoon season (Figure 5.14) suggests a weakening of the orographic rain over the states, due in large part to the changes in the intense precipitation regime. These results warrant the necessity for undertaking impact studies of such scenarios for accurate assessment of local and regional-scale vulnerability to climate change. Moreover, these outcomes are useful for state-specific climate change risk assessments, adaptation planning, improving their climate management strategies, and for providing information to policy makers.

*Rajendran K, Sajani Surendran and Kitoh A**

*MRI, Japan

6
SOLID EARTH MODELLING PROGRAMME

Solid Earth Modelling group research activities are multidisciplinary (Engineering and Earth Sciences) and multi-component (GNSS Geodesy, computational seismology, geology, geophysics, physics and modelling). The major focus of the group is data analysis and modelling to gain significant insights in to sub-surface process in the earth's crust. During the year 2013-2014 group has contributed to GNSS based deformation modelling along the 2500 Km Himalayan arc from Ladakh Himalaya in the west to Arunachal Himalaya in the east, Slip models for 2004 Sumatra-Andaman rupture, establishment of real-time data telemetry VSAT's for Andaman GNSS Network, GPS measurements for landslide deformation monitoring, GPS observations south of Palghat-Cavery shear zone to study the zonal variability of tectonic co-seismic deformation, seasonal perturbations in Inter-seismic deformation of North-East India. In the field of tectonic-geomorphology, research focus was on Nahan Salient of Western Indian Sub-Himalaya and drivers of drainage growth in an actively uplifting area. In computational seismology the group had majorly contributed to seismic hazard studies in Indian subcontinent as a whole as well as specific seismic hazard assessment in Himalayas, Gujarat and peninsular India. During this year, we have initiated seismic broad band experiment in Kashmir Himalayas, studied crustal structure of Dharwar region along E-W corridor and estimated the source process of the Sikkim earthquake (18th September 2011), In addition we have used finite element method to gain significant insights in to wave propagation and deformation in different medium.

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- *Seismotectonic implications of strike–slip earthquakes in the Darjiling–Sikkim Himalaya*

- *Contemporary Deformation in the Kashmir-Himachal, Garhwal and Kumaon Himalaya: Significant insights from 1995-2008 GPS time series*
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- *2004 M 9.3 Sumatra-Andaman Rupture Extent and Slip Distribution, and its Implications on the Regional Tectonics.*
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- *Source Process of the Sikkim Earthquake 18th September, 2011, Inferred from Tele-seismic Body-wave Inversion.*

6.1 Inverse Modelling of GPS-derived Present Day Active Deformation in Ladakh Himalaya by CSIR-4PI (erstwhile C-MMACS) Scientists

Inverse modeling GPS derived deformation rates over an eleven year period indicate low slip rate of Karakoram fault suggesting that the motion of Tibet does not confirm to plate-like motion which would result in rapid strike slip motion along the Karakoram fault. Instead, large-scale tectonics in Tibet is best described as deformation of a continuous medium where the slip rates on the strike slip faults differ little from those on normal and thrust faults, and all faults constitute passive markers of discontinuities in the strain field that translate and rotate with a deforming continuum.

Sridevi Jade

6.2 Global Navigation Satellite Systems (GNSS) and Earthquake Hazard

GNSS geodetic studies over two decades have given precise and accurate quantitative estimates on the persistent northeastward motion of the Indian plate with the plate-tectonic velocities varying from 5.94 cm/yr at Maldives in the south to 3.18 cm/yr at Leh, located in Ladakh Himalaya. This considerable reduction in velocity of ~3 cm/yr is largely being accommodated in the plate boundary zone where Indian plate thrusts beneath the Eurasian plate. This change in velocity i.e. baseline shortening between two sites causes high stress buildup and strain accumulation along the plate boundary regions which in intermittently released as earthquakes.

Sridevi Jade

6.3 Seismotectonic Implications of Strike–slip Earthquakes in the Darjiling–Sikkim Himalaya

The 18 September 2011 (*Mw* 6.9) strike–slip event suggests that the Darjiling Sikkim Himalaya (DSH) is likely to contain an active transverse strike–slip faulting. High-precision Global Positioning System measurements (1997–2006) indicate that a maximum of ~4 mm/year convergence is being accommodated in this region and DSH is locked south of 27ºN both east and west of GTF (Gish Transverse Fault) about 10 km north of the Himalayan mountain front. About 3–4 mm/year sinistral strike–slip is postulated on GTF north of 27ºN.

Dislocation based forward modelling using two thrust dislocations with oblique slip and a sinistral strike–slip dislocation generated velocities that were closest to the measured back-slip velocity field in DSH. Given all this, the role of transverse zones in Himalayan deformation may be significant and must be therefore studied and better understood. These observations suggest that a fresh look at our ideas on the Himalayan deformation is required as it appears to be more complex than visualized by the current models.

Malay Mukul, Sridevi Jade, Kutubuddin A, Matin A

6.4 Contemporary Deformation in the Kashmir-Himachal, Garhwal and Kumaon Himalaya: Significant Insights from 1995-2008 GPS time series

Time-averaged (1995-2008) GPS derived surface velocities, convergence and extension rates along arc-normal transects in Kumaon, Garhwal and Kashmir-Himachal regions in the Indian Himalaya indicate that this region is accommodating ~ 2 cm/yr of the India-Eurasia plate motion (~4 cm/yr). The total arc-normal shortening of the northwest Himalayan wedge varies between ~10 -14mm/yr which is being accommodated differentially along the arc-normal transects; ~5-10 mm/yr in Lesser Himalaya and 3-4 mm/yr in Higher Himalaya. Most of the convergence in the Lesser Himalaya of Garhwal and Kumaon is being accommodated just south of the MCT (Main Central Thrust) fault trace, indicating high strain accumulation in this region which is also consistent with the high seismic activity in this region. Also for the first time an arc-normal extension has also been observed in the Tethyan Himalaya of Kumaon. In addition the results also gave an estimate of co-seismic and post-seismic motion associated with the 1999 Chamoli earthquake which is modeled to derive the slip and geometry of the rupture plane.

Sridevi Jade, Malay Mukul, Gaur V K, Kumar K, Shrungeshwar T S, Satyal G S, Dumka R K, Jagannathan S, Ananda M B, Dileep Kumar P, Banerjee S

6.5 Seasonal Perturbations in Inter-seismic Deformation of North-East India

GPS time series is a manifestation of long term plate motion along with contribution from some non-tectonic forcing. The non-tectonic forces causing deformation of the crust are, to say a few, ocean and body tides of the Earth, interhemispheirc exchange of fluids, snow melt, groundwater runoff, Glacial Isostatic adjustment, atmospheric loading, etc. The Earth as a whole responds to external forces as an elastic body. As was shown by Darwin in 1882, changes of the weight of the atmospheric column due to variations of pressure result in “distortion of the upper strata of the Earth” [i.e. deformation of the crust] called atmospheric pressure loading [http://gemini.gsfc.nasa.gov/aplo/]. The magnitude of the effect can be up to 15-20mm and it can

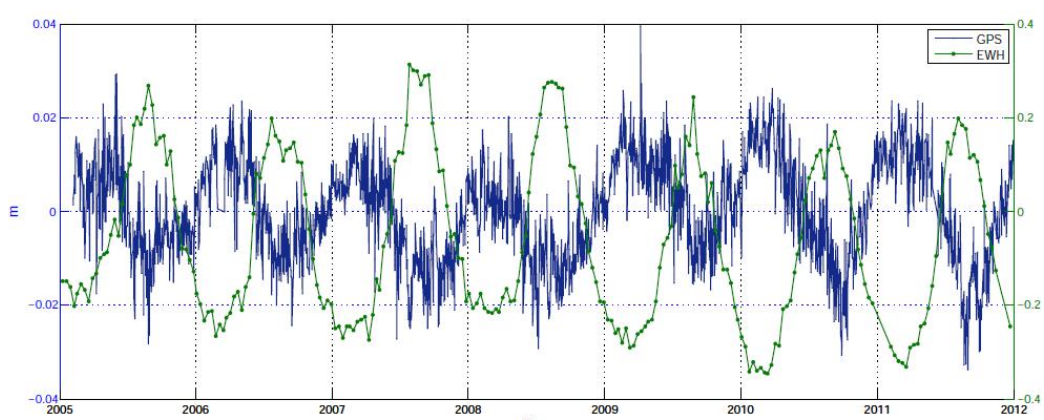

Figure 6.1 Comparison of GPS vertical time series of Tezpur and GRACE derived equivalent water thickness

vary as much as 10mm within a 24 hour period. As a result, this physical phenomenon affects the coordinates of geodetic sites (VLBI, GPS, SLR, DORIS etc) and should be accounted for in all high precision geodetic analyses. On the other hand, the solid Earth crust also deforms due to the largest mass movement on the solid earth through global hydrological cycle, the exchange of water between ocean, land, and ice sheets. We have studied the hydrological loading and its effect on crust in North Eastern India using GPS and GRACE (figure 6.1). The deformation reaches up to ~10-20mm in vertical whereas ~2-3mm in horizontal components. In addition, power spectral analysis of GPS time series is opted to find out the frequency of perturbations and seasonality in the time series. Power spectral densities demonstrate that colored noise is mostly abundant in the lower frequency domains whereas at higher frequencies the spectrum mostly corresponds to white noise (figure 6.2). The spectral index of most components are within $-1<\alpha<1$ and suggest a dominance of fractal white noise in the time series. Autocorrelation studies also favoring the presence of white noise by showing highest peak at $i\Delta t=0$. In order to investigate the seasonality, time series is decomposed to find its trend and the seasonal signal has been extracted from the power spectrum. The power spectrum of every component (North, East and Up) shows its biggest peak at 0.73cycles/year and next prominent peak is found at 2.15cycles/year at one of the stations. This assessment of deformation associated with non-tectonic forcing, like atmospheric loading, along with tectonics is vital since it not only affects the earthquake nucleation process and stress build up in the crust but also effectively alters the drainage pattern which is the lifeline of the North-Eastern India.

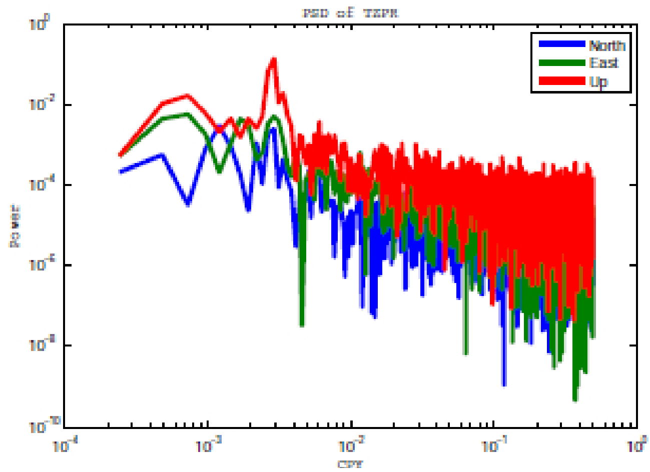

Figure 6.2 Power spectra of Tezpur GPS time series

Jagat Dwipendra Ray[1], Vijayan M S M and Ashok Kumar[1]
[1]Tezpur University, Tezpur

6.6 GPS Geodetic Observations in Southern Peninsular India to study the Pre, Co & Post Seismic Deformations Associated with 2012 M8.6 Indian Ocean Strike Slip Earthquakes

On 11th April 2012 a strike-slip earthquake of magnitude M8.6 – 13th strongest earthquake since 1900 as well as strongest strike slip earthquake ever recorded in human history – struck the Indian ocean basin west of Sumatra-Andaman subduction zone with an unprecedented after shock of magnitude M8.2 within two hours. The earthquake occurred at Indo-Australian diffused tectonic boundary and it was felt in Indian, Australian as well as Sunda plates. From the magnitude, nature and location it was attributed to a rare event associated with major plate boundary process of tectonic scale which may happen once in million years. A GPS geodetic

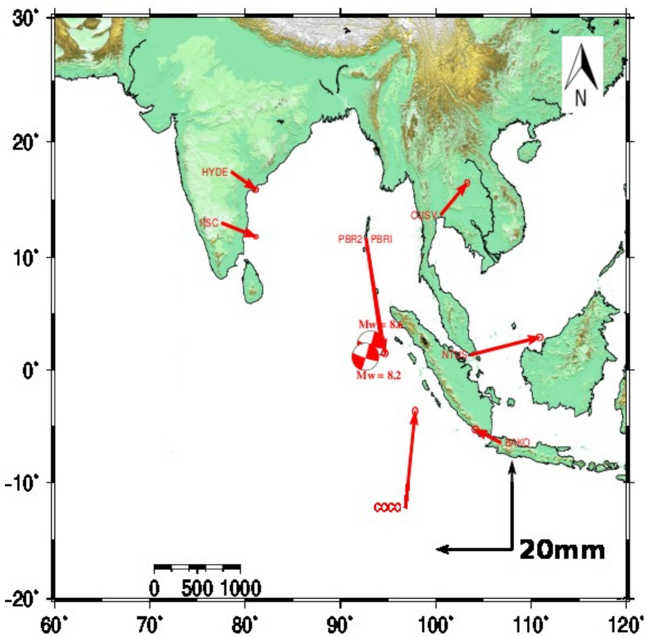

Figure 6.3 Map Showing the co-seismic displacement at IGS stations associated with 11th April 2012 Indian Ocean strike slip earthquakes

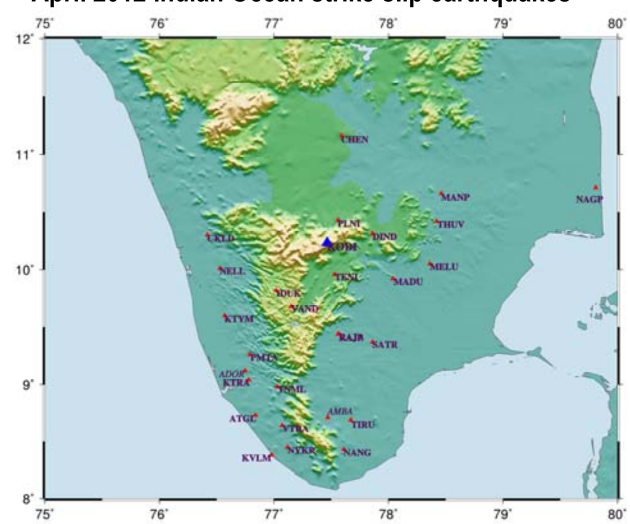

Figure 6.4 Map showing the campaign stations of southern peninsular India where GPS geodetic observations were carried out.

investigation was carried out using IGS station observations to study the impact of such a strongest and rare earthquake on the deformation of the crust.

Co-seismic deformation associated with the strongest earthquakes were estimated using the observations from IGS stations situated in Australian plate, Indian plate, African plate, Philipine plate and Andaman micro plate. The results of this preliminary study show the large scale deformation at sites situated in different tectonic plates as far as thousands of kilometers away from the epicenter (figure 6.3). Indian sites in peninsular India has displaced from 7.7 to 9.6 mm towards SSE direction. In order to further refine the co and post-seismic deformation pattern across the faults, lineaments and shear zones of Southern peninsular India associated with such strongest earthquakes, GPS based geodetic observation campaign was carried out from September to October 2013.

The GPS based geodetic observations were carried out at 31 stations south of Palghat-Cavery shear zone for the period of 3 continuous days at each station (figure 6.4). The observations will be useful to study the zonal variability of tectonic co-seismic deformation in this region in addition to the deformation across the Achan-Kovil shear zone.

Vijayan M S M, Simon Justin, Shrungesh T S and Anil Earnest

6.7 Establishment of Continuous Mode GPS station and Landslide Observation using GPS Geodetic Observations

A new study has taken up as part of the 12th FYP EDMISSIBLE to study the landslides using GPS based observations in collaboration with CSIR CBRI, Roorkee. Two landslides has been

Figure 6.5 GPS observation points in the two selected landslides in Chamoli districts of Uttarakhand

Figure 6.6 Continuous mode GPS geodetic observation facility at CSIR CBRI, Roorkee established by CSIR-4PI (ERSTWHILE C-MMACS). Insert shows (left) the web interface and (right) the instrument setup.

identified by CSIR CBRI in Chamoli district of Uttarakhand (Figure 6.5). *CSIR-4PI* (erstwhile C-MMACS*)* and CSIR CBRI has carried out first GPS based geodetic survey at various points on the landslides to study the stability. Prior to the campaign mode observation, a continuous mode GPS geodetic observation facility has been established at CSIR CBRI, Roorke and a real-time data stream has been established with CSIR-4PI (erstwhile C-MMACS) and CSIR CBRI for continuous monitoring (Figure 6.6). These observations will be used along with consecutive campaigns in the forthcoming years to study the landslides.

Vijayan M S M, Shrungesh T S, Sarkar S, Kanungo D P*, Amit Rana1 and AnilMaleta**
*CSIR CBRI, Roorkee

6.8 Absence of Intermontane Valleys in the Nahan Salient of Western Indian Sub-Himalaya

Direct evidence of faulting along the Himalayan mountain front is very rare. The most conspicuous indicators for the presence of a structural discontinuity and an active tectonic boundary are manifested in the geomorphology. In most of the cases, a topographic break defines the outermost Himalayan thrust fault i.e. Himalayan Frontal Thrust (HFT). However, the nature of this tectono-geomorohic boundary tends to vary significantly along the strike of the mountain belt. In some sectors, it is marked by the presence of elongated intermontane valleys popularly known as 'duns', whereas other sectors are conspicuous by their absence. The Nahan sector of the Western Indian Himalaya is one such area that is characterized by the absence of intermontane valley. Here, in this article we emphasize that the absence of intermontane valleys in the Nahan sector gives rise to a distinctive geomorphic expression of the active tectonic boundary. In the Nahan sector, active slip along the underlying thrust faults and splays has resulted in the accumulation of high relief spread over a relatively smaller area. This led to the absence of the duns in this area. Also, the topographic boundary closely corresponds to a number of drainage anomalies establishing the active tectonic nature of the HFT. The drainage anomalies mainly include the deflection of streams, widening of channels and increase in their sinuosity as they approach the mountain front. The increase in the sinuosity of the channels is also marked by degradation activity and presence of broad flat terrace surface that confirm to the tectonic uplift in this area.

Figure 6.7 Field manifestation of the Himalayan Frontal Thrust (HFT) in the Nahan Salient.

Singh T, Awasthi A K[1], Ravindra Kumar[2] and Virdi N S[3]
[1]Graphic Era University, Dehradun, [2]Panjab University, Chandigarh.
[3]Wadia Institute of Himalayan Geology, Dehradun.

6.9 Active Uplift, Surface Relief and Mass Redistribution Drive Drainage Growth

As the topography builds up, surface relief tends to increase and interact with the surface processes, mainly drainage system. Evolution and growth of drainage are part of the whole process. Drainage basins spread over different spatial scales have been used to gauge subtle uplifts along small active faults traces and also along large spreading fault-related folds (ridges) etc. We look into the drivers of drainage growth in an actively uplifting area. At the same time we investigate the mode by which drainage basins grow over time. In the same context, we investigate the growth of drainage basins and its relationship with the surface relief.

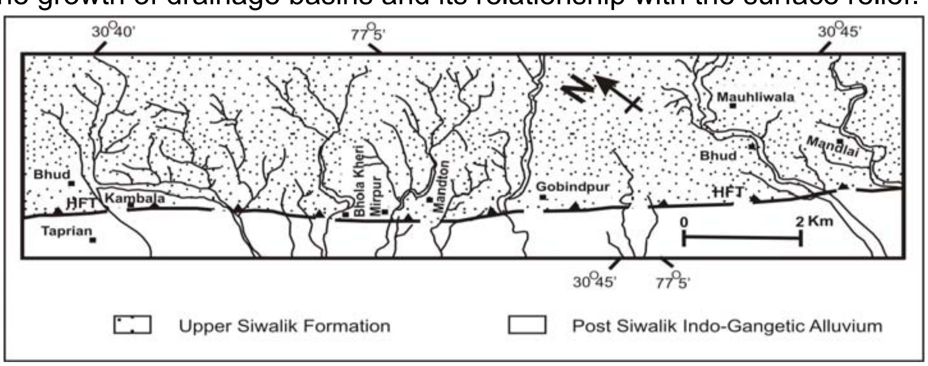

Figure 6.8 Coalescence and lateral migration of drainage as alternate ways of network evolution.

Our investigations reveal that the drainage basins evolve by maintaining their elongation ratios. Local increase in surface slope induces the drainage basins to look for alternative modes of evolution i.e. coalescence, lateral migration and headward growth etc. In conclusion, both different growth modes together play a dominant role in redistribution of mass from actively uplifting areas to adjoin depocentres through drainage basin growth.

Tejpal Singh, Awasthi A K[1], *Janani Srinivasan*[2], *Kanmani Kamaraj*[2], *Rebba Mary Raju*[2], *Sreeraj T*[2], [1]Graphic Era University Dehradun, [2]Bharathidasan University, Tiruchirappalli

6.10 Seismic Hazard and Risks Estimates for Himalayas and Surrounding Regions Based on the Unified Scaling Law for Earthquakes

This paper has been completed under the Indo-Russian DST-RFBR project sponsored by Department of Science and Technology, Government of India and Russian Foundation for Basic Research, Russian Federation. In this paper, we accept the hypothesis that the seismic process is self-similar, at least locally, and estimates the coefficients A, B, and C using the Scaling Coefficients Estimation (SCE) algorithm. We analyze the earthquake catalog from USGS/NEIC and provide the maps of the A, B, and C coefficients for the different scales and discuss their likely relationship with the observed continental deformation and related structure of the Earth. The parameters A, B, and C of this Unified Scaling Law for Earthquakes (USLE) in Himalayas and surrounding regions have been studied on the basis of a variable space and time scale approach. The observed temporal variability of the A, B, and C coefficients indicates significant changes of seismic activity at the time scales of a few decades. For Himalayan region, the values of A, B and C have been estimated mainly ranging from -1.6 to -1.0, from 0.8 to 1.3, and from 1.0 to 1.4, respectively. Figure 1 demonstrates the distribution of the estimated values for each of the three USLE coefficients and using these coefficients the expected maximum magnitude M with 1% and 10% probability of exceedance in 50 years based of the higher resolution settings and rich seismic data have been estimated.

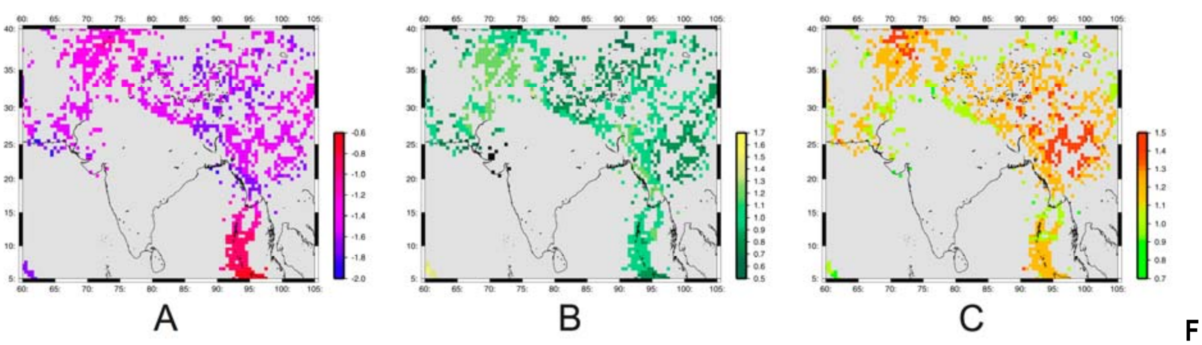

Figure 6.9 The distribution of the USLE coefficients in space (based on the USGS/NEIC Global Hypocenters Database Systems, 1965-2011).

For more comprehensive estimation of seismic hazard, we complement the final map of the expected maximum magnitude M based on USLE with the reported maximum magnitude in 1900-2010 to estimate the hazard map of expected ground shaking in terms of PGA. In order to

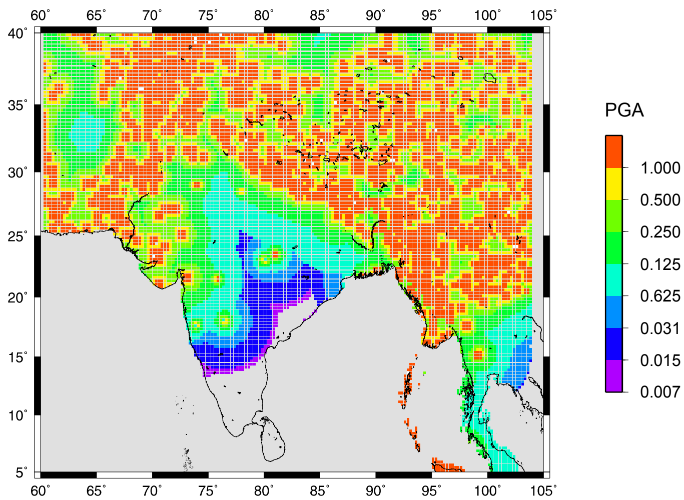

Figure 6.10 Final deterministic seismic hazard map

produce deterministic seismic hazard map, a source-receiver distance is the estimated at a grid of 0.25° x 0.25° and for each source of different magnitude, PGA is calculated and the maximum at each cell is plotted as shown in Figure 6.10.

Any kind of risk estimates results from a convolution of the hazard with the exposed object under consideration along with its vulnerability –

$$R(g)=H(g) \star O(g) \star V(O(g)),$$

Where H(g) is natural hazard at location g, O(g) is the exposure of objects at risk at g, and V(O) is the vulnerability of objects at risk.

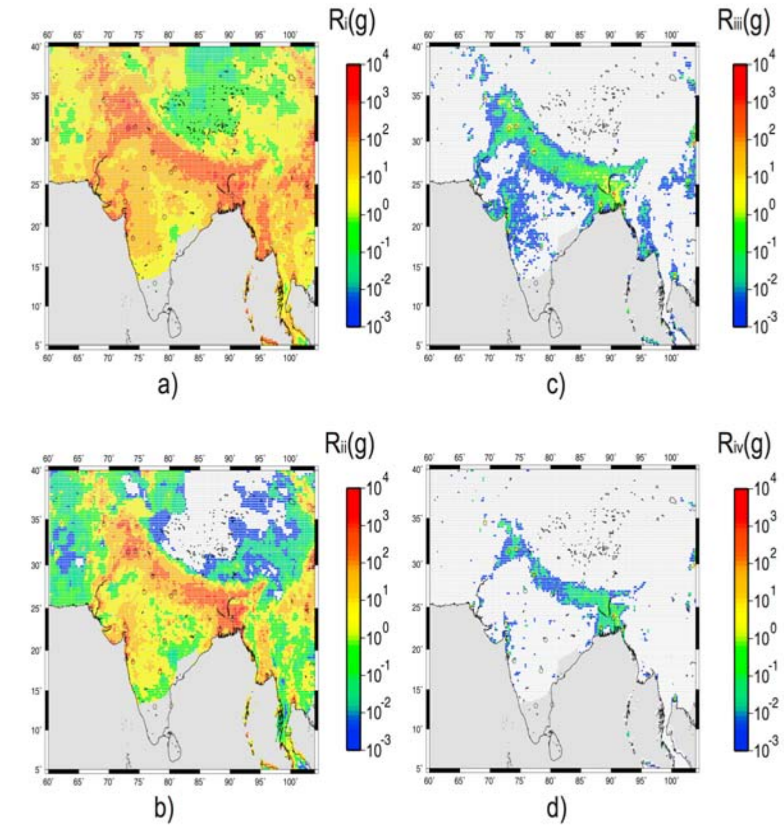

Figure 6.11 Oversimplified convolutions of seismic hazard map H(g) with the population density distribution

Using the population density distribution based on Gridded Population of the World, Version3 (GPWv3 for 2010, we estimated the seismic risks in four levels (figure 6.11), each of the four risk scales is covering the top seven decimal orders of the risk values, so that the cells in red are 1000000 times more dangerous than those in blue. The collapse of the risky areas to the region of the densest population appears rather natural demonstrating how non-linearity of conditions changes expectation of seismic risk. It is notable that, as expected, the mega-cities and their agglomerations are at the top of risk distributions.

Imtiyaz A Parvez, Anastasia Nekrasova and Vladimir Kossobokov**
*Institute of Earthquake Prediction Theory & Mathematical Geophysics, Moscow

6.11 The Role of Microzonation in Estimating Earthquake Risk

This work is dedicated to understand the role of seismic zonation and microzonation, as well as understanding seismic risk analysis and mitigation strategy. The merits and demerits of various approaches to estimating earthquake hazard are discussed in terms of whether it is probabilistic, deterministic, or neodeterministic. The importance of geotechnical, geomorphological, and geological databases for seismic microzonation has been highlighted along with various techniques available to characterize site conditions. A variety of tools currently in use illustrate the basic principles of microzonation mapping at different scales. The main parameters involved in earthquake loss assessments and evaluating the influence of soil conditions on these estimates are discussed using Earthquake Loss Assessment for Response and Mitigation (QLARM), an advanced seismic risk estimation tool, for a few case histories. Various numerical and experimental methods express the local soil response to ground shaking. Discussions among scientists on the best parameter or parameters to define site conditions are not closed. Vs values that tend to be commonly used in national building codes and recent Ground Motion Prediction Equation (GPMEs) are one of them, but recent studies indicate that it could misestimate site amplification. We presented a few other parameters that help in defining the site effect. For example, the advanced study aimed at Neodeterministic Seismic Hazard Assessment (NDSHA) allow for the development of a set of regional and local scale maps of the expected ground motion at bedrock and surface level, based on the physical modeling of ground shaking from a wide set of possible scenario earthquakes. These maps can be defined in terms of peak ground displacement, velocity, acceleration, or any other ground motion parameter that can be extracted from the set of complete synthetic seismograms describing ground shaking at the different sites. Recently, displacement-based and energy approaches have made significant advances. The former approach is based on the assumption that limiting displacement demands can reduce structural and nonstructural damage; the displacement response spectrum, as the input, is of great significance to displacement based design just as the acceleration response spectrum is to the traditional force based design. The latter approach, beyond the potentiality of designing earthquake-resistant structures by balancing energy demands and supplies, allows us to properly characterize the different types of time histories (impulsive, periodic, with long duration pulses, etc.) that may correspond to an earthquake ground shaking, simultaneously considering the dynamic response of a structure. Earthquake risk assessment requires various types of data that are often disconnected from microzonation ones because their implementation remains tricky. Indeed, it is not straightforward to use existing microzonation data in seismic scenarios because relationships to derive amplification factor from parameters used to define site conditions are missing. Research in this direction should improve the estimate in the future.

*Imtiyaz A Parvez and Philippe Rosset**

*WAPMERR, Geneva, Switzerland

6.12 Probabilistic Seismic Hazard Assessment for Gujarat Region of Western India: An Application of a Bayesian Extreme-Value Model of the Results

Amongst all hazard assessment techniques available presently, Bayesian theory provides a more reliable measure of hazard assessment and it has the unique feature that we can add new data on availability to obtain a realistic evaluation of seismic hazard. Here, the approach of Bayesian extreme-value distribution is adopted to evaluate hazard parameters for Gujarat region. The seismic moment, slip rate, earthquake recurrence rate and magnitude frequency parameters are the basic parameters to obtain the prior estimate of seismicity. We prepared the earthquake data set of magnitude Mw ≥ 4.0, spanning the period from 1330 to 2012 using a catalogue of national and International and other published catalogues to prepare a reliable, homogeneous and complete earthquake catalogue in terms of all magnitude types from 1705 to 2012 in view of completeness. The entire region is divided into three seismogenic zones (figure 6.12) on the basis of seismotectonics, historical and current seismicity, clustering of events and geological lineament. These are Kachchh, Saurashtra and Gujarat mainland zone. We computed the probability for T=2, 5, 10, 20, 50 and 100 years for each zone.

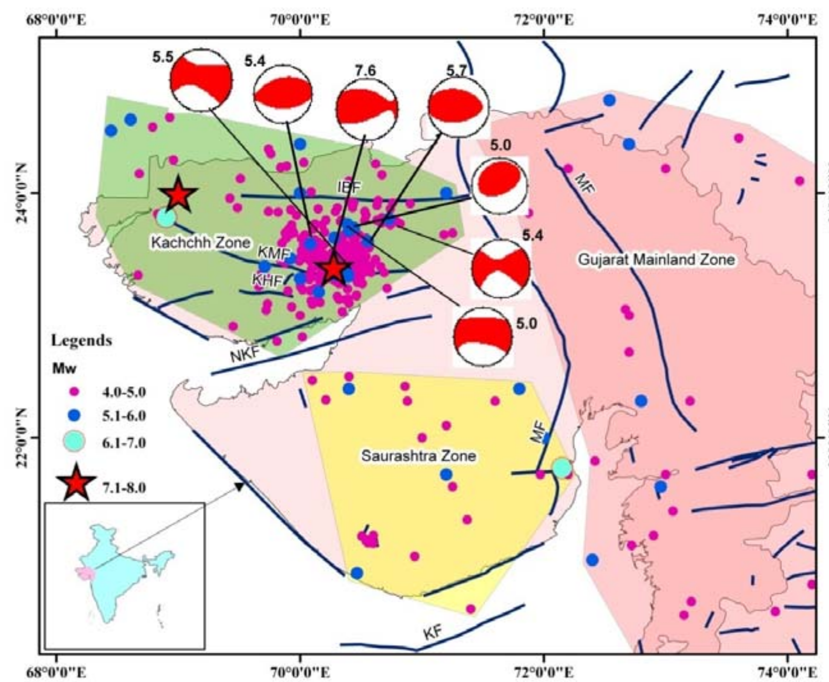

Figure 6.12 Seismotectonics features and epicentral location of earthquakes with three zones namely Kachchh, Saurashtra and Gujarat Mainland based on the local geology and earthquake clusters.

We adopted the well-known approach of extreme-value statistics and used Bayesian analysis imposing magnitude distribution using the Gutenberg-Richter b-value. The random variables α and β are estimated by means of Bayes' theorem with prior distributions. In the statistical methods, normally a large number of observations are needed to estimate return periods and probabilities. We have used seismicity data of 308 years to analyze the earthquake hazard parameters and probability of occurrence. Prior values of the parameters are estimated based on the maximum likelihood criterion. The seismic hazard is described in the form of hazard curves i.e. probabilities versus magnitude for short-term and long-term period in each zone. For the Gujarat region, first time we obtained probability using Bayesian model.

The Kachchh region exhibits higher probability for occurrence of moderate to strong magnitude and Saurashtra and Gujarat mainland shows moderate probability for the same. The variation in probability for Saurashtra zone and Gujarat mainland zone is higher compared to Kachchh zone but the probability of occurrence of earthquakes is less in both these zones compared to Kachchh zone for the same coefficient of variances. These results have potentially useful implications in the probabilistic seismic hazard assessment for the entire Gujarat state. The zone wise comparative seismic hazard categorization could be useful for design purposes to identify the priority regions for earthquake resistant designs. The seismic potentiality presented in this study can be interpreted for both short-term as well as for long-term seismic hazard, especially, for region like Kachchh which witnessed several moderate to large earthquakes in the past and recent past and aftershock activity is still going on in the region after the Jan 26, 2001 Bhuj (M_w 7.7) earthquake. Consequently, this region is more vulnerable to moderate to large earthquakes in near future.

*Imtiyaz A Parvez and Parul C Trivedi**

*India Meteorological Department, Ahmedabad

6.13 Estimation of Peak Ground Acceleration (PGA) in Peninsular India for Hazard Analysis.

Peninsular India, normally considered as a stable continental part of the Indian subcontin ent, has experienced several damaging earthquakes of magnitude greater than 6.0 in last couple of decades. Earthquakes occurred in various places in Peninsular India: Latur (1993: Mw 6.1), Jabalpur (1997, Mw 5.8) and recent Bhuj (2001, mw 7.6), which has claimed thousands of precious lives and damage to infrastructure accounted for huge economic losses (Figure 6.13). Although occurrence of large earthquakes is very low of an order of several decade to centuries but impact on society is very high. Thus, it becomes important to quantify the Peninsula Hazard for future events in terms of possible ground shaking. A comprehensive earthquake database with location, date and magnitude of past earthquakes is required to estimate reliable seismic hazard parameters to be used in a hazard study. The Catalog used in this study has been generated based on available information from various sources. Most recent events included from International Seismologicl Centre (ISC) and Preliminary Determination of Earthquakes (PDE) data (National Earthquake Information Center [NEIC]). Generally instrumental and more reliable data is available after 1960 from ISC, from US Geological Surveys USGS since 1973 and India Meteorological Department (IMD). After collection of the earthquake data from various sources, pre and aftershocks had been removed from the catalog as earthquake assumes to be occurred independently. Regression analysis has been made on Harvard Centroid Moment Tensor (CMT) data to establish various magnitude conversion relations and all magnitude converted to Moment magnitude (Mw) for the peninsular Indian catalog.

The seismicity parameters, (*a, b*) from Gutenberg Richter formula, first estimated for complete peninsular catalog for two different period (1800-2011) and (1960-2011). In both cases *b* values are very low 0.68 and 0.79. Source zone 1, which represents Gujarat region, exhibits very low *b* values and represents a region close to transformation boundary. Therefore, the catalog dataset was divided into sets for Gujarat region and Peninsular India (Excluding Gujarat or source zone 1). A very low value estimated from Gujarat catalog while rest of the data from peninsular India (Excluding Gujarat) gave *b* value 1.08 which is in line with global value for a larger region.

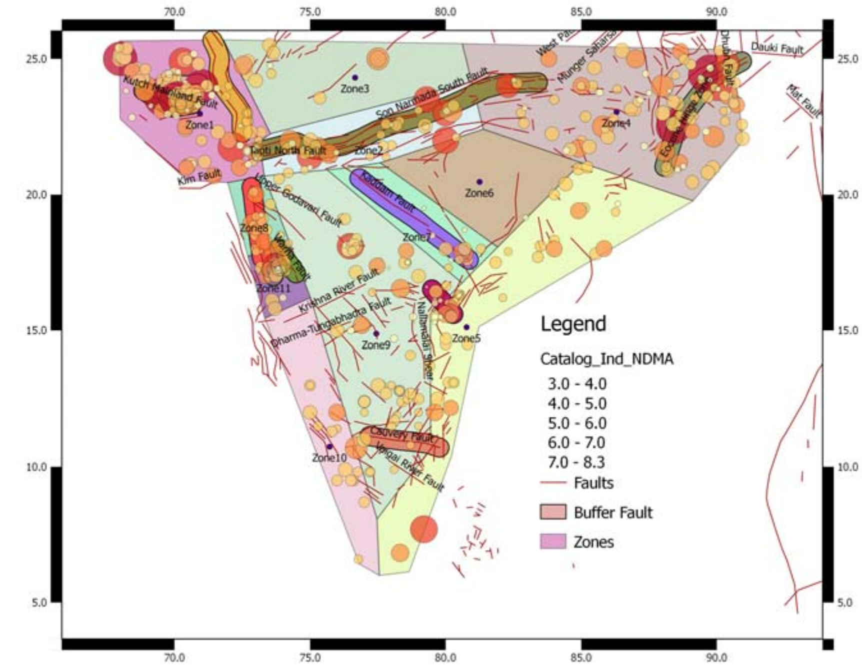

Figure 6.13 Map showing fault map (Seismotectonic Atlas of GSI) of Peninsular India with Earthquake catalog (circle). Color and size of circle indicate magnitude of the earthquake. Buffer zones are representing buffers generated for fault model.

Three data models have been generated for the computation of Hazard map: Classical Seismic Zones, Point Source and Fault Model. The Peninsular India region is divided into ten-source zones based on geology, earthquakes distribution and faults. Smaller zones do not have a sufficient number of earthquakes to perform credible statistical analysis thus, *b* value is fixed for each zone 1.08 and *a* value is estimated for each zone. Point source models established with a notion to use existing earthquake energy distribution and hence earthquake catalog has been used to create this model. In Peninsular India, details of existing faults and their potential is hardly available for establishing a good fault model. Thus, ten prominent faults or fault zones have been chosen based on the associated seismicity and geology of the region which include Narmada Son lineament, Allahbund fault etc. A buffer zone of 0.2 delta has been used on either side of the fault line to create an envelope rather than using the fault line (Figure 6.13). The envelope represents the possible region for rupture around the fault. Attenuation relations are required to compute ground acceleration thus, attenuation relation recommended by Global Earthquake Model (GEM) committee has been considered for similar tectonic setting. Two models Atkin06 and Toro97 considered for Peninsular (Stable continental region). However, Gujarat has a different tectonic setting than rest of the Peninsular region, thus, considered as active crustal region. For Gujarat, Akkar & Bommer 2010 model was considered from GEM recommendation.

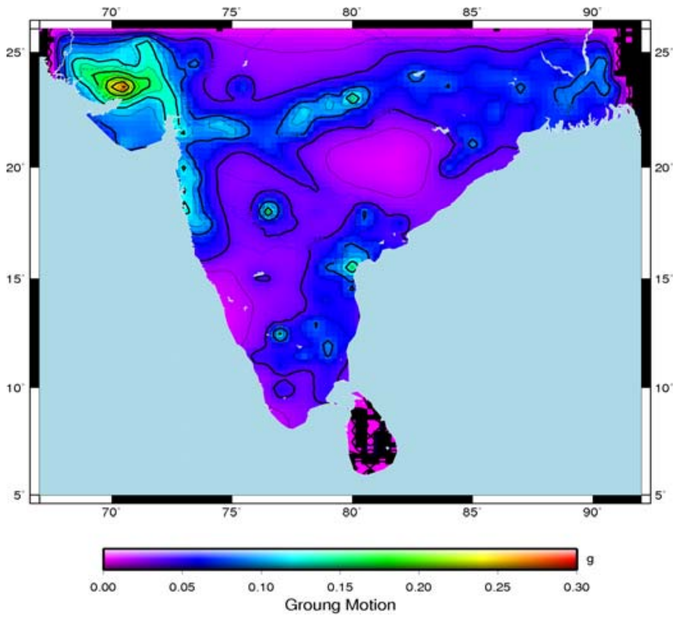

Figure 6.14 Probabilistic seismic hazard map of peninsular India showing spatial distribution of peak ground acceleration estimated for 10% probability of exceedance in 50 years, which correspond to return period of 475 years. PGA values are computed based on logic tree formulation.

The estimation of probabilistic seismic hazard for a region is represented by the annual exceedance rate of ground-motion parameter above a certain level. The Probabilistic seismic hazard map for PGA, at 10% probability of exceedance in 50 year with average return period of 475, based on combination of logic tree is shown in Figure 6. From the hazard map (figure 6.14), highest ground-motion, PGA at 10% of exceedance in 50 years, observed in Runn of Kuchchh, Gujarat in the range of 0.14 to 0.26 near Bhuj then, followed by Narmada-Son Lineament with the highest 0.19g near Jabalpur. For Mumbai and Koyana, a similar PGA estimated with 0.1g.

Ashish, Daniela Kuehn, Imtiyaz A Parvez and Conrad Lindholm**
*NORSAR, Norway

6.14 Neo-Deterministic Seismic Hazard Map of India

Rapid urbanization, development of critical structures and lifelines, such as dams and Nuclear Power Plants, industrialization of cities and the concentration of populations, living or settling in hazardous areas, are all matters of growing concern. Thus, the recent social and economic development exposed to earthquake hazards implies future heavier loss of life and economic damage, unless reliable preventive actions are enforced following the rapid rise of interest about environment concerns and increased official and public awareness about earthquake hazard in India. The first ever neo-deterministic seismic hazard map of India by computing synthetic seismograms with input data set consists of structural models, seismogenic zones, focal mechanisms and earthquake catalogues was published 2003 by C-MMACS. Last decade has witnessed an increased activity in seismological experiments and provide more detailed and denser information of subsurface structures. Now, there is a need to revise the existing deterministic hazard map with high-resolution structural model, new available focal mechanism data, extended source types and updated earthquake catalogues. The present study is aimed to generate and new updated NDSHA map for India with updated inputs available till date. Realistic synthetic seismograms are constructed by the modal summation technique to model ground motion at the sites of interest, using the available knowledge of the physical process of earthquake generation (source position and orientation of the focal mechanism), level of seismicity (distribution of maximum observed magnitude) and wave propagation in anelastic media. From these synthetic signals engineering parameters can be extracted in order to assess the seismic hazard. Therefore, we can also estimate these parameters in those areas where very limited (or no) historical or instrumental information is available. As examples of the results that can be obtained, we show the maps of the distribution of maximum displacement (D_{max}), maximum velocity (V_{max}) and design ground acceleration (DGA) over the investigated area.

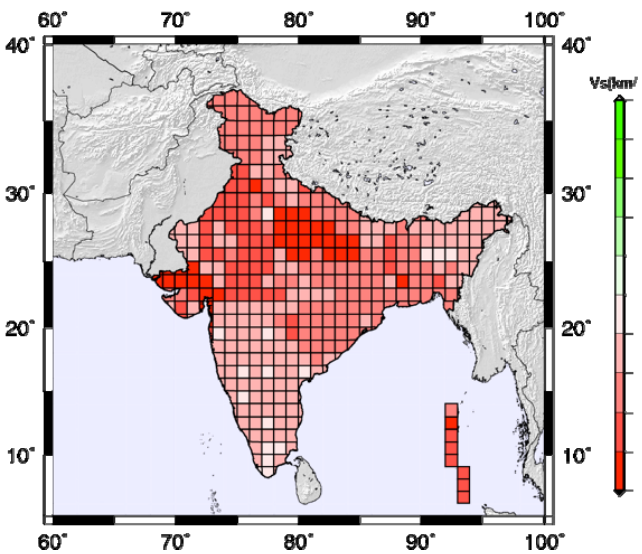

Figure 6.15 Shear wave velocity Vs in the upper most layer for each 1x1 degree cell.

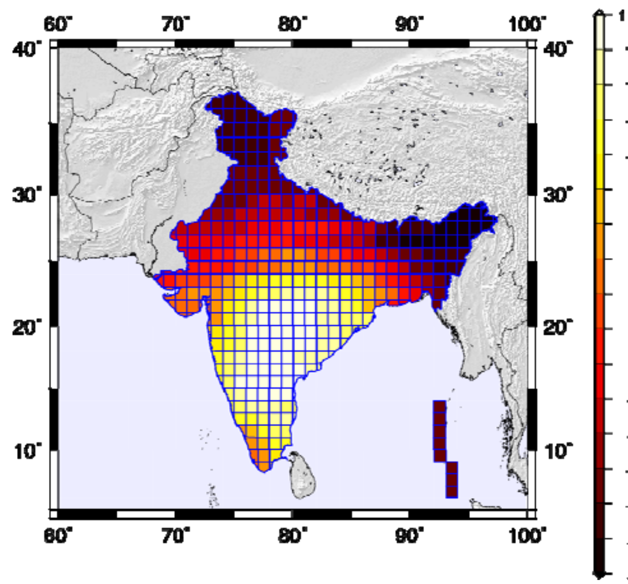

Figure 6.16 The distribution of Qs at each 1 x degree cell in the uppermost layer.

In order to revise the deterministic seismic hazard map, firstly a high-resolution velocity map at 1 x 1 degree cells of resolution have been prepared constituting 387 cells, which include subcontinent region Nepal, Bangladesh, Bhutan and Andaman & Nicobar Island. For each cell, the structural parameters that contain P wave velocity, S wave velocity, density, layer thickness, Qp and Qs are compiled. An example of shear wave velocity Vs and Qs of upper most layers is shown in figures 6.15 and 6.16 respectively. Earthquake catalogues and databases are other important parameters and in the present study, the earthquake data set spanning the time interval from 25 to 2011 has been used based on pre-instrumental and historical macro seismic information. We have used the database from the international agencies like NOAA, ISC, NEIC, CNSS, CMT and national agencies like IMD and NDMA and several published research papers. Figure 6.17 shows the smoothed seismicity map of India and adjacent areas along with the representative focal mechanisms in figure 6.18. The simulated seismograms are efficiently computed with the modal summation technique for 1 Hz considering layered anelastic models for wave propagation, which are representative of the average properties of the crust and upper mantle along the considered source site paths. However, we could also extend the computations to higher frequencies (5 or 10 Hz), and are planning to implement the use of a finite source model for the scaling. From the set of complete simulated seismograms, various engineering parameters e.g. the Maximum displacement, velocity, acceleration and Designed Ground Acceleration (DGA) have been extracted.

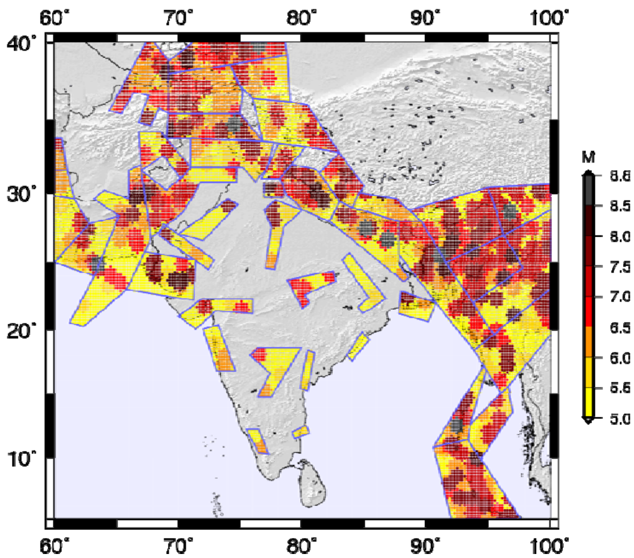

Figure 6.17 The smoothed seismic sources plotted in the respective seismogenic source zones used for the computation of synthetic seismograms

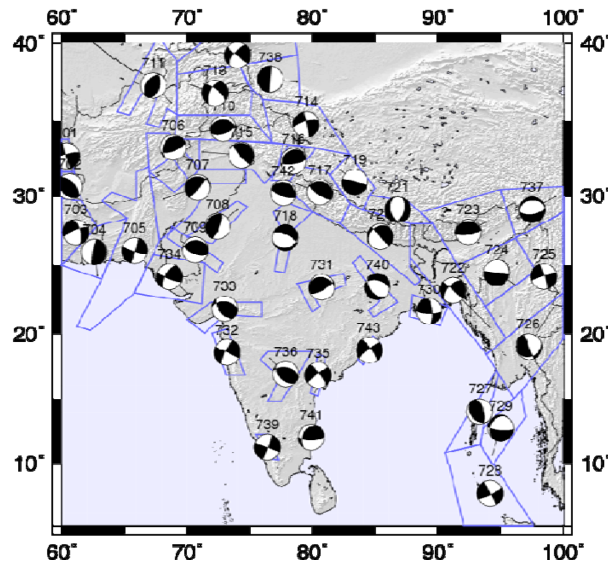

Figure 6.18 Seismogenic Zones defined on the basis of geology, tectonics, earthquake catalogue and the earthquake focal mechanism for each zone.

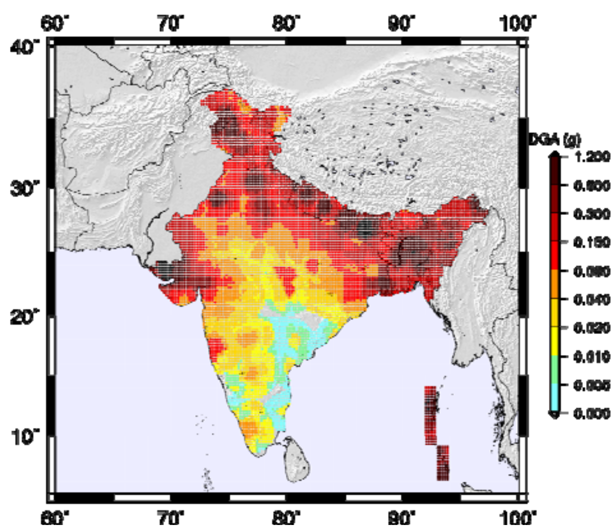

Figure 6.19 Spatial distribution of the estimated design ground acceleration in g.

The maximum values of DGA have been estimated over the northeast Indian region in the epicentral zone of the great Assam earthquakes of 1897 and 1950 (Figure 6.19). The DGA values obtained for this region fall in the range above 0.6 g. The Bihar-Nepal and Central Himalayan region have DGA values between 0.3 and 0.6 g. In part of western Uttar Pradesh and in the epicentral zone of the Uttarkashi earthquake of 1991 the estimated DGA values are between 0.15 and 0.3 g.

Imtiyaz A Parvez, Andrea Magrin, Franco Vaccari*, Ashish, Ramees R Mir and Panza G F**
*Department of Mathematical and Geosciences, University of Trieste, Italy

6.15 Crustal Imaging of Dharwar Region across E-W Corridor

Some of the fundamental problems confronting Earth scientists are to understand the structure, dynamics, origin and evolution of continental crust. An experiment was designed to study the crustal and mantle structure along the east-west corridor across Dharwar Craton for constraining models of crustal evolution. CSIR-4PI (erstwhile C-MMACS) has collaborated with the National Geophysical Research Institute (NGRI), Hyderabad and operated broadband seismometers in locations throughout India with research interests centered on the southern Indian shield. During the period between April 2010 and March 2013 twelve stations were operated on an approximately straight SWW-NEE line in East and West Dharwar Craton and distributed along approximately straight line with an average spacing of 15 km with a greater density in the middle of the profile as low as 5 km.

Earthquake waveform data (recorded at 100 sps) is archived regularly. Teleseismic earthquake waveforms were extracted based on USGS earthquake catalog from data archive and converted to SAC format. The receiver function is calculated by using time domain iterative deconvolution for all distant earthquakes representing the time delay between direct P and P to S converted phase from an interface and time delay corresponds to the depth of the interface (see figure 6.20). The amplitude vector for each receiver function (corrected for the effect of incidence angle) is back-projected along a ray-path calculated for a standard earth model. In this case, IASP91 global model was used to convert travel times from the P-S conversion into depth. The volume along the profile was divided into bins of 1 km height and length along the profile but with a very wide dimension perpendicular to the profile. Amplitudes of the rays traversing each bin were summed and averaged to give the amplitude of the bin.

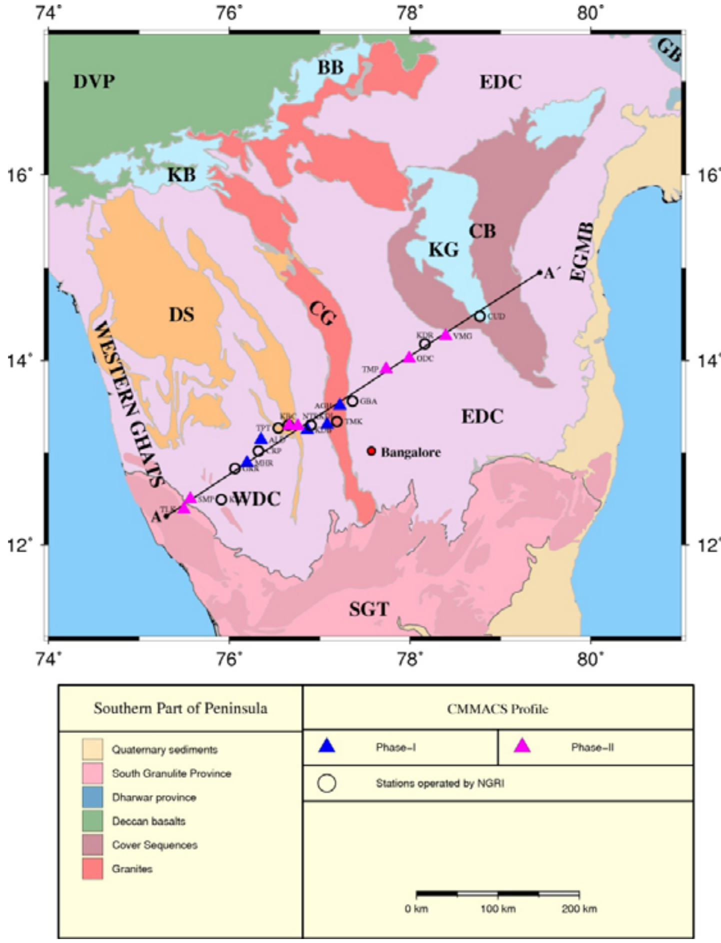

Figure 6.20 Major Geological terrains, tectonic features of Dharwar Craton and seismic stations (pink and blue triangle and black circle) operated in the region. Profile AA' represents the section along which stations are projected. EDC: East Dharwar Craton; WDC: West Dharwar Craton; SGT: Southern Granulite Terrain; DVP: Deccan Volcanic Province; CB: Cuddapah Basin; KB: Kaladgi Basin; BB: Bhima Basin.

The strike of the Dharwar in this region is roughly north south and to allow for the oblique angle of profile AA' (figure 12), stations have been projected on to the profile along lines AA'. Ideally, the location of stations should fall precisely along the profile but in practice they are scattered by up to 20 km to either side. The resulting CCP depth migration for profile AA' is plotted in Figure 13. The crust-mantle boundary is clearly visible beneath the Dharwar craton as the only laterally continuous strong amplitude positive interface. In east Dharwar, The general trend is flat Moho at a depth of 36-38 km. On the other hand in west Dharwar, Moho depth varies from 42-44 km and a presence of strong intra-crustal amplitude at a depth of ~15 km.

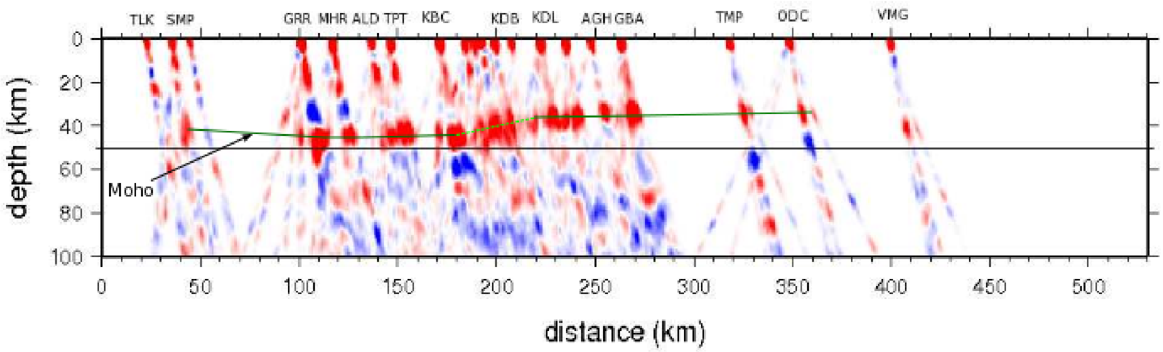

Figure 6.21 CCP depth-migrated receiver function profile along Profile AA'. The interpreted Moho is marked as a small green solid line and a dotted line for possible transition zone of contact between East and West Dharwar craton.

Transition zone between east and west Dharwar Craton observed between chitradurga schist belt and closepet granite represented/sampled by stations NTR, KDB, GRH, BRS and KBC (see Figure 6.21). This zone shows a smooth variation in moho depth

Ashish and Imtiyaz A Parvez

6.16 Seismic Broadband Experiment in Kashmir Himalayas

Five broadband seismic stations in Kashmir Valley are operational in continuous mode from June 2013 and recording seismic data at 100 samples per second using ~80 W solar panels for uninterrupted power supply. The second phase of this project will be operational this year with 10 more stations to get a clearer picture of crust and upper mantle of the Kashmir valley, which will eventually enhance our understanding of rheology of this region (figure 6.22).

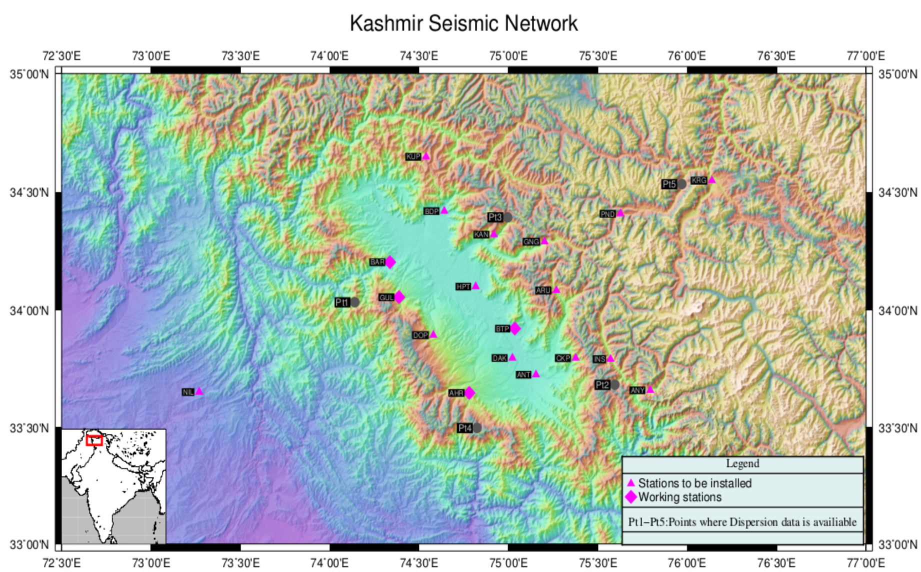

Figure 6.22 Proposed and currently working seismic stations. Diamonds are the currently working stations (from June 4, 2013), triangles are the proposed stations some of these sites were visited last year. NIL is Nilore Pakistan IRIS station whose data is freely available online.

Using four stations (Aharbal, Batpal, Gulmarg and Baramulla) data, we have estimated crustal structure beneath these seismic broadband stations in Kashmir valley from receiver function analysis. Seventy earthquakes (figure 6.23) with good signal to noise ratio, magnitude >= 5 and epicentral distance between 30 and 90 degrees were chosen to determine the S wave velocity structure beneath each station. Three of the stations were located on Pir Panjal range of Kashmir Himalaya. We use receiver function data, which are sensitive to velocity transitions and vertical travel times, together with surface-wave dispersion measurements, which are sensitive to the average velocity but relatively insensitive to sharp velocity contrast, to estimate the variations of crustal structure beneath four stations in Kashmir Himalaya. To avoid bias in the inversion, we have used the same AK135 continental model whose lower part is not permitted to change at all stations. Receiver function data was prepared before the joint inversion by setting the time from -45 to +57 seconds and header of each was filled with value of Gaussian width value (1.6), ray parameter. Receiver functions with close value of delta and backazimuth were binned together to increase the signal to noise ratio. At all stations starting model was Kennet's AK135. Inversion sensitivity has been tested by varying parameters, like influence parameter 'p', damping factor and fixing Vp/Vs or Vp only. For tests done on various value of damping factor and p value, we chose the value of p ~ 0.1 for all stations, the results for AHR station are given in figure 6. It is evident from inversion results that region is quite complex in crust and upper mantle.

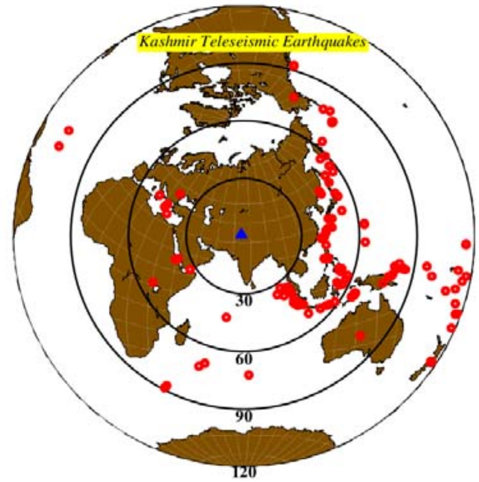

Figure 6.23 Teleseismic earthquakes (red circles) recorded by four seismic stations (Blue triangle) in Kashmir valley. The events having epicentral distance in the range 30 to 90 degrees were used for receiver function study.

The radial receiver function have first Moho multilple received at about 6.5 sec, H-k stacking revealed a complex behavior of the crustal which can be due to different mid-crustal layers. Receiver functions were jointly inverted with fundamental mode Rayleigh wave velocity to constraint the crustal thickness beneath each station. The results satisfy the predictions of H-k stacking as all the four stations reveal complex seismic crustal structure.

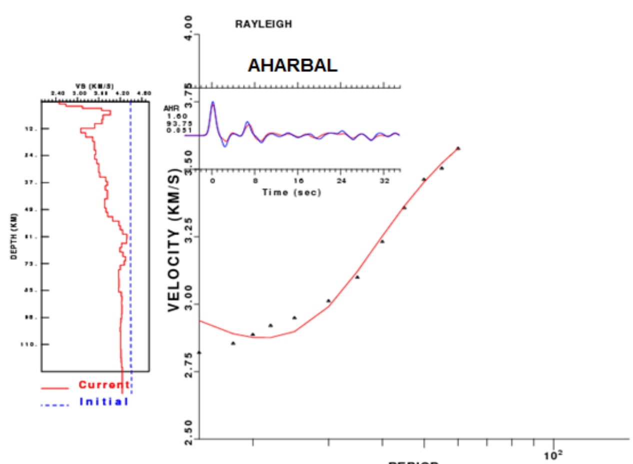

Figure 6.24 Joint inversion results for Aharbal seismic station.

Moho beneath each station varies in the range of 50-55 km. Moho at BTP has to slightly deeper than the other three stations as this station is more northwards and due to northward subduction of Indian plate beneath the Eurasian plate the Moho has to be slightly deeper here than of other two stations (AHR and GUL) which are located on Pir Panjal range of Kashmir Himalaya. Moho beneath Aharbal (AHR) station was found about ~52 Km , Gulmarg (GUL) ~55 Km, Baramulla (BAR)~ 52 Km and Batpal (BTP) ~ 56 Km. Vp/Vs ratio at all stations is in the range of 1.73 to 1.76.

Imtiyaz A Parvez, Ramees Mir and Ashish

6.17 Finite Element Method for Deformation in Porous Thermoelastic Material with Temperature Dependent Properties

The present study is focused on the numerical investigation in time domain of the deformation in thermoelastic material with one relaxation time (Lord and Shulman theory) with voids under dependence of modulus of elasticity and thermal conductivity on reference temperature. For numerical investigation of the concern problem, the finite element method with eight node isoparametric finite elements has been used. The results demonstrate that finite element method can reliably predict the deformation of the medium. Our results illustrate the temperature distribution, the displacement component, volume fraction field and the stresses.

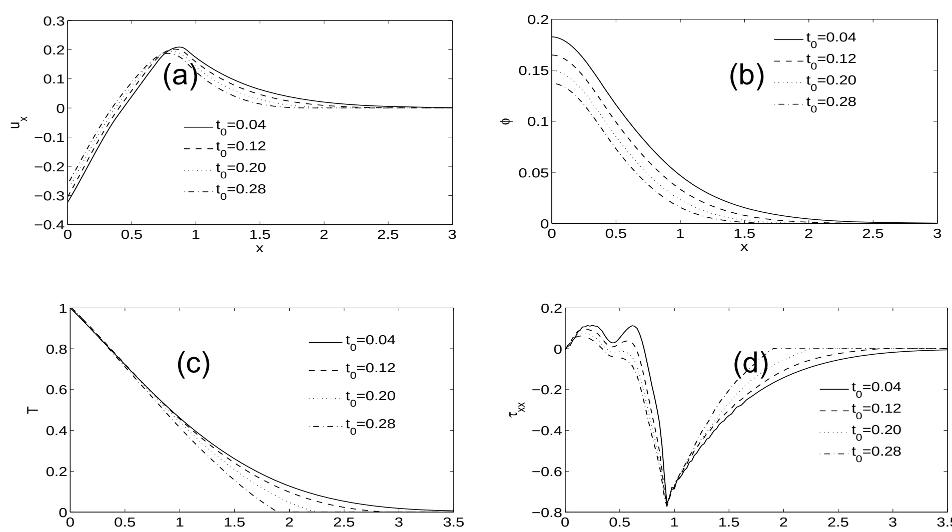

Figure 6.25 Horizontal displacement of solid particles (a), Volume fraction field (b), Temperature distribution (c), distribution of tangential stress component (d), with respect to *x* for different thermal relaxation time t_0 at *y=0*.

From figure 6.25, we observed that obtained results satisfy the prescribed boundary (stress free surface) conditions. We find that the relaxation time t_0 has a significant effect on the field variables (displacement, temperature, volume fraction field and stresses), as expected. As increase of distance *x* the effect of thermal shock on the field variables is reducing till a certain distance then after it is almost zero. The maximum temperature (T) and volume fraction field (Φ) has been found at the surface x=0.

Sushant Shekhar and Imtiyaz A Parvez

6.18 Finite Element Analysis of Wave Propagation in Thermoelastic Saturated Porous Medium

A general finite element approach is used for the numerical investigation of the wave propagation in transient thermoelastic saturated porous media in time domain. For that, the Biot's theory for wave propagation in saturated porous solid is modified to study the effect of thermal shock in the thermoelastic porous medium. Our results present the displacements of the fluid and solid particles, temperature distribution and the stresses over the surface and in depth. The effect of thermal shock on the surface of the half space $x \geq 0$ has been discussed and comparison has been made with the results predicted for the given field variables (displacements, temperature and stresses) for given depths (y = 0 and y = 1).

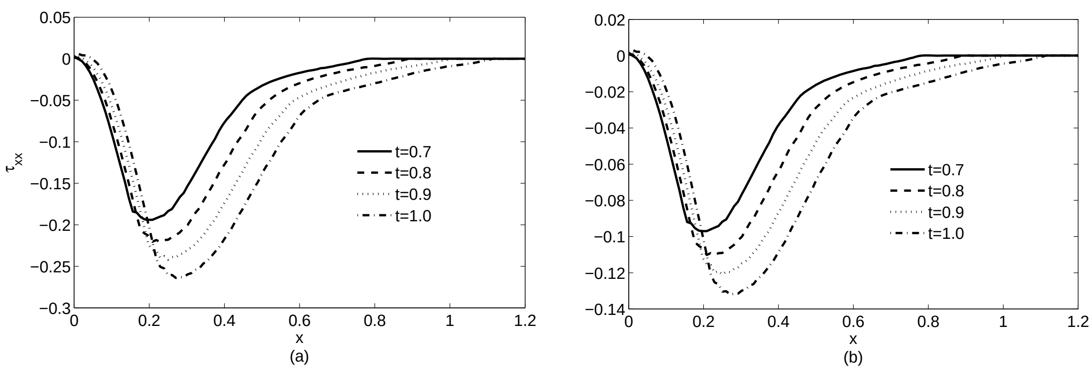

Figure 6.26 The distribution of tangential stress component with respect to *x* for different time step; (a) y=0, (b) y=1.

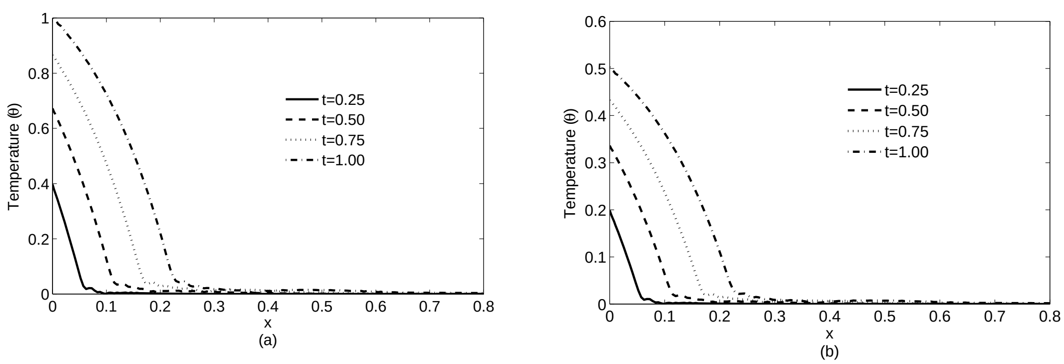

Figure 6.27 Temperature distribution with respect to *x* for different time step; (a) y=0, (b) y=1.

The numerical results satisfy the stress free boundary conditions that have been shown in figure 6.26. The thermal shock is applied on the surface x=0 therefore the maximum temperature will be at boundary zones, has been shown figure 6.27. From the numerical results, we observed that the study time has significant effect on the field variables, as expected. The thermal shock effect on the field variables is reducing from (y = 0 to y = 1) and its effect is clearly shown in figures 6.26 and 6.27 which satisfy the assumed boundary condition.

Sushant Shekhar and Imtiyaz A Parvez

6.19 Finite Element Method for Transient Wave Problem in Thermoelastic Saturated Poro-Viscoelastic Medium

The present study is aimed to the numerical investigation in time domain of the mechanical wave propagation through thermoelastic saturated poro-viscoelastic soil, involving complete Biot's theory. All the coupling and a hysteretic Rayleigh damping are taken into consideration for this study. For numerical investigation of the present problem, the finite element method with eight node isoparametric finite elements has been used. Our results illustrate the temperature distribution, the displacement components of solid and liquid phases and the stresses. An appreciable effect of damping coefficient η and relaxation times t_0 is observed on various results. We show the transient effect of thermal shock on the particle displacements, temperature and stresses in thermoelastic saturated porous medium.

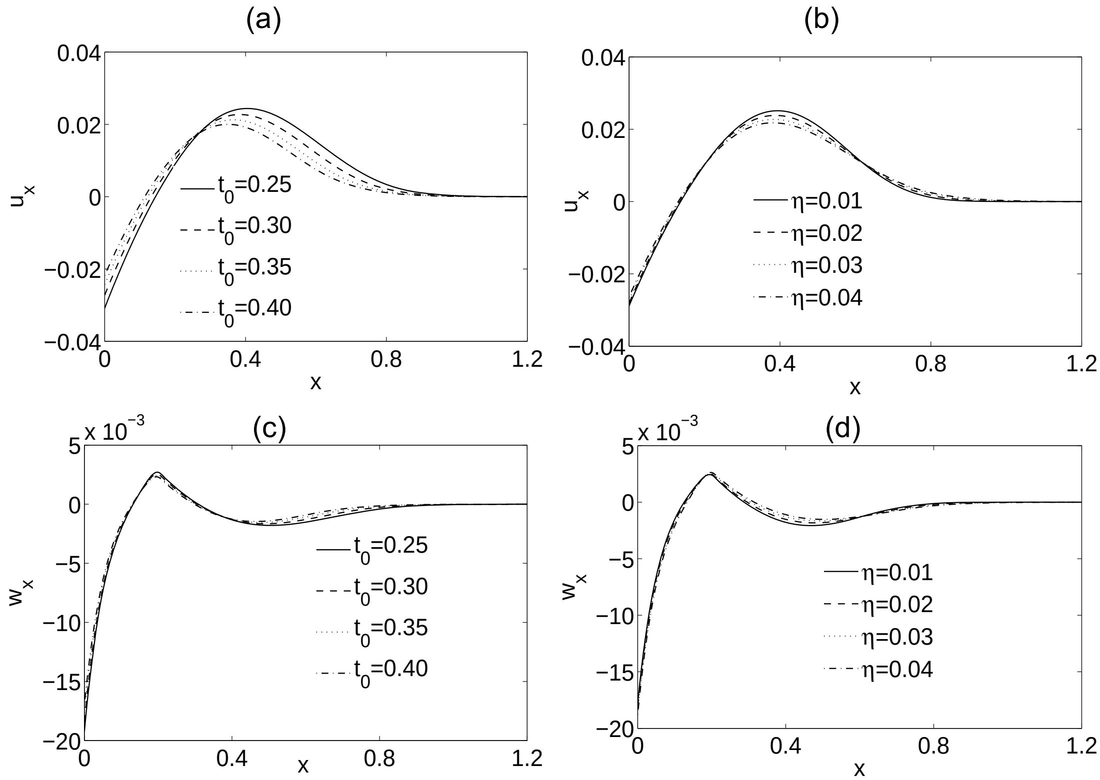

Figure 6.28 Horizontal displacements (u_x, w_x) of solid and fluid particles with respect to *x* for different values of thermal relaxation time t_0 (a) and (c) and for different values of damping coefficient η (b) and (d)

We observe that the obtained results satisfy the prescribed boundary conditions. We find that the relaxation time t_0 and damping coefficient η have significant effect on the field variables (horizontal displacement of solid and fluid particles), as expected (figure 6.28). As increase of distance *x* the effect of thermal shock on the field variables is reducing and finally its value is zero.

Sushant Shekhar and Imtiyaz A Parvez

6.20 2004 M 9.3 Sumatra-Andaman Rupture Extent and Slip Distribution, and its Implications on the Regional Tectonics

2004 M 9.3 Sumatra-Andaman earthquake was one of the biggest instrumentally recorded plate-boundary event. For this study, we complied various published surface deformation values, which are observed using precise geodetic techniques, and reported by various agencies in and around the Sumatra-Andaman region to estimate a co-seismic slip distribution model. A fault geometry of along arc dip angle range between 8-12 degrees with a thrust to oblique thrust mechanism and depth of rupture extending not deeper than 30 km gave the best fit surface displacements for the near and far-to-the source sites for both the horizontal and vertical offset values. We specified the fault surfaces in 3 dimensions by nodes which are given by their longitude and latitude and depth. Nodes are placed along depth contours of the faults and each depth contour has the same number of nodes. The co-seismic slip amplitude was then estimated at these nodes. This elastic deformation was calculated by integrating over small patches in the regions between these nodes using the Okada method.

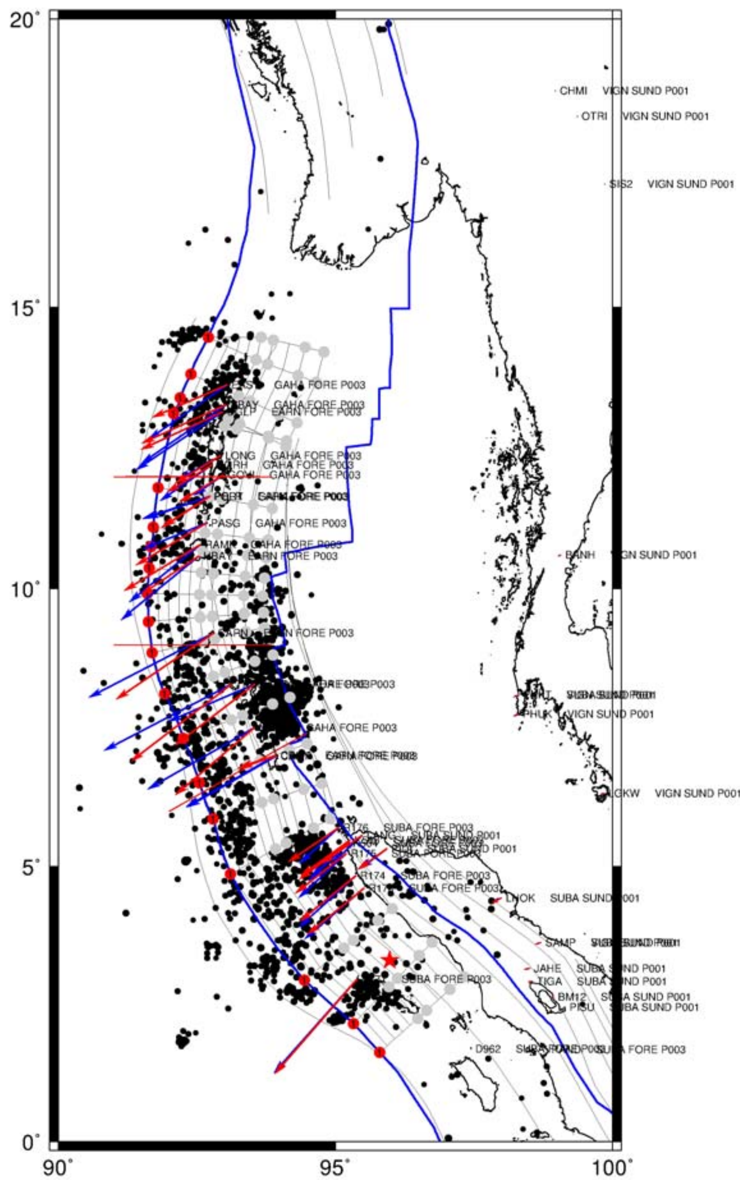

Figure 6.29 Co-seismic surface displacements observed (blue arrows) and predicted (red arrows) around the Sumatra-Andaman region for the 2004 M 9.3 earthquake (red star for location). Four character codes represent the GPS site followed by source publication and the code of tectonic plate it belongs. Filled circles are the fault nodes where red ones are considered to be on the ocean floor and grey ones are on the sub-surface on respective depth contour lines. Black filled circles are the aftershocks till 1st January, 2005. Blue lines are major tectonic boundaries.

Based on the estimated slip distribution, there was a significant slip extending to the shallower portions near the trench axis over most of the southern part of the rupture (Sumatra and Nicobar Islands), but not in the Andaman segment. At the north and southern ends of the rupture, the rupture was confined to the deeper portions of the plate interface, and these two segments have a steeper dip and greater depth than the rest. Slip magnitude varies considerably over the rupture, averaging ~16 m for the Sumatra and Nicobar region, and 5-8 m for most of the Andaman section. This model predicts a patch of very high slip offshore of Port Blair. Along arc rheological variations are not taken care in this model, which do have an effect on the slip distribution.

Anil Earnest

6.21 Establishment of Real-Time Data Telemetry VSAT's for Andaman GNSS Network

Geodetic monitoring does have significant scientific importance in understanding the deformational rates, fault-slips and kinematics of a plate boundary zone. High-rate geodetic observations help in identification of zones with sudden variations in slip-rates or zones with silent or slow slips. CSIR-4PI (erstwhile C-MMACS) has initiated a network of high rate GNSS observatories along the Andaman & Nicobar Island chain to understand the nature of tectonic processes happening along this margin for the past few years called Andaman Nicobar Geodetic Network (ANGN). Real-time analysis of the hence collected data from these observational networks can shed new insights on the seismogenic processes there but needs a data relay setup from Andamans to the data receipt/analysis setup at CSIR-4PI (erstwhile C-MMACS). Earlier we had setup a real-time GNSS data receipt and analysis engine at CSIR-4PI (erstwhile C-MMACS) and has tested it using global real-time IGS data streams. As part of this initiative, we made a network of real-time data relay from the earlier established 3 CGPS sites at Andamans and a newly established CGPS site using VSAT terminals through ERNET, India. These sites are provided with 64kbps dedicated bandwidth to stream-out the data to CSIR-4PI (erstwhile C-MMACS) servers or to reach the Internet enabled receivers for maintenance.

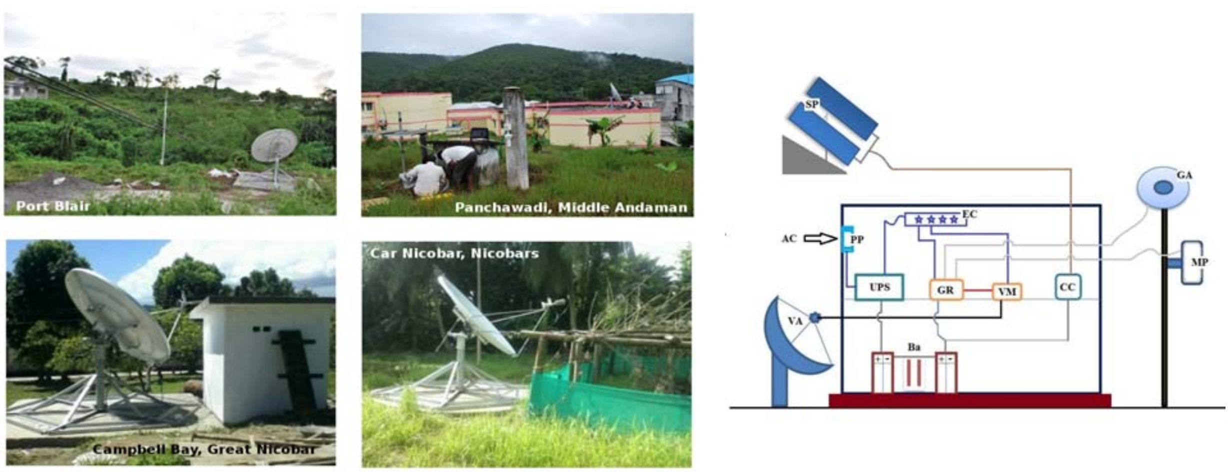

Figure 6.30 a) Data-relay VSAT setups established at Port Blair, Panchawadi, Campbell Bay and Car Nicobar (clockwise). b) Schematic diagram of the established setup at a GNSS site at A&N Islands. AC – External power supply, PP – Distribution Box, EC – Circuit Breaker, VA-- VSAT Antenna, CC— 10Amp Solar Charge Controller, Ba – SMF Battery, MP — MetPACK, GA — GNSS Antenna, VM—VSAT Modem, GR — GNSS Receiver, UPS -- UPS, SP — Solar PV module.

The newly established station is located at Campbell Bay, Great Nicobar the southern-most tip of Indian political territory, a zone of high amount of seismicity with it proximity to the Andaman trench and the West Andaman Fault. All the CGPS sites are collocated with met-packs. Real-time GNSS tracking data is being stored and analyzed at CSIR-4PI (erstwhile C-MMACS) servers located at Bangalore. A web-front-end is being developed for data/results dissemination for the ANGN. This research initiative is being implemented with the local logistical support of various government agencies of A&N Administration like Dept. of Agriculture, Dept. of Light House and Light Ships, Navodaya Vidyalaya, Pondicherry University and Dept. of Animal Husbandry and Veterinary Services.

Rajeev Krishnan, Sunilkumar T C, Anil Earnest and Vijayan M S M

6.22 Source Process of the Sikkim earthquake 18th September, 2011, Inferred from Tele-Seismic Body-Wave Inversion.

A moderate earthquake of magnitude Mw 6.9 occurred on 18 September 2011 at north Sikkim which is close to the Sikkim-Nepal border. The hypocenter parameters determined by the Indian Meteorological Department (IMD) shows that the epicentre is at 27.7°N, 88.2°E and focal depth of 58 km, located closed to the north-western terminus of Tista lineament. The epicentral region of Sikkim bordered by Nepal, Bhutan and Tibet, comprises a segment of relatively lower level seismicity in the 2500km stretch of the active Himalayan Belt. The largest historically known great earthquake in its vicinity is the 1934 Bihar Nepal border earthquake of M 8.3, located to the south-west of Sikkim, an event that caused intensity VIII damage in the Sikkim Himalaya. The north Sikkim earthquake was felt in most parts of Sikkim and eastern Nepal; it killed more than 100 people and caused damage to buildings, roads and communication infrastructure. Several landslides and rock falls followed the earthquake, which increased the death toll and impaired rescue operations. The National Earthquake Information Centre (NEIC) of US Geological Survey (USGS) located the epicentre of the main event to the immediate west of the IMD location. The focal mechanism solution for the main shock suggests dextral strike-slip faulting, possibly along a NW-SE oriented fault. This trend is consistent with the structural trend defined by the well located micro-earthquakes as well as the fault plane inferred from focal mechanisms.

We used the teleseismic body wave inversion methodology technique to determine the earthquake source parameters and the kinematic rupture process of the fault. This technique has been successfully applied to many earthquakes. The study of the rupture process is important to understand the source properties of an earthquake. Different methods are developed both in time domain and in frequency domain. Langston and Barker (1981, 1982), developed a generalized inverse technique based on the moment tensor formalism. Teleseismic body wave inversion methodology was proposed by Kikuchi and Kanamori (1982, 1986 and 1991). In the first paper, a numerical method is developed to study complex body waves into a multiple shock sequences. Assuming that the events have identical fault geometry and depth, the far field source time function is obtained as a superposition of ramp functions. In the next paper they considered a general case where the rupture process consists of sub events with arbitrary source parameters. And in the third paper they developed a method to determine the mechanism and the rupture process considering that the main fault consists of a set of sub faults, each of which could have different focal mechanism.

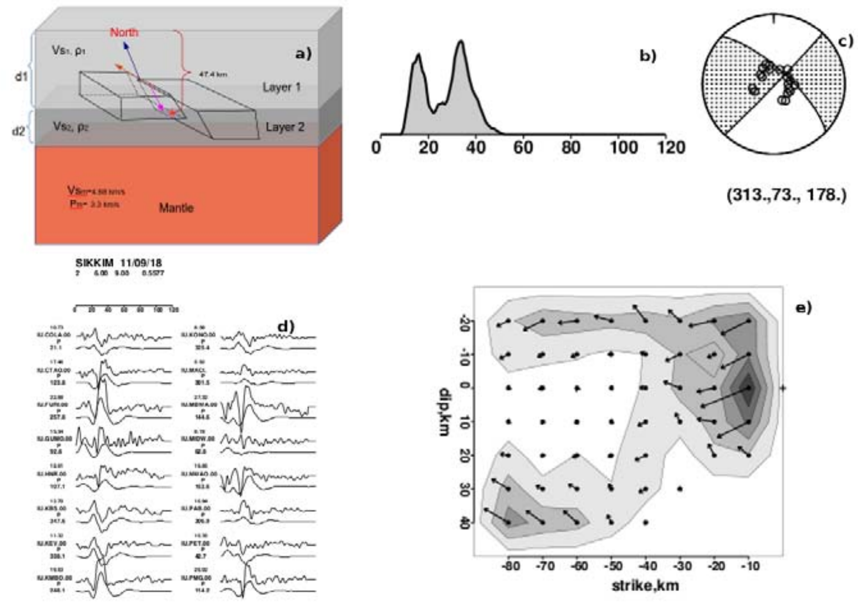

Figure 6.31 a) Schematic diagram of fault geometry used. b) Source time function used. c) Focal mechanism determined d) Comparison of the observed teleseismic body waveform data (upper trace) with the calculated waveform (lower trace). The numbers below the station code indicate maximum amplitude. and e) Distribution of co-seismic slip pattern along the strike.

The CMT and USGS focal mechanisms of the Sikkim event indicate strike-slip faulting. To determine the source parameters of this earthquake, body wave inversion modelling is applied using the methodology adopted by Kikuchi and Kanamori (1991). Broadband digital data were selected, recorded at teleseismic distances between 30-90 degrees with a good signal to noise ratio. Teleseismic distances in this range were used, in order to avoid upper mantle and core triplications and to limit the path length within the crust. Synthetic waveforms were generated using a simple triangular source time function, in order to determine the components of the moment tensor and the focal depth of the mainshock. The result of the inversion was a focal mechanism indicating strike slip type faulting at a depth of 44.7 km. The total seismic moment $M_o = 2.42 \times 10^{26}$dyn·cm equivalent to Mw = 6.9 earthquake was obtained through this study. This is consistent with the Global CMT and USGS solution. The determined fault plane solution is: strike, φ=313°, dip, δ=73° and rake, λ =163°. From this model, we found out that the average slip value of Sikkim earthquake is 0.3979m.

Sunilkumar T C and Anil Earnest

7

CSIR 800 COORDINATION CENTRE

During the 12 months from April 2013-March 2014, the CSIR-800 team focused efforts in program implementation, and coordinated field visits.

Progress in Karnataka TECHVIL

Water being the major issue at Raichur, the CSIR-800 team in collaboration with the State Water shed development board organized a preliminary survey and awareness program on Water shed management among the villagers.

A team from CSIR-NGRI visited Palakanmardi village and conducted Electrical Resistivity Survey; ERT survey was carried along five profiles in and around Palkanmardi village in order to locate suitable sites for construction of artificial recharge structures to recharge groundwater and dilute arsenic contamination. In all the profiles, the horizontal weathered mantle was seen only up to a depth of 20 to 25 m, below which very high resistivity hard rocks, possibly representing gneisses, are present. It is inferred based on high resistivity that these rocks hardly contain any fracture suitable for storing groundwater. Therefore, the water bearing zone in this area is expected to be confined only up to 25 m depth below ground level.

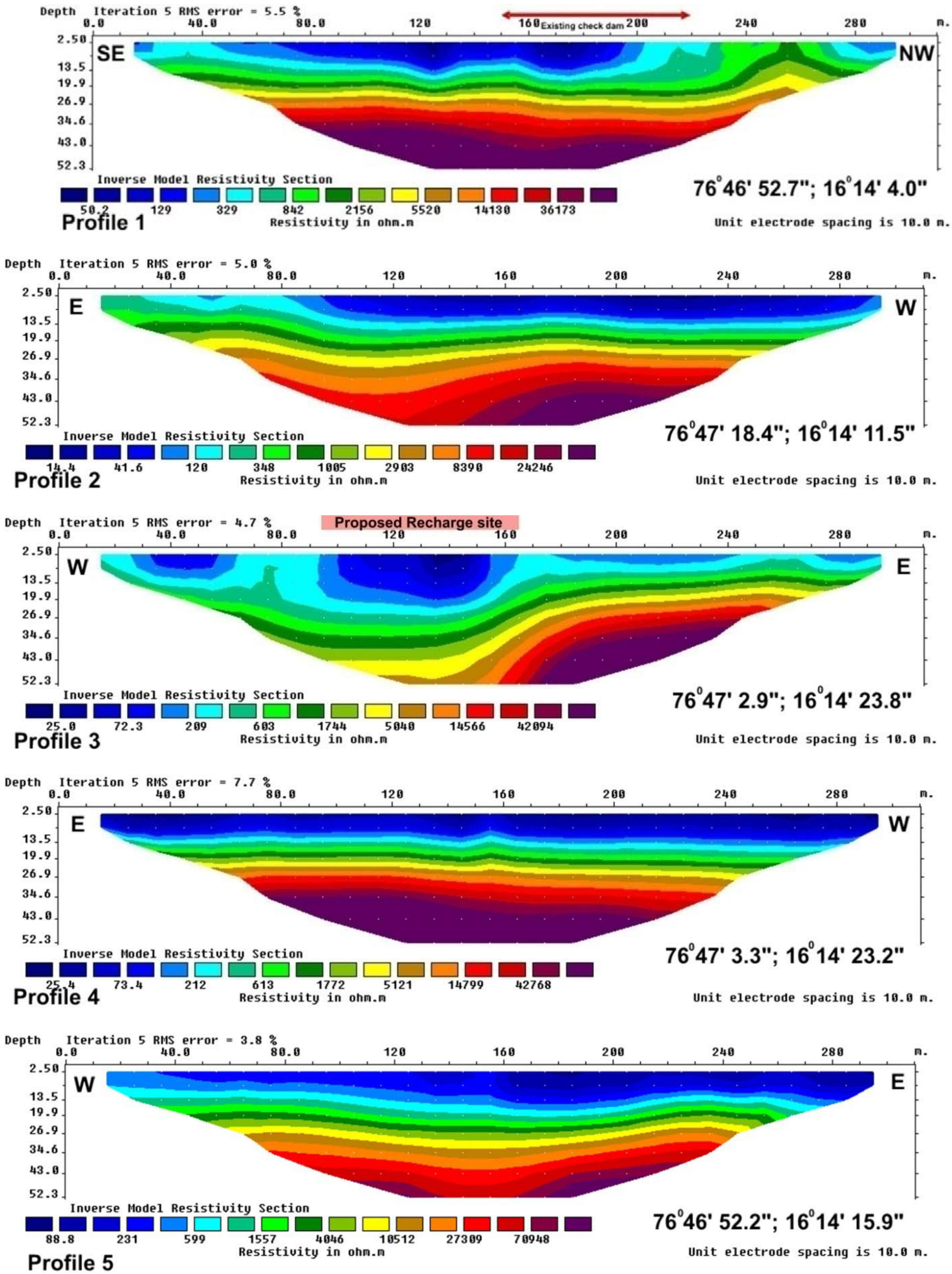

Figure 7.1 Comparing the results of all the profiles, the low resistivity pocket at the profile location between 90-170m of profile 3 is better and may be considered for construction of check dam.

Field Visits

CSIR-800 implementation is in the 400+ villages that make up the 28 TECHVIL clusters, so familiarity with field conditions is important as a monitoring mechanism of technology opportunities and effectiveness. Successful field visits were made to Bogalur TECHVIL in Tamil Nadu, Nalgonda, Jakaram and Prathipadu TECHVIL in Andhra Pradesh Ambiste TECHVIL in Maharastra, Unnao and Barabanki TECHVIL in Uttar Pradesh, and Palakanmardi TECHVIL in Karnataka

GVK Design Competitions

CSIR-CECRI, CSIR-IHBT and CSIR-IMMT announced a competition among the local architectural colleges and Engineering colleges to design the Gram Vigyan Kutir (GVK) for their respective TECHVILS and awarded prizes to the best design from the entries received.

In particular, CSIR – Bogalur received and reviewed nine entries. Prof Ravindran, Gandhigram University chaired the meeting, and shortlisted 3 entries for ranking by DG. DG, CSIR ranked the three entries through Skype.

Program Visibility

Building Inauguration
CSIR-800 team moved to the CSIR-800 Coordination centre on 4th February 2013. The building was inaugurated by DG CSIR on 2nd September 2013.

CSIR-800 Website
CSIR-800 Program's website is now functional under the domain www.csir800.org. This portal is being used to advertise Design challenges and broadcast success stories.

Collaborations with Various Institutes

CSIR-800 collaborated with the National Institute of Design, Bangalore to attract designers to design rural technologies for the CSIR-800 TECHVIL. There was great enthusiasm among the students and the faculty of the institute.

One of the major goals of the CSIR-800 is to avail smokeless cooking systems in the villages, in this regard Indian Institute of Science, University of Agricultural Sciences and Pointec Pvt Ltd was approached for collaboration. Prof Mukunda and his team extended their support by willing to share and test the Smokeless chulha's designed by them. UAS and Pointec Pvt Ltd were interested in testing the BIOCHAR generated from the chulha as an organic fertilizer substitute.

Status Review Meet

CSIR-800 program status review was organized on 31 July 2013 and 1 Aug 2013 at the CSIR HQ. All implementing labs of CSIR-800 program presented the progress to the DG, CSIR. Some of the main outcomes of the review meeting are listed below,

1. Coordinators, AcSIR and CSIR-800, would list thematic titles for students to address in TECHVILS. DG suggested students from different labs could group together and address the same project titles.
2. DG interacted with Directors of CFTRI, IHBT, NBRI & CIMAP, CLRI, CGCRI, NEERI, NEIST and PG Rao to fast forward their TECHVILs.
3. DG suggested:

- Setting up a charitable fund account for CSIR-800 activities, inviting donations that carried tax benefits;
- Fitting out freight containers as a temporary solution until the GVK was built.

8

KNOWLEDGE PRODUCTS: PUBLICATIONS, PRESENTATIONS…..

Knowledge creation, knowledge enhancement, knowledge dissemination and knowledge management have been among the core activities of CSIR-4PI (erstwhile C-MMACS). Ever since its inception, CSIR-4PI (erstwhile C-MMACS) has maintained a high knowledge output in terms of publications and other scientific programmes, knowledge synthesis and exchange through conferences, workshops, brainstorming sessions, etc.

On the occasion of Silver Jubilee Year (1988-2013) CSIR-4PI (erstwhile C-MMACS) has brought out a publication ***"Compendium of Publications: Silver Jubilee Issue"*** *with collection of abstracts of all CSIR-4PI (erstwhile C-MMACS) publications since its inception. Also a* ***"Coffee Table Book'*** *to cover the events organised by CSIR-4PI (erstwhile C-MMACS) for the last 25 years with glimpses of the ongoing activities in CSIR-4PI (erstwhile C-MMACS) was brought out.*

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- *In-house Seminars/Lectures*
- *Guest Lectures*
- *Visitors at CSIR-4PI (erstwhile C-MMACS)*

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Conference/Workshops/Seminars/Scientific Meetings organized by CSIR-4PI (erstwhile C-MMACS)

Workshop on Inverse Problems and Applications (With Special Emphasis on High Dimensional Data Assimilation), 06 - 10 May 2013

Physical theories allow us to make predictions: given complete description of the physical system, we can predict the outcome of some measurements. This problem of predicting the result of measurements is called the forward problem. The inverse problem consists of using the actual result of some measurements to infer the values of the parameter that characterizes the system.

In this workshop we cover the basic requirement to understand the methods involved in solving a problem through inversion. We have speakers covering the advance techniques like Kalman filtering, 4D var and data assimilation techniques. All the five days we will have numerical problems and hands on sessions.

Technology Day Lecture, 11 May 2013

Technology Day Lecture delivered by Prof Ashok Misra, Former Director, Indian Institute of Technology – Bombay, and Chairman, Intellectual Ventures on Fostering Creativity and Inventions in Science & Technology, 11 May 2013.

Workshop on Harnessing Improved Weather and Climate Information for Renewable Energy Generation under Public Sector Linkages Program, CSIR-4PI (erstwhile C-MMACS) and TERI, Bangalore, 13-22 May 2013

The workshop on Harnessing improved weather and climate information for renewable energy generation was being organized under the AusAID Public Sector Linkages Program (PSLP) by Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia jointly with CSIR-4PI (erstwhile C-MMACS) and TERI Bangalore from 13-22 May 2013 at CSIR-4PI (erstwhile C-MMACS).

The objective of the workshop was to train participants about Conformal Cubic Atmospheric Model (CCAM) of CSIRO, Australia for its validation and application in India and to share information on renewable energy resource assessments over India and Australia. This 10-day capacity building workshop provided training on the use of a mesoscale atmospheric model for the purpose of assessing wind and solar resource. The workshop was based around the transfer of expertise built by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the use of weather/climate observations and in the development of regional modelling for the renewable energy sector, particularly using the CSIRO mesoscale model, CCAM

National Symposium on Recent Advances in Cyber Security (RACS), 6-7 June 2013

Cyber space is known for its inherent security vulnerabilities. The scale and sophistication of cyber threats continues to increase exponentially across the globe. Considering the high global and national significance of Cyber Security, CSIR-4PI (erstwhile C-MMACS) had organized a National Symposium on Recent Advances in Cyber Security (RACS) on 6th and 7th June 2013 at S R Valluri Auditorium, National Aerospace Laboratories. The main theme of the two day Symposium was "Security Dynamics of Indian Cyber Space and Associated Challenges". The primary objective of the Symposium was to bring together the Cyber Security community in the country to discuss the state-of-the-art in the domain including both research and practical aspects.

The program was unique to the fact that there were reputed speakers to address and provide comprehensive coverage of all most all areas of cyber security. About 150 participants from various Academic, Research (including about 20 CSIR laboratories), and private IT industries participated and benefited out from the presentations and discussions. The program was part of the silver jubilee celebration of CSIR-4PI (erstwhile C-MMACS).

ArcGIS Desktop Training as part of the GIS Laboratory 5-14 August 2013

GIS Application Laboratory in the Network Building developed under IAIMS project is now has Arc GIS 10.1 including four extensions (Spatial Analyst, Geo Statistical Analyst, Data Interportability and 3D Analyst) with four licenses. As part of this, ESRI has given a seven-day training on GIS (4 days for basic and 3 days for specific applications) at CSIR CMMACS.

Silver Jubilee International Conference on Computational and Data Intensive Science, 26 - 28 August 2013

CSIR-4PI (ERSTWHILE C-MMACS) invited the international scientific community to the conference in Bangalore to discuss latest developments in the Computational and Data Intensive Paradigm of research. The main aim is to bring together experts working on these fields using vast amount of data and high performance computing. The conference will feature a structured program encompassing all branches of data intensive science and high performance computing. Highlights of the conference include keynote presentations by world-leading experts, contributed papers.

HPC Workshop, 29 August 2013

As an extension of the International Conference on Computational and Data Intensive Science, a One Day HPC Workshop was organized for the CSIR Scientists to get acquainted with the usage of the 360TF supercomputer, so that the facility can be used by them remotely. Apart from CSIR-4PI (ERSTWHILE C-MMACS) Intel provided training to the participants about maximizing the performance of the system.

Workshop on Seismic Vulnerability and Risk Assessment, 21-26 October 2013

The workshop was organized under the ongoing Indo-Norwegian project "Earthquake Hazard and Risk Reduction on the Indian Subcontinent (RRISC)". The objective of the workshop was to develop capacity building among young students in particular from earthquake engineering background to teach them a broad aspects of seismic desgin of buildings, their responses to different kind and size of earthquakes, seismic attenuation and ground motion prediction equations, different building typology and scenario ground motion modlling. Fifteen final year B Tech students from BMS college of Engineering as recommended by college and five students from CSIR-4PI (erstwhile C-MMACS) had attended the workshop. The lectures and tutorials were condcuted in the morning session and the field trip was arranged in the afternoon to see various building typologies in Bangalore city. Prof Raghunath, Civil Engineering Department of BMS College also accompanying the students.

Celebration of International Open Access Week, 24th October 2013

CSIR-4PI (erstwhile C-MMACS) & CSIR National Aerospace Laboratories jointly celebrated the International Open Access Week on Thursday 24th October 2013 Conference Hall, Network Building, CSIR-4PI (erstwhile C-MMACS), Bangalore. The programme started with an invocation by Mr G N Mohapatra and followed by welcome address by Prof Seshu, Head, CSIR-4PI (erstwhile C-MMACS) and address by Dr Girija Gopalratam, Advisor, Management & Administration, NAL Dr Poornima Narayan, Head, ICAST, NAL presented a lecture on CSIR Initiatives and Dr Francis Jayakanth, J R D Tata Library, IISc, Bangalore delivered his talk "What is Open Access and why should we care? " He emphasized that OA is an excellent model of publishing for researchers, teachers, and academician. OA helps developing countries to get access the latest developments in global context. He also spoke about author's concerns and copyright issues, effective way to achieve OA.

Vigilance Awareness week 2013

The Valedictory function of Vigilance Awareness Week - 2013 was organised by CSIR – NAL and CSIR-4PI (erstwhile C-MMACS) on Thursday, the 31st October, 2013 at S R Valluri Auditorium, NAL, Bangalore. Prof P Seshu, Head, CSIR-4PI (erstwhile C-MMACS) welcomed the gathering and informed that the main purpose of observing the week dedicated to Vigilance Awareness is to rededicate ourselves and to reaffirm our commitment to see that public service in our country is rendered with dedication, sincerity and honesty. The Chief Guest Dr Shalini Rajneesh, IAS and Secretary to Government of Karnataka, Department of Personnel and Administrative Reforms and also incharge of implementing Karnataka Guarantee of Services to Citizens Bill, 2011 popularly known as “Sakala”, in her lecture on “Reinventing Government” gave brief details of the “SAKALA” Act. Shri Shyam Chetty, Director, presided over the function. He said that this year the theme of observing Vigilance Awareness Week is “Promoting Good Governance – Positive Contribution of Vigilance”. Shri Shyam Chetty, Director, CSIR – NAL and Prof P Seshu, Head, CSIR-4PI (erstwhile C-MMACS) distributed prizes for the winners of various competitions conducted in connection with the Vigilance Awareness Week for the students of Kendriya Vidyalaya, NAL and the employees of NAL and CSIR-4PI (erstwhile C-MMACS).

DST-PAC Atmospheric Science Meeting, 29-30 November, 2013

The Department of Science & Technology (DST), Government of India Fourth Meeting of the Programme Advisory Committee on Atmospheric Sciences (PAC-AS) was held during 29 – 30 November, 2013 at CSIR CMMACS. Head, CSIR CMMACS welcomed the DST PAC Board experts. About 25 Principal Investigators from all over India presented their new project proposals and progress of existing project proposals during the two day DST-PAC review meeting.

Women's Day Celebrations, 7 March 2014

CSIR - National Aerospace Laboratories and CSIR-4PI (erstwhile C-MMACS) organized the Women's Day Celebrations on 7th March 2014 at S R Valluri Auditorium. This year, two eminent personalities from diverse fields were invited as guests of honour: Ms Vatsala Watsa, IAS (Retd) Former Additional Chief Secretary, GoK and Ms Roopa Iyer, renowned Dancer, Choreographer and Movie Director. Dr Poornima Narayan, Chairperson, International Women’s Day Celebrations, NAL welcomed the gathering and introduced the chief guests to the audience by highlighting the multi-faceted achievements of the guests of honour. Lecture on “Women as Administrators-Challenges and Opportunities” was presented by Ms Vatsala Watsa in an extremely impressive, yet informal manner. Ms Roopa Iyer talked on the importance of Satya & Dharma. She stressed that a woman should not fight for equality, instead she should strive to scale greater heights to automatically earn the respect from all. In his presidential address, The Director, NAL remarked that he was amazed at the level ladies can multitask & deliver. He thanked the guests for their presence and for delivering such motivating lectures.

Invited Talks

Anil Kumar V, Trends in Supercomputing, National Conference on Scientific Computing (NCSC-2013), Indian Institute of Information Technology (IIIT), Trivandrum, 20-21 June 2013.

Anil Kumar V, DDoS Attacks on the Internet: The Challenges and Countermeasures, TEQIP sponsored Industry Institute Interaction Programme, PSG College of Technology, Coimbatore, 22-23 November 2013.

Goswami P, Weather Informatics for New Age Applications, World Meteorological Day, Special Lecture, Department of Physics, Bangalore University, Bangalore, 19 March 2014.

Patra G K, High Performance Secure Communication Protocol using Public Key Cryptographic Techniques based on Neural Networks, International Conference on Multimedia Processing, Communication and Information Technology, JNN College of Engineering, Shimoga, 19-21 December 2013.

Patra G K, Mathematical Models in Designing Cryptographic Primitives: An Inter-disciplinary Approach, Workshop on Mathematical Modelling in Computer Science and Information Technology, Vellore Institute of Technology, Vellore, 20-22February, 2014,

K Rajendran, Role of Ocean and Atmospheric Dynamics in Climate change, 1st Climate Science and Policy Workshop, IIT Bombay, 6-7 March 2014.

K Rajendran, Glaciers, Paleo-climate Conditions, International Conference on Climate Change and the Himalayas: Current Status and Future Perspective, CSIR NISCAIR, New Delhi, 28-31 October 2013

Sajani Surendran, Climate change and the Indian monsoon, 1st Climate Science and Policy Workshop, IIT Bombay, 6-7 March 2014

Senthilkumar V, National Workshop on Synthesis and Characterization of Nanomaterials (NWSCN-14), V O Chidambaram College, Thoothukudi, 25 -26 February 2014

Swathi P S, Marine Ecosystem Modelling and Debugging Parallel Codes, Summer School on Fundamentals of Ocean Modelling on Global and Regional Scales, INCOIS Hyderabad, 5-14 August, 2013

Shukla A K, Homotopy Analysis Method for Nonlinear Differential Equations with a Non-Homogeneous Term, National conference on Recent Advancements in Numerical Methods and its Applications 2014, University of Pondicherry, January 27, 2014

In-house Seminars/Lectures

Prakasa Rao E V S, C-MMACS, Assessment and Modelling of Agricultural System Processes for Climate Change Adaptation, 27 September 2013

Swathi P S, C-MMACS, A Brief Introduction to IPCC's Assessment Report 5 (AR5), 13 November 2013

Mahfooz Sheikh M, C-MMACS, FPGA based Solutions— A Perspective, 27 March 2014

Guest Lectures

Attreyee Ghosh, IISC Bangalore
Understanding the Deep Earth: Lessons from Geodynamic Modeling, 25 April 2013

Madhulika Bhati, NISTADS, New Delhi
Chemical Processes in the Environment: Modelling and Application, May 2 2013

Prashant Mandlik, UDC, USA
Phosphorescent Organic Light-Emitting Diodes (PHOLEDs), May 9 2013

Ashish Lele, NCL, Pune
From Macromolecular Structure to Polymer Processing: Bridging length and time scales, 16 May 2013

Raghu Murtugudde, ESSIC, USA
Dynamic-Thermodynamic Coupling and Ecosystem-Biogeochemical Variability in the Tropics, May 17 2013
Climate Change and the Cooperative Species, May 20 2013

Rajendran L, DM, Tamil Nadu,
Nonlinear Reaction-Diffusion Equations in Physical Chemistry, June 13 2013

Bharath Shekkar, GDCSM, USA
Modelling Seismic Waves in Viscoelastic, Anisotropic, Heterogeneous Media, 20 June 2013

Rahul Mangharam, CISU, USA
Closing the Loop with Cyber-Physical System Modelling, June 27 2013

Surajit Sen, PSU, USA
Strong Nonlinearity - Solitary Waves, Breathers and Quasi-Equilibrium and Why We Care...., 25 July 2013

Asha Gopinathan, MRDG, Bangalore
Simulation of the Brain - From Neurons to Large Scale, 5 September 2013

Jindal V K, Punjab University
Interesting Observations of Theoretical Investigations in Fullerenes, Carbon Nanotubes and Graphene, 3 October 2013

Rao J S, ALTAIR, Bangalore
Multi-physics based Optimization Approach to the Design of Advanced Turbomachinery, 7 October 2013

Gopalakrishnan S, IIT, Mumbai
Development of Efficient Galerkin Methods for Modeling Tsunamis and Storm-Surges, 21 November 2013

Prasad K, Multi-Tech Systems, USA
M2M (Machine-to-Machine) communications and "Internet of Things" - an Industry Perspective, 22 November 2013

Dharmaraju R, Centre for Disaster Management, Mysore
R & D Strides for Landslide Risk Mitigation, 4 March 2014

Visitors at C-MMACS

Tilak Krishna Mahesh Agerwala, VP, Systems/IBM, USA, 03 April 2013.

Shamjith, C-DAC, Bangalore, 9, 15 & 17 April 2013.

Arunachalam, C-DAC, Bangalore, 10 & 16 April 2013.

Attreyee Ghosh, Assistant Professor, IISc Bangalore, 25 April 2013.

Lan David Locker, Managing Director, Zephir Ltd, UK, 08 May 2013

Mohar Chattopadhyay, Research Scientist, CSIRO, Australia, 13 to 22 May 2013.

John Mc Gregor, Don Gunasekara, Alberto Troccoli, Scientist CSIRO, Australia, 13 to 22 May 2013.

Raghu Murtugudde, Professor, University of Maryland, 15 to 20 May 2013.

Mckeon Gregory Keith, APAC, Service Manager, SQI, Australia, 14 June 2013.

Parul Trivedi, Ahmedabad, 12 to 20 June 2013.

Bharath Shekar, CSM, USA, Bangalore, 20 June 2013.

Rahul Mangharam, CISU, USA, 27 June 2013

Bobby Philip, IISc, Bangalore, 8 July 2013.

Mohan Ram, DG, Ernet India, 11 July 2013.

Shri Kamalesh, Bangalore, 11 July 2013.

N L Sarda, IIT, Bombay 11 July & 17 December 2013

Subrata Karuna, C-DAC, Bangalore 12 July 2013.

Chandrashekar, Director, CSIR-CEERI, Pilam, 17 July 2013.

Viswajanani, CSIR-PPD, New Delhi, 17 - 19 July 2013

Bharadwaj, IISc Bangalore, 17 July 2013.

Surajit Sen, New York, 22 to 26 July 2013.

Devin Jensen, Vice President Altair, USA, 21 August 2013.

William Matthew Braithwaite, Senior Engineer, NVIDIA, 27 August 2013.

B Bhattacharjee, NDMA, New Delhi, 29 August 2013.

Huseyin Levent Akyil, Software Engineer, Intel, Bangalore, 17 September 2013.

Werner Krotz Wogel, Marketing Engineer, Intel, Bangalore, 17 September 2013.

Barry Edward, Director of Sales, USA, 18 September 2013.

Daniela Kuehn, Researcher, NORSAR, Berlin 21 September 2013.

Malolan R Cadambi, Greenshore Energy Pvt Ltd, 4 October 2013.

C V S Prakash, Mr Nagaraj Acharaya, Mr Deepak, Greenshore Energy Pvt Ltd, 4 October 2013.

C Amarnath, IIT Bombay, 7 October 2013.

Rao J S, ALTAIR**,** Bangalore, 7 October 2013.

Daniela Kuehn, Researcher, NORSAR, Berlin 21 October 2013.

Dominik Lang, Sr Research Engg, NORSAR, 21 October to 01 November 2013.

Gil Briman, VP, Mellanox Technologies Inc, 13 November 2013.

Marc Clifford Sultzbaugh, Senior VP, Mellanox Technologies, 13 November 2013.

Shaheed Jawahar, Chennai, 19 November 2013

K Prasad, Engg, Manager, Multi-Tech Systems, India, 22 November 2013.

S Gopal Krishnan, IIT, Bombay, 21 to 22 November 2013.

P K Mohanty, Additional Chief Secretary, Govt of Kerala, Trivandrum, 10 December 2013.

Sreekantan Nair, Director, Environment Directorate, Kerala, 10 December 2013.

Ravi S Nanjundiah, CAOS, IISc Bangalore, 10 December 2013.

Sangeetha Iyer, Amritha School of Engineering, Bangalore, 17 December 2013.

Valentine Anantharaj, Arthur Sanford Bland, Jeffrey Allen Nichols, Arthur Bernard Maccabe, Xiaolin Cheng, R&D Staff, Oak Ridge National Laboratory, USA, 19 December 2013.

Yukimasa Adachi, Researcher, MRIJM, 13 to 23 January 2014.

Greg McKeon, Director, Services, SGI Asia Pacific, 04 February 2014.

Dominik H Lang, Sr Research Engg, Germany, 19 February 2014.

Ramesh Venkata Peri, Architect, S/W Dev. Tools, Intel, America, 19 March 2014.

Sanjiv Motichand Shah, General Manager, Technical S/W Tools, Intel, Kenya, 19 March 2014.

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CSIR-4PI (erstwhile C-MMACS) ACADEMIC PROGRAMME

In keeping with its objective of developing skill and expertise in Mathematical Modelling and Computer Simulation in the country, CSIR-4PI (erstwhile C-MMACS) maintains an active academic programme. The activities span the entire spectrum from Ph D guidance to undergraduate/postgraduate student projects to specialized courses. The recently introduced Student Programme for Advancement of Research Knowledge (SPARK) is intended to provide a unique opportunity to bright and motivated students of reputed Universities to carry out their major project/thesis work and advance their research knowledge in mathematical modelling and simulation of complex systems. Students and professionals from a wide spectrum of organizations including industries across the country have been benefiting from our various academic programmes over the years. CSIR-4PI (erstwhile C-MMACS) is very actively engaged with the AcSIR (Academy of Scientific and Innovative Research) PhD program in Mathematical and Information Science.

Inside

- *Ph D Programme*
- *Thesis/Project by M. Tech/BE/MCA students*
- *Faculty Participation*

Ph D Programme

Anil Earnest

Sunilkumar T C, (AcSIR), Geodynamics of Plate-Boundary Zones
Silpa K, (AcSIR), Crustal Deformation and Earthquake Cycles

Goswami P

Gouda K C, Multi-scale Modelling and Forecasting of Monsoon Weather and Processes
Mohapatra G N, Impact of Local Climate Variability and Anthropogenic Processes in Extreme Weather Events over India
Sumana Sarkar, Multisector Application of Seasonal Forecast: Crop yield, Vector-Borne Diseases and High Impact Weather Events over India
Kantha Rao, Multi-scale Modelling and Analysis of Surface and Soil processes over the Indian Region.
Shiv Narayan Nisad, Analysis and Modeling of Sustainability over India under Different Scenarios of Climate Change and Socio-Economic Conditions
Shaktidhar Nayak, (AcSIR), Development and Evaluation of a Model Configuration for Local Climate Projection over India
Eswari V, (GSI), Analysis of Impact of Climate Change on Wind Regimes and Implications for Wind Energy potential over the Monsoon Region.

Parvez I A

Sushant Shekhar, (AcSIR), Seismic Wave Propagation in Non Homogeneous Anisotropic Incompressible Media.
Ramiz Raja Mir, (AcSIR), Evolution of Crustal and Mantle Structure in Kashmir Himalaya.

Parvez I A (Co-guide)

Parul Trivedi, (Saurashtra University), Source Modelling and Seismic Hazard Study in Kuchcha Region

Patra G K

Siddhartha Saha, Security in a Distributed Environment

Patra G K and Sarda N L (IIT Bombay)
Ashapurna Marndi, (AcSIR), Scientific Data Analysis and Data Intensive Research

Sangeeta Iyer K and ***Patra G K (Co-guide*****)**

Santhana Lakshmi S**,** Design of Cryptographic Protocols using Computational Intelligence Techniques
Supriya M, Trust Building in Distributed Storage using Cryptography.

Prathap G and Pradhan S C (IIT KGP)

Senthilkumar V, Small scale effect on Structural Behaviour of Carbon Nanotubes

Rajendran K

Ipsita Putatunda, (AcSIR), Methods of Physical Assimilation for Short Range Numerical Weather Prediction.
Jayasankar C B (AcSIR), Climate Change Modeling Studies

Rajendran K (Co-guide)

Kulkarni Shashikant (IIT Bombay), Downscaling over Monsoon Region

Ramamohan T R and Srinivas S

Anant Kant Shukla, Homotopy Analysis Method for Nonlinear Differential Equations with a Non-Homogeneous term
A Subramanyam Reddy, Heat and Mass Transfer Effects on a Viscous Fluid in Flow Regions with Expanding or Contracting Walls

Ramesh K V

Alfred Johny, Simulation of Indian Summer Monsoon using CMIP5 Climate Simulations
Safeer K B, Evaluation of Upper Ocean Variability Simulated by IPCC Climate Simulations
Edwin Raj E, (UPASI TRF TRI) Climate Impact Assessment on Tea Production over South India

Sajani Surendran (Co-guide)

Nithin Patil (IIT Bombay), Aerosol Radiative Forcing and Impact on Climate

Sridevi Jade

Shrungeshwar T S, Research Topic: Active deformation and water vapor studies in Indian subcontinent

Sridevi Jade and Ashok Kumar

Prakash Burman (Tezpur Univeristy), Estimation of Precipitable Water Vapor and Crustal deformation in Northeast India

Sridevi Jade and Malay Mukul (IIT Bombay)

Kutubuddin Ansari (IIT Bombay), Modelling of Global Positioning System (GPS) based surface defromation using Dislocations
Ashok Shaw (IIT Bombay), Geological and Contemporary deformation in the internal thrust sheets of the highest Darjeeling Sikkim Himalayas

Ravi Babu (VIT) and ***Tejpal Singh (Co-guide)***
Nisha (VIT), Remote sensing/GIS applications in mineral spectra identification

Vijayan M S M

Shimna K, (AcSIR), seismo-ionospheric coupling and upper atmospheric perturbations induced by acoustic gravity waves

Vijayan M S M and Senthilkumar V (Co-guide)

Lalit Kumar, (AcSIR), Finite Element Modelling of deformation of the Indian plate

Ashok Kumar and ***Vijayan M S M (Co-Guide)***

Jagat Dwipendra Ray, Space based geodetic study on active tectonics and seasonal perturbations in interseismic deformation of North-East India

Thesis/Project by BE/M. Tech/MCA students

Anilkumar V

Analysis of correlation DDOS attacks on wired networks, Arnika Tripathi (M Tech), NIT Surathkal, July, 2013
Correlated low-rate attacks on router buffers, Pavithra J (M Tech), Dayananda Sagar College of Engineering, Bangalore, August 2013

Mahapatra G N

Development of software for image processing using satellite data, Mohan, Thimeya, Prajwal, Bhatrat, (BE), VTU Karnataka, June 2013.
Software for spatio-temporal climate data analysis using remote sensing data, S Redappa (MCA), Dayananada Sagar College, Bangalore, July 2013

Parvez I A

Seismic data analysis based on GUI and generic mapping tools, Reena Arya, Devi Ahilya Vishwavidyalaya, Indore

Patra G K

Design of word based stream cipher using neural cryptography, Nandini G, JNN College of Engineering, Shimoga, September 2013
Analysis of public key cryptography based on neural cryptography and its application, Chitra R, SJBIT, Bangalore, August 2013
Enhancing trust of cloud storage services using zero knowledge protocols, Asha R, Athiya Shereen, Ayesha Noorain and Ramendra Kumar, KSN Institute of Technology, May 2013
Cloud security assurance, Tejas Rao, NIT Surathkal, July 2013

Ramesh K V

Modelling the impact of climate change on available solar electricity resource potential, Aswin V S, IIITMK, Thiruvanathapuram
Impact modelling of climate change on hydroelectricity production, Revathy Rajakumaran, VIT, Vellore.
Understanding changing trends in global mean temperature, Pravat Kumar Nayak
Simulation of relationship between water discharge rate and instantaneous velocity, Suraj K, Chandni C V, Vidhulakshmi K U, IIITMK, Thiruvanathapuram

Rakesh V

Impact of satellite observed sea surface temperature on forecasting of tropical cyclones over the Indian Ocean, Shruti Jha, Devi Ahilya University, Indore
High resolution numerical simulation of high impact weather systems, Anand M, Cambridge Institute of Technology, VTU, Bangalore

Senthilkumar V

Symbolic computation for carbon nanostructures using MAXIMA, Rekha Penmatsa (M Tech), MVJ College of Engineering, Bangalore
Buckling behavior of carbon nanotubes using molecular simulation, Ashutosh Agarwal (M Tech), School of Nanoscience and Technology, NIT Calicut
Vibration analysis of 2-noded and 3-noded bar with mesh distortion using python programming, M Sreeja (M Sc), IIITM, Kerala
Wave propagation of nanorods/nanotubes, Mohan Sriram Nayaka (M Sc), IIITM, Kerala
Stress analysis of 2-noded and 3-noded bar with mesh distortion using python programming Nicy Varghese (M Sc), IIITM, Kerala
Element distortion of 8-noded, 9-noded, 16-noded finite elements using ADINA, V Lingesh (BE), Kumaraguru College of Technology, Coimbatore
Dynamic analysis of flat plates, Pranav Sridhar (B.E) Amrita Vishwa Vidyapeetham, Bangalore

Tejpal Singh

Digital elevation models, Ateev Chopra (BTech), VIT University, Chennai,

Vijayan M S M

Software to calculate ionospheric total electron content using GPS, Gloria Varghese, IIITM-Kerala
Geospatial data mining: Database in open platform, Rajeswaran S, Adhiyaman College of Engineering, Hosur.
GPS based estimation of co-seismic crustal deformation due to 11th April, 2012 Indian ocean strike-slip earthquakes, Chandramouli A R., GokulmK, Mangala Surya S S and Sivasanari T, Bharathidasan University, Trichy.

Faculty Participation

Academy of Scientific and Innovative Research

Anil Earnest, Earthquake and Volcano Deformation, January 2014

Parvez I A, Research Methodology, January 2014

Patra G K, High Performance Scientific Computing, January 2014

Ramamohan, T R, Introduction to Non-linear Dynamics, January 2014

Ramesh K V, High Performance Computing, August 2013

Senthilkumar V, Advanced Numerical Techniques**,** August 2013

Vijayan M S M, GNSS Remote sensing for Geodesy, August 2013

Workshop on Inverse Problems and Applications (With Special Emphasis on High Dimensional Data Assimilation), 06 - 10 May 2013

Gaur V K

06/05/2013: Modelling Uncertainty: Random Walk and the Binomial distribution; Poisson and Gaussian distributions
Matrices: Characteristic Equation, Eigenvalues and invariability of a matrix;

07/05/2013: Vector Spaces and subspaces; Matrix inverses
Formulating Inverse problems; well posed problems and notions of existence, uniqueness, stability and regularization
Over, under and Mixed determined Inverse problems. Quality of solutions and experiment design Bayes Inversion and Kalman Filter

09/05/2013: Kalman filter of higher orders, Adjoint methods, 4D Var Data Assimilation

Indira N K

06/05/2013: Rapid review of probability theory; Marginal, Joint and conditional probabilities; notions of independence. Bayes Theorem and applications

Swathi P S

06/05/2013: Numerical problems and Hands on session

07/05/2013: Numerical Problems and Hands on session

09/05/2013: Kalman filter of higher orders, Adjoint methods, 4D Var Data Assimilation
Numerical Problems and Hands on session

10/05/2013: Carbon Flux estimation
Numerical Problems and Hands on session

Thangavelu R P

06/05/2013 Numerical problems and Hands on session

ICTP Summer School, INCOIS, Hyderabad, 5-13, August 2013.

Swathi P S, Fundamentals of Ocean Climate Modelling at Global and Regional Modelling

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COLLABORATIVE PROGRAMMES & PROJECTS

Multi-institutional, national and international collaborative research programmes have been the core of CSIR-4PI (erstwhile C-MMACS) overall research. CSIR-4PI (erstwhile C-MMACS) to-day has active collaboration with a number of national and international institutions.

Inside

- *CSIR Network Projects*
- *CSIR Non-Network Project*
- *12th Five Year Plan Projects*
- *11th Five Year Plan Projects*
- *CSIR Empower Project*
- *Grant-in-aid Projects*
- *Collaborative Projects*
- *In House Project*

CSIR Network Projects

Integrated Analysis for Impact, Mitigation and Sustainability (IAIMS): Regional Climate Modelling at Decadal Scale – *PI: Goswami P*

Nodal Lab: CSIR-4PI (erstwhile C-MMACS)

Network Partners:

CSIR Central Institute of Medicinal and Aromatic Plants (CIMAP)
CSIR Indian Institute of Chemical Biology (IICB)
CSIR Indian Institute of Chemical Technology (IICT)

Setting up of State-of-the-art HPC Facility for CSIR, *PI: Thangavelu R P and Mudkavi V Y*

Network Partners:

CSIR National Aerospace Laboratories (NAL)

12th Five Year project

Advanced Research in Engineering & Earth Sciences (ARiEES): Data Intensive Modelling and Crowd Sourcing Approach - *Nodal officer: Sridevi Jade,*

Nodal Lab: CSIR-4PI (erstwhile C-MMACS)

Participating Labs:

CSIR National Aerospace Laboratories (NAL)
CSIR National Institute of Oceanography (NIO)
CSIR National Geophysical Research Institute (NGRI)
CSIR Central Building Research Institute (CRRI)
CSIR North East Institute of Science and Technology (NEIST)

Indian Aquatic Ecosystems: Impact of Deoxygenation, Eutrophication and Acidification (Indias Ideas) Physical Sciences Cluster: **Modelling and Simulation of Subsurface Oxygen Distribution in the North Indian Ocean, *PI: Sharada M K, Co-PI: Swathi P S***

Nodal Lab: CSIR National Institute of Oceanography (NIO)

Participating Lab:

CSIR-4PI (erstwhile C-MMACS)
CSIR Centre for Cellular and Molecular Biology (CCMB)
CSIR National Geophysical Research Institute (NGRI)

Probing The Changing Atmosphere and its Impacts in Indo-Gangetic Plains and Himalayan Regions (Aim-IGPHim), *PI : Swathi P S, Co-PI: Indira N K*

Nodal Lab; CSIR National Physical Laboratory (NPL)

Participating Lab:

CSIR-4PI (erstwhile C-MMACS)
CSIR Central Road Research Institute (CRRI)
CSIR Institute of Himalayan Bioresource Technology (IHBT)
CSIR Institute of Minerals and Materials Technology (IMMT)
CSIR National Botanical Research Institute (NBRI)
CSIR National Environmental Engineering Research Institute (NEERI)
CSIR North East Institute of Science and Technology (NEIST)

Engineering of Disaster Mitigation and Health Monitoring for Safe and Smart Built Environment (EDMISSIBLE): GPS based Integrated Landslide Modelling for Realistic Hazard Assessment, *PI: Sridevi Jade, Co-PI: Vijayan M S M*

Nodal Lab: CSIR CBRI

Participating Lab:

CSIR-4PI (erstwhile C-MMACS)
CSIR Central Road Research Institute (CRRI)
CSIR Central Scientific Instruments Organisation (CSIO)
CSIR National Environmental Engineering Research Institute (NEERI)
CSIR North East Institute of Science and Technology (NEIST)
CSIR Central Glass & Ceramic Research Institute (CGCRI)
CSIR Electronics Electronics Engineering Research Institute, (CEERI)
CSIR Central Mechanical Engineering Research Institute (CMERI)

Genomics and Informatics Solutions for Integrating Biology (GENESIS), ***PI: Thangavelu R P***

Nodal Lab: CSIR IMTECH

Participating Lab:

CSIR Centre for Cellular and Molecular Biology (CCMB)
CSIR Central Drug Research Institute (CDRI)
CSIR-4PI (erstwhile C-MMACS)
CSIR Central Leather Research Institute (CLRI)
CSIR Central Institute of Medicinal and Aromatic Plants (CIMAP)
CSIR-Institute of Genomics & Integrative Biology (IGIB)
CSIR Institute of Himalayan Bioresource Technology (IHBT)
CSIR Indian Institute of Chemical Biology (IICB)
CSIR Indian Institute of Chemical Technology (IICT)
CSIR Indian Institute of Toxicology Research (IITR)
CSIR National Chemical Laboratory (NCL)
CSIR National Botanical Research Institute (NBRI)
CSIR Institute for Interdisciplinary Science and Technology (NIIST)
CSIR Head Quarters

Development of suitable design methodology for extraction of coal at greater depths (>300 m) for Indian geomining conditions (Deep Coal), ***PI: Patra G K***

Nodal Lab: CSIR CIMFR

Participating Lab:

CSIR Central Mechanical Engineering Research Institute (CMERI)
CSIR-4PI (erstwhile C-MMACS)
CSIR National Geophysical Research Institute (NGRI)

11th Five Year project

Visualization Infrastructure for Scientific Insight by Observation and Navigation (VISION) – ***PI: Patra G K***

Augmentation of CSIR Multi-tera FLOPS Supercomputing Facility: ***PI: Anil Kumar V***

CSIR Empower Project

Quantitative Estimation of the Prevalence and Nature of IP Spoof based Denial-of-Service Attacks in the Indian part of the Internet through Backscatter Analysis of Network Telescope Data, ***PI: Anil Kumar V***

Grant-in-aid Projects

Analysis of Indian National GNSS Network Data for Reference Frame Realisation, PWV and TEC Computation – *PI: Sridevi Jade, Co-PI: Vijayan M S M*

Plate Kinematics Geodynamics and Earthquake Occurrence Processes in the Andaman Nicobar Region Using Real Time Geodetic and Seismological Observations and Earthquake Awareness Centre at Port Blair, MoES – *PI: Sridevi Jade*

Collaborating Institutions:
CSIR National Geophysical Research Institute, Hyderabad

Future Climate Change Projection for Kerala using High Resolution Climate Model, Department of Environment and Climate Change, Government of Kerala, – *PI: Rajendran K, Co-PI: Sajani Surendran*

Collaborating Institutions
Divecha Centre for Climate Change (DCCC)
Indian Institute of Science (IISc), Bangalore

Impact of Physical Assimilation of Vertical Profiles of Latent Heating and Moisture on Short-Range Weather Forecasting, ISRO Megha-Tropiques Mission Project – *PI: Rajendran K,* *Co-PI: Srinivasan J*

Collaborating Institutions
Indian Institute of Science (IISc), Bangalore

Modelling of Marine Biogeochemical Cycles in the Indian Ocean, MOES – *PI: Sharada M K*

Shock Mitigation using Tapered Granular Alignments, ARMREB, DRDO – *PI: Krishna Mohan T R*

Indo-Norwegian Network Project: Earthquake Hazard and Risk Reduction on the Indian Subcontinent (RRISC), Norwegian Embassy in India – *PI: Parvez I A*

Seismic Hazard and Risk Assessment based on Pattern Recognition: Himalayas and Adjacent Territories, DST-RFBR – *PI: Parvez I A*

Crustal and Mantle Structure along the East-West Corridor across Dharwarcraton for Constraining Models of the Crustal Evolution, DST – *PI: Parvez I A*

Integrating Disease Prediction with Weather and Climate Models Seamlessly, British Council, UKIERI – *PI: Goswami P, Co-PI: Gouda K C*

Industrialization of Weather Informatics, Services and Technologies, KSNDMC, *PI: P Goswami*

Investigation of Mega City Effects on the Genesis and Intensity of Extreme Rainfall Events and their Impact, DST - *PI: S Himesh, Co-PI: P Goswami*

Role of Background Error Statistics in Meso-scale Data Assimilation, DST - *PI: V Rakesh, Co-PI: P Goswami*

Extreme Weather and Climate Events in the 21st Century Projections from Different Climate Scenario, DST - *PI: K V Ramesh, Co-PI: P Goswami*

Collaborative Projects

Climate Change and Variability: Modeling, Analysis and Downscaling in the context of Indian Monsoon, India – *PI: Rajendran K, Co-PI: Sajani Surendran*

Collaborating Institutions
Divecha Centre for Climate Change (DCCC)
Indian Institute of Science (IISc), Bangalore
Meteorological Research Institute (MRI/JMA)

Aqua-Planet Experiment Project: WCRP/WGNE Project – *Co-PI: Rajendran K*

Collaborating Institutions:
Meteorological Research Institute (MRI)

Active Tectonics of the Darjeeling-Sikkim Himalayas using Global Positioning System (GPS) based Geodesy – *PI: Sridevi Jade, Co-PI: Malay Mukul*

Collaborating Institutions:
IIT Mumbai

Operation of Permanent and Campaign Mode GPS Stations for Quantification of Tectonic Deformation Field in Himalayan Terrain – *PI: Sridevi Jade and Kireet Kumar*

Collaborating Institutions:
GBPHIED, Almora

In-house Projects

Empirical modelling and Relationship of the Primary Productivity with Other Ocean Parameters in the Indian Ocean *- PI: Indira N K*

Monitoring Continuously Operating CSIR-4PI (erstwhile C-MMACS) GPS Station Located in the IISc Campus and Real-Time Operational Data Hub at CSIR-4PI (erstwhile C-MMACS), *PI: Sridevi Jade.*

Site-specific Ground Motion Modelling And Microzonation Studies in Delhi City, *PI: Parvez I A*

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TEAM CSIR-4PI (erstwhile C-MMACS) – NEWS AND UPDATES

The greatest strength of CSIR-4PI (erstwhile C-MMACS) is "Team CSIR-4PI (erstwhile C-MMACS)", the dedicated group that takes CSIR-4PI (erstwhile C-MMACS) forward. One of the smallest of CSIR laboratories, CSIR-4PI (erstwhile C-MMACS) today is a young and vibrant institution of research.

Inside

- *Team CSIR-4PI (erstwhile C-MMACS)*
- *Awards/Honours/Recognition*
- *Services on External Committees/Membership of Professional Bodies*
- *Deputations*

Staff List

Head
Seshu P (Till 31 January 2014)
Ramamohan T R (From 1 February 2014)

Honorary Emeritus Scientist
Gaur V K
Yajnik K S

Distinguished Scientist
Balganesh T S
Ehrlich Desa
Prakash V
Sinha U N

Scientists
Anil Earnest
Anilkumar V
Ashapurna Marndi
Ashish
Goswami P
Gouda K C
Gyanendra Nath Mohapatra
Himesh S
Indira N K
Kantha Rao Bhimala
Krishna Mohan T R
Partha Sarathi Goswami
Parvez I A
Patra G K
Prakasa Rao E V S
Rajendran K
Rakesh V
Ramesh K V
Rameshan K
Sajani Surendran
Senthilkumar V
Sharada M K
Sridevi Jade
Swathi P S
Tejpal Singh
Thangavelu R P
Vijayan M S M

Quick Hire Fellow
Tavpritesh Sethi

Research Associate
Jurismita Baruah

Senior Research Fellows
Anant Kant Shukla
Ipsita Putatunda
Shiv Narayan Nishad
Sushant Shekhar
Shaktidhar Nahak
Sumana Sarkar

Junior Research Fellows
Shafeer K
Lalith Kumar
Sunil Kumar T C
Jayasankar C B
Silpa K

Expert Consultant
Kalyani Devasena C

Technical Officers
Prabhu N
Suchanda Ray

Stores & Purchase
Ravinder Kumar

Administration
Anilkumar Angadi
Neethu S Induchodan
Raman P K
Sathyanarayana K

Technical Staff
Chandrashekar Bhat
Dileep Kumar P
Sita S
Stella Margaret A

Project Assistants/Graduate Trainees/ Diploma Trainees

Ahkshaey Ravi
Ajilesh PP
Alfred Johny
Arnika Tripathi
Boddapati Anil
Deepthi M
Dhanya S
Kumaragouda Gondar

Mathan Kumar R
Nagarjun PMD
Neethu C
Parthasarathi Baril
Payoshni Samantray
Prashanth Meti
Kiran Kumar Reddy S
Praveen S
Rajeev K
Ramees Raja Mir
Ravichandran C
Rekha KC
Remya S
Renu Goyal
Sanjeeb Kumar Sahoo
Saranya V
Savithri KP
Shelva Srinivasan MK
Shilpa R
Shimna K
Shobharani G
Sowbhagya P
Sundara Deepthi MV
Surya Prakash M
Swathi TK
Vinutha D

Awards/Honors/Recognitions/Ph D Awarded

Ph D Awarded

K C Gouda: Awarded Ph D from Mangalore University

Services on External Committees/ Membership of Professional Bodies

Anil Earnest
Member, American Geophysical Union (AGU)
Member, Society of Exploration Geophysicists (SEG)
Member, Society of Earth Scientists (SES)
Associate Member, International GNSS Service (IGS)
Member, Asia Oceania Geo-sciences Society (AOGS)

Anil Kumar V
Life Member, Computer Society of India
Member, Selection Committee, C-DAC, India
Member, National Organizing committee on Second NKN Annual Workshop 2013
Member, Technical evaluation committee for Video conferencing Aeronautical Development Agency
Member, Assessment Committee, C-DAC, Bangalore
Reviewer, Journal Security and Communication Networks

Goswami P
Member, General Body, KSNDMC
Member, Research Council, CSIR IMMT
Member, Executive Council, KSNDMC
Member, DST Programme Advisory Committee-Atmospheric Science
Member, National Expert Committee, ICZM Project (West Bengal), World Bank
Chairman, IMD Committee on Fog Forecasting
Member, MoES Advisory Committee on Monsoon Forecasting
Member, National Advisory Committee (NAC) of Intromet-2013

Gouda K C
Life Member, Indian Meteorological Society
Ex-officio Member, MoES Committee for Long Range Forecast of Monsoon

Himesh S
Life Member, Institution of Engineers, India
Life Member, Indian Society for Technical Education
Life Member, Indian Association for Environmental Management
Life Member, Indian Meteorological Society

Parvez I A
Coordinator, AcSIR, CSIR-4PI (erstwhile C-MMACS)
Member, Hindi Technical Advisory Committee (HTAC) NAL.
Member, Technical Expert Committee of Karnatala State Natural Disaster Monitoring Centre (KSNDMC), Department of Science and Technology, Government of Karnataka.
Life Member, Indian Society of Earthquake Technology
Life Member: Indian Society of Earthquake Science
PhD Examiner, Indian School of Mines, Dhanbad
Member, Advisory Committee, Gujarat State Disaster Management Authority (GSDMA)

Indira N K
Member, Working Group of Greenhouse Gases, MoES
Member, Advisory Board, Dept. of Mathematics, Dayananda Sagar college of Engineering, Bangalore.

Krishna Mohan T R
Life Member, Indian Complex Systems Society

Patra G K
Life Member, Computer Society of India
Life Member, Indian Meteorological Society
Life Member, Cryptology Research Society of India
Life Member, Orissa Information Technology Society
Life Member, Advanced Computing and Communication Society
Life Member, International Association of Engineers
Adjunct faculty, Department of computer Science, Amrita School of Engineering, Bangalore
Member, Board of Studies, Mathematics Department of Mount Carmel College, Bangalore
Member, Doctoral Committee, Vellore Institute of Technology
Member, Advisory Board of School of Computer Science and Engineering, Vellore Institute of Technology, Vellore
Member, Programme Committee, National Conference on Parallel Computing Technologies
Member, Technical Program, 2^{nd} International Conference on Advances in Computing, Communications and Informatics

Prabhu N
Member, Computer Society of India

Prakasa Rao E V S
Sectional Committee Member, Natural Resources Management, National Academy of Agricultural Sciences.
Fellow, National Academy of Agricultural Sciences.
Fellow,Indian Society of Agronomy.
Life member, Indian Society of Agronomy.
Life member, Indian Society of Soil Science.
Life member, Indian Society of Spices.
Life member, Essential Oil Association of India.
Member, Editorial Board, Indian Perfumer.
Panel Member, Procurement of materials from a single source as per Karnataka Transparency in Public Procurement Act of Karnataka Soaps & Detergents Ltd., Bangalore.
Member, Doctoral Committee, Centre for Research and Development, Prist University, Tamil Nadu

Rajendran K
Member, Working Group on Climate Change, Kerala State Planning Commission, Govt of Kerala.
Member, Board of Studies in Atmospheric Sciences, CUSAT, Cochin
Organizing Secretary and Organization Committee Member, International Conference on Climate Change and the Himalayas: Current Status and Future Perspective
Examination Setter, Numerical Weather Prediction Course, Department of Meteorology, Cochin University of Science and Technology, Kerala

Rakesh V
Life member, Indian Meteorological Society
Joint secretary, Indian Meteorological Society Bangalore Chapter

Sajani Surendran
Member, Working Group III, NCAP Project of MoEF.
Examination Setter, Numerical Weather Prediction Course, Department of Meteorology, Cochin University of Science and Technology, Kerala
Life member, Indian Meteorological Society

Senthilkumar V
Life Member, Indian Association for Computational Mechanics (IndACM)
Life Member in Indian society for Advancement of Materials and Processing Engineering (ISAMPE)
Member, International Association of Engineers
Editorial Board Member, Journal of Modelling and Simulation in Design and
Member, IAENG Society of Industrial Engineering
Member, IAENG Society of Mechanical Engineering

Sridevi Jade
Life Member, Indian Geotechnical Society
Member, International Society of Soil Mechanics and Foundation Engineering
Founder Life Member, Indian Society of rock mechanics and tunneling technology
Expert Member, Research Advisory Council (RAC),member of Wadia Institute of Himalayan Geology.
Expert member, Technical Advisory Committee, Government of Karnataka
Expert Member, National GPS Programme Expert Group, Department of Science and Technology (DST)
Expert Member, Women Scientist Scheme expert committee, DST
Member, Information Sciences cluster 12th FYP Work Group/Task Force
Associate Member, International GNSS Service

Swathi P S
Expert Member, Assessment committee for scientists, NIO, Goa.

Thangavelu R P
Life Member, Computer Society of India
Life Member, Cryptology Research Society of India

Vijayan M S M
Member, American Geophysical Union
Associate Member, International GNSS Service (IGS)

Deputation

Parvez I A
NORSAR, Norway Institutional Co-Operation Program between CSIR-4PI (erstwhile C-MMACS) and NORSAR. June 23 - July 8, 2013

Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences, Moscow, Russia, 14-24 August, 2013.

Abdus Salam International Centre for Theoretical Physics (AS-ICTP), Trieste, Italy to work with Solid Earth and Non-Linear Dynamics (SAND) Group, 16-31 January 2014

Ashish
NORSAR, Oslo, Norway under institutional co-operation program between CSIR-4PI (erstwhile C-MMACS) and NORSAR, 1-30 Jun 2013


CSIR-FOURTH PARADIGM INSTITUTE (CSIR-4PI)
(Formerly CSIR-Centre for Mathematical Modelling and Computer Simulation)
Silver Jubilee Foundation Day & International Conference on
Computational and Data Intensive Science
S.R. Valluri Auditorium, CSIR-NAL, Bangalore
August 26-28, 2013
Platinum Sponsors
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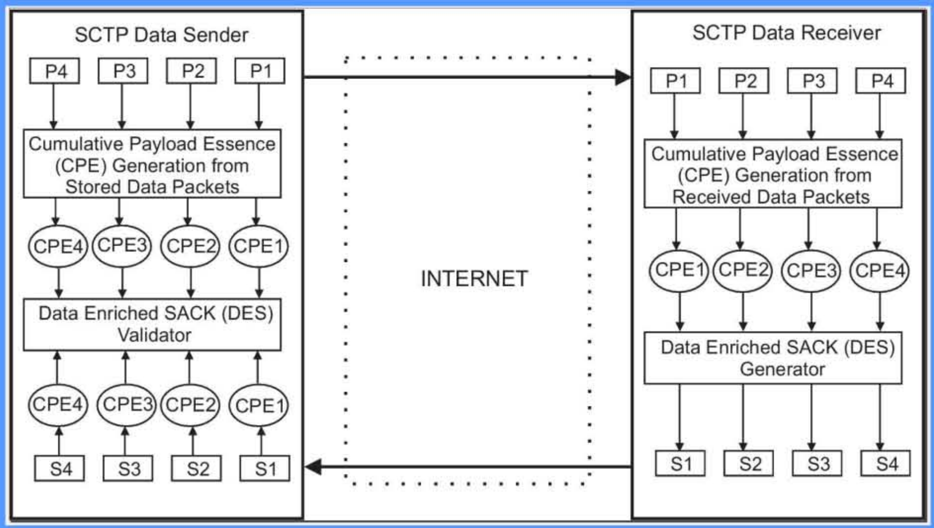
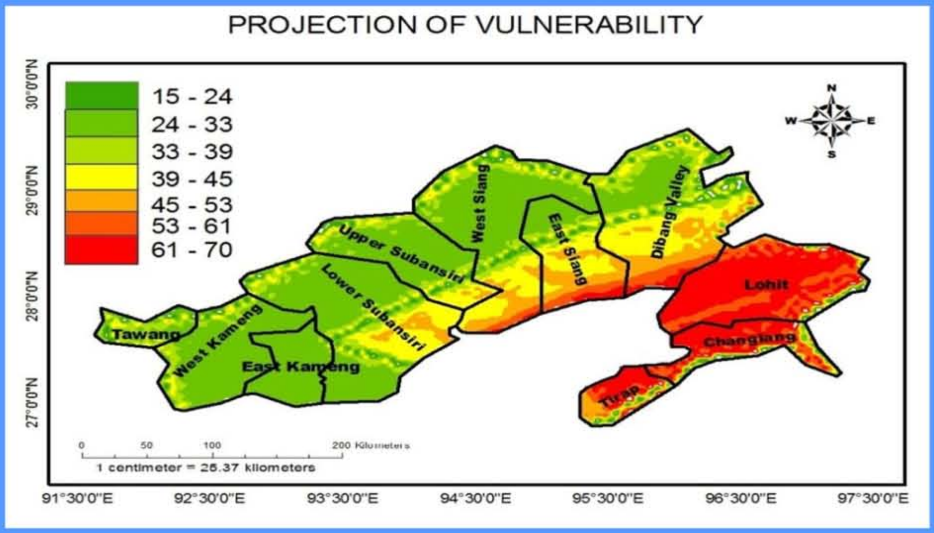

SCTP Data Sender
P4
P3
P2
P1
Cumulative Payload Essence (CPE) Generation from Stored Data Packets
CPE4
CPE3
CPE2
CPE1
Data Enriched SACK (DES) Validator
CPE4
CPE3
CPE2
CPE1
S4
S3
S2
S1
INTERNET
SCTP Data Receiver
P1
P2
P3
P4
Cumulative Payload Essence (CPE) Generation from Received Data Packets
CPE1
CPE2
CPE3
CPE4
Data Enriched SACK (DES) Generator
S1
S2
S3
S4


PROJECTION OF VULNERABILITY
15 - 24
24 - 33
33 - 39
39 - 45
45 - 53
53 - 61
61 - 70
N
W
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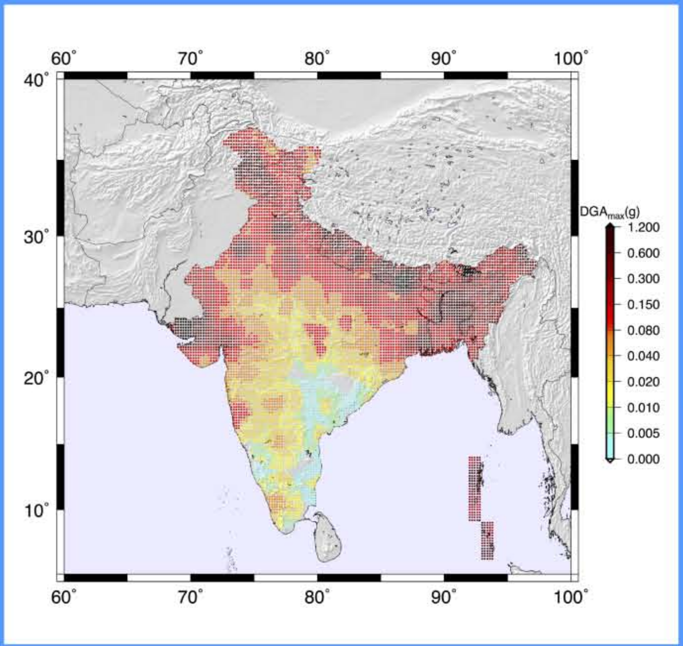
S
Tawang
West Kameng
East Kameng
Lower Subansiri
Upper Subansiri
West Siang
East Siang
Dibang Valley
Lohit
Changlang
Tirap
0
50
100
200 Kilometers
1 centimeter = 25.37 kilometers
30°0'0"N
29°0'0"N
28°0'0"N
27°0'0"N
91°30'0"E
92°30'0"E
93°30'0"E
94°30'0"E
95°30'0"E
96°30'0"E
97°30'0"E


60°
70°
80°
90°
100°
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20°
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DGA$_{max}$(g)
1.200
0.600
0.300
0.150
0.080
0.040
0.020
0.010
0.005
0.000