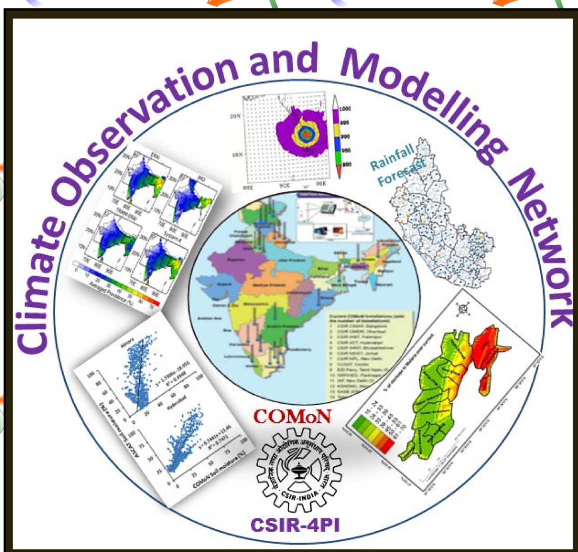
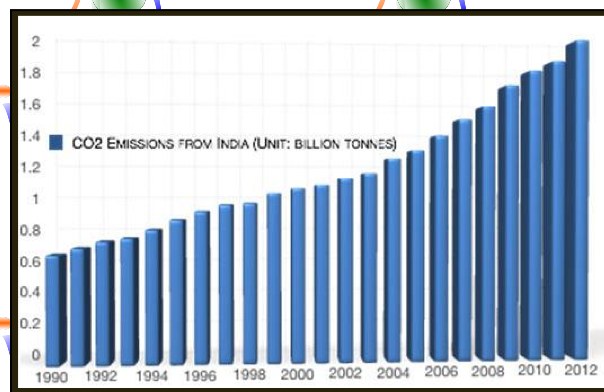
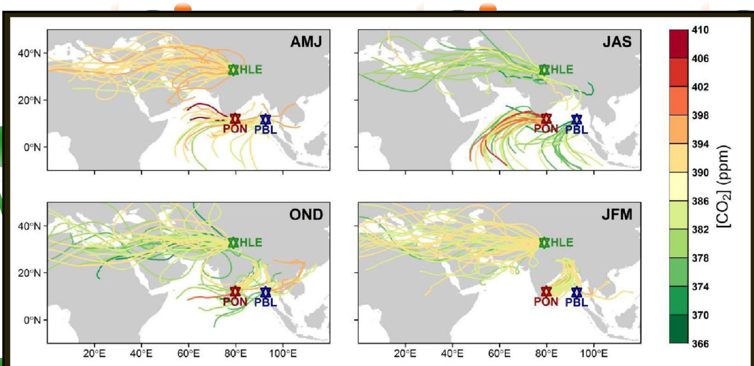
Computing Insights

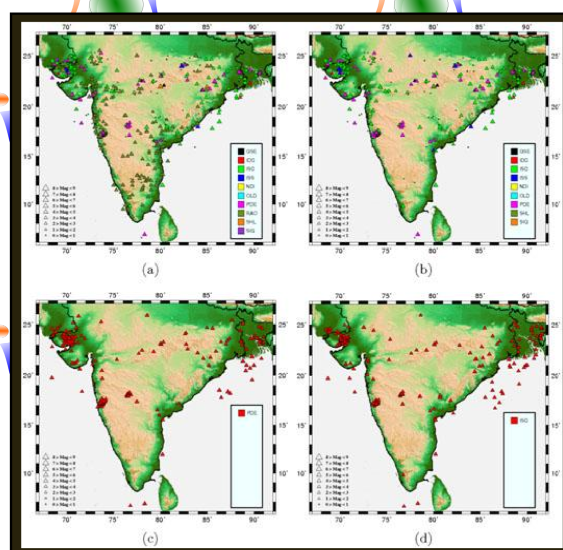
CSIR-Fourth Paradigm Institute

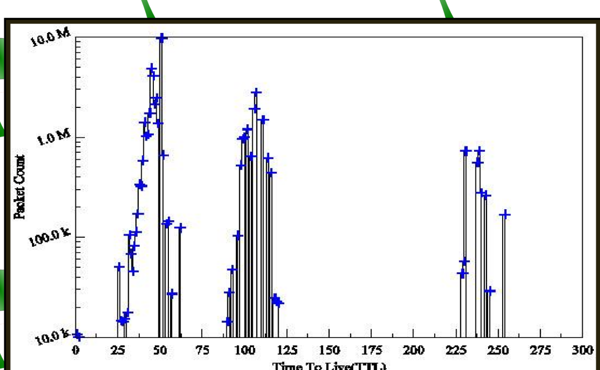
Annual Report 2014 – 2015

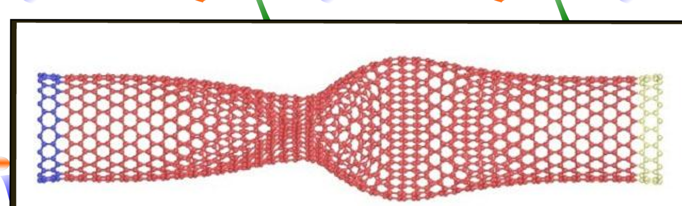




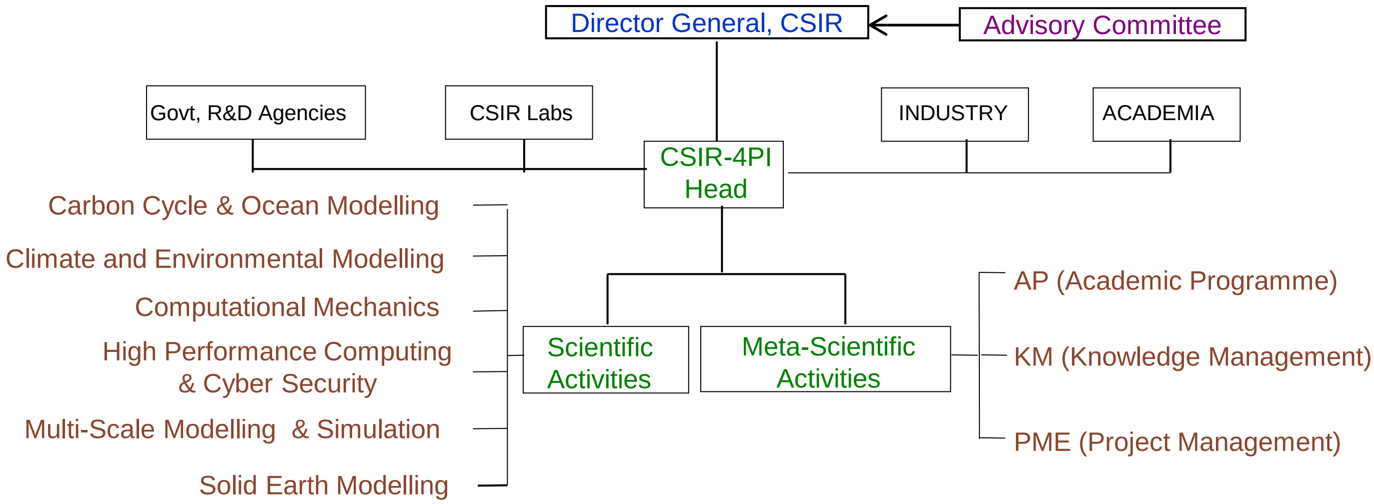








ORGANISATIONAL STRUCTURE OF CSIR-4PI



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Head, CSIR-4PI Bangalore

CSIR-4PI, Wind Tunnel Road, Bangalore 560 037, India

Fax: +91 80 25220392
E-mail: head@csir4pi.in
Tel: +91 80 2522 4667
Website: http://www.csir4pi.in

CSIR-4PI

Annual Report 2014-2015

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Editorial Team
Ramamohan T R
Rameshan K
Suchanda Ray

Published by
Head
CSIR Fourth Paradigm Institute
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.

Preface

It is my great pleasure to present the Annual Report for 2014-15 highlighting the scientific achievements for the year along with other information. CSIR-4PI continued to march towards improving their niche areas of research in different subjects. The scientists of CSIR-4PI has taken up major projects in diverse areas of research and their contributions in multi-disciplinary areas are much acknowledged in the form of 47 publications in SCI and non SCI journals, 22 Conference publications and 25 Conference presentations during 2014-15. The institute continued its interactions with various national and international agencies through their collaborative research work. The major highlights of the year are briefed here for different groups.

The Intergovernmental Panel for Climate Change (IPCC) has clearly established anthropogenic greenhouse gases (GHG) as the main drivers of global warming and climate change. However, the budget of GHGs are still far from being established robustly due to lack of accurate measurements of GHG concentrations and gaps in modelling the carbon, nitrogen and oxygen cycles, especially the oceanic component. At CSIR 4PI, we have been contributing to both these efforts – (a) by establishing WMO-standard GHG stations and using this data to obtain robust fluxes by inversion and (b) making fundamental contributions to the processes in the carbon cycle, incorporating these into 3-D ocean circulation and biogeochemistry models to study the inter-annual variations of the carbon, nitrogen and oxygen cycles.

The primary strength of CEMP is its multi-disciplinary research and outreach. The year 2014-15 has seen this potential and efforts of CEMP realized through several high-impact multi-disciplinary SCI publications. These publications (total of 21, SCI: 10 + 11 others) in 2014-15 covered diverse topics from assessment of virtual trade in water (Nature Scientific Reports), modeling of malaria (PLOS ONE), extreme rainfall events (Climate Dynamics) and demonstrate the power of generic mathematical modeling, computer simulation and data analysis. The process models are developed completely in-house from computer coding to validation. 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 high-resolution forecasting of Date of Onset of Monsoon saw the 13th successful year in 2014. Along with these applicable products, three students and scientists also submitted Ph D from CEMP. A number of international (UKIERI, CSRIO,..) and national (NDMA, ICRI, ICAR,..) agencies have approached CEMP for collaborative R&D. To enhance and integrate the efforts for applicability, an inter-group synergy on Integrated Disaster Assessment and Modelling (IDAM) Programme was initiated in 2014.

The homotopy analysis method was applied to a number of problems and satisfactory results were obtained. These problems consisted of systems of coupled nonlinear ordinary differential equations. Work was initiated on including particle inertia in our earlier work on periodically forced suspensions. Work on kernel determination for one dimensional carbon nanostructures was initiated.

During the year, the 360 TFLOPS CSIR Supercomputing facility continues to serve the CSIR scientific community for all their supercomputing needs. The facility is operational on a round-the-clock basis and it is being accessed by CSIR Scientists over the high speed National Knowledge Network.

The research in Cyber Security continues to produce innovative results in security aspects of next generation transport layer protocols, trust assessment of public cloud infrastructure and characterization of malicious cyber incidents. The team has prosed a new acknowledgement generation scheme called Data Enriched SACK for SCTP protocol.

The broadband seismic arrays was established in Kashmir Himalayas and quantified the first ever information about a consistent Moho geometry of the region even overlying décollement. We have also established seismic hazard and risk assessment based on multi-scale analysis embedded in Unified Scaling Law for Earthquakes (USLE) approach. We gave region specific dislocation models for Indian Himalaya and Indo-Burmese Arc, present day deformation rates in Assam Valley and adjoining region and initiated Landslide deformation modeling.

Multiscale Modeling and Simulation Group is involved in working with a multiscale, earth system model to address climate and climate change issues specific to India. Studies of tropical climate, Indian monsoon and variability, climate projections under different global warming scenarios, aerosol impact on climate, dynamical downscaling and statistical model-bias removing methods are being carried out employing an unprecedentaly high resolution global climate model, regional climate model, aerosol process model and earth system model. Since 2012, climate change projections for the state of Kerala are provided to Directorate of Environment and Climate Change, Government of Kerala.

The academic programme of CSIR-4PI is progressing very well with increasing number of students enrolling for the SPARK programme. A number of students from premier institutions in India joining for their project work under the guidance of scientists in different areas. Three students received their 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 . It is my privilege to express my gratitude to DG, CSIR and members of our Advisory Committee for their support & guidance. 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 and providing advice and guidance to the scientists. I take this opportunity to thank all scientists and other staff members of CSIR-4PI for their commitment to this unique organization.

Head, CSIR-4PI

Highlights 2014-15

- ***Climatalogical and interannual simulations of the carbon, nitrogen and oxygen cycles in the ocean***
- ***Simulations reproduced observed features such as subsurface chlorophyll maxima, primary productivity and profiles of nutrient concentrations well***
- ***Accurate measurements of greenhouse gases concentrations***
- ***Correlated measurements of different species to identify common sources***
- ***Impact of monsoon on GHG concentrations seen clearly***
- ***Eighth Successful year of advance forecasting of Date of Onset of Monsoon; zero error in the advance forecasting of the onset for 2014***
- ***Fifth successful year of Hobli (Village Cluster) Level forecasting over Karnataka enhanced to Gram Panchayat level in 2014***
- ***Multi-disciplinary SCI Publications: Climate Projections, Malaria model, Air pollution model, Crop disease, sustainability***
- ***IPCC Assessment Report 5 Lead Authorship (Working Group I, Chapter 14)***
- ***International Workshop on Assessment, Modelling and Applications of Renewable Energy (AMARE) 20-22 May 2014, Hyderabad, India***
- ***Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014***
- ***National Discussion Meeting on Modelling and Projections for Spices, Aromatic and Medicinal Plants, Coffee and Tea (MP-TRACS), August 26, 2014, C- MMACS***
- ***MOU with Indian Cardamom Research Institute for joint collaboration on forecasting of capsule rot of cardamom***
- ***Integrated Disaster Assessment and Modelling (IDAM) Programme with inter-group synergy***
- ***Proposed a Best fit Gaussian kernel which clearly gives most accurate fit, improving even upon the fourth-order strain gradient kernel.***
- ***Molecular Simulations carried out for the carbon nanotube***
- ***Application of the homotopy analysis method to a number of technically important problems***
- ***Equations derived for including particle inertia for perioidically forced particles in simple shear flow***
- ***Kernel determination for one dimensional carbon nanostructures***
- ***Centralised 360 TF Supercomputing facility for CSIR computational scientists***
- ***Earth System Model: New version of the coupled ocean-atmosphere climate model***

- ***Impact of increased GHG emissions for the state of Kerala***
- ***RCP 8.5 scenario climate change projection for India using high resolution Global Climate Model***
- ***Role of mean and variability of Indian summer monsoon rainfall in reliability of future projections in CMIP5 coupled models***
- ***Comparing statistically downscaled simulations of Indian monsoon at different spatial resolutions***
- ***Implementation of regional climate model for climate change applications***
- ***Bivariate PDF analysis of latent heating over the tropics***
- ***Cyclonic events in Megha-Tropiques tata***
- ***Rainfall and aerosol optical depth from an aerosol coupled GCM during the abnormal Indian Summer Monsoon of 2000***
- ***Characteristics of MODIS aerosol optical depth during 2002 drought monsoon***
- ***Trust rating for public cloud infrastructure***
- ***Active landslide monitoring in Chamoli district of Uttarakand***
- ***Present day rotation of Assam valley and adjoining regions***

Research & Development Programmes

1

CARBON CYCLE & OCEAN MODELLING

The sources and sinks of greenhouse gases (GHG) need to be estimated robustly, both in space and time, before we can come up with meaningful limitations in emissions. Large data gaps exist in world-class WMO-standard measurements of GHGs which lead to large uncertainties in estimated fluxes.

The bottom-up approach models all the processes of the marine carbon, nitrogen and oxygen cycles essential to get basin-wide estimates of the air-sea fluxes as well as the estimation of oxygen minimum zones which have a large impact of the marine ecosystem. Climatalogical and interannual simulations of the carbon, nitrogen and oxygen cycles in the ocean captured several observed phenomena-existence of subsurface chlorophyll maxima, biological productivity, temperature and salinity profiles, presence and extent of oxygen minimum zones - in the Indian Ocean, especially the Arabian Sea. Sensitivity experiments with parameters that control iron-limitation yielded some insights into the processes which control biological productivity. These simulations are perhaps the most sophisticated as they combine a state of the art biogeochemical model (TOPAZ) with an advanced ocean general circulation model (Modular Ocean Model).

The top-down approach inverts GHG measurements to yield robust fluxes. We have compiled weekly-biweekly flask measurements of GHG gases made with a gas-chromotograph complying with WMO standards from three stations, Hanle, Pondicherry and Port Blair. The measurements clearly reveal the impact of the monsoons on GHG concentrations, with lows in the SW monsoon and highs during NE monsoon. Back-trajectories from these stations show that Hanle is mostly influenced by winds from Central Asia while the other two are influenced by the monsoons. Correlation between methane and carbon monoxide show common origin of the two species (biomass and waste burning).

Inside

- ***Flask measurements of greenhouse gases at Hanle, Pondicherry and Port Blair***
- ***Carbon cycle study in the north Indian Ocean***

1.1 Flask measurements of greenhouse gases at Hanle, Pondicherry and Port Blair

We have recently completed 5 years of flask measurements, conforming to WMO-standards, of carbon dioxide, methane, carbon monoxide, nitrous oxide, sulphur hexafluoride, and hydrogen from clean background sites, Hanle (32.78 °N, 78.96 °E, 4517 m a.s.l., HLE), Pondicherry (12.01 °N, 79.86 ° E, 20 m a.s.l, PON) and Port Blair (11.65 °N, 92.76 °E, 20 m a.s.l., PBL). The 5-day back-trajectories of the air masses reaching these stations are shown in Figure 1.1.

Hanle mostly samples air from Central Asia, Middle East and North Africa while the other two stations sample air from both Southwest and Northeast monsoons. Flask samples in Hanle were collected (weekly-biweekly) in the mornings while in the other two, they were collected in the afternoon after the sea breeze set in. The samples are representative of the background concentration, unaffected by immediate local sources.

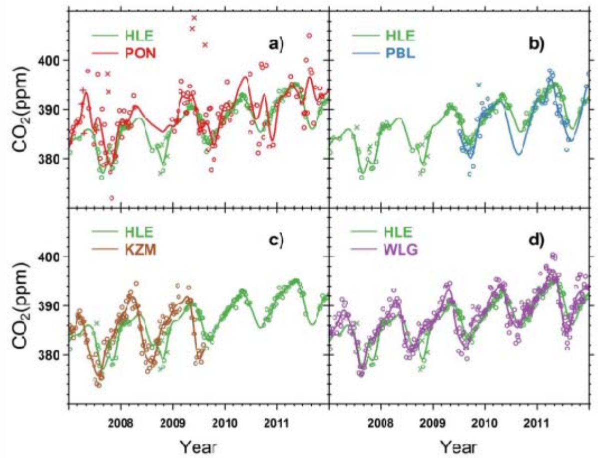


Figure 1.2 **Time series of carbon dioxide flask measurements. Two Asian stations (Kazhakstan, KZM and Mt. Waligaun WLG) are also shown.**

The measurements of carbon dioxide at the three sites along with two other measurements at other Asian stations (KZM, Kazhakstan, WLG – Mt. Wauligan, China) are shown in Figure 1.2. The smoothed curves in all the figures are based on a standard procedure which includes a first-order polynomial for the growth rate and two harmonics for the annual cycle as well as a low pass filter with 80 and 667 days as short-term and long-term cutoff values, respectively. The anomalies are the residuals

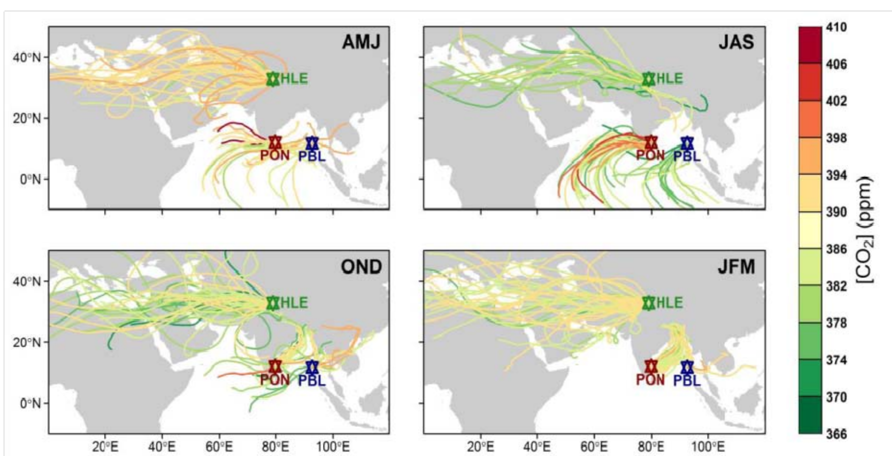


Figure 1.1 **Five-day back-trajectories and concentrations generated using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT4) model driven by wind fields from the Global Data Assimilation System (GDAS) archive data based on National Centers for Environmental Prediction (NCEP) model output (https://ready.arl.noaa.gov/gdas1.php). Back-trajectories are coloured according to individual carbon dioxide measurements on corresponding sampling dates.**

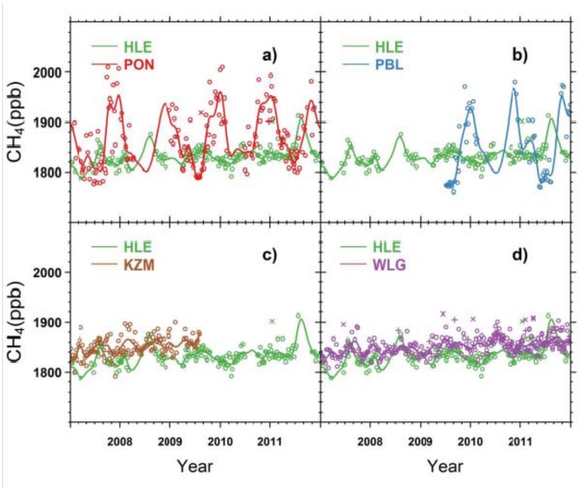


Figure 1.3 **Time series of methane flask measurements. Two Asian stations (Kazhakstan, KZM and Mt. Waligaun WLG) are also shown.**

of the data from the smoothed curves. HLE observed an increase in CO_2 mole fractions from 382.3±0.3 ppm to 391.4±0.3 ppm between 2007 and 2011, with annual mean values being lower (by 0.2–1.9 ppm) than KZM and WLG. At PON, the annual mean CO_2 mole fractions were generally higher than at HLE, with differences ranging between 1.9–4.3 ppm (Figure 1.2a). The annual mean CO_2 gradient between PON and HLE reflects the altitudinal difference of the two stations, and the larger influence of CO_2 emissions at PON, mostly from South India. Seasonal cycles at PON and PBL reflecting the effect of monsoon circulation can be clearly seen. Measurements of methane are shown in Figure 1.3. At HLE, annual mean CH_4 increased from 1814.8±2.9 to 1849.5±5.2 ppb between 2007 and 2011. The multiyear mean CH_4 value at HLE was lower than at KZM and WLG on average by 25.7±3.1 and 19.6±7.8 ppb.

The seasonal cycle in methane is more pronounced in Pondicherry and Port Blair due to agriculture and biomass burning than at Hanle which is in a cold desert. Correlations between the anomalies of methane and carbon monoxide measurements can be seen in Figure 1.4. It can be seen that the two are closely correlated indicating sources of common origin, usually incomplete combustion of biomass.

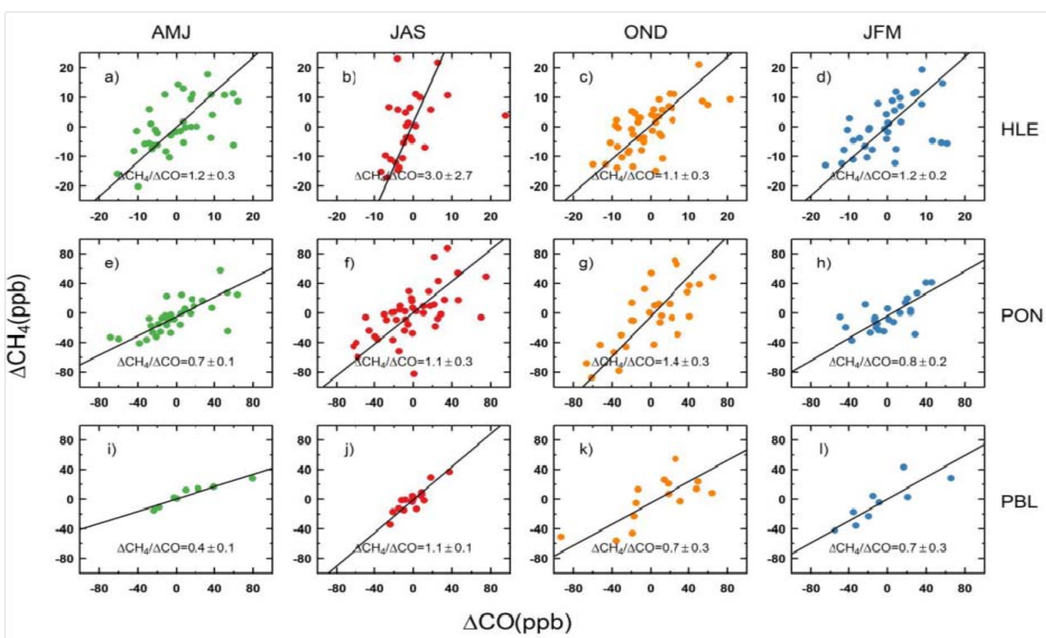


Figure 1.4 Scatter plot of carbon monoxide and methane residuals

This data will provide a valuable base for constraining India's sources and sinks of greenhouse gases.

N K Indira, P S Swathi, V K Gaur, Prashant Meti, Nagaraj Naik, Akash Choudhury, Shambulinga, Prabhat Prabhu, B C Bhatt*, M V Reddy*, D Angchuck*, S S Jorphail*, M V Reddy#, S Balakrishnan#, S Patnaik#, M Begum**, S Durairaj**, S Kirubagaran **, X Lin^, M Ramonet^, M Delmotte^, M Schmidt^
*Indian Astronomical Observatory, Hanle
#Pondicherry University
**NIOT
^LSCE

1.2 Carbon cycle study in the north Indian Ocean

The major objective is to understand the physical-biological-chemical processes in the ocean which influence the primary productivity and carbon flux across the air-sea interface. This study is carried out by incorporating biological and chemical process models in the ocean general circulation model and evaluating the results of a three dimensional physical-biological-chemical model (TOPAZ) using data from different sources for spatial, monthly, seasonal and interannual variations. 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, inter annual and spatial variations of SST and surface chlorophyll (Chl) in the AS and the BOB using the satellite data. Simulation results on Temperature, Salinity, Chlorophyll, Nitrate, Oxygen, Silicate are compared with the Cruise Data from Indian JGOFS programme. Spatial variations of different biogeochemical variables with depth along 65º E Transect have been studied using the climatological simulations of the TOPAZ model and Indian JGOFS Cruise data.

Depth Profiles of temperature, salinity, nitrate, dissolved inorganic carbon (DIC), oxygen, chlorophyll and primary productivity (PP) from the climatologi-

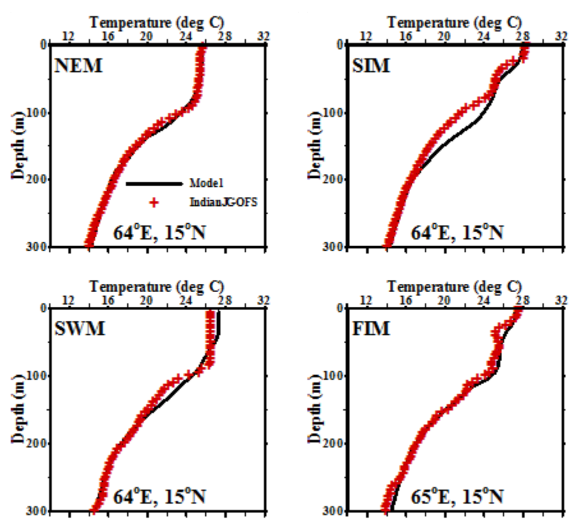


Figure 1.5 Comparison of depth profiles of temperature (º C) from model with Indian JGOFS data at (15º N, 65º E) during four seasons

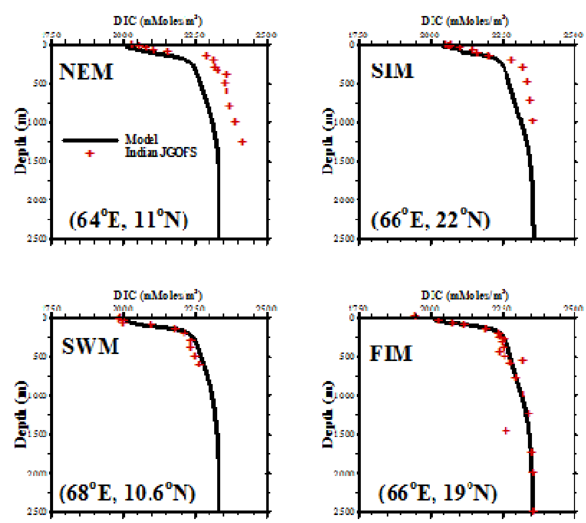


Figure 1.6 Comparison of depth profiles of Dissolved Inorganic Carbon (mMoles/m³) from model with Indian JGOFS data for four seasons

cal model simulations are compared with the Indian JGOFS data at many (more than 10) locations for four seasons (NEM, North East Monsoon – December, January, February; SIM, Spring Inter Monsoon – March, April, May; SWM, South West Monsoon – June, July, August; FIM, Fall Inter Monsoon- September, October, November). Figure 1.5 shows the comparison of depth profiles of temperature from the model with Indian JGOFS data at one station during four seasons and it is noted that temperature obtained from the model compares well with the data. It is noted that spatial variation of temperature with depth from the model is able to capture many of the features observed during Indian JGOFS cruises (Report and Research Papers related to Indian JGOFS Cruise) Comparison of DIC with depth (Figure 1.6) at various stations shows that DIC from the model is less than the cruise data during NEM and SIM but is close to the data during SWM and FIM.

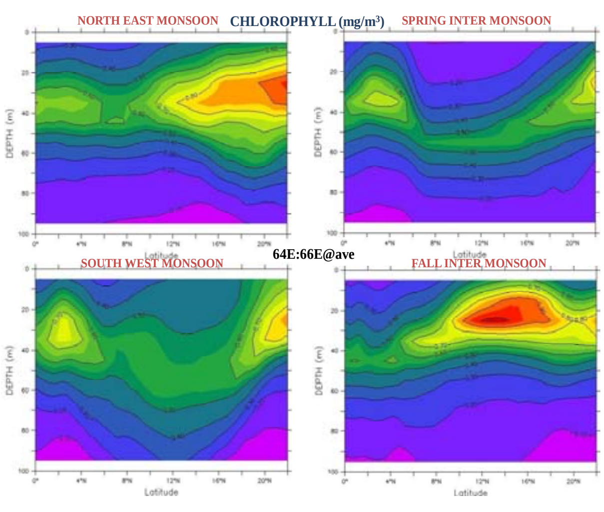


Figure 1.7 Latitudinal variation of Chlorophyll (mg/m^3) with respect to depth along 65º E transect

Spatial variation of Chl with depth along 65º E transect (Figure 1.7) shows that subsurface maximum exists during all seasons. Chl values are higher in the regions north of 16º N and maximum values of Chl are obtained during FIM and NEM. Chl values are lower in the regions between 6º N and 16º N during all seasons.

Spatial variations of temperature, nitrate and Chlorophyll along the 65º E transect clearly indicate that regions with low temperature have high nitrate and chlorophyll concentration during different seasons.

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 for spatial and seasonal variations of different biogeochemical components. It is noticed that when $(Fe:N)_{irr}$ is reduced (For Exp b, value of $(Fe:N)_{irr}$ is 1/4th of the value used in Exp a) PP and Chl increase, NO_3 and pCO_2 decrease in the northwest AS, during January-March and August-December (Figure 1.8). But PP, Chl, NO_3 and pCO_2

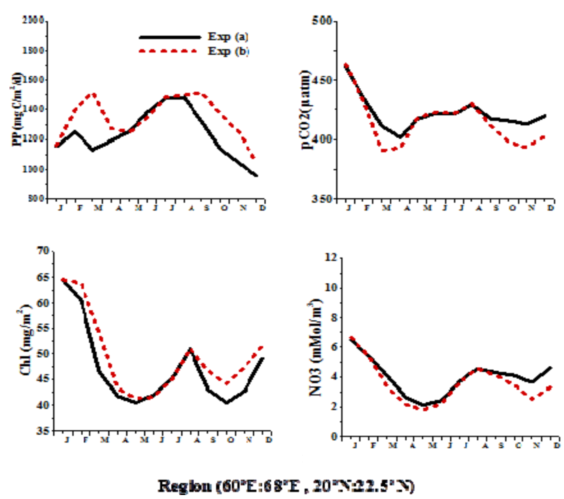


Figure 1.8 Monthly variation of depth integrated Primary Productivity (mgC/m^2/d) and Chlorophyll (mg/m^2), Nitrate averaged over top 50m (m Moles/ m^3) and surface pCO_2 in northwest Arabian Sea

did not show any change in the east AS and most of BOB 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 west AS. Model results are being analysed to understand the effect of iron limitation on primary productivity due to different phytoplankton and regeneration processes.

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 (Dunne et al., 2010) coupled with MOM4p1 has been used to carry out the numerical simulations for 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 in the global domain. 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 Indian JGOFS Cruises at many stations in the AS. 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 in the AS as observed in Indian JGOFS Programme, but the oxygen concentration from the model is more than the data by 5 to 10 units. Spatial variation of Oxygen with depth along the 65º E transect (Figure 1.9) shows that, oxygen concentration is less than 20 Mol/m^3 in the regions north of 10º N and is 5 Mol/m^3 between 16º and 20º N during all seasons.

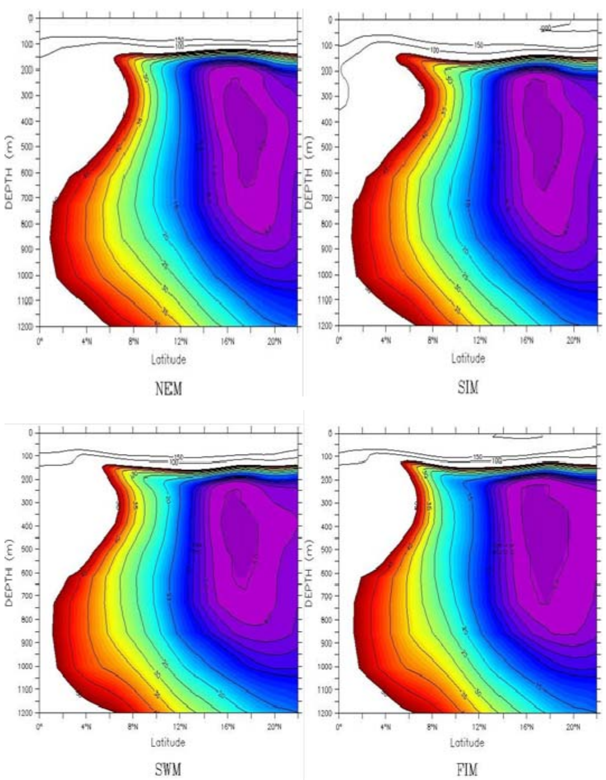


Figure 1.9 Latitudinal variation of Oxygen (m Moles/m^3) with respect to depth along 65º E transect

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.

M K Sharada, C Kalyani Devasena, M V Sundara Deepthi, M K Shelva Srinivasan, P S Swathi, K S Yajnik

3

CLIMATE & ENVIRONMENTAL MODELLING PROGRAMME

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 are disseminated by KSNDMC for the benefit of the farmers. CEMP had been the first to develop an industrial interface in weather informatics.

Inside

- ***COMoN: Status and utilization***
- ***Panchayat-Level forecast over Karnataka: Fifth year of collaborative outreach***
- ***Long-range high resolution forecasting of monsoon 2014 thirteenth year of experimental forecasting***

- *Assessment of climate change over India*
- *Simulation of heavy rainfall events over Indian region: a benchmark skill with a GCM*
- *Model configuration for predicting tropical cyclone over Indian Ocean*
- *Impact of data assimilation on high-resolution rainfall forecasts: A spatial, seasona, and category analysis*
- *Comparison of COMoN soil moisture data with remote sensing (ASCAT) data*
- *Dynamical model of daily CO concentration over Delhi: assessment of forecast potential*
- *Prevention of malaria through pro-active vector sanitation*
- *Virtual water trade and time scales for loss of water sustainability*
- *Towards seasonal forecasting of malaria in India*
- *Weather-based forecast model for capsule rot of small cardamom*
- *Quantitative assessment of relative roles of drivers of acute respiratory disease*
- *Integrated disaster assessment and modelling over the Himalayan region*
- *Simulation and analysis of a heavy rainfall event over Bengaluru*

2.1 COMoN: Status and utilization

The CSIR Climate Observation and Modelling Network (COMoN) was established as a part of the CSIR Network Project Integrated Analysis for Impact, Mitigation and Sustainability (IAIMS : NWP-52). Through a synergy between a number of CSIR laboratories, IAF, DRDO, universities and state Govt, a network of 26 climate monitoring systems have been installed covering various parts of the country, from the Himalayas to coastal regions. COMoN is unique for its multi-application design.

The observations from COMoN has allowed to address diverse issues like

- Ground truthing of remotely-sensed soil moisture
- Data Optimality for meso-scale forecasting
- Model calibration for air pollution forecasting
- Identification of mechanism of fog over Delhi

Geographical Distribution of CSIR COMoN Towers

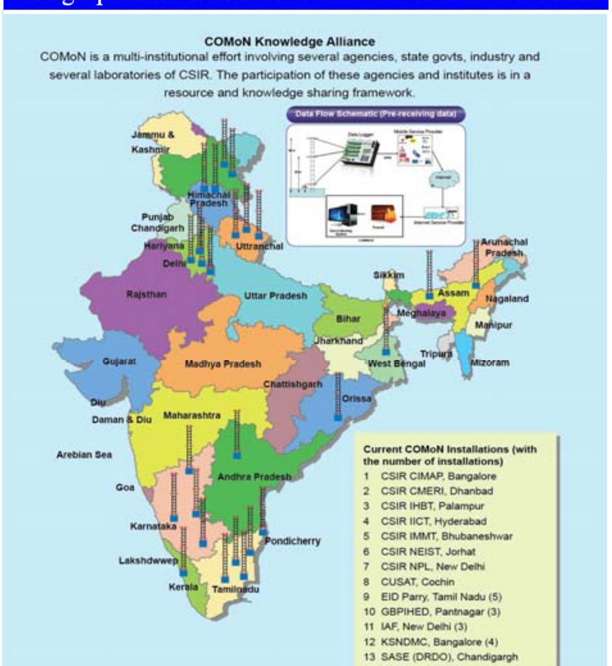


Figure 2.1

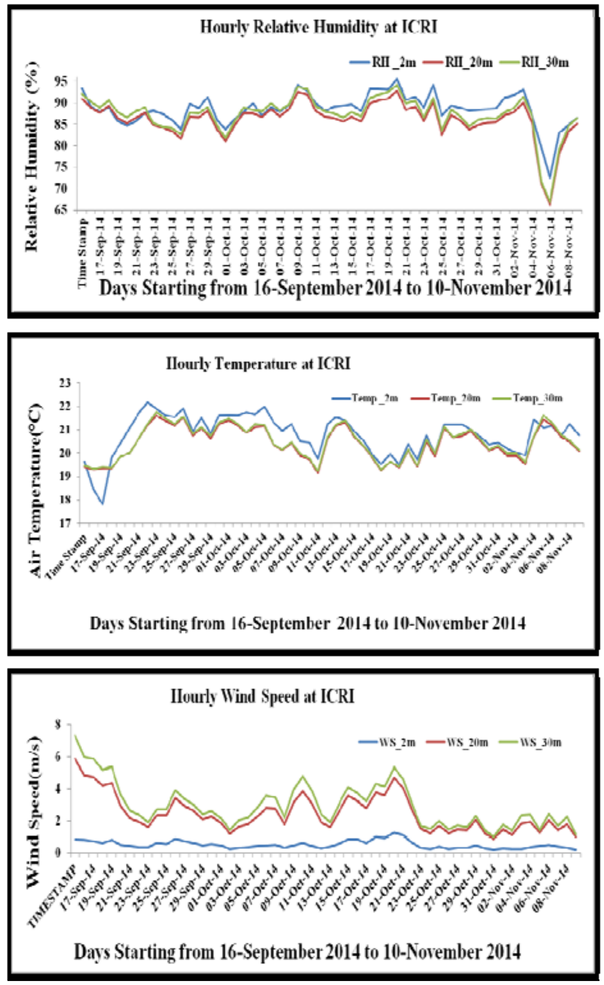


Figure 2.2 Hourly relative humidity, air temperature and wind speed at three levels during 16 September- 10 November, 2014 at COMoN Station at India Cardamom Research Institute, Myladampura

These results have passed through international per review, as evidenced by publications in high-impact SCI Publications.

COMoN provides an excellent opportunity for sustained, multi-sector R & D in monitoring and assessment in diverse areas like health, disaster, agriculture.

P Goswami and S Himesh

2.2 Panchayat-Level forecast over Karnataka: Fifth year of collaborative outreach

Weather informatics like rainfall advisories can enhance farmers' income and aid water and energy efficient agriculture. In a pioneering effort in the country, CSIR Centre for Mathematical Modelling and Computer Simulation (C-MMACS, repositioned 4PI) and Karnataka State Disaster Monitoring Centre (KSNDMC) have initiated rainfall forecasts at hobli-level (~ 10 Km) over Karnataka to. The Hobli-level rainfall forecast system over Karnataka is a culmination of collaboration between CSIR 4-PI and KSNDMC over more than a decade. Apart from other activities between the two organizations the hobli level meso scale rainfall forecasting activity started in 2010 and has now completed four years of rigorous testing, validation from the ground observations made from the telemetric rain gauge/weather monitoring network established by KSNDMC. However, given the tremendous spatial variability of rainfall, the forecasts need to be at still higher resolution. Based on a request from KSNDMC, forecasts at Gram Panchyat Level have been initiated in 2014. Results of Gram Panchyat Level forecast evaluation with KSNDMC rain gauge observation for the initial two months are presented. Comparison of number of hoblis where rainfall occurred for each day for the months of June and July with corresponding hoblis from morning and afternoon forecasts shows that forecast is reasonably skilful particularly for the month of July (Figure 2.3). The afternoon forecast is closer to observation compared to morning forecast. The forecast shows slight underprediction for the months of June compared to observation and in general majority of hoblis are with a bias within the range -3 to +3. The quality of forecasts is assessed by computing the correlation coefficient between forecasted and observed rainfall. A large number of hoblis with high values of correlation shows the agreement between forecasted and observed rainfall. We have also computed the root mean square errors in morning and afternoon forecasts by comparing with observed rainfall.

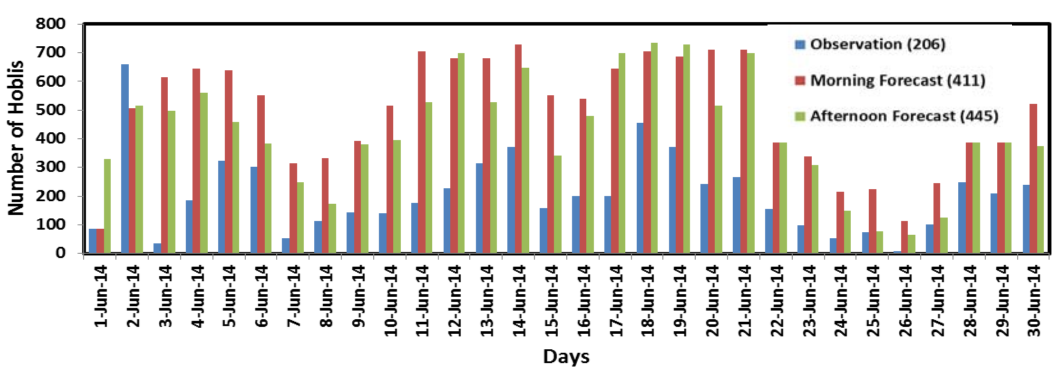


Figure 2.3 Comparison of number of hoblis where rainfall is observed (>1 mm) for the months of June with corresponding hoblis from Morning and Afternoon Forecasts.

Majority of hoblis (more than 500) in RMSE category < 10 mm clearly indicates good forecast skill and as seen earlier afternoon forecast is more skilful compared to morning forecast.

V Rakesh and P Goswami

2.3 Long-range high resolution Forecasting of monsoon 2014

Enhancement of scope and skill in monsoon forecasting skill remains a national priority and a major scientific challenge; in spite of decades of efforts by the world scientific community, the skill of monsoon forecasts at user relevant scales remain poor. CSIR-4PI has taken up this challenge with advanced and innovative mathematical modeling and algorithms.

Date of onset of monsoon

The date of onset of monsoon (DOM) with the first sustained and significant rainfall over Kerala signifies the arrival of the main agricultural season in India. Thus, accurate and advance prediction of DOM can help agricultural planning like preparation of land and sowing schedule.

Table 2.1 Performance of CSIR-4PI Experimental Forecasts of Monsoon Onset

Year	Forecast	Announced	Error
2007	May 26	May 28	+2
2008	May 28	May 31	+3
2009	May 23	May 23	0
2010	May 29	May 31	+2
2011	May 29	June 03	+5
2012	June 05	June 05	0
2013	June 01	May 31	1
2014	**June 07**	**June 07**	**0**
Average Error			**1.6 Days**

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.

Following methodologies developed at CSIR-4PI , the forecast of date of onset was issued in April, 2014; it matched with the date of onset announced **by IMD (June 07, 2014).**

It is worth mentioning that in the eight years of advance forecasting of Date of Onset (Table 2.1) there had been only one year (20) with large error (~5 days; the average error (~2.2 days) is well below the natural variability (~6 days).

Regional category Forecasts

Following its standard procedure, CSIR-4PI issued its experimental forecasts in early April, 2014.

Table 2.2 Categories for different regions from CSIR-4PI **forecast and Observation**

Region	Extent	June-August		June		July		August		% of Agreement
		CM	IMD	CM	IMD	CM	IMD	CM	IMD	
All-India	Continental land	N	N	D	D	D	N	N	N	75
North-India	(72-84 °E, 24-30 °N)	N	D	D	D	N	D	N	D	25
South India	(75-78°E, 8-12°N)	N	N	N	D	N	N	N	E	50
Central India	(72-84°E, 20-28°N)	D	D	D	D	D	N	N	D	50
North-east India	(92-96°E, 24-30°N)	N	N	D	D	E	D	N	N	75
North-west India	(68-75°E, 24-30°N)	E	D	D	D	N	N	E	D	50

Table 2.2 represents a comparison of the category forecast and observation both at monthly and seasonal scale for the different regions over India.

As there are still not many forecasts with detailed spatio-temporal variability as provided in CSIR-4PI forecasts, a direct comparison of forecasts is not possible; however, there is good agreement with observations (IMD) over several regions Table 2.2.

K C Gouda and P Goswami

2.4 Climate change assessment over India: Impact on economy

A major challenge for planning and adaptation is identification of reliable projection. A critical aspect of climate change that has received relatively less attention is the impact on the economy. India's economy strongly dependent on agriculture and allied sectors. However impact of climate change over India on its economy is less explored. Perhaps the biggest challenge in creating an accurate and quantitative knowledge base for assessing and developing adaptation strategies is the uncertainties in the climate projections.

The 20th century climate simulations from CMIP3 for the period 1951-2000 and the historical experiment simulations from CMIP5 for the period 1951-2005 are validated against observations and selected models are used for creating future scenarios. The All Model Ensemble (AME) includes 36-model simulations from CMIP5 and 24 simulations from CMIP3. The Event Based Ensemble (EBE) is based on the ability to simulate the observed pattern of extremes (monsoon) events for the period 1951-2012 within an acceptability condition of maximum of ±25% (Figure 2.4 b, c) differences between the observed and the simulated monsoon categories .In the present case, three categories are defined in terms of departures (R_a) in all Indian summer monsoon rainfall (ISMR) from long-period mean: deficient (<= -10%), normal (-10<&>10%) and excess (>=10%). Based on the criteria, the EBE consists of 5 models from CMIP5 and 6 models from CMIP3 from the total simulations. The reliability of the EBE projections is also evident from the fact that

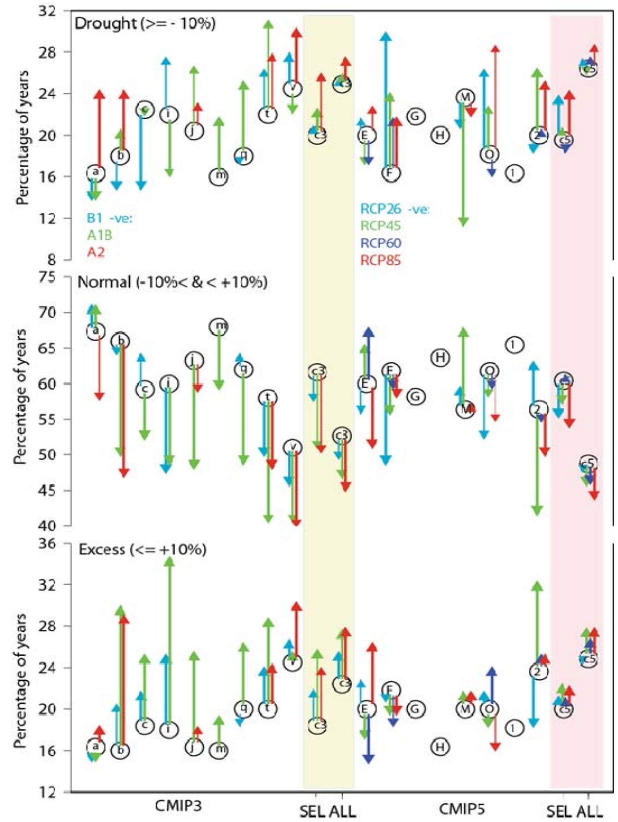


Figure 2.4 Distribution of climate projections for Indian summer monsoon rainfall under different climate scenarios by the individual climate models, which constitute the event based ensemble (EBE) from both CMIP3 and CMIP5.

most of the individual models (Figure 2.4) in this ensemble projected the same sign of change with different magnitudes; also each simulation is individually comparable to the corresponding ensemble average.

These results shows that while a definite reliability can not be assigned to future climate projections carefully developed and evaluated methodologies can be adopted to minimize uncertainties for decision support.

K V Ramesh, K B Shafeer, Alfred Jhony and P Goswami

2.5 Simulation of heavy rainfall events over Indian region

Extreme rainfall events (ERE) contribute a significant component of the Indian summer monsoon rainfall. Thus an important requirement for regional climate simulations is to attain desirable quality and reliability in simulating the extreme rainfall events. While the global circulation model (GCM) with coarse resolution are not preferred for simulation of extreme events, it is expected that the global domain in a GCM would allow better representation of scale interactions, resulting in adequate skill in simulating localized events in spite of lower resolution. At the same time, a GCM with skill in simulation of extreme events will provide a more reliable tool for seamless prediction. The present work provides an assessment of a GCM for simulating 40 ERE that occurred over India during 1998–2013. It is found that, expectedly, the GCM forecasts underestimate the observed (TRMM) rainfall in most cases, but not always. Somewhat surprisingly, the forecasts of location are quite accurate in spite of low resolution (~50 km). An interesting result is that the highest skill of the forecasts is realized at 48 h lead rather than at 24 or 96 h lead. Diagnostics of dynamical fields like convergence shows that the forecasts can capture contrasting features on pre-event, event and post-event days. The forecast configuration used is similar to one that has been used for long-range monsoon forecasting and tropical cyclones in earlier studies; the present results on ERE forecasting, therefore, provide an indication for the potential application of the model for seamless prediction.

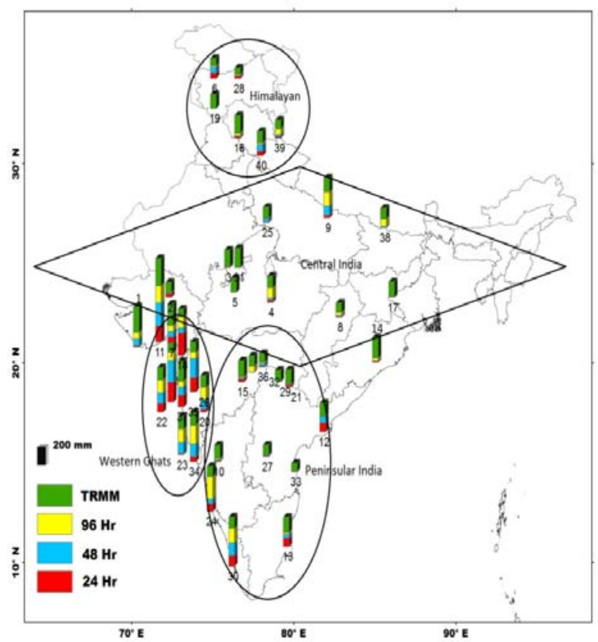


Figure 2.5 Distribution of the forty Extreme Rainfall Events over the four regions considered for regional analysis shown schematically. The bars represent the maximum daily rainfall over a 2°x2° box around the observed location simulated by GCM at 3 forecast leads (24Hr, 48Hr and 96Hr) and the observed daily rainfall on that event day from TRMM.

The extreme rainfall events impact diverse sectors like agriculture, energy, public health and tourism.

The present results show that it is feasible to use a properly calibrated GCM configuration to forecast ERE about 48 hours in advance. Combined with subsequent networking through radar and GIS, such forecasts can provide valuable inputs for pro-active disaster management.

Work is currently under progress to calibrate and validate the GCM for forecasting ERE over other locations and at larger loads.

P Goswami and B Kantha Rao
Climate Dynamics, 2014

2.6 Model configuration for predicting cyclone over Indian Ocean

With rapid enhancement in computing, there is need for evaluation of strategies for tropical cyclone simulations. Although limited area models (LAM) with their high resolutions appear to be the first choice to simulate tropical cyclones with their convective nature, our results show that an atmospheric General Circulation Model (GCM), even with relatively coarser resolution, provides a better candidate, especially at longer (>24-hour) leads. Considered for all the categories and for the moderate cyclones, the 96-hour lead forecasts with GCM are superior to those with LAM; for the severe cyclones, they are comparable. On the other hand, for 24-hour forecast lead, the LAM forecasts are superior to those with GCM for the severe cyclones. It is thus possible to conceive a strategy combining both LAM and GCM for tropical cyclone forecasting. While this conclusion cannot be claimed to be valid for any pair of GCM and LAM, our results provide the basis for such a forecasting strategy.

In actual application, it is possible to improve skill further through techniques like objective debiasing and assimilation of observations. However, such improvement is expected for both LAM and GCM; thus our basic conclusion regarding comparative performance is likely to remain unchanged.

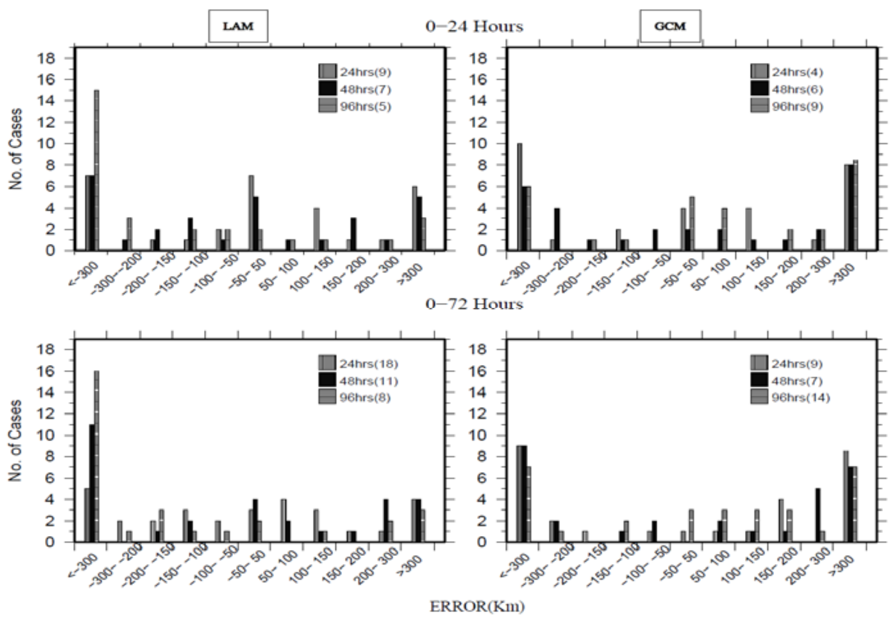


Figure 2.6 Histogram of errors in simulated track for different lead hours for LAM and GCM. The number in the bracket represents the number of cases with error between (top) -100 to +100 km and (bottom) -200 to +200 km.

With growing computing power, it is now possible to carry out simulations with GCM at sufficiently high resolutions for a applications. At the sametime, there is need for a seamless forecast flatform; a GCM provides a natural candidate for such seamless forecasting.

G N Mahapatra and P Goswami

2.7 Impact of data assimilation on high-resolution rainfall forecasts

Advances in assimilation of observations can provide key inputs for improvement in forecast skill, especially at short range. However, there are many issues that need in-depth exploration. In limited area models (LAM) that are generally used for short-range forecasting, the impact of data assimilation is likely to depend on the background state through lateral boundary forcing; this may introduce certain seasonality in the impact of data assimilation on rainfall forecasts. It is also likely that the impact of data assimilation on forecasts will have certain spatial variability. Similarly, the impact of data assimilation may also depend on the category (intensity) of rainfall. These aspects for rainfall forecasts at high resolution were examined using a LAM (An advanced version of Weather Research and Forecasting Model). We have carried out twin simulations with and without data assimilation; the simulations without data assimilation are used as the benchmark. Analysis of simulations for 40 sample days distributed over the years 2012–2014 over Karnataka was carried out to estimate impact of data assimilation. The results showed strong seasonality and location dependence in impact of data assimilation. Our results also show that improvement due to data assimilation is higher/lower for lower/higher rainfall categories.

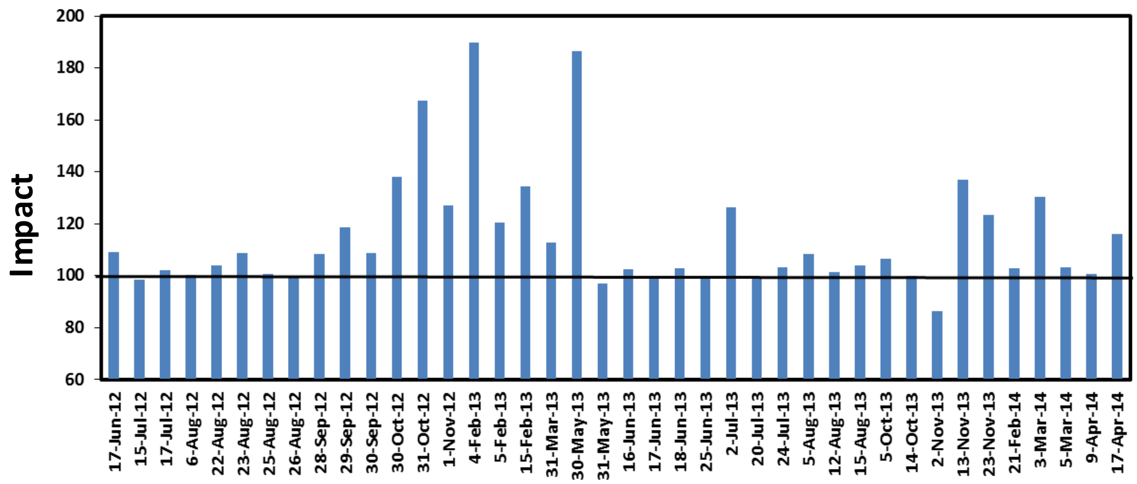


Figure 2.7 Impact index (in %; defined as the ratio of number of hoblis over Karnataka with impact ratio >1 to that having values <1) against different cases computed by validating forecasted daily rainfall with rain-gauge observations.

Assimilation of data is one of the key elements in a forecast cycle; even small improvements in the assimilation methodology can have significant impact of forecast skill. The results have important implications in design of observation system and assessment of impact of forecasts.

V Rakesh and P Goswami
J Geophys. Res. Atmos., 2015

2.8 Comparison of soil moisture of COMoN and remote sensing (ASCAT)

Accurate soil moisture data, critical for many applications such as agriculture and estimation of ground water, is limited worldwide and particularly over India. A long-term sustained soil moisture observation at four vertical levels (5, 15, 50, and 100 cm) is now available at several locations over India under a multi-institutional effort Climate Observations and Modeling Network (COMoN) led by CSIR, India. At the same time, a high resolution (0.1° × 0.1°) 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 have carried out a comparative analysis of gridded ASCAT soil moisture data and in situ COMoN station data over six locations during the period 2010–2013. at daily, weekly, monthly, and seasonal timescales. Analyses show that (Figure 2.8) the two data sets are generally consistent, although there are seasonalities in the agreement; the correlation coefficient is higher for the wet season (summer, autumn), and moderate for dry season (winter, spring). The correlation coefficients range from 0.73 to 0.91 (above 99% significance level). The results quantify the reliability and robustness of ASCAT soil moisture over different climatic regions in India and also identify certain differences between the two data sets from different observation platforms.

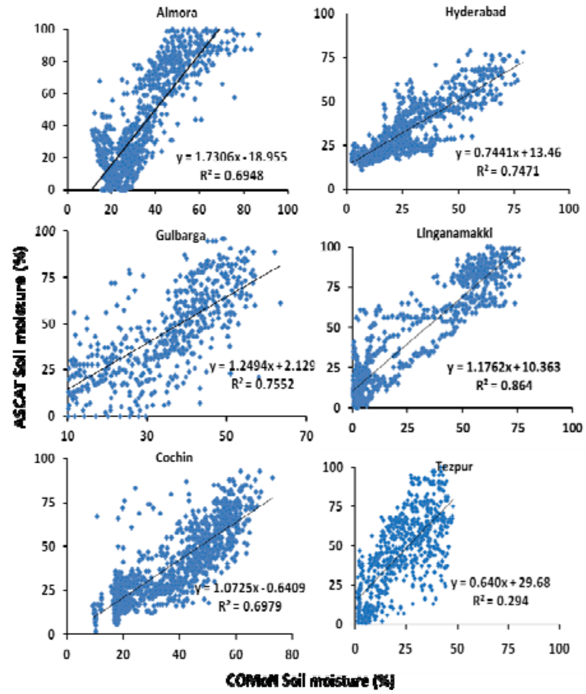


Figure 2.8 Scatter plot of soil moisture from ASCAT and COMoN, x-axis represents the COMoN while y-axis represents the ASCAT.

Work is now under progress to develop algorithms for synthesizing station soil mixture data from COMoN with gridded soil mixture data from ASCAT for a spatially homogeneous data set. Such a homogeneous soil moisture data set will have applications in several sectors like agriculture (moisture adequacy), water resources (ground water modeling) and vulnerability (landslides)

K R Bhimala and P Goswami

2.9 Forecast model for daily CO concentration over Delhi

Advance and accurate forecasts of air pollutant concentrations have many applications at different scales, from traffic planning to health advisories. However, such models need to incorporate local factors and must be validated against local observations for applicability. Dynamical models of species concentration driven by meteorological fields provide a promising avenue for pollution forecasts and control.

ous local sources like vehicular emission, domestic appliances and industrial sources; large-scale factors like advection are incorporated through the meteorological fields. Together with our earlier results, the present work adds to the robustness and enhanced scope of dynamical forecast of air pollution.

For all the three years as well as their average, the number of days in different concentrations bins are very similar (figure 2.9) forecasts based as fields from MM5 and those based on NCEP Reanalysis (used as benchmark).

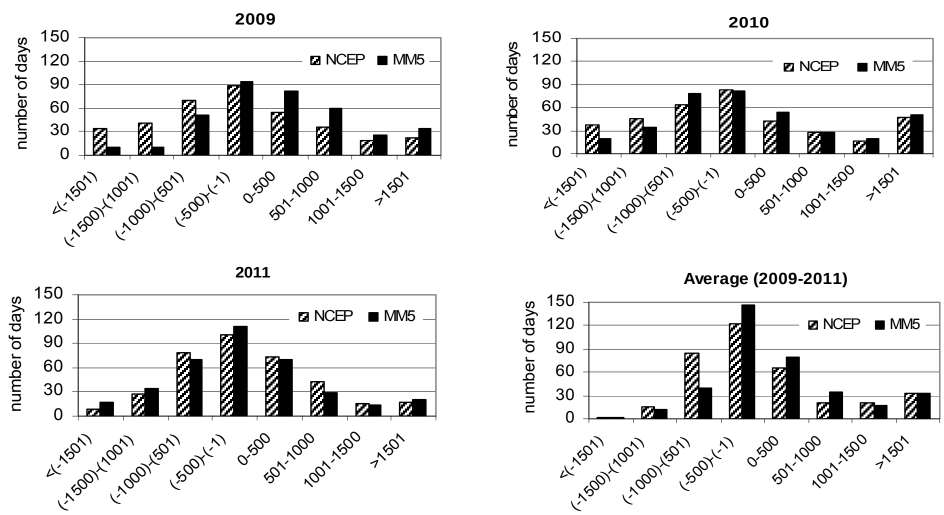


Figure 2.9 Histogram of errors showing the number of days in different error bins (observed-simulated) for the duration 2009-2011. The simulations with NCEP are based on area-averaged daily fields from NCEP Reanalysis for the day of the forecast and meso-scale (MM5) model. The observed concentration data is from CPCB.

It has been shown earlier that a dynamical model successfully simulates, in forecast mode, the observed (CPCB, India) daily concentrations of SPM, RSPM, SO2 and NO2 over Delhi. The present work shows that the model skill is also significant in predicting CO. We have used a meso-scale atmospheric model (MM5) to generate the meteorological forecasts that drive the species consentration model. The species concentration model incorporates vari-

The air pollution model calibrated and validated for Delhi and other urban air basins can be also applied to assess and design traffic in terms of parameters like road width and time to reduce air pollution..

Jurismita Baruah and P Goswami

2.10 Prevention of malaria through pro-active vector sanitation

Response to outbreaks of malaria is still mostly re-active, based on general schedule or post-outbreak decision. However, abundance of the mosquito vector that leads to outbreaks of malaria can vary significantly depending upon the environmental conditions, making a general schedule less effective. Further, exposure of the [incidental] human host to bites also determines the intensity of the epidemic. Identification of potential sites and time of vector genesis can, therefore, enable proactive vector sanitation and reduction of encounters between mosquito and human through exposure advisories. Validated quantitative relations between weather variables and malaria vector, along with recent advances in meteorological monitoring and mesoscale weather forecasting, integrating other critical components like GIS and communication now make such a platform feasible. A forecast model for vector (mosquito) genesis was developed at CSIR-4PI based on a mathematical model driven by the meteorological variables incorporating factors related to transmission and socio-economics. The model was calibrated and validated over Arunachal Pradesh and subsequently, over all the 28 states of India. A feasibility analysis as well as a proof of concept was explored using the malaria model, driven by the meteorological fields. The meteorological forecasts were generated using an atmospheric meso-scale model (WRF) calibrated over India. Experimental forecasts of vector genesis, hosted on the institution's web page for limited period showed (Figure 2.10) the general quality and consistence of the forecasts. Such an approach and methodology would lead to a paradigm shift through ensuring wellness rather than treatment; the applicability of the approach to some other diseases is discussed.

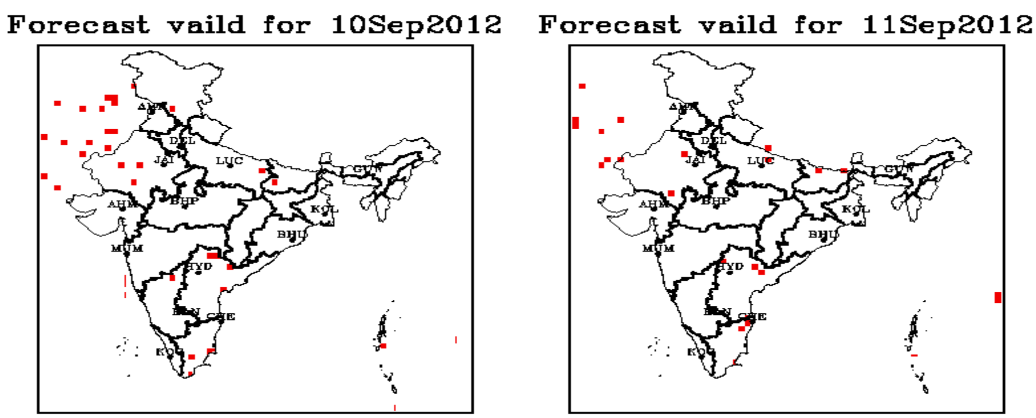


Figure 2.10 Spatial distribution of locations of vector genesis based on forecasts from the malaria model with meteorological fields derived from atmospheric meso-scale forecast.

It is worth emphasizing that the atmospheric forecast configuration applied is essentially the same that has been applied for generating Panchayat-level rainfall forecasting over Karnataka for the past five years.

Thus an integrated forecast platform can be developed for multiple applications.

P Goswami
Current Science, 2015

2.11 Virtual water trade and time scales for loss of water sustainability

A comparative regional analysis, Assessment and policy design for sustainability in primary resources like arable land and water need to adopt long-term perspective; even small but persistent effects like net export of water may influence sustainability through irreversible losses.

An important but mostly overlooked process is the virtual trade of water. The term virtual trade has been used in various contexts in case of water; here we refer to the transfer of water embedded in exported/imported grains and other agricultural products. While the water used in production is reusable in general, the water embedded in exported grains and agricultural products is irrecoverable. Although it may be a slow process, a net export of embedded water can reduce a nation's water sustainability. With growing consumption, this virtual water trade has become an important element in the water sustainability of a nation. We estimate and contrast the virtual (embedded) water trades of two populous nations, India and China, to present certain quantitative measures and time scales. Estimates show that export of embedded water alone can lead to loss of water sustainability. With the current rate of net export of water (embedded) in the end products, India is poised to lose its entire available water in less than 1000 years; much shorter time scales are implied in terms of water for production. The two cases contrast and exemplify sustainable and non-sustainable virtual water trade in a long term perspective. It is noteworthy that while India's recent trade balance in virtual water is negative (export/

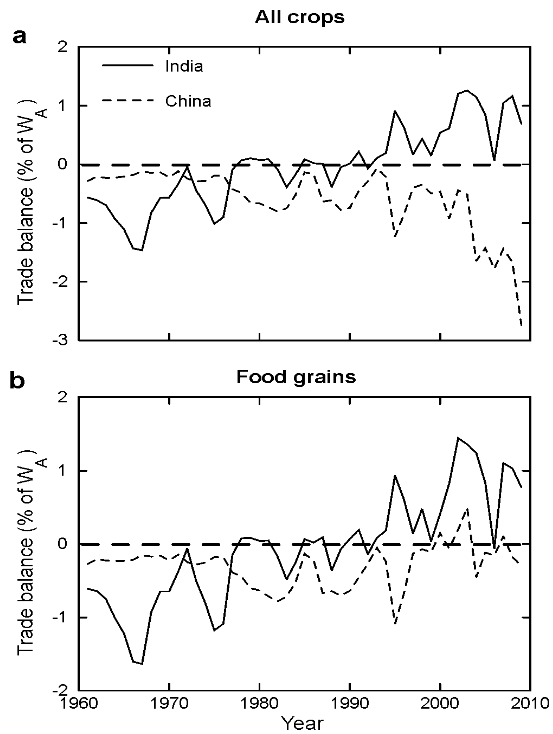


Figure 2.11 Trade balance in terms of total water involved in production as percentage of water available for all crops (a) and food grains (b) for India (solid line) and China (dash line).

import), China has maintained a positive trade balance in virtual water water essentially since 1960. At the same time, China possesses a much larger water resource than that of India.

It is important therefore, to evolve an export/import policy for agricultural products so that there is a zero or positive (more import) balance in virtual water trade. Such policies can take into account type of agricultural products as well as countries to trade with for net import through virtual water.

P Goswami and Shivnarain Nishad
Nature Scientific Reports, 2014

2.12 Towards seasonal forecasting of malaria in India

Outlook of disease burdens can help advance planning and preparedness. For diseases like malaria that depend on vector (mosquito) population, weather conditions play a decisive role. Thus seasonal disease outlooks are possible through disease model driven by seasonal forecasts. A 30-year hindcast of the climatic suitability for malaria transmission in India was explored using meteorological variables from a state of the art seasonal forecast model to drive a process-based, dynamic disease model. The spatial distribution and seasonal cycles of temperature and precipitation from the forecast model were compared to three observationally-based meteorological datasets. These time series are then used to drive the disease model, producing a simulated forecast of malaria and three synthetic malaria time series that are qualitatively compared to contemporary and pre-intervention malaria estimates. The area under the Relative Operator Characteristic (ROC) curve is calculated as a quantitative metric of forecast skill, comparing the forecast to themeteorologically-driven synthetic malaria time series.

The forecast shows probabilistic skill in predicting the spatial distribution of *Plasmodium falciparum* incidence when compared to the simulated meteorologically- driven malaria time series, particularly where modelled incidence shows high seasonal and interannual variability such as in Orissa, West Bengal, and Jharkhand (North-east India), and Gujarat, Rajastan, Madhya Pradesh and Maharashtra (North-west India). Focusing on these two regions, the malaria forecast is able to distinguish between years of

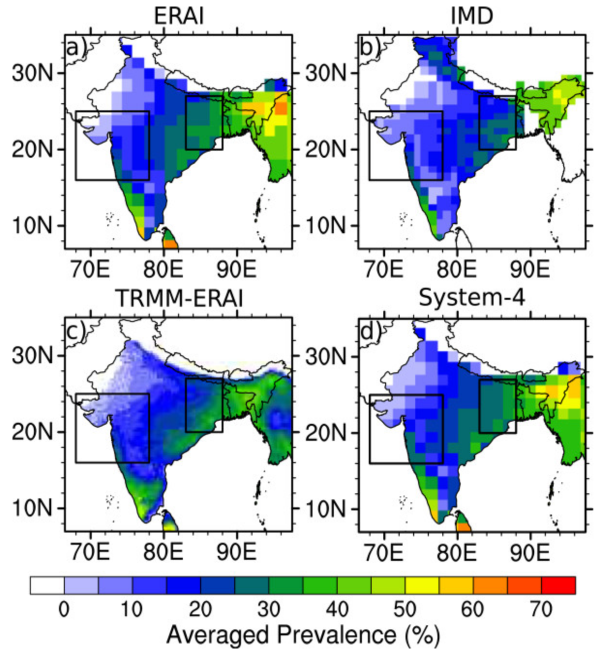


Figure 2.12 Annual average malaria prevalence (%). Output is shown from the Liverpool Malaria Model (LMM) driven by a) ERAI (1981–2010), b) IMD (1981-2002), c) TRMM precipitation and ERAI temperature (TRMM-ERAI, 1998–2010) and d) the System-4 forecast (1981–2010) .The two boxes enclose the regions of interest in Northwest and Northeast India.

"high", "above average" and "low" malaria incidence in the peak malaria transmission seasons, with more than 70% sensitivity and a statistically significant area under the ROC curve. These results are encouraging given that the three month forecast lead time used is well in excess of the target for early warning systems adopted by the World Health Organization. This approach could form the basis of an operational system to identify the probability of regional malaria epidemics, allowing advanced and targeted allocation of resources for combatting malaria in India.

J M Lauderdale, C Caminade, A E Heath, A E Jones, D A MacLeod, K C Gouda,U S N Murty, P Goswami, S R Mutheneni, A P Morse
Malaria Journal, 2014

2.13 Forecast model for capsule rot of small cardamom: A CSIR-ICRI synergy

Small cardamom is an economically important spice crop. However, cardamom is susceptible to several diseases that significantly reduce yield. Proactive prevention of these diseases based on advance warning can enhance the efficiency of disease control and reduce environmental load of pesticides. Many of these diseases are governed by weather variables (for example, through control of fungal growth). This work presents a disease (capsule rot of cardamom) forecast model based on a set of meteorological variables. While no single weather variable provides successful simulation, an optimal combination of weather variables provides sufficient skill for advance warning of the disease.

CSIR-4PI and Indian Cardamom Research Institute (ICRI) had initiated a collaboration to develop and validate forecast model for capsule rot of small cardamam. A forecast model was developed at CSIR-4PI which was then validated with data provided by ICRI.

The simulations of monthly disease incidences for the two years of 2008 and 2010 show good correspondence with observations, with correlation coefficient between observations and simulations significant in each case (Figure 2.13). However, there are over predictions in the months of September-December; although these errors in the predictions for the winter months are generally below thresholds to effect decisions, they need further improvement and attraction feature of the forecasts is their

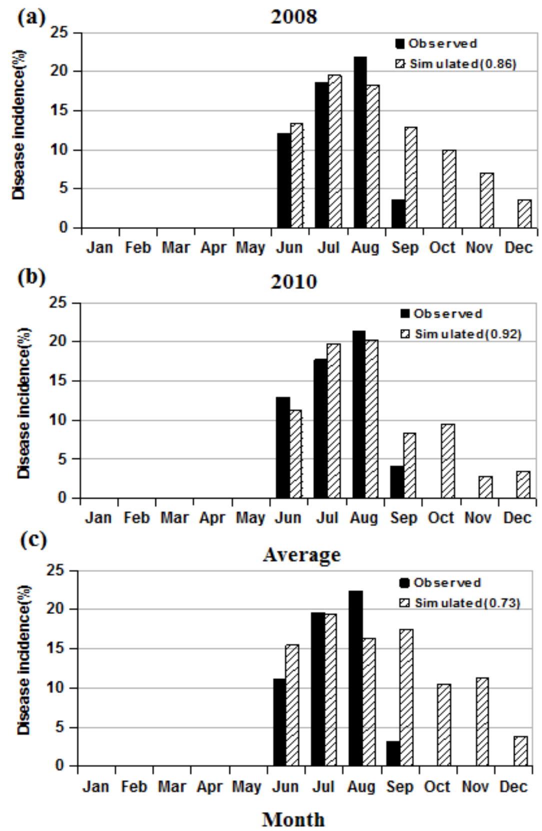


Figure 2.13 Observed and simulated values of disease occurrence with the forecast model for (a) 2008 (b) 2010 and (c) average.

ability to capture the abrupt but appreciable disease onset.

There is need for further calibration and validation of the model, especially at daily scale; the establishment of multi-level weather profiler at ICRI under The CSIR Climate Observation and Modelling Network (COMoN) provides an opportunity for such development. At the same time, the model is being extended to other weather driven crop diseases like castor botryties and alter maria leaf blight in sunflower.

P Goswami, R Goyal, E V S Prakasa Rao, K V Ramesh, M R Susharshan and D Ajay
Current Science, 2014

2.14 Quantification of relative roles of drivers of acute respiratory diseases

Several thousands of people, including children, suffer from acute respiratory disease (ARD) every year worldwide. Pro-active planning and mitigation for these diseases require identification of the major drivers in a location-specific manner. While the importance of air pollutants in ARD has been extensively studied and emphasized, the role of weather variables has been less explored. With Delhi with its large population and pollution as a test case, we have examined the relative roles of air pollution and weather (cold days) in ARD.

Data from both National Centers for Environmental Prediction (NCEP) and The CSIR Climate Observation and Modelling Network (COMoN) and Indian Meteorological Department (IMD) were used to identify days with temperature below a thresholds (Cold Days). Pollution (Respiratory Particulate Matter) concentrations were adopted from the public-domain data from the Central Pollutions Control Board (CPCB, India). The ARD deaths were considered both in terms of actual numbers and as % of (annual) pollution. The data for the period 1991-2011 showed complex inter annual variabilty in the number of cold days as well as the number of ARD deaths.

It was found that both the number of cold days and air pollution play important roles in ARD load; however, the number of cold days emerges as the major driver. These conclusions are consistent with analyses for several other states in India. The robust association between ARD load and cold days provides basis for estimating and predicting ARD load through dynamical model, as well as impact of climate change. In particular, high-resolution forecasts from atmospheric meso-scale models can be used to generate and issue advisories for vulnerable locations. Such measures can reduce disease incidences leading to improvement in healthcare and quality of living.

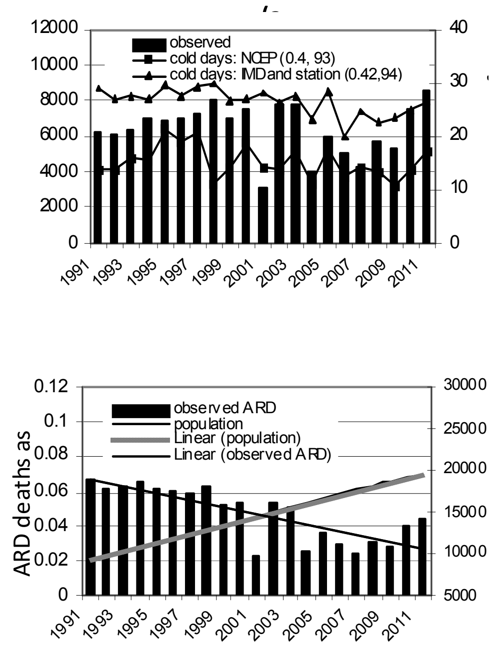


Figure 2.14 Number of ARD deaths reported during 1991-2011 with (a) percentage of cold days (20^{0}C) and (b) ARD deaths as percentage of population and annual population. The corresponding observed ARD deaths have been adopted from Government of NCT of Delhi. The first number in bracket in the top panel represents the correlation coefficients between number of deaths from observations and percentage of cold days, with the significance level (second number).

P Goswami and J Baruh
Nature Scientific Reports 2014

2.15 Integrated disaster assessment and modelling over the Himalayan region

An important but missing aspect of vulnerability analysis is a multi-scale approach. While events like earthquakes have large disaster potential, they are relatively rare, with long return periods. On the oth-erhand, episodes of extreme rainfall events are quite frequent, with considerable demage potential.

Further, extreme rainfall can also act as triggers for landslide events. Finally, vulnerability critically depends upon the socio-economics of the region.

The changing climate combined with socio-economic transformations introduces new vulnerability in many regions. Of particular importance is the Himalayan region characterized by high seismicity, as well as extreme rainfall events; growing socio-economic activities in this region in the recent years have made it vulnerable to a wide spectrum of natural events. However, a comprehensive and integrated assessment of vulnerability of this region in the changing socio-climatic conditions is missing, as most analyses tend to focus on one or the other event (scale).

An important but missing aspect of vulnerability analysis is a multi-scale approach. While events like earthquakes have large disaster potential, they are relatively rare, with long return periods. On the other hand, episodes of extreme rainfall events are quite frequent, with considerable damage potential.

Further, extreme rainfall can also act as triggers for landslide events. Finally, vulnerability critically depends upon the socio-economics of the region.

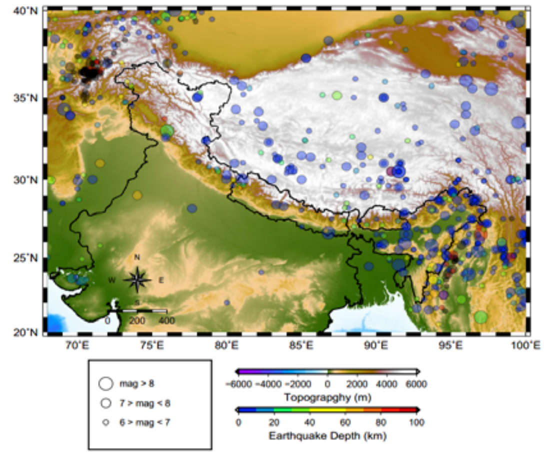


Figure 2.15 Digital elevation map of the Himlalaya-Tibetan region representing location of epicenter of historical earthquakes (circles) with magnitude greater than 6.0 up to December 2011. Colour scale and diameter of the circles indicates depth and magnitudes respectively. Background: Shuttle Radar Topography Mission (SRTM) elevation map.

An integrated analysis of vulnerability of this region, in the form of a quantified vulnerability index, to geological as well as a class of meteorological events was developed. The vulnerability index was then superposed on socio-economic backdrop. It was found that the combined analysis brings out aspects not revealed by any isolated analysis.

The present work is a part of the inter-disciplinary (inter-Group) effort to develop an integrated Disaster Assessment and Modelling (IDAM) for pro-active disaster management through assessment, forecasting and projections. IDAM is being developed as a multi-application utility to strategic as well as social sections.

P Goswami, I A Parvez, G N Mohapatra, S Himesh, K V Ramesh, K C Gouda ,Rakesh V, B Kantha Rao, Ashish

2.16 Simulation of a heavy rainfall event: Case study over Bengaluru

This study is about the meso-scale simulation, diagnostics and analysis of heavy rainfall event that occurred on 8th of October 2013 over Bengaluru, the capital city of Karnataka in India. The city normally receives good amount of rain during Northeast monsoon in addition to regular Southwest monsoon. One of the rain gauges out of 19 located in the city, recorded the highest total (24-hour accumulated) rainfall of 123 mm on the event day. The simulated results are based on high resolution (2-km) and time-ensemble simulations (3 initial conditions) using the 3-nested Weather Research and Forecast (WRFV3) model (Figure 2.16). Simulated rainfall was compared with Tropical Rainfall Measuring Mission (TRMM) and rain gauge data (Figure 2.17) and found be in be in good agreement with observation. The model was able to reproduce the entire lifecycle of the event with closely matching observation in terms of; time of initiation, time evolution (Figure 2.18), highest intensity, spatial distribution and location.

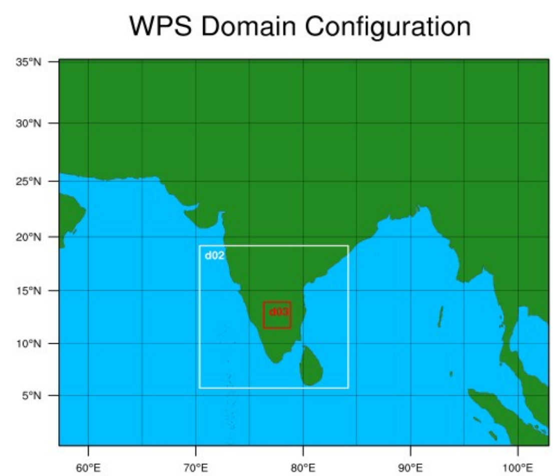


Figure 2.16 WRF Model Simulation Domain

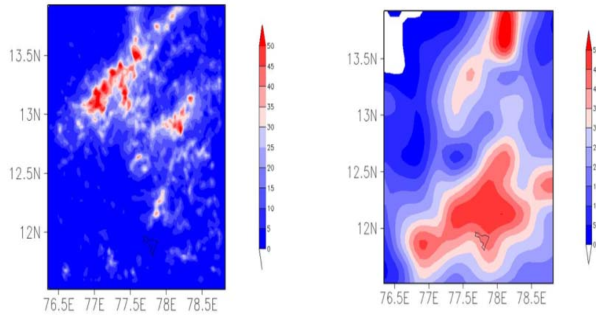


Figure 2.19 Spatial distribution of simulated rain (left) compared with TRMM data. Despite the discernable differences between the TRMM and model results, model captured the high intensity convective cells and overall pattern reasonably well.

The performance of the model in simulating this event was assessed in terms percentage error for intensity and location. The intensity error in terms of 24-hour accumulated maximum rain was found to be 19.3 %

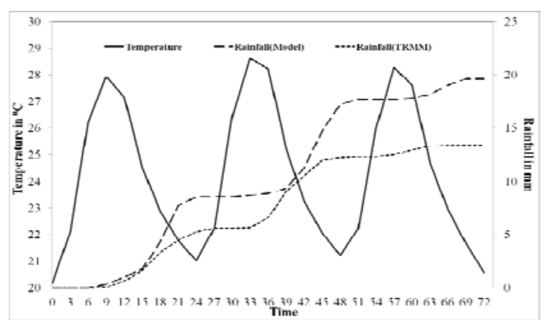


Figure 2.18 Time evolution of domain averaged (inner domain D3) simulated rainfall and surface temperature. It may be seen that the model successfully simulated the diurnal pattern of surface temperature. Time evolution of the simulated rain is seen to be in close agreement with TRMM data.

and 8 % with respect to TRMM (0.25°) and rain gauge (averaged over 6 rain gauges) observation respectively. The location error was found to be about 40 km (0.48°E, 0.15°N) and 10km (0.08°E, 0.05 °N) w.r.t TRMM and rain gauge respectively.

S Himesh, S K Sahoo , K C Gouda, G N Mohapatra and P Goswami

2.17 Model configuration for fog forecasting

A popular strategy for forecasting fog is to drive a fog process model with meteorological forecasts from an atmospheric model. The best candidate for an atmospheric model to drive a fog forecasts at high spatial distribution is an atmospheric meso-scale model Several studies have employed this strategy for development and evaluation of fog fore-casts models. A critical question in adopting and calibrating such an atmospheric model is its ability to simulate the contrasts in the meteorological vari-ables for foggy and non-foggy days. It is expected that the meteorological fields will have different characteristics for foggy and non-foggy days. How-ever, due to the prevailing background conditions and local processes, the differences are likely to be site-specific and season-specific. The magnitudes of contrasts in different fields at different levels for foggy and non-foggy days indicate the precision and accuracy required in simulation of the meteorologi-cal fields for forecasting fog; smaller contrast in a field means that a model requires more accurate prediction of this field. Our results that T and RH have 1 degree and 5 % contrasts, respectively near the ground, imply an accuracy of at least 1 degree and 5% to skillfully predict fog with a NWP model. The objective of the present study is to carry out such a validation of an atmospheric meso-scale model (MM5) over a fog-prone metropolis (Delhi). While we consider validation of the forecasts of the variables themselves in terms of standard measures, the focus is on simulating and validating the ob-served contrast in the meteorological fields for foggy and non-foggy days. The observational analy-sis showed the contrasts in the meteorological fields to be present also in the upper levels; accordingly, the simulated contrasts were also examined against the corresponding observed values; independent data sets were used wherever possible (Figure 2.19).

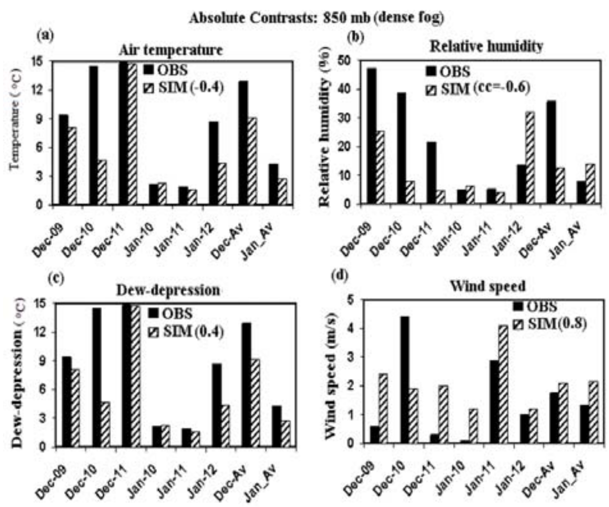


Figure 2.19 Monthly averages of observed (black bars) and simulated (shaded bars) absolute contrasts in (a) air temperature (°C), (b) relative humidity, (c) dew-depression and (d) wind speed between composites of non-foggy days and dense fog days at 850 mb. Observed mete-orological variable is adopted from radiosonde observa-tion at 00 UTC over Delhi Safdurjang airport for the months December and January through 2009-2012. Simu-lated variable is adopted from area averaged forecasts around Delhi from an atmospheric meso-scale model MM5 for the same period. The numbers in the bracket are the correlation coefficients between observed and simulated contrasts for each of the respective variable.

The contrasts for the different years also show ap-preciable differences; this inter annual variability is likely an indication (and possible measure) of varia-tions in the large-scale conditions from year to year, and their effect on fog occurrence over a location. Similarly, it is important to identify the critical val-ues and meteorological conditions for formations and dissipation of various types of fogs under differ-ent large-scale conditions.

Sumana Sarkar and P Goswami

3

COMPUTATIONAL MECHANICS

Work initiated on homotopy analysis method has been continued. A number of industrially significant problems have been considered and it has been demonstrated that the homotopy analysis method gives good results. It is also planned to extend our work on periodically forced suspensions to inertial particles. Work on computational nanomaterials and nanomechanics of complex materials has also been carried out. As part of the progress work on kernel determination for one dimensional carbon nano-structures has been carried out.

Inside

- ***Influence of heat transfer on MHD flow in a pipe with expanding or contracting permeable wall***
- ***Thermal-diffusion and diffusion-thermo effects on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation***
- ***Hydro magnetic flow of a nanofluid in a porous channel with expanding or contracting walls***
- ***Mass transfer effects on viscous flow in an expanding or contracting porous pipe with chemical reaction***
- ***The effect of particle inertia on periodically forced triaxial ellipsoids in creeping shear***
- ***Computational nanomaterials and nanomechanics of complex materials***
- ***Kernel determination for one dimensional carbon nanostructures***
- ***Nanoscale effect on vibration analysis of double walled carbon nanotube using nonlocal continuum model***

3.1 Influence of heat transfer on MHD flow in a pipe with expanding or contracting permeable wall

This investigation deals with the analysis of heat transfer and MHD viscous flow in a porous pipe with expanding or contracting wall as shown in Figure 3.1 below. Using suitable similarity transformations, the governing equations are reduced to a system of coupled nonlinear differential equations. The resulting equations are solved by employing the homotopy analysis method (HAM). The main findings are summarized as follows:

1. For a constant wall expansion ratio α, the dimensionless axial velocity near the center increases with increasing suction while it decreases with increasing injection.
2. For given increase in Hartmann number (M), the dimensionless axial velocity decreases little away from the pipe wall. For every level of injection or suction, for the case of wall contraction, the absolute dimensionless radial velocity decreases with increasing |α| whereas it increases as α increases for the case of wall expansion. The absolute dimensionless radial velocity decreases as M increases.

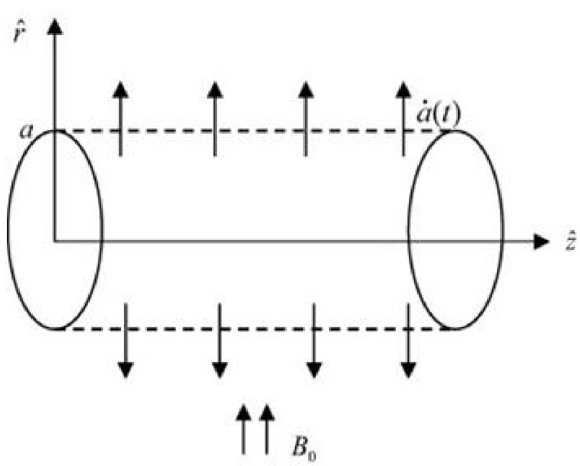


Figure 3.1 Porous pipe with expanding or contracting wall.

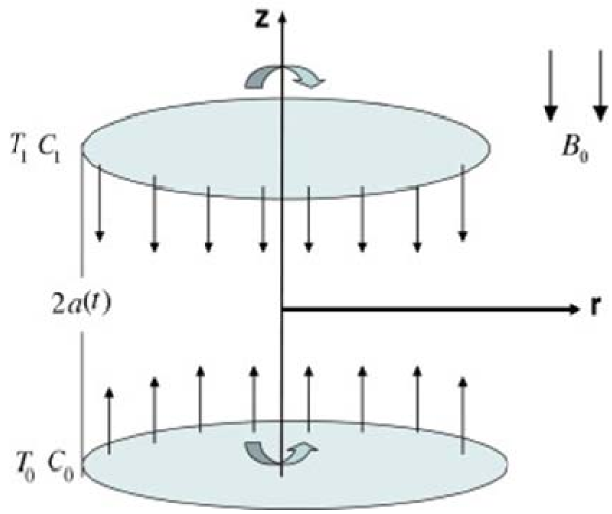
$\hat{r}$ –Expansion or contraction direction
$\dot{a}$(t)- Rate of expansion or contraction
a- Radius of the pipe
B_0- Magnetic Field

3. For every level of suction or injection, θ (dimensionless temperature) increases as α increases for the case of wall expansion while it decreases as |α| increases for the case of wall contraction. Further, θ decreases with increasing Pr (Prandtl number).
4. The absolute wall shear stress increases as M increases.
5. The absolute axial pressure distribution |ΔPr| decreases as M increases.

Anant Kant Shukla*[#]*, T R Ramamohan, S Srinivas*, A S Reddy*
[#]Amrita University, Coimbatore
***** VIT University, Vellore

3.2 Thermal-diffusion and diffusion-thermo effects on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation

This investigation examines the effects of thermal-diffusion and diffusion-thermo on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation as shown in Figure 3.2. Convergence of the obtained series solutions is analyzed. The results obtained by HAM are in good agreement with numerical solutions obtained by a shooting method coupled with Runge–Kutta scheme. The temperature distribution increases while the concentration decreases with an increase in R (permeation Reynolds number), R* (rotation Reynolds number), Du (Dufour number), and Sr (Soret number).



C_0,T_0- Concentration and Temperature of Bottom Plate

C_1,T_1- Concentration and Temperature of Top Plate

2a- Distance between the two plates

B_0- Magnetic Field

Figure 3.2 The model for expanding or contracting porous disks

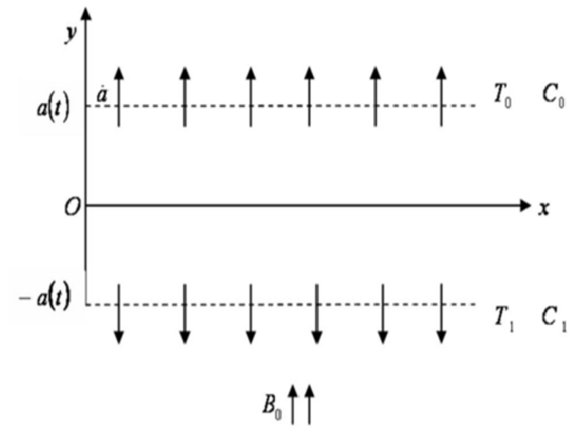
Anant Kant Shukla[#], T R Ramamohan, S Srinivas*, A S Reddy*

[#]Amrita University, Coimbatore

*VIT University, Vellore

3.3 Hydro magnetic flow of a nanofluid in a porous channel with expanding or contracting walls

The present study investigates the hydro magnetic flow of a nanofluid in a two-dimensional porous channel between slowly expanding or contracting walls as shown in the Figure 3.3. Assuming symmetric injection (or suction) along the uniformly expanding porous walls and using a similarity transformation, the governing flow equations are reduced to nonlinear ordinary differential equations. The resulting equations are then solved analytically by by using the homotopy analysis method (HAM).



C_0,T_0- Concentration and Temperature of Top wall

C_1,T_1- Concentration and Temperature of Bottom wall

2a- Distance between the two plates

$\acute{a}$- Rate of expansion or contraction

B_0- Magnetic Field

Figure 3.3 Two-dimensional domain with expanding or contracting walls

The convergence of the obtained series solutions is analyzed through the minimization of the averaged square residual error. A comparison between analytical and numerical solutions is presented for validation in both graphical and tabular forms. The results obtained by HAM are in very good agreement with numerical solutions obtained by the shooting method coupled with a Runge-Kutta scheme. The effects of various physical parameters such as wall expansion ratio, Brownian motion parameter, thermophoresis parameter, and Lewis number on flow variables are discussed. The analysis shows that for the case of contracting walls, the temperature increases for a given increase in Brownian motion parameter, and the thermophoresis parameter. In addition, the nanoparticle concentration increases with an increase in Brownian motion parameter and Lewis number.

S Srinivas* , A Vijayalakshmi*, T R Ramamohan, A S Reddy*

*VIT University, Vellore

3.4 Mass transfer effects on viscous flow in an expanding or contracting porous pipe with chemical reaction

An analysis is performed to study the effects of mass transfer and chemical reaction on laminar flow in a porous pipe with an expanding or contracting wall. The pipe wall expands or contracts uniformly at a time dependent rate. The governing equations are reduced to ordinary differential equations by using a similarity transformation. An analytical approach, namely, the homotopy analysis method is applied in order to obtain the solutions of the ordinary differential equations. The convergence of the obtained series solutions is analyzed. The effects of various parameters on flow variables is discussed. It is noticed that the wall expansion ratio significantly increases the axial velocity and the concentration for the case of wall expansion and it decreases the axial velocity for the case of wall contraction irrespective of injection or suction. Further, it is observed that the concentration (ϕ) decreases for a destructive chemical reaction $(\gamma > 0)$ and increases for a generative chemical reaction $(\gamma < 0)$. The concentration reduces as Schmidt number (*Sc*) increases. The corresponding problem related to a porous pipe flow with a stationary wall can be recovered from the present analysis in the limiting case where the wall expansion ratio approaches to zero (i.e., $(\alpha = C\ )$.

S Srinivas* , A S Reddy*,
T R Ramamohan,
[#]Amrita University, Coimbatore
VIT University, Vellore

3.5 The effect of particle inertia on periodically forced triaxial ellipsoids in creeping shear

This investigation deals with determining the effects of particle inertia on periodically forced inertial ellipsoids in creeping shear.

Starting from the ellipsoid equation, the position and orientation of an arbitrary rigid body is described in terms of seven generalized co-ordinates, namely Cartesian components of the centre of mass vector (c) and a four component vector of Euler parameters (e) . The Euler parameters are defined in an orthogonal rotation matrix which is in a fixed Cartesian co-ordinate system. These equations are then converted to the body fixed rotating frame. Since Newton's laws are valid only in a fixed (or a laboratory frame of reference), the moment of inertia of the particle is found in the fixed frame by the Euler transformation. Jeffery's torque, as derived for constant shear rate, is planned to be used for the periodic torque with the equations derived by Hamilton's Equations with Euler parameters for rigid body dynamics modelling. The resulting equations were non-dimensionalized. The resulting ODEs will be solved using the ODE solvers (ODE45 and ODE113) with high accuracy as provided by MATLAB. Wolfram Mathematica has been used extensively for the matrix operations and evaluating the definite integrals required.

Amar Narayan, T R Ramamohan

3.6 Computational nanomaterials and nanomechanics of complex materials

Computational simulations of nanostructures at atomic levels are expensive in terms of cost. CSIR 4PI's High Performance Super computers have been used to simulate and analyse the properties of carbon nantotubes and graphene. Molecular Dynamics Simulations (MDS) are used for modification of existing continuum models to predict behavoiur of nanostructures without conducting experiments. Higher order gradient mathematical models are proposed to replace existing continuum elasticity models by addressing their pitfalls as compared with the lattice dynamics results. Modelling and Simulation of complex materials like graphene; penta-graphene and Meta materials need to be investigated further.

V Senthilkumar

3.7 Kernel determination for one Dimensional carbon nanostructures

Recently, growing interest in terahertz physics of nanoscale materials and devices has drawn more attention to the Carbon Nanotubes (CNTs) phonon dispersion relation, especially in the terahertz frequency range. Since terahertz physics of nanoscale materials and devices are major concerns for CNT wave characteristics, small-scale effects must be considered since the wavelength in the frequency domain is of the order of nanometers. Explicit dispersive solutions are derived in the work, from which small-scale effects can be clearly observed. Such observations are vital for applying continuum models to obtain CNT wave characteristics. To help in development of improved and efficient continuum models for predicting the mechanical response of CNTs it is imperative to determine the best kernel that can capture the physics of small scale effects as discussed above. The most popular approach for determining the kernels is by matching with phonon dispersion curves. Several important kernels have already been discussed. Additionally, one more "BEST FIT" approach used by Sundararaghavan and Waas [2010] is implemented in which the fourier transform of the kernel is directly estimated by matching the atomistic data to the dispersion curves predicted from the nonlocal continuum model theory. The predictions of different kernels are compared. The longitudinal wave dispersion curves in single walled carbon nanotubes (SWCNT) are used to estimate the non-local kernel for use in continuum elasticity models of nanotubes. The dispersion data for an armchair (10,10) SWCNT was obtained using lattice dynamics of SWNTs while accounting for the helical symmetry of the tubes (Sundararaghavan, Waas [2010]).

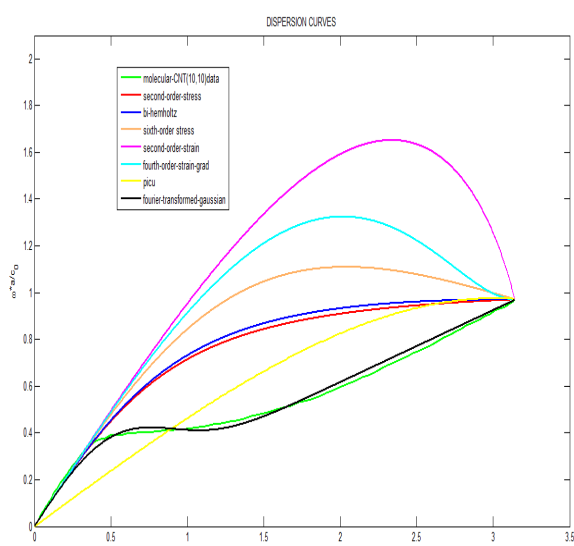


Figure 3.4 Phonon dispersion curve (comparison with the atomistically computed longitudinal mode of (10,10) nanotube) with various models.

Dispersion curves (Figure 3.4) for the nanotube computed from this approach are used to obtain the expression for α(k) (the Fourier transform of the non-local kernel) through comparison with the one dimension carbon nanotube model. The Best fit (fourier transformed Gaussian) kernel gives the best fit to the atomistically computed kernel. Gradient theories which reasonably reproduce the phonon dispersion curve for the Born-Kármán model of lattice dynamics (harmonic spring model) are not able to predict complex lattice dynamics found in the case of nanotubes. Picu kernel also fails because it has been constructed for a special case of interatomic potentials depending only on pair interactions (or through embedded functions that are functions of radial distance only). Such an approach cannot be successfully used for CNTs since carbon atom interactions in the CNT are typically multibody potentials that depend on atom coordination (Brenner potential) or three or four body interactions (Force field potentials).

V Senthilkumar, T Chaudhary[*]
[*]IIT, Varanasi

3.8 Nanoscale Effect on Vibration Analysis of Double Walled Carbon Nanotube using Nonlocal Continuum Model

The double walled carbon nanotube is modelled as two single walled carbon nanotubes connected with van der Waals force. Various frequency modes with different initial conditions for the present mathematical model are analysed using a semi-analytical method. The frequency ratio is defined as the ratio between nonlocal frequencies to classical continuum model frequency. The frequency ratio for boundary conditions like Simply Supported (Figure 3.5),

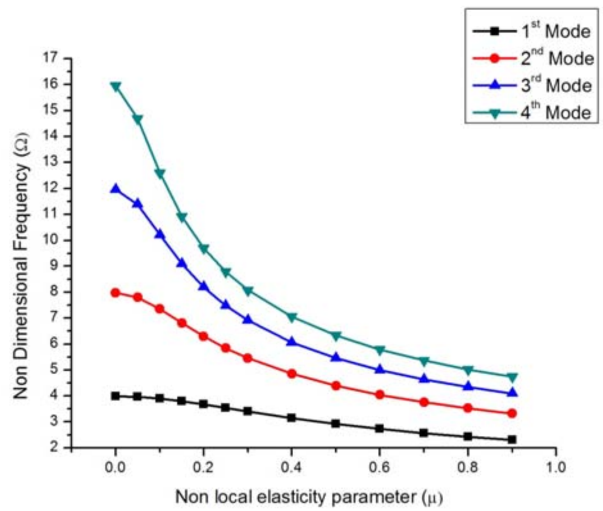


Figure 3.5 Small scale effects on first four mode frequency parameter for SS condition

Clamped Clamped and Clamped Hinged is decreasing with the increase of the nonlocal effect. However it increases for the Clamped Free boundary conditions of the double walled carbon nanotube. Further it has been observed that increase in the nonlocal parameter decreases the non dimensional frequency for the first four modes.

V Senthilkumar, G Prathap[*]***, S C Pradhan***[**]
[*]NIIST Trivandrum, [**]IIT Kharagpur

4

HIGH PERFORMANCE COMPUTING & CYBER SECURTY

Computation is the third pillar of scientific discovery. It is an in-expensive way to achieve high science, which complements theory and observations. It has become such a necessity that, the capability and credibility of a scientific organization is currently judged by the computational facility it has access to. CSIR 4PI provides state-of-the-art High Performance Computing facility to the computational scientists and researchers of CSIR to address Grand Challenge problems in their frontier areas of science and engineering through a centralized High Performance Computing facility. The facility at CSIR 4PI is one of the fastest in the country and is aimed at providing multiple architectures suitable for domain specific applications. The facility is accessed by all the CSIR laboratories, through the high speed National Knowledge Network. The group is involved in research on cyber security. Under the 12th five-year plan of CSIR work has been initiated to develop a "Cyber Security Research & Observation" abbreviated as "CySeRO" to carry out research in the field of Cryptography and Cyber Security.

Inside

- ***Active TCP responder for cyber security inference***
- ***Leveraging bigdata technologies for cyber security inference***
- ***Hierarchical trust model based on security to rate cloud service providers***
- ***Secure key stream generation using particle swarm optimization***
- ***High Performance Computing***

4.1 Active TCP responder for cyber security inference

It has been well established that malicious activities on the Internet trigger certain special type of network traffic called 'unsolicited packets'. There exist a wide variety of malicious activities like worm propagation, port-scanning, Internet Protocol (IP) address spoofed Denial-of-Service attacks, etc. which generate unsolicited packets. CSIR Fourth Paradigm Institute, under its Cyber Security Research and Observation (CySeRO) programme, has been collecting and analyzing such unsolicited packets for better security inference.

It is a general perception that Internet hosts from where these unsolicited packets originate are hosting malware. Hence, the source addresses of these unsolicited packets are typically considered as the identity of infected hosts on the Internet. However, there is a potential risk of misidentification due to the prevailing IP address spoofing on the Internet. IP address spoofing is the process by which the actual source IP address of a packet is replaced with the IP identity of somebody else for obvious reasons. Hence the source IP address claimed in the unsolicited packets needs to be validated before using them for further inference.

We are developing a framework for source address validation of unsolicited packets. The software is developed in python using the scapy library. It consists of two tightly coupled modules: a passive packet listener to receive unsolicited packets and an active responder which prepares and sends appropriate TCP/IP packets as a response to the unsolicited packets. Acceptable and timely response, subsequent to this, from the remote host is analyzed to determine whether the initial unsolicited packet was IP address spoofed or not.

Considering the fact that majority of the unsolicited packets are based on the Transmission Control Protocol (TCP), the most popular and widely used transport layer protocol on today's Internet, our first version of the active responder validates only TCP packets. It listens to TCP connection requests (SYN packets) and responds to such requests with protocol compliant connection response (SYN/ACK). Further response to SYN/ACK, if any, is validated according to the TCP specification to ascertain the authenticity of the unsolicited SYN packet. This leads to the responder successfully establishing a TCP connection with the sender of the unsolicited packets through the well-known three-way handshake mechanism of TCP. The active responder is being integrated to the CySeRO testbed. Its preliminary deployment for a period of one-week in our NKN (National Knowledge Network) perimeter leads to interesting observations.

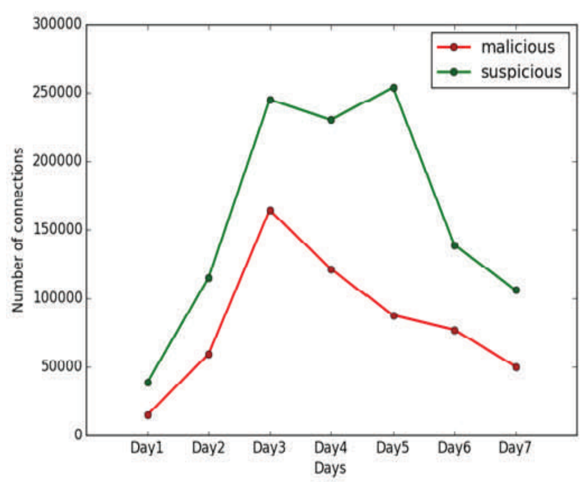


Figure 4.1 Classification of unsolicited packets through active TCP responder.

In Figure 4.1, suspicious indicates the number of SYN requests received and malicious indicates the source IP address validated connection by our active responder. It is important to note that only about half of the suspicious connection requests could be confirmed as malicious. The remaining connections either have spoofed source IP addresses or did not purposefully respond to the active responder's traffic.

We are currently strengthening our active responder with advanced classification schemes based on the further response received by our active responder. Our ongoing work uses TCP RST packets and values in the protocol fields such as TTL (Time to Live), Fragmentation Identify, Time Stamp Echo, etc. for further inference and classification. Active TCP responder will also be expanded to an active application responder (e.g. http responder) to respond to unsolicited application traffic for interacting with the *malicious hosts* until the host terminates the connection for timely extraction of *malicious payloads*. The responder can also be extended for other transport layer protocols like Stream Control Transmission Protocol (SCTP) and Multi Path Transmission Control Protocol (MPTCP).

V Anil Kumar, Sujata, Chinmaya Mohini and Kirthi Sagar

4.2 Leveraging bigdata technologies for cyber security inference

Cyber Security is a source of bigdata. For effective cyber security inference at regional, national and global scale, one needs to deal with massive amount of diverse data. Such data typically include application level logs from Internet servers, user access patterns, security logs from middle boxes such as firewalls, Intrusion Detection Systems (IDS) and Intrusion Prevention Systems (IPS), raw network packets consisting of multi-layer protocol information and application payload, etc. Among them, raw network packets, if collected, stored and analyzed, can lead to vital security inference.

Raw network packets on high-speed network can grow to several tera-bytes in a relatively short span of time. They are typically semi-structured with standard protocol headers and varying forms of payloads in each packet. Collecting, storing and effectively querying such volume of semi-structured data needs state-of-the-art technologies. CSIR-4PI, for its CySeRO (Cyber Security Research and Observation) programme, is exploring next generation database technologies to deal with the massive amount of raw network packets classified as unsolicited packets. In particular, we have designed a NOSQL (Not Only Structured Query Language) based database using the emerging bigdata tool called Cassandra.

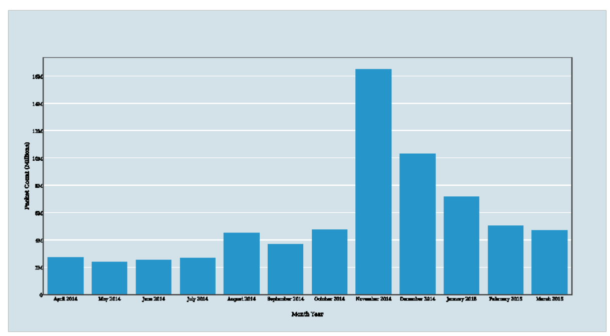


Figure 4.2 Volume of Unsolicited Packets

Our database currently consists of about 100 million raw unsolicited network packets. Each packet consists of multi-layer protocol headers (TCP/IP/Ethernet) and application payload. Using a customized web interface, queries can be launched to extract any protocol information from the raw packets in a timely manner. For time optimization of long-term queries, we have incorporated multi-thread based queries.

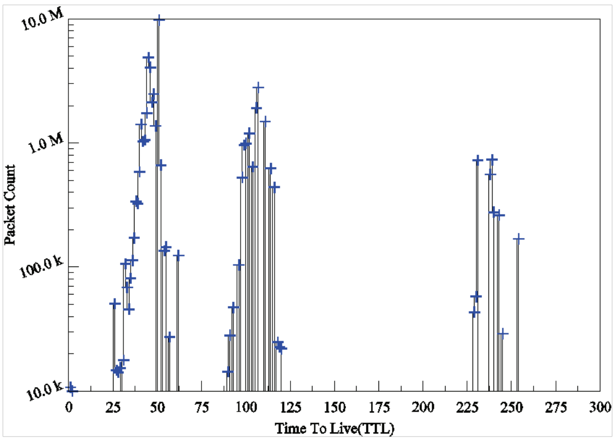


Figure 4.3 TTL Distribution of Unsolicited Packets

Figure 4.3 gives packet-count vs. time information extracted from the database for the past 12 month period. Figure 4.3 shows the extracted TTL (Time To Live) information from the Internet Protocol (IP) header of the raw packets. The three clusters below 64, 128 and 256 indicate the three widely used default TTL on the Internet.

V Anil Kumar, Navi Thejesh, Sudeep Nesakumar

4.3 Hierarchical trust model based on security to rate cloud service providers

In large scale distributed systems like cloud computing, customers need to interact with unknown cloud service providers (CSP) to carry out tasks or transactions. The ability to reason about and assess the possible risks in carrying out such transactions is necessary for providing a safe and trustworthy environment. Cooperative characteristics of distributed computing systems enforce a proper and secure trust management to be in place to minimize the risks posed by different malicious agents. Trust is the estimation of competency of a resource provider in completing a task based on dependability, security, ability and availability in the context of distributed environment. It enables users to select the best resources in the heterogeneous cloud infrastructure.

Typically a trust evaluation model comprises of two stages and three Key Performance Indicator (KPI). The first stage is the implementation with the help of Mamdani Fuzzy Inference System (FIS), which evaluates Performance, Financial and Agility parameters. The second stage implementation takes the output of the first stage FIS and helps to obtain the trust rating for each plan of the CSP.

In these models no emphasis is given to data security, including the risk of loss, unauthorized collection. So the model is extended to include two more parameters - Security and Usability. The Security parameter is described in terms of the Physical Security, Internal Security and Network Security levels available with the cloud provider, while the Usability parameter of the model is calculated based the contributions from the Understandability, Easability and Flexibility. Figure 4.4 shows the block diagram of the proposed model based on security.

Table 4.1 shows the trust values of the CSPs corresponding to the model in Figures 4.4. Here the Recommended Trust values are higher than the Direct Trust values except for Rackspace Performance Two due to higher total processing cost (in $) for the user requests. This is also reflected as a considerable reduction in Recommended Trust value for the Finance based model.

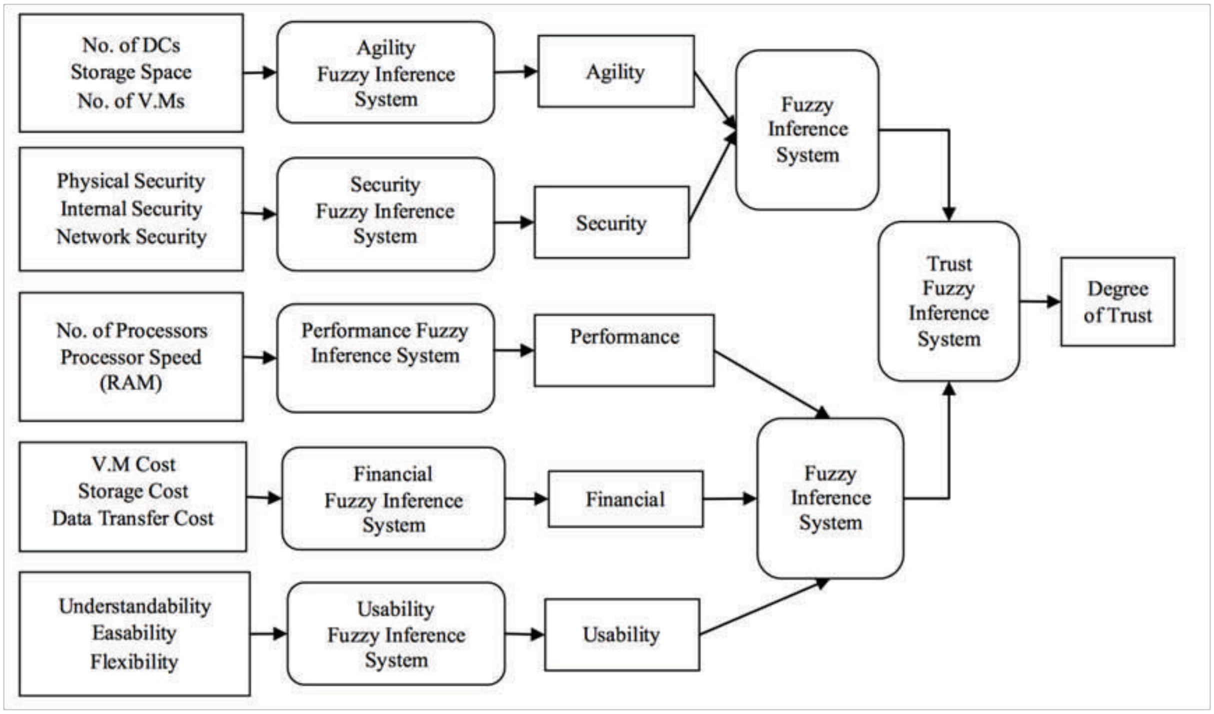


Figure 4.4 Hierarchical Model Based on Security

Table 4.1 Trust values of different CSPs with security as a parameter

CSP and Server type	**Security based**	
	Direct Trust	Recommended Trust
Gogrid Standard Dedicated Server	0.589	0.606
Gogrid Advanced Dedicated Server	0.585	0.607
Gogrid Ultra Dedicated Server	0.585	0.661
Gogrid Elite Dedicated Server	0.679	0.679
Rackspace Enhanced One	0.578	0.605
Rackspace Enhanced Two	0.585	0.585
Rackspace Performance One	0.67	0.755
Rackspace Performance Two	**0.755**	**0.67**
Amazon EC2 Small	0.471	0.578
Amazon EC2 Medium	0.586	0.619
Amazon EC2 Large	0.65	0.755
Cloud flare Pro	0.498	0.578
Cloud flare Business	0.64	0.649
Cloud flare Enterprise	0.67	0.67

Another important observation is that the priority based model is better in distinguishing between various plans. In the non-hierarchical model, where all parameters have equal weights, trust values of all the plans fall in a shorter range makeing it difficult to rank the CSPs. But in a priority based model with Finance / Security, the range varies from 0.471 to 0.755. Thus we can rank the various service provider plans.

Thus it is seen that with Security as the main requirement Rackspace Performance One and Amazon EC2 Large would be preferable. Such a conclusion cannot be arrived from a non-hirarichel model.

M Supriya*, Sangeeta K*, G K Patra
*Amrita School of Engineering, Bangalore

4.4 Secure key stream generation using particle swarm optimization

Neural Synchronization has been used to construct a cryptographic key agreement protocol using Particle Swarm Optimization (PSO) to accelerate the mutual learning between the sender and receiver in a Tree Parity Machine (TPM) neural network. PSO is a population based optimization algorithm that is motivated from the simulation of social behavior. Each individual in PSO flies in the search space with a velocity that is dynamically adjusted according to its own flying experience and its companions' flying experience. Compared with other evolutionary algorithms, such as GA, PSO algorithm possesses some attractive properties such as memory and constructive cooperation between individuals, so that it has more chance to "fly" into the better solution areas more quickly and discover reasonable quality solution much faster.

Neural cryptography defined by Kinzel and Kanter uses multilayer feed forward neural network called a tree parity machine. Here the two partners (A and B), receive the identical input vector and are trained, with the output of their partner. Each TPM consists of K hidden units and each hidden units receive different N inputs. Synchronization in this process is a stochastic, and is well balanced by attractive and repulsive forces. Though the method is very encouraging, it is weak in security, against Majority Flipping Attack (MFA).

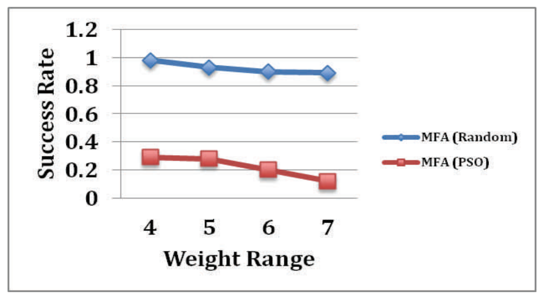


Figure 4.5 Probability of Success between a Random and PSO based initial weight vector against Majority Flipping Attack

PSO is used to find a best-fit weight vector, such that the synchronization happens faster. By doing so it does not give enough time for the attacker to synchronize. Figure 4.5 shows the probability of success by Majority Flipping attack with Random and PSO based weight vector. It can be seen that the possibility of success is very low in case of PSO based initial weights. Unlike the case of random initial weights, where the probability of success remains high even with increase in weight range, in PSO based initial weights, the probability becomes negligible with higher weight range. This promises to be a potential public-key key exchange mechanism.

S Santhanalakshmi*, Sangeeta K*, G K Patra
* Amrita School of Engineering, Bangalore

4.5 High Performance Computing

The centralized High Performance Computing facility located at CSIR 4PI is the main lifeline of the computational scientists across CSIR. 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 155th fastest in the world. The supercomputer after its released to the CSIR community on 6th September 2013, has clocked more than 86% of average utilization during 2014-15.

Figure 4.6 CSIR centralized 360TF High Performance Computing Facility.

Each node in the system is a HP Blade server, with two Intel Xeon E-5 2670 (8 cores, Sandy bridge) processors. There are 1088 such computing nodes distributed over 17 numbers of 42U 600mm width racks, resulting in 2176 physical processors and 17408 processing cores. For communication among the nodes, the nodes are connected using high speed FDR infiniband interconnect (providing a dedicated 56 Gbps interconnect bandwidth) in a FAT tree topology and a high availability mode. To achieve the high throughput and high availability, the nodes are connected through two numbers of centralized Mellanox 648-port core switch and a number of 16 port leaf switches to the computing and storage racks in redundancy mode. Memory per core is one of the important aspects of the system. The nodes are designed with 4GB memory per core, which results in about 68TB of distributed memory in the total system. However, 48GB memory can be used for shared memory inside a single node for parallel applications.

A LUSTRE parallel, online storage, plays an important role in the overall performance of the system. The high performance computing system has a high performance parallel file system of about 2.1 Peta Byte (3 Peta Byte pre-formatted) capable of providing minimum 20 Gbps simultaneous read and write capability. The storage based on the popular open source LUSTRE file system, is optimized for performance and data availability, by using hardware RAID in a RAID6 configuration, parallel I/O through 8 numbers of object servers and two numbers of redundant metadata servers.

Figure 4.7 shows the intra-day maximum usage (number of nodes) for the year 2014-15. The size of the problems run by the CSIR computational scientists range from 1 node (16 cores) to about 250 nodes (4000 cores). It is interesting to note that the maximum nodes used in a day have reached 100% most of the days, indicating the heavy utilization of the systems by scientists and researchers. Figure 4.9 shows the percentage distribution of usage by different CSIR Laboratories in various fields of computational sciences, such as Biological, Chemical, Engineering, Earth and At-

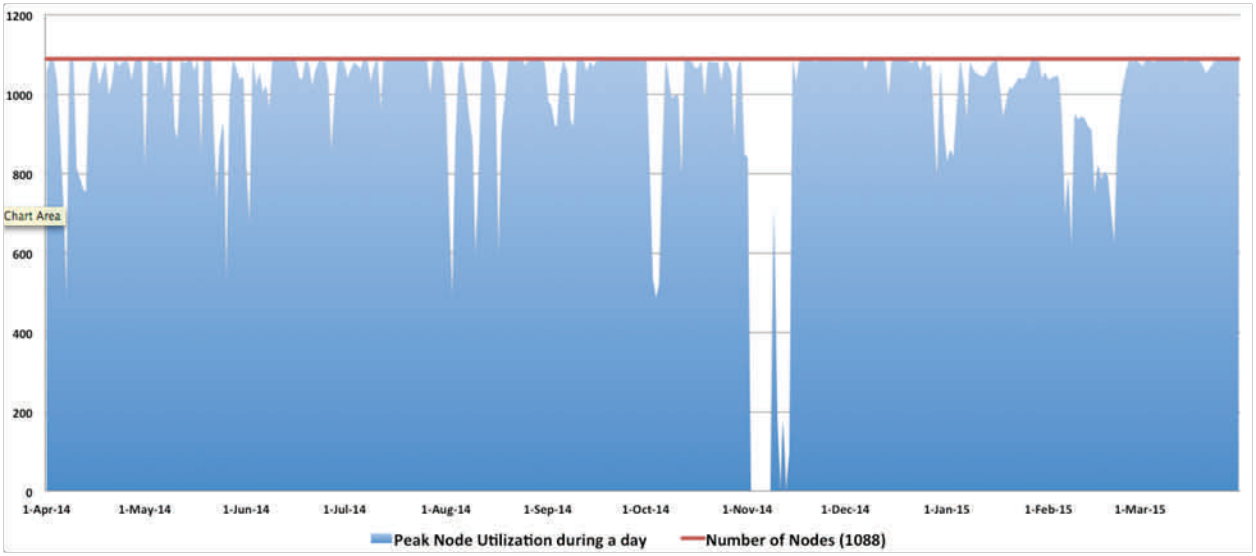


Figure 4.7 Intra-day maximum node used since the 1st September 2013 till 31st March 2014

mosphere, Physical and Information Sciences. The jobs are run in both capacity and capability mode for solving scientific problems, depending the nature of the models.

The demand of computing by CSIR community can be judge by the continuous heavy usage of Altix ICE cluster (Figure 4.8) even after being in service for more than 3 years. The system with 2304 numbers of processing cores distributed over 192 nodes inter-connected in the form of an enhanced hypercube using the QDR (32Gbps) infiniband interconnect was heavily utilized in the year 2014-15. The system has Intel Westmere-EP Hex core processors running at 2.93/3.06 GHz frequencies, with each node having 12 processing cores with 24 GB of memory in a shared memory configuration, while the system as a whole has 4608 GB of memory across the 192 nodes in a distributed architecture. The peak performance of the system is 27 TFLOPS. This system also uses a LUSTRE parallel file system of 30TB for high performance storage access during computation.

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.

Efficient utilization of a system depends on maximizing the usage and minimizing the wait period. All the High Performance Computing systems at CSIR 4PI use PBSPro workload manager, Intel compilers and other essential software to efficiently manage and run jobs on the system. The workload manager not only ensures efficient usage of the system but also provides an easy user interaction and submission interface.

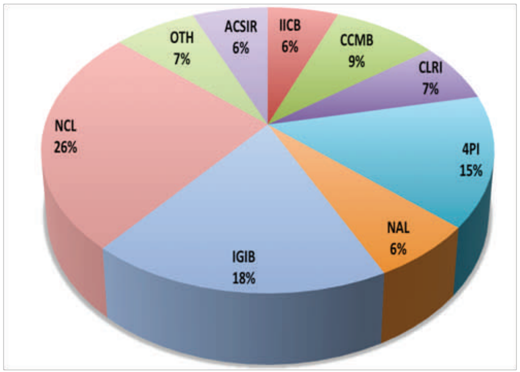


Figure 4.9 Distribution of usage of 360TF system in percentage by major CSIR labs from 1st April 2014 till 31st March

High Performance archival Storage

The parallel file systems are typically expensive, hence, normally used as scratch, to achieve performance, during job computation. To store and archive results, which need to be preserved for a longer period, an archival system based on a high performance SAN (Storage Area Network) is made available to the users. 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 about 1.5 PB of offline storage. The home areas of all the users are centralized on a Network Attached Storage (NAS) of 200TB.

Data Center

The HPC systems are supported by a Tier-3 equivalent state-of-the-art data center along with an associated energy farm. The water based cooling mechanism using Rear Door Heat Exchangers (RDHX) makes the datacenter, one of the high density and high power efficient datacenters in the country.

The Power Usage Efficiency (PUE) of less that 1.5 is one of the best-achieved PUEs in a country like India. 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 a well-designed Building Management Service (BMS). 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

National Knowledge Network (NKN), has greatly enabled high speed and reliable access to the centralized computing facility from other CSIR laboratories. Currently the NKN connectivity to CSIR-4PI is at 1 Gbps. The institute also has a backup connectivity of 8 Mbps through ERNET. Scientists and researchers of CSIR- 4PI and CSIR NAL (all the three campuses) use the facility from their desktops through a 10 Gbps high-speed 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 shifted to newer systems, for efficient communication and data dissemination. An new

Unified Threat Management (UTM) has been procured and installed to address multiple security threats. This ensures safe communication with Internet through both the NKN and ERNET links.

Software Enhancements

To keep pace with the fast enhancement of hardware, application software were maintained and upgraded. Some of the heavily used software are ABAQUS, CFD-ACE+, IDL, GAMIT/GLOBK, Tecplot, S-Plus, Hyperworks, Fluent, ANSYS, OpenFOAM etc. CSIR 4PI also encourages use of open source software and most software required for modelling and simulations are made available on the HPC systems for users. The systems are used extensively for running complex models in the field of ocean, atmosphere, earth and engineering, biology, chemistry.

Other Technical Services

Technical support was provided to a large number of users from CSIR-4PI & CSIR 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 under the SPARK program. Technical advices and consultancies were provided to various institutions within and outside CSIR.

R P Thangavelu, G K Patra, V Anilkumar,
Ashapurna Marndi, N Prabhu, Nagaraju
V Y Mudkavi*, 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) need to represent atmospheric processes such as multiscale organization of organized convection and aerosol-cloud-radiation feedback.

Under CSIR-4PI 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

- ***Earth System Model: New version of the coupled ocean-atmosphere climate model***
- ***Impact of increased GHG emissions for the state of Kerala***
- ***RCP8.5 scenario climate change projection for india using high resolution global climate model***
- ***Role of mean and variability of Indian summer monsoon rainfall in reliability of future projections in CMIP5 coupled models***
- ***Comparing statistically downscaled simulations of indian monsoon at different spatial resolutions***
- ***Implementation of regional climate model for climate change applications***
- ***Bivariate PDF analysis of latent heating over the tropics***
- ***Cyclonic events in megha-tropiques data***
- ***Rainfall and aerosol optical depth from an aerosol coupled GCM during the abnormal Indian summer monsoon of 2000***
- ***Characteristics of MODIS aerosol optical depth during 2002 drought monsoon***

5.1 Earth System Model: New version of the coupled ocean-atmosphere climate model

A large number of climate phenomena and climate variability are strongly dependent on the coupling between ocean and atmosphere and the feedbacks among various components of the climate system. A clear understanding of this coupling and feedbacks thus plays a pivotal role in predicting the global pattern of climate variables and their variability especially associated with the global warming. Hence, it is essential to incorporate the complex processes involving biological and chemical components of the climate system (e.g., the processes related to aerosols and GHGs, as well as the feedback processes between carbon cycle and climate change) as well, into the climate model. Such a climate model, viz. the Earth System Model (ESM) enables us to represent the important components of the climate system including terrestrial and oceanic material transport, as well as their interactions, reasonably well. A global coupled ocean-atmosphere general circulation model (GCM), developed by Meteorological Research Institute (MRI, Japan), coupled with an ESM module, is now installed and benchmarked. The coupling between ocean and atmosphere in this climate model involves exchange of Sea Surface Temperature (SST) from ocean to atmosphere and heat flux components, freshwater flux and horizontal momentum flux in return. Further improvement of this version, is being carried out so as to help in better understanding and predicting the changes in the climate system.

Two versions of the climate model (CGCM2.3 and CGCM3) are analyzed to assess the improvements/ drawbacks of the modified version. SSTs from the climatological simulation of the two versions are shown in Figure 5.1. It can be seen that the mean SST patterns from the simulations compare well with that from HadISST in capturing the large-scale aspects. However, it can be seen that the model

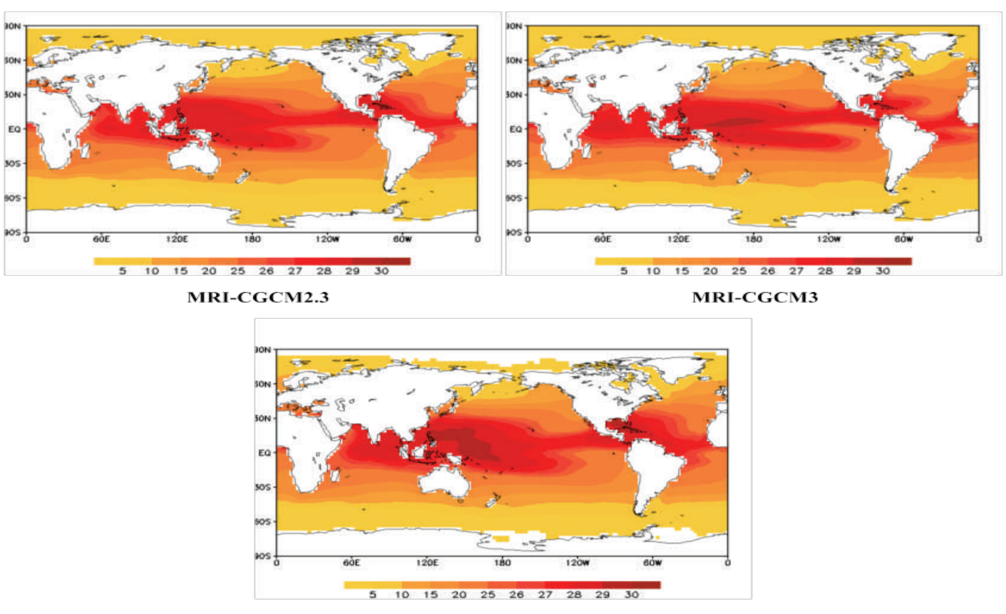


Figure 5.1 50 year climatological June to September mean SST from the simulations of CGCM2.3, CGCM3, and HadISST (1941-1990) observation.

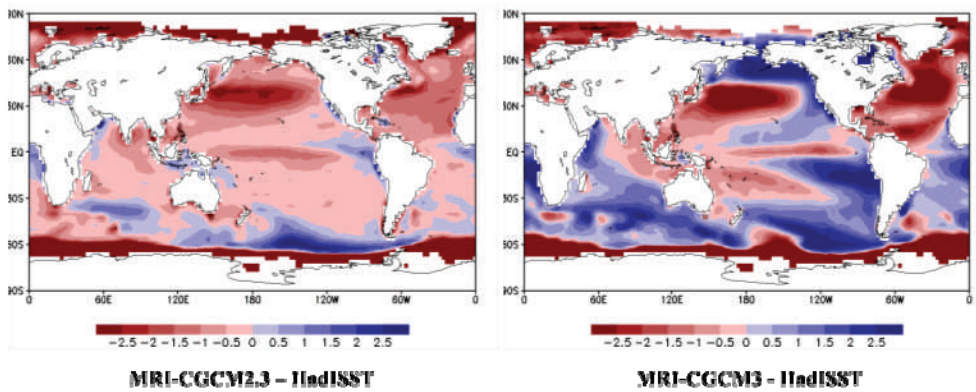


Figure 5.2 Difference between simulated (by CGCM2.3 and CGCM3) and observed climatological June to September mean SST over a period of 50 years (1941-1990).

climatology departs from the observed fields over some parts, which are referred to as the climate bias of the models. Such a bias can be a serious hindrance in using the model to study climate and climate change. Figure 5.2 shows the bias in simulating seasonal mean SST. A significant cold bias is seen over the northern Pacific, which is stronger in the newer version of CGCM3. This could be partly due to the exclusion of flux adjustment that was employed in the CGCM2.3.

This initiative taken at CSIR Fourth Paradigm Institute (CSIR-4PI) through an in-house collaborative project involving CSIR 4PI, Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA), and Divecha Centre for Climate Change (DCCC) Indian Institute of Science, aims in developing a skillful Earth System Model based on the coupled ocean-atmosphere GCM for climate studies of Indian region. This effort is poised to employ modified sub-grid scale parameterization scheme suitable for Indian region in the climate model.

Stella Jes Varghese, Sajani Surendran, K Rajendran
Y Adachi (JMA***), A Kitoh*** (University of Tsukuba),
S Yukimoto and R Mizuta (MRI, Japan)

5.2 Impact of increased GHG emissions for the state of Kerala

There is strong evidence for the occurrence of climate change in the form of global warming. Over the last few decades, temperatures have risen nearly everywhere as is the case for India. These trends in temperature and summer monsoon rainfall have accelerated since the 1990s. According to climate scientists, the accumulation of CO_2 and other greenhouses gases (GHGs) in the atmosphere is the fundamental cause of recent global warming. In support, CO_2 emissions show a clear increase over the last two decades, regionally as well (Figure 5.3). The more GHGs there are in the atmosphere, the more heat is trapped and the higher the Earth's temperature becomes. Today the major cause of the increase in CO_2 emissions is human activity (anthropogenic). Anthropogenic GHG emissions also include methane (CH_4) and nitrous oxide (N_2O) and others such as hydrofluorocarbons that are released by various industrial processes. Global emissions of CO_2, similar to the emissions from India, continues to rise.

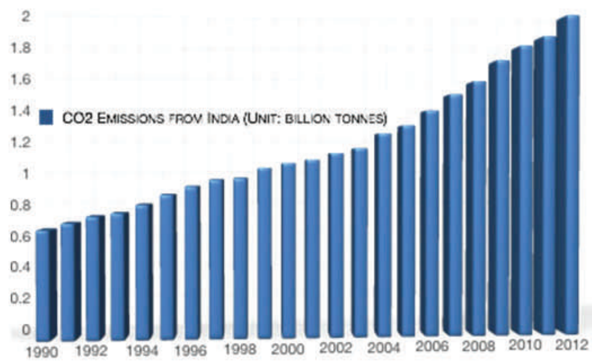


Figure 5.3 Simulated changes in CO_2 emissions from India since 1990 based on EDGAR data.

The major sources of anthropogenic GHGs in India show that the energy sector and especially electricity and heat are responsible for the majority of GHG emissions from India (Fig. 5.4). Direct agriculture activities (23%) are about as important as industry (15%) and transport (6%). Contribution from land-use changes consisting mainly of the harvesting of agriculture and forestry products and the clearance of natural vegetation for agriculture and constructions is also an important source.

Kerala, the southern state of India, is known for its green landscape, water bodies, rolling mountains and narrow valleys. With high rainfall, chains of backwater bodies, many rivers, reservoirs, lakes, ponds, springs and wells, the state is considered as the land of water. When the neighboring states are harnessing large quantum of surface and groundwater sources for irrigation, hydro power generation, domestic and industrial purposes, the scope for development of this precious resource is very limited in Kerala due to its unique characteristics. For the last three decades, Kerala is frequently facing dry spells followed by acute drinking water scarcity. The rivers hardly contain any water during the summer months; only a few reservoirs and lakes get filled up even in the monsoon and household wells and ponds are increasingly getting dry in summer. The water resource situation becomes worse in deficit monsoon years.

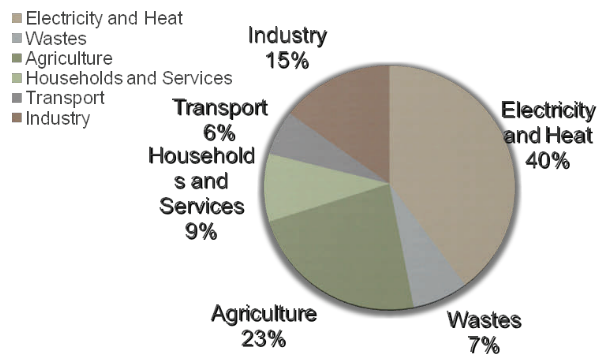


Figure 5.4 GHG emissions by India (2004) by sector (Source: PEW Centre's International Brief 2: `Climate Change Mitigation Measures in India', September, 2008).

Across the state, impacts of climate change are already in evidence. Extreme rainfall events and warm extremes have become more frequent and intense, intense dry spells during monsoon are common and patterns of rainfall are likely changing. Even if emissions of GHGs were substantially reduced now, climate would continue to change for some time to come and the potential consequences for humans and ecosystems are significant. In ecosystems, changing climate could alter the distribution patterns of plant and animal species, reduce the productivity and abundance of species, and change habitats. Sea level could be affected, threatening the natural and built environments on the coasts and in fresh water systems, especially when combined with effects of more intense coastal storms. This report presents the projections of possible climatic changes associated with global warming, impacts of climate change and some discussions on how we as a state can begin adapting to them in beneficial ways.

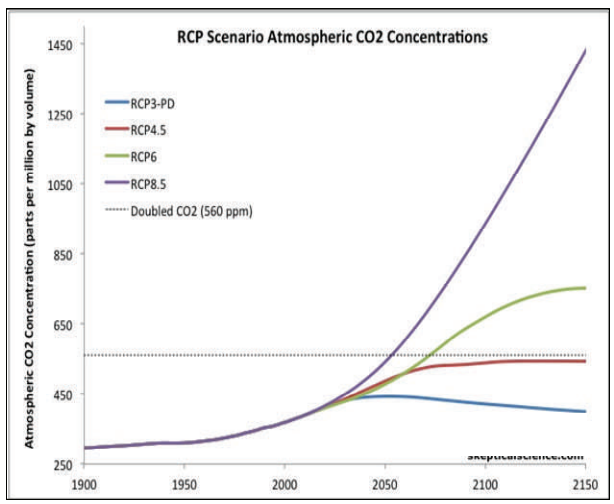
Kerala receives an annual average rainfall that is about 2.5 times more than that of all-India average. Southwest (SW, from June to September or JJAS) and Northeast monsoon (NE, from October to November or ON) are the two monsoon seasons of the state, of which SW monsoon is the dominant rainy season. About 84% of the annual rainfall is received during the monsoon period between June and November (68% during SW and 16% during the NE) and the remaining 16% during the non-monsoon period of December to May.

The climate of Kerala is changing in ways that can be attributed to human-caused emissions of GHGs. The state is warming. Average maximum and minimum temperatures for the last decade were the highest in the state from 1901 through 2007. This increasing trend is clear in both annual mean and the mean of SW monsoon season, for both maximum temperature (T_{max}) and minimum temperature (T_{min}). It is also to be noted here that there is a close linkage between rice grain yield and T_{min} with a tendency for reduction in yield with increase in the T_{min}. The observed rainfall trend over Kerala shows that there is significant decrease in southwest monsoon rainfall in recent times. Annual and SW monsoon rainfall departures from present-day reference period (1961-1990) climate and the recent trends using India Meteorology Department (IMD) sub-divisional rain gauge rainfall show clear decreasing trends over the state. The distribution of yearly rainfall for the JJAS period and rainiest period of July-August for the entire state also bring out the declining trend in rainfall.

Sajani Surendran and K Rajendran
Akio Kitoh (MRI, Japan)
Ravi S Nanjundiah (DCCC, IISc)

5.3 RCP8.5 scenario climate change projection for India using high resolution global climate model

We have analyzed 20-km model time-slice simulation under the forcing of representative concentration pathways (RCP) 8.5 (RCP8.5) which corresponds to a radiative forcing of 8.5 W m^{-2} in 2100, and represents an extension and improvement of the SRES-A2 emissions scenario of IPCC-AR4. Moreover, the RCP8.5 pathway serves as an upper bound of the RCPs. Future projections by time-slice simulations of 20-km AGCM under RCP8.5 global warming scenario (Figure 5.5) show widespread but spatially varying increase in rainfall over the interior regions of peninsular, west central, central northeast and northeast India (Figure 5.6) and significant reduction in orographic rainfall over the west coast (consistent with the recent observed trends.



RCP8.5 – The path we are on (unabated emissions)
RCP2.6 (RCP 3-PD) – Aspirational path

Figure 5.5: Four scenarios of IPCC AR5, named after the radiative forcing (global energy imbalance) caused by human emissions around the year 2100.

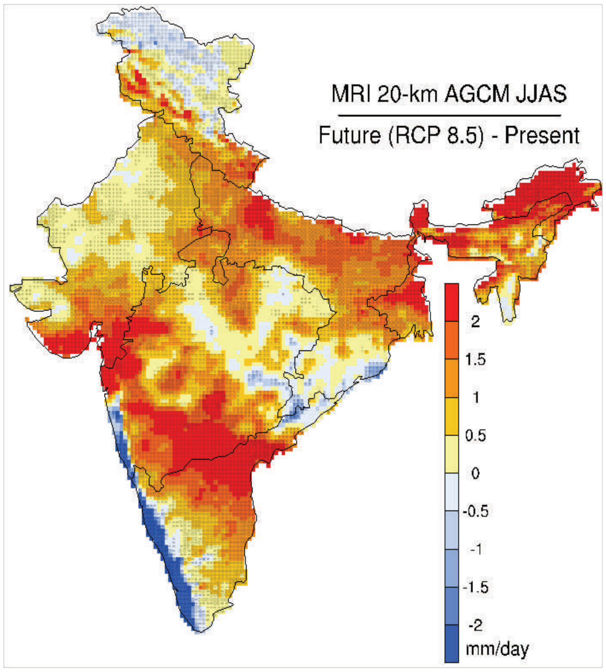


Figure 5.6 Projected future changes in JJAS mean rainfall over India by 20-km climate model under RCP8.5 scenario. Within each colour, the symbols corresponds to changes as percentage of mean summer monsoon rainfall (< 5%: no symbol, 5-15%: dots, 15-25%: open circle and >25%: plus)

Future projections of Indian summer monsoon rainfall with high-resolution regional climate models or IPCC models project relatively uniform change in monsoon rainfall over India. Spatial distribution of the changes in summer monsoon precipitation due to global warming shows larger spatial variability with more regional details in simulations with 20 km resolution (Figure 5.6). This shows that high-resolution simulations are essential to extract useful regional climate change information. The pattern in precipitation is uneven in ultra-high resolution models with distinct spatial heterogeneity (Figure 5.6).

K Rajendran and Sajani Surendran
Akio Kitoh (MRI, Japan)

5.4 Role of mean and variability of indian summer monsoon rainfall in reliability of future projections in CMIP5 coupled models

The state-of-the-art coupled general circulation models (CGCMs) from Coupled Model Intercomparison Project phase five (CMIP5) are used to quantitatively estimate the projected changes in the Indian summer monsoon, its variability, and the basic seasonal cycle. The CMIP5 models project clear future temperature increase but diverse changes in Indian summer monsoon rainfall (ISMR) with considerable intermodel spread. The interannual variability (IAV) measured based on the coefficient of variation shows nearly equal chance for future increase or decrease and it varies from -15.4% to 9.7% (Figure 5.7). This diverse nature lead us to classify the models to derive reliable estimates of the climate change impact on the mean ISMR and its IAV, and the seasonal cycle which are important for regional climate change impact assessments.

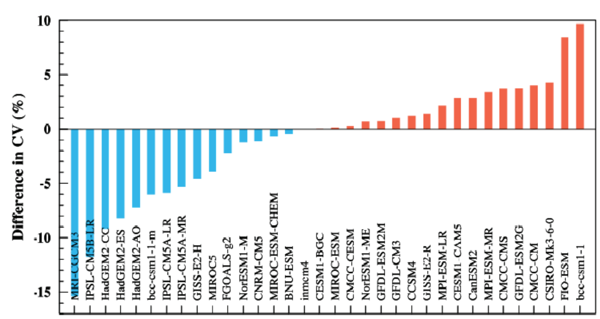


Figure 5.7 Projected change in coefficient of variation of ISMR for 34 CMIP5 models.

Observed seasonal cycle and the present-day and projected seasonal cycles from most of the models manifest not only the projected intensification in rainfall throughout the year but also changes in the

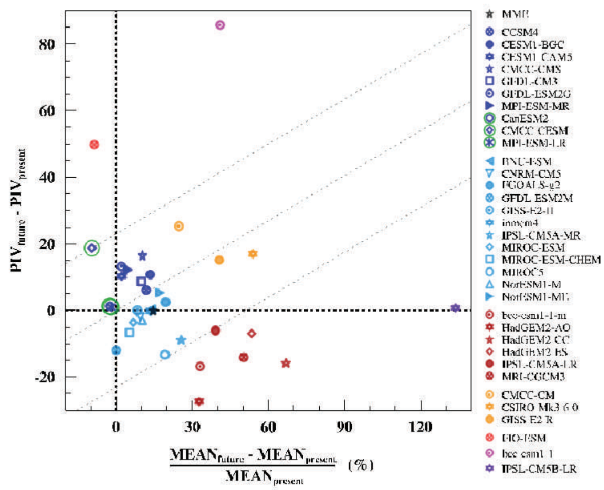


Figure 5.8 Projected change in PIV versus change in mean ISMR (w.r.t. present-day mean in %) for 34 CMIP5 models, groups A (7 models, blue), B (12 models, sky blue), C (6 models, red), and D (3 models, orange) and three outliers (outside slanted lines y = 0.45x ± 23, and around y = 0.45x). Three models are classified into group E (green circles around blue symbols).

timings of onset, peak, and withdrawal of indian summer monsoon in the future scenario. To obtain the robust signals from the existing models, we grouped the models based on their relative changes of mean and variability. Physically consistent groups of models are derived from the relationship between the projected changes in ISMR and its IAV (Figure 5.8). Further, these groups are validated based on the k-mean clustering based Dunn's Index and the reliability ensemble averaging (REA). We have chosen the most reliable groups such as Group A (having reliability of 0.724) and Group B (0.703) to derive the robust results (the groups and group member models are described in Figure 5.8). The frequency distribution of monthly rainfall shows, the extreme precipitation (>24.5 mm/day) frequency is enhanced by about 0.80% (0.31%) for group A (group B). Based on these both physically consistant group of models (together of 19 models) project a future increase of mean ISMR by 0.74 mm/day with an uncertainty of ±0.36 mm/day and also project future increase in IAV (change in CV) as 0.91%.

C B Jayasankar , Sajani Surendran, K Rajendran

5.5 Comparing statistically downscaled simulations of Indian monsoon at different spatial resolutions

Impacts of climate change are typically assessed with fairly coarse resolution General Circulation Models (GCMs), which are unable to resolve local scale features that are critical to precipitation variability. GCM simulations must be downscaled to finer resolutions, through statistical or dynamic modelling for further use in hydrologic analysis. In this study, we use a linear regression based statistical downscaling method for obtaining monthly Indian Summer Monsoon Rainfall (ISMR) projections at multiple spatial resolutions, viz., 0.05°, 0.25° and 0.50°, and compare them.

We use 19 GCMs of Coupled Model Intercomparison Project Phase 5 (CMIP5) suite and combine them with multi model averaging and Bayesian model averaging. We find spatially non-uniform changes in projections at all resolutions for both combinations of projections. Our results show that the changes in the mean for future time periods (2020s, 2050s, and 2080s) at different resolutions, viz., 0.05°, 0.25° and 0.5°, obtained with both Multi-Model Average (MMA) and Bayesian Multi-Model Average (BMA) are comparable. We also find that the model uncertainty decreases with projection times into the future for all resolutions. Figure 5.9 shows the uncertainty for SMR projections at differ

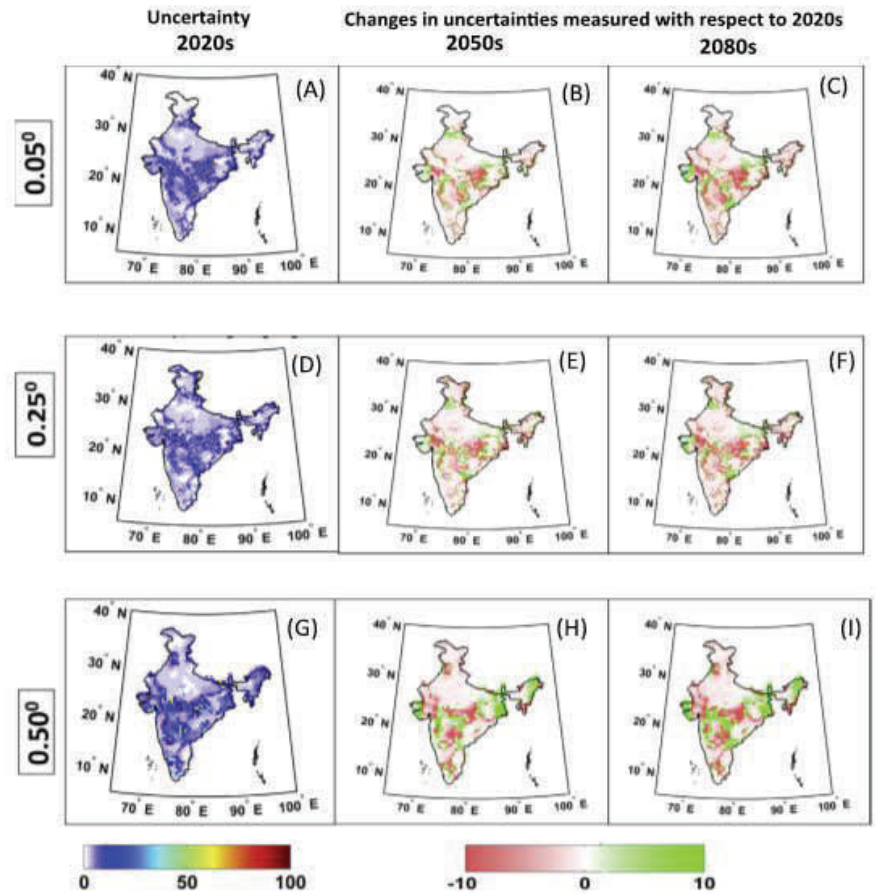


Figure 5.9 Projected change in coefficient of variation of ISMR for 34 CMIP5 models

ent resolutions and for different time windows 2020s (2010–2039), 2050s (2040–2069) and 2080s (2070–2099). The relative changes in uncertainties across different resolutions are measured with respect to 2020s. We find that the model uncertainty is highest for the 2020s and then it gradually decreases with the lead time. This is true at all resolutions. The possible reason is that with the increase in lead time, the climate change signal becomes more prominent compared to internal variability and model uncertainty due to the imposed radiative forcings (Hawkins and Sutton, 2009), resulting in a decrease in the CV values.

We compute Signal to Noise Ratio (SNR), which represents the climate change signal in simulations with respect to the noise arising from multi-model uncertainty. This appears to be almost similar at different resolutions. The present study highlights that, a mere increase in resolution by a way of computationally more expensive statistical downscaling does not necessarily contribute towards improving the signal strength. Denser data networks and finer resolution GCMs may be essential for producing usable rainfall and hydrologic information at finer resolutions in the context of statistical downscaling.

K Shashikanth, C G Madhusoodhanan,
Subimal Ghosh and T I Eldho (IIT-Bombay)
K Rajendran
Raghu Murtugudde (University of Maryland, USA)

5.6 Implementation of regional climate model for climate change applications

A high-resolution non-hydrostatic model, Weather Research and Forecasting (WRF-CLIM) model is implemented to study climate change projection of Indian summer monsoon (ISM) at ultra-high resolutions. Here we present the simulation of 2002, a drought ISM year simulated by the model forced with reanalysis data. The model is integrated from 1st may and continuously ran up to 30th September (5 months) of the year.

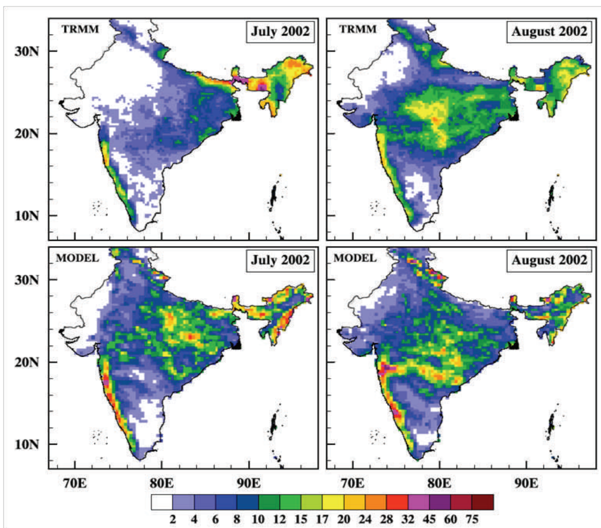


Figure 5.10 Observed and simulated (by WRF-CLIM) precipitation for July and August months of 2002.

The model-simulated precipitation is compared with the observed precipitation from TRMM. Figure 5.10 shows simulated and observed TRMM precipitation for the peak ISM months of July and August. We can see that, even though the simulated July precipitation is overestimated, the models capture the spatial heterogeneity seen in the observation especially in August and orographic rainfall is well simulated by the model in both months. We expect that suitable combination of physical schemes and numerics of the model configuration can give a better simulation of ISM rainfall. After extensive sensitivity experiments, the model can be used for future studies such as the climate change impact on regional scales.

C B Jayasankar and K Rajendran

5.7 Bivariate PDF analysis of latent heating over the tropics

A study with 13-year (1998-2010) mean apparent diabatic heating (Q_{1R}) along with its partitioning due to shallow, convective and stratiform heating for tropical land and ocean reveals that the vertical distribution of total latent heating modulates due to the difference in proportion of convective and stratiform contribution at each level and the positive convective heating is mainly confined in the lower troposphere below ~5 km, whereas positive stratiform heating contribution is in the upper troposphere (above ~7 km) for both land and ocean domains. Stratiform heating is mostly negative below ~5 km and positive above ~5 km, whereas convective heating is positive throughout 0 to 16 km.

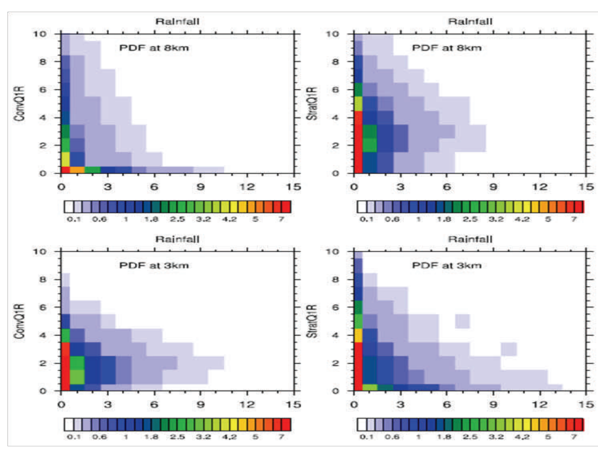


Figure 5.11 Bivariate PDF of rainfall with convective (left panels) and stratiform (right panels) heating at 8km (top panels) and 3km (bottom panels) for a representative oceanic domain of East Pacific.

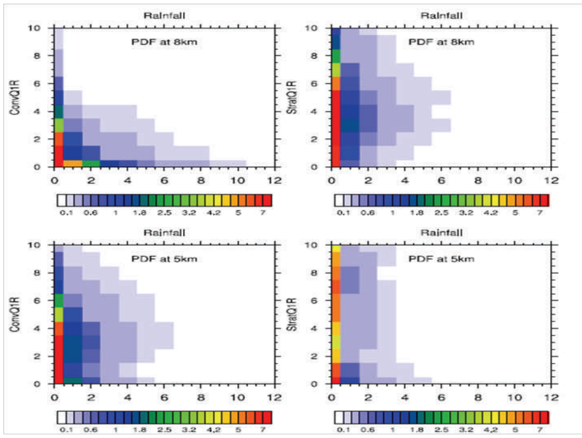


Figure 5.12 Bivariate PDF of rainfall with convective (left panels) and stratiform (right panels) heating at 8km (top panels) and 3km (bottom panels) for a representative land domain of India.

Bivariate Probability Distribution Function (PDF) analysis with Q_{1R} and rainfall data [only on the grids where heating is convectively positive] at each vertical level from 2 km to 9 km for stratiform as well as for convective heating depicts that over ocean lower level peak (~3 km) is primarily due to convective heating whereas at the same level the contribution from the stratiform heating is negligible (Figures 5.11 and 5.12). At higher altitude (~8 km), PDF over ocean confirms the major contribution from the stratiform heating to the total heating compared to convective heating. Over land the single peak from ~5-8 km is largely contributed by convective heating which peaks at ~5 km and with a small contribution from stratiform heating that peaks at ~8 km.

Ipsita Putatunda and K Rajendran

5.8 Cyclonic events in megha-tropiques data

Megha-Tropiques (MT) orbital data has been converted to daily layer averaged Relative Humidity (RH) data for six layers from 1000 hPa to 100 hPa. Figure 5.13 shows global RH for a single layer (1000-850 hpa) on a particular day of 20th June 2012.

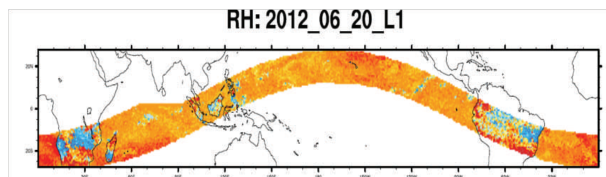


Figure 5.13 Relative humidity using Megha-Tropiques SAPHIR data for the first layer (1000-850 hPa) on 20 June 2012.

Initial analysis of MT Relative Humidity and Outgoing Longwave Radiation (OLR) data well captures weather events like the cyclones 'Nilam', 'Thane'. Figure 5.14 shows the progression of Thane cyclone from 27 October to 29 October 2012.

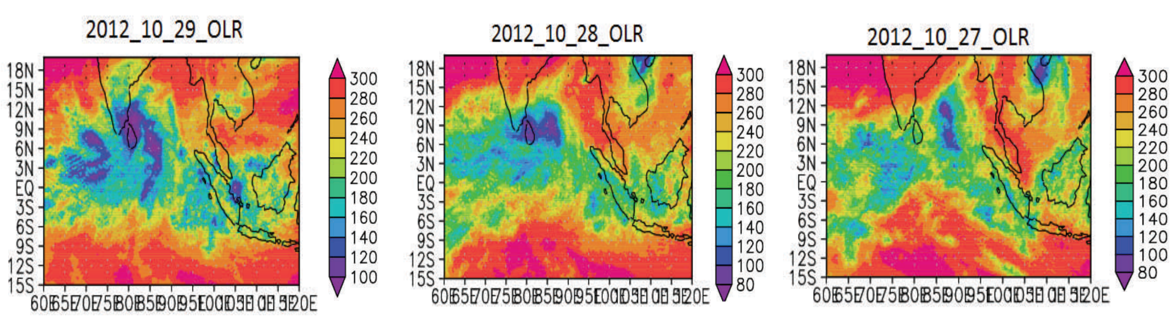


Figure 5.14: Megha-Tropiques OLR from SCaRaB showing the progression of cyclone THANE from 27 October to 29 October 2012.

Ipsita Putatunda and K Rajendran

5.9 Rainfall and aerosol optical depth in an aerosol coupled GCM during the abnormal Indian summer monsoon of 2000

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 which play important roles in the radiative energy and water cycle balance. Previous studies investigated the influence of enhanced anthropogenic aerosol on convective precipitation due to indirect radiative forcing from General Circulation Model (GCM) simulations with a focus on the differences between the experiment with the present -day aerosol emissions (PD) and the pre-industrial aerosol emissions (PI), averaged for 5 years for the period from January 2001 to December 2005 (i.e., D=PD-PI).

The model simulates 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. A signal in precipitation is observed only over central India in the monsoon season. This reduction in precipitation mainly stems from convective precipitation.

The spatial distribution of seasonal rainfall in JJAS over India for the abnormal year 2000 is compared with the simulated rainfall and atmospheric aerosol parameters in Figure 5.15, to understand the mechanism behind the impact of aerosol perturbation on rainfall and to validate the simulated aerosol variables against the observations. Occurrence of high positive AOD ranging from 0.4 and 0.7 is evident over the Arabian sea, while the southern part of the Arabian Sea has very less AODs. The model is able to capture the magnitude over the Arabian Sea and

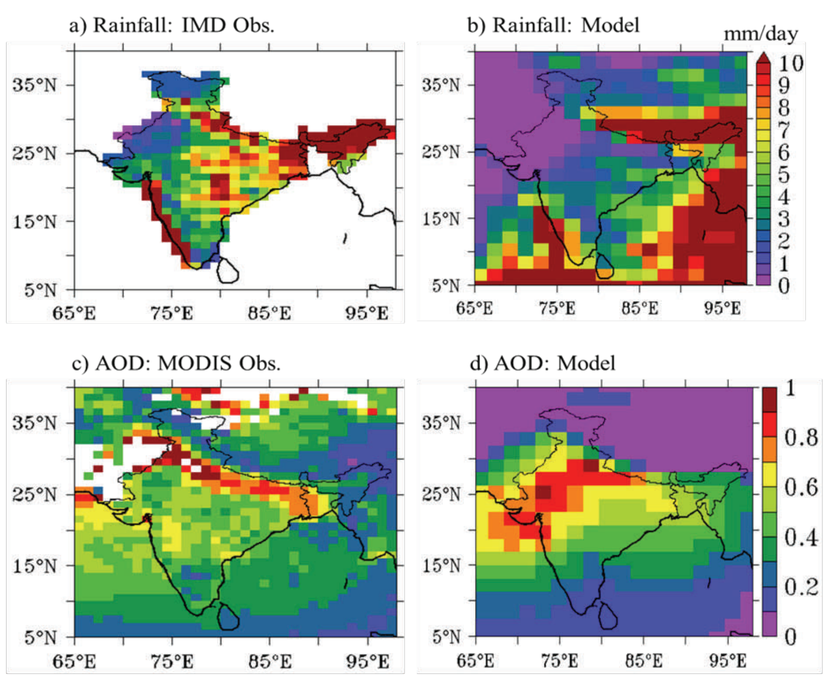


Figure 5.15 JJAS mean a) rainfall from IMD, b) rainfall from model, c) AOD from MODIS and d) AOD from model during the abnormal year 2000 of Indian summer monsoon.

some parts of Gangetic plain over India. Simulated rainfall shows disagreement with observation in central India and parts of Western Ghats, which needs to be addressed.

Nitin Patil and C Venkataraman (IIT-Bombay)
Sajani Surendran

5.10 Characteristics of MODIS aerosol optical depth during 2002 drought monsoon

The recent monsoon drought of 2002 resulted in economic losses of billions of dollars and caused the lowest rainfall in the historical records during the last 135 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. We investigated MODIS (MODerate Resolution Imaging Spectroradiometer) derived Aerosol Optical Depth (AOD) at 550 nm and its variability in the mid monsoon month of July, over India. AOD has been estimated using Level-2 MODIS Terra Data Version 6 and gridded to uniform grid and into monthly averages. The aerosol optical characteristics and rainfall during 2002 drought monsoon are compared against those during 2013 (Figure 5.16). Note that the AOD varies drastically over the Indian region during both years. The spatial loading of AOD during the drought year 2002, shows that there is persistence of high AOD values. The analysis shows that the high values of aerosol optical depth (AOD) occur during the drought monsoon month of July-2002, compared to July-2013 (Figure 5.16). Low rainfall amounts during the drought lead to an increase in AOD as compared to that in 2013.

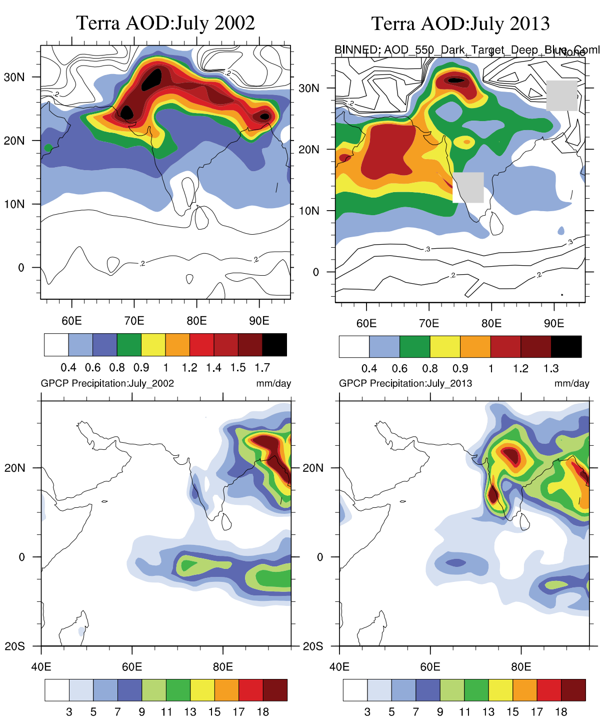


Figure 5.16 MODIS monthly averaged AOD's for July of a) 2002 and b) 2013 along with corresponding rainfall from GPCP data for July of c) 2002 and 2013.

Arya V B and Sajani Surendran

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). 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 2014-2015 group has contributed to preliminary estimation of crustal structure beneath Kashmir Himalayas, probabilistic earthquake hazard maps for South India, site response study of Bangalore city, reflection and refraction of attenuated waves in different media. In the field of GNSS based Geoscience research the group has contributed to region specific dislocation models in Sikkim Himalayas, Active deformation rates in Assam Valley and adjoining regions, Precipitable water vapor variability in Northeast India and Landslide deformation studies.

Inside

- ***Crustal deformation models of Indian Himalayas and Indo-Burmese Arc***
- ***Crustal strain, troposphere and ionosphere studies in Indian subcontinent***
- ***Region specific dislocation models in Darjiling- Sikkim Himalaya.***
- ***GPS derived regional deformation rates in Assam Valley and Kopili fault***
- ***Integrated Water Vapor (IWV) variability over northeast India***
- ***Present- day active deformation studies in Garhwal Himalayas***
- ***Landslide deformation studies in Uttarakhand, India***
- ***Seismic hazard and risks assessment based on the Unified Scaling Law for Earthquakes***
- ***Crustal structure beneath Kashmir Himalaya: A preliminary estimation from five broadband stations***
- ***Probabilistic earthquake hazard assessment for Peninsular India***

- ***Site response study in Bangalore city using H/V spectral ratio of microtremor***
- ***Reflection and refraction of attenuated waves at an imperfectly bonded interface between cracked elastic solid and porous solid saturated with two immiscible viscous fluids***
- ***Reflection and refraction of attenuated waves at the interface between cracked poroelastic medium and porous solid saturated with two immiscible fluids***
- ***Propagation of torsional surface in an inhomogeneous anisotropic fluid saturated porous double layers lying over gravitating dry sandy Gibson half space***

6.1 Crustal deformation models of Indian Himalayas and Indo-Burmese arc

Inverse Models have been developed for the Indian Himalayas from Ladakh in the west to Arunachal Himalaya in the east and the Indo-Burmese Arc. Horizontal surface deformation obtained from GPS time series for the past 20 years in these regions has been inverted to estimate the subsurface dislocation geometry and slip. These models have given constraints on the geometry of Main Himalayan Thrust and the varying slip in Ladakh, Garhwal, Kumaon, Nepal, Sikkim, Bhutan and Arunachal Himalaya. In the Indo-Burmese Arc these models point to segmentation of deformation along the North-South and East-West directions. For the first time surface deformation modelling has been carried out for the 2500 km stretch Himalayan Arc from west to east giving significant insights in to the seismic vulnerability of this major plate boundary which has a huge impact on the hazard assessment of this ecologically sensitive region

Sridevi Jade, Saigeetha Jagannathan, T S Shrungeshwara

6.2 Crustal strain, troposphere and ionosphere studies in Indian subcontinent

Continuous GPS(CGPS) data of a network of ~ 55 stations in the Indian continent for a period of 20 years (1995-2014) are analysed to obtain the time series of North, East and up displacements. These GPS time series are used to derive the strain accumulation across the Indian subcontinent thus delineating the zones of high stress buildup which is the main cause of earthquakes. Atmospheric delays obtained from the GPS analysis of CGPS sites is used to estimate the Integrated Water Vapor (IWV) and Total Electron Content (TEC) over the Indian subcontinent which is a crucial input to research related to GPS meteorology and ionosphere anomalies.

Sridevi Jade and T S Shrungeshwara

6.3 Region specific dislocation models in Darjiling-Sikkim Himalaya.

We used high-precision Global Positioning System (GPS) to geodetically constrain the motion of stations in the Darjiling-Sikkim Himalayan (DSH) wedge and examine the deformation at the Indian-Tibetan plate boundary using IGS (International GPS Service) fiducial stations. To obtain additional insight north of the Indo-Tibetan border and in the Darjiling-Sikkim-Tibet (DaSiT) wedge, published velocities from four stations J037, XIGA, J029 and YADO were also included in the analysis. India-fixed velocities or the back-slip was computed relative to the pole of rotation of the Indian Plate (Latitude 52.97 ± 0.22º, Longitude - 0.30 ± 3.76º, and Angular Velocity 0.500 ± 0.008º/ Myr) in the DaSiT wedge. Dislocation modelling was carried out with the back-slip to model the best possible solution of a finite rectangular dislocation or the causative fault based on dislocation theory that produced the observed back-slip using a forward modelling approach Three dislocation models (figure 6.1) were attempted and all the models simulate the frontal measured back-slip well. However, the one-dislocation model breaks down when we include velocities measured north of the Indo-Tibetan border . A two-dislocation model is needed to simu

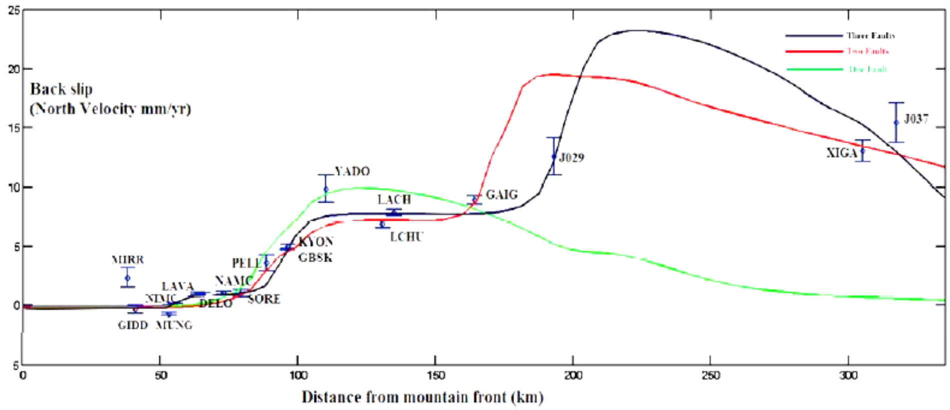


Figure 6.1 Modelled back-slip velocity for one-dislocation (green-line), two-dislocation (red-line) and three dislocation (black line) along with measured back-slip velocity of the GPS station

late the back-slip in the entire wedge. However, a three-dislocation model simulates the measured back-slip in the entire Darjiling-Sikkim-Tibet Himalayan wedge best (Figure 6.1).

A Kutubuddin, Malay Mukul, Sridevi Jade

6.4 GPS derived regional deformation rates in Assam Valley and Kopili fault

Northeast India is a seismo-tectonically complex and active region due to its unique location. GPS derived velocity field of northeast India quantifies the current status of the tectonic activity in Assam valley and Kopili fault area of northeast India. India fixed velocities of Assam valley indicate oblique deformation from west to east along the Assam valley. The GPS site velocities in the vicinity of Kopili fault indicate ~2 mm/yr dextral motion along Kopili fault. Results indicate strain accumulation in the valley with active deformation along Kopili fault. The slip of the Kopili fault is contributing to seismic moment accumulation (~70.74 X 10^{15} Nm/yr), sufficient to drive possible future earthquakes (Mw ≥ 5.17). The stressed Kopili fault region may witness future earthquakes thereby releasing the accumulated strain energy. GPS velocities indicate that the Assam valley may be fragmented along Kopili fault.

Prakash Barman, Sridevi Jade, Ashok Kumar

6.5 Integrated water vapor (IWV) variability over northeast India

Northeast India (Figure 6.2) has a unique geographical position which is bounded by the Himalayas and Tibetan plateau to the north, Bengal Basin to the south and Mishimi Hills to the east. The Patkoi-Naga-Chin-Arakan-Yoma (Indo-Myanmar) Hill ranges are situated in south east forming a North-South concave arc. The Shillong plateau and Mikir Hills are high rise areas of the region with elevation greater than 1000m over the Bangladeshi plains. Cherrapunji, located in Shillong plateau, is the world's wettest place and this is due to the unique orography of the region. The northeast India is the extreme north corner for the Indian monsoon flow where southwesterly moisture flow is confined to

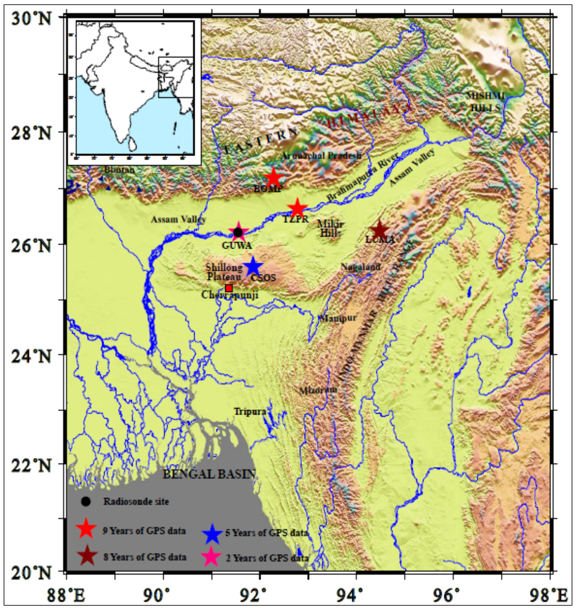


Figure 6.2 Orography of northeast India along with river system along with location of the GPS sites

Indian subcontinent by the Himalayas to the north and is directed westward. During monsoon, the region is badly flooded by the overloaded river Brahmaputra and its tributaries by the rain water of Bhutan and Arunachal Himalayas. In-depth study of GPS derived IWV variability water vapor over northeast India for a nine year period is carried out to better understand the rainfall pattern in this region leading to the flood hazard.

Prakash Barman, Sridevi Jade, Ashok Kumar

6.6 Present- day active deformation studies in Garhwal Himalayas

Garhwal Himalayas located in Uttarakhand is one of the most seismically active regions in the northwestern Himalayas. GPS time series (1996-2006) of this region indicate convergence of around 11mm/yr which is being accommodated in Lesser Himalaya just south of MCT (Main central Thrust) fault trace

Figure 6.3 Campaign survey GPS set-up at Sukhi, Uttarakhand

over a distance of 40-70 km. The Chamoli earthquake of 29th March 1999 with magnitude Mw6.5 (30.38° N, 79.21° E) occurred just south of the MCT fault trace in this region. Two GPS sites at Auli and Tungnath recorded both the co-seismic and post-seismic displacement of Chamoli earthquake. Auli and Tungnath baseline recorded an extension of 9 mm/yr which is due to the post-seismic relaxation of the Chamoli earthquake. GPS remeasurements were carried out in 2014 for all the GPS sites in Garhwal Himalaya to quantify the present-day active deformation in this region.

T S Shrungeshwara, N R Pavithra, G Chiranjeevi Vivek , Sridevi Jade and CBRI team

6.7 Landslide deformation studies in Uttarakhand, India

Large number of slope failures have been triggered on the main highways in Garhwal Himalayas since Chamoli earthquake of 6.6 magnitude in 1999. Over the years, one such National Highway from Chamoli to Badrinath along the river Alaknanda is majorly affected due to landslides in Uttarakhand region. The upstream part of Alaknanda River often

Figure 6.4 Continuous GNSS station at CSIR-CBRI Roorkee

triggers landslides especially during rainy seasons. Several landslides were triggered along this highway during the 2013 cloud burst in this region The landslides along this National Highway are mostly debris slides or rock slides. As part of this study, CSIR-Central Building Research Institute (CBRI) in collaboration with CSIR-4PI selected two landslides in Jalgwar village, Chamoli district, Uttarakhand. The selected landslide in Jalgwar village is situated with in latitude 30.45 N – 30.48 N to longitude 79.44 E – 79.47 E. GPS measurements were carried out in October 2014, January 2015 and March 2015 to monitor the landslide movement.

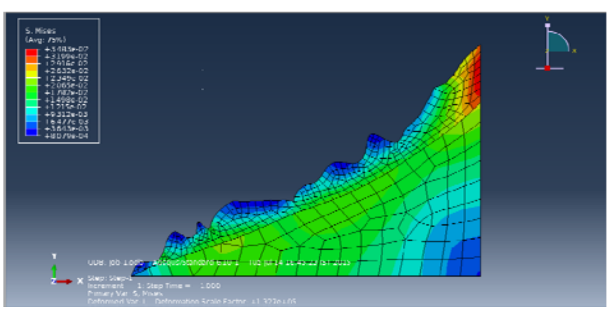


Figure 6.5 Schematic representation of the slide of soil in the landslide due to various loads acting over it

The data were analyzed using GAMIT/GLOBK software and Track - GPS differential phase kinematic positioning program to calculate position estimates of landslide points treated as kinematic stations along with nearby static reference stations. Position estimates calculated by the track program and these positions over a period of time are used for calculating the strain rates between the points. Preliminary estimates show shortening of baselines for landslide 1 indicating the relative motion within the landslide is convergence. For landslide 2 there is extension of baselines between the landslide points indicating the sense of motion within the landslide. Along with the geodetic measurements an effort has been initiated to model the landslides using Finite Element Modelling technique along with various geotechnical parameters such as pore water pressure, permeability co-efficient, Mohr's- Coulomb criteria and Principal stresses. In addition continuous GNSS station is established in March 2015 at CBRI campus, Roorkee to serve as a reference site to constrain deformation south of frontal Himalaya.

T S Shrungeshwara, G Chiranjeevi Vivek, N R Pavithra, A K Dharma Teja, Sridevi Jade & CBRI team

6.8 Seismic hazard and risks assessment based on the Unified Scaling Law for Earthquakes

The Unified Scaling Law for Earthquakes, USLE, that generalizes the Gutenberg-Richter recurrence relation, has evident implications since any estimate of seismic hazard depends on the size of territory that is used for investigation, averaging, and extrapolation into the future. Therefore, the hazard may differ dramatically when scaled down to the proportion of the area of interest (e.g. a city) from the enveloping area of investigation. In fact, given the observed patterns of distributed seismic activity the results of multi-scale analysis embedded in USLE approach demonstrate that traditional estimations of seismic hazard and risks for cities and urban agglomerations are usually underestimated. More

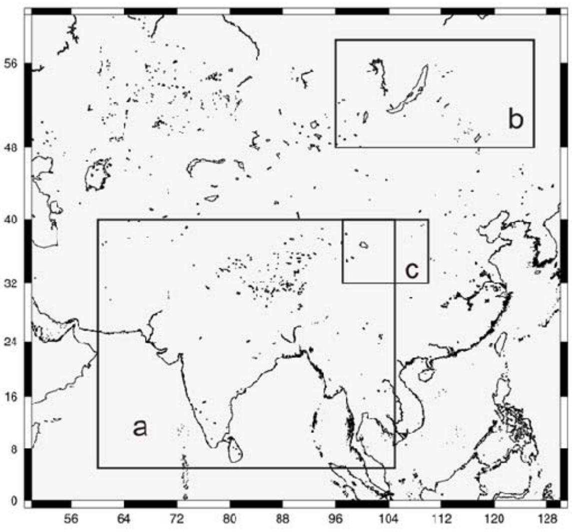


Figure 6.6 The three regions: the Himalayas and surroundings (a), Lake Baikal (b) and Central China (c).

over, the USLE approach provides a significant improvement when compared to the results of probabilistic seismic hazard analysis, e.g. the maps resulted from the Global Seismic Hazard Assessment Project, GSHAP. In this paper, we apply the USLE approach to evaluating seismic hazard and risks to population of the three territories of different size representing a sub-continental and two different regional scales of analysis – i.e. the Himalayas and surroundings, Lake Baikal, and Central China regions (Figure 6.6).

The USLE coefficients were used for estimation and mapping the expected maximum magnitude *Mmax* with a 10 % chance of exceedence in 50 years specifically, for each 0.5° × 0.5° cell at seismic location on a regional map (Figure 6.7). Figure 6.8 shows the three regional seismic hazard maps in terms of Peak Ground Acceleration (PGA) determined for each grid point from a source of *Mmax.* The maximum of acceleration values computed at a grid point is assigned to it. We have opted the minimum and maximum distances of 10 and 500 km, respectively. There exist many different risk esti-

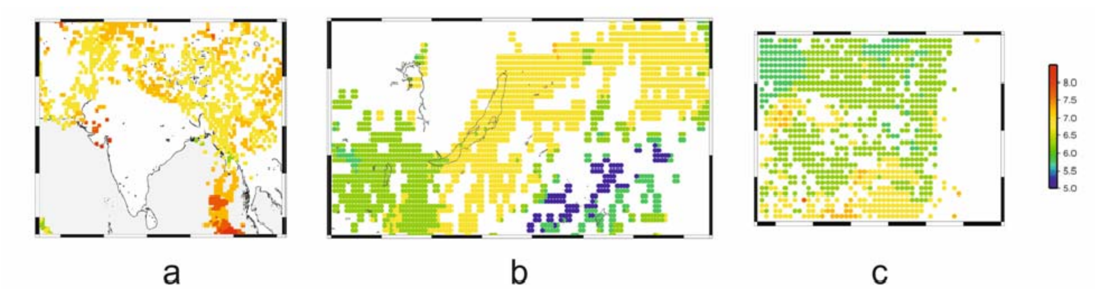


Figure 6.7 The seismic hazard maps for the three regions in terms of *Mmax*: the Himalayas and surroundings (a), Lake Baikal (b), and Central China (c)

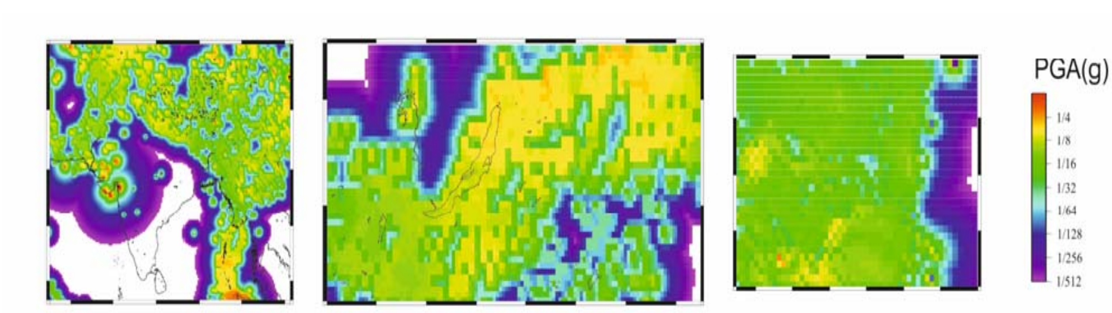


Figure 6.8 The seismic hazard maps for the three regions in terms of PGA (in g) based on USLE approach: the Himalayas and surroundings (a), Lake Baikal (b), and Central China (c)

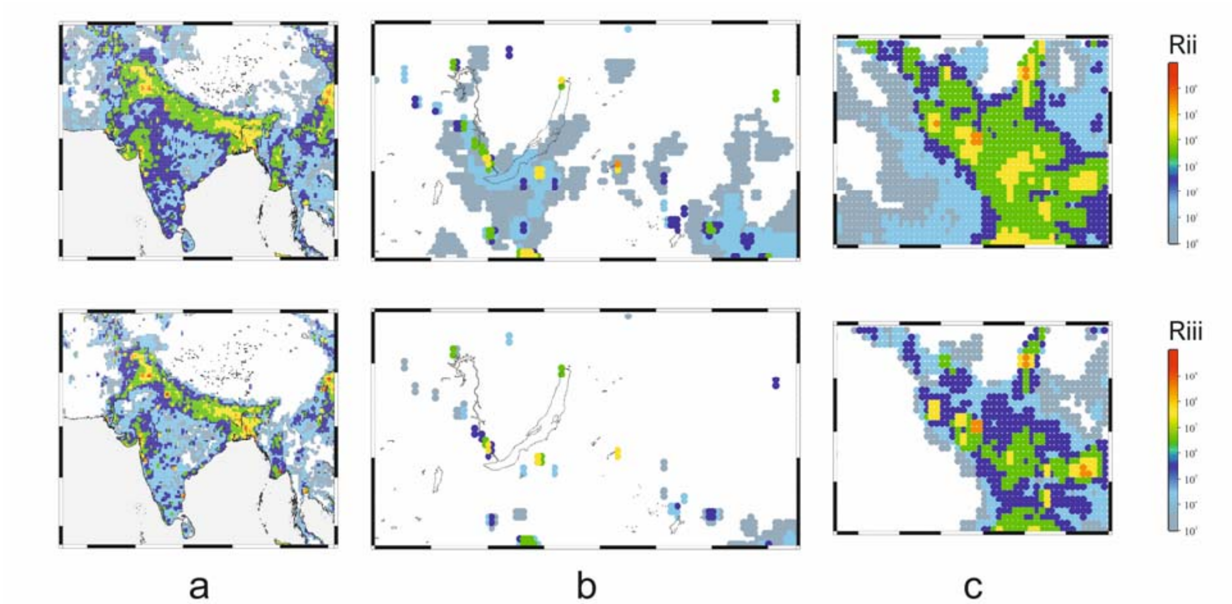


Figure 6.9 The maps of seismic risk for population of the three regions: the Himalayas and surroundings (a), Lake Baikal (b), and Central China (c). Oversimplified convolutions of seismic hazard map H(g) with the population density distribution P: Rii (g) = H(g) · ∫gP · P (upper row) and Riii (g) = H(g) · ∫gP · P_2 (bottom row).

mates even if the same object of risk and the same object of risk and the same hazard are involved. The variety may result from the different laws of convolution, as well as from different kinds of vulnerability of an object of risk under specific environments and conditions. Both the conceptual issues must be resolved in a multidisciplinary problem oriented research performed by specialists in the fields of hazard, objects of risk, and object vulnerability. To illustrate the concept, we perform the two oversimplified convolutions of seismic hazard assessment map based on USLE with the population density. The resulting maps of the two risks in arbitrary units are given in Figure 6.9. The first estimate in a cell g is based on the individual vulnerability in proportion to the population density at a given site, Rii (g) = H(g) · ∫gP · P, where ∫gP is the integral of the population density over the cell g, i.e. the number of individuals within the area of the cell g. The second risk estimate is Riii (g) = H(g) · ∫gP · P^2. Both appear to be rather natural due to specifics of man-made environment inflicted in the areas of high concentration of individuals. To avoid misleading interpretations, we have to emphasize that the risk estimates presented for the three regions under study are given for academic methodological purposes only.

Anastasia Nekrasova* Imtiyaz A Parvez, Vladimir Kossobokov* and X Tao**
[*]Institute of Earthquake Prediction Theory & Mathematical Geophysics, RAS, Moscow
[**]Harbin Institute of Technology, People's Republic of China.

6.9 Crustal Structure beneath Kashmir Himalaya: A preliminary estimation from five broadband stations

An attempt has been made to map the detachment plane in Kashmir Himalaya to identify possible asperities that would allow a more realistic modelling of seismic hazard in the region. The results presented here constitute the first information about a consistent Moho geometry of the region even as we densify the network to attempt high-resolution images of the Moho and the overlying décollement.

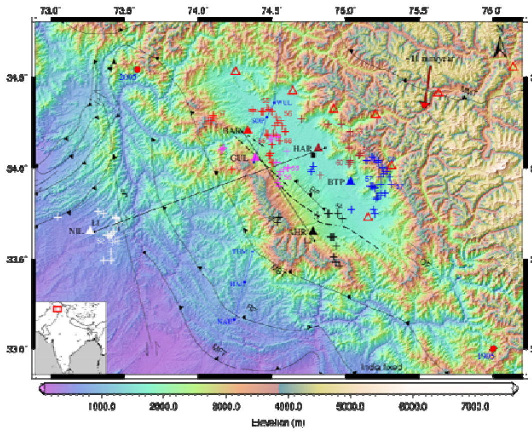


Figure 6.10 Shows map of Kashmir Valley and adjacent areas. Hollow red triangles are the stations which are to be installed; others are the stations (BAR, GUL, AHR, BTP and NIL) whose data were used in this study. NIL (white triangle at bottom left) is the IRIS station in Nilore Pakistan. Crosses are piercing points representing upcoming Ps converted phases at Moho for respective station (color match). Figures near to piercing points are Moho depths from forward modelling.

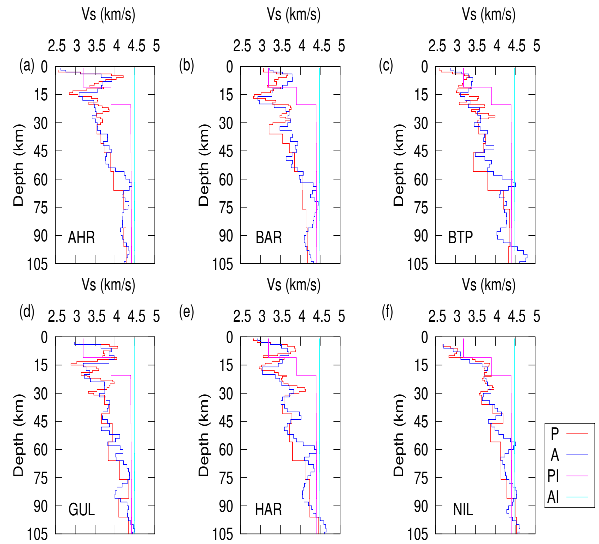


Figure 6.11 Shows comparison of inversion using AK135 and PREM models for all stations. We see a LVZ beneath all except NIL, P means inversion using PREM model and A means inversion using AK135 model. AI=AK135 initial model and PI=PREM initial model.

We investigate the crustal structure beneath the intermountain Kashmir valley carved within the Great Himalaya by the differential uplift of its south-western part, which constitutes the northern Pir Panjal ranges. The data for our analysis comes from five broadband seismic stations located on hard rock sites of the valley, three on its south-western and two adjoining its north-eastern edges. Four Guralp 3TD broadband seismic sensors were operated at bedrock sites (Figure 6.10 AHR, BAR, BTP and GUL) from June 2013 to June 2014, and a fifth Nanometrics Trillium 120P seismometer at HAR close to Srinagar from September to November 2014. Additionally, we use the data from the IRIS station at Nilore (NIL) in Pakistan. For the present analysis, we use data pertaining to all M>6 earthquakes in the epicentral range of 30 to 100 degrees, and selected only the high quality records. Data at all these stations were recorded continuously at a sample rate of 100 samples per second and time stamped using a GPS receiver at all the stations.

Receiver Functions (RFs) at these sites were calculated using the iterative time domain deconvolution method and jointly inverted with surface wave dispersion data to estimate the shear wave velocity structure beneath each station. To enhance the signal to noise ratio of the weak conversions, receiver functions were stacked in small bins of close backazimuth and delta values. This enhances discrimination between lateral variations within stations. Furthermore, a tight stacking of RFs with Backazimuth BAZ $\leq 8°$ and delta $\leq 5°$ obviates the blurring of stacks because of attenuation in Ps phases and facilitates identification of later reverberations. To further test the results of inversion (figure 6.11), we applied forward modelling by dividing the crust beneath each station into 4-6 homogeneous, isotropic layers. Moho depths were separately calculated for closely spaced clusters of Moho piercing points from the inversion of high quality stacked receiver functions pertaining to these piercing point. Their uncertainties were further constrained within ±2 km by trial forward modelling as Moho depths were varied over a range of ±6 km in steps of ±2 km and the synthetic receiver functions matched with the inverted ones. The final values were also found to conform to those independently estimated using the H-K stacks. The Moho depths on the south-western edge of the valley are close to 55 km, but increase to about 58 km towards the eastern edge, suggesting that here, as in the central and Nepal Himalaya, the Indian plate dips north-eastwards beneath the Himalaya. We also calculated the V_p/V_s ratio beneath these 5 stations which were found to lie between 1.7 and 1.76, yielding a Poisson's ratio of ~0.25 which is characteristic of a felsic composition.

Ramees R Mir, Imtiyaz A Parvez, Vinod K Gaur, Ashish, Rakesh Chandra* and Shakil A Romshoo*

*University of Kashmir, Srinagar

6.10 Probabilistic earthquake hazard assessment for Peninsular India

Peninsular India, usually considered as a stable continental part of the Indian subcontinent, has experienced damaging earthquakes of magnitude ∼6 and more in the last couple of decades. Earthquakes occurred in various places in Peninsular India: Latur (1993, Mw 6.1), Jabalpur (1997, Mw 5.8) and most recently Bhuj (2001, Mw 7.6), claiming thousands of lives and causing huge economic losses due to the dam- age to infrastructure. Although the fre-

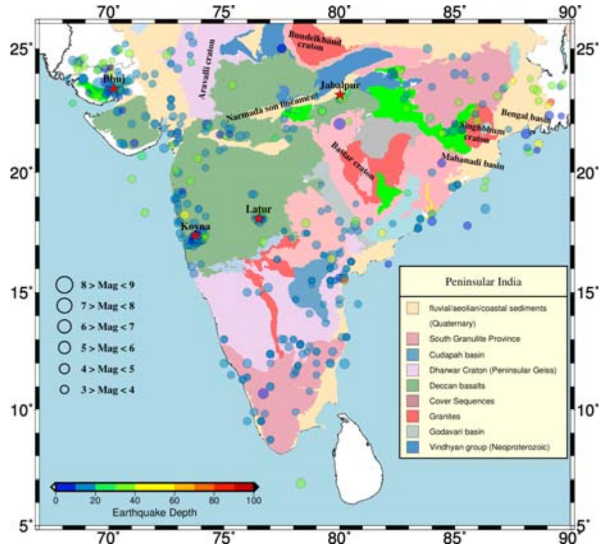
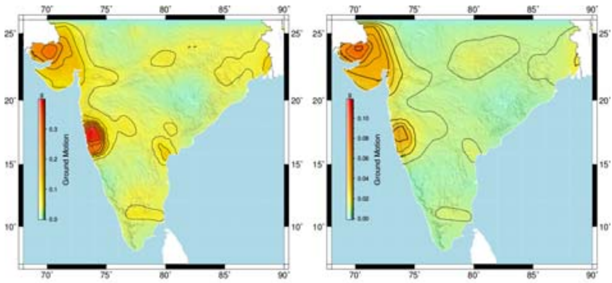


Figure 6.12 Geology of Peninsular India derived from the Geological Map India (GSI, 2000), and locations of historical earthquakes (circles). Colour and diameter of circles indicate depth and magnitude, respectively. Red stars indicate major events that occurred during the past 50 years.

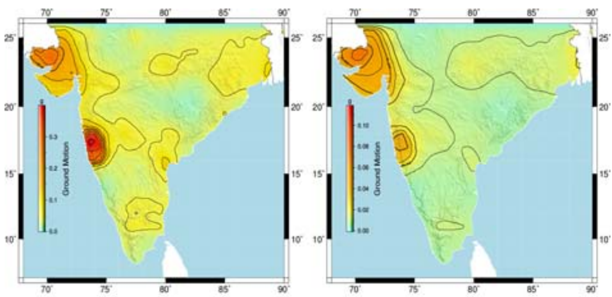
quency of occurrence of large earthquakes is low, their impact on society is high. Thus, it becomes important to quantify the seismic hazard for Peninsular India for future events in terms of potential ground shaking, while at the same time acknowledging difficulties and the inherent uncertainties. The seismicity and major geological features are illustrated in Figure 6.12.

In this paper, a new probabilistic seismic hazard assessment (PSHA) is presented for Peninsular India. The PSHA has been performed using three ferent recurrence models: a classical seismic zonation model, a fault model and a grid model. The development of a grid model based on a non-parameterised recurrence model using an adaptation of the Kernel based method that has not been applied to this region before. The results obtained from the three models have been combined in a logic tree structure in order to investigate the impact of different



(a) (b)

Figure 6.13 Hazard maps computed for 10% probability of exceedance in 50 years (return period 475 years), using a logic tree approach with equal weights for all three seismicity models; displayed at (a) PGA and (b) a spectral acceleration of 1 Hz; see colour bar for values.



(a) (b)

Figure 6.14 Hazard maps computed for 10% probability of exceedance in 50 years (return period 475 years), using a logic tree approach with weights of 0.4, 0.2 and 0.4 for the zonation, fault and grid model, respectively; displayed at (a) PGA and (b) a spectral acceleration of 1 Hz; see colour bar for values.

weights of the models. Three suitable attenuationrelations have been considered in terms of spectral acceleration for the stable continental crust as well as for the active crust within the Gujarat region. While Peninsular India has experienced large earthquakes e.g. Latur and Jabalpur, it represents in general a stable continental region with little earthquake activity, as also confirmed in our hazard results.

On the other hand, our study demonstrates that both the Gujarat and the Koyna regions are exposed to a high seismic hazard (Figures 6.13 and 6.14). The peak ground acceleration for 10% exceedance in 50 years observed in Koyna is 0.4 g and in the Kutchh region of Gujarat up to 0.3 g. With respect to spectral acceleration at 1 Hz, estimated ground motion amplitudes are higher in Gujarat than in the Koyna region due to the higher frequency of occurrence of larger earthquakes. We discuss the higher PGA levels for Koyna compared Gujarat and do not accept them uncritically.

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

6.11 Site response study in Bangalore city using H/V spectral ratio of Microtremor

Bangalore a highly developed and dense city, also the capital of Karnataka is situated in the Peninsular Deccan plateau of India. The seismicity level of Bangalore is low to moderate and it lies in seismogenic zone II. There are no frequent earthquakes reported in Bangalore and surrounding area except that the city has felt in 1900 Coimbatore earthquake (M=6.0). However, due to high alteration of soil structure such as dried up lakes for erosion and encroachment, it becomes a matter of interest for scientists how these buildings (constructed on sedimentary deposits) will react to any moderate/large earthquake. We have estimated the site responses at the Bangalore city using the single station spectral ratio method widely known as H/V spectral ratio technique. For computation of the spectral ratio using Nakamura's method, the GEOPSY software has been used. This spectral ratio provides a good estimate of the fundamental frequency of the site although the site amplification factor is over estimated. Site response analysis is a fundamental part

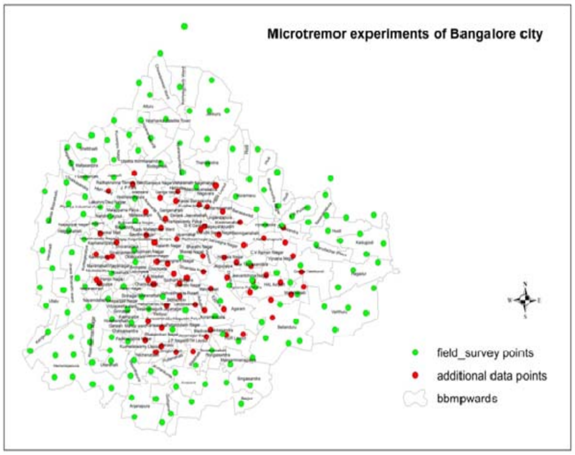


Figure 6.15 The location of sites for microtremor data collection in Bangalore city

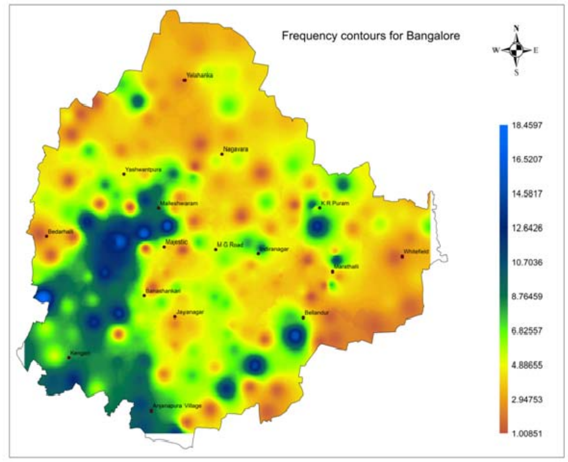


Figure 6.16 Distribution of fundamental frequency (f0) estimated from H/V spectral ratio using Nakamura's technique.

of assessing seismic hazard in earthquake prone areas. Although there are number of methods to evaluate seismic hazard, but due to its low cost and simplicity, ambient seismic noise (microtremor) measurement is preferred by many. Microtremors are short period vibrations that result from human activity (traffic, machinery), atmospheric loading, wind etc. The main objective of this project is to compute the horizontal to vertical spectral ratio (H/V ratio) using Nakamura's technique, which generates the peak period fundamental frequency. In addition, on soft soil sites, where contrast is high between bedrock and top soil they usually exhibit a clear peak that is well correlated with the fundamental resonant frequency. It is now commonly accepted in the earthquake engineering community that soft soils can play a large role in ground motion and must be included in seismic zoning. The phenomenon responsible for the amplification of the ground motion in areas with soft sediments is the trapping of seismic waves within sediments due to acoustic impedance contrast between sediment and bedrock. The interference of these trapped waves leads to resonances whose shapes and frequencies are well correlated with geometrical and mechanical characteristics of the structure.

For this study more than 200 single station ambient noise measurements (Figure 6.15) are performed and the data is processed. The predominant frequencies surveyed in Bangalore city range between 1.0~18 Hz and it is found that they are higher in the southwest part compared to southeast part (Figure 6.16). Comparing them with the overburden thickness inferred from various borehole locations validates the reliability of the result. The resonant frequency obtained from the observations correlated very well with the one obtained from soil thickness and shows extensive lateral variation in soft sediments thickness. The mapping of resonant frequency permits identification of zones at risk. It can be used as a tool for prevention, planning and retrofitting measures, also to define safety zones for reconstruction after a destructive earthquake.

Imtiyaz A Parvez, Reshma Bhat, Haseeb Rehman, Bhavani Kambala and Prajith KC

6.12 Reflection and refraction of attenuated waves at an imperfectly bonded interface between cracked elastic solid and porous solid saturated with two immiscible viscous fluids

The present study describes the propagation of elastic waves across the imperfectly bonded interface between the cracked elastic solid and porous solid saturated with two immiscible viscous fluids. We assume that both the media are loosely connected to each other and the connected coefficient or bonding parameter is represented here by ψ. The interface between these two media is assumed at $x_3 = 0$.

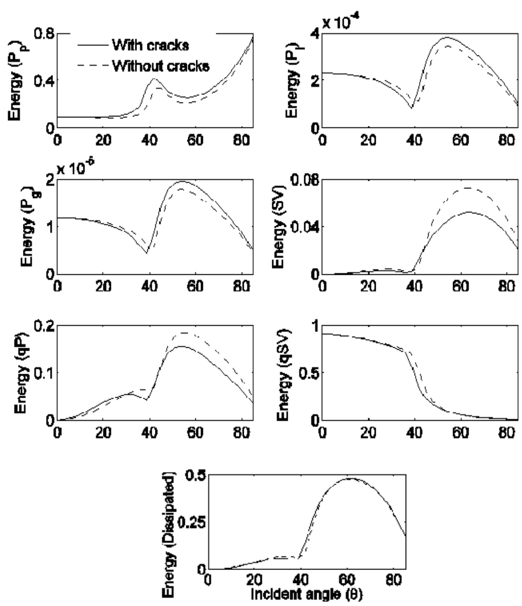


Figure 6.17 Energy shares of incident P_p wave by the reflected (P_p, P_l, P_g, SV) waves, refracted (qP, qSV) waves and energy dissipation at the interface $x_3 = 0$ with incidence direction θ for presence and absence of the cracks in elastic half space.

We solve the dynamical equations with the help of the assumed harmonic solution. The obtained results are in the form of Christoffel equations and these results provide four inhomogeneous waves in a porous medium, of which three are longitudinal waves and one is a transverse wave. The reflection coefficients and energy share have been solved for given boundary conditions at a loosely bounded interface. The energy matrix defines the distribution of the incident energy to the four reflected waves, two refracted waves and some energy is lost at the interface and is defined as dissipation energy. The final results related to energy share satisfy the conservation law of energy. We have also conducted a comparative study between the presence and absence of vertical aligned cracks in the elastic half space. For the numerical validation of the present study, we assume that the first medium is water and CO_2 saturated sandstone and second medium is basaltic rock. From figure 6.17, we find that the vertically aligned cracks in the elastic half space give significant deference in the energy share of the incident wave by reflected and refracted waves. In the absence of the cracks, less energy will be absorbed at the loosely bounded interface in the form of dissipated energy.

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6.12 Reflection and refraction of attenuated waves at the interface between cracked poroelastic medium and porous solid saturated with two immiscible fluids

The present study generalizes the study of the previous problem in which we assume that the poroelastic solid saturated with two immiscible fluids is in contact with the cracked poroelastic solid with sin-

P_1

gle fluid at $x_3 = 0$. We assume that viscosity is present in both media. To solve these elastodynamic equations, we have used the Helmholtz technique for finding the harmonic solutions. In the process, scalar potentials provide five longitudinal waves and vector potentials provide two transverse wave for both media. The inhomogeneous propagation of the incident wave, reflected waves and refracted waves are specified through the respected propagation directions and attenuation directions. The incident wave propagates through the cracked poroelastic solid and is incident at a point on the interface $x_3 = 0$ result as three reflected waves and four refracted waves. The energy matrix defines the distribution of incident energy to the three reflected waves, four refracted waves and some of the energy will be spent on the interaction of the waves with each other. The final results related to energy share satisfy the conservation law of energy.

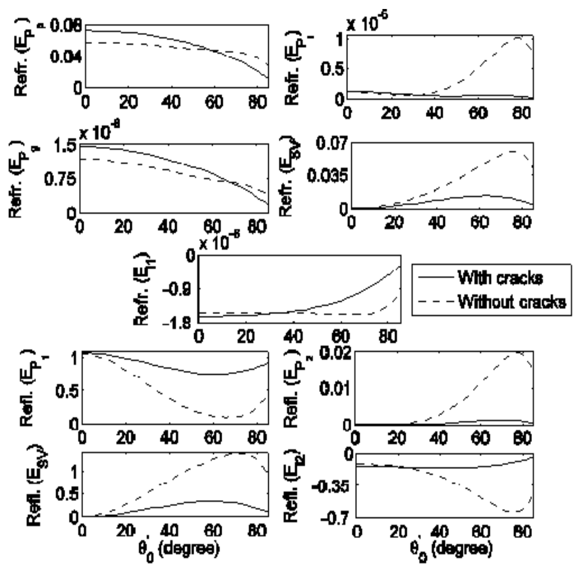

Figure 6.18 Energy shares of incident P_p wave by the refracted (P_p, P_l, P_g, SV) waves, reflected (P_1, SV) waves and the interaction energies E_{l1} and E_{l2} at the interface $x_3 = 0$ with incidence direction $\theta_0^{'}$ for presence and absence of the cracks in poroelastic half space.

For a given incident P_l wave, the presence of cracks in the poroelastic solid has significant effects on the energy share of the incident wave by reflected, refracted and the interaction energies E_{l1}, E_{l2} see figure 6.18. The energy shares of refracted slow P_i and P_g waves are very small in comparison to other energy shares.

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6.13 Propagation of torsional surface in an inhomogeneous anisotropic fluid saturated porous double layers lying over gravitating dry sandy Gibson half space

We try to determine the existence of torsional surface waves in inhomogeneous fluid saturated second porous layer lying in between an inhomogeneous fluid saturated first porous layer and an inhomogeneous dry sandy Gibson half space under initial stresses. Based on the previous available literature it is clear that in the crust different inhomogeneities are available from place to place. In the present study, we assume that the inhomogeneity varies in both of the porous layers quadratically and exponentially in rigidity, density and initial stress and in the Gibson half space, inhomogeneity varies linearly in rigidity and initial stress. We use the separation of variable technique for solving the dynamical equations. We consider a numerical example for the validation of the proposed model, namely a water saturated limestone layer sandwiched in between a kerosene saturated sandstone and a dry sandy half space

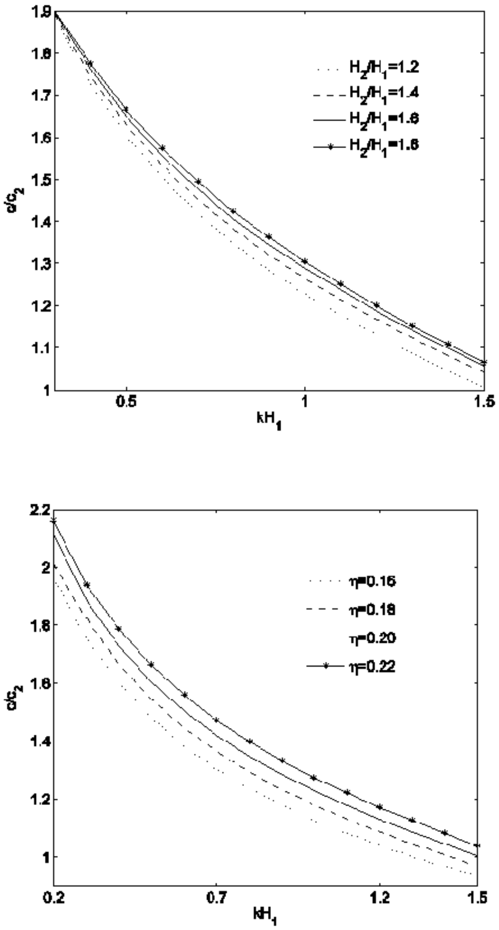

Figure 6.19 Variation of the dimensionless phase velocity (c/c_2) with dimensionless wave number kH_1 for given values of (a) width ratio (H_2/H_1), (b) sandy parameter η.

(Gibson half space). The phase velocity of torsional surface waves in sandwiched layer (second porous layer) is computed numerically. From the present study it is clear that:

(1) The width of the porous layer plays an important role in the study of torsional surface waves.

(2) The sandy parameter η that represents dry sandy Gibson half space has a significant effect on phase velocity of torsional surface waves (Figure 6.19).

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7

CSIR 800

The Govt of India launched multiple programs and schemes in 2014-2015 to improve living conditions of its peoples through a variety of schemes. These schemes perfectly fit the TECH-VILS as proposed in the CSIR-800 program. In terms of specific projects, we have defined an intervention to improve the quality of care that villages receive at their first point of call - the Primary Health Centre. In doing so, we have demonstrated that in its fullest implementation, the CSIR-800 Program can contribute in a small but significant way to Digital India, DigiLocker, Make in India and Skill India.

Based on our earlier interactions with Primary Health Centres we noted that poor infrastructure adversely affected the quality of health care administered. Accordingly we drafted the DS project to survey selected Primary Health Centres across the country for information on the workload of the doctors and PHC staff, the instruments available, the IT infrastructure and the IT skills. The proof-of-concept solution we implemented had a low cost solution for outdated medical instruments, non-existent health records management, and inadequate IT infrastructure prevalent in a majority of the PHCs surveyed.

The project was collaboratively conducted with CSIR-CLRI, CSIR-IMMT, CSIR-AMPRI, CSIR-IHBT, CSIR-CGCRI, and CSIR-NEIST. We conducted:

- *A feasibility study of the most necessary parameters to inform on a patient's general health in rural areas; and*
- *Initial field tests to assess training needs of PHC staff to handle medical instruments and create records using a specially designed App running on a mobile platform.*

We also mentored 4 groups of final year medical electronics students in their project work to develop the same medical instruments that were demonstrated in the Primary Health Centers.

In our next project we expect funds to develop a device to monitor the jolts that a patient receives when transported along rural roads in an ambulance. By creating suitable visible cues, we expect to create awareness and modify behaviour of ambulance drivers, and hence improve the ride quality for patients.

Implementation of the Primary Health Center program

Selection of Primary Health Centers

We selected those labs with an active group developing technologies for rural development, while also insuring geographical distribution. Six areas were selected based on the earlier distribution of TECHVILS. Ten Primary Health Centers each in Himachal Pradesh, Madhya Pradesh, Odisha, and twenty Primary Health Centers in North-Eastern region, West Bengal, Tamil Nadu were identified for an in-depth survey to document their strengths and constraints.

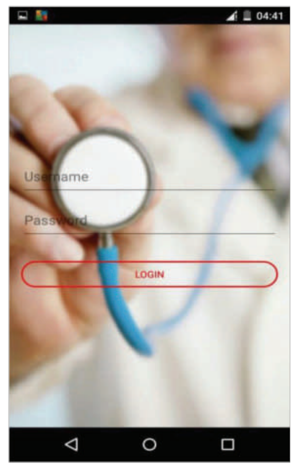
PHC Surveys

Project assistants were recruited by each of the CSIR labs to conduct a survey to assess the state of the selected PHCs against those issued by Indian Public Health Standards. This field work was coordinated by the CSIR lab with the support of the Medical Officer and the PHC staff.

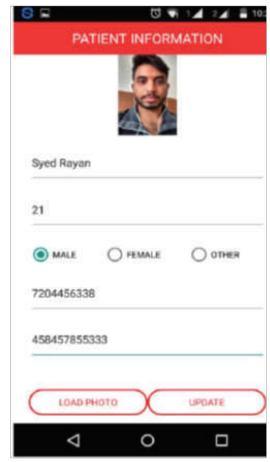
Capturing basic health parameters

Project assistants who were recruited by the labs to conduct the surveys were taught to use standard over-the-counter digital medical instruments - Blood Pressure Monitor, Pulse oxymeter, Blood sugar, Body temperature and Weigh scales and an accompanying App. Patient health data from these 5 medical instruments was entered on the tablet together with a scan of the hand-written diagnosis and other details such as clinical test reports and prescribed medication. These were demonstrated to the PHC staff in 40 PHCs where this experiment was conducted. The staff was also taught how to create a Unique Health Record (UHR) number and generate a one page report that could be printed and handed to the patient for reference. In effect this was a simple but effective way to create a secure e-health record for the patients.

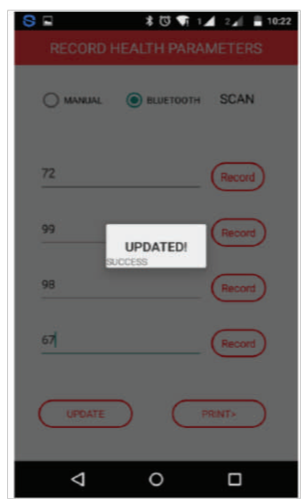
Some screen shots of the app are shown below.



Login page



Patient information page



Health record page

Patient record summary page

Results of the Survey

The survey of Primary Health Centers has confirmed what is generally assumed of these "first-point-of-care” in our villages. PHCs generally lacked not only in providing adequate care, but patients were further disempowered as they had no recourse to their medical records if they wished to be treated elsewhere. Our field demonstrations on IT were well received and were seen as a low cost but effective, high quality solution to reducing the workload on doctors, and empowering patients with access to their medical health records enabling them to consult other specialists when the need arose.

IT training needs for PHC staff

The demonstrations at the PHCs in Tamil Nadu, with nearly full coverage of computers and internet connectivity, were interesting as the PHC staff was able to assess the merits of different software for medical records and showed that they had fully embraced the IT advantages. PHCs in Assam have about 40% coverage of computers and internet connectivity. Some of the PHC staff have the necessary aptitude for IT work and are able to operate the App. It may be appropriate to consider the services of NGOs to operate the instruments and print the reports for the doctor – who can save precious moments to use on diagnoses.

Student projects

We mentored 4 groups of students from a local college in their final year project work. The projects were aligned to developing high quality medical instruments namely a Pulse Oxymeter, a non-contact IR thermometer, and a smart weighing scale. The fourth group wrote an App for a tablet which allowed data from medical instruments to be entered manually and create a record for a patient.

We hope that in the following year, we will b able to develop a device to monitor the jolts that a patient receives when transported along rural roads in an ambulance. By creating suitable visible cues, we expect to create awareness and behavior modification in an ambulance driver, and hence improve the ride quality for patients.

CSIR-800: ***Ehrlich Desa and Vinoth Balasundar. [Project Asst Varun Bhat]***

CSIR scientists (Labs): ***Amudeshwari A (CLRI), R K Sud (IHBT), J P Shukla (AMPRI), Swachcha Mazumdar (CGCRI), D P Sanda (IMMT), SP Saikia (NEIST)***

BMS College students: ***Akshat Shrivastava, Ashwini HS, Darshana Chandrasekhar, Hamsa Varsha, Niharika Nidhi, Rayan Syed, Shambavi R, Viren G S***

Research Publications and Other Information

8

KNOWLWDGE ACTIVITES & PRODUCTS

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

Inside

- ***Publications in Journals***
- ***Publications in Books/Proceedings***
- ***Presentations in Conferences/ Symposia/ Workshops/ Seminars***
- ***Participation in Conferences/ Symposia/ Workshops/ Training Programmes***
- ***Conference/Workshops/Seminars/Scientific Meetings at CSIR-4PI Invited Talks***
- ***Seminars/Lectures***
- ***Visitors at CSIR-4PI***

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Shyla B, **Gouda K C**, Laxmikantha B P, Climate Change Studies over Bangalore using Multi-source Remote Sensing Data and GIS, *Proceedings of AGU Fall Meeting,* San Francisco, 15-19 Dec, 2014.

Shruti Y, **Gouda K C**, Nageswar Rao P P, Bhat N, Impact of Climate Change on Sugarcane Crop at Regional Scale: A Study with Remote Sensing and GIS, *Proceedings of AGU Fall Meeting,* San Francisco, 15-19 Dec, 2014.

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Presentations in Conferences/Symposia/ Workshops/Seminars

Anil Earnest, Active tectonic deformation: Possible applications of NISAR data on plate boundary processes, NISAR Science Workshop, ISRO-SAC, Ahmadabad, 17-18 November 2014.

Bhimala K R, The role of soil moisture in malaria transmission over India, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore

Sahoo S K**, Gouda K C, Himesh S, Goswami P**. Simulation of extreme rainfall event over Himalayan Region using WRF model in Climate Symposium 2014, EUMETSAT, WCRP and ESA held at Darmstatdt, Germany, 13-17 October 2014.

Nagaraj Bhat, **Gouda K C**, Samantray P, **Goswami P,** Monitoring and Modelling of the Climate Variability over the Western Ghats, *The Climate Symposium-2014,* EUMETSAT, WCRP and ESA, Darmstadt, Germany, 13-17 October 2014.

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Himesh S, COMoN observations: Weather and climate variability, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore.

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Juri Barua, Drivers of acute respiratory diseases, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore.

Mahapatra G N, Regional Issues: extreme heat waves in Odisha and role of weather informatics, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore.

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Patra G K, Mathematical models in designing cryptographic primitives: An inter-disciplinary approach, International Multi-conference on Innovations in Engineering and Technology (IMCIET-2014), Vijaya Vittala Institute of Technology, Bangalore.

Rajendran K, Sajani Surendran and Kitoh A**,** Relevance of climate change projection for India, Kerala Environment Congress 2014 on Water and energy security: Issues, challenges and potentials, Centre for Environment and Development, 22-23 August 2014, Kochi.

Praveen S, **Rakesh V,** Extreme rainfall events over urban cities: evaluation of forecast skill of a mesoscale model, TROPMET-2015: National Symposium on Weather and Climate Extremes, IMS & Punjab University, Chandigarh, 15-18 February 2015.

Rakesh V, High resolution weather forecasting with data assimilation, Workshop on Assessment, Modelling and Applications of Renewable Energy (AMARE), 20-22 May 2014, CSIR IICT, Hyderabad.

Rakesh V, Weather informatics for disease forecasting, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore.

Alfred Johny, **Ramesh K V,** Understanding the relationship between climate extremes and vector borne diseases in India, TROPMET 2015, National Symposium on Weather and Climate Extremes, IMS & Punjab University, Chandigarh, 15-18 February 2015.

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Ramesh K V, Climate Resilient Pro-Active Healthcare through Climate Projections, Indo-UK Workshop on Weather and Climate Informatics for Pro-Active Health-care (WACIPH), 26-27 November, 2014, CSIR-4PI, Bangalore.

Neethu C, Shafeer K B, **Ramesh K V**, Understanding the variability and change in coastal rainfall extremes during Southwest and Northeast monsoon seasons under different climate scenarios, TROPMET 2015, National Symposium on Weather and Climate Extremes, IMS & Punjab University, Chandigarh, 15-18 February 2015.

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Internal Reports

Shrungeshwara T S, **Chiranjeevi Vivek G, Pavithra N R,** Anil Kumar M, Neelu Sharma, Sarkar S **& Sridevi Jade,** Landslide deformation studies in Uttarakhand, India**,** TR CM 1501, March 2015.

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Kantha Rao, P Goswami, K C Gouda, G K Patra, S N Nishad, Divergence of Simulations due to machine dependence: Implications for accuracy of simulations and forecasts, RR CM1501.

Shrungeshwara T S**, Pavithra N R, Chiranjeevi Vivek G,** Anil Kumar M, Sarkar S**, Sridevi Jade,** GPS Site details and observations in Garhwal Himalayas, Uttarakhand, India, PD CM 1501, February 2015.

Conferences/Symposia/Workshops/Seminars attended

Anil Kumar V, 3rd NKN Workshop, IIT Guwahati, 15-17 December 2014

Anil Kumar V, International Conference on High Performance Computing and Applications (ICHPCA-2014), Bhubaneswar, 22- 24 December 2014

Anil Kumar V, National Seminar on Big Data Challenges and Opportunities, Avinashalingam University, Coimbatore, February 19-20. 2015

Ashapurna Marndi, Workshop on Visualization for Big Data, C-DAC, Bangalore, 18 September, 2015,

Pavithra N R, Induction Training Programme for Scientists, CSIR-HRDC, Ghaziabad, 15 – 24 December 2014.

Rajendran K, 2nd Asian Network on Climate Science and Technology (ANCST), Workshop on Atmosphere-ocean interactions in the Indo-Pacific basin and their impact on Asian climate, Indian Institute of Science, Bangalore, 23-24 November 2014.

Sajani Surendran, 2nd Asian Network on Climate Science and Technology (ANCST), Workshop on Atmosphere-ocean interactions in the Indo-Pacific basin and their impact on Asian climate, Indian Institute of Science, Bangalore, 23-24 November 2014.

Vijayan M S M, CSIR Leadership Development Programme (LDP-Module IV), CSIR-HRDC, New Delhi, 20-23 April 2014

Vijayan M S M, NISAR Science Workshop, Space Application Centre (ISRO), Ahmedabad, 17-18 November 2014

Invited Talks

Anil Kumar V, Multipath TCP: An innovative transport layer protocol for high performance data transfer, GARUDA-NKN Partner Meet, IISc, Bangalore, 19-20 September 2014

Anil Kumar V, Cyber security in context of big data, National Seminar on Big Data Challenges and Opportunities – A perspective with Security and Social Media Analytics, Avinashalingam University, Coimbatore, 19-20 Feb.. 2015

Anil Kumar V, Supercomputing performance from a protocol and interconnect perspective, Key-Note Talk, International Conference on High Performance Computing and Applications (ICHPCA-2014), 22-24 Dec., Bhubaneswar

Goswami P, Science for Nation Building: Climate, Civilization and Nation, National Science Day 2015, Institute of Advance Study in Science and Technology (IASST, Pachim Boragaon, Guwahati, 1 March 2015.

Goswami P, Agriculture, Disaster and Governance: Sustainable and Disaster Resilient Agriculture through Climate and Weather Informatics, International Conference on Governance in Agriculture and Allied Sectors, Hyderabad, 18-19 December 2014

Goswami P, Proactive Disaster Management: Towards Actionable Forecasts, National Seminar on Disaster Management-Science and Technology Tools in Preparedness, Early Warning and Mitigation Measures, 25-27 September, 2014, Geological Society of India

Goswami P, Sustainable Agricultural Diversification, Lead Talk, Symposium on Agricultural Diversification for Sustainable Livelihood and Environmental Security, Ludhiana, 18-20 November 2014.

Goswami P, Towards100% Renewable Energy: A Vision to Reality,Workshop on Assessment, Modelling and Applications of Renewable Energy (AMARE), 20-22 May, 2014.

Gouda K C, Disaster management using geospat1al tools, Karnataka Remote Sensing Application Centre, Bangalore, 12 July 2014.

Gouda K C, Living with modelling & simulation, Departmentt of Computer Science & Engineering, S M V Institute of Technology & Management, Udupi, 17 Oct 2014.

Gouda K C, Cloud computing for climate informatics**,** international conference on futuristic innovations and challenges to diversity management, emerging technologies & sustainability for inclusive industrial growth, Jyotinivas College, Bangalore, 30-31 October 2014.

Gouda K C, Modeling, simulation and optimization for monsoon prediction**,** International Conference on Modeling, Simulation and Optimizing Techniques, Post Graduate Department of Mathematics, DAV College, Jalandhar, 12-14 Feb, 2015.

Gouda K C, Simulation study of extreme rainfall events due to cloud burst using a non hydrostatic model**.** TROPMET-2015, International conference on weather extremes, IMS & Punjab University, Chandigarh, 15-18, 12-14 Feb, 2015.

Patra G K, Mathematical models in designing cryptographic primitives: An inter-disciplinary approach, Berhampur University, Odisha, November 9, 2014

Patra G K, The big super-compute: Where HPC meets big data, National Seminar on Big Data Challenges and Opportunities – A perspective with Security and Social Media Analytics, Avinashalingam University, Coimbatore, 19-20Feb., 2015.

Rajendran K, Regional Climate Change Projections over India: Problems and Prospects, Science of Climate Change: Indian Ocean and Monsoon, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, 1-2 September 2014.

Rajendran K, Regional Climate Change Projections over India: Problems and Prospects, Meteorological Research Institue, Japan, 8 Jan 2015.

Rajendran K, Multimodel future projections of Indian summer monsoon, Earth System and General Circulation Modelling Session, Climate Modelling Workshop, IIT-Bombay, 20 March 2015.

Sridevi Jade, GNSS Geodetic Studies- Natural Hazard, CSIR-CBRI, 28 October 2014.

Conference/Workshops/Seminars/ Scientific Meetings organized by CSIR-4PI

The Technology Day, 7 May 2014, S R Valluri Audotorium.

This year's Technology Day function featured a splendid lecture by Dr S Christopher, Outstanding Scientist and Director, Centre for Airborne Systems (CABS), Bengaluru. In his talk on Airborne Early Warning and Control (AEW&C) Systems in India-: Past, Present and Future, Dr Christopher gave an account of how the surveillance system evolved into a force multiplier. He spoke in length on the challenges overcome during the development and flight integration of AEW&C system to make it a highly reliable state-of-the-art surveillance system. He highlighted new technologies developed and patented during the process of meeting the programme requirements.

International Workshop on Assessment, Modelling and Applications of Renewable Energy (AMARE) 20-22 May 2014, Leonia Resorts, Hyderabad, India

AMARE was co-organized by CSIR-4PI, CSIRO, Australia and CSIR IICT; was supported by the Australian

Department of Foreign Affairs and Trade (DFAT) PSLP India activity *Harnessing improved weather and climate information for renewable energy generation* and hosted by CSIR IICT. The primary objective of the event was to fill the current gap in understanding the availability of renewable energy resources in India, and to create a platform for developing a roadmap for meeting the grand challenge of 100% renewable energy. Capabilities and tools needed to evaluate the feasibility and implications of a 100% renewable energy scenario was the focus of the workshop. The participation was by invitation, and included eminent experts/representatives from India and Australia.

Workshop on Weather and Climate Informatics for Pro-Active Healthcare (WACIPH), 26-27 November, 2014

The workshop, funded under the UKIERI project *Integrating disease prediction with weather and climate models seamlessly* (INDRASS), was organized to develop an effective synergy by bringing together a number of active research groups and stake holders to develop an integrated and applicable platform for pro-active healthcare at short and long time scales. A major goal of the workshop was to identify available components, map expertise and strengths and plan an integrated platform for pro-active healthcare; the sessions were thus focused on discussions around selected topics. In addition to the scientists from CSIR-4PI and the University of Liverpool, several R&D organizations and state departments participated in the Workshop.

National Science Day, S R Valluri Auditorium 26 February 2015

CSIR - National Aerospace Laboratories and CSIR-4PI jointly organized National Science Day Celebrations. Science day lecture was delivered by Dr. M Annadurai, Programme Director, IRS & SSS, ISRO, Bangalore

International Women's Day Celebrations 2015

CSIR - National Aerospace Laboratories and CSIR-4PI organized the International Women's Day Celebrations on 6th March 2015 at S R Valluri Auditorium. This year the theme for International Women's Day is "*Make it happen*". The guests of honour, this year, were Dr. V. Shubha, Chief Scientist & Head, Airport Instrumentation Group, CSIR-NAL and Ms. Subhashini Vasanth, well-known dancer & founder trustee, Vasantha Ratna Foundation for ART.

Seminars/lectures

Lakshmivarahan S, University of Oklahoma, USA
Quantification of Forecast Uncertainty and Data Assimilation using Wiener's Polynomial Chaos Expansion, 30 June, 2014

Dirk Smit, VP, Exploration Technology R&D and SHELL Chief Scientist for Geophysics, Netherlands
Compute Challenges to meet Future Energy Demand, 08 July, 2014

Ashwin Pananjady, IIT, Chennai
Optimization and Scheduling: Tackling Hard Communication Problems through Probabilistic Algorithms, 06 August 2014

Swaminathan Krishnan, California Institute of Technology, USA
Quantitative Risk Assessment Using Rupture-to-Rafters Simulations, 26 August 2014

Narayan Behera, Institute of Bioinformatics and Applied Biotechnology, Bangalore
An Evolutionary Data Mining Algorithm to Find the Candidate Gene for Disease Diagnostics, 11 Sep, 2014

Manik Talwani, Research Professor, Rice University, USA
My Fifty Years of Adventures with Measuring Gravity over the Oceans (and on the Moon), 28 Nov, 2014

Visitor's at CSIR-4PI

Danial Kerstin Kuehn, Researcher, NORSAR, Norway, 19-30 May 2014

Dominik Harald Lang, Abdelghani Meslem, Researcher, NORSAR, Norway, 22-24 May 2014

Conrad Daniel Lindholm, Researcher, NORSAR, Norway, 23 May 2014

Dowchu Drukpa, Chief Seismologist, Ministry of Economic Affair, Bhutan, 23 May 2014

Dirk Smit, Fons Kroode, Rob Eppenga, Bertwin van Beest, Suhas Phadke, Shrirang Karandikar, Shell Technology, July 2014

Nitin Patil, IIT Bombay, 21 -25 July 2014

Supantha S Paul, IDP Climate Study, IIT Bombay, 8 August 2014

Kiran Akella, Scientist, DRDO, 12 August 2014

Jrffery Phillip Adie, Principle System Engineer, SGI Asia Pacific, 26 August 2014

Swaminathan Krishnan, SEGT Lab, California, USA, 26 August 2014

Abdelghani Meslem, Researcher, NORSAR, Norway, 10 October 2014

Nitin Patil, IIT Bombay, 12 October 2014

Anastasia Nekrasova, Russian Academy of Science, 3-14 November 2014

Supantha S Paul, IDP Climate Study, IIT Bombay, 10 November 2014

Joseph William Spencer, Univ of Liverpool, 21 November 2014

John Stephan Marsland, Univ of Liverpool, 21 November 2014

Frans Pierre Coenen, Univ of Liverpool, 21 November 2014

Manik Talwani, Rice University, 27-28 November 2014

Conrad Daniel Lindholm, Researcher, NORSAR, Norway, 1-3 December 2014

Gil Briman, VP, Mellanox Technologies, USA, 17 December 2014

Mark Clifford Sultzbaugh, Sr VP, Mellanox Technologies, USA, 17 December 2014

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ACADEMIC PROGRAMME

In keeping with its objective of developing skill and expertise in Mathematical Modelling and Computer Simulation in the country, CSIR-4PI 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 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

Mohapatra G N, (Berhampur University), Impact of Local Climate Variability and Anthropogenic Processes in Extreme Weather Events over India

Kantha Rao, (Mangalore University), Multi-scale Modelling and Analysis of Surface and Soil processes over the Indian Region.

Shiv Narayan Nisad, (Mangalore University), Analysis and Modeling of Sustainability over India under Different Scenarios of Climate Change and Socio-Economic Conditions

Sumana Sarkar, (Mangalore University), Multisector Application of Seasonal Forecast: Crop yield, Vector-Borne Diseases and High Impact Weather Events over India

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.

Gouda K C

Nagaraj Bhat (VTU), Weather Informatics using Remote Sensing & GIS.

Radhika T V (VTU), Efficient and Large-Scale Climate Simulation Analysis in Cloud Computing Cluster

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.

Farrukh Altaf, (AcSIR), Integrated Natural Disaster Assessment using GIS applications in Kashmir Himalayas.

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

Kulkarni Shashikant (IIT Bombay), Downscaling over Monsoon Region

Ramesh K V

Alfred Johny, (AcSIR), Simulation of Indian Summer Monsoon using CMIP5 Climate Simulations

Safeer K B, (AcSIR), 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

Arya V B (AcSIR), Analysis of meteorological and aerosol observations

Stella Jes Varghese (AcSIR),Computational modeling of coupled climate system

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

Sridevi Jade

Shrungeshwara T S (Kuvempu University), 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

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

M Tech/ME/MCA/BE Projects

Anil Kumar V

Transport Layer Feature Enhancement in Linux Kernel, Chinmaya Mohini (M Sc), Pondicherry University, May 2014

A Customized Software Tool for Filtering and Analyzing Network Packets in a Linux based Distributed System, Sudeep Nesakumar S (M Tech), Vellore Institute of Technology, May 2014

Implementation of wget on SCTP, Navya Meriam Joseph, Rachana, Ranjani and Sithara (B E), New Horizon College of Engineering, VTU, July 2014

Database Design for Massive Network Traffic, Patrick E, (B Tech), Karunya University, March 2015

Simulation Studies on Buffer Sizing in Internet Routers Using NS3, Karthika S Nair, (MCA), Mahatma Gandhi University, January 2015

Client-Server Application Implementation on Stream Control Transmission Protocol, Akshita Sharma, Azeena Kulsum, Gopal Sharma and Nimisha Dutta, MVJ College of Engineering, VTU, July 2014

Gouda K C

Development of Electric Load Forecasting Model in different Climate Change Scenario, Vinutha H D **(**M Tech), SJB Institute of Technology (VTU), Bangalore, June 2014.

Weather Modeling and Simulation in cloud computing platform, Bhaavan M (M Tech), SJB Institute of Technology (VTU), Bangalore, June 2014.

Evaluation of High Resolution Weather Model for Regional Climate Studies, Indu B (M Tech), SJB Institute of Technology (VTU), Bangalore, June 2014.

Precision Agriculture Information System using Remote sensing Data and Dynamical crop model, Mukhesh Gowda (M Tech), SJB Institute of Technology (VTU), Bangalore, June 2014.

Assessment of water resource for KRS Reservoir using Remote Sensing and GIS Manumohan V H (M Tech), Karnataka Remote Sensing Application Centre (VTU), Bangalore, May 2014

Integrated geo-spatial approach for monitoring climate change and its impact ocver Bangalore Urban District, Shyla B (M Tech),, Karnataka Remote Sensing Application Centre (VTU), June 2014.

Study of Impact of climate parameters on Sugarcane yield over Bvagalkot using Remote sensing, Shruthi Y (M Tech), Karnataka Remote Sensing Application Centre (VTU), June 2014

Modelling Impacts of Climate change on Road Infrastructure at Regional Scale, Pooja V (M Tech), SJB Institute of Technology (VTU), Bangalore, June 2014.

Development of software system for weather informatics, Shadiya Aman (M C A), Jyoti Nivas College (Bangalore University), Bangalore.

Development of Integrated system for weather and climate data analysis, Abhitha J (M C A), Jyoti Nivas College (Bangalore University), Bangalore.

A survey on the Hydro-meteorological disaster events over India, Smrutishree Lenka (M Sc), Ravenshaw University, Odisha

Virtualization Approaches and Migration Management in Cloud Computing, Anurag Patro and Dines Dwivedi (B Tech), National Institute of Technology, Rourkela, June 2014.

Patra G K

Implementation of public key cryptography, Shilpa A, Sweta Priya M, Tasmiya Sanam, Usha Shivappa Ambig, Don Bosco Institute of Technology, May 2014

Efficient Fully Homomorphic Encryption for Secured High Performance Computing, Nilotpal Chakraborty, Devi Ahilya University, May 2014

Secure Computation over Cloud using Fully Homomorphic Encryption, Anusha Biakanti, Anjana N B, Divya A, K Divya, CMR Institute of Technology, June 2014

Multiparty Key Agreement using Neural Cryptography, Vandana Arya, East Point Engineering & Technology, Bangalore, June 2014

Rakesh V

Analysis of remote sensing satellite data to study the thermodynamic processes of extreme weather events, Archana V, Indian Institute of Information Technology and Management, Kerala, India

Mathematical modeling and analysis of tropical cyclones over the Indian Ocean, Muhassin Babu M M, Indian Institute of Information Technology and Management, Kerala, India.

Analysis of trends in temperature during last century for major cities in Kerala, Athira V S, Indian Institute of Information Technology and Management, Kerala, India

Ramesh K V

Understanding the relationship between climate and pulses over India, Arti Mehta, SHIATS, Allahabad

Understanding the Variability and Trends in Pulses over India, Nidhi Kumari, SHIATS, Allahabad

Modelling the relationship between climate and ecosystem, Pathang V S, Indian Institute of Information Technology and Management Kerala.

Identification of 3d structure of hotwaves and data modelling, Jean Rose John, Indian Institute of Information Technology and Management Kerala

Modelling and simulation of reservoir water level and hydro power Generation, Vidhu Lakshmi K U, Indian Institute of Information Technology and Management Kerala Trivandrum

Modelling and structural analysis of three dimensional structure of rain events, Indhuja Nandan K, Indian Institute of Information Technology and Management Kerala Trivandrum.

Senthilkumar V

Nonlocal continuum mechanics and dispersion of plane waves, Tushar Chaudhary, B.Tech, IIT(BHU), July 2014

Faculty participation

Academy of Scientific and Innovative Research

Patra G K, High Performance Scientific Computing, January 2015 semester

Rajendran K, Tropical Meteorology and Monsoon, January 2015 semester

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COLLABORATIVE PROGRAMMES & PROJECTS

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

Inside

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

CSIR Network Projects

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) - ***Nodal officer: Sridevi Jade***

Nodal Lab: CSIR-4PI

Participating Labs:

CSIR National Aerospace Laboratories (NAL)
CSIR National Institute of Oceanography (NIO)
CSIR National Geophysical Research Institute (NGRI)
CSIR Central Building Research Institute (CBRI)
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
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
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***

Nodal Lab: CSIR Central Building Research Institute (CBRI)
CSIR Electronics Electronics Engineering Research Institute, (CEERI)

Participating Lab:

CSIR-4PI
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 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
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

A High performance computing (HPC) system for simulation and visualization of deep mining and geosciences problems, 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 Central Institute of Mining and Fuel Research (CIMFR)

Participating Lab:

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

11th Five Year project

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

Grant-in-aid Projects

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

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

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*

Diagnosis of Increased Seismic Hazard in Himalayas and Adjacent Territories. (DST-RFBR), – *PI: Parvez I A*

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

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

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

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

Modelling for Pro-Active Disease Control for Cardamom Systems: A Pilot Study over Idukki, Kerala, ICRI – *PI: Goswami P, Co-PI: Ramesh K V*

Investigation of Relative Roles of Local and Large-scale Circulation in the Dynamics of Cloudburst using Simulation with a Non-hydrastatic Model, DST - *PI: Gouda K C*

Mathematical Modeling of some Nano Fluid Flows, National Board of Higher Mathematics, Vellore Institute of Technology – *PI:* *Srinivas S**, Co-PI: Ramamohan T R***

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

Monitoring Continuously Operating CSIR-4PI GPS Station Located in the IISc Campus – *PI: Sridevi Jade.*

Site-specific Ground Motion Modelling and Micro-zonation Studies in Delhi City– *PI: Parvez I A*

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TEAM CSIR-4PI – NEWS AND UPDATES

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

Inside

- ***Team CSIR-4PI***
- ***Awards/Honours/Recognition***
- ***Services on External Committees/Membership of Professional Bodies***
- ***Deputations***

Head
Shyam Chetty

Honorary Emeritus Scientist
Gaur V K
Yajnik K S

Distinguished Scientist
Balganesh T S
Ehrlich Desa
Prakash V

Scientists
Anil Earnest
Anilkumar V
Ashapurna Marndi
Ashish
Chiranjeevi Vivek
Goswami P
Gouda K C
Gyanendranath Mohapatra
Himesh S
Indira N K
Kantha Rao Bhimala
Krishna Mohan T R
Parvez I A
Patra G K
Pavithra N R
Rajendran K
Ramamohan T R
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
Shafeer K B
Shaktidhar Nahak
Shiv Narayan Nishad
Sushant Shekhar
Sumana Sarkar

Junior Research Fellows
Lalith Kumar
Stella Jes Varghese
Sunil Kumar T C
Jayasankar C B
Silpa K
Arya V B
Farrukh Altaf

Technical Officers
Prabhu N
Suchanda Ray

Stores & Purchase
Ravinder Kumar (Till 06-01-2015)
Nandeesh (Joined on 22-01-2015)

Administration
Anilkumar Angadi
Neethu S Induchodan
Raman P K
Sathyanarayana K

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

Project Fellows/ Senior Project Fellows
Ajilesh PP
Alfred Johny
Akash Chowdhury
Dharma Teja A K
Ganesan P
Kambala Ganga Bhawani
Kirthi Sagar V
Murthy D H R
Nagaraj Naik
Nagaraju G
Navi Thejesh
Neethu C
Parthasarathi Barik
Prajith K. C
Prashant Meti S
Payoshni Samantray
Praveen S
Ramees Raja Mir
Reshma Bhat
Sanjeeb Kumar Sahoo
Shelva Srinivasan M K
Suri Babu D

Awards/Honors/Recognitions/Ph D Awarded

Senthilkumar V, Received IEI Young Engineers Award in Aerospace Engineering Division for the year 2014-15, The Institution of Engineers India

Ramesh K V, Mentor and resource person on Climate and Weather Informatics, DST INSPIRE Camp, Chennai, 21 October 2015

Goswami P, Lead Author, Working Group I, IPCC Fifth Assessment Report, Chapter 14

Gouda K C, Best paper award in the 3rd National Conference on Current trends in Computer Science and Engineering (CSECONF-14) , Jain University, Bangalore, 14 June 2014

Ph D Awarded

Anant Kant Shukla, Awarded from Vellore institute of Technology
Subramanyam Reddy, Awarded from Vellore institute of Technology
Parul Trivedi, Awarded from Saurashtra University

Services on External Committees/ Membership of Professional Bodies

Anil Kumar V
Member, Internet Society (ISOC)
Life Member, Computer Society of India
Member, Computer Network Security Advisory Committee, Indian Institute of Astrophysics, Bangalore
Member, Program Committee, International Conference on High Performance Computing and Applications (ICHPCA-2014)
Member, Technical Programme Committee, International Conference on Electronics Computing and Communication Technologies (IEEE CONECCT-2015)
Member, Thesis Evaluation Committee, Center for Cyber Security, Amrita Vishwa Vidyapeetham, Coimbatore
Member, Selection Committee, C-DAC, Bangalore
Member, Selection Committee, Indian Institute of Astrophysics, Bangalore
Member, Assessment Committee, C-DAC, Bangalore
Member, Program Committee, National Conference on Parallel Computing Technologies PARCOMPTECH 2015
Nodal Officer, National Knowledge Network

Goswami P
Member, General Body, KSNDMC
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
Vice President, Indian Meteorological Society, Bangalore Chapter
Member, Scientific Organizing Committee, International Conference Energy & Meteorology (ICEM), USA

Gouda K C
Life Member, Indian Meteorological Society
Ex-officio Member, MoES Committee for Long Range Forecast of Monsoon
Member, Advisory Board, Dept. of CSE, Dayananda Sagar college of Engineering, Bangalore.
Member, Board of Studies, Dept. of MCA, Dayananda Sagar University, Bangalore
Member, Board of Studies, School of Computer Science, Jain University, Bangalore
Member, M.Tech. Thesis Evaluation Committee, VTU.
Member, Doctoral Committee, VTU.
Member, Advisory Committee, International Conference on Modeling, Simulation and Optimizing Techniques (ICMSOT 2015)
Member, Advisory Committee, International Conference on Futuristic Innovations and Challenges to Diversity Management, Emerging Technologies & Sustainability for Inclusive Industrial Growth
Member, Advisory Committee, National Conference on Information Technology for Sustainable Future (NCITSF 2014)

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

Indira N K
Member, Advisory Board, Dept. of Mathematics, Dayananda Sagar college of Engineering, Bangalore.
Member, Board of Studies, Dayananda Sagar University, Bangalore
Member, Working Group for greenhouse gases, aerosol and greenhouse gas monitoring research, Ministry of Earth Sciences, Govt. of India.

Parvez I A
Coordinator, AcSIR C-MMACS
PhD Examiner, Indian Institute of Technology Kanpur.
Member, Advisory Committee Gujarat State Disaster Man-

agement Authority
Member, Technical Expert Committee of Karnataka State Natural Disaster Monitoring Centre
Life Member, Indian Society of Earthquake Technology
Life Member, Indian Society of Earthquake Science

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, Advisory Board, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore
Member, Board of Studies, Mathematics Department, Mount Carmel College, Bangalore
Member, Board of Studies, Department of Mathematics, KIIT University, Bhubaneswar
Member, Doctoral Committee, Vellore Institute of Technology

Prabhu N
Member, Computer Society of India

Rajendran K
Member, Working Group on Climate Change, Kerala State Planning Commission, Government of Kerala.
Member, Board of Studies in Atmospheric Sciences, CUSAT (2011-2014).

Rakesh V
Life Member, Indian Meteorological Society
Joint Secretary, Indian Meteorological Society, Bangalore Chapter

Sajani Surendran
Member, Working Group III National Carbonaceous Aerosol Project, Ministry of Environment and Forests.
Senthilkumar V
Nodal Scientist, CSIR 4PI Micro Small & Medium Enterprises (MSME)
Editorial Board Member, Journal of Modelling and Simulation in Design and Manufacturing (JMSDM)
Life Member, Indian Association for Computational Mechanics (IndACM)
Life Member, Indian society for Advancement of Materials and Processing Engineering (ISAMPE)
Member, International Association of Engineers
Member, IAENG Society of Industrial Engineering
Member, IAENG Society of Mechanical Engineering

Sridevi Jade
Expert Member, Research Advisory Council (RAC), Wadia Institute of Himalayan Geology
Expert member, Technical Advisory Committee, Government of Karnataka
Expert Member, Women Scientist Scheme DST
Member, Information Sciences cluster 12th FYP Work Group/Task Force
Life Member, Indian Geotechnical Society
Member, International Society of Soil Mechanics and Foundation Engineering
Member, International GNSS service (IGS)
Founder Life Member, Indian Society of Rock Mechanics and Tunneling Technology

Swathi P S
Expert Member, Assessment Committee, NIO

Deputation

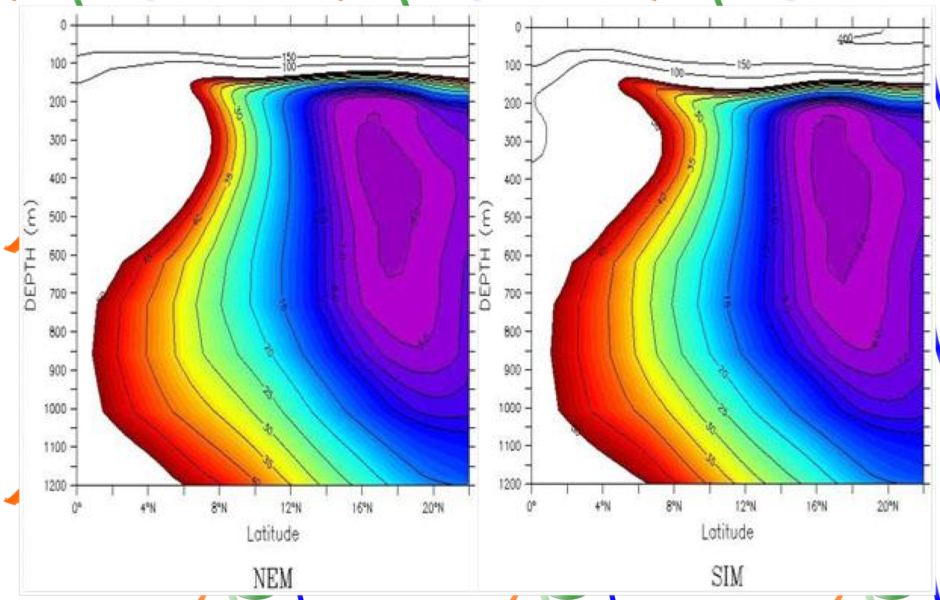
Ashish
Visited NORSAR, Norway under institutional co-operation program between CSIR-CMMACS and NORSAR, August 20 – September 6 2014

Parvez I A
Visited the Institute of Earthquake Prediction Theory and Mathematical Geophysics Russian Academy of Sciences, September 20 – October 4 2014.

Visited NORSAR, Norway under institutional co-operation program between CSIR-CMMACS and NORSAR, August 20 – September 6 2014

Rajendran K
Meteorological Research Institute (MRI), Japan Meteorological Agency Tsukuba Japan, under Project R-8-118 , 4-17 January 2015

Sanjeeb Kumar Sahoo
Visited Germany to present paper in The Climate Symposium -2014, organized by EUMETSAT, WCRP and ESA, Darmstadt, Germany, Oct 13-17, 2014



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Annual Report 2014–2015