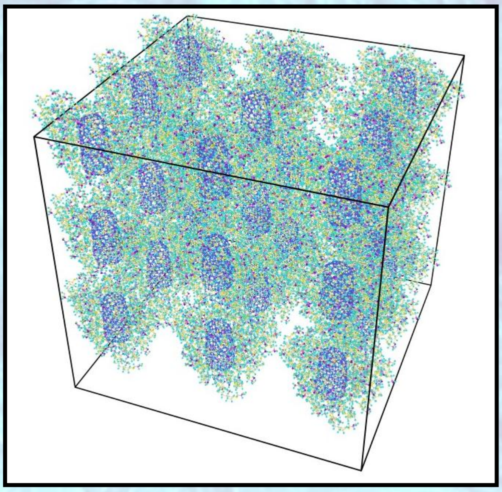
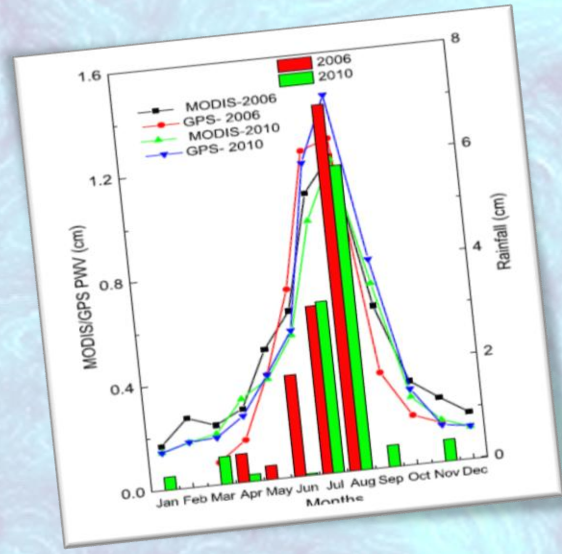
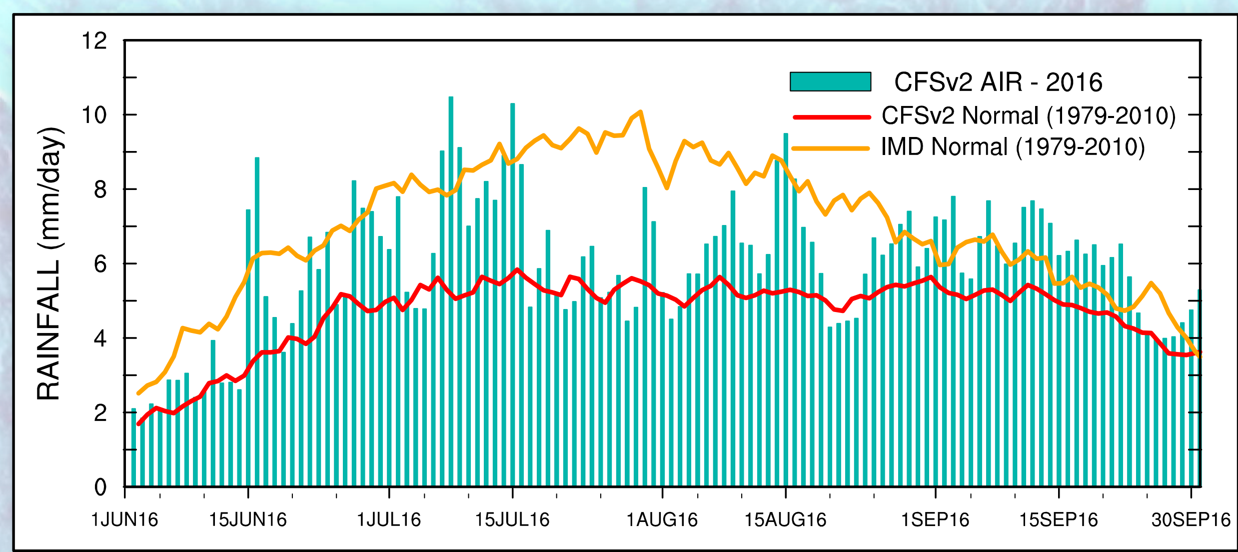
CSIR-Fourth Paradigm Institute

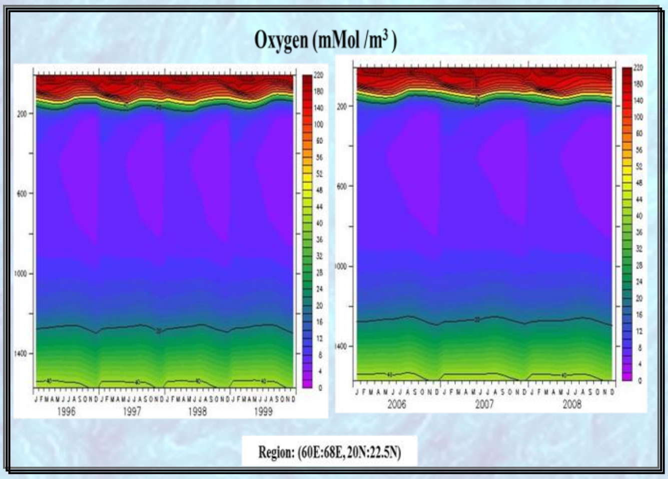
Annual Report 2015 – 2016

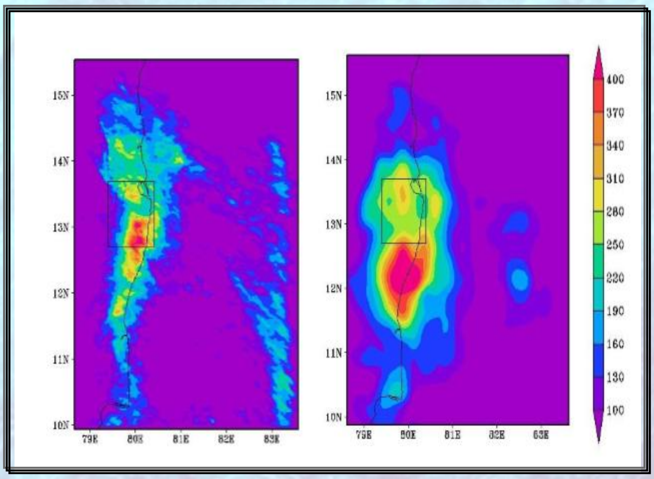
CSIR-4PI



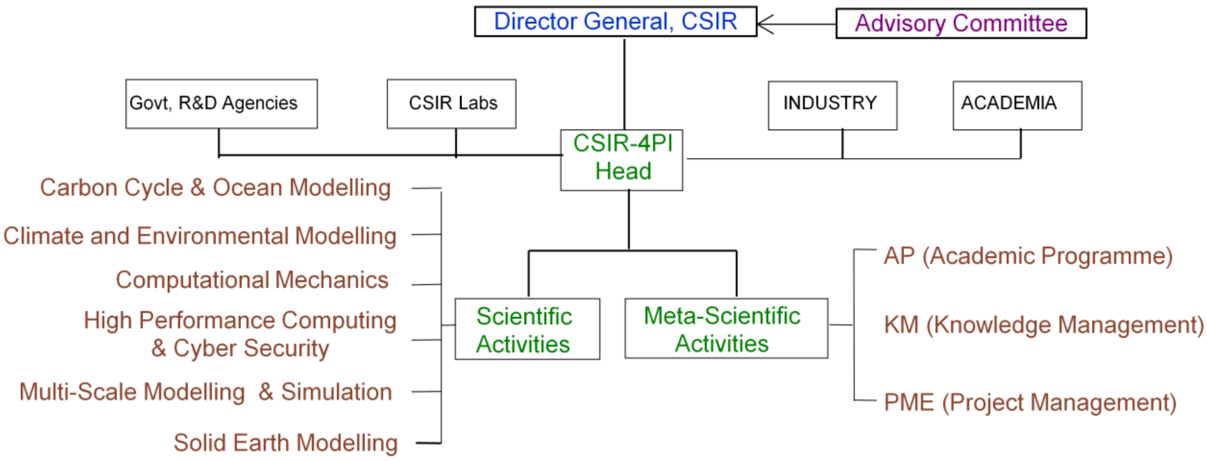








ORGANISATIONAL STRUCTURE OF CSIR-4PI



Vision :

To provide modeling, simulation and data intensive capability powered by high performance computing and informatics research.

Mission :

Develop knowledge products in earth system and information sciences for societal good by exploiting modeling, simulation and data science capabilities.

Mandate :

➢To develop reliable knowledge products for decision support in Earth,

Engineering and Information Science.

➢To be the national leader in High Performance Computing as service that will power modeling and informatics across CSIR.

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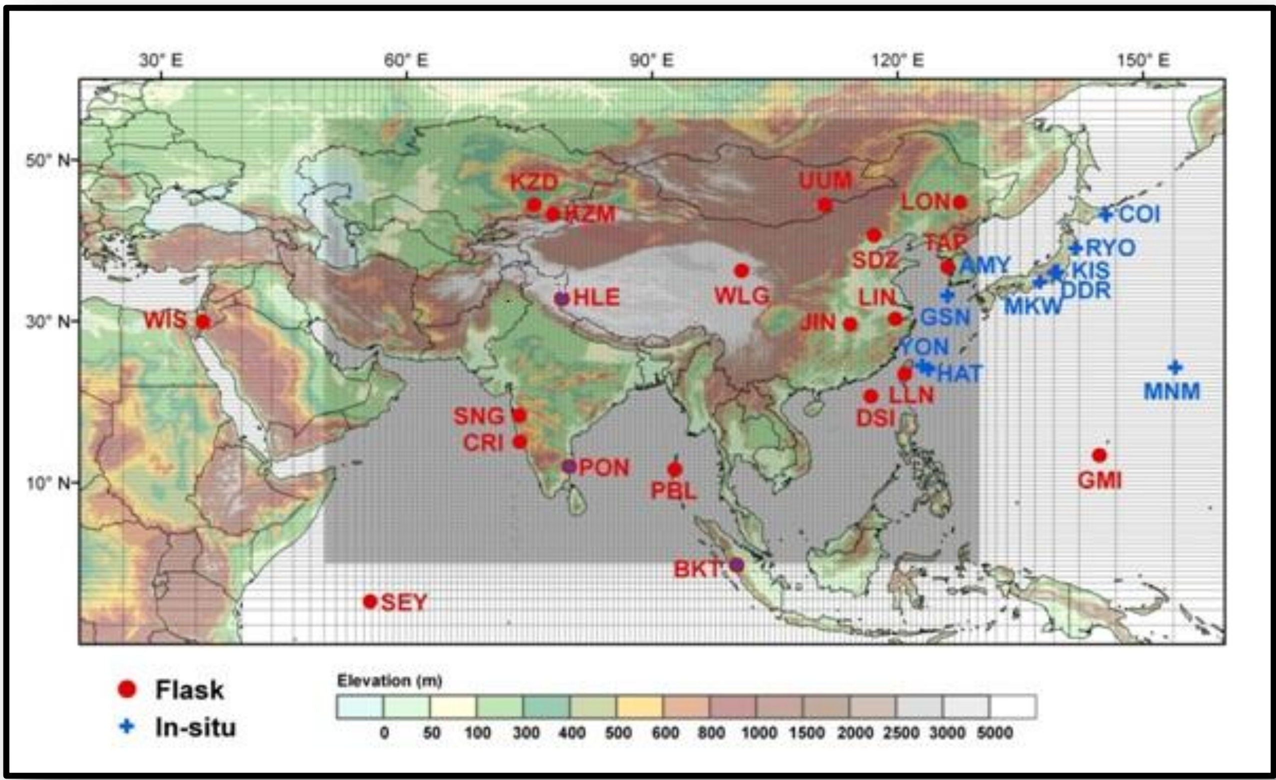
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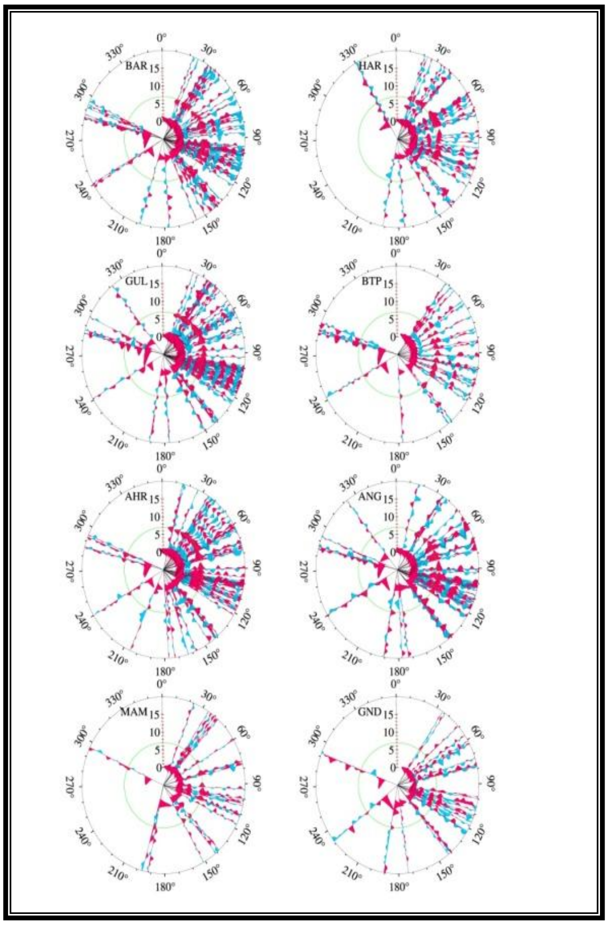

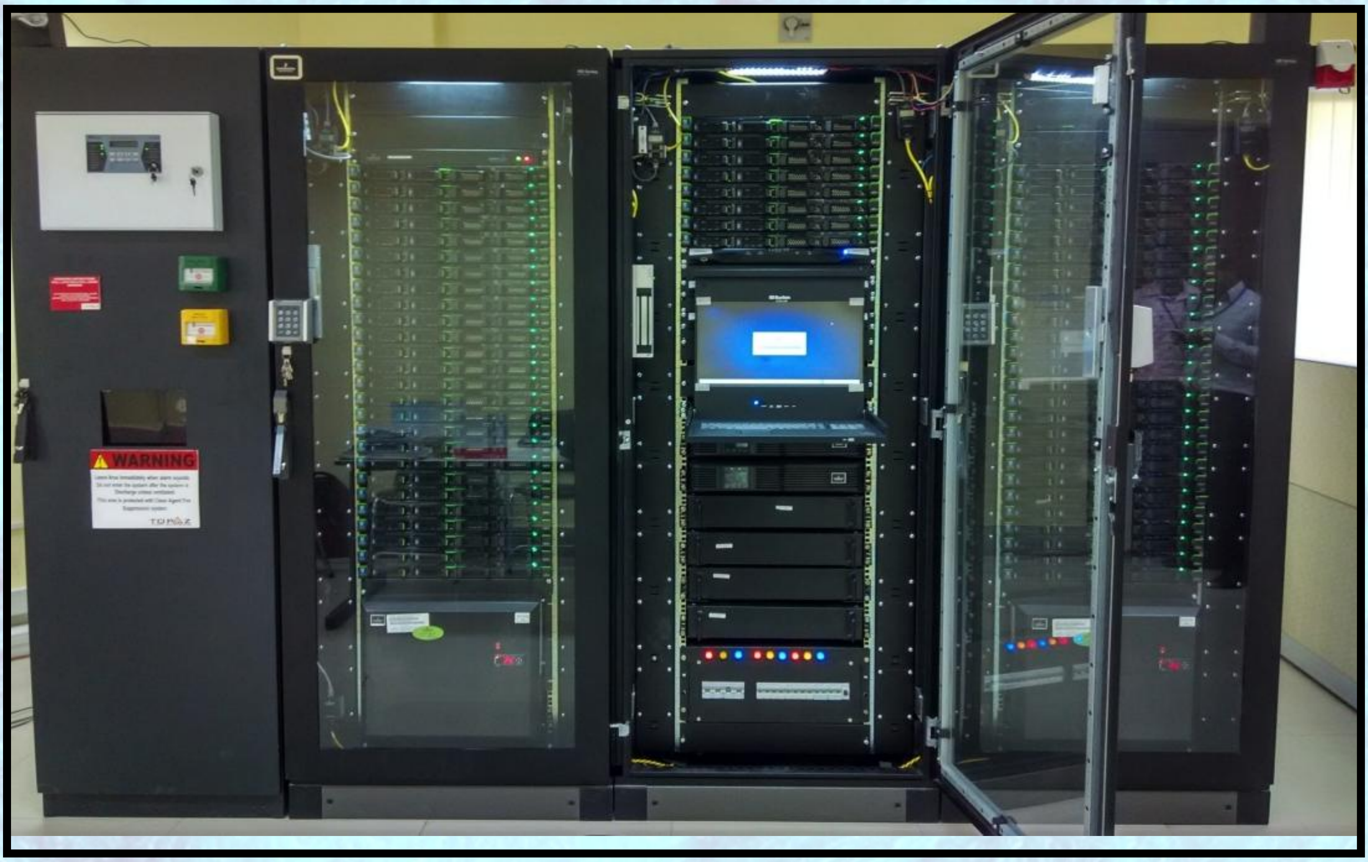

Highlights

- ***Climatologically and interannual simulations of the carbon, nitrogen and oxygen cycles in the ocean especially in relation to the presence of oxygen minimum zones.***
- ***Quantification of denitrification in the Arabian Sea.***
- ***Simulation of iron fertilisation for oceanic sequestration of carbon.***
- ***WMO-standard measurements of greenhouse gases and analysis.***
- ***Setting up a primary standard GHG station at Hosakote.***
- ***Fine resolution modelling of GHG transport.***
- ***MoU signed between CSIR-4PI and IIA, Bangalore for the following three research components of CSIR-4PI.***
- ***Development of climate & weather informatics applications: Swastha Bharat, Samarth Bharat, Renewable energy***
- ***Development of predictive assessment model for Vector Borne Diseases***
- ***Modelling of high impact weather events***
- ***Developed a methodology to assess the skill of high resolution rainfall forecast for specific agricultural applications***
- ***Fundamental contribution to the understanding of the role vertical shear of wind on daily variability of monsoon rainfall***
- ***14th Successful year of long-range forecasting of monsoon***
- ***High resolution regional dynamical downscaling of climate for multi-sector***
- ***applications***
- ***Reliable climate projections for estimating projected changes in Vector Borne Diseases***
- ***Estimation of economically viable wind-generated electricity potential***
- ***The modified Homotopy Analysis Method (HAM) to analyse nonlinear problems.***
- ***Higher-order stress gradient theory based on bi-Hemholtz operator for analysing nanostructure using nonlocal continuum models.***
- ***Continuation of Ananta Supercomputer as the main lifeline of computational scientists of CSIR***
- ***Establishment of a Cyber Security Research and Observation (CySeRO) platform.***
- ***Characterization of Internet Background Radiation in terms of TCP port-wise distribution of malicious connection attempts based on data collected through CySeRO program.***
- ***Improvement to Tree parity Machine based cryptographic system using Link weights***
- ***Prediction of Indian rainfall during the summer monsoon season on the basis of links with equatorial Pacific and Indian Ocean climate indices***
- ***NCEP CFSv2 Retrospective Runs and Prediction of 2016 Indian Summer Monsoon***
- ***Precipitation-aerosol relationship over the Indian region during drought and excess summer monsoon years***
- ***Climate Change Projections with High Confidence using Mulit-physics Ensemble Simulations***
- ***Ultra-high Resolution Regional Climate Simulation for Lakshadweep Islands, through Dynamical Downscaling***

- ***Diagnostic Study of NCEP CFSv2 Retrospective Runs Performed at CSIR-4PI***
- ***Aerosol-Cloud Relationship and Aerosol Indirect Effect on Clouds***
- ***An Algorithm for TRMM PR Spectral Latent Heating Retrieval***
- ***Multi-scale Modelling of Lithosphere-Atmosphere-Ionospheric Coupling: A new initiative***
- ***Perturbation in the equatorial Ionosphere and its mode of propagation triggered by 11 April 2012 Indian Ocean earthquake***
- ***Spectral analysis of decade long geodetic daily position time series and its noise characteristics***
- ***Multi-scale simulation framework for short-term crustal deformation processes modelling: Benchmarking of a strike-slip problem***
- ***Indo-Burman Ranges: Myanmar sliver deformation and the locked sinking Indian lithosphere***
- ***Blind thrust faulting during 2015 Nepal earthquake: Insights from finer scale Slip distribution models***
- ***Source scaling and centroid half duration estimates for Andaman-Nicobar region***
- ***First crustal structure model and seismicity beneath Kashmir Himalayas.***
- ***First seismic risk model for Gujarat region based on seismic hazard and population density.***
- ***Probabilistic Earthquake Hazard in Peninsular India***
- ***PhD entitled "A theoretical study of wave propagation in heterogeneous and isotropic/anisotropic media" awarded under AcSIR.***
- ***Preliminary estimate of Euler pole of rotation of Indian tectonic plate***
- ***GPS-PWV and GPS-TEC studies specific to Indian subcontinent***
- ***GNSS observation network in Kashmir Himalaya***
- ***PhD entitled "Estimation of Precipitable Water Vapor and Crustal deformation in Northeast India" awarded jointly with Tezpur university.***

Preface

Science with a human touch is more useful than science for the sake of science. This is the main driving force of all of the modelling, simulation and high performance computing activity of the CSIR Fourth Paradigm Institute. The modelling and simulation effort at CSIR-4PI has remained focussed on earthquake hazard, carbon cycle and ocean modelling, atmospheric modelling and climate change projections. Over the years, the modelling tools and technologies have matured enough to take on challenging problems, the previous year being no exception. These activities require the muscle power of high performance computing which is provided by an able team, not only for CSIR-4PI but for all of computational scientific work force of CSIR. As we move towards a more digitally enabled world, we face the challenges of cyber security. Concrete steps have been taken in this direction as well. As we move forward, the much needed competence in data and comptuational science will need to be built to realise the new goals of the institute. In what follows, we summarise the major scientific contributions during 2015-2016.

Several countries have submitted firm plans at the COP 21 meeting of UNFCCC at Paris to mitigate climate change by adopting a variety of strategies. In order to implement these strategies and study their effectiveness, we need robust estimates of the fluxes between atmosphere, land and ocean at good spatial and temporal scales. Lack of accurate measurements of Green House Gas (GHG) concentrations and gaps in modelling the carbon, nitrogen and oxygen cycles, especially the oceanic component have hampered efforts to obtain robust estimates. At CSIR 4PI we have contributed (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 interannual variations of the carbon, nitrogen and oxygen cycles.

Climate and environmental modelling is on multidisciplinary and applied research for direct societal benefits. The knowledge products developed under this intiative are geared to be application oriented and provide basis for weather and climate informatics for end-users in the area of agriculture, health and energy. The research on the dynamics of Indian Monsoon, process modeling, high impact weather events and urbanization has continued as they form important components of the ongoing programme.

Climate change is a major concern for the future of humanity as it threatens our very existence. There has been major global thrust and it is only appropriate that we understand the climate change impact from Indian perscpective. Our approach here is to perform advanced simulation of weather and climate, to project future climate change, assess associated vulnerability and provide efficient adaptation and mitigation strategies. Moreover, this is a data intensive paradigm where numerics and computing strategies relevant for different scales in a dynamical system are combined to arrive at an effective computational solution than the one obtained from the strategy dealing with the most relevant single scale. In initial phase of the program, ultra-high resolution weather and climate model framework was developed to address multi-scale processes of the atmosphere and analyze the data from observations and these simulations to effectively arrive at inferences. General Circulation Models (GCMs), coupled ocean-atmosphere climate model and earth system model with emphasis on processes such as multiscale *organization of organized convection and aerosol-cloud-radiation feedbacks, were employed. Recently, multiscale problems ranging from surface processes and climate aspects from surface to ionosphere are being addressed.*

Earthquake hazard is another major concern for India. Even small intensity earthquakes result in huge loss of life owing to poor buildings and other emergency infrastructure. The institute has made pioneering efforts in this are over the years. During 2015-16, broadband seismic network in Kashmir Himalayas was augmented to give good spatial coverage which resulted in first crustal shear velocity model of Kashmir valley. Major contributions during the year are quantification of seismic hazard in the Peninsular India, seismic hazard and risk model for Gujarat region, establishment of GNSS observation network in Kashmir Himalaya, modeling of GPS derived landslide deformation, in-depth study of PWV variability at Hanle: high altitude (~ 4500m) site in Trans-Himalaya. Mega project in collaboration with Kashmir University has been awarded by Ministry of Earth Sciences to study the geological characterization of Kashmir valley with the objective of quantifying hazard and risk in the valley.

In the domain of computational mechanics, homotopy analysis method (HMA) was used to study the complex systems like structures containing nanofluid with viscous and thermal effects. The present method captures the behaviour of the structures and results are very well close to the analytical method. The modification of the HMA yielded good results. The wave propagation analysis of granular sphere was simulated using discrete element approach. The effective mechanical properties of nanocomposites are found through continuum models.

One of the main objectives of institute is to provide state-of-the-art high performance computing environment for the whole of CSIR. The 360 TFLOPS Supercomputing facility, Ananta continued to be the centralized computing facility serving this 200 and odd computational scientists across CSIR with the nodes usage reaching its full capacity in most of the days during this year. The usage has been in diverse field of science like Biological, Chemical, Engineering, Earth and Atmosphere, Physical and Information Sciences. This facility is being accessed by CSIR scientists through the high speed National Knowledge Network on a round-the-clock basis.

One of the major milestones achieved this year is the installation of Cyber Security Research and Observation (CySeRO) platform. CySeRO is a sophisticated test-bed for experimental research and data analysis. This facility is certainly going to boost the ongoing research in Cyber Security and Cryptography.

In the years to come, we look towards consolidating some of the modelling efforts the institute has continued to make and bring in the new capability in data and computational science which is now emerging as the new face of science.

Vidyadhar Mudkavi, Head CSIR-4PI

CSIR-4PI

Annual Report 2015-2016

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Front cover page: (clockwise from top left) *Carbon Nanotube reinforced Polymer Nanocomposite, Precipitable Water Vapor (PWV) derived from GPS and MODIS data at Hanle, high altitude site (~4500m) in Trans-Himalaya with observed rainfall, Seasonal monsoon forecast for 2016 (green bars) along with National Monsoon Mission Model NCEP CFSv2 normal (red) and IMD normal (yellow). CFSv2 Predicted above normal monsoon for 2016, thesimulated 3-day accumulated (29th Nov 00 hr to 2nd Dec 00 hr) rain (mm) over Chennai, TRMM rain is shown for comparision in the right panel.Interannual variation of Oxygen (mMol/m^3) with respect to depth during 1996 to 1999 and 2006 to 2008,*

Inside Back cover**: **(clockwise from top) *Horizontal grid with a zoom over Asia. Locations of GHG stations are also shown, Continuous GNSS station with MET Sensor at Gulmarg, Kashmir, Radial and transverse receiver functions with increasing ray back-azimuths for Anantnag station, Kashmir*

Back cover**: **(clockwise from top) *Cyber Security Research and Observation Test-bed at CSIR-4PI*

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

1
CARBON CYCLE & OCEAN MODELLING

Fluxes of greenhouse gases (GHG) between different compartments of the earth system – atmosphere, land and ocean – need to be quantified robustly before we can close the carbon budget of the planet. It is essential that we do this at good spatial and temporal scales because it is the cornerstone of our efforts to mitigate climate change by controlling anthropogenic emissions. There are two approaches to this effort and CSIR-4PI has made important contributions to both.

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. We do this by combining a state of the art biogechemical model (TOPAZ) with an advanced 3D ocean circulation model (MOM). Climatalogical and interannual simulations of the carbon, nitrogen and oxygen cycles in the ocean have 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.

The top-down approach inverts very accurate GHG measurements to yield robust fluxes. Data from three stations, Hanle, Pondicherry and Port Blair have been collected and analysed. A fine resolution model to simulate the transport of GHG is under development. A new GHG station with primary standards is under commissioning at Hosakote near Bangalore

Inside

- *Modelling of marine biogeochemical cycles in the north Indian Ocean*
- *Greenhouse gas measurements*
- *Fine resolution modelling of Greenhouse Gas (GHG) transport in Asia*

1.1 Modelling of marine biogeochemical cycles in the north Indian Ocean

Oceans have a large capacity to absorb CO_2, thus reducing the amount of CO_2 in the atmosphere. The physical and dynamical properties of the ocean influence the distribution of nutrients and carbon, which in turn affects life in the oceans. The physical and biogeochemical processes which influence nutrient availability, biological productivity and carbon cycle are essential in inferring anthropogenic changes. Modelling studies along with insitu and remote sensing data are useful in the study of significant processes like mixed layer depth variability, uptake dynamics for different nutrients, regeneration/ remineralization processes, new production etc. Synthesis of mathematical models of different complexity and data from various sources is required to understand the effect of climate variability and feedbacks on the estimation of primary productivity and carbon flux. Since long time series observations on marine ecosystem variables are very few in the Indian Ocean, use of mathematical models would help us to improve our ability to understand the marine ecosystem.

In the present study, a three dimensional coupled physical-biogeochemical model TOPAZ is used to study carbon cycle in the Indian Ocean. The coupled model is forced with CORE data to carry out climatological and interannual model simulations in the global domain.

The focus of this study is to understand the spatial and temporal variations of physical and biogeochemical components which influence the distribution of primary productivity, oxygen, carbon flux across the air-sea interface; and evaluating the model simulation results with observations from various sources on different scales.

It is noted from model evaluation studies that simulationswith climatological forcings are able to capture many of the significant features of the spatial and seasonal variations of Sea Surface Temperature (SST), mixed layer depth (MLD), surface Chlorophyll (Chl), primary productivity (PP) integrated over the euphotic zone, Nitrate (NO_3) and partial pressure of CO_2 (pCO_2) at the surface when compared with data from satellites (TMI, MODIS, SeaWiFS) and World Ocean Atlas (WOA) in the north Indian Ocean. Also, the depth profiles of temperature, salinity, nitrate, dissolved inorganic carbon (DIC), oxygen, chlorophyll and primary productivity (PP) from the climatological model simulations are evaluated using the cruise data from US JGOFS, Indian JGOFS and BOBPS at many (more than 15) locations in the Arabian Sea and Bay of Bengal for different seasons.

To understand the physical-biological-chemical processes responsible for the seasonal and interannual variability of biogeochemical variables in different regions in the Arabian Sea and Bay of Bengal, detailed analysis of Sea Surface Temperature (SST), Mixed Layer Depth (MLD), Depth-integrated Chlorophyll & Primary Productivity, Nitrate, Oxygen, Surface pCO_2, Carbon Flux, etc. is carried out, for the period 1997 to 2009 using the results of model simulation and available satellite data. It is noticed that SST, MLD, PP, Chl, pCO_2, Carbon flux show interannual variations in the regions west of 65^o E & north of 12^o N (Figure 1.1) and spatial extent of suboxic zone (Oxygen < 6 m Mol/m^3) shows significant interannual variability (Figure 1.2). This kind of analysis of model simulation results on various biogeochemical components and fluxes is carried out to relate the interannual variability of spatial extent of suboxic zonesand carbon flux at the air-sea interface to SST, MLD, PP, Chl, nutrients etc. in different regions of AS and BOB.

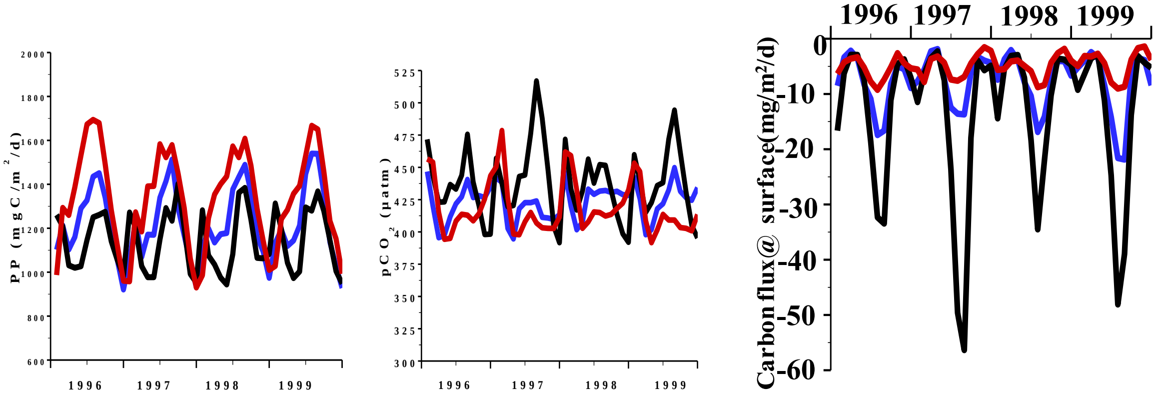

Figure 1.1 Comparison of PP, pCO_2 and Carbon Flux at the air-sea interface for different regions

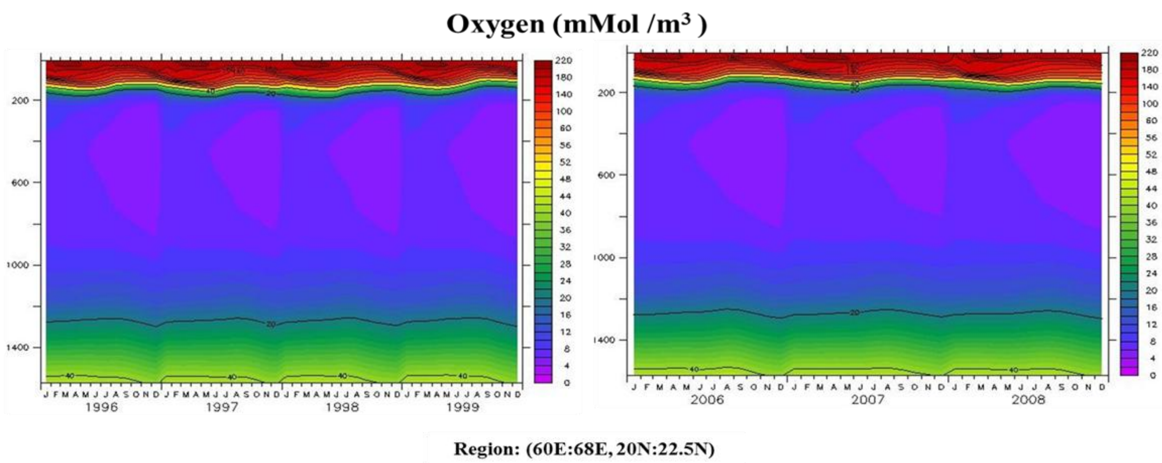

Figure 1.2 Interannual variation of Oxygen(mMol/m^3) with respect to depth during 1996 to 1999 and 2006 to 2008

Detailed analysis of model results on some of the biogeochemical variables, subsurface processes, values of model parameters is being carried to relate the interannual variability of Carbon Flux at the air-sea interface and extent of Oxygen Minimum Zone with Primary Productivity, pCO_2, MLD, SST, ENSO events etc.

Denitrification flux in the Arabian Sea

It is assumed in the model simulations that denitrification process will occur in the Oxygen Minimum Zone (OMZ) when the oxygen concentration is below 5 m mol/m^3. The dependence of denitrification on the volume of OMZ, amount of primary productivity and the ENSO events (El Nino and La Nina) are studied by analyzing the model simulation results.

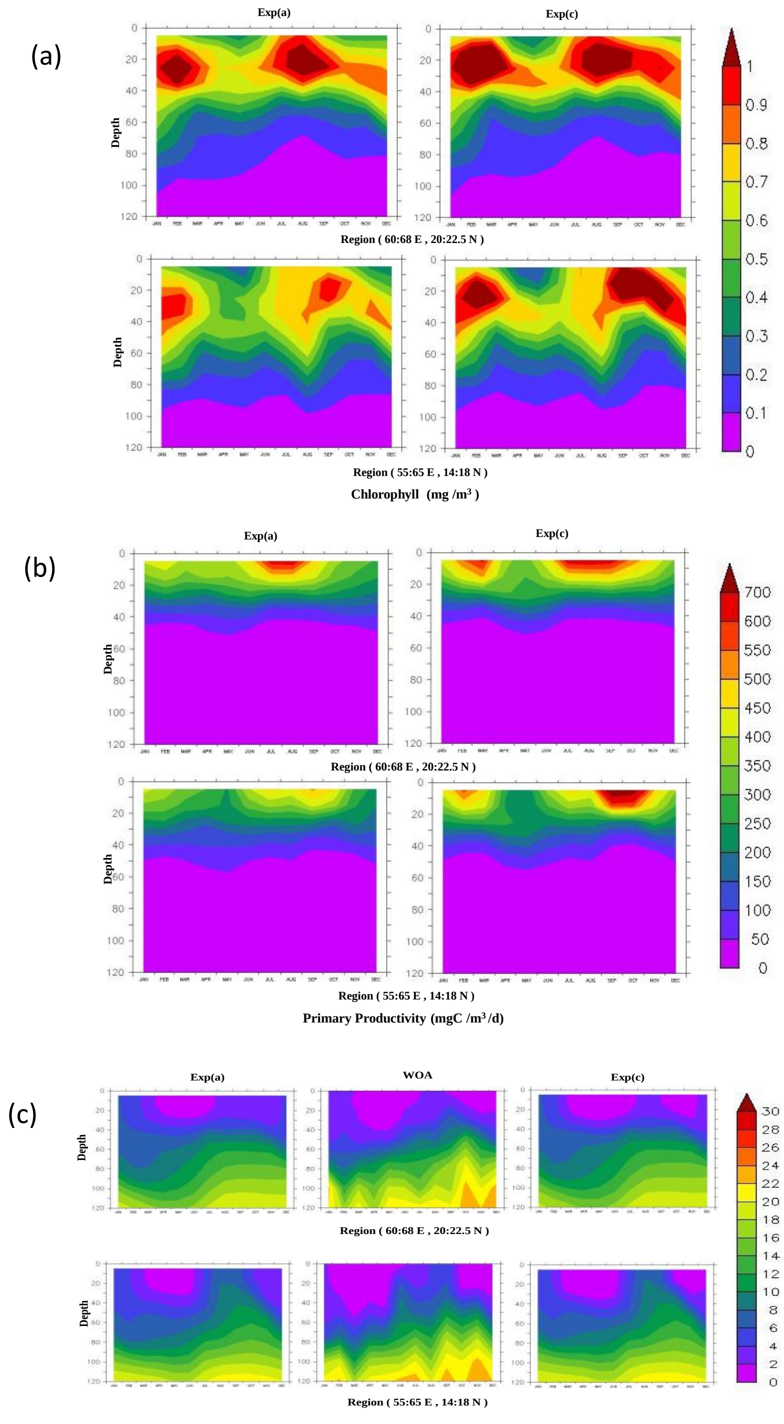

Figure 1.3 a & b: Comparison of Chlorophyll (mg/m^3) and Primary Productivity (mg C/m^3/d) with respect to depth for two model simulations with different iron limitation parameter (Exp (a) & (c)), Figure c: Comparison of Nitrate (m Mol/m^3) with respect to depth for two model simulations with different iron limitation parameter (Exp (a) & (c)) and the WOA

It is noted that denitrification flux in the AS from the simulation results varies between 20 and 40 TgN/year which is comparable with the estimates based on calculations of nitrate deficit. The interannual variation of annual average of denitrification flux in the AS and processes in the OMZ are studied during 1949 to 2007. It is clear from the simulation results that denitrification flux depends on the PP and the volume of OMZ. Also, lower values of denitrification flux, volume of OMZ and PP correspond to El Nino years and higher values correspond to La Nina years. Consumption of oxygen below the euphotic zone depends on the amount of dissolved and particulate organic matter and remineralisation processes. If PP is high (low), the concentration of organic matter is high (low) and consumption of oxygen for remineralization processes is high (low). Hence, higher (lower) PP leads to the increase (decrease) in the volume of OMZ and higher (lower) denitrification flux.

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). Monthly, seasonal and interannual variations of PP and Chl integrated over the euphotic zone and sea surface pCO_2 and Carbon flux are analysed in detail to understand the sensitivity of the two different $(Fe:N)_{irr}$ values and also physical processes in various biogeochemical provinces in the Arabian Sea (AS). It is noted that (i) the model simulation with lower iron limitation increases PP and Chl in the west and central AS especially during North-East monsoon (NEM) and Fall Inter-monsoon (FIM)seasons and hence reduce pCO_2 (ii) model results show that iron limitation has significant influence on PP, Chl, nitrate (Figures 1.3a, b & c)as well as pCO_2 in the west and north-west regions of the AS but not in the east AS. (iii) There is no significant change in the Carbon Flux due to change in iron limitationacross the air-sea interface in the Arabian Sea implying that interannual variability in carbon flux may be associated with physical processes.

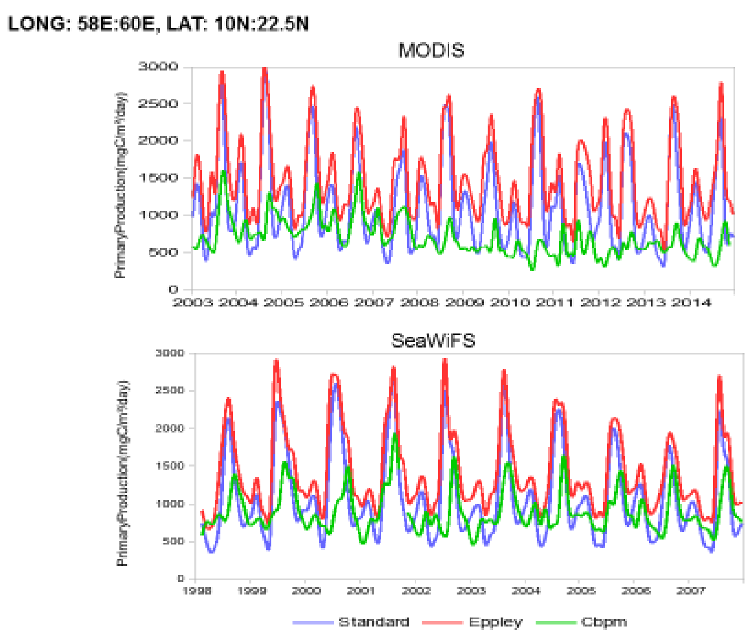

Figure 1.4 Comparison of Interannual Variation of Primary Productivity derived using three different algorithms for MODIS and SeaWiFS satellites in the West Arabian Sea

Analysis of satellite data on primary productivity

Data on Net Primary Productivity derived from Chlorophyll from SeaWiFS and MODIS satellites using VGPM (Vertically Generalized Production Model) have been analysed for Arabian Sea (AS) and Bay of Bengal (BOB) for spatial, monthly, seasonal and interannual variabilities.Net primary production obtained from three algorithmsare compared in different regions in the AS for monthly variations (Figure 1.4). It can be noticed that NPP values obtained from Cbpm is much less than standard and Eppley VGPM in all the regions of AS. NPP values from Eppley VGPM is more than Standard VGPM in many regions in AS.

Data on Net Primary Productivity, Surface Chlorophyll, Sea Surface Temperature from different satellites have been analysed in detail for climatological and interannual variations in different regions of the AS and BOB. Model simulation results are being evaluated using these data.

Sharada M K, Swathi P S, Kalyani Devasena C, Shelva Srinivasan M K, Amritha Babu, Anusha C, Suganya R, Sofia Evelin, Ravichandran C, Yajnik K S, Azharudin M

1.2 Greenhouse gas measurements

One of the outstanding research tasks in Climate Change Research remains the reduction of uncertainties in the current estimates of Carbon fluxes exchanged between the atmosphere and the underlying oceans/land surface, especially in India and Asia and the surrounding seas. Current uncertainties in estimates of CO_2 fluxes are of the order of 0.5 GTC (Giga Ton of Carbon) or larger in regions of poor data coverage (Asia, Africa etc.). We need to reduce this substantially before we can use these estimates in treaty negotiations.

The problem is to infer estimates of CO_2 sources and sinks using observations of CO_2 concentrations from a network of stations. To do this well, we need a good coverage of stations, high quality measurements, a good temporal coverage, a good transport model and a robust inversion procedure.

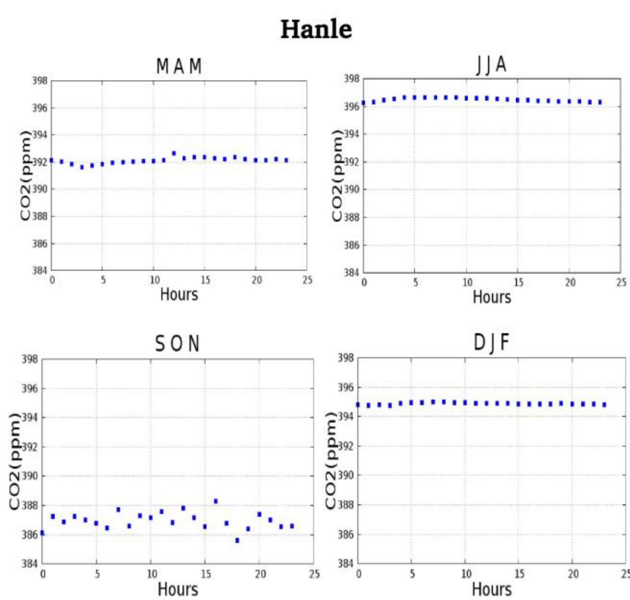

Figure 1.5 Seasonal variations of CO_2 in Hanle

This will require the establishment of high precision CO_2 measurement stations based on WMO protocols and a careful network design for locating stations optimally, in addition to the already functional stations. Measurements have to be made at relatively clean sites which are reasonably far away from large local sources such as major cities. Coastal locations are preferred as both continental and oceanic air masses are sampled. Keeping all the points made above in mind three continuous measurement stations for GHGs (greenhouse gases) are set up in Port Blair, Pondicherry and Hanle where the data is collected every 5 seconds for CO_2 and CH_4 and downloaded at CSIR-4PI for analysis and modelling. At Port Blair we have another instrument measuring N_2O and CO also. These are the national facilities and have to continue working for long time to come and the data from these instruments will be invaluable for India's policy makers.

Diurnal variation of CO_2 in 4 seasons at Hanle and Pondicherry are shown in Figure 1.5 and 1.6, respectively. It can be seen that Hanle, on account of its lack of vegetation does not have a noticeable diurnal cycle while Pondicherry has a very pronounced one with a range of nearly 30 ppm. Besides vegetation, the onset of the sea breeze has a significant impact in lowering the CO_2. The variation across seasons is about 8 ppm at Hanle between SON and MAM season while it is lowest during SON at Pondicherry as well. The variation for CH_4 is quite similar to CO_2 at both stations (Figures 1.7 and 1.8).

A fourth GHG (greenhouse gas) station is being installed near Bangalore in the IIA campus in Hosakote for continuous measurement of CO_2, CH_4, N_2O and CO as seen in the picture Figure 1.9. This station is also equipped with the primary standards of gases for calibration of the instruments as prescribed by WMO for precise measurements of GHGs. This can be treated as a reference station for all the GHG stations making precise measurements of GHGs presently in India.

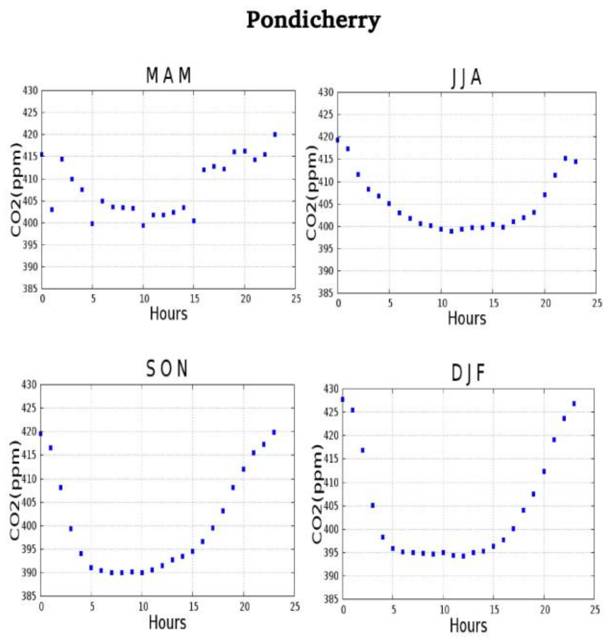

Figure 1.6 Seasonal Variations of CO_2in Pondicherry

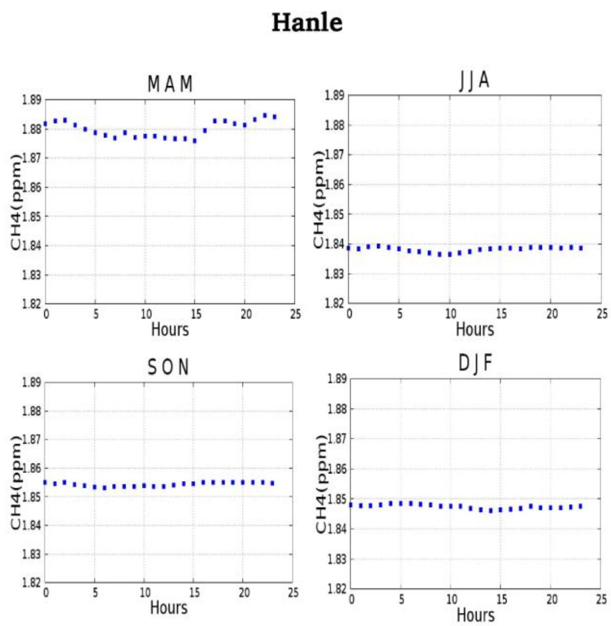

Figure 1.7 Seasonal Variations of CH_4 in Hanle

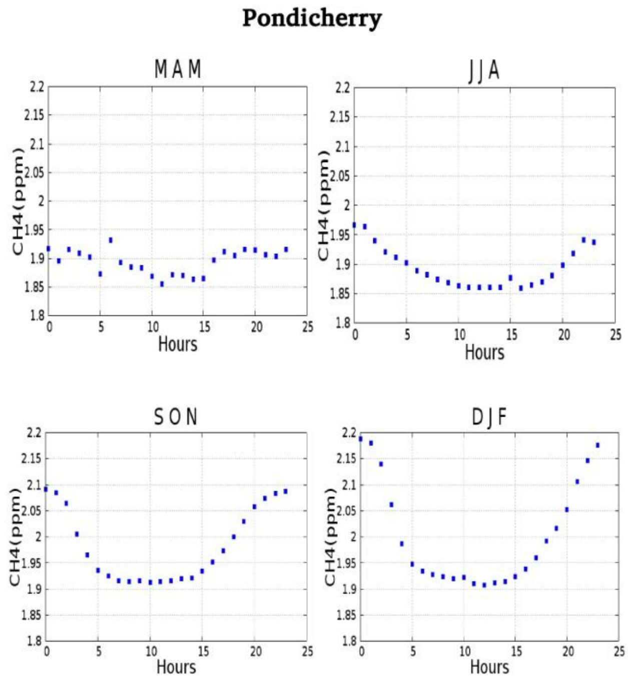

Figure 1.8 Seasonal Variations of CH_4in Pondicherry

Figure 1.9 GHG Instruments and tower at Hosakote

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) and the results have been published in Atmospheric Chemistry and Physics.

Indira N K, Swathi P S, Prashant Meti, Nagaraj Naik, Akash Choudhury, Natesh S, Smrutishree Lenka, Sambit Kumar Panda, Nunna Bala Ankaiah, Ramonet M and Delmotte M, LSCE

1.3 Fine resolution modelling of GHG transport in Asia.

The increasing availability of atmospheric measurements of GHGs from surface stations can improve the retrieval of fluxes at higher spatial and temporal resolutions by inversions, provided that chemistry transport models are able to properly represent the variability observed locally at different stations. Asia, especially, South and Southeast Asia (SEA) is a region with large and uncertain emissions of the two main anthropogenic greenhouse gases, carbon dioxide (CO_2) and methane (CH_4).

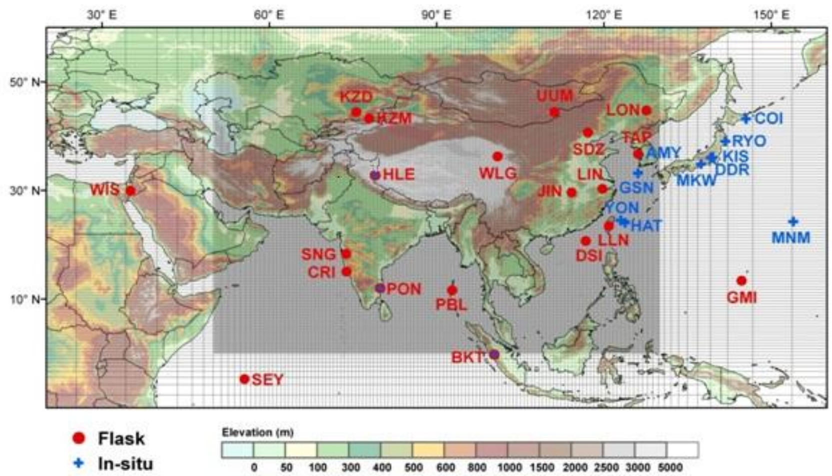

Figure 1.10 Horizontal grid with a zoom over Asia. Locations of GHG stations are also shown.

Monitoring networks have expanded in SEA during the past decade and this can contribute significantly to the robust estimation of GHG fluxes. In this study, we simulate concentrations of CH_4 and CO_2 using a zoom version (ZASIA) of the global chemistry transport model LMDzINCA during the period 2006–2013 along with uniform resolution (REG) of coarser resolution (2.5^o in longitude and 1.27^o in latitude). The ZASIA model (see Figure 1.10) has a high horizontal resolution of ~0.66° in longitude and~0.51° in latitude over SEA and a coarser resolution elsewhere. Both models have 19 sigma pressure levels in the vertical. The models are forced by surface fluxes which vary from interannual to climatological.The performance of the models is evaluated for annual gradients between sites, seasonal, synoptic and diurnal variations by comparing data from 20 flask and 13 continuous surface stations over SEA and adjacent regions.

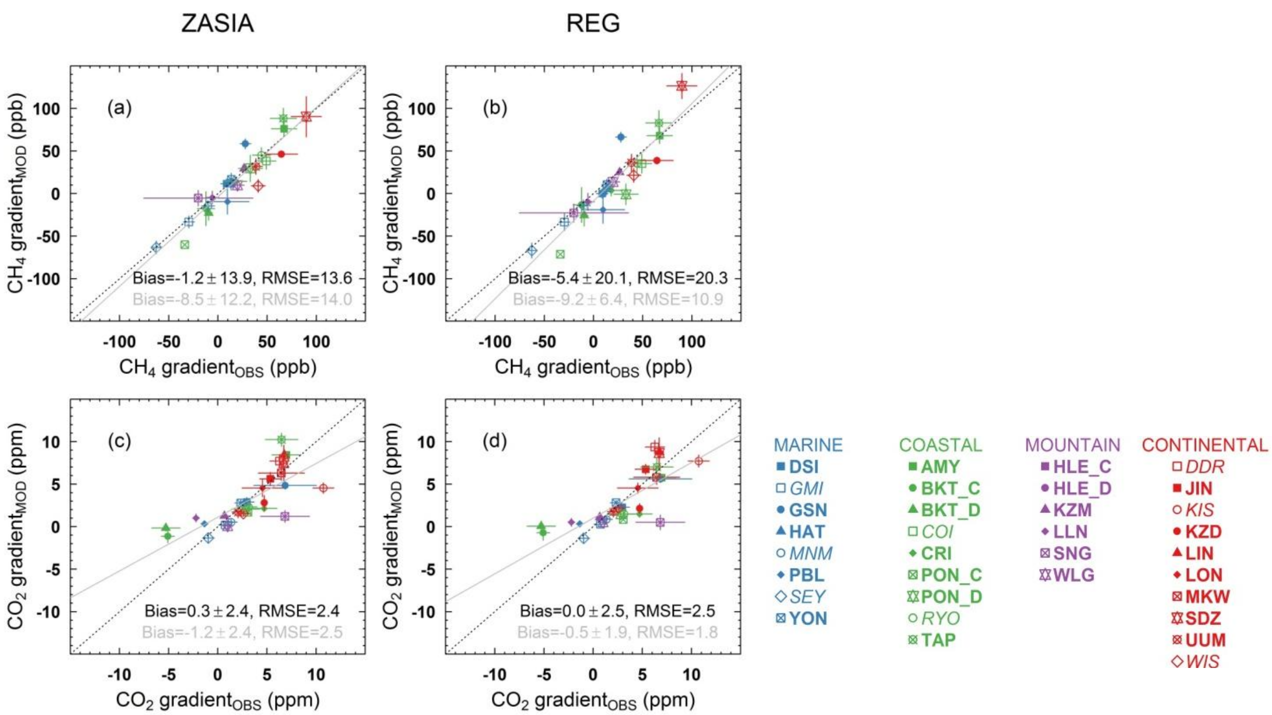

Figure 1.11 Scatter plots of simulated and observed mean annual gradients of CH_4 (a, b) or CO_2 (c, d) between HLE and other stations. For both tracers, the simulated gradients are based on simulations from ZASIA (a, c) and REG (b, d). In each panel, the black dotted line indicates the identity line, whereas the grey solid line indicates the linear line fitted to the data. The italic type and open symbols in the legend denote stations outside the zoomed region.

Figure 1.11 shows the mean annual gradients between Hanle (HLE) and other stations in the world shown in the same figure. The performance of the zoomed model is seen to be better than the unzoomed version for CH_4 while there is not much difference between the two for CO_2.

Swathi P S, Indira N K, Lin X and Michel Ramonet (LSCE)

2
CLIMATE AND ENVIRONMENTAL MODELLING PROGRAMME (CEMP)

The CEMP with its core strength of multidisciplinary modeling has been continuously innovating and developing end-user driven and actionable knowledge products, which are target oriented and of direct societal benefits.

The emphasis continues to be on understanding of the climate system and applications through multi-disciplinary modelling by combining climate science with water, agriculture, health, energy and sustainability in general.

CEMP synergistically uses both open source as well as in-house codes, processes models, NWP models, global circulation models, visualization and analysis tools in HPC environment.

The CEMP has pioneered in generating demand based and farmer driven forecast at hobli-level in the state of Karnataka in collaboration with KSNMDC.

CEMP has been continuously developing innovative methodologies to improve high-resolution 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.

Inside

- *An Evaluation strategy of skill of high resolution rainfall forecast for specific agricultural applications*
- *Long-range high resolution forecasting of monsoon 2015*
- *Organization of vertical shear of wind and daily variability of monsoon rainfall*
- *High resolution regional dynamical downscaling of climate over South Asia*
- *Sensitivity of heavy rainfall to land use changes: A case study over Uttarakhand*
- *Northeast Monsoon Extreme 2015: Simulation of Heavy Rainfall event over Chennai during 27th November to 2nd December*
- *Trends in rainfall and surface temperature over different Indian urban cities*

- *Study of Extreme rainfall events over Indian domain*
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- *Role of Large scale circulation dynamics of cloudburst over India*
- *Performance evaluation of mesoscale model lead hour in predicting tropical cyclone over north Indian Ocean*
- *Evaluation of ASCAT soil moisture data with in-situ observations over different agro-climatic regions in Indian*
- *Relationship of winter fog frequency over Indo-Gangetic Plains of India and regional climate variability*
- *Wind-generated electricity potential for Andaman and Nicobar Islands*
- *Dynamics of land-atmosphere coupling during heat waves in 2015*
- *Projected changes in vector borne diseases (Malaria) over India*
- *Analysis of vector borne disease across Karnataka using geospatial technique*
- *Relation between Rainfall and on Occurrences of Dengue cases over India*

2.1 An evaluation strategy of skill of high resolution rainfall forecast for specific agricultural applications

A strategy for validation of rainfall forecasts for specific agricultural applications is presented. Our focus is mainly on design of specific forecast advisories that are risk-free and useful in spite of their inherent errors. The strategy works for the specific applications because the forecast advisories are based on when NOT to irrigate or apply fertilizer/pesticide because rain is predicted (risk-free because wrong forecast only delays irrigation/application of fertilizer/pesticide within tolerance). Thus unlike in conventional forecast evaluation, we consider a forecast as valid if the forecasted rain (or no rain) is correct for the day of the forecast (D0C) or the next day or the day after (designated D1C and D2C, respectively), as the farmer can afford to postpone the field application for a couple of days beyond the scheduled date. The methodology has been evaluated for rainfall forecasts over Karnataka (a state in south-west India with nearly 56% of the workforce engaged in agriculture). Here, we present forecast validation against rain gauge observations at comparable model resolutions for the South-West (June-September) and the North-East (October-December) monsoon seasons during 2011-2014. Our analyses demonstrate that forecasts over several areas which may appear as less reliable based on conventional evaluation (D0C) are found to have useful skill for the specific agro-applications as evident from evaluation based on D1C and D2C criteria (Figure 2.1). Our analysis shows that the evaluation strategy presented is effective during non-rainy (January-May) season also. It is pointed out that such an approach can help to meet the challenges in designing and implementing best practices in agriculture by combining immediate gains for the end users.

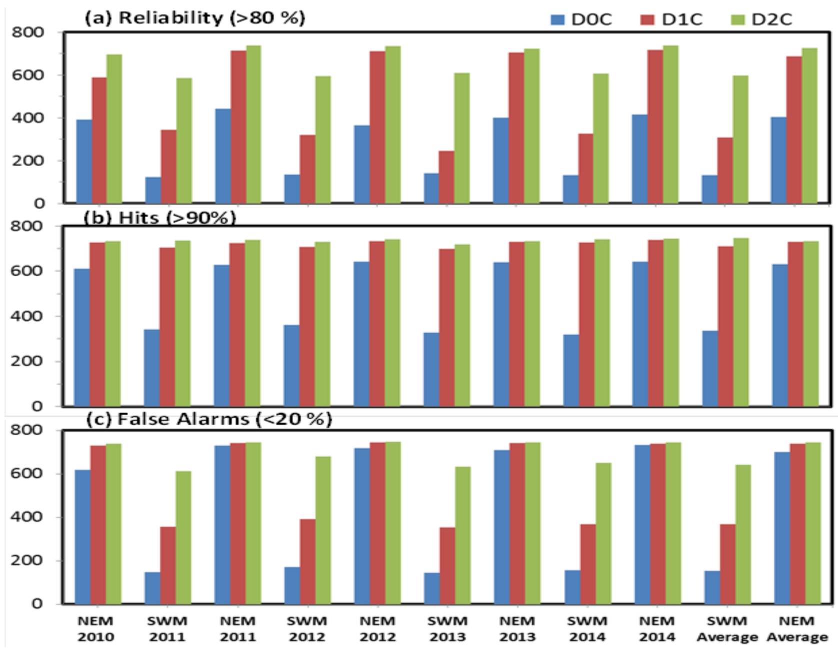


Figure 2.1 Number of hoblis that fall in (a) Reliability >80%, (b) Success/Hit Ratio > 90% and (c) False Alarm < 20% during the SWM and NEM for the years 2010-2014 along with seasonal averages. The three bars represent results for three forecast criteria; D0C (blue), D1C (red) and D2C (green).

Rakesh V and Goswami P

2.2 High resolution long-range dynamical forecasting of Indian monsoon 2015

Forecasting of monsoon at user-relevant lead and resolution continues to be a national priority and a scientific challenge. CSIR-4PI pioneered long-range dynamical forecasting of Monsopon in India with its experimental forecasts in 2001. The experimental forecasts, issued in April and validated after the monsoon, helped to create a robust proof of concept against the prevailing dogma. The mission of the CSIR-4PI team is now to develop and validate methodology for monsoon forecasting at user relevant spatial and temporal scales and to enhance the capabilities of India in monsoon forecasting through validated proof of concept.

The first outlook for monsoon 2015 (onset, monthly and regional rainfall anomalies) from long-range, high-resolution monsoon forecasting platform from CSIR-4PI was made available in the middle of April, 2015. These forecasts were based on information on the atmospheric state (initial conditions) available until beginning of April, 2015.

There have been, however, major changes in the atmospheric states in the subsequent period, making a deterministic forecast for monsoon 2015 more difficult. We have therefore generated probabilistic forecasts for monsoon 2015 based on the entire set of forecasts. The validation with IMD observations is presented in figure 2.2.

Seasonal (June-August) rainfall anomalies based on 4PI long-range forecasts (2nd Outlook) and IMD observation indicates there is good match over most regions; the error is generally limited to category one error.

The CSIR-4PI experimental forecasts are currently restricted to monthly spatial distributions, although we have explored climatological area-averaged daily rainfall as well as daily rainfall over Kerala for identification of date of onset of monsoon. The summary of spatial distribution of seasonal rainfall anomalies for JJA and their comparison with the corresponding observation is presented in Figure 2.2. Table 2.1 represents the comparison of the category forecast and observation both at monthly and seasonal scale for the different regions over India.

Seasonal (June-August) rainfall anomalies (% of respective mean)

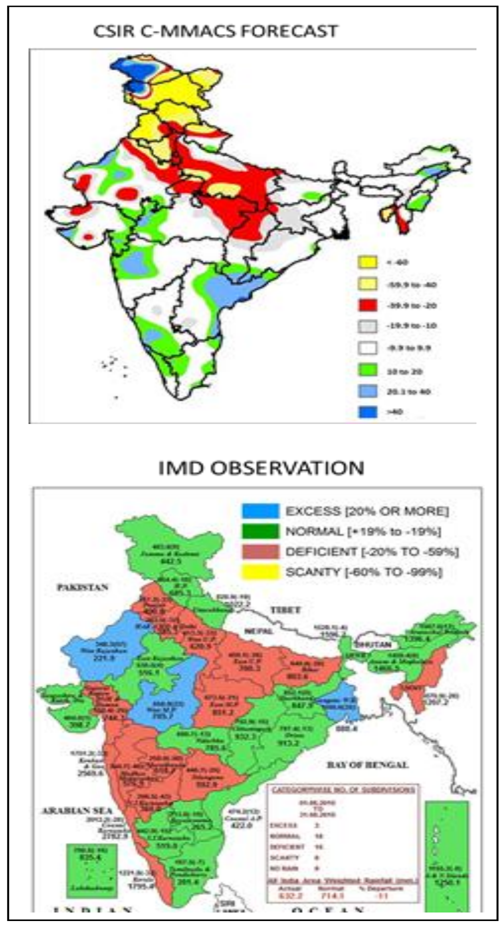


Figure 2.2 Seasonal (June-August) rainfall anomalies from CSIR-4PI long-range high resolution forecasts (top panel), IMD observation for Jun-Aug 2014 (bottom panel).

Table 2.1 Comparison of the forecast and observation both at monthly and seasonal scale for the different regions over India.

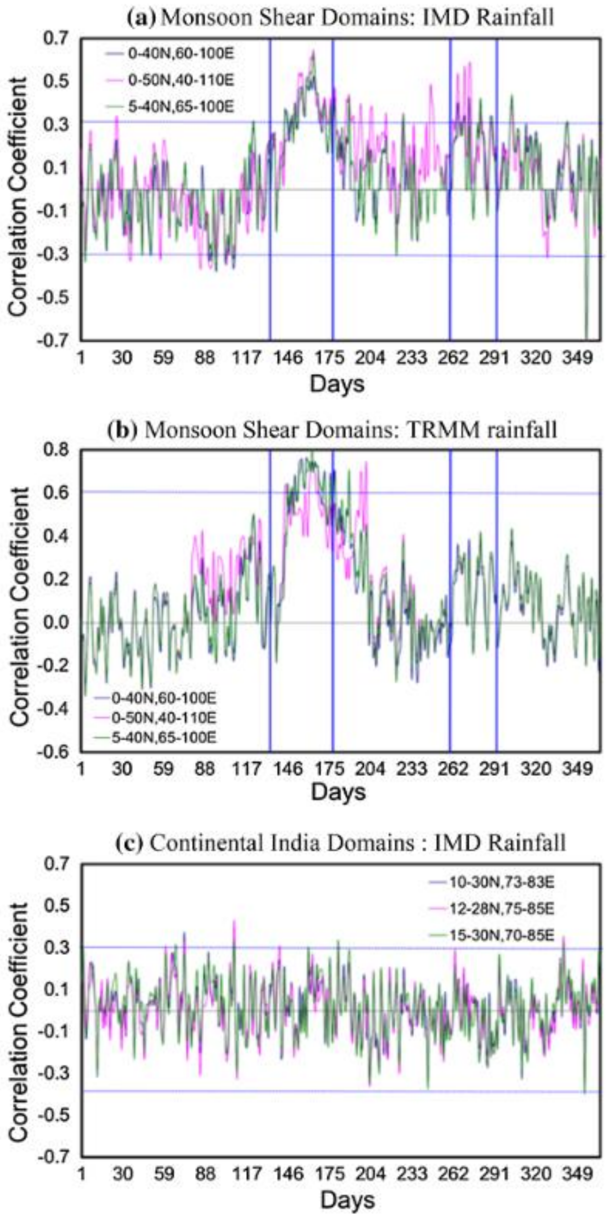
	JJA		June		July		August		% of agreement
Region	Pred	Obs	Pred	Obs	Pred	Obs	Pred	Obs	
All India	Deficit	Deficit	Normal	Normal	Normal	Deficit	Drought	Deficit	75
North-India	Deficit	Deficit	Normal	Normal	Deficit	Deficit	Drought	Deficit	100
South India	Normal	Normal	Normal	Normal	Normal	Deficit	Normal	Deficit	50
Central India	Normal	Deficit	Normal	Excess	Deficit	Normal	Normal	Deficit	0
North-east India	Normal	Normal	Normal	Normal	Deficit	Deficit	Normal	Normal	100
North-west India	Normal	Normal	Normal	Excess	Deficit	Normal	Deficit	Deficit	50

There is overall good agreement; only a few locations show error of more than category one. Thus the risk of using these forecasts, in principle, is minimal.

Gouda K C and Goswami P

2.3 Organization of vertical shear of wind and daily variability of monsoon rainfall

Very little is known about the mechanisms that govern the day-to-day variability of the Indian summer monsoon (ISM) rainfall; in the current dominant view, the daily rainfall is essentially a result of chaotic dynamics. Most studies in the past have thus considered monsoon in terms of its seasonal (June-September) or monthly rainfall. We show that the daily rainfall in June is associated with vertical shear of horizontal winds at specific scales. While vertical shear had been used in the past to investigate inter annual variability of seasonal rainfall, rarely any effort has been made to examine daily rainfall. Our work shows that, at least during June, the daily rainfall variability of ISM rainfall is associated with a large scale dynamical coherence in the sense that the vertical shear averaged over large spatial extents are significantly correlated with area-averaged daily rainfall. An important finding from our work is the existence of a clearly delineated monsoon shear domain (MSD) with strong coherence between area-averaged shear and area-averaged daily rainfall in June; this association of daily rainfall is not significant with shear over only MSD. Another important feature is that the association between daily rainfall and vertical shear is present only during the month of June. Thus while ISM (June-September) is a single seasonal system, it is important to consider the dynamics and variations of June independently of the seasonal ISM rainfall.



The close association between vertical shear and rainfall in June is also clear from the abrupt rise from essentially non-significant CC between area-averaged all India daily rainfall (Figure 2.3a) and shear at 850 hPa averaged over MSD to significant CC; this CC again falls below significance in the post-monsoon months (Figure 2.3a). This conclusion also holds for an independent rainfall data set (TRMM) for the period 1998-2012; once again, ISM daily rainfall and vertical shear averaged over MSD show strong CC but only in June (Figure 2.3b). In contrast, there are few days with significant CC between daily rainfall (IMD) and shear averaged over the continental India (Figure 2.3c).

Figure 2.3 Annual cycle of correlation co-efficient between all India daily rainfall (IMD Gridded Data) and vertical shear of horizontal wind (850mb) from NCEP reanalysis over different domains (MSD) and (b) over smaller domains (ISM). The horizontal dash lines indicate the 99 % significance of correlation (CC > 0.32).The analysis is carried out for the period 1951-2003. (c) Annual cycle of correlation co-efficient between domain averaged rainfall and vertical shear of horizontal wind (850 hPa) over different domains (optimum). The horizontal line indicates the 99 % significance of correlation (CC > 0.66).

The association between large-scale organization of circulation and daily rainfall is suggested as a basis for attempting prediction of daily rainfall by ensuring accurate simulation of wind shear.

Gouda K C and Goswami P

2.4 High resolution regional dynamical downscaling of climate over South Asia

The high resolution spatio-temporal climate information is essential to quantify the climate impact on different sectors like renewable energy, agriculture, vector borne diseases etc. However, these studies are limited by its spatial resolution due to lack of high resolution simulations and lack of high density observations. For this purpose, climate is dynamically downscaled using Weather Research and Forecasting (WRF) regional atmospheric model over south Asian region. For this the WRF model at 4-km horizontal resolution is forced with NCEP FNL Operational Global Analysis data as the initial and boundary condition (reinforced for every single day) and integrated for a period of 15 years (2001 to 2015). The downscaled data is archived on hourly timescale. The downscaled rainfall data is compared with multiple observations like IITM and TRMM rainfall on meteorological sub-division over India on monthly time scale. The correlation coefficient between monthly rainfall data with sub divisional observed rainfall is shown in Figure 2.4. Results show the observed characteristics of large scale mean features and spatial variations of rainfall over different region.

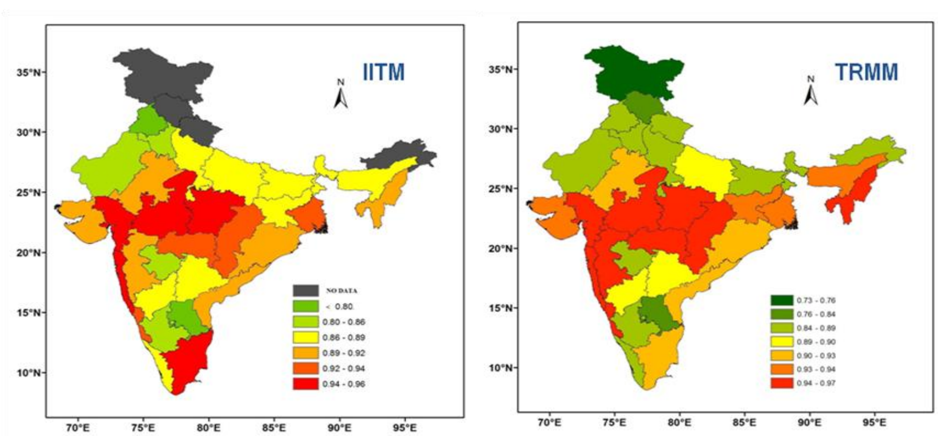


Figure 2.4 Spatial correlation coefficient between observation (IITM, TRMM) and High resolution downscaled data.

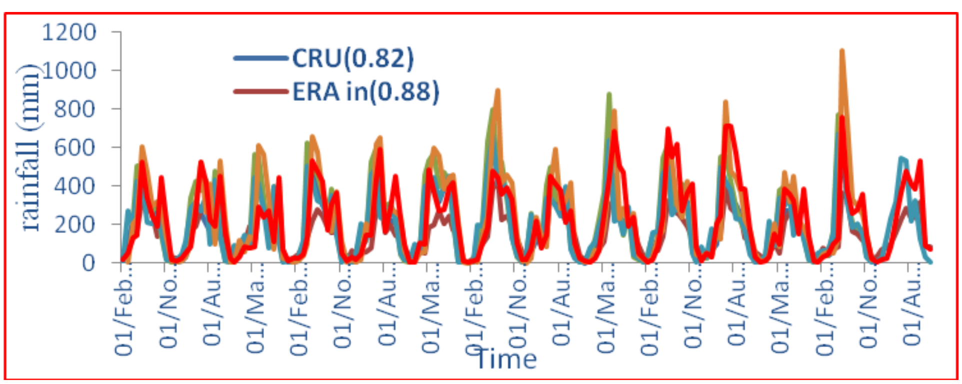


Figure 2.5 All India monthly area averaged rainfall is compared with multiple observations. The red colour line represents the high resolution rainfall.

Figure 2.5 shows the time series of the rainfall comparison and the correlation with different data sets. The monthly downscaled rainfall is significantly correlated with most of the multisource observations. The spatial distribution of high resolution data shows the seasonal cycle and inter-annual variability.

High resolution rainfall is used to understand and quantify the relationship between climate variables and energy potential (wind and hydro). This data is also used to develop multidisciplinary applications like; renewable energy estimates (wind, solar and hydro), impact studies on agriculture and hydrology.

Shafeer K B and Ramesh K V

2.5 Sensitivity of heavy rainfall to landuse changes: A case study over Uttarakhand

This study is about the impact analysis of different land use data on the simulation of an unusually rare heavy rainfall event which occurred between 14th and 18th of June 2013, over Uttarakhand, one of the north-western state of India. This is a 20 year rare extreme rainfall event that sustained over large spatial extent (about 50,000 sq km) for over 3-4 days. The highest daily average rainfall of 13.3 cm occurred between 03 UTC-16th and 03 UTC 17th June 2013 over the entire state of Uttarakhand and a single station (Dehradun) received maximum rainfall (37cm) on 17th June 2013. This event resulted in huge loss of lives and property. In the present work, high-resolution (2-km) time ensemble simulations were carried out using Weather Research and Forecast model (WRFV3) with 3-nest configuration. The model was initialized with $1^{o}x1^{o}$ FNL data. The TRMM ($0.25^{o}x0.25^{o}$) and rain gauge observations (by India Meteorological Department) are used to compare and validate the simulated rainfall. In order to study the impact of land use change on the heavy rainfall simulation, different vegetation

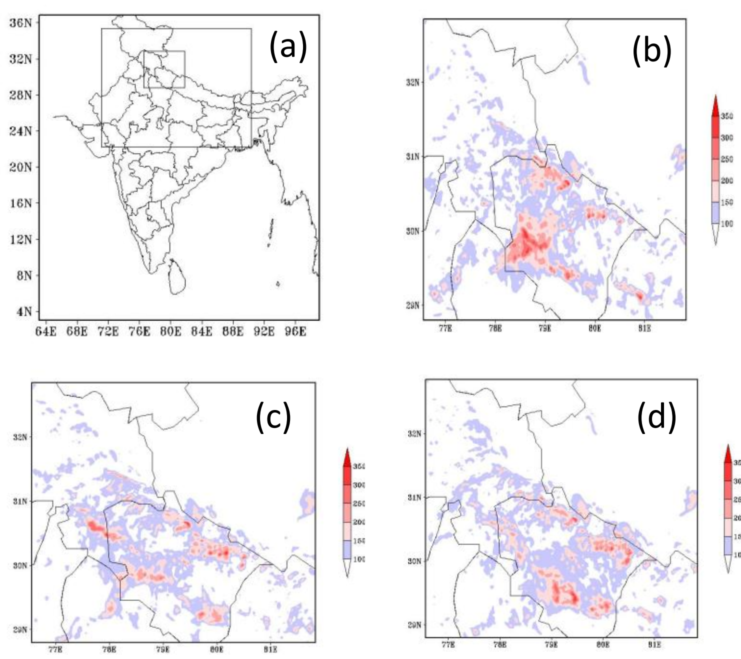


Figure 2.6 Model domain (a) and Spatial distribution of total accumulated rainfall in mm (14th -17th) June 2013 over Uttarakhand for different land use scenarios: (a)- (2012-13) ISRO, (b) (2004-05) ISRO, (c) USGS 24-category. Strikingly different pattern of spatial distribution is evident. Simulations based on ISRO data are found be more accurate than USGS based simulations.

data sets are used for the simulation. The sensitivity analysis of simulated rainfall to different vegetation data sets was performed using 3 sets of land use data; USGS-24 category (1992-93) and 2 data sets from National Remote Sensing Centre, India i.e. IRS-P6, AWiFS (2004-05) and AWiFS (2012-13). Simulated rainfall was found to be remarkably sensitive to different vegetation data sets (Figure 2.6). Comparison of simulated rainfall averaged over Uttarakand (78E-80.5E, 28.5N-31N) with that of station data (averaged over 23 raingauge stations) indicated that AWiFS based simulation are comparatively more accurate with less % simulation error; 18.6 % (USGS), 2.1% (AWiFS, 2004-5) and 4.4 % (2012-13 respectively. Another interesting aspect is that TRMM was found to be underestimated when compared to rain-gauge by over 40%. These results will be used further to evaluate and quantify impacts of the event in-terms of the vulnerability and damage potential through geospatial analysis to identify and delineate high-risk zones.

Himesh S, Sahoo S K, Gouda K C, Rakesh V, Ramesh K V, Kantha Rao, Mohapatra G , Ajilesh P, Samantray P P

2.6 Northeast Monsoon Extreme 2015: Simulation of Heavy Rainfall event over Chennai during 27th November to 2nd December 2015

An Industrial metropolitan city of Chennai, the capital city of the state of Tamil Nadu in Southern India was flooded due to sustained rainfall and multiple extreme rainfall events during 2015 North-East monsoon season. The total cumulative rainfall between 7th Nov - 7th Dec 2015 was around 1400 mm. The city witnessed the heaviest rainfall of the century with 490 mm of rain in 24 hours over many parts of Chennai on 1st December 2015. In this study, this rare event has been simulated using the state-of-the-art Weather Research and Forecasting model (WRFV3.5) in 3-nest configuration, with innermost domain (2-km) centered over Chennai. Simulation experiment was carried out with different parameterization schemes and initial conditions (FNL, $1^o x 1^o$ re-analysis fields). Ensemble average rainfall of the simulated event is compared with the satellite observation (TRMM) and Indian Meteorological Department (IMD) observations.

Analysis of the results has shown that the WRF model successfully simulated the extreme rainfall events both in terms of intensity, time evolution, spatial patterns and location. The percentage of simulation error for the event in terms total accumulated rain with respect to TRMM and IMD data are 8.5% and 12% respectively. Prevailing large-scale meteorological conditions like pressure and wind patterns were also analyzed by comparing the simulated fields with FNL re-analysis fields. This configuration of the Model was also able to simulate the patterns of these large-scale conditions reasonably well. The Figure 2.7 shows model domains the observed rainfall (IMD data) during Nov 7th to Dec 7th 2015 and comparison of simulated rain with observations. The spike shown by pink oval is simulated here (27th Nov to 2nd Dec 2015).

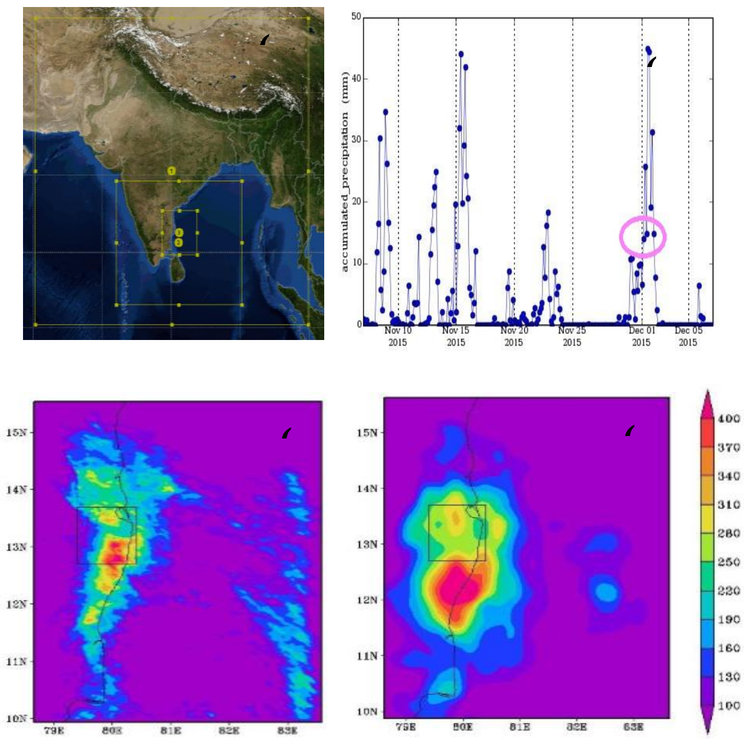


Figure 2.7 The panel (a) show model domains over Chennai and the right panel shows observed rainfall (IMD) during 7th Nov to Dec 7th 2015. Panel (c) is simulated 3-day accumulated (29th Nov 00 hr to 2nd Dec 00 hr) rain (mm), TRMM rain is shown in (d) for comparison.

Himesh S, Sahoo S K, Gouda K C, Rakesh V, Ramesh K V, Kantha Rao Mohapatra G N, Ajilesh P, P P Samantray

2.7 Trends in rainfall and surface temperature over different Indian urban cities

This study is aimed at looking for plausible signature of the impact of urbanization on rainfall and surface temperature trend over different Indian cities which have undergone massive urbanization since independence. The analysis was focused on studying rainfall patterns of different intensity and surface temperature. This analysis is based on 47 years (1961 to 2007) of APHRODITE (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources) data, which is 0.25° resolution. The rainfall and temperature trends are studied for JJAS period using computational boxes of different sizes (2^ox2^o, 1^ox1^o, 0.5^ox0.5^o, 0.25^ox0.25^o) centered over cities. Daily rainfall intensities of different categories (A:2-5, B:5-10, C:10-20, D:20-30, E:30-40, F:40-50 and G:>50 mm/day) are considered in the analysis. Annual and decadal trends are also analysed. It was found that different categories of rainfall events show different trends over different cities. In the case of Bengaluru and Ahmedabad increasing trend was evident for D to G categories. The Kolkata had shown increasing trend for A to E categories. Chennai predominantly showed increasing trend for F and G categories. Mumbai, on the other hand showed significant increasing trend in G-category (>50 mm/day). Interestingly, Cochin and Delhi have shown decreasing trend across categories, except for A category. In general, this pattern was similar for different computational boxes. Analysis of temperature trend indicates positive trend of 0.02^{o}C /year for Ahmadabad and Mumbai and 0.01^{o}C/year for Bangalore, Chennai and Cochin. Delhi and Kolkata on the other hand have shown neutral trend.

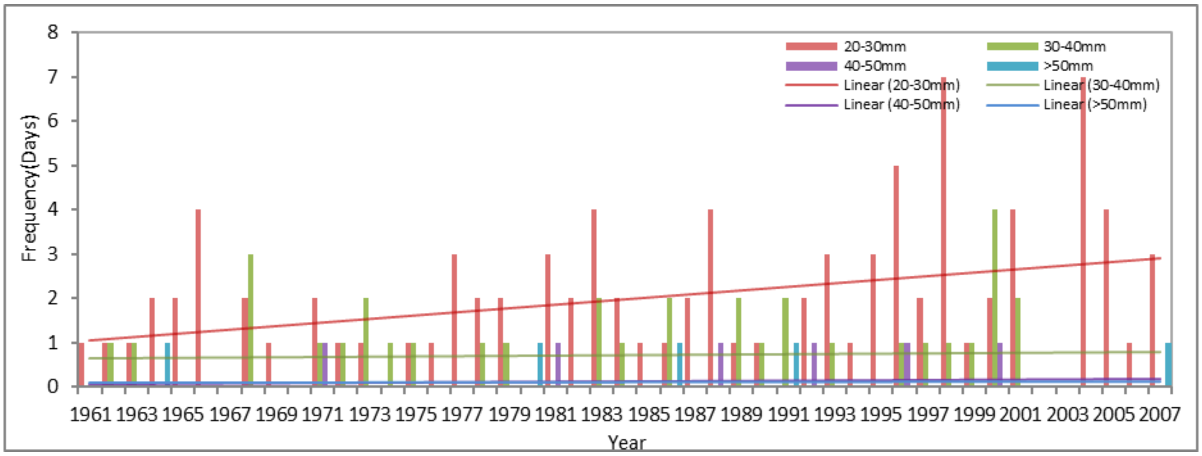


Figure 2.8 Trend of annual rainfall: Bangalore shows an increasing trend in low intensity rainfall (20-30mm/day) category

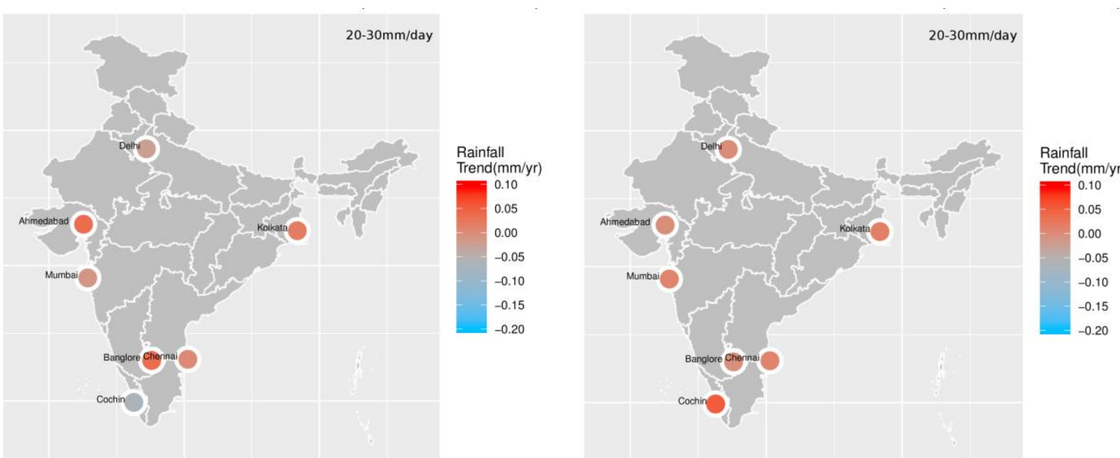


Figure 2.9 Trend analysis of South West (Left panel) and North East (Right panel) monsoon rainfall for the category 20-30mm/day for different cities in India.

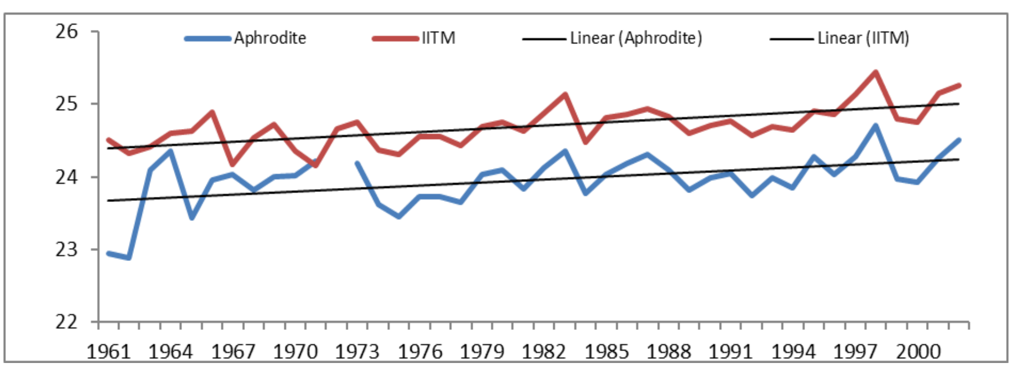


Figure 2.10 Temperature trend for Bangalore using Aphrodite and IITM Temperature data.

The annual rainfall trend for different categories is shown in Figure 2.8, rainfall trend (20-30 mm/day) for SW and NE monsoon is shown in Figure 2.9. Comparison of temperature trend between Aphrodite and IITM data for Bangalore is shown in Figure 2.10, both data sets show similar trend.

Himesh S, Ajilesh P, Gouda K C, Rakesh V, Ramesh K V, Kantha Rao, Mohapatra G , Sahoo S K, Samantray P P

2.8 Study of extreme rainfall events over Indian domain

Extreme rainfall events (ERE) are hydro meteorological disasters which cause potential catastrophic effects on human activities and infrastructure. The frequency and intensity of the ERE over India shows an increasing trend. The potential use of a calibrated LMDZ Variable resolution General Circulation Model (GCM) which provides high resolution over the Indian domain is tested in this work for the advance and accurate prediction of rainfall during ERE over Indian region.

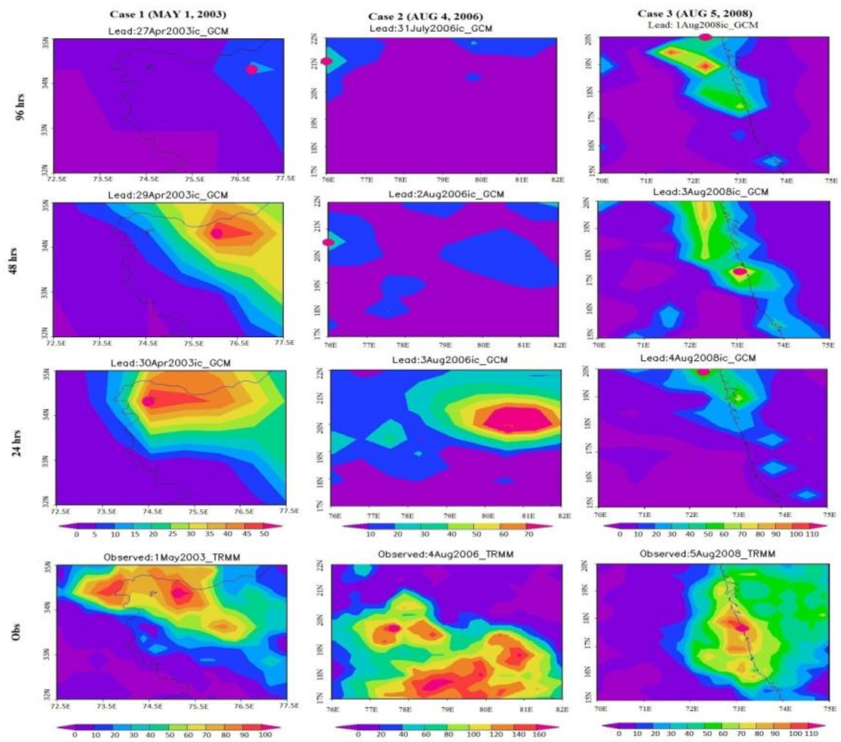


Figure 2.11 Comparison of model simulated and TRMM observed rainfall during EREs

In the present work three EREs (case1: 1st May 2003 over Uttarakhand, case 2: 4th August 2006 over Kaleswaram and case 3: 5th August 2008 over Mumbai) are being simulated using the GCM. The simulations are carried out with three initial conditions i.e. 24 hr, 48 hr and 96 hr before the events. The results obtained from the simulations of different leads 96hr, 48hr and 24hr are presented in the 1st, 2nd, 3rd row and the corresponding observation from Tropical Ra (TRMM) is presented in the 4th row in figure 2.11. Three events case wise are presented column wise i.e. column 1 to 3 represent the case 1, 2 and 3 events respectively. It is found that model could capture the intense heavy rainfall well in advance i.e., 24 to 48 hours but with some locational error.

Nahak S, Gouda K C and Goswami P

2.9 Forecasting of monsoon extreme rainfall events associated with tropical disturbances over the Arabian Sea and Bay of Bengal

Even though monsoon rainfall over the India is mostly governed by large-scale circulations, it exhibits tremendous variability in spatio-temporal distribution within a monsoon season. Recent studies show that there is an increasing trend in extreme rainfall within a monsoon season. Though, a good monsoon rainfall is good for agricultural and economic sectors, extreme rainfall events can cause severe socio-economic damage especially in places of high population and infrastructure. Hence, predicting such extreme rainfall events is very important and challenging problem. During the south-west (June-September) and north-east (October-December) monsoon season in India, tropical depressions which formed over the Bay of Bengal and the Arabian Sea are one of the major causes for such extreme rainfall events. Many studies have shown that the presence of tropical disturbances (low pressure systems) contribute significantly to the seasonal monsoon rainfall. In this study, capability of one of the widely used mesoscale model called Weather Research and Forecasting (WRF) model in simulating such extreme rainfall events during the two monsoon (south-west and north-east) seasons is examined. Nested domain WRF simulations were conducted for selected tropical disturbances occurred during the period 2003 to 2012 over the Arabian Sea and Bay of Bengal. We have verified the model forecasted rainfall against TRMM and IMD observations. The forecast skill of WRF model in simulating rainfall is evaluated in terms of location, magnitude and spatial distribution. WRF model under-predicted (average difference less than -10 mm over land area) the magnitude of rainfall over the land region while it over-predicted (average difference more than 10 mm over land area) rainfall over ocean for majority of cases. Over the land area, WRF model under-predicted the area of rainfall (area of rainfall less than 30% compared to observation) for majority of the cases. For 2 cyclone cases, model over-predicted (area of rainfall more than 30% compared to observation) area of rainfall. Out of the 9 cases examined, location error in maximum rainfall intensity is more than 150 km in 6 cases; only for 2 cyclone cases location error in maximum rainfall is below 100 km. These results point towards the necessity of improvement in model forecast through improved initial condition (data assimilation) and improved model configuration (higher resolution in horizontal and vertical).

Praveen S and Rakesh V

2.10 Role of large scale circulation dynamics in cloudburst over India

In the recent decade there has been increasing trend in the Extreme Rainfall Events (ERE) due to the cloud burst over India, particularly over the Himalaya region. The locations of the cloud burst events over the Himalayan region during 2003-2014 are presented in the Figure 2.12, which clearly shows there are quite high number of cloud burst events well distributed in the latitude 28^{o}-31^{o} N and longitude ranging 77^{o} -80^{o}E.

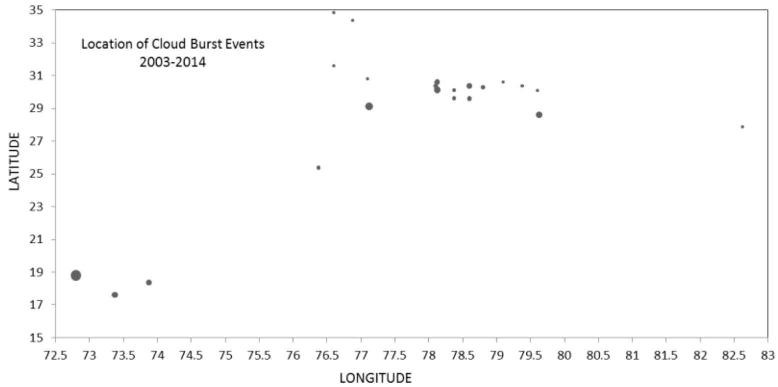


Figure 2.12 Spatial distribution of location where ERE due to cloud burst occurred during 2003 to 2014

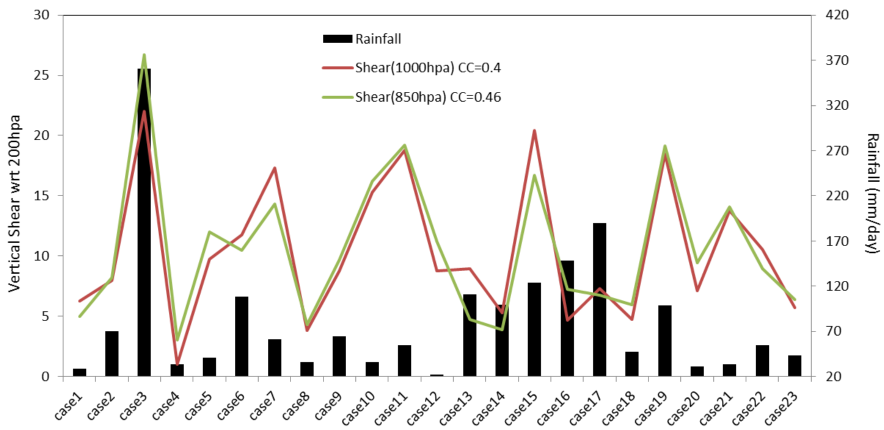


Figure 2.13 Comparison of Rainfall and Shear (1000 & 850hpa with respect to 200hpa) at the location of ERE due to cloud burst.

To understand the large scale wind structure, the vertical wind at all the levels are analyzed for the cloud burst cases and it is observed that there is strong vertical shear distribution. In the present study where the organization of vertical shear of wind and daily variability of monsoon rainfall over ISMR is well correlated. This indicates that the association between large-scale organization of circulation and daily rainfall is suggested as a basis for attempting prediction of daily rainfall by ensuring accurate simulation of wind shear. For the localized extreme rainfall due to cloud burst events also needs to be related with the vertical wind shear. So the vertical wind shear at two levels i.e. 850 hpa and 1000 hpa with respect to 200 hpa levels are computed for the selected cloud burst events and the localized area averaged shear is compared with the rainfall in figure 2.13 below, which shows there is strong positive correlation between the rainfall due to cloud burst events and the vertical wind shear. This study needs to investigate more to understand the dynamics of the cloud burst.

Gouda K C, Samantray P and Goswami P

2.11 Evaluation of mesoscale model skill with different leads in predicting tropical cyclones over the north Indian Ocean

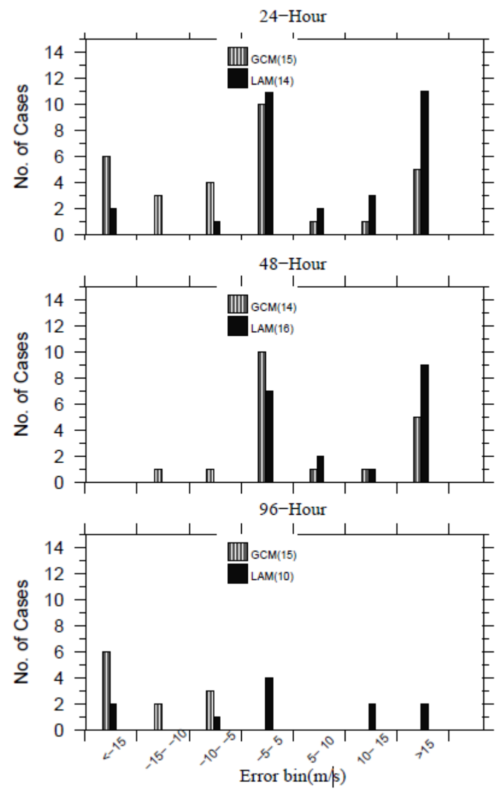


Figure 2.14 Histogram of error in forecasting maximum intensity with mesoscale model and GCM at 24-hour, 48-hour and 96-hour lead for 30 cyclone cases. The number in the bracket represents the number of cases in the error bin -10 to +10 m/s for the respective cases.

With rapid enhancement in computing power as well as rise in user requirements, there is a thrust to adopt new forecast strategies for tropical cyclones. Although, mesoscale models with their high resolutions appear to be the first choice to simulate tropical cyclones, careful treatment is needed while configuring them for practical applications. One important aspect is selecting proper lead time to initiate a cyclone forecast as model spin up has an important influence on model dynamics and physics. In this study, we have conducted simulations with different lead times for several cyclone cases of different intensities. Our results demonstrate that for majority of low intensity cyclones (14 and 16 out of 30 cyclone cases) model error falls in the error bin of ± 10m/s in 24 and 48-hour lead while errors are high in many cases where simulations are carried out with 96-hour lead time. In case of moderate cyclones, for 7 out of 19 cases model errors are coming under the error bin of ± 10m/s with 24 and 48 hour lead. However, errors are very high for simulations with 96 hour lead time. These conclusions hold for severe cyclone cases also. Once again, intensity and track errors are relatively less with 24 and 48 hour leads when compared to 96 hour lead. Our results show that mesoscale model are reliable candidate for cyclone simulation especially at the shorter lead (<24 hours). In order to see whether a global circulation model (GCM) can simulate cyclones with better accuracy compared to mesoscale models, we repeated the experiments with GCM also. Results show that though mesoscale model is superior to GCM in terms of accuracy at shorter leads, at higher leads (>96 hour) GCM performs better than mesoscale model (Figure 2.14). These results points towards the necessity of coupling GCM with mesoscale models for more reliable cyclone prediction at longer leads. Similarly, assimilation of observations may further improve forecast skill.

Mohapatra G N and Rakesh V

2.12 Evaluation of ASCAT soil moisture data with in-situ observations over different agro-climatic regions in Indian

Soil moisture is widely recognized as a key variable in studies related to environment, meteorology, hydrology, agriculture and climate change. Spatial and temporal variations of soil moisture are critical inputs to many applications like sowing schedule, irrigation requirements, and ground water storage. Soil moisture plays a critical role in surface radiation budget through partitioning of sensible and latent heat fluxes and also plays an important role in partitioning of rainfall into runoff and infiltration. Unfortunately, in-situ soil moisture observations are sparse worldwide because of the difficulties involved in resources, logistics and maintenance. However, the recent advances in satellite remote sensing technology have allowed measurement of soil moisture at high spatial and temporal resolutions. A long term sustained soil moisture observation at four vertical levels (5cm, 15cm, 50cm and 100cm) is now available at several locations over India under a multi-institutional program Climate Observations and Modelling Network (COMoN) led by CSIR, India. At the same time, a high resolution (0.1°x0.1°) daily (moving 5-day mean) surface relative soil moisture data set has now become available from the Advanced Scatterometer (ASCAT). There is a need to compare remotely sensed observations with in situ observations to ensure consistency and quantify uncertainties. We present (Figure 2.15) a comparative analysis of gridded ASCAT soil moisture data and in situ COMoN station data over six locations (Almora, Hyderabad, Cochin, Gulbarga, linganamakki, Tezpur) in India during the period 2010-2013. Analyses show that 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 are in the range of 0.73 to 0.91 and above 99% significance level.

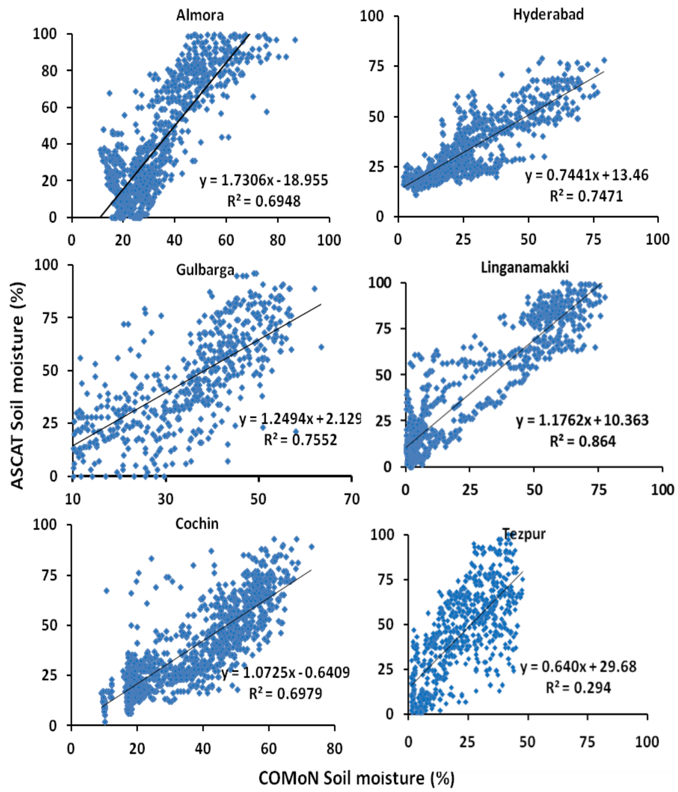


Figure 2.15 Scatter plot shows the agreement between ASCAT and COMoN soil moisture observations at daily scale, x-axis represents the COMoN while y-axis represents the ASCAT.

Kantha Rao Bhimala

2.13 Relationship of winter fog frequency over Indo-Gangetic Plains of India and regional climate variability

Over northern India, most of the fog formation is due to radiative cooling but, advection fog has also been observed. Radiation fog usually forms near the surface under clear skies in stagnant air in association with an anticyclone. Conditions favoring the formation of radiation fog include a clear sky and very light wind. This is generally associated with an inversion structure caused by radiation cooling of the ground and/or near-ground air and the heating of upper layers by adiabatic compression in the course of extensive anti-cyclonic development. When considering the overall fog phenomenon, mechanisms leading to its formation are in many ways conditioned by the large-scale environment (flow conditions, cloudiness, presence of precipitation etc.). Therefore, characterizing the large-scale weather patterns associated with the onset of events represents a useful baseline in establishing the character of environmental conditions leading to fog.

To investigate the long-term variation in fog frequency (FF), we have compiled daily FF reports recorded at Delhi, Lucknow, Allahabad and Hissar since 1980. A 24-h period from 00 UTC to 00 UTC of the next day is characterized as a fog day if in one or more of the 8 3-hourly synoptic reported fog for the present weather (WW=41 to 49). To assess regional inter-annual variability, all records were aggregated into a single IG plain FF series covering winters (DJ) from 1980 through 2012.

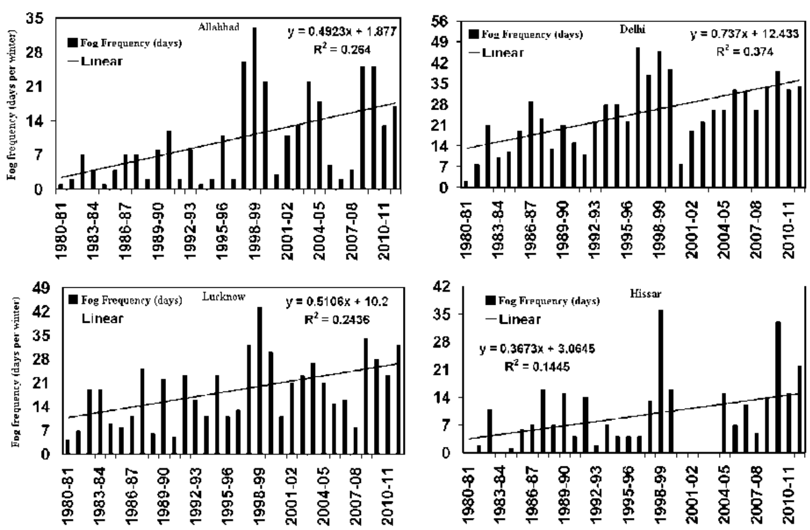


Figure 2.16 Inter-annual variability in winter (December-January) Fog frequency (visibility < 1 Km) days at Allahabad, Delhi, Lucknow and Hissar from 1980 to 2012.

Figure 2.16 shows inter-annual variation in the DJ total FF recorded at the four observatories over 1980–2012 with linear trends. Inter-annual FF series from the four stations are compared among themselves and found to be strongly correlated (r ~ 0.7), suggesting the importance of common response to synoptic-scale climate forcing. From 1980 to 1989 the FF varied around a mean of 16%, followed by a gradual increase through 1990s and 2000s with a mean of 27.6% and 30.3% respectively. The record maximum was observed in the year 1998-1999 with FF 63%.

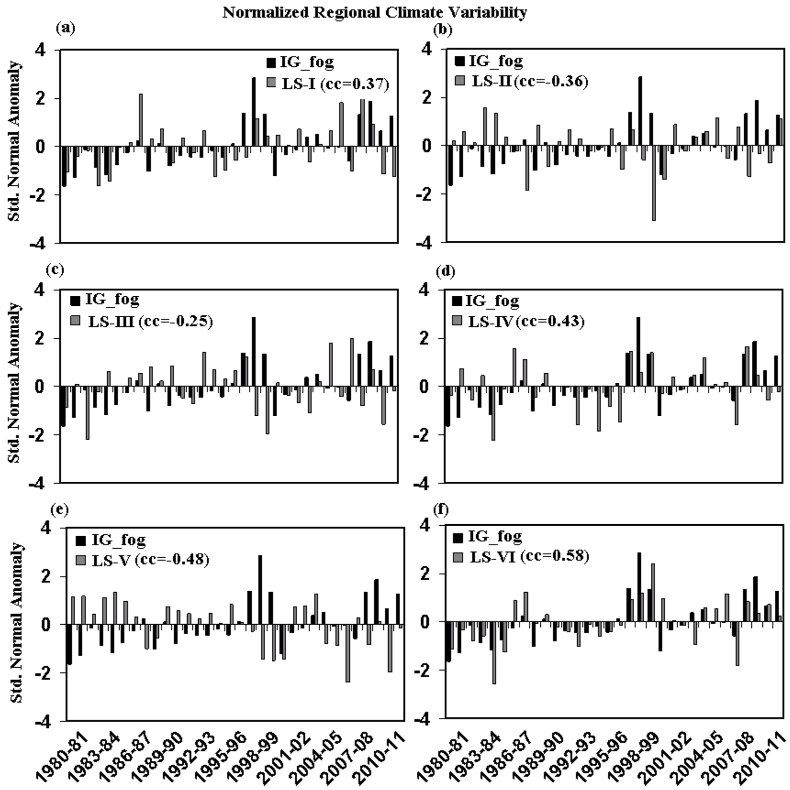


Figure 2.17 Inter-annual variability of winter time (December-January) IG fog frequency and other regional (averaged over 20°N- 35°N and 70°E- 92°E) climate variables from NCEP; plot includes: (a) 500 mb geopotential height anomaly (LS-I), (b) v-wind component at 1000 mb (LS-II), (c) wind divergence at 1000 mb(LS-III), (d) difference in specific humidity between 925 and 700 mb (LS-IV), (e) difference in temperature between 850 and 700 mb (LS-V), (f) difference in relative humidity between 850 and 700 mb (LS-VI) during the period 1980-2012. All series normalized to zero mean and unit variance. The numbers inside the brackets represent correlation coefficient between IG fog frequency and the large scale variables for the respective cases. The 95% significance of correlation is 0.3.

To investigate the relationship between the winter FF and local atmospheric environmental changes in December and January, the inter-annual variations in 500 geopotential height anomalies, meridional wind and wind divergence at 1000 mb, difference in specific humidity between 925 and 700 mb, difference in temperature and relative humidity between 850 and 700 mb were examined across the IG plain for the period 1980-2012. These large-scale fields have been derived from NCEP with areal average (20°N- 35°N and 70°E- 92°E) across IG plain. Large-scale meteorological variables such as geopotential heights, sea level pressure (SLP), zonal and meridional wind component at surface and higher pressure levels, 850-mb temperature, specific humidity and relative humidity were obtained from the National Centre for Environmental Prediction (NCEP) reanalysis which is a retroactive record of more than 50 years' worth of global analyses of atmospheric fields.

Figure 2.17 shows that various large-scale variables are significantly correlated with the FF variability over IG plains of India.

2.14 Wind-generated electricity potential for Andaman and Nicobar islands

The potential of wind power as a source of electricity, which is an alternative to conventional fossil fuels, are generally used in remote regions, like islands for electricity generation. Utilization of renewable energy can make us less dependent on fossil fuels, which in turn can help us to reduce carbon emissions. This study focuses on quantifying a realistic assessment of the potential for wind-generated electricity in Andaman and Nicobar islands, which experiences two monsoon wind regimes. Wind fields are derived from high resolution hourly winds from dynamically downscaled climate for the period 2001-2015 to estimate the potential.

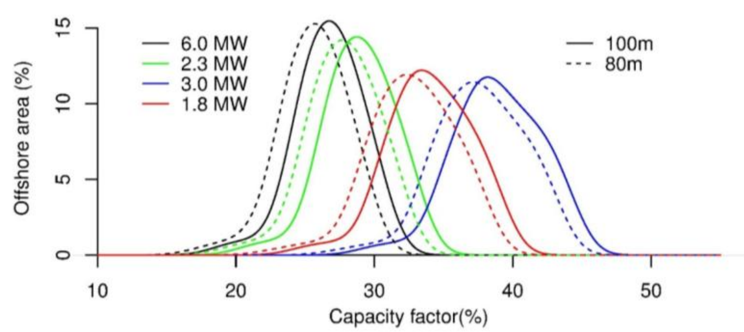


Figure 2.18 The distribution of offshore potential area based on the capacity factor for different capacity offshore wind turbines at 80m and 100m heights.

This region experiences high spatio-temporal variability in winds at 80 and 100m heights. Both the monsoon seasons and pre-monsoon period experience high speed wind regimes. The orographic distribution shows there is no suitable space for onshore wind turbine, hence this study examines the offshore potential for wind generated electricity for different capacity turbines. Most of the selected locations (depth less than 250 m) have the average capacity 20%, while low capacity turbines (3.0 MW and 1.8 MW) have high capacity factor (Figure 2.18). The annual distribution of wind shows that 62+-2% can be utilized for electricity generation. The offshore location, turbine cost and electricity potential are used to quantify the economic viability to identify the offshore locations. This region has high capacity factor, which shows that 66% of electricity can be generated from wind. The projections of electricity requirement in the island is used to quantify the optimum requirement of turbines up to 2050, so that 66% requirement is met by offshore wind turbines on the identified locations. This study will be extended to Indian main land to identify viable areas of onshore and offshore wind generated electricity potential.

Shafeer K B and Ramesh K V

2.15 Dynamics of land-atmosphere coupling during heat waves in 2015

Heat-wave is one of major natural health hazard, which is identified as, not only merely due to series of days with extremely hot temperature, but also due to periods when sustained heat produces an excess mortality. Studies have shown that the heat waves are formed due to progressive accumulation of heat, which is enhanced with soil desiccation and lead to further increase in air temperature over mid-latitudes. However, there are few studies which attempted to understand the evolution of heat waves over tropics, especially South Asia, which is dominated by monsoon climate. The studies are few due to non-availability of high-resolution observations. In this study, we examine the evolution of mega heat wave. For this purpose, we develop a high-resolution (4x4 Km) downscaled of climate data for the period of 2001-2015 from Weather Research and Forecasting (WRF) Simulations. The high-resolution data is validated with available station observations Global summary of the Day (GSOD), which is prepared by the National Climatic Data Center. The results show that there is a strong accumulation of heat (Figure 2.19) over Telangana, Orissa, West Bengal, Bangladesh, Uttar Pradesh, Bihar region, which started heat accumulation from 10 May onwards, continue to increase and persisted till 30th May 2015 with the help of high-resolution soil and atmospheric data. We quantify the relative roles of soil moisture-temperature coupling, and contributions of large scale features in the evolution of the mega heat wave.

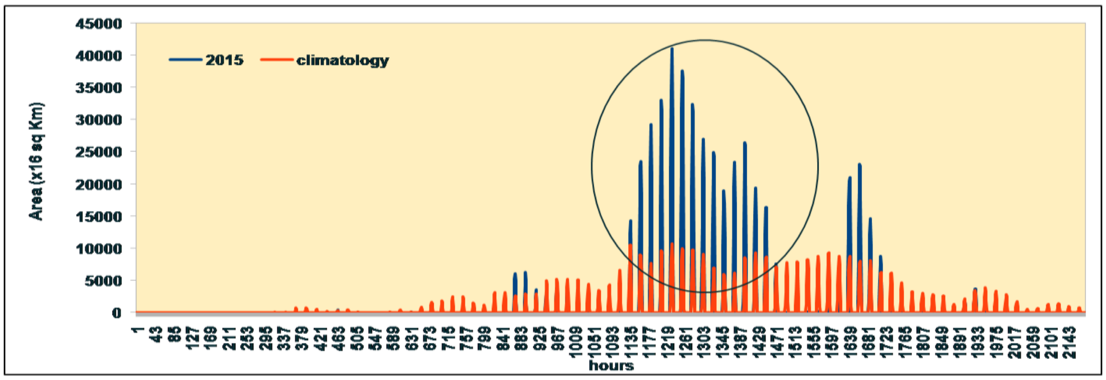


Figure 2.19 Temporal Evolution of heat wave 2015 (blue) during April 01 00UTC to June 30 23UTC is compared with same days climatology (red) of 2001-2015. The Y-axis shows the area coverage of the grid points above 45^{o}C.

Over south Asia, pre-monsoon is the warmest season of the year with anomalously high daily temperatures and if relative humidity is also increased, then it will adversely affect the human health and comfort. For example, May 2015 mega heat wave over India took more than 2500 lives. So, identification of types of heat waves, role of vegetation, soil moisture and its long-term changes are of critical importance to the development of an appropriate risk management and mitigation strategies.

Neethu C, Shafeer K B and Ramesh K V

2.16 Projected changes in vector borne diseases (Malaria) over India

Malaria, a mosquito-borne infectious disease caused by parasitic protozoans of the *Plasmodium* genus, is detrimental to public health and affected countries. Studies have documented that the potential days for malaria occurrence and transmission depend on weather variables. The objective of this study is to explore the relationship between climate variables and the occurrences of Vector Borne Diseases (VBD), especially malaria in India. Current evidence suggests that inter-annual and climate change (trends) have a direct influence on the epidemiology of vector-borne diseases (VBD). Malaria, dengue, Filariasis, Kala-azar, Chikungunya and Japanese Encephalitis are among the most important vector-borne diseases in the tropics, which causes high mortality in India. The rainfall/temperature/humidity of the region play an important role in the occurrence/spreading of VBD. We use CMIP3 and CMIP5 model simulations to analyse the disease occurrence in historical as well as for future projections over India. We adopted different criteria for calculating the potential days region-wise depending on the weather variables. The criteria are for Temperature (18^{o}C-32^{o}C), Rainfall (1.5-20 mm/day) and Relative Humidity (20-80%).

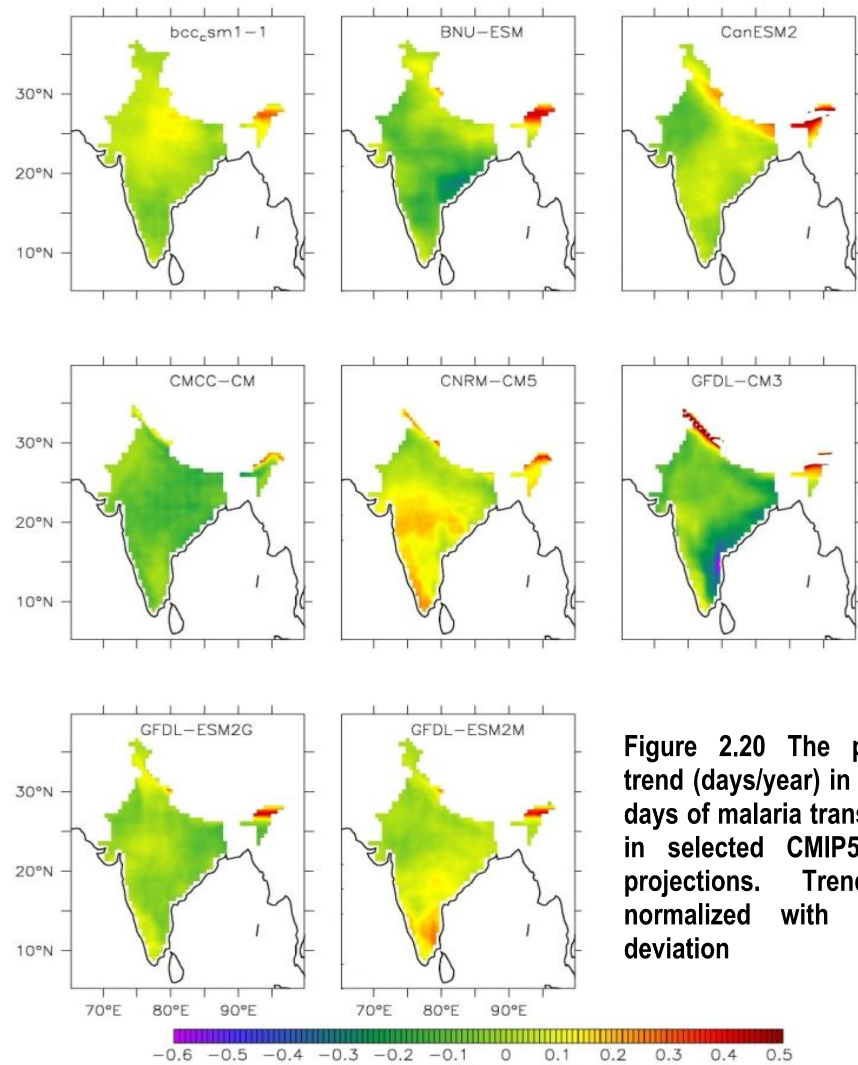


Figure 2.20 The projected trend (days/year) in potential days of malaria transmission in selected CMIP5 RCP45 projections. Trends are normalized with standard deviation

The state-wise data of disease cases/deaths reported for India is obtained from Indiastat. The climate variables (rainfall, temperature and humidity) from different reanalysis (MERRA, ERA40, ERA Interim, NCEP and JRA55) are used to validate the IPCC historical model simulations. The variables are used in the time period of 1951-2005 to find out the number of potential days for the malaria occurrence and transmission. The IPCC models were selected based on the performance and capturing of features in observations/reanalysis. We calculated the correlation coefficient between the disease cases reported (state-wise and region-wise) and the weather variables. The selected models were used for future projections (2016-2099).

Results show that future climate is going to be highly conducive for malaria transmission over the West-coast of India, central India and northeast India (Figure 2.20). As climate models show higher dispersion, it is necessary to quantify the reliability of projections.

Alfred Johny and Ramesh K V

2.17 Analysis of vector borne disease across Karnataka using geospatial technique

The outbreak of vector borne diseases in different parts of Karnataka has created a serious health concerns. There were many incidents of deaths reported in some of the rural areas due to lack of health amenities, poor intervention and lack of awareness. There are various factors like the geographical location, local environmental conditions, climate change which contribute to the spread of the vectors resulting in disease outbreak. Apart from that the factors like socio economic and high population density, which in turn aggravate the problem.

In the present study, the spatio-temporal analysis of the spread in vector borne diseases over different regions of Karnataka is carried out using multi-source observation and geospatial analysis. Here, for the analysis, Dengue Fever, Chikungunya, Malaria and Japanese Encephalitis for the periods 2001 to 2014 are carried out, using the availability of disease-wise data for the entire Karnataka Region at district scale.

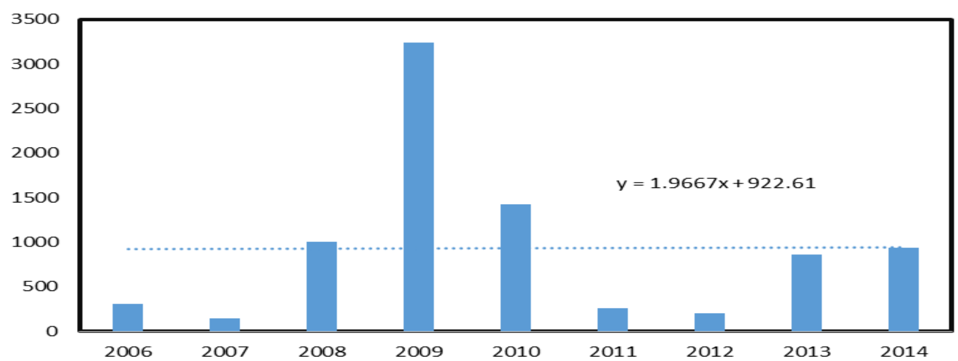


Figure 2.21 Annual frequency distribution (number of cases reported) of Chikungunya patients over Karnataka for the period 2006-2014. The line indicates the trend line for the period of analysis.

The data for the analysis of Vector Borne disease was collected for all the districts of Karnataka from NVBDC Karnataka. Here, the data analysis was mainly carried out for Dengue, Chikungunya, Malaria and Japanese Encephalitis using the statistics and the trend analysis (Figure 2.21). GIS based frequency maps (using Arc GIS 10.0) show the positive trend in the cases of occurrences of the various vector borne diseases. In these maps Red tone indicates the high incidence (>500 cases), Blue tone indicates moderately high (100-500 cases), Yellow tone indicates low (1-100 cases) and Green indicates no incidence at all (Figure 2.22). The Spatio-temporal analysis was also performed to find out the most affected region, so that control measures can be adopted to prevent the diseases.

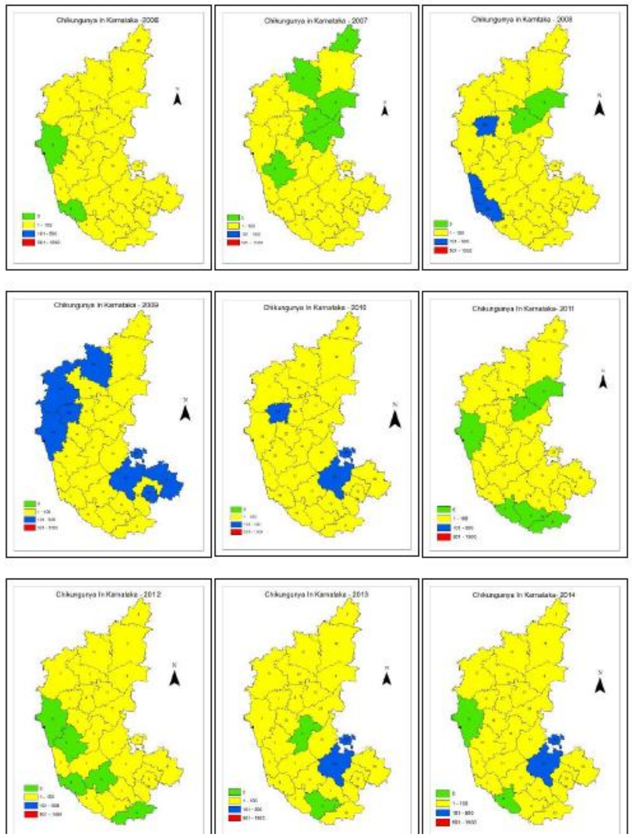


Figure 2.22 Annual frequency distribution (number of cases reported) of Chikungunya patients over Karnataka for the period 2006-2014.

The trend analysis of the various cluster of vector borne diseases can be used to study the correlation of the diseases with weather variables like climate, rainfall and temperature to develop a predictive model for vector borne disease.

Gouda K C and Shashikala[1], Pavithra[1] and Lakshmikanth B P[1]
[1]Karnataka State Remote Sensing Application Centre, Bangalore

2.18 Relation between Rainfall and on Occurrences of Dengue cases over India

There is increasing trend in Dengue, one of the most dangerous VBD over some parts of India. Analysis of observed data shows the spreadability and occurrence of Dengue is more during 1998-2012 over 6 states (Delhi, Haryana, Punjab, Gujarat, Rajasthan and Goa) in India. This study analyzed the relationship between rainfall and occurrence of dengue cases at the state scale. It is found that the increasing trend in the extreme rainfall events generally leads to accumulation of water and these are conducive for the vectors to spread Dengue.

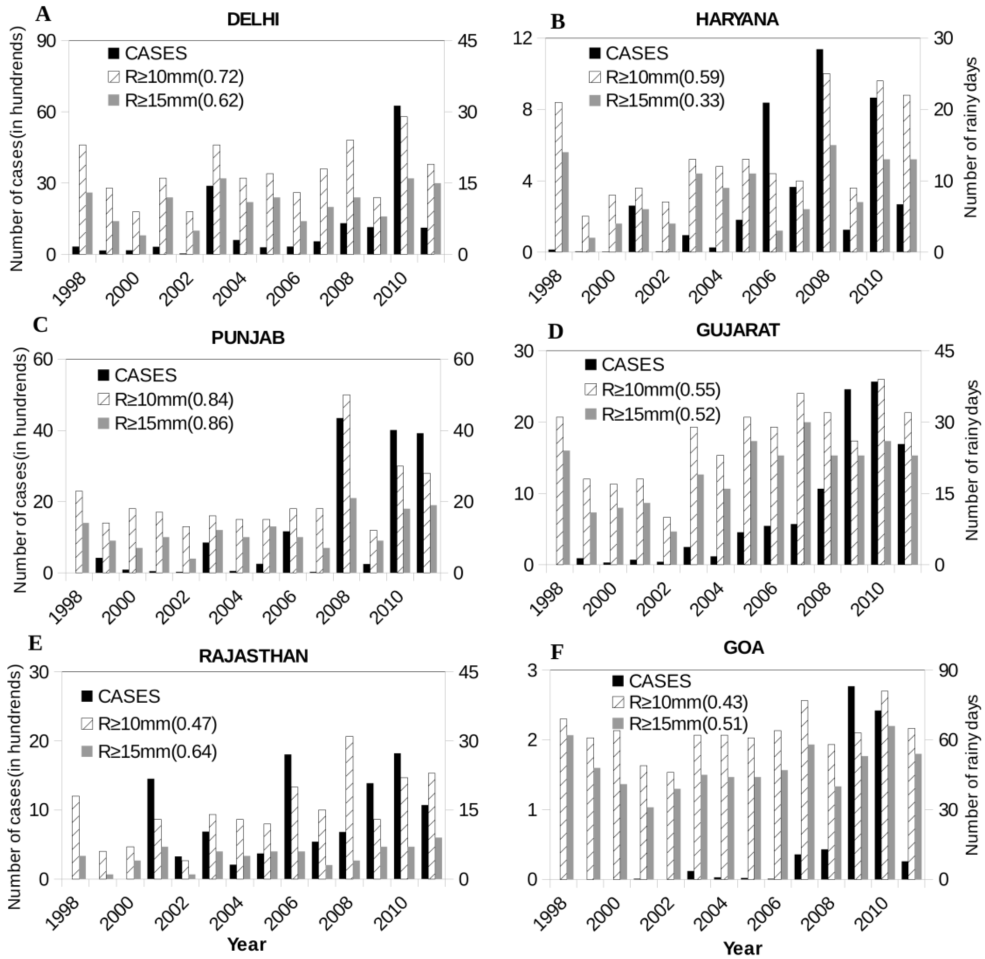


Figure 2.23 Inter annual variability in the annual number of heavy rainfall days and the annual dengue cases for the six states. The numbers in the brackets represent correlation coefficients between dengue cases and the annual number of rainy days for the respective rainfall categories for the period of 1998-2011; the 95% significance of correlation is 0.497.

On a year-to-year basis also, each state exhibits significant (≥95%) correlation between the annual number of dengue cases and the heavy rainfall days (Figure 2.23). It may be noted that for each of the states and for each of the 15 years, there is non-zero number of heavy rainfall (R≥10mm/day) days; however, there are examples like, for Haryana, Goa and Rajasthan during 1998-2000, for which the number of dengue cases were essentially zero (Figure 2.23). It may be also noted that for states like Goa, Gujarat and Punjab, there are indications of sharp increases in the number of dengue cases.

Barik P S, Gouda K C and Goswami P

3
COMPUTATIONAL MECHANICS

Sophisticated mathematical modelling aided by powerful computing and visualization has the potential to provide cutting-edge to industry; generation of cost-effective solutions, process optimization and product design are some of the areas where modelling and simulation can play critical to enabling role. The CSIR-4PI Computational Industrial Mechanics Programme (CIMP) seeks to develop and apply tools of mathematical modelling and computer simulation in diverse areas of engineering.

Inside

- *Computational Modelling and Simulations of Nanocomposite Properties*
- *Dispersion of plane waves with higher-order nonlocal continuum model using bi-Helmholtz operator approach*
- *Nanotechnology: Continuum to Atomic Scales*
- *Computational Stability Analysis of Graphene Sheet*
- *MHD flow of a nanofluid in an expanding or contracting porous pipe with chemical reaction and heat source/sink*
- *Thermal-diffusion and diffusion-thermo effects on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation*
- *Influence of thermal radiation on unsteady flow over an expanding or contracting cylinder with thermal-diffusion and diffusion-thermo effects*
- *Mass transfer effects on viscous flow in an expanding or contracting porous pipe with chemical reaction*
- *Impact dispersion using 2D and 3D composite granular*

3.1 Computational modelling and simulations of nanocomposite properties

Nanocomposites have superior material properties comparedto composite materials with micro-mechanical properties. The effective material properties of composites contain randomly oriented nanostructured fibers and are modeled with continuum models. The stress-strain relations based on longitudinal and transverse directional properties are computed. The Mori-Tanaka model or Halpin-Tsai are used to study the mechanical properties of nanocomposite structures. The Molecular Dynamics Simulations are used as an alternative way to determine the mechanical properties of structures made up of nanocompositematerials.

Senthilkumar V

3.2 Dispersion of plane waves with higher-order nonlocal continuum model using bi-Helmholtz operator approach

The continuum models fail at atomic scale. The nonlocal continuum models are good at predicting dispersion characteristics of waves better than the conventional continuum models. The nonlocal continuum approach based on Eringen model predicted the dispersion nature which is in agreement with atomic based Born-Karman model.

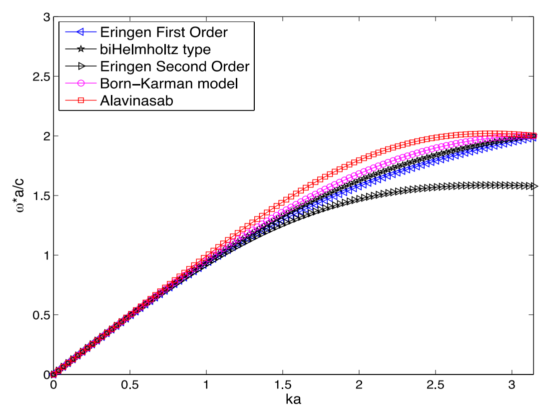


Figure 3.1 The dispersion characteristics gradient models

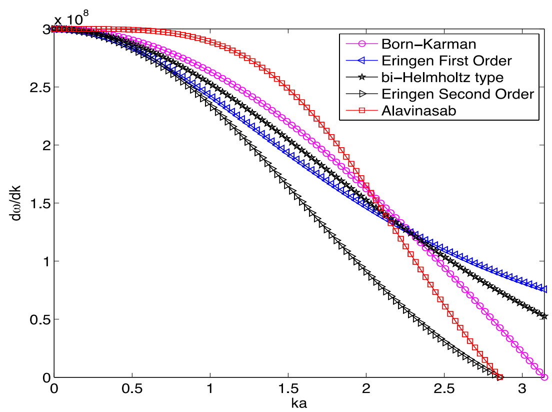


Figure 3.2 The group velocity characteristics gradient models

For the first time, the higher-order stress gradient model with bi-Helmholtz operator has been proposed. The present model has been examined with the other models like Eringen model, Alvinasab model, and Eringen second order model. The Born-Karman model is the realistic model to study the atomic level interaction and small sized structures. From Figure 3.1, it is very clear that the present model has very close agreement with atomic based model compare to all other models. The group velocity also predicted better than other models as shown in Figure 3.2.

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*(*IIT BHU, Varanasi)*

3.3 Nanotechnology: Continuum to atomic scales

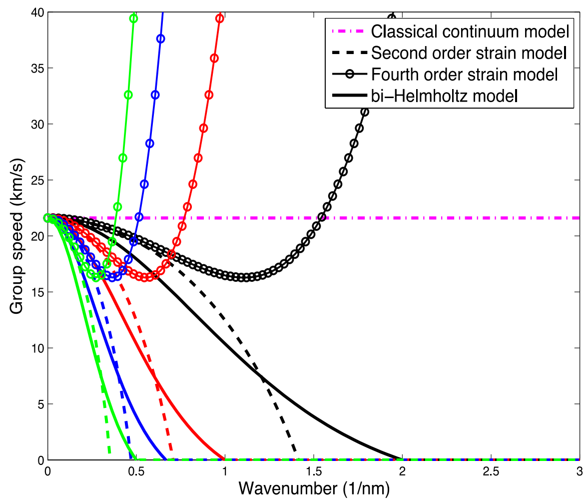

Figure 3.3 Group speed of carbon nanorod with various gradient models

The nonlocal continuum models are modeled with lattice parameters/distance between the atoms etc. The second order strain model, fourth order strain model and bi-Helmholtz models have two small-sized parameters. Depending on the applications, these parameters are considered. The carbon nanorod with ultrasonic frequency analysis are analyzed and the group speeds are studied (Figure 3.3) for the axial waves. It is clear that the bi-Helmholtz model predicts the group speed better than the other gradient models. These small-scale parameters are evaluated using lattice dynamics models. The experimental studies are expensive and difficult to control at atomic level. So molecular dynamics is used to calibrate the small-scale parameters.

Senthilkumar V

3.4 Computational stability analysis of graphene sheet

The equivalent continuum model with nonlocal continuum effect is developed to study the stability analysis of Graphene sheet. Unlike continuum models, the present model involves boundary conditions with small-scale effect. The Differential Quadrature Method (DQM) has been developed to study stability analysis of graphene sheet. Combining matrix methods of analysis for structures and DQM, analyses are carried out. The collocation polynomials are used as basis functions. The computational programming code has been developed and critical stability studies are carried out.

Senthilkumar V and Shriyans Bagla*
(*IIT BHU, Varanasi)

3.5 MHD flow of a nanofluid in an expanding or contracting porous pipe with chemical reaction and heat source/sink

In the present investigation, an analytical approachhas been used to study the influence of chemical reaction on MHD flow of a nanofluid in an expanding or contracting porous pipe in the presence of heat source/sink. The pipe wall expands or contracts uniformly at a time dependent rate. Similarity transformations have been invoked to reduce the governing flow equations into coupled nonlinear ordinary differential equations. Homotopy analysis method (HAM) is employed to obtain the analytical solutions of the ordinary differential equations. The convergence of the obtained series solutions is analyzed. The effects of various physical parameters such as wall expansion ratio, Brownian motion parameter, thermophoresis parameter, Lewis number, chemical reaction parameter and heat source/sink parameter on flow variables have been discussed. Further, for the case of hydrodynamic viscous fluid, we find a good agreement between the HAM solutions and solutions already reported in the literature.

Srinivas S*, Vijayalakshmi A*, Subramanyam Reddy A*
and Ramamohan T R *(*VIT, Vellore)*

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

The present work investigates the effects of thermal-diffusion and diffusion-thermo on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation. The partial differential equations governing the flow problem under consideration have been transformed by a similarity transformation into a system of coupled nonlinear ordinary differential equations. Homotopy analysis method is employed in order to obtain the solutions of the ordinary differential equations. The effects of various emerging parameters on flow variables have been discussed numerically and explained graphically. Comparison of the HAM solutions with the numerical solutions is performed.

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*(*VIT, Vellore, **Amrita Vidyapeetham, Coimbatore, Vellore)*

3.7 Influence of thermal radiation on unsteady flow over an expanding or contracting cylinder with thermal-diffusion and diffusion-thermo effects

An analytical study is conducted to present thermal radiation, Dufour, and Soret effects on unsteady viscous flow over a contracting cylinder. The coupled nonlinear partial differential equations are transformed into a system of coupled nonlinear ordinary differential equations by using a suitable similarity transformation. The homotopy analysis method (HAM) and HAM with a nonhomogeneous term are employed to obtain analytical solutions for the system of coupled nonlinear ordinary differential equations. A significant reduction in the averaged square residual error is obtained when the nonhomogeneous term is introduced. A comparison between analytical and numerical solutions is presented for validation. The effects of various emerging parameters on flow variables are discussed. It is found that the temperature distribution increases with an increase in Dufour number, but decreases with an increase in Soret number. The concentration distribution decreases for a given increase in the Dufour number, but increases with an increase in Soret number.

Srinivas S*, Shukla A K **, Ramamohan T R and Reddy A S*
*(*VIT, Vellore, **Amrita Vidyapeetham, Coimbatore, Vellore)*

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

In this work, 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. HAM 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 have been 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 the 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.,$\alpha=0$).

Srinivas S*, Reddy A S* and Ramamohan T R*(*VIT, Vellore)*

3.9 Impact dispersion using 2D and 3D composite granular packing

We present a study of efficient dispersion of an impact onto structured and potentially scalable granular beds. We use discrete element method based dynamical simulations of shock wave propagation and dispersion in 2D and 3D arrangements of granular spheres. The spheres are geometrically packed in a nested columnar structure, which leads to the severe attenuation and spreading of the incident energy within the structure. We further show that by incorporating inhomogeneity in material properties, or by introducing layers of a dissimilar material in the middle of the arrangement, impact mitigation can be enhanced significantly. Such an arrangement can therefore be useful in the design of effective impact decimation systems. Using a 2D arrangement we first show the basic idea behind impact dispersion in such an arrangement. With this understanding the system is scaled to 3D. The influence of the system size and material properties on the wave propagation within the packing is also presented.

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*(*State University of New York, USA ,**DA-IICT, India)*

4
HIGH PERFORMANCE COMPUTING AND CYBER SECURITY

In contemporary research computation is the main pillar of scientific discovery, which provides an in-expensive way to achieve high science, complementing theory, experiment and observation. The capability and credibility of a scientific organization is often judged by the computational facility the researchers have access to. CSIR-4PI provides state-of-the-art High Performance Computing(HPC) facility to the computational scientists and researchers across CSIR to address Grand Challenge problems in their frontier areas of science and engineering. The facility at CSIR-4PI is a centralized HPC facility. It is one of the top supercomputers of the country and provides multiple architectures suitable for domain specific applications. All the CSIR laboratories, through the high speed National Knowledge Network, access this facility. In addition to providing access to HPC, the group is also involved in research on cyber security. Under the 12thfive-year plan of CSIR works have been initiated to develop a "Cyber Security Research & Observation" abbreviated as "CySeRO" to carryout research in the field of Cryptography and Cyber Security.

Inside

4.1 Cyber security research and observation platform at CSIR-4PI

It is well known that cyber security research is highly experimental driven. In order to strengthen the ongoing and future research in this area, CSIR Fourth Paradigm Institute (CSIR-4PI) has established a Cyber Security Research and Observation (CySeRO) platform. CySeRO is a sophisticated test-bed for experimental research and data analysis. The test-bed is hosted in a self-contained data center spread across three racks and equipped with inbuilt cooling, UPS, Fire Detection and Suppression, water leakage detection, CCTV, etc. Figure 4.1 shows a picture of the CySeRO test-bed environment.

Figure 4.1 Cyber Security Research and Observation Test-bed at CSIR-4PI

It is a highly reconfigurable and observable environment consisting of 60 nodes. Each node is a rack-mountable server of 1 U size equipped with multiple network interface cards. Each node can be configured as a router or data transmitter or receiver. The test-bed permits emulation of multi-hop network topology and tracking of packet movement across the test-bed. Upcoming Internet protocols like Stream Control Transmission Protocol (SCTP) and Multi Path Transmission Control Protocol (MPTCP) are deployed on the test-bed environment, in addition to standard TCP/IP protocol suite. A wide variety of network tools like tcpdump, pcap library, wireshark, iperf, etc., are also installed on the test-bed.

CySeRO is currently being used for various cyber security and protocol engineering related experimentsin different emulated network conditions like varying packet drop, end-to-end latency, queuing schemes, etc., at packet granularity. Network emulation is performed using 'tc' and 'dummynet' network emulation tool. The reconfigurable test-bed is also being extensively used for cryptographic research including security analysis of newly designed cryptographic protocols. This enables to test the robustness of these protocols towards countering different forms of attacks. The test-bed is also capable of generating near true random numbers, which are very essential for testing these cryptographic protocols.

Anil Kumar V, Patra G K and Thangavelu R P

4.2 Characterization of internet background radiation

Internet background radiations, also known as unsolicited packets, have become an integral part of the overall Internet traffic. It is reasonably well established that any local network connected to the Internetreceives a sizable amount of unsolicited packets proportionate to the size of the public Internet Protocol (IP) address space allotted to the local network. Unsolicited traffic originates from a wide verity of malicious activities such as Internet wide port scan for identification of vulnerable hosts and services, automated worm propagation, reflections from denial-of-service and distributed denial-of-service attacks due to IP address spoofing, etc.

CSIR-4PI, as part of its Cyber Security Research and Observation (CySeRO) programme, has been collecting and analyzing such unsolicited packets for gaining insight into security dynamics in the cyber space. Considering the fact that source IP address of unsolicited packets could be subjected to spoofing, it is important to validate the source address of these packets before using them for further analysis. An active TCP responder is being developed for responding to these unsolicited packets in a protocol compliant manner to solicit further response for address validation. A preliminary version of the active TCP responder is experimentally deployed at CSIR-4PI. Figure 4.2 shows the data collected in a 240 days period starting from May 2015.

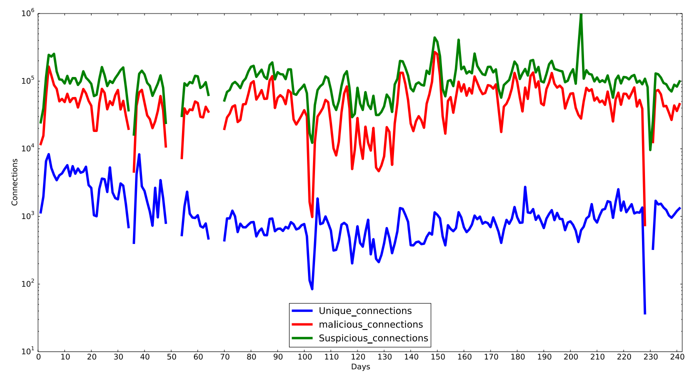

Figure 4.2 Unsolicited TCP connections

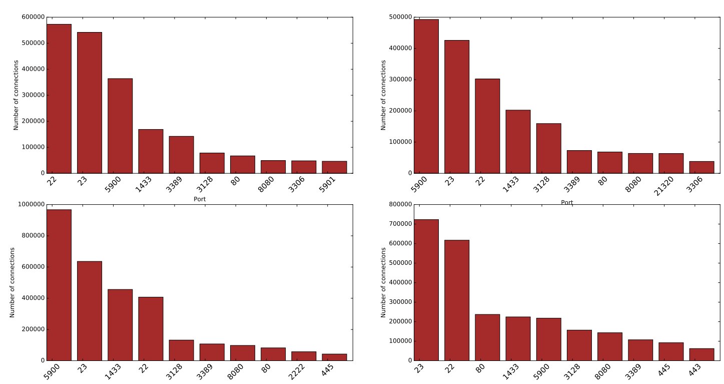

Figure 4.3 TCP port-wise distributions of malicious connection attempts

The data associated with malicious connections are being subjected to further analysis. Towards, this we divided the entire malicious TCP connections into four blocks with each block corresponding to 60 days of data. Figure 4.3 shows one representative result providing additional information about the destination TCP ports with which the malicious hosts are attempting to establish TCP connection.

Each port represents a unique application service. For example, port number 22 (secure shell) and port number 23 (telnet) are two variants of remote login service on Linux and Unix operating systems. Likewise, port number 5900 is the default VNC remote control port. This indicates that majority of the malicious connections are initiated with an intention to gain remote access for possible installation of bots or other malicious programs.

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4.3 Synchronization of chaos in multiple three-dimensional chaotic maps and its application in cryptography

In recent years, extensive studies have been done in the theory of chaos in different fields of physics, mathematics, engineering, biology, chemistry, economics and atmospheric sciences. Since the beginning of last decade, the use of continuous as well as discrete dynamical systems has been quite popular to develop cryptosystems. Chaoticare the complex mathematical systems that show sensitivity to initial conditions. In such systems, any uncertainty in the beginning (no matter how small) will produce rapidly escalating patterns in the prediction of system's future behavior. These properties are found suitable for cryptosystems.

Here a block cipher is designed to encrypt data using separate chaotic maps for different portions of the plain-text. Sender and receiver systems are synchronized using chaotic synchronization process and are used to generate secret keys. These secret keys can be considered as pseudo-random and applied individually to each block. Such a coupled, chaos-based approach makes the process of key-prediction practically impossible and provides protection against common statistical attacks.

Table-4.1: Governing equations and system parameter values in chaotic range used in the present cryptosystem

Chaotic Map	Map Number	Governing Equation	System parameters
RA	0	$\dot{x} = -y - z$ $\dot{y} = x + ay,$ $\dot{z} = b + z(x - c)$	$a = 0.432$ $b = 2$ $c = 4$
RFE	1	$\dot{x} = y(z - 1 + x^2) + \gamma x$ $\dot{y} = x(3z + 1 - x^2) + \gamma y$ $\dot{z} = -2z(\alpha + xy)$	$\alpha = 1.1$ $\gamma = 0.87$
LA	2	$\dot{x} = \sigma (y - x),$ $\dot{y} = x (\rho - z) - y,$ $\dot{z} = x y - \beta z.$	$\sigma = 10$ $\beta = 2.67$ $\rho = 28$

Our primary focus is on identical synchronization with drive-response (unidirectional) coupling technique. Two identical chaotic systems (with random initial conditions, but identical system parameters) are synchronized at both the ends that intend to communicate. The values of system states at (and after) synchronization point are used to generate keys and realize a PRNG. Weproposea cryptographic algorithm using multiple three-dimensional chaotic maps. We use 3 three-dimensional chaotic maps – Rössler Attractor (RA), Rabinovich–Fabrikant

Equations (RFE) and Lorenz Attractor (LA) - and for convenience, we identify each chaotic map by an integer index(map number N). The Governing equations are shown in Table 4.1.

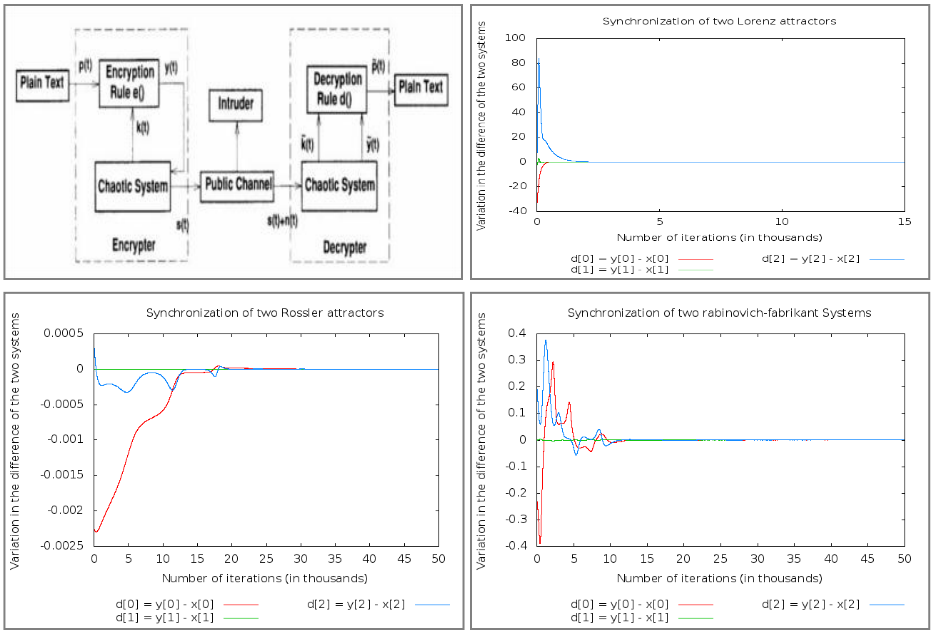

Figure 4.4 Schematic Diagram of a Chaotic Cryptosystem and the synchronization of chaos in a Lorenz, Rössler and RFE Attractor

The convergence in Figure 4.4 indicates the successful synchronization using the three different attractors. The security analysis is as follows:

Cipher text-only attack (COA): In this type of attack, the intruder has access only to the cipher text. For this type of attack, this algorithm depends on the arbitrary system states that drive the evolution of chaotic maps and the order in which they are applied. Initial values for all three system states is chosen randomly between [-1, 1] with decimal precision of up to 6 digits. So, the probability that an intruder can correctly assume the actual message or secret key by intercepting only the encrypted text is ~ 1/(N*3!), where N = 46656 (permutations for 6 decimal places).

Known-plaintext attack (KPA): In this type of attack, intruder has samples of both the plaintext and its encrypted version. However, since the proposed algorithm is based on stream cipher protocol, and each individual character has been encrypted with different key generated from a chaotic system with randomly chosen initial system states, so the probability for an intruder in this attack to correctly identify the secret key is nearly same as cipher text-only attack.

Hence, even for moderate values of system parameters, the probability to break the system tends to zero. So, the proposed approach is fairly unbreakable against above attack models for cryptanalysis.

4.4 A secure key exchange protocol using link weights and dynamic TPM

Artificial Intelligence (AI) concepts have been inherited in cryptography for secure key exchange named as Neural Cryptography. Tree Parity Machine (TPM) which is the main building block of neural key exchange is developed and used for secure communication. In this approach, the participants only need to perform basic arithmetic operations instead of complex number theory approach. The two participants who share their output and input bits in public domain can securely synchronize each other by TPM architecture. However the process can be mimicked by an attacker with the powerful Majority Flipping Attack (MFA) on TPM. The proposed work mainly focuses on overcoming Flipping Attack and Majority Flipping Attack.

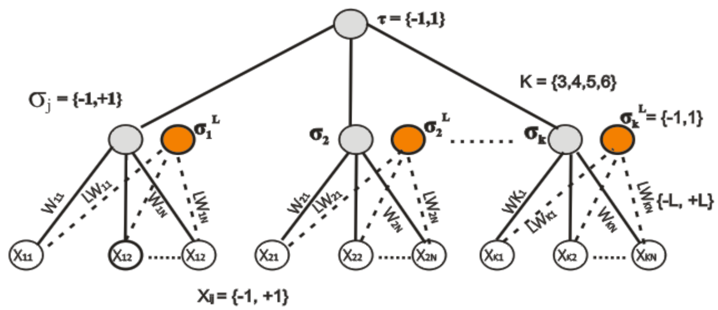

Figure 4.5: A Dynamic TPM with link weights

The TPM is a feed forward three layer artificial neural network consisting of N input units, K hidden units and an output unit. In order to improve the security of key exchange, a tricky synchronization has been applied on TPM. The number of hidden units K is selected at random at each time step, it is selected among four values 3, 4, 5, and 6 and the size of input vector is determined using constant multiple of LCM of four values. In addition to that, a link weight is connected to a TPM weight, which learns whenever its corresponding weight undergoes learning methods. Synaptic depth (L) of weights signifies security of TPM. Increasing the value of synaptic depth decreases the probability of success for an attacker. Synaptic depth is increased without affecting the performance of TPM significantly by connecting the link weight with the TPM weight. Interestingly, the link weights converge to the link weights of participant's TPM. Convergence of link weights happens faster than convergence of TPM weights. Hence, the mutual information gained with the help of link weights is used in deciding the value of K, which is the number of hidden units at the particular iteration of TPM synchronization. Once the link weights are activated, the TPM no longer has the constant K, instead it obtains the dynamic K at every time steps; it is termed as Dynamic TPM and it is shown in the figure 4.5.

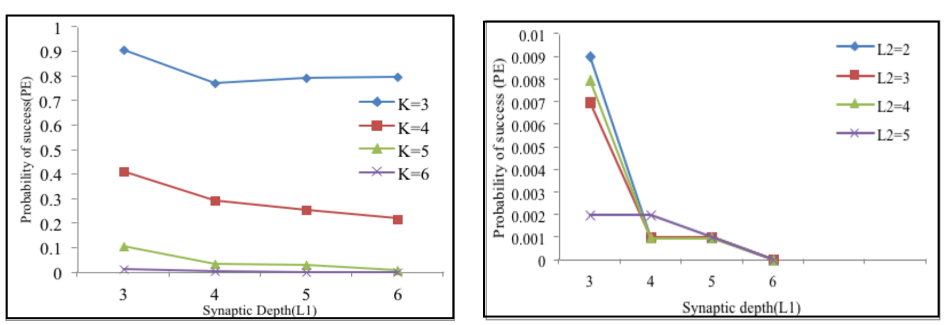

Figure 4.6: (a) Probability of attacker's success as a function of synaptic depth L in TPM averaged over 1000 runs (b) Probability of attacker's success as a function of synaptic depth L in Dynamic TPM averaged over1000 runs.

An Eavesdropper, who listen this network having similar architecture and accessing every public parameter, has disadvantages in synchronizing to genuine participant. Probability of success of an attacker is high when it synchronizes to legitimate TPMs, which is depicted in figure 4.6 (a). In case of Dynamic TPM with link weights, the probability of success of an attacker is exponentially reduced, which is illustrated in the figure 4.6 (b).

Patra G K, Ganesan P

4.5 High performance computing

CSIR-4PI has been providing centralized High Performance Computing facility for the 200 and odd computational scientists across CSIR. It hosts the largest supercomputer, Ananta, of CSIR in additions to few small size clusters as well as storage and network infrastructure.

Ananta (Figure 4.7) has a peak computing power of 360TF and a sustained computing capability of 334TF on the High Performance LINPACK (HPL) and is currently listed as the 7th fastest system in the country and 300th (as of March 2016) fastest in the world. The supercomputer has the distinction of having high average utilization of more than 95% during 2015-16 and an uptime of more than 99%.

Figure 4.7 CSIR centralized 360TF High Performance Computing Facility.

Ananta is a Cluster Platform 3000 with 1088 computing nodes, each of which is a single HP Blade server, with two Intel Xeon E-5 2670 (8 cores, Sandy bridge) processors. The computing nodes are distributed over 17 numbers of 42U 600 mm width racks, resulting in 2176 physical processors and 17408 processing cores. The inter-node communication, which is of high importance in HPC are based on high speed FDR infiniband (providing a dedicated 56 Gbps interconnect bandwidth) in a FAT tree topology in a high availability mode. This is achieved by connecting the nodes using two numbers of centralized Mellanox 648-port core switch through a large number of 16 port leaf switches located in each computing as well as storage rack in a complete redundant mode. The system is equipped with 4GB memory per core, which amounts to about 68 TB of distributed memory in the total system. However, the 48 GB memory located inside a single node can be used for shared memory parallel applications.

An online storage using LUSTRE parallel file system plays an important role in achieving faster data access to individual nodes for carrying out computation in an efficient and fast manner. The high performance parallel file system has a usable capacity of about 2.1 Peta Bytes (3 Peta Bytesraw) and is capable of providing a minimum of 20 Gbps simultaneous read and write. The storage is optimized for performance and data availability using hardware RAID in a RAID6 configuration, parallel I/O through 8 numbers of object servers and two numbers of redundant metadata servers.

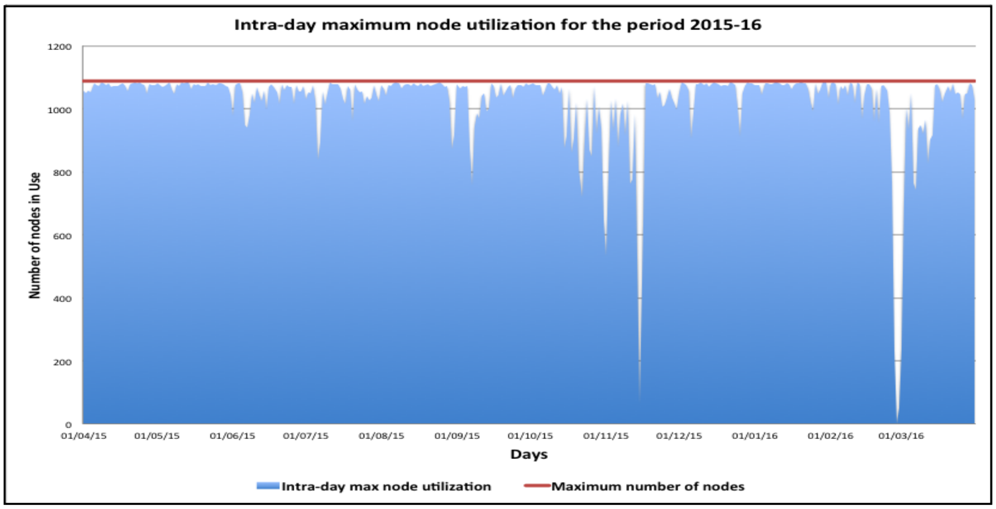

Figure 4.8 Intra-day maximum node used since the 1st April 2015 till 31st March 2016

The highlight of the system is the availability and the average usage of the system. Figure 4.8 shows the intra-day maximum usage in terms of number of nodes for the period 1st April 2015 till 31st March 2016. The size of the problems run by the CSIR computational scientists range from a single node (16 cores) to about 250 nodes (4000 cores). It is interesting to note that the nodes used in a day for most of the days have reached almost the full capacity. This indicates the heavy requirement of computational powers for carrying high science by the scientists and researchers in various fields of computational sciences, such as Biological, Chemical, Engineering, Earth and Atmosphere, Physical and Information Sciences, who use the system in both capacity and capability mode for solving scientific problems. Figure 4.9 shows the distribution of usage by different CSIR laboratories.

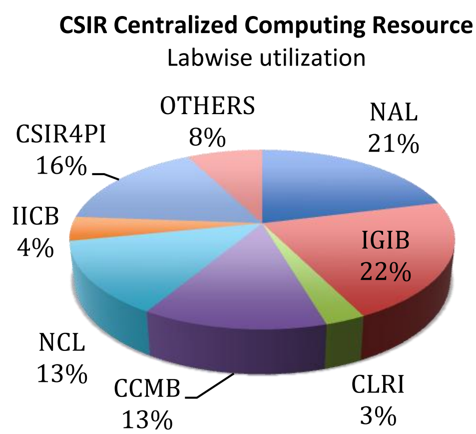

Figure 4.9 Distribution of usage of 360TF system in percentage by Major CSIR labs from 1st April 2015 till 31st March 2016.

In addition to the 360TF super computing system, the Altix ICE cluster has been of great demand (utilization by different CSIR laboratories in Figure 4.10) for solving smaller size problems. This system (Figure 4.11) has 2304 processing cores distributed over 192 nodes interconnected with enhanced hypercube topology using the QDR (32Gbps) infini band interconnect. The system is powered by Intel Westmere-EP Hex core processors running at 2.93/3.06 GHz frequencies, wherein each node has 12 processing cores with 24 GB of memory in a shared memory configurations, while the system as a whole has 4608 GB of memory across the 192 nodes in a distributed architecture. The peak performance the system is 27 TF. This system also uses a LUSTER parallel file system of 30TB for high performance storage access during computation.

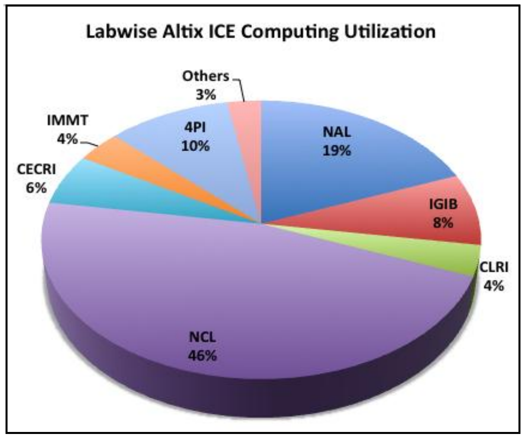

Figure 4.10 Percentage utilization of Altix ICE systems by users from different laboratories of CSIR.

Figure 4.11 Altix ICE systems with 2304 processing cores distributed over 192 nodes and 30 TB of parallel file system along with all associated hardware and software.

The secret of the efficient utilization of a system is the intelligent way of job management. PBS Prowork load manager does this on all the high performance computing system at CSIR-4PI and provides uniform user experience across all systems. The workload manager not only ensures efficient usage of the system but also provides an easy user interaction and submission process. Also the system is equipped with highly optimized Intel compilers and application software both commercial and open source.

High performance archival storage

The parallel file systems are typically used as scratch, to achieve performance, during job computation. However, they are quite expensive. Hence, to store and archive the results, which needs to be preserved for longer period, an archival system based on a high performance SAN(Storage Area Network) is made available to the users. As the data generated grows, the archival system is also upgraded regularly to support the growing needs of storage. The SAN archival system has four LTO Gen 5 drives. Currently the virtualized 3-tired storage solution has 6 TB online (FC), 20TB of near-line (SATA) and scalable offline storage, which can be scaled up to multiple petabytes. The home areas of all the users are centralized on a Network Attached Storage (NAS) of 200TB except the 360TF centralized supercomputing system.

Data center

The 360 TF centralized HPC system, Ananta, is located in a Tier-3 equivalent state-of-the-art data center supported byan energy farm. The highlight of the datacenter is the water based cooling system, viz., Rear Door Heat Exchangers (RDHX), which makes the datacenter as one of the high density and highly power efficient datacenter in the country.

The datacenter has achieved a Power Usage Efficiency (PUE) of less than 1.5, and is one of the best-achieved PUEs in a country like India. The energy farm consists of two redundant compact substations of 1.25 MVA each and for ensuring 24X7 power supply to the datacenter three numbers of diesel generators, an underground diesel yard of more than 15000 liters capacity, three numbers of UPSes with battery backup is available.

The datacenter as well as the energy farm is monitored 24X7 using a 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 are monitored continuously to ensure that the system is available to users.

Network facilities

Thanks to National Knowledge Network (NKN), CSIR computational scientists across the country are in a position to connect to the centralized HPC as well as other systems through a high speed and reliable access. The NKN connectivity to CSIR 4PI is currently at 1 Gbps, established through a redundant path. In addition, CSIR-4PI have a backup connectivity of 8 Mbps through ERNET mainly used for mail communication. The Scientists and researchers of CSIR 4PI and NAL (all the three campuses) use the facility from their desktops through a 10Gbpshigh-speedbackbone. All network services namely DNS (Domain Name Server), NIS (Network Information Services), WWW (World Wide Web),institutional repository, webmail, mail services, Intranet and Internet gateways(both for ERNET and NKN connections) have been provided for efficient communication and data dissemination. Unified Threat Management (UTM) system ensures protection of the CSIR 4PI networks as well HPC system from multiple security threats through both the NKN and ERNET links.

Software enhancements

Software enhancements are a continuous process wherein the application software are procured, maintained and upgraded. Some of the heavily used software are ABAQUS, IDL, GAMIT/GLOBK, Tecplot, S-Plus, Hyperworks, Fluent, ANSYS, OpenFOAM etc. CSIR 4PI 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.

Other technical services

Technical support services were provided to a large number of users across CSIR. The team also has provided technical support for establishing HPC facilities at other CSIR laboratories. This includes the HPC system at CSIR CIMFR, Dhanbad under the collaborative research project DeepCoal. The team also has audited the OneCSIR portal and have provided recommendation to improve the security. 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.

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5
MULTI-SCALE MODELING PROGRAMME

The group was established in 2011 as an emerging, effective and future-oriented modeling program fully exploiting the power of HPC at CSIR-4PI, initially in the field of atmospheric sciences to advance the simulation of weather and climate, to project future climate change, assess associated vulnerability and provide efficient adaptation and mitigation strategies. Moreover, this is a data intensive paradigm where numeric's and computing strategies relevant for different scales in a dynamical system are combined to arrive at an effective computational solution than the one obtained from the strategy dealing with the most relevant single scale. In initial phase of the program, the group sought to develop an ultra-high resolution weather and climate model framework to address multi-scale processes of the atmosphere and analyze the data from observations and these simulations to effectively arrive at inferences. General Circulation Models (GCMs), coupled ocean-atmosphere climate model and earth system model with emphasis on processes such as multi scale organization of organized convection and aerosol-cloud-radiation feedbacks, were employed.

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5.1 Prediction of Indian rainfall during the summer monsoon season on the basis of links with equatorial Pacific and Indian Ocean climate indices

Our study attempts to develop simple empirical models for prediction of all-India rainfall (AIR) during the summer monsoon season (Indian Summer Monsoon Rainfall or ISMR), based on a composite index of El Niño Southern Oscillation (ENSO) and Equatorial Indian Ocean Oscillation (EQUINOO).The following data sets for the period 1958-2010, were used in this study: (i) ISMR and updates from Indian Institute of Tropical Meteorology (http://www.tropmet.res.in), (ii) NINO3.4 index [sea surface temperature (SST) anomaly over NINO3.4 (120°–170°W, 5°S–5°N) region] obtained from Climate Analysis Section, National Center for Atmospheric Research, USA (http://www.cgd.ucar.edu), (iii) surface wind data from National Center for Environmental Prediction (http://www.cdc.noaa.gov) and (iv) DMI, the Indian Ocean Dipole mode index from http://www.jamstec.go.jp.

The ENSO index is defined as the negative of the NINO3.4 SST anomaly (normalized by the standard deviation). We use an index of EQUINOO based on the anomaly of the zonal component of the surface wind at the equator (60°E–90°E, 2.5°S–2.5°N). The zonal wind index (henceforth EQWIN) is taken as the negative of the anomaly of the zonal wind so that positive values of EQWIN are favourable for the monsoon.

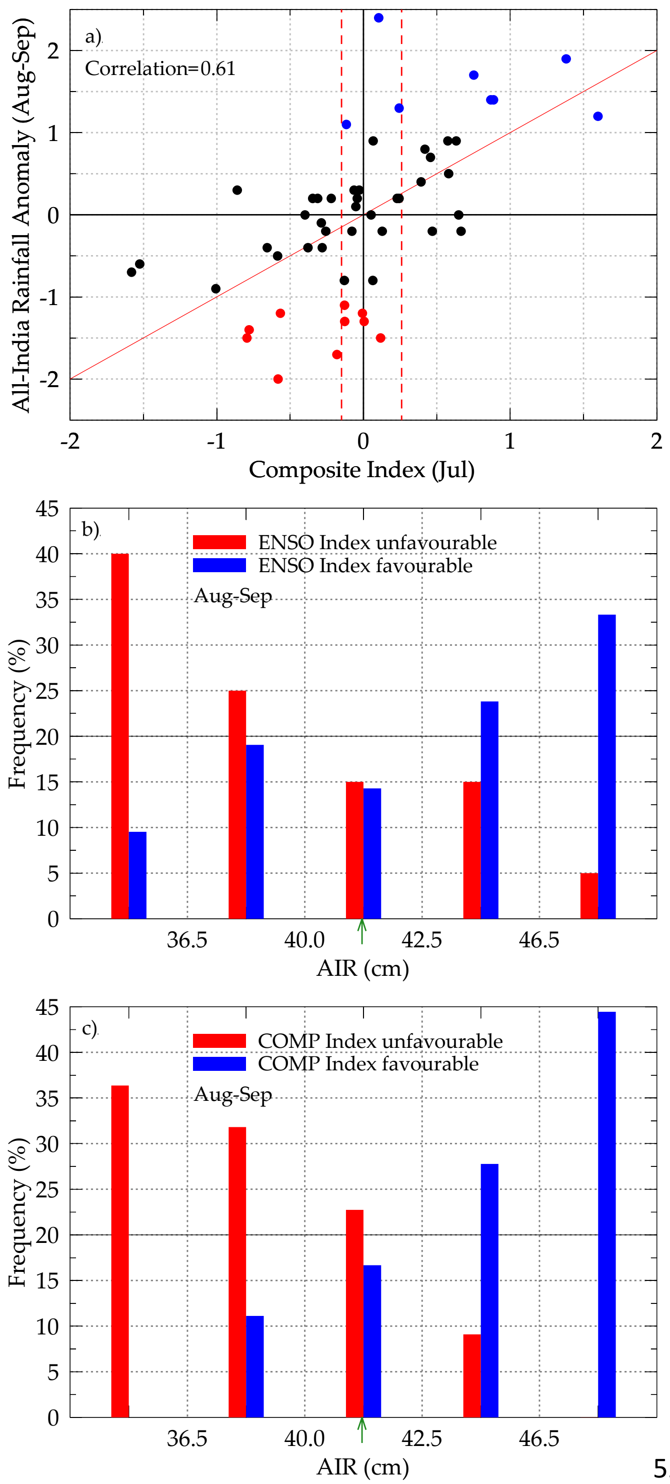

Figure 5.1 a) Normalized all India rainfall anomaly predicted for August-September rainfall against the composite index for July (a); Frequency of occurrence (%) in different categories of normalized August-September anomalies for years for favourable & unfavourable values of ENSO index (b); and of the composite index (c). Green arrows in the x-axes in (b) and (c) indicate climatological mean August-September all-India rainfall (AIR).

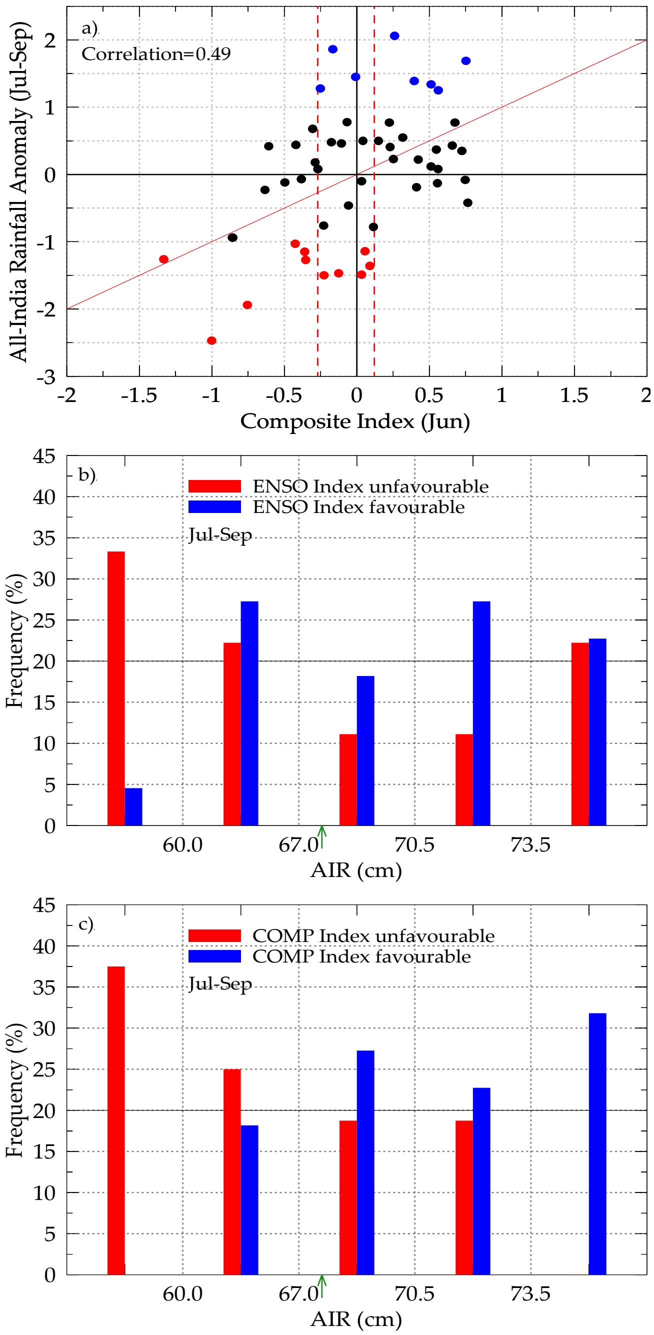

Figure 5.2 a) Normalized all India rainfall anomaly predicted for July-September rainfall against the composite index for June (a); Frequency of occurrence (%) in different categories of normalized July-September anomalies for years for favourable and unfavourable values of ENSO index (b); and of the composite index (c). The green arrows in the x-axes in (b) and (c) indicate the climatological mean July-September all-India rainfall (AIR).

We formed composite indices to predict ISMR, the all-India rainfall during July-September and August-September, by using ENSO and EQUINOO indices for the month proceeding the period for which the rainfall is predicted. For example, all-India rainfall for periods July-September and August-September are predicted using the values of EQWIN and ENSO index prior to that period. The July-September rainfall is significantly correlated with the ENSO index and EQWIN for the month of June and for the linear combination of these two indices determined by bivariate analysis i.e. the composite index. The August-September rainfall is even better correlated with July value of the composite index. In each case, the correlation of the rainfall with the composite index is much higher (statistically significant at 90% level) than that from ENSO index alone. The variation of relationship of the August-September (July-September) rainfall with the composite index for the July (June) determined by multiple linear regression is shown in Figure 5.1a (Figure 5.2a). ENSO and EQWIN together explain 24% and 37% of the variance of the July-September and August-September respectively. Further, it is possible to generate one-sided predictions for the non-occurrence of extremes and low probability of a particular sign of the rainfall anomaly for a certain range of values of the composite index. Thus, it is seen from Figure 1a that if the value of the June composite index is larger than 0.2 (smaller than -0.3), the chance of the July-September rainfall being deficit (in excess) is small and there are no droughts (excess rainfall seasons). When the July composite index (Figure 5.2a) is larger than 0.12 (smaller than -0.12), there are very few years with below (above) normal rainfall and no droughts (excess rainfall seasons).

The frequency distributions in five categories of August-September (July-September) rainfall which have 20% chance when the entire data set is considered for favourable and unfavourable phases of ENSO and of the composite index of the ENSO index and EQWIN, derived by linear multiple regression analysis, for July (June), are shown in Figure 5.1b, c (Figure 5.2b,c) respectively. It is seen that the sign of ENSO has a large impact on the chance of occurrence of the lowest rainfall category in both the cases. It is interesting that ENSO has very little impact on the frequency of the highest July-September rainfall category. On the other hand, EQUINOO and hence the composite index has a substantial impact on the highest July-September rainfall category. Note that for both the cases, unfavourable (favourable) values of the composite index (of magnitude larger than 0.15), there is no chance of occurrence of the highest (lowest) rainfall categories. Thus the incorporation of EQWIN is seen to have had a substantial impact on the frequency distributions.

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Francis P A (Indian National Centre for Ocean Information Services)
and Rajeevan M (Ministry of Earth Sciences)

5.2 NCEP CFSv2 retrospective runs and prediction of 2016 Indian Summer Monsoon

Predominantly agrarian economy of India owes greatly to timely monsoon and is therefore imperative to accurately forecast monsoon variability for the benefit of India's economy. Coupling of ocean and atmosphere is found to be necessary to obtain a realistic prediction of tropical climate on various timescales. A fully coupled ocean-land-atmosphere model developed by National Center for Environmental Prediction Climate Forecast System version 2.0 (NCEP CFSv2) was implemented at our institute and seasonal predictions in hindcast mode, initiated with five different initial conditions; 21st April, 26th April, 1st May, 6th May and 11th May, for a period of 38 years starting from 1979, were carried out (Figure 5.3).

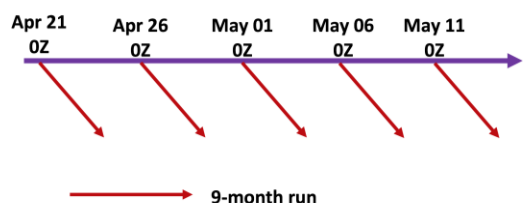

Figure 5.3 Setup of retrospective seasonal runs of NCEP CFSv2 made at CSIR-4PI

The model is found to have good skill in simulating rainfall over east and west coast India, although a dry bias exists over land. A correct representation of deep convection processes and sea surface temperature is necessary for simulating the right rainfall over the subcontinent. We have analyzed major characteristics of Indian summer monsoon

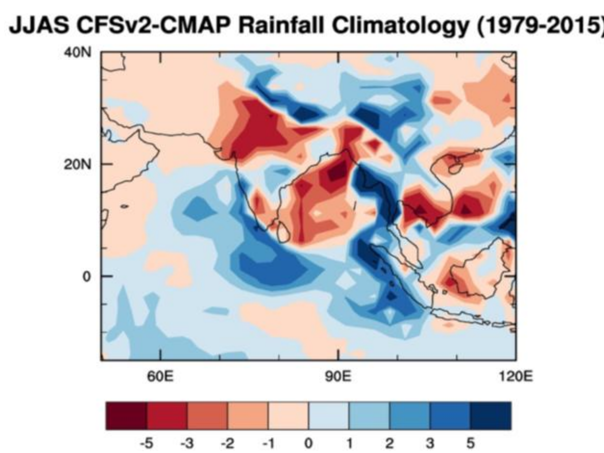

Figure 5.4 Difference between simulated (CFSv2) and observed (CMAP) climatological June to September mean rainfall over 1979-2015 in mm day^{-1}

(JJAS rainfall) by these simulations. The model bias in CFS is first analyzed. The model simulates rainfall maxima over Western Ghats and Bay of Bengal, however, large dry bias exists over Central India. Figure 5.4 shows the bias in model with respect to observation. A pronounced dry bias is seen over regions including parts of monsoon zone.

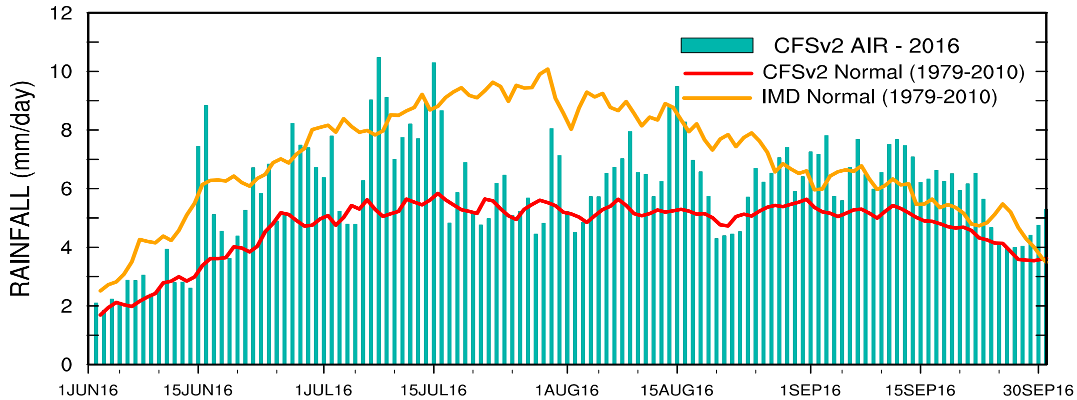

Figure 5.5 Seasonal monsoon forecast for the year 2016 (bars) along with CFSv2 normal (red) and IMD normal (yellow)

CFSv2 forecast for the year 2016 shows above normal rainfall for the country as a whole for the current monsoon season (Figure 5.5).

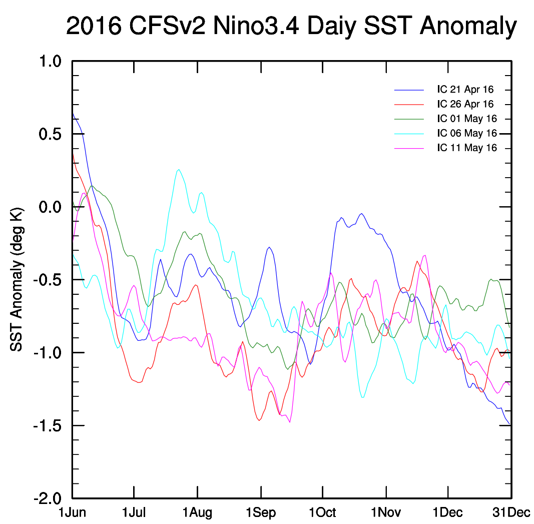

Figure 5.6 Nino 3.4 daily SST anomaly for the monsoon season 2016.

According to the India Meteorological Department (IMD)'s latest update on this year's monsoon, the departure is -3% from long period average for the months June, July and August. Qualitatively there is an agreement between the observation and forecast.

The NINO3.4 sea surface temperature (SST) daily anomaly shows a ENSO neutral conditions in the initial phase of monsoon season that turn to weak La Nina condition in the latter part of the season. (Figure 5.6). This is in good agreement with other observed anomalies.

We are also looking into the teleconnections in CFSv2 to see how well they are captured in the model. From our prior findings, we found higher resolution and deep convection are capable of simulating Indian monsoon with greater fidelity. With this understanding, it is pertinent to look into improving the forecast model for Indian region by removing the model bias.

Rajendran K, Sajani Surendran and Stella Jes Varghese

5.3 Precipitation-aerosol relationship over the Indian region during drought and excess summer monsoon years

The climate effects of aerosols and climatological response of Indian summer monsoon circulation to the direct radiative effect of natural and anthropogenic aerosols is investigated using the Community Atmosphere Model (CAM3) that has comprehensive treatment of the aerosol-radiation interaction, coupled to two different ocean boundary conditions: (1) prescribed climatological sea surface temperatures (SSTs) and (2) an ocean model (CCSM3).As atmospheric general circulation models (GCMs) cannot simulate aerosol loadings directly, this GCM employs a chemical transport model driven by meteorological analysis fields to simulate different species of aerosols. The aerosol climatologies were derived from the simulations of the aerosol transport model.

Our analysis of a suite of climate simulations of a global atmospheric general circulation model (AGCM); the first without any aerosol forcing (henceforth referred to as the AGCM control or `NO_AERO' simulation) and with 5 different representations of aerosol direct radiative forcing, viz., i) total aerosols (10 species of sulphate, carbonaceous, dust and sea salt) referred to as `ALL_AERO', ii) scattering sulphate aerosols alone, `SUL_AERO' and iii) black carbon (soot) alone, `ABS_AERO'. In addition, we have carried out a simulation where the aerosols over the Indian region are prescribed from ISRO's ACE aerosol observations (`ACE_AERO') and a simulation with constant global aerosol simulation, `BKG_AERO'. All the integrations are of 10-year duration after spin-up. Aerosol direct impact due to total aerosols which are dominated by scattering aerosols (as by sulphate aerosols), causes significant reduction in summer monsoon precipitation over India.

Additionally, we have performed climate simulations of the coupled version of the GCM (CGCM, in which CAM3 is coupled to an active ocean model) with total aerosols (`CNTL') and with doubled anthropogenic absorbing aerosols such as black carbon and dust (`DABS_AERO'). These integrations were of 25-year duration after spin-up.

We studied the changes in wind and associated circulation parameters' climatology under different aerosol scenarios (with respect to the control simulation without aerosols (CNTL or NO_AERO)) by analyzing a set of climate simulations with mainly three types of aerosol direct radiative forcing viz. due to (i) total aerosols (AGCM ALL_AERO run), (ii) scattering aerosols (AGCM SUL_AERO run) and (iii) doubled amount of anthropogenic absorbing aerosols (CGCM DABS_AERO run).

Analysis of simulation with doubled anthropogenic aerosols suggests that anthropogenic and natural aerosols significantly affect the circulation but in nearly opposite ways; anthropogenic aerosols tend to have a net local warming effect and strengthening of rainfall and the circulation, but natural aerosols (scattering aerosols) tend to result in net cooling and weakening of cross equatorial monsoon circulation and rainfall.

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

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

Aerosol radiative forcing perturbation over Indian region alone is found to have both local and remote climate impacts. Analysis of simulation with observed climatological aerosol optical depths (ACE_AERO) shows that marked climate sensitivity occurs not only over the region of loading but over remote tropical regions as well. This suggests the degree of impact of regional aerosols on climate through circulation changes and warrants the need to prescribe realistic aerosol properties in strategic regions such as India.

The degree to which the aerosol impacts the radiative forcing depends on many factors including non-aerosol properties, e.g., presence of cloud and surface albedo. Aerosol forcing is also influenced notably by the surface albedo and cloudiness where it is highly impacted by the clouds which affect the aerosol direct radiative forcing at the TOA level. For example, studies of aerosol simulations show that changes in cloud amount associated with changes in rainfall can strongly limit temperature changes. The aerosol forcing, which includes reflection and absorption, is considerably augmented by the internal climate feedbacks to result in a much more complex spatial distribution than the forcing associated with greenhouse gases which is relatively uniform in space. With all different ways of prescribing aerosols, the simulations tend to reduce the total cloud amount over the continental convective regions. The region with maximum reduction in cloudiness (e.g., north of ~17°N) experiences increased surface solar absorption associated with weakened atmospheric solar depletion due to reduced cloudiness. This suggests that the aerosol-climate direct effect itself is highly non-linear because of aerosols feedback into cloud-radiation interaction, particularly over continental monsoon regions.

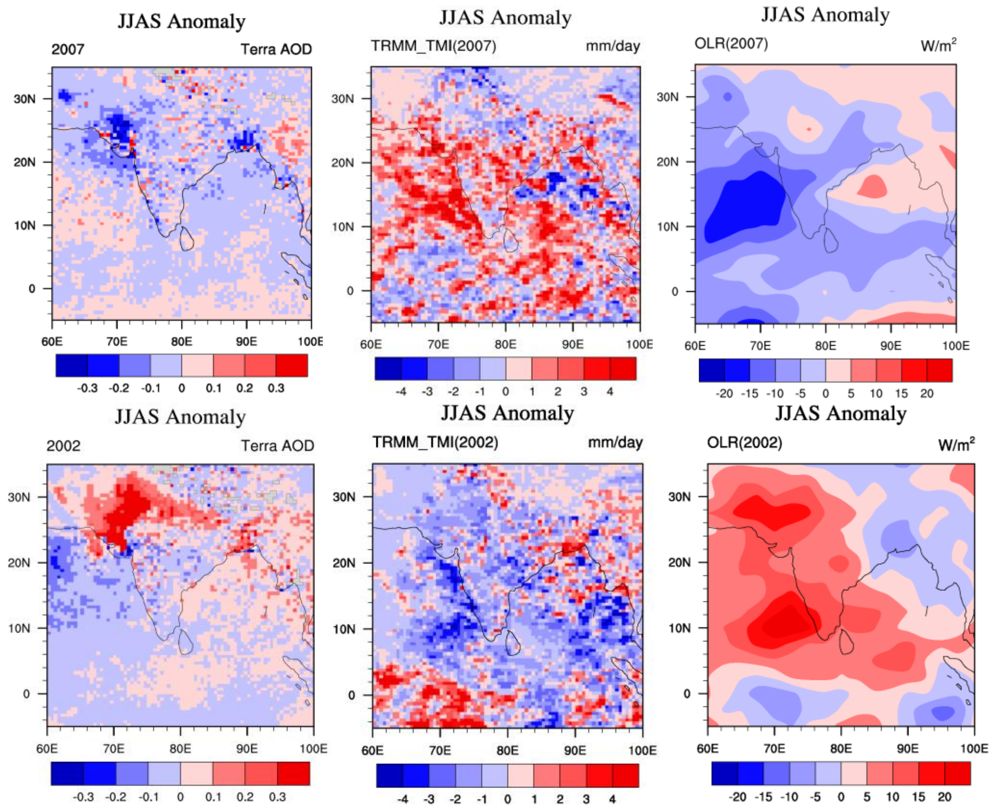

Figure 5.7 Seasonal (JJAS) anomalies of AOD, rainfall and OLR in a drought (top) and excess rainfall year (bottom).

Aerosol Optical Depth (AOD) at 550nm based on Level-2 data from MODIS (MODerate Resolution Imaging Spectroradiometer) remote sensor on-board Terra satellite (Collection 6) gridded to uniform grid is analyzed. In addition, level-3 MODIS cloud effective radius (CER) and cloud optical thickness (COT) since 2000, are also used. For the present analysis we have utilized Tropical Rainfall Measuring Mission (TRMM) 3G68 PR 2A25 and TMI 2A12 for the period 2000-2014. The daily values are computed from the hourly datasets. In addition, (i) outgoing long wave radiation (OLR) measured by the NOAA satellites, archived at http://www.cdc.noaa.gov as a proxy for tropical convection and (ii) ISMR its updates from Indian Institute of Tropical Meteorology (www.tropmet.in) are also analyzed.

All-India summer monsoon rainfall shows considerable interannual variability. This variability is also governed by cloud-radiative feedbacks. In view of this an attempt has been made to investigate the interannual variability in ISMR and its relationship with aerosol radiative effects over the Indian region in monsoon season (June-September, JJAS) using latest satellite derived aerosol datasets.

The AOD, rainfall and convection during 2002 drought monsoon are compared against those during 2007 (Figure 5.7). AOD varies drastically over the Indian region during both years, but the spatial loading of AOD during the drought year 2002 shows that there is persistence of high positive AOD anomalies. The analysis showed that even on monthly scale this difference is seen, i.e., high values of aerosol optical depth (AOD) occur during the drought monsoon month of July-2002, compared to July-2007 (not shown). Low rainfall amounts during the droughts are associated with an increase in AOD as compared to that in excess monsoon years. Thus, AOD anomalies appear to show near-inverse relationship with precipitation. AOD anomalies were highly positive in July of the drought years, 2002 and 2004 (when the normalized all-India rainfall anomalies were -4.07 and -1.25 respectively) and they were highly negative in July 2005 (when ISMR anomaly was 1.51). We have seen that aerosol and cloud characteristics exhibit strong association to rainfall variability and variability in cloud effective radius and cloud optical thickness is also found to be consistent with aerosol effect.

Sajani Surendran, Rajendran K and Arya V B

5.4 Climate change projections with high confidence using mulit-physics ensemble simulations

Analysis of present-day climatological rainfall simulations over the Indian region shows that while several CMIP5 simulations compare well with observation, a large group of models simulate less than 2 mm/day over the core monsoon region over the Indian subcontinent. Further, the biases in the mean monsoon simulation are found to be related to those in simulating mean seasonal variation of rainfall over the Asia-Pacific region, in addition to the large bias in simulating mean SSTs over the Indo-Pacific region.

Indian summer monsoon rainfall exhibits large interannual variability, which is significantly related to El Niño and equatorial Indian Ocean Oscillation (EQUINOO). The CMIP5 simulations show deficiency in capturing ISMR's link with both equatorial Pacific and Indian Ocean Indices. The projected changes in ISMR is also linked to the changes in these teleconnections which hampers the confidence in their future projections. In addition, the CMIP5 models show significant biases in simulating the present-day precipitation and sea surface temperature (SST) climatologies. In light of these issues, the level of confidence in the predictions made by these climate models for the Indian monsoon region remains limited which could be largely due to inadequacies in the representation of tropical high-resolution processes and the monsoon.

The model used in this study is the latest Meteorological Research Institute AGCM, MRI-AGCM3.2. The model was run at horizontal resolutions of T_L959 (MRI-AGCM3.2S, the 20-km model) and T_L319 (MRI-AGCM3.2H, the 60-km model). At 20-km resolution the model is run with two cumulus convection schemes that were used for the multi-physics ensemble simulations: prognostic Arakawa–Schubert (AS) cumulus convection scheme and a new cumulus convection scheme referred to as Yoshimura scheme (YS). The YS scheme is derived from Tiedtke scheme, but modified to represent all top-level cumulus plumes by interpolating two convective updrafts with maximum and minimum rates of turbulent entrainment and detrainment. At 60-km resolution the model is run with an addition cumulus convection scheme of Kain–Fritsch (KF) convection scheme. For the present-day climate simulation, these models were integrated in Atmospheric Model Intercomparison Project (AMIP)-type runs with the observed historical SST and sea ice data of HadISST.

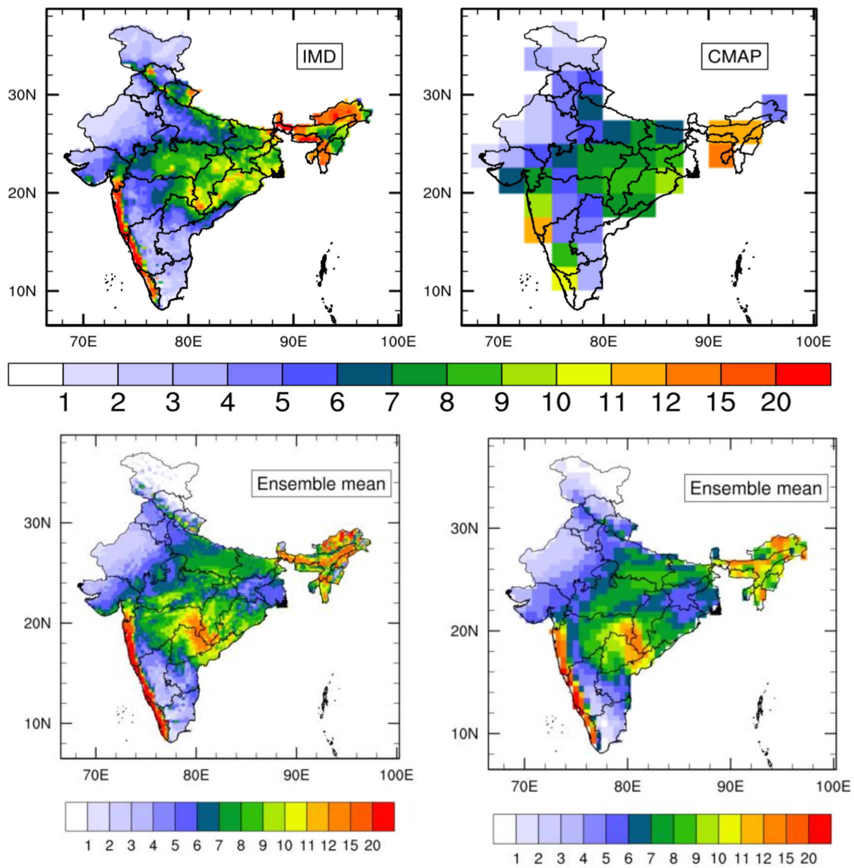

Figure 5.8 JJAS mean rainfall over India (mm day^{-1}) from observations of IMD (top-left) and CMAP (top-right) and MME simulation of present-day mean summer monsoon rainfall at 20-km (bottom-left) and 60-km (bottom-right) resolutions.

These multi physics ensemble runs are used to investigate the future projection of climate change patterns for India. The projections are determined through time-slice integrations of these models, which have shown marked fidelity under different configurations in representing the present-day climate of India in all seasons especially in summer, in simulating all the major features of the mean summer monsoon rainfall over India. For example, the ensemble mean simulation of summer (JJAS) monsoon rainfall over India at 20-km and 60-km resolutions are compared with respective observed climatology based on India Meteorological Department (IMD) data and CMAP rainfall data. The simulations show remarkable skill in capturing the regional rainfall maxima over central India, West-coast orographic region and the northeastern India (Figure 5.8).

The boundary SST data for the future were prepared by superposing: (1) future change in SST projected by CMIP5 multi-model ensemble (MME) mean; (2) the linear trend of SST projected by MME during 2075–2099; and (3) the detrended observed SST for the period 1979–2003. Future sea-ice distribution was obtained in a similar fashion. At 60-km resolution, we have used the projections with four different spatial patterns in sea surface temperature (SST) changes: one with the mean SST changes by the 28 models of the Coupled Model Inter comparison Project Phase 5 (CMIP5) under the Representative Concentration Pathways (RCP)-8.5

scenario, and the other three obtained from a cluster analysis, in which tropical SST anomalies derived from the 28 CMIP5 models were grouped.

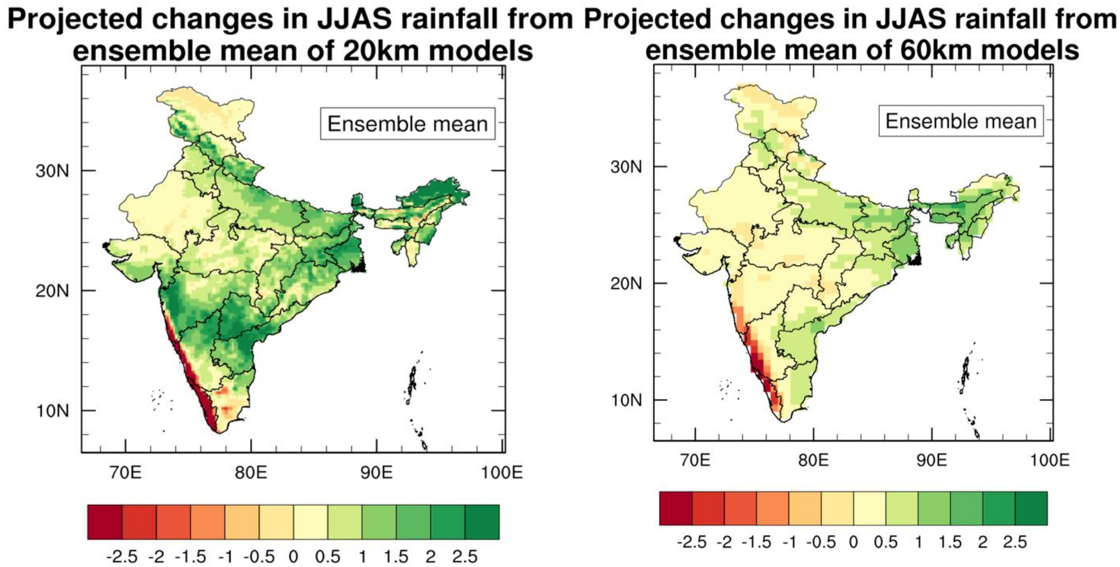

Figure 5.9 Projected future changes in JJAS mean rainfall over India (mm day^{-1}) by MME simulation at 20-km (left) and 60-km (right) resolutions.

Future projections by the MME of time-slice simulations at 20-km and 60-km resolutions under RCP8.5 global warming scenario show widespread but spatially varying increase in rainfall over the interior regions of peninsular, west central, central northeast and northeast India (Figure 5.9) and significant reduction in orographic rainfall over the west coast (consistent with the recent observed trends). Future projections of ISMR with high-resolution regional climate models or IPCC models project relatively uniform change in monsoon rainfall over India. Spatial distribution of the changes summer monsoon precipitation due to global warming shows larger spatial variability with more regional details in simulations with 20-km/60-km resolution (Figure 5.9). 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.

Over Western Ghats, the drastic reduction of wind by steep orography predominates over the moisture build-up effect (that causes enhanced rainfall under a warmer environment), in reducing the rainfall over the southern west coast. Over this region, faster rate of increase of temperature at higher levels as compared to lower levels (upper-tropospheric warming effect) leads to increased dry static energy and vertical gross moist static stability which in turn weakens the vertical ascent, large-scale monsoon circulation and thereby rainfall.

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5.5 Ultra-high resolution regional climate simulation for Lakshadweep Islands, through dynamical downscaling

The regional climate model simulation with very high resolution is necessary to represent Islands of few kilometer square areas. After several sensitivity studies, we have implemented a very high-resolution non-hydrostatic regional climate model (Weather Research and Forecasting (WRF) model) nested with global model. This dynamical downscaling framework is used to study the regional simulation of a Lakshadweep Island (indicated in the Figure 5.10).

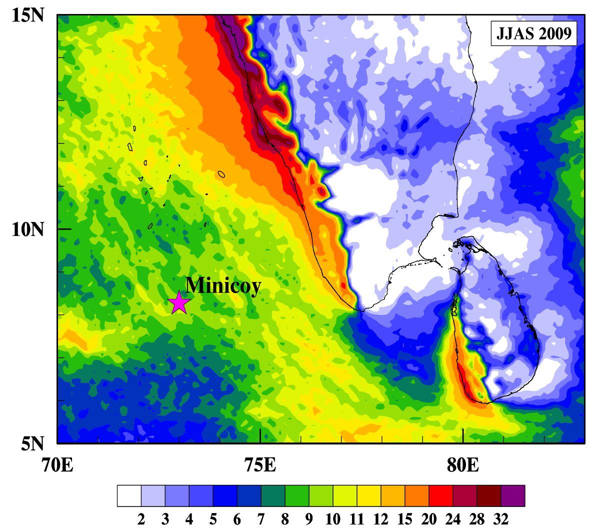

Figure 5.10 Regional model simulated June to September averaged rainfall (mm/day) over the southern part of Indian peninsula. Minicoy station is marked as star.

In order to test the skill in simulating present-day climate, we have performed a 12-month simulation of the year 2009 with 3 domains and best configuration tailored for Indian region; the model integration is started from 1st January and ends on 31st December. This regional model have high dependency on the lateral boundary forcing (LBF), here the reanalysis data is used as the LBF.

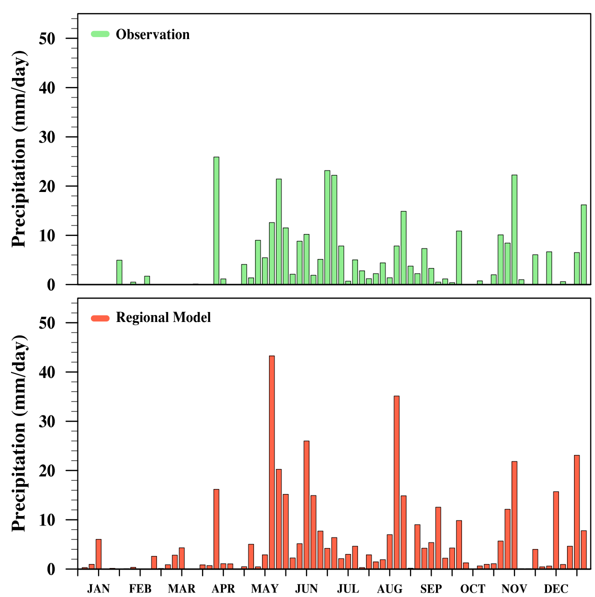

Figure 5.11 Pentad precipitation (mm/day) for the year 2009, from Minicoy Island station observation (top) and regional model simulation (bottom)

For validating the regional simulation, we have selected Minicoy (8.3°N, 73°E), which is one of the Lakshadweep Islands. The 2-meter temperature (T2M) and precipitation are compared with the 3-km resolution regional simulation for the year 2009. Figure 5.10 shows the model simulated June to September averaged rainfall (mm/day) over the peninsular India and Lakshadweep region, inside of which the Minicoy station is marked as star (Magenta). The simulated precipitation is well comparable with the TRMM observation (not shown). In Figure 5.11, the top panel shows the pentad precipitation from the Minicoy station observation and the bottom panel shows the model-simulated pentad precipitation for the year 2009. The model precipitation of Minicoy is computed based on the average of 4-grid point around the station location (8.3°N, 73°E). Despite a subtle tendency for the simulated to overestimate precipitation in some pentad, the simulation is well comparable with the

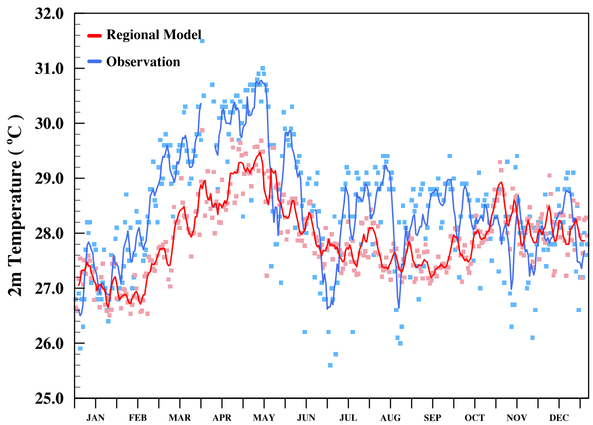

Figure 5.12 Daily 2-meter temperature (°C) for the year 2009, from Minicoy Island station observation (Blue) and regional model simulation (Red)

observation. The model simulated T2M of the island shows closer match with the observation (Figure 5.12). From February to May, the magnitude of simulated T2M is slightly underestimated and afterwards the simulation and observation follow closely. Hence, these results indicate that the model has reasonable fidelity in simulating the regional climate information at shorter time scales.

Similarly, longer period simulation needed to be analyzed to understand the model reliability in simulating the regional climate, which reveals numerous regional details and also this model can be employed for simulating the future projections. And we can extract many climate related variables from this very high-resolution regional climate model to find the changes in the climate and extremes. This is very useful for assessing potential impact of climate change of the respective region and is crucial for agriculture and economy as well as it helps to plan and execute the adaptability.

Jayasankar C B and Rajendran K

5.6 Diagnostic study of NCEP CFSv2 retrospective runs performed at CSIR-4PI

The vagaries of monsoon are complex; the climate modeling community considers it as challenging to understand and predict its behavior. Predominantly agrarian economy of India owes greatly to timely and adequate monsoon. Thus it is imperative to forecast monsoon to serve this purpose. Climate models are mathematical representation of climate by dividing earth, ocean and atmosphere into a grid. Coupling of ocean and atmosphere is advisable to obtain a realistic simulation of monsoon on various timescales.

As part of National Monsoon Mission of India, a fully coupled ocean-land-atmosphere model, National Centers for Environmental Prediction (NCEP) Climate Forecast System Version 2.0 (CFSv2) was installed and tested at the HPC in CSIR-4PI, Bangalore. The atmospheric component of the model is NCEP Global Forecast System (GFS) model with triangular truncation of 126 or 382 waves in horizontal and finite differencing in the vertical with 64 sigma-pressure hybrid layers. It is coupled to a four-layer NOAH Land Surface Model and two-layer Sea Ice Model. The oceanic component is Modular Ocean Model version 4 (MOM4).

The model is integrated with five different initial conditions; 21st April, 26th April, 01st May, 06th May and 11th May and this 5-member ensemble runs are analyzed for Indian summer monsoon (June to September) season.

Figure 5.13 shows the JJAS climatology of the five ensemble members along with corresponding observed climatology based on GPCP data for the period 1979-2016.The climatology shows remarkable skill in simulating the spatial distribution of rainfall over India, although there is dry bias prevalent over land.

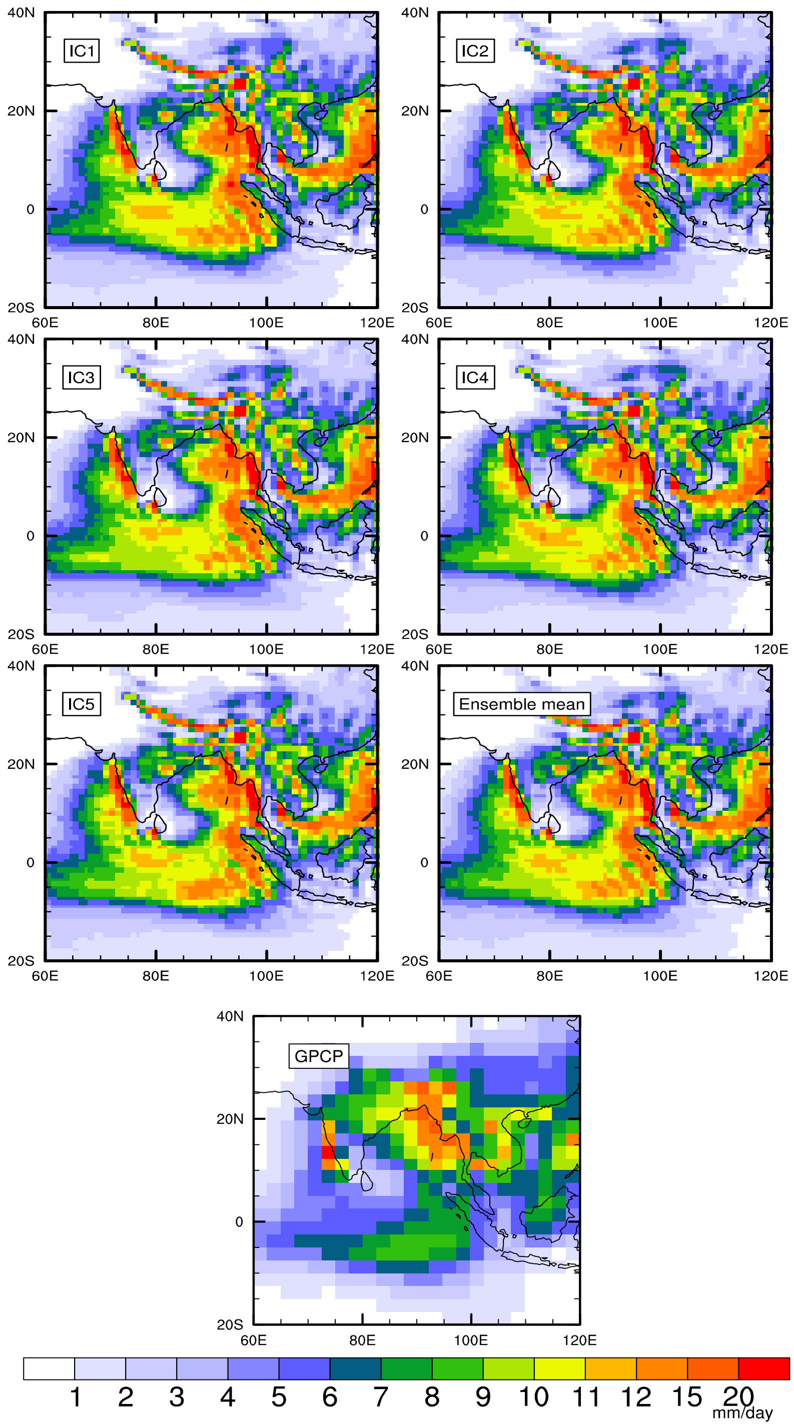

Figure 5.13 JJAS rainfall climatology for various initial conditions (IC1: 21st April, IC2: 26th April, IC3: 1st May, IC4: 6th May, IC5: 11th May), ensemble mean and observation (TRMM 3B43) for the period 1979-2015.

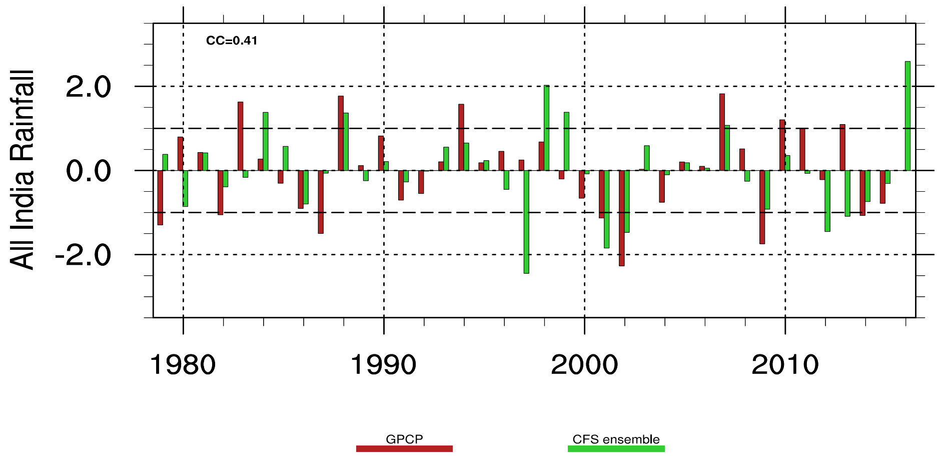

Figure 5.14 Interannual variability (IAV) of all-India summer monsoon rainfall (ISMR) during 1979-2016 in ensemble mean of NCEP CFSv2 retrospective runs and GPCP observed rainfall.

The interannual variability of the model simulation helps in understanding how well it can capture the summer monsoon variability and its teleconnections with El Niño-Southern Oscillation (ENSO), Equatorial Indian Ocean Oscillation (EQUINOO) etc. The standardized anomaly of all India averaged rainfall of the model is compared with that of observation (GPCP) for the period 1979-2016. Figure 5.14 shows the interannual variability of Indian summer monsoon rainfall. The data shows a correlation coefficient of 0.41 which is a measure of the fidelity of the model in simulating the interannual variability. Thus, it is seen that there exists a lot of scope for improving the skill of seasonal prediction of the model.

Stella Jes Varghese, Sajani Surendran and Rajendran K

5.7 Aerosol-Cloud relationship and aerosol indirect effect on clouds

Aerosols are tiny floating particles (liquid or solid) in the atmosphere. These particles alter earth radiation budget by scattering and absorbing the solar radiation that energize the formation of clouds. Our study investigates the aerosol-precipitation interactions over Indian region during contrasting monsoon years. In order to understand the aerosol-precipitation relationship the knowledge of the interaction between aerosols-clouds are inevitable.

To monitor atmospheric aerosols, the best possible method is through satellite measurement, because the ground-based measurements (Lidar and Sun photometer) and in-situ measurements (aircraft and balloons) are very limited in space and time and these aerosol particles transport over long distance from the source region.

The present study uses latest version of various satellite derived aerosol product such as MODIS (MODerate Resolution Imaging Spectro-radiometer). The aerosol parameter we analyzed for this study is aerosol optical depth (AOD), which is the measure of how much aerosol exists in the atmosphere. AOD has been estimated based on 550nm Level-2 (swath data) MODIS data. MODIS atmospheric aerosol product provides full global coverage of aerosol properties from Dark Target and Deep Blue algorithm. The frequency of MODIS Level-2 data is 144 files per day. Each granule is binned and averaged to uniform grid to make daily data at 0.5^0 x 0.5^0 resolution. Cloud properties such as Cloud Effective Radius (CER), Cloud Optical Thickness (COT), Cloud Top Height (CTH) are analyzed using MODIS Level-3 processed data at 1°×1°resolution.

Tropical Rainfall Measuring Mission (TRMM) derived daily and monthly data for the period 2000-2014 is used. Daily and monthly interpolated OLR at 2.5°×2.5°resolution from NOAA satellites is also utilized. In addition, ERA-Interim circulation dataset at 0.5°×0.5°resolution is also used for this study. To analyze the latent heat profile, we used TRMM monthly latent heat product. This data is available from December 1997 to June 2011 at horizontal resolution of 0.5°.

JJAS climatology of AOD shows high values of AOD over the Indo-Gangetic plains (Figure 5.15), where most of the industries are located and are densely populated. During monsoon period low-level winds are stronger and transports marine aerosols into the land region. OLR serves as the proxy for the rainfall.

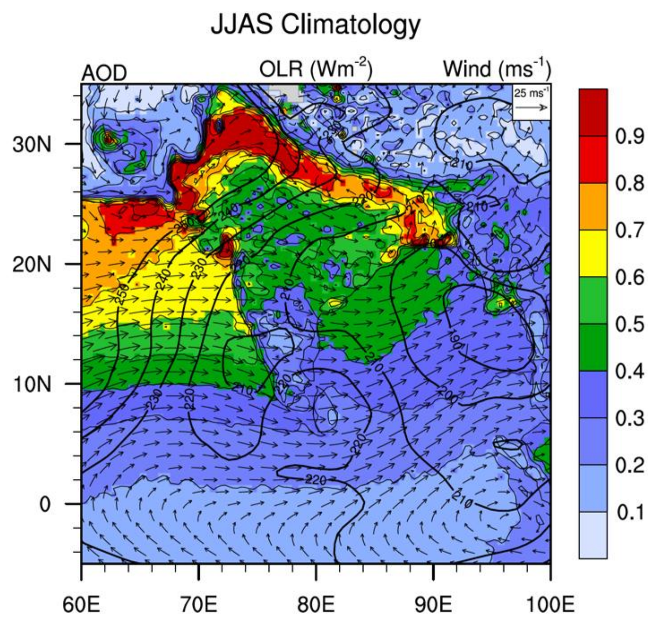

Figure 5.15 JJAS Climatology of AOD, OLR and winds for the period 2000-2014. The shaded contours corresponding to AOD, on which overlaid are winds (arrows) and convection (OLR in contour lines).

Aerosols can interact with clouds and precipitation in many ways, acting either as cloud condensation (CCN) or ice nuclei (IN), or as absorbing particles, redistributing solar energy as thermal energy inside cloud layers. In the context of global climate change, aerosol and cloud interactions remain the most uncertain factor because the mechanisms that link aerosol to cloud properties change are carried out through processes that are not well understood. Investigations involving cloud and aerosol showed positive, negative or no correlation between aerosol and cloud properties in general and cloud water path particularly. It is observed that for AOD value below the peak ($AOD_{\mathbf{peak}}$), mean cloud properties especially the cloud water path (CWP), and mean AOD are positively correlated. The correlation between mean CWP and mean AOD is negative for aerosol loading above $AOD_{\mathbf{peak}}$.

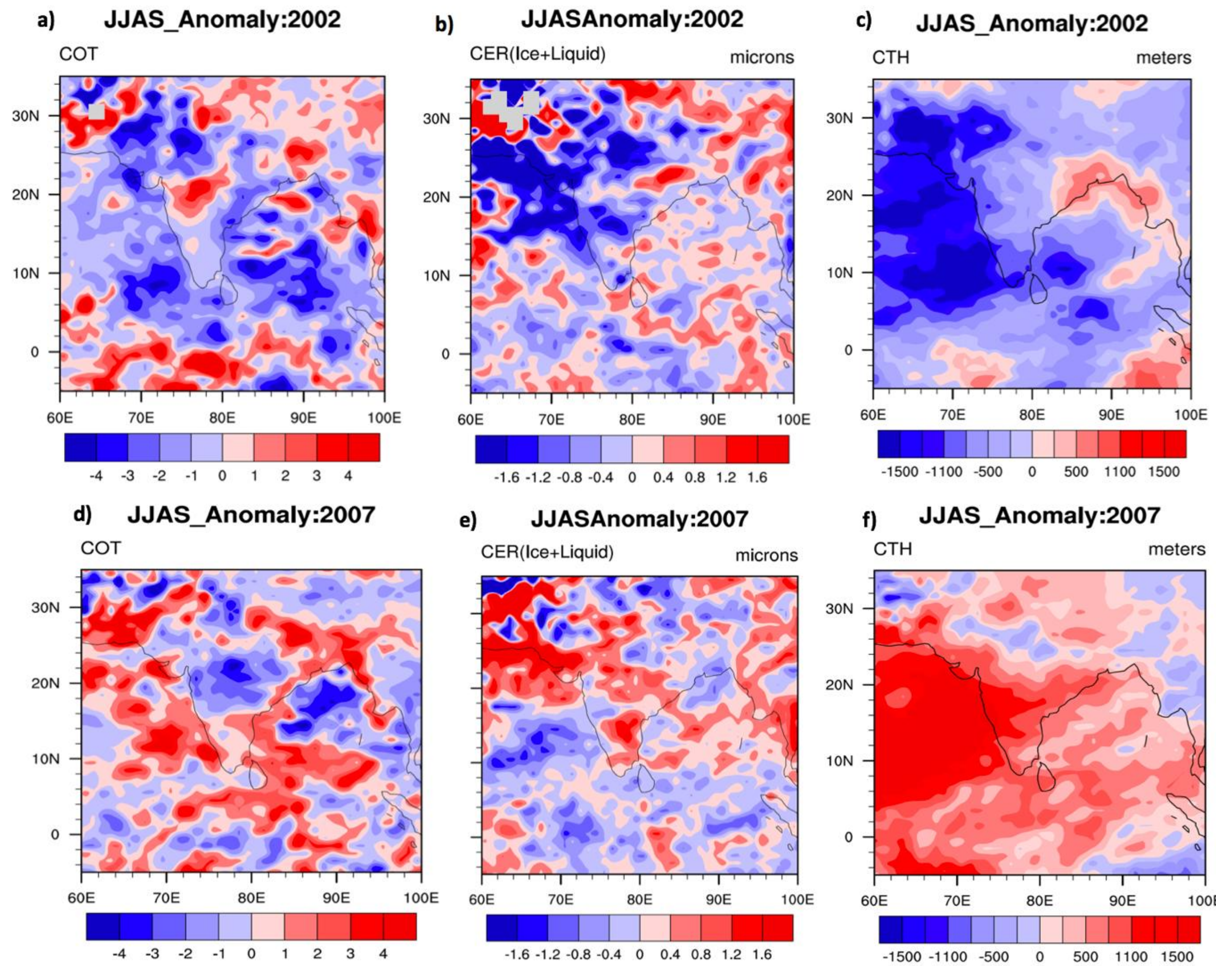

Figure 5.16 JJAS anomalies of cloud properties such as cloud optical thickness (COT), cloud effective radius (CER) and cloud top height (CTH) during 2002 drought year (a-c) and excess monsoon of 2007 (d-f).

The comparison of JJAS anomalies of COT, CER and CTH during drought monsoon 2002 and excess monsoon 2007 is shown in Figure 5.16. As aerosols are effective CCN, their variability is expected to modulate the cloud optical properties such as CER and COT. Overall, anomalies are significantly lower in 2002 while AODs are higher, implying an association between aerosols and clouds, and possibly an evidence for the indirect radiative effect of aerosols on clouds. These results emphasize the fact that when aerosols become abundant, they can decrease the cloud effective radius. COT and CTH are also less. More analysis is being done to understand this aspect.

Arya V B and Sajani Surendran

5.8 Preliminary study of convectively coupled equatorial waves

Convectively Coupled Equatorial Waves (CCEWs) are important class of propagating disturbances which affect tropical mean convection and climate. They produce prominent intraseasonal fluctuations over tropics. Some of them travel all around the world zonally and some move in pole ward direction from equator. Proper understanding of these waves is essential for the prediction of variability at all the time scales.

Outgoing Long wave Radiation (OLR) measurement is the easiest way to track the convective components of convectively coupled waves. OLR interpreted in a large scale sense acts as a proxy for large areas of cloudiness/convection. In the tropics, a low OLR value represents an active convection whereas a high OLR value represents a suppressed convection. So in this study we are using OLR as a proxy for convection. As an initial step we focus on 30-70 day mode before studying the CCEWs.

Here we use daily interpolated OLR of 2.5^{o} resolution from NOAA. From daily OLR, 30-70 day anomaly was filtered out. It is evident from figures that there are well defined northward propagations of convective anomalies from equator region. We take a wet year (excess rainfall year,1988) and a dry year (deficit rainfall year,1982) to see the contrasting behaviours of intraseasonal oscillations (ISOs).

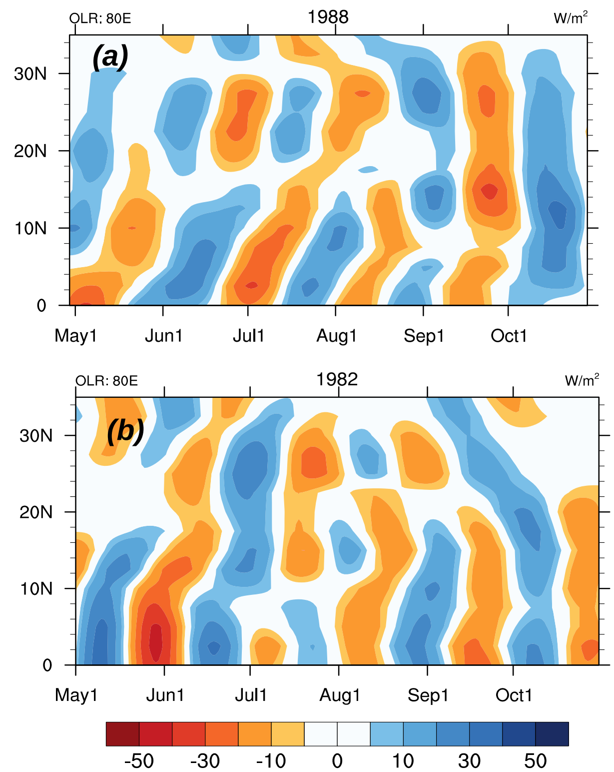

Figure 5.17 30-70 day OLR anomalies at 80^{o}E longitude in a) 1988 and b) 1982.

Figure 5.17 represents 30-70 day filtered OLR anomalies of 1988(an excess monsoon year) and 1982 (a deficit monsoon year) during May to October. Here red contours represent negative anomalies whereas blue contours represent positive anomalies. These coherent bands of positive and negative anomalies represent break and active phases respectively. In 1988, starting from May, a convective phase moves from equator to north and it reaches land by the end of May. This coincides with the monsoon onset. Alternate phases depict the occurrence of near-inverse anomalies between continental India (~15^{o}-30^{o}N) and equatorial region (0^{o}-10^{o}N). In 1988, propagations are clearer, coherent and with longer period compared to 1982 during which the propagations are either fast or incoherent.

Nirmala J Nair, Rajendran K and Sajani Surendran

5.8 An algorithm for TRMM PR spectral latent heating retrieval

Even though Tropical convective precipitation systems have major role in the global climate system, our understanding of it is very poor because of not only its complexity in spatial and vertical distribution but also having very short lifespan for such systems. Diabatic heating estimates used in this study are from TRMM – PR utilizing the Spectral Latent Heat (SLH) algorithm. TRMM satellite launched in December 1997 is having a space borne precipitation radar, which has a 13.8GHz Ku band frequency. It is having temporal resolution of around 16 orbits per day and horizontal resolution of around 5 km. Its swath width is around 247 km consists 49 angle bins. One granule of PR data is one orbit which is having around 9140 scans. The latent heat profiles have 19 layers at the fixed heights of 0.0-0.5 km, 0.5-1 km, 1-2 km etc. up to 17-18km.

We have taken this Level-2 swath data and converted it into gridded data using nearest neighbor algorithm. Here for distance calculations we used great circle distance formula. The resultant data is having spatial resolution of 0.25 degree and we keep the temporal and vertical resolution same as the original data for not to miss even short life convective systems. Using this data, we analyze the four dimensional distributions (including time) of the apparent heat source (Q_1) – radiative heating (Q_R), apparent moisture sink (Q_2) and Latent heating in relation with the near surface precipitation rate and storm top height. This resultant data set clearly explains the major characteristics of tropical convection.

Also we develop a vertically integrated $Q_1 - Q_R$, Q_2 and Latent Heat utilizing a new algorithm build on a time based RMS weighting function. Figure 5.18 is the monthly average of weighted vertical Integrating $Q_1 - Q_R$ for the month of July 2003. Here we have taken daily average of the gridded data and then for each spatial grid we have computed a RMS value based on 31 days of July and by taking this RMS value as weighting function for estimating the daily vertical Integration. The pattern explains the major features of tropical convection such as ITCZ distribution including Indian summer monsoon convective centres.

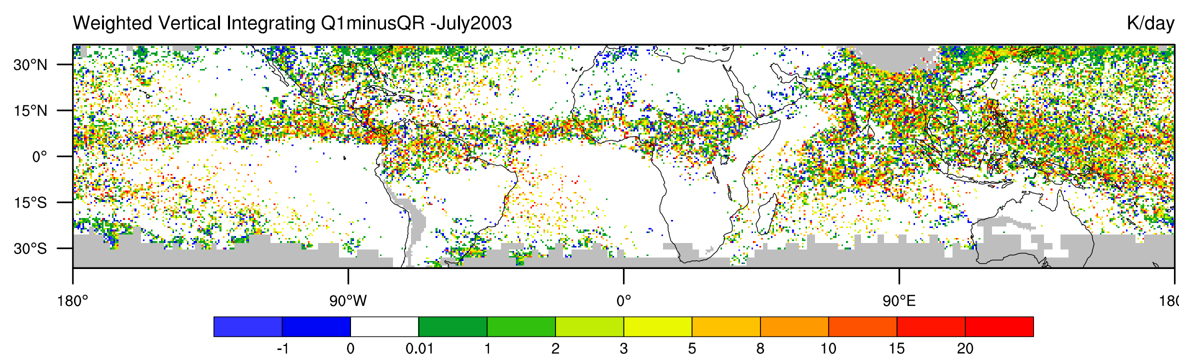

Figure 5.18 is the monthly average of weighted vertical Integrating $Q_1 - Q_R$ for the month of July 2003

This compares well with the monthly averaged near surface precipitation rate for the same month. From this distribution we could explain the tropical precipitating cloud systems. So in future we plan to apply these techniques for all the remaining data set so that we could analyze the tropical convection structure and explain its generic aspects.

Athira U Nambeesan, Rajendran K and Sajani Surendran

6
SOLID EARTH MODELLING PROGRAMME

Solid Earth Modelling Programme's (SEMP) research focus is integration of GNSS, Computational seismology, tectonics, geology, ground motion modeling for quantification of natural hazard (earthquake, landslides, extreme events) specific to Indian subcontinent (Indian Himalayas, Northeast India and Rigid Indian Plate). This programme is multidisciplinary (Engineering and Earth Sciences) and multi-component. Some of the major contributions during the year 2015-2016 are establishment of Multi-parameter (GNSS and Broadband seismic) observation network in Kashmir Himalaya, GPS based landslide deformation modelling, preliminary estimate of Indian reference frame, spatio-temporal variability of GPS-PWV and GPS-TEC specific to Indian subcontinent. Broadband seismic network in Kashmir Himalaya gave first crustal shear velocity model of the intermontane Kashmir valley longitudinally carved within the northwestern Great Himalaya barely 70 km to the southeast of the Hazara syntaxis. In addition Unified Scaling Law for Earthquake (UCLE) has been applied to model the earthquake hazard and convolved with population density to image the risk model of Gujarat. Probabilistic earthquake hazard assessment in Peninsular India has been completed. During this period, two PhD's were awarded and the group has about 150 citations for their research publications. We network with large number of premier institutions in the country and abroad and scientists of this group serve as expert members in several national and international committees.

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6.1 Estimation of Indian reference frame from CGPS network analysis

Indian GPS network data from GPS sites established by us and our collaborators are analysed for a period of 17 years (1997-2014) using GAMIT/GLOBK along with IGS stations as shown in figure 1. Daily loose GAMIT solutions with their covariance matrix were obtained which are then combined using GLORG for reference frame definition by stabilizing the IGS sites to their ITRF08 coordinates and velocities. To account for errors in modeling the orbits and atmosphere in the long time series and time correlated sources of errors in position estimates including monument instability, we included random-walk noise at the level of 2 mm/year in the coordinates for all stations during the GLORG reference frame stabilization. The positions and velocities of all the GPS sites were thus obtained in the ITRF08 reference frame. GPS times series in North, East, Upthus obtained for one sample site located in Hanle, Ladakh is given in figure 6.2. ITRF2008 velocities thus estimated from rigorous global analysis along with error ellipses are given for all the sites in figure 6.1.

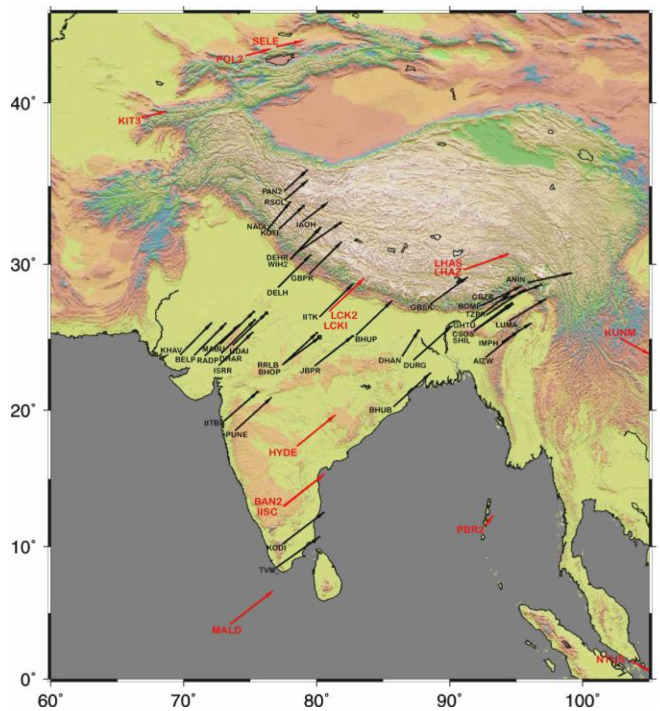


Figure 6.1 ITRF2008 velocities estimated from GPS global data analysis for 17 year period

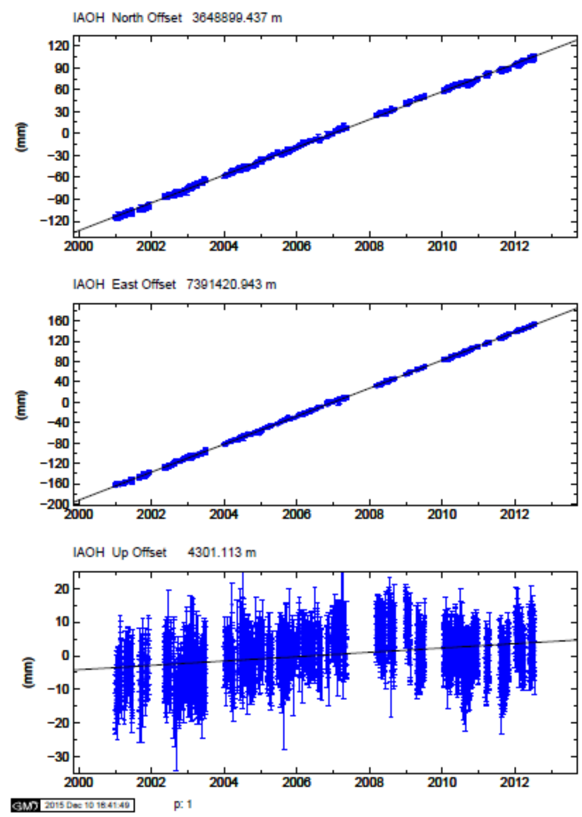


Figure 6.2 North, East and Up times series of Hanle station from 2000-2012

Using the ITRF08 GPS site positions and velocities of sites located onrigid Indian plate and Maldives IGS site located in Indian Plate, Indian reference frame is estimated using GLORG and the euler pole of rotation of Indian Plate in ITRF2008 thus estimated is located at 52.449±0.225°N, 1.145±1.200°E with angular velocity of 0.499375±0.004731.

Sridevi Jade and Shrungeshwar T S

6.2 Inverse modelling of GPS horizontal surface velocities in Northeast India

GPS derived velocity field in Shillong Plateau, Assam Valley, Eastern Himalaya and Indo-Burmese Arc using GPS measurements spanning 11 years (2002-2013) is used for modelling the region-specific deformation field. Inverse modelling is based on the Okada dislocation theory and weighted least-square inversion. The best fit model is the one for which the residual between the observed and modelled displacements is minimal. Computations are performed iteratively yielding the final dislocation parameters that best match the GPS observed surface deformation pattern. The inverse model thus obtained gives constraints on the geometry and the slip of the sub-surface dislocations which cause the surface horizontal deformation. These models give significant insights into the strain accumulation and stress buildup in this tectonically active region.

Sridevi Jade, Shrungeshwar T S, Prakash Barman

6.3 Computation of strain rates from GPS displacements

GPS derived ground displacements at tectonic plate, regional and local scale are used to study the tectonic effects (crustal deformation) as well as kinematics of a single landslide. Crustal deformation is determined from analysis of GPS ground observations from a continuous and campaign network of GPS stations spatially distributed over the study region. Precise time series of positions/displacements in north, east and up obtained from the analysis of GPS data is used to determine the crustal strain rates at tectonic scale, regional strain rates across faults and slow relative motion of landslide at a local scale. A set of multi-temporal coordinates of experimental points (EPs) are used to get the information on the kinematics. Strain rates at different scale i.e., from tectonic plate, regional and local scale can be estimated from a given GPS displacements (or velocity) data set. The GPS strain analysis is carried out using Lagrangian approach, wherein it starts with an initial configuration and projects to a final deformed configuration. Two dimensional deformation rate field is calculated in a region, starting from the velocities of a series of observational points (EPs) adequately distributed in this region. The input data are the velocities derived by the processing of field GPS measurements. At each location, a uniform strain rate field is assumed, and a least squares inversion is performed over strain velocity solutions and their covariance for six unknowns to estimate the strain. The obtained deformation pattern is a set of the principal components of the strain calculated on a regular grid. A trial run to compute the strain rate from the published GPS displacements and velocities has been performed.

Pavithra N R and Sridevi Jade

6.4 Spatial and temporal variability of GPS derived PWV

The radio signals transmitted from GPS satellites to the ground receivers are delayed in the atmosphere and such delay in the troposphere i.e., Zenith Total Delay (ZTD) gives a crucial parameter to estimate the Precipitable Water Vapour (PWV) from GPS data. Zenith Total Delay (ZTD) consists of Zenith Hydrostatic Delay (ZHD) and Zenith Wet Delay (ZWD).To derive PWV from ZTD, required surface pressure and temperature values were taken from Meteorological sensors collocated adjacent to GPS receivers. The Meteorological sensors record temperature and pressure at a 5 sec interval with 0.2ppm accuracy. The errors associated with GPS PWV estimates depend on the (i) uncertainty associated with estimation of Zenith Total Delay (ZTD) from GPS observations, (ii) accuracy of the observed surface pressure and temperature values recorded by meteorological sensors and (iii) weighted mean temperature of the atmosphere. Several studies were conducted to estimate the absolute and relative errors in PWV associated with errors in ZTD, P and T_m by taking partial derivatives of the above equations and concluded that the accuracy of PWV estimated by GPS is about 2-3 mm at various locations of the Indian subcontinent. For dry sites with low PWV values, the ZTD is almost completely due to ZHD and small errors in ZTD and ZHD would contribute to large errors in ZWD i.e., (ZTD-ZHD) and in the retrieval of GPS PWV. GPS PWV thus estimated for the Indian network for all the GPS sites collocated with met sensors during 2001-2013 is given in figure 6.3.

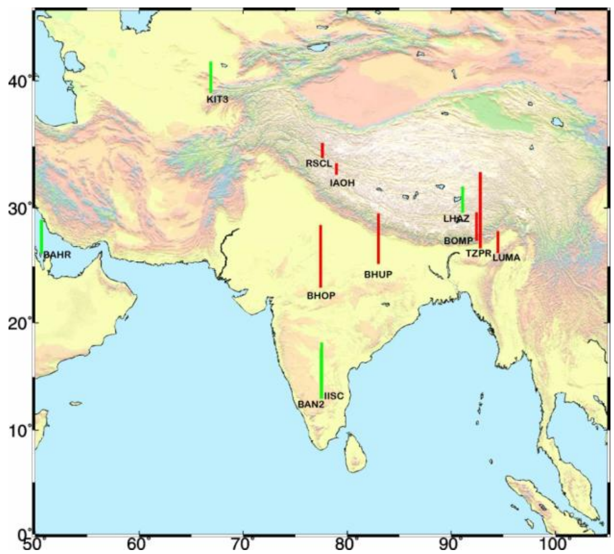


Figure 6.3 Mean GPS-PWV column estimated for a 13 yr period at GPS sites with collocated Met-Sensors

Mean GPS PWV (figure 6.5) of Indian GPS sites varies between 6mm at high altitude (4500m) Hanle site to 44 mm at Tezpur site in northeast India located almost at the (120m) MSL height.

Interannual, seasonal, diurnal variability of PWV has been studied for all the sites and results for high altitude Hanle site for a period of 8 years are dicussed here. The Yearly mean PWV of Hanle site is ~ 4.2 mm for all the years except for slightly higher PWV of ~4.9 mm for 2006 and lower PWV for

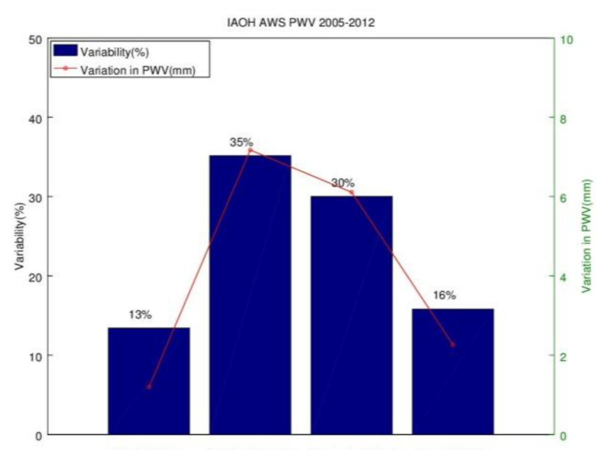


Figure 6.4 Inter-seasonal variability of GPS-PWV for 8 year period

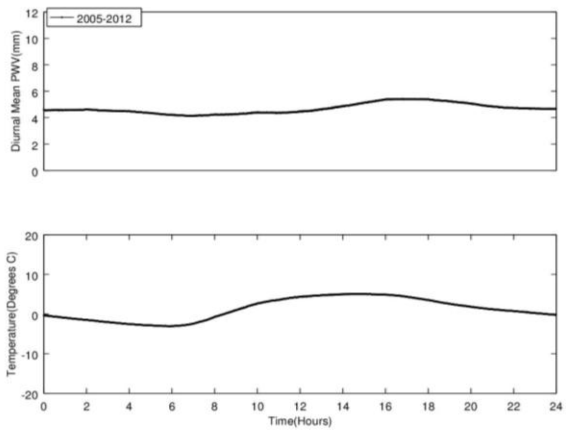


Figure 6.5 Diurnal Variability of GPS-PWV estimated at 30 sec interval for a eight year period along with surface temperature recorded at 5 sec interval.

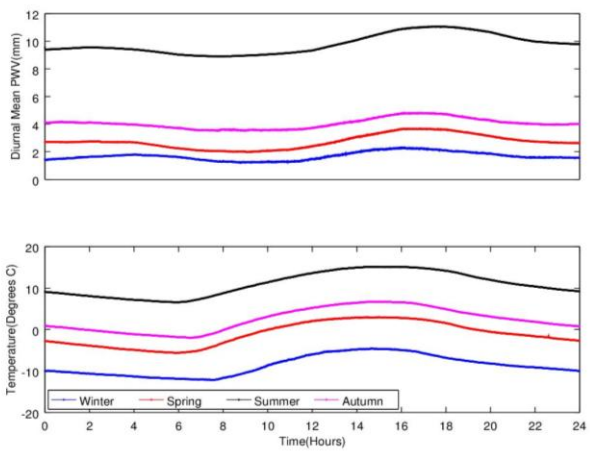


Figure 6.6 Seasonal diurnal variability of GPS PWV and surface temperature

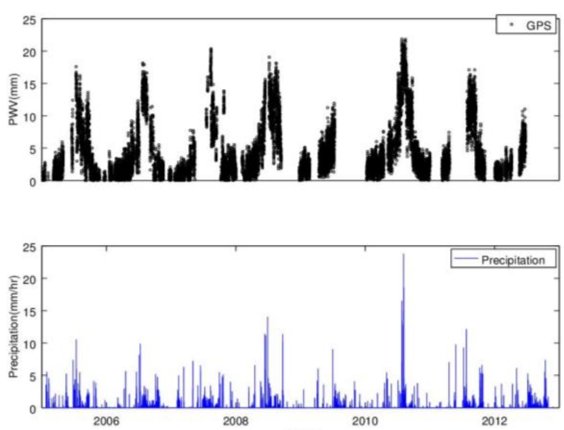


Figure 6.7 GPS-PWV at 30 sec interval for eight year period along with TRMM precipitation.

~3.6mm for 2009. High average PWV for 2006 coincides with the record highest rainfall of 131 mm received at Hanle during the year. Low PWV in 2009 is due to the low rainfall of ~80 mm during this year. Rest of the years received average rainfall of 105 mm and hence the PWV is consistent with this value. The season to season variability of GPS PWV (2005-2012) is plotted in figure 6.4. The results indicate percentage variability between winter-spring-autumn is almost half of the value of Spring-Summer-autumn which is typical of high altitude sites with dry weather.

GPS-PWV is estimated every 30 sec for the eight year period (2005-2012) and has been plotted in the figure 6.5to study the diurnal variability of PWV at Hanle. PWV at this site indicates a very distinct diurnal variability which peaks at 16-18 hr of the day with a low value at 6-8 hr which is consistent with the day time temperatures in this region. Season wise diurnal variability is also plotted along with the temperature in figure 6.6.

Precipitation (mm/hr) is estimated from The Tropical Rainfall Measuring Mission (TRMM, 3B41RT version 7data products from http://gdata1.sci.gsfc.nasa.gov/) with spatial resolution of 0.25 X 0.25° grid averaged over Hanle site. This data is compared with 30s interval GPS PWV estimated at Hanle and is shown in figure 6.7 which indicates a similar trend between the two parameters during the eight year period. The peak values of precipitation coincide with the peak values of 30s PWV estimated from GPS. The high precipitation for all the years occurs during July–August which is due to high moisture content n the atmosphere as a result of high temperature and relative humidity at site during these months.

6.5 Validation of water vapor retrieval from MODIS using GPS PWV over IAO-Hanle, in trans-Himalayan Region

Integrated PWV retrieved from Moderate Resolution Imaging Spectro-radiometer (MODIS) in near-infrared channels is examined with the PWV estimated from the Global Positioning System (GPS) data with measured surface temperature and pressure values over Hanle, located at a high-altitude (~4500m) trans-Himalayan region. Since the accuracy of MODIS derived PWV over the large elevated topography of the region is not well studied, the present work focus is on the validation of MODIS PWV using the GPS data during 2005-2012.

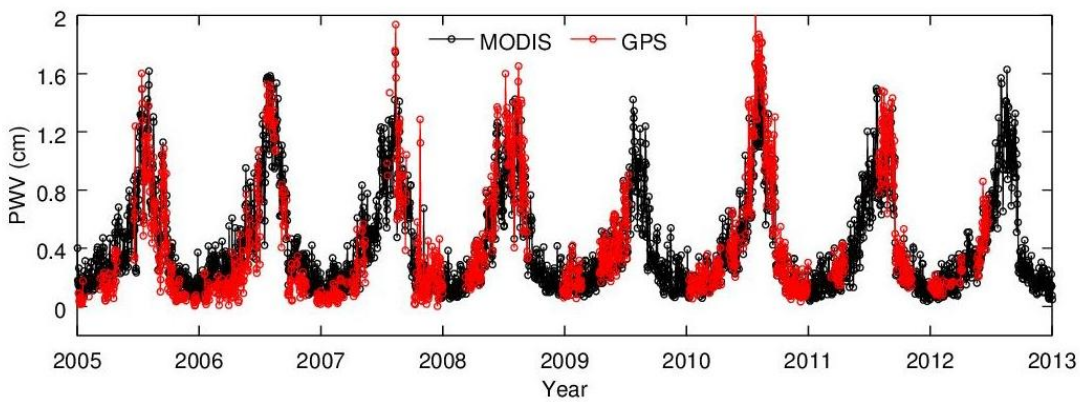


Figure 6.8 Daily PWV(cm) between the MODIS and GPS data

The study reveals that MODIS PWV compares well with the GPS PWV data with bias -0.018 cm, root mean square error (RMSE) 0.137 cm and coefficient of determination (R^2) 0.91. The two types of data products are compared (Figure 6.8) on short (daily) and long temporal (monthly-seasonal) scales in order to evaluate the seasonal dependence of PWV. The peak values of PWV from MODIS and GPS data at the site varied from 1.7 to 2.05 cm and 1.2 to 1.4 cm as the daily and the monthly means, respectively which occurred during August. However, the seasonal peak of PWV occurred during summer as 0.88 and 0.97cm for MODIS and GPS data, respectively. The present study noticed that about 85% of the total PWV estimated from MODIS as well as GPS data lies below 1.0 cm over the site. The seasonal study of PWV reveals that MODIS data is found to be underestimating the PWV when compared to GPS data with bias -0.095 cm and RMSE 0.215 cm particularly during summer. This is due to dry and high-altitude terrain of Hanle particularly during summer months. However, there are marginal differences (bias varied from 0.007 to 0.017 cm) during the remaining seasons and seasonally R^2 varies from 0.62 to 0.87. Total rainfall over Hanle is recorded from the AWS installed at the site and the measured rainfall during year 2006 and 2010 follows similar trend with good correlation when compared with MODIS and GPS PWV estimated at the site. PWV estimated at Hanle for the year 2010 indicate a peak PWV of ~1.4 cm during August with daily peak value of 2.05 cm which coincides during Leh cloud-burst in August 2010.

Ningombam S, Sridevi Jade and Shrungeshwara T S

6.6 MODIS, ERA-Interim and GPS PWV

PWV is the total water vapor contained in an air column from the Earth's surface to the top of the atmosphere. Atmospheric water vapor is highly variable in both space and time across Earth, and knowledge of distribution of water vapor is essential in understanding weather and climate studies. The Moderate Resolution Imaging Spectro-radiometer (MODIS) is the first space instrument to obtain PWV with near-infrared (NIR) bands and the traditional IR bands, which provides an opportunity to monitor PWV with wide coverage during both daytime and night time. However, the accuracy of PWV Measurements obtained with IR bands is much lower than that with NIR bands. Global Positioning System (GPS) is another practical tool for measuring PWV on a global basis, which uses the delay in radio signals due to the permanent dipole moment of atmospheric water vapor molecules to infer PWV The advantages of the GPS-derived PWV are continuous measurements in all weather conditions, high accuracy long-term stability and low cost. In addition to GPS and MODIS, ECMWF (European Centre for Medium Range Weather Forecast) data with good spatial resolution ($0.75^0 \times 0.75^0$) is used to retrieve PWV. In this study PWV is retrieved using MODIS NIR with $1^0 \times 1^0$ resolution in day time and ERA-Interim (ECMWRF) with $0.75^0 \times 0.75^0$ horizontal resolution. Gridded data from ECMWF and MODIS are interpolated to the specific latitude and longitude of GPS station to obtain precise PWV values. PWV thus obtained is compared with GPS-PWV estimated for every 2 hours using continuous GPS data in India for a period of 11 years (2002-2013). Sample comparison plot for Bangalore IGS station is given in the Figure 6.9.

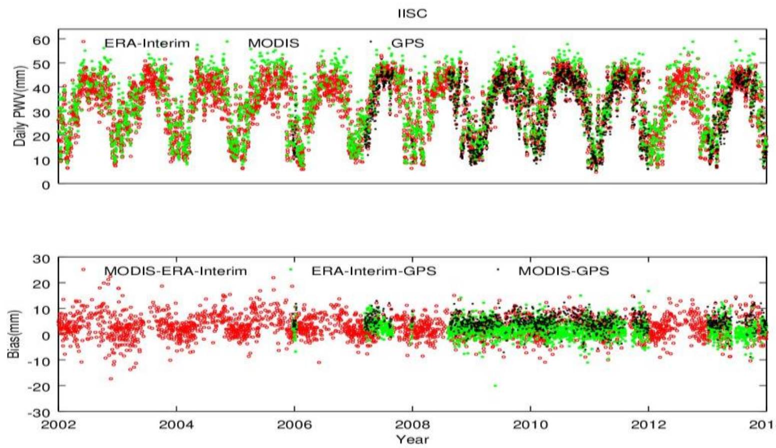


Figure 6.9 Comparison of MODIS, ERA-Interim and GPS PWV (Perceptible Water Vapor) at IISC, IGS site located at Bangalore for a 12 year period.

Sridevi Jade, Boddapati Anil and Shrungeshwara T S

6.7 Assimilation of GPS PWV and ZTD in WRF-NWP model

Accurate and reliable weather forecasting is important for agriculture, aviation and many other human activities. Accuracy of weather forecast can be improved by assimilation of atmospheric PWV into Numerical Weather Prediction (NWP) model. In Convective and Orographically-induced Precipitation Study (COPS) over Europe, assimilation of GPS ZTD has shown clear positive impact on the precipitation forecasting. In Turkey, assimilation of GPS PWV for three specific heavy snow case indicated reduction in the biases and improvement in precipitation forecasts. Impact of GPS-PWV and ZTD assimilation in Weather Research and Forecasting (WRF)-NWP model by Central Weather Bureau, Taiwan during typhoon Kalmaegi gave 29% reduction of the forecast error during first 6-hr rainfall forecast. In India, an attempt is made for the first time to assimilate PWV and ZTD estimated using nationwide GPS data into the WRF model. The WRF Model is a next-generation mesoscale NWP model designed for both atmospheric research and operational forecasting needs. WRF can generate atmospheric simulations using real data (observations, analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while providing recent advances in physics, numerics, and data assimilation. WRF is currently in operational use at NCEP, AFWA, and other centers. The accuracy of the WRF output will be assessed by comparing the model forecast data with in-situ observations. Any improvement in forecasting capability is highly desirable for Indian Agrarian economy. The experiment is expected to yield strengths and short-comings of the assimilation on forecast and also help to tune the WRF model for Indian region.

Sridevi Jade and Prakash Barman

6.8 GPS-TEC estimation

Four GPS observables, carrier phase delays L1 and L2 and code pseudorange group delays P1 and P2 expressed in range units are used for GPS TEC (Total Electron Content) estimation. GPS data analysis using GAMIT is used to extract the ionosphere delay of GPS observables from the one-way residuals for each PRN i.e. satellite after cleaning the data. These are used to derive the Slant Total Electron Content (STEC) and VTEC which is termed as TEC is given by

$TEC=VTEC= STEC\ (H_{ion}/L_{\theta})$

Where H_{ion} is the mean ionosphere thickness and L_{θ} is ray path length

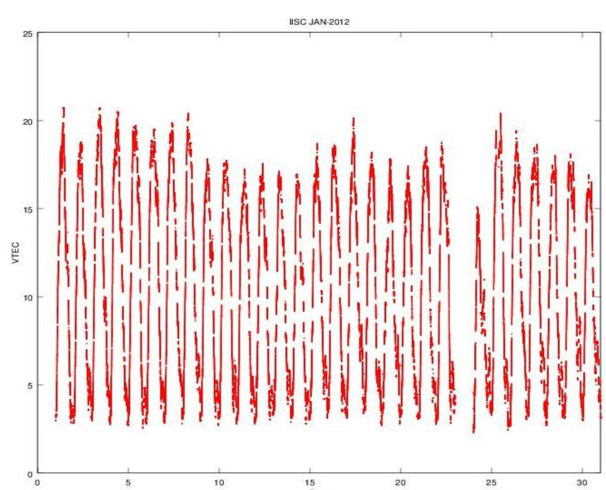


Figure 6.10 Daily variation of GPS TEC at IISC, Bangalore

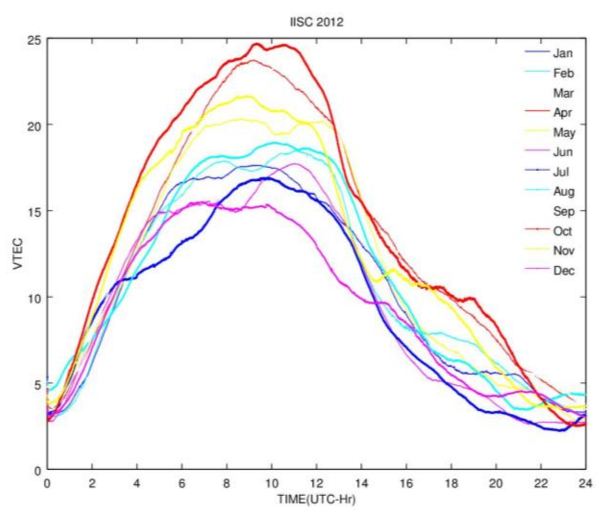


Figure 6.11 Seasonal and diurnal variation of GPS TEC at Bangalore

TEC thus estimated for Indian GPS sites is used to study the spatial, inter-annual, seasonal and diurnal variability of ionosphere over Indian subcontinent. Daily variability of TEC for a period of 30 days in January for IGS station in Bangalore is given in Figure 6.10. Diurnal and seasonal variability of GPS-TEC for a one year period is given in Figure 6.11 which indicates that the time of occurrence of diurnal peak of TEC varies with the season, This study gives significant insights into the variability of TEC which exhibits features like annual, semiannual and day-to-day variability, equatorial noon time variation and equatorial ionization anomaly. In-depth study of variability of GPS-TEC over Indian subcontinent is required to identify ionospheric anomalies and their association with seismic activity.

Sridevi Jade and Shrungeshwar T S

6.9 Establishment of continuous mode Global Navigation Satellite System (CGNSS) network in Kashmir Valley

Kashmir Valley lies in one of the most seismically active regions of India. The knowledge presently available on strain build-up, release and occurrence of earthquake is not adequate enough to assess the seismic vulnerability of the Kashmir valley. Strain build-up when combined with the seismic activity and geodynamics of the region gives information on seismic gaps. To estimate strain and surface deformation in Kashmir Himalayas, establishment of Continuous mode Global Navigation Satellite System (CGNSS) stations in Kashmir Valley is envisaged in collaboration with University of Kashmir, Srinagar, Jammu & Kashmir. CGNSS stations are equipped with geodetic grade dual frequency receivers that observe signals from most of the available GNSS satellites constellations (GPS, GLONASS, Galileo, BeiDou, QZSS). Receiver setup is housed inside the room and antenna is mounted over the RCC pillar as shown in figure.

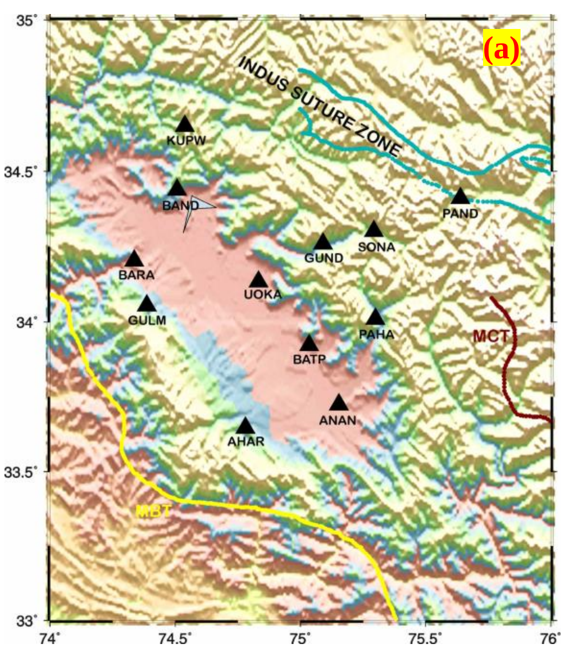


Figure 6.12 (a) Kashmir Valley CGNSS Network
(b) CGNSS Station (Batpal) in Kashmir Valley (Insert shows instrument setup)

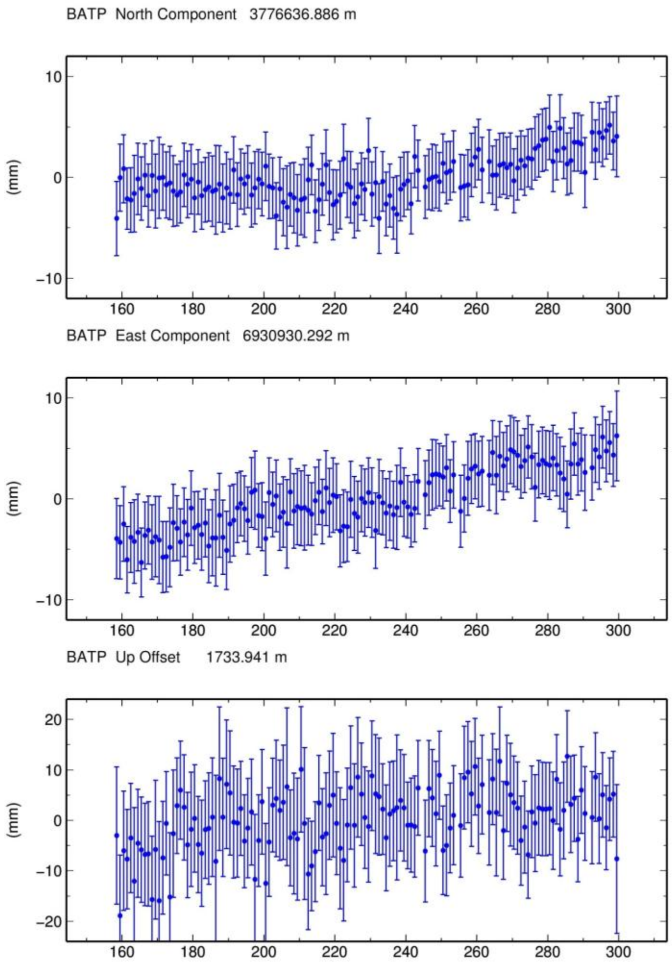


Figure 6.13 Batpal Time Series

Also GNSS data of higher sampling rate of 1 Hz is collected for these stations. Pre-Seismic, Co-Seismic and Post-Seismic motion can be captured using high sampling rate GNSS data. From May to November 2015, twelve CGNSS stations are established along the arc-normal transects in Kashmir valley as shown figure6.12. Two stations are collocated with meteorological sensors. The data collected at these sites is analysed and the daily precise position in North, East and Up with error bars is estimated. Sample time series plot for Batpal station is given in Figure6.13. These daily positions over a period of one year would give the precise velocity estimate of these sites in ITRF08 reference frame and the relative motion between the sites gives the surface deformation rates in Kashmir Valley.

Chiranjeevi Vivek G, Suri Babu D, Ramees Raja Mir, Dharma Teja A K, Sunil Babu M G, Niranjan N, Parvez I A, Sridevi Jade & UOK team

6.10 Landslide studies using Global Positioning System (GPS)

Gharwal Himalayas falls in seismic zone-V and also in high hazard zone. In the upper reaches of Alaknanda valley of Gharwal Himalayas, there are several landslide potential zones along the Chamoli-Badrinath National Highway (NH-58), Uttarakhand. NH-58 is a landslide prone zone due to the adverse geological formation, steep slopes, highly dissected topography, seismically active area and high rainfall. CSIR-Central Building Research Institute (CBRI) in collaboration with CSIR-4PI has selected two landslides in Jalgwar village, Chamoli district, Uttarakhand for monitoring. These landslides are of debris slide types with minor rock slides at the flanks (Figure 6.14). Area is also in the vicinity of Main Central Thrust (MCT) which is seismically active. Main cause of the slide is due to very highly weathered dolomites on a steep slope and the rock formation is highly crushed at several places.

Figure 6.14 View of Landslides

Figure 6.15 Continuous, reference and control GPS stations (clockwise from left)

For the first time in India, specific landslides (Figure 6.15) are studied using Global Positioning System (GPS). GPS measurements were conducted to measure the overall landslide motion and inter-landslide motion. Continuous mode GPS (CGPS) station (CBRI) was established in CBRI campus, Roorkee which runs throughout the year and Campaign mode reference station (LSLI) was established in relatively stable region within aerial distance of 1 Km from landslides which runs only during GPS measurements period in landslides (Figure 6.16). These CGPS station and campaign mode reference station were used to define a stable reference frame to measure the displacement solely due to the landslide motion. Landslide control points (Figure 6.17) are established in landslide 1 and landslide 2 to measure the overall landslide motion as well as deformation within the landslide (Intra Landslide motion).

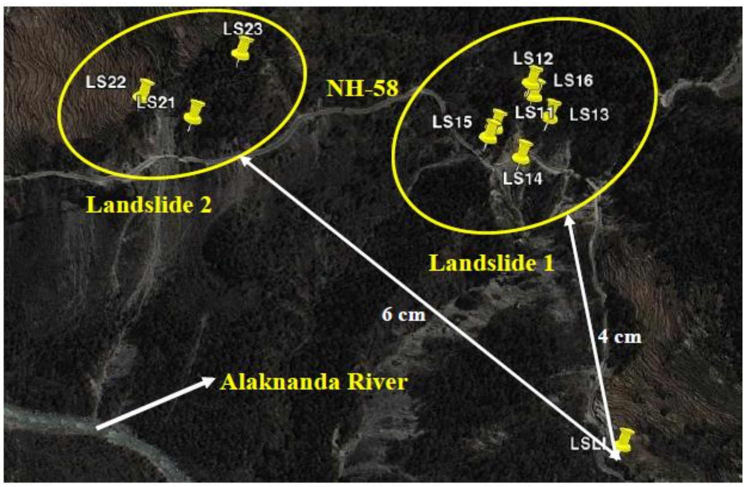


Figure 6.16 Landslides with GPS control points and reference station (LSLI)

GPS data is analysed to determine the precise positions of CBRI, LSLI and landslide control points along with the velocities and rate of change of baseline lengths between the GPS points. Results indicate shortening between CBRI continuous station at Roorkee and reference station (LSLI) inferring long term tectonic motion since CBRI station is at foot hills of Himalayas and LSLI station in transition zone of lesser and higher Himalayas. Baseline length changes between landslide control points and reference station gives the overall motion of the order of 4 cm and 6 cm for landslide 1 and landslide 2 respectively (Figure 6.16). Deformation rates within the landslide vary from 2 to 5 cm in the different sections of the landslides.

Shrungeshwara T S, Chiranjeevi Vivek G,
Anil Kumar Maletha, Shantanu Sarkar and Sridevi Jade

6.11 Modelling of landslides using Finite Element Method (FEM)

Use of finite element method using solvers like ansys, abaqus, hyper mesh to model the landslides under both static and dynamic failure conditions have greatly increased recently. In order to gain the realistic results which can be a base for predicting Landslide movement, the model specifications should be selected in a way close to natural conditions. However in any numerical modelling, there exists some divergences between model and prototype which are inevitable, the loading condition, surrounding soil and boundary condition are selected as close as an actual movement of a slope. Towards this two field cross sections CD and MN of landslide 1 are modeled using finite element program ABAQUS. Two sections are created using the geometry and the soil properties given by field observations and material properties are assigned for the multiple layers consisting of sandy silt, sandy gravel, weathered dolomite, Parameters used are Young's modulus, cohesion and angle of friction between layers of landslides, density, Poisson's ratio, soil porosity. The interactions between different layers are kept as friction surfaces acting as rough surface.

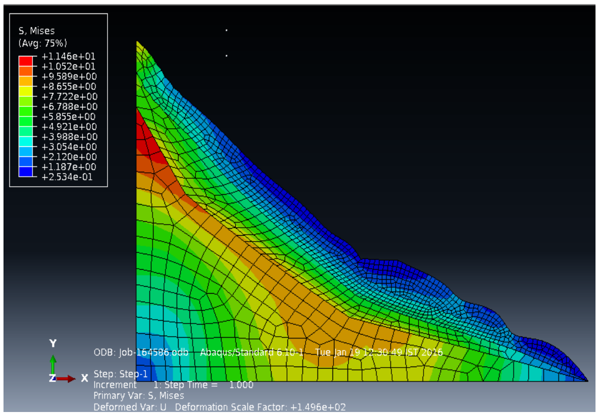


Figure 6.17 (a) Von misses stress distribution for CD Profile

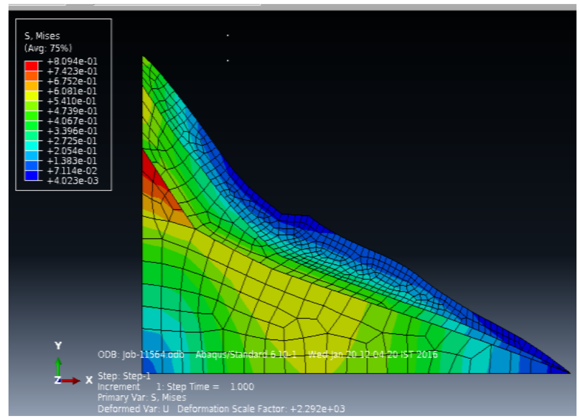


Figure 6.17 (b) Von misses stress distribution for MN Profile

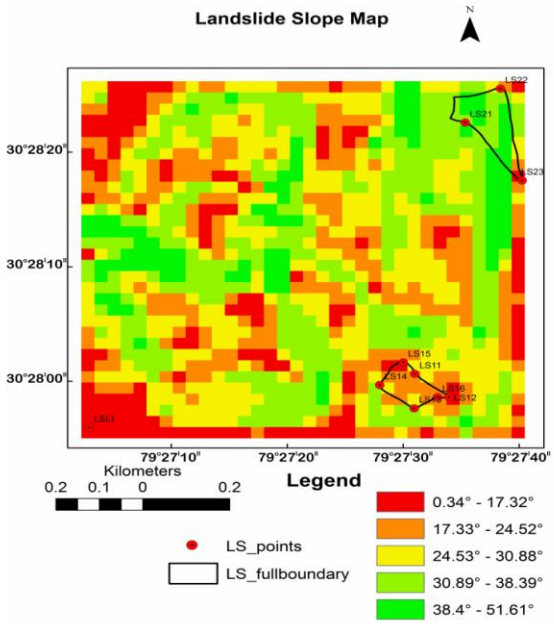
Finite element analysis is carried out with two base steps. At the first step the gravity forces from material density of different layers is calculated and the model is in equilibrium state and stable in static condition, as the study is focused on the dynamic instability of the slope. The second step of the analysis will be started by imposing the dynamic excitation. Forces and loads acting on the slides are given accordingly keeping gravity as main concentrated force acting along whole part. Landslide-1 FEM model was generated for the MN and CD profiles. Displacement magnitude and strain rates obtained using FEM are consistent with GPS in-situ measurements. *Corresponding stress* distribution using the FEM in the multiple layers of landslide for the two cross sections is given in figure 6.17 a and b.

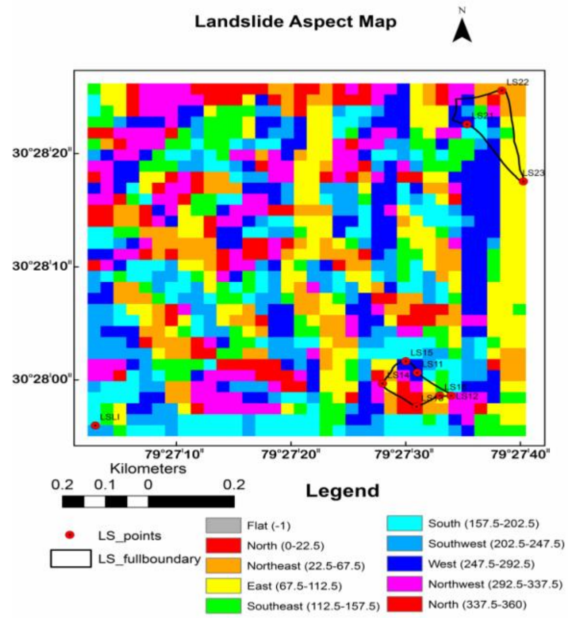
Sridevi Jade, Dharma Teja A K and Kokilagadda Swathi

6.12 Digital Elevation Model (DEM) for landslide studies

DEM is a Digital model or 3D representation of a terrain surface created from terrain elevation data and it could be acquired through various techniques such as Photogrammetry, Lidar, Land surveying, Remote sensing techniques etc.. DEM models are used often in Geographic Information Systems (GIS) and Global Positioning System(GPS). They are the most common basis for digitally produced slope map, aspect map, hill shade map, relief map and contour map. SRTM (Shuttle Radar Topographic Mission-Figure 6.18) DEM of 3 arc-second (90 meter) resolution is used to generate Slope and Aspect map of landslide study area consisting of two landslides in Jalgwar village, Chamoli district, Uttarakhand, using Arc GIS software as shown in Figure 6.18. It gives the information about elevation of study area and it shows landslide points are placed in range of 1497 m to 1567 m elevation with respect to MSL (Mean Sea Level).

Figure 6.18 Slope and Aspect Map of the landslide study region





Slope map indicates the topography of an area and gives the measure of steepness or the degree of inclination of a feature relative to the horizontal plane and it can be expressed either in degrees or as a percentage. Aspect map gives the direction of the slope for a terrain and measured clockwise in degrees from 0 to 360, where 0 is north-facing, 90 is east-facing, 180 is south-facing, and 270 is west-facing. Using DEM it is possible to detect minor change in terrain height. Topographic parameters (coordinates and area) derived from DEM is being used in further refinement of Finite Element Model of the landslide.

Sridevi Jade, Sunil Babu M G and Shrungeshwar T S

6.13 GPS measurements in landslides, Uttarakhand

Two epochs of GPS re-measurements were carried out in March, 2015 and October, 2015 in the landslide region located in Jalgwar village, Chamoli district, Uttarakhand. As a part of this continuous mode Global Navigation Satellite System (CGNSS) receiver (CBR1) installed in March 2015 at CSIR-CBRI Campus was upgraded and presently tracks most of the available GNSS constellations. Earlier station (CBRI) was dismantled. This station is made accessible over the internet for remote access, management and data download. CGNSS station is collocated with Meteorological sensor which gives temperature, relative humidity and atmospheric pressure. GPS observations at both the continuous sites are analyzed in static

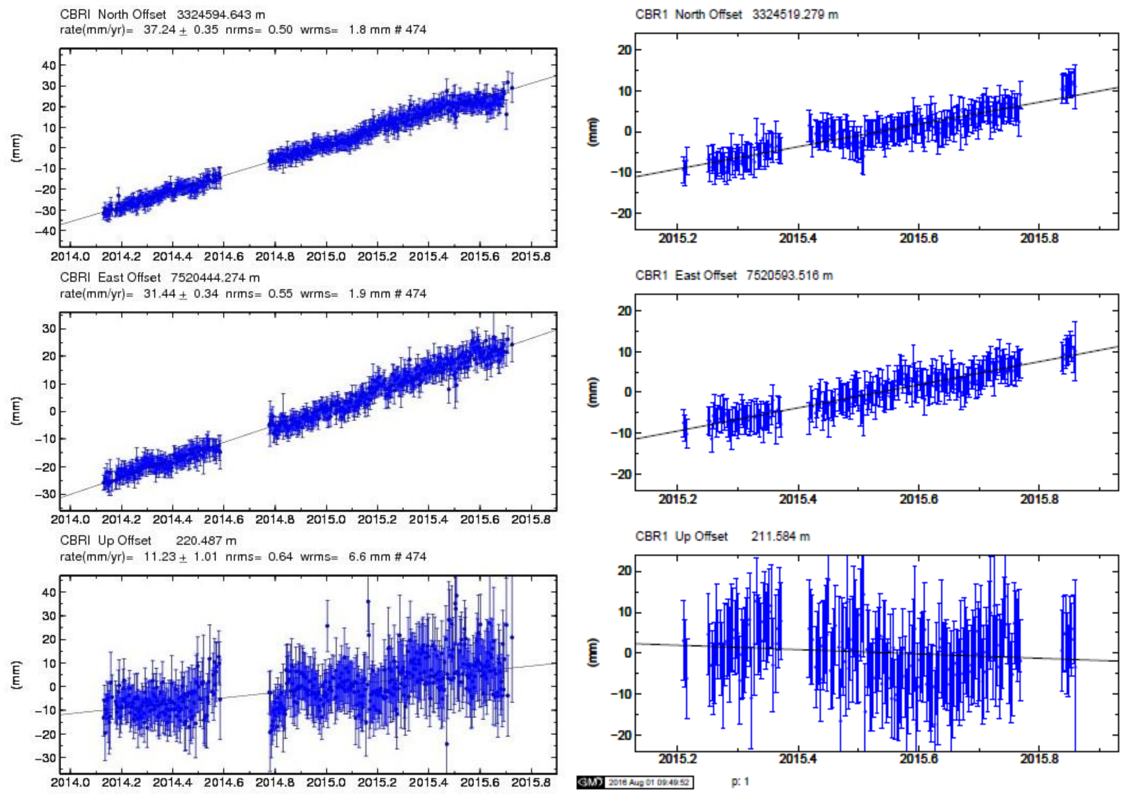


Figure 6.19 (a) CBRI (CGPS) Time series **Figure 6.19 (b)CBR1(CGNSS) Time series**

mode to determine the precise position and velocity of the continuous station. Time series of earlier CGPS station (CBRI) and the present CGNSS station (CBR1) is given in figure 6.19.

Shrungeshwar T S, Chiranjeevi Vivek G, Dharma Teja A K,
Sunil Babu M G, Sridevi Jade and CBRI Team

6.14 Seismic hazard and risk assessment based on the Unified Scaling Law for earthquakes: State of Gujarat, India

The Gujarat region is located within the tectonic plate of India; about 500 km from a transform plate boundary (Bendick et al., 2001) is seismically one of the most active regions in India. The reliable assessment of seismic hazard of Gujarat is a major issue, particularly after the catastrophic Bhuj earthquake happened on January 26, 2001 (Mw7.7) resulting in a huge loss of lives (above 20,000 fatalities). There are many studies on seismic hazard assessment of Gujarat region in the recent past; however, none of these studies have been used to implement the associated seismic risk for the region. In this study, we not only combined and compared the seismic hazard from various probabilistic and neo-deterministic models but also integrated it with the population density data available after the 2011 census to assess the seismic risk of Gujarat region.

We apply 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.

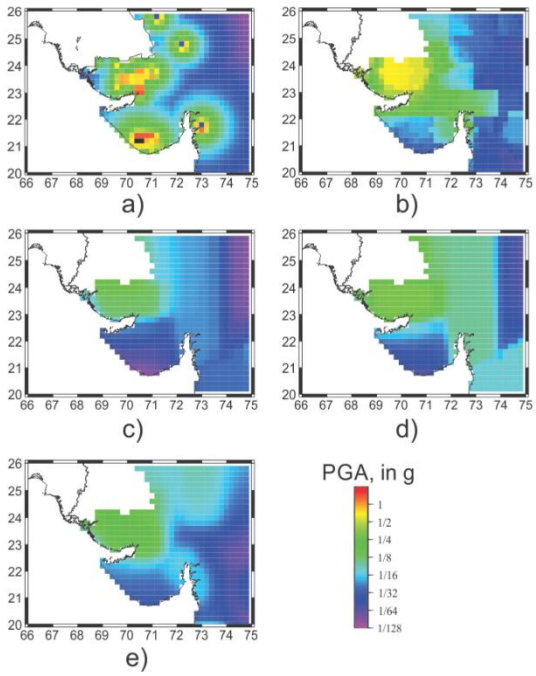


Figure 6.20 The five seismic hazard maps in terms of PGA (in g) a) based on USLE approach, b) DGA, c) DGA10%, d) DGA2%, e) as given on the final GSHAP seismic hazard map.

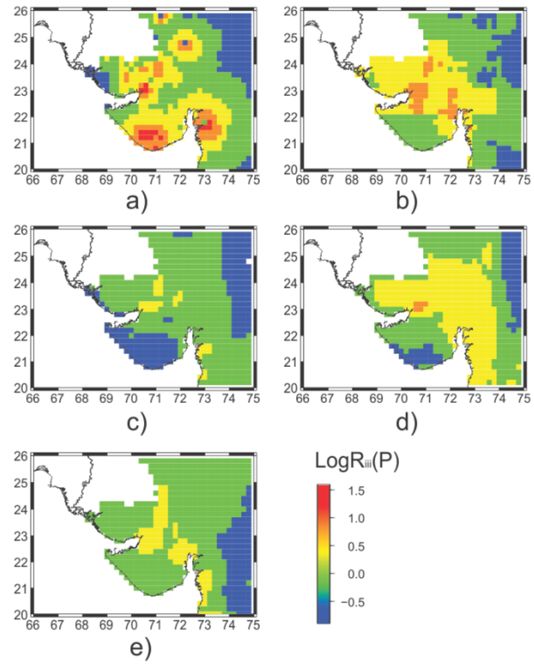


Figure 6.21 The maps of seismic risk $R_{iii}(g)$ for population of Gujarat region. Oversimplified convolutions, $R_{iii}(g) = H(g) \bullet \int_g P \bullet P^2$, of the India's Census 2011 population data with seismic hazard assessment H(g) based on USLE (a), b) DGA, c) DGA10%, d) DGA2%, e) GSHAP approaches (seismic hazard maps in Fig.6.20).

To assess a more adequate earthquake hazard for the state of Gujarat, we apply USLE and cross compare the seismic hazard maps compiled for the same standard regular grid 0.2°×0.2° (i) in terms of design ground acceleration (DGA) based on the neo-deterministic approach, (ii) in terms of probabilistic exceedence of peak ground acceleration (PGA) by GSHAP, and (iii) the one resulted from the USLE application (Figure 6.20). Finally, we present the maps of seismic risks for the state of Gujarat integrating the obtained seismic hazard, population density based on India's Census 2011 data, and a few model assumptions of vulnerability (Figure 6.21).

The present study for the State of Gujarat, India discloses a possibility of much higher risks than those on the existing probabilistic seismic hazard maps when naturally fractal distribution of earthquake loci is taken into account along with tectonic evidence and pattern recognition arguments. First of all it refers to the two areas to the North of continuation to the Arabian Sea of the Narmada-Son Lineament that crosses the entire Indian subcontinent; in particular, these are the areas to the North of Gimar Hills and Baroda Plane, where the USLE approach suggests a possibility of significant or even great earthquakes. Further investigation of the Kathiawar Peninsula tectonic structure and dynamics along with pale-seismological searches may help with reliable information for resolving the problem of seismic safety in the region.

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6.15 Crustal structure and seismicity beneath Kashmir Himalaya

Crustal structure and seismicity beneath the Kashmir valley are studied using data from eight broadband seismometers installed during 2013-2015. Moho depth and other intracrustal velocity contrasts are mapped from teleseismic data recorded at these stations. Local earthquakes are also analyzed both from first five month collected data and phase data obtained from International Seismological Centre (ISC) to understand the undergoing thrusting process in the region. A low velocity zone (LVZ) lies at the depth of ≈12-14 km beneath valley but upwarps slightly as we move further NE, which might be due to upthrusting of Zanskar shear zone and Dharlang shear zone. Moho beneath valley is (≈53-56 km) but steeply deepens beneath Pir Panjal and also towards NE.

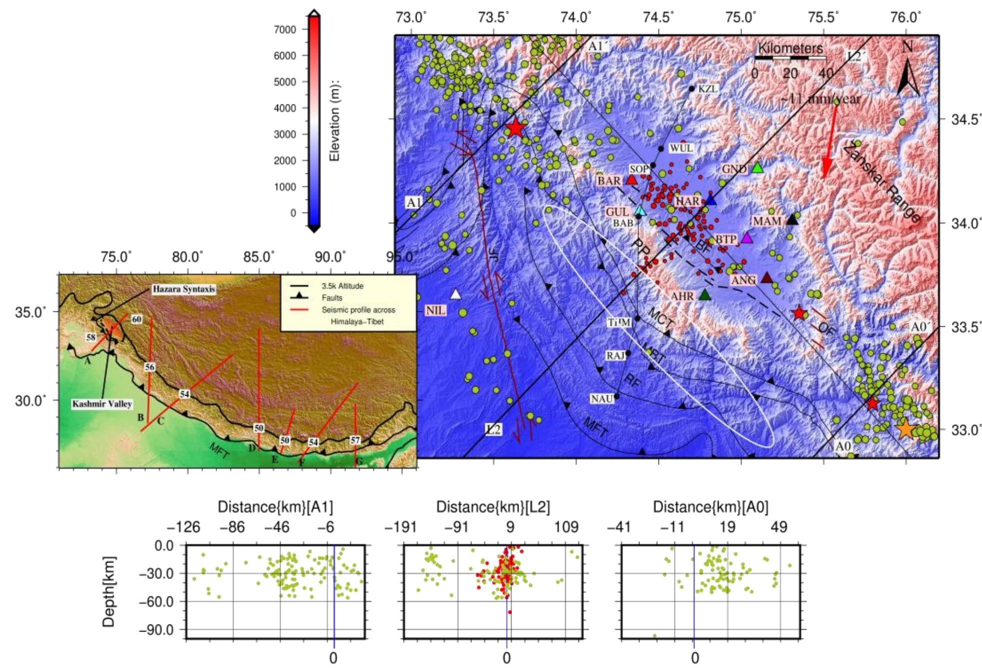

Figure 6.22 Main map shows Kashmir valley with stations by black triangles, brown color shows the relocated epicenters for M>=2.9 events whose phase data were obtained from ISC and red ones are the locally recorded events by our network which also have been relocated. White ellipse shows a possible rupture area of 1555 earthquake. Elevation data are taken from SRTM with scale shown on left. Red vector shows convergence rate of the Valley treated India fixed; stars are some recent earthquakes in the region. Black dots connected with lines are the record points of deep seismic sounding profile. NIL, is IRIS station in Nilore, Pakistan. Left inset shows map of the Himalayas with major faults with red rectangle highlighting the study region. Bottom shows the seismicity along different profiles with distances reckoned from axis of the valley (blue line). Note sparse seismicity towards NE of the valley which may be due to locking line beneath the Zanskar.

All the seismic stations (Figure 6.22) are located on hard rock sites of valley, three on its south-western and four adjoining its north-eastern margin. Receiver Functions (RFs) at these sites were calculated using iterative time domain deconvolution method and jointly inverted with surface wave dispersion data to estimate shear wave velocity structure underneath. The estimated Moho depths were further constrained within ±2 km by trial forward modeling. The Moho depths on the south- western edge of valley are close to 55 km (Figure 6.23), slightly shallower than the Pir Panjal further southwestward but about 15 km deeper than beneath sub-Himalaya about 30 km to southwest. The Moho depth increases to about 60 km towards its northeastern edge, indicating that here, as in the Central and Nepal Himalaya, the Indian plate dips north-eastwards beneath the Himalaya. A persistent low velocity interface at 12-16 km depth possibly delineates northward dipping decollement along which Tibet overrides the Indian plate. A total of 215 local earthquakes were located, which were further improved using Double-Difference algorithm. Earthquakes M≥2.9 with phase data for P and S arrivals were obtained from ISC (1964-2013).

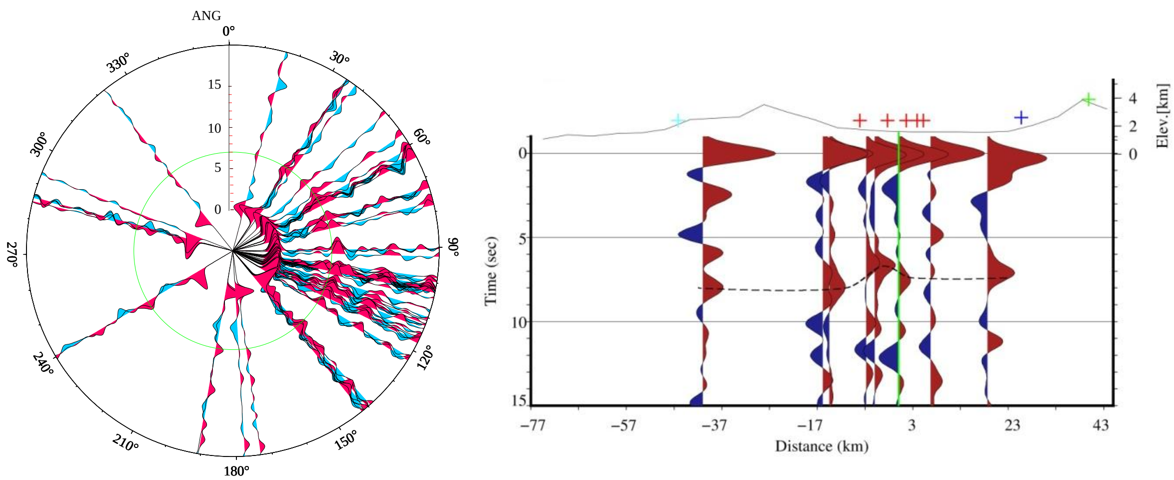

Figure 6.23 Left shows polar plot of RFs at station ANG, with vertical axis marking time in seconds. Note a positive phase arriving ~7sec, observable on most of RFs which marks the arrival of Moho Ps phase. Also note large gaps in back-azimuth (BAZ) between 140-170, 190-240, 240-280, 300-320, 330-360 degrees, which are due to absence of teleseismic events in those BAZ. Right shows selected RFs along SW-NE (from left-right) profile across the Kashmir Valley, with green line denoting axis of the Valley and distances along x-axis are measured w.r.t. the axis. Plus signs at top shows location of piercing points of different events recorded at different stations. Elevation data is taken from SRTM, note a spline fiited to Ps Moho phase showing upwarp of Moho beneath the Valley, Moho beneath Pir Panjal is slightly deeper than the Valley.

The Moho marking base of the valley apparently dips rather steeply ≈ 20°northeastwards of Main Boundary Thrust only to become very gentle ≈ 3.5° underneath valley but transition that must occur somewhere beneath Pir Panjal cannot be resolved by our data. Intriguingly, the Moho whilst generally dipping northeastward beneath valley shows a slight upwarp along its axis. A prominent low velocity interface at ≈ 12-16 km is also found to occur in most inversions of receiver functions and their existence is ineluctably required by forward modeling. It possibly identifies a piece of decollement beneath valley and holds promise to show existence of asperities on either side of valley on detailed exploration. The well constrained findings of this experiment are shear velocity structure beneath the valley obtained by jointly inverting RFs with

SWD data, further rigorously tested by forward modeling and set of relocated earthquakes which conform locking line beneath Valley.

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6.16 Moho imaging in Dharwar craton

The Indian shield is an amalgamation of smaller craton formed by geodynamic process from Mesoarchean to Neoproterozoic. Southern part of the shield is largely occupied by Dharwar craton (Figure 6.24). On the surface, craton is divided into the Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC) separated by 2.5 Ga Closepet granite or Chitradurga Schist Belt (CSB) as boundary. In western Dharwar, CSIR-4PI had operated twelve broadband stations during 2010 and 2013 across the east – west corridor in two phases to image moho and Crustal structures along profile AA' (Figure 6.24). Data from Ten additional broadband stations, operated by CSIR – NGRI close to the profile AA', are also used in this study.

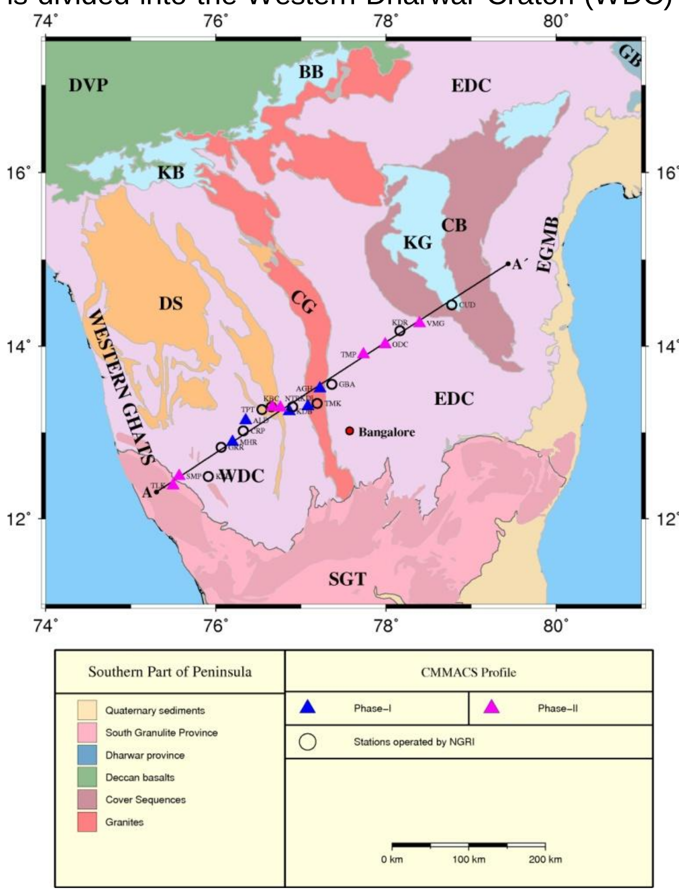

Figure 6.24 Geological map of the region showing major geological and tectonic features of Dharwar craton and location of broadband stations (pink, blue and black) used in this study. Profile AA' repersent the section along which station are projected. EDC: East Dharwar Craton; WDC: West Dharwar Craton; SGT: Southern Granulite Terrain; DS: Dharwar Schist; CG: Closepet granite; CB; Cuddapah Basin; KB: Kaladgi Basin; DVP: Deccan Volcanic Province; BB: Bhima Basin.

Broadband Stations data were recorded in continuous mode at 100 sps. Earthquake waveform were extracted for the teleseismic events occurred between 30^o to 100^o epicentral distance from the network. A total 22 stations were used in this study including stations from CSIR – NGRI. Receiver functions are generated for all the teleseismic waveform data for M > 5.5 and visually selected for final analysis. To estimate moho depth, three methodologies are used; H-K stacking, joint inversion of receiver function and Rayleigh wave group velocity data and CCP depth migration. H-K stacking used a grid search method, by adding amplitudes of Ps phase and its multiples, to estimate moho depth (H) and V_p/V_s ratio assuming average V_p of the crust. Joint inversion of receiver functions were performed with Rayleigh wave group velocity to constrain moho depth and average velocity respectively. Receiver functions from 22 stations have been used to image the crust and upper mantle using Common Conversion Point (CCP) stacking technique to create time to depth migration of radial receiver functions.

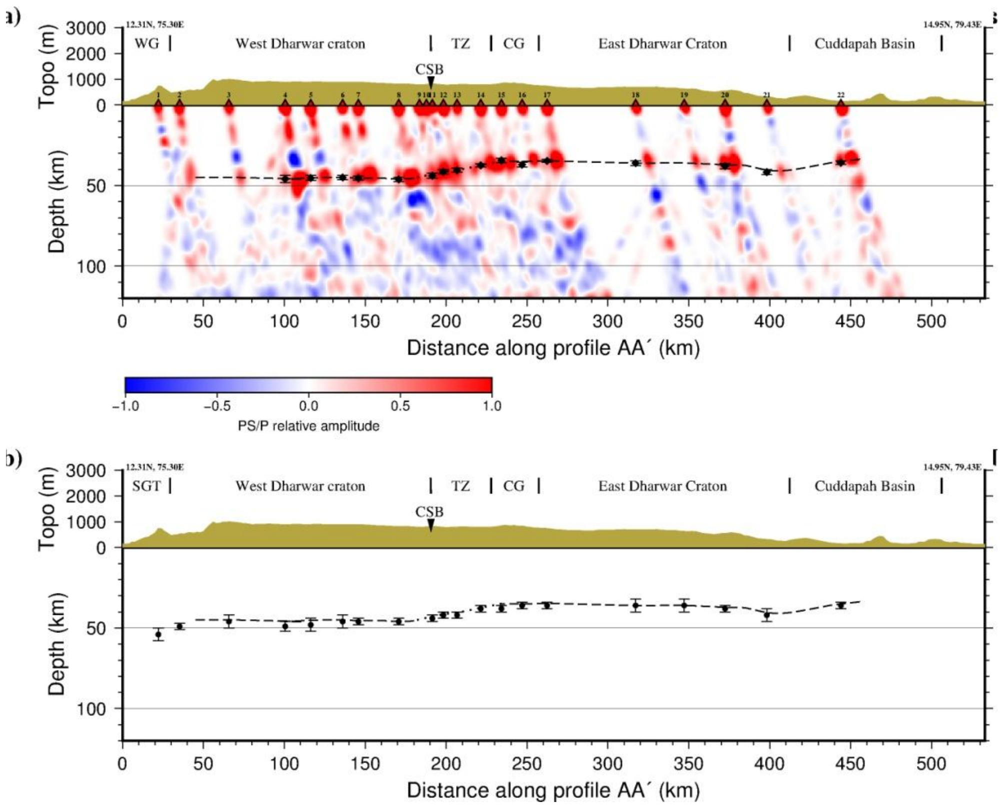

Figure 6.25 Common Conversion Point (CCP) Depth migration of receiver function along-with topography and tectonic feature projected along the profile AA'. (a) CCP depth Image along profile AA' along-with moho depth estimated from H-K stacking of receiver function. Interpreted moho marked by dashed black line. (b) showing moho depth along the profile estimated from joint inversion of receiver function and Rayleigh wave group velocity along with interpreted moho from CCP depth image.

The resulting CCP depth migration for profile AA' is plotted in Figure 6.25. The crust-mantle boundary is clearly visible beneath the Dharwar craton as the only laterally continuous strong amplitude positive interface (red). In east Dharwar, The general trend is flat Moho at a depth of 36--38 km. On the other hand in west Dharwar, Moho depth varies from 46--50 km and a presence of strong intra-crustal amplitude at a depth of ~15 km. Average Moho depth results are largely consistent with earlier studies carried out in the vicinity of profile. The Moho depth increase gradually between Colosepet granite and Chitradurga Schist Belt from station NTR and BRS. This section of profile is identified as a transition Zone (TZ) between EDC and WDC. The results also suggest moho offset at two places of an order of ~4--6 km; beneath EDC and west of Cuddapah Basin at station VMG; Beneath Western Ghat at station TLK. Results from H-K stacking and joint inversion are mostly consistent with CCP migrated results. Approx. 40 km transition zone identified between CG and CSB, characterized by gradually increasing moho depth. This zone represents the contact between EDC and WDC between Chitradurga schist belt and Closepet granite and presence of intra-crustal structure coincide with Chitradurga schist belt.

Ashish and Imtiyaz A Parvez

6.17 Strong ground motion estimation in Western Himalaya & adjacent areas

Ground motion estimation can be done by various ways like deterministic, stochastic and hybrid methods. It is well known that slip on a fault is random in nature and high frequency waves appearing on a seismogram are difficult to generate using deterministic methods as they depend on small scale heterogeneities of the fault plane which further demands to incorporate more parameters thus augmenting the difficulty of using deterministic methods *(Aki, 1987)*. Also regions where no/less strong motion records are available use of stochastic methods seems to be a viable choice. An extended ruptures subfault motions can be computed efficiently using this method. Here gross features of the earthquake are quantified deterministically and details of the process are defined stochastically, particularly peak ground motions (peak acceleration etc.)

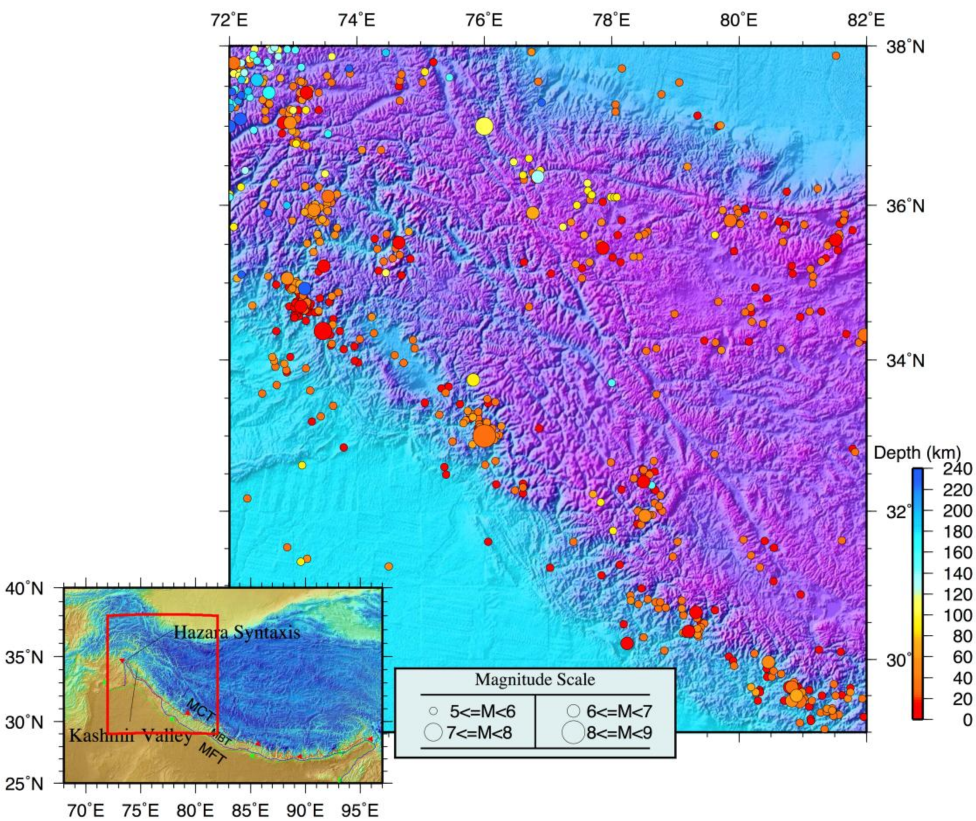

Figure 2.26 Shows seismicity map of NW Himalaya and adjacent areas for M≥5, pre-instrumental earthquakes have been taken from different sources. Each earthquake is color coded according to depth, notice deep events in Hindukush region. Inset shows the location of study region.

Ground motion has been generated using a finite fault stochastic modeling method. Here a finite fault is considered and is divided into number of subfaults, where each subfault is treated as a point source. Using random-vibration theory, peak values of ground motion are estimated and a random slip is chosen on all subfaults. Traditional stochastic estimation methods use a fixed corner frequency (f_{max}) of acceleration spectra. A dynamic corner frequency approach has been applied where rupture begins with a higher f_{max} and progresses towards lower f_{max}. It also uses an analytical method to simulate accurately near-fault ground motions by generating long-period pulses caused by the forward directivity of the rupture.

Above method will be used to generatesuites of ground motion in western Himalaya and adjacent areas by considering all M≥5 earthquakes in the region shown in Figure 2.26. For earthquakes M≤ 7, hypocentral depth is taken as 10 km, for 7<M<8 as 15 km and M≥ 8 as 25 km. We know that Kashmir Valley is covered by ~1300 m of sediments, site amplification will be considered and ground motion thus simulated will be compared with, when only considering rock and crustal amplification. Since we don't have any strong motion records of local/regional earthquakes from the region, we are using attenuation (Hypocentral distance vs acceleration) relations estimated for western Himalaya to validate our model. As this region has enough slip deficiency to drive a ~M8 earthquake and majority of the population within the Valley are located on loose sediments of the basin, this study will be important for the assessment of seismic hazard in the region. Figure 6.27 shows that after tuning of parameters in stochastic model, simulated ground motion is quite similar to the ground motion attenuation law of Western Himalayas.

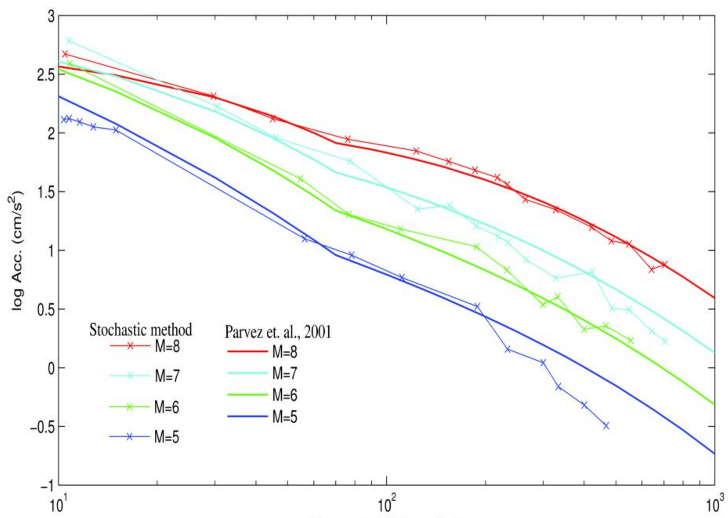

Figure 6.27 Shows the comparison of log acceleration (cm/s²) Vs Hypocentral distance (km) for Western Himalaya (solid lines, see legend) and stochastic method (line segments with crosses).

Ramees R Mir, Imtiyaz A Parvez, Vinod K Gaur

6.18 Study of tank with inclined braced staging

The responses of an intze tank with unbraced staging, inclined bracing (single-inclined brace and cross brace) at alternate levels of staging and inclined bracing throughout the height of staging have been compared. The models have been analyzed in accordance with the draft of IS 1893 (part 2) using STAAD. Pro a finite element software. The displacement of the tank reduced significantly when the staging had inclined braces. The study also found that the position of the inclined bracing in the staging (with and without bracing at ground level) had a considerable effect on the response of the tank. Liquid storage tanks are important structures and it is imperative that these structures remain functional following an earthquake. Hence it is necessary to understand the behavior of the tanks under seismic loading. In this study, single-inclined braces and cross braces had been incorporated to the staging of the tank at alternate levels and their response had been compared with that of a tank with unbraced staging and single-inclined brace and cross brace throughout the height of staging.

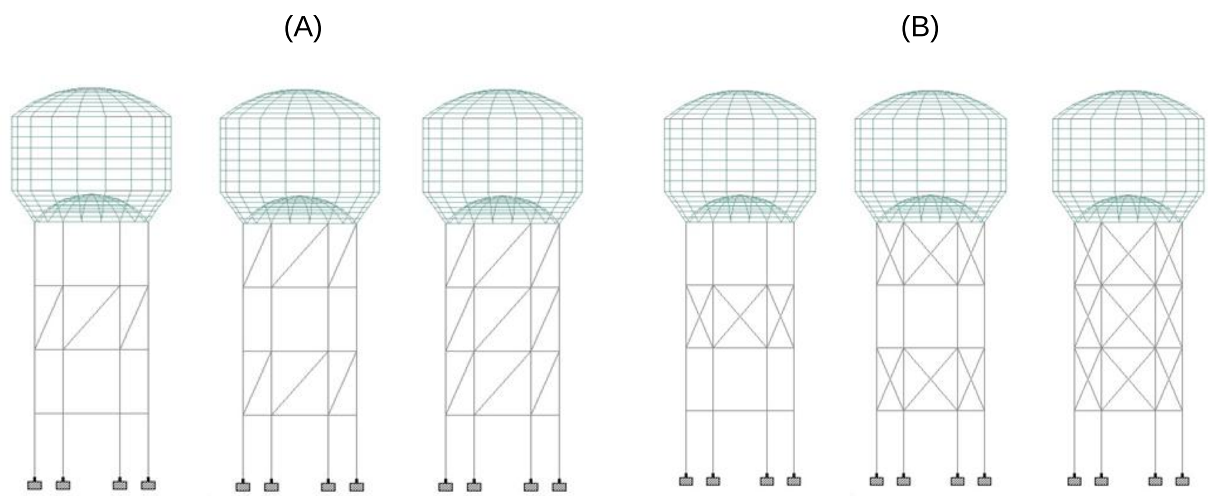

Figure 6.28 Intze Tank with type1, type2 and type3 for Single Braced (A) staging and Cross Based (B) of 16 m height

The liquid in the tank is divided into two liquids; one which moves with the wall of the tank container called impulsive liquid with mass m_i and the other that moves relative to the wall of the container called the convective liquid with mass m_c. The pressure exerted on the wall and base of the container by these liquids is called as hydrodynamic pressure. The elevated tank is treated as a two degree of freedom system, where one mass constitutes the impulsive mass along with the structural mass of the tank and the other constitutes the convective mass. The spring mass parameters depend on the aspect ratio of the tank and have been calculated using the draft of IS 1893 (part 2) and the IIT-GSDMA guidelines; analyzed for seismic zone II. A response reduction factor of 2.5 had been adopted as the frame was assumed to be a special moment resisting frame (SMRF) and an importance factor of 1.5 had been considered as per IS 1893 (Part 1). Figure 6.28 shows the configurations with inclined and crossed bracing at alternate levels of staging as type1 and type2 and the configuration with bracing throughout the height of staging is type3. Type1 configuration does not have bracing in the ground level whereas type2 has bracing at the ground level. On an average, the displacement of type1, type2 and type3 of single-diagonal braced and cross braced staging configurations was considerably less than the radial braced and horizontal cross braced staging configurations when the tanks were analyzed for self-weight of the structure, hydrostatic and hydrodynamic pressures in the container. Hence to reduce the displacement of an elevated tank, staging with cross bracing and single-diagonal bracing can be adopted instead of radial and horizontal-cross bracing. The present study can be concluded that staging with single-diagonal bracing at alternate levels with bracing at ground level is a better alternative than the other staging configurations considered in this study.

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6.19 Adaptive nonlinear pushover analysis on L-shaped building

The demand of reliable nonlinear static pushover analysis on structures subjected to earthquake forces has resulted in adaptive pushover analysis in the recent times, which considers the effect of higher modes of vibration and progressive stiffness degradation of structural members. The irregularities in the buildings are considered to be damage amplifiers since they make the failure in structures brittle during the incidence of an earthquake force. In Nonlinear static method, a mathematical model is simulated by incorporating the nonlinear characteristics like load-deformation relations into the constituent elements of the structure. The model is loaded with gravity loads and subjected to monotonically increasing lateral load representing the inertia forces in an earthquake. The structure will be pushed till the target displacement is exceeded at the control node. This conventional pushover method recommended by ATC-40 and FEMA-356 considers the only effect of the dominant mode of vibration. In the case of irregular structures, mainly in plan irregular buildings, the torsional mode of vibration will cause considerable damage to the structures during earthquake incidences. However, the effect of torsional mode of vibration will be neglected in conventional pushover analyses.

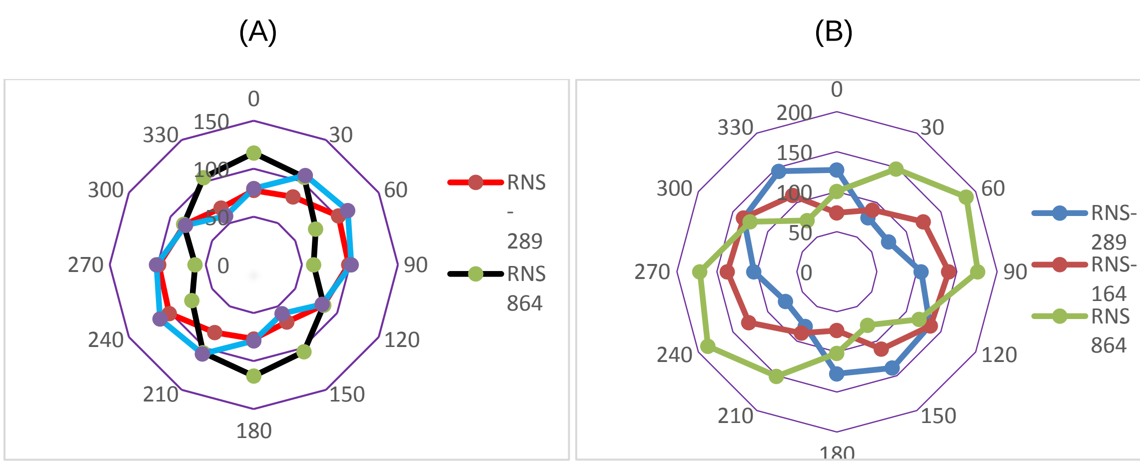

Figure 6.29 Maximum top displacements along X direction (A) and Y direction (B) for one of the Models for all bidirectional orthogonal earthquake components.

The consideration of higher mode of vibration led to the development of adaptive nonlinear static pushover analysis. Incorporation of adaptive methodology in the conventional pushover analysis is done in following steps. (1) Definition of nominal load vector and inertia force. (2) Calculation of load vector after the lateral load increment. (3) Calculation of scaling vector and updating the loading vector. The first step is carried out only at the beginning of the analysis and other steps are repeated at every equilibrium stage of the analysis is reached. Following the above-mentioned steps, the effect of higher modes of vibration is also taken into account in the analysis. Figure 6.29 shows the variation of top displacement at the control node for the different angle of incidences. It is seen that for different earthquakes of same peak ground acceleration give the different angle of incidence of maximum response.

This study evaluates the performance of the plan irregular building (L-shaped) using nonlinear adaptive pushover when subjected to seismic forces. From the time history analysis along different direction shows that there is a significant variation in the response of the models considered with different angle of incidence. The critical angle of incidence depends on the chosen engineering parameter and the seismic input properties. This shows that there is a clear uncertainty in the definition of the critical angle.The uncertainty can be represented in the form of coefficient of variation, which is the ratio of standard deviation to mean demand value. This value varies from 0.16 to 0.36 confirming that variation in the seismic demand due to angle of incidence cannot be neglected.

Prajwal T P, Imtiyaz A Parvez and Kiran Kamath

7
KNOWLEDGE PRODUCTS: PUBLICATIONS, PRESENTATIONS…

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.

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Publications in Journals

1. Sushma Patil, **Anil KumarV**, et al. Remote extraction of malicious payload for SCTP, *International Journal of Computer Science and Mobile Computing*, 14 (6), 86-91, 2015
2. **Ashish**, Lindholm C, **Parvez I A** and Kühn D, Probabilistic earthquake hazard assessment for Peninsular India, *Journal of Seismology*, 20(2), 629-653, 2016
3. **Goswami P**, Prevention of malaria through forecast based precision vector sanitation and exposure advisory: A Conceptual and Feasibility Analysis, *Current Science*, 108 (1), 19-21,2015
4. **Goswami P**, **Gouda K C,** Meeting Report: Weather and climate informatics for proactive healthcare, *Current Science***,** 108 (7), 1204-1206, 2015
5. **Goswami P, Rao E V S P,** Smart and sustainable agriculture through weather and climate informatics and multi-scale modeling, *CAB Reviews*, 10, 032, 1-13,2015
6. **Goswami P, Rakesh V,** An assessment of optimality of observations for high-resolution weather forecasting, *Pure and Applied Geophysics*, doi:10.1007/s00024-015-1155-1,2015
7. **Goswami P, Sumana Sarkar,** Analysis and quantification of contrasts in observed meteorological fields for foggy and non-foggy days, *Meteorology and Atmospheric Physics*, doi:101007/s00703-015-0384-2, 127, 605–623**,** 2015
8. Rajwade YA, Swain DK, Tiwari KN, Mohanty UC, **Goswami P,**Measures under the climate change scenarios in rice based cropping system in India, *Environmental Processes*, doi:101007/s40710-015-0115-1,1-19, 2015
9. **Goswami P, Shivnarain Nishad**, Dynamical formalism for assessment and projection of carrying capacity in different socio-climatic scenarios, *Current Science*, 109 (2), 280-287, 2015
10. **Goswami P, Shivnarain Nishad,**Selvaratnam D, A deterministic model of a research organization's evolution and dynamics of performance,*Palgrave Communications,*doi: 101057/palcomms, 1:15012,2015
11. **Gouda K C, Goswami P,** Organization of vertical shear of wind and daily variability of monsoon rainfall, *Meteorology and Atmospheric Physics*, ISSN 0177-7971,doi:10.1007/s00703-016-0437-1, 1-13, 2016
12. Radhika TV, Kumar S S, **Gouda K C,** A Study on the different aspects of the virtual private cloud, *International Journal of Applied Engineering Research*, 10 (86), 343-347, 2015
13. Ajay K P, **Gouda K C**, Nagesh H R, High-Performance Climate Data Analysis using Hadoop, International Journal of Innovation Technology and Research, 197-202, 2015
14. X Lin, **Indira N K** et al**.,** Long-lived atmospheric trace gases measurements in flask samples from three stations in India, *Atmos. Chem. Phys*., doi:10.5194/acp-15-9819-2015, 15, 9819–9849, 2015
15. **Jurismita Baruah, Goswami P**, Dynamical model of daily CO concentration over Delhi: Assessment of forecast potential, *Current Science*, 108 (7), 1369-1374,2015

16. **Kantha Rao B, Goswami P,** A Comparison of ASCAT soil moisture data with in situ observations over the Indian region: A multiscale analysis, *IEEE Transactions on Geoscience and Remote Sensing*, doi: 10 1109/TGRS 2015 2422377, 2015

17. Sen S, **Krishna Mohan T R** and Tiwari M, Impact dispersion using 2D and 3D compositegranular, Powder and Particle, 2016

18. Trivedi P C and **Parvez I A**, Characterization of Source Parameters and some Empirical Relations Between them for Kachchh Region, Gujarat, India: Implication of January 26, 2001 Bhuj Earthquake and Its Aftershock Sequence, *International Journal of Geosciences,*6 (10), 1127-1139,2015

19. Sneha Adhikari, **Parvez I A** and Kiran Kamath, Study of tank with inclined braced staging. *International Journal of Innovative Research in Science, Engineering and Technology*, 5(9), 66-72. doi:10.15680/IJIRSET.2016.0505511, 2016

20. Prajwal T P, **Parvez I A** and Kiran Kamath, Adaptive NSP on L-shaped building. International Journal of Innovative Research in Science, *Engineering and Technology*, 5(9), 143-148. doi:10.15680/IJIRSET.2016.0505523, 2016

21. **Rajendran K, Sajani Surendran,** Kitoh A and **Stella Jes Varghese,** Reduction of uncertainty associated with future changes in Indian summer monsoon projected by climate models and assessment of monsoon teleconnections, *Proceedings of SPIE* (ISSN: 1996-756X), 98820D, doi:10.1117/12.2229392, 2016

22. **Sajani Surendran**, Sulochana Gadgil, Francis P A, Rajeevan M, Prediction of Indian rainfall during the summer monsoon season on the basis of links with equatorial Pacific and Indian Ocean climate indices. *Environmental Research Letters* (ISSN: 1748-9326), 10 (094004), doi:10.1088/1748-9326/10/9/094004, 2015

23. **Sajani Surendran**, **Rajendran K**, and **Arya V B,** Precipitation-aerosol relationship over the Indian region during drought and excess summer monsoon years, *Proceedings of SPIE* (ISSN:1996-756X), 98820Q, doi:10.1117/12.2229447, 2016

24. Santhanalakshmi S, Sangeeta K, **Patra G K**, Analysis of neural synchronization using genetic approach for secure key generation, security in computing and communications, *Communications in Computer and Information Science,*536, 207-216, doi: 10.1007/978-3-319-229157-20, 2015

25. Supriya M, Sangeeta K, **Patra G K**, Trustworthy cloud service provider selection using multi criteria decision making methods*, Engineering Letters*, 24 (1),1-10, 2016

26. Supriya M, Sangeeta K, **Patra G K**, A fuzzy based hierarchical trust framework to rate the cloud service providers based on infrastructure facilities, *International Journal of Performability Engineering*, 12(1), 55-62,2016

27. Srinivas S, Vijayalakshmi A, Subramanyam Reddy A, and **Ramamohan T R**, MHD flow of a nanofluid in an expanding or contracting porous pipe with chemical reaction and heat source/sink, *Propulsion and Power Research*, 5(2),134-148, 2016

28. Srinivas S, Reddy A S, **Ramamohan T R** and Shukla A K, Thermal-diffusionand diffusion-thermo effects on MHD flow of viscous fluid between expanding or contracting rotating porous disks with viscous dissipation, *J. Egyptian Math.Soc.*, 24(1), 100-107, 2016

29. Srinivas S, Shukla A K, **Ramamohan T R** and Reddy A S, Influence ofthermal radiation on unsteady flow over an expanding or contracting cylinder with thermal-diffusion and diffusion-thermo effects, *J. Aerospace Engg.* 28(5), 2015
30. Srinivas S, Reddy A S and **Ramamohan T R,** Mass transfer effects on viscous flow in an expanding or contracting porous pipe with chemical reaction, *Heat Trans. Asian Res.*, 44(6), 552-567, 2015
31. **Ramamohan T R**, Shivakumara I S and Madhukar K, Numerical Simulation of the Dynamics of a Periodically Forced Spherical Particle in a Quiescent Newtonian Fluid at Low Reynolds Numbers, ***Lect Notes Comp Sci,***5544:591-600, 2009
32. **Shekhar S**, **Parvez I A**, Reflection and refraction of attenuated waves at the interface between cracked poroelastic medium and porous solid saturated with two immiscible fluids, *Transport in Porous Media,*113(2), 405-430,2016
33. **Shekhar S, Parvez I A,** Propagation of Torsional surface waves in an inhomogeneous anisotropic fluid saturated porous layered half space under initial stress with varying properties, *Applied Mathematical Modelling*, 40, 1300-1314, 2016
34. **Shekhar S**, **Parvez I A,** Propagation of torsional surface waves in a double porous layer lying over a Gibson half space, *Soil Dynamics and Earthquake Engineering,* 80, 56-64, 2016
35. **Shekhar S**, **Parvez I A**, Wave propagation across the imperfectly bonded interface between cracked elastic solid and porous solid saturated with two immiscible viscous fluids. *International Journal of Solids and Structures*, 75, 299-308, 2015
36. Ningombam S S, **Sridevi Jade**, **Shrungeshwara T S**, Validation of water vapor retrieval from Moderate Resolution Imaging Spectro-radiometer (MODIS) in near infrared channels using GPS date over IAO-Hanle, in the trans-Himalayan region, *Journal of Atmospheric and Solar-Terrestrial Physics*, http://dx.doi.org/10.1016/j.jastp.2015.11.019, 137, H-J. Song, 76-85, 2016
37. Varma O P and **Sridevi Jade**, Report on 4th Edition of Pan-India Debating Competition on promoting communication skill in post-graduate Earth System Sciences Students, *Journal Indian Geological Congress (IGC),*7(2), 55-62. 2015.
38. CatherineJ K, **Vijayan M S M,** Syeda Rabiya U B, **Shimna K**, Gahalaut V K and Ramesh D S, Dichotomy in mode propagation of coseismic ionospheric disturbance: Observations from 11 April 2012 Indian Ocean earthquake, *Journal of Geophysical Research: Space Physics*,120(5) 3854-3867

International Patent Published

Anil Kumar V and Debabrata Das, Method and Device for Detecting a Malicious SCTP Terminal, International Patent Application No. WO 2015/118553 A1, Published under the Patent Cooperation Treaty by *World Intellectual Property Organization* (WIPO), 13 Aug, 2015

National Patent Filed

Anil Kumar V and Debabrata Das, Method and device for robust Multi Path Transmission Control Protocol (MPTCP) against data sequence signal manipulation attack, Provisional Patent Application No. 2186DEL2015, 20 July 2015

Publications in Proceedings

1. Nagaraj Bhat, **Gouda K C**, Manumohan and Reshma Bhat , Monitoring and Estimation of Reservoir Water Volume using Remote Sensing and GIS, ***Proceedings of EGU General Assembly***, Vienna, Austria. id.1123, 12-17 April, 2015
2. Chowdari K K, Girisha R and **Gouda K C**, A study of rainfall over India using data mining, ***IEEE International Conference on Emerging Research in Electronics, Computer Science and Technology*** (ICERECT), Mandya, IEEE, doi: 10.1109/ERECT.2015.7498985, 44-47,2015
3. Shruti, **Gouda K C**, Anandkumar K R, Understanding the Impact of Climate Change on the Human Disease: A Survey, ***Proceedings of the International Conference on Information Science & Technology for Sustainability & Innovation*** (ICISTSI' 2015), Jain University, Bengaluru, doi:10.3850/978-981-09-4426-1_129, 22-23 May, 2015.
4. Niveditha P V, **Gouda K C** and Rashmi B C, Modelling and Analysis of Weather and Climate, ***Proceedings of The International Conference on Information Science & Technology for Sustainability & Innovation*** (ICISTSI' 2015), Jain University, Bengaluru, doi:10.3850/978-981-09-4426-1_115, 22-23 May, 2015.
5. Kavyashree B P, **Gouda K C** and Lakshmikantha G C, Data Mining Approach for Climate Studies, ***Proceedings of The International Conference on Information Science & Technology for Sustainability & Innovation*** (ICISTSI' 2015), Jain University, Bengaluru, doi:10.3850/978-981-09-4426-1_116, 22 -23 May, 2015.
6. Priya P, **Gouda K C** and Bhavana Gowda D M, Software System for Dynamical Crop Modelling, ***Proceedings of the International Conference on Information Science & Technology for Sustainability & Innovation*** (ICISTSI' 2015), Jain University, Bengaluru, doi:10.3850/978-981-09-4426-1_120, 22-23 May, 2015.
7. Samantray P, **Gouda K C**, **Goswami P**, Study of Extreme Rainfall Events over Odisha using observation and simulation, ***Proceedings of the International Scientific Conference our Common Future under Climate Change***, Paris,109, 7-10 July, 2015,
8. Nagaraj Bhat and **Gouda K C**, Climate Change Studies over WesternGhats Region using Remote Sensing & GIS Modelling, ***Proceedings of the International Scientific Conference Our Common Future under Climate Change***, Paris,141, 7-10 July, 2015
9. Parthasarathi Barik, **Gouda K C**, Nagaraj Bhat, **Goswami P**, Impact of Climate change in the Mangrove Distribution across the Indian Coast, ***Proceedings of AGU Fall Meeting,*** San Francisco, 14-18Dec, 2015
10. Shaktidhar Nahak, **Gouda K C**, **Goswami P**, Simulation of Extreme Rainfall Events over India using Variable resolution GCM, ***Proceedings of National Symposium on Understanding and Forecasting the Monsoon Extremes,***IITM Pune, 23-24 February, 2016
11. Rahisha T, **Gouda K C** and Sreedhara V, Shoreline Change Model for Coastal Zone management off Mangalore Coast, ***Proceedings of the UGC-Sponsored Fourth International UGIT Conference on Remote Sensing and GIS Applications on Coastal Management***, Mangalore,16-17Feb, 2016

12. **Gyanendranath Mohapatra**, Swetha Manjunath, Sasmita Behera , and Pratap Kumar Mohanty, Tropical Cyclone Track Analysis Over Indian Coast Using Spatio-Temporal data-mining, ***EGU General Assembly,***17, EGU2015-1038, 2015

13. Ajilesh P P, **Himesh S, Rakesh V** and Sahoo S K, Analysis of Urban Heavy Rainfall Events during Monsoon Period using High Resolution Observation and Mesoscale Modelling, ***Proceedings of IMSP Annual Monsoon Workshop and National Symposium on Understanding and forecasting the monsoon extremes***, IITM, 23-24February, 2016

14. Sahoo S K, **Himesh S, Gouda K C**, Ajilesh PP, Samantray P, **Rakesh V,** et al.,North-East Monsoon extreme 2015: simulation of heavy rainfall event over Chennai during 27th November to 2nd December, ***Proceedings of IMSP Annual Monsoon workshop and National Symposium on Understanding and forecasting the monsoon extremes***, IITM, 23-24February, 2016

15. Ajilesh P P, **Himesh S, Rakesh V, and Goswami P,** Impact of urbanisation on rainfall pattern and surface temperature over selected Indian cities, ***National Space Science Symposium*** (NSSS2016), VSSC, Trivandrum, 09-12 February, 2016

16. **Kantha Rao** and **Goswami P**, Divergence of simulations due to machine dependence: Assessment and Implications on Climate Informatics, ***Proceedings of the Fifth International Workshop on Climate Informatics,*** CI 2015, ISBN: 978-0-9973548-0-5, September 2015.

17. Chhibber Nalin, **Patra G K**, Synchronization of chaos in multiple three-dimensional chaotic maps and its application in cryptography, ***International Symposium on Technology Management and Emerging Technologies*** (ISTMET), IEEE, doi: 10.1109/ISTMET.2015.7359058, 355 - 359, 2015,

18. Praveen Sand **Rakesh V,** Forecasting of monsoon extreme rainfall events associated with tropical depressions over the Arabian sea and Bay of Bengal, ***Proceedings of IMSP Annual Monsoon workshop and National Symposium on Understanding and forecasting the monsoon extremes***, IITM, 23-24February, 2016

19. Neethu C and **Ramesh K V,** Understanding the dynamics of land-atmosphere coupling during heat waves in 2015, **National Space Science Symposium 2016**, VSSC Thiruvananthapuram, 9-12 Feb 2016.

20. Alfred Johny and **Ramesh K V,** Understanding of the ocean-atmosphere coupling during extreme events in east coast of India, **Annual Monsoon Workshop – 2015 and National Symposium on Understanding and Forecasting the Monsoon Extremes**, IITM, Pune, 23-24February, 2016.

21. ShafeerK B, **Ramesh K V**, Alfred johny, Neethu C, Developing new high-resolution drought severity Index over India and its relationship with large-scale features, **Annual Monsoon Workshop – 2015 and National Symposium on Understanding and Forecasting the Monsoon Extremes,** IITM, Pune

22. **Vijayan M S M**, Role of Physics in understanding natural disasters, ***Proceedings of National Conference on Advances in Material Science,*** 5544, 591-600,2016

Publications in Books

Magrin A, **Parvez I A**, Vaccari F, Peresan A, Rastogi BK, Cozzini S, Bisignano D, Romanelli F, **Ashish**, Choudhury P, Roy KS, Mir RR, Panza GF, Neo-deterministic Definition of Seismic and Tsunami Hazard Scenarios for the Territory of Gujarat (India), S D'Amico (ed.), ***Earthquake and Their Impacts on Society, Springer Natural Hazards***, 193-212, 2016

Presentations in Conferences/ Symposia/ Workshops/ Seminars

1. Nekrasova A, Kossobokov V and **Parvez I A,** Earthquake hazard and risk assessment based on unified scaling law for earthquakes: State of Gujarat, India, *EGU General Assembly Conference* 18, 7794, 2016

2. Sahoo S K, **Gouda K C, Himesh S,** Ajilesh P P, Samantray P, **Mohapatra G N, Ramesh K V, Rakesh V and Kantha Rao,** Northeast Monsoon Extreme 2015: Simulation of Heavy Rainfall event over Chennai during 29 November to 2 December, Annual Monsoon Workshop 2015 and a *National Symposium on Understanding and Forecasting the Monsoon Extremes*, IMS & IITM-Pune, 23-24 February 2016

3. Ajilesh P P, **Himesh S**, **Rakesh V**, **Goswami P**,Impact of Urbanization on Rainfall and Surface Temperature Trends Over Different Indian Cities in *National Space Science Symposium – 2016*,VSSC, Thiruvanathapuram, Kerala, 9-12 Feb, 2016

4. Ajilesh P P, Sahoo S K, **Gouda K C, Himesh S, Mohapatra G N**, **Ramesh K V, Rakesh V** and **Kantha Rao**, Analysis of Urban Rainfall Events during Monsoon Period using High Resolution Observation and Mesoscale Modelling,Annual Monsoon Workshop 2015 and a *NationalSymposium on Understanding and Forecasting the Monsoon Extremes*, IMS & IITM-Pune, 23-24 February 2016

5. Rahisha T, **Gouda K C**, Laxmikanth BP, Change Detection Study in Karnataka Coast line Using Remote Sensing and Geographic Information System, *National Conference on Geospatial Information & Technology Advancement* (GITA-2K15), SMV Inst. of Tech. & Mgt., Udupi, 16-17Oct, 2015.

6. Nischitha N, **Gouda K C**, Laxmikanth BP, Monitoring Ambient Air Quality Level over Bengaluru using Remote Sensing & GIS, *National Conference on Geospatial Information & Technology Advancement* (GITA-2K15), SMV Inst. of Tech. & Mgt., Udupi, 16-17Oct, 2015.

7. Sobha N V, **Gouda K C**, Laxmikanth BP, Ground Water Mapping over Bengaluru using GIS *National Conference on Geospatial Information & Technology Advancement* (GITA-2K15), SMV Inst. of Tech. & Mgt., Udupi, 16-17Oct, 2015.

8. **Himesh S**, Sahoo S K, **Gouda K C**, **Mohapatra G N** and **Goswami P,** *Simulation and Analysis of a Heavy Rainfall Event over Bengaluru during October 2013*, TROPMET 2015, a *National Symposium on Weather and Climate Extremes,*IMS & Panjab University, Chandigarh,15-18 February 2015.

9. **Kalyani Devasena C, Sharada M K** and **Swathi P S,** Ocean biogeochemical studies of the Arabian sea using Model simulations and observations, *Eighth National Women's Science Congress*, 7-8 November 2015, Bengaluru

10. **Kalyani Devasena C, Sharada M K** and **Swathi P S,** Impact of Physical processes on Marine Ecosystem Dynamics, *IO50-NIO International Symposium*, Dec.2015

11. Shelva Srinivasan M K**, Kalyani Devasena C, Swathi P S, Sharada M K** andSundara Deepthi MV**,** Effect of Iron limitation on Primary Productivity and Carbon Flux in the Arabian Sea using a 3-D Biogeochemical Model, *IO50-NIO International Symposium*, Dec.2015

12. Neethu C, Shafeer K B and **Ramesh K V,** Dynamics of soil moisture-temperature coupling during temperature extremes: Annual Monsoon Workshop 2015 and National Symposium on Understanding and Forecasting the Monsoon extremes, IITM Pune, 23-24 Feb,2016

13. Alfred Johny and **Ramesh K V**, Reliable heat wave projections over India for twenty first century, National Space Science Symposium 2016, VSSC Trivandrum, 9-12 February, 2016.

14. Shafeer K B and **Ramesh K V,** Evaluation of Indian Summer Monsoon using high resolution simulation, National Space Science Symposium 2016, VSSC Trivandrum, 9-12 February, 2016.

15. **Sharada M K, Swathi P S, Kalyani Devasena C,** Sundara Deepthi MV and Shelva Srinivasan MK, Study of subsurface oxygen distribution in the north Indian Ocean, *IO50-NIO International Symposium*, Dec.2015

16. ShrungeshwaraT S, **Chiranjeevi Vivek G**, Anil Kumar Maletha, Shantanu Sarkar, **Sridevi Jade**, Landslides studies using Global Positioning System (GPS), *5th International Conference on Future Earth Perspectives in South Asia*, Tiruchirappalli, 05-07Feb, 2016

Internal Reports

1. **Chiranjeevi Vivek G,** Suri Babu D,Mir RR, **Parvez IA** and **Sridevi Jade**, Establishment of CGNSS Stations in Kashmir Valley, TRCM1502, 2016

2. **Kantha Rao B**, **Himesh S, Rakesh V,** et. al. Multi-level Soil Moisture characteristics over Indian region using observation data, RRCM1601, 2016

3. **Himesh S,** Ajilesh P**,** Sanjeeb K Sahoo, **Rakesh V,**et al.,Analysis of Rainfall and Surface Temperature Patterns over Select Indian Cities, RRCM1602, 2016

4. **Rakesh V, Goswami P** and Srinivasa Reddy G S, Operational High resolution Rainfall Forecasts over Karnataka: Evaluation Report (September 2010-March 2015), RRCM1503, September 2015

Participation in Conferences/ Symposia/ Workshops/ Training Programmes

Ashapurna Marndi
Cyberoam Training Programme, 29-30April, 2015
Fifth elephant Machine Learning & Analytics Conference,16-17 July 2015
Workshop on IPv6 for Enterprises, 18 August, 2015
Data Science for Big Data Analytics (DSBDA'15), 14-16October, 2015

Chiranjeevi Vivek.G
International Conference on Future Earth Perspectives in South Asia, Dept. of Geography, Bharathidasan University, Tiruchirappalli, 05-07February, 2016

Workshop on Fundamentals of GNSS/IRNSS and Applications to Atmospheric Science, National Atmospheric Laboratory, Gadanki, 26February, 2016.

Mohapatra G N
Taylor & Francis Group Journal's Editorial Roundtable 2016, Bengaluru, 9 March 2016.

Gouda K C
Journal’s Editorial Roundtable organized by Taylor & Francis Group,Bengaluru, 8March 2016.
DST-Lockheed Martin India Innovation Growth Workshop, Bengaluru, 5 February 2016.

Senthilkumar V
Conference on Computational PDE 2015, TIFR Center for Applicable Mathematics, Bengaluru, 21- 23December, 2015

Rajendran K
CTCZ-Subgroup Meeting-Large Scale Component, COAS, IISc, 7-8 August 2015
Climate Change and Extreme Events, National Workshop on Technology Development and Application for Climate Change, NIO-RC, Kochi, 17 March,2016

Sajani Surendran
CTCZ-Subgroup Meeting-Large Scale Component, COAS, IISc, 7-8 August 2015

Vijayan M S M
National conference on Advances in material science, Department of Mathematics, M V Muthiah Government Arts College for Women, Dindigul, February 12,2016
Role of Physics in understanding natural disasters**,** National Conference on Advances in material science,12February,2016

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

4th Edition of Pan-India Debating Competition

CSIR-Fourth Paradigm Institute hosted the 4th edition of Indian Geological Congress (IGC) Pan-India debating competition on the topic Sustainable development in India is not possible without applications of knowledge of earth sciences on 27th November, 2015. The Indian Geological Congress (IGC) conceived the Pan-India debating competition in March 2013 to identify talent in oration and make the young scientists to be concerned with the dreaded results of climate change, atmospheric pollution & related problems, which have turned to be challenges; now. As India is a large country, organization of the event had been divided into FIVE Editions to cover the entire country, to be followed by the finale’ in New Delhi.

As a part of this, 4th edition is exclusively for Southern part of India held in CSIR-4PI. 24 students, research scholars participated from several south-Indian universities/institutes. Participants debated extempore about the sustainable development, importance of renewable resources, expertise needed to use the natural resources in a balanced way without affecting the nature and knowledge in earth sciences field. Three Judges- Dr. Indira NK , CSIR-4PI; Prof. Varma OP, President and Prof. Dave VKS, Secretary of IGC have graded the participants based on preclude, content, substance, style, language, conclusion and time availed. Three participants were awarded with cash prize and certificate. This event was coordinated by Dr. Sridevi Jade and compeered by Mrs. Pavithra NR.

Foundation Day

Foundation Day of CSIR-4PI was celebrated on 11th August 2015. Foundation Day Lecture was delivered by Prof.K Kesava Rao, Dept. of Chemical Engineering, IISc, Bengaluru. Annual Report of CSIR-4PI for 2014-15 was released.

Technology Day Celebrations 2015

Seventeenth Technology Day Lecture on Successful Innovation in Aerospace by the Chief Guest Mr David Jon Ranson, Managing Director, Moog India Technology Center, Bengaluru, on Monday, 11 May 2015, S R Valluri Auditorium, NAL, Bengaluru

Symposium on Complex Systems and Applications, September 29 2015

National Workshop on Technology Development and Application for Climate change studies (NATDAC)

CSIR-4PI conducted one-day National Workshop on Technology Development and Application for Climate Change Studies (NATDAC) on 17th March 2016, at NIO Regional Centre, Kochi. In this workshop advanced training was given to about 25 registered participants selected from nation-wide applications, comprising young scientists, staff and researchers from various universities and colleges. Participants were trained through hands-on session to learn how to estimate and analyse climate change and its impacts. In addition, three domain experts viz. Prof. P. V. Joseph, Dr. N. Subash, Dr. M. R. Ramesh Kumar gave lectures and classes as resource persons. The workshop was organized by Dr. K. Rajendran and was coordinated by Dr. Sajani Surendran.

Invited Talks

Anil Kumar V

Attacks and Countermeasures in Critical Infrastructure, Information, Network and Smart Grid Security Workshop, Central Power Research Institute (CPRI), Bengaluru, 3-4, March 2016

Packets, Attacks and Protocols in Cyberspace, Special team of IT professional of Government of India, C-DAC, Noida, 13 January, 2016

Feedback manipulation and associated Concerns in next generation transport layer protocol on the Internet, Embedded Safety and Security Summit 2015, NIMHANS Convention Center, Bengaluru, 17 June 2015

Supercomputing for Mathematicians, Mathematics Faculty Training Programme of Vishveshwaraya Technological University, M S Ramaiaha College of Engineering, 14 July 2015

Security Challenges and Countermeasures in Next Generation Transport Protocols, Technical Workshop on Trends on Networking and Communication, International Institute of Information Technology (IIIT-B), Bengaluru, 21 April, 2016

Gouda KC

Disaster Management using Geospatıal Tools, Karnataka Remote Sensing Application Centre, Bengaluru, 12 July 2015

How Technology is Changing the Face of Innovations, Jyoti Summit, The Quantum leap in it 2020, Jyotinivas College, Bengaluru, 10th October 2015

Climate Data Research in the age of Big Data, Nagarjuna College of Engineering& Technology, Bengaluru, 12 Sep 2015

Application of Cloud Computing in different sectors, Key note address, FDP on Cloud Technology, SJBIT, Bengaluru, 22Jan 2016

Living with Modelling, Simulation and GIS, Thematic Workshop on use of GIS in Informed Planning & Decision Making, Centre for Innovation in public systems and Ministry of Communication & Information Technology, Govt. of India, New Delhi, 29-30 March 2016

Patra GK

An Inter-disciplinary Modelling Approach for Designing Cryptographic Primitives

Department of Mathematics, M S Ramaiah Institute of Technology, Faculty Development Program on Applied Mathematical Modelling, 15 July 2015
JNN College of Engineering, Shimoga on 16 December 2015
Mount Carmel College, Bengaluru on 20 February 2016

Rajendran K

Role of seasonal cycle and interannual variability in future projection of Indian summer monsoon rainfall, LORRI Workshop on Air Pollution and Climate Change in South Asia: Bridging the Science, Imperial College, London, 9 July 2015

Future Climate Narratives for Southern India, Expert Elicitation Workshop, London School of Economics and Political Sciences, London, 10 July 2015

CMIP5 Based Climate Projections and Uncertainties over South Asia, Seventh National Workshop on Science of Climate Change and Sustainable Development, NCESS, Thiruvananthapuram, 19-20 August 2015

CMIP5 Projections of Changes in Indian Summer Monsoon Rainfall, National Climate Science Conference, DCC, IISc, Bengaluru, 2-3 July 2015

Climate and Extreme Events under Global Warming Scenarios for Indian Coastline and Islets, VACCIN Workshop, Kadmat, Lakshadweep, 11-14 March 2016

CLIMEX and MOSAICC, First PIs' Meet of VACCIN, NIO-RC, Kochi, 31 July 2015

Monsoon 2015, Monsoon Cafè, DCC, Indian Institute of Science, Bengaluru, IIT Bombay,12 August 2015

CFSv2 Seasonal Forecast of Monsoon 2015, Monsoon Cafè, DCC, Indian Institute of Science, Bengaluru, IIT Bombay, 30 September 2015

Extreme June Rainfall over India and Link with Pacific in an Ultra-high Resolution atmospheric GCM, IMS Workshop, IITM, Pune, 24 February 2015

Ramesh K V

Weather and Climate informatics for industrial and societal applications, INSPIRE SC. CAMP, DST, National Institute Science & Technology, Orissa,Govt. India, 27-31 January, 2016,.

Weather and Climate informatics: Applications Agriculture and renewable energy, 1st International Conference on Climate Science Frontiers of Climate Research to Enhance Cooperation of Climate Information and Services for Sustainable Development Planning in North East India, Interdisciplinary Climate Research Center Department of Physics, Cotton College, Cotton College State University, Guwahati on 7-8 March 2016

Sajani Surendran

Extreme June Rainfall over India and Link with Pacific in anUltra-high Resolution atmospheric GCM, IMS Workshop, Indian Institute ofTropical Meteorology, Pune, 24 February 2015.

Sridevi Jade

Inverse Modelling of GPS derived surface displacements, FDP on Theory and Applications of Mathematical Modelling in Engineering, MSRIT, Bengaluru, 13 July 2015.

Paradigm's of Science, National Seminar on Mathematical Modelling on the occasion of National Mathematics Day, GITAM University, Bengaluru, 22 December 2015.

Vijayan M S M

RoleofPhysicsinunderstandingnaturaldisasters, National conference on Advances in material science, Department of Mathematics, M. V. Muthiah Government Arts College for Women, Dindigul, 12February, 2016

Physics of Earthquakes, Festophys'16, Gandhigram Rural University, Gandhigram, February 18, 2016

Seminars/Lectures

Sushant Shekhar, AcSIR Ph. D. Scholar, CSIR-4PI, A Theoretical Study of wave Propagation in Heterogeneous and Isotropic/ Anisotropic Media, June 18, 2015

Shreyas J S (Spark Scholar) NIT, Rourkela, Mathematical Model for (Auto)- Immune Resistance Based on Pathogen Gradient, July 10, 2015

Per Nyber, Cray Inc, Seoul, Korea, Global trends in Weather and Climate Modelling, Oct 7, 2015

Maya Yajnik, Solution Architect, Ericsson, New Jersey, USA, Emerging Trends in the Telecommunications industry, Monday, Oct 12, 2015

Surajit Sen,Prof, Dept of Physics, Univ of NY &Brock University, Canada, Physics of and with Nonlinear waves–Why they Matter, Oct 8, 2015

Luiz DeRose, Director, Cray Inc.,Performance and Programmability Challenges in Current and FutureSupercomputers,February 8, 2016

Visitors at CSIR-4PI

M Rajeevan, Director, IITM,14 May 2015.

Gil Briman, VP, Mellanox Technologies Inc. USA, 30 September 2015

Surajit Sen, Prof., Dept. of Physics, SUNYAB (Buffalo), NY, 05-09 October 2015

Per Nyberg,Director, Business Development, CRAY Inc, 5-7 October 2015

Nitin Patil, Centre for Climate Studies, IIT Bombay, 6-8 January 2016

Luiz DeRose, Director, Programming Environments, CRAY Inc, USA, 8 Feb 2016

Fabio Galetti, ABB (USA), 9 Feb 2016

8
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 guidence toundergraduate/postgraduate student projects to specialized courses. 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 &Innovative Research) PhD program in Mathematical and Information Science,Physical Science and Engineering Science.

Inside

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

Ph D Programme

Anil Earnest

Sunilkumar TC, (AcSIR), Geodynamics of Plate-Boundary Zones

Silpa K, (AcSIR),Crustal Deformation and Earthquake Cycles

Goswami P

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

Eswari V, (GSI), Analysis of Impact of Climate Change on Wind Regimes and Implications for Wind Energy potential over the Monsoon Region

Goswami P (Guide), Gouda K C (Co-guide)

Shaktidhar Nayak, (AcSIR), Development and Evaluation of a Model Configuration for Local Climate Projection over India

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

Payoshni Samantray, (VTU), Study of Extreme Rainfall Events due to Cloud Burst using Observation and Model Simulation

Himesh S (Guide), Gouda K C (Co-guide)

Sanjeeb Kumar Sahoo, (VTU), Impact of Urbanization on High Impact Weather Events & Local Climate

Parvez I A

Ramiz Raja Mir, (AcSIR), Evolution of Crustal and Mantle Structure in Kashmir Himalaya

Patra G K and Sarda N L (IIT Bombay)

Ashapurna Marndi, (AcSIR), Scientific Data Analysis and Data Intensive Research

Sangeeta 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

Rajendran K

Ipsita Putatunda, (AcSIR), Methods of Physical Assimilation for Short Range Numerical Weather Prediction

Jayasankar C B,(AcSIR), Climate Change Modeling Studies

Rajendran K (Co-guide)

Kulkarni Shashikant**,** (IIT Bombay), Downscaling over Monsoon Region

Ramesh K V

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

Safeer K B, Evaluation of Upper Ocean Variability Simulated by IPCC Climate Simulations

Edwin Raj E, (UPASI TRF TRI) Climate Impact Assessment on Tea Production overSouth India

Sajani Surendran

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

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

Sajani Surendran (Co-guide)

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

Chiranjeevi Vivek G, (AcSIR), GNSS studies in Indian subcontinent

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 inducedby acoustic gravity waves

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/BE/MCA students' Thesis/Project

Anil Kumar V

Spoorti S Doddamani, (M.Tech), VIT University, Vellore, May 2015, Performance Evaluation of Databases of Big data in Analyzing Dynamic Cyber Threats

Sushma Patil, (M.Tech), Visvesvaraya Technological University, Karnataka, May 2015, Remote Extraction of Malicious Payload for SCTP

Kumar Saras and Kriti Didwania, (B.Tech), Kalinga Institute of Industrial Technology (KIIT) University, Odisha June 2015, Performance Tuning of Apache Cassandra Database

Sujata Patnaik, (MCA), Behrampur University, July 2015, Active TCP Responder

Ashapurna Marndi

Kavyashree K R, Vishvesvarya Technological University, May 2016, Electricity load Forecasting using Deep Learning Technique based on Time Series Data

Gouda K C

Pavithra,(M.Tech),(VTU), Bengaluru, June 2015, Climate Change and Agricultural Sustainability Studyusing RS and GIS

Shruthi S, (M.Tech), SJB Institute of Technology (VTU), Bengaluru, June 2015, Study of Impacts of Climate Change on Public Health using Modelling and Data Mining

Ajay K P, (M.Tech), Visvesvarya Institute of Technology (VTU), Mudubidri, June 2015, Multi-source Spatio-Temporal Climate Data Analysis in Cloud Computing Environment

Kavyashree, (M.Tech), V K Institute of Technology (VTU), Bengaluru, June 2015, Study of Climate Change and its Impacts using Spatio-temporal Data mining

Priya P, (M.Tech), V K Institute of Technology (VTU), Bengaluru, June 2015, Crop Modelling System Using High Resolution Multi-Source Data and HPC

Niveditha P V, (M.Tech), V K Institute of Technology (VTU), Bengaluru, June 2015, Regional Climate Study using Numerical Weather Modelling and Remote sensing Data

Bhavya Garewal and Bhavesh Jangid, (B.Tech),(CIT), Abu road, Rajasthan, July 2015, Solar energy assessment over Rajasthan

Shetty Neha Karunakar, Pratheek P Hegde, Srikanth Rao P and **Shricharana U**, (B.Tech), SVM Institute of Technology, Udupi, July 2015, Weather Informatics

Shetty Shreya Shashidhar, Sankusha D S and **Amrusha**, (B.Tech), SVM Institute of Technology, Udupi, July 2015,Weather and Climate Data Analysis

Sankerth G S, (B.Tech),Jain University, Bengaluru, June 2015,Weather analytical survey and Visual Effects R&D

Parvez I A

Sneha Adhikari (M.Tech) Department of Civil Engineering, Manipal Institute of Technology (2015-16), Study of Seismic Response of an Elevated Liquid Storage Tank with Different Staging Configurations.

Prajwal T P (M.Tech) Department of Civil Engineering, Manipal Institute ofTechnology (2015-16), Non Linear Seismic Response Analysis of Irregular Buildings Considering the Direction of the Earthquake Forces

Patra G K

Shreeya G Degaonkar, Sparsha Uday, Varuni R, Sandesh C G, BNM Institute of Technology, Bengaluru, May 2015, Effective Authentication for pervasive Computing using E-MAC.

Medini HK, (M.Tech), JNN College of Engineering, November 2015, Design of Lightweight Hash Function using Tree Parity Machine

Priyanka B R, (M.Tech), JNN College of Engineering, November 2015, Design of Word based Stream Cipher using Tree Parity Machine

Arpitha P, (M.Tech), JNN College of Engineering, November 2015, Design of Lightweight Hash Function using Permutation Parity Machine

Vidya M H, JNN College of Engineering, November 2015, Design of Word based Stream Cipher using Permutation Parity Machine

Sai Rakshit S Harathas, (B.Tech), Department of Electronics and Communication, NIT Goa, July 2015, Study and Analysis of Cryptography, Primality Tests and Factorization Tests

Sasswat Kumar Mishra, (B.Tech), IIIT, Bhubaneswar, July 2015,Cryptography, Primality Testing and Parallel Computing using OpenMP

Mahapatra G N

Swetha M, *(M.Tech),* SJB Institute of Technology,Bengaluru, Software System For Analyzing Cyclone Data Over North Indian Ocean

Ramesh K V

Aakash V, Abdul Fatah M, Arun Muthuram M, Elaiyatamilan M and Sajimol S *(M.Tech)***,** Bharathidasan University, Tiruchirappalli, Assessment of variability and change in environment over Western Ghats: An application of geo and weather informatics.

Senthilkumar V

Shriyans Bagla, Indian Institute of Technology (IIT-Bhu), Varanasi, July 2015, Application of Differential Quadrature Method in Free Vibration and buckling analysis of nanobeams and plates based on Euler-Bernoulli beam theory

Vijayan M S M

John P Pappachen, Cochin University of Science and Technology, Kochi, June 2015, combined effect of 11th April 2012 Mw8.6 & Mw8.2 Wharton Basin strike slip earthquakes: Near and Far field co-seismic deformation

Summer Research Fellowship Programme

Parvez I A

Merlin Joice A, Anna University, Summer Research Fellow of Indian Academyof Sciences, Distribution Of Seismic Hazard And Its Impact To Population.

Taichengmong Rajkumar, Indian School of Mines, Dhanbad, Determination of Focal Mechanism of Earthquakes in Indian Region.

Yash Jain, Indian School of Mines, Dhanbad, Ground Motion Simulation ofNepal Earthquake.

Ramesh K V

Nayana B N, Indira Gandhi First Grade Womans College, Sagar, Understanding the rainfall variability and change over South and North Karnataka for the period 1871 -2010

Swaraj Banerjee, Hansraj College, Delhi University, Understanding the relationship between Sedimentation in the Ganga-Brahmaputra Delta and the Climatic factors

Aman Kumar Jaiswal, Indian School of Mines, Dhanbad, Understanding the relationship between Forest fire and Aerosol optical depth: pollution load on environment.

Faculty Participation

Academy of Scientific and Innovative Research (AcSIR)

Parvez I A, Research Methodology, January-July 2016 semester
Patra G K,High Performance Scientific Computing, January-July 2015 semester

Patra G K, Adjunct faculty, Department of Computer Science, Amrita School of Engineering, Bengaluru

Swathi P S

Ten lectures on parallel programming with MPI, numerical solutions of shallow water and heat equationsat the SERB Summer School on Fundamentals on Oceanic Processes and Modelling, 19 May – 11 June, 2015, IIT Delhi

9
PROJECTS & COLLABORATIVE PROGRAMMES

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

Inside

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

CSIR 12th Five Year Network Projects

Advanced Research in Engineering & Earth Sciences (ARiEES): Data Intensive Modelling and Crowd Sourcing Approach *- 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 (CRRI)
CSIR North East Institute of Science and Technology (NEIST)

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

Nodal Lab: CSIR National Institute of Oceanography (NIO)
Participating Lab:
CSIR-4PI
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 CBRI
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 Electronics Electronics Engineering Research Institute, (CEERI)
CSIR Central Mechanical Engineering Research Institute (CMERI)

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

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

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

Nodal Lab: CSIR CIMFR
Participating Lab:
CSIR Central Mechanical Engineering Research Institute (CMERI)
CSIR-4PI
CSIR National Geophysical Research Institute (NGRI)

Vulnerability assessment and development of adaptation strategies for climate chance impact with special references to costs and island ecosystems of India (VACCIN*), PI*: Rajendran K / Sajani Surendran

Nodal Lab: CSIR-NISCAIR
Participating Lab:
CSIR-National Institute of Science Communication And Information Resources
CSIR-Institute of Genomics & Integrative Biology (IGIB)
CSIR Central Road Research Institute (CRRI)
CSIR National Environmental Engineering Research Institute (NEERI)
CSIR- Central Salt & Marine Chemicals Research Institute
CSIR-4PI
CSIR National Institute of Oceanography (NIO)
CSIR Institute for Interdisciplinary Science and Technology (NIIST)
CSIR National Geophysical Research Institute (NGRI)
IIT Kharagpur
Kolkata University
Fishery Survey of India

Grant-in-aid Projects

Modelling of marine biogeochemical cycles in the Indian Ocean, MOES **–** *PI: Sharada M*

Plate kinematics geodynamics and earthquake occurrence processes in the Andaman Nicobar region using real time geodetic and seismological observations and earthquake awareness centre at Port Blair, MoES, *PI: Sridevi Jade*

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

Investigation of mega city effects on the genesis and intensity of extreme rainfall events and their impact, DST - *PI: S Himesh, 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*

Diagnosis of Increased seismic hazard in Himalayas and adjacent territories, DST, Government of India, DST-Russian Federation of Basic Research - *PI: Imtiyaz.A.Parvez*

Mathematical modeling of capsule rot disease of small cardamom, mathematical modeling of capsule rot disease of small cardamom, *ICRI - PI: Goswami P, Ramesh K V*

Investigation of relative roles of local and large-scale circulation in the dynamics of cloudburst using simulation with a non-hydrostatic model, DST - *PI*: *Gouda K C*

Carbon cycle studies of the Indian Ocean using ocean biogeochemical model simulation and observations, DST, Women Scientist Scheme A - *PI: Chikka Kalyani Devasena, Swathi PS*

Volcanic deformation studies using dinsar techniques, under dmsp r&d: earthquake precursors, Department of Space, GOI - *PI: Anil Ernest, Co-PI: Tejpal Singh*

National carbonaceous aersols programme (ncap): working group iii-carbonaceous aersols emissions, source appointment and climate effects, Ministry of Environment, Forest and Climate Change (MoEFCC) GOI - *PI: Sajani Surendran*

Geological characterization of the Kashmir valley with the objective of quantifying probabilistic hazard and risk in the high risk areas of the valley using a logically integrated set of GEO- Scientific Investigation, Department of Earth Science, GOI - *PI: Imtiyaz.A. Parvez*

Mathematical modeling of some nano fluid flows, National Board of Higher Mathematics, *PI: S Srinivas Co-PI: Ramamohan T R.*

Collaborating Institutions
Vellore Institute of Technology

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)

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

Collaborating Institutions:

IIT Mumbai

Operation of permanent and campaign mode GPS stations for quantification of tectonic deformation field in Himalayan terrain – *PI: Sridevi Jade and Kireet Kumar*

Collaborating Institutions:

GBPHIED, Almora

In-House Projects

Empirical modelling and relationship of the primary productivity with other ocean parameters in the Indian Ocean - *PI: Indira N K*

Monitoring continuously operating CSIR-4PI gps station located in the iisc campus and real-time operational data hub at CSIR-4PI - *PI: Sridevi Jade*

Site-specific ground motion modelling and microzonation studies in Delhi city - *PI: Parvez I A*

Integrated Disaster Assessment and Modeling (IDAM) - *PI: S Himesh*

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STAFF, NEWS & UPDATES

CSIR Centre for Mathematical Modelling and Computer Simulation (CSIR CMMACS) was set up in 1988 with the mandate to develop expertise, excellence and facilities for undertaking major mathematical modelling and simulation problems in identified areas primarily of relevance to CSIR. CSIR C-MMACS was repositioned in 2013 as CSIR-Fourth Paradigm Institute (CSIR-4PI) to provide the country a unique positioning in the domain of computational and data intensive research powered by high performance computing and informatics research. One of the smallest of CSIR laboratories, CSIR-4PI today is a young and vibrant institution of research.

Objectives:

- *To develop capability for addressing critical issues of scientific significance and social benefit.*
- *To enhance the scope and strength of mathematical modeling through development of new techniques/algorithms etc.*
- *To train and develop high-quality man-power in the area of Mathematical Modeling and Computer Simulation.*

Inside

- *Staff list*
- *Awards/Honors/Recognition*
- *Services on External Committees/Membership of Professional Bodies*
- *Deputations*

Staff list

Head
Shyam Chetty

Honorary Emeritus Scientist
Gaur V K
Yajnik K S

Distinguished Scientist
Ehrlich Desa
Prakash V

Scientist
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

Project Monitoring and Evaluation
Sharada M K (additional charge)
Suchanda Ray (additional charge)

Technical Officer
Prabhu
Suchanda Ray

Stores & Purchase
Nandeesh M J

Administration
Anilkumar Angadi
Neethu S Induchodan
Raman P K
Sathyanarayana K

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

DST Women Scientist
Chikka Kalyani Devasena

Quick Hire Fellow
Tavpritesh Sethi

Research Associate
Jurismita Baruah
Mohammad Mafooz
Prakash Barman

SRF/JRF
Arya V B
Farrukh Altaf
Ipsita Putatunda
Jayasankar C B
Shafeer K B
Shaktidhar Nahak
Silpa K
Stella Jes Varghese
Sumana Sarkar
Sunil Kumar T C
Sushant Shekhar

Project Fellow/ Senior Project Fellow
Addala Koti Dharma Teja
Ajilesh P
Akash Choudhury
Alfred Johny
Amritha Babu
Athira U Nambeesan
Boddapati Anil
Chilukuri Anusha
Chinmaya Mohini
Donupudi Suribabu
Ganesan P
Gourab Maiti
Haseeb Rehman

Kambala Ganga Bhavani
Kirthi Sagar V
Kokkiligadda Swathi
Lavanya S
Murthy DHR
Nagaraju G
Nagaraj Naik
Natesh S
Navi Thejesh
Neethu C
Nirmala J Nair
Nunna Bala Ankaiah
Parthasarathi Barik
Payoshini Samantray
Prajith KC
Prashant Meti
Praveen S
Rakesh Teja Konduru
Rammes Raja Mir
Renu Goyal
Reshma Bhat
Sambit Kumar Panda
Sanjeeb Kumar Sahoo
Shelva Srinivasan
Smruthishree Lenka
Srinivatsav K
Sudeep Nesakumar
Sundara Deepthi
Sunil Babu

Project Assistant
Suganya R
Sofia Evelin
Sarath Kumar

Graduate Trainee
Jayalakshmi D C

Awards/Honours/Recognition

Anil Kumar V, Fellowship from Internet Society (ISOC) to be part of the 95th IETF (Internet Engineering Task Force) Standardization Meeting at Buenos Aires, Argentina

Goswami P, appointed as Director, NISTADS

Rajendran K, Appointed as Associate Editor, Journal of Earth SystemSciences, Indian Academy of Science

Sridevi Jade, chief guest for National conference on Mathematical Modelling and paradigm shift in science at GITAM university, Bangalore on the occasion of Ramanujam birthday which is observed as National Mathematics Day.

Vijayan M S M
Chief guest, Festophys'16, 18 February 2016, Departmentof Physics, Gandhigram Rural University, Gandhigram, Tamilnadu.

Chief Guest, Blossom16 - Annual Day, 17 March 2016, FirstStep Public School CBSE, Kanavaipatti, Tamilnadu

Ph D awarded

Sushant Shekhar,AcSIR
Prakash Burman, Tezpur Univeristy
Kutubuddin Ansari, IIT Bombay
Mohapatra G N, Berhampur University
SenthilkumarV, IIT Kharagpur

Services on External Committees/Membership of Professional Bodies

Anil Earnest

Member, American Geophysical Union (AGU)
Member, Society of Exploration Geophysicists (SEG)
Member, Society of Earth Scientists (SES), India
Associate Member, International GNSS Service (IGS)
Member, Asia Oceania Geosciences Society (AOGS)

Anil Kumar V

Life Member, Computer Society of India
Member, Internet Society (ISOC)
Member, Cyber Security and IT Policy Committee National Aerospace Laboratories, Bangalore
Member, Technical Programme Committee, International Conference on Electronics Computing and Communication Technologies (IEEE CONECCT-2015)
Member, Program Committee, National Conference on Parallel Computing Technologies, PARCOMPTECH, 2015
Member,M Tech Thesis Evaluation Committee, Center for Cyber Security, Amrita Vishwa Vidyapeetham, Coimbatore
Member, Selection Committee, C-DAC, Bangalore
Member, Assessment Committee, C-DAC, Bangalore
Nodal Officer, National Knowledge Network

Goswami P

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

GoudaK 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, Technical Committee, International Conference on Information Science & Technology for Sustainability & Innovation" (ICISTSI' 2015), Jain University, Bangalore, 22-23 May, 2015.
Member, National Advisory Committee,National Conference on Geospatial Information and Technology Advancement (GITA-2K15), Bantakal, 16-17 October, 2015

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 School of Mines, Dhanbad.
Member, Advisory Committee, Reviewing Committee of Scientific Projects at National Institute of Rock Mechanics (NIRM), Kolar
Member, Hindi Technical Advisory Committee (HTAC) of NAL.
Member, Technical Expert Committee of Karnataka State Natural Disaster Monitoring Centre (KSNDMC), Department of Science and Technology, Government of Karnataka.
Life Member: Indian Society of Earthquake Technology
Life Member: Indian Society of Earthquake Science

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
Member, Advisory Committee for 1st International Conference on Computer, Electrical and Modelling Systems
Member, Advisory Board of School of Computer Science and Engineering, Vellore Institute of Technology
Member, Board of Studies, Mathematics Department, Mount Carmel College, Bangalore
Member, Board of Studies of Department of Mathematics, Government Science College, Bangalore
Member, Doctoral Evaluation Committee, Anna University, Chennai
Member, Empowered Technical Committee for Centre for Modelling, Simulation and Design, University of Hyderabad.

Rajendran K

Member, Working Group on Climate Change, Kerala State Planning Commission, Government of Kerala.
Member, Board of Studies in Atmospheric Sciences, Cochin University of Science & Technology, Cochin, India, (2011-2014).
Life Member, Indian Meteorological Society

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.
Life Member, Indian Meteorological Society

Senthilkumar V

Advisory Board, Fundamentals and Trends in Additive Manufacturing, Training Program on Additive Manufacturing, March 2016
Editorial Board Member in 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

Sharada M K

Member, Advisory Committee, Faculty Development Program,MSRIT, Bengaluru

Sridevi Jade

Life Member, Indian Geotechnical Society
Member, International Society of Soil Mechanics and Foundation Engineering
Founder Life Member, Indian Society of Rock Mechanics and Tunneling Technology
Member, International GNSS Service (IGS)
Expert Member, Research Advisory Council (RAC),member of Wadia Institute of Himalayan Geology.
Expert member, Technical Advisory Committee, Government of Karnataka
Member, Information Sciences cluster 12th FYP Work Group/Task Force
Member, Doctoral Committee, Tezpur University

Swathi P S

Member, Purchase Committee, NAL
Member, Assessment Committee, NIO
Member, Assessment Committee, NAL

Thangavelu R P

Life Member, Computer Society of India
Life Member, Cryptology Research Society of India

Deputations

Chiranjeevi Vivek.G

Visited Astronomical Institute of the University of Bern, Bern, Switzerland, 25 – 29 January, 2016

Goswami P

Visited Colorado, USA to participate and deliver a plenary lecture at the 3rd International Conference in Energy and Meterology 2015, 23-26 June 2015

Parvez I A

Visited NORSAR, Norway under Indo-Norwegian project, 23 August –. 5 Sept, 2015.
Visited Earth Observatory of Singapore, Nanyang Technological University in Singapore, 11-14November, 2015.
Visited the Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences 84/32 Profsoyuznaya Street, 117997 Moscow, Russia, 16-29November, 2015.

Swathi P S

Visited Princeton University, USA – Modelling a living planet, A symposium celebrating the research of Prof. J. L. Sarmiento, 14-15 March, 2016

Rajendran K

Visit on invitation to Imperial College and LSE, London, 7-12 July 2015.

Ramees Raja Mir, SPF

Attended the International Training Course on Seismology, Seismic Data Analysis, Hazard Assesment and Risk Mitigation at the German Research Centre for Geosciences, Potsdam, Germany, 10 August –. 4 Sept, 2015

Tavpritesh Sethi, QHF

Attended the Big Data in Biomedicine Conference, Stanford, USA, 20-22 May 2015