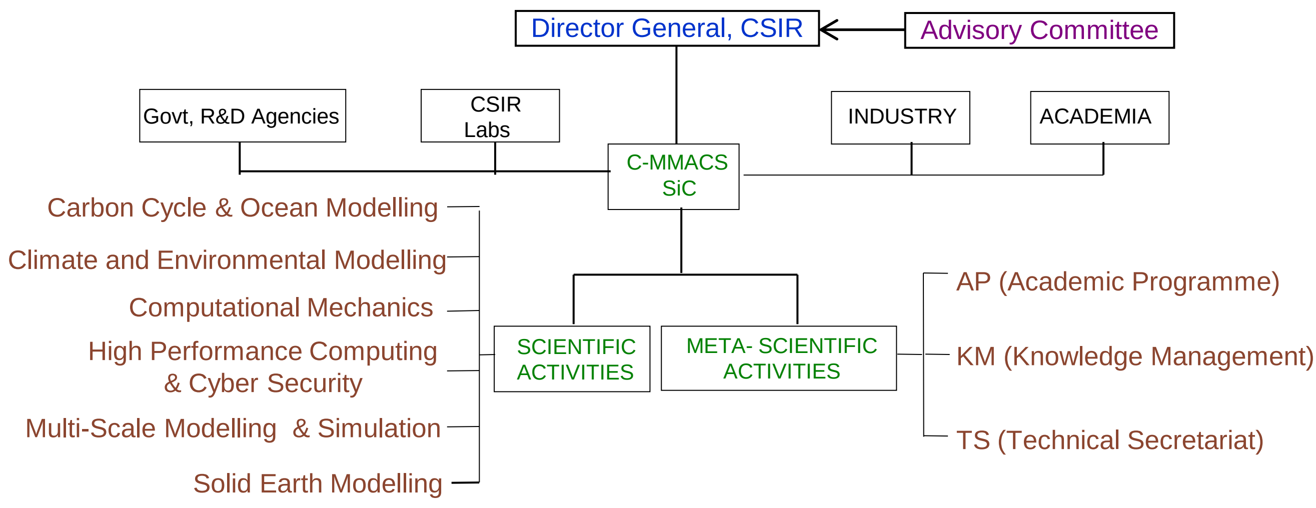
CSIR C-MMACS
Annual Report
2012 - 2013

CSIR C-MMACS
1988 2013
SILVER JUBILEE

Modelling for Science
Modelling for a Better Future

CSIR Centre for Mathematical Modelling and Computer Simulation
BANGALORE

ORGANISATIONAL STRUCTURE OF C-MMACS



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Prof P Seshu
Scientist-in-Charge
C-MMACS, Bangalore

C-MMACS, Wind Tunnel Road, Bangalore 560 037, India
Fax: +91 80 25220392
Tel: +91 80 2522 4667
E-mail: sic@cmmacs.ernet.in
Website: http://www.cmmacs.ernet.in

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CSIR Centre for Mathematical Modelling & Computer Simulation
NAL Belur Campus
Wind Tunnel Road
Bangalore 560037
http://www.cmmacs.ernet.in

Editorial Team
N K Indira
Suchanda Ray

Designed & Printed by
G Nagaraju

Assisted by
Sibasankar Badatya

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Hindi Section, NAL

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Scientist-in-Charge
CSIR Centre for Mathematical Modelling & Computer Simulation
NAL Belur Campus
Wind Tunnel Road
Bangalore 560037
Ph No: 080-25051920, 25224667
Fax: 080-25220392
E mail: seshu@cmmacs.ernet.in

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To all staff members of the C-MMACS for inputs to the report.

Foreword

CSIR C-MMACS, established in 1988, is celebrating its Silver Jubilee Year (2012-2013). This is a very special year for CSIR C-MMACS and it is a great privilege for me to present the Annual Report. A number of events were organized through the year since the Inauguration Programme of the Silver Jubilee year by DG, CSIR Prof S K Brahmachari on 3rd August 2012. This year has also been special since CSIR C-MMACS has been repositioned as nucleus of Fourth Paradigm Institute (CSIR 4PI), to provide the country a unique positioning in the domain of computational, data intensive research and discovery. The CSIR-4PI would function in a hub and spoke model. The hub will be in Bangalore and the spokes will be at Delhi, Chennai, Pune, Hyderabad, Kolkata, Nagpur and Chandigarh. The newly installed supercomputing facility at the centre will be the backbone for the new research ventures in areas of earth system, bio-molecular and bio-medical, chemical and physical sciences.

The 360 Tera Flop (peak) High Performance Supercomputing facility at CSIR-4PI is the largest CPU based installation in the country and 82nd in the world as per the November 2012 list. It was a great effort by the HPC group at CSIR-4PI, as well as other service departments of CSIR NAL such as Electrical, Estate & Building and Purchase to establish this complex facility along with its associated infrastructure. The system riding over the National Knowledge Network, will provide the much needed boost to the computational scientists of CSIR in all disciplines.

The commissioning of continuous measurement stations at Pondicherry and Port Blair was a major achievement last year. In addition to a Picarro instrument measuring CH_4 and CO_2 at very high precision, Port Blair has a LGR instrument which measures N_2O and CO. A new Picarro instrument was installed in Hanle. The robust inversion of CO_2 fluxes from Temperate Asia by our group, perhaps the first paper from India on this topic, has been published in Current Science recently. We have completed climatological and inter-annual simulations of the biogeochemistry of the global oceans using the TOPAZ model embedded within the Modular Ocean Model. Analysis of these simulations have revealed interesting insights into the interannual variablilty of chlorophyll, primary production, pCO_2 etc. in the Indian Ocean.

In the field of Solid Earth modelling, a new CSIR XII Five year plan project on GPS based Integrated Landslide Modelling for hazard assessment has been sanctioned with CSIR CBRI as the nodal Lab initiating GPS based landslide research for the first time in the country. Also the research in GPS based PWV and TEC have for the first time provided potential tools for early warning of geohazards. CSIR-CMMACS GPS continuous station established in Andamans as part of CSIR XI FYP gave an estimate of surface deformation suffered by Andaman island due to April 2012, northern Sumatra earthquake. Seismic hazard map of Himalayas and High -resolution velocity map of India has been generated. CSIR

XII five year plan also includes Modeling and Simulation of Ground Motion parameters expected from scenario earthquakes using extended source and site response, modeling of high resolution complex crustal and mantle structure using broadband seismology and attenuation models for seismic and coda waves.

Climate and Environmental Modelling Programme continues to generate the experimental long-range high-resolution forecast of monsoon to IMD. An important outreach programme in weather informatics is in collaboration with Karnataka State Natural Disaster Monitoring Centre (KSNDMC). Using novel methodology developed at CSIR C-MMACS, weather informatics are provided to farmers through KSNDMC. The CSIR Climate Observation and Modelling Network (CSIR COMoN) initiative now has 24 towers at different locations in India and the data is used for the research work.

Analytical solutions for nonlinear problems are often difficult to obtain. The homotopy analysis method with some modifications was used to obtain limit cycle solutions for the forced Van der Pol Duffing oscillator. The effect of an elastic medium on the vibration frequencies of carbon nanotubes have been investigated by analytical studies using the differential quadrature method and the differential transform method.

Academic programme of CSIR C-MMACS has taken a firm root now, with increasing number of students enrolling for the SPARK programme. The year saw a good number of students from premier institutions in India joining for their project work under the guidance of scientists in different areas. In this year, Himesh S, Jurishmita Baruh, Swapan Mallick and J Saigeetha secured their Ph.D. degrees.

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

Prof P Seshu
Scientist-in-Charge

आमुख

सीएसआईआर सी-मैक्स, जिसकी स्थापना 1988 में हुई, अपना रजत जयंती वर्ष (2012-2013) मना रहा है। सीएसआईआर सी-मैक्स के लिए यह वर्ष अत्यंत महत्वपूर्ण है और संस्थान की वार्षिक रिपोर्ट प्रस्तुत करना मैं अपना सौभाग्य मानता हूँ। सीएसआईआर के महानिदेशक प्रो एस के ब्रह्मचारी के करकमलों से 3 अगस्त 2012 को रजत जयंती वर्ष के उद्घाटन के पश्चात् संस्थान में वर्ष भर अनेक कार्यक्रमों का आयोजन होता रहा है। यह वर्ष सीएसआईआर सी-मैक्स के लिए इस करण से भी अविस्मरणीय रहेगा चूंकि इसी दौरान सीएसआईआर सी-मैक्स को चौथे प्रमुख पैराडाइम संस्थान (सीएसआईआर-4पीआई) के रूप में मान्यता प्राप्त हुई, जिससे कि देश में अभिकलन, डाटा गहन अनुसंधान एवं अन्वेषण के क्षेत्र में महत्वपूर्ण स्थान दिया जा सके। सीएसआईआर-4पीआई एक पहिये की धुरी मतलब हब और स्पोक की तरह कार्य करेगा। हब बेंगलूर में होगा जब कि स्पोक दिल्ली, चेन्नै, पुणे, हैदराबाद, कोलकाता, नागपुर और चण्डीगढ़ में होंगे। संस्थान में हाल ही में सूपरकंप्यूटिंग की सुविधा कायम की गई, जिसकी मदद से अनेक क्षेत्रों में जैसे भू-प्रणाली क्षेत्र, जैवाण्विक क्षेत्र एवं जैव-चिकित्सा क्षेत्र, रासायन एवं भौतिक विज्ञान के क्षेत्रों में नए-नए अनुसंधान किए जा सकेंगे।

सीएसआईआर-4पीआई की 360 टेरा फ्लॉप (पीक) उच्च निष्पादन वाली सूपरकंप्यूटिंग सुविधा, नबम्बर 2012 की सूची के अनुसार, सीपीयू आधारित सबसे बड़ा देशी संस्थापन है और विश्व में इसका 82वॉ स्थान है। सीएसआईआर-4पीआई के एचपीसी ग्रूप के बृहद् प्रयास का ही यह परिणाम है। इस जटिल सुविधा को उसकी सहयोगी अवसंरचना के साथ सफल स्थापित करने में सीएसआईआर-एनएएल विद्युत अनुभाग, संपदा एवं भवन अनुभाग तथा क्रय अनुभाग ने काफी सहयोग दिया है। राष्ट्रीय ज्ञान नेटवर्क पर आधारित इस प्रणाली से सीएसआईआर के समस्त अभिकलनीय वैज्ञानिकों को वांछित सहयोग प्राप्त होता रहेगा।

पांडिचेरी एवं पोर्ट ब्लेयर में सतत मापन स्टेशनों का प्रवर्तन पिछले वर्ष की उल्लेखनीय उपलब्धि कही जा सकती है। उच्च विभेदन पर CH_4 और CO_2 के मापन वाले पिकारो उपकरण के अलावा पोर्ट ब्लेयर में N_2O और CO के मापन हेतु एलजीआर उपकरण भी लगाया गया है। हैनले में एक नया पिकारो उपकरण लगाया गया है। प्रशांत एशिया से CO_2 प्रवाह के मजबूत व्युत्क्रम पर हमारे ग्रूप का एक आलेख हाल ही में 'करंट साइंस' पत्रिका में प्रकाशित हुआ है, जो संभवत: भारत की ओर से इस विषय पर प्रकाशित प्रथम आलेख है। हमने वैश्विक महासागरों की जैव-भू-रसायन पर जलवायु-विज्ञान संबंधी अनुकरण एवं अंतर-वार्षिक अनुकरण किया है और इस अनुकरण में हमने मॉडुलर ओशन मॉडल में अंत:स्थापित टोपाज़ मॉडल का प्रयोग किया है। इन अनुकरणों का विश्लेषण करने के परिणाम स्वरूप, हिन्द महासागर में क्लोरोफिल, प्राइमरी प्रोडक्शन, pCO_2 आदि से संबंधित अंतरवार्षिक परिवर्तनशीलता पर अनेक रोचक तथ्य सामने आए।

ठोस भू प्रतिरूपण के क्षेत्र में, देश में पहली बार जीपीएस आधारित भूस्खलन अनुसंधान पर कार्य आरंभ हुआ है। सीएसआईआर-सीबीआरआई के नेतृत्व में जीपीएस आधारित एकीकृत भूस्खलन प्रतिरूपण पर आपदा अनुमान लगाने की एक नई सीएसआईआर बारहवीं पंच वर्षीच योजना स्वीकृत हुई है। साथ ही, जीपीएस आधारित पीडब्ल्यू एवं टीईसी पर चल रहे अनुसंधान में पहली बार भू-आपदाओं के समय पूर्व

चेतावनी देने के सशक्त औजारों का प्रयोग किया गया है। सीएसआईआर ग्यारहवीं पंच वर्षीच योजना के अधीन अंदमान में सीएसआईआर-सीमैक्स के जिस सतत स्टेशन की संस्थापना की गई, उसकी मदद से उत्तर सुमात्रा भुकंप के कारण अंदमान द्वीप में अप्रैल 2012 में घटित पृष्ठीय विरूपण का अनुमान लगाया जा सका। हिमालय के भूकंपीय मानचित्र और भारत के उच्च-विभेदन मानचित्र बनाए गए। सीएसआईआर बारहवीं पंच वर्षीच योजना के अधीन फिलहाल अनेक कार्य चल रहे हैं, जैसे विस्तारित स्रोत एवं साइट प्रतिकिया का उपयोग करते हुए परिदृश्य भूकंपों के भू चाल पैरामीटरों का प्रतिरूपण एवं अनुकरण; ब्रॉडबैंड भूकंप विज्ञान एवं कोडा तरंगों के क्षीणन मॉडल के आधार पर उच्च-विभेदन जटिल क्रिस्टलीय और पपड़ी संरचना का प्रतिरूपण।

जलवायु एवं पर्यावरण प्रतिरूपण कार्यक्रम के अधीन पहले की तरह आईएमडी को मानसून संबंधी प्रायोगिक एवं दीर्घ-परास उच्च-विभेदन युक्त पूर्वानुमान उपलब्ध कराए जा रहे हैं। मौसमी सूचना के क्षेत्र में सीएसआईआर-सीमैक्स द्वारा विकसित नवीनतम कार्यप्रणाली का उपयोग करते हुए कर्नाटक राज्य प्राकृतिक आपदा अनुश्रवण केन्द्र (केएसएनडीएमसी) के तत्वावधान में किसानों को मौसमी सूचना दी जा रही है। सीएसआईआर के जलवायु प्रेक्षण एवं अनुश्रवण नेटवर्क (सीएसआईआर कॉमन) के अधीन अब भारत के विभिन्न प्रांतों में कुल 24 टॉवर लगाए गए हैं इनसे प्राप्त डाटा का अनुसंधान कार्य में लाभ उठाया गया है।

अरेखीय समस्याओं में विश्लेषणात्मक समाधान प्राप्त करना वास्तव में कठिन है। अस्वाभाविक वॉन डर पॉल डफिंग दोलक के सीमित साइकिल समाधान निकालने के लिए कुछ परिवर्तनों के साथ समस्थेय विश्लेषण विधि का उपयोग किया गया है। कार्बन नैनोट्यूब की कंपन आवृत्तियों पर एलास्टिक मीडियम के प्रभाव पर विश्लेषणात्मक अध्ययन किए गए हैं और उसकी जांच करने में अवकलक क्षेत्रफलन विधि एवं अवकलक रूपांतरण विधि का उपयोग किया गया।

स्पार्क कार्यक्रम में प्रवेश लेने वाले छात्रों की बढ़ती संख्या के साथ-साथ सीएसआईआर-सीमैक्स के शैक्षणिक कार्यक्रम की जड अब मजबूत हो गई है। इस वर्ष विभिन्न विषयों के वैज्ञानिकों के मार्गदर्शन में भारत के प्रमुख संस्थानों से परियोजना कार्य हेतु आने वाले छात्रों की संख्या काफी अधिक रही है। इस वर्ष संस्थान के हिमेश एस, जरुष्मिता बरुआ, स्वपन मल्लिक एवं जे साईगीता ने पीएचडी की उपाधि प्राप्त की है।

सीएसआईआर-सीमैक्स के अनुसंधान कार्य में समर्थन देने हेतु मैं सभी संबंधित राष्ट्रीय एवं अंतार्राष्ट्रीय विभागों व संगठनों के प्रति अपना हार्दिक आभार प्रकट करता हूँ। सीएसआईआर के महानिदेशक एवं हमारी सलाहकार समिति के सदस्यों को उनके समर्थन व मार्गदर्शन हेतु आभार प्रकट करना मैं अपना सौभाग्य मानता हूँ। मैं सीएसआईआर–एनएएल के निदेशक श्री श्याम चेट्टी को हार्दिक धन्यवाद देता हूँ जिन्होंने अपनी व्यस्तता के बावजूद सीएसआईआर-सीमैक्स के कार्यक्रमों के पल्लवन में विशेष रुचि दिखाई है। सीएसआईआर–एनएएल के समस्त प्रभागों के प्रति उनके संपूर्ण समर्थन के लिए धन्यवाद देता हूँ। मैं इस अवसर पर प्रो वी के गौड़, डॉ के एस यजनिक, डॉ यू एन सिन्हा, डॉ एरलिच देसा एवं डॉ बालगणेश के प्रति भी आभार प्रकट करता हूँ, जो सीएसआईआर-सीमैक्स के कार्यकलापों में निरंतर सम्मिलित रहे और वैज्ञानिकों को समय-समय पर सलाह व मार्गदर्शन करते रहे। अन्त में, सीएसआईआर-सीमैक्स के समस्त वैज्ञानिकों एवं कर्मचारियों को इस अनुपम संगठन के प्रति उनकी समर्पण भावना हेतु हार्दिक धन्यवाद देता हूँ।

प्रो पी शेषु
वैज्ञानिक-प्रभारी

HIGHLIGHTS

- *Continuous measurement stations at Pondicherry and Port Blair*
- *Installation of new Picarro instrument at Hanle*
- *Robust estimation of CO_2 fluxes from Temperate Asia using data from Hanle*
- *Climatological and inter-annual simulations of global ocean using Topaz and MOM.*
- *Insights into the interannual variablilty of a few biogeochemical components and fluxes in the Indian Ocean.*
- *Development of epidemiology (malaria) model for Arunachal Pradesh*
- *Dynamical air pollution forecast model validated for Delhi*
- *Simulation of heavy rainfall in Delhi: Validation with COMoN data*
- *Hobli level rainfall forecast over Karnataka*
- *Advance forecasting of date on Onset of Monsoon with C-MMACS forecast methodology*
- *Variation of the frequency of the forced Van der Pol Duffing oscillator*
- *A non – perturbative technique to obtain limit cycles and quasi-periodic solutions for forced nonlinear oscillators.*
- *Demonstration of the possibility of apriori determination of the structure of phase space for forced nonlinear oscillators*
- *Formalism for prediction of loads on a spherical particle moving in a quiescent fluid at arbitrary Reynolds numbers*
- *The thermal effect on the dynamic frequency of a Single Walled Carbon nanotube with elastic support has been investigated using pseudospectral and finite element methods.*
- *14 years of GPS time-series along 2500km Indian Himalayan arc using combined global GPS data analysis*
- *Co-seismic displacement ~ 30 mm/yr of CSIR-CMMACS Port Blair continuous station due to April 11, 2012 two M8.6 and M8.2 earthquakes which occurred on the western coast of northern Sumatra.*
- *Ionospheric TEC Perturbations derived from GPS signals - Possibility for Tsunami Early Warning using on Shore GPS Network*
- *GPS PWV (Precipitable Water Vapor) - A potential tool to detect cloudbursts and extreme rainfall events.*
- *Estimation of Seismic Hazard and risks for Himalayas and Surrounding Regions based on Unified Scaling Law for Earthquakes*
- *High resolution velocity model of India towards generating the Neo- Deterministic Seismic Hazard Map of India*
- *First ever Deterministic seismic hazard map for India using modeling and simulation of ground motion.*
- *Notable contributions to the computational approaches and practice of quantifying strong ground motion at a site towards microzonation of seismically vulnerable areas.*

- *Quantifying the seismic attenuation characteristics of the various Indian regions, a critical parameter in hazard quantification, using Coda, P- and S- wave attenuation.*
- *Broadband computational seismology for the Indian lithosphere modeling and understanding the evolution of crustal and mantle structure.*
- *Commissioning of India's fastest supercomputing facility at CSIR C-MMACS*
- *Establishment of a Tier-III equivalent Data Centre for hosting the computational facility*
- *Breaking into world's top 100 for the first time in history of CSIR.*

Research & Development Programmes

1

CARBON CYCLE AND OCEAN MODELLING

The cycling of carbon between the different compartments of the earth system (atmosphere, land, ocean and cryosphere) is of crucial importance in the study of climate change. The cycle is modulated by several processes: primary production, regeneration, transport and transfer across the compartments. At C-MMACS, we have been studying some of these aspects in great detail. We have established WMO standard GHG measurement stations and used this data in an inverse atmospheric transport model to yield robust sources and sinks of CO2. These estimates will fill a crucial gap in the carbon budget. We have also made sophisticated simulations of the oceanic bio-geochemical cycle to study the marine component of the cycle. This study is extremely crucial as the oceans are poorly sampled and we have to use modelling extensively to fill gaps in data and knowledge.

Inside

- *Measurement stations for GHGs*
- *Evaluation of the Biogeochemical model simulations using data from US JGOFS Cruises and Satellites in the Arabian Sea and Bay of Bengal*

1.1 Measurement stations for GHGs

One of the outstanding research tasks in climate change research remains the reduction of uncertainties in the current global 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 0.5-1.0 GTC (Gigaton 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.

Figure 1.1 Installation of the instruments with the weather sensors at IAO, Hanle in Ladakh. Inlet fixed on the top on the building

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 1.2 Picarro instrument measuring CO2 and CH4

This will require the establishment of new 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) have been set up in Port Blair, Pondicherry and Hanle where the data is collected at every 5 secs. for CO_2 and CH_4 and downloaded at C-MMACS for analysis and modelling. At Port Blair we have another instrument measuring N_2O and CO also. These are 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.

Figure 1.3 Calibration cylinders for the instruments

Figure 1.4 Picarro and LGR instruments measuring CO_2/CH_4 and N_2O/CO

Figure 1.5 Sequencer which puts the instruments for calibration

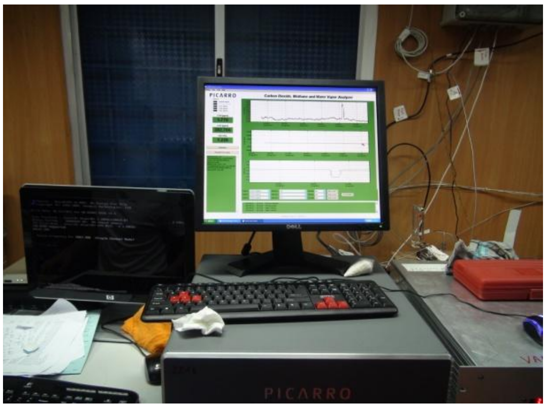


Figure 1.6 Picarro displaying CO_2 and CH_4 values

Figure 1.7 Wind sensor measuring wind speed and direction at 30m

Figure 1.8 GPS recording the UTC time

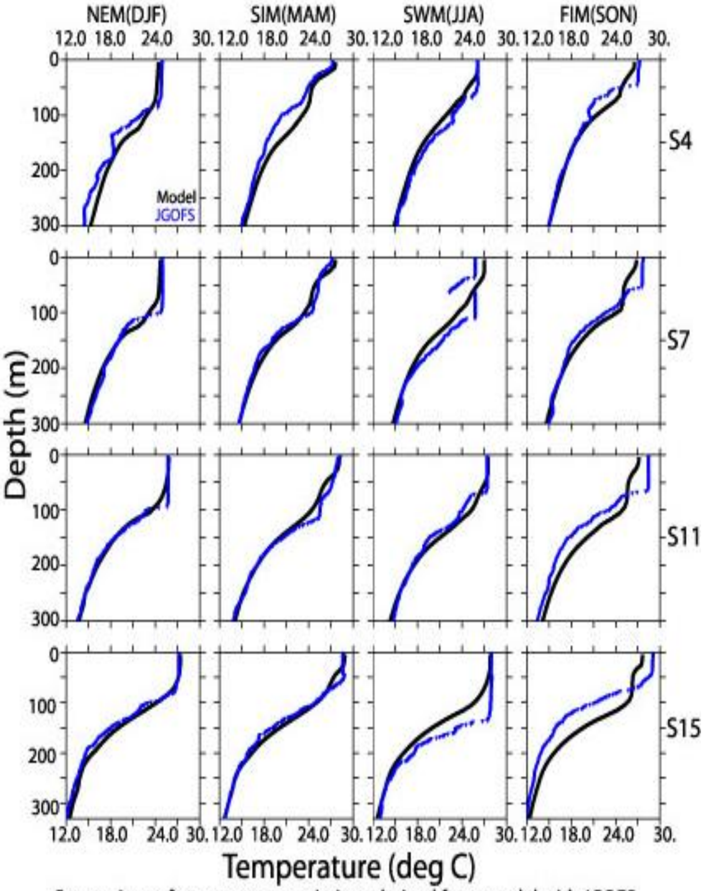
Figure 1.9 The station at Port Blair showing the 32 m tower with the weather sensors mounted on it and also the inlet fixed on the top to measure GHGs which is connected to the instruments inside the cabin (installed next to the tower). The required equipments (calibration gases, flow and temperature regulators) for precise measurements as prescribed by WMO can be seen in the pictures above. The whole set up is near the coast in Port Blair and the measurements will reflect the effects of diurnal variations of the local winds (land and sea breezes), seasonal variations due to the monsoons and long range transport from China, SE Asia, Australia and the Indian subcontinent.

N K Indira, P S Swathi, V K Gaur,
B C Bhatt, IIA, Bangalore, M Ramonet
and his team from LSCE, France

1.2 Evaluation of the Biogeochemical model simulations using data from US JGOFS Cruises and Satellites in the Arabian Sea and Bay of Bengal

In the present study, evaluation of the 3-D global ocean model coupled with complex biogeochemical model TOPAZ with large number tracers has been done by comparing the depth profiles of Temperature, Salinity, Primary Productivity (PP), Chlorophyll (Chl), Nitrate and Oxygen with US JGOFS Cruise data at four stations in the Arabian Sea and, seasonal and spatial variations of Chlorophyll and SST in the Arabian Sea and Bay of Bengal using the satellite data from MODIS.

The physical model is modular Ocean Model (MOM4p1, Griffies et al., 2004) developed at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (GFDL). The model has 50 vertical levels, out of which 25 are in the top 250 m to resolve the mixed layer properties. The horizontal resolution of the model is 1^o globally with $1/3^o$ resolution near the equator. Technical details of the model are given in the MOM4p1 technical guide (Griffes, 2007). Vertical mixing is computed using K-profile parameterization (KPP-Large et al., 1994). The biogeochemical model TOPAZ developed at GFDL (Dunne et al., 2010) has been coupled with MOM4p1. This prognostic ocean biogeochemistry model contains 25 tracers including three phytoplankton groups (diatoms, eukaryotic phytoplankton, diazotrophs), two forms of dissolved organic matter (labile and semi-labile), nutrients (N,P,Si and Fe). The growth rate of phytoplankton is calculated based on Geider et al 1997. The model has eight dissolved inorganic variables (Nitrate, ammonium, phosphate, silicate, oxygen, iron, carbon and alkalinity).



Comparison of temperature variations derived from model with JGOFS observations during various seasons at four locations

Figure 1.10 Comparison of temperature variations derived from model with JGOFS observations during various seasons at four location

Comparison with Cruise measurements

The depth profiles of seasonal average values of temperature, salinity, nutrients, oxygen, chlorophyll and PP from the climatological simulations of the model are compared with US JGOFS cruise data at four stations, namely, S4 (59.8°E, 17.2°N), S7 (62° E, 16° N) S11 (65° E, 14.5°N) and S15 (65°E, 10°N) upto 300m depth. Model profiles of temperature (Figure 1.10) and salinity compare well with the observations at many stations and many of the seasons. The deviations of the model from the observations may be due to the forcing at short time scales and model resolution.

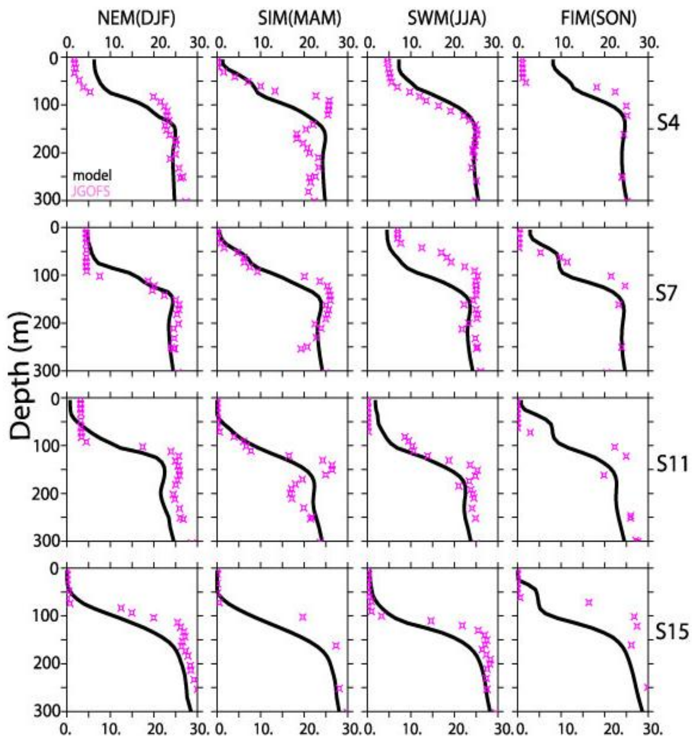


Figure 1.11 Comparison of Nitrate variations derived from model with JGOFS observations during various seasons at four locations

The PP profiles compare well with observations during North East Monsoon (NEM) and Fall Inter Monsoon (FIM) for all the stations. The model is not able to capture high productivity observed during South West Monsoon (SWM) because model results are averaged over three months. In central Arabian Sea (AS), PP from the model is much higher than the observed values during FIM for stations S11 and S15. Oxygen variations are high with respect to depth during all seasons at all stations. It can be noticed that there is a considerable decrease in oxygen below 100m. Model simulations are able to capture the oxygen minimum zone below 180m (Figures not shown).

Vertical profiles of Nitrate (Figure 1.11) from surface to 300m depth are compared with US JGOFS cruise data. The model is able to capture the low values of nitrate as observed in the Cruise data in the upper ocean and high values below the nitracline for many seasons at many stations.

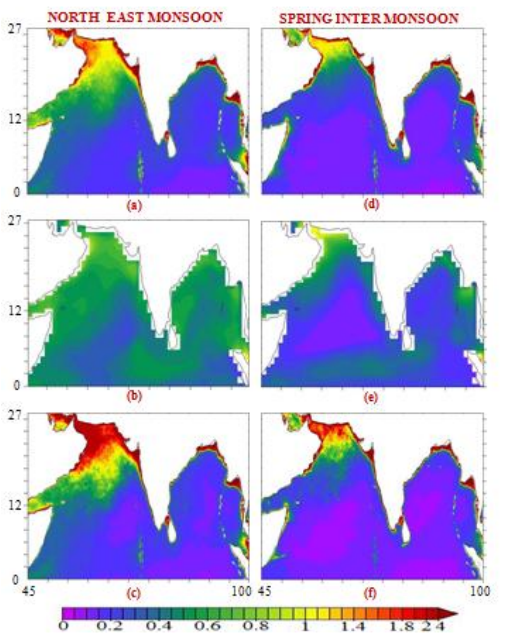


Figure 1.12 Spatial variation of Chlorophyll (mg/m³) in the north Indian Ocean for NEM and SIM (a) & (d) SeaWiFS, (b) & (e) Model, (c) & (f) MODIS Aqua

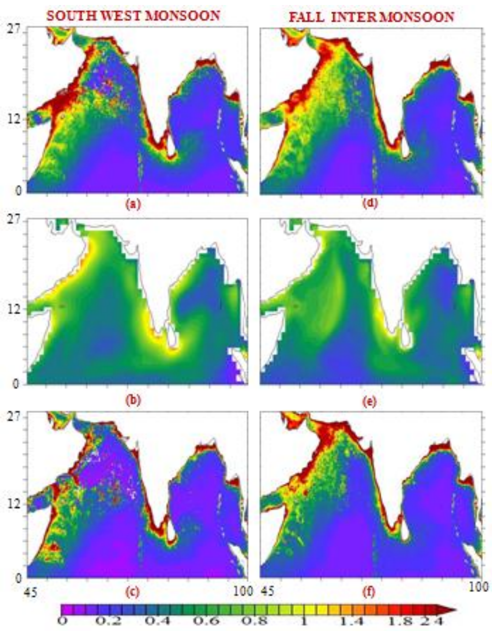


Figure 1.13 Spatial variation of Chlorophyll (mg/m³) in the north Indian Ocean for SWM and FIM (a) & (d) SeaWiFS, (b) & (e) Model, (c) & (f) MODIS Aqua

In figures 1.12 and 1.13, Chl in the upper 20m from the model simulations for four seasons are compared with the seasonal averages of surface Chl obtained from SeaWiFS and MODIS climatological data. It can be noticed that major features of the spatial variation observed in SeaWiFS and MODIS data like high Chl in the west AS, low Chl in central AS and most parts of Bay of Bengal (BOB) are captured by the model during SWM, Chl is low everywhere in AS and BOB except the north AS during Spring Inter Monsoon (SIM). Chl is higher near the south coast of India during SWM and FIM and is much lower in the north AS during NEM than in SeaWiFS and MODIS data.

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

2

CLIMATE AND ENVIRONMENTAL MODELLING PROGRAMME (CEMP)

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

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

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

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

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

Inside

Monsoon Forecasting

- *Advance Dynamical Forecast of Date of Onset of Monsoon*
- *Long-Range High Resolution Forecasting of Monsoon, Post-Season Evaluation: 2012*

Forecast Methodology

- *Mesoscale Data Assimilation for Improved Weather Prediction*
- *Simulation of Heavy Rainfall over Delhi : Validation with COMoN Data*
- *Predictability of a Dynamical System with Embedding Dynamics*
- *Optimum Model Configuration for Simulation of Tropical Cyclone*
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Weather, Climate; Health Energy and Crop

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- *Hobli-level Rainfall Forecasts over Karnataka*

CSIR Climate Observation and Modelling Network (COMoN)

2.1 Climate Observation and Modelling Network: Current Status

India, with its large latitudinal extent from the tropics to the sub-tropics, exhibits large diversity in its climate and climate change; monitoring, understanding and modelling of this climate diversity requires a carefully designed observation system covering the country. The National Action Plan on Climate Change identifies knowledge and data infrastructure as a critical component.

In addition to sustained operation, a climate observation network requires careful design for choice of application to diverse processes like agriculture, ecology, energy and other sectors. Thus the choice of type of sensors, location and mounting of these sensors also need to take into account the end-use of the data, especially its use in cross-sector applications. In particular, the observations need to include the minimum number of variables necessary for an assessment of regional climate and multi-sector applications. For example, near-surface observations alone cannot provide sufficient information for climate monitoring and modelling; it is necessary to have sustained observations above the surface for sampling large-scale circulation.

To create a comprehensive observation network that, through sustained operation, can lead to a quantitative assessment of climate and climate change over India. CSIR, under its 11th Five Year Programme (2009-14) has initiated a Climate Observation and Modelling Network (COMoN). COMoN has been established through resource sharing participation of a number of agencies and institutions; it thus provides an active and effective platform for multi-agency cross-sectoral research in the area of climate and environment. At short term, the network helps to calibrate and validate models of high-impact weather like extreme rainfall; at long term, it also serves to validate climate simulations over India. With multi-level and sub-surface observations, COMoN covers locations from the Himalayas to the North-East to Cochin.

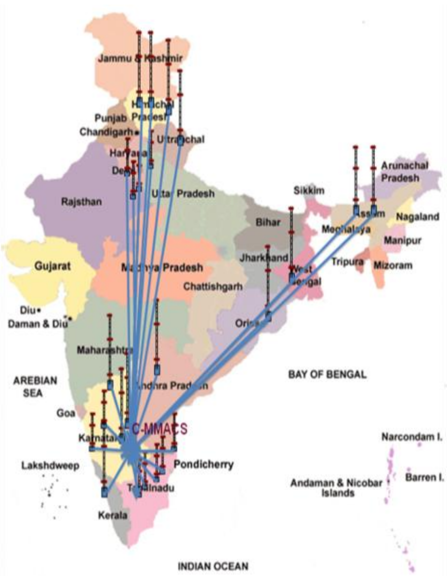

Figure 2.1 Geographical distribution of COMoN Towers

COMoN now has 24 operational climate profilers throughout the country, some of them operational for more than three years. A wealth of data has been collected and the network has been shown to be stable and sustainable. The flexible mounting of COMoN allows application specific as well as special observation campaign (e.g logarithmic mounting). The network has been designed for geographical coverage to ensure monitoring of India's climate diversity and strategic application, with provision for easy augmentation; thus COMoN provides a basic infrastructure for diverse applications. Due to its Multi-level mounting, COMoN allows calculation of vertical gradients and contrast between conditions near the surface and upper (30 meter) level. Out of these 24 profilers, 14 have been identified for for such augmentation with sophisticated instruments like cielometer and disdrometer; and such augmentation has been completed in most of the selected sites.

S Himesh and P Goswami

2.2 Analysis of Heavy Rainfall Event over Delhi using COMoN Data

Under CSIR Climate Observation and Modelling Network (COMoN) there are three meteorological profilers that constitute the Mesoscale Observation Network for Urban Systems (MONUS); MONUS has been operational for more than 3 years at Hindon, Rajokri and CSIR NPL.

Observations can provide useful advance information about the imminent weather event in terms of signature of the developing weather systems. Here we present an analysis of hourly observations from COMoN-MONUS for the episode of unusual and heavy rainfall over Delhi on 5th February 2013. The COMoN-MONUS observations did exhibit certain interesting atmospheric conditions associated with the event. One of the important advantages of COMoN observations is high-frequency data at 3 vertical levels. Atmospheric temperatures at three different levels (2m, 20m and 30m) from the MONUS observations reveal both interesting vertical and horizontal structures.

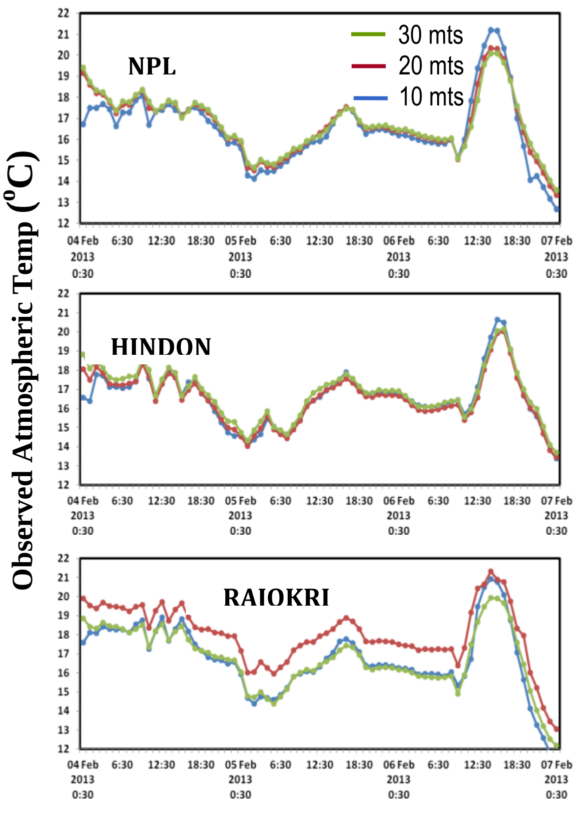

Figure 2.2 MONUS observations show pre-event higher atmospheric temperature during the heavy rainfall event over Delhi on Feb 5th 2013.

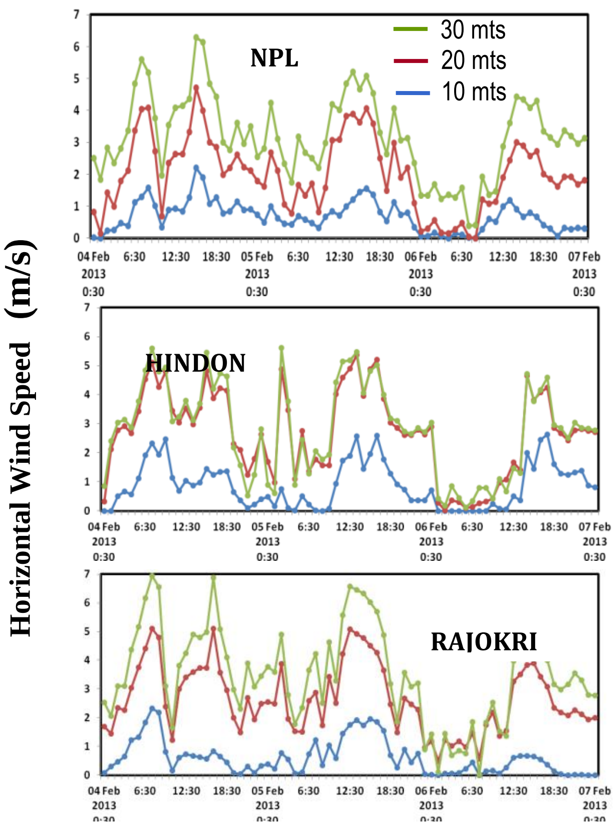

Figure 2.3 MONUS observations show higher horizontal wind speed just before the event during the heavy rainfall event over Delhi on Feb 5th 20013. This is one of the common features before the onset of such events

Pre-event elevated temperature is evident at all the three stations and three vertical levels, which is one of the conducive atmospheric conditions for the onset of the event, by the way of providing necessary heating. Pre-event increase in horizontal wind speed by 2 to 3 times may be seen at different stations and at different levels (Figure 2.3). This increased wind speed may play an important role in the transport of moisture (horizontal advection).

S Himesh and P Goswami

2.3 Simulation of Indian Monsoon in IPCC Climate Simulations

Regional climate systems, like the Continental Indian Monsoon (CIM), determine the sustainability of a large section of the world's population; accurate projections of such energetic and large regional systems are also critical to determine the future of the global climate system. The assessment of the reliability of the trends is made further complex by the fact that the observed trend itself has a degree of uncertainty; and different observed data sets show appreciable differences among them. To avoid any bias in the evaluation, we have considered six observed data sets from different sources. We have also considered ensemble formed through an equal-weight averaging for both observations and simulations. For gaining insight, we considered three (equal-weight average) ensembles based on the levels of the statistical significance of the trends: high significance ($P < 0.01$), low significance ($P < 0.05$) and all-average observations. For model simulations, such as trends and correlation coefficients, we have adopted a value $P < 0.2$ as the acceptable level of significance in view of inherent uncertainties in simulations.

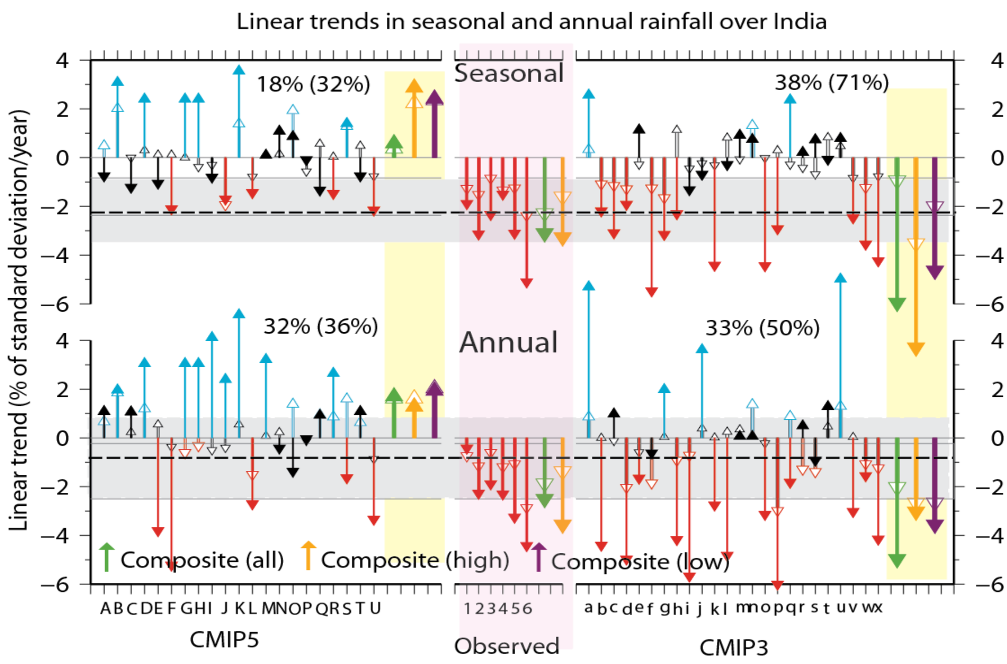

Figure 2.4 Current trends in the seasonal (June-September) and the annual rainfall over India (Continental Indian Monsoon, CIM; 70-85E, 10-35N) from CMIP5 (left panels), CMIP3 (right panels) climate simulations compared with the trends in the multiple observations (middle panel). For the observations the trend in the different composites (highlighted, yellow) represent average of all (green), high significance (P < 0.01, orange) and low significance (P <0.05, purple) ensembles. The trends are expressed as percentage of respective standard deviation for the period 1951-2005. The percentage of models that simulated significant negative trend as against the total number of significant trends (positive and negative) is shown in each panel; the numbers in the brackets show the percentage of the total simulations with negative trend in the respective case. The blue lines indicate significant (P < 0.2) positive trend, red lines indicate significant (P < 0.2) negative trend and the black lines (P > 0.2) indicate insignificant trends. The dash line indicates the observed composite trend and the grey band represents the dispersion in the observed trends.

K V Ramesh and P Goswami

2.4 Advance Dynamical Forecast of Date of Onset of Monsoon

Accurate and advance forecast of the date of onset of monsoon (DOM) has many applications in diverse sectors. Although such advance (> 15 days) forecast of rainfall variability with sufficient accuracy is not considered possible yet, we have presented a novel conceptual framework and its validation for advance forecasting of date of onset of monsoon. In particular, we have argued that large transitions like the onset of monsoon should have a high signal-to-noise ratio, and should be predictable. Along with this hypothesis, a dynamical framework with a general circulation model (GCM) optimized over India (variable-resolution GCM from LMD, France) was adopted (Goswami and Gouda, 2010); further, objective criteria and algorithm for identifying the date of onset from the GCM simulations were developed.

These methodologies have been followed to generate advance (> 15 days) forecast of the date of onset of monsoon. The C-MMACS forecasts of date of onset, announced in April, 2012, matched with the date of onset announced by IMD (June 04, 2012).

C-MMACS began its experimental forecast of DOM in 2003, with communication to India Meteorological Department (IMD), Govt of Karnataka and other agencies since 2007. The 6 year performance of dynamical prediction of DOM shows an average error of 2 days (Table 2.1), with only one year with large error of 5 days.

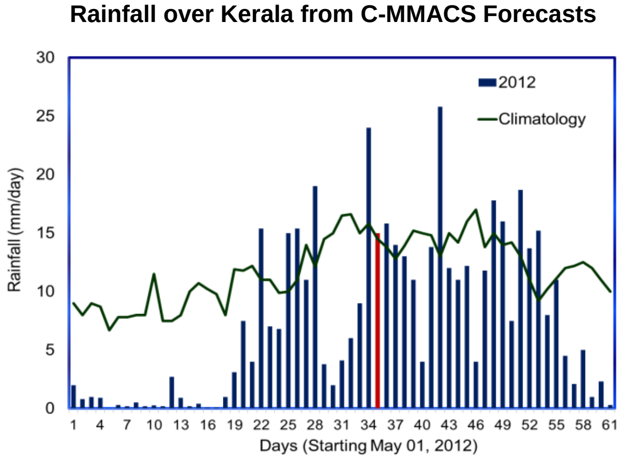

Figure 2.5 Area-average (75-77°E,8-12°N) daily rainfall over Kerala during May 01 to June 30, 2012 from C-MMACS first outlook for 2012 monsoon.

Table 2.1 Performance of C-MMACS Experimental Forecasts of Monsoon Onset

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

These post forecast validations, along with statistical evaluation of hindcasts (P Goswami and K C Gouda 2010) firmly establish the validity of the conceptual and methodological framework for advance forecasting of DOM.

*Reference: Goswami, P., K. C. Gouda, 2010: Evaluation of a Dynamical Basis for Advance Forecasting of the Date of Onset of Monsoon Rainfall over India.Mon. Wea. Rev., **138**, 3120–3141.*

K C Gouda, P Goswami

2.5 Long-Range High Resolution Forecasting of Monsoon, Post-Season Evaluation: 2012

To develop forecast to meet end user's need, C-MMACS pioneered dynamical, long-range forecasting of monsoon at high resolution in the country. As the methodology adopted was unconventional, C-MMACS had been communicating its experimental forecasts generated in April to various agencies, including India Meteorological Department (IMD) and Karnataka State Natural Disaster Monitoring Centre (KSNDMC) for robust and objective post-season evaluation.

Following its standard procedure, C-MMACS issued its experimental forecasts of monsoon 2012 in early April, 2012; these were presented in the pre-season meeting organized by IMD in mid April, 2012; the contribution is acknowledged in IMD's official announcement.

Following its philosophy of user-centric forecast methodology, forecasts are issued at high resolution (~50 KM). A comparison of the forecast of June-August rainfall with the corresponding observation from IMD shows good agreement (Figure 2.6) expect over a few locations. Thus, the forecast could capture the overall normal rainfall and the areas of excess rainfall. However, the forecasts showed deficit rainfall over parts of north-west India and Uttar Pradesh, not seen in the observation. Similarly, a few areas of deficit rainfall, such as part of north-east India and Orissa, were not captured in the forecast.

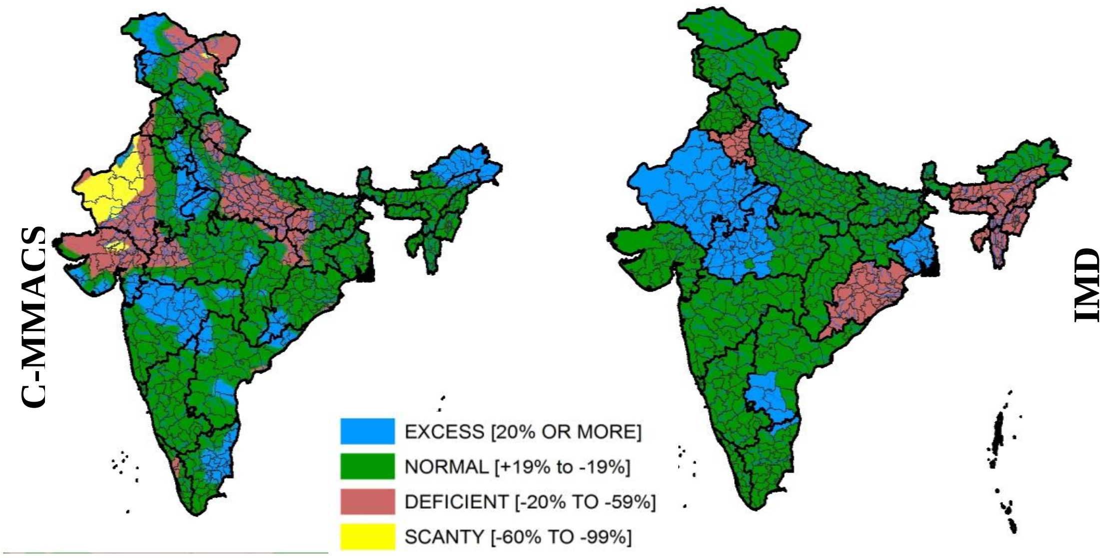

Figure 2.6 Seasonal (June-August) rainfall anomalies from C-MMACS long-range high resolution forecasts (left panel) and IMD observation (right panel) for monsoon 2012.

Overall, only a few locations show error of more than one category; thus the risk of using these forecasts, in principle, is minimal. With 2012 being the 10th year of experimental forecast, robust statistics are building up for the validity of C-MMACS methodology.

K C Gouda and P Goswami

Forecast Methodology

2.6 Mesoscale Data Assimilation for Improved Weather Prediction

One of the major challenges in high resolution weather forecasting is the quality of initial condition. The analysis available for model initial and boundary condition are generally from global models and may not represent the weather phenomena that are highly localized. An effective solution for improving the quality of initial condition is through assimilation of observations. Here we present impact of assimilation of real- time observations from various sources on advance rainfall forecast at high resolution set up by CSIR C-MMACS for dissemination through Karnataka State Natural Disaster Monitoring Centre (KSNDMC, Govt. of Karnataka). Another difficulty in improving numerical forecast at finer spatial scales is the coarse resolution of initial analysis. We analyzed the impact of assimilation of various observational data such as AWS network established by KSNDMC, Radiosondes, AWS from IMD and CSIR (COMoN) (Figure 2.7). The improvement due to assimilation is estimated by conducting control simulations (without assimilation).

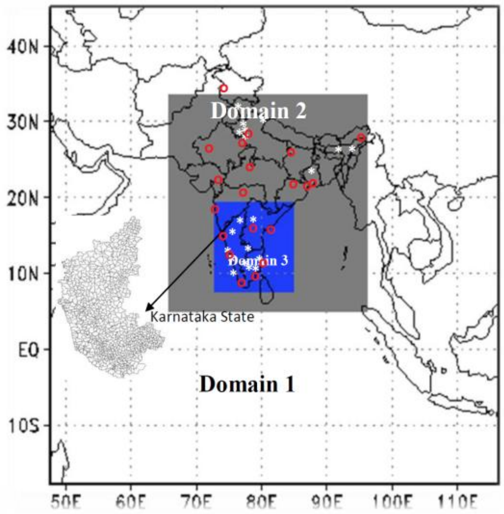

Figure 2.7 Model domains used for the numerical simulations. The horizontal resolutions of domain 1, Domain 2, and Domain 3 are 36, 12, and 4 Km respectively. The hobli division and AWS locations over Karnataka, for which the forecast is generated, are shown in the inset. The locations of radiosonde and tower are marked by circle (red color) and star (white color) respectively.

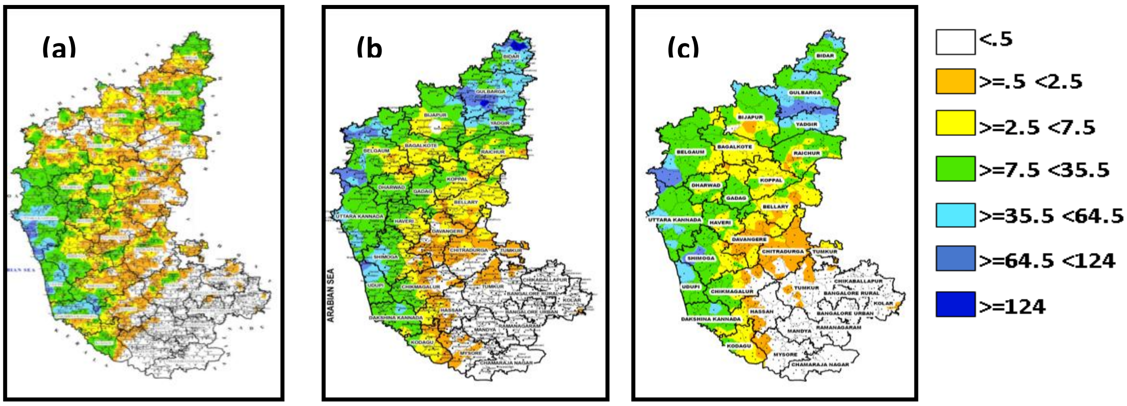

Figure 2.8 24 hour accumulated rainfall on 02 October 2012 (a) from observed and the model forecasts (b) without assimilation and (c) with assimilation.

Our analysis shows that the rainfall forecasts have improved with assimilation of observations for most of the days. It is clear from Figure 2.8 that the large over prediction of rainfall, particularly over the northern part of Karnataka, in control simulation without assimilation (Figure 2.8b) is significantly reduced after assimilation (Figure 2.8c). More detailed statistical analyses for a large number of cases have been conducted for quantifying the impact of assimilation.

V Rakesh & P Goswami

2.7 Simulation of Heavy Rainfall over Delhi: Validation with COMoN Data

Accurate forecast of episodes of heavy rainfall in terms of onset, intensity and location can be a major input to pro-active disaster management. Both high-resolution simulation and validation at appropriate vertical and horizontal resolution are important for this.

The heavy rainfall event that occurred over Delhi on Feb 5th 2013 recorded (> 40 mm) heaviest rainfall in February in the past 70 years. Here we present results from the forecast of the event and its validation with CSIR –COMoN (Climate Observation and Modelling Network) data. Comparison of the time evolution of the forecasted rainfall with that from station averaged data from the COMoN profilers towers (NPL, Hindon, Rajokri) shows considerable agreement even at hourly scale (figure 2.9). The overall pattern of onset-peak-decay is reflected in the simulation.

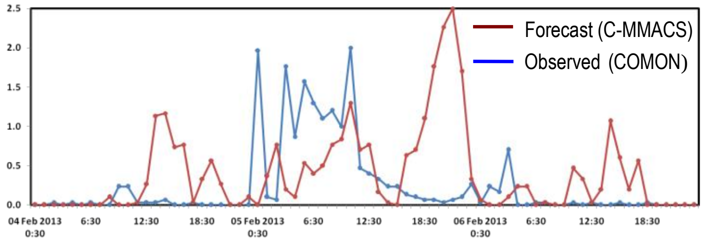

Figure 2.9 Growth and decay of hourly rainfall during the heavy rainfall event over Delhi on Feb 5th 2013. Forecast from CSIR C-MMACS compared with station-averaged hourly rainfall from CSIR COMoN observations at NPL, Hindon and Rajokri.

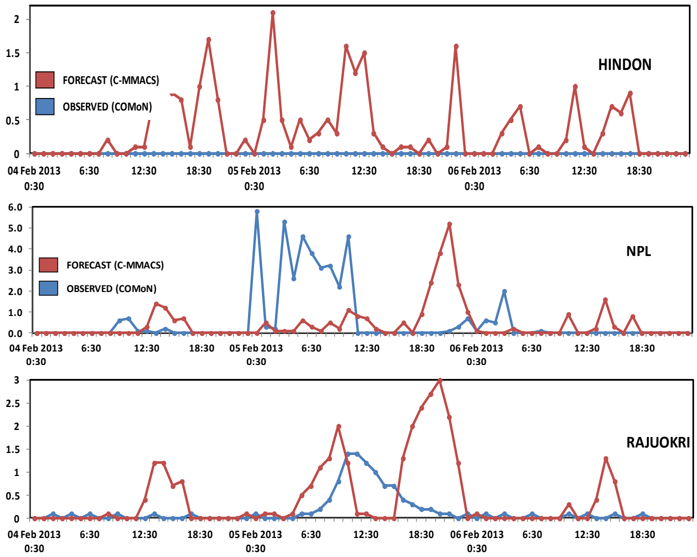

Figure 2.10 Time evolution of forecast and observed (COMoN) rain around Delhi during the heavy rainfall event. The peak of the event was on 5th Feb 2013.

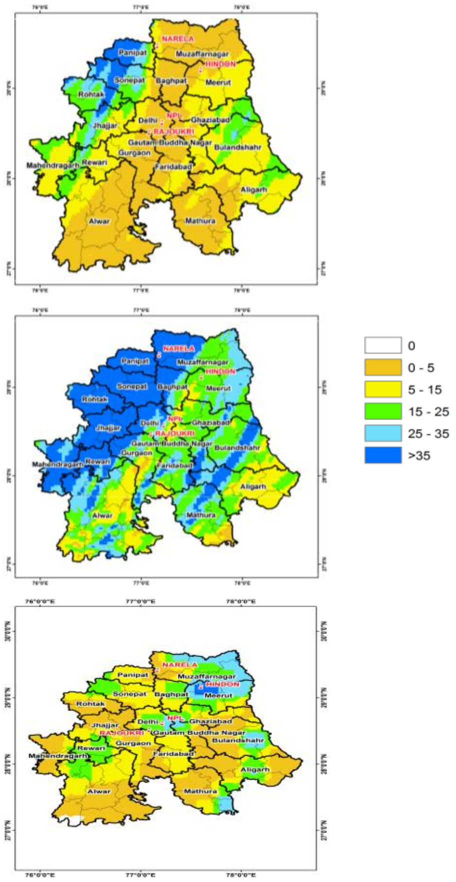

Figure 2.11 Day-wise spatial distribution of rainfall high spatial variability, high intensity during peak or mature stage of the event (middle panel) is seen.

A station wise comparison of forecast and simulation (figure 2.10) shows the high degree of variability (onset, intensity and duration) amongst the neighboring stations only a few kilometers apart. The forecast of the spatial distribution of the precipitation shown in Figure (2.11), once again reveals high spatial variability, growth and decay of the event. There are, of course, still many challenges, as can be seen in terms of discrepancies between forecast and model with regards to intensity and onset of the event.

S Himesh, V Rakesh and P Goswami

2.8 Predictability of a Dynamical System with Embedding Dynamics

A key issue in forecasting is the limit to predictability. The concept of limits to predictability, primarily due to sensitivity of non-linear systems to initial conditions, has played important role in our overall scientific approach, and in particular, in forecasting weather. The concept and the techniques of ensemble prediction arose in an effort to reduce uncertainties in the forecast due to small differences in the initial conditions. In our scenario (hypothesis), an ensemble of initial states constructed out of observations spread over time (Long Initial manifold: LIM) will contain more information about the embedding dynamics than that with states extracted over a short period of time (short initial manifold: SIM). To examine the implications, we have considered the Lorenz system with three variables as a representative non-linear system.

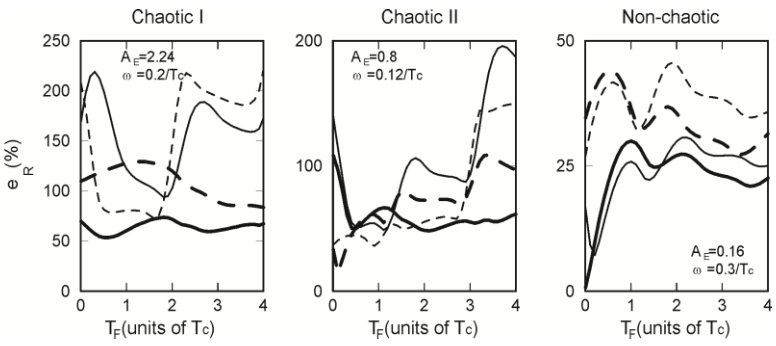

Figure 2.12 Impact of forecast lead on forecast error with and without embedding for different dynamical regimes. Relative error as a function of forecast lead with no embedding (NE; A_E=0.0) and with embedding (WE; $A_E \neq 0.0$). The thin solid line and the thick solid line represent, respectively, relative error for LIM with no embedding (NE) and with embedding (WE). The thin dash line and the thick dash line represent the corresponding results for SIM.

It is found that the relative error with LIM can be much smaller in the presence of embedding dynamics (chaotic regime I and chaotic regime II) shown in Figure 2.12. The relative error with LIM (thick solid line) with embedding ($A_E \neq 0$) is much smaller than the corresponding value for SIM (thick dash line); the errors for LIM and SIM with no embedding (NE) are comparable (thin lines), as expected.

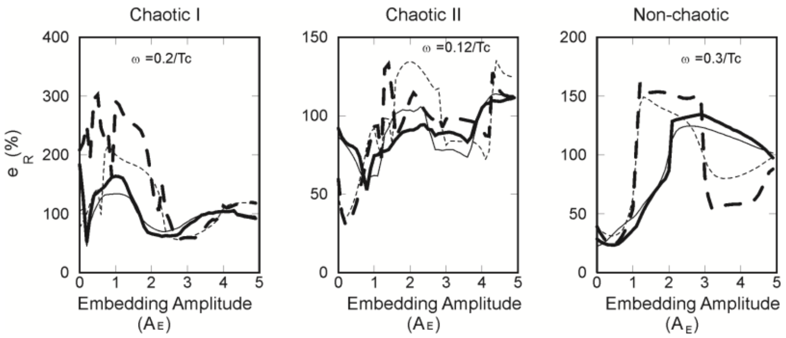

Figure 2.13 Impact of the embedding amplitude on the forecast relative error for the variable X for the three regimes of the Lorenz system. The thin solid line and the thick solid line represent, respectively, relative error for LIM for the forecast lead 1.5 Tc and 2.5 Tc. The thin dash line and the thick dash line represent the corresponding result for SIM. The embedding frequency adopted for each regime is given in the respective panel.

An examination of the relative errors as a function of the amplitude of the embedding dynamics shows the relative error to be generally smaller with the non-zero A_E (Figure. 2.13), especially for LIM. The forecast errors with LIM are smaller than those with SIM at all values of embedding amplitudes for forecast lead T_F =1.5 to 2.5 Tc.

These results indicate a need for re examination of our approach and strategy for assessment of predictability of natural dynamical systems like atmosphere and ocean.

Shiv Narayan Nishad, P Goswami

2.9 Optimum Model Configuration for Simulation of Tropical Cyclone

Mesoscale simulations are sensitive to a host of processes that represent physical and dynamical mechanisms as well as numerical formulation. While the important role of parameterization of convective processes has been well recognized, relatively little is known about the role of the mesoscale domain in simulation of tropical cyclones. It has been recognized that one of the necessary requirements in mesoscale simulations is to minimize the adverse impact of Lateral Boundary Conditions (LBC) on the model solution; this is typically achieved by keeping the lateral boundaries away from the region of interest by considering a large enough domain. On the other hand, too large a domain would mean considerably long travel time for the large scale circulations (through LBC) to affect the model dynamics in the interior of the domain. The impact of domain size on mesoscale simulations is thus expected to be non-trivial; besides, the choice of the domain also implies a choice of the geographical coverage, which in turn affects the nature of surface forcing like orography and vegetation.

A series of simulations for 10 cyclones of different intensities over the Bay of Bengal were carried out with five different domains and three different cumulus parameterization schemes.

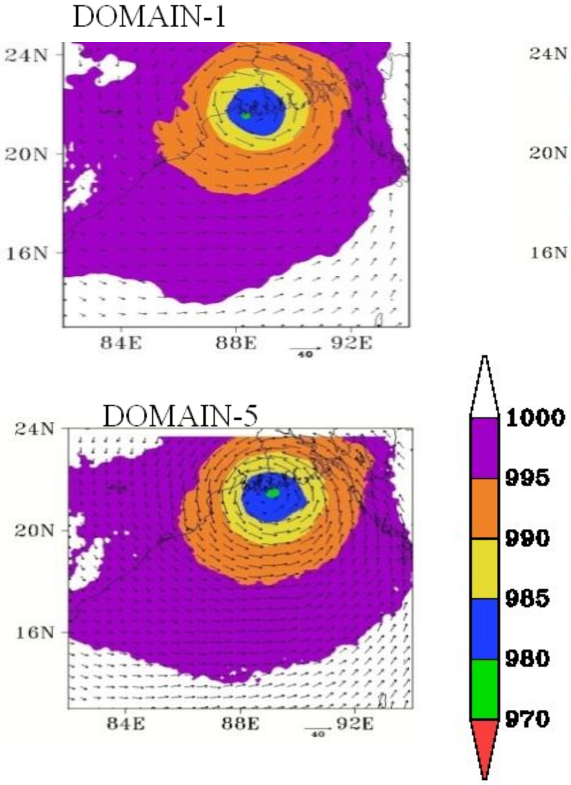

Figure 2.14 Surface Pressure (mb) and vector wind for cyclone AILA at 2009:05:25:06 hour for different domains. All the simulations were carried out with initial condition extracted from NCEP FNL (1°X1°) 06 hour Data on 23 May 2009, Observed (Pmin)=974hpa.

Clear differences in the structure, location and intensity of the simulated tropical cyclones can be seen with different simulation domains with the same model configuration. These results are being used for improved simulation of tropical cyclones.

Gyanendranath Mohapatra and P Goswami

2.10 Simulation of Extreme Rainfall using a Global Circulation Model

The evidence is increasing that the influence of the land surface is significant on local, regional and global climate on timescales from days to decades and beyond. Soil moisture is one of the key variables which control the exchange of water vapor and heat flux between the land surface and the atmosphere through evaporation and plant transpiration. Soil moisture plays an important role in various hydrological processes acting over a range of spatio-temporal scales, like partitioning of rainfall into infiltration and runoff, partitioning of net radiation into sensible and latent heat. In the present study we have examined the role of soil moisture on extreme rainfall events (ERE) simulations using a Variable Resolution –General Circulation Model (VaR-GCM). We have chosen more than 10 extreme rainfall events that occurred at different geographical regions over India. To assess the impact of soil moisture on the simulation of extreme rainfall, we have conducted two simulations of the EREs at with (96 hours lead). In the first simulation we have initialized with climatological soil moisture as control run and second simulation with dynamical soil moisture a test run.

It was found that the dynamical soil moisture led to significant improvement in the simulation of rainfall intensity as well as location. The accurate simulation of time of onset, location intensity and duration of localized extreme rainfall events continues to be a challenge worldwide. The present simulation is significant in that context.

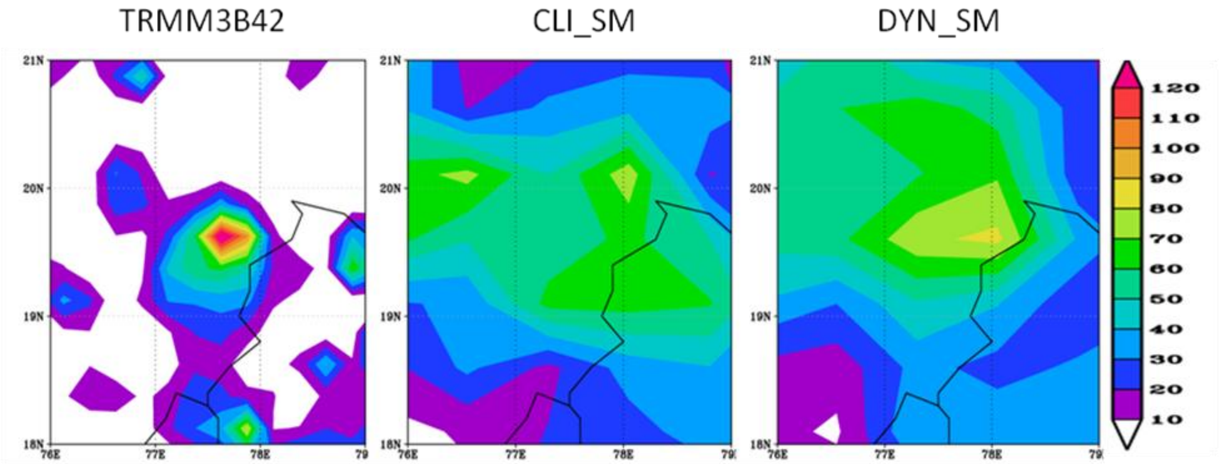

Figure 2.15 Simulation of Jul30, 2011 heavy rainfall event in central India. Left panel shows the observed rainfall structure from TRMM 3B42, middle and right panel show the simulated rainfall with climatological and dynamical soil moisture initialization. After initializing with dynamical soil moisture there was a significant improvement in rainfall intensity and location.

These results indicate that with appropriate physics and configuration, a global circulation model may be used to simulate localized extreme rainfall events. This, in turns, paves the way for a seamless simulation/prediction system.

Kantha Rao B, P Goswami

2.11 Evaluation of Dynamical Meso-Scale Fog Forecasting over Delhi

The fog model developed at CMMACS has been tested with the meteorological variables generated from a meso scale model (MM5). The model comes with multiple choices for parameterizations of various processes such as cumulus convection, Planetary Boundary Layer (PBL) and radiative forcing. It can support multiple nests with varying horizontal grid spacing and has non-hydrostatic dynamics. A simulation has been carried out with a single domain (10 km resolution) with the same physics. These high-resolution forecasts provide physically consistent fields and produce realistic mesoscale structures. However, systematic biases are also present in the simulations. The biases adversely impact forecast quality and the operational usefulness of the forecast. To improve the forecast, a 7-day running mean bias removal technique has been applied and which involves adjusting the model forecast based on the mean bias from forecasts in the recent past (e.g., in the past 7 days). The corrected forecast fields have been used in dynamical fog model. It has been found that the debiased mesoscale forecasts significantly improve the accuracy of the visibility forecasts over Delhi (Figure 2.16).

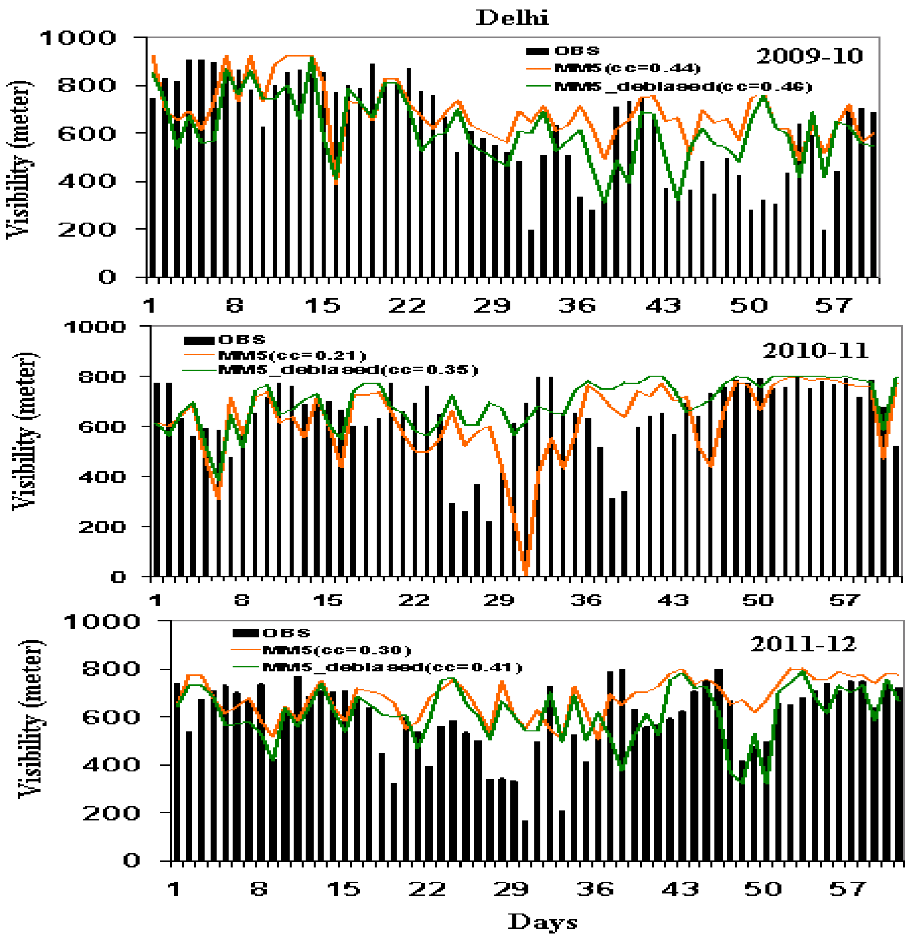

Figure 2.16 Performance of the fog model in simulation of daily average visibility over Delhi for the winter months Dec-Jan for 2009-10(upper panel), 2010-11(middle panel) & 2011-12(bottom panel).The numbers in the brackets represent correlation-coefficient between observed and simulated visibility.

These results indicate the potential of the dynamical fog model towards more accurate simulation of visibility using the skill of debiased mesoscale forecasts.

Sumana Sarkar & P Goswami

2.12 Estimates of ARI cases using Dynamical Model of Air Pollution

Several thousands of people, including children, suffer from Acute Respiratory Infection (ARI) in Delhi every year. Association between ARI cases and weather parameters as well as different air pollutants in Delhi are analyzed at monthly and annual scales using data collected in field studies during 2000-2005. Over Delhi, the number of cold days and air pollution (RSPM) together determine ARI load; the number of cold days plays the important role. The predictive model combining dynamical forecasts of air pollution and the weather variables can simulate the observed annual cycle and the inter-annual variability in ARI well.

Earlier observational works have shown clear relation between weather variables and ARI morbidity (Figure 2.17). However, relative roles of weather variables and air pollution in ARI morbidity have been less explored.

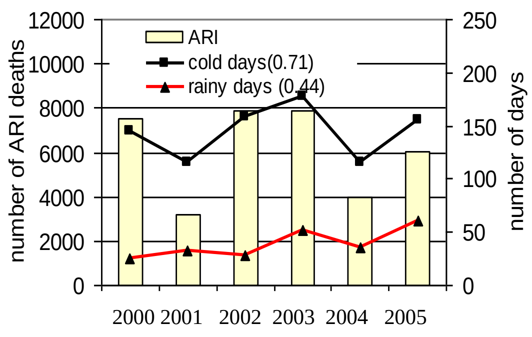

Figure 2.17 Number of deaths from respiratory diseases (filled bar), number of cold days (≤24^{0}C) and number of rainy days (>4mm/day) for 2000-2005. The meteorological variables have been taken from NCEP daily reanalysis data. The numbers in the brackets represent the correlation coefficient between number of deaths and number of days. Correlation coefficients for other temperature thresholds considered are: 0.43 for 21^0, 0.48 for 22^0, 0.62 for 23^0, and 0.64 for 25^0.

We have explored the potential of predicting the number of ARI cases and explore the relative roles of the three variables. The number of annual ARI deaths estimated using observed number of cold days, observed RSPM as well as NO_2 compares well with the observed ARI deaths (Figure 2.18).

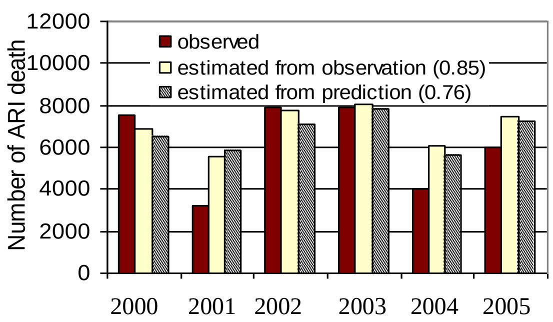

Figure 2.18 Number of deaths from respiratory diseases for the years 2000-2005 from observation (red bar), and estimates with observed (yellow bar) and with predicted (shaded bar) values of pollutant and the meteorological variables using the predictive equation for ARI deaths for different simulations. The observed pollution data is from the Central Pollution Control Board, India and the predicted pollutant concentrations are from a dynamical air pollution model. The meteorological variables for driving the dynamical pollution model have been taken from 5-day forecasts from an atmospheric general circulation model. The numbers in each panel represent the correlation coefficients between observation and estimates for the respective cases.

The results show that advance estimates of ARI morbidity may be assessed using such predictive models. Such models can help in better preparedness in terms of stocking of medicines etc.

J Baruah & P Goswami

2.13 Climate Change and Malaria: Analysis over 28 States of India

Pro-active and effective control of malaria requires identification of the major drivers of the epidemic. Another important issue is the assessment of impact of climate change on malaria. Malaria depends on vector abundance which, in turn, depends on a combination of weather variables, each in a given range, as well as on land-use. Malaria incidence also depends on the exposure of the (incidental) human host and thus on the change of human population. We consider 28 states of India, characterized by distinct and complex variability in malaria epidemiology, to examine the relative roles of weather variables (vector abundance) and change in human population. An annual vector load for each of the 28 states of India is defined based on the number of vector genesis days computed from daily temperature, rainfall and humidity adopted from NCEP daily reanalysis; a potential epidemiology is defined by taking into consideration the change in the population. The vector load and potential epidemiology are compared with observed epidemiology. The annual epidemiological data (2001-2010) is taken on blood samples that tested positive. For most states, epidemiology is very well correlated with the vector load calculated with the combined conditions of daily values of temperature, rainfall and humidity; no single weather variable has any significant association with the observed epidemiology. Our results imply the possibility of pro-active and efficient vector sanitation and control using monitoring of relevant weather parameters. At the same time, our results emphasize the need to consider all the three weather variables for assessing impact of climate change on malaria.

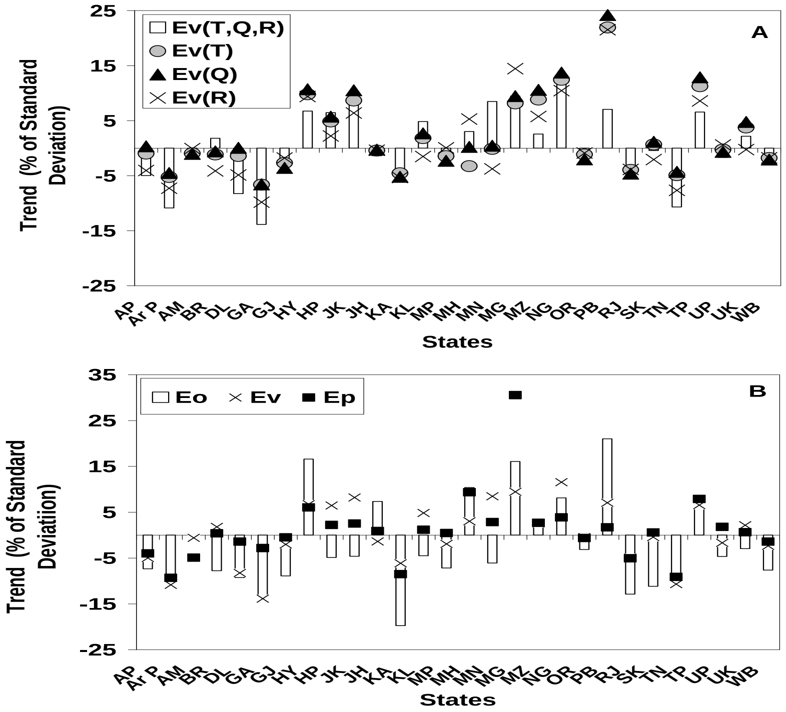

Figure 2.19 Top Panel: Linear trends in vector load (EV), expressed as percentage of respective standard deviation, calculated based on genesis constraint of only temperature, only humidity, only rainfall and combined for the period of 1961-2010. Bottom Panel: Observed epidemiology (EO), calculated vector load (EV) and calculated epidemiology potential (EP) for the 28 states based on data for the period 2001-2010.

These results indicate that vector genesis based on the three variable provide an accurate representation of the epidemic.

P Goswami and T K Swathi

2.14 Impact of Weather on Yields of Palmarosa (*Cymbopogon martinii*)

Crop processes such as plant vegetative (biomass) growth and production of plant metabolites are affected by weather variables. Identification of these relations is critical for developing crop-weather models for various applications. While considerable attention has been paid to impact of weather on crops like rice, not much is known about relation between weather variables and secondary metabolites such as in medicinal and aromatic plants; here we outline some findings on palmarosa.

Palmarosa (*Cymbopogon martinii*) is an important perennial aromatic grass which is adoptable to moisture-stress conditions. It yields an essential oil on steam distillation of above-ground biomass which is a source of a secondary metabolite, geraniol, widely used in flavours and fragrances. Weather plays an important role in the secondary metabolite production. The data collected over a period of 15 years (1980-1995) in Bangalore to study the relation between weather and biomass and essential oil yields have revealed that the biomass and essential oil yields are strongly correlated with rainfall (r = 0.86)(fig.2.20)

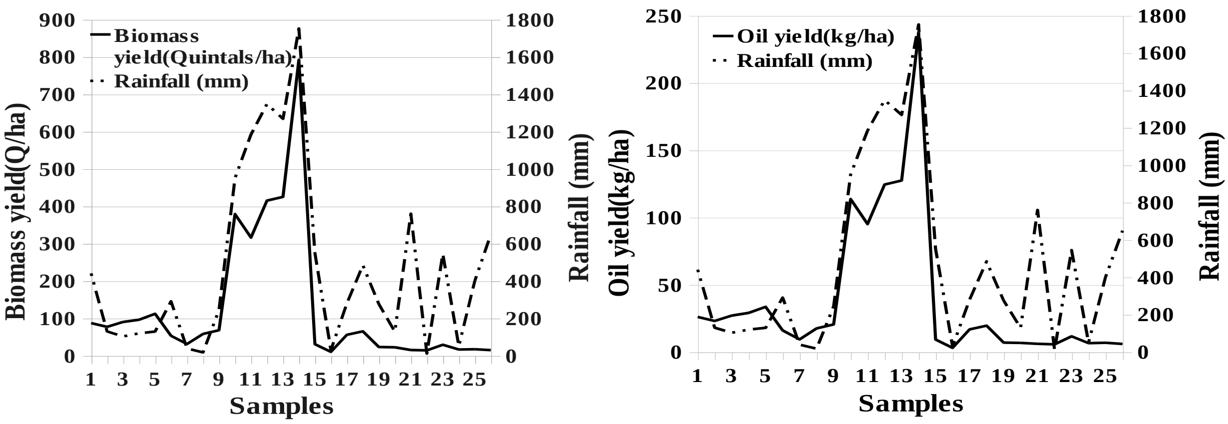

Figure 2.20 Relation between rainfall and yields of biomass and essential oil of palmarosa with rainfall

It can be seen that rainfall has significant association with both biomass and oil yields. Temperature did not impact the yields of biomass and essential oil (r = 0.10)

Quantitative and accurate assessment of impact of climate change on various crop processes and crop yield requires reliable and robust quantitative relations between crop parameters and the weather variables. These analyses presented here provide important inputs and constraints in developing crop-climate models for different plant species.

EVSP Rao, Binsha, P Goswami

2.15 Modelling Available Photovoltaic Power Potential in Top 6 Photovoltaic Cells

Photovoltaic (PV) is a relative newcomer among other electricity (clean energy) generating technologies; major steps towards commercializing photovoltaic cell began in the early 1950s. The efficiency of photovoltaic cells depends on surface downwelling radiation and ambient temperature. In general, the solar radiation incident on the earth's atmosphere reaches the earth's surface varies from 10-70% of the solar radiation reaching at surface, which depends on fully cloudy sky to clear sky. Using the basic behaviour of the PV cell, we modelled its characteristics with respect to ambient temperature and radiation were estimated with. monthly climatological surface solar radiation and temperature; six different solar panels currently available in the market were used to calculate the power.

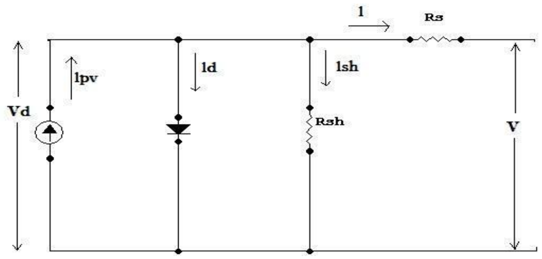

Figure 2.21 Equivalent circuit diagram of PV cell

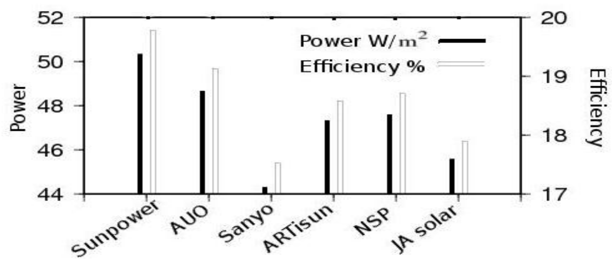

Figure 2.22 Theoretical efficiency and power modelled based on characteristics of individual PV cells in normal operating conditions

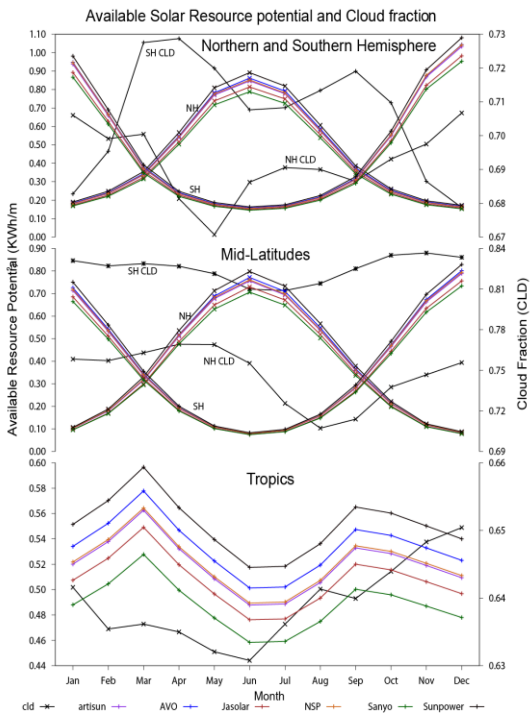

Figure 2.23 The theoretical available power computed for different months using different solar panels.

The mathematical model employed uses an equivalent circuit of the single-diode model of a PV cell (Figure 2.21). The solar cell can be seen as a current generator, which generates the current. The dark current flows in the opposite direction of photon-generated current. The series resistance (Rs) is caused by the fact that a solar cell is not a perfect conductor. The parallel resistance (Rp) is caused by leakage of current from one terminal to the other due to poor insulation; ideally Rs = 0 and Rp = ∞. The value of V_{OC} varies with temperature and radiation. The theoretical power generated and efficiency computed for different solar panels (Figure 2.22) show significant variations between the solar panels.

There are variations in the available resource potential computed among the northern and southern hemisphere (Figure 2.23). It may be seen that the seasonal cycle of power (averaged over six solar panels) is strongly correlated with domain averaged cloud cover (Figure 2.23). These results indicate potential of assessing and managing solar energy using weather data and forecasts.

K V Ramesh, S Aswin and P Goswami

2.16 Agricultural Self-Sustainability: Global and Regional Analysis

Agricultural self-sustainability (ASeS) is defined as the condition in which total food requirement of a people is produced from the agricultural activities alone. There are many factors that affect agricultural self-sustainability like growing population, increasing food demand, decline in arable land, decline in agricultural productivity, and climatic factors.

ASeS has to follow a constrained dynamics due to limited primary resource (arable land) but competing demands due to growth in population, change of consumption habit and climate change.

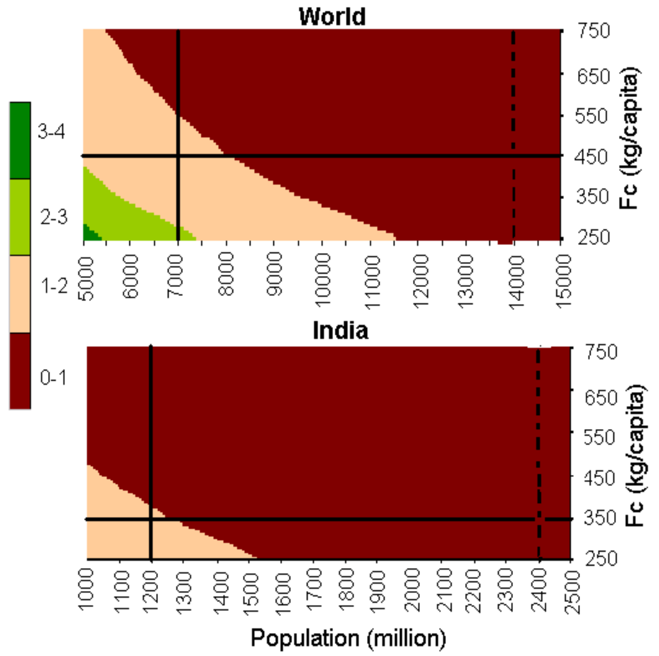

Figure 2.24 Agricultural self-sustainability (ASeS) as a function of population and per capita food consumption. The horizontal solid line represents the ASeS for the current per capita food consumption. The vartical solid line represents ASeS in the current population scenario for the respective case.

Most of the approaches to study agricultural self-sustainability do not provide a dynamical formalism that allows quantitative assessment and projections in a self-consistent framework. We have developed a model for the quantification of the agricultural self-sustainability. The model has been applied to the world, India, China and the USA and also to calculate the requirement of technology to maintain agricultural self-sustainability.

Figure 2.24 shows the status of the agricultural self-sustainability as a function of the population and per capita food consumption. The horizontal line represents the current status of the agricultural self-sustainability in per capita food consumption.

It may be seen that India is already at the threshold of losing ASeS; increase in per capita food consumption can add to a loss of ASeS. A dynamical formalism can help to quantity and project ASeS under different scenarios.

Shiv Narayan Nishad, P Goswami

2.17 Hobli-level Rainfall Forecasts over Karnataka

A collaborative programme between C-MMACS and Karnataka State Natural Disaster Monitoring Centre, Govt. Karnataka (KSNDMC) was initiated in 2010 to generate hobli-level rainfall forecasts over Karnataka. While a dynamical forecast model skill depends on many factors and varies from region to region and careful configuration and calibration can improve region-specific skills. Here, we present evaluation of real-time rainfall forecast at hobli-level (a cluster of adjoining villages with average area of the order of 10 square kilometers) using a meso-scale forecast model (WRF) over Karnataka state (with nearly 56% of the workforce engaged in agricultural activities) for the south-west (June-September) and north-east (October-December) monsoon season of 2011. A highlight of the study is the validation of the rainfall forecasts against observations at comparable resolution from the telemetric rain-gauge network established by KSNDMC. Statistical evaluations show the forecasts to have "useful skill" for the end users. In order to analyze spatial distribution of errors in rainfall prediction (irrespective of observed magnitude of rainfall) we have computed the coefficient of variation (CV) for South West Monsoon (SWM) and North East Monsoon (NEM) (Figure 2.25). The relatively small values of CV indicate the usefulness of the forecast. However, the CV in forecasts over northern part of Karnataka is found to be high during NEM. The evaluation has also identified some areas with systematic bias and relatively higher forecast error for further improvement of forecast skill.

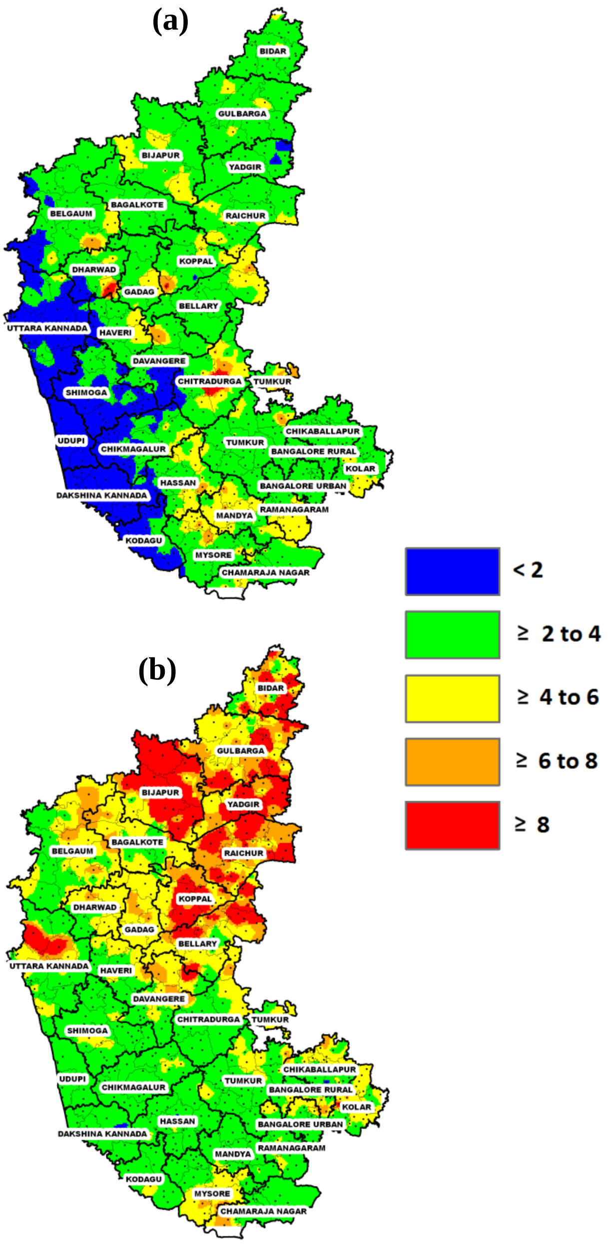

Figure 2.25 Average Coefficient of variation in the forecasts of daily accumulated rainfall for (a) SWM and (b) NEM season 2011.

These forecasts are disseminated by KSNDMC to a wide spectrum of users; from policy makers to executives and to farmers.

V Rakesh & P Goswami

3

COMPUTATIONAL MECHANICS

Analytical solutions for nonlinear problems are difficult to obtain. A variety of solutions have been studied in the literature and these analytical solutions have led to valuable insights. We have used the homotopy analysis method with some modifications to obtain limit cycle solutions for the forced Van der Pol Duffing oscillator. We have been able to determine the variation of the frequency of the limit cycle with the variation of the damping parameter, the nonlinear term and the external forcing frequency. In addition we have developed an analytical technique to obtain the limit cycle and quasi-periodic solutions for the forced Van der Pol and the forced Van der Pol Duffing oscillator. We have developed an expression to find the force and torque acting on a spherical body moving in a quiescent fluid at arbitrary Reynolds numbers by using a 'reciprocal' theorem using the formalism developed by Magnaudet. The derived expression is generated from the Navier – Stokes equations. The effect of an elastic medium on the vibration frequencies of carbon nanotubes have been investigated by analytical studies using the differential quadrature method and the differential transform method. Most of the literature uses the linear Winkler model. There is little work and information available about the Pasternak model as an elastic support. The combined effects of Winkler and Pasternak modulus over the dynamic frequencies have been investigated for higher modes for the first time. Finite Element Vibration Analysis of a Single Walled Carbon Nanotube Resting on an Elastic Foundation in Thermal Environment has also been carried out.

Inside

- *The variation of the frequency of the limit cycle for the forced Van der Pol Duffing oscillator by the homotopy analysis method*
- *Analytical limit cycle and quasi-periodic solutions for the forced Van der Pol and the forced Van der Pol Duffing oscillators: A new homotopy approach*
- *Prediction of loads on a spherical particle moving in a quiescent fluid at arbitrary Reynolds number by using a 'Reciprocal theorem'*
- *Finite Element Vibration Analysis of a Single Walled Carbon Nanotube Resting on Elastic Foundation in Thermal Environment*
- *Pseudospectral Analysis for Vibration of Carbon Nanotubes*

3.1 The variation of the Frequency of the Limit Cycle for the Forced Van Der Pol Duffing Oscillator by the Homotopy Analysis Method

Nonlinear oscillators contain very rich dynamics with respect to different initial conditions and different parameter values. Only a few attempts can be found in the literature for the development of analytical solutions for these oscillators. Limit cycle solutions have been reported in the literature especially for the Van der Pol and the Van der Pol Duffing oscillators without forcing by one analytical approach namely, the homotopy analysis method. For the first time we consider the forced Van der Pol Duffing oscillator and obtain its analytical limit cycle solutions. As a first step we take the case where the frequency of the nonlinear oscillator is same as the external forcing frequency.

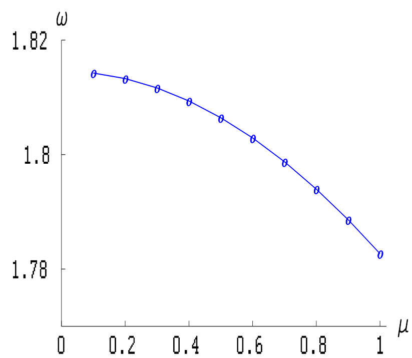

Figure 3.1 Variation of the frequency of the limit cycle vs. the damping parameter.

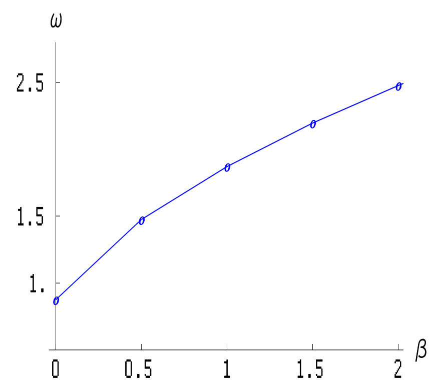

Figure 3.2 Variation of the frequency of the limit cycle vs. the nonlinear term.

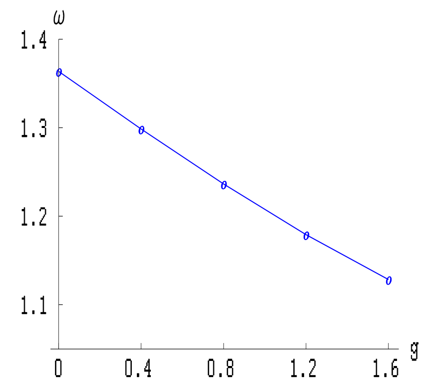

Figure 3.3 Variation of the frequency of the limit cycle vs. the magnitude of the external forcing.

We develop analytical solutions for this oscillator by the homotopy analysis method by minimizing the square residual error of the problem. The variation of the frequency of the limit cycles with respect to the damping parameter, the nonlinear term and the magnitude of the external frequency is shown in Figures. [3.1-3.3].

*Anant Kant Shukla, T R Ramamohan, S Srinivas**
*(*Sr. Prof., School of Advanced Sciences, VIT University, Vellore: 632 014, India)*

3.2 Analytical Limit Cycle and Quasi-Periodic Solutions for the Forced Van Der Pol and the Forced Van der Pol Duffing Oscillators: A New Homotopy Approach

We obtain limit cycle solutions as well as quasi-periodic solutions for the forced Van der Pol oscillator and the forced Van der Pol Duffing oscillators analytically. To the best of our knowledge no attempt has been made so far for the determination of limit cycles and quasi-periodic solutions, analytically for these problems. We propose a modification of the homotopy analysis method to obtain the solution expressions. The phase plots are presented in Figures.[3.4-3.6] and [3.7-3.9]

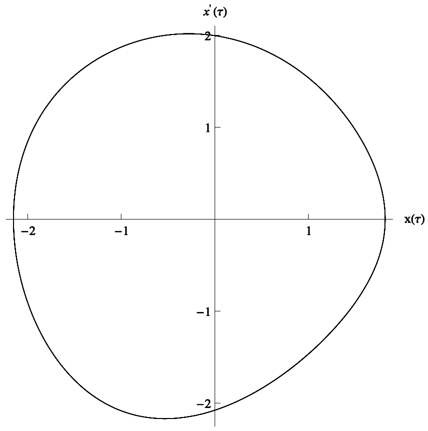

Figure 3.4 HAM phase plot: limit cycle of period one for the forced Van der Pol oscillator.

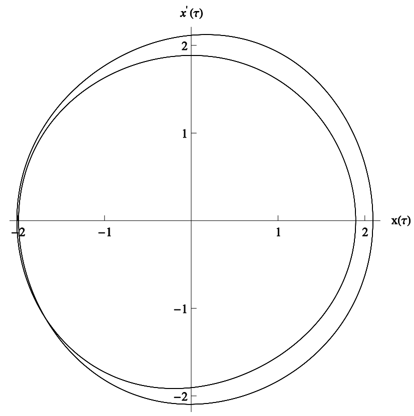

Figure 3.5 HAM phase plot: limit cycle of period two for the forced Van der Pol oscillator.

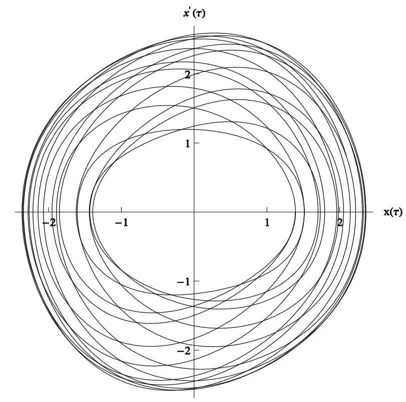

Figure 3.6 HAM phase plot: quasi-periodic solution for the forced Van der Pol oscillator.

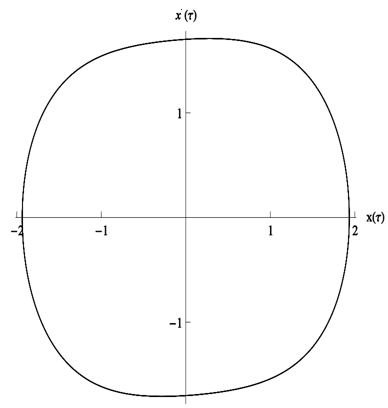

Figure 3.7 HAM phase plot: limit cycle of period one for the forced Van der Pol Duffing oscillator.

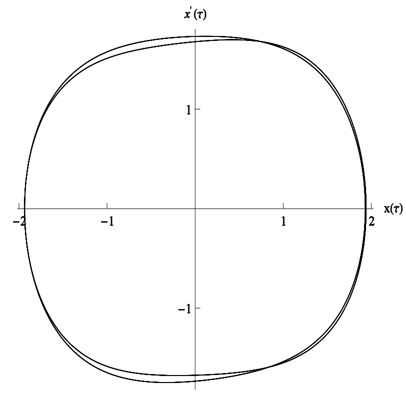

Figure 3.8 HAM phase plot: limit cycle of period two for the forced Van der Pol Duffing oscillator.

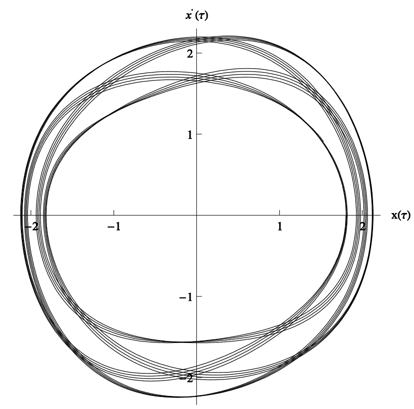

Figure 3.9 HAM phase plot: quasi-periodic solution for the forced Van der Pol Duffing oscillator.

for the forced Van der Pol oscillator and the forced Van der Pol Duffing oscillator respectively by the proposed approach. In our computation we obtain limit cycle solutions of period one and two and quasi-periodic solutions as well. These results are new to the literature.

*Anant Kant Shukla, T R Ramamohan, S Srinivas**

**Sr. Prof., School of Advanced Sciences, VIT University, Vellore: 632 014, India*

3.3 Prediction of Loads on a Spherical Particle Moving in a Quiescent Fluid at Arbitrary Reynolds Number by Using a ‘Reciprocal Theorem’

The ‘reciprocal’ theorem equation is formulated for the case of a spherical body moving in a quiescent fluid at arbitrary Reynolds number by using the formalism of Magnaudet (2011). We have used tensor calculus and used the properties of the fluid flow. In this reciprocal theorem the auxiliary fields derived are harmonic functions and are irrotational and hence they can only satisfy the kinematic boundary conditions on the surface boundary. Hence for the formalism derived above the primary and auxiliary velocity fields do not satisfy the same set of boundary conditions exactly. This is the reason we use quotation marks for the word ‘reciprocal’ throughout the report.

The auxiliary velocity potential function is solved as a boundary value problem by using separation of variables. It results in an equation which contains Legendre polynomials. The velocity potential function is then substituted in the ‘reciprocal’ theorem equation and the equation is expressed solely in terms of velocities, the velocity potential function and velocity gradients.

The formalism developed has wide applications in different fields like oceanography, meteorology, flight dynamics and mechanical, chemical, marine and aeronautical engineering. The formalism is validated for the zero Reynolds number case where the formalism yields the Stokes equation. Simulation of the formalism requires the velocity field and gradient of the velocity for high Reynolds number flow.

Reference: Jacques Magnaudet, A ‘reciprocal’ theorem for the prediction of loads on a body moving in an inhomogeneous flow at arbitrary Reynolds number, Journal of Fluid Mechanics, 689, 564-604, December 2011.

Sai Naga Sri Harsha Chittajallu, T R Ramamohan, Thundil Karupparaj *
**** Prof., Energy Division, SMBS, VIT University, Vellore: 632 014, India***

3.4 Finite Element Vibration Analysis of a Single Walled Carbon Nanotube Resting on Elastic Foundation in Thermal Environment

In the present study, the dynamic characterization of a carbon nanotube using nonlocal Euler-Bernoulli beam theory considering thermal and elastic foundation effects is investigated. A Galerkin finite element technique is used to formulate the governing differential equation of motion for the transverse vibration of a CNT. The validity of the developed finite element formulation is investigated by comparing the results in terms of natural frequencies with those results available in literature. Various parametric studies are also performed to study the effect of non-local parameter and Winkler modulus on natural frequencies of a carbon nanotube under various boundary conditions. The effect of thermal environment on the natural frequencies is also investigated.

The effects of Winkler’s modulus and the scale coefficients on the natural frequencies under various boundary conditions such as simply supported at both ends, clamped at both ends, clamped at one end and simply supported at the other end and clamped at one end and free at the other end are investigated at a temperature of 0^0 K. The non-dimensional natural frequencies for the fundamental mode are investigated and it has been observed that the natural frequencies increase at all the modes considered here with an increase in Winkler’s modulus irrespective of the boundary conditions. This is due to the fact that bending stiffness increases with increase in Winkler’s modulus. It can also be observed that the natural frequencies decrease at all the modes considered here with an increase in small scale parameter irrespective of the boundary conditions.

The effects of temperature and the scale coefficients on the natural frequencies under various boundary conditions discussed previously are studied at zero Winkler's modulus. It can be observed that the natural frequencies increase with increase in temperature irrespective of the boundary conditions. This is due to the fact that bending stiffness increases with increase in temperature. It can also be realized that the natural frequencies decrease with increase in small scale parameter irrespective of the boundary conditions.

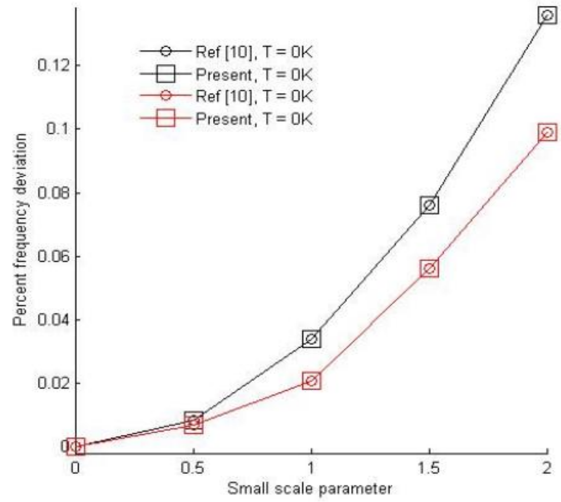

Figure 3.10 Effect of temperature on the variation of frequency with small scale coefficient

The capability of prediction of the natural frequency using Euler-Bernoulli beam theory with local and nonlocal parameter is investigated by evaluating non dimensional frequency at various Winkler modulus at a temperature of 0 K, and the results are presented for simply supported boundary condition in Figure 3.10. It can be clearly observed that due to the incorporation of nonlocal effect i.e. small scale coefficient in the governing differential equation of motion, the frequency predicted by the theory of nonlocal elasticity is lower than that predicted by the classical theory of elasticity.

V Senthilkumar and K Shashidhar[*]
([*]VIT Vellore)

3.5 Pseudospectral Analysis for Vibration of Carbon Nanotubes

Nonlocal theories are successful in predicting the mechanical properties of nanotubes. The effect of an elastic medium on the vibration frequencies are investigated by analytical studies using the differential quadrature method and the differential transform method. Most of the literature uses the linear Winkler model. There is little work and information available about the Pasternak model as an elastic support. The combined effects of Winkler and Pasternak modulus over the dynamic frequencies have not been investigated for higher modes. The present work aims to fill this void. Many researchers have decoupled the two coupled Timoshenko model into a single model with certain approximations or integration. Here we solve the coupled equation without decoupling it. The analytical solution expression is very tedious when solving the present coupled model. Hence the pseudospectral method based on Chebyshev polynomials is used in the present analysis.

Effect of Winkler and Pasternak Support

The nonlocal vibration frequency of a single walled carbon nanotube with Winkler and Pasternak elastic support is analyzed by considering shear deformation effects. The pseudospectral method

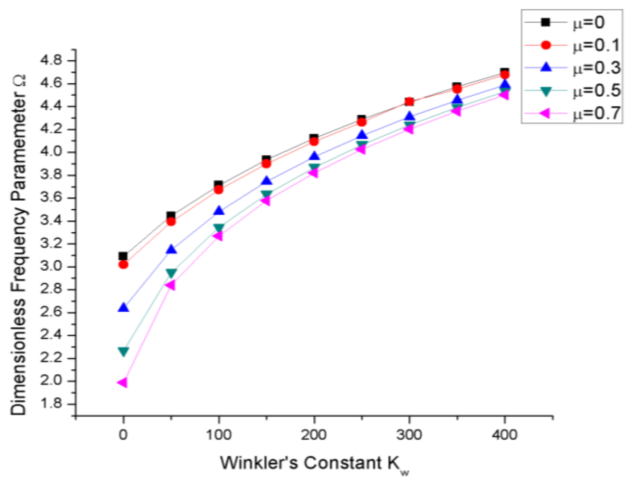

Figure 3.11 Effect of Winkler Constant on frequency with various nonlocal parameter values

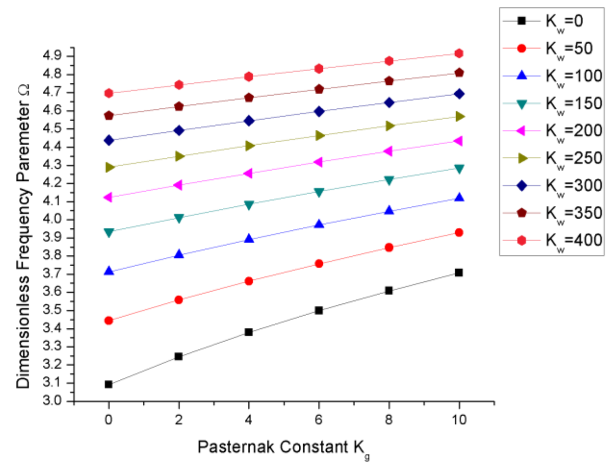

Figure 3.12 Effect of Pasternak Constant on frequency with various nonlocal parameter values

converges very fast with fewer grid points and gives closer precision results compared to analytical results. The combined effect of Winkler and Pasternak modulus is analyzed. It is seen in the Figure 3.11, that the vibration frequency decreases with the small scale parameter and Winkler's constant.

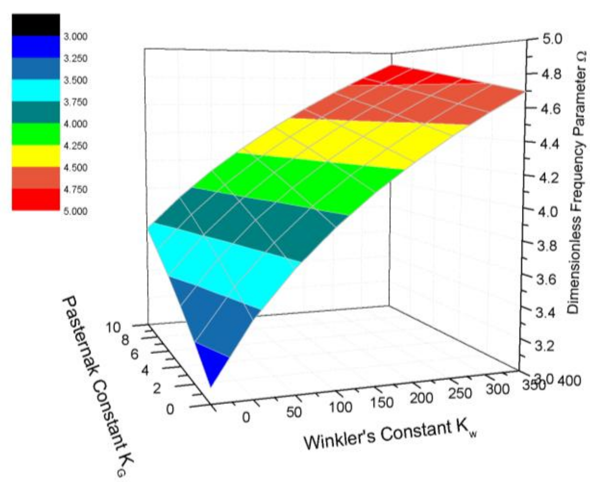

Figure 3.13 3-Dimensional plot of Winkler and Pasternak modulus of Pinned-Pinned Nanotube

Similarly in Figure 3.12, it is seen that an increase in both the Winkler and Pasternak modulus causes an increase in the frequency. The 3-D plot illustrates the same graphically in Figure 3.13. The reason being an increase in both Winkler and Pasternak stiffness causes the increase in bending stiffness of the carbon nanotube. Also when the Winkler and Pasternak parameter increases simultaneously, the frequency increases. The Pasternak modulus influences the frequency more compared to the Winkler Modulus.

*V Senthilkumar and A Gupta**
*(*IIT Guwahati)*

4

HIGH PERFORMANCE COMPUTING & CYBER SECURTY

Computation is the third pillar of modern scientific research. In contemporary research, the capability of an organization is judged by the computational facility it has access to. CSIR C-MMACS is committed to providing world-class computational facility to all the computational scientists and researchers of CSIR to address Grand Challenge problems in their frontier areas of science and engineering. The facility at CSIR C-MMACS is one of the fastest in the country and is aimed at providing multiple architectures suitable for domain specific applications. With CSIR C-MMACS in the limelight for its HPC facility, cyber security becomes an important aspect. Hence, the HPC group is also involved in research in the field of Cryptography and Cyber Security.

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- *Feedback Manipulation Flooding Attack on Stream Control Transmission Protocol*
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- *Neural Synchronization by Mutual Learning Using Genetic Approach for Secure Key Generation*
- *High Performance Computing*
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4.1 Estimating Trust Value for Cloud Service Providers using Fuzzy Logic

Trust is strongly connected with confidence and it implies some degrees of uncertainty, hopefulness or optimism. It plays an important role when we talk about business models such as cloud, where everybody is worried about their privacy and security. Generally the most relevant sources of information considered by the trust and reputation models are direct experiences and witness information, from which the trust is estimated. Our model architecture concentrates on the estimation of trust value for Cloud Service Providers (CSP) in Inter (direct experience) Domain. We have simulated an environment using Cloud Analyst.

The Cloud Analyst enables us to model different scenarios of CSPs and user bases, and provides a comprehensive output detailing the response time, Data Center processing time and total cost involved in the communication and computation. The model parameters are chosen based on the attributes defined by Service Measurement Index (SMI). These include Accountability, Agility, Assurance, Financial, Performance, Security, Privacy, and Usability. Each of these attributes consists of a set of Key Performance Indicators (KPIs), which describe the data to be collected for measurement. We discuss Performance, Financial and Agility in our work (Table 4.1).

Table 4.1 Factors and its Key Performance indicators

Factors Impacting Degree of Trust	KPIs of the corresponding attribute
Performance	Accuracy, Functionality, Stability, Interoperability, Service Response Time
Financial	Acquisition and training cost, Ongoing cost, Profit or Cost Sharing
Agility	Adaptability, Capacity, Elasticity, Extensibility, Flexibility, Portability, Scalability

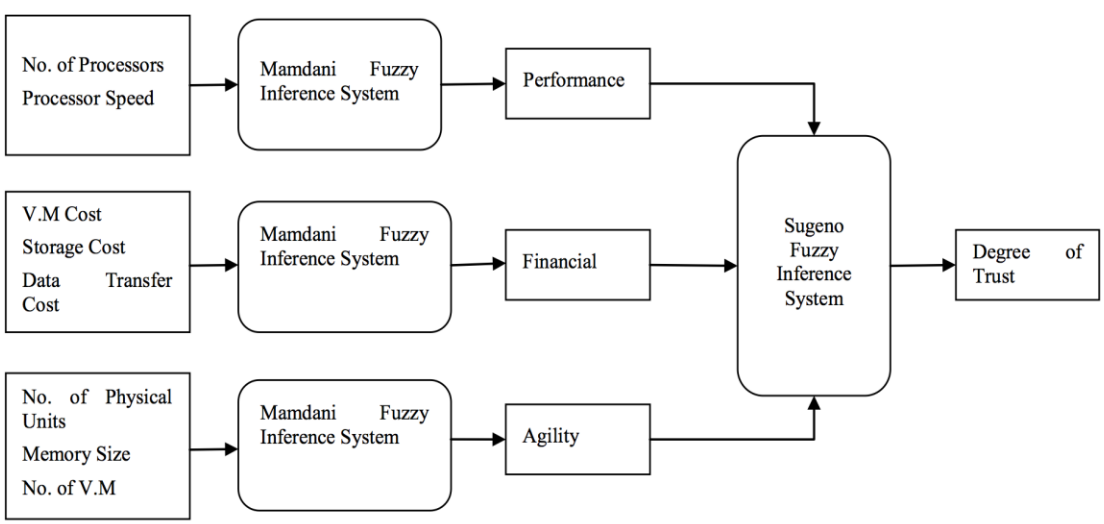


Figure 4.1 A diagrammatic representation of different stages of the cloud trust model.

The evaluation of the trust value for CSP comprises of two stages as shown in Figure 4.1. The first stage is the implementation with the help of Mamdani Fuzzy Inference System (FIS). It takes Performance, Financial and Agility as inputs and produces a range of values, (low, medium, high, and very high) which could be easily fed as input to the next level of processing. The second stage is the implementation using Sugeno FIS. It takes the output of the Mamdani FIS and helps to obtain the trust rating for the CSP. The Trust FIS is the final Fuzzy model which takes the output of the previous blocks and gives a crisp value for the Trust rating a viz one of the five: very poor, poor, good, excellent, and outstanding. There are a large number of rules defined for these values of trust rating and a sample is listed below.

If (Agility is low) and (Financial is low) and (Performance is low) then (Trust_Rating is poor)

The two fuzzy models: Mamdani and Sugeno are combined together using FIS blocks of Simulink, which on execution provide a trust rating using the well defined rules. Assuming equal weights for all the rules, the values for trust rating is estimated for each CSP from above described model are classified in Table 4.2. As different users would have different expectation from their CSP, weights can vary and based on this, the rating of the CSP would differ.

Table 4.2 Estimation of trust for different Cloud Service Provider with different degrees of Agility, Financial and performance

CSP	Agility	Financial	Performance	Trust
CSP A	0.45	0.856	0.347	Poor
CSP B	0.451	0.5	0.348	Good
CSP C	0.151	0.5	0.346	Very Poor
CSP D	0.45	0.857	0.8	Excellent
CSP E	0.451	0.5	0.15	Very Poor

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

4.2 Feedback Manipulation Flooding Attack on Stream Control Transmission Protocol

Stream Control Transmission Protocol (SCTP) is a relatively new transport layer protocol standardized by the Internet Engineering Task Force. It has several unique features such as multi-homing, multi-streaming, enhanced security and authentication measures like signed cookies, multiplexing of multiple user messages in a single SCTP packet etc. Today, there exist a number of client-server applications, including prototype implementation of Apache web server and Firefox web client (http over SCTP), which operate over SCTP. Further, SCTP has also demonstrated promising results as a transport layer protocol for supercomputers, which typically involve massively parallel and densely interconnected hardware, through transporting MPI (Message Passing Interface) over SCTP.

SCTP is a feedback protocol with inbuilt flow and congestion control features. The SCTP sender sends the data packets through the forward path and the receiver provides feedbacks such as acknowledgement (ACK) on receipt of data, window update, congestion notifications etc. through the reverse path. Feedback manipulation could be a potentially vulnerable in any feedback protocol. This work focuses on a sophisticated attack scenario, which we call as feedback manipulation flooding attack (FMFA), where the congestion control feature of standard SCTP sender is tactically exploited for launching Denial-of-Service (DoS) attacks.

Flood generation in FMFA is achieved through *optimistic ACKing* in which a receiver sends SACK chunks to data chunks, which are expected from the sender in response to its previous SACKs. For this, an SCTP receiver (attacker) manipulates the cumulative TSN ACK field and optionally the a_rwnd field of the SACK chunks. The attacker, like a genuine SCTP receiver, initiates a file transfer from the SCTP sender. The SCTP receiver module on the attacker establishes an association with the SCTP sender through the well-known Four-way handshake process. Once the association is established the attacker knows the initial TSN of the SCTP sender, which the sender uses to index the subsequent data chunks. For example if the initial TSN is α, the TSN of first, second, third data chunks will be α +1, α +2, α +3 and so on. This information is sufficient for the attacker to generate SACK without actually receiving the data chunks. After receiving the first couple of data chunks, the attacker sends a series of SACK chunks in which the cumulative TSN ACK of successive SACK chunks is incremented by one (α +1, α +2, α +3 and so on). At the SCTP sender side, each SACK is valid as it acknowledges new data that the sender has previously sent. Hence, they are used to send out new data chunks, which constitute the actual flood.

We implemented the SCTP FMFA in real system and conducted experiments over the Internet. The main objective of our real-world experimentation is to demonstrate the practicality of the attack in an environment involving real end-systems, routers and Internet links. In our experiments, the SCTP sender and receiver are 14 hops apart on the Internet. Both the sender and receiver run Fedora variant of Linux having kernel 2.6.39 with SCTP source code built into the kernel.

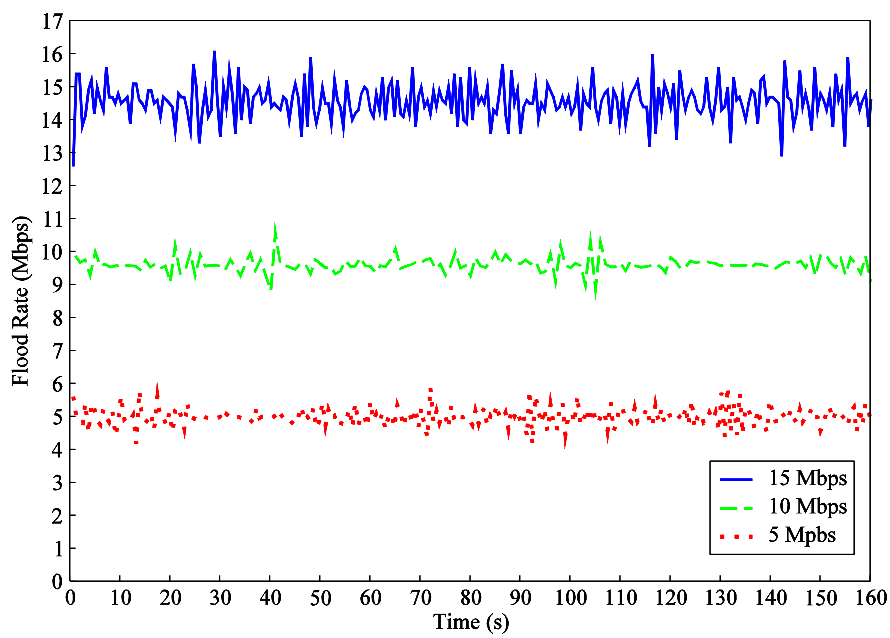


Figure 4.2 Flood rate induced from Linux SCTP sender through feedback manipulation attack

We performed multiple experiments using the same sender- receiver pair. In all experiments, the SCTP receiver (attacker) establishes an association with the SCTP sender and initiates data transfer using iperf. After receiving the first two data chunks, the SCTP receiver sends a series of SACK chunks in which the cumulative TSN ACK field of successive SACKs is incremented by one. Our first experiment demonstrates a case in which the SCTP sender is exploited to generate flood at a rate of 5 Mbps. Similar experiments were carried out to generate a flood rate of 10 &15 Mbps. Figure 4.2 shows the observed results. These results demonstrate the feasibility of varying flood rate to desired value by controlling the inter SACK time gap.

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

4.3 Design and Analysis of Parallel Algorithm for Finding Mersenne Prime Numbers

To know a number is prime or not, is of great interest in the field of cryptography. This problem is computationally expensive. Hence, most of the time probabilistic methods are used to determine it with a certain degree of uncertainty. Since the discovery of AKS algorithm (a polynomial time deterministic algorithm) by three researchers from IIT Kanpur in 2002, many attempts have been made for its efficient implementations. However, the algorithm is still computationally infeasible for moderately large numbers. With the computing technology going towards multi to many core architecture, it is important to exploit them to solve these computationally expensive problems.

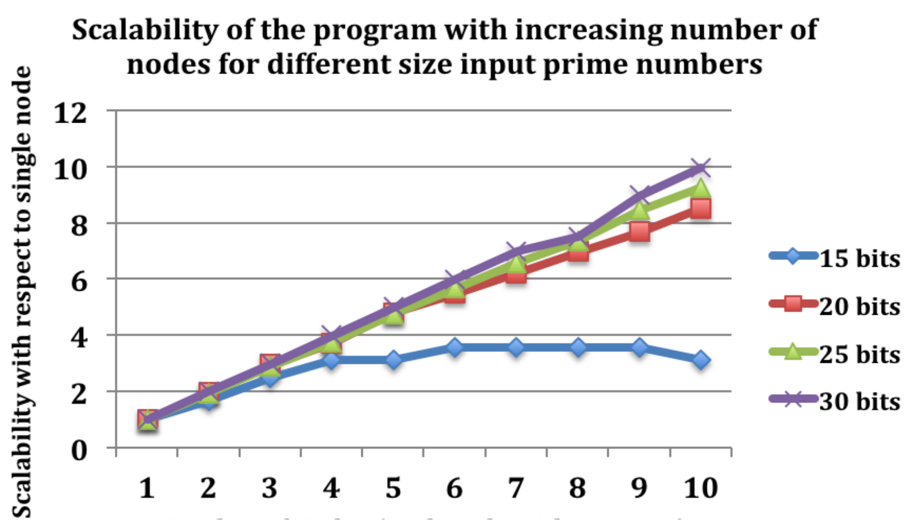


Figure 4.3 Scalability of the parallel code for different numbers of nodes

The program is tuned for Mersenne prime numbers. However, all prime numbers below 10^{10} were tested to test the scalability. The above figure shows the scalability of the program with increasing number of nodes for some sample sizes of input prime numbers. It is observed that the program scales linearly with number of nodes for different input size of the prime number. The program is still being optimized and modified so that it can be used as a benchmark for large systems (even peta-scale) by choosing sufficiently large input size prime numbers.

G K Patra

4.4 Neural Synchronization by Mutual Learning Using Genetic Approach for Secure Key Generation

One of the most challenging problems in secret key cryptography is the key exchange problem. i.e exchanging of the secret key before the real communication. Neural cryptography for key exchange has been an effort in this regard, which does not depend on number theory or any conditional security. However, it suffers from certain man-in-the middle attack called majority-flipping attack. Hence, one of the approaches to overcome the problem is to make the synchronization happen faster, so that the attacker does not get enough time and information to complete the attack. In this regard large number of efforts are on in global scenario.

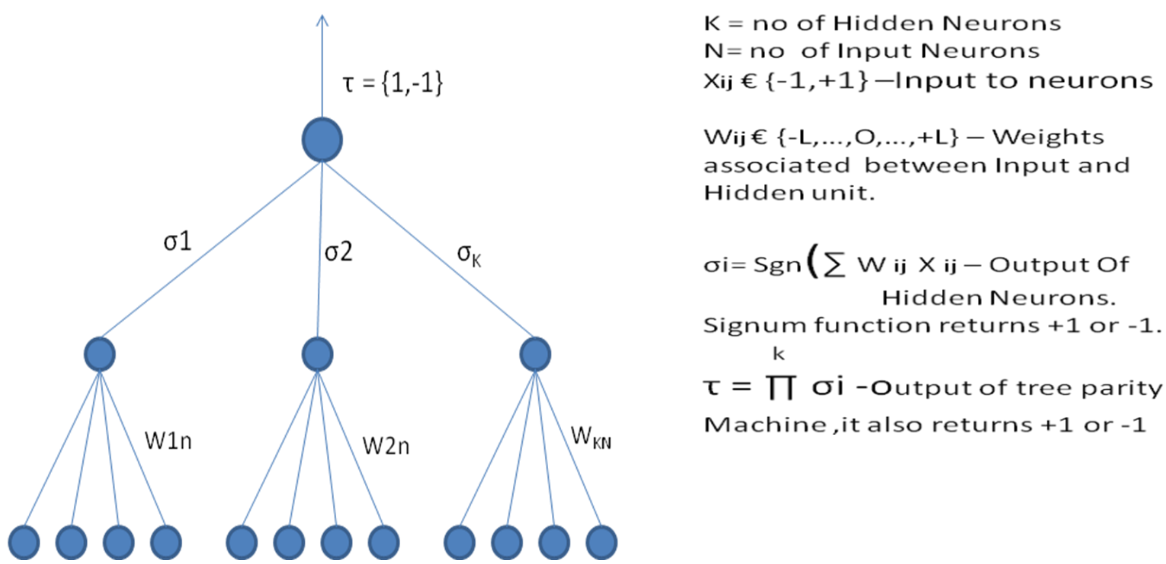


Figure 4.4 A Tree Parity Machine used in Neural Synchronization

A typical neural synchronization uses a Tree Parity Machine (TPM), in a three layer neural network (Figure 4.4). The synaptic weight vector acts as the secret key. To start with, the weight vectors are randomly selected by two communicating partner. But over a period of week interaction cycles, and mutual learning, the random weight converges. Most of the successful attacks are due to the slow synchronization process. Hence, one of the method to counter the attack is to possibly decrease the synchronization time.

Here, a Genetic Algorithm (GA) based weight selection approach is proposed to hasten the synchronization. Genetic algorithms are based on the real processes of natural selection and survival of the fittest. The genetic algorithm can be described as follows. First, it starts with a certain population of individuals selected at random from the model space. Then, an iterative procedure follows, in which each of its iterations form three basic steps: selection, crossover and mutation. Finally, the iteration is ended, when certain convergence criterion is achieved.

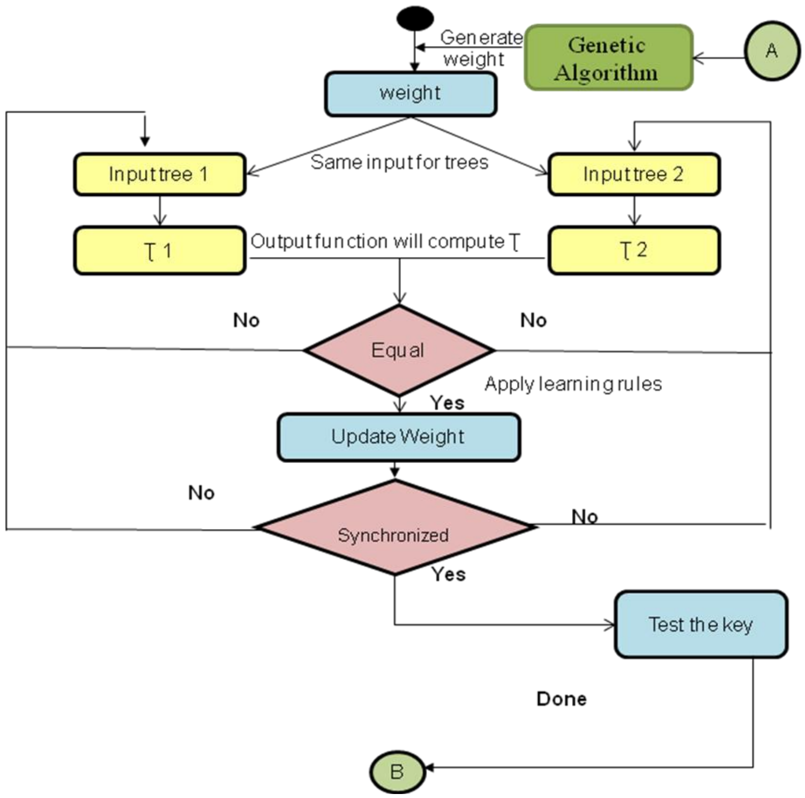


Figure 4.5 Flow Chart for Genetic Algorithm based Neural Synchronization

Here, the objective function is defined considering a range criterion. The fitness function f*(x)* is given by:

$$f(x) = \begin{cases} -L & x < -L \\ x^2 & -L \le x < L \\ L & x \ge L \end{cases}$$

The fitness value for each string in the population is calculated. Based on the fitness value, most fitted strings from the population are selected using Roulette Wheel selection method. On the selected strings, crossover and mutation are performed based on the Crossover rate (Pc) and Mutation rate (Pm). This completes one cycle of GA process. If the termination condition is met, the iteration is stopped and the new population generated will be considered as the optimal solution. Figure 4.5 shows how new optimal weights generated by GA are used in the TPM network for mutual learning by both the parties.

Table 4.3 Average number of iterations with different weight range using Random and Genetic weights obtained over 100 samples.

Weight range	*Random weights*	*Genetic weights*
3	350	150
4	547	263
5	923	300
6	1185	650

Table 4.3. Shows the average number of iterations taken to generate the key using random weights and genetic weights respectively**.** The experimentations conducted suggests that the genetic algorithm approach reduces the number of iteration by nearly 50% as compared to random weight approach.

S.Santhanalakshmi* , Sudarshan T S B*, GK Patra
****Faculty, Amrita School of Engineering, Bangalore***

4.5 High Performance Computing

CSIR in order to boost its high science and provide its computational scientists the latest state-of-the-art computational facility, has established India's largest High Performance Computing (HPC) facility at CSIR C-MMACS under the 11th five year plan. The system, which was ranked 58th in June 2012 and subsequently became 83rd in the world's top 500 supercomputers in November 2012, has been designed as a centralized facility of CSIR (Figure 4.6). It provides computational capabilities in different fields of computational sciences, such as Biological Sciences, Chemical Sciences, Engineering Sciences, Earth and Atmosphere Sciences, Physical Sciences etc. The system can be used in both capacity and capability mode of computing.

Figure 4.6 CSIR centralized 300TF High Performance Computing Facility. The system consists of 22 numbers of 42U racks with 1088 nodes with more than 2 Peta Byte of usable parallel file system.

The HPC system installed at CSIR C-MMACS is currently the fastest in the country and is theoretically capable of computing a peak of 362 Tera Floating Point Operations Per Second (FLOPS). However, the sustained performance achieved by the system using a standard High Performance LINPACK (HPL) is about 303 Tera FLOPS. The system is a cluster of 1088 computing nodes distributed over 17 numbers of 42U 600mm width racks. Each node is a HP Blade server, with two Intel Xeon E-5 2670 (8 cores, Sandy bridge) processors. Hence, the system has 2176 physical processors and 17408 processing. The nodes are connected to each other using high speed FDR infiniband interconnect from Mellenox in a FAT tree topology, which is capable of providing a dedicated 56 Gbps interconnect bandwidth. The state-of-the art interconnect is achieved through a large number of 16 port leaf switches in the computing racks with two 648-port core switch. High level of redundancy is maintained, so that any failure in cable and switch will not effect the ongoing computation. The switching equipment is placed in two 42U racks of 800mm width. One of the important aspects of the system is the memory per core. The memory across the nodes is distributed, while the memory inside a node can be used as shared memory. The system has about 68 TB of main memory, and individual nodes are provisioned with 64 GB of shared memory.

The other important factor that affects the performance of a system is the storage, where the jobs are run. The speed at which the I/O can be achieved, dictates the overall performance of an application. Looking at the importance of the storage, a high performance parallel file system from DDN is installed. The size of the storage is about 2.1 Peta Byte (3 Peta Byte unformatted) and is capable of providing more than 20 GBps read and write throughput. This storage is powered by open source LUSTRE file system, with performance tuning for the specific hardware. It provides hardware RAID in a RAID6 configuration. The parallel I/O is achieved through 8 numbers of object servers and are controlled through two numbers of redundant meta data servers. The storage is hosted inside three 42U racks and can be accessed by all the nodes of the HPC system simultaneously. The system was selected using a competitive bidding process, with rigorous benchmarking of computationally intensive models like WRF, MoM and Open Foam. Currently, the system is being tested for its stability and reproducibility of the benchmarks and is planned to be made available for users later.

While the installation of the 300TF HPC system is the highlight of this year, the computational needs of the CSIR scientists was handled by the Altix ICE cluster (Figure 4.7). The system, with 2304 numbers of processing cores, distributed over 192 nodes, interconnected in the form of an enhanced hypercube using the QDR (32Gbps) infiniband interconnect, was heavily used with almost 100% utilization throughout the year. The system is equipped with Intel Westmere-EP Hex core processors running at 2.93/3.06 GHz frequencies. Each node has 12 processing cores with 24 GB of memory in a shared memory form, while the system as a whole has 4608 GB of memory across the 192 nodes in a distributed architecture. The peak performance the system is 27 TFLOPS. A lustre parallel file system of 30TB handles the storage requirements for the computing system.

CSIR C-MMACS also has a shared memory system, which still continues to be the largest in the country. The Altix 4700 system is configured with 288 Intel Itanium2 processing cores (9140M, 1.66GHz, 18 MB cache), 608 GB of shared memory, 3.6 TB of RAID storage. The LINPACK benchmark delivered a sustained performance of 1.72 TFlop (1.91 TFlop peak). This system runs most of the memory intensive programs. This system is used extensively for providing agency specific forecasts to Karnataka State Natural Disaster Management Center at scheduled times (currently twice in a day).

The computing load on all these servers are managed through a workload management software called PBSPro, which not only ensures the efficient usage of the system but also provides an easy user interaction and submission process.

These systems are being used by a large number of CSIR laboratories and the major users are from CSIR National Chemical Laboratories, Pune, CSIR Central Electrochemical Research Institute, Karaikudi, CSIR National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram apart from researchers at CSIR C-MMACS and CSIR NAL.

Figure 4.7 Altix ICE system with 2304 processing cores distributed over 192 nodes and 30 TB of parallel file system along with all associated hardware and software.

High Performance Storage

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

Data Center

One of the important activities during the period is to design, and to establish of a Tier-3 equivalent state-of-the-art data center (figure 4.8) to host the 300TF HPC system along with the storage. Built as a turnkey project the datacenter is designed in an existing room, and is being developed from the scratch. The datacenter is capable of hosting 36 computing racks. The highlight of the datacenter is the cooling infrastructure. It is equipped to cool the racks using ultra modern water-cooling mechanism through Rear Door Heat Exchangers (RDHX). Cold water is supplied to the data center through water pipes, from three numbers of 100TR outdoor chiller plants configured in a n+1 configuration. The water travels to the computing system, through coiled pipes in the rear doors, and absorbs the heat generated by the system and sends the hot water back to the chiller unit for cooling. This cooling infrastructure ensures high and efficient cooling with less power consumption.

Figure 4.8 Tier-3 equivalent State-of-the-art Datacenter with associated infrastructure (a) The energy farm (b) The power distribution units (c) Fire Suppression system and (d) Un-interrupted power supply with associated battery banks

This has resulted in a very high Power Usage Efficiency (PUE) of less than 1.5 for the whole of the datacenter. The data center is supported by an energy farm consisting of two numbers of compact substations of 1.25MVA each and backup power by using three numbers of diesel generators in a n+1 configurations. An underground diesel yard of capacity more than 15000 liters of diesel is established to provide continuous diesel supply to the diesel generators. To provide continuous, uninterrupted power supply three numbers of UPSs are established with battery backup of about 15 minutes each at the basement of the building.

One of the important aspects of the datacenter is the monitoring facility through building management service. The systems including the electrical infrastructure are monitored continuously through the integrated building management services. This datacenter is equipped with fire detection and suppression system, very early smoke detection system, water leakage system, CCTV and public address system.

Network Facilities

Communication facility plays an important role, while providing centralized facilities. The CSIR C-MMACS HPC facility is utilized by the researchers from other CSIR laboratories through a 1 Gbps National Knowledge Network (NKN) and also through an 8 Mbps Internet gateway connected to the Internet through ERNET. Scientists and researchers of CSIR C-MMACS and CSIR NAL (all the three campuses) use the facility from their desktops through a high speed local networks interconnected using a 10 Gbps backbone. CSIR C-MMACS continues to provide E-mail facility to 6 nodes of CSIR C-MMACS and CSIR NAL. All network services namely DNS (Domain Name Server), NIS (Network Information Services), WWW (World Wide Web) institutional repository (https://cir.cmmacs.ernet.in) and Internet gateways (both for ERNET and NKN connections) have been managed and maintained at CSIR C-MMACS.

Software Enhancements

Application software were maintained and upgraded to keep pace with hardware enhancements. The heavily used software are ABAQUS, CFD-ACE+, IDL, GAMIT/GLOBK, Tecplot, S-Plus, Hyperworks, Fluent, ANSYS, OpenFOAM etc. The current list of hardware and software in the computing environment is available at the CSIR C-MMACS website http://www.cmmacs.ernet.in. The systems are used extensively for running complex models in the field of ocean sciences, atmosphere sciences, earth sciences and aerospace engineering. A new analytics software is procured to monitor the utilization of the high performance computing systems.

Other Technical Services

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

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

4.6 Development of Data Preparation System

With increase in processing speed, the paradigm of data preparation and its storage changes. The volume of processed data is usually substantial, so for all research purposes it has become desirable to process the raw data, make computation and analysis for the subject of investigation and discard the voluminous data.

With this in view, a software has been developed. Currently it is customized for NCEP - FNL data. The software supports extraction, interpolation, conversion to spectral format with various transformations including preparation of divergence and vorticity from horizontal velocity fields.

U N Sinha, Mohammed Mahfooz Sheikh,
Anupama K, Suraj Mani

4.7 Enhancing performance of Floswitch

Some of the gate arrays used in CSIR NAL Floswitch in Flosolver Mk8 had remained unused. This was considered to pipeline some of the instructions to synergize gate arrays and state machine. The result of this exercise was a new version of Floswitch whose effectiveness is shown in Figure 4.9.

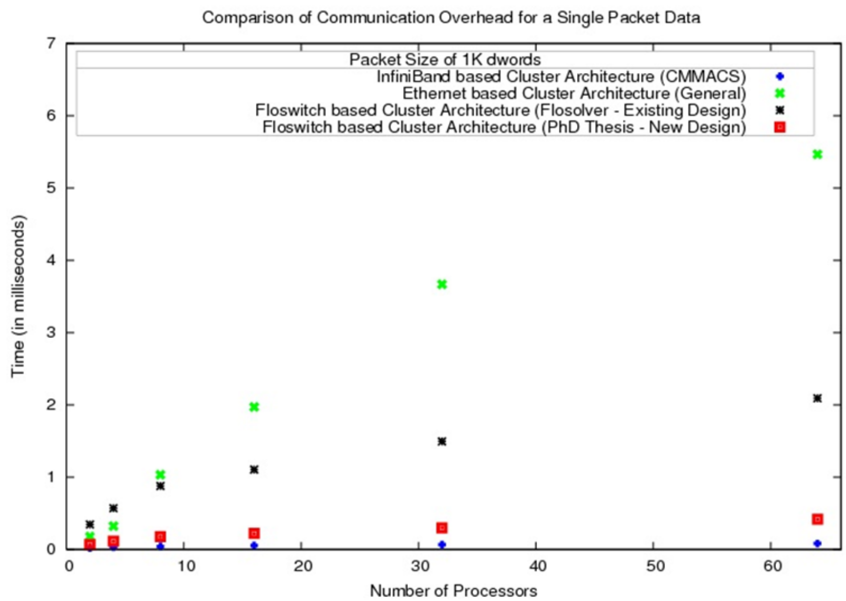


Figure 4.9 Performance of Communication Devices

It is clearly seen that Floswitch with this modification has a communication performance comparable with that of InfiniBand based communication.

InfiniBand based communication is robust and is easily configurable and most of all it is the standard used in the industry. It is important to note that a simple customized devices can give comparable performance in specific cases.

The design and development activities of the flowswitch resulted in an award of PhD Degree for Mahfooz from Mangalore University in 2013.

U N Sinha, Mohammed Mahfooz Sheikh

4.8 CSIR-4PI-Varsha

Performance of CSIR-NAL-VARSHA for forecast of rain during September had not been satisfactory and has been a source of concern.

A new version of Varsha named 4PI-Varsha, incorporating improvements in numerics and data preparation, has been made. The result for the month of September 2012 with initial conditions at 00Hr,06Hr,012Hr and 018Hr for 1st September 2012 are shown in the Figures 4.10-4.13.

Detailed verification is in progress and the cases examined so far (over 5 years of simulation) have been confirming the trend of overall improvement.

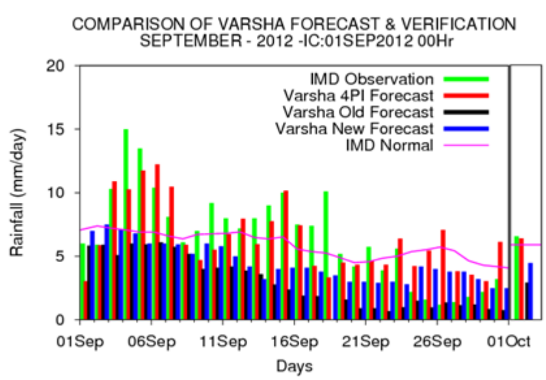


Figure 4.10 Initial Condition 01SEP 2012-00Hr

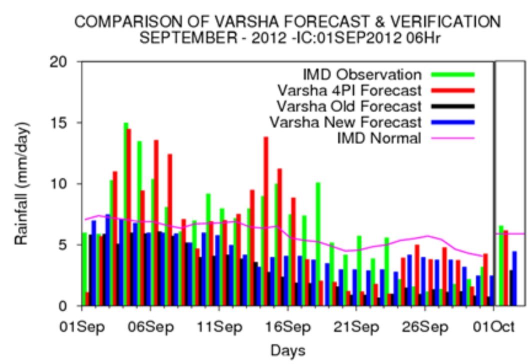


Figure 4.11 Initial Condition 01SEP 2012-06Hr

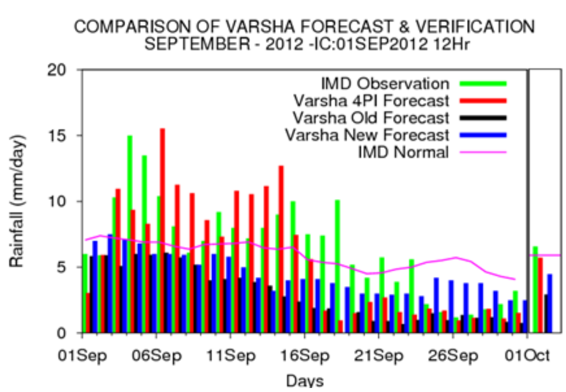


Figure 4.12 Initial Condition 01SEP 2012-12Hr

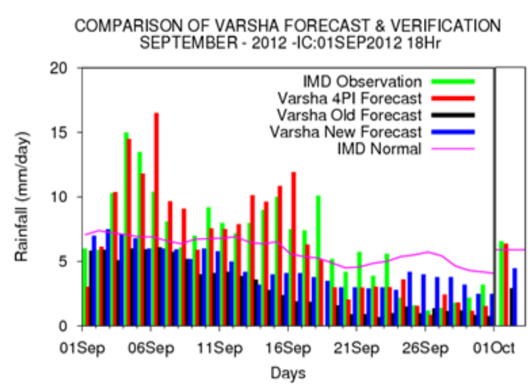


Figure 4.13 Initial Condition 01SEP 2012-18Hr

U N Sinha, Mohammed Mahfooz Sheikh, Anupama K, Suraj Mani

5

MULTISCALE MODELING AND SIMULATION

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

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

Inside

5.1 Aerosol Impact on Circulation and Plausible Causative Mechanism

To study the climate effect of aerosols, it is necessary to couple climate and chemistry/aerosol models. The interactive coupling of complex climate model and full chemistry schemes is still computationally too demanding and alternatively we have employed an offline aerosol transport model simulated aerosol loadings to a global climate model. Thus, the aerosol climatologies were derived from the 10-year simulations of the aerosol transport model.

We have conducted a set of 4 climate simulations of an atmospheric model; the first without any aerosol forcing (henceforth referred to as the control AGCM simulation, `NO_AERO') and with three different representations of aerosol direct radiative forcing (1. total aerosols (10 species of sulphate, carbonaceous, dust and sea salt, `ALL_AERO'), 2. scattering sulphate aerosols alone, `SUL_AERO' and 3. black carbon (soot) alone, `ABS_AERO'). In addition, we have carried out a constant global aerosol simulation (`BKG_AERO') and a simulation where the constant aerosols over the extended Indian region, are prescribed from ISRO's ACE aerosol observations (`ACE_AERO'). The aim of the first of these two experiments was to get the climate sensitivity to a uniform aerosol forcing. With the second experiment we have examined the climatic response to a substantial regional aerosol perturbation. All the integrations are of 10-year duration after spin-up.

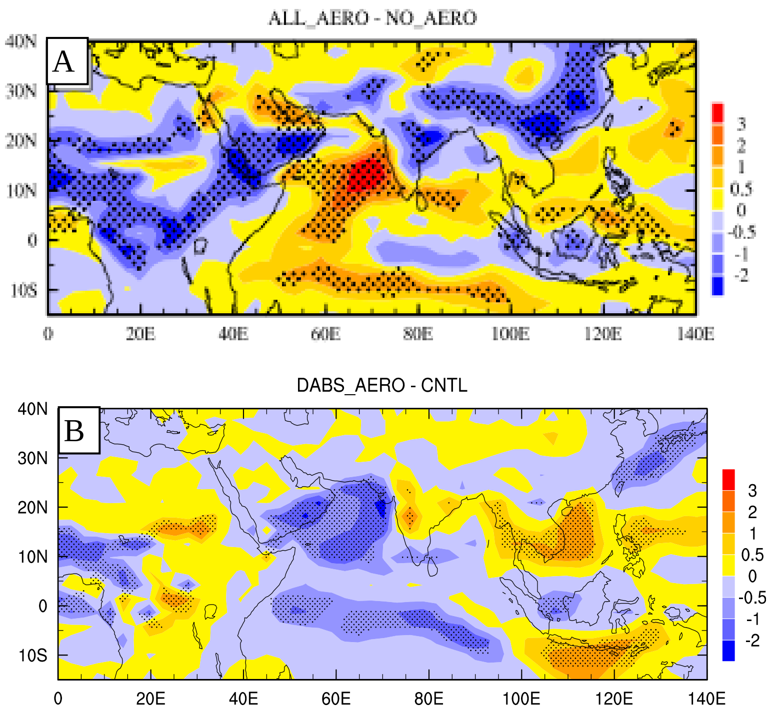


Figure 5.1 JJAS mean precipitation differences (mm day^{-1}) for a) ALL_AERO with respect to NO_AERO and b) DABS_AERO with respect to CNTL. Differences significant at 95% level are stippled.

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 aerosols such as black carbon and dust (`DABS_AERO'). These integrations are of 25-year duration after spin-up.

Aerosol direct impact due to total/scattering aerosols causes significant reduction in summer monsoon precipitation over India (Figure 5.1A). 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 (Figure 5.1B) and the circulation, but natural aerosols (also scattering /total aerosols) tend to result in net cooling and weakening of cross equatorial monsoon circulation and rainfall.

Total aerosol forcing reduces surface solar absorption over the primary rainbelt region of India and reduces the surface temperature. The simultaneous warming in the south reduces the land-ocean temperature contrast and thereby weakens the circulation, climatological summer cross equatorial winds and the advection of moisture into the monsoon zone. This increases atmospheric convective stability, and decreases convection, clouds, and precipitation.

Aerosol radiative forcing perturbation over Indian region alone is found to have both local and remote climate impacts. Analysis of simulation with climatological aerosol optical depths over the extended Indian region derived from network of observations merged with MODIS data over India, 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.

Sajani Surendran and Ravi S Nanjundiah (IISc, Bangalore)

5.2 The Aqua-Planet Experiment (APE): CONTROL SST Simulation

The World Climate Research Programme (WCRP) of World Meteorological Organization's (WMO) has a Commission for Atmospheric Sciences/Joint Scientific Committee (CAS/JSC) working group on numerical experimentation's (WGNE) to perform "Aqua-Planet" Experiments (APE) with a basic sea surface temperature distribution offer an opportunity for applying atmospheric models to simplified surface conditions for examining the behavior of physical parameterizations and the interactions of parameterizations with the dynamical cores. The details of the experiments are available at http://www-pcmdi.llnl.gov/projects/amip/ape/. The APEs are based on 8 different SST fields, of which 5 are zonally symmetric varying in latitude only and 3 impose tropical longitudinal perturbations on one of those zonally symmetric distributions. Of these 8 profiles we consider the one which is zonally symmetric and labeled CONTROL. The specified zonally symmetric SST in °C is given by $27\,[1 - \sin^2(3\phi/2)]$ for latitude ϕ between $\pm\pi/3$, and 0 for $|\phi| \geq \pi/3$. Complete details can be found on the APE website and in the APE ATLAS (http://opensky.library.ucar.edu/collections/TECH-NOTE-000-000-000-865).

Climate simulations by 16 atmospheric general circulation models (AGCMs) are compared. The idealized configuration is designed to expose differences in the circulation simulated by different models. Basic features of the aqua-planet climate are characterized by comparison with Earth's climate. Aspects of the circulation generated more directly by interactions between the resolved fluid dynamics and parameterized moist processes vary greatly. The tropical Hadley circulation forms either a single or double inter-tropical convergence zone (ITCZ) at the equator, with large variations in mean precipitation. The equatorial wave spectrum (Fig. 5.2) shows a wide range of precipitation intensity and propagation characteristics. Kelvin mode-like eastward propagation with remarkably constant phase speed dominates in most of the models. Westward propagation, less dispersive than the equatorial Rossby modes, dominates in a few models or occurs within an eastward propagating envelope in others.

There are spectral peaks associated with the equatorial wave modes in all the models, but the fraction of total power greatly varies in these modes. In a few models the modes are embedded in a background spectrum whose power increases with period, while in others most of the

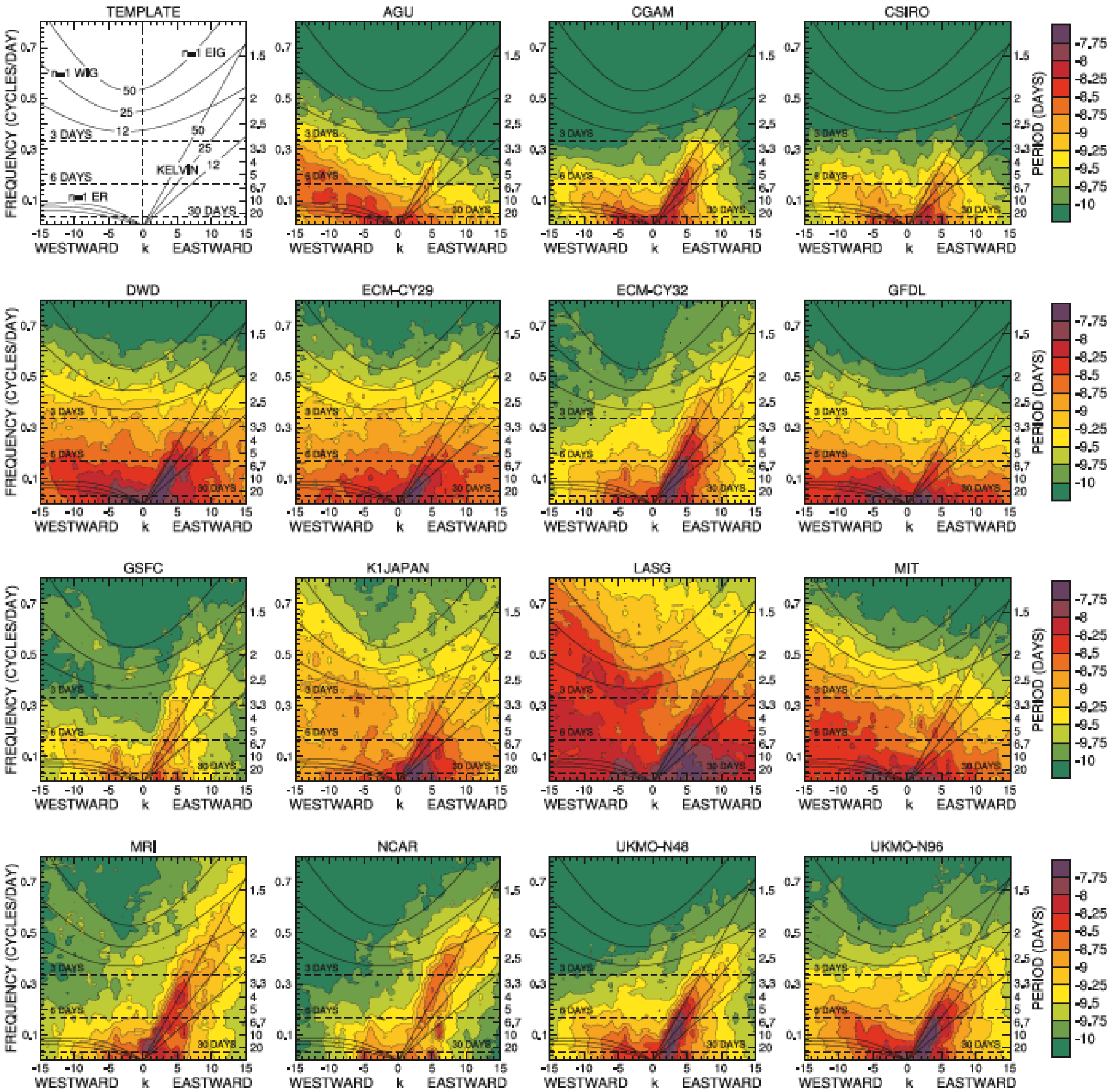


Figure 5.2 Wavenumber-frequency diagrams of log of power of symmetric equatorial precipitation averaged from 10°S to 10°N. Dispersion curves for the symmetric theoretical equatorial modes are included for reference.

power project onto the Kelvin and equatorial Rossby modes. A stronger background spectrum is characterized by more intermittent large-scale eastward propagation, so occurs in those models which contain short lived, smaller scale westward propagation within an eastward propagating envelope. Eastward propagating Kelvin modes are present in all models, and dominate the spectrum in almost half. Westward propagation dominates in a smaller number of models, either as a westward bias in the background spectrum, or as a stronger projection onto the equatorial Rossby modes. However, westward low frequency power is generally less dispersive than the Rossby modes, with higher zonal wave numbers “lifted” to higher frequency. This is likely to be a doppler shifting due to the presence of easterly zonal flow throughout the equatorial troposphere in the APE CONTROL.

K Rajendran and APE Principal Investigators
from 16 international atmospheric modeling groups

5.3 The Aqua-Planet Experiment (APE): Response to Changed Meridional SST Profile

This study explores the sensitivity of Atmospheric General Circulation Model (AGCM) simulations to changes in the meridional distribution of sea surface temperature (SST). The simulations are for an aqua-planet, a water covered Earth with no land, orography or sea-ice and with specified zonally symmetric SST. Simulations from 14 AGCMs developed for Numerical Weather Prediction and climate applications are compared. Four experiments are performed to study the sensitivity to the meridional SST profile. These profiles range from one in which the SST gradient continues to the equator, to the one which is flat approaching to the equator, all with the same maximum SST at the equator. The zonal mean circulation of all models shows strong sensitivity to latitudinal distribution of SST. The Hadley circulation weakens and shifts poleward as the SST profile flattens in the tropics. One question of interest is the formation of a double versus a single ITCZ. There is a large variation between models on the strength of the ITCZ and where in the SST experiment sequence in which the transition is from a single to double ITCZ. The SST profiles are defined in such a way that the maximum gradient increases and moves poleward as the equatorial SST gradient flattens. This leads to a weakening of the mid-latitude jet accompanied by a poleward shift of the jet core. Tropical wave activity and tropical precipitation frequency distributions are also considered. The details of each of them vary greatly between models, both in terms of a given SST and in terms of the response to the change in SST. One additional experiment is included to examine the sensitivity to an off-equatorial SST maximum. The upward branch of the Hadley circulation follows the SST maximum off the equator. The models that form a single precipitation maximum, when the maximum SST is on the equator, shift the precipitation maximum off equator and keep it centered over the SST maximum. Those that form a double ITCZ with minimum on the equatorial maximum SST, shift the double structure off the equator, keeping the minimum over the maximum SST. In both these situations only modest changes appear in the shifted profile of zonal average precipitation. When the upward branch of the Hadley circulation moves into the hemisphere with SST maximum, the zonal average zonal, meridional and vertical winds all indicate that the Hadley cell in the other hemisphere dominates. This is from the published paper in APE special issue (Williamson et al., APE special issue, Journal of Meteorological Society of Japan, 2013, 91A, doi:10.2151/jmsj.2013-A03).

K Rajendran and APE Principal Investigators
from 16 international atmospheric modeling groups

5.4 How Dependent is Simulation of Indian Summer Monsoon Rainfall on Model Resolution?

Advances in climate modeling now provide the opportunity by utilizing global general circulation models (GCMs) at very high-resolution, for projections of future climate and extreme events. Diagnostics of global atmospheric GCM simulations at different horizontal resolutions of 20 (Fig. 5.3c), 60 (Fig. 5.3d), 120 (Fig. 5.3e) and 180 (Fig. 5.3f) kms reveals the marked skill of 20 km mesh GCM in capturing regional characteristics of climatological summer monsoon rainfall over India.

Figure 5.3 reveals numerous regional details of the summer (June, July, August, September average, referred to as JJAS) mean rainfall over India based on two different observations from APHRODITE and IMD. The major rainfall centres include meridionally oriented orographic maximum along the west coast of the Indian Peninsula, relative maxima over the central Indian region, parts of the Indo-Gangetic plain and the northeast region. The narrow west coast orographic region has two distinct topographical and climatic features: to the west lies a coastal plain with heavy rainfall (windward side) and to the east lies a plateau with less rainfall (leeward side). This illustrates the requirement for ultra high resolution GCMs to provide important regional characteristics, especially in the context of orographic precipitation. There is a close comparison between the two data sets in representing the prominent features of summer mean rainfall and its spatial gradient over India.

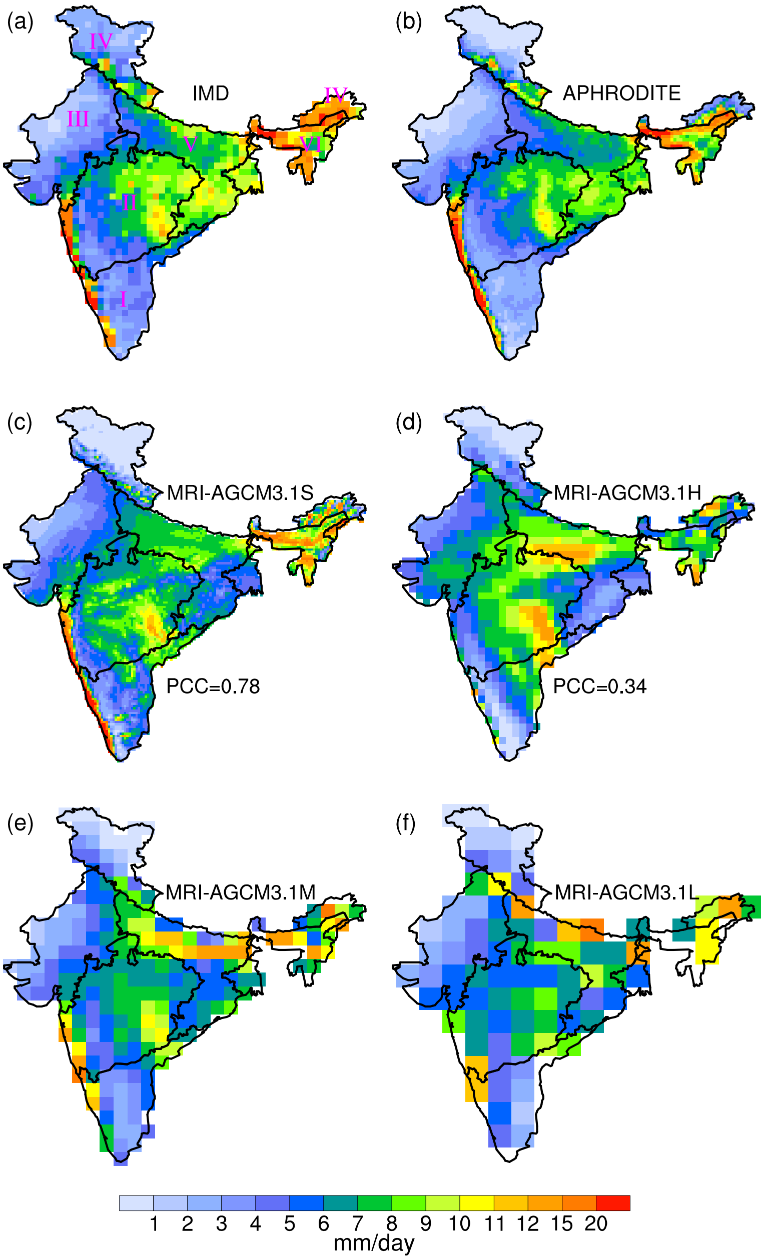


Figure 5.3 JJAS mean rainfall over India (mm/day) from IMD (a), APHRODITE (b) and present-day climate (PDC) simulations with Arakawa-Schubert (AS) deep convection scheme at four resolutions, MRI-AGCM3.1S (c), MRI-AGCM3.1H (d), MRI-AGCM3.1M (e) and MRI-AGCM3.1L (f).

The 20-km model captures many aspects of the regional distribution of observed rainfall especially the rainfall over parts of core monsoon region of West Central and Central Northeast regions. As observed, the southeast part of the Peninsular India and Northwest India, precipitation is relatively weak. However, there is a slight underestimation of rainfall over southeastern parts of Central Northeast India around West Bengal. On comparison, all lower resolution simulations fail to simulate the west coast orographic rainbelt and rainfall over Northeast India and Hilly Regions. In terms of intensity, location and extent of the major rainbelts and relative distribution of high and low rainfall, 20-km model tends to give improved simulation especially over the west coast, and northeast and Hilly Region of India. Regional details of rainfall over core monsoon zone are also close to observation. Accordingly, the pattern correlation coefficient (PCC) against IMD mean rainfall increases to 0.78 in 20-km model from 0.34 in 60-km model (insignificant for lower resolution models).

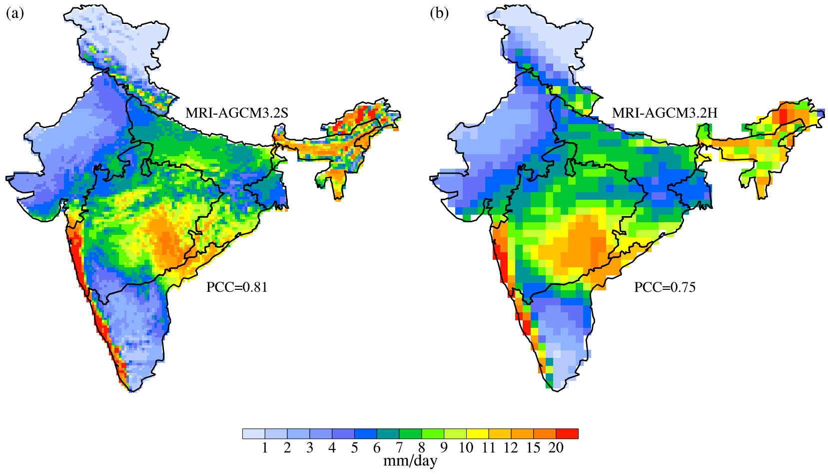


Figure 5.4 Same as Figure 5.3, but for PDC simulations of the model with YS deep convection scheme for MRI-AGCM3.2S (a) and MRI-AGCM3.2H (b).

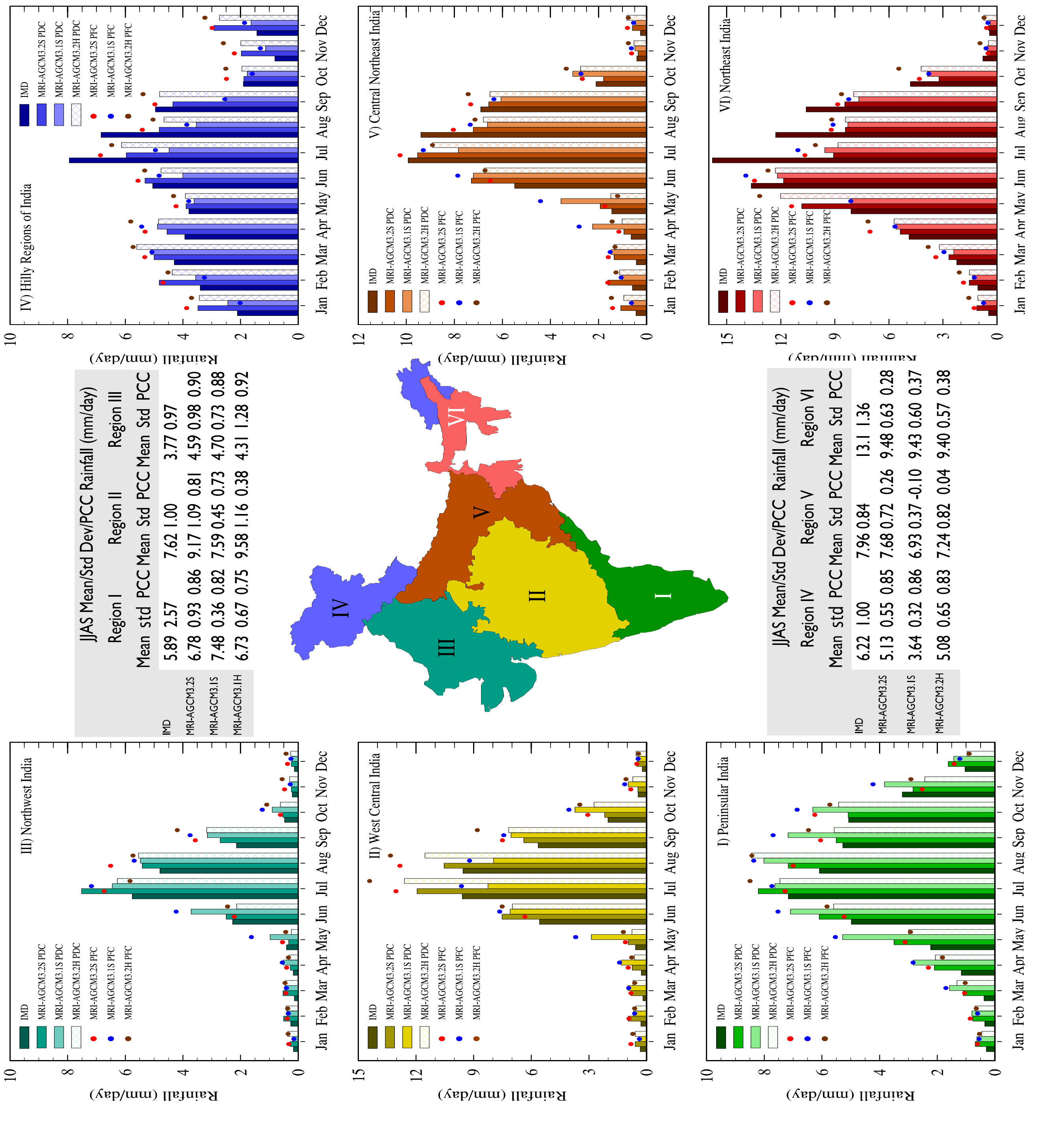
Figure 5.4 illustrates the impact of deep convection on seasonal mean monsoon from the two high-resolution simulations of 20-km and 60-km. When new Yoshimura Scheme (YS) for deep convection is used, there is a marked improvement in the simulation of rainfall and PCC increases to 0.81 for 20-km model from 0.75 for 60-km. A 20-km global climate model yields a quasi-realistic climatological monsoon rainfall simulation on a regional scale as well.

K Rajendran, S Sajani and A Kitoh (MRI/JMA, Japan)

5.5 Annual Cycle of Rainfall for Homogeneous Regions of India: Present Day Climatology and Future Projected Changes

Mean rainfall annual cycles for homogeneous regions of India from IMD observation and present-day climate (PDC) simulations of 20-km model (with two different convection schemes MRI-AGCM3.1S and MRI-AGCM3.2S) and 60-km model (with MRI-AGCM3.1H), are shown in Figure 5.5. There are marked seasonality in observed precipitation associated with the summer monsoon over all regions, except the Hilly Regions. The sudden enhancement in monthly precipitation associated with the onset phase, persistence of intense rainfall during June to September and the sharp reduction after the withdrawal in September are well manifested in observation and simulations. The model shows reasonable skill in capturing the phases of rainfall annual variation with some quantitative differences. In some cases, simulations show a tendency for overestimating the mean rainfall and MRI-AGCM3.2S simulation is able to bring down this anomaly (e.g., Regions I, II and III).

Observed and simulated mean, standard deviation, and PCC (Inset Table in Figure 5.5) for different regions show that over Peninsular India (Region I) and Northwest India (Region III), 3.2S version makes the summer mean and variability of rainfall closer to observation. For West Central India (Region II), the new scheme improves the variability (with a slight overestimation in mean rainfall), but sensitivity to higher resolution appears to have contributed towards improved spatial distribution (higher PCC). Over all, there are noticeable improvements in the simulation of mean, variability and annual variation of regional rainfall in MRI-AGCM3.2S. Projected future climate (PFC) simulations of these versions by time-slice method also shows overall future enhancement in the annual cycle.



JJAS Mean/Std Dev/PCC Rainfall (mm/day)

	Region I			Region II			Region III		
	Mean	std	PCC	Mean	Std	PCC	Mean	Std	PCC
IMD	5.89	2.57		7.62	1.00		3.77	0.97	
MRI-AGCM3.2S	6.78	0.93	0.86	9.17	1.09	0.81	4.59	0.98	0.90
MRI-AGCM3.1S	7.48	0.36	0.82	7.59	0.45	0.73	4.70	0.73	0.88
MRI-AGCM3.1H	6.73	0.67	0.75	9.58	1.16	0.38	4.31	1.28	0.92

JJAS Mean/Std Dev/PCC Rainfall (mm/day)

	Region IV			Region V			Region VI		
	Mean	std	PCC	Mean	Std	PCC	Mean	Std	PCC
IMD	6.22	1.00		7.96	0.84		13.1	1.36	
MRI-AGCM3.2S	5.13	0.55	0.85	7.68	0.72	0.26	9.48	0.63	0.28
MRI-AGCM3.1S	3.64	0.32	0.86	6.93	0.37	-0.10	9.43	0.60	0.37
MRI-AGCM3.2H	5.08	0.65	0.83	7.24	0.82	0.04	9.40	0.57	0.38

Figure 5.5 Mean rainfall annual cycle for homogeneous regions of India from IMD observation and PDC and PFC (projected future climate, shown in filled circles) simulations of MRI-AGCM3.2S, MRI-AGCM3.1S, and MRI-AGCM3.2H. Observed and simulated mean and standard deviation, and PCC for PDC simulations are given in tables.

Rajendran, S Sajaniand A Kitoh (MRI/JMA, Japan)

5.6 Climate Change Projection for Extreme Events

Future projections by time-slice simulations of 20-km AGCM with two different convection schemes (MRI-AGCM3.2S and MRI-AGCM3.1S) under global warming scenario (Figure 5.6) show widespread but spatially varying increase in rainfall over the interior regions of peninsular, west central, central northeast and northeast India (~5–20% of seasonal mean) and significant reduction in orographic rainfall over the west coast (~10–15%, consistent with the recent observed trends).

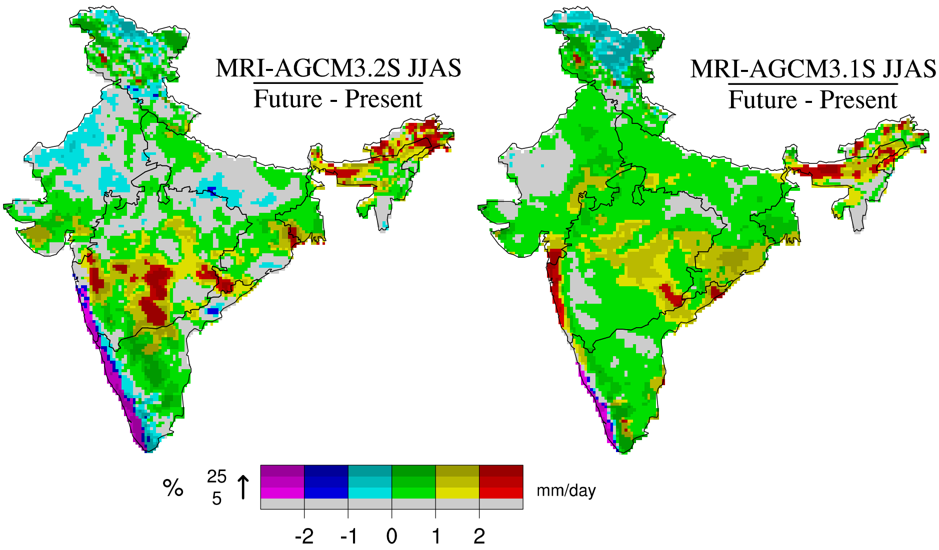


Figure 5.6 Projected future changes in JJAS mean rainfall over India by MRI-AGCM3.2S and MRI-AGCM3.1S. Within each colour the gradient in hue corresponds to changes as percentage of mean summer monsoon rainfall(< 5%: grey, 5–15%, 15–25% and >25%).

So far, future scenarios for Indian summer monsoon rainfall with high-resolution regional climate models projected relatively uniform climate change. Spatial distribution of the changes summer monsoon precipitation due to global warming show larger amplitude with more regional details in simulations with 20 km resolution (Figure 5.6) as compared to lower resolution projections. This shows that high-resolution simulations are essential to extract useful regional climate information. The pattern in precipitation is uneven in ultra-high resolution models with distinct spatial in homogeneity (Figure 5.6).

The model MRIAGCM3.2S projects spatially heterogeneous increase in warm days and extreme hot events over India. Projections indicate that during monsoon (JJAS), the number of warm days and extreme hot events

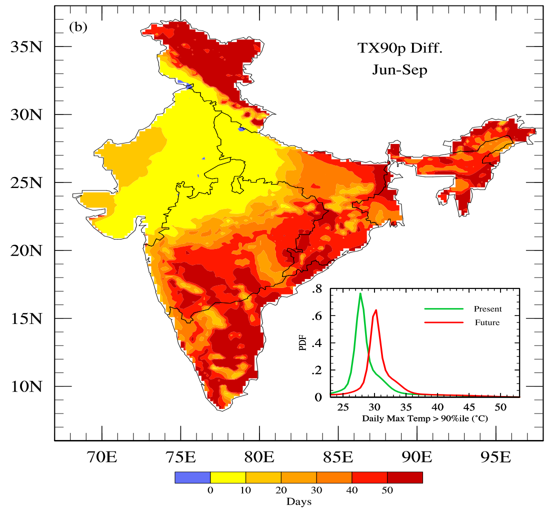


Figure 5.7 Projected Extreme Hot Events in Future. Future changes in number of days in JJAS with daily maximum temperature greater than 90 percentile, between PFC and PDC simulationsof MRI-AGCM3.1S. Probability density functions (PDFs) of the daily maximum temperature above 90 percentile in JJAS, for PDC and PFC simulations (inset).

(TX90p) will be increased in future (Figure 5.7) over the entire country. As seen in the case of the annual cycle of monthly mean temperature, at the end of the 21st century, simulations also predict an increase in maximum temperature throughout the year Figure 5.7 also shows the probability density functions (PDFs) for the daily maximum temperature above 90 percentile for JJAS season. The mean and standard deviation of PDC are different from those of PFC simulation, indicating a clear shift towards warmer conditions at the end of the century. Differences between the distributions for the occurrence of warm days in the PDC and future warming climate (PFC) suggest that there will be increase in extreme maximum temperatures in future. This is from published paper in special section on atmospheric and oceanic sciences, Current Science, 2013, 104 (10). (http://www.currentscience.ac.in/Volumes/104/10/1409.pdf).

K Rajendran, S Sajani, C B Jayasankar and A Kitoh (MRI/JMA, Japan)

5.7 Vertical Profiles of Atmospheric Latent Heating

The latent heat released by precipitating cloud systems is the primary agent of the vertical energy transport from the surface to the atmosphere. The interaction of diabatic heating and the circulation is further complicated by the fact that the vertical structure of the heating is related to the microphysical processes within convective systems.

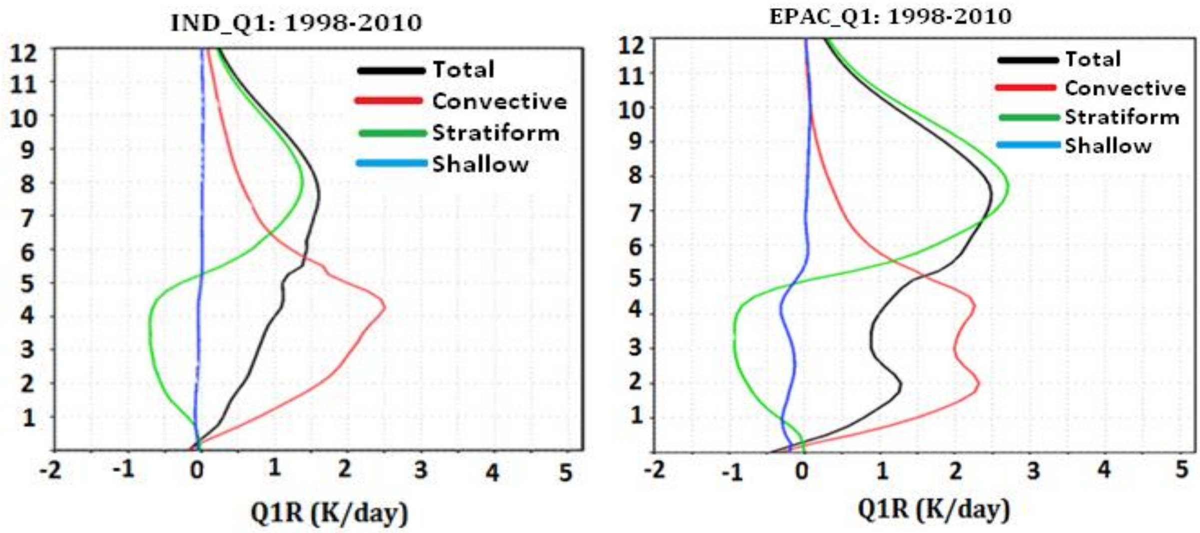


Figure 5.8 Vertical heating profiles over Indian continent (10°N-27.5°S, 70°E-90°E) and East Pacific (0°-15°N, 90°W-120°W) for cumulus (red), stratiform (green) and shallow (blue) types of clouds. The black curve shows total vertical heating pattern.

Level 3 monthly gridded TRMM data, with horizontal resolution of 0.5° and vertical resolution of 0.25km, from 37°S to 37°N for thirteen years (1998-2010) has been used in this study to understand the vertical heating profiles in the atmosphere. Based on the climatological location of ITCZ the representative ocean and land domains of the global tropics are selected for analysis. The main objective was to identify the dominant modes of the latent heating. Figure 5.8 compares the profiles for total, convective, stratiform and shallow convection heating for land and ocean domains.

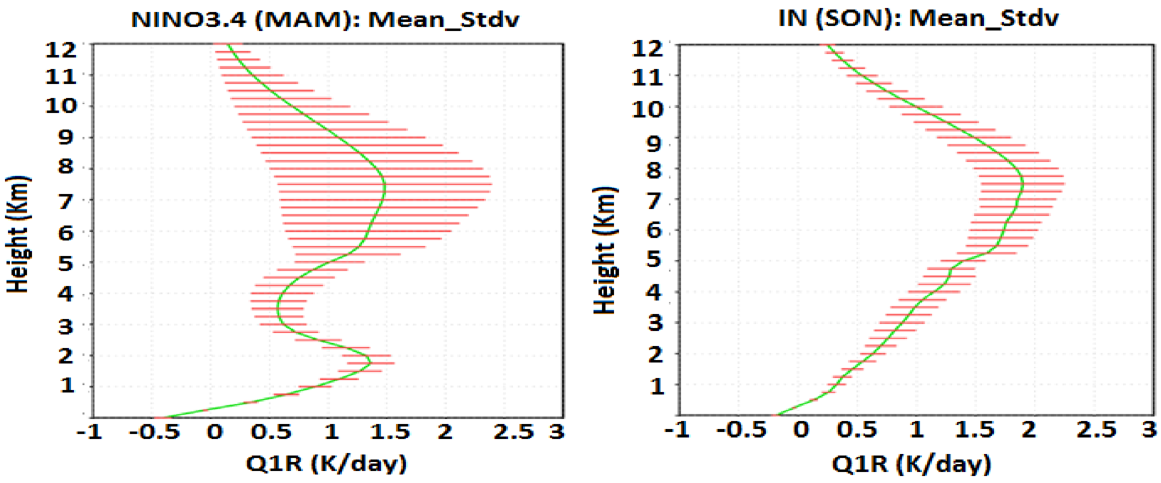


Figure 5.9 Vertical heating structure over NINO3.4 (5S-5N; 170W-120W) and Indian subcontinent. Seasonal mean (MAM: March-April-May and SON: September-October-November) is shown in green and red horizontal bars show the standard deviation.

Vertical heating profiles for these domains have been analysed using data derived from CSH (Convective Stratiform Heating) and SLH (Spectral Latent Heating) algorithms. In this study the seasonal mean, annual mean, standard deviation and interannual variability over different land and ocean domains have been analysed. The results show a clear difference of total vertical heating structure between land and ocean; with a single peak over land regions and double peak over oceans (Figure 5.9).

Ipsita Putatunda and K Rajendran

5.8 Analysis of Megha-Tropiques Data

Megha-Tropiques (MT) satellite mission is a collaborative effort between Indian Space Research Organisation (ISRO) and French Centre National d'Etudes Spatiales (CNES) for studying the water cycle and energy exchanges in the tropics. The main objective of the mission is to understand the life cycle of convective systems that influence the tropical weather and climate and their role in associated energy and moisture budget of the atmosphere in tropical regions. It was successfully deployed into orbit by a PSLV rocket in October 2011.

MT provides scientific data on the contribution of the water cycle to the tropical atmosphere, with information on condensed water in clouds, water vapour in the atmosphere, precipitation, and evaporation. Its circular orbit is 867 km with an inclination angle of 20° to the equator. We have converted the Level 2 SAPHIR (Sounder for Probing Vertical Profiles of Humidity, a sounding instrument with 6 channels near the absorption band of water vapour at 183 GHz) relative humidity (RH) data provided to the principal investigators of the pre-launch mission projects, into gridded Level 3 form. MT Level 2 data is provided for each day per orbit for six vertical layers (averaged). The regridding method that we have used is "patch" method which is quite similar to the technique called "patch recovery" which is commonly used in finite element modelling. It typically results in better approximations to values and derivatives when compared to bilinear interpolation.

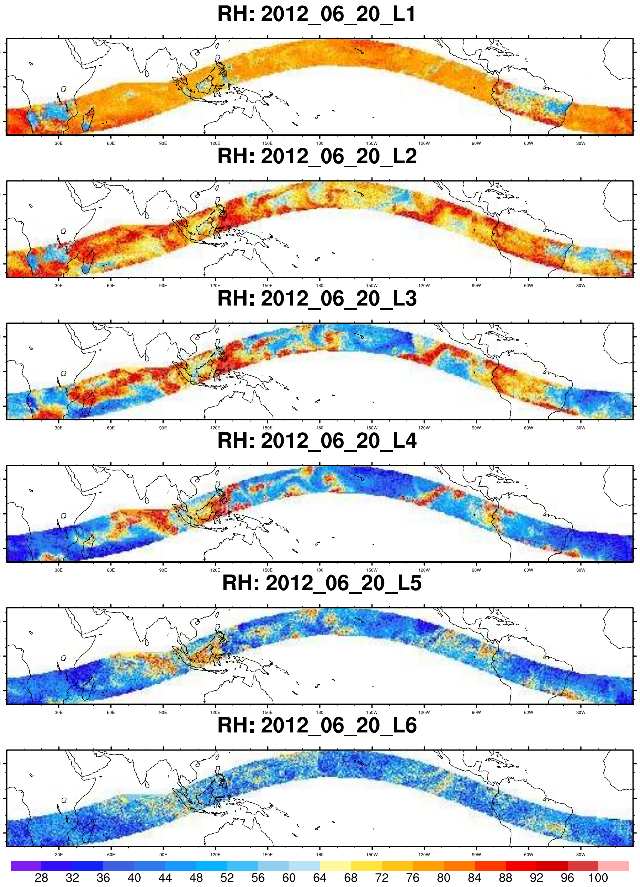


Figure 5.10 RH for six vertical layers from Level 2 MT data of a full orbit per day (20 June 2012).

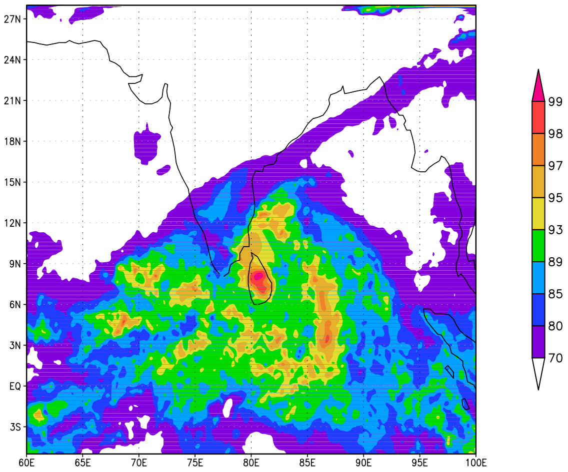


Figure 5.11 Second layer RH from Level 3 MT data for 30 June 2012.

We have completed the conversion of SAPHIR Level 2 daily data into Level 3 gridded form for the duration in which data was available and initiated preliminary analysis. Figure 5.10 illustrates the level 2 data for a full orbit. The severe cyclone 'Nilam' occurred over the Indian region during this period with its mature phase occurring during 28 - 30 October 2012. Figure 5.11 shows RH for the second layer (L2) on 30th October 2012, using the Level 3 SAPHIR data. The cyclonic pattern of high RH is clearly seen over the south-eastern coast of Indian Peninsula in the converted Level 3 data.

Ipsita Putatunda and K Rajendran

SOLID EARTH MODELLING PROGRAMME

Solid Earth Modelling group has niche expertise in GNSS geodesy and Computational seismology with scientists from Engineering, seismology, geology, geophysics and physics background. Significant research achievements of the group during 2012 -2013 are: (i) Combined global data analysis of 14 years of GPS data along the Himalayas from west to east, (ii) PWV (Precipitable Water Vapor) and TEC (Total Electron Content) derived from GPS signals provide an indicator for the early warning of geohazards (Cloud bursts, extreme rainfall event and Tsunamis), (iii) The first geodetic estimate from the volcanic arc of Andaman-Nicobar subducting margin gives a composite signal of deformation which is of tectonic as well as volcanic origin, (iv) CSIR-CMMACS GPS continuous station in Port Blair, Andaman gave an estimate of co-seismic static offset of the April 11 2012, Northern Sumatra earthquake, (v) Seismic hazard map of Himalayas with spatially distributed Peak Ground Acceleration was generated and (iv) High-resolution velocity map of India is generated from compilation of shear velocity data available from different sources and study.

In Computational Seismology, Solid Earth Modelling Programme is actively engaged in quantifying the seismic hazard in the Indian subcontinent, in terms of expected ground motions based on rigorous source modeling and computer simulation, incisive experiment design and intensive field investigations. These resulted in the creation of the first deterministic seismic hazard map of the country and have since been greatly elaborated both in the progressive enrichment of the scientific approach and experiment based hazard quantification of specific metropolises, notably Delhi, Ahmedabad and Bangalore. We run broadband seismic network in Dharwar and now in Kashmir to understand local, regional seismicity and understanding the evolution of crustal and mantle structure using teleseismic earthquakes. We also focus towards the application of seismic hazard in mitigating the seismic risk from the national scale to urban scale based on unified scaling law for earthquakes.

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6.1 Geodetic Constraints from the Volcanic Arc of the Andaman – Nicobar Subduction Zone

We report first ever Global Positionaing System (GPS) derived surface deformation rates in the Barren and Narcondum volcanic islands east of Andaman–Nicobar archipelago which lies in the Bay of Bengal, a zone that generates frequent earthquakes, and coincides with the eastern plate boundary of India. The tectonics of this region is predominantly driven by the subduction of the Indian plate under the Burma plate. Andaman sea region hosts few volcanoes which lies on the inner arc extending between Sumatra and Myanmar with the sub-aerial expressions at Barren and Narcondum Islands. Barren Island, about 135 km east-north-east (ENE) of Port Blair, is presently active with frequent eruptive histories whereas Narcondum is believed to be dormant. We initiated precise geodetic campaign mode measurements at Barren Island between 2007 to 2012 and one year (2011-2012) continuous measurements at Narcondum island during 2011-12. Preliminary results from this study forms a unique data set, being the first geodetic estimate from the volcanic arc of this subducting margin. Our analysis indicates horizontal convergence of the Barren benchmark to south-westward (SW) direction towards the Andaman accretionary fore-arc wedge where as the Narcondum benchmark recorded northeast (NE) motion.

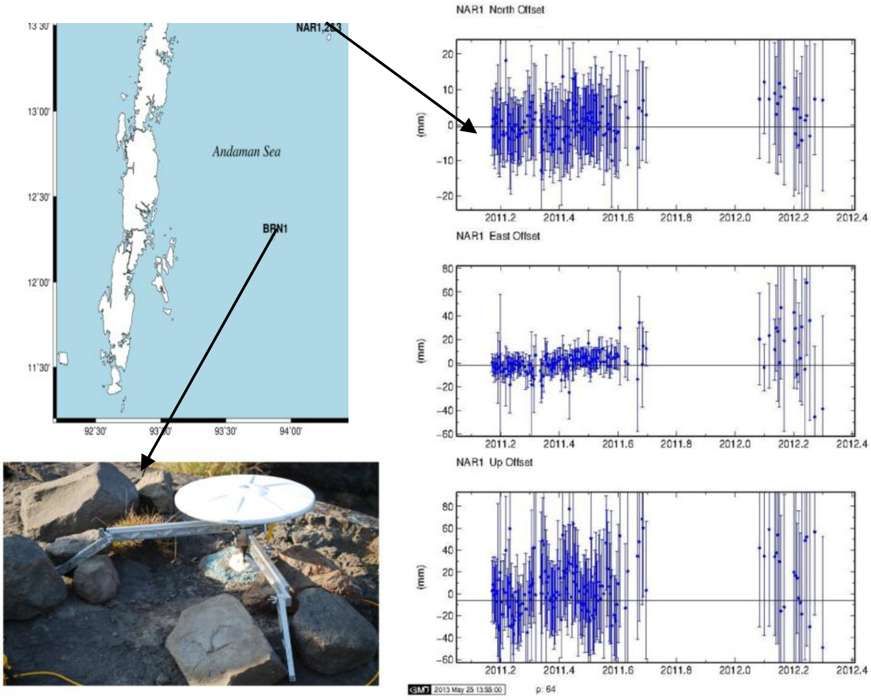

Figure 6.1 Left top panel: location map showing Barren (BRN1) and Narcondam (NAR1) volcanoes. Right panel shows one year long position time-series estimated from the data collected on a continuously observing bench mark from Narcondam volcano. Left bottom panel shows a campaign observation survey being carried-out at Barren Island volcano.

West of the Andaman fore-arc there is NE oriented subduction of the Indian plate which is moving at the rate of ~5 cm/yr. Convergence rates for the Indian plate from the Nuvel 1A model show oblique convergence towards N23°E at 5.4 cm/yr. GPS derived inter seismic motion of Andaman islands prior to 2004 Sumatra earthquake is ~4.5 cm/yr towards NE. The marginal sea basin east of Barren Island at the Andaman spreading ridge has a north-north-west (NNW) orienting opening of the sea-floor at 3.6 cm/yr. However the recent post seismic measurements of Andaman islands indicate rotation of displacement vectors from SW to NNE during 2005 to 2012. In this tectonic backdrop, the estimated rate of displacement of the volcanic islands probably represents a composite signal of tectonic as well as volcanic origin. Also, on the vertical component both the benchmarks shows significant uplift.

Post-2004 magnitude M 9.2 Sumatra-Andaman earthquake, massive clustering of earthquakes were observed along this volcanic arc. Whether the frequent eruptions at Barren Island is remotely connected with any of the larger earthquakes in the Sumatra-Andaman region may be a difficult question to answer. The earthquake-volcano interactions and the possible threat of major eruptions in near future triggered by ongoing slow viscous relaxation of the lower crust-upper mantle, can cause a renewed activity at this region.

Anil Earnest, Rajeev K, Vijayan MSM, Shrungeshwara T S and Sridevi Jade

6.2 Crustal Deformation Associated with the 2012 M8.6 and M8.2 Strike-Slip Earthquakes at the Andaman Nicobar Region

On April 11, 2012 two M8.6 and M8.2 earthquakes occurred on the western coast of northern Sumatra. The causative strike-slip faulting occurred within the marine lithosphere of the Indo-Australia diffuse boundary. The epi-central locations of the earthquakes are southwest of the Sunda-Andaman subduction zone where the India/Australia plates converges north-northeast with respect to the Andaman micro plate and Sunda arc with a velocity of approximately 52 mm/yr.

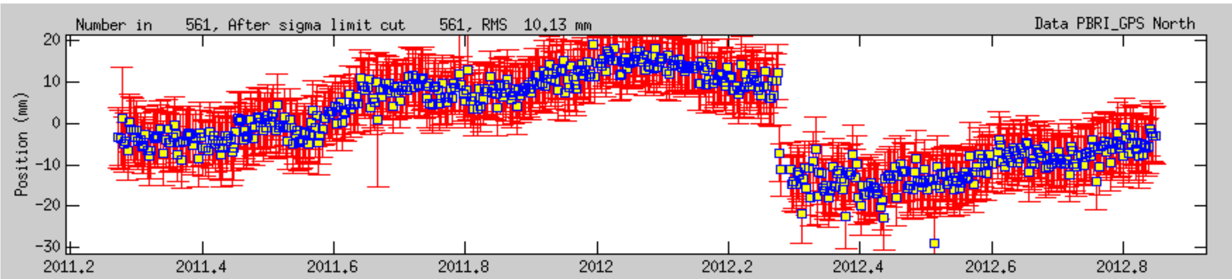

Figure 6.2 Static surface offset recorded at a continuously operating GPS geodetic site at Port Blair. Note the sudden co-seismic shift towards south, an after effect of the 2012 strike-slip Indian Ocean earthquakes.

These two large intraplate earthquakes has generated static offsets on Earth's crust as far as Indian mainland. Data from network of continuosly operating high rate GPS receivers at Andaman and Nicobar Islands also caught the static offsets generated due this earthquake. The North offset values which shows the strike-slip nature of the faulting process associated with the 2012 Indian Ocean twin earthquakes.

Rajeev K, Anil Earnest, Vijayan MSM, Shrungeshwara T S, Mohan[1] P M and Sridevi Jade
1 Dept. Of Ocean and Island Studies, Pondicherry University, Port Blair.

6.3 Post-seismic Deformation Transients from the Andaman Nicobar Region: 2005 – 2013

We estimated the post-seismic deformation from 2005 to 2013 using the near-field geodetic data collected from the Andaman-Nicobar Islands and far-field Continuous GPS data available from SUGAR, UNAVCO and IGS datasets. The 2004 Mw 9.2 Sumatra-Andaman mega-thrust rupture broke the whole 1300 km long fore-arc sliver boundary of the Indo-Burmese collision. Earlier events of 1679 (M ~7.5), 1881 (M ~7.9), 1941 (M 7.7), and 2002 (M 7.3) generated spatially restricted ruptures along this margin. GPS based geodetic measurements of post-seismic deformation following the 2004 M 9.2 Sumatra-Andaman earthquake gives insights on the spatio-temporal evolution of transient tectonic deformation happening at the Sunda-Andaman margin.

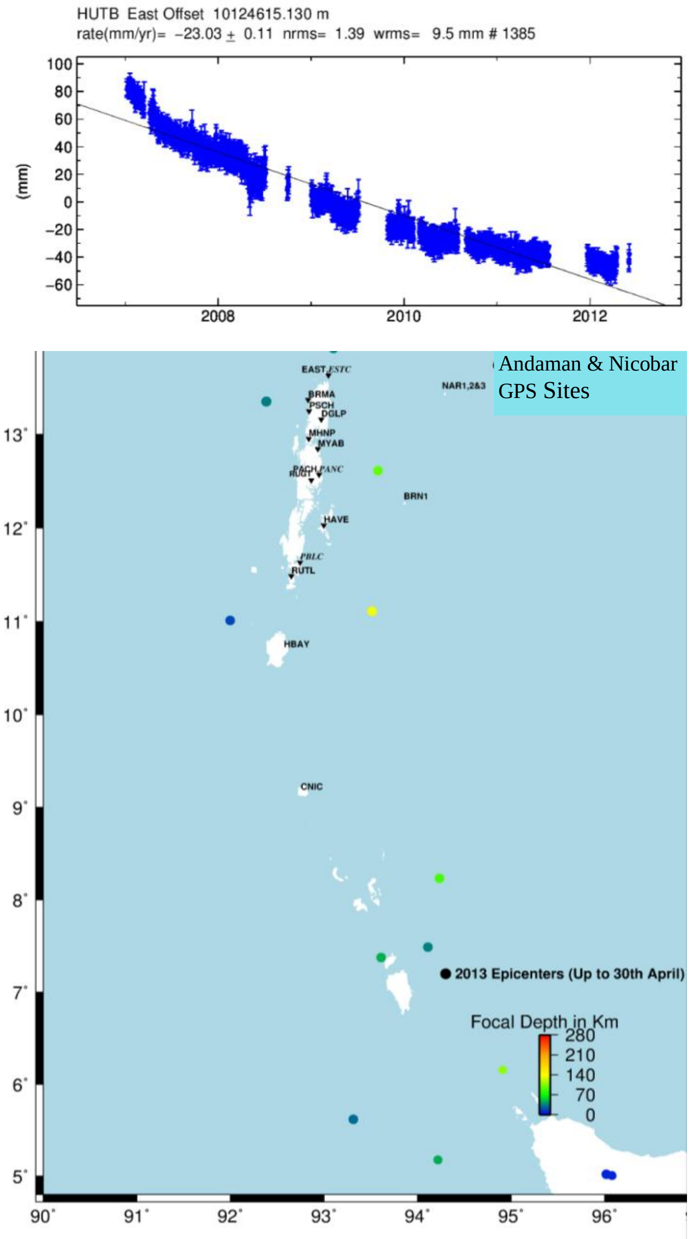

Figure 6.3 Upper-panel shows the relaxation pattern observerd at one of the GPS site at Little Andamans, post the 2004 M9.2 earthquake. Bottom figure shows the CSIR CMMACS campaign mode GPS locations and continuously operating GPS sites at Andamans with seismicity distribution information in the background.

Precise geodetic data analysis indicates that the GPS benchmarks in the Andaman-Nicobar region moved immediately after 2004 event towards the sea-ward trench in the SW direction, following the pattern of the co-seismic offset directions. This may be because of the continued predominant after-slip occurrence around the 2004 rupture zone due to the velocity-strengthening behavior The GPS time series indicate slow and transient progressive reversal of motion direction away from the oceanic trench (and the co-seismic offset direction) of the coastal and inland GPS sites of Andaman-Nicobar Islands. The site displacement transients indicate a rotation of the displacement vector moving from south-west to north during this period. Post-seismically our benchmarks show steady uplift and can be attributed to the steady relaxation being taking place, part of the subduction zone earthquake cycle. Spatio-temporal analysis of the earthquakes shows dense shallow seismicity in the back-arc region, normal and thrust faulting activity towards the trench. The hypo-central distribution highlights the shallow subduction at the northern segment, which becomes steeper and deeper to the south. The stress distribution, inferred from the P and T-axes of earthquake faulting mechanisms, represents the compressional fore-arc and extensional back-arc stress regimes.

Anil Earnest, Vijayan MSM, Sridevi Jade, Rajeev K and Shrungeshwara T S

6.4 Combined GPS data analysis to derive 14 years (1994-2008) GPS time series for Indian Himalayan Arc from West to East.

The Indo-Eurasian Himalayan Collision boundary has a wedge-shaped geometry which extends over 2500 km from west to east and its frontal region is a fold-thrust belt (Figure 6.4) characterized by several thrust faults that sole with the basal detachment of the Himalayan wedge or the Main Himalayan Thrust. The entire Himalayan arc is tectonically active as it continues to display seismicity resulting from deceleration of the Indian plate along its boundary. Strain buildup in this region when combined with the seismic activity and geodynamics of this region would give information on suspected seismic gaps which may experience large earthquakes in future. The knowledge presently available on the cycles of strain buildup and release and periodicity of earthquakes along the various segments of Himalaya is not adequate enough to make predictions even for shorter periods.

Since the advent of precise GPS Geodesy in 1994, contemporary deformation in Indian sub-continent has been quantified by CSIR C-MMACS using extensive multi-institutional GPS experiments in most difficult terrains like Kashmir Himachal, Ladakh, Gharwal, Kumaon, Sikkim and Arunachal Himalaya to determine the strain accumulation and stress buildup which is the direct and precise indicator of seismic potential. Combined GPS data analysis has been carried out using the continuous and campaign GPS measurements from 1994-2008 in the Indian Himalayas from Ladakh in the west to Arunachal Pradesh in the east to precisely quantify the strain accumulation in the Himalayan arc over the period of 14 years. Indian Himalayan data was analyzed using GAMIT/GLOBK software along with the data from IGS (International GPS Service) stations and continuous GPS stations in rigid Indian plate to obtain the loosely constrained daily solutions. These were then combined using Global reference frame definition by stabilizing the IGS stations to their ITRF05 (International Terrestrial Reference Frame) coordinates and velocities. Random-walk noise at the level of 2 mm/year is included in the coordinates for all stations to account for errors in modelling the orbits and atmosphere in the long time series, time correlated sources of errors in position estimates including monument instability.

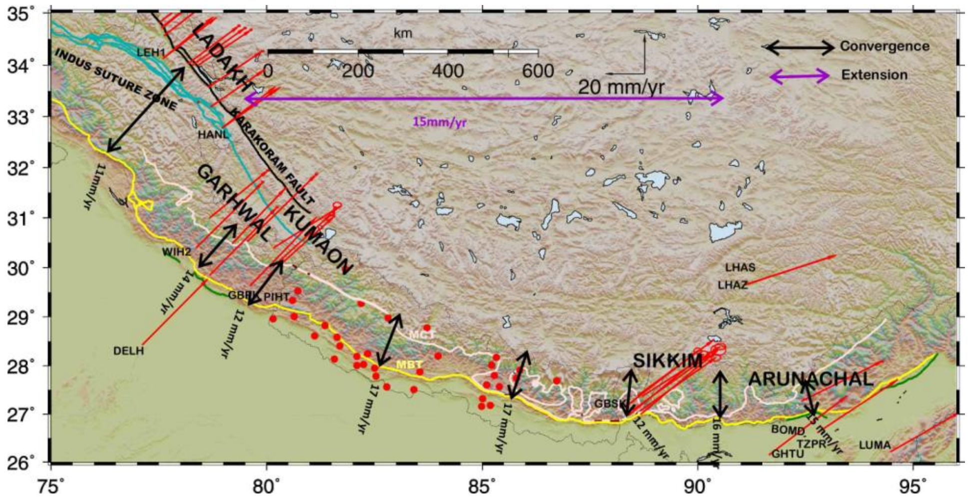

Figure 6.4 GPS derived convergence rates across the Himalayan Arc from West to East. Velocities of the GPS sites (red arrows) and the east-west extension rate are also shown in the figure. The GPS sites of Nepal Himalaya (red dots) are plotted along with the GPS derived shortening rates as reported by Bettinelli et al. [2006].

Results indicate that arc-normal convergence rate of 11 mm/yr (Figure 6.4) is being accommodated in Kashmir Himachal Himalayan wedge south of Ladakh, 14 mm/yr in Garhwal Himalayas, ~12 mm /yr in Kumaon Himalayas, ~14 mm/yr in Western Nepal Himalaya, ~17 mm/yr in Central and Eastern Nepal Himalaya, ~12 mm/yr in Sikkim Himalaya , ~16 mm/yr in eastern Bhutan and ~15 mm/yr in western Arunachal Himalaya indicating high strain accumulation in Himalayan arc resulting in significant stress buildup in this region. This arc normal convergence result in under thrusting of Indian continent below the radially oriented Himalayan belt at a constant rate. The results also indicate east west extension rates of ~ 15 mm/yr between Ladakh and south eastern Tibet, which is consistent with the Indo-Tibetan convergence. In summary, deformation rates in Himalayan arc over 14 years derived from combined global data analysis, suggest that the motion of Tibet does not confirm to plate-like motion. Instead, large-scale tectonics in Tibet is best described as deformation of a continuous medium where the slip rates on the strike slip faults differ little from those on normal and thrust faults. All faults constitute passive markers of discontinuities in the strain field that translate and rotate with a deforming continuum.

Bettinelli, P., Avouac, J. P., Flouzat, M., Jouanne, F., Bollinger, L., Willis, P., and Chitrakar, G. R. (2006). Plate motion of India and interseismic strain in the Nepal Himalaya from GPS and DORIS measurements. Journal of Geodesy, 80(8-11), 567-589.

Sridevi Jade

6.5 GPS Geodesy for Seismic Vulnerability of Indian Subcontinent

The grand challenge in assessing the seismic vulnerability of Indian subcontinent using GPS (Global Positioning Systems) geodesy is to integrate the GPS derived active deformation with the geology and tectonics of the region to model the regional deformation to give the stress/strain rate. The complexity involved is to model the deformation across spatial and temporal scales. We also need to model the troposphere and ionosphere in the Indian subcontinent to derive the precise estimates of surface deformation. All these complex models form a key input for precise earthquake hazard quantification (Figure 6.5). This requires niche expertise in GPS geodesy , Engineering, seismology, geology, geophysics and physics.

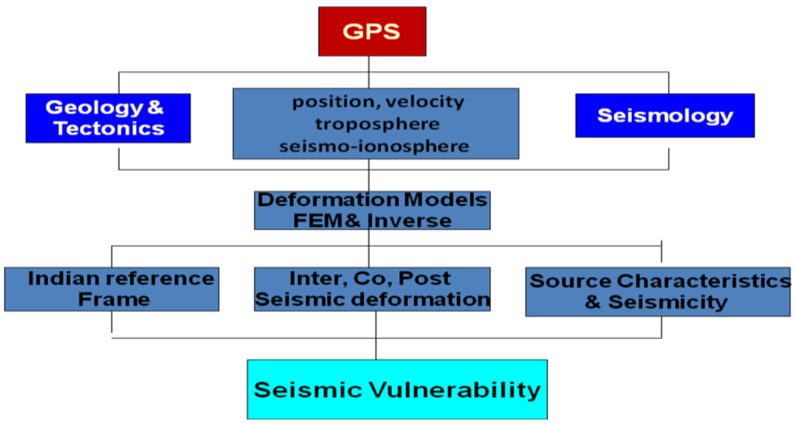

Figure 6.5 Work flow chart for quantifying seismic vulnerability of Indian subcontinent using Global Positioning System

Precise-positioning provided by GPS could be used in high-precision geodesy for several geosciences applications such as continental deformation studies, landslide hazard mapping, glacier dynamics, volcano deformation, troposphere and ionosphere modeling, InSAR (Interferometric Synthetic Aperture Radar), GIS (Geographical Information System) etc.. Recently GPS is termed as GNSS (Global Navigation Satellite System), also includes other navigation satellite systems, e.g., GALILEO by European union, GLONASS by Russia and many other space based navigation systems of different countries other than satellite operated in USA. In India GPS is being used for numerous applications in diverse fields like aircraft and ship navigation, surveying, geodetic networks, crustal deformation studies, cadastral mapping etc.

GNSS/GPS geodesy is being extensively used by the scientific community to quantify the present day motion between different tectonic plates and deformation related to earthquake occurrence processes. Specific to Indian tectonics, GPS geodesy has lead to several firsts in quantifying the kinematics of the Indian Plate i.e. Indian plate motion, N-S, E-W strain accumulation in India, convergence rates in Indian Himalayas, co-seismic and post-seismic deformation related to Bhuj, Sumatra and Kashmir earthquakes (http://www.cmmacs.ernet.in/~gps). In India, the co seismic and post seismic deformation due to 2001 Bhuj and 2004 Sumatra earthquake has been modelled to give the geometric to the rupture plane and the associated slip. Inter seismic deformation in Ladakh Himalaya has been modelled to give the slip along the Karakoram fault in this region.

GPS signals suffer delay during transmission in the ionosphere and troposphere which causes significant errors in estimation of the positions can be used to precisely quantify the precipitable water vapor(PWV) column in the atmosphere which can help meteorologists in their research and total electron content (TEC) which is a crucial input to the ionosphere modeling. Globally, GNSS geodesy is used extensively for PWV estimation, troposphere modelling, landslide hazard mapping, glacier dynamics, GIS and InSAR integration whereas in India the research in these areas is in the initiation stages. Research in the areas of volcano deformation studies and ionosphere modeling using GNSS geodesy is at initial stage both at national and international level.

GPS based crustal deformation studies is presently being carried out by a few research organizations in the country . Estimation of seismic hazard of Indian subcontinent using GPS requires a major national programme on GNSS based seismic hazard with all the agencies involved as stake holders. This programme has to to bring coordination between these agencies and departments involved in to address critical issues such as network maintenance/ operation, training, real time streaming of data, Indian reference frame stabilization, web hosting of regional deformation rates and associated seismic vulnerability of Indian subcontinent.

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6.6 Perturbations in GPS PWV Retrievals during Cloudburst, Extreme Rainfall and Passage of Cyclone

Variability and quality of tropospheric Precipitable Water Vapour (PWV) retrievals from dual frequency geodetic GPS data during the extreme rainfall, cloudburst and passage of cyclone were studied during the following events:

(i) cloudbursts on 26 July 2005 cloudburst causing approximately 950 millimetres (37 in) of rainfall in Mumbai over a span of eight to ten hours; the deluge completely paralysed India's largest city and financial centre
(ii) A series of cloudbursts on August 6, 2010, in Leh, left over 1000 persons dead (updated number) and over 400 injured in the frontier Leh town of Ladakh region in Jammu and Kashmir and
(iii) Heavy rainfall at Bangalore on 1st November 2012 during the passage of Nilam cyclone.

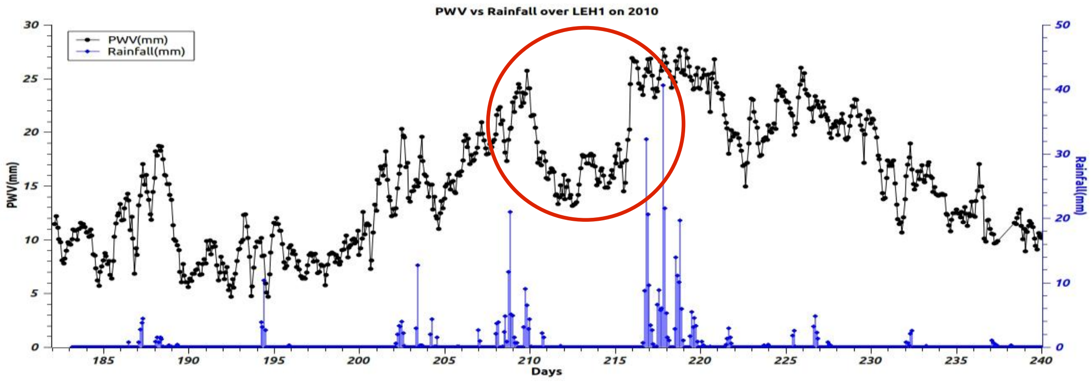


Figure 6.7 Variability of GPS PWV before, during and after Leh Cloud burst in August 2010 (DoY:218)

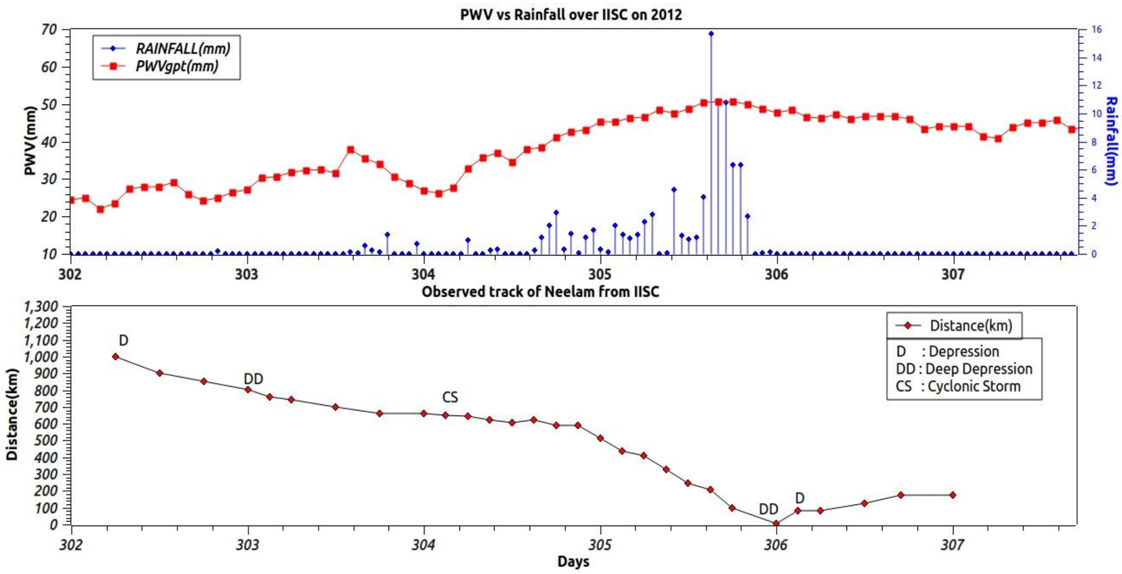


Figure 6.8. Variability of GPS PWV and TRMM rainfall at Bangalore before, during and after passage of Nilam cyclone during November, 2012. Bottom plot shows the daily distance between IISC, Bangalore and Nilam cyclone

To improve the quality of GPS PWV estimation, a priori Zenith Tropospheric Delay(ZTD) was modelled using Observed Pressure and Temperature (OPT); and, Global Pressure and Temperature (GPT) model was used whenever OPT was not available. The GPS PWV thus estimated for these period was compared with radiosonde observations, PWV from Numerical Weather Prediction Models, and TRMM rainfall estimates. It is noticed that the variability in GPS PWV is well correlated with radiosonde and rainfall data. The results indicated that there is a "dry spell" just before the extreme rainfall. The variability of PWV before, during and after the Leh cloud burst has been given in the figure 6.7 along with TRMM accumulated rainfall. Similar effects have been observed during the Mumbai extreme rainfall event too. In the case of Nilam cyclone which caused severe rainfall over Bangalore, there is a clear indication of increase in PWV when the Nilam Cyclone approached the IISC station, Bangalore (figure 6.8). These results indicate that all weather operable and cost effective GPS PWV estimates may be useful to improve the quality of numerical weather forecasting especially in the case of Quantitative Precipitation Estimation (QPE) and Quantitative Precipitation Forecasts (QPF).

M S M Vijayan, T S Shrungeshwara, and Sridevi Jade

6.7 Ionospheric TEC Perturbations Associated with 26th December 2004 Indian Ocean Tsunami: Possibilities for Tsunami Early Warning using on Shore GPS Network

Global Positioning System (GPS) is primarily developed as a satellite based navigation tool for defence applications. Since 1994, GPS was opened for civilian use which turned it into a multifaceted tool, especially in the fields of surveying and Earth Sciences. Recent developments proved that noise in the GPS positioning caused by heterogeneous atmosphere on the propagation of GPS signals can be inverted into an invaluable signal to probe the atmosphere. GPS signals suffer delay during transmission in the ionosphere and troposphere which causes significant errors in the estimation of position. Ionosphere is a dispersive medium which speeds up the carrier phase and slows down the code of GPS signals. The ionospheric delay is directly proportional to the number of free electron on the propagating path termed as Total Electron Content (TEC). This delay which causes error in the estimation of position can be utilized to determine the TEC which is a crucial input to the ionosphere modelling. TEC thus estimated as a by product from GPS based geodetic/surveying observations and its anomalous variations can be used as an indicator for the early warning of tsunami, earthquake, etc without any additional observations cost.

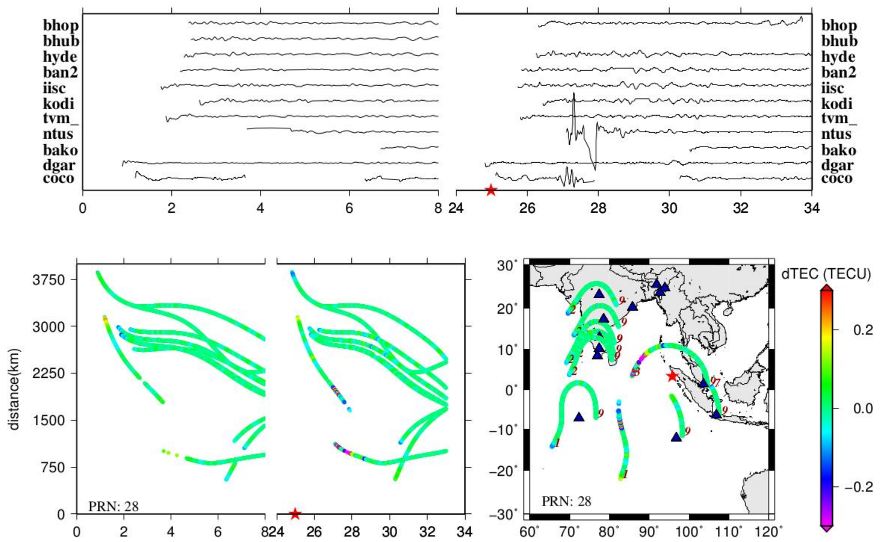


Figure 6.9 TEC perturbations(dTEC) associated with 26th December 2004 tsunami. Time series (Top) from 25th to 26th December 2004 shows the dTEC observed at stations NTUS and COCO. Distance plot (Bottom Left) gives the dTEC with respect to distance from the source of earthqauke on 25th and 26th December 2004 (X-axis is UTC time). Map (Bottom right) shows the spatial variability of dTEC at SIPs along the satellite track PRN28 on 26th December 2004. Time of observation is engraved adjacent to the satellite track in UTC. Red stars in Top and bottom left figure represents the time of the earthquake and in bottom right figure it represents epicentre of the earthquake.

We have computed IonosphericTEC and its perturbation at an interval of every 30s using signal delay derived from more than 10 GPS satellites at more than 20 Continuous mode geodetic GPS (CGPS) stations. Th CGPS stations are spread across Indian subcontinent. Computed TEC clearly indicates the regular ionopsheric spatio-temporal variations during quiet days. The animation (snapshot in the case of print version) given herewith shows the TEC at each Sub-ionospheric Point(SIP). SIP is the foot print of Ionospheric Pierce Point (IPP) where the GPS signal pierces the thin shell ionosphere. To depict the diurnal variability of ionosphere the TEC built-up over time during Day of the Year 2004 (DoY) 335 and 336 [i.e. 30th November 2004 and 1st December 2004] has animated from 05:30 IST on DoY 335 to 05:00 IST on DoY 336. Animation also shows the Sun synchronous variation of TEC.

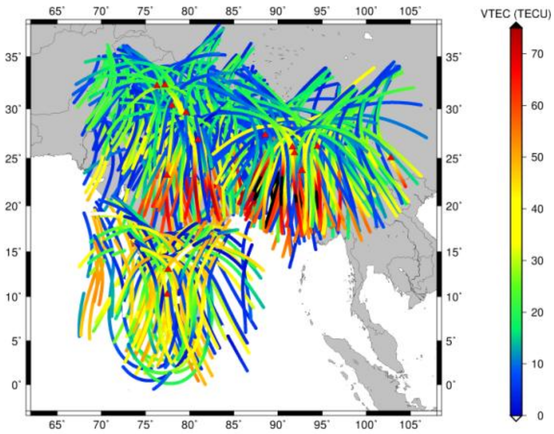


Figure 6.10 Animation shows TEC at SIPs computed using Indian geodetic GPS network from 0530 IST on DoY 335 to 0500 IST on DoY 336 in the year 2004.

TEC thus computed has been differenced and filtered using a band pass filter to remove out non tsunamigenic perturbations. Filtered dTEC is used to study the post-seismic Travelling Ionospheric Disturbances (TID) induced by the Acoustic Gravity Waves (AGW) which were generated by open ocean Tsunami (triggered by 26th December 2004 Sumatra-Andaman earthquake). Figure 6.9 shows the ionospheric TEC perturbations associated with tsunami when it travels in the open ocean at 2-3 UTC – an hour before tsunami were reached the eastern coast of India. Time series in the figure shows the TEC perturbation during a day before the earthquake and on the earthquake day. TID propagation with respect to the distance from the earthquake are also shown in the figure. Similar signatures are identified at various times before tsunami waves reached Indian coast at various Indian GPS stations. These results provide confidence on possibilities of early warning of devastating tsunamis using land based GPS observations.

MSM Vijayan, K Shimna, and Sridevi Jade

6.8 Ionodetect: A Software to Compute Ionospheric TEC Perturbations using Dual Frequency Geodetic GPS Data

A software named Ionodetect has been developed in C language to compute ionospheric TEC and its spatio-temporal perturbations using dual frequency observations from geodetic grade GPS receivers of any make. The software is capable of modelling TEC values using International Reference Ionosphere 2012 (IRI12) and compare it with TEC computed from geodetic GPS data. In addition it also computes the perturbation in TEC along the receiver track to study the ionospheric perturbations associated with various phenomena ranging from space, weather to earthquakes and tsunami.

Ionodetect uses RINEX observation and navigation files as input. It has six modules: one is flaw less reading of RINEX files, the second is computation of TEC using both code and phase, third is phase leveling, fourth is Differential Code Bias(DCB) correction, fifth is estimation of TEC perturbation, and sixth is modelling of TEC at SIPs using IRI12. It also checks the quality of RINEX observation file and then it carries out cycle slip correction by calling GPS tool box. Observables, time and date of observation will be read from the cycle slip corrected observation file.

TEC is computed using both code and phase measurements. TEC computed using L1 & L2 code is noisy and the TEC computed from L1 & L2 phase is relative and suffers from ambiguity. So it carries out phase leveling by combining both code and phase TEC values along the phase connected arc to get noise and ambiguity removed. However, the TEC value is still suffered from Differential Code Bias (DCB) of satellite and receiver. The satellite DCB is eliminated using the values estimated by IGS analysis centres and the receiver DCB is estimated and corrected using Ma and Maruyama (2003) algorithm with a slight modification. After correcting for the receiver bias the TEC values along the signal path – i.e. slant TEC is converted to Vertical TEC using the secant function at the iononspheric height h_m.

Ionodetect also estimates the ionospheric perturbations by differencing the TEC over time along the signal path. Then it removes the geometrical effect from the dTEC by calibrating it for the differential geometrical distance covered by the satellite over a period of time.

In order to compare the computed TEC, Ionodetect invokes internally the International Reference Ionosphere IRI2012 to model the TEC at each Sub-ionospheric pierce points. This will also be useful to study the performance of the model.

Ma, G., and T. Maruyama (2003), Derivation of TEC and estiamtion of instrumental biases from GEONET in Japan, Ann. Geophys., 21, 2083-2093

M S M Vijayan, Gloria Varghese# and K Shimna

#Indian Institute of Information Technology and Management – Kerala, Trivandrum

6.9 O-isotope based Palaeoprecipitaion Record from the Himalayan Foreland Basin Sediments

The Himalayan foreland basin sediments were deposited during a crucial time of Tertiary Himalayan orogeny. This period witnessed large scale uplift of the Himalayan range, a major regional tectonic event that is believed to have resulted in the present South Asian monsoonal climate. The erosion of uplifting Himalayan range supplied an increased load of sediments that are archived in the Himalayan foreland basin. These sediments are significant in revealing the palaeoclimatic history of the Asian continent that is useful in understanding the effect of orogeny on climate. Palaeoprecipitation record from the NW Himalaya since Miocene times and its regional correlation within the Himalayan mountain belt have been carried out using O-isotopes as proxy palaeo-recorders for reconstruction of palaeoclimatic history. In the Jammu region, the δ18O values vary from −12.31‰ to −5.89‰, which

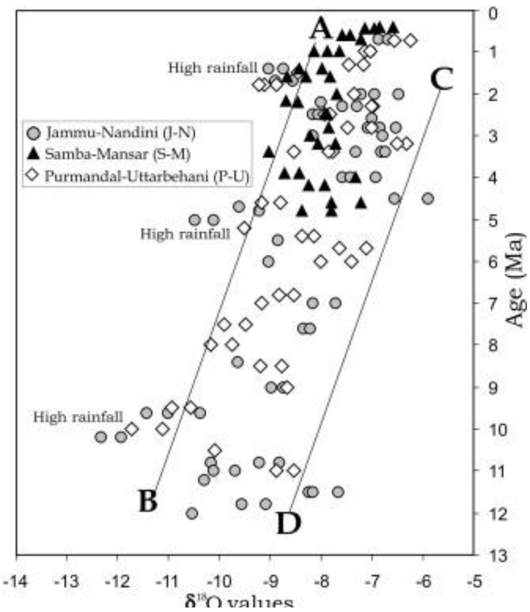


Figure 6.11 Plot of δO18 values versus geological age in Mega annum (Ma).

become ~2‰ enriched from the oldest to the youngest analyzed sediments except for largely depleted δ18O values around 10 Mega annum (Ma), 5 Ma and 1.8 Ma. This ~2‰ increase is to an approximate 3°C increase in mean annual air temperature. Conversely, largely negative δ18O values indicate periods of intense rainfall or stronger monsoonal conditions. An increase of 2.6‰ in δ18O values has been found from the 10 Ma rainfall event to that at 1.8 Ma which indicates a reduction of ~173 mm in rainfall intensity and amount during the period. Hence, precipitation reconstructions indicate a progressive increase in aridity from ~12 Ma to Recent excluding a short term increase in rainfall or monsoon intensity at around 10 Ma, 5 Ma and 1.8 Ma. The general increase in average δ18O values can be explained by changes in both continentality and latitude of the moisture source. It seems likely that this long term increase in δ18O values was due to the uplift of the Himalayas and the Tibetan Plateau in the north which acted as a barrier to the passage of air masses from Central Asia in the north, thereupon with time restricting the source of air masses to the south from the Indian Ocean.

S Singh, B Parkash*, A K Awasthi* and T Singh*
*Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee.

6.10 The Sub-Himalayan Fold-Thrust Belt in the 1905-Kangra Earthquake Zone: A Critical Taper Model Perspective for Seismic Hazard Analysis

The broader epicentral area of the M=7.8, 1905 Kangra earthquake(s), North India, affecting the Sub-Himalayan hills is characterised by two major rentrants (Kangra and Dehradun) interposed by the Nahan Salient. The first order topography between the main bounding thrust faults i.e. Himalayan Frontal Thrust and the Main Boundary Thrust show marked lateral variation in the mean gradient, characterised by a very small mean slope angle (ca. 1°) in correspondence with the reentrants and higher values (ca. 3°) in the salient. These large scale tectonic and topographic features show consistent correspondence with the peculiar macroseismic field of the 1905 event(s), which is characterised by two distinct intensity maxima, separated by a distance of about 150 km, clearly overlapping the two major tectonic reentrants. What still remains uncertain is whether both rupture areas represent two distinct and independent faults that were reactivated almost contemporing likely due to a dynamic stress transfer and triggering effect or a unique continuous shear zone characterized by two major patches of co-seismic slip interposed by a large and strong barrier.

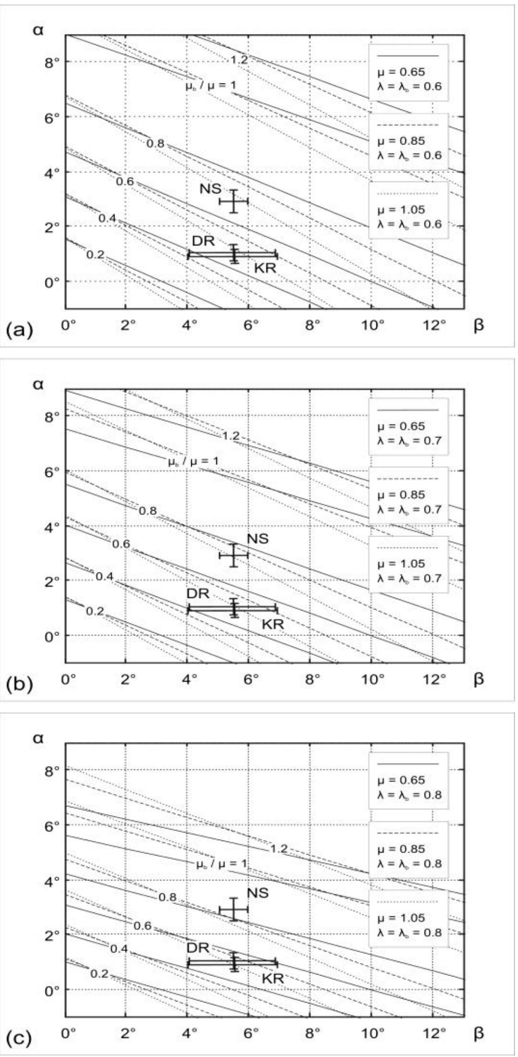


Figure 6.12 Different sets of critical taper conditions represented as α versus β and under different values of λ, μ and μ_b. For each plot, the group of curves depend on μ/μ_b ratio (tested from 0.2-1.2).

Based on geological and geophysical information and mechanical constraints, it is possible to suggest different seismotectonic scenarios and constraints for improving the seismic hazard assessment. The seismogenic volume of the external sector is investigated in terms of critical taper model to clarify the possible correlations between tectonics, topography and seismicity in the Sub-Himalayan belt. Numerous values of a versus b have been calculated by systematically varying the principal parameters (m: internal friction of the wedge; mb: friction along the basal detachment; l: ratio between pore fluid pressure and vertical stress component within the wedge; lb: ratio between pore fluid pressure and vertical stress component within the basal detachment shear zone).

$$\alpha = \frac{(1-\lambda_b)\cdot\mu_b - (1-\lambda)\cdot K\cdot\beta}{1+(1-\lambda)\cdot K}$$

where K is approximated as follows, considering φ = atan(μ)

$$K = \frac{\sin(\varphi)}{1-\sin(\varphi)} + \frac{\sin^2(\varphi_b)+\cos(\varphi_b)\cdot\sqrt{\sin^2(\varphi)-\sin^2(\varphi_b)}}{\cos^2(\varphi_b)+\cos(\varphi_b)\cdot\sqrt{\sin^2(\varphi)-\sin^2(\varphi_b)}}.$$

Three possible seismotectonic scenarios are explored in order to constrain their likelihood and nature of future seismicity. The investigations suggest a potential seismic gap in the area corresponding to the Nahan Salient, which may experience in the future an event of significant magnitude.

Tejpal Singh, A K Awasthi and R Caputo#
*Department of Earth Sciences, Indian Institute of Technology Roorkee
#Department of Earth Sciences, University of Ferrara, Ferrara.

6.11 Estimation of seismic hazard and risks for Himalayas and surrounding regions based on Unified Scaling Law for Earthquakes

To estimate seismic hazard the basic law of seismicity, the Gutenberg-Richter recurrence relation, is applied in a modified form involving a spatial term: $\log N(M,L) = A - B\,(M-5) + C \log L$, where $N(M,L)$ is the expected annual number of earthquakes of a certain magnitude M within an area of linear size L. The parameters A, B, and C of this Unified Scaling Law for Earthquakes (USLE) in Himalayas and surrounding regions have been studied on the basis of a variable space and time scale approach. The observed temporal variability of the A, B, C coefficients indicates significant changes of seismic activity at the time scales of a few decades. At global scale, the value of A ranges mainly between -1.0 to 0.5, which determines the average rate of earthquakes that accordingly differs by a factor of 30 or more. The values of B concentrates around 0.9 ranging from under 0.6 to above 1.1, while the fractal dimension of the local seismic prone setting, C, changes from 0.5 to 1.4 and more. For Himalayan region, the values of A, B and C have been estimated mainly ranging from -1.6 to -1.0, from 0.8 to 1.3, and from 1.0 to 1.4, respectively. We have used the deterministic approach to map the local value of the expected peak ground acceleration (PGA) from the USLE estimated maximum magnitude or, if reliable estimates are not possible, we got in from the observed maximum magnitude during 1900-2012 (Figure 6.13). In result, the seismic hazard map of Himalayas with spatially distributed PGA was prepared. Further an attempt is made to generate a series of the earthquake risk maps of the region based on the population density exposed to the seismic hazard.

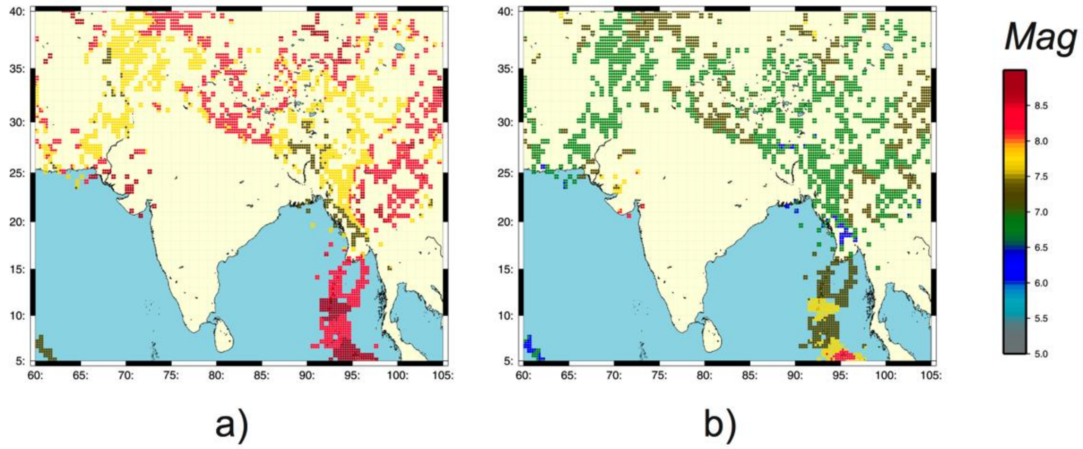


Figure 6.13 The expected maximum magnitude M with probability of exceedance in 50 years 1% (a) and 10% (b) (based on the USGS/NEIC Global Hypocenters Database System, 1965- 2011).

Further an attempt is made to generate a series of the earthquake risk maps of the region based on the population density exposed to the seismic hazard. There are many risks generated by earthquakes. These should not be ignored in any realistic and responsible seismic risk evaluation and knowledgeable disaster prevention. Our study attempts to contribute modestly to an urgent revision of the seismic hazard maps from the first principles, including (i) background methodologies and (ii) implementation in assessment of seismic risks.

(Anastasia Nekrasova, Imtiyaz A Parvez and Vladimir Kossobokov*)*
**Institute of Earthquake Prediction Theory & Mathematical Geophysics, RAS, Moscow, RussianFederation*.

6.12 New approaches for seismic hazard studies in the Indian subcontinent

Earthquakes constitute among the most feared natural hazards and these occur with no warning, which can result in great destruction and loss of lives, particularly in developing countries. One way to mitigate the destructive impact of such earthquakes is to conduct a seismic hazard assessment and take remedial measures. This article aims at demonstrating significant contributions in the field of seismic zonation and microzonation studies in the Indian subcontinent. The Indian subcontinent is one of the most seismically prone areas in the world. The recent earthquakes in the Indian subcontinent have demonstrated that nearly 56% of the region falls in Seismic Zones V, IV and even III and most of the existing structures are highly vulnerable to seismic threat. Seismic hazard and risk assessment is a complex and evolving procedure that involves inputs from different disciplines of earth sciences. It is also very important to see the effect of local soil conditions, particularly for megacities and large urban areas, as it has been observed from many earthquake scenarios, the major damage to the buildings and man made structures is mostly found in the area of soft sediments. The constructive interference of incoming waves due to the effect of 2D or 3D geological structure produce very strong ground motions and that needs the inputs from the disciplines of geology, geophysics, seismology, geotechnical engineering and engineering seismology. A meaningful microzonation can, therefore, be achieved only through a multidisciplinary approach. This pre-disaster mitigation effort can attain its desired objectives if the scientific findings percolate down to the societal and user levels for the benefit of the community. The mapping of the predominant frequency of resonance and corresponding amplifications permits identification of zones at risk. It can be used as a tool for prevention planning and retrofitting measures and also to define safety zones for reconstruction after a destructive earthquake. The historical seismicity and seismic zonation studies as well as the present scenario of seismic hazard assessment in the Indian subcontinent, whether through probabilistic or deterministic approaches, are discussed. It has been found that many parts of the Himalayan region have peak acceleration values exceeding 0.6g. The epicentral areas of the great Assam earthquakes of 1897 and 1950 in northeast India represent the maximum hazard with acceleration values reaching 1.2–1.3 g. The peak velocity and displacement in the same region is estimated as 120–177 cm/s and 60–90 cm, respectively. These results can be used as a preventive definition of the seismic hazard without waiting for the great earthquake to occur. Furthermore, such multidisciplinary approach may help to those earthquake and civil engineers who wish to undertake comprehensive and detailed studies of earthquake hazard. To mitigate seismic risk, it is necessary to define a correct response in terms of both peak ground acceleration and spectral amplification. These factors are highly dependent on local soil conditions and on the source characteristics of the expected earthquakes. This article also presents the findings of site-specific hazard assessment in megacities. The contributions in the field of earthquake hazard have been very valuable and beneficial not only for science but also for society. It can also be used reliably to formulate the building codes with a great impact on the effective reduction of their seismic vulnerability. The deliverable of this article may civil engineers to make to site-specific design spectra based on average or maximum amplification and implementing in revising the building codes.

Imtiyaz A Parvez

6.13 Recognition of Earthquake-Prone Areas in the Himalaya: Validity of the Results

Accurate definition of potential earthquake sources plays a main role on the development of seismic hazard assessment regardless of the applied methodology, either probabilistic or deterministic. In this project, we analyze the earlier results carried out in identification of earthquake-prone areas in the Himalaya. Number of seismogenic nodes prone to M6.5+ has been defined in the region using pattern recognition approach. This methodology is based on the idea that large earthquakes correlate with morphostructural nodes, specific structures formed at the intersections of fault zones. The fact that earthquakes nucleate at nodes was first established for the Pamirs and Tien Shan regions.The role of intersecting faults in the control of earthquake origin was later observed in different tectonic settings by other researchers.

After 1992 four earthquakes M6.5+ occurred in the Himalaya. Figure 6.14 shows locations of the events. We studied the parameters of these events and their correlation with nodes and found that the high seismic potential of node no. 5, where the 2005 Muzaffarabad earthquake took place, was estimated by pattern recognition more adequately as compared with the GSHAP data. Seismic potential of the area of the 2005 Muzzafarabad earthquake is underestimated by the probabilistic GSHAP approach.

We included in the analysis the 1991 Uttarkashi earthquake as this event was not used at the learning stage of recognition. The Uttarkashi earthquake occurred at node no. 24 where earthquakes of target magnitudes were unknown during pattern recognition. The 1999 Chamoli

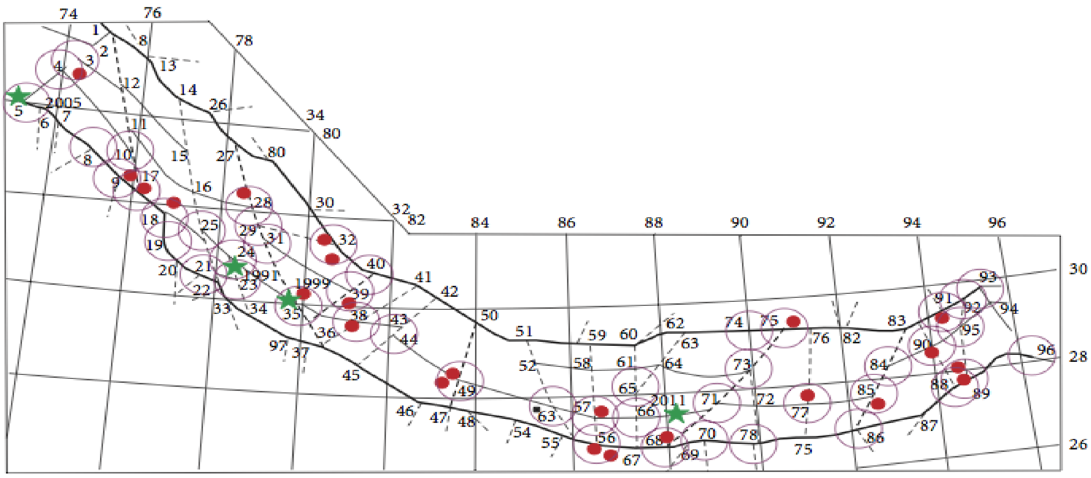


Figure 6.14 Himalaya: MZ map, seismogenic nodes for M6.5+, and post-publication earthquakes M6.5+.

earthquake occurred at the recognized nodes no. 35 that was used at the learning stage of pattern recognition. The devastating 2005 Muzzafarabad earthquake correlates at no. 5. The 2011 Sikkim earthquake occurred between two nodes no. 66 and no. 71 at the distance of 70 km from node no. 66. The epicenter of this event clearly correlates with the second rank lineament. Finally, the performed analysis shows that three out of four post publication earthquakes confirm the results of recognition obtained earlier. Therefore, we can conclude that the pattern recognition approach applied for earthquake prone areas identification provides sufficiently reliable information to be used for seismic hazard research.

A Gorshkov*, Imtiyaz A Parvez and O. Novikova*

**Institute of Earthquake Prediction Theory & Mathematical Geophysics, RAS, Moscow, Russian Federation.*

6.14 Estimation of input parameter in Peninsular India for Earthquake Hazard Analysis.

Peninsular India, normally considered as a stable continental part of the Indian subcontinent, has witnessed several damaging earthquakes of magnitude greater than 6.0 in last couple of decades. Thus, it becomes important to quantify the peninsula Hazard for future events in terms of possible ground shaking. Seismic parameters (a, b) has been estimated for the peninsular India and various seismic source zone in order to setup model parameters for hazard assessment of the region. Indian Peninsular Catalog has been generated with earthquakes information from various sources including USGS, ISC, IMD, ISS etc. and historic catalog. After collection of the earthquake data from various sources, pre and aftershocks has been removed from the catalog as earthquake assumes to be occurred independently. “Cluster 2000” program, from USGS, used to remove time-dependent events from the earthquake catalog. The procedure recognize cluster in space and time window after each main shock. Regression analysis has been made on Harvard CMT data to establish various magnitude conversion relations and all magnitude converted to Moment magnitude (Mw) for the peninsular Indian catalog.

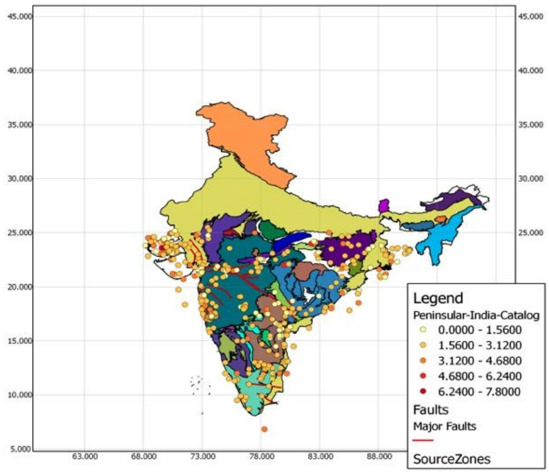


Figure 6.15 Geological and Major Faults map of India (Seismo-tectonic Atlas of GSI 2000, Geological Map GSI). Map also showing distribution of earthquake from peninsular India catalog (Circles) and color of the circles represent earthquake magnitude.

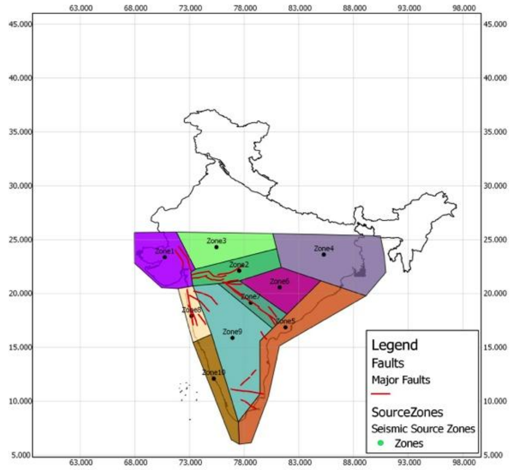


Figure 6.16 Ten Seismogenic zones defined based on the geology, major and active faults and earthquake distribution and their mechanism in peninsular India.

Peninsular India has quite a number of faults systems with relatively low seismic activity associated with them as compared to Himalayan tectonic region, as it is a stable continental region. For Probabilistic Seismic Hazard Analysis (PSHA), it is necessary to delineates spatial regions of the seismic zones based on geology, faults and earthquake occurrences. A map of Geology, Faults and epicenters of earthquake is shown in Figure 6.15. Peninsular India has been divided into ten Seismogenic Zones based on faults system. Earthquake occurrences and geology of the region (Figure 6.16). The seismic activity of a region or source zone is characterized by the Gutenberg-Richter (G-R) recurrence relation

$$\log_{10} N(m) = a - bm \quad (1)$$

Where, N(m) is the number of earthquakes greater than or equal to magnitude m that are expected to occur during a specified period of time. '*a*' is the log of the number of earthquake of magnitude zero or greater expected to occur during the same time. '*b*' is the slope of the curve which characterizes the proportion large earthquake relative to small earthquakes.

The seismic parameters, (*a,b*) in equation (1), first estimated for complete peninsular catalog for the period (1800-2011) and (1960-2011). In both the cases *b* values is very low 0.69 and 0.77 respectively. Then we divided the catalog into sets for Gujarat region and Peninsular India. The regression results now show a very stable *b* value for peninsular India close to one for both periods ie (1800-2011) and (1960-2011). On the other hand, source zone 1 still shows very low *b*value in Gujarat region. Source zone of Gujarat region has different tectonic setting (Close to transform boundary) as compared to the rest of the peninsula, so the region needs to be treated separately from peninsular India and thus the catalog has been analyzed separately for Gujarat and Peninsular India. Comparative seismic parameter (*a,b*) values have been estimated. Even the *b* value for peninsular India is approximately same for both the periods (1800-2011; 1960-2011) but considering the large uncertainties in the location and magnitude for pre instrumental/ historical data set, we limited our analysis on regression only for the period of 1960 onwards.

6.15 High resolution velocity model of India towards generating the Neo- Deterministic Seismic Hazard Map of India

In the Indian subcontinent, Himalayan belt is one of the most active regions in the world with a record of several great earthquakes in last two centuries. The region still possesses the potential for great earthquake, which threatens the millions of lives. In order to minimize the economic and human lives loss from great earthquakes requires a constant analysis of seismic hazard after certain time interval in a changing scenario. First Deterministic hazard map for the India has been published almost a decade ago in 2003. Last decade has seen a rapid increase in seismological activities, which has provided more detailed and denser information of subsurface structures. Now, there is a need to include all the high-resolution structural models, focal mechanism and earthquake catalog.

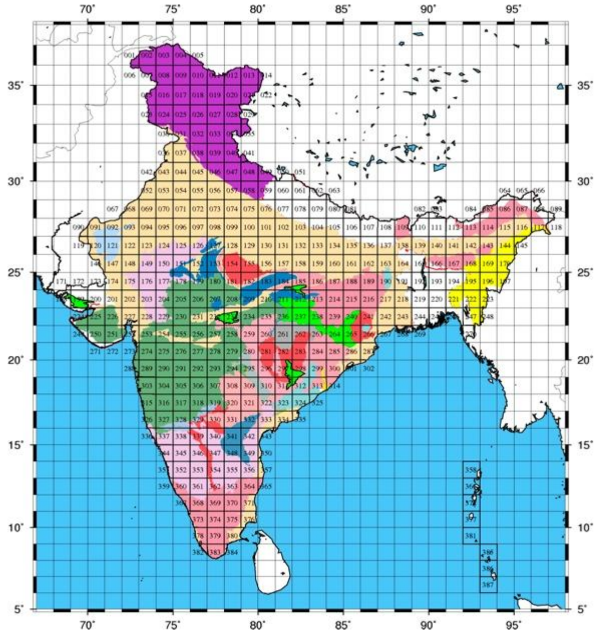


Figure 6.17 India Map showing geology of India (Geological Map of India, GSI) and 1x1 degree velocity cell marked with number of cell.

In order to revise hazard map, first a high-resolution velocity map is required which require compilation of shear velocity data available from different sources and studies. The Indian subcontinent region is divided into 1x1 degree cells and constitutes of 387 cells, which include subcontinent region Nepal, Bangladesh, Bhutan and Andaman & Nicobar Islands. Most of the cells have square shape except at the edges, which were terminated at political boundaries (see figure 6.17). All Velocity data were collected from broadband studies, DSS studies and surface wave data. For each cell two files were generated for shape (por files) and velocity (stp files), which contain P wave velocity, S wave velocity, density, layer thickness, Qp and Qs for the structure. Southern Indian region is fairly well covered by receiver functions experiments while some regions have poor coverage or no coverage at all. Velocity models were averaged out for the cells where more than one result was available. Cells with no coverage has been assigned the velocity copying or averaging the velocity models from adjacent cells based on the geology of the region and remaining cells assigned from the previous study Figure 6.18 is showing map with details of velocity cells and their sources. Black

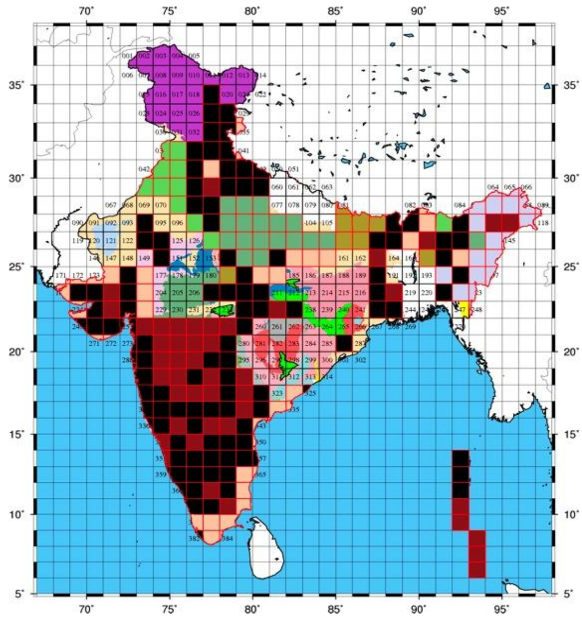


Figure 6.18 Map showing geology of India (Geological Map India, GSI) and velocity cells. Colors filled cells represent velocity models has been assigned from various studies Receiver function, Surface wave and DSS.

cells represents velocity models taken from receiver function or DSS study, red represent average velocity model from adjacent cells, flash color represent copied velocity model from adjacent cells. There are some groups of cells assigned with similar color represents one velocity model assigned to a region obtained from VELEST or surface wave study. All velocity models have been tested for accuracy and consistency in the modeling program.

Imtiyaz A Parvez and Ashish

6.16 CDP imaging of Dharwar Region for Phase I and completion of phase II of BB experiment.

An array of broadband & short period seismographs were established during April 2010 till December 2011 in Dharwar craton across the east-west corridor in phase I. During Jan-Mar 2012, profile was extended in both NE and SW direction in Phase 2 of the experiment with addition of six more stations. Two additional stations (GRH and BRS) have been planned to install middle of the phase - I profile during July-Aug 2012 in order to increase the resolution near the possible contact between east and west Dharwar. Some of the stations have been shifted from phase – I to new locations except KDB, which is the base station of the array. NE extension of profile receive REFTEK 130 data logger with Lennartz 5s sensors. Details of stations are presented in table 1. The experiment was successfully completed in March 2013 and all stations were lifted from the field.

Table 6.1 List of seismic stations operated under East-West Dharwar BB profile in Phase – I & II.

Station Name	Station Code	Lattitude (N)	Longitude (E)	Altitude (m)
Agarhara	AGH	13.5129	77.2198	715
Kaidala	KDL	13.3022	77.0792	770
Kadaba	KDB	13.2483	76.8592	780
Aldahalli	ALD	13.1415	76.3502	849
M. Hirihalli	MHR	12.8891	76.1953	850
Honaseanally	HNS	13.7466	77.5306	674
Timmamidipally	TMP	13.9060	77.7332	663
OD Cheveru	ODC	14.0228	77.9867	605
Vemulagondi	VMG	14.2637	78.3913	375
Girenhally	GRH	13.2889	76.7572	781
Beersandra	BRS	13.2956	76.6639	763
Sampaji	SMP	12.4958	75.5761	651
TalaKaveri	TLK	12.3854	75.4934	1255
Gorur	GRR	12.8270	76.0620	792
Chennarayapatanam	CRP	13.0210	76.3230	824
Tiptur	TPT	13.2740	76.5360	785
Kibannahalli	KBC	13.3290	76.6890	763
Nittur	NTR	13.3470	76.8860	712
Tumkur	TMK	13.3430	77.1940	842
Gauribidnur	GBA	13.5640	77.3570	681

Earthquake waveform data (recorded at 100 sps) is archived regularly. Teleseismic earthquake waveforms were extracted based on USGS earthquake catalog from data archive and converted to SAC format. Receiver function is calculated by using time domain iterative deconvolution for all distant earthquakes recorded. A receiver function represents the time delay between direct P and P to S converted phase from an interface and time delay corresponds to the depth of the interface.

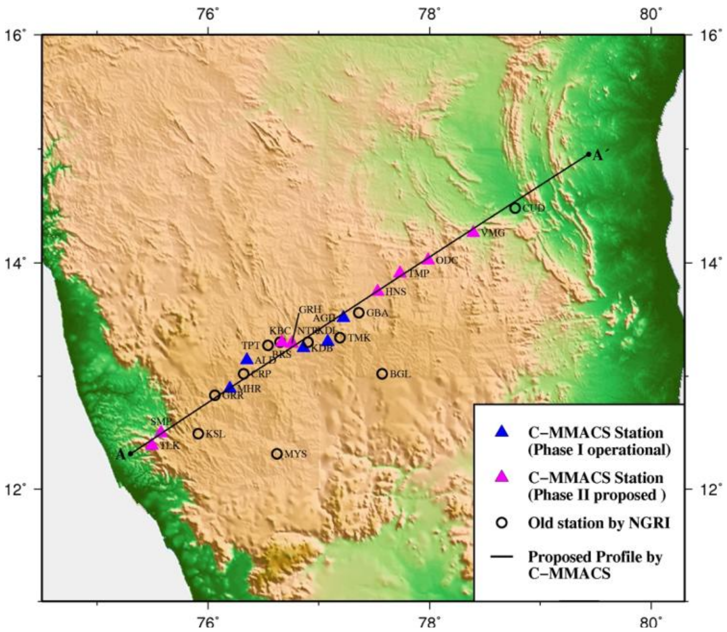


Figure 6.19 Regional map of South India showing C-MMACS stations location of Phase I (blue triangle), NGRI stations (circle black) and location of station for Phase II (red triangle).

Receiver functions from stations deployed in Phase I (see Figure 6.19) and operated by NGRI have been used to image the crust and upper mantle using common conversion point (CCP) time to depth migration of radial receiver functions. Now, a complete image of east-west profile is expected to come which will include data from all stations from phase – I, II and stations operated by NGRI near the profile. Phase I results suggest a possible contact between east & west Dharwar lies somewhere between KBS and KDB. Phase II has boost the resolution between these two station by addition two more broadband stations approx ~ 5 km apart.

Ashish and Imtiyaz A Parvez

6.17 Seismic Broadband Experiment in Kashmir Himalayas.

Being bestowed with the nature's appealing beauty and enough resource of fresh water and fertile soils, the Kashmir Himalayas has also experienced lot of loss in terms of lives and property due to devastating earthquakes which have occurred in the valley (1123,1735,1885,1555 etc.) and nearby seismically active regions. Despite the fact that Kashmir has written history of ~5000 years but the historical texts don't have single scientific account of earthquakes until 1885 Kashmir earthquake, which was extensively studied by E.A.Jones. So there is a need to set a seismic experiment, which can generate the 3D subsurface images of the valley and will tell tantalizing story of the faults active in the region.

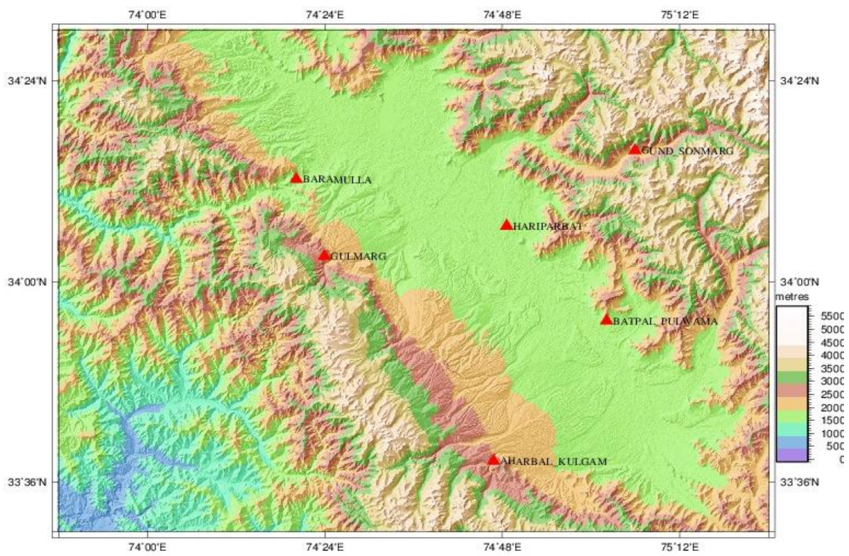


Figure 6.20 Geographical location of Kashmir Himalaya and the sites where Broadband stations have been installed.

We have designed an experiment to deploy ~ 35 Broadband seismic stations covering the entire Jammu and Kashmir in collaboration with Kashmir University, NGRI, IISER Kolkata and Shri Mata Vaishno Devi University. In the first phase of the experiment, we have successfully installed five Seismic Broadband stations in the Kashmir valley (figure 6.20). The Gund Sonmarg site (red triangle in the upper right corner) is ready with construction and will be instrumented soon. The instruments installed are Guralp 3TD seismometers with Guralp Digital Communication Modules (DCM or data loggers) with a storage of 40 /80 GB (USB flash drive). The instruments lie instandard velocity output band of 120 sec-50 Hz, output sensitivity of 1500 V/ms^{-1} and are having a peak output of +- 10 V differential.

Figure 6.21 The housing of broadband instruments and installation of equipments

All these stations are located with a possibility of housing the GPS instrument as well to study the crustal deformation. The instruments (figure 6.21), which are currently active in the first phase, will record the earthquakes arriving from any part of the globe. This knowledge when available will provide insights into the geometry of fundamental structures that support the shallower layer of brittle rocks where earthquakes occur. Additional detailed seismic investigations related to seismic tomography, source modeling, crustal deformation, active fault mapping and finally earthquake hazard in the valley can be considered. Meanwhile the data generated can be used for other studies like Microzonation and earthquake risk, which will further guide in the formulation of site specific land use plans.

Imtiyaz A Parvez, Ramees Mir, Ashish and V K Gaur

6.18 Crustal Structure of Leh And Hanle - Using Receiver-Function Analysis and Joint Inversion of Body and Surface Seismic Waves

Seismic Tomography is an imaging technique that uses the information carried by reconnoitering earthquake waves arriving at the surface, to create computer generated, three-dimensional images of the Earth's interior. The location of the Kashmir valley over the subducting Indian plate is a major reason for earthquakes occurring here in the past and near future. Earlier earthquakes like earthquake of 1555, which continued for seven days have done lot damage to both lives and property. Similarly 1885 earthquake claimed about 3000 deaths with a great loss of cattle and huge damage to property. Also the earthquake which occurred on 8 October 2005 about 75 miles west north west of Srinagar near the city of Muzaffarabad in Pakistan occupied Kashmir, it's epicentre was 16.2 miles deep, Lives claimed were >80,000 and the magnitude as recorded by USGS was Mw 7.6. Population of Kashmir in 1873 was 492000 (NYT 1885) and considering that at the time of 1885 earthquake the population was same then it had wiped 0.61% of the population (3000 deaths).

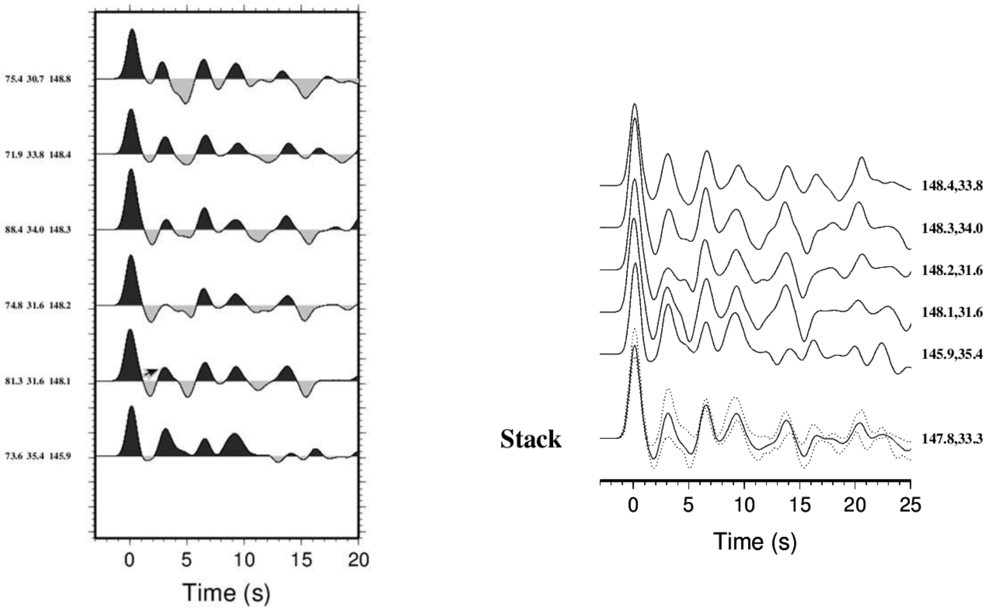


Figure 6.22 Receiver functions and their stacking from the Hanle station with epicentral distance.

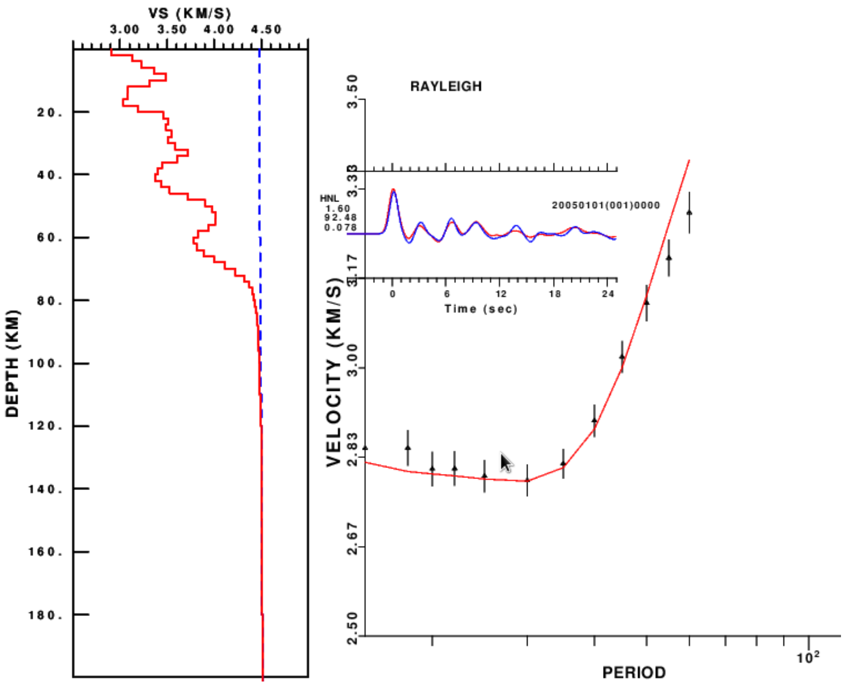


Figure 6.23 Hanle station inversion results and fundamental mode Rayleigh phase wave velocity.

Receiver function analysis is a fundamental tool which helps us to image subsurface of earth and develop high resolution crustal images similar to CATSCAN- now a widely tool in medical imaging. We have used the teleseismic broadband seismic data to compute the receiver function at Leh and Hanle seismic stations. Before generating receiver functions we have removed the long period noise by cutting the seismogram 20 sec prior to its beginning and 40 sec after its beginning time. In order to extract converted phases of shear wave that is SV and SH waves, the NS and EW seismograms are rotated to Radial and Transverse components using rotation matrices. Then teleseismic radial receiver functions for all the magnitudes greater than 5.5 events lying within an epicentral range of 30-100 degrees using the iterative time domain deconvolution method were generated . We then binned the receiver functions in respect of stations that were sufficiently close to each other and shared a more or less common the path of travel to the receiver. These receiver functions were then stacked to improve the signal to noise ratio. The shear wave velocity structure beneath the stations were calculated using receiver function analysis and joint inversion method. Figure 6.22 shows the receiver functions calculated from the Hanle station with epicentral distance of 30 to 100 degrees (shown in left panel) and the right panel shows the stacking of these receiver functions to increase the signal to noise ratio. Figure 6.23 shows the shear wave velocity structure beneath the station having Moho at ~80 km. Blue line shows initial reference model (here PREM) and red line the current updated model. Right figure shows the change of the Rayleigh wave velocity with respect to period (1/frequency). Inset red receiver function (RF) indicates average observed RF and blue is average model generated RF. As seen both model generated and observed RF's have superior goodness of fit.

Ramees Mir and Imtiyaz A Parvez

6.19 Charaterization of source parameters and some empirical relation between them for Kachchh region, India: Implication of Jan 26, 2001 Bhuj earthquake and its aftershock sequences.

Earthquake Hazard analysis involved with seismic activity is based on the estimation of the future earthquake potential in a given region. The future earthquake potential of a fault commonly is evaluated from estimates of fault rupture parameters. Source parameters of light to moderate and large earthquakes are important for understanding the differences and similarities between dynamic ruptures of small and large earthquakes and clarifying the scaling relations. The purpose of this study is to present new and revised empirical relationships between various source parameters to describe the empirical database used to develop these relationships and to draw first-order conclusions regarding the trends in the relationships. We studied total 195 aftershocks of magnitude more than 4.0 for aftershock sequence of Jan 26, 2001 Bhuj earthquake (figure 6.24). The data include shallow-focus (hypo central depth less than 40 km), continental intraplate earthquakes from Jan 26, 2001 to Dec 31, 2010 recorded by different seismological observatories of India Meteorological Department. We adopted the spectral technique for source parameters estimation, where S-wave displacement spectrum is considered. We applied FFT-Fast Fourier Transform to compute displacement spectrum. We follow the Brune source model for our estimation and computed s-phase displacement spectra considering the geometrical spreading and inelastic attenuation. The estimated values of source parameters shows close approximate to the global values. We estimate source parameters and in turn derived some empirical relations between different source parameters. They exhibit direct or inverse proportion to linear or power scale.

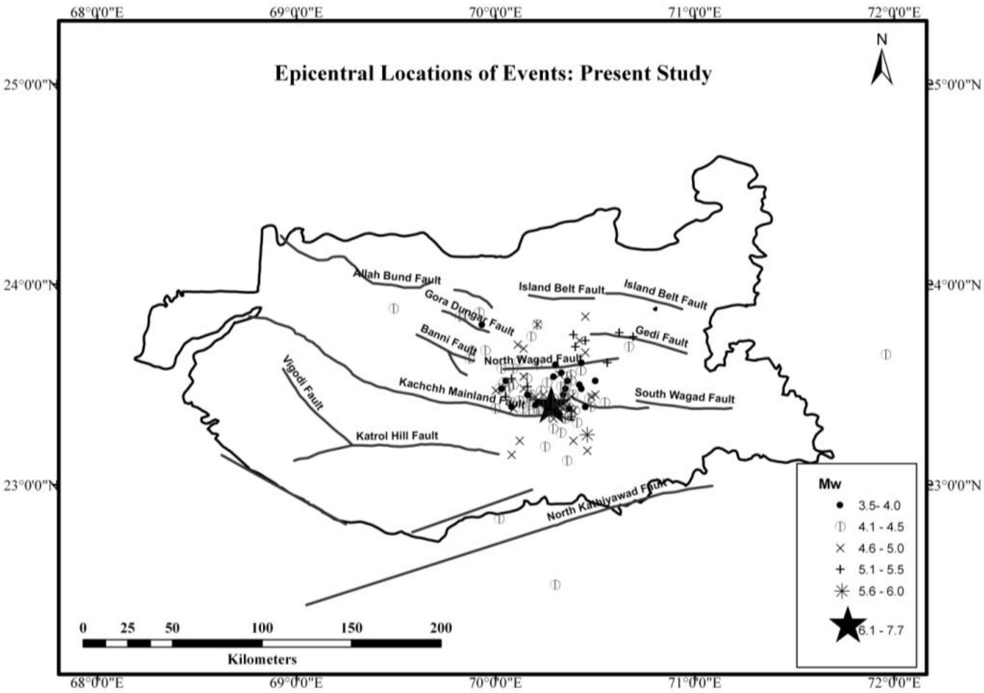


Figure 6.24 Epicentral locations of seismic events (*Mw*≥3.5) for the present study.

Interrelation between moment magnitude, seismic moment, rupture parameters, corner frequency and radiated energy can be summarized as $Mw \propto f_c^{-0.17}$ and $M_0 \propto f_c^{-2.98}$, $A \propto f_c^{-1.98}$, $R \propto f_c^{-0..99}$, $Mw=0.59\log M_0-4.9$, $M_0 \propto A^{1.5}$and $M_0 \propto R^{2.99}$. While for radiated energy we found $E_R=2x10^{-5} M_0+3x10^{11}$ and log $E_{R=}1.2\ M_{w+}6.4$. Stress drop distribution over the region is very scattered and due to its peculiar behavior it is difficult to derive empirical relation with other source parameters. We also derive apparent stress drop and scaled energy for our analysis. Sufficient accuracy on measuring source parameters like stress drop, rupture dimensions, radiated energy etc. helps to understand earthquake processes. It has considerable implications for studies of earthquake rupture physics and seismic hazards for large earthquakes.

Parul C Trivedi and Imtiyaz A Parvez

6.20 Effect of rotation, magnetic field and initial stress on propagation of plane waves in transversely isotropic dissipative half space

The present study is concerned with the propagation of plane waves in transversely isotropic dissipative half space with certain condition such as effect of rotation, magnetic field and initial stresses. The equations of motion from Biot's theory are solved for propagation of harmonic plane waves. The derived expression of reflection coefficients and energy ratios are obtained for incidence of qP and qSV waves. Reflection coefficient and energy shares of each reflected qP and qSV waves are studied for the incidence of an incidence qP or qSV wave at the free plane boundary of the dissipative elastic medium. This is required to ensure the conservation of incident energy at the boundary.

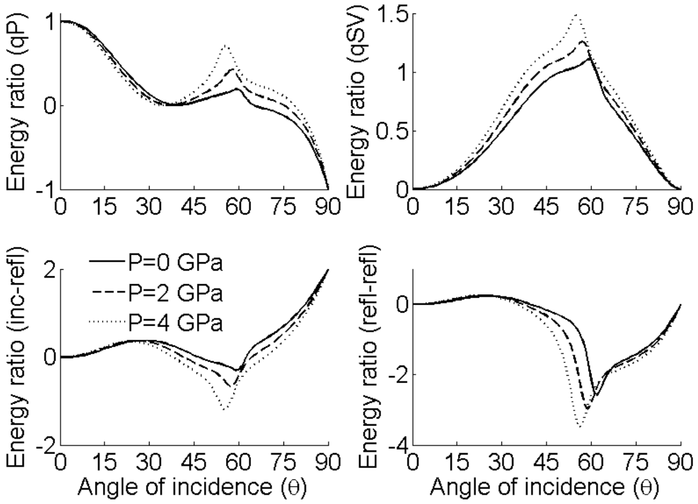


Figure 6.25 Energy shares of reflected (qP and qSV) waves, incident and reflected waves interaction and interaction among reflected waves, variations with the incident angle (θ) and initial stress (P) for incident (qP) wave.

For copper alloy material, reflection coefficients and energy ratios are computed and presented graphically with angle of incidence for different values of initial stress and rotation parameter in presence of magnetic field (figure 6.25). From the graphical representation it is observed that the presence of initial stresses, rotation parameter and magnetic field affect significantly to reflection coefficients and energy ratios.

Sushant Shekhar and Imtiyaz A Parvez

7

CSIR-800 COORDINATION CENTRE

The 12 months from April 2012-March 2013 was a period of consolidation of resources and infrastructure for the CSIR-800 Coordination Center. Simultaneously we focused efforts in program implementation, gave the program visibility, coordinated field visits, and created infrastructure.

Program implementation

Program implementation occurred on several fronts:

1. Finalizing approaches in Needs Assessment surveys to determine relevant technology solutions addressing actual issues in a TECHVIL;
2. Assembling a team of resource scientists to provide back-stopping support for TECHVILS;
3. Recruiting consultants to coordinate efforts in the needs assessment surveys, corporate out-reach, technology advisories, GIS mapping, and coordination on TECHVIL activities;
4. Submitting the Detailed Project Report for village-level implementation using allocated CSIR-800 funds; and
5. Occupying the CSIR-800 Coordination Centre.

1. Needs Assessment Survey Workshop, Consultancy Development Centre, Delhi, Dec 2012

A one day interactive session on CSIR-800 needs assessment survey was held at CDC office, New Delhi on 10th December 2012. Experts from CSIR, CDC, Tata Institute o Social Sciences, and Delhi School of Economics along with representatives from MART (a social marketing outfit), and Indicus Analytics were invited for an interactive session facilitated by CDC. The main outcome of the interactive session is the guidelines to take the needs assessment survey forward.

2. Resources Meeting, Dec 2012

Resource persons of CSIR-800 were called in for a one day workshop on 14th December 2012. This workshop was held in the CMMACS conference hall. A brief about various aspects and issues related to taking CSIR-800 program forward were discussed. Guidelines for engaging NGO's were discussed and a way forward charted out. The CSIR-800 website was previewed in the workshop.

3. Recruitment of consultants, Jan 2013

Shortlisted candidates for 5 consultancy positions were called for interviews in January 2013 in response to advertisements in national and local dailies. The consultants have joined and are working in the areas of needs assessment surveys, GIS mapping, technology advisories, corporate interaction, and coordinating TECHVIL logistics. This is in addition to the two management consultants who are backstopping program requirements from CSIR-HQ, New Delhi.

4. *DPR effort, Feb 2013*

A Detailed Project Report (DPR) was drafted for the CSIR-800 program. The DPR was framed covering various aspects – technology solutions for the problems of the target beneficiaries, program strategy, legal framework of operations, project impact on the environment, management arrangements, project time-frame and Budget details.

5. *CSIR-800 Coordination Centre, Feb 2013*

DG- CSIR allocated the CSIR-800 program its own precincts in the former CSIR-CFTRI guest house at the National Aerospace Laboratories, Kodihalli campus. The program earlier operating from C-MMACS moved to the CSIR-800 Coordination Centre on 4th February 2013.

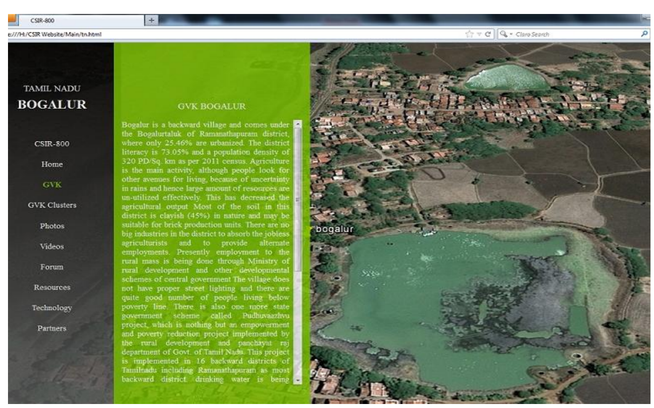
Program Visibility

Program visibility was through:

(i) Providing CSIR TECHVIL directors a platform to inform NGOs, MSMEs and other partners on CSIR-800 technologies;
(ii) Invite feedback on a beta version of the CSIR-800 website;
(iii) Responses to queries raised by Members of Parliament on the program; and
(iv) Public lectures to corporate bodies on opportunities for CSR actions.

1. *CSIR-800 Workshop at CSIR 70th anniversary celebrations, Sept 2012*

As a part of CSIR 70th anniversary celebrations, a one day workshop was organized at IGIB, Delhi. The workshop was inaugurated by DG, CSIR with Dr Sam Pitroda and Samir Mehta from the National Innovation Council speaking at the inauguration. This was followed by success stories of NGOs and corporate. In the second half of the workshop, a panel of CSIR directors responded to questions from the audience on the dimensions of the CSIR-800 program.



2. *CSIR-800 Website, Dec 2012*

In line with DG's wish to involve students in all aspects of the CSIR-800 program, the CSIR-800 team designed a new web site and invited SASTRA University Thanjavur to send a student to further develop the backend. Shri Santhana Krishnan, an undergraduate engineer, spent 2 weeks creating the algorithms for the website.

3. *Answering Short notice Parliament Questions, Mar 2013*

   Long-term on-going programs may attract parliamentary attention. Interestingly, the CSIR-800 program is informing even before its formal launch on the experience CSIR scientists have of working in the villages. As CSIR has a long and successful track record of societal outreach, such queries allowed CSIR to also showcase its earlier successes in the area that formed the bases for formulating the CSIR-800 program.

4. *Public interactions to inform potential partners the opportunities in the CSIR-800 Program*

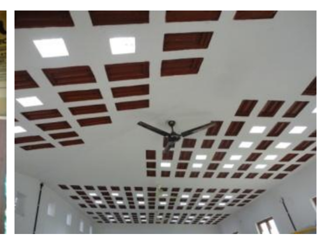
   Personal pitches form an important means of bringing in partners to augment CSIR-800 efforts. Talks at business platforms open corporate CSR programs to complementing CSIR-800 efforts. The first of these talks from the Coordination Centre (delivered by Dr E Desa) was at the Annual CII meeting of Goa Chapter in March 2013. CSIR labs separately make efforts in this area.

Field Visits

CSIR-800 implementation is in the 400+ villages that make up the 28 TECHVIL clusters. Therefore familiarity with field conditions is important as a mechanism to capture technology opportunities and effectiveness. Some illustrative field visits were:

1. *Visit to Mysore: CSIR-CBRI Low cost housing initiative, Aug 2012*

   Visits to low-cost houses in Doddahundi built under collaboration between CSIR-CBRI and Mysore Nirmithi Kendra, Mysore informed on their potential use in CSIR-800 project . The Kendra also showed a project of constructing filler roofs that would be an equally useful technology



2. *NALGONDA TECHVIL clusters and meeting with CESS, Feb 2013*

   Visit to the Mandollagudam, AP TECHVIL cluster informed on water quality/quantity issues of village clusters, and leads on beneficial technology upgrades. The meeting with the Centre for Economic and Social Studies, Hyderabad brought a partner to the CSIR-800 program for the Needs Assessment Survey (NAS) in TECHVIL clusters.

3. *Selecting a TECHVIL in Karnataka Jan 2013 – Mar 2013*

   Under advice from state government Karnataka, a TECHVIL in either Tumkur or Raichur district will be selected. Many visits were paid to different sites in Tumkur (finally rejected), emphasizing the importance of village visits and alignment with state agencies.

Research Publications and Other Information

8

KNOWLEDGE PRODUCTS: PUBLICATIONS, PRESENTATIONS…..

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

Inside

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ISRO Sponsored Workshop on YOUTHSAT Data Utilisation for Ionospheric Studies, 14 - 15 October 2012, SPL ISRO, Trivandrum

Thangavelu R P

ATIP/A*CRC Workshop on Accelerator Technologies in High Performance Computing: Does Asia lead the way? 7-10, May 2012, A*CRC, Singapore
CSIR IT Nodal Officers Conference 2012, CSIR-SERC, Chennai, 29-30 November 2012

Invited Talks

Anant Kant Shukla, Homotopy method for nonlinear systems along with Mathematica implementation of the method, Indian Institute of Space Science and Technology (IIST), Trivandrum, 27- 28 August, 2012

Anil Kumar V, National Conference on Cyber security: issues and challenges, VIT University, Vellore, March 2013.

Parvez I A
Earthquake Zonation and Hazard Assessment in the Indian Subcontinent, Keynote Speaker: Hindi Day at National Aerospace Laboratories, Bangalore, 14 September 2012.
Earthquake Hazard Assessment in the Indian Subcontinent – regional scale, at International School on use of e-infrastructures for Advanced Seismic Hazard Assessment In Indian Subcontinent, 4-7 February 2013.
Earthquake Hazard Assessment in the Indian Subcontinent – local scale, at International school on use of e-infrastructures for Advanced Seismic Hazard Assessment in Indian Subcontinent, 4-7 February 2013.

Patra G K, Mathematical Modelling: Art or Science, Sixth International Conference on Information Processing, UVCE Bangalore, 10 August 2012

Rajendran K
Influence of Climate Change on Southern States of India, Meteorological Research Institute, Tsukuba, Japan, 18 March 2013.
Modelling of monsoon: Progress and challenges, Discussion Meeting on Intel proposal for ICRI on Weather & Climate Modelling, IISc, Bangalore, 29-30 October 2012.

Ramesh K V, Mathematical Modelling and Computer Simulation in Climate Modelling, Shri Sakthikailassh Women's College, Salem, 22 September, 2012.

Seshu P, Thermo-mechanical Contact Behaviour of Pressure and Calandria Tubes in a Nuclear Reactor Postulated Accident Scenario, Fourth International Congress on Computational Mechanics and Simulation, IIT Hyderabad, 10 December, 2012

Sridevi Jade
Advanced Research in Engineering and Earth Sciences: Data Intensive Modelling and Crowd Sourcing Approach, Information Sciences Cluster Meeting, August 2012, CSIR, Delhi
GNSS based Geo-science Research, School Students of Madhya Pradesh, October 2012, CMMACS, Bangalore

P S Swathi
Parallelising the heat equation, Think Parallel, C-DAC Course on Parallel Programming, June 2013
Debugging serial and parallel codes, Intensive Course on Parallel Programming with MPI and Open MP, C-MMACS, August 2013
Marine ecosystem modelling, TERI-BCCR Climate School, October 2013

Tejpal Singh, Earth structure and deformation using Geospatial Technology, Workshop on Advanced Applications of Geospatial Technology, University of Mysore, Mysore, 1 March, 2013

Thangavelu R P, High Performance Computing in India: Current Status and CSIR Initiatives, Altair HTC / PBS Conference, Bangalore, 18 July 2012

Conference/Workshops/Seminars/Scientific Meetings at C-MMACS

Silver Jubilee Celebration

C-MMACS Foundation Day and Inaugural of C-MMACS Silver Jubilee programme

Intensive Course on Parallel Programming with MPI/OpenMP for Scientific Computing
27-31 August 2012, C-MMACS

Over the years, the trend of multi-core chips has revolutionalised the high performance computing (HPC) scenario and immensely benefitted computational science streams. Computational biology, bio-informatics, computational chemistry, high-fidelity CFD analysis of airplanes, climate science are all prime examples of beneficiaries of such a revolution. CSIR has a direct stake in all these fields of scientific endeavour.

Now-a-days most desktops and laptops come with dual or quad-core processors and it is common to see high end HPC systems with several hundreds of cores. Moving from TeraFLOP systems to PetaFLOP systems, computer hardware manufacturers are already pushing the frontiers for exaFLOP systems. More than just the sheer compute power, modern day data centres provide a HPC environment i.e., *raw computing power, storage and data management, visualization, ease of remote computing with minimal front end systems, access to facilities on the go, availability of vast pool of software tools etc*. Recognising the importance of such HPC facilities in realizing the CSIR's vision of pursuing the emerging fourth paradigm of data intensive computational scientific research, CSIR is actively pursuing setting up of its supercomputing facilities in a pyramidal architecture.

While the cost of computing has in general come down over the years, such HPC systems are still very expensive for a developing economy such as ours. Thus it is imperative that concerted efforts are simultaneously put in place for the optimal utilization of such facilities. To exploit the on-chip parallelism in HPC systems fully, the software must be parallel and should scale efficiently with the number of cores. The importance of availability of skilled manpower in parallel programming cannot therefore be overemphasised. In an effort to cater to this need, we organised an intensive training programme exclusively for CSIR scientists.

The course covered a wide range of topics: Computer Architecture, Introduction to Parallel Computing, C-MMACS Computing system, Numerical Methods - Algebraic Equations, Quadrature, Interpolation, Linear systems, Numerical Solution of ODE/PDE, MPI and OpenMP, Debugging, Intel Tools (Compiler, Optimiser, V-Tune Amplifier and Performance Analyser, and Parallel I/O. In addition there were case studies from a few disciplines: computational chemistry, data mining, spectral methods for CFD and computational biology. There was an intense hands-on component which supplemented the theory component well. Dr. S. K. Brahmachari interacted with the participants informally over video conference.

Twenty five scientists from 12 CSIR laboratories participated in the course. The feedback we received from the participants indicated that they felt that the course was timely and useful and they would apply many of the concepts quickly in their research.

Open Day Celebration, CSIR C-MMACS on Sep 28th 2012

Under the Silver Jubilee Year (2012-2013), we have organized CSIR C-MMACS's Open Day on September 28, 2012. It was a proud and happy moment for all of us at CSIR C-MMACS as we entered into our Silver Jubilee Year. Open Day had provided the opportunity to explore and experience our facilities, meet our scientists, staff and students and participate in our exhibition, videos, experiments, infrastructure and also get the opportunity to see one of the most advanced super computing facilities, listed number one in the country and 58th in the world. It was a one day program and many school/college students, staff from other research organisations visited us and benefited from our programs and research, that are international in scope, vision and standards. The cloud seeding demonstration, ground motion visualization, demonstration of worldwide earthquake occurrence, crustal deformation through GNSS, Carbon flux measurement and the HPC facility were some of the main attractions to the visitors.

National Workshop on Climate Observation and Modelling Network: Collaborative Utilization Plan (COMoN-CUP) on 22-23 march 2013.

India, with its large latitudinal extent from the tropics to the sub-tropics, exhibits large diversity in its climate and climate change; monitoring, understanding and modelling of this climate diversity requires a carefully designed observation system covering the country. The National Action Plan on Climate Change identifies knowledge and data infrastructure as a critical component. However, approach to monitor and assess climate and climate change should be cross-sectoral, integrating relevant components. A long-felt and a critical gap for such comprehensive and cross-sectoral approach had been a carefully designed and sustained observation network.

To create a comprehensive observation network that, through sustained operation, can lead to a quantitative assessment of climate and climate change over India, CSIR, under its project 11th Five Year Progrrame (2009-14) has initiated a Climate Observation and Modelling Network (COMoN). COMoN is unique in its scope and coverage; the Network may further expand in the coming years.

The Workshop was organized to bring together a group of users, including the COMoN Alliance Partners as well experts and potential users to evolve value added, multi-disciplinary applications with COMoN data and formulate a roadmap. Participation from potential participants was invited through open advertisement (Curr Science) with financial support to young resarchers, while a few eminent experts were invited; most of the experts invited responded and participated in the event. Dr B Bhattacharjee, H'ble Member, NDMA and Chairman, Inaugural Session, appreciated the vision and efforts behind creating a knowledge infrastructure like COMoN.

In-house Seminars/Lectures

Rameshan Kallummal, Dominant Response of Sea Surface Temperature in a Warming World, 12 April 2012

Sajani S, Monsoon Sensitivity to Aerosol Radiative Forcing, 3 May 2012

Guest Lectures

Kody J H Law, Mathematics Institute, University of Warwick Coventry, UK, Filtering the Navier Stokes Equations, 26 April 2012

S Sadagopan, International Institute of Information Technology, Bangalore, Supercomputing – Changing Colour & Hue, 11 May 2012

Dhruv Balwada, Florida State University, USA, Preliminary results from diapycnal and isopycnal mixing experiment in the Southern Ocean (DIMES): Dispersion in the Antarctic Circumpolar Current (ACC), 22 May 2012

D Shankar, CSIR National Institute of Oceanography, Goa, ADCP Observations and coastal-trapped waves on the shelf of the west coast of India, 24 May 2012

Arun Srinivasa, Texas A&M University, USA, On the use of information theoretic algorithms for energy minimization and related tasks, 7 June 2012

A S Vasudeva Murthy, TIFR-Centre for Applicable Mathematics, Bangalore, Numerical solution of PDE's posed on unbounded domains, 14 June 2012

Mandar Gurav, High Performance Computing Laboratory, IIT Mumbai, HPC application development & tools, 25 June 2012

Gopal S Pingali, Global Specialty Service Area Hub & Cloud Centre of Excellence, IBM Center, Bangalore, Cloud enabled mobile services: A game changer, 5 July 2012

Surajit Sen, State University of New York, USA, How to make a system with its own nonlinear force law and why is it worthwhile, 19 July 2012

Prasad Perlekar, Eindhoven University of Technology, Netherlands, Life at high Reynolds numbers, 30 July 2012

Sitangshu Bhattacharya, Nanoscale Device Research Laboratory, Department of Electronic Systems and Engineering, IISc, Bangalore, Computational study of electro-thermal management in next generation interconnect materials, 9 August 2012

Amitava Moitra, Pennsylvania State University, USA, Magnesium Alloy Design: A perspective on multi-scale modelling, 16 August 2012

Abhishek Kumar Mishra, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, Simulations of nano-materials: from nano-electronics to environment friendly technologies, 23 August 2012

Michel Ramonet, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), France, 50 Years of atmospheric CO_2 monitoring: Lessons and Perspectives, 29 August 2012

Pinaki Biswas, Indian Institute of Science, Bangalore, Crack tip fields and fracture mechanisms in single crystals, 30 August 2012

Marc Delmotte, Laboratoire des Sciences du Climat et de l'Environnement (LSCE), France, The French greenhouse gases monitoring network: RAMCES-ICOS, 24 September 2012

Bhanu Pratap Das, Indian Institute of Astrophysics Bangalore, The god particle: Computing its footprints in an atom, 18 October 2012

Kota Murali, IBM India, Bangalore, Theory and simulations challenges in nanotechnology, 22 November 2012

Dominik H Lang, Stiftelsen NORSAR Kjeller, Norway, Earthquake damage and loss assessment predicting the unpredictable, 13 December 2012

Narayan Rangaraj, IIT, Mumbai, Role of mathematical modelling and simulation in operations management, 18 December 2012

Anil K Singh, CSIR NAL, Bangalore, Deformation of solids at multimegabar stresses: Strength and elasticity from x-ray diffraction data, 17 January 2013

Binay Panda, Bio-IT Centre Institute of Bioinformatics and Applied Biotechnology, Bangalore, Complexity of eukaryotic genomes peeked through next-generation sequencing data, 24 January 2013

Avinash Erank, Department of Electrical and Computer Engineering, George Mason University Virginia, USA, Novel functional applications of biomedical ultrasound imaging, 31 January 2013

Elizabeth Maya, M V, Chemical Oceanography, CSIR National Institute Of Oceanography, Goa, Carbon and nitrogen stable isotopic studies in coastal waters around Goa, India, Monday, 4 February 2013

Visitors at C-MMACS

Stephen Geoffrey Bovis, Vice President, Hewlett-Packard, Asia Pacific and Japan, 2 April 2012.

Roger Schmidt, IBM Fellow & Vice President, IBM, USA,2 April 2012.

Swapan Sarkar, Scientist-G, CSIR NPL, Delhi, 12-14 April 2012.

Kody J Law, Post Doctoral Fellow, University of Warwick, 26 April 2012.

Edward Jay Turkel, Worldwide Marketing Manager, Hewlett-Packard, 16 May 2012.

Marc Sultzbaugh, Mellanox Technologies, 23 May 2012.

Prof Bhattacharyya, Vice Chancellor, Tezpur University, 27-29 May 2012.

C Slayi, Asst. Prof, IIT Kharagpur, 2-6 June 2012.

Mukesh Tiwari, Professor, DA-IICT, Ahmadabad, 18-20 July 2012.

Giridhar, Principal Scientist, CSIR CECRI, 4 July 2012.

D Narayana Rao, Director, SRM University, Chennai, 7-8 July 2012.

Viren Sardana, Scientist, CSIR CSIO, Chandigarh, 17-19 July 2012.

Ripul Ghosh, Scientist, CSIR CSIO, Chandigarh, 17-19 July 2012.

Goutam Banergee, Chief Scientist, CSIR-CIMFR, Dhanbad, 17-19 July 2012.

Ranjan Kumar, Senior Scientist, CSIR-CIMFR, Dhanbad, 17-19 July 2012.

D Chavan Prakash, Senior Scientist, CSIR-CIMFR, Dhanbad, 17-19 July 2012.

Surajit Sen, Professor, State University of New York, USA, 17-20 July 2012.

P Perlekar, Post Doctoral Fellow, Technische Universiteit Eindhoven, Netherlands, 29-31 July 2012.

Shanker Trivedi, Vice President, Worldwide Sales, NVIDIA, USA, 6 August 2012.

Steven Lee Scott, CTO, NVIDIA, USA, 6 August 2012.

Shakil Romshoo, Professor, University of Kashmir, 11 August 2012.

Rakesh Chandra, Asst.Professor, University of Kashmir, 11 August 2012.

Maroof Qadri, Asst Professor, University of Kashmir, 11 August 2012.

Abhishek Kumar Mishra, Scientist, JCASR, Bangalore, 23 August 2012.

Ross Davis, Director, Hewlett-Packard, Singapore, 4 September 2102.

David William Turek, Vice President, IBM, USA, 21 August 2012.

Bastien Gal, Scientist, LSLE, France, 29-30 August 2012.

Michel Ramonet, Scientist, LSLE, France, 29-30 August 2012.

Ulrich Georg Vollath, General Manager, Trimble Navigation Limited, USA, 10 September 2012.

Anthony Ernest Carrozza, Executive President, SGI, USA, 11 September 2012.

Remya R , JRF, NIO, Goa, 18-19 September 2012.

Marc Delmotte, Scientist, LSLE, France, 24-25 September 2012.

Keith Charles Askey, Hewlett-Packard, Singapore, 1-6 October 2012.

Promod K Verma, Director-General, Scientific Advisor, Govt. of Madhya Pradesh, 5 October 2012.

Binnoraj, Govt. of Karnataka, 10 October 2012.

Pierre Michelin, Wipro, Francaise, 9 November 2012.

Cargemel, Wipro**,** Francaise, 9 November 2012.

Raj Hirwani, Head, URDIP, Pune, 27 November 2012.

Tarakanda Jana, NISCAIR, New Delhi, 27 November 2012.

Sangwan S, NISCAIR, New Delhi, 27 November 2012.

Alakananda, CSIR HQ, 27 November 2012.

Andrew P Morse, Professor, University of Livepool, 26-30 November 2012.

Daniel Pare, IBM**,** Singapore, 6 December 2012.

Gururaj Rao, Vice President, IBM, Bangalore, 6-8 December 2012.

David William Turek, Vice President, IBM, USA, 6-8 December 2012.

Dominik Harald, Norway, 11-16 December 2012.

Damida Kerstin Kuha, Norway, 11-16 December 2012.

Bartosz Protas, Professor, Department of Mathematics and Statistics, Canada, 19 December 2012.

Paul Jeong, Entrepreneur Centre, IISc, Bangalore, 24 January 2013.

V S Prakash, Director, KSNDMC, 29 January 2013.

B C Arya, Head, RAPD, NPL, 29 January 2013.

B Manikiam, ISRO, Bangalore, 29 January 2013.

Luiz A DeRose, Cray Inc, USA, 29 January 2013.

Antony Pinto, Techviz, Bangalore, 31 January 2013.

Julie Laure Bethonneau, Techviz, Bangalore, 31 January 2013.

Vicent Lim, Senior Engineer, Data Direct Networks, Australia, 4-9 February 2013.

Andrew David Wyatt, Vice President, Asia Pacific, Cray Inc, USA, 13 February 2013.

Om Prakash, Boeing India, 15 February 2013.

Jeong Beom Ihn, Boeing Company, USA, 15 February 2013.

Daniel E Groneck, Boeing Company, USA, 15 February 2013.

Krishnan K Sankaram, Boeing Company, USA, 15 February 2013.

Turek David William, Vice President, IBM, USA, 20 February 2013.

Michael Heheberger, IBM T J Watson Research Centre, USA, 20 February 2013.

Michelin Pierre, Bull, France, 21 February 2013.

Declat Damien, Bull, France, 21 February 2013.

Girard Pascale Valerie Sophic, Bull/Wipro, Bangalore, 21 February, 2013.

Stephen Wheat, General Manager, Intel, USA, 1 March 2013.

Seung Ju Na , HPC Product Manager, Intel, 1 March 2013.

Avinash Palaniswamy, Vice President, Intel, USA, 1 March 2013.

Roger Schmidt, Vice president & IBM Fellow, IBM, USA, 5 March 2013.

Michel Jean Marie, Bull, France, 15 March 2013.

Loic Jean Pierre Marie, Bull, France, 15 March 2013.

Pierre Irenee Marie, Bull, France, 15 March 2013.

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C-MMACS ACADEMIC PROGRAMME

In keeping with its objective of developing skill and expertise in Mathematical Modelling and Computer Simulation in the country, C-MMACS maintains an active academic programme. The activities span the entire spectrum from Ph D guidence to undergraguate/postgraduate student projects to specialized courses. 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.

Inside

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

Ph D Programme

Anil Earnest

Sunilkumar T C, (AcSIR), Geodynamics of Plate-Boundary Zones

Goswami P

Gouda K C, Multi-scale Modelling and Forecasting of Monsoon Weather and Processes
Mohapatra G N, Impact of Local Climate Variability and Anthropogenic Processes in Extreme Weather Events over India
Swapan Mallick, Development and Evaluation of an Algorithm for Objective Bias Correction of Dynamical Forecasts at Different Scales
Sumana Sarkar, Multisector Application of Seasonal Forecast: Crop yield, Vector-Borne Diseases and High Impact Weather Events over India
Kantha Rao, Multi-scale Modelling and Analysis of Surface and Soil processes over the Indian Region.
Shiv Narayan Nisad, Analysis and Modeling of Sustainability over India under Different Scenarios of Climate Change and Socio-Economic Conditions
Shaktidhar Nayak, Development and evaluation of a model configuration for local climate projection over India
Eswari V (GSI), Analysis of Impact of Climate Change on Wind Regimes and Implications for Wind Energy potential over the Monsoon Region.

Parvez I A

Sushant Shekhar, Seismic Wave Propagation in Non Homogeneous Anisotropic Incompressible Media.
Parul Trivedi (Saurashtra University), Source Modelling and Seismic Hazard Study in Kuchcha region

Sudarshan T S B and **Patra G K**

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

Patra G K and Sarda N L

Ashapurna Marndi, Scientific Data Analysis and Data Intensive Research

Prathap G and Pradhan S C (IIT KGP)

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

Rajendran K

Ipsita Putatunda, Methods of Physical Assimilation for Short Range Numerical Weather Prediction.
Kulkarni Shashikant (IIT Bombay), Downscaling over Monsoon Region

Ramamohan T R and Srinivas S

Anant Kant Shukla, Development of Analytical Solutions for the Dynamics of Periodically Forced Particles in Simple Shear Flow at Zero Reynolds Number
A Subramanyam Reddy, Fluid Flows in Vibrating Channels.

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
E. Edwin Raj (UPASI TRF TRI) climate Impact assessment on tea production over south India

Sajani S

Nithin Patil (IIT Bombay), Aerosol radiative forcing and impact on climate

Sridevi Jade and Ashok Kumar

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

Sridevi Jade and Malay Mukul

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

Sridevi Jade

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

Ravi Babu (VIT) and **Tejpal Singh**

Nisha (VIT), Remote sensing/GIS applications in mineral spectra identification

Vijayan M S M and Senthilkumar V

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

Vijayan M S M and Ashok Kumar

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

M Sc/M Tech Project Guided

Anil Earnest
Plate tectonics, earthquakes and crustal deformation, Saurabh Wagh, IIT-Roorkee.

Active tectonic deformation at the NW region of India, Aswini K K, CUSAT

Patra G K
Design of Word Based Stream Cipher using Neural Synchronization, Sneha Joseph Alexandria, Manipal Centre for Information Sciences and Divya R, BMS College of Engineering, August 2012

Study of RSA Cryptosystem and Attacks on it, Ravi Mangal, IIT Roorkee, August 2012

Cryptanalysis of RSA using Quadratic Sieve, Nithyalaxshmi, PSG College of Technology, Coimbatore

Chaotic Synchronization and its Application to Cryptography, M Mahesh, Guru Gobind Singh Indraprastha University, New Delhi, September 2012

Performance Analysis of Neural Cryptographic System using FPGA, Rajendra Babu M, Manipal Centre for Information Sciences, September 2012

Ramamohan T R

Formalism for Prediction of Loads on a Spherical Particle Moving in a Quiescent Fluid at Arbitrary Reynolds Number by using a 'Reciprocal Theorem', Sai Naga Sri Harsha Chittajallu, VIT University, Vellore, May 2013.

Ramesh K V

Rainfall Variability and food-grain production in India, Siddhartha Srivastava, IAS, Bangalore/BHU

Modeling relationship between climate and AGDP, Anjali, Indraprastha College for Women, Delhi University

Climate change and Human health over India, Saryu Garg, IAS, Bangalore

Federated triticum substantiate system, Rajesh T and Logs Aanath, IAS bangalore

Senthilkmar V

M.Tech thesis guided of Shri. K.Shashidar titled "Vibration Analysis of Carbon Nanostructures" at School of Mechanical and Building Science, VIT, Vellore in 2012-2013 under SPARK Programme.

Tejpal Singh

Comparative Study of Digital Elevation Models for Varying Topographic Relief, Daisy Paul K VIT University, Vellore.

Vijayan M S M

Software to Calculate Ionospheric Total Electron Content using GPS, Gloria Varghese, IIITM-Kerala

Geospatial data mining: Database in Open Platform, Rajeswaran S, Adhiyaman College of Engineering, Hosur, Tamil Nadu.

Achieving Control of Lesion Growth in CNS with Minimal Damage, **Mathan K Raja,** Oct 4, 2012.

Faculty participation

Academy of Scientific and Innovative Research (AcSIR)

Gaur V K
Statistical Physics, Aug. 2012 semester
Reasoning and quantitative thinking, Jan. 2013 semester

Patra G K
High Performance Scientific Computing, Aug. 2012 semester

Swathi P S
Numerical Analysis & High Performance Computing, Jan. 2013 semester

MATLAB Training Programming

Senthilkumar V
CSIR NEIST, Jorhat , 03 - 05 October 2012

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COLLABORATIVE PROGRAMMES & PROJECTS

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

Inside

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

CSIR Network Projects

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

Nodal Lab: C-MMACS

Network Partners:

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

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

Network Partners:

CSIR National Aerospace Laboratories (NAL)

12th Five Year project

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 Centre for Mathematical Modelling and Computer Simulation (CMMACS)
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 Centre for Mathematical Modelling and Computer Simulation (CMMACS)
CSIR Central Road Research Institute (CRRI)
CSIR Institute of Himalayan Bioresource Technology (IHBT)
CSIR Institute of Minerals and Materials Technology (IMMT)
CSIR National Botanical Research Institute (NBRI)
CSIR National Environmental Engineering Research Institute (NEERI)
CSIR North East Institute of Science and Technology (NEIST)

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

Nodal Lab: CSIR CBRI

Participating Lab :

CSIR CSIR Centre for Mathematical Modelling and Computer Simulation (CMMACS)
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: *R.P.Thangavelu*

Nodal Lab: CSIR CBRI
Participating Lab :
Institute of Microbial Technology (IMTECH)
CSIR Centre for Cellular and Molecular Biology (CCMB)

CSIR Central Drug Research Institute (CDRI)
CSIR Centre for Mathematical Modelling and Computer Simulation (CMMACS)
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
CSIR National Chemical Laboratory
CSIR National Botanical Research Institute (NBRI)
CSIR Institute for Interdisciplinary Science and Technology (NIIST)
CSIR Hqs

11th Five Year project

Analysis and Measurement of Concentrations of Carbon Dioxide, Methane and other Trace Gases over India at Andaman & Nicobar Islands for Inferring Sources and Sinks of Carbon over Indian Sub-Continent – *PI: Indira N K*

Collaborating Institutions:
National Institute of Ocean Technology Chennai
Indian Institutes of Astrophysics (IIA)
Laboratoire des Sciences du Climate et de l' Environnment (LSCE), France

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

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

CSIR Empower Project

Impact of Regional Aerosol Radiative Forcing on Indian Monsoon, *PI: Sajani Surendran – Co-PI: Rajendran K*

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

Sponsored Projects

Estimation of crustal deformation and tropospheric precipitable water vapour content in North-eastern India using GPS measurements, MoES – *PI: Sridevi Jade, Co-PI: Vijayan M S M*

Collaborating Institutions:
Tezpur University, Tezpur, Assam

Analysis of Indian National GNSS Network data for Reference frame realisation, PWV and TEC computation – *PI: Sridevi Jade, Co-PI: Vijayan M S M*

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

Collaborating Institutions:
CSIR National Geophysical Research Institute, Hyderabad

Future climate change projection for Kerala using high resolution climate model, Department of Environment and Climate Change, Government of Kerala, – *PI: Rajendran K*

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

Impact of physical assimilation of vertical profiles of latent heating and moisture on short-range weather forecasting, ISRO Megha-Tropiques Mission Project – *PI: Rajendran K, Co-PI: Srinivasan J*

Collaborating Institutions
Indian Institute of Science (IISc), Bangalore

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

Estimation of Carbon Fluxes in the Indian Ocean, MOES – *PI: Swathi P S*

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

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

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

Seismic Hazard and Risk Assessment based on Pattern Recognition: Himalayas and adjacent territories. (DST-RFBR) – *PI: Parvez I A*

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

Collaborative Projects

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

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

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

Collaborating Institutions:
Meteorological Research Institute (MRI)

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

Collaborating Institutions:
IIT Mumbai

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

Post-seismic deformation: Insights from recent giant plate boundary ruptures – *PI: Anil Earnest, Co-PI: Vijayan M S M*

Monitoring Continuously Operating C-MMACS GPS Station Located in the IISc Campus and real-time operational data hub at CSIR CMMACS, *PI: Anil Earnest, Co-PI: Sridevi Jade.*

To check the efficiency of HAM proposed by CSIR- CMMACS with other approximate analytical methods for nonlinear problems*, PI: Ananth*

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

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Team C-MMACS – News and Updates

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

Inside

- *Team C-MMACS*
- *Awards/Honours/Recognition*
- *Services on External Committees/Membership of Professional Bodies*
- *Deputations*
- *Promotions*

Staff List

Scientist-in-Charge
Seshu P

Honorary Emeritus Scientist
Gaur V K
Yajnik K S

Distinguished Scientist
Balganesh T S
Ehrlich Desa
Samir K. Brahmachari
Sinha U N

CSIR Technical Consultant
Srinivasan Suryanarayan

Scientists
Anil Earnest
Anilkumar V
Ashapurna Marndi
Ashish
Goswami P
Gouda K C
Gyanendra Nath Mohapatra
Himesh S
Indira N K
Kantha Rao Bhimala
Krishna Mohan T R
Partha Sarathi Goswami
Parvez I A
Patra G K
Prakasa Rao E V S
Rajendran K
Rakesh V
Ramamohan T R
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

Senior Research Fellows
Jurismita Baruah
Anant Kant Shukla

Junior Research Fellows
Ipsita Putatunda
Shafeer K
Shaktidhar Nahak
Shiv Narayan Nishad
Sushant Shekhar
Sumana Sarkar

Expert Consultant
Kalyani Devasena C

Technical Officers
Ananda M B
Prabhu N
Suchanda Ray

Controller of Stores & Purchase
Ravinder Kumar

Administrative Staff
Neethu S Induchodan
Udaya Kumar

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

Project Assistants/Graduate Trainees/ Diploma Trainees

Ahkshaey Ravi
Ajilesh PP
Alfred Johny
Boddapati Anil
Chandra Sekhar Kolli
Jayasankar CB
Kumaragouda Gondar
Lalit Kumar
Mathan Kumar R
Madhukar K
Manikanda Prabhu
Nagarakshitha VM
Nagarjun PMD
Neethu C
Parthasarathi Baril
Payoshni Samantray
Prabhath P Prabhu
Praveen S
Rajeev K
Rekha KC
Remya S
Renu Goyal
Sandhya I
Sanjeeb Kumar Sahoo
Saranya V
Savithri KP
Shambulinga Kondagoli
Shelva Srinivasan MK
Shimna K
Shobharani G
Sowbhagya P
Sundara Deepthi MV
Sunil Kumar TC
Swathi TK
Vinutha D

Awards/Honors/Recognitions/Ph D Awarded

Rao E V S P

The Indian Society of Agronomy (ISA) Gold Medal for the year 2009

IMPHOS-FAI Award on Role of Phosphorus on Yield and Quality of Crops for the year 2012

Dr Rao receiving Indian Society of Agronomy Gold Medal from Dr.Charan Das Mahant, Minister of State (Agriculture), Govt. of India.

Dr Rao receiving World Phosphate Institute-Fertilizer Association of India Award from Shri Srikant Kumar Jena, Minister of State, Chemicals & Fertilizers (Independent Charge),Govt. of India.

Patra G K

Design and Analysis of Parallel Algorithm for Finding Mersenne Prime Numbers, Runners up in Garuda Challenge – 2012.

Sridevi Jade has been invited to be the member of Expert Committee, Applied Geoscience, National Geo-science Award, Ministry of Mines

Ph D Awarded

Himesh S: Completed Ph D from Bangalore University
Jurishmita Baruh: Completed Ph D from Mangalore University
Swapan Mallick: Completed Ph D from Mangalore University
A J Saigeetha: Completed Ph D from Gandhigram Rural University

Services on External Committees/ Membership of Professional Bodies

Anil Earnest

Member,Technical Committee for up-gradation of seismic stations network of Wadia Institute of Himalayan Geology, Dehradun.

Anil Kumar V

Life Member, Computer Society of India
Expert Member, Scientist Selection Committee, C-DAC, India

Expert Member, M Tech Thesis Evaluation Committee, Vellore Institute of Technology, Vellore
Expert Member, Assessment Committee, C-DAC, India
Panel Member, Evaluation Committee, GARUDA Challenge - 2012, C-DAC, Bangalore.
Member, Programme Commitee, National Conference on Parallel Computing Technologies, PARCOMPTECH INDIA 2013
Technical Reviewer, IEEE International Conference on Electronics, Computing, Communication Technologies, IEEE CONECCT2013

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
Member, National Advisory Committee (NAC) of Intromet-2013

Gouda K C

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

Himesh S

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

Parvez I A

Nodal Officer, AcSIR, C-MMACS
Deputy Sec. Editor, Journal, Problems of Engineering Seismology, Establishment of the Russian Academy of Sciences, Institute of Physics of the Earth. OY Schmidt, Russian Academy of Sciences.
Member, Hindi Technical Advisory Committee (HTAC) of NAL.
Member, Technical Expert Committee of Karnatala State Natural Disaster Monitoring Centre (KSNDMC), Department of Science and Technology, Government of Karnataka.
Life Member, Indian Society of Earthquake Technology
Member, Assessment of the suggested threat due to an M9 earthquake in Kashmir Himalaya, Ministry of Earth Sciences, Government of India.
Member, Cluster group for Physical Sciences courses nomenclature of AcSIR

Indira N K

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

Krishna Mohan T R

Life Member, Indian Complex Systems Society

Patra G K

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

Life Member, Orissa Information Technology Society
Life Member, Advanced Computing and Communication Society
Life Member, International Association of Engineers
Expert Member, Assessment Committee, Indian Institute of Astrophysics, Bangalore, India
Adjunct faculty, Department of computer Science, Amrita School of Engineering, Bangalore
Member, Board of Studies, Mathematics Department of Mount Carmel College, Bangalore
Member, Doctoral Committee, Vellore Institute of Technology
Member, Programme Committee, National Conference on Parallel Computing Technologies
Member, Technical Marketing, International Conference on Cloud Computing and Service Engineering

Prabhu N
Member, Computer Society of India

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

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

Rakesh V
Life member, Indian Meteorological Society.

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

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

Member, IAENG Society of Industrial Engineering
Member, IAENG Society of Mechanical Engineering

Sharada M K
Member, American Geophysical Union

Sridevi Jade
Life Member, Indian Geotechnical Society
Member, International Society of Soil Mechanics and Foundation Engineering
Founder Life Member, Indian Society of Rock Mechanics and Tunneling Technology
Expert member, National Geo-Science Program, Ministry of Earth Sciences (MoES)
Expert member, Applied Geo-science, National Geo-science Award, Ministry of Mines
Expert Member, Research Advisory Council (RAC), Member of Wadia Institute of Himalayan Geology.
Expert member, Technical Advisory Committee, Government of Karnataka
Expert Member, National GPS Programme Expert Group, Department of Science and Technology
Expert Member, Women Scientist Scheme expert committee, DST
Expert Member, Technical committee for preparation of geodetic GPS Specifications
Expert Member, National GPS sub group, Ministry of Earth Sciences
Member, Information Sciences cluster 12th FYP Work Group/Task Force
Member, Doctoral Committee, Gandhigram Rural University, Gandhigram, Tamilnadu
Member, Doctoral Committee**,** Tezpur University, Tezpur

Swathi P S
Member, American Geophysical Union
Expert Member, Asseessment committee for scientists, NIO, Goa.

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

Vijayan M S M
Member, American Geophysical Union

Deputation

Goswami P, Third Lead Author Meeting for the WG I contribution to the IPCC AR5, Marrakech, Morocco, 19-16 April 2012

Goswami P, Fourth Lead Author Meeting for the WG I contribution to the IPCC AR5, Hobart, Australia, 13-18 January 2013

Goswami P, CSIRO Marine and Atmospheric Research, Australia, 13-18 January 2013

Goswami P, Meeting at University of Liverpool related to UK India Education Research Initiative (UKIERI) Project, Liverpool, 21-27 May 2012

Goswami P, Meeting at University of Liverpool related to UK India Education Research Initiative (UKIERI) Project, Liverpool, 12-20 August 2012

Indira N K, LSCE, France to work with the scientists at LSCE, 18 October - 8 November 2012

Jayasankar C B, Visiting Scientist at Meteorological Research Institute/Japan Meteorological Agency, Tsukuba, Japan, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 10 February - 30 March 2013.

Patra G K, A* CRC institutes, Singapore to attend ATIP/A* CRC Workshop on Accelerator Technologies in High Performance Computing: Does Asia lead the way? 7-10, May 2012

Rajendran K, Visiting Scientist at Meteorological Research Institute/Japan Meteorological Agency, Tsukuba, Japan, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 10 February - 30 March 2013.

Swathi P S, LSCE, France, to work with the scientists at LSCE, 11 February – 2 March 2013

Thangavelu R P, A* CRC institutes, Singapore to attend ATIP/A* CRC Workshop on Accelerator Technologies in High Performance Computing: Does Asia lead the way? 6 - 13, May 2012

Event Gallery

INAGURATION OF SILVER JUBILEE

INTENSIVE COURSE ON PARALLEL PROGRAMMING

CSIR C-MMACS OPEN DAY CELEBRATION









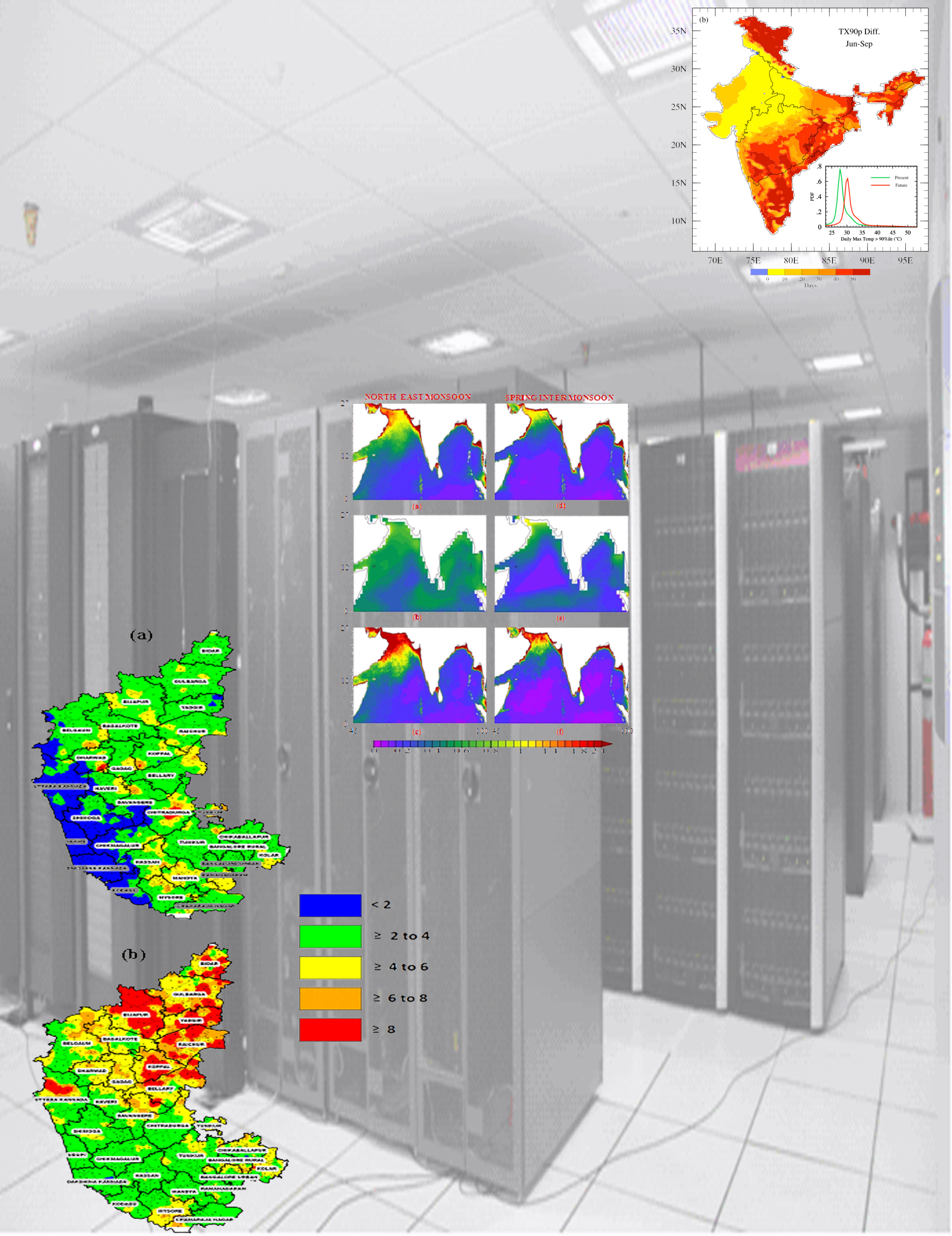
TECHNOLOGY DAY

Farewell to Mr M B Ananda

COMoN-CUP Work shop

Release of Annual Report 2011-12 at CSIR C-MMACS by DG, CSIR on 3rd Aug 2012

Scientists-in-charge of CSIR C-MMACS (Past and Present) with former Directors of CSIR NAL and DG, CSIR



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Jun-Sep
35N
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70E
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PDF
Present
Future
Daily Max Temp > 90%ile (°C)
Days
NORTH EAST MONSOON
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< 2
≥ 2 to 4
≥ 4 to 6
≥ 6 to 8
≥ 8