Council of Scientific and Industrial Research

FOURTH PARADIGM INSTITUTE

N W T C Road, Bangalore-560037

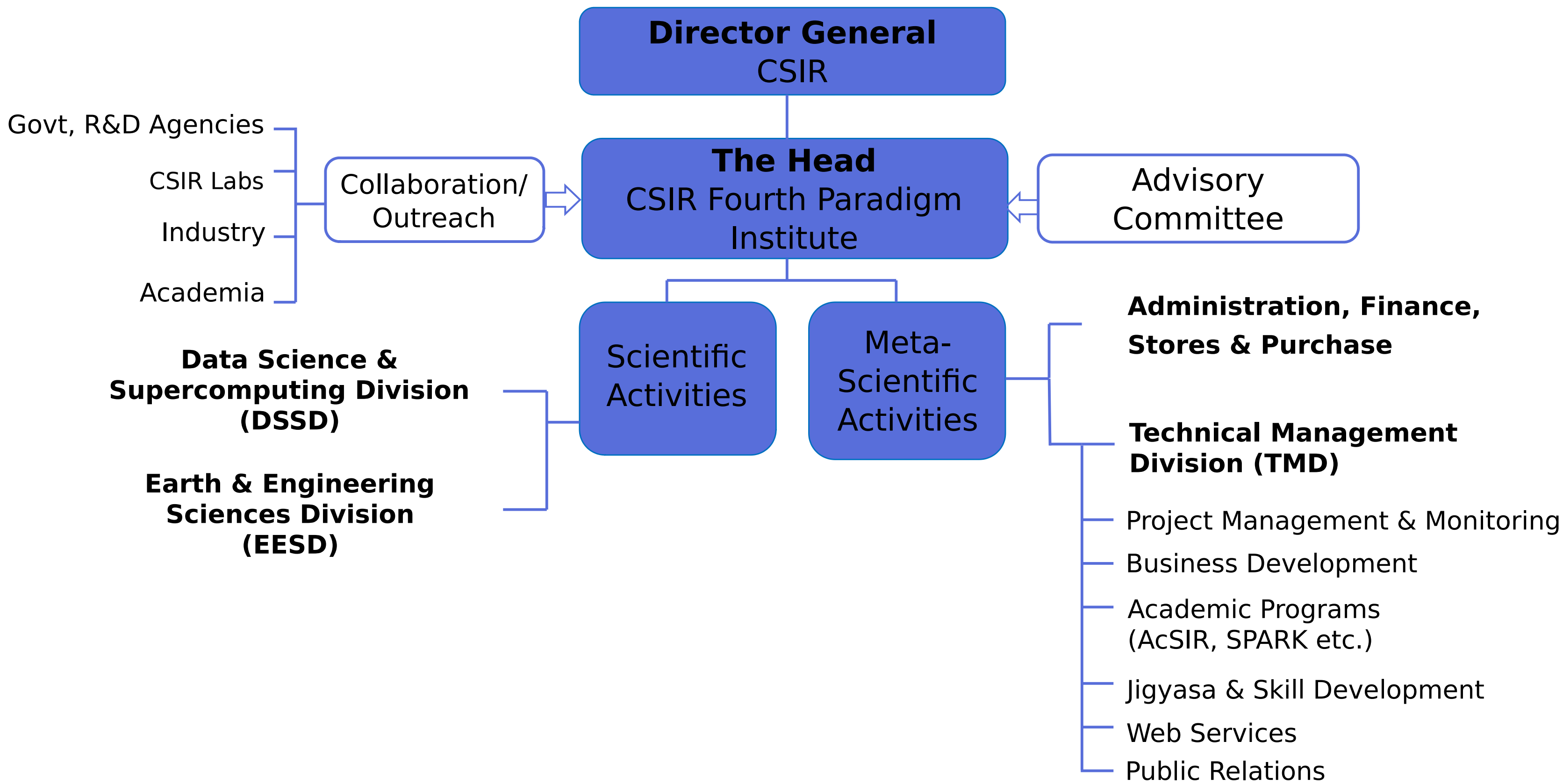
CSIR-4PI

ANNUAL REPORT

2021-2022

Azadi Ka Amrit Mahotsav

Organisational Chart



VISION

To synergize the strong expertise in various disciplines across CSIR and build a unified platform that embodies a rich set of big data enabling technologies and services with optimized performance to facilitate research collaboration and scientific discovery.

MISSION

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

MANDATE

To develop reliable knowledge products for decision support in Earth, Engineering and Information sciences as well as to host centralised supercomputing facility for CSIR.

THE ADVISORY COMMITTEE

PUBLISHED BY:
THE HEAD
CSIR FOURTH PARADIGM INSTITUTE
WIND TUNNEL ROAD
BENGALURU - 560 037
KARNATAKA, INDIA
FAX: +91 80 2522-0392
TEL: +91 80 2505-1921
E-MAIL: HEAD@CSIR4PI.IN
Web: www.csir4pi.res.in
Twitter: https://twitter.com/CSIR_4PI
YouTube: https://www.youtube.com/channel/UCQohBZOe9QoFOLCQH8x7i8w

COMPILED BY:
Dr. Anil Earnest

COVER PAGE DESIGN BY:
Ravichandran C and Pavithra N R

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We acknowledge the inputs provided by all the scientists and staff of the CSIR-Fourth Paradigm Institute in making this report. We thank Smt. M K Sharada, Dr. G K Patra, and Dr. K C Gouda for their time and efforts in the timely completion of this report. The photography section of CSIR-NAL is duly acknowledged for providing the event photos. Typesetting is done using LaTeX collaborative authoring tools available at www.overleaf.com.

0.1 Preface

CSIR Fourth Paradigm Institute (CSIR-4PI) made major strides in promoting mathematical modelling and data-driven research culture across CSIR and accelerates the pace of discovery in the areas of interest to CSIR. The year started with Shri. Jitendra J Jadhav, Director NAL taking additional charge as the Head of our Institute. Subsequently, I was appointed as the Outstanding Scientist and Head of the Institute. This Annual Report gives a cursory glance at all our major activities and outcomes during 2021-2022. Though the global pandemic cast a shadow on all our activities, I must say that it has been a great year for CSIR-4PI due to several reasons!

During this year, CSIR-4PI was restructured into two scientific divisions: Data Science and Super Computing Division (DSSD), and Earth and Engineering Science Division (EESD). In addition, Technical Management Division (TMD) was created for meta-scientific activities. Our Advisory Committee (AC) was reconstituted with Smt. Nivruti Rai, Country Head of Intel India as the chairperson and highly distinguished team of expert members from diverse fields.

We had internal brainstorming sessions spread over two weeks to identify the institute's thrust areas for the next five years which resulted in a detailed Vision and Strategy document for CSIR-4PI. This document was discussed in detail in all the eight theme vertical meetings of CSIR and it was concluded that we should support data science needs as horizontal across the eight theme verticals in addition to providing the supercomputing facility.

I state with immense pride that our research "Disaster Management: Synthesis of modelling, measurements and data analytics" was showcased as part of 80 success stories in 80 years of CSIR. We continue to excel in our earth and engineering science research with several outstanding contributions this year resulting in several high-impact publications and citations.

Geoscience research activity gave seismic potential of the northwest Himalaya and Indo-Burmese arc. We augmented our seismic observation network in Jammu and remote terrains of Kashmir, Ladakh Himalaya. Further, using our seismic network we gave significant insights on ionosphere variability using GPS data, sensor orientation and noise analysis of broadband seismic data, sub-surface shear wave velocity at a regional scale in Kashmir Valley using microtremor array data.

Our advanced weather and climate research activity gave a better understanding of biogeochemical cycle models in the northern Indian ocean, sea surface temperature variability, experimental hindcasts for Indian summer monsoons, simulations of monsoon active-break cycles, dynamical downscaling framework for climate change projections, Indian summer monsoon variability and so on. Our Covid related research provided an assessment of tropical weather impact on the spatio-temporal spread of Covid-19 during the early stage in India as well as an assessment of air pollution status during Covid-19 lockdown over Bangalore City. An algorithm that helps in reliable Tsunami early warning was also developed during this period.

With the deep commitment and hard work of DSSD staff, we were able to achieve robust up-times and availability of our computational resources to several research groups across CSIR. Our efforts on refreshing existing HPC facilities were carried out on war footing resulting in placing an order for CSIR HPC, AI & ML Platform with a capacity of more than 2 Petaflops to address the growing computational requirements (both traditional as well as AI computing) of scientists across CSIR laboratories. The 1.2 PetaFlops computing platform donated by AMD, Inc. was installed and released for exclusive Covid-19 research by Indian researchers. The activities on protocol engineering resulted in securing an Indian patent this year. The network-telescope based cyberspace observation mechanism helped in gathering cyber intelligence and understanding the quantum of malicious activities over the Internet.

We were able to provide AI-based Covid predictions for policymakers, especially to the Government of Karnataka to help in taking appropriate strategies in containing the pandemic spread and management. This year we extended domain agnostic AI/ML/DL research to several diverse disciplines across CSIR. In our institute, we provided data science-based insights on the spread of the pandemic as well as on the AI-based decision support systems for agriculture and crop management.

We conducted an international conference on extreme weather events at Kullu, Himachal Pradesh. This conference gave us a platform to disseminate our research findings to state and district disaster management agencies. CSIR-4PI organised a major event "Festival of Games and Toys" at IISF 2021 to inculcate scientific temper among students through traditional games and toys, thus giving a boost to the indigenous industry. Our young scientists conducted the institute's Jigyasa and Skill initiative programs with a new zeal that saw the participation of more than 500 students.

This year's metrics indicate several high-impact scientific publications, global citations for our research work, one Indian patent, grants for new projects, doctoral degree awards, post-graduate dissertations and training of a highly talented scientific workforce, and so on. Further, R. P. Thangavelu, Chief Scientist received the Dr. APJ Abdul Kalam HPC award 2021 for his contribution to HPC ecosystem in the country. We continue collaborations with several institutes, agencies, and industries to achieve new heights in our R&D as well as outreach. I am privileged for being part of these efforts and confident that CSIR-4PI will play a significant role to address computational and the data science needs of CSIR and the country in the coming years.

Dr Sridevi Jade
Head
CSIR Fourth Paradigm Institute


Council of Scientific & Industrial Research
CSIR-4PI
Ministry of Science & Technology Govt. of India
CSIR - FOURTH PARADIGM INSTITUTE

Contents

II Earth & Engineering Sciences

I Data Science & Supercomputing

1. CSIR Centralized Computational Cyber Infrastructure

Since its inception, CSIR-4PI provides High Performance Computing (HPC) with state-of-the-art computational facilities and is currently hosting one of the largest supercomputing and Artificial Intelligence (AI) ecosystem for CSIR.

Inside:

- High Performance Computing
- HPC cloud resource at CSIR for COVID-19 research support for Indian researchers

1.1 High Performance Computing

CSIR centralized High-Performance Computing has been the main lifeline of the computational scientists of CSIR laboratories across India. The Ananta supercomputer is integrated using two generations of processors i.e Sandy Bridge, (362TF of peak) and Intel Skylake, (127TF of peak) which lead to peak computing capability of 489 Tera Flops (TF). The Ananta supercomputer is a cluster consisting of total of 1136 computing nodes, with 1088 nodes having two eight-core Intel Xeon E5 2670 processors each and 48 nodes, having two eighteen-core Intel Xeon Gold 6140 processors each, distributed over 18 racks.

Figure 1.1: CSIR centralized 489 TF High Performance Computing Facility.

The capacity of the total memory of the system is about 77TB. The inter-node communication is powered by high-speed FDR (for Sandy bridge nodes) and EDR (for Skylake nodes) InfiniBand providing a dedicated 56 and 100 Gbps interconnect bandwidth respectively. All the 1136 nodes access LUSTRE parallel file system of about 3 Petabytes which is capable of providing a minimum of 20 Gbps simultaneous read and write performance. The PBSPro workload manager ensures efficient usage of the system.

The efficient support infrastructure is a crucial requirement for the smooth running of the HPC facility. The Ananta supercomputer is located in a Tier-3 equivalent state-of-the-art data center efficiently supported by a state-of-the-art energy farm. The most

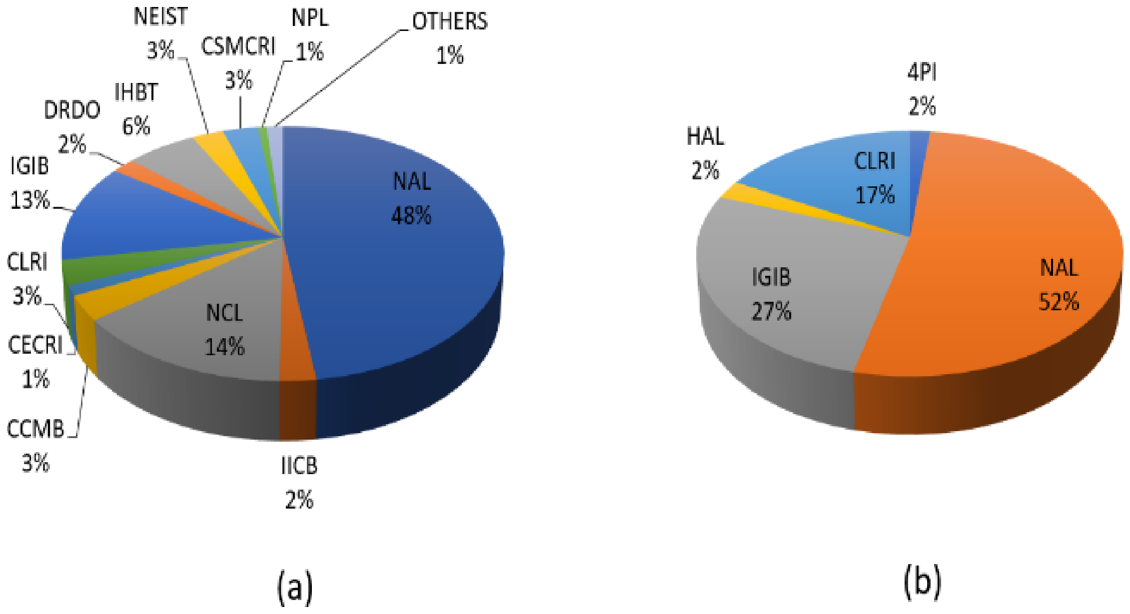


Figure 1.2: Percentage utilization of Ananta supercomputer (a) Sandy bridge nodes (b) Skylake nodes by different CSIR laboratories during the period 1st April 2021 to 31st March 2022.

noteworthy component of the data center is the water-based cooling mechanism called Rear Door Heat Exchangers (RDHX). Due to this, the data center is one of the high-density and high power-efficient data centers (Power Usage Efficiency (PUE) of less than 1.5) in the country. An energy farm consisting of two numbers of redundant compact substations of 1.25MVA each and three numbers of diesel generators, an underground diesel yard (more than 15000 liters), three numbers of UPS with battery backup ensure 24X7 power supply to the data center.

This facility is actively used for solving different compute-intensive grand challenge problems in different areas such as Aerospace, Biology, Computational Chemistry, Environmental Science, etc. The usages of Sandy bridge and Skylake based compute nodes by different CSIR laboratories are depicted in Figures 1.2a and b respectively.

R P Thangavelu, G K Patra, Anilkumar V, Ashapurna Marndi, Prabhu N and Veeresh

1.2 HPC cloud resource at CSIR for COVID-19 research support for Indian researchers

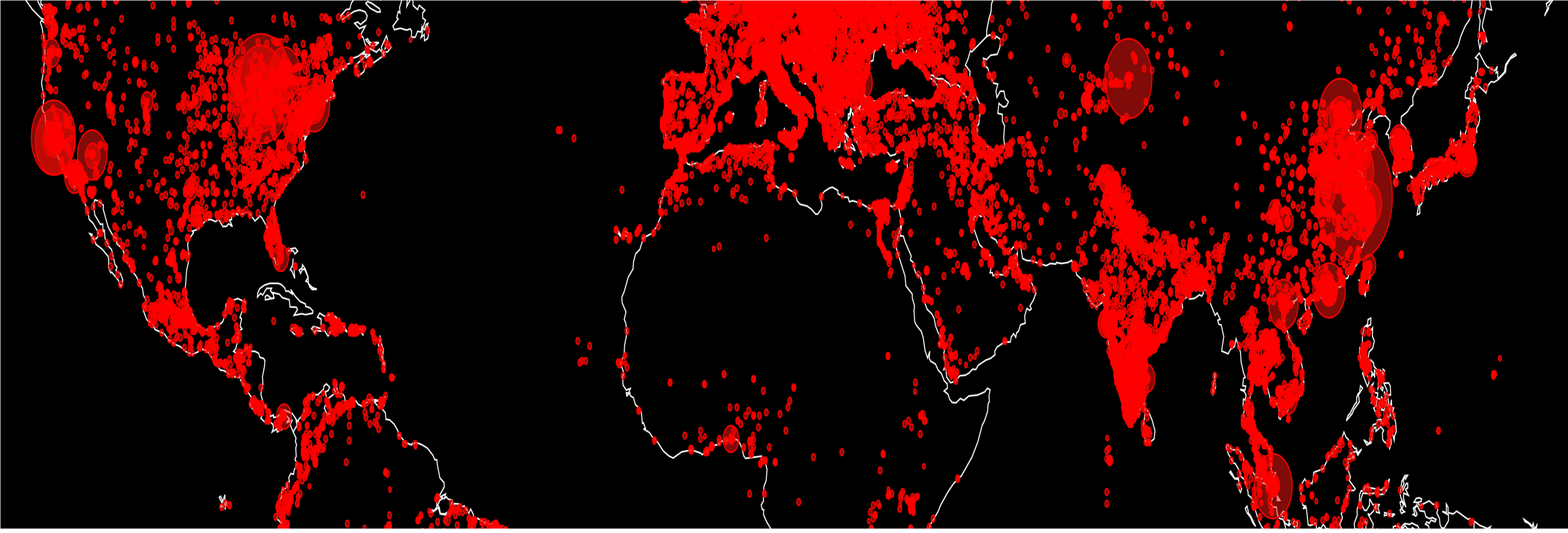
To support the fight against COVID-19, COVID CARE (CSIR AMD Research Engagement) Network - a collaborative effort of CSIR and AMD - is planning to make available multi-dimensional, multi-source primary/secondary data and compute system capabilities to Indian researchers. The system, built by AMD to deliver more than one PetaFlops of compute power and dedicated for Covid research, will be remotely accessible over a high-speed national knowledge network from CSIR Fourth Paradigm Institute (CSIR-4PI), Bengaluru. This is established as a part of AMD's COVID-19 HPC Global fund to understand the various aspects of infectious diseases and develop effective global responses.

Figure 1.3: AMD donated HPC cloud resource for exclusive COVID-19 reserach.

The system is configured with 24 nodes of AMD EPYC based system, each with 8 AMD Radeon Instinct MI-50 GP-GPUs, 48 GB CPU Memory and 128 GB GPU memory. In addition DDN, India has also donated a 250TB parallel file system to be used as a scratch file system.

The objective of this collaborative effort is to bring together a wide spectrum of Indian experts with global participation and crowd sourcing of students and citizens in order to address problems posed by COVID-19 and find suitable deployable solutions by effectively utilizing the high performance computing platform at CSIR-4PI with the basic principle of“Open Source Innovation and Data Sharing Policy”.

R P Thangavelu, G K Patra, Anilkumar V, Ashapurna Marndi, Prabhu N and Veeresh



2. Cyber & Data Security Research and Privacy

Considering CSIR-4PI's expertise and it‘s mandate to peruse data-intensive research in domains of national importance, the Institute intends to take a lead role in data-driven research in cyber & data security research and privacy. Below are some of the major studies carried out to gain a better understanding of security and privacy issues,

1. Data sequence signal manipulation detection through challenge-response scheme
2. Network Telescope: Observations and analysis

2.1 Data sequence signal manipulation detection through challenge-response scheme

Data Sequence Signal (DSS) manipulation is an inherent vulnerability in Multipath Transmission Control Protocol (MPTCP), which was exposed in our previous work. The vulnerability can be exploited for creating adverse scenarios including generation of non-responsive traffic, which disobeys the Internet congestion control mechanism. Detection and mitigation of DSS manipulation and associated exploitations are challenging due to multiple factors. Towards this, we proposed a novel implicit challenge-response scheme called Data Sequence Map (DSM) skipping through which a MPTCP data sender can detect incoming packets with DSS manipulation performed by the MPTCP data receiver.

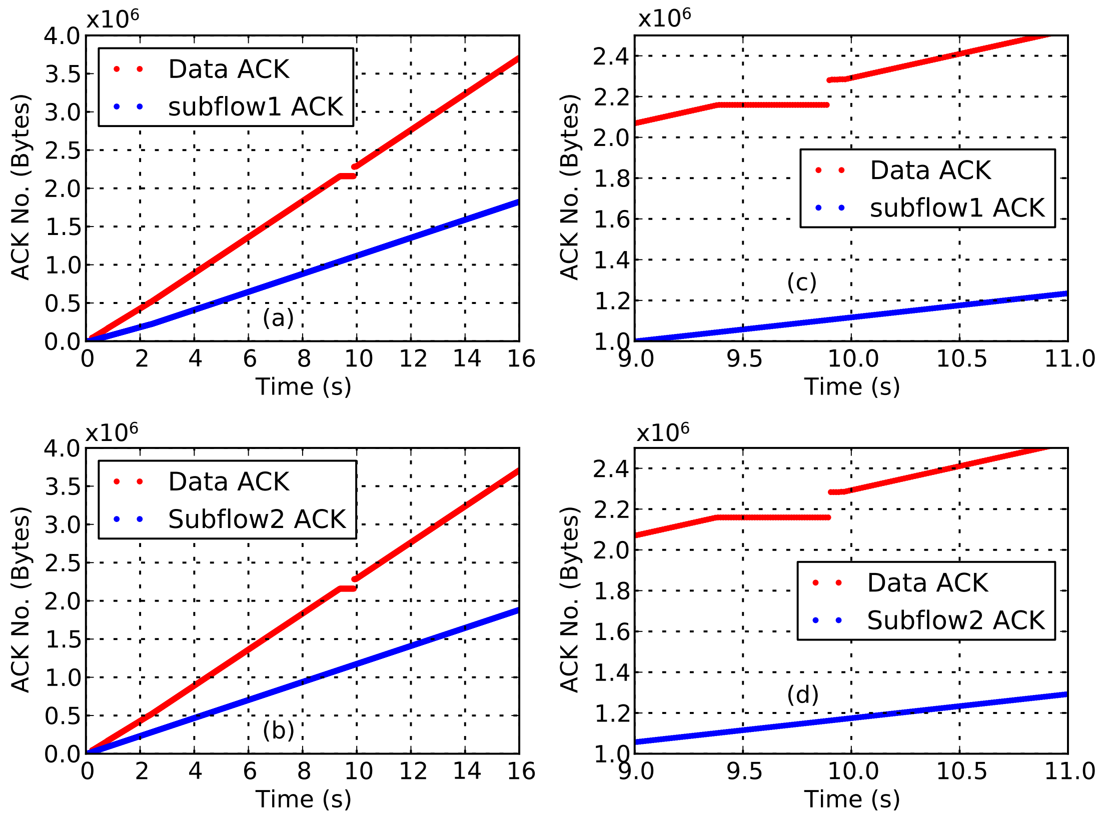


Figure 2.1: The default Data ACK and subflow ACK generation pattern of a MPTCP data receiver during map skipping and subsequent transmission of the skipped map.

In map skipping, an implicit challenge is introduced by deliberately skipping (i.e., not transmitting) the data sequence mapping for a randomly chosen in between data packet, and solicit an implicit response to this from the data receiver. A genuine receiver responds to the challenge by acknowledging new data packet received at the MPTCP subflow level without acknowledging the data at the connection level i.e., the subflow acknowledgement (ACK) number will increase, whereas the Data ACK will point to the map skipped Data

Sequence Number (DSN). The skipped map is transmitted slightly later, preferably after receiving the response to the skipped map. Neither the challenge nor the response involves transmission of any extra bytes between the MPTCP endpoints (i.e., the data sender and data receiver), and this makes map skipping both efficient and incrementally deployable. For proof-of-concept, map skipping is implemented in Linux Kernel and the response to the challenge is validated.

Figure 2.1 shows the Data and subflow ACK generation pattern of genuine MPTCP data receiver during map skipping. The subplot (a) and (b) correspond to subflow1 and subflow2, and subplot (c) and (d), respectively, show the enlarged portions of subplot (a) and (b), where the effect of map skipping is highlighted. Note that even after the map skipping is performed, the subflow ACK continues to increase, whereas the Data ACK points to the DSN for which the map is skippedthe signature of map skipping. However, when the skipped map (after its subsequent transmission) reaches the data receiver, it generates a cumulative Data ACK to acknowledge all the data transmitted after the map skipping, and the data transmission progresses further on both the subflows. In fact, the data receiver buffers all the received data with DSN map skipped DSN, till the skipped map is provided, and subsequently generates a cumulative Data ACK to acknowledge the buffered data, as soon as the skipped map reaches the receiver.

***V Anil Kumar and Debabrata Das*[#]**
[#] IIIT Bangalore

2.2 Network Telescope: Observations and analysis at CSIR-4PI

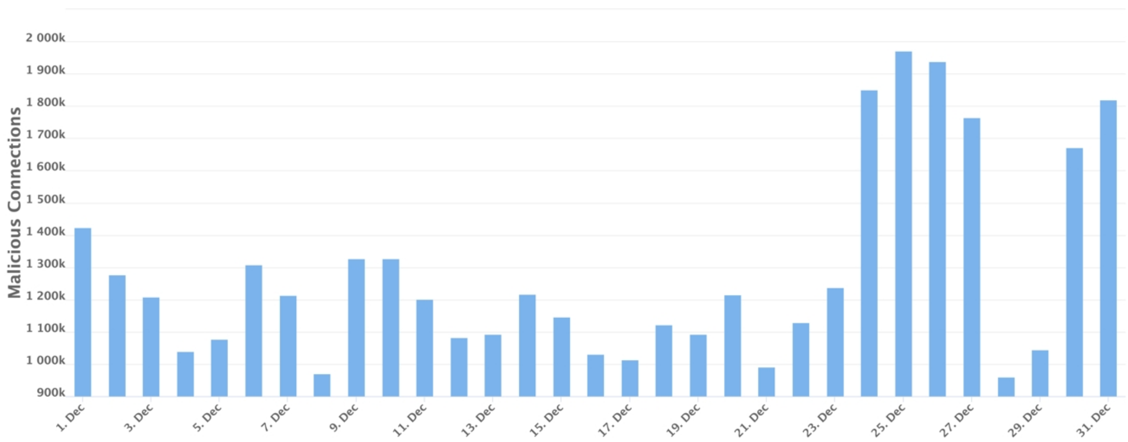


Figure 2.2: Daily distribution of TCP connections observed at Network Telescope.

As part of the ongoing Cyber Security Research and Observation (CySeRO) programme, CSIR-4PI has been pursuing the design, development and experimental deployment of the Darknet / Network Telescope technology for gathering cyber intelligence. A Proof-of-Concept implementation of the resulting Network Telescope was deployed on around 200 sensors at the CSIR-4PI for a continuous period of one month starting from 1 to 31

December 2021. During this period, the Telescope observed several millions of Internet Background Radiations (IBRs) originating from all over the cyberspace. These IBRs were subjected to validation against source Internet Protocol (IP) address spoofing and daily distribution of TCP connections, after source IP address validation, is shown given Figure 2.2.

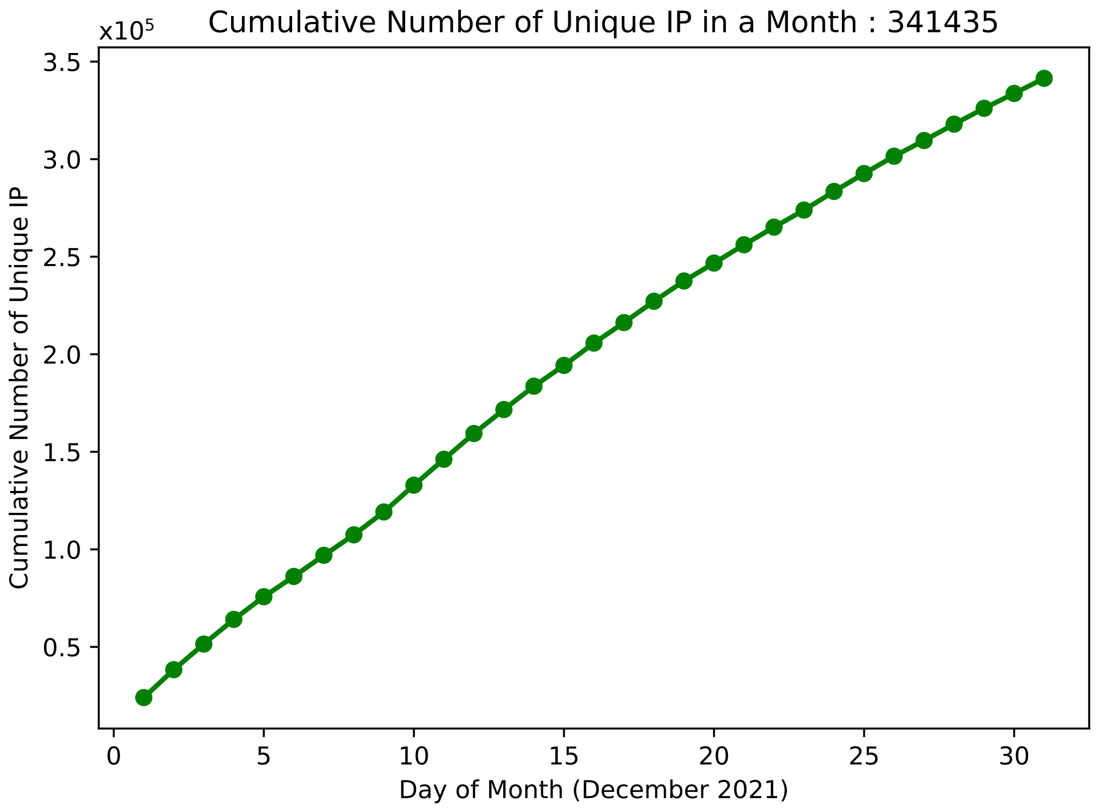


Figure 2.3: Cumulative number of unique IP, which established TCP connection with Network.

Our further analysis of these validated connections the results of multiple malicious activities taking place in the cyberspace and they include stateless and stateful scanning, service discovery, automated brute-force password cracking attempts, propagation of malicious payload propagation (e.g., worm propagation), etc. Figure 2.3 and Figure 2.4, respectively show the cumulative number of unique IP addresses and unique Autonomous System Numbers (ASN), which were observed through the Network Telescope.

As seen in Figures 2.3 and 2.4, about 0.34 million unique IP addresses located at various geographical parts on the Internet belonging to more than 9000 unique ASNs contacted to the Network Telescope with about 39 million TCP connections established. The raw data

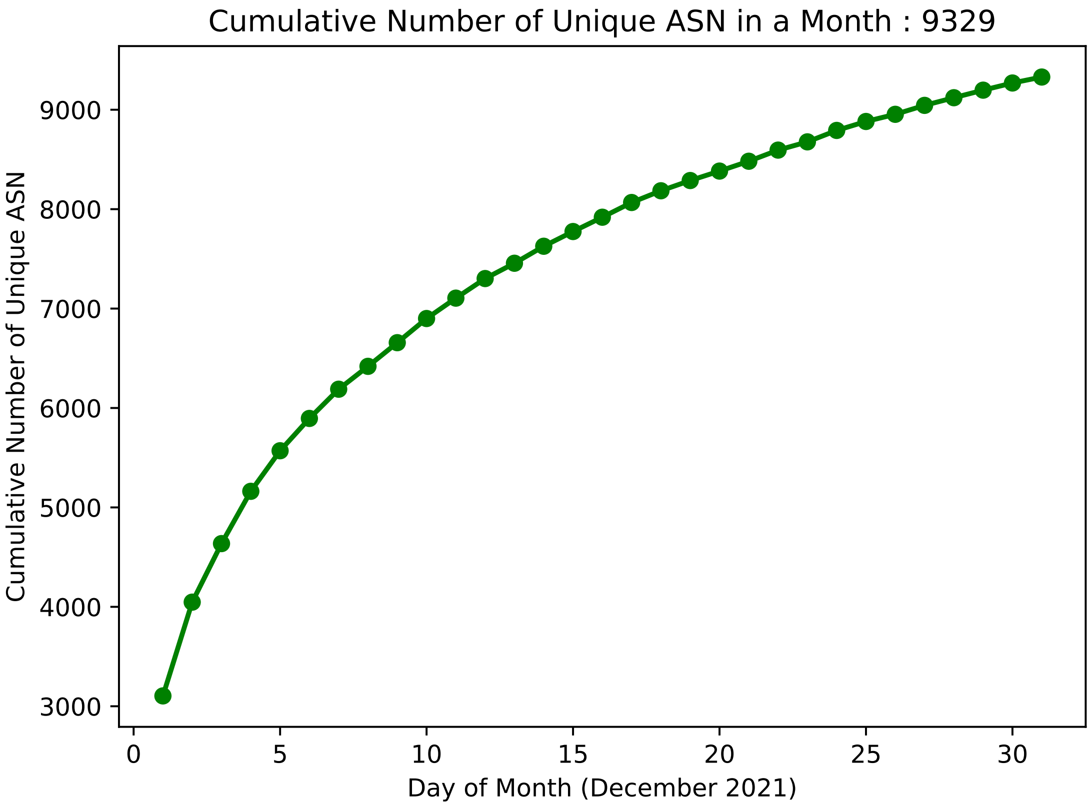


Figure 2.4: Cumulative number of unique ASN from where the TCP connection originated.

obtained from the Network Telescope is an asset, and its detailed analysis from various angles can provide strategic insight on the origin and nature of malicious activities taking place on the Internet.

V Anil Kumar, Jahnavi Meda, H N V Dutt, Madhavi Kori and Priyadarshini

3. Domain Agnostic Data Science & AI Research

This domain aims to synergize the strong expertise in various disciplines across CSIR including CSIR-4PI and build a unified platform that embodies a rich set of big data enabling technologies and services with optimized performance to facilitate research collaborations and scientific discoveries.
Inside:

- Prediction of COVID positive cases and supply chain management
- Estimation of crop production using Deep Learning techniques
- Development of weather integrated LSTM model for COVID-19 predictions over India
- Big data analytics and Artificial Intelligence methods for decision making in agriculture

3.1 Prediction of COVID positive cases and supply chain management

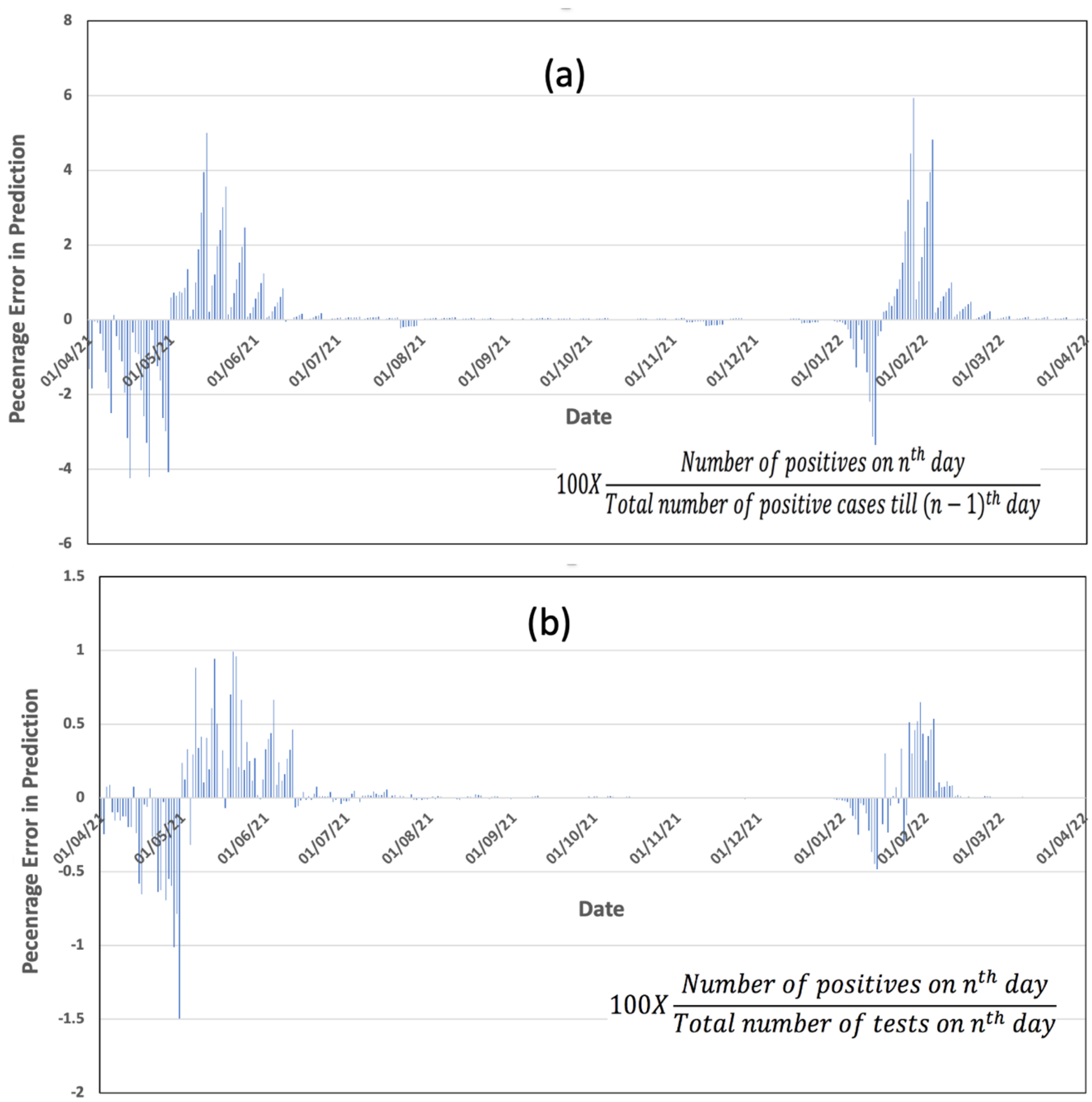


Figure 3.1: Percentage error in prediction of COVID for Karnataka presented from 1st April 2021 to 31st March 2022 (a) number of positive cases using daily percentage increase (b) number of positive cases using the daily positivity rate (ratio of positive cases and the tests conducted.)

As we all know, COVID-19 created a havoc in last two years disrupting the way we used to work and behave. One of the important aspects which really created a bigger challenge is the supply chain management related to the healthcare. Especially the medical instruments, medicines etc. One cause was the sudden increase in the demand and the other is the inability to know in advance the requirements both in terms of the quantity as well as the location. Hence, prediction of the likely number of COVID-19 positive cases becomes essential in order to plan for the supply of the essentials. On the request from the government of Karnataka, CSIR-4PI was providing weekly prediction and 15 days outlook every Saturday, which are acknowledged by the government as a useful input for their policy planning.

The predictions are based on an ensemble of LSTM (Long Short-Term Memory) variants and provide a bound to the likely number of cases so that the government can plan accordingly. The Figures 3.1 shows that the predictions during the period 2021-22 have been in the range of 4% in the peak Corona period using the daily positive increase in cases as the parameter, while in the case of positivity rate the error have been about 1.5%.

G K Patra, V Y Mudkavi and K C Gouda

3.2 Estimation of crop production using Deep Learning techniques

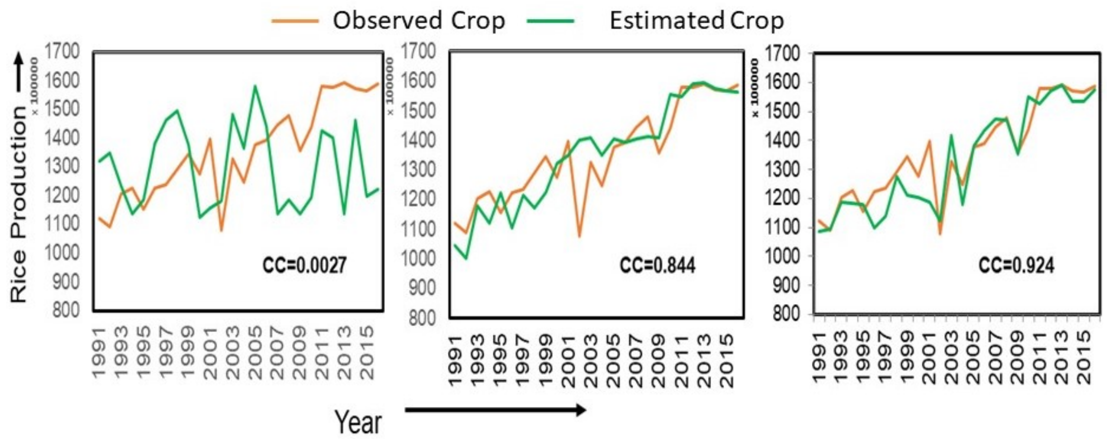


Figure 3.2: Prediction of India's Rice production in different conditions.

Advance prediction of crop production in any country helps policymakers to take timely decision on how much to export or import after satisfying food requirements of a country. In this study, we have performed a rigorous sensitivity analysis to identify the correct input data set from 20 neighbouring countries' crop (rice) production for designing a predictive model based on long short-term memory (LSTM). we have also incorporated rainfall data with an optimal input set (optimal combination of neighbouring countries' rice production) that leads to better accuracy. Finally, we have validated our proposed predictive model with export-import data. We have calculated all possible combinations (i.e. 2^{20}- 22) from 20 neighbouring countries' rice production using mathematical combination and result of sensitivity analysis reveals that rice productions of only eight countries (i.e Bangladesh, Sri Lanka, Nepal, Myanmar, Pakistan, Thailand, Philippines and Iran) have a significant impact on India's rice production. We have designed the predictive model in three different scenarios for predicting India's rice production. First model is trained with only rainfall data, second model is trained with eight neighbouring countries' rice production obtained from sensitivity analysis model, and third model is updated by incorporating India's rainfall data in second model. As shown in Figure 3.2, prediction accuracy of third model is better than first two models. Predictive model is validated with net flow (export - import) as shown in Figure 3.3 which depicts that net flow is following trend of predicted as well as observed crop production during 1991 to 1993 and 2005 to 2015.

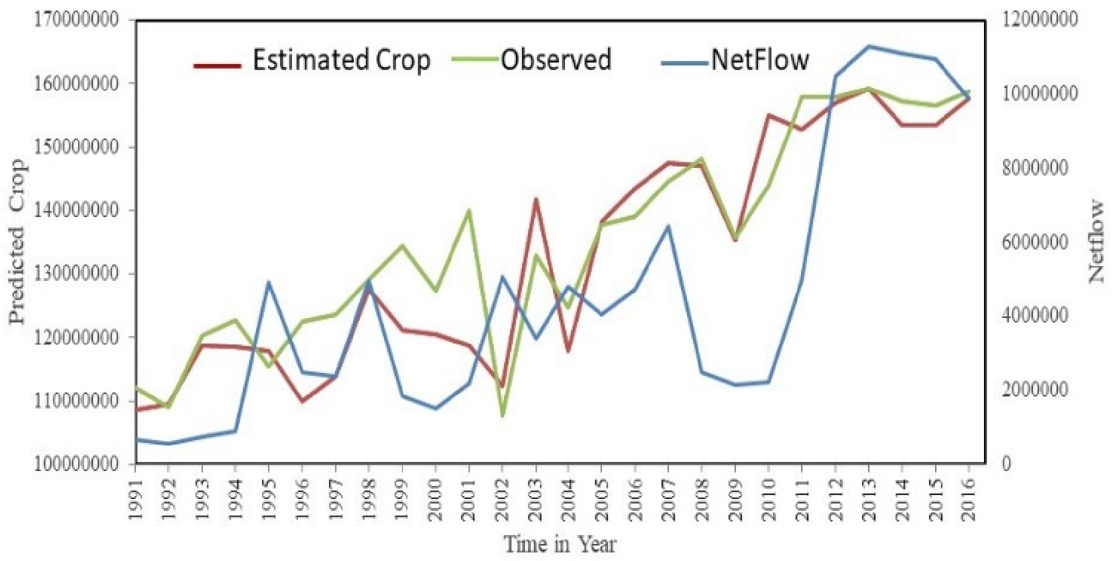


Figure 3.3: Relationship between crop production (predicted & observed) and net flow.

Ashapurna Marndi, K V Ramesh and G K Patra

3.3 Development of weather integrated LSTM model for COVID-19 predictions over India

The COVID-19 (coronavirus disease 2019) is a highly contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). To control the disease spread, full or partial lockdowns are implemented in the country which severely impacted multiple sectors including health, education, economy, and agriculture. Reliable predictions of COVID-19 outbreaks over different states in India are very important to handle the medical infrastructure, logistics, and proactive health measurements. The development of mathematical and statistical models are difficult to forecast the caseload for different states in India due to the complex mechanisms involved in disease transmissions

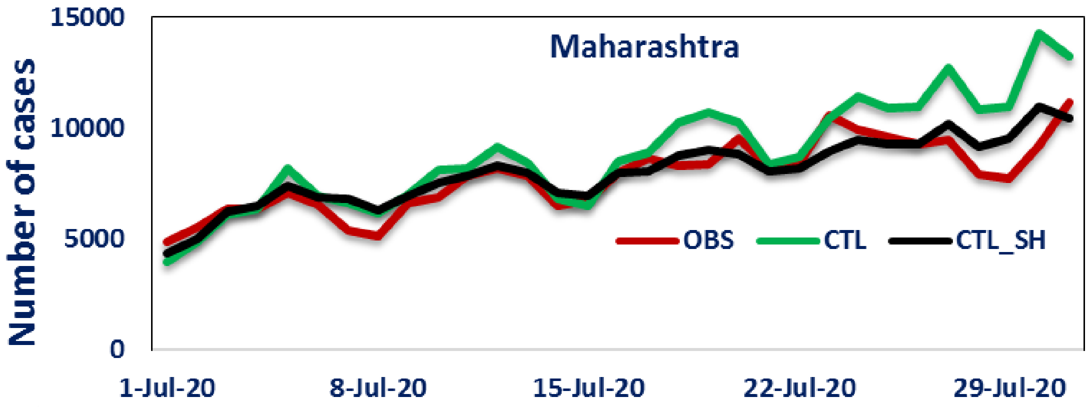


Figure 3.4: Presents the comparison of model predictions with observations.

like different virus variants, socio-economic conditions, population density and migration, and climatic conditions. Machine learning and deep learning techniques have proved their capability in time series forecasting of such non-linear problems. We compared between LSTM model simulated COVID-19 time series data with observed data over Maharashtra for the period 1st July, 2020 to 31st July, 2020 (See Figure 3.4). This control experiment (CTL) was conducted by training the model with time series of COVID−19 case data. The multivariate LSTM experiment (CTL_SH) was conducted by optimizing the model with covid-19 case data and the specific humidity data. In the present study, we have developed a COVID-19 forecasting model using long short-term memory (LSTM). The study found that the optimized model skill is reasonably good in most of the states in India. However, integration of weather parameters like specific humidity improved the model skill.

Kantha Rao B, GK Patra, and Srinivasa Rao M*

* CSIR-IICT, Hyderabad

3.4 Big data analytics and Artificial Intelligence methods for decision making in agriculture

Considering the complexities implicit in future pathway, emerging technologies with paradigm shifts need to be harnessed to evolve agricultural research to meet the requirements of future generations. One such paradigm which attracted thought leaders is Big Data Analytics and Artificial Intelligence. Agricultural sciences are very diverse and complex and the available tools of data management and statistical analysis are unable to provide all necessary answers to agricultural value chain. Big Data analytics have the potential to unravel answers in a way to aid agricultural research and its reach which needs expertise from diverse scientific disciplines. Artificial Intelligence (AI) tools are perceived to provide solutions to agricultural problems and result in precision agronomic practices. In the review, an attempt has been made to present state of art, data collection

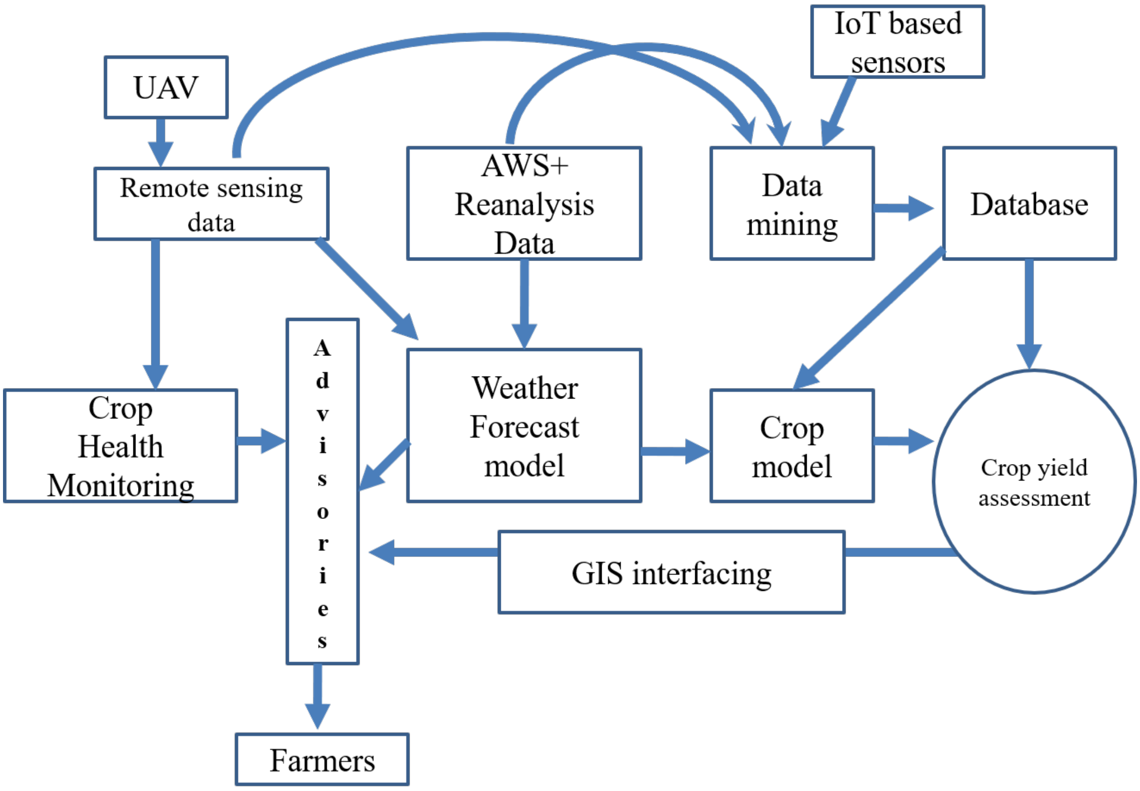


Figure 3.5: Big-data analytics platform for generating farm advisories.

methods, data analytics and delivery of Big Data and AI based agronomy. Also, sufficient caution has been flagged to debunk some myths around Big Data and AI, which fortunately serves well the new agronomy as it provides us with enough opportunities to tune these technologies to agriculture, by learning lessons from other sectors (Figure 3.5). Quality of agronomic and environmental data is a prime requirement. Contribution by public organizations in basic research of developing algorithms and private organizations and NGOs customizing and delivering the new technologies is suggested as a pragmatic approach.

E.V.S. Prakasa Rao, V. Rakesh and K.V. Ramesh

II Earth & Engineering Sciences

4. Advanced Weather & Climate Research

CSIR-4PI has a unique positioning in CSIR as the only lab for advanced weather & climate research and its impact on multiple sectors like agriculture, health, water, energy, disaster management etc. CSIR-4PI has the niche expertise to carry out this inter-disciplinary research and below are some of the major outcomes this year.
Inside:

- Modelling for biogeochemical cycles in the north Indian Ocean
- Changes in sea surface temperature variability over six post WWII decades
- Measurement and analysis of greenhouse gases
- Assessment of Aerosol Optical Depth over Indian Subcontinent during COVID19 lockdown (March - May 2020)
- New dynamical framework for the prominent low frequency events in the Tropical Pacific
- About eighty percent of the tropical Indian Ocean surface would warm above 28^{O}C by 2070
- New ocean-atmosphere coupled mechanism that sustains the secular expansion of the Indian Ocean Warm Pool
- Assessing ISM circulation characteristics and moisture source indices in a changing climate: insight from a ultra high resolution HighResMIP CMIP6 climate scenario
- Experimental Indian summer monsoon hindcasts by the National Monsoon Mission Model on CSIR-4PI HPC Anantha: Initial condition dependence of forecast skill
- Earth System Model century simulations on CSIR-4PI HPC Anantha: Representation of monsoon active-break cycle
- Dynamical downscaling framework for climate change projections on CSIR-4PI HPC Anantha: Resolution impact on monsoon projections
- Global cloud-resolving model (GCRM) simulation of semidiurnal variation of rainfall

- Indian summer monsoon variability and teleconnections in global climate models
- Factors responsible for interannual variability of Indian summer monsoon rainfall
- Water Vapour characteristics and radiative effects at high-altitude Himalayan sites
- Skill of sub-kilometer forecasts from WRF model in simulating extreme rainfall events over the Bangalore city
- An Assessment of Relation of Meteorological Parameters and COVID-19 transmission at the early stage during March-May 2020 in India
- Assessment of Air Pollution status during COVID-19 Lockdown (Mar-May 2020) over Bangalore City in India
- Effect of large-scale oceanic and atmospheric processes on the Indian summer monsoon
- Temperature-duration-frequency analysis over Delhi and Bengaluru city in India

4.1 Modelling for biogeochemical cycles in the north Indian Ocean

Results of TOPAZ (marine biogeochemical model) simulations using NCEP fluxes are analysed in detail for spatial, seasonal and interannual variations of various biogeochemical components in the north Indian ocean. Model validation studies are carried out using the recent data from World Ocean Circulation Experiment (WOCE) on Oxygen, Silicate, Nitrate and Alkalinity for some of the stations in the Arabian Sea (AS) and the Bay of Bengal (BOB). It is noted that model is able to capture well the depth-wise variations of oxygen and oxygen minimum zone, nitrate, silicate and alkalinity (Figure 4.1) at different locations in the AS and BOB.

Monthly variation of different components of Total Primary Productivity (PP) with respect to depth, namely, PP due to large Phytoplankton (PP-L), PP due to small phytoplankton (PP-S) and PP due to diazotrophs (PP-D) are analysed in detail for several regions in the AS and BOB. It is observed that PP-D is very low compared to PP-S and PP-L in all the regions in the AS and BOB, and PP-S is more than PP-L during all months except during October and November in the west AS (Figure 4.2). In many of the regions of AS and BOB, PP-L is very low during Spring Intermonsoon season (March to May). Total primary productivity (PP) is low in BOB compared to AS during all months and PP-L is very low compared to PP-S during all months. Analysis of contribution of PP-S and PP-L to PP is essential to understand the estimation of carbon flux at the air-sea interface and also the sinking of detritus and consumption of oxygen due to detritus.

Monthly variations of Chlrophyll(Chl), Dissolved Inorganic Carbon (DIC), Temperature and Oxygen for the years 2015-2018 are shown in Figure 4.3 for one region each in AS and BOB. It can be noticed that Chl and DIC are lower in BOB compared to AS and Temperature in the upper layers is higher in BOB than in AS. Suboxic zones are observed between 200 to 1000m depth in the AS whereas suboxic zones are between 200 to 600m in the BOB. Interannual variations in the extent of suboxic zone is noticed in the AS.

Detailed analysis on the biogeochemical components and processes are being done using TOPAZ model simulations with Core Fluxes and NCEP fluxes, to understand the carbon and nitrogen cycles in the suboxic zones in the AS and BOB and estimation of impact of climate change on marine ecosystem. Also, model validation studies in different regions of the AS and BOB will be continued using data on physical, biological and chemical variables from cruises and ARGO floats.

M K Sharada and C Kalyani Devasena

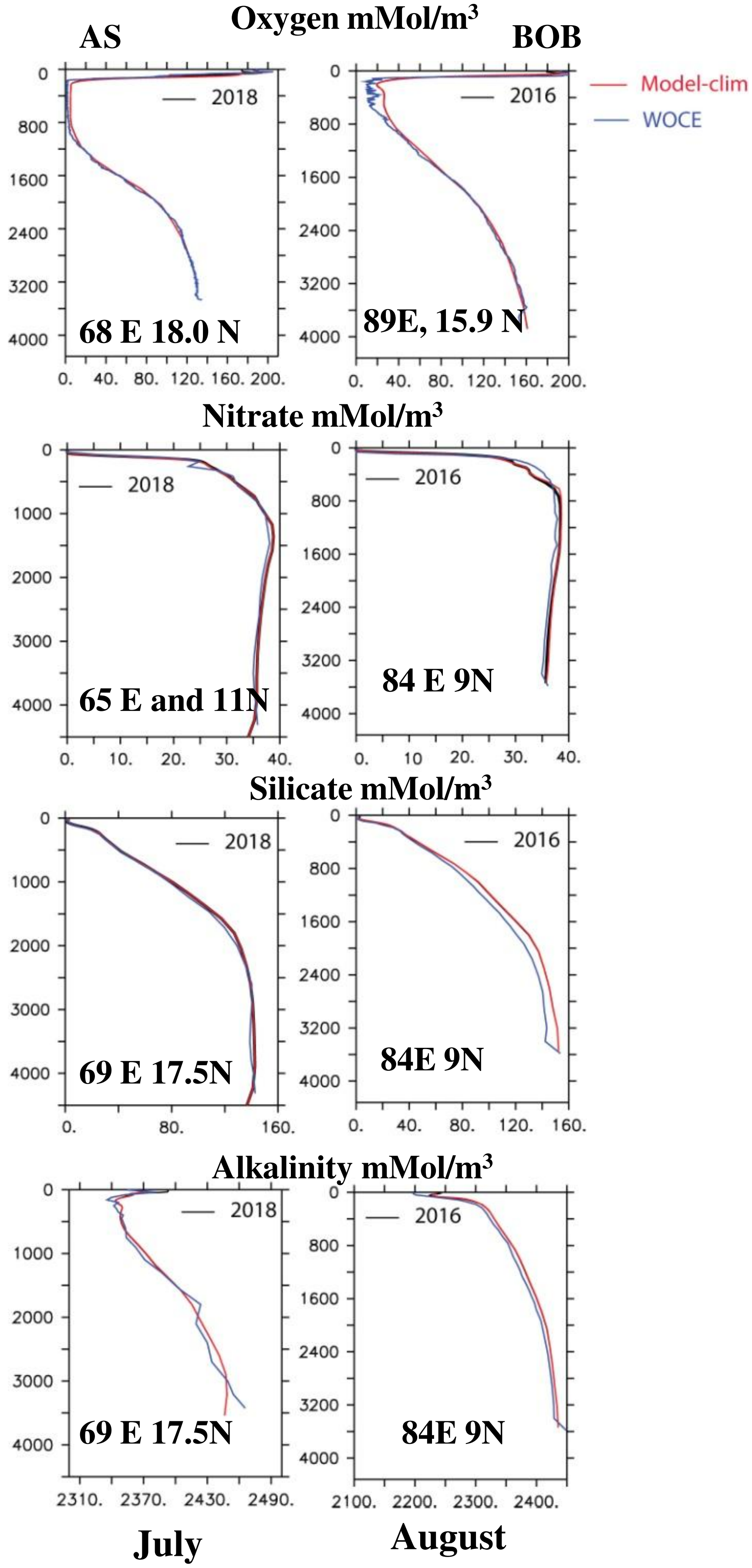


Figure 4.1: Validation of model results with WOCE sections in Arabian Sea and Bay of Bengal.

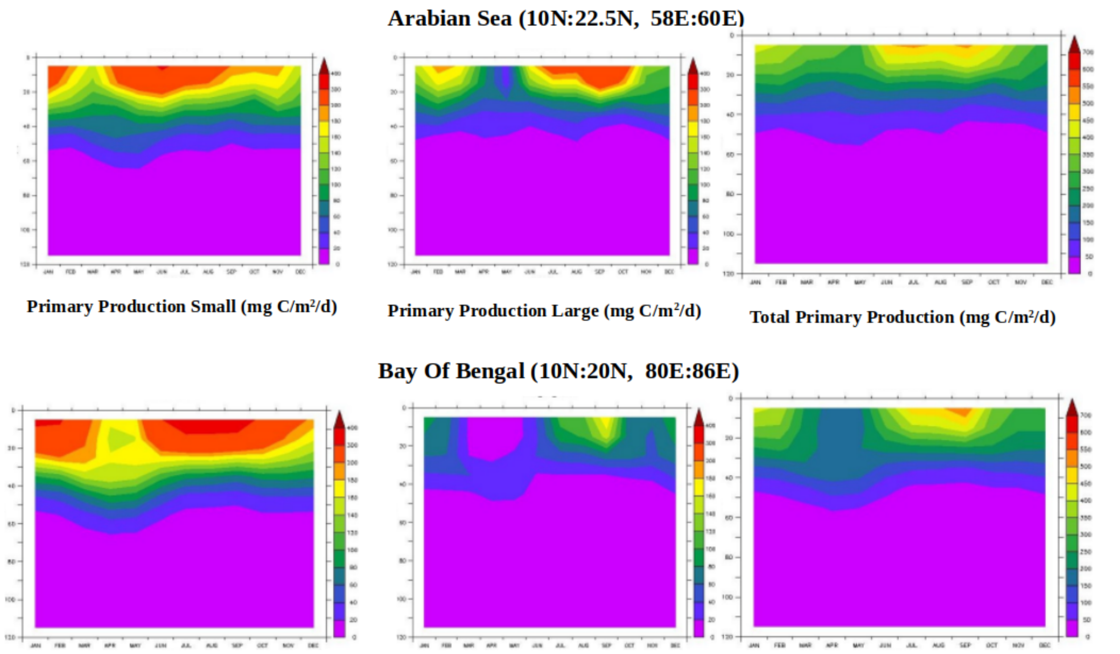


Figure 4.2: Monthly variation of Primary Productivity due to Large Phytoplankton (PP-L: mg C/m^2/d), Small Phytoplankton (PP-S: mg C/m^2/d) and Total Primary Productivity (PP: mg C/m^2/d) with respect to depth for two regions, one each in Arabian Sea and Bay of Bengal.

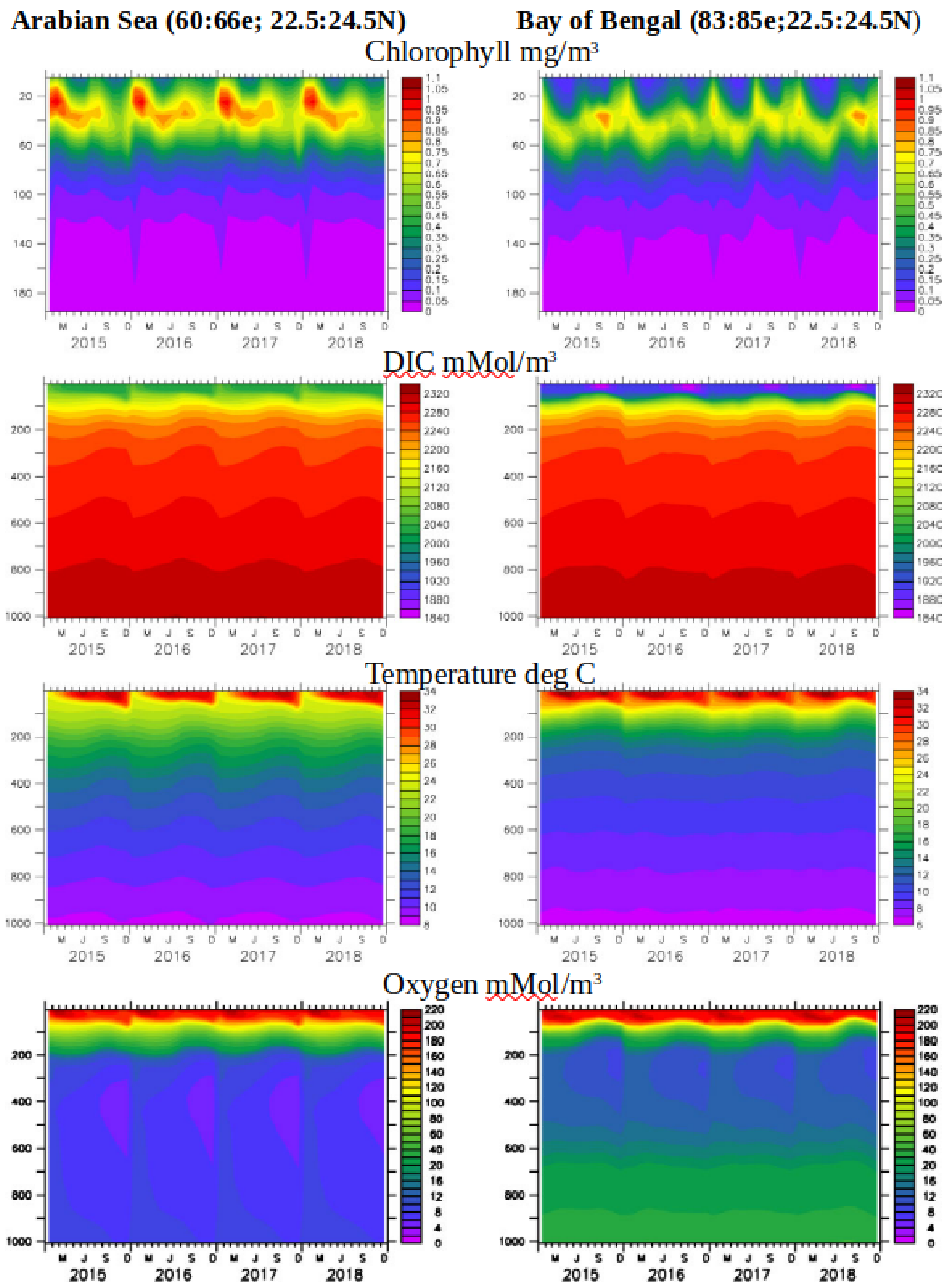


Figure 4.3: Monthly variation of Chlorophyll (mg/m^3), Dissolved Inorganic Carbon (mMol/m^3), Temperature (deg C) and Oxygen (mMol/m^3) with respect to depth during 2015-2018 for two regions, one each in Arabian Sea and Bay of Bengal.

4.2 Changes in sea surface temperature variability over six post-WWII decades

Sea Surface Temperature (SST) is one of the most important climate parameters. Apart from being a major determinant of average global surface temperature rise, its year-to-year variations in sensitive regions, such as Central and East Equatorial Pacific Ocean associated with ENSO, influence rainfall over far flung regions. We have compared variance of SST anomaly over two tri-decadal periods in the post-WWII era to study the effect of ocean warming on inter-annual variability of SST. We have also given a new method to decompose an annual cycle into three orthogonal parts: annual mean, low frequency (LF, periods: 4-12 months) and high frequency (HF, periods: 2-3 months) components.

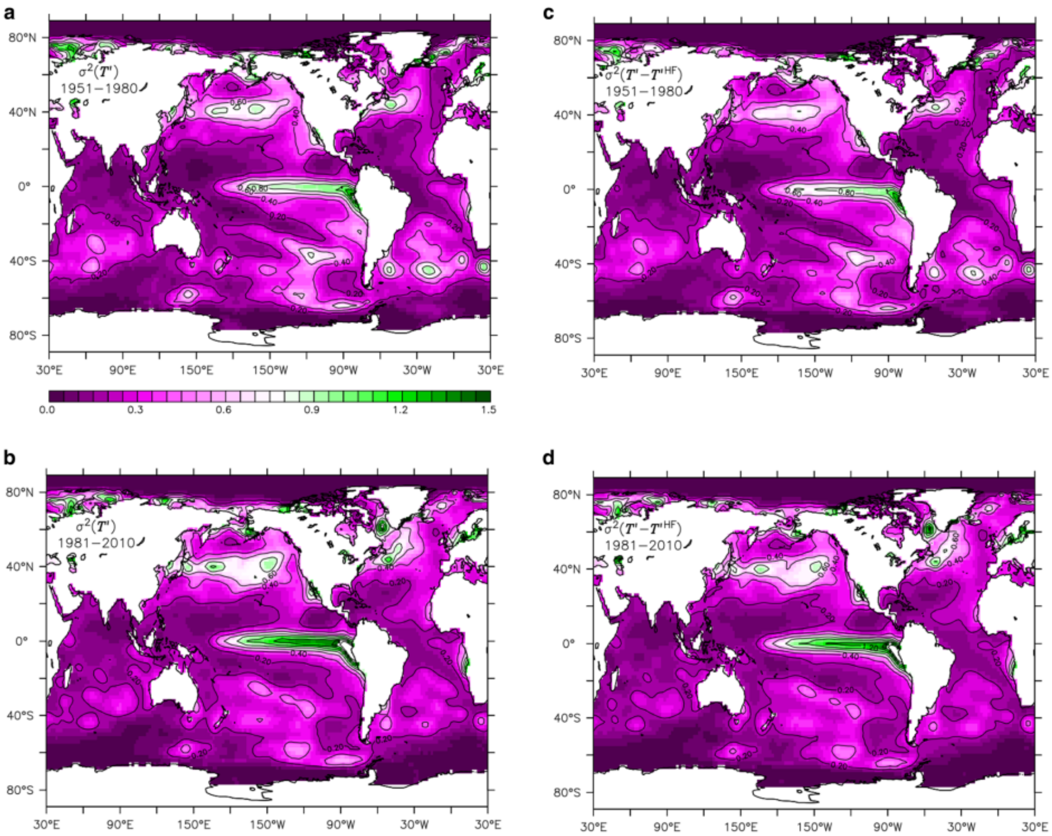


Figure 4.4: Changes in Sea Surface Temperature Anomaly Variance (in $^{o}C^{2}$) from 1951-1980 (a) to 1981-2010 (b). Filtering out the HF component reduces the variance, but leaves its spatial distribution and change overtime largely unchanged (c and d). Calculations are based on global monthly SST dataset ERSSTv5.

We have identified sixteen oceanic regions of high variability, which are clustered in four latitudinal bands: 2 in the Equatorial Cluster (EC), 4 each in Northern and Southern Midlatitude Clusters (NC & SC) and 6 in Arctic Cluster (AC). The largest increase in

SSTA variance occurs in EC and the largest decrease in SC, while AC has the most diverse changes. Apart ffar flung-connection effects on precipitation in distant areas, these changes have local and regional consequences on marine ecosystems, fishing and, in high latitudes, on shipping. Further information can be found in J. Earth Syst. Sci. (2021), 130 144. K S Yajnik, C Kalyani Devasena.

K.S Yajnik

4.3 Measurement and analysis of greenhouse gases

The emissions to the atmosphere pose a significant threat to human health, ecosystems and the global climate, though in a less visible and immediate way. The layer of Greenhouse Gases (GHG), including carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and others, in their optimum concentration in Earth's atmosphere, acts like a protective blanket which maintains its temperature and the natural ecosystem.

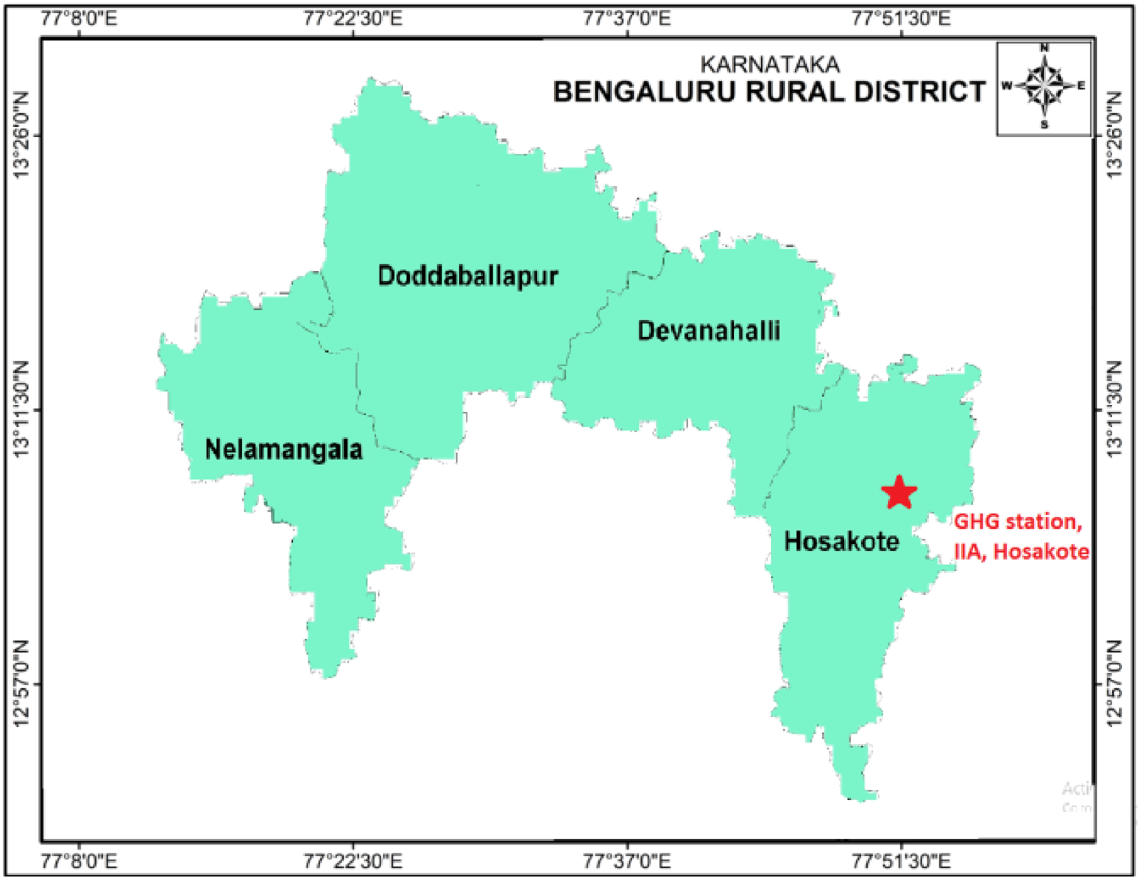


Figure 4.5: Location of Green House Gas station at IIA Hosakote.

In this direction, CSIR-4PI institute has taken initiative to setup stations for continuous measurement of major GHG species such as CO2, CH4 and N2O in collaboration with

IIA - Hosakote, IOA - Hanle, Pondicherry University and NIOT - Port Blair to conduct intensive research on the atmospheric and oceanic parts of the carbon cycle. The discrete sampling is also ongoing through flask measurement to validate continuously measured data; the samples are analyzed by international collaborator. The measurement of data collected are as per WMO standard, the measured data are processed through standard techniques and corrected as per international standards using calibration gases.

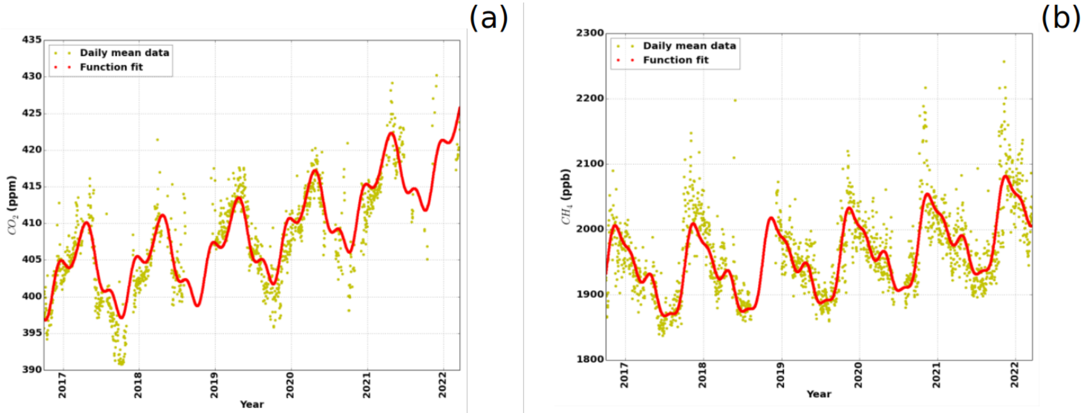


Figure 4.6: Time series data of (a) Carbon dioxide and (b) Methane emissions (Dailfar flungat Hosakote, Karnataka (Oct 2016- Mar 2022).

The IIA, Hosakote campus is located in the district of Bangalore rural with 12.9265^{0}N, 77.6213^{0}E as shown in Figure 4.5. This region may be highly influenced by air pollution from urban regions of Bangalore city and local emissions from places surrounded by Hosakote.

The measured values of Carbon dioxide, Methane emissions species were presented in time series for the period October 2016 to March2022 with considering daily average values for Hosakote region (Figure 4.6). It's been observed, the average value of Carbon dioxide emission is 433.92 ppm with maximum variation of 433.92 ppm, minimum value dropped down to 387.21 ppm. Similarly, average value of Methane emissions observed to be 1966.43 ppb with maximum value shoot up to 2257 ppb. The database generated shall be used to identify sources and sinks of anthropogenic carbon in the western part of Bangalore rural district using advanced inverse modelling techniques.

Iranna Gogeri, Ravichandran C, Sumathy T and Sunil Babu M G

4.4 Assessment of Aerosol Optical Depth over Indian Subcontinent during COVID−19 lockdown (March - May 2020)

The COVID-19 pandemic has created a major threat to human beings and huge losses over the globe. In order to control the pandemic spread, almost all parts of the world imposed lockdown. The imposed lockdown drastically impacted on reduction in the atmospheric pollution and also resulted in net decrease in aerosol optical depth (AOD) in the atmosphere. In this study, the reduction in the AOD during the COVID-19 lockdown over the Indian subcontinent is being assessed using the moderate resolution imaging spectro-radiometer (MODIS) satellite data available in Giovanni version 4.34 developed by NASA.

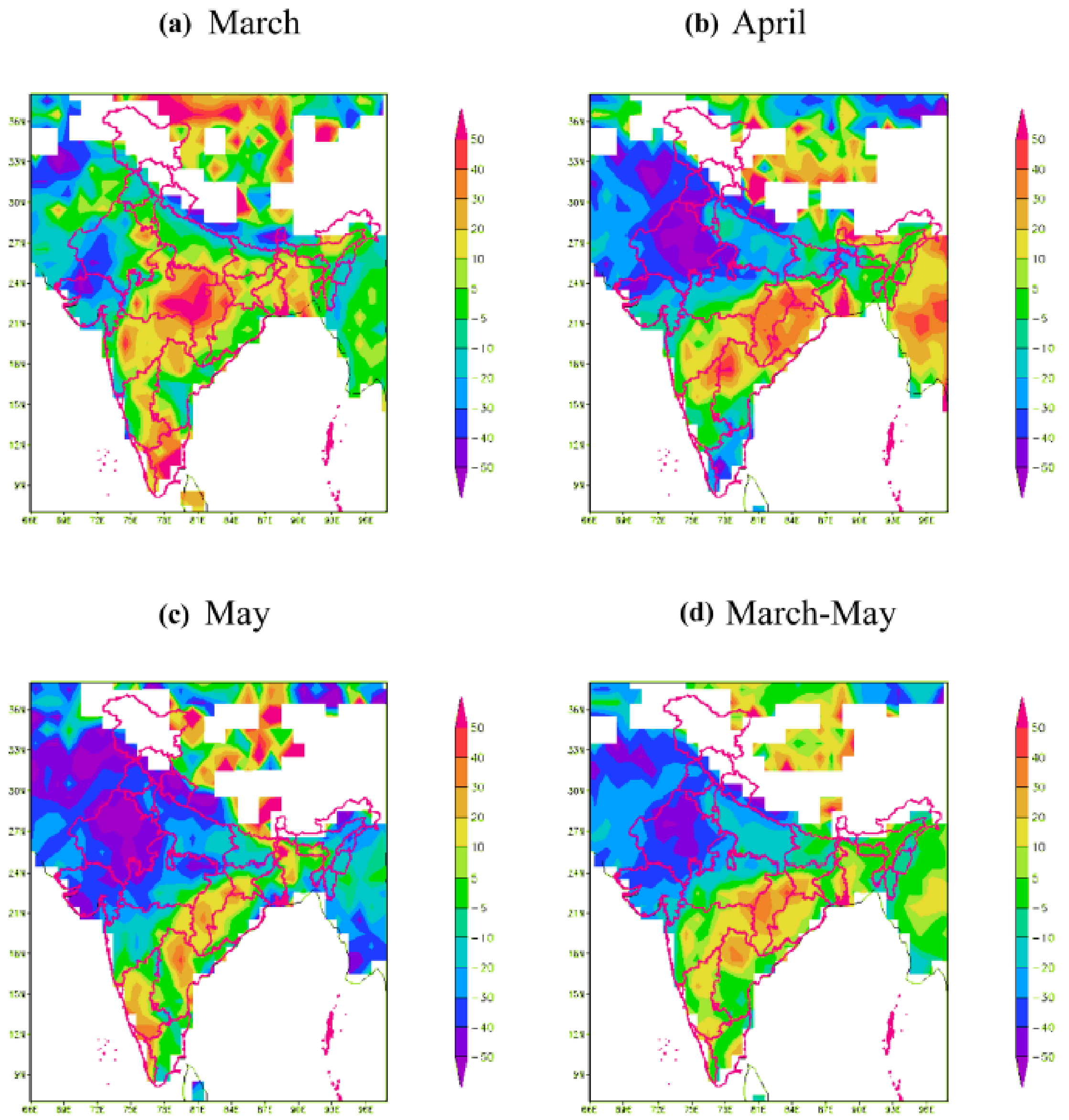


Figure 4.7: Monthly AOD anomaly (expressed as % of long-term mean) during year 2020 over Indian subcontinent for the year 2020 (a) March, (b) April, (c) May and (d) summer [March−May].

The long-term mean analysis is computed considering 20 years (i.e., 2000-2019) data on Terra platform with a temporal resolution of daily and monthly and spatial resolution of

1 degree. The dataset of AOD with a temporal resolution of monthly was used for investigation of AOD anomaly for March, April and May 2020, and the seasonal variation (March to May 2020) is also assessed. Similarly, the daily scale dataset was used to investigate the percentage change in AOD during pre-lockdown and lockdown period with respect to long-term mean. The key findings in the present study show that reduction in AOD level over Indian subcontinent is approximately 14.75% during the lockdown period with spatial variation in the magnitude from region to region. The level of AOD is greatly reduced in the northern part of India ($\sim$ 22.53%), whereas changes in the southern part of India are much less ($\sim$ -0.31%); this may be due to ongoing anthropogenic activities during the lockdown period in this region. Furthermore, a positive AOD anomaly was observed in the eastern and central regions of India (i.e., over the states of Odisha, Chhattisgarh, Telangana, Jharkhand, West Bengal, Part of Maharashtra and Karnataka). However, negative AOD anomaly was observed in the north and northwest regions of India, whereas not much change in the AOD anomaly in other parts of the country. The overall assessment of the AOD level shows a net decrease over the Indian subcontinent during the lockdown period, i.e., March to May 2020. This kind of assessment study will surely help the government for the sustainable policy decisions for atmospheric pollution control by implementing proper lockdown procedures over various parts of the country.

The variation AOD anomaly level in the month of March 2020 which represents the phase 1 lockdown (only 10 days) in India shows a reduction in AOD level across the nation except for few states like Madhya Pradesh, Maharashtra and some parts of Telangana, Chhattisgarh, Odisha, Karnataka, Tamilnadu, Rajasthan and West Bengal. During the month of April 2020, when the phase 2 lockdown has been strictly imposed for a whole month, the AOD level has been further reduced with respect to the long-term mean as compared to the level of AOD during the previous month. However, increase in the AOD level was observed across southeastern and northeast states during April 2020 as shown in Figure 4.7.

Krushna Chandra Gouda, Iranna Gogeri and Aruna Singanahalli Thippa Reddy*

* CSIR National Aerospace Laboratories, Bangalore.

4.5 New dynamical framework for the prominent low frequency events in the Tropical Pacific

The qualitative and quantitative definitions of El Niño-Southern Oscillation (ENSO) continue to challenge climate scientists. Much research has been conducted to compare and contrast El Niño events in the Eastern Pacific (EP) and Central Pacific (CP) and to understand how ENSO might change in response to greenhouse warming. The signals of ENSO extracted in the previous studies, with a few exceptions, are based on anomalies with respect to the mean annual cycle (i.e, traditional anomalies). This approach ignores the need to account for year-to-year changes in the characteristics of leading seasonal modes. Moreover, the precise physical reasoning to fix a base period to define anomalies that would help physically contextualize ENSO's natural variability with global warming is absent. This study examines the prominent low-frequency variability by allowing interannual amplitude modulation of annual cycles (ACs). For this purpose, the necessary

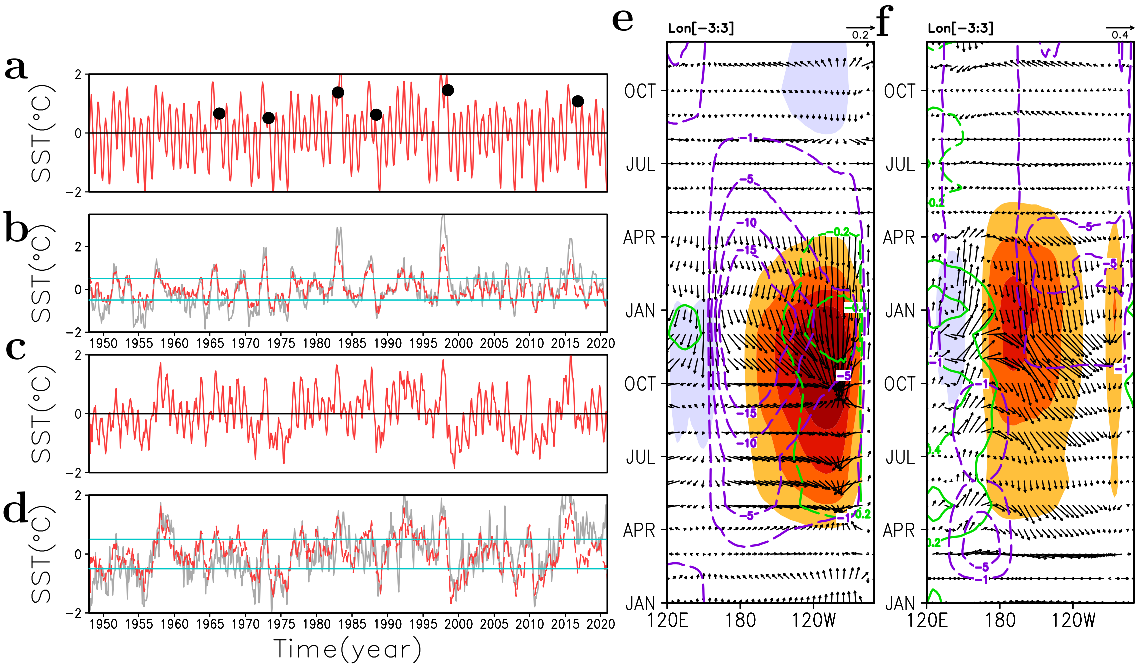


Figure 4.8: The area-averaged time series in the eastern equatorial Pacific (a and b), and the north-eastern Pacific (c and d). The time series for SST-AC3 and SST-AC4 are shown in a and c, respectively. The time series of their area-averaged anomaly are the red lines in b and d. These deviations from the mean ACs of SST-AC3 and SST-AC4 are denoted as SST-AC3a and SST-A4a, respectively. The time series estimated from the traditional anomaly are the gray lines in b and d. The solid circles in the panel a indicate the years of positive-mergers. The latitudinal averages of composite-means of AC3a (e) and AC4a (f) warm events are shown in the Time-Longitude planes. SST in shades, wind as vector, negative OLR in purple contours and positive (negative) SLP as green continuous (dashed) contours. Units of SST, wind, OLR, and SLP are ^{o}C, m sec^{-1}, Watts m^{-2}, and hPa, respectively.

diagnostics for extracting multiple (i.e., four) ACs of each of the five climate variables have been implemented. In this context, anomalies are the deviations from each of the four long-term mean ACs. We show that all interannual warm/cold events in tropical Pacific regions are abnormal modulations of the amplitudes of the third and fourth ACs of sea surface temperature (SST) with their significant variances in the EP and CP regions, respectively (Figure 4.8). A strong El Niño happens when the positive amplitude modulations cause the overlap of two consecutive positive phases of the third AC of SST. The absence of such overlaps during the negative amplitude modulations contributes significantly to the positive skewness of SST anomalies. The decadal changes in their zonal propagation characteristics are more random than systematic. Thus, these results confirm that the warm/cold events in EP and CP are dynamically linked to two distinct ACs. This disentanglement of low-frequency variability of different dynamical origins has clarified warm/cold events' identifications and co-varying spatio-temporal characteristics among the examined variables. An overriding insight culled from these simple analyses is that the same sets of physical and dynamical processes drive both the ACs and ENSO. As a result, the dynamics of annual cycles should always be explicitly included in statistical analysis and conceptual or theoretical modelling of ENSO.

Rameshan Kallummal

4.6 About eighty percent of the tropical Indian Ocean surface would warm above 28^{O}C by 2070

In recent years, the Indian Ocean region has seen major shifts in weather patterns and climate variations. The warming of the Indian Ocean surface at a higher rate than other oceans is an important driver of such changes. If this warming continues unabated, the Intergovernmental Panel on Climate Change report warns, the region will witness a further rise in local cyclones, extreme rainfall, and sea levels. We show that the observed surface temperature (ST) in the tropical Indian Ocean has monotonically warmed about one degree centigrade since 1950.

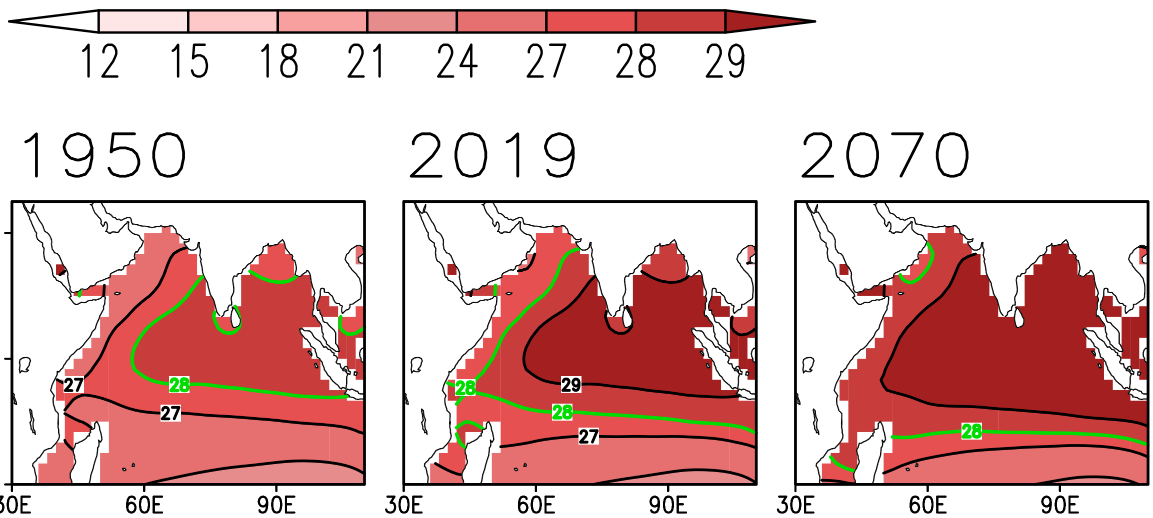


Figure 4.9: Spatial patterns of secular warming mode (SWM) extracted, by Nonlinear Laplacian Spectral analysis algorithm, from Sea Surface Temperature observations: Annual-means for 1950 and 2019 . To identify Indian Ocean Warmpool, the 28^{o}C isotherms are shown in green contour. The predicted pattern for the year 2070 is also shown.

Concurrently, the observed Indian Ocean Warm Pool (IOWP) - the region where ST exceeds 28^{0}C - has expanded non-linearly (Figure 4.9, green contours in panels 1950 and 2019). By 2070, the projected estimates of these warming trends show that the IOWP would cover about 80 percent of the tropical Indian Ocean at the present latitudinal expansion rates (Figure 4.9, green contour in panel 2070). Irrespective of the season, the ST near Indonesia would remain above 31^{0}C by 2080 and beyond. As a result, the Indian Ocean is expected to play a larger role in future climate change.

Rameshan Kallummal

4.7 New ocean-atmosphere coupled mechanism that sustains the secular expansion of the Indian Ocean Warm Pool

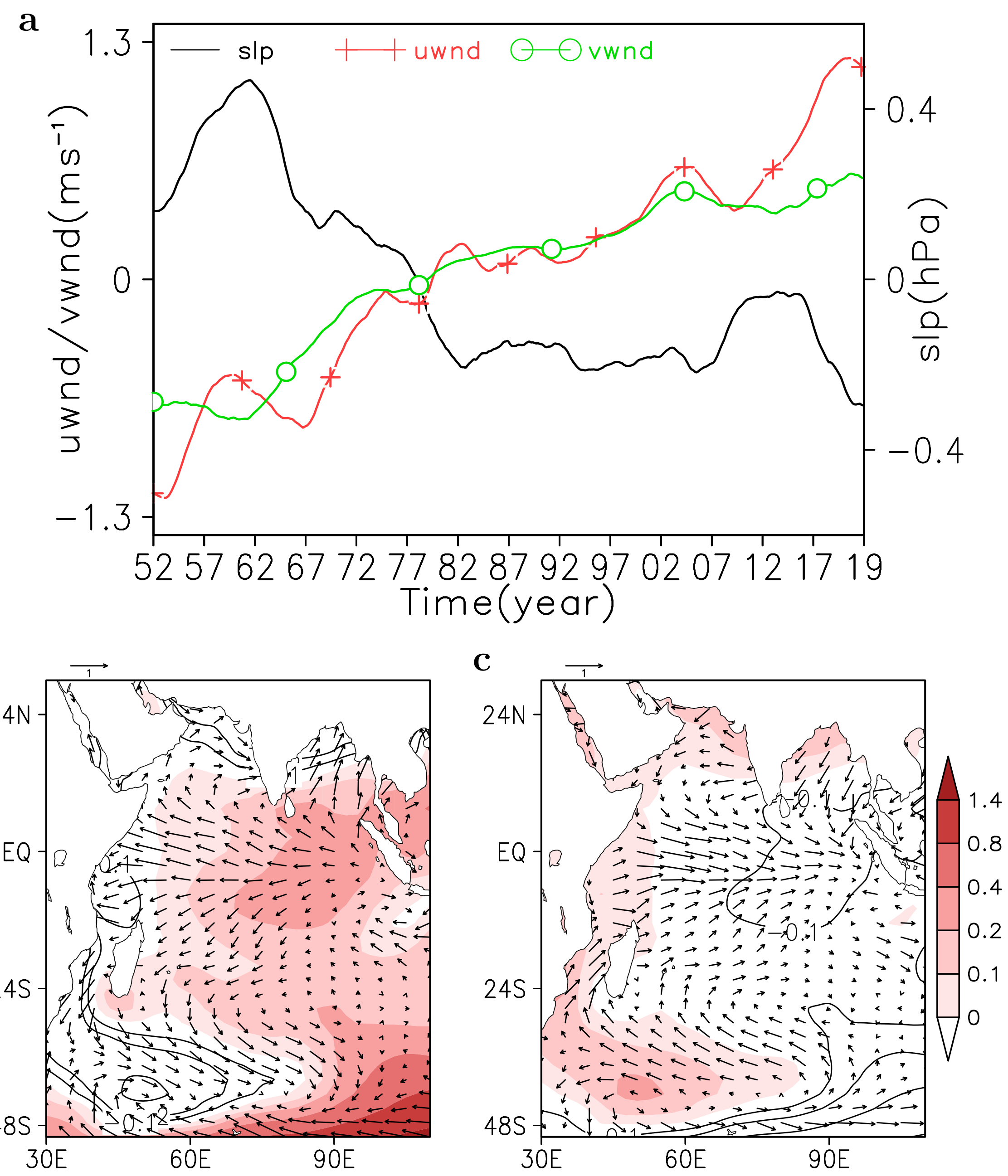


Figure 4.10: Area-average time series of non-linear secular modes in the regions of large Theil-Sen slopes (a): SLP (85^o-95^oE, 6^oS-4^oN); UWND: (50^o-60^oE, 6^oS-4^oN); VWND: (34^o-42^oE, 30^o-20^oS). Time-mean spatial patterns of secular modes of SLP (shades) and wind vector (b) for 1952-1971. The panel c same as panel b, but for 2000-2019. Shades represent positive values and lines indicate negative values.

The co-variations between the secular signals of wind and sea level pressure (SLP) indicate that the ocean-atmosphere coupled interactions support the expansion of the Indian Ocean Warm Pool (IOWP) by rising SST preferentially in the eastern tropical IO (Figure 4.10). This rise would enhance local atmospheric convection, thereby resulting in a further decrease of SLP over IOWP. The resultant increase in the SLP zonal gradient would intensify equatorial westerlies further. The intensification of equatorial westerlies, by the equation of continuity, should draw more surface air from both hemispheres. Thus, the convergence of meridional winds over the equator also increases. These dynamics, through wind-induced advection of SST and suppression of upwelling, further enhance equatorial SST. In the northern IO, SST changes could also be related to the weakening of latent heat fluxes. The opposite trends of SST (not shown) and the overlying SLP (Figure 4.10)a, black line) suggest that the surface temperature gradients drive low-level convergence. As the nonlinear decomposition is done separately on each of the variables, the dynamically coupled variations are not mathematically coerced. Thus, under global warming, IO is slowly shifting toward the state of northern summer, particularly so within the narrow tropical region spanning from 10^oS to 10^oN.

Rameshan Kallummal

4.8 Assessing ISM circulation characteristics and moisture source indices in a changing climate: insight from a ultra high resolution HighResMIP CMIP6 climate scenario

Under the global warming scenario, the increased land-ocean temperature contrasts, and the low-level monsoon circulation anomalies have a concomitant impact on the enhanced precipitation activities over the Indian subcontinent. Thus, assessing the Spatio-temporal changes in low-level circulations and associated moisture source indices under the present and future projected climate scenario, at a higher spatial scale, is a prerequisite for understanding the dynamics behind the regional precipitation extremes during Indian Summer Monsoon (ISM) seasons .One of the major components of ISM is the transport of integrated water vapour (IWV) through zonal and meridional circulations (vertically integrated moisture flux transport, VIMF) which greatly affects the distribution of rainfall patterns and the associated moisture budgets over Indian monsoon regimes.

The main goal of this study is to assess the climatological characteristics and the interannual variability of the low-level wind circulation indices, vertically integrated moisture flux, and moisture transport indices over the ISM moisture-sources region (15^oS45^oN, 40^oE120^oE) for the present climate (1980-2010) as well as for the future periods (near-future: 2026-50; far-future: 2075-90).

The MRI-AGCM3.2S (resolution $\sim$20 km) global climate model outputs from the CIMIP6 under HighResMIP (High-Resolution Model Inter-comparison Project) experiments (hereafter referred to as HMIP-20K) are used in this analysis. The wind and moisture transport indices have been formulated based on 850 Mb level zonal and meridional wind components: IWV, VIMF, and vertically integrated moisture transport divergence (VIMD) over various moisture-source regions over the ISM domain. The HighResMIP configuration has been applied to generate realistic climate simulations; validation has been done against ERA5 reanalysis data.

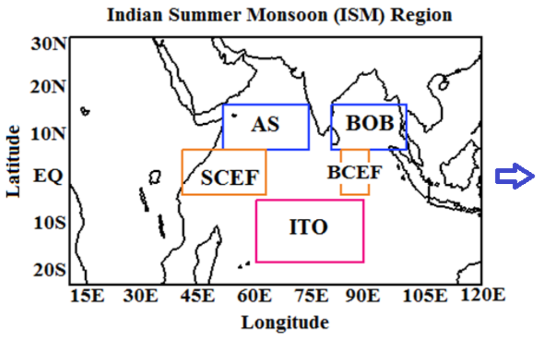


Fig. 1a

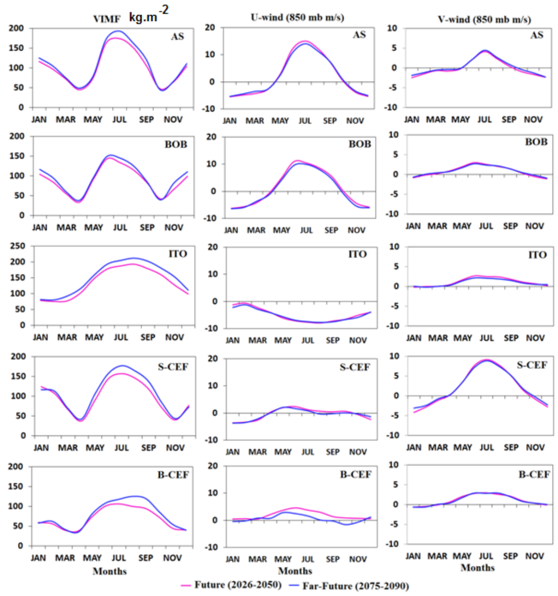


Fig. 1b

Figure 4.11: The study area (Indian Summer Monsoon, ISM domain) with five moisture source regions viz. Arabian Sea (AS, 5^{o}-15^{o}N, 48^{o}-78^{o}E), Bay of Bengal (BOB, 5^{o}-15^{o}N, 80^{o}-100^{o}E), Somali CEF (SCEF, 5^{o}S-5^{o}N, 40^{o}-62.5^{o}E), Bay of Bengal CEF (BCEF, 5^{o}S-5^{o}N, 82.5^{o}-90^{o}E) and Indian Trade Ocean (ITO, 20^{o}-5^{o}S, 60^{o}-90^{o}E).Fig.1b Projected mean seasonal cycle of vertically integrated moisture flux transport (VIMF, 1stcolumn, kg.m^{-2}), the zonal component of winds at 850 hPa level (2ndcolumn, m/sec) and the meridional component of winds at 850 hPa (3rdcolumn, m/sec) from ultra high resolution (20 KM) climate simulations from HMIP-20K for near-future (purple line) during 2026-2050 and for far-future (blue lines) periods through 2075-2090 over moisture sources regions of Arabian Sea (AS, 1st row), Bay of Bengal (BOB, 2nd row), Indian Trade Ocean (ITO, 3rd row), Somali cross-equatorial region (SCEF, 4th row) and the Bay of Bengal cross- equatorial flow region (BCEF, 5th row).

The simulations and the projections from HMIP-20K are used to understand the vertically integrated moisture flow over the ISM region, focusing on the monsoon sources regions (AS, BOB, ITO, SCEF, and BCEF) during the present climate (1980-2010) and towards the middle and end of the 21st century; (2026-2050) and (2071-2100). Overall, the HMIP-20K model have simulated the mean moisture transport and wind circulation indices reasonably well over the ISM domain.

4.9 Experimental Indian summer monsoon hindcasts by the National Monsoon Mission Model on CSIR-4PI HPC Anantha: Initial condition dependence of forecast skill

We were funded for a project under the Phase-II of the National Monsoon Mission Programme by the Ministry of Earth Sciences (MoES), Government of India, to contribute to improving the prediction of year-to-year variation of all India summer monsoon rainfall (ISMR) by the National Center for Environmental Prediction (NCEP) Climate Forecast System version 2 (CFSv2) model. The MoES selected CFSv2 as the national prediction model. We set up CFSv2 ensemble prediction system on CSIR-4PI HPC, Anantha and carried out experimental hindcasts/reforecasts (referred to as CFSv2-CSIR reforecasts).

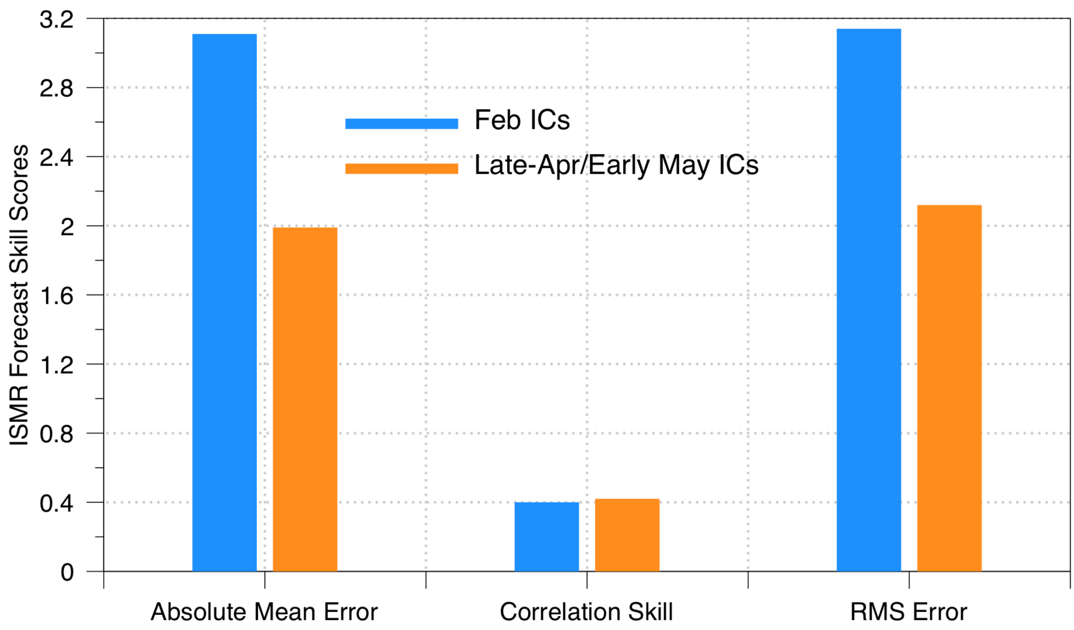


Figure 4.12: Three forecast skill scores comparing the skill of CFSv2-CSIR reforecasts with Feb (blue bars) and Late-Apr/Early-May (orange bars) initial conditions (ICs) during the hindcast period of 1982-2010.

Prediction for ISMR is generated by integrating CFSv2 from initial conditions (ICs) of weather at some time prior to the monsoon season. We examined the factors responsible for the widely reported highest ISMR forecast skill for February ICs in CFSv2-CSIR reforecasts. Skill for February ICs is the highest only based on the correlation between observed and predicted year-to-year variation of ISMR, whereas other skill scores indicate the highest skill for late-April/early-May ICs having shorter yet useful forecast lead-time (Figure 4.12). Higher correlation for February ICs arises from correct forecasting of 1983 ISMR excess, which is however due to the wrong forecast of La Niña and correlation drops to a lower value than that for late-April/early-May ICs if 1983 is excluded. Forecast skill for sea-surface temperature (SST) variation over equatorial central Pacific (ENSO) in Boreal summer is lowest for February ICs indicating the role of dynamical drift induced by long forecast lead-time. Model deficiencies such as oversensitivity of ISMR to ENSO and unrealistic ENSO influence on the variation of convection over the equatorial Indian Ocean lead to errors in ISMR forecasting. In CFSv2, ISMR is mostly decided by ENSO whereas in observation it is influenced by ENSO and variation of convection over the equatorial Indian Ocean independently. Thus, to achieve accurate ISMR forecasting, it is essential to improve CFSv2 physics schemes with an aim of minimizing the errors in forecasting ENSO and variation of rainfall over the Indian Ocean.

K. Rajendran, Sajani Surendran, Stella Jes Varghese & A. Chakraborty*

* Indian Institute of Science, Bangalore.

4.10 Earth System Model century simulations on CSIR-4PI HPC Anantha: Representation of monsoon active-break cycle

We have implemented the Community Earth System Model (CESM) version 1.2.2 (CESM 1.2.2) of the National Center for Atmospheric Research (NCAR) on CSIR HPC, Anantha. This model contains the Community Atmosphere Model version 5.3 (CAM5.3) as the atmospheric component. CAM5.3 includes a detailed Modal Aerosol Module that parameterizes the aerosol size distribution using seven log-normal modes of Aitken, accumulation, primary carbon, fine soil dust, fine sea salt, coarse soil dust and coarse sea salt, each having an internal mixture of a set of fixed chemical species.

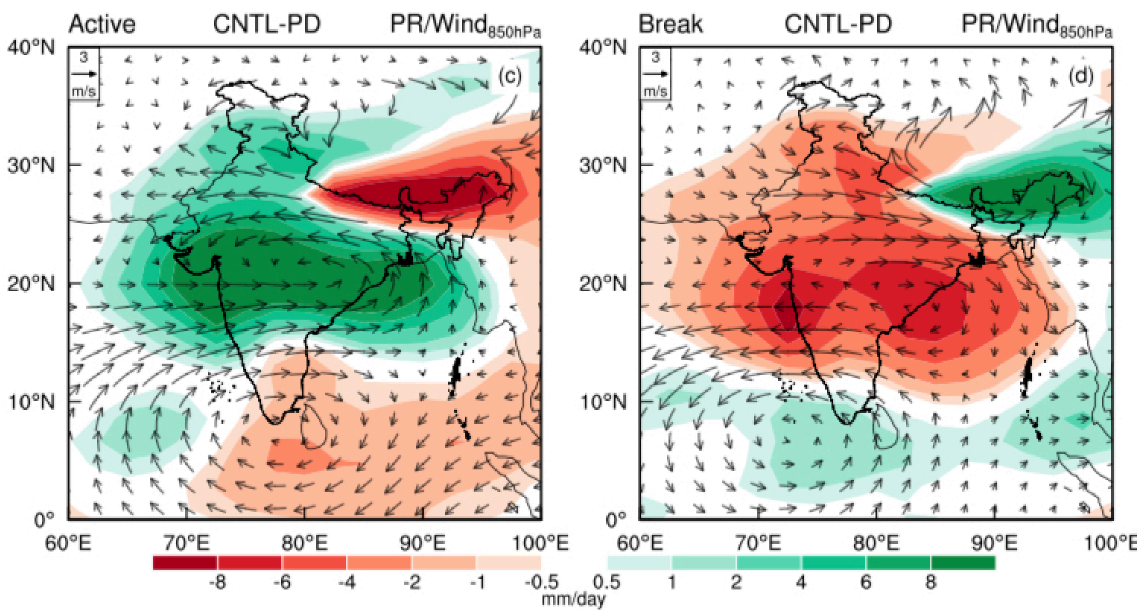


Figure 4.13: Composite anomalies of rainfall and 850 hPa wind vectors during active (left panel) and break (right panel) spells of Indian summer monsoon from CESM control simulation with present-day emissions, CNTL-PD.

As per the mode, MAM7 simulates the mass mixing ratios of internally mixed sulfate, ammonium, primary organic matter, secondary organic matter, black carbon, soil dust, and sea salt. The simulated aerosols are allowed to interact with radiation representing the aerosol direct and semi-direct effects. MAM7 accounts for aerosol processes viz. emission, nucleation, coagulation, condensational growth, water uptake, in-cloud and below-cloud scavenging, gas and aqueous phase chemistry, dry deposition and gravitational settling, and production from evaporated cloud and rain droplets.

The control simulation of 100 years duration after spin-up, is performed using the fully coupled CESM (hereaafter referred to as CNTL-PD). The CNTL-PD used year-2000 aerosol emissions representing the industrial period or the present-day. Emissions for this experiment are from the IPCC AR5 emission data set. The CNTL-PD shows marked fidelity in capturing major characteristics of rainfall, circulation, aerosol and cloud properties during the active and break phases as seen from their composite anomalies (Figure 4.13). This simulation is analyzed to understand the aerosol impact on the monsoon along with additional aerosol climate experiments.

Sajani Surendran, K. V. Ajay Anand, Suraj Ravindran* and K. Rajendran
* Indian Institute of Technology, Delhi.

4.11 Dynamical downscaling framework for climate change projections on CSIR-4PI HPC Anantha: Resolution impact on monsoon projections

High-resolution regional climate model (RCM) simulations are found to be very useful in deriving realistic climate change projection information. We used a high-resolution dynamical downscaling framework for India implemented in CSIR-4PI HPC, Anantha (hereafter referred to as CCSM4-WRF). To delineate the advantage of high resolution, we compared the results of 9-km resolution CCSM4-WRF simulations against the 50-km resolution RCM simulations under the Coordinated Regional Climate Downscaling Experiment-South Asia (CORDEX-SA) program. Quantitative estimations show that the majority of CORDEX-SA models exhibit large dry bias (< -4 mm/day) and low pattern correlation coefficient (PCC) over the Western Ghats (WG). Mean climatology of Indian summer monsoon (ISM) rainfall simulated by high-resolution CCSM4-WRF outperforms the CORDEX-SA RCMs with low negative biases ($\sim$1 mm/day) and high PCC ($\geq$0.755). This skill of CCSM4-WRF provides better confidence in its future projection at the local scale.

CCSM4-WRF projects future intensification of monsoon rainfall over most parts of India and reduction over southern WG, which is consistent with recent observed trends, but none of the CORDEX-SA RCMs could simulate this rainfall reduction. For all-India rainfall, the ensemble mean of CORDEX-SA models projects an increase of 1.3 $\pm$ 0.9 mm/day and CCSM4-WRF projects 0.67 mm/day. We estimated the projected changes of mean summer monsoon rainfall at the end of the twenty-first century over homogeneous regions of India, based on the MME of 14 CORDEX-SA models, along with intermodal spread as well as CCSM4-WRF (Figure 4.14). The projected changes by comparatively

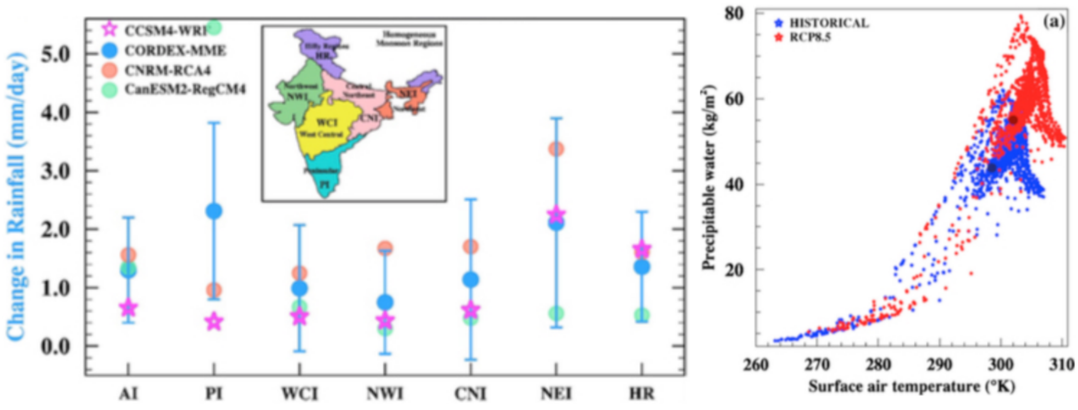


Figure 4.14: (a) The projected changes in Indian summer monsoon rainfall for all-India average and different homogeneous zones of India (left panel). (b) CCSM4-WRF simulated mean summer monsoon precipitable water (kg/m2) over all the grid points over India plotted against the corresponding surface air temperature (řK) for the present-day (historical) and future (RCP8.5) scenarios. The values averaged over all the grid points of India for the present-day and future are represented by large blue and red filled circles respectively.

skilful CORDEX-SA models (such as CNRM-RCA4 and CanESM2-RegCM4) are also shown in Figure 4.14a. MME projects an overall rainfall enhancement over all the homogeneous regions but exhibits considerable intermodel spread over most of the regions.

It is known that future warming leads to an enhancement in the atmospheric water vapour content. Hence, the projected future changes in atmospheric water vapour content were examined using the CCSM4-WRF simulated precipitable water (PWAT in kg/m^2). Figure 4.14b shows the CCSM4-WRF simulated mean summer monsoon PWAT over India against the corresponding surface air temperature (T2m in ^{0}K) for present-day (historical) and future (RCP8.5) scenarios. The filled circles represent the respective values averaged over India. There is a clear increase in the future PWAT (from 43.84 kg/m2 in the present-day to 54.97 kg/m^2 in future) along with the increase in air temperature (from 298.52^{0}K to 302.03^{0}K), i.e., an average of 3.5^{0}K increase in T2m leads to a PWAT increase of 11.13 kg/m^2.

Projected changes in socioeconomic variables such as population and gross domestic product (GDP) exhibit future enhancement over most parts of India but with spatial heterogeneity. Shared socio-economic pathways scenarios show pronounced future population growth over Indian coastal areas and large enhancement in productivity over urban areas. Therefore, climate change projection information of ISM rainfall, together with enhanced future population and GDP, is useful for taking necessary steps for adaptation and mitigation in a sustainable manner.

K. Rajendran, Sajani Surendran and C. B. Jayasankar*
* Florida State University, USA

4.12 Global cloud-resolving model (GCRM) simulation of semidiurnal variation of rainfall

General circulation models (GCMs) or global climate models exhibit difficulties in capturing the diurnal and semidiurnal variation of rainfall over the tropics. In GCMs, the improper representation of the diurnal/semidiurnal cycle affects the surface water balance and shortwave cloud forcing. The major reason for this inability is the inaccuracies in the representation or parameterization of the deep convection in GCMs. A finer mesh non-hydrostatic model with explicit cloud processes is one way to overcome this problem.

We have employed a 3.5-km-mesh Nonhydrostatic Icosahedral Atmospheric Model (NICAM), a global cloud-resolving model (GCRM), to improve the simulation of the diurnal modes in terms of the entrainment rate by focusing on the representation of the transition of continental convection from shallow to deep. NICAM was configured to run with an explicit cloud microphysics scheme using a mesh size of a few kilometers without using a cumulus parameterization scheme. The cloud microphysics scheme is a simple three-category scheme in which airborne and precipitating hydrometeors are prognostic variables. Cloud ice and snow are diagnosed by the temperature-dependent ratio between liquid and ice phases from airborne and precipitating hydrometeors. NICAM was integrated for a week coinciding with the period of an active MJO (Madden-Julian Oscillation) event. NICAM simulation is compared with data from Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI), Precipitation Radar (PR), and Global Satellite Mapping of Precipitation, as well as infrared data from geostationary satellites.

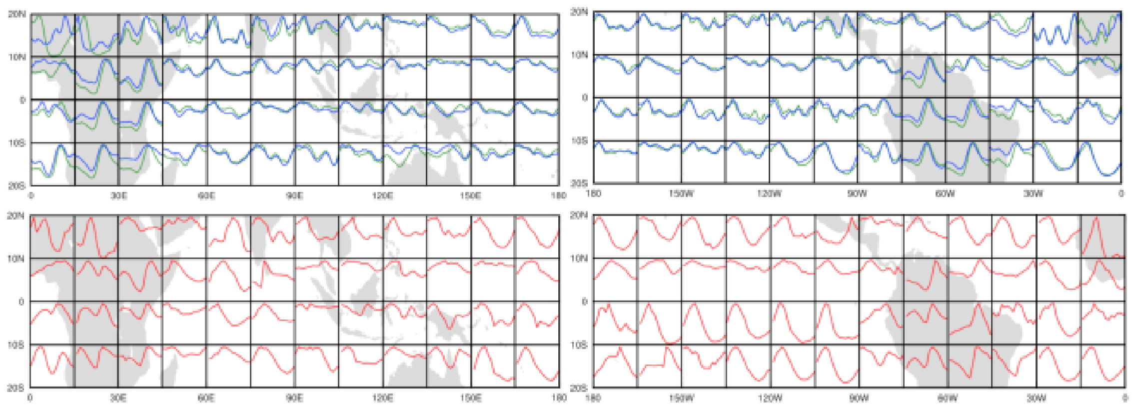


Figure 4.15: (a) Map of the daily time series of mean rainfall over the 10^0x15^0 latitude-longitude grid boxes over the tropics constructed from the TMI (green) and PR (blue) satellite observations (top panels). In each grid box, the x-axis spans from 0 to 23 LST (local standard time) and the y-axis is the rainfall rate normalized to the maximum rainfall rate. (b) Bottom panels: Same as (a) but from the NICAM simulation.

Figure 4.15a shows the global tropics view of daily variation in rainfall rate normalized with the maximum rainfall rate at each box, from TMI (green) and PR (blue). Expectedly, the dual peak structure of the semidiurnal (two local peaks a day) variation of surface rainfall rate over the tropics is simulated well by NICAM. Many boxes show semidiurnal variation in rainfall rate, especially over Africa, the maritime continent, and the Amazon. There are some grids where the diurnal variation differs between the PR and TMI datasets, probably due to the difference in observation coverage between PR and TMI. There also are few grids that indicate more than two peaks. Figure 4.15b shows the global view of daily variation in rainfall rate normalized to the maximum value in each grid from the NICAM simulation. We can see that NICAM simulates the semidiurnal variation in rainfall rate over Africa, the maritime continent, and the Amazon. However, the semidiurnal variation is not reproduced by the NICAM simulation over some basins such as the South Pacific and the Indian Ocean where TMI and PR indicate a relatively smaller signature of semidiurnal variation.

K. Rajendran, T. Inoue*, M. Satoh* and H. Miura*

* The university of Tokyo, Japan

4.13 Indian summer monsoon variability and teleconnections in global climate models

In the beginning of the modeling era, simulations of monsoon by GCMs addressed aspects such as the seasonal variation of tropical circulation, role of mountains, and the mean features. The models, in general, simulated the monsoon circulation with reasonable fidelity, but failed to simulate more detailed characteristics of rainfall distribution. Simulations were sensitive to parameterizations and most of the shortcomings appeared to be near the orography. As part of the TOGA Monsoon Numerical Experimentation Group (MONEG), contrasting years of ISMR were studied using GCMs forced with observed global SST. Many models showed significant dynamical drift that resulted in rainfall bias. The coarse resolution of these models constrained them from correctly representing the complex topography and coastlines as well as sub-grid scale processes. Soon, the ability of the models in simulating the monsoon became a critical benchmark to qualify for reliable simulation of tropical climate variability.

Phase two of the MONEG project began the era of Model Intercomparison Projects (MIPs) in which the ability of the models in simulating the observed climate is assessed through a standard set of experiments. When each modelling group does a specific set of experiments, it offers a wide range of possibilities to compare the outputs with observation as well as those of other models. Through this method, a range of model behaviours can be extracted along with identifying their respective strengths and weaknesses. The 10-year integrations of atmospheric general circulation models (AGCMs) forced with observed SST of 1979-1988, were made under phase-1 of the Atmospheric MIP (AMIP1). AMIP simulations can be considered to show the potential skill of the models since they are being driven by observed boundary conditions. Subsequently, the World Climate Research Programme (WCRP) of the Working Group on Coupled Modelling (WGCM) organized the Coupled Model Intercomparison Project (CMIP) in the mid-1990s. It was developed from the AMIP1 to coordinate the coupled model simulations worldwide to advance our knowledge of climate variability and change. During the initial generations of CMIP1 and CMIP2, the design was simple with a long control simulation and analyses of different climate models helped in understanding the differences in model response. With the evolution of CMIP, the suite of experiments also increased with more detailed and elaborate twentieth-century simulations.

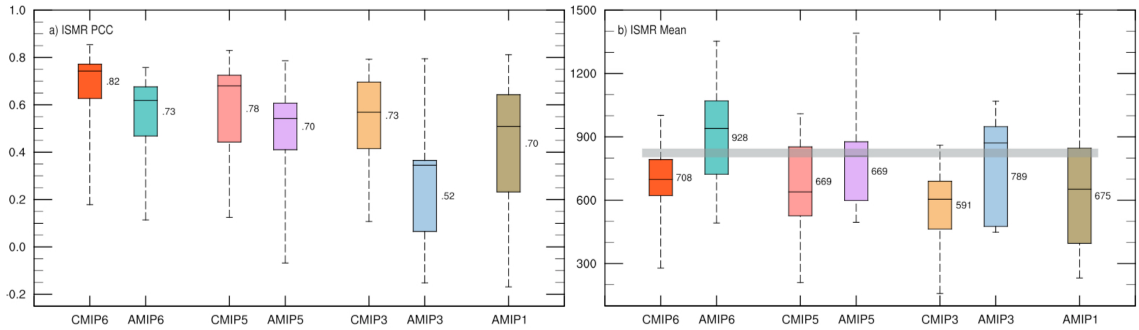


Figure 4.16: a) Box and whisker plots showing the Pattern Correlation Coefficients (PCCs) of mean summer monsoon rainfall over India against the corresponding IMD observation for CMIP6, AMIP6, CMIP5, AMIP5, CMIP3, AMIP3 and AMIP1 models. Whiskers show the maximum and minimum values among the PCCs of the member models and the box shows the interquartile range or the first to the third quartile (the second quartile or the median is shown as the solid line inside the box) of the PCCs (left panel). The PCC for the MME of models from each MIP is written on the right side of its box. b) Same as a), but for all-India summer monsoon rainfall (μ) in mm (right panel). The range of observed estimated for the periods corresponding to different MIPs is shown as the solid grey line across the MIPs.

A major paradigm shift occurred with the introduction of CMIP3 when the model outputs from the state-of-the-art climate models were made accessible to the scientific community at large. The immediate yet less known phase called CMIP4 supplemented the experiments done in CMIP3. The next major phase shift happened with CMIP5 which was majorly built upon CMIP3 and included idealized processes and feedback-oriented experiments whose outputs facilitated further understanding of the climate system. Very recently, the WCRP has defined phase-6 of the CMIP, the CMIP6. At present, more than 60 global modeling centres have contributed to CMIP6 to enhance our understanding of climate and climate change.

Over the years, the ability of the climate models to simulate the mean climate including monsoon has increased. However, the models are not perfect like our theoretical understanding of climate, which is still incomplete and certain simplifying assumptions are still unavoidable in the models. These imperfections introduce biases into model simulations. Over these years, we have refined our theoretical understanding, improved the physical parameterizations, increased the number and quality of observations, and increased our computational capabilities exponentially. With these advancements, the complexity of climate models has substantially increased so that the current models are far more comprehensive than the models of the 1990s. With the introduction of more powerful supercomputers, the current models are also capable of resolving finer-scale details, though the resolution of the CMIP6 models is still not sufficient. Along with the development in the current generation of models, another complexity is added along because of the introduction of sources of possible errors in the new processes. The uncertainty regarding these processes remains unanswered. Against this background, it is pertinent to ask how much the climate models have improved and how far we can trust the latest generation of coupled models in simulating ISM, which is crucial for its prediction and future projection as well.

A diagnostic assessment of the simulation of ISM byăthe latest generation of CMIP6 models is thus relevant and important. We analyzed the performance of global climate models of 6th generation of Coupled Model Intercomparison Project (CMIP6) in simulating climatological summer monsoon rainfall over India, interannual variability (IAV) of all-India summer monsoon rainfall (ISMR) and its teleconnections with rainfall variability over equatorial Pacific and Indian Oceans. In this study, the performance of CMIP6 models is evaluated primarily by comparing them to observation, by taking care of their internal variability. Specifically, we examine if the representation of the major characteristics of summer monsoon rainfall over. India have improved in CMIP6 models and if so, how it has evolved across the successive generations of the AMIPs and CMIPs since AMIP1. Each generation of MIP is expected to have a range in performance, but it is necessary to understand the general improvement across different phases. For this, we also compare the MMEs of AMIP1, AMIP3, CMIP3, AMIP5, CMIP5, AMIP6 and CMIP6 models.

The multimodel ensemble mean (MME) of 61 CMIP6 models shows the best skill in simulating mean monsoon rainfall over India, from the pattern correlation coefficient (PCC with respect to the observation) which is shown in Figure 4.16, compared to the MMEs of 6^{th} generation atmosphere-only models (AMIP6) and the previous generations of Atmospheric and Coupled Model Intercomparison Projects (AMIPs and CMIPs). Systematic improvement and reduction in bias are evident from lower to higher AMIPs/CMIPs from the improvement in the pattern correlation coefficient. The persistence of errors in atmosphere-only models hints that the source of errors could be with atmosphere models.

K. Rajendran, Sajani Surendran, Stella Jes Varghese and Anjali Sathyanath

4.14 Factors responsible for interannual variability of Indian summer monsoon rainfall

It is well known that most of the cloud systems that give rainfall over the Indian region during the monsoon are generated over the surrounding oceans and propagate onto the Indian region. Understanding the relationship of the Indian summer monsoon rainfall (ISMR) with convection over different parts of the Indo-Pacific Ocean is key to predicting the variation of Indian summer monsoon rainfall. The strong opposite relationship of ISMR with SST variation over the equatorial Pacific Ocean in interannual time scales, the El Niño-Southern Oscillation (ENSO) is widely studied. Another interannual mode that is related to ISMR variability is the Equatorial Indian Ocean Oscillation (EQUINOO, Gadgil et. al., GRL, 2004, https://doi.org/10.1029/2004GL019733) which is a dipole structure of opposite phases in convection/SST/rainfall between the two poles over the western Equatorial Indian Ocean (EIO) and the eastern EIO (as depicted in Figure 4.17). The positive phase of EQUINOO is favourable for ISMR and the negative phase of EQUINOO is unfavourable for ISMR. Research on modeling this mode is in infancy. Current climate models are found to be seriously deficient in simulating this mode. We have initiated

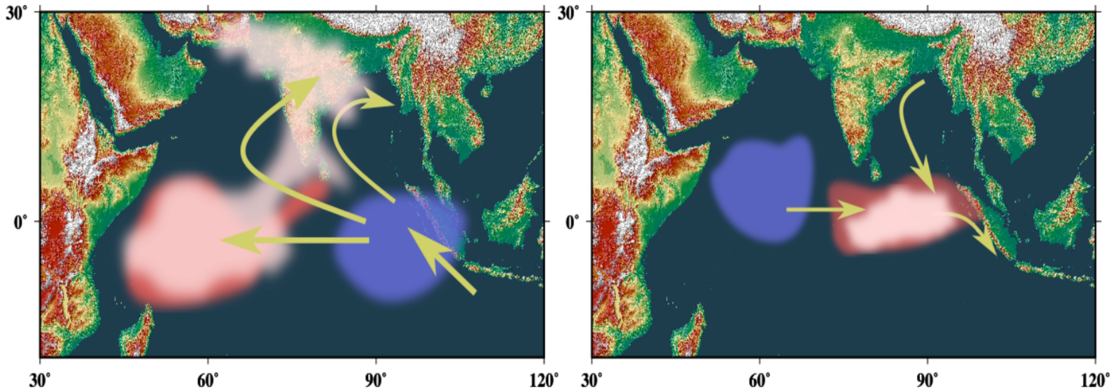


Figure 4.17: a) Positive (left) and negative (right) phases of EQUINOO. The positive phase is defined as the state of the equatorial Indian Ocean (EIO) with i) warmer SSTs (red shade) and enhancement of convection (clouds) over the western EIO, ii) suppression of convection and colder SSTs (blue shade) over the eastern EIO and iii) associated changes in the zonal wind with the vectors showing easterly anomalies over the central EIO. The negative phase is associated with i) colder SSTs and suppression of convection over the western EIO, ii) warmer SSTs and enhancement of convection over the eastern EIO and iii) associated changes in the zonal wind anomalies with the vectors showing westerly anomalies over the central Indian Ocean.

efforts in simulating EQUINOO and the ISMR-EQUINOO relationship using a climate model.

Sajani Surendran and Sulochana Gadgil*
* Indian Institute of Science, Bangalore

4.15 Skill of sub-kilometer forecasts from WRF model in simulating extreme rainfall events over the Bangalore city

In this study, the skill of sub-kilometer resolution forecasts from Weather Research and Forecasting (WRF) model in simulating the Urban Extreme Rainfall Events (UERE)s are examined. This study also compared the model performance for forecasts initialized from different forecast cycles in a day. Our examination for two UERE cases showed that forecast initialized at 0600 UTC yielded best results in term of forecasting spatial distribution and intensity of rainfall (Figure 4.18). Our analysis also indicated that increasing model resolution further in convection permitting resolution (<3 km) has only marginal impact of spatial distribution of rainfall while model skill in simulating rainfall intensity slightly improved with increasing resolution. As expected, simulation by not deploying a cumulus scheme at cloud resolving resolution do not make significant difference in spatial distribution, however, inclusion of cumulus scheme improved quantitative precipitation forecast skill. The inferences from this study are useful for modelers working on improving operational forecast skill of UEREs using mesoscale model.

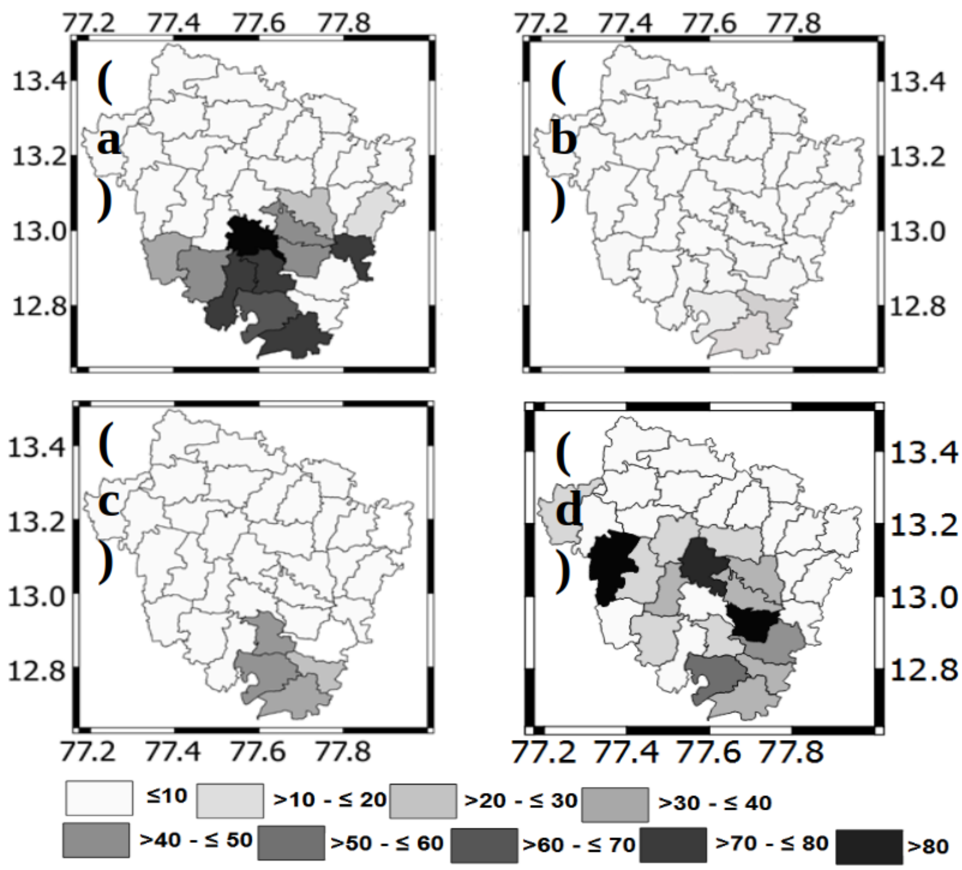


Figure 4.18: (a) Spatial distribution of 24 hours accumulated observed rainfall (mm) over the Bangalore city for the period 0600 UTC 14 to 06000 UTC 15 August 2017 with the corresponding model simulations from the innermost domain D4 for different model initial conditions, (b) -1800 UTC (c) 0000 UTC and (d) 0600 UTC; - sign indicates previous day.

V Rakesh, G N Mohapatra and Ajay Bankar

4.16 Water Vapour characteristics and radiative effects at high-altitude Himalayan sites

We analyzed long-term aerosol and Precipitable Water Vapour (PWV) properties at two high-altitude sites (Nainital and Hanle) over the central Himalayan and western Trans-Himalayan regions from 2008 to 2018. First-time assessment of the seasonality and variation in combined aerosol and water vapour radiative effects are also attempted, aiming to investigate the atmospheric effect on solar radiation over the Himalayan range that is especially important for the regional climate. A synergy of ground-based measurements from sun photometers, GPS (Global Positioning System) observations, radiosondes, along with the satellite and reanalysis data was used to examine inter-annual and seasonal variability of PWV and specific humidity over both sites. The PWV is highest in monsoon and much lower during the dry winter season with slightly higher values at Nainital compared to Hanle. The vertical profiles of PWV from satellite and reanalysis data reveal a great consistency on a seasonal basis. The PWV is considered as one of the main greenhouse gases that exhibits a positive radiative effect at the Top of the Atmosphere (TOA). The results highlight the importance of water vapour and aerosol radiative effects in the climate sensitive Himalayan range.

U.C. Dumka*[*], D.G. Kaskaoutis [,@], Pradeep Khatri[α], Shantikumar S. Ningombame[β], Rahul Sheorana[*], Sridevi Jade, T.S. Shrungeshwara and Maheswar Rupakheti[γ]

[*] Aryabhatta Research Institute of Observational Sciences, Nainital, India

Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Palaia Penteli, Athens, Greece

[@] Environmental Chemical Processes Laboratory, Department of Chemistry, University of Crete, Crete, Greece

[α] Center for Atmospheric and Oceanic Studies (CAOS), Graduate School of Science, Tohoku University, Japan

[β] Indian Institute of Astrophysics, Bangalore

[γ] Institute for Advanced Sustainability Studies, Postdam, Germany

4.17 Effect of large-scale oceanic and atmospheric processes on the Indian summer monsoon

There are several important large-scale oceanic and atmospheric processes like El Niño-Southern Oscillation (ENSO), MaddenJulian Oscillation (MJO), and Indian Ocean Dipole (IOD) which have significant impact on global weather and climate system. This article reviews the mechanism and dynamics of ENSO, MJO, and IOD processes and their impact on global and regional weather and climate particularly the Indian summer monsoon rainfall. Generally, these processes are coupled oceanatmosphere phenomenon and associated dynamics control the global weather and climate system. Sea surface temperature (SST) anomaly in the central and equatorial pacific region respectively results the warm (El Niño) and cold (La Niña) events and it has strong impacts globally. Similarly, MJO is a dominant phase of intra-seasonal variability in the tropical region and also has significant impacts on the global system like strong wind, convective waves, extreme rainfall, cyclones, and ENSO.

The IOD is often termed as the counterpart of pacific El Niño and La Niña in Indian Ocean which mainly measures the SST gradient between Arabian Sea and the eastern Indian Ocean. IOD also linked to ENSO and the shifting warm/cool pool results in the summer monsoon rainfall variability in the India Ocean as well as continental Indian region. All these phenomena have direct impact on the Indian monsoon circulation system, so in this work, these impacts are quantified using the India Meteorological Department (IMD) observed rainfall data over Indian subcontinent as a case study. This work also provides the review of the studies using observation and modelling to understand the dynamics of all the three processes. This review and analysis work will help in understanding the process feedback on the regional rainfall distribution and there is a need of near-future modelling research on these processes and their impacts on weather and climate system and associated sectors.

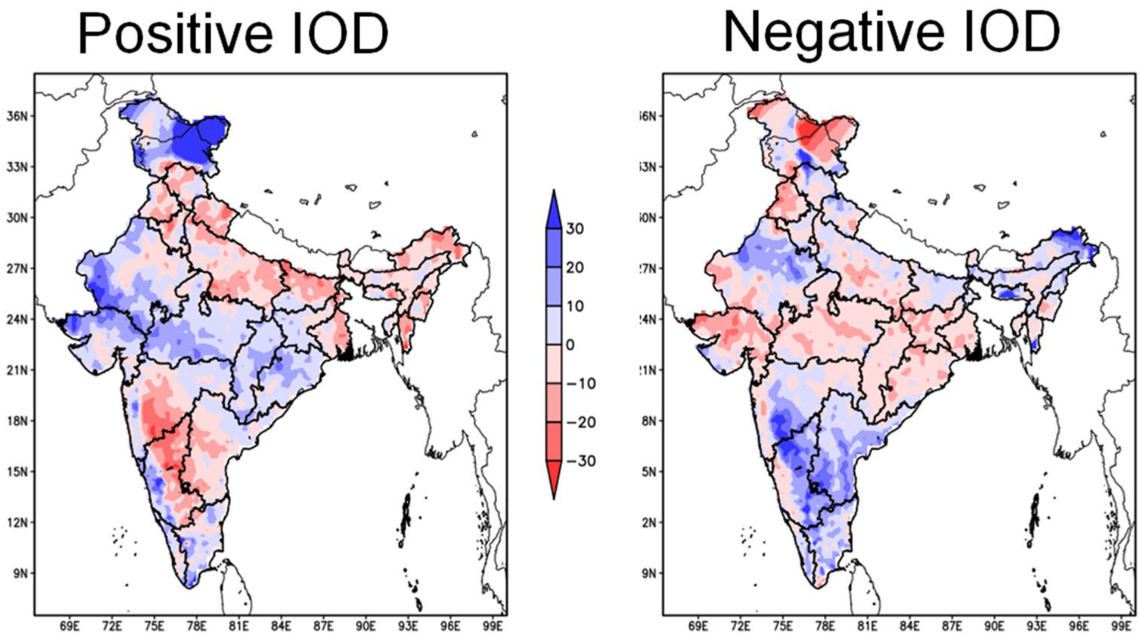


Figure 4.19: Spatial distribution of normalized rainfall anomalies (expressed as % of climatology) over continental India using the IMD gridded data composite over positive IOD and negative IOD.

Smrutishree Lenka, Rani Devi, Joseph, C.M. and K C Gouda

4.18 Temperature-duration-frequency analysis over Delhi and Bengaluru city in India

The extreme temperature events are a concern in recent years due to climate variability particularly in India as there is an increase in the temperature intensity, frequency, and duration. This study represents stationary temperature-duration-frequency (TDF) analysis over two mega cities in India Delhi (north) and Bengaluru (south) using the daily maximum temperatures at meteorological stations for the period 1969-2016 observed by India Meteorological Department (IMD).The interannual variability of maximum temperature and the maximum daily recorded value indicates the increasing trend in both the cities. The study investigates the extreme analysis of the maximum temperature using two distributions, i.e., Gumbel's Extreme Value Type 1 (GEVT) and Log Pearson Type III (LPT), for return periods 2, 5, 10, 25, 50, and 100 years at both the locations and the positive temporal trend is observed. The TDF curves were build using annual maximum temperature values for total 8 durations (different days) of 48 years analyzed and results show the increasing trend of maximum temperature at lower duration and high return period values. The TDF is also used for prediction of the maximum temperature for the 2 hottest years in India, i.e., 2012 and 2015, and it is comparable with the observed maximum temperature. Similarly, the predictions for 11 years, i.e. 2006 to 2016, over both the cities are simulated using both the GEVT-I and LPT-III and the models have better potential skill in predicting

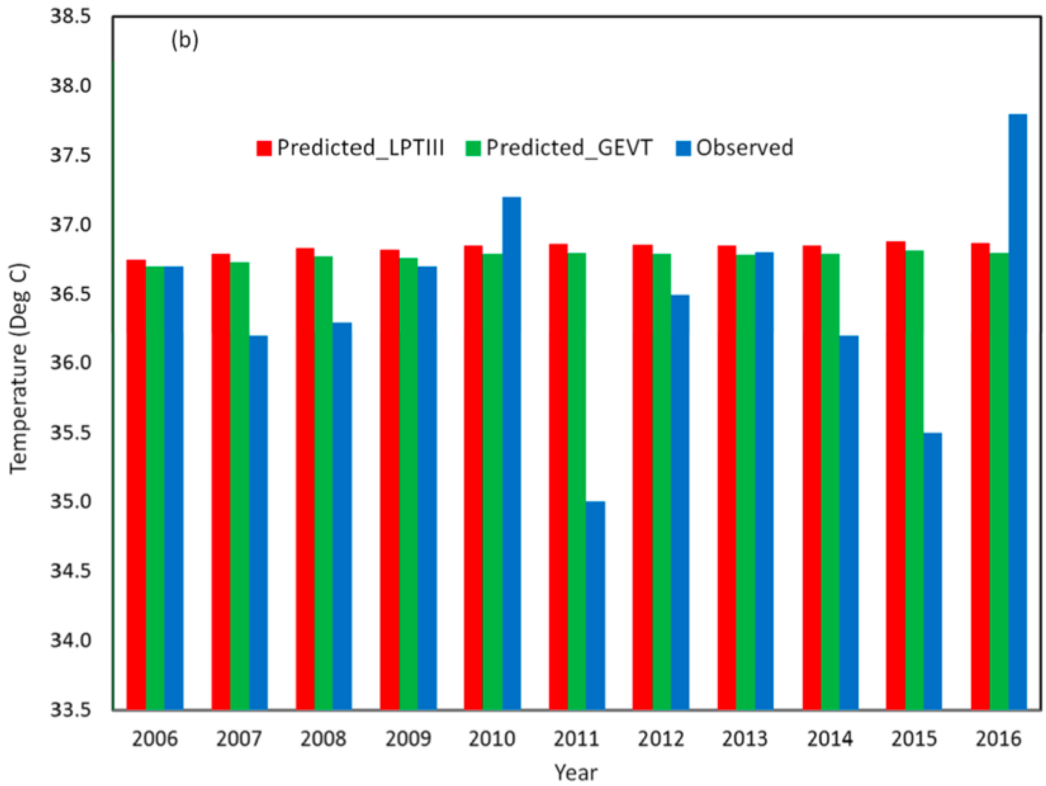


Figure 4.20: Comparison of observed and predicted maximum temperature of 1-day duration over Bengaluru for the period 20062016 using a 5-year return period

the extreme maximum temperature. These results can be useful for the sectors like health, energy, agriculture, urban management, and ecology management and can help the policy decision makers and disaster managers in the mitigation and adoption steps to face the extreme temperature disaster at city scale.

Rani Devi, K C Gouda and Smrutishree Lenka

4.19 An Assessment of Relation of Meteorological Parameters and COVID-19 transmission at the early stage during March-May 2020 in India

The Corona virus disease 2019 (COVID-19) mainly caused by the novel severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) became a global pandemic by March 2020. Actual there is no strong evidence of weather and COVD-19 spread relation as it is a new virus. This study is mainly focussed on the tropical weather impact on the spatio-temporal spread of COVID-19 during the early stages i.e. March-May 2020 in India, which is a large country where the disease has shown an exponential growth. This study is an attempt to assess the relationship of major meteorological parameters like

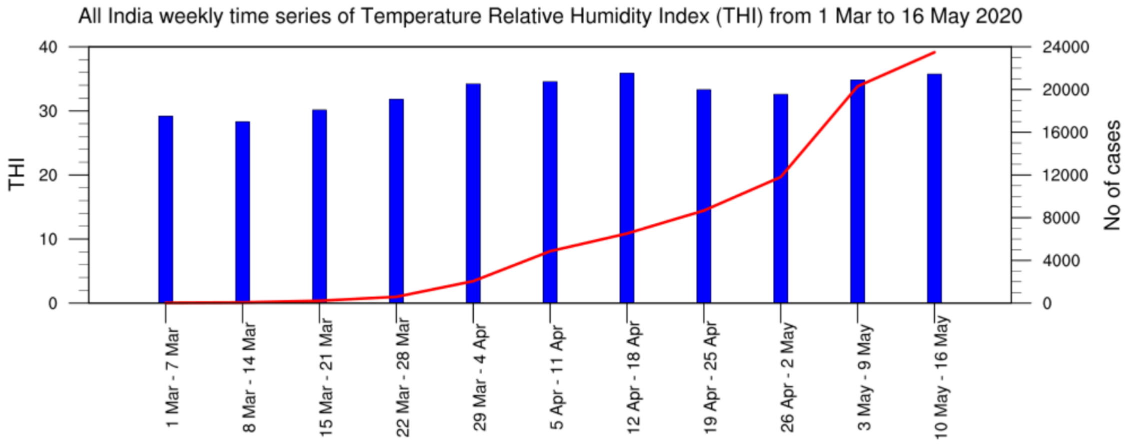


Figure 4.21: Weekly variation of COVID-19 infected cases (red line) observed in India and THI (blue bar) averaged over continental India for the period 01 March- 16 May 2020. The correlation between two time series is 0.6 in both the cases.

solar radiation, air temperature and relative humidity with the positive cases of COVID-19 for the period March-May 2020 which is the summer season or pre-monsoon season over India. The time series and significant correlation analysis at daily, weekly scale and the spatial analysis of weather and COVID-19 cases are presented. The results show significant correlation of solar radiation and atmospheric temperature with COVID-19 cases both at daily and weekly scale in India whereas relative humidity has low correlation in the study period. But the temperature relative humidity index (THI) a measure of the thermal stress shows positive correlation with the disease spread. These results can be a good input for developing the integrated modelling framework for the COVID-19 forecasting using state of art numerical weather prediction model and disease process modelling.

Krushna Chandra Gouda, Mahendra Benke, Priya Singh, Nikhilasuma Pernaj, Chandrika Murali, Reshama Kumari, Geeta Agnihotri, Sneh Joshi, Smrutishree Lenka, Rani Devi, Suryanaryana Murty Upadhyayula and Himesh Shivappa

4.20 Assessment of Air Pollution status during COVID-19 Lockdown (Mar-May 2020) over Bangalore City in India

The coronavirus disease 2019 (COVID-19), which became a global pandemic by March 2020, forced almost all countries over the world to impose the lockdown as a measure of social distancing to control thee spread of infection. India also strictly implemented a countrywide lockdown, starting from 24 March to 12 May 2020. This measure resulted in the reduction of the sources of air pollution in general: industrial, commercial, and vehicular pollution in particular, with visible improvement in ambient air quality. In this study, the impact of COVID-19 lockdown on the ambient concentration of air pollutants over the city of Bangalore(India) is assessed using Continuous Ambient Air Quality Measurement (CAAQM) data from 10 monitoring stations spread across the city. The data was obtained from Central Pollution Control Board (CPCB) and Karnataka State Pollution

Control Board (KSPCB). The analysis of the relative changes in the ambient concentration of six major air pollutants (NO, NO_2, NO_X, PM2.5, O_3, and SO_2) has been carried out for two periods: March-May 2020 (COVID-19 lockdown) and the corresponding period of 2019 during when there was no lock-down. The analysis revealed a significant reduction in the concentration of ambient air pollutants at both daily and monthly intervals. This can be attributed to the reduction in sources of emission; vehicular traffic, industrial, and other activities. The average reduction in the concentration of NO, NO_2, NO_X, PM2.5, and O_3 between 01 March and 12 May 2020 was found to be 63%, 48%, 48%, 18%,and 23% respectively when compared to the same periodin 2019. Similarly, the comparative analysis of pollutant concentrations between pre-lockdown (0123 March 2020) and lockdown (24 March-12 May 2020) periods has shown a huge reduction in the ambient concentration of air pollutants, 47.3% (NO), 49% (NO_2), 49% (NO_X), 10%(SO_2), 37.7% (PM 2.5), and 15.6% (O_3), resulting in improved air quality over Bangalore during the COVID-19 lockdown period. It is shown that the strict lockdown resulted in a significant reduction in pollution levels. Such lockdowns may be useful as emergency intervention strategies to control air pollution in megacities when ambient air quality deteriorates dangerously.

K C Gouda, Priya Singh, Nikhilasuma P, Mahendra Benke, Reshama Kumari, Geeta Agnihotri, Kiran Hungund, Chandrika M, Kantharao B, V Ramesh, and Himesh S

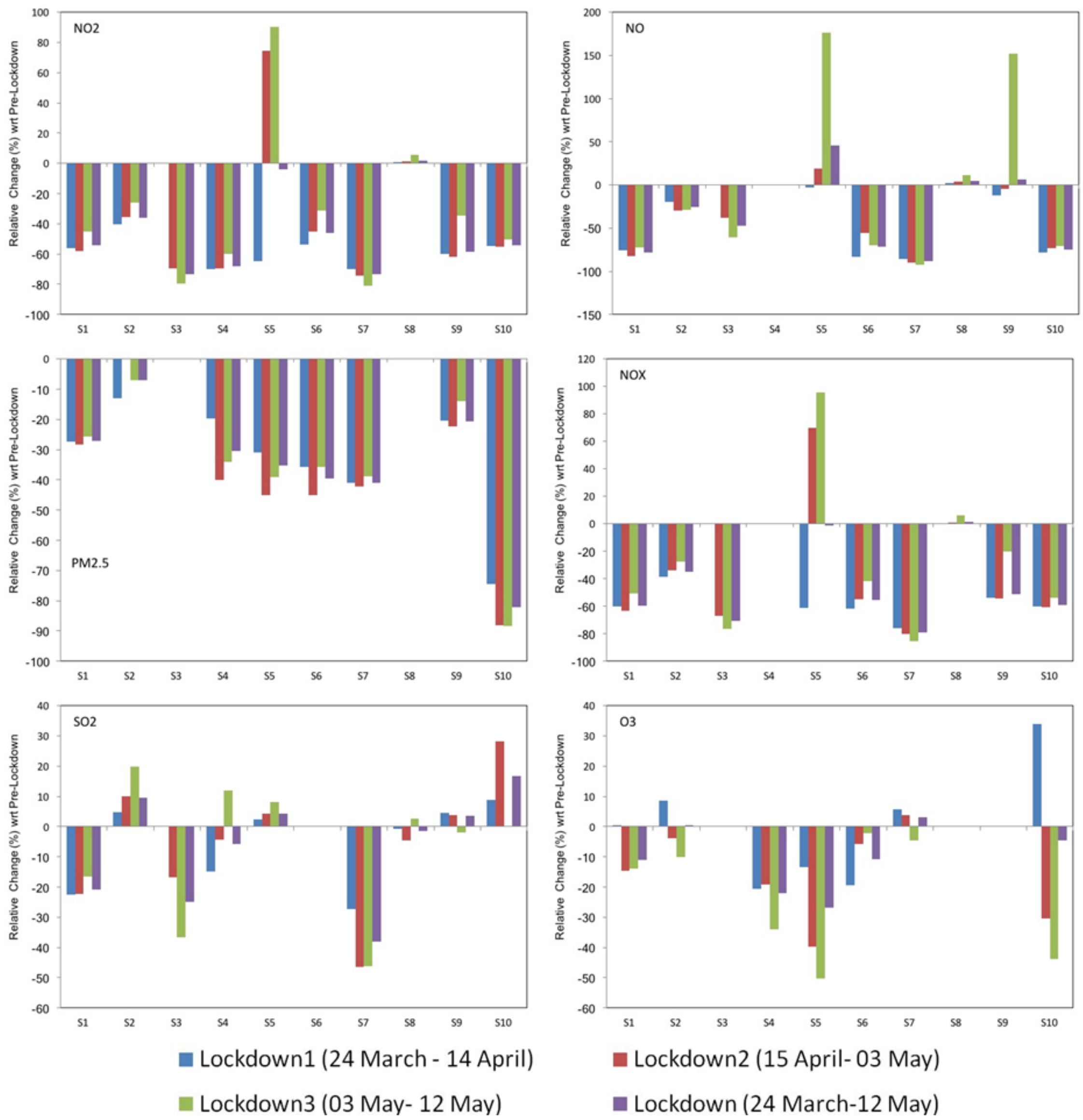


Figure 4.22: Relative percent change in the pollutant concentration observed at 10 pollution monitoring stations in Bangalore during different phases of COVID-19 lockdown.

5. Geosciences & Engineering Research

Building on the niche expertise available at CSIR-4PI in GNSS and computational seismology and the existing capability in modelling and simulation the following research addresses earthquake hazard and risk assessment, which has a huge societal impact. Inside:

- Estimation of geodetic and seismic strain rates in Himachal, Jammu, Kashmir and Ladakh Himalaya
- Evaluation of TEC from IRI-2016 model over the Indian subcontinent using GPS derived TEC
- Equatorial F-region irregularities over Indian sub-continent
- Establishment, operation and maintenance of cGNSS stations
- Effect of hydrological loading on seismicity and local deformation in Kashmir Himalaya
- Calculation of noise estimates for multi-GNSS stations
- Sensor orientation and noise analysis of Kashmir Zanskar seismic network
- Off-great-circle propagation of seismic surface waves in the NW Himalaya: Effect on uncertainty quantification of corresponding dispersion measurements
- Sub-surface shear wave velocity at regional scale in Kashmir Valley using microtremor array data
- L_g wave attenuation study in the Kashmir Himalaya
- The effect of non-uniform spatial sampling in imaging the ionosphere using GNSS
- Efficiency of Spatio-Periodic Levelling Algorithm in resolving sharp static variation for reliable GNSS based tsunami early warning: Theoretical and observational assessment
- The Indo-Burmese arc and its seismic potential
- Corrected model for Axial vibration of double-walled nanorod and making sense of Pasternak medium and magnetic effects
- Approximate Critical Buckling Solutions for Triple-walled Carbon Nanotube

5.1 Estimation of geodetic and seismic strain rates in Himachal, Jammu, Kashmir and Ladakh Himalaya

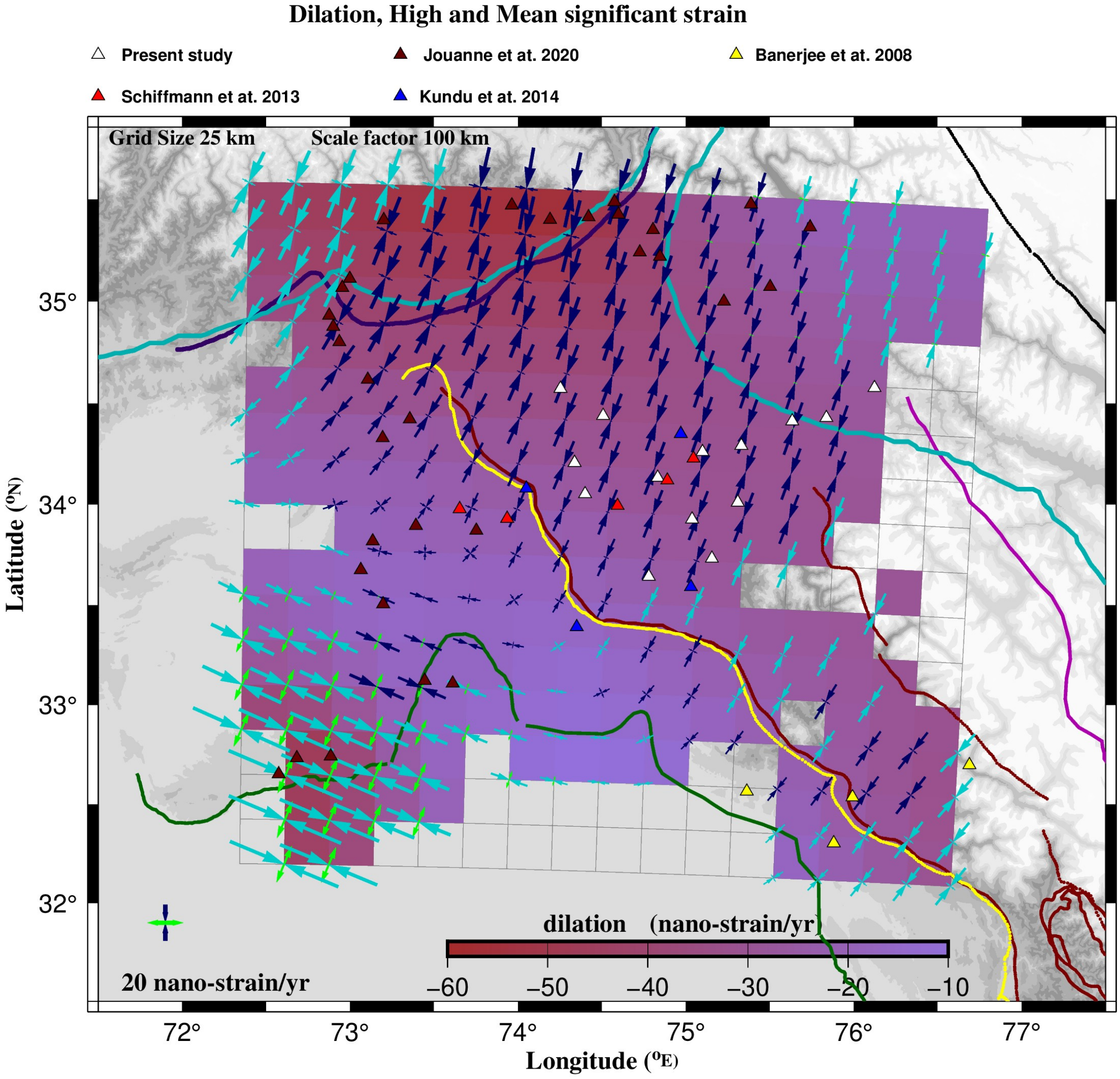


Figure 5.1: Geodetic strain rates and dilation in the study region.

The current study area (32-35.5^{o}N; 72.5-77^{o}E) covers the rupture zones of the 1905 Kangra earthquake and 2005 Muzaffarabad earthquake in the Northwest Himalaya (Himachal, Jammu, Kashmir and Ladakh) which is tectonically complicated and seismically active. The seismic potential of the study region is analysed using both GPS derived strain rates during the last 26 years and seismic strain rates for 50, 200 and 500 years of compiled earthquake data. Both the instrumental era (1964-2021) and historical earthquakes in this region since 1500 A.D are used to determine seismic strain rates. Magnitude completeness (Mc), Cumulative magnetic moment and Seismogenic thickness are calculated using ZMAP tool. Based on the Mc value, fault plane solutions from GCMT catalogue are used for the seismic moment estimation. Seismic strain is calculated using Kostrov formulations techinque. Geodetic strain rates of 58 sites are estimated (Figure 5.1) using grid-strain program. This study contributes to understand seismic hazard assessment in this region.

Sridevi Jade, T.S. Shrungeshwara, Bhavani Narukula, Chiranjeevi G Vivek, I. A. Parvez

5.2 Evaluation of TEC from IRI-2016 model over the Indian subcontinent using GPS derived TEC

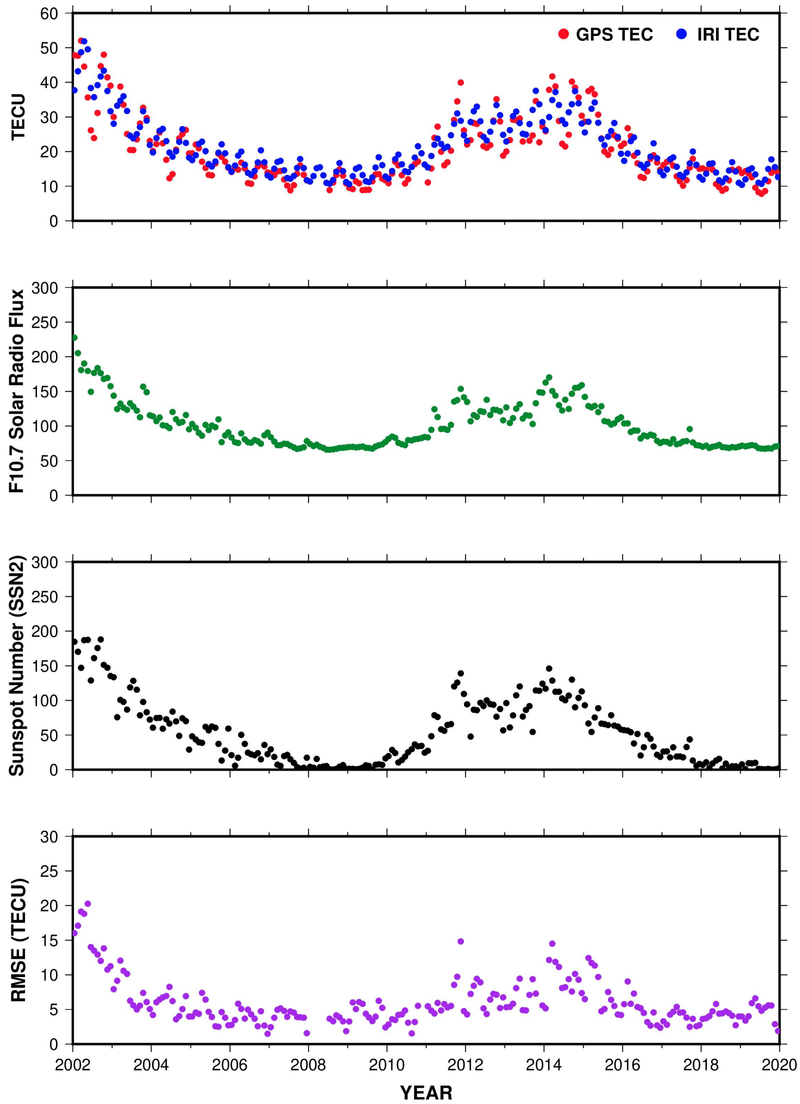


Figure 5.2: Monthly mean GPS TEC and IRI TEC, monthly RMSE, monthly averages of F10.7 solar radio flux and sunspot numbers (SSN2) at IISC GPS station for the period 2002 to 2019.

We probed the performance of latest version of International Reference Ionosphere (IRI-2016) for predicting Total Electron Content (TEC) at equatorial, low latitude and EIA regions using TEC from geodetic Global Positioning System (GPS) receivers at four latitudinally aligned locations (-5^o to 20^o Geomagnetic) over Indian sub-continent from 2002 to 2019. IRI predicted TEC values underestimate and overestimate the GPS TEC values depending on the local time of the day, season, solar activity, and geomagnetic location of observation. High discrepancies are observed between IRI TEC and GPS TEC during the daytime hours, spring equinox seasons, and high solar activity phases, which could be attributed to the intensity level of solar irradiance, varied strength of EEJ and global meridional thermospheric circulations. We plotted the monthly IRI TEC and GPS TEC values along with the monthly Root Mean Square Error (RMSE), monthly averaged F10.7 solar radio flux and revised sunspot numbers (SSN2) in Figure 5.2, which indicate the identical variation trends. These trends show that RMSE values are dependent on the background TEC which in turn depends on the solar cycle activity. Hence, we emphasize possible improvements in IRI-2016 model with respect to solar dependence over the equatorial and low latitude region. Further, IRI model is unable to capture the extreme variability of ambient ionization around the EIA crest region which could be revisited for possible improvements. In brief, the important extracts from our analysis are in line with regional and global efforts for improving the climatological and weather variability of IRI model and its extended Ionosphere Real-Time Assimilative Model (IRTAM).

Siva Sai Kumar Rajana, T.S. Shrungeshwara, Chiranjeevi G. Vivek, Sampad Kumar Panda*[*] *and Sridevi Jade
[*] Center for Atmospheric Science, Department of ECE, KL Deemed to be University, Koneru Lakshmaiah Education Foundation, Guntur, Andhra Pradesh.

5.3 Equatorial F-region irregularities over Indian sub-continent

Electron density irregularities in the ionosphere is the one of the known space weather effects and it is very important due to its significant impact on satellite radio communication. Trans-ionospheric signals such as the Global Positioning System (GPS) signals may experience the fluctuations or scintillations in the phase and amplitude due to movement of irregularities across the signal path, with a resultant impact on the overall performance of the system. Ionosphere irregularities mostly occur after sunset around magnetic equator. Equatorial F-region Irregularities (EFI) is linked to the enhancement of eastward electric fields around post-sunset hours, which leads to unstable condition in the plasma structure known as Rayleigh-Taylor (R-T) instability. Dual frequency GPS signals are used to estimate the ionospheric Total Electron Content (TEC). Using this TEC, Rate of change of TEC Index (ROTI) is calculated which can detect the plasma irregularities. ROTI is the GPS based index parameter proxy to scintillation index (S4) based on the phase uctuation associated with the presence of irregularities. ROTI is used to investigate the morphology of the EFI during different seasons over Indian latitudes covering magnetic equator to the mid latitudes. Also, the influence of solar activity on the occurrence of severe and moderate EFI is analyzed. This study may help to understand the background conditions that cause the ionospheric irregularities over Indian latitudes.

Siva Sai Kumar Rajana, Sridevi Jade, Chiranjeevi G. Vivek, T. S. Shrungeshwara

5.4 Establishment, operation and maintenance of cGNSS stations

To study the seismic vulnerability in Jammu, Kashmir and Ladakh, five more cGNSS stations are established in addition to the already established stations (Figures 5.3 & 5.4). Operation and maintenance of already established eighteen stations was carried out. Some of these stations are remotely accessible and data is streamed in near real-time to CSIR-4PI servers.

Figure 5.3: cGNSS station established in Gurez valley, J&K.

Chiranjeevi G Vivek, T. S. Shrungeshwara, Ramees Raja Mir, Rajendra Kumar Dash, Sridevi Jade, I. A. Parvez, Fayaz Bhat, Ahmed Hussain, Siva Sai Kumar Rajana and Sree Sai Karthik G

5.5 Effect of hydrological loading on seismicity and local deformation in Kashmir Himalaya

Total Water Storage (TWS) from Gravity Recovery And Climate Experiment (GRACE) satellite data is analyzed to calculate the hydrological loading variation and its relationship with seismicity. GRACE is a joint mission by National Aeronautics and Space Administration (NASA) & German Aerospace Centre to measure Gravity Anomaly of the

Figure 5.4: cGNSS station established in Bogdang, Ladakh.

Earth, which is caused by changes in the mass on the Earth surface. It uses two Low Earth Orbit (LEO) satellites separated by distance of 220 km. The change in the distance between these two satellites gives the surface mass density variation, which is given as Liquid Water Equivalent (LWE) thickness. Vertical component of the GPS time series processed using GAMIT software is compared with LWE data to study the effect of hydrological loading on local deformation. Figure 5.5 shows LWE thickness of Srinagar city from 2016 to 2021. Maximum LWE thickness of 21 cm is observed in May, 2016 and minimum is -32.6 cm in October, 2021 which can be correlated with the GPS vertical component for further studies. Also the effect of hydrological loading on seismicity of this region is studied.

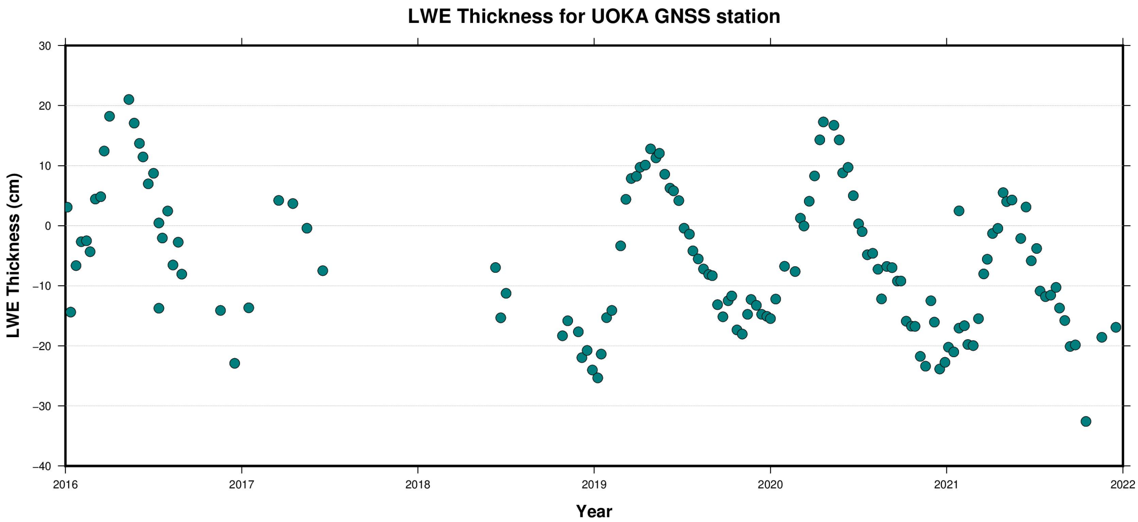


Figure 5.5: Liquid Water Equivalent (LWE) thickness of Srinagar city.

Rajendra Kumar Dash, Bhavani Narakula, T. S. Shrungeshwara, Chiranjeevi G. Vivek and Sridevi Jade

5.6 Calculation of noise estimates for multi-GNSS stations

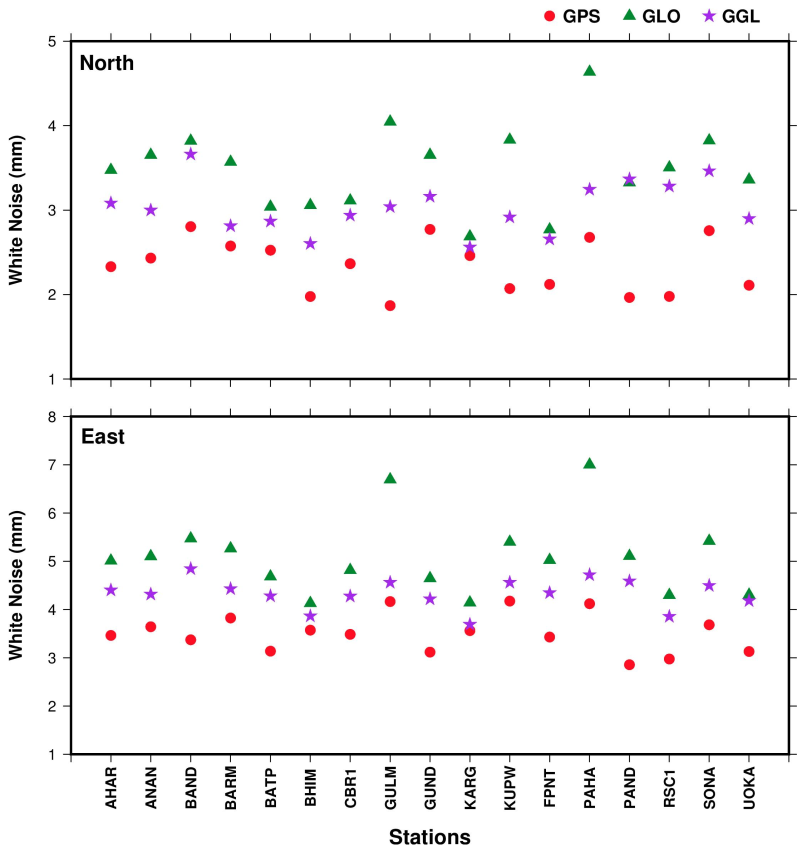


Figure 5.6: White noise in North and East component of multi-GNSS time series.

Noise estimates are calculated for the stand-alone GPS, Glonass and combined GPS, Glonass time series. Velocity estimates are determined by the noise levels in position estimates and length of the time series. Mainly time series consists of uncorrelated noise in time which can be reduced significantly by repeated or more measurements and temporally correlated noise which influences long time series. It is observed that even though velocity estimates are comparable, results show both the North & East component white noise levels are high for stand-alone Glonass (GLO) & combined GPS-Glonass (GGL) compared to stand-alone GPS (GPS) time series (Figure 5.6). Also noise levels are more for the stations with more multipath effect.

Chiranjeevi G. Vivek, Sridevi Jade, T.S. Shrungeshwara

5.7 Sensor orientation and noise analysis of Kashmir Zanskar seismic network

We estimated misorientation angles of the Kashmir-Zanskar network's 13 broadband seismic sensors, as well as their effects on anisotropy determinations and great-circle-path

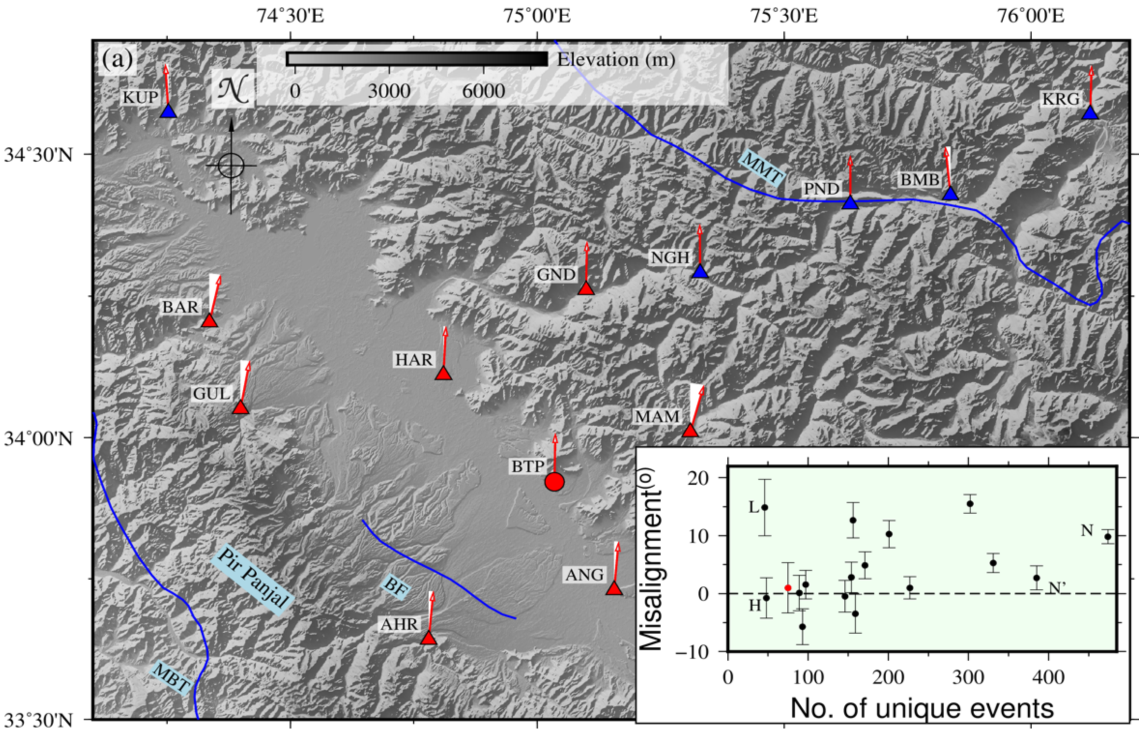


Figure 5.7: Misorientation of each of the broadband seismometers (triangles and a red circle) measured from north with positive misorientations in the east and negative orientations in west. Red triangles are first deployments around mid 2014 and blues are 2nd deployments 2017. Station BTP with misorientation of 0.99 degree is shown by red dot. Inset shows relation between number of unique measurements (x-axis) used to determine the misorientation (on y-axis) for all stations.

deviations, using global Rayleigh waves. The misorientations were calculated by subtracting the backazimuths of Rayleigh waves from the backazimuths of the great-circle-arcs connecting the source and receiver. We found that three of the sixteen had 5 to 10 degree orientation errors with respect to geographic north, four had 10 to 16 degree errors, and the rest had <5 degree errors (Figure 5.7). These misalignments caused significant energy leakage in the transverse component receiver functions, resulting in sharper amplitudes and polarities after correction. Indeed, the fast component's SKS-derived azimuths were found to be quite sensitive to instrument misalignment, suffering a 16^0 shift from a 15.5^0 error in orientation. Misalignment corrections revealed significant, up to 20^0, off-great-circle arc deviations even along shorter path arrivals from regional events, providing a qualitative ordination of the region's heterogeneities. We also compared global high and low-noise models, as well as near-source earthquake models, to the probability distribution functions of the estimated power spectral density of ambient noise at each station. The findings provide a first-order assessment of this network's small earthquake detection capability, down to M1.0, which is supported by some of the smallest events discovered.

Ramees R Mir, Imtiyaz A Parvez, Gabi Laske* and Vinod K Gaur
*Scripps Institution of Oceanography, University of California San Diego

5.8 Off-great-circle propagation of seismic surface waves in the NW Himalaya: Effect on uncertainty quantification of corresponding dispersion measurements

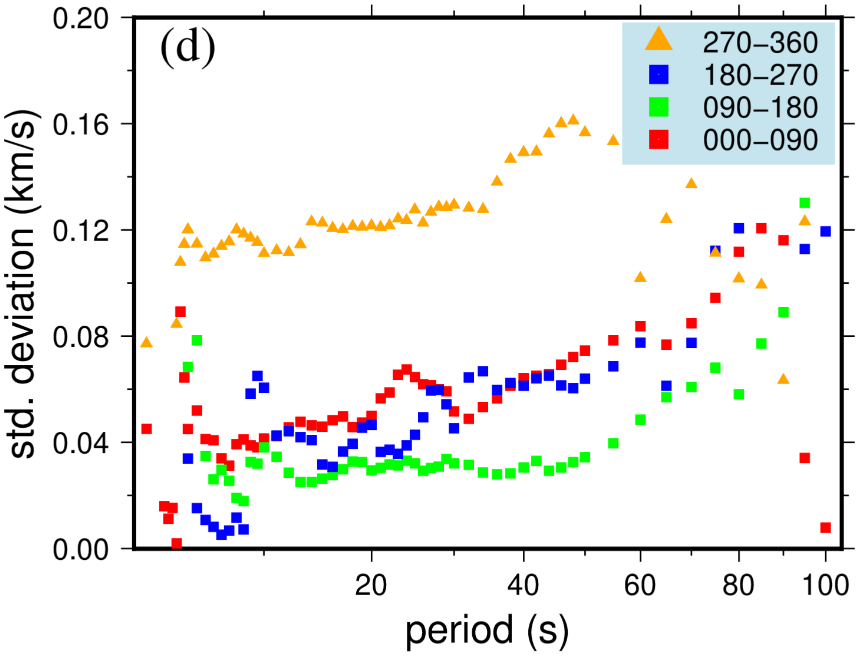


Figure 5.8: Shows back-azimuthal average standard deviation of all clusters as function of period (x-axis). Whole dataset is divided into 4 quadrants with back-azimuthal bin of 90 degrees (see legend). Note the standard deviation for quadrant 270-360 degrees is almost twice than rest of the data.

The steering of surface waves away from the great-circle path containing source and receiver is caused by the heterogeneity of the medium through which they traverse. Off-great-circle propagation has been observed in various regions around the globe, e.g., NE China, southern California, mainland Europe, etc. It was previously assumed that using shallow, regional earthquake sources (depth $\leqslant$ 90 km) would eliminate such issues in the Himalayas. We will show that regional events recorded by the Kashmir-Zanskar experiment in NW Himalaya deviate from the great-circle path by up to 20^0. These observations from $\sim$8 years of data recorded by the network led to a detailed ordination of regions' heterogeneities. We further developed a simple clustering algorithm to spatially stack source-receiver paths that are closer by $\sim$2% of their respective path lengths. After visualization, we removed the outliers and computed error statistics for each of the 450 clusters. We observe that clusters from the Pamirs, Hindu-Kush and Tien-Shan have more variance, i.e., more outliers, as demonstrated by our earlier findings. As a result, clusters originating or recorded in such heterogeneous regions were assigned an error twice the standard deviation (i.e., $\pm 2\sigma$) rather than $\pm 1\sigma$ for the remaining paths (Figure 5.8). This resulted in the creation of a redundant database of fundamental-mode dispersion measurements for the region, with close-to-realistic error bounds obtained on over 7000 source-receiver paths. These individual paths will be used in a Bayesian framework to obtain a detailed 3-dimensional shear-wave velocity structure of the region.

Ramees R Mir, Imtiyaz A Parvez and Vinod K Gaur

5.9 Sub-surface shear wave velocity at regional scale in Kashmir Valley using microtremor array data

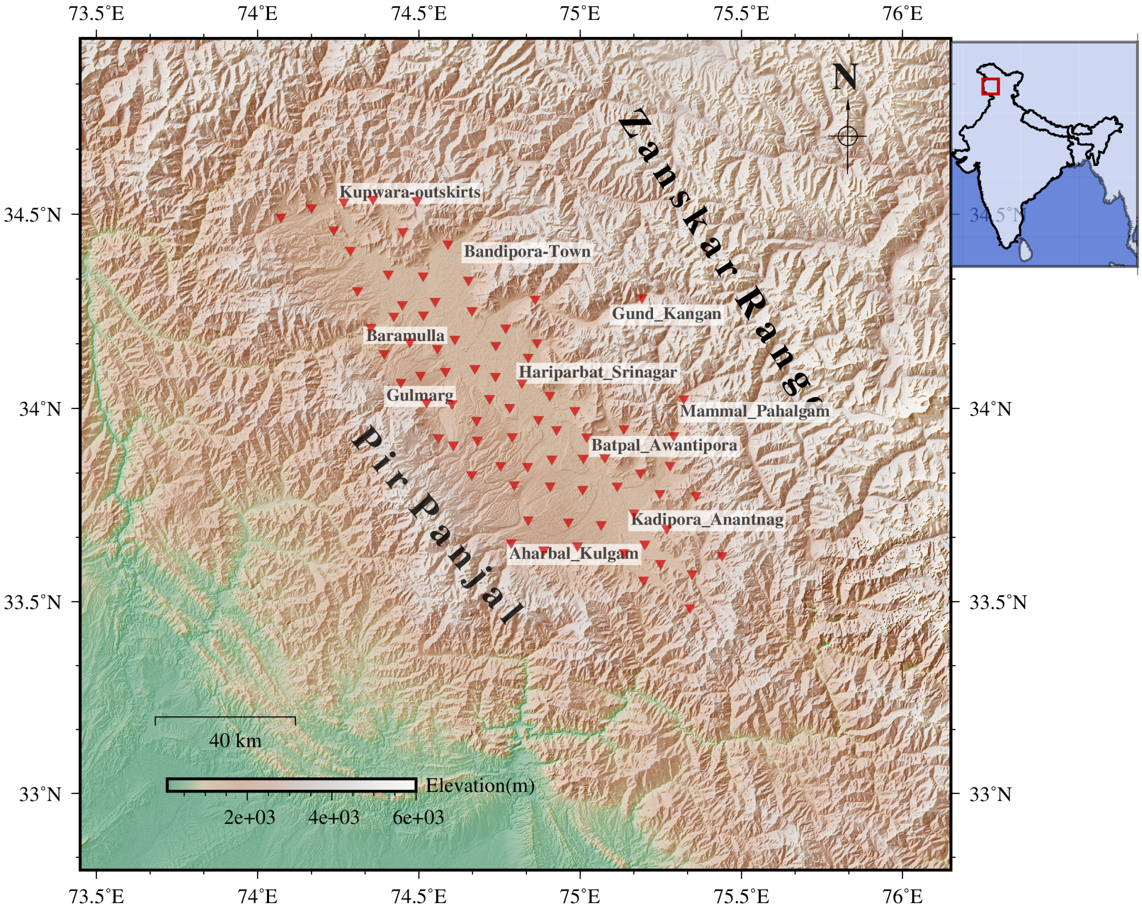


Figure 5.9: Map of Kashmir valley and triangles show the location where microtremor array data have been acquired.

Microtremors (ambient noise) are low amplitude seismic waves which are present everywhere at the earth,s surface. It represents a low energy wavefield consisting of interfering waves propagating from a range of different sources and direction, typically with amplitudes of the order of 10^{-4} to 10^{-2} mm. Microtremors with frequencies above 1 Hz are generally associated with man-made cultural sources (such as road traffic, trains, machinery, etc.), while those below 1 Hz are associated with natural phenomena such as wind and wave action and variation in atmospheric pressure. Though the microtremor wave field consists of both body waves and surface waves, but at sufficient distance from any source of seismic energy, most of the energy propagates as surface waves. It shows distinctive characteristics that strongly correlate with that of the subsurface structure, thereby providing an invasive tool for geoscientists to probe the shallow earth. We have completed the microtremor array data collection, using 7-10 measurement stations simultaneously to record vertical component of the ambient vibration. Then, the frequency-wavenumber (f-k) and the spatial autocorrelation (SPAC) methods have been used to analysed the Rayleigh wave phase velocity spectrum (dispersion curve) and spatial autocorrelation curve, respectively. Since surface waves show individual dispersion property due to the layering of soil deposits, Vs profile of subsurface ground layers can be obtained from developed theoretical equations and using inversion analysis. So far, 80 sites were analysed for first level of microtremor arrays in Kashmir Valley using Lennartz 5 sec period seismometer and MiniShark data acquisition systems (Figure 5.9) for a grid of 5 x 5 km with equilateral triangle array symmetry. At every site 2-3 geometry of array ranging from 25 m to 140 m have been designed and data were acquired for at least 1 hour for each geometry. In this study, the data is generated along different lithological contrast, edges of the valley and even wetlands areas. Now, the dispersion curves are being inverted using neighborhood algorithm in order to create high resolution shear wave velocity structure of the sub-surface in the entire Kashmir valley. The preliminary analysis of the data shows very heterogeneous and contrast materials, particularly along the fringes of the valley, however, in the center it shows very deep soft sediments (Karewa) with nearly homogeneous properties.

S Vishal Gupta, Imtiyaz A. Parvez and Prosanta K. Khan*

* Department of Applied Geophysics, Indian Institute of Technology (Indian School of Mines), Dhanbad.

5.10 L_g wave attenuation study in the Kashmir Himalaya

The Kashmir region, situated in the North-West part of Himalaya, has seismic broadband network established by CSIR-4PI since 2013. This network is established to understand the geodynamics and seismicity of the region. Apart from the lithospheric structure and seismicity, Lg wave analysis has been attempted to study the lateral variation of seismic attenuation (Q_o) along the two profile AA' across structure and BB' along the structures (Figure 5.10).

Low resistivity in the crust could be due to the presence of graphite, fluids, partial melt, aqueous fluid, or a combination. Effect of fluid or melt is more dominant in attenuation (1/Q) than shear wave velocity which varies in the crust by less than 20%, whereas Q varies by a factor of 3 on major continents. The L_g phase is a prominent seismic phase observed over continental paths at regional to teleseismic distances. It is generated by either superposition of higher mode surface waves or multiple reflected shear energy in the crust and travels with a group velocity of about 3.5 km/s. Therefore, the study of L_g attenuation is important to investigate the presence of even small aqueous fluid/melt distribution in the crust. This study aims to map lateral variation of Lg attenuation across the major structural features of the Kashmir Himalaya using the interstation Qo computation approach.

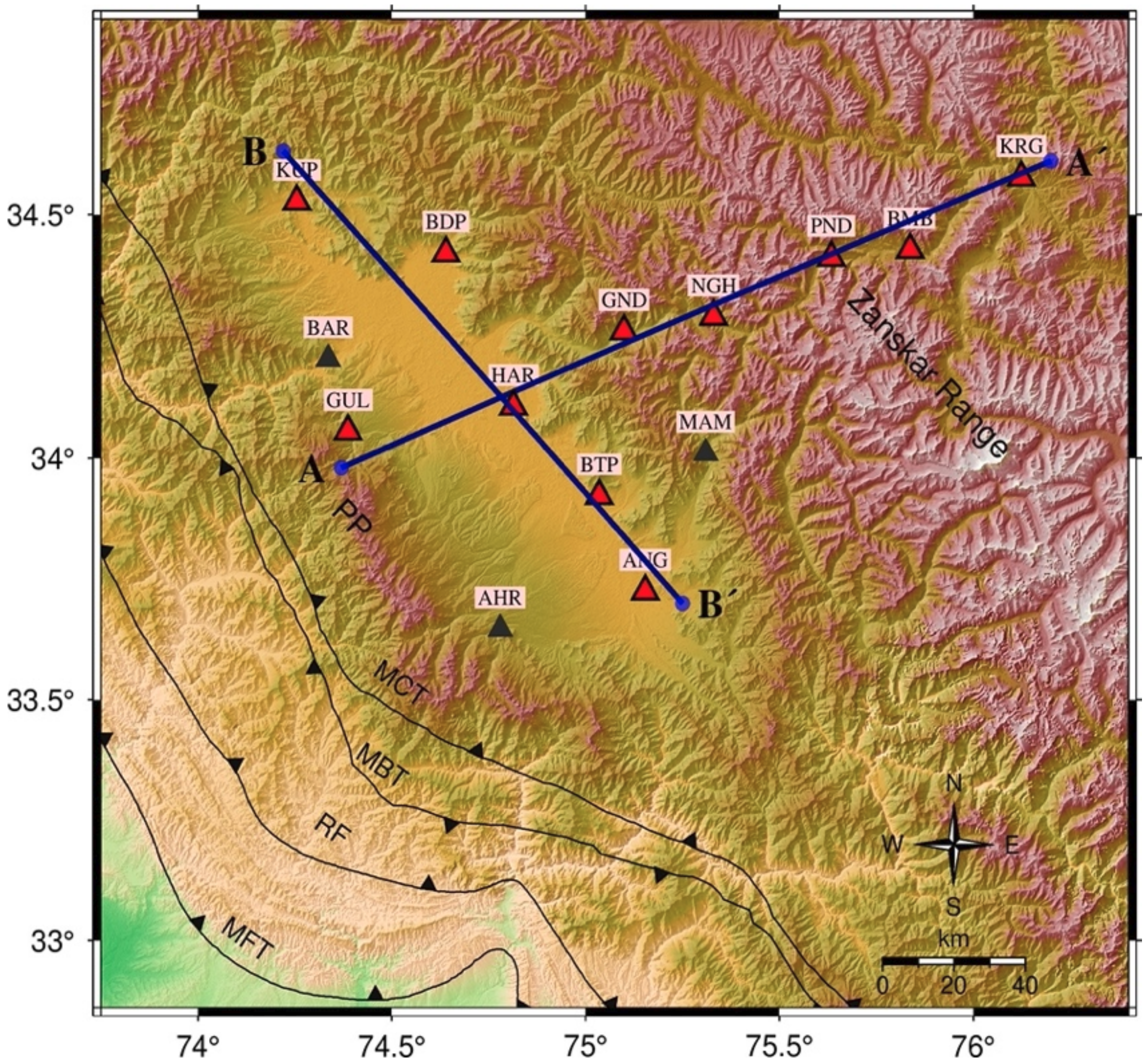


Figure 5.10: Map of the study region showing topogyaphy and geological boundaries marked by black line: MFT: Main Frontal Thrust; MBT: Main Boundary Thrust; MCT: Main Central Thrust. Two profile AA' and BB' are shown in the figure along which crustal attenuation is estimated. The triangle represents seismic stations location operated in the region. Red triangle represents the stations used for attenuation analysis.

For L_g wave study, we selected events with in $\pm 15^o$ azimuth to the profiles from both directions and delta range of 4 to 15 degree. All the events were extracted but selected only with very high signal to noise ratio for further analysis. All waveforms were filtered with frequency 0.5 to 2.0 Hz and instrument response is removed. L_g phase is extracted from seismogram using velocity time window of 3.0 to 3.6 km/s for spectral analysis.

5.11 The effect of non-uniform spatial sampling in imaging the ionosphere using GNSS

GNSS observations sampled at uniform time intervals place the Ionospheric Pierce Points (IPP) i.e. the points in the ionospheric thin shell where the microwave signals transmitted from GNSS satellites pierce the ionosphere on the way to reach the receiver at the ground at nonuniform spatial intervals.

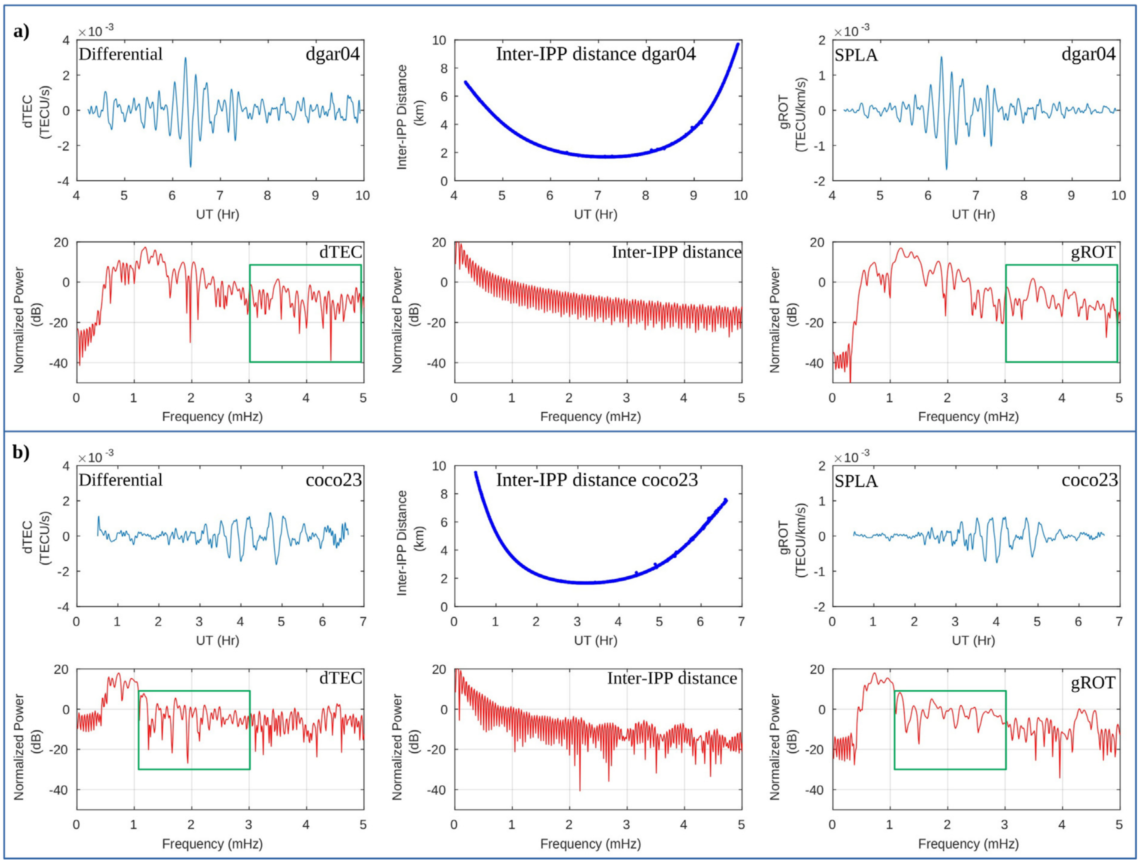


Figure 5.11: Time series of TIP, inter-IPP distances, and its normalized Lomb-Scargle periodograms correspond to satellite-receiver pairs (a) dgar04 and (b) coco23. Top panels are time series of TIP obtained using differential method (left) and SPLA (right), and times series of inter-IPP distance (middle). The bottom panels are normalized Lomb-Scargle periodograms (red) of the respective time series (blue) given above. Inter-IPP frequencies within range of acoustic gravity components are only shown here for clarity. Prominent portions of the aliased TIP and its dealiased counterpart obtained using SPLA (gROT) are marked with green boxes.

The ionospheric dynamics and perturbations in ionospheric electron density caused by various sources are increasingly studied using the Total Electron content measured at these IPPs. We found that the unaddressed nonuniform spatial sampling in GNSS observations causes significant aliasing in the ionospheric perturbations observed using GNSS receivers. The periodogram of the Tsunami induced Ionospheric Perturbations (TIP) observed from the Indian Ocean islands Diego Garcia (DGAR) and Coco Island (COCO) shows the aliasing associated with the non-linear inter-IPP distance caused by the non-uniform spatial sampling (Figure 5.11). We also showed that the algorithm developed by us at CSIR-4PI named as Spatio-Periodic Leveling Algorithm (SPLA) is successful in dealiasing the aliases caused by such non-uniform spatial sampling (Figure 5.11). In addition, the SPLA is successful in detecting the ionospheric perturbations using the observations carried out at low elevation angles which are conventionally being discarded owing to the elevation-dependent errors.

Vijayan M.S.M. and K. Shimna

5.12 Efficiency of Spatio-Periodic Levelling Algorithm in resolving sharp static variation for reliable GNSS based tsunami early warning: Theoretical and observational assessment

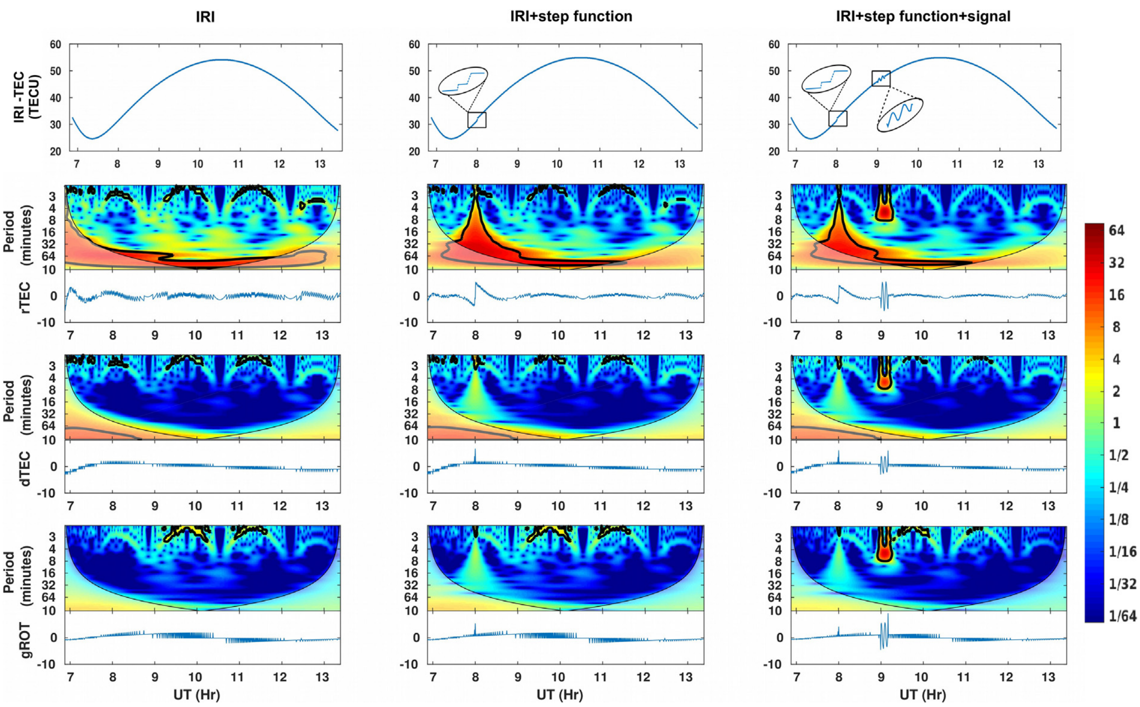


Figure 5.12: (Top row) Time series of synthetic IRI-TEC (left), Synthetic IRI-TEC superimposed with sharp static variations for the first scenario (middle), and Synthetic IRI-TEC superimposed with sharp static variations and simulated perturbation for the second scenario (right). Inlets show magnified portion of the sharp static variations and simulated perturbation. (2nd, 3rd and 4th rows) Normalized rTEC, dTEC and gROT obtained from the synthetic signals and its continuous wavelet transforms.

Tsunami early warning using GNSS based observations of tsunami induced ionospheric perturbations is emerging as a new technique to augment the conventional tsunami early warning. However, the conventional methods used to identify the Tsunami Induced Ionospheric Perturbations (TIP) are suitable for post-event research detecting the TIPs and establishing the physics of tsunami-ionospheric coupling. In addition, these techniques inherently contain pseudo signals associated with various factors like subjective selection of polynomials to remove the trend, aliasing due to non-uniform spatial sampling and lacunae in resolving sharp static variations from TIPs, etc. To overcome these limitations and develop a method suitable for real-time operation, we tested the Spatio-Periodic Leveling Algorithm (SPLA) developed by us at CSIR-4PI by employing theoretical simulations and using GNSS observations carried out on the 26th December 2004 Indian Ocean Tsunami.

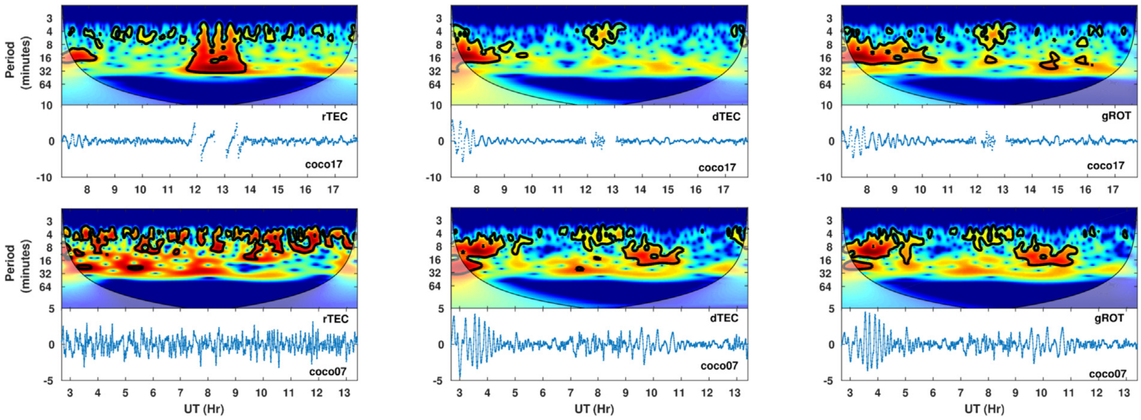


Figure 5.13: Continuous Wavelet Transform of TIPs obtained along COCO17 and COCO07 using residual method, differential method and SPLA.

Initially, the algorithm was tested on a synthesized TEC superimposed with a simulated step function and an ionospheric irregularity similar to the one induced by a tsunami. The synthetic TEC was obtained from International Reference Ionosphere (IRI) model (Figure 5.12). This theoretical validation revealed that the SPLA is efficient in resolving tsunami signatures from sharp static variations (Figure 5.12). Later, we extended our validation using real GPS observations containing breaks similar to the sharp static variations. The results affirmed the resolving efficiency of SPLA (Figure 5.13). Furthermore, the validation tests disclosed that the SPLA significantly improves the signal-to-noise ratio of the ionospheric tsunami signatures in addition to resolving the artifacts like sharp static variations. This will be useful to reduce false alarms.

Vijayan M.S.M. and K. Shimna

5.13 The Indo-Burmese arc and its seismic potential

A closer look through the focal mechanism data of Indo Burmese Arc (IBA) shows large spatial variability and style of faulting (Figure 5.14). We categorized the data using a ternary visualization of the relative proportion of variations in normal, thrust, and strike-slip faulting components for the respective segments. These ternary diagrams use the plunge of the maximum, intermediate, and null compressional axes.

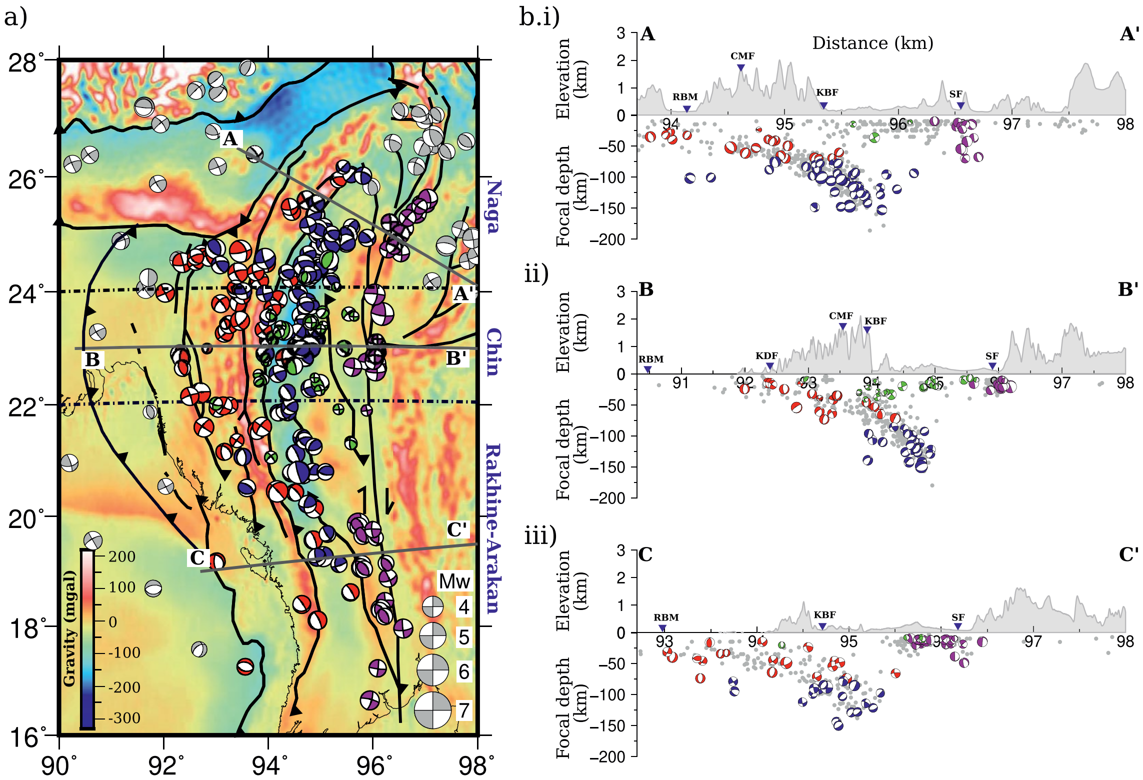


Figure 5.14: (a) Focal mechanism solutions from the Indo Burmese Arc (IBA) viz; the Rakhine-Arakan, Chin, and Naga segments. The background image is the free-air gravity distribution of the IBA (b) Depth-wise distribution of faulting mechanism solutions across the profiles shown in Figure 2a: Naga (AA'), Chin (BB') and Rakhine-Arakan (CC') segments. Corresponding topography, along the same profile lines are also plotted above. Labeled inverted blue triangles represent major tectonic discontinuities. RBM: Rakhine-Bangladesh Megathrust, KDF: Kaladan Fault, CMF: Churachandpur Mao Fault, KBF: Kabaw fault, SF: Sagaing Fault.

The shallow Rakhine-Arakan segment shows a considerable number of normal faulting earthquakes with steeply plunging P-axes. Also seen here are a few pure strike-slip earthquakes. Those intermediate events seen here are mostly oblique-reverse with downdip T-axis. The IBW majorly hosts strike-slip to compressional earthquakes of lower magnitude than those within the slab or the SF region. Traces of normal-oblique faulting are also observed here.

5.14 Corrected model for Axial vibration of double-walled nanorod and making sense of Pasternak medium and magnetic effects

A reliable mathematical provides correct scientific inferences in the mathematical modeling of structures. Though the axial vibration of the double-walled nanorod model by Aydogdu (Journal of Vibration and Control, Vol. 21, Issue 16, (2015), 3132-3154) analyzed its importance, inconsistent and wrong terms occurred in his model. The present proposed model takes care of the earlier mistakes for the correct scientific understanding. Further, for the axial vibration study, the modeling of the Pasternak medium and magnetic forces are analyzed. Interestingly, the Pasternak medium and magnetic effects are insensitive to the dimensionless axial frequencies of the double-walled nanorod. So it remains a challenge to model the axial vibration effects of nanorod with Pasternak medium and magnetic force. This study shows that still more understanding is required in this field.

V. Senthilkumar

5.15 Approximate Critical Buckling Solutions for Triple-walled Carbon Nanotube

The mathematical model for the buckling effect of a triple-walled carbon nanotube takes form with the contribution of three different buckling loads, namely inner, middle and outer nanotube. The reliable and quick estimate of three nanotube buckling loads has been computed with Bubnov-Galerkin Method and Petrov-Galerkin Method with suitable polynomials for three different boundary conditions, namely simply-simply, clamped-clamped and clamped-simply supported. The sensitivity of boundary conditions reveals that the first critical buckling load behaves differently compared to the second and third buckling loads' behavior with the increase in nanotube length.

V. Senthilkumar

III

Knowledge & Technical Management

6. Academic Programmes

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

- Academy of Scientific and Innovative Research (AcSIR)
- Student Programme for Advancement of Research Knowledge (SPARK)
- Research Fellowship Programme
- Faculty Participation
- CSIR-Integrated Skill Initiative
- Jigyasa Programme at CSIR-4PI

6.1 Academy of Scientific and Innovative Research (AcSIR)

CSIR-4PI has an active research program leading to Ph.D. degree in a multitude of arenas. It provides a stimulating atmosphere, which fosters creativity and encourages innovative thinking and research. The PhD program consists of flexible course work, computational training tutorials and a research proposal to demonstrate attainment of a high degree of scientific ability which is followed by advanced research leading to a PhD thesis on a specific topic. The PhD program is normally completed in 4-5 years. During the first year, the students have to go through a course work covering basic and advanced topics. The students are encouraged to take courses in inter-disciplinary areas. As part of the PhD program, the PhD student is expected to give at least two seminars.
In the year 2021-2022, Prof V Y Mudkavi joined AcSIR at CSIR-4PI as a Distinguished Emeritus Professor and Prof S K Brahmachari as a Mentor for promotion of Data-Driven Applied & Translational Research.
During 2021-2022 four students received their PhD degrees in the faculty of Physical Sciences from AcSIR. They are:

1. Stella Jes Varghese (Guide: Dr S Sajani and Co-Guide: Dr K Rajendran)
2. Silpa K (Guide Dr Anil Earnest)
3. Ipsita Putatunda (Guide Dr K Rajendran
4. Arya V B (Guide: Dr S Sajani)

One student Rani Devi (Guide: Dr K C Gouda) completed the PhD comprehensive viva in May 2021.

And, two students newly enrolled for PhD in the faculty of engineering sciences:

1. Iranna Gogeri (Guide: Dr K C Gouda)
2. Tarun Pandey (Guide: Dr V Anil Kumar)

During 2021-2022 following faculties offered PhD course works:

1. Dr G K Patra
2. Dr K V Ramesh
3. Dr V Anil Kumar
4. Dr K C Gouda
5. Dr G N Mohapatra
6. Dr Ashapurna Marndi

K C Gouda

PhD Guidance

- **Himesh S (Guide), Gouda K C (Co-Guide)**
  1. Sanjeeb Kumar Sahoo, Impact of urbanization on high impact weather events & local climate, Visvesvaraya Technological University, Belgaum, Karnataka.
- **Himesh S (Guide), Rakesh V (Co-Guide)**
  1. Ajilesh P, Characteristics of urban extreme rainfall events over the indian cities: an observational and modelling study, Visvesvaraya Technological University, Belgaum, Karnataka.

- **Kantha Rao Bhimala** (Guide) and **Patra G K** (Co-Guide)
    1. Raghavendra Prasad Babu Kanike, Identification of relationship between land surface parameters and monsoon rainfall over India.
- **Gouda K C**
    1. Radhika TV, (VTU), Efficient and Large-Scale Climate Simulation Analysis in Cloud Computing Cluster.
    2. Payoshni Samantray, (VTU) Study of Extreme Rainfall Events due to Cloud Burst using Observation and Model Simulation.
    3. Rani Devi (AcSIR), Dynamics High Impact Weather Climate over India.
    4. Smrutishree Lenka (VTU), Role of air-sea interaction processes on climate system.
    5. Iranna Gogeri (AcSIR).
- **Mohapatra G N (Guide), Rakesh V (Co-guide)**
    1. Smrati Purwar, (AcSIR), Modelling of spatio-temporal variation in urban extreme rainfall events with special focus on localised versus large-scale impacts.
- **Patra G K**
    1. S Gunasekaran, AcSIR, Challenges in Design, development and testing of Autonomous Aerial Refueling capability.
    2. Manmohan Brahma, AcSIR, Optimization of DNN inference on CPU/GPU Platform.
    3. Anju Sharma, AcSIR, Multi-sensor data fusion strategies and algorithms for health assessment of Mechanical systems.
- **Parvez I A**
    1. S Vishal Gupta, IIT(ISM) Dhanbad, Site specific seismic hazard study in Kashmir Valley.
    2. Gopinath Chakkaravarthy, Amrita Vishwa Vidyapeetham, Gravitational waves and it's impact on tectonics and earthquakes.
- **Rajendran K**
    1. Ipsita Putatunda, AcSIR, Characteristics of heating and moisture in tropics: An observational study. PhD thesis viva-voce completed on 9 June 2021.
- **Rakesh V**
    1. Ajay Bankar, AcSIR, Impact of Data Assimilation in Mesoscale model simulations.
- **Ramesh KV**
    1. Neethu C, VTU, Karnataka, Modelling the role of land-atmosphere interaction during heat waves.
    2. Swetha Sivakumar, AcSIR, Modelling theăroleăofăair-sea interactions onătropicalăcyclone intensification and a post cyclone damage assessment usingămulti-spectralăRemote Sensing observations.
- **Sajani Surendran**
    1. Arya V B, AcSIR, The impact of regional aerosols on Indian summer monsoon rainfall and variability. PhD thesis viva-voce completed on 22 January 2022.
- **Sajani Surendran (Guide), Rajendran K (Co-guide)**
    1. Stella Jes Varghese, AcSIR, Impact of resolution and deep convection scheme

on simulation of Indian summer monsoon and its projection under multiple RCPs using multiforcing ensembles. PhD thesis viva-voce completed on 25 May 2021.

- **Sridevi Jade**
  1. Chiranjeevi G. Vivek, AcSIR, GNSS signal processing and analysis to study impact on position estimates.
  2. Siva Sai Kumar Rajana, KLEF University, Global Navigation Satellite System (GNSS) based remote sensing of long and short-term ionospheric variability over Indian sub-continent.

6.2 CSIR-4PI Student Programme for Advancement of Research Knowledge

The Student Programme for Advancement of Research Knowledge (SPARK) of CSIR-4PI has been successfully operational for the past ten years. This flagship student programme of the Institute provides a flexible framework for motivated students from all over the country to participate in the research programme of CSIR-4PI and thereby advance their research knowledge. Under SPARK, the students typically carry out their major project/thesis work with the joint guidance of the CSIR-4PI scientists and faculty members of their respective University/Institute. Students are also encouraged to visit CSIR-4PI for internship as well as for short-term exploratory research work. The programme is open to all Indian students who have formally enrolled for higher degrees, like BE/B.Tech/ME/M.Tech/M.Sc/MCA/Ph.D, etc. Applications are being received and processed online throughout the year.

Despite the COVID-19 pandemic-related restrictions, SPARK program has been successfully running, mainly through the online mode, during the year 2021-2022. Students were provided guidance and need-based access to IT and computational resources remotely over the Internet. During 2021-2022, a total of 56 applications were received and subsequent to scrutiny and shortlisting, training was provided for 34 students.

V Anil Kumar, Ashish, Sajani Surendran and Stella Margeret

M.Tech/BE/MCA student thesis/projects supervised by

- **Anil Earnest**
  1. Mrinmoy Tamulli, MSc Tech. Applied Geophysics, Dibrugarh University, Assam.
- **Gouda K C**
  1. Sweta Kumawat, Jain University
  2. Abhinav B Roy, IISER Thiruvananthapuram
  3. Shantanu Singh Chauhan, PES University , Bangalore.
  4. Kirteen Reddy, NITTE, Mangalore
  5. Alok Chaudhury, UCET, Vinoba Bhave University, Hazaribag
- **Patra G K**
  1. Pritika Barshilia, National Institute of Technology, Goa.
  2. Vayun K Soni, National Institute of Technology, Hamirpur.

- **Rakesh V**
    1. Geo Tom, Kerala University of Fisheries and Ocean Studies (KUFOS), Kerala.
    2. Selja Saji, Kerala University of Fisheries and Ocean Studies (KUFOS), Kerala.
- **Ramesh K V**
    1. Neethu C S, Kerala university of fisheries and ocean studies (KUFOS), Kerala.
    2. Naveen, Kerala university of fisheries and ocean studies (KUFOS), Kerala.
    3. Hamsaa sk, National Institute of Technology , Rourkela.
- **Senthilkumar V**
    1. V Anirudh, B.Tech (Engineering Physics), Delhi Technological University, Delhi.
    2. Bharat Bhushan, B.Tech (Mechanical), National Institute of Technology, Patna.
    3. B Vivek Kalyan, B.Tech (Mechanical), B M S College of Engineering, Bangalore.

6.3 Faculty Participation

1. **Ashapurna Marndi**, Advanced Training on High Performance Computing, Cyber Security and Data Science, CSIR-4PI, 21st March to 25th March 2022.
2. **G K Patra**, Security and Privacy Concerns of Vehicular & Flying Ad-hoc Networks during one Week AICTE ISTE online refresher program on Mobile & Cloud Security: Challenges and Directions, Computer Engineeing Department, A. V. Parekh Technical Institute, Rajkot, 3rd June 2021 to 9th June 2021.
3. **Gouda K C**, Delivered talk and Resource person in AICTE Training And Learning (ATAL) Academy Online Elementary FDP on "Research Challenges in Atmospheric Sciences with a Computing Edge" from 20/12/2021 to 24/12/2021 at M S Ramaiah Institute of Technology.
4. **G N Mohapatra**, “Modelling and forecasting of high impact weather events in the Beas basin, and designing a prototype Advance warning system for mitigation of their adverse impact”, 30th July 2021, Conference hall, GBP-NIHE, HPRC Mohal, Kullu. Himachal Pradesh.
5. **Thangavelu R P**, Advanced Training on High Performance Computing, Cyber Security and Data Science, CSIR-4PI, 21st March to 25th March 2022.

6.4 CSIR-Integrated Skill Initiative

Council of Scientific and Industrial Research (CSIR) started a programme ‘CSIR-Integrated skill Initiative’ in line with “Skill India” mission. Under this umbrella, various CSIR laboratories have participated and conducted training programs under different domains across pan India. Under this project, CSIR-Fourth paradigm Institute (CSIR-4PI) is also participating and has conducted two types of training: Advance training programme on high performcence somputing, cyber security and data science and the Student programme in Advancement in Knowledge (SPARK). SPARK is a student academic programme where students from universities can do their internship and project work in association with CSIR-4PI researchers.

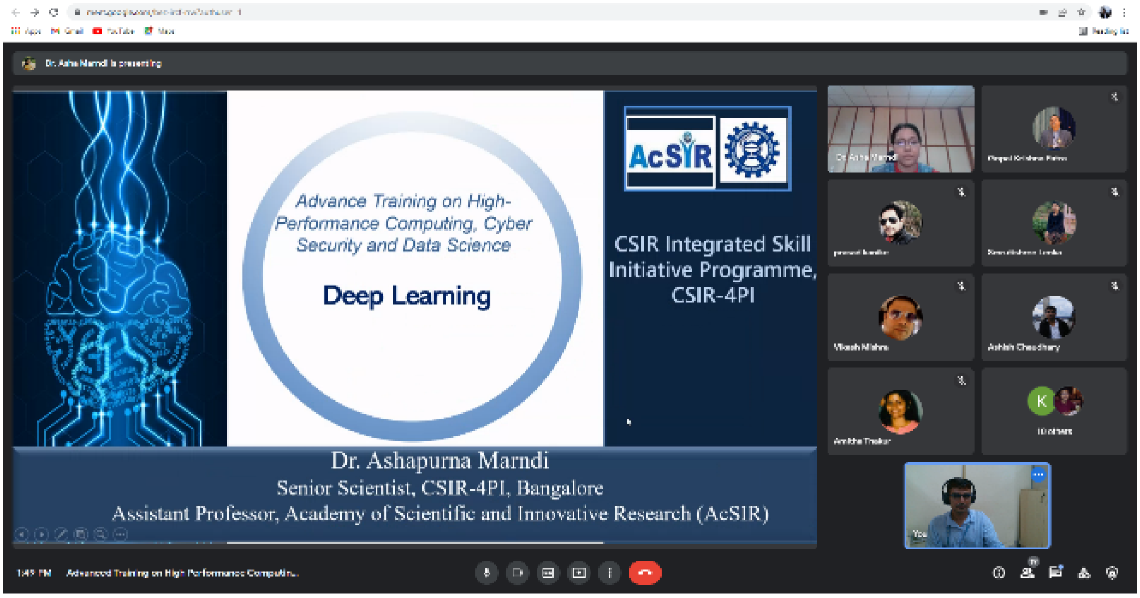


Figure 6.1: Dr. Ashapurna Marndi gives a lecture on Deep Learning techniques under the Advance training programme on high performcence somputing, cyber security and data science.

Under the skill Initiative Programme of CSIR, CSIR-4PI has organized a training programme on “Advanced Training on High Performance Computing, Cyber Security and Data Science” from March 21^{st} - 25^{th} March 2022. Speakers from both CSIR and other prestigious Institutes in India participated as Faculty members of the training programme. The participants of the programme include undergraduate, postgraduate, Ph.D., and professionals from various Institutes/Universities in India. A total of more than 20 people were trained as part of this programme.

Ashish

6.5 Jigyasa Programme at CSIR-4PI

The JIGYASA project was officially sanctioned to CSIR-4PI on September 16th 2021. The main objective was to inspire the current young generation with an indelible imprint of science using concepts of STEM, to join research which shall lead to creating “AATMA NIRBHAR BHARAT”. The journey began with a curtain raiser event for IISF2021: Festival Of Games And Toys hosted by CSIR-NML ON 29TH November 2021, wherein Dr. Sridevi Jade & Mrs. Pavithra N R gave a preview of what students can expect from Festival of Games & Toys.

The major portion of JIGYASA programme was conducted in India International Science Festival: Festival of Games Toys (G&T), from December 10th to 13th at Panjim, Goa, wherein the students were given live demonstration and explained several concepts of Physics, simple science of toys making,etc. The event was held in Hybrid mode : offline participation was limited to 500 students whereas daily online participation saw 2000+ PAN India.

Next based on the interests seen among the students in the IISF 2021 event we organized a YOU-TUBE LIVE webinar : VISMAYA VIGYANA SERIES from 16th 18th February 2022. This webinar saw a live participation of around 2000-2500 students via online mode, Dr. Sridevi Jade inaugurated with a talk on “Paradigms of Science”, here she enunciated as how the paradigms have revoultionized the R&D system. Dr. Sajani Surendran presented on “Physics of Indian Summer Monsoon”, This talk was a huge hit among students as they were thrilled to see the how earth rotation and revolution caused all the variants in our ecosystems. Dr. Ashapurna presented “Artificial Intelligence : Its application in different Sectors”. She very conveniently explained the each and every concept of AI and finally we had Dr. G C Anupama conclude the webinar series with “Wonders of Cosmos”, which was truly a delight to experience.

On the occasion of “International Day of Women and Girls in Science” Dr. Sridevi Jade spoke on “GNSS/GPS and its applications in Science” on 11th February 2022 , she elaborated how GPS/GNSS was being used for R&D. This talk was a PAN India event organized in collaboration with CSIR-HQS and CSIR-4PI.

CSIR-4PI JIGYASA programme was concluded with an outreach programme to Kendriya Vidayalaya, NAL and 3 more shools in Bangalore. Dr. K C Gouda, Dr. Ashish and Mr. Iranna Kumar, scientists of this centre, explained the concepts of Weather Informatics, Geo-Hazard mapping and High-Performance Computing to the students.

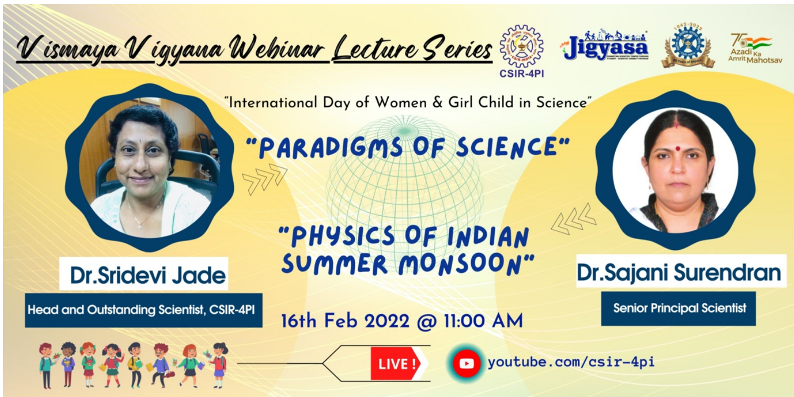


Figure 6.2: Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science. Banner displaying day-I talks on “Paradigms of Science” and “Physics of Indian Summer Monsoos”.

Pavithra N R

Figure 6.3: Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science. Banner displaying day-II talk on "Artificial Intelligence (AI): Its application in different sectors.

Figure 6.4: Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science. banner displaying day-III talk on "Wonders of Cosmos".

7. Knowledge Activities & Products

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

- Patents Granted
- Publications in Journals
- Publications in Books/Proceedings
- PresentationsinConferences/Symposia/Workshops/Seminars
- Participation in Conferences/Symposia/Workshops/Training Programmes
- Guest Lectures
- Invited Talks
- Conference/Workshops/Seminars at CSIR-4PI
- In-house seminars/lectures
- Visitors at CSIR-4PI
- Events

7.1 Patents Granted

1. V Anil Kumar and D Das, Method and System for Detection and Elimination of Optimistic SACK Spoofing Based Denial-of-Service Attacks on SCTP through Data Enriched SACK, Indian Patent No. 364591, 13/04/2021.

7.2 Publications in Journals

Bhimala, K. R., Patra, G. K., Mopuri, R., & Mutheneni, S. R. (2021). Prediction of covid-19 cases using the weather integrated deep learning approach for india. *Transboundary and Emerging Diseases*.

Devi, R., Gouda, K., & Lenka, S. (2022). Temperature-duration-frequency analysis over delhi and bengaluru city in india. *Theoretical and Applied Climatology*, *147*(1), 291–305.

Dumka, U., Kaskaoutis, D., Khatri, P., Ningombam, S. S., Sheoran, R., Jade, S., Shrungeshwara, T., & Rupakheti, M. (2022). Water vapour characteristics and radiative effects at high-altitude himalayan sites. *Atmospheric pollution research*, *13*(2), 101303.

Earnest, A., Sunilkumar, T., & Silpa, K. (2021). Sinking slab stress and seismo-tectonics of the indo-burmese arc: A reappraisal. *Tectonics*, *40*(8), e2021TC006827.

Gouda, K. C., Mahendra, B., Priya, S., Nikhilasuma, P., Reshama, K., Chandrika, M., Geeta, A., Sneh, J., Smrutishree, L., Rani, D., Murty, U. S., & Himesh, S. (2021). An assessment of relation of meteorological parameters and covid-19 transmission at the early stage during march-may 2020 in india. *Vayumandal*, *47(02)*, 73–86.

Gouda, K. C., Singh, P., Benke, M., Kumari, R., Agnihotri, G., Hungund, K. M., et al. (2021). Assessment of air pollution status during covid-19 lockdown (march–may 2020) over bangalore city in india. *Environmental Monitoring and Assessment*, *193*(7), 1–13.

Gouda, K. C., Gogeri, I., & Thippa Reddy, A. S. (2022). Assessment of aerosol optical depth over indian subcontinent during covid-19 lockdown (march–may 2020). *Environmental Monitoring and Assessment*, *194*(3), 1–11.

Gupta, S. V., Parvez, I. A., & Khan, P. K. (2022). Imaging subsurface geological complexity (2d/3d) beneath the greater srinagar region of the kashmir basin, northwest himalaya. *Near Surface Geophysics*, *20*(1), 94–114.

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Jayasankar, C. B., Rajendran, K., & Sajani, S. (2021). Does increasing the spatial resolution in dynamical downscaling impact climate change projection of indian summer monsoon, population and gdp? *Theoretical and Applied Climatology*, *145*(1), 441–453.

Kallummal, R. (2022). Projected engulfment of tropical indian ocean by anthropogenical warmpool. *Climate Dynamics*, 1–13.

Lenka, S., Devi, R., Joseph, C. M., & Gouda, K. C. (2022). Effect of large-scale oceanic and atmospheric processes on the indian summer monsoon. *Theoretical and Applied Climatology*, 1–16.

M.A.Lokoshchenko, N.F.Elansky, L.I.Alekseeva1, Bogdanovich1, A., Agnihotri, G., Himesh, S., & Gouda, K. C. (2021). Analysis of thunderstorm activities in moscow and bengaluru. *Vayumandal*, *7(1)*, 12–23.

Marndi, A., Ramesh, K. V., & Patra, G. (2021). Crop production estimation using deep learning technique. *Current Science*, *121*(8), 1073–1079.

Mir, R. R., Parvez, I. A., Laske, G., & Gaur, V. K. (2022). Sensor orientation and noise analysis of the kashmir-zanskar seismic network: An appraisal from 2014 to 2020. *Journal of Seismology*, 1–18.

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Neethu, C., & Ramesh, K. (2022). High-resolution spatiotemporal variability of heat wave impacts quantified by thermal indices. *Theoretical and Applied Climatology*, *148*(3), 1181–1198.

Prakasa Rao, E. V. S., Rakesh, V., & Ramesh, K. V. (2021). Big data analytics and artificial intelligence methods for decision making in agriculture. *Indian Journal of Agronomy*, *66*, S279–S287.

Rajana, S. S. K., Shrungeshwara, T., Vivek, C. G., Panda, S. K., & Jade, S. (2022). Evaluation of long-term variability of ionospheric total electron content from iri-2016 model over the indian sub-continent with a latitudinal chain of dual-frequency geodetic gps observations during 2002 to 2019. *Advances in Space Research*, *69*(5), 2111–2125.

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Rajendran, K., Surendran, S., Varghese, S. J., & Sathyanath, A. (2022). Simulation of indian summer monsoon rainfall, interannual variability and teleconnections: Evaluation of cmip6 models. *Climate Dynamics*, *58*(9), 2693–2723.

Rakesh, V., Mohapatra, G., & Bankar, A. (2021). Historical extreme rainfall over the bangalore city, india, on 14 and 15 august 2017: Skill of sub-kilometer forecasts from wrf model. *Meteorology and Atmospheric Physics*, *133*(4), 1057–1074.

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Vijayan, M. S. M., & Shimna, K. (2022). Detecting aliasing and artifact free co-seismic and tsunamigenic ionospheric perturbations using gps. *Advances in Space Research*, *69*(2), 951–975.

Yajnik, K. S., & Devasana, C. K. (2021). Changing variability of sea surface temperature in the post-wwii era. *Journal of Earth System Science*, *130*(3), 1–13.

7.3 Publications in Books/Proceedings

1. Ashapurna Marndi, GK Patra, Attention Based Ensemble Deep Learning Technique for Prediction of Sea Surface Temperature, Congress on Intelligent Systems, Soft Computing Research Society,(Virtual Mode) Springer, 4th-5th Sept, 2021
2. Gouda K C, Predictive Modeling of the Spread of COVID-19: The Case of India. 2021, Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, Kumar, N., Vinodhini, M., Venkatesha Prasad, R.R. (eds), vol 383. Springer, Cham. doi.org/10.1007/978-3-030-79276-3_11, Springer, Switzerland.
3. Mir R R, Parvez I A and Gaur, V K (2021) Shear wave velocity structure beneath North-Western Himalaya and adjoining areas. Pre-Print (Earth ArXiv) DOI:https://doi.org/10.31223/X5DK68
4. Parvez, I.A. (2021) Application of neo-deterministic seismic hazard assessment to India. In: Panza G, Kossobokov V, De Vivo B, Laor E (Eds) (2021) Earthquakes and Sustainable Infrastructure: neo-deterministic (NDSHA) approach guarantees prevention rather than cure. Imprint: Elsevier. Paperback ISBN: 9780128235034), pp. 525-541.
5. Selja Saji , V. Rakesh and Abish .B, Effect of Covid-19 Lockdown Induced Changes in Aerosol Optical Depth and Greenhouse Gas Concentration for Major Cities and Industrial Hubs in India, Proceedings of International Symposium on Tropical Meteorology Changing Climate: Consequences and Challenges (INTROMET-C4), INTROMET-2021, CUSAT Cochin, Kerala, November 23-26, 2021.
6. Geo Tom, V. Rakesh and Abish .B, Effect of Covid 19 Lockdown Induced Changes in Atmospheric Meteorological Profiles for Major Cities and Industrial Hubs in India, Proceedings of International Symposium on Tropical Meteorology Changing Climate: Consequences and Challenges (INTROMET-C4), INTROMET-2021, CUSAT Cochin, Kerala, November 23-26, 2021.
7. K. V. Ramesh and V. Rakesh, Integrated data analytics platform for sustainable crop management: Developing intervention strategies for increasing quality production, Proceedings of 5th International Agronomy Congress, PJTSAU, Hyderabad, Telangana, India, November 23-27, 2021.
8. V. Senthilkumar, Axial wave propagation of carbon nanorod conveying fluid with elastic support using nonlocal continuum elasticity, Mathematical Methods in Dynamical Systems, CRC Press, Taylor & Francis Group, Edited by S. Chakraverty and Subrat Kumar Jena, 2022 (Accepted and In Press)
9. Vijayan M.S.M. and K. Shimna (2021) Nature, Dynamics and sensitivity of Tsunami-Ionospheric coupling: Insights from 26th December 2004 Indian Ocean Tsunami, NSF Convergence workshop on Bringing Land, Ocean, Atmosphere and Ionosphere Data to the community for hazard alerts, AGU, Abstract ID:789886

7.4 Presentations in Conferences/Workshops/Seminars

1. Mir R. R., Parvez, I. A., V. K. Gaur (2021) Orientation of broadband seismographs in the Kashmir Himalaya: Effect on vector-based studies, European Geophysical Union General Assembly. https://meetingorganizer.copernicus.org/EGU21/EGU21-14708.html
2. Kantha Rao, Research Challenges in prediction of extreme weather events over Himalayan region: International Conference on Extreme weather events under changing climate, March-10-11, 2022, Kullu, Himachal Pradesh.
3. Stella Jes Varghese, K. Rajendran, Sajani Surendran and A. Chakraborty, Dependence of Indian summer monsoon rainfall forecast skill of CFSv2 on initial conditions and the role of bias in SST boundary forcing, European Geophysical Union (EGU) General Assembly 2021, https://meetingorganizer.copernicus.org/EGU21/EGU21-7046.html, EGU21-7046, 30 April 2021.
4. V. B. Arya, Sajani Surendran and K. Rajendran, Possible indirect effect of dust aerosols during monsoon breaks over India, , 4th International Conference on Atmospheric Dust-DUST 2021, https://www.dust2021.atmodust.net/wp-content/uploads/2021/09/SRA-vol_11-1.pdf, Torre Cintola Conference Centre-Monopoli, Italy, 7 October 2021.
5. Priyanshi Singhai, A. Chakraborty, Sajani Surendran, K. Rajendran, Global Teleconnections to the Indian Summer Monsoon in CFSv2 model: Tropics vs. Midlatitude, European Geophysical Union (EGU) General Assembly 2021, https://meetingorganizer.copernicus.org/EGU21/EGU21-4880.html, EGU21-4880, 30 April 2021.
6. Rameshan K, Indo-Pacific Warm Pool Will Envelop Eighty Percent of the Tropical Indian Ocean by 2070, AGU Fall meeting 2021 (2021-12-15), Poster Presentation (Virtual Mode).
7. Rameshan K, Deciphering characteristics of Central and Eastern Pacific ENSOs from the amplitude-modulated seasonal cycles, AGU Fall Meeting 2021 (2021-12-14), Oral Presentation (Virtual Mode).
8. Sridevi Jade, Natural Hazards and real time GNSS, India - Russia Scientific Webinar on Disaster Management Technologies, 1-2 December 2021.
9. Sridevi Jade, Real time GNSS and Natural Hazards, Invited panel presentation, Preconference workshop, Indian Geotechnical Conference 2021, 15 December 2021
10. Sridevi Jade, GPS/GNSS Science Applications, CSIR-Jigyasa Webinar, International Day of Women and Grils in Science, 11 February 2022.Women and Girls day science day.
11. Sridevi Jade, Paradigms of Science, Vismaya Vigyana Webinar series, CSIR-4PI Jigyasa, International Day of Women and Grils in Science, 16 February 2022
12. Sridevi Jade, GNSS/GPS Science Applications, National Science day lecture, ISRO, Bangalore, 28 February 2022.
13. Sridevi Jade, GNSS for CORS: Current Scenario and Way Forward, Key note presenter and discussion panel member, Webinar on Continuously Operating Reference System (CORS) in India- Prospects for Navic, SATNAV Programme, ISRO, 21 April 2021.
14. G N Mohapatra, Modelling and forecasting of high impact weather events in the Beas basin, and designing a prototype Advance warning system for mitigation of their adverse impact, 30th July 2021, Conference hall, GBP-NIHE, HPRC Mohal,

Kullu. Himachal Pradesh.

15. Vijayan M.S.M, Nature, Dynamics and sensitivity of Tsunami-Ionospheric coupling: Insights from 26th December 2004 Indian Ocean Tsunami, NSF Convergence workshop on Bringing Land, Ocean, Atmosphere and Ionosphere Data to the community for hazard alerts, AGU, May 24-28, 2021.
16. Nidhi Singh, Sudhansu Sekhar Rath,Sayanta Ghosh, Renu Lata, Prashant and K C Gouda, Python Based Data Processing for Rainfall Study, International Conference on Extreme Weather Events under Changing Climate(ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
17. Sudhansu Sekhar Rath, Nidhi Singh, Sayanta Ghosh, Renu Lata , Prashant and K C Gouda, Advanced Warning System for High Impact Weather Event over the Beas River Basin, International Conference on Extreme Weather Events under Changing Climate(ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
18. Sayanta Ghosh, Renu Lata, Sudhansu Sekhar Rath , Nidhi Singh , Isha Thakur , R. K. Singh , Prasant and K. C. Gouda, Assessing the Anthropogenic Influence on Regional Climate Variability using Satellite Data in Beas Valley, International Conference on Extreme Weather Events under Changing Climate(ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
19. Nikhilasuma P and K C Gouda Assessment of changes in Rainfall Distribution over Karnataka, International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
20. P Samantaray and K C Gouda, Analysis of Extreme Rainfall due to Cloud burst events over Himalayan belt using Multiscale Observation and Non Hydrostatic Model, International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
21. Smrutishree Lenka, K C Gouda, Rani Devi and C M Joseph, Analysis of Extreme Rainfalldue to Cloud burst events over Himalayan belt using Multiscale Observation and Non Hydrostatic Model, International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
22. Reshama Kumari and K C Gouda, Assessment of vegetation distribution over Beas basin International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
23. Rani Devi, K C Gouda and Smrutishree Lenka Assessment of spatio temporal changes of cold wave in recent period over India, International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022), GBPNIHE, Kullu, HP, March 10 11, 2022
24. C Neethu and K V Ramesh, Projections of heat waves over seven temperature homogeneous zones of India from CMIP6 models, November 23-26, 2021, International Symposium on Tropical Meteorology (INTROMET-2021) on changing climate: consequences and challenges, TROPMET Proceedings, 2021, C4-21

7.5 Participation in Conferences/Workshops/Training Programmes

- **Ashapurna Marndi**
  1. CSIR Sponsored - Two days Virtual International workshop on Privacy- Pre-

serving Artificial Intelligence Techniques for Machine Learning (IWAIML-21) held on 26th and 27th November, 2021.
2. One-day Symposium on Applications of Machine Learning methods in Physics held on 18th Dec, 2021.

- **Chiranjeevi G. Vivek**
  1. Online Workshop on NavIC/GNSS: Technique and Applications organized by National Atmospheric Research Laboratory, Gadanki, 3-5 August, 2021.
  2. Workshop on "To study the tremors in Kalaburagi, Vijayapura and Bidar districts" organized by KSDMA during 8-9 November, 2021.
- **G N Mohapatra**
  1. Participated in International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022) in Indian Himalayan Region held during theăMarch 10-11, 2022 (Hybrid Mode)
- **Gouda K C**
  1. Conducted a training for the stakeholders from different departments of Govt. of Bihar in the BSDMA, Patna in November 2021 and March 2022 on the pollution mapping in Patna city along with CSIR NEERI.
  2. Conducted two capacity building workshops in Kullu district for the Himalayan meteorological disaster events during October 2021.
  3. Organized sessions for teachers and research scholars in the International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022) held at GBPNIHE, Kullu on Disaster management in Himalayan region during 10-11 March 2022.
  4. Participated in the he RISK-KAN working group on early warnings meeting on on 27th May on communicating early warnings for systemic risks.
- **Mir R R**
  1. Two days workshop on tremors in northern districts of Karnataka organized by Karnataka State Disaster Kalaburgi Management Authority, Kalaburgi, 8-9th November, 2021.
- **Vijayan M.S.M.**
  1. Nature, Dynamics and sensitivity of Tsunami-Ionospheric coupling: Insights from 26th December 2004 Indian Ocean Tsunami, NSF Convergence workshop on Bringing Land, Ocean, Atmosphere and Ionosphere Data to the community for hazard alerts, AGU, May 24-28, 2021, Online.
  2. EGU General Assembly 2021, 19-30 April 2021, Online

7.6 Guest Lectures

- N Purna Chandra Rao
  - Environmental Seismology A new tool for monitoring, detection and early warning of Geohazards, Chief Scientist, CSIR-NGRI, Hyderabad, Former Director, NCESS, Thiruvananthapuram, 17. March 2022

7.7 Invited Talks

- **Anilkumar V**
  1. Cyberspace and Attacks: New Observations and Perspectives with Changing Scenario, National Power Training Institute, 25 February, 2022.
  2. Supercomputing and Cybersecurity: An Engineering Perspective, AICT sponsored faculty development programme, MVJ college of Engineering, 01 September 2021.
  3. Packets, Protocols and Attacks in Cyberspace: The Trends and Dynamics, Eminent Lecture Series #7, Amritha Vishwa Vidya Peetham, 28 August 2021.
  4. Supercomputing Performance from an Architecture and Interconnect Perspective, CSIR Integrated Skill Initiative Programme, 21-25 March 2022.
  5. Design and Implementation of Programable Network Architecture for Zero Trust Architecture, 3rd meeting of ZTA Working Group, 19 April 2021.
- **Thangavelu R P**
  1. High Performance Computing and Applications: A CSIR Perspective, Faculty Development Programme “STTP on Recent Advances in HPC and DL”, NITTE Meenakshi Institute of Technology, Bangalore, 15 Sep 2021.
- **G K Patra**
  1. Blockchain: A New Technology of Trust, Powered by Cryptography, addressing the IEEE student members on the occasion of IEEE hours on 15th May 2021 through online virtual mode
  2. VANET Sybil attack mitigation, presentation to the leadership team of Cognizant, 24th June 2021
- **Parvez I A**
  1. An overview on earthquake zonation and microzonation studies in India, at the 5th National Geo-Research Scholars Meet: Webinar (22-23 July, 2021) organized by Wadia Institute of Himalayan Geology, Dehradun. The workshop was attended by more than 350 participants from different Universities of India.
- **Kantha Rao**
  1. AICTE Training And Learning (ATAL) Academy Online Elementary FDP on "Research Challenges in Atmospheric Sciences with a Computing Edge " from 20/12/2021 to 24/12/2021 at M S Ramaiah Institute of Technology.
- **K Rajendran**
  1. Invited lead talk on Progress in the simulation of Indian summer monsoon, variability and teleconnections over different generations of IPCC climate models, Intromet-2021 of Indian Meteorological Society, 24 November 2021.
  2. Invited panelist and session chair for Changing climate: Consequences and Challenges (C4-41), Intromet-2021 of Indian Meteorological Society, 24 November 2021.
  3. Invited lecture on reliable climate change projections for India, National Science Day lecture, Jyoti Nivas College Autonomous, Bengaluru, 28 February 2022.
- **K C Gouda**
  1. Chief guest and delivered a talk on “Statistics for understanding weather and climate” Symbiosis statistical Institute, Pune, June 29, 2021.

2. “High impact weather events Modelling”,GBP-NIHE, HPRC Mohal, Kullu. Himachal Pradesh, 30 July 2021.
3. “Modelling and forecasting of high impact weather events in the Beas basin”, District Disaster Management Authority, Kullu, Himachal Pradesh, 03 Aug 2021.

- **Ramesh K V**
  1. Lead talk in the 5th International Agronomy Congress 2021-Agri-Innovations to Combat Food and Nutrition Challenges on Integrated data analytics platform for sustainable crop management: Developing intervention strategies for increasing quality production 23-27 November 2021 at PJTSAU, Hyderabad, Telangana, India.
- **V. Senthilkumar**
  1. Guest Lecture delivered on Applications of Differential Calculus and Linear Algebra in Engineering Science at M.V. J. College of Engineering on 19.01.2022.
- **Sridevi Jade**
  1. Natural Hazards and real time GNSS, India - Russia Scientific Webinar on Disaster Management Technologies, 1-2 December 2021.
  2. Real time GNSS and Natural Hazards, Invited panel presentation, Preconference workshop, Indian Geotechnical Conference 2021, 15 December 2021
  3. GPS/GNSS Science Applications, CSIR-Jigyasa Webinar, International Day of Women and Girls in Science, 11 February 2022.
  4. GNSS/GPS Science Applications, National Science day lecture, ISRO, Bangalore, 28 February 2022.
  5. GNSS for CORS: Current Scenario and Way Forward, Key note presenter and discussion panel member, Webinar on Continuously Operating Reference System (CORS) in India- Prospects for Navic, SATNAV Programme, ISRO, 21 April 2021.

7.8 Conference/Workshops/Seminars at CSIR-4PI

- **Sajani Surendran**
  1. Seminar on Physics of Indian Summer Monsoon Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science, Jigyasa Programme, 16th February 2022.
- **Ashapurna Marndi**
  1. “Deep Learning Approaches for Earth Science Data Analytics” in occasion of #80Years 80 Success Stories campaign as a run-up to CSIR’s 80 years celebrations and the grand celebration of #AzadiKaAmritMahotsav for showcasing the CSIR-4PI success stories held on 7th December 2021.
  2. “Artificial Intelligence and its Applications in Different Sectors” in Vismaya Vigyan Jigyasa Webinar Series in occasion of International Day of Women & Girl Child in Science held on 17th February 2022.

7.9 In-house seminars/lectures

1. PhD Thesis Viva-voce lecture on Impact of resolution and deep convection scheme on simulation of Indian summer monsoon and its projection under multiple RCPs using multiforcing ensembles, 25th May, 2021, Stella Jes Varghese, AcSIR, CSIR-4PI.
2. PhD Thesis Viva-voce lecture on Characteristics of heating and moisture in tropics: An observational study, 9th June, 2021, Ipsita Putatunda, AcSIR, CSIR-4PI.
3. PhD Thesis Viva-voce lecture on The impact of regional aerosols on Indian summer monsoon rainfall and variability, 22nd January, 2022, V B Arya, AcSIR, CSIR-4PI.

7.10 Visitors at CSIR-4PI

- **Shri Chetan Prakash Jain**, JS & FA, CSIR / DSIR, 01 Sept 2021
- **Sayanta Ghosh**, PA, GBPNIESD, Kullu, 17 Oct 03 Nov 2021
- **Ms Nivruti Rai**, Country Head, Intel India, 26th Oct 2021
- **Mr Manish Sharma**, Intel India, 26th Oct 2021
- **Mr Vivek Kumar Rai**, Intel India, 26th Oct 2021
- **Dr G. Narahari Sastry**, Director CSIR-NEIST, Jorhat, 29th Oct 2021
- **Shri Jitender Singh**, Registrar, Rajiv Gandhi National Aviation, 12th Nov 2021
- **Shri Krishna Murari**, AGDM, HAL, 12th Nov 2021
- **Dr Aravind C Ranade**, Vijnana Bharati, New Delhi, 24th Nov 2021
- **Shri Jayant Sahasrabudhe**, Vijnana Bharati, New Delhi, 24th Nov 2021
- **Sri Vivekanand Pai**, Vijnana Bharati, New Delhi, 24th Nov 2021
- **Prof Jayant R Harista**, Sr Professor, IISc, Bangalore, 20th Dec 2021
- **Prof R Govindarajan**, SERC and CSA, IISc, Bangalore, 12th Feb 2022
- **Dr Purna Chandra Rao**, Chief Scientist, CSIR-NGRI, 17 18 Mar 2022

7.11 Events at CSIR-4PI

Ambedkar Jayanti Celebrations

Figure 7.1: CSIR-4PI along with CSIR-NAL celebrated Ambedkar Jayanti Celebrations on 14/04/2021 at CSIR-NAL Campus, Bangalore.

Technology Day Celebrations

Figure 7.2: CSIR-4PI along with CSIR-NAL celebrated National Technology day on 11/05/2021 at CSIR-NAL Campus, Bangalore.

Independence Day Celebrations

Figure 7.3: CSIR-4PI, along with CSIR-NAL, celebrated the Independence day and hoisted the national flag on 15th August, 2021.

80th CSIR Foundation Day

Figure 7.4: CSIR-4PI, along with CSIR-NAL celebrated the 80th CSIR Foundation Day on 26th September, 2021.

Dr. Sridevi Jade taking charge of The Head, CSIR-4PI

Figure 7.5: Dr. Sridevi Jade taking charge of The Head, CSIR-4PI from Shri. Jitendra J Jadhav, on 26th September, 2021.

Vigilance Awareness Week

Figure 7.6: CSIR-4PI conducted a vigilance awareness program on the fourth week of October 2021.

Flag Hoisting on Kannada Rajyotsava Day

Figure 7.7: CSIR-4PI, along with CSIR-NAL celebrated the "Kannada Rajyotsava" day by hoisting the Kannada flag at CSIR-NAL campus on 01 November 2021.

Farewell to Shri. Anil Angadi

Figure 7.8: Farewell to Shri. Anil Angadi on 11 November 2021 at CSIR-4PI Conference Hall.

Karnataka Rajyothsava Celebrations 2021: jointly organised by CSIR-4PI & CSIR NAL

Figure 7.9: Karnataka Rajyothsava Celebrations 2021 jointly organised by CSIR-4PI & CSIR NAL on 26 November 2021 at S R Valluri Auditorium CSIR-NAL.

IISF-2021 Outreach Events by CSIR 4PI

Figure 7.10: CSIR 4PI hosted series of outreach events for India International Science Festival-2021 on 29. November 2021 and 30. November 2021.

Mega Science, Technology and Industry Expo at IISF

Figure 7.11: Glimpses of CSIR 4PI participation in the Mega Science Technology and Industry Expo at IISF, Goa, 10-13 December 2021.

Inauguration of Festival of Games and Toys Event coordinated by CSIR-4PI in IISF 2021 at Goa

Figure 7.12: CSIR-4PI coordinated the festival of Games and Toys event in IISF 2021 at Goa on 10 December 2021.

CSIR-4PI Foundation day

Figure 7.13: CSIR-4PI conducted it's foundation day on 20 December 2021. Prof. Jayant R Harista, Dept. of Computational Science, IISc delivered foundation day lecture on "Data Science and Astrology: Is there a difference".

Vishwa Hindi Divas

Figure 7.14: CSIR-4PI, along with CSIR-NAL celebrated the Hindi Divas at the CSIR-NAL campus, Bangalore on 10/01/2022.

Farewell to Shri Harikrishnan V, FAO, CSIR-4PI

Figure 7.15: CSIR-4PI bid farewell to Shri Harikrishnan V, FAO, CSIR-4PI on 10 January 2022 on his retirement from CSIR service.

Republic Day Celebrations

Figure 7.16: CSIR-4PI celebrated the Republic day jointly with the CSIR-NAL by hoisting National Flag. The institute name board was lit-up in tri-colour, joining with the true spirit of #Azadi Ka Amrit Mahotsav.

GNSS/GPS and its applications in science

Figure 7.17: As part of the celebration of “International Day of Women and Girls in Science” under the CSIR Jignyasa programme Dr. Sridevi Jade, Head and Outstanding Scientist of CSIR-4PI delivered a Live Webinar on “GNSS/GPS and its applications in science” on 11. February 2022.

Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science

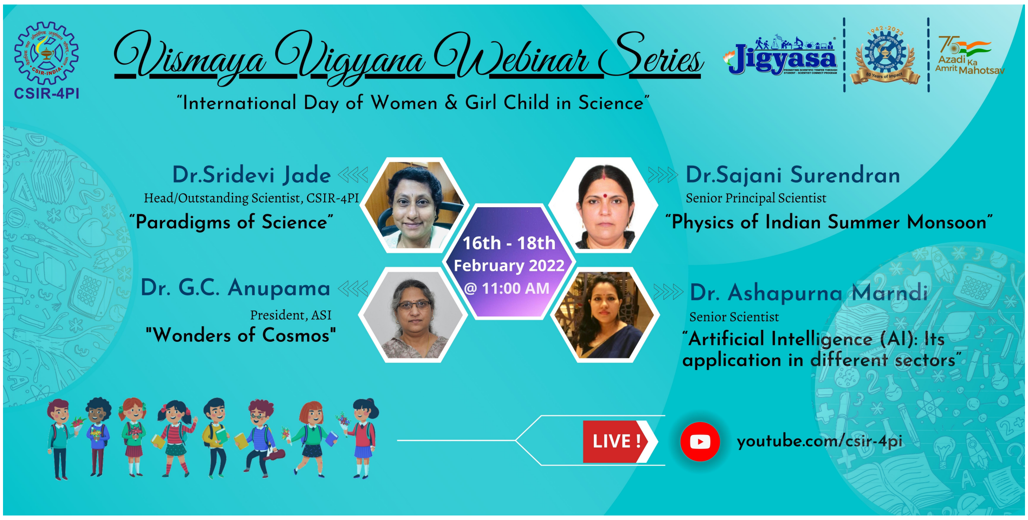

Figure 7.18: CSIR-4PI conducted Vismaya Vigyana Webinar Series Celebrating International Day of Women & Girl Child in Science on 15 and 16 February 2022

International Mother Language Day Celebrations

Figure 7.19: CSIR-4PI and CSIR-NAL jointly organised the International Mother Language day Celebrations on 21 February 2022 at the Director‘s Conference Hall, CSIR-NAL.

International Women‘s Day celebration

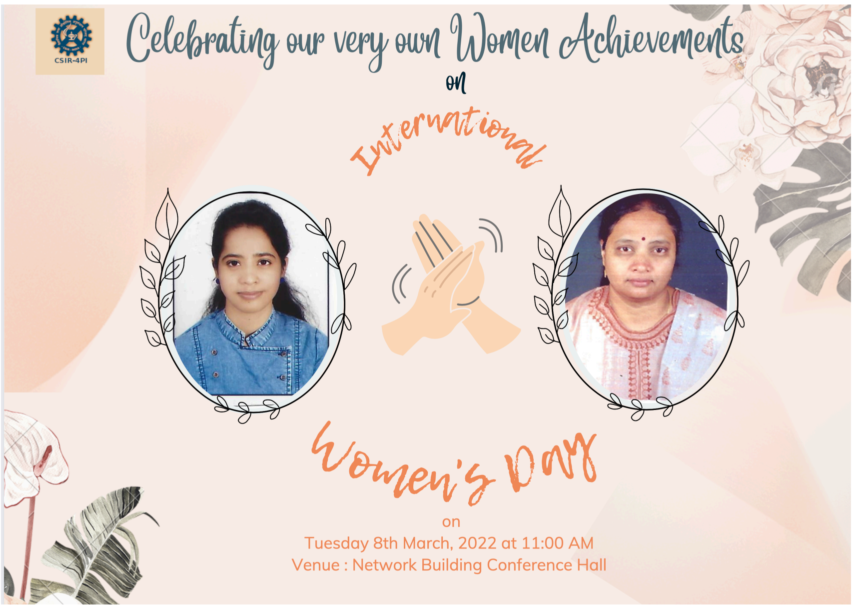

Figure 7.20: CSIR-4PI celebrated the International Women‘s Day on 8 March 2022.

Joint celebration of International Women's Day by 4PI and NAL

Figure 7.21: CSIR-4PI & CSIR-NAL jointly celebrated the International Women's Day on 8 March 2022 at Valluri Auditorium.

Advanced Training on High-Performance Computing, Cyber Security and Data Science

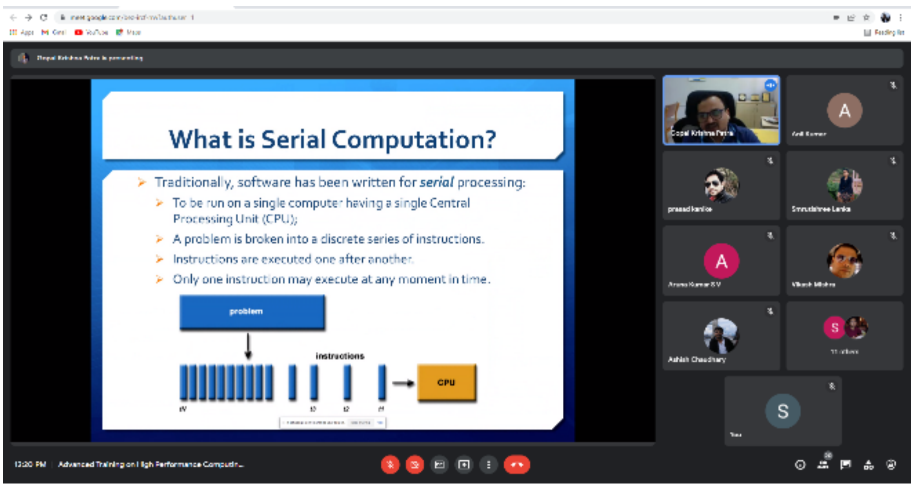

Figure 7.22: Dr. G K Patra talks on computational techniques during the "Advanced Training on High-Performance Computing, Cyber Security and Data Science" offered under the CSIR-Integrated Skill Initiative at CSIR-4PI.

7.12 Some major events organized by CSIR-4PI

National Science Day celebration by AcSIR (Jointly organised by CSIR-NAL and CSIR-4PI)

National Science Day was celebrated jointly by AcSIR, CSIR-National Aerospace Laboratories and CSIR-4PI, Bangalore at CSIR-NAL on 28th February 2022. In this connection Prof. Dipankar Banarjee, Department of Materials Engineering, IISc, Bangalore has delivered National Science Day Lecture on "Materials in Flight". As part of Azadi Ka Amruth Mohotsav celebration, CSIR-NAL and CSIR-4PI jointly initiated the AcSIR Lecture Series. Dr. Ramesh Sundaram, Chief Scientist and Head, Advanced Composites Division, CSIR-NAL, Bangalore has delivered the First Lecture "Health Monitoring of Composites Structures" under this series.

Figure 7.23: National Science Day Celebrations jointly organised by CSIR-4PI and CSIR -NAL.

Various events namely, Essay writing competition, Cartoon drawing and Poster presentation were organized during 15-Feb-2022 to 18-Feb-2022. The AcSIR Ph.D students both from CSIR-NAL & CSIR-4PI took part in these events. The prizes were distributed to the winners. The AcSIR Faculty was actively involved in organizing the events. The following are the glimpses of National Science Day Celebrations organised by AcSIR.

Welcome address by Mr. Jithendra Jadev ,
Director, CSIR-NAL

Inaugural address by Dr. Sridevi Jade,
Head, CSIR - 4PI

Figure 7.24: Glimpses of National Science Day Celebrations organised by AcSIR.

CSIR-4PI at India International Science Festival -2021

India has a rich tradition of local toys and has talented and skilled artisans with expertise in making good toys, noting that some parts of the country are developing as toy clusters.ăThere is a need through the toys industry to bring back the glorious past and also spruce up the golden future and in fact to get vocal for local toys. Folk toy traditions include animals made from leather, figurines from terracotta or Neem wood, and puppets from betel nut and cloth. Done right, these remain some of the most eco-friendly toys possible. The materials were traditionally sourced locally; paints were natural dyes. The same applies for the development of computer games based on Indian concepts and history.

The toys and games are not just for the sake of passing the time but they are very good mind sharpeners. Traditional Indian toys are not just for fun but are also informative. They help kids in learning skills like Mathematics, hand-eye coordination, Sensory-development etc. The program motivates the development of mental concentration and logical thinking and as well provide platform to display their products (toys and games) by local manufacturers.

The India International Science Festival (IISF) 2021 was conducted from 10th to 13th December 2021 at Panjim, Goa. The event along with other programmes hosted IISF: GAMES & TOYS programme in an hybrid mode which was co-ordinated and organized by CSIR-4PI in support with Vijnana Bharathi and NCPOR. The salient feature of IISF: GAMES & TOYS were

1. Short film screening at the inauguration.
2. Traditional & creative exhibits
3. Panel discussion
4. Talk show / Fab-Lab Show.

The ultimate goal was to

1. To promote creativity, self-reliance and global platform for local toys and games.
2. Inculcation of a scientific attitude among students through games and toys.
3. Showcasing of glorious past of country.

On 10th December the programme was inaugurated by Prof. Harilal Menon, VC Goa University as chief guest , Sh. Vivekanand Pai as special guest under presidency of Dr. Sridevi Jade. The event begun with live demonstration from Dr. Jayant Joshi, (from B.A.R.C. Mumbai) on topic of Science behind toys while the afternoon session was handled by the team of IIT-Gandhinagar (which included Shri.Manish Jain, Shri. Tapas Hira and Shri. Pankaj Godara) wherein the topics of Physics and Geometry were dilately taught using simple newspaper models which were made by students from instructions from IIT-Gandhinagar team members.

Day 2 i.e 11th December 2021started with Shri. Gopal Khanna showcasing his historical collection of toys prior to Independence. The session was followed by Fun with flying things basic Aerodynamics Made Easy topic taught by Mr. Ananth Raam. This session was total HIT among the student community, Mr.Ananth Raam elaborated over the concepts of thermodynamics with practical demonstration. The post lunch session had continuation of Physics concepts explanation by Mr. Jayanth Joshi. The day ended with a panel discussion regarding Challenges for Indian Games and Toys Industry among the

Figure 7.25: Highlights of CSIR-4PI participation in the India International Science Festival 2021 at Goa.

panellists included Sh. Sazid Chogule, Co- Founder, Luma World, Mumbai, Sh. Aditendra Jaiswal, Founder & CEO Srijan Sanchar, Dr. Parag Mankeekar, Neeti Solutions, Pune, Mrs. D Roopa, IPS & MD, Cauvery Handicrafts and Shailendra Jaiswal, Principal Executive Director, DRDO-HQ, New Delhi. Here every panellists put forth the challenges they faced in terms of product design, marketing, getting the idea right or monetary issues of China v/s India.

The final day 12th December 2022 included sessions from Mrs. Mittal Salia, a sports psychologists who encouraged students to work more on cognitive skills rather than text book mugging & emphasized that students only learn when parents provide an environment & opportunity for the kids to grow. The next session was Deepak's Fab Lab Show by Mr. Prateek & Chyp, this was the showstopper for the entire event wherein concepts of centrifugal force, nitrogen gas gun, centre of mass and other were cleverly taught to students.

The event was concluded by Chief Guest Sh. Jayant Sahsrabuddhe (National Organizing Secretary VIBHA) along with Special Guest Dr. Sridevi Jade, Head, CSIR-4PI under the Presidency of Prof. I. K. Pai, Vice-President, Vigyyan Parishad. The programme offline participants were limited to 500, while online saw a participation of 2000 from PAN-India on daily basis.

Pavithra N R, Kaustubh Omar[α], Lathika[β], Shubhangi S Shenvi Agni[γ], Amey K N Shirodkar[θ]

[α] - Vijnana Bharati, [β] - NCPOR, Panaji, [γ] - VPHSS, Goa, [θ] - CTNHSS, Goa.

International conference "Extreme Weather Events under Changing Climate (ICEWECC-2022)"

CSIR 4PI organized an international conference during March 10-11 2022 on "Extreme Weather Events under Changing Climate (ICEWECC-2022)" at G. B. Pant National Institute of Himalayan Environment- Himachal Regional Center (GBPNIHE-HRC), Mohal, Kullu in collaboration with GBPNIHE and District Disaster Management Authority (DDMA), Kullu. The conference was sponsored by NMHS, MoEFCC, Govt of India during March 10-11 2022.

The Chief Guest of the inaugural function of the conference was Prof. V.K. Gaur, Honorary Emeritus Scientist, CSIR-4PI, Bangalore whereas Special Guests were Dr. Sridevi Jade, Head, CSIR-4PI, Bangalore and Dr Surender Paul, Director, Indian Meteorological Department, Shimla Regional Centre. Guest of Honour and Special Guest of the Valedictory session were Sh. Parshant Sirkek, Additional District Magistrate (ADM), Kullu District and Dr. Brian Golding, Hi-Weather Co-Chair, World Meteorological Organisation (WMO).

Over 200 participants attended the conference through virtual mode from different parts of the world including USA, Australia, Thailand, Pakistan, China, Indonesia and nearly 60 participants joined through physical mode. 3 Plenary Talk have been delivered by Dr John McGregor (CSIRO, Australia), Prof K Ashok (Univ. of Hyderabad) and Dr

Figure 7.26: CSIR 4PI organized an international conference during March 10-11 2022 on“Extreme Weather Events under Changing Climate (ICEWECC-2022)” at G. B. Pant National Institute of Himalayan Environment- Himachal Regional Center (GBPNIHE-HRC), Mohal, Kullu in collaboration with GBPNIHE and District Disaster Management Authority (DDMA), Kullu. The conference was sponsored by NMHS, MoEFCC, Govt of India during March 10-11 2022.

Richard Johnson, Bath Spa University, United Kingdom. Eight invited speakers across world delivered keynote lectures during the 2 days of deliberation. The main aim of the conference was to provide a forum for researchers, Scientists and professionals across the world to share their research findings, and the current trend of research in the field of climate change and its impact on environment and increasing number extreme weather events in IHR. Disseminating research results, various ideas on controlling environmental degradation and disaster management for a better life for the people of the IHR. About 24 research papers have been presented by the participants during the 2 day conference. There was a field visit to the disaster prone area in Kullu-Manali after the conference on 12th March 2022. The meeting was coordinated by Dr K C Gouda, Project leader, Dr Renulata, Co-PI, Mr R K Singh, Head, GBPNIHE-Kullu and Sayanta Ghosh along with the project team (Sudhanshu, Nidhi, Smruti, Nikhila, Reshma and Rani) from CSIR 4PI.

Figure 7.27: Inaugural session of ICEWECC-2022.

Figure 7.28: Valedictory session of ICEWECC-2022.

Capacity building workshop and Natural Disaster Awareness seminar for local community of Kullu

During July-August, 2021, 3 capacity building and awareness programmes were organized in the District Kullu, Himachal Pradesh by CSIR Fourth Paradigm Institute in collaboration with G.B. Pant National Institute of Himalayan Environment, Kullu, Himachal Pradesh and District Disaster Management Authority (DDMA) Kullu. The seminars were organized at village Palchan (Panchayats Palchan, Burua and Shanag) on 31/07/21 and village Katrain (Naggar, Rumsu, Manadalgarh and Hurang Panchayat) on 03/08/2021.

Figure 7.29: Glimpses of the capacity building and awareness seminar at Village Palchan (July 31, 2021).

The purpose of the meeting was to make familiar the local residents with the objectives of the ongoing NMHS project on Himalayan Disaster modelling and to harness the outputs from the discussions on disaster management methods. The meeting was organized under the flagship of the National Mission on Himalayan Studies for developing an advanced warning system for the high-impact weather events such as flash floods, cloud bursts, mudslides etc. in the Beas Basin. One discussion session with the district administration of Kullu district was organized at DDMA office, Kullu on 03/08/2021.

Figure 7.30: Glimpses of capacity building and awareness seminar at Village Palchan (August 3, 2021).

8. Projects & Collaborative Programmes

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

- CSIR Projects
- Major Lab Projects
- Grant-in-aid Projects
- Sponsored Projects
- Collaborative Projects
- In-House Projects
- MOU’s Signed

8.1 CSIR Projects

1. Assessment and Forecasting of Extreme Weather Events Over the Indian Region Using Mesoscale Model, PI: Dr. V Rakesh

8.2 Major Lab Projects

1. Development of a modelling platform for Hydro-Meteorological Disaster early Warning System for Major Cities in India (HDWS), PI: Dr. GN Mohapatra
2. Setting-up of CSIR HPC, AI and ML Platform (CHAMP), PI: Shri. R P Thangavelu
3. HPC Cloud Resource at CSIR for COVID-19 Research Support for Indian Researchers, PI: Dr. Gopal Krishna Patra
4. Integration of GNSS and Broadband data for High Resolution Velocity Structure and Crustal Deformation in Jammu, Kashmir and Ladakh Himalayas (IGBHK), PI: Dr. Sridevi Jade
5. CSIR JIGYASA 2.0 Virtual Laboratory Integration Project (First Tranche), PI: Smt. N R Pavithra
6. CSIR Integrated Skill Initiative Phase II Programme, PI: Ashish

8.3 Grant-in-Aid Projects

1. Influence of Upper Ocean Physical Processes on the Oxygen and Nutrient Variability in the North Indian Ocean using eddy permitting coupled ecosystem model of the global Ocean, DST, Women Scientist Scheme A PI: Dr. Chikka Kalyani Devasena
2. Enhancement of the quality of livelihood opportunities and resilience for the people in the Indian Himalayas, through design of intervention strategies aimed at maximizing resource potential and minimizing risks in urban-rural ecosystem, MoEFCC PI: Dr. K.V. Ramesh
3. Integrated system dynamical model to design and Testing Alternative intervention strategies for effective remediation Sustainable water management for two selected river basins of Indian Himalaya, MoEFCC PI: Dr. K. V. Ramesh
4. Hyper spectral imaging for sharper definitions of Himalayan ecosystems and its high value plant species under climate uncertainties, MoEFCC PI: Dr. K.V. Ramesh
5. Design and Development of a Hybrid Modelling System for the Management of select horticultural crops in Andhra Pradesh, YSRHU PI: Dr. K.V. Ramesh
6. Analysis of urban heat islands', air pollution dynamics and extreme Heat wave phenomena in India and Russia, DST - PI: Dr. K C Gouda
7. Developing a Public Health Informatics Platform in India for a Systems View of Health and Diseases under Epidemiology Data Analytics (EDA) of Interdisciplinary Cyber Physical Systems (ICPS) Programme of DST, DST - PI: Dr. K C Gouda
8. Modelling and Forecasting of High Impact Weather Events in the Beas basin, and Designing a Proto-type Advance Warning System for Mitigating their Adverse Impacts, MoEFCC - PI: Dr. K C Gouda
9. Design Intervention Strategies for Mitigating the Impacts of heat waves through modified land cover, DST Women Scientist Scheme A, PI: Smt. C Neethu

10. Improving the Prediction of Thunderstorms using Dual - Resolution Hybrid Ensemble - Variational Data Assimilation System using WRF Model, MoES PI: Dr.V Rakesh
11. A Darknet / Network Telescope Based Cyber Security Monitoring and Inference Framework, MEITY PI: Dr. V Anil Kumar
12. Feasibility Evaluation, Impact Quantification and Mitigation of Low-Rate Cyber Attacks on Multipath Transmission Control Protocol (MPTCP), DST - PI: Dr. V Anil Kumar
13. National Carbonaceous Aerosol Programme (NCAP): Working Group III Carbonaceous aerosol emissions, source apportionment and climate effects, MoEFCC - PI: Dr. Sajani Surendran
14. Improving the prediction of the extremes of the interannual variation of the Indian Summer Monsoon Rainfall (ISMR) by CFSv2, MoES PI: Dr. K Rajendran
15. Assessment of regional hydrology using space borne gravity observations: Robust estimation of deformation due to hydrological loading in NE-India and Upper Ganga river basin, DST - PI: Dr. M Sithartha Muthu Vijayan & Co-PI: Dr. K. Rajendran
16. Geological characterization of the Kashmir valley with the objective of quantifying probabilistic hazard and risk in the high-risk areas of the valley using a logically integrated set of Geo-Scientific Investigation, MoES - PI: Dr.Imtiyaz A Parvez

8.4 Sponsored Projects

1. Detection and Mitigation of Sybil Security threat and its associated attacks in Vehicular Ad-hoc Networks (VANETs), Cognizant Technology Solution Private Limited PI: Dr. Gopal Krishna Patra

8.5 Collaborative Projects

1. Collaborative Research Project on Climate Change for Patna and its Agglomeration, NEERI, Nagpur, PI: Dr. K C Gouda

8.6 In-House Projects

1. GNSS and Seismic Network in the Indian Subcontinent, CSIR, PI: Dr. Sridevi Jade
2. Development of High Precision Greenhouse Gases (GHG) Database in Indian Context, PI: Shri. Iranna K G

8.7 MOU's Signed

1. Memorandum of Understanding between CSIR Fourth Paradigm Institute (CSIR-4PI), Bengaluru and Dr Y S R Horticultural University (YSRHU), Venkataramannagudem, West Godavari - 534101, Andhra Pradesh, 17-07-2021.
2. Memorandum of understanding between CSIR Fourth Paradigm Institute (CSIR-4PI), Bengaluru and Dr. Y.S.R horticultural university (YSRHU), Venkataramannagudem, West Godavari - 534101, Andhra Pradesh, 23-11-2021.

9. Staff News & Updates

CSIR Centre for Mathematical Modelling and Computer Simulation (CSIR CMMACS) was set up in 1988 with the mandate to develop expertise, excellence and facilities for undertaking major mathematical modelling and simulation problems in identified areas primarily of relevance to CSIR. CSIR CMMACS was repositioned in 2013 as CSIR Fourth Paradigm Institute (CSIR-4PI) to provide the country a unique positioning in the domain of computational and data intensive research powered by high performance computing and informatics research. One of the smallest of CSIR laboratories, CSIR4PI today is a young and vibrant institution of research.

Inside:

1. Staff List
2. Awards/Honours/Recognition
3. Services on External Committees/Membership of Professional Bodies
4. Newly Joined Staff
5. Promotions

9.1 Staff List

Head
Sridevi Jade

Honorary Scientists
Dutt H N V
Gaur V K
Indira N K
Mudkavi V Y
Rao E V S P
Swathi P S
Yajnik K S

Scientists
Anil Earnest
Anilkumar V
Ashapurna Marndi
Ashish
Chiranjeevi Vivek
Gouda K C
Gyanendranath Mohapatra
Himesh S
Iranna Gogeri
Kantha Rao Bhimala
Parvez I A
Patra G K
Pavithra N R
Rajendran K
Rakesh V
Ramesh K V
Ramashan K
Sajani Surendran
Senthilkumar V
Sharada M K
Thangavelu R P
Vijayan M S M

Technical Officer
Prabhu

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

Administration
Ramaprasad,B.S
Sreedevi, KKVSS
Abhijina
Sujatha Keshava Murthy
Anilkumar Angadi

Finance and Accounts
Harikrishnan,V
Abhimanyu Kumar Tiwary
Narayana Murthy Pulla

Stores & Purchase
Vikash Chandra Mishra

DST Women Scientists
Chikka Kalyani Devasena
Neethu C

National Post-Doctoral Fellow
Dhanya Thomas

SRF/JRF/RA
Kanike Raghavaendra Prasad Babu
Rani Devi
Smrathi Purwar
Smruthishree Lenka
Sumana Sarkar
Sudhansu Sekhar Rath
Swetha

Project Assistants/ Project SRF/JRF
Aishwarya Pampapathi
Ajay Anand
Ajay Vijay Bankar
Arun Prasad
Fayaz Ahmad Bhat
Ipsita Putantunda
Janani Sri R
Josin Thomas
Madhvee Kori
Nidhi Singh

Nikhilasuma
Priyadharshni
Priya Singh
Rajendra Kumar Dash
Reshma Kumari
Rushikesh Dipak Gudadhe
Shruthi S
Venkatesh Gouda
Vishal Gupta

9.2 Awards/Honours/Recognition

- **Gouda K C** , Chief Guest and delivered talk in the WMO day celebration at Meteorological Centre, IMD, Bengaluru on 23rd March 2022
- **Thangavelu R P**, HPE-Intel "Dr. A P J Abdul Kalam HPC Award 2021" for his contributions in Planning, Design, Implementation and Management of large scale HPC systems in India.
- **Rani Devi**, Best paper presentation (3rd) in the International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022) held at GBPNIHE, Kullu, 10-11 March 2022.
- **Smrutishree Lenka**, Best paper presentation (1st) in the International Conference on Extreme Weather Events under Changing Climate (ICEWECC-2022) held at GBPNIHE, Kullu, 10-11 March 2022.

9.3 Services on External Committees/Membership of Professional Bodies

- **Anil Earnest**
  1. Member, American Geophysical Union (AGU)
  2. Member, Society of Exploration Geophysicists (SEG)
  3. Member, Society of Earth Scientists (SES), India
  4. Associate Member, International GNSS Service (IGS) Member, Asia Oceania Geosciences Society (AOGS)
  5. Member, Seismological Society of America (SSA)
- **Anilkumar V**
  1. Member, Zero Trust Working (ZTA) Group, Ministry of Electronics and Information Technology (Meit), GoI for preparation of national-level standards and guidelines for Cyber Security policy implementation.
  2. Head, Programmable Network Architecture (PNA) sub-committee for Zero Trust Architecture Working Group for MeitY.
  3. Member, Project Review and Steering Group (PRSG), MeitY.
  4. Member, Selection committee C-DAC, Bangalore
  5. Member, Assessment Committee, C-DAC, Bangalore
  6. Member, Board of Studies, Coimbatore Institute of Technology (CIT).
  7. Member, Review committee for patent renewal recommendation, CSIR-NAL
  8. Member, Internet Society (ISOC)
  9. Life Member, Computer Society of India
- **Gouda K C**
  1. Member in the High Impact Weather Project (HIWeather) of the World Meteorological Organization

2. Life Member, Indian Meteorological Society
3. Life Member, Indian Society of remote sensing
4. Executive member, India Meteorological Society, Bangalore Chapter
5. Member, Indo-Africa group on Research on vector borne disease
6. Member, Advisory Board, Dept. of CSE, Dayananda Sagar college of Engineering, Bangalore
7. Member, Board of Studies, Dept. of MCA, Dayananda Sagar University, Bangalore
8. Member, Board of Studies, School of Computer Science, Jain University, Bangalore
9. Member, M.Tech Thesis Evaluation Committee, VTU
10. Member, M.Tech Examiner, VTU
11. Member, Doctoral Committee, VTU
12. Member, Doctoral Committee, Jain University
13. Member, PhD thesis Evaluation Committee, Andhra University, AP
14. Member, M.Sc examiner, Berhampur University, Odisha
15. Member, Project review committee (PRC), DSIR-PRISM

- **Chiranjeevi G. Vivek**
  1. Associate Member, International GNSS Service (IGS)
- **Himesh S**
  1. Life Member, Indian Society for Technical Education
  2. Life Member, Indian Society for Environmental Management
  3. Life Member, Indian Meteorological Society
- **Parvez I A**
  1. Member, Selection and Assessment Committee of IIT Kanpur
  2. Member, Selection committee for the admission of AcSIR PhD students of CSIR NAL.
  3. Nodal Officer, Disaster Management Cell of CSIR 4PI and CSIR NAL.
  4. Member, Hindi Technical Advisory Committee (HTAC) for CSIR NAL.
  5. Member, Task Force of Bureau of Indian Standards Map Subcommittee, CED 39:4, Government of India to prepare a Probabilistic Seismic Hazard Map of India.
  6. PhD Examiner, Indian School of Mines, Dhanbad and IIT Roorkee.
  7. Member, Hindi Technical Advisory Committee (HTAC) of CSIR NAL.
  8. Life Member: Indian Society of Earthquake Technology
  9. Life Member: Indian Society of Earthquake Science
  10. Member, Editorial Board, Seismic Instruments, Springer Nature Switzerland AG
- **Patra G K**
  1. Member, Industrial Advisory Board, School of Computer Science and Engineering, Vellore Institute of Technology.
  2. Member Selection Committee, National Centre for Disease Informatics and Research, Indian Council of Medical Research.
  3. Member, Technical Expert Group for IT Infrastructure Procurement and Implementation, Kidwai Memorial Institute of Oncology, Bangalore.
  4. Technical Member, Advisory committee for establishment of Networking In-

frastructure and Data center at the new permanent campus of IIT, Dharwad

- **Rajendran K**
  1. Associate Editor, Journal of Earth System Sciences, Indian Academy of Science
  2. Member, Scientific committee, State Planning Board for Climate Change, Government of Kerala
  3. Member, Board of Studies in Atmospheric Sciences, Cochin University of Science & Technology, Cochin, Kerala.
  4. Member, Working group for Modeling, National Monsoon Mission Programme, MoES, GoI.
  5. Executive Council Member, Indian Meteorological Society
  6. Life Member, Indian Meteorological Society
- **Rakesh V**
  1. Life Member of Indian Meteorological Society
  2. Member, Indian Society of Agronomy
- **Sajani Surendran**
  1. Member, Working group for Modeling, National Monsoon Mission Programme, MoES, GoI.
  2. Member, Working Group III, National Carbonaceous Aerosol Project, MoEFCC, GoI.
  3. Life Member, Indian Meteorological Society
- **Sridevi Jade**
  1. Life Member, Indian Geotechnical Society
  2. Life member, Indian Geological Congress
  3. Member, Indian Science Congress
  4. Member, International Society of Soil Mechanics and Foundation Engineering
  5. Founder Life Member, Indian Society of rock mechanics and tunneling technology
  6. Associate Member, International GNSS Service (IGS)
  7. Senate Member, AcSIR
  8. Expert Member, Committee for CSIR Emeritus Scientist Schemes 2021-2023
  9. Executive Committee Member, Karnataka State Natural Disaster Monitoring Agency, Government of Karnataka
  10. DG Nominee, National Supercomputing Mission Executive Board (NSM-EB)
  11. Expert member, Technical Advisory Committee, Government of Karnataka
  12. Reviewer, for Several International and National SCI Journals
- **Thangavelu R P**
  1. Life Member, Computer Society of India
  2. Life Member, Cryptology Research Society of India
  3. Member, Cloud Computing Innovation Council of India
  4. Member, Expert Group on Infrastructure, National Supercomputing Mission, GoI
  5. Member, Executive Committee, Karnataka State Natural Disaster Monitoring Centre, Bangalore
  6. Member, Technical Expert Group for IT Infrastructure Procurement and Im-

plementation, Kidwai Memorial Institute of Oncology, Bangalore
7. Member, Technical Evaluation Committee for procurement of HPC system for Gas Turbine Research Establishment, Bangalore.

- **Vijayan M S M**
  1. Member, American Geophysical Union (AGU)
  2. Member, European Geophysical Union (EGU)
  3. Member, International Association of Geodesy (IAG)

9.4 Newly Joined Staff

- Mr Ramaprasad, B. S , Controller of Administration
- Mr Abhimanyu Kumar Tiwary, FAO (Additional Charge)
- Mr Vikash Chandra Mishra, Stores and Purchase Officer
- Mrs K K V S S Sreedevi, Section Officer
- Mr Narayana Murthy Pulla, Section Officer (FA)
- Mr Abijna, Section Officer (G)
- Ms Sujatha Keshava Murthy (Assistant Section Officer)

9.5 Promotions

- Mr. Prabhu promoted as Sr. Technical Officer (3) on 28.08.2018
- Mrs. Suchanda Ray promoted as Principal Technical Officer on 21.9.2018
- Dr. G.K. Patra promoted as Chief Scientist on 01.01.2019
- Mr. Veeresh promoted as Technician (2) on 30.12.2019
- Mrs. Pavithra NR promoted as Sr. Scientist on 09.04.2020
- Dr. Kantha Rao Bhimala promoted as Principal Scientist on 11.08.2020
- Dr. Gyanendranath Mohapatra promoted as Principal Scientist on 24.10.2021

9.6 Superannuation/Resignation

- Shri. Harikrishna, Finance & Accounts Officer, Voluntary Retirement, 10.01.2022
- Shri. Anil Kumar Angadi, Assistant Section officer, Resignation, 16.11.2021

Index

Symbols

A

B

C

T

V

W

Women Staff of CSIR-4PI on the occasion of International Women's Day 2022.

RIGHT TO INFORMATION (RTI)

CSIR-Fourth Paradigm Institute, Bangalore, is committed towards information transparency under the Right to Information Act 2005. The Institute makes available all the information on it's website www.csir4pi.res.in, in lines with the spirit of the RTI Act 2005.

During last financial year, CSIR-4PI has received a total of 76 RTIs and 70 RTIs were disposed. Apart from this, the CPIO has submitted the quarterly and the annual transparency audit reports as well, for the reporting period of 2021-22. Details of the officers dealing with RTI's are as follows:

1. Shri Ashish, CPIO, Senior Scientist
2. Shri R P Thangavelu, FAA, Chief Scientist
3. Shri B S Ramaprasad, Transparency Officer, COA

INSTITUTIONAL FACILITIES

CSIR-4PI