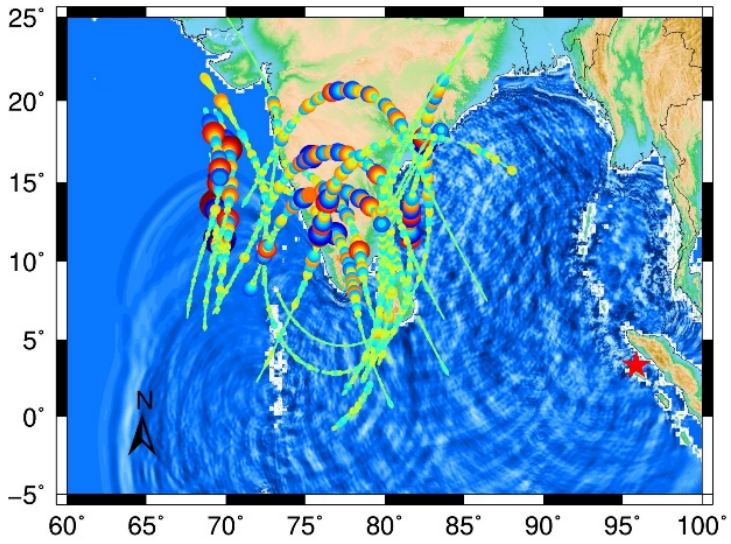
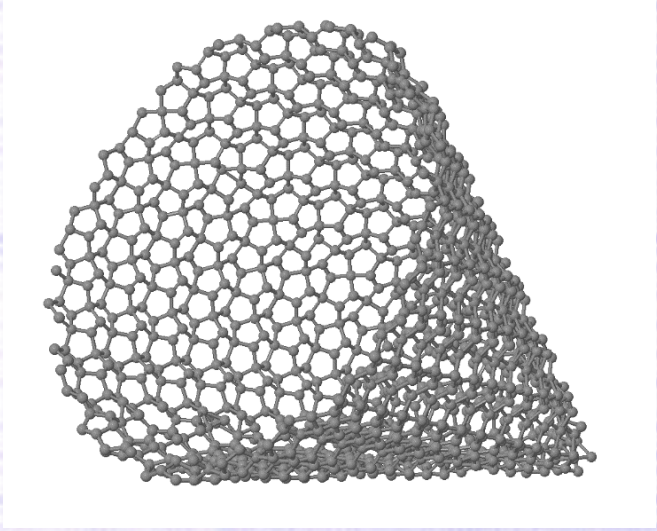
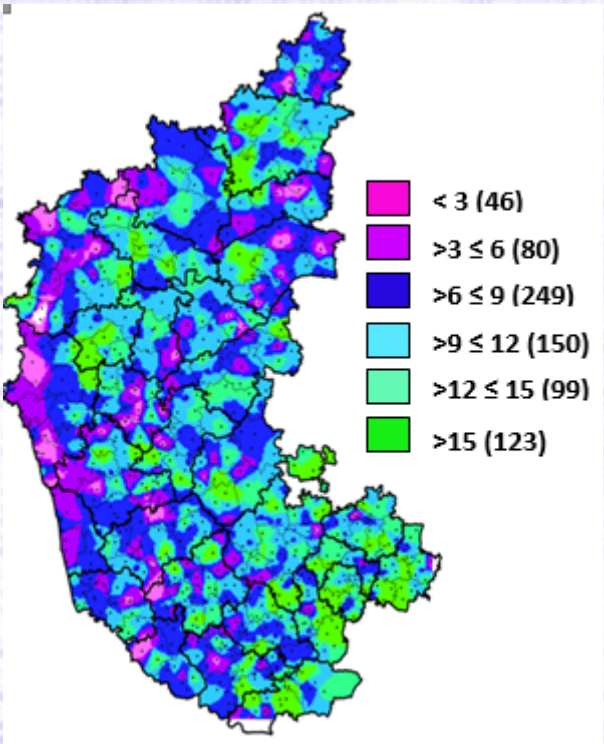
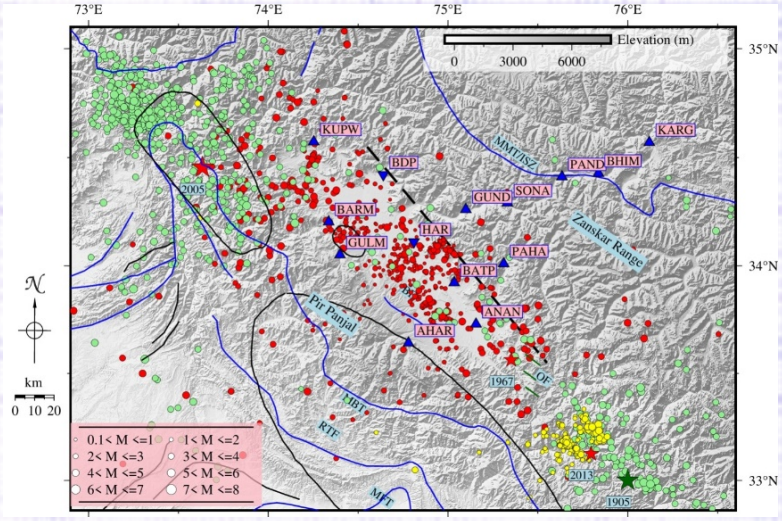
CSIR FOURTH PARADIGM INSTITUTE
Annual Report 2020 - 2021

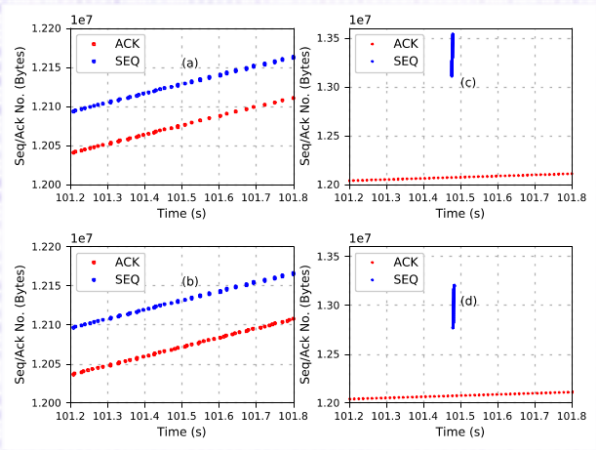
CSIR-4PI

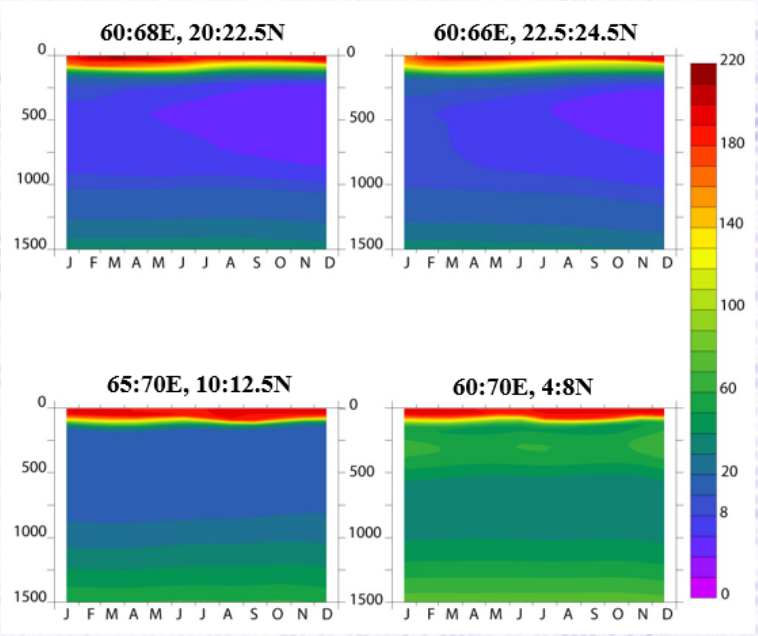




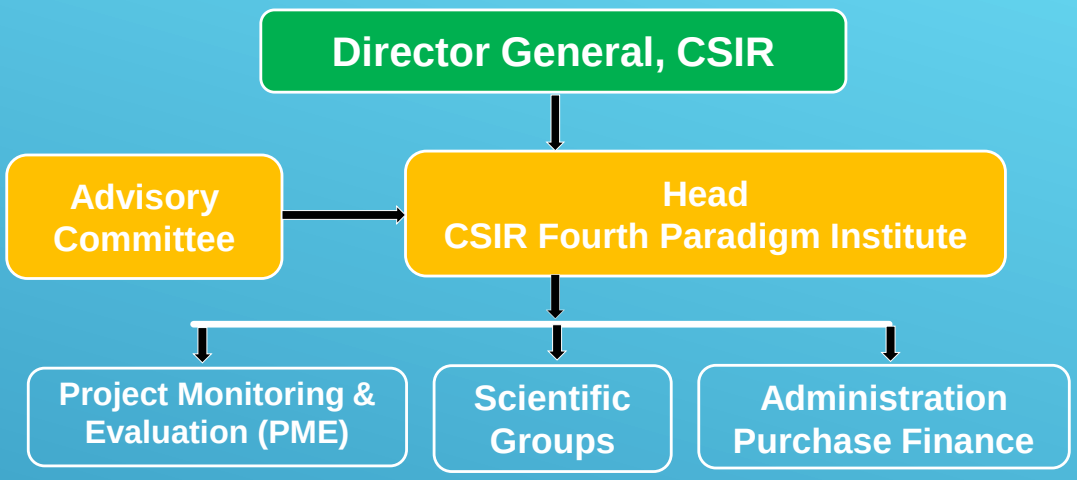








ORGANIZATION CHART



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Vision

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

Mission

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

The mission statement thus encompasses continuation of existing modelling and simulation work in earth sciences and places emphasis on exploiting data science capabilities across domains.

Mandate

To develop reliable knowledge products for decision support in Earth, Engineering and Information Sciences.

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

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Acknowledgements
To all staff members of CSIR-4PI for inputs to the Annual Report.

Preface……

The year 2020 began with a lockdown! For the Institute the biggest challenge was to ensure continued upkeep and running of the high performance computing (HPC) system and make it available for COVID related simulations by computational biology and chemistry groups across CSIR. It was remarkable that we could continue to provide this crucial support under by far the most difficult situation faced by the Institute. Maintaining seismic network and the four GHG stations were also just as important. We rose to the occasion and ensured that our efforts in data collection, maintenance of important facilities and modeling activities continued uninterrupted.

While Covid disrupted our normal work, an opportunity came by when AMD, USA, contacted CSIR-4PI with a proposal to donate HPC platform exclusively for COVID research. It was a new situation not just for the Institute but also for CSIR as no such donation was ever received in the past. We pursued this and successfully signed off an agreement with AMD, USA and paved way for installation of HPC system rated at around 1.2 PetaFlops. Concurrently, we also received approval for refresh of existing HPC system aiming to provide 1 PetaFlops CPU compute and about 20 AI PetaFlops which should boost the research across CSIR. Third party evaluation mandated by Finance Commission was also completed in record time for this project.

The Institute continued to make significant strides in the core modeling areas. These are summarized below.

Ocean modeling efforts led to quantification of depletion of oxygen in the Arabian sea. The model established the roles of primary production in oxygen and remineralization and nitrification in its consumption. The extent of oxygen minimum zones were also well simulated. These are significant findings as ocean health is just as important in a connected eco-system. Green House Gas (GHG) measurements compliant with WMO standards showed that there is an increase of 2.5 ppm in the annual average from 2019 to 2020 which amounts to atmospheric loading of 5.3 Gigatonnes of Carbon in 2020. These findings have direct bearing on our aspiration to become Carbon neutral by 2030.

An MoU was signed with University of Kashmir and Indian Institute of Astrophysics for academic and scientific collaboration in the areas of seismic studies and GHG measurements. A major lab project was also sanctioned with a budget allocation of Rs 3.5 Crores to undertake seismic research in the Jammu, Kashmir and Ladakh region. Our focus remains on implications of crustal structure and crustal velocities on the seismic hazard of tectonically active northwest Himalayas.

In a major finding owing to integration for the first time the GNSS and broadband data it is clear that a major earthquake of 7.8 magnitude is overdue in this region. In another significant achievement, impact of GPS, Glonass and combined GPS & Glonass signals on the position and velocity estimates of Indian subcontinent was established and the same has been published.

As mentioned, we continued to provide uninterrupted access to HPC system to all the stakeholders which was particularly critical in the Covid times. Under the guidance of HPC Policy Committee of CSIR, it was decided to refresh existing HPC facility with focus on AI and ML which will impact our research activities in the future. A project with investment of Rs 50 Crores was cleared by CSIR HQ. During this time, we established procedure to provide robust AI based Covid cases prediction. We started providing weekly update to Government of Karnataka on the outlook of cases for Bangalore and the state. Our work on cybersecurity and cryptography continues to hold importance as two projects were amply supported by MeitY and DST under the Interdisciplinary Cyber Physical Systems (ICPS) mission of GoI.

Weather and climate research continue to play important activities of the Institute. The expertise in this area has also helped us provide inputs on the impact of weather on epidemiological diseases with emphasis on COVID. As regards to climate change, development of systems models have provided us with an ability to understand seasonal monsoon and climate under different aerosol scenarios, formulation of new algorithms.

Scientific output was significant as always. We published 29 articles and 22 projects are under progress.

CSIR-4PI remains small as of now with high impact in its traditional area of earth sciences research. Although small but significant steps have been taken to embrace the true spirit of the fourth paradigm, much remains to be done. The area of AI is progressing fast. It critically depends on well trained human resource with broad understanding in different scientific domains. The positioning of CSIR-4PI is truly central and as such needs to much attention in building up capability in the area of AI with focus on scientific research domains of CSIR. It is time to take that step.

Dr V Y Mudkavi

Head CSIR Fourth Paradigm Institute

Contents

1. Carbon Cycle & Ocean Modelling

An understanding of the carbon cycle and ocean processes and circulation is a very important component in the development of earth system models. At CSIR-4PI we have been actively engaged in several aspects of this study, especially in the determination of fluxes between atmosphere, ocean and land, through modelling and measurements, Modelling of biogeochemical cycles of carbon, nitrogen, phosphorous, trace metals and oxygen in the ocean, WMO-standard measurements of greenhouse gases and analysis and a detailed study of the decadal variability of sea surface temperature (SST) formed the major activities of the group.

With the use of the Modular Ocean Model and a complex biogeochemical model called TOPAZ, we examined the oxygen cycle very closely in the Arabian Sea. The presence of a suboxic zone in the Arabian Sea is well known, but quantification of the contributors to this depletion is still under debate. With the help of our model, we established the roles of primary production in oxygen production and remineralisation and nitrification in it consumption. The extents of the oxygen minimum zones were simulated very well. Hanle in Ladakh is an extremely clean site uncontaminated by local sources. It is ideally suited for the measurement of the background carbon dioxide concentration which could reflect the global increase of carbon in the atmosphere from year to year. WMO-standard carbon dioxide measurements here showed an in increase of 2.5 ppm in the annual average from 2019 to 2020 which translated to an atmospheric loading of 5.3 Gigatonnes of carbon in 2020. Methane increased by 15 ppb in the same period. Measurements at Hoskote, near Bangalore, showed similar increases in carbon dioxide and methane. No significant change in carbon monoxide was noticed while nitrous oxide showed a secular increase.

A new orthogonal decomposition procedure involving annual mean, low and high frequency components was applied to study sea surface temperature anomalies from 1950-2010. There was a pronounced asymmetry between northern and southern hemispheres. Sixteen high variability clusters were identified of which six were in the Arctic indicating the vigorous changes happening there.

Inside:

- Suboxic Zone in the Arabian Sea and Bay of Bengal
- Greenhouse gases data collection and analysis

1.1 Suboxic Zone in the Arabian Sea and Bay of Bengal

Analysis of the results of numerical climatological and interannual simulations of the marine biogeochemical model (TOPAZ) (i) at a resolution of 0.25 degree forced with CORE fluxes for the period 1949 to 2009 and (ii) at a resolution of 1 degree forced with NCEP fluxes for the period 1978 to 2018 in the global domain are carried out for the study of suboxic zones in the Arabian Sea and Bay of Bengal. The physical model is the modular Ocean Model (MOM5) and the biogeochemical model TOPAZ developed at GFDL has been coupled with MOM5. The model is spun up for 200 years with climatological forcing using bulk formulae to compute surface fluxes.

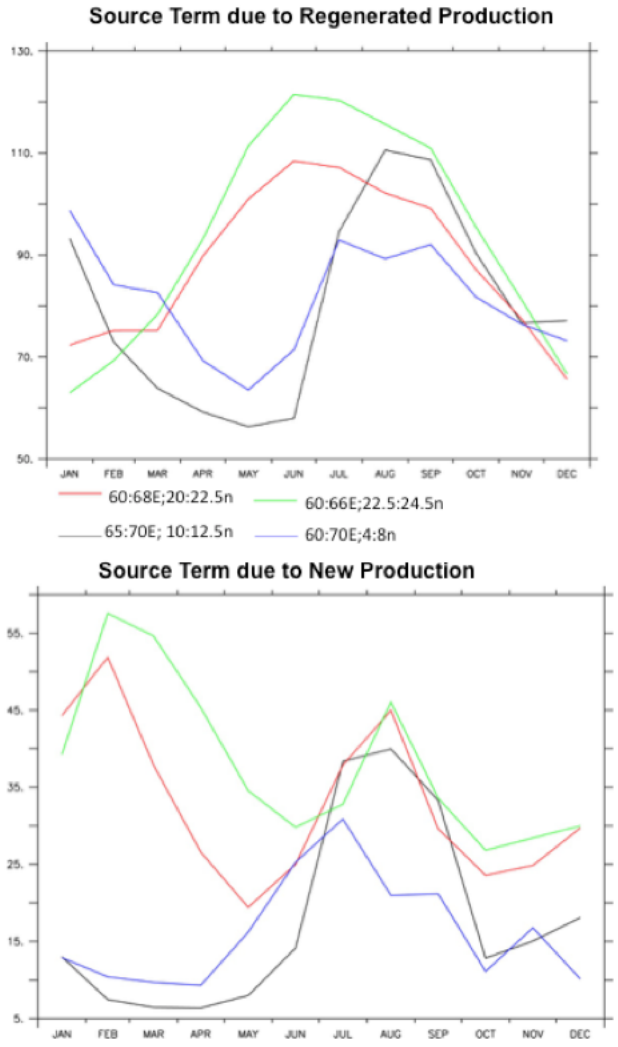

Figure 1.1: Monthly variation of contribution of Regenerated and New Production (mMol/m^2/d) to Oxygen Source Term in the regions of OMZ (60:68^{0}E, 20:22.5^{0}N; 60:66^{0}E, 22.5:24.5^{0}N) and non-OMZ (65:70^{0}E, 10:12.5^{0}N; 60:70^{0}E, 4:8^{0}N) in the Arabian Sea.

Detailed analysis of the source and sink terms of the oxygen equation in the model (TOPAZ) is carried out to understand the contribution of various biogeochemical processes to spatial, seasonal and interannual variations of oxygen concentration in the Arabian Sea (AS) and the Bay of Bengal (BOB). Productivity of large and small phytoplankton, and diazotrophs, due to nitrate (NO3) and Ammonium (NH4) and nitrogen fixation by diazotrophs contribute to the source of oxygen, whereas

oxygen is consumed by ammonium produced from non-sinking particles, sinking particles and dissolved organic matter, and for nitrification.

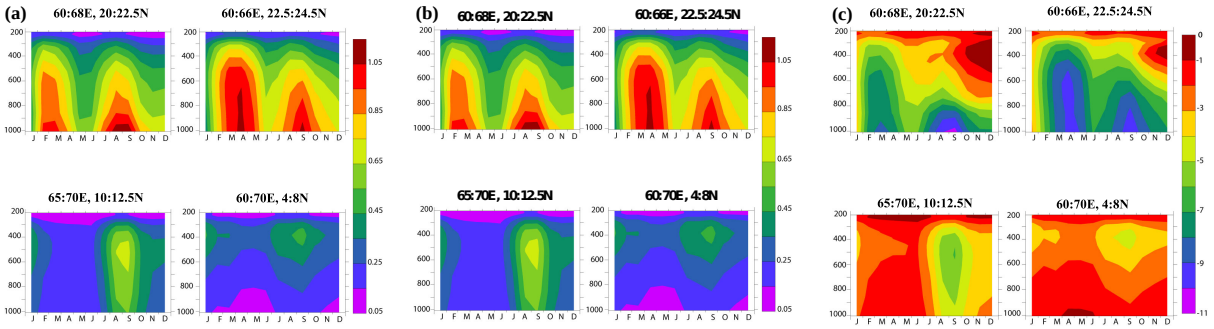

Figure 1.2: Monthly variation of consumption of oxygen with respect to depth in the regions of OMZ and non-OMZ regions (as in Figure 1.1) in the Arabian Sea, due to (a) Remineralization of Detritus (mMol/m^3/d) and (b) Nitrification (mMol/m^3/d), (c) Source minus Sink terms of oxygen (mMol/m^3/d) with respect to depth.

Contribution of total productivity due to NO_3 (New Production) and NH_4 (Regenerated Production) to oxygen source term (Figure 1.1) is higher in the regions of Oxygen Minimum Zone (OMZ) compared to regions in non-OMZs, during all seasons. It can be observed that production of oxygen due to new production is negligible during January-May and October-December in the non-OMZ, whereas it is high during NEM and SWM in the OMZ. Contribution of regenerated production to oxygen source term is high during May-September in the OMZ compared to non-OMZ, and it is higher compared to contribution due to new production during all seasons. It is also noted that both new and regenerated production are higher in the regions of OMZ compared to non-OMZ regions during many months, and regenerated production is higher than new production during all seasons. Variations of sink terms of oxygen with respect to depth for four regions two each in OMZ ($60{:}68^0$E, $20{:}22.5^0$N; $60{:}66^0$E, $22.5{:}24.5^0$N) and non-OMZ ($65{:}70^0$E, $10{:}12.5^0$N; $60{:}70^0$E, $4{:}8^0$N) in the AS are analysed in detail. It is noted that the consumption of oxygen due to production of NH_4 from grazing, heterotrophs and dissolved organic nitrogen (LDON and SDON) is negligible (figure not shown), whereas consumption of oxygen for nitrification and remineralization of detritus are very high in the regions of OMZ between 200 and 1000m depth. Consumption for (i) Remineralization of detritus is maximum during February-May and August-October (Figure 1.2a) and (ii) Nitrification is very high during March-December (Figure 1.2b).

Variation of Source minus Sink terms (JO_2) with respect to depth for four regions in the AS is shown in Figure 1.2c. It is observed that JO_2 is negative and higher in magnitude during all seasons in the regions of OMZ compared to the regions in non-OMZ, between 200 and 100m depth. Since JO_2 is negative and having higher values in the OMZ regions, oxygen concentration is very low between 200 and 1000m depth (Figure 1.3). It can be summarized that consumption of oxygen due to remineralization and nitrification processes at depths below 200m are responsible for the low oxygen concentration between 200 and 1000m depth in the OMZ.

Variation of source and sink terms of Oxygen are analysed for one of the regions ($89{:}90^0$E, $14{:}15^0$N)in the OMZ of Bay of Bengal. The term representing the Source minus Sink (JO_2) is negative between 200 and 1000m depth and is high in magnitude during January to April, leading to very low concentration of Oxygen (< 10 m Mol/m3) between 200 and 600 m depth during all seasons. It is noted that consumption of oxygen due to remineralization and nitrification processes at depths below 200m are very high as in the Arabian Sea (figure not shown).

Interannual variation of carbon flux at the air-sea interface and pCO_2 from model simulations,

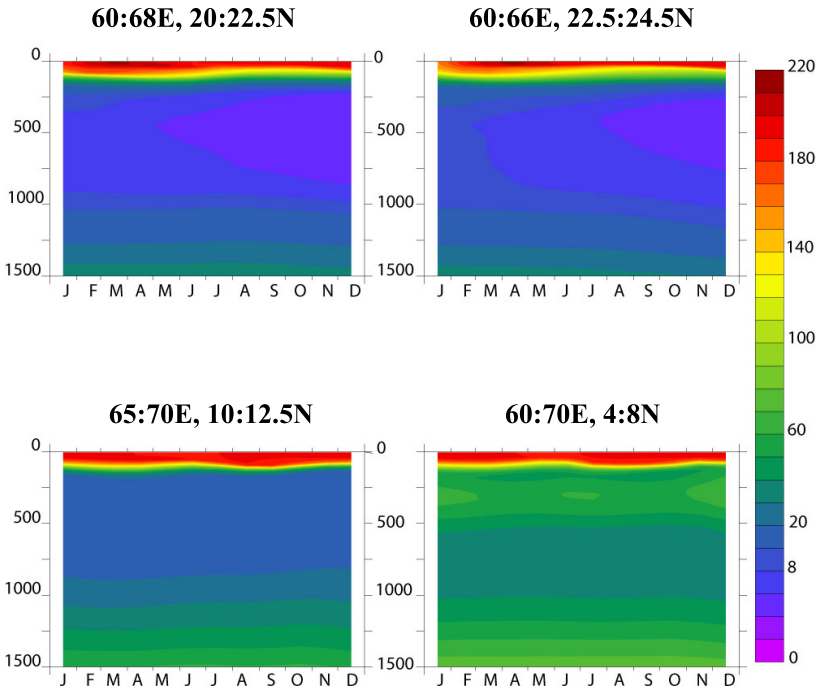

Figure 1.3: Monthly variation of Oxygen (mMol/m^3) with respect to depth in the regions of OMZ and non-OMZ (as in Figure 1.1) in the Arabian Sea.

for two regions in the OMZ and one region in the non-OMZ during 2006 to 2008 is shown in Figure 1.4. It can be observed that both carbon flux from ocean to atmosphere and pCO_2 are higher for the regions in OMZ compared to a region in non-OMZ. Detailed analysis of physical, chemical and biological processes like upwelling, primary productivity, recycling of nutrients etc. will be carried out to understand the carbon and nitrogen cycle in the OMZ regions of north Indian Ocean. Comparison of spatial and seasonal variations of various biogeochemical variables and fluxes from CORE and NCEP simulations in the north Indian Ocean are being carried out.

1.2 Greenhouse gases data collection and analysis

Measurements of greenhouse gases continued through the year at the stations Hanle, Pondicherry and Hoskote, setup by CSIR-4PI, as per WMO standard. Also, discrete sampling of air through flask measurements are done at these stations. The stations were regularly maintained and continuous data from these stations were collected at regular intervals. The data collected from these GHG stations are processed with ICOS protocol and are plotted to see year to year variations. The database of greenhouse gases generated can be used to identify sources and sinks of anthropogenic carbon using advanced inverse modelling techniques.

1.2.1 Measurements at Hanle

The within-hour standard deviation of CO_2 for 2020 is shown in Figure 1.5(a). It can be seen that of the 8637 hourly values, nearly 70% have a standard deviation less than 0.1 ppm, indicating that there is very little within-hour variability at the site. Besides variability at noon (UTC) and midnight (UTC) are also very similar. As Hanle is in an elevated cold desert with very little diurnal variability and minimal local influence, all 24-hour data can be considered for processing.

The daily means of carbon dioxide along with a curve consisting of a constant, linear, quadratic

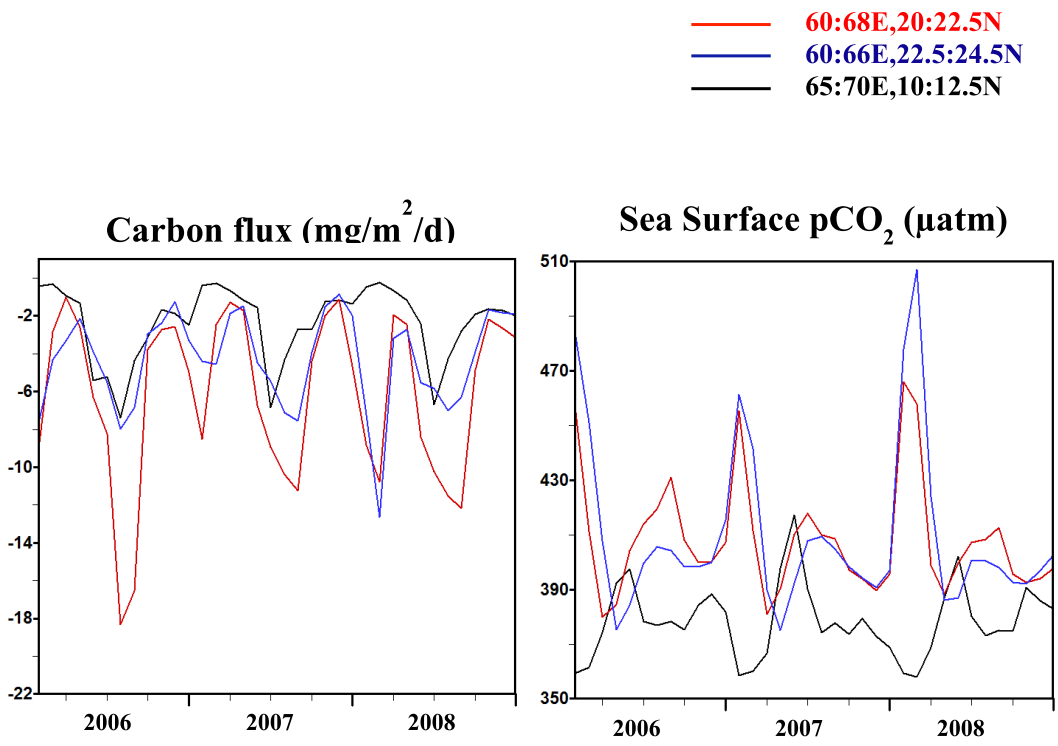

Figure 1.4: Interannual variation of Carbon Flux at the surface of the ocean (mg C/m^2/d) and pCO_2 (μatm) in two regions of OMZ and one region in the non-OMZ from two model simulations (forced with CORE fluxes at 1 degree resolution) for the years 2006-2009.

and 4 harmonics terms at Hanle is shown in Figure 1.5(b). The change in the annual average between 2019 and 2020 is roughly 2.5 ppm indicating a global atmospheric loading of 5.3 Giga tonnes of carbon.

The daily means and the function fit for CH_4 are given in Figure 1.5(c). In contrast to the minimum in CO_2 during monsoon months, CH_4 is maximum in this period. The air reaching Hanle has picked up CH_4 from paddy cultivation and wetlands as it flows over northern India. The increase in the annually averaged CH_4 from 2019 to 2020 is 15 ppb.

The wind is mostly from SW, SSW direction reaching average speeds of 6-7 m/s as shown in Figure 1.5(d). The CO_2 concentration is lowest when the wind is from these directions and is highest when it is easterly or westerly.

The data from Pondicherry was processed similarly for CO_2 and CH_4 and which show similar year to year variation for CO_2 and CH_4 as seen in Hanle.

1.2.2 Measurements at Hoskote

Four species CO_2, CH_4, CO and N_2O are measured here. Figure 1.6(a) shows the daily data and function fit of CO_2. Unlike Hanle, there is a lot of scatter due to local influence. The increase in annual average CO_2 from 2019 to 2020 is 2.3 ppm. Methane measurements can be seen in Figure 1.6(b). There is an increasing trend with an annual increase of 20 ppb between 2019 and 2020.

Carbon monoxide measurements seen in Figure 1.6(c) do not show the trend seen for CO_2 and CH_4. There is a pronounced annual cycle with double peaks in January and April and a minima in August. The amplitude is over 100 ppb. Nitrous oxide increased from 331 ppb to 335 ppb over three years indicating an increase in industrial activity around Hoskote as can be seen in Figure 1.6(d).

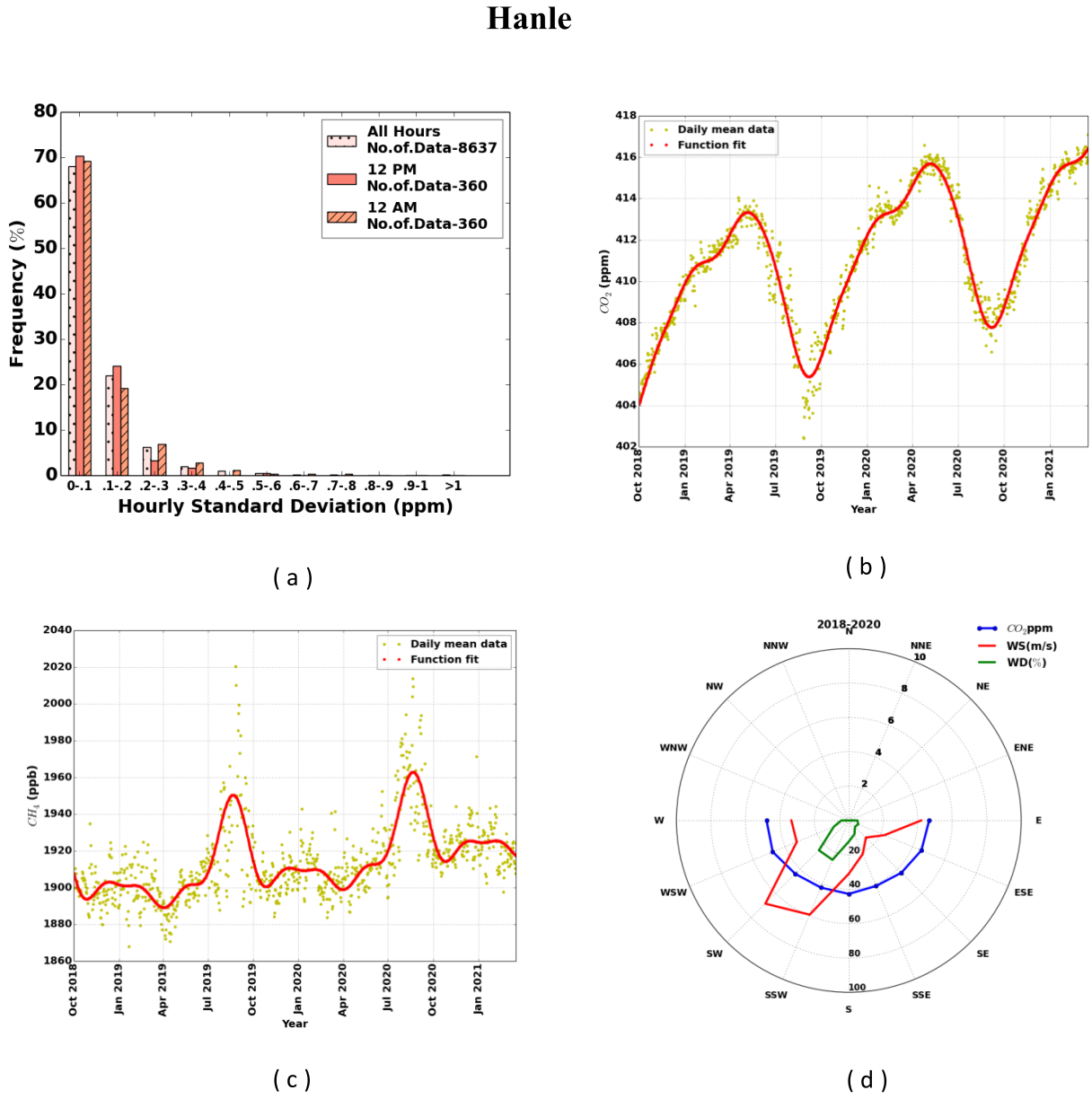

Figure 1.5: Frequency table of hourly standard deviation in 2020 at Hanle (b) Daily-mean data and function fit for CO_2 (ppm) (c) Daily mean data and function fit for CH_4 (ppb) (d) Rose plot of CO_2 (ppm) (measured value – 406 ppm), wind speed (m/s) and wind direction frequency percentage. The scales for CO_2 (ppm) and wind speed (m/s) go from 0 to 10 while wind frequency percentage goes from 0 to 100.

1.2.3 Diurnal Variation at Hoskote

The wind speed and wind direction at Hoskote for summer and monsoon seasons are shown in Figure 1.7. Wind in winter is from the east, in summer from SE-SSW and during monsoon from WSW and post monsoon S-SW. Wind speeds are highest in monsoon reaching speeds of 5.3 m/s around 6:00 UTC. The highest values of CO_2 and CH_4 are around 430 ppm and 2.1 ppm, respectively, in summer around midnight UTC. Enhanced vertical mixing and photosynthetic activity lead to reduction in CO_2 during daytime hours. The amplitudes of the diurnal variation for

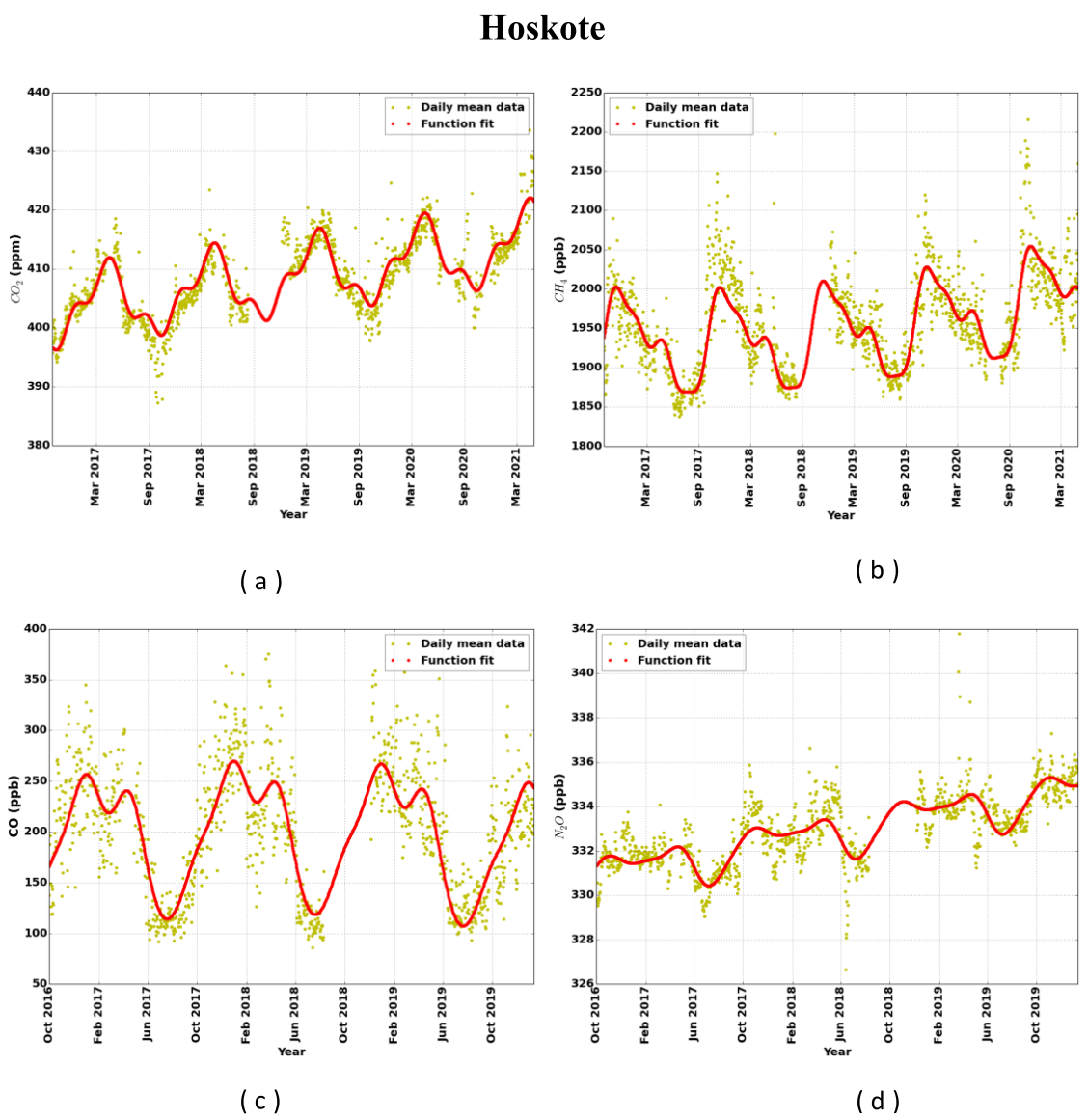

Figure 1.6: Daily mean data and function fit for CO_2 (ppm) (b) Daily mean data and function fit for CH_4 (ppb) (c) Daily mean data and function fit for CO (ppb) (d) Daily mean data and function fit for N_2O (ppb).

CO_2 are around 13, 15, 13 and 22 ppm in winter, summer, monsoon and post monsoon seasons. The amplitudes in case of CH_4 range from 0.08 to 0.17 ppm approximately.

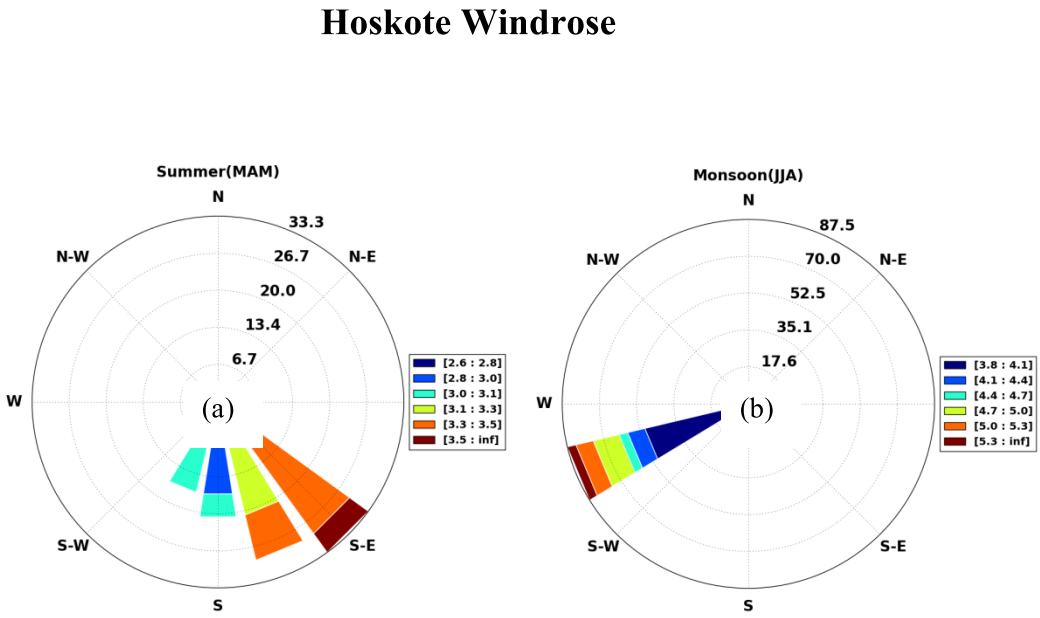

Figure 1.7: Rose plot of wind direction and Wind speed at Hoskote in (a) Summer (b) Monsoon.

2. Climate & Environmental Modelling Programme

The research activities of CEMP have been aimed at providing solutions to weather and climate-related problems to minimize their adverse impact on the environment and public. Major research activities of CEMP are; Monsoon, climate and Weather Informatics, Smart Agriculture, Sustainability of water resources, modeling the impact of climate and weather on epidemiological diseases (malaria, COVID-19), Urban Air Quality Modeling, and hydro-meteorological disaster modelling. Group activities are also aligned with missions of Government of India (Samarth Bharat, Swasthya Bharat). The team carries out its research and analysis through open-source codes, state-of-the-art models (LAMs, GCMs, and NWPs), in-house algorithms and visualization tools, field and satellite data sets.

Inside:

2.1 Multi-Criteria Ensembles for hydro-meteorological analysis of a flash flood event over the megacity of Bangalore

A novel ensemble forecast methodology is used in this study to conduct a hydro-meteorological assessment of a flash flood event that occurred on the morning of 15th August 2017 over the megacity of Bangalore, India. The flash flood was triggered by the intense short-duration rainfall that was associated with the passage of westward propagating low-pressure system, causing extensive damage across the city. A coupled hydro-meteorological (WRF/WRF-Hydro) modelling framework with extensive hydrologic parameterization (convective-permitting) and subgrid-scale (300 meters) resolution is used to generate short-range (0-12 hrs lead time) prediction of quantitative precipitation, and spatial runoff. Multi-criteria ensembles are generated with both stand-alone and fully coupled atmospheric- hydrological modelling frameworks to quantify the impact of different land surface parameterization schemes (partitioning co-efficient and the different planetary boundary layer schemes) on the skill of the model to simulate precipitation and runoff. The Spatio-temporal characteristics of the ensembles thus generated have been validated against a high-resolution Indian Monsoon Data Assimilation and Analysis (IMDAA).This study has demonstrated (Figure 2.1) the potential skill of the coupled model in simulating hydro-meteorological variables (rainfall and runoff) over the megacity of Bengaluru. The proposed methodology can be used to improve the skill of the model for the short-range prediction of flash floods.

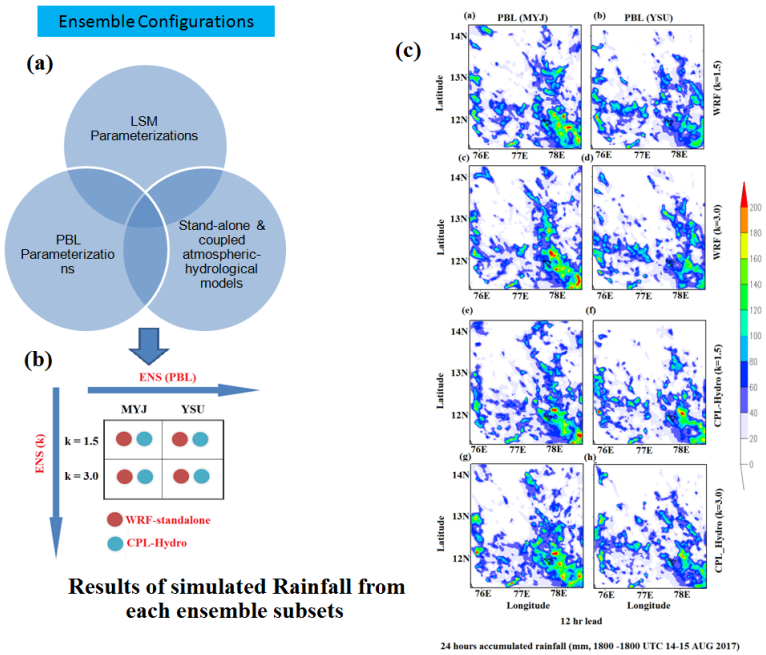

Figure 2.1: Schematics showing the multi-criteria ensembles (a, b) by using WRF -standalone and Coupled hydro (CPL-Hydro). Simulations have been carried out with two PBL schemes; MYJ and YSU. The panel c shows the spatial distribution of 24 hr accumulated simulated rainfall (from 1800 UTC of 14th August to 1800 UTC of 15th August) for the two ensemble configurations. It is shown that ENSCPL-Hydro configuration is better than ENSWRF ensemble configurations.

2.2 Application of big data analytics and artificial intelligence in Agronomic research

Modern statistical tools complemented in designing field experiments and immensely contributed to drawing useful inferences for developing good agronomic practices for increased crop production, input use efficiencies, and environmental sustainability. To enhance the reach of agronomic research, the use of emerging tools of big data analytics, geo-referenced satellite information, and imaging, and artificial intelligence (AI) based techniques that can process large data sets are described which could be validated by agronomic field experiments. Some areas of data science for use in agronomy include: satellite and Unmanned Aerial Vehicle (UAV) based data acquisition, Internet of Things (IoT), AI (machine and deep learning), and big data analytics. For example, the rice blast disease was captured by UAV based multispectral image of 5 mm ground resolution, placing the UAV at 10m height (Figure 2.2). Recent studies demonstrated that using the AI-based algorithms the accuracy in yield prediction and image classification is enhanced up to 85%. Our study using all India wheat production data for a period of 58 years showed that Bi-directional Long Short-Term Memory (LSTM) model reduced error in time series prediction to the order of 50% in comparison with conventional statistical models. Since agronomists aim for a holistic understanding of agro-ecosystems, System Dynamic Model (SDM) of specific agricultural systems wherein the topography, climate, hydrology, natural resources, and societal requirements are coupled along with their feedback impacts on agronomic systems has been introduced and discussed.

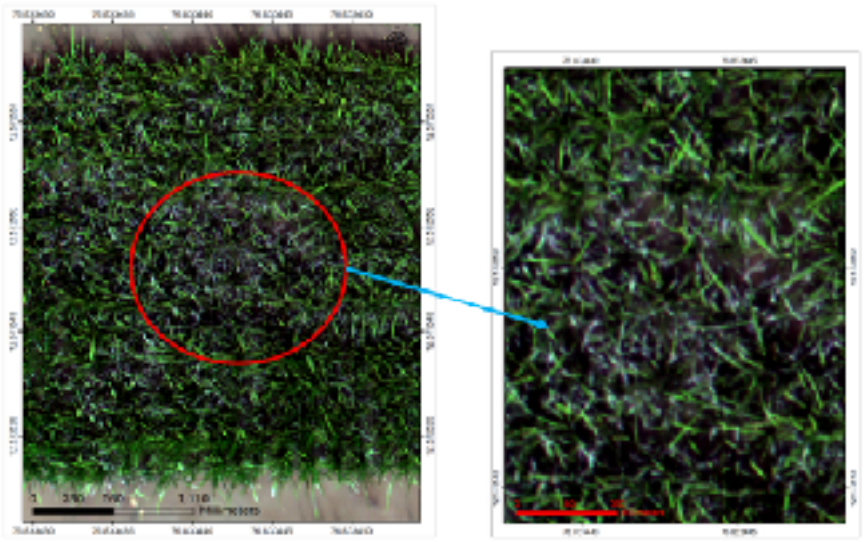

Figure 2.2: UAV based multispectral imaging of rice field; 5 mm resolution image taken from multi spectral camera (left), rice blast disease is clearly visible in the enhanced image (right).

2.3 An assessment of potential economic gain from weather forecast based irrigation scheduling for marginal farmers in Karnataka, a southern state in India

This study is aimed to assess the usefulness of weather forecasts for irrigation scheduling in crops to economise water use. The short-term gains for the farmers come from reducing costs of irrigation with the help of advisory for when not to irrigate because rain is predicted (risk-free because the wrong forecast only delays irrigation within tolerance). Here, a quantitative assessment of saving (indirect income) if irrigation is avoided as rain is imminent (as per forecast), using a five-year

archived forecast data over Karnataka state at hobli (a cluster of small villages) level is presented. Estimates showed that the economic benefits to the farmers from such advisories were significant. The potential gain in annual income from such forecast based irrigation scheduling was of the order of 10-15% (Figure 2.3). Our analysis also indicated that the use of advisory by a small percentage of more than 10 million marginal farmers (land holding <3 acres) in Karnataka could lead to huge cumulative savings of the order of many crores.

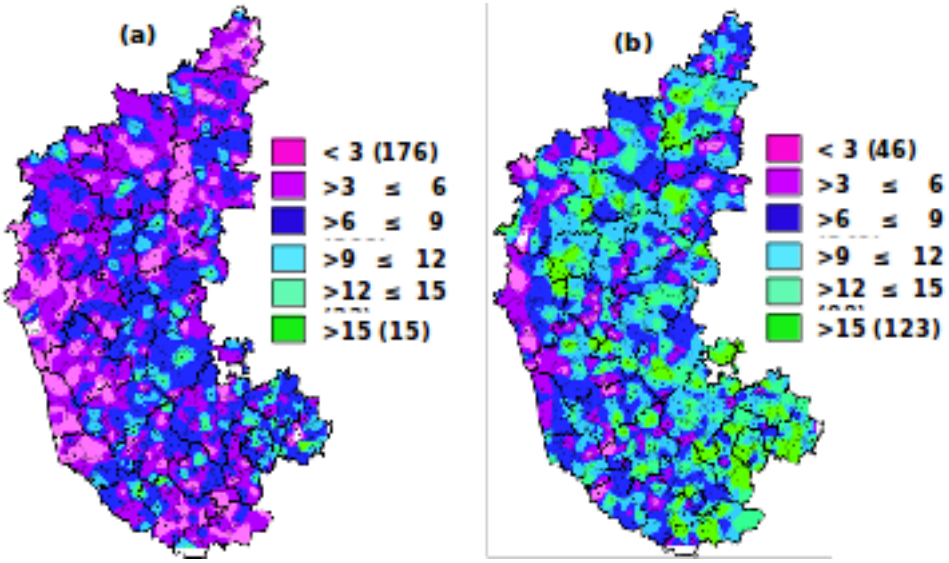

Figure 2.3: Assessment of the economic impact of forecast based irrigation scheduling; (a) for 10 days and (b) 7-day continuous dry spell scenario; these figures show the percentage potential gain in annual income (Indian rupees, Rs 1,20,000 per year is considered as annual income) for a farmer over different parts of Karnataka cumulative for the five years (2011-2015). The number in the bracket shows the number of hoblis in each range.

2.4 Spatio-temporal rainfall variability over different meteorological subdivisions in India: analysis using different machine learning techniques

Understanding and quantifying the long-term variability of rainfall at the regional scale is important for a country like India where economic growth is very much dependent on the agricultural production which in turn is closely linked to rainfall distribution. Using machine learning techniques viz., cluster analysis (CA), and principal component analysis (PCA), the spatial and temporal rainfall patterns over the meteorological subdivisions in India are examined. Monthly rainfall data of 117 years (1901–2017) from the Indian Meteorological Department over 36 meteorological subdivisions in India is used in this study. Using the hierarchical clustering method, six homogeneous rainfall clusters were identified in India. Among the rainfall clusters, Group 1 had 30% dissimilarity with Groups 2, 3, and 4, while Group 5 and 6 are highly dissimilar (more than 90%dissimilarity) compared to the rest of the groups. Rainfall seasons in each group were further classified into dry, wet, and transition periods (Figure 2.4). The duration of the dry period is smaller in the group which consists of subdivisions from the southern part of the country. The transition period between the dry and wet periods was found to be smaller for subdivisions in the coastal region. Both CA and PCA showed high rainfall variability in Groups 5 and 6, which comprise subdivisions from the northeast, Kerala, Konkan, and coastal Karnataka, and low rainfall variability in Groups 1 and 2 which comprise subdivisions from the east, north, and central part of the country. A Strong negative

trend in annual and Indian summer monsoon rainfall is seen in northeast India and Kerala, while a positive trend is observed over the costal Karnataka and Konkan region. The negative trend in post-monsoon rainfall, particularly over the peninsular and northeast India, indicates a weakening of northeast monsoon rainfall in the country.

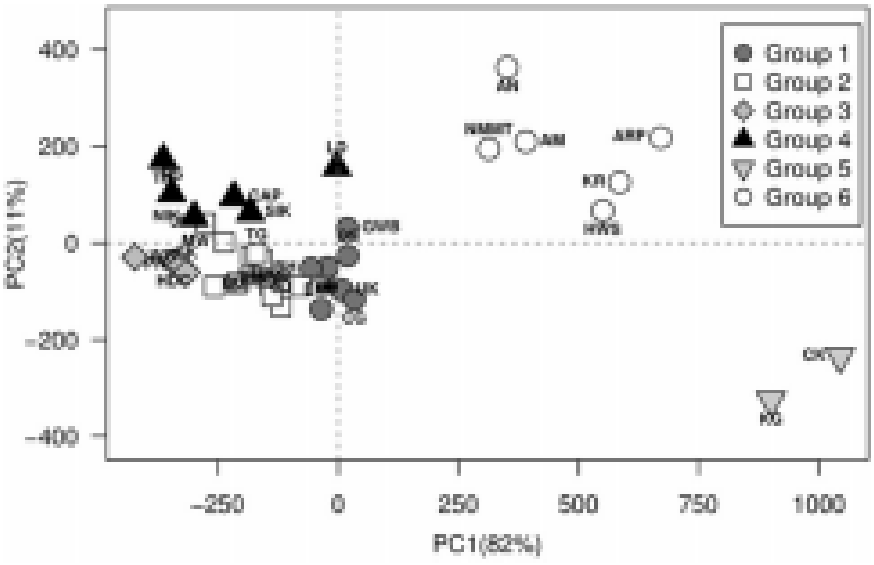

Figure 2.4: First factorial plane of the principal components PC1 and PC2 for different spatial groups showing rainfall variability for the period 1901–2017.

2.5 Evaluation of the skill of the WRF model in the simulation of the spatial distribution of Rainfall over the metropolitan city of Bangalore, India.

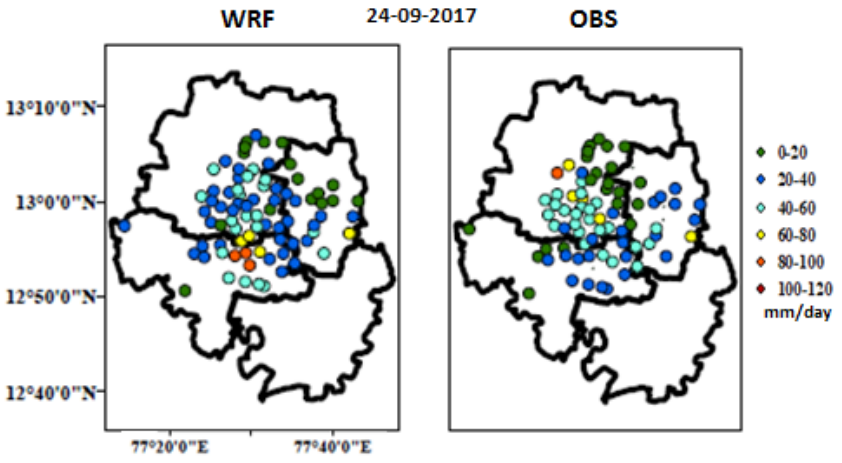

Figure 2.5: Comparison between the WRF model simulated (left panel) and observed (right panel) 24 hour accumulated rainfall at 81 rain-gauge stations over Bangalore.

Urbanization alters the natural land cover with an impervious surface like concrete and asphalt, forms the urban canopy due to the building structures, and modifies the thermal and dynamic

characteristics of the surface layer. These changes in turn significantly influence the surface heat balance, exchange of water vapor and momentum between the surface layer and atmosphere, and urban precipitation. The present study evaluates the skill of the Weather Research and Forecasting (WRF) model to simulate the spatial distribution of rainfall over the metropolitan city of Bangalore, India. The novelty of the present study is that the WRF model simulations were compared with a high-density rain gauge network (81 rain gauge stations) over Bangalore. Our analysis shows that the model under-estimated (Bias score <1) the rainfall for most (87%) of the stations and the model accuracy in the forecasting of rainfall was more than 70% for 16% of stations in the city. The RMSE values were ranging between 18 and 28 mm/day for most of the rainfall events (Figure 2.5). Our analysis also found that the under-estimation of the Convective Available Potential Energy (CAPE <2000J/kg) may be the possible reason for the simulation of low-intensity rainfall (<10mm/day) in most of the stations in Bangalore. Proper representation of the urban morphology, air pollution, and anthropogenic heat data in the WRF modelling system may improve the model skill to capture the spatial variability in rainfall over highly urbanized cities in India.

2.6 An optimum initial manifold for improved skill and lead in long-range forecasting of monsoon variability.

Using an initial manifold approach, an ensemble forecast methodology is shown to simultaneously increase lead and realizable skill in long-range forecasting of monsoon over continental India. Initial manifold approach distinguishes the initial states that have coherence from a collection of unrelated states. In this work, an optimized and validated variable resolution general circulation model is being adopted for long-range forecasting of monsoon using the multi-lead ensemble methodology. In terms of realizable skill (as against potential) at resolution (60km) and lead (2–5 months) considered here, the present method performs very well. The skill of the improved methodology is significant, capturing 9 of the 12 extreme years of monsoon during 1980–2003 in seasonal (June–August) scale. Eight-member ensemble-average hindcasts carried out for realizable skill with lead of 2 (for June) to 5 (for August) months and an optimum ensemble is presented. In terms of inter-annual variability in area-averaged (75-85oE, 8-28oN) seasonal (June-August) rainfall, defined as departure from corresponding 24 years (1980-2003) mean, Optimum initial Manifold (OIM) outperforms both Compact Ensemble and Large Ensemble (Figure 2.6). The OIM has a phase synchronization of 67% with a correlation coefficient of 0.44 between all-India seasonal (JJA) rainfall anomalies, significant at 99% confidence level for the degrees of freedom involved.

2.7 Impact of Urbanization on Heavy Rainfall Event: A Case Study over a Megacity of Bengaluru, India

This study is about the simulation and observational analysis of a heavy rainfall event (HRE) and its sensitivity to land-use changes. The impact of urbanization on processes and mechanisms of rainfall including cloud processes is discussed. This study is based on high-resolution (2 km), time-ensemble simulation of one of the HREs that occurred on 27 May 2017 over the city of Bengaluru in the southern part of India. The simulations are carried out using the Weather Research and Forecasting (WRF) model, which is coupled with a single-layer urban canopy model (UCM). The high-resolution (30 s) land-use data derived from the Indian Space Research Organization (ISRO) for the year 2016–2017 is shown to be realistic in representing the current land-use scenario with a threefold increase in urbanization when compared to USGS land-use data of 1991–1992. Simulated rainfall was found to be remarkably sensitive to land-use changes as shown by control (USGS) and test (ISRO) simulations. The rainfall intensity and spatial distribution are close to observation in test simulations with relatively less error at station scale with a correlation of 0.49 (95% significance) when compared to control simulations, indicating the importance of realistic

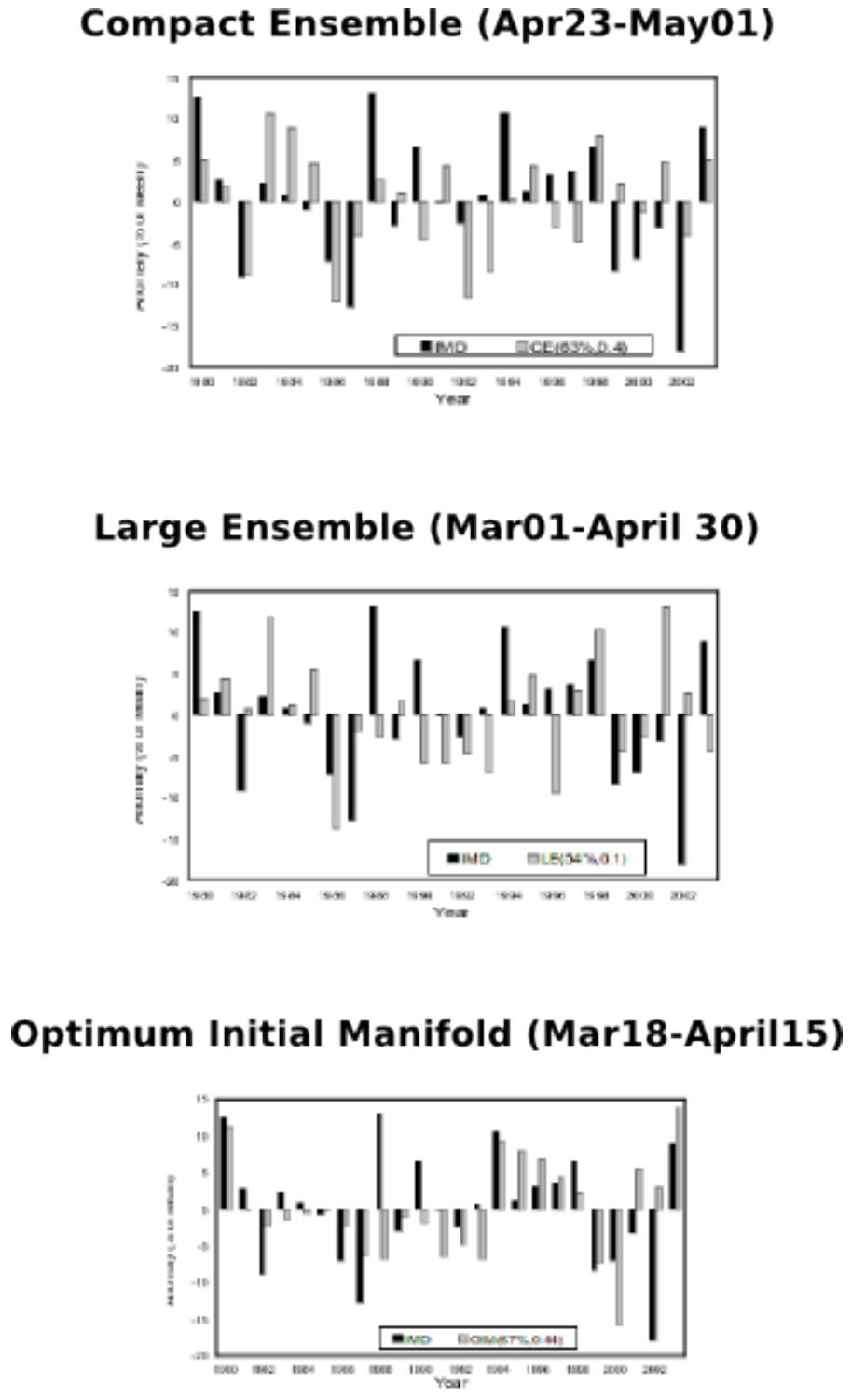

Figure 2.6: Inter annual variability in the all India monsoon seasonal (June-August) rainfall anomaly (expressed as % of respective mean) for (a) Compact Ensemble (b) Large ensemble and OIM. The two numbers in the bracket in each panel represent, respectively, the phase synchronization (%) and correlation coefficient with observed (IMD) rainfall anomalies.

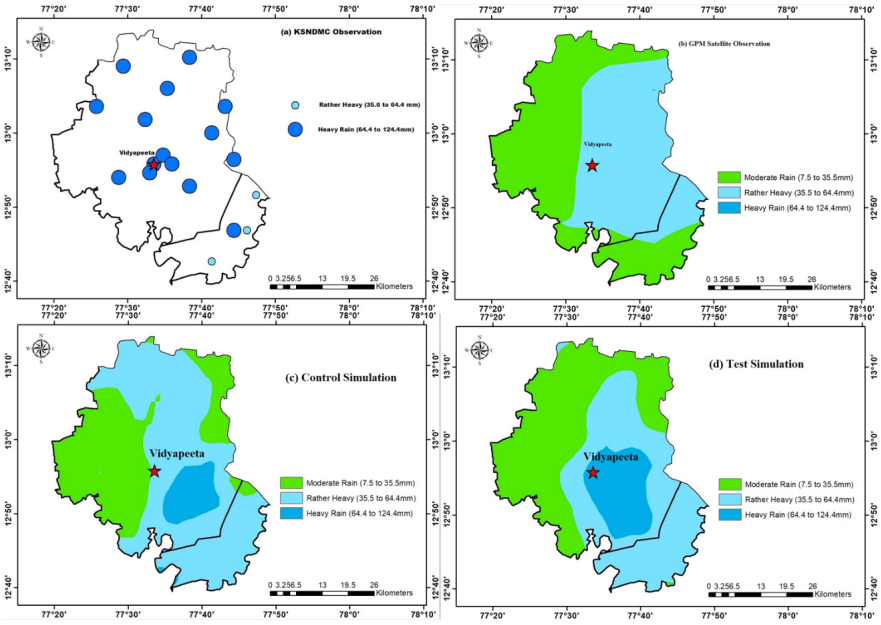

Figure 2.7: Comparison of 24-hr accumulated rainfall (mm) from (a) KSNDMC station observation (b) GPM Satellite observation and (c) control & (d) test simulations during 00UTC 27thMay 2017 to 00UTC 28th May 2017. Red star represents Vidyapeetha, the location of maximum rainfall (120 mm) observed by KSNDMC station observation.

representation of land use in the model and its impact on heavy rainfall processes (Figure 2.7). The test simulation which represents the current urbanization scenario has shown a significant increase in rainfall by over 100–200%. The surface energy fluxes and thermodynamic indices as shown by test simulations are favorable to HREs, and also consistent with the current land-use scenario with increased urbanization. This study demonstrated how a realistic representation of land-use data in the model can help to improve model skill. The main limitation of this research work is that it is based on the generic parameterization of urbanization using single-layer UCM. An in-depth study based on multi-layer UCM and city-specific parameterization of urbanization using sub-kilometer-scale land-use data including buildings would further enhance our understanding on this subject.

3. High Performance Computing & Cyber Security

CSIR-4PI continues to serve computational scientists and researchers across CSIR by providing them 24x7 High Performance Computing (HPC) resources backed with high speed and redundant National Knowledge Network (NKN) connectivity to address grand challenge problems in frontier areas of science, technology and engineering. A grant is received from CSIR to establish CSIR centralised HPC, AI & ML Platform (CHAMP) to further cater to the computational requirements of scientists of various CSIR laboratories located across the country. A donation of about 1.2 PF compute power has been received from AMD, USA to carry out COVID related research across India. Cyber security and Cryptography continues to be the major research area of the group with notable scientific outcome. Two Grand-in-Aid R&D projects in the area of cyber security are being executed with external funding from Ministry of Electronics and Information Technology (MeitY) and Department of Science and Technology, under the Interdisciplinary Cyber Physical System (ICPS) mission of Government of India.

Inside:

3.1 Cyber Security Research: Demonstration of Maliciously-induced-Bursts

Cyber security continues to be one of the major research areas of the group with notable scientific outcome. A cyber security R&D project sponsored by the Interdisciplinary Cyber Physical System programme of Department of Science and Technology (DST) has resulted in identification of an interesting traffic pattern called Maliciously-induced-Bursts (MiB) on a futuristic transport protocol called Multi Path Transmission Control Protocol (MPTCP). MiB is demonstrated by exploiting a newly exposed vulnerability called Data Sequence Signal Manipulation in MPTCP. The highlights of results from this research are shown in Figure 3.1 (a)-(d) using a MPTCP connection consisting of two sub flows in a network testbed environment. Figure 3.1 (a) and (b) corresponds to a normal scenario in which MPTCP Data Sequence Signal carrying acknowledgements (ACK) are used to clock out new data sequences (SEQ). On the other hand, Figure 3.1 (c) and (d) show the MiB, which are triggered in response to manipulated Data Sequence Signals. Notably, several manipulated segments do not instantly trigger any data sequence, rather they are accumulated over a period of time. Subsequently, at one point in time, one of them triggers a bunch of full-size back-to-back data sequences triggering a MiB. Such MiBs are harmful because they consume substantial amount of buffer space on bottleneck routers and switches, and can also result in sharp increase in queue length, excessive queuing delay and packet loss - the primary causes for performance degradation in packet switched networks.

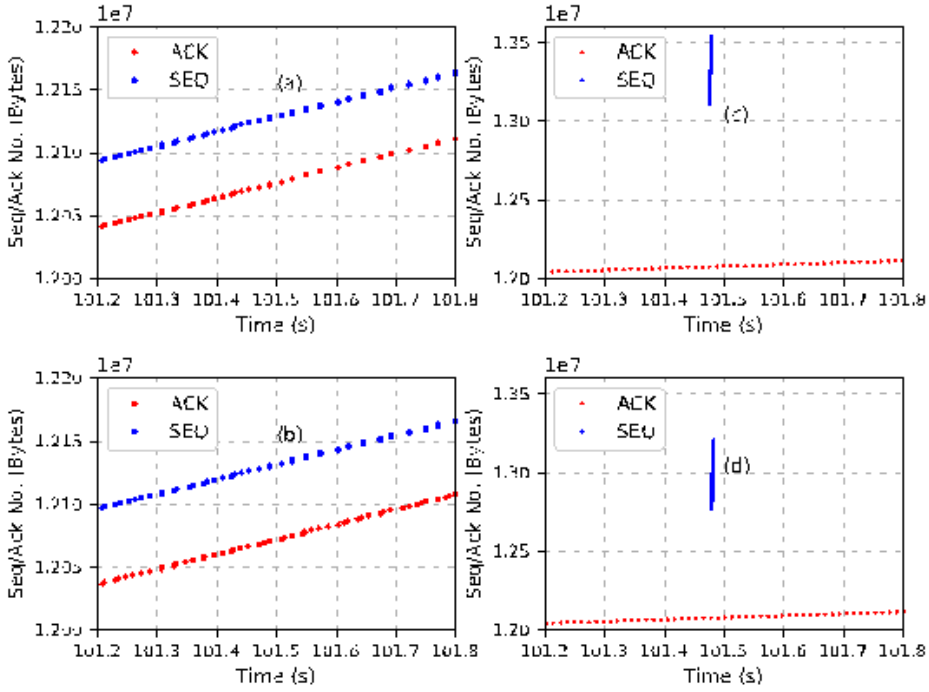

Figure 3.1: The transmission pattern of MPTCP sender at packet granularity under normal scenario and during MiB: Subplots (a) and (b) correspond to subflow1 and subflow2 under normal scenario, and subplots(c) and (d) correspond to subflow1 and subflow2 with MiB.

3.2 Multi-pronged approaches to short-term prediction of COVID-19 positive cases in India

The coronavirus disease 2019, known as COVID-19 pandemic is one of the worst human tragedies of recent times. One of the important aspects of preparedness for the pandemic was to establish a proper supply chain management and delivery system for medical equipments, medical consumables and medicines. One of the biggest challenges of supply chain management and delivery system is to distribute the resources in a fair and optimal manner. However, lack of sufficient prior information about the demands results in inefficient management. We aim to design models that can estimate the number of COVID-19 positive cases which can act as useful input for supply chain management and delivery system.

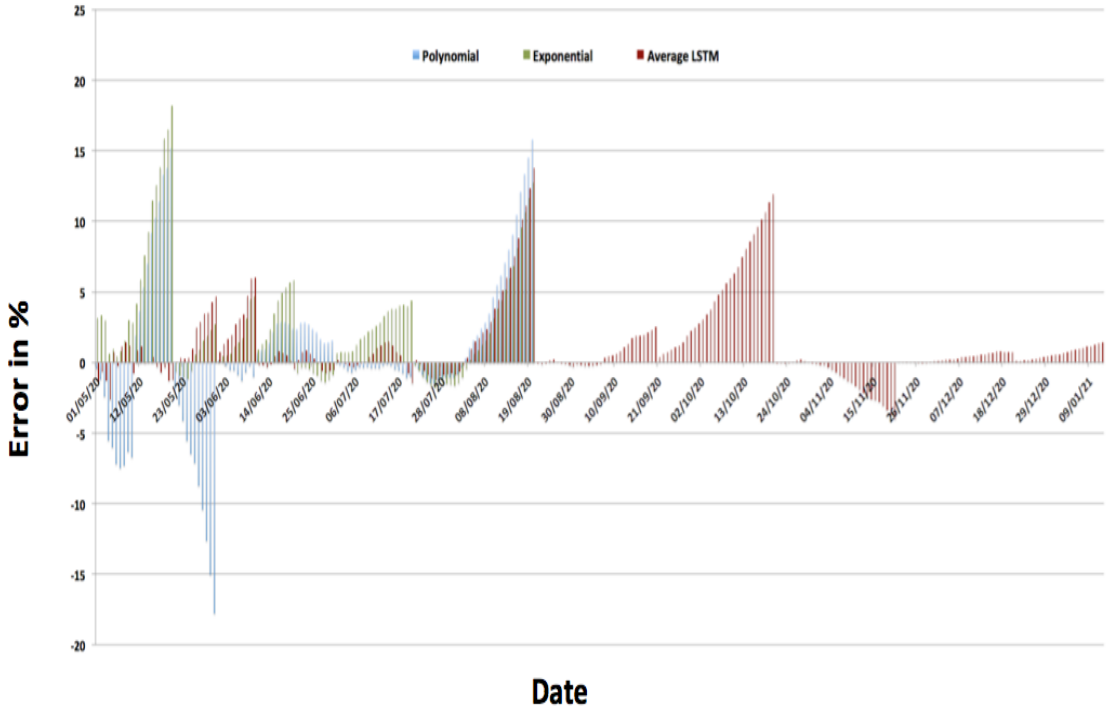

Figure 3.2: Relative error in percentage for prediction of cumulative COVID-19 cases in India using the regression (polynomial and exponential) and the deep learning models (variants of LSTM) at CSIR-4PI. The predictions were done for a block of 10 days starting from 1st May 2020 (i.e. 1st May, 11th May and so on for the next 10 days) and gradually the lead time was increased to one month.

We have used regression (polynomial as well as exponential) as well as deep learning framework based on Long Short Term Memory (LSTM) to provide the prediction on a weekly basis. A sample outcome is presented in Figure 3.2, which demostrates the skill of the prediction framework in terms of percentage of error. LSTM framework is useful for COVID-19 case prediction at national, state (Karnataka) and district (Bengaluru) level. It is possible to automate the data-gathering and prediction process and provide inputs for policy makers. These models cannot predict arrival of a peak – but it can certainly pick up the trend once it sets in.

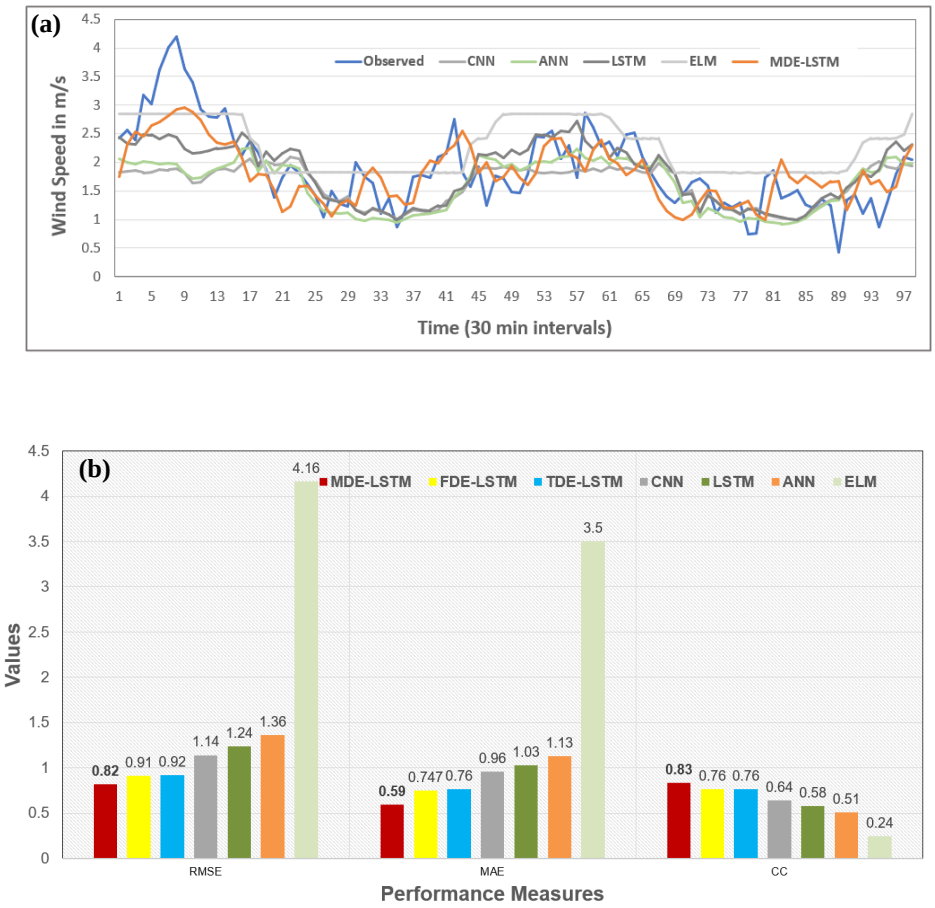

Figure 3.3: (a) Comparison of predicted wind speed from MDE-LSTM, CNN, LSTM, ANN, ELM vs observed wind speed. (b) Comparisons among different performance metrics obtained in various approaches.

3.3 Multidimensional Ensemble LSTM for Wind Speed Prediction

Wind energy is an environmental friendly green energy resource that can be well utilised to generate electricity for industrial and domestic purposes. Better prediction of wind speed in reasonable advance time is an essential requirement as it helps in determining the amount of electricity generated by a turbine. However, the accurate prediction of wind speed becomes challenging because of the stochastic behaviour of wind. Artificial intelligence techniques, especially deep learning algorithms, are recently been successful in addressing atmospheric prediction problems on time series data. A novel time series forecasting algorithm named Multidimensional Ensemble LSTM (MDE-LSTM) derived from Long Short-Term Memory (LSTM) technique has been proposed for predicting wind speed at 6 hours lead time. Here, the input dataset is first distributed over time dimension called (TDE-LSTM) and then over frequency dimension (FDE-LSTM) to prepare distinct varieties of dataset that are fed to individual LSTM, whose outputs are again given as inputs to ensemble LSTM to produce the final output. The proposed method is demonstrated with half an hour interval data for the duration 2010 to 2013 from a meteorological tower located in Bangalore. The potential efficiency of the proposed approach has been compared with existing AI based methods such as Convolutional Neural Network (CNN), LSTM, Artificial Neural Network (ANN), Extreme Learning Machine (ELM) in terms of different performance measures as shown in Figure 3.3(a) and 3.3(b). As plotted in Figure 3.3(a), it is evident that MDE-LSTM outperformed

all other approaches. This has also been observed from the histogram drawn in Figure 3.3(b).

3.4 Atmospheric Temperature Prediction Using Ensemble Deep Learning Technique

In the area of climatology research, temperature is one of the pivotal atmospheric parameters that plays significant role in measuring climate changes. It is important to understand the climate change because, it impacts various activities such as agriculture, solar energy production, travel, climate conditions in extreme cold or hot places, etc. In order to deal with such activities, it is required to predict atmospheric temperature with higher accuracy at sufficient lead time. Generally, complex and dynamical climatology models are used to compute atmospheric temperature. However, these models are time and compute intensive. Therefore, we need alternate approaches to make prediction of different atmospheric variables. With advancement of artificial intelligence, deep learning techniques especially, LSTM is capable of providing better solutions with higher efficiency for time series prediction problems. We have proposed ensemble LSTM to predict atmospheric temperature in seven days lead time. We have considered the effects of other atmospheric parameters such as wind speed, pressure, humidity along with atmospheric temperature to predict temperature at future timestamps. We have used half an hour interval data for the duration 2010 to 2013 from a meteorological tower located in Bangalore to evaluate the efficiency of our proposed algorithm.

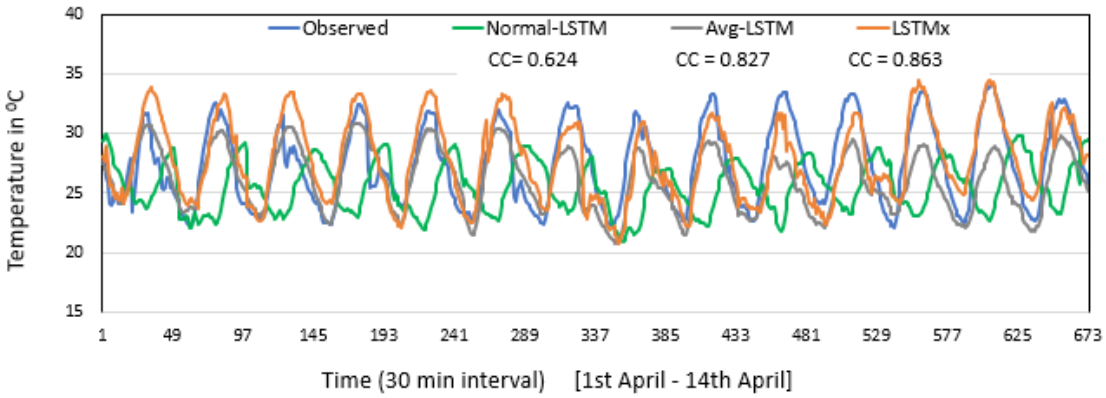

Figure 3.4: Comparison of predicted atmospheric temperature from Ensemble LSTM (LSTMx), Average LSTM, normal LSTM vs observed atmospheric temperature.

As shown in Figure 3.4, the result using proposed method (LSTMx) has performed other methods like normal LSTM and average LSTM. We have also compared different performance metrics such as RMSE, MAE, CC etc. and found the performance of our proposed model superior than other models. The comparison of experimental outcome of the proposed technique with results of existing approaches convincingly justifies the logic behind our technique.

3.5 High Performance Computing

CSIR-4PI continues to provide High Performance Computing (HPC) resources to the computational scientists across various CSIR laboratories. This facility is actively used for solving different compute intensive grand challenge problems in the areas of Aerospace, Computational Biology, Computational Chemistry, Material Science, Physical & Environmental Science etc.

Figure 3.5 represents the picture of the CSIR centralised 489 TF HPC Facility. This supercomputer, the Ananta, has a peak computing capability of 489 TeraFLOPS (TF). The system is

tightly integrated using two generations of Intel processors i.e. Sandy Bridge, (362 TF of peak) and Skylake, (127 TF of peak).

The supercomputer Ananta is a cluster of 1136 computing nodes distributed over 18 racks, with 1088 nodes each having two eight-core Intel Xeon E5 2670 processors and another 48 nodes each having two eighteen-core Intel Xeon Gold 6140 processors. The total memory of the system is about 77 TB. The inter-node communication are powered by high-speed FDR / EDR InfiniBand interconnect. All the 1136 nodes access LUSTRE parallel file system of about 3 Petabytes that is capable of providing a minimum 20 Gbps simultaneous read and write performance. The PBSPro workload manager ensures efficient usage of the system.

Figure 3.5: CSIR centralised 489 TF HPC Facility.

The efficient support infrastructure plays a pivotal role in the smooth running of the HPC facility. The Ananta supercomputer is positioned in a Tier-3 equivalent state-of-the-art datacenter efficiently supported by a state-of-the-art energy farm. The most significant component of the datacenter is the water-based cooling mechanism with Rear Door Heat Exchangers (RDHx) that has enabled the datacenter as one of the high density and high power-efficient datacenter in the country having Power Usage Efficiency (PUE) of less than 1.5. The energy farm consists of two redundant compact substations having capacity of 1.25 MVA each, three 1010 KVA diesel generators, an underground diesel yard having capacity of more than 15000 litres, and three numbers of UPS (400 KVA each) with battery backup for ensuring 24x7 power supply to the datacenter.

4. Multi-scale Modelling Programme

This is a data intensive paradigm which addresses multiscale problems ranging from weather and climate, century-scale climate projections, space-based geodesy, computational geodynamics, surface processes and climate aspects from surface to ionosphere. The group continued development of system models and carried out the simulations of climate change, seasonal monsoon and climate under different aerosol scenarios, formulation of algorithms for analysis of simulations and deriving inferences in the field of climate sciences, lithosphere-hydrosphere-atmosphere-ionosphere interactions and computational geodynamics.

Inside:

4.1 On the build-up of dust aerosols and possible indirect eAect during Indian summer monsoon break spells using recent satellite observations of aerosols and cloud properties

Association of higher (lower) rainfall with lower (higher) Aerosol Optical Depth (AOD) is consistent with the understanding that increased washout (build-up) and shorter (longer) lifetime of aerosols occur in wetter (drier) conditions. Given the life-time of aerosols, it is imperative to examine how aerosols impact active/break (wetter/drier than normal) spells, prominent intraseasonal variability (ISV) of Indian summer monsoon (ISM), through their composite analysis using recent satellite observations of aerosols and cloud properties, circulation and rainfall. Dust aerosols can act as CCN and participate efficiently in cloud processes during active phase. During breaks, build-up of desert dust transported by prevalent circulation, is associated with lower cloud effective radius implying aerosols' indirect effect where they can inhibit cloud growth in the presence of reduced moisture and decrease precipitation efficiency/rainfall. Correspondingly, correlation albeit small, between intraseasonal anomalies of AOD and rainfall is negative, when AOD leads rainfall by 3–5 days implying that indirect aerosols impact is effective during breaks, though it is not the dominant responsible factor. During breaks, lower shortwave flux at top of atmosphere hints at dust-induced semi-direct effect. As breaks are permanent features of ISM, incorporation of dust-induced feedbacks in models, is essential for improved ISV simulation and ISM prediction.

4.2 Future changes in rice yield over Kerala using climate change scenario from high resolution global climate model projection

The impact of climate change on agricultural yield is one amongst the major concerns the world is witnessing. Our study focusses on rice yield prediction for an agricultural research station in Kerala with the help of climate change scenario input from the Meteorological Research Institute (MRI) Global Climate Model (GCM) projection under Representative Concentration Pathway 8.5 (RCP8.5). We have used Cropping System Model (CSM) Crop Estimation through Resource and Environment Synthesis (CERES) Rice within Decision Support System for Agrotechnology Transfer (DSSAT) package for predicting the yield. Our study has the novelty of using very high-resolution climate data from a model which is highly skilful in capturing the present-day climate features and climatic trends over India (in particular, over the Western Ghats), as input for simulating the future crop yield. From this study, we find that the rice yield decreases due to rise in temperature and reduction in rainfall, thereby reducing the crops maturity time in the future. Based on our results, the adaptation measures suggested to achieve better yield under future warming conditions are: (i) to opt for alternative rice varieties which have tolerance to high temperatures and consume less water, and (ii) shifting of planting date to the most appropriate window.

4.3 High-resolution climate change projection of northeast monsoon rainfall over peninsular India

In this study, projected changes in mean northeast monsoon (NEM) rainfall and associated extreme rainfall and temperature events, over peninsular India (PI) and its six subdivisions, are quantified. High-resolution dynamically downscaled simulations of the Weather Research and Forecasting (WRF) regional climate model driven by the boundary conditions from the Community Climate System Model version 4 (CCSM4) model (WRF-CCSM4) are compared with statistically downscaled simulations of NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP). Over PI, these downscaled simulations show low bias in mean NEM rainfall ($\leq$ 0.44 mm/day) and high pattern correlation coefficient (0.75), giving confidence in their future projections. Under future warming over PI, both downscaled simulations project future significant enhancement in

NEM rainfall with WRF-CCSM4 projecting 1.98mm·day1 (83.78% change with respect to the present-day mean) whereas the multimodel ensemble (MME) of eight NEX-GDDP models project 0.67 $\pm$ 0.58mm·day1 (19.78%) by the midddle of the century and 1.42±0.97mm·day1 (42.76%) by the end of the century. Analysis of extreme rainfall events shows that WRF-CCSM4 projects future enhancement (reduction) in extreme rainfall (R95p) days over 91.4% (8.6%) of grid-points over PI. In future, coastal areas of Karnataka and Andhra Pradesh will likely experience increased extreme rainfall occurrence by more than 25 days and 15–20 days respectively. Projected future enhancement in the mean and extreme NEM rainfall is attributed to the increased precipitable water under a warming climate. Future projection of extreme temperature indices shows an increase in minimum and maximum temperatures over PI during the NEM season. Over PI, future winter nights and days are found to be warmer than those in the present day and the temperature change in future winter nights is found to be larger than that in winter days. This climate change information would help decision-makers in evaluating existing policies and devising revised policies to reduce risk due to climate change.

4.4 Hydrology induced horizontal displacements of Nepal Himalayas and North-East India detected using GRACE gravity observations and GPS

The area of North-East India and Nepal Himalaya undergoes seasonal deformations due to the variation of the surface mass loads induced mainly by annual monsoon precipitation. The present study focuses on comparing seasonal horizontal deformations of the Earth's surface obtained over the area of North-East India and Nepal Himalaya using Global Positioning System (GPS) and the corresponding ones obtained from Gravity Recovery and Climate Experiment (GRACE) satellite mission data. Seasonal deformations of the Earth's surface in horizontal components were determined using daily observations from 36 GPS stations located in North-East India and Nepal Himalaya and GRACE-based Global Geopotential Models (GGMs). The consistency between these seasonal horizontal deformations was investigated using three statistical criteria, namely: the correlation, Weighted Root Mean Square (WRMS) reduction and Nash-Sutcliffe model Efficiency (NSE). The results indicate that nearly 89% of the seasonal deformations obtained using GPS and GRACE correlates well. However, the percentage of WRMS reductions (Figure 4.1) and median value of NSE shows poor agreement. The results reveal that seasonal horizontal deformations are influenced by local tectonics and emphasize the need of a realistic Earth model for better constraining the surface deformations over the area investigated.

4.5 Aliasing and Artifact free detection of ionospheric perturbations induced by Tsunami – A possible tool for tsunami early warning

Earthquakes and tsunamis killed more people than all other types of natural disasters, claiming nearly 884,000 lives, globally, between 1980 – 2014. Among these two natural disasters, tsunamis were the most deadly with an average of 79 deaths for every 1,000 people affected, compared to four deaths per 1,000 in the case of earthquakes, which make tsunamis almost twenty times more deadly than earthquakes. As there is no mechanism exists at present to forecast or predict the earthquakes and tsunamis, timely detection and early warning are the only alternative to reduce the loss of lives caused by these disasters. Monitoring ionospheric perturbation induced tsunamis using ground based GPS receivers can be a promising tool for the timely detection and early warning, provided the aliasing and artifacts free detection of ionospheric perturbations are ensured. Theoretical simulations and observational validation of the algorithm developed by Shimna and Vijayan at MSMP, CSIR-4PI reveals that the algorithm SPLA (Spatio-Periodic Levelling Algorithm) successfully removes the aliases and artifacts from ionospheric perturbations. Furthermore, the results show that SPLA is efficient to extract tsunami induced ionospheric perturbations from low

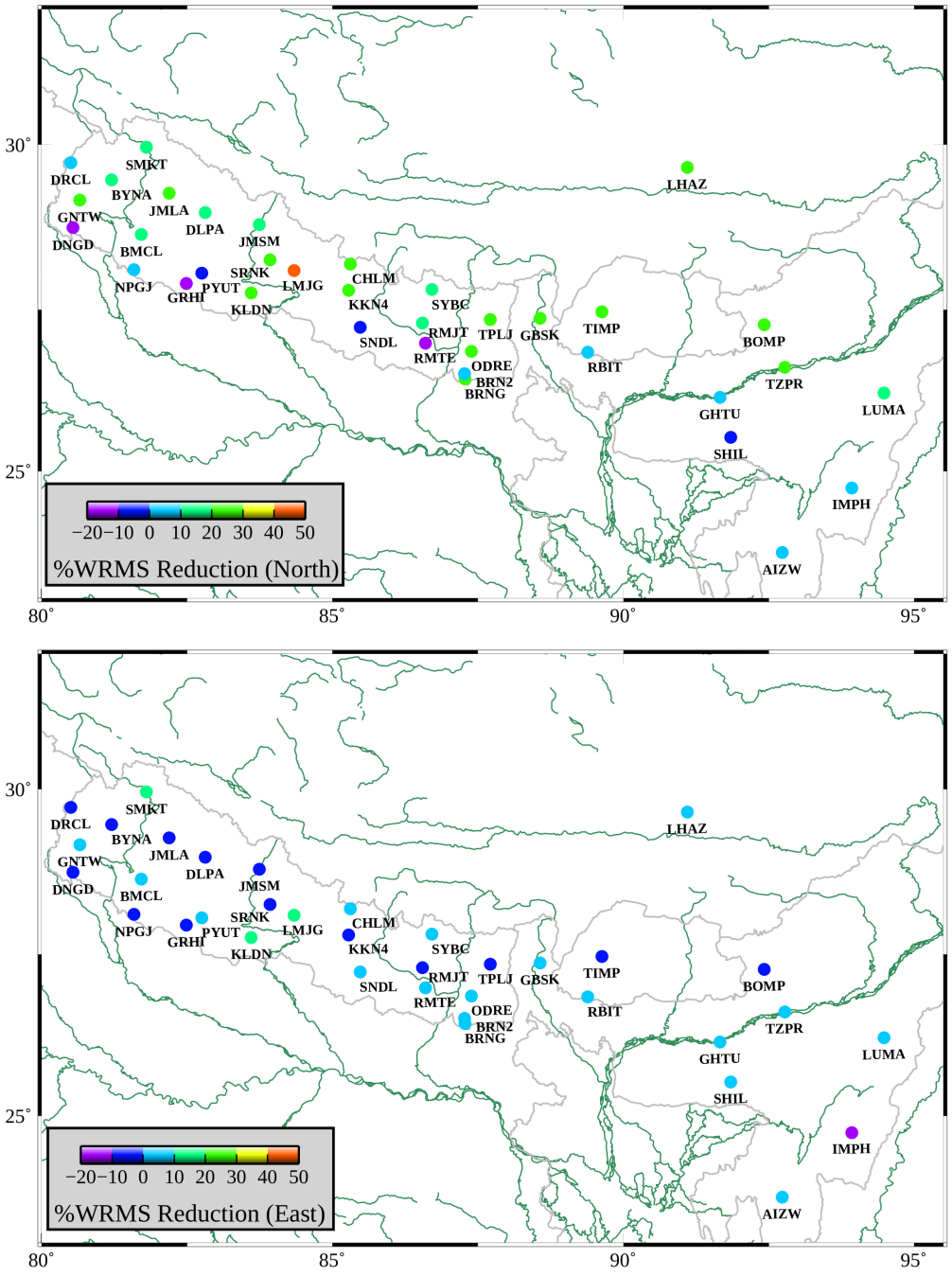

Figure 4.1: The WRMS reduction obtained after reducing the seasonal deformations obtained from GRACE data from the seasonal deformations determined from GPS data.

elevation observations and capable of detecting tsunamis propagating as far as 800 km away from the coast using inland GPS receivers. The locations of the ionospheric perturbations obtained from GPS observations using SPLA matches well with the simulated 26th December 2004 Indian Ocean tsunami (Figure 4.2). The results obtained in this study indicate that the potential of ionospheric observations for tsunami early warning.

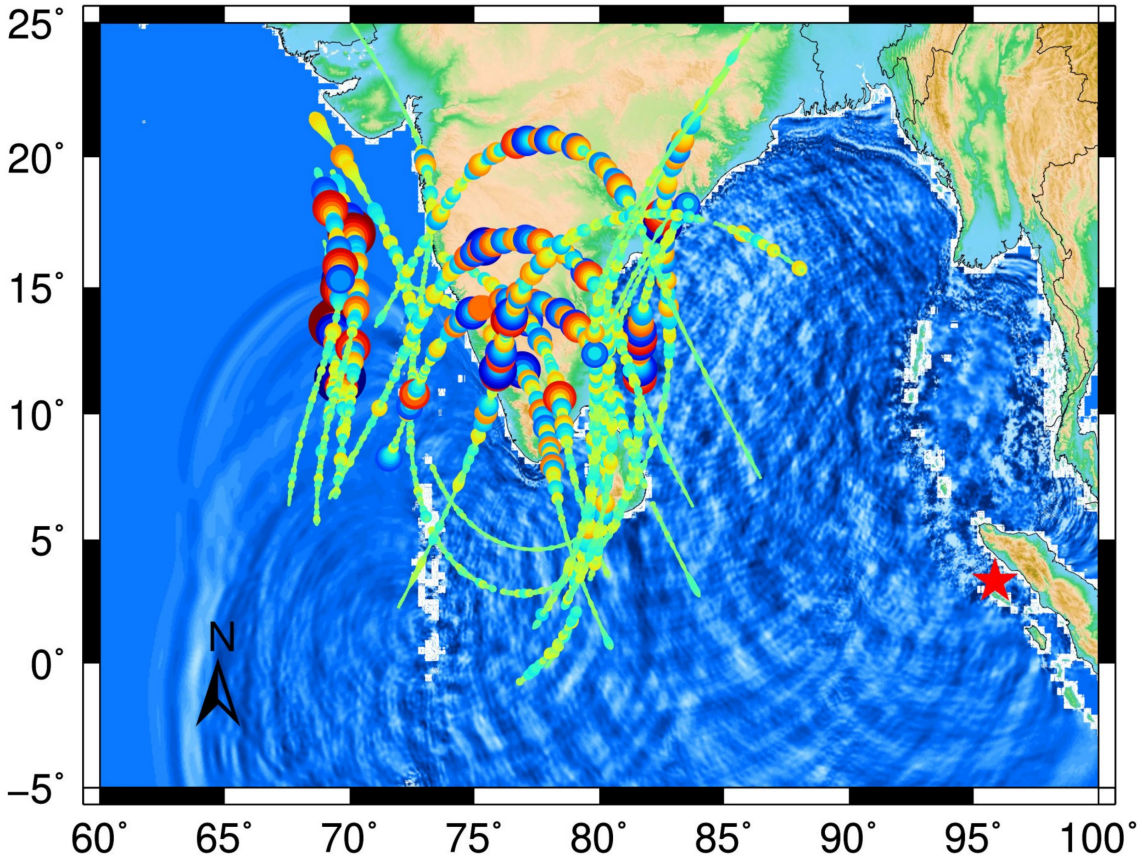

Figure 4.2: Ionospheric perturbations induced by 26th December 2004 Indian Ocean tsunami. The ionospheric perturbations detected at a height of 350 km above the ocean surface are plotted over the numerically simulated tsunami.

4.6 Stream gradient indices and the active tectonics of the Central Himalaya

The evolution of the landscape is generally considered to be associated with active tectonic processes and erosion. Our understanding on the topographic evolution of a convergent orogen can be looked through the river drainage network of that region. The 2500 km long Himalayan arc orogen sets an ideal region to study the active tectonic orogenic process using river channel morphological analysis. For this rivers from the central Himalayan region, like the Yamuna, Bhagirathi, Sharda, Ghagra and Kali Gandaki are selected. For this we computed the normalized steepness index and river knick points distribution. The longitudinal profile of the transient stream typically shows convexity whereas the graded stream show concave up. High normalized steepness index values indicate faster surface uplift. Areas that are undergoing faster surface uplift are identified by high normalized steepness index (Ksn) values (Figure 4.3). This study indicates that the regional river channel profiles represent a uplift tectonics in a compressional environment.

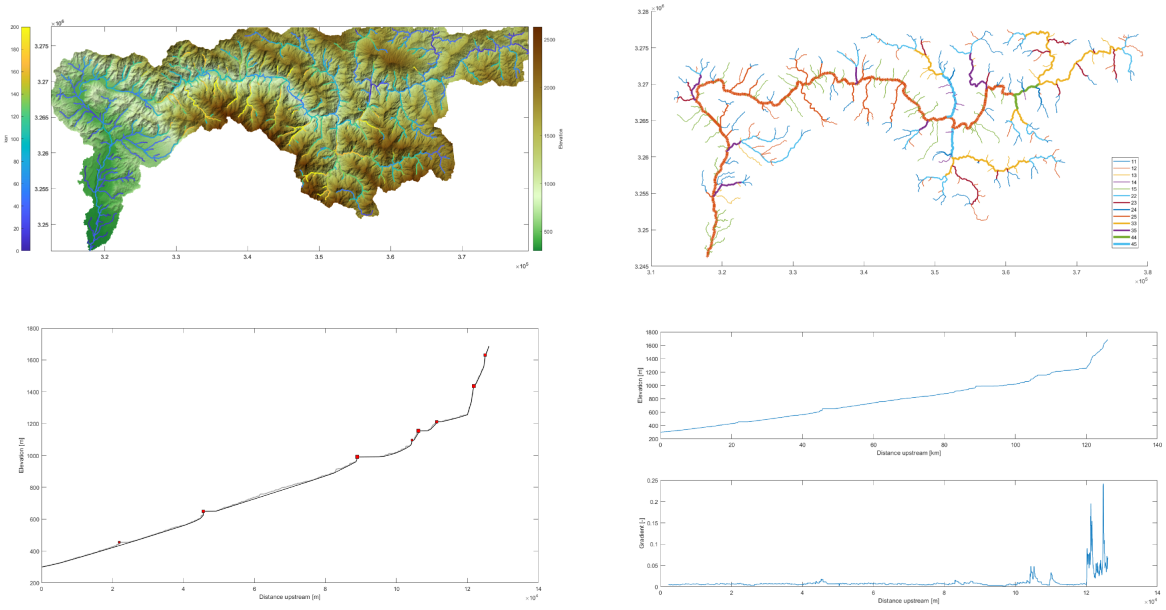

Figure 4.3: Digital elevation model of Kosi river and tributaries indexed with normalized steepness index (Ksn) values. (Top left), Drainage side branching used in the analysis (Top right), Knick points along the river profile (Bottom left) and the stream line gradient index (Right bottom).

5. Solid Earth Modelling Programme

During this year the group signed MOU with University of Kashmir and Indian Institute of Astrophysics for academic and scientific collaboration. Further, Major Lab project with a budget of ∼INR 3.5 crores was sanctioned to our group for seismic studies in Jammu, Kashmir and Ladakh region, On the research front, we majorly focused on the implications of crustal structure and crustal velocities on the seismic hazard of tectonically active northwest Himalaya. For the first time, we integrated the GNSS and Broadband data in Kashmir valley and adjoining regions and concluded that magnitude Mw ∼7.8 earthquake is over due in this region. We published the first high resolution (0.5 X0.5 degree) shear wave velocity structure of northwestern Himalaya extending from Hindu Kush through Kohistan-Nanga Parbat to Kashmir Himalaya, as well as the Pamirs in the north and Lesser Himalaya along with the foreland basin including the Hazara syntaxis in the south providing significant insights in to low and high velocity layers and Moho depth. We analysed the broadband seismic observation network data of Kashmir-Zanskar region to estimate the sensor orientation, seismic noise and their effect on seismic anisotropy. Microtremor measurements of Srinagar city were used to obtain the two and three dimensional subsurface geological features which in turn aid in mitigating the earthquake impact. We gave detailed crustal structure model of Gharwal Himalaya from foothills to south Tibet detachment. Further, composite analysis of strain budget using geodetic and seismic moment rates of Gharwal-Kumaun region of northwest Himalaya indicate high locked strain budget which has a potential to generate a megathrust earthquake (Mw 8). GNSS remote sensing studies yielded correlation between atmospheric opacity and water vapour for two decades at high altitude Indian Astronomical observatory at Hanle in northwest Himalaya. In addition, GNSS remote sensing studies gave significant insights in to the short and long term ionosphere variability over Indian subcontinent. For the first time we published the Impact GPS, Glonass and Combined GPS+ Glonass signals on the position and velocity estimates of Indian subcontinent. Our research yielded about 7 high impact SCI publications and about 300 citations during this year.

Inside:

- 3D-Shear wave velocity structure beneath North-Western Himalaya and adjoining areas
- Misorientation and Noise analysis of the Kashmir-Zanskar seismic network

- Imaging subsurface geological complexity (2D/3D) beneath Greater Srinagar region of Kashmir basin, Northwest Himalaya
- Nature of MHT in Garhwal Himalaya using shear wave velocity modelling
- Atmospheric opacity and water vapor trends over high altitude astronomical observatory at Hanle
- Evaluation of the Performance of IRI model VTEC using GPS TEC
- Implications of high GNSS rates in Kashmir Valley
- GNSS and its impact on position estimates in Indian subcontinent
- Seismic Potential of Gharwal-Kumaun Himalayas
- Estimation of Seismic strain rates in North-West Himalaya

5.1 3D-Shear wave velocity structure beneath North-Western Himalaya and adjoining areas

A detailed shear-wave velocity structure (Vs) is necessary for precise earthquake locations, modeling of earthquake hazard etc. Here we develop a high-resolution (0.5*0.5 degrees) Vs model of NW Himalaya utilizing data from Kashmir-Zanskar network and nearby national and international deployments. The model was obtained by inverting 2-D surface wave tomographic maps using a Bayesian approach. This method enables us to report robust errors on our Vs estimates unlike linear(ized) inversion schemes. The tomographic maps were also inverted for Moho depths and the obtained depths were compared with those reported by other workers. The results yield the first high resolution shear wave velocity structure of northwestern Himalaya extending from Hindu Kush through Kohistan-Nanga Parbat to Kashmir Himalaya, as well as the Pamirs in the north and Lesser Himalaya alongwith the foreland basin including the Hazara syntaxis in the south. The major findings are: a) a pervasive low velocity layer (3km/s) beneath the region at 30 km depth b) shallow high-velocity signature beneath the high-crystalline complexes of the NW Himalaya and gneiss domes of the Pamirs (Figure 5.1) c) high velocity root of the Nangaparbat syntaxis and d) shallow Moho beneath the NW Himalaya by 10 km compared to its adjoining regions.

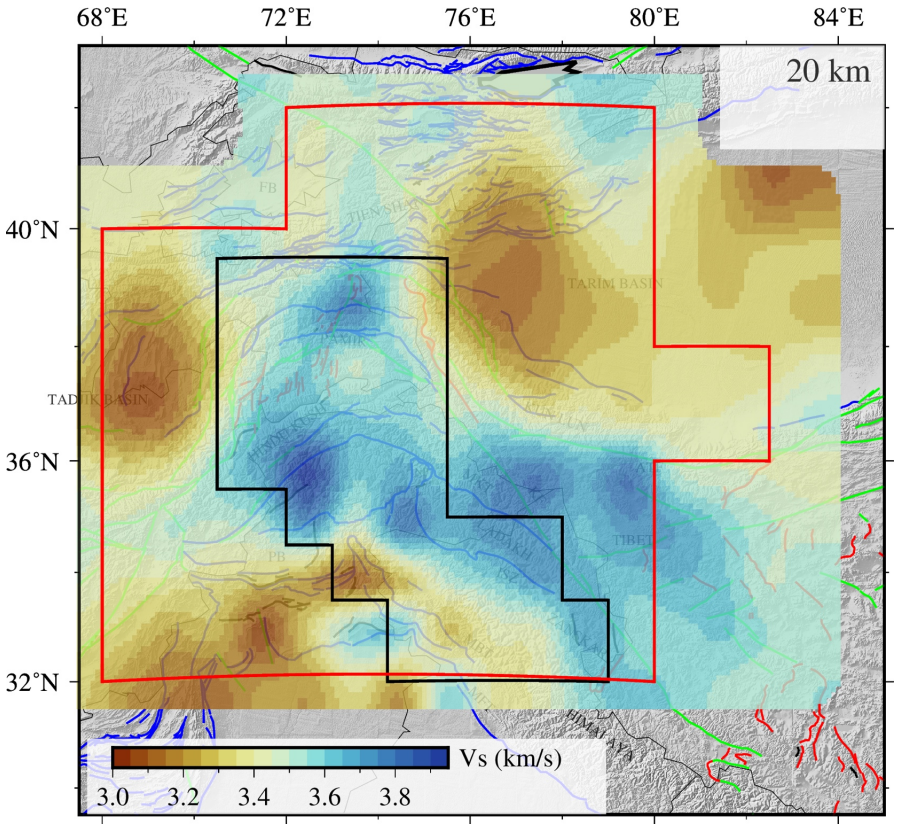

Figure 5.1: Shows the posterior Vs slice at the depth of 20 km. Red and black polygons respectively demarcate resolvable regions of resolution $1^0 \times 1^0$ and $0.5^0 \times 0.5^0$.

5.2 Misorientation and Noise analysis of the Kashmir-Zanskar seismic network

High quality data recording is first and foremost goal for all seismic networks preferably for temporary ones – owing to their shorter duration. Despite considering all factors like instrument

siting on in-situ bedrock, less anthropogenic noise, well-marked geographic orientation, etc. still errors in sensor positioning and noise does affect or restrict the data usage for further analysis. Here for Kashmir-Zanskar network we estimate sensor misorientation (e.g. see Figure 5.2 for station KRG) as well as seismic noise at all broadband stations since their inception. The former is done by using global surface wave records of earthquakes (M>=5) and the latter use about a month-long continuous data, recorded at 100 samples per second, during summer season to estimate energy content of various recorded frequencies. We observe that obtained misorientations have a strong influence over seismic anisotropy measurements of the region, whilst having less influence over the crust-mantle boundary (Moho) depth estimates. Also, we found that within Kashmir basin the earlier reported microseismic events (ML $\sim$1) are well distinct due to less ambient noise of the recording stations.

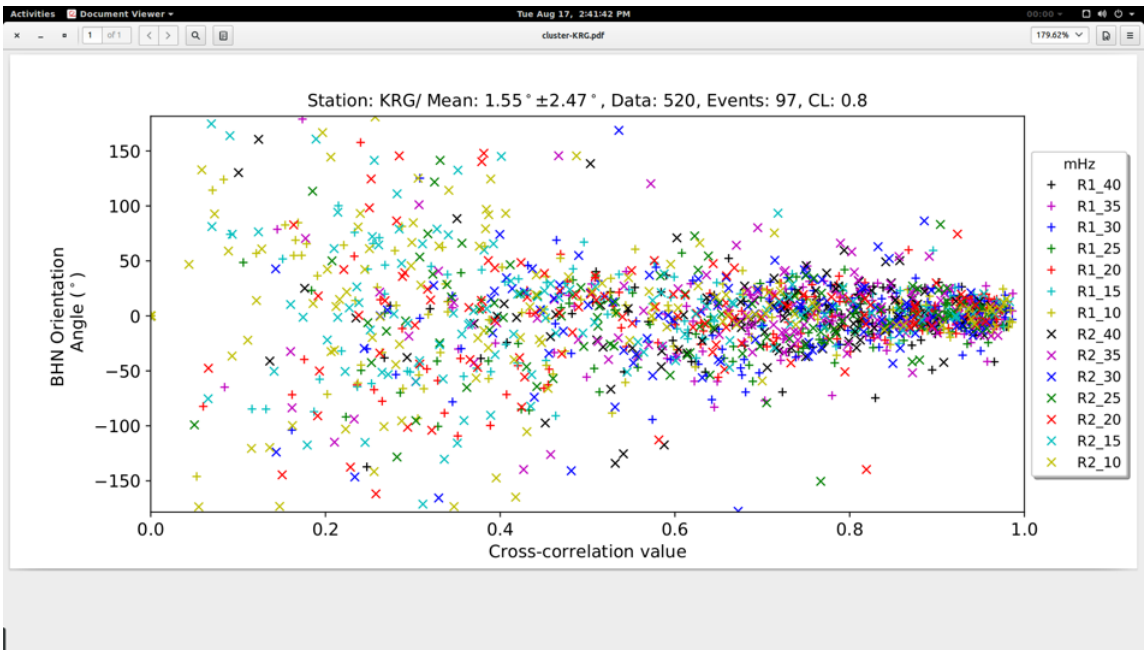

Figure 5.2: Final result at station Kargil having mean misalignment of 1.55^0 using 97 unique events. The individual measurements ('+' and 'x') are obtained for frequency range 10-40 mHz for both first-minor (R1) and first-major (R2) arcs.

5.3 Imaging subsurface geological complexity (2D/3D) beneath Greater Srinagar region of Kashmir basin, Northwest Himalaya

A high resolution microtremor measurement in Greater Srinagar city of Kashmir valley has been analyzed to image 2D and 3D subsurface geological complexities. This region falls under a highly seismogenic Himalayan belt and sits atop of deep sedimentary lake bed with laterally varying thickness of soft sediments. Srinagar region is a major economic center and capital city of Kashmir valley with 2 million inhabitants living at high seismic risk. To accomplish subsurface complexity beneath the city, we present: (1) High-resolution subsurface shear wave velocity Vs structure using the Horizontal to Vertical Spectral Ratio (HVSR) inversion, (2) time averaged shear wave velocity for top 30 meters of soil column (VS30) map with NEHRP site classification, and (3) azimuthal behaviour of HVSR peaks, all of which unravel the subsurface spatial heterogeneity and engineering efficacy beneath the study area (Figure 5.3). The presented potentiality of microtremor

HVSR (mHVSR) technique over Srinagar region which lies on the eastern edge of basin with significant topographic irregularities indicates uneven distribution of local site effects (primary and secondary) in case of strong ground motion. The novel comprehensive results can be promising in engineering analyses of local ground and structural responses in order to mitigate the impact of earthquake risk in the city and adjoining regions.

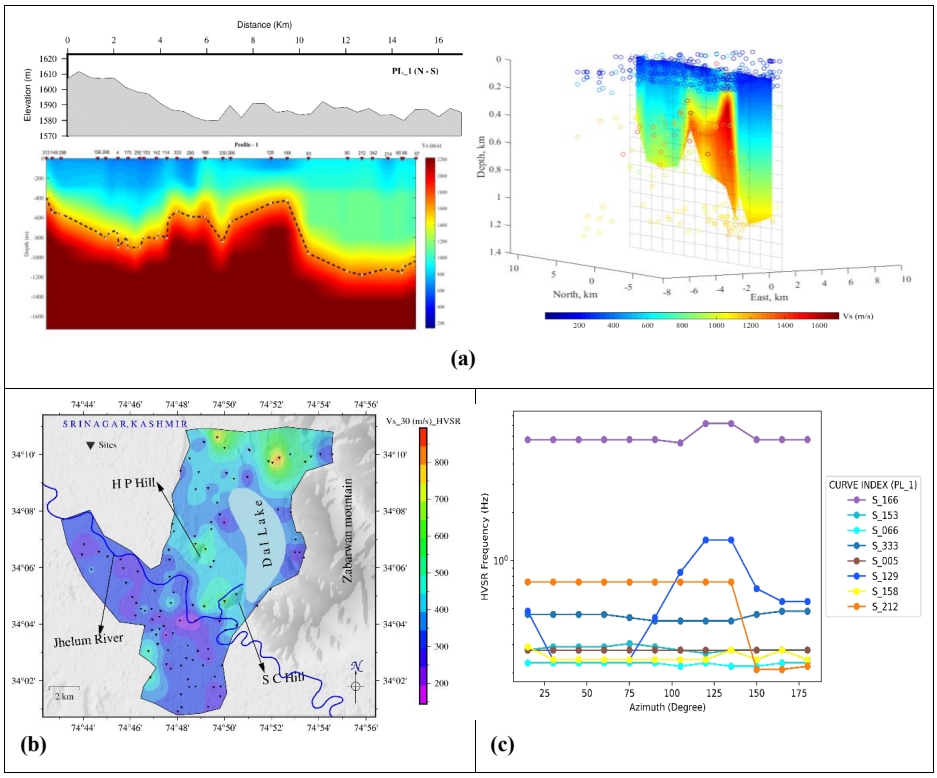

Figure 5.3: (a) The Vs profile (2D and 3D) cross-section with topographic variation, (b) V_{S30} distribution for Srinagar metropolitan region and, (c) azimuthal variation (at the interval of $=15^0$) of HVSR peak frequency across the Srinagar region and its suburbs.

5.4 Nature of MHT in Garhwal Himalaya using shear wave velocity modelling

The Himalayan range, formed due to continued subduction of the Indian plate beneath the Eurasian plate beginning about 55 Ma ago, is structurally dominated by various thrusts and detachment such as the Southern Tibetan Detachment (STD), the Main Central Thrust (MCT), Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT). It is widely accepted that most of the thrust of the Himalayan range (MCT, MBT & MFT) are rooted into a common decollement termed the Main Himalayan thrust (MHT), which is a detachment between the base of Himalayan thrust wedge and the top of the subducting Indian plate.

We investigated crustal structure of Garhwal Himalaya using joint inversion of interpolated receiver functions along a NE-SW profile from 19 seismic stations and surface wave data with high resolution. The estimated velocity image highlights several important features of the crust in the region. The geometry of the Main Himalayan Thrust (MHT) along which the Indian crust under-thrusts is mapped as flat - ramp - flat structure across the Himalaya. The flat section is at a depth of about 8 km beneath the southern edge of the Himalaya and dipping at 3^0N. This geometry is inferred from the presence of low shear velocity (3.1-3.4 km/s) representing wet sediments

dragged along the MHT and lying above the crystalline Indian crust with Vs of 3.6 km/s. At the front of High Himalaya, the dip of MHT changes significantly to about 35^0 – 40^0 representing the ramp, reaching to a depth of 20 km and continuing as a nearly flat structure beneath the High Himalaya and further north (Figure 5.4). The increase of dip to 40◦ would significantly reduce the seismic decoupling zone width to about 33%, influencing the capacity to store elastic energy and hence the amount of slip deficit at the time of rupture. In the middle crust at a depth 20– 30 km we observe low velocity below the northern part of the Lower Himalaya. Thickness of the crust is ∼50 km beneath the Sub and lower Himalaya and increases abruptly in the front of High Himalaya to 60 km and remains so till the southern part of Tethys Himalaya. The observed thick crust with lower seismic velocity (and rigidity) beneath the High Himalaya could be responsible for its high topography.

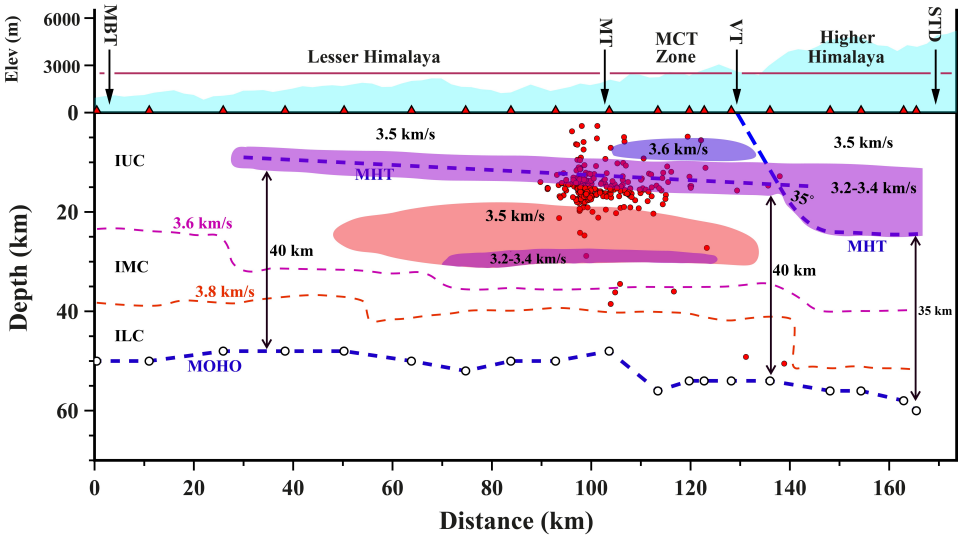

Figure 5.4: A schematic representation of velocity structure model of the crust along a NE-SE profile in Garhwal Himalaya from HFT to STD. IUC- Indian Upper Crust, IMC- Indian Middle crust, ILC, Indian Lower crust.

5.5 Atmospheric opacity and water vapor trends over high altitude astronomical observatory at Hanle

Atmospheric opacity at 220GHZ over Indian Astronomical Observatory (IAO) at Hanle is estimated using Radiometer data from 2006 to 2018 and compared with high temporal resolution GPS-PWV (Global Positioning System- Precipitable Water Vapor). The results indicate linear correlation (Figure 5.5) with a correlation coefficient of 0.8. Opacity at Hanle increased 44% during this period due to the dynamics of regional and global hydrological cycle. Water vapor at nine high-altitude astronomical observatories spatially spread across the globe using satellite and reanalysis data indicate increasing trends pointing to non-uniform dynamic hydrological cycles. This study was carried out to identify future sites for establishment of infrared and sub-millimeter astronomical facilities.

5.6 Evaluation of the Performance of IRI model VTEC using GPS TEC

The empirical model International Reference Ionosphere (IRI) is developed under the joint sponsorship of the Committee on Space Research (COSPAR) and the International Union of Radio Science

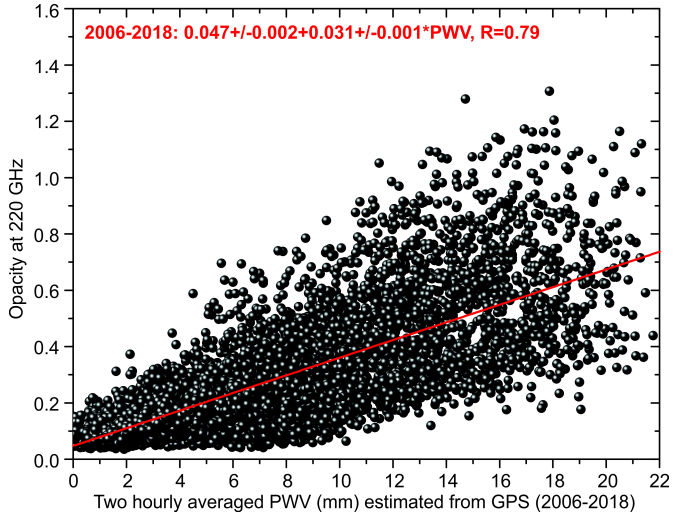

Figure 5.5: Scatter plot between 2 hourly opacity and GPS-PWV over IAO-Hanle.

(URSI) is the worldwide most used model for ionospheric parameters. Using worldwide a network of ionosondes, incoherent scatter radars, different topside sounders, and in-situ instruments IRI model provides the electron density, electron temperature, Vertical TEC (VTEC), and so on. TEC

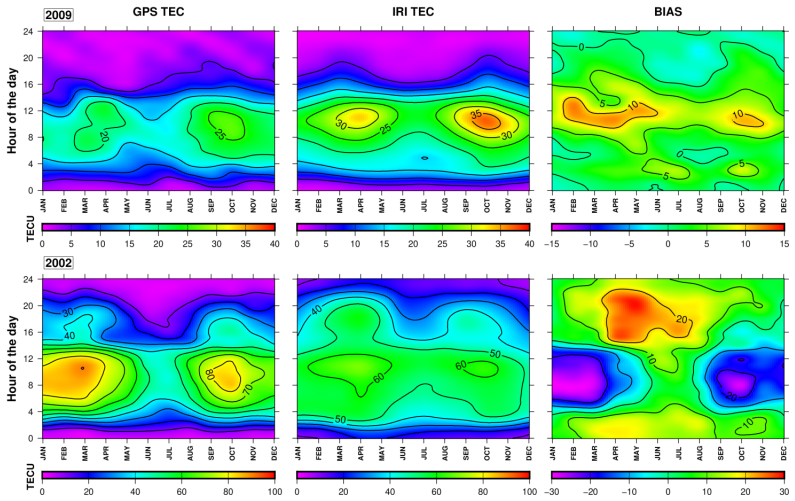

Figure 5.6: Diurnal monthly mean contour plots of IRI and GPS TEC, bias at IISC in 2002 and 2009.

variations are high in the equatorial and low latitude regions due to Fountain effect associated with the Equatorial Electro Jet (EEJ) current, plasma fountain, and Equatorial Ionization Anomaly (EIA). The long-term validation of the IRI model VTEC on Indian low latitude and equatorial regions are studied using Global Positioning System derived TEC (GPS TEC) calculated from dual-frequency GPS signal observables (L1, L2, P1, and P2) recorded in ground stations. Figure 5.6 shows the contour plots of diurnal monthly mean IRI model VTEC, GPS TEC, and bias in the year 2002 (high solar activity year) and 2009 (low solar activity year) at low latitude station IISC, Bangalore. This study will help to improve the IRI model performance for PNT applications in the Indian region.

5.7 Implications of high GNSS rates in Kashmir Valley

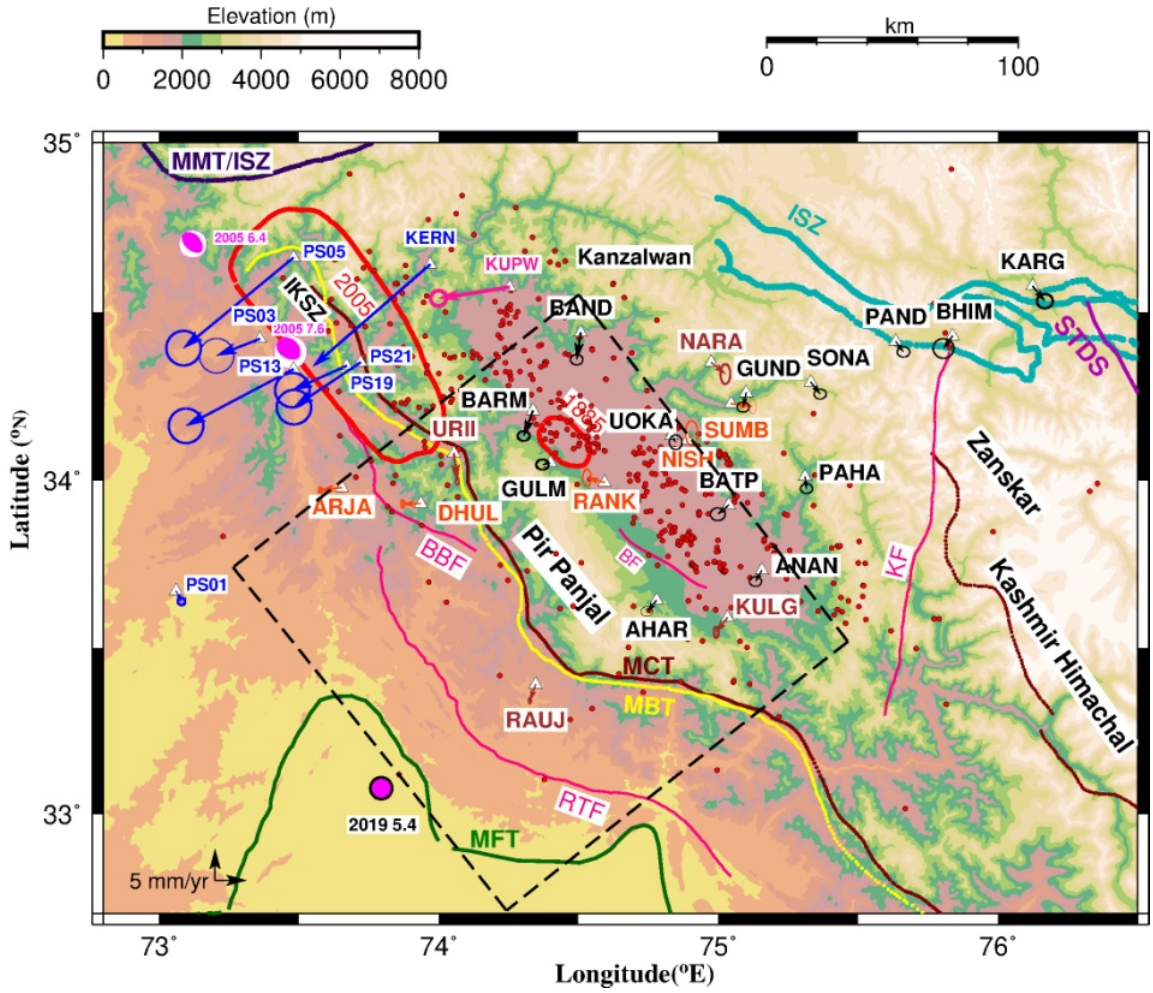

Figure 5.7: Topographic Map of Kashmir valley and adjoining regions along with surface projection of dislocation plane (dashed box) with residual velocities of the cGPS sites Solid red circles denote seismic events of M≥1 from collocated broadband network. India fixed velocity (bold Pink) is plotted at KUPW GPS site to the extreme northwest of Kashmir valley. Blue velocity vectors at Pakistan GPS sites denote post seismic displacements of October 2005 Muzaffarabad earthquake during March 2007 to August 2009 and Indian GPS site KERN soon after the earthquake.

Crustal deformation rates using Kashmir cGNSS (Continuous Global Navigation Satellite System) observation network (2008-2019) indicate oblique surface deformation of about 16mm/yr in Kashmir Valley and adjoining regions. Inverse modeling of surface crustal rates give slip of 16mm/yr at a depth of 15km (Figure 5.7) along the 145km wide Main Himalayan Thrust (MHT). High geodetic strain rates observed to the north of Kashmir valley and south of Zanskar ranges is consistent with northern edge of locked MHT mapped using seismic activity and inverse models. Since there was no earthquake since 1555, the total slip during the intervening 465 years is 7.6m which is capable of generating Mw 7.8 earthquake in Kashmir valley which is corroborated by the high scalar geodetic moment accumulation rate and micro-seismicity recorded in Kashmir valley.

5.8 GNSS and its impact on position estimates in Indian subcontinent

This study evaluates the impact of multi-GNSS (Global Navigation Satellite System) signals on the estimation of precise position with millimetre accuracy. Compared to standalone satellite system like Global Positioning System (GPS), multi-GNSS improves start-up time, performance, satellite visibility, accuracy, spatial geometry and reliability but on the flip side it increases the noise, signal interference, hardware complexity of receiver, inter-system interference and computation complexity which may degrade the performance. Our pilot study indicates that multi-GNSS does not significantly improve the positional accuracy but it eliminates the dependency on a particular satellite system in the long term.

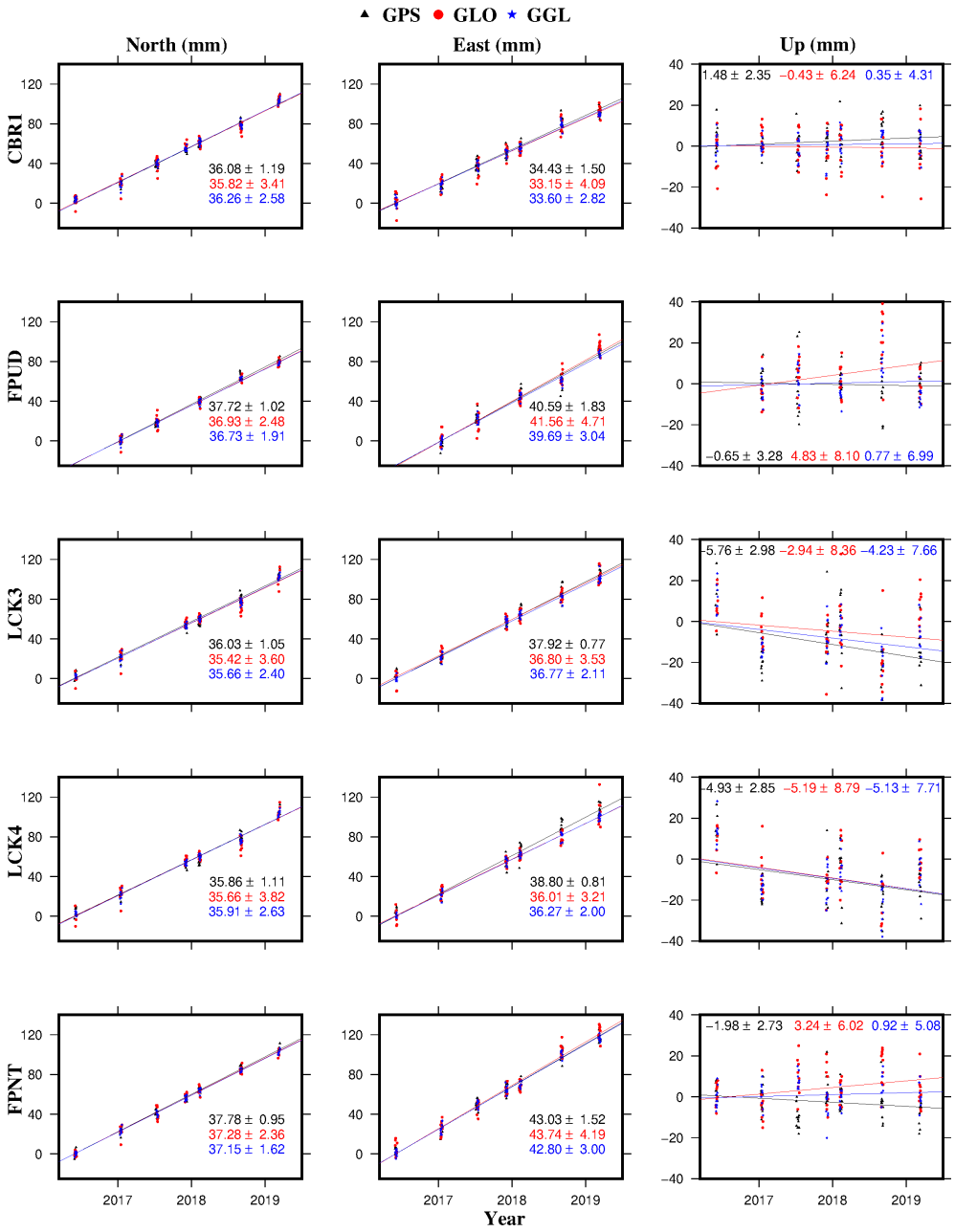

Figure 5.8: Multi-year time series of N.E and U positions/velocities using stand alone and combined GPS and Glonass observations.

Position time series (Figure 5.8) of multi-GNSS is much more stable than single GNSS with errors. For Indian subcontinent, GPS solution gives precise estimates of position and rates (Figure 5.8) compared to Glonass and combined GPS-Glonass solutions. This is due to poorly resolved additional ambiguity terms in GLO and GGL solutions for long baselines and also due to poor spatial spread of IGS sites equipped with multi-GNSS receivers.

5.9 Seismic Potential of Gharwal-Kumaun Himalayas

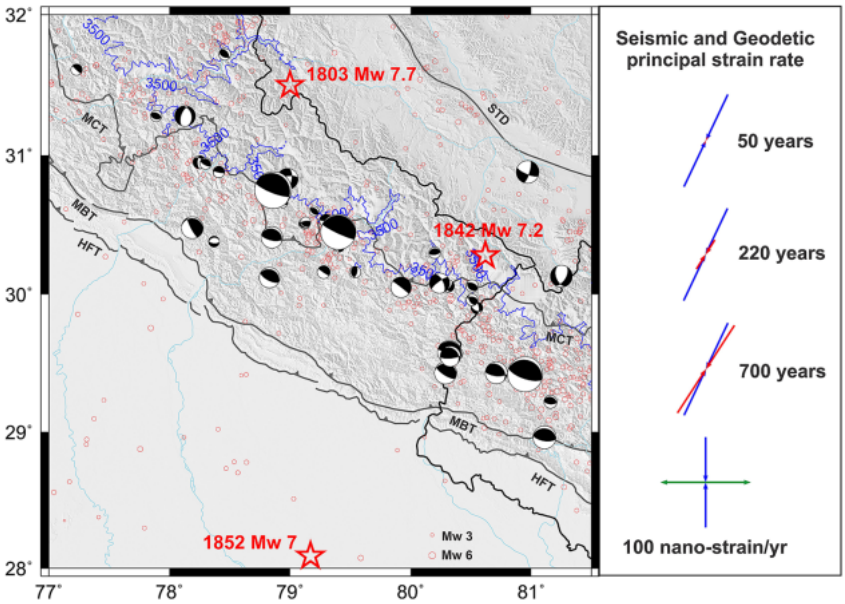

Figure 5.9: Seismicity and major faults in Kumaun-Garhwal region. The rightmost plot represents the comparison of amount and orientation of principal strain rates derived from geodetic and seismic data.

Composite analysis of past 20 years of GPS strain rates and seismic strain rates from 50, 220 and 700 years earthquake catalogue was carried out to estimate the seismic potential of Gharwal-Kumaun (GH-KU). Results indicate geodetic compression rate of 113 nano strain/year towards NNE in the Higher Himalaya. Seismic strain rates estimated are about -10ns/yr for 50 years, -38ns/yr for 220 years and -115ns/yr for 700 years of earthquake catalogue (Figure 5.9). This indicates that the length of seismic catalogue used for seismic strain analysis should be comparable to the recurrence period of megathrust earthquakes for the released seismic strain energy to be equal to the stored elastic strain energy. The orientation axes of the principal strain rates derived from geodetic and seismic strain rates from catalogue of different duration point to $N25^0$ to $N35^0$ compression (Figure 5.9). Analysis of strain budget using geodetic and seismic moment rates of GH-KU indicate high strain accumulation with locked strain budget of $\sim$ 5E + 21 Nm in the past 700 years which has a potential to generate a megathrust earthquake (Mw $\geq$ 8) in the present scenario.

5.10 Estimation of Seismic strain rates in North-West Himalaya

Seismic strain rates in North-West Himalayan are calculated using compiled earthquake catalogue of International Seismological Centre (ISC) for instrumental period (1964 to 2020). Magnitude completeness, seismogenic thickness and cumulative seismic moment are derived using ZMAP tool

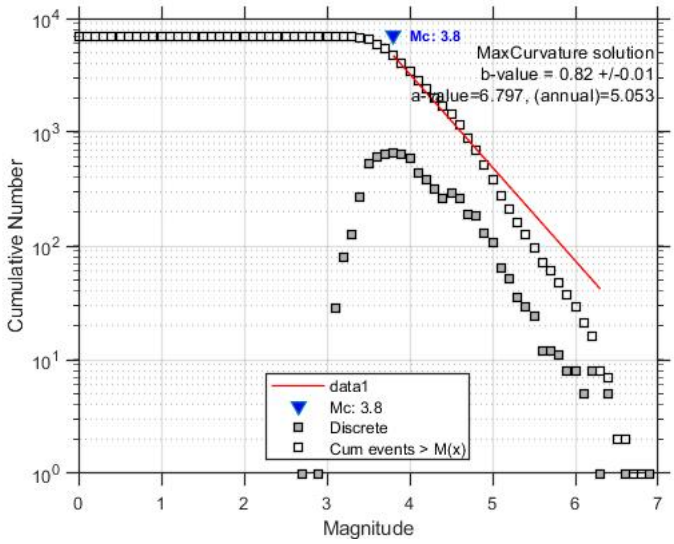

Figure 5.10: b-value estimation using magnitude completeness from maximum curvature method. The square and shaded square shows the cumulative and non-cumulative number of different size of events respectively.

and plotted in Figure 5.10 which gives magnitude completeness as 3.8. Hence, we utilized the fault plane solutions of the earthquakes Mw$\geq$3.8 from Global Centroid Moment Tensor (GCMT), USGS catalogues and also from the earlier studies in this region to estimate the seismic strain. The focal mechanisms of earthquakes reveal the orientation of stress/strain in this particular region. Therefore calculation of seismic moment (Mo) with known fault plane solutions gives the deformation caused by the earthquake. Total seismic moment of the region is the sum of seismic moment of each event which is converted in to seismic strain using kostrov formulations. This study provides the knowledge about seismic hazard assessment in the North-West Himalayan region.

6. Other Research Activities

Inside:

- Penta-graphene Nanocone
- Buckling Load Estimation for Double-walled Carbon Nanotube
- Critical Evaluation of Fractional calculus based on Eringen's nonlocal model for 1-D wave propagation
- The Warming Mode of Tropical Indian Ocean Surface
- A Seasonal Cycle relevant to El Nino-Southern Oscillation

6.1 Penta-graphene Nanocone

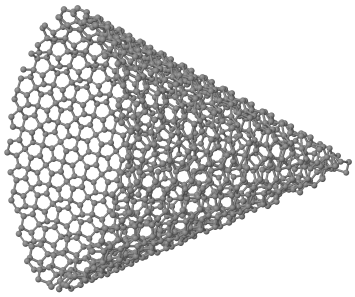

Figure 6.1: Penta-graphene nanocone.

The present work aims to generate the coordinates for the penta-graphene nanocone (Figure 6.1) structure. The main difference between carbon nanocone and penta-graphene is the number of atoms. The penta-graphene structure consists of five carbon atoms, while carbon nanocone consists of six carbon atoms. In the literature, there exists no attempt to explore such a structure. The indigenous software code helps in generating the coordinates. The penta-graphene nanocone structure development is tricky because of penta-graphene atoms located in different planes. The mechanical properties of this structure are of greater interest to researchers in further applications in nanotechnology areas.

6.2 Buckling Load Estimation for Double-walled Carbon Nanotube

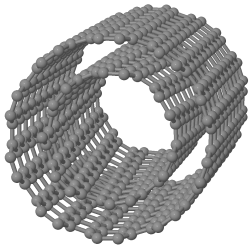

Figure 6.2: Double-walled carbon nanotube.

The Euler critical buckling loads of double-walled carbon nanotube (Figure 6.2) are estimated using a semi-analytical method. Many approximate numerical methods determined the critical buckling loads in the literature. But the present study corrects the typographical mistakes in the previous literature study. Unlike different numerical methods that estimate the buckling loads for various boundary conditions, the semi-analytical method predicts robust results, which works well for any boundary conditions. The five different boundary conditions used in the present investigation are simply-simply, clamped-clamped, clamped-simply, clamped-free, and clamped-sliding restraint. Also, unlike other methods, the present methodology is free from polynomial development.

6.3 Critical Evaluation of Fractional calculus based on Eringen's nonlocal model for 1-D wave propagation

In recent years, fractional calculus attracted researchers in modeling nanostructure with nonlocal continuum elasticity. The wave propagation study reveals that the nonlocal fractional model based on Eringen's model predicts the dispersion curve with an excellent match compared to lattice dynamics. Even the phase velocity results gave fantastic results with lattice dynamics. But the group velocity results show that it fails to match with lattice dynamics results at the end of the first Brillouin zone. So this compromise has to be made if a nonlocal fractional calculus model based on Eringen's model is used for the wave propagation approach.

6.4 The Warming Mode of Tropical Indian Ocean Surface

The Sea Surface Temperature (SST) in the tropical Indian Ocean (IO) has monotonically warmed about one-degree centigrade since 1950; this has been attributed to the increasing greenhouse gas in the atmosphere. The remotely induced changes in local wind, ocean circulation, and surface-flux also modify IO SST variability on interannual time scales. Both change local deep atmospheric convection patterns and alter the climate phenomena like Asian Monsoons and El Nino Southern Oscillation. Spatial patterns of remotely-forced responses may be different from those generated by anthropogenic factors. Therefore, their influences on weather and climate events also differ. Moreover, the Spatio-temporal characteristics of the observed warming of the IO SST and its statistical link to the Indian Ocean Warm Pool (IOWP) are still unclear. The observed patterns and rates of warming estimated via linear regression are sensitive to duration and epoch under consideration. The linear methods also fail to differentiate the spatial patterns of SST associated with the multi-decadal warming from those remotely forced. However, the discrimination of their response patterns is necessary for future climate prediction and climate change adaptation. This study discriminates the basin-wide monotonic warming mode of the IO surface from the internally and remotely forced variability. Instead of the amorphous trend patterns reported earlier, the radically different warming signal reported shows that the monotonic warming in the observed IO SST has the spatial pattern of summer-mean SST and the Warm Pool as its most conspicuous feature. The highest warming is (0.17 ^{0}C per decade) in the IOWP and not in the other IO regions identified in the previous studies. By 2070, the IOWP will cover about 80 percent of tropical IO at the present latitudinal expansion rates. The mean states of SST, wind, and surface pressure are shifting towards an endless summer. Irrespective of the season, the SST near Indonesia would likely remain above 31 ^{0}C by 2080 and beyond; this would substantially increase local rainfall intensity and frequency. We also argue that the basin-wide warming is due to anthropogenic forces' rectification by coupled processes in ocean-atmosphere mixed layers.

6.5 A Seasonal Cycle relevant to El Nino-Southern Oscillation

The most remarkable features captured by climate modes of five variables in the Pacific are the sub-seasonal developments of cold/warm SST in equatorial EP, and positive/negative OLR extending from WP to EP along the Equator; they pattern-wise resemble those associated with the canonical La Nina/El Nino. The positive (negative) SST anomalies appear in March (September), peak in May (December), and decay by August (February). From March to July, nearly the whole tropical pacific is covered by a cyclonic wind system and the opposite one from September to December. These wind systems emanate from the band of subtropical high-SLP and culminate in the band of low-SLP in the opposite hemisphere. The equatorial waveguide during these two periods is occupied by a reversing wind system. During the warm SST phase (i.e., March to July), the north-easterly wind (predominated by northerly component over the north of the Equator) becomes north-westerly

as it crosses the Equator. This wind system increases SST by suppressing upwelling along the Equator and the eastern coastlines, causing a subsequent reduction in latent heat loss and further enhancement of magnitude and westward expansion of SST along the Equator. The intensification of both the wind converges and negative OLR over the equatorial region occurs. The cold SST phase (i.e., September to January) is driven by a nearly opposite wind system and suppressed convection; both of which are initiated around September. Such wind system generates cold water upwelling to further lower SST and suppress the convection. Similar observed relationships between SST, wind, SLP, low-level wind convergence, and atmospheric convection have been evoked often to explain many elements of tropical variability. It is instructive to note that the intensification of positive (negative) SST after March (October) are, not by coincidence, also the onset months of ENSO anomaly.

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, brain storming sessions, etc.

Inside:

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

7.1 Publications in Journals

Agnihotri, Geeta, KC Gouda, and Someshwar Das. "Characteristics of pre-monsoon convective systems over south peninsular India and neighborhood using tropical rainfall measuring mission's precipitation radar". In: *Meteorology and Atmospheric Physics* 133.2 (2021), pages 193–203.

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7.2 Publications in Books/Proceedings

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- K. Rajendran, Sajani Surendran, S. J. Varghese, Anjali Sathyanath, Simulation of Indian summer monsoon rainfall, interannual variability and teleconnections: Evaluation of CMIP6 models, 2021, Research Square, https://www.researchsquare.com/article/rs-242562/v1. USA.
- K. Rajendran, Sajani Surendran, S. J. Varghese, Multiforcing ensemble projection based climate change information over Kerala for adaptation strategies, 2020, In: Impact of Climate change on hydrological Cycle, Eco system, Fisheries and Food Security, Eds: B. M. Kurup, M. R. Boopendranath, M. Harikrishnan and A. V. Shibu, Narendra Publications, New Delhi (www.nphi ndia.com). India.
- Kiran Kumar V, K. V. Ramesh and V. Rakesh, Deep LSTM model for Indian Summer Monsoon Rainfall prediction using indices, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Kumari, R., Gouda, K. C., Singh, U., Maca, P., Bimla, K. R., S, Himesh., Nikhilasuma., Benke, M. V., Rao, S., and USN, Murty.: Hydro-meteorological Impact on Malaria Diseases at Regional Scale in India, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-20045.
- L B Shyamasundaar, V Anil Kumar, et al. "Analyzing Big Data Originated from Data Communication Networks using K-Means Algorithm to Understand the Nature of Incoming Malicious Connections", Third International Conference on Multimedia Processing, Communication & Information Technology (MPCIT), IEEE Explore, pp. 129-132, 2020.
- Marndi A., Patra G.K. ,Atmospheric Temperature Prediction Using Ensemble Deep Learning Technique. In: Sharma H., Saraswat M., Yadav A., Kim J.H., Bansal J.C. (eds) Congress on Intelligent Systems. CIS 2020. Advances in Intelligent Systems and Computing, vol 1335. Springer, Singapore,5-6 September 2020 https://doi.org/10.1007/978-981-33-6984-918
- Marndi A., Patra G.K. (2021) Multidimensional Ensemble LSTM for Wind Speed Prediction. In: Sharma H.,
- Gupta M.K., Tomar G.S., Lipo W. (eds) Communication and Intelligent Systems. Lecture Notes in Networks and Systems, vol 204. Springer, Singapore.26-27 December 2020https://doi.org/10.1007/978-981-16-1089-947
- Neethu C and K. V. Ramesh, Impact of heat waves on vegetation cover and ground water, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Neethu C and K. V. Ramesh, Variability and change in human thermal comfort during heat waves over India, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- R Harish, A Aswin Kumar, V Anil Kumar and P PAmritha, "Facilitating Cryptojacking Through Internet Middle Boxes", Advances in Electrical and Computer Technologies, Lecture Notes in Electrical Engineering, vol. 711, pp. 41-52, Springer, Singapore, 2021.
- S Lenka, K C Gouda, Rani Devi and C M Joseph, Wind Shear And Thermal Gradient Analysis Over Indian Summer Monsoon Region, Proceedings of IC R TEETIMP-2020, Dayananda Sagar College of Engineering, Bangalore, 7-9 Dec 2020
- Sulochana Gadgil, P. A. Francis, K. Rajendran, Ravi S. Nanjundiah and Suryachandra Rao, Role of Land- Ocean Contrast in the Indian Summer Monsoon Rainfall, 2021: In: The Multiscale Global Monsoon System,Eds: Eds. C.-P. Chang, K.-J. Ha, R. H. Johnson, D. Kim, G. N. C. Lau, B. Wang, World Scientific Series on Asia- Pacific Weather and Climate, Volume 11, Singapore (https://doi.org/10.1142/11723).
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- Sumana S and Himesh S, A Hydro meteorological Analysis of a flash flood over the megacity of Bangalore: Assessing the forecast skill of the model and the impact of urbanization on flash flood, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020 (Virtual)
- V Anil Kumar and Debabrata Das, “Data Sequence Map Flooding in MPTCP Framework: Potential Challenges and Efficient Countermeasures", the proceedings of 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT 2020), IEEE publication, July 2020.
- Venkatesh Gowda P K, K. V. Ramesh and V. Rakesh, LULC classification using Convolutional Neural Network, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020

7.3 Presentations in Conferences/Symposia/Workshops/Seminars

- Anil Kumar V, Data Sequence Map Flooding in MPTCP Framework: Potential Challenges and Efficient Countermeasures, 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT 2020), IIT Kharagpur, July 1-3, 2020.
- G K Patra “A framework for connected vehicle security research”, National Conference on AI & Perception Engineering, 30th July 2020
- Gupta, S. V. , Parvez, I. A. and Khan, P. K. Subsurface Shear wave velocity (Vs) mapping in Srinagar region of Kashmir Basin using microtremor data, American Geophysical Union, Fall Meeting 2020, Abstract No. NS009-04 (AGU)
- Kiran Kumar V, K. V. Ramesh and V. Rakesh, Deep LSTM model for Indian Summer Monsoon Rainfall prediction using indices, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Kumari, R., Gouda, K. C., Singh, U., Maca, P., Bimla, K. R., S, Himesh., Nikhilasuma., Benke, M. V., Rao, S., and USN, Murty.: Hydro-meteorological Impact on Malaria Diseases at Regional Scale in India, EGU General Assembly 2020, Online, 4–8 May 2020, EGU2020-20045.
- Neethu C and K. V. Ramesh, Impact of heat waves on vegetation cover and ground water, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Neethu C and K. V. Ramesh, Variability and change in human thermal comfort during heat waves over India, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Priyanshi Singhai, A. Chakraborty, Sajani Surendran, K Rajendran, Association of Indian Summer Monsoon Variability with Mid-latitude Teleconnection in CFSv2, AGU Fall Meeting A226-0007, https://agu.confex.com/agu/fm20/meetingapp.cgi/Paper/742569. American Geophysical Union, USA. 16 December 2020.
- Rani Devi & Gouda K C. Temperature Variability over Indian Himalayan Region, IISF-2020 (Virtual Mode) held in New Delhi, 22-25 Dec 2020.
- Ray, J.D., Devaraju, B., Vijayan, M.S.M., & Godah, W., (2021). Geodetic monitoring of the hydrological changes in Nepal Himalaya, March 29-31, 2021, https://iccc.iag-aig.org/iccc-workshops/ws21
- S Lenka, K C Gouda, Rani Devi and C M Joseph, Wind Shear And Thermal Gradient Analysis Over Indian Summer Monsoon Region, Proceedings of IC R TEETIMP-2020, Dayananda Sagar College of Engineering, Bangalore, 7-9 Dec 2020
- Senthilkumar V, Kumar, J and Singh, R.K., Multi-walled Pentagraphene Nanotube, Young

Scientist Conference, IISF-2020, 23rd December 2020 (Virtual Event)

- Smrutishreelenka & Gouda K C. Quantifying Rainfall Extremes over Continental India, IISF-2020 (Virtual Mode) held in New Delhi, 22-25 Dec 2020.
- Sumana S and Himesh S, A Hydro meteorological Analysis of a flash flood over the megacity of Bangalore: Assessing the forecast skill of the model and the impact of urbanization on flash flood, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020 (Virtual)
- Venkatesh Gowda P K, K. V. Ramesh and V. Rakesh, LULC classification using Convolutional Neural Network, Proceeding of TROPMET 2020, on Weather and Climate Services over Mountains Regions on Tropical Meteorology, NESAC, Shillong, 14 – 17 December 2020
- Vijayan, M.S.M., Vincent, A., & Rajendran, K. (2021). Utilising geodetic estimation of crustal response to changes in hydrological loading as a tool to measure climate change: opportunities and challenges, IAG-ICC 2021 workshop on Geodesy for Climate Research, March 29-31, 2021, https://iccc.iag-aig.org/iccc-workshops/ws21

7.4 Participation in Conferences/Symposia/Workshops/Training Programmes

- **Anil Kumar V**
  "Data Sequence Map Flooding in MPTCP Framework: Potential Challenges and Efficient Countermeasures", 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT 2020), IIT Kharagpur, July 1-3, 2020.

- **Ashapurna Marndi**
  India International Science Festival Young Scientists Conference (IISF YSC), virtual mode, 22-24 December 2020.
  RAISE 2020 - Responsible AI for Social Empowerment, Virtual Summit on Artificial Intelligence hosted by Ministry of Electronics IT, Govt India, virtual mode, 5-9 October 2020.
  Sessions on HPC and AI/ML of Vaishvik Bhartiya Vaigyanik (VAIBHAV) Summit virtual mode, 4-5 October 2020.

- **Gouda K C**
  Young Scientist Conference at IISF-2021 in the theme "Current Pandemic and Crisis" held at New Delhi during 22-25 Dec 2020 and delivered a talk on "Weather and COVID-19 Spread, Is there any linkage "
  Future directions of Subseasonal to Seasonal Prediction over South Asia" during 29-31 March 2021 at IITM, Pune, India. WMO Data Conference, 16-18 Nov 2020.
  "Cloud anatomy structure during cloudburst events over India" in the IISF-2020 (Virtual Mode) held in New Delhi, 22-25 Dec 2020.

- **Patra G K**
  "A framework for connected vehicle security research", National Conference on AI & Perception Engineering, 30th July 2020

- **Sajani Surendran**
  Climate Change: Challenges and Response, LBSNAA CDM online training programme for women scientists, Centre for Disaster Management Lal Bahadur Shastri National Academy of Administration, Mussoorie, 05 Oct 2020.

- **Vijayan M.S.M**
  IAG-ICCC 2021 workshop on Geodesy for Climate Research, Online, March 29-31, 2021.

Brain storming meeting on “Satellite Observations and Modeling of GRACE Data for Terrestrial Applications” organized by CSIR-NGRI, Online, 9th February, 2021.
Groundwater Monitoring using Observations from NASA’s Gravity Recovery and Climate Experiment (GRACE) Missions. NASA Applied Remote Sensing Training Program (ARSET). Online, 25th June, 2020.
COSEG Fall 2020 meeting on Solid Earth Science and Sea Level Change, Online, 12th – 13th November, 2021.
VAIBHAV-2020 Session [V13H4S3] on “Hydrological models & projections and space-based observations for decision-making”, Online, 18th October 2020.
TCS GNSS Data product webinar conducted by European Plate Observing System (EPOS), Online, 18th & 19th January, 2021.

7.5 Invited Talks

- **Anil Kumar V**
  Feedback Manipulation in Next Generation Transport Layer Protocols, International Institute of Information Technology – Bangalore (IIIT-B), 20, January 2021.
  Darknet Traffic Analysis and Security Inference, AICTE Faculty Development Programme on Artificial Intelligence and Its Applications in CPS, 5-9, October 2020.

- **Ashapurna Marndi**
  “Machine Learning Training Programme”, in the Inversion and Machine Learning Applications for Geoscience Data Analysis, 8-27th March 2021 (sponsored by MoES, Govt. of India).

- **Gouda K C**
  Chief Guest and delivered talk on “Mathematical Modeling with Engineering Applications” in the fresher’s day at Mangalore Institute of Institute of technology engineering, Mangalore, 14th Oct 2020.
  Chief guest and delivered talk on “Understanding NEP-2020”, An initiative of Unnat Bharat Abhiyan by VTU ON 23-SEPT-2020 at Sir MVIT, Bangalore.
  Delivered talk on “Artificial Intelligence for Societal Applications”, DEC 9 2020, Dayananda Sagar College of Engineering, Bangalore, 9th Dec 2020.
  Delivered talk on "Computer Science Engineering for Society", Mangalore Institute of Technology & Engineering, Mangalore, 14Oct 2020.

- **Mohapatra GN**
  Invited talk as Chief guest for “MATLITE Club Activity - PI DAY” on 14th march 2021 organised by department of mathematics MVJ College of Engineering, Whitefield, Bangalore.
  Chief Guest and speaker for the National mathematics day-2020, entitled “Mathematical Modelling with Engineering Applications” through online mode on 22nd December 2020 MVJ College of Engineering, Whitefield, Bangalore.

- **Patra G K**
  “The Interesting Paradox of Security & Privacy”, in international webinar titled - Importance of Cyber security in the world of Pandemics and Social Media on May 6th 2020.
  “Machine Learning Tutorials”, in the Inversion and Machine Learning Applications for Geoscience Data Analysis, 8-27th March 2021 (sponsored by MoES, Govt. of India).
  “Critical Infrastructure Security”, panel discussion of Data security and Privacy in the VAIBHAV summit, 18th October 2020.

"Outcomes of the Data science vertical" to the advisory board of VAIBHAV summit, 30th October 2020.
"Cyber Security R&D of CSIR", DSCI Road show on 6th November 2020.
"Data Science Activities @ CSIR-4PI", CDISE Skolkovo Institute of Science and Technology (Skoltech), Russia, 18th December 2020.
"VISION of Data Science for CSIR", a joint presentation for CSIR-4PI and CSIR-NIIST at the Indo-Belarus scientific collaboration on 17th February 2021.

- **Rajendran K**
  Invited as panelist for the Vaishwik Bharatiya Vaigyanik (VAIBHAV) Summit which was a global virtual summit of overseas and resident Indian researchers and academicians organized by Ministry of S T, GoI and delivered a talk in the summit on "High resolution climate model projections over India and adaptation strategies for rice yield changes" under section V11H5S2 (Climate Change: Moving towards a climate resilient environment and society-advent of novel techniques and tools, Vertical: Environmental Sciences Horizontal: Climate Change), 16 October 2020.

- **Rakesh V**
  Invited Talk in international workshop on "Agricultural Pest and Disease Simulation Modelling under different Climate Change Scenarios", organized by ICRISAT, Patancheru & UAS, Bangalore from 24th -28th August 2020.
  Talk Title: Weather and climate informatics for crops: Crop Model configuration, simulation, generation of Agro-advisories, Future Climate scenarios.

- **Ramesh K V**
  Invited Talk in international workshop on "Agricultural Pest and Disease Simulation Modelling under different Climate Change Scenarios", organized by ICRISAT, Patancheru & UAS, Bangalore from 24th -28th August 2020, Talk Title: "Application of Big Data Analytics and Artificial Intelligence in Crop disease forecasting".

- **Sajani Surendran**
  Aerosol indirect effects on Indian Summer Monsoon, NCAP Project Review Meeting, MoEFCC, GoI, 25 April 2020.

- **Vijayan M.S.M**
  "The Physics of GPS and Satellite based Navigation" in a national webinar organized by PSNA college of Engineering and Technology, Dindigul, Tamilnadu.
  "Satellite Geodesy: An emerging tool to explore Relativity, Plasma Physics and the Dynamic Earth" in a national webinar on Emerging Trends in Physics, organized by Government Arts College for Women, Salem, Tamilnadu.

7.6 Visitors at CSIR-4PI

- **Ms K Sangeetha**, Amrita School of Engg, 27 May 2020
- **Dr Vijay Patel**, ADA – AcSIR meeting, 15 Sept 2020
- **Mr Raja Seevan**, Indian CST, 07 Dec 2020
- **Mr SK Dwivedi** & **Mr. PD Bagul**, HAL, Nasik, 30 Dec – 15 Jan 2021
- **Mr S Herkal**, Entuple Technologies Pvt Ltd, 12 Jan 2021
- **Mr Surinder Singh Narula**, Axiomatic ITech pvt ltd, 02 Feb 2021

8. Academic Programme

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 a unique opportunity to bright and motivated students of reputed Universities to carry out their major project/thesis work and advance their research knowledge in mathematical modelling and simulation of complex systems. Students and professionals from a wide spectrum of organizations including industries across the country have been benefiting from our various academic programmes over the years. CSIR-4PI is very actively engaged with the AcSIR (Academy of Scientific & Innovative Research) PhD program in Mathematical and Information Science, Physical Science and Engineering Science.

Inside:

- Ph.D Programme
- M.Tech/BE/MCA student's Thesis/Project
- Research Fellowship Programme
- Faculty Participation

8.1 Ph.D Programme

- **Anil Earnest**
  Silpa K, (AcSIR), A study on Indian plate seismogenesis using kinematic slip distribution models of selected earthquakes. Submitted.

- **Gouda K C**
  Radhika TV, (VTU), Efficient and Large-Scale Climate Simulation Analysis in Cloud Computing Cluster.
  Payoshni Samantray, (VTU), Study of Extreme Rainfall Events due to Cloud Burst using Observation and Model Simulation.
  Rani Devi (AcSIR), Dynamics High Impact Weather & Climate over India.
  Smrutishree Lenka (VTU), Role of air-sea interaction processes on climate system.

- **Himesh S** (Guide), **Rakesh V** (Co-guide)
  Ajilesh P (VTU), Charecterstics of Urban Extreme Rainfall Events over the Indian Cities: An Observational and Modelling Study.

- **Himesh S** (Guide), **Gouda K C** (Co-guide)
  Sanjeeb Kumar Sahoo (VTU), Impact of Urbanization on High Impact Weather Events Local Climate.

- **Kantha Rao Bhimala** (Guide), **G K Patra** (Co-guide)
  Prasad Babu Kanike (AcSIR), Data Analytics to Identify the Relationship between the Land Surface Meteorological Parameters and Indian Summer Monsoon Rainfall.

- **Mohapatra G N** (Guide), **Rakesh V** (Co-guide)
  Smrati Purwar (AcSIR), Modelling of spatio-temporal variation in urban extreme rainfall events with special focus on localised versus large-scale impacts.

- **Parvez I A**
  Ramiz Raja Mir (AcSIR), The study of crustal evolution and Earthquake Hazard in Kashmir Himalayas. Awarded.
  S Vishal Gupta (ISM Dhanbad), Site specific seismic hazard study in Kashmir Valley, Northwest Himalayas.

- **Patra G K**
  Ashapurna Marndi (AcSIR), Time Series Analysis with Deep Learning: Applications to Environmental Data. Awarded.
  S Gunasekaran, (AcSIR), Challenges in Design, development and testing of Autonomous Aerial Refueling capability.
  Manmohan Brahma, (AcSIR), Optimization of DNN inference on CPU/GPU Platform.
  Anju Sharma, (AcSIR), Multi-sensor data fusion strategies and algorithms for health assessment of Mechanical systems.

- **Rajendran K**
  Ipsita Putatunda, (AcSIR), Characteristics of heating and moisture in tropics: An observational study. Submitted.

- **Rakesh V**
  Ajay Bankar (AcSIR) Impact of data assimilation in mesoscale models.
  Praveen S (VTU), Role of background error statistics in mesoscale data assimilation.

- **Ramesh KV**
  Alfred Johny (AcSIR), Simulation of Indian Summer Monsoon using CMIP5 Climate Simulations Edwin Raj E, (UPASI TRF TRI), Climate Impact Assessment on Tea Production over South India. Awarded.
  Neethu C V (VTU), Modelling the role of land-atmosphere interaction during heatwaves.
  Swetha Sivakumar,(AcSIR), Modelling the role of air-sea interactions on tropical cyclone intensification and a post cyclone damage assessment using multi-spectral Remote Sensing observations.

- **Sajani Surendran**
  Arya V B, (AcSIR), The impact of regional aerosols on Indian summer monsoon rainfall and variability. Completed Pre-thesis Colloquium.

- **Sajani Surendran** (Guide), **Rajendran K** (Co-guide)
  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. Submitted.

- **Sridevi Jade**
  Chiranjeevi Vivek G, (AcSIR), GNSS signal processing and analysis to study impact on position estimates.
  Sivasai Kumar Rajana, KLEF university GNSS based remote sensing over Indian Subcontinent.

- **Vidyadhar Mudkavi**
  Kanaka Muthu, CSIR-NAL, (NIT), Experimental and computational investigation of diffuser augmented small wind turbine.
  Rinku A, CSIR-NAL, (IISc, Bangalore), Modular design of ribs in aircraft wings using topology and size optimization and non-dimensional analysis.

- **Vijayan M S M**
  Shimna K, (AcSIR), Detection and Characterisation of Ionospheric Perturbations Induced by Tsunami, Strike-Slip and Thrust Earthquakes. Awarded.

8.2 M. Tech/BE/MCA student's Thesis/Project

- **Anil Earnest**
  Rakesh Kumar Sahoo, Quantitative River Profile Analysis to Investigate the Active Tectonic of the Central Himalaya, Department of Geology, Central University of Karnataka, January 2021.

- **Gouda KC**
  Kiran M Hungund, M.Tech (Geo-informatics), Karnataka Remote Sensing Application Centre (VTU), Bengaluru, Surface Temperature and pollution Analysis using Remote Sensing and GIS techniques.

Sweta Kumawat, Jain University, Summer 2020
Preetam S, Dayananda Sagar Institute of Technology, Bangalore.
Sudeep Kumar and Shyam, Cambridge Inst of Technology,Bangalore.
Subham Chatterjee, Jadavpur University, Kolkata (CSIR SRTP).
Leander V Felix, Reva University, Bangalore (CSIR SRTP).

- **Patra G K**
  Mr Mrinmoy Roy, Lovely Professional University, Phagwara, Panjab, CSIR Summer Research and Training Program (SRTP).
  Deepra Ghosh, Depart. Of Stastics, Calcutta University, Kolkata, West Bengal, (SRTP).
  Shreenidhi N, Dept. of Applied Mathematics & Computational Sciences, PSG College of Technology, Coimbatote, Tamilnadu, (SRTP).
  Bharathi A, Dept. of Applied Mathematics Computational Sciences, PSG College of Technology, Coimbatore, Tamilnadu, (SRTP).
  Deepak Kumar, Dept. of Mathematics Computing, IIT ISM Dhanbad, Jharkhand,(SRTP).

- **Ramesh K V**
  Vishrutha Bangera, MIT Manipal, Quantification of impact of climate change on procurable water and its future prospects over Dakshina Kannada region.
  Raksha Shetty, MIT Manipal, Developing mitigation strategies for climate stress in integrated farming systems over Udupi District: a system dynamic approach.
  Krithika K M, MIT Manipal, Change detection and analysis of the land use and land cover for Almora district in the state of Uttarakhand.
  Krithika K M, MIT Manipal Dynamics of pollutants distribution over Bangalore.
  Vinaya S, Cochin University of Science Technology, Kochi, A brief study on Mangrove cover in Cuddalore district, Tamil Nadu.

8.3 Research Fellowship Programme

- **Sumana Sarkar**
  RA, CSIR
  Assessing the Impact of regional climate change on hydrological Processes and water budget over Cauvery river basin in Karnataka

8.4 Faculty Participation

- **Gouda KC**
  Training programme on AI, ML and Big Data for in-service Indian Statistical Service (ISS) officers at C R Rao AIMSCS, Hyderabad on 18th September 2020 and 17th March 2021.
- **Marndi Ashapurna**
  Machine Learning Training Programme", in the Inversion and Machine Learning Applications for Geoscience Data Analysis, 8-27th March 2021 (sponsored by Min. of Earth Sciences Govt. of India).
- **Parvez I A**
  Earthquake Hazard Studies in India, at the International Virtual Workshop on Global Seismology and Tectonics organized by CSIR NEIST, Jorhat as Key-Note speaker on September 25, 2020.
- **Patra G K**
  Machine Learning Training Programme", in the Inversion and Machine Learning Applications

for Geoscience Data Analysis, 8-27th March 2021 (sponsored by Mi. of Earth Sciences Govt. of India).

The COVID19 activities using various mathematical and statistical backgrounds at CSIR-4PI and the contribution of open source software for faster research", Five day online Faculty Development Program on "Mathematical Concepts by using Free Open Source Softwares (FOSS)" from 21st to 25th July 2020" at BMSITM, Bengaluru.

- **Rakesh V**
  Expert workshop on "Agricultural Pest and Disease Simulation Modelling under a Climate Change Scenario" Jointly organized by UAS, Bangalore & ICRISAT, Patancheru (24-28th August 2020)
  Data modelling: Developing different (regression, VAR, ARIMA) models for crop disease forecasting.
  Hands on Basic training on data handling and programming and experiments with Data models
- **Ramesh K V**
  Expert workshop on "Agricultural Pest and Disease Simulation Modelling under a Climate Change Scenario" Jointly organized by UAS, Bangalore ICRISAT, Patancheru (24-28th August 2020)
  Hands on "Application of Deep learning techniques in developing disease forecast models: time series and Image analytics

9. Projects & Collaborative Programmes

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

Inside:

- CSIR Projects
- Major Lab Projects
- Grant-in-aid Projects
- Sponsored Projects
- Collaborative Projects
- In-House Projects

9.1 CSIR Projects

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

9.2 Major Lab Projects

- Development of a modelling platform for Hydro-Meteorogical Disaster early Warning System for Major Cities in India (HDWS), PI: Dr. G.N.Mohapatra
- Setting-up of CSIR HPC, AI and ML Platform (CHAMP), PI: Shri. R.P.Thangavelu
- HPC Cloud Resource at CSIR for COVID-19 Research Support for Indian Researchers, PI: Dr. Gopal Krishna Patra
- 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

9.3 Grant-in-Aid Projects

- 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
- 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
- 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
- Hyperspectral imaging for sharper definitions of Himalayan ecosystems and its high value plant species under climate uncertainties, MoEFCC – PI: Dr. K.V. Ramesh
- Analysis of urban ‘heat islands’, air pollution dynamics and extreme Heat wave phenomena in India and Russia, DST - PI: Dr. K C Gouda
- 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
- 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
- Design Intervention Strategies for Mitigating the Impacts of heat waves through modified land cover, DST Women Scientist Scheme A, PI: Smt. C Neethu
- Quantification of past changes and assessment of present status of water bodies distribution over Bengaluru, CSIR - NEERI - PI: Dr. K.V. Ramesh
- A Darknet / Network Telescope Based Cyber Security Monitoring and Inference Framework, MEITY – PI: Dr. V Anil Kumar
- Feasibility Evaluation, Impact Quantification and Mitigation of Low-Rate Cyber Attacks on Multipath Transmission Control Protocol (MPTCP), DST - PI: Dr. V Anil Kumar
- National Carbonaceous Aerosol Programme (NCAP): Working Group III - Carbonaceous aerosol emissions, source apportionment and climate effects, MoEFCC - PI: Dr. Sajani Surendran
- Improving the prediction of the extremes of the interannual variation of the Indian Summer Monsoon Rainfall (ISMR) by CFSv2, MoES – PI: Dr. K Rajendran
- 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
- 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

9.4 Sponsored Projects

- 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

9.5 Collaborative Projects

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

9.6 In-House Projects

- Monitoring continuously operating CSIR-4PI GNSS station located in the IISC Campus and real-time operational data hub at CSIR-4PI, PI: Dr. Sridevi Jade

10. 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:

- Staff List
- Awards/Honours/Recognition
- Services on External Committees/Membership of Professional Bodies
- Promotions

10.1

Staff List

Head
Vidyadhar Y Mudkavi

Honorary Scientists
Dutt H N V
Gaur V K
Indira N K
Ravichandran K S
Sinha U N
Srinivas Bhogle
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
Sridevi Jade
Thangavelu R P
Vijayan M S M

Project Monitoring and Evaluation
Sharada M K (additional charge)

Technical Officer
Prabhu

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

Administration
Anilkumar Angadi
Balakrishna K R

Stores Purchase
Mary Suneetha William

DST Women Scientists
Chikka Kalyani Devasena
Neethu C

SRF/JRF/RA
Ajay Vijay Bankar
Aishwarya Pampathi
Bandesh
Dhananjay Kumar C
Gurulingappa
Jayashree Sridhar
Kanika Raghavendran Prasad Babu
Mahendra Vishnu Benke
Malini PJ
Nikhilasuma P
Priya Singh
Rani Devi
Reshama Kumari
Rameesh Raja
Smrati Purwar
Smrauthishree Lenka
Swetha S
Sumana Sarkar
Sunena Rose

Project Assistants/ Project SRF/JRF

Ajay Anand K V
Anjali Sathyanath
Asha Vincent
Devarkonda Aniladevi
Dilipbabu Loganathan
Jahnavi Meda
Pankaj Sharma
Pradeep Kumar Jha
Shruti S
Shyamasundar LB
Venkatesh Gouda PK
Vrinda Sharma
Dilip Babu Loganathan
Kavuri Meghana

10.2 Awards/Honours/Recognition

- **Anil Kumar V**
  Awarded Ph.D by International Institute of Information Technology Bangalore (IIIT-B) for the thesis entitled “Feedback Manipulation in Next Generation Transport Layer Protocols: Emerging Threats and Countermeasures” in 2021.
- **Ashapurna Marndi**
  Awarded Ph.D by Academy of Scientific and Innovative Research (AcSIR) for thesis titled "Time Series Analysis with Deep Learning: Applications to Environmental Data", December 2020.
- **Senthilkumar V**
  Keynote talk titled "Computational Solid Continum Mechanics: Research and Challenges", at 2^{nd} International Conference on Aeronautics and Beyond, on 21 August 2020.

10.3 Services on External Committees/Membership of Professional Bodies

- **Anil Earnest**
  Member, American Geophysical Union (AGU)
  Member, Society of Exploration Geophysicists (SEG)
  Member, Society of Earth Scientists (SES), India
  Associate Member, International GNSS Service (IGS)
  Member, Asia Oceania Geosciences Society (AOGS)
  Member, Seismological Society of America (SSA)

- **Anil Kumar V**
  Member, Working Group for Zero Trust Architecture for Ministry of Electronics and Information Technology (MeitY)
  Member, Project Review and Steering Group (PRSG), Ministry of Electronics and Information Technology (MeitY), Government of India
  Member, Board of Studies for Computer Science and Engineering, Coimbatore Institute of Technology (CIT), Coimbatore, 2021
  Mentor, Network Protocol Analysis Group, C R Rao Advanced Institute for Mathematics, Statistics and Computer Science (AIMSCS), Hyderabad
  Head, Programmable Network Architecture Subcommittee of Zero Trust Architecture for Ministry of Electronics and Information Technology (MeitY)
  Member, Promotion Assessment Committee for Technical Staff, National Aerospace Laboratories (NAL), Bangalore, 2021
  Member Promotion Review Committee of Scientists, C-DAC Bangalore
  Member, Advisory committee for enhancement of High Performance Computing facility, CR Rao AIMSCS, Hyderabad
  Member, Technical Expert Group for IT Infrastructure Procurement and Implementation, Kidwai Memorial Institute of Oncology, Bangalore
  Member, Performance evaluation committee, C-DAC, Bangalore
  Member, Internet Society (ISOC)
  Life Member, Computer Society of India

- **Gouda K C**
  Member in the High Impact Weather Project (HIWeather) of the World Meteorological Organization
  Life Member, Indian Meteorological Society

Life Member, Indian Society of remote sensing
Member, High-Weather Project of World Meteorological Organization
Executive member, India Meteorological Society, Bangalore Chapter
Member, Indo-Africa group on Research on vector borne disease
Member, MoES Committee for Long Range Forecast of Monsoon
Member, Advisory Board, Dept. of CSE, Dayananda Sagar college of Engineering, Bangalore
Member, Board of Studies, Dept. of MCA, Dayananda Sagar University, Bangalore
Member, Board of Studies, School of Computer Science, Jain University, Bangalore
Member, M.Tech Thesis Evaluation Committee, VTU
Member, M.Tech Examiner, VTU
Member, Doctoral Committee, VTU
Member, Doctoral Committee, Jain University
Member, PhD thesis Evaluation Committee, Andhra University, AP
Member, M.Sc examiner, Berhampur University, Odisha
Member, Project review committee (PRC), DSIR-PRISM
Advisory Member, Tropmet-2019 held at Andhra University
Advisory Member, COAST-2020 held at Berhampur University

- **Himesh S**
  Life Member, Indian Meteorological Society
  Life Member, IAEM
  Life Member, Institution of Engineers

- **I.A. Parvez**
  International reviewer, Russian International Affairs Council (RIAC), the review board of Russian Science Foundation (RSF) to participate in the peer review of scientific projects submitted to RSF competition.
  Member, Editorial Board, Dataset Papers in Geosciences: Datasets International, New York, USA
  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.
  PhD Examiner, Indian School of Mines, Dhanbad and IIT Roorkee
  Member, Selection committee of CSIR NAL, to select the PhD students for AcSIR to bring innovative and scientific achievements to the Institute.
  Member, Hindi Technical Advisory Committee of CSIR NAL.

- **Patra G K**
  Associate Dean, Mathematical Information Sciences of AcSIR
  Member, Senate of Academy of Scientific and Innovative Research
  Member, Industrial Advisory Board, School of Computer Science and Engineering, Vellore Institute of Technology.
  Member, CSIR SRF/RA Selection committee in the area of “Electrical, Electronics, Instrumentation Computer Engineering Sciences (ENG-43)”
  Member Selection Committee, National Centre for Disease Informatics and Research, Indian Council of Medical Research.
  Member, Technical Expert Group for IT Infrastructure Procurement and Implementation, Kidwai Memorial Institute of Oncology, Bangalore.
  Member, Committee to select best thesis award of AcSIR under the physical sciences.

Member, Technical Committee, IEEE Third International Conference on "Multimedia Processing, Communication information Technology.
Member, Program Committee, International Conference on Information Processing (ICInPro-2021)

- **Rajendran K**
  Associate Editor, Journal of Earth System Sciences, Indian Academy of Science
  Member, Scientific committee, Kerala State Planning Commission, Govt. of Kerala
  Member, Board of Studies in Atmospheric Sciences, Cochin University of Science & Technology, Cochin, Kerala.
  Subject expert member, Faculty selection committee, Department of Atmospheric Sciences, CUSAT, Kerala
  Subject expert member, Faculty selection committee, Department of Environmental Sciences, CUSAT, Kerala
  Member, examination board, CSIR Fellowship.
  Member, Working group of National Monsoon Mission, MoES, GoI.
  Executive Council Member, Indian Meteorological Society.
  Life Member, Indian Meteorological Society.

- **Rakesh V**
  Life Member of Indian Meteorological Society

- **Sajani Surendran**
  Member, Working group of National Monsoon Mission, MoES, GoI.
  Member, Working Group III, National Carbonaceous Aerosol Project, MoEFCC, GoI.
  Life Member, Indian Meteorological Society.

- **Sridevi Jade**
  Life Member, Indian Geotechnical Society.
  Life member, Indian Geological Congress.
  Member, Indian Science Congress.
  Member, International Society of Soil Mechanics and Foundation Engineering.
  Founder Life Member, Indian Society of rock mechanics and tunneling technology.
  Associate Member, International GNSS Service (IGS).

- **Thangavelu R P**
  Life Member, Computer Society of India.
  Life Member, Cryptology Research Society of India.
  Member, Cloud Computing Innovation Council of India.
  Member, Expert Group on Infrastructure, National Supercomputing Mission, GoI.
  Member, Executive Committee, Karnataka State Natural Disaster Monitoring Centre, Bangalore.
  Member, Technical Expert Group for IT Infrastructure Procurement and Implementation, Kidwai Memorial Institute of Oncology, Bangalore.
  Member, Technical Evaluation Committee for procurement of HPC system for Indian Institute of Technology, Dharwad.
  Member, Technical Evaluation Committee for procurement of HPC system for Gas Turbine Research Establishment, Bangalore.

- **Vidyadhar Y Mudkavi**
  Member, Executive Board, National Supercomputing Mission (NSM).
  Chairman, Technical Evaluation Committee (TEC), Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX), Indian Institute of Tropical Meteorology (IITM), Pune.
  Chairman, Technical Advisory Committee (TAC), UAV Development for Atmospheric Measurements, IITM Pune.
  Co-Chairman, Interdisciplinary Committee for Tejas Wake Clearance, Aeronautical Development Agency (ADA), Bengaluru.
  Secretary, Trust for Advancement of Aerodynamics in India (TAAI), Bengaluru.
  Member, National Advisory Committee, CAIPEEX, IITM, Pune.
  Member, Technical Advisory Panel (TAP) for various departments of Government of Karnataka.
  Member, Expert Committee, eVidhana, Government of Karnataka.
  Life member, Aeronautical Society of India (AeSI).
  Member, Indian Academy for Mathematical Modeling and Simulation (IAMMS).
  Member, Computer Society of India.
  Fellow, The Institution of Engineers (India).

- **Vijayan M S M**
  Member, American Geophysical Union (AGU)
  Member, European Geophysical Union (EGU)
  Associate Member, International GNSS Service (IGS)

10.4 Promotions

- **Smt. M.K. Sharada** promoted as Chief Scientist
- **Dr. Sajani Surendran** promoted as Sr. Principal Scientist
- **Shri. Chiranjeevi Vivek** promoted as Sr. Scientist

Farewell function of Dr. Mudkavi on his superannuation.

Signed MOU between Indian Institute of Astrophysics, Bengaluru, India and Council of Scientific and Industrial Research -Fourth Paradigm Institute (CSIR-4PI) , Bengaluru, India dated 28 January 2021 for collaboration on GPS based Geoscience studies with existing observation network, GHG data generation of existing observation network and studies in atmospheric chemistry of Earth.


DG SET 1
DG SET 2
DG SET 3