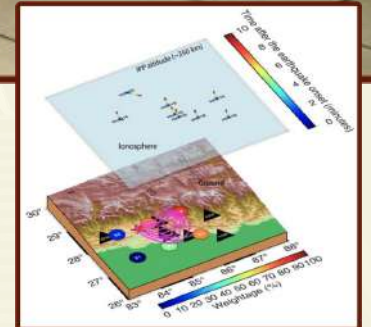
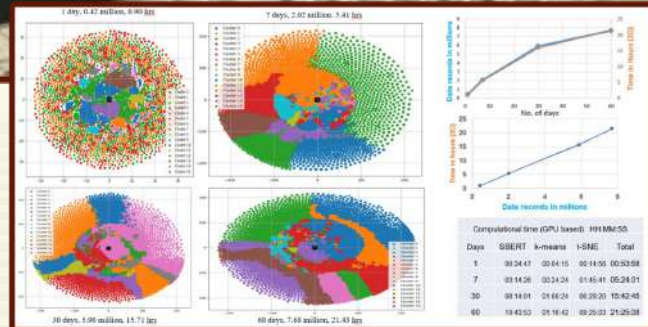
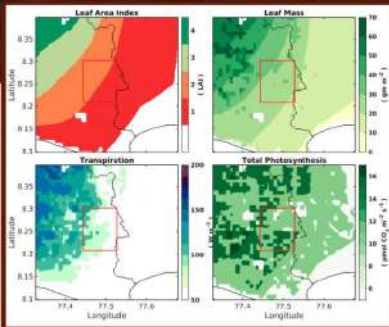
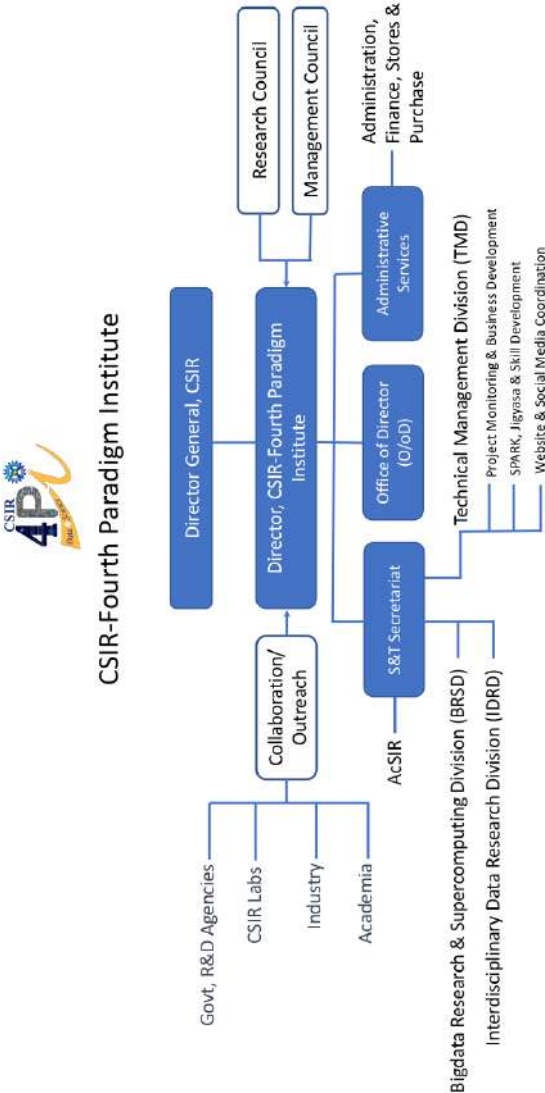


2024 -2025 वार्षिक रिपोर्ट ANNUAL REPORT



Organisational Chart



Vision

To synergize the Transdisciplinary Pan-CSIR expertise and build a unified platform that embodies a rich set of big data enabling technologies and services with optimized performance to facilitate data intensive scientific discovery in the country.

Mission

To Pioneer data driven interdisciplinary research in diverse fields through state-of-the-art data science ecosystem and impactful industrial partnerships for the betterment of Society.

Mandate

To develop cutting edge data science products as a horizontal across the CSIR Themes and position as an Institute of Excellence in Bigdata and Artificial Intelligence.

विजन

ट्रांसडिसिप्लिनरी पैन-सीएसआईआर विशेषज्ञता को समन्वित करना और एकीकृत मंच का निर्माण करना जो देश में गहन डेटा वैज्ञानिक अनुसंधान को सुविधाजनक बनाने हेतु अनुकूलित निष्पादन के साथ बिगडेटा को सक्षम करने वाली तकनीकों और सेवाओं को समृद्ध बनाना।

लक्ष्य

समाज की उन्नति के लिए अत्याधुनिक डेटा विज्ञान पारिस्थितिकी तंत्र एवं प्रभावशाली औद्योगिक साझेदारी के माध्यम से विविध क्षेत्रों में डेटा संचालित इंटरडिसिप्लिनरी अनुसंधान को आगे बढ़ाना।

अधिदेश

सीएसआईआर थीम में क्षेत्रीय रूप से अत्याधुनिक डेटा विज्ञान उत्पादों को विकसित करना और बिगडेटा एवं आर्टिफिशियल इंटेलिजेंस में उत्कृष्ट संस्थान के रूप में स्थान बनाना।

Published By:
The Director
CSIR Fourth Paradigm Institute
Wind Tunnel Road
Bengaluru – 560 037
Karnataka, India
Fax: + 91 80 2522–0392
Tel: + 91 80 2505–1921
E–mail: director@csir4pi.in
Web: www.csir4pi.res.in
X (Twitter): x.com/CSIR_4PI
YouTube: www.youtube.com/@csir-4pi
Facebook: www.facebook.com/csir4pi
Linkedin: www.linkedin.com/company/csir-fourth-paradigm-institute-bangalore

Compiled By:
Dr. Anil Earnest

Cover Page Design By:
Shri. Ravichandran C

Released on, 27 October 2025

Copyright © 2024 CSIR Fourth Paradigm Institute

Acknowledgements

We extend our gratitude to all the scientists and staff of the CSIR–Fourth Paradigm Institute for their invaluable contributions to this report. This report was typeset in $\text{\LaTeX}$ using the collaborative authoring platform Overleaf (www.overleaf.com).

The Research Council

Chairperson

- Prof K K Aggarwal, President, South Asian University (SAU), Rajpur Road, Maidan Garhi, New Delhi – 110 068

External Members

- Prof P Seshu, Professor, Department of Mechanical Engineering, Indian Institute of Technology (IIT), Powai, Mumbai – 400 076
- Dr. T Srinivasa Kumar, Director, Indian National Centre for Ocean Information Services (INCOIS), "Ocean Valley", Pragathi Nagar (BO), Nizampet (SO), Hyderabad – 500 090
- Dr. S D Sudarsan, Executive Director, Centre for Development of Advanced Computing (C-D, 68, Electronics City, Bengaluru – 561229
- Prof Sanghamitra Bandopadhyay, Director, Indian Statistical Institute (ISI), 203, Barrackpore Trunk Road, Kolkata – 700 108

Agency Representative

- Secretary, Ministry of Electronics and Information Technology (MeitY), or his nominee

Sister Laboratory

- Director, CSIR–Central Mechanical Engineering Research Institute, Mahatma Gandhi Avenue, Durgapur – 713209

DG's Representative

- Dr. (Mrs.) Viswajanani J Sattigeri, Head, Traditional Knowledge Digital Library, Vigyan Suchna Bhawan (CSIR–NIScPR Building), Satsang Vihar Marg, New Delhi – 1 10067

Laboratory Director

- Director, CSIR–Fourth Paradigm Institute (CSIR–4PI), Bengaluru – 560037

The Management Council

1. Director, CSIR–4PI – Chairperson
2. Dr. K. J. Sreeram, Director, CSIR–CLRI – Member
3. Dr. G. K. Patra, Chief Scientist – Member
4. Dr. I. A. Parvez, Chief Scientist – Member
5. Dr. Ashish, Principal Scientist – Member
6. Dr. Lakshmikanthan P., Senior Scientist – Member
7. Smt. Gutta Jainavi, Senior Scientist – Member
8. Sh. Prabhu, Sr. technical Officer– Member
9. Finance & Accounts Officer – Member
10. Administrative Officer – Member–Secretary

Preface



2024 has been a Landmark year as CSIR–Fourth Paradigm Institute was designated as ‘National Laboratory’ of CSIR with ‘Director’ on 19 June 2024 after more than a decade of its re–positioning as CSIR–4PI in 2013. I would like to put on record the unstinted support of Dr. N. KalaiSelvi, Secretary DSIR and Director General CSIR for this iconic milestone of being designated as 37 National Laboratory of CSIR. This enabled the institute to further consolidate its position as the one and only Data Science Lab of CSIR and gave impetus to CSIR for advancement of data intensive scientific discovery in the country.

We continue to augment our existing world class centralized CSIR supercomputing facility and scalable cloud storage to empower data driven transdisciplinary research across CSIR. During this year, we received NSM–EB in–principle approval for setting up 4 PetaFlops (GPU–4PF) supercomputing facility to be commissioned by December 2025. We also scaled up the MEGHA, CSIR cloud infrastructure from 4 to 11 PiB.

Keeping in view of the National Laboratory status of the institute, we initiated proposal for allocation of independent campus for the Institute. With the support of CSIR–HQ, area measuring 23 acres was allocated to the Institute with a 2–to–3–year timeline to complete the full implementation of the recommendations of Space Allocation Committee.

During this year the Institute crossed the subcritical staff strength threshold with the joining of 14 newly recruited scientists thus empowering the Institute with young and talented work force to fast forward the ongoing scientific activities. Further, recruitment of 20 Scientific positions was completed thus further strengthening the scientific staff of the Institute. In addition, provisional screening of 17 technical positions was completed thus paving way towards additional manpower for the Institute.

First Research Council (RC) meeting was convened with Prof. K. K, Aggarwal as Chairman along with eminent expert members covering diverse fields. RC commended the National Lab status of the institute and gave a clear direction and road map for the future. RC appreciated the research accomplishments, technical advancements and societal contributions made during the year. Management Council (MC) of the Institute met for the first time Chaired by Director, CSIR–4PI along with sister laboratory Director Dr. K. J. Sreeram, Director, CLRI as the member to look in to operation and management of the institute and give necessary suggestions..

One of the notable accomplishments of Bigdata research and supercomputing division (BRSD) is obtaining in–principle approval for CSIR Mission mode project titled ‘CSIR League for AI–based Industrial Manifestation (CLAIM)’ with CSIR–4PI as a nodal lab and 15 CSIR labs participating in the project. Focus of this mission is make CSIR future industry ready with data driven translational research aiming at smart manufacturing and automation, human centric AI, development of AI tools and algorithms. Ongoing Cyber Security research activity sponsored by MEITY has now moved towards advanced phase of Next–Gen cybersecurity and AI driven threat intelligence. Domain agnostic AI research activity has expanded its scope with AI applications to new emerging fields such as farmer centric agriculture, traffic, health and advanced climate

models.

Interdisciplinary data research division (IDRD) proposed a new mission mode project titled 'Assessment and Mitigation of Geo-Hazard in Himalaya' jointly with several CSIR labs. Progress made in the ongoing CSIR mission mode project "Region Specific Smart Agro-technologies for Soil and Plant Health (RSSA)" with CSIR-4PI as Nodal lab and 10 participating CSIR labs was commended by Sectorial Monitoring Committee (SMC) and several leads were identified for taking the project forward. This division continues to make globally cited contributions in advanced weather and climate research, multidisciplinary geoscience and engineering research with several grant in aid projects of societal relevance and high impact SCI publications.

AcSIR doctoral programme continues to march forward with contributions of brilliant and motivated students in furthering the institutes high impact research contributions of global relevance. Student Programme for Advancement of Research Knowledge (SPARK) of CSIR-4PI is successfully running for more than a decade and this year saw enrolment of about 77 Bachelors, Masters and doctoral students for research exposure, mentorship, and industry visits. Training was imparted to 313 students with diverse backgrounds from rural regions under the CSIR skill initiative program with renewed focus on interdisciplinary approach aligning with Digital and Skill India national missions. Jigyasa program provided valuable exposure to advanced science topics for 500+ school students through training, summer workshops, student-scientist interaction and competitions. Jigyasa webinar series on interdisciplinary topics garnered about 3000 views.

As detailed in the events section of the report, several events were conducted this year which enhanced the visibility and outreach of the Institute. Notable events of the institute in this year are OWOT (One Week One Theme) pan-CSIR initiative covering ANB and EED themes of CSIR; IISF 2024 Curtain raiser programme; participation in Krish Mela 2024 and Bangalore Tech Summit 2024. This year was marked by high profile visits and interactions with eminent personalities i.e., Shri Somanath, Secretary DOS, Chairman ISRO and Mentor CSIR-4PI; Dr. V. K. Saraswat, Member, NITI Aayog; Shri. Amit Aggarwal, Secretary, Department of Pharmaceuticals.

Awards and Recognitions of the Institute listed in the report increased the visibility of the Institute and created new opportunities. I am deeply honoured to receive IISc distinguished Alumni Award 2024 for data driven research contributions. We continue to march forward with our new and young scientific work force through academic/industry collaborations and societal outreach.

I am deeply honoured and privileged to witness the transformation of this Institute to CSIR National Laboratory and put on record the support and contribution received from CSIR leadership, Chairperson and Members of AC, RC and MC, Academic and Industry collaborators, Staff and Students of the institute. I am confident that with continued rigour and motivation, with the support of each and every one of you, the institute will reach its goal of being 'Institute of Excellence in Bigdata and Artificial Intelligence' in the near future.

Dr. Sridevi Jade
Head/Director, CSIR-4PI
(2024 – 2025)

प्रस्तावना



2024 एक ऐतिहासिक वर्ष रहा है क्योंकि सीएसआईआर-चौथा पैराडाइम संस्थान वर्ष 2013 में सीएसआईआर-चौथा पैराडाइम संस्थान के रूप में पुनर्स्थापन के एक दशक से भी अधिक समय बाद 19 जून 2024 को सीएसआईआर की 'राष्ट्रीय प्रयोगशाला' के रूप में 'निदेशक' पद के साथ नामित किया गया। मैं सीएसआईआर की 37वीं राष्ट्रीय प्रयोगशाला के रूप में नामित होने की इस महत्वपूर्ण उपलब्धि के लिए डीएसआईआर की सचिव और सीएसआईआर के महानिदेशक डॉ. एन कलै सेल्वी के अथक सहयोग को अंकित करना चाहती हूँ। यह संस्थान को सीएसआईआर की एकमात्र डेटा साइंस लैब के रूप में अपनी स्थिति को और मजबूत करने में सक्षम बनाया और देश में डेटा-गहन वैज्ञानिक खोज को आगे बढ़ाने के लिए सीएसआईआर को प्रोत्साहन दिया।

हम सीएसआईआर में डेटा-आधारित अंतर्विषयक अनुसंधान को सशक्त बनाने के लिए अपनी मौजूदा विश्व स्तरीय केंद्रीकृत सीएसआईआर सुपरकंप्यूटिंग सुविधा और स्केलेबल क्लाउड स्टोरेज को बढ़ाना जारी रखा है। इस वर्ष के दौरान, हमें दिसंबर 2025 से आरंभ होने वाले 4 पेटाफ्लॉप्स (GPU-4PF) सुपरकंप्यूटिंग सुविधा की स्थापना के लिए NSM-EB से सैद्धांतिक स्वीकृति प्राप्त हुई। हमने MEGHA, CSIR क्लाउड इंफ्रास्ट्रक्चर को 4 से बढ़ाकर 11 PiB किया।

संस्थान की राष्ट्रीय प्रयोगशाला की स्थिति को ध्यान में रखते हुए, हमने संस्थान के लिए एक स्वतंत्र परिसर के आवंटन का प्रस्ताव शुरू किया। सीएसआईआर-मुख्यालय के सहयोग से, अंतरिक्ष आवंटन समिति की सिफारिशों के पूर्ण कार्यान्वयन को पूरा करने के लिए 2 से 3 वर्ष की समय-सीमा के साथ संस्थान को 23 एकड़ क्षेत्र आवंटित किया गया।

इस वर्ष के दौरान, संस्थान ने 14 नए नियुक्त वैज्ञानिकों के शामिल होने के साथ ही सब-क्रिटिकल स्टाफ की सीमा को पार कर लिया, जिससे संस्थान में चल रही वैज्ञानिक गतिविधियों को तेजी से आगे बढ़ाने के लिए युवा और प्रतिभाशाली कार्यबल के साथ सशक्त बनाया गया। इसके अलावा, 20 वैज्ञानिक पदों की भर्ती की गई, जिससे संस्थान के वैज्ञानिक कर्मचारियों का सामर्थ्य में बढ़ोत्तरी हुई। इसके अतिरिक्त, 17 तकनीकी पदों की अनंतिम स्क्रीनिंग पूरी की गई, जिससे संस्थान के लिए अतिरिक्त जनशक्ति का मार्ग प्रशस्त हुआ।

प्रोफेसर के.के. अग्रवाल की अध्यक्षता में अनुसंधान परिषद (आरसी) की पहली बैठक आयोजित की गई, जिसमें विविध क्षेत्रों के प्रतिष्ठित विशेषज्ञ सदस्य शामिल हुए। आरसी ने संस्थान की राष्ट्रीय प्रयोगशाला की स्थिति की सराहना की और भविष्य के लिए एक स्पष्ट दिशा और रोडमैप प्रस्तुत किया। आरसी ने वर्ष के दौरान किए गए शोध उपलब्धियों, तकनीकी प्रगति और सामाजिक योगदान की सराहना की। संस्थान की प्रबंधन परिषद (एमसी) की पहली बैठक आयोजित की गई, जिसकी अध्यक्षता सीएसआईआर-4पीआई के निदेशक ने की, साथ ही सहयोगी प्रयोगशाला के निदेशक डॉ. के.जे. श्रीराम, निदेशक, सीएलआरआई, संस्थान के संचालन और प्रबंधन पर विचार करने और आवश्यक सुझाव देने के लिए सदस्य के रूप में उपस्थित रहे।

बिगडेटा अनुसंधान और सुपरकंप्यूटिंग प्रभाग (बीआरएसडी) की उल्लेखनीय उपलब्धियों में से एक सीएसआईआर मिशन मोड परियोजना 'सीएसआईआर लीग फॉर एआई-बेस्ड इंडस्ट्रियल मैनिफेस्टेशन (सीएलएआईएम)' के लिए सैद्धांतिक अनुमोदन प्राप्त करना है, जिसमें सीएसआईआर-4पीआई एक नोडल प्रयोगशाला है और इस परियोजना में 15 सीएसआईआर प्रयोगशालाएँ भाग ले रही हैं। इस मिशन का उद्देश्य सीएसआईआर को भविष्य के उद्योग के लिए डेटा-आधारित ट्रांसलेशनल अनुसंधान के साथ तैयार करना है, जिसका उद्देश्य स्मार्ट विनिर्माण और स्वचालन, मानव-केंद्रित एआई, एआई उपकरणों और एल्गोरिदम का विकास है। MEiTY द्वारा प्रायोजित वर्तमान साइबर सुरक्षा अनुसंधान गतिविधि अब अगली पीढ़ी की साइबर सुरक्षा और एआई-आधारित खतरे की खुफिया जानकारी के उन्नत चरण की ओर

बढ़ गई है। डोमेन-एग्रोस्टिक एआई अनुसंधान गतिविधि ने एआई अनुप्रयोगों के साथ किसान-केंद्रित कृषि, यातायात, स्वास्थ्य और उन्नत जलवायु मॉडल जैसे नए उभरते क्षेत्रों में अपना दायरा बढ़ाया है।

अंतर्विषयक डेटा अनुसंधान प्रभाग (आईडीआरडी) ने कई सीएसआईआर प्रयोगशालाओं के साथ मिलकर 'हिमालय में भू-खतरे का आकलन और शमन' शीर्षक से एक नई मिशन-मोड परियोजना का प्रस्ताव रखा है। सीएसआईआर-4पीआई को नोडल लैब और 10 सहभागी सीएसआईआर प्रयोगशालाओं के साथ चल रही सीएसआईआर मिशन मोड परियोजना "मृदा एवं पादप स्वास्थ्य हेतु क्षेत्र-विशिष्ट स्मार्ट कृषि-प्रौद्योगिकियाँ (आरएसएसए)" में हुई प्रगति की क्षेत्रीय निगरानी समिति (एसएमसी) द्वारा सराहना की गई और परियोजना को आगे बढ़ाने के लिए कई प्रमुख व्यक्तियों को शामिल किया गया। यह प्रभाग उन्नत मौसम एवं जलवायु अनुसंधान, बहु-विषयक भूविज्ञान और अभियांत्रिकी अनुसंधान में सामाजिक प्रासंगिकता की कई अनुदान सहायता परियोजनाओं और उच्च प्रभावी एससीआई प्रकाशनों के साथ विश्व स्तर पर उद्धृत योगदान जारी रखा है।

एसीएसआईआर डॉक्टरेट कार्यक्रम प्रतिभाशाली और प्रेरित छात्रों के योगदान के साथ आगे बढ़ रहा है, जिससे संस्थान के वैश्विक प्रासंगिकता वाले उच्च प्रभावी शोध योगदानों को आगे बढ़ाया जा रहा है। सीएसआईआर-4पीआई का शोध ज्ञान उन्नयन हेतु छात्र कार्यक्रम (स्पार्क) एक दशक से भी अधिक समय से सफलतापूर्वक चल रहा है और इस वर्ष शोध अनुभव, मार्गदर्शन और उद्योग भ्रमण के लिए लगभग 77 स्नातक, परास्नातक और डॉक्टरेट छात्रों का नामांकन हुआ। सीएसआईआर कौशल पहल कार्यक्रम के अंतर्गत ग्रामीण क्षेत्रों के विविध पृष्ठभूमि वाले 313 छात्रों को प्रशिक्षण दिया गया, जिसमें डिजिटल और स्किल इंडिया राष्ट्रीय मिशनों के साथ संरेखित अंतर्विषय दृष्टिकोण पर नए सिरे से ध्यान केंद्रित किया गया। जिज्ञासा कार्यक्रम ने प्रशिक्षण, ग्रीष्मकालीन कार्यशालाओं, छात्र-वैज्ञानिक संवाद और प्रतियोगिताओं के माध्यम से 500 से अधिक स्कूली छात्रों को उन्नत विज्ञान विषयों का बहुमूल्य अनुभव प्रदान किया। अंतर्विषय विषयों पर जिज्ञासा वेबिनार श्रृंखला को लगभग 3000 बार देखा गया।

जैसा कि रिपोर्ट के कार्यक्रम भाग में विस्तार से बताया गया है, इस वर्ष कई कार्यक्रम आयोजित किए गए जिससे संस्थान की दृश्यता और पहुँच में और वृद्धि हुई। इस वर्ष संस्थान के उल्लेखनीय कार्यक्रमों में सीएसआईआर के एएनबी और ईईडी विषयों को शामिल करते हुए ओडब्ल्यूओटी (एक सप्ताह एक थीम) अखिल-सीएसआईआर पहल; आईआईएसएफ 2024 कर्टेन रेज़र कार्यक्रम; कृष मेला 2024 और बेंगलूरू टेक समिट 2024 में भागीदारी शामिल है। इस वर्ष उच्च प्रोफाइल यात्राओं और प्रतिष्ठित हस्तियों के साथ बातचीत की विशेषता रही, जैसे कि श्री सोमनाथ, सचिव, अंतरिक्ष विभाग एवं अध्यक्ष इसरो और मेंटर सीएसआईआर-4पीआई; डॉ. वी. के. सारस्वत, सदस्य, नीति आयोग; श्री अमित अग्रवाल, सचिव, फार्मासिटिकल विभाग।

रिपोर्ट में सूचीबद्ध संस्थान के पुरस्कारों और मान्यताओं ने संस्थान की दृश्यता बढ़ाई और नए अवसर प्राप्त हुए। डेटा-संचालित शोध योगदान के लिए आईआईएससी विशिष्ट पूर्व छात्र पुरस्कार 2024 प्राप्त करके मुझे अत्यांत गर्व और सम्मान महसूस हो रहा है। हम शैक्षणिक/उद्योग सहयोग और सामाजिक आउटरीच के माध्यम से अपने नए और युवा वैज्ञानिक कार्यबल के साथ आगे बढ़ रहे हैं।

मुझे इस संस्थान के सीएसआईआर राष्ट्रीय प्रयोगशाला में रूपांतरण का साक्षी बनकर अत्यंत सम्मानित और गौरव महसूस हो रहा है और मैं सीएसआईआर नेतृत्व, एसी, आरसी और एमसी के अध्यक्ष एवं सदस्यों, शैक्षणिक एवं उद्योग सहयोगियों, संस्थान के कर्मचारियों और छात्रों से प्राप्त समर्थन और योगदान को अंकित करती हूँ। मुझे विश्वास है कि निरंतर परिश्रम और प्रेरणा के साथ, आप सभी के सहयोग से, यह संस्थान निकट भविष्य में 'बिगडेटा और आर्टिफिशियल इंटेलिजेंस में उत्कृष्टता संस्थान' बनने के अपने लक्ष्य को प्राप्त कर लेगा।

डॉ. श्रीदेवी जेड
प्रधान/निदेशक, सीएसआईआर-4पीआई
(2024 - 2025)

Director's Message



It is with immense pride and pleasure, I present the Annual Report for the year 2024–2025, a document that encapsulates the scientific endeavours, technological advancements, and societal contributions of the CSIR–Fourth Paradigm Institute (CSIR–4PI). This year has been one of significant growth and accomplishments, as we continue to solidify our position as a national laboratory of excellence in data-intensive scientific discovery, a period that marks a pivotal moment in our institute's history. Year 2024–25 is distinguished by a monumental achievement: the official designation of CSIR–Fourth Paradigm Institute (CSIR–4PI) as a “National Laboratory” of CSIR, effective from June 19, 2024. This is a significant milestone in our journey, affirming our unique and critical role in advancing data-intensive scientific knowledge and application for the nation. This recognition is the culmination of years of dedicated efforts of my predecessors, especially Dr. Sridevi Jade. I extend my profound gratitude to the CSIR leadership for their vision and support, and to every member of the CSIR–4PI family – our scientists, staff, and students – whose relentless pursuit of excellence made this landmark achievement possible. I also thank our advisory committee and collaborators for their invaluable contributions towards this process. Our vision to synergize transdisciplinary expertise and build a unified platform for big data has been the cornerstone of our activities. This report details the remarkable progress built upon this new foundation. Our world-class computational infrastructure, centred around the CHAMP High-Performance Computing facility and the CSIR–Megha cloud, continues to empower transdisciplinary research. The Bigdata Research & Supercomputing division has made significant strides in national priorities like cybersecurity, generative AI, and scalable data processing. The advancements made in detecting cyber threats through network telescope data analysis and developing resilient IT infrastructures are particularly noteworthy. In our Interdisciplinary Data Research, we have continued to tackle complex challenges with societal relevance. Our work in Advanced Weather & Climate Research has yielded crucial insights into greenhouse gas concentrations, the impact of pollution on public health, and improved forecasting models for extreme weather events. The Geosciences & Engineering Research has made significant contributions to understanding seismic hazards, ionospheric phenomena, and tectonic deformation, leveraging advanced computational models and multi-instrument analysis. These efforts underscore our commitment to pioneering data-driven research for the betterment of society. Creation and dissemination of knowledge remain central to our mission. Through our robust academic programs, including the AcSIR PhD program and the SPARK initiative, we have mentored the next generation of scientists and engineers. This report highlights the vibrant academic environment at CSIR–4PI, marked by numerous publications, workshops, and collaborative projects. Our Jigyasa outreach program has successfully ignited scientific curiosity in hundreds of students, connecting our research with the community and fostering a culture of scientific inquiry. None of these achievements would have been possible without the unwavering dedication and brilliance of our scientists, technical and administrative staff, research fellows, and students. A remarkable highlight of the year was the joining of 14 new

scientists, which has significantly strengthened our scientific workforce. As we embrace our new role as a National Laboratory, we are more energized than ever to harness the power of data science and AI to address India's most pressing challenges. This report is a testament to our collective resolve to pioneer data-driven discovery for a prosperous and sustainable future. I extend my deepest gratitude to each member of the CSIR-4PI family for their invaluable contributions. I also wish to thank our research council, members of the management committee, collaborators from various CSIR labs, academic institutions, and industry partners for their constant support and guidance. As we move forward, we are excited and motivated by the opportunities that lie ahead. We will continue to harness the power of data science and artificial intelligence to address the nation's most pressing challenges, from climate change to cybersecurity. This annual report is not just a record of the past year's accomplishments; it is a testament to our collective resolve to push the frontiers of science and technology for a prosperous and sustainable future.

Dr. G. K. Patra
Director, CSIR-4PI

निदेशक का संदेश



मैं, वर्ष 2024-2025 की वार्षिक रिपोर्ट अत्यंत गर्व और प्रसन्नता के साथ प्रस्तुत कर रहा हूँ। यह एक ऐसा दस्तावेज है जो सीएसआईआर-चौथा पैराडाइम संस्थान (सीएसआईआर-4पीआई) के वैज्ञानिक प्रयासों, तकनीकी प्रगति और सामाजिक योगदान को समाहित करता है। यह वर्ष महत्वपूर्ण विकास और उपलब्धियों का वर्ष रहा है, क्योंकि हम डेटा-गहन वैज्ञानिक खोज में उत्कृष्टता की एक राष्ट्रीय प्रयोगशाला के रूप में अपनी स्थिति को निरंतर सुदृढ़ कर रहे हैं, यह अवधि हमारे संस्थान के इतिहास में महत्वपूर्ण है।

वर्ष 2024-25 अभूतपूर्व उपलब्धि के लिए महत्वपूर्ण है: सीएसआईआर-चौथा पैराडाइम संस्थान (सीएसआईआर-4पीआई) को दिनांक 19 जून, 2024 से सीएसआईआर की "राष्ट्रीय प्रयोगशाला" के रूप में आधिकारिक रूप से नामित किया गया है। यह हमारी यात्रा में एक महत्वपूर्ण मील का पत्थर है, जो राष्ट्र के लिए डेटा-गहन वैज्ञानिक ज्ञान और अनुप्रयोग को आगे बढ़ाने में हमारी अद्वितीय और महत्वपूर्ण भूमिका की पुष्टि करता है। यह सम्मान मेरे पूर्ववर्तियों, विशेषकर डॉ. श्रीदेवी जडे के वर्षों के समर्पित प्रयासों का परिणाम है। मैं सीएसआईआर को दृष्टिकोण और समर्थन में उनके नेतृत्व के लिए, और सीएसआईआर-4पीआई परिवार के प्रत्येक सदस्य - हमारे वैज्ञानिकों, कर्मचारियों और छात्रों - के प्रति हार्दिक आभार व्यक्त करता हूँ, जिनकी उत्कृष्टता की निरंतर खोज ने इस ऐतिहासिक उपलब्धि को संभव बनाया। मैं इस प्रक्रिया में उनके अमूल्य योगदान के लिए हमारी सलाहकार समिति और सहयोगियों को भी धन्यवाद देता हूँ।

अंतर-विषयक विशेषज्ञता को समन्वित करने और बिग डेटा के लिए एक एकीकृत मंच बनाने का हमारा दृष्टिकोण हमारी गतिविधियों की आधारशिला रहा है। यह रिपोर्ट इस नई नींव पर हुई उल्लेखनीय प्रगति का विवरण देती है। चैम्प उच्च-प्रदर्शन कंप्यूटिंग सुविधा और सीएसआईआर-मेघा क्लाउड पर केंद्रित हमारे विश्वस्तरीय कम्प्यूटेशनल बुनियादी ढांचा, अंतर-विषयक अनुसंधान को सशक्त बनाता है। बिगडेटा अनुसंधान एवं सुपरकंप्यूटिंग प्रभाग ने साइबर सुरक्षा, जनरेटिव एआई और स्केलबल डेटा प्रोसेसिंग जैसी राष्ट्रीय प्राथमिकताओं में महत्वपूर्ण प्रगति की है। नेटवर्क टेलीस्कोप डेटा विश्लेषण के माध्यम से साइबर खतरों का पता लगाने और सुदृढ़ आईटी बुनियादी ढांचे के विकास में हुई प्रगति विशेष रूप से उल्लेखनीय है।

अपने अंतःविषयक डेटा अनुसंधान में, हमने सामाजिक प्रासंगिकता की जटिल चुनौतियों का सामना करना जारी रखा है। उन्नत मौसम एवं जलवायु अनुसंधान में हमारे कार्य ने ग्रीनहाउस गैस सांद्रता, जन स्वास्थ्य पर प्रदूषण के प्रभाव और चरम मौसम की घटनाओं के लिए बेहतर पूर्वानुमान मॉडल पर महत्वपूर्ण परिज्ञान प्रदान की है। भूविज्ञान एवं इंजीनियरिंग अनुसंधान ने उन्नत कम्प्यूटेशनल मॉडल और बहु-उपकरण विश्लेषण का लाभ उठाते हुए भूकंपीय खतरों, आयनमंडलीय परिघटनाओं और विवर्तनिक विरूपण को समझने में महत्वपूर्ण योगदान दिया है। ये प्रयास समाज की बेहतरी के लिए अग्रणी डेटा-संचालित अनुसंधान के प्रति हमारी प्रतिबद्धता को रेखांकित करते हैं।

ज्ञान का सृजन और प्रसार हमारे मिशन का केंद्रबिंदु बना हुआ है। सीएसआईआर पीएचडी कार्यक्रम और स्पार्क पहल सहित हमारे मजबूत शैक्षणिक कार्यक्रमों के माध्यम से, हमने अगली पीढ़ी के वैज्ञानिकों और इंजीनियरों का मार्गदर्शन किया है। यह रिपोर्ट सीएसआईआर-4पीआई के जीवंत शैक्षणिक वातावरण पर प्रकाश डालती है, जो कई प्रकाशनों, कार्यशालाओं और सहयोगी परियोजनाओं द्वारा उल्लेखनीय हैं। हमारे जिज्ञासा आउटरीच कार्यक्रम ने सैकड़ों छात्रों में वैज्ञानिक जिज्ञासा को सफलतापूर्वक प्रज्वलित किया है, हमारे शोध को समुदाय से जोड़ा है और वैज्ञानिक अन्वेषण की संस्कृति को बढ़ावा दिया है।

इनमें से कोई भी उपलब्धि हमारे वैज्ञानिकों, तकनीकी और प्रशासनिक कर्मचारियों, शोध अध्येताओं

और छात्रों के अटूट समर्पण और प्रतिभा के बिना संभव नहीं होती। वर्ष का एक उल्लेखनीय आकर्षण 14 नए वैज्ञानिकों का शामिल होना था, जो हमारे वैज्ञानिक कार्यबल को महत्वपूर्ण रूप से मजबूत किया है। एक राष्ट्रीय प्रयोगशाला के रूप में अपनी नई भूमिका को अपनाते हुए, हम भारत की सबसे गंभीर चुनौतियों का समाधान करने के लिए डेटा विज्ञान और एआई की शक्ति का उपयोग करने के लिए पहले से कहीं अधिक ऊर्जावान हैं। यह रिपोर्ट एक समृद्ध और टिकाऊ भविष्य के लिए डेटा-संचालित खोज में अग्रणी होने के हमारे सामूहिक संकल्प का प्रमाण है।

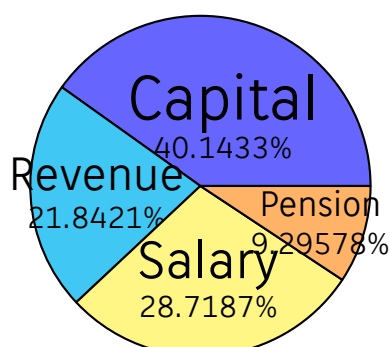
मैं सीएसआईआर-4पीआई परिवार के प्रत्येक सदस्य को उनके अमूल्य योगदान के लिए अपनी हार्दिक कृतज्ञता व्यक्त करता हूँ। मैं अपनी अनुसंधान परिषद, प्रबंधन समिति के सदस्यों, विभिन्न सीएसआईआर प्रयोगशालाओं, शैक्षणिक संस्थानों के सहयोगियों और उद्योग भागीदारों को उनके निरंतर समर्थन और मार्गदर्शन के लिए भी धन्यवाद देना चाहता हूँ।

जैसे-जैसे हम आगे बढ़ रहे हैं, हम आगे आने वाले अवसरों से उत्साहित और प्रेरित हैं। हम जलवायु परिवर्तन से लेकर साइबर सुरक्षा तक, देश की सबसे गंभीर चुनौतियों का समाधान करने के लिए डेटा विज्ञान और कृत्रिम बुद्धिमत्ता की शक्ति का उपयोग करना जारी रखेंगे। यह वार्षिक रिपोर्ट केवल पिछले वर्ष की उपलब्धियों का लेखा-जोखा ही नहीं है; यह एक समृद्ध और टिकाऊ भविष्य के लिए विज्ञान और प्रौद्योगिकी की सीमाओं को आगे बढ़ाने के हमारे सामूहिक संकल्प का प्रमाण है।

डॉ. जी के पात्र
निदेशक, सीएसआईआर-4पीआई

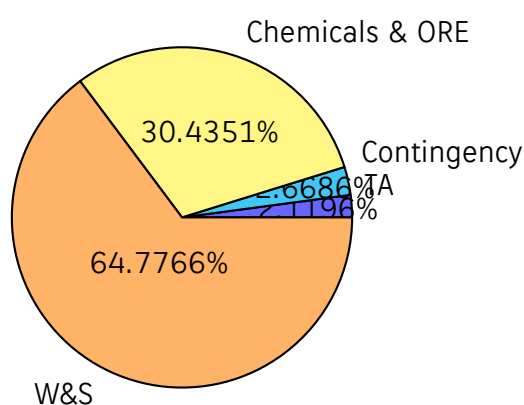
Financial Performance Indicators

Infra & CSIR Projects Allocation for the FY 2024–25



(Amount in Rupees)				
Sl.No.	Head of Allocation	Infra	CSIR Projects	Total
1	Capital	15,87,21,961.00	1,07,00,000.00	16,94,21,961.00
2	Revenue	7,02,89,474.00	2,18,93,729.00	9,21,83,203.00
3	Salary & Allowances	11,89,08,295.00	22,97,106.00	12,12,05,401.00
4	Pension	3,92,32,183.00	–	3,92,32,183.00
	Total	38,71,51,913.00	3,48,90,835.00	42,20,42,748.00

Details / Breakup of Infra / CSIR Projects Allocation for the FY 2024–25



Details / Breakup of Infra / CSIR Projects Allocation for the FY 2024–25

Sl.No.	Head of Allocation	Infra	CSIR Projects	Total
1	TA	30,50,463.00	22,97,106.00	53,47,569.00
2	Contingency	54,82,734.00	12,49,887.00	67,32,621.00
3	Chemicals & ORE	5,61,39,826.00	2,06,43,842.00	7,67,83,668.00
4	W&S, Equipment	15,27,22,354.00	1,07,00,000.00	16,34,22,354.00
	Total	21,73,95,377.00	3,48,90,835.00	25,22,86,212.00

Details of Lab Reserve Generation

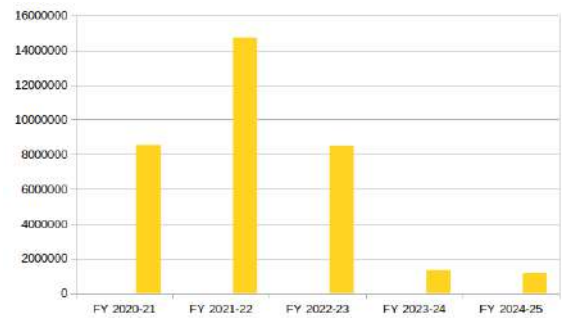


Figure 1: Details of Lab Reserve Generation.

Details of Lab Reserve Generation

1	FY 2020–21	85,35,856.00
2	FY 2021–22	1,47,20,156.85
3	FY 2022–23	85,07,778.00
4	FY 2023–24	13,11,855.00
5	FY 2024–25	11,71,500.00

Details of Lab Reserve Expenditure

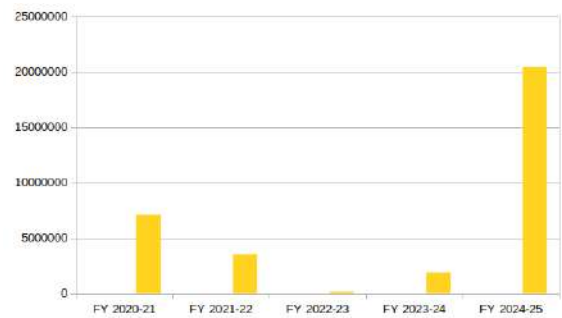


Figure 2: Details of Lab Reserve Expenditure.

Details of Lab Reserve Expenditure

1	FY 2020–21	70,62,728.00
2	FY 2021–22	35,09,179.00
3	FY 2022–23	1,45,151.00
4	FY 2023–24	18,80,754.00
5	FY 2024–25	2,04,26,087.00

Contents

I Bigdata Research & Supercomputing

1	CSIR-4PI Computational Cyber Infrastructure	23
1.1	CSIR HPC, AI & ML Platform (CHAMP)	24
1.2	Energy Farm: HPC Support Infrastructure	25
1.3	CSIR-Megha: Scientific Scalable Cloud Storage at CSIR-4PI	26
1.4	CSIR-4PI HPC Health Monitoring System	27
2	Cyber Security and Data Privacy Research	29
2.1	Scalable Data Processing and Clustering Pipeline for Threat Detection: From Analytics Server to HPC with GPU Acceleration	30
2.2	Semantic Clustering and Vector Database Integration for Threat Intelli- gence	31
2.3	Building Resilient IT Infrastructure: Integrating Internal Network Secu- rity and Internet Redundancy	34
2.4	Stitching the Shadows: Multi-Packet Payload Analysis and the Mozi Botnet's Exploitation of IoT Devices	34
2.5	Steps towards enhancing Organisational Cybersecurity Posture	35
2.6	Network Telescope Data Analysis Mapped to the Cyber Kill Chain	36

3	Domain Agnostic Data Sciences and AI Research	39
3.1	Development of Custom Android Application for field data collection to generate low-cost farmer services for disease and pest management.	41
3.2	Diffusion Model to generate high quality synthetic face images	42
3.3	Detection of Sybil Attacks in 5G-Enabled VANETs Using Image-Based Anomaly Detection: A Simulation Study in Bengaluru	43
3.4	Leveraging Generative Modeling for Traffic Image Generation	44
3.5	Benchmarking and Performance Assessment of WRF on CHAMP.	46
3.6	Multi-Sensor Satellite Image Cloud Classification with Deep Learning	48
3.7	Image Annotation to help machine learning models	49

II Interdisciplinary Data Research

4	Advanced Weather & Climate Research	53
4.1	Targeted Monitoring of 16 Indices for Improved Climate Forecasting	55
4.2	Measurements and Analysis of Greenhouse Gases	57
4.3	Local Wind Patterns on CO ₂ Concentrations at Hoskote	59
4.4	Development of ML models for paddy disease detection for server-based and edge-device applications.	61
4.5	High-Resolution Coupled Agro-Meteorological Forecasting System at CSIR-4PI.	62
4.6	Unraveling the impact of atmospheric engineering on extremes through chemistry-weather-climate Interactions.	64
4.7	Particulate Matter Pollution in a Coastal Industrial City and its Impact on Human Health: A Generalized Additive Model Analysis	65
4.8	Sensitivity of microphysics parameterization approaches in WRF Model in simulating intensity and spatial distribution of Extreme rainfall over Bangalore, India	66
4.9	Impact of different land use data on WRF model short-range forecasts during pre-monsoon and monsoon seasons in India	68
4.10	Relative Impact of Assimilation of Multi-Source Observations using 3D-Var on Simulation of Extreme Rainfall Events over Karnataka, India	69
4.11	Sensitivity of orography and precipitation data in simulating streamflow over the Western Indian Himalayan region using SWAT model	70
4.12	Understanding of Marine Carbon Dynamics in the Northern Indian Ocean through Coupled Physical-Biogeochemical Modelling - A Brief Note	72
5	Geosciences & Engineering Research	75
5.1	Distinct lithosphere-asthenosphere boundary (LAB) beneath the western Himalaya: insights from seismic imaging	77

5.2	Comparative Evaluation of Seismic Denoising Techniques: A Deep Learning and Signal Processing Approach	78
5.3	Deployment of broadband seismic array across the Mahabaleshwar Plateau, Deccan Trap, Maharashtra	80
5.4	Estimation of Precipitable water vapor during Extreme rainfall event (ERE) in Himalaya	81
5.5	Morphology of equatorial F-region irregularities over the Indian longitude sector using GPS-derived ROTI observations	82
5.6	Noise analysis of multi-GNSS time series	83
5.7	Impact of hydrological, atmospheric loading on geodetic deformation over Indian subcontinent	84
5.8	Multi-Instrument Analysis of Ionospheric Equatorial Plasma Bubbles over the Indian and Southeast Asian Longitudes During the 19–20 April 2024 Geomagnetic Storm	85
5.9	Case study on the Mw 6.2 Dipayal Earthquake of October 3, 2023 using InSAR data products	86
5.10	Validating InSAR Methodology Using the 2020 Monte Cristo Range Earthquake	87
5.11	Ionospheric imagery of earthquake source region using the Co-seismic Ionospheric Perturbations	90
5.12	Building Low-Cost GNSS Receiver for Ionospheric Total Electron Content (TEC) Estimation	91
5.13	Dynamic Stress Changes on the East Anatolian Fault	93
5.14	Outer-arc Active Tectonic Deformation off the Nias-Nicobar Trench	94
5.15	Buckling studies of triple-walled carbon nanotube using the pseudospectral method with backward substitution approach for general boundary conditions.	96
5.16	Revisiting the Mindlin microstructure isotropic strain gradient elasticity theory for Form-I, Form-II, and Form-III with length scales.	96

III

Knowledge & Technical Management

6	Academic Programmes	99
6.1	Academy of Scientific and Innovative Research (AcSIR)	100
6.2	CSIR-4PI Integrated Skill Initiative Programme	104
6.3	CSIR-4PI Jigyasa program	109
6.4	Faculty Participation	118
7	Knowledge Activities and Products	119
7.1	Publications in Journals	120
7.2	Publications in Books/Proceedings	121

7.3	Internal Reports	122
7.4	Presentations in Conferences/Workshops/Seminars	122
7.5	Participation in Conferences/Workshops/Training Programmes	122
7.6	Invited Talks	123
7.7	Conference/Workshops/Seminars at CSIR-4PI	124
7.8	In-house seminars/lectures	124
7.9	Visitors at CSIR-4PI	125
7.10	Events at CSIR-4PI	127
7.11	Significant Events	154
8	Projects & Collaborative Programmes	163
8.1	Grant-in-Aid Projects	164
8.2	Other Lab Projects (OLP)	164
8.3	Headquarter Controlled Projects (HCP)	165
8.4	Network Projects (NWP)	165
8.5	MOU's Signed	165
9	Staff News & Updates	167
9.1	Staff List	168
9.2	Awards/Honours/Recognition	170
9.3	Services on External Committees/Membership of Professional Bodies	172
9.4	Newly Joined Staff	175
9.5	Promotions	176
9.6	Foreign Deputations	176
9.7	Superannuations	176
9.8	Staff relieved from CSIR-4PI	176



Bigdata Research & Supercomputing

1	CSIR-4PI Computational Cyber Infrastructure	23
2	Cyber Security and Data Privacy Research	29
3	Domain Agnostic Data Sciences and AI Research	39

1. CSIR-4PI Computational Cyber Infrastructure

The CSIR Fourth Paradigm Institute (CSIR-4PI) in Bengaluru, India, hosts a sophisticated Computational Cyber Infrastructure designed to facilitate high-end research in data-intensive scientific discovery. This state-of-the-art facility provides the CSIR-wide research community with access to powerful high-performance computing (HPC) clusters, massive data storage capabilities, and high-speed network connectivity through the National Knowledge Network. The infrastructure, which includes one of the fastest supercomputers in the country, is engineered to tackle grand challenge problems across a multitude of disciplines such as earth and environmental sciences, aerospace engineering, and materials science. By offering a centralized platform for advanced computation and data analytics, the CSIR-4PI empowers researchers to push the boundaries of science and engineering, fostering innovation and a deeper understanding of complex systems.

Inside:

- CSIR HPC, AI ML Platform (CHAMP)
- Energy Farm: HPC Support Infrastructure
- CSIR-Megha: Scientific Scalable Cloud Storage at CSIR-4PI
- CSIR-4PI HPC Health Monitoring System

1.1 CSIR HPC, AI & ML Platform (CHAMP)

The centralized High-Performance Computing (HPC) facility at CSIR, named CHAMP (shown in Figure 1), is architected to support both CPU and GPU-intensive workloads. The system comprises 410 dual-socket CPU nodes, each configured with AMD 7763 processors, offering 128 cores and 512 GB RAM per node. Collectively, the system features 52,480 processor cores and 205 TB of RAM, delivering a peak compute capability of ~ 2 PFLOPS, with sustained performance of ~ 1.4 PFLOPS as per HPL benchmark results.

Complementing the CPU infrastructure, the system includes 12 GPU-enabled compute nodes, each integrated with 4 GPUs (each is A100 GPU Card), offering an aggregate peak performance of 960 TFLOPS, and sustaining approximately 600 TFLOPS on HPL benchmarks, translating to around 30 AI PetaFLOPS. The system's storage



Figure 1.1: CSIR HPC, AI & ML Platform (CHAMP)

backbone is powered by a LUSTRE parallel file system with an effective capacity of ~ 8 PiB. For high-speed communication between nodes, the cluster employs HDR 200 InfiniBand switches, using HDR 100 InfiniBand links to each node, arranged in a fully non-blocking FAT tree topology, ensuring low-latency and high-bandwidth interconnects. The usage pattern of CHAMP supercomputer during April 2024 to March 25 is given in the Figure 1.2.

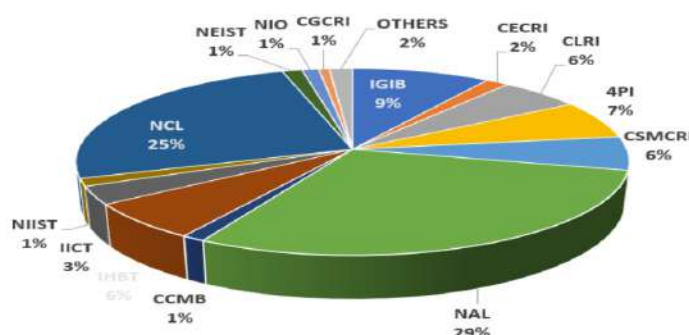


Figure 1.2: Usage of CHAMP cluster in April 2024– March 25

1.2 Energy Farm: HPC Support Infrastructure

The CSIR-4PI Energy Farm is a state-of-the-art, purpose-built facility that serves as the critical backbone for the institute's power-intensive High-Performance Computing (HPC) infrastructure. Engineered for 24/7, all-weather, uninterrupted operation, this facility houses a sophisticated ecosystem of power and cooling systems essential for running the supercomputers. This includes a dedicated high-tension electrical substation, a suite of large-capacity diesel generators for backup power, and a massive, multi-megawatt Uninterruptible Power Supply (UPS) system to ensure a clean and stable power feed. To manage the immense heat generated by the computational clusters, the Energy Farm employs an advanced cooling system comprising large-scale chillers and cooling towers. This robust infrastructure is fundamental to guaranteeing the high availability, reliability, and optimal performance of the HPC resources that drive the institute's data-intensive scientific research.

The reliability and efficiency of the CHAMP Supercomputer are supported by a robust, state-of-the-art Tier-3 equivalent data center, powered by an advanced Energy Farm that ensures seamless, round-the-clock operations.

Cooling is implemented through a hybrid mechanism comprising Direct Contact Liquid Cooling (DCLC), water cooling, and air cooling. DCLC handles approximately 60% of the cooling load for CPU nodes, while air cooling covers the remaining 40%. GPU compute nodes are maintained using active Rear Door Heat Exchangers (RDHx). This cooling strategy is optimized to achieve a Power Usage Effectiveness (PUE) of approximately 1.3548.

The energy infrastructure (shown in Figure 1.3) includes redundant compact substations with a cumulative capacity of 1.25 MVA, supported by three 1010 KVA diesel generators and an underground diesel yard with a capacity of 15 KL. Additionally, the original three 400 KVA UPS units have been upgraded to two 600 KVA modular UPS systems, each consisting of 4x300 KVA modules, complemented by ample battery backup. This setup ensures a 24x7 uninterrupted power supply to the HPC facility.



Figure 1.3: The HPC energy management infrastructure.

1.3 CSIR–Megha: Scientific Scalable Cloud Storage at CSIR–4PI

Megha cloud storage (shown in figure 4) is CSIR's centralized storage hosted at 4PI. Its ~ 11 PiB scale-out architecture based storage for scientific data store and retrieval purpose. The cloud storage is equipped with snapshots, encryption, LDAP, compression etc.

CSIR–Megha, cloud storage offers several key benefits to CSIR. It fosters collaboration among researchers by allowing access to data from anywhere with an internet connection, enabling real-time sharing of datasets and findings, which accelerates research and development. It also enhances data security, as CSIR can leverage built-in security features to ensure the confidentiality, integrity, and availability of sensitive research data, while meeting regulatory requirements and protecting intellectual property. Additionally, by integrating with CHAMP, researchers can conduct complex data analysis, predictive modeling, and AI-driven research, promoting innovation across multiple domains. Furthermore, cloud storage enables scientists of CSIR to conduct collaborative research, knowledge exchange, and the diffusion of innovation across geographical boundaries.

CSIR–Megha, cloud storage consists of two numbers of Sync & Share Servers used for entry and share point for Data store and share. Six number of storage controller of Megha cloud have intelligence to route and manage the actual data. This cloud storage has nine number of expansions (JBODs) that serve as the storage units where the actual data is stored. This cloud storage offers robust technical features including authentication and authorization, encryption, LDAP integration, two-factor authentication, deduplication and compression, replication, snapshotting with retention policies, and file locking to ensure secure, efficient, and reliable data management.

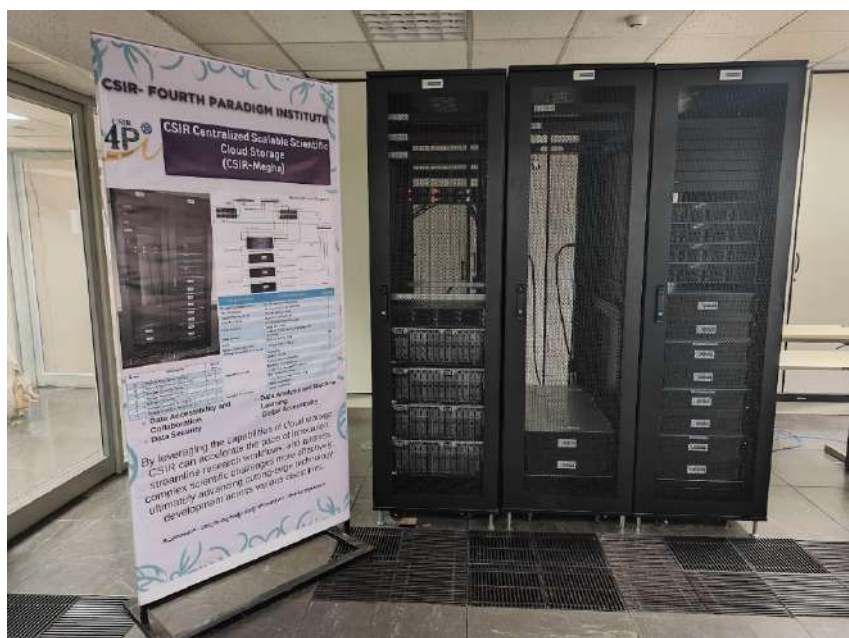


Figure 1.4: CSIR–Megha: Scientific Scalable Cloud Storage at CSIR–4PI.

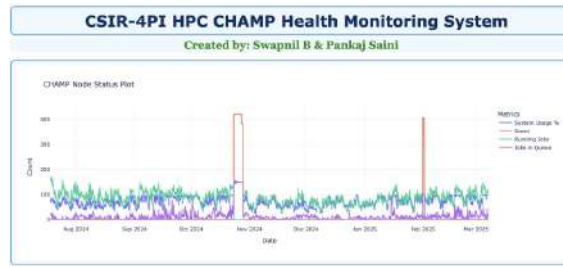
1.4 CSIR-4PI HPC Health Monitoring System

In large-scale HPC environments, where clusters, networking devices, and storage systems are tightly interconnected, monitoring becomes a critical administrative task. Failures at any layer whether or not they immediately affect performance, can lead to serious operational challenges. Traditionally, each infrastructure component is monitored separately using dedicated tools, making system-wide visibility fragmented. This emphasizes the need for a unified, end-to-end monitoring solution that provides a holistic view of system health, analyze the live enormous amount of collected data and enables early detection of anomalies.

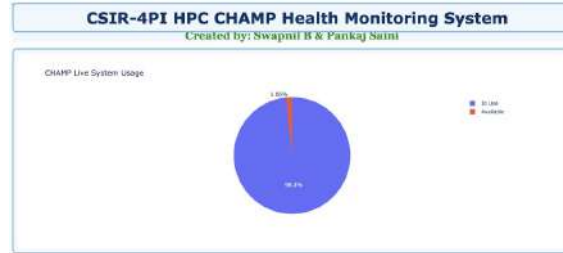
This Monitoring System exercise integrating data across all CHAMP-HPC layers i.e. Cluster (node availability, job queues), persistent storage, System low level platform params (CPU temperatures and node power consumption) into a single real-time dashboard. By correlating this data over time using statistical methods, such as tracking average system load versus power consumption, it empowers administrators to make informed decisions and maintain maximum system efficiency. The goal is to proactively identify issues before they escalate and ensure uninterrupted system performance through clear, live visualization of all critical metrics.

The system implements a comprehensive health monitoring solution for CHAMP infrastructure by collecting, processing, and visualizing real-time data from both software and hardware sources. Data is gathered using a combination of kernel services, PBSPro job scheduler outputs and iDRAC/Redfish APIs, capturing critical metrics like CPU temperature, power consumption, system load, and job status. These metrics are processed using advance backend processing engine that run periodically, ensuring clean, structured data is available for backend analysis and correlation.

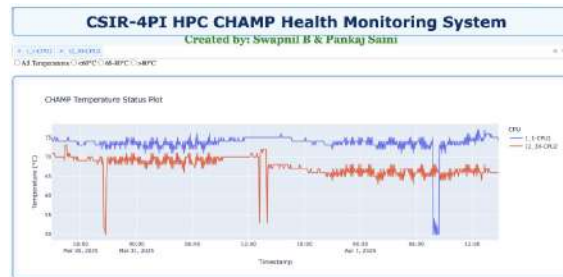
An interactive web application serves as the platform's interface, with a relational database storing historical data for efficient querying. The backend exposes RESTful APIs, while the frontend built with Dash and Plotly technologies provides interactive dashboards that visualize system performance and trends in real time. This setup enables administrators to monitor node health, detect inefficiencies, and make data-driven decisions through a responsive and scalable application.



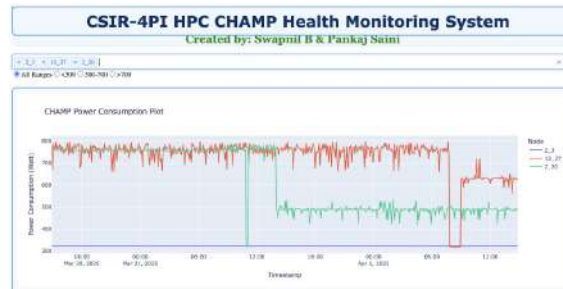
(a)



(b)



(c)



(d)

Figure 1.5: (a) Node Status Plot (b) Live System Usage Chart (c) CPU Temperature Profile (d) Power Consumption Plot.

Swapnil Burungale, Pankaj Saini and V Anil Kumar

2. Cyber Security and Data Privacy Research

The CSIR Fourth Paradigm Institute (CSIR-4PI) in Bengaluru is at the forefront of cybersecurity and data privacy research in India, driven by its Bigdata Research & Supercomputing Division (BRSD). The institute's research is centered on addressing the complexities of modern cyber threats through detection, characterization, and mitigation. A key initiative is the "Cyber Security Research and Observation" (CySeRO) program, which focuses on analyzing unsolicited network traffic to infer malicious activities and developing robust frameworks for validating the source of these threats. The research also extends to crucial areas of cryptography and data privacy, with a special emphasis on creating lightweight, AI-based security algorithms suitable for resource-constrained environments like the Internet of Things (IoT) and connected vehicles. The team has made significant contributions to the design and analysis of key agreement protocols and word-based stream ciphers. Recognizing the "big data" nature of cybersecurity, the institute is also pioneering the use of next-generation database technologies to effectively manage and analyze vast volumes of network data for security inferences.

Inside:

1. Scalable Data Processing and Clustering Pipeline for Threat Detection: From Analytics Server to HPC with GPU Acceleration
2. Semantic Clustering and Vector Database Integration for Threat Intelligence
3. Building Resilient IT Infrastructure: Integrating Internal Network Security and Internet Redundancy
4. Stitching the Shadows: Multi-Packet Payload Analysis and the Mozi Botnet's Exploitation of IoT Devices
5. Steps towards enhancing Organisational Cybersecurity Posture
6. Network Telescope Data Analysis Mapped to the Cyber Kill Chain

2.1 Scalable Data Processing and Clustering Pipeline for Threat Detection: From Analytics Server to HPC with GPU Acceleration

In recent days, Machine learning has enabled automatic analysis of darknet traffic by detecting anomalies, patterns, and potential cyber threats, even when the traffic is unlabeled. To do such analysis, clustering techniques such as K-Means, DBSCAN, etc., are widely used. For the large-scale TCP packet data captured at CySeRO active network telescope(s), K-Means clustering was initial choice to cluster the packets after pre-processing, especially those with malicious payload. The data used in this study was captured via a /23 active network telescope. With the primary objective of analyzing the change in malicious activity over darknet, the dataset has been split into various scales based on duration of data collection, viz., one day, one week, one month and two months. This allows us to examine how computational performance of pre-processing and clustering scales up with increasing analysis duration and this is a two-step process. Initially, raw data was pre-processed on a standalone server with large memory capacity (378 GB DDR RAM) and clustering was attempted. It became amply evident that for data spanning more than one week, the standalone sever cannot handle this data in a reasonable amount of time. After thoroughly profiling the pre-processing and clustering pipeline, we narrowed down to three key bottlenecks. They are:

1. The payload embedding pipeline
2. Clustering
3. Visualization of Clusters

Embedding pipeline: The two major steps in embedding involved data cleaning and converting it into embeddings using pre-trained SBERT (Sentence-BERT). The data cleaning has been vectorized and batch processing was carried out by splitting the data as input to SBERT on GPU. The batch size was chosen to maximize the GPU VRAM utilization.

Clustering: The clustering pipeline of K-Means involves computation of distance between points, cluster assignment and centroid update with multiple initializations. All of these steps have been independently parallelized on GPU and multiple initialization (Random partition, K-Means++ , etc.,) and Elbow method have been evaluated for choice of k, stability, and performance.

Visualization of Clusters: Although the clusters have been constructed in high dimensional SBERT space, we adapted t-SNE (t-distributed Stochastic Neighbor Embedding) based 2D/3D visualization to understand the qualitative characteristics of clustering.

A-100 GPU cards on our CHAMP server were used for the purpose. The entire optimization has significantly speed-up the process, with times reduced to mere seconds per batch, even for large datasets. From scalability perspective, the move to High Performance Computing environment allowed handling significantly larger datasets, enabling to scale the analysis up to or more than 60-day datasets while keeping processing times manageable. The move towards a more optimized, parallelized processing setup has dramatically reduced computation time, making it feasible to pro-

cess larger datasets in shorter time-frames and thus proportionally improving the preliminary objective of viewing changes in malicious activity over time. Particularly parallelization of K-means clustering and t-SNE visualization, have enabled us to perform near real-time clustering and analysis on large-scale datasets, ensuring more efficient and scalable threat intelligence processing.

To conclude, HPC and GPU accelerated Embedding, Clustering, visualization have proven essential for scaling up the analysis of network telescope data over longer duration's up to 180 days. The results are shown below for 60-days with visualization in mind. Figure 2.1 provides a t-SNE plot of clustered data for one day, one week, one month and two months' period, including table for breakup of computational time for various activities. It may be noted processing time is linear function of number of data records. SBERT & t-SNE are the major contributors for computational effort.

Figure 2.2 compares the computational time on HPC for normal & optimized procedures used, clearly showing the drastic computational time reduction by optimization.

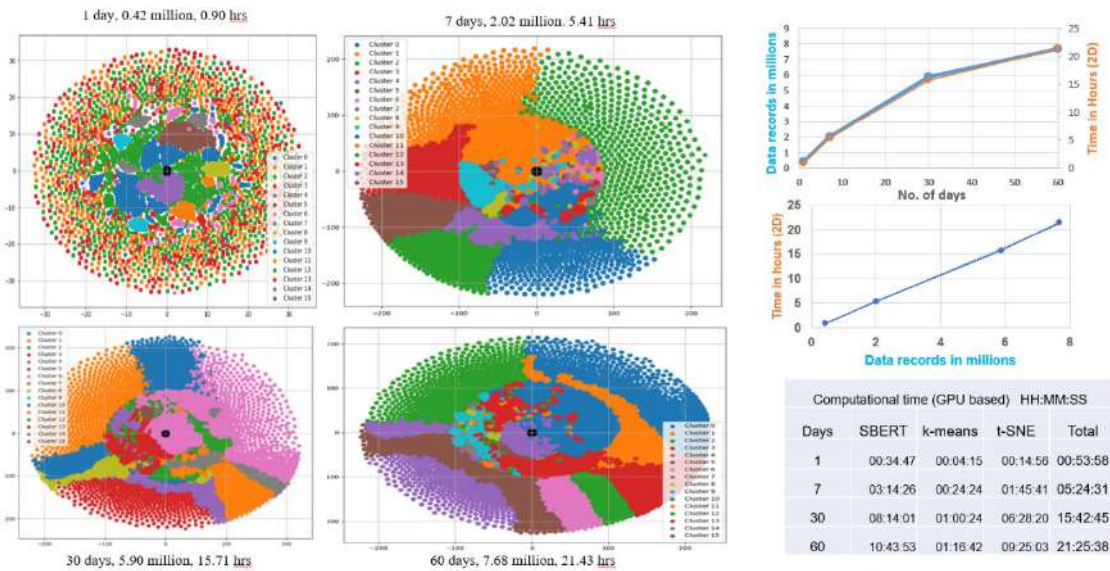


Figure 2.1: t-SNE plots for data spanning from one to sixty days.

Prajwal, V Anil Kumar, Nallana Mithun Babu and H N V Dutt

2.2 Semantic Clustering and Vector Database Integration for Threat Intelligence

Vast amounts of scanning traffic captured from a wide range of malicious threat actors at network telescopes provide a powerful resource for proactive mitigation of Cyber threats. However, effectively extracting timely, actionable threat intelligence from this massive volume of darknet data remains a significant challenge. We explore the applicability of artificial intelligence (AI) techniques to mitigate these challenges and provide actionable threat intelligence from large-scale darknet data. In this work, K-means clustering technique has been applied to analyze active network telescope

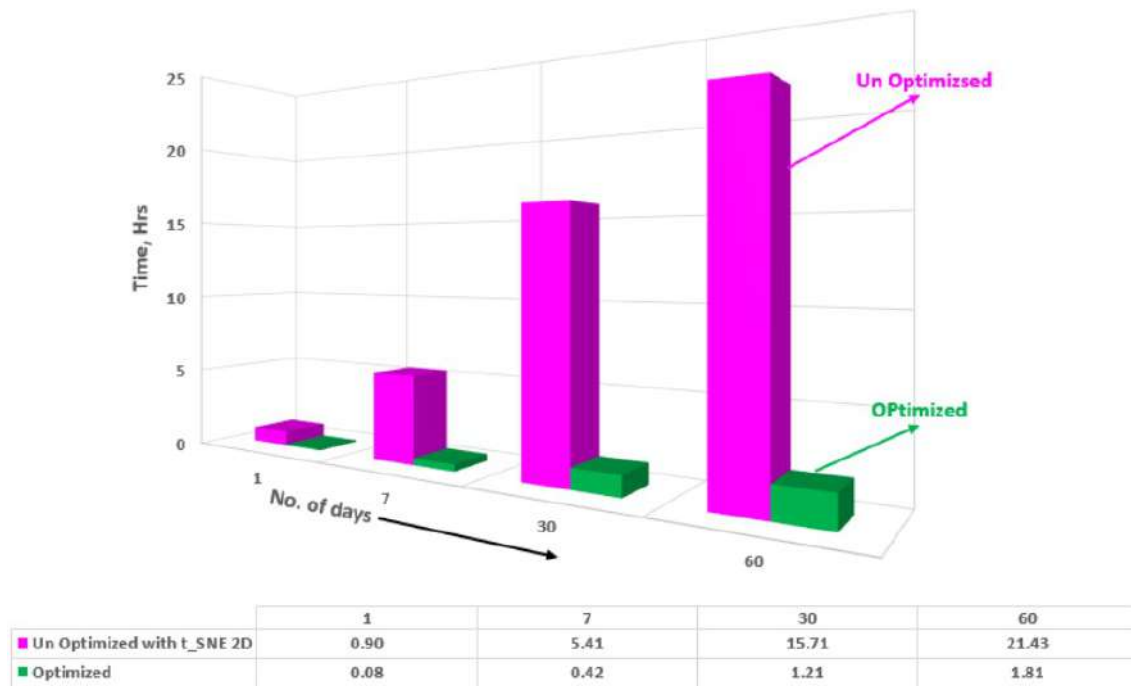


Figure 2.2: Comparison of the computational time on HPC for normal & optimized procedures.

data, specifically focusing on malicious payloads. Due to their textual and often complex structure, Natural Language Processing (NLP) techniques have been utilized to convert these payloads into meaningful vector embeddings that preserve semantic relationships. To operationalize these insights and support real-time threat correlation, a vector database capable of performing high-performance similarity searches across the clustered embeddings has been integrated. This enabled scalable and efficient comparison between new incoming threat data and historical patterns from sources such as past incident records and internal datasets. For fast and scalable vector search, Facebook AI Similarity Search (FAISS) has been employed—an open-source library optimized for efficient similarity search and clustering of dense vectors. Incoming threat payloads are embedded using Sentence-BERT (SBERT), and then compared against the centroids of known clusters using cosine similarity. Each new threat is evaluated based on its similarity score:

- If the similarity score is high (above a defined threshold), the threat is likely a known or recurring pattern.
- If the score falls below the threshold, the payload is flagged as a potentially novel threat, warranting further analysis.

This score-based filtering mechanism allows us to automatically distinguish between familiar threats and anomalous behavior, supporting proactive threat hunting and reducing analyst burden. If a time marching approach is adopted at predefined intervals, this could be potentially used to generate triggers automatically to alert any regulatory authorities by automating the process. Shown in Figure 2.3 is a plot similarity score versus data point index between July 15th 2024 (1000 rows) and October 1st 2024 (4000 rows). Blue circles correspond to similarity score less than 60%, red

circles correspond to similarity score greater than 60%. It may be noted that similarity score approaching one implies that the payloads are almost 100% similar, whereas similarity score tending to zero means that the two pay loads are entirely different. Figure 2.4 gives a threshold sensitivity analysis of similarity scores. For example, a cosine similarity score below 0.6 implies that 15% of data points are possible new threats between these two days.

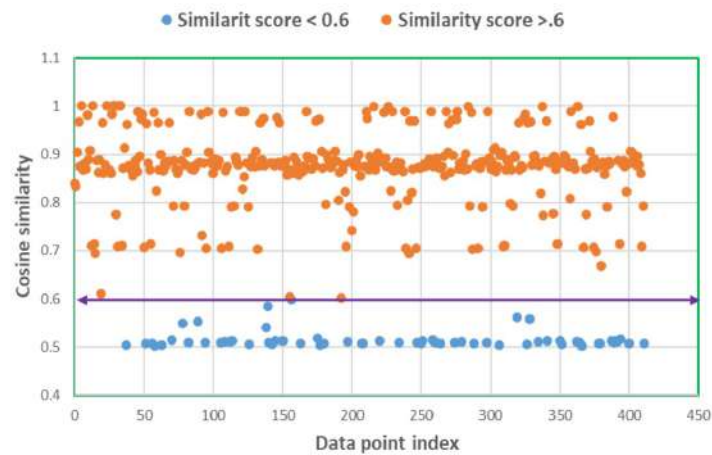


Figure 2.3: FAISS based threat classification.

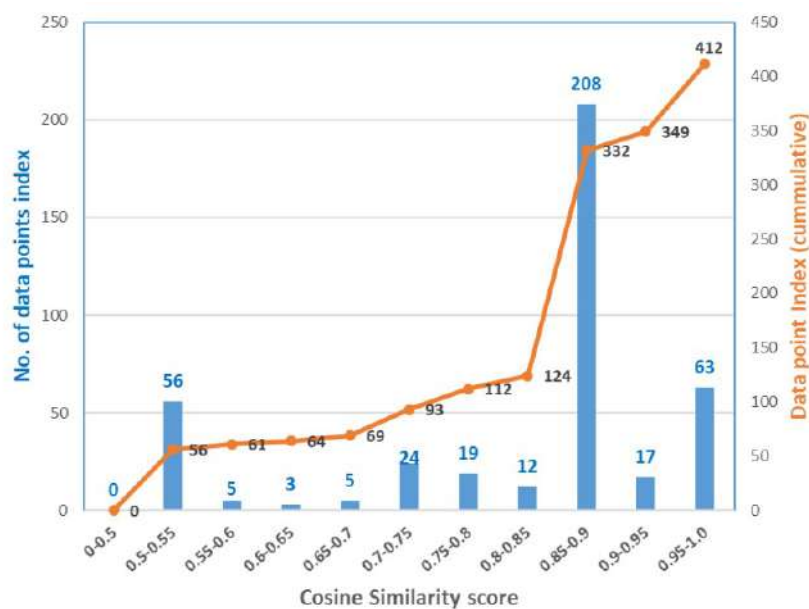


Figure 2.4: Threshold sensitivity analysis.

2.3 Building Resilient IT Infrastructure: Integrating Internal Network Security and Internet Redundancy

Integrating Internal Network Security

In the modern digital landscape, where cybersecurity threats are increasingly sophisticated, maintaining the integrity of internal networks is a critical priority. To ensure that no malicious activities are occurring within the organization, an activity has been initiated to check all internal network endpoints using ARP scanning. ARP scanning identifies devices on the local network by mapping IP addresses to MAC addresses, allowing to monitor which devices are connected at any given time. Automated ARP scanning has significantly improved our network visibility by maintaining an up-to-date inventory of connected devices. By comparing scan results with approved MAC address lists, it enables real-time detection of unauthorized or rogue devices, flags anomalies such as IP/MAC spoofing, and ensures compliance through regular logging and reporting. This implementation enables the detection and removal of unauthorized devices, along with faster threat response and improved asset tracking for audit readiness. Automated ARP scanning has proven to be a valuable addition to our cybersecurity toolkit. It supports our ongoing commitment to safeguarding organizational assets, ensuring data integrity, and fostering a culture of security awareness. As our IT infrastructure continues to evolve, such proactive security measures will remain a cornerstone of our digital resilience strategy.

Internet Redundancy

In today's digital world, internet connectivity is the backbone of nearly every business operation. Many organizations still rely on a single internet service provider leaving vulnerable to unexpected outages that can disrupt operations and damage organization's reputation. For an organization that hosts cloud infrastructure and provides High Performance Computing (HPC) facilities to the entire CSIR (Council of Scientific and Industrial Research), a single point of failure in internet connectivity could halt crucial research computations, interrupt access to shared resources, and impact users across multiple laboratories and research institutions. Implementing redundant internet links ensures that the organization stays connected even if the primary connection fails. This secondary link, ideally from a different ISP automatically takes over in the event of an outage. This setup not only minimizes downtime but also supports seamless operation of cloud services and uninterrupted access to HPC resources.

Gutta Jahnavi, V Anil Kumar and Md Talib Hasan Ansari

2.4 Stitching the Shadows: Multi-Packet Payload Analysis and the Mozi Botnet's Exploitation of IoT Devices

Unveiling Hidden Threats: Multi-Packet Payload Analysis in Darknet Traffic

In the analysis of network telescope data, identifying malicious activity often involves examining payloads that do not reside within a single packet. This is because of many forms of cyberattacks, particularly those involving exploitation or malware delivery which are transmitted over multiple packets due to size limitations inherent in protocols like TCP/IP. For instance, the Maximum Transmission Unit (MTU) restricts the size

of each packet, requiring larger payloads to be split across several transmissions. As a result, simply inspecting individual packets in isolation can miss the broader context or intent of the attack. To derive meaningful insights from this fragmented data, we must reassemble these packets into complete streams. TCP reassembly is a critical step in this process, allowing the reconstruction of application-layer data such as HTTP requests, shell commands, or binary payloads. For example, an attacker might send part of a shell command in one packet and complete it in another, then only by stitching these fragments together can the full command such as a call to download and execute malware is being revealed. Reassembled payloads are used to analyze and identify known attack signatures, malware variants, or Indicators of Compromise (IOCs), which are essential for threat intelligence and defense strategy. Without this reconstruction, critical details of an attack can remain hidden within fragmented traffic, leading to missed detections or incomplete forensic insights.

Insights from Malicious Payload Used in Mozi Botnet Attack The payloads observed in the network telescope data indicate a coordinated and malicious campaign targeting vulnerable IoT devices, with strong ties to the Mozi botnet. Attackers are exploiting known vulnerabilities in services such as UPnP and CGI scripts like `board.cgi` to gain unauthorized access. A key tactic includes sending POST requests to endpoints like `picsdesc.xml`, attempting to manipulate configuration files related to UPnP, which allows automatic port forwarding—exposing internal services to the internet. Additionally, command injection techniques using parameters like `desthost=` are employed to download and execute malicious binaries such as `Mozi.m`, which is saved as `/tmp/gpon80` and then executed. These payloads are associated with Mozi variants like `Mozi.a` and `Mozi.m`, which are designed to compromise IoT devices and integrate them into a large-scale botnet. Once infected, the device establishes communication with a peer-to-peer command-and-control (C2) network, allowing it to participate in DDoS attacks, perform data exfiltration, or propagate the malware across the network. This campaign demonstrates a full-fledged malware deployment phase, showcasing the attacker's intent to take over devices, maintain persistence, and scale a botnet infrastructure for disruptive or strategic cyber operations.

Gutta Jahnavi, V Anil Kumar and Md Talib Hasan Ansari

2.5 Steps towards enhancing Organisational Cybersecurity Posture

Implementing High Availability Firewall: A Critical Step High Availability (HA) firewalls are vital for ensuring uninterrupted network security. When the firewall is a single point of failure, downtime can disrupt operations, expose vulnerabilities, and impact business continuity. HA provides redundancy by automatically switching to a secondary unit during failure, maintaining seamless protection. However, configuring HA demands precision, any misstep can cause synchronization issues, failover loops, or even complete outages. Proper planning, testing, and documentation are essential. It is crucial to note that the existing firewall has been upgraded and additional firewall has been deployed to achieve high availability network service at CSIR-4PI.

Open Source Syslog Deployment: Enhancing Log Management Deploying an open

source syslog solution is a smart move for scalable, cost-effective log management. It enables centralized logging from network devices, servers, and applications, simplifying monitoring, auditing, and troubleshooting. Tools like rsyslog, syslog-ng, or Graylog offer flexibility and integration with alerting and analytics platforms. However, successful deployment requires careful configuration—defining log sources, setting proper filters, and securing log transport to prevent tampering. Open source solutions empower organizations with transparency and control but demand attention to detail for stability and compliance. rsyslog has been configured successfully to receive logs from critical devices. Enhancements are in progress. Syslog provides a powerful foundation for proactive infrastructure monitoring and incident response.

Scanning Endpoints for APT IOCs During Vigilance Awareness Week: As part of Vigilance Awareness Week, a comprehensive scan of all endpoints was conducted to detect Indicators of Compromise (IOCs) related to modern Advanced Persistent Threats (APTs). APTs operate silently, often bypassing conventional security, making proactive detection essential. Using updated threat intelligence and Endpoint Detection and Response (EDR) solutions, the initiative aimed to uncover hidden threats and enhance organizational resilience. This exercise emphasized the importance of continuous monitoring and timely threat hunting. Conducting such scans during Vigilance Week reinforces a culture of cybersecurity awareness and accountability, ensuring that security isn't just a practice—but a mindset across the organization. The activity was concluded with no presence of IOCs in any endpoint.

Md Talib Hasan Ansari, V Anil Kumar, and Gutta Jahnavi

2.6 Network Telescope Data Analysis Mapped to the Cyber Kill Chain

CSIR-4PI hosts an indigenously developed active Network Telescope to generate real time threat intelligence by automatically collecting and analysing malicious data from Internet Background Radiation (IBR). As part of a proactive research initiative, Network Telescope data was analyzed and mapped against the Cyber Kill Chain to better understand attacker behaviours and the stages of intrusion targeting Cyber space environments. Network Telescope sensors deployed across unused IP space, passively collect data on unsolicited traffic, such as scans and probes, providing a valuable window into global threat activity. The analysis revealed a consistent pattern of malicious behaviour that aligned with several stages of the Kill Chain framework developed by Lockheed Martin as depicted in picture below. The above picture mapping of a malicious payload extracted from the Network Telescope database. In the Reconnaissance stage, widespread scanning activity targeting specific ports and services was observed—clearly indicating adversaries searching for exploitable Cyber space assets. Weaponization and Delivery were inferred from payload patterns and connection attempts to exposed services, suggesting the delivery of malware or exploits targeting known vulnerabilities.

During the Exploitation and Installation phases, attempts to establish persistence through command-and-control (C2) call-backs using netcat listener was detected. While the complete payloads were not captured, traffic patterns and behavioural indi-

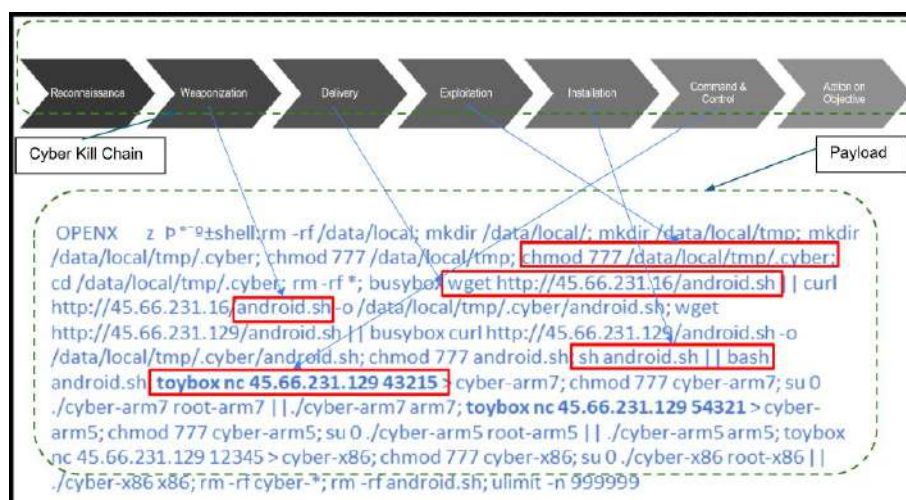


Figure 2.5: Mapping to Cyber Kill Chain.

cators provided strong evidence of attackers preparing for the Command-and-Control phase. Finally, while Actions on Objectives could not be directly observed, the nature of the attempted connections suggested data exfiltration or lateral movement objectives.

Mapping these activities to the Kill Chain allowed for a more structured understanding of threats and helped identify key defensive gaps. This exercise demonstrated how passive telemetry, when correlated with established threat models like the Cyber Kill Chain, can provide actionable intelligence to enhance detection, prevention, and response strategies. The findings emphasize the importance of threat-informed defense planning and reinforce the need for continuous monitoring and analysis to stay ahead of modern cyber adversaries.

Md Talib Hasan Ansari, V Anil Kumar, and Gutta Jahnavi

3. Domain Agnostic Data Sciences and AI Research

CSIR-4PI's Domain Agnostic Data Sciences and AI Research focuses on developing fundamental data science and artificial intelligence methodologies that can be applied across a wide array of scientific and engineering fields. This research is not tied to a single domain, but rather aims to create versatile, scalable, and robust algorithms and platforms for data-driven discovery. The core of this initiative lies in exploring and advancing foundational areas of machine learning, deep learning, and statistical modeling to tackle challenges inherent in large-scale, complex datasets, regardless of their origin.

The research team at CSIR-4PI works on developing novel techniques for data assimilation, feature engineering, predictive modeling, and pattern recognition that are transferable across diverse applications, from earth and environmental sciences to healthcare and materials science. A significant aspect of their work involves creating sophisticated data analytics platforms that can ingest, process, and analyze heterogeneous data streams, enabling researchers to extract meaningful insights and build predictive models without needing to be experts in the underlying computational technologies. By concentrating on the development of these core, domain-agnostic capabilities, CSIR-4PI is empowering a broad spectrum of researchers to leverage the power of AI and big data, thereby accelerating scientific innovation and addressing complex real-world problems.

Inside:

1. Development of Custom Android Application for field data collection to generate low-cost farmer services for disease and pest management.
2. Diffusion Model to generate high quality synthetic face images Detection of Sybil Attacks in 5G-Enabled VANETs Using Image-Based Anomaly Detection: A Simulation Study in Bengaluru
3. Leveraging Generative Modeling for Traffic Image Generation
4. Benchmarking and Performance Assessment of WRF on CHAMP.

5. Multi-Sensor Satellite Image Cloud Classification with Deep Learning
6. Image Annotation to help machine learning models

3.1 Development of Custom Android Application for field data collection to generate low-cost farmer services for disease and pest management.

India centric Agricultural Datasets, especially those collected on-field play a key role in development and benchmarking of various Classical and Machine Learning Models. As per Annual Status of Education Report (ASER) 2022, 74.8% of rural households has a smartphone and application based services through these smart phones is helpful in decision making at their farm field. With this objective, as part of Region Specific Smart Agro Technologies Mission mode project, we started collecting the disease and pest datasets from farmer fields selected under the project. Unlike the openly available existing datasets, this data set is collected in various farmer fields distributed across India, for diverse crops, weather conditions, disease, and pest infestations. To make the dataset more balanced, data is also being collected from experimental farms in collaboration with UAS, Bangalore.

For the manual field data collection, a custom Android application has been developed by the project team that can be installed across various devices starting Android Jelly Bean (Version 4). The features of Android application is as follows: I) The landing page consists of crop selection, field location, date of data collection. Once these details are populated by Agronomist, she/he can move to next screen where mobile camera with manual focus is used to collect the RGB image. II) The collected image can be healthy or one of few crop-specific diseases prevalent in Indian fields. The disease label information along with time-stamp, geo-tag and other meta data is saved into an organized directory structure. III) Google Drive sync feature enables incremental data sharing and centralizing the data collection process. Once data is collected, it is rigorously validated for quality and the pre-processed data is internally distributed through data version control management system for AI/ML groups for further modelling. The final aim is to release a copyrighted dataset for public/research use. IV) The current version of Application is 4.2 (4th Major Version with 2nd Revision) and has been under continuous improvement with feedback from on-field data collection team.

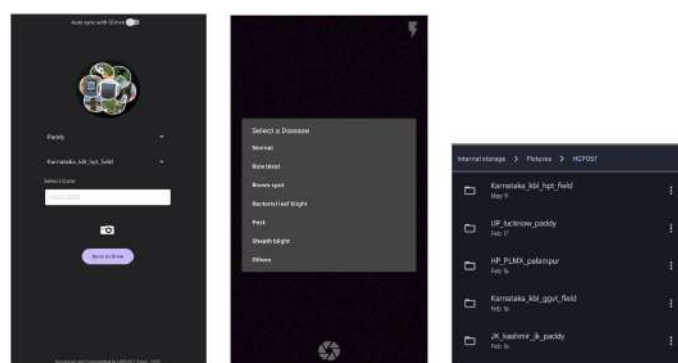


Figure 3.1: Screen capture of various pages of developed android application, folder structure and sample data.

N. Mithun Babu, Sri Hari, Hemanth, Dhanjay, And V. Rakesh

3.2 Diffusion Model to generate high quality synthetic face images

We have implemented diffusion model to generate high quality synthetic face images. A diffusion model consists of three major components: a forward process, a reverse process, and a sampling procedure. The aim of diffusion model is to learn a diffusion process that generates a probability distribution for a given dataset from which we can make sample images. The model learns the latent structure of a dataset by modelling the way in which data points diffuse through their latent space. The model is trained to reverse the process of adding noise to an image. After training to convergence, it can be used for image generation by starting with an image composed of random noise for the network to iteratively denoise. In forward process, Gaussian noise will be gradually added to the original images to make them pure noise images. In reverse denoising diffusion process, neural network is trained to gradually denoise an image starting from pure noise, until it generates actual image. Fig 1 shows the block diagram of diffusion model.

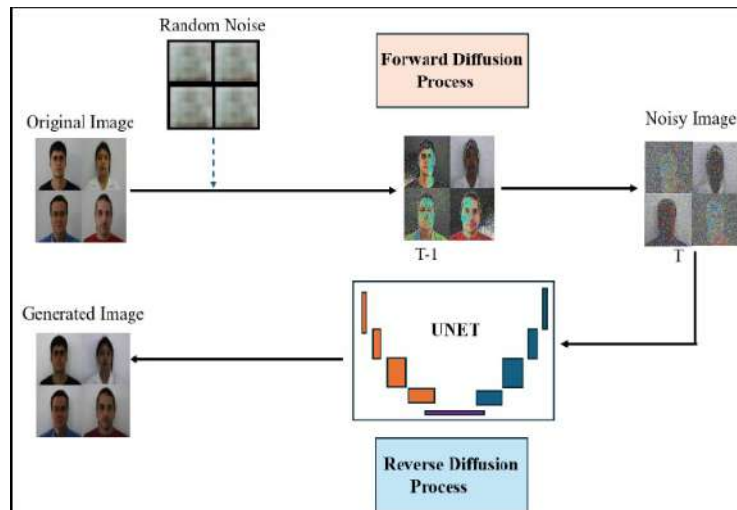


Figure 3.2: Block diagram of Diffusion model.

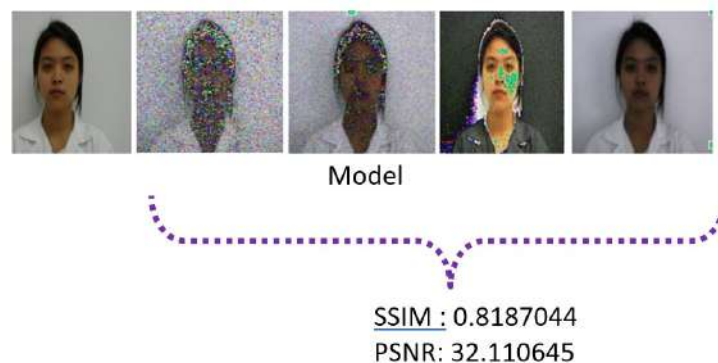


Figure 3.3: Synthetic face image generated by using Diffusion.

3.3 Detection of Sybil Attacks in 5G-Enabled VANETs Using Image-Based Anomaly Detection: A Simulation Study in Bengaluru

In the evolving landscape of intelligent transportation systems, 5G-enabled Vehicular Ad Hoc Networks (VANETs) have emerged as a critical component for enabling real-time communication between vehicles and infrastructure. These networks enhance road safety, traffic efficiency, and support autonomous driving by facilitating high-speed, low-latency data exchange. However, the decentralized and dynamic nature of VANETs also introduces significant security challenges. One of the most concerning threats is the Sybil attack, where a malicious vehicle forges multiple fake identities (Sybil nodes) to manipulate traffic information, disrupt routing protocols, or deceive nearby vehicles. Such attacks can severely compromise the reliability and safety of VANETs, leading to traffic congestion, accidents, or system-level failures. Detecting and mitigating Sybil attacks is therefore crucial for maintaining the integrity of vehicular networks, especially as 5G connectivity expands the capabilities and complexity of these systems. As part of the AITS Mission mode project, Sybil attack identification has been successfully implemented in a 5G VANET scenario on the simulator. Both real and virtual vehicles were simulated to implement a Sybil attack scenario in a map of Bengaluru. In Figure 1, three real vehicles are represented as node[0], node[1], and node[2], while two virtual vehicles, created by an attacker, are marked with red circles. Each vehicle transmits traffic view images from its driving viewpoint at pre-defined time intervals. The simulation effectively models real-world traffic conditions and adversarial behaviors, enabling controlled experimentation of attack scenarios. Each vehicle runs a local anomaly detection algorithm to identify Sybil attacks. When

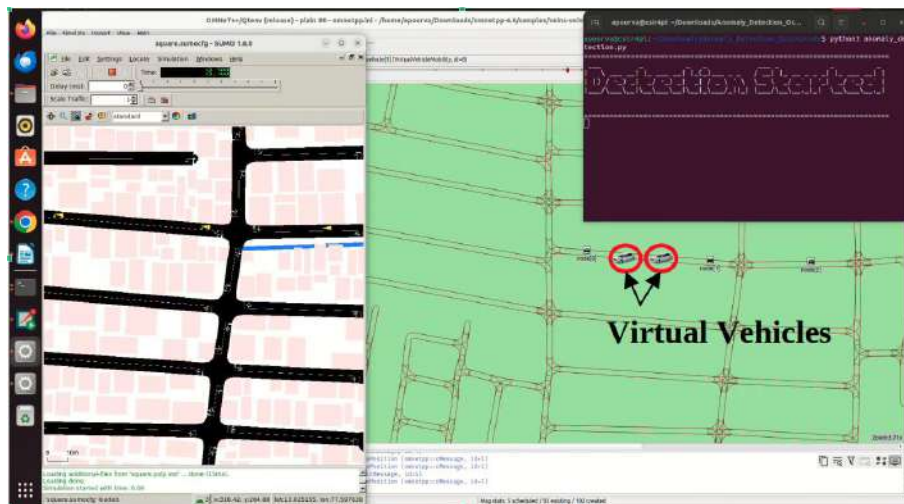


Figure 3.4: SReal & Virtual Vehicles.

vehicles receive images, they are analyzed to detect inconsistencies indicative of an attack. For example, vehicle 1 acts as the attacker, introducing two virtual vehicles and initiating the attack at a specific time. In Figure 5.17.a, the attack is triggered as the attacker transmits images from a real dataset to deceive the system. Figure 5.17.b demonstrates successful anomaly detection, where the vehicles identify the attack and revert to their normal path.



Figure 3.5: (a) Attacker sends messages to other vehicles (b) Anomaly detected and vehicles moving on their usual path.

Gaurav Melkani, Apoorva Jangir, Nallana Mithun Babu, Nagarathna R, and Gopal Krishna Patra

3.4 Leveraging Generative Modeling for Traffic Image Generation

Generative modeling has emerged as a powerful tool in computer vision, enabling the creation of highly realistic synthetic images that closely mimic real-world scenarios. In the context of vehicular networks, such models can be exploited to simulate advanced adversarial attacks, such as Sybil attacks, with increased realism and complexity. Generative Adversarial Networks (GANs) and diffusion-based models have demonstrated the capability to produce images that are visually indistinguishable from real camera data, posing significant challenges to conventional anomaly detection systems.



Figure 3.6: Generated Images (Unconditional – StyleGAN3).

As a part of the AITS Mission, we study the application of StyleGAN3 for unconditional image generation, producing high-fidelity synthetic road views that enhance the visual realism of virtual (Sybil) vehicles in a simulated 5G VANET environment. To further improve temporal coherence, conditional image generation is implemented using the Brownian Bridge Diffusion Model (BBDM), which predicts future road scenes based on the current visual input. This method ensures the generation of temporally consistent and contextually accurate images, enabling seamless integration into real traffic environments. As a result, the simulated Sybil attacks become more convincing and challenging to detect, effectively testing the resilience of anomaly detection systems under sophisticated adversarial conditions. Figures 5.18 & 5.19 shows a sample of generated images using unconditional and conditional GANs respectively.



Figure 3.7: Shows a sample of generated images using BBDM conditional GAN.

3.5 Benchmarking and Performance Assessment of WRF on CHAMP.

As part of the performance evaluation of the numerical weather prediction (NWP) models, the WRF Working Group 2 (WG2) established a benchmarking protocol to assess the computational performance and scalability of the Weather Research and Forecasting (WRF) model across different computing platforms. The benchmarks were designed to measure model integration speed while deliberately excluding initialization and input/output (I/O) overhead. Two standardized test cases were defined: a 48-hour simulation over the Continental United States (CONUS) at 12 km resolution for October 2001, and a 9-hour simulation at 2.5 km resolution for June 2005. Users were required to download the official WRF benchmark code https://www2.mmm.ucar.edu/wrf/users/benchmark/v44/benchdata_v44.html, compile it with NetCDF and MPI libraries, and run the simulations using the provided namelist and input data files. Performance metrics included simulation speed, defined as the ratio of model time step to average integration time per step, and floating-point performance (GFLOPS), computed from operation counts and runtime statistics. Output accuracy can be verified against reference outputs using WRF's `diffwrf` utility provided within the suite. Submissions included configuration files, system details, log files, and difference statistics, providing a consistent framework for comparing HPC system performance for WRF.

Following this standard, a comprehensive benchmarking exercise was conducted on the CHAMP HPC cluster using the 12 km CONUS test case from the official WRF (version 4.4) benchmark suite provided by the University Corporation for Atmospheric Research (UCAR). The benchmark evaluated parallel integration performance by measuring the average simulated per real second during a 12-hour window, excluding initialization and I/O. Tests were run on CHAMP's dual-socket AMD 64-core (Zen 3, 3.24 GHz) nodes with 128 cores per node, 192 GB RAM, and an InfiniBand interconnect. To assess compiler performance and numerical consistency, WRF was compiled and executed using AOCC 4.2.0 (AMD LLVM 16.0.3), with identical input data, domain configuration, and 144 MPI tasks (single domain, 12 km grid spacing, 425 x 300 process grids, 144 MPI tasks). The test results have been compared with their outputs in GCC 10.1 and Intel ifort/icc 2019.1.1, using them as reference data.

Performance Results: The average simulation speeds (in model seconds per real second) from the `rsl.out.0000` logs revealed that the AOCC-compiled WRF achieved a consistent 4× speedup over the GCC build and outpaced the Intel build by 2× as well. Across repeated trials, the average time to compute is 0.3578 seconds per time step by AOCC, 1.5730 seconds by GCC, and 0.8459 seconds by Intel. This positions AOCC as both the fastest and most efficient compiler for WRF on our AMD-compatible HPC nodes, enabling rapid turnaround for high-resolution, ensemble, or any other resource-intensive experiments.

Numerical Consistency Assessment: To verify scientific integrity, outputs from the AOCC-compiled runs were compared against both GCC and Intel outputs using WRF's `diffwrf` utility and a custom Python script (provided by UCAR) computing variable-wise statistical differences (Min, Max, Average, Std Dev, Skew) using point-by-point verification to ensure that the two runs are consistently producing results within an acceptable range. One such comparison results are shown in Table 1 for AOCC vs. GCC; however, AOCC vs. Intel results are not included due to space constraints, which

also depicts a similar picture. Results showed that for all critical fields (wind speed, temperature, surface pressure, humidity, precipitation, etc.), differences remained negligible, well within expected floating-point variability limits across compilers.

- Mean differences were essentially zero (within 10^{-3} for primary variables).
- Standard deviations were consistent across comparisons.
- No physical field divergence or error growth was observed.
- The skewness values were minor, suggesting that AOCC did not generate any systematic bias.

Both AOCC vs. GCC and AOCC vs. Intel comparisons confirmed numerical reproducibility and physical consistency. The largest absolute differences occurred in rain and microphysics-related variables (typical for stochastic processes in numerical models) but remained within statistically acceptable tolerance. Conclusion: The AOCC compiler

Variable Name	Minimum	Maximum	Mean	Std Dev	Skew
U	-10.6277	19.2862	-0.000210039	0.231392	1.65478
V	-11.376	23.9736	0.000674232	0.234198	1.71401
W	-4.04098	2.41887	-1.87E-05	0.019635	-10.7711
T	-4.67627	7.1478	0.000386114	0.101105	-0.57818
P	-259.617	181.148	0.132798	2.89305	-1.5279
PB	-0.0546875	0.09375	0.00325833	0.0102593	3.18288
Q2	-0.00133208	0.00190005	-8.56E-07	6.47E-05	-0.123432
T2	-3.81308	2.23505	0.00373162	0.114143	-2.51918
TH2	-3.9512	2.23883	0.00322894	0.116833	-2.68862
PSFC	-135.312	107.164	0.498301	5.79438	-0.981502
U10	-3.15509	3.88884	-0.000219031	0.176597	0.227584
V10	-4.61104	7.03803	0.00503971	0.227992	4.80775
QVAPOR	-0.0040416	0.00315837	-4.84E-08	4.46E-05	-2.53086
QCLOUD	-0.001356	0.001516	1.90E-07	1.35E-05	6.77389
QRAIN	-0.000874345	0.00048638	-9.40E-08	4.79E-06	-32.3151
QICE	-0.000168187	0.000121111	-2.48E-08	8.92E-07	-5.09061
QSNOW	-0.00307697	0.00214498	-1.07E-07	1.59E-05	-19.3648
SMOIS	-0.088315	0.0333159	-1.77E-05	0.000685154	-36.0063
RAINC	-7.82732	8.26882	0.00223037	0.131298	1.7527
RAINNC	-9.06317	14.7662	-0.00951779	0.318226	0.961923
OLR	-68.1222	72.0783	0.704545	3.97794	0.56016
PBLH	-3177.24	3199.69	0.352566	157.722	0.0692412

Table 3.1: AOCC–GCC comparison statistics.

demonstrates clear advantages on AMD-based HPC infrastructure (achieving more than 4× faster integration speeds than GCC and more than 2× faster than Intel), outperforming both the compilers while preserving numerical integrity.

Recommendation: Based on these results, it is recommended that AOCC be adopted as the preferred compiler for WRF runs on CHAMP's AMD-compatible HPC partitions.

3.6 Multi-Sensor Satellite Image Cloud Classification with Deep Learning

This study presents a deep learning framework for automatic classification of multi-sensor satellite images into “cloudy” and “cloud-free” categories, employing a MobileNetV2-based convolutional neural network. The model was systematically trained and fine-tuned on diverse datasets (IRS AWiFS, Landsat, Sentinel), leveraging advanced augmentation and transfer learning techniques to improve generalization across spatial resolutions.

Model performance was rigorously evaluated using key metrics such as accuracy, precision, recall, and F1-score. Notably, the proposed model achieved exceptional results, with overall accuracies exceeding 99.94% on AWiFS, 99.97% on Landsat, and 99.96% on Sentinel satellite datasets. A summary of the main performance metrics is provided in Table 1 of the paper, while the confusion matrix and associated precision-recall values further confirm the reliability of cloud detection, supporting the preprocessing pipeline for Earth observation projects. A comparative bar chart demon-

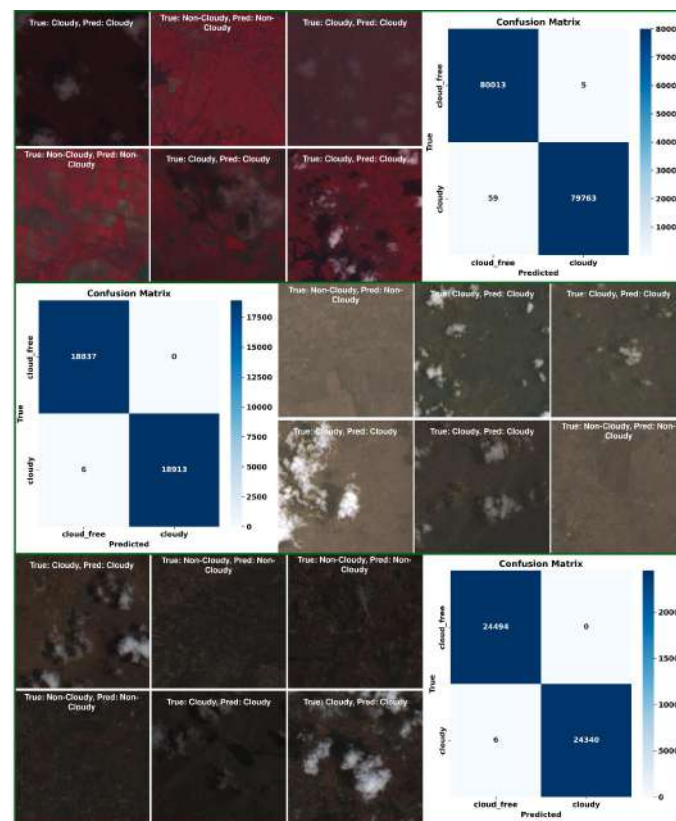


Figure 3.8: Multi-resolution satellite data classification for IRS, Landsat, and Sentinel datasets, with performance evaluation using confusion matrices.

strates that the MobileNetV2 architecture consistently outperforms other state-of-the-art deep learning models (VGG16, InceptionV3, Xception, ShuffleNetV2, EfficientNet-Lite4) in terms of accuracy across all datasets, reaffirming its suitability for operational cloud classification in remote sensing workflows. These results establish a scalable and

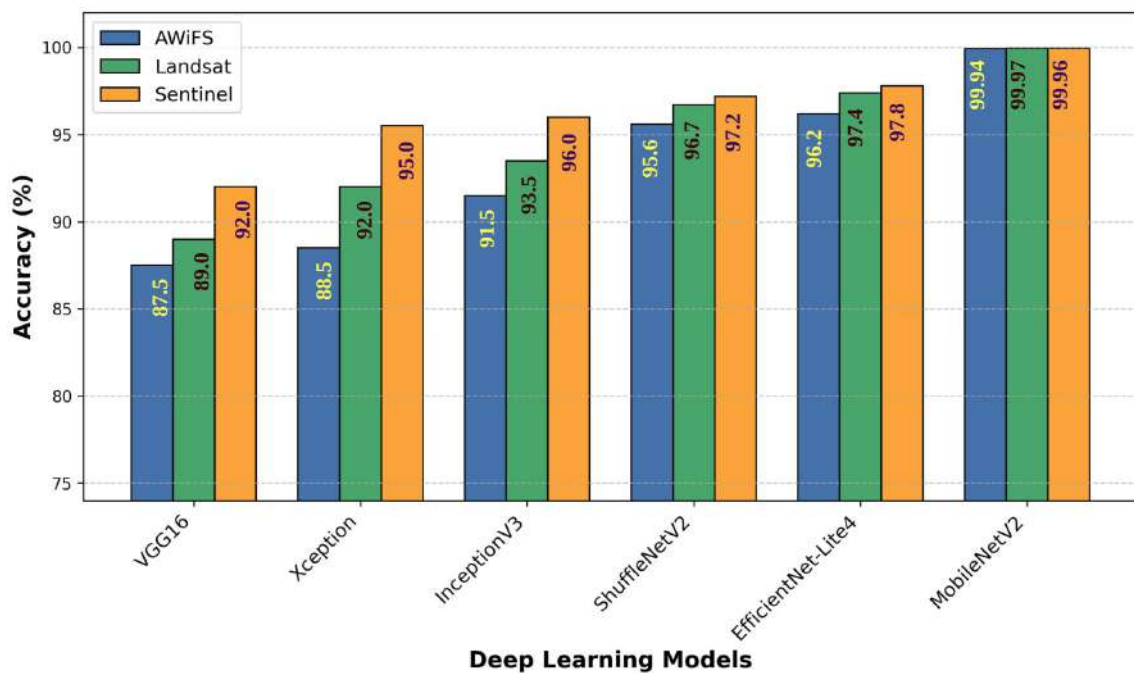


Figure 3.9: Multi-resolution satellite data classification for IRS, Landsat, and Sentinel datasets, with performance evaluation using confusion matrices.

robust methodology for cloud detection, directly supporting accurate land cover analysis, environmental monitoring, and multi-temporal satellite data applications.

Rakesh Asery, Burungale Swapnil Birudev, Pankaj Saini

3.7 Image Annotation to help machine learning models

Image annotation is a key step in computer vision that involves labeling or marking parts of an image to help machine learning models understand what is shown. This includes identifying and tagging objects, regions, or specific features within images using tools such as bounding boxes, polygons, key points, or segmentation masks. These labels are essential for training AI models to perform tasks like object detection, image classification, and semantic segmentation. Traditionally, image annotation is performed manually using software tools, where human annotators draw shapes around objects and assign corresponding labels. While effective, this manual process can be slow and labor-intensive, especially for large datasets.

To address these challenges, automated annotation methods are becoming increasingly popular. These involve the use of pre-trained AI models that can predict object locations and generate annotations automatically. In some cases, human review is applied afterward to correct or refine these predictions. Automation significantly speeds up the data preparation process, ensures greater consistency, and helps build large, high-quality datasets needed for training robust computer vision systems.

This work focuses on studying and analyzing Indian traffic using image data collected from the cities of Bangalore and Hyderabad. The primary goal is to detect and classify vehicles commonly found on Indian roads. To achieve this, we use pre-trained

object detection models such as YOLO (You Only Look Once) and Faster R-CNN. These models are commonly trained on the COCO dataset, which includes 80 standard object categories like person, car, bus, and bicycle.

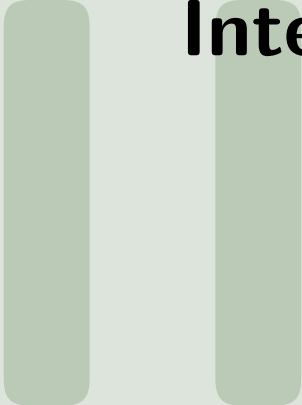
However, the COCO dataset does not include many vehicle types specific to Indian roads, such as auto-rickshaws, tempos, and tractors. As a result, standard models trained only on COCO are not able to detect these vehicles effectively. We evaluated several YOLO versions, including YOLOv3, YOLOv5, and others. Among these, YOLOv5 delivered the most reliable and accurate detection results. Its balance of speed, accuracy, and ease of use made it the ideal choice for further development.

To improve detection of Indian-specific vehicles, we plan to retrain the YOLOv5 model using a combined dataset: COCO Dataset: For common objects like cars, persons, and bicycles. Indian Driving Dataset (IDD): For Indian vehicles such as auto-rickshaws, trucks, tractors, and tempos. By training on this combined dataset, the model will be able to recognize both standard COCO classes and region-specific classes relevant to Indian road conditions.

The use of pre-trained models like YOLOv5 has greatly improved the speed and consistency of image annotation by automatically labeling common traffic objects. These models have reduced manual effort and supported accurate annotations when combined with human review. Future work will focus on improving model performance for region-specific vehicles using diverse Indian traffic data along with fine-tuning and domain adaptation techniques. Below shows some output annotated images.



Figure 3.10: Annotated Image.



Interdisciplinary Data Research

4	Advanced Weather & Climate Research	53
5	Geosciences & Engineering Research	75

4. Advanced Weather & Climate Research

The CSIR Fourth Paradigm Institute (CSIR-4PI) has a unique positioning in CSIR as the only lab involved advanced climate modelling R&D and its impact on multiple sectors like agriculture, health, water, energy, disaster management etc., focusing on the complex dynamics of the Earth's atmosphere and oceans. Leveraging its formidable high-performance computing (HPC) capabilities, the institute develops and runs sophisticated numerical models to improve the prediction of weather phenomena and understand long-term climate change, with a particular emphasis on the Indian monsoon. Researchers at CSIR-4PI are actively involved in improving regional and global climate models. Their work encompasses a wide range of topics including ocean modeling, data assimilation to integrate observational data into models for better accuracy, and studying the impact of climate change on extreme weather events. By combining theoretical knowledge with cutting-edge computational power, CSIR-4PI plays a vital role in providing crucial scientific insights for agriculture, water resource management, and disaster mitigation in India. Below are some of the major outcomes this year.

Inside:

1. Targeted Monitoring of 16 Indices for Improved Climate Forecasting
2. Measurements and Analysis of Greenhouse Gases
3. Local Wind Patterns on CO₂ Concentrations at Hoskote
4. Development of ML models for paddy disease detection for server-based and edge-device applications.
5. High-Resolution Coupled Agro-Meteorological Forecasting System at CSIR-4PI.
6. Unraveling the impact of atmospheric engineering on extremes through chemistry-weather-climate Interactions.
7. Particulate Matter Pollution in a Coastal Industrial City and its Impact on Human Health: A Generalized Additive Model Analysis
8. Sensitivity of microphysics parameterization approaches in WRF Model in simu-

- lating intensity and spatial distribution of Extreme rainfall over Bangalore, India
9. Impact of different land use data on WRF model short-range forecasts during pre-monsoon and monsoon seasons in India
 10. Relative Impact of Assimilation of Multi-Source Observations using 3D-Var on Simulation of Extreme Rainfall Events over Karnataka, India
 11. Sensitivity of orography and precipitation data in simulating streamflow over the Western Indian Himalayan region using SWAT model
 12. Understanding of Marine Carbon Dynamics in the Northern Indian Ocean through Coupled Physical-Biogeochemical Modelling – A Brief Note

4.1 Targeted Monitoring of 16 Indices for Improved Climate Forecasting

Understanding and predicting the El Niño–Southern Oscillation (ENSO) is crucial for global climate forecasting. Our extensive research has unveiled a novel approach to comprehending the intricate interplay between atmospheric and oceanic processes that drives ENSO dynamics. We have precisely identified specific geographic regions (Figure 4.3A) where atmospheric conditions—particularly east–west (zonal) and north–south (meridional) winds, and surface pressure fluctuations—exhibit high variability and exert a significant influence on ENSO.

For example, the observed weakening of zonal winds in the high–variance region of the first seasonal cycle of zonal wind (U1) plays a crucial role in facilitating the eastward propagation of the warm water pool in the Western Pacific. This, in turn, leads to a pronounced warming in the central and eastern Pacific, a hallmark feature of El Niño events. Furthermore, the occurrence of stochastic westerly wind bursts around the high–variance regions’ second (U2) and third (U3) seasonal cycles of zonal wind act as both a trigger and an amplifier of El Niño events, thereby intensifying the critical feedback loops between the atmosphere and the ocean. These bursts, by accelerating ocean–atmosphere interactions, significantly amplify subsequent anomalies.

Beyond winds, the high–variance regions of surface pressure (P) situated at both extremities of the Pacific basin are instrumental in modulating the Southern Oscillation. Changes in cross–equatorial southerly winds near the high–variance region of the first seasonal cycle of meridional wind (V1) directly influence the climatological cold tongue, further impacting ENSO variability. To provide a holistic and complete picture, the four seasonal cycles of SST, each representing distinct types of variability, collectively capture the crucial spatial co–variability within the tropical Pacific, offering an unparalleled and more comprehensive understanding of ENSO’s inherent complexity. Additionally, the prominent decadal signal identified in the first seasonal cycle of SST (S1) may well reflect the observed decadal fluctuations in the intensity of ENSO events.

Separating the effects of external forcings (such as anthropogenic climate change, solar variability, and volcanic eruptions) from internal climate drivers (like ocean–atmosphere interactions and oceanic gyre dynamics) on SST anomalies presents a significant challenge. Accurately estimating the contribution of internal variability is complicated by the intricate interplay of climate processes, overlapping signals across multiple timescales, and limitations in observational data. Further uncertainty arises from biases in representing teleconnections and non–stationary relationships within a warming climate.

We have found that the extraction of four seasonal cycles from each of the variables and sixteen indices (Figure 4.3B) representing the area–averaged time series in their high–variance region has effectively addressed these complex issues and has improved the accuracy of SST anomaly predictions. Thus, enhanced forecast skill by relying exclusively on predictors within the equatorial Pacific basin, thereby eliminating dependence on remote variables or complex internal forcing predictors.

Given these findings, we strongly recommend establishing a continuous monitoring program in these identified high–variability regions (Figure 4.3A). Such a program

would foster a more detailed understanding of atmospheric–oceanic links, enabling us to further refine seasonal climate prediction and push the boundaries of empirical climate forecasting.

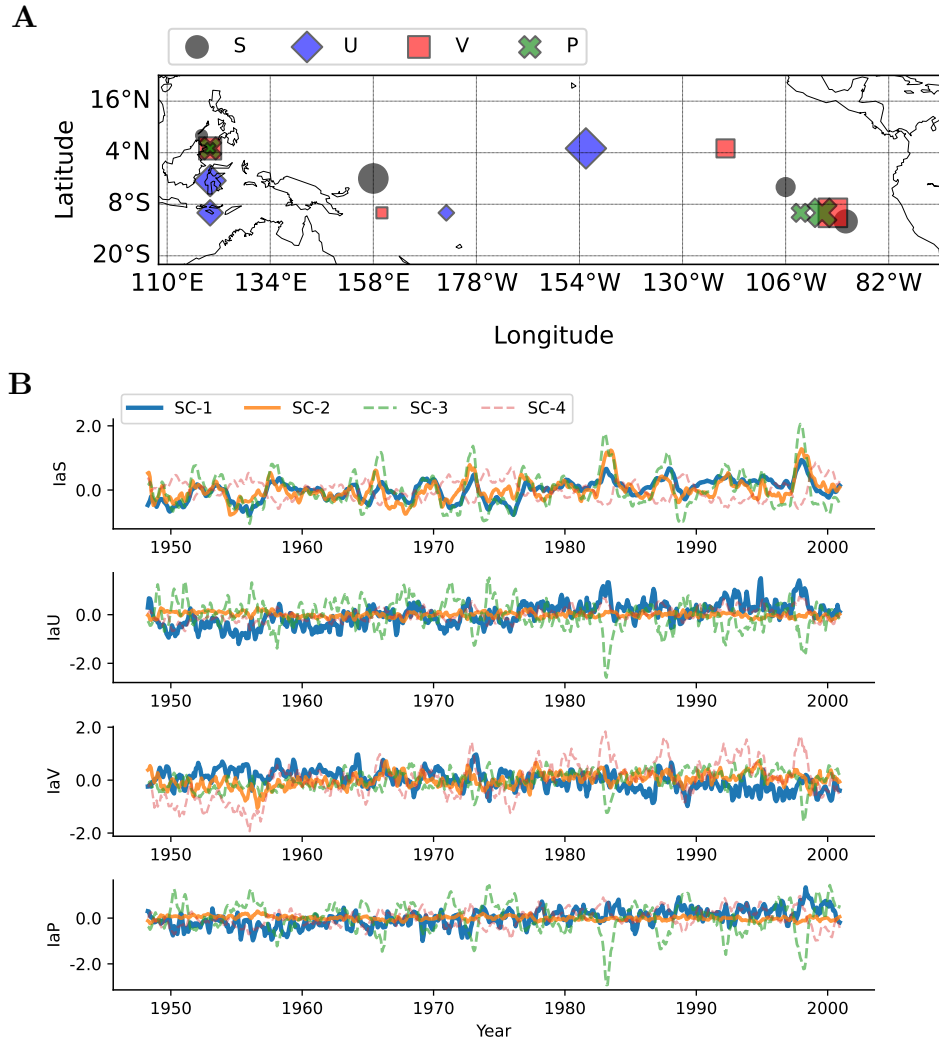


Figure 4.1: High-variance regions and area-averaged anomaly time series for 16 seasonal cycles (SC), encompassing four cycles for each variable: Sea Surface Temperature (SST, denoted as S), zonal and meridional wind components (U and V, respectively), and surface pressure (P). A illustrates key regions identified for targeted observations, where symbol sizes decrease from the first seasonal cycle (SC1) to the fourth seasonal cycle (SC4), indicating four high-variance regions per variable. B presents time series reflecting deviations from the corresponding long-term seasonal cycle. For SST, S1 captures the long-term warming trend, while S3 and S4 represent variability specifically associated with Eastern Pacific and Central Pacific ENSO events, respectively. The prefix 'la' denotes area-averaged anomalies.

4.2 Measurements and Analysis of Greenhouse Gases

The greenhouse gases (GHG) carbon dioxide (CO_2) and methane (CH_4) are continuously monitored as per the World Meteorological Organization (WMO) standards at the Hanle (HLE) and Hoskote (HSK) stations throughout the year. This ongoing measurement study plays a crucial role in identifying the sources and sinks in the region. In addition to continuous measurements, discrete air samples are collected at regular intervals, either to provide data coverage during outages in continuous monitoring or to correlate and validate the continuous measurements. Furthermore, meteorological instruments installed at both sites are utilized to analyze the relationship between GHG concentrations and local weather conditions aiding in the interpretation of observed variations.

NOAA's curve fitting method is applied to annual carbon dioxide (CO_2) and methane (CH_4) data measured at HLE and HSK to analyze the seasonal patterns, long-term trends, and to forecast future concentrations. The time series data is decomposed to extract the trend and seasonal cycle, while the residuals are analyzed to study inter-annual and short-term variations. To smooth the high-frequency noise, the residuals are first transformed into the frequency domain using Fast Fourier Transform (FFT). A low-pass filter is then applied, and the data is transformed back to the time domain using the inverse FFT. This process helps isolate the background concentrations of CO_2 and CH_4 , minimizing the influence of local sources (Figure 4.2). In this approach, the long-term growth is captured by a polynomial term, and the annual oscillations are modelled using harmonics of the yearly cycle.

At the HSK site, the mean background concentration of CO_2 in 2024 was approximately 426.62 ppm. Past observations indicate that CO_2 levels at this site have been increasing steadily at a rate of about 3–4 ppm annually. Similarly, the average CH_4 concentration in 2024 was about 2036.6 ppb with an observed annual increase of 16 ppb. At the HLE site, the CO_2 concentration in 2024 averaged around 423.23 ppm reflecting a lower annual growth rate of approximately 2.6 ppm per year compared to HSK. In case of CH_4 , the background concentration in 2024 was measured at approximately 1945.9 ppb with average increment of about 13 ppb annually. Figure 4.3

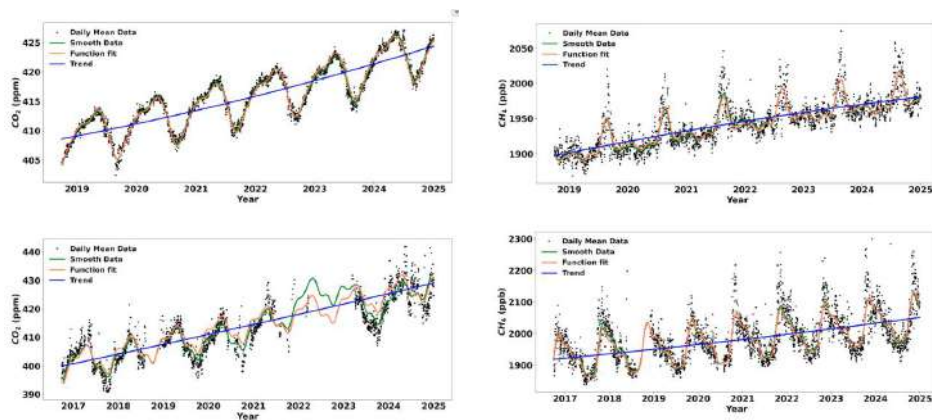


Figure 4.2: Background GHG concentrations at Hanle and Hoskote (a) HLE- CO_2 (b) HLE- CH_4 (c) HSK- CO_2 (d) HSK- CH_4

shows the growth rate of CO_2 in both the stations are increasing over time which indicates the accumulation of CO_2 in the atmosphere. Hanle shows a lower and steady growth rate whereas in HSK has a higher steady consistency. Hanle may be influenced by localized sinks, vegetation or lower emission sources nearby. Since Hoskote is closer to urban and industrial sources where the CO_2 uptake is lower. The spike in HSK suggests a potential regional emission event or any climate anomalies, indicating high emission of CO_2 compared to HLE. At HLE, CH_4 concentrations show a gradual decline in growth rate following a peak in 2020, which may suggest a reduction in emissions potentially linked to seasonal variability or changes in anthropogenic activity. In contrast, HSK exhibits a consistent annual increase in CH_4 levels, indicating sustained or rising emissions at the site.

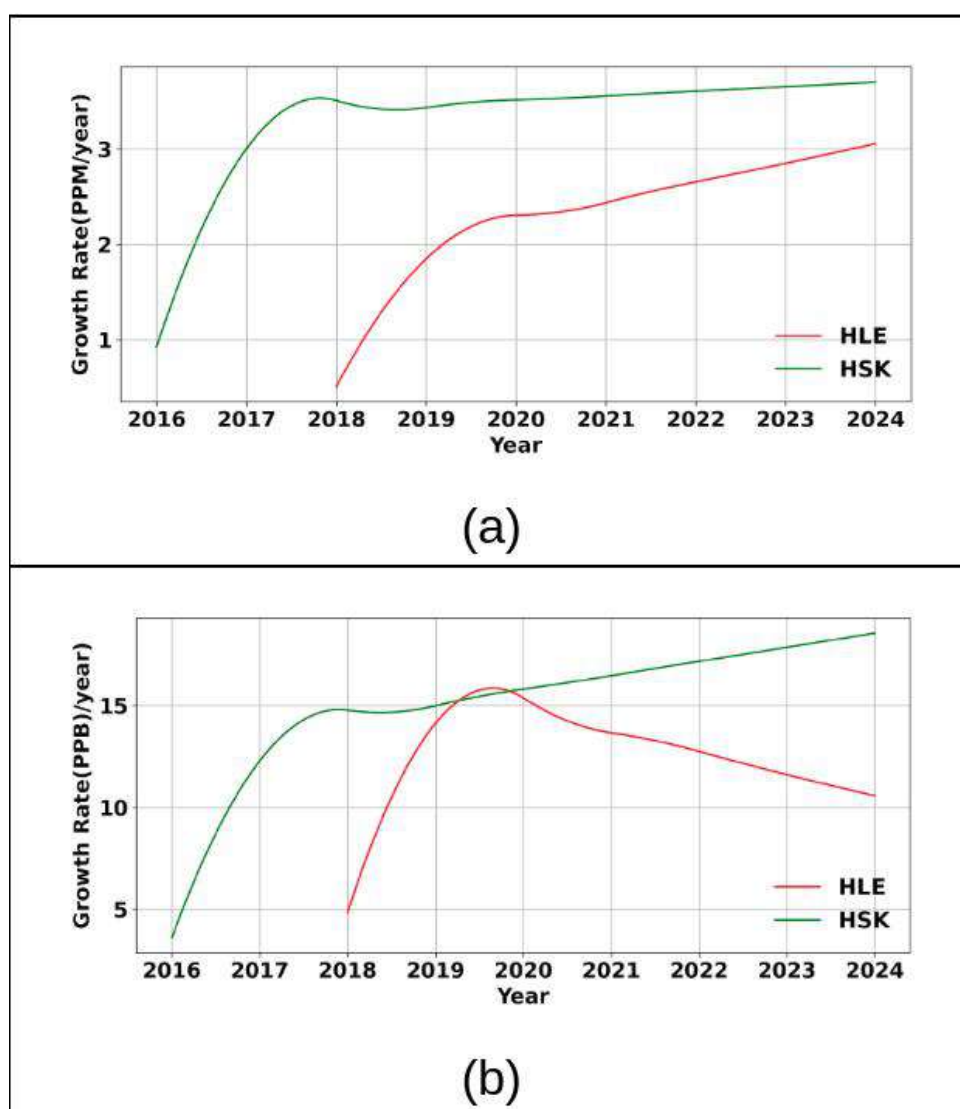


Figure 4.3: Growth rate of (a) CO_2 (PPM) (b) CH_4 (PPB) at HLE and HSK .

Lakshmikanthan P, Gayathri R, Vivekananda Hazra, Prasanna Konatham, Sumathy T,
Sunil Babu and Ravichandran C

4.3 Local Wind Patterns on CO₂ Concentrations at Hoskote

With the onset of the winter season, it is observed that the prevailing wind direction in Hoskote originates from the east and the higher CO₂ concentrations occur during periods of low wind speed (Figure 3 and Figure 4). There is east–west flow of wind which is prevailing during winter season. During winter, CO₂ levels range between 422 ppm and 440 ppm approximately, averaging to around 433.045 ppm. The wind speed at a 30m height averages 2.7 m/s during this season. During summer (MAM), CO₂ levels vary in the range of 425.5 ppm and 441.51 ppm, with winds blowing at 3.11 m/s mostly from the south and southeast. Monsoon season (JJA) sees westerly winds accompanying CO₂ levels ranging between 419 ppm and 437.94 ppm, with an average wind speed of 4.47 m/s. Post-monsoon (SON) brings back southern winds, with CO₂ levels between 418 ppm and 440 ppm with an average wind speed of 3.13 m/s. Summer seems to have more CO₂, while the monsoon has lower concentrations. The highest CO₂ concentration can be observed in summer and the lowest is observed during the post monsoon season at HSK. In HSK, methane (CH₄) concentrations reach the lowest during the monsoon and highest in winter among all seasons. In contrast to this, HLE CH₄ concentrations reach their peak during the monsoon season compared to other seasons.

The relationship between the wind and the transport of pollutant is described through the backward and forward concentration dispersion plots (Figure 5). All season's wind direction suggest that these winds are responsible for bringing pollutants into the region under consideration. The trajectories trace back the path of the wind to reveal the sources or regions from where the pollutants originate and are carried.

The Hysplit model is utilized to determine the dispersion movement of CO₂ within the Hoskote region across all four seasons. The emission rate is determined based on measurements obtained from the Picarro G2301 analyzer. The backward concentration extends approximately 120 km and exhibits significant variations across seasons. Except for the monsoon season, all other seasons experience higher concentrations represented by yellow in the plot.

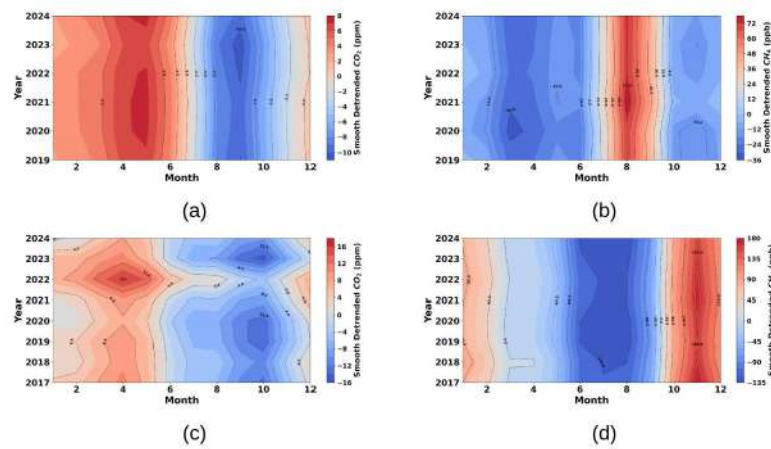


Figure 4.4: Smooth detrended concentration at Hanle and Hoskote a) HLE–CO₂ (b) HLE–CH₄ (c) HSK–CO₂ (d) HSK–CH₄

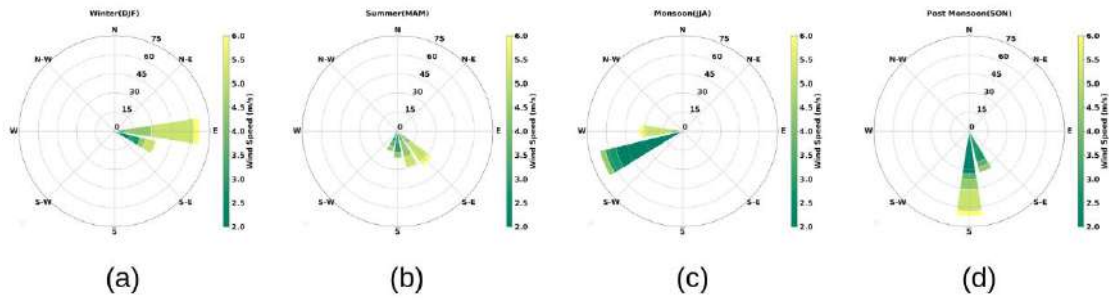


Figure 4.5: Seasonal wind direction and wind speed at HSK site (a) Winter (DJF) (b) Summer (MAM) (c) Monsoon (JJA) (d) Post Monsoon (SON).

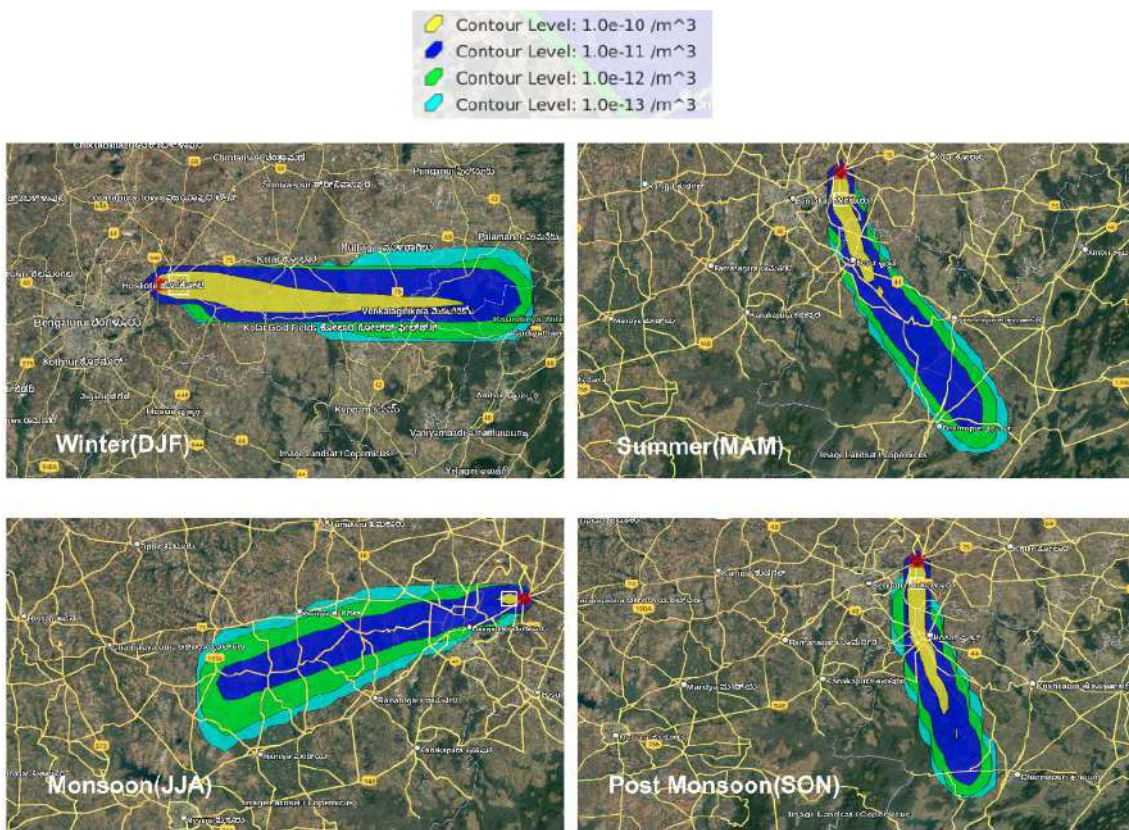


Figure 4.6: Seasonal CO₂ concentration dispersion using HYSPLIT for HSK site.

Lakshmikanthan P, Gayathri R, Vivekananda Hazra, Prasanna Konatham, Sumathy T, Sunil Babu and Ravichandran C

4.4 Development of ML models for paddy disease detection for server-based and edge-device applications.

Deep Learning has become a popular approach over the last decade to solve problems with image/video/complex input modalities. Early crop disease detection from images is one such problem where these approaches can be quite effective. As part of CSIR Mission project “Region specific smart agro-technologies for enhancing soil and plant health”, we are developing an entire modeling framework starting from ML model selection to deployable fine-tuned models that achieve >95% accuracy on openly available crop disease datasets.

Results shown here are from model training and validation on publicly available paddy doctor dataset <https://paddydoc.github.io/> and the fine-tuned model from this study will be further used for training and validation on the real farmer field paddy disease data collected as part of the ongoing mission project. The entire pipeline is briefed as follows: State of the art ML model families are compared for their accuracies (Top-1) on ImageNet dataset using Pytorch-image-models library [Deep Learning for Coders, 2020 by Jeremy Howard and Ross Wightman]. These accuracies along with inference time and model size are shown in Figure 4.7.

Each of these model families has models of various sizes and are trained using supervised or self-supervised approaches. So, ideally an ensemble of these models can provide different features necessary for disease prediction. Few selected sets of model

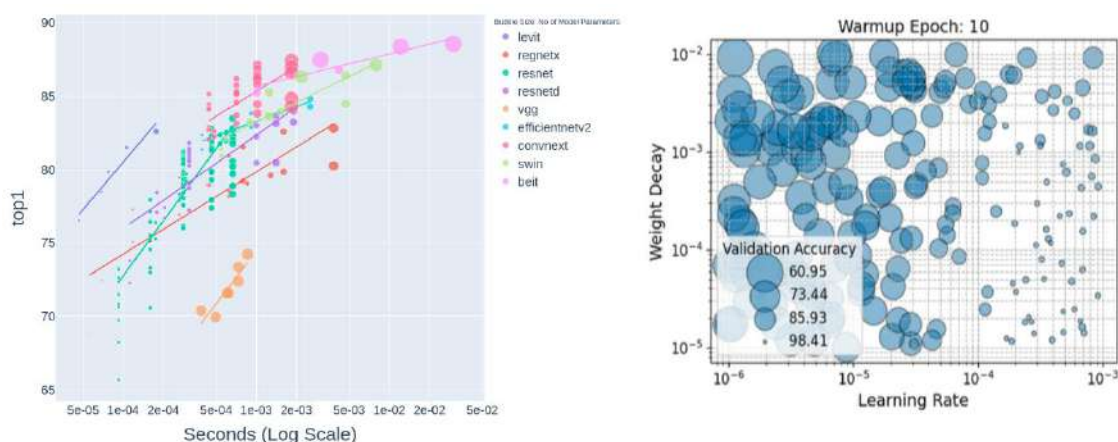


Figure 4.7: (a) Model accuracy vs inference time of various fore-front models with size of circle indicating no of parameters. (b) Accuracy of models during hyper parameter search (between warmup epochs, learning rate and weight decay).

families like BieT, LeViT, Efficient Net, Resnet, ConvNeXt, RegnetX are further screened for disease prediction with basic fine tuning without any extensive hyperparameter tuning. After this, the best performing models are finetuned with hyper-parameter tuning strategies. like selection of sensitive hyper parameters of a particular model from original work/extension literature.

A randomized grid search using a scheduler is deployed to find a region of suitable hyper-parameter space with high validation accuracy. Within this high-validation accuracy region, we select one set of hyper-parameters and perform Bayesian ap-

proach to find the optimal hyper-parameters. By hyperparameter tuning, we could achieve accuracy/recall of >95%. While model selection, we tried to keep a balance between accuracy and inference time so that a light weight version of the model can be deployed for real field application ported on server and run on edge devices such as Android mobile phones.

Meghashree, N. Mithun Babu and V. Rakesh

4.5 High-Resolution Coupled Agro-Meteorological Forecasting System at CSIR-4PI.

The ongoing project focuses on implementing a high-resolution agro-meteorological forecasting system for southern India by coupling the Weather Research and Forecasting (WRF) model with the Noah-MP (multiphysics) land surface scheme. The primary objective is to provide hyper-local forecasts of key agricultural parameters, including rainfall, temperature, soil moisture, evapotranspiration, and crop growth indices, thereby enabling improved irrigation scheduling, pest management, and yield prediction. The system downscales global forecast products, such as the National Centers for Environmental Prediction Global Forecast System (NCEP-GFS), using nested WRF domains, refining spatial resolutions from 9 km down to 333 meters over agriculturally significant regions, including Nagercoil, Kottayam, Mandya, and Hospete.

The WRF model setup employs version 4.6.1 of the Advanced Research WRF, integrated with Noah-MP (dynamic vegetation and irrigation modules). Seven nested, two-way interactive domains are configured, with lateral boundary updates at three-hourly intervals. The parent domain (d01) operates at a 9 km resolution, while the innermost nests achieve a grid spacing of 333 meters, allowing field-level weather simulations. The vertical grid comprises 48 levels, extending up to 50 hPa. Key physics options include the YSU planetary boundary layer scheme, WDM7 microphysics, RRTMG radiation schemes, and Kain-Fritsch convection parameterization for the coarse domains. Noah-MP configurations incorporate dynamic leaf area index (LAI) prediction, Ball-Berry stomatal resistance, irrigation scheduling, and groundwater interaction. Each simulation cycle runs for 6 hours, initialized at 00, 06, 12, and 18 UTC daily, producing hourly outputs. Forecast operations are fully automated through scripting systems that manage namelist updates, job submissions, and post-processing tasks. Continuous operational forecasts have been running on the high-performance computing cluster, utilizing approximately 256 cores per forecast cycle, with an average wall time of four hours, from 1 November 2023 (00:00 UTC) to 31 December 2024 (18:00 UTC). Early results are encouraging. Model-simulated LAI over paddy fields in Hospete and Kottayam shows a realistic seasonal progression, peaking around July (Figure 4.8). However, discrepancies have been noted, with the model overestimating LAI during the tillering stage and underestimating it during the milking phase. These biases are under active investigation through the examination of crop parameterization, soil moisture spin-up, and consistency of atmospheric forcing. Sample output images (as shown below, for the Nagercoil field) of LAI, leaf mass, transpiration, and photosynthesis indicate internally consistent spatial patterns and reasonable magnitudes, aligning with expected crop physiological responses (Figure 4.9). Post-

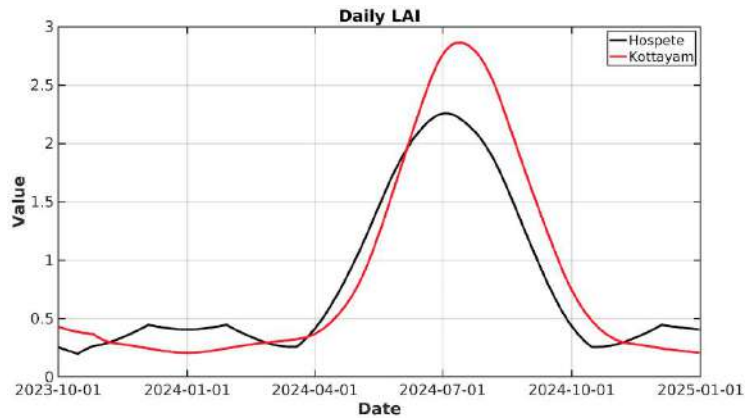


Figure 4.8: Variation in LAI for Hospete and Kottayam.

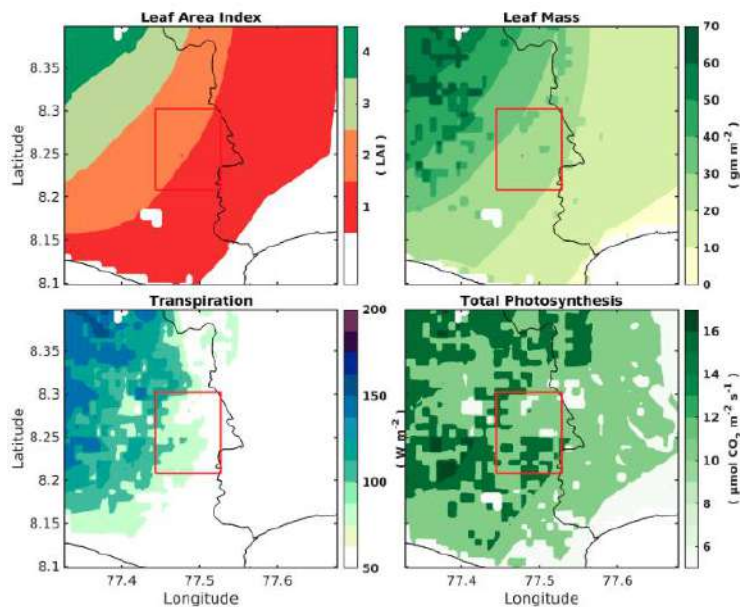


Figure 4.9: LAI images for the Nagercoil field, leaf mass, transpiration, and photosynthesis indicate internally consistent spatial patterns and reasonable magnitudes, aligning with expected crop physiological responses.

processing pipelines have been established to convert raw model outputs into agro-meteorological indices relevant to field management and decision support. The output raw data volume is approximately 20 TB for the full simulation period (November 2023 to December 2024). Technical challenges addressed so far include implementing crash recovery protocols for long-duration simulations, validating soil moisture initialization, and refining nested domain configurations to minimize boundary artifacts. The system is currently operational and delivering physically credible forecasts, with ongoing work dedicated to refining crop model parameters, improving long-term forecast stability, and validating simulation results against field observations and satellite datasets.

4.6 Unraveling the impact of atmospheric engineering on extremes through chemistry–weather–climate Interactions.

Stratospheric Aerosol Injection (SAI), a prominent atmospheric engineering strategy, aims to mitigate climate change by injecting aerosols, most commonly sulphates, into the stratosphere to reflect a portion of incoming solar radiation back into space. This approach is intended to offset global warming by temporarily lowering surface temperatures and buffering against certain climate extremes. However, SAI induces complex feedbacks across atmospheric chemistry, weather patterns, and climate systems.

The Earth's atmosphere is governed by intricate interactions between photochemistry, radiation, and circulation (Figure 4.10). Introducing aerosols into this dynamic system can alter both stratospheric and tropospheric processes, affecting not only temperature and precipitation but also the oxidative balance of the atmosphere. Changes in sunlight and aerosol concentrations directly influence the lifetime of greenhouse gases like methane, thereby modulating long-term climate responses. Despite extensive modelling of SAI's radiative impacts, its influence on tropospheric chemistry and its cascading effects on weather and climate extremes remains underexplored. This calls for an integrated approach that links chemical feedbacks with meteorological and climatic processes. By unraveling these chemistry–weather–climate interactions, we can better understand the potential consequences and trade-offs of engineering the atmosphere. Most advanced climate models do not fully capture these chemi-

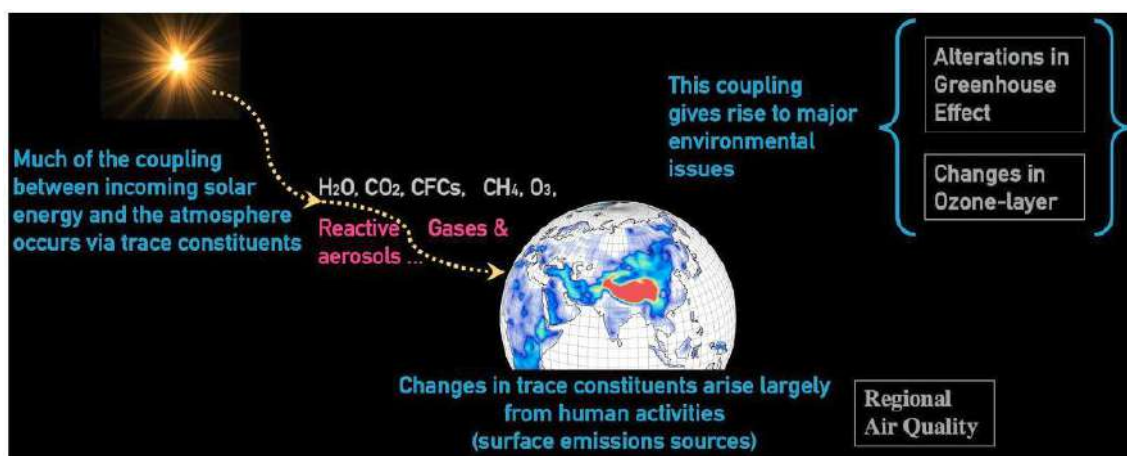


Figure 4.10: Schematic representation of the role of atmospheric composition in modulating incoming solar radiation.

cal feedbacks, often using simplified schemes that overlook tropospheric responses. Yet, these interactions could significantly influence the radiative effects of SAI and its consequences for air quality, health, agriculture, and ecosystems. Despite their importance, tropospheric chemical feedbacks are largely understudied in SAI context. Only a handful of studies have addressed this, and even fewer have accounted for key processes or long-term feedbacks. We aim to fill this gap by examining how sulphate-based SAI affects atmospheric chemistry across both the stratosphere and troposphere, and how these changes could reshape its overall climate impact.

With this aim, we are developing and implementing a comprehensive climate modelling framework that integrates all interactive processes involving gas-phase and aerosol-phase chemistry, including aqueous-phase interactions. Incorporating detailed chemistry feedbacks into climate models is a key step toward:

1. A complete characterization of the human influence
2. Constructing scenarios and predictions for consideration as policy or intervention options
3. Formulating informed choices to address multiple issues related to air quality

We are also designing targeted sensitivity studies to:

1. Understand the impacts of weather/climate modification efforts viz. atmospheric engineering through solar radiation modification (SRM) viz. SAI and weather modification through cloud seeding, on extremes such as
 - active/break spells (excess/deficient rainfall)
 - heat and cold waves over India.
2. Assess the influence of changing atmospheric concentrations of reactive gases and aerosols on weather and climate extremes.
3. Provide localized and regional insights into the effects and risks of weather/climate modification, supporting informed decision-making.

Sajani Surendran and K Rajendran*

* – KSCSTE–Institute for Climate Change Studies, Kerala

4.7 Particulate Matter Pollution in a Coastal Industrial City and its Impact on Human Health: A Generalized Additive Model Analysis

We investigated the impact of particulate matter (PM) pollution on public health in a representative coastal industrial megacity in India. PM has emerged as the primary pollutant in the region, with a significant increasing trend in PM concentrations observed in recent years, based on air quality data from the Central Pollution Control Board. This trend is particularly pronounced over the city's major industrial zone.

Analysis of the Air Quality Index (AQI) highlights alarmingly high PM levels not only in industrial areas but in residential neighbourhoods as well, raising serious public health concerns. The study also indicates that favourable meteorological trends which previously contributed to reductions in PM concentrations, are no longer significantly mitigating pollution levels, suggesting that increasing emissions are overwhelming these natural dispersion mechanisms.

Using a Generalized Additive Model (GAM), we examined the potential relationships between PM_{10} and NO_x emissions and hospitalizations for cardiovascular, pulmonary, asthma, and respiratory infections. GAM is a flexible statistical approach that predicts an outcome variable by combining smooth, non-linear functions of predictor variables in an additive framework. Unlike linear models, where the relationship between the predictors and the response is strictly linear, GAM allows for more complex, non-linear relationships while maintaining interpretability. The model predicts the

response variable by summing the effects of individual predictor variables. Each predictor is modeled with its smooth function, allowing different predictors to contribute to the outcome in distinct ways. The general form of the GAM is:

$$y = \beta\theta + f_1(x_1) + f_2(x_2) + \dots + f_p(x_p) + \varepsilon \quad (4.1)$$

where ($f_1, f_2, \dots, f_p$) are smooth functions, and ε is the error term, y is the predicted response (i.e., numbers of hospitalizations due to cardiovascular, pulmonary, asthma, and respiratory infections), and the x 's are the predictors (PM_{10} and NO_x). Instead of using fixed coefficients (as in linear regression), GAM uses a sum of smooth functions to capture non-linear relationships between each predictor and the response variable. These smoothers can vary in flexibility depending on the data. GAMs retain interpretability because the effect of each predictor is modeled separately. While the relationships between predictors and the outcome can be nonlinear, the additive nature of the model means it's still possible to interpret the contribution of each predictor. GAMs offer flexibility without overfitting the data by controlling the smoothness of each function. This can be done through regularization techniques like penalized regression or selecting an optimal degree of smoothness via cross-validation. They are useful when you want to capture complex trends in the data but avoid the over-complexity of fully non-parametric models. In essence, GAMs strike a balance between the flexibility of non-parametric models and the interpretability of linear models, making them a powerful tool for modeling real-world data with nonlinear relationships.

Our GAM analysis revealed a strong correlation between pollutant emissions and incidence of pulmonary diseases, particularly within the industrial areas over the past five years. These findings underscore the urgent need for governmental policy interventions to curb PM pollution and mitigate its adverse health effects on local communities.

V. B. Arya ^φ, Sajani Surendran and K Rajendran*

^φ – Indian Institute of Tropical Meteorology, Pune

* – KSCSTE–Institute for Climate Change Studies, Kerala

4.8 Sensitivity of microphysics parameterization approaches in WRF Model in simulating intensity and spatial distribution of Extreme rainfall over Bangalore, India

The role of cloud microphysics scheme in simulating urban EREs over Bangalore city, we used five microphysics schemes to conduct the experiments. Microphysics plays critical role in the model, since it resolves water vapour, cloud, and precipitation processes. We simulated 30 EREs out of which 15 are local and 15 nonlocal cases distributed over 34 hoblis of the Bangalore city. We considered two single moment scheme (Eta and Goddard microphysics) which provide flexibility in size distribution parameter as function of temperature which captures most of the vertical variability and it decreases nearly with isothermal profile. Whereas, in the three double moment schemes (New-Thompson, Morrison double-moment and WRF Double moment 6 class) the total number of concentrations may increase the representation of ice crystal

accumulation which suggest a means of improving upon single moment prediction. The variations in water vapour (mixed phase process) and condensate in the forms of cloud water, rain, cloud ice, and precipitation ice (snow/graupel/sleet) are predicted by the Eta schemes. Water vapour and total condensate are the two constituents that are advected in the model which is created by merging the distinct hydrometeor fields. Earlier studies showed that ice, snow, and graupel processes may be simulated with very high precision using the Goddard scheme. To account for both the number concentration and the mixing ratio, we evaluated double moment schemes such as the New–Thompson scheme (Thompson et al., 2008), Morrison double–moment scheme (Morrison et al., 2009), and WRF Double–Moment 6–class scheme (WDM6) (Hong et al., 2009). It adds value thorough examination of the particle size distribution, computation of the rates of microphysical processes, and analysis of the evolution of clouds and precipitation.

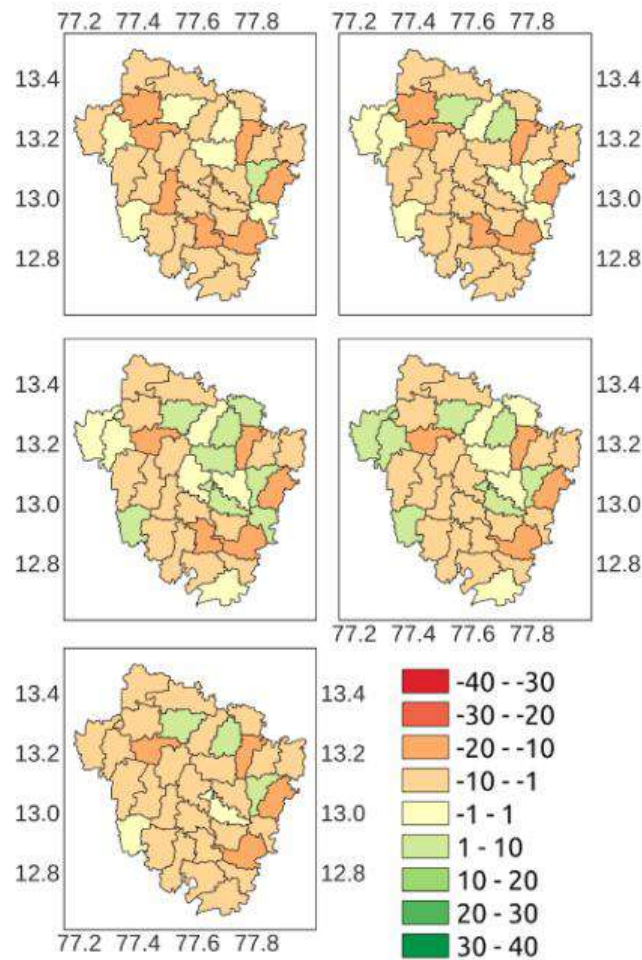


Figure 4.11: Spatial distribution of bias (mm) in 24 hour accumulated rainfall with five micro–physics schemes averaged over the entire local ERE cases.

4.9 Impact of different land use data on WRF model short-range forecasts during pre-monsoon and monsoon seasons in India

Urban land use change typically results in significant alterations to microclimatic conditions and has been linked to alterations in rainfall distribution. There is a need for clear quantification of regional drivers, including improved land use patterns in the model simulation, to examine the impact of land use change on rainfall patterns. This study focuses on the impact of land use representation in short-range rainfall forecasts from Weather Research and Forecasting (WRF) model simulation over India during pre-monsoon and monsoon rainfall season. In the control experiment (CNT), land use data from MODIS-2001 is employed, while in the sensitivity experiments EXP1 and EXP2, updated 2019 land use datasets incorporating recent urban classifications from MODIS and ISRO, respectively, are utilized to define the model's lower boundary conditions. Quantitative error metrics and forecast skill scores indicate enhanced

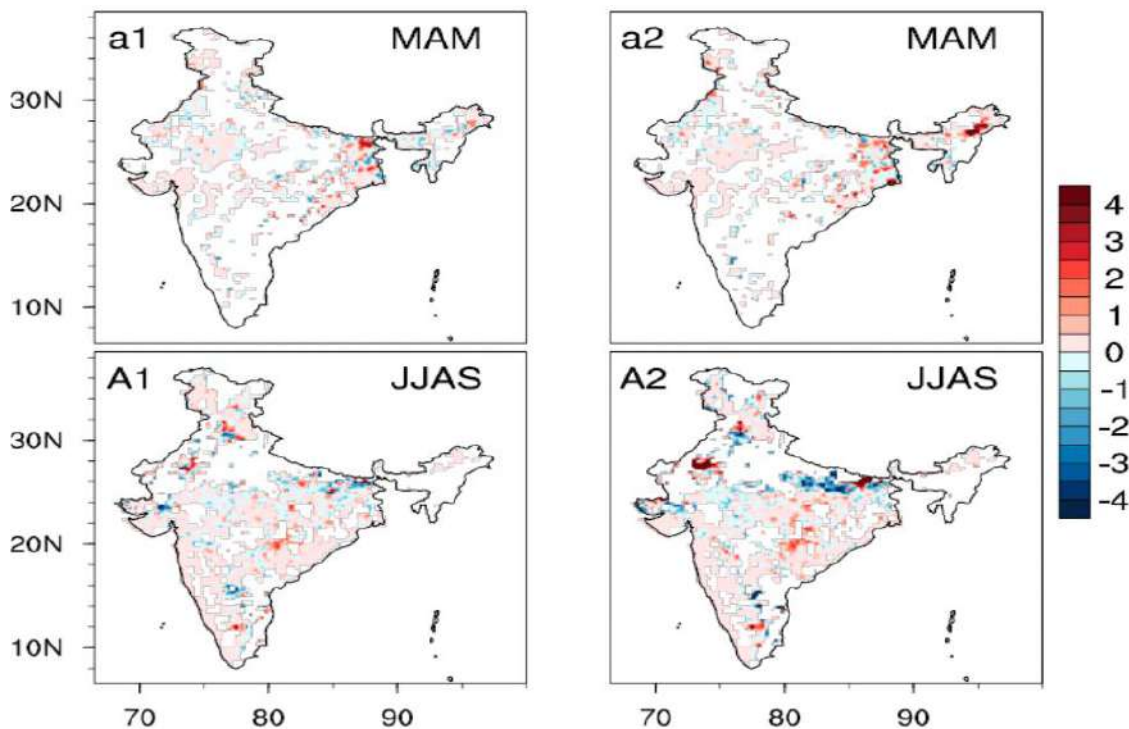


Figure 4.12: Improvement parameter with respect to CNT computed for experiments based on Bias score in 24-hour accumulated rainfall forecasts (at grid points having significant (>95%) correlation) during MAM (top panel) and JJAS (bottom panel); EXP1 (a1, A1) and EXP2 (a2, A2). Positive area represents improvement in experiments with respect to CNT and vice versa.

model performance during the pre-monsoon and monsoon seasons when assimilating realistic recent land use datasets from MODIS and ISRO. The Extreme Dependency Index (EDI) further demonstrates that the model's capability to predict rare, high-intensity rainfall events is enhanced when recent land use datasets are incorporated

into the simulations. The inclusion of updated and realistic land use classifications from MODIS and ISRO resulted in improved simulation of surface meteorological variables and lower-tropospheric profiles. Improvement in predicting surface variables is higher over the southern, coastal, and eastern parts of India during both seasons. Validation with radiosonde data shows that forecast improvements in temperature and humidity are mainly below 750 hPa, while wind speed shows a noticeable impact extending to higher atmospheric levels in both seasons. Among the two sensitivity experiments, the ISRO-based land use simulation showed greater improvement, especially during the monsoon season.

Ipsita P, Rakesh V, Randhir Singh*, G N Mohapatra

* – Indian Space Research Organization (ISRO), SAC, Ahmedabad

4.10 Relative Impact of Assimilation of Multi-Source Observations using 3D-Var on Simulation of Extreme Rainfall Events over Karnataka, India

This study explores the impact of assimilating diverse observational data on forecasting extreme rainfall events (EREs) using a three dimensional variational (3D-Var) assimilation approach. It focuses on 38 EREs across three meteorological divisions in Karnataka, India, using a high-resolution (03-km) Weather Research and Forecasting (WRF) model with three nested domains. Five distinct experiments were conducted, including a Control experiment without assimilation, and subsequent experiments integrating observations from various sources like atmospheric profiles from Atmospheric InfraRed Sounder (AIRS) and Moderate resolution Imaging Spectroradiometer (MODIS) satellites and radiosondes, ocean surface wind observations from Advanced Scatterometer (ASCAT), Special Sensor Microwave Imager (SSM/I), and WindSAT satellites and buoys, ground observations from Karnataka State Natural Disaster Monitoring Centre (KSNDMC), as well as a combined assimilation experiment with all available observations. The accuracy of rainfall forecasts is evaluated by comparing model outputs with high-resolution telemetric rain-gauge (TRG; 6480 stations) data and other meteorological parameters against telemetric weather station (TWS; 860 stations) data from KSNDMC. Assimilation experiments show positive improvements over control experiment in predicting rainfall. Results consistently indicate underprediction of rainfall in the intricate topographical region of the Western Ghats (WG) across all experiments, contrasting with overprediction along the coastal areas of Karnataka. The experiment involving Ocean Winds showcased a substantial 40% reduction in rainfall overprediction (above 2 mm threshold). Both Ocean Winds and Station Data assimilation notably enhanced rainfall prediction accuracy over most of the regions in Karnataka, with Ocean Winds exhibiting the highest improvement (53%), closely followed by Station Data (50%). Importantly, assimilating Ocean Winds and Station Data aided in reducing overprediction, while assimilating Satellite Profiles reduced underprediction in the interior part of Karnataka but increased overprediction over the coastal region compared to the control experiment. Frequency of occurrence of rainfall is considerably enhanced along the coastline in all 3D-Var experiments. Bias score indicates

to 2018. The customised and configured version of Soil and Water Assessment Tool (SWAT) model is used to simulate and understand the climate change impact on the streamflow variability in the upper Jhelum basin. Advanced land Observing Satellite — Phased Array type L-band Synthetic Aperture Radar (ALOS PALSAR, 12.5m), CARTOSAT (32m) and Shuttle Radar Topography Mission (SRTM, 30m) Digital Elevation Models (DEMs) along with LULCs at intervals of every 5 year from 2001 to 2019 are used to simulate the SWAT model. The model simulations are carried out with multisource rainfall from fifth generation ECMWF atmospheric reanalysis (AgERA5 0.1°), India Meteorological Department (IMD 0.25°) and Tropical Rainfall Measuring Mission (TRMM 0.25°). After identifying the streamflow sensitivity parameters to tune the model results using SWAT– Calibration Uncertainty Program (SWAT–CUP), the model is validated for the period 2004 to 2018 (Figure 4.14). The impact of LULC change was prominent in simulated surface parameters and the simulation results were more realistic when ALOS PALSAR and CARTOSAT DEMs were used. Model performance evaluation parameters such as Coefficient of Determination (R^2), Nash–Sutcliffe efficiency coefficient (NSE) and percentage bias (PBIAS) obtained were 0.77 (0.80), 0.80 (0.83) and 18.69 (10.69) respectively for ALOS PALSAR (CARTOSAT) DEMs. Simulation results with European Centre for Medium–Range Weather Forecasts Agricultural Reanalysis 5th Generation (AgERA5) rainfall data was the closest with the observation with correlation and NSE of 0.77 and 0.80. It is noticed that the annual streamflow for the whole watershed is decreased during the monsoon months while snowmelt is found to be increasing in the summer months over the years from 1979 to 2018.

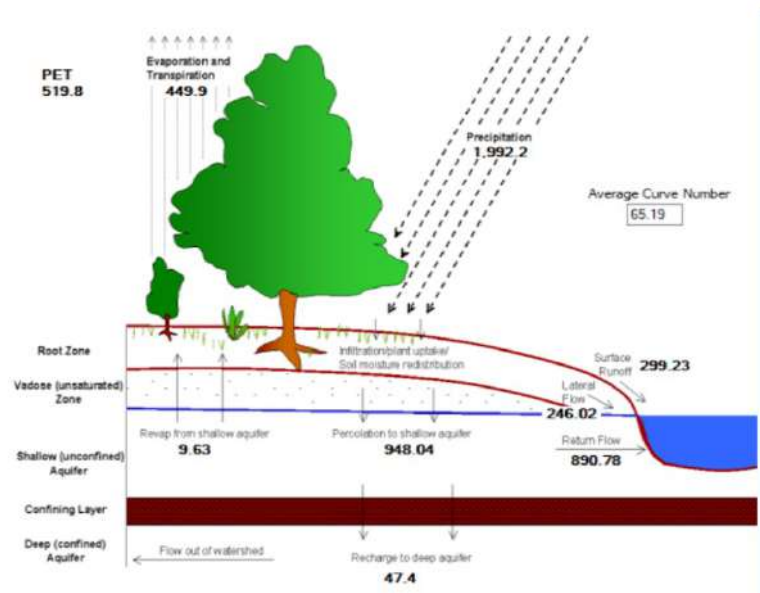


Figure 4.14: Representation of annual water balance for various hydrological processes from the SWAT model output.

4.12 Understanding of Marine Carbon Dynamics in the Northern Indian Ocean through Coupled Physical–Biogeochemical Modelling – A Brief Note

The northern Indian Ocean is characterized by a highly dynamic interplay of physical and biogeochemical processes, including seasonally reversing monsoon-driven circulation, stratification from freshwater influx, steep vertical nutrient gradients, extensive oxygen minimum zones, and marked variability in primary productivity. These natural drivers, combined with growing anthropogenic influences, shape the region's carbon dynamics. The NIO exhibits pronounced variability in carbon fluxes and primary productivity, driven by both natural and human-induced factors. Seasonal monsoon cycles, for instance, cause shifts in ocean circulation, stratification, and nutrient availability, which in turn affect primary production and carbon export. Observational data and model simulations indicate a declining trend in primary productivity in parts of the NIO, particularly south of 12°N latitude. This decline is attributed to reduced vertical mixing and weakened upwelling, processes that are being further suppressed by enhanced stratification due to climate warming. At the same time, regions north of 12°N are experiencing increased nutrient input from atmospheric sources, such as anthropogenic aerosols, which partially offset the decline in productivity. This interplay of climate-driven and anthropogenic influences highlights the complexity of carbon cycling in the NIO. Therefore, understanding carbon cycling in this area is vital, as it affects the global carbon budget, regulates regional climate, and plays a critical role in sustaining marine ecosystem productivity. In this context, coupled physical–biogeochemical models have emerged as transformative tools, offering new insights into the mechanisms governing marine carbon dynamics in the northern Indian Ocean (NIO). Coupled physical–bio–geochemical models are designed to simulate the interactions between ocean circulation and bio–geochemical processes, such as nutrient cycling, primary production, and carbon sequestration. High-resolution models, such as those based on the MOM (Modular Ocean Model), allow researchers to capture the fine-scale dynamics of the NIO, including the effects of eddies, upwelling, and riverine inputs. These models are often nested within larger-scale global circulation models and are initialized with climatological datasets. Despite challenges related to computational demands and data scarcity—especially for bio–geochemical variables—these models have proven effective in reproducing observed patterns of productivity and carbon fluxes in the region. Recent modeling studies emphasize that the climate-induced changes, such as ocean warming and increased stratification, have led to a reduction in net primary production (NPP) in the central Arabian Sea and western Bay of Bengal. This is primarily due to a decline in the upward supply of nutrients from deeper waters, as evidenced by deepening nitracline depths and heightened nutrient limitation. At the same time, atmospheric nitrogen deposition has increased by approximately 60% in recent decades, providing an external nutrient source that partially compensates for the decline in productivity. Model simulations estimate that this deposition supports about 0.6% of total primary production in the NIO, with localized effects more pronounced in regions with high aerosol input. However, while additional nitrogen from atmospheric deposition can enhance primary production, it does not significantly in-

crease the efficiency of carbon export to deeper waters, meaning its capacity to offset climate-driven productivity losses is limited at the basin scale.

Despite these advances, significant challenges remain as the data scarcity, especially in the Bay of Bengal and remote parts of the Arabian Sea, limits the ability to validate and refine model simulations. Capturing the full range of variability in the NIO requires high-resolution models, which are computationally intensive. Furthermore, many models do not fully account for changing external nutrient sources, such as increased atmospheric deposition and riverine inputs, potentially underestimating their impact on bio-geochemical cycles. Uncertainties also persist in the representation of fine-scale physical processes and in the parametrization of key bio geochemical interactions. Inter-model discrepancies, particularly in projections of future primary production, highlight the need for improved parameter optimization and expanded observational datasets. Looking forward, advancing the understanding of marine carbon dynamics in the NIO will require next generation of coupled models with higher spatial resolution, improved parametrization, and a more comprehensive treatment of evolving external nutrient sources. Interdisciplinary collaboration will be essential to integrate physical, chemical, and biological perspectives and to ensure that models accurately reflect the complexity of the NIO system. Ultimately, coupled physical-bio geochemical modeling stands as a cornerstone for predicting the future of carbon cycling and ecosystem health in the northern Indian Ocean, informing both scientific understanding and policy decisions in the face of rapid environmental change.

Gayathri R, P Lakshmikanthan, Vivekandanda Hazra & Prasanna Konatham.

5. Geosciences & Engineering Research

CSIR-4PI's research in geosciences and engineering leverages its powerful high-performance computing (HPC) infrastructure to model and understand complex Earth systems and solve intricate engineering challenges. The institute's activities in this domain are deeply rooted in computational mechanics and data analysis, applying these skills to a range of problems from the microscopic to the continental scale. A significant focus of CSIR-4PI is on the modelling of geological and geophysical phenomena. We also contribute to materials science by simulating material behavior at the atomic and molecular levels, helping in the design of new materials with desired properties. By integrating advanced modeling with their supercomputing power, CSIR-4PI provides critical insights that drive innovation and solve realworld challenges in both geosciences and engineering.

Inside:

1. Distinct lithosphere–asthenosphere boundary (LAB) beneath the western Himalaya: insights from seismic imaging
2. Comparative Evaluation of Seismic Denoising Techniques: A Deep Learning and Signal Processing Approach
3. Deployment of broadband seismic array across the Mahabaleshwar Plateau, Deccan Trap, Maharashtra
4. Estimation of Precipitable water vapor during Extreme rainfall event (ERE) in Himalaya
5. Morphology of equatorial F-region irregularities over the Indian longitude sector using GPS-derived ROTI observations
6. Noise analysis of multi-GNSS time series
7. Impact of hydrological, atmospheric loading on geodetic deformation over Indian subcontinent
8. Multi-Instrument Analysis of Ionospheric Equatorial Plasma Bubbles over the Indian and Southeast Asian Longitudes During the 1920 April 2024 Geomagnetic

Storm

9. Case study on the Mw 6.2 Dipayal Earthquake of October 3, 2023 using InSAR data products
10. Validating InSAR Methodology Using the 2020 Monte Cristo Range Earthquake
11. Ionospheric imagery of earthquake source region using the Co-seismic Ionospheric Perturbations
12. Building Low-Cost GNSS Receiver for Ionospheric Total Electron Content (TEC) Estimation
13. Outer-arc Active Tectonic Deformation off the Nias-Nicobar Trench
14. Dynamic Stress Changes on the East Anatolian Fault
15. Buckling studies of triple-walled carbon nanotube using the pseudospectral method with backward substitution approach for general boundary conditions.
16. Revisiting the Mindlin microstructure isotropic strain gradient elasticity theory for Form-I, Form-II, and Form-III with length scales.

5.1 Distinct lithosphere–asthenosphere boundary (LAB) beneath the western Himalaya: insights from seismic imaging

We present a high-resolution image of the crust and lithosphere–asthenosphere boundary (LAB) beneath the Kashmir valley and surrounding regions (north–western Himalaya) to a depth of 160 km, utilizing data from 22 seismological stations deployed in three phases between 2015 and 2024 (figure 5.1). Data modeling was conducted through joint inversion of receiver functions and Rayleigh wave group velocity dispersion data within the period of 5–100s, alongside common conversion point (CCP) migration. The velocity image reveals several important features. The Main Himalayan Thrust (MHT) in the shallow crust is identified as a flat structure, as indicated by low shear wave velocity (V_s) measurements between 3.1 and 3.4 km/s, located above crystalline Indian crust, which has a V_s of ~ 3.6 km/s. The middle crust (25–42 km) exhibits a reduced V_s of 3.4 km/s beneath the northeastern part of the Kashmir valley, likely attributed to the presence of fluids released during the metamorphism of the subducting Indian crust. An anomalous feature beneath the

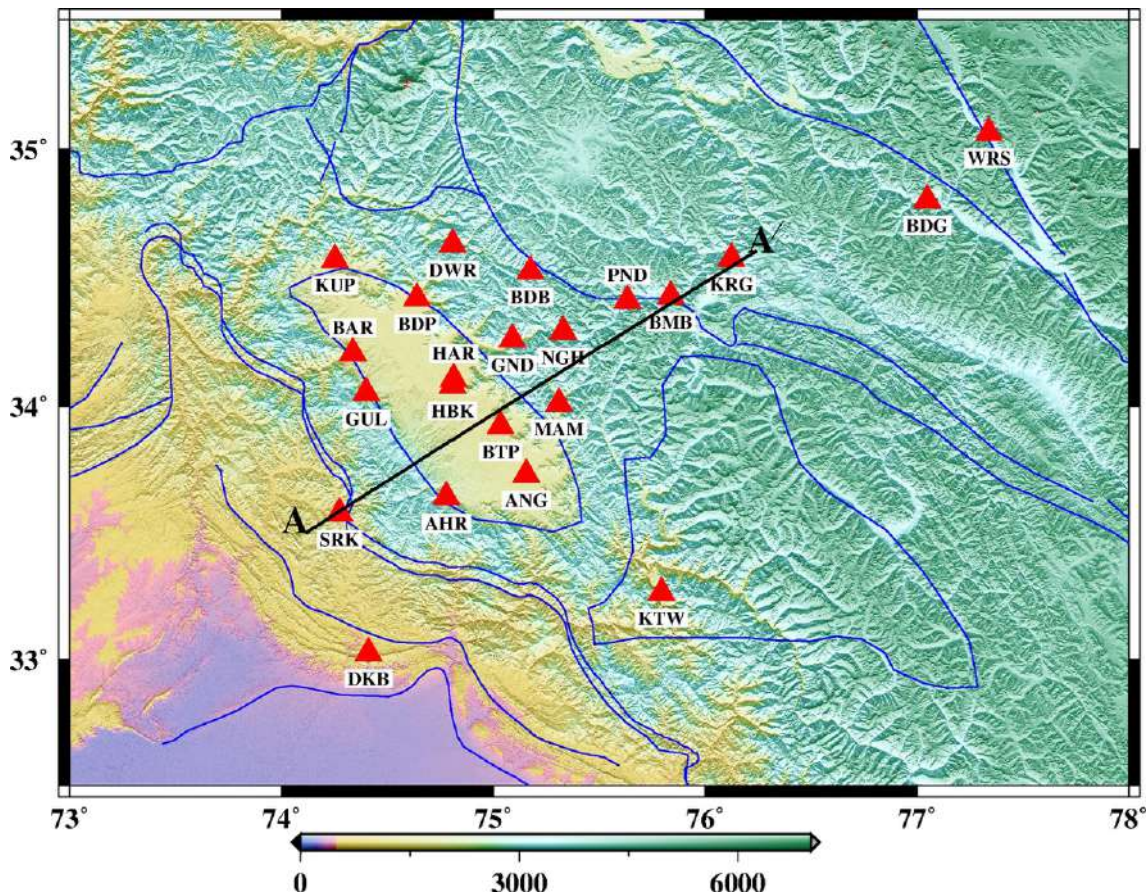


Figure 5.1: Broadband seismic network in NW Himalayas and the cross-section AA' where the 2D cross-section is presented for lithosphere–asthenosphere boundary (LAB).

southwestern part a 25–30 km thick high velocity layer ($V_s > 4.0$ km/s) at the base of the crust, interpreted as a response to dense magma underplating. Moho depth is

~75 km in the southwestern part of the Kashmir valley, whereas it is ~65 km in the northeastern part (figure 5.2). A significant thinned lithosphere at 70–80 km below the eastern part of the Kashmir Valley, progressively increase to 110 km to east of the Kashmir valley.

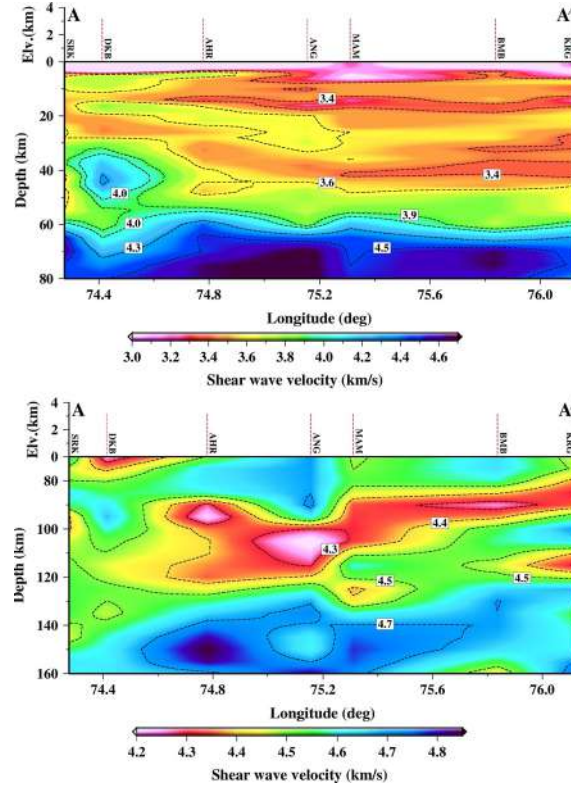


Figure 5.2: Cross-section AA' with crustal and mantle shear wave velocity structure.

Gokul Saha and I A Parvez

5.2 Comparative Evaluation of Seismic Denoising Techniques: A Deep Learning and Signal Processing Approach

This work focuses on robust estimation of seismic magnitude by combining the three orthogonal ground motion components—East–West, North–South, and Vertical—recorded at multiple CSIR–4PI regional stations. The magnitude is computed as the vector norm of these components, providing an accurate and station-independent measure of earthquake strength. This approach enables precise characterization of seismic events through temporal analysis and peak detection in the raw waveform data. This study evaluates a range of seismic denoising algorithms—including classical filters (Butterworth, Fourier, Wavelet), advanced techniques (Kalman Smoother, STA/LTA, FFT-based Wiener), and a deep learning-based autoencoder—on real seismic datasets. Each method is assessed for noise reduction, peak preservation, computational efficiency, and performance metrics such as Mean Squared Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM). As summarized in the combined results table, advanced methods like Total Variation Denoising,

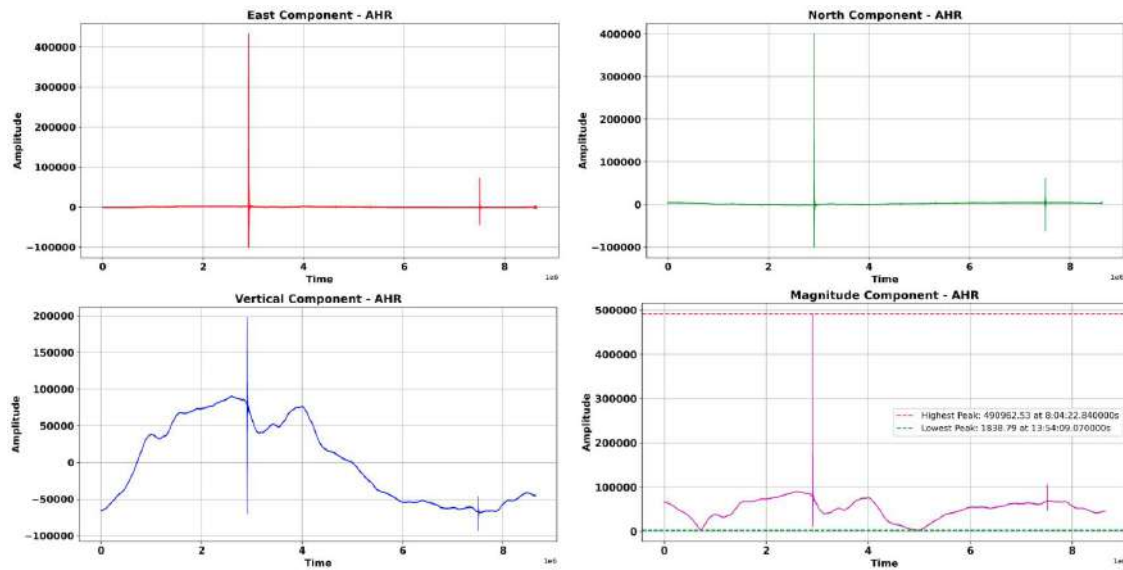


Figure 5.3: Individual plots for the East, North, Vertical components, and the Magnitude of station AHR.

Wavelet Denoising, FFT-based Wiener, and Autoencoder-based approaches deliver superior noise suppression and signal fidelity, supporting more reliable seismic analysis.

Algorithm	Noise Reduction	Peak Preservation	Key Observations	MSE	PSNR	SSIM
Butterworth Bandpass	High	High	Frequency band selection	0.046812	13.2965	0.5578
Fourier Transform	Moderate	Low	Frequency-based noise filtering	0.046128	13.3603	0.5600
Wavelet Denoising	High	Excellent	Balancing noise suppression and signal localization	0.000001	58.3849	0.9999
Median Filtering	Moderate	Moderate	Removing spike-like noise	0.000075	41.2757	0.9973
Savitzky Golay	Moderate	High	Preserving signal features	0.000095	40.2187	0.9965
Total Variation Denoising	High	High	Edge-preserving noise removal	0.000001	81.4500	1.0000
Kalman Smoother	High	High	Real-time signal enhancement	0.024095	16.1807	0.7170
STA/LTA Filtering	Moderate	Moderate	Earthquake event detection	0.031899	14.9623	0.6130
FFT-Based Wiener	High	High	Adaptive noise reduction	0.000023	50.9877	0.9978
Autoencoder Denoising	High	Moderate	Learning-based noise reduction	0.000006	52.0291	0.9995

Table 5.1: Combined Qualitative and Quantitative Evaluation of Seismic Denoising Algorithms.

A comprehensive side-by-side comparison in the table further guides the selection of the most appropriate denoising technique for specific seismic monitoring and research applications.

5.3 Deployment of broadband seismic array across the Mahabaleshwar Plateau, Deccan Trap, Maharashtra

The Deccan Traps in western India are one of the world's largest continental volcanic provinces, formed by extensive basaltic lava flows over 60 million years ago. Despite their geological significance, the deeper subsurface structure beneath these basalt layers remains poorly understood due to the complexity of the volcanic cover. To address this, a linear array of broadband seismic stations was deployed across the Mahabaleshwar Plateau in the western Deccan Traps region, Maharashtra.

A total of seven seismic stations were installed along an east–west transect, with an approximate spacing of 10 kilometers between them. The array spans a total distance of about 70 kilometers, and sites were carefully selected to minimize cultural and environmental noise, ensuring high–quality seismic recordings. Each station is equipped with a broadband sensor, GPS timing, solar power supply, and data logging system. The primary aim of this deployment is to collect high–resolution seismic data that will help reveal the crustal structure beneath the basalt cover. The array is expected to operate continuously for at least one year, capturing both local and distant seismic events. The data will be used to examine variations in seismic wave speeds, identify any potential low–velocity zones that may indicate past magma activity, and understand how the thick basalt flows affect seismic wave propagation. This initiative marks an important step toward building a detailed understanding of the internal architecture of the Deccan Traps, which is essential for broader studies on volcanic provinces, tectonic evolution, and regional geohazards.

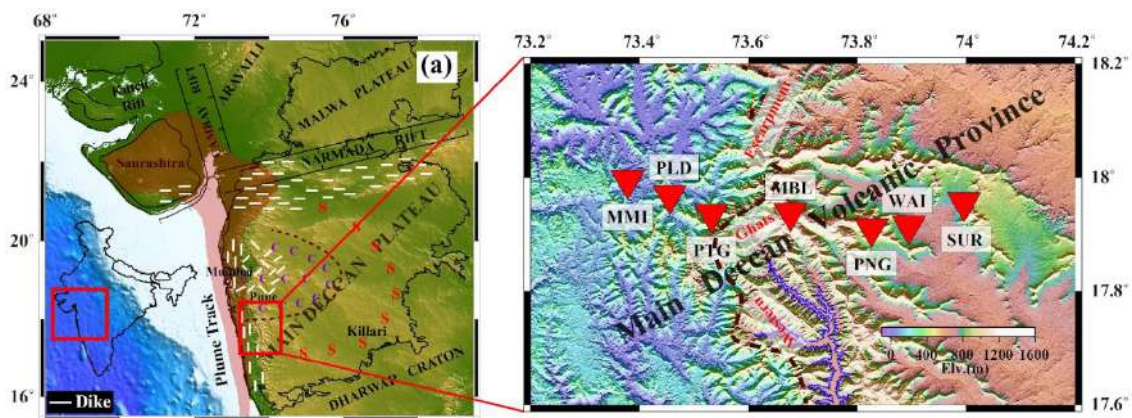


Figure 5.4: (a) A topographic map showing the Deccan Volcanic Province (DVP) as well as plume track (pink shade), compound magma flow ('C') and simple flow ('S'). (b) Map showing the location of the deployed seismic stations (red inverted triangle) across the Mahabaleshwar Plateau, Maharashtra.

Rajendra Kumar Dash, Gokul Saha, Ashish, I A Parvez and S S Rai^φ

^φ – Department of Earth and Climate Science, Indian Institute of Education and Research (IISER), Pune.

5.4 Estimation of Precipitable water vapor during Extreme rain-fall event (ERE) in Himalaya

This study analyses precipitable water vapor (PWV) derived from continuous Global Positioning System (cGPS) stations across 2500 km Himalayan arc from Ladakh in the western Himalaya to the Eastern Himalayan syntaxis in the east which is essential for weather forecasting, with a focus on extreme rainfall events (EREs) and cloudbursts. By processing cGPS data, we assessed PWV variations and validated GPS-derived PWV against ECMWF Reanalysis v5 (ERA5) datasets and ground-based meteorological sensor observations. Our findings reveal a marked PWV surge before EREs, suggesting its potential as a key predictor for early warning systems. Maximum PWV reached to 27 mm prior to the rainfall event at Gulmarg station (GULM) (Figure 5.5). This indicates PWV starts increasing gradually and moisture accumulates slowly in Gulmarg located at an elevation ~ 2675 m. The cold temperature at this altitude likely reduces evaporation which leads to a longer time for moisture buildup. Therefore, rainfall prediction is easier in this case since moisture gradually builds up over time. The all-weather reliability of GPS derived PWV ensures consistent PWV monitoring, offering advantages over other methods. This study insights into PWV dynamics to strengthen regional weather prediction and disaster preparedness across the region. Forecasting EREs and Cloudbursts can protect lives and infrastructure by providing timely early warning alerts, particularly in the Himalayan region.

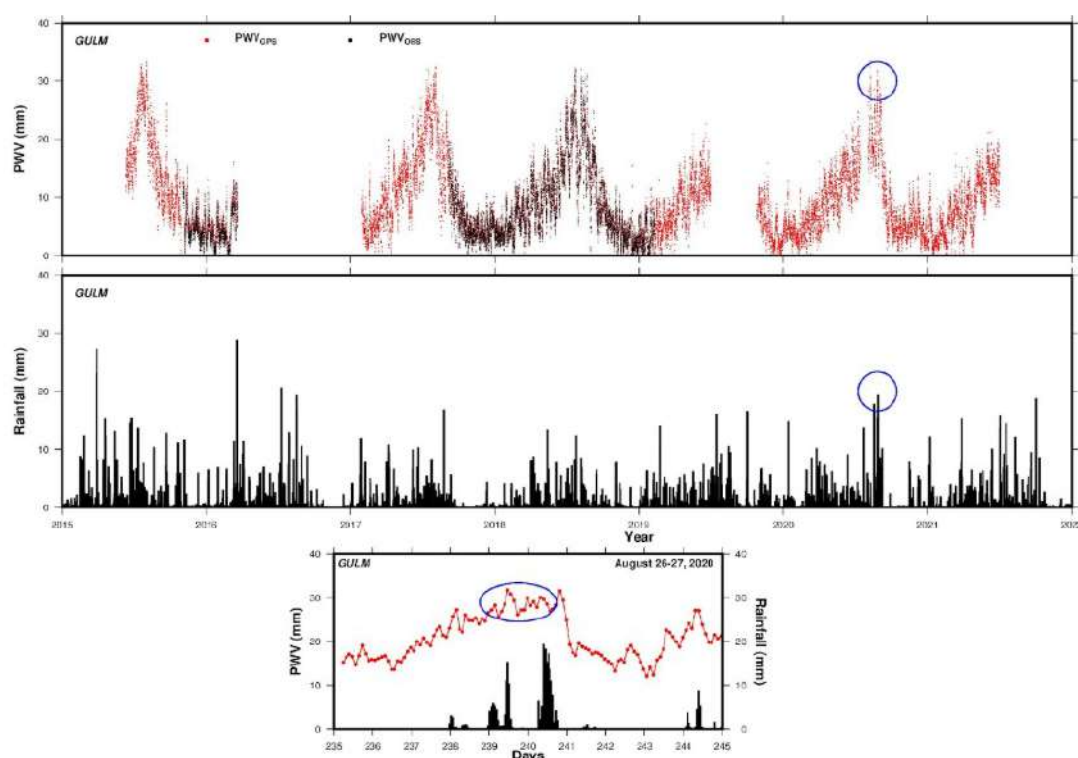


Figure 5.5: GPS derived PWV versus rainfall at Gulmarg station in Kashmir Himalaya.

5.5 Morphology of equatorial F-region irregularities over the Indian longitude sector using GPS-derived ROTI observations

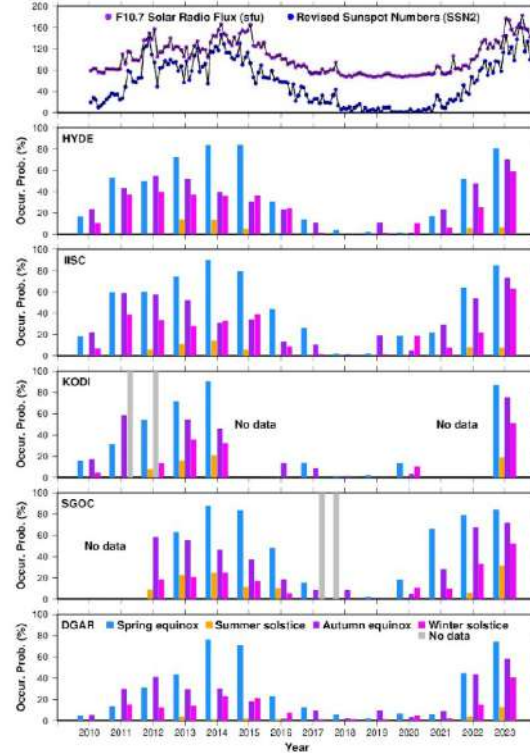


Figure 5.6: Occurrence probability of Seasonal average ROTI during 2010–2023 for stations situated from southern EIA region to northern EIA region along with monthly average SSN2 and F10.7 solar radio flux.

The characteristics of Equatorial F-region Irregularities (EFIs) along the Indian longitude sector are examined using GPS-derived ROTI data from 2010 to 2023, under both quiet and disturbed geomagnetic conditions. The study reveals that the occurrence of EFIs is strongly influenced by the solar cycle. EFIs are notably more intense in the EIA regions during periods of maximum solar activity, which is linked to higher ambient electron density in the F-layer. Also, the occurrence of EFIs shows an equinoctial asymmetry, with more intense EFIs observed during the spring equinox than the autumn equinox during the peak and declining phases of the solar cycle. In contrast, during the ascending phase of the solar cycle, severe EFIs are more common during the autumn equinox than the spring equinox. The occurrence probability of EFIs is highest in the equinox seasons, followed by the winter and summer solstices, particularly during periods of high solar activity (Figure 5.6). Analysis of EFIs during two major geomagnetic storm events (17 March 2015 and 08 September 2017) reveals that storm-induced Prompt Penetration Electric Fields (PPEFs) affected the typical intensity of the dusk-time Pre-Reversal Enhancement (PRE), leading to the poleward spread of ionospheric irregularities into mid-latitude regions with the spatial time delay. However, the westward electric fields and fluctuating IMF Bz during geomagnetic storms created the conditions similar to the Counter Electrojet (CEJ), which suppressed

dusk–time ionospheric irregularities in dip equatorial and low–latitude regions on 17 March 2013. This study provides a comprehensive understanding of the behaviour of ionospheric irregularities under varying conditions, providing valuable insights for future research on the spatiotemporal characteristics and forecasting of EFIs in the region.

Siva Sai Kumar Rajana, Sampad Kumar Panda*, Sridevi Jade, Chiranjeevi G. Vivek

* – Space Technology and Atmospheric sciences Research centre (STAR), Department of Electronics and Communication Engineering, K L University, Vijayawada, Andhra Pradesh, India

5.6 Noise analysis of multi–GNSS time series

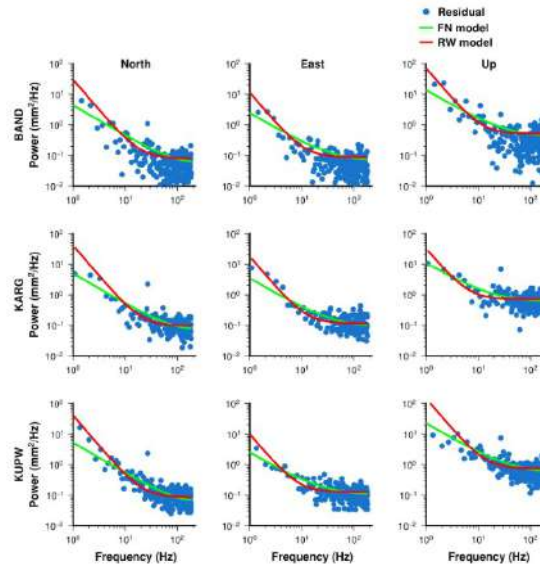


Figure 5.7: Power Spectral Density of Bandipore, Kargil and Kupwara GPS time series.

Noise analysis of the GNSS time series is very crucial to understand and interpret the results in geodetic studies. GNSS time series may not be ideal and it often contains noise that can lead to inaccurate parameter estimates and the increased uncertainties. For the first time in India and adjoining regions, noise analysis is performed for multi–GNSS data sets. Maximum Likelihood Estimation (MLE) and spectral analysis are used to characterize the dominant noise model in the stand–alone GPS, Glonass and combined GPS, Glonass daily position time series. These analyses indicated that Flicker Noise plus White Noise (FNWN) model is the most preferred noise model for all the multi–GNSS time series. However, cGNSS stations (BAND, KARG, KUPW) experienced random walk noise in different components of the GPS time series. To validate these results, power spectral analysis is performed for these stations time series. Flicker noise and random walk noise models are fitted with the residuals of observations as illustrated in Figure 4. Random walk noise is the best fit model for the East component of Kargil station compared to the flicker noise model. North and Up components of Kupwara and Bandipore stations respectively shows intrusive random walk noise along

with the flicker noise. This anomaly may be due to soil and weather disturbances that cause subtle movement of station monument with respect to the deeper crust. However, longer duration of data is required to exactly assess the random walk noise in the time series. Except these anomalies, all the other components confirm FNWN as the best fit model.

Chiranjeevi G Vivek, Sridevi Jade, Siva Sai Kumar R

5.7 Impact of hydrological, atmospheric loading on geodetic deformation over Indian subcontinent

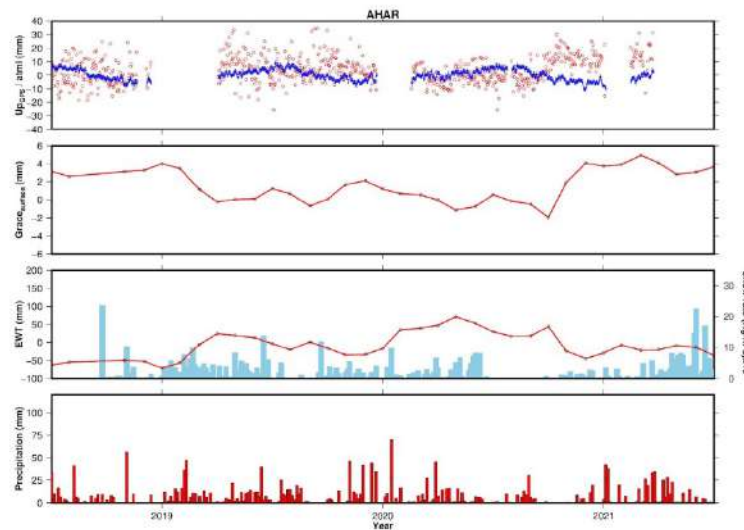


Figure 5.8: GNSS Up component of Aharbal station along with GRACE surface deformation, EWT, Snow rate and precipitation during 2018–2022.

The study focusses on horizontal and vertical seasonal deformation rates of the Earth surface using continuous Global Navigation satellite system (cGNSS) and Gravity recovery and Climate experiment (GRACE) data over the Indian sub-continent. Around 32 cGNSS stations from 2002–2021 are used to compare the impact of seasonal loading on deformation. The vertical and horizontal deformation obtained by GAMIT/GLOBK software, along with GRACE and Atmospheric loading deformation time-series are processed for better understanding the tectonic and non-tectonic signals. The basic idea is to separate seasonal signals, estimated from GRACE to GNSS time-series which will provide the tectonic signals. Increased water mass like rainfall and snow compresses the Earth's crust causes subsidence. The Himalayan region undergoes seasonal snow loading, intense monsoons, and groundwater changes, all influencing crustal movement. Figure 5.8 shows the vertical component of Aharbal station along with GRACE surface deformation, Equivalent Water Thickness (EWT), snow rate and precipitation. Annual cycles show uplift in winter due to snow mass and subsidence in summer due to melt and rain-driven loading. GRACE and EWT data confirm this elastic deformation

pattern with occasional sudden drops likely linked to earthquakes or irrigation. Monsoon precipitation contributes to additional subsidence by altering groundwater levels and pore pressure. The study of hydrological loading gives insights into water cycle variability and changes in terrestrial water storage (TWS). Addressing these effects is essential for precise geophysical studies.

Rajendra Kumar Dash, Suribabu Donupudi, Sridevi Jade, Shrungeshwara T S,
Chiranjeevi G Vivek, Ashish

5.8 Multi-Instrument Analysis of Ionospheric Equatorial Plasma Bubbles over the Indian and Southeast Asian Longitudes During the 19–20 April 2024 Geomagnetic Storm

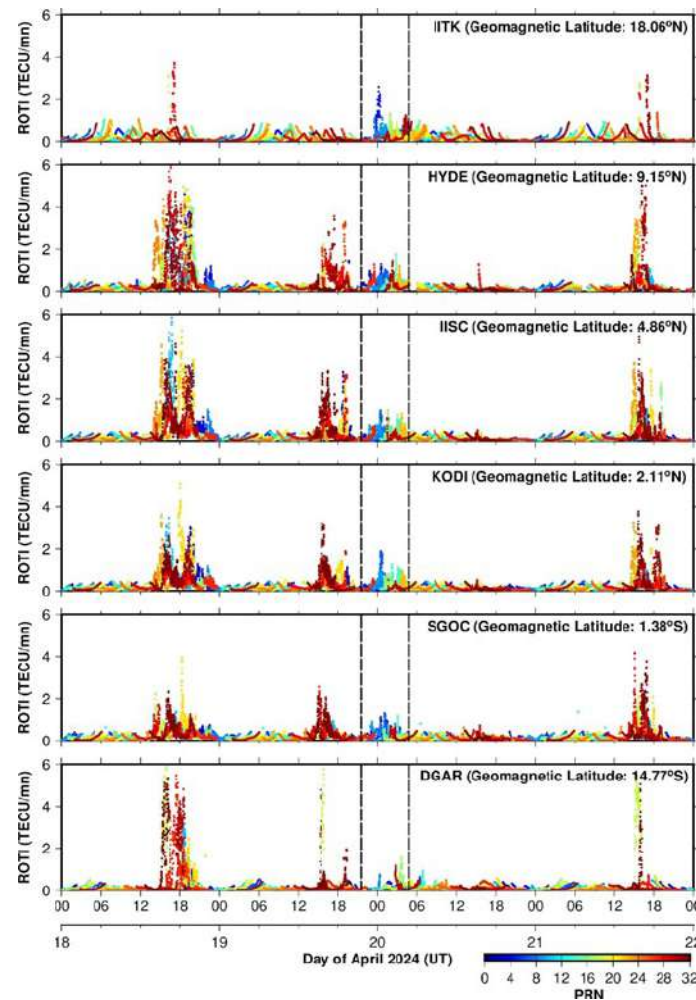


Figure 5.9: Occurrence probability of Seasonal average ROTI during 2010–2023 for stations situated from southern EIA region to northern EIA region along with monthly average SSN2 and F10.7 solar radio flux.

This study investigated the occurrence of near-sunrise Equatorial Plasma Bubbles (EPBs) and the suppression of dusk-time EPBs during the geomagnetic storm

of 19–20 April 2024 (SYM–Hmin = -139 nT) over the Indian and Southeast Asian longitude sectors using multi-instrument observations. The results show no notable changes in the ionospheric electric fields during the main phase of the storm, which lasted from post-sunset to midnight in the study region. During the storm recovery phase, the IMF Bz turned northward, leading to overshielding penetrating electric fields and which triggered the formation of near-sunrise EPBs. Figure 5.9 shows that these EPBs persisted for more than three hours after the sunrise terminator. The EPBs initially developed in the Southeast Asian region and then moved westward towards the Indian longitude sector, following the sunrise terminator. The study also revealed that storm-induced electric fields suppressed the occurrence of post-sunset EPBs in the dip equatorial and low-latitude regions between 70°E and 90°E longitude sectors during the recovery phase. The findings highlight that even moderate geomagnetic storms can generate near-sunrise EPBs over a wide longitude range due to penetrating electric fields in overshielding conditions, which can significantly impact trans-ionospheric signals.

Sampad Kumar Panda*, Siva Sai Kumar Rajana, Chiranjeevi G. Vivek, Jyothi Ravi
Kiran Kumar Dabbakuti**, Wangshimenla Jamir***, Punyawati Jamjareegulgarn****

* – Space Technology and Atmospheric sciences Research centre (STAR), Department
of Electronics and Communication Engineering, Koneru Lakshmaiah Education
Foundation, Vaddeswaram, Andhra Pradesh, India

**Department of Internet of Things, Koneru Lakshmaiah Education Foundation,
Vaddeswaram, Andhra Pradesh, India

***Department of Geography, Nagaland University, Lumami, Nagaland, India

****King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon
Campus, Chumphon, Thailand

5.9 Case study on the Mw 6.2 Dipayal Earthquake of October 3, 2023 using InSAR data products

A focused case study was conducted on the October 3, 2023, M6.2 earthquake near Dipayal in Western Nepal (29.39°N , 81.19°E), which occurred along the Almora Fault—a key tectonic structure in the Central Himalayan region. Due to its shallow depth (~ 5 km) and proximity to active fault zones, the event provided a valuable opportunity to examine surface deformation patterns in a seismically sensitive area. To assess co-seismic ground displacement, InSAR (Interferometric Synthetic Aperture Radar) analysis was performed using Sentinel-1 satellite data from both ascending and descending passes (Figures 5.10 & 5.11). The processed interferograms displayed phase variations in the range of -3.14 to $+3.14$ radians, indicating ground movement consistent with moderate seismic activity. These patterns were visualized through wrapped phase maps, with seismic events (Mw 3.0–6.2) overlaid for spatial context. Despite these findings, significant terrain-related noise and decorrelation were observed, particularly in the central study area where topographic relief is highest. While some phase fringes appeared in southern regions of the interferogram, they lay outside the main zone of interest and lacked reliability for displacement estimation. The decorrelation in the epicentral zone limited the ability to extract clear deformation signals. This analysis

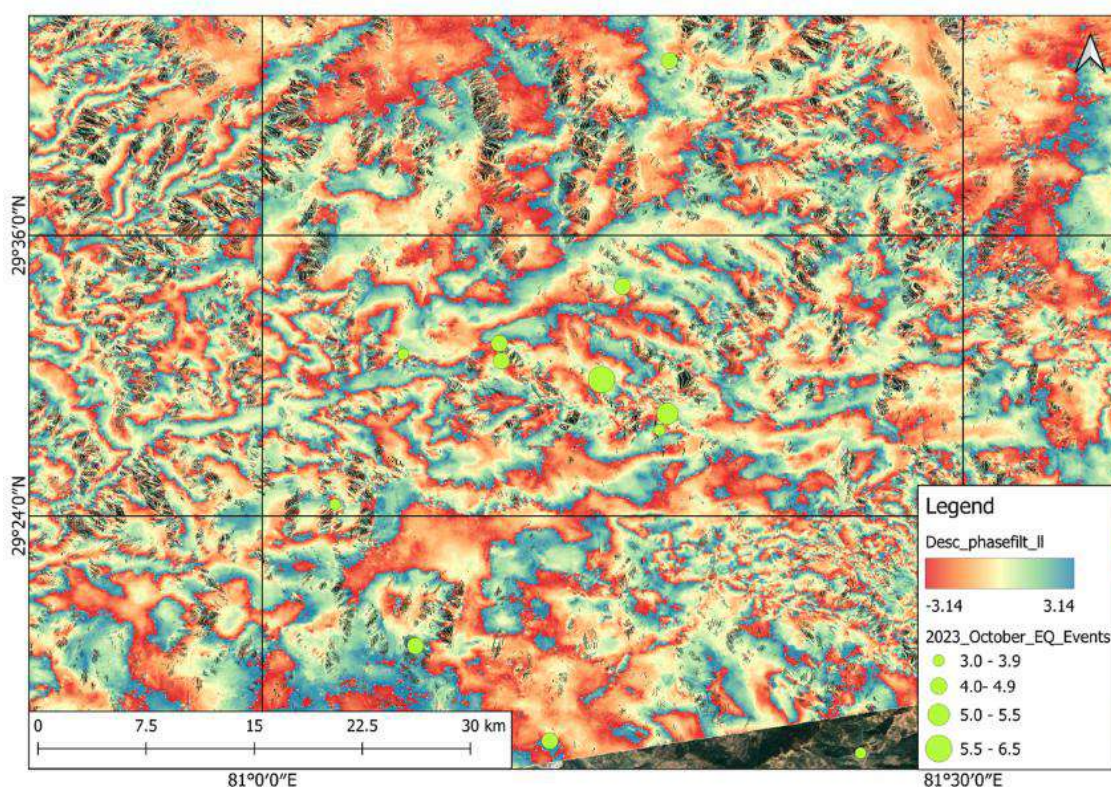


Figure 5.10: Ascending Phase map for Mw 6.2 earthquake in Dipayal, Western Nepal (29.39°N , 81.19°E ,

underscores the challenges of using InSAR in mountainous regions like the Himalaya, where steep topography can degrade data quality. However, it also demonstrates the value of combining satellite-based techniques with ground-based GPS observations to better understand regional strain patterns and support future seismic monitoring efforts.

Pavithra N R

5.10 Validating InSAR Methodology Using the 2020 Monte Cristo Range Earthquake

The Monte Cristo Range in Nevada was selected as a test site for validating InSAR-based ground deformation analysis due to its favorable conditions. Located in an arid environment, the region exhibits minimal vegetation cover, which helps reduce atmospheric and surface noise in satellite-based interferometric observations. Furthermore, the area experienced a single major seismic event—the Mw 6.5 earthquake on May 15, 2020—allowing for a clear analysis without interference from overlapping ruptures or persistent aftershocks. This case provided an ideal benchmark to assess the reliability of my InSAR processing workflow. Using the GMTSAR software package, a series of interferograms and displacement maps were generated to examine co-seismic deformation. These results (Fig. 3–5) were then compared to previously

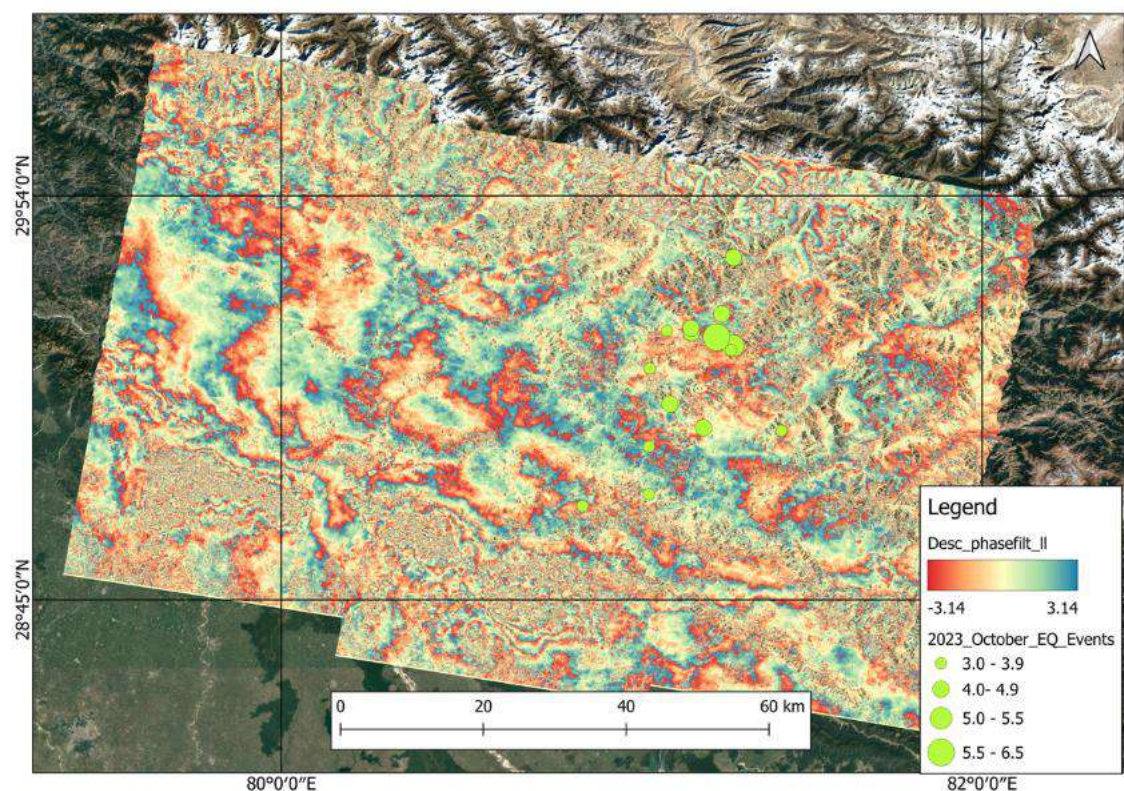


Figure 5.11: Descending phase interferogram for the Mw 6.2 Dipayal earthquake, Western Nepal (Epicenter: 29.39°N, 81.19°E).

documented displacement patterns for the same event. The close alignment of my outputs with known deformation fields and ground displacement magnitudes (Table 1) demonstrated the robustness of the approach. Overall, this validation exercise confirmed the accuracy and reproducibility of the InSAR method in a controlled setting. It also established a solid foundation for applying the same workflow to more terrains.

Parameter	This Study	Published Results
Software Used	GMTSAR	GMTSAR
Max East–West Displacement	±12 cm	Up to ~20 cm horizontal displacement
Displacement Pattern	Bilateral lobe: Westward (–) and Eastward (+) zones	Bilateral horizontal displacement typical of left–lateral
Coseismic Deformation Symmetry	Asymmetric but consistent with left–lateral rupture	Asymmetric deformation pattern reported
Earthquake Location	Mapped with red star (fig 5) at ~117.85°W, 38.05°N	Mw 6.5 event: 38.163°N, 117.833°W

Table 5.2: Comparison of Coseismic East–West Displacement Results: This Study vs. Published 2021 Monte Cristo Earthquake Analysis.

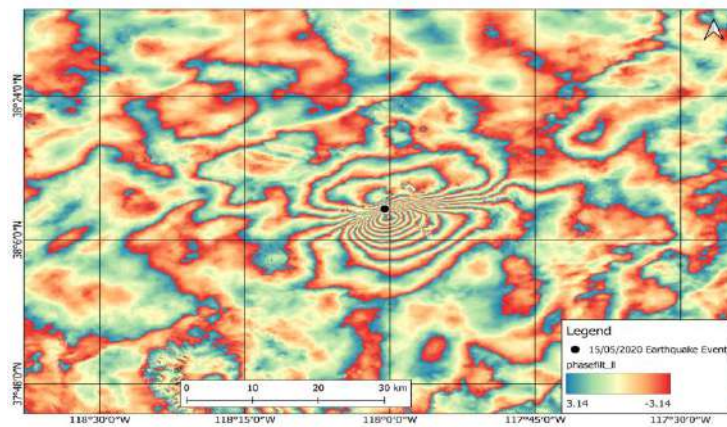


Figure 5.12: Ascending track Interferogram generated using GMTSAR.

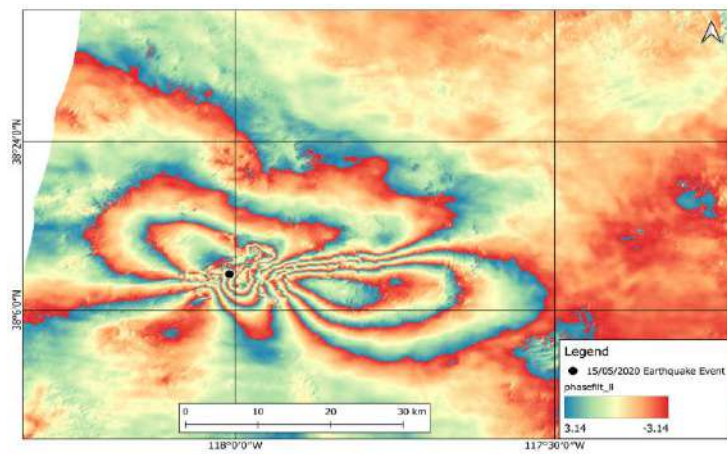


Figure 5.13: Descending track Interferogram generated using GMTSAR.

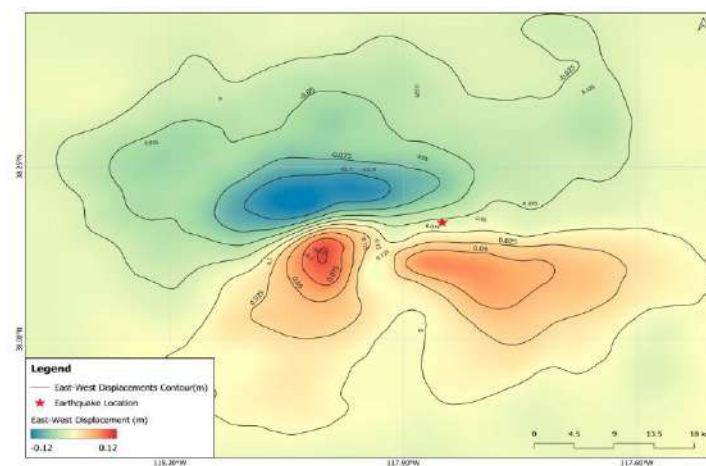


Figure 5.14: Modeled East–West Coseismic Displacements using GMTSAR for the 2020 Monte Cristo Earthquake.

5.11 Ionospheric imagery of earthquake source region using the Co-seismic Ionospheric Perturbations

Each earthquake has distinct rupture characteristics, which manifest as unique amplitude and arrival-time features in its ionospheric signals, known as Coseismic Ionospheric Perturbations (CIPs). To extract the responsible ground source locations solely from observed CIPs and to understand the impact of earthquake occurrence time on these signals, we analyzed earthquakes with various rupture complexities and occurrence time. As part of this work, we developed a novel methodology that uses only ionospheric data to identify the locations of the corresponding nearfield ground sources. An overview of this approach is shown in Figure 5.15. A key insight from our study highlights the importance of removing background electron density before comparing CIP amplitudes with their respective seismic sources. To investigate this, we employed the relative filtered gradient rate of vertical TEC (FgROT). Notably, after eliminating the effect of the background electron density, the relative FgROT values became comparable across different cases. This finding is illustrated in Figure 5.16.

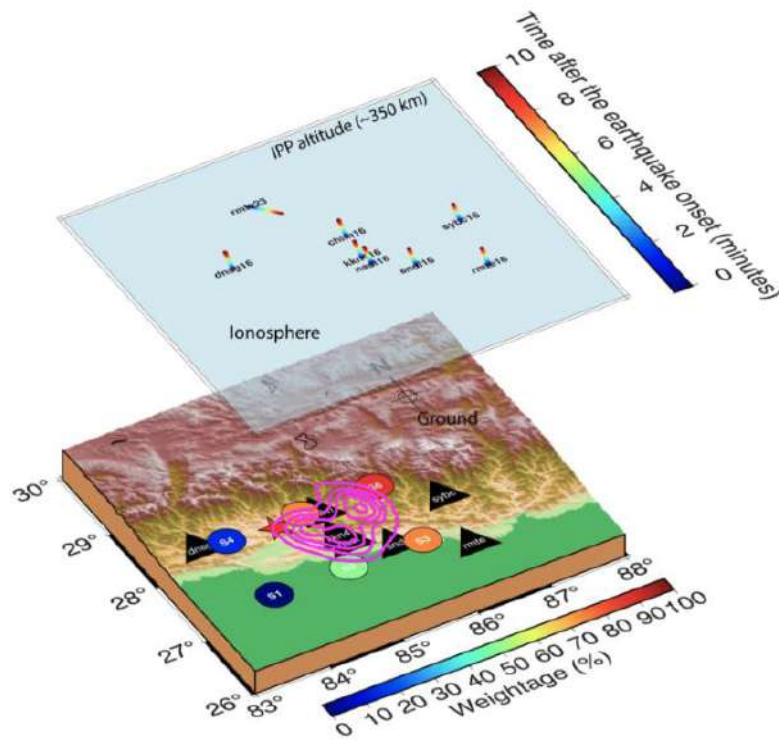


Figure 5.15: The satellite tracks are shown in the top layer with the corresponding trajectory time in colors. The magenta contours are the rupture contours taken from Fan and Shearer (2015). The weightage estimated using our new methodology represents the probability of the responsible ground sources (colored disks). The good correlation between the maximum probable sources (colored disks) and the rupture area can be noticed.

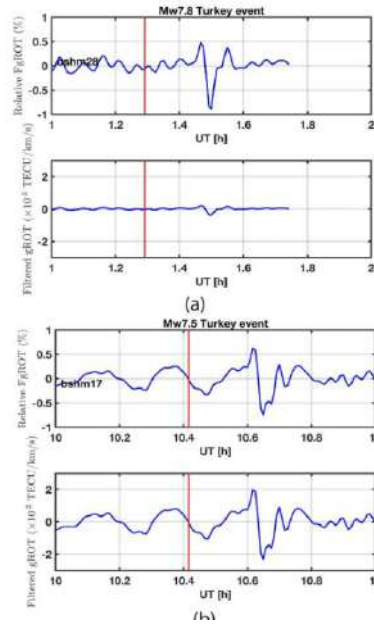


Figure 5.16: (a) Filtered FgROT and Relative FgROT calculated for Mw7.8 Turkey–Syria doublet earthquake for the bshm –PRN28 station –satellite pair (b) same as (a) calculated for Mw7.5 Turkey– Syria event for the station–satellite pair bshm–PRN17.

Dhanya Thomas and M. Sithartha Muthu Vijayan

5.12 Building Low–Cost GNSS Receiver for Ionospheric Total Electron Content (TEC) Estimation

The ionosphere, influenced by space weather events such as solar flares, plays a significant role in degrading satellite–based communication and positioning systems. Total Electron Content (TEC)—the count of free electrons along the path between a satellite and receiver—affects the accuracy of GNSS signals. Industrial grade receivers used for TEC estimation are prohibitively expensive, limiting their broader usage in educational and research contexts. To bridge that gap we designed a low–cost alternative using commercially available components.

A dual–frequency GNSS receiver module from Ublox ZED series, was chosen due to its compatibility with GPS, GLONASS, Galileo, and BeiDou satellite systems. The hardware setup included the GNSS module and a dual–frequency patch antenna (Figure 3). This setup enabled continuous collection of raw GNSS data over a 24–hour period (Figure 4), which was then converted into the standard RINEX format. The collected data was used to estimate TEC, leveraging both pseudo–range and carrier–phase measurements. Analysis of 24–hour TEC data showed smoother variations from GPS signals compared to GLONASS, with GLONASS occasionally exhibiting negative TEC values, possibly due to instrumental bias related to its FDMA signal access technology (Figure 5). The results could be further improved by correcting differential code biases. However, the initial results are promising and the estimated values are within

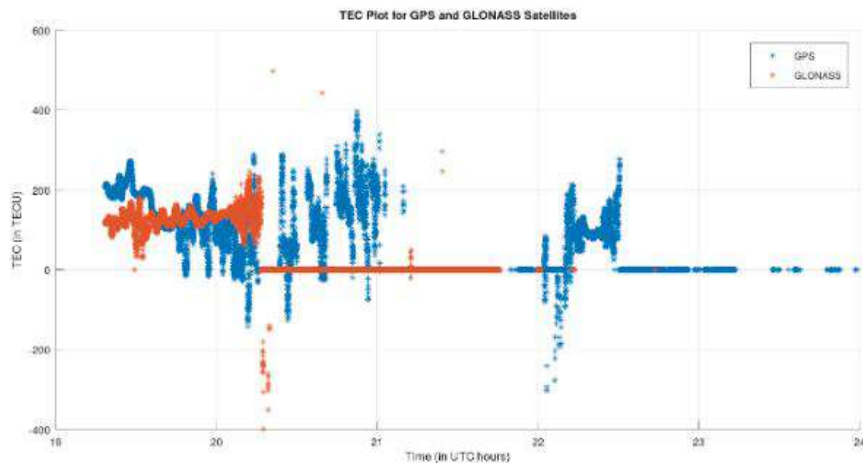


Figure 5.19: TEC estimated from the low-cost GNSS observations. Dual frequency signals used for TEC estimates (with differential code biases) are from GPS satellite G27 (blue) and GLONASS satellite R09 (red).

M. Sithartha Muthu Vijayan, Kanagambujam Venkatramani*, and Brindha K*

* – National Institute of Technology, Trichirappalli

5.13 Dynamic Stress Changes on the East Anatolian Fault

Through this study we investigated the spatio-temporal stress changes along the East Anatolian Fault (EAF) in the background of the February 6, 2023, Turkey earthquake doublet. By analyzing earthquake focal mechanism data across significant regimes, we looked at the evolution of the lithospheric stress field in distinct zones. The analysis revealed significant spatial variations and a dynamic stress reversion process; in the vicinity of the mainshock, the stress field transitioned from an oblique-normal state to a normal-oblique regime before reverting to its preseismic condition. We note a predominant $\sim$ N-S to NNE-SSW orientation for the maximum horizontal stress (SHmax), aligning with the Arabian plate's convergence and highlighting complex stress partitioning. Notably, zones that experienced the highest coseismic slip, such as on the Pazarcık and Çardak Faults, showed a significant anticlockwise rotation of SHmax after the earthquake, which likely signifies the dissipation of arc-normal stress. Furthermore, the research establishes a strong correlation between stress relief and afterslip, where areas with high afterslip, like the Pazarcık segment, demonstrated nearly complete stress release, while regions with minimal slip showed only partial relief. These findings provide critical insights into post-earthquake fault mechanics and seismic hazard scenarios.

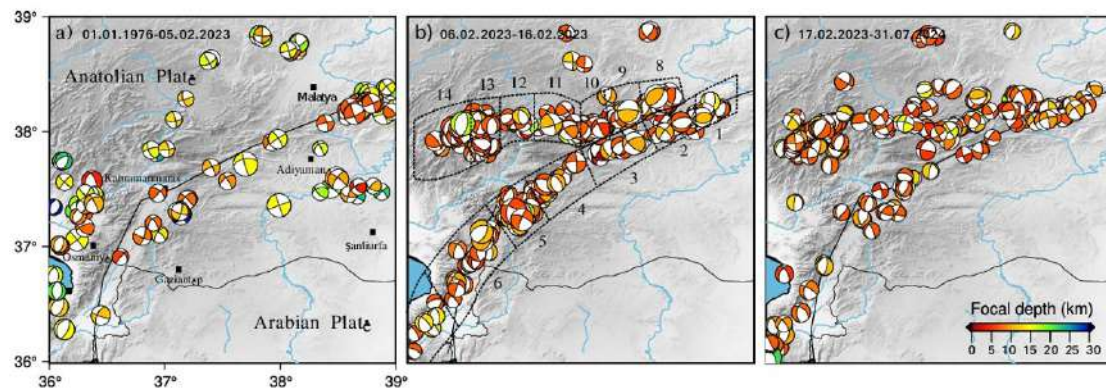


Figure 5.20: Earthquake faulting mechanism distribution map for the different time and the space segments in the vicinity of February 6, 2023, Turkey earthquake doublet.

Anil Earnest

5.14 Outer-arc Active Tectonic Deformation off the Nias–Nicobar Trench

This study provides significant insights into the complex tectonic processes occurring in the outer-arc region seaward of the Nias–Nicobar Trench, a critical part of the Sunda subduction zone. This area is characterised by intense seismic activity, including the generation of major earthquakes, and understanding its deformation is crucial for seismic hazard assessment. We integrated lithospheric stress modelling with seismic slip models from recent earthquakes to analyse the active deformation mechanisms. The primary focus is on the “outer-arc,” the region on the subducting oceanic plate just before it enters the trench. This area is subject to immense bending stresses as the Indo–Australian Plate flexes downwards beneath the Sunda Plate. The models reveal that the upper part of the subducting oceanic lithosphere experiences significant tensional stress. This leads to the formation of trench-parallel normal faults. These faults are a direct consequence of the plate bending and are responsible for many of the earthquakes observed in the outer-rise and outer-arc region. The stress orientation is typically characterised by a trench-perpendicular tensional axis, consistent with extensional tectonics. The study also highlights a layered stress profile within the oceanic plate. While the upper crust is under tension, the deeper part of the lithosphere is under compression. This compressional stress at depth helps to balance the forces acting on the plate as it bends, a concept known as the “bending moment.” The research indicates that pre-existing structures on the seafloor of the Indo–Australian Plate, such as fracture zones and seamounts, act as zones of weakness. These features can influence the location and orientation of newly formed faults and can localise seismic slip during an earthquake, leading to complex rupture patterns. The modelled high-stress zones show a strong correlation with the locations of significant earthquakes, including the notable 2012 Indian Ocean earthquake (M_w 8.6). The seismic slip distributions from such events align well with the predicted patterns of stress re-

lease, validating the models. The study suggests that the interplay between bending stresses and inherited structures governs the seismic behaviour of this region.

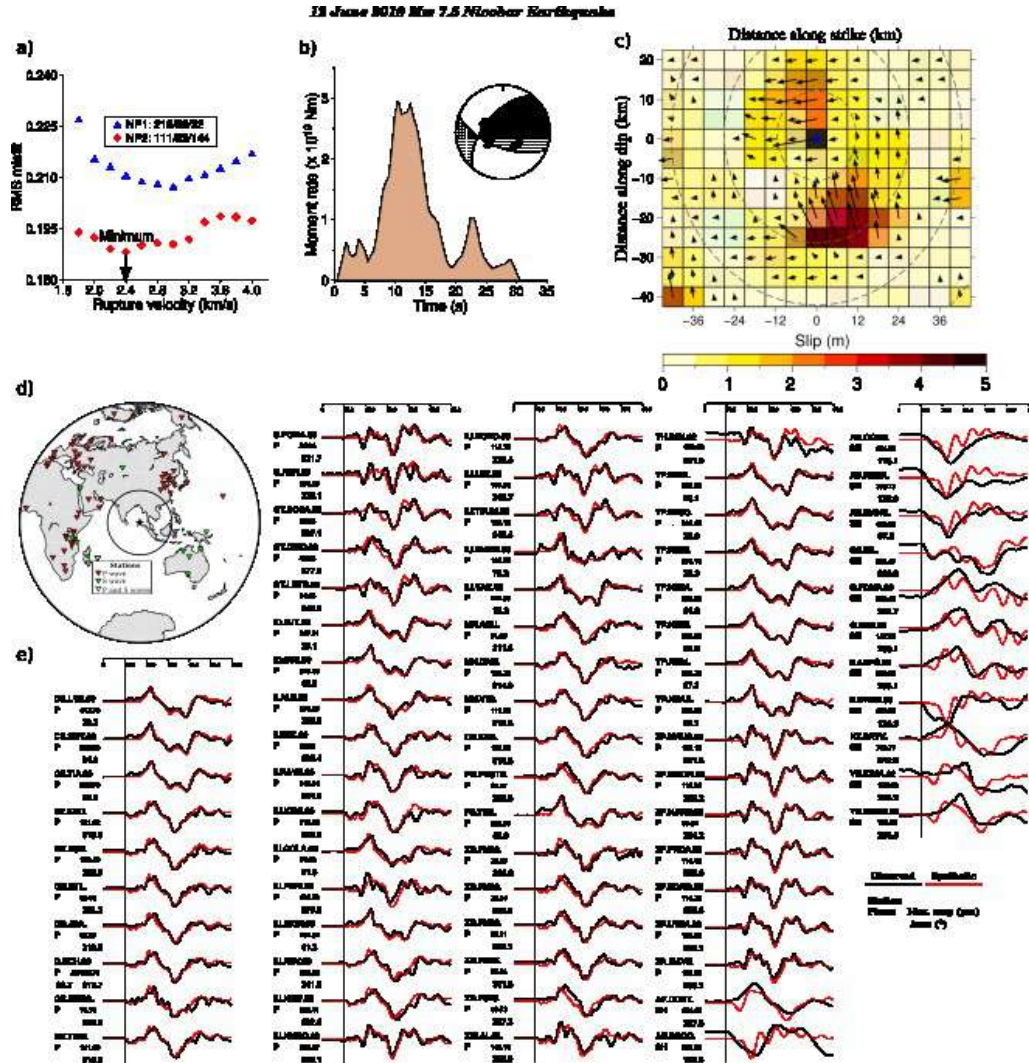


Figure 5.21: Simulation results of 12/06/2010 Mw 7.5 Nicobar earthquake. a) Rupture velocity iterations (diamonds & triangles are nodal planes). b) Moment rate function and focal mechanism. c) Final slip distribution model with rupture time front contours (gray dashed lines). Blue star indicates the depth of the event source. d) seismographs from which waveform data were fetched. e) Comparison of synthetic (red) to observed wave-forms (black).

5.15 Buckling studies of triple-walled carbon nanotube using the pseudospectral method with backward substitution approach for general boundary conditions.

The present study focuses on determining the critical buckling studies of triple-walled carbon nanotubes using the model formulated by the Euler-Bernoulli theory. Further, we use five boundary conditions, namely simply-simply, simply-clamped, clamped-clamped, clamped-free, and clamped-sliding restraint support. Many numerical models addressed different boundary conditions. However, they fail to provide close results with exact solutions. It occurs in boundary conditions like clamped-free and clamped-sliding restraint support due to the buckling load terms present in those boundary conditions and also in governing equations. Also, solving the coupled model with less computation time and estimating higher buckling loads is challenging. We use the pseudospectral method by exploiting the backward substitution approach to solve the critical buckling loads of triple-walled carbon nanotubes for higher buckling loads with less computation time. The elegance of the present approach is handling the presence of buckling loads in the boundary conditions without any issues. The comparison of present results with other numerical methods like differential quadrature and differential transform shows the superior performance of this method. Further, the present works obtain the higher mode shapes for higher critical buckling loads.

Senthilkumar V and Prajval K*

* – IISER, Thiruvananthapuram, Kerala

5.16 Revisiting the Mindlin microstructure isotropic strain gradient elasticity theory for Form-I, Form-II, and Form-III with length scales.

Mindlin proposed the microstructure linear elasticity theory to model micromorphic effects in isotropic solids using crystal parameters. It takes the form of three types: Mindlin Form-I, Form-II, and Form-III. Since Mindlin used Toupin constants, this theory refers to the Toupin-Mindlin strain gradient theory. The Form-II model is discussed extensively in the literature in comparison with Form-III. In the literature, Mindlin form-III model shows a lack of attention due to alternating tensor terms present in the model. The present work estimates the material constants of Mindlin microstructure Form-III strain gradient elasticity theory for isotropic cases with two-length scales. We found that for an isotropic case, all the length scales of Form-I, Form-II, and Form-III result in the same value.

Senthilkumar V and Uday Singh*

* – NISER, Bhubaneswar, Odisha



Knowledge & Technical Management

- 6 Academic Programmes 99
- 7 Knowledge Activities and Products
119
- 8 Projects & Collaborative Pro-
grammes 163
- 9 Staff News & Updates 167

6. Academic Programmes

CSIR-4PI maintains an active academic programme, keeping its objective of developing skill and expertise in mathematical modelling & computer simulation, data intensive research in the country. The activities span the entire spectrum from PhD guidance to undergraduate/postgraduate student projects to specialized courses. Student Programme for Advancement of Research Knowledge (SPARK) is intended to provide an unique opportunity to bright and motivated students of reputed Universities to 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 Sciences, Physical Sciences and Engineering Sciences.

Inside:

1. Academy of Scientific and Innovative Research (AcSIR)
2. CSIR-Integrated Skill Initiative Programme at CSIR-4PI
3. 4.4 CSIR Jigyasa
4. 4.5 CSIR-4PI Student Programme for Advancement of Research Knowledge (SPARK)
5. 4.6 Faculty Participation

6.1 Academy of Scientific and Innovative Research (AcSIR)

The Academy of Scientific & Innovative Research (AcSIR) is established with the goal of maximizing the number of qualified researchers and professionals in the domains of science and engineering, equipped with skills in innovation and interdisciplinary integration. AcSIR imparts course instruction and awards degrees in frontier areas of science and technology. At CSIR-4PI, the AcSIR PhD program is offered in three disciplines: Physical Sciences (PS), Engineering Science (EE), and Mathematical and Information Sciences (MIS). Our program targets students intending to pursue research careers in interdisciplinary and multidisciplinary areas, both within and outside academia. Our primary objective is to provide students with a strong technical background, enhance their capacity for analytical thinking, and tackle new challenges for advancing science and society.

The PhD program is typically completed within 5 years. During the first year, students undergo coursework covering basic and advanced topics, with encouragement to take courses in interdisciplinary fields. They also participate in computational training tutorials and develop a research proposal on topics of high relevance and novelty, which includes a state-of-the-art review, methodologies, and recommendations, demonstrating a high level of scientific ability. Additionally, students are required to undertake a 6–8 week project related to rural areas, aligned with the themes of the CSIR-800 program. The aim of this project is to engage with rural communities, understand their challenges, and propose improvements in areas such as energy, education, environment, agriculture, health, food, and water. Students must pass a comprehensive examination designed to assess their overall comprehension of various subjects. This is followed by advanced research leading to a PhD thesis on a specific topic. To date, CSIR-4PI has produced 15 PhD graduates since its inception.

All academic activities related to PhD students, including screening and selection of students in two sessions every year, scheduling of coursework offered by faculty (open to AcSIR students of all CSIR labs), allocation of supervisors, coordination of Doctoral Advisory Committee (DAC) meetings and Comprehensive Examinations, and management of PhD thesis submissions and oral examinations, are overseen by the AcSIR coordinator. The coordinator also maintains records of students' performance in coursework, progress reports of PhD work, and all AcSIR-related information and documents pertaining to doctoral students. AcSIR PhD student, Mr Akash Deep Dixit (10MM23A45002) secured admission to the RMIT-AcSIR JDP 2025 Fellowship under MIS subject category. The first meeting of Academic Committee, AcSIR@CSIR-4PI was convened on September 20, 2024 at 11 AM. Six important Agenda items were discussed and approved, and the approved minutes were circulated.

Formed the AcSIR Science Club at CSIR-4PI with the following office bearers:

- Mr. Manjunatha G S (20EE22J45002): President
- Ms. Swetha S (10MM20A45002): Vice President
- Mr. Akash Deep Dixit (10MM23A45002): Secretary

Six new AcSIR faculties joined AcSIR as Assistant Professors:

1. Dr Suribabu Donupudi (19 March 2025)
2. Dr Konatham Prasanna (19 March 2025)
3. Dr Sangeetha S (19 March 2025)

4. Dr. Gayathri R (21 November 2024)
5. Dr. Nagarathna R (21 November 2024)
6. Dr. Vivekananda Hazra (21 November 2024)

In the academic year 2024–2025, two students joined the PhD (PS) and one student joined PhD (ES) program in the August 2024 session, and two students joined PhD (ES) program in the January 2025 session. In the end of previous academic year, there were 17 PhD students are on roll. Chiranjeevi Vivek G (Reg. No. 20EE16J45001) completed PhD PTOC on 26/02/2025. Thesis defence and viva voce examination of Rani Devi (10MP19A45001), Smarti Purwar (Reg. No. 10MM18A45001) and Kanike Raghavendra Prasad Babu (Reg. No. 20EE18A45002) were conducted on 29/10/2024, 06/08/2024 and 03/12/2024 respectively.

Sajani Surendran
AcSIR Coordinator, CSIR–4PI

PhD Guidance under AcSIR@ CSIR–4PI

- Sridevi Jade
 1. Chiranjeevi Vivek Ganapa, AcSIR–20EE16J45001, PhD (Engg.), Sridevi Jade (Guide), Ashish (Co-guide)
 2. Narukula Durga Bhavani, AcSIR–10PP24A45002, PhD (PS)
- Patra G K
 1. S Gunasekaran, AcSIR–10MM20A45003, PhD (MIS)
 2. Manmohan Brahma, AcSIR–20EE20A45001, PhD (Engg.)
 3. Apoorva Jangir, AcSIR–20EE24A45001, PhD (Engg.)
- Anilkumar V
 1. Tarun Pandey, AcSIR–20EE22J45001, PhD (Engg.).
 2. Akash Deep Dixit, AcSIR–10MM23A45002, PhD (MIS).
- Ramesh K V (Guide), Rakesh V (Co-guide)
 1. Swetha S, AcSIR–10MM20A45002, PhD (MIS).
- Gouda K C
 1. Swadesh Mohapatra, AcSIR–10PP24J45002, PhD (PS).
- Rakesh V
 1. Rakhi, AcSIR–10MM23J45001, PhD (MIS).
 2. S Arun Prasad, AcSIR–20EE25J45003, PhD (Engg.)
- Kantha Rao B (Guide) and Gouda K C (Co-Guide)
 1. Pankaj Sharma, AcSIR–10MM24J45001, PhD (MIS).
- Ashapurna Marndi
 1. Rashmi K S, AcSIR–20EE22A45001, PhD (Engg.).
- Ashish
 1. Rajendra Kumar Dash, AcSIR–10PP24A45001, PhD (PS)
- Lakshmikanthan P
 1. Deepak Singh Baghel, AcSIR–20EE18J45003, PhD (Engg.).
 2. Manjunatha G S, AcSIR–20EE22J45002, PhD (Engg.).
- Nagarathna R.
 1. Madhvee Kori, AcSIR–20EE25J45002, PhD (ES)

PhD Guidance under AcSIR@CSIR–NAL

- Senthilkuamr V
 1. Shivaprasad, M V, AcSIR, Raja, S., CSIR–NAL (Supervisor) and V. Senthilku–mar (Co–Supervisor) from January 2023
 2. Mutturaj H Medar, AcSIR, Raja, S., CSIR–NAL (Supervisor) and V. Senthilku–mar (Co–Supervisor) from January 2023
 3. Sivaranjani, T, AcSIR, Pavan Kumar, D V T G., CSIR–NAL (Supervisor) Raja, S., CSIR–NAL (Co–Supervisor) and V. Senthilkumar (Co–Supervisor) from January 2024
 4. Akshatha, H.T., AcSIR, Sathiya Naarayan (Supervisor) and V. Senthilkumar (Co–Supervisor) from August 2024

PhD Guidance – external universities

- Sridevi Jade

Siva Sai Kumar Rajana, KL University, Global Navigation Satellite System (GNSS) based remote sensing of long and short–term ionospheric variability over Indian sub–continent.

M.Tech/BE/MCA student thesis/projects supervised by CSIR–PI scien–tists

- Sithartha Muthu Vijayan M
 1. Kanagambujam Venkatramani and Brindha K, Building Low–cost GNSS Re–ceiver for Ionospheric TEC Estimation and Analaysis, Department of Elec–trical and Electronics Engineering, National Institute of Technology, Trichi–rappalli, Tamilnadu, India, 3rd May 2024
- V. Senthilkumar
 1. Prajval K, Integrated BS–MS, An Internship Project Report on “Stable Nu–merical Methods to Solve Eigenvalue Differential Equations of Integer and Fractional Orders”, IISER Thiruvananthapuram, July 2024.
 2. Uday Singh, Bachelor of Science, An Internship Project Report on “Revisit–ing Mindlin’s Strain Gradient Theory”, (NISER), May to July 2024, UG.
 3. Kirthna Surag, An Internship Project Report on “Machine Learning Mod–els for Prediction of Longitudinal and Transverse Phonon Frequencies in Metals”, BITS Goa, July 2024.
- G N Mohapatra
 1. J Srujan Vishwakarma “Prediction of Rainfall Pattern Using Very High–Resolution CHIRPS and IMD Rainfall Data using Machine Learning Technique” submit–ted in partial fulfilment of requirement for the award of the degree Bachelor of Engineering Of Visvesvaraya Technological University.
- Ashapurna Marndi
 1. Fairoz Khan, Image to Image Generation Using Diffusion Model
 2. Huzaifah Fatima, Image to Image Generation Using Diffusion Model
 3. Mohammed Amin Khan, Image to Image Generation Using Diffusion Model
 4. Ifra Kaunain, Image to Image Generation Using Diffusion Model
 5. B S Shreesha, Capsule Network Implementation for Medical Image Analysis

6. Shreesha R, Capsule Network Implementation for Medical Image Analysis
 7. Tarun , Traffic Simulation in Unreal Engine
 8. Dhanush H, Traffic Simulation in Unreal Engine
 9. Ansh vivekyog, Federated Learning concept
 10. Swathi V E, Malaria Classification Using Deep Learning Architecture
- Rakesh V
 1. SNEHA VARGHESE for M. Sc. Atmospheric Sciences Project Report “INVESTIGATING THE INFLUENCE OF URBAN HEAT ISLAND ON RAINFALL – A CASE STUDY OVER BENGALURU URBAN AND CHENNAI” Submitted in partial fulfillment of requirement for the award of the degree Of Department of Physics and Nanotechnology, SRM Institute of Science and Technology, Chennai.

6.2 CSIR–4PI Integrated Skill Initiative Programme

As part of the CSIR Integrated Skill Initiative – Phase II (2020–25), CSIR–Fourth Paradigm Institute (CSIR–4PI), Bengaluru, has reinforced its pivotal role in national capacity building through the structured delivery of advanced skill development programs.

During the financial year 2024–25, the institute trained 313 students, emphasizing practical knowledge and technical competence in high-demand scientific domains.

CSIR–4PI Student Programme for Advancement of Research Knowledge (SPARK)

The Student Programme for Advancement of Research Knowledge (SPARK) of CSIR–4PI has been successfully operational for more than past ten years.

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. The programme is intended to increase the interaction between scientists and faculty members of academic institutes along with their students towards a long term research collaboration.

The Student Programme in Advancement in Knowledge (SPARK) is a dedicated academic initiative designed to foster collaboration between CSIR–4PI scientists and students from various universities and academic institutions. Under SPARK, the students typically carry out their major project/thesis work with the joint guidance of the CSIR–4PI scientists and faculty members of their respective University/Institute.

As a longstanding CSIR–4PI initiative, this year SPARK provided 77 students from B.Tech, M.Tech, M.Sc., and Ph.D. backgrounds with research exposure, mentorship, and industry visits. It remains instrumental in cultivating early interest in computational and Earth sciences.

CSIR–4PI's training efforts for the year were distinguished by their interdisciplinary approach and alignment with national missions like Digital India and Skill India. The programs were carefully curated to address skill gaps in various areas. The major Impact and Outcomes are: 313 students trained, including significant participation from underrepresented regions and diverse academic backgrounds.

Enhanced national capacity in frontier areas of science and engineering. Continued emphasis on practical, hands-on exposure for developing job-ready competencies. Strengthened collaboration between academia, research, and industry.

Key programs conducted under CSIR–Integrated Skill Initiative Programme at CSIR–4PI are listed below:

55th Earth Day

55th Earth Day was celebrated on May 4th by Tree Plantation under Skill India Initiative at CSIR-4PI and Dr. Harini Santhanam spoke on "Sustainable e-waste management in the age of digitization". 21 students and 4 faculty members of Fullinfaws College participated.



One-day workshop on 13 May 2024

CSIR-4PI conducted One-day workshop on 13 May 2024 under the CSIR-4PI Skill Initiative, empowering the next generation of woman tech leaders. Students from GSSS Institute of Engineering and Technology for Women dive into the world of Super-computing & Cybersecurity.



One Week One Theme (OWOT) – Energy and Energy Devices (EED) Program

As part of One Week One Theme (OWOT) – Energy and Energy Devices (EED) Program, CSIR-4PI hosted one day Skill Event on “Harnessing High-Performance Computing for Innovation in Energy Solutions” on June 26, 2024. Shri. M P Ramesh, President, Wind Resource and Technology was the Chief Guest and he delivered a talk on “Wind Power – An Opportunity to Innovate”. Dr. Kavita Joshi, Principal Scientist, CSIR-NCL Pune, delivered a talk on “Catalysing Innovation Through Computation”. Dr Asha-purna Marndi and Shri Prabhu from CSIR 4PI presented their talks on “Wind speed prediction: AI-Powered forecasting for enhanced energy efficiency” and “HPC Architecture and its application” respectively. Around 70 students and teachers from St. Joseph’s University, Cambridge Institute of Technology and Nitte Meenakshi Institute of Technology, Bengaluru participated in the event and visited the facilities of CSIR 4PI.



NSM–HPC Systems & AI: from Theory to Practice

3. The NSM–HPC workshop titled “NSM–HPC Systems & AI: from Theory to Practice”, held on July 4–5, 2024, at CSIR–4PI under the CSIR Integrated Skill Initiative, offered AcSIR students comprehensive training in high–performance computing and AI. This workshop is organized in collaboration with C–DAC Bangalore, featuring hands–on sessions with the Param Utkarsh HPC system, significantly enhancing participant’s computational skills and research capabilities. This initiative exemplifies CSIR’s dedication to equipping young researchers with cutting–edge technological expertise, fostering advanced skill development essential for scientific innovation. The event was well–received, marking a significant step in empowering young researchers with advanced HPC knowledge.



Ashish, Prabhu N & Pavithra N R

6.3 CSIR–4PI Jigyasa program

The CSIR–Fourth Paradigm Institute (CSIR–4PI), under its Jigyasa 2.0 program, orchestrated a dynamic and multifaceted series of outreach events from April 2024 to March 2025. Led by Mrs. Pavithra N R and Dr. Gayathri R, the initiative successfully engaged hundreds of students and teachers through a variety of formats, including hands–on workshops, scientist interactions, webinars, and creative contests, fostering a culture of scientific inquiry and exposing young minds to cutting–edge research.

The year kicked off with a five–day Summer Camp for 68 students and 2 teachers from four different schools. The camp featured lectures on topics like the Paradigms of Science and Astronomy and included fun, hands–on activities. July 2024 was a busy month with three major events. A Scientist–Student interaction on July 3rd brought 48 students from Moraji Desai Residential School to learn about High–Performance Computing (HPC), Cyber Security, GNSS, and Climate Informatics. On July 18th, another interaction was held for 45 students and teachers from Government High School Shivanapura, focusing on supercomputers, climate modeling, and cybersecurity, complemented by tours of the HPC and GPS facilities. From July 22nd to 26th, CSIR–4PI hosted a five–day Teachers Training Workshop for 42 high school science and math teachers, covering topics from Calculus and Atmospheric Physics to AI and HPC, along with practical physics experiments.

In August 2024, creativity and scientific interaction continued. A “Doodle Art Contest” on the theme “Artificial Intelligence: Boon or Bane” saw participation from 178 students across 12 government schools, with winners announced during Independence Day celebrations. On August 22nd, a scientist–student interaction was organized for 50 students from Dr. B R Ambedkar Residential School, who attended sessions on Seismology, GPS, and HPC, and visited the institute’s research facilities.

September 2024 featured a three–day webinar series by Dr. M. Sithartha Muthu Vijayan titled “Seismic Sounds in the Sky: Detecting Earthquakes and Tsunamis via Ionospheric Anomalies”. The online event successfully educated students on innovative disaster detection methods and garnered over 1,853 views on YouTube.

October 2024 focused on skill development with a Python Programming Workshop from October 4th to 10th. Led by Dr. Vidyadhar Mudkavi, the workshop introduced 38 students to Python basics, terminal commands, and Jupyter Notebooks, and included visits to the HPC facility and Energy Farm.

November 2024 was marked by three distinct events. On November 5th, a Curtain Raiser for the India International Science Festival (IISF) 2024 was held for 50 students from Divine Mercy School, featuring interactive sessions and facility tours. In celebration of Janjatiya Gaurav Diwas on November 25th, 47 students from KPS Narsapura, Kolar, were introduced to Geographic Information Systems (GIS) and visited the HPC, Energy Farm, and Cybersecurity facilities. Finally, on November 27th, a Scientist–Student Interaction for 27 students from Delhi Public School, Whitefield, focused on the applications of AI and HPC.

The activities in December 2024 included a two–part webinar on the “History and Applications of Computer Vision” by scientist Mr. Mithun Babu on the 2nd and 3rd, attracting 643 views. On December 20th, an engaging, hands–on DNA extraction experiment was conducted for 9th–grade students at Jaigopal Garodia Rashtrorothana

Vidyalaya as part of the CSIR Scientific Aptitude Assessment study.

Throughout the year, the Jigyasa program at CSIR-4PI has consistently provided valuable exposure to advanced scientific concepts and technologies, successfully inspiring scientific curiosity and a deeper understanding of real-world research among students and educators alike.

JIGYASA: SUMMER CAMP SCIENTISTS – STUDENTS INTERACTION

CSIR-4PI organized and conducted “JIGYASA: SUMMER CAMP” a SCIENTISTS – STUDENTS INTERACTION from 15th to 19th April 2024 (5 days). A total of 68 students from 4 schools participated. Lectures on Paradigms of Science, Astronomy, Algebra & Art in geometry were conducted by renowned personalities with fun filled hands-on sessions. The students were briefed regarding High-Performance Computing (HPC), Green House Gas (GHG), Cyber Security Lab, Global Navigation Satellite System Set-up.



Scientist–Student Interaction

CSIR–4PI JIGYASA Team organized and conducted Scientist–Student interaction on July 3, 2024. A total of 48 Students (19 Girls + 29 boys) and 2 teachers from Moraji Desai Residential School, Hunasedoddi campus, Ramanagara District participated. Students were briefed upon topics of HPC, Cyber Security, GNSS & Climate informatics.



Scientist–Student Interaction

CSIR–4PI JIGYASA Team organized and conducted Scientist–Student interaction on July 18, 2024. A total of 42 students (23 boys + 19 Girls) and 2 teachers from Government High School, Shivanapura, Hoskote participated. They got a glimpse of HPC, Cybersecurity, GNSS, and Agritech.



Doodle Art Contest with the theme 'Artificial Intelligence: Boon or Bane'

CSIR-4PI organized a Doodle Art Contest with the theme "Artificial Intelligence: Boon or Bane" from 15th July to 4th August 2024. A total of 178 students (70 boys and 108 girls) from various government schools in Bangalore participated. The contest received entries from 12 schools, where students creatively explored AI's impact, presenting diverse interpretations of its potential benefits, challenges, and ethical implications. Prizes were distributed to the winners during the Independence Day celebration on 15th August 2024 at the CSIR 4PI campus. The first prize was awarded to Yogahari (class 9) from KPS VV Puram, the second prize to Arjun N (class 8) from KPS KR Puram, and the third prize to Jeevan S (class 10) from KPS Hegganahalli. Consolation prizes were given to Likitha B (class 8) from KPS KR Puram, Sufiya (class 8) from KPS Attiguppe, and Shashank R (class 9) from JGRV Kalyan Nagar.



Scientist–Student Interaction

CSIR–4PI Jigyasa Team organized a scientist–student interaction on 22nd August 2024. A total of 50 students (28 boys and 22 girls) and 4 teachers from Dr. B R Ambedkar Residential School, Ramanagara participated. They attended sessions on Seismology, GHG, GNSS and an introduction to HPC, followed by visits to HPC, energy farm and cybersecurity facilities.



CSIR-4PI JIGYASA – YouTube webinar series

CSIR-4PI JIGYASA is organizing a YouTube webinar series daily from 11–11.30 AM, 18–20 September 2024, titled "Seismic Sounds in the Sky: Detecting Earthquakes and Tsunamis via ionosphere anomalies highlighting cutting-edge science



Scientist–Student Interaction

On 27th November 2024, CSIR-4PI Jigyasa Team organized a Scientist–Student Interaction for 27 students (15 boys, 12 girls) and 2 teachers from Delhi Public School, Whitefield. The program included interactive sessions on Applications of Artificial Intelligence and Introduction to High–Performance Computing (HPC), followed by guided tours of the High–Performance Computing (HPC) facility, Energy Farm, and Cybersecurity Facility, offering students practical insights into cutting-edge technologies and their applications.



DNA extraction experiment

CSIR 4PI under CSIR: JIGYASA initiative conducted DNA extraction experiment under the CSIR Scientific Aptitude Assessment study with 9th standard students of Jaigopal Garodia Rashtrorothana Vidyalaya , Kalyannagar on 20th December 2024



JIGYASA: Teachers' workshop

CSIR-4PI JIGYASA Team organized and conducted Teachers' Workshop from July 22 to 26 July 2024. 42 Government High School Science and Mathematics teachers (Kannada, English & Urdu medium) participated in a five-day Teachers Training Workshop. The lectures delivered by the scientists in CSIR-4PI included applications of physics and mathematics, covering topics such as Calculus, Probability, Atmospheric Physics, Earthquakes, GNSS, Heat Transfer, and Agri-tech. The workshop also introduced High Performance Computing and concepts of Artificial Intelligence (AI). Multiple hands-on sessions with physics experiments were conducted as part of the training.



6.4 Faculty Participation

1. Sajani Surendran, Invited resource person for a 1-week climate change workshop and hands-on Training Sessions to around 25 research scholars across National institutions, in dynamically downscaled regional climate models, concepts and principles of climate, and analytical methods for climate change assessment, organized by Kerala State Council for Science, Technology and Environment (KSCSTE), September 2–6, 2024.
2. Rakesh V, Delivered a set of invited lectures at the ICTS “Workshop on Data Assimilation in Weather and Climate models” held from May 6 – 17, 2024 at the ICTS campus, TIFR, in Bengaluru, India. The program aimed to equip participants with a comprehensive understanding of data assimilation, fostering expertise in both theory and practical applications
3. Rakesh V, Given lectures as part of the training programme for Indian Statistical Service (ISS) probationers, Ministry of Statistics and Programme Implementation (MoSPI) from May 20– June 14, 2024.
4. Rakesh V, Given lectures in the CSIR – Human Resource Development Centre, Ghaziabad Programme on the ‘Application of Drone Technology in Smart Agriculture and Precision Farming’ during 19–21 February, 2025.

7. Knowledge Activities and Products

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

Inside:

1. Publication in Journals
2. Publications in Books/Proceedings
3. Internal Reports
4. Presentations in Conferences/Workshops/Seminars
5. Participation in Conferences/Workshops/Training Programmes
6. Invited Talks
7. Conference/Workshops/Seminars at CSIR-4PI
8. In-house seminars/lectures
9. Visitors at CSIR-4PI
10. Events at CSIR-4PI
11. Significant Events

7.1 Publications in Journals

1. Sethi B, Gouda K C, Sahu S C, Mallick M K, Panigrahi A and Samal S K (2024) "Homogeneity Adjustment of Surface Temperature Data and Study of The Climate Variability Over Coastal Odisha by A Climate Departure Index", *Pure and Applied Geophysics*, Vol 181, Issue 7, 1661–1696, IF 1.9, <https://doi.org/10.1007/S00024-024-03465-5>
2. Devi R, Goud K C and Lenka S (2024) "Assessment of Long-Term Spatio-Temporal Variability of Hot Extremes and Associated Physical Mechanism Over India", *Stochastic Environmental Research and Risk Assessment*, Vol 38, Issue 7, IF 3.9, <https://doi.org/10.1007/s00477-024-02744-W>
3. Rajana S S K, Panda S K, Jade S and Vivek C G (2024) "Morphology of Equatorial F-Region Irregularities Over the Indian Longitude Sector Using GPS-Derived ROTI Observations", *Advances in Space Research*, Vol 74, Issue 7, IF 2.8, <https://doi.org/10.1016/j.asr.2024.06.039>
4. Samantray P and Gouda K C (2024) "A Comprehensive Study of Atmospheric Dynamics Associated with Cloudburst Events In 2022 Over Indian Himalayan Region", *Journal of Earth System Science*, Vol 133, Article No 151, IF 1.3, <https://doi.org/10.1007/S12040-024-02370-8>
5. Silpa K and Earnest A (2024) "Outer-Arc Active Tectonic Deformation Off the Nias – Nicobar Trench: Insights from Lithospheric Stress and Seismic Slip Models", *Journal Asian Earth Science*, Vol 276, IF 2.7, <https://doi.org/10.1016/j.jseaes.2024.106299>
6. "PSI derived measurements of monsoon induced anomalous deformation before the earthquake swarm activity: a case study in the Saurashtra, Western India" *Environmental Earth Sciences* (IF 2.8)
7. Singhai P, Chakraborty A, Jana K, Rajendran K, Surendran S and Pegion K (2024) "The Curious Case of a Strong Relationship Between ENSO And Indian Summer Monsoon in Cfsv2 Model", *Dynamics of Atmospheres and Oceans*, Vol 108, Article No 101504, IF 1.9, <https://doi.org/10.1016/j.dynatmoce.2024.101504>
8. Bankar A, Rakesh V and Purwar S (2024), Relative Impact of Assimilation of Multi-Source Observations Using 3D-Var on Simulation of Extreme Rainfall Events Over Karnataka, India, *Atmospheric Research*, Vol 310, IF 4.5, <https://doi.org/10.1016/j.atmosres.2024.107777>
9. Sant D A, Makwana G K, Sukumaran P, Parvez I A, Rangarajan G, Krishnan K (2025), Modeling Near-Surface Velocity Inversion in A Sediment Sequence Using Microtremor HVSr, *Soil Dynamics and Earthquake Engineering*, Vol 190, IF 4.2, <https://doi.org/10.1016/j.soildyn.2025.109235>
10. Sampad K P, Siva S K, Vivek C G, Dabbakuti R K, Jamir W, Jamjareegulgarn P (2025) Multi-Instrument Analysis of Ionospheric Equatorial Plasma Bubbles over the Indian and Southeast Asian Longitudes During the 19–20 April 2024 Geomagnetic Storm "Multidisciplinary Digital Publishing Institute (MDPI)" 17(6) <https://doi.org/10.3390/rs17061100>
11. Nagarathna Ravi, Thishyan Raj T and Vipul Arora, "TeLeS: Temporal Lexeme Similarity Score to Estimate Confidence in End-to-End ASR," in *IEEE/ACM Transactions on Audio, Speech, and Language Processing*, vol. 32, pp. 4399–4408,

2024, doi: 10.1109/TASLP.2024.3416687.

12. Panda, S. K., Rajana, S. S. K., Vivek, C. G., Dabbakuti, J. R. K. K., Jamir, W., & Jamjareegulgarn, P., (2025). Multi-Instrument Analysis of Ionospheric Equatorial Plasma Bubbles over the Indian and Southeast Asian Longitudes During the 19–20 April 2024 Geomagnetic Storm. *Remote Sensing* 17 (6).

7.2 Publications in Books/Proceedings

1. Jade S & Shrungheshwara T S (2024), GPS Deformation and Earthquakes in Himalaya, *Natural Hazards and Risk Mitigation*, Pp 33–74, https://doi.org/10.1007/978-981-97-7658-0_3
2. Shimna K, R.K Archana, C Vineeth, T.K. Pant, & M.S.M. Vijayan. Anomalous response of equatorial ionosphere during the recovery phase of May 2024 Gan-non super storm from GOLD observation. *ESS Open Archive* . February 04, 2025. doi:10.22541/essoar.173867412.25978990/v1
3. K Shimna, R K Archana, C Vineeth, T.K. Pant, & M.S.M. Vijayan. Rapid Transition of asymmetric EIA crest during the main phase of geomagnetic storm of April 23, 2023: A unique observation based on GOLD satellite. *ESS Open Archive* . November 28, 2024. doi:10.22541/essoar.173282173.33085359/v1
4. Shruthi S K, Nagarathna R, T. Thishyan Raj, and Vipul Arora, "BADCH: Backtracking and Adaptive Chunking for Longform Speech Recognition," 2025 National Conference on Communications (NCC), IIT Delhi, India, 2025.
5. Bhavayukta S, Nagarathna R, "Hate Speech Detection and Marker Identification Approach", International Conference on Wireless Communications Signal Processing and Networking, India, 2025.
6. G N Mohapatra and Rakesh V, 2024, Modeling and simulation of Hailstorm events over Karnataka during pre-monsoon season using high resolution Mesoscale model, National Symposium on Tropical Meteorology (TROPMET- 2024), Indian Meteorological Society, 10–12 December 2024, National Institute of Technology, Rourkela Odisha
7. G N Mohapatra and Rakesh V, 2024, Modelling of Spatio-Temporal Variation of Extreme Rainfall Events and Improving Model Forecast using Machine Learning technique over Bengaluru city. Page 22, National Conference Recent Trends in Ocean and Atmospheric Science (RTOAS -2025) 31st January to 1st February – 2025
8. Ajay Bankar & V Rakesh, Improving Extreme Rainfall Prediction in Karnataka Through 3D-Var Assimilation of Atmospheric Profiles and Ocean Winds" December 04–06, 2024. The 14th Asia/Oceania Meteorological Satellite Users Conference IMD Delhi.
9. Ipsita P & Rakesh V "Identification of Extreme Rainfall Hotspots over Homogeneous Rainfall Regions in India". TROPMET Conference, 2024, NIT Rourkela, Odisha.
10. Rajana, S.S.K., Panda, S.K. and Vivek, C.G., (2024), Ionospheric Perturbations over the Low-Latitude Indian Region During the Geomagnetic Storm of 26–28 February 2023. 2024 IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2024), Athens, Greece, 1–4.

7.3 Internal Reports

1. Swapnil Burungale, Pankaj Saini and V Anil Kumar, CSIR-4PI HPC Health Monitoring System, Technical report (4PI/TR/2502).

7.4 Presentations in Conferences/Workshops/Seminars

1. Medar M H, Raja S and Senthilkumar V, "Studies on Shape Memory characterisation and shape control of GF-SMP Composites", Global conference on Aero-nautical, Aerospace and Mechanical Sciences, GCAAMS 2024, GAT, Bangalore, 03-04th May 2024.
2. Senthilkumar V, "Peridynamics Modelling and its Applications Using Nonlocal Models", two-day National-level Technical Seminar on Emerging Technologies in Aerospace Development, organized by the Department of Aerospace Engineering, MIT Campus, Anna University, Chennai, 03-04th May 2024.
3. E. V. S. Prakasa Rao, Market Opportunities for MAP-based value products in ToT on Promotion of Medicinal and Aromatic Plants (MAP) under DAY-NRLM (Deendayal Antyodaya Yojana – National Rural Livelihoods Mission), 29-31 July 2024, NIRDPR, Min. of Rural Development, GOI, Hyderabad.
4. E. V. S. Prakasa Rao, Can Agro-ecosystems perspectives help in vetiver oil production and livelihoods- a case study from southern India. 3rd South African Conference on Essential and Vegetable oils: Local to global EAST OR WEST, HOME IS BEST, 25-26 July 2024 Pretoria, South Africa.
5. Ipsita P, Rakesh V, Identification of Extreme rainfall hotspots over rainfall homogeneous regions in India, National Symposium "TROPMET 2024" at National Institute of Technology Rourkela (NITR), Rourkela, Odisha (December 10-12, 2024)
6. Ipsita P, Rakesh V, Extreme rainfall hotspots in India based on spatio-temporal variability of rainfall using unsupervised clustering techniques at EGU General Assembly 2025 both in Vienna and online (27 April-2 May, 2025)
7. Swapnil Burungale, Power aware HPC – Strategies for energy efficient computing, Sustainable Science and Technology for Vikasit Bharat – 2025, Bhubaneswar.
8. Swathi VE, Ashapurna Marndi "Comparative Analysis of Different Deep Learning Models for Malaria Detection", October 26-27, 2024, 6th International Conference on Sustainable and Innovative Solutions for Current Challenges in Engineering & Technology (ICSISCET 2024)
9. Rakesh Asery, B. Swapnil, S. Pankaj, "Multi-Sensor Satellite Image Cloud Classification with Deep Learning," IEEE Conference ICDSAAI 2025, Chennai, India.

7.5 Participation in Conferences/Workshops/Training Programmes

- Ashish
 1. Participated in a Workshop on Mission Karmayogi – Integrated Government Online Training (iGOT) Platform for CSIR Lab Nodal Officers held at CSIR-HRDC, Ghaziabad from December 17-19, 2024.
- Nagarathna Ravi

1. 5-day CDAC HPC training program
 2. AI powered defence in CSIR-NAL.
- Ashapurna Marndi
 1. Attended Leadership programme on Humanistic “Leadership for India in an AI Driven World” (26–30 August, 2024) organized by NIAS, Bangalore.

7.6 Invited Talks

- Sithartha Muthu Vijayan M
 - Sounds of Earthquakes & Tsunamis in the sky, Teachers Training Workshop, JIGYASA, CSIR-4PI, Bangalore on 22nd July 2024
 - Machine Learning and its Applications, Inaugural talk in Faculty Development Programme on Machine Learning and its applications for Instrumentation and Control Systems, Department of Electronics and Instrumentation Engineering and Medical Electronics Engineering, M.S. Ramaiah Institute of Technology, Bangalore on 29th July 2024
 - Seismic Sounds in the Sky: Detecting Earthquakes and Tsunamis via ionospheric anomalies — Part 1, webinar conducted by JIGYASA CSIR-4PI on 18th September 2024 https://www.youtube.com/watch?v=7u_OSs7gArI
 - Seismic Sounds in the Sky: Detecting Earthquakes and Tsunamis via ionospheric anomalies — Part 2, webinar conducted by JIGYASA CSIR-4PI on 19th September 2024 <https://www.youtube.com/watch?v=6XrOzi3YcTo>
 - Seismic Sounds in the Sky: Detecting Earthquakes and Tsunamis via ionospheric anomalies — Part 3, webinar conducted by JIGYASA CSIR-4PI on 20th September 2024 <https://www.youtube.com/watch?v=1TMpkyTfPKO>
 - Introduction to AI & ML (Artificial Intelligence and Machine Learning), Interdisciplinary Refresher Course — Physical Sciences, UGC-Malaviya Mission Teacher Training Centre, The Gandhigram Rural Institute-DTBU, Ministry of Education, Govt. of India, Gandhigram, Tamilnadu on 05th October 2024
 - AI & ML disruptions in teaching Physical Sciences, Interdisciplinary Refresher Course — Physical Sciences, UGC-Malaviya Mission Teacher Training Centre, The Gandhigram Rural Institute-DTBU, Ministry of Education, Govt. of India, Gandhigram, Tamilnadu on 05th October 2024
- E. V. S. Prakasa Rao
 - “Research Priorities in the Use of Digital Technologies in Agriculture in India” in the Technical Session of the theme “Digital Agriculture” in the XVII Agricultural Science Congress, National Academy of Agricultural Sciences, Pantnagar, Uttarakhand, India from February 20– 22, 2025, on the theme “Frontier Sciences and Technologies in Agriculture for Developed India”.
- Nagarathna Ravi
 - ‘Thiagarajar College of Engineering, Madurai — January 11, 2025 — topic — “Decision Support System using AI driven Speech Recognition”.
- G N Mohapatra
 - Invited Speaker for National Conference on Recent Trends in Ocean and Atmospheric Science (RTOAS-2025) Program (31st January – 1 st February 2025) P. G. Department of Atmospheric Science Fakir Mohan University

Balasore, Odisha

- Participated in the EMBO conference to present the paper and to display the technology development in RSSA project. “Industry, Farmer and Academia Meet” held at CSIR-IHBT, Palampur on February 26, 2025
- KRISHIMELA– 2024 at University of Agriculture Science Bengaluru from November 14–17th 2024 and showcased the digital technologies developed at CSIR.
- “Applications of Numerical Methods in Engineering” Department of Mathematics, MVJ College of Engineering (An Autonomous Institute), Whitefield, Bangalore, Karnataka.on 26th June 2024.
- Earth Science Open day Popular talk on “Study of Tropical Cyclone formation, Track and Intensity over North Indian Ocean” , 26th September 2024.
- Rakesh V
 - “3rd International Conference on Higher Education Institute Challenges Solutions for Sustainable Development Goals 2024”, organized by the Centre for Research in Environment, Sustainability Advocacy and Climate Change (REACH) SRMIST, Kattankulathur

7.7 Conference/Workshops/Seminars at CSIR-4PI

Python Programming Workshop for students from 4th to 10th October 2024.

The CSIR Fourth Paradigm Institute (CSIR-4PI) successfully conducted a Python Programming Workshop for students from 4th to 10th October 2024. 38 students (28 boys and 9 girls) from 9th to 12th class participated in the five-day event designed to introduce them to Python programming. Dr. Vidyadhar Mudkavi, Honorary Scientist at CSIR-4PI, led several sessions, starting with basic Python concepts such as writing simple programs, repetitive calculations, solving equations, and plotting graphs. Students also engaged in hands-on practice using terminal commands and Jupyter Notebooks. Highlights of the workshop included a visit to the High-Performance Computing (HPC) facility, where participants were introduced to supercomputers, and cybersecurity test-bed. Students also explored CSIR-4PI's Energy Farm. The workshop provided valuable learning experiences, equipping students with essential programming skills and fostering their interest in technology.

7.8 In-house seminars/lectures

- Nagarathna Ravi, Dive into Large Language Models (LLMs) Overview – March 18, 2025; Popular talk on language models – CSIR Open Day– Sept 26, 2024 in CSIR-4PI.
- Ashapura Marndi, Wind Speed Prediction: AI-Powered Forecasting for Enhanced Energy Efficiency under OWOT (Energy) event in CSIR-4PI on 26th June 2024.



- Ashapurna Marndi, Moderated Panel discussion on AI Enabled Technologies & Systems(AITS) under OWOT (AEISS Theme) event on 22nd August, 2024.

7.9 Visitors at CSIR-4PI

- Prof. KK Aggarwal, President, SAU, Delhi
- Dr. Sanghamitra, Director, ISI
- Prof. Seshu, Porfessor, IIT Bombay
- Ms. Viswajanani JS-Head-TKDL, CSIR-Hqrs
- Dr. Naresh Chandra Murmu, Director, CSIR-CMERI
- Dr. Haribabu P, Associate Director, C-DAC, Bangalore
- Dr. Srinivas, Director-INCOIS
- Dr. K J Sreeram, Director, CSIR-CLRI
- Dr. V. K. Saraswat, Member, NITI Aayog, New Delhi.
- Shri Mahendra Kumar Gupta , Joint Secretary,CSIR
- Prof V Ramesh- Goethe University, Frankfurt
- Dr. Aparna Akula-CSIR-CSIO
- Dr. Debi Prasad Das-CSIR-IMMT
- Dr. Anjali Sharma-CSIR-NPL
- Dr. Mohan Rao-CSIR-CRRI

- Dr. Samit Datta–CSIR–CMERI
- Dr. Sanjay Singh–CSIR–CEERI
- Dr. Veran Sardana–CSIR–IGIB
- Dr Saxena P K, PSA Fellow & Former Director, SAG, DRDO
- Smt Savita Utreja, Scientist G and Group Coordinator, MeitY
- Dr Sambuddho, Head (CSE) & Associate Professor (CSE) IIIT Delhi
- Dr. Navdeep S Chahal , Associate Director & Scientist F, C–DAC Mohali
- Dr Yudhishthira Sapru, Scientist E, CERT–In
- Dr Manuj Aggarwal, Scientist–D, MeitY
- Shri. Swarun Kameswara Nanduri, Scientist D, CERT–In
- Shri Pranjal Johri, Scientist C, MeitY
- Shri. Amit Aggarwal, Secretary, Department of Pharmaceuticals
- Dr. Hemant Darbari, Mission Director, NSM

7.10 Events at CSIR-4PI

Visit of Shri S Somanath, Secretary, DoS / Chairman, ISRO and Mentor, CSIR-4PI.



Shri S. Somanath, Secretary, DoS/Chairman, ISRO and Mentor, CSIR-4PI visited on 02-04-2024. A momentous and memorable interactive session and address by Shri Somanath. A brief overview of CSIR-4PI with focused presentations on climate modelling, cyber security, AI and also there was a visit to HPC, GNSS & GHG.

Rashtriya Boudhik Sampada.



Rashtriya Boudhik Sampada Mahotsav/World IP day event organised at CSIR-4PI with undergraduate students and faculty on 03 May 2024.

Swachhata Pakhwada



CSIR-4PI organized and conducted Swachhata Pakhwada Campaign at CSIR-4PI with swachhata pledge and cleanliness drive by staff.

National Technology Day



CSIR-4PI organized "National Technology Day" on June 10, 2024. Dr G K Patra, Chief Scientist welcomed and introduced the Chief Guest Dr. Rajalakshmi Menon, Director-CABS. She delivered a talk on "AirBorne Surveillance System". Dr Sridevi Jade presided over the function and Dr Imtiyaz A Parvez, Chief Scientist and In charge, TMD presented the vote of thanks.

Dr. B.R. Ambedkar Jayanti



CSIR-4PI celebrated “Dr. B.R. Ambedkar Jayanti” on June 11 2024 with an inspirational talk by Prof. Karunakaran Rai B, NMIT, Bengaluru on “Understanding present Bharat through Babasaheb Ambedkar”

Observation of International Yoga Day 2024



On June 21, 2024, CSIR-4PI Organized "Observation of International Yoga Day 2024" at CSIR-4PI with a yoga workshop for all the staff. Dr Ashish and Dr Ashapurna Marndi instructed and guided on different postures of Yoga to the staffs.

CSIR-4PI foundation day



CSIR-4PI foundation day was celebrated on July 15, 2024. Dr. N. Kalaiselvi, Director General, CSIR and Secretary DSIR attended the function in virtual mode. The function was inaugurated by Dr Sridevi Jade, Director, CSIR-4PI. Dr G K Patra, Chief Scientist welcomed and introduced the guests to the august gathering. Dr Shailesh Nayak, Director, National Institute of Advance Science was the Chief Guest, who delivered the Foundation Day lecture on "Vision of Earth System Science". Dr Suman Kumari Mishra, Director, CSIR-CGCRI was the guest of honour and addressed the gathering. Presidential address was given virtually by our Director General, CSIR, Dr. N. Kalaiselvi. Chief Guest and the Guest of honour distributed the prize to Scientific and Administrative Staffs. The program was concluded by the vote of thanks by Dr Imtiyaz A Parvez, Chief Scientist and Head, TMD.

78th Independence Day



CSIR-4PI Celebrated 78th Independence Day on August 15, 2024. This Independence Day was highly significant and special as our institute celebrated this event first time after being designated as 'National Laboratory' of CSIR on 19 June 2024. Dr Sridevi Jade unfurled the National flag and took the Rashtriya Salute followed by singing of the National Anthem. She then inspected the March Past and delivered the Independence Day speech.

National Sports Day



CSIR-4PI organized Sports events on the occasion of National Sports Day on August 29, 2024, conducting the games like hitting the wicket, book balancing race, basket-ing the ball, Table Tennis, Chess and Plank Challenge. The event was concluded on August 30 and Prizes were distributed to all the winners.

Hindi Week Celebrations



Hindi Week was celebrated with great enthusiasm at CSIR-4PI, Bengaluru from 02 September 2024 to 06 September 2024 with various Hindi competitions and a grand Hindi Diwas was organized on 24 September 2024 under the chairmanship of Dr. Sridevi Jade, Principal/Director, CSIR-4PI, Bengaluru. On this occasion, Dr. Ritu Karidhal, Group Director, URSC, Bengaluru was the Chief Guest of the program.

Swachhata Hi Seva



"Swachhata Hi Seva" translates to Cleanliness is service and is a campaign in India aimed at promoting cleanliness and sanitation. Launched by the government of India, it encourages citizens to participate in activities that enhance cleanliness in their surroundings, emphasizing the importance of hygiene for public health and well-being. SWACHHATA HI SEVA (SHA) 2024 was observed by CSIR 4PI during with the following agendas: Plantation Drive, Cleanliness drive, swachhta awareness campaigns, Cleaning of office premises and outskirts of the Campus, Disposal of unused files/papers, Dusting of chairs, conference table, plants and paintings of Conference Hall, Repair, wherever required of electronic equipment etc.

Open Day



CSIR open day was observed on 26th September 2024, on the occasion of 83rd CSIR foundation day. On this day, we invited everyone to embark on a journey of discovery and innovation. The Open day started with a lot of curious spectators and we ended up with a remarkable total of enthusiastic participants eager to learn and connect.

Ayurveda Day



CSIR-4PI celebrated Ayurveda Day on 28th October 2024 under the Theme "Ayurveda Innovation for Global Health". The inaugural session started with lighting of the lamp by the distinguished guests on the dais. A brief introduction and welcome address were given by Dr. V Anilkumar, Chief Scientist. Ayurveda Day lecture was delivered by Dr. Srinibash Sahoo, Research Officer, Central Ayurveda Research Institute (CARI) Bengaluru, emphasised the prevention of illness through Ayurveda. The presidential address was given by Dr. Sridevi Jade, Director, CSIR – 4PI followed by the vote of thanks proposed by Dr. Ashish, Principal scientist. A team of doctors from CARI, Bengaluru conducted Ayurveda awareness programme, health check-up, on-site medicine distribution and donated medicinal saplings for plantation.

Vigilance Awareness Week–2024



CSIR–4PI celebrated Vigilance Awareness Week–2024 during 28th October 2024 to 3rd November 2024. Shri Mahendra Kumar Gupta, Joint Secretary, CSIR, honoured the valedictory function as Chief Guest. With the theme “Culture of Integrity for Nation’s Prosperity”, it was the first occasion when Vigilance Awareness Week was observed independently after given the National Laboratory status of CSIR.

CSIR Foundation Day at CSIR-4PI



CSIR Fourth Paradigm Institute (CSIR 4PI) celebrated 83rd CSIR Foundation Day on 11.11.2024 (Monday). Padma Bhushan Dr. V. K. Saraswat, Member, NITI Aayog, New Delhi honored the function as Chief Guest. The inaugural session started with lighting of the lamp by the distinguished guests on the dais. In his welcome address Dr. Gopal Krishna Patra, Chief scientist introduced the Honourable Chief Guest to the gathering. The Foundation Day lecture was delivered by the Chief Guest on "Securing Tomorrow: Unravelling the intersection of AI and Cybersecurity".

Vishwa Hindi Diwas



Vishwa Hindi Diwas was celebrated in CSIR-4PI, Bengaluru on 10 January 2025 in Dr. KS Yajnik Conference Hall. Mrs Nirmala, Hindi Officer has convened the program. Dr. Sridevi Jade presided over the program and Dr. Harish Barshilia, Advisor (M&A) and Chief Scientist, CSIR-NAL, Bengaluru was the chief guest. Shri Suresh Chandra Shukla, Editor, Spiel-Darpan, Oslo, Norway joined us online and he was the guest of honour. Smt Sudha Rani P, CoA welcomed and introduced the Chief guest and the Guest of Honour. Dr I A Parvez, Chief Scientist and Vice President, OLC presented the vote of thanks.

76th Republic Day Celebrations



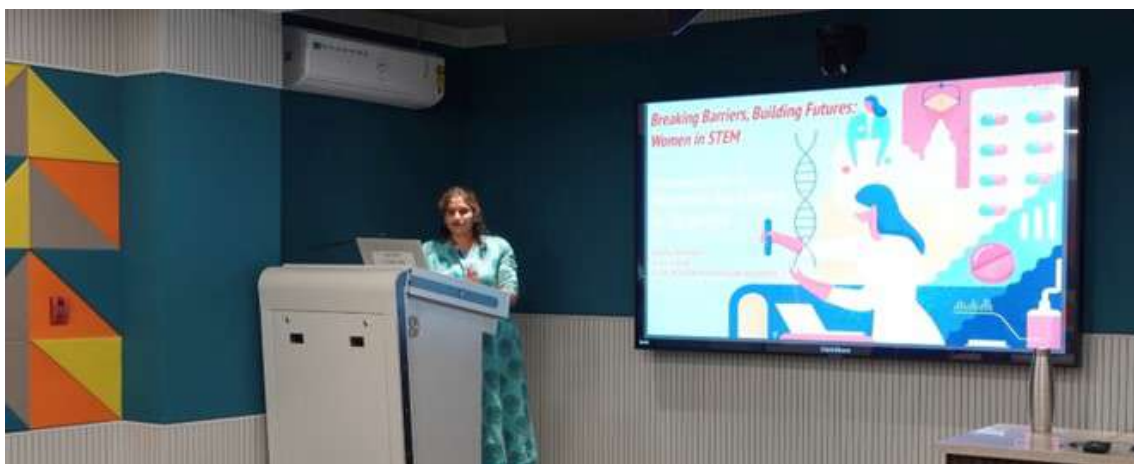
76th Republic Day Celebrations was celebrated in CSIR-4PI, Bengaluru on 26th January. The national flag was unfurled by Dr Sridevi Jade, Director CSIR 4PI who also presided the parade by security personals.

International Mother Language Day



International Mother Language was celebrated at CSIR-4PI with Chief Guest Prof. Dominic, Director, Department of Kannada Studies, Bangalore University. Events in multiple languages were conducted and Souvenir was released to mark the day

International Day of Women and Girls in Science



International Day of Women and Girls in Science at CSIR–4PI was celebrated with captivating talks on 'Breaking Barriers, Building Futures: Women in STEM' by Jahnavi and 'Unveiling the Unsung' by Ipsita.

National Science Day



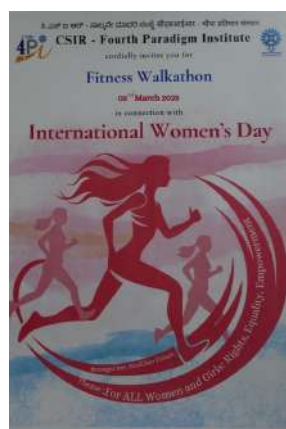
National Science Day –2025 celebration at CSIR–4PI with a talk on Astronomy by Chief Guest Dr. G C Anupama, Former President, Indian Astronomical Society & INSA Senior Scientist.

International Women's Day Celebration



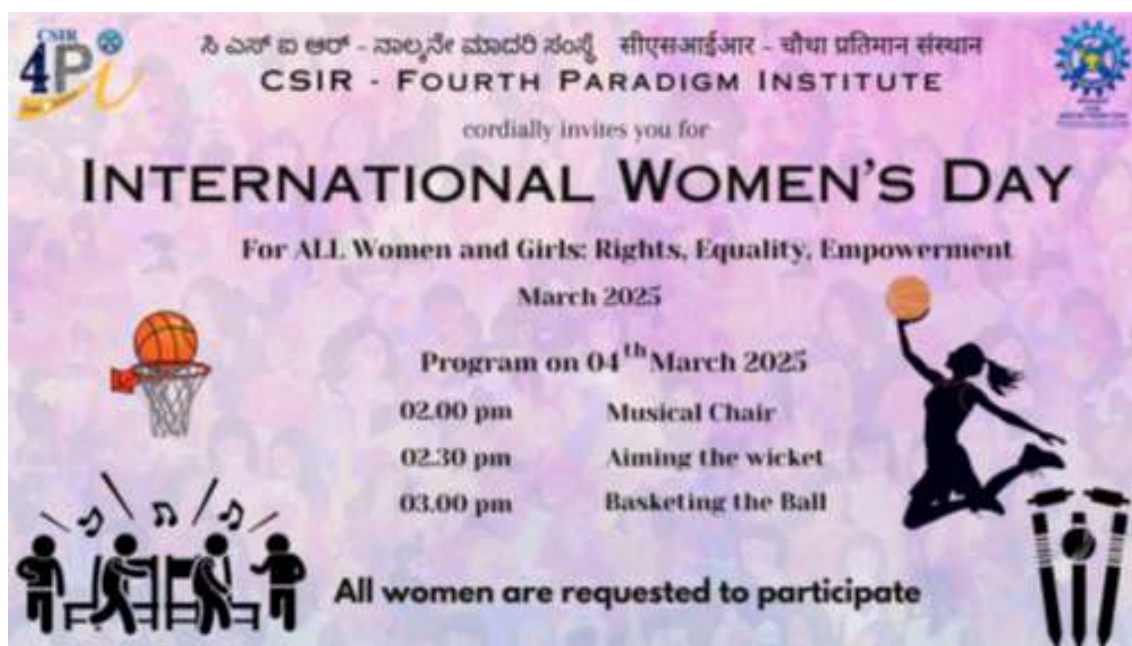
In celebration of International Women's Day 2025, CSIR-4PI organized ten days long program filled with engaging activities and events from 3rd March to 12th March 2025. The program actively involved women in a series of activities aimed at promoting physical fitness and mental well-being, aligning with the campaign theme of Fit India Mission 'Stronger Her, Healthier Future'. Various competitions involving sports, games and awareness talk focusing on fitness and mental well-being were planned and conducted in accordance with the directives from CSIR headquarters and the Fit India Mission.

International Women's Day Celebration – Day 1 (March 3, 2025): Fitness Walkathon



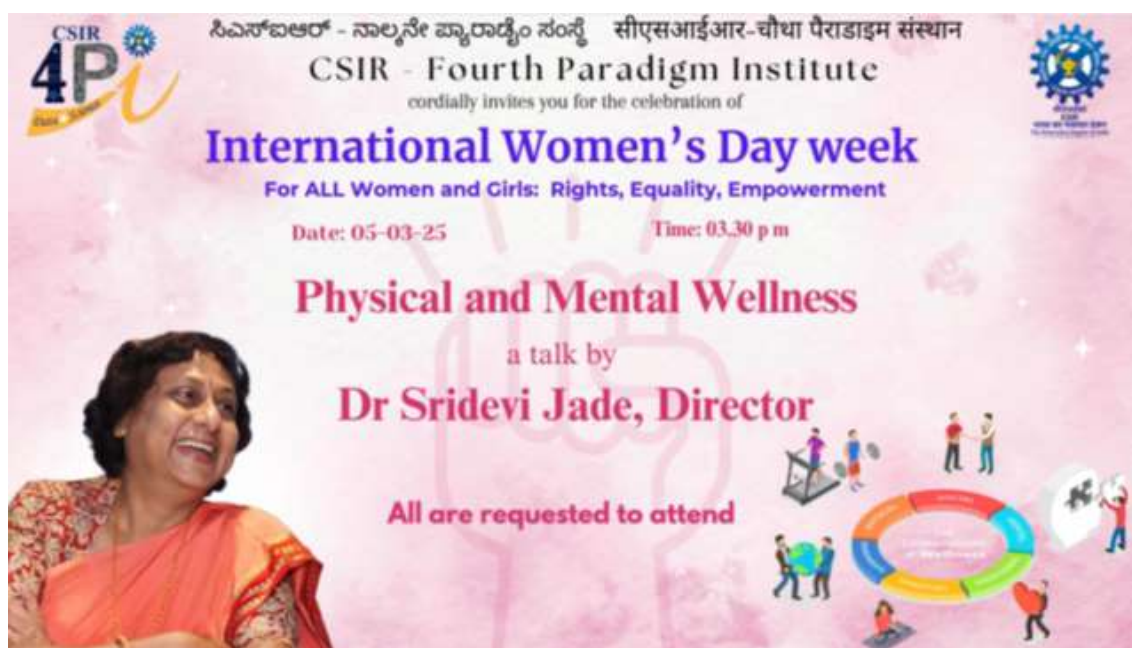
The inaugural event of the week was a fitness walkathon, which saw enthusiastic participation from women of all ages. The Director of CSIR-4PI flagged off the event from the premises of the CSIR-4PI main building. The competition was conducted in two categories based on age. Category one, for participants below 40 years of age, had 34 energetic participants who demonstrated both stamina and spirit. Category two, for those aged above 40, saw a turnout of 7 participants, each showcasing remarkable tenacity and vigor. Three winners from each category were identified, and prizes were distributed to the winners at the concluding event of the Women's Day celebration on 12th March 2025.

International Women's Day Celebration – Day 2 (March 4, 2025): Musical Chair, Basketing the Ball, and Aiming the Wicket



The second day featured a trio of fun-filled, engaging and interactive activities focused on promoting mental well-being. The three key events conducted were Musical Chair, Basketing the Ball, and Aiming the Wicket. These activities were designed not only to entertain but also to enhance social interaction, which play a vital role in maintaining mental health.

International Women's Day Celebration –Day 3 (March 5, 2025): Talk on Physical and Mental Awareness



A thought-provoking talk was delivered by Dr. Sridevi Jade, Director of CSIR-4PI, on the crucial topic of "Physical and Mental Awareness," where she emphasized the importance of holistic well-being. The session sparked enthusiastic interactions and discussions, with the entire CSIR-4PI community, free from gender bias, openly sharing their views and ideas. The engaging exchange of thoughts highlighted the collective commitment to fostering both physical and mental health within the organization.

International Women's Day Celebration – Day 4 (March 6, 2025): Yoga Session



A rejuvenating yoga session was conducted by Dr. Ashapurna, Principal Scientist, promoting relaxation and mindfulness. The session was well-received by the participants, who actively engaged in the practice. A total of 16 participants attended, and the session began with warm-up exercises and concluded with a few advanced yoga poses.

International Women's Day Celebration – Day 5 (March 7, 2025): Rangoli Competition



International Women's Day Celebration – Day 6 (March 11, 2025):
Cooking without fire and Mehendi Competition



International Women's Day Celebration – Day 7 (March 12, 2025): Concluding Ceremony



The concluding ceremony of the International Women's Day (IWD) celebrations, with the theme "For All Women and Girls: Rights, Equality, Empowerment," was held on March 12, 2025, at the CSIR – Fourth Paradigm Institute. This remarkable event took place in the Dr. K.S. Yajnik Conference Hall. The program commenced with the lighting of the lamp and an invocation, followed by a warm welcome address by Mrs. P. Sudharani, COA. Dr. Gayathri, Senior Scientist, presented the IWD report, highlighting key activities conducted over the past ten days.

7.11 Significant Events

"One Week One Theme" (OWOT) on Agriculture Nutrition and Biotechnology (ANB) hosted by CSIR–Fourth Paradigm Institute (CSIR–4PI)

On November 7, 2024, CSIR–4PI organized a "One Week One Theme" (OWOT) event under the theme of Agriculture Nutrition and Biotechnology (ANB). This event was part of a broader initiative by CSIR, where all 37 laboratories participated by holding individual events focused on eight key thematic areas of CSIR's mission. OWOT was an opportunity to showcase innovative approaches and technological advancements developed by CSIR laboratories. CSIR–4PI led the AgriTech Mission Mode Project under



the ANB theme, focusing on enhancing soil and plant health through advanced technological solutions. Dr. Gyanendranath Mohapatra, Principal Scientist and Convener of the event, opened the session with a warm welcome to all attendees, including the Chief Guest, Guest of Honor, Director, distinguished dignitaries, farmers, students, and other participants. Dr. Mohapatra provided an overview of the event, outlining its objectives and the significance of the ANB theme for CSIR–4PI. The Chief Guest, Dr. B.N. Srinivasa Murthy, former Horticulture Commissioner of the Department of Agriculture, Cooperation, and Farmers Welfare, and Guest of Honor, Dr. Vibha Malhotra Sawhney, Head of TMD CSIR, graced the occasion with their insights. They shared their extensive knowledge on implementing state-of-the-art technologies such as AI/ ML, and data-driven models in precision agriculture, stressing their critical role in enhancing agricultural productivity and sustainability. The Chief Guest, Dr. B.N. Srinivasa Murthy, offered insights into the ground realities of smart agriculture and how farmers can fully use the available technologies. Dr. Vibha Malhotra Sawhney, the Guest of Honor, mentioned the importance of conserving soil and plant health using advanced tools. She also emphasized the need to deliver technology-driven advisories to farmers at the grassroots level. Presiding over the event, Dr. Sridevi Jade, Director of CSIR–4PI, discussed the importance of collaboration among farmers, students, and other stakeholders. She highlighted how these groups can collectively

benefit from the advancements showcased at OWOT, using technology to drive innovation in agriculture.

In the next session Dr V Rakesh who is the Nodal Principal Investigator from CSIR 4PI presented the overall progress of the Mission project. In this session, there was interaction and discussion among the delegates from CSIR Laboratories, farmers and students from several institute with academia from agriculture University focused on various real time farmers issues while they are growing their crops in the field on day to day basis. One of the important issues discussed was technology intervention in the precision agriculture, like resolution of the hyperspectral camera and its technique to capture the drone image at the early stage of disease infection.

During the life cycle of the crops, management of water supply and irrigation, soil quality and maintenance of nutrition level at its different stages, strategy for efficient and economically viable spraying of pesticide, herbicides and insecticides, different technique applied for drone image analytics were discussed in the session. The use of soil optix instruments to measure the soil nutrition was somewhat unique and very quick to assess the soil quality at the particular farm field just running over that farm fields. In addition to this, many farmers asked about the technique of leveling the farm fields and spraying the pesticides with minimum expenditure and maximum profit that can strengthen their economic condition. There was discussion from the panel to establish crop phenological model which can provide advisories for the plant health conditions and crop yield model for crop production capacity in long run process for the specific region with available observed data.

During the exhibition, CSIR-4PI demonstrated various handheld instruments that are pivotal for data observation and modeling in agriculture. CSIR-NAL showcased UAV applications in agriculture by conducting live demonstrations of drones at the CSIR-4PI exhibition grounds. Other CSIR laboratories, including CSIR-CIMAP and CSIR-CSIO, presented advanced indigenous sensors designed for agricultural applications, such as hyperspectral imaging sensors used at different levels of the farm field and also displayed an indigenous data logger.

As the nodal agency for the Agri-Tech Mission Mode Project, CSIR-4PI demonstrated IoT-based sensors and explained how they are developing AI and ML models for hyperspectral image analytics and meteorological data collection. They presented a holistic approach to agricultural monitoring, involving soil sample collection from different crop fields based on crop calendars. This approach maps out the entire crop lifecycle, from sowing to cultivation, helping optimize agricultural practices with precision.

Farmers from various regions, including Hospete, Mandya, and Kottayam, attended the event, sharing their field experiences and discussing how technology has benefited them in real-time scenarios. These interactions highlighted the potential of technology to increase crop yield and improve farmers' income. The event provided an interactive platform for delegates, students, farmers, and scientists to exchange ideas and address questions from participants on the use of technology in enhancing crop yields. Approximately 25 farmers from various regions actively engaged in discussions, sharing how these innovations have positively impacted their farming practices.

The session concluded with a vote of thanks, followed by the national anthem, marking the successful completion of a vibrant and insightful OWOT session focused

on advancing agriculture through technology.

Curtain Raiser of IISF (Indian International Science Festival)–2024

The IISF 2024 Curtain Raiser Programme was held on 5th November 2024 at CSIR–Fourth Paradigm Institute (CSIR–4PI), Bangalore to promote the upcoming India International Science Festival at IIT Guwahati. The event is organized by key scientific bodies like CSIR, VIBHA, and government ministries, with the theme “Transforming India into a Science and Technology driven Global Manufacturing Hub”. The programme



featured an inaugural session with welcome address by Dr Imtiyaz A Parvez, Head, TMD, keynote address by Chief Guest Dr. Ramesh H (VIBHA) who highlighted the significance of IISF and the contributions of Vijnana Bharati (VIBHA) to promoting science with a Swadeshi spirit. Dr. Sridevi Jade, Director (CSIR–4PI) emphasized the importance of engaging with science for national progress. She also discussed the cutting–edge research conducted at CSIR–4PI and its alignment with IISF’s objectives. Participants included 50 students and 2 faculty members from New Horizon



Engineering College, Bengaluru, under the Skill Initiative. In addition, 50 students (14 boys, 36 girls) and 5 teachers from Divine Mercy School, Bangalore also participated. The program included engaging and interactive sessions. Participants also had the opportunity to visit the High–Performance Computing (HPC) facility, Energy Farm, and Cybersecurity Facility, gaining hands–on insights into cutting–edge technologies and their real–world applications. The event successfully set an exciting tone for the upcoming IISF 2024, fostering scientific curiosity and innovation among students.

Janjatiya Gaurav Diwas

CSIR Fourth Paradigm Institute (CSIR 4PI) celebrated Janjatiya Gaurav Diwas on 25th November 2024, to commemorate the 150th birth anniversary of Bhagwan Birsa Munda. Participants included 47 students (20 boys, 27 girls) and 3 teachers from KPS Narsapura, Kolar. Mr. Manish Chaudhary from Vanavasi Kalyana delivered a talk on the significance of the day. He emphasized the importance of preserving tribal heritage. The event aimed to raise awareness about the contributions of tribal communities. The program included an engaging session on Introduction to Geographic Information Systems (GIS), highlighting its applications in various fields. Additionally, students visited the High-Performance Computing (HPC) facility, Energy Farm, and Cybersecurity Facility, providing them with hands-on exposure to advanced technologies and their practical applications. The event aimed to inspire young minds while commemorating the contributions of tribal communities to the nation's heritage.



Participation in Krishi Mela 2024

CSIR-4PI participated in Krishi Mela 2024 in Bengaluru, the CSIR-4PI stall showcased advancements in Integrated Farming and Climate/Smart Digital Agriculture. The focus was on the CSIR Mission 'Region Specific Smart Agro Technologies for Soil and Plant Health (RSSA)', in collaboration with UAS Bangalore. At the Krishi Mela 2024, Dr. S.V. Suresha, Vice Chancellor of the University of Agricultural Sciences (UAS), Bangalore, visited the CSIR-4PI stall, where he was briefed about the CSIR RSSA mission. This mission, a key focus of this year's Krishi Mela theme 'Climate-Smart Digital Agriculture'.



Bangalore Tech Summit 2024

CSIR-4PI participated in the Bengaluru Tech Summit 2024, showcasing and engaging with a wide range of stakeholders, including start-ups and MSMEs (Micro, Small, and Medium Enterprises). This participation highlights CSIR-4PI's commitment to fostering innovation and collaboration across sectors. The event offered CSIR-4PI an excellent platform to demonstrate its cutting-edge research, technological advancements, and solutions that have real-world applications. CSIR 4PI also received "Sustainable Stall Award" as protector (category) for being a steward of positive change and championing sustainable practices at Bengaluru Tech Summit 2024.



Hindi workshop

A Hindi workshop was organized for all CSIR-4PI scientific and technical officers/employees CSIR-4PI, Bengaluru on June 25, 2024. Dr. Imtiyaz A Parvez, Vice Chairman, OLIC and Chief Scientist, CSIR-4PI welcomed the gathering. Smt. Nirmala Bai SP, Hindi Officer, CSIR-4PI spoke on Official Language Policy of the GoI, usage of Hindi on computers, voice typing, translation and Hindi keyboard. Shri Abhimanyu Tiwari, F&AO highlighted the basic concepts of finance and accounting in Hindi and Shri Vikas Chandra Mishra, SPO gave detailed information on stores and purchase processes in Hindi.



Hindi workshop

A Hindi Workshop is organised for all the regular employees of CSIR-4PI, Bengaluru on 30.08.2024 @ 2.00 pm in Dr. KS Yajnik Conference Hall. During the workshop, along with the lecture on Official Language Policy, a lecture on Conduct Rules, Dos Don'ts by Shri Rambabu T, Administrative Officer also delivered.

Hindi workshop

A Hindi Workshop was organized for all the Administration/Finance & accounts/Stores & Purchase Officers/Staff at CSIR-4PI, Bengaluru on 16th December 2024. In this



workshop Dr. Krishna Chandra Gauda, Senior Principal Scientist enlightened all the participants on the interdisciplinary areas of CSIR-4PI and informed them about the research and development work being done in the interdisciplinary field at CSIR-4PI and also told about the achievements of CSIR-4PI by giving live examples in his presentation in Hindi and Shri Prabhu N, Principal Technical Officer also presented the information on the technical work being done at CSIR-4PI and especially on the supercomputers of CSIR-4PI in Hindi.



8. Projects & Collaborative Programmes

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

Inside:

1. Grant-in-Aid Projects
2. Other Lab Projects (OLP)
3. Headquarter Controlled Projects (HCP)
4. Network Projects (NWP)
5. MOU's Signed

8.1 Grant-in-Aid Projects

1. National Carbonaceous Aerosols Programme (NCAP): Working Group III–Carbonaceous Aerosol Emissions, Source Apportionment and Climate Effects, Ministry of Environment, Forest and Climate Change (MoEF&CC), PI– Dr. Sajani Surendran
2. Improving the prediction of Thunderstorms using Dual–Resolution Hybrid Ensemble–Variational Data Assimilation System using WRF Model, Ministry of Earth Sciences (MoES), PI– Dr. V Rakesh
3. Ionospheric Imagery of Earthquake Source Region using the Co–seismic Ionospheric Perturbations (CIPs), Science and Engineering Research Board (SERB), Department of Science and Technology, PI– Dr. Dhanya Thomas
4. Impact Assessment of New and Emerging Waste Management Technology on Human Life, Ministry of Science & Technology, Department of Science and Technology, PI–Dr. Lakshmikanthan P
5. A Physically based Coupled Modeling Testbed for Assessing Hydrological Impact and Design of Sustainable Intervention Strategies to Mitigate Adverse Impacts on Surface Water Cycle Process Under Future Climate over Monsoon Driven River Basins of India, Women Scientist Scheme A (WOS–A), Department of Science & Technology, PI– Dr. Sumana Sarkar
6. Analysis and Modeling of Thunderstorm Events in India, Ministry of Science & Technology, Department of Science and Technology, PI– Ms. Payoshni Samantray
7. Network Telescope Feed for Threat Intelligence Generation, Ministry of Electronics and Information Technology, PI– Dr. V Anil Kumar
8. Architecture and Dynamics of Magma Reservoir in Deccan Volcanic Province: Seismological–Geochemical Synthesis, Science and Engineering Research Board (SERB), DST, PI– Dr. Imtiyaz A Parvez
9. Development of Privacy Preserving Machine Learning Framework for Healthcare Data, Ministry of Science & Technology, PI– Ms. Shruthi S Deepak
10. Impact of natural and anthropogenic climate variabilities on the physical and biogeochemical processes over Indian Ocean and their links to extreme events, Ministry of Earth Sciences, PI– Dr. Kantha Rao Bhimala

8.2 Other Lab Projects (OLP)

1. Development of High Precision Green House Gases (GHG) Database in Indian Context, PI–Dr. Lakshmikanthan P
2. GNSS & Seismic Network in the Indian Subcontinent, PI– Dr. Sridevi Jade, Co–PI Dr. Imtiyaz A Parvez and Shri Chiranjeevi Vivek G
3. Vehicular Platform for Algorithm Testing and Traffic Data Collection, PI– Dr. G.K Patra
4. Comprehensive HPC, AI, Cloud Storage & Institutional IT Infrastructure Management @ CSIR–4PI, Dr. Ashapura Marndi

8.3 Headquarter Controlled Projects (HCP)

1. AI-enabled Technologies & Systems (AITS), PI- Dr. G K Patra, Co-PI- Dr. Ashapurna Marndi
2. Phenome India-CSIR Health Cohort Knowledge base, PI- Dr Ashapurna Marndi, Co-PI- Dr. Gopal Krishna Patra
3. CSIR JIGYASA 2.0 Virtual Laboratory Integrated Project (CJVL), PI- Smt. Pavithra N R, Co- PI: Dr. Gayathri R
4. Region Specific Smart Agrotechnologies for Enhancing Soil and Plant Health (RSSA), PI- Dr. V Rakesh, Co-PI- Dr. G N Mohapatra

8.4 Network Projects (NWP)

1. CSIR Integrated Skill Initiative-Phase II Programme, PI- Dr. Ashish, Co-PI- Mr. Burungale Swapnil Birudev

8.5 MOU's Signed

1. MoU signed on 5th April, 2024 between CSIR-4PI and Tamil Nadu Agricultural University to collaborate in the CSIR project on "Region Specific Smart Agriculture" to facilitate/ help CSIR project team in conducting regular field observations, IoT measurements, drone survey and experiments in coordination with local farmers and jointly develop disease prediction models.
2. Addendum MoU is signed on 24th July, 2024 between CSIR-4PI and University of Agricultural Science, Bangalore (UAS) for conducting field experiments as part of CSIR Mission mode project "Region Specific Smart Agro Technologies for Enhancing Soil and Plant Health.

9. Staff News & Updates

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

Inside:

1. Staff List
2. Awards/Honours/Recognition
3. Services on External Committees/Membership of Professional Bodies
4. Newly Joined Staff
5. Promotions
6. Foreign Deputations
7. Superannuations
8. Staff relieved from CSIR-4PI

9.1 Staff List

Head/Outstanding Scientist/Director
Sridevi Jade

Honorary Emeritus Scientists

Gaur V K
Yajnik K S
H N V Dutt
Srinivas Bhogle
Rao E V S P

Distinguished Emeritus Professor
Mudkavi V Y

Scientists

Anil Earnest (Dr)
Anil Kumar V (Dr)
Ashapura Marndi (Dr) (Smt)
Ashish (Shri)
Chiranjeevi Vivek G (Shri)
Gayatri R
Gopal Krishna Patra (Dr)
Gutta Janhavi
Gyanendranath Mohapatra (Dr)
Imtiyaz Ahmed Parvez (Dr)
Kantha Rao Bhimala (Dr)
Kota Solomon Raju (Dr)
Krishna Chandra Gouda (Dr)
Lakshmikanthan C P
Manish Kumar
Md Talib Hasan Ansari
Mithun Babu N
Nagarathna R
Pankaj Saini
Pavithra N R
Prasanna K
Rajendran K (Dr)
Rakesh Asery
Rakesh V (Dr)
Ramashan K (Dr)
Sajani Surendran (Dr) (Smt)
Sangeetha
Sanjeev Ekka
Senthilkumar V (Dr)
Sithartha Muthu Vijayan (Dr)

Suribabu Donupudi
Swapnil burungale
Thangavelu R P
Vivekananda Hazra

Technical Officer
Kalidhas N, PTO
Prabhu, PTO

Technical Staff

Stella Margaret A, Sr.Technician (2)
Veeresh, Technician (2)
Dileep Kumar P, Lab Assistant

Administration

Mangala S, COA
Sudharani P, COA
Abhimanyu Kumar Tiwary, FAO
Vikash Chandra Mishra, SPO
Radha Ramani, PPS
Nirmala Bai, Hindi Officer
Ved Prakash , SO (G)
Abhijna, SO (G)
R P B N Kishore, SO (F&A)
Jitakala, PS
Rajalakshmi V, PS
Sujatha Keshava Murthy, ASO (G)
Rahul, ASO (G)
Gyalten Phuntsok Tsering, ASO (F&A)
Juliya John, JSA (G)
Vinod M Sharma, JSA (G)
Aishwarya P Venkitesh, JSA (G)
Dhanya Dharman D, JSA (F&A)
Kishan Kumar Singh, JSA (S&P)
Priya Lakshmaiah, JST

Research Fellows, Project Staff, Women
Scientists

Sumana Sarkar (Dr)
Payoshini
Shruthi S Deepak
Swadesh Mohapatra

Pankaj Sharma
Akash
Rakhi
Swetha S
Ipsita Patunda
Apoorva Jangir
Sharath Kumar E
Bhargavi
Manjunatha G S
Prescila Raj
Arvind Raj A
Prajwal H S
Dhananjay Kumar C
Prema
Hemanth Kumar M
Katta Hari Charan
Sreejaya T
Bhagyashree Narayana Hegde

Prasanth S V
Shubha A S
Rajendra Kumar Dash
Lekhana K
Rajitha R
Sharath L R
Reena James
Sri Hari
Surya P
Arun Prasad S
Puspendu Roy
Gopika Prgana Gujjula
Sushmitha A
Suthin Kumar
Puja Sahu
Thatiparthi Kotshwaramma
Meghashree

9.2 Awards/Honours/Recognition

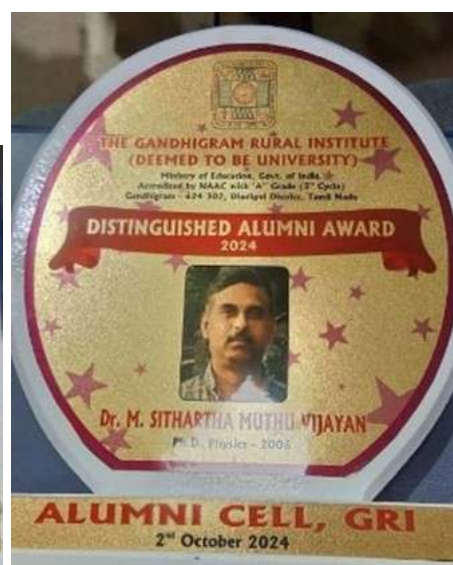
Sridevi Jade

Dr. Sridevi Jade received distinguished Alumni Award 2024 from Indian Institute of Science.



Sithartha Muthu Vijayan M

Distinguished Alumni Award 2024 by Gandhigram Rural Institute (Deemed to be University), Ministry of Education, Govt. of India, Gandhigram, Tamilnadu on 02nd October 2024.



Member (elected), International GNSS Service's Ionosphere Committee.
Chief Guest, inauguration of the Faculty Development Programme on Machine Learning and Applications for Instrumentation and Control Systems, Ramaiah Institute of Technology, 29th July 2024.

Ashapurna Marndi

Dr. Ashapurna Marndi received CSIR Raman Research Fellowship for the year 2024–2025.

Pankaj Saini

Mr. Pankaj Saini, Scientist, CSIR-4PI has won GOLD at National level Abilympics in Computer Programming.



9.3 Services on External Committees/Membership of Professional Bodies

- Anil Earnest
 1. Member, American Geophysical Union (AGU)
 2. Member, Society of Exploration Geophysicists (SEG)
 3. Member, Society of Earth Scientists (SES), India
 4. Associate Member, International GNSS Service (IGS)
 5. Member, Seismological Society of America (SSA)
- Anilkumar V
 1. Member Project Review and Stering Group (PRSG) of Ministry of Electronics and Information Technology (MeitY) on project "Enhancing Security using Lightweight Cryptography in IoT with one M2M as the service Platform and 3GPP-5G as the underlying Communication Network.
 2. Special Invitee, Advisory Board meeting, Society for Electronics Transaction and Security, Chennai.
 3. Member, Advisory Committee for Information, Communication and Technology Division, CSIR-NAL
 4. Member Project Review and Stering Group (PRSG) of Ministry of Electronics and Information Technology (MeitY) on project "Establishment of a National Facility for Security Testing, Evaluation and Certification of IoT Devices & Embedded Systems leading to Security Assurance".
 5. Member, search committee for Engagement of Mentors at Society for Electronics Transaction and Security, Chennai.

6. Member, Scientist Selection Committee, Center for Development of Advanced Computing (C-DAC), Pune.
 7. Member, Assessment and Promotion Committee for Scientists at Society for Electronics Transaction and Security, Chennai.
 8. Expert member, Committee for Regulation, Scheme and Syllabus for Post graduate diploma in cyber security, Kannur University.
 9. Member, Selection Committee for AcSIR Ph.D Admission of CSIR-NAL.
 10. Member, Board of Studies, Coimbatore Institute of Technology (CIT)
 11. Member, Internet Society (ISOC)
 12. Life Member, Computer Society of India
 13. Member, Review committee for patent renewal recommendation, CSIR-NAL
- Gouda K C
 1. Member in the High Impact Weather Project (HIWeather) of the World Meteorological Organization.
 2. Life Member, Indian Meteorological Society
 3. Life Member, Indian Society of remote sensing
 4. Executive member, India Meteorological Society, Bangalore Chapter
 5. Member, Indo-Africa group on Research on vector borne disease
 6. Member, Board of Studies, School of Computer Science, Jain University, Bangalore
 7. Member, Board of Studies, Department of Meteorology and Oceanography, Andhra University, Vishakhapatnam, Andhra Pradesh
 8. Member, Advisory Board, Dept. of CSE, Dayananda Sagar college of Engineering, Bangalore.
 9. Member, Board of Studies, Dept. of MCA, Dayananda Sagar University, Bangalore
 10. Member, Board of Studies, School of Computer Science, Jain University, Bangalore
 11. Mentor in the ATAL Innovation Centre of SoA University, Bhubaneswar
 12. Member, M.Tech. Thesis Evaluation Committee, VTU.
 13. Member, M.Tech. Examiner, VTU.
 14. Member, Doctoral Committee, VTU.
 15. Member, Doctoral Committee, Jain University.
 16. Member, PhD thesis Evaluation Committee, Andhra University, AP
 17. Member, M.Sc. examiner, Berhampur University, Odisha
 18. Member, Project review committee (PRC), DSIR-PRISM
 19. Member, Assessment Committee, CSIR NAL
 - Chiranjeevi G. Vivek
 1. Associate Member, International GNSS Service (IGS)
 - Kantha Rao Bhimala
 1. Board of Studies Member: Dept. of. Mathematics, Dravidian University, Kuppam.
 - Parvez I A
 1. Member, Selection and Assessment Committee of IIT Kanpur
 2. Member, Selection committee for the admission of AcSIR PhD students of

CSIR NAL.

3. Nodal Officer, Disaster Management Cell of CSIR NAL and CSIR 4PI
 4. Member, Hindi Technical Advisory Committee (HTAC) for CSIR NAL
 5. Member, Task Force of Bureau of Indian Standards Map Subcommittee, CED 39:4, Government of India to prepare a Probabilistic Seismic Hazard Map of India.
 6. PhD Examiner, Indian School of Mines, Dhanbad and IIT Roorkee
 7. Member, Hindi Technical Advisory Committee (HTAC) of CSIR NAL.
 8. Life Member: Indian Society of Earthquake Technology
 9. Life Member: Indian Society of Earthquake Science
 10. Member, Editorial Board, Seismic Instruments, Springer Nature Switzerland AG
- Patra G K
 1. Member, Industrial Advisory Committee, Computer Stream, Manipal Institute of Technology.
 2. Member Selection Committee, National Centre for Disease Informatics and Research, Indian Council of Medical Research.
 3. Member, Expert Evaluation Committee of VIABHAV proposals for ICT theme.
 4. Member, Data management sharing policy committee: PI-CHeCK CSIR.
 5. Member Advisory Committee "International Conference on Computations and Data Science" IIT, Roorkee.
 - Rakesh V
 1. Life Member of Indian Meteorological Society
 2. Member, Indian Society of Agronomy
 - Sajani Surendran
 1. Member, Working Group III, National Carbonaceous Aerosol Project, MoE-FCC, GoI.
 2. Life Member, Indian Meteorological Society
 - Sridevi Jade
 1. Member, CSIR Advisory Board
 2. CSIR Nominee, Executive Board Member, National Supercomputing Mission (NSM-EB)
 3. CSIR Nominee, Member, Scientific Advisory Committee, National Mission on Interdisciplinary Cyber Physical Systems (NM-ICPS)
 4. Senate Member, AcSIR
 5. Expert Member, Committee for CSIR Emeritus Scientist Schemes 2021-2023
 6. Expert Member ASPIRE Engineering Science Committee 2023-2025
 7. Executive Committee Member, Karnataka State Natural Disaster Monitoring Agency, Government of Karnataka.
 8. Expert Member, International panel for GNSS Remote Sensing for future missions and sciences.
 9. Expert member, Technical Advisory Committee, Government of Karnataka
 10. Life Member, Indian Geotechnical Society
 11. Life member, Indian Geological Congress
 12. Member, International Society of Soil Mechanics and Foundation Engineer-

ing

13. Founder Life Member, Indian Society of rock mechanics and tunneling technology
 14. Associate Member, International GNSS Service (IGS)
 15. Reviewer, for Several International and National SCI Journal
- Thangavelu R P
 1. Life Member, Computer Society of India
 2. Life Member, Cryptology Research Society of India
 3. Member, Cloud Computing Innovation Council of India
 4. Member, Expert Group on Infrastructure, National Supercomputing Mission, Gol
 5. Member, Executive Committee, Karnataka State Natural Disaster Monitoring Centre, Bangalore
 6. Member, Technical Expert Group for IT Infrastructure Procurement and Implementation, Kidwai Memorial Institute of Oncology, Bangalore
 7. Member, Technical Evaluation Committee for procurement of HPC system for Gas Turbine Research Establishment, Bangalore.
 - Vijayan M S M
 1. Member, American Geophysical Union (AGU)
 2. Member, European Geophysical Union (EGU)
 3. Member, International Association of Geodesy (IAG)
 4. Elected as a Member of International GNSS Service (IGS) Ionosphere Committee (Formerly IGS Ionospheric Working Group).
 - E. V. S. Prakasa Rao
 1. Expert Committee Member "Precision Agriculture and Management of Natural Resources" National Agriculture Science Fund, Indian Council of Agricultural Research
 2. Member, Executive Committee, National Academy of Agricultural Sciences, New Delhi
 3. Chairman, Advisory Committee, ICAR–NASF funded project on The development of a handheld sensor technology for non–destructive quality prediction of two economically important medicinal plants and the improvement of their quality", ICAR–Directorate of Medicinal and Aromatic Plants Research, Anand, Gujarat.

9.4 Newly Joined Staff

- Gayathri R, Sr. Scientist
- Sangeetha, Sr. Scientist
- Gutta janhavi, Sr. Scientist
- Nagarathna R, Sr. Scientist
- Prasanna K, Scientist
- Sanjeev Ekka, Scientist
- Suribabu Donupudi, Scientist
- Vivekananda Hazara, Scientist
- Manish Kumar, Scientist

- Mithun Babu N, Scientist
- Pankaj Saini, Scientist
- Rakesh Asery, Scientist
- Swapnil Burungale, Scientist
- Md Talib hasan Ansari, Scientist
- Sudha Rani P, COA
- Rahul, ASO
- Gyalten Phuntsok Tsering, ASO

9.5 Promotions

- Shri Prabhu as Principal Technical Officer

9.6 Foreign Deputations

- Ashapura Marndi – deputation to Goethe University, Frankfurt am Main, Germany on award of Raman Research Fellowship for a period of three months from 01.11.2024 to 30.01.2025

9.7 Superannuations

Staff superannuated from CSIR-4PI during the period from 01.04.2024 to 31.03.2025

1. Shri R P Thangavelu
2. Smt Mangala S

9.8 Staff relieved from CSIR-4PI

List of staff relieved from CSIR-4PI on Resignation/ Transfer for the period from 01.04.2023 to 31.03.2024

- Dr Rajendran K – on deputation to KSCSTE-ICCS, Kottayam, Kerala



Agri Nutri Biotech (ANB) theme “ONE WEEK ONE THEME” programme conducted at CSIR–4PI on 7th November 2024 and Invited to participate in Krishimela–2024 held at University of Agricultural Science Bangalore 14–17 November 2024.

Right to Information (RTI)

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

Details of the officers dealing with RTI's are as follows:

1. Dr. Ashish, CPIO, Principal Scientist
2. Dr. Anilkumar V, FAA, Chief Scientist
3. Smt. P Sudha Rani Controller of Administration, Transparency Officer



सीएसआईआर-चौथा पैराडाइम संस्थान
CSIR - FOURTH PARADIGM INSTITUTE
 Wind Tunnel Road, Bengaluru-560037

 csir4pi.res.in

 youtube/@CSIR-4PI

 twitter/CSIR-4PI

 facebook.com/csir-4pi