Ministry of Earth Sciences

De-risking the Risk of Solid Earth Hazards

Scoping Report of a Joint Natural Environment Research Council – Ministry of Earth Sciences Workshop

10th & 11th January 2023

Held at the Shangri-La Eros Hotel, New Delhi, India

Contents

Summary

In January 2023, the Natural Environment Research Council (NERC) of UKRI and India's Ministry of Earth Sciences (MoES) held a joint UK-India scoping workshop facilitated by UKRI India on 'De-risking the Risk of Solid Earth Hazards'.

Inaugurated by the Indian Minister of Earth Sciences and Science & Technology, Dr Jitendra Singh and British Deputy High Commissioner Christina Scott, the workshop took place in New Delhi between 10th and 11th January 2023, bringing together scientific experts from the UK and India to identify opportunities for a potential joint UKRI-MoES bilateral programme on the topic. Over the course of the two days, participants discussed the current research landscape, strengths and expertise present within India and the UK, and opportunities for bilateral research.

The key outcome of the workshop was the identification of the highest priority research areas. Seven themes were identified, and listed below are the top four highest priority matched areas for potential UK-India research collaboration:

1. Improved risk and vulnerability maps/models
2. Improved forecasting and early warning
3. Improved data analysis and infrastructure
4. Development and testing of low-cost sensing technologies and tools

Summary of Workshop Discussions

The format of the workshop was built around five interactive breakout sessions:

1. UK and India Overview of Landscape of Research and Country strengths, including Tools and Facilities

2. Identifying Gaps in Research, focussing on: Earthquakes; Landslides; Marine Hazards; Rock Physics and Boreholes

3. Identifying Opportunity Areas for Bi-lateral Cooperation

4. Effective Project Requirements

5. Prioritisation of Ideas

The key discussions and ideas that came up in the breakout discussions are listed below:

Breakout session 1. UK and India Overview of Landscape of Research and Country strengths, including tools and facilities

Discussions around current expertise included:

- Submarine intraplate mass transport, sedimentation and faulting
- Subaerial mass transport sedimentation and faulting
- Landslides (monsoonal, co-seismic) mapping and modelling
- Seismic network operational activities
- Seismic wave propagation and ground motion modelling including site specifics
- Experimental rock mechanics and borehole seismology, downhole geophysical data and geotechnical characterisation
- Remote sensing
- Multi-risk vulnerability, vulnerability mapping and risk modelling
- Early warning systems
- Interdisciplinary approach
- Citizen science
- Sensor technology

Breakout Session 2. Identifying Gaps in Research, focussing on: Earthquakes; Landslides; Marine Hazards; Rock Physics and Boreholes

Earthquake Research Gaps

1. Operational earthquake risk reduction

  - calculating Mw for smaller earthquakes
  - complete catalogues using Mw
  - improvement in shakemaps with local data and models

- calculating site response (can form part of microzonation)

2. Main contributions to hazard in New Delhi
    - large distant and moderate close
    - missing ground motion models/impact on design codes
    - very different source and wave propagation
3. Risk
    - combining hazard with exposure and vulnerability
    - what fragility curves are appropriate
    - mapping exposure
4. Site-specific risk
    - using best quality data (geophysical, geological, engineering)
    - producing highly bespoke hazard and risk for high hazard micro-zone
    - high resolution shakemap/intensity maps using sparse information (20km – 200km spacing of sensors)
    - focal mechanisms for small events
5. Big data assimilation for hazard/risk machine learning approaches

Landslides Research Gaps

1. Effective and low cost early warning systems
2. Rainfall threshold calculation and seismic (e.g. train track)
    - rainfall coverage/landslide multi-year data and landslide hazard information is not always widely available/accessible
    - large volume of InSAR data now available but need to enable access
3. Web based landslide geospatial data dissemination
4. Susceptibility modelling using AI and ML technology and tools
5. System-based vulnerability mapping (e.g. safer schools and dwellings)
    - citizen science
    - internet of things
6. Integrating run out modelling
    - high resolution satellite imagery
7. Sensor technology
8. EO/airborne
    - drones, LiDAR, radar

Marine Hazards Research Gaps

1. Intra-plate seismicity

2. Need for more seismic and GPS observations

3. Understanding the seismogenic potential of shallow subduction zones

- land experiments
- ocean bottom geodesy
- bathymetric mapping of seafloor
- palaeo-reconstructions
- mapping of sedimentary structures and their origin

4. Tsunamigenic flow potential regions

- history of tsunami inundation through collection of ground data (e.g. core samples)
- buoy installations for coastal tsunamis
- storm/cyclone induced hazards

5. Impacts and risks

- monitor the effects on biological and environmental systems

Rock Physics and Boreholes Research Gaps

1. High temperature rock physics and mechanics

- 1000°C plus fluid flow
- permeability evolution with temperature
- high temperature acoustic emissions – source parameter determination of lab faults
- seismic-aseismic strain partitioning – why so variable?
- friction – slip weakening in presence of high temperatures

2. Scaling lab measurements to field to region

3. Depth dependent rheology from borehole core

- earth observation

4. Downhole/deep borehole observatory

- new sensors e.g. optical for deep borehole measurements and alternative technologies
- reducing earthquake location uncertainties
- AI/ML tools to detect earthquakes, identify seismic phases and locate earthquakes for cross-domain multi-station datasets

5. Data repository for rock physics/rock mechanics

- Open access

All tables highlighted the need for training and capacity building in:

- participatory rural appraisal methods i.e. interdisciplinary training on natural/social sciences
- historical methods
- AI/ML
- field skills/new mapping approaches

They also identified a requirement to provide more PhD and ECR opportunities (e.g. post-docs, fellowships, exchanges) within these research disciplines.

Breakout Session 3. Identifying Opportunity Areas for Bilateral Cooperation

Participants were asked to consider the importance of geographical area, singular vs cascading hazards, benefit and impact whilst discussing opportunity areas. Groups agreed that no one geographical area was relatively more important than any other, and that no single hazard was more important but that cascading hazards were important. Benefits included improved understanding and models, which would ultimately lead to better planning, warnings, reducing vulnerability and mitigation of disasters.

The following were opportunity areas identified by the participants:

1. Characterisation of seismic hazards and vulnerability-based risk in the intra-plate region

2. Multi-hazard regional modelling

3. Seismic co-hazards and risks

4. Strategies for loss reduction (seismic and other hazards and impact chains)

5. Data infrastructure, analytics, governance and sensor technology

6. Addressing cascading and multi-hazards

7. Estimation of earthquake parameters and hazard parameters with AI/ML and also pattern recognition technique

8. Strengthening real time operational monitoring of earthquakes by assessing shallow magnitude earthquakes including fault plane solution

9. Understanding landslide mechanism and issuing early warning systems, mapping vulnerability and landscape for a pilot area

10. Addressing vulnerability and response to early warning and public education for different groups by strengthening technology and social systems with special focus on safe schools and health care systems

11. Forecasting risks: short/long term hazard forecasting of landslides, earthquakes/aftershocks, tsunamis. Early warning. From hazard to risk (incorporate vulnerability), most forecasts/early warning are statistical/empirical, difficult to transfer to other cases, research need to underpin these, robust statistical methods with physics/geology, locally developed, nationally transferable, can be developed individually but hazard chain important (earthquake, landslide, tsunami) e.g. landslide dependent on shakemap tsunami dependent on earthquake, benefit focus on highly studied areas transferability means models equally valid in less studied regions. More physics/geology, the more transferable (but potentially less data driven)

12. Understanding intraplate India: very poorly understood, hidden faults, unknown/variable state of stress, lack of dense sensor networks, onshore and offshore observations, hard to see what's happening lack of observations, relatively high magnitude of completeness, intraplate zone understudied but has ~30year M6+ occurrence, very limited geophysical surveys for seismic source/crust/subsoil in intraplate zone, swarm activity regular – seismogenesis needs to be investigated with geo-seismological methods, national scale, need to know crustal structure/seismogenesis/faulting in intraplate zone to better understand hazards

13. Risk and resilience: risk requires convolution of hazards and vulnerability/exposure, applicable for earthquake/landslide/tsunami (coastal area), poorly understood – building fragility and building stock, site specific geophysical/geotechnical studies, microzonation – hazard and risk at city scale, geotechnical information for liquefaction potential – bedrock depth. Impacts local, risk highly heterogeneous at small scale, can target high rise structures e.g. retrofitting schools, hospitals

14. Improving use of geodesy in operational event response (national/regional), real time GNSS approaches, rapid InSAR analysis

15. Improving hazard risk mapping

16. Understanding seismic potential of shallow subduction zones

Breakout session 4. Effective Project Requirements

Participants were asked to describe what they felt were the ideal project requirements, and these included:

- 4 (+1) years project length
- Projects in the region of £1M+ to £4M
- Data access
- Equity, Diversity and Inclusion

Projects should include:

- PhDs, post-docs, ECRs, international exchanges
- Capital and field costs
- Outreach and education (public and schools)

- Impact (publications, reports, guidelines, policy briefs, patents, evacuation systems)

It was noted that to be able to answer a lot of the research questions effectively then there was a need to incorporate specialists from other disciplines such as:

- Engineers (civil, structural, instrumentation)
- Social scientists
- Data scientists
- Historians

Partners could include:

- UK universities and research centres
- MoES and affiliated institutes and academic institutes
- Government agencies (central and state)
- Local governments/schools/hospitals
- Communities and civil society
- Business and commerce (e.g. insurance)
- Citizen science
- National Management Disaster Authority
- Indian National Center for Ocean Information Services
- National Center for Seismology
- Bureau Indian Standards
- Indian meterological department
- National Centre for Earth Science Studies

Breakout session 5. Prioritisation

The ideas from session 3 were grouped into themed areas, and the attendees were asked to add any information which they felt was important to each theme. Attendees were also asked to prioritise the areas by identifying their top two choices.

Improved data, analysis and infrastructure

- Integration of borehole data with rock physics experiments on borehole cores
- Analysis of big data sets using AI/ML techniques to understand and analyse the earthquakes and signals hidden in the time series data sets
- Improving seismic observatories in diffused intraplate region of Indian ocean
- Earth observation including InSAR and GNSS for event response
- Temporal datasets – multi-year
- Use of landscape evolution models to understand underlying processes
- Multi-hazard datasets for ML training
- Acquisition of bathymetric data, geological and geophysical data (seismic reflection/magnetic)
- Estimation of earthquake parameters using AI/ML and pattern recognition techniques of phases

- Generate laboratory dataset for ML/AI and scaling laboratory data with field observations
- Rainfall sensors – automated
- Capacity building in rock physics for earthquake processes
- Better geo-spatial mapping – easier to access improved data analysis on infrastructure
- Catalogues (earthquake) homogenisation and seismicity for advance research
- Risk based inventory for rapid/efficient data collection and catastrophe modelling
- High resolution digital elevation models (e.g. Lidar)
- Historical archival analysis
- Social surveys (e.g. participatory)
- Integration of rock mechanics/rock physics experimental data with borehole datasets

Development of low-cost sensing technologies and tools

- High resolution digital elevation models e.g. drones
- Low-cost seismometers (MEMs)
- Low cost early warning systems for landslides to be installed in landslide susceptibility zonation areas in India
- India should have a repository at national level for D-InSAR database
- Hyperspectral (proximal/drone/satellite) for rock/soil
- Internet of things and wireless networks for embedded sensors for early warning systems
- For real-time measurement of smaller magnitude earthquakes including focal mechanism
- Earth observation including InSAR
- Low-cost instruments to record earth vibrations especially earthquakes
- Low-cost development of seismic and GPS sensors
- Multi-sensor swarm approach
- Post-event survey and recovery support
- Citizen science

Improved risk and vulnerability maps/models

- Bayesian data assimilation
- Agent based modelling
- Links between observed/reported intensity and instrumental metrics
- Access to databases – catalogues, strain rates, fault maps, topography, to improve recurrence model
- Multi-scale scenarios based on susceptibilities
- Region specific/physics based ground motion models
- Vulnerability mapping and risk assessment/loss
- Integrate geodetic strain with other datasets (e.g. seismicity, faults) to improve hazard assessment
- Citizen science

- Improved data/analysis is needed to achieve this goal and link to better mitigation
- In seismically high hazard zones already studied through microzonation
- Improved evidence base and community engagement
- Scenario mapping
- Crowd sourcing and data mining from social media

Improvement of planning management and mitigation strategies

- Strategies for sustainable/green building structures
- Planning strategies for risk reduction (avoiding high hazard through planning)
- Interdisciplinary effective collaboration
- Fast rehabilitation – water sanitisers, protect from threats etc.
- Participatory approach and co-development
- Digital twins development for scenarios modelling
- Vulnerability mapping
- Fragility of structure typologies
- Community engagement
- Synergy with tomorrow's cities for new-build urban planning
- Anticipatory actions
- Impact chains analysis
- Improved public and outreach strategies
- Scenarios tailored to users and co-developed with them
- Research and innovation in designing green building models as a tool for improvement in building structures in earthquake zones
- Inter-plate earthquake simulation

Understanding cascading and multi-hazard regions

- Must include vulnerabilities of groups
- Earthquake hazard parameters and landslide hazards
- Man-made activities
- Cascade from natural to physical to social systems
- Multi-hazard risk assessment
- Impact of climate change (and societal?) on cascading/multi-hazards in the future
- Combined hazards due to earthquake triggered pre-conditioned landslide
- Enhances susceptibility/sensitivity models
- Understanding shallow subduction zone
- Earthquake forecasting
- Hazard/risk map of India in the same way as EU
- Mapping of mass transport turbidic deposits on continental margins – their impact on the submarine pipelines/cables or geological terrains

- Tsunami modelling from different factors (earthquake, landslides..)
- Himalayan seismic hazard
- Nowcasting/real time prediction of earthquake impacts including damage and secondary/cascading hazards
- Lab to field scaling through interpretation of lab data with high resolution borehole seismological data and application of AI/ML techniques to study earthquake precursors

Improved forecasting and early warning

- Earthquake early warning
- Landslide early warning
- Physics based empirical models
- Landscape sensitivity – understanding link between deposits/landscape, landslide triggers and behaviour
- Bridging the gap between statistical and theoretical models towards transferable forecasting models
- Local ground motion prediction equations, site response characterisation, and early warning using SMA/BBS
- Communication from field station to central station and effective dissemination
- Cost effective geophysical methods e.g. electricity, electromagnetic
- Real time GNSS for rapid earthquake response and earthquake early warning
- Landscape and vulnerability mapping
- Better and fast communication systems to operate early warnings successfully
- Sensor density increase e.g. raw gauges
- Precursor studies
- Improving source models by integrating InSAR, GNSS, seismology
- Integration of community based and physically based early warning systems
- Operational earthquake forecasting during swarms, aftershock sequences and induced seismicity
- Using ML to make use of sparse monitoring data
- Using site specific investigations

Understanding the intra-plate region better

- Need for 3D seismic tomography especially in intra-plate earthquakes zones
- Identification of deformation zones/areas in terms of seismic/geo hazards. Fault mapping
- Understanding the state of stress of the intra-plate region
- Need for multi-geophysical study to understand the intra-plate region
- GNSS network of studying the plate motion fault monitoring
- Strain rates on faults from InSAR and GNSS
- Laboratory rock mechanics experiments to study earthquake nucleation
- Intra-plate seismicity through borehole drilling
- Understanding of crustal deformation mechanism in Indian Ocean and seismotectonics of the intra-plate region

- Active fault investigation after delineation of fault by geophysical surveys
- Oceanic intra-plate earthquake activity
- Intensive active fault mapping in the intra-plate regions. Generation of data setQ implementation of AI/ML techniques to analyse the data to understand intra-plate earthquakes
- Dating of tectonic geomorphic landforms to constrain long-term rates of fault motion
- Observations and data collection along the central Indian Ocean – Ocean Bottom Seismometers deployments and seafloor/fault mapping
- Are rock mechanics experiments able to image stress or earthquake rate in SCR
- Laboratory rock mechanics to understand fault dynamics and earthquake nucleation processes
- Earthquake characteristics in the intra-plate zone. Stress drop link to borehole

Participants were asked to highlight anything which they felt was not captured within the theme areas above as 'Others'

Others

- Shallow subduction zone (Andamans) – is the fault locked?
- Tsunami hazard and risk
- Ocean Bottom Seismometers
- Seafloor geodesy
- Active seismic data for fault mapping
- Seismo-tectonic mapping of the subduction deformation zone – Andaman-Sumatra Zone

General information surrounding the themes were also captured

Hazards

- Seismic
- Anthropogenic
- Coastal
- Liquefaction
- Landslides
- Tsunamis
- Volcanoes

Vulnerable Groups and structure

- Schools
- Healthcare
- Tourists
- Gender
- Disability

- Critical infrastructure

Geographic Areas

- Mega cities
- Himalayas
- Intra-plate regions
- Coastal
- Andaman
- Oceans

The order of prioritisation areas **matched** on both the Indian and the UK side were as follows:

1. Improved risk and vulnerability maps/models

2. Improved forecasting and early warning

3. Improved data analysis and infrastructure

4. Development and testing of low-cost sensing technologies and tools

5. Understanding the intra-plate region better

6. Improvement of planning management and mitigation strategies

7. Understanding cascading and multi-hazard regions

The top areas of prioritisation for each country were as follows

<u>UK delegates</u>	<u>Indian delegates</u>
1. Understanding cascading and multi-hazard regions	1. Improved data analysis and infrastructure
2. Improved risk and vulnerability maps/models	2. Understanding the intra-plate region better
2. Improved forecasting and early warning	3. Improved risk and vulnerability maps/models
2. Improved data analysis and infrastructure	4. Improved forecasting and early warning

Annex

Background

The Natural Environment Research Council (NERC) is the UK's leading public funder of environmental science. The NERC studies the whole planet, from the edge of the atmosphere to the centre of the Earth and excels at revealing the environmental challenges confronting the world. Tackling these complex problems requires us to go further, bringing together deep understanding of environmental science with a whole-systems approach.

The Ministry of Earth Sciences (MoES), under the Government of India, is mandated to provide services for weather, climate, ocean and coastal state, hydrology, seismology, and natural hazards, to explore and harness marine living and non-living resources in a sustainable manner for the country and to explore the three poles of the Earth (Arctic, Antarctic and Himalayas).

UKRI India plays a key role in enhancing the UK-India research and innovation relationship. Since the New Delhi office opened in 2008, over £330 million has been invested by the UK, Government of India and third parties to co-fund research and innovation programmes throughout India.

During pre-pandemic discussions between NERC and MoES, the research topic area of solid earth hazards emerged as a priority for both funders. At that point the partners collectively drafted an initial concept note as the basis for a potential programme. Activity was paused temporarily during the pandemic, with conversations being revisited during 2022. It was agreed that this research area remained a priority for both countries and that further consultation should take place with experts from the scientific communities of both countries. Consequently, a scoping workshop was arranged by NERC, MoES and UKRI-India for January 2023 to bring the two communities together.

Concept Note

The vast majority of deaths from solid earth hazards such as earthquakes and related landslides occur in low- and middle-income countries, where the attendant damage to essential infrastructure, devastation of local economies, and mass displacements of people can set back development by decades. Between 2-3 billion people in the developing world are exposed to earthquake and volcanic risks, both in rapidly growing cities and in vulnerable rural environments.

Much of the strategic research focus of past programmes into geohazards and 'de-risking risk' has been within single countries; we are proposing a programme of work across boundaries, looking holistically at geohazards across India and neighbouring countries.

Scientific understanding of the processes behind disasters has grown immensely over the past 50 years, and feeds into growing resilience in economically prosperous regions. In contrast, the human consequences of natural disasters in low and middle income countries are rising ever more rapidly. To address this problem, there is a critical need for fundamental research on the physical processes that lead to failure of the brittle layers beneath the crust and sub-crust, to develop low-cost solutions to identifying and quantifying these geohazards over vast regions, and to devise mitigation strategies that are appropriate to widely varying – and rapidly evolving – political, social, and economic contexts.

Potential areas of focus for a programme of research may include, but are not limited to:

- Physics of rock failure: Earthquakes, Landslides. Combining data sets from laboratory, remote-sensing, and field observations;
- The development of Earth Observation and AI techniques to identify geohazards, map vulnerabilities, explore mitigation strategies, and guide responses to disasters;
- Sensor technologies for dense monitoring of crustal deformation;
- Improved quantification of hazards and risks;
- Dynamic scenarios – guiding long-term development of cities and regions in response to geohazards;
- Hazard potential of tsunamigenic zones;
- Study of ionospheric disturbance by studying TEC using GPS;
- Study of focal mechanism using real time GPS &SMA data.

Building resilience to geohazards presents a major challenge that requires collaborative international action by researchers, policymakers, governments, private sectors, and civil societies. UK earth scientists played central roles in the development of the current understanding of tectonic activity and its relation to geohazards. The UK has extensive, and long-lasting, relationships with researchers in disaster-prone countries across the developing world, not least with key research teams in India who have a unique understanding of the challenges faced by India and the surrounding region.

Agenda

WORKSHOP AGENDA		
10th January 2023		
10.00 – 11.00	Registration	
11.00 – 12.10 INAUGURATION		
11.00 – 11.05	Inviting dignitaries on Dias	Welcome note by Sukanya Kumar, Acting Director of UKRI India
11.05 – 11.07	Lighting of the Lamp	All
11.07 – 11.10	Bouquet presentation to the guests on the stage	Basheera Shaik
11.10 – 11.20	Impact video showcasing UKRI-Government of India collaborations	Video showcasing UKRI-GOI collaborations
11.20 – 11.25	Address by Director, National Center for Seismology	Dr. O.P. Mishra
11.25 – 11.30	Address by Head (Seismology/Geosciences) MoES	Dr. Neloy Khare
11.30 – 11.35	Address by Head of Resilient Environment, Natural Environment Research Council	Wendy Matcham
11.35 – 11.40	Address by the British Deputy High Commissioner to India	Christina Scott CMG
11.40 – 11.45	Address by MoES Secretary	Dr. M Ravichandran
11.45 – 12.00	Address by the Honourable Minister of Earth Sciences	Dr. Jitendra Singh
12.00 – 12.05	Presentation of souvenir and mementos to the dignitaries on dias	
12.05 – 12.10	Vote of thanks for the guests by senior scientist of National Center for Seismology	Dr. G. Suresh
Workshop Day 1		
12.10 – 12.25	Tea break	
12.25 – 12.35	Setting the scene	Wendy Matcham and Dr. O.P. Mishra
12.35 – 13.15	India Research Landscape in Solid Earth Hazards	Dr. O. P. Mishra
13.15 – 14.15	Lunch	
14.15 – 15.00	Speed Networking	

15.00 – 15.30	UK Research Landscape in Solid Earth Hazards	UK Academic Experts
15.30 – 16.15	Breakout Session 1. UK and India Overview of Landscape of Research and Country strengths, including tools and facilities	
16.15 – 16.30	Tea Break	
16.30 – 17.30	Breakout Session 2. Identifying Gaps in Research. 1. Earthquakes 2. Landslides 3. Marine Hazards 4. Rock Physics and Boreholes	
Workshop Day 2		
10.15 – 10.30	Summary of Day 1	Dr. Sukanta Roy
10.30 – 12.00	Breakout Session 3. Identifying Opportunity Areas for Bi-lateral Cooperation.	
12.00 – 13.00	Breakout Session 4. Effective Project Requirements	
13.00 – 14.00	Lunch	
14.00 – 15.00	Breakout Session 5. Prioritisation	
15.00 - 15.10	Summarising the workshop outcomes	Wendy Matcham
15.10 – 15.30	Next steps	Dr. O.P. Mishra
15.30	Close	Sukanya Kumar

Participants

	Designation	Organisation
UK Attendees		
Dr Sarah Boulton	Associate Professor of Active and Neotectonics and Deputy Head of the School of Geography, Earth and Environmental Sciences	University of Plymouth
Professor Benjamin Edwards	Professor of Engineering Seismology	University of Liverpool
Dr Andy Gibson	Director for the Centre for Applied Geoscience	University of Portsmouth
Professor Ian Main	Professor of Seismology and rock physics	University of Edinburgh
Professor Irene Manzella	Head of the Centre for Disaster Resilience and Associate Professor in Geotechnical Engineering for Natural Hazard Risk Management at the Faculty of Geo-information and earth observation (ITC)	University of Twente, Netherlands
Dr David Milledge	Research Fellow in the School of Engineering	Newcastle University
Professor Peter Sammonds	Professor of Geophysics and Climate Risks	University College London
Professor Tim Wright	Professor of Satellite Geodesy at the University of Leeds and director of COMET, the NERC Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics.	University of Leeds
Indian Attendees		
Dr. G. Suresh	Scientist-G	National Centre for Seismology
Dr. J. L. Gautam	Scientist-F	National Centre for Seismology
Dr. A. P. Pandey	Scientist-F	National Centre for Seismology
Sh. R. K. Singh	Scientist-E	National Centre for Seismology
Dr. H. S. Mandal	Scientist-E	National Centre for Seismology
Dr. Sanjay Kumar Prajapati	Scientist-E	National Centre for Seismology
Dr. Babita Sharma	Scientist-E	National Centre for Seismology

Dr. Kapil Mohan	Scientist-E	National Centre for Seismology
Dr. A. P. Singh	Scientist-E	National Centre for Seismology
Dr. Himanshu Mittal	Scientist E	National Centre for Seismology
Dr. Ambikapathy Ammani	Scientist-C	National Centre for Seismology
Dr. Sukanta Roy	Director	Borehole Geophysics Research Laboratory (BGRL), Karad, Pune
Dr. Deepjyoti Goswamy	Scientist-D	Borehole Geophysics Research Laboratory (BGRL), Karad, Pune
Dr. Anup Kumar Sutar	Scientist-D	Borehole Geophysics Research Laboratory (BGRL), Karad, Pune
Dr. V. Nandakumar	Scientist-G	National Centre for Earth Science Studies (NCESS), Thiruvananthapuram
Dr. Padma Rao B	Scientist-C	National Centre for Earth Science Studies (NCESS), Thiruvananthapuram
Dr. Lachit Singh	Scientist-C	National Centre for Polar and Ocean Research (NCPOR), Goa
Dr. Nisha Nair	Scientist-C	National Centre for Polar and Ocean Research (NCPOR), Goa
Dr. H.S. Maldal	Scientist-E	Ministry of Earth Sciences
Organising Team		
Daniel Knight	Programme Manager, Resilient Environment Team	Natural Environment Research Council, UKRI
Michelle Manning	Senior Programme Manager, Resilient Environment Team	Natural Environment Research Council, UKRI
Wendy Matcham	Head of Resilient Environment and Joint Head of Healthy Environment	Natural Environment Research Council, UKRI
Dr. O.P. Mishra	Director of NCS, Scientist G & Advisor to the Ministry of Earth Sciences	Ministry of Earth Sciences
Dr. Arun Gupta	Scientist-E	Ministry of Earth Sciences
Sukanya Kumar	Acting Director	UKRI India
Yuri Luikham	Programme Manager	UKRI India
Basheera Shaik	Senior Programme Manager	UKRI India
Maisie England	Joint Head of Engineering	Engineering and Physical Sciences Research Council, UKRI