IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Integrated study of landslide using ambient seismic noise continuous monitoring, remote sensing and geomechanical methods**	
Project Number	**IMURA1109**	
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IITB Department:	Earth Sciences	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
*(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	***Earth Sciences** and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1	***Artificial Intelligence and Advanced Computational Modelling***
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	***Sustainable Societies***
7	***Infrastructure***

The research problem

The landscape of our planet is the result of the competition between tectonic processes of building mountain slopes, and erosional processes of breaking the rises and transporting sediments away. Climate carves landscapes through disparate processes over different timescales, from the action of rainfall runoff to cataclysmic landslides, triggering the response of deep tectonics, restoring/rearranging elevation through lithosphere flexure and slower mantle rebound. The contribution of each surface process varies owing to the variations in climate, prompting a viscoelastic response of the solid Earth, which in turn modifies the surface, in a feedback between climate and tectonics. Mounting evidence of such feedback is reported, highlighting how extreme climate has triggered events such as landslides and earthquakes, via, e.g., rainfall-driven increased erosion or pore pressure increases, thawing permafrost, cohesion reduction or increase hydrophobicity from fires. Additionally, these processes have occurred at an unprecedented scale, such as the Taiwan orogeny and the Himalayan front. On one hand, this corroborates the idea of large-scale feedback between deep solid Earth support and topography evolution, on the other it proves our ability to address such hazard limited. In a scenario of growing climatic extremes, understanding the hazard associated with climate-triggered catastrophic landslides has an obvious societal impact.

Landslides represent the geomorphological process that can induce changes over time in the physical, hydrogeological, and mechanical properties of the involved materials. As a geohazard, this frequently results in significant disruptions to life, infrastructure, and development projects such as railways, roads, power lines, and hydro projects. Between 2004-2016 alone, an estimated 55,997 people were killed worldwide in 4,862 distinct landslide events (not counting those caused by Earthquakes), with Asia being the most affected continent (Froude & Petley, 2018). India ranks first in terms of fatal land landsides (Froude & Petley, 2018). A study shows 10,305 people have died in India due to landslides and associated causes during the 1998–2018 period (Martha et al., 2021).

Landslides and related mass movement activities are common and ubiquitous on mountainous terrain. These have been occurring since the geological past in the Himalaya, however, their magnitude and frequency have been increasing during recent years, primarily due to changing climatic scenarios in the form of increased incidences of extreme rainfall as well as due to high anthropogenic pressure on the slope. The working group of the Intergovernmental Panel on Climate Change (IPCC) also warns the global

warming, and hence the increased extreme weather events across India and South Asia (Kuar et al., 2021). This will have a major implication on the slope instability and the distribution of landslides in the Himalayan region. The triggering factor that causes the landslides are diverse (including geological, geomorphological, and hydrological conditions, climatic factor and earthquakes) and can also occur in conjunction with each other. Anthropogenic influences are undoubtedly contributing to the intensification of the landslide phenomenon. The occurrence of recent landslides during the last few years in Himachal and Uttarakhand put up a concern among the scientific community regarding the need to identify potential areas with high deformation and more specific the landslides.

Project aims

Monitoring of landslide changes in remote mountainous terrain is logistically challenging, expensive and time consuming. Remote Sensing based delineation of potential landslide areas integrated with the ground based spatiotemporal monitoring of ground motion can help in forecasting of the possible failure along the slopes and thus can reduce landslide disaster risk and avoid the occurrence of disasters. Geophysical methods help to construct a framework based on physical properties that may be linked with site characterization (e.g., a landslide and its subsurface channel geometry, recharge pathways, rock fragments, mass flow rate, etc.) and dynamics (e.g., quantification of the rheology, saturation, fracture process, toe erosion, mass flow rate, deformation marks and spatiotemporally dependent geogenic pore-water pressure feedback through a joint analysis of geophysical time series, displacement and hydrometeorological measurements from the ground, air and space).

Deformation mapping from InSAR dataset:

Satellite based Synthetic Aperture Radar interferometry (InSAR) represents a possibility of mapping surface deformation at fine spatial resolution in order to characterize the aspects of terrain motion and hazardous processes. This can be used to quantify the state of activity of slope instability. This provides millimetre-scale measurements of ground surface deformation that can be used to identify and monitor landslide. The proposed study will use novel InSAR deformation detection approach, which uses double difference time-series with local and regional spatial filters and pixel clustering methods to identify and monitor slow-moving landslides without making a priori assumptions of the location of landslides (Bekaert et al. 2020). To mark the active landslides from the

clusters, those clusters will be marked which have the highest velocity (i.e. largest signal to noise ratio) and largest spatial signal.

Deformation monitoring from ambient seismic noise dataset:

Geophysical methods provide direct insight into subsurface changes, in contrast to the surface deformation by the remote sensing method. For monitoring purposes, it is essential to identify reversible/irreversible ongoing changes in real-time due to physical processes (crack formation, alteration, and destabilization for rock instabilities) that could potentially lead to failure. Landslide (LS) areas are primarily located in a very challenging geography. It is crucial to address the problem with logistics, cost, timescale, and accuracy. In the last decade, passive seismology has emerged as a potential tool like ambient noise spectral analysis and Ambient Noise Interferometry (ANI) methods used for site-characterization and sub-surface deformation monitoring. Using the seismic interferometry principle, the seismic wavefield will be constructed by cross-correlating the two receiver pairs, and this will be performed for all receivers' pairs. Further, this cross-correlation, referred to as Green's function can easily distinguish between body waves and surface waves according to the arrival of the waveform. The fundamental mode of surface wave is one of the vital waveforms dominant in Green's function and has dispersive properties of the medium. To image the high-resolution structure, surface waves (SW) will be utilized, which are strongly sensitive to the near-surface shear wave velocity. Long term continuous monitoring of seismic ambient noise will help us to detect the small-scale deformation in landslide prone region. Short-time dependent (period of days to weeks) correlogram from ambient seismic noise (Sens-Schonfelder and Wegler, 2006, Breton et al. (2021)) has shown a drop in shear-wave velocity days before the rupture of a clayey landslide (Mainsant et al., 2012b). The velocity drop (dv/v) is related to the properties of its elastic parameters and represents a decrease in rigidity (softening) in the underground layers, which is directly related to the failure. Compared to other methods, many advantages of using ANI for landslide studies and monitoring such as continuous monitoring, dense coverage, a non-destructive approach, and cost-effectiveness. Further, more detail can be found in the recent reviews of work done by Breton et al. (2021) and Hussain et al. (2022).

Integration of detailed rock-mechanical studies from landslide prone region:

Geomechanical considerations are key to understand the mechanism of landslides. The geometry, composition, and structural discontinuities present in the slope have a

significant impact on the behaviour of the slope mass. The susceptibility of slopes to failure is primarily influenced by unfavourably oriented structural discontinuities, material strength, slope geometry, the severity of local weathering, tectonic activity, and the annual average rainfall in the region. A detailed rock-mechanical study based on experimental characterisation of geomaterials and further numerical modelling of the slopes will help ascertain the potential for triggering of landslides in the vulnerable regions.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

Keeping the above stated facts into consideration the proposed study is intended to be carried out with the following objectives-

- Identifying and mapping the area with significant deformation using SAR datasets and thereby delineating area with potential landslides.
- Spatial and temporal monitoring of landslides using Seismic Ambient Noise datasets.
- Integrated study of SAR and seismic data to locate the active deformation zones and thereby forecast potential landslides using precursory signatures.
- Detailed experimental and simulation rock-mechanical studies to ascertain the potential causes for triggering of landslides.

Expected outcomes

Highlight the expected outcomes of the project

This integrated study on landslides using the remote sensing and ambient seismic noise method will help to identify the zones with considerable ground motion (i.e., Uttarakhand and Himachal Pradesh). The monitoring of specific landslides using the seismic ambient method will help to forecast potential landslides depending upon the precursory signatures and understand the controlling process.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

Analysis of InSAR and ambient seismic data required advance and heavy computation modelling. This work has a direct societal, infrastructure benefit in terms of planning, mitigation, and assessment of landslide hazards. The research will help the planners and stakeholders in decision-making.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

From IITB

Prof. Anand Singh
Prof. Ashish Juneja

From Monash
Dr. Andrew Gunn, expert in geomorphology

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Essential Qualifications: MSc/MTech in Geology/Geophysics or relevant field
Desirable: *Experience* of InSAR data processing, Engineering Geology, Geomechanics or seismology.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

GS543: Computer Programming for Geosciences
GP403: Earthquake and Engineering Seismology
GS422: Geomorphology, Remote Sensing & GIS
GS507: Engineering and Ground Water Geology

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.