UNDERSTANDING, MODELLING AND PREDICTING LANDSLIDES IN HIGH MOUNTAIN AREAS (NORWAY) – IS GLOBAL WARMING INCREASING MOUNTAIN HAZARDS?

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Project partner: Landslide Unit - Norwegian Water and Energy directorate

HIGHLIGHTS: mountain hazards, risk management / Early Warning, CASE partner, Norway, Global warming / Climate change / cryosphere (permafrost melting), high quality data, advanced analytical techniques, multi-disciplinary project.

IMPORTANCE OF THE AREA OF RESEARCH

The observed increase in the rate and severity of mass movements in mountainous areas all over the world has been interpreted as signals of permafrost degradation due to global warming (e.g. [1], [2], [3]), a trend that is expected to accelerate over the next several decades due to anthropogenic climate change [4]. Rising mean temperatures at planetary scale combined with regional and local-scale extreme heatwaves will become more frequent over the next decades, both having a tremendous impact in cryosphere-related hazards [5]. While current regional models for permafrost degradation and slope stability capture broad-scale spatial changes, an improved understanding of cryosphere-slope interactions is urgently needed in order to forecast extreme events with sufficient response time to allow evasive/preventive actions to be taken (e.g. Early Warning Systems, effective evacuations, etc.).

This research will exploit a unique and timely opportunity to combine rich streams of real-time data – with new models to extract and predict future catastrophic landslides. It is anticipated that this project will have a tangible impact on risk management strategies in the forecasting of mass movements in high-mountain areas. The outputs of this research will be used for decision making on slope failure risk during crisis thanks to the joint efforts both from risk management stakeholders in Norway (Norwegian Water and Energy directorate, NVE) and academics in the UK (University of Leeds).

Fig.1. *Aerial image of the Mannen mountain in Norway, acquired by project partner during routine site inspection (more info: https://goo.gl/ryxRAU).*

PROPOSED RESEARCH - aims and objectives

We propose an exciting and truly multi-disciplinary PhD opportunity to create a paradigm shift in methodologies for forecasting the temporal occurrence of a catastrophic landslides in High Mountain areas, where the instabilities are controlled both by a progressive strength reduction -associated with permafrost degradation- and a seasonally intermittent water flow through deep fractures. Exceptional data of an active slope failure that is being captured in real-time by Norwegian project partner (NVE), will be analysed using time-dependent models of brittle failure, which importantly apply to all brittle slope failures worldwide ([6], [7]). Examples of high quality datasets Norway (fig.1) include –but is not limited to- slope kinematics sensors such as real-time in-situ extensometers, state of-the-art remote sensing techniques (GB-Radar, drones, time-lapse cameras), environmental forcing such as precipitation, snow melting, solar radiation, air temperature, rock temperature at different depths, detailed weather forecast, etc. [8]. Accessing to these fundamental observations, the PhD student will unpick and model the highly non-linear landslide response to both the environmental forcing and the progressive movement of the slope, using a new physically-based time-invariant model for forecasting slope kinematics (fig. 2) [9]. Back and forward analysis of tipping point behaviours will be carried out in order to model better extreme and often unexpected events (the so called *black swan* events [10]). The outputs of this investigation will not only be transferrable to other rock slope failures in permafrost settings, but also constitute the basis of a new generation of Early Warning Systems.

According to your particular research interests, the focus of this work may involve one or several of the following elements: (1) Develop and apply time-varying physically based models for predicting slope instability using state of the art Engineering Geological and hydrological principles and techniques (2) Data Science (e.g. AI, support vector machine, neural networks systems, multivariate regression analysis, Bayesian theories, etc.) in order to couple complex links between external forcing (rainfall, temperature), infiltration and slope kinematics. (3) Geophysics: using advanced Electrical resistivity tomography (ERT) and ground penetrating radar (GPR) monitoring to investigate permafrost degradation (4) Remote Sensing: using state of-the-art Earth Observation techniques (GB-Radar, drones, time-lapse cameras, etc.) in order to fully understand the 4D evolution of slopes affected by permafrost degradation and study the influence of external forcing; (5) Computing: design real-time platform and a new generation of Early Warning Systems based on real-time modelling of slope kinematics.

SCIENTIFIC BACKGROUND AND METHODS

Permafrost in steep bedrock is abundant in many cold mountain regions, and its degradation can cause slope instability that is unexpected and unprecedented in location, magnitude, frequency, and timing [11]. The complexities that obstruct a straightforward forecasting of the acceleration and deceleration phases observed on slope failures in alpine areas include complex model parameterization and a series of epistemic and parametric uncertainties. Well-established strain-rate failure models, such as the power-law acceleration rate [12] and inverse failure models that were built under the assumption of constant stress conditions may explain the lack of agreement between these simple models and field observations, questioning the ability to predict landsliding. In addition, current models for progressive slope degradation in permafrost do not yet take into account the time-varying behaviour of the slope [13]. At present, critical strains (safe, permissible deformation prior to failure), detectable limits (changes in slope behaviour away from a background behaviour), and the transition from secondary to tertiary creep, are maturing conceptually in this field, but have not been quantified. Constraining the values of the hydrological and geotechnical parameters on deterministic models has proven to be complex due both to the spatio-temporal variability and the non-linear, hysteretic and highly scale-dependent behaviour observed both in-situ and under lab conditions. The availability of Big Data together with the use of modern data analysis techniques is instigating paradigm shifts across multiple disciplines, including inverse modelling techniques to analyse slope accelerations as response to rainfall [14].

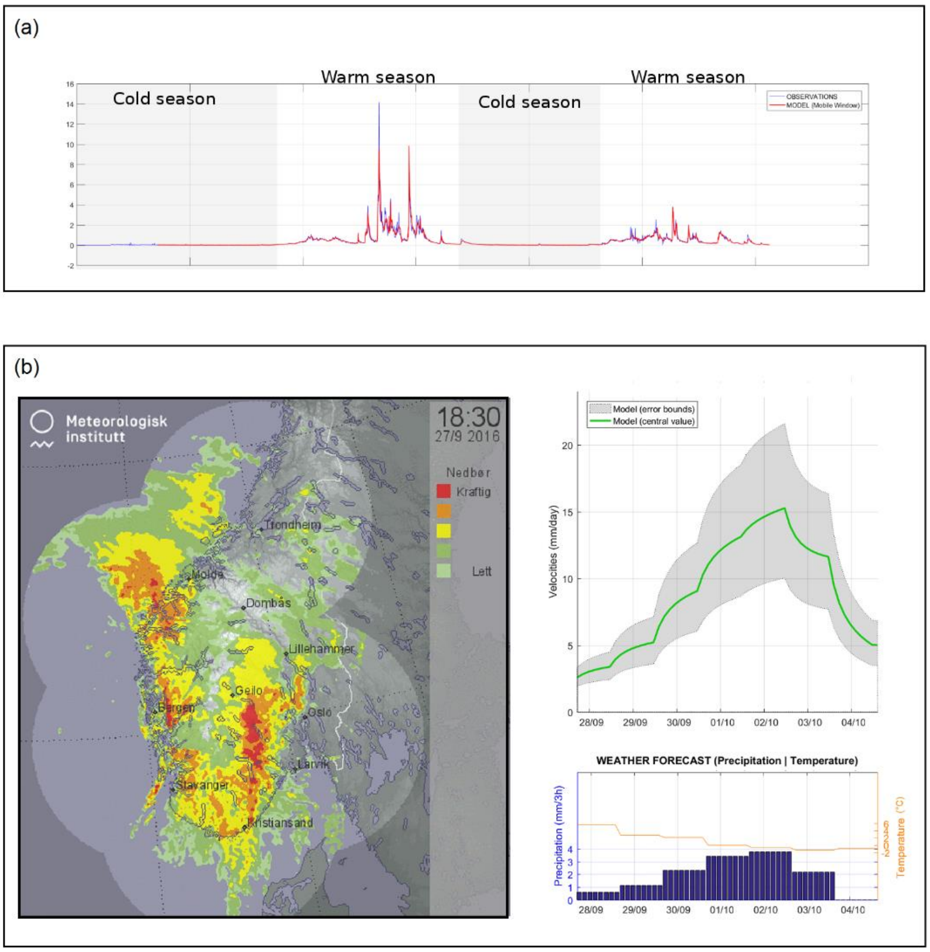

Fig.2. Example of landslide modelling according to measured precipitation and forecasted weather conditions.

TRAINING AND RESEARCH GROUP

The student will be supervised by a multi-disciplinary group with a wide range of expertise including Landslide Modelling, Permafrost Degradation, Early Warning Systems, Hydrology and Risk Management. The student will join the Rock Mechanics/Engineering Geology, Geotechnical and Hydrology (RMEGGh) cluster within the Institute of Applied Geoscience (IAG) at the University of Leeds, a highly multi-disciplinary with a strong international profile, including around 75 PhD students and postdoctoral researchers of multiple nationalities. Your research will benefit from peer support, group seminars and social interaction in the multi-discipline research environment within the group and the larger School. Substantial foundation training will be provided in year one concerning those key areas that were identified as 'gaps' and that will reinforce the student skills in order to secure a successful PhD project. The student will be in close contact with lead supervisor and supervisory team for guidance and support. From year two, it is highly expected that the PhD applicant will be leading his own PhD project, with appropriate and one-to-one / group meetings as requested.

The successful applicant will have an opportunity to participate in group presentations, national and international meetings, etc. You will be trained in -and encouraged to- preparing posters, presentations and academic publications as direct outcomes of your results. Other transferrable skills while completing your PhD will include excellent project management abilities, team-working, problem solving attitude, innovation, international experience, etc. Last but not least, you will have access to a broad spectrum of training workshops put on by the Faculty at Leeds that include an extensive range of training workshops in technical aspects, through to managing your degree, to preparing for your viva (http://www.emeskillstraining.leeds.ac.uk/).

ENHANCED TRAINING OPPORTUNITIES THANKS TO CASE STUDENTSHIP

Given that the studentship will be delivered in collaboration with an industry partner (NVE), the successful applicant will be expected to spend a minimum of 3 months in a real-world experience outside the academic environment in Norway. This partner allow accessing to training, facilities and expertise not available in an academic setting alone. Internships are likely to be undertaken early, as they provides opportunities to collate background information held by the partner. The main strategy for coping with large rockslides in Norway has been the implementation of high-quality monitoring systems for alerting the population over the imminent failure of unstable areas through different levels of danger (8), and all this priceless data, knowledge and equipment will be shared to the prospective PhD student. During the studentship, the successful applicant will have opportunities to undertake fieldwork in West Norway. A close contact with the project partners is guaranteed along the studentship, including prof. Lars Blikra from the The University of Tromsø and head of the Landslides section at the Norwegian Water Resources and Energy Directorate; he will be directly involved in this project as PhD advisor and responsible during the studentship. The student will also be trained in the importance of close interaction with responsible agencies, authorities and the media during future landslide crisis such as https://goo.gl/2H7C9p.

RELATED GRADUATE AND UNDERGRADUATE SUBJECTS

Engineering Geology, Geohazards, Geology/Geological Sciences, Cryosphere, Remote Sensing, Geo-Computing, Geomatics, Rock Engineering, Civil Engineering, Earth Surface Processes, Geophysics, Hydrogeology, etc. (it is not expected that the PhD applicant will arrive with all the skills, and it is expected that the PhD project will evolve according to the student background, research interests and motivation)

REQUIREMENTS

Applicants are invited from UK/EU citizens who should have, or expect to gain, a high academic achievement (first-class honours or a minimum of 2:1) BSc or MSc in the GeoSciences, Physical Sciences, or Mathematical/Computational Sciences. Only highly motivated individuals with the ability to solve complex problems, the patience to deal with multifaceted data, a talent for applied mathematics / interest in computers and a love for the outdoors will be considered.

FURTHER INFORMATION

Please contact the lead supervisor (A.Abellan@leeds.ac.uk) for further information related with the project or any other specific questions concerning what the successful applicant will be expected to do and educational background. We encourage interested applicants to get in touch and arrange an informal skype meeting to discuss details of the project.

FURTHER READING

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