BUILDING RESILIENCE TO AVALANCHES AND OTHER CLIMATE-DRIVEN GEOHAZARDS THROUGH INTERNATIONAL COLLABORATION IN EDUCATION: EXPERIENCE FROM THE GEOMME PARTNERSHIP

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ABSTRACT: The GEOMME international partnership for 'Climate-driven GEOhazards Mitigation, Management, and Education' fosters collaboration in research and education on climate-driven geohazards across South Korea, Japan, and Norway. The initiative focuses on enhancing societal resilience against gravitational mass flows through excellence in education and research, aiming to improve the adaptive capacities of partner nations via research-based education and knowledge exchange. The partnership is focusing on four emerging scientific themes: (1) understanding geohazards in a changing climate, (2) modeling hazard processes at various spatial scales, (3) monitoring and early warning, and (4) sustainable hazard and risk mitigation. Each of these themes is addressed by an educational package including an introductory online module and an in-depth, in-person course. we targeting graduate students, practitioners, and researchers. Snow avalanches, particularly challenging in Norway and Japan, are a central focus, with recent efforts emphasizing climate change considerations in hazard assessments and regional avalanche modeling. The partnership's interdisciplinary approach, integrating expertise from other hazards like landslides, enhances both avalanche understanding and broader geohazard mitigation strategies.

KEYWORDS: Avalanches, Geohazards, Resilience, Education, International collaboration

1. INTRODUCTION

The ongoing global climate change is likely to result in more frequent and intense snowfall and rainfall, which is in turn expected to increase the frequency of climate-driven hazards such as avalanches and landslides. To develop researchers and practitioners capable of dealing with these threats and to promote international collaboration, an international partnership was initiated in 2021 to collect expertise from South Korea, Norway, and Japan. The partnership, named GEOMME (short for *Climate-driven GEOhazards Mitigation, Management, and Education*) includes the Norwegian Geotechnical Institute (NGI) and University of Tromsø (UiT; Norway), Korea Institute of Geoscience and Mineral Resources (KIGAM) and Korea Advanced Institute of Science and Technology (KAIST), National Research Institute for Earth Science and Disaster Resilience (NIED; Japan) and Niigata University (NU; Japan).

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These nations all face significant challenges from climate-driven geohazards. For instance, all are prone to landslides triggered by intense rainfall, and Norway and Japan experience frequent avalanches in mountainous regions during the snow season. Enhancing societal resilience to these hazards is critical, as they pose substantial risks to human life and infrastructure. The three nations all possess a great deal of knowledge on these topics, and the partnership's objective is to collaborate on these shared challenges through research, education, and knowledge exchange. By leveraging the unique expertise, experiences, and research infrastructure of each country, the partnership aims to develop innovative strategies for hazard mitigation and risk management, ultimately contributing to greater adaptive capacity and resilience in the face of the evolving geohazards.

A core activity in the partnership is the development of education packages, each consisting of a pre-study module and a research-based course, to contribute to the adaptive capacities of the partner nations to address climate-driven natural hazards through knowledge exchange. The international collaboration will allow us to build teach-

ing modules which leverage wider perspectives and experience. As a result, those taking the course acquire a unique skill set for problem solving in their home countries that they otherwise would not.

Another key component of the partnership is exchange of knowledge and research experience. Avalanches present major challenges in Norway and Japan and are naturally a central topic within the consortium. Recent activities have focused on methodological approaches to account for climate change in snow avalanche hazard assessments and current state-of-the-art in regional scale avalanche modelling. The partnership benefits from incorporating expertise from other hazard types, for instance drawing from landslide management strategies that are successful in South Korea. This interdisciplinary approach not only improves understanding and mitigation strategies for avalanches but contributes to a comprehensive framework for addressing multiple geohazards. Leveraging the collective knowledge and experiences of the partner nations, GEOMME aims to innovate in the areas of hazard and risk assessment, and community resilience building – enabling the creation of adaptable solutions tailored to the unique environmental and societal contexts of each region.

The purpose of this contribution is to: (1) introduce the training program and materials, which include the curriculum, teaching methodologies, and the integration of research and practice; (2) demonstrate the development of digital resources for emerging topics in snow avalanches and other gravitational mass flows; (3) showcase international collaboration and knowledge exchange.

2. GEOMME TRAINING PROGRAM

Together, the GEOMME partners develop one education package each year, each consisting of a pre-study module and an in-person course. The material primarily targets graduate students and practitioners. The topics, as well as the responsibility for developing and hosting activities, have rotated between the partner countries according to the following schedule:

2022: Geohazards in a Changing Climate (host country: Norway)

2023: Modelling hazard processes at different spatial scales (Japan)

2024: Advanced monitoring and early-warning systems for landslides hazards (South Korea)

2025: Green mitigation solutions (TBD)

Pre-study modules are primarily designed as a 'level-setting' tool to allow students to develop an understanding of key themes and basic technical competencies (e.g. programming or GIS tools) before attending the in-person course. The module material has been hosted locally and shared directly with the participants until now; however, we will make the material openly available, for example, through the 'OpenLearn Create' platform developed by The Open University.

In-person courses are designed to be research- and experience-based, providing students with opportunities to engage with current methodologies and develop observational and field skills, such as data collection. Practically, short courses are designed to last a total of two weeks: one week consists of classroom lectures and practical exercises, while the second week focuses on fieldwork and excursions. The lectures are delivered by researchers from the GEOMME partners and other experts from the partner counties. The excursions also include visits to sites of past disasters to observe the actual conditions and the implemented countermeasures. Student evaluation has been in the form of a written report after course completion.

Partnership experience – This two-part methodology has proven to be an effective approach for a short course where students need to focus on specific and advanced topics. When followed, the pre-study modules allow a culturally, linguistically, and academically diverse student group to prepare for the intensive in-person course. The availability of written instructions and course materials in the common language (English) has been invaluable for ensuring an acceptable level of communication, irrespective of variations in language proficiency. It has also been important to create an inclusive course environment where students feel comfortable engaging with each other and the course lecturers.

2.1 2022 – Geohazards in a Changing Climate

The course in Tromsø, Norway took place in August 2022. The participants were 18 graduate students and researcher partners from the partner countries and Italy. The course was also widely attended by the project partners to establish a common format for future activities in the education packages.

The theme of the course was Geohazards in a Changing Climate. Lectures were given on the current state of climate change in the partner nations and the relationship between climate change and the occurrence of geohazards such as rockfalls, landslides, and avalanches. In addition, exercises in the form of group discussions were conducted on how geohazards might change due to climate change.

The course leveraged opportunities in the region surrounding Tromsø to expose participants to the spectrum of hazard processes occurring in Arctic Norway and introduce them to local planning challenges and climate adaptation.

During the course, field trips were also made to visit hazardous areas of snow avalanches, landslides and rockfalls around Tromsø (Figure 1). The focus was on mitigation that is both functional but potentially insufficient for climate adaptation needs.

Figure 1: Excursion to avalanche-protection dams in Lavangsdalen, near Tromsø, Norway.

2.2 2023 – Modelling hazard processes at different spatial scales

The course in Niigata, Japan was held in November 2023. 20 students and early career practitioners attended with good balance from the partner nations. There were 12 lecturers from the project partners, as well as guests from other Japanese research organizations.

The focus of this course was on Modelling hazard processes at different spatial scales. The course was structured into the following sections to meet the established learning outcomes: (1) hazard and risk – in the context of Japan, (2) phenomenology of gravitational mass flows, (3) release and runout modelling of snow avalanches, (4) modelling debris flows, (5) models over different spatial scales, and (6) multihazard assessments.

During the first week, participants conducted classroom-based activities. The structure each day was 3-hours of teaching in the morning followed by hands-on activities in the afternoon. For the exercises the students were organized into groups to ensure that a mixture of backgrounds (both nationalities and academic) was present to tackle the problems. The exercises were carried out using GIS software (QGIS) to test avalanche dynamics simulation and hazard mapping methods.

During the second week, course participants and partners participated in an excursion to visit and conduct field observations at sites of relevance for snow avalanches, landslides, volcanos and tsunami around the central part of Japan (Figure 2). Visits were also made to the unique experimental facilities of the National Research Institute for Earth Science and Disaster Resilience (NIED) in Shinjo and Tsukuba, which reproduce snowfall (Figure 3) and heavy rainfall, respectively. In addition to focusing on a suite of hazard processes, topics during the excursion also extended to development of hazard inventories and the societal impacts of hazard events.

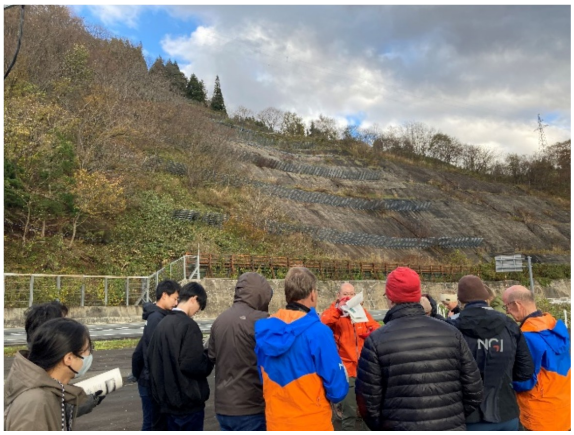

Figure 2: Excursion to past avalanche hazard area and protection structures in Yamagata, Japan.

Figure 3: Inside the Cryospheric Environment Simulator at NIED (Shinjo, Japan).

Partnership experience – Effective learning in GEOMME is achieved by integrating theoretical lectures with practical field trips and hands-on exercises, such as using GIS and modelling software and fieldwork. The inclusion of participants from diverse international and interdisciplinary backgrounds has resulted in a better learning

experience, fostering a broad exchange of ideas across domains – which is crucial for addressing climate-related challenges experienced globally. Leveraging local environments and facilities during the courses, such as the specialized research infrastructure at the partner institutes and in different countries, offers unique, context-specific learning. For those organizing similar courses, it is beneficial to integrate interactive and practical experiences with theoretical learning. This not only provides a good basis for looking at global perspectives and approaches but also gives participants the opportunity to get to know each other and create strong and lasting networks.

3. FOCUS ON SNOW AVALANCHE HAZARDS

Snow avalanches present significant challenges in both Norway and Japan due to their mountainous terrains and winter climates. In Norway, avalanches are a frequent natural hazard, posing risks to remote communities, infrastructure, and transportation networks. Similarly, Japan has a high risk of avalanches, with half of the country classified as a heavy snowfall area, not only in the mountains but also in the plains. This makes avalanche threats possible even near populated areas and critical infrastructure.

Although there are differences between the two countries in terms of climates (temperature and precipitation) and avalanche path topography, the promotion of knowledge exchange on avalanche mitigation measures will lead to universal avalanche management that can cope with climate change.

These challenges underscore the importance of snow avalanche research and education within GEOMME, as understanding and mitigating avalanche risks is crucial for the safety and resilience of these regions.

4. INTERDISIPLINARY AND INTERNATIONAL COLLABORATION

4.1 Avalanche education across boarders

There is much to be learned from the teaching and research practices relating to avalanche hazards in the partner countries, with recent methodological advancements being integrated into the educational program in GEOMME. The partnership has developed curriculum content that incorporates state-of-the-art techniques such as terrain analysis, the use of remote sensing tools, and physically based models that allow for the inclusion of the impacts of climate change.

On the research and experimental side, Japan and Norway have historically focused on different avalanche sizes. In Norway, much of the avalanche research has focused on the impacts of large dry-snow avalanches on infrastructure and buildings. This includes research conducted at NGI's test site Ryggfonn in western Norway. Conversely, full-scale testing in Japan has focused on addressing smaller, more frequent avalanche events and wet-snow avalanches. Collaboration between the two countries provides an opportunity to leverage the unique research focus and infrastructure in both locations, resulting in efficient collaboration and the transfer of knowledge between contexts.

4.2 Knowledge transfer from other hazard types to avalanches

The GEOMME partnership emphasizes the transfer of knowledge from working with other geohazards, such as landslides and rockfalls, to enhance the understanding and management of snow avalanches. For example, techniques developed for monitoring and mitigating landslides – such as slope stability analysis, process-specific modelling, and community-based risk management – are adaptable and can be applied for other hazard types. This exchange of ideas and approaches both enriches the educational aspects but also supports the development of students and practitioners with adaptable strategies for mitigating avalanche risks and addressing other hazards which may also be present in mountainous environments. The interdisciplinary approach ensures that the lessons learned from one type of hazard can inform and improve the management of others, ultimately leading to more effective and resilient mitigation strategies to address the complex and interconnected challenges posed by climate-driven geohazards.

5. FUTURE DIRECTIONS

The GEOMME partnership will continue to expand on our educational and research initiatives, with a focus on cross-hazard collaboration. Future activities, in 2025, will focus on sustainability in natural hazard mitigation – including the design and implementation of Nature-based Solutions for multihazard disaster risk reduction. The ongoing exchange of ideas and best practices among partner nations will ensure that GEOMME can develop educational and research activities which contribute to greater community resilience and more effective mitigation strategies for the partner nations.

While this contribution focuses on the educational aspects of GEOMME, progress towards the other goal of the partnership—building up long-lasting research partnerships in the field of natural hazard management between the three countries—

deserves also to be mentioned. Research partnership between countries with different problems, focus areas, organizational structures and —not least—different history and culture cannot simply be established by decree. Instead, a multi-year programme like GEOMME is an ideal incubator: a not too large group of researchers have many opportunities to meet and to get to know each other during courses and excursions (including social gatherings), conferences and online seminars, to become acquainted with the partner countries and their cultures, their natural hazards problems, research institutions and specific contributions to our common research problems. The GEOMME partnership facilitates this process also through researcher exchanges lasting from a week to several months.

These activities have led to several research collaborations in diverse fields. One of them, within the field of snow avalanches, is mutual participation in snow-avalanche experiments at the large site Ryggfonn in western Norway and the small sites Mizuno-no-sawa and Moiwa in Niseko on Hokkaido. As a first result, a joint NIED −NGI poster at the ISSW 2024 discusses why and how to carry out small-avalanche experiments.

Another initiative targets detailed large-scale avalanche hazard indication maps in Japan and Norway. Due to differences in climate, topography and legislation, the Norwegian focus presently is on mapping extreme (mostly dry-snow) avalanches with an occurrence probability of 0.001 per year endangering settlements. In Japan, the main interest lies with relatively frequent (wet-snow) avalanches hitting critical transportation routes. NGI's code NAKSIN uses topographical criteria for finding potential release areas, long time series of gridded weather data to estimate the corresponding release probabilities, and a dynamical run-out model to find the endangered areas. Thus, it can in principle be equally well applied to the situation in Japan. However, each of the model components should be improved to encompass both situations equally well: The criteria determining the release area of a frequent, small wet-snow avalanche differ significantly from those of an extreme dry-snow event. In small avalanches, the slab stability is more affected by the supporting stresses across the slab perimeter than in large avalanches, and the snow strength depends strongly on the water content of the snow. The effects of the latter should also be incorporated in the run-out model. Finally, when applying such a model to a transportation corridor, one is mostly interested in the probability of an avalanche reaching a given point rather than in the run-out distance of an avalanche with a given occurrence probability. First steps for adapting NAKSIN to the Japanese conditions and needs have been taken by the GEOMME partners. They hold promise of making the model more "future-proof" in a warming climate also in Norway and widen the range of practical problems it can be applied to.

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