Abstract Book

Geohazards Day
24th October 2024
Conference Day

program

8:30	Registration, coffee, snacks
9:00	Conference opening
9:10	**Keynote - Kikki Kleiven (Bjerknessenteret)**: Det ekstreme er den nye normalen
9:40	Bjørn Ole Skorgevik, Karianne Staalesen Lilleøren and Bernd Etzelmüller: Analyse og farevurdering av isskred fra breer i Jotunheimen
10:00	Christopher D'Ambiose, Vilde Hansen, and Louise Vick: Slushflow classification
10:20	Coffee break with poster session
11:20	Maren K. Karlsen, Mathilde B. Sørensen and Lars Ottemöller: A new national seismic hazard assessment for Norway
11:40	Vikram Maji, Lars Ottemöller and Stéphane Rondenay: Observation of local and teleseismic activity with Distributed Acoustic Sensing (DAS) in Svalbard, Norway
12:00	Marianna Anichini and Mathilde B. Sørensen: What hydroacoustic data can teach us for earthquake monitoring in the High Arctic
12:20	Lunch break
13:20	**Keynote - Martine Sagen Bekken (NVE):** Manns minne er kort…
13:50	Åse Hestnes and Karoline Ertesvåg: Skredfarevurderinger i Bergen kommune
14:10	Iris Peeters: Testing the significance of vegetational parameters on shallow landslide occurrence - for landslides triggered in August 2023 during the extreme weather event Hans
14:30	Erin Lindsay, Alexandra Jarna Ganerød, Graziella Devoli, Johannes Reiche, Steinar Nordal and Regula Frauenfelder: How satellite radar backscatter data can improve timely detection of landslides in cloudy or dark conditions
14:50	Coffee break with poster session
15:30	**Keynote - Hallvard Berg (Energidepartementet):** *Tryggare framtid – førebudd på flaum og skred;* om stortingsmeldingen som ble levert før sommeren
16:00	Kristel Kaselaan, Elco Luijendijk and Eoghan P. Reeves: Hydrochemical study of quick clays at Tiller-Flotten, Norway
16:20	Jo Brendryen, Christian Haug Eide, Rune Mattingsdal, Md Jamilur Rahman and Haflidi Haflidason: Shallow sedimentary gas as geohazard for offshore wind installations
16:40	Final remarks and closing of conference
17:00	End of conference
18:00	Dinner

Geohazards Day
25th October 2024
Excursion Day

program

Time	Location	Description
07:45	Meet at Realfagbygget - UiB Natural Science Building	Meeting point: at the **middle** of the **Realfagbygget building**, by the **garage entrance** Address: Allégaten 41, 5007 Bergen
8:00	Departure from Realfagbygget	**NB! the bus will leave at 8.00 sharp!**
09:30	**1. Mundheim**	*Rockfall: A house barely missed by a rock boulder*
10:00-10:30	Ferry break**	
10:50	**2. Eitrheim**	*Rock avalanches and mitigation measures*
11:00	**3. Odda**	*History of snow, slush, and flood avalanches, along with rockfalls, and mitigation measures*
12:15-12:45	Lunch break**	
13:00	**4. Tyssedal**	*Avalanches and rockfalls*
14:45	**5. Granvin**	*Past floodings & quick clay - past events and mitigation measures*
15:45	**6. Voss**	*History of flooding in Voss, focus on the period 2014-2022*
16:30-17:00	Break**	
17:00	Return to Bergen	
19:00	Arrival at Realfagbygget - UiB Natural Science Building	Address: Allégaten 41, 5007 Bergen, as for departure
	**Access to restrooms included in each break	

Geohazards Day
24th October 2024
Conference Day

talks

Analyse og farevurdering av isskred fra breer i Jotunheimen

Bjørn Ole Skorgevik[1], Karianne Staalesen Lilleøren[1] & Bernd Etzelmüller[1]

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Gjennom de siste 30-årene, har temperaturen på høye breddegrader steget dobbelt så raskt som det globale gjennomsnittet, med en rate på 0,6 °C per tiår. Denne temperaturstigningen, er noe som påvirker dagens utbredelse av isbreer og permafrost. I tillegg til store utslipp av klimagasser, skaper tining av permafrost også potensielt utfordringer i høye fjellområder, knyttet til instabilitet i skråninger. For eksempel i Alpene, er det i løpet av flere somrer funnet korrelasjon mellom hetebølger og økt steinsprang aktivitet. Tining av permafrost kan også endre tilstanden og stabiliteten i isbreene. Der permafrost er lokalisert under breene, blir bresålen kald (dvs. under 0°C), noe som resulterer i at breen fryser fast i underlaget. Varmere klima og tining av permafrost i slike tilfeller kan lede til en endring i det termiske regimet av slike isbreer og lede til isskred dersom helningen på underlaget er bratt nok. I Alpene er flere store isskred koblet til tining av permafrost, inkludert en hendelse i Dolomittene i 2022 der deler av en isbre kollapset, noe som resulterte i 11 dødsfall. På Juvvasshøe i Jotunheimen, overvåkes temperaturen i permafrosten kontinuerlig, og målinger gjennom over 20 år viser en trend hvor temperaturen øker med 0,02°C per år. Dette betyr at også kalde isbreer i Jotunheimen kan stå ovenfor et skifte i temperaturregime. Ved bruk av multikriterieanalyse i ArcGIS, er målet i denne oppgaven å lokalisere breer som potensielt blir påvirket av permafrosttining, og i tillegg er bratte nok til å produsere isskred. Videre vil det utføres en farevurdering av disse breene. Ved å kartlegge hvor og antallet folk som er på tur i ulike områder i Jotunheimen kan konsekvensen av eventuelle isskred vurderes. Dette gjøres i kombinasjon med å analysere rekkevidden til isskred gjennom simulering i RAMMS.

Slushflow classification

D'Ambiose, C.[1*], Hansen, V.[1], Vick, L.[1]

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Slushflows are a type of rapid mass movement where water saturated snow flows downhill. Slushflows come in many different sizes, have different triggering mechanisms, and contain debris ranging from simply snow and ice to soil, rock and vegetation. Slushflows are often misclassified as debris flows, wet snow avalanches or river/stream ice jam processes. Norway reports 5 to 20 larger slushflows each year which have economic impacts such as damage to infrastructure, road closures, and even fatalities. For improved slushflow hazard assessment a robust classification system must be used to precisely describe what size and type of process is being forecasted, modeled, or investigated. A classification system would be beneficial for both scientific research, data collection, and operational hazard mitigation strategies. Slushflows have been well defined as a sub-category of mass flows mostly defined by the composition of the mass. However, they have not been systematically broken down into sub-categories that describe the formation, type of movement, size, and quantity of entrained material. These sub-categories are needed because the types of slushflow, the terrain from which they initiate, and the triggering mechanism can differ greatly. Quite extreme rain on snow or melt events have predictive power for slushflow activity when all slushflow types and sizes are analyzed together. However, many slushflow events occur during periods of moderate rain on snow or melt events. Weather and snowpack data alone are not able to predict slushflow activity during moderate rates of melt or rain. Some of the nuances of slushflow formation may be uncovered when single slushflow types and/or sizes are investigated independently. Independently investigating slushflow types and sizes will also help define the spatial patterns of slushflow formation. We propose a classification system which includes some traits from snow avalanche classification, such as size and release mechanisms and build on this to include other unique traits such as water availability and indication of debris materials. A classification system will allow further research on precise sub-classes of slushflow, because as a whole slushflow behavior is too diverse to describe as a single process.

A new national seismic hazard assessment for Norway

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The last publicly accessible national hazard evaluation for earthquakes in Norway was published in 2000. In the 24 years since this study was published, the quantity and quality of available data has increased significantly. New methods and tools have become available, and there has been an exponential increase in computational power, leading to more complex processing routines and calculations. This all contributes to reducing the epistemic uncertainty connected to seismic hazard assessment. Norway is located on the western edge of the stable, cratonic Fennoscandian shield. The level of seismicity is low to moderate, with events rarely exceeding magnitude 5.5. This study aims to develop a new probabilistic seismic hazard model for Norway. The study area covers continental Norway, including a 300 km perimeter, and the seismic hazard model has been harmonized with the neighbouring countries. The hazard estimates are calculated using the Open Quake Engine. Input earthquake data are mainly from the Norwegian National Seismic Network, supplemented with data from other national and international catalogues. The data is harmonized and quality assured using automated routines, with manual quality control to ensure a consistent, reliable, and representative catalogue. The analysis results in an up-to-date and improved open access evaluation of the seismic hazard in Norway. This new hazard model can support better preparedness and an improved understanding of the economic and societal risk earthquakes may pose. The methods and input data used for the analysis will be presented together with preliminary results.

Observation of local and teleseismic activity with Distributed Acoustic Sensing (DAS) in Svalbard, Norway

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[2]Bjerknes Centre for Climate Research, Bergen, Norway

Oceans cover around three quarters of the earth–surface, however, our understanding of subsurface deformations and detection of submarine earthquakes are limited by the technical challenges associated with implementation of marine seismic instrumentation. Distributed Acoustic Sensing (DAS) has emerged as a well-established technology that can transform the extensive network of ocean-bottom optical fiber-based telecommunication cables into a dense array of seismic strainmeters. In this study, we report three local earthquakes with magnitudes between 2–5 Mw near the Mid–Atlantic Ridge and a teleseismic earthquake of 7.8 Mw which is located ~4800 km away in Türkiye following the available DAS data from Svalbard. The initial 66 km of the standard telecom G.652D single mode fiber-optic cable connecting between Ny-Ålesund and Longyearbyen are interrogated using OptoDAS manufactured by Alcatel Submarine Networks. The OptoDAS interrogator uses a gauge length of 8.16 m and the data are recorded at a sampling frequency of 625 Hz. The arrival of S–phase is evident on the submarine section of the cable even without additional processing. However, processing steps are required to make the P visible. The following pre-processing steps are adopted to enhance the signal-to-noise ratio (SNR). A range of bandpass filters are assessed to determine the optimal frequency window of observed body waves. Finally, different wave phases are distinguished by analyzing the data in various domains such as time–distance (t–x), time–frequency (t–f), frequency–distance (f–x) and frequency–wavenumber (f–k) domain. Visualization in f–k domain allows identification and separation of coherent seismic signals from oceanic noise in each frequency band based on their characteristic phase velocities (c = f/k).

What hydroacoustic data can teach us for earthquake monitoring in the High Arctic

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Despite the efforts in monitoring earthquakes using sensors placed in land stations and ocean bottom seismographs (OBS), there is still a large seismic monitoring gap to cover remote oceanic areas, such as the High Arctic. Within the framework of the EU-funded High Arctic Ocean Observation System (HiAOOS) project, we aim to exploit acoustic data to improve earthquake monitoring coverage, specifically for the slowly spreading Gakkel Ridge that hosts most of the seismicity of the arctic area. Four Ocean Bottom Hydrophones (OBHs) have been deployed in key locations around the ridge and data will be continuously collected for two years (2024-2026). In the meantime, we are developing new analysis methods exploring audio files previously collected during the Coordinated Arctic Acoustic Thermometry Experiment (CAATEX). From this dataset (a total of 505 hours of recordings), we compiled a catalogue of earthquakes recorded in the high Arctic Ocean and detected 21 events presenting P and T seismic phases. Afterwards, we compared the newly created acoustic catalogue with that of the Norwegian National Seismic Network (NNSN) to evaluate the detection performance of the acoustic moorings compared to the existing land station data. Finally, we used seismic events detected by both the hydrophones and seismographs as a reference to evaluate the location accuracy obtained with the acoustic data.

Skredfarevurderinger i Bergen kommune

Åse Hestnes[1*] og Karoline Ertesvåg[1]

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Hendelser der skred eller steinsprang har rast ned på vei og bebyggelse er stadig i mediebildet. Det er ingen tvil om at slike hendelser utgjør en fare for de som bor og ferdes i skredfarlige områder. Å sikre all infrastruktur og bebygde områder vil være både kostbart og tilnærmet umulig i et land med bratt terreng som Norge. Bevisstgjøring i form av skredfarevurderinger, som synliggjør type skredfare og sannsynlighet, er derfor svært viktig for å planlegge en trygg vekst av samfunnet. I 2024 har Sweco vurdert 11 områder i Bergen kommune på oppdrag fra NVE (Norges vassdrag- og energidirektorat) hvor bebyggelse ligger innenfor NVEs aktsomhetssoner for skred i bratt terreng. Slike skredfarevurderinger gjennomføres etter NVEs bransjestandard; *utredning av sikkerhet mot skred i bratt terreng*, hvor vurdering av faren for steinsprang, steinskred, snøskred, og jord, flom- og sørpeskred utredes. I tett bebygde områder gir slike vurderinger særlig utfordringer; krevende tilkomst, tiltredelse på privat eiendom, stedvis eksisterende sikringsmidler av ukjent årgang og tilstand, og det faktum at spor etter tidligere skredaktivitet kan være fjernet og ikke lenger er synlig. En kombinasjon med bruk av ulike digitale verktøy, kompetanse og lokalkunnskap muliggjør arbeidet. Skredfarevurderingene i Bergen kommune ferdigstilles i første halvdel av 2025. Disse vil kvantifisere risiko for skredfare og vise faresoner for de gitte områdene. Vurderingene vil inngå som en del av beslutningsgrunnlaget for kommunens planarbeid og andre interessenter. Å ha skredfaresoner til stede ved planlegging av tiltak er viktig for dagens sikkerhet da de kan brukes til å optimalisere plassering av nye tiltak. I et langsiktig og bærekraftig perspektiv er skredfarekartlegginger aktuelle fordi et klima i endring tvinger oss til å se fremover og være mer føre-var på farer som kan ramme samfunnet vårt.

Testing the significance of vegetational parameters on shallow landslide occurrence - for landslides triggered in August 2023 during the extreme weather event Hans

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In Norway, shallow landslides are mainly triggered by high-intensity and/or long-duration rainfall events. The extreme rainstorm Hans in August 2023 was a high-intensity event that fell on already saturated ground and triggered 700 shallow landslides in Southern Norway. With climate change expected to increase the frequency of extreme rainfall events, it is important to improve the prediction of shallow landslide initiation points. In my master's thesis, I used the Random Forest statistical modelling method to assess the role of topography, geology, climate, event-meteorology as well as often-overlooked factors related to vegetation and forest cover. To account for variations in the environmental factors across the study area, both spatial and non-spatial Random Forest models were used, incorporating spatial autocorrelation to improve predictive accuracy. Important factors were unusually high accumulated rainfall, elevation, and the lack of underground biomass. Forested terrain had higher rainfall thresholds before landslides occurred, leading to a lower landslide probability compared to non-forested areas. Spatial Random Forest models outperformed non-spatial models, underscoring the importance of considering spatial dependencies in landslide susceptibility assessments. The results suggest that incorporating vegetational factors can improve landslide occurrence assessment. Future research should focus on enhancing model performance by using higher-quality terrain and vegetation data, and by including soil characteristics.

How satellite radar backscatter data can improve timely detection of landslides in cloudy or dark conditions

Erin Lindsay[1]*, Alexandra Jarna Ganerød[2,3], Graziella Devoli[4], Johannes Reiche[5], Steinar Nordal[1], Regula Frauenfelder[6]

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Following extreme weather events, responders require timely information on the location of landslides, floods, and avalanches. Satellite images can help detect such events; however, cloud cover and darkness often inhibit timely detection using optical satellite imagery. Radar, as an active cloud-penetrating sensor, provides an alternative information source in cloudy or dark conditions. In Norway, new Sentinel-1 images are available every 1-3 days. However, these images are underutilized for landslide detection due to the more complex processing steps and a limited understanding among geoscientists of how to interpret landslides in radar imagery. To improve the understanding of landslide signatures in radar backscatter images, a global study comprising 30 landslide case studies was conducted using C-band Sentinel-1 backscatter images, processed with a repeatable Google Earth Engine script. A multidisciplinary literature review and discussions with experts informed the creation of a conceptual model summarizing the findings. The main factors identified as controlling landslide expression included the orientation of the landslide relative to the sensor, vegetation conditions, surface roughness, and, to a lesser extent, soil moisture. The conceptual model illustrates how landslides are likely to appear under different vegetation conditions. In some cases, morphometric features such as scarps, deposits, and ponding were also visible. The primary factors limiting landslide visibility were geometric distortions, spatial resolution, mixed vegetation types, and snow cover. This study provides a foundational theory for the further development of deep learning-based automatic landslide detection tools, enabling timely detection following triggering events or for continuous monitoring. This research was funded by the Research Council of Norway, through the research project SFI Klima 2050 [grant number 237859].

Hydrochemical study of quick clays at Tiller-Flotten, Norway

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The development of quick clays has been studied for over 50 years in Norway to evaluate and mitigate risk of quick clay landslides. One of the main remaining challenges is qualifying the spatial distribution of quick clays and understanding the hydrological processes driving the desalinisation of quick clays, which determines their sustainability to landslides. Quick clays are susceptible to landslides because of their loosely bound structure, so called "card house" structure, which has been weakened by the leaching of the salts from the clays originally deposited in a marine environment. Recent advances in analytical techniques present an opportunity to enhance our understanding of quick clay hydrochemistry. The objective of this study is to provide insight into the desalinisation process and determine which type of freshwater acts as the primary driver of the desalinization of the originally marine pore water in quick clays. To achieve this objective, I studied the pore water chemistry of a large set of samples with a dense spacing (>1-2 m) at the Tiller-Flotten quick clay research site near Trondheim. Pore water samples were extracted from depths of 4 to 20 m and hydrochemistry analysed using ion chromatography (IC) and inductively coupled plasma optical emission spectrometry (ICP-OES). After the hydrochemical analysis, ion composition and ionic ratios of the pore water were compared to rainwater, seawater and groundwater from neighbouring bedrock and quaternary aquifers. The results indicate a freshening trend in the quick clay pore water, though all samples remain relatively more saline than quaternary groundwater, bedrock groundwater or rainwater. The studied clay deposits appear to be influenced by slow groundwater flow, with cation composition stabilizing below a depth 8 meters. However, the upper part of the clay deposits has been chemically weathered, which has likely been driven by homogeneous diffusion from shallow rainwater. These findings are significant as they confirm that locally infiltrated rainwater and groundwater flow play a critical role in the desalinization process and the overall development of quick clays, impacting their stability and susceptibility to landslides.

Shallow sedimentary gas as geohazard for offshore wind installations

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Shallow gas, defined as gas charged sediments occurring within the upper 1000 m of the seafloor has long been recognized as a major geohazard for drilling on the Norwegian Continental Shelf (NCS). The potential hazard shallow gas poses for offshore wind installations such as monopile turbine fundaments or suction anchors has, however, received less attention. With the stated goal of awarding NCS area for offshore wind development equivalent of 30 GW before 2040, some 54 000 km^2 has been identified as potential offshore wind areas. As shallow gas is abundant on the NCS including thousands of places where gas is seeping to the water column, the identified offshore wind areas is bound to intersect with presence of shallow gas. Therefore, it is imperative to take shallow gas into account in the geohazard assessment. Little is known about the vulnerability of sea-bed installation for shallow gas. However, sediment tank experiments have shown that sedimentary gas migration may reduce the capacity and cause failure of suction buckets in soft clay. Here, we discuss the shallow gas occurrence on the NCS in relation to the proposed offshore wind areas and suggest strategies for identifying where shallow gas might become a problem.

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**National Course in Geohazards - UiB

How might climate change increase the chances of Jøkulhlaups at Jostedalsbreen, what are the potential consequences?

Habteab Isack Asfaha[1], Liouba Croiset[1], Natalie Melbø Hvattum[1*], Synne Nordheim Kristiansen[1] & Sebastian Munkvik[1]

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Jøkulhlaup (Glacial Lake Outburst Flood) is described as a sudden release of vast amounts of water from glacially dammed lakes. Jostedalsbreen, located in Norway, is Europe's largest continental glacier, and from the 1900's, it experienced a total of 14 jøkulhlaup events, whereas 6 events happened during the last two decades. The global warming causes faster glacier melting, increasing the amount of accumulated water in glacial lakes. In recent years in Western Norway, the temperature has risen even higher. Additionally, the ice calving could be a trigger factor for outburst in these subglacial lakes. Due to climate change, the ice loss and expansion of glacial lakes contributes to an important natural hazard that needs attention. Establishing an early warning system and continuous monitoring at Josterdalsbreen could minimize the risk and consequences of jøkulhlaup. Designing drainage of glacial lakes, building dams and necessary infrastructure in susceptible areas can reduce hazards and increase resilience of the local communities. To tackle the problem at its source, the most important thing to limit the increase in risks is to reduce our greenhouse gas emissions, which are the cause of climate change.

The 2014 flooding event in Flåm

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In late October 2014, Flåm experienced the worst flooding event in a century, following a period of heavy precipitation. A multitude of people were evacuated, with 252 residents evacuated in Aurland alone. The flood caused extensive damage to infrastructure and agricultural areas, with the total cost amounting to several hundred million NOK. As climate change is predicted to cause a wetter climate in Norway, increased precipitation is likely to cause more frequent and devastating flooding events in the future, with a larger number of people expected to be impacted. The goal of this study is to enhance risk management strategies in Flåm, focusing on lessons learned from the flooding catastrophe that occurred in October 2014. First, we investigate the causes and their socio-economic impacts on the affected communities. By utilizing GIS, we analyze the affected areas in Flåm through change-detection methods to visualize the extent of the damage before and after the event and compare it to how Flåm looks today. Second, we evaluate the preparedness planning prior to the event and assess how effective it was in minimizing the damages as well as the effectiveness of the emergency warning systems. Third, we explore which security measures have been implemented and what protective measures could be put into place to mitigate the impact of potential future floods.

Analyzing the landslides in Vistdalen following intense rain event in July 2023

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On 30th July 2023, intense rainfall triggered multiple landslides in Vistdalen, Molde. This study investigates the conditions leading up to the landslides, focusing on the combination of slope gradient, sediment composition and extreme precipitation. The analysis draws on rainfall data and hazard assessments of the valley, which indicated potential landslide risks. The findings highlight the need for better communication and mitigation strategies as landslide hazards continue to pose a threat in Vistdalen.

4D Monitoring of Geohazards Using Autonomous UAV Systems: First Case Studies on Complex Unstable Rock Slopes and Glacier Icefalls in Norway

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Monitoring mass movements, such as deformation in unstable rock slopes and glacier icefalls, is essential for understanding process dynamics and mitigating associated risks. Traditional monitoring methods often encounter challenges related to accessibility, frequency, and spatial coverage. This study introduces the deployment of autonomous unmanned aerial vehicles (UAVs) from stationary on-site docks for change detection. The main focus lies on identifying and tracking displacement patterns, as well as detecting changes that may indicate early signs of potential failures. We compare data collected by UAVs with traditional in-situ monitoring techniques. Furthermore, we explore its integration into existing monitoring networks for enhanced automation, data accuracy, and spatial and temporal resolution. We present preliminary monitoring results from two case studies in Norway: (1) a complex unstable rock slope and (2) two glacier icefalls. Autonomous UAVs can conduct regular flights from their base stations to capture high-resolution aerial imagery for photogrammetric mapping. These systems can detect subtle deformations and displacements of rock or ice down to a centimetre scale. The findings demonstrate the versatility of autonomous UAVs in both long-term monitoring and critical acceleration phases. During the latter, they provide an immediate "eye-in-the-sky" solution. In long-term monitoring, this system proves to be cost-effective and flexible, minimizing the need for frequent site visits while efficiently covering large, inaccessible areas. The proof of concept presented in this study underscores the feasibility and effectiveness of employing autonomous UAV systems for near-continuous geohazard monitoring. These systems enhance data collection frequency, reduce the reliance on human operators, and provide reliable monitoring in remote and steep terrain. However, challenges persist in ensuring safe operation in difficult weather conditions, low visibility, and complying with local aviation regulations for autonomous UAV operations. Our findings highlight the potential of autonomous drone systems to improve early warning and contribute to more effective risk management strategies for geohazards.

Fysiske konsekvenser av klimaforandringer: Skredkartlegging og evaluering i Jotunheimen

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Min masteroppgave er en del av et regionalt forskningsprosjekt som undersøker hvordan klimaendringer påvirker fjellredningstjenesten og fjellsporttrafikken i Jotunheimen. Med et spesielt fokus på hvordan breer og permafrost endrer seg og hvilke konsekvenser dette har for tilgjengelighet og naturfarer som skred og flom, tar masteroppgaven sikte på å kartlegge skredrelaterte landformer i Jotunheimen. Hovedmålene med masteroppgaven inkluderer å analysere utvalgte områder, som området rundt Besseggen, for landskapsendringer fra isbreer og skred. Skredrelaterte landformer som skredvifter, skredgroper, skredløp, skredkanter og skredfronter vil bli kartlagt ved hjelp av moderne verktøy og metoder som digitale terrengmodeller, flyfoto, satellittbilder og feltobservasjoner. Masteroppgaven vil bruke både tidligere og nyere skredhendelser som case-studier, med særlig fokus på økt skredaktivitet etter ekstremværet Hans. Ettersom slike ekstremværhendelser ser ut til å bli mer hyppige, er kartleggingen viktig for å forstå fremtidig skredaktivitet. For å simulere dynamikken til utvalgte skredhendelser, vil RAMMS (Rapid Mass Movement Simulation) bli benyttet. Dette simuleringsverktøyet etterligner reelle skredprosesser og visualiserer skredenes bevegelse gjennom landskapet, noe som gir innsikt i deres potensielle effekter og risiko. Den utførte kartleggingen skal evalueres mot de nyeste skred-aktsomhetskartene fra NGU og NGI. Kartene som brukes i dag ble utarbeidet i 2014, og de nye kartene skal oppdateres med potensielle løsne- og utløpsområder i Norge. Gjennom koblingen mellom masteroppgaven og det bredere forskningsprosjektet, håper denne studien å bidra til en bedre forståelse av hvordan fjellturismesystemet kan forholde seg til fysisk klimarisiko i Jotunheimen.

Geofarer i karst? Øvre Strandjordgrotte – en aktiv flomgrotte i Rana, Nordland

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Grotter er en velkjent landform som i stor grad tiltrekker seg oppmerksomhet for sin spektakulære morfologi og uoppdagede hulrom, men kunnskap om hvordan landformen har blitt dannet og geofarene knyttet til dem er ikke like kjent. I Norge er flertallet av grottene dannet i marmor som et resultat av oppløsning av berggrunnen – også kjent som *karst*. Karst kan defineres som den gjenværende berggrunnen etter at oppløsing har forekommet. Berggrunnsoppløsningen foregår ved at (surt) vann trenger inn i sprekker eller svakhetssoner i en oppløselig berggrunn. Nedbør og snøsmelting er den dominerende vanntilførselen for karstutviklingen som fins i Norge. Masterprosjektet tar for seg en aktiv flomgrotte lokalisert i Dunderlandsdalen i Rana, Nordland. Grotten er en del av elveløpet til Strandjordelven og ligger nedstrøms for et kraftverk. Dette medfører at vannføringen i grotten er svært varierende. Grottens plassering er nær E6 i området og leder Strandjordelva under veien og kommer opp igjen gjennom flere kilder i nærheten av Ranaelva. Morfologien i grotten er preget av et kaotisk forløp og klassifiseres som en labyrintgrotte. Endringen i vannføring, og da spesielt ved flomhendelser, er med på å endre stabiliteten til berggrunnen i grotten. Dette kan over tid medføre kollaps på overflaten. Gjennom feltarbeid har det blitt registrert en rekke kollapser på overflaten over grottesystemet som tilsier at det har skjedd endringer i berggrunnens stabilitet over tid. Disse kollapsene kan være et resultat av tilbaketrekning av innlandsisen, men viser likevel den potensielle faren som forekommer i et karstlandskap.

How did the extreme weather event Hans impact Gol, and to what extent was the community resilient?

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In August 2023, remnants of the two low-pressure systems Petar and Antoni merged above Eastern Europe, remaining over Norway for several days, and resulting in considerable amounts of precipitation. The collision of these two systems and the resulting storm was named “Hans”. The extreme weather event Hans caused national widespread damage, specifically in Gol, where the majority of social and economic damage was a result of floodings, with little to no landslide hazards causing direct threats. This study aims to evaluate the impact of the extreme weather event in Gol and assess the resilience of the community in response. The study primarily relies on literature gathered from official authorities in the aftermath of the event, and looks at how the extreme weather developed, discussing the physical and human impacts it caused. The focus is on community resilience, evaluating how it changes throughout the event: in the before, during and after. We conclude the study by identifying the lessons learned from the event, and briefly evaluate strategies to strengthen Gol’s resilience for future extreme events.

Remote sensing based mapping of landslides in Norway and the potential of earthquakes as a trigger mechanism

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The combination of topography and the abundance of water resources makes Norway considerably vulnerable to landslide processes. Fluctuations in water table levels, primarily caused by seasonal runoffs, are widely recognized as the most common triggers of landslides in Norway. Nevertheless, studies suggest that earthquakes, though less frequent, also play a role in initiating these events. Furthermore, even though the intraplate seismicity of Norway results in generally lower magnitude earthquakes, recent research has expanded the understanding of landslide triggers in Norway, showing evidence of earthquake-induced landslides (EQIL). This study aims to improve understanding of earthquakes' potential to trigger landslides in Norway. For selected, recent larger (M>3.5) earthquakes, we systematically search for potentially triggered landslides in Sentinel-2 imagery and the Norwegian Water Resources and Energy Directorate (NVE) inventory. Based on historical records of earthquake-triggered landslides, we define spatial (150 km) and temporal (30 days before and after the earthquake) thresholds for landslide extraction. The results are then correlated to the precipitation data to exclude landslides triggered by rainfall. Given the uncertainties of landslide initiation timing, we are examining seismic databases for landslide signals from the nearest seismic stations. This allows us to precisely pinpoint the timing of landslides detected via optical satellite imagery and registered in NVE inventory, overcoming challenges such as cloud coverage and limited temporal resolution. Our approach aims to distinguish between landslide triggering mechanisms, particularly precipitation versus earthquakes, and to establish the magnitude and distance thresholds relevant to EQILs. These preliminary findings aim to clarify the dynamics of cascading earthquake-landslide events in Norway, contributing to a deeper understanding of these complex natural processes.

Kartlegging av skjulte bevegelser: En ustabil fjellside ved Ovriseggi, Vik kommune, Vestland

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Norge har flere ustabile fjellsider, ofte som følge av avlastningen etter istidene. Dette er en del av vår geologiske arv. Et av disse områdene er Ovriseggi i Vik kommune, hvor et lite fjellparti er klassifisert som høy-fare objekt og periodisk overvåket av Norges Geologiske Undersøkelse (NGU), mens resten av fjellsiden ikke er kartlagt i detalj i dag til tross for at den viser mange tegn på bevegelse. Utallige sprekker har utvidet seg over tid og skapt utfordringer for dyrehold og jordbruk. Vårt mål er derfor å kartlegge de geomorfologiske og strukturgeologiske forholdene for hele fjellsiden ved Ovriseggi og lage en detaljert geologisk modell. Hypotesen hittil er at fjellsiden er påvirket av dyptliggende gravitasjonelle skråningsdeformasjoner (DSGSD), noe som kan forklare de langsomme, men vedvarende deformasjonene i terrenget. Feltarbeidet inkluderer strukturmålinger av blotninger i både stabile og ustabile deler av fjellsiden. Så langt har vi samlet over 850 målinger, med fokus på foliasjon, sprekkesystemer og lineamenter. Videre skal vi analysere fjellsidens bevegelsesmønstre, inkludert mulige glideplan, blant annet ved kinematiske analyser. Morfologien antyder en rotasjonsbevegelse, noe som styrker hypotesen om DSGSD. I tillegg til feltarbeid har vi intervjuet lokale aktører fra Vik og planlegger å studere historisk data fra gårdene Stedje og Undi, som ligger i det ustabile området. Foreløpige resultater viser tydelige tegn på tidligere og pågående bevegelse, inkludert åpne sprekker, grabenstrukturer og flere rygger. Fjellet består hovedsakelig av godt folierte fyllitter, stedvis med kvartsårer. Et parti på sirka 0,3 km^2 i sørvest av området viser størst tegn på aktiv deformasjon, men utenfor dette området åpner seg hull på jordene på årlig basis. Lokale har rapportert om sauer som har satt seg fast i skulte sprekker, og vi har observert improviserte løsninger for å tette igjen hullene i tomtene. Utfordringer knytt til det understreker viktigheten av kartleggingen for det lokale jordbruket.

Når landskapet er mer enn bare en fin bakgrunn: velkommen til NGF Geomorfologi!

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Vi, som er interessert i geomorfologi, ser og opplever naturen som et aktivt landskap som endrer seg hele tiden. Landskapet streber etter en uoppnåelig likevekt og bruker mange forskjellige prosesser, som ulike typer skred, fluviale, glasiale og eoliske prosesser, til å erodere materiale fra en plass og avsette det på en annen. Slik forsvinner noen landformer, eksisterende landformer endres, og nye landformer dannes. Gjennom disse landformene og prosessene forteller landskapet en unik historie om geologiske prosesser og klima i fortid og nåtid, og tillater teorier om fremtidige prosesser. Denne informasjonen kan vi bruke til blant annet bedre miljøforvaltning og geofarevurderinger. Er du også glad i å lese og forstå landskapet? Da kan du bli med i NGF Geomorfologi, en faggruppe under Norges Geologisk Forening (NGF). I faggruppen vil vi lage møtepunkter og styrke nettverksbygging, informere om geomorfologi-relaterte aktiviteter og tilby sosiale, lavterskel sammenkomster. NGF Geomorfologi vil være en plattform for unge geomorfologer og et kontaktpunkt for tverrfaglig samarbeid mellom utenlandske og norske geomorfologer. NGF Geomorfologi representerer Norge i organisasjonen International Association of Geomorphologists (IAG) og som medlem i NGF Geomorfologi kan du benytte deg av IAG nettverket og fordeler knyttet til medlemskapet.

Applying Distributed Acoustic Sensing to monitor hazard events along railways in Norway

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The Norwegian railway extends over 4000 km, connecting cities and communities through numerous tunnels, along fjords, and across mountainous regions. This extensive network is exposed to natural hazards such as flooding and landslides, which can cause short- and long-term road closures, derailments, and substantial social and economic disruption. Key issues are primarily related to culvert and embankment failures, mostly caused by internal erosion due to water seepage, blocked culverts, and sinkhole settlements. These problems are challenging to detect through visual inspections, even by trained personnel. While geophysical methods (e.g., Seismic, Ground Penetrating Radar - GPR) and remote sensing can identify such risks, they require substantial financial and resource investments. Distributed Acoustic Sensing (DAS) offers a cost-effective solution, providing high-resolution elastic-wave records over long distances. Existing fibre optic cables can serve as continuous seismic sensors, detecting passing elastic waves to infer ground information. As part of the Sound Transport Network project (S-TRANET), DAS will be utilized on unused fibre cables along Bergensbanen to monitor underground changes, particularly water content. The initial test site is the Bolstadøyri-Evanger railway section near the Vosso river, an area prone to flood-related hazards where geotechnical measurements are available to provide useful information. The site will first be characterized using geophysical methods and groundwater measurements to enhance DAS measurements. Standard geophones will be deployed alongside DAS measurements, and GPR data are being analyzed in conjunction with existing geotechnical results. A planned groundwater borehole will help monitor water-table changes over time. Standard surface-wave analyses and ambient noise interferometry will be applied to derive local shear wave velocity models and monitor changes over time. We will present the project and preliminary results acquired by passive recording with 3-component 14-Hz geophones along a 90-m stretch, analyzing signals from trains and environmental noises.

Effekten av bjørk- og granskog på sannsynligheten for snøskred i Sogndalsdalen

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Denne studien har som mål å teste effekten av skog med ulik tresjiktsdekning på snødekkets egenskaper. I snøskredterreng kan tresjiktet påvirke sannsynligheten for snøskred på flere måter. Tresjiktet avskjærer snøfall og begrenser snømengden som når bakken. Trærne skjermer for vinden og kan hindre transport av snø og etablering av flaksnø. Tresjiktet avskjærer også innkommende og utgående stråling, noe som reduserer variasjonen i temperaturen på snøens overflate og kan begrense dannelsen av fasetterte krystaller og overflaterim. Selv om disse effektene er godt dokumentert i internasjonale studier, finnes det få observasjonsstudier i norsk klima med lokale skogtyper. Denne studien skal derfor utforske effekten av skog på snødekkeegenskaper i et norsk, svakt oseanisk klima. Studien vil ikke bare forbedre vår forståelse av hvordan skogstrukturer påvirker risikoen for snøskred, men vil også kunne bidra med nytt kunnskapsgrunnlag for forvaltningen av skog i skredterreng i fremtiden. For å samle data, skal det graves snøprofiler på tre forskjellige lokaliteter i Sogndalsdalen gjennom vintersesongen 24/25 (en lokasjon plasseres i bjørkeskog, en annen i granskog, og som referanseflate plasseres en lokasjon i åpent terreng). Ved å undersøke variabler som snødybde, lagdeling, temperaturgradient og vedvarende svake lag skal observasjonsstudiet se på hvordan ulike skogegenskaper som tresjiktsdekning og treslag påvirker snøstratigrafien og snøskredfaren. Data for nedbør, vindretning- og hastighet, lufttemperatur, relativ luftfuktighet, snødybde, snøens vannekvivalent og lang- og kortbølgestråling skal samles inn med en værstasjon for den åpne lokasjonen og en værstasjon felles for de to skogdekte lokasjonene. Studien er en del av en masteroppgave ved studieprogrammet Climate Change Management ved Høyskolen på Vestlandet og bygger på emnet Snø og snøskred (GE448).

Kartlegging av skredfare langs strekningen mellom Ylvisåker og Ølmheim, Sogndal kommune, Vestland

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Strekningen mellom Ylvisåker og Ølmheim er en av de mest skredutsatte delene av riksvei 55 mellom Sogndal og Leikanger. Området har en lang skredhistorikk med hovedsakelig steinsprang fra den øst- til sørøst vendte fjellsiden. Skredhendelser har ført til hyppige avstengninger og trafikksikkerhetsutfordringer. I dette prosjektet utfører vi strukturgeologisk kartlegging av blotninger langs veien og fjernkartlegging av fjellsiden ved bruk av drone og fotogrammetri for å kunne identifisere dominerende sprekkesett og svakhetssoner i berggrunnen. Sprekkeorientering og -frekvens vil, i tillegg til analyse av blokker i avsetninger fra tidligere skredhendelser, gi en indikasjon på forventet blokkstørrelse. Disse dataene skal videre brukes til å simulere steinspranghendelser fra forskjellige mulige løsneområder for å kunne forstå utløpsmønstre, beregne risiko og foreslå mulige sikringstiltak. I 2019 ble det fjernet en stor steinblokk (grovt estimert 100 m^3) i utløpsområde til fordel for utbygging av naust. Konsekvensene av fjerningen skal evalueres ved å kjøre steinsprangmodelleringer på høydemodeller fra både før og etter utbyggingen. Dette prosjektet vil bidra til en omfattende og oppdatert skredfarevurdering som vil være viktig for de fastboende, barnehagen i området og de1100 personene som pendler langs denne strekningen daglig.

Rainfall-Driven Landslides in Jølster, July 2019: Causes and Mitigation Strategies

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On 30 July 2019 an extreme rain event triggered many shallow landslides in Jølster, western Norway. Post-event mapping identified 120 source areas for the landslides and debris floods. Extensive damage to properties and infrastructure in the region was recorded, along with one mortality, and over 150 residents evacuated. This study investigates the local causal factors contributing to these hazards, the mechanisms by which torrential rainfall initiated the landslides, and their system interactions to aggravate the severity of the disaster. Prior warm, dry conditions lowered the local water table considerably compared to the area average and caused the formation of fissures in the soil. Contrasted with the sudden onset of heavy precipitation, water infiltrated rapidly through these fissures, leading to localized high porewater pressure and surface runoff. Shallow landslides were induced only 1-2 hours after the precipitation - too short a time for the soil to become fully saturated, a key temporal factor. Thus, predictions were inaccurate by 2-3 hours. Surprisingly, none of the largest affected paths had a history of debris-flow activity, despite the geological setting of steep glacial valley slopes consisting of exposed bedrock and thin soil cover lending a high susceptibility to such events. To avoid a severe recurrence of such disasters, mitigation measures are essential. High resolution susceptibility and risk maps should be integrated in hazard management and planning. Contemporary climate records should be utilized in calculating the return period range estimates of these mass movements. Physical intervention methods of slope stabilization such as drainage, revegetation, and retaining walls, among others, can be considered in enhancing slope stability.

Integrering av praktiske ferdigheter og arbeidslivsrelevans i geovitenskapelig utdannelse gjennom praksis: Innsikt fra GEOV298 – GeoPraksis

(EN) Integrating practical skills and work-life relevance in Geoscience Education through internships: Insights from GEOV298 GeoPraksis

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Arbeidslivsrelevans i høyere utdanning har lenge vært ettertraktet blant studenter, næringsliv og styringsmakter. GeoPraksis (GEOV298) er et emne ved Institutt for geovitenskap på Universitetet i Bergen som ble etablert i 2022 for å møte denne etterspørselen. Emnet er bygget opp med syv seminarer med tematikk fra ulike aspekter av arbeidslivet, samt en treukers praksisperiode hos en av våre samarbeidspartnere. På denne måten inkorporerer emnet studentaktiv læring med realistiske problemstillinger hvor studenten får testet sitt kunnskapsnivå, sine generiske ferdigheter og sin evne til å samarbeide i tverrfaglige arbeidsgrupper. En viktig del av emnet er refleksjon rundt praksisoppholdet og egenvekts. Refleksjonsnotater og studentdialog gjør det mulig å tilpasse undervisningen og praksisukene til studentene og bedriftene sine behov. En uforutsett, men positiv effekt av emnet, er den økte selvtilliten og følelsen av tilhørighet blant studentene, som ser at de og deres kompetanse verdsettes. Dette motiverer dem også til å forfølge masterstudier og en videre karriere i det geovitenskapelige miljøet.

Work-life relevancy in higher education has long been sought out for students, employers and governing powers. GeoIntern (GEOV298) is a course at the Department of Earth Science that was established in 2022 to answer this demand and bring our students closer to future employers. The course-design is based on seven learning modules focusing on practical skills relevant to work-life and a three-week internship with a geo-relevant company. In this way, the course incorporates student-active learning with realistic problem-solving scenarios that test students' geoscientific knowledge, generic skills, and collaborative abilities in interdisciplinary working groups. Reflective notes and ongoing student dialogue allow instructors to adjust the format and content of the teaching both during and after each semester. An unforeseen, yet positive effect of the course is the increased confidence and sense of belonging among students, who recognize that society values them and their expertise. This also motivates them to pursue further master's studies.

Nytt vidareutdanningsemne ved HVL frå våren 2025: Skredfarevurdering i bratt terreng

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Kvifor studere skredfarevurdering i bratt terreng?

Kartlegging av skredfare i bratt terreng etter byggteknisk forskrift TEK17 er ei kompleks oppgåve som krevjar djuptgåande teoretisk kunnskap om ulike skredtypar, inkludert prosessforståing, identifisering av potensielle lausneområder, gjenkjenning av avsetning og landformer samt innsikt i modelleringsverktøy. Saman utgjer det kompetanse ein treng for å identifisere, vurdere og kvantifisere årleg sannsyn for skred, og dermed avklare den lokale skredfaren i eit avgrensa område. Slike utreiingar krevjar fleire års praktisk erfaring og blir utført av ein rekke konsulentselskap, men og ved arbeidsplassar i statleg sektor. Kanskje jobbar du allereie med skredfareutredning men har lyst på fagleg påfyll for å føle deg tryggare i dine val eller du ønsker deg en slik jobb men følar at du ikkje dokumentere naudsynt kompetansen på cv'en? Då er vidareutdanningskurset for deg.

Kva lærer du?

Gjennom kurset vil du få ei brei teoretisk innsikt i ulike skredtypar, lærer om effekt av skog, relevante meteorologiske og klimatiske utløysingsfaktorar for skred, lovverk og teknisk rettleiar og skredmodelleringsverktøy. Under de digitale samlingane skal vi jobbe med utfordringar som går utover den nasjonale rettleiaren for utgreiing av sikkerheit mot skred i bratt terreng. Deltakare vil rekne på, kartlegge og diskutere problemstillingar henta frå praksis. Under de fysiske samlingane står feltarbeid sentralt – det vil være fokus på komplekst terreng med samansett skredproblematikk. I slutten av emne skal du levere ei prosjektoppgåve som utgjer ein skredfarekartlegging av eit aktuelt område. Denne vil vere lik det som er forventa i arbeidslivet, du får tilbakemelding frå erfarne fagperson undervegs og oppgåve tel som avsluttande eksamen i emne. Etter fullført emne skal du være i stand til å planlegge, utføre og formidle skredfarevurdering i bratt terreng etter TEK17 og takle utfordringar som rettleiaren ikkje gir eit fullgodt svar på.

EPOS-Norway – Research Infrastructure for Geohazards (EPOS-NG)

Mathilde B. Sørensen[1] and the EPOS-NG team

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The EPOS-Norway – Research Infrastructure for Geohazards (EPOS-NG) will be established, starting from early 2025, with funding from the Research Council of Norway's Infrastructure program. EPOS-NG aims to be the go-to infrastructure for research on geohazards in Norway (i.e., landslides, tsunamis, earthquakes, and cryospheric hazards). Complementary to EPOS ERIC and building on research infrastructure developed during EPOS-Norway (EPOS-N) phase 1, EPOS-NG will establish new pools of instruments that are easily accessible to all geoscientists in Norway. We will develop an enhanced and extended state-of-the-art data portal to provide nationwide access to a range of geoscience data as well as computational and visualisation services. The EPOS-NG instrument pools include rapid-deployable seismometers, ocean bottom seismographs, Distributed Acoustic Sensing and Distributed Temperature and Strain Sensing instrumentation, Transient Electromagnetic measurement capacity, piezometers, self-potential sensors and ground-based interferometric radar systems. The new instruments will facilitate research on a wide range of processes including seismicity, slope stability and landslides, groundwater and soil conditions, permafrost and cryospheric processes. Combined with new services for tsunami hazard assessment, as well as novel datasets on InSAR displacement trends and historical and palaeoseismological events, new links can be established through comprehensive, multidisciplinary studies. Effective data integration and visualisation will be achieved via the EPOS-N portal, which was developed in EPOS-N phase 1 and will be substantially enhanced in close dialogue with the users in EPOS-NG. The portal combines data from distributed monitoring networks, innovative services for advanced data analysis and national databases within geosciences into a single national e-infrastructure, following FAIR principles. EPOS-NG thus represents a unifying nationwide research infrastructure, including all the relevant physical infrastructures and providing a national hub for solid Earth science data and services. In this presentation, I will present the plans for EPOS-NG and describe how the community can be involved in and benefit from the activities.

A Case Study in Drilling Hazard Mitigation: Pore Pressure and Fracture Gradient Analysis of the Well 'X', Kutai Basin, Indonesia

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The Kutai Basin is characterized by heterogeneous stratigraphy, high-pressure formations, and potential drilling hazards, requiring precise pressure prediction to avoid wellbore instability and non-productive time (NPT). Well 'X', an exploration well in the onshore Kutai Basin, Indonesia, targeted a deeper reservoir in Miocene deltaic sandstones. It serves as a case study in applying advanced pore pressure and fracture gradient (PPFG) prediction techniques to optimize drilling. Real-time pore pressure monitoring and fracture gradient analysis were implemented during the drilling of Well 'X', with adjustments made to total depth due to unforeseen conditions. Initially planned to reach 11,046 ft MD/10,157 ft TVD, the well encountered a 'shoulder effect' during the 12-¼" and 8-½" sections. A Formation Integrity Test (FIT) at 7000 ft TVD indicated 21 ppg EMW. At 7430 ft TVD, a shoulder effect revealed a pore pressure of 12.34 ppg EMW. A dynamic FIT in this interval yielded a fracture pressure of 18 ppg EMW. The appearance of the shoulder effect reduced the pressure window between the mud weight and the fracture pressure. This narrowing of the pressure window posed a significant hazard for continued drilling, as it increased the risk of wellbore instability. At 9,368 ft MD, a high gas reading indicated increased reservoir pressure, likely to be encountered again with isolated sand, with pressures exceeding 16.46 ppg EMW. This significantly increased drilling risks. After evaluating potential resources and risks, drilling was halted, and the final TD was set at 9,368 ft MD / 8,768 ft TVD. Key takeaways from Well 'X' emphasize the critical role of real-time pressure monitoring and adaptive drilling strategies to maintain wellbore stability and operational safety in high-pressure formations. Proper pressure window management and timely risk assessments are essential to minimize hazards and make informed decisions in challenging geological settings.

LUSI Mud Volcano: Ongoing subsurface geohazard in East Java

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Sidoarjo mudflow or as known as LUSI or Lumpur Sidoarjo is a catastrophic geohazard that erupted unexpectedly in May 2006. This disaster occurred in Sidoarjo, East jaca. The mud volcano has changes the landscape of East java. The mud keeps spreading until it was declared a national disaster with thousands of victims. The mud and water flooding has destroyed over 10,000 buildings, 4 death, and over 15,000 evacuated. Based on geological findings, there are no signs that the mud flow activity will stop soon, which is having a significant impact on the surrounding environment and local communities. The triggering mechanisms remains controversial, there are several hypotheses have been proposed. There is a little seismic which make it difficult to conclude. An alternative hypothesis suggests that seismic waves generated by the earthquake could have influenced the subsurface fluid dynamics (Roeloffs, 1998, Brodsky et al., 2003; Kitagawa et al., 2006). Different theories suggesting it may have resulted from an underground blowout due to issues in the wellbore (Davies et al., 2008; Davies et al., 2007; Tingay et al., 2008), an eruption triggered by overpressured shale through reactivated faults (Mazzini et al., 2007a; Mazzini et al., 2007b), or the release of superheated hydrothermal fluids at high temperatures through fault zones acting as conduits (Sudarman and Hendrasto, 2007). This research explores the geological processes behind the eruption, with LUSI offering a unique opportunity to investigate the mechanisms of mud volcanism.

Quantifying inheritance in rock avalanches

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Inherited cosmogenic nuclides are a well-known, though often neglected uncertainty when performing ^{10}Be exposure dating in rock avalanche deposits. Ignoring this can lead to overestimations of several thousand years when determining the timing of the failure. To facilitate more reliable exposure ages, this uncertainty needs to be assessed and quantified. The field site investigated is the Hølen rock avalanche located south of Tromsø where 16 ^{10}Be ages have been conducted. The ages cluster together without any obvious outliers indicating that inheritance may not be a problem at this site. However, three boulder surfaces from the distal part of the deposit yield ages up to 600 years older than the others. A new model can estimate the probable inheritance in a pre-failure slope and the likelihood of sampling a boulder surface with inheritance. Results reveal a ~22% chance of overestimating the age of the rock avalanche event with 500 years if the boulder originates from the upper 10 m of the pre-failure slope for a mid-Holocene rock avalanche. If it originates from the upper 3 m this probability increases to ~72%. Identifying where boulders containing significant inheritance end up in the deposit can improve the sampling practice of rock avalanche deposits. The discrete element model *Melody 2D* was used to track individual boulders from the pre-failure slope to the deposit for different failure geometries. The results show that it is most likely to sample boulders with inheritance in the distal part of the deposit. It is therefore recommended to sample boulder surfaces from the proximal part of a deposit. Additionally, simulations show that the largest boulders in a deposit tend to originate from the surface of the pre-failure slope and should therefore be avoided when sampling for surface exposure dating.

Models of the Holocene desalinization of quick clays

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Quick clays pose an important geohazard that has led to loss of life in many places, including in Norway. Quick clays can form in marine clays in which the initial saline pore water has been replaced by fresh water. Numerous geophysical surveys in Norway and elsewhere have shown that the distribution of quick clays is very heterogeneous and time consuming to map, and that saline and desalinized clays can often be found adjacent to each other without any clear patterns. To our knowledge there have been no models of the process of desalinization of marine clays over the Holocene that could help explain the heterogenous spatial distribution of quick clays. Here we present new numerical models of the desalinization of these clays in the Holocene by diffusion and groundwater flow. We compare these models with a review of geophysical and porewater chemistry data in Norway and elsewhere. In addition, we discuss new high-resolution porewater chemistry from a quick clay site near Trondheim. The results reveal that diffusion from clays to adjacent permeable sediments can account for the desalinization of thin clay formations over the Holocene. However, thick clay formations need additional solute transport by groundwater in the clay formation itself to explain the observed desalinization. This is somewhat surprising given the very low permeabilities of clay and suggest that heterogeneity and preferential flow paths in these formations may play a role.

Understanding the Extreme Weather Event Hans – Norway, August 2023

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Hans was an extreme weather event that hit Norway, from the 7th to the 9th of August2023. This event triggered significant flooding and over 700 landslides, which led to mass evacuations and extensive infrastructural damage. The total costs of Hans were estimated to be around 4 billion NOK. As the frequency of events like Hans is expected to increase, understanding their causes and impact is essential for enhacing society's resilience. This study addresses the key drivers of Hans and its linkage to global warming by analyzing spatial precipitation and soil moisture data from the Meteorological Institute (MET) and The Norwegian Water Resources and Energy Directorate (NVE). In addition, field observations and a supplementary literature review were utilized. Recent studies show that the event resulted from the convergence of two low-pressure systems, originating from Britain and the Baltics. These systems merged, creating a low-pressure system that moved eastward towards Norway, which is unusual as weather patterns typically approach from the west. Intense rainfall persisted over three days, exceeding 120 mm and affecting areas with return periods greater than 100 years. South-Eastern Norway, one of the driest areas of the country with less than 500 mm of precipitation per year, was the region most affected by Hans. This region had already experienced an unusually wet summer, which saturated the soil and hindered its ability to absorb rapid and sustained rainfall, inciting the floods. The importance of discussing this event lies in its debated connection to global warming and its implications for society in the near future. Climate predictions warn of increasing precipitation, in both frequency and intensity. While Hans seems to follow this trend, there is no direct evidence that global warming itself caused the event - It may simply be an outlier like many other extreme weather events.

Staying ahead of nature: geohazard monitoring & mitigation in Bogelia.

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In May 2015, two glide snow avalanches hit highway E-16 at Bogelia (Vaksdal municipality) within ten days of each other, following extreme precipitation events. The avalanches resulted in a blockage of approximately 100 m of the main road between Voss and Bergen. The area is identified as being prone to geohazards such as small avalanches and rockfall. However, the events in May 2015 represented a clear anomaly in size and impact from previous avalanches of considerably smaller scales. Considering ongoing climate change, two questions arise: (1) How will the type, frequency, and size of geohazards change in this area with climate change? (2) Are the existing mitigation measures at Bogelia suitable to minimize the risk for people and infrastructure? The present mitigation measures were assessed during an excursion to the avalanche site. Data on slope steepness, sediment type and land use were obtained from national databases and merged in a risk map using ArcGIS Pro. Predictions for changes in annual mean temperatures, precipitation and snow depth were obtained from the "Klima i Norge 2100" report. The report summarizes climate model outputs based on different climate change scenarios. Based on the collected information, a risk area was identified above E-16 at Bogelia, which indicates that there is a high potential for new landslides or rockfalls. Additionally, anticipated changes in precipitation due to climate change will cause the number of rockfalls and landslides to increase, whereas the risk of snow avalanches will likely diminish. The present mitigation measures will need to be maintained, and new mitigation measures aimed towards water management on the slopes should be implemented.

Flood mitigation measures during and after the extreme weather event Hans in Ål

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During the extreme weather event Hans in August 2023, a combination of a locally high precipitation exceeding 125 mm within 48 hours and the spatial extent of Hans filling the catchment area of Hallingdalselve affected the municipality of Ål significantly. Here we present an overview of the consequences of Hans for Ål, using field observations, meteorological data and official flood and mitigation reports. The previously existing infrastructure of the municipality of Ål was not designed to withstand these water masses. Therefore, as an immediate response to Hans, the municipality implemented temporary mitigation measures (e.g. the use of sand bags along the river). The severity of the impacts due to Hans however, called for urgent mitigation planning and led to a quick start of the construction process for the new measures in the municipality of Ål. The focus of these mitigation measures lies on the increase of the capacity of pathways for water in Ål and on the ability to lead greater water masses safely through the area. The main mitigation constructions concern the safe guidance of even larger water masses through the municipality since they are only dimensioned for a 200-year flood event. Here we present a description of the technical details of the mitigation plan and constructions. We further discuss the temporal and financial effort that are linked to consequences, the planning and building of these mitigation measures.

Rockfalls in Nærøydalen

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Nærøydalen is a valley with frequent rock falls and snow avalanches. To keep the inhabitants of the valley and passersby safe, it is important to keep an eye on the valley sides. Therefore, we went out to Nærøydalen to take a closer look at Hallinggrovi, one of the many fans created by rock falls and avalanches over time. At this site we observed the fan itself, but also the mitigation already in place to protect the houses and roads. The observations showed an active fan with rocks sorted from smallest at the top, to largest at the bottom with smaller sandy sediments in between. Parts of the fan was less active with more vegetation on top. An avalanche barrier was built to redirect any rockfall material away from the infrastructure. These observations help us better understand the processes in play and how to protect people from possible hazards. By looking at this fan we could collect data, look at it to understand the situation, and then mitigate the area. In addition to observations, we also applied scientific literature. In conclusion, these types of areas need to be continuously monitored to keep the safety of the inhabitants in the future.

Flooding: the future of Lærdal

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Lærdal, a small village in Norway, has long been susceptible to flooding due to its geographical and hydrological characteristics. The Lærdalselvi River, which drains a large catchment area, receives most of its water from the mountainous regions of Filefjell and Hemsedal fjellet. This large catchment area makes the village particularly vulnerable to flooding, a risk that is likely to increase in the future due to climate change. According to flood mapping from the Norwegian Water Resources and Energy Directorate (NVE), a 200-year flood would have a severe impact on Lærdal. In the event of extreme flooding, with water levels reaching up to 5 m, most of Lærdal, including the town center, would be submerged. This would pose a significant risk to homes and key infrastructure (hospitals, schools…). That is why current building regulations say that any new structures, excluding garages and sheds, must include flood protection measures. These precautions are crucial in mitigating flood damage and protecting essential infrastructure in the village. While various technical solutions have been proposed, each comes with financial and environmental trade-offs. One possible solution could be relocating the residents, but this is not a simple option, as many are deeply attached to their region. Moreover, selling a home located in a high-risk flood zone would likely result in a significant financial loss.

Flood mitigation in Voss, Western Norway: repeated flooding of lake Vangsvatnet

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Voss, situated at the east shore of Lake Vangsvatnet is prone to flooding due to the lake's narrow outlet and the bi-annual water discharge regime, driven by spring snowmelt and autumn rainfall. With historical flooding records dating back to 1604, as well as continuous observation of the monthly maximum water discharge since 1892, an increase in frequency of these floods is observed. The outlet channel has been widened twice already, in 1865-1866 and 1990-1991. Additionally, due to climate change, precipitation as well as local extreme precipitation events are expected to increase. All this presents challenges for the municipality of Voss. Various mitigation alternatives researched by NVE are presented, most involving flood tunnels of some kind as well as local measurers like levees or walls. All costing substantial amounts, causing cost-based analysis to also be performed. If the flood patterns in Voss keep changing in line with climate changes, future mitigations will be necessary to keep Voss a safe place to live.