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Abstracts in Oral Session

Floods and Droughts: Nature's Extremes in a Warming World

03-06-2025 - 13:00 - 14:15

Gróska – Main Hall

The value of pluvial flood mapping: an analysis of the flood in Gävle 2021

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Pluvial flooding caused by localized high-intensity rainfalls is a major natural hazard already today, and it is expected to become even worse in a warmer climate with more intense rainfall extremes. In order to assess pluvial flood risk, most Swedish municipalities hace performed pluvial flood mapping. Different approaches are used, from pure topographical analysis to fully coupled hydrodynamic modelling. Typically a rainfall with a 100-year return period is used although also 200 years is rather common.

In August 2021, the city Gävle on the Swedish east coast was hit by a record-breaking rainfall, with 121 mm in 3 hours measured in the nearest official gauge. This is the largest 3-hour accumulation registered in official measurements, and the estimated return period is >3000 years. This caused severe flooding in the city and extensive damage to buildings and infrastructure. The total estimated cost for the event is >160 MEUR, which makes it the most expensive pluvial flood in Sweden to date.

One key question after such an event concerns the value of conventional pluvial flood mapping in this situation; to which extent could the evolution and impacts of the flooding from this >3000-year rainfall be anticipated from conventional 100-year flood mapping? We investigate this by numerically reconstructing the 2021 flood, based on high-resolution reconstructions of the space-time rainfall as well as observations of inundation, and comparing with conventional mapping. The results are intended to support the interpretation of pluvial flood maps by municipalities and particularly their application in a “worst-case” context.

Ice jams in Latvia – can we predict them?

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Ice jam is a significant hydrological phenomenon that occur when ice masses accumulate, obstructing the natural flow of water. Ice jam occurrence during rivers' freeze-up and breakup can lead to severe flooding, infrastructure damage, and economic losses. Recent ice-jam flood event on Daugava River at Jekabpils city in winter 2023 revealed the utmost importance of this research. In the frame of the ICEREG project

Conceptual Model of the ice-jam formation was developed. By gathering data and analysing historical ice-jam flood events in the project pilot rivers Daugava and Lielupe we tried to identify patterns, assess risk factors, and provide insights into the conditions that contribute to ice-jam formation. Climate data analysis was done for both historical and future climate. Future climate patterns give an insight of the ice jam formation further. There are several factors having an impact on ice-jam formation: meteorological conditions, ice thickness and ice cover stability; character of water level rising; morphometric characteristics of the riverbed; and, to some extent, the direction of water flow. As the analysis shows the air temperature and water flow value is one of the most significant indicators for ice jam occurrence. Based on the analysis of hydrometeorological data conceptual model of the ice-jam formation was created.

How ice jam floods will change in the future in the lowland rivers?

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Conditions for ice jam flood formation may change significantly in the future. Ice jam patterns could be shifted geographically – floods may become less frequent in some traditionally affected areas (due to warming), therefore in the new regions the flood intensity could increase.

The aim of this research is to implement ice jam flood hazard mapping based on historical data and climate scenarios and to assess future trends in flood change. The study objects are two low-land river catchments from northern Lithuania (Mūša and Lėvuo). The two methods have been combined for ice jam flood hazard assessment. This is the HEC-RAS 1D hydrodynamic model and the SYKE developed ice-jam calculations tool “Excel-VBA”. Calculated water discharges of different probabilities, according to historical data and SSP245 and SSP370 scenarios, and ice jam parameters are input data for hydrodynamic models. The ice jam flood hazard maps are prepared for three future periods: near (2021–2050), mid (2041–2070), and far (2071–2100).

The results indicate that the ice jam floods will decrease in the future, compared to the reference period (1985-2014). The biggest decrease in the ice jam floods is expected to be in the far future under the SSP370 scenario, and the slight increase will be in the near future under the SSP245 scenario.

The authors would like to thank Interreg VI-A Latvia–Lithuania Programme 2021–2027 for financial support of the project ‘Ice-jam flood risk management in Latvian and Lithuanian regions with respect to climate change’ (ICEREG).

Developing storm surge models of the Norwegian coastline

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For the coastal nation of Norway, storm surge and coastal hazards can have devastating consequences, especially considering sea level rise due to climate change. Because of the complex geometry of the fjords, a high-resolution model is required to resolve the features and better understand the impacts of storm-induced flooding. The existing coastal models are both too coarse and difficult to scale; hence, we must develop a new finite element model. This research aims to create high resolution meshes for both the Oslo Fjord and the entire coastline.

The initial Oslo Fjord mesh performed similarly to the Norwegian Meteorological Institute’s FjordOs. This iteration introduces more land to the mesh, providing more insight on the effects of flooding further into

the fjords, and eventually the opportunity for more complex models, such as compound flooding. We use the Advanced CIRCulation model (ADCIRC) with these new meshes to simulate the effects of tides and winds along the shoreline. The results from these are compared to existing Norwegian and global models, as well as water level gauges, to evaluate the new meshes' performance.

Impacts of climate change on winter floods: Spatial variability, trends, and bivariate frequency of rain-on-snow and soil frost

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Rain-on-snow (RoS) events are projected to become more frequent and affect more regions around the globe with the increase in temperatures and shifting of precipitation patterns due to climate change. However, to date, little research has addressed the coincidence of RoS and frost for the historical and future climatic conditions that can amplify surface flooding. The goal of this study was to assess the impacts of climate change on the frequency, magnitude, and trends of RoS events co-occurring with soil frost at three sites with different cold climates (sub-arctic, continental, and arctic tundra). Field observations were used to evaluate the spatial variability and trends in hydro-meteorological variables for the period dating back to 1949 and to calibrate and validate the Simultaneous Heat and Water model (SHAW) and the Accumulation and Ablation model (SNOW-17), which provided long-term soil temperature, frost, and snow depth data. RoS volume during frost was estimated for future emission scenarios (RCP 2.6, 4.5, and 8.5) with four regional climate models. Results highlight that RoS will remain an important (if not the largest) contributor to winter runoff events albeit its volume is projected to decrease by the end of the century. Frost depth was projected to decrease at the three study sites, fastest at coastal northern, and to mostly disappear in the south study site for the high-emissions scenario.

Zaqout, T. and Andradóttir, H.Ó. (2024). Impacts of climate change on winter floods: Spatial variability, trends, and bivariate frequency of rain-on-snow and soil frost, *J. of Hydrology,* 638, 131439

Nature/Climate-Based Planning, Policy, and Management

03-06-2025 - 13:00 - 14:15

Askja N-132

Fair Water – management of floods and droughts through collaboration and co-creation

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Water management in Sweden is currently under refinement with focus on holistic solutions to handle floods and droughts. This presentation will exemplify current problems and suggest methods for collaborative decision-making across sectors to facilitate multipurpose and fairness in water allocation. Motala ström River basin (15,500 km^2) in Sweden has a very active river association, encompassing authorities, municipalities and private sector, such as industries, agriculture, forestry, insurance, tourism, hydropower, water and sanitation companies. This association was engaged for testing ideas on how to apply a living-lab concept to co-create knowledge for more efficient decision-making and management of floods and drought. The aim was both to prevent extreme events and to reduce damage during an on-going crisis.

To facilitate the discussion, extreme scenarios was produced by modelling the joint effects of combined historical events (observed in the catchment or nearby). These scenarios were well accepted by participants as they could easily relate to them, although the combined effect was severe regarding flooded areas and hydrological/agricultural drought. Risk areas were identified and potential effect from various physical measures in the landscape or water management were explored in numerical modelling. The results were surprising to many actors and shifted their views on best management practices. Likewise, scenario-based training on collaborative decision-making during a crisis was judged very effective to speed up communication and decisions. Hydrological tools were thus considered useful, although some local adaptation was needed for acceptance. Moreover, hydrological knowledge was found to play an important role for reaching consensus and implementing actions.

A Significant Directive for a Small Nation – Embracing a New Perspective

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The implementation of the European Water Framework Directive (2000/60/EC) in Iceland, transposed into national law in 2011 (no. 36/2011), introduced a transformative approach to water management. This directive represents a substantial commitment for a small nation with vast, uninhabited areas and abundant water resources. Ensuring that all water bodies are maintained in good condition and that resource renewability is guaranteed poses a significant challenge, particularly in a society characterized by numerous small municipalities with limited capacity. Knowledge about pressures and availability of water resources is both fragmented and limited. Additionally, adapting to a new mindset where water is considered a precious resource in a changing climate is challenging for many Icelanders. The adoption of the first River Basin Management Plan in 2022 marked the full realization of the Water Framework Directive in Iceland. For the first time, permits issued across various sectors must be evaluated in accordance with the directive's requirements. These requirements mandate that polluting industries and sectors exerting pressure on water bodies assess their impacts and determine whether the environmental

objectives for water bodies are at risk. Furthermore, the directive necessitates monitoring the effects of various industries on water bodies. Gradually, Iceland is progressing towards verifying that its water bodies are in good condition overall and that resources are managed sustainably.

ICEWATER - Implementation of the first River Basin Management Plan in Iceland

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Iceland is implementing its first River Basin Management Plan (RBMP) whereas most European countries are planning their fourth RBMP cycle. Iceland aims to accelerate the implementation of the current RBMP and aligning it with the rest of Europe. Three overarching constraints to implementation have been identified:(1) Iceland has a small population, a large land area and fragmented administration,(2) the current RBMP in Iceland has significant gaps due to lack of data and (3) communication and cooperation is fragmented across the board. To address these barriers ICEWATER, a strategic integrated project co-funded though the European Union's LIFE Programme, aims to enhance the implementation of the existing plan and provide input into the second RBMP. ICEWATER is an ambitious project, with a total budget of 39,6 million euros, focusing on increasing cooperation and mobilising human and financial resources. It aims to increase capacity and knowledge with dissemination and communication of information, removing administrative and legislative barriers for implementation. Several demonstration activities will be carried out with the aim of reducing pressure on water in Iceland. The impact of these activities will be communicated and disseminated to facilitate their replication in Iceland. ICEWATER covers the whole of Iceland and involves various governmental bodies, the research community, municipalities, the public, industry and other stakeholders. The consortium consists of 22 domestic partners who will bring the necessary expertise to implement the first RBMP in Iceland. ICEWATER started in January 2025, is coordinated by the Icelandic Environment and Energy Agency and is funded for six years.

Changes in Ecological Flow in Latvia in the Context of Climate Change

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Ecological flow is a key element for the health of lotic ecosystems and their sustainable management. This study analyses changes in ecological flow due to climate change and operating hydropower plants. The impact of hydrological alterations caused by hydropower plants and climate change on the ecological flow was analysed using hydrological and river habitat data from 18 small hydropower plants (capacity < 1 MW) in Latvia which are located on 11 lowland rivers. Monthly discharge data from two periods 1960 to 1990, 1991 to 2020 and from the climate change scenarios for period 2071-2100 were used to assess the potential impact of climate change on ecological flow. Ecological flow regime was calculated using the meso-scale habitat – discharge simulation model MesoHABSIM which includes hydrological, biological and habitat data. Model was adapted to Latvian conditions during LIFE GoodWater IP project. Modelling of climate changes was carried out with early flood warning and hydrological forecasting system WSFS. Analysis of our obtained results show that water discharge is decreasing during summer and autumn. Moreover, the low flow period is becoming longer. Hence, implementation of the sustainable ecological flow regime during these months will be really challenging, especially for salmonid fish species. It is expected that the number of days when aquatic habitats are under stress will continue to increase and there is a high risk of not achieving the objectives of the Water Framework Directive.

Applying Explainable Artificial Intelligence for snowmelt-driven streamflow prediction in Finland

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Explainable Artificial Intelligence (XAI) has emerged alongside rapid advancements in Artificial Intelligence, yet its applications are still limited within hydrology, particularly in modelling snowmelt-driven streamflow. Traditional hydrological models such as the Snowmelt Runoff Model (SRM), Hydrological Simulation Program—Fortran (HSPF), and the Variable Infiltration Capacity (VIC) model have been used for snowmelt-driven streamflow predictions. However, these models struggle to capture the complex, nonlinear interactions between temperature, precipitation, snowmelt, and streamflow, especially in the face of climate change. Machine learning and deep learning models have shown improved accuracy in handling these complexities, but they are often "black-box" models, where individual relationships between streamflow and its drivers are difficult to interpret. This limits their practical use in hydrology, where clear insights into the underlying processes are crucial for informed environmental management. This pioneering study applies XAI techniques to snowmelt-driven streamflow forecasting in the cold-temperate catchments of Finland. We build XAI models, including SHAP and LIME, that accurately predict streamflow using hydrometeorological data (snow water equivalent, precipitation, temperature) and offer transparent, interpretable insights into the mechanisms that drive spring-time streamflow. We present preliminary results of the study, that demonstrate the benefits of XAI in forecasting streamflow. They also provide valuable insights into the complexity of hydrological processes and enhance decision-making for water resource management and flood prediction in snowmelt-dominated regions like Finland.

Groundwater: The Hidden Source that Keeps Us Flowing

03-06-2025 - 13:00 - 14:15

Askja N-131

The Evolving Role of Subsurface Processes in High Arctic Water Circulation: Insights from Fuglebekken

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Climate change is dramatically transforming the Arctic landscape. Permafrost thawing and changes in active layer thickness (ALT) are significantly affecting hydrological processes in these regions. This study investigates the relationship between ALT variations, groundwater levels, and catchment responses in the High Arctic.

The unglaciated Fuglebekken catchment near the Polish Polar Station Hornsund on Spitsbergen served as the study area. The analysis incorporated (a) observations from boreholes, piezometers, and surface water and (b) simulations using the HBV rainfall-runoff model.

Results highlighted the crucial role of groundwater storage in water circulation within the Fuglebekken catchment. This was evident in both observations and model simulations. The slow runoff reservoir underwent significant changes, indicating a shift toward subsurface flow pathways.

Additionally, the study found significant temporal variability in the model parameter KS, representing a slow runoff reservoir. This parameter exhibited two peaks: one at the beginning of the ablation season due to snowmelt and permafrost thawing, and another in September due to high precipitation. Other parameters showed less temporal variability and were often within their parametric uncertainty.

This research provides valuable insights into the evolving hydrological dynamics of High Arctic catchments under changing climate conditions.

Spatial and temporal variation in stable water isotopes of precipitation in Finland

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This study aims to compile all available data on stable water isotopes (δ^2H and $\delta^{18}O$) in precipitation across Finland. Long-term monitoring results are essential for improving our understanding of hydrogeological processes, investigating how factors such as latitude and altitude influence the isotopic composition of precipitation, and assessing the impacts of climate change on the hydrological cycle.

The research compiles the isotopic analyses of precipitation collected from January 2000 until the end of 2023. Data collection was conducted by the Geological Survey of Finland, the University of Oulu, the University of Helsinki, and the Finnish Meteorological Institute. Precipitation samples were collected from stations distributed across Finland, with sampling frequencies varying from monthly to, in some cases, weekly or even event-based sampling.

The study focuses on constructing Local Meteoric Water Lines (LMWLs) and evaluating their representativeness. Additionally, it explores how the isotopic signature of precipitation is transferred into the groundwater by comparting results from a previous study (Kortelainen and Karhu, 2004).

The comprehensive dataset offers valuable insights into the isotopic composition of precipitation across Finland. The analysis will aim to identify trends in isotopic variation linked to climatic events, thus offering a deeper understanding of local and regional hydrogeological processes. The long-term monitoring dataset serves as a crucial resource for evaluating climate change-driven alterations in the hydrological cycle.

Reference

Kortelainen, N.M., Karhu, J.A., 2004. Regional and seasonal trends in the oxygen and hydrogen isotope ratios of Finnish groundwaters: A key for mean annual precipitation. J. Hydrol. 285, 143–157.

Integrated Geological Mapping for Urban Resource Utilization and Management: A Case Study from Bømoen, Norway

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Urban development often relies on external inputs such as aggregates, water, and energy. In response to the significant increase in urbanization and the resulting surge in resource consumption and environmental impacts, our study in the Bømoen area of Voss, Norway, demonstrates that pre-development mapping of geological resources is essential for sustainable resource utilization, management and urban planning. This integrated approach reveals the potential for local self-sufficiency of shallow geothermal energy for heating and cooling, clean water and aggregates.

Our analysis estimates a total sand and gravel volume of ~55M m³, comprising of ~37M m³ unsaturated and ~18M m³ of high-transmissivity saturated material, indicating significant potential for both aggregate extraction and groundwater use. Hydrogeological evaluations suggest that the aquifer could support rates of at least 600 l/s for water supply and shallow geothermal energy. With groundwater temperature at ~6°C, estimated yearly thermal energy production is 90 GWh.

Among planned industrial use is shallow geothermal energy for biogas production, larvae production and food production. Using groundwater for heating and cooling of greenhouses reduces energy consumption by ~80%. Inducing CO_2 from the biogas facility can increase yields by up to 30-50%, since hatches can be closed due to direct groundwater cooling leading to stable CO_2 levels.

The results of the study are integrated into development plans and will help direct what, where and how to build. The project demonstrates that geological resources offer stable, renewable and affordable energy that, along with other resources, serves as a foundation for sustainable development and circular economy.

HYGLO Water Oriented Living Lab

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The Geological Survey of Finland (GTK) has established a network of hydrogeological test sites, which have been incorporated into the new EU Water Oriented Living Lab (WoLL) Atlas 2024. WoLLs are characterized as real-life, water-centric demonstration and platform environments that embody a cross-sector nexus approach (1). Our local partners represent water companies, universities, municipalities, governmental agencies or local associations.

The HYGLO WoLL comprises ten test sites, strategically situated in diverse geological settings across Finland facilitating research in various domains, including water resource management, groundwater-surface water interactions, the role of groundwater in the carbon cycle, the interface between sedimentary and bedrock aquifers, managed aquifer recharge, and the study of mining and pristine environments. It aims to advance hydrogeological research and address global change phenomena in subarctic and arctic regions by establishing research platforms to investigate issues like flooding, droughts, extreme weather, events snow cover changes, and groundwater recharge.

Comprehensive studies on the hydrogeology and hydrogeochemistry of sites have been conducted, with conceptual or numerical 3D hydrogeological models either completed or in progress. Numerical flow modeling, incorporating climate change scenarios, transport modeling, and risk and vulnerability assessments will be undertaken at select sites.

Each site is equipped with observation wells, CTD sensors, multiparameter sensors, and, in some cases, weather stations and soil moisture stations. Continuous data collection will be facilitated by LoRaWAN telemetry. Additionally, groundwater samples are collected for chemical and isotopic analysis biannually. The HYGLO WoLL offers research platforms for national and international research collaboration.

References

Water Europe (2019). Atlas-of-the-EU-Water-Oriented-Living-Labs.pdf (watereurope.eu)

Modelling sediment thickness and bedrock morphology based on public data

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The spatial distribution of sediment thickness and bedrock morphology is crucial for understanding the terrestrial hydrosphere. Water storage capacity significantly influences runoff responses from rainfall and snowmelt events. In rainfall-runoff modeling, water storage is often treated as a calibration parameter and is determined through inverse modeling. While this approach may suffice for models focused solely on discharge quantity, a changing environment demands the inclusion of factors such as water quality, landslide risks, and the interaction between evapotranspiration and precipitation at the catchment scale. In this regard, the distribution of unconsolidated sediments and the underlying bedrock morphology become critical variables. In this study, we addressed the question how to mimic equally plausible surfaces of sediment thickness and bedrock morphology which honor different kind of available data. We evaluate alternative mathematical approaches where the guiding principle was to use digital elevation models, gridded geological maps, and point data from public well databases for conditioning. Case studies indicate clearly that incorporating the geographic location of bedrock outcrops and the bedrock morphology significantly reduce the estimation uncertainties. By integrating numerical solutions of the biharmonic equation with conditional stochastic simulations, we achieved equally probable realizations of sediment thickness and bedrock morphology with minimum estimation errors. These results indicate a general and mathematically valid approach for standardized procedures which can be applied for regional assessments.

Floods and Droughts: Nature's Extremes in a Warming World

03-06-2025 - 14:45 - 16:00

Gróska – Main Hall

Determining trends in occurrence of dry and wet events using gridded precipitation data in Finland

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Agricultural water management is challenged by changing climatic conditions. Climate warming and changing dry and wet extremes require improved management methods, while the growing season in northern countries may be increasing in length.

The aim was to produce a spatial analysis of gridded precipitation data in Finland and detect how and where dry and wet periods are changing within agricultural areas. A further goal was to focus on critical areas with the clearest trends and use a hydrological model to simulate how the wet and dry extremes are reflected in the groundwater depth and drain discharge. The meteorological analysis was conducted by applying the standardized precipitation index (SPI), which was used to produce the number and mean length of summer dry and wet periods. The existence of temporal changes in these variables over recent decades was tested using the Mann-Kendall trend test.

The hydrological modelling in critical locations was realized with the FLUSH model. Two different parameterizations were adopted from earlier studies in coarse-grained and fine-grained agricultural soils. Standardized hydrological indices were produced from the simulation results for groundwater depth and drain discharge.

The results provide a view on how trends in meteorological conditions propagate to hydrological variables. SPI-based dry and wet events showed varying trends in the coastal agricultural area, while the majority of the country had no significant trends. The hydrological simulation results of groundwater depth and drain discharge demonstrated the challenges of increasing occurrence of wet periods for agricultural water management in addition to droughts.

Coupled urban-rural water infrastructure management under hydroclimatic extremes with decision support system (SW4F)

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This paper presents a multi-level risk assessment model integrating machine learning and innovative modeling frameworks for managing coupled urban-rural water infrastructure under hydroclimatic extremes. Preliminary results from four case river basins in Sweden and Norway demonstrate tools for risk assessment and integrated modeling of flooding from urban drainage systems coupled with river

catchments. The focus is on enhancing resilience and adaptation capacity of water infrastructure and quantifying ecosystem services of wetlands. The results will be based on an EU-funded project including several work packages (WPs) such as increased understanding of climate change impact, multi-level risk assessment, scenario- and event-based hydrological modeling, sensor design for water quality, life cycle assessment in IWRM, and development of decision support tools. These efforts aim to improve understanding of hydroclimatic impacts, enhance water infrastructure resilience, and provide tools for flood protection and climate change adaptation. The project will deliver in-depth insights into hydroclimatic extreme scenarios, risk levels, and water quality variations, as well as improved knowledge of water and wastewater infrastructure resilience under various climate conditions. Additionally, it will offer tools, data, and scientific evidence for addressing challenges related to flood protection, hydrological and hydraulic performance, water supply quality, CSOs, pollution control, and cost-effective measures for climate change adaptation and mitigation. The results will lead to positive economic and environmental impacts, better preparedness of societal actors in water infrastructure and technological developments.

Estimation of precipitation extremes in Iceland

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In Iceland, periods of intense rainfall have led to localised damage on numerous occasions. Recent examples include heavy precipitation in July 2024, with over 220 mm in 24 hours recorded in a station in the Snæfellsness peninsula, while record-breaking rainfall amounting to almost 570 mm over five days were measured at the origin of landslides in the town of Seyðisfjörður in December 2020. These recent occurrences are a reminder of how crucial reliable estimates of precipitation extremes are for assessing the spatial and temporal variability of precipitation.

The aim of this presentation is to give an overview of what has recently been done in Iceland and show ongoing work on that topic. This includes a new set of 1M5 maps of 24-hour precipitation thresholds for a 5-year event, based on gridded precipitation from a reanalysis dataset, as well as examples of Intensity-Duration-Frequency curves calculated for stations around Iceland based on both observation and simulation timeseries. Additional results based on downscaled precipitation projections from the CMIP6 dataset will also be discussed.

A method for estimating design flood for urban and natural catchments

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In this study we investigate the relationship between extreme precipitation, soil moisture states and floods. We will use the calibration of a rainfall-runoff model (The Distance Distribution Dynamics model DDD) to parameterise an event model (DDDEvent). DDDEvent can be run for varying precipitation intensities and sequences and subsurface states. One especially important model parameter in the DDD model is the subsurface capacity. If the soil moisture in the catchment exceeds the subsurface capacity, very rapid overland flow occurs generating the highest flood peaks. Results show, not unexpectedly, that varying the soilmoisture state gives a range of runoff responses to a given precipitation input; and more importantly, an extreme precipitation event does not necessarily produce an extreme flood event. When we simulate runoff for different precipitation input and varying soil moisture states, we obtain a conditional distribution of runoff, given a precipitation intensity. Furthermore, when we simulate runoff for all possible (realistic) precipitation values we obtain a conditional distribution of precipitation given a runoff magnitude. From the conditional (empirical) distributions we can use a 2D kernel density estimate to

assess the probability for a certain value of runoff when we have the probability of the precipitation. We compare the simulated events to a flood frequency analysis based on observed flood data and find good agreement when the DDDEvent model is run drawing subsurface states from a soil moisture distribution with a mean equal to the catchments's estimated subsurface capacity.

Flood frequency analysis of rivers in Latvia in a changing climate

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In this study, we conducted a flood frequency analysis using L-moments and the annual maximum water level and discharge series methods. Five widely used probability distributions (PDs) — extreme value type I (EV1), generalized extreme value (GEV), log-Pearson type III (LP3), three-parameter lognormal (LN3), and generalized logistic (GLO) — were selected to analyze the statistical characteristics of observed flood data for the period 1950/51 to 2022/23 (hydrological years). The main objectives of this study are to: (1) identify the best-fit PDs for flood volumes, water levels, and flood durations for the entire study period as well as the two sub-periods with different climate impacts (1950/51–1986/87 and 1987/88–2021/22) within each hydrological region; and (2) analyze severe floods (with a probability of ≤10%) based on annual flood data in the context of a changing climate.

The results of the study confirmed that the time series of annual maximum data for the rivers of Latvia best fit the GEV distribution. A relatively less diversity of PDs was found for 1987/88–2022/23 and for the entire study period. A comparison of the study periods revealed that from 1987/88 to 2022/23, the number of major floods during the spring season decreased significantly across all HRs, while it increased slightly during the winter season, except in the Western HR. This suggests a seasonal shift in river discharge patterns, characterized by a reduced flood risk in spring and a tendency toward increased flooding during winter. However, at present, the number of major winter flooding events remains low.

Nature/Climate-Based Planning, Policy, and Management

03-06-2025 - 14:45 - 16:00

Askja N-132

Nordic approach to drought risk management: Drought policies

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Droughts pose significant challenges to water resources management globally, even to countries with ample water resources. This study examines the Nordic approach to drought risk management, focusing on the similarities and differences in drought policies across Nordic countries. The study compares drought policies between Finland and Sweden, providing an analysis of drought related policies, implementation strategies and mitigation efforts. The analysis covers how recent severe drought events in the Nordic countries and Europe have influenced drought policies, complementing the author's study on risk assessments.

Our initial results suggest that while Finland and Sweden have ample water resources, droughts can still cause societal impacts. Both countries are part of the European Union and prioritize sustainable water management and climate adaptation, but there are notable differences in their policy frameworks and implementation strategies, related to droughts and adaptation. However, similarities in their policy exist, such as the importance of risk assessment, cross-sectoral collaboration, the integration of scientific research into policy-making, and the need for continuous monitoring and evaluation. Additionally, the initial results underscore the importance of international cooperation in sharing best practices and developing joint initiatives.

Next steps aim to include other Nordic and Baltic countries to this analysis, highlighting their approaches and challenges, as well as differences or similarities among them. The authors encourage other Nordic and Baltic drought researchers to join the assessment in making it into a broader Nordic and Baltic assessment and provide recommendations for practitioners and policy-makers.

Future-proofing cities: adapting stormwater design to climate change

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Urban areas are increasingly facing the challenge of frequent flooding, driven by climate change and the decrease of natural areas due to dense urbanization. This study examines the impact of neglecting climate change during the design process on urban flooding risk, using the Storm Water Management Model (SWMM). The study focuses on two urban catchments in Northern Europe, Estonia, where stormwater design standards were recently revised. The research analyzes how the use of climate factors influence the stormwater system design, from statistical to hydraulic response. The statistical analysis reveals a notable change in pluvial flooding risk, which will increase remarkably according to the climate factors. The modeling results confirm these findings as the hydraulic behavior with climate factors is notably different compared to the stationary assumption. While there are no flooding manholes and surcharged pipes without climate factors, the climate change induced design values caused flooding in

10% of the nodes and almost all the pipes were surcharged. This study demonstrates the importance of taking account for changing climate patterns in stormwater system design. The research underscores the risks associated with outdated design guidelines, including increased flood frequency and the related possible economic loss. This research provides valuable insights for policymakers, urban planners, and engineers in neighboring countries with similar climate, urging them to prioritize the implementation of climate factor to the stormwater design guidelines to maintain the determined flooding risk in urban areas in the face of evolving environmental challenges.

ALAI's Pivotal Role in LIFE ICEWATER: Fostering Municipal Capacity for Sustainable Water Solutions

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The Association of Local Authorities in Iceland (ALAI) plays a pivotal role in the LIFE ICEWATER project, connecting key actors and ensuring effective collaboration among municipalities. ALAI is committed to facilitating knowledge sharing and capacity building, empowering local authorities to tackle water management challenges effectively.

Through innovative "waterthons" and collaborative campaigns, ALAI promotes stakeholder engagement and highlights the importance of municipal input to tailor solutions that meet their unique needs. The project will implement pilot projects focusing on blue-green solutions and natural approaches to enhance freshwater quality, preventing pollution from wastewater disposal and more.

Participating municipalities, such as Kópavogur, Ísafjörður, Grundarfjörður, Hveragerði and Reykjavík, will benefit directly from tailored activities designed to enhance their water management practices. ALAI ensures that lessons learned from these pilots are disseminated widely, providing valuable insights to all municipalities in Iceland, thereby fostering an inclusive environment for knowledge exchange. By bridging theoretical knowledge with practical implementation, ALAI aims to make the replication of successful strategies smoother and more effective, ultimately enhancing local capacities for sustainable water management and benefiting communities across Iceland. Furthermore, ALAI is integral to collaboration on regulatory reforms and developing an After-LIFE Plan that guarantees ongoing outreach and reliable

Organic phosphorus flame retardants and bisphenol in municipal wastewater, runoff and drinking water in Iceland

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Micropollutants in surface and drinking water are of emerging concern because of their toxicity, long lifetime and potential of bioaccumulation in the food chain. Phenols and OPFR (organic phosphorus flame retardants) originate in a range of consumer-based products and building materials. Phenol is a component of soaps, toys, paints, lacquers, perfumes, varnish removers and disinfectants. Flame retardants, include organohalogen and organophosphate chemicals such as polybrominated diphenyl ethers (PBDEs) and Tris(2,3-dibromopropyl) phosphate. They are used in furniture, children’s products,

electronics, building materials, wire and cable, to prevent fires. A significant portion is also used in the plastics industry. Because of their abundant use, some of these chemicals are priority substances in the revision of the EU drinking water directive. Moreover, with expanding human activities in the warming Arctic, these compounds are expected to become more prevalent there. The overarching goal of this research is to assess the chemical concentration of flame retardants and phenols in drinking and wastewater in the capital region of Reykjavík, Iceland. Twenty-eight water samples were taken over a two-year period, targeting both hot/cold and wet/dry seasons. The samples were analyzed at the Norwegian University of Life Sciences. Results will be discussed in relation to international literature. The research sheds light on the origins and loads of land-based pollutants released to the sub-arctic water environment.

ON POWER - nature-based solutions and planning

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ON POWER (ON) operates three power plants in Iceland: two geothermal and one hydropower. From the start ON has focused more and more on nature-based planning and solutions to mitigate some of the challenges associated with power generation. In this presentation, we want to highlight some of the work that has been implemented, works that are in progress and ideas of future development: nature-based bank protection, nature-based fish passage, cooling ponds, eco-flow regimes, flood forecasting and sediment transfer options.

Over recent years, ON has recognised the potential of integrating natural processes with engineered solutions, which can enhance environmental resilience and optimise energy efficiency. The company has collaborated with local institutions and environmental experts to monitor changes in surrounding ecosystems and adapt its operations accordingly. These partnerships have led to less impact on water bodies, reduced riverbank erosion, improved habitats conditions and increased biodiversity around power plant sites. Innovative projects, such as nature-based bank protection and eco-flow regimes, are gradually transforming traditional energy generation practices into more sustainable models. Moreover, ongoing studies on sediment transfer regimes and the use of flood forecasting are expected to mitigate environmental impacts further and increase energy efficiency. On-going initiatives aim to build a fish passage at Andakilsa river and develop cooling ponds system at Nesjavellir that blend seamlessly with the local landscape. This approach to power generation reflects ON’s commitment to safeguard natural habitats better while meeting energy demands.

Groundwater: The Hidden Source that Keeps Us Flowing

03-06-2025 - 14:45 - 16:15

Askja N-131

Evaluating the Impact of Land Use Fragmentation on Groundwater Nitrate Contamination: A Multi-Scale Spatial Analysis in Denmark

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Groundwater contamination by nitrates is a significant environmental concern, particularly in agricultural regions where land use patterns influence nitrogen leaching. This study investigates the effect of land use fragmentation on groundwater nitrate concentrations in Denmark by analyzing fragmentation indices at multiple spatial resolutions. High-resolution (10m) land use data were used to examine the scale dependency of fragmentation effects (50m, 100m, 500m, and 1000m). Using a moving window approach, we computed key fragmentation metrics, including patch density, edge density, and Shannon diversity index, for over 500,000 land use grid cells across Denmark. The fraction of each landcover type is also produced from high resolution land use data. To assess the predictive power of these metrics, we integrated them into a machine learning-based groundwater nitrate prediction model, trained on groundwater nitrate measurements collected. Model performance was evaluated across different land use resolutions. Additionally, statistical tests, including Spearman correlation analysis and SHAP-based feature importance ranking, were conducted to determine which fragmentation indices most influence groundwater nitrate levels. Preliminary results indicate that land use fragmentation at 100m and 500m resolutions exhibits the strongest correlation with groundwater nitrate concentrations, suggesting an optimal scale for nitrate modeling. High patch density and edge complexity in agricultural areas were associated with elevated nitrate levels, likely due to increased exposure of soil to nitrogen leaching processes.

Revealing groundwater patterns in the Baltic States: data challenges and groundwater memory effect

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Groundwater is essential for human consumption and the sustainability of groundwater-dependent ecosystems. However, the quality and reliability of groundwater level data - the primary source of information - frequently pose data quality challenges that can negatively affect analysis and assessment.

Interactive tool was developed within R Shiny environment to support groundwater data rescue efforts - identifying error types and repairing or removing erroneous groundwater head values (Retike et al., 2022). The repaired time series contained missing values that exhibited temporal patterns. These patterns guided the selection of appropriate imputation algorithms, with performance assessed through realistic gap simulations (Bikse et al., 2023). The best-performing method, missForest successfully imputed up to two years long continuous data gaps. Next, the treated data set was used to uncover spatial patterns in groundwater resilience, utilizing the groundwater memory effect as a proxy. Spatial modeling, performed using random forest algorithms, highlighted the significant role of catchment,

climate, and topographic features in controlling groundwater resilience, while land use and geological factors also played an important role in certain areas.

The research is supported by GRANDE-U project “Groundwater Resilience Assessment through iNtegrated Data Exploration for Ukraine” (NSF Awards No. 2409395/2409396).

References:

Retike, I., Bikše, J., Kalvāns, A. et al. 2022. Rescue of groundwater level time series: How to visually identify and treat errors. Journal of Hydrology, 605, 127294.

Bikše, J., Retike, I., Haaf, E., Kalvāns, A. 2023. Assessing automated gap imputation of regional scale groundwater level data sets with typical gap patterns. Journal of Hydrology, 620, 129424.

Assessing Model Transferability for Groundwater Nitrate Prediction in Data-Scarce Regions Using Bayesian Deep Learning, and Cumulative Logits Network

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Groundwater nitrate contamination is a significant environmental concern, particularly in regions with limited monitoring data. This study develops a Bayesian Deep Learning framework utilizing cumulative logits and transfer learning to predict groundwater nitrate concentrations in data-scarce regions. The model architecture included three fully connected layers with 256, 128, and (num_classes-1) neurons, respectively, along with batch normalization and dropout layers. Training was conducted using the AdamW optimizer with a learning rate of 0.001 and different weight decay, while uncertainty estimation was performed using Monte Carlo dropout with 100 forward passes. We trained the model using 14750 nitrate data from Europe, excluding Denmark, to evaluate its transferability to Denmark’s groundwater system. A cumulative logit loss function is used to enforce ordinal constraints, improving interpretability and predictive accuracy. Monte Carlo sampling enables uncertainty quantification, providing confidence intervals for predictions. Model performance was evaluated, and results demonstrate that the proposed model effectively outperforms the traditional classification-based random forest (RF) model based on accuracy (0.70) and MSE (1.14), and Kendall’s Tau (-0.07). Comparison of groundwater data observation in Denmark with prediction of model showed less correlation and was not effectively predicted groundwater quality in Denmark. The uncertainty estimates highlight regions where the model exhibits lower confidence, aiding in risk assessment and decision support. The proposed framework demonstrated higher accuracy compared to the RF approach; however, its transferability to Denmark was limited, highlighting challenges in applying the model to data-scarce regions.

Integrating Freeze-Thaw Dynamics and Frozen Ground Impermeability in the HBV Model

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The HBV hydrological model, or Hydrologiska Byråns Vattenbalansavdelning model, has demonstrated wide applicability across diverse catchments globally. However, in polar regions, it encounters challenges in representing processes associated with the freezing and thawing of the ground. This study addresses these limitations by adapting a semi-distributed version of the HBV model to incorporate two permafrost-related processes: the freeze-thaw cycle of groundwater and the impermeability of frozen ground. The performance of these adaptations was evaluated in the Fuglebekken catchment at Hornsund, SW Spitsbergen. Four model configurations were tested: the original semi-distributed HBV, a version adapted

for frozen ground impermeability, a version adapted for the freeze-thaw cycle of groundwater, and a version incorporating both adaptations. Comparative analysis revealed that the adapted models provided a more accurate representation of hydrological dynamics in the permafrost-dominated environment, particularly during seasonal transitions. The results highlight the significance of accounting for permafrost-related processes in hydrological modeling of polar catchments. This work underscores the need for further development and validation of hydrological models to improve predictions under changing climatic conditions in Arctic regions.

Applying HydroBlocks model over Finland to model temporal and spatial trends in soil conditions

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HydroBlocks (Chaney et al., 2016), a hydrological land surface model, simulates the movement of water and energy between the atmosphere and the Earth's surface and subsurface. The model computes soil conditions, at a given time, even on a regional scale based on meteorological, elevational, soil and land use data. As outputs, the model gives, among other things, snow water equivalent (swe), snow depth, soil temperature, soil water and ice contents as well as surface and subsurface runoffs. The model makes it possible to have information on the surface and subsurface conditions which lack in-situ measurements, especially with high spatial coverage.

HydroBlocks model was configured for Finland, ran for the years 2000-2023, with 90m spatial resolution and 1 hour time step. The modeling results were validated and calibrated against observational data from snow (swe) and soil stations (soil temperature and soil water content) across Finland. The simulations show that HydroBlocks can generally predict snow conditions and soil moisture and temperature across Finland. However, it is essential to have adequate data of soil types and their hydraulic properties.

The output data generated by HydroBlocks can be used in number of environmental applications. Considering my PhD research, soil temperature and soil water and ice content can be used to study a phenomenon called frost quakes, which cause fracturing of the top soil layer (Okkonen et al., 2020). In addition, in the future, we can use HydroBlocks to assess water infiltration, groundwater recharge rates, surface and subsurface flow across Finland.

Groundwater drought in Norway and Sweden: Extremeness, drivers and impacts

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Groundwater (GW) plays a vital role in sustaining ecosystems, agriculture, and drinking water supplies in Norway and Sweden. However, the region is increasingly influenced by climate change and more frequent extremes. Shifts in temperature and precipitation patterns influence GW recharge, leading to prolonged periods of reduced availability. These changes amplify the risk of GW drought, with profound implications for water resources, management, and ecosystem health. This study investigates the dynamics of GW droughts using well observations and hydrometeorological data to provide a

comprehensive evaluation of GW variability and trends under changing climatic conditions. GW levels in the region are influenced by shifting precipitation patterns, temperature increases, and altered snowmelt regimes. We employ Pastas, an advanced physics-based modeling framework, to simulate GW system dynamics in responses to climatic drivers. This approach enables us to cope with irregular gaps in GW observations through a hybrid method combining Pastas and linear statistical techniques to produce daily time-series. By leveraging 213 GW level time-series (1990-2023), we examine temporal changes in GW level, seasonal fluctuations, and the duration of drought events. The Standardized Groundwater Index (SGI) is applied to benchmark historical events and evaluate its performance in identifying past drought conditions. This research underscores the importance of integrating observational and modeling approaches to better understand the response in GW to climate extremes, such as 2018 and 2022 drought. The findings aim to inform adaptive water management policies and enhance the resilience of GW systems across the region. This work contributes to the GroundedExtremes Water4All project.

Floods and Droughts: Nature's Extremes in a Warming World

04-06-2025 - 09:00 - 10:15

Gróska – Main Hall

Improving pluvial flood warnings in Denmark

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The current pluvial flood warning system in Denmark is based on rainfall threshold exceedances. The warnings are at local, municipal level and include a text description as well as a link to flood inundation maps based on simple pre-simulated bluespot technology. However, feedback from key stakeholders, municipal authorities and water utilities, reveal several challenges: frequent false alarms, limited information on forecast uncertainties, and misaligned warning thresholds with national drainage design standards. Additionally, many utilities lack clear guidance on pre-event actions and often respond only after a flood event occurs.

In response, the Danish Meteorological Institute (DMI) has launched a new project in collaboration with Danish water utilities to develop a more user-tailored pluvial flood warning service. The project aims to integrate meteorological data with urban hydrological insights, refining warning criteria, visualizing rainfall forecast uncertainties, mapping pluvial flooding scenarios, and developing actionable procedures for utilities and municipalities.

The expected outcomes include more accurate, relevant warnings, tailored information, a deeper understanding of rainfall uncertainties, and improved emergency response for pluvial flooding. By incorporating both meteorological and hydrological expertise, the project seeks to create a flood warning system that is both scientifically robust and practically useful for stakeholders in the water sector.

This presentation will display the current system, discuss its merits and shortcomings, and explain how we plan to improve these.

Impact-based flood warning – rapid development of a national system for Denmark

Michael Butts [1, 2] Cecilie Thrysøe [1], Maggie Henry Madsen [1], Raphaél Payet-Burin [1], Sanita Dhaubanjar [1], Jonas Wied Pedersen [1], Phillip Aarestrup [1], Grith Martinsen [1], Charlotte Agata Plum [1], Sara Lerer [3], Emma Dybro Thomassen [1]

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Denmark faces significant risks from urban flash floods, fluvial flooding, and coastal storm surges. The impacts of these floods will become even more severe with climate change. Following the severe flooding in Denmark in 2020 and Central Europe in 2021, the Danish Meteorological Institute (DMI) was appointed as the national authority for flood early warning. A new Flooding and Hydrology Unit was then established to develop an operational system to forecast storm surge, pluvial, and fluvial flood impacts and inform the Danish emergency services.

Effective flood mitigation and emergency management requires reliable, timely, and accurate flood forecasts. The additional requirement to deploy tools within the first 18 months meant that we adopted

pragmatic approaches for model-based forecasting, balancing resolution, complexity, data availability, computational efficiency and time to deliver.

In the first year, DMI developed a real-time flood mapping service for storm surges, together with Scalgo, covering Denmark's coastline with hourly water level forecasts. This service became operational in October 2022, then tested and evaluated during the 100+-year storm in October 2023. A corresponding pluvial flood mapping service launched in May 2023, integrates topography-based flood modelling that accounts for urban drainage and infiltration. Finally, a rule-based warning system for fluvial flooding went operational in July 2023.

Through workshops with the emergency services, we gathered feedback to improve our services and guide further development. This presentation outlines the rapid development of these capabilities, operational challenges, and plans for expanding the system with machine learning and hydrological modelling for multi-model fluvial forecasting.

Flood modelling and risk assessment for the river Storåna in Sandnes, Norway

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Climate change and more frequent occurrence of extreme events have been the main drivers for flooding in rivers and cities, which increased level for risk assessment for human beings, properties, and the functioning of the critical infrastructure systems during the extreme events. Different from large river basins, intensive rainfall or storm events in cities can generate significant runoff from local impervious areas to the small rivers, cause flooding in very short times, which is a common challenge for many municipalities with rivers going through the city areas. Municipalities need tools to predict the flooding and conduct risk assessment quantitatively.

In this paper, a risk assessment was performed based on the results from a 1D-2D coupled HECRAS model developed for the river Storåna in Sandnes Municipality of Norway. The model has run for rainfall up to 200-year return periods, also taking into account the impacts of climate change with projected extreme scenarios, the inundation maps were created accordingly. The flood inundation areas, the affected buildings and residents, and the critical infrastructure system units at risk are specified, which will formulate a support information for municipality's flood risk management during the emergency. Further, HEC-LifeSim model was developed to estimate potential loss of life and construct Frequency–Number of fatalities (F–N) curves. HEC-LifeSim integrates evacuation time, population characteristics, and traffic networks to quantitatively estimate the number of fatalities, thereby enhancing the reliability of flood risk assessment and decision-making support.

Fonnbu: a research station in an alpine climate to investigate the hydrological cycle, snowpack melting and flood generation in a changing climate

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The study presents preliminary results from the analysis of meteorological- and hydrological records from Grasdøla mountain river catchment (595-1400 masl.) which endures an alpine climate characterized by cold, wind, snow cover and glacier coverage (6%). Records are being used to explore aspects of the hydrological cycle including flood events, snowpack melting, and changes in river-flow within the context

of a changing climate. Mountain areas are particularly vulnerable to climate change, making them key location for detecting early-warning signs of hydrological and meteorological changes.

Historical data back to 1974 reveal no evident trends in the snowpack and temperature records. Flood flows back to 2006 are reasonably reproduced by a hydrological model of the catchment while snowpack and snowpack melting are underestimated by the model.

Meteorological data (precipitation, air temperature, snow depth, radiation, and wind) are recorded at the Fonnbu research station, located at 950 masl. on Strynefjellet in western Norway, near Jostedal glacier. Records were initially limiting to winter seasons, but hourly year-round data are available from 2006. Understanding the connection between weather and snowpack development, and conditions leading to snow avalanches, has been a central research topic at Fonnbu since 1973.

The study proposes ideas to further use the data recorded at Fonnbu, together with flows from Grasdøla river, to address topics related to rain-induced natural hazards (flash floods, slush avalanches, mass transport, landslide), and investigate hydrological processes to improve flow forecasting and safety of infrastructure including dams in the context of a changing climate.

The effect of univariate and multivariate bias-adjustment on climate change signals and climate extremes

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Outputs from regional climate models provide valuable information about how the climate might evolve in the future. However, significant bias can occur when comparing model outputs with observations which require further processing before the climate projections can be used directly in climate impact studies. Precipitation and temperature as the most important climate drivers in hydrological modelling face similar challenges. Previous studies have shown that climate change signals might be modified because of bias-adjustment methods. The scientific community has not reached a consensus on to what degree such a modification is a desirable feature.

The effect of bias-adjustment on climate change signals is analysed by comparing precipitation and temperature projections from an ensemble of regional climate model runs for two Norwegian catchments before and after bias-adjustment, focusing on seasonal changes and trends. We use two bias-adjustment methods – a univariate and a multivariate – provided by MIdAS tool (Berg et al., 2022). The univariate method adjusts the variables independently of each other, while the multivariate method aims to both correct the univariate cumulative distribution function and the correlation between the variables.

The period of 1971-2000 is used for calibrating the bias-adjustment methods. Climate change signals are derived from the historical period (1971-2000) and RCP4.5 and RCP8.5 scenarios (2071-2100). This study also examines the possible impact on estimation of extreme events such as meteorological droughts and prolonged wet periods.

Berg, P., Bosshard, T., Yang, W. and Zimmermann, K. (2022): MIdASv0.2.1 - MultI-scale bias AdjuStment, Geosci. Model Dev., 15, 6165–6180, https://doi.org/10.5194/gmd-15-6165-2022.

Nature/Climate-Based Planning, Policy, and Management

04-06-2025 - 09:00 - 10:15

Askja N-132

Providing robust low-flow indices for minimum-flow requirements

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Low-flow indices are used to determine minimum streamflow in regulated rivers, to ensure enough water to support local ecosystems. Measuring low flow is challenging for a variety of reasons, such as ice formation in winter and vegetation growth in summer. Developing robust regionalized low-flow indices is useful as it will be less sensitive to extreme values and measuring errors. The Norwegian Water and Energy Directorate (NVE) presents a selection of low-flow indices in the mapping tool NEVINA for both gauged and ungauged catchments: the 5-percentile of streamflow (Q95), yearly and by summer/winter season; Base Flow Index; and the “common low flow”, the 33-percentile of the yearly 16th lowest measured streamflow value. This selection of low-flow indices has been revised together with the main users to provide more ecologically relevant and robust indices. As such the calculation procedure for Q95 is changed, while the mean annual minimum 7-day and mean annual minimum 90-day streamflow are added. To test the robustness of the indices, the sensitivity to extreme values and years with uncertain data quality will be assessed based on the reliability of the indices through a bootstrapping approach such that accuracy and reliability are consistent through systematic resampling of the dataset.

Here, we present the results of the low-flow indices for catchments from the hydrological reference dataset. Indices, their variability and trends are presented for the whole country and regional differences are assessed. Whether and how minimum-flow requirements should account for climate change is discussed with the main users at NVE.

Assessment of future water balance change in a snow-glacier-dominated regime basin in Norway

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Ecosystems worldwide are affected by climate change, but these changes happen faster in the Nordic latitudes and higher elevation zones. These temperature increases and shifts in rainfall/snowfall patterns affect water resources and put ecosystems and water users under pressure.

To address the future change in water availability, we used the Community Water Model (CWatM) and adapted the model to a Norwegian case study in several ways. We included an energy balance term in snow modelling, calibrated for snow water equivalent and observed discharge, and linked the Open Global Glacier Model (OGGM) to simulate the change in the glacierized area and outflow from glaciers.

The model is set up for the Otta basin (~4000km^2) in Innlandet county, Norway. The basin is snow-regime dominated with limited precipitation in the valley (~300mm/yr). CWatM uses a daily resolution on 1x1 km^2 cells. For this contribution, we focus on the effect of snow and glaciers, but water demand from forestry, agriculture, and reservoir operations is also included. The model is calibrated using a historical set of meteorological data, reservoir volumes and station snow water equivalent. Future projections of climate variables are using a regional downscaled and bias-corrected set of 11 General Circulation - Regional Circulation Models (GCM-RCPs) x 3 Representative Concentration Pathways (RCPs) up to the year 2100.

We will show the development of glaciers and the change of components of the terrestrial water balance under different future projections, emphasizing the change from a snow-glacier regime towards a rain-dominated regime.

CAMELS-Nordic, a large-scale hydrometeorological and catchment properties dataset for Norway and Sweden

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Historically, hydrologic studies have focused on one or a small number of basins. In many cases, these studies were limited by data availability and computational resources. In the last 20 years, the availability of large hydrological datasets, such as gridded meteorological data sets and streamflow timeseries, and increased computing resources have empowered large-sample hydrology studies. Having accessible and high-quality large datasets available to the science community facilitates the evaluation of hydrologic processes and prediction questions. To support modeling and climate research efforts in the Nordics the CAMELS (Catchment Attributes and Meteorology for Large-sample Studies)-Nordic was collected and processed into a coherent dataset for the entirety of Norway and Sweden. CAMELS-Nordic combines not only meteorological and hydrological, but also topography, climate, streamflow, land cover, ans soil data with python package to update time series automatically where possible. The development of the data package takes advantage of high-quality and freely available data from various Norwegian, Swedish, and European agencies. It includes: (1) daily forcing data (e.g. observations, interpolations, and modeled data) for catchments located in Norway and Sweden; (2) daily streamflow data; (3) digital elevation model; (4) catchment properties (size, location, elevation, and catchment files); (5) landcover; and (6) soil type data. Dataset time series span 1980 to 2022.

Quantifying changes in flow regime due to hydropower plant operations using Indicators of Hydrologic Alteration in six lowland rivers of Lithuania

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Aquatic ecosystem health is directly linked to the natural flow regime. Managing hydrological regime at sustainable levels is principal to achieving good river hydromorphology and reaching EU WFD goal of good ecological status in all rivers. Hydropower plants (HPPs) may significantly alter river flow dynamics and put pressure on the natural fluvial ecosystems. This is a common problem in Lithuania, where effective legislation protecting the flow regime is lacking, as the methodological approach to the legislation is not linked to ecological indicators. In this study, we aim to (1) establish the natural hydrological patterns of selected rivers using the HBV hydrological model and (2) quantify the changes to flow regime and discharge as a result of HPP operations. We focused on six regulated Lithuanian rivers: Šušvė, Jūra, Bartuva, Venta, Mūša and Lėvuo. The HPPs in the studied rivers began to operate between

1999 and 2005, therefore created hydrological models before HPP operation allowed us to simulate unaltered rivers flow and compare those modelled results with the historical observations once the HPPs began to operate. We have adopted the Indicators of Hydrologic Alteration (IHA) to quantify changes in hydrological patterns in the studied rivers. The results suggest that in the studied rivers, with the hydropower plant operations, the occurrences of critical IHA parameters significantly increased during the warm period. The finding of this study may aid understanding the impact of HPPs on the natural flow dynamics and aid effective decision making regarding more sustainable HPP operations.

Ecology: Bridging Water and Life for a Balanced Future

04-06-2025 - 09:30 - 10:15

Askja N-131

Spatio-Temporal Analysis of Soil Moisture Dynamics in High Arctic Catchments Using In-Situ Sensors and UAV Imagery

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Understanding the variability of soil moisture is essential for analyzing changes in the water balance of high Arctic catchments near the Polish Polar Station, Hornsund, Svalbard, where climate change is rapidly altering the hydrological processes. This study combines in-situ and remote sensing approaches to investigate spatio-temporal soil moisture dynamics in these catchments. TOMST TMS-4 sensors and Sentek Drill & Drop probes were deployed to provide high-resolution soil moisture measurements across multiple depths and locations.

In addition to ground-based data, UAV-derived thermal and multispectral imagery was employed to assess spatial conditions. Land Surface Temperature (LST) from thermal imagery and Normalized Difference Vegetation Index (NDVI) from multispectral imagery were used in the NDVI-LST triangle method to estimate a Soil Moisture Index (SMI). This index was validated against in-situ measurements to investigate relationships between vegetation cover, topography, and soil moisture variability. Preliminary results indicate clear spatial and temporal patterns of soil moisture driven by vegetation cover, microtopography, and soil properties. The integration of UAV platforms with ground sensors enables scaling from point measurements to catchment-wide processes, offering a cost-effective method to monitor climate-driven shifts in the water balance.

This research contributes to a better understanding of hydrological processes in Arctic environments, where changes in the permafrost and Active Layer Thickness (ALT) conditions have profound implications for the spatial distribution of soil moisture.

From glacier melt to ecosystem change: hydrological and biodiversity responses of the river Vestari-Jökulsá

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Glacier retreat due to climate change is expected to significantly alter hydrological and chemical parameters in glacier-fed streams, impacting biodiversity. To assess these long-term changes, we revisit the Vestari-Jökulsá river (Iceland), where the combination of hydrological, chemical and ecological parameters were first analyzed in 1996 and 1997. By comparing new data from 2022 with these historical records, we can evaluate shifts in water quality and macroinvertebrate communities after 26 years.

Observations already indicate that over the past three decades, the glacier terminus has retreated approximately 541m, accompanied by an increase in daily minimal runoff. To dive deeper into these

changes and to understand the impact, our study measures key hydrological and chemical parameters, including conductivity, temperature, discharge, sediment load, pH, nutrient concentrations, dissolved organic carbon, river stability, and chlorophyll concentration. Additionally, we assess macroinvertebrate diversity and density to determine how changing glacial meltwater contributions affect downstream ecosystems.

By integrating hydrological and biological assessments, this study will provide a glimpse into the long- term effects of glacier retreat on arctic river ecosystems. The results will contribute to a broader understanding of biodiversity responses to climate-driven hydrological shifts, with implications for predicting future ecological developments in glacier-fed streams.

In French small water bodies (SWB), is microplastics presence in sediment an indication of water column contamination?

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Environmental contamination by plastics is a global issue. It concerns macroplastics and microplastics (MP, ranging in size from 0.1 to 5000 µm). This second form of contamination is having an impact on the entire biosphere. Although contamination was first detected at sea in the 1970s, plastic emissions are not predominantly due to activities at sea, but mainly from those on land (industry, agriculture, transport, etc.). Recent studies estimate that the annual quantity of MP released into the environment is between 10 and 40 million tonnes, and could double by 2040. These particles are carried away by wind or rain, and washed into running water. Once in river systems, MP behave in different ways, depending on their characteristics and on environmental conditions. Some will remain suspended in the water column, while others will bind to suspended matter, subsequently feeding the sediments of rivers, SWB and oceans.
Since 2022, our team has been collecting water samples to provide innovative data on the contamination of SWB by MP. In 2024, sediment samples were collected to explore the contamination of this complex compartment. Because of their various characteristics, MP are likely to bind to suspended matter from tributaries and feed the sedimentary compartment of SWB. Their behaviour, once in the sediment, is still unknown (sorption, release of compounds, etc.), but these results tend to show that their presence in the sediment is not negligible, and that they are present at the base of the hydrographic networks, waiting to be released during SWB management.

Floods and Droughts: Nature's Extremes in a Warming World

04-06-2025 - 10:45 - 12:00

Gróska – Main Hall

A nexus-based assessment of future drought in a glacierised, regulated catchment in Norway

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Droughts have significant impacts on the environment and water resources we humans rely on. In Norway, electricity production relies on hydropower, and agricultural production depends on irrigation in certain regions. Already observed and expected hydroclimatic changes including increased interannual variability in precipitation, less snow, melting glaciers and intensified drought could have serious environmental and socioeconomic consequences that necessitate adapted water resources management. We applied the Water-Energy-Food nexus concept to investigate climate change impacts on key nexus demands hydropower and agriculture, in the ~4000km2 glaciated Otta catchment. The relevant hydrological states and fluxes were simulated with the Community Water Model coupled to the Open Global Glacier Model and driven by regionally downscaled climate scenarios.

We developed a coherent set of indices to characterize past and future meteorological, streamflow, soil moisture and reservoir drought regimes, and assessed general hydroclimatic trends in the catchment. At the catchment scale, all four types of drought increased in intensity, duration and frequency in future, despite general increases in runoff and precipitation. However, there were spatial differences in how drought characteristics changed, which provided insights into how sub-catchments with more agriculture or specific reservoirs might be affected. Adaptation scenarios tested were shown to be highly effective at reducing risks associated with future drought regimes, so our results can provide key information for developing location-specific adaptation strategies tailored to each nexus demand and to increase resilience to drought. Our approach can also be applied to other catchments to help develop effective adaptation strategies for future climate change.

Future extreme drought in Fenno-Scandinavia revealed through high-resolution climate modelling

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Current drought projections often rely on coarse-resolution models that may underestimate extreme events. We employed, for the first time, a convection-permitting regional climate model (CPRCM) at 3 km resolution to investigate future meteorological drought patterns in Fenno-Scandinavia. Using the

Standardized Precipitation Index (SPI) and a novel multi-threshold analysis method, we identified crucial shifts in drought characteristics.

While moderate drought frequency decreases, the high-resolution projections reveal increases in extraordinary and unprecedented drought frequency. This increase is most significant during the crop-growing season, with no clear sign of a decrease in moderate drought frequency. By mid-21st century, large parts of Fenno-Scandinavia are projected to face droughts of unprecedented intensities. CPRCM simulations show higher drought frequencies compared to traditional regional climate models, especially for the most intense droughts. This indicates a current underestimation of drought risk with severe implications for water management, agricultural planning, and ecosystem resilience. Our results demonstrate how high-resolution modelling and our novel multi-threshold analysis method can improve our understanding of future drought.

We are expanding this research using the same method with additional indices. This aims to improve our understanding of future drought development in the extended Nordic region. This is done using EURO-CORDEX ensemble data. Preliminary results will be presented.

Assessing Climate Change Impacts on Hydrological Extremes in the Enns River Basin Using MIKE SHE

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Understanding the impacts of changing climate patterns on future water resources is crucial for developing effective adaptation strategies. Within the DISTENDER project (EU Horizon-ID 101056836), we assess the resilience of European watersheds to climate stressors by modeling future water scenarios and identifying sustainable water management practices.

Using the MIKE SHE hydrological model, We analyze climate change's effects on hydrological extremes (floods and droughts), groundwater recharge, and water storage (soil moisture) in the Enns River basin (southern tributary of the Danube River), Austria. The model was calibrated and validated against observed runoff data, achieving Nash-Sutcliffe efficiencies between 0.62 and 0.84 for various gauges. Future projections (2021–2050) under different Shared Socioeconomic Pathways (SSPs) were obtained from CMIP6 and statistically downscaled.

Hydrological variables were evaluated across twelve climate model runs, comparing them to a reference period (1980–2010). Changes in recurrence rates were analyzed for selected gauge locations, alongside spatial maps of projected variations.

Results indicate a rise in extreme precipitation events, increasing maximum daily rainfall and drought duration. While average annual soil moisture slightly declines, drought duration extends. Runoff and groundwater recharge projections show mixed trends with increases and decreases, but extreme flood magnitudes (1% flood event) and drought severity increase significantly under most climate scenarios.

These findings highlight the urgent need for proactive adaptation measures to mitigate climate change impacts on hydrological extremes and ensure sustainable water management in the Danube River basins.

Agile development of a national flood warning system in Denmark

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[1] Danish Meteorological Institute, Weather Research Department, Copenhagen, Denmark

Major flood events, such as the 2011 Copenhagen cloudburst and the devastating 2021 Central European floods, have highlighted the need for an effective national flood warning system in Denmark. In

response, the Danish Meteorological Institute (DMI) is developing a flood warning framework to support municipalities and emergency services in managing and mitigating flood risks.

The project applies an agile development approach using the SCRUM framework. This iterative methodology facilitates continuous evaluation of progress, alignment with end-user needs, and delivery of high-value outputs. In the development process, IT developers, hydrologists, and meteorologists collaborate to integrate technical, hydrological, and meteorological expertise, ensuring a robust and user-focused warning system. The iterative nature of SCRUM enables the team to remain adaptable to changing requirements and stakeholder feedback, enhancing the system's practical applicability.

However, integrating SCRUM into a research environment poses unique challenges, such as balancing the deep analytical focus of academic research with the time-bound, outcome-oriented principles of agile development. These challenges require ongoing reflection and adjustment to ensure that the project remains aligned with its goals and delivers maximum value to end users.

The presentation will describe the project's structure, the benefits and challenges of applying SCRUM in a research-driven context, and the current progress and ambitions for the flood warning system. This case study highlights how agile methodologies can be tailored to address complex, multidisciplinary challenges in the public sector.

Spatiotemporal Snow Cover Variability in Iran's Mountainous Regions Using MODIS Data, 2001-2021

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The extent of snow cover is critical for hydrological systems, ecosystem stability, and water resources, especially in arid and semi-arid environments like Iran. Hence, this study explores the spatio-temporal variability of historical (2001-2021) snow cover frequency (SCF) and end date (SED) in the mountainous regions of Iran, utilizing Moderate Resolution Imaging Spectroradiometer (MODIS) data via Google Earth Engine (GEE) platform. Approximately 25% of Iran's territory (≈ 412,000 km^2) is devoid of snow, primarily in areas of low altitudes and southern latitudes, indicating the influence of geographical factors on snowfall patterns. The Alborz and Zagros mountain ranges, particularly at peaks such as Sahand, Sabalan and Damavand, experienced the highest snow accumulations. The highest SCF was recorded in 2008, linked to the unusual activity in the polar high-pressure system. However, SCF has shown a decline since 2010, notably in central and eastern Iran, regions prone to drought. Unexpectedly, no consistent downward trends were detected in the annual mean SED, with the earliest and latest SEDs in 2018 and 2007, respectively. Significant decreases in snow cover were predominantly observed across the Alborz and Zagros ranges during these years (2007-2018), reflecting the impacts of global warming and climate change on Iran's snow resources over time. In contrast, a slight increase in snow cover was noted in the southwest parts of Iran. Such findings lay a foundation to formulate adaptation and mitigation strategies for water resource management, which play a significant role in acting towards achieving the 2030 United Nations Sustainable Development Goals (SDGs).

Rivers and Lakes: Nature’s waterways, shaping life and land

04-06-2025 - 10:45 - 12:00

Askja N-132

Laser scanning of northern river transition zone characteristics – A review

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Northern river systems exhibit distinctive biodiversity in transition zones (riparian, littoral and hyporheic) where the aquatic and terrestrial systems interact. These zones are controlled by geo- and hydrodiversity features shaping their unique ecological structure. Riverine transition zones are globally recognized as geo- and biodiversity hotspots as they support diverse mosaics of habitats, land cover, vegetation patterns, and species distributions. Despite their importance, transition zones have often been overlooked as they are facing many threats due to anthropogenic activities and climate change altering their natural development. However, it remains largely unknown how to quantify and monitor the change of these structurally complex zones in space and time.

Over the last two decades, the technical and methodological advancements of close-range remote sensing, particularly laser scanning, have revolutionized how we characterize the structure and composition of river transition zones. Laser scanning technologies can provide non-intrusive, cost-effective, repeatable, and spatially continuous data over wide landscapes with varying temporal and spatial resolutions. The cutting-edge mobile laser scanning platforms, such as unmanned surface vehicles, and drones combined with novel multispectral sensors (including green wavelength with capability to penetrate water surface) have allowed an efficient and precise mapping of both over- and underwater characteristics of river systems. Here, we review the current state-of-the art of laser scanning technologies to quantify and monitor transition zone characteristics. Specifically, we synthesize the existing knowledge of how the level of spatial, temporal and spectral detail of laser scanning data may affect the observable detail and richness of transition zone characteristics.

Towards public benchmark of open source hydrological model Shyft

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Shyft is an open-source toolbox for uncertainty analysis and energy market simulation, including **Shyft.hydrology**, which focuses on hydrological forecasting and modeling. The toolbox is developed by Statkraft AS in cooperation with University of Oslo. It facilitates collaboration between industrial sector and academia. **Shyft.hydrology** consists of components with varying complexity, representing different hydrological processes, which can be combined into conceptual models. **Benchmarking** these components is crucial for assessing model **reliability** and **robustness** across **diverse conditions.**

We present a public benchmark of **Shyft.hydrology** using historical streamflow simulations for **109 catchments in Norway**, covering five hydrological regimes: **mountain, inland, Atlantic, Baltic, and transient.** The **calibration period spans 1981–2000,** and **validation covers 2001–2020.** Five

conceptual models, with and without precipitation correction, were compared against a **climatological benchmark.** Models were calibrated using **10 goal function variants** (e.g., KGE, LKGE, bcKGE, KGE_LKGE, KGE_bcKGE, NSE, LNSE, bcNSE, NSE_LNSE, NSE_bcNSE) and evaluated with **KGE, NSE, and PBIAS.**

Results indicate that all selected Shyft.hydrology models outperform mean and median flow benchmarks in most cases. A recently developed model, incorporating radiation correction on inclined surfaces, Penman-Monteith evapotranspiration, a snow-tiles temperature index model, and the Kirchner routine for surface flow, outperforms others but requires precipitation correction for all regimes except transient. Mountain and inland regimes show high sensitivity to precipitation correction, though comparisons are limited due to differences in catchment populations. KGE_bcKGE emerges as a strong general-purpose calibration target within the **Shyft.hydrology** toolbox.

This work contributes to the **SnowSub** project (Assessing snow sublimation for hydropower production in Norway).

A new lake ice model for estimation of the breeding habitat of the endangered Saimaa ringed seal in a changing climate

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A lake ice model of Watershed Simulation and Forecasting System (WSFS-Ice) was developed for estimation of ice and snow conditions in Lake Saimaa during the pupping season of the Saimaa ringed seal. This model is also used for operational lake ice monitoring and forecasting in Finland. The WSFS-Ice model is based on energy balance, enabling reliable estimation of the ice cover evolution in current and future climate. The model was calibrated against ice thickness, ice type, snow depth and snowdrift depth observations. A delta-change method was used to alter control period temperature and precipitation observations and the effect of CO_2-concentration on longwave radiation was estimated according to various climate scenarios. A sensitivity analysis of the effect of wind speed, humidity and cloudiness on lake ice and snowdrift formation was performed. Snowdrifts on lake ice provide vital breeding habitats for the endangered Saimaa ringed seal. Based on climate scenarios with intermediate representative concentration pathway (RCP4.5), the breeding habitat of the Saimaa ringed seal deteriorates during the 21st century. The mean depth of the snowdrifts is projected to decrease approximately to half from the 1981–2010 to 2070–99 period and at the same time the ice-covered period is reduced by one and a half months. During the mildest winters the ice cover is projected to melt even before the pupping season has ended. The results highlight the importance of climate change mitigation and active conservation measures to enhance seal population growth, enabling it to survive in a changing climate.

Estimation of Water Quality Parameters Using Remote Sensing Data and Deep Transformer Networks

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Continuous monitoring of Water Quality Parameters (WQPs) is vital for maintaining the sustainability of aquatic ecosystems. Thanks to their broad coverage, high revisit frequency, and rich spectral information, Remote Sensing (RS) data are pivotal in this field. However, estimating WQPs from RS data is inherently

challenging due to the complex spectral behaviors of various water constituents, atmospheric interference, and sensor limitations. Artificial intelligence (AI)—and more specifically Deep Learning (DL), a subset of Machine Learning (ML)—provides a promising approach to these nonlinear, complex tasks. Although numerous DL architectures, such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), have been proposed, they often struggle to capture sequence-related characteristics, particularly medium- and long-term dependencies. In contrast, Transformers are regarded as cutting-edge backbone models because of their self-attention mechanism, which is especially suited to handling sequential problems. Accordingly, this research reconsiders WQP retrieval from RS data from a sequence-data perspective, leveraging state-of-the-art Transformer-based neural networks. To the best of our knowledge, Transformers have not yet been applied in this field. The proposed methodology was tested for estimating WQPs using Sentinel-2 satellite imagery. The results demonstrated that Transformers outperformed other DL architectures, as well as traditional ML methods such as Random Forest (RF) and Support Vector Regression (SVR). The proposed approach can be utilized to effectively monitor surface water quality across Nordic nations.

Spatial Data Processing for Water Quality Modeling: A Case Study of the Berze River in Latvia

Ieva Siksnane [1] Ainis Lagzdins [1], Arturs Veinbergs [1]

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Hydrological models provide simplified representations of natural systems, integrating surface and subsurface processes. By incorporating quantitative and qualitative datasets, these models assess hydrodynamic conditions within a catchment and identify nutrient sources, transport pathways, and fluxes. A key function of a model is predicting variations in total nitrogen (TN) and total phosphorus (TP) leaching, essential for water quality preservation. This aligns with Council Directive No. 91/676/EEC, which aims to mitigate agricultural nitrate contamination.

The Nordbalt-Ecosafe project focuses on maintaining nitrogen and phosphorus concentrations within ecologically safe limits in the Nordic-Baltic region. The SWAT+ model is employed to quantify daily nutrient fluxes, source contributions, and retention mechanisms, supporting data-driven watershed management.

Model development in SWAT+ begins with spatial data acquisition and preprocessing, including delineation of catchment boundaries and characterization of hydrological attributes. The case study is based on the Berze River catchment, located in the central part of Latvia (area 882 km²) with ongoing water quality monitoring since 2005.

Integrated spatial datasets include: river networks, 15 water sampling points, one hydrological gauging station, sub-catchment boundaries, a high-resolution digital elevation model (DEM), Corine Land Cover 2018 data, soil texture classifications, crop distribution from 2017 to 2022, digitized lakes and drained areas, and wastewater treatment plant locations.

This study provides guidelines for spatial data preparation for SWAT+ modeling of the Berze River. Geospatial data processing is conducted using ArcGIS Pro and QGIS, ensuring precise spatial analysis.

This study was funded by a grant from the EU Horizon project NORDBALT-ECOSAFE (Grant Agreement No. 101060020).

Green Engineering: Nature-based solutions in urban areas, agriculture, forestry, mining, aquaculture, and more

04-06-2025 - 10:45 - 12:00

Askja N-131

Carbon Sequestration through Blue-Green Infrastructure

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Blue-green stormwater solutions are an inherent component of climate resilient cities. Historically, their primary function was to reduce the flood risk associated with more intense rainfall and protect receiving waters by filtrating water and pollutants through soil and vegetation. More recently, they are valued for their carbon sequestration potential as well as ecological, aesthetic and recreational functions. BGOs are therefore both an adaptation and mitigation measure against climate change. The goal of this research was to assess the carbon sequestration potential of the most common and flexible form of BGI. Two bioretention cells were constructed in the summer of 2024 following best practices, with 45 cm sand and soil mixture, a drainage layer and diverse set of native herbaceous plants as well as shrubs. Carbon fluxes were monitored using an EGM portable gas analyzer on weekly basis in two configurations of these cells, as well as nearby extensive green roofs constructed in 2014 and 2017 respectively and grass lawn. The results from the first year of plant establishment confirm a strong seasonal cycle, with limited carbon sequestration activity in winter. The new bioretention cells sequestered a similar amount as the older adjacent grass lawn, but more than the two types of extensive green roofs with only 5-10 cm soil layer. The results will be discussed in relation to international literature.

Digital tool for agricultural water management – easy access simulation with open gridded meteorological data

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Hydrological models are customary tools for numerical assessment of water management alternatives to control water table, soil moisture, drain discharge, surface runoff, and evapotranspiration, and as a result, improve crop growth and mitigate environmental impacts. From the water management designer's viewpoint, hydrological modelling is still not easily available or usable for their practical purposes. The aim was to develop an automated tool for bridging open meteorological data sources with state-of-the-art hydrological model FLUSH to allow easy data access and operation of a model. A script and graphical user interface were constructed as part of the Mavela project to extract meteorological data, generate model input data, and allow a user to run hydrological simulations based on a user-defined soil type, water management, and location settings. The tool is applicable over whole Finland, where daily gridded weather data are openly available to generate historical model input series. The tool is a demonstration how a research tool can be transformed into a user-friendly interface, where seamless operation of the model is facilitated. Stakeholder feedback from professionals in the field of agricultural water management was gathered to detect their priorities regarding the outcomes of the tool. The simulation results of the tool were tested against hydrological measurements available from experimental research sites in southern and central Finland. Comparison against the experimental data provided view on the accuracy and limitations of the tool.

Intensified forest management: balancing the demand for renewable resources with environmental considerations

Ivars Kļaviņš [1, 2] Zane Kļaviņa [1, 2], Arta Bārdule [1], Zane Lībiete [1]

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Forestry is one of the main economic sectors in Latvia. With forest cover exceeding half of the territory and the use of sustainable practices, Latvia has become an important player in the market. Biomass is the main renewable energy source consumed in the EU that greatly contributes to the mitigation of the effects of climate change by substituting fossil fuels. Furthermore, forest woody biomass, already an important renewable resource in Latvia, still has the potential to be utilized on a larger scale. Besides the traditionally harvested stem wood, the extraction of nutrient-rich logging residues and lower value timber for energy is increasing. Consequently, the environmental effects of intensified forest management must be carefully considered to avoid undesirable consequences.

This presentation summarizes key findings of several related experiments, demonstrating changes in soil solution, surface water, groundwater, and site productivity after stem-only harvesting, whole-tree harvesting, whole-tree harvesting with stump removal as well as in control sites with no intervention. Furthermore, natural occurrence, levels, methylation and transport of Hg in management-induced depressions (ruts and mounding pits) were studied.

Retaining logging residues in eutrophic sites may stabilize nutrient losses, while in oligotrophic sites it may cause additional leaching. Stump harvest inevitably enhances mineralization, but enhanced regenerated stand productivity was not observed. The management-induced depressions were identified as Hg methylation hotspots with significantly higher MeHg concentrations in sediments than in the surrounding soil. Furthermore, lower total Hg concentrations were observed in sediments than in surrounding soil, indicating transport away from the source in the past.

Where it begins: water quality and its protection in forest drainage systems

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Freshwater resources are abundant in Latvia; however, with only 3% of the country's surface waters corresponding to high ecological quality and 34% classified as good, there is significant potential for improvement. Moreover, nutrient loading has been recognized as a major threat to the Baltic Sea ecosystem. Although other sectors such as agriculture and industrial sector have a greater impact on water quality, forests cover more than a half of country’s land area, and their management may have a significant impact on water quality. Therefore, maintaining relatively good water quality in forest drainage systems is essential to prevent deterioration of water quality in connected water bodies.

In order to demonstrate the impact of various forestry-related activities on water quality, in this presentation, findings from several studies are summarized, including the catchment-scale impacts of drainage network maintenance, fellings and forest road construction; testing custom water protection structures; distribution and levels of mercury and methylmercury; the impact of beaver dam removal; quantitatively evaluating effects of forestry activities using critical load modelling approaches.

Drainage network maintenance mitigated acidification risks by increasing runoff and promoting the discharge of confined aquifer waters, but also significantly increased export of nitrogen compounds. Disturbed sites had higher DOC and nitrogen concentrations compared to undisturbed sites. MeHg concentrations in sediments were higher in undisturbed sites. Beaver dam removal caused short-term water quality changes in drainage ditches, while pristine beaver site maintained stable and favorable conditions. Custom water protection structures were most effective in reducing TSS export as well as concentrations.

Stormwater planning in closed depression landscape – Gryfino, Poland

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Closed depression landscapes are more vulnerable to hydrological changes from urbanization due to the absence of natural outlets. Urban development leads to increased runoff, which accumulates in low-lying areas, heightening flood risks and sediment buildup that obstructs groundwater infiltration, ultimately degrading hydrological function. Without proper stormwater planning, cities incur high costs for retrofits like pumping systems, flood control infrastructure, or buying flood-damaged properties.

A conceptual stormwater management plan provides strategies for managing and directing stormwater runoff to protect the environment, public health, and safety. Blue-green infrastructure, is a strategically planned network of natural and semi-natural areas in the urban environment designed to deliver ecosystem services.

A study in Gryfino, Poland, evaluated the hydrological changes in an urbanizing neighborhood using this approach and recommended changes in zoning, public infrastructure, and the implementation of blue-green infrastructure to reduce flood risk, enhance water quality, and ensure long-term hydrological sustainability. The study found that while blue-green infrastructure could significantly improve post-development hydrology, it cannot fully mitigate urban impacts. Implementing blue green solutions reduced flood stage/depth increases by 30%-80% in closed depressions compared to pre-development conditions. A stormwater plan was developed to floodproof roads, allocate land for stormwater treatment, and define overflow paths to protect infrastructure. However, institutional barriers like zoning regulations, development practices, and cultural norms hindered full implementation of the plan's recommendations.

Risk Assessment, Mitigation Measures, and Management Effectiveness

04-06-2025 - 13:00 - 14:15

Gróska – Main Hall

The Impact of Climate Change on Water Stress in a Highly Regulated River: Sensitivity to Changes in Energy Demand, Water Use, and Regulations

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Climate projections for the Drammen River basin indicate a slight increase in annual runoff with an increase during winter and a decrease during summer. These changes in runoff will, in conjunction with changes in energy demand, regulations (licensing) of hydropower reservoirs, domestic, industrial and agricultural water demand, affect energy production and the severity of water stress events.

As part of the HorizonEurope STARS4Water project, the aim of this study is to combine climate projections with different narratives for energy demand, environmental restrictions (regulations) and water demand to identify when it is more likely that critical situations violating regulatory constraints might occur, and if the frequency and severity of such events will change. This information can guide planning and optimization of available water resources.

We first estimate changes in water availability and energy production for CMIP5-RCP4.5 projections using three combinations of GCM and RCMs combined with two different downscaling methods (Climate in Norway 2100 NCCS report no. 1/2017, Hanssen-Bauer et al 2017). The HBV and LISFLOOD hydrologic models are used to calculate changes in runoff for a future period as compared to a reference period. Subsequently, the simulated runoff is used as input to the One-area Power-market Simulator EOPS (aka VansimTap) to estimate changes in energy production, reservoir water level and environmental flows.

In a second step, we investigate how narratives of selected socio-economic developments might affect water stress in the basin. The narratives include changes in energy demand regulations (licensing) and water demand.

Challenges to water access in Arctic communities at times of global changes

Pernille Erland Jensen [1] Ida Huusmann Knøfler [1], Judith Marechál [1]

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Lack of access to in-home piped water comes at significant health impact. In Greenland many rural households do not have access to piped water, and water resources are too limited to support the desired increased water consumption by piping in some of the unserved communities. Because lakes are the predominant water resource in Greenland, climate change impacts may further destabilize water access. We assessed the current water accessibility in Greenland and found that 10% of households do not have access to piped water. Most of the unserved households are in the rural communities, where 78% fetch water from an outdoor public tap house. The service deficits increased with distance to the capital region. We also assessed the potential to expand water access and found that of 14 communities where some households are served, seven have ample and seven have somewhat challenged water resources. Of 40 communities with limited or no piped water, 20 have ample water resources, six somewhat restricted water resource, and 14 little/no opportunity to expand/increase their water resource. Finally, we evaluated how potential climate change impacts could affect the water accessibility in Greenland and found that despite the prospects of increased meltwater volumes, significant threats to quantity as well as quality persist. We conclude that efforts to evaluate and quantify these emerging threats are as needed as adaptations to secure health in communities subsisting on limited resources.

The MEDiate project: A framework for assessing multi-hazard interactions and compound risk

Matthew James Roberts [1]
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Funded by the European Union, the MEDiate project is developing a Decision Support System (DSS) for disaster risk management that integrates multiple interacting hazards and cascading impacts, using a resilience-informed, service-oriented, and people-centred approach. Central to the project is the transition from single-hazard analysis to a comprehensive multi-hazard framework - an essential shift in the face of climate change and increasing systemic risk. This presentation introduces the MEDiate DSS and its underlying methodologies, with a specific focus on flood hazard interactions as a key component of the project. Flood-related hazards, including compound flooding, river–coastal interactions, and flash floods, are among the most frequent and damaging in Europe, often producing cascading effects across natural and built environments, including critical infrastructure. The project identifies and classifies these flood interactions according to their physical mechanisms: multivariate, preconditioned and triggering, temporally compounding, and spatially compounding. This typology is then applied across case studies in Oslo (Norway), Nice (France), Essex (UK), and Seyðisfjörður (Iceland). These testbeds represent diverse geographic, climatic, and urban settings, enabling the project to explore both localised and systemic flood risks. The DSS integrates hazard interaction data, climate projections, and exposure models to support the visualisation, planning, and prioritisation of resilience measures. Ultimately, MEDiate aims to provide stakeholders with actionable insights into how specific interventions can reduce the compounded risks posed by future floods, thereby supporting more informed, equitable, and future-oriented risk management.

Climate-Induced Shifts in Critical Source Areas and Their Implications on Nutrient Loads: A Case Study of the Vantaanjoki River Basin

Abubaker Omer [1] Harri Koivusalo [1], Eliisa Lotsari [1]

[1] Aalto University, Espoo, Finland

Critical Source Areas (CSAs) are key contributors to nutrient pollution in watersheds, yet their spatial distribution is often assumed to be static in regulatory and mitigation frameworks. Climate change is expected to alter temperature regimes, precipitation patterns, hydrological processes, and nutrient transport dynamics, potentially shifting CSAs over time. Such shifts in CSAs may challenge existing water quality management and nutrient load reduction strategies for meeting environmental targets in the river basin. This study investigates how climate change impacts CSA locations and their implications for achieving targets of nutrient load reductions in the Vantaanjoki River Basin, Finland. Using SWAT+ hydrological modeling coupled with CMIP6 climate projections, we simulate CSA spatial variability under different future climate scenarios (SSP2-4.5, SSP5-8.5) and timeframes (2021–2050, 2051–2075, 2076–2100). We aim to evaluate whether current nutrient load controls (i.e., wastewater treatment, agricultural best practices, and stormwater retention) remain effective in preventing eutrophication as CSAs shift and explore the need for adaptive, climate-responsive controls. By applying this approach over a human-impacted watershed facing increasing climate variability and urban pressures, this study will provide insights for regional water management and policy adaptation. The findings will contribute to developing a dynamic nutrient control framework, paving the way for the integration of real-time monitoring and decision-support modeling to support adaptive watershed management. This research aims to guide the future-proofing of nutrient load regulation against climate variability and inform policy adaptations for improved water quality management in Finland and beyond.

Assessment of jökulhlaup hazard and risk in Iceland

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A jökulhlaup is a flood caused by the sudden emptying of a water body within a glacier, and occasionally by rapid melting of ice caused by a volcanic eruption. The water bodies can be supraglacial lakes, proglacial lakes, or subglacial lakes. Jökulhlaups are an important part of the hydrology of Iceland's glaciers. Altough a vast majority of jökuhlaups are much smaller, the largest events observed have a maximum discharge on the order of hundred thousand cubic meters per second and a maximum flood volume on the order of cubic kilometers. In Iceland, jökulhlaups are most often caused by an interaction between glaciers and geothermal and/or volcanic activity. These floods are one of the main natural hazards related to glaciers in Iceland. Jökulhlaups may endanger people and livestock and there has been an enhanced risk to people in recent years due to increased tourist activity in exposed areas. Jökulhlaups can damage different infrastructure such as roads, communication lines, farmland, hydropower plants and power supply systems. There are around 1–3 hazardous floods per decade causing damage. The hazard and the risk caused by jökulhlaups needs to be assessed and quantified for land-use planning and risk reduction. The main findings from this work include i) that the local risk in certain proglacial areas is such that further development of accommodation cannot be recommended, and ii) that the individual annual risk of death due to a jökulhlaup for people working in the proglacial area can be higher than in general traffic.

Rivers and Lakes: Nature’s waterways, shaping life and land

04-06-2025 - 13:00 - 14:15

Askja N-132

Impacts of warming climate and defrosting sedimentary systems on the evolution and material transport of seasonally frozen high-latitude rivers

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Nordic rivers experience significant seasonal variability due to ice formation, freeze-thaw cycles, and changing climatic conditions, affecting flow hydraulics, sediment transport, and riverbank stability. This research explores the hydro-morphodynamic behavior of seasonally ice-covered rivers, focusing on flow velocity variations, sediment erosion susceptibility, and long-term changes in sediment transport under projected climate scenarios.

Field measurements from Pulmanki River (Finland) and Sävar River (Sweden) provide empirical data for assessing ice-covered and open-channel flow differences. Using Acoustic Doppler Current Profiler (ADCP) measurements, we analyze how river ice modifies velocity profiles, shear stress distributions, and turbulence compared to open-water conditions. Furthermore, geotechnical analyses, including triaxial shear tests, are conducted on riverbank sediments to determine their erosion susceptibility and response to freeze-thaw cycles. Results highlight the varying erosion resistance between different sediment compositions and the impact of seasonal hydrological changes.

Hydraulic comparisons are based on ADCP-derived cross-sectional flow visualizations. These cross-sectional images provide direct insight into how flow characteristics change between ice-covered and open-channel conditions, enabling a robust comparison of hydraulic dynamics under different seasonal states. Additionally, large-scale sediment transport simulations with the CAESAR-Lisflood model integrate climate projections to assess how altered discharge patterns influence long-term sediment dynamics.

Findings suggest that shorter ice-covered seasons will lead to increased wintertime erosion and modified sediment transport regimes, impacting river morphodynamics and downstream ecosystems. This research provides crucial insights for predicting climate-induced hydrological changes in high-latitude rivers and supports adaptive water resource management strategies in cold regions.

Defining a frost-free season for minimum-flow requirements

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Estimates of low-flow indices in ungauged catchments are needed for example to guarantee environmental flows in case of hydropower or other types of river regulations. In regions with prolonged frost-periods, summer and winter low-flows should be distinguished as they are caused by different processes and affect riverine ecosystems differently. In Norway, the required minimum-flows for river regulations are based on the 5th percentile (Q95; the flow, which is equalled or exceeded during 95% of the time) for a fixed summer season (May 1 – September 30). However, how well this fixed summer season corresponds to the local frost-free season varies throughout the country and might change due to climate change. We therefore investigate different criteria for defining a frost-free season and assess the sensitivity of Q95 and AM7 (annual minimum 7-day discharge) to the choice of definition.

We use a national reference dataset of near-natural catchments with 30 years of daily discharge data (1991-2020) and derive annual series of start ($Start_{FFS}$) and end (End_{FFS}) of the frost-free season for each catchment from the gridded (1x1 km) SeNorge2018 temperature data. We analyse variability and trend in the $Start_{FFS}$ and End_{FFS}-series (for different definition criteria) and in the derived annual Q95- and AM7-series and compare the results with using a fixed summer season. The definition of the end of the frost-free season is particularly critical in catchments where the lowest summer low-flows occur at the end of the frost-free season, where it has the largest effect on AM7.

Understanding Changes in Iceland's Streamflow Dynamics in Response to Climate Change

Hörður Bragi Helgason [1, 2] Óli Grétar Blöndal Sveinsson [1], Andri Gunnarsson [1], Bart Nijssen [2]

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The hydrological cycle in high-latitude regions is undergoing significant changes due to climate change. Iceland, with its extensive data from undisturbed catchments, provides a unique opportunity to study these changes. Recent decades have seen warming outpace global warming trends in Iceland, along with increased precipitation and reduced glacier mass. Our study uses the LamaH-Ice dataset, which includes streamflow observations, atmospheric forcings from climate reanalyses, and catchment characteristics, to investigate changes in Iceland's streamflow dynamics over recent decades. We first examine the long-term variability in streamflow and its primary drivers, correlating it with major climate indices. We then analyze trends during the last 30 and 50 years in annual, seasonal, and daily streamflow volumes, the timing of the spring freshet, and extreme flow conditions, linking these changes to environmental conditions and catchment attributes.

Results show high inter-annual variability, decadal fluctuations, and strong correlations with the Arctic Oscillation, as reported in earlier studies. Streamflow trends vary by location and river type, with increased precipitation driving higher annual average flows in most rivers, while summer flows have decreased in most rivers. This study is the first to report coherent regional and seasonal trends in Icelandic streamflow. Annual low flows have increased in most rivers, glacial rivers show positive streamflow trends during the last 50 years, but negative trends during the last 30 years. This study enhances our understanding of Icelandic hydrology and contributes to global knowledge on climate-induced hydrological changes.

Understanding climate variability and water resource resilience in Estonian catchments

Oliver Koit [1] Joonas Pärn [2], Siim Tarros [2], Marlen Hunt [2], Hoang Anh Chu Nguyen [1], Pamela Abreldaal [1], Annabel Eensoo [2], Jaanus Terasmaa [1], Rauno Künnapuu [3]

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[3] Estonian Environment Agency, Tallinn, Estonia

This research presents an overview of multiple ongoing and planned studies assessing climate change impacts on Estonian water resources. We apply time series analysis, spatial analysis, and machine learning models on historical hydroclimatic, water quality, and spatial datasets to evaluate both short- and long-term hydroclimatic variability and water resource resilience. Historical data analysis forms the conceptual basis for an ongoing pilot catchment monitoring program, which provides inputs for developing hydrological models aimed at assessing future climate scenario impacts on water resources.

Focus study results highlight how climate change reshapes Estonian water resources, revealing patterns of hydrological sensitivity, groundwater connectivity, and shifts in runoff and nutrient fluxes. Preliminary findings identify distinct catchment clusters with varied responses to climate drivers, such as increased DOM and NTOT loading linked to land use and warming trends. Climate shifts are altering seasonal runoff, reducing spring floods, and intensifying winter flows. Machine learning models show promise in estimating groundwater dependence, aiding assessments in ungauged catchments.

These studies, both ongoing and planned, illustrate the interactions between climate, land use, and water resources, emphasizing the need for adaptive management strategies. The research is part of the LIFE21-IPC-EE-LIFE-SIP AdaptEst initiative, supported by the Ministry of Climate, Estonian Environment Agency, Geological Survey of Estonia, and Tallinn University.

Community-Based Water Monitoring: Citizen Science Tools for Springs, Lakes and Rivers

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Citizen science is an effective and cost-efficient method for environmental monitoring that produces valuable data for tracking water quality trends. Volunteer data collection provides critical information on waterbodies that might otherwise go unmonitored. We present two volunteer-based monitoring programmes in Estonia targeting different water resources. The first programme, an alternative to traditional monitoring, focuses on springs. The web-based application allikad.info, launched in 2021, allows volunteers to report, verify, and update the locations, conditions, and water quality of springs. So far, 344 users have contributed data, including over 1700 new springs, 2700 observations, and more than 8000 photos.

In 2024, the new application veestik.info was launched for surface water monitoring of lakes, rivers, and other water bodies. Volunteers can create new observation stations, submit observations, and review or correct existing data, which is then verified by administrators. The databases are publicly available, supporting transparency and open science. Together, these applications complement traditional water monitoring networks, promote community engagement, and raise awareness of the links between human activity and water quality. Our findings show that citizen science can improve water resource management and conservation by filling gaps in monitoring networks and integrating volunteer-collected data into government databases. We have also found that partnerships with educational institutions, such as schools and universities, generate robust long-term data, while targeted media campaigns and social media usage significantly boost volunteer engagement. We are exploring possibilities of AI to enhance data collection and quality assurance through automated guidance, feedback, smart image analysis, and interactive mapping.

Green Engineering: Nature-based solutions in urban areas, agriculture, forestry, mining, aquaculture, and more

04-06-2025 - 13:00 - 14:15

Askja N-131

The optimal bioretention cell design: striking the balance between substrate, saturation and vegetation

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This study examines how media composition, vegetation, and saturation zones influence dissolved nutrient removal in bioretention cells.

Twenty-four polyethylene columns (400 mm diameter, 80 cm depth) were used to test two media types: a control mix (90% pumice, 10% coconut coir) and an amended mix (10% iron-coated sand from a Danish drinking water treatment plant). For each media type, four configurations were tested in triplicate: (1) media only, (2) media with vegetation (*Carex appressa*), (3) media with a 40 cm saturation zone, and (4) media with both a saturation zone and vegetation.

Columns received simulated rainfall (4.3 mm in 10 minutes, three times per week) with semi-synthetic runoff spiked with PO_4^{3-} and NO_3^-. Findings indicate that iron-coated sand significantly enhances phosphorus (P) retention. While previous studies have demonstrated the effectiveness of water treatment residuals, ochre sludge, and lab-produced iron-coated media in P capture, utilizing iron-coated sand from drinking water filters emerges as a viable, sustainable, and innovative alternative. Vegetation had minimal impact on nutrient retention, whereas the presence of a saturation zone significantly improved phosphate and nitrate removal across both media types.

Despite concerns that reducing conditions in the saturation zone could trigger P release, no such effect was observed. This was likely due to limited carbon availability, as coconut fibers were placed only in the top 40 cm. Additionally, nitrate, a preferred electron acceptor, may have prevented Fe^{3+} reduction. Overall, these findings highlight the importance of integrated bioretention designs for effective stormwater treatment.

Characterisation of marine plastics recycling technologies and definition of a blue circular bioeconomy concept

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The issue of marine plastics, characterised by the accumulation of large quantities of plastic waste in the oceans, stands as one of the most critical environmental crises of the 21st century. It is estimated that over 8 million tons of plastics enter the oceans each year, affecting marine life, coastal ecosystems, and even human health. Among the proposed solutions, ocean plastic recycling stands out as a viable and

essential strategy to tackle this challenge. The need to remove plastics from the oceans is evident, but the technical, logistical, and economic challenges are considerable. While marine plastic recycling is a promising solution, it still faces various barriers. This paper delves into the recycling technologies and innovations focused on marine plastics, emphasizing the potential of advanced tertiary and quaternary recycling processes. These methods offer the potential to transform degraded plastics by breaking them down into fundamental chemical components or converting them into energy, thus addressing both the removal of impurities and the recovery of valuable resources.

This paper also identified the European and global companies currently engaged in the process of ocean plastic recycling with each type of technology or those with the potential to become leaders in this field. Additionally, the possibility of forming industrial clusters that can collaborate to accelerate innovation and effectiveness in ocean recycling operations will be explored. Finally, a matrix of relationships between technologies and companies was created, focusing on the environmental, economic and social benefits, and the possible final destinations of each by-product after recycling.

The practical application of nature-based solutions to river management: case studies from Iceland, Norway and Scotland

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Engineering or management works are often required where infrastructure such as roads, pipelines, cables, buildings and agricultural land interact with rivers and their floodplains. Activities such as flood embankments, bank protection, dams/ weirs, channel realignments, dredging, bridges/ culverts and flow deflections are common engineered solutions to a range of river management issues, including flood risk, channel scour/ erosion, water abstraction, energy generation and land management. While such works must deliver a functional outcome, there is an increasing requirement that they are sustainable in the longer term and sensitive to the natural environment. Such objectives are best achieved by working with natural river processes, finding solutions that aim to reproduce/ reinstate the natural form and function of stable channel-floodplain systems. This ‘nature-based’ approach is now at the heart of decision making by regulatory bodies of many countries and, delivered appropriately, also provides significant benefits to ecology/ biodiversity, climate change resilience and societal wellbeing.

We describe the background to this approach, the advantages of its application and the regulatory/ legislative context (particularly in relation to WFD objectives). Importantly, we provide practical examples of design/ construction methods as case studies of works that have been implemented in Iceland, Norway and Scotland. These will cover common river management activities, including bank protection, flood risk management, barrier (i.e. dam/ weir) management, sediment management and ecological restoration. These examples will focus on higher energy environments common in Nordic areas, where consideration of physical process in the design of stable and sustainable river works is especially important.

Heavy metals in runoff from a neighborhood employing nature based solutions

Hrund Ólöf Andradóttir [1] Stefanía Valdimarsdóttir [1], Tarek Zaqout [1]

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Urriðaholt is the first BREEAM (Building Research Establishment’s Environmental Assessment Method) certified neighborhood in Iceland. The stormwater is managed predominantly from this residential neighborhood via blue green solutions. For example, roof runoff is conveyed to an infiltration pit, parking areas are permeable. Street runoff and overflow from lawns is connected to a grass swale. The goal of this study was to assess whether the surface runoff was less polluted in an urban cathment that employed nature based solutions. Stormwater samples were collected via an autosampler during four

events spanning different seasonal runoff mechanism such as a rain on snow, intense summer reain, and heavy spring and fall rain. The volumentric inflow rate was also monitored. Samples were analyzed for conductivity, turbidity, total suspended solids (TSS) and heavy metals. The result showed that the heavy metal concentrations in Urriðaholt tended to be on the same order of magnitude as measured in another urban neighborhood not employing nature based stormwater solutions. The reason was likely that most of the runoff were directed of the street, and limited runoff from grass lawns. Overall the runoff coefficient of the neighborhood was much lower, and hence the pollutant loads, supporting the notion that the pollutants were stored, at least temporarily, in the local soils.

Influence of soil and vegetation cover in the hydrological performance of bioretention cells in cold maritime climate

Gonzalo Patricio Eldredge Arenas [1] Hrund Ólöf Andradóttir [1], Tarek Zaqout [1]

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Bioretention cells are the most commonly employed nature-based stormwater solutions in urban areas. In this presentation, the preliminary results of the hydrological performance of four bioretention cells in Iceland will be discussed. The cells were constructed based on best practices, incorporating a 45 cm thick filter media with a customized blend of local soil and sand, 25 cm drainage layer and surface cover with diverse herbicious local plants. Two of the cells also included native flowers and shrubs with deeper roots. Two duration synthetic runoff experiments were conducted on weekly basis from December 2024 to May 2025. The performance of the cells to infiltrate and delay runoff was estimated from runoff hydrograph. Results shed insights to how sensitive the cells are to changing weather and soil conditions and whether the performance drops significantly in winter during soil frost and snow cover. The role of deep rooted plants and soil media will also be considered.

References

CIRIA. (2015). *The SuDS manual C753.*

Khan, U. T., Valeo, C., Chu, A., & van Duin, B. (2012). Bioretention cell efficacy in cold climates: Part 1 - hydrologic performance. *Canadian Journal of Civil Engineering*. doi:https://doi.org/10.1139/l2012-110

Zaqout, T., & Andradóttir, H. Ó. (2021). Hydrologic performance of grass swales in cold maritime climates: Impacts of frost, rain-on-snow and snow cover on flow and volume reduction. *Elsevier*. doi:https://doi.org/10.1016/j.jhydrol.2021.126159

Risk Assessment, Mitigation Measures, and Management Effectiveness

04-06-2025 - 14:45 - 16:00

Gróska – Main Hall

Soil amendments as water protection measures – farmers' and advisors' perspectives on bottlenecks and opportunities

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Agriculture significantly contributes to nutrient loads in the Baltic Sea, which necessitates the implementation of effective management strategies to mitigate environmental impacts. Soil amendments — such as gypsum, structure lime, and pulp and paper mill sludges — have been shown to reduce nutrient leaching, improve soil health and structure, and potentially boost crop yields. However, their uptake by agriculture practitioners remains limited by challenges with supply, cost-effectiveness, and prevailing preconceptions among stakeholders.

We present the results of stakeholder-based research aimed at identifying the existing bottlenecks and opportunities associated with the broader adoption of soil amendments in agricultural systems. We interviewed a total of 11 farmers and 5 advisors in Southwest Finland, within an agriculture dominated catchment draining into the northern Baltic Sea. Additionally, we collected survey responses from 22 advisors. The data were analyzed using a mixed-methods approach.

The research adds to the scant literature elucidating grassroots-level understanding of utilization of soil amendments. Results identifying the stakeholder knowledge gaps and misconceptions can be used to better promote sustainable agricultural practices leading to improved water quality in the Baltic Sea region.

This research is part of AIN3 and DIWA doctoral pilot projects funded by the Ministry of Education and Culture (Finland), the Ministry of Environment (Finland) and the Research Council of Finland.

Impacts of structure lime on soil properties in agricultural lands for water protection

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The primary motivation of lime application is to raise soil pH, impacting chemical, physical, and biological properties. Structure lime, a mixture of calcium carbonate (agricultural lime) and active calcium (quick lime, CaO or slaked lime $Ca(OH)_2$), increases Ca^{2+} concentration in soil solution, enhancing ionic strength. This promotes formation of water-stable aggregates through flocculation of soil particles and

reduces erosion and phosphorus leaching from fields. Hence, use of structure lime as a soil amendment has gained attention as a water protection measure. In Swedish studies, significant reduction of especially particulate phosphorus but also dissolved reactive phosphorus was observed after applying structure lime to clay soils.

While long-term liming effects have been observed in Swedish conditions, there is less knowledge about this in Finland. Although structure lime can reduce phosphorus leaching, its impacts on soil fertility may need more investigation. We found statistically significant increase in soil pH and calcium concentration up to four years after structure lime application, consistent with the long-term effects observed in Swedish soils. Interestingly, electrical conductivity was significantly higher during the first two years after soil treatment but returned to the pre-treatment level by the third and fourth years. Magnesium concentration showed a decreasing trend in the first three years, potentially due to cation exchange reaction, although the changes were not statistically significant. This suggests that potential mahnesium leaching should be considered when applying lime. Plant available phosphorus was significantly higher after the first, second and fourth years of amendment, probably because of increased soil pH.

Simulating jökulhlaups from the Bárðarbunga caldera (Vatnajökull ice cap, Iceland) triggered by subglacial volcanic activity

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Jökulhlaups can emerge from the subglacial Bárðarbunga caldera, triggered by volcanic activity. The direction of the floodpath can vary significantly depending on the location of the eruption site with respect to the subglacial hydrological catchments of different rivers, either flowing north, west or south from the Vatnajökull ice cap. Jökulhlaups flowing southwest are the theme of the current work. Different scenarios are analysed by numerical simulation of the floods using two-dimensional, depth-averaged shallow water equations for flow over three-dimensional topography. The software used is the open-source GeoClaw (www.clawpack.org). It solves the governing equations employing the high-resolution shock-capturing finite-volume method. To concentrate grid cells in regions of interest as the flow evolves, the software applies block-structured adaptive mesh refinement (AMR), which is here needed due to the combination of a large simulation area and small grid cells, nominally producing about 150 million cells without the AMR. The physical time duration of each scenario is 10 days, which took up to 90 days to calculate on a single 64 core node. Five scenarios are examined, with different volumes (from 100 to 2,700 Gl), maximum discharge (6,000 to 100,000 m3/s), duration (hours to days) and release location at the edge of the glacier. The simulations were performed on supercomputers provided by the Icelandic e-Research Infrastructure (IREI) at the University of Iceland, supported by the Infrastructure Fund of the Icelandic Center for Research, Icelandic Roadmap for Research Infrastructures. This project was funded by the Avalanche Fund and Landsvirkjun (the National Power Company of Iceland).

Small water supplies in Nordic countries: climate change effects, risks and contingency planning

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Small water supplies are defined in Nordic countries as supplies with less than 500 consumers or serving water less than 100 m3/d. They are the most abundant water supply by number in the Nordic region. Their management differ from larger ones as in many cases they have limited and/or voluntary staff, are user owned or cooperatives, might have limited processing of water and mostly have less comprehensive monitoring requirements. We have surveyed small drinking water supplies in the Nordic region to better understand the perception of the small utilities regarding the consequences of climate change (CC) now and in the future. We asked them which effects they experienced or considered serious for the safety of the water supply and which regulations considering CC adaptation they had used to mitigate CC challenges in the water supply. We found that small water supplies have experienced several incidents associated to changing climate. Heavy rains, drought, changes in cold climate hydrology and landslides were most frequently mentioned. Many supplies had not yet experienced any effects, possibly because groundwater is the most common source for small water supplies. Impacts of changing conditions to water supply management itself were scarcely discussed. This lack of attention might be due to the lack of implementation of CC as a theme in the national risk- based approach (RBA) guidelines. We think CC must be addressed in national RBA implementation and regulation. We also see the need for simple guidelines made available to small supplies.

Broadening best practice for remediation treatment of shallow lakes, lagoons and bays in LIFE SIP WetEST

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In this presentation we will give an overview on the project LIFE SIP WetEST “Enabling collaborative efforts for systemic change in Estonian river basin management” and mainly its work package 7 titled “Broadening best practice for remediation treatment of shallow lakes, lagoons and bays”. The overall project aims at achieving and maintaining the good status of waters in the Western-Estonian River Basin District. The work package 7 focuses on developing comprehensive strategies for remediating entire water bodies with innovative remediation measures, including the restoration of submerged macrophyte communities through techniques such as fish manipulation and enclosure aquaculture. Two pilot areas are selected: Lake Harku and Haapsalu Bay. In Lake Harku, the main focus is on biomanipulation by removing 100 tons of sunbleak (*Leucaspius delineatus*) which is known to have a negative effect on the large mesozooplankton. The removal of sunbleak should alleviate the grazing pressure on large zooplankton, thus suppressing phytoplankton through a trophic cascade. Parallel measures are to detect and remove the main nutrient sources from the catchment. In Haapsalu Bay a mussel- and seaweed farms are established in order to mitigate pollution loads and improve water body status. The project aims to develop suitable technology for algae and mussel cultivation in Haapsalu Bay, along with recommendations for nutrient removal and utilization of cultivated biomass. An in-depth business analysis on the sustainability of mussel cultivation will be carried out to ensure the sustainability of the action and find a successor to the Haapsalu Bay aquaculture project.

Rivers and Lakes: Nature’s waterways, shaping life and land

04-06-2025 - 14:45 - 16:00

Askja N-132

Predicting spatial variation of cross section properties for hydraulic modeling in small low-land streams

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River cross section properties and bed depth are key factors for hydraulic modelling accuracy. They cannot be readily derived from open terrain data because LIDAR is blocked by the water surface, and surveying cross sections is a tedious and expensive task.

To facilitate the setup of large-scale hydraulic models, this study investigates the prediction of river cross-section properties through a machine learning framework, based on 5,000 surveyed cross-sections in Denmark. Similar to other studies, we simplify the cross-section by a power-law with three parameters; bankfull width, depth, and shape. An additional parameter, vertical offset, is included to position the cross-section relative to digital terrain data.

In our dataset, several of the cross-section parameters exhibit clear linear relations to features that can be extracted from open terrain data. Width and depth of the cross-section and vertical offset strongly correlate with bankfull width derived from terrain data and standard deviation of the surrounding terrain, respectively. The shape is not directly correlated to any digital terrain features.

To predict the cross-section parameters we employ a neural network architecture combining an autoencoder and a feedforward neural network, with geospatial input features. The model effectively predicts shape factor with *R-squared* of 0.91*,* However, bankfull width, depth and vertical offset remain more challenging, with *R-squared* values of 0.71, 0.34 and 0.69, respectively. Residual analysis reveals systematic errors for channelized rivers, and increased residuals in anthropogenic areas. We expect that model performance improves with careful data filtering and tailoring architectures to the different parameters.

Flume experiments for studying the impact of ice on stream hydraulics in a subarctic river

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Seasonally freezing rivers and associated watersheds cover one-third of Earth’s landmass. Meanwhile, climate change impacts various hydrological processes and river ice duration and extent are declining. River ice influences river hydrodynamics significantly: compared to open-channel flow, flow resistance is increased in ice-covered conditions leading to altered water levels, flow velocities, and turbulence characteristics. However, due to challenging data acquisition, detailed information about different ice-covered flow processes has remained limited. Flume experiments have been used successfully to study ice-covered flow, yet the materials used as ice cover have typically been smooth and floating, which does

not accurately represent the wavy under-ice topography and bank-fast ice observed in mid-winter conditions in subarctic rivers.

In this study, the effects of river ice on stream hydraulics will be investigated using stable proxy ice in an indoor flume. The flume is 16.0 m long, 0.6 m wide and 0.8 m deep. The topography of the proxy ice and channel bed will be derived from mid-winter field measurements from the subarctic Pulmankijoki River in northern Finland. This setup and using discharges adapted to field measurements allows for studying the effects of surface roughness conditions representing field conditions on a 1:1 scale. Flow velocity and pressure will be measured, to study the stream hydraulics under pressurised and non-pressurised flow conditions. The objective of this study is to solve identified research gaps related to ice-covered flow hydraulics including turbulence characteristics under smooth-rough ice cover.

Impacts of changing discharge regimes and effects of ice cover on fluvial environments

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In more than half of the Earth's rivers, ice cover is observed at some point during the hydrological year. Ice cover influences rivers' hydrological and geomorphological processes, forming an additional frictional layer over the channel. Globally, the duration of the ice-covered period is shortening, and changes in the timing of ice formation and breakup are becoming increasingly evident. These changes include ice breakup episodes in early winter before permanent ice cover forms, mid-winter breakups, and earlier spring breakups. In some areas, rivers that once experienced permanent ice cover annually no longer do. Changes in river discharge regimes have also been observed with earlier spring flood timings and increased wintertime discharge.

This study examines the effects of changes in discharge regimes in Finland and the loss of ice cover on fluvial environments. It combines an analysis of recent changes in the discharge regimes of unregulated Finnish rivers with studies on the impacts of flow on sediment transport beneath ice cover during the ice-covered period. The presented findings quantify past changes and give insights into the processes currently occurring under ice cover. Moreover, the results can be utilised to assess the effects of climate change on Northern Hemisphere rivers, particularly concerning the loss of permanent river ice cover.

From intermittent to continuous: enhancing under-ice flow monitoring with advanced sensor system

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Ice cover significantly alters river flow dynamics by introducing friction at the ice-water interface, shifting the high-velocity core closer to the riverbed, and modifying shear forces that influence sediment transport. Climate change further complicates these processes as winter base flow increases and ice conditions change. Rising temperatures reduce the extent and stability of river ice, making discharge patterns more variable and impacting under-ice sediment transport processes. Therefore, real-time, continuous monitoring of under-ice discharge and sediment dynamics is essential. As part of an experimental study, a new measurement method was tested against the traditional, labour-intensive approach in a Finnish river under mid-winter conditions. Instead of conventional cross-sectional stationary measurements taken from drill holes at one-metre intervals once or twice per winter, the new system used side-looking acoustic Doppler sensors mounted on four-metre-long aluminium frames, with three sensors per frame evenly spaced. These frames were placed vertically into the river along the outer bank through large drill holes,

enabling the sensors to measure flow across the entire horizontal cross-section and at three depths: near the ice surface, mid-water column, and near the riverbed. The sensors remained in the river for four days, continuously recording under-ice flow and sediment transport conditions. This pilot deployment aimed to assess whether these sensors could replace the conventional method for long-term, continuous monitoring. Traditional cross-sectional measurements were conducted at sensor locations to compare data accuracy and spatiotemporal resolution. The results will help evaluate the feasibility of continuous hydrological monitoring in ice-covered conditions, which remains challenging today.

Growth of frazil at a sub-arctic meandering river

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The knowledge of supercooling and related frazil ice phenomena in rivers is critical for purposes of flow control, and estimation of the conveyance capacity of the channels, in particular, at rivers having long and severe winters. The development of the frazil ice has been studied, especially in flume environments. However, the spatial analyses of the frazil ice, e.g., where it is anchored in river bed, are rarer, especially in meandering sandy river systems. It is expected that the frazil ice will attach to bottom in low velocity areas around bends and in areas where the channel constricts. In a meandering river, the spatial extent of frazil ice and its anchored form have rarely been measured in detail based on aerial image data sets combined with reference flow measurements from consecutive days.

The aim of this study is to detect the development of the spatial distribution of anchored frazil ice in a sandy-gravelly and meandering sub-arctic river. The work is based on field measurements done in mid-October 2021. The data includes aerial orthophotos from a four day period, when frazil ice anchored in the river bed of the Pulmankijoki River, in northern Finland. Flow velocities, measured with time-lapse cameras and with Acoustic Doppler Current Profiler, were used for detecting the causes of the anchoring of the frazil ice. Hydrodynamic modelling is performed to gain further information about the hydraulic characteristics within the regions of the anchored ice. Preliminary results are presented and discussed.

Rivers and Lakes: Nature’s waterways, shaping life and land

05-06-2025 - 09:00 - 10:15

Gróska – Main Hall

Seasonal Streamflow Forecast for the Upper Blue Nile Basin Using ECMWF-SEAS5 and WASA-SED

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Seasonal streamflow and sediment forecasting are essential for effective water resource management. Accurate forecasts require robust evaluations of numerical weather prediction (NWP) and hydrological models to represent atmospheric and hydrological conditions reliably. This study integrates the ECMWF-SEAS5 precipitation product with the WASA-SED model to generate seasonal streamflow and sediment forecasts for the Upper Blue Nile Basin in Ethiopia, home to Africa’s largest reservoir, the Grand Ethiopian Renaissance Dam (GERD), with a capacity of 74×10^9 m³. The Blue Nile River contributes approximately 60% of the Nile’s total flow.

The WASA-SED model was calibrated and validated using daily river flow data (2001–2011). Calibration results yielded a Nash–Sutcliffe Efficiency (NSE) of 0.80 and a Relative Error (RE) of 10.32%, while validation achieved NSE = 0.81 and RE = 6.82%. Seasonal forecasts were generated for June–December 2024 (Rain Season) using daily simulations with an ensemble of 51 forecast members, each extending up to seven months ahead.

The accuracy of the forecasts was evaluated by comparing monthly rainfall and discharge predictions with observed values. Results show that both models reliably capture seasonal variations, with notable skill in predicting extreme rainfall and discharge events, and can be used to forecast droughts and floods and reservoir operation on a seasonal scale.

The forecasting system, developed in collaboration with local research partners, provides actionable insights for proactive water resource management in Ethiopia, Sudan, and Egypt. Its design ensures long-term applicability beyond the project’s duration.

Keywords: Seasonal Forecasting, ECMWF-SEAS5, WASA-SED, Upper Blue Nile Basin, Streamflow, Sediment Dynamics, Drought, Flood

A differentiable programming framework for joint estimation of catchment runoff and rating curve dynamics in coupled hydrological-hydraulic models

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Monitoring of rivers is essential for flood predictions and water resources management. Coupled hydrological-hydraulic models are an important tool as they simulate both runoff-generating processes that feed rivers as well as the physical relationship between discharge and water level during channel routing. However, calibrating such models requires observations of both water levels and discharge, the latter of which are often derived empirically through rating curves. A rating curve is fitted to gauged discharges and water levels, but may change over time due to seasonal vegetation dynamics, erosion/sedimentation and time-variable backwater effects. In vegetated lowland rivers, time-variable channel roughness is needed to capture the effect of submerged vegetation on the hydraulic resistance. To address these issues, we propose a new differentiable setup that jointly estimates both catchment runoff and channel roughness.

In the setup, we link A) two neural networks receiving inputs of meteorological forcings and time, and predicts both runoff from the catchment as well as the seasonal variations in channel roughness caused by vegetation growth with B) a gradually-varied flow solver converting between discharge and water level in the river channel considering backwater effects. The neural networks are efficiently calibrated via backpropagation using only field observations, i.e. high-frequency water level observations and bi-weekly, manual gaugings of river discharges. The rating curve estimation and rainfall-runoff model calibration are thus formulated as a coupled inverse problem and solved jointly. In a synthetic test case, we show that we can efficiently calibrate a hydrologic-hydraulic model that predicts runoff and time-varying roughness.

Hydrological characteristics of Finnish catchments: national scale classification

Nasim Fazel [1] Juho Jakkila [1], Tero Niemi [1], Eero Siivola [1], Anna-Kaisa Ronkanen [1], Cintia Cintia Bertac Uvo [1, 2], Noora Veijalainen [1]

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Effective water resource management requires a comprehensive understanding of hydrological variability, especially in regions with diverse catchments shaped by different physical and climatic conditions. Defining robust hydrological regions supports optimized flood forecasting and risk reduction, rainfall-runoff modelling, and climate change impact assessments and adaptation. In this paper, we classify thousands of catchments into a few distinct hydrological response types by building on established methods. Traditionally, catchment regionalization has relied on a combination of physical, climatological and hydrological attributes. However, advances in computational methods now allow for more sophisticated approaches.

We use simulated data from 1971-2020 generated by the nationwide WSFS-P hydrological model, covering 6173 sub-catchments in Finland (including transboundary catchments), as the basis for our classification. To identify distinct hydrological regions, we first apply commonly used data reductio techniques (e.g. PCA, UMAP) followed by clustering algorithms (e.g. K-means, DBSCAN) to a large dataset containing catchment attributes. We then refine our dataset to determine which catchment attributes most effectively capture the variability of hydrological responses across the country. Furthermore, we compare classifications based on aggregated catchment attributes with those derived directly from daily timeseries of climatological and simulated hydrological data, evaluating the potential advantages and disadvantages of each approach.

Our study aims to refine hydrological classification frameworks by integrating advance machine learning techniques into them. The goal is to enhance analyses and management of both gauged and ungauged catchments.

AI Enhanced Hydrological Modelling Workflows: A Case Study for Snow-To-Streamflow Modelling in the Yukon River Basin

Darri Eythorsson [1] Kasra Keshavarz [1], Wouter Knoben [1], Cyril Thébault [1], Mohamed Ismaiel Ahmed [1], David Casson [1], Alain Pietroniro [1], Martyn Clark [1]

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Process-based hydrological models are powerful tools for understanding complex environments like those in Nordic regions. However, their increasing complexity poses challenges related to the high-dimensional decision space encompassing model structure, process representations, and parameter estimation, presenting substantial obstacles to robust application. This presentation introduces a new paradigm for hydrological modeling that leverages novel advances in language based Artificial Intelligence (AI) to navigate this complexity, enhancing the entire modeling workflow from conceptualization to evaluation.

We present a case study applying this paradigm using the CONFLUENCE hydrological modeling framework augmented with an AI-support system (INDRA) in the Yukon River Basin, a data-sparse watershed with rugged terrain, permafrost, and significant snow influence. The AI-assistance, powered by a network of large language models (LLMs), guides crucial modelling decisions throughout the workflow. This includes suggesting appropriate model configurations, informing parameter estimation strategies by recommending suitable ranges and calibration approaches, and automating workflow execution.

This approach addresses the challenges of high-dimensionality by distilling expert knowledge into actionable project tailored guidance, improving workflow efficiency, and ensuring reproducibility through systematic documentation of all decisions. This new paradigm shows promise for accelerating scientific discovery in data-sparse, complex environments. By automating tasks and providing intelligent decision support, this approach allows researchers to focus on higher-level scientific questions, such as understanding climate change impacts on hydrological processes and informing water resource management. This work highlights the transformative potential of AI to enhance hydrological modeling practices, offering a pathway toward more efficient and objective workflows that can address pressing water resource challenges.

Boreal Meandering Rivers in Change

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Meandering rivers exist worldwide, independent of hydro-climatological conditions. Their unique geomorphology, evolution, and dependence on external and internal forces have been studied for decades. Nevertheless, it is not fully understood which factors control their development.

In boreal and subarctic regions, warming is projected to surpass the global average, already advancing and reducing the magnitude of spring-time snowmelt discharges while increasing the magnitude and frequency of autumn/early winter discharges due to heightened rainfall and zero-crossing events. Flow peaks during summertime have become more prevalent due to increased heavy summer rains. Thus, it is unlikely that climate change would have no impact on river behavior in this region.

Understanding changes in river systems has always been important for their conservation and restoration, but climate change makes it even more crucial. Recent technological advancements, the availability of earth observation data time series, and increased computing capacity have revealed intriguing new aspects of meandering river evolution and its possible controls in various environments. Climate change has been claimed to affect, for example, Arctic rivers by slowing their evolution.

This study focuses specifically on meandering rivers in the boreal/subarctic region. The aim is to integrate field-based insights of meandering processes, earth-observation-based investigations of meander evolution, and hydro-climatological and environmental data to gain new insight into the hydro-climatological controls of meandering in this region. The goal is to increase the understanding of boreal/subarctic meandering river systems and their responses to environmental changes.

Risk Assessment, Mitigation Measures, and Management Effectiveness

05-06-2025 - 09:15 - 10:15

Askja N-132

LIFE for understanding the sedimentation processes in artificial reservoirs: Lithuanian case

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Sediment management in artificial reservoirs is a critical aspect of water resource management and has become a real challenge to preserve ecosystems from degradation. Reservoirs created by dams trap sediments that would naturally flow downstream, leading to various environmental and operational challenges. Over time, sedimentation reduces reservoir storage capacity, impacting flood control and hydropower generation. The interruption of sediment continuity affects downstream ecosystems, altering habitats and nutrient cycles. The research aims to assess changes in the reservoir sedimentation using physical measurements and remote sensing techniques. Three artificial reservoirs (two with hydropower plants and one – without) were selected for this study to understand the mentioned complex relationships in Lithuania. The sediment sampling was done at the inflow to the reservoir, in the reservoir and downstream of the dam once per quarter during the period of 2024–2025 together with bathymetry measurements. Satellite data was used to evaluate changes in the shoreline over time. The results revealed intensive sedimentation at the beginning of two reservoirs and a significant loss of effective upstream reservoir area. Moreover, the fraction size of sediments evenly decreased towards the dam and stabilized from the middle of the reservoirs.

This research has received funding from the European Union's LIFE Programme under grant agreement LIFE22-IPE-LT-LIFE-SIP-Vanduo/101104645. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting can be held responsible for them.

Risk based flood forecasting for Norway – the process, where are we and what next

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The existing Norwegian flood warning system is based on streamflow magnitude and warnings issued for regions. The primary objective of the FlomRisk project is to update the operational flood warning system to better reflect the impact of floods. This includes new solutions for operational service including static maps displaying exposed areas, flood impact, available observation and model runs for selected areas. Furthermore, local, site-specific forecasting systems are tested for five pilot municipalities.

Through a co-creation process with five pilot municipalities, four key needs have been identified to enhance response to flood warnings: i) An early situational overview to understand what the warnings imply for emergency situations; ii) Customized overviews of the situation and potential consequences before and during the event; iii) Effective communication both internally within the organization and externally towards residents and the media; iv) Establishing simple and sufficient documentation of consequences and measures taken during a flood situation

Based on the identified needs, prototypes for decision support tools for municipalities have been developed. These tools contain information from customized modeling tools specific to the respective areas, providing improved insight during flood events. The existing information should be downloadable and integrable into the municipality's digital solutions. These prototypes also provide valuable insights into the information needs of municipalities and emergency units before, during, and after flood events. New model setups for the pilot municipalities encompass everything from flood size to affected areas and impact calculation tools that offer flexibility in testing cost estimates and warning thresholds.

Enhancing Ribasim for reservoir operations: validating a new version with Canteen and expanding to the Drammen basin

Fatima Monji [1] Kolbjørn Engeland [2], Peter Gijsbers [1], Trine Jahr Hegdahl [2], John Kucharski [3], Martin Visser [1], Bart de Koning [4], Martin Pronk [4], Judith ter Maat [1], Harm Duel [1], Hege Hisdal [4]

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The Drammen Basin in Norway offers a unique opportunity to enhance Ribasim, a water resources planning tool developed by Deltares, to better simulate reservoir operations. Ribasim is designed to model the physical behaviour of managed open water systems, utilizing control rules and a prioritized water allocation strategy. This makes it an essential tool for effective water resources management under changing conditions.

Currently, new functionality is added to the Ribasim code enabling rule-based control options (discrete or continuous) as well as control by optimized allocation to simulate complex reservoir behaviour. This work directly supports the objectives of the STARS4Water project (EU Horizon No 101059372), which aims to improve understanding of climate change impacts on water availability and assess vulnerabilities to ecosystems, society, and the economy at the river basin scale.

To validate these new features, we leverage results from the Canteen model, a reservoir operations model used in the United States. Canteen has been applied to a variety of reservoirs, including the Wilson reservoir in Kansas, serving as a benchmark to assess Ribasim’s ability to replicate realistic reservoir dynamics.

In parallel with this validation, Ribasim is applied to simulate reservoir behaviour in the Drammen Basin, broadening the tool's scope and ensuring its applicability across diverse geographical contexts. This will enable Ribasim to model water systems with varied operational and management strategies.

Ultimately, this project seeks to enhance Ribasim’s ability to simulate reservoir operations, improving water resources planning and management and ensure efficient water allocation.

The impact of deep glacial water diversions from a hydroelectric reservoir in the thermal dynamics of a sub-arctic lake

Cintia Luz Ramón Casanas [2] Hrund Ólöf Andradóttir [1], Francisco Rueda Valdivia [2], Morgane Celine Priet-Mahéo [1]

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Interbasin water diversions associated with hydroelectric power operations can influence the physics and water quality of downstream receptor lakes. Little is known about the impact of such diversions in sub-arctic and arctic lakes, which are characterized by weak summer stratification and a high relative contribution of cold and highly turbid tributaries of glacial origin. From 2003 to 2007, Lake Lagarfljót (53 km^2, 65°N) experienced a series of changes in its natural hydrological conditions as part of the 690 MW Kárahnjúkar hydroelectric project. The most significant change was the damming and diversion of a second glacial river into the lake, reducing its hydraulic residence time by a factor of three, and increasing its background turbidity levels by one order of magnitude. A three-dimensional hydrodynamic modeling approach was developed to assess the impacts of this project on the Lake's physics. The results revealed that advective heat fluxes now have a similar magnitude to atmospheric heat exchanges or even dominate the lake's heat balance during the second half of the thermal stratification period. The diversion of deep water from upstream reservoir led to a net cooling of both the surface (median ≈1°C) and deep (median ≈0.6 °C) layers of the lake during summerso that the lake column became less stable and the thermal stratification period shorter.

Ramón, C.L., Priet-Mahéo, M.C., Rueda, F.J. and Andradóttir, H.Ó. (2024). The impact of deep glacial water diversions from a hydroelectric reservoir in the thermal dynamics of a sub-arctic lake, *J. of Hydrology,* 635, 131081

Supporting informed decision making by co-creation of a policy dashboard for the Drammen river basin

Judith ter Maat [1] Fatima Monji [1], VAnni Hermawan [2], Harm Duel [1], Trine Jahr Hegdahl [3], Kolbjørn Engeland [3], Hege Hisdal [3]

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River basin managers and other stakeholders within their river basin have a collaborative need to better understand water resources availability under climate change and socio-economic developments. This is essential to be able to formulate effective actions to address the current and future water resources management.

The EU STARS4Water project consortium collaborates with key stakeholders in 7 river basins spread over Europe to deliver new data services, models and other tools. One of the activities is the co-creation of a policy dashboard to support informed decision-making.

The dashboard development within STARS4Water is a stakeholder-driven process:

To co-create participatory understanding of the water system

To identify meaningful indicators in consultation with stakeholders

In iterative steps co-design dashboards with end-users, for participatory risk assessment.

To adjust the initial set-up for the dashboard based on feedback from stakeholders.

To present results of risk assessments in dashboards and discuss outputs with stakeholders.

The information in the dashboard can be updated when improved data or more accurate models become available, without having to change the user interface or back-end database handling.

In 2025 a dashboard will be developed for the Drammen in Norway. This basin is impacted by changing climate like changes in seasonal river flow and more extreme high and low flow events. The socio-

economic developments may introduce balancing potential trade-offs between growing agricultural water use and hydropower production. The dashboard will help stakeholders to jointly discuss such possible actions for improved water resources management.

The presentation and/or poster shows first results of the activities.

Rivers and Lakes: Nature’s waterways, shaping life and land

05-06-2025 - 10:45 - 12:00

Gróska – Main Hall

Observed impacts of climate change on the water balance in Sweden 1961-2020

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Records of observed annual precipitation and runoff for over 100 watersheds were used to examine trends in the water balance of Sweden for the period of 1961-2020. We used the water balance equation to estimate evapotranspiration losses in each watershed. Changes in storage between years were neglected as our focus is on long-term trends. In the different watersheds, the increase in precipitation typically ranged between 1-5 mm/year, whereas the increase in evapotranspiration ranged between 1-4 mm/year and change in runoff ranged between 0-3 mm/year. Most watersheds (77%) have a statistically significant increase in precipitation over this time period. At the same time, only a smaller fraction of watersheds (21%) has a statistically significant increase in runoff. Instead, the increase in precipitation was balanced by a statistically significant increase in evapotranspiration in most watersheds (63%). A spatial analysis of the observed trends in terms of absolute change revealed that precipitation increases were strongest in the southwest and in the north. Evapotranspiration trends were strongest in the south of Sweden whereas runoff trends were strongest in the north of Sweden. We have shown that a simple water-balance study allows for exploring temporal trends in hydrological fluxes. We also note that, as the study is entirely based on observations, it can be used as a complement to climate models in explaining temporal trends in water availability to guide planning, policy and management.

Hydrodiversity: A Key to Enhancing River System Resilience in a Changing Climate

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Rivers and their surrounding landscapes are shaped by dynamic hydrological, geomorphological, and ecological interactions. Hydrodiversity, the variability of water-related processes and features, plays a fundamental role in maintaining ecosystem resilience, yet remains an underdeveloped concept in hydrological sciences. Understanding hydrodiversity is crucial for sustainable river basin management, especially in the face of climate-driven hydrological shifts and increasing anthropogenic pressures.

This study explores hydrodiversity as a practical framework for assessing river system dynamics, emphasizing its role in shaping connectivity, sediment transport, and biodiversity patterns in Nordic water systems. Transition zones—riparian, littoral, and hyporheic—are particularly sensitive to seasonal fluctuations, including snowmelt-driven flooding and ice-cover regimes. However, shifts in precipitation patterns, altered land use, and water management interventions threaten these natural balances.

We propose a multi-method approach for quantifying hydrodiversity, combining high-resolution remote sensing (e.g., multispectral LiDAR, UAV-based monitoring) with hydrological and geomorphological modeling to capture spatial and temporal variability. These tools enable a more precise evaluation of hydrodiversity’s role in shaping river resilience and guide adaptive water management practices.

By integrating hydrodiversity into river restoration strategies, we align with international and regional policies, such as the EU Biodiversity Strategy for 2030, the Nature Restoration Law**,** and Nordic water governance frameworks. Recognizing hydrodiversity as a central component of river health offers new opportunities for sustainable hydrological planning and climate adaptation in water-rich, yet vulnerable, environments.

International cooperation in hydrology to enhance water resources assessment in a changing climate

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The World Meteorological Organization's (WMO) Global Hydrological Status and Outlook System (HydroSOS) provides global assessments of hydrological status and outlooks, covering variables like river flow, soil moisture, snow water equivalent and groundwater. By indicating regions at risk of droughts and floods and predicting how these conditions will evolve in the next weeks and months, HydroSOS supports timely decision-making and risk mitigation for water resource challenges intensified by climate change, population growth, and economic activities, with floods and droughts impacting millions and causing substantial economic losses.

Addressing these issues requires accurate knowledge of hydrological conditions and a coordinated international approach to monitoring, data sharing, and integrating innovative solutions. The WMO Hydrological Observing System (WHOS) and the World Hydrological Cycle Observing System (WHYCOS) provide foundational data for HydroSOS by enabling standardized hydrological data exchange across national, regional, and global levels. WHOS integrates heterogeneous data sources through open standards and brokering, while WHYCOS enhances observational capacities regionally. These systems form the hydrological component of the WMO Integrated Global Observing System (WIGOS) and the WMO Information System (WIS) to ensure data exchange. The WMO Global Hydrometry Support Facility (HydroHub) enhances the effectiveness of WHOS and WHYCOS and improves hydrological monitoring through the uptake of innovation and capacity development. This contributes to the Early Warnings for All (EW4All).

Fostering international cooperation is essential to improving resilience to water-related risks. Collaborative efforts among WMO Members, international organizations, and scientific communities enable better monitoring, prediction, and adaptation, promoting sustainable water resources management in a changing climate.