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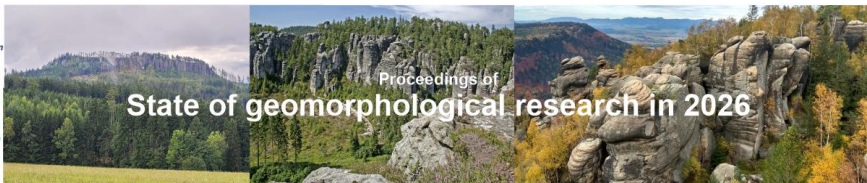


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## **Vegetation Health Dynamics in the Riparian Zones of the Danube: Case Study of the Slovak Danube**

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### **Abstract**

Riparian forests are important components of river ecosystems. Along the middle Danube River, these forests have been heavily altered by centuries of human activity, including river regulation and forest management, and substantial efforts have been made to restore them. To assess the health of these forests, we used 40 years of satellite imagery to track vegetation health and examine how forests were influenced by climate change. We found that vegetation has remained relatively healthy over time. Restored forests, where side channels were reopened to improve water flow, showed stronger signs of recovery than other forests, especially those with improved water connections. However, we also found that these forests are very sensitive to water stress. They can withstand short, dry periods, but their recovery is much weaker during long droughts. Overall, our research demonstrates how riparian forests respond to management interventions and climate pressures, and how satellite-based monitoring can measure the effects of hydrological reconnection of floodplain forests on vegetation health.

### **Keywords**

Riparian forests, vegetation health, floodplain restoration, forest management

The study was supported by the Science Grant Agency (VEGA) of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences [Grant No. 02/0016/24] and by the Slovak Research and Development Agency under Contract No. APVV23-0265.

## Geomorphological expression of eastward-propagating thrusts at Las Peñas-Las Higueras range, Southern Precordillera, Argentina

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### Abstract

The Pampean Flat Slab subduction ( $27^{\circ}$ – $33^{\circ}30'$  S) in the Central Andes features a broken foreland in Argentina with Quaternary intraplate deformation concentrated along the eastern Precordillera thrusts. Despite generating the country's most significant historical earthquakes, these seismogenic sources and their geomorphic expression remain poorly characterized. Understanding this expression is crucial because landscape deformation is the primary record of seismic activity, particularly for thrusts that generally do not reach the surface.

In the southern Precordillera, the Las Higueras-Las Peñas range comprises the Andean frontal deformation zone. Present-day topography is driven by NNW-striking, east-verging structures: the Las Higueras (LHTS) and Las Peñas (LPTS) Thrust Systems. The latter defines the mountain-piedmont junction, and propagates through splays that form anticlines successively incorporated into the hanging wall as deformation migrates eastward.

In the southern sector of the Las Higueras-Las Peñas range, five morphotectonic domains were recognized at La Escondida Creek. These morphotectonic domains correspond to areal units with relatively uniform morphological habits delimited by west-dipping reverse faults. Within these domains, outcrops reveal older Quaternary sedimentary packages underlying the surface-mapped units, which are separated by erosive angular unconformities. These units exhibit stratigraphic variations in thickness and dip that differ from upper levels, suggesting distinct deformation histories, and a variable relationship between fault activity and sedimentation rates. Their analysis, combined with fault-propagation fold forward modeling, is key to reconstructing the spatial and temporal evolution of the LPTS. The results suggest that the active front evolves through the propagation of initially blind branches into the footwall, and then the propagating thrusts truncate previously deposited units, developing a blind or emergent character depending on the P/S ratio and exposure to erosion. The recognition of these stages indicates that the system has migrated steadily eastward, with the most recent activity concentrated in the easternmost morphotectonic domain with shortening rates between 0.2-1.00 mm/yr. This sector marks the beginning of a new deformation cycle, corresponding to the initial stages of the proposed evolution, and could eventually record a surface rupture.

### Keywords

Tectonic geomorphology, Active Tectonics, Andean Southern Precordillera, Piedmont foreland evolution.

## **Preliminary morphotectonic analysis of the Las Planchadas range, northern Famatina System, Argentina**

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### **Abstract**

The northern sector of the Famatina System in the Central Andes of Argentina lies within a transitional region between the Pampean flat-slab segment and the normal subduction regime near the southern boundary of the Puna plateau ( $\sim 27^\circ$ ). This system comprises several north-trending orographic units, of which the Las Planchadas range is the northernmost, bounded to the east by the Neogene Fiambalá broken foreland basin. Although several Pleistocene-Quaternary N-S striking faults with reverse and strike-slip kinematics are documented in this region, detailed neotectonic studies are still scarce. Therefore, the existence of a Quaternary deformation front, its location, and the specific characteristics of its seismogenic sources remain unknown. Furthermore, seismic catalogs record shallow earthquakes in the area, and several urban settlements are situated over deformed Plio-Quaternary alluvial deposits, highlighting the need for a more comprehensive understanding of the local seismic hazards.

Through a combination of fieldwork, remote sensing, and high-resolution digital elevation models derived from drone flights, a detailed morphotectonic map was constructed. The arid climate and subsequent channel incision across uplifted alluvial surfaces provide well-preserved exposures of the underlying Neogene bedrock and its relationship with warped Plio-Quaternary surfaces, showing anomalous slope changes as well as stratigraphic dips that exceed present-day channel gradients. These features, in conjunction with drainage network anomalies, such as channel deflections, fluvial captures, and deeply incised channels, reveal the presence of scarps potentially associated with second-order faults related to the major mountain-building thrusts. This evidence suggests the existence of a Quaternary deformation front along the eastern flank of the Las Planchadas range. Moreover, observations within Neogene outcrops suggest that the primary deformation mechanism may be influenced by flexural-slip, which is subsequently transmitted to the overlying alluvial cover. However, further geochronological data and detailed structural analyses remain essential to fully characterize these processes.

### **Keywords**

Tectonic geomorphology, Famatina System, Active Tectonics.

## Assessing sediment connectivity of gravel-bed river using multitemporal LiDAR datasets.

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### Abstract

Anthropogenic alteration of river systems has disrupted natural sediment fluxes, channel adjustment, and habitat continuity, creating major challenges for river management and restoration. European-scale assessments indicate that over 200,000 km of formerly free-flowing river habitats have been widely modified by barriers and impoundments, while more than one million barriers fragment river networks and constrain the transfer of water, sediment, and biota. Fluvial research also shows that sediment connectivity is highly context-dependent and still insufficiently integrated into many catchment management strategies. Sediment management is therefore central to understanding ongoing river transformation. EU Water Framework Directives, these pressures are directly linked to river continuity, river-bed structure, and morphological conditions required to support ecological status, highlighting the need to assess sediment dynamics in transformed river corridors. This study investigates the Ondava River in the western Carpathians of eastern Slovakia to reconstruct channel transformation and evaluate spatial-temporal patterns of sediment distribution. Field sampling of gravel-bar sediment was combined with laboratory sieving and photosieving to compare grain-size estimates and support statistical calibration. These data were integrated with sUAS-derived topography, LiDAR data, orthophotos, historical aerial imagery, and DEMs of Differences to identify lateral channel dynamics, quantify gravel-bar transformation, detect zones of sedimentation and erosion, and examine long-term morphological evolution. Particular emphasis on the place of continuous detection of grain-size distribution and its relationship to surface texture and topographic roughness derived from high-resolution imagery and point clouds. The study aims to improve understanding of sediment transport, sediment connectivity, and gravel-bar evolution, while demonstrating the potential of sUAS-based workflow for detailed grain-size characterization and geomorphological assessment of dynamically transforming river systems.

### Keywords

sediment connectivity, gravel-bar, GSD, channel dynamics, LiDAR, DoD

This work is supported by the Slovak Research and Development Agency under Grant No. 02/0016/24; and grant APVV contract No. 23-0265. DoktoGrant [No. APP0705].

## **The role of bank ice in shaping local hydraulics and riverbank erosion under winter conditions**

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### **Abstract**

Winter conditions significantly alter river processes, yet the role of bank ice in shaping local hydraulics and riverbank erosion remains insufficiently quantified, particularly using accessible field methods. This study investigates the influence of bank ice formation on flow conditions and bank retreat in small to medium mountain streams under natural winter conditions. A cost-effective, field-based approach was applied, combining repeated photographic documentation, simple measurements of ice extent, float-based surface velocity observations, and direct monitoring of bank retreat using erosion pins.

Observations were conducted across selected river reaches characterized by varying bank materials and channel morphology, enabling comparison between ice-affected and ice-free sections. The results indicate that bank ice modifies local hydraulic conditions by reducing the effective flow cross-section and redistributing flow velocity, often leading to increased flow concentration within the main channel. In some cases, ice cover exerted a protective effect on the bank surface, limiting direct fluvial erosion, while in others it contributed to localized instability during freeze–thaw cycles and ice detachment.

The study demonstrates that meaningful insights into winter riverbank processes can be obtained without the use of advanced instrumentation, providing a practical framework for low-cost monitoring of cold-region fluvial dynamics. These findings contribute to a better understanding of seasonal controls on bank erosion and highlight the importance of incorporating winter processes into river management and geomorphological assessments.

## **AI-driven methodologies for processing and interpreting landslide monitoring data**

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### **Abstract**

The poster presents preliminary results from the first three months of the Strategy AV21 project focused on developing a comprehensive framework for the analysis and interpretation of long-term monitoring data.

Our work builds on an existing infrastructure where continuous automated measurements of displacements and deformations, together with related environmental variables, generate extensive time series, stored in a database and visualized through the Grafana platform. The main objective is to move beyond data storage and visualization towards the extraction of actionable knowledge for understanding and forecasting system behaviour in long-term monitoring of displacements and deformation processes. A unified environment is being developed that integrates data acquisition, storage, computational processing, and visualization into a single workflow. This setup enables systematic testing and comparison of different approaches to time series analysis, ranging from classical statistical methods to machine learning and AI-based techniques, with an emphasis on efficient data handling and method interoperability.

The ongoing work focuses on implementing methods for anomaly and changepoint detection, linking precursory signals to observed system responses, and exploring approaches to short-term forecasting and threshold identification. Particular attention is given to the interpretation of heterogeneous geotechnical measurements within a consistent analytical framework.

In the longer term, the framework is intended to support a digital twin concept, connecting real-world measurements with model-based approaches to improve process understanding and interpretation in evolving environmental conditions. The results contribute towards the development of early warning systems and more robust risk assessment methodologies.

## **Thermal Activity in Hard Coal Spoil Heaps: Processes and Manifestations in the Ostrava–Karviná Coalfield, Czechia**

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### **Abstract**

Thermal activity represents one of the most important post-depositional processes affecting the evolution of hard coal spoil heaps and may persist for decades or even centuries. It is primarily driven by oxidation of residual coal and sulfidic minerals contained in the deposited spoil material. These initial reactions lead to a gradual increase in temperature within the spoil heap body and may eventually result in spontaneous combustion and high-temperature alteration of the spoil material. Resulting pyrometamorphism forms thermally altered rocks such as clinkers and paralavas. As a result, both the structure of the spoil heap body and the characteristics of the deposited material are modified, giving rise to a range of characteristic features such as rock cliffs, postgenetic gravitational cracks, small cavities within burned blocks, fumaroles, and secondary mineralisation.

The Ostrava–Karviná Coalfield represents one of the regions where thermal activity in hard coal spoil heaps has historically been widespread. According to literature sources, several dozen thermally affected hard coal spoil heaps were recorded in the region during the second half of the twentieth century, while its manifestations persist at some sites to this day. This poster presents thermal activity as an important process affecting hard coal spoil heaps and illustrates its typical manifestations using selected examples.

### **Keywords**

Anthropogenic geomorphology; spontaneous combustion; pyrometamorphism; thermally altered rocks; landforms

## **We Publish It as Geomorphology, We Sell It as Something Else: Professional Invisibility as a Disciplinary Challenge**

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### **Abstract**

Tooth (2009) argued that geomorphology was becoming "invisible": its knowledge is widely applied, yet the discipline is rarely named in policy frameworks. Woodward (2015) quantified this using Google Books N-grams, showing a decline in the term's use since the early 1990s — paradoxically coinciding with rising journal output.

This contribution extends extends this line of inquiry with three lines of evidence from the Czech Republic: marginal public awareness (Google Trends), robust academic production (Web of Science), and case studies showing that the that analogous patterns of erasure operate in applied practice.

Two mechanisms drive this invisibility. First, geomorphology renamed: applied work is classified under adjacent domains such as geology or water management — exemplified by the EU Water Framework Directive's adoption of "hydromorphology." Second, geomorphology hollowed out: the term appears in procedures such as Environmental Impact Assessment but lacks the methodological substance that comparable disciplines such as pedology or biology possess.

This is not a recent problem. In 1990, Czudek diagnosed a strikingly parallel situation in Czechoslovakia: geomorphological knowledge is widely applicable, yet practitioners lack the training or incentive to use it, and engineering-geomorphological problems are routinely solved without geomorphological expertise. He called for applied geomorphology units and courses at technical universities. Thirty-six years later, neither has materialised — suggesting a persistent structural feature rather than a recent decline.

International examples show that the gap can be narrowed through practice guidelines or professional accreditation, but their transferability to smaller national communities remains an open question. The presentation asks whether the current invisibility is a problem to be solved — and if so, what minimum viable step a small association can take.

### **Keywords**

applied geomorphology, professional visibility, disciplinary identity, geomorphological practice, Central Europe, Czech Republic

Czudek, T., 1990. K problematice aplikované geomorfologie. Sborník ČSGS 95, 195–200.

Tooth, S., 2009. Invisible geomorphology? *Earth Surface Processes and Landforms* 34, 752–754. <https://doi.org/10.1002/esp.1724>

Woodward, J., 2015. Is geomorphology sleepwalking into oblivion? *Earth Surface Processes and Landforms* 40, 706–709. <https://doi.org/10.1002/esp.3692>

## **Landslide Dynamics: From Hazards to Systemic Drivers of Landscape Evolution**

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### **Abstract**

Landslides are traditionally studied as natural hazards, but this perspective overlooks their fundamental role as dynamic agents of Earth surface processes. This project funded by GACR aims to redefine landslide dynamics by investigating them as systemic drivers of landscape evolution, integrating geomorphic, climatic, and geochemical feedbacks. The project is structured around four interconnected objectives: (i) quantifying how landslides uniquely drive drainage divide migration and fluvial network reorganization; (ii) developing a physics-based Thermal Stress Landslide Susceptibility Index (TSLSI) to capture climate-sensitive preconditioning of slopes; (iii) tracking landslide-generated sediment pulses and modeling their geomorphic impacts under future climate scenarios; and (iv) quantifying the previously unexplored potential of landslide scars to act as significant CO<sub>2</sub> sinks through accelerated chemical weathering. By combining remote sensing, field surveys, geochemical analysis, and numerical modeling across diverse litho-climatic settings in the Himalayas and Alps, this project aims to establish a new paradigm where landslides are recognized as key catalysts in the climate-coupled evolution of landscapes.

### **Keywords**

Landscape Evolution, Drainage Divide Migration, Thermal Stress, Sediment Pulses, CO<sub>2</sub> Sequestration, Geomorphic Feedbacks

## Determining the southern limit of the periglacial zone in the lowlands of the Pannonian Basin during the Last Glacial Maximum

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### Abstract

Previous studies have identified various landforms believed to have periglacial origins in the low-lying areas of the Pannonian Basin (maximum elevation of 300 m a.s.l.). Examples of these landforms include patterned ground, frost wedge pseudomorphs, drop soils, cryoturbation, and asymmetric valleys. Climate model-based reconstructions suggest that the southern boundary of the European permafrost zone may have extended into the Pannonian Basin. However, reconstructions based on other proxies – such as palaeobotany, malacology, and stable-isotope analysis of large mammal teeth – contradict these findings. This contradiction has sparked a long-standing debate over the existence of Pleistocene permafrost in Hungary. Although investigating a relatively recent geological past in a well-known region, substantial uncertainty and a lack of reliable data remain in the Pannonian Basin.

Over the past decade, a buried polygonal network of cropmarks has been identified across northwest Hungary, spanning various landscapes, including the foothills of the Bakony Hills, older (slightly elevated) alluvial fans, and younger alluvial fans of the Réepe, Gyöngyös, and Rába rivers. A V-shaped crack system was identified in gravel pits using ground-penetrating radar (GPR), drone orthophotos, satellite imagery, and traditional fieldwork for sampling and describing macroforms. These structures were identified as sand-wedge-like formations, ranging in depth from 1.5 to 3.5 meters and in right-angle width from 0.6 to 2 meters. While the typical diameter of these non-orthogonal polygons is smaller than similar forms found in Northern and Western Europe, some large structures measure an impressive 4 to 5 meters in width and feature rectangular polygon joints. The cracks were filled with slightly or moderately sorted fine sand transported by wind. The numerical ages of the filling sediment, determined through optically stimulated luminescence (OSL), indicate they were formed during the last glacial maximum (LGM) or post-LGM cold periods, similar to findings from other European sites. Although sand wedges can form under a wide range of temperature conditions, we believe that the data regarding their shapes and the sediments within them are underutilised. More detailed comparative studies could help reconstruct the environmental conditions of the European sand wedge zone during the LGM.

### Keywords

thermal contraction cracks, polygonal cropmarks, discontinuous permafrost, LGM, NW Hungary

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## Preservation potential of sand wedges – what do we know?

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### Abstract

One of the most common and spectacular macro-scale features of lowland periglacial environments are thermal contraction cracks (TCC). TCCs filled with allochthonous sand are called sand wedges. Initially, mm-wide sand veins are formed, which develop into sand wedges if followed by repeated lateral accretion. Sand wedges are called primary structures when they are filled exclusively with sand throughout their lifetime. However, secondary structures are filled with mineral material after the melting of wedge ice. Sand wedges tend to form polygonal networks from a plan view. The morphological (shape, diameter, angles etc.) and topographical properties (elevation, slope, microtopography) of these networks have been studied in different settings. These variables refer to local conditions which contribute to or limit sand wedge development. Sand wedge development is possible in areas where 1) vegetation cover is limited or absent, 2) snow is either deflated or winter precipitation is very low, and 3) sediment source is locally available for aeolian transport. Depending on the complexity of these factors, sand wedges can reach depths of up to 10 m, and widths of up to a few meters. Primary sand wedges are found today in the dry valleys of Antarctica, the polar deserts of Arctic Canada, and Northern Greenland.

The inherently supply-limited periglacial aeolian systems in which sand wedges might develop are further complicated by 1) hydrological factors, 2) active layer processes, and 3) the textural properties of the surface sediments. This means that, currently, sand wedge development is restricted to a few areas globally. Although sand wedges have been disregarded in modern periglacial research, it is clear that sand wedges have great preservation potential. They preserve sediments in a unique way by acting as a sediment trap, therefore their analysis can provide a sedimentological-geomorphological “window” into the past. The characteristics of their morphometry, their infilling sediments, as well as numerical dating possibilities (especially optically stimulated luminescence techniques) create a unique possibility to utilise sand wedges as valuable paleoenvironmental archives.

This work attempts to summarize relict and recent sand wedges across the globe and to give an overview about the main factors responsible for their development. Their main characteristics are discussed through geomorphological and sedimentological aspects. Since more than 25 years has passed since the last big summary paper on sand wedges, this presentation will focus on new results as well. Further inputs for a potential collaboration from the conference participants will be greatly appreciated.

### Keywords

Thermal contraction cracks, periglacial, aeolian, sedimentary archive

## Slope Stability in the Vicinity of the Semanín Fault (Eastern Bohemian Basin)

Zbyněk Fojt<sup>1</sup>

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### Abstract

The study of slope deformations in the area between Ústí nad Orlicí and Semanín provides new insights into the spatial distribution, variability, and controlling mechanisms of landslides developed within the marginal part of the Bohemian Cretaceous Basin. The investigated area is structurally influenced by the Semanín Fault zone and is lithologically composed predominantly of Cretaceous marlstones, claystones, and sandstones, whose contrasting mechanical properties, in combination with hydrogeological conditions, create a pronounced predisposition for slope failures and ongoing mass movement activity. These conditions are further enhanced by the geomorphological setting of the area, where relatively steep slopes and dissected relief contribute to the redistribution of material along hillsides.

A multi-methodological approach integrating remote sensing techniques, detailed morphological analysis, structural geological measurements, and electrical resistivity tomography (ERT) was applied to obtain a comprehensive understanding of slope processes and their spatial variability. Based on high-resolution digital terrain models, slope gradient maps, and geomorphological indicators, more than 200 previously undocumented slopes affected by landsliding were identified and classified. Subsurface conditions were subsequently investigated using ERT profiles, which enabled the detection of resistivity contrasts corresponding to lithological boundaries, internal deformation zones, and potential slip surfaces, thereby providing important constraints for the interpretation of slope structure.

The results indicate that slope deformation is predominantly controlled by the presence of mechanically weak and plastic substrates, particularly marlstones and claystones, which facilitate block-type movements of more competent overlying units such as sandstones. The interface between these lithological units appears to represent a key structural control on landslide initiation, propagation, and long-term evolution. ERT data reveal complex internal architectures of landslide bodies, including displaced and rotated blocks, zones of reduced resistivity interpreted as water-saturated materials, and accumulation areas, all of which reflect the polygenetic and multi-phase character of slope deformation within the study area.

The Semanín Fault represents the principal tectonic structure within the study area and plays an important role in shaping the geological framework in which slope deformation develops, particularly through its influence on lithological distribution and structural conditions of the bedrock. Although its direct expression in subsurface data is not the primary focus of this study, its presence is considered a key factor in the broader interpretation of slope processes within the region.

In addition to the structural and lithological controls, particular attention was given to the occurrence of potentially datable materials within landslide bodies. Field observations and shallow probing indicate that weakly developed or locally buried soil horizons may be preserved within accumulation zones or above slip surfaces. Such buried soils could, under suitable conditions, provide valuable material for the chronological reconstruction of landslide activity, for example through radiocarbon dating or other geochronological methods. The identification and further investigation of these horizons therefore represent a promising direction for future research focused on the temporal evolution of slope processes.

**Keywords:** Landslides, slope deformation, electrical resistivity tomography (ERT), Semanín Fault, Bohemian Cretaceous Basin

## **Boom, bust, and flush: the geomorphic life cycle of large wood in a steep headwater stream**

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### **Abstract**

Cascades of hydrogeomorphic disturbances exert first-order control on the spatio-temporal dynamics of large wood (LW) in mountain channels. Here, we quantify how sequential disturbances, namely a debris flow in 2010 following extensive windthrow, an intervening quiescent phase (2010–2024), and an extreme flood in 2024, structured LW recruitment, storage, and remobilization along a ~2 km steep headwater reach of the Klepáčský Stream (Hrubý Jeseník Mountains, Czechia), locally influenced by degraded check dams constructed in the 1960s. Repeated LW inventories (2016, 2023, 2025) document contrasting geomorphic signatures of the two disturbance pulses. The 2010 debris flow initiated substantial LW recruitment and channel-wide deposition, generating a persistent storage signal that demonstrates pronounced geomorphic memory. During the subsequent quiescent period, LW dynamics approached a quasi-steady state, with recruitment largely balanced by decay and fragmentation, and only localized increases associated with background riparian mortality. In contrast, the high-magnitude 2024 flood (the Boris storm; approximately 100-year recurrence interval in this region) acted predominantly as a transport-limited flushing event, resulting in net LW depletion, with only minor, spatially restricted inputs from a small hillslope debris flow. These observations indicate that the system currently operates in a source-limited phase of the LW cycle, where depletion of recruitable wood following earlier disturbances, combined with the present age structure of riparian stands, constrains contemporary inputs and governs LW mobility trajectories. Thirteen degraded, unmaintained check dams function as secondary storage nodes, presently retaining ~29% of total LW volume despite advanced structural deterioration, highlighting their disproportionate role in modulating longitudinal connectivity of wood flux.

### **Keywords**

large wood; mountain stream; flood; debris flow; the Hrubý Jeseník Mts.

## **Formation of salients and recesses in the eastern Himalaya: Geomorphic and structural insights from the Jaldhaka recess and Itanagar salient**

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### **Abstract**

The Himalayas, the world's largest orogenic belt, formed through N–NE-directed subduction driven by continental convergence, with a present-day rate of ~24 mm/year in the northeastern sector. Rapid orogenesis produces high-relief landscapes and structurally complex fold–thrust systems. Differential thrust growth and oroclinal bending generate cusped–lobate patterns (salients and recesses) along the Himalayan front, reflecting spatio-temporal variations in deformation along the Himalayan Frontal Thrust (HFT), notably in the Jaldhaka recess and Itanagar salient.

The Jaldhaka recess (Darjeeling–Sikkim–Bhutan Himalayas), between the Tista and Torsa rivers, is characterised by orogen-parallel and transverse faults. Rivers follow transverse faults and display deflections and nickpoints across thrusts. A deformed Quaternary piedmont preserves scarps of ~90 m (Chalsa), ~60 m (Matiali), and ~80 m (Thaljhora backthrust), with uplift phases at ~72 ka, ~54 ka, and ~31–28 ka, respectively. Landslides are common along transverse structures.

Further east, the Itanagar salient near the Eastern Himalayan Syntaxis exhibits Quaternary deposits thrust over Neogene sediments along the HFT. The Dikrang and Ranga rivers drain the region, which also hosts active structures such as the Main Boundary Thrust (MBT) and Tipi thrust, along with extensive landslide zones.

Our results identify a ~25 m-high E–W scarp along the Torsa River as a previously unrecognised HFT splay (Totopara thrust), supported by stream deflection patterns and Ground Penetrating Radar (GPR) evidence. The scarp curves northward into an NNE–SSW transverse fault, indicating structural linkage between frontal splays and transverse deformation.

In the Itanagar salient, we show that the Quaternary terrace system south of the HFT initiated at ~69 ka. A prominent ~100 m-high scarp, previously interpreted as a normal fault, is reinterpreted as an MBT splay, with uplift constrained to ~59 ka based on dated Quaternary deposits.

We further demonstrate that transverse faults in the Jaldhaka recess are best explained as lateral ramps of HFT splays, whereas those in the Itanagar salient function as tear faults, highlighting contrasting deformation mechanisms along the Himalayan front.

### **Keywords**

Eastern Himalayas, Salient and Recess, Thrust, Transverse faults.

## **A probabilistic framework for the estimation of specific stream power and its implications for sediment transport processes**

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### **Abstract**

Specific stream power (SSP) is a fundamental metric that links channel hydraulics to fluvial erosion processes, yet it is commonly treated deterministically despite uncertainties in key variables such as discharge, channel-bed roughness, and energy slope. Uncertainties in these parameters can introduce significant bias in the interpretation of sediment transport processes, especially during high-magnitude discharge events. In this study, we present a probabilistic framework to quantify uncertainty in Manning's roughness and energy slope, and propagate these uncertainties through the SSP model to evaluate the implications for the suspended sediment transport process. We applied a hierarchical Bayesian approach with the Markov chain Monte Carlo method (Metropolis–Hastings) to calibrate Manning's roughness and energy slope across multiple discharge events in a bedrock-dominated cross-section of the Netravati River in the Western Ghat escarpment of India. The posterior distributions indicate a decrease in Manning's roughness and an increase in energy slope with increasing discharge. Additionally, we observed a marginal decrease in the variability of these hydraulic parameters during high-discharge conditions. When these uncertainties are propagated into the SSP model, we observed greater variability in SSP values under lower roughness and higher energy slope conditions, i.e., for higher discharge events. Finally, we have categorized the suspended sediment concentration (SSC) values based on the average sediment load over the past 10 days and plotted them against the median fit line of the theoretical SSP-SSC relationships. We observed that the uncertainties in hydraulic parameters significantly contribute to observed scatter beyond sediment availability-evacuation effects. These findings collectively indicate that incorporating uncertainties in the hydraulic parameters may improve the interpretation of sediment transport dynamics and provide a more realistic assessment of riverine geomorphic processes.

### **Keywords**

Hierarchical Bayesian model, Manning's equation, specific stream power, suspended sediment transport.

## **An ERT survey across the water and the rock face to study a landslide: challenges and solutions**

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### **Abstract**

Electrical resistivity tomography (ERT) is a versatile geophysical method for imaging shallow subsurface structures, materials, and discontinuities. It is widely applicable across diverse environments, including soils, sediments, and bedrock, provided reliable electrode contact can be established. However, significant logistical challenges arise when survey profiles must traverse obstacles such as flowing water bodies or steep rock faces. Although specialized equipment for aquatic ERT surveys exists, it is often expensive and operationally demanding.

We present a low-cost and practical field setup that enables ERT data acquisition across flowing water bodies using standard equipment. The proposed “airborne” configuration is specifically designed for fast-flowing rivers. A steel cable is suspended above the water using a pulley-block system, from which electrodes are deployed on thin wires weighted with metal nuts. This arrangement ensures stable electrical contact with the water column while minimizing the risk of equipment loss. All surveys are complemented by bathymetric data acquired using boat-mounted sonar or an acoustic Doppler current profiler (ADCP), and subsequently processed using Res2DInv software.

The applicability and adaptability of this approach are demonstrated through a case study at the Březno landslide site. Here, an ERT profile successfully spanned both a river channel and an adjacent rock face, enabling investigation of a clay-rich landslide triggered by riverbank erosion. The results highlight the potential of this method as a cost-effective alternative to specialized aquatic ERT systems, anyway problematic in fast-flowing water.

## **Estimating surface grain-size distributions from UAV imagery: Upper Acheloos River, Greece**

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### **Abstract**

Sediment grain size is a key control on sediment transport, channel morphology, and habitat conditions in gravel-bed rivers. It is widely used as an input parameter for modelling, particularly for in-channel vegetation dynamics, where it influences burial and uprooting processes during sediment transport, alternatively it can be used for deriving hydraulic roughness (e.g., using Strickler's equation). Recent advances in aerial and unmanned aerial vehicle (UAV) imagery have enabled rapid, high-resolution photogrammetric analyses, offering more efficient and spatially comprehensive alternatives to traditional field-based grain-size measurements, particularly in large river systems with high sediment storage. This study evaluates the use of high-resolution UAV imagery combined with automated grain-size measurements using BASEGRAIN software to quantify surface sediment along the Upper Acheloos River in western Greece.

Drone surveys were conducted across four river reaches representing a downstream gradient of geomorphic conditions. From these surveys, orthophotos with a spatial resolution of 50 mm/px were generated for mapping and visualization. Grain-size distributions were extracted from selected patches of the original high-resolution imagery (approx. 2-7 mm/px) using BASEGRAIN, which detects and measures individual clasts from photographs. From the resulting grain-size metrics of and orthophotos were created detailed maps of grain-size distributions and derived roughness values (via Strickler's equation) across bar surfaces and the study reaches. The results highlight the potential of UAV-based photogrammetry and automated image analysis to provide detailed and spatially continuous grain-size information, that can be useful for vegetation and hydraulic models.

### **Keywords**

Photogrammetry, grain-size, UAV imagery

## **Why is it still important to study the barrier effect on Czech rivers?**

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### **Abstract**

The transformation of the river continuum is a phenomenon that has long been studied from the perspective of river morphology. The impacts of constructed barriers on watercourses have led to a fundamental shift in the functioning of river processes in terms of intensity and frequency. The current state of hydromorphology calls for restoration activities that not only eliminate the impact of various types of barriers on the geomorphological function of watercourses but also create conditions for optimal river management, which must respect flood control measures while supporting the sustainability of the biological functions of the river environment. This paper summarizes the situation in the Czech Republic and highlights the importance of fluvial geomorphology for river management. The application of the concept of river health also appears crucial, as it seeks to comprehensively assess the condition of the river and conceptually incorporates restoration interventions in the river landscape. The approaches are presented using the example of restoration concepts in large-scale protected areas, but also note the potential for restoration through the floods of autumn 2024. The issue of large river restoration is discussed in particular, where a number of critical situations arise.

The paper is based on the results of the TACR project, reg. no. SQ01010138: "Comprehensive analysis of large rivers and their tributaries in large-scale protected areas from the perspective of preserving and revitalizing their geodiversity and biodiversity."

### **Keywords**

Fluvial systems, barriers, river morphology, sediment transport, river health, river restoration

## **Erosion-Driven Moraine-Dam Breach Modelling and Downstream Flood Exposure in Cascading GLOFs**

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### **Abstract**

Accelerated glacier retreat driven by climate warming has promoted rapid expansion of glacial lakes, significantly increasing the likelihood of glacial lake outburst floods (GLOFs) and associated downstream hazards. In the Sikkim Himalaya, the Gurudongmar Lake Complex (GLC) comprises four interconnected lakes with a combined storage of  $\sim 148 \times 10^6 \text{ m}^3$  and an expansion rate of  $74 \pm 3\%$ . This study integrates a two-dimensional, erosion-based moraine-dam breach model (TELEMAC-2D coupled with SISYPHE) with one-dimensional hydrodynamic flood routing (HEC-RAS) to simulate cascading multi-lake outburst scenarios and quantify downstream impacts. Model simulations, constrained by remote sensing and field observations, indicate that under an extreme 80% overtopping breach scenario, peak discharge may reach  $\sim 8882 \text{ m}^3/\text{s}$ , with a total released volume of  $\sim 59.4 \times 10^6 \text{ m}^3$ . Simulated flood depths and extents substantially exceed those recorded during the October 2023 South Lhonak GLOF, highlighting an elevated hazard potential in the region. Exposure analysis across 19 settlements, using a  $15 \times 15 \text{ m}$  grid framework, identifies Thangu Valley and Chungthang as the most vulnerable zones, characterized by high inundation depths and significant infrastructure exposure. Sequential breach scenarios, particularly involving combinations such as GL-2–GL-1 and GL-3–GL-1, demonstrate amplified flood magnitudes, emphasizing the critical role of cascading lake failures in hazard escalation. This study advances understanding of moraine-dam erosion processes and multi-lake GLOF dynamics, and provides a robust modelling framework for risk assessment and mitigation in the Eastern Himalaya and other glacierized mountain regions.

**Keywords:** GLOFs; Moraine-dam breaching; cascading lake failure; Hydrodynamic modelling; Exposure assessment; Eastern Himalayas.

## When the devil's in the details. Geomorphometry of extremely rugged sandstone terrain in light of UAV LiDAR elevation data – the Hejda mesa, Broumovska vrchovina, Czechia

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### Abstract

The Hejda mesa (641 m a.s.l.) is located south from Teplice nad Metuji town in the Broumovska vrchovina (N Czechia). It is built of Upper Cretaceous sedimentary rocks of Police Basin with a caprock of quartz arenite underlain by mudstones and marls. Although the mesa is little known to broader public compared to other sandstone landform assemblages of the region, its top surface represents a fine example of distinct rock-cut morphology comprising a very dense net of joint-guided clefts and canyons. As such, it was a subject of geomorphological mapping in the 1980s and early 1990s, however, there were no attempts of detailed morphometric analysis of its relief until very recent studies which utilized a state-wide airborne LiDAR elevation dataset – the DMR5G model. Though, two major flaws of this dataset became explicitly visible when paired with local extreme terrain ruggedness. First, low density of original point cloud disables proper representation of steep rock walls, clefts or smaller tors or boulders, especially under tree canopies. Second, point classification errors, which create model artifacts in areas where whole rock towers or large boulders are missing. Thus, the usability of DMR5G in geomorphometric approach was relatively constrained.

In this study we aimed to provide a brand new insight into geomorphometry of the most dissected part of mesas caprock zone as well as to show how increasing the DEM resolution into sub-meter values can impact any quantitative analyses of such type of relief. For this purpose, we conducted the UAV laser scanning on December 11th, 2025, using the GreenValley LiAir V70 mounted on DJI Matrice 300 RTK, which resulted a point cloud of mean density 557 pts/m<sup>2</sup>. Also, an additional point-cloud of mean density 359 pts/m<sup>2</sup> was derived using structure from motion photogrammetry, based on a set of photos from DJI Mavic 3 Enterprise. Finally, it was possible to obtain high-resolution DEMs of 1 m, 0.4 m and 0.15 m resolution which are a result of manual raster filtering in ArcGIS Pro environment. Consequently, these datasets were used to calculate and visualize the slope inclination, negative openness and zonal standard deviation of slope (surface roughness parameter).

The results show that use of the UAV-LiDAR-based elevation data should be recommended for geomorphological research in forested and extremely rugged sandstone terrains, especially if other available elevation datasets are of insufficient quality. Landforms such as vertical rock walls, narrow clefts or minor tors or boulders can be much better represented by DEM of resolution higher than 0.4 m. However, in conditions of spatially variable vegetation coverage, the issue of non-uniform DEM quality still has to be taken into account while interpreting the results of geomorphometric analyses.

### Keywords

Sandstone geomorphology, geomorphometry, airborne laser scanning, unmanned aerial vehicles

## **A Socio-hydrological Perspective on the Development of Roma Settlements on Floodplains in Slovakia**

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### **Abstract**

A significant segment of the Roma population in Slovakia lives in segregated settlements. These settlements are younger than Slovak towns and villages (most were established in the 20th century) and have undergone dynamic development, particularly in recent decades. Much of this development can be reconstructed using aerial photographs, which enables the study of the co-evolution of the river landscape and Roma settlements located on floodplains.

This study examines adaptation to life on the floodplain between 1949 and 2021 in four Roma settlements. It focuses on the construction of flood protection infrastructure and migration to areas outside flood-prone zones, as well as changes in the surrounding river landscape. In addition to aerial and satellite imagery, we used the DMR 5.0 digital elevation model, the Atlas of Roma Communities, and hydrological data, including maximum annual discharge of adjacent watercourses during the monitored period, flood recurrence intervals, and hydrological yearbooks published by the Slovak Hydrometeorological Institute.

In all monitored locations, the erosion–accumulation balance was strongly skewed toward accumulation, causing the active river channels to shift away from the Roma settlements. Nevertheless, the settlements expanded more rapidly toward the adjacent watercourses, resulting in a decreasing distance between the settlements and the channels. During the study period, various types of flood protection infrastructure, such as embankments and channel modifications, were constructed in these localities. Nevertheless, the flood exposure of these Roma settlements continues to increase.

### **Keywords**

Socio-hydrology, Roma communities, Floods, Floodplain

### **Acknowledgement**

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## **Morphological changes in Odra meander belt due to 2024 flood, Poodří PLA**

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### **Abstract**

In September 2024, the Odra River near Ostrava city experienced its largest flood on record ( $Q_{\max} = 692 \text{ m}^3/\text{s}$ ,  $N > 100$ ). In terms of peak discharge, this event exceeded the flood of July 1997 ( $Q_{\max} = 688 \text{ m}^3/\text{s}$ ,  $N > 100$ ). Thanks to several years of intensive research on morphological changes in a ca. 4 km long meander belt of the Odra River in Poodří PLA (southwest of Ostrava, Czechia), we have our own orthophotos of the area from the time before and after the flood of September 2024. Visual inspection of post-flood changes in the meander belt, both in the field and on orthophotos, indicated that no major morphological changes had occurred in the river channel, unlike, for example, during the last major flood in May 2010 ( $Q_{\max} = 404 \text{ m}^3/\text{s}$ ,  $N = 20$ , the third-largest recorded flood here). The annual mean bank edge retreat (aMBR) was calculated by measuring the distances of the erosion bank edges of 9 selected meanders on available orthophotos (1993-11/2024). The length of the comparison periods depended on the availability of aerial photographs and orthophotos and was 7, 3, 2, and 1 year. Although the chosen methodology loses accuracy when going deeper into the past, the obtained results made it possible to compare the extent of meander bank retreat due to erosion between periods of high and low flow, including all three of the largest recorded floods.

During the period covering the flood in September 2024 (orthophotos from 03/2024 and 11/2024), the aMBR was 1.24 m. Results also show that between 1993 and 2014, more significant morphological changes occurred due to erosion (aMBR  $\sim 2$  m) than in the period after 2014 (aMBR  $\sim 1$  m). The greatest retreat of the meander banks occurred between 2009 and 2012 (aMBR 3.1 m), likely due to the  $Q_{20}$  flood in May 2010. Neither of the two largest floods (July 1997 and September 2024) had such a pronounced impact compared to other periods, as the flood of 2010 did.

### **Keywords**

Meandering river, Bank edge retreat, Largest floods on record, Poodří PLA

## On the margins of permafrost areas

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### Abstract

Despite the growing research interest in high-latitude environments and mountainous regions, which respond most rapidly to contemporary climate change, significant uncertainties remain regarding the spatial extent of permafrost and its properties. Numerous permafrost studies continue to rely on paradigms derived directly from earlier, not necessarily up-to-date research. This paper focuses on marginal zones of permafrost occurrence, which are particularly challenging to detect and to formulate general patterns for. These include the literal edge of perennially frozen ground at the land–sea interface, the climatic boundary of permafrost distribution, as well as specific environments of microclimatic and relict permafrost. These typically small and isolated permafrost occurrences are referred to by the author as *COLDSPOTS*. The paper briefly presents results of ground thermal regime investigations using geophysical methods alongside direct measurements from boreholes. The findings are based on field studies conducted at selected sites in polar and subpolar regions, including Svalbard, Greenland, Iceland, Lapland, and King George Island (Antarctic Archipelago). The results indicate the influence of seawater intrusion along coastlines, as well as a generally different extent of permafrost in climatic marginal areas of the Arctic and Antarctic than is commonly assumed. The paper also discusses the potential persistence of permafrost in European mid-mountain environments. The research was carried out with financial support from the National Science Centre (project OPUS22, UMO-2021/43/B/ST10/00297).

### Keywords

permafrost spreading, cold region coasts, COLDSPOTS, Arctic, Antarctic, Bohemian Massif

## **Hydro-geomorphic Controls on post river training river adjustment. A case study of the Belá River, Western Carpatian.**

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### **Abstract**

The research focused on the eight-year geomorphic adjustment and recovery potential of one of the unique braided wandering systems within the highly protected Natura 2000 network, following a river training intervention in 2018. The study employed a multi-dimensional approach, utilizing river reach and catchment-specific morphometric parameters, a maximum likelihood classification scheme on high resolution orthophotos (2018-2024), detailed field survey with cross-sectional analysis (2015-2025), statistical testing (Kruskal-Wallis and Wilcoxon) and finally hydraulic modeling by 2D HEC RAS to identify the spatio-temporal changes in the studied time horizon and the hydrogeomorphic response mechanism to the induced challenges. The finding provides insight that, rather than reverting to the intake condition, the disturbed sections followed a unique adjustment pathway. On the middle-stream river reach (RR03), a gradual adjustment accompanied by lateral migration and active sediment transport was identified along with the significant reduction in gravel bar area, and pioneer shrub vegetation. Whereas the further middle-stream river reach (RR07) displayed episodic adjustments driven by hydraulic threshold (3.4 m/s -3.7 m/s), resulting in the widening and reformulation of in-channel geomorphic units. In contrast, the upstream river reaches RR08 and RR11 shows oscillatory adjustment and transitional stabilization, in which the channel morphology is regulated by the interactions among flow energy (3.4-3.7ms<sup>-1</sup>), vegetation encroachment, and bar reworking. The results support our hypothesis of a gradual adjustment towards a new steady-state equilibrium, resulting from the interaction between geomorphometric condition and the hydraulic gradient, rather than returning to the original intake condition. By combining natural-based geomorphometric control with hydraulic assessment, the study offers a paradigm for ecologically sustainable river management to forecast evolution across various river segments following river training interventions. The research presented was funded by VEGA 2/0016/24 and APVV-22-0428 projects.

### **Abstract**

geomorphic recovery, river training, hydraulic modelling, equilibrium, Belá River.

## **Braided river geomorphic transformation due to small hydropower plant operation, the Belá River case study**

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### **Abstract**

The current problem with the longest Slovak braided river, Belá, is the loss of morphological diversity, primarily through the simplification of the river bed, its cutting into the bedrock, and gradual backward erosion. In several places, typical flysch of the Inner Carpathian Paleogene (claystones, siltstones and sandstones) emerges from the bedrock. These phenomena are not natural and are mainly caused by external interventions within river management. This contribution aimed to conduct complex geomorphic analyses of the river reach affected by small hydropower plant operations, evaluating floodplain evolution and in-channel processes. We focused on several specific aims: i) identification of the long-term morphological transformation of the studied river reach based on historical and current remote sensing data since the half of the 20th century; ii) analysis of the hydrological regime impact as a mutual force with anthropogenic influence for river reach degradation; iii) measurement of bathymetric changes in the former and bypassed channel; iv) identification of the in-channel and the floodplain ledges; and v) provide critical insight into management-issued activities in the studied area. The spatial-temporal hot-spot analysis reveals the extent of channel incision and perched-floodplain formation linked to small hydropower station construction. The extent and intensity of incision heading both upstream and downstream. The research presented was funded by VEGA 2/0016/24 and APVV-22-0428 projects.

### **Keywords**

braided river, floodplain, small hydropower plant, geomorphic response, Belá River

## Temperature-driven cyclic deformation in clay-rich soils and shallow landslides

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### Abstract

Temperature-driven surface and near-subsurface soil movements in temperate climates remain poorly understood despite projected shifts in thermal regimes. This study examines cyclic, reversible deformations in clay-rich soils and shallow landslides, focusing on interactions among land surface temperature, precipitation, and soil moisture. Using InSAR, thermal imagery, and in situ monitoring (ShapeAccelArray), we analyse stable and unstable sites to separate thermally induced movements from gravitational deformation. Results show that reversible displacements - typically aligned with annual temperature cycles - can occur independently of pore-water pressure. At a Czech site in Tertiary claystones, seasonal movements (2-8 mm) track temperature and decrease with depth. These responses are strongest in clay-rich soils, where seasonal desaturation and temperature-dependent water retention affect mechanical behaviour. Comparisons between expansive and non-expansive clays reveal distinct deformation patterns, and differences between landslide bodies and adjacent stable terrain suggest material weakening. By integrating regional datasets (InSAR, temperature, precipitation, soil moisture) with field monitoring and landslide inventories, we assess deformation drivers, landslide contrasts, conditions where gravitational movement dominates, and links between surface and shallow subsurface responses.

### Keywords

Soil deformation, Land surface temperature, Clay-rich soils, InSAR monitoring

## **Channel widening following the 2023 Storm Daniel flood: a remote sensing analysis of the Acheloos River (Greece)**

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### **Abstract**

Extreme hydrometeorological events play a fundamental role in shaping landscape dynamics, particularly in mountainous environments where floods and landslides act as dominant geomorphic drivers capable of inducing rapid and extensive channel adjustments. The September 2023 Storm Daniel event triggered widespread flooding and caused significant geomorphic changes across Mediterranean river systems. This study investigates the geomorphic response of a fluvial system to this event, with a specific focus on channel widening along the Acheloos River in the Pindos Mountains (Greece).

The analysis is based on multi-temporal PlanetScope imagery (3 m spatial resolution) and combines supervised image classification with morphometric analysis. Key surface classes, including water, exposed sediment, and vegetation, are identified using land cover classification supported by spectral indices (e.g., NDVI, NDWI, and BSI), and are subsequently used to delineate channel boundaries and quantify changes in channel width before and after the flood event. Morphometric characteristics are further used to describe the geomorphic setting and support the interpretation of observed spatial patterns.

Pre- and post-event comparisons indicate substantial channel widening and significant spatial variability along the river profile, with greater widening observed in upstream, steeper reaches. These findings highlight the heterogeneous nature of post-flood channel adjustments and emphasise the importance of accounting for longitudinal variability in fluvial responses to extreme flooding.

### **Keywords**

channel adjustment, change detection, morphometric analysis, longitudinal profile

## **UAV-LiDAR-aided large-scale geomorphological mapping of sandstone rock cities of Broumovská vrchovina, Czechia**

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### **Abstract**

Geomorphological maps play a crucial role in geomorphological research, presenting the distribution of landforms and facilitating the recognition of different processes. Contemporarily, the process of detailed geomorphological mapping is complex as it usually relies on traditional field observations and measurements coupled with an extensive use of remote sensing techniques such as airborne laser scanning (ALS LiDAR) or photogrammetry. Integration and processing of such quantitative and qualitative datasets in geographic information systems (GIS) environment enables a proper recognition and cartographic presentation of landforms at the level of detail never seen before.

Here, we present the advantages of using an unmanned aerial vehicle (UAV) LiDAR data for mapping highly rugged areas with limited accessibility. We focus on two sandstone cities located in north-east Czechia: Hejda and northern part of Adršpašské skály. They are assemblages of erosional landforms that consist of closely spaced residual rock massifs separated by narrow intersecting slots and corridors. The ubiquity of boulder covers, high vertical rock walls and the presence of dense undergrowth make it hard or impossible to penetrate certain areas. After creating new digital elevation models with the resolution of up to 0.15 m we were able to verify and improve our previous work at Hejda and to map a part of Adršpašské skály what, using only field methods, would be impossible.

### **Keywords**

rock cities, geomorphological mapping, UAV-LiDAR, sandstone landforms

## How reliable is the LSPIV method in detecting the direction and velocity of surface flow in meandering river?

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### Abstract

Measuring the velocity and direction of water flow in river channels is crucial for research in hydrology and fluvial geomorphology, which is contributing to practical management of watercourses. In recent years, in addition to traditional hydrometric methods, imaging techniques have been increasingly used, particularly the Large-Scale Particle Image Velocimetry (LSPIV), which, when combined with UAV, enables non-invasive measurement of surface flow velocity and direction. However, the accuracy of this method, particularly in meandering streams, remains a subject of question. The aim of this study is to assess the reliability of the LSPIV method in determining the velocity and direction of surface flow in a meandering river and to identify the factors that influence its precision and accuracy.

Measurements were conducted at two cross-profiles of a meander in the Odra River. Reference data were obtained using a SonTek FlowTracker 2 device. Simultaneously, two video recordings were captured using a DJI Phantom 4 Pro drone, one with natural and one with artificially added tracer particles (wood shavings). Recordings were processed using the LSPIV method in Fudaa-LSPIV software, and further, using an image-based method (based on optical flow) in SSIMS-Flow software. For both approaches, scenarios with and without orthorectification were analysed, resulting in four scenarios per each software per profile. The results of the LSPIV method were statistically compared with both reference data and results from the optical flow method.

Spearman's rank correlation coefficient ( $r_s$ ) was used to assess the relationship between the measured and reference values, reaching values up to 0.915 for SSIMS-Flow (in all scenarios  $r_s$  was significant), while considerably lower values were observed for the LSPIV (in all scenarios  $r_s$  was insignificant). Both methods tend to overestimate low flow velocities. LSPIV tends to underestimate higher flow velocities, whereas the optical flow method shows a tendency to overestimate them (but the error is smaller than with LSPIV). The presence of artificial tracer particles improves the performance of both methods, particularly LSPIV. The performance of the optical flow method doesn't seem to depend too much on both the presence of tracer particles and the application of orthorectification (results from SSIMS-Flow are similar for all combinations of these 2 factors).

The results indicate that the LSPIV has a limited reliability for determining surface flow velocity and direction in meandering rivers, particularly under conditions without visible tracers. In contrast, the optical flow approach provides more consistent and accurate results across all tested scenarios.

### Keywords

LSPIV, Reliability, Surface flow, Meandering river, Poodří PLA

## Geosystem services and disservices: definitions, concepts, classification frameworks

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### Abstract

Ecosystem services (ES) are defined as the benefits that people obtain from ecosystems. The concept, although sometimes considered controversial and too anthropocentric, is widely accepted and discussed in scientific literature and serves as a basis for nature conservation and sustainable management of natural resources. Originally, the ecosystem services were perceived as benefits provided mainly by living nature, and geodiversity was omitted. However, in recent years, the so-called concept of geosystem services (GS) has been developed and used as a basis and justification for conservation efforts and relevant planning and management of abiotic resources (or geodiversity). In the scientific literature, GS are defined as benefits that geosystems provide to human society, and they reflect the geodiversity contributions to ecosystems.

Ecosystem disservices (EDS) may be defined as the ecosystem processes and functions that affect humans in negative ways, causing damage and costs, and are perceived as harmful or unpleasant under a certain value system. The concepts and frameworks related to EDS have been examined in recent decades in the scientific literature; however, geodiversity is not taken into account very often. Thus, examining the position of geodiversity within the ecosystem disservices framework, introducing the basic concepts, definitions and developing classification approaches for geosystem disservices (GDS) is a highly relevant topic not only in the field of geodiversity and geoheritage research. Generally, GDS may be considered as results and outcomes of functions, structures, and aspects related to abiotic entities, processes and interactions that may impact human well-being and are assessed as damaging under a relevant value system at a particular moment. Nevertheless, it is necessary to mention that the attitudes to geodiversity depend on the societal context, time and space; the same entity can be valued as a geosystem service or disservice, depending on the lifestyle, culture, age, experience, or historical period. In this contribution, possible classification frameworks of GDS are presented and discussed. They are based especially on already defined and used frameworks for ecosystem disservices and applied on geosystems, such as impact-oriented classification, classification based on spatial scale, or classification based on distinguishing the natural or human-induced types of disservices. For every classification framework, several examples are presented. The advantages and limits of particular classification systems are discussed, and future research directions are outlined.

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## Viewpoint geosites in Podyjí National Park (Czechia) as valuable resources for geotourism and geoeducation

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### Abstract

Viewpoints are generally considered one of the most attractive sites regarding tourism and recreation, but sometimes, their potential for Earth-science education (geoeducation) and geotourism is not recognised and used adequately. Viewpoint geosites have already been defined in scientific literature as localities that enable observation of landscape and comprehension of geodiversity (rocks, landforms, hydrological elements and their mutual relationships), and they are considered as sites that join high aesthetic and scientific values. These sites may be both natural (e.g., rock outcrops, mountain tops) and man-made objects (e.g., watchtowers, view terraces). In this paper, several examples of viewpoints from Podyjí National Park (both natural and man-made structures) are presented. For effective management, rational use, and adequate development of geoeducational and geotourist activities on these specific and important sites, it is necessary to identify their characteristics and potential, so the guidelines for the assessment of their potential are proposed. The results show that viewpoint geosites in Podyjí National Park (Czechia) have significant potential for the development of geotourist activities (including the geoeducational ones) and contribute to the promotion and sustainable use of geodiversity and geoheritage in the area. The methodological procedures used in this study are discussed, and their contribution to a better understanding of geodiversity's importance in landscape and a more effective use of these resources for Earth-science education and geotourism development is highlighted.

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## **Changes in limit of snow patches and activity of debris flows on Mt. Babia Góra (1725), Western Carpathians, since the Little Ice Age in the light of geomorphological mapping and lichenometrical dating**

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### **Abstract**

The authors employed lichenometric dating of *Rhizocarpon geographicum* to identify historic phases of debris flows and snow patch persistence on Mt. Babia Góra (1725 m), the highest peak in the Polish Beskidy Mountains. The intention was to offer a meaningful step forward in the debate about the nival and glacial past of that isolated massif which stands out from the surrounding mountain ranges due to its height, relatively harsher climate and lower vegetation zoning. The authors found that the most intense periods of debris flow activity occurred during the Little Ice Age and during the last 30 years. In this respect, the massif was found to be very similar to both medium-height mountains with elements of high-mountain relief, such as the Karkonosze Mountains, and to high mountain ranges, such as the Tatra Mountains. In addition, the periods with the largest snow patches on Mt. Babia Góra's subalpine zones coincided with those in the Tatra and Karkonosze mountain ranges, as well as with the periods of glacial advance in the Alps. Snow patch maximums on Mt. Babia Góra differ between the southern and northern slopes of this east-west oriented massif. On the south-facing slope the patches peaked in the early 19<sup>th</sup> century and then shrank, while the ones on the north-facing slope retained their large dimensions until very late in that century.

## And then there were three... – On the path to understand the evolution of a very unusual mesa (Nikolsdorfer Wände, Saxony, Germany)

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### Abstract

A general model of landscape evolution in sedimentary tablelands assumes their progressive fragmentation into an array of residual plateaus, mesas and buttes. Fluvial dissection and escarpment retreat involving a variety of hillslope processes, including large-scale mass movements, are the principal components of the model. However, specific trajectories of geomorphic evolution from plateaus to remnant hills may be different. The Elbsandsteingebirge in Saxony (Germany) offer an excellent opportunity to study the pathways of tableland fragmentation, comprising about 50 residual sandstone-capped hills of different shapes and sizes.

In this presentation we focus on a small and relatively low (<60 m in height) mesa of Nikolsdorfer Wände in the north-western part of Elbsandsteingebirge, which stands out due to its very unusual outline. It shows a highly contorted course of its outer escarpments, with three distinctive spurs in the northern part, suggesting ongoing fragmentation into several smaller residual hills. However, it is not immediately clear how has this unusual shape evolved and which specific processes are involved. To address these questions, landform recognition and geomorphological mapping were used, aided by the examination of various cartographic sources (maps at 1:30,000 and 1:10,000 scales) and high-resolution digital terrain models (DTMs) available for Saxony, which are based on the data from airborne LiDAR scanning campaigns conducted in the years 2011–2025. The Digitale Geländemodell (DGM2) was released in 2012 with a nominal resolution of 2 m × 2 m, followed in 2017 by an improved DGM1 dataset of 1 m × 1 m resolution, and finally by a 0.4 m × 0.4 m DTM based on the point cloud acquired in 2025. Critical examination of these resources, at increasing spatial scales, revealed that various pathways of geomorphic evolution could be suggested and our insights are somehow scale-dependent. A scenario involving spring sapping and fluvial dissection, suggested by coarse cartographic materials, proved to be in the need of significant modification as we examined more and more detailed digital elevation data. At the same time, detailed field mapping not only helped to verify the accuracy of DTMs (especially important at the early stages of research), but it also revealed landforms of critical importance for deciphering the likely pathways of geomorphic evolution, not evident even from the 0.4 m × 0.4 m DTM. Thus, two main lessons from this research are: (1) the spatial scale of terrain data (maps, DTM) may significantly influence our understanding of landform patterns and evolution, and (2) even with the availability of digital data of unprecedented accuracy, landform mapping in the field remains a key component of geomorphic research.

### Keywords

Sandstone geomorphology, mesas, landform evolution, LiDAR DTMs

## **3D technology and machine learning for remote environmental monitoring and assessment of the river health**

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### **Abstract**

Riparian zones are among the most biologically diverse and productive ecosystems on Earth. They are shaped by underlying physical processes associated with river flow, including erosion and deposition of sediment, periodic inundation, and groundwater-surface water exchange. High-resolution point cloud topographic data offers new opportunities for detailed assessment and monitoring of streams, from catchment areas to local studies. The main aim is to develop a protocol for the seamless generation of 3D point clouds that encompass the biophysical parameters of the riverine ecosystem, including species composition and properties; discharge, channel depth, and grain size. For analysis, a 1 km-long reach of the Belá River was selected. Here we applied and compared the method for the combination of UAV-SfM point cloud (DJI Phantom) with point cloud from mobile laser scanner FARO ORBIS, and traditional TLS measurement (Riegl VZ-1000) for generating a complex 3D virtual model of the channel. Monitoring this habitat is a critical element of the Water Framework Directive (2000/60/EÚ) and national environmental assessments of river channels. A comprehensive approach to assessing the physical structure of habitat types is necessary for river management and for maintaining good qualitative status of water bodies. The paper was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA) No. 2/0016/24, and by the Agency for Research and Development Support on the basis of the Contract No. APVV-23-0265.

### **Keywords**

Lidar, point cloud, Faro Orbis, vegetation succession, UAV

## Multiscale analysis of geodiversity in the Western Carpathians

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### Abstract

The geodiversity of the Western Carpathians, a province of the Carpathian region located in Central Europe, is exceptionally high due to significant lithological, pedological, geomorphological, hydrological, and land-cover variability. The Western Carpathians cover approximately 70,000 km<sup>2</sup> and lie primarily in Poland and Slovakia, although they also extend into parts of Hungary, the Czech Republic, and Austria.

The region is characterized by a complex geological structure composed of two major geomorphologic subprovinces: (1) the Outer Western Carpathians, built mainly of Carpathian flysch consisting of alternating layers of sandstones, claystones, and shales; (2) the Inner Western Carpathians, composed predominantly of crystalline and metamorphic rocks as well as carbonate formations, sandstones, and shales, with superimposed Neogene volcanic rocks.

The geological complexity of the region is reflected in a wide variety of landforms shaped by glacial (fossil), periglacial, karst, slope, and fluvial processes.

The main objective of this study is to highlight geological, geomorphological, and land-cover diversity at both the macro scale—across the entire Western Carpathians—and the micro scale within selected mesoregions, including the highest Carpathian range, the Malá Fatra Mountains, the Pogórze Wielickie Foothills, and the Sub-Tatra region.

The analysis was conducted using geodiversity maps for the study area, developed from geological maps, a digital terrain model, and CORINE Land Cover data. The geodiversity map of the Western Carpathians shows that the highest geodiversity values occur mainly in high-elevation areas composed of crystalline and carbonate rocks. However, detailed analyses reveal that zones of high geodiversity may also occur within areas classified as having medium geodiversity at the regional scale, and vice versa. This demonstrates that while province-scale maps are useful for identifying areas with high geoheritage potential, detailed geoheritage assessment requires higher-resolution analyses at finer spatial scales. Such detailed maps can also support the identification of new areas requiring geoconservation and contribute to the development of new regions for sustainable tourism.

### Keywords

Geodiversity, geoheritage, geoconservation, sustainable tourism, Western Carpathians, Malá Fatra Mts., Pogórze Wielickie Foothills, Sub-Tatra region

Acknowledgement: The research was supported by the Slovak VEGA Grant Agency (project no. 2/0072/24).

## **Shaped by Sediment: The Processes That Redefine Flood Magnitude and Risk**

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### **Abstract**

During the last decade, Gisborne has been hit by a series of severe storms, with Cyclone Gabrielle in February 2023 being the most damaging. Gabrielle delivered 488 mm of rain in 48 hours at Hikuwai, triggering widespread flooding, landslides, road closures, bridge failures, and major impacts on homes, land, and essential services. But in this region, rainfall is only part of the story. Tairāwhiti's highly erodible landscape produces some of the highest sediment yields in the world, and this sediment plays a major role in how floods behave.

During extreme storms, huge volumes of sediment are released from hillslopes, gullies, and landslides. These sediment pulses can rapidly raise riverbeds, narrow channels, and increase the chance of avulsions. As a result, floods can become larger and more destructive than hydrology alone would predict. To understand future flood risk, we must understand how sediment moves through the whole catchment—from the steep source areas to the floodplains where it is stored or re-mobilised.

Our assessment uses a wide range of geomorphic data, including landslide and gully mapping, connectivity analysis, aerial imagery, photogrammetry, LiDAR and bathymetric LiDAR, cross-section surveys, and evidence from past flood levels and silt deposits. Together, these tools help us see how sediment pathways change over time and how rivers adjust in response.

Working closely with local communities is essential. Their knowledge, history, and cultural connection to the land help ensure that any recommendations are practical, meaningful, and grounded in place.

By combining geomorphic change analysis with improved flood modelling and applying the PARA framework, this project aims to support effective, long-term flood mitigation over the next 5–7 years.

In Gisborne, floods are shaped not just by water, but by sediment—and understanding this is key to building a safer, more resilient future.

### **Keywords**

Sediment, Flood Risk, Flooding, Cyclone Gabrielle, Geomorphic Assessment, Fluvial Geomorphology

## Failed tablelands as the (largest?) terrestrial landslide areas

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### Abstract

Some of Earth's largest terrestrial landslides occur along the margins of sedimentary and volcanic tablelands, where coalescent failures extend across hundreds to thousands of square kilometres. Yet, despite Strahler's seminal work on the Colorado Plateau in the 1940s, these landslides have received limited attention, and many questions about their origin, timing, and evolution remain unresolved. This neglect partly reflects their remote distribution, as many occur far from populated regions, commonly in arid and high-latitude environments. Drawing on a worldwide review and recent advances in mapping, dating and numerical modeling, we synthesize current understanding of failed tablelands and illustrate it with field case studies from Patagonia, the Caspian Depression, Antarctica, and the Caucasus foothills. Contrary to earlier views, tablelands are affected not only by retrogressive rotational slides, but rather by a wide range of mass movements, including lateral spreads, topples, earthflows, rock avalanches, and various types of shallow landslides. We show that the key precondition for large landslides in tablelands is not caprock thickness itself, but the presence and long-term continuous exposure of weak sub-caprock units beneath resistant caprock. In this setting, caprock acts mainly passively, preserving and elevating weak rocks in steep escarpments where they become prone to failure. The degree of exposure of weak sub-caprock lithologies also influences landslide style, with flow-like landslides occurring preferentially where the ratio between caprock and sub-caprock thickness is low. Failed tablelands may evolve over million-year timescales, with prolonged quiescence alternating with renewed instability. Although retrogressive failure dominates long-term plateau consumption, advancing movements and reactivation of older landslide bodies may recur where active agents such as rivers, glacier and fluctuating lake levels persist at the base of the escarpment. Against the backdrop of ongoing climate change, landslide activity is accelerating in tablelands that were long regarded as stable. This is especially evident in polar tablelands (e.g. Greenland), where permafrost degradation is increasing slope instability. At the same time, major landslide events have also recently occurred in arid and semiarid tablelands (e.g. Patagonia, Sahel) following extreme hydrometeorological events.

### Keywords

Tablelands, landslides, retrogressive slides, catastrophic slope failures, escarpment retreat.

## **Assessing the potential of tree-ring growth and vessel anatomy to date the formation of a flooded subsidence depression**

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### **Abstract**

Mining subsidence can induce significant changes in local hydrological conditions, often resulting in the formation of permanently waterlogged depressions. The timing of these changes is, however, often difficult to constrain using conventional methods. This contribution explores the potential of dendrogeomorphological approaches to identify subsidence induced hydrological change using *Alnus glutinosa*. Tree-ring data were analysed to evaluate both radial growth responses and wood anatomical characteristics under changing environmental conditions. The results indicate that radial growth changes provide a reliable indicator of disturbance associated with hydrological change, whereas anatomical responses are more variable and differ among individual trees. These findings highlight the potential of tree-ring analysis as a tool for reconstructing subsidence related hydrological changes in anthropogenic landscapes and improving the temporal resolution of such reconstructions.

### **Keywords**

Mining, subsidence, dendrogeomorphology, tree-ring analysis

## **Morphogenetic Domains as Process-Based Landscape Units: A Case Study of the Stołowe Mountains**

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### **Abstract**

The concept of morphogenetic domains refers to spatial units characterized by homogeneous lithology, similar relief morphology, and a consistent set of geomorphic processes responsible for landscape development. First introduced as “fields” by Tricart (1960) and later expanded into “morphogenetic domains” by Parzóch (2001), this approach enables the division of complex landscapes into process-based units distinguished by dynamics of geomorphic processes.

This study applies the concept to the Stołowe Mountains (SW Poland), an area with contrasting geological structure built of sedimentary tableland rocks and crystalline basement. A total of nine morphogenetic domains were identified, including six within sedimentary rocks and three within crystalline units. Each domain was characterized in terms of dominant and subordinate geomorphic processes, their intensity, and spatial occurrence, allowing for the identification of distinct morphodynamic regimes. The results demonstrate strong relationships between lithology, structure, and process activity, confirming the applicability of morphogenetic domains as an effective tool for interpreting landscape organization and evolution.

### **Keywords**

morphogenesis, Stołowe Mountains, geomorphometry

## Relief–structure relationships in the Krzeszów Basin, SW Poland

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### Abstract

The Krzeszów Basin, located in the central part of the Intra-Sudetic Synclinorium (SW Poland, NE Bohemian Massif), has received limited attention in regional studies of relief evolution. Existing interpretations are scarce and rely mainly on geological mapping conducted in the 1970s. This study combines new detailed geological mapping with geomorphometric analysis based on ALS LiDAR-derived digital terrain models to reassess the relationships between lithology, bedrock structure, and relief.

The new geological map refines the distribution of Upper Cretaceous, Permian, and Triassic sedimentary rocks and provides improved constraints on the tectonic framework of the Krzeszów Basin. The results indicate a more complex structural architecture than previously assumed, with basin geometry controlled by a system of NW–SE- and subordinate NE–SW-trending faults and lithological contrasts, rather than by a simple brachysynclinal structure.

Quantitative geomorphometric analysis reveals systematic relationships between lithology, structural framework, and relief morphology. Ridge orientation, slope gradients, and the valley network are closely aligned with mapped structural elements (i.e. joints and faults) and lithological boundaries. Distinct morphometric signatures are associated with different lithological units, reflecting contrasts in resistance to erosion and slope-process response. Moreover, the occurrence of dry valleys (wind gaps) and the spatial pattern of closed depressions point to episodes of drainage reorganisation, potentially linked to an Elsterian (Sanian 2) ice lobe occupying the basin during the Pleistocene.

The Krzeszów Basin represents a distinct intramontane basin, where present-day relief preserves the imprint of complex sedimentary conditions, Late Cretaceous–early Paleogene inversion tectonics, and subsequent neotectonic activity, as well as periglacial climate. The combined use of new geological mapping and LiDAR-based geomorphometry provides a revised framework for analysing relief development in an intramontane basin and highlights the importance of rock control on landscape evolution.

### Keywords

geological mapping, Krzeszów Basin, geomorphometry

## Temperature-Driven Rock Slope Dynamics: Insights from four monitoring sites in Czechia

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### Abstract

Rock slope dynamics result from a complex interaction between geological structure and external climatic/weather factors. In this study, we present a statistical analysis of crackmeter time series aimed at identifying the influence of meteorological and thermal variables on surficial joint displacement dynamics. The data were obtained from monitoring four rock slopes in Czechia, which differ in their lithological (sandstone, granite, limestone), and morphological characteristics, altitude, and aspect.

Each site is equipped with a modular monitoring system comprising crackmeters installed in selected joints of partial blocks, a weather station located directly within the slope, and a thermal probe placed in a 3-meter-deep sub horizontal borehole. In total, 22 crackmeters monitor the displacement of 11 blocks representing different expected dynamic types – from purely thermally induced expansion/contraction, to toppling, sliding, and wedging destabilization.

The dataset includes at least two years of hourly-resolution time series, enabling the assessment of both short-term (diurnal) and long-term (seasonal) block behavior. The analysis focuses on the relationship between joint displacement and climatic variables, primarily air temperature, solar radiation, and subsurface thermal conditions. The study also includes an analysis of borehole temperature data, which allows comparison of the thermal regime between sites. These differences between blocks are likely driven by factors such as slope orientation and local microclimatic conditions.

The results reveal significant variability in block response depending on geological and morphological context—some blocks exhibit purely thermally driven cyclic behavior, while others show combined effects of thermal expansion and gravitationally induced destabilization. This study emphasizes the need for site-specific monitoring approaches and highlights the importance of long-term, high-resolution data for understanding rock slope surficial dynamics. The findings contribute to a better understanding of the role of climatic variables in rock slope stability and provide a framework for future modeling of slope behavior.

### Keywords

rock slope, thermo-mechanical dynamic, rock fall, monitoring, crack meter

## **Rhine Graben rift system-related multi-junction and other analogs: Large-scale circular lithospheric segmentation indicated in regional topographic and hydrographic data**

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### **Abstract**

Many rift-related triple-junctions from various geological periods have previously been investigated worldwide. Some of these large extensional lithospheric phenomena have even involved complex circular configurations composed of numerous associated, in all directions distributed radial and arcuate elements. They therefore exhibit an overall multi-junction character, which has so far been only poorly addressed. Based on a systematic spatial analysis of regional topography and/or hydrography, an extensive Cenozoic circular structure appears to have developed across Europe, centered on the axially converging Upper Rhine Graben, Lower Rhine Graben, Hessian Grabens, and the more distant Eger Graben components of the European Cenozoic Rift System. The related annular architecture is expressed by (1) pervasive block fracturing, newly visualized by selected consistent closed surface contours and (2) common fan- or, less, multi-arc-shaped geometries extracted from continental river networks. A wide-scale spectrum of features is included, ranging from general mountain- or basin-belt orientations through trends of circumferential, centrifugal, or centripetal river reaches and corresponding valleys to consistent sets of sharp stream bends. Using a similar research approach, we also detected several analogous circular phenomena in Africa and Asia. Despite potential links to various known geometrically corresponding geological structures, including magma plumbing systems and mantle plumes, it is still difficult to determine the principal evolutionary processes and more precise temporal constraints of these circular architectures.

### **Keywords**

topography, rift junction, fluvial network, radial feature, arcuate feature

## Drivers behind the Sajó River's active channel zone pattern

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### Abstract

Our contribution investigates natural reaches of the Sajó River (Hungary) over the period 1952–2020, focusing on the spatio-temporal dynamics of the active channel zone (ACZ) and on the key natural and anthropogenic factors controlling its development.

Precipitation variability was assessed using the Standardized Precipitation Index (SPI) and the Rainfall Anomaly Index (RAI). Anthropogenic interventions were identified from archival aerial photos and from Bertalan et al. (2019), while the influence of human activities on streamflow was evaluated using a double mass curve. The relationship between erosion intensity and land-use categories was tested using the Mann–Whitney U test.

The results reveal distinct spatio-temporal patterns in ACZ development, with the most pronounced lateral shifts and channel widening occurring between 1952 and 1956. Although a comparable duration of flood flows was observed in 2005–2011, erosion intensity was considerably lower. This trend is primarily linked to land-use changes, particularly the expansion of forest and shrub vegetation at the expense of permanent grasslands. The results suggest that vegetation development contributed to progressive channel stabilization and a reduction in lateral mobility, highlighting the importance of floodplain land-use change as a driver of long-term ACZ evolution

### Keywords

Meandering River, Active Channel Zone, Spatiotemporal Evolution, Drivers of Change

## **Geomorphometric predictors of Norway spruce dieback caused by subcortical insect in the Veľká Fatra National Park, Slovakia**

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### **Abstract**

Studies examining the impact of environmental controls on the occurrence of trees infested by subcortical insects typically focus on forestry variables, along with well-known topographic factors such as elevation and slope. However, little attention has been given to the broader range of variables that can be derived from the digital elevation models (DEM).

In this analysis, we selected nine geomorphometric characteristics: elevation, slope, southness, profile curvature, planar curvature, area solar radiation, Topographic Wetness Index, Topographic Position Index, and Terrain Ruggedness Index. Their influence on the presence of infested forest was inspected using logistic regression models in Veľká Fatra National Park (Slovakia) and its buffer zone. The response variable raster was produced by the semi-automated classification of the Sentinel-2 imagery from five consecutive years (2017 - 2021).

Both univariate and multinomial models showed low classification performance when trained on the entire study area. Additional models were computed for two hotspots of the most dynamic infestation: one located in the foothill of the mountain range and another one on its ridge. While the model trained on the low-situated hotspot reached  $AUC = 0.77$ , the score of the high-situated one was only  $AUC = 0.62$ . This suggests that the spatial patterns of infestation in the Norway spruce natural environment were more independent from topographic factors comparing to the infestation in the low-lying monoculture. In the foothill spot, Terrain Ruggedness Index was the strongest predictor ( $AUC = 0.73$ ).

Moreover, we tested whether incorporating extra geomorphometric predictors (beyond elevation and slope) to the model has the potential to improve its classification performance. In the foothill hotspot, this was confirmed by both the DeLong test and an increase in AUC of 0.05, supporting the concept of using a broader set of DEM-derived variables in similar studies.

### **Keywords**

Geomorphometric predictors, subcortical insect, logistic regression, Veľká Fatra

### **Acknowledgement**

This work was supported by the Scientific Grant Agency of The Ministry of Education, Science, Research, and Sport in Slovakia under project VEGA 1/0217/23.

## **From UAV-based surveys to Bayesian spatial models: Integrating multi-scale observations to understand glacial, peri- and paraglacial landscape change**

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### **Abstract**

Transitional glacial, peri-, and paraglacial landforms provide evidence of ongoing climate warming, which can only be understood in the context of their spatial and temporal evolution. High-resolution UAV-based photogrammetry enables quantification of short-term geomorphic changes at local scales, while multi-temporal and multi-sensor remote sensing extends these insights to regional scales and longer time frames. Bayesian spatial models, including variable selection and sparse Gaussian process regression, allow assessment of landslide distribution following glacier retreat and disentangle the influences of environmental drivers and deglaciation. Complementary studies of rock glacier velocity illustrate how these landforms serve as Essential Climate Variable, linking geomorphic processes directly to climate monitoring. Together, these approaches demonstrate how combining high-resolution monitoring with spatial statistics enables a process-based understanding of glacial, peri- and paraglacial landscape reorganization under climate change, with potential applications for hazard assessment.

### **Keywords**

UAVs, SfM photogrammetry, airborne imagery, statistical modeling, landforms in transition

## **Paraglacial Landslides in a Deglaciating Volcanic Landscape: Evidence from Cerro Tronador**

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### **Abstract**

Rapid glacier retreat modifies mountain landscapes and often promotes slope instability in recently deglaciating terrain. The Patagonian Andes are among the most rapidly deglaciating mountain regions worldwide, yet systematic landslide inventories remain limited. This study presents a landslide inventory and relative chronology for the Cerro Tronador region located at the border between Argentina and Chile in the northern Patagonian Andes.

Cerro Tronador is an extinct stratovolcano covered by an ice cap with several outlet glaciers that have undergone pronounced thinning and retreat during recent decades. These environmental changes, combined with steep topography and complex geological conditions, create favourable conditions for landslides. The landslide inventory was compiled through systematic visual interpretation of multi-temporal satellite imagery ranging from declassified Corona KH-4 imagery acquired in 1967 to recent high-resolution optical satellite data. The mapping was complemented by remote sensing analyses including vegetation indices, tasseled cap transformation and difference of DEMs to improve detection of recent and reactivated landslides. Landslides were classified according to landslide type and evaluated within a relative chronological framework.

The inventory comprises nearly 200 mapped landslides distributed across the slopes of Cerro Tronador. A substantial proportion of these landslides are located within areas deglaciating since the Little Ice Age, indicating a link between glacier retreat and slope instability. Shallow landslides dominate the inventory, particularly debris slides and debris flows. These are accompanied by rockfalls, rock slides, and a limited number of slope deformations and rock avalanches. The relative chronology reveals multiple phases of landslide activity, ranging from older landslides predating the earliest satellite imagery to more recent events and local reactivations, reflecting the progressive response of the landscape to deglaciation.

### **Keywords**

Paraglacial Processes; Landslide Inventory; Remote Sensing; Post-LIA Glacier Retreat; Cerro Tronador

## Forest management and geomorphic controls on large woody debris and debris dams in a small Hungarian catchment

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### Abstract

This study investigates the occurrence and geomorphological significance of large woody debris (LWD) and debris dams (DD) in a small, forested stream in a low-mountainous area. It emphasises the relationships between debris dam composition, the quality of the surrounding forest, and their roles in sediment retention and channel morphology. The primary research question examines how forest composition, management practices, and catchment morphological characteristics affect the quantity, structure, and spatial distribution of LWD and DD. While the ecological and geomorphological importance of woody debris is well recognised internationally, previous research in Hungary has not investigated the combined effects of forest management and catchment morphology on woody debris dynamics in low-mountain streams.

This research adopts a comprehensive perspective, interpreting the patterns of LWD and debris dams as the result of interactions among forest tree species composition, forestry-related factors, and catchment-scale geomorphological influences. To support this analysis, detailed field surveys were conducted to characterise stream morphohydrological conditions, measure the morphometric properties of LWD and DD, calculate Rosgen's large woody debris index (LWDI), and assess the geological and geomorphological context of the catchment using GIS-based methods. The study evaluated the spatial variability of woody debris characteristics across different forest management regimes and channel segments within the catchment.

The findings deepen our understanding of the indirect impacts of forest management on stream channel geomorphology and advocate for the development of more sustainable forestry practices to preserve the ecological integrity of low-mountain catchments. Additionally, these results provide a valuable framework for assessing woody debris dynamics in similar forested headwater systems outside the study area.

### Keywords

logjam, stream channel, DD, LWD, GIS, LWDI

### Acknowledgements

We would like to thank the Doctoral School of Earth Sciences at the University of Pécs for supporting this research. We are grateful for the Ministry of Agriculture's assistance. The International Management (University of Pécs) supported the attendance at this conference.

## How Shape, Slope, and Scale Matter: A Geomorphic Comparison of Flash Flood-Prone Microwatersheds

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### Abstract

Flash floods in small headwater catchments pose an increasing geomorphic and hydrological hazard in Central Europe, especially as extreme rainfall events become more frequent. Despite their significance, the relative impact of watershed geometry, slope conditions, and spatial scale on flash flood susceptibility (FFS) remains poorly understood. This study presents a comparative geomorphic analysis of flash flood-prone microwatersheds in the Mecsek Hills of Hungary, utilising GIS-based morphometry and detailed field observations to assess how geomorphic parameters influence runoff dynamics.

The analysis employs hydrologically corrected digital elevation models (DDM-10, with a horizontal resolution of 10 m and an average elevation reliability of  $\pm 0.7$  m) and GIS-derived morphometric parameters. This assessment is further enhanced by channel-scale field surveys and GIS-based geomorphic mapping. A set of key indices—such as catchment area, basin length, drainage density, texture, elongation, circularity, relief ratio, and Gravelius coefficient—was selected based on established morphometric frameworks. These parameters are analysed regarding their direct or inverse relationships with the potential for flash flood generation.

The results indicate that scale effects, including a small catchment area and a short basin length, increase flash flood sensitivity by shortening the concentration time, thereby promoting a rapid runoff response. However, this effect is significantly influenced by other geomorphic controls. In particular, shape parameters are crucial: elongated basins (characterised by low elongation ratios, form factors, and circularity ratios) tend to reduce peak discharge by distributing runoff over time, thus lowering overall FFS. Conversely, more compact basin geometries are expected to facilitate synchronous flow contributions, although such configurations are less common in the studied region.

The influence of slope conditions manifests at both the catchment and channel scales. The relief ratio and channel gradient are directly associated with runoff velocity and erosion potential, with steeper upstream sections promoting rapid flow concentration. The channel analysis revealed considerable longitudinal variability, with gradients ranging from very gentle ( $<1\%$ ) to steep ( $>15\%$ ), reflecting transitions between depositional and erosional regimes. However, slope effects are often localised and modified by structural elements such as bedrock steps and accumulations of woody debris, which can reduce flow energy and serve as natural barriers within the channel system.

A key finding of this study is that no single morphometric parameter controls flash flood susceptibility. Instead, FFS results from the interaction among scale, shape, and slope factors. This underscores the limitations of single-parameter approaches and advocates for the use of integrated, multi-factor morphometric frameworks. Overall, the study demonstrates that GIS-based geomorphic analysis is a robust tool for identifying and comparing flash flood-prone microwatersheds, while also emphasising the importance of field validation in interpreting channel-scale processes.

### Keywords

geomorphic mapping, morphometric parameters, headwater catchments, low mountains, Hungary

## **Back-Analysis based Rockfall modelling in glacial lake catchments of the Eastern Face Monte Rosa Massif, Italy**

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### **Abstract**

Warming in the European Alps has been significant ( $\sim 2^{\circ}\text{C}$ ) since the late 19th century leading to accelerated deglaciation and degradation of permafrost. The east face of the Monte Rosa Massif (Italy) highlights these changes and also exhibits accelerated rockfall incidences. The enhancement of freeze-thaw cycle coupled with schistosity in paragneiss lithologies plays a prominent role in the same. The catchment of Lago delle Locce and Lake Azzurro makes them vulnerable to such potential rockfall events. This study includes a multi-temporal remote sensing approach using Landsat, Sentinel-2B, and high-resolution orthophotos (1951–2024) to monitor the lake evolution and also map recent rockfall runouts. A deterministic rigid-body model, RAMMS::Rockfall, has been utilised to simulate rockfall trajectories over a 3D terrain. The model has been calibrated through back-analysis of a December 2024 rockfall event, optimizing rock shape (real\_equant\_1.2) and size (10 m) to match observed runout distances on snow-covered terrain. Potential Detachment Zones (PDZs) has been identified based on topography-based criteria including slopes  $>29^{\circ}$  and elevations  $>2\ 800$  m a.s.l. restricted by ridges in the lakes' catchment area. Further, the study determines the minimum detachment areas required for rockfall runouts to impact Lago delle Locce by applying the optimized simulation parameters corresponding to these PDZs. The study provides a robust framework to assess the rockfall hazards in proglacial lake catchment while considering the geological and topographical criteria.

### **Keywords**

Rockfall hazard, RAMMS::Rockfall, Proglacial lake, Monte Rosa Massif, Lago delle Locce lake

## **Connectivity-Based Approach to Erosion and Sedimentation in Small Catchments**

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### **Abstract**

This study assesses sediment (dis)connectivity and associated erosion–sedimentation dynamics across five agricultural catchments in the South Moravian and Zlín regions. The main aim was to apply and evaluate the GeoWEPP-C concept, which integrates the GeoWEPP erosion model with multi-source connectivity assessment, and to determine its suitability under conditions typical of the Czech Republic. The methodological framework combined a field-based inventory of risk objects along watercourses, the ECA model for lateral connectivity, orthophoto interpretation, documented erosion events, and UAV imagery for validation.

The results indicate that longitudinal connectivity is generally high in all catchments, although locally influenced by clusters of hydraulic structures or vegetation overgrowth, particularly within built-up areas. Lateral connectivity shows considerable spatial variability, strongly shaped by land use, terrain morphology, and management practices. Intensively cultivated areas such as Štítary and parts of Bošovice exhibit high densities of risk objects and elevated susceptibility to concentrated overland flow, whereas forested catchments (Holešín, Rozseč) act as effective buffer zones intercepting mobilised sediment.

ECA modelling demonstrated that steeper catchments – Holešín, Rozseč and southern Bošovice – are more prone to the development of laterally connected runoff pathways, while flatter landscapes such as Štítary and Ostrožská show lower susceptibility. GeoWEPP modelling identified Štítary as the most erosion-prone catchment, emphasising the role of factors beyond slope angle, including rainfall intensity, soil properties, vegetation cover, and the configuration of field tracks. While GeoWEPP outputs corresponded well with observed erosion features and UAV-validated events, their accuracy was limited by the spatial resolution and quality of input data.

Overall, the study reveals several previously undocumented critical points of concentrated runoff and provides site-specific recommendations for enhancing landscape connectivity and mitigating future erosion risks in Czech agricultural catchments.

### **Keywords**

sedimentary connectivity; water erosion; GeoWEPP-C; lateral and longitudinal connectivity; agricultural catchments

## **Investigation of active tectonic activity along the San Andreas Fault in southern California from TM-71 network observations**

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### **Abstract**

The TM-71 extensometer network provides high-resolution monitoring of active tectonic deformation along major faults in southern California. Using the Moiré interference technique, TM-71 instruments record three-dimensional relative displacements between fault blocks with sub-millimetre precision (<0.01 mm). Data is acquired daily and processed semi-automatically (SAMRD3D), enabling continuous visualization and analysis in both Cartesian (x, y, z) and fault-related (s, h, p) coordinate systems. The monitoring network in southern California, established in 2012 and expanded in 2023, currently covers the Superstition Hills, San Jacinto, and Elsinore fault systems. Time series from all sites reveal a strong annual dilatational signal driven by temperature variations.

The Imler Road site (Superstition Hills Fault) provides the most comprehensive dataset, documenting long-term slow dextral slip with a transition from compressional to extensional regime during 2020–2022. This evolution culminated in an M4.5 earthquake in May 2023, producing ~25 mm of co-seismic displacement followed by additional aseismic slip, reaching a total of 41 mm. Surface observations indicate a bi-modal slip distribution along the fault trace.

At Ocotillo (Elsinore Fault), preliminary data show a similar transition to extension in February 2024, coinciding with an earthquake swarm (M4.8). The Anza site (San Jacinto Fault) records gradual subsidence of the southwestern block and a notable change in deformation periodicity along the p-axis between 2023 and 2025.

These observations demonstrate the capability of the TM-71 network to capture both long-term tectonic trends and short-term seismic responses, providing valuable insights into fault kinematics and the interaction between aseismic creep, seismic events, and environmental effects.

### **Keywords**

TM-71 extensometer; fault slip monitoring; San Andreas Fault system; tectonic deformation; slow slip; aseismic creep; earthquake-triggered displacement; Moiré technique; fault kinematics; southern California

## Orthophoto survey and GIS-based morphometric analysis of buried periglacial polygons in Hungary

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### Abstract

During the Pleistocene, periglacial processes created networks of polygonal thermal contraction cracks in the lowlands of the Pannonian Basin. The distinctive V-shaped cross-section of these frost-related structures has been sporadically documented in classical studies from the 1950s and 1960s. However, the mapping and detailed morphometric analysis of these buried features have received limited attention. This study aims to map the spatial distribution and statistically analyse the morphometric characteristics of polygonal cropmarks, identified as buried relict sand wedge-like structures, with particular focus on the Kemeneshát, Répce, Kapuvár, and Ikva plains. We applied a combination of drone imagery, satellite images, orthophotos, digital elevation models, and geological maps to observe and digitise the polygons. A large dataset ( $n > 4000$ ) of polygonal features delineated by cropmarks was collected at high spatial resolution (40–50 cm). After digitising the network, we created a geodatabase of morphometric parameters to describe these forms. The analysis included various parameters, such as area, number of sides, and topographic variables of the polygons. Additionally, we performed descriptive statistics, a t-test, a correlation analysis, and principal component analysis (PCA) in MS Excel, MATLAB, and the R environment.

The majority of polygons identified in the study area are irregular hexagons, heptagons, and octagons, typically formed in early- and middle-Pleistocene fluvial gravel deposits and in late-Pleistocene atypical brown loess. These polygons are located on gentle slopes, with elevations ranging from 130 to 240 meters above sea level. The diameter of the polygons typically ranges from 10 to 25 metres. The visibility of the polygons is influenced not only by soil physical parameters but also by the agricultural use of individual land parcels. Consequently, the digitisation process revealed over 200 isolated patches. This situation complicates both the statistical analysis of the density and connectivity and the interpretation of the results. Analysing the mapped polygonal structures alongside modern analogues and other relict European regions can clarify the environmental conditions under which these features formed.

The preliminary results of this study offer new insights into the development of relict periglacial features and support a reassessment of their geomorphological significance in reconstructing Pleistocene environmental conditions in the Pannonian Basin.

### Keywords

Pleistocene, sand-wedge polygon, cropmarks, morphometry, Pannonian Basin

### Acknowledgement

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## **Structural, Tectonic and Erosional Controls Governing the Evolution of Sandstone Mesas: Insights from Central European Landscapes**

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### **Abstract**

The formation and evolution of sandstone table mountains (i.e. mesas and buttes) result from a combination of geological and geomorphological processes. Key factors include: (i) structural predispositions – such as lithology, stratigraphy, and bedrock architecture (e.g. bedding planes) – which govern the initial shaping of sandstone bedrock into mesa forms; (ii) tectonic activity inducing rock mass fracturing along faults or fault zones; (iii) weathering, which weakens the rock and facilitates disintegration; and (iv) erosional processes removing fractured and weathered material through outflow channels and fluvial transport. While structural, tectonic, and erosional factors establish the predisposition and govern the long-term evolution of sandstone mesas, current landscape dynamics at most sites are predominantly driven by gravitational slope processes, which destabilise the rock mass and initiate collapse mechanisms including toppling, block subsidence, rockslides, and rockfalls. To investigate these dynamics, we applied a multidisciplinary approach combining: (I) geomorphological analyses based on LiDAR-derived DEMs and field mapping; (II) structural measurements revealing both gravitational displacements (e.g. tilting, rotation) of rock blocks under investigation and tectonic fracturing patterns predisposing the rock mass to breakdown; (III) electrical resistivity surveying, clarifying (a) thickness of resistant caprock sandstones, (b) extent and course of fault structures, (c) evidence of block subsidence, and (d) washing out of sandy material (eluvium and colluvium) by flowing water from the mesas, notably from features such as the “Zlomová rokle” gorge (literally “Fault Gorge”) dividing the Hejda mesa into two halves; and (IV) displacement monitoring using TM-71 crack gauges, confirming gravitational movements of observed rock blocks and indicating ongoing gravitational collapse of the studied mesas. Our findings from Central European sandstone landscapes support the hypothesis that the combined action of structural, tectonic, weathering, erosional, and gravitational processes is key to the disintegration and long-term morphological evolution of sandstone mesas.

### **Keywords:**

geomorphological analysis, electrical resistivity surveying, displacement monitoring, structural predispositions, tectonic control, Central European sandstone landscapes

## **Decadal and seasonal turbidity dynamics in high-mountain lakes: Remotely sensed spatiotemporal analysis across lakes from the Himalayas and adjacent mountains**

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### **Abstract**

Rapid deglaciation and changing climatic conditions in the higher altitudes of the Himalayas are altering the hydro-sedimentary characteristics of high-mountain lakes, which serve as sensitive indicators of environmental change. In this ongoing research, we present the decadal (2016-2025) and seasonal spatiotemporal dynamics of turbidity across 202 high-altitude lakes across (>3,200 m a.s.l.) distributed over the Hindukush-Karakoram-Western Himalayas (HKK-WH) and Eastern Himalayas and Nyainqentanghla (EH-NQ). These lakes exhibit varying degrees of glacier connectivity. Turbidity was assessed using the Normalized Difference Turbidity Index (NDTI), employed as a proxy for suspended sediment concentration in these oligotrophic systems. As Sentinel-2 L2A atmospherically corrected products have limited validity for water analysis, we cross-validated snow, cloud and glint masked NDTI from the Sentinel-2 L1C, with NDTI derived from ACOLITE-based atmospheric correction outputs, and demonstrated strong agreement ( $r^2=0.84$ ,  $r=0.93$ ). Furthermore, seasonal variability was represented using decadal monthly median NDTI values with corresponding median absolute deviation (MAD). Man-Kendall statistics reveals spatially heterogeneous decadal trends across both regions, with greater variability observed in EH-NQ compared to HKK-WH. Lakes with differing glacier connectivity exhibit distinct seasonal turbidity patterns, which also vary regionally. The glacially connected lakes show a peak turbidity in monsoon months, while the lakes connected to the glaciers via surface conduits show different trends across these two regions. We suggest glacial dynamics, climatic conditions and geomorphology as factors influencing turbidity dynamics, although it requires further detailed investigation.

### **Keywords**

Turbidity, high-mountain lakes, NDTI, glacial connectivity, Himalayas

## **Beyond storm Boris (2024): Hillslope–channel responses to unprecedented rainfall in the Hrubý Jeseník Mountains**

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### **Abstract**

An extraordinary rainfall event affected Central Europe during the passage of Storm Boris in September 2024. The Hrubý Jeseník Mountains (northeastern Czechia) recorded the highest precipitation totals since measurements began in the late nineteenth century. We evaluated hillslope–channel responses in the most severely impacted headwater catchments and placed this event in a long-term regional context. A field inventory identified 30 new debris-flow paths—approximately 28% of all historically documented paths—reaching up to 20 m in width and extending from several tens of meters to as much as 1000 m in length. Despite unprecedented multi-day precipitation totals (up to 703 mm in 72 h) and 24-hour totals (up to 386 mm), debris-flow magnitudes were comparable to those of past events, indicating a strong topographic predisposition. Approximately 80% of both new and previously known debris-flow paths fall within the upper two deciles of a combined Topographic Wetness Index–Melton Ruggedness Number metric (calculated using SAGA GIS and ArcGIS Pro). Analysis of hourly gauge data and an intensity–duration (ID) curve shows that the 2024 event was unprecedented for rainfall durations exceeding 10 hours. Increasing hourly rainfall intensity likely explains the relatively high debris-flow occurrence compared with earlier large-scale precipitation events. Long-term persistence of extreme rainfall was examined using wavelet transform analysis of regional May–October daily maxima (1900–2024). The early twentieth century exhibited short-term (5–10-year) cyclicity in extreme (95th percentile) and very extreme (99th percentile) rainfall, whereas recent decades show more random and nonstationary patterns. Our results highlight a rising debris-flow risk in medium-altitude mountain areas—where such hazards are often underestimated—call for stronger mitigation measures, and underscore the importance of long-term extreme-weather analyses for assessing the impacts of increasing hydroclimatic variability.

### **Keywords**

Debris flow, Extreme rainfall, Storm Boris 2024, Intensity-duration relationship, Topographic indices, Hrubý Jeseník Mountains, Central Europe

## Geomorphometry of Valleys within the Rhyolitic Massif of the Krucze Mountains, Central Sudetes

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### Abstract

Using a 10-metre resolution DEM, a geomorphometric analysis of the valley network in the southern part of the Krucze Mountains (Vraní hory) in the Central Sudetes was carried out in the SAGA-GIS and QGIS environments. The Krucze Mountains are composed of laminated and vesicular, as well as non-vesicular, massive rhyolites. The eastern ridgeside of the mountains is also composed of rhyolite breccias. These rhyolites were formed as a result of volcanic processes in the Lower Permian. Their thickness in the Krucze Mountains reaches up to 600 m. The morphology of this area was visualised using the RRIM (Red Relief Image Map) algorithm. On this basis, valley floors and morphological axes were identified. In SAGA GIS, in addition to basic geomorphometric parameters (Compound Basic Terrain Analysis), valleys and ridges (Valley and Ridge Detection = VRD) were identified using the 'Top Hat Approach'. The VRD algorithm also produces a raster dataset depicting Valley Depth (=VD). Studies have shown that the valleys on the eastern ridgeside have a W–E orientation. On the western ridgeside, the valleys are oriented NNE–SSW, but the largest of them has an N–S orientation. The valleys in this part of the massif are also deeper (VD up to 92 m, average 36 m), and the slope of their sides reaches 39° (average 18°). For the valleys on the eastern ridgeside, these parameters are 77 m (average VD – 19 m) and 29° (average – 9°), respectively. The reason for this morphological diversity, apart from local variations in elevation (the western part of the massif rises to a maximum of over 800 m, whilst the eastern part averages 650–750 m above sea level), is likely also due to the composition of the bedrock. The western part is dominated by massive varieties of rhyolites, whilst rhyolite breccias are found over a significant area in the eastern part. The geomorphometric analysis also identifies characteristic features of the valley distribution (valley network), which likely relate to zones of weakness in the bedrock associated with the internal structure of the rhyolite massif (system of streams/lava cones).

### Keywords

Valley morphology, Geomorphometry, Rhyolitic Massif, Central Sudetes

## Influence of DEM accuracy and resolution on morphometric dating based on complex catchment hypsometry

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### Abstract

Morphometric methods are a valuable set of techniques for studying the neotectonic evolution of the landscape and dating tectonic events. To date, several approaches have been developed for this purpose. One of them is the morphometric method proposed by Demoulin (2011, 2012), which has been developed to provide age estimates of the most recent tectonic perturbations preserved in the fluvially eroded landscape. The method relies on calculating a composite R index derived from three hypsometric integrals associated with the studied drainage basins. Values of derived R indices strongly correlate with catchment size, and this relationship, expressed by the Sr index and its change over time following a perturbation, forms the basis of morphometric dating. While the method has been applied across several terrains worldwide, the effects of DEM accuracy and resolution on the results it produces have not been studied.

This study evaluates the performance of the R/Sr method using three input DEMs (DMR5.0, DMR3.5, and SRTM1), derived from various data sources and differing in resolution and accuracy. As a test area, we chose the Malá Fatra Mountains, where there is already some evidence of uplift history available. Two different approaches executed the core computations of the hypsometric integral, while a double correction for catchment geometry was implemented for the resulting R indices. Secondly, the effect of these corrections and different calculation approaches has been analysed. A crucial step in morphometric analysis is defining an optimal channel initialisation threshold. This threshold was estimated for each DEM using standard Slope-Area (S-A) analysis and the geometric metrics that tested the spatial agreement between DEM-extracted channel networks and reference network from the national geodatabase ZBGIS. Both methods indicate considerable threshold variability across the used DEMs.

Our results suggest that age estimates vary significantly depending on the input DEM resolution and accuracy. Although the estimated ages are affected differently by R index corrections across the analysed catchments, these corrections generally yield lower dating estimates compared to uncorrected values. Regardless of the DEM used, the results indicate spatially heterochronous neotectonic activity across the main geomorphological subunits of the Malá Fatra Mountains. Further research will focus on optimising the method to achieve the most accurate age estimates, regardless of the DEM used.

### Keywords

Drainage basin; complex hypsometry; R index; DEM; Resolution and accuracy impact;

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## GIS-based spatial assessment of pluvial flood hazard: a case study from Slovakia

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### Abstract

This study aims to assess pluvial flood hazard assessment in the Nitra River Basin in western Slovakia using high-resolution spatial analysis. Several physical-geographical factors influencing surface water accumulation and infiltration were analyzed using geographic information systems (GIS) and detailed spatial datasets. The considered factors included morphometric parameters (topographic wetness index, sediment transport index, and curvature) and factors affecting surface water infiltration (soil texture, lithology, and land use/land cover). All datasets were processed to a spatial resolution of 1 m to match the high-resolution digital elevation model (DEM) derived from national airborne laser scanning (DMR5.0). The processed factors were subsequently standardized in GIS to reflect their relative influence on pluvial flooding. Categorical variables were reclassified to five classes according to their susceptibility to surface water accumulation, whereas continuous variables were rescaled to a range from 1 to 5. The standardized factors were then assigned equal weights and integrated using a linear combination approach to derive a pluvial flood hazard index (PFHI), representing the spatial distribution of pluvial flood susceptibility across the study basin. Using the equal interval classification method, the resulting PFHI map classifies the basin into five hazard levels. Moderate hazard covers the largest portion of the basin (39.14%), followed by high hazard areas (31.73%). Low hazard zones represent 18.9% of the basin, while very high and very low hazard classes account for 2.58% and 7.89%, respectively. The results of this pluvial hazard assessment can support the official Preliminary Flood Risk Assessment process in Slovakia, where pluvial flooding is increasingly recognized as a hazard comparable in importance to fluvial flooding. Acknowledgment: Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V03-00085. This research was also supported by the VEGA agency under the grant number 2/0016/24.

### Keywords

Pluvial flooding, spatial assessment, geographic information systems, Slovakia

## **Modeling pluvial flood inundation using machine learning trained on detailed spatial data and hydraulically generated water depths: a case study**

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### **Abstract**

Pluvial flooding triggered by heavy rainfall is an increasingly significant hazard, as it affects areas outside of river channels. This study aims at machine learning-based modeling of flood inundation using hydraulically simulated water depths alongside high-resolution spatial predictors. A two-dimensional hydraulic model (MIKE+) and rain-on-grid method were employed to generate flow depth data for four rainfall intensities (20, 40, 60, and 80 mm/h), ensuring physically training inputs for the machine learning models. A set of physical-geographical predictors, including slope, curvature, topographic wetness index, sediment transport index, flow accumulation, height above the nearest drainage, surface roughness, and normalized vegetation difference index, was compiled and tested for multicollinearity, confirming their appropriateness for modeling purposes. The neural network (NN) algorithm was then used to estimate both flood extent (classification task) and water depth (regression task) within the Teplica study domain, western Slovakia. A 10-fold cross-validation strategy was employed during the training process. The results show that NN delivers various performance depending on tested folds, with F1-scores between 0.69 and 0.89 for flood extent prediction. Predicted water depths closely matched the hydraulic simulations, with RMSE values ranging from 2.5% to 14.0%, MAE values from 1.2 to 4.8%, and minimal bias (-3.1 – 2.3%). Performance differed depending on rainfall intensity and spatial context: classification was more accurate at lower rainfall intensities, while water depth predictions improved at higher intensities. Due to a relatively large study area and the NN algorithm itself, model training took from 20.7 minutes to 2.7 hours for classification and from 19.3 minutes to 4.5 hours for regression. The study suggests that machine learning models trained on hydraulic simulation outputs can reproduce flood patterns in previously unseen areas to a reasonable extent. Acknowledgment: Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V03-00085.

### **Keywords**

Pluvial flooding, flood extent, water depths, neural network, geographic information systems