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Abstracts

Towards a global understanding of fine-scale spatial patterns in alpine-treeline ecotones

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Abstract

The approach of forest towards the alpine treeline is rarely smooth or complete. Instead, tree cover often starts to break up into patches or single trees as the climatic treeline is approached, forming a more or less broad ecotone, though some montane forests reach their upper limit as a closed front. In most treeline ecotones, the uppermost trees are located below the climatic potential elevation for tree growth, and this elevational difference is increasing due to the fast current global warming, lifting the potential treeline to higher elevations. The spatial pattern of tree cover in the ecotone may indicate how fast forest can be expected to track warming trends by shifting uphill. For example, we hypothesize that discrete forest borders indicate the operation of positive feedback switches and hence low responsiveness to climate change, while diffuse ecotones indicate the opposite. To test this and other hypothesis about pattern-dynamics relationships and to ultimately use spatial patterns as indicators, we need to be able to map and quantify these patterns at a large number of sites, ideally globally. This is becoming increasingly feasible thanks to advances in very-high resolution remote sensing, machine learning for image analysis, and various methods for quantifying ecotone patterns. Using these advances, we mapped fine-scale alpine-treeline ecotone patterns globally for the first time, based on Google-Earth-sourced images of over seven thousand 1-ha plots, and related them to potential regional drivers, including climate, terrain, land use, and tree taxa. We found that these factors could predict almost half of the variation in ecotone pattern, in spite of the imperfect data used, indicating high predictability and ecological meaning of these patterns. We will present this study and other initiatives for mapping fine-scale ecotone patterns and discuss how they can advance our understanding of treeline-ecotone dynamics in mountains around the world.

Decoupled temperature and hydroclimate signals during the Late Glacial – Holocene transition in the Bale Mountains, Ethiopia

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Abstract

Understanding past climate variability and extremes and their influence on hydrological systems is essential for anticipating future climate change impacts. Afro-alpine ecosystems provide valuable paleoclimate archives due to their remoteness and limited influence from modern anthropogenic disturbance.

Here we reconstruct the past ~17 kyr of environmental change in the Bale Mountains of southeastern Ethiopia, the largest tropical alpine ecosystem in Africa. Our study is based on a sediment core recovered from Central Lake (*06°51′16.1″N, 39°52′56.1″E; 4020 m a.s.l.*) (Chernet et al. 2025). We combine sediment geochemistry, GDGT-derived temperature proxies, compound-specific isotopes of sugar biomarkers and leaf-wax lipids, and pollen assemblages to reconstruct climate variability, lake dynamics, and ecological responses.

The multiproxy record reveals three major phases in lake evolution. During the Late Glacial (17–10.7 cal kyr BP), the lake system was relatively stable and hydrologically buffered. In the Early–Middle Holocene (10.7–3.2 cal kyr BP), strengthened effective moisture and enhanced lake–catchment connectivity led to the development of a stable open-lake system. Since ~3.2 cal kyr BP, the lake transitioned to a seasonally influenced palustrine system associated with increasing evaporative stress.

Hydrological and ecological responses were nonlinear, with a clear decoupling between temperature and hydroclimate during the Younger Dryas. This pattern likely reflects shifts in regional atmospheric circulation superimposed on a climate-sensitive alpine environment. Lake-water isotopes and dust flux indicate that evaporative balance and atmospheric circulation exerted stronger control on lake dynamics than temperature alone.

Our results highlight the sensitivity of tropical alpine lake systems to hydroclimate variability and demonstrate the value of multi-proxy approaches for disentangling local limnological processes from regional climate forcing in afro-alpine environments.

Chernet, S., Bittner, L., Gil-Romera, G., Lemma, B. Bliedtner, M., Zech, R., Glaser, B., Bromm, T., Szidat, S., Zech, W. and Zech, M., 2025. A Late Glacial and Holocene sugar biomarker-based $\delta^{18}O$ paleoclimate record from the Afro-alpine Central Lake, Bale Mountains, Ethiopia. Global and Planetary Change 253, 104975.

Mountain Pastoralism in a Changing World

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Abstract
Grasslands are one of the largest terrestrial ecosystems worldwide. They provide manifold ecosystem services and represent the material basis for the world's most extensive agricultural production system: grassland-based livestock farming. A central feature of grassland-based animal husbandry is flexible mobility, which allows pastoralists and their animals to access disperse feed and water resources that are only temporarily available. Mountains are home to approximately one-third of the world's grassland areas. These grasslands have been used for centuries in extensive ways, with all forms of pastoral practices there characterized by a strong vertical mobility due to the topography and fragmentation of the landscapes. The long-standing spatiotemporal grazing systems and pastoral livelihoods are being increasingly put under pressure. This contribution provides an overview of a variety of challenges mountain grasslands and pastoral communities have faced recently and those they face today in different mountain regions. An extensive body of academic literature related to mountain pastoralism published since the turn of the millennium grounds the overview provided in this lecture.

Effects of Warming Climate and Land Use Change on Ecosystem Processes in Icelandic Rangelands as Mediated by Plants

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Abstract

The Arctic is warming around four times faster than the globe, leading to visible ecosystem changes such as Arctic greening and browning, due to shifts in plant community composition and productivity (NDVI). Those shifts are accompanied by altered community functional trait composition, potentially, influencing associated ecosystem processes. Functional trait composition may either shift toward resource acquisition or conservation, depending on other environmental factors such as land use. Understanding warming influences functional traits, ecosystem processes and their relationship is critical in predicting ecosystem responses to climate change. The aim of this study was to understand how community-weighted mean (CWM) plant functional traits relate to ecosystem processes (CO_2 fluxes, decomposition and greenness) and how fenced sheep grazing cessation alone (F) and warming combined with grazing cessation (F+W) influence the relationship. I used a long-term warming experiment site at Auðkúluheiði in the Icelandic highlands, where a one ha fence excludes grazing and warming has been simulated for almost 30 years with open-top chambers. Ecosystem process responses differed between treatments, with fenced plots (both F and F+W) increasing ecosystem respiration and F+W plots enhancing decomposition. F+W plots had a stronger effect on CWM plant functional traits than F, shifting communities toward a more conservative yet competitive trait composition (larger plants). The relationship between CWM plant functional traits and ecosystem processes was weak, but significant, and no trait independently explained variation in processes independent of treatments. This suggests that by removing the grazing disturbance that warming along with grazing cessation enhanced the CWM trait-process relationships.

From monitoring to future projections: Alpine Glacier Demise in the 21st century

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Abstract

Ongoing climatic change is driving the continuous demise of mountain glaciers in the recent past having consequences for water resources, natural hazards, and sea-level rise. Satellite observations show an alarming trend towards increasing loss rates, particularly in the European Alps. There, model projections suggest that glaciers will largely disappear from the mountain landscape by the end of the century. Under the most optimistic scenarios with a regional warming below ~3°C, only one third of the ice volume can be preserved. Most glaciers will disappear. Only glaciers that can retreat to high altitudes – primarily in the Western Alps – will survive.

Here, we will redraw this picture by combining 3D glacier evolution modelling with systematic data assimilation. In this way, a seamless record of glacier evolution in the European Alps is produced, spanning the time period 2000 to 2100. The main strength of our approach is that it avoids geometric simplifications typically applied in the current generation of regionally applicable glacier models. Together with inverse and ensemble techniques for data assimilation, our approach can directly ingest map products of observed surface velocities and of the observed 2000-2020 elevation change. For the future projections, we exclusively rely on high-resolution regional climate models, which better represent the atmospheric conditions over mountainous regions. Moreover, we consider the full range of climate scenarios. Our results largely corroborate the above-described fate for the European glacier population. For the first time, 3D simulations.

Mountains as Interconnected Resource and Knowledge Spaces: Historical Mining and Landscape Change in the Harz and Andes

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Abstract

Mountains were for a long time conceptualized as peripheral and isolated geographical spaces, characterized by a comparatively late history of human settlement. They were interpreted as places of refuge and frequently associated with socio-economic backwardness. However, over recent decades, interdisciplinary research, such as from archaeology or geography, provided evidence for earlier patterns of human occupation than previously recognized. Studies have highlighted the existence of complex socio-cultural interactions between mountain regions and their adjacent foothills, as well as among distinct mountain ranges.

Against this background, this study analyzes mountain regions with a focus on mining related to exchange processes and landscape changes in a historical context. Owing to their rich mineral resources, mountains serve as key sites of extraction. In the beginning of the 16th century, silver became a central driver of global flows of finances and materials during the Early Modern Period. Advanced mining techniques embedded in differentiated systems of the organization of work and resources and the consideration of sustainability aspects allowed the exploitation of hydrothermal ore veins at depths to 1,000 meters.

Focusing on case studies from the Harz Mountains and the Andes, this paper argues that geographical inaccessibility did not hinder technological development. Rather, mountain regions functioned as hubs of supra-regional exchange, cooperation, and innovation. The mobility of miners and experts, along with the transfer of knowledge in oral and written forms, fostered early connections between distant mining centers in mountain regions. The environmental and technical challenges of mountain mining stimulated adaptive solutions that not only shaped socio-economic structures but also produced significant and lasting landscape transformations. At the same time, the specific naturals settings of each region required locally adapted extraction strategies, resulting in diverse environmental impacts. In light of the current environmental challenges caused by metal mining on a global scale, understanding the historical context is crucial for a necessary social transformation

Supraglacial Vegetation on the Debris-Covered Belvedere Glacier, Italian Alps

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Abstract

Characteristics of plant growth on the surface of debris-covered glaciers (DCGs) include the unstable and partly mobile ground caused by ice changes, frequent disturbances and high daily temperature fluctuations. Despite these seemingly limiting factors, supraglacial debris is known to host high biodiversity and, in some locations, even forests. Due to unique microclimatic conditions, the role of debris-covered glaciers as a refuge for both thermophilous and cryophilous plants under changing climatic conditions have been discussed. Through a combined approach of field surveys and remote sensing, insights on composition and prevalence of these ecosystems can be gained, providing information on the role and significance of supraglacial vegetation in alpine environments.
During the summer of 2025, vegetation sampling was conducted on 21 plots of 10 m² each on the Belvedere Glacier below the east face of Monte Rosa, Italian Alps. With the use of high spatial resolution Unmanned Aerial Vehicle (UAV) – derived imagery, vegetation cover on selected areas was assessed via supervised classification methods. Orthophotos derived from aerial photography (SWISSTOPO) were used to analyse changes in vegetation cover from 2017 – 2023 through NDVI (Normalized Difference Vegetation Index) analysis.
Supraglacial vegetation was detected from the lower end of the glacier at approximately 1840 m a.s.l. to an elevation of 2140 m a.s.l. A total of 64 vascular plant species were identified. Especially dense vegetation cover including shrubs was found to be concentrated on the less mobile and lower lying glacier termini but also detected on very mobile sections of the glacier. In the course of the last decade, a strong increase of supraglacial vegetation cover as well as glacier-induced movement of vegetation patches were recorded on the glacier. Due to the often small and sparse growth form of supraglacial vegetation, the vegetation cover was underestimated in the UAV-derived images and orthophotos.

Gössnitzkees (Schobergruppe, Hohe Tauern) – ein stark schuttbedeckter Gletscher im Klimawandel

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Abstract

Das Gössnitzkees liegt im Talschluss des Gössnitztals im Kärntner Teil der Schobergruppe in den Hohen Tauern. Die Schobergruppe mit ihren 30 Dreitausendern ist aufgrund ihrer Topographie und klimatischen Situation an der Südabdachung der Alpen relativ gering vergletschert. Das Gössnitzkees, der größte Gletscher der Schobergruppe, ist ein von Lawinen ernährter Kargletscher und aktuell fast vollständig von Schutt bedeckt. Die visuelle Gletscherabgrenzung ist aufgrund der Schuttbedeckung in Fernerkundungsdaten, aber auch in-situ erschwert bzw. oft nicht möglich. Gletscherrückgang und Permafrostdegradation führten in den letzten Jahren zu vermehrtem Steinschlag. Infolgedessen musste ein Alpenvereinsweg in unmittelbarer Nähe des Gössnitzkeeses gesperrt bzw. aufgelassen werden.

Zur Unterstützung der Gletscherforschung am Gössnitzkees nutzt die Grazer Arbeitsgruppe für Permafrost- und Gletscherforschung unterschiedliche Messmethoden: Geodätische Messungen, terrestrische Fotogrammetrie, TLS, Luftbildvermessung (Flugzeug, Drohne), ALS, Satellitenvermessung (optische Sensoren, RADAR), geophysikalische Messungen (Georadar, Geoelektrik, Hammerschlagseismik) und Klimamessungen (Meteorologie, Bodentemperatur in verschiedenen Tiefen).

In diesem Beitrag geht es um das Weiterschreiben der Gletschergeschichte des Gössnitzkeeses mit Auswertungen von aktuellen Luftbildern und geodätischen Messungen und der Inwertsetzung durch Daten aus dem Klimamonitoring, wie z.B. der Temperatur.

Ergebnisse beinhalten die Flächen- und Volumenänderung. Die aktuellsten Luftbilder stammen aus 2021. Das Gössnitzkees ist demnach in vier Teilflächen zerfallen. Die aktuelle Fläche ist nur mehr ein Viertel der Ausdehnung von 1850 (letzter Hochstand, erkennbar im Gelände durch die markanten Ufermoränen). Die mittlere Eisdickenabnahme liegt in etwa bei 0,5 m/Jahr. Die Schuttbedeckung erlaubt auch die hochgenaue, flächendeckende Bewegungsmessung, also die Ermittlung von 3D-Verschiebunsgvektoren. Anhand der ermittelten Geländehöhenänderung und des Bewegungsmusters lässt sich der Gletscherrand relativ genau ableiten.

Die alljährlichen geodätischen Messungen (1996-2025, 30 Epochen) zeigen einen signifikanten Rückgang der jährlichen Eisschmelze sowie der Fließgeschwindigkeit. Aufgrund der Volatilität der Messgrößen ist das Klimasignal (Temperaturanstieg) nur über längere Zeiträume erkennbar. Die Änderung der Eisdicke korreliert mit dem Grad der Schuttbedeckung, die Fließgeschwindigkeit mit der Eisdicke.

Keywords: Hohe Tauern, Gössnitzkees, schuttbedeckt, Gletschermonitoring, Gletscherrückgang, Klimawandel

Performance assessment of freely available digital elevation models for mapping of rock and ice walls in high-mountain regions.

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Abstract

Digital elevation models (DEMs) are fundamental for applications in high mountain regions, including topographic mapping, hydrological modelling, and hazard assessment. This study evaluates the suitability of freely available global and regional DEMs for representing steep and complex high-mountain terrain using test sites in the Himalayas and Karakoram. The results demonstrate that high-quality topographic maps can be produced from heterogeneous DEM sources, provided that careful selection, void handling, and processing are applied.

Begegnungen im Himalaya – Drei Ausstellungen zu ‚Himalayan Encounters. Hidden views from 170 years ago' in Indien

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Abstract

Alexander von Humboldt war der kosmopolitische Forscher und aufgeklärte Geograph, der Mitte des 19. Jahrhunderts die Schlagintweit-Brüder aus München, ihres Zeichens Geographen und Geologen, zusammen mit Carl Ritter in der Berliner Schule der Geographie ausbildete und auf eine groß angelegte Expedition vorbereitete. Mit Hilfe freundschaftlichen Beziehungen des Preußischen Königs Friedrich Wilhelm IV zu Königin Viktoria wurden die Forscher an die britische Ostindiengesellschaft zur Aufnahme des Magnetismus im indischen Subkontinent vermittelt. Aus dieser in den Jahren 1855-1857 durchgeführten Unternehmung wurden 750 Aquarelle, Ölgemälde und kolorierte Fotographien zurückgebracht, die als eindrückliche zeitgenössische Zeugnisse der landschaftlichen Dokumentation aus neuen Blickwinkeln dienten, die die Perspektive auf Gletscher, Flüsse, Heiligtümer und ländliche Lebensbedingungen lenkte. Mehr als die Hälfte davon sind erhalten und wurden 2015 teilweise im Alpinen Museum in München in einer umfassenden Ausstellung zu den Ergebnissen der Schlagintweit-Expedition ausgestellt. Als einziger indischer Gast nahm Prof. Shekhar Pathak auf Einladung von Prof. Hermann Kreutzmann von der Freien Universität an der Ausstellungseröffnung teil. Beim nachfolgenden Besuch der Archive des Alpinen Museums und der Staatlichen Gemäldesammlung kam der dringende Wunsch auf, diese in Indien entstandenen Zeichnungen und Gemälde, aber dort nie gezeigten Gemälde einer weiteren interessierten Öffentlichkeit zugänglich zu machen.

In diesem Frühjahr gelang es nun, eine auf den Himalaya zugeschnittene Auswahl von 77 Gemälden und Zeichnungen in drei Ausstellungen im India International Centre in New Delhi, in der Doon Library & Research Centre in Dehradun und im CRST College in Nainital zu zeigen. Aus der Himalaya-Region stammten wichtige Helfer und Begleiter der Schlagintweit-Brüder, deren Biographien dort bekannt sind. Mit diesen Ausstellungen wurde die Brücke zwischen Berlin und Indien bekräftigt. Die außerordentlich hohe Resonanz spiegelte sich in den Besucherzahlen, Presse- und Medienberichten wider und weckte den Ruf nach weiteren ähnlich gelagerten Kooperationen.

Ermöglicht wurde die Reproduktion und Rahmung der Bilder für die Ausstellung durch eine Bewilligung aus der Flexiblen Projektförderung aus der Freien Universität, einem Zuschuss aus der Ernst-Reuter-Gesellschaft und Beiträgen aus der Schlagintweit-Familie. In Indien fungierte die People's Association for Himalayan Area Research (PAHAR), die als Stiftung und Nichtregierungsorganisation in der Erhaltung der Himalaya-Wälder und der Stabilisierung der bergbäuerlichen Lebensbedingungen engagiert ist, als Projektpartner und Treuhänder der Exponate.

Der Katalog zur Ausstellung ist unter https://pahar.org/himalayan-encounters-catalogue/ abrufbar

Nunataks - a realistic chance for plants to survive glacial periods?

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Abstract

Nunataks are summit regions and ridges that have protruded from the ice shield of glacial periods as they do today in Greenland. Because of microclimate benefits of south-exposed rock cliffs or scree slopes, it has been discussed for almost a century, that a certain fraction of the current alpine flora could have survived the glacial era in such microhabitats. How realistic is this? One way of answering this question is the exploration of the actual microclimate conditions on sites that resemble a nunatak setting today. Does the solar heating rise temperatures sufficiently to compensate an estimated 7-9 K cooling, assumed to have prevailed during the last glacial maximum (LGM)? Such a cooling of mean air temperature corresponds to roughly 1300 to 1600 m of elevation. Data from close to the Swiss Dom summit (4540 m) where the small cushion plant *Saxifraga oppositifolia* has been found, and from a site at the Swiss Jungfraujoch (3470 m) where are surprisingly rich nival flora can be observed in rock crevices, permit estimating the Nunatak climate during the LGM. It seems the niche for survival was very narrow during the LGM, confined to the lowest ice-free locations, close to the edge of the ice dome at 2600-2800 m elevation in the Western Alps. Only a rather small fraction of the current nival flora is expected to thrive under such conditions. From these data, it seems that the majority of alpine taxa had to re-migrate from low elevation refugia. It remains uncertain, how low air temperatures actually were during the LGM, and thus, what size of an elevation difference the microclimate effect has to 'produce' in order to facilitate angiosperm plant life above the ice dome during that coldest period. Körner C, Hiltbrunner E (2026) Alpine Botany.

Towards accumulation monitoring in the Pamir Mountains

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Abstract

Accumulation on glaciers is one of the most unknown parameters for glaciers in many parts of the world. While ablation can be modelled to a satisfactory degree with the use of reanalysis data and suitable engery balance models, accumulation is considerably more difficult to determine, due to the large gradients between observations in the valleys and conditions at high altitudes. Therefore, accumulation from regional circulation models and reanalysis approaches are prone to high uncertainties.

This is especially true for High Mountain Asia, where observations in high elevation basins are mostly absent. Within the DFG-ANR project RECAP, we developed a system of automatic snow stations, which are designed to provide essential data for mass balance and accumulation investigations. During 2024 and 2025, we installed several stations on Fedchenko Glacier, the largest glacier in the Pamir Mountains. We use high-resolution reanalysis data from an updated MAR regional simulation to investigate the temporal and spatial variability of the surface mass balance in the extensive accumulation region of Fedchenko Glacier. This analysis will provide a new insight into the glacier-atmosphere feedback and the long-term evolution of this glacier.

Before and after the Earthquake: Development Trajectories in the Himalayan Riskscape of Langtang from 1949 to 2025

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Abstract

Urbanisation and land use systems in disaster-prone high mountain areas or riskscapes have emerged as important research topics and major planning challenges at a global scale with the Himalayan region as a hotspot. The case study of Langtang Valley in Nepal is characterized by rapid socio-economic changes over several decades, driven by increasing mountain tourism and massive construction work in the aftermath of the 2015 Gorkha earthquake-triggered rock and ice avalanche. This study presents an assessment of settlement changes from the late 1940s until the current setting of post-disaster reconstruction based on a multi-source dataset including remote sensing imagery, photographs, travel guidebooks, interviews and participatory mapping and provides empirical evidence on rapid reconstruction in a high mountain riskscape. Ten years after the disaster, the number of buildings in two villages of the valley is 22% and 111% higher compared to the situation before the earthquake. A high densification in settlement centres can be observed, which results from building restrictions in hazard-prone areas.

Molecular Palaeoecology: Exploring human impact with polycyclic aromatic hydrocarbons and fecal biomarkers at Moossee, Switzerland

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Abstract

Human impact has considerably shaped European landscapes for at least the past 7,000 years. In palaeoecology, this impact is mainly studied using pollen and charcoal analyses from lake and peat sediments to infer past vegetation and fire activity. While these proxies generally provide insights into past land use, they are influenced not only by human activity but also by climate, making it challenging to distinguish between natural and anthropogenic variability. Further, more detailed information about characteristics of human presence, livestock or the specific use of fire cannot be derived relying on these proxies alone. Archeological findings can partly provide these information, but they are locally restricted and usually only discontinuously available. Fecal biomarkers and polycyclic aromatic hydrocarbons are relatively new molecular methods in palaeoecology, with the potential to provide complementary information about the intensity and character of past land use continuously and at high temporal resolution: PAHs are molecular proxies for palaeofires providing information on fire characteristics such as temperature, distance or fuel. In addition to PAHs, Fecal biomarkers (sterols) can be used to trace the input of feces derived from humans and livestock present in the lake catchment.

Lake sediments from Moossee are an ideal geoarchive to apply Molecular Palaeoecology, because the presence of humans is documented by lake pile-dwellings since the Neolithic. Moreover, the sediments are varved and precisely dated, and high-resolution pollen and charcoal data are available. Recently, we established a high-resolution leaf wax *n*-alkane δD record to reconstruct past hydroclimate at this site.

Here we present a 15 ka record of polycyclic aromatic hydrocarbons (PAHs) and fecal biomarkers from Moossee, Switzerland, with a temporal resolution of 30 years (>400 samples).

This presentation will briefly introduce PAHs and fecal biomarkers and then continue with a discussion of this new dataset in the context of the existing geochemical, palaeoecological and geoarchaeological evidence at Moossee and across the Swiss Plateau.

Effects of grain size on plant diversity patterns in a Mediterranean mountain

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Abstract

Understanding how spatial grain size and sampling design influence biodiversity patterns is essential for interpreting plant diversity along elevational gradients. We investigated these effects in the Central Apennines (Italy) along an elevational gradient from 1,100 to 2,486 m a.s.l. Plant presence/absence data were collected from 83 randomly selected nested plots, each including seven grain sizes ranging from 0.25 x 0.25 m to 16 x 16 m. Alpha, beta, and gamma diversity were calculated at both the nested-plot and grain-size levels and analyzed across the elevational gradient. Gamma diversity was estimated within 100-m elevational bands by aggregating species occurrences across nested plots and grain sizes, while beta diversity was calculated using Sørensen dissimilarity among plots and grain sizes and within elevational bands. Grain size significantly influenced observed diversity patterns. Alpha diversity showed a clearer elevational trend at larger grain sizes, with species richness decreasing with increasing elevation. Gamma diversity followed a similar pattern, increasing with grain size but declining with elevation. In contrast, beta diversity remained stable along the elevational gradient but decreased as grain size increased. Our results highlight the strong influence of spatial grain size on plant diversity patterns along elevation gradients and underline its importance in biodiversity assessments. The nested sampling approach applied here provides a robust framework for examining diversity patterns and testing ecological hypotheses across elevational gradients.

Belvedere Glacier in the Italian Alps: A cryosphere laboratory

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Abstract

The heavily debris-covered Belvedere Glacier, located in the Valle Anzasca in the Piedmont, Italy, is one of the rare surge-type glaciers in the Alps. The glacier covers an area of about 4.53 km² and is largely fed by snow and ice avalanches from the Monte Rosa east face, being the most prominent rock face in the Alps. Since the early 2000s, a surge-type event, large mass movements and a glacial lake outburst flood have led to an increase scientific attention.

Since 2021, the 4EU+ cooperation between the universities of Milan, Prague, and Heidelberg has started to investigate cryospheric changes, interactions, related hazards, and potential mitigation strategies. A wide range of data and methodological approaches have been conducted to investigate glacier and debris-cover changes. Data and methods include:

- historical reports and paintings (such as the sketch maps and panoramic views of Adolf Schlagintweit from 1851)
- landscape photographs (especially from Vittorio Sella from the 1890s) and repeat photography
- remote sensing analysis (including aerial photographs and digital elevation models since 1953)
- in-situ field mapping, measurements and monitoring (for detailed geomorphological maps)
- absolute and relative dating to investigate the age of rock avalanches.

This multi-source dataset enables an in-depth understanding of cryospheric dynamics over a long period of time with a high temporal and spatial resolution. First results have been published in a special issue of AUC Geographica. To support stakeholders in territorial planning, an open-access spatial database is developed for data sharing. For a broader outreach, a poster exhibition in Prague and a film documenting fieldwork activities have been carried out.

Secrets of a subalpine mire: What can sterols and PAHs tell us about human settlement history of the Fotsch Valley

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Abstract

For many years, the Fotsch Valley (Stubai Alps, Austria) attracts (geo-)archaeological interest due to its Mesolithic encampment site "Ullafelsen" (1869 m a.s.l.). In addition to (geo-)archaeological studies of soil profiles (e.g. Lerch et al., 2022), subalpine mires represent important geoarchives offering the potential to reconstruct the paleoenvironment of the valley. Namely, the "Potsdamer Hütte Mire" (1970 m a.s.l.) (Lerch et al., 2023) and the "Schwarzmoos" (2010 m a.s.l.), both covering almost the entire Holocene, were selected for multi-proxy investigations.

Here we present the first sterol and polycyclic aromatic hydrocarbon (PAH) records established for the Schwarzmoos. Accordingly, herbivore fecal biomarkers indicate the beginning of alpine pastoralism around 5800 yrs ago (beginning of the Copper Age). Increased herbivore fecal input is also documented for the Iron Age and the Roman Period, whereas surprisingly not for the Middle Ages. The PAH contents as over-regional indicator for fire activity increase dramatically only around 3000 yrs ago with the beginning of the Iron Age. Retene-based indices point, however, to the reduced combustion of coniferous biomass around 5800 yrs BP coinciding with leaf wax biomarker-based strong local vegetation changes and thus may provide additional information for improving our understanding of human–environment interactions in the valley.

Lerch, M., Bromm, T., Geitner, C., Haas, J. N., Schäfer, D., Glaser, B., & Zech, M. (2022): Human and livestock faecal biomarkers at the prehistorical encampment site of Ullafelsen in the Fotsch Valley, Stubai Alps, Austria–potential and limitations. In *Biogeosciences*, *19* (4), 1135-1150. https://doi.org/10.5194/bg-19-1135-2022

Lerch, M.; Stutzriemer, M.; Bliedtner, M.; Bromm, T.; Sehrt, M.; Feistmantl, N. et al. (2023): Holocene landscape evolution, palaeoclimate and human impact in the Fotsch Valley, Stubai Alps, Austria: Interrogating biomarkers, stable isotopes, macrofossils and palynological indicators from a subalpine mire archive. In *The Holocene* 33 (9), pp. 1118–1131. DOI: 10.1177/09596836231176485.

Resurvey of fine-scale vegetation patterns in mountain tundra in northern Finland

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Abstract

Arctic tundra vegetation is responding to rapid climate change, including a progressive shrub expansion, increasing species richness, and upslope distribution shifts. Tundra vegetation patterns are significantly determined by fine-scale environmental conditions, particularly wintertime microclimates, such as soil temperature and snow cover, in addition to mesotopography, geomorphological processes, soil moisture, soil pH, and soil nutrients. Accordingly, vegetation shifts are expected to reflect local environmental gradients, and they may occur at fine scales over a shorter time frame. Yet the role of these factors in driving fine-scale changes and the timing remains insufficiently understood. Here, we aim to examine short-term vegetation shifts at fine scales, focusing on vascular plant species richness and its relationship to fine-scale environmental gradients. Species richness is essential to assess vegetation transitions, as it enhances ecosystem functioning. Vegetation data were resampled in the summer of 2024 and 2025 along fine-scale environmental gradients and latitudes, comprising a total of 378 plots. However, temporal trends in species occurrences were observed in several species, such as *Pedicularis lapponica* and *Deschampsia flexuosa*, on more than 40 plots during the 2011–2025 study period. Analysis of their species distributions is underway to assess whether significant spatial shifts in community composition occurred, albeit with stable species richness. Full results, including refined analysis of species richness-environment relationships, will be presented at the conference.

How to assess winner and loser species in vegetation resurvey data (i.e. GLORIA) using non-parametric abundance data – comparing different modifications of Cliffs' Delta.

Anke Jentsch and Peter Wolff

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Abstract

In recent decades, species composition change across European mountain summits has been studied mainly using cover data. Additionally, global vegetation resurvey studies also collect species abundance data. However, assessing winner and loser species from non-parametric abundance data in time series analyses needs different analytical approaches.

Here, we present modifications of Cliffs' Delta

$$d_1 = \frac{1}{number\ of\ plots} \sum_{k=1}^{number\ of\ plots} sign(abundance\ last\ resurvey_k - abundance\ 1.\ survey_k)$$

that have been applied for winner-loser-assessment at the Gloria site (DE-NPB, resurveyed between 2007 and 2024) in the National Park Berchtesgaden in Germany. Let's discuss:

$$d_2 = \frac{1}{n}\sum_{k=1}^{n}(abundance\ last\ resurvey_k - abundance\ 1.\ survey_k)$$

$$d_3 = \frac{1}{n}\sum_{k=1}^{n}|sign(abundance\ last\ resurvey_k - abundance\ 1.\ survey_k)|$$

$$d_4 = \frac{1}{n}\sum_{k=1}^{n}|(abundance\ last\ resurvey_k - abundance\ 1.\ survey_k)|$$

Key words: *GLORIA, winner, loser, Cliffs' Delta, abundance data, vegetation, resurvey*

Lake Sediments Reveal Human Impact and Environmental Changes in the Pamir-Alay, Tajikistan

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Abstract

Like other mountain areas, the Pamir-Alay in Tajikistan is very sensitive to human impact and climate change. Its history is closely tied to large empires, the legendary Silk Road and the distribution of pastoralism and agriculture across Eurasia. These developments have been connected to climate change, but a general lack of palaeoenvironmental records and other limitations make a clear association difficult. Thus, Tajikistan and the Pamir-Alay are very well suited for analysing past climate and its relationship with human impact.

We present newly acquired biomarker and geochemical data from a 65 cm long sediment core retrieved from Lake Shamar, which is located at 2,000 m altitude above the Surkhob Valley. Preliminary dating of bulk sediments suggests a basal age of ~2,000 years BP, which would cover the period of the historic Silk Road. So far, we have acquired *n*-alkane and faecal biomarker (steroids) data in a resolution of 1 cm, while polycyclic aromatic hydrocarbons (PAHs) are available in a lower resolution. The concentration and the preservation of the *n*-alkanes allow future compound-specific δ^2H measurements to reconstruct palaeohydrology. The steroid data suggests an increasing human and herbivore input during the last few decades, while the presence of horses is indicated in the oldest section of the core. The PAHs show a significant increase at the top of the core; most likely related to the increase of fossil fuel burning. Measurements of the PAHs in a higher resolution are in progress, as well as radiocarbon dating of terrestrial macros. Overall, our results indicate the high potential of a multi-biomarker approach to analyse the relationship between land use, climate and associated environmental changes.

Photosynthesis capacity along environmental gradients in the southern Ecuadorian Andes

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Abstract

Capacity of photosynthetic carbon assimilation can be estimated by two parameters, the maximum use of light energy (maximum rate of electron transport, J_{max}) and the maximum use of CO_2 (maximum rate of RubisCO activity, V_{Cmax}), both as rates per squaremeter leaf surface and second. For comparison both parameters are determined under normalized environmental conditions. We compared the photosynthetic capacity of trees of an evergreen tropical mountain rain forest along an elevation gradient from 1000 to 3000 m and of a tropical seasonally dry forest at the dry and the rainy season, respectively. The highest values were recorded by the deciduous trees of the dry forest during the rainy season.

Establishment of a first PAH record for Central Lake, Bale Mountains, Ethiopia – evidence for humans as "fire species" on the Sanetti Plateau?

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Abstract

Humans are often considered and widely accepted as "fire species" in paleoenvironmental studies. The DFG Research Unit "The Bale Mountain Exile Hypothesis" aimed amongst others at answering the question "Since when and how intensively did humans shape the afro-alpine Sanetti Plateau in the Bale Mountains, Southeastern Ethiopia?" While archaeologists and paleoenvironmental researchers found evidence for (i) human occupation of the Bale Mountains already during 47-31 cal kyr BP and (ii) recurring fire events affecting the Ericaceous Belt during the Late Glacial and the Holocene, unambiguous evidence for pre-historical human-induced fire events is still missing (Mekonnen et al., 2022 and references therein).

Within this follow-up study, we started to analyze polycyclic aromatic hydrocarbons (PAHs) from sediment samples of Central Lake on the Sanetti Plateau (Chernet et al., 2025) to evaluate their potential as fire proxy. First results show high PAH contents especially during the Late Glacial, whereas the Holocene sediments yielded lower PAH contents. The PAH ratio FluA/(FluA+Pyr) suggests, however, that this pattern does not necessarily reflect fire intensity, but rather selective degradation. While distinguishing between natural versus anthropogenic fires remains challenging, we will present and discuss further PAH indices and their potential for reconstructing fire history.

Chernet, S., Bittner, L., Gil-Romera, G., Lemma, B. Bliedtner, M., Zech, R. et al., 2025. A Late Glacial and Holocene sugar biomarker-based $\delta^{18}O$ paleoclimate record from the Afro-alpine Central Lake, Bale Mountains, Ethiopia. Global and Planetary Change 253, 104975.

Mekonnen, B., Glaser, B., Zech, R., Zech, M., Schlütz, F., Bussert, R. et al., 2022. Climate, vegetation and fire history during the past 18,000 years, recorded in high altitude lacustrine sediments of the Sanetti Plateau, Bale Mountains (Ethiopia). Progress in Earth and Planetary Science 9:14, https://doi.org/10.1186/s40645-022-004.

Subarctic cold spot Faroe Islands shows decreasing floristic diversity and no thermophilization in summit vegetation over the past two decades.

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Abstract
The Faroe Islands represent a subarctic, mountainous, 'cold spot'. However, it is currently difficult to predict whether the archipelago's climate is warming or cooling as a result of global warming (due to a possible weakening of the North-Atlantic-Current).

Here, we present novel data on plant community dynamics from floristic summit monitoring over two decades on weathered basalt volcanic bedrock – as part of the Global Observation Research Initiative on Alpine Environments (GLORIA). Richness and abundance of angiosperm and cryptogam species was recorded across an altitudinal gradient from 372 m - 752 m asl. Floristic pattern was resurveyed between 2005 - 2025. Here, we present plant community dynamics along with novel metrics for analyzing "winner" and "loser" species.

The total summit vegetation species pool of Faroe Islands consists of 80 plant species (50 forbs, 24 graminoids, 6 dwarf shrubs, 20 mosses, 9 lichens). Bryophytes dominate vegetation cover on higher summits, graminoids on lower summits. However, although the rate of richness change across continental European mountain summits is generally increasing, which has been correlated with rising temperatures, our data from the Faroe Islands suggest that more species have disappeared than newly appeared. Thus, we present evidence of local species loss.

Remarkably, species redistribution dynamics at Faroe Islands over the last two decades result in a lower "Thermophilization Indicator" D = -0.023 ($S_{2025} – S_{2005}$) than the European average D = 0.054. Such a decrease in thermophilization of mountain summit vegetation has rarely been presented elsewhere so far.

The state of the Bavarian Glaciers

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With the disappearance of the Southern Schneeferner in 2022, the number of Bavarian glaciers was reduced to four: Nördlicher Schneeferner and Höllentalferner in the Wetterstein Mountains, as well as Blaueis and Watzmann Glacier in the Berchtesgaden Alps. The glaciers are surveyed every few years; the two most recent measurement campaigns were carried out using digital photogrammetry based on drone imagery. For small glaciers, this method represents an ideal combination of low workload and high accuracy.

The glaciers are critically endangered, and their disappearance is inevitable — only the timing remains uncertain. Between 2023 and 2025, the total glacier area decreased from 36 ha to 26.2 ha (-27.2 %). In this period, the two glaciers in Berchtesgaden lost 46.0 % of their surface area, and their complete disintegration is imminent. The Northern Schneeferner (-27.7 %) will likely also be gone by the end of this decade, while the Höllentalferner (-9.2 %) may survive a few years longer.

The impacts on humans remain relatively limited: at the Blaueis Hut of the German Alpine Club, the summer water supply is likely to become problematic, and at the Höllentalferner, the downwasting of the glacier surface has already enabled two major rockfalls. The effects on biodiversity, particularly on microorganisms, are not yet known and would certainly be a worthwhile goal for research.

Ice Cliffs: Hot Spots of Melting on the debris-covered Belvedere Glacier, Italy

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Abstract

As thick layers of debris shield ice from solar radiation, debris-covered glaciers often indicate reduced retreat compared to clean ice glaciers. However, downwasting can strongly affect this kind of glaciers, potentially causing instabilities in surrounding environments (e.g., lateral moraines). In recent years, multiple studies have demonstrated that ice cliffs can contribute substantially to increased melting rates. Despite their significance, ice cliffs are often neglected and only a limited number of long-term studies have been conducted on selected glaciers.

This study aims to examine the spatial and temporal development of ice cliffs on the debris-covered Belvedere Glacier, located beneath the eastern face of Monte Rosa. High-resolution aerial and UAV imagery from 2005 to 2025 are delineated to study the formation, persistence, and morphological development of ice cliffs.

A combined methodology involving semi-automatic image analysis and field observations was conducted. Two field campaigns carried out in August and September 2025 revealed rapid changes in ice cliffs, with variations of up to five meters backwasting within just two months. Preliminary findings indicate distinct aspect-related differences: south-facing ice cliffs show initially very high melting rates but tend to flatten quickly and become subsequently covered by downslope-moving debris, whereas north-facing ice cliffs persist for longer periods. Both remote sensing data and field observations suggest that ice cliffs frequently tend to form in proximity to supraglacial lakes, ponds or surface runoff channels, where enhanced melting promotes their development and longevity, in turn contributing to the expansion of nearby supraglacial lakes. The preliminary results highlight the significant role of ice cliffs in controlling ablation rates of debris-covered glaciers. Despite their dynamics and importance, they remain insufficiently studied, emphasizing the need for further detailed research.

Transient snow line altitudes of glaciers in the European Alps from multi-mission remote sensing data (2000–2025)

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Abstract

Glaciers are considered an integral part of the hydrological cycle in mountainous regions because their meltwater runoff regulates the levels of large streams and ensures food security. In order to assess the future state of glaciers under different emission scenarios, information on the snow line altitude (SLA) – the transition between exposed ice and snow - is an important parameter to constrain surface mass balance modelling.

Here, we present a database comprising approximately 200,000 measurements from glaciers in the European Alps between 2000 and 2025. SLAs are based on image acquisition of medium-resolution optical remote sensing satellites which provide a measurement repeat rate up to a few days over the last decade. Bare ice and snow-covered glacier parts are automatically classified using glacier- and image-specific thresholding of surface reflectance in visible and infrared spectra. Validation of the created snow lines against manually delineated SLAs at selected glaciers reveals a high levels of agreement, with an average vertical deviation (root mean square error) of ~100 m.

The derived SLA measurements enable the observation of intra- and inter-annual changes in snow cover across the Alps, identify short-term melting and refreezing events, and determine the maximum extent of surface melt during late summer. For the entire glacierized area of the European Alps, we observe an increase in late summer snow lines of ~150 m since 2000, indicating an increase in surface melt, even in the glacier accumulation areas at high altitudes.