TAGUNGSBAND

Jahrestagung des Arbeitskreises Hochgebirge

digiAKH 2021

16. – 17.04.2021

Zoom-Meeting beitreten
https://uni-augsburg.zoom.us/j/96070194303?pwd=UU9kaU1WUE5BbUEyTmx4Q2JVNnlKZz09

Meeting-ID: 960 7019 4303
Kenncode: 2%n&bC

Isis Alexandra Offen, Udo Schickhoff
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Land use/land cover changes in Ischgl, Tyrol (Austria)

Natural landscapes of the European Alps have been reshaped by humans for millennia. Cultural landscapes evolved which have again been substantially modified by land use impacts related to ski tourism in recent decades. One of the "big players" in the ski tourism business is Ischgl in Tyrol (Austria). Our study provides a short introduction to land use/land cover changes since the mid-20th century. We collected ground truth data in July 2019, conducted interviews with local notables, and evaluated responses to questionnaires sent out to randomly selected people. The evaluation of CORINE and tiris land cover data complements the remote sensing analysis. Furthermore, a comparison between photographic archive material and recent photographs was conducted, completed by a cartographical mapping of the village. In general, the number of ski runs was significantly extended and increased notably in the last 60 years, while the village has densified. Although income generation has diversified, the number of peasants has not changed substantially. Many of them see animal husbandry and hay production as compensation for their intensive winter-tourism engagement and part of their local identity as well as a service to preserve the traditional cultural landscape. Part-time farming and investments in heavy machines are only possible due to the profit of the tourism. Ischgl subdistrict can be considered as a striking example of ski tourism-induced extensive social, economic and ecological changes.

Michael Dietze
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Listen to whispering rocks - The potential role of environmental seismology in mountain research

Mountain research has a bold track record in deciphering the dynamics and evolution of landforms at critical slope limits. While iconic objects such as oversteepend slopes, massive rock slides, glaciers and rock glaciers have attracted the attention of scientists and inspired the interpretation of their formation for decades, it is the actual processes, which are suggested to govern their formation, that are usually quite hard to survey as they happen in nature. This amiguitity is due to the often unpredictable, event based, rapid yet episodic nature of their occurrence. While dedicated devices for measuring these processes inevitably exist, they are either confronted with a small spatial footprint (point measurement) or temporal discontinuousity (time lapse data), or even both of these drawbacks. As a consequence, important processes like rock fall, granular mass movement, stick-slip deformation, bedload agitation, hillslope-channel coupling, thermal weathering, or averaged information about ground moisture change, substrate rheology, and temperature diffusion can be studied under natural conditions only in exceptional cases. Here I summarise recent developments in the field of environmental seismology, an emerging discipline that studies the seismic signals emitted by Earth surface processes, with a focus on existing and potential applications in mountain environments. I present seismic approaches to detecting, tracking and quantifying rare and rapid mass transport processes, provide an overview of the capabilites of seismology to survey the preparation phase of large events, and discuss the arising potential to continuously study event triggers at different temporal scales. The overarching aim of the contribution is to foster a discussion about potential research questions that could be tackled in future joint (i.e., established and seismic sensor) instrumentation projects.

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Dendroecological analyses of different conifer species along an elevation gradient in the central Himalaya, Nepal

The extreme and complex topography of the Himalaya leads to substantial variations in climatic variables such as radiation, air temperature, and precipitation, resulting in high spatial variability of local climatic conditions. Nepal, located on the southern slope of the Himalayas, is under the South Asian Summer Monsoon (SASM) influence and receives most of its annual precipitation during the summer monsoon season (June-September). Due to the weakening of the SASM, the frequency of drought events increased in recent years, with adverse effects on the human population but also forest ecosystems. In this study, we examined the response of different conifer species to local moisture conditions along an elevation gradient from the subtropical to the subalpine forest belts (550-3720 m a.s.l.). We examined tree-ring width (TRW) and stable oxygen isotopes in tree-ring cellulose (?18OTR) in different conifer species, namely *Pinus roxburghii, Pinus wallichiana, Tsuga dumosa,* and *Abies spectabilis*. TRW showed site- and species-specific climate-growth relationships along the elevation gradient, whereas the average resilience and resistance during drought events followed a declining trend with increasing elevation. The mean ?18OTR was declining with increasing elevation and decreasing men temperature. Inter-annual variations of ?18OTR were correlated to hydroclimatic variables during the summer monsoon season at all sites and for all studied species, with stronger correlations at higher elevations. These preliminary results show that the ecological conditions of Himalayan conifer trees are generally controlled by the regional monsoon climate. However, the local site conditions may alter the strength of the climate response to a varying degree in different tree-ring parameters.

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Palaeoclimatic and morphodynamic implications of Holocene boulder-dominated periglacial and paraglacial landforms in Rondane, South Norway

Periglacial, paraglacial and related boulder-dominated landforms constitute a valuable, but often unexplored source of palaeoclimatic and morphodynamic information. The timing of landform formation and stabilization can be linked to past cold climatic conditions which offers the possibility to reconstruct cold climatic periods. In this study, Schmidt-hammer exposure-age dating (SHD) was applied to a variety of boulder-dominated landforms (sorted stripes, blockfield, paraglacial alluvial fan, rock-slope failure) in Rondane, eastern South Norway for the first time. On the basis of an old and young control point a local calibration curve was established from which surface exposure ages of each landform were calculated. The investigation of formation, stabilization and age of the respective landforms permitted an assessment of Holocene climate variability in Rondane and its connectivity to landform evolution. The obtained SHD age estimates range from 11.15 ± 1.22 to 3.99 ± 1.52 ka which shows their general inactive and relict character. Most surface exposure ages of the sorted stripes cluster between 9.62 ± 1.36 and 9.01 ± 1.21 ka and appear to have stabilized towards the end of the 'Erdalen Event' or in the following warm period prior to 'Finse Event'. The blockfield age with 8.40 ± 1.16 ka is indicates landform stabilization during 'Finse Event', around the onset of the Holocene Thermal Maximum (~8.0–5.0 ka). The paraglacial alluvial fan with its four subsites shows age ranges from 8.51 ± 1.63 to 3.99 ± 1.52 ka. The old exposure age points to fan aggradation following regional deglaciation due to paraglacial processes, whereas the younger ages can be explained by increasing precipitation during the onset neoglaciation at ~4.0 ka. Surface exposure age of the rock-slope failure with 7.39 ± 0.74 ka falls into a transitional climate period towards the Holocene Thermal Maximum (~8.0–5.0 ka). This indicates that climate-driven factors such as decreasing permafrost depth and/or increasing hydrological pressure negatively influencing slope stability. The obtained first surface exposure ages from boulder-dominated landforms in Rondane give important insights to better understand the palaeoclimatic variability in the Holocene.

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CaBOL - DNA Barcoading in den alpinen Bereichen des Kaukasus

Die Kaukasusregion ist einer der Biodiversitäts-Hotspots unseres Planeten (Myers et al. 2000). Das vom BMBF finanzierte Projekt Caucasus Barcode of Life (CaBOL) zielt darauf ab, zahlreiche Tier- und Pflanzenarten des Kaukasus zu katalogisieren und in einer Referenzdatenbank zu speichern und öffentlich zugänglich zu machen. Neben dem Erstellen von DNA-Barcodes, befasst sich das Projekt mit der Identifizierung möglicher Refugialgebiete im Kleinen Kaukasus während des Letzteiszeitlichen Maximums (LGM). Während des LGM dienten die Regionen um Kintrishi und Yenoqavan vermutlich als Refugien für verschiedene Waldlebensräume und Organismen.

Myers, N., Mittermeier, R., Mittermeier, C. et al. Biodiversity hotspots for conservation priorities. Nature 403, 853-858 (2000). https://doi.org/10.1038/35002501

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Glacier decrease, climate variability and socio-economic changes as a threat for traditional irrigation-based land use systems in the Trans-Himalaya, Mustang/Nepal

High mountain ecosystems play a major role in the global water cycle and are extremely sensitive to changes in the climate system. Modifications in the hydrological system affect both, socio-economic structures in mountain regions as well as in the downstream lowlands. The northern catchment of the Trans-Himalayan Kali Gandaki river system (Mustang/Nepal) is characterized by an extreme gradient in precipitation from a sub-humid to a semi-arid climate and associated strong spatial-temporal differentiation of annual precipitation distribution over a short horizontal distance. The water resources used for irrigation and drinking water in the Mustang-Himalaya are mainly composed of monsoonal summer precipitation as well as meltwaters from ice and snow. Based on optical satellite imagery (Landsat MSS/TM/ETM+/OLI and Sentinel-2A MSI), information on multi-temporal changes of the cryosphere in the Kali-Gandaki catchment since the Little Ice Age were quantified. The results indicate an overall drastic loss of the glacierized area of -40% compared to the LIA. Interestingly, smaller glaciers in the Trans-Himalayan catchment covering a small initial area (<1 km²), indicate an average loss of almost 80% of the surface area. The changing cryosphere suggests a lower proportion of glacial runoff, which will be of decisive relevance for local water resources and thus also for the local irrigation agriculture, especially during the dry phases in winter and pre-summer. The livelihood of the rural population in the Mustang district depends to a large extent on agriculture for food security as the main source of income. Therefore, local water availability, access to water resources and its sustainable management are essential to secure local livelihoods. Although locals have adapted their economic and land-use systems over centuries to the challenges in harsh mountain environments, fast recent and future climate change requires very short-term reactions. In addition, an immense increase in tourism (pilgrims and trekkers) result into an increased water demand, accompanied by the construction of a passable road that enables new trading opportunities. Maps of two Trans-Himalayan villages (Marpha and Kagbeni) from the early 1990s have recently been updated by the authors and indicate a significant change in crop rotations and a doubling or almost fourfold increase in fruit trees within 30 years. This trend is being accompanied by an explosive increase of tourism-related infrastructure (almost 90%), which will lead to conflicting demands for various actors.

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Skiing industry and globalization in Alpine landscapes: is urbanization threatening health?

Both conservation and the sustainable use of mountain biodiversity can ensure human and ecosystem health and increase the resilience of socio-ecological systems. In this sense, mountain municipalities are increasingly promoting their landscapes as prime destinations for sports, wellness, and even medical tourism. In the upper Paznaun Valley, some invest in cable cars to improve the destination's attractiveness for visitors, others claim for gentle tourism and traditional cultural practices. Diverging views on conservation and use of socio-ecological production landscapes thus lead to intense debates on sustainable development. The present study shows that a view back in history can help to understand current environmental changes and their consequences for local people. Located near the border between Austria, Switzerland, and Italy, a nodal point of cross-Alpine mobility, the upper Paznaun Valley is inhabited and agriculturally used since millennia. With decreasing trade, the prosperity of the region decreased, forcing families to send their children abroad for work. Tourism started in the late 19th century, changing (but not entirely replacing) agricultural land use and increasing mobility and the exchange of goods, people, and ideas. Consequently, poverty was alleviated, the provision of affordable (clean) energy improved, and transport infrastructure expanded throughout this high-alpine environment, with high investments in avalanche mitigation measures, thus deeply altering the socio-ecological production landscape. Changes in agricultural land use led to decreasing biodiversity. At the same time, glaciers retreated by up to one third of their former area, and the rapid succession of plants in the ice-free glacier areas are creating new ecological niches. The present study is based on direct field observations, interviews with the mayors of two communities, and archival work. It illustrates that the communication of pathways of sustainable development in past and present is a necessary endeavor to ensure a balanced development of healthy and biodiverse socio-ecological production landscapes.

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The influence of land use changes on the climate in South Asia and Himalaya regions

Land-atmosphere interactions have been considered for numerous decades in a number of studies throughout the globe (Deng et al 2013, Foley et al. 2005). One branch of research in this field, is to look at the radiative and non-radiative changes in surface energy fluxes and water budget due to Land Use and Land Cover Changes (LULCC), the so called biogeophysical effects (BGP). Most papers agree on noticeable radiative surface cooling in temperate regions as a result of increase surface albedo and non-radiative warming in the tropical regions (Li et al 2016, Brovkin et al 2013a, Lee et al., 201, Pitman et al 2009, Davin and de Noblet-Ducoudré, 2010), leaving mid-latitudes with unclear findings (Swann et al 2011). Although these findings show a very small but significant effect on global scale (Perugini et al 2017), they highlight the rel-evance of such investigation when put into a regional or latitudinal perspective (Lee et al 2011). One of the regions highly affected by climate change are the monsoonal regions, as described in Wang (2017). That is especially the case of South Asia monsoon region who is known for being a very vulnerable area to the effects of climate change (Turner and Annamalai 2012). The region is home to one fourth of world's population where their citizens are not only vulnerable due to their high dependence on the monsoon regime but also due to (food) in-securities faced by its communities (Lal 2013, Almazroui et al 2020). Some authors went even further on looking at the potential effects of irrigation on anomalous glacier behavior on High mountain Asia finding that irrigation could work as opposite forcing to global rising temper-atures on glaciers in Kunlun Shan, and parts of Pamir and northern Tibet (Kok et al 2018). To our (my) knowledge there is no thorough study examining the role of land use land over changes (LULCC), through BGP effects, in shaping the climate of South Asian region using freely available GCMs simulations. More particularly relating to irrigation as mechanism in modulating climate and climate extremes. The word "thorough" here reflects not only the simulated impacts of LULCC on recent past and pre-industrial (picontrol) climates but it also includes future analysis, land use transitions in the region and the irrigation case as modifier of climate extremes. The research is not only notably innovative for opening the spectrum of analysis but especially for having a regional tone, many times being appropriated when dis-cussing LULCC as mitigation tool. The thorough analysis focuses on looking at LULCC patterns over the study period; the sta-tistical significance of changes, including field of significance; impacts of LULCC on annual and seasonal means from coupled model simulations; irrigation as the land management aspect particular to the transregional study area; and climate extremes in future projections.

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Sonderwirtschaftszonen. Erfolgsinstrument für Entwicklung im Hochgebirge

Sonderwirtschaftszonen (SWZ) sind abgegrenzte Areale, die sich hinsichtlich ihrer Wirtschafts-, Handels- und Steuergesetze vom Rest eines Landes unterscheiden. Mit ihrer Einrichtung geht die Vorstellung einher Wettbewerbsvorteile zu schaffen, die insbesondere ausländische Unternehmer zu Direktinvestitionen in innovative, technologiebasierte und kapitalintensive exportorientierte Unternehmungen motivieren. Diese sollen sich mittelfristig zu Wachstumspolen mit erhöhter Wertschöpfung entwickeln, welche wiederum langfristig regionale Disparitäten abbauen und die volkswirtschaftliche Entwicklung des Landes voranbringen. Vor diesem Hintergrund ist die Einrichtung von SWZ in Schwellen- und Transformationsländern zu sehen, die eine verbesserte Positionierung im globalen Marktgeschehen anstreben. Ausgehend von einer allgemeinen Darstellung der Thematik möchte der Beitrag zwei konkrete Projekte in Tadschikistan vorstellen, welche dieses Erfolgsnarrativ differenzierter erscheinen lassen. Der Beitrag stützt sich auf eigene Beobachtungen vor Ort, Expertengespräche, öffentliche und nichtpublizierte Projektdarstellungen, sekundärstatistische Daten und Rechtsgrundlagen.

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Does climate change affect vegetation differently on siliceous and calcareous summits of the European Alps?

Bedrock is an essential driver of alpine plant diversity. With ongoing climate change, the alpine life zone is expected to undergo major changes. An overall increase of species richness on mountain summits has been found, however there is considerable heterogeneity in its extent. Whether vegetation in siliceous or calcareous regions will be more strongly affected by climate change is still an open but highly relevant question in conservation biology. Detailed monitoring data are necessary to understand ongoing processes accelerating or slowing down changes and the threat of diversity loss. Here, we present a study investigating patterns in surface cover types (vascular plants, litter, bare ground, scree and rock) species richness and turnover (new and lost species) and their change over 14 years on siliceous versus calcareous summits of the European Alps. By analysing the relationship of species richness/turnover with vascular plant cover we aimed to detect ongoing competition in dense communities. Fine-scaled monitoring data collected within the GLORIA project (Global Observation Research Initiative in Alpine Environments) from permanent plots (1 x 1 m) in each cardinal direction on 24 summits distributed along elevation gradients in each of six regions (three siliceous, three calcareous) across the European Alps were used. The study provided evidence that vegetation attributes generally differed between bedrock types and showed contrasting changes over 14 years. Surface cover types changed differently over time: On siliceous bedrock, vascular plant cover decreased, coupled with an increase in litter, and it marginally increased on calcareous bedrock. The unimodal richness-cover relationship and species losses at high plant cover may indicate competition as a driver for vegetation change on alpine summits. Richness increased over time on siliceous bedrock but slightly decreased on calcareous bedrock in particular due to losses in plots with high plant cover. The exceeding number of lost species might be the first sign of a negative trend in species richness with drought possibly being an increasing problem for summit vegetation. Continued monitoring will be necessary to confirm the observed trends.

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Spatiotemporal analysis of abrupt change in Landsat time series in the eastern Hindu Kush

The land cover change in the eastern Hindu Kush region is driven by human activity and impacts of environmental change. Floods and landslides are recurring natural disasters due to which vegetation in the valleys has undergone numerous changes. So far, little research has been carried out to map past disasters and their impact on the environment and human land use. This study aims to explore the abrupt changes in vegetation and their possible drivers, such as floods and landslides. In this study we used Breaks For Additive Seasonal and Trend (BFAST) for time series analysis of Landsat data. The BFAST tool iteratively decomposes the time series into trend, seasonal and remainder components. Here, we analyze the trend component to discover abrupt changes caused by disasters. All available surface reflectance-derived data was accessed from the Landsat data archive of USGS (World Reference System-2, Path 151 and Row 35) for 1988 to 2019. Data was acquired from the corresponding scenes of Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI). We applied BFAST Modified Soil Adjusted Vegetation Index (MSAVI) and mapped changes for the eastern Hindu Kush region (22,164 km2). The number of abrupt changes detected varied between zero to eight for each pixel. Approximately 95% of pixels in the study area experienced at least one abrupt change from 1988 to 2020. A large number of pixels were affected by abrupt changes in 1991, 1995, 1998, 2007, and 2016. The timing and magnitude of flood events were also detected. Detected changes are then interpreted visually and through secondary data. In applying BFAST, we were able to detect past disasters (e.g., floods) in the study area. BFAST is well suited to detect disturbances and map their spatial and temporal patterns in large areas. The results of the study will be cross-checked with data from questionnaires and interviews with locals in the area and to investigate climate-induced human migration in the region.

Andrés Gerique, Kim Vanselow
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Amenity-led migration and naturbanization processes inside a protected area: The case of El Chaltén, Argentina

El Chaltén is a village created in 1985 within Los Glaciares National Park, in Argentine Patagonia. Since then, this urban center has had a rapid development supported by nature tourism and immigration. Basing on the amenity migration and naturbanization concepts we investigate why El Chaltén was created, who are its inhabitants and visitors, and above all, what are the environmental impacts of the resulting urbanization process inside this area of the national park. We use a mixed method approach that includes fieldwork, quantitative and qualitative interviews, and remote sensing time series of the Normalized Difference Vegetation Index. Although the negative effects seem to be limited, there are factors that can endanger the fragile balance between a growing population and tourism demand on the one side and an effective conservation on the other side.

Dagmar Brombierstäudl, Susanne Schmidt, Marcus Nüsser
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Distribution and Relevance of Aufeis (Icing) in the Upper Indus Basin

In the semi-arid high mountains of the Upper Indus Basin (UIB), meltwater supply from the cryosphere is vital for irrigated agriculture and hydropower generation. An overlooked cryosphere component that is critical for this is aufeis, which appears as a sheet-like formation of ice layers, created by successive and laminated freezing of flowing water. This study aims to redress the lack of knowledge about aufeis in the UIB by creating an inventory of aufeis fields and analysing their spatial distribution. The study is based on time-series analysis based on Landsat imagery from 2010 to 2020, supported and validated by several field campaigns carried out between 2014 and 2020. In total, more than 3700 aufeis fields were detected covering an area of about 298 km². The spatial distribution of the occurrence indicates a distinct elevation range between 4000 m a.s.l. and 5500 m a.s.l. and is marked by a pronounced longitudinal increase to the east. Contrary to the western part of the UIB including Gilgit-Baltistan, where only some few and small aufeis fields can be detected, 65% of the aufeis covered areas (195 km²) exist on the Tibetan Plateau. Our database fills an important research gap and will help in further cryosphere studies in the UIB and beyond.

Marcus Nüsser, Susanne Schmidt
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Glacier Changes on the Nanga Parbat 1856-2020: A multi-source retrospective analysis

Contemporary changes in the Himalayan cryosphere are an important concern in the global climate change debate. In this context, the glaciers of the Upper Indus Basin deserve special attention because of their importance for freshwater supply in the mountain valleys and the adjoining lowlands. However, detailed long-term glacier monitoring studies are rare due to the lack of historical data with sufficient spatio-temporal resolution. Due to relatively frequent observation, the north-western Himalayan massif of Nanga Parbat offers the possibility of analysing and quantifying glacier changes over the period between 1856 and 2020. Using a multi-temporal approach with diverse datasets including historical maps, photographs, remote sensing data, digital elevation models and field surveys, this study reveals slight changes in glacier-covered area, which decreased by 7% between 1934 and 2019 based on an investigation of 63 glaciers. A detailed analysis of five glaciers in the Rupal Valley over the period 1856-2020 identifies diverse response patterns and highlights the importance of ice and snow avalanches, surge-type dynamics and site-specific topographic particularities for individual glacier changes. The results show high similarity with the stable glacier mass in the Karakoram. This study demonstrates the advantages of combining multiple sources and types of data in order to achieve consilience and offer robust insights.

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Air pollution in mountainous terrain -- a new approach from the UNESCO World Heritage Site Geirangerfjord, Western Norway

Since 2015, we run a long-term air quality monitoring program in the UNESCO World Heritage Site “Geirangerfjord”, Western Norway, investigating the quantities, spatio-temporal distribution and meteorological drivers of PM emitted by cruise ships and local land traffic in complex terrain. Here, we show, for the first time, that ultrafine particles (PM 2.5) suspended in the entire air volume of along the mountain-to-fjord topography are partly accumulating over long periods of time (e.g. weeks and months), and weather-driven decontamination is limited. This can result in long-lasting periods of high air pollution. Spatio-temporal distribution patterns and cumulative effects of particles are more complex than previously assumed. Investigations dealing with air pollutants should carefully consider such potential cumulative effects, particularly in mountainous terrain.