2024

Eichstätt

International Commission on Continental Erosion (ICCE)

Symposium on the sensitivity of erosion and sediment transport to recent climate change

ICCE Symposium July 23rd-26th Eichstätt, Germany

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Welcome address

Dear colleagues, dear guests,

on behalf of the team at the Chair of Physical Geography, I'd like to extend a warm welcome to you all at the 2024 symposium of the International Commission on Continental Erosion.

We're happy to host this meeting that brings together 47 colleagues young and not-so-young from 17 countries – enough people to expect a diverse and interesting programme, and yet small enough to be experienced as familiar. This makes the meeting likely to achieve its aims, and this is what we wish for all participants: To facilitate networking and discussion, the opportunity to present one's work to a diverse, open-minded and friendly audience and to receive constructive feedback that might be a key to improve or to pave the way for new collaborations. Some colleagues will find that there's quite a lot of people who do similar research, for example on sediment cascades and budgets under climate and environmental change in alpine areas, on soil erosion, or in the Mediterranean. Others will be eager to exchange ideas not although, but because the respective colleagues work with a different method, on a different subject, in a different area. You will notice that our meeting programme leaves ample time between the oral sessions; stroll around the poster exhibition and meet the authors, sit down together in the courtyard or gather around one of the high tables during the lunch and coffee breaks in small groups. In the evenings, we will continue our conversations and enjoy Bavarian hospitality, food and drinks. Finally, I'm looking forward to discussing the dynamics of erosion and deposition with those of you who join the excursion to a "classical" study area where many colleagues have been studying sediment cascades and budgets for many years: the Reintal, located just south of Garmisch-Partenkirchen.

Don't hesitate to ask one of us if you have questions, for example our four student assistants Arezoo, Carolin, Maike or Till, and we'll be happy to help. I wish everyone a fruitful and nice conference, and I'd like to thank everyone, organisers and participants, who have helped and are helping to make this symposium a success.

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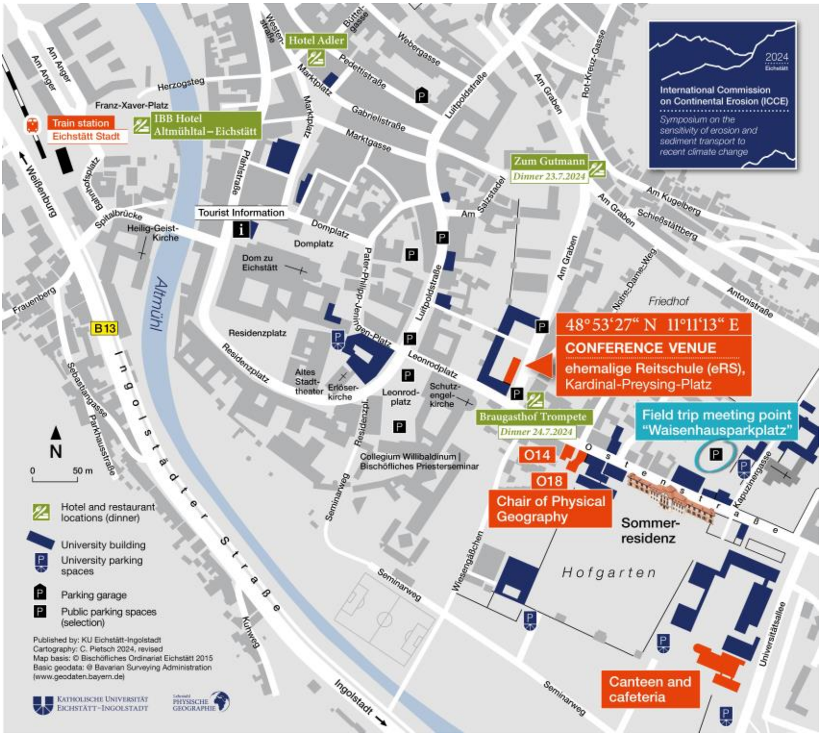

Worth knowing

- Internet connections during the conference: 1. Gast-KUEI, 2. BayernWLAN (free and without registration) or 3. eduroam
- Opening hours Registration desk and times for putting up the posters: Tuesday, 23.07.2024, from 19:00 and Wednesday, 24.07.2024, 08:00 - 09:00.

Conference schedule

Tuesday, 23.07.2024

Start	Activity	Location
19:00	Icebreaker reception (Opportunity to register)	eRS building and courtyard

Wednesday, 24.07.2024

Start/End Time	Activity	Location
08:00 – 09:00	Registration	Courtyard/ eRS002
09:00 – 09:30	Welcome addresses - *Prof. Dr. Klaus Stüwe* *Vice President KU Eichstätt* - *Prof. Dr. Tobias Heckmann* *Local Organiser* - *Prof. Dr. Paolo Porto* *ICCE President*	eRS 101
09:30 – 10:50 *(09:30 Das,* *9:50 Demmel,* *10:10 Hinsberger,* *10:30 Molnar)*	Session 1: General erosion processes and models *Moritz Altmann and Toni Himmelstoß*	eRS 101
10:50 – 11:20	Coffee break	Courtyard
11:20 – 13:00 *(11:20 Agostini,* *11:40 Chalov,* *12:00 Habel,* *12:20 Hoffmann,* *12:40 Mohammadi Raigani)*	Session 2: Sediment dynamics in rivers and lakes *Diana Kara and Manuel Stark*	eRS 101
13:00 – 14:00	Lunch break	Courtyard

14:00 – 15:30 *(Attendence Time: Group A: 14:00-14:30, Group B: 14:30-15:00)*	Poster Session 1: *Group A: Argentin, Gianini, Mager, Martinet, Pitscheider Group B: Acharyya, Brzezińska, Ivanov M., Ivanov V., Jemai, Kechnit, Prokopeva*	eRS 001
15:30 – 16:00	Coffee Break	Courtyard
16:00 – 17:40 *(16:00 Bayens, 16:20 Garipova, 16:40 Novak, 17:00 Repnik, 17:20 Rom)*	Session 3: Sediment dynamics and connectivity in alpine catchments *Peter Molnar and Martin Trappe*	eRS 101
17:40 – 19:00	Break	
19:00	Conference dinner	Wirtshaus zum Gutmann Restaurant

Thursday, 25.07.2024

Start/End Time	Activity	Location
08:30 – 09:30	Keynote lecture and discussion *Prof. Dr. Georgina Bennett, University of Exeter, UK Sliding, flowing, rocking and rolling: Monitoring climate change impacts on landslides with remote sensing and smart boulders Tobias Heckmann*	eRS 101
09:30 – 10:30 *(09:30 Golosov, 09:50 Ivanov, 10:10 Porto)*	Session 4: Soil erosion I *Sergey Chalov and Michał Habel*	eRS 101
10:30 – 11:00	Coffee break	Courtyard
11:00 – 12:20 *(11:00 Fiener, 11:20 Pic, 11:40 Sommer, 12:00 Vîrghileanu)*	Session 5: Soil erosion II *Sarah Betz-Nutz and Jakob Rom*	eRS 101
12:20 – 13:20	Lunch break	Courtyard

13:20 – 14:50 *(Attendence Time: Group C: 13:20-13:50, Group D: 13:50-14:20)*	Poster Session 2: *Group C: Betz-Nutz, Himmelstoss, Kara, Kharchenko, Tan; Group D: Altmann, Pehnert, Sannino, Tiwari*	eRS 001
14:50 – 15:20	Coffee Break	Courtyard
15:20 – 16:40 *(15:20 Cuello-Llobell, 15:40 Stark, 16:00 Company Ferrer, 16:20 Eekhout)*	Session 6: Geomorphological dynamics in the Mediterranean *Florian Haas and Paolo Porto*	eRS 101
16:40 – 17:00	Coffee break	Courtyard
17:00 – 18:30	ICCE Board Meeting - Participants are welcome to join this meeting	eRS 101
18:30 – 19:15	Break	
19:15	Conference dinner	Brauerei-gasthof Trompete Restaurant

Friday, 23.07.2024

Start/End Time	Activity	Location
07:45 (meeting time), 08:00 (departure) – evening	Field trip, leader: Tobias Heckmann and Martin Trappe, Meeting point Eichstätt: Waisenhausparkplatz	Reintal Valley, Bavarian Alps

Keynote Lecture

Sliding, flowing, rocking and rolling: Monitoring climate change impacts on landslides with remote sensing and smart boulders

Prof. Dr. Georgina Bennett, University of Exeter, UK

Sliding, flowing, rocking and rolling: Monitoring climate change impacts on landslides with remote sensing and smart boulders

Georgina Bennett[1]

[1]Department of Geography, University of Exeter, UK

Landslides are a major process of erosion and hazard in mountainous regions and along coasts around the world and it is critical to understand their response to climate change. Furthermore, landslides in mountainous regions deliver large quantities of sediment to the fluvial system, yet the transport of this sediment downstream and within floods is poorly understood. Landslide frequency and magnitude are generally assumed to increase with climate change, but as I will show in this talk with examples from California and the Swiss Alps, this is not always the case. I will also show two new innovative tools for monitoring landslides and their interaction with floods. The talk will move from sliding and flowing, to rocking and rolling. I will start with an example of slow-moving landsliding in northern California where landslides had a depth-dependent response to an unprecedented drought in 2015, with many landslides slowing down. I will then show how debris-flows may decrease into the future at certain elevations in Alpine catchments due to sediment supply limitations, as increasing temperatures preclude freeze-thaw weathering towards the latter half of the 21st century. Moving downstream, I will show how landslide sediment supply is critical to reproduce observed patterns of sediment transport and channel erosion in floods with examples from Colorado and the Philippines. Floods in mountainous regions with high rates of landsliding should potentially be modelled as sediment-rich flows rather than clear-water flows. Finally, I will give an overview of the development of Smart Boulders for monitoring landslides in near-real time. These boulders lie dormant on landslides until they are woken up by tilting or rocking above a certain threshold angle at which point they record sliding, flowing and rolling movements and may help to better understand cascading landslide dynamics and alert of hazardous movement.

Oral Sessions

Session 1: General erosion processes and models

A comprehensive assessment of impacts of climate change on rainfall erosivity in India

Subhankar Das[1], Manoj Kumar Jain[1]

[1]Indian Institute of Technology Roorkee, India

Soil erosion poses a substantial risk to global sustainability, and the imminent effects of climate change could exacerbate these risks. The Rainfall Erosivity Index (R-factor), as per the Universal Soil Loss Equation, holds a crucial role in shaping soil erosion dynamics, especially in climate-driven research. With rainfall erosivity directly linked to annual soil loss under constant soil and land use conditions, any alteration in rainfall erosivity can significantly affect soil erosion rates. This study comprehensively analysed spatiotemporal variations in rainfall erosivity across India, considering two distinct Shared Socio-Economic Pathways (SSP245 and SSP585). Utilising a bias-corrected dataset from the Coupled Model Intercomparison Project-6 (CMIP6), encompassing data from 13 models, bioclimatic variables were derived to estimate rainfall erosivity for historical and future periods. The findings unveil a noteworthy rise in mean rainfall erosivity across India in the near future (2015-2040), with respective increases of +13 % and +15 % under SSP245 and SSP585 compared to the historical period. This trend amplifies in the far future (2041-2070), projecting a rise of +22 % and +31 % under SSP245 and SSP585 pathways, respectively. Particularly, northwestern and central India are anticipated to undergo a significant escalation in rainfall erosivity in the near and distant future. The observed changes in rainfall erosivity patterns, linked to climate change, have the potential to profoundly impact India's land and water resources, especially given its reliance on agriculture.

A parametrization of climate-driven triggering mechanisms for sediment erosion

Sophia Demmel[1], Elena Leonarduzzi[2], Peter Molnar[1]

[1]Institute of Environmental Engineering, ETH Zurich, Switzerland
[2]Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland

Global sediment source-to-sink pathways are in the first instance driven by the mechanisms of sediment erosion from mountain basins, i.e. the sediment production process. Typically, the majority of sediment is delivered to the fluvial system from a small fraction of the basin area. These hotspots of erosion are determined by the interplay of geological, geomorphological and land surface properties, and are activated by climatic and hydrological processes in a continuous or intermittent, pulse-like, manner. The parametrization of governing mechanisms that trigger erosive activity is the foundation for assessing potential future changes in the sediments available for transport in a river system, for example under climate change. While the underlying physical processes of sediment erosion are complex, climate-driven predisposing and triggering factors can be simplified into meaningful indices. We present the potential of modelling these indices as high-intensity rainfall, low-intensity continuous rainfall, antecedent wetness, snowmelt, freeze-thaw cycles, and frost cracking over the past 50 years in the Alpine Rhine catchment, Switzerland, based on gridded daily data of precipitation and temperature from the Federal Office of Meteorology and Climatology MeteoSwiss. In the past, approaches for determining threshold values were successfully used to evaluate the rainfall-dependent triggering mechanism of mass movements like shallow landslides based on the characteristics of the triggering rainfall event (Leonarduzzi et al., 2017) and including antecedent soil wetness state (Leonarduzzi et al., 2021). Our analysis aims to extend the list of climate-induced erosion mechanisms by considering the interaction of precipitation and temperature as triggering factors for sediment erosion, and to expand the catalogue of possible Alpine sediment production processes. These triggering mechanisms can be linked to various erosion processes over different timescales; here we focus on the correlation with discrete mass movement events like shallow landsliding, debris flow and rockfall records from the Swiss natural hazard database (StorMe, Swiss Federal Office for the Environment FOEN). Partitioning the triggering factors of mass movement sediment supply events provides a useful method on the basis of which we can better anticipate climate-related changes in sediment erosion due to increasing temperatures and precipitation intensities.

Leonarduzzi, E., Molnar, P., McArdell, B.W. (2017): Predictive performance of rainfall thresholds for shallow landslides in Switzerland from gridded daily data. Water Resour. Res., 53, 6612–6625. https://doi.org/10.1002/2017WR021044.

Leonarduzzi, E., McArdell, B.W., Molnar, P. (2021): Rainfall-induced shallow landslides and soil wetness: comparison of physically based and probabilistic predictions. Hydrol. Earth Syst. Sci., 25, 5937–5950. https://doi.org/10.5194/hess-25-5937-2021.

Application of a 2D hydrodynamic-numeric model to simulate erosion caused by heavy precipitation

Rebecca Hinsberger[1], Alpaslan Yörük[2]

[1]Physical Geography and Environmental Research, Saarland University, Saarbrücken, Germany
[2]Hydraulic Engineering and Water Management, University of Applied Sciences, Saarbrücken, Germany

Erosion is a significant factor that intensifies soil degradation and desertification (IPCC, 2021). Considering water-induced erosion, the largest amount of soil loss is attributed to single precipitation events with high precipitation intensities (Parkin et al., 2008). As these precipitation events occur more frequently due to climate change, erosion will also increase. By modeling these events, areas at risk can be identified and countermeasures can be considered. Thus, on-site impacts such as soil loss, and off-site impacts such as discharge of sediment-bounded nutrients and pollutants into rivers or damage caused by sediment masses in settlement areas, can be reduced. In Germany, flooding and heavy precipitation events are simulated using two-dimensional hydrodynamic-numeric models (2D models) in order to determine the risk of (flash) floods. These models, for example HydroAS, simulate the hydraulics by solving the complete shallow water equations. In addition, there are add-on modules available to simulate sediment transport in river channels. Here, the hydraulics of the 2D model is combined with the sediment transport module. These modules are often based on the Exner formula for considering changes in riverbed elevation and transport capacity formulas such as Meyer-Peter-Müller or Engelund-Hansen. These transport capacity formulas are derived from empirical data with channel framework conditions. There are also models to simulate erosion on croplands, for example WEPP or EUROSEM. Here, the focus is on the erosion processes. Transport capacity is considered using formulas based on empirical data derived from channel (Yalin, 1963) or surface framework conditions (Govers, 1990). In this context, hydraulics are required to determine the forces acting on the soil. Often, lots of soil characteristics are used to estimate infiltration and surface discharge shares. However, the runoff process is considered using simplified hydraulic approaches such as the kinematic wave. For simulating erosion on croplands due to heavy precipitation, the 2D model HydroAS and a classical erosion approach are combined. The add-on module for the 2D model is expanded by a transport capacity approach for overland flow. This combination achieves both a high-quality hydraulic approach and a suitable erosion approach. Initial tests were conducted with this approach at pilot sites where linear erosion was measured after a heavy precipitation event. Different results were obtained when using different transport capacity approaches.

Key difficulties in making accurate projections of climate change impacts on sediment yields in Alpine basins by numerical modelling

Peter Molnar[1], Jacob Hirschberg[1], Georgina Bennett[2], Nadav Peleg[3]

[1]Institute of Environmental Engineering, ETH Zurich, Switzerland
[2]Department of Geography, University of Exeter, UK
[3]Institute of Earth Surface Dynamics, University of Lausanne, Switzerland

In this presentation, we look at the topic of the sensitivity of erosion and sediment transport to recent climate change from a geomorphic numerical modelling perspective. It is known that large uncertainties are involved in the prediction of climate change impacts on sediment yields in river basins, especially in mountains where climatic forcing is highly dependent on elevation and temperature changes are key, and where precipitation changes are notoriously difficult to predict by climate models. First, we will review typical approaches that convert GCM-predicted future climate into changes in sediment yields, for example by ramping up soil erosivity by a rainfall-dependent change factor, and highlight their shortcomings. Second, we will go through a typical climate change uncertainty allocation example, where total uncertainty is partitioned by Monte Carlo analysis into that due to greenhouse gas emission uncertainty, climate model uncertainty, stochastic uncertainty also called internal climate variability, and impact model uncertainty. The latter is the uncertainty involved in the parameters and structure of for example a geomorphic model that uses climate as an input to simulate sediment fluxes. Third, we apply this framework to a very active debris flow catchment in the Swiss Alps (Illgraben) with the SedCas model (Hirschberg et al., 2021), to show (a) that irreducible internal climate variability is a significant part of the uncertainty in sediment yield predictions, and that both precipitation and temperature changes matter; and (b) that elevation and temperature-dependent changes in sediment supply may be just as important for sediment yield variability as changes in rainfall or runoff. We argue that this is a critical lesson, which points to limitations of geomorphic models based on sediment transport-capacity alone, and highlights that climate change effects on weathering and sediment production at hillslope scales need to be

carefully considered in numerical models for climate change impact studies in alpine catchments. This includes field studies that investigate how a range of possible sediment production processes, like freeze-thaw cycles, rainfall triggering of mass events, permafrost thaw, soil creep, and others, may respond to climate change.

Hirschberg, J., Fatichi, S., Bennett, G. L., McArdell, B. W., Peleg, N., Lane, S. N., et al. (2021). Climate change impacts on sediment yield and debris flow activity in an Alpine catchment, J. Geophys. Res.: Earth Surface, 126, https://doi.org/10.1029/2020JF005739.

Session 2: Sediment dynamics in rivers and lakes

Long-term floodplain changes due to climatic forcing

Ludovico Agostini[1], Peter Molnar[1]

[1]Institute of Environmental Engineering, ETH Zurich, Switzerland

Landscape features in river basins are closely linked to past and current climate. Channel morphology is one of those, and it responds to discharge and sediment transport variations with a characteristic temporal scale. The adaptation time depends on the spatial scale of the observed morphological structure; thus, a smaller floodplain will respond more rapidly to changes in the boundary conditions. The external forcings that control the morphological evolution of a floodplain (morphological trajectory) are defined by the geological environment and the climatic stressors, with climate change being the primary driver of variation. In this research, we aim to quantify the floodplain adjustment over time by monitoring changes in slope, width and bed morphology. When interpreting a channel's morphological trajectory, sediment feed and the bedload flux present the greatest modelling uncertainties due to their high fluctuations and stochastic nature. Additionally, bedload intensity is rarely measured and often results are highly subjected to methodological bias. The analysed catchments are distributed across the Lepontine and Rhaetian Swiss Alps, in the upper sections of the Glogn, Plessur, Cluozza and Trupchun valleys. These alpine catchments are particularly suitable for this study because of their short response time and bedload transport-limited conditions. These characteristics are ensured by small floodplains, only first order streams and the abundance of available sediment sources. In the present contribution, we combine: gridded RhiresD (precipitation) and TabsD (temperature) datasets (MeteoSwiss, 2024), a conceptual hydrological model, calibrated on the PREVAH (Zappa & Brunner, 2019) simulations, a morphological model (Agostini, 2022) and measurements from the SWISSIMAGE aerial images archive (1946-2022) (Federal Office of Topograhy swisstopo, 2022). Our aim is to define a conceptual climate-hydrology-morphology model to analyse the floodplain sediment supply, storage and transport sensitivity to climate changes. With this framework, we seek to develop an understanding of the statistical cascade, from the climate forcing, through the hydrological processes, to their morphological signature. By observing the channel evolutionary trajectories, we can compare whether the morphological changes are consistent with the climatic forcing and possibly infer the effects of climate change on bedload variability. Understanding how the external catchment forcing impacts the channel morphology permits to quantify the overall basin sensitivity to sediment transport.

Agostini, L. (2022). La risposta della sezione caratteristica di alvei fluviali all'alterazione delle variabili guida.

Federal Office of Topograhy swisstopo. (2022). A journey through time – aerial images. Retrieved from: https://www.swisstopo.admin.ch/en/timetravel-aerial-images

MeteoSwiss. (2024). MeteoSwiss Data Access Point. Retrieved from https://hyd.ifu.ethz.ch/research-data-models/meteoswiss.html

Zappa, M., & Brunner, M. (2019). Hydro-meteorological simulations for the period 1981-2018 for Switzerland. EnviDat. doi:doi:10.16904/envidat.76

Temporal dynamics of sediment sources and discharges in the heavily urbanized catchment of the Moscow

Sergey Chalov[1], Sergey Kharchenko[1]

[1]Faculty of Geography, Lomonosov Moscow State University, Russian Federation

Moscow megacity is experiencing the largest net population growth in Russia and across Europe, which has led to significant environmental problems. Among them changes of streamflow raters, water quality as well as and suspended and bed sediment regimes of the small rivers located entirely within the city have most pronounced effects of urban ecosystem. High-frequency (30-minute) streamflow and sediment dynamics monitoring was performed in 2019-2023 across the Setun River – the major tributary of the Moskva River with 190 km2 catchment area located entirely within Moscow City. Quantification of sediment supply was undertaken using established sediment fingerprinting approaches, with the target samples taken at monthly or weekly basis at the downstream section (76 integrated suspended sediment samples taken by analogue of Philipps sampler during 4 years). The discriminant sediment properties and similarities between integrated suspended samples of the main river at the catchment downstream and streambanks (10 samples), topsoil (124 samples) and pavement sediment sources ("road sediment", 77 samples) were studied based on ICP-MS databank for 54 chemical elements. Heavy transformation of the catchment (e.g. over 40 % of the catchment is covered by impervious surface types) explains entirely new type of streamflow regime which is characterized by high number of short-term peak flow events (up to 28 per year) and short rainstorm flood wave catchment response, involving infiltrated and hillslope-routed fraction of rainfall, which is varied from 6 to 11 hours and more than twice as rapid compared to non-urbanized conditions. The geospatial analysis demonstrates significant changes in land use parameters from upstream to downstream areas of the catchment, the main streamflow dynamics features remain constant, while sediment transport conditions, such as annual and maximal sediment concentrations, are increased downstream. The study reveals 3-4 times increase in suspended and bed load yields, as well as significant turbulent fluctuations in sediment concentration levels. An

MixSIAR unmixing model based on Bayesian statistical laws which explained discriminations of the sediment sources by most REE elements (Ce La Nd Pr Tb Ti Tl U Yb) indicated that suspended-sediment samples reaching river outlet are from mostly streambanks (56 ± 20 %) and topsoil (41 ± 20 %) with a smaller component from pavement sediment sources (3 ± 1 %). During and after high storm events increased contributions of the streambanks (up to 80–90 %) explain dominant role of channel erosion in yearly sediment transport in the urban catchment. Maximum topsoil contributions are observed in the spring and winter months (+ 5–7 % above the averages), and minimum in the summer and fall months (-4.5 – -7 % below the average).

Assessing Sediment Dynamics and Trapping Efficiency in the Mackenzie Delta Lakes: Modeling and Empirical Insights

Michał Habel[1], Berenger Koffi[1/2]

[1]Faculty of Geographical Sciences, Kazimierz Wielki University, Bydgoszcz, Poland
[2]UFR Environment, Université Jean Lorougnon GUEDE, Côte d'Ivoire

In this work, we propose the study of lakes in Mackenzie Delta, Arctic Canada, which receive fluvial sediments from the river when spring floodwater levels rise above natural levees. The Mackenzie Delta (13,000 km^2) significantly affects flows of water, sediment and nutrients to the Beaufort Sea because the ~45,000 delta lakes and the large delta floodplain have a very large water storage capacity. We want to present the scope of our project, which aims to understand sediment trapping conditions in Arctic river delta no-closure lakes to assess the impact on the overall sediment transport balance. This goal will be achieved by developing a sediment transport model based on the theory of settling basins while incorporating the Gamma distribution law. This model will enable us to assess the efficiency of sediment trapping, sediment settling velocity, and deposition rates, considering the dynamics of sedimentation velocity and sediment re-suspension processes. This approach will provide new knowledge about current and future sediment transport patterns within river deltas in areas of rapid permafrost thaw. The expected results after completion of the project are: learn how the lakes in the Mackenzie Delta influence the value of sediment transport to the Arctic Ocean during the annual cycle; determine the settling velocity of suspended solids and the impact that the proven release of methane from bottom sediments has on velocity; determine the impact of extreme phenomena on sedimentation and sediment re-suspension in no-closure lakes of the Mackenzie Delta; calculate the load of sediments accumulated and released for transport in the Mackenzie River Delta; learn about the reliability of the adopted settler theory method, particularly in the sediment transport by currents of particles present in the water column and on the bottom; velocity of the fall of particles into the water column, with or without flocculation (particle aggregation); the condition of the deposition of particles on the sedimentary bed; possibilities of erosion of bottom sediments by currents and swells; and the quality of consolidation of multi-layer sediments (via transfer flows between the sediment layers). A series of field observations were planned to determine the characteristics of the morphometric parameters, suspended solids and sediments present in the no-closure lake of the Mackenzie Delta and evaluate the impact that the settlement velocity of suspended solids and the flow rate have on the sediment trapping capacity of the lakes in the Mackenzie Delta.

Suspended sediment transport in the German waterways: Climate-induced changes under Anthropocene conditions

Thomas Hoffmann[1]

[1]Federal Institute of Hydrology, Koblenz, Germany

Sediment dynamics in German river systems are strongly modified by human actions in their contributing catchments and along the river channels. These changes disturb the ecological functioning of river systems with negative effects on riverine ecosystem services. To understand the changing sediment dynamics in the German waterways and provide effective sediment management strategies, the German Waterways and Shipping Authority is maintaining several sediment monitoring networks. Here we aim to review the changing nature of suspended sediment dynamics during the last decades using an extensive dataset with more than half a million estimates of suspended sediment concentration. Results from the trend analysis indicate that most waterways show declining suspended sediment concentrations and loads between 1990 and 2010 despite likely increases of soil erosion rates in Central Europe during the same time. At most monitoring stations, the declining trend of suspended sediment transport halted around 2010, indicating the importance of accelerated soil erosion by water during the last decade that witnessed increasing rainfall erosivity due to the increase in frequency and intensity of rainstorm events. To evaluate future trends of soil erosion and sediment delivery to waterways in Germany, we applied a soil erosion model based on the Universal Soil Loss Equation (USLE) in conjunction with predictions of the rainfall erosivity factor R. Therefore, we used convection-permitting climate simulations (CPS) that have a high and to date unexploited potential for climate impact studies on soil erosion because of their high spatio-temporal resolution and their more accurate representation of heavy rainfall. Our results show that rainfall erosivity will increased by up to 84% in the far future. This increase is much higher than previous estimates based on annual precipitation simulated with an ensemble of regional climate models. Thus, we argue that suspended sediment supply will increase under anticipated climate change.

Modeling the daily suspended sediment load in the Taleghan basin, using deep and shallow machine learning algorithms

Zeinab Mohammadi Raigani[1], Hamid Gholami[1]

[1]Department of Natural Resources Engineering, University of Hormozgan, Bandar-Abbas, Hormozgan, Iran

The phenomenon of sediment transport and erosion in rivers and watersheds are complex environmental and hydrological problems. The inherent nonlinearity and complexity of suspended sediment dynamics, which are impacted by the geographical variability of basin parameters and climatic patterns, make it difficult to predict suspended sediment load (SSL) accurately in hydrological processes. The objective of this study was to predict daily suspended sediment load in the Taleghan basin, in northern Iran, by applying and comparing the performance of three shallow machine learning (ML) models (Cubist, random forest-RF, and support vector machine with Linear Kernel—SVMLinear) and a deep learning (DL) model (dense deep neural networks-DDNN). Daily discharge, rainfall, and sediment data from 2000 to 2018 were used to train and test (80 % of training and 20 % of testing, respectively), the applied DL and shallow ML models. The performance of these models for predicting SSL was assessed using the root mean square error (RMSE) and the Nash Sutcliff coefficient (NSE), as well as the visual inspection using Taylor diagrams, temporal variation graphs, and scatter plots. The comparison of prediction accuracy of the models demonstrated that both DL and shallow ML algorithms could satisfactory predict daily SSL, particularly the Cubist (RMSE= 431.36, NSE= 0.95) and the DDNN (RMSE= 456.28, NSE= 0.94) models, which exhibited the lowest prediction error and highest efficiency metrics. In addition, the Taylor diagram confirmed that the DDNN and shallow ML models achieved the best match between observed and predicted values for various hydraulic parameters. According to the varImp function from Caret package, the most important predictor variables for the SSL modeling were the daily river discharge on the sediment collection date. These results indicate that performance of deep and machine learning models are promising methods for predicting and understanding sediment dynamics in river basins over time and recent climate change.

Session 3: Sediment dynamics and connectivity in alpine catchments

Sediment connectivity in proglacial environments: spatio-temporal pattern of sediment deliver from hillslopes to alluvial plains of the Haut Glacier d'Arolla catchment in the Swiss Alps

Mathilde Bayens[1], Stuart Lane[1]

[1]Institute of Earth Surface Dynamics, University of Lausanne, Switzerland

Since the early 1980s Alpine catchments have experienced rapid glacier recession, increasing water yield and sediment transport capacity. Evidence of what this means for sediment supply, the balance between changing supply and capacity, and hence sediment export in mountain environments is less clear. In particular, the role played by connectivity in transporting sediment through proglacial landscape is less frequently considered. Through erosion and deposition, sediment transport leads to modification of the landscape and thus the ease with which sediment can move though the landscape, that is the degree of connectivity. For instance, glacier recession leads to sidewall debuttressing and fall in local base level leading to intense erosional processes on sidewalls (e.g. gully development) which increases potential connectivity from upstream to downstream. In geomorphology the term 'connectivity' often refers to two different but complementary definitions. The first definition refers to structural connectivity within the configuration or arrangement of the systems, whereas the second refers to functional connectivity describing dynamical processes operating within a structurally connected system. Structural connectivity is a common result in papers because it is easy to compute with the sediment connectivity index developed by Cavalli et al. (2013) which requires only DEM as input. This project is more focused on the functional connectivity and addresses the spatio- temporal evolution of sediment delivery from hillslopes to alluvial plains based on high resolution DEMs. The difference of very high resolution DEMs (0.1m resolution) of a large alpine proglacial moraine over the summer season of 2023 reveals areas of erosion and deposition. These DEMs are then used to assess sediment routing based on TopoToolBox developed by Schwanghart and Kuhn (2010) and adapted for sediment transport of gully systems by Dai et al. (2021). The method quantifies the sediment transport necessary to conserve mass following from measured morphological change and is based on a multiple flow routing. The results show that micro-topography is the primary control on disconnection and that the hillslopes are extremely poorly connected from the proglacial stream. The results suggest that declining subglacial sediment evacuation due to glacier thinning is unlikely to be compensated for by hillslope eroded sediment due to the effects of disconnection.

Sedimentary source-to-sink pathways and erosion in Alpine Rhine basin

Sofia Garipova[1], David Mair[1], Naki Akçar[1], Fritz Schlunegger[1]

[1]Institute of Geological Sciences, University of Bern, Switzerland

Our study aims at exploring the sedimentary source-to-sink pathways in the Alpine Rhine, Switzerland, acknowledging the influence of climate on the mechanisms of erosion and sediment production. We apply a combined geomorphological and geological approach to define: (I) which parts of the basin are involved in production of sediment; (II) how the different local sediment sources are distributed in space and time, and (III) and how and when they are activated. We focus on determining the distinct sediment properties of these sources, and on tracing their source signals through the channel network of the Alpine Rhine. The characterization of sediment sources is based on data obtained during field observations. We consider the size of clasts and their petrographic composition to specify the source signal for the bedload. We additionally characterized the petrographic properties of the suspension load including the bulk geochemical and mineralogical composition of sand and the concentrations of cosmogenic ^{10}Be and ^{26}Al in riverine quartz minerals. These properties are used to quantify the different mechanisms such as rainfall-driven overland flow erosion and mass failure processes including landsliding and debris flows (Battista et al., 2020). We then apply a principal component analysis to this dataset to identify the signal properties of the different sediment sources, and by mixing modelling we estimate the relative contribution of various sediment supply mechanisms on the bulk sediment budget of a basin. Complementing it with the results of a morphometric analysis of the topography (Stutenbecker et al., 2016), we explore what conditions (climate, lithology, glacial inheritance) may cause the generation and routing of the material. To overall goal is to enhance our understanding of the interaction between climate dynamics and sedimentary processes in the Alpine Rhine basin.

An overview of the multimethod research of sedimentation dynamics on alpine alluvial fans in the Planica Valley (NW Slovenia)

Andrej Novak[1]

[1]Geological Survey of Slovenia, Ljubljana, Slovenia

Alluvial fans are common landforms in the alpine environments that are built by a variety of different sedimentary processes categorized as debris flow, debris flood, hyperconcentrated flow, and water flow. These processes differ in hydraulics and physical properties of the flowing material and in transport mechanism characteristics. The processes on fans are governed by several factors such as bedrock characteristics, slope inclination, vegetation cover, climatic conditions and are often triggered by intense rainfall events. The post-glacial Planica Valley in NW Slovenia is characterised by steep slopes composed mainly of Upper Triassic carbonates and locally of claystone, mudstone, and marl layers. Several Quaternary sedimentary bodies cover the valley floor of which the most active and numerous are the Holocene alluvial fans. Here we present an overview of an approximately a decade long research of alluvial fan processes which encompasses sedimentary analysis, dating of deposits, monitoring of depositional activity, and linking dated events to triggering precipitation records. Detailed sedimentary analysis focuses on identifying the predominant building process of fans and is based on structural and textural analysis of deposits found in outcrops and on the surface of fans. Majority of the fans are built by fluvial and/or sheetflood depositional processes which are characterised by up to 20 centimetres thick layers of either imbricated open-framework gravels or closed-framework sandy-gravels, containing less than 1 % of mud fraction. On the surface several sieve-lobe deposits are also present. Fluvial and sieve-lobe deposits are typical for places where bedrock is composed of carbonates, which do not weather into fine-grained particles (silt and clay). Sporadic and rare debris flows occur where claystone, mudstone, and marl are present, which weather into fine grains. Debris-flow deposits are characterised by up to three-metre-thick packages of crudely stratified matrix- to clast-supported muddy-sandy-gravel containing up to 16 % of mud fraction. Based on ^{14}C dating of paleosoil horizons the oldest dated debris-flow event occurred in the 17th century. Dendrogeomorphological dating allowed to construct more than a century long spatio-temporal chronology of debris-flood deposits with an annual precision. Precipitation records from the nearby meteorological station were related to the dated events to determine the exact date and amount of triggering rainfall. Further on we compared the number of affected trees to the return period of individual triggering meteorological events to establish the magnitude of debris flooding. Five-year aerial survey using Unmanned Aerial Vehicle enabled to monitor depositional activity on a seasonal resolution and directly link depositional events to the precipitation records. The monitoring concluded that at least one depositional event with over 1000 m^3 of sediment transport occurs per year. The results of the multimethod research offer a reconstruction of complex alluvial fan sedimentation and erosion activities on different temporal scales, which are strongly related to the bedrock geology and to triggering precipitation events.

Peak water, peak sediment and the moderating effect of sediment connectivity in controlling sediment yield from deglaciating Alpine river basins

Leona Repnik[1], Arnaud Breillad[2], Alessandro Giovanardi[1], Francesco Comiti[3,4], Mattia Gianini[1], Anne-Laure Argentin[3], Felix Pitscheider[3], Stuart N. Lane[1]

[1]Institute of Earth Surface Dynamics, University of Lausanne, Switzerland
[2]Ecole Nationale Sciences Geographiques, Paris, France
[3]Faculty of Agricultural, Environmental and Food Sciences, Free University of Bozen-Bolzano, Italy
[4]Department of Land, Environment, Agriculture and Forestry, University of Padova, Italy

Climate change is resulting in rapidly increasing temperatures in the European Alps, rising faster than the global average. Many of the resulting consequences are well studied, including glacier retreat and permafrost melt. However, very little is known about the impacts of rising temperatures on how sediment sources and sediment transport on hillslopes and from glaciers will respond. The extent to which connectivity moderates the transport of newly eroded sediment to the drainage network is also unknown. This is primarily due to a lack of historical records and continuous monitoring of bedload transport. One solution to this challenge is to undertake landscape-scale reconstruction of erosion and deposition patterns from photogrammetric analysis of historical imagery; and to couple these data to a two-dimensional mass balance and sediment routing treatment. This allows identification of the extent to which eroded sediment can reach the river and catchment outlet. In this paper, we apply this method to the Turtmann and Matter valleys (Valais, Switzerland). Both have extensive areas of glacier cover, itself declining rapidly. Using aerial historical photogrammetry, historical Digital Elevation Models (DEMs) of the valleys were produced. A 2021 DEM was used as a reference to create a DEM of Difference (DoD), highlighting areas of erosion and deposition. A comparison to geomorphological maps allows for an understanding of the geomorphological processes that have taken place to result in these patterns. Routing of erosion and deposition using a mass balance treatment allows us to estimate yield to the basin outlet to quantify the

extent to which eroded sediment can connect with the drainage network. Our results show extremely high levels of disconnection between hillslope sources of erosion and the drainage network in both cases; and that this is related to the legacy of glacial landforms. The vast majority of eroded sediment is likely deposited before it can reach stream channels. This implies that the primary coarse sediment transport signal seen in rivers in these systems will be glacially-derived. In the future, and under continued climate warming, glaciers will eventually become small enough that water yield and hence sediment transport capacity will decline. As the glaciers thin, glacial erosion will also decline. Thus, glacially sourced sediment supply to rivers will decrease and this will not be compensated by any climate-driven increases in hillslope erosion due to high levels of disconnection in the basin. Whether this conclusion applies to all Alpine deglaciating basins will depend on sediment connectivity from hillslopes to the drainage network. This will determine when and the extent to which we will see a “peak sediment” signal following “peak water”.

Evaluation of a Regional Climate Model regarding debris flow frequencies since 1850 in the frame of the SEHAG working group

Jakob Rom[1], Florian Haas[1], Tobias Heckmann[1], Madlene Pfeiffer[2], Moritz Altmann[1], Fabian Fleischer[1], Toni Himmelstoß[1], Sarah Betz-Nutz[1], Diana-Eileen Kara[1], Michael Becht[1]

[1]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany
[2]Institute of Geography, University of Bremen, Germany

In the frame of the interdisciplinary and international SEHAG (SEnsitivity of High-Alpine Geosystems to climate change since 1850) working group, the effects of climate change on various alpine systems are analysed. High mountain regions are exceptionally affected by the climate warming in recent decades. Individual components of the various geosystems react differently to these changes. Within the working group, processes from climatology, glaciology, hydrology and biology are analysed individually, as well as the interactions between these processes. Another thematic focus of the SEHAG working group is geomorphology in general and changes in debris flow systems in particular. Debris flows are one of the major sediment sources in high alpine catchments and occur as natural hazards worldwide. However, the future development of debris flow frequencies with respect to climate change is not well understood. This uncertainty is based on two main causes. First, debris flows occur only rarely, so a long and complete time series of debris flow events spanning multiple decades is necessary to detect any systematic changes. Second, most debris flows are triggered by high-intensity short-duration rainfall events. However, most recorded precipitation data neither has a sub-daily temporal resolution in order to detect such short-duration events, nor cover a long enough timespan to be able to detect changes in the frequency of such events. In the Horlachtal catchment, which is a side valley of the Ötztal in Tyrol, Austria, a total of 991 debris flows between 1947 and 2022 were registered based on the evaluation of area-wide orthoimages. Because these remote sensing data allow only for interval-censored dates of debris flows, a high-resolution time series of debris flows events (e.g. daily time series) was not yet possible. In addition, a Regional Climate Model (RCM) based on dynamical downscaling of the Advanced Research WRF (Weather Research and Forecasting (version 4.3)) Model was calculated in the frame of the SEHAG working group. This model covers the years between 1850 and 2015 and provides 15-minutes precipitation data at a 2x2 km resolution. In this paper, we use the RCM in combination with the debris flow record to calibrate a numerical model for the triggering of debris flows. With the help of this model, we are able to generate a detailed and high-resolution time series of past debris flows in the Horlachtal since the end of the Little Ice Age in 1850. The evaluation of this time series with regards to changes in debris flow frequencies points to possible trends in future debris flow development in a changing climate.

Session 4: Soil Erosion I

Key drivers of water erosion changes on agricultural lands of different parts of the East European Plain in the Anthropocene

Valentin Golosov[1,2], Evgenia Shamshurina[1,2], Andrey Zhidkin[2]

[1]Department of Geography, Lomonosov Moscow State University, Moscow
[2]Dokuchaev Soil Science Institute, Moscow

A sharp increase in the use of agricultural machinery, chemical fertilizers and pesticides and significant changes in soil cultivation technologies have characterized the period since the middle of the last century. A significant marker of the beginning of this time window, which is currently called the Anthropocene, is the arrival of the man-made radioisotope cesium-137 on the Earth's surface. It was associated with the beginning of nuclear explosion test in the open atmosphere in the mid-1950s. Currently, ^{137}Cs is widely used as a tracer to estimate erosion and sedimentation rates. Within the southern megaslope of the East European Plain, large areas were later contaminated with Chernobyl-derived ^{137}Cs. At present, ^{137}Cs is used in a given area to determine the rates of sediment redeposition in the sediment sinks for at least two time windows. Detailed studies to estimate the sedimentation rate in dry valley bottoms were carried out on 10 small arable catchments located in different parts of the East European Plain. At each studied sites, the ^{137}Cs vertical distribution was studied in 3-6 sections located along the bottoms of dry valleys. The results obtained made it possible to assess the trends in changes in the rate of water erosion on arable land in various parts of the southern forest, forest-steppe and steppe zones of the East European Plain, as well as to assess the influence of various factors, including climate change, the set of crops sown and soil cultivation methods, on the intensity of erosion processes. It has been established that the maximum reduction in the water erosion rates over the past 30-35 years has occurred on cultivated lands of the south of the forest zone. A slight increase in the erosion rate was detected in the south of the steppe zone. The reduction in the water erosion rate prevails in the rest of the steppe and forest-steppe zones. It was found that reduction of erosion rates gradually increases in direction from southwest to northeast in forest-steppe zone. The identified trends in changes over time in the water erosion rates correlate well with trends in changes in river sediment yield in various parts of the East European Plain during the Anthropocene.

Long-term transformation of Chernobyl contamination recognized with re-sampling technique in the Upa River basin, Central Russia

Maxim Ivanov[1], Ivanova Nadezhda[2], Anna Usacheva[1,3], Nickolai Lugovoi[1,2], Nikita Dimchuk[1,4], Polina Fominih[1,2], Nikitam Kvasov[1,4], Yulia Poletayeva[1,2], Valentin Golosov[1,2]

[1]Institute of Geography, Russian Academy of Science, Moscow, Russian Federation
[2]Department of Geography, Lomonosov Moscow State University, Moscow, Russian Federation
[3]Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (IGEM), Russian Academy of Sciences, Moscow
[4]Moscow Timiryazev Agricultural Academy, Russian Federation

On the territory of Central Russia, the most detailed studies on sediment budget and redistribution of particulate Cs-137 were carried out in the basin of the Upa River. Recently the major part of sediments eroded from arable lands re-deposited either within cultivated slopes or in the upper reaches of the fluvial network (slope hollows and bottoms of dry valleys) due to serious decreasing of erosion during snow-melting in European part of Russia. Decades a re-sampling technique applied with bomb-derived Cs-137 fallout is widely used method to assess soil redistribution rates within cultivated fields. But it requires long-time periods to be successfully implemented. The given approach hasn't been used in areas with high level of Chernobyl-derived Cs initial fallout. The results of the first experience of re-sampling study within the small agricultural catchment within the Upa river basin in Tula region are presented. Statistically reliable changes in the Cs-137 deposits for time window 1997 - 2023 were identified for the studied cultivated catchment. The mean decrease in Cs-137 deposits is about 11% for 26 years. Assessed changes in Cs-137 deposits was used in soil erosion radiocesium conversion model. The result is consistent with USLE and WaTEM/ SEDEM models. The concentration of Cs-137 in sediments re-deposited in dry valley bottoms during the post-Chernobyl period experienced a sharp decrease in the first years after Chernobyl-derived Cs-137 initial fallout and then remains relatively stable with a smooth downward trend. As it was learned earlier from examination of bottom sediments in artificial reservoir rapid decrease of particulate Cs-137 concentration in sediment yield. The leading factors of such decrease was effective remediation measures and changes in sediment budget components. The study was conducted within the framework of project of RSF â„– 23-77-10045.

Exploring the ability of $^{210}Pb_{ex}$ to estimate long term soil erosion rates and to document recent climate change over an experimental catchment in Southern Italy

Paolo Porto[1]

[1]Dipartimento di Agraria, University Mediterranea of Reggio Calabria, Italy

During the last decades, climate change effects have caused a general increase of heavy rainfall events in many areas of the world. These events produced an increase of soil erosion rates and this affected the economy of both cultivated and forested areas in many countries. Predicting soil loss in order to reduce it to acceptable values is one of the main goals of farmers and forest planners but this requires techniques able to obtain reliable estimates of soil erosion rates. In this context, the use of fallout radiotracers proved to be an important tool to understand better the consequences of climate change in these areas and to propose effective countermeasures. In this contribution, an experiment carried out in Southern Italy, that involves the use of $^{210}Pb_{ex}$ measurements over an experimental catchment, to estimate soil erosion rates during the last decades was performed. The overall results, associated with direct observations of sediment yield, indicate an increase in soil erosion rates during the last 15–20 years and suggest the use of this technique to detect climate change in these areas.

Session 5: Soil Erosion II

Assessing the impact of climate change on soil erosion by water

Peter Fiener[1]

[1]Institute of Geography, University of Augsburg, Germany

Climate change exerts multiple impacts on water-induced soil erosion. Regarding the change in annual rainfall erosivity, the picture is clearest. Despite a small potential increase in mean temperature, a substantial increase in annual rainfall erosivity is generally expected in a warmer world. Data from Germany show that annual erosivity has approximately doubled within the last 60 years. Regarding the seasonality of soil cover by different crops, the influence of climate change is more diverse. Changes in sowing and harvesting dates can lead to more or to less soil protection, while an expansion of warm-season crops, in particular C4 row crops like maize, generally reduce soil protection. Wildfires and irrigation may additionally increase erosion. Overall, more water erosion can be expected in many regions. Implementing soil conservation to safeguard the world's soils and their ability to store water becomes even more important as climate change amplifies the variability of precipitation.

From the hillslope to the river: multi-scale sediments transfers monitoring in the Beaujolais vineyard (France)

Jessica Pic[1], Mathieu Fressard[2], Nadia Carluer[3], Étienne Cossart[1]

[1]Université Jean Moulin Lyon 3, CNRS – UMR 5600 Environnement Ville Société, Lyon, France
[2]CNRS - UMR 6266 Identité et Différenciation de l'Espace, de l'Environnement et des Sociétés, France
[3]Riverly, INRAE, Villeurbanne, France

Sloping vineyards are known to undergo high levels of soil erosion, associated with complex sediment transfer patterns within catchments. These are due to specific cultivation practices (such as the absence of topographical boundaries, soil management practices and rows along slope direction) and to specific landscape structure related to soil erosion management (such as drainage networks and sediment traps). Consequently, documenting sediment transfers in this context is needed to better understand the sediment connectivity dynamics from hillslopes to rivers. The Beaujolais vineyard (France) was chosen to conduct this study on account of its presumed high soil erosion and sediment transfer rates due to vine monoculture on steep slopes associated with systematic weeding of vine plots. Continuous monitoring of water discharge and of suspended solids fluxes was conducted on three study sites at nested scales during two years to assess the transfers rates between the landscape compartments: a single vine plot (2800 m^2), a catchment head (4 km^2) and a large catchment (143 km^2). The results point out the jerky transfers throughout the sediment cascade. At the plot scale, soil erosion occurs mainly during summer, simultaneously to the heaviest rainfall. In between two summers, sediments are transferred from the hillslope to the river and carried away gradually. In the river, four flood types were identified depending on their contribution to the sediment transfers. The geomorphological continuum is hardly ever activated pointing out the cultivation practices and the anthropogenic drainage networks influence on the transfers at the different scales. Indeed, the soil bunds within the plot seem to hinder the sediment transfers while the ditch network seems to facilitate the transfers to the river at the catchment scale. Consequently, addressing the future transfers needs to take into account the changes of the landscape

structure (chemical weeding reduction to the benefit of permanent interrow grass cover), the Climate change impact on rainfall erosivity and the patterns of plot to river connectivity affected by structures design.

Modern and Late Quaternary erosion in eastern South Africa

Christian Sommer[1,2]

[1]Institute of Geography, Department of Geosciences, University of Tübingen, Germany
[2]Heidelberg Academy of Sciences and Humanities, Germany

Anthropogenic land use practices and modern climate change are known drivers of erosion, but in the historical perspective long-term cycles of landscape stability also play a role. The Drakensberg and its foothills in the eastern part of South Africa rise more than 2000 m within 200 km from the Indian Ocean coast and feature a variety of climate, vegetation, and geomorphic zones. A high degree of erosional activity, mainly gully and sheet erosion, affect 2 % of the surface, and the widespread presence of Quaternary colluvium make it a suitable area to investigate past and present landscape activity. We present results that address the modern threat of land degradation such as gully susceptibility maps derived from predictive models, an inventory of recent gully activity based on historical orthophotos, and numerical modelling to understand their evolution over time. Furthermore, we address the historic dimension of erosion activity with initial results from sedimentary stratigraphic analysis, where multiple episodes of gully and sheet erosion and subsequent infill have preserved cut-and-fill stratigraphies. Regional correlation and OSL dating suggest multiple phases of landscape stability (soil formation) and instability (erosion) throughout the Late Pleistocene. We discuss our results in the context of multiple existing hypotheses explaining such episodes in a regional setting. Our results evaluate the relevance of anthropogenic and natural factors for erosion and show that gully erosion played a role for modern communities as well as for hunter gatherers during the Middle Stone Age whose remains are found in the stratigraphy.

The evolution trajectory of soil erosion rates in the context of climate change and land cover dynamics. A case study from Romanian Subcarpathian Region

Marina Vîrghileanu[1], Ionuț Săvulescu[1], Bogdan-Andrei Mihai[1], Carmen-Gabriela Bizdadea[1], Monica-Gabriela Paraschiv[1]

[1]Faculty of Geography, University of Bucharest, Romania

Soil erosion by water is a global environmental problem and one of the most widespread forms of land degradation in Europe (European Commission 2020), described as the removal of the fertile upper layer of soil, affecting soil health and productivity (FAO, 2019). Projections show an increase by 13-22.5 % in soil erosion rates in the European Union by 2050, with losses of up to 100 % in some areas (JRC – ESDAC, 2015). Water soil erosion occurs under the influence of both natural and anthropogenic factors, but the highest sensitivity of soil erosion rates is related to climate change and land cover/use transformations. Climate change is considered to be the main driver of soil loss in many global and continental studies (Borrelli et al., 2020), while unsustainable human activities effects, including land cover changes, are more evident at local scales (Brandolini et al., 2023; Minervino Amodio et al., 2023), being responsible for the acceleration of soil erosion, with estimated rates of 100-1000 times higher than natural erosion rates (FAO, 2019). Therefore, accurate mapping at local level of the potential soil loss rates provides useful particular value to policy makers in searching for sustainable soil-use solutions in a specific area. In Romania, there are few studies addressing soil erosion dynamics. Patriche (2023) simulated the rainfall erosivity factor for different climatic scenarios, while other studies focused mainly on mapping the areas prone to water soil erosion, based on national or international grid datasets (Prăvălie et al., 2020). The aim of our study is to assess the historical and present-day status of soil erosion rates for the last 35 years in searching for future possible evolution trajectory of soil erosion, based on different directions the land cover might follow, beyond the climatic change trend which is already taken into account. Our approach follows three main steps: 1) accurate mapping of the soil erosion drivers at local level based on GIS and Remote Sensing techniques; 2) estimating the soil erosion status at different temporal moments, based on RUSLE model; 3) identifying the trajectory evolution of soil erosion rates by simulating future soil erosion pattern based on different scenarios of land cover/use changes. The analysis focuses on the hilly areas of Subcarpathians, a non-arable region with a heterogenous landscape, resulted by a high anthropogenic pressure during the last 100 years, reflected in slopes prone to soil erosion process. Our results show an overall decrease in soil loss rates during the last 35 years, up to 50 % in some areas, as an effect of the land abandonment process or by reducing the agricultural and industrial exploitation, while the scenario-based analysis proves the effects of different land management practices over soil loss rates evolution. The analysis of the evolution trajectory of soil erosion rates under different conditions is a necessary step forward to identify predictive changes in soil erosion, as a decision-making tool for sustainable management strategy.

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Session 6: Geomorphological dynamics in the Mediterranean

Water and suspended-sediment long-term fluxes in a burnt Mediterranean catchment

Francesc Cuello-Llobell[1,2,3], Julián García-Comendador[1,2,3], Josep Fortesa[1,2,3], Jaume Company-Ferrer[1,2,3], Adolfo Calvo-Cases[4], Joan Estrany[1,2,3]

[1]Natural Hazards and Emergencies Observatory of the Balearic Island, University of the Balearic Islands, Spain
[2]Mediterranean Ecogeomorphological and Hydrological Connectivity Research Team. Department of Geography, University of Balearic Islands, Spain
[3]Institute of Agro-Environmental & Water Economy Research, University of Balearic Islands, Spain
[4]Inter-University Institute for Local Development, Department of Geography, Universitat de València, València, Spain

Sediment cascade provides an approach to the catchment system fluxes through the landscape and linking between processes and landforms. Observations from headwaters to downstream parts in catchments, as a sediment cascade exercise, by using long-term (i.e., >10 yr.) water and sediment fluxes at various scales allows to detect degradation thresholds and better understand the catchment sensitivity. Under this context, a small mountainous Mediterranean catchment (4.8 km^2) is being monitored since 2013, just after a severe large wildfire in Mallorca, Spain. It is characterized by the massive presence of soil conservation structures (65 % of the catchment) which indicates the former but intense agricultural activity. Two gauging stations were installed following a nested approach: at the uppermost part (Sa Murtera; 1.19 km^2) and at the outlet (Sa Font de la Vila), continuously monitoring water and sediment fluxes. The aim of this work is assessing water and suspended-sediment long-term fluxes during the post-fire period, encompassing the last 10 years (when revegetation process was occurring. For this purpose, water and suspended sediment data were computed at annual, monthly, seasonal and event scales to analyze the evolution during the last decade. The first post-fire flood contribution was the 82 % and 72 % of total sediment load at Sa Murtera and Sa Font de la Vila respectively during the study period, elucidating the impacts of wildfires by increasing soil erosion rates. Seasonal events distribution was dominated by autumn and winter (71 %), although

sediment delivery was strongly concentrated in autumn when sediment availability was higher due to low vegetation cover and sediment production processes after long dry periods, concentrating 60 % of the amount, followed by winter with 39 %. In addition, high-intensity storms in autumn also contributed to a higher sedimentary response, involving that 54 % of sediment was delivered in October. Whilst sediment generation was essentially limited to these events, runoff was spreader along the hydrological year, being winter the season with a highest contribution (72 %), triggered by soil saturated conditions. Autumn and spring contributed with 17 % and 11 %, respectively. An annual average suspended-sediment yield of 5.84 and 3.53 t km $^{-2}$ yr $^{-1}$ at the uppermost station and the downstream one, respectively, illustrating the high impact triggered by the wildfire mainly in the headwater, as well as downstream sediment transmission losses caused by lithological variations in permeability and the influence of non-burnt areas downstream. At event scale, all these trends were confirmed for Sa Font de la Vila station with high-peak suspended-sediment concentrations (average 11,848 mg l^{-1}) during events mostly occurred in autumn while the highest peak discharges occurred mostly in winter (average 1.53 m^3 s^{-1}). By contrast, a greater variability was recorded in Sa Murtera despite recording autumn and winter the higher peaks also. The long-term assessment of hydrosedimentary dynamics after a large wildfire explained the catchment functioning after fire disturbances. Further assessment should explain the role of vegetation succession and abandoned soil conservation structures in predicting the evolution of sediment yields by means of machine learning based on the 10 years' time-series.

Investigations on the dynamics of geomorphologic processes in a recultivated iron ore mine based on multitemporal UAS data over a period of 10 years (2013-2023)

Manuel Stark[1], Jakob Rom[1], Florian Haas[1], Georgia Kahlenberg[1], Michael Becht[1]

[1]Chair of Geography, Cath. University of Eichstätt-Ingolstadt, Germany

Open-cast iron mines have existed worldwide for thousands of years. After the end of mining activities, these anthropogenic landforms tend to undergo increased geomorphologic processes. In many regions, erosion-reducing measures are being taken to counteract these processes, depending on the natural conditions. These include terracing of slopes, wooden barriers to reduce slope-wash-processes and drainage channels to drain the runoff from the slopes. This study focuses on the quantification and analysis of geomorphological processes on sparsely vegetated slopes of a re-cultivated iron ore mine on the Italian island of Elba using UAS and digital photogrammetry (SfM-MVS) over 10 years. Steep slopes with a central drainage channel and a sediment reservoir at the outlet of the mine (slopes) characterize the study area. The DoD from four different DEMs (2013, 2018, 2022 and 2023) as well as further analyses of various relief parameters and various cross-sectional analyses show strong surface changes due to different geomorphological processes, such as rill erosion, gullying, slope collapse and deposition of eroded material. Four geomorphologic hot spots were identified. The major surface changes were observed in the area of the main drainage channel (-2 m), on the exposed slopes (-2.7 m) and in the sediment collection reservoir (+0.6 m). The areas show different patterns and degrees of erosion and deposition of material depending on the study period. Slope-aquatic processes mainly lead to undercutting and collapse of the exposed slope flanks and strong sediment discharge from the slopes into the reservoir at the outlet. The erosion rates for the entire study site amount to 0.10 to 0.23 m*a-1. Precipitation events above the 95 % and 99 % percentile in all observation periods indicate a strong influence of intense rainfall events on the geomorphological process dynamics. Furthermore, the multi-

temporal analyses show a change in the drainage paths. This applies both to the smaller drainage channels below the terraced slopes and to the major drainage channel. The constantly changing surface shapes are evidence of the continuing high level of activity of the geomorphological processes in the mining area.

Post-fire ecogeomorphic patterns in a terraced Mediterranean microcatchment: an integrated approach combining ground –and drone-sense data

Jaume Company Ferrer[1,2,3], Francesc Cuello-Llobell[1,2,3], Julián García-Comendador[1,2,3], Josep Fortesa[1,2,3], Jordi Cristóbal[4], Adolfo Calvo-Cases[5], Joan Estrany[1,2,3]

[1]Natural Hazards and Emergencies Observatory of the Balearic Island, University of the Balearic Islands, Spain
[2]Mediterranean Ecogeomorphological and Hydrological Connectivity Research Team. Department of Geography, University of Balearic Islands, Spain
[3]Institute of Agro-Environmental & Water Economy Research, University of Balearic Islands, Spain
[4]Department of Geography, Universitat Autònoma de Barcelona, Spain
[5]Inter-University Institute for Local Development, Department of Geography, Universitat de València, València, Spain

Biota affects climate, and climatic conditions dictate the mechanisms and rates of erosion that control topographic evolution, as depicted by Dietrich and Dunne (2006). As a result, ecogeomorphology accurately evaluates landscape dynamics considering vegetation controls the resisting forces in slope-dependent transport. It becomes even more important in drylands such as the Mediterranean Region, since major changes are occurring in land use and climatic conditions due to global change with effects on the systems' ecogeomorphological functioning. Under this context, connectivity and coupling are crucial concepts for understanding and modelling the role of biotic dynamics in (eco-)geomorphic processes. In this work, an innovative approach combining continuous ground monitoring with drone data is proposed in a terraced microcatchment (with area around 4.9 ha) affected by a severe wildfire in 2013. Continuous data is being collected by means of twelve soil moisture and temperature probes at different soil depths (10 cm and 50 cm) and hydrological connectivities by a flux tower in an abandoned farm terrace. Drone-generated data consisting of: (1) a sediment connectivity index (IC) calculated from a high-precision DEM (25 cm spatial resolution); (2) two Temperature-Vegetation Dryness Index (TVDI) generated from land surface temperature and NDVI data acquired on clear sky days on 10th August 2023 and 25th January 2024 were used for assessing ecogeomorphic patterns. IC and TVDI values corresponding to the exact locations (ca. 1 m^2) where the soil probes are located were extracted for both flights. Afterwards, Pearson correlation coefficients were calculated for these values in relation to soil volumetric water content (VWC) and soil temperature at each location during the flights. In addition, spatial regression, bivariate Moran Index and local bivariate relationships were calculated for the IC and TVDI data. The flights corresponding to the seasons of highest (summer) and lowest (winter) solar radiation (a spring 2024 dataset will also be presented at the ICCE symposium) was used to assess the role of driving factors within ecogeomorphological dynamics. As a general trend in the abandoned farm terrace, the most important feedback process was the effect of vegetation in reducing soil temperature and enhancing soil VWC favouring ecosystem regeneration. This same pattern was observed at microcatchment scale by the TVDI, indicating water availability in the plant-soil system. The presence of vigorous vegetation promoted higher water resources, while sparsely vegetated areas presented drier conditions. Similarly, IC was reduced as TVDI values indicated greater water volume. So, vegetation acted as a hydrosedimentary trap, reducing connectivity pathways and the number of coupling hotspots within the system, thus enabling greater resource storage and a reduction in potential soil erosion. Bare soil areas (1.4 % and 4.6 % of the total microcatchment area in winter and summer, respectively) presented the highest connectivity and drier conditions, acting as coupling hotspots by generating pathways for water and sediment flow. Results show how vegetation density acts as negative feedback in erosion processes, limiting the efficacy of overland flow and surface wash.

Assessing the hillslope-channel contributions to the catchment sediment balance under land use and climate change

Joris Eekhout[1], Antonio Jódar-Abellán[1], Efraín Carrillo-López[1], Carolina Boix-Fayos[1], Joris de Vente[1]

[1]CEBAS-CSIC, Murcia, Spain

Most soil erosion models simulate hillslope erosion processes, such as sheet and rill erosion. However, observations have shown that channel erosion processes become important at larger spatial scales, which are hardly ever considered in soil erosion impact assessments. Hence, to get a full understanding of the impacts of global change on the catchment-scale sediment balance, models are needed that combine hillslope soil erosion processes with channel morphodynamics. Here we present a modification to the SPHY-MMF model that includes a novel channel morphodynamics module, which determines erosion and deposition in rills and channels, besides sheet erosion that was previously implemented in the SPHY-MMF model. We applied the model to a Mediterranean study area in southeast Spain. The model was calibrated using observed check dam sediment yield data, which gave satisfactory results for check dams located in the channels. The model was subsequently applied under historical land use change and future climate change scenarios. The model simulations show that channel erosion contributes substantially (35 %–40 %) to the total sediment yield, highlighting the importance of accounting for channel erosion in catchment-scale sediment budget estimations. The land use change scenarios were applied in a smaller subcatchment, which is characterized by reforestation and check dam construction between 1956 and 2016. The results show an 80 % decrease in sediment yield at the outlet, because of the implementation of these soil conservation measures. The results also show a slight increase of rill and channel erosion, which may be a response to the decrease in sediment input from the hillslopes. The climate change scenarios show that the different erosional processes (i.e. sheet, rill, channel) are projected to decrease or increase, depending on the projected change in annual and extreme precipitation. From this we conclude that interactions between different

erosional and depositional processes should be considered when studying the impact of global change on the catchment-scale sediment balance. This will also allow policy makers to plan conservation measures more efficiently, by applying measures close to the sources with the highest contribution to the catchment-scale sediment yield, accounting for possible interactions with other erosion or deposition processes within the catchment.

Poster Sessions

Group A

Argentin, Anne-Laure

Gianini, Mattia

Mager, Sarah

Martinet, Cécile

Pitscheider, Felix

Predictions of changing bedload transport capacity in the Alps under climate change

Anne-Laure Argentin[1], Pascal Horton[2], Bettina Schaefli[2], Felix Pitscheider[1], Mattia Giannini[3], Leona Repnik[3], Simone Bizzi[4], Stuart Lane[3], Francesco Comiti[1,5]

[1]Faculty of Agricultural, Environmental and Food Sciences, Free University of Bozen-Bolzano, Bolzano, Italy
[2]Institute of Geography, Oeschger Centre for Climate Change Research, University of Bern, Switzerland
[3]Institute for Earth Surface Dynamics, University of Lausanne, Switzerland
[4]Department of Geosciences, University of Padova, Italy
[5]Department of Land, Environment, Agriculture and Forestry, University of Padova, Italy

Climate change is having a major impact on hydrology in the Alps, both through its meteorological effects, such as increasingly frequent intense precipitation events, and through the melting of glaciers. The disruption of hydrological regimes by climate change has already been the subject of a great deal of research. However, this is much less the case with respect to sediment transport in general and bedload transport in particular. As part of the ALTROCLIMA project, we are studying the impact of climate change on bedload transport in the 21st century. This work presents our research bedload transport capacity as one dimension of future bedload transport changes, i.e. in addition to bedload supply. The main challenge with such estimation is that the uncertainty of climate models is very high, as they are based on different greenhouse gas concentration scenarios (Representative Concentration Pathway, RCP). These range from the very optimistic scenarios, with a drastic reduction in emissions, to the most pessimistic scenarios, based on a continuation or increase in greenhouse gas emissions. Further models of future climate may provide predictions on a daily scale, but have to be downsampled to sub-daily scales especially in Alpine glaciated basins where daily changes in melt and runoff cause considerable sub-daily changes in discharge and hence bedload transport capacity. The downsampling processes introduce uncertainties inherent to meteorological processes, and it becomes essential to model a set of downsampled models using RCP to obtain a representative range of possible outcomes. In this work, we present a daily-scale semi-lumped model combined with sub-daily downscaling to predict sub-daily river discharge under recent climate change in various alpine catchments located in Switzerland and Italy, with a focus on the Arolla valley. Semi-lumped models, unlike distributed hydrological models, allow us to model a set of hydrological realizations very quickly. One of the main drawbacks of semi-lumped modeling methods is that such a model only calculates flow at the hydrological unit level and at the model outlet. To circumvent this problem, we show that it is possible to spatially generalize the optimal parameters found at the outlet for the sub-catchments of the study area, enabling us to obtain flow data at multiple points within the modeled area. Finally, we apply a temporal upscaling method to obtain diurnal flow statistics as a function of season. The combination of a semi-lumped model with a method of generalization in space and upscaling of daily predictions in time, allows us to model a large set of hydrological scenarios from numerous climate scenarios using regular computational capabilities, thus enabling to simulate how bedload transport capacity has been changing during the last 5 decades of climate warming and consequent deglaciation.

Bedload transport histories in heterogeneous Alpine glaciated catchments

Mattia Gianini[1], Leona Repnik[1], Anne-Laure Argentin[2], Felix Pitscheider[2], Francesco Comiti[2] and Stuart N. Lane[1]

[1]Institute of Earth Surface Dynamics, University of Lausanne, Switzerland
[2]Faculty of Agricultural, Environmental and Food Sciences, Free University of Bozen-Bolzano, Bolzano, Italy

On a global scale, the Alpine regions are the most vulnerable to the temperature increases associated with climate change. Multiple studies reveal glacier retreat, permafrost degradation, and aquatic ecosystem impacts as key outcomes of rising temperatures. Given their importance, future projections for cryosphere and hydrological cycle evolution until the end of the 21st have been made. However, despite being a serious natural hazard and an element capable of influencing aquatic ecosystems, few studies show how climate change has affected sediment transport in general and bedload transport in particular. The difficulty of measuring it in nature means that there are few time-series available globally that extend back in time and none that focus on deglaciating river basins. One method of overcoming this problem is to use data collected from the water intakes of Alpine hydroelectric companies. Many were built in the hydropower expansion of the 1960s, often in high altitudes glacial basins, and have sediment traps where water and sediment have to be separated before water can be transferred to storage. Such traps have to be flushed when bedload deposits reach a certain level. By knowing the volume of the sediment traps and the packing density of the sediment, it is possible to reconstruct the bedload history for a given catchment. By, collecting flow data passing through the intake, it is possible to reconstruct the associated sediment transport capacity and so start to understand the extent to which this transport is supply-limited. In this paper we present the application of this method to different basins located in the southwest of the Alps (Switzerland). These basins are heterogeneous with different rates of glaciation and different climatic and geographical characteristics. Using the data and information on flushing, it was possible to quantify the number of flushes carried out annually for a very large number of intakes. By using the construction plans of the intakes and collecting information on the operating rules applied by the water companies, it was possible to estimate the volume of sediment released during each flush. This information was used to estimate the volume of bedload exported from these reservoirs over a period of approximately 60 years. The results show a different evolution of bedload transport between the catchments analysed, highlighting how local factors can play an important role in controlling bedload export from glaciated catchments. In general, however, an upward trend in sediment transport since the late 1980s is observed for most of the catchments analysed, coinciding with the sudden increase in atmospheric temperatures; however, many also show a temporary slowing down of export in the 1990s; and a possible evolution to a peak sediment export in the 2010s. Current work is seeking to understand these changes and notably how they relate to subglacial evacuation of quarried sediment.

Climate change impacts on river flows and suspended sediment in the Haast River, New Zealand

Sarah Mager[1], Sophie Horton[2], Daniel Kingston[1]

[1]School of Geography, University of Otago, New Zealand
[2]University of Canterbury, New Zealand

Forecasts of the effects of climate change on New Zealand mountain catchments project a significant reduction in snow days and ice cover, as well as significant changes in precipitation and runoff generation. Changes in snow and spring melt processes and the distribution of rainfall will impact the amount of suspended sediment transported through mountain catchments, and potentially its seasonal distribution. Forecasting is, however, hampered by a paucity of long-term monitoring of rainfall or runoff in New Zealand's mountain catchments, and few measurements of suspended sediment. To investigate the effect that climate change will have on suspended sediment concentrations we used the Haast River as a case study, applying the HBV-light model to forecast runoff for 2081–2100 under for RCP4.5 and 8.5 using six GCMs. The preliminary modelling suggests a modest reduction in runoff, although there is considerable uncertainty between the different GCMs, which suggests that in terms of discharge-rated suspended sediment, the flux of material varying by -20 to +15 % in the future. The reduction in ice and snow may further reduce the production of suspended sediment in the headwaters, potentially resulting in temporary suspended sediment exhausting during late summer and autumn – an effect that has already been detected by in situ measurements of nephelometric turbidity. The overall impact of climate change is likely to alter sources of sediment and the phasing of its release into the river network, and as such may affect the suitability of existing sediment rating curves for estimating physical weathering fluxes in mountain catchments.

Assessment of changes in fine sediment fluxes based on CMIP5 climate change scenarios

Cécile Martinet[1]

[1]EDF-DTG, Grenoble, France

Mountain catchments produce large quantities of fine sediments that end up in downstream reservoirs. This is the case of the Asse catchment, located in the French Mediterranean Pre-Alps, for which a fine sediment production and transport model, called Sediment'eau, has been developed. This model is being used to forecast daily sediment fluxes at the outlet of the catchment for the following six days. The aim of our study is to use the existing Sediment’eau model for the Asse catchment at « Clue de Chabrières » (377 km^2 and 720 t/km^2/y) to investigate the fine sediment response under the impacts of changing climatic conditions. In this study, we assess changes in fine sediment fluxes by coupling successively climate projections, a hydrological model and a sediment flux model, all of these models being applied at a daily time-step. 1/ Climate projections are issued from Explore2 project and we focus on the Representative Concentration Pathways RCP 8.5 with high carbon emissions. 17 couples of Global and Regional Climate Models (GCM and RCM) were selected as part of the project. The ADAMONT method was used to downscale the daily climate projections using SAFRAN as observational dataset (bias correction). 2/ Liquid precipitations and discharges are simulated with the daily hydrological Mordor SD model (Garavaglia et al., 2017). 3/ Fine sediment fluxes are simulated with the daily Sediment’eau model. The fine sediment flux Sediment’eau model is a conceptual model which involves both a direct transfer of sediment from hillslopes (driven by rainfall) and a temporary storage of sediment in the river network. It performs relatively well (R^2 = 0.74, KGE = 0.74 for a daily 2012-2020 evaluation), although the hourly version performs much better. The results show mainly changes in the regime of fine sediment fluxes with more sediments in winter (January to March) and less sediments in spring and summer between the future period (2070–2100) and the reference period (1980–2010). For the autumn period, when the greatest quantity of sediment is produced, changes appear to be relatively limited. The intensity of the twenty most significant events shows an increase for the majority of the 17 scenarios between the two periods. But this increase seems limited except for 2 scenarios. The previous results already provide an indication of what could happen in the future concerning fine sediment fluxes in Mediterranean catchment. They could be completed by using the entire modeling chain (i.e. climate projections, hydrological model and sediment flux model) at hourly time steps. Such calculations would be more robust for sediment flux modelling, but hourly precipitation scenarios for climate change are still under investigation.

A sensitivity analysis for bedload transport modelling in Alpine river catchments

Felix Pitscheider[1], Anne-Laure Argentin[1], Mattia Giannini[2], Leona Repnik[2], Simone Bizzi[3], Stuart Lane[2], Francesco Comiti[1,4]

[1]Faculty of Agricultural, Environmental and Food Sciences, Free University of Bozen-Bolzano, Bolzano, Italy
[2]University of Lausanne, Institute for Earth Surface Dynamics, Lausanne, Switzerland
[3]Department of Geosciences, University of Padova, Padova, Italy
[4]Department of Land, Environment, Agriculture and Forestry, University of Padova, Agripolis, Legnaro, Italy

Bedload transport in Alpine rivers greatly affects their ecological dynamics, their flood hazards, as well as the efficiency of hydropower schemes. The ongoing rapid climate change is having a substantial impact on bedload transport by affecting both the volumes of sediments supplied to a river and the river's capacity to carry the sediments downstream. To investigate and quantify changes in bedload transport in Alpine regions, the ALTROCLIMA project is employing novel approaches to estimate its recent changes and future evolution under different climate change scenarios. To look into the future, we work towards designing a modelling chain that allows us to estimate the bedload flux and erosion/deposition patterns. This modelling chain exploits the D-CASCADE modelling framework, which we are adapting for Alpine catchments. The development of the adapted model is performed in the Solda catchment (Italy). This catchment has specifically been chosen because of the availability of continuous measurements of the bedload transport history since 2014, which are needed for the calibration and validation process. We feed the model with climatological and hydrological conditions for this period as well as reconstructions of sediment supply and grain size distributions, allowing us to estimate the bedload transport for the past period. The hydrological conditions are modelled for each reach through the semi-lumped model "Hydrobricks", and we conducted extensive pebble counts to characterize the grain size distributions of most reaches. Since bedload transport in Alpine rivers depends on various factors, some difficult to quantify, we perform a sensitivity analysis of the D-CASCADE modelling framework. Apart

from the hydrological forces needed to carry volumes of sediments downstream, the geomorphological conditions of the river network, as well as the sizes and volumes of the sediments stored in and supplied to the system play a crucial role. We run the D-CASCADE model with a variation of input data for the years 2014-2020, for which validated bedload transport volumes are available to test against. This allows us to understand the significance of grain size distributions throughout the catchment, the impact of supplied volumes, as well as to determine the desired precision for river geometries. Furthermore, a variety of bedload transport formulas were tested for their accuracy in estimating sediment fluxes in high Alpine catchments. This study represents the first time that the results of a network scale sediment transport model are validated against continuously measured data at the catchment outlet. The sensitivity analysis gives crucial insight for reaching our final objective of yielding reasonably accurate estimations of future bedload transport. These estimations are expected to enable the identification of significant trends in volumes, as well as their scatter throughout the catchment, for the 21st century.

Group B

Acharyya, Rituparna

Brzezińska, Marta

Ivanov, Maxim

Ivanov, Victor

Jemai, Sabrine

Kechnit, Djamel

Prokopeva, Kristina

"Deep scour holes" in the Mackenzie River Delta as a response of the fluvial environment to global environmental changes

Rituparna Acharyya[1], Michał Habel[1]

[1]Faculty of Geographical Sciences, Kazimierz Wielki University, Bydgoszcz, Poland

The global challenge of climate change is particularly impacting the fluvial environment, with floods causing significant changes in river bed geometry. The Arctic is experiencing the most significant temperature increases, leading to the thawing of permafrost. This thawing is causing changes in erosion-accumulation patterns of river beds and distribution channels within deltas and estuaries, as well as an increase in water and sediment flow during the winter season. A recent study focused on "deep hole" erosional features in the distributary channels of the Mackenzie River Delta. Since the 1980s, scientists have observed numerous depressions called "deep scour holes" with depths of up to 48m and averaging 20-25m. Dr. hab. Michał Habel and his team conducted the latest research in Kolyma and Mackenzie, exploring the geometric features of these forms and attempting to understand the hydrodynamic, geological, and geomorphological factors influencing their formation. In collaboration with Canadian teams, analysis has been conducted on archival bathymetric data from 1974 to 2023 and continuous monitoring research in the Mackenzie Delta. They classified these forms in terms of their geometry, stage of development, and genesis.

Model of overbank sedimentation in the upper section of the Tagliamento River

Marta Brzezińska[1], Dawid Szatten[1], Monika Szymańska-Walkiewicz[1], Rituparna Acharyya[1], Maurizia Sigura[2], Francesco Boscutti[2,3], Valentino Casolo[2,3], Elisa Pellegrini[2], Giorgio Alberti[2,3], Giacomo Trotta[2,4], Daniéle Lagnaz[5], Florent Jouy[6], Jana Chmieleski[7], Michał Habel[1]

[1]Faculty of Geographical Sciences, Kazimierz Wielki University, Bydgoszcz, Poland
[2]Department of Agrifood, Environmental and Animal Sciences, University of Udine, Udine, Italy
[3]National Biodiversity Future Center, Palermo, Italy
[4]Department of Life Sciences, University of Trieste, Trieste, Italy
[5]Zurich University of Applied Science, Zurich, Switzerland
[6]Eberswalde University for Sustainable Development, Eberswalde, Germany
[7]Nationalpark Unteres Odertal, Germany

The upper reach of the Tagliamento River floor is laden with coarse-grained sediments generated from Alpine sand and limestone. There are three principal depositional zones: active riverbed, floodplain, and mid-channel vegetated riverine islands. The upper reach is distinguished by mixed system channels, including braided and braided-anastomosed development. This region is profoundly affected by the annual cycle of seasonal events, including autumn and spring floods and fresh sediment deposits, occurring on channel levees and vegetated islands. In our research, we examined scenarios of overbank deposition on floodplains and vegetated riverine islands. We obtained twelve cores containing extra-channel sediments, and modelled lithofacial profiles for each of them. The model shows the deposition of both very fine and coarse particles has occurred during freshets. Certain floods have a particularly violent course, resulting in an accumulation of matrix-type sequences in the modelled profiles. Finally, we developed a conceptual model for off-channel sedimentation, which will be input into a future 2D morphological model of the upper Tagliamento.

Sediment transport study of small periglacial watersheds of North Caucasus: case study of the Djankuat creek

Victor Ivanov[1], Valentin Golosov[1]

[1]Department of Geography, Lomonosov Moscow State University, Moscow

The catchments of alpine rivers are one of the most sensitive regions to climate change. Deglaciation of watersheds intensifies erosion. However, the parameters of sediment runoff in periglacial catchments are not fully understood. For the North Caucasus region, governmental bedload monitoring on small periglacial watersheds was conducted at one location in the mid-20th century. However, it is estimated that approximately 10 million people live in this region, which poses a challenge to hydrological and geomorphological natural disasters such as landslides, mudflows, flash floods, and soil degradation. This work aims to clarify a gap in sediment transport origin by analyzing data from long-term monitoring of bed and suspended sediment runoff in a typical small periglacial catchment of the Djankuat Creek ($F = 9{,}1\ km^2$, Qmean = $1{,}5\ m^3/s$). Methods of this study include direct measurements of bed load by Helley-Smith sampler, assessment of sediment diameter of the bed load and the floodplain deposits, and historical channel mitigation estimates. Thus, it was revealed that the total sediment load of the Djankuat is 10,3·10â kg/year, and only 13 % is caused by bed load. Deposition rates here are 4.8 mm/year, which is close to the rates of Caucasus Mountains uplift of 4.76 mm/year. A ten-fold difference between floodplain sediments diameter and bed load samples makes it possible to assume that deposition in the floodplain is possible only in rare floods with a water discharge of about 30 m^3/s.

Record of sediment yield variations during deglaciation in the Lake Syltrankel sediments (Elbrus region, Central Caucasus)

M.M. Ivanov[1,2], A.L. Gurinov[1], V.N. Golosov[1,2], N.V. Kuzmenkova[1,2], M.Yu. Alexandrin[1], M.I. Uspenskiy[1,2], I.G. Shorkunov[1], E.V. Garankina[1,2], P. Sabatier[3]

[1]Institute of Geography, Russian Academy of Science, Moscow
[2]Department of Geography, Lomonosov Moscow State University, Moscow
[3]Université Savoie Mont Blanc, CNRS, EDYTEM, Le Bourget du lac, France

Deglaciation is argued to be a general trend of environmental transformation worldwide and in particular in the high mountains of the Central Caucasus caused by global climate change. The sediment deposits of alpine lakes may be used as a high-resolution environmental archive. The deglaciation history of the alpine Lake Syltrankel catchment (Elbrus region, Central Caucasus) from the end of the XIX century until the end of the XXth century was reconstructed via the examination of sediment deposits and documentary sources. Visual analysis of the collected sediments provided preliminary information on the stages in the history of the chosen waterbodies. Additionally, under the assumption of annual deposition of laminated sediments (varves), their counts were used to estimate the duration of sedimentation. Modern radioisotope techniques, including the use of natural ($^{210}Pb_{ex}$) and artificial radionuclides fallout (^{137}Cs), in combination with varve counting allow reliable dating of collected sediment. Mineralogical and geochemical analyses of lake sediments and samples within the catchment provided a information for the identification of sediment sources. The verification of sediment core exploration was possible via the analysis of independent documentary records of deglaciation. In particular, expedition reports, topographic maps, and photographs of the ground, air and space were valuable sources for reconstructing the conditions of glaciers over different time windows. It was recognized that over the past 140 years, the change in glacial cover has been the main factor in the transformation of sediment yield entering in the Lake Syltrankel. Different stages of sedimentation for the period beginning no earlier than 1881 CE were distinguished. As new catchment areas were released from under the glaciers, the transfer distance, intensity of mechanical sorting and intrabasin accumulation of detrital material increased. The modern stage presumably began in the late 1920s. It is characterized by the consistent accumulation of only fine-grained laminated sediments. At earlier stages, due to the proximity of the glacier edge to the lake, coarse-grained particles could enter the reservoir together with meltwater. The obtained results indicate the potential for studying changes in the sedimentation regime and glacial retreat dynamics.

Water Erosion Evaluation using USEL model integrating RS and GIS tools : Case study of Tributaries of Sebkha El Maleh Watershed, Gabes, Southern-Tunisia

Sabrine Jemai[1], Abdeldjalil Belkendil[2], Amjad Kallel[3], Habib Abida[1]

[1]Faculty of Sciences of Sfax, University of Sfax, Tunisia
[2]Faculty of Science and Technology, University of Tlemcen, Algeria
[3]Maître de conférences, National Engineering School of Sfax, University of Sfax, Tunisia

Water erosion is recognized as a serious major problem of land degradation in arid environnements. The present research focused on the application of USLE model (Universal soil loss equation) combined with the Remote Sensing (RS) and the Geographic Information System (GIS) tools in Tributaries of Sebkha El Maleh Watershed located in Gabes, Southern-Tunisia. The main goal is to assess the risk of soil erosion in the studied watershed. This will help to distinguish vulnerable areas to risk of erosion in case of land management plans and with the aim of minimizing additional soil losses. It was conducted based essentially on five main parameters of model like the soil erodibility, the basin topography, the land vegetation cover, the field management practice and the rainfall erosivity with an application of high spatial resolution datasets (DEM 12.5 m, Sentinel-2 10 m). The obtained results showed an average soil loss of about 16.82 t/ha/yr in the study area. The findings of spatial distribution of water erosion map indicated that 97.08 % of area of Tributaries of Sebkha El Maleh Watershed is under low risk of soil erosion. The soil erosion rate classified into four categories according to its severity, and 2.92 % of the areas found under moderate to very high erosion risk (concentrated mainly in the northern part of the basin). Results may be an effective instrument for planners and decision-makers of water and soil conservation strategies to reduce the soil erosion in Gabes, South Tunisia particularly regarding erosion hotspot areas.

Employing an Entropy-Based Approach for Bathymetry and Discharge Estimation in Large Rivers

Djamel Kechnit[1], Raphael M. Tshimanga[1], Abdelhadi Ammari[2], Mark A. Trigg[3], Andrew B. Carr[3], Farhad Bahmanpouri[4], Silvia Barbetta[4], Tommaso Mora-Marco[4]

[1]Basin Water Resources Research Center – CRREBaC & Regional School of Water, University of Kinshasa (UNIKIN), Congo
[2]National Higher School of Hydraulics (ENSH), Algeria.
[3]School of Civil Engineering, University of Leeds, UK
[4]Research Institute for Geo-Hydrological Protection - National Research Council (CNR IRPI), Perugia, Italy

Accurate bathymetry data are crucial for understanding the complex flow dynamics and sediment transport processes within large rivers. Furthermore, it also aids in updating navigation maps for waterways that experience significant navigation activities and river monitoring. Nonetheless, estimating the bathymetry of large rivers is challenging due to the complexity and variability of the riverbed. To address this issue, this study implements an entropy theory-based approach to assess bathymetry and discharge over 29 cross-sections along a 1740 km reach of the Congo River. The method relies on near-surface velocity analysis to estimate bathymetry. Two optimization methods are implemented for estimating the entropy parameter of the flow depth: a) through a generic algorithm, and b) based on in-situ measurements. The resulting simulated bathymetry shows good agreement compared to the measurements obtained via the Acoustic Doppler Current Profiler (ADCP), with a correlation that varies from 0.49 to 0.88. The bathymetry results are subsequently used to estimate the 2D cross-sectional flow velocity distribution and, consequently, to assess the river discharge. The mean errors between the simulated results and the observed values for flow area, discharge, and mean velocity are found to be equal to 2.7 %, 1.3 %, and 1 %, respectively. This finding has significant implications for remote sensing applications and the advancement of novel non-contact methods for large river monitoring.

Planform changes in the Lena River Delta under current climate warming

Kristina Prokopeva[1], Sergey Chalov[1,2]

[1]Faculty of Geography, Lomonosov Moscow State University, Moscow, Russian Federation
[2]Faculty of Geographical Sciences, Kazimierz Wielki University, Bydgoszcz, Poland

Lena River Delta is the largest delta in Arctic. The main features of the research area are the location in the continuous permafrost zone and a large number of channels on an area of over 32 000 km^2. Current climate warming influence on water regime, sediment dynamics and planform changes in the delta branches. Significant change of air and permafrost temperatures and solar radiation have occurred at the beginning of the XXI century and its changes could amplify new processes of thermal-erosion and thermal-denudation. According to ERA5-Land reanalysis data here the increase in warming rate from an average June-September air temperature is from 4.1 °C for the period 1950–99 to 6.1°C during 2000–21, which is higher than in the adjacent Arctic regions. Based on analyses of satellite images from 1964 to 2021 riverbed migration and Island locations change across distributaries of the Lena Delta. Riverbank degradation driven by thermal erosion and thermal denudation processes (which are in turn related to air and soil temperature increases) is proved to be the primary factor of the sediment increasing from delta to the sea and flow distribution between the branches. An increase in intensity of channel planform changes observed in the downstream and a decrease in the top of the delta. Maximum rates characterized the Trofimovskaya channel and Olenekskaya branches. Significant changes were found for the Islands mainly consisting of the Ice Complex or Yedoma – fine-grained materials rich in organics and ice. The most pronounced bank retreat (up to 15 m/year) is observed at the areas of Ice Complex on the Sobo-Sise Island. The delta sea coast is significantly impacted by thermal-abrasion processes.

Group C

Betz-Nutz, Sarah

Himmelstoß, Toni

Kara, Diana-Eileen

Kharchenko, Sergey

Tan, Florence

How proglacial channels and floodplains in the Eastern European Alps responded to decades of deglaciation: A comparative study using digital elevation models from historical aerial images and recent airborne LiDAR and UAV surveys

Sarah Betz-Nutz[1], Toni Himmelstoß[1], Diana-Eileen Kara[1], Moritz Altmann[1], Jakob Rom[1], Florian Haas[1], Michael Becht[1], Tobias Heckmann[1]

[1]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany

The system of proglacial streams in the Alps has experienced significant changes since the end of the Little Ice Age. Previous studies showed different patterns of aggradation and degradation in proglacial channels over time. This leads to the question of which factors determine the sediment dynamics in the channels and on their floodplains in the long term with ongoing glacier melting. Possible influencing variables are the distance of a channel section to the recent glacier tongue and the percentage of glaciation in the catchment area. Moreover, we suppose an influence of local topographic characteristics such as the slope gradient and the width or confinement of the channel. In addition to these factors, there is also the question of whether large individual events overlay a trend of aggradation or degradation. In order to analyse the long-term morphodynamics in channels and the factors influencing it, we used numerous digital elevation models (DEMs) covering several decades and different streams within four catchments in the central and southern Eastern Alps (Kaunertal, Horlachtal and Jamtal in Tyrol and Martelltal in South Tyrol). The DEMs were generated from aerial images dating back until 1953. From the 2000s on, DEMs from airborne LiDAR and UAV surveys were available. This data basis enables a comparative investigation and the identification of local topographic influences.

Structure or forcing? Controls on functional sediment connectivity of debris flows during a 2022 heavy precipitation event in the Horlachtal, Austrian Alps

Toni Himmelstoss[1], Jakob Rom[1], Diana-Eileen Kara[1], Sarah Betz[1], Moritz Altmann[1], Florian Haas[1], Michael Becht[1], Tobias Heckmann[1]

[1]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany

Climate change has the potential to amplify sediment transport rates in alpine geosystems, for instance, by exposing moraines with more easily erodible materials or by enhancing the transport capacity of meltwater streams through increased glacier melt and more frequent intense precipitation events. The extent to which such local changes influence the overall sediment yield of a catchment is largely governed by sediment connectivity, the potential of geomorphic systems to route material through themselves. In this way, connectivity has a direct impact on the sensitivity of sediment transport to recent climate change. For analytical purposes, a distinction is often made between structural and functional connectivity. Structural connectivity pertains to the spatial arrangement of system components and is rather static, whereas functional connectivity reflects the actual transfer of sediments and is driven by external forcing. This study focuses on slope-type debris flows because they are one of the most important processes transferring sediments from slopes to channels and are also quite common on recently exposed, steep lateral moraines. If climate change alters the frequency and magnitude of heavy precipitation events, it can be assumed that both the frequency and functional connectivity of debris flows are altered as well. Our goal is to assess the impact of system structure and meteorological forcing on the functional connectivity during a heavy rainfall event that caused widespread debris flow activity in July 2022. 156 debris flows could be mapped for this event using aerial imagery and two airborne LiDAR digital elevation models. Functional connectivity is quantified by the degree of coupling of debris flows to the channel network and the spatially variable sediment delivery ratio. We assess system structure using the Index of Connectivity (IC) by Borselli et al. (2008), refined by Cavalli et al. (2013) for alpine catchments, while representing meteorological forcing through the event-specific rainfall totals within debris flow catchment areas, derived from adjusted radar data. Our findings indicate that system structure had a more pronounced effect on debris flow functional connectivity than the spatial variability of the forcing. This underscores the importance of not only forecasting debris flow frequency and magnitude under future climate scenarios but also considering potential shifts in the structural connectivity of the geosystems where they occur.

Impact of Precipitation Events on Suspended Sediment Dynamics: Long-term Monitoring in the Upper Kaunertal, Austria

Diana-Eileen Kara[1], Toni Himmelstoss[1], Sarah Betz-Nutz[1], Moritz Altmann[1], Jakob Rom[1], Florian Haas[1], Tobias Heckmann[1], Michael Becht[1]

[1]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany

Suspended sediment transport in high alpine streams is influenced by discharge and sediment supply. The deglaciation of alpine valleys affects these dynamics by exposing more moraine material and increasing glacial melt rates, which can mobilize subglacial sediment. To specifically understand the connections between suspended sediment load and various hydrometeorological conditions, targeted studies are essential. Hence, this study extracted and analysed high-precipitation snow melt and glacier melt events based on the triggering hydrometeorological forcings, alongside with turbidity, and suspended sediment data. Suspended sediment concentrations were measured at high temporal resolution (15 min) at the Gepatschalm gauge station on the River Fagge in Upper Kaunertal Tyrol, Austria, from 2012 to 2022. Additional suspended sediment measurements are ongoing at seven other stations in Upper Kaunertal for the 2024 melt season. The aim is to identify local sources of suspended sediment that respond to specific triggering configurations, leading to characteristic responses in the total suspended sediment load, representing an event-based reaction of sediment sources. These events were compared with the associated multitemporal Digital Elevation Models to provide insights into sediment supply and their spatial distribution. Findings suggest a clear linkage between increased suspended sediment concentration and short-term precipitation events. This event-based approach provides a detailed understanding of how specific hydrometeorological forcings impacts suspended sediment load in glacier-covered high-alpine areas, enabling the development of effective adaptation strategies for addressing reservoir sedimentation. This study can serve as a foundation for a more

in-depth investigation of the changing hydrometeorological conditions caused by climate change on sediment dynamics.

High-precision local fitting of elevation models with spatially varying georeferencing errors using the ILEM algorithm in R

Sergey Kharchenko[1]

[1]Lomonosov Moscow State University, Russian Federation

High precision matching of multi-temporal DEMs is required to estimate rates of geomorphological processes. This can be achieved by using GNSS georeferencing. However, in many cases, when GCPs (ground control points) are unevenly distributed on the surface and their number is small, the residual error of georeferencing is still too large for estimating the rates of relatively slow processes (millimeters or centimeters or even the first decimetres per a surveys period). This is particularly true for the structure-from-motion approach (elevations in each pixel are reconstructed by interpolation, usually by splines), and to a much lesser extent for laser scanning. In this case, approaches called co-registration are used to refine an existing absolute georeferencing or to create only a relative georeferencing of one survey to another. There are some methods, implemented as software algorithms, used for co-registration of DEMs. In a first approximation, they can all be divided into those based on global transformation (Nuth & Caab, Shean, AMES Stereo Pipeline, etc.) and local transformation of the registered DEM (CODEM, ILEM, etc.). In global transformation, the same mathematical operations - shift, scaling, rotation, tilting, affine distortion - are applied to the whole area of the registered DEM. Since SfM-derived DEMs have unevenly distributed planar and elevation georeferencing errors over the area, global algorithms often do not provide acceptable co-registration accuracy and precision. The author developed the ILEM (Iterative Local fitting of Elevation Models) algorithm, which uses visual topographic pattern matching to find optimal DEM transformations. The entire area of the registered DEM is divided into hexagons with a step of N meters and a radius of the hexagons of k*N meters. The boundary conditions of the expected maximum shift in plan to the reference DEM are set. Then each hexagon on the registered DEM is shifted unilaterally relative to its pair on the reference DEM. The value of the DoD's standard deviation is recorded for each X and Y shift value. In areas (within hexagon boundaries) where neither erosion nor accumulation areas occupy more than 50 % of the area over time, the median SD DoD should tend to be zero. However, it does not reach zero due to various sources of uncertainty. The shift values at which the smallest SD DoD is achieved are usually those that correspond to the optimum shift in the plan. From the histograms of the distribution of the optimal displacement and the maximum acceptable error metric, it can be seen that in most cases there are no changes in the relief of a part of the territory (the displacement in most cases is approximately one value, the SD DoD forms a pronounced peak in the graph). The residual elevation error is reconstructed only from hexagons for which an exact match to the topographic pattern has been established (kriging or linear regression). The unresolved error after elevation correction is then estimated. The method in some cases outperforms the most modern competitors.

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Assessing total uncertainty in sediment yield observations: a Monte Carlo approach

Florence Tan[1], Pasquale Borrelli[2], Matthias Vanmaercke[1]

[1]Department of Earth and Environmental Sciences, KU Leuven, Belgium
[2]Department of Sciences, University of Roma Tre, Italy

The inherent yet often unquantified variability in sediment yield (SY) observations is an important limitation in sediment research which can affect, amongst others, the assessment of sediment flux sensitivity to climate change. Calculations of SY from discharge (Q) and suspended sediment concentration (SSC) measurements are subject to multiple sources of error, including the sampling method, the sampling scheme and frequency, the load calculation method, and the measuring period. While the uncertainty caused by these individual sources of error has been estimated in many different contexts, their combined effect on SY calculations remain for the most part unquantified. Here, we aim to provide realistic ranges of total uncertainty on metadata-limited SY measurements worldwide by means of Monte Carlo simulations. Using available long-term daily Q and SSC series, we quantify the effect of each source of error, as well as their relative importance, on SY calculations. We apply this method on a (spatially) diverse selection of >200 gauging stations and further explore the relationship between SY uncertainty and climate or upstream area. Preliminary findings suggest that the range of uncertainty in SY calculations is largely influenced by the sampling frequency, whereas the load calculation method and the sampling scheme can introduce important biases. Measuring errors on individual Q and SSC observations have relatively little impact on total SY uncertainty. When considering long-term average SY, the length of the measuring period then becomes the most important source of uncertainty. Overall, the combined effect of these sources of error can lead to deviations of ca. one order of magnitude from the true SY. This considerable uncertainty range can have important implications for future development and interpretation of SY models.

Group D

Altmann, Moritz

Pehnert, Hanna

Sannino, Annalisa

Tiwari, Jagriti

Simulation of erosion on a Little Ice Age lateral moraine in the glacier forefield of the Grastal glacier (Tyrol, Austria) using Erosion-3D

Moritz Altmann[1], Peter Fischer[2], Florian Haas[1], Teresa Benzing[1], Christian Sender[1], Jakob Rom[1], Fabian Fleischer[1], Toni Himmelstoß[1], Tobias Heckmann[1], Michael Becht[1]

[1]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany
[2]Soil Geography and soil erosion, Cath. University of Eichstätt-Ingolstadt, Germany

For the reconstruction of morphodynamics in alpine catchments, e.g. on Little Ice Age (LIA) lateral moraines, multitemporal digital elevation models (DEMs) and DEM of Differences (DoDs) are well suited. This can be done over several decades using DEMs based on airborne and terrestrial laser scanning since the 2000s as well as historical aerial photographs since the middle of the 20th century using Structure-from-Motion (SfM) photogrammetry. However, there are often several years to decades between available data sets. Therefore, sediment transport and morphodynamics must be aggregated over longer time scales. The distinction between geomorphologically inactive and active periods and the attribution of individual erosion events to the corresponding precipitation intensities is therefore often problematic. Using the physically based soil erosion model Erosion3D (E3D), we show the simulation of soil erosion and accumulation on a steep and unvegetated slope section of a LIA lateral moraine. The study area is located in the glacier forefield of the Grastal glacier in the Horlachtal valley in Tyrol, Austria, which is mainly characterised by fluvial process dynamics. The input parameters for E3D included a DEM, several physical soil parameters and, in this case, precipitation data from the automatic weather station Horlachalm (TIWAG) in the Horlachtal valley, located about 6 km from the study site. The E3D simulations were calibrated using a section of the study area and the corresponding erosion volume calculated by the DoD for the years 2021 to 2022. Subsequently, a spatial and temporal validation of the erosion volumes simulated with E3D was carried out in comparison to the erosion volumes calculated with the corresponding DoDs. The E3D simulation results show that the

erosion volume (net erosion) of the entire slope section of each available epoch (2006 to 2017, 2017 to 2019, 2019 to 2021, 2021 to 2022) can be simulated well and is within the respective error range of the calculated erosion volumes using the DoDs. This demonstrates the applicability of the erosion model E3D to the geomorphological activity of this LIA lateral moraine. Therefore, the aim is to improve the temporal resolution of the geomorphological activity of the selected slope section using the E3D simulation. Erosion can now be simulated and thus quantified for every year between 2006 and 2022. This ultimately enables a better understanding between erosion and the corresponding precipitation events.

Inventory of Gully Dynamics in the Upper Umfolozi, KwaZulu-Natal, South Africa

Hanna Pehnert[1], Christian Sommer[1,2], Volker Hochschild[1]

[1]Institute of Geography, Department of Geosciences, University of Tübingen
[2]Heidelberg Academy of Sciences and Humanities

Gully erosion is a widespread environmental problem present in South Africa with the phenomenon being more prominent in the central and eastern parts of the country. This natural gradient is exacerbated by various factors such as topography, geology, climate change, and land use history. In particular, the former homelands in the eastern province of KwaZulu-Natal are prone to erosion due to higher population densities and subsequent high anthropogenic pressure making gullies a characteristic landscape feature (Olivier et al., 2023). This phenomenon is also strongly pronounced in regions covered by colluvial sediments (Bernini et al., 2021). The study area in the Upper Umfolozi catchment along the Jojosi river includes both, areas of former homelands and colluvial sediments of the Masotcheni Formation underlining the interest in the region. Our study addresses two issues: the first is to complete the mapping of gully erosion in this still understudied region of Northern KwaZulu-Natal. Second, the gully inventory, combined with data on different influencing factors will help to understand the main drivers of gully erosion and differentiation within gully types and activity in this region. An inventory of current gully erosion forms present in the area is compiled as the first main output. It is created using aerial images from historic flight campaigns in 1944, 1956, 1981, and 1991 as well as recent satellite imagery. In addition, imagery from UAV flight campaigns in 2022 and 2023 is available for one specific gully system. In total, these data cover almost 80 years with rough time intervals of 20 years. In a second step, each gully entry is further described with the current gully type out of the six types first introduced by Ireland et al. (1939). Maximum length, maximum width, and mean width are also recorded. In combination with the historic imagery, the gully activity over the past 80 years is added to the inventory. Hereby, growth is the main identifying factor for recent gully activity. Young and dynamic gullies are characterised by high growth rates whereas older gullies become more static and are associated with lower erosion rates (Sidorchuk, 1999, 2021). Afterwards, the types and activity are studied taking data on main influences into account. The selected factors are terrain indices derived from a digital elevation model, precipitation, geological formation, dominant soil type, vegetation, and land cover. Our study shows gully development and gully activity in the Upper Umfolozi catchment in KwaZulu-Natal for nearly 80 years since 1944. The completed inventory includes more than 250 gullies and gully systems in a 200 km^2 study area. All entries are described with one of the six gully types, length, width, and activity. Additional data allows the identification of key influences within the area. The results of the gully erosion drivers provide insights for further understanding the processes of land degradation in northern KwaZulu-Natal and will provide useful information for adapting conservation methods.

Ten years of high-resolution UAV surveys for erosion monitoring in a badlands area site of Central Italy

Annalisa Sannino[1], Manuel Stark[2], Francesca Vergari[1], Florian Haas[2]

[1]Dept. of Earth Sciences, Sapienza University of Rome, Italy

[2]Chair of Physical Geography, Cath. University of Eichstätt-Ingolstadt, Germany

Sub-humid badland areas exhibit a rapid and complex evolutionary dynamic involving several geomorphological processes, including sheet erosion, rill erosion, gully erosion, and mass movements, which simultaneously shape the badlands hillslopes. The badlands landforms of Southern Tuscany (central Italy), locally referred to as "calanchi" and "biancane," have been extensively researched to quantify their morphodynamics over time, focusing on erosion rates and human impact factors such as land use and land cover changes. Over time, various methods and tools have been employed, progressively transitioning from traditional ones, like erosion pins, to the adoption of cutting-edge technology such as Digital Photogrammetry with Structure from Motion with Multi-View-Stereo (SfM-MVS) techniques applied to drone-acquired data. The latter method has gained widespread popularity in geomorphological research due to its capability to extract high-resolution Digital Elevation Models (HR-DEMs), facilitating the quantification of erosion and deposition rates through multi-temporal comparisons, as well as inferring topographic characteristics associated with major geomorphological processes. The aim of this study is to analyze multi-temporal photogrammetric data derived from 10 years of monitoring in the Scalonca stream basin, a tributary of the Orcia River. Specifically, by generating multi-temporal HR-DEMs, the decade-long trends in erosion rates are examined in terms of volumetric changes, also considering the precipitation patterns as potential triggering factors. Additionally, as these data allow to detailed mapping of erosion landforms, using the high-resolution orthofotomosaics, the, derived high-resolution topographic factor maps (HR-TMs), such as slope, curvature, roughness, and connectivity indexes, are correlated to the effects of the main geomorphological processes, in order to delineate the erosion causal factors, the topographic signatures of the various erosion forms and their spatial and temporal evolution.

Sensitivity analysis of hillslope sediment delivery in grazing land

Jagriti Tiwari[1], Bofu Yu[1], D. Mark Silburn[2]

[1]Australian River Institute, School of Engineering and Built Environment, Griffith University, Nathan, Australia
[2]Department of Environment, Science and Innovation, Toowoomba, Australia

Sediment delivery from small plots led to transportation and deposition of sediment in hillslope grazing or pasture land. Specifically, in bare areas or areas with lower ground cover, it is necessary to address the effect of hydrological, and environmental factors on total soil loss at various scales. Through an event-based historical case study of a small runoff plot (TrB2) located within Springvale catchment in the Nogoa sub-basin of the Fitzroy basin, Central Queensland, the efficiency of revised and modified versions of Universal Soil Loss Equation (USLE) models have been identified. The Modified USLE model which includes the combination of rainfall and runoff erosivity, with $R^2 = 0.74$, was found to be suitable for improved sediment yield prediction. This modelling study can be further applied to other areas to explore the sensitivity of soil erosion and sediment yield in grazing land. Therefore, this work addresses the need for rehabilitation and sustainable management of land, and water resources which supports multiple United Nation's Sustainable Development Goals.

Editorial office

Tobias Heckmann, Diana Kara,
Claudia Pietsch and Moritz Altmann

Chair of Physical Geography
Catholic University of Eichstätt-Ingolstadt
Ostenstraße 18
85072 Eichstätt, Germany

https://www.ku.de/mgf/geographie/physische-geographie