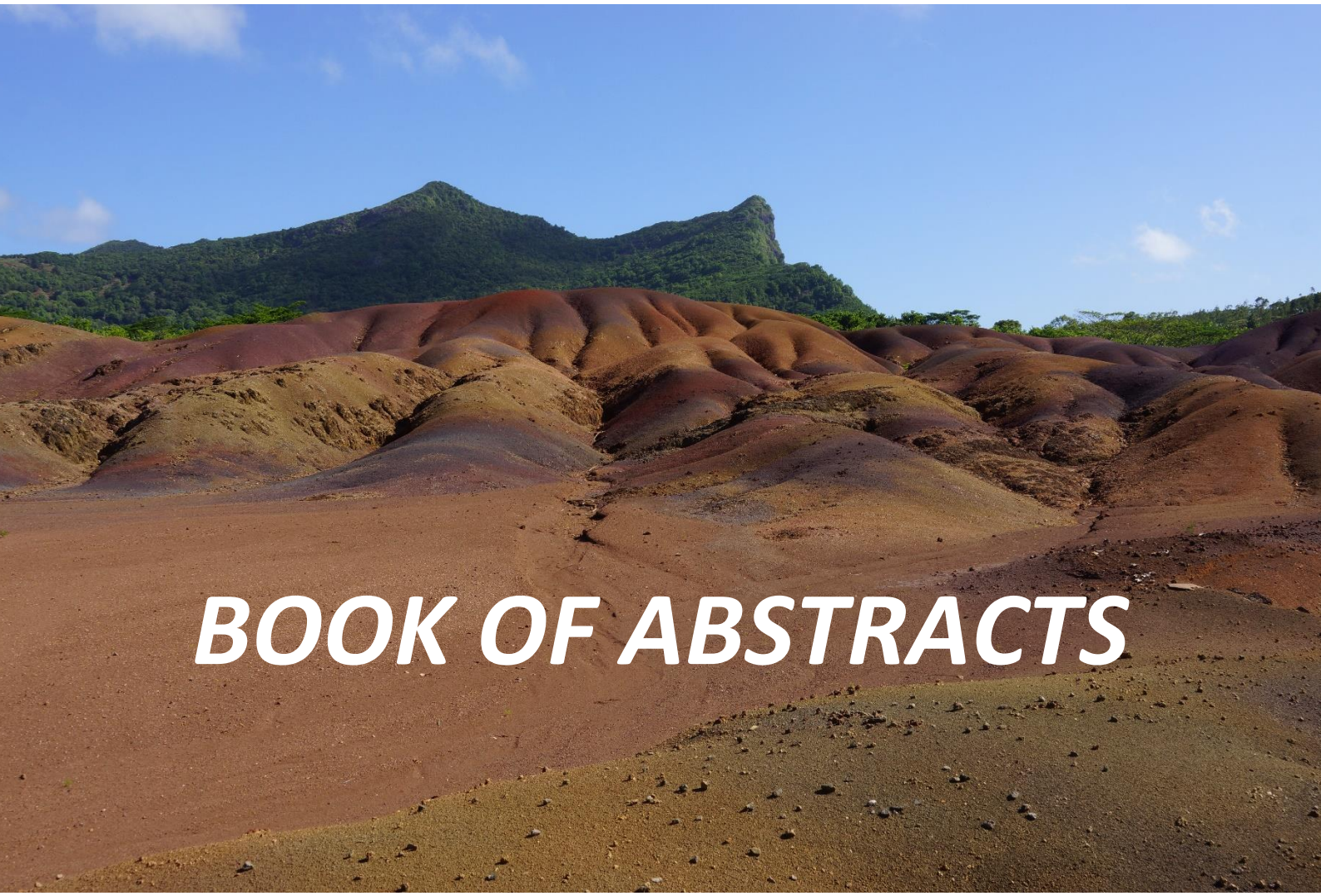
1st Workshop

of the IAG/AIG Working Group DENUCHANGE:

Denudation and Environmental Changes in Different Morphoclimatic Zones

Storkowo-Szczecinek (Poland), September 25-27, 2018



BOOK OF ABSTRACTS

IAG/AIG Working Group on Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE)

Association of Polish Geomorphologists

Institute of Geoecology and Geoinformation Adam Mickiewicz University in Poznań Poland

IAG/AIG International Association of Geomorphologists

Denudation and Environmental Changes in Different Morphoclimatic Zones

Editors:
Joanna Gudowicz, Achim A. Beylich, Zbigniew Zwoliński

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Foreword

There is general agreement that global environmental changes will have significant effects on Earth surface systems. The question how global environmental changes will affect our landscapes and the way we interact with it is therefore of highest importance. Denudation, including both chemical and mechanical processes, is of high relevance for Earth surface and landscape development and the transfer of solutes, nutrients and sediments from headwater system through main stem of drainage basin systems to the world oceans. Denudation is controlled by a range of environmental drivers and can be significantly affected by human activity.

The better understanding of possible effects of ongoing and accelerated environmental changes on present-day denudation requires systematic and quantitative studies (environmental monitoring) on the actual drivers of denudational processes in differentiated landscape controls. Only if we have an improved knowledge of drivers, mechanisms and rates of contemporary denudational processes across a range of different selected climatic environments, possible effects of global environmental changes on denudation can be better assessed. Special focus must be given to selected morphoclimatic zones that react particularly sensitive to ongoing climatic changes and human activities.

A systematic geomorphologic comparison of present-day denudation rates in different defined climatic zones combined with a coordinated analysis and compilation of the respective key controls of denudation that is presently occurring in the different selected morphoclimatic settings is still largely missing.

The working group on Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE) (2017 – 2021) will help to close this still existing key knowledge gap and shall contribute to a better understanding of the possible effects of global environmental changes on contemporary Earth surface systems.

The main aims and objectives of the working group are to:

- Define and select a range of different morphoclimatic zones that react particularly sensitive to ongoing climate change and human activities;

- Provide a systematic quantitative analysis (detailed compilation and comparison) of chemical and mechanical denudation rates in defined drainage basin systems in these different selected morphoclimatic zones worldwide;
- Provide a coordinated and integrated analysis and compilation of the respective key drivers of contemporary denudation occurring under the various present-day morphoclimates;
- Define and develop denudational models for different spatial scales of drainage basins and morphoclimatic zones;
- Define the morphometric signature of denudational processes for different spatial scales of drainage basins and morphoclimatic zones;
- Address the key question how climate changes are affecting contemporary denudation rates in different morphoclimatic zones;
- Address the key question how human activity is affecting contemporary denudation rates in different morphoclimatic zones.

Achim A. Beylich

September 25, TUE: Oral sessions

The new I.A.G. / A.I.G. Working Group on Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE): Scientific need, key research questions and planned activities

Achim A. Beylich[1] and the DENUCHANGE Team

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There is general agreement that global environmental changes will have significant effects on Earth surface systems. The question how global environmental changes will affect our landscapes and the way we interact with it is therefore of highest importance. Denudation, including both chemical and mechanical processes, is of high relevance for Earth surface and landscape development and the transfer of solutes, nutrients and sediments from headwater system through main stem of drainage basin systems to the world oceans. Denudation is controlled by a range of environmental drivers and can be significantly affected by human activity.

The better understanding of possible effects of ongoing and accelerated environmental changes on present-day denudation requires systematic and quantitative studies on the actual drivers of denudational processes in differentiated landscape controls. Only if we have an improved knowledge of drivers, mechanisms and rates of contemporary denudational processes across a range of different selected climatic environments, possible effects of global environmental changes on denudation can be better assessed. Special focus must be given to selected morphoclimatic zones that react particularly sensitive to ongoing climatic changes and human activities.

Environmental drivers and rates of solute and solid fluxes in largely undisturbed cold climate environments have been analyzed in the I.A.G. / A.I.G. Working Group SEDIBUD (2005 – 2017). However, a systematic geomorphologic comparison of present-day denudation rates in different defined climatic zones combined with a coordinated analysis and compilation of the respective key controls of denudation that is presently occurring in the different selected morphoclimatic settings is still largely missing.

The working group on *Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE) (2017 – 2021)* can help to close this still existing key knowledge gap and shall contribute to a better understanding of the possible effects of global environmental changes on contemporary Earth surface systems.

The scientific activities of DENUCHANGE will be particularly focused on:

- Cold regions
- Arid regions
- Semi-arid regions
- Tropical regions
- Temperate regions

The main aims and objectives of the working group are to:

- Define and select a range of different morphoclimatic zones and settings that react particularly sensitive to ongoing climate change and human activities;
- Provide a systematic quantitative analysis (detailed compilation and comparison) of chemical and mechanical denudation rates in defined drainage basin systems in these different selected morphoclimatic zones and settings worldwide;
- Provide a coordinated and integrated analysis and compilation of the respective key drivers of contemporary denudation occurring under the various present-day morphoclimates;
- Define and develop denudational models for different spatial scales of drainage basins and morphoclimatic zones;
- Define the morphometric signature of denudational processes for different spatial scales of drainage basins and morphoclimatic zones;
- Address the key question how climate changes are affecting contemporary denudation rates in different morphoclimatic zones;
- Address the key question how human activity is affecting contemporary denudation rates in different morphoclimatic zones.

DENUCHANGE builds on the activities and the existing group of scientists from the SEDIBUD working group (2005 - 2017) and:

- Brings together various groups of geomorphologists working on denudation in different morphoclimatic zones;
- Provides a multinational and interdisciplinary forum for scientists from the bio-geophysical disciplines applying a wide range of different methods and techniques for analyzing denudational processes and denudation rates in different morphoclimatic zones.

Key activities and products of the working group will include:

- The organization of annual working group planning meetings and scientific workshops in 2018 - 2021;
- The organization of advanced training courses/workshops on methods and techniques for the quantitative analysis of denudation for young scientists;
- The organization of scientific sessions and discussion meetings at relevant international conferences (e.g., I.A.G./A.I.G., AGU, EGU) in 2018 - 2021;

- The publication of journal special issues connected to these annual workshops and conference scientific sessions;
- The conception, preparation and publication of a synthesis book on Denudation and Environmental Changes in Different Morphoclimatic Zones.

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September 25, TUE: Invited lectures

The pattern of morphoclimatic zones on the Earth

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Supply of various amounts of solar radiation to the terrestrial Earth's surface from the North Pole to the South Pole causes diversified reactions of geomorphological processes shaping the morphological surface of the Earth. On a diverse supply of solar radiation shall be imposed in addition to its seasonal variability throughout the year. As a result of the repeated delivery of radiation in daily, seasonal, annual, multi-year and even longer cycles and the corresponding dominant, secondary and extreme processes produce on the globe a distinctive belt system matching separate morphoclimatic zones. There is analyzed Köppen-Geiger's climatic maps according to the observed data for the period of 20th century (Rubel, Kottek 2010).

Morphoclimatic zone classifications by Büdel (1963), Tricart, Cailleux (1965) and Hagedorn, Poser (1974) were evaluated. Büdel (1963) claims that at each point on the earth climate determines the fundamental combination of morphogenetic processes. His classification is based primarily on morphological criteria which correlate to climate. Tricart, Cailleux' (1965) proposed classification is based on two types of criteria: large climatic and biogeographic zones that provide the principal divisions, and subdivisions based on the preceding criteria combined with paleoclimatic differences. Hagedorn and Poser (1974) used a combination of geomorphological processes and factors indicating the spatial order of landforms. Zonal morphological and climatic variation of the Earth, therefore, reflects the spatial distribution of the nature and intensity of the ancient and modern processes of erosion, denudation and accumulation.

These classifications were compared with the results of Iwahashi, Pike (2007) tests. They obtained terrain class values, as well as terrain series values for the entire world. Comparison contains newly calculated data for terrain classes and series, for individual morphoclimatic zones according to the classifications of Büdel (1963), Tricart, Cailleux (1965) and Hagedorn, Poser (1974). Differences for the entire world data between the original Iwahashi, Pike (2007) data and the three classifications are relatively small and fall in the range of -3.1 to 2.4%. This means that at the scale of the entire world — regardless of the morphoclimatic zone classification methods — the results are similar, despite the fact that glacial zones are not allowed for in the calculations. Extremely interesting information is provided by the analysis of data for the 16-fold terrain classes, which indicate significant differences in individual morphoclimatic zones according to different classifications.

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September 25, TUE: Invited lectures

Mechanical denudation of the selected areas in Europe

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Mechanical denudation represents a results, in long time periods, of mass movements, water erosion and wind erosion. This presentation is focused on the runoff of solid particles from a given area (eg. from drainage basin) due to linear cutting of slopes and erosion of river channels, as well as the runoff from other areas due to surface soil wash. The erosion of slopes and river channels is accompanied by sediment deposition. The both processes occur alternately in the scale of different areas and their product indicates the trend of lowering or overbuilding of an area. Solid particles of different size discharged from a drainage basin are then transported as a bottom or suspended material. The size of the runoff of this material beyond a control station is defined as net denudation (denudation netto, outflow denudation). It shows only the size of solid material loss in an area studied (eg. in drainage basins of different size) but does not indicate the differentiation of intensity of this process within studied areas. The measurements of bottom material are more difficult to carried out than suspended material. This is why only suspended material is measured, which is the base to estimate the size of material loss in drainage basins in local, regional and global scales. The size of suspended material is always underestimated which results from the applied measurement and calculation methods. Basing on mean values from multi-annual periods of the size of suspension transportation in control stations [$t \cdot yr^{-1}$], unit runoff denudation [$t \cdot km^{-2} \cdot yr^{-1}$] from sub-catchments of drainage basins is calculated and shown in form of isolines. The value of these isolines decreases with increase of the catchment basin area, which reflects the increase of losses during the transportation. The losses in transportation of suspended material are determined by sediment delivery ratio SD [%], which may even exceeds 99% in large drainage basins. This suggests considerable caution in analyses of the size of material transportation in water courses.

Taking into account the mentioned above remarks, the author analysed the size of transportation of suspended material in three areas of Europe: (1) the Carpathian Mountains and their foreland, (2) the drainage basin of the Baltic Sea, (3) area of Poland, with special reference to the catchment basin of the Vistula River. Data from hydrological stations of 14 countries of the period 1950-1995 were carefully assessed. The size of unit runoff denudation [$t \cdot km^{-2} \cdot yr^{-1}$] shows considerable spatial differentiation connected with different lithology, land relief energy, geomorphological processes, climatic and hydrological processes. Minimum values [< 5 $t \cdot km^{-2} \cdot yr^{-1}$] are typical for the areas of old-glacial relief, whereas the maximum values [> 2000 $t \cdot km^{-2} \cdot yr^{-1}$] are typical for the seismically active Sub-Carpathian zone. The relation between unit runoff denudation [$t \cdot km^{-2} \cdot yr^{-1}$] and runoff index H [mm]

shows typical bimodal distribution in each of the areas studied. The increase of mechanical denudation was determined in the areas with dominated agricultural use, especially in the mountains. The size of loss in the transportation of the suspended material in the Carpathian foreland was estimated. The largest deposition of this material occurs in the valleys adjacent to the Sub-Carpathians. The estimated indexes of mechanical denudation and material deposition should be taken into account while planning location of water dams on rivers.

September 25, TUE: Invited lectures

Delivery denudational material for fluvial transport in lowland catchment

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Only a part of the material mobilised by denudational-erosional processes in a slope system reaches a stream channel and leaves its catchment. Even in a 1st-order catchment only a small part of it is involved in the delivery of sediment for fluvial transport, and the range of the supply zone varies with the amount and intensity of precipitation, soil moisture, and vegetation cover. The problem of the delivery of material from a catchment to a stream channel is only rarely addressed in the case of lowland areas of Poland with their negligible direct connection between the slope system and that of fluvial transport, even during extreme weather events. The connection between those two systems is strongly affected by the morphology of river valleys, and the place of their direct connectivity is often only the valley head. An analysis of the nature of links between the systems was carried out in a catchment (in north-western Poland) 10.7 km^2 in area, drained by a 4th-order stream. On completing the geomorphological mapping five principal sources of mineral and organic solid particles have been distinguished. They are: the drainage system embracing supply through streams and groundwater outflows, the wetted perimeter of the river channel, which means supply from the channel bed and banks, the floodplain, via surface and underground supply, biogenic supply, and man-made supply.

In lowland rivers, bed and bank erosion are thought to be the primary processes responsible for the supply of material transported in the river channel. The wetted channel perimeter is the most important zone of suspended load supply. The efficiency of supply from this zone depends on its morphology, geological structure, and the stage of vegetation growth. Worth noting are man-made and animal sources, which are abundant but of episodic nature, mostly unrelated to water stages.

The low connectivity between the studied stream channel and its catchment in terms of clastic sediment supply is associated with the rate and character of the water cycle, and as a result, with the mechanism of material delivery to the stream channel. The substantial contribution of groundwater to the alimentation of the streams leads primarily to the supply of dissolved material and the dominance of ionic flow over suspended flow in the stream channel.

September 26, WED: Oral sessions

State Environmental Monitoring in Poland, organization of Integrated Monitoring of Natural Environment

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Determinants of State Environmental Monitoring development in Poland:

- State priorities in social, economic and scientific politics.
- Changes in the system of state economy management.
- Connections between natural environment monitoring in Poland and assumptions of European monitoring and nature protection plans.
- Introduction of new methods and measurement technics in the environmental monitoring.
- Education of staff in natural environment monitoring and environment organization and management.
- Dissemination of natural environment monitoring results in assessment of the environment state and development prognosis (among others the Monitoring Library).
- Realization of basic natural environment monitoring functions: organizational, meritorious, educational, and fundamental – applicatory.

Present-day tendencies of natural environment changes in Poland:

- Natural environment in Poland is under constant changes (differentiated in time and space), both due to natural and human induced processes.
- As well particular elements of the natural environment (i.e. air, land surface, soil, plants) as landscape structures are subjected to the changes.
- Climate changes with increased frequency of extreme processes with catastrophic effect (hazards) and increasing human impact are characteristic features of natural environment changes in Poland.
- Character and rate of natural environment changes in Poland (Europe) should be compared with the state of natural environment of northern Europe polar areas (Svalbard archipelago).

The IMNE measurement programme is implemented basing on the following aspects:

- The balance of energy and matter in a river and/or lake catchment,
- The flow of the matter in the atmosphere-plant-soil profile-groundwater,

- The monitoring (bioindication) of selected biological elements of the geo-ecosystem sensitive to changes in energy balance, biogenes and toxic elementsPresentation of abiotic and biotic resources of surveyed geoecosystems and ways of their protection
- Determination of type and character of geoecosystems hazards and pointing at ways for their prevention
- Determination of the probability of above-average, extreme and catastrophic events occurrence
- Information about geoecosystems on particular order

Research and applicatory problems of Integrated Monitoring of Natural Environment:

- Recognition of natural environment functioning mechanisms in selected geoecosystems
- Geoecosystems functioning environmental determinants
- Recognition of energy and matter circulation settings within geoecosystems of different size and structure
- Threshold values of resistance of selected geoecosystem spheres vs. natural and human induced stimulants
- Extreme processes and their influence on geoecosystems functioning
- Water circulation pattern as a base for geoecosystems classification
- Geoecosystems typology criteria as a base for regional repartition of the state, province etc.
- Geoecosystems transformations under climate change and human impact

September 26, TUE: Oral sessions

Spatiotemporal variability, environmental controls and rates of contemporary mechanical and chemical denudation across selected glacierized and non-glacierized drainage basin systems in western and central Norway

Achim A. Beylich[1], Katja Laute[1]

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The mountainous landscapes of Norway are characterized by Pleistocene glaciations and, connected to this, a dominance of glacially sculpted landforms like U-shaped valley systems, fjords, cirques, lakes and hanging valleys. The spatiotemporal variability, environmental controls and quantitative rates of contemporary mechanical and chemical denudation have been studied since 2004 in selected drainage basin systems in the very steep mountainous and partly glacierized (Jostedalsbreen ice cap) fjord landscape of the inner Nordfjord in western Norway, and since 2011 in non-glacierized and permafrost free catchment systems in the boreal-oceanic and only moderately steep mountain landscape situated south of the Trondheim fjord in central Norway. Our work has included high-resolution and year-round meteorological, hydrological and geomorphologic process monitoring with the detailed analysis of fluvial suspended sediment, bedload and solute transport together with the application of fingerprinting techniques and the comparison of computed contemporary mechanical denudation rates with long-term denudation rates calculated from the geophysical analysis of Holocene sediment fills in existing lake systems. The size of the selected drainage basin systems ranged from 60.1 km^2 (Bødalen drainage basin in western Norway) to 156.3 km^2 (Homla drainage basin in central Norway), and the topographic relief of the selected drainage basins ranged from a minimum of 697 m in central Norway to a maximum of 2031 m in western Norway. In western Norway, the relative share of drainage basin areas being currently covered by glaciers ranged from a minimum of 18% to a maximum of 38%. Sporadic to discontinuous permafrost can only be expected in elevations above 1500 m a.s.l..

For the partly glacierized drainage basin systems in the fjord landscape of western Norway it is found that there are significant intra- and inter-annual variations with respect to contemporary fluvial mechanical denudation, with these variations being mostly controlled by meteorological events and by varying sediment availability. Present-day annual rates of fluvial mechanical denudation show a high spatial variability and range from a minimum of 18.6 t $km^{-2}yr^{-1}$ to a maximum of 44.6 t $km^{-2}yr^{-1}$ across different glacier-connected drainage basin systems of the inner Nordfjord. Main controls of the detected spatial variability of contemporary mechanical denudation are the share of drainage basin area being covered by glaciers, the varying efficiency of small proglacial lakes and anastomosing stream stretches in trapping material, and the steepness and the degree of vegetation cover of ice-free

drainage basin surface areas with sedimentary covers. Because of supply-limited conditions, the intensity of fluvial mechanical denudation is altogether much more related to the availability of sediments than to channel discharge. The contemporary mechanical denudation rates found in the inner Nordfjord are in the same order of magnitude than the Holocene mechanical denudation rate in this area. Mechanical denudation dominates clearly over chemical denudation, with mean annual (atmospherically corrected) rates of chemical denudation being very low and ranging from a minimum of 2.8 t $km^{-2}yr^{-1}$ to a maximum of 6.0 t $km^{-2}yr^{-1}$.

Compared to this, in the non-glacierized mountain landscape located south of the Trondheim fjord in central Norway chemical denudation with a mean annual (atmospherically corrected) rate of 12.1 t $km^{-2}yr^{-1}$ clearly dominates over mechanical denudation with a mean annual rate of only 3.6 t $km^{-2}yr^{-1}$. Mechanical denudation in central Norway is strongly event-controlled and the highest share of annual fluvial sediment transport occurs in May during the peak of spring snowmelt.

Mechanical denudation and chemical denudation are altogether low in both western Norway and central Norway. Mechanical denudation in the inner Nordfjord in western Norway is clearly lower than in many other (partly) glacierized landscapes worldwide which is mainly due to the high resistance of the predominant gneisses towards glacial erosion and weathering, the altogether only small amounts of sediments being available, the stable and nearly closed vegetation cover of ice-free surface areas with sedimentary covers, and the efficiency of sediment storage in the existing proglacial lakes and anastomosing stream channel stretches. The great steepness of the landscape, the small areal extent of surface areas with sedimentary covers and the small thickness of sedimentary covers are major controls of the very low rates of chemical denudation in this area. In central Norway the low rates of mechanical and chemical denudation are explained by the cool climate combined with a nearly closed and continuous vegetation cover, small thicknesses of sedimentary covers, the high weathering resistance of the predominant bedrock and the comparably low topographic relief in this area.

Our results support the existing opinion that mechanical denudation is of significant importance and dominates over chemical denudation in (partly) glacierized drainage basin systems. However, our investigated drainage basin systems in western Norway, being connected to the Jostedalsbreen ice cap through various outlet glaciers, show remarkably low rates of drainage basin wide mechanical denudation. As a result, the mountainous landscapes of western and central Norway appear to be rather stable which is reflected in low denudation rates and which is largely explained by the high resistance of the predominant bedrocks towards weathering and erosion, and by the limited availability of significant sedimentary covers. Based on our findings on environmental controls of contemporary mechanical and chemical denudation, it is expected that postulated changes of the current wind, air temperature and precipitation regimes will lead to increasing drainage basin wide mechanical and chemical denudation rates in both glacierized and non-glacierized drainage basin systems in western and central Norway.

September 26, TUE: Oral sessions

Potential geomorphic and denudational effects of a changing snow-avalanche activity in western Norway

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Snow avalanches are natural slope processes, representing a part of the mountain process-response system. The formation of snow avalanches is characterized by the complex interaction between terrain characteristics, snowpack, and meteorological conditions. Consequently, it is likely that the frequency and magnitude of both ordinary and extreme snow avalanche events will be modified through the documented effects of climate change. In the mountainous fjord landscapes of western Norway snow avalanches represent one of the dominant denudational slope processes and have a high relative importance regarding sedimentary mass transfers.

This study focuses on possible effects of climatic variations on snow-avalanche activity within one of Norway's most snow avalanche-prone areas. We have statistically analyzed long-term homogenized meteorological data from seven official meteorological stations, three of them with a long-term record of 120 years (1896-2015). In addition, gained results and insights from a four-year (2009-2012) high-resolution snow avalanche monitoring investigation conducted in the same study area are incorporated.

Meteorological records for western Norway show the general trend that the last 100 years, and especially the last three decades, have been warmer and wetter than the time periods before. Magnitude-frequency analyses of monthly precipitation sums for the winter period exhibit an increase of precipitation especially during the last three decades with the tendency that more precipitation can be expected in February and March. An increase of the monthly precipitation sums (snow fall) during the winter period along the southwest coast of Norway may lead to a generally higher snow-avalanche frequency. Due to more frequent periods with air temperatures close or above the freezing point during the winter period, the probability of wet/full-depth snow avalanches and slush flows will increase.

Full-depth snow avalanches are characteristic for the peak avalanche season (March-May) and represent the type of snow avalanches which are commonly most capable (due to a higher snow density) of transferring sediment masses downhill. An increase of full-depth snow avalanches might lead to a generally higher sediment mobilization at rock surfaces, a higher re-mobilization along rock- and talus cone surfaces as well as higher sediment transfers further downhill. Correspondingly, a

higher hillslope-channel connectivity can be expected too as snow avalanches are capable of transporting debris material far enough to reach stream channels. The current coincidence of the ongoing enlargement of proglacial areas which comprises the exposure of unstable sedimentary covers along hillslopes and an increase in snow-avalanche activity will lead to a recognizably higher sediment reworking and sediment supply into stream channels in the future. In the supply-limited fluvial systems of the mountainous fjord landscape in western Norway, this increase in sediment supply will certainly lead to increasing rates of drainage basin wide mechanical fluvial denudation.

September 26, TUE: Oral sessions

The assessment of influence of soil erosion by water in the transformation of agricultural slopes of the Wiśnicz Foothills

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The main aim of the paper is to assess influence of soil erosion by water in the transformation of agricultural slopes of the edge of Wiśnicz Foothills. The dominant lithology in the area consists of flysch series belonging to the sub-Silesian overthrust, and the Miocene clays and the sandstones, which are covered with the Quaternary loess-like formations. The soil cover is weakly differentiated with Stagnic Luvisols. Low hills are typical in the morphology of the area. The ridges and the slopes are covered with thick, loess-like formations.

Results presented come from measurements of soil erosion by water on seven runoff plots in 2007–2009 hydrological year. The plots were located on a convex–concave slope facing north, ~50 m from a catchment divide. The meteorological station that collected the precipitation data is located close to this plots. All the plots were 2 m wide. Four of them were 22.1 m each, the remaining three were 11.1, 5.5 and 2.8 m respectively. The slope steepness of the plots was 8o. The plots were protected using plastic foil and closed off with a 2-m Gerlach gutter, which catches water and material eroded from each plot and then sends them to a separate water tank with a limnigraph. After each rainfall, measurements of surface flow and soil erosion were taken. Measurements were performed following each precipitation event characterized by effective erosion.

It has been established that slope wash is an occasional process. The morphological effectiveness of soil erosion by water is variable during the year and differentiated along the slope in the catchment. The amount of the sediment depends mainly on the type of vegetation cover and the crop structure.

Rainfalls during short periods of slope transformation have various effectiveness which depends on their parameters (EI_{30} or I_{30}) and the qualities of the ground on which the rain falls. The regularities shown in the study are related to potentially erosive rains established according to Universal Soil Loss Equation – USLE. There were 212 rainfalls meeting the criteria, and their total duration amounted to 2% of the time of summer half-years in the period of measurements. The individual erosiveness of rains changed from 2.32 to 3367.1 $MJmmha^{-1}h^{-1}$. In this zone of the Carpathian Foothills rain erosivity exceeding 200 $MJmmha^{-1}h^{-1}$ is, an extreme value. There were only 19 events of that type in the study period, on average 0.8 a year and they took place exclusively in the summer months, mainly in July and June.

September 26, TUE: Oral sessions

Sediment variability in a small catchment of the Polish Western Carpathians during transition from centrally planned to free-market economics

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Knowledge of suspended sediment (SS) transport in rivers provides important information on fluvial system dynamics, especially concerning erosion and deposition processes as well as water quality. A river sediment regime is affected by four related drivers: i) meteorological and hydrological factors, ii) disturbance of the landscape (natural mass movements), iii) human activity and iv) changes in sediment sources. SS transport in small mountain streams shows high spatial and temporal variability; therefore, it differs significantly from sediment transport in large rivers. The purpose of the study was a recognition of suspended sediment (SS) transport in small catchment (13 km^2) located in the Polish Carpathians affected by various forms of human activity in the period 1970–2017. This period covers two stages of socio-economic development with contrasting forms of human activity: the centrally-planned economy related to the communist system up to 1989 and the period of a free-market economy following. Analysis indicates an increase in the grassland and forest area of the analysed catchment by 90% and 10%, respectively, and a decrease in cultivated land by 82%. Changes in land use and land cover (LULC) have reduced the soil erosion by 74% as calculated using the Revised Universal Soil Loss Equation. At the same time, there was an increase of population, number of buildings, construction works along the stream, and decrease of cart roads. Hydro-meteorological data as well as SSL have not shown a statistically significant trend despite changes in forms of human activity in 1970–2017. In the first three decades of the analysed period (1970–1979, 1980–1989 and 1990–1999), SSL gradually decreased. In 2010–2017, suspended sediment load was the highest in the whole investigated period. The Principal Component Analysis (PCA) confirmed that it was effect of appearance of new sediment sources associated with intensification of landslides and new forms of human activity, such as construction works. The imposition of rainfalls on these factors has resulted in an increase in SSL and masked the effects of LULC change in the catchment. Conducted analysis showed that proper recognition of changes in sediment sources in the catchment is fundamental for correct interpretation of long-term sediment transport in the streams.

September 26, TUE: Oral sessions

Hydrogeomorphic process activity in the mining area of Călimani Mountains (Eastern Carpathians, Romania) – a dendrogeomorphic approach

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During the second half of 20th century, the mining activities for sulfur-rich ore extraction and processing produced significant morphological changes in the central part of the Călimani Mountains. Sediment transfers along the disturbed stream channels started during the mining period and are still ongoing today, more than two decades after the cessation of the mining activities in 1997. Neither rehabilitation works nor erosion control measures were undertaken to stabilize the spoil heap deposits. In these remote mountain areas, little is known about the spatio-temporal activity of the hydrogeomorphic processes responsible for sediment transfers. For the present study, dendrogeomorphic investigations were carried out in order to document the history of hydrogeomorphic activity along the stream channels below the spoil heaps. Tree-ring analysis allowed us to reconstruct a minimum of ten major hydrogeomorphic events, spanning the period 1970–2017. The high frequency of major hydrogeomorphic process activity (return intervals of 4.7 years) might be explained by the rainwater accumulation on the spoil heap platform and the availability of sediments, which flow down the talus and then follow along the stream channels.

September 26, WED: Poster session

Slope denudation, streamwork, and trends of relief development in selected mountain regions in Iceland, Sweden and Norway

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The various mountainous landscapes of Iceland, Sweden and Norway are characterized by Pleistocene glaciations and, connected to this, a dominance of glacially sculpted landforms like U-shaped valley systems, cirques, lakes and hanging valleys. The thickness of glacigenic deposits from this period can vary significantly across different mountain landscapes. In consideration of such legacies, these formerly glaciated landscapes today can be considered at a unique stage of readjustment (recovery) with respect to spatial organization of currently active geomorphic process domains and the magnitude and patterns of sediment storage and sedimentary fluxes. Accordingly, the postglacial relief development in these landscapes is controlled by a wide range of environmental drivers. This study focuses on environmental drivers of denudational earth surface processes and trends of postglacial relief development in five selected valley systems in formerly glaciated mountain landscapes in eastern Iceland, northern Sweden and western Norway. The selected valley systems Austdalur (23.0 km^2) and Hrafndalur (7.0 km^2) in eastern Iceland, Latnjavagge (9.0 km^2) in northern Sweden, and Erdalen (79.5 km^2) and Bødalen (60.1 km^2) in western Norway are considered to be representative valley systems for the respective mountain regions they are situated in. Our investigations include a detailed geomorphological mapping of the study areas, the quantitative compilation of contemporary mass transfers in the five valley systems, the quantitative analysis of current Ho/Hi index values for the slope systems in the valleys as well as a semi-quantitative description of changes of valley cross-sectional and longitudinal profiles since deglaciation. As a result, all U-shaped valley systems are characterized by an ongoing valley widening due to the continuing retreat of the existing rock-walls. However, the different valley systems show significant variations in the intensity of slope-channel coupling, in their slope and valley-floor storage behavior, in the development of their longitudinal valley profiles, and in the general intensity of denudational earth surface processes and postglacial relief modification. Accordingly, trends of postglacial relief development appear to be rather complex in the different mountain landscapes. It is found that the specific characteristics of the glacially sculpted and inherited valley morphometries are the most important control of the detected differences in slope-channel coupling, storage behavior and longitudinal valley profile development. Lithology and the given weathering resistance of the predominant bedrock are most important for the general intensity of denudational processes and postglacial relief modification. Apart from Hrafndalur which is characterized by rhyolites with particularly low weathering resistance, postglacial modification of the inherited glacially sculpted valley morphometries is altogether little and the landforms have not yet

adjusted to the geomorphic surface processes that have been operating under postglacial morphoclimates.

September 26, WED: Poster session

The pattern of contemporary denudation within the shore of Polish NW lakes in conditions of tourist use

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So far, works on the effect of tourist use on denudation have usually focused on mountain areas. Research confirms that changes in mountain geoecosystems are not always a natural manifestation of landscape evolution, but often result from poorer resistance to degradation caused by heavy tourist use. In spite of a great number of studies concerning this problem, few address the effect of tourists on the denudation of lakeland areas. Hence, Lake Radacz and Lake Wierzchowo was selected to determine the pattern of denudation in its shore area, especially in the scarp zone with tree roots, with the help of geodetic surveys conducted in the years 2010-2014. On the basis of observations and the research, stages in the evolution of the shore zone of Lake Radacz and Lake Wierzchowo were distinguished that were correlated with meteorological conditions affecting the number of recreationists on the beach.

In the summer, changes in the shore zone of lakes depend on seasonal variations in weather conditions, mainly the pattern of precipitation and air temperature, and on seasonal vegetation growth. Those factors directly affect the intensity of denudation processes (scarp retreated to 50 cm and beach decreased to 10 cm). The morphogenetic changes observed here in the years 2010-2014 would not be so intensive if it was not for tourist use and tourist capacity index in excess of 20 persons/100 m^2/hour.

September 26, WED: Poster session

The problem of including extreme mass movement events in a sediment budget: illustrations from the work of Heinrich Jäckli

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The Swiss engineering geologist Heinrich Jäckli was the pioneer of sediment budget methodology (Jäckli, 1957). This methodology has become central in modern geomorphology (Slaymaker and Embleton-Hamann, 2009). The goal of his research was "a quantitative analysis of the dynamics of a mountainous area". In pursuing this goal, Jäckli developed a new term "geological mass transfer" which he defined as the product of sediment mass and sediment transport distance divided by time (initially annually but secondarily over geological time). Jäckli was also apparently the first to employ estimates of geomorphic work (in Joules km^{-2} a^{-1}) carried out by each geomorphic process (Embleton-Hamann and Slaymaker, 2006).

He had good data for the contribution of deep-seated slides in the Bündner schist. He also had good information on the incidence of rock fall (11 events between 1805 and 1950); he had studied 17 rock glaciers in some detail (1949-1956) and instrumented two of them; for slow creep of slope debris he used published data from the Swiss topographical survey and the Swiss building authorities. Clastic sediment and dissolved solids flux information was routinely monitored (Jäckli, 1957).
The central continuing problem is that of comparing continuous (dissolved solids flux), semi-continuous (creep and clastic sediment flux) and low frequency and unique events (varieties of mass movement processes) over a common time scale with respect to their contribution to geological mass transfer. Specifically, in the case of the upper Rhine basin above Lake Constance (Bodensee), Jäckli could not figure out the comparative importance of geological mass transfer by semi-continuous fluvial processes, a large debris flow event that had occurred in 1944 and the enormous pre-historic Flimser bergstürz (rock avalanche) which had not been accurately dated at the time of his research (Poschinger and Kippel, 2009).

By making the working assumption that the upper Rhine basin is a system in which erosion and deposition of clastic sediments are balanced and the only net output is dissolved matter Jäckli calculated that the fluvial and geochemical systems dominate in their contribution to geological mass transfer. But he also realized that the Flimser bergstürz completely transformed the morphology of the upper Rhine. An exceptional debris torrent on August 24, 1944 near Linthal did cause significant aggradation. Because we have no information on how exceptional the 1944 debris torrent was the role of debris torrents is seriously underestimated. The Flimser Bergsturz, on the other hand, as a result of

accurate dating can now be given its true quantitative role in the sediment budget. The implication of a revised version of Jäckli's data base is that the Flimser Bergsturz can be considered a small part of the annual sediment budget with respect to volume moved and a much smaller contributor than "normal" slides. If the "work done" budget is considered, the Flimser Bergsturz is much more important than "normal" slides but is substantially less important than fluvial sediment and dissolved solids transport. The reason for this is that the fluvial processes transport the sediments much further from headwaters to sink and operate semi-continuously throughout the year.

Jäckli was one of the first to recognize the general and continuing problem of magnitude and frequency of operation of geomorphic processes.

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September 26, WED: Poster session

Debris-flow functioning and their contribution to sedimentary budgets: the Peyronnelle sub-catchment of the Guil River (Upper Queyras, Southern French Alps)

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Mountain environments are very sensitive to climate change, and they can be affected by any change in temperature and precipitation patterns, that may result in increasing natural hazards and risks for the population living downstream. This is particularly true in first order catchments, where control parameters of the torrential functioning (slopes, rocks, inherited debris storages, etc.) influence directly the sediment budget and dynamics, the modes of debris transport, and indirectly impact the hydrological system at a larger scale. Here we consider a sub-catchment in Queyras (Southern French Alps), and try to assess its role in the sediment cascade and its connectivity with adjacent mountain slopes, as a part of SAMCO (ANR 12 SENV-0004 SAMCO) research project on "Mountain Hazard Assessment in a Context of Global Changes".

The Upper-Guil catchment (317 km²) is particularly prone to high magnitude/low frequency flash flood events associated to Lombarde easterlies (June 1957 and 2000; October 2000; June 2008 and 2011). It is characterized by high denudation rates on schist bedrock supplying a high, fine and coarse sediment load. Coming from small torrential tributaries, these events strongly increase damages on the valley bottom. Steep slope gradients also make the catchment predisposed to torrential and gravitational hazards such as debris flows, landslides or avalanches. However, despite high denudation rates observed on free faces located on the upstream parts of the catchment, an extreme rainfall event does not systematically imply a strong sedimentary response at the outlet.

In order to understand this "sediment delivery problem", we tried to evaluate the respective role of water and sediment supply on flood impact for its more representative and active sub-catchment: the Peynin catchment (≈15 km²). We proceed on two steps in order to build a 20 years' time scale sediment budget. Firstly, we characterize the sediment transport processes and the associated sediment cascade with a focus on debris flows due to their importance in this catchment (grain-size analysis, hydrological measures, Pit-Tags monitoring, and meteorological records). Secondly, we estimate, map and quantify

temporary sediment storages. Finally, a preliminary analysis of functional connectivity (*i.e*. process-based connectivity) is made with Vensim® software to estimate the respective role of threshold and processes frequencies in the sediment response of the catchment.

Results show the prominence of debris flows in the seasonal renewal of sediment storages. The desynchronization between hydro-meteorological signal and sedimentary response is explained by a time recharge to have matured sediment storage. Finally, for the last 20 years, the volumes of sediments produced by weathering in the Peynin catchment were estimated to 183.10^3 m^3, those stored to 166.10^3 m^3 (90%) and those exported downstream to 17.10^3 m^3 (10%). Recent climate trends suggest more damaging events to come.

September 26, WED: Poster session

Tributary catchments in the humid *vs.* dry Himalaya of Nepal: functioning, debris transport and impacts in the Kali Gandaki valley in a context of climate change

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Small river catchments play a major role in the overall denudation of the Himalayas, as they may generate extreme, geomorphic events. Their potential impacts on the morphology and functioning of trunk rivers are significant, and should be considered when developing infrastructure and settlements along the valley floor. We present and compare two examples of such catchments, tributaries of the Kali Gandaki (West Central Nepal): the Ghatte Khola (7.8 km^2), in the southern monsoonal (precipitation >2000mm/a) Himalaya, and the Panda Khola (64,1 km^2), in the northern dry continental (precipitation <300 mm/a) Himalaya, that are both subject to debris flow events.

The Ghatte Khola behaves as a "landslide catchment": debris flows events are generated by a persistent planar slide zone (dip slope), reactivated by pre- or monsoon heavy rainfall on the upper, forested catchment. Up there, the narrow channel is temporary clogged by landslide masses, until sudden, landslide outburst floods occur. Downstream, the channel is entrenched across the 5-8 m thick debris fan: repeated debris flows events are the cause of bank erosion and stream channel widening. At the Kali Gandaki junction, the volume of debris may be large enough to impede the Kali Gandaki flow for a few hours, as attested by field investigations (geomorphic mapping, sediment analysis, repeated photographs), completed by interviews with villagers during the last 40 years. Climate trend suggests an increase of monsoon precipitation, hence potentially more debris flow to come.

North of the Higher Himalaya, the Panda Khola (= the "mad" stream) is quite representative of the dry, continental Himalaya as it develops from high glacierized peaks (>5500 m asl.). Debris flows appear as a quite common mode of transport, yet they are more frequent since the last decades (the last significant event occurred in early spring 2016). Though detailed studies are still in progress, it seems that the acceleration of permafrost degradation in relation to increasing temperature trend affects the steepest rock walls, i.e. the west wall of Muktinath Himal (6045 m asl.). Resulting rockfalls and rock avalanches (altitudinal drop of more than 3,000 m) likely are at the origin of debris flow events, and of subsequent, repeated disorders on the large confluence fan with the Kali Gandaki.

Eventually, on both sides of the Himalayan range, such moderate to high-magnitude/frequency events are very efficient to foster sediment fluxes and create temporary sediment storages at the Kali Gandaki

junction. In this valley, the road open in 2007 is now planned to become a 2-way metal road, as an annex of the new “Silk Road”: called “the Kali Gandaki corridor”, it will cross Mustang down to Lumbini at the border of India. In this context, the functioning of such debris flow catchments creates potential new hazards to infrastructure (e.g. the ongoing construction of new bridges) and will increase the functional, social and economic vulnerability in this valley.

September 26, WED: Poster session

Debris flow susceptibility mapping using frecquency ratio model in Parâng Mountains (Southern Carpathians, Romania)

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Debris flow is a widespread geomorphic process in high areas of Parâng Mountains being a threat to human life, property and infrastructure due to their sudden occurrence and destructive force of their flow. This study is a contribution to future hazard assessment in the investigated area, being focused on mapping of the terrain susceptibility to debris flow. For this purpose, the following instability factors were analyzed: slope, elevation, aspect and Compund Topographic Index CTI (automatically generated from a Digital Elevation Model of 10 m spatial resolution), lithology (extracted from geological maps at 1:200.000 scale) and vegetation landcover (mapped on ortophotoplans). Spatial distribution pattern of debris flow tracks was mapped on ortophotoplans and validated by field survey. The frequency ratio model was applied for the analysis of debris flow susceptibility. First the frequency ratio was calculated for each class of factor and then, the frequency ratios were summed in order to obtain the debris flow susceptibility index. Areas with higher values of frequency ratio are areas that are more prone to debris flow. This model helped to achieve the zonation of terrain susceptibility into five categories: very low, low, moderate, high and very high. The debris flow susceptibility map was validated through the relative density index (R-index) by taking into consideration the debris flow inventory map. The validation results shows that the used model is appropriate for debris flow susceptibility mapping in our study area.

This study represents a contribution to the project ZONAGEOTOUR «Zonage des aléas géomorphologiques dans les espaces touristiques des massifs du Parâng (Roumanie) et du Pirin (Bulgarie)» (Geomorphic hazard zonation in tourism-frequented areas of Parâng Mts., Romania and Pirin Mts., Bulgaria), funded by the *Agence Universitaire de la Francophonie (AUF)* and *Fonds de Recherche Scientifique (FRS) de Bulgarie*.

September 26, WED: Poster session

Influence of GIS data quality on SWAT model stream flow and sediment simulations in the Parsęta river watershed

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GIS-based water quality modelling results, such as the Soil and Water Assessment Tool (SWAT) predictions, are dependent on the quality of input data. The aim of this study was to assess the influence of the DEM resolution and the soil database parameters on the water runoff and sediment yield outputs. The study included the evaluation of different DEM data and soil maps available for the territory of Poland.

The study was carried out in the Parsęta river basin which is situated in the north-western Poland. The watershed is located in temperate climatic zone and represents a landscape typical for lowlands influenced by glacial and periglacial processes of the Pleistocene. Three different sources of DEM data were tested: DEM created by interpolation of contour lines derived from the topographic maps on a scale of 1:10 000, DEM obtained from the Digital Terrain Elevation Data Level 2 (DTED2), DEM obtained from the CGIAR-CSI (SRTM v 4). Three sources of soil information were used: Digital forest map and Soil-agricultural maps, Harmonized World Soil Database (HWSD v 1.2), FAO-UNESCO map. The collected data were analyzed in 9 various combinations.

The evaluation was performed using historical streamflow and sediment concentration data from the watershed outlet on annual, monthly and daily basis. The model performance was evaluated based on R^2, Nash & Sutcliffe model efficiency (NSE) and Percent Bias (PBIAS). The obtained results varied depending on the applied input data and adopted time step of the output data. The study indicates the possibilities and limitations of selected GIS data in the achievement of a required accuracy of the model prediction.

September 26, WED: Poster session

Splash erosion on experimental slope in Western Polish Carpathian under natural rainfall

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Splash erosion is one of the most important factors affecting the denudation system of river catchment. The result of splash is the destruction of the structure and reducing of the permeability of soil, which is the cause of occurrence of slopewash. A number of relationships describing the splash mechanism was found in laboratory conditions. The necessity to carry out field measurements is postulated in the world literature and reflects the need to verify results of laboratory tests and theoretical studies. The aim of the study was to examine the effect of different environmental factors on splash erosion basing on cups method in natural condition. Moreover, the effect of the soil particle size and distribution on splash and the relationship between splash and downwash erosion were studied. This was the first long-term study (2012-2016, from May to October) in the Polish Carpathians slopes, where Inceptisol predominate. Splash erosion was variable and showed a strong correlation with environmental factors, including rainfall parameters, land use (black fallow, meadow) slope gradient (11°, 0°) and also particle size of soil and usage time (organic matter content, OM). The analysis showed statistically significant differences (U Mann-Whitney test) between the results obtained on individual experimental plots. Splash erosion on the slope with black fallow was 95 times higher than in the meadow and up to 20 times higher than in flat areas. The average downslope splash was 75% higher than the upslope splash and the soil particles were detached to maximum heights of 50 cm (downslope). The silt fraction dominated up to 20 cm, and the sand fraction at greater heights. There was a positive correlation between splash erosion and downwash and a negative correlation between splash erosion and OM. This research contributes to knowledge about the dynamics of the splash erosion, and the results could be valuable for the development of rainfall erosion models and control strategies against water erosion in mid-mountain areas.

September 26, WED: Poster session

River Bedload Trap - review of bedload measurement in different regions

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Measurements of bedload transport using the River Bedload Trap (RBT) were initiated in the Scott River on Spitsbergen in 2009. The study confirmed high effectiveness of the implemented measurement strategy and technical solutions for quantitative bedload transport rates and flux. This solution was patented in Poland in 2011 [210267] and generally in Europe in 2014 [EP 2333161]. The device has been commercialized and since 2015 has been manufactured by the Geomor-Technik. Great availability of this device allowed to extend the research by RBT to various areas of the Arctic, the Antarctic and moderate geographical zones. Two types of the RBT sets intended for gravel-bed and sandy-bed rivers will be presented. Five different sites of bedload transport measurements will be shown, including the Antarctic (Arctowski: Fosa and Siodło Creeks) and the Arctic (Petunia: Ebbaelva, Dynamiskbekken; Kaffiøyra: Waldemar Stream, Calypsobyen: Scott River) research stations. The application of RBT for continuous monitoring of bedload flux in the conditions of the High Arctic and Antarctic gravel-bed rivers and the North Poland proved to facilitate obtaining high efficiency and credible results.

September 26, WED: Poster session

The application of repeat high-definition TLS surveys as a tool for the inventory of geomorphic changes

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Geomorphic processes in the catchment are controlled by climatic factors with both global and regional character (weather, occurrence of extreme events), and local factors (e.g. structural conditions, sediment lithology). They contribute to the development of the relief of valley floors and channel morphology. In the High-Arctic conditions, primary factors responsible for the development of the relief of proglacial valleys include structurally determined morphometric parameters of the catchment, and particularly the inclination and width of the valley floor. The assessment of sediment supply to a proglacial river was performed by means of Terrestrial Laser Scanning (TLS) repeated surveys. The results of application of the 3D laser scanning technology for two field surveys (from 2010 and 2013) will be shown. The measurements were performed by means of a medium-range stationary Leica Scan Station C10 laser scanner. Complex measurements of the valley bottom were performed from interrelated measurement sites. At each of the sites, a point cloud was obtained constituting a model space composed of 5 M pt. Their integration resulted in obtaining a Digital Surface Model (DSM) with an accuracy of ± 0.9 cm. The accuracy of the model permitted precise measurements of parameters of the discussed landforms. The paper presents a comparison of high accuracy TLS-based DEM's aimed at the evaluation of current changes in the proglacial valley morphology. The implementation of TLS permitted complete assessment of the course of modern geomorphic processes.

September 26, WED: Poster session

The state of geoecosystems in Poland on the basis of Integrated Monitoring of Natural Environment

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The paper aims to identify the natural environment of Polish geo-ecosystems and their changes within 1994-2013. The research on the natural environment has been implemented for 20 years under the Integrated Monitoring of Natural Environmental programme (National Environmental Monitoring) at selected geo-ecosystems (research basins) being representative for specified Polish landscape zones.

The aim of the Integrated Monitoring of Natural Environmental programme (IMNE) is to provide data for defining the current environmental status and, based on multi-year observation cycles, to present short- and long-term environmental changes in the conditions of climate changes and growing human impact on the environment. The results obtained from the conducted observations are the basis for preparing short- and long-term forecasts of the development of the natural environment and presenting the directions for threats and methods for preventing them.

The basic object of IMNE research refers to a river or lake catchment area within which test research areas are located being representative for the landscape under analysis. In the year 2013 the measurement network includes 11 Base Stations located in the major Polish landscape zones:

- Baltic Coastland - Wolin station in Szczecin Coastland;
- Young-glacial Lakeland - stations: Storkowo in Western Pomeranian Lakeland, Koniczynka in Chelmno-Dobrzyn Lakeland, Puszcza Borecka in Masurian Lakeland, Wigry in Lithuanian Lakeland, Różany Strumień in Poznań Lakeland;
- Old-glacial Lowland - Kampinos station in Central Mazovia Lowland;
- Upland - Roztocze station in Roztocze Upland, Święty Krzyż station in Kielce-Sandomierz Upland
- Medium and High Mountains - Szymbark station in Central Beskidy Mountains/Central Beskidy Foothills and Karkonosze in Giant Mountains.

The analysis on trends of geo-ecosystem and their changes in Poland considers the long-term dynamics of some selected geo-indicators:

- climate: thermal-precipitation and precipitation trends,
- quality of atmospheric precipitation: ph/SEC classification of atmospheric precipitation, share of acidic factors in the acidification of precipitation, sodium-chloride indicators of regional disparities in the quality of precipitation
- quality of underground waters: nitric nitrogen $N\text{-}NO_3$, sulphur sulphate $S\text{-}SO_4$
- quality of surface waters: nitric nitrogen $N\text{-}NO_3$, sulphur sulphate $S\text{-}SO_4$, ionic balance of sulphur sulphate $S\text{-}SO_4$ and nitric nitrogen $N\text{-}NO_3$ (acidic factors), denudation balance, eutrophication of surface waters.

The IMNE being a scientific and research programme aims to recognise the operation of geo-ecosystems, their protection and preservation within the Poland's landscape structure. In terms of the methodology, the IMNE is based on the concept of system functioning, implements the assumptions of preserving geo-diversity and biodiversity of the whole country.

September 26, WED: Poster session

Impact of rainfall variability on soil erosion in field plots (Chwalimski Potok catchment, NW Poland)

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Soil erosion by water is one of the most important morphogenetic processes taking place within the lowland geoecosystems in Poland. Soil erosion research have been run at the testing plots selected within the Chwalimski Potok catchment (NW Poland) since the early 90s (Szpikowski 2003). The discussed area is located within the 1st order catchment being a subsystem of the Młyński Potok catchment and then followed by the upper Parsęta catchment. The location of the area in the upper Parsęta catchment (which can be regarded to be representative for young glacial areas of the moderate climatic zone (Kostrzewski et al. 1994) determines formation of the current landscape structure, including the operation of soil erosion within (Kostrzewski 1998). The main goal of research conducted in 2012-2014 was related to evaluate rainfall impact to soil erosion processes. It was realized by stationery observation and quantitative researches on testing plot and by computation rainfall characteristics: intensity, kinetic energy and erosivity (rainfall erosivity index EI30).

Rainfall annual totals in 2012-2014 hydrological years were rather close to long-period (1987-2011) average. Although other rainfall characteristics significantly differed from previous years. Annual totals of rainfall with intensity above 5 $mm \cdot h^{-1}$ did not exceed 66% of mean annual value (from 2001-2011). Similar dependence have been observed at rainfall erosivity index values - in 2012-2014 annual totals of EI30 did not reached the value of 200 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1}$, whereas long-period average equals 392 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1}$. There were also no rainfalls with erosivity greater than 50 $MJ \cdot mm \cdot ha^{-1} \cdot h^{-1}$. Annual values of overland flow amounted from 31,2 $dm^3 \cdot m^{-2}$ to 38,8 $dm^3 \cdot m^{-2}$ and the runoff coefficient equaled 4,6% in 2012, 5,4% in 2013 and 7,2% in 2014. Maximal monthly overland flow was caused by intensive melt in February 2012. During winter half-year, runoff was also initiated by lasting many hours rainfalls with very low intensity and erosivity, whereas in summer half-year, such events were caused by short, intensive and erosive rainfalls. Magnitude of soil loss in 2012 has been the least in 20-years period since 1994. Nevertheless, in 2013 and 2014, in spite of very low rainfall erosivity, annual soil loss exceeded the median value from 1994-2010. The achieved results show that annual soil erosion primarily depends on individual rainfall and erosive events. Therefore, magnitude of soil erosion cannot be estimated only on the basis of rainfall totals, but it is necessary to consider intensity and erosivity of single rainfall events.

September 26, WED: Poster session

Transition zone from hillslope to fluvial processes - formation and development of the 1st-order valley network in postglacial areas (the Dębnica catchment, Pomeranian Lakeland, NW Poland)

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A uniform valley system of the northern slope of Pomerania started to form on the recession of the inland ice of the Pomeranian Stage of the Vistulian Glaciation (15.2 ka). The development of the valley network involved a gradual integration of depression produced by glacial, fluvioglacial and periglacial processes into a system of river runoff. The process of the intergration and development of river network is still in progress, but its basic stage took place at the close of the Vistulian. The further evolution of the valley network thus formed included the appearance and development of 1 st-order landforms (using Harton's hierarchical lassification of the river network). The pattern of this lower-order valley network is susequent upon the directions of the trunk valleys determined by the structure and relief of the older substratum. The main research aims are characterise the development of 1 st-order valleys in the post-glacial areas of West Pomerania (Dębnica catchemnt) and to present stages of their inclusion into the river runoff network via groundwater.

The study area chosen was the Dębnica catchment of 289.5 km^2 in area, which belongs to two macro-regions: the West Pomeranian Lakeland and the Koszalin Coastal Region. The Dębnica is a left-bank tributary of the Parsęta, with a length of 42 km and a mean gradient of 2.8‰. The relief of its catchment has developed as a result of the transgression of the Pomeranian Stage inland ice of the Vistulian Glaciation and frontal-areal deglaciation on the northen slope of the lakeland elevation. The valley network in the Dębnica catchment is an example of a system of depressions of glacial, fluvioglacial, fluvial and erosional-denudational origin.

The network of 1st-order valleys can start with shallow wash hollows, solifluction hollows, denudation hollows and valleys, erosional dissections and erosional-denudational valleys (colluvial valleys). Land depressions of this type have the ability to concentrate enough water from overland runoff to initiate the processes of wash and rill erosion. Some of these valleys are now drained only episodically by streams nourished directly by precipitation and local groundwater horizons, and therefore having a variable discharge throughout the year. The initial valley landforms inherited from earlier morphogenetic cycles went through successive stages of being dissected and filled with sediments. The deepening of some of the denudational and erosional landforms has led to the dissection of aquifers and the drainage of groundwater onto the surface, thus starting permanent flows in formerly

dry valleys. The role of the chief erosion factor was then taken over by groundwater outflows. At first the morphometry of alcoves reflected the elongation and gradient of the bottoms of the initial landforms in which they had formed. As a result of seepage erosion and mass movements, narrow headwater alcoves gradually kept widening and assumed a spindle-like shape. Vertical erosion led to the levelling and deepening of the older landforms, the steepening of their slopes, and in effect, a modification of the inherited cross-profile from a V-shaped into a flat-bottomed one.

September 26, WED: Poster session

Assessment of soil erosion based on plots measurements in chosen areas in Poland

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Monitoring of soil erosion in natural field conditions is very important for the assessment of soil erosion threat. The obtained results provide general information on the intensity of the process in a local scale, simultaneously verifying parameters used in the estimation of soil erosion with the application of models. In the years 2007-2009, measurements of overland flow and soil erosion were performed with the application of an identical method of measurement at 5 sites in Poland, namely Storkowo (West Pomeranian Lakeland), Udziejek (Suwałki Lakeland), Bogucin and Guciów (Lublin Upland), and Łazy (The edge of the Carpathian Foothills). At each of the sites, three runoff plots were established with a width of 2 m and length of 22.1 m. One of them was maintained with no vegetation (as black fallow), and crops typical of the regions were cultivated on the remaining ones, namely cereal, potatoes or sugar beets, or grass. Runoff plots had an inclination from 4 to 8^{o}. Annual precipitation on particular objects and in the study period varied from 453 mm (Udziejek, 2008) to 814 mm (Łazy, 2007), and the rainfall erosivity index from 567 (Udziejek, 2008) to 1828 MJ·mm·ha^{-1}·h^{-1} (Bogucin, 2007). Generally higher precipitation occurred on objects located in the west and south of Poland. The rainfall erosivity index were lower in the northern part.

Soil losses were particularly determined by lithology and type of crop. For the fallow and root crops, the runoff coefficient varied from 0.4% (loose sands) to 16% (clayey silt), and for cereal from 0.1% (loose sands) to 2.5% (loamy silt and clayey silt). Mean annual soil erosion on the black fallow and root crop cultivation varied from 2.4 to 3 t/ha on loamy sand and sand to 73 t/ha on clayey silt. On permanent grasslands it was the lowest: 0.022-0.026 t/ha. Cereals also reduced erosion – in that case the coefficient varied from 0.21 to 0.24 t/ha (sandy soils) to 1.3 t/ha (loamy silt).

Losses of soil were correlated considerably stronger with the rainfall erosivity index than with sum of precipitation. The plant cover factor was determined empirically (C), as well as the soil erodibility factor (K). By susceptibility to erosion, the analysed soils can be ordered from the most to the least susceptible as follows: loamy silt (0.059), clayey silt (0.037), loamy sand (0.011-0.0130), and loose sand (0.004 Mg·ha·h·MJ^{-1}·mm^{-1}·ha^{-1}). The comparison of overland flow and losses of soil from plots with no

vegetation and with crops in an annual cycle points to a considerable importance of intensive precipitation in spring and early summer in the erosion of soil on slopes under agricultural use. Cultivations in the middle of the vegetative season considerably reduced overland flow and losses of soil.

The research was conducted in the scope of a project of KBN No. 2 PO4E 053 30 “Environmental and anthropogenic conditions of overland flow in Poland (based on the example of selected areas)”.

September 26, WED: Poster session

Chemical and mechanical denudation in the central part of the Drawa River catchment (NW Poland)

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The today's denudation system of low-level areas within the moderate climatic zone depends on the dynamics of river transport. Regular research studies on the conditions and volumes of matter brought into the river allows to determine its seasonal variability and volumes. So far no hydro-mechanical research studies conducted in the central part of the Drawa river basin determined mechanical and chemical denudation on the grounds of regular measurements.

The field studies were based on monitoring of some selected elements of the geographical environment. Their focus was to determine the dynamics of river transport in the system of river catchments treated as a spatial element of energy and matter flows and circulations, in reference to the concept of operation of the today's denudation system of early-glacial catchments. The main objectives of the research studies are as follows:

1. recognition of water flows and circulations and their conditions in river catchments within the central part of the Drawa river basin,
2. determination of physical-chemical properties of waters within some selected catchments in the central Drawa river basin: Słopica, Korytnica, Moczelska Struga, Sucha and Płociczna together with tributaries: Runica and Cieszynka,
3. determination of chemical and mechanical denudation levels of some selected river catchments within the central part of the Drawa river basin,
4. indication of potential hydrological and hydro-chemical threats for water geo-eco-systems and their operation within the central part of the Drawa basin and the Drawieński National Park.

The Drawa basin, a river with its length of 200 km, occupies an area of 3287 km^2 and extends south of the maximal range of the Pomeranian Phase of the Vistula glacial period. The northern part of the Drawa river basin lies within the area of the Macro-region of the Western Pomeranian Lake District with its central part at the South Pomeranian Lake District and its southern part within the Toruńsko-Eberswaldzka Pro-glacial Valley. A very large - taking into consideration the Polish conditions - part of the Drawa catchment is occupied by forests (60%) and a relatively small part - by agricultural areas (35%).

The catchments within which the research studies on denudation conditions and levels were conducted are located in the central part of the Drawa basin, the Drawska Plains and the Wałeckie Lake District. Within the area in 1990 the Drawieński National Park was established. Its aim is, among others, to protect the Drawa river, its waters, Płociczna, its tributary as well as adjacent, naturally valuable, fragments of the Drawska Backwoods. Flat or slightly curved out-wash areas enhanced with kettle-hole hollows and glacial troughs at many places are a dominant element of the Drawska Plains relief. The today's river-lake network - to a large extent - occupies various generations of tunnel valleys which - within the area covered with the research studies - form very complex slated systems. Some river catchments located within the Wałecki Lake District are characterised by their very varied land relief with more morrain forms coming from the Krajeńska Phase of the Vistula glacial period. The catchments selected to be researched are characterised by varied physic-geographical indicators, which generate, among others, to varied volumes of denudation within these areas.

The research studies of denudation conditions and volumes were conducted in the following river catchments: Słopica, Korytnica, Moczelska Struga, Sucha, Płociczna, Runica and Cieszynka. The research studies were conducted once a month in 2013 (taken as a hydrological year). Within the area water flow volumes were measured in the selected hydrometric profiles by means of an acoustic meter (ACD) made by OTT while temperatures of river waters, electrolytic conductivity, pH reaction and concentration of dissolved oxygen were measured by means of a multi-function meter (HI9898) by Hanna Instruments equipped with a multi-parameter probe. All the taken water probes were analysed at the Geo-ecological Station, the Adam Mickiewicz University in Storkowo. The analysis specifies volumes of suspended solids by means of the drying and weighing method as well as ion composition (anions: HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, SiO_2, cations: Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+).

Topographical maps scaled 1:10000 in the 1965 system with its reference to the 1992 system taken from the Archive of maps of the Faculty of Geographical and Geological Sciences, the Adam Mickiewicz University, the Grid Map of the Polish Hydrographical Division and data from the 2012 Corine Cover Project were used for cartographical applications.

Average (mean) flows measured at the established hydro-metrical profiles of the examined catchments are within their broad limits and reflect their areas, water circulations and water resources. Water circulations are indicated by a ratio of unit outflows being very diverse and dependant both on ground lithology as well as local conditions of underground water circulations formed within a considerable part of the examined areas through drainage reaching the deeply intended Drawa river valley. The examined catchments are not subject to significant anthropogenic pressures, as evidenced by their indicators of land use and terrain coverage which are reflected in the chemical composition of the examined waters.

These river waters have pH at a level being characteristic to neutral or slightly-alkaline reaction (7-8.5 pH units). Water mineralisation can be specified at an average level - a vast majority of the taken probes showed electrolytic conductivity in the range within 300-400 µS cm^{-1}. Values below 300 µS cm^{-}

[1] were characteristic to Moczelska Struga while values higher than 400 µS cm^{-1} to Płociczna at the Kępa Krajeńska station.

Bicarbonate and calcium ions are dominant in the examined waters taken into consideration their percentage ion composition (on the grounds of concentration in eq dm^{-3}). All the waters examined so far presented a regular hydro-geo-chemical bicarbonate-calcium type (according to the Szczukariev classification).

Physical and chemical properties of the examined waters generally characterise low temporal variability - their coefficients of variability (Cv) for most of their parameters are within a couple up to several %. Clearly higher temporal variability - expressed through their indicators of variability within several up to several tens % - is demonstrated by biogenic components such as: nitrates, phosphate and ammonium ions.

There is a relatively low level of mechanical denudation of the examined catchments and ranges within 0.1 (Moczelska Struga) up to 2.5 (Korytnica) t km^{-2} $year^{-1}$. Chemical denudation is much higher, though also varied for individual catchments and ranges within 0.6 (Moczelska Struga) up to 121.0 (Cieszynka) t km^{-2} $year^{-1}$. Loads of dissolved matter exceed loads of suspended matter several times which causes that chemical denudation - at 90-100% - determines today's denudation of river catchments within the central part of the Drawa basin.

Conclusions:

1. The geodiversity and biodiversity of the Drawa basin geoecosystem causes that levels of individual sub-catchments are very varied taking into consideration their lithological, hydrological and anthropogenic conditions - linked with each other (one another).
2. Some bicarbonate ions (even up to 50%) which are present in river waters come from dissolved carbon dioxide from the air. Such a high level of reduction of bicarbonate ions reduces the calculated chemical denudation by about 30% and for the denudation discharging minor loads of dissolved ions (Moczelska Struga and Sucha) from 80% up to more than 100%.
3. In relation to the presented conditions, the sub-catchments differently respond to the supply of nutrients; therefore in-depth understanding of their operation makes the grounds to organise and perform appropriate monitoring in order to protect the Drawieński National Park and its waters against potential degradation.

September 26, WED: Poster session

Denudational types of cliff coast, Wolin Island-Southern Baltic

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Denudation is the basic process modeling the surface of the Earth and determines the circulation of matter in a complex natural system. The type of processes shaping the relief of our planet, as well as the rate of its transformation are conditioned mainly by the geological structure, the morphology of the ground surface, as well as the climate. The spatial diversity of the denudation system largely determines the individuality of particular types of geo-ecosystems.

In the global system of the Earth's surface, denudation system of sea coasts take a special place. The coastline geoecosystem is characterized by a large geological and morphological diversity. In areas characterized by significant denivelations, coasts are represented by steeply descending cliffs towards the sea. This type of coast amounts about 80% of the coastal zone of the world but in the vast majority are rocky cliffs. Morphological variability of the cliff coasts is characterized by high dynamics, however, the diversity of denudation processes depends mainly on the geological structure. The rocky cliffs are shaped mainly by the abrasion-process and rockfall-process. A much larger spectrum of denudation processes occurs on non-consolidated cliffs. This type of coastline is commonly found on the southern coast of the Baltic Sea and is represented by post-glacial cliffs. In the geology of these cliffs, three types of sediments with different genesis can be distinguished: cohesive sediments with a glacial or limnic origin, sandy sediments of fluvial, glacifluvial and aeolian genesis as well as organic sediments, which are usually represented by Holocene peat and tertiary brown coal.

On the other hand, the intensity of denudation processes and their time variability is strongly conditioned by the seasonal variability of types of weather. There are five morphogenetic seasons on the Wolin Island cliff coast: spring, summer, autumn, autumn-winter and winter. In each of the distinguished seasons, the morphology of cliffs is shaping by characteristic group of denudation processes.

On the basis of the dominant type of denudation processes modeling particular cliff sections, we can distinguish the basic denudation types of cliffs: rockfall-type, earthflow-type, talus-type and landslide-type. The listed types of denudation are characteristic for cliffs with a homogeneous geological structure (rockfall-type and earthflow-type for clay cliffs, as well as talus-types and landslide-types for sandy cliffs). However, in cases of greater geological differentiation, the denudation system becomes

more complex due to the greater number of processes involved in shaping the cliff morphology. In such situations, combined types are separated: rockfall-landslide-type and landslide-earthflow-type.

September 26, WED: Poster session

Source to mainsteam: spatial transformation from sediment geochemistry to surface water hydrochemistry; Brøggerdalen, NW Spitsbergen

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Present-day paraglacial areas arising in the High Arctic during the Holocene are evidence of large changes in relief and deposits of polar regions. Geosuccession, thus the change of the morphogenetic domain from subglacial to subaerial one implies changes of morphogenetic factors and processes in areas recently exposed to the ice covers. The effect of changes in the morphogenetic domain is the constitution of a new set of landforms. Among the dominant processes that transform contemporary areas freed from the glaciers are slope and fluvial processes expanded in periglacial conditions. During the summer campaign of the project "Late-glacial and present landscape evolution following deglaciation in a climate-sensitive High-Arctic region" we made three field mapping, namely geomorphological, sedimentological and hydrogeochemical in the area left by the retreating glacier Brøgger in the valley Brøggerdalen west of Ny-Alesund on Brøggerhalvoya (NW Spitsbergen). Intensive glacier recession since the Little Ice Age has created a new set of landforms, for which we examined the chemical properties of sediments and water flowing down the slopes of the valley to the valley floor, i.e. main stem of Brøggerelva. Geochemical properties of deposits and hydrochemical transformations of fresh waters flowing in paraglacial watercourses became the main objective of the study. On the poster we present the results of field studies, i.e. the spatial distribution of geochemical properties of slope deposits and hydrochemical properties of surface water, and chemical transition from the slope system to a fluvial one. It was found that despite the major relief changes in the valley of the Brøggerbreen contemporary geochemical and hydrochemical transformations of deposits and fresh waters do not stand up now too great diversity. These processes taking place under the influence of environmental changes affect the course and rate of denudation processes in the polar zone.

September 27, THU: Oral session

Negative environmental effects along a rainfall gradient at a desert fringe, Northern Negev desert, Israel

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Dryland areas are usually regarded as highly sensitive to climate change. A positive relationship between average annual rainfall and environmental variables is often assumed by many scientists for such areas. However; the global climatological models fail to address an important issue: with decreasing average annual rainfall water resources may be highly dependent on surface properties, which greatly influence the degree to which water will percolate, or will be transformed into runoff, thereby significantly affecting the spatial redistribution of water resources. In other words, a climate change in dryland areas would be expected to have differential effects in a rocky area, in a loess covered area or in a sandy area. The northern Negev area offers unique conditions for the study of the possible effects of the foreseen climate change along a rainfall gradient, under changing surface conditions. Two case studies are considered. The first deals with the environmental effects of loess penetration into the area, during a wet climatic phase. The second considers the differential effects of biological topsoil crusts on the water regime in a sandy area. Data obtained draw attention to the complex relationships between annual rainfall, surface properties, water availability and ecosystem structure. In the two areas considered the increase in the average annual had a negative effect on the water resources and related ecological properties.

September 27, THU: Oral session

Prevention and Measurement of Soil Erosion in Food Production Areas of Tropical Lands/Brazil: denudation controllers “makers”

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The research area is in MATOPIBA Region (region formed by Maranhão, Tocantins, Piauí e Bahia States), where there are intensive food productions, mainly corn, soy beans, beans, rice, manioc, fruits and other vegetables, as well as cotton, in business and familiar scales. If the correct soil management is not done, the food production will increase de denudation rates, by means of laminar and gully erosions. This research had started in 2015, for reducing soil loss and transport/deposition of sediments, decreasing impact of denudation in local and regional environments and in the oceans. The research consists in adaptation and creation of techniques and equipment to identify and inventory the process and erosion events, for differentiate natural and human process. It was used different satellite imagens and UAVs to identify de events in the field. To study the process, it was stablished 13 periodical colleting points of water, in Branco River Basin and Ondas River Basin (both are sub-basin of Grande River – Bahia State), where the water samples are collected during and after rain events, and after 15 days in the dry season. The samples are used to quantitative analyses of the suspended sediments and a van dorn bottles, constructed and popularized by de graduate students, area used to collect bottom sediments. As results of this research, it was mapped 743 erosion events, and the most part is natural events (50,92%), followed by re-stabilized erosion process (40,69%). The soil erosion related to human activities represents 8,33%, but they are which generates more negative impacts, with largest impacts to the environment. After to research the erosions, quantifying sediments in the 13 sample points, and showing the results in the first phase related to suspended sediments, it was observed that there is an intensive gradient of soil loss, specially in the Intermediary Plateaus, where there are human bad soil uses, with naked soils and non-technified agriculture, where use to occur the largest denudation rates. It is necessary to highlight that because of cultural and socio-economics reasons, the laws of environmental protection are not applied with the same rigor for environmental conservation in this place, which is naturally with more fragilities for denudation (soil type and declivity). Where the denudation rates are more intensives, it was identified sediments transports 100 times larger than in the region where there are food productions in large scale, where the laws to protect the nature is applied and followed by farmers and governments institutions. In the Ondas River, it is necessary to consider that in 17,42% of its area, related to no conservation technique ofs soil use, produces 52% of the sediments rates detached during the raining season. At this moment, the research is aiming to continue generating data, which will be used to manufacture “social-economics” equipment (solidary economy), with Judiciary Environmental System and Farmers as a partners for

manufacturing hardwares and APPs to monitors continually the denudation rates, popularizing the information in the web.

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September 27, THU: Oral session

Morphostructural analysis of Ethiopian Highland based on remote sensing

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The morphometric analysis of lineaments, valleys and signs of erosion taken from a digital elevation model (DEM) made it possible to not only confirm most of the conclusions of the morphotectonic development of the area from the previously published results of structural, petrological, tectonic and geochronological analyses from the Ethiopian Highlands, but to also to expand our knowledge by applying several new hypotheses. Faults, lineaments and valleys are predominantly oriented in a direction compatible to the published concepts of the tectonic development of the area. Overall, the most abundant NE-SW and NNE-SSW lines reflect a change of extension from a NW-SE to WNW-ESE direction during the Pliocene (~40° rotation), in relation to the creation and development of the Main Ethiopian Rift. The most pronounced morphological manifestations of the extension of the MER and western Afar during the Quaternary are confined to the borders of the MER, and the morphometric characteristics values indicate a very short-lived effect of the stress field on the development of the landscape. The directions of the Pre-Neogene rift structures to the NW-SE and WNW-ESE are compatible with the oldest elements of the current landscape, i.e. the most developed high order valleys, and with the relict fragments of the radial valley network in the upper Blue Nile Basin, which could have been drained across current shoulders of the MER to the S and E before the Late Miocene. Trellis (in the eastern part of the study area near the Main Ethiopian Rift) and dendritic drainage patterns (in the western part of the study area) dominate the upper part of the Blue Nile Basin. The transition from the trellis to the dendritic drainage patterns reflects the decreasing importance of tectonics on the arrangement of landscape patterns associated with increasing distance from the Main Ethiopian Rift. In addition, the NW-SE belt of the trellis and rectangular drainage patterns in the western part of the study area corresponds to the direction of the Pre-Neogene rift structures. Parallel and drainage patterns occur on watershed ridges and radial drainage patterns occur on the slopes of Cenozoic shield volcanoes.