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Fourth I.A.G. / A.I.G. SEDIBUD Workshop, Kingston, Ontario, Canada:
Quantitative Analysis of Sedimentary Fluxes and Budgets in Changing Cold Climate Environments:
Scaling Issues, New Techniques, Modelling and Data Management

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REPORT

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Quantitative Analysis of Sedimentary Fluxes and Budgets in Changing Cold Climate Environments: Scaling Issues, New Techniques, Modelling and Data Management

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Summary:

Climate change affects all Earth surface systems but with the arguably greatest impact in high-latitude and high-altitude cold environments. In these areas, climate change shapes earth surface processes not just by altering vegetation cover and human activities but also through its impact on frost penetration and duration within the ground surface layers. All of these factors influence patterns of erosion, transport and deposition of sediments and related fluxes (e.g., nutrients, solutes, carbon).

It is a challenge to develop a better understanding of how these factors combine to affect sedimentary transfer processes and sediment budgets in cold environments. Our baseline knowledge on the weathering, erosion, sedimentary transfer and depositional processes operating within Holocene to contemporary climates forms our basis for predicting the consequences of predicted future climate change and related vegetation cover changes. However, much of this information is limited in terms of spatial and temporal coverage and needs to be extended and consolidated. Only when we have these reliable models response to landscape and climate change we will have fuller understanding of probable future changes to these regions.

Central issues of this ***Fourth SEDIBUD Workshop*** are:

- Scaling issues within sediment budget studies
- The application of new techniques within sediment budget studies
- Modelling
- Data management

Keywords: **Sedimentary Fluxes**	**Sediment Budgets**	**Cold Environments**
Scaling Issues	**Geomorphologic Process Analysis / Monitoring**	**New Techniques**
Modelling	**Inter-Site Comparisons**	**Climate Change**

Fourth Workshop of I.A.G./A.I.G. SEDIBUD

Sediment Budgets in Cold Environments

Quantitative Analysis of Sedimentary

Fluxes and Budgets in Changing

Cold Climate Environments:

Scaling Issues, New Techniques, Modelling

and Data Management

Kingston, Ontario, Canada

October 13-16, 2009

I.A.G./A.I.G. SEDIBUD

Sediment Budgets in Cold Environments

http://www.geomorph.org/wg/wgsb.html

Fourth I.A.G./A.I.G. SEDIBUD Workshop

Quantitative Analysis of Sedimentary

Fluxes and Budgets in Changing

Cold Climate Environments:

Scaling Issues, New Techniques, Modelling

and Data Management

October 13 – 16, 2009

Location

Queen's University

Kingston, Ontario, Canada

Scientific Organisers

Assoc. Professor Scott F. Lamoureux (Canada)

Assoc. Professor Achim A. Beylich (Norway)

Dr. Armelle Decaulne (France)

Programme,

Accepted Abstracts of Workshop Contributions

&

List of Accepted SEDIBUD Key Test Sites

Editors:

Achim A. Beylich, Scott F. Lamoureux & Armelle Decaulne

October 13 - 16, 2009

Content

Preface

This Fourth Workshop of the *I.A.G. / A.I.G. Working Group SEDIBUD – Sediment Budgets in Cold Environments* takes further the central issues discussed within the SEDIBUD Programme (http://www.geomorph.org/wg/wgsb.html).

The main focus of this Fourth SEDIBUD Workshop is on

- Scaling issues within sediment budget studies
- The application of new techniques within sediment budget studies
- Modelling
- Data management.

The Workshop takes place from October 13 to 16, 2009, and is hosted by Queen`s University, Kingston.

We welcome all participants to this Workshop.

Kingston, October 2009

Scott F. Lamoureux (Canada)
Achim A. Beylich (Norway)
Armelle Decaulne (France)

Workshop Programme & Schedule

Tuesday, October 13, 2009

Participants arrive at Kingston airport, train station or via private vehicle. Shuttle vans will take participants to QUBS. Dinner at QUBS, followed by a social event in the evening.

Wednesday, October 14, 2009

07:30 – 08:30
Breakfast at QUBS

09:00 – 09:10
Opening of the Fourth I.A.G./A.I.G. SEDIBUD Workshop and Welcome to Kingston

09:10 – 09:30
Overview of SEDIBUD Objectives and Aims of this SEDIBUD Workshop

Paper Presentations

Paper Session 1

Chair: Irina Overeem

09:30 – 09:50
Petteri Alho, Claude Flener, Jukka Käyhkö, Eliisa Lotsari, Joni Mäkinen & Noora Veijalainen: Hydraulic modelling as a tool for estimating sediment behaviour in fluvial systems.

09:50 – 10:10
Luidmila A. Anisimova & Nikita I. Tananaev: Sediment load of the Aldan River, Central Yakutia, and its change due to climate shift.

10:10 – 10:30
Achim A. Beylich, Susan Liermann & Katja Laute: Spatio-temporal variability of sediment sources and fluvial transport in two glacier-fed mountain catchments in Nordfjord, western Norway.

10:30 – 11:00
Coffee break

Paper Session 2

Chair: John F. Orwin

11:00 – 11:20
Ted Lewis & Scott F. Lamoureux: Modelling the impacts of projected 21st century climate change on river discharge and suspended sediment transport at Cape Bounty, Canadian High Arctic.

11:20 – 11:40
Susan Liermann, Achim A. Beylich, Geir Vatne, Lena Rubensdotter & Louise Hansen: Quantitative analysis of Holocene to contemporary fluvial sediment fluxes and sediment deposition/storage within two glacier-fed tributary catchments in the Nordfjord region, western Norway.

11:40 – 12:00
David Morche & Alexander Bryk: Bed load transport as a function of geomorphic connectivity?

12:00 – 13:30

Lunch at QUBS

Paper Session 3

Chair: Scott F. Lamoureux

14:00 – 14:20
Armelle Decaulne, Þorsteinn Sæmundsson, Ólafur Eggertsson, Katja Laute & Achim A. Beylich: Using dendrogeomorphology to address frequency and magnitude of recent snow avalanches on colluvial surfaces in cold mountain environments

14:20 – 14:40
Bernd Etzelmüller, Hanna Ridefelt & Ivar Berthling: Using geomorphometry to address spatially distributed regional sediment fluxes in cold mountain environments

14:40 – 15:00
Irina Overeem, Dan McGrath, Sebastian H. Mernild, Bent Hasholt & Koni Steffen: Modeling sediment plumes in Sondre Stromfjord, Greenland as a proxy for run-off from the Greenland Ice Sheet

15:00 – 15:30
Coffee break

Paper Session 4

Chair: Achim A. Beylich

15:30 – 15:50
Scott F. Lamoureux & Ted Lewis: Impact of recent permafrost disturbance on suspended sediment transport and seasonality in downstream rivers and lakes at the Cape Bounty Arctic Watershed Observatory (CBAWO), High Arctic, Canada

15:50 – 16:10
Nikita I. Tananaev: Impact of permafrost conditions on quantification of sediment fluxes and related channel type stability issues

16:15 – 17:00: Poster Session
Achim A. Beylich, Scott F. Lamoureux, Armelle Decaulne, John C. Dixon, John F. Orwin, Jan-Christoph Otto, Þorsteinn Sæmundsson, Jeff Warburton & Zbigniew Zwolinski: Sediment Budgets in Cold Environments: The I.A.G. / A.I.G. SEDIBUD programme.
Achim A. Beylich & the SedyMONT-Norway Team: Timescales of sediment dynamics, climate and topographic change in mountain landscapes – Erdalen and Bødalen site project (SedyMONT-Norway).
Dagmar Kleemann, Achim A. Beylich, Barbara Zippel & Dorothea Gintz: Biofilm analysis in cold environments: Usage of biofilm for detecting mobile or stabile river channels.
Katja Laute, Achim A. Beylich, Geir Vatne & Louise Hansen: Hillslope processes and their variation over time within two tributary catchments in Nordfjord, western Norway.
John F. Orwin, Nicolas J. Cullen and Sean J. Fitzsimons: The fluvial sediment transfer response to energy balance 'tipping' of melt generation, Joyce Glacier, McMurdo Dry Valleys, Antarctica: preliminary results.

17:15 – 18:45
Working group sessions

19:00
Dinner at QUBS. Evening social event. Time for boating (canoes, pontoon, swimming, walking) around QUBS.

Thursday, October 15, 2009

Breakfast at QUBS. Bag lunch for trip. Excursion to Chaffey's Locks (Rideau Canal), Charleston Lake Park (short hike), St. Lawrence River/Thousand Islands, Fort Henry (Banquet), and return to QUBS.

Friday, October 16, 2009

Breakfast at QUBS. Working group sessions. Lunch at QUBS, shuttle in afternoon to Kingston and transportation stations. Informal meetings at Queen's University and/or in Kingston. Departure of workshop participants.

Workshop

Accepted Extended Abstracts

Hydraulic modelling as a tool for estimating sediment behaviour in fluvial systems

Petteri Alho (1), Claude Flener (1), Jukka Käyhkö (1), Eliisa Lotsari (1), Joni Mäkinen (1) & Noora Veijalainen (2)

(1) Department of Geography, University of Turku, Finland
(2) Hydrological Services Division, Finnish Environment Institute, Helsinki, Finland

Hydraulic modelling has become increasingly popular method in hydrological process studies. Potential benefits of this modelling exercise include simulation of flow characteristics for changing climatic conditions in the future, and its impact on erosion-sedimentation processes in the channel and on the floodplains. We have investigated river Tana and its tributary Pulmanki in northern Fennoscandia in an attempt to simulate and predict their seasonal flow and flooding characteristics together with sedimentary processes under a changing climate (yrs 2071-2100). The channels have a high sediment yield due to the thick fluvioglacial and glaciomarine deposits filling the valley and therefore, the capacity of the river to transport the abundant sediments is of crucial importance.

So far, few studies have combined hydraulic modelling results with detailed geomorphological/sedimentological findings of river system formations. In this study, we demonstrate an approach using a 2D hydraulic model and raster-based flow parameter calculations, which have been verified with sedimentological findings. We have investigated point-bar formations submerged by a recent flood by comparing estimations of various flow parameters such as flow velocity, bed shear stress, and stream power with the associated sedimentology of the point-bars.

Our results demonstrate that the 2D hydraulic model can be utilized to estimate flow parameter trends in point-bar environments. This approach allows us to estimate flood processes at least on a local scale.

A challenge remains in modelling channel evolution in the long run and for longer stretches. We are still in the process of trying to understand the complex interaction between flow characteristics, channel bedforms and sediment yield in a temporal realm instead of a single snapshot in time. Should the approach prove successful, it could be employed in flood prediction and river restoration projects.

Sediment load of the Aldan River, Central Yakutia, and its change due to climate shift

Luidmila A. Anisimova [(1)] & Nikita I. Tananaev [(2)]

[(1)] Moscow State University, Moscow, Russia
[(2)] Lena Basin Waterways & Navigation Administration, Yakutsk, Russia

Sediment fluxes in cold environments are highly affected by current climate transformation. The aim of this paper is to evaluate total sediment load and to estimate how it changes in case of discharge increasing due to climate shift.

The selected key water object is the Aldan River. The basin area is 696000 km^2, and the water regime is East-Siberian (classification made by B.D. Zaykov), with deep winter low-flow, high spring freshet and autumn low-flow interrupted with 2-3 major flood events.

The total fluvial load is obtained by summing up bed and suspended fluxes estimated separately. The suspended sediment transport rate can be estimated from the «sediment rating curve»: $R = f(Q)$. For the Aldan River (at Verhoyansky Perevoz) the annual suspended sediment transport is 2803 thousand tons.

The bed-material flux can be evaluated by using the in Russia widely used method of N.I. Alexeevsky (1998). It is based on the assumption that the prevalent form of bed-material transport is the migration of bedforms of different size, with smallest overlaying large ones. Alexeevsky identified a hierarchy of forms ranging from miniforms to megaforms. For sandy channels, 5 bed-form classes were observed, named A to E, and for pebble channels – 4 levels (A to D). Class *A* forms are the largest ones, with their size being comparable to channel width. Class *B* dunes are overlaying class *A*, and so on. Class D forms are microforms. Each bedform class has its characteristic height (which is depth-dependant) and “drift” velocity. Alexeevsky established a linkage between bed form dimensions and channel order. Migration of classes *A-C* is observed during flood events, while class D-E forms are scoured at high discharge. They move only at low-flow periods.

Daily bed-load discharge for each class of dunes is defined according to the Shamov equation:

$$G = khC_D B\sigma ,$$

where k is form coefficient of dunes; h is dunes height, m; C_D is velocity of dunes migration, B is active river bed width, m; σ is sediment density, kg m^{-3}. It is estimated separately for high and low flow periods. The annual bed-load discharge is defined as the total of both periods, estimated as daily discharge multiplied by duration of respective period.

For the Aldan River (at Verhoyansky Perevoz) the annual bed-load transport is 2768 thousand tons. Total sediment transport is 5571 thousand tons.

According to recent estimates, by the end of the 21st century possible climatic changes can lead to increase of water flow and soil temperature. Forecasts regarding the Aldan River assume an annual and spring freshet flow increase by 14 %. Low winter flow and flow of summer-autumn period will increase by 5 % and 31 % respectively. The role of single flood events will increase, leading to a redistribution of maximum loads (poorest water quality) from spring freshets to summer rain-induced events. Bed load is expected to increase by 10 %, and suspended sediment flux in this case should increase by 42 %. This will lead to drastic changes in riverbed morphology and dynamics, hazards for navigation safety, operation of water intake facilities and other land-use activities within the river valley.

Spatio-temporal variability of sediment sources and fluvial transport in two glacier-fed mountain catchments in Nordfjord, western Norway

Achim A. Beylich, Susan Liermann & Katja Laute

Geological Survey of Norway (NGU), Quaternary Geology & Climate group & Norwegian University of Science and Technology (NTNU), Department of Geography, Trondheim, Norway

Continuous and year-round monitoring and analysis of runoff, solute and suspended sediment transport are carried out in the Erdalen and Bødalen catchments in Nordfjord, western Norway. Both valleys are typical U-shaped and glacier-fed valleys in the mountain landscape of western Norway characterised by very steep valley-fjord systems. Outlet glaciers of the Jostedalsbreen icefield are covering the uppermost parts of both valleys. The runoff regimes in Erdalen and Bødalen are complex, with peak runoff occurring during snow melt in spring, glacier melt in summer and heavy rainfall events in fall. Different sediment sources are activated during different periods of the year. Runoff peaks in fall appear to be most relevant with respect to fluvial sediment transport. Heavy rainfall events cause saturation overland flow and trigger debris flows with connected wash processes on slopes. Connected to this are significantly increased sediment supplies from slopes into channels. Altogether, fluvial sediment transport and fluvial mechanical denudation in Erdalen and Bødalen are supply-limited and the annual suspended sediment yields can vary significantly between different years. Annual suspended sediment yields are to a high extent determined by the annual number of heavy rainfall events as well as by air temperatures in July and August determining the range of runoff peaks in summer, and by the total amount of wintry snow storage controlling the range of peak runoff in spring. Changes in melt season duration and intensity, along with changes of total precipitation, the number of heavy rainfalls and the balance between snowfall and rainfall will significantly impact the activation of sediment sources and will cause changes in fluvial transport in both Erdalen and Bødalen.

Sediment Budgets in Cold Environments: The I.A.G. / A.I.G. SEDIBUD programme

Achim A. Beylich [1, 2], Scott F. Lamoureux [3], Armelle Decaulne [4, 5], John C. Dixon [6], John F. Orwin [7], Jan-Christoph Otto [8], Irina Overeem [9], Þorsteinn Sæmundsson [5], Jeff Warburton [10] & Zbigniew Zwolinski [11]

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[2] Norwegian University of Science and Technology (NTNU), Department of Geography, Trondheim, Norway
[3] Queen`s University, Department of Geography, Kingston, Canada
[4] University Blaise Pascal & Laboratory of Physical and Environmental Geography GEOLAB, CNRS, Clermont-Ferrand, France
[5] Natural Research Centre of North-western Iceland, Saudarkrokur, Iceland
[6] Department of Geosciences, University of Arkansas, Fayetteville AR, USA
[7] University of Otago, Department of Geography, Dunedin, New Zealand
[8] Department of Geography and Geology, University of Salzburg, Salzburg, Austria
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[10] Durham University, Department of Geography, Durham, UK
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Amplified climate change and ecological sensitivity of polar and cold environments has been highlighted as a key global environmental issue (ACIA 2004). Projected climate change in cold regions is expected to alter melt season duration and intensity, along with total precipitation and the balance between snowfall and rainfall. Similarly, changes to the thermal balance are expected to reduce the extent of permafrost and increase active layer depth. These effects will undoubtedly change surface water environments in cold environments and alter the flux of sediment, nutrients and solutes, but the absence of data and analysis to understand the sensitivity of the surface water environment are acute in cold regions.

The **SEDIBUD (Sediment Budgets in Cold Environments)** working group of the International Association of Geomorphologists (I.A.G./A.I.G.) has been formed to address this key knowledge gap (Beylich, 2007; Beylich et al., 2007). The Steering Committee of this international program is composed of ten scientists from nine different countries:

Achim A. Beylich (*Chair*) (Norway)
Armelle Decaulne (*Secretary*) (France)
John C. Dixon (USA)
Scott F. Lamoureux (*Vice-Chair*) (Canada)
John F. Orwin (New Zealand)
Jan-Christoph Otto (Austria)
Irina Overeem (USA)
Þorsteinn Sæmundsson (Iceland)
Jeff Warburton (UK)
Zbigniew Zwolinski (Poland

The central research question of this global program is to ***assess the contemporary sediment fluxes in cold climates, with emphasis on both particulate and dissolved components***. Initially formed as European Science Foundation (ESF) project SEDIFLUX (2004-2006) (Beylich et al., 2005; 2006), SEDIBUD has expanded to a global group of researchers with field research sites located in polar and alpine regions in the northern and southern hemisphere. Research carried out at each site varies by program, logistics and available resources, but typically represent interdisciplinary collaborations of geomorphologists, hydrologists, ecologists, and permafrost scientists and glaciologists with different levels of detail. SEDIBUD has developed a key set of primary research data requirements intended incorporate results from these varied projects and allow analysis across the network. Sites will report annual climate conditions as well as total discharge and particulate and dissolved fluxes. To support these efforts, the SEDIFLUX Manual (Beylich & Warburton, 2007) (http://www.ngu.no/FileArchive/237/2007_053.pdf) has been produced to establish common methods and data standards (Beylich, 2007; Beylich et al., 2007). In addition, a framework for characterising fluvial sediment fluxes from source to sink in cold environments has been published (Orwin et al., in press).

SEDIBUD currently has identified 38 Key Test Sites with a goal to extend the network to at least 40-45 sites that cover the widest range of cold environments

possible. Additionally, it is expected that collaboration within the group will act as a catalyst to develop new sites in underrepresented regions. Close coordination and collaboration with a number of International Polar Year (IPY) research programs including: International Tundra Experiment (ITEX), Circumpolar Active Layer Monitoring (CALM) and Arctic Coastal Dynamics (ACD/ACCO Net) are providing further opportunities for collaborative research to address broader polar environmental research issues (Lamoureux et al., 2007; Beylich et al., 2008).
More detailed information on the I.A.G./A.I.G. SEDIBUD programme can be found at http://www.geomorph.org/wg/wgsb.html.

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Timescales of sediment dynamics, climate and topographic change in mountain landscapes – Erdalen and Bødalen site project (SedyMONT-Norway)

Achim A. Beylich & the SedyMONT-Norway Team

Geological Survey of Norway (NGU), Quaternary Geology and Climate group & Norwegian University of Science and Technology (NTNU), Department of Geography, Dragvoll, Trondheim, Norway

The focus of this NFR funded Norwegian Individual Project (IP5, 2008-2012) within the European Science Foundation (ESF) EUROCORES TOPO-EUROPE programme (*http://www.esf.org/topoeurope*) is on the Erdalen and Bødalen catchments (tributary streams) in Nordfjord, western Norway.

The innovative approach of this new project is the integrated quantitative study of longer-term (Holocene), sub-recent and contemporary sedimentary fluxes, budgets and process rates using a novel combination of advanced methods and techniques.

With respect to the main aims and objectives of ESF SedyMONT, the following main key aims of the Erdalen and Bødalen site project can be stressed:

(i) Analyse how the inheritance of the landscape due to the influence of the Last Glacial Maximum (LGM) has affected process rates over time (paraglacial system),

(ii) Document changes in process rates over different timescales by combining existing quantitative knowledge on Holocene process rates with newly generated data on sub-recent and contemporary process rates.

Monitoring programmes in Erdalen and Bødalen, in combination with repeated analyses of surface water chemistry, atmospheric solute inputs and granulometric analyses of suspended sediments provide high-resolution data to analyse and quantify present-day sedimentary and solute fluxes as well as sediment sources, denudation rates, and meteorological and topographic / landscape morphometric controls of denudative processes. In addition to standard methods for monitoring bedload transport, innovative techniques like shock sensors, PIT tags and biofilm analysis are applied to analyse channel stability / mobility and bedload transport rates in both valleys.

The volume and composition of lake sediments are studied using echosounder, georadar and different coring techniques. Investigations on volumes and architecture of storage elements (valley infills, deltas, talus cones) using different geophysical methods like georadar and seismic refraction surveys are carried out to further improve the quantitative knowledge on Holocene process rates. Detailed mapping is performed and interpreted in combination with digital elevation models and data.

The process rates in Erdalen and Bødalen are compared with denudation rates in other cold environment catchments.

Using dendrogeomorphology to address frequency and magnitude of recent snow avalanches on colluvial surfaces in cold mountain environments

Armelle Decaulne [(1)], Þorsteinn Sæmundsson [(2)], Ólafur Eggertsson [(3)], Katja Laute [(4)] & Achim A. Beylich [(4)]

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Snow avalanches are common in mountain areas of various kinds of cold environments. The more or less severity of wintry conditions determines the thickness, durability and stability of snow cover during the cold season. Winter conditions therefore condition the frequency and magnitude of snow avalanches. The aim of this research is (1) to use dendrogeomorphology as a proxy to extract the chronology of snow avalanches on colluvial surfaces (talus and cones) by the analysis of tree-ring growth, and (2) to study the various impacts of snow avalanches on different tree species, i.e. the formation and dating of reaction wood. The study sites are located in Northern Iceland (Fnjóskadalur, Dalsmynni and Ljósavatnskarð valleys) and in Western Norway (Erdalen and Bødalen valleys).
All sites are typical U-shaped valleys with important bedrock valley walls that develop downslope in slope accumulations, swept by numerous snow avalanches leaving geomorphological evidences of a significant avtivity. The currently investigated tree species is *Betula sp.*, birches being common in both areas. The results provide a temporal catalogue of snow-avalanche events during the last ±100 years in areas with shortest historical records, and determine the changes in snow-avalanches activity during the same period, correlated to snow-cover changes in the upper catchment areas. Such results are of interest for (1) the understanding of global changes on snow-avalanche activity in cold mountain areas, and (2) getting a better knowledge of past frequency and magnitude of snow avalanches in areas of poor historical records, in relation with natural hazards.
The study is part of the large EURO-DENDRO project (MSH fundings from Clermont-Ferrand, France) that also includes study sites in France (Massif Central) and Romania (Carpathian Mountains) and hardwood (*Alnus sp., Fagus sp., Quercus sp.*) as well as softwood (*Abies sp.*, *Picea sp.*, *Pinus sp.*) trees species.

Using geomorphometry to address spatially distributed regional sediment fluxes in cold mountain environments

Bernd Etzelmüller [1], Hanna Ridefelt [2] & Ivar Berthling [3]

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[3] Department of Geography, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

Addressing sediment fluxes and budgets in a catchment scale is an important link between local-scale process geomorphology and regional-scale landscape development. The use and analysis of high-resolution digital elevation models (DEM) coupled with field-based measurements provide tools to address spatially distributed sediment movement rates and fluxes in a regional scale. The presentation will first review the methodological principles, before showing examples from southern Norway (Finse area) and northern Sweden (Abisko area).

Biofilm analysis in cold environments: Usage of biofilm for detecting mobile or stabile river channels

Dagmar Kleemann (1), Achim A. Beylich (2, 3), Barbara Zippel (4) & Dorothea Gintz (5)

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Investigations of biofilm on mountain stream gravels have been performed in Nordfjord (Erdalen (since 2007) and Bødalen (since 2009)) in Norway and at the Partnach River (Reintal (since 2008)) in the Bavarian Alps in Germany. After sampling of gravels the biofilm was fixed with a 4 % formalin solution and later transferred into sterile water to keep the 3D-structure of the biofilm. This allows measurements of the thickness of the biofilm and the distribution of algae and bacteria within the EPS (extracellular polymeric substances) structure with a laser-scanning microscope (LSM) at the UFZ Magdeburg (Germany). The thickness and the volume (μm^3) of EPS, algae and bacteria developed on the selected sample stones, taken at different depths in the channels and at different times, vary very widely at the single stone itself and between the locations and in the timescale. A trend could be detected. The relation of EPS/Bacteria and EPS /Algae differs between subsurface samples (taken in 5 to 10 cm depth) and stones sampled at the surface. In most cases the total amount of biofilm EPS on the surface gravel was higher than on the subsurface samples. At a very stable channel stretch in Erdalen the EPS-volume and the amount of algae increased over time, but the bacterial content varies very high within the time frame. At a channel stretch with a positive sediment budget, as based on previous investigations, a clear trend to less biofilm in the subsurface material was observed. At a channel stretch with previously detected slow net-erosion the measured EPS- volume was on a high level as compared to other sampling sites. The development of algae and bacteria volume varied together very widely over the time with no detected trend. The samples collected in the Partnach River, Reintal, show a clear pattern at all three sampling points, with the ratio of EPS and algae, and EPS/ bacteria increasing with the depth in the subsurface.

This work has been supported by the Geological Survey of Norway (NGU) and by the projects ESF NFR-SEDYMONT and DAAD-NFR-Biofilm.

Impact of recent permafrost disturbance on suspended sediment transport and seasonality in downstream rivers and lakes at the Cape Bounty Arctic Watershed Observatory (CBAWO), High Arctic, Canada

Scott F. Lamoureux & Ted Lewis

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We report results from an ongoing study of sediment fluxes in the Canadian High Arctic at the Cape Bounty Arctic Watershed Observatory (CBAWO), located on the south-central coast of Melville Island (74°50'N, 109°30'W). Sediment transport has been studied in paired watersheds since 2003, and a series of smaller sub-basins subject to varying degrees of permafrost disturbance that occurred after record warm temperatures in July, 2007.

Results indicate that the disturbances substantially change the character and timing of suspended sediment transport in this environment. Disturbances occurred in Holocene raised marine sediments that drape the landscape below c. 70 m asl. Suspended sediment yield from highly disturbed sub-basins may exceed 400% greater than the larger watershed and is most evident during times when discharge is high, such as snow melt and after heavy rainfall. In one case, where flow is sustained by a perennial snow bank, flow is maintained throughout the season and high suspended sediment concentrations have been measured.

Downstream impacts have been most apparent during baseflow conditions in the larger rivers. Prior to disturbance in 2007, the West River was characterized by low discharge in July and August with minimal suspended sediment. During similar low flow in 2008, the West River had substantially higher suspended sediment transport, and the material was composed of fine clay. Hence, during this ecologically-sensitive period, the river was unusually turbid. The source of the turbidity could be traced to three locations in the watershed where inflow from disturbances was active.

The West Lake is a comparatively large and deep basin. Measurements of turbidity in the spring of 2009 indicated high turbidity levels in the lower 20 m of the water column, exceeding any previous measurements in the lake, including during the intense snow melt period. We hypothesize that sustained delivery of fine clay (<0.7 μm) by the river during the autumn increased the sediment load in the lake, and that the clay did not settle during the winter as has normally been the case.

These results demonstrate that permafrost disturbance in this environment affects downstream water quality and sediment loads in a number of important ways. Ongoing analysis of 2009 data, including grain size analysis of the baseflow sediment load should provide further insights into these processes.

Hillslope processes and their variation over time within two tributary catchments in Nordfjord, western Norway

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Hillslopes occupy large areas of the earth surface. The rates of hillslope processes are exceptionally varied and affected by many influences of varying intensity. Hillslope-channel coupling and sediment storage of slopes are important factors that influence sediment delivery through catchments, especially in steep environments. Within sediment transfers from sources to sinks in drainage basins, hillslopes function as a key element concerning sediment storage, both for short term periods as between rainstorms as well as for longer periods in colluvial deposits. This introduces a disparity of timescales between periods of sediment yield and sediment supply.

This study presents the initial stage of a PhD project, integrated in the Norwegian Individual Project within the collaborative research programme SedyMONT (Timescales of sediment dynamics, climate and topographic change in mountain landscapes). The research is carried out within the Erdalen and Bødalen catchments of the Nordfjord valley-fjord system, situated in the innermost part of the Nordfjord. Both catchments can be described as steep U-shaped and glacier-fed tributary valleys. The runoff regime is complex with a high variability of discharge over the year. Instrumentation in both catchments includes an automatic weather station as well as five stationary stations for continuous and year-round monitoring of runoff, fluvial suspended sediment and solute transport.

The main aims of the PhD project are (i) to analyse the spatial distribution of hillslopes, their present-day structure and current process rates, (ii) the identification of sediment sources and delivery pathways/hillslope-channel coupling over Holocene to contemporary timescales as well as (iii) the quantification of slope storage volumes. The methodical process based approach includes orthophoto-interpretation, slope profile surveying and photo monitoring, geomorphological mapping, GIS and DEM computing as well as a combination of field geophysics (georadar, seismic refraction surveys), the application of advanced techniques for bed load monitoring (including impact sensors and pit tags) and different dating techniques (lichenometry and dendrochronology). Appropriate hillslope test sites are chosen for monitoring present-day rates of slope processes as well as for geophysical investigations. Slope profile surveying and geomorphological mapping are carried out at each test site. Horizontal lines of painted stones (tracer) and straight lines of wooden stakes are installed in each case at different elevations on the hillslope test sites. Furthermore, continuous measurements of solute yields from slope systems are carried out. Pebble counts are conducted in defined channel test stretches downhill following a distinct sampling design. Within the same channel stretches impact sensors and pit tags are applied concerning bed load monitoring.

Research on current complex slope processes, sediment storage volumes and present-day sediment transfer rates can contribute to a better understanding of postglacial landscape evolution as well as the prediction of possibly future trends of landform development.

Modelling the impacts of projected 21st century climate change on river discharge and suspended sediment transport at Cape Bounty, Canadian High Arctic.

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We present discharge and suspended sediment flux estimates to the year 2100 for the West River at the Cape Bounty Arctic Watershed Observatory (CBAWO), located on Melville Island in the Canadian High Arctic. Discharge predictions were made using the distributed hydrologic model WATFLOOD, and sediment yields were predicted using a rating curve method based on monitored relationships between discharge and suspended sediment concentration made at CBAWO from 2003-7. Models were forced using downscaled air temperature and precipitation from the A1b and A2 scenarios from the global climate model CGCM3. Under the A2 scenario, total seasonal runoff and maximum daily discharge are expected to double by 2100, and the melt season will increase in length by 30 days, mostly in autumn. Sediment yield increases will be much more extreme, and are expected to increase by 100 to 600 %, but these are almost certainly minimum estimates given that the model does not account for changes in landscape stability and sediment transport.

These results are the first systematic sediment modelling reported from the Canadian High Arctic and our modelling framework could be utilized at other SEDIBUD key sites as well.

Quantitative analysis of Holocene to contemporary fluvial sediment fluxes and sediment deposition/storage within two glacier-fed tributary catchments in the Nordfjord region, western Norway

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Quantification of fluvial sediment transport and sediment budgets is challenging. Analysing sedimentary fluxes and budgets as well as their controls at different timescales (Holocene to contemporary) is a basis for assessment and prediction of the complex landscape responses to Holocene to recent changes in temperature, precipitation and runoff. Therefore, investigations on climate variability back in time and its influence on previous landscape development are essential for the understanding of the present environment response system.

The ongoing PhD work is imbedded in the NFR funded Norwegian project within the ESF SedyMONT programme (Timescales of sediment dynamics, climate and topographic change in mountain landscapes). The studies are carried out within the two tributary valleys Erdalen and Bødalen in the Nordfjord region in western Norway. Both selected mountain catchments are steep and U-shaped valleys with a connection to the Jostedalsbreen ice field (outlet glaciers cover the uppermost parts of both valleys). Erdalen and Bødalen are characterised by sub-arctic oceanic climate. Thus, both valleys show a complex runoff system with high variability of discharge over the year. Both valleys drain into lakes and are characteristical valley-fjord systems in western Norway.

The PhD project is mainly focused on Holocene to contemporary fluvial sediment fluxes and sediment budgets with interpretation of controlling factors, with special interest in (i) the timing of sediment delivery and the spatial distribution of sediment sources, (ii) monitoring of contemporary accumulation rates within the Bødalen delta and detailed analysis of the delta morphometry, (iii) the spatial and temporal variabiliy (short/annual and long term) of the fluvial sediment transfer and temporal storage.

A wide range of advanced methods is applied (interpretation of aerial photographs, DEM, different coring techniques, geophysical techniques, PIT tags & shock sensor tracer techniques, pebble count, etc.). Granulometrical and morphometrical investigations on the bed surface material of seven selected test stretches (defined in 2006) as well as the ascertainment of channel morphometry within a braided sandur system located in Erdalen are repeated and along the longitudinal profiles pebble counts are conducted. The contemporary sedimentation or the short term/seasonal mass accumulation within four lakes (Strynvatnet, Lovatnet, Sætrevatnet and Vetlevatnet) are monitored by using moored sediment trap arrays. For detection of current accumulation rates over a period of 3 to 4 years a monitoring grid out of wooden stakes are fixed within the Sætrevatnet delta. In addition, the mentioned investigations are integrated with continuous and year-round process monitoring (meteorological parameters, runoff, dissolved and suspended sediment concentration) in Erdalen and Bødalen. Furthermore, different coring techniques and analytical methods (e.g. Russian corer, Piston coring technique, X-Ray analysis, grain size distriburtion) are applied for interpretation of lake sediments regarding the Holocene developement of both valleys.

Bed load transport as a function of geomorphic connectivity?

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A large percentage of the total fluvial annual sediment flux in high-mountain catchments is transported as bed load. This is especially true in river systems with obviously unlimited sediment supplies from unstable banks, talus cones, and channel beds. The Reintal, a SEDIBUD-key site, is a natural high-mountain laboratory where sediment-transport processes and fluvial cascading systems can be studied in detail. Due to a 2005 dam-break flood, the river system is in a state of disequilibrium making it an exceptional study site for investigating these processes.
Based on results from our previous research, we will discuss our recent findings specifically with respect to geomorphic connectivity.

The emerging key questions are:

1. Is there increased geomorphic connectivity post dam-break?
If so, how can it be quantified?
2. What are the most important bed load-transport phases in the system and how do they work?
3. What is the time lag between lateral sediment input to the river and reworking by fluvial processes?
4. Are there conclusions, which can be drawn from bed load particle shape or size parameters?

In our presentation we will give a progress report on the current state of our research and attempt to answer these key questions.

The fluvial sediment transfer response to energy balance 'tipping' of melt generation, Joyce Glacier, McMurdo Dry Valleys, Antarctica: preliminary results

John F. Orwin, Nicolas J. Cullen and Sean J. Fitzsimons

Department of Geography, University of Otago, Dunedin, New Zealand

The generation of ephemeral stream flow, and thus sediment transfer, in the Antarctic McMurdo Dry Valleys is primarily driven by melt sourced from the vertical walls and upper surfaces of cold-based glaciers, coupled with melt input from buried proglacial ice and near surface permafrost melt. Before melt occurs, significant radiative input is required to raise these surfaces to the melting point. As a result, there is a 'tipping' point which when reached, results in widespread surficial ice melt, the generation of runoff and commencement of fluvial sediment transfer. In this study we seek to identify the nature and timing of this 'tipping' point and the fluvial sediment transfer response to it. Four-component incoming and outgoing radiation and surface mass loss were measured at a weather station installed on the Joyce Glacier, Garwood Valley during the beginning of the melt season in the austral summer, 2008. The fluvial components of this study were measured at a gauging station monitoring flow, suspended and dissolved sediment load and temperature at the top of the permafrost (ca. 0.8m depth). The station was installed on a proglacial ephemeral stream draining the true left margin of the Joyce Glacier. The energy balance for the glacier surface showed that Julian Day (JD) 331 to 338 was characterized by unstable atmospheric conditions with radiative flux into the glacier and ground surfaces dominated by net radiation, Q* of which SW↓ was the major component. Surface ice mass loss was dominated by sublimation from both the glacier surface and the ice filled stream channel. During this period, both ground and glacial surfaces showed a gradually warming trend with two periods of limited, localized channel flow associated with clear sky conditions and peak SW↓. This limited flow resulted in flushing of fine sediments stored on the frozen channel surface and from ice-cored moraines bounding the channel. Suspended sediment concentrations of up to 7000 mg L-1 and total dissolved solids of up to 100 mg L-1 were recorded during these initial flushes, the highest of the field season. Following this limited mobilization was a period of significant cooling with snowfall, cloud and a subsequent drop in ground and ice surface temperature and the shutting down of the fluvial system. JD 341-343 marked the 'tipping' point between limited, localized flow and a full system response. These two days were characterized by clear sky conditions and high SW↓ coupled with sensible heat, QS, input tending towards positive as the over ice air temperature approached the ice surface temperature. As a result, the energy available for melt, QM, became positive with a surface lowering of ca. 10 mm. Proglacial ground temperatures also showed a significant warming with values approaching 0oC, suggesting melt input from melting ground ice. The fluvial response to this 'tipping' event was immediate and comprehensive with full channel flow, the complete removal of winter channel ice and significant transfer of sediment, including bedload. Changes in flow showed a strong, positive relationship with daily fluctuations in QM as did sediment transfer. It is unclear if this relationship continues throughout the remainder of the melt season, or if there is a decoupling from diurnal variations in QM and/or changes in sediment sources and availability. Ongoing data collection during 2009/10 should result in a better understanding of the geomorphic and hydrologic significance, or otherwise, of fluvial sediment transport processes in cold, arid polar environments.

Modeling sediment plumes in Sondre Stromfjord, Greenland as a proxy for run-off from the Greenland Ice Sheet

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In situ measurements to quantify run-off and sediment loads from the Greenland Ice Sheet (GrIS) are hindered by logistical difficulties associated with the large, remote and spatially diverse nature of the ice sheet. Large-scale modeling studies suggest that run-off accounts for approximately 50% of the annual mass loss from the ice sheet, however, and it is suggested that Greenland is a major contributor to the Arctic-wide sediment budget. Both parameters need more accurate quantification with empirical measurements.

This study shows that remote sensing of sediment plumes can be used to characterize the onset, duration and intensity of run-off. Our field site is Kangerlussuaq (Søndre Strømfjord), the longest fjord in Greenland, into which the Watson River flows, which drains approximately 6,300 km^2 of the ice sheet. Discharge and SSC measurements are observed at the mouth of the Watson River from 2007 onward, it is one of the SEDIBUD selected sites.

Runoff characteristics into Kangerlussuaq were compiled from Band 1 (620-670 nm, 250 m resolution) of the MODerate-resolution Imaging Spectroradiometer (MODIS) from 2001-2008. This study demonstrated that over this 8 yr period the onset of plume formation occurred earlier, with the onset occurring 9 days earlier in 2008 compared to 2001. The onset of the plume is intrinsically related to the onset of melt, supported by a positive correlation (r^2=0.82) between the formation of the plume and the onset of ablation at the S5 (490 m asl, 6 km from ice margin) Kangerlussuaq Transect automatic weather station (2003-2007). There is a similar positive correlation (r^2=0.90) between the cessation of ablation and the settling of the plume.

In addition, a relationship between reflectance values from MODIS and in situ discharge and suspended sediment concentrations (SSC) has been established for two sampling campaigns during the 2008 melt season. This allows using MODIS plume characteristics, such as plume length, to be used for seasonal water flux reconstructions. Numerical plume modeling constrains the total sediment fluxes. Our predictions match observed records within 2 and 11% for 2007 and 2008 and provide an independent measure of river runoff and sediment fluxes coming of the GrIS.

Impact of permafrost conditions on quantification of sediment fluxes and related channel type stability issues

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In cold environmemts permafrost is a framework of major physiographical processes. This paper briefly outlines role of permafrost conditions in sediment flux formation within the watersheds of major Russian Arctic rivers. Research is based on a dependency between suspended sediment load and stream discharge, which is commonly named "rating curve":

$R = AQ^m$, (1)

Parameters A and m were determined for more about 20 large and middle rivers within the Russian Arctic using long-term data (up to 70 years). Correlation between these parameters and physiographical conditions (watershed elevation, precipitation etc) is well known. The parameters' intercorrelation was derived for studied dataset, which expresses in general equation:

$A=ae^{\beta m}$, (2)

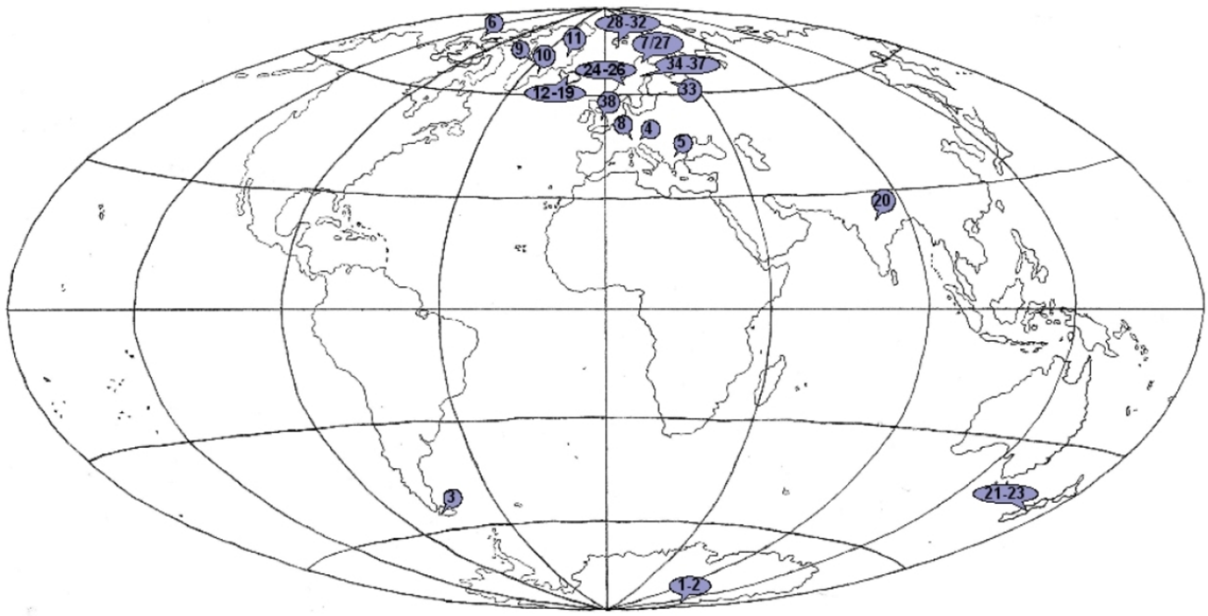
Eq. 2 parameters a and β appear to be regionally distributed and spatially determined (Table 1). This dependence follows sectorial division of Russian permafrost, developed by N.N. Romanovskiy, with sectors delineation based on permafrost conditions (southern border latitude, ice thickness, soil temperature). Within major sectors (Middle-Siberian, East-Siberian and Pacific), variations in elevation and water regime lead to variations in sediment total fluxes.

Calculations of suspended sediment fluxes for major Russian Arctic rivers were carried out using the derived equations, which take into account regional differentiation. Calculation results show that moving eastwards fluxes decrease until Cherskiy Range, and show increase in Kolyma basin and further. Rivers in mountainous regions generally have larger specific sediment discharge. Calculations of bedload sediment fluxes were conducted using N. I. Alexeevsky method, based on assumption that all bed load is moved by river in bedforms. Rivers with Far-Eastern type of water regime carry relatively larger amounts of bed load due to high input from rain-induced flood events.

The W_R/W_G ratio varies from 4-6 for large rivers of alluvial plains up to 0.5-0.25 for small mountain flows. Spatial analysis was done, linking sediment flux parameters with channel characteristics and geocryological conditions. This gives us a link between physiographical (including permafrost), hydrological conditions and sediment fluxes; the latter are one of the major factor of channel processes. Global change will thus have major impact on channel form stability through sediment fluxes and W_R/W_G ratio, in some conditions causing channel adjustment to new conditions (channel form shift). The ways of future changes therefore can be found in current relationships between sediment flux and channel morphology.

List of Accepted

SEDIBUD Key Test Sites



Antarctica
1. Joyce Glacier, Garwood Valley
2. Garwood Glacier, Garwood Valley

Argentina
3. Laguna Potrok Aike

Austria
4. Pasterze

Bulgaria
5. Musala area

Canada
6. Cape Bounty

Finland
7. Kidisjoki

Germany
8. Reintal

Greenland
9. Kangerlussuaq-Strømfjord
10. Mittivakkat glacier catchment
11. Zackenberg

Iceland
12. Botn í Dýrafirði
13. Reykjaströnd
14. Tindastóll
15. Fnjóskadalur-Bleiksmýrardalur
16. Hofsjökull, northern forefield
17. Austurdalur
18. Hrafnadalur
19. Orravatnsrústir

India
20. East Dabka Watershed (Kumaon Himalaya)

New Zealand
21. Douglas Glacier
22. Godley Valley
23. Unnamed Valley

Norway
24. Erdalen
25. Bødalen
26. Vinstradalen
27. Tana catchment
28. Dynamiskbekken (Svalbard)
29. Ebbaelva (Svalbard)
30. Hørbyeelva (Svalbard)
31. Kaffiøyra (Svalbard)
32. Scottelva (Svalbard)

Russia
33. Mezen

Sweden
34. Latnjavagge
35. Kärkevagge
36. Kårsavagge
37. Låktavagge

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