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Third I.A.G. / A.I.G. SEDIBUD Workshop, Boulder, U.S.A.: Sediment Fluxes and Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments

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REPORT

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Third I.A.G. / A.I.G. SEDIBUD Workshop, Boulder, U.S.A.: Sediment Fluxes and Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments

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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 erosion, sedimentary transfer and depositional processes operating within Holocene and contemporary climates and as landscape systems evolved and under given vegetation covers, 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 ***Third SEDIBUD Workshop*** are the

- Further discussion of relevant science questions to be addressed within SEDIBUD,
- Presentation and further discussion of the SEDIFLUX Manual (Revised Version),
- Presentation of accepted SEDIBUD key test sites (catchments),
- Development of the SEDIBUD Metadata Database,
- Development of links and collaborations with the CSDMS Working Groups and
- Development of ideas to continue and extend the scientific activities within SEDIBUD.

Keywords: **Sedimentary Fluxes**	**Sediment Budgets**	**Cold Environments**
Global Network of Key Test Sites (Catchments)	**Geomorphologic Process Analysis / Monitoring**	**Metadata Database**
Inter-site Comparisons	**Modelling**	**Climate Change**

Third I.A.G. / A.I.G. SEDIBUD Workshop

Sediment Budgets in Cold Environments

Sediment Fluxes and Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments

Boulder, CO, U.S.A.

September 9-13, 2008

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

Sediment Budgets in Cold Environments

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

Third I.A.G. / A.I.G. SEDIBUD Workshop

Sediment Fluxes and Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments

September 9 – 13, 2008

Location

Mountain Research Station (MRS, INSTAAR)

Boulder, CO, U.S.A.

Scientific Organisers

Assoc. Professor Achim A. Beylich (Norway)

Assoc. Professor Scott F. Lamoureux (Canada)

Dr. Armelle Decaulne (France)

Professor Nel Caine (U.S.A.)

Dr. Irina Overeem (U.S.A.)

Programme,

Accepted Abstracts of Workshop Contributions,

List of Accepted SEDIBUD Key Test Sites

Editors:

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

September 9 - 13, 2008

Content

Preface

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).

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- Development of ideas to continue and extend the scientific activities within SEDIBUD.

The Third SEDIBUD Workshop takes place from September 9 to 13, 2008, and is hosted by the *Institute of Arctic and Alpine Research (INSTAAR, MRS)*, *University of Colorado at Boulder*.

We welcome all participants to this Workshop.

Achim A. Beylich
Scott F. Lamoureux
Armelle Decaulne
Nel Caine
Irina Overeem

Programme and Schedule

Tuesday, September 9, 2008

15:30: Joint bus transfer from INSTAAR (Boulder) to the Mountain Research Station (MRS)

Arrival at the MRS: Registration and dinner.

Wednesday, September 10, 2008

09:00 – 09:10

Opening of the Third I.A.G. / A.I.G. SEDIBUD Workshop and welcome (AB, NC, IO)

09:10 – 09:30

Overview of SEDIBUD objectives and aims for this Third SEDIBUD Workshop (AB, SL)

Paper Session 1

Chairs: John C. Dixon & Scott F. Lamoureux

09:30 – 09:50
Richard Johnson & Jeff Warburton
Significance of event versus post-event sediment transfer processes in a UK upland sediment system

09:50 – 10:10
Armelle Decaulne & Þorsteinn Sæmundsson

Recent debris transfer on colluvial cones: Processes, distribution and frequency – a case study from the Fnjóskadalur valley, Central North Iceland

10:10 – 10:30
Helgi Páll Jónsson, Halldór G. Pétursson & Þorsteinn Sæmundsson

Rock slides and rock avalanches in the Skagafjörður area, Central North Iceland – a report on a work in progress

10:30 – 10:50
Þorsteinn Sæmundsson, Halldór G. Pétursson, Armelle Decaulne, Helgi Páll Jónsson, Ingvar A. Sigurðsson, Esther H. Jensen & Matthew J. Roberts

The Morsárjökull rock avalanche in the southern part of the Vatnajökull glacier, south Iceland

10:50 – 11:10

Coffee break

Paper Session 2

Chairs: John F. Orwin & Armelle Decaulne

11:10 – 11:30
Scott F. Lamoureux & Melissa Lafrenière
Suspended sediment yields associated with different landscape disturbances at the Cape Bounty Arctic Watershed Observatory (CBAWO), High Arctic, Canada

11:30 – 11:50
Irina Overeem & James P.M. Syvitski
Changing circum-arctic river sediment supply

11:50 – 12:10
Jukka Käyhkö, P. Alho, E. Lotsari, N. Veijalainen, C. Flener & S. Hämäläinen
Fluvial geomorphic dynamics of a subarctic catchment under changing climatic conditions

12:10 – 12:30
Katja Laute, Achim A. Beylich, Louise Hansen & Karl-Heinz Schmidt
Investigations on sub-recent sedimentation and erosion rates within a braided sandur system in Erdalen (Nordfjord, western Norway)

12:30 – 13:30

Lunch

14:00 – 17:30
Working group sessions

18:00
Dinner

Thursday, September 11, 2008

Paper Session 3

Chairs: Irina Overeem & Achim A. Beylich

09:30 – 09:50
D. L. Macalady & O. M. Sæther
The characteristics of natural organic matter (NOM) in sub-Alpine environments

09:50 – 10:10
Colin E. Thorn, Robert G. Darmody, Johan Holmqvist & John C. Dixon
Comparison of Radiocarbon Dating of Buried Paleosols Using Arbuscular Mycorrizae Spores and Bulk Soil Samples

10:10 – 10:30
Jeff Warburton & Martin Evans
Significance of macroscale peat flux for carbon export in upland fluvial systems

10:30 – 11:00

Coffee break

Paper Session 4

Chairs: Jeff Warburton & Þorsteinn Sæmundsson

11:00 – 11:20
John C. Dixon, Colin E. Thorn & Robert G. Darmody
Geochemical budgeting in cold climates: examples from Lapland and the Colorado Front Range.

11:20 – 11:40
Achim A. Beylich, Louise Hansen, Susan Liermann, Dorothea Gintz, Katja Laute, Geir Vatne, Ola Fredin, Valentin Burki & Ivar Berthling
Sediment dynamics and sub-recent sediment budget of the braided sandur system at Sandane, Erdalen (Nordfjord, western Norway)

11:40 – 12:00

John F. Orwin

Monitoring inter-annual suspended sediment flux variability in an actively deglaciated mountain belt, Godley Valley, New Zealand

12:00 – 12:20
Ross D. Powell
Erosion Rates of High Latitude Glaciated Basins in a Warmer World

12:30 – 13:30

Lunch

14:00 – 17:30

Working group sessions

18:00

Dinner

Friday, September 12, 2008

Field Excursion

Dinner

Saturday, September 13, 2008

Departure from the MRS in the morning

Science Meeting Presentations:

Accepted Extended Abstracts

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], Irina Overeem [8], Þorsteinn Sæmundsson [5], Jeff Warburton [9] & Zbigniew Zwolinski [10]

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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] University of Colorado, Institute of Arctic and Alpine Research, Boulder, CO, USA

[9] Durham University, Department of Geography, Durham, UK

[10] Adam Mickiewicz University, Institute of Paleogeography and Geoecology, Poznan, Poland

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 nine scientists from eight 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)

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 first edition of 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). Ongoing revision will continue to improve the manual to facilitate inter-comparison of research results.

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) will provide further opportunities for collaborative research to address broader polar environmental research issues (Lamoureux et al., 2007; Beylich et al., 2008).

Detailed information on the SEDIBUD programme can be found at http://www.geomorph.org/wg/wgsb.html.

References:

ACIA (2004):Impacts of a Warming Arctic: Arctic Climate Impact Assessment. ACIA Overview Report. Arctic Climate Impact Assessment. Cambridge University Press, 2004.

Beylich, A.A. (2007): Quantitative studies on sediment fluxes and sediment budgets in changing cold environments – potential and expected benefit of coordinated data exchange and the unification of methods. *Landform Analysis*, **Vol. 5**: 9-10.

Beylich, A.A., Etienne, S., Etzelmüller, B., Gordeev, V.V., Käyhkö, J., Rachold, V., Russell, A.J., Schmidt, K.-H., Sæmundsson, Þ., Tweed, F.S. & J. Warburton (2005): Sedimentary Source-to-Sink-Fluxes in Cold Environments – Information on the European Science Foundation (ESF) Network SEDIFLUX. *Zeitschrift für Geomorphologie N.F.*, Suppl.-Vol. **138**: 229-234.

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Beylich, A.A., Lamoureux, S.F. & A. Decaulne (2007): Coordinated quantitative studies on sediment fluxes and sediment budgets in changing cold environments – examples from three SEDIBUD key test sites in Canada, Iceland and Norway. *Landform Analysis*, **Vol. 5**: 11-12.

Beylich, A.A., Lamoureux, S.F. & A. Decaulne (2008): SEDIBUD – Sediment budgets in cold environments: Introduction. *Zeitschrift für Geomorphologie* N.F., **52**(1): 1-2.

Beylich, A.A. & J. Warburton (Eds.) (2007): Analysis of Source-to-Sink-Fluxes and Sediment Budgets in Changing High-Latitude and High-Altitude Cold Environments. SEDIFLUX Manual. First Edition. NGU Report, **2007.053**. 158pp.

Lamoureux, S.F., Beylich, A.A. & A. Decaulne (2007): Sediment Fluxes and Budgets in Changing High-Latitude and High-Altitude Cold Environments. Sediment Budgets in Cold Environments (SEDIBUD) Second Workshop; Abisko, Sweden, 15-19 September 2007. *EOS*, Vol. **88** (52), 25 December 2007: 580.

Sediment dynamics and sub-recent sediment budget of the braided sandur system at Sandane, Erdalen (Nordfjord, western Norway)

Achim A. Beylich [1, 2], Louise Hansen [1], Susan Liermann [3], Dorothea Gintz [3], Katja Laute [3], Geir Vatne [2], Ola Fredin [1], Valentin Burki [4] & Ivar Berthling [2]

[1] Geological Survey of Norway, Quaternary Geology and Climate group, Trondheim, Norway

[2] Norwegian University of Science and Technology, Department of Geography, Trondheim, Norway

[3] Martin-Luther-University of Halle-Wittenberg, Institute of Geosciences, Halle (Saale), Germany

[4] University of Zurich - Irchel, Department of Geography, Zurich, Switzerland

This study analyses sediment dynamics and the sub-recent sediment budget of a braided sandur system in a U-shaped valley with connection to the Jostedalsbreen ice cap in Nordfjord, western Norway. The sandur, located in the upper Erdalen valley at Sandane, is characterized by a gravely braid plain 1600 meters long and maximum 700 metres wide. The elevation of the braid plain is ca. 480 m a.s.l. up-stream at the confluence of two tributaries and approximately 460 m a.s.l. at its down-stream end where channels merge to one channel passing over a threshold of moraine and bedrock. Upvalley the sandur system is characterised by coarse deposits build up in a period of increased sediment delivery during the Little Ice Age advance. Downvalley are younger fine-grained flood sediments.

Special focus of this study is on (i) the detection of different zones with negative, positive or balanced sub-recent (following the Little Ice Age advance) sediment budget within the braided sandur system, (ii) the identification of sediment sources upstream of Sandane and at the slope systems to both sides of the braided sandur system and (iii) the analysis of the sub-recent (following the Little Ice Age advance) sediment budget of the entire Sandane system.

A combination of methods is applied including geomorphologic and vegetation mapping, detailed granulometric and channel morphometric analyses in selected channel stretches of the braided sandur system, ^{14}C dating of flood deposits in the lower part of Sandane, lichenometry at exposed blocks in eroded areas in the upper part of Sandane, dendrochronology as well as detection of stable / mobile channel stretches and monitoring of current fluvial sediment transport using stationary stations in combination with different tracer techniques (painted stone lines, shock sensors, biofilm analysis).

The upper part of Sandane is characterised by a negative sub-recent sediment balance, with erosion of coarse sediments from the Little Ice Age advance. In comparison, the lower part of Sandane has a balanced to slightly positive sub-recent sediment budget with formation of younger flood sediments and more stable channels. Altogether, the sub-recent sediment budget of Sandane, following the Little Ice Age advance, appears to be slightly negative.

Present-day coupling of slope and fluvial systems is limited and only a rather small amount of material is directly transported from the slopes into the braided sandur. Sediments from upstream tributaries are transported through the upper part of Sandane without storage. Apart from flood deposits, material is only temporally stored in channels in the lower part of Sandane before export during peak-runoff. Altogether, fluvial sediment transport following the Little Ice Age appears to be supply-limited.

Recent debris transfer on colluvial cones: Processes, distribution and frequency – a case study from the Fnjóskadalur valley, Central North Iceland

Armelle Decaulne [(1)] & Þorsteinn Sæmundsson [(2)]

[(1)] University Blaise Pascal Clermont 2, CNRS Geolab UMR6042, Clermont-Ferrand, France

[(2)] Natural Research Centre of Northwestern Iceland, Sauðárkrókur, Iceland

At present time snow avalanches and debris flows are the main contributors to cone development in the Fnjóskadalur valley, Central North Iceland.

Although frequent, such processes have very variable return periods, and they tend to migrate over the cones with time.

The Fnjóskadalur valley is remote, located out of all anthropogenic activity, enabling to rely on geomorphological evidences that figure the largest magnitudes than could be expected for both processes.

The aim of the study is:

to spatially and temporarily distribute the process over the cone,

to evaluate the frequency of maximum runout distance of debris transfer according to the involved slope dynamics,

in a natural hazard and risk mitigation perspective, the study will evaluate the relevance of transfer methods of results into inhabited areas.

Different techniques are applied to date the events:

lichenometry

vegetal cover,

rock hardness

dendrochronology

The same methods are used to follow the process migration over the cone surface.

The results show that the longest runout distances have to be expected from snow avalanches, which extend far downslope the colluvial cones and cover the whole cone surfaces, although preferential paths are distinguished.

Also, the return period of such extreme snow avalanches is high, as underlined by the combined results from vegetal cover, lichenometry and rock hardness. Debris flows are less frequent than snow avalanches; their runout distance is more limited, as is their migration on the cone surfaces. The geomorphological evidences studied in remote areas prove to be useful for risk assessment and extreme event projection into inhabited areas with topographical model.

Geochemical budgeting in cold climates: examples from Lapland and the Colorado Front Range.

John C. Dixon (1) Colin E. Thorn (2) & Robert G. Darmody (3)

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(3) Department of Natural Resources and Environmental Sciences University of Illinois, Urbana, IL 61801 U.S.A

Geochemical processes are important, and often significant components of sediment budgets in cold climates. In fact in many instances the amount of material (mass) removed as dissolved load from drainage basins exceeds that removed as solid load by fluvial action and redistributed on hillslopes by gravity processes. The nature of chemical processes operating in cold climates however is generally poorly understood as for a long time it was presumed that chemical processes in such environments were insignificant or at best of only minor significance. While this view has been slowly changing over the past 50 years since the publication of Jäckli's classic work from the Alps and Rapp's classic work from Kärkevagge in Swedish Lapland, it is still persists to a large extent in the cold climate literature.

This paper examines the nature of additions, storages, and outputs from the geochemical system, drawing on observations from Swedish Lapland and the Colorado Front Range. Inputs into the geochemical sediment budget are derived from numerous sources including precipitation (both rain and snow), addition from organics, and in association with dry fall deposition. Chemical constituents are derived from the weathering of both bedrock and regolith. Chemical constituents derived from these sources are to a large extent released into the surface and subsurface hydrologic system as observations indicate that solution is the dominant chemical weathering process, but some cations are also incorporated into the neoformation of clay minerals. Over time, these materials constitute the bulk of the fine component of residual and transported soils. In addition, the formation of rock coatings of great diversity is observed on rock walls, hillslope debris and stream coatings. In particular, coatings are dominated by Fe, Si, Ca, Al and K and thus represent storage, and perhaps removal of these elements. The third major component of storage is the uptake of chemical constituents by vegetation and microorganisms. Geochemical output from drainage basins occurs primarily as solute load in water exiting the basin. In addition however there is geochemical loss from the drainage basin in association with the transportation of solid load.

The geochemical system in cold climates, like the solid sediment system consists of a series of sources, storages and sinks, yet unlike the solid sediment system the structure and complexities of the geochemical system has been largely neglected by cold climate geomorphologists.

Significance of event versus post-event sediment transfer processes in a UK upland sediment system

Richard Johnson [1] & Jeff Warburton [2]

[1] Halcrow Group Limited, Lyndon House, 62 Hagley Road, Edgbaston, Birmingham, B16 8PE. UK

[2] Catchment, River and Hillslope Science Research Group, Department of Geography, Durham University, Science Laboratories, Durham, DH1 3LE. UK

Investigations of sediment transfer in upland catchments are rarely conducted over a sustained period of time, consequently a fuller understanding of the changing nature of sediment supply, storage, and yield is often lacking. Recent contemporary sediment budget studies from the Wet Swine Gill headwater catchment in the Lake District, Northern England, UK (a 0.65 km^2, first-order tributary), provide evidence of changes in sediment transfer dynamics over the period 2002-2008.

The first sediment budget from this catchment in 2002 describes the impact of a hillslope debris slide and channelised debris flow event. The termination of the debris flow in the channel meant that the vast majority of slide failure material (203 ± 36 t) was not transferred to the downstream fluvial system. However, the exposure of hillslope sediments to post-event erosion processes and the creation of an erodible in-channel sediment store have arguably had a more enduring impact. In this regard a second sediment budget (June 2003- January 2004) demonstrates:

Channel sediment yield downstream of the in-channel debris slide deposits far exceeds upstream fluvial sediment delivery by two orders of magnitude (4t and 0.02t, respectively). This confirms the event sediment store became a post-event sediment supply.

Erosion of sediment from the exposed hillslope slide scar (c. 1.3t) was less than channel erosion. However this was dominated by gully erosion of the slide scar, rather than by erosion of the scar margins (0.35t) and un-gullied scar surface (0.03t).

Vegetated hillslope locations with event and post-event sediment deposits yield less sediment than exposed (unvegetated) hillslope locations (0.05-0.6t).

Sediment yield from both the hillslope and channel sediment sources is sensitive to high-magnitude, low-frequency trigger events including summer thunderstorms, and winter rainfall/ snow-melt events.

Fixed point photography and cross-sectional measurements over the last six-years have shown a continuation of slide scar gully erosion, and recent measurements of the slide scar indicate that the sediment yield from post-event reworking has now exceeded the importance of sediment delivery from the initial event.

These results suggest that event and post-event sediment flux in small headwater catchments is more complex than short-term investigations would immediately suggest and; clearly establishes a need for continued, long-term investigation of sediment systems in environmental locations potentially sensitive to the impacts of predicted climate change.

Rock slides and rock avalanches in the Skagafjörður area, Central North Iceland – a report on a work in progress

Helgi Páll Jónsson [(1)], Halldór G. Pétursson [(2)] & Þorsteinn Sæmundsson [(1)]

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[(2)] Icelandic Institute of Natural History, Akureyri, Iceland.

Rock slides and rock avalanches are common phenomena in the Icelandic landscape. The majority of these landforms, termed berghlaup in Icelandic, are thought to have occurred shortly after the last deglaciation of Iceland and also at various time intervals throughout the Holocene. However many questions are unanswered about their absolute age, triggering mechanism and formation. These landforms mostly occur in the basaltic Tertiary lava pile areas in Iceland, but are rarely found in the hyaloclastite formations closer to the volcanic zone intersecting the country. Icelandic rock slides and rock avalanches differ considerably in shape and size, although having obvious similar morphological characteristics. The majority of rock slides and rock avalanches in Iceland are of unknown age and only few of them are contemporary events or can be dated from historical sources. The common view is that rock slides and rock avalanches were most frequent during or just after the last deglaciation of Iceland, in Late Weichselian and Early Holocene times, in areas where glacial undercutting left U-shaped valleys with gravitationally unstable slopes, prone to rock fall and landslide events. At present only few rock slides or rock avalanches have been mapped or studied in any detail. The mechanisms that trigger rock slides and rock avalanches in the Icelandic bedrock are still far from being understood, but the most likely explanation is an interaction between multiple factors such as; the bedrock structure, tectonic features, hydrology, groundwater level and climatic events, such as periods of extensive precipitation or snow melting. As Iceland is a country of high seismic activity, earthquake events may play important role in triggering the rock slides and rock avalanches. The first phase of our present research project will focus on rock slides and rock avalanches in the Skagafjöður area, western part of the Tröllaskagi peninsula, central north Iceland. Since there is no geodatabase for Icelandic rockslides available at present, our short term goal is to develop such an inventory in the Skagafjörður area, by using the latest advances in GIS technology combined with satellite imagery and aerial photos as an aid in collecting areal information and in mapping surface features. This will lay the groundwork for further field mapping and dating. Our long-term goal is to use our findings and the information collected in this project to advance the current understanding of rock slide and rock avalanche phenomena in Iceland.

Fluvial geomorphic dynamics of a subarctic catchment under changing climatic conditions

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[(2)] Water Resources Engineering, Helsinki University of Technology / Hydrology Unit, Finnish Environment Institute

Based on contemporary climate scenarios, polar regions are expected to undergo dramatic climatic alterations, including changes in hydrological cycles. Changes in the amount and form of precipitation, the spatiotemporal extent and water content of snow cover, evapotranspiration, ground frost and active layer will affect river discharges at seasonal and annual scales. Anticipated premature spring floods and more frequent autumn floods may trigger numerous secondary processes such as alterations in erosiondeposition dynamics in the channel. Full picture of these changes is still blurred.

We report preliminary results and future prospects of project TULeVAT *("The future of floods in Finland";* project period 20092011), a collaborator in the IPY initiative ID 104 "ArcticHydra".

Our aim is to formulate a general hydrogeomorphological system model for river Tana by taking into account not only the projected changes in climate but also the sedimentary processes that evolve in conjunction with the graded profile evolution within a century time scale.

Based on observed hydrological data from years 19712000, plus a selection of climate models and emissions scenarios, daily future discharges have been modelled for 30year period intervals until 2100. Digital elevation model (DEM) of the river bed was produced with the aid of detailed echo sounding using RTKGPS positioning plus determination from aerial truecolour photographs. This was subsequently combined with Norwegian and Finnish elevation models for supraaquatic river banks to produce a DEM for inundation mapping. Preliminary scenarios for future flooding (207099) have been generated with 1D hydraulic modelling. The results suggest that spring floods will be substantially smaller in future climate.

Currently, we concentrate e.g. on sediment budget and dynamics of the main channel by combining field observations with 2D hydraulic modelling. This approach may offer a tool for forecasting dynamics of channel geometry under changing conditions. Furthermore, analyses of the land cover and discharges on subcatchment level will improve our understanding of the dynamic hydrological processes in subarctic climate.

Suspended sediment yields associated with different landscape disturbances at the Cape Bounty Arctic Watershed Observatory (CBAWO), High Arctic, Canada

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This work is part of a long-term monitoring and research program of paired watersheds (approximate 0.1, 1.0 and 10 km^2 scales) and lakes at Cape Bounty, located on the south-central coast of Melville Island, Nunavut, in the Canadian High Arctic. The overarching goal of this work has been to identify the processes that control fluxes of water, sediment, particulate, solutes, and dissolved carbon and nitrogen from the watersheds towards the goal of incorporating these processes into a comprehensive watershed model to identify the impact of projected climate change. In this study, a series of streams were monitored in 2006-8 to investigate the sediment yields from land surfaces subject to different degrees of disturbance. Extensive permafrost disturbance during 2007 was caused by exceptionally high summer temperatures and rare moderate intensity rainfall. We added additional stream monitoring sites for 2008 to identify the sediment yield from these recent, highly disturbed sites to generate a range of landscape types and disturbance ages.

Snowcover characteristics and pre-melt snow water equivalence (SWE) are the most important factors in generation of runoff and sediment delivery. Undisturbed watersheds appear to transport minimal suspended sediment during snowmelt, but summer rainfall can mobilize substantial sediment. Disturbed watersheds generate high suspended sediment yields during snowmelt and rainfall, and increased turbidity during low discharge phases. The increased sediment yields appear to last for decades in some cases, and indicate slow stabilization of exposed sediment sources and limited vegetation recovery.

These results will be linked to a landscape vegetation model based on high resolution remote sensing to define watershed sediment sources over the larger watersheds and the region. Additionally, these results will contribute to the interpretation of the sedimentary records in the downstream lakes, which will provide insights into the net watershed effects of permafrost disturbances on sediment yield.

Investigations on sub-recent sedimentation and erosion rates within a braided sandur system in Erdalen (Nordfjord, western Norway)

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The main objective of this study is to obtain quantitative information on sub-recent sedimentation and erosion rates from floodplain deposits within a braided sandur system in upper Erdalen. The investigations are contributing to ongoing research activities (since 2004) on Holocene, sub-recent and contemporary sedimentary source-to-sink fluxes and sediment budgets in Erdalen (Beylich et al., this issue).

Erdalen is a very steep U-shaped and glacier-fed tributary catchment of the Nordfjorden valley-fjord system, located in western Norway. The upper Erdalen catchment (approx. 50 km²) compromises three distinct areas: the braided-sandur system (approx. 1.5 km²) developed on Holocene valley infill sediments as well as two tributary valleys (sub-catchments). The elevation of the braided-sandur system ranges from approximately 460 to 480 m a.s.l.

The spatial distribution and thickness of the floodplain deposits were investigated through sedimentological analyses. Sampling for ^{14}C dating was carried out from soil profiles along the banks of six different selected channels within the braided sandur system. Preliminary results indicate that the flood plain sediments were deposited after the Little Ice Age advance. Referring to Shepard's classification system the grain size distribution ranges from silty sand to gravelly sediment, clearly dominated by sand. Furthermore the flood plain sediments are poorly to very poorly sorted. Different sedimentary facies types are present and different phases of flooding may be identified. The results will be used to calculate sedimentation rates and to estimate the volume of floodplain sediments.

In addition, relative dating techniques like dendrochronology and lichenometry are applied, because some distinctive site- and species characteristics can provide additional information about sedimentation or erosion processes. Within the braided sandur system the tree species grey alder (alnus incana) is dominant. However, eroded areas in the upper parts of the braided sandur system are mainly characterised by different cryptogam species like moss and lichen.

The characteristics of natural organic matter (NOM) in sub-Alpine environments

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Natural organic matter (NOM) refers to the complex and chemically and physically diverse substances that result directly or indirectly from the photosynthetic activity of plants. In the geosciences this term is usually limited to substances derived from the partial decay of detrital materials originating from terrestrial and aqueous plants.

In the sub-Alpine environment, the most common source of NOM along the diagenetic pathway from living plants to fossil fuels is materials roughly resembling peat found in bogs and fens. When these are leached by melting snow and rain, organic acids, such as humic and fulvic substances may color natural waters. It is also assumed that leaching of NOM will be intensified in sub-Alpine environments with change towards a warmer and wetter climate. This may affect the quality of natural water and lead to increased costs of water treatment.

The role of NOM in the transport and transformations of inorganic and organic matter, natural and anthropogenic, in terrestrial and aquatic systems, e.g. a river catchment, is less known. This is currently an area of increasing research activity.

Monitoring inter-annual suspended sediment flux variability in an actively deglacierizing mountain belt, Godley Valley, New Zealand

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Ice retreat in response to climate change represent a major perturbation to hydrologic and sediment transfer patterns within mountain landscapes. This perturbation occurs because unconsolidated, easily mobilized glaciogenic sediments exposed during glacial retreat are commonly subject to rapid reworking and mobilization by hydrologic and geomorphic processes. A major barrier to our understanding of how sediment flux responds to deglacierization is finding a reliable and accurate way to characterize the links between sediment sources, glacial retreat and hydrologic routing to the fluvial channel on annual and inter-annual timescales. This lack of longer-term data hampers assessment of the downstream implications for fluvial and lacustrine systems as glaciers continue to retreat. In this paper I present the details of a remote, telemetered monitoring network recently installed in the headwaters of the Godley Valley, New Zealand. This site is part of the SEDIBUD global monitoring network and consists of three proglacial river gauging stations and two lacustrine gauging stations on a proglacial lake. Suspended sediment flux is monitored using an array of custom-built turbidimeters to the cellular phone network via a series of repeaters. This communication network allows daily data transfer back to a server in Dunedin. These field measurements should result in a better understanding of the spatial and temporal controls on suspended sediment flux patterns in deglacierizing basins.

Changing circum-arctic river sediment supply

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Modern Arctic rivers are controlled by a number of processes that are specific to high-latitude and cold-climate regions. Important implications for river characteristics include 1) strong seasonality of river discharge due to a short melting season, 2) high sediment supply if basins are extensively glaciated, 3) lake outbursts and ice jams favoring extreme events and river flooding and 4) pulses of water flooding the still frozen river mouth from a melting hinterland.

We quantified controlling parameters for 50 Arctic rivers basins delineated from GTOPO30 DEM, existing climate data and time series of discharge gauging stations (ArcticRIMS, HYDAT, USGS and GRDC databases). The World Glacier Inventory data (NSIDC) and circum-Arctic map of permafrost (NSIDC) were analyzed to quantify glacier extents and relative permafrost areas for each basin. MODIS Aqua/Terra satellite imagery of 15 fluvio-deltaic systems illustrated high- and low flow season properties. The World Inventory of Dams was analyzed for presence of reservoirs in the selected Arctic river basins.

Subsequently, we model monthly river sediment flux for all 50 systems based on specific basin characteristics (ie drainage area, relief and presence of lakes or reservoirs) and climate characteristics (temperature and precipitation and snow fall statistics) as well as glacier dynamics. The model predictions are validated to observed total loads for a subset of 38 rivers.

Our data corroborates that climatic warming over the last century coincides with an Arctic-wide increase in total annual river discharge. Remarkably though, seasonality of the discharge and similarly of modeled sediment loads, generally decreased over the last decade, partly due to construction of dams, but likely due to changing seasonal precipitation. The importance of glaciers supplying high sediment supply rates was found to strongly scale with river drainage basin area; relatively small basins have larger glaciated areas proportionally. Also, small basins are most impacted by extreme discharge events, e.g. frequent lake outbursts due to rapid glacier melt, whereas the effects of these local events are dampened in the largest Arctic basins. We aim to better understand these complexities and scaling relations to reliably assess circum-arctic river sediment supply to the coastal zone.

Erosion rates of high latitude glaciated basins in a warmer world

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Glacimarine basins are excellent repositories for glacially eroded sediment when valley glaciers or ice sheets terminate within them. In those situations glacimarine basins receive all sediment eroded from an entire catchment because such drainage basins generally have their total area covered by the glacier. Consequently the basin experiences little sediment storage with relatively direct transfer from land into the marine receiving basin. Research has shown that the primary depocenter for all of that sediment is at or near the grounding line where the glacier terminates on the sea floor. Furthermore, greater than 98% of the sediment accumulates in the ice-contact sea floor basin with an exponential decay of sediment accumulation away from the grounding line. Thus, determining annual sediment accumulation rates in an ice-contact basin provides an accurate measure of sediment yields and glacial erosion rates of the entire glaciated basin.

When these data are collected from glacimarine basins worldwide there are significant differences in rates among basins under different glacial regimes. Lower sediment yields and erosion rates occur in progression through orders of magnitude increments from basins under cool-temperate climates through subpolar climates to those under cold polar regimes. Furthermore, these plots show that the sediment yields and inferred erosion rates appear to be controlled more by volume of meltwater at the bed and perhaps not intuitively, may not be related to basin area, as with fluvial drainage basins. This infers that glaciers under a particular climatic regime can over-deepen and erode their beds effectively to yield the same amount of sediment no matter the drainage basin area. Thus a logical conclusion as global warming continues, is the prediction that in the near term, higher erosion rates in high latitudes will be the norm, leading to higher sediment loads in streams and silting of lakes, estuaries and continental shelves at a faster rate than in the recent past. Longer term, once the glaciers have melted and vegetative succession is proceeding, sediment erosion and yields will decrease.

The Morsárjökull rock avalanche in the southern part of the Vatnajökull glacier, south Iceland

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On the 20th of March 2007 a large rock avalanche fell on Morsárjökull, one of the outlet glaciers from the southern part of the Vatnajökull ice cap, in south Iceland. This rock avalanche is considered to be one of the largest rock avalanches, which have occurred in Iceland during the last decades. It is believed that it fell in two separate stages, the main part fell on the 20th of March and the second and smaller one, on the 17th of April 2007. The rock avalanche fell on the eastern side of the uppermost part of the Morsárjökull outlet glacier and covered about 1/5 of the glacier surface, an area of about 720,000 m^2. The scar of the rock avalanche is located on the north face of the headwall above the uppermost part of the glacier. It is around 330 m high, reaching from about 620 m up to 950 m, showing that the main part of the slope collapsed. It is estimated that about 4 million m^3 of rock debris fell on the glacier, or about 10 million tons. The accumulation lobe is up to 1.6 km long, reaching from 520 m, to about 350 m. Its wideness is from 125-650 m, or on average 480 m. The total area covered by the lobes is around 720,000 m^2 and its mean thickness is 5.5 m. The surface of the lobe shows longitudinal ridges and grooves and narrow flow-like lobes, indicating that the debris mass evolved down glacier as a mixture of a slide and debris flow. The debris mass is coarse grained and boulder rich. Blocks over 5 to 8 m in diameter are common on the edges of the lobe up to 1.6 km from the source. No indication was observed of any deformation of the glacier surface under the debris mass.

The first glaciological measurements of Morsárjökull outlet glacier were done in the year 1896. It is evident that the glacier has retreated considerably and during the last decade the melting has been very rapid. It is thought that undercutting of the mountain slope by glacial erosion and the retreat of the glacier are the main causes of this rock avalanche. No seismic activity or climate signals such as heavy rainfall or intensive snowmelt were recorded prior to the rock avalanche, which could be interpreted as triggering factors.

Comparison of radiocarbon dating of buried paleosols using arbuscular mycorrizae spores and bulk soil samples

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Dating paleosols, while technically vexing, is of multidisciplinary importance. A pilot study shows that vesicular-arbuscular mycorrizae (now more commonly called arbuscular mycorrizae or AM) spores offer the prospect of being a medium for radiocarbon dating of paleosols. AM spores are ubiquitous, commonly forming in near-surface soils, and are well preserved upon burial. Spore dates from buried paleosols in Kärkevagge, Swedish Lapland are consonant with regional glaciation history and stratigraphically sound. Paleosols buried in an alpine meadow downslope of a cliff in Kärkevagge (a U-shaped glacial trough in northern Sweden) revealed ages of ^{14}C yr B.P.150 ± 37 at a depth of 7 cm and 1,455 ± 41 at a depth of 18 cm when using AM spores. The same paleosols were also dated using soil organic matter (SOM) and a series of increasingly aggressive pretreatments and combustion temperatures. The SOM dates yielded were extremely sensitive to pretreatment and combustion temperature with dates as old as ~ 40k ^{14}C yr B.P. As cosmogenic dating from nearby locations suggest exposure dates upon deglaciation of ~9-10k yr B.P., the SOM dates are considered unreliable. AM spores appear to afford a stable and useful way of dating paleosols in alpine landscapes and one that is not open to geogenic, as opposed to pedogenic, contamination.

Human induced scour pools in the river Gaula, Central Norway

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This study analyses scour pools, deep pools that does not extend across the entire channel bed, in the lower part of the river Gaula, Central Norway. The scour pools are found to have steep slopes towards the river banks, and several scours have been considered a potential hazard by geotechnical engineers as they are located closely to quick-clay areas, and could potentially trigger quick-clay slides.

This paper aims at studying scour pool formation with a special focus on (i) morphology and location of the scour pools in relation to river planform geometry, (ii) scour pool location in relation to human intervention in the stream channel.

The river Gaula is a steep, flood prone river, with high bedload transport competence. The lower 35 km has a low gradient (≈ 0.001) and are located below the postglacial marine limit. Postglacial isostatic rebound has gradually lowered base level, causing the river to incise into glacimarine sediments. Over the last ca. 100 yrs, extensive bank protection schemes have stabilised the channel to prevent lateral migration and erosion. Large-scale gravel mining in the mid 1900s has in places lowered the bed by several meters and exposed marine clays.

The bed topography of selected river reaches was mapped using either an Acoustic Doppler Current Profiler (ADCP) or echo sounder combined with differential GPS for positioning. Current profiles where sampled using ADCP. The bed of several scours has been filmed with underwater video camera to obtain information of the bed-surface-sediment characteristics.

The results show that the scour pools display large variations with respect to length-depth ratios. The scour dimensions vary from 100 to 1000 m in length and 30 to 50 m in width. All the deepest scours are located near human constructions that in different ways have constricted the river channel. The scours can therefore be termed "forced pools". The constrictions cause recirculating eddies to form, which produces vortices in the shear zone between the recirculating eddy and the main flow. Underwater video shows the scour pools to be developed in cohesive clay, giving rise to high local gradients within the pools.

Significance of macroscale peat flux for carbon export in upland fluvial systems

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Peatlands contain up to 30% of global terrestrial carbon. However, many of these sensitive environments are seriously threatened by changing climate and human-induced degradation. Upland peatlands form a significant part of this resource in the UK and scientists have developed carbon budget models to describe these systems. Although such models are becoming increasingly sophisticated, the export of large (c.100-1000 mm length scale) peat blocks and debris has never been included. However, peat block transport is an important component of the total organic sediment flux in upland fluvial systems and must be included in carbon budget estimates. Understanding the nature of this unique process and the potential magnitude of this flux is essential because fluvial components are the second most important component in the upland terrestrial carbon budget and carbon budget studies are now being used by upland managers to implement strategies on carbon stewardship. This project aims to determine, for the first time, the significance of large peat block transport (> 100 mm) in the carbon budget of an upland catchment. We will test three main hypotheses:

The initiation of peat block transport (by flotation) is a function of block dimensions and the local hydraulics of the flowing river. *Such a process has never been fully documented.*

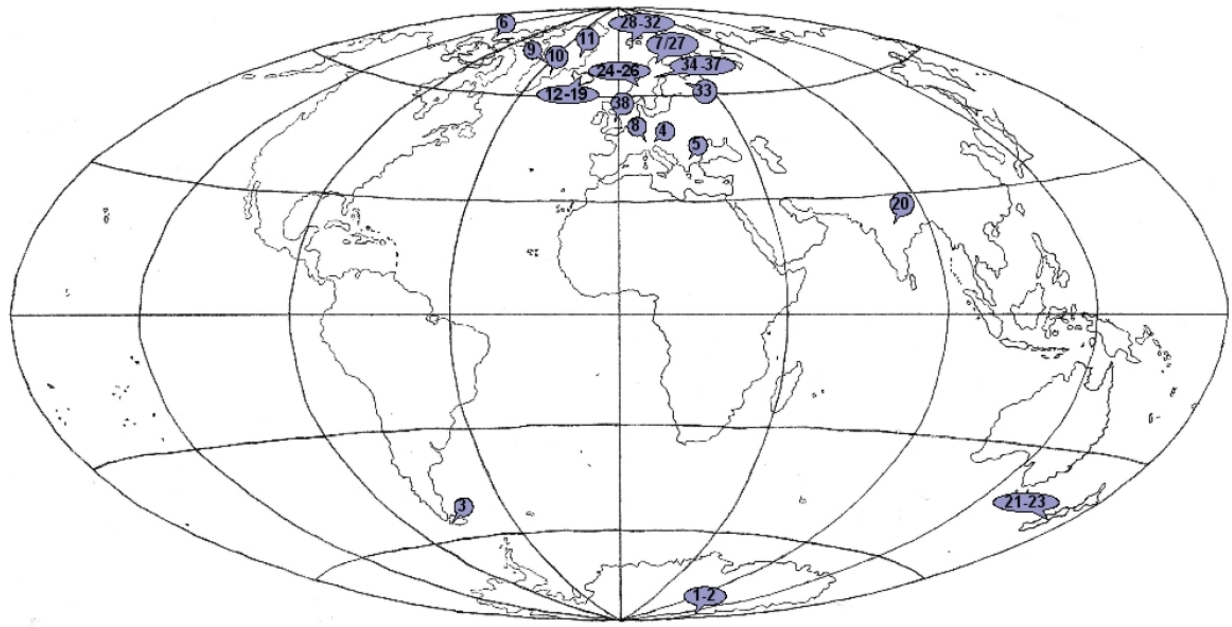
The total peat block flux is a significant component of the total fluvial carbon flux and, in some high flow events may exceed the particulate organic flux. *There is currently no quantitative data to test this.*

Where active in-channel peat block transport occurs, the river reaches downstream will show elevated values of particulate organic carbon due to rapid abrasion and breakdown of peat blocks.

These three hypotheses are tested at a range of scales: micro (individual peat block scale); meso (peat blocks store at the river bar scale), macro (peat block river reach sediment budget) and catchment scale. The experiments are undertaken at the Moor House and Upper Teesdale National Nature Reserve in the North Pennines, UK. Monitoring is nested at these four scales and involves a novel, integrated system of data loggers, environmental sensors and three remote digital cameras. This paper describes the background to the project and presents preliminary findings of the monitoring.

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)

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33. Mezen

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

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38. Moor House

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