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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

Achim A. Beylich*

Geological Survey of Norway, Landscape & Climate group, Trondheim, Norway
Norwegian University of Science and Technology, Department of Geography, Trondheim, Norway

Polar and mountainous regions are among the most sensitive regions to climate change. The European Science Foundation (ESF) SEDIFLUX Network has been analysing the impact of climate change on landforms in high-latitude and high-altitude cold environments, via the mobilisation, movement and deposition of sediments by slope processes, rivers, glaciers, coastal processes and wind.

SEDIFLUX has over the last years evolved into a coordinated multidisciplinary and multinational effort to monitor the changing structure of landforms in cold environments and has led to a series of coordinated research initiatives. The efforts conducted within the SEDIFLUX Network were urgently needed, given the critical importance of studying the impact of projected climate change on the land structure of such sensitive environments. There is especially strong synergy with the International Tundra Experiment (ITEX), whose focus is to determine the relationship between changing climate and circumpolar plant species. The impact of climate on plant species would be mediated partly through changes in land structure brought about by sediment transfers.

SEDIFLUX has established a sustainable framework for long-term research to coordinate multinational, interdisciplinary monitoring networks, a first in the field of geomorphology. SEDIFLUX is now providing the basis for further research. One of the major outcomes produced by the SEDIFLUX group will be the SEDIFLUX Manual, which will provide guidelines and protocols for monitoring and sediment budget studies in selected globally distributed cold environment key test catchments. These long-term monitoring campaigns will apply unified approaches and standardized methods to generate comparable datasets from different cold environments for the development of a metadata database and for modelling the impact of climate change on sediment transfers and sediment budgets.

The new I.A.G./A.I.G. Working Group SEDIBUD (Sediment Budgets in Cold Environments) (http://www.geomorph.org/wg/wgsb.html) builds on, continues and extends activities, which have been started within SEDIFLUX. There is a wide range of high-latitude and high-altitude cold environments that need to be studied, from high Arctic / Antarctic to sub-Arctic / sub-Antarctic, alpine and upland sites. This provides a great opportunity to investigate relationships between climate, vegetation cover and sedimentary transfer processes across a diverse range of cold environments, with the ability to model the effects of climate change and related vegetation cover adjustments through space-for-time substitution.

Climate change affects Earth surface systems all over the world but with arguable the greatest impact in high-latitude and high-altitude cold environments. In these areas climate change shapes earth surface processes not just by altering vegetation and human activities but also through its impact on frost penetration and duration within the ground surface layers. Climate change also exerts a strong control on cryospheric systems, influencing the nature and ex-

* e-mail: Achim.Beylich@ngu.no

tent of glaciers and ice sheets, and the extent and severity of glacial and paraglacial processes. Changes within the cryosphere have major knock-on effects on glacifluvial, aeolian and marine sediment transfer systems. All of these factors influence patterns of erosion, transport and deposition of sediments. However it is a major challenge to develop a better understanding of how these factors combine to affect sedimentary transfer processes and sediment budgets in cold environments. As a starting point our baseline knowledge of the sedimentary transfer processes operating within our current climate and under given vegetation cover, as a basis for predicting the consequences of future climate changes and related vegetation cover changes needs to be extended. Only when we have these reliable models will we have fuller understanding. It is therefore necessary to collect and compare data from different cold environments, and use this to assess a range of models and approaches for researching the relationships between climate change, vegetation cover and sediment fluxes.

Results from ongoing geomorphologic studies on sediment fluxes and sediment budgets in selected SEDIBUD key test sites are presented. Quantitative longer-term studies on sediment transfers and sediment budgets are carried out in five selected small cold environment catchments (<30 km^2) in Iceland, Swedish Lapland, Finnish Lapland and Norway. Investigations in East Iceland (Austdalur and Hrafndalur), Swedish Lapland (Latnjavagge) and Finnish Lapland (Kidisjoki) have been conducted for over six years whereas studies in Western Norway (Erdalen) have just been started three years ago. The five catchments are seen as clearly defined landscape units where detailed studies on sediment transfers and sediment budgets using unified techniques and approaches (including monitoring of present-day denudative processes as well as quantitative analysis of storage elements) – providing comparable data sets from the different cold environments – are possible. The five catchments are considered to be representative for the selected target areas in East Iceland, Swedish Lapland, Finnish Lapland and Western Norway.

Main focus of the research programme is on analysing the role of the factors morphoclimate, vegetation cover, ground frost, human impact, relief and lithology for present-day sediment fluxes, denudation rates, sediment budgets and relief development in the five different study sites. Direct comparison of the data collected in the different cold environment target areas provides information on variations in the absolute and relative importance of different denudative processes and helps to get more insight into the spatial differentiation of cold environments.

The two selected catchments in subarctic-oceanic East Iceland are characterized by very steep alpine relief and a partly destroyed vegetation cover (as caused by direct human impact). Mechanical denudation dominates over chemical denudation. Austdalur (basalt) is showing lower mechanical denudation rates than Hrafndalur (less resistant Rhyolithes). The slightly less steep Latnjavagge in arctic-oceanic Swedish Lapland (mica schist) is characterized by clearly lower mechanical denudation rates, which is mainly due to a very stable and closed vegetation cover and stable step-pool systems developed in the creeks. In this valley chemical denudation appears to be slightly higher than mechanical denudation. Kidisjoki in subarctic Finnish Lapland (gneisses) is situated in the area of the Baltic Shield and shows very low chemical and mechanical denudation rates. Chemical denudation dominates over mechanical denudation. All four catchments are characterized by altogether low denudation rates. Chemical denudation ranges from 2.6 t $km^{-2}yr^{-1}$ in Kidisjoki to ca 8 t $km^{-2}yr^{-1}$ in East Iceland. All four valleys are characterized by restricted sediment availability. More than 90% of the annual fluvial sediment transport occurs within a few days during snowmelt and/or rainfall generated peak-runoff. Only in the very steep catchments with partly destroyed vegetation cover in East Iceland mechanical denudation dominates over chemical denudation.

Erdalen is a characteristic and very steep U-shaped valley in the fjord landscape of western Norway (Nordfjord). The sub-Arctic Erdalen catchment is connected to the Jostedalsbreen ice cap and is in its uppermost areas glaciated. Current investigations in this key test site include the quantitative analysis of storage elements like talus cones, valley fillings and lake sediments by using different geophysical techniques, the year-round monitoring of meteorological parameters, ground temperature, permafrost, runoff, fluvial solute and sediment transport as well as the analysis of slope processes like rockfalls, avalanches and debris flows by combining different monitoring and dating techniques.

The possible potential and expected benefit generated by coordinated data exchange and the unification of methods and techniques applied to long-term process monitoring/analysis, the quantitative investigation of storage elements and for sediment budget studies in cold environments is presented. Comparable data sets generated in other cold environment key test sites in polar and alpine regions that follow the guidelines and protocols provided in the SEDIFLUX Manual will be added to a metadata database developed within the global I.A.G./A.I.G. SEDIBUD programme. The SEDIBUD metadata database will be used to model effects of projected climate change on solute fluxes, sediment fluxes and sediment budgets in sensitive cold environments worldwide.