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Controls and spatio-temporal variability of runoff, solute fluxes and chemical denudation in the fjord landscape of the inner Nordfjord, western Norway

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This study performed over an investigation period of six years (2004 - 2010) focuses on controls and spatio-temporal variations of runoff, surface water chemistry, solute concentrations, solute fluxes and chemical denudation rates in a steep, cold climate and glacier-fed drainage basin system in the fjord landscape of western Norway. The selected Erdalen drainage basin (79.5 km2) is considered to be a typical valley system of the Nordfjord region in western Norway and is connected to the Jostedalsbreen ice cap through two outlet glaciers (Vesledalsbreen and Erdalsbreen).

The computed mean annual chemical denudation rate in the Erdalen drainage basin is 6631 kg km-2yr-1, which is in a similar range of magnitude than annual chemical denudation rates in a number of other cold region catchment systems worldwide. The Erdalen drainage basin is homogenously composed of gneisses, which is reflected in a homogenous relative (as a percentage) chemical composition of surface water across the entire drainage basin system. At the same time, the mean annual TDS values of surface water sampled in creeks draining defined subsystems within Erdalen show a rather high spatial variability. The main controls of this detected spatial variability are (i) differences in slope deposit / regolith thickness, (ii) differences in slope angle, (iii) differences in areal regolith cover, (iv) differences in vegetation cover, (v) differences in snow cover and ground frost conditions, and (vi) differences in elevation (m a.s.l.).

Inter- and intra-annual temporal variations of runoff, water chemistry, solute concentrations, solute fluxes and chemical denudation rates are clearly determined by the combined effects of inter- and intra-annual temporal variations of precipitation, air temperature and solar radiation. Intra-annual temporal variations of surface water TDS values reflect the dilution of base flow from the drainage basin by (i) thermally controlled snowmelt in spring (April - June), (ii) thermally determined glacier melt in summer (July - August), and (iii) both more frequent and more intense rainfall events in fall (September - November). The highest monthly solute gross yields over the year (with altogether 43% of the total annual solute gross yield) are recorded in the spring period (three months period April - June), which is due to high runoff during spring snowmelt and comparably higher TDS values than during major glacier melt in summer (July - August). In fall (three months period September - November) comparably high amounts of ion poor rainwater, in combination with a fast surface drainage (saturation overland flow) of a significant share of rainwater during heavy rainfall events and lower air temperatures as well as clearly lower solar radiation inputs lead to comparably lower TDS values in surface water than in spring.

Altogether, the mean annual surface water TDS values in Erdalen are rather low, which can be explained by (i) shallow thickness of regolith across the very steep drainage basin, (ii) the small percentage of surface areas showing a significant cover of regolith, (iii) the cool climate in the fjord landscape of western Norway, and (iv) the weathering resistance of the predominant gneisses within Erdalen. Despite the rather low mean annual TDS values computed for the Erdalen drainage basin, chemical denudation is a comparably important and spatially very variable denudative process and should therefore not be neglected when studying slope development as well as slope- and catchment-wide denudation rates and mass budgets in this kind of steep, mountainous cold climate drainage basins.

Predicted climate change and the connected shifts in temperature and precipitation regimes are expected to have significant impacts on the intensity and on the temporal variability of chemical processes and chemical denudation in the fjord landscape of western Norway.