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What does a lake sediment terrigenous input record actually tell us? Tentative answers based on a multi-lakes source-to-sink approach in the 4000 km^2 Arve-Rhône alpine catchment

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Since the emergence of paleolimnology as a scientific discipline, numerous studies attempted to link terrigenous input to environmental variables. In particular, it has been proposed that the total amount of river-borne sediment should be used as a mirror of "humidity", assuming the erosion flux is mainly driven by climate changes. Alternatively and in a sense, at the opposite, the recent development of Holocene paleo-studies and the growing interest for the reconstruction of past human-environment interactions led to postulate that since at least the Bronze age, humans became the main driver of erosion patterns. Indeed there is not really a scientific debate, each "church" hanging to its position: "pro-human" vs. "pro-climate". In this paper, we attempt to light the debate, based on an original approach which was led in the framework of the Pygmalion program. Rather than studying a single lake record, we tried to integrate results at various time and spatial scales within a 4000 km^2, lithologically and morphologically complex catchment.

The chosen area lies at the northern edge of French Alps: Arve river catchment, which drains among others the Mont Blanc massif, and its continuation after its junction with river Rhône, downstream Lake Geneva. After a river course of ca. 250 km, Lake Bourget represents a partial sink for erosion products when river Rhône flows within the lake during major floods. In this, Holocene-long sediment cores from Lake Bourget can be interpreted as a regional record of terrigenoux fluxes. Thanks to a set of 20 tributary samples, we led a source-to-sink approach, based on Nd isotopes. This led us to identify from the sediment record fluctuations in the main provenance of sediments. Moreover, the high resolution record of chemical weathering proxies (clay mineralogy and K/Ti ratio) gave important information upon the role of soil genesis in erosion patterns. This approach stated that the Little Ice Age has been an exceptional period of erosion compared to whole Holocene, most of the additional flux coming from the glaciated catchment of the Mont Blanc massif.

Despite the fact that it provided valuable information, the Lake Bourget record did not yield a complete image of erosion patterns in the catchment area. We hence studied two additional sediment records at high altitude, one being potentially submitted to human pressure on soil stability, the other one being a proglacial lake in which fluxes are dominated by torrential floods and glacier activity.

Confronting all records, we found that despite humans became a major forcing of erosion patterns in non-glaciated high altitude catchments as early as the Bronze age, very few tracks of this was recorded at a large scale (i.e. in Lake Bourget). Even a dramatic rise in erosion processes attributed to intense pasturing during Roman period at high elevation did not substantially increase erosion fluxes downstream. On the contrary, flood frequency in both high altitude sites is well correlated with Lake Bourget record, arguing for a strong climate control upon hydrological patterns. This is confirmed by independent paleohydrological proxies in Lake Bourget itself. However, even at a regional scale, the imprint of human activities was detected in Lake Bourget, through changes in the pedogenetic origin of erosion products. This anthropic forcing did not lead to a rise in erosion flux, on the contrary it was made more detectable thanks to relatively dry climate periods leading to low terrigenous fluxes.

All together, it appears in our case study that terrigenous fluxes can be dramatically dominated by human impact for a given time period and in a particular sub-catchment. However this does not affect the sediment budget at a large-catchment scale. In mountain regions it appears also that glacier-triggered erosion can dominate changes

in erosion processes even if it is restricted in a small area ($\sim$10% of the catchment, here).