Post-glacial geomorphic and erosion response in the western European Alps and Pyrenees
(3-yr PhD funding)

PhD supervisor : Pierre Valla (pierre.valla@univ-grenoble-alpes.fr)

Institution : Institute of Earth Sciences (ISTerre, https://www.isterre.fr/), CNRS - University Grenoble Alpes, Grenoble, France

Collaborations (national) : Edytem Chambery, EVS Lyon, HNHP Perpignan, Geosciences Rennes

Scientific questions and objectives of the PhD project : Quantifying landscape dynamics has proven problematic in the context of current climate change (e.g. *Lane, 2013*) because geomorphic processes operate at interrelated timescales. Alpine landscapes were progressively shaped during the Quaternary under oscillating glacial-interglacial conditions, but the net impact of glaciation on mountains is spatially variable (*Whipple et al., 1999; Champagnac et al., 2014*). Furthermore, modern mountain erosion integrates both (1) the long-term response (i.e. 1-10 kyr) to glacial retreat and glacial conditioning of topography, and (2) the recent impact of climate change (i.e. 10-100 yr) as a result of glacier shrinking and permafrost thawing (e.g. *Bodin et al., 2015*). Predictions of the geomorphic response to future climatic scenarios have consequently remained limited. All these observations point toward the need for a better assessment of mountain landscape sensitivity to climate forcing over a range of timescales. In this PhD project, we aim at investigating the geomorphological record in two natural settings (western European Alps and Pyrenees) to quantify postglacial erosion processes and sediment transfer since the Last Glacial Maximum (LGM, ca. 20 ka), addressing the following question: ***what are the interactions, threshold effects and response times between climate change, glacier retreat and erosion processes in alpine settings since the LGM?***

The post-glacial landscape response has been apparently different between the western Alps and Pyrenees. In the western Alps, post-LGM glacier retreat has resulted in landscape rejuvenation through river incision (*Valla et al., 2010; Norton et al., 2011*) and slope movements (e.g. *Cossart et al., 2008*), with high rates of sediment production over modern to millennial timescales (*Hinderer et al., 2013*). In the Pyrenees, the post-glacial geomorphic response has been limited, with scarce slope instabilities (*Jarman et al., 2014*) and relatively low sediment production (*Delmas et al., 2009*). Catchment-wide erosion rates reveal contrasting erosion regimes in the western Alps (*Delunel et al., 2020*) and Pyrenees (*Genti, 2015; Crest, 2017*), with proposed apparent slope or elevation control on post-glacial geomorphic processes, raising the issue of disentangling the respective contribution of glacial pre-conditioning, glacier retreat and current climate change in mountainous erosion regimes. This forms the central question of this PhD project, with the aim to quantify spatial and temporal variations in postglacial erosion coupled to sediment provenance. The overall objectives of this project are to **(1)** quantify the spatial (western Alps vs. Pyrenees) and temporal (since the LGM to late Holocene) variability in mountain erosion rates using catchment-wide denudation data, **(2)** understand and trace sediment production and transfer during lateglacial to postglacial timescales, with potential source changes over time, and finally **(3)** better understand how geomorphic agents and timescales interact to regulate the landscape response to a changing climate and associated glacier retreat.

To achieve these different objectives, the PhD project will be organized around a multi-method approach. First, the PhD student will use in-situ cosmogenic nuclides (^{10}Be quartz ; *Gosse and Philipps, 2001*) in modern river sands (*Granger and Schaller, 2014*), targeting different catchments in the Pyrenees to complement existing datasets (*Genti, 2015; Crest, 2017*). This work will allow to establish a database for the Pyrenees for geomorphic comparison with the western European Alps (*Delunel et al., 2020*). In addition, the PhD student will acquire new in-situ cosmogenic nuclide data (^{10}Be/^{26}Al, potentially ^{14}C) in Lateglacial and Holocene sediment archives (lacustrine and floodplain deposits, floodplain and alluvial fan) as tracer for paleo-erosion (*Savi et al., 2014*) or paleo-environmental conditions (*Kapannusch et al., 2020*). Sediment provenance will also be investigated using mineralogical (*Stutenbecker et al., 2018*) and geochemical (*Arnaud et al., 2016*) analyses together with detrital thermochronology (*Stock et al., 2006; Godon et al., 2013*) to quantify temporal changes in river-sediment sources since the LGM. Sediment transfer times will finally be evaluated for lateglacial to postglacial deposits with bulk sediment geochemistry to derive weathering indices (e.g. *Bahlburg and Dobrzinski, 2011*) and U-Th series to date the time of sediment production (i.e. the comminution age; e.g. *Dosseto et al., 2008*) and infer the budget contribution of re-mobilized glacial sediments during the Lateglacial/Holocene as well as to evidence complex sediment transfer (*Cogez et al., 2018*). Ultimately, the PhD student will work on surface-process modeling using the state-of-the-art Landlab model (*Hobley et al., 2017*) which predicts landscape evolution and sediment production (river and hillslope processes) under climate forcing. We will focus on the influence of rainfall variability on stochastic river processes and landslide triggering, and on other potential factors driving the geomorphic response to glacial/interglacial transition (topographic pre-conditionnig, stored subglacial sediments, tectonic/isostatic uplift etc.).

Organization and application details : The PhD student will develop his/her project at the Institute of Earth Sciences (ISTerre, Univ. Grenoble Alpes) under the supervision of Pierre Valla and in close collaboration with researchers from ISTerre and other national institutes. The PhD candidate should have knowledge in quantitative geomorphology, Quaternary geology and/or sedimentary geochemistry. Some skills in topographic analysis, GIS mapping and numerical modeling would be advantageous to lead this project and establish planned collaborations. The doctoral project is financially supported by the **ANR-PIA MAGICLIM project** ("MountAin Glacier fluctuations and landscape dynamIcs under a changing CLIMate" - PI P. Valla) which will cover all financial expenses for fieldwork missions, analyses and planned travels (collaborations and conferences) within the framework of the PhD project. The PhD student will also be part of the **MOPGA program** and will participate to associated conferences/workshops.

Applicants should have a **MSc degree** in geology, geophysics, geography, or any related quantitative discipline in natural sciences, with strong interests in earth surface dynamics. Successful applicants should have strong written and oral communication skills in English (French skills can be advantageous). Interested candidates should send their complete application (including a curriculum vitae, a copy of MSc diploma/grades, a max. 1-page motivation letter with research interests, along with the names and addresses of two referees) via e-mail in a **single PDF file** to Pierre Valla (pierre.valla@univ-grenoble-alpes.fr).

Deadline for application is **September 6th 2021**, the start of the PhD project is scheduled for **November/December 2021**. Questions can be directly addressed to Pierre Valla.

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