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Two millennia of torrential activity reconstructed from alpine lake sediments: towards regional patterns of extreme precipitation changes

B. Wilhelm (1), F. Arnaud (1), C. Giguet-Covex (1), P. Sabatier (1), C. Crouzet (2), and J.J. Delannoy (1)

(1) EDYTEM, University of Savoie-CNRS, Le Bourget-du-Lac, France (wilhelm_bruno@yahoo.fr, 00 33 [0] 4 79 75 87 77),
(2) ISTERRE, University of Savoie-CNRS, Le Bourget-du-Lac, France

In mountain areas extreme precipitation events trigger torrential floods, characterized by a sudden and intense rise of discharge causing large human and economic losses. Their frequency and/or intensity are expected to increase in the context of global warming. However, the relationship between such events and climate changes remains difficult to assess. Long-term geological records of intense events could enable to extend documented records beyond the observational data for a better understanding of local to regional flood hazard patterns in relation to past climatic changes and hence improving predictive models.

In this context, lake sediment records appear a relevant archive as they are continuous records in which the identification of high-energy sediment layers allows to reconstruct flood calendar. In addition, the flood intensity can be reconstructed from the coarse fraction of each flood layer. Frequency and intensity of past torrential floods were thus reconstructed from four high-elevation lake records of the French Alps, in the framework of Pygmalion research program. Studied sites were selected along a north-south transect over this region to investigate the flooding responses to different climatic influences (westerlies in the north and Mediterranean influences in the south). High-resolution geochemical and sedimentological analyses were undertaken for an exhaustive identification of flood layers and several dating methods (short-lived radionuclides, 14C, correlation with historic events, paleomagnetism) were combined to reduce age uncertainties as much as possible.

Over the entire French Alps, the torrential-flood frequency increases at a secular timescale during the cold period of the Little Ice Age (LIA; 1300-1900 AD). This increase seems in agreement with a regional high wetness, already described in the literature, possibly related to an increase in cyclonic activity. Superimposed to this secular trend, a pluri-decadal variability appears at different times depending on the site location (i.e. north-western or southern French Alps). In the north, peaks of flood frequency match well with high summer temperatures, while in the south they seem to be associated to solar maxima and negative phases of the North Atlantic Oscillation. Furthermore, the most extreme events occur during the warm Medieval Climate Anomaly (800-1300 AD) in the north while in the south the intensity of these events increases during the cold LIA period.

Our results reveal major differences in the evolutions of the torrential-flood activity at a regional scale. This suggests that extreme precipitations over this part of the Alps are influenced by different forcing factors. In the north-western French Alps, warming seems to plays an important role, favouring the increase of both flood frequency and intensity at a pluri-decadal time scale. Inversely, at the same time scale, in the Southern French Alps, flood frequency and intensity seem to be strongly linked to meso-scale atmospheric circulations in relation to the North Atlantic Oscillation (see abstract from Wilhelm et al. in session CL4.3 for details). Our study hence suggests one should expect a generalised decrease of torrential flood frequency all around the Alps. However, in northern French Alps only, an increase in torrential flood intensity is expected by analogy with the MWP pattern.