Geophysical Research Abstracts
Vol. 21, EGU2019-2623, 2019
EGU General Assembly 2019

Challenges in Stable Isotope Paleoaltimetry in the Alps

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Paleoelevation reconstructions have gained attention over the past decades due to the importance of quantifying surface uplift for understanding the subsurface density structure, isostatic compensation of orogens, and interactions between surface processes, tectonics and climate. However, most studies to date have focused on paleoelevation reconstructions of orogenic plateaus. Here, we address the potential and challenges of applying stable oxygen isotopes-based paleoaltimetry to 'smaller' orogens such as the European Alps. We do this by answering two questions: i) what is the maximum signal of topographic change that could be preserved in oxygen isotope paleo-precipitation records, and ii) what is the contribution of climatic changes to such isotopic records. In order to address these questions, we use a high-resolution ($\sim 0.75°$) isotope tracking general circulation model (ECHAM5-wiso) and provide sensitivity experiments with reduced and increased topography over the Alps, and experiments with realistic paleoenvironmental boundary conditions for the Last Glacial Maximum (LGM) and the Pliocene. Results indicate that although a maximum signal of 5-6 ‰ in oxygen isotope ratios of local precipitation is predicted during topographic development, this signal is likely obscured by a signal associated with climatic change. Our paleoclimate simulations with realistic paleoenvironmental boundary conditions show that global climate change imprint precipitation $\delta^{18}O$ within 5 ‰ i.e. is comparable to the signal from the topographic uplift. Thus, we argue that the magnitude of the isotopic signal from the topographic change is similar to that from global climate change events, thereby making it difficult to decipher the two in the proxy record without additional knowledge on paleoclimate. Our modeling results allow disentangle climatic and topographic signals in the geologic stable isotope record and indicate that stable-isotope based reconstructions of paleotopography largely benefit from an integration of multi-proxy methods, lowland reference proxy records and climate modeling.