



Linking modern glaciological data to early Holocene glaciers: The scaling problem

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Modern directly measured glaciological data comprise more than 50 years now and are complemented by additional 125 years of length change records and 200 years of instrumental climate data. The direct mass balance data comprises a number of ablation and accumulation measurements at a few percentage of today's Alpine glaciers, revealing today's linkage of meteorological parameters to mass balance. The length records cover a higher percentage of glaciers and are much longer than mass balance data, but still show a general glacier retreat. Early instrumental data is not available in the vicinity of glaciers, and is biased towards lower elevations. Despite of those limitations, a number of empirical and theoretical models of the glacier-climate interaction have been developed which can be applied to relate glacier stages from the last glacial maximum (LGM) onwards to specific climatic conditions. Independent from the specific model, a number of basic principles as well as unknown boundary conditions leave room for a large bandwidth of possible climatic interpretations.

To be able to quantify at least the magnitude of this bandwidth, from the basic principles of glacier-climate interaction the path dependence and the spatial and temporal scale problem have to be taken into account, as well as the idea of non-equilibrium states causing moraines. From today's models, the boundary conditions of cloud cover and surface texture (and thus radiative balance) as well as unknown thermal and basal properties of the ice might play an important role. These factors are illustrated and quantified by long time series of the Austrian Alps. Changes of these parameters are often neglected also in numerical modelling of today's glaciers. Nevertheless, today's field data in combination with simple models allow a first rough estimate of possible uncertainties in interpretation of previous climatic conditions. Much longer, but nevertheless important to keep in mind, remains although the list of open questions.