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A compilation of Western European terrestrial records 60–8 ka BP: towards an understanding of latitudinal climatic gradients

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ABSTRACT

Terrestrial records of past climatic conditions, such as lake sediments and speleothems, provide data of great importance for understanding environmental changes. However, unlike marine and ice core records, terrestrial palaeodata are often not available in databases or in a format that is easily accessible to the non-specialist. As a consequence, many excellent terrestrial records are unknown to the broader palaeoclimate community and are not included in compilations, comparisons, or modelling exercises. Here we present a compilation of Western European terrestrial palaeo-records covering, entirely or partially, the 60–8-ka INTIMATE time period. The compilation contains 56 natural archives, including lake records, speleothems, ice cores, and terrestrial proxies in marine records. The compilation is limited to include records of high temporal resolution and/or records that provide climate proxies or quantitative reconstructions of environmental parameters, such as temperature or precipitation, and that are of relevance and interest to a broader community. We briefly review the different types of terrestrial archives, their respective proxies, their interpretation and their application for palaeoclimatic reconstructions. We also discuss the importance of independent chronologies and the issue of record

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synchronization. The aim of this exercise is to provide the wider palaeo-community with a consistent compilation of high-quality terrestrial records, to facilitate model-data comparisons, and to identify key areas of interest for future investigations. We use the compilation to investigate Western European latitudinal climate gradients during the deglacial period and, despite of poorly constrained chronologies for the older records, we summarize the main results obtained from NW and SW European terrestrial records before the LGM.

1. Introduction

Since the discovery of abrupt climate change at decade-to-century time-scales during the Last Glacial period, evidence of rapid climate variability has become available from an ever-growing number of palaeo-archives worldwide. In the North Atlantic region, the climate of the Last Glacial period is characterized by a number of abrupt warming events referred to as Dansgaard–Oeschger events, which are most strongly expressed in the Greenland ice cores (Dansgaard et al., 1993). North Atlantic marine records of the Last Glacial period are sometimes dominated by ice rafting events, the so-called Heinrich events (Hemming, 2004) while other terrestrial archives from Western Europe do not always show a strong response to such climatic events (Ampel et al., 2010). The abrupt climate variability of the Last Glacial period differs from the slowly varying orbital parameters that are believed to be the main drivers of climate change during this period.

The present work is concerned with the 60–8 ka period, covering the second half of the Last Glacial, including the Last Glacial Maximum (LGM, ca 22–18 ka BP) and the deglacial period (ca 14.7–11.7 ka BP), and the early Holocene (ca 11.7–8 ka BP). Furthermore, the period is divided into Marine Isotope Stage 3 (MIS3, ca 60–28 ka BP), MIS2 (ca 28–11.7 ka BP), and part of MIS1 (last 11.7 ka). Within the INTegration of Ice-core, MArine, and TErrestrial records (INTIMATE) community, the Greenland ice core stratigraphy (Rasmussen et al., 2014) has been applied as a template for North Atlantic climate variability for the 60–8 ka period (Blockley et al., 2012).

Compilation of palaeoclimatic evidence from palaeo-archives is a prerequisite for obtaining an overview of past climatic change. Bringing palaeo-records from various archives together on a common chronological framework allows individual records to be placed in a broader context, exploration of both temporal and spatial evolution of climate, and investigation of the drivers and mechanisms behind past climatic changes together with the resulting impacts of climatic change (Birks and Birks, 2014). Furthermore, data compilations enable model–data comparisons which can help to decipher the mechanisms that drive climatic change.

A number of important studies have provided compilations of records of past climatic variability between 60 and 8 ka on both global and regional scales. Voelker (2002) provided the first global compilation of marine and terrestrial sites, showing evidence of centennial-scale climatic change during the Last Glacial period. Since then, this evidence has been supported and extended by a number of high resolution records, such as Antarctic ice cores (EPICA, 2006), Cariaco Basin and Arabian Sea sediment cores (Deplazes et al., 2013), and Asian and American speleothems (Wang et al., 2001, 2007; Fleitmann et al., 2009; Asmerom et al., 2013). The deglacial period provides more records and accurate chronologies than earlier periods, and a comprehensive compilation of global proxy records is provided by Clark et al. (2012) and Shakun et al. (2012).

Other studies focused on the climate of the Last Glacial in the North Atlantic region, which is strongly influenced by the presence of large continental ice sheets (Svendsen et al., 2004). Björck et al. (1996) linked deglacial records from different North Atlantic archives. Voelker et al. (personal communication) provide the most recent compilation of high resolution North Atlantic surface water temperatures for the last 60 ka, and a comprehensive compilation of Last Glacial millennial-scale European vegetation records was provided by Fletcher et al. (2010a).

This paper presents a new compilation of Western European quantitative terrestrial climate records in the 60–8 ka INTIMATE time period (Fig. 1, Table 1) with a focus on the deglacial period. We briefly describe the different terrestrial archives, their respective proxies, interpretation and application for palaeoclimatic reconstructions. Furthermore, we discuss the importance of chronologies and record synchronization. We investigate Western European latitudinal climate gradients during the deglacial period, and discuss the period before the LGM.

2. Data compilation and selection criteria

The present compilation broadly covers Western Europe (with 15°E of longitude as an approximate boundary) and is complemented by parallel compilations covering Eastern Europe (Feurdean et al., 2014), the Austrian and Swiss sectors of the Alpine region (Heiri et al., 2014) and marine North Atlantic records (Voelker et al., personal communication). The scarcity of records from Scandinavia for this time period does not require an additional compilation and those sequences are included here. The present compilation includes published records from lakes, speleothems, ice cores, and terrestrial proxies in marine records. The following selection criteria were applied to obtain a dataset with a balanced geographical and temporal distribution:

- The record must cover a relevant interval of the 60–8-ka INTIMATE time frame, even if it is not continuous.
- The record must include at least one quantitative or semi-quantitative climate-related variable (proxy or reconstruction). For example, temperature proxy/estimates, precipitation proxy/estimates, vegetation/biome parameters, or lake level estimates. Preferably, all parameters have an error estimate attached to them.
- An age model must be available. Preferably the age model is independent, or tightly linked to a well-dated archive. All information about how the age model is constructed must be provided and, preferably, uncertainty estimates should be available.
- Included records must be published or made available for this work.

Our compilation includes 56 Western European records of past climatic conditions on land, mostly presenting temperature and precipitation reconstructions, but also records of dust supply and vegetation biomes (Table 1; Fig. 1, Electronic Supplementary Material). The compilation contains 38 records from lake sediments, 9 records from speleothems, one ice core record and 8 records of terrestrial remains (e.g. pollen) in marine sediments. Loess,