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Increasing vegetation and climate gradient in Western Europe over the Last Glacial Inception (122–110 ka): data-model comparison

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Abstract

High-resolution terrestrial (pollen) and marine (planktic and benthic isotopes, coarse fraction, and *N. pachyderma* (s)) analyses have been performed in the Marine Isotope Stage (MIS) 5 interval of IMAGES core MD99-2331 retrieved in the northwestern Iberian margin. This study shows the occurrence of a Zeifen Interstadial/Stadial succession on land and in the ocean during the first part of MIS 5e. In northwestern Iberia, the Eemian is marked from 126 to 122 ka by the development of deciduous *Quercus* forest at the same time as Mediterranean forest colonised southern Iberia, and deciduous *Quercus-Corylus* forest occupied northernmost European regions. From 121 to 115 ka *Carpinus betulus* forest developed in NW Iberia indicating a winter cooling by 2 °C on land and an increase in annual precipitation by 100–200 mm along with a Sea Surface Temperature

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(SST) decreasing trend off Iberia. A similar cooling has been documented at the same time in northern Germany (52° N) by the replacement of deciduous forest by coniferous (*Abies-Picea*) formations, implying a southward displacement of the deciduous tree line between ~60° N and 50° N as early as 120 ka. The southward migration of the tree line between 72° N and 58° N simulated by the Earth Model of Intermediate Complexity MoBidiC from 122 and 120 ka and considered as a major process to initiate the last glaciation is, therefore, compatible with data. Between 115 and 110 ka, the substantial ice accumulation in northern high latitudes (MIS 5e/5d transition) was synchronous with successive drops, C26 and C25, in northeastern Atlantic SST. In northwestern Iberia *Abies-Pinus* trees developed at the expense of *Quercus-Carpinus* forest. A tundra-like environment occupied northern Germany, marking the end of the interglacial in northwestern Europe at 115 ka, and boreal forest likely colonised northeastern France. The first displacement of the vegetation belts at 121 ka was enhanced at 115 ka indicating an amplification of the vegetation and climate gradients in northeastern Atlantic and European borderlands probably related with the well-developed ice caps at that time. The comparison between the general trend in the estimated and simulated MoBidiC winter and summer temperatures for latitudes between 35 and 45° N, shows that both follow quite straightforwardly the precession signal although the simulated and reconstructed temperatures agree better in the South than North of 40° N. Annual precipitation is exhibiting opposite trend in the data and in the model. This contradiction is likely the fact that the zonal climate simulated by the model may not accurately represent the regional climate features, as reconstructed from the pollen.

Keywords: Eemian; MIS 5; Last Glacial Inception; western Europe; northwestern Iberia; EMIC; climate simulation; pollen; vegetation; climate reconstruction

1. Introduction

The last interglacial/glacial transition (122 to 110 ka BP) has been in the past the focus of a number of studies with models of different complexity [1,2]. These studies have put forward the role of land processes, and specifically changes in vegetation, for entering in the last glaciation. The replacement of taiga by tundra acts as positive feedback on accumulation of perennial snow because snow covered tundra has a larger albedo than snow covered taiga. In particular, the Earth Model of Intermediate Complexity (EMIC), MoBidiC, has simulated between 122 and 120 ka a southward migration of the tree line by 14° in latitude, from 72° to 58° N, and decrease in summer temperatures by 2–3°C in the midlatitudes (30–50° N) of Eurasia [3]. Detailed comparison between these simulations and palaeoenvironmental data is required to assess the ability of such models to simulate the observed climatic variability and to discuss the mechanisms responsible for it. However, this comparison is generally impaired by the lack of a reliable chronology of terrestrial records for that time period [4]. Pollen sequences from the continental realm covering the last interglacial period have often a time scale dependent on the marine stratigraphy [5] which is based either on the assumption that the whole MIS 5e interval coincides with the Eemian period on land [6,7] or that Eemian not only encompasses MIS 5e but much of MIS 5d as well [8] giving different time spans, from 12,000 to 23,000 yr, for the duration of the Eemian.

The Eemian Interglacial is recognised by a succession of tree-dominant pollen assemblage biozones, bracketed between open vegetations of the previous and succeeded glacial periods, which have a remarkable consistency right across temperate areas of western and northern Europe [9,10]. Further, palynological investigations of the maar lakes in central Italy, of the Greek long sequences of Ioannina and Tenagi–Philippon and of the southwestern Iberian margin core MD95-2042 show that the Eemian in the Mediterranean region can be brought into the same perspective as northwestern European sequences [11,12]. It has been shown recently, on the basis of the direct correlation between pollen and marine proxy records from deep sea core MD95-2042 [13,14] that the onset of the Eemian lagged the beginning of MIS 5e by 6000 yr and the accumulation of substantial ice volume (MIS 5e/5d, ~115–110 ka) was synchronous with a 5000 yr long lasting deciduous forest in southern Iberia. The U/Th-derived chronology of this Portuguese core and the varve-dated German sequences has allowed the reassessment of the chronology of the vegetational succession over the Eemian for these