Palaeogeography, Palaeoclimatology, Palaeoecology 459 (2016) 552–569

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Response of Central European SST to atmospheric pCO_2 forcing during the Oligocene – A combined proxy data and numerical climate model approach

Walliser E.O. [a], Lohmann G. [b], Niezgodzki I. [b,c], Tütken T. [a], Schöne B.R. [a,*]

[a] Institute of Geosciences, University of Mainz, Johann-Joachim-Becher-Weg 21, 55128 Mainz, Germany
[b] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Am Alten Hafen 26, 27568 Bremerhaven, Germany
[c] ING PAN - Institute of Geological Sciences Polish Academy of Sciences, Research Center in Kraków, Senacka 1, 31-002 Kraków, Poland

A R T I C L E I N F O

Article history:
Received 4 March 2016
Received in revised form 21 July 2016
Accepted 22 July 2016
Available online 26 July 2016

Keywords:
Sea surface temperature
Oxygen isotopes
Sclerochronology
Bivalve shell
Shark tooth
Global warming

A B S T R A C T

CO_2-induced global warming will affect seasonal to decadal temperature patterns. Expected changes will be particularly strong in extratropical regions where temperatures will increase at faster rates than at lower latitudes. Despite that, it is still poorly constrained how precisely short-term climate dynamics will change in a generally warmer world, particularly in nearshore surface waters in the extratropics, i.e., the ecologically most productive regions of the ocean on which many human societies depend. Specifically, a detailed knowledge of the relationship between pCO_2 and seasonal SST is crucial to understand interactions between the ocean and the atmosphere. In the present investigation, we have studied for the first time how rising atmospheric pCO_2 levels forced surface temperature changes in Central Europe (paleolatitude ~45 °N) during the mid-Oligocene (from ca. 31 to 25 Ma), a time interval of Earth history during which global conditions were comparable to those predicted for the next few centuries. For this purpose, we computed numerical climate models for the Oligocene (winter, summer, annual average) assuming an atmospheric carbon dioxide rise from 400 to 560 ppm (current level to two times pre-industrial levels, PAL) and from 400 to 840 ppm (= three times PAL), respectively. These models were compared to seasonally resolved sea surface temperatures (SST) reconstructed from $\delta^{18}O$ values of fossil bivalve shells (*Glycymeris planicostalis*, *G. obovata*, *Palliolum pictum*, *Arctica islandica* and *Isognomon maxillata sandbergeri*) and shark teeth (*Carcharias cuspidata*, *C. acutissima* and *Physogaleus latus*) collected from the shallow water deposits of the Mainz and Kassel Basins (Germany). Multi-taxon oxygen isotope-based reconstructions suggest a gradual rise of temperatures in surface waters (upper 30 to 40 m), on average, by as much as 4 °C during the Rupelian stage followed by a 4 °C cooling during the Chattian stage. Seasonal temperature amplitudes increased by ca. 2 °C during the warmest time interval of the Rupelian stage, with warming being more pronounced during summer (5 °C) than during winter (3 °C). According to numerical climate simulations, the warming of surface waters during the early Oligocene required a CO_2 increase by at least 160 ppm, i.e., 400 ppm to 560 ppm. Given that atmospheric carbon dioxide levels predicted for the near future will likely exceed this value significantly, the Early Oligocene warming gives a hint of the possible future climate in Central Europe under elevated CO_2 levels.

1. Introduction

Unabated CO_2 emissions will result in atmospheric concentrations of this greenhouse gas of over 900 ppm by the end of the current century (Collins et al., 2013) and up to 1800 ppm 300 years later (Zachos et al., 2008). In this scenario, surface temperatures are expected to increase significantly, specifically at higher latitudes, causing polar ice to melt and eventually disappear (e.g., Körper et al., 2013). Reduced meridional temperature gradients will lead to substantially different circulation patterns (e.g., Cai and Chu, 1998; Hansen et al., 2004) with major repercussions on seasonal to multi-annual climate dynamics (e.g., Marshall et al., 2001; Solomon et al., 2007), i.e., within the time-scales of human perception.

Despite the relevance for human societies and the global economy, it is still not well constrained how short-term climate variability will change in a generally warmer world (e.g., Collins et al., 2010). For example, will summers become hotter and winters colder, and how much for a given atmospheric pCO_2? How will seasonal temperature amplitudes change in nearshore surface waters? These settings are the ecologically most productive regions of the ocean on which many human societies depend, and they are particularly sensitive to short-term climate

* Corresponding author.
E-mail address: schoeneb@uni-mainz.de (B.R. Schöne).

http://dx.doi.org/10.1016/j.palaeo.2016.07.033