High-resolution statistical palynology reveals climatic changes in coastal wetlands of the Early Eocene proto-North Sea

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Abstract

Long-term effects of present global warming on ecosystems on timescales beyond those covered by the human record are mostly a matter of speculation. However, the reaction of ecosystems to global warming on different timescales can be inferred from detailed studies of greenhouse periods and short-term warming events as repeatedly known from the geologic past. The Early Eocene Climatic Optimum (EECO) and its superposed short-term warming events such as the Paleocene-Eocene Thermal Maximum (PETM) represent the last greenhouse period before today. It is especially suited for comparisons to the presently developing greenhouse since fauna and flora had already reached an evolutionary state similar to today. The sedimentary succession of the former Helmstedt Lignite Mining District in northern Germany includes the upper Paleocene to lower Eocene Schöningen Formation and the middle Eocene Helmstedt Formation in an estuarine setting at the southern edge of the proto-North Sea. It therefore covers the entire Paleogene greenhouse phase and its gentle demise almost continuously. Due to the interaction between changes in sea level, salt withdrawal in the subsurface and climate-related changes in runoff from the hinterland the area was subject to frequent changes between marine and terrestrial conditions.

A robust age model is now based on eustatic sea level changes, biostratigraphy, and radiometric ages as well as bulk organic carbon isotopic data. Negative carbon isotope excursions allow to identify long- and short-term hyperthermals of the early Eocene such as, e.g., the EECO and the PETM. Therefore, the more than 200 m thick succession with about 13 lignite seams of up to 15 m thickness offers the rare opportunity for tracing the effects of long-term changes and short-term perturbations of the climate on the diversity and composition of plant communities by using pollen and spores as proxies during ca. 10 million years of the late Paleocene to middle Eocene.
Here, we present high-resolution palynological analyses of several hundred samples from the lower part of the Schöningen Formation, which includes the PETM and other short-term warming events. Distinct changes in the palynoflora which are correlated with shifts in δ13C TOC values show that changes in the wetland vegetation can be attributed to known thermal events. However, multivariate statistical analyses also allow to identify successional stages within the peat-forming vegetation independent of climatic perturbations. They may have been related to changes in hydrologic conditions and/or nutrient resources and effects of peat aggradation. Therefore, the combination of a robust age model with high-resolution palynological analysis and the application of multivariate statistics allows for a unique insight into the dynamics of a terrestrial ecosystem during the Paleogene greenhouse.

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