Geophysical Research Abstracts
Vol. 15, EGU2013-8163, 2013
EGU General Assembly 2013

A terrestrial stable isotope record of rainfall pattern and extreme North Atlantic circulation dynamics during the Mid-Miocene Climatic Optimum in Central Europe

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Recent climate models predict that future global warming will affect Western Europe and the Mediterranean region primarily through a change in rainfall distribution leading to higher frequency droughts especially in the Mediterranean region. Understanding continental hydrology during past analogue warming phases is, therefore, key to evaluating the magnitude and persistence of probable future aberrations in European rainfall patterns. The Mid-Miocene Climatic Optimum (MMCO), between 17 and 15 Ma, is often regarded as a potential analogue to projections of future climate change. Here, we aim to document the impact of the MMCO on the hydrological cycle in Central Europe and relate changes in rainfall patterns to North Atlantic circulation dynamics. We present a highly resolved terrestrial oxygen isotope (δ^{18}O) record of Miocene rainfall (22.6 to 13.7 Ma) from carbonate-bearing paleosols in the North-Alpine foreland basin of Switzerland. Soil weathering profiles are commonly thick and consist of reddish pedogenic mudstones containing abundant carbonate concretions and calcified roots. Our high-resolution age model for these soils is based on magnetostratigraphy and bio-chronostratigraphy and allows resolving the fluctuation in δ^{18}O of rainfall over the MMCO with a resolution comparable to the marine stable isotopic record (ca. 100 ka). We identify as primary signal, significantly low δ^{18}O values restricted to the MMCO between 17.6 and 14.5 Ma recorded within both, mudstones (20.8 $\pm$ 0.9 ‰ SMOW) and carbonate nodules (19.8 $\pm$ 0.4 ‰ SMOW). The pedogenic carbonates then record an abrupt increase in δ^{18}O exceeding 2 ‰ , during the mid-Miocene climate transition (14.5 to 14 Ma). The first-order δ^{18}O pattern of the Alpine paleosols tracks the general trend of the benthic foraminifera δ^{18}O record of the North Atlantic; yet with much larger amplitude. These exceptionally low oxygen isotope ratios during the MMCO warm period require a change in seasonality to wetter conditions during the winter months and further a strengthened cold season hydrological cycle during global warming in Central Europe. We relate this increase in seasonality to a long-term establishment of a positive North Atlantic Oscillation mode that stabilized over the time of the MMCO (17.6 to 14.5 Ma) as a response to global warming. Such a circulation dynamics warrants stronger precipitation gradient between Northern and Southern Europe. If the MMCO indeed is an analogue for projected climate change, then a scenario of enhanced reduction in winter rainfall in Southern Europe and coeval summer droughts in the Mediterranean region are corroborated by our data.