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Climatic conditions governing extensive Azolla bloom during the Middle Eocene

Rolande Dekker (1), Eveline N. Speelman (1), Judith Barke (2), Tiuri Konijnendijk (1), Jaap S. Sinninge Damste (1,3), Gert-Jan Reichart (1,4)

(1) Utrecht University, Fac. of Geoscience, P.O.box 80021, Utrecht, Netherlands (r.dekker6@students.uu.nl), (2) Utrecht University, Institute of Environmental Biology, 3584 CD Utrecht, Netherlands, (3) Netherlands Institute for Sea Research (NIOZ), P.O.box 5, Texel, Netherlands, (4) Alfred Wegener Institute

Enormous amounts of intact mega- and microspores from the free floating aquatic fern Azolla were found in sediments recovered during Integrated Ocean Drilling Program expedition 302, indicating that Azolla grew and reproduced in situ in the Eocene Arctic Ocean. In general, the Early/Middle Eocene is characterized by enhanced greenhouse conditions with elevated sea surface temperatures (SSTs) in the Arctic (~10ºC), while tropical sea surface temperatures (SSTs) were only a little warmer than today (with a mean annual temperature (MAT) of 32-34 ºC) (Pearson et al., 2007). The consequently reduced temperature gradient between the equator and the poles and the presence of freshwater at the North Pole as indicated by the presence of the freshwater fern Azolla (Brinkhuis et al., 2006) provide important boundary conditions for understanding the hydrological cycle and latent heat transport during this interval.

Here we reconstruct variations in SST and mean annual air temperature using the TEX86 and MBT temperature proxies for the Azolla interval. Sediments from around the Arctic Basin have been analyzed, including samples from Alaska, the Mackenzie Basin, Greenland (IODP core 913b), and Denmark. Furthermore, a high resolution sea surface temperature record for the Azolla interval has been constructed from sediment samples from the Lomonosov Ridge, showing a cyclic signal.

Model experiments have shown that the here confirmed low equator-to-pole temperature gradient modulated the hydrological cycle. Since the growth of Azolla is restricted to low salinity conditions, changes in the hydrological cycle are proposed to coincide with the cyclic occurrence of Azolla throughout the interval. To confirm the overlapping presence of high quantities of Azolla and increased precipitation, changes in the hydrogen cycle are reconstructed by creating a high resolution hydrogen isotope record throughout the interval. By performing compound specific analyses (D) on terrestrial derived n-alkanes, extracted from Eocene Arctic sediment, an assessment of the D of incoming Arctic precipitation and humidity can be made. In addition, hydrogen isotope analyses on Azolla specific biomarker (1, 20 diols) is used to reconstruct the D composition of the surface waters. The results from the compound specific isotope analyses are combined with the outcomes of a coupled-atmosphere-isotope model. This model shows a reconstruction of the isotopic composition of Arctic Eocene precipitation and run-off. Data-model integration will make it possible to mechanistically link Azolla occurrences and precipitation patterns.