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Arctic Ocean circulation during the anoxic Eocene *Azolla* event

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The *Azolla* interval, as encountered in Eocene sediments from the Arctic Ocean, is characterized by organic rich sediments (4wt% Corg). In general, high levels of organic matter may be caused by increased productivity, i.e. extensive growth of *Azolla*, and/or enhanced preservation of organic matter, or a combination of both. Anoxic (bottom) water conditions, expanded oxygen minimum zones, or increased sedimentation rates all potentially increase organic matter preservation. According to plate tectonic, bathymetric, and paleogeographic reconstructions, the Arctic Ocean was a virtually isolated shallow basin, with one possible deeper connection to the Nordic Seas represented by a still shallow Fram Strait (Jakobsson et al., 2007), hampering ventilation of the Arctic Basin. During the *Azolla* interval surface waters freshened, while at the same time bottom waters appear to have remained saline, indicating that the Arctic was highly stratified. The restricted ventilation and stratification in concert with ongoing export of organic matter most likely resulted in the development of anoxic conditions in the lower part of the water column. Whereas the excess precipitation over evaporation maintained the freshwater lid, sustained input of Nordic Sea water is needed to keep the deeper waters saline. To which degree the Arctic Ocean exchanged with the Nordic Seas is, however, still largely unknown.

Here we present a high-resolution trace metal record (ICP-MS and ICP-OES) for the expanded Early/Middle Eocene section capturing the Azolla interval from Integrated Ocean Drilling Program (IODP) Expedition 302 (ACEX) drilled on the Lomonosov Ridge, central Arctic Ocean. Euxinic conditions throughout the interval resulted in the efficient removal of redox sensitive trace metals from the water column. Using the sedimentary trace metal record we also constrained circulation in the Arctic Ocean by assessing the relative importance of trace metal input sources (i.e. fluvial, eolian, and through seawater inflow). Excess vanadium accumulation during the *Azolla* event (80 ppm), basin volume and surface area, average vanadium sea (1.8 ppb) and river water (1.0 ppb) concentrations, together indicate that an inflow of Nordic Sea water of 0.2 Sv is needed to sustain vanadium levels. The same calculation using molybdenum gives an inflow of only 0.02 Sv. These low inflow rates imply Arctic Ocean (deep) water residence times of 2000 - 20000 years, respectively.

Based on climate modeling we calculated a summed net amount of precipitation for the Eocene Arctic Basin (Precipitation – Evaporation + Runoff) of 0.46 Sv. Together these notions indicate that a compensating inflow of saline North Atlantic water occurred, accompanied by an outflow of more fresh waters, resulting in a bi-directional, two-layer flow through the (proto-) Fram Strait. Consequently, the limited exchange of water through the Fram Strait implies that a relatively low export productivity would have been sufficient to render Arctic bottom waters anoxic.

Jakobsson, M., Backman, J., Rudels, B., Nycander, J., Frank, M., Mayer, L., Jokat, W., Sangiorgi, F., O'Regan, M., Brinkhuis, H., King, J., Moran, K. (2007). The early Miocene onset of a ventilated circulation regimen in the Arctic Ocean. *Nature* 447, 986–990.