EGU26-18109, updated on 15 Mar 2026
https://doi.org/10.5194/egusphere-egu26-18109
EGU General Assembly 2026
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Polar temperature seasonality from the Early Jurassic

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The phenomenon of polar amplification causes high-latitude warming to exceed the global mean and enhances seasonal variations in temperature and precipitation. As such, it complicates the understanding of both modern and past global warming impacts in polar regions. Characterizing the climate change in polar regions is further hampered by limited data coverage and persistent challenges in interpreting local paleoenvironmental archives.

To help address these knowledge gaps, we present bulk and seasonally resolved stable oxygen ($\delta^{18}O$) and clumped isotope (Δ□□) data from exceptionally well-preserved bivalves from the Early Jurassic North Pole (eastern Siberia), spanning the late Pliensbachian icehouse-Toarcian hothouse transition. Upper Pliensbachian *Harpax* specimens show pronounced seasonal $\delta^{18}O$ variability of 1.5-6 ‰, corresponding to apparent temperature ranges of 6-26 °C assuming invariant seawater $\delta^{18}O$. In contrast, seasonally resolved clumped isotope data do not yield a statistically significant seasonal temperature difference (1.4 ± 1 °C). Together with a low mean Δ□□ temperature of ~3.5 ± 1 °C, this discrepancy implies that the large $\delta^{18}O$ amplitude reflects strong seasonal variability in seawater $\delta^{18}O$, likely driven by enhanced precipitation, and/or meltwater input in a relatively proximal sedimentary setting with near-freezing mean annual temperatures.

By contrast, Toarcian *Dacryomya jacutica* specimens show reduced $\delta^{18}O$ variability of 1-2 ‰ (~4-8 °C) and a larger, statistically significant seasonal Δ□□ temperature difference of 5.9 ± 1.3 °C, with a mean Δ□□ temperature of ~10.3 °C. The agreement between $\delta^{18}O$ and Δ□□-derived seasonality indicates a limited contribution of seawater $\delta^{18}O$ variability during the Toarcian and points to a shift toward more distal sedimentary conditions. Collectively, these results provide one of the first quantitative constraints on Arctic temperature seasonality under greenhouse climate conditions in deep time.