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Temperature seasonality from the Early Jurassic North Pole

BARBORA KRIZOVA[1], THOMAS LETULLE[2], MATHIEU DAËRON[3], ARNAULD VINÇON-LAUGIER[4], MIKHAIL ROGOV[5], OLEG LUTIKOV[6], YANNICK DONNADIEU[7] AND GUILLAUME SUAN[8]

[1]Laboratoire de Géologie de Lyon: Terre - Planètes – Environnement, UMR CNRS 5276, Université Claude Bernard Lyon 1, ENS de Lyon
[2]University of Padova
[3]Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL)
[4]Laboratoire de Géologie de Lyon
[5]Geological Institute of Russian Academy of Sciences, Russia
[6]Laboratory of Phanerozoic Stratigraphy, Geological Institute of Russian Academy of Sciences, 119017 Moscow
[7]CEREGE, Aix Marseille University
[8]Univ Lyon, UCBL, ENSL, CNRS, LGL-TPE, F-69622, Villeurbanne, France

The effects of climate change manifest stronger in the polar regions compared to low latitude areas. During periods of global warming, this phenomenon of polar amplification results in faster temperature rise and more pronounced seasonality of temperatures and precipitation compared to the global mean. The driving mechanisms and paleo archives of this polar amplification during the recent and past global warming are still poorly understood, mostly because of low data coverage in high latitudes. An additional complication in interpreting past temperature proxies is the potential bias towards warmer seasons, due to growth cessation during the winter.

As an attempt to fill these knowledge gaps, we present bulk shell and seasonally resolved stable isotope data from exceptionally well-preserved Pliensbachian-Toarcian bivalves from Eastern Siberia, an area located near the North Pole during the Early Jurassic. Our bulk shell clumped isotope data indicate that the polar sea temperatures increased by ~10 °C from the late Pliensbachian icehouse to the Toarcian hothouse. Preliminary sclerochronological $\delta^{18}O$ profiles of the upper Pliensbachian bivalve *Harpax spinosus* show no signs of abrupt growth cessations. However, the significantly lower number of data points representing the cooler season suggests slower growth rates, which may lead to an overestimation of mean annual temperatures based on bulk shell analyses. Assuming a seasonally invariant seawater $\delta^{18}O$ value, the ~1-2 ‰ amplitude of $\delta^{18}O$ fluctuations would correspond to a seasonal temperature difference of ~4-8 °C. Given the low late Pliensbachian temperatures (3-4°C) estimated regionally using the *Harpax* bulk shell clumped isotope data, this seasonal range suggests sub-freezing seawater temperatures during the winter months, which aligns with both sedimentological and climate modeling evidence. However, our estimates of the seasonal temperature range could be misinterpreted if seawater $\delta^{18}O$ fluctuated seasonally, a possibility that will be tested using seasonally-targeted clumped isotope analyses.