Eocene sea surface temperature reconstructions from bivalve clumped isotope measurements

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Reconstructing meridional temperature gradients remains a critical problem in understanding Eocene climate. Recent reconstructions of peak Eocene sea surface temperatures have revised estimates towards warmer values in both the tropics and high latitudes. However, uncertainty due to proxy biases remains a concern, particularly regarding empirically calibrated organic paleothermometers. Carbonate clumped isotope paleothermometry offers a novel approach for reconstructing temperature from biogenic carbonates that does not require assumptions regarding the isotopic composition of seawater. Previous data (Came et al., 2007) and our preliminary measurements of modern bivalve carbonates suggest that clumped isotope paleothermometry records growing-season temperature in both aragonitic and calcitic bivalves.

We have applied clumped isotope paleothermometry to Eocene bivalves from Seymour Island, Antarctica (paleolatitude ~65°S) and from the U.S. Gulf Coastal Plain (~28°N). Peak early Eocene sea surface temperatures at Seymour Island are approximately 18°C, and decline to 13 to 14°C by the middle to late Eocene. Paired clumped isotope analyses of primary shell aragonite and secondary calcite cement suggests that clumped isotope measurements record shell growth temperatures and are not overprinted during burial. Reconstructed temperatures from Seymour Island are generally consistent with bivalve $\delta^{18}O$ derived temperatures based on a seawater $\delta^{18}O$ value of -1‰. However, these temperatures are as much as 14°C cooler than TEX_{86} derived temperatures from the East Tasman Rise at a similar paleolatitude. This discrepancy suggests either major zonal temperature heterogeneity at high latitudes, or unresolved biases affecting TEX_{86} paleothermometry in Eocene subpolar environments

Early Eocene bivalve clumped isotope temperatures from the U.S. Gulf Coast (Hatchetigbee Formation, Alabama) average 27 ± 2°C, a value that is corroborated by similar temperatures derived from bivalve $\delta^{18}O$ and MBT/CBT analyses. TEX_{86} analyses indicate slightly warmer temperatures averaging 28 ± 0.3°C using the reciprocal calibration of Liu et al. (2009). Clumped isotope measurements of seasonally-specific growth bands within bivalve shells indicate a small seasonal temperature range of 2 ± 2°C, whereas the large variability observed in $\delta^{18}O$ values indicates seasonal variation in precipitation and/or continental runoff. Our multiproxy temperature estimates from the Gulf Coast are cooler than other early Eocene reconstructions at both lower and higher latitudes.

Viewed together, Eocene clumped isotope paleotemperature estimates from Seymour Island and the U.S. Gulf Coast suggest a reduced temperature gradient between subtropical and subpolar regions relative to modern conditions, consistent with other studies. However, temperatures from both sites are cooler than recent paleotemperature estimates from similar latitudes, particularly compared to temperatures inferred from TEX_{86} measurements. These discrepancies point to either a large-scale zonal temperature variability in the Eocene, to significant differences between sea-surface and shallow benthic temperatures, or to unconstrained inter-proxy biases. Further multi-proxy studies involving clumped isotope measurements will help to resolve this question.