Winter temperatures drive climate change in the Paleogene subtropics

LINDA C. IVANY[1], JOCELYN A. SESSA[2], EMILY J. JUDD[3], ETHAN L. GROSSMAN[4], HAGIT P. AFFEK[5], AND PETER D. DOUGLAS[6]

[1]Syracuse University, Syracuse NY 13244 lcivany@yr.edu
[2]Academy of Natural Sciences of Drexel University, Philadelphia, PA 19103 js4558@drexel.edu
[3]Syracuse University, Syracuse NY 13244 ejjudd@yr.edu
[4]Texas A&M University, College Station, Texas 77843 e-grossman@tamu.edu
[5]The Hebrew University, Jerusalem 9190401 Israel Hagit.Affek@mail.huji.ac.il
[6] McGill University, Montreal, Quebec Canada H3A 0E8 peter.douglas@mcgill.ca

Mean annual temperature (MAT) is the currency for discussions of climate change in Earth's distant past, and with good reason of course. However, MAT is a balance between winter and summer seasonal extremes, and changes in MAT can be driven by changes in either or both of these. Seasonally resolved paleotemperature data are therefore required to resolve the fundamental underlying mechanisms through which mean climate change comes about. These data, however, are difficult and time consuming to generate, and datasets have thus far been mostly restricted in time and space.

We present data from more than 400 fossil bivalves, gastropods, otoliths, and corals spanning the Paleogene of the US Gulf Coastal Plain. Specimens were serially sampled along the axis of growth to yield 7,744 $\delta^{18}O$ analyses spanning 1,152 distinct years of data. Intra-annual temporal resolution is sufficient in 831 years to allow for model-based reconstructions of summer and winter temperatures, as well as MAT. Isotope-derived paleotemperatures are augmented by those from clumped isotopes on select shells and TEX_{86} analysis of sediment samples from key stratigraphic intervals, including the early Eocene climatic optimum window, which is largely devoid of skeletal carbonate.

Proxy-based MAT estimates suggest cooling from an early Eocene peak just above 30 °C to early Oligocene values in the low 20s. Seasonally resolved $\delta^{18}O$ data and model fits reveal an increase in seasonal range from the early Eocene through the early Oligocene from 3°C to 8°C. Cooling MAT is driven by a statistically significant decline in winter temperatures, while summer temperatures are largely unchanged throughout the section. The late middle Eocene is characterized by markedly higher variance in temperatures, perhaps due to inclusion of the warm middle Eocene climatic optimum episode in an otherwise cooler interval.