High-resolution Atmospheric $p$CO$_2$ Reconstruction across the Paleogene Using Marine and Terrestrial $\delta^{13}$C records

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The early Paleogene (63 to 47 Ma) is considered to have a greenhouse climate\(^1\) with proxies suggesting atmospheric CO$_2$ levels ($p$CO$_2$) approximately $\sim2\times$ pre-industrial levels. However, the proxy based $p$CO$_2$ reconstructions are limited and do not allow for assessment of changes in $p$CO$_2$ at million to sub-million year time scales. It has recently been recognized that changes in C$_3$ land plant carbon isotope fractionation can be used as a proxy for $p$CO$_2$ with quantifiable uncertainty\(^2\). Here, we present a high-resolution $p$CO$_2$ reconstruction ($n = 597$) across the early Paleogene using published carbon isotope data from both terrestrial organic matter and marine carbonates. The minimum and maximum $p$CO$_2$ values reconstructed using this method are broad (i.e., 170 +60/-40 ppmv to 2000 +4480/-1060 ppmv) and reflective of the wide range of environments sampled. However, the large number of measurements allows for a robust estimate of average $p$CO$_2$ during this time interval ($\sim400 +260/-120$ ppmv), and indicates brief (sub-million-year) excursions to very high $p$CO$_2$ during hyperthermal events (e.g., the PETM). By binning our high-resolution $p$CO$_2$ data at 1 million year intervals, we can compare our dataset to the other available $p$CO$_2$ proxies. Our result is broadly consistent with $p$CO$_2$ levels reconstructed using other proxies, with the exception of paleosol-based $p$CO$_2$ estimates spanning 53 to 50 Ma. At this timescale, no proxy suggests $p$CO$_2$ higher than 2000 ppmv, whereas the global surface ocean temperature is considered to be $>10^\circ$C warmer than today. Recent climate modeling suggests that low atmospheric pressure during this time period could help reconcile the apparent disconnect between $p$CO$_2$ and temperature and contribute to the greenhouse climate\(^3\).

References