# Climate and carbon-cycle response to astronomical forcing over the last 35 Ma.

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On a million-year time scale, the characteristics of insolation forcing caused by cyclical variations in the astronomical parameters of the Earth remain stable. Nevertheless, Earth's climate responded very differently to this forcing during different parts of the Cenozoic. The $\delta^{18}O_{benthic}$ megasplice (De Vleeschouwer et al., 2017) allowed for a clear visualization of these changes in global climate response to astronomical forcing. However, many open questions remain regarding how carbon-cycle dynamics influence Earth's climate sensitivity to astronomical climate forcing. To provide insight into the interaction between the carbon cycle and astronomical insolation forcing, we built a benthic carbon isotope ($\delta^{13}C_{benthic}$) megasplice for the last 35 Ma, employing the same technique used to build the $\delta^{18}O_{benthic}$ megasplice.

The $\delta^{13}C_{benthic}$ megasplice exhibits a strong imprint of the 405 and 100-kyr eccentricity cycles throughout the last 35 Ma. This is intriguing, as the oxygen isotope megasplice loses its eccentricity imprint after the mid-Miocene climatic transition (MMCT). In other words, the carbon cycle responded differently to astronomical forcing, compared to global climate during the late Miocene. We visualize this difference in response by the application of a Gaussian process, which renders the dependence of one variable (here $\delta^{13}C_{benthic}$ or $\delta^{18}O_{benthic}$) in a multidimensional space (here precession, obliquity and eccentricity). Together, the $\delta^{13}C_{benthic}$ and $\delta^{18}O_{benthic}$ megasplices thus provide a unique tool for paleoclimatology, allowing for the quantification and visualization of the changing paleoclimate and carbon-cycle response to astronomical forcing throughout geologic time. Finally, we compare the speed of carbon cycle perturbations in the geologic past with the speed of the ongoing human-induced disturbance of the carbon cycle: We find that the current rate of change in $\delta^{13}C_{benthic}$ exceeds the fastest carbon-cycle perturbations of the last 35 Ma.

De Vleeschouwer et al. (2017). *Geology* **45**, 375-378.