Carbon cycle constraints on the Cenozoic silicate weathering feedback

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During the mid-Cenozoic (35-24 Ma), there was a profound shift in Earth's climate, from the high temperatures and high pCO_2 of the Eocene to the relatively low temperatures and low pCO_2 of the Neogene. The mechanism(s) behind the nearly 700 ppm drop in pCO_2 across this transition, however, remain elusive. Here, we utilize the growing compilation of carbon (C) cycle proxies to quantify imbalances in the ocean-atmosphere C cycle over the Cenozoic. On 1 Ma timescales, C is input to the ocean-atmosphere reservoir via volcanism and organic C weathering and removed via silicate weathering and organic C burial. Our goal is to constrain the magnitude of permissible changes in the silicate weathering feedback given records of calcite compensation depth (CCD), atmospheric pCO_2, and carbonate burial.

First, we find that, over 1 Ma timescales, the C cycle over the Cenozoic has been remarkably balanced. Second, to explain the 700 ppm pCO_2 drop in the mid-Cenozoic, only approximately 10^{18} moles of C must be removed from the ocean-atmosphere reservoir. This quantity is equivalent to 30% of the total C in the modern ocean-atmosphere reservoir. Spread across the mid-Cenozoic, this removal flux represents an only 1-2% increase over the input fluxes.

To explain these results via changes in weathering requires a shift in the strength of the silicate weathering feedback. We define the strength of the weathering feedback as the relationship between chemical weathering fluxes and climate (or pCO_2). Hence, the shift in climate states across the mid-Cenozoic is attributed not to variations in the magnitude of the weathering flux, but to changes in the relationship between weathering fluxes and pCO_2 (or a change in the functional form of the weathering feedback). In the Eocene, the strength of the weathering feedback was lower than in the Neogene, resulting in potentially greater imbalances in the ocean-atmosphere C cycle and elevated pCO_2. Consequently, we show that this increase in the strength of the silicate weathering feedback can potentially explain the drawdown of pCO_2 across the mid-Cenozoic to the low pCO_2 characteristic of the Neogene.