Impact of oceanic circulation changes on atmospheric $\delta^{13}CO_2$

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$\delta^{13}CO_2$ measured in Antarctic ice cores provides constraints on oceanic and terrestrial carbon cycle processes linked with millennial-scale changes in atmospheric CO_2. However, the interpretation of $\delta^{13}CO_2$ is not straightforward.

Using carbon isotope-enabled versions of the LOVECLIM and Bern3D models, we perform a set of sensitivity experiments in which the formation rates of North Atlantic Deep Water (NADW), North Pacific Deep Water (NPDW), Antarctic Bottom Water (AABW) and Antarctic Intermediate Water (AAIW) are varied.

We study the impact of these circulation changes on atmospheric $\delta^{13}CO_2$ as well as on the oceanic $\delta^{13}C$ distribution.

In general, we find that the formation rates of AABW, NADW, NPDW and AAIW are negatively correlated with changes in $\delta^{13}CO_2$: namely strong oceanic ventilation decreases atmospheric $\delta^{13}CO_2$. However, since large scale ocean circulation reorganizations also impact nutrient utilization and the Earth's climate, the relationship between atmospheric $\delta^{13}CO_2$ levels and ocean ventilation rate is not unequivocal. In both models atmospheric $\delta^{13}CO_2$ is very sensitive to changes in AABW formation rates: increased AABW formation enhances the transport of low $\delta^{13}C$ waters to the surface and decreases atmospheric $\delta^{13}CO_2$. By contrast, the impact of NADW changes on atmospheric $\delta^{13}CO_2$ is less robust and might be model dependent. This results from complex interplay between global climate, carbon cycle, and the formation rate of NADW, a water body characterized by relatively high $\delta^{13}C$.