**Updated Time-varying Maps of Surface Ocean $\delta^{13}C$ of DIC and the $^{13}CO_2$ Isotopic Disequilibrium Flux with Uncertainty**

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Estimates of spatial and temporal patterns in the $^{13}C$:$^{12}C$ ratio (expressed as $\delta^{13}C$) of surface ocean dissolved inorganic carbon (DIC) are essential for interpreting atmospheric $\delta^{13}C$ of $CO_2$. The work described here is part of a larger project focused on using atmospheric $CO_2$ and $\delta^{13}C$ measurements to quantify terrestrial and oceanic net carbon fluxes as well as isotopic fractionation by terrestrial plants. Previously, we compiled a dataset of more than 8700 surface ocean $\delta^{13}C$ of DIC measurements collected from research vessels and ships of opportunity from 1978 to 2018. In this analysis, we use a trend analysis over different regions of the global oceans and the approach of Takahashi et al. [2009] to create monthly maps of $\delta^{13}C$ of DIC on a 4˚ (latitude) x 5˚ (longitude) spatial grid from 1990 to 2021. These values are then used to calculate the $^{13}C$ isotopic disequilibrium flux at the same spatial and temporal resolution. The uncertainty of the $\delta^{13}C$ of DIC is estimated using cross-validation whereby surface ocean $\delta^{13}C$ of DIC observations are withheld and then compared to gridded predictions. We then use the cross-validation statistics to inform a Monte Carlo scheme to estimate the uncertainty of $^{13}C$ isotopic disequilibrium flux for each grid cell. We use the same Monte Carlo scheme to assess the uncertainty of both the gross and net air-sea $CO_2$ flux from 1990 to 2021 and compare this uncertainty to the spread of estimates based on widely-available surface ocean partial pressure of $CO_2$ ($pCO_2$) products covering the same time interval. We find that uncertainties related to air-sea gas exchange can be substantial relative to the spread among estimates due only to differences in the $pCO_2$ product used in the flux estimate.

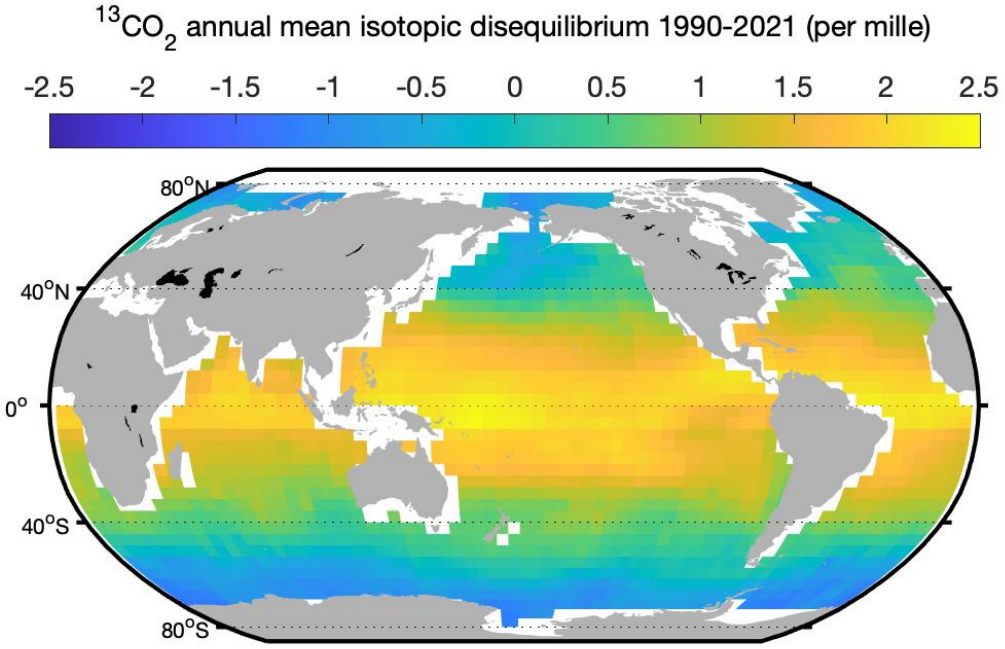


**Figure 1.** Fig. 1. Annual mean $^{13}CO_2$ isotopic disequilibrium in per mille for 1990-2021.