Atmospheric signatures of large-scale variations in the isotopic fractionation of terrestrial photosynthesis.

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The CO_2 flask program at the Scripps Institution of Oceanography has resolved trends in the $^{13}C/^{12}C$ isotopic composition of atmospheric CO_2 from 1977 to present. A major feature of these data is a secular trend towards lower $\delta^{13}C$ values, known as the carbon-13 Suess effect. The ^{13}C Suess effect, like that for ^{14}C, is driven primarily by the input of CO_2 from fossil fuels. Fossil-fuels are slightly depleted in ^{13}C because they were ultimately formed from photosynthesis, which involves selective uptake of $^{12}CO_2$ over $^{13}CO_2$. The emission of fossil-fuel CO_2 therefore lowers the atmospheric $^{13}C/^{12}C$ ratio. A second important influence on the ^{13}C Suess effect is natural back-and-forth exchanges of CO_2 with land and ocean carbon reservoirs. These gross exchanges, also known as "isofluxes" or “disequilibrium fluxes”, scramble carbon atoms between reservoirs, thereby spreading the Suess effect into the land and oceans while reducing the atmospheric signal. A third influence is net gains or loss of carbon by the land biosphere, which is depleted in ^{13}C because of photosynthesis, similar to fossil-fuels. A sink for excess CO_2 on land therefore offsets the influence of fossil-fuel burning, not just on CO_2 amount, but also on its isotopic composition. In contrast, ocean uptake of excess CO_2 has little influence on $\delta^{13}C$ of atmospheric CO_2.

Here we update these records and compare them to results of a simple global carbon cycle model which treats the atmosphere and land biospheres as well-mixed reservoirs and the ocean as a 1-D diffusive system. Rather than focusing on using the $\delta^{13}C$ and CO_2 concentration data to resolve global land and ocean carbon sinks, we instead use the data/model comparison to show that there must exist an additional process, previously neglected, that reduces the atmospheric $\delta^{13}C$ Suess effect. The need for this process has become more evident as the records have grown in length. We suggest that the missing process is a systematic global increase in the isotopic discrimination of land photosynthesis. This increase has implications for global trends in leaf-level water-use efficiency, which will be discussed.