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Interannual variations in $\Delta(^{17}O)$ of atmospheric CO_2 suggest a strong link with stratospheric input

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We present multiple year records of the triple oxygen isotope signature $\Delta(^{17}O)$ of atmospheric CO_2 conducted with laser absorption spectroscopy, from Lutjewad in the Netherlands (53° 24'N, 6° 21'E) and Mace Head in Ireland (53° 20' N, 9° 54' W). Measurements were done on flask samples covering the period 2017-2022. The average uncertainty of 0.07 ‰ is about 3 times smaller than the total observed variability. A positive $\Delta(^{17}O)$ originates from intrusions of stratospheric CO_2, whereas values close to zero result from equilibration of CO_2 and water, predominantly happening inside plants due to enhanced dissolution in the presence of carbonic anhydrase. A biosphere driven seasonal signal is, however, not observed in the records. Both records show significant interannual variability, of up to 0.3 ‰. The total range covered by smoothed monthly averages from the Lutjewad record is -0.065 to 0.046 ‰, which is significantly higher than the range of -0.009 to 0.036 ‰ that was simulated with a 3-D transport model. One of the major model uncertainties is the representation of the stratospheric influx of $\Delta(^{17}O)$. We modified the model using the 100 hPa 60-90° North monthly mean temperature anomaly as a proxy to scale stratospheric downwelling. This results in a strong improvement of the correlation coefficient of the simulated and the observed year-to-year $\Delta(^{17}O)$ variations at Lutjewad over 2019 and 2022 from 0.37 to 0.81 (N=22). To infer terrestrial carbon fluxes, the contribution of the stratosphere to the observed signal should therefore be considered. In fact, as the $\Delta(^{17}O)$ of atmospheric CO_2 seems to be dominated by stratospheric influx, it might be used as a tracer for stratosphere-troposphere exchange. To further study the potential of $\Delta(^{17}O)$ of atmospheric CO_2 as a tracer for stratosphere-troposphere exchange at Lutjewad, we installed a laser absorption spectrometer at the measurement station for in-situ measurements. At Lutjewad numerous other atmospheric species are monitored, such as N_2O, Rn and ^{14}C. This will enable us to deepen our knowledge on the mechanisms that drive the interannual variability of $\Delta(^{17}O)$ of atmospheric CO_2 that we observe at Lutjewad.