AGU FALL MEETING

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13–17 December 2021

GC25C-0665 - Lifetime of Excess Atmospheric Carbon Dioxide

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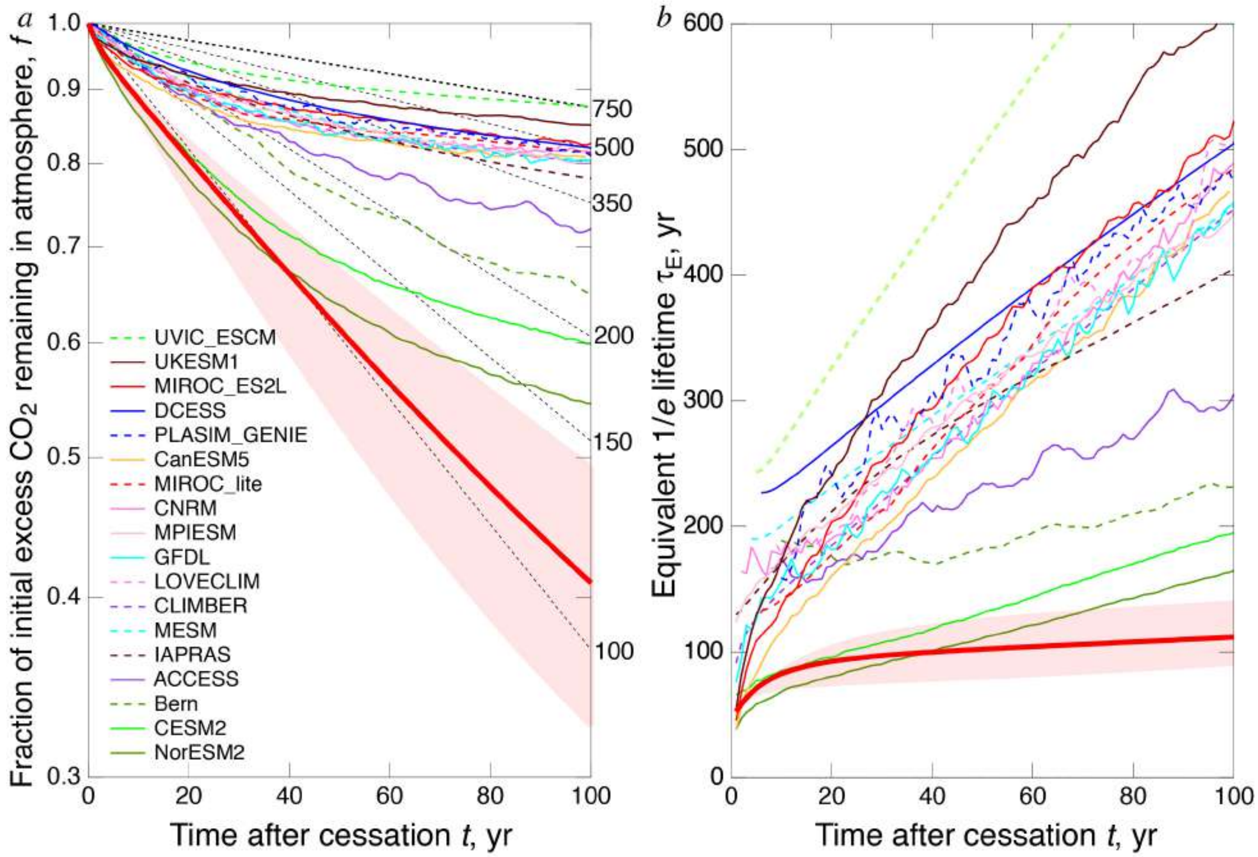
Abstract

The lifetime of excess atmospheric CO_2 (above preindustrial) x_{CO2} governs the future consequences of present x_{CO2} and those of future CO_2 emissions. Recent assessments of the decrease of x_{CO2} following abrupt cessation of anthropogenic emissions (zero emissions commitment, ZEC) inferred from studies with carbon-cycle (CC) models (*e.g.*, Joos *et al.*, *ACP*, 2013; MacDougall *et al.*, *BG*, 2020) vary substantially, with the fraction of x_{CO2} remaining in the atmosphere 100 years after cessation, $f_{CO2}(100) = x_{CO2}(100)/x_{CO2}(0)$, ranging from 0.55 to 0.85 (Figure 1*a*; Schwartz, *JGR*, 2018; Schwartz, in review).

In this study prior atmospheric and oceanic CO_2 and future x_{CO2} for ZEC were calculated with a 5-compartment global model. Model compartments are the atmosphere, upper and deep ocean, and labile and obdurate terrestrial biosphere (TB). Model parameters are obtained mainly from observation (*e.g.*, rate of uptake of heat by the deep ocean) and theory (*e.g.*, CO_2-dependent solubility of CO_2 in seawater); uptake of CO_2 by the two TB compartments is apportioned by parameterization, with parameters rather narrowly constrained by observations of CO_2 and radiocarbon. CO_2 is found to decay much more rapidly than in CC models; $f_{CO2}(100) = 0.41 \pm 0.8$ (1 σ), Figure 1*a*. These results indicate that cessation of anthropogenic CO_2 emissions would result in discernible decrease in atmospheric CO_2 on a time scale as short as a human lifetime, much faster than in current CC models.

Shown in Figure 1*b* is a quantity denoted $\tau_E(t)$, the equivalent 1/*e* lifetime of x_{CO2}, as a function of time subsequent to cessation of emissions *t*, evaluated as $\tau_E(t) = -1/\ln f_{CO2}(t)$. $\tau_E(t)$ is a generalization of the relation between half-life of a decaying quantity and its 1/*e* lifetime and is an integral measure of decay over time *t*. The present model yields $\tau_E(t)$ of excess atmospheric CO_2 about 100 years, much shorter than obtained with current CC models.

Figure 1. *a*, Fractional excess CO_2 $f_{CO2}(t)$ as function of time *t* following abrupt cessation of anthropogenic CO_2 emissions as calculated in a recent model intercomparison (MacDougall *et al.*, 2020) and with present model (best estimate, thick red, and uncertainty range); dotted black lines denote exponential decay with lifetime indicated at right. *b*, Equivalent 1/*e* lifetimes as function of *t*.



Plain-language Summary

Knowledge of the lifetime of excess atmospheric CO_2 (above preindustrial) x_{CO2} is essential to assess the consequences of present x_{CO2} and of future CO_2 emissions. Recent assessments of decrease of x_{CO2} following abrupt cessation of anthropogenic emissions (zero emissions commitment, ZEC), as inferred from studies with carbon-cycle (CC) models vary substantially, with the fraction of x_{CO2} remaining in the atmosphere 100 years after cessation f_{CO2}(100 yr) ranging from 0.55 to 0.85. Here a 5-compartment global model was used to calculate prior atmospheric and oceanic CO_2 (based on emissions history) and future x_{CO2} for ZEC. Model compartments are the atmosphere, upper and deep ocean, and labile and obdurate terrestrial biosphere (TB). Model parameters are obtained mainly from observation and theory; apportionment of uptake of CO_2 by the two TB compartments is parameterized, with parameters rather narrowly constrained by observations of CO_2 and radiocarbon. Decay of CO_2 is much more rapid than obtained with current CC models, with f_{CO2}(100 yr) = 0.41 ± 0.8. These results indicate that cessation of anthropogenic CO_2 emissions would result in discernible decrease in atmospheric CO_2 on a time scale as short as a human lifetime, much greater decrease than calculated with current CC models.