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What can be learned about carbon cycle climate feedbacks from the CO2 airborne fraction?

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The ratio of CO2 accumulating in the atmosphere to the CO2 flux into the atmosphere due to human activity, the airborne fraction AF, is central to predict changes in earth's surface temperature due to greenhouse gas induced warming. This ratio has remained remarkably constant in the past five decades, but recent studies have reported an apparent increasing trend and interpreted it as an indication for a decrease in the efficiency of the combined sinks by the ocean and terrestrial biosphere. We investigate here whether this interpretation is correct by analyzing the processes that control long term trends and decadal-scale variations in the AF. To this end, we use simplified linear models for describing the time evolution of an atmospheric CO2 perturbation. We find firstly that the spin-up time of the system for the AF to converge to a constant value is on the order of 200–300 years and differs depending on whether exponentially increasing fossil fuel emissions only or the sum of fossil fuel and land use emissions are used. We find secondly that the primary control on the decadal time-scale variations of the AF is variations in the relative growth rate of the total anthropogenic CO2 emissions. Changes in sink efficiencies tend to leave a smaller imprint. Therefore, before interpreting trends in the AF as an indication of weakening carbon sink efficiency, it is necessary to account for trends and variations in AF stemming from anthropogenic emissions and other extrinsic forcing events, such as volcanic eruptions. Using atmospheric CO2 data and emission estimates for the period 1959 through 2006, and our simple predictive models for the AF, we find that likely omissions in the reported emissions from land use change and extrinsic forcing events are sufficient to explain the observed long-term trend in AF. Therefore, claims for a decreasing long-term trend in the carbon sink efficiency over the last few decades are currently not supported by atmospheric CO2 data and anthropogenic emissions estimates.