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A model-based constraint on CO_2 fertilisation

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We calibrate Earth system model parameters, applying the constraint of the post-industrial increase of atmospheric CO_2 concentration, in order to derive a probabilistic estimate of the strength of CO_2 fertilisation of the terrestrial biosphere. This estimate is independent of CO_2 enrichment experiments and is implicitly net of other limiting factors such as nutrient availability. It is essential to consider the uncertain emissions due to land use change (LUC) in an analysis of this type. We describe the LUC scheme for the GENIE Earth system model that we have developed for this purpose.

We first built an emulator of the change in atmospheric CO_2 concentration (1850 to 2000), using output from an ensemble of GENIE simulations. This emulator allows us to fully and evenly probe the 28-dimensional input parameter space. A Bayesian calibration of the emulator suggests that the increase in gross primary productivity (GPP) in response to a doubling of CO_2 from preindustrial values is very likely (90% confidence) to exceed 20%, with a most likely value of 40-60%. We additionally derive calibrated estimates of globally integrated carbon fluxes. These are consistent with existing estimates. The present-day land-to-atmosphere flux (1990-2000) is estimated at -0.7 GTCyr-1 (likely, 66% confidence, in the range 0.4 to -1.7 GTC yr-1). The present-day ocean-to-atmosphere flux (1990-2000) is estimated to be -2.3 GTCyr-1 (likely in the range -1.8 to -2.7 GTC yr-1). We estimate cumulative net land emissions over the post-industrial period (land use change emissions net of the CO_2 fertilisation and climate sinks) to be 66 GTC, likely to lie in the range 0 to 128 GTC.

It is important to note that we do not represent all of the possible contributing mechanisms to the terrestrial sink. The missing processes are therefore subsumed into our calibration of CO_2 fertilisation. If the missing processes comprise a net sink then our estimate represents an upper bound.