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Future evolution of coral reef carbonate production from a global climate-coral reef coupled model

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Coral reefs are currently under threat due to climate change and ocean acidification. However, future atmospheric CO_2 levels, climate change and associated impacts on coral reefs remain uncertain. Critically, corals not only respond to atmospheric and climatic conditions but modify them. The calcification of corals modifies the concentration of dissolved inorganic carbon and total alkalinity in the upper ocean, impacting air-sea gas exchange, atmospheric CO_2 concentrations, and ultimately climate. These feedbacks between atmospheric conditions and coral biogeochemistry can only be accounted for with a coupled coral-carbon-climate model.

To simulate coral-mediated climate-carbon interactions, we have implemented a coral reef calcification module into the iLOVECLIM Earth system model of intermediate complexity. We then performed an ensemble of 210 parameter perturbation simulations to derive carbonate production parameter values that optimise the simulated distribution of coral reefs and associated carbonate production rates. The tuned model simulates the presence of coral reefs and regional-to-global carbonate production values in good agreement with data-based estimates. We have used this new coupled model to project future changes in coral reef carbonate production. The use of a computationally efficient intermediate complexity model allows us to cover a large range of possible futures that encompass different emissions scenarios (SSPs), climate sensitivities (hence different levels of warming) as well as the possibility of coral reefs adapting to higher SSTs which would reduce the risk of bleaching. We found a high sensitivity of the simulations to the ability of corals to adapt to thermal changes and to climate sensitivity, with the possibility of 20 to 100% coral extinction in scenario SSP1-2.6 depending on these parameters. This highlights the importance of improving the constraints on these factors in models and observations.