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Assessing global macroalgal carbon dioxide removal potential using a high-resolution ocean biogeochemistry model

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Carbon dioxide removal (CDR) has become part of the portfolio of solutions to mitigate climate change. In combination with emission reductions, CDR may be critical to achieving the goal of limiting global warming to below 2°C, as outlined in the Paris Agreement. Due to its potential high productivity and environmental co-benefits, macroalgae cultivation has recently become a prominent ocean-based CDR strategy. However, estimates of the CDR potential of large-scale deployment are highly limited. Here we simulate idealized global deployment of macroalgae-based CDR using the NEMO-PISCESv2 ocean biogeochemical model at high spatial resolution (0.25° nominal horizontal resolution). Macroalgae growth is confined to the upper 100m of the water column in Exclusive Economic Zones (EEZ) free of sea ice and with an appropriate nitrate/phosphate regime. Although the loss of dissolved inorganic carbon (DIC) through macroalgal growth enhances the flux of atmospheric carbon into the ocean, this increase in carbon uptake is less than the rate of macroalgal production. In the absence of any nutrient limitation on growth, the enhancement in ocean carbon uptake is only 73-77% of the carbon lost from the water column due to macroalgal production. However, when macroalgae nutrient limitation/uptake is additionally accounted for, the increase in ocean carbon uptake accounts for only 41-42% of the potential carbon lost through macroalgae production. These inefficiencies are due to ocean transport replacing part of the DIC lost in the upper water column with DIC from depth, the influence of local nutrient concentrations on the vertical profile of macroalgal production, and feedbacks on the nutrient resources available for phytoplankton net primary production. CDR efficiency is shown to scale near-linearly between scenarios assuming 1% to 10% of the global EEZ area is cultivated for macroalgae. The efficiency of macroalgal CDR shows significant regional variability, with much of the enhancement in ocean carbon uptake (43%-46%) occurring outside EEZs, posing potential difficulties to national scale accounting.