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Pathways for avoiding ocean biogeochemical damage: Mitigation targets, mitigation options, and projections

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Tipping points are thresholds beyond which large, abrupt and possibly irreversible changes in the climate system or in large scale ecosystems would occur. The crossing of such tipping points under anthropogenic forcing poses a threat to biodiversity, food security, and human societies. However, due to the complexity of the processes involved, it remains notoriously difficult to determine exact thresholds that need to be avoided to stay within a “safe operating space” for humanity. Here, we map, for a variety of mitigation metrics, the crossing of thresholds, which we define to represent a wide range of deviations from the unperturbed state. We assess the crossing of these thresholds in a wide range of plausible future emission pathways: two climate mitigation scenarios (one with a strong overshoot) and one no-mitigation high-emissions scenario. These scenarios are simulated by the latest generation of Earth system models and by two Earth system models of intermediate complexity, for which we created large perturbed-parameter ensembles. Using this comprehensive model database we provide estimates of when and at which warming level 4 mitigation targets (thresholds) for 14 different impact metrics are exceeded along with an assessment of uncertainties. We find that under the high-emissions scenario, even the highest thresholds for many of the impact metrics are exceeded with high confidence, such as the expansion of ocean areas that are undersaturated with respect to aragonite, decreases in plankton biomass, Arctic summer sea ice extent, strength of the Atlantic meridional overturning circulation (AMOC), and subsurface oxygen concentration. The risk of exceeding a given mitigation target decreases under low-emissions and overshoot scenarios. Yet, exceedance of ambitious targets for aragonite undersaturation, Arctic summer sea ice extent, and steric sea level rise (SSLR) are projected to be difficult to avoid (high confidence) even under the low-emissions scenario. The overshoot scenario reduces the risk of exceeding mitigation targets related to Arctic summer sea ice extent, SSLR, AMOC and plankton biomass compared to the high-emissions scenario, particularly in the long-term. Uncertainties in Earth system model projections of net primary production prevent us from concluding on the risk of mitigation target exceedance for this impact

metric.