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Projecting net primary production in a sea of uncertainty: next steps and why should we care?

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Ocean net primary production (NPP) consists of CO2 fixation by marine phytoplankton and hence supports most marine food webs, fisheries and ocean carbon sequestration. Recent Earth System Model (ESM) projections of NPP changes under global warming scenarios, performed as part of the 6th phase of Coupled Model Intercomparison Project (CMIP6), show large uncertainty both in the magnitude and spatial distribution of NPP, which may have consequences for assessing ecosystem impacts and ocean carbon uptake. NPP uncertainty has increased since the previous intercomparion project (CMIP5), and likely does not even capture the full range of possible outcomes due to the general simplicity of ecosystem parameterizations employed in ESMs and the failure to account for non-climate drivers. Here, we exploit the full set of ESM projections from CMIP6, documenting NPP uncertainties and identifying certain physical and biogeochemical mechanisms that give rise to these uncertainties. We then use different versions of the IPSL ESM to explore (1) the specific role of N-fixation by diazotrophs in the upper ocean and (2) the influence of coupling to higher trophic levels in shaping the response of NPP, marine ecosystems and biogeochemistry to anthropogenic climate change. We show that the response of N-fixation to global warming is a key driver of NPP projection uncertainties in the coming decades, even determining the sign of the global NPP response. Despite contrasting projections of future NPP, all our model versions simulate similar and significant reductions in planktonic biomass. This suggests that plankton biomass may be a more robust indicator than NPP of the potential impact of anthropogenic climate change on marine ecosystems across models. In a second step, we show that an explicit coupling to higher trophic levels modifies the response of lower trophic levels (plankton) and shifts the ecosystem equilibrium, but seems to have limited influence on 21st century anthropogenic carbon uptake under the RCP8.5 high emissions scenario. These results provide new insights regarding the expectations for trophic amplification of climate impacts through the marine food chain and regarding the necessity to explicitly represent marine animals in Earth System Models.