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# Oceanic $N_2O$ emissions in the $21^{st}$ century

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Climate change will cause multiple perturbations in ocean biogeochemistry during the next century. Changes in temperature, carbonate chemistry, salinity and dissolved oxygen concentration will drive changes which remain highly uncertain, especially in the oceanic nitrogen cycle. Of particular interest regarding feedbacks to the Earth System are the oceanic emissions of nitrous oxide. $N_2O$ is a powerful greenhouse gas with a residence time of more than 100 years in the atmosphere. Moreover, $N_2O$ has been identified as the leading ozone depletion emission since 2010.

Oceanic $N_2O$, with an annual contribution of 3.6 Tg N and hence 30% of the total natural sources, is produced by bacterial processes called nitrification and denitrification. These processes are enhanced in regions of high productivity, with denitrification occurring where oxygen concentrations are low, typically below 60 $\mu$mol/L. Different parameterizations for $N_2O$ production have been proposed over the past decade and considered by current ocean biogeochemical models. However, significant uncertainties remain in particular with respect to the future evolution of $N_2O$ production under climate change.

We implemented several published parameterizations of $N_2O$ production into the biogeochemical model PISCES and estimated the change in $N_2O$ production, inventory and $N_2O$ sea-to-air flux between 2005 and 2100, under the high emission scenario RCP8.5. This approach is complemented by an offline analysis of 8 model output datasets which contributed to the Coupled Model Intercomparison Project (CMIP5).

Projections of $N_2O$ flux from the ocean to the atmosphere yield a 5% decrease on average in 2100. North- and southwest basins in the Pacific and Atlantic oceans show the largest reduction in $N_2O$ emissions, while the flux tends to increase in regions where the Oxygen Minimum Zones (OMZs) are located, i.e., Eastern Tropical Pacific and Bay of Bengal. The projected expansion of the OMZs, from 6.5 to 8.5 $10^6$ $km^3$in our experiments, will be responsible for a 10% increase in the $N_2O$ inventory at the Eastern Tropical Pacific that could be potentially outgassed.

Two mechanisms are identified as the main drivers for the overall decrease in $N_2O$ flux. On the one hand, there is a weakening of the sequence primary production - export of organic matter to depth - remineralization of organic matter, and hence $N_2O$ production via nitrification. On the other hand, the increasing stratification slows down the $N_2O$ transport from the ocean interior to the surface.

The consistency of our model experiments with the analysis of other CMIP5 model projections give robustness to the hypothesis that the two mechanisms proposed -reduction in export production and increase in stratification- are the main regulators of future oceanic $N_2O$ emissions to the atmosphere.