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Towards a coupled nitrogen cycle representation in NorESM – ocean biogeochemistry

Joeran Maerz[1], Dirk Jan Leo Olivié[2], Tomas Torsvik[1], and Christoph Heinze[1]
[1]Geophysical Institute and Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway (joeran.maerz@uib.no)
[2]Norwegian Meteorological Institute, Oslo, Norway

The nitrogen cycle is substantially anthropogenically perturbed with potential negative consequences on biogeochemical cycles, for the climate and society. Within the project ESM2025, we therefore aim at an improved representation and interactive, emission-driven nitrogen cycle in the Norwegian Earth system model (NorESM) to foster providing information about future societal impacts.

We here focus on the ocean biogeochemistry component iHAMOCC of NorESM, where major upgrades have been carried out with a particular focus on processes related to the highly potent greenhouse gas N_2O. We included two more tracers, namely NH_4^+ and NO_2^-, which enabled an explicit representation of major canonical ocean nitrogen cycle pathways in both, the water column and the sediment. The in parallel substantially improved atmosphere chemistry of NorESM enabled us to realize the thus far technical capability to interactively couple air-sea N_2O and NH_3 fluxes as well as receiving atmospheric dry and wet deposition fluxes in the form of NH_x and NO_y. Concomitantly, interactive atmosphere-land N_2O and nitrogen deposition fluxes were implemented, further increasing NorESMs capability for coupled nitrogen cycle simulations. The improved NorESM atmosphere and ocean component are currently individually in fine-tuning and spin-up phase in close preparation for first interactively coupled simulations.

Preliminary, partially still in transient ocean-only climatological atmosphere-forced simulations show a reasonable oceanic N_2O emission pattern, also quantitatively close to recent reconstructions of Yang et al. 2020 (4.2 TgN/yr, doi:10.1073/pnas.1921914117), while the global ammonia emissions are at the lower end of current estimates (2-27 TgN/yr). With the current improved oceanic nitrogen cycle representation, N_2O production during nitrification in well-ventilated areas is closely linked to primary production through subsequent decay and ammonification of organic nitrogen. By contrast, the transition zones of oxygen deficit zones (ODZs) entail microbial key processes of both aerobic and anaerobic N_2O production and anaerobic N_2O consumption, making those regions to hotspots of nitrogen cycling relevant to N_2O. For the sediments, productive ocean and shelf regions feature higher N_2O sediment-water column fluxes per unit area than deep sea regions, in line with current observational knowledge. In total, however, the sediments globally contribute significantly less to N_2O production than the water column. In brief, future evolution of export fluxes and ODZs can hence be expected to determine the oceanic N_2O release in response to ongoing climate change.

With the recent developments in NorESM, we increased the representation of nitrogen cycle-relevant processes and enhanced the thus far technical capability to simulate the nitrogen cycle emission-driven and interactively coupled across major Earth system components, while envisaging to also increase NorESMs land-ocean nitrogen transport representation.