NEMO-MEDUSA

Model type: MEDUSA is the marine biogeochemistry component of the UK Earth System Model (UKESM1) which will be used for the next IPCC Assessment Report (AR6). It was selected for this role through a UK-wide inter-comparison of similar biogeochemical models[1]. MEDUSA is a plankton ecosystem model founded on the base biogeochemical cycles of nitrogen, silicon, iron, carbon and oxygen. The biological components included are the phytoplankton (plants) and zooplankton (animals) at the bottom of the food chain, together with the non-living organic matter that is produced by them (including that in seafloor ecosystems). MEDUSA has been developed to study the processes of nutrient cycling, the fate of anthropogenic CO_2, ocean acidification and the impact of climate change on marine ecosystems. Global-scale simulations of MEDUSA exist at a range of resolutions from low (1-degree) to high (1/12-degree). Though always simulated globally, a particular regional focus of MEDUSA is the Arctic Ocean, where climate change is having its most pronounced effects, both in terms of the physical environment (e.g. sea-ice) and marine ecology (e.g. enhanced productivity). MEDUSA is coupled with the Nucleus for European Modelling of the Ocean (NEMO) general circulation model. The NEMO model is used with an off-line module, Ariane, for lagrangian investigations such as marine pollution assessment.

Existing Models for UK shelf seas:

NEMO-MEDUSA has been developed for global applications, and validation has naturally focused at the large scale, such as basins, ahead of fine-scale regions like the UK shelf. However, future versions of NEMO-MEDUSA will include more detailed representations of shelf and coastal physical processes, as well as assessments of its performance at regional scales, including the UK shelf seas.

Existing uses:

- Impacts of climate change and direct anthropogenic stressors (e.g. anthropogenic input of nutrients) on the functioning of marine ecosystems.
- Detailed regional (e.g. Arctic, marine hotspots) impact assessments of future change, especially that of key ocean currents and larger-scale circulation.
- Marine ecosystem climate change indicators and climate multi-stressors for the global domain and LMEs, including indices of marine ecosystem vulnerability.
- Provision of physical and biogeochemical projections for system models engaged in the development of strategies for adaptation to climate change (e.g. for coastal communities dependent on living marine resources).
- Forward projections of extreme ocean events that affect marine ecosystems (e.g. changes in SST, upwelling and stratification regimes, ocean circulation).

Potential new uses:

- Assessing the impact of major pollutants on marine ecosystems (e.g. large-scale spills, Fukushima-style events).
- As its highest resolution approaches fully-resolved shelf dynamics, expanding shelf applications of the model (e.g. harmful algal blooms, anthropogenic eutrophication, deoxygenation of the shelf and coastal zones).
- Developing online decision-making tools for the impact of climate change on living marine resources.
- Assessing the sustainability of mesopelagic fish as a food resource and / or as a fragile ecosystem.

Key modelling issues:

- Improving the representation and capabilities of shelf processes (both physical and biogeochemical) as model resolution continues to increase
- Include anthropogenic perturbations to shelf ecosystems (e.g. anthropogenic nutrient input)
- Add further biogeochemical complexity (e.g. processes impacted by climate change) and extend connectivity to higher trophic levels (i.e. upwards and downwards)

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[1] Kwiatkowski et al. (2014). Biogeosciences Discus, 11, 10537–69.