Project information

Project title

ECOAN WP3-OA8: Coupled climate-ecosystem-Acidification modelling from Organism to Basin

Year

2017

Project leader

Phil Wallhead (NIVA), Solfrid S. Hjøllo (IMR)

Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)

pan-Arctic

Participants

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Flagship

Ocean Acidification

Funding Source

KLD

Summary of Results

D1.1: Comparison of SINMOD and NORWECOM coupled physical biogeochemical models in the Barents and Nordic Seas

During 2017, SINMOD and NORWECOM model output were intercompared with climatological data from WOA (World Ocean Atlas) for the surface waters of the Barents and Nordic Seas. For temperature, both models showed good agreement with WOA for annual mean values but the summer maxima in NORWECOM appeared to be a little too early (Figure 1). Annual mean sea surface salinity (SSS) in SINMOD was too low in the Greenland Sea (34.2 vs. 34.6 psu in WOA) while SSS in NORWECOM was around 0.5 psu too high in all regions (Figure 2). Surface dissolved inorganic nitrogen (DIN) was too high the Barents Sea in winter in both models, and NORWECOM surface DIN drawdown was generally too early, probably linked with the early temperature maxima (Figure 3). Depth-integrated primary production showed a similar annual cycle in both models and in all regions (Figure 4). Annual mean surface pH was similar in all models and subregions (i.e. between 8.1 and 8.15, total scale, Figure 5). Annual mean aragonite saturation state (Ω_{ar}) was also consistent between models, and both models showed higher Ω_{ar} in the Norwegian Sea (2.1-2.2 vs. 1.8-1.9, Figure 6). Currently available observational data do not appear to be adequate to assess regional annual average surface values of (pH, Ω_{ar}) during the test period (2006-2015).

Barents Sea primary production in a future climate is being studied using three different models: NORWECOM.NPZD, SINMOD and NORWECOM.E2E. Their set-up, period, emission scenario and forcing differ, and so thus the projections. This is an attempt to meet some of the demands from the climate community to include several members into an ensemble, and thereby form an evaluation of the realism in the projections. Our results show that one model suggests an increased primary production, one suggests a decrease and one suggests no change in the level of Barents Sea primary production. These results clearly underline the difficulty in difficulties in detecting clear climate change signals.

In a paper submitted fall 2017, the biogeochemistry from a global climate model (NorESM) was validated and compared with results from a regional model (NORWECOM.E2E) for the present day situation. For the global model we observed too low primary production and a delayed onset of the spring bloom. Both models were close to observations for pH and Ar, while NorESM was in the high end of CO2 flux estimates. In a future climate, there was general agreement between the two models regarding trends, except for the development in sea surface salinity. There was no trend in future net primary production in any of the models, while the trends in modelled pH and Ar were the same in both models. The largest discrepency was in the development of the CO2 uptake, where the regional model suggested a slightly reduced uptake in the future.

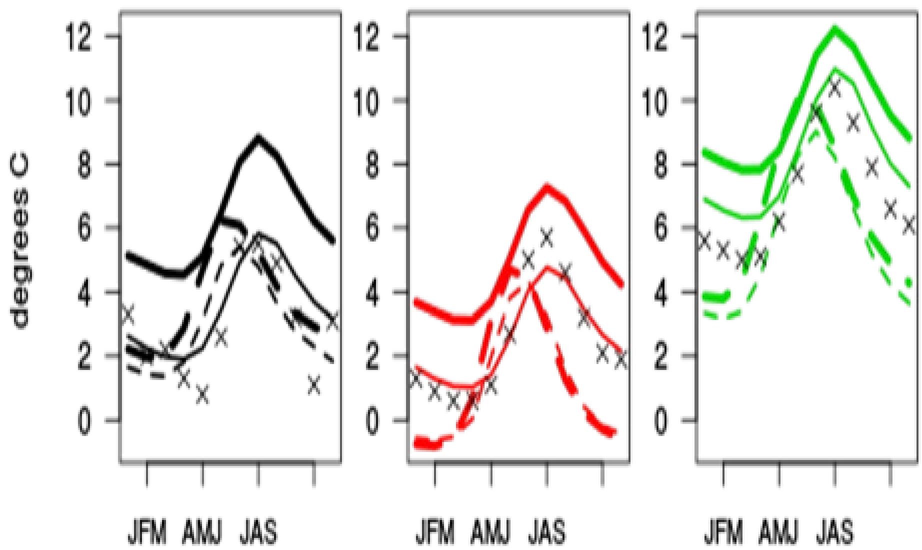

Figure 1. Sea surface temperature in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). Thin lines show present day averages (2006-2015) and thick lines show future averages (2060-2069). Crosses show averages from WOA climatology

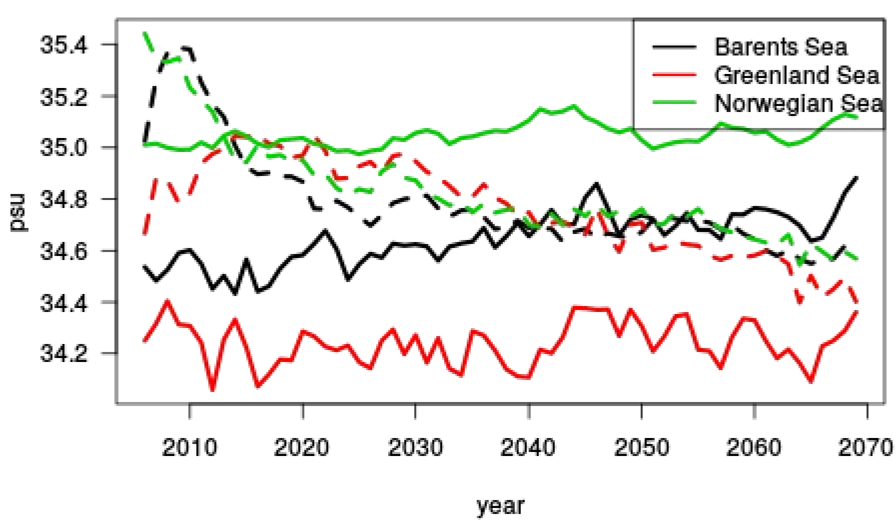

Figure 2. Annual mean sea surface salinity in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). WOA climatology gave 34.5, 34.6, and 35.0 psu for Barents, Greenland, and Norwegian Seas respectively.

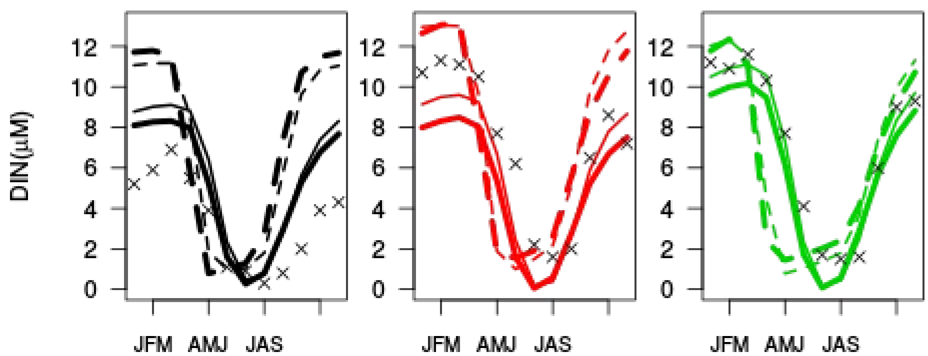

Figure 3. Surface dissolved inorganic nitrogen (0–10m average) in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). Thin lines show present day averages (2006-2015) and thick lines show future averages (2060-2069). Crosses show averages from WOA climatology.

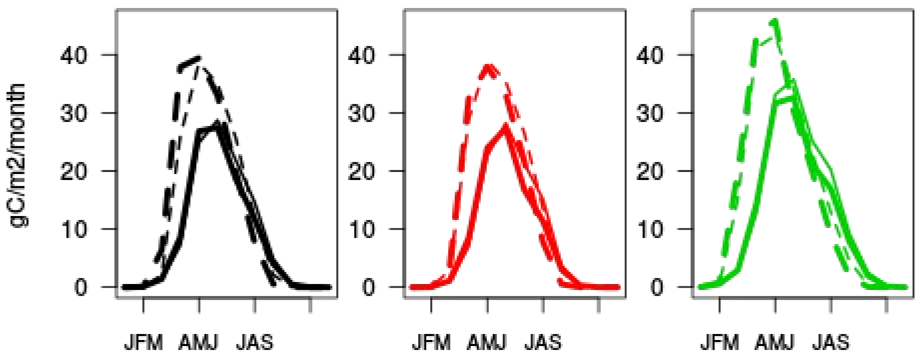

Figure 4. Depth-integrated gross primary production in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). Thin lines show present day averages (2006-2015) and thick lines show future averages (2060-2069).

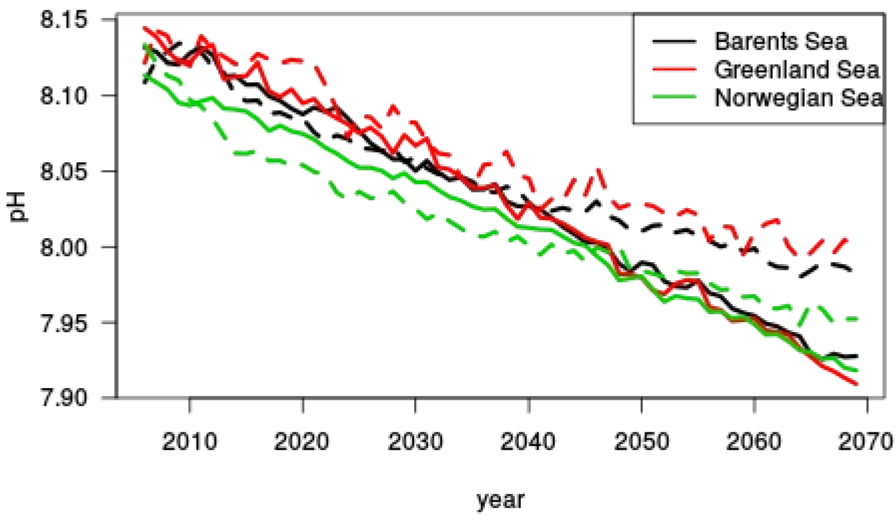

Figure 5. Annual mean pH (0-10m average) in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). Thin lines show present day averages (2006-2015) and thick lines show future averages (2060-2069).

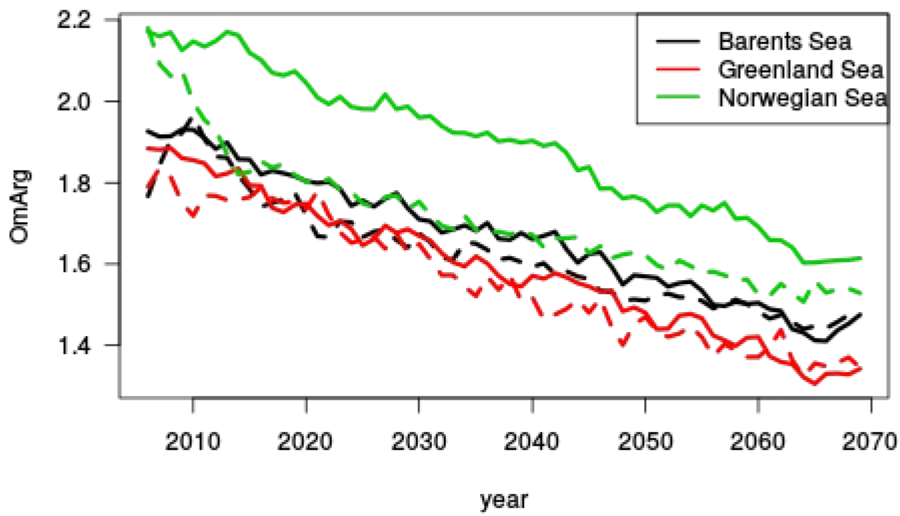

Figure 6. Annual mean aragonite saturation state (0-10m average) in SINMOD (solid lines) and NORWECOM (dashed lines) for the Barents (black), Greenland (red), and Norwegian Seas (green). Thin lines show present day averages (2006-2015) and thick lines show future averages (2060-2069).

D2.1: OA Impacts on Higher Trophics using NoBa

During 2017, the NoBa model was run in hindcast mode (Figure 7) and for a future scenario (Figure 8). Apart from the differences in physical forcing, the largest difference between the forecast and hindcast simulation is the fisheries. For now, the fisheries in the climate projection is held constant at the current level. This is common practice among several similar ecosystem models. Fisheries in the hindcast simulation is represented by historical timeseries. Another possibility is to implement harvest control rules (HCR) for all harvested species. However, several of these species does not have HCRs implemented for management, so neither of the two methods are optimal.

As seen in other studies, the response was dampened through the ecosystem, with the strongest responses at the primary production and zooplankton level. The responses in the climate projection simulation are stronger at the phytoplankton level compared to those seen in the historical simulation. There are more negative responses at the demersal fish level in the future projections compared to the hindcast, where most of the responses were positive.

The simulations where several perturbations were combined caused the stronger responses, where simulation 6 (dark green) stands out in both periods. In this run, growth rate, consumption rate and mortality was changed (decreasing growth rate, decreased consumption rate and increased mortality).

There are large uncertainties connected to these simulations, also in terms of the responses at the zooplankton level, where the experts disagreed to a large degree on what the most probable reaction to changes in the ocean acidification. Still, the large range of perturbation changes gives an indication to what processes that will cause strong responses in the ecosystem, and at what guild level we'll experience these. It is also interesting to see the differences in response rates between the pelagic guilds and the demersal guilds, potentially due to the difference in number of species being harvested in the two guilds.

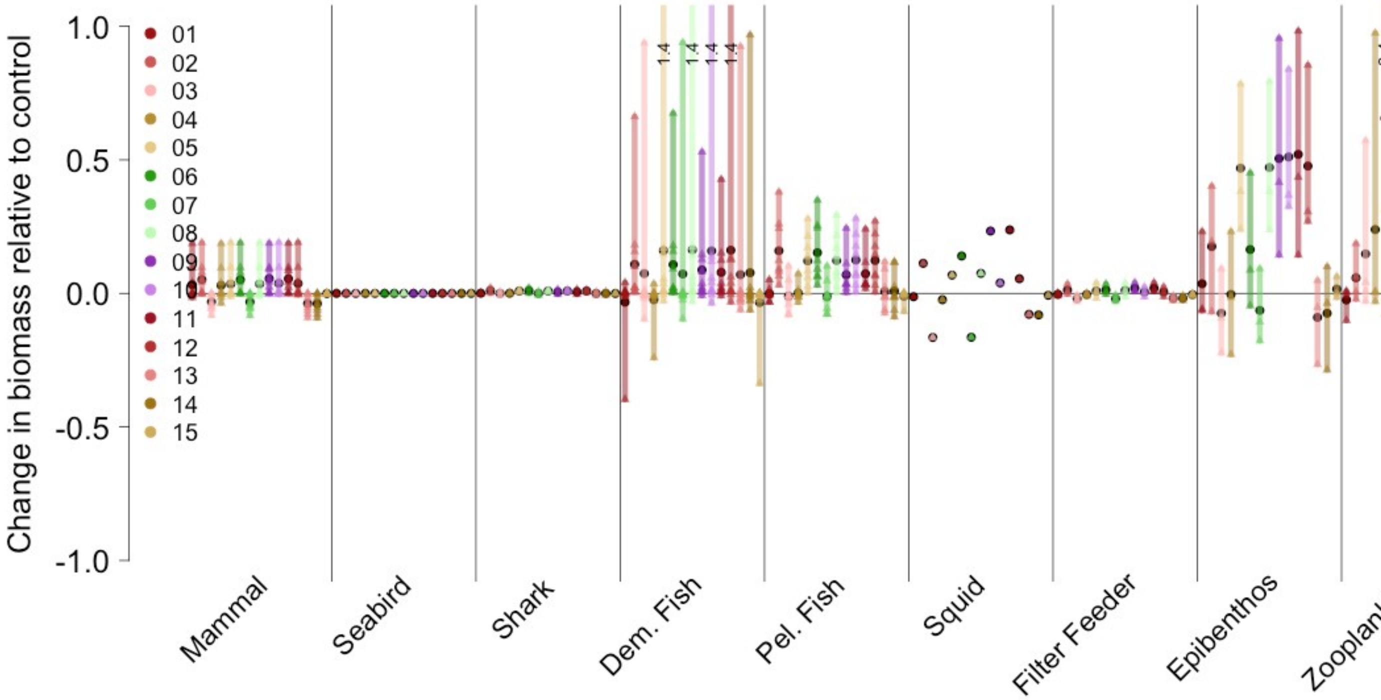

Figure 7. Hindcast simulations with NoBa Atlantis. Ecosystem responses presented in guilds. Average responses presented with dark circles. Each functional group/species represented by dots.

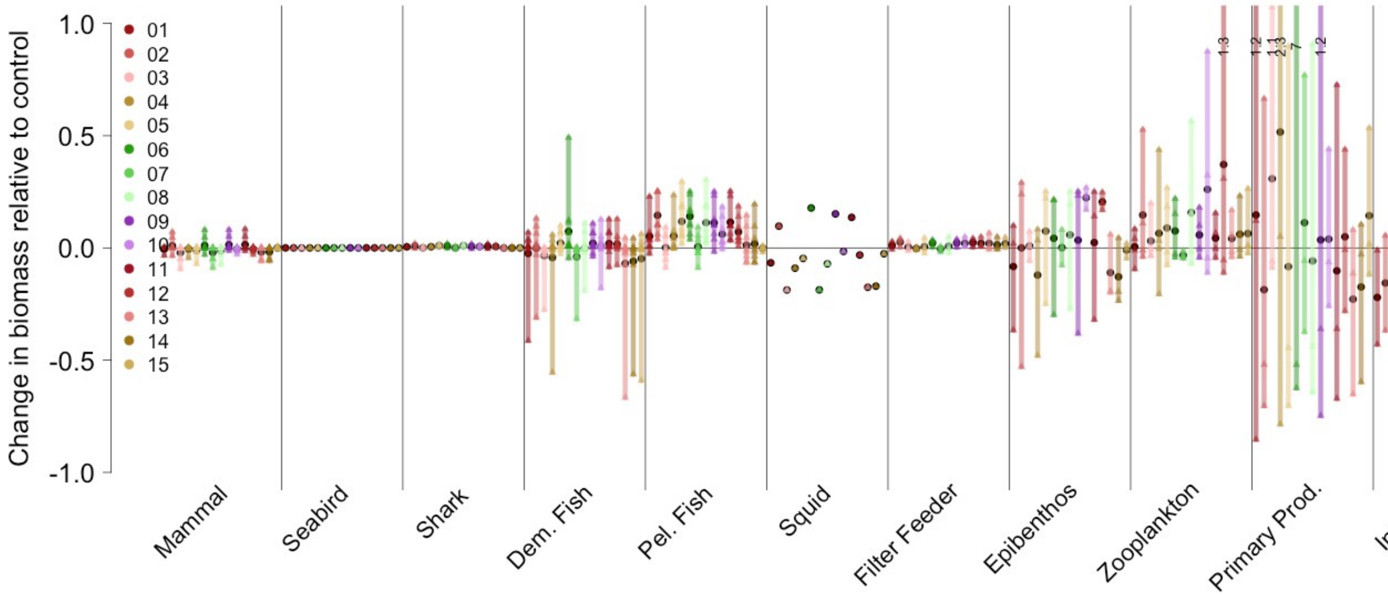

Figure 8. Projection simulations with NoBa Atlantis. Ecosystem responses presented in guilds. Average responses presented with dark circles. Each functional group/species represented by dots.

D4.1: Report on the parameterization of benthic fluxes and boundary conditions for 3D modelling of the wider effects of the benthic response to Arctic OA

During 2017, the work on modification of the biogeochemical model BROM for studying present-day and future OA scenarios was started. Original BROM modules (Yakushev et al., 2017) were additionally subdivided and now BROM “basic “biogeochemistry model consists from 14 modules: BROM_bio, BROM_main nutruents, BROM_bact, BROM_nitrogen, BROM_silicon, BROM_sulfur, BROM_carbon, BROM_methane, BROM_manganese, BROM_Fe, BROM_eq_constants, BROM_Alk, BROM_calcium, BROM_pH. Module BROM_methane was modified and the methane exchange through water/air boundary on was parameterized.

We also developed a new transport model compatible with FABM and BROM_biogeochemistry – the 1D Ice-Pelagic-Benthic IPBM (Yakubov et al., 2016, submitted) – which allows the coupled simulation of ice, water column, and upper sediments. The current IPBM setup is partly coupled to the European Regional Seas Ecosystem Model (ERSEM) and partly to the Bottom RedOx Model biogeochemistry module (BROM-biogeochemistry) using the Framework for Aquatic Biogeochemical Models (FABM) (Figure 9).

A test run region was selected in the Laptev Sea outer shelf with active methane seepage (Figure 10). For the model forcing we used modelling predictions from a ROMS+ERSEM run. The chosen region represents an area where methane fluxes are very high, and could indicate the potential for methane flux increase if the permafrost thawing progresses. Besides, there is available field data collected in the expeditions during the last years. The preliminary results of calculations demonstrate reasonable behavior of the biogeochemical and carbonate system processes (Figure 11,12,13), including the sediment-water interface bio.

In 2018 we plan to use the 1D IPBM/BROM/ERSEM model for analyzing the details of the biogeochemical transformations in the interconnected ice-water-sediment media and to apply a vertical BROM-2D transport model to study the small scale spatial variability in the benthic environment biogeochemistry.

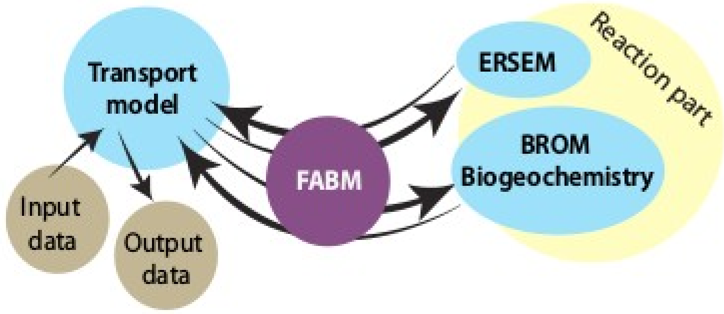

Figure 9: The model coupling scheme

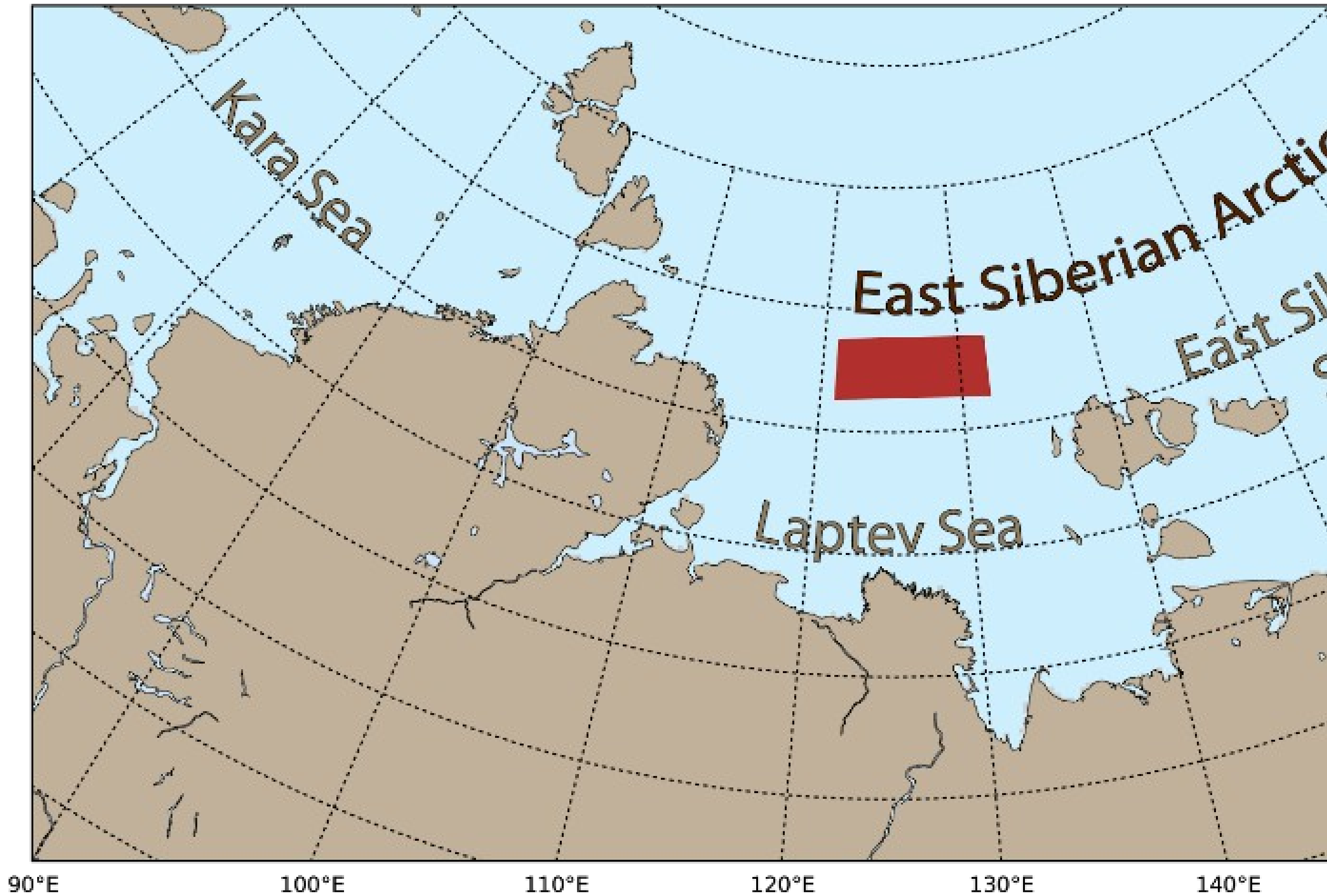

Figure 10: Position of modelled region

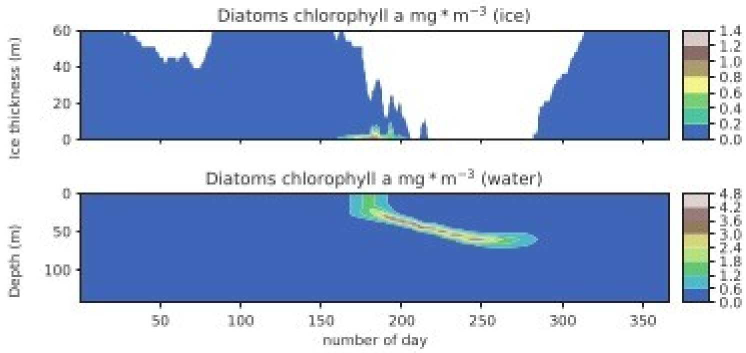

Figure 11: Diatoms

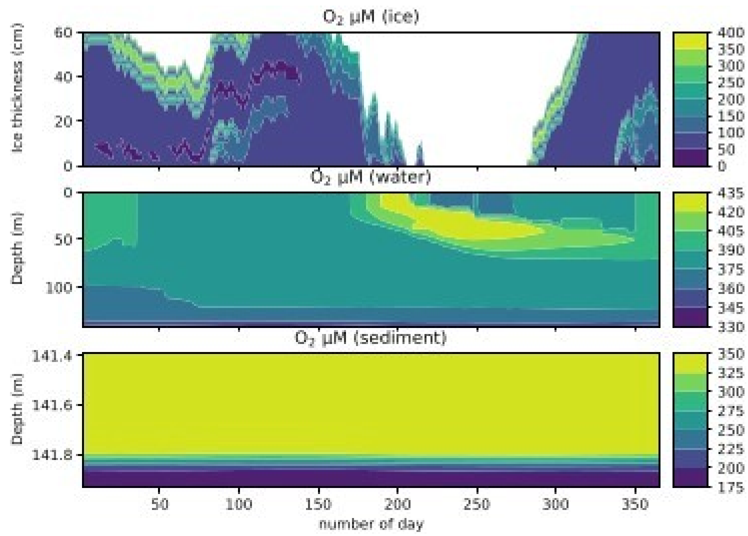

Figure 12: Dissolved oxygen

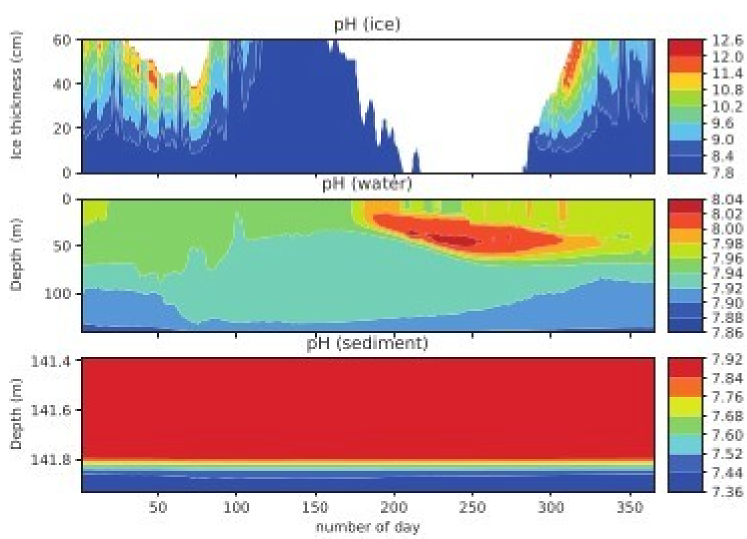

Figure 13: pH

For the Management

The project is progressing as planned and is on track to meet all milestones and deliverables.

Published Results/Planned Publications

Published

- Wallhead, P.J., Bellerby, R.G.J., Silyakova, A., Slagstad, D., Polukhin, A.A. Bottom water acidification and warming on the western Eurasian Arctic shelves: Dynamical downscaling projections, Journal of Geophysical Research, Oceans, accepted. doi:10.1002/2017JC013231.

- Yakushev, E. V., Protsenko, E. A., Bruggeman, J., Wallhead, P., Pakhomova, S. V., Yakubov, S. Kh., Bellerby, R. G. J., and Couture, R.-M. (2017), Bottom RedOx Model (BROM v.1.1): a coupled benthic–pelagic model for simulation of water and sediment biogeochemistry, Geosci. Model Dev., 10, 453-482, doi:10.5194/gmd-10-453-2017

Planned

Skogen M.D, Hjøllo, S.S., Sandø,A,B and Tjiputra,J.: Future ecosystem changes in the Northeast Atlantic: A comparison study between a global and regional models". Submitted to ICES Journal of Marine Science.

Skogen M.D., Mousing E.A., Hjøllo S.S., Wallhead P. in prep. Projections of primary production in the Barents Sea in a future climate

Wallhead P., Hansen C., Skogen M.D. in prep. Testing and developing zooplankton mortality closure models by end-to-end ecosystem simulation.

Hjøllo, S.S., Thor P, Wallhead P. in prep. Metabolic Ocean Acidification effects on Copepods; from observed effects on individuals to modelled population effects in NORWECOM.E2E.

Wallhead P., Bellerby R., Staalstrom A., Kristiansen T. in prep. AERSEM: A new flexible-stoichiometry biogeochemical model for the Arctic Ocean.

Seifert, Hansen et al., in prep. Early assessments of expected ecosystem changes, for use in economic and management analyses. Impact of ocean acidification on Arctic fisheries as example.

Communicated Results

Project results were communicated to the ECOAN group during the annual workshop in May and to the wider scientific community at the ESSAS conference in Tromsø in June. As part of a linking project on Norwegian coastal zone management (ACIDCOAST), SINMOD acidification projections have been communicated at a stakeholder workshops in Lofoten, Rosendal, and Bergen during September and November. Results from NorESM-ROMS downscalings have been presented internally at IMR.

Interdisciplinary Cooperation

The project has successfully interfaced with experimental scientists in WP2 in regard to communicating likely levels of future acidification and addressing how orgnanismal sensitivity to OA may be parameterized in models. By nature the project is interdisciplinary since modelling ocean acidification and its impacts involves an interaction of physical, chemical, and biological processes.

Could results from the project be subject for any commercial utilization

No

Conclusions

The project is meeting its deliverables and is producing peer-reviewed science publications involving cross-institutional and cross-disciplinary collaborations. Results have been communicated to management, marine stakeholders, and the general public as well as with the Flagship and the wider science community.