Project information

Project title
FRAMMOB: Arctic Ocean acidification modelling
Year
2014
Project leader
Richard Bellerby (NIVA) and Morten Skogen (IMR)
Participants

Arild Sundfjord (NPI), Agneta Fransson (NPI), Evgeniy Yakushev (NIVA), Andre Staalstrøm (NIVA), Philip Wallhead (NIVA), Melissa Chierici (IMR), Ole-Anders Nøst (ApN), Cecilie Hansen (IMR)

Flagship
Ocean Acidification
Funding Source

Fram Centre + In-kind

Summary of Results

1. One important objective for this task was to couple the Biogeochemical model ERSEM with the physical model ROMS. The Met office in Norway uses an older version of ROMS (version 3.5). Version 3.6 has a much more flexible way to handle open boundary conditions. This flexibility is important when biogeochemistry is coupled to the physics. We have tested ROMS-3.6 coupled to a simplified biogeochemical model (Oxydep) on different model domains with different horizontal resolution, 20 km for an Arctic domain and 800 m for a smaller domain along the Norwegian coast. The update of the model code handles earlier problems with open boundary conditions.

The ROMS-3.6 code was prepared for coupling with the biogeochemical ERSEM, through FABM (Framework for Aquatic Biogeochemical Models). Agreements have been made with the developers of ERSEM, for a joint final effort for coupling of ROMS and FABM/ERSEM.

1-dimensional C-N-P-Si-O-S-Mn-Fe Bottom RedOx Model (BROM) was re-coded as a FABM transport and biogeochemical model (in co-operation with the PML) and offline coupled with GOTM and the test runs for the polar environment (the North Sea) were done. We numerically demonstrated the possibility of changes of the bottom redox conditions from normoxic to anoxic as a reaction for vertical mixing (connected with the temperature increase) and biological productivity. The alkalinity modeling block was improved by including redox processes important in suboxic and anoxic conditions connected with cycling of N,S,Mn,Fe.
We numerically demonstrated the role of CO2 consumption by chemosynthetics in the carbonate system changes, in particular an increase of carbonate saturation while changing of hypoxic to suboxic conditions.

The BROM biogeochemistry block was divided into 3 parts: BROM_bio, BROM_redox and BROM_carb. Coupling of ERSEM and BROM_redox was tested for GOTM run for the Gotland Deep (in collaboration with PML).

2. To enable the assessment of model skill and contemporary distributions of biogeochemical parameters in the Arctic Ocean (Task 1), we collated data from three major compilations (WOD, CARINA and ARCSS-PP) and developed a Matlab toolkit to extract, interpolate, and compare these data to output from the SINMOD biogeochemical model. The data extraction function allows for redundancy checking, quality control, vertical interpolation, depth-averaging and extrapolation to the ocean floor. Skill assessment functions compare model to data estimates using observed vs. predicted plots, profiles of means and standard deviations within a defined subregion, and horizontal

maps of time averages. In future work we hope to complete the comparison of carbonate system variables by calculating (pH, Omega etc.) using CO2SYS.m with the same calculation options/scales for both model and data. Currently we are completing an interpolation function that will calculate data- based prediction intervals for any given time in the last 30 years and around any given latitude/longitude/depth.

3. The project OA timelines of key physiological stressors (e.g. pCO_2, pH and omega) were developed for key regions and depths relevant for key calcifying pelagic and benthic organisms and ecosystem. Regions with high and low ecosystem diversity and regions with high and low contemporary, mid-term and long-term ocean acidification were also explored. Geomapping is currently underway to develop scenarios of ecosystem migration, extinction and safety for key species and ecosystems of the Arctic.

4. The project used the Nordic and Barents Sea (NoBA) version of Atlantis, which covers an area of 4 million square kilometers, represented by 63 polygons. The polygons are defined to be as homogeneous as possible with respect to hydrography and topography. In the vertical, the NoBa model has seven depth levels and one sediment layer. NoBa is forced by time series of temperature, salinity and volume fluxes from the ROMS model. In the NoBa model we have included 52 key species and functional groups, based on literature research and expert opinions on which groups/species that are important to give a realistic representation of the ecosystem. These include phytoplankton, benthos, zooplankton, fish (both planktivore and piscivore), seabirds and marine mammals. Atlantis also includes the possibility of forcing with time series of pH, or adding a pH change over time. Using the 20C3M control run and the A1B emission scenario, a downscaling of the GISS-AOM global climate model (Sandø et al., 2013) will be used to force the NoBa model for a reference (1981–2000) and a future climate (2046–2065) simulation respectively including pH fields from simulations with the NORWECOM.E2E ecosystem model (Skogen et al., 2014) using the same GISS-AOM forcing. At present the forcing files for the NoBa system has been prepared and the simulations are ready to be started. The results with a first comparison between the reference and future climate simulations are planned to be ready mid December.

5. Initial discussions took place on how to couple between the carbonate system sea ice dynamics (SICCA) and ecosystem and biogeochemical models, and on model validation using WP1 data.

For the Management

The complexity of changes in multiple system drivers in the Arctic is so great that off-line approaches developed by extrapolating contemporary understanding of individual drivers are inadequate for providing scenarios of ocean acidification for experimental direction of management use.

A coupled approach through downscaled modeling, rigorously tested with observational data and experimental process information, is required.

Important initial discussions took place on how to couple between sea ice carbonate system dynamics (SICCA) and ecosystem and OA models.

Published Results/Planned Publications

Yakushev E., Protsenko E. 2014. Modelling carbon transformation at the sediment- water interface. Fourth EAGE CO2 Geological Storage Workshop, Stavanger, April 2014, extended abstract, DOI: 10.3997/2214-4609.20140077

Yakushev E.V., Protsenko E.A., Bruggeman J. 2014. Bottom RedOx Model (BROM) general description and application for seasonal anoxia simulations. . NIVA (to be submitted in November 2014).

Yakushev E., Protsenko E., Bruggeman J., Bellerby R., Pakhomova S., 2014. Varying redox conditions in benthic biogeochemistry: simulations with Bottom ReDox Model (BROM). Biogeosciences (to be submitted in December 2014).

Yakushev E., Makkaveev P., Staalstrøm A., Norli M., Khlebopashev P., Protsenko E., Yakubov Sh., Stepanova S., Braaten H.-F. Expeditional study of carbonate system parameters in the Templefjord (Shpitzbergen) in winter period. In preparation to Oceanology

Sandø, A.B., Melsom, A., Budgell, P.W., 2014. Downscaling IPCC control and future scenarioes with focus on the Barents Sea. Ocean Dynamics 64:927-949. Skogen, M.D., Olsem, A., Børsheim, K.Y., Sandø, A.B. and SKjelvan, I. (2014). Modelling ocean acidification in the Nordic and Barents Seas in present and future climate. Journal of Marine Systems 131:10–20.

Hansen, Skogen et al., (in prep.). Effects of ocean acidification on the Barents sea ecosystem

Communicated Results

Bellerby R.G.J., *Southern Ocean Acidification*, Richard Bellerby (Invited Weyprecht Lecture), 2014 SCAR Open Science Conference, Auckland, New Zealand (included and Arctic comparison)

Bellerby R.G.J., Challenges (and opportunities) for developing reasoned scenarios of coastal and marine ecosystems in a changing climate, Coastal Climate Symposium, ECNU, Shanghai, China

Bellerby R.G.J., Arctic Ocean Acidification. Arctic Change Conference, Ottawa, 2014

Workshops and meetings on data and model evaluation

Fransson A. et al. Workshop /meeting Nov. 2014, Tromsø, between NPI and IMR initial discussions on how to couple between carbonate system sea ice dynamics (SICCA) and ecosystem and OA models.

Fransson A. et al., Meeting skype: Nov. 2014, Participants of NPI, IMR and UiB Fransson et al. Meeting skype: Aug. 2014, Participants of NPI, IMR and UiB Fransson A. P. Thor, M. Chierici, M. Granskog, P. Duarte et al. Meeting + skype: June. 2014, Participants of NPI, IMR and Akvaplan-Niva

Interdisciplinary Cooperation

Interdisciplinary cooperation benefited from discussions between biological modellers and chemical and physical oceanographers. However, the research groups worked much alone and there was not the strong inter-disciplinary dialogue that was intended. Nevertheless, for the first time, biogeochemical modellers are delivering new data to be coupled to the HTL models.

Budget in accordance to results

The work described could not have been performed without the funding.

The funding enabled new developments of the model setups, provided support for model analysis and data comparison. It funded a workshop where coupled, interdisciplinary approaches for Arctic OPA modeling was discussed. It enabled the development of a new proposal to the Fram Centre.

The Fram Centre funding has promoted further proposals for cross-cutting funding with Sea ice Technology flagship and with the other OA WP's.

Due to cuts in the funding compared to the initial budget indication not all the original research planned could be done. However, all work agreed before the start of the project under the new budget was achieved.

Could results from the project be subject for any commercial utilization

No

Conclusions

The project has lead to initial discussions between WP1 and WP4 for collaboration between the OA WP's for the biogeochemical modeling. Set-up and first experiences with pH submodule of Atlantis have been obtained.