Ecosystem model intercomparison within the framework of AOMIP: ideas, experiments and logistics

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Arctic Ocean is an area where physical factors play a disproportionately significant role in plankton productivity compared with the rest of the World Ocean.

Arctic primary production in a global ocean-ecosystem-ice model

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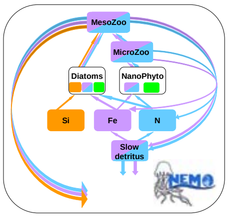
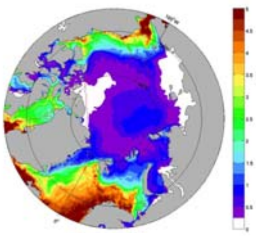
Here we analyse the results from simulations of the 1/4 degree resolution global ocean NEMO model coupled with the MEDUSA biogeochemical model and LIM2 ice model, with a particular focus on the Arctic basin. All results are shown for year 1998

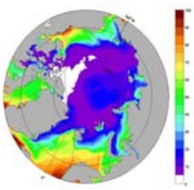


- Nitrogen-based plankton ecosystem model
- Size-structured plankton community (P2-Z2-D2)
- Simplified iron cycle to permit HNLC regions
- Silicon cycle for export-important diatoms
- Slow- / fast-sinking detritus pathways for export
- Inclusion of ballast model of export remineralisation

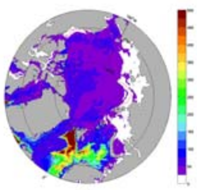


Annual primary production (mgC/yr)

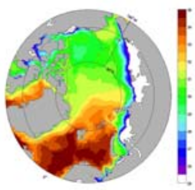
Light and nutrient limitations are two factors controlling Arctic primary production.
The nutrient regime of the surface AO is affected by two main mechanisms of the nutrient supply: deep winter mixing and horizontal exchange with pacific and Atlantic sector.
In addition to extreme seasonal changes of the short wave radiation, light penetration is strongly influenced by the presence of the ice. Two characteristics are of prime importance for the light limitation of phytoplankton: days of open water in the areas of seasonal ice cover and ice concentration (rather than on the ice thickness) in the areas covered by the multiannual ice.



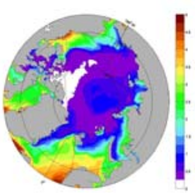
Annual mean short-wave radiation (Wt/m2)



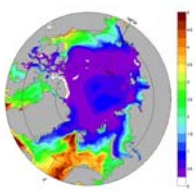
Maximum depth of the UML (m)



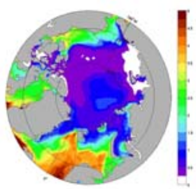
Annual Mean salinity



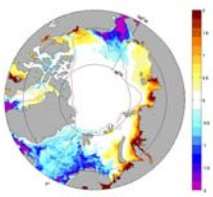
Annual primary production (mgC/yr) calculated from the linear regression model
Prod= a*SW+b
Where SW is Annual mean short-wave radiation shown above. Correlation coefficient between primary production from the full model and from regression model is **0.82**. Difference (in mgC/m2/yr) between Primary production from the regression model and primary production from the fully coupled ecosystem model is shown below.

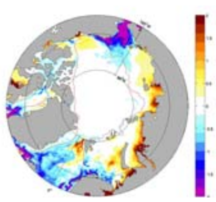


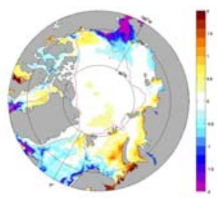
Annual primary production (mgC/yr) calculated from the linear regression model
Prod= a*SW+b*hmax+c
Where SW is Annual mean short-wave radiation and hmax is maximum depth of the UML over a year (shown above). Correlation coefficient between primary production from the full model and from regression model is **0.85**. Difference (in mgC/m2/yr) between Primary production from the regression model and primary production from the fully coupled ecosystem model is shown below.



Annual primary production (mgC/yr) calculated from the linear regression model
Prod= a*SW+b*hmax+c*S
Where SW is Annual mean short-wave radiation, hmax is maximum depth of the UML over a year and S is annual mean surface salinity (shown above). Correlation coefficient between primary production from the full model and from regression model is **0.92**. Difference (in mgC/m2/yr) between Primary production from the regression model and primary production from the fully coupled ecosystem model) is shown below.







Our results show that even simplest regression model performs quite well. An obvious area of poor performance is Pacific inflow where primary production is extremely high and the main mechanics of nutrient supply is horizontal advection.

AOMIP: ideas for ecosystem intercomparison

First of all, let's acknowledge potential problems with intercomparison of different ecosystem models embedded into different physical models of different resolution forcing by different atmospheric fields.

Such an approach would lead to substantial amount of work and a lot of inconclusive results. To gain any understanding from ecosystem model intercomparison experiment either physics or biology must be identical.

Our results (left panel) show that Arctic primary production unlike any other region in the World Ocean is disproportionately influenced by physics. 82% of the variability in annual primary production (north of 66N) can be explained by distribution of the annual mean short-wave radiation (taking into account ice cover). A linear regression model which takes into account annual mean short wave radiation, maximum depth of winter mixing and surface salinity explains 92% of variability in primary production.

On the basis of these results a two-stage ecosystem intercomparison study is proposed

Phase 1 (Pan-Arctic/Global models with existing ecosystems)

The working hypothesis of the Phase 1 is that our results are robust and in Arctic about 90% of the variability of the primary production can be explained by the variability in the physical factors independently on what ecosystem model is implemented.

Thus we can have a constructive way forward for comparison of the various ecosystem models by comparing the relevant physics first. Then we can proceed by explaining the rest by difference in our ecosystem models or additional physical factors (e.g. horizontal nutrient transport).

Provided that (1) is correct all models can train a regression model using three suggested 2D fields to estimate *2D annual mean primary production*.

On the basis of model comparison with observations, the best model will be selected, and its regression will be used in phase two.

Logistics: participants provide 3 physical fields identified above (max UML, S, short-wave rad) as well as mean annual primary production. Additional fields of interest (to be discussed): grazing, f-ratio, Chlorophyll (or biomass), nutrients.

Outcome: regression models for the phase 2

Extra: validation of all participating models against the following data

- UML depth climatology (monthly means)
- Satellite-derived Chl-a (monthly means)
- Satellite derived primary production (Pabi et al., 2008) and synthesis by Carmack et al. (2006)
- Nutrient climatology

Phase 2 (physics only models)

The aim of phase 2 is to estimate Primary Production based on regression model of Phase 1 (possibly including "best performing regression" and "regression of best performing model") using as many physical models as possible. Comparison of these estimates should give a clear indications of the following:

- which geographical areas are the most sensitive to the errors in the physical models
- how sensitive ecosystem model to the errors in the physical fields
- what level of ecosystem model complexity in Arctic is appropriate in the climate modelling

Logistics: participants provide 3 physical fields identified above (max UML, S, short-wave rad)