Project information

Project title
Development of MODel for prediction of Eutrofication and SedimenTation from fish cage farms (MODEST)
Year
2018
Project leader
Ole Anders Nøst
Geographical localization of the research project in decimal degrees (max 5 per project, ex. 70,662°N and 23,707°E)
Osterfjorden – 60.5 N, 5.5 E Sagfjorden – 68.0 N, 15.5 E Olaneset – 70.2 N, 22.3 E Kjelneset – 64.6 N, 11.4 E
Participants

Anders Stigebrandt (Ancylus)

Magnus Drivdal (Akvaplan-niva)

Tore Hattermann (Akvaplan-niva)

Øyvind Leikvin (Akvaplan-niva)

Reinhold Fieler (Akvaplan-niva)

Frank Gaardsted (Akvaplan-niva)

Rune Storvold (Norut)

Rune Graversen (UiT)

Evgeniy Yakushev (NIVA)

Andrè Staalstrøm (NIVA)

Flagship
MIKON
Funding Source

Framsenteret

NFR

FHF

Cermaq

Summary of Results

In the MODEST project, we are working to develop a model for predictions of eutrofication and sedimentation from fish cage farms. Originally the model was implemented for two fjord systems, Osterfjorden in Hordaland and Sagfjorden in Steigen. However, in 2018 the model has been applied in several separate projects for the fish farming industry in northern Norway. The sedimentation model development in MODEST has greatly benefitted from this due to further refining of methods, testing and validation through these projects. An example of comparison between modelled deposition and observed bottom conditions can be seen in Figure 1. A direct comparison between the model results and the observations is not straightforward since there are bottom samples only at a few stations, but the areas at the bottom most affected by sediment fallout in the model at least qualitatively seem to agree quite well with the observed pattern. For this location, the model was used as a predictive tool for the footprint of the fish farm, and a model prediction of the effect of doubling production is shown in Figure 2. Another scenario that was considered for this location was to increase production by a factor of 1.4 and at the same time increase the number of cages and increase the space between them (Figure 3). As seen when comparing Figures 1 and 3, the reconfiguration of the farm compensates for the increase in production, so that the sedimentation rates are similar in the both cases.

In 2018 one of the main priorities has been to further develop the sedimentation model within the framework of FABM (Framework for Aquatic Biochemical Models, Bruggeman and Bolding, 2014) that is coupled to FVCOM. The main achievement has been to implement and test resuspension in the model code. In the model the resuspension formulation is based on the parametrizations by Ariathurai and Arulanandan (1978) and Warner et al. (2008), where three model constants are used; critical bottom stress, bottom porosity and a bed erodibility constant. So far these empirical constants are chosen based on the experimental study by Law et. Al. (2016), where the erodibility constant varies based on the bottom type. Currently there are lab studies at IMR done in the NFR SustainAqua project to update the values of these empirical constants, and these results will be directly applicable in the model. An example of how resuspension affects the model result at a location with strong currents is shown in Figure 4. From Figure 4 it can be seen that the spreading of sediments is patchier when including resuspension, similar to the results in Broch et al. (2017).

Still, one of the main challenges in the modelling work is validation against observational data, which is scarce and often very limited for the cases studied so far. During the work with resuspension it became clear that the sensitivity of the model to the empirical model constants is very strong and site specific, depending on bottom topography, coastline and current speed at the locations. Due to this, we found it beneficial to test resuspension at more sites than originally planned, and more work was put into setting up the model for new locations. The model is recently set up for two new areas where data is available from targeted observation campaigns, one in Trøndelag and one in Finnmark. A subgrid of one of three fish farms studied in the Trøndelag area can be seen in Figure 5. At the location in Finnmark (Olaneset) a detailed observational campaign was recently done through the NFR project SustainAqua, lead by the Norwegian Institute of Marine Research (IMR), and the modelling work will contribute to both projects. The cooperation between MODEST and the SustainAqua project and IMR has been extensive and has lowered the costs of setting up common grids by splitting this between the projects.

A paper presenting the sedimentation/resuspension model developed in MODEST is in production, and the results from the locations in Trøndelag and/or Olaneset will be used as cases. Most of this work will be completed by end of 2018, and planned submission for review is spring 2019.

During 2018 Niva has continued work on a biogeochemical O-N-P-Si-C-S-Fe-Mn model BROM (Yakushev et al., 2017) coupled with a 2 dimensional vertical benthic-pelagic transport model 2DBP has been developed for analysis of fish farm discharge and simulated interconnected changes in the water column and the sediments biogeochemistry. This model can use hydrodynamic forcing any ocean model (such as FVCOM) to analyze changes in the distribution of dissolved oxygen, and an example is shown in Figure 6.

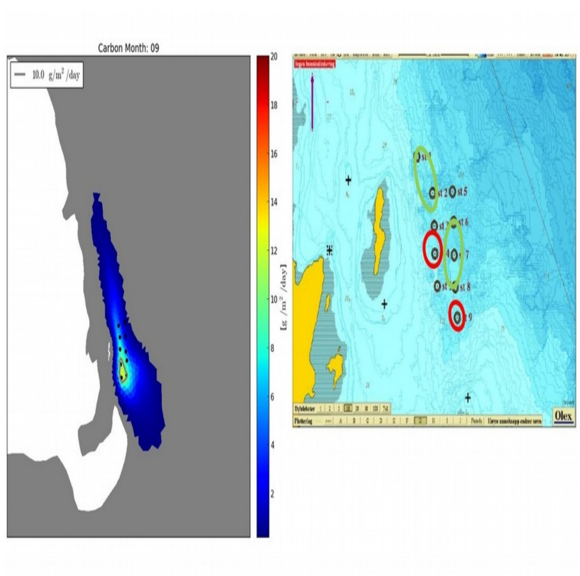

Figure 1:Comparison of sedimentation in model (left panel) and observed bottom conditions (right panel). The individual cages of the farm are indicated by black dots (left) and dark circles (right). Red circles (right panel) indicate grab samples with high amount of sediments. The model indicate higher sedimentation rates under the cages to the south and closer to land. This fish farm is located in Økssundet in Sagfjorden (Nordland).

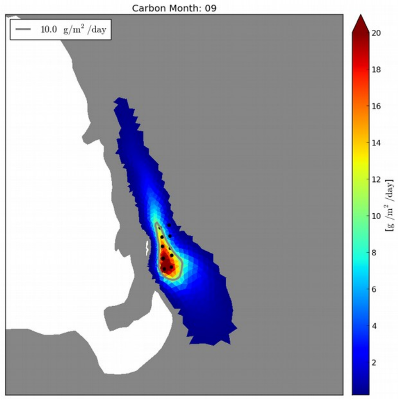

Figure 2: The modelled effect on the bottom sediments of doubling the production at the location shown in Figure 1.

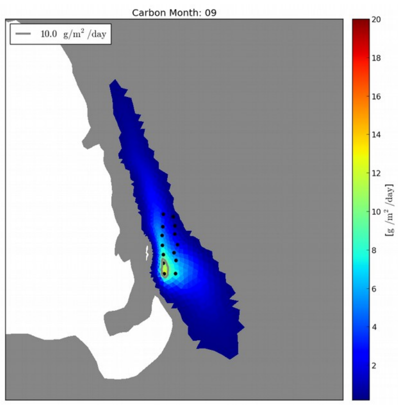

Figure 3: The modelled effect on the bottom sediments of increasing the production at the location shown in Figure 1 by a factor of 1.4, but at the same time increase the number of cages (black dots) and increase the distance between them.

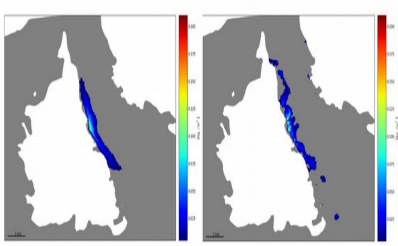

Figure 4: Modeled sediment concentration (kg/m2) at the bottom after 1 week of release from a fish farm in Økssundet. The panel to the right shows the result without resuspension and the right panel shows the result with resuspension.

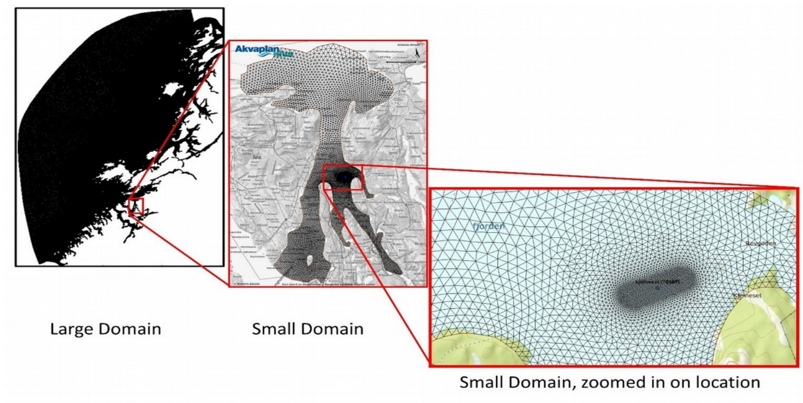

Figure 5: Model domains for Trøndelag (left: large domain), zooming in on the subdomain (middle) and on the immediate vicinity of the fish farm (right). The Large domain (left) covers most of Trøndelag and some of Nordland while the small domain (middle) is nested into the larger and covers the area around the fish farms at Kjelneset. The large domain was run to assure a realistic circulation and has a resolution of about 800 m at the outer boundary down to approximately 70 m. The small domain has higher resolution, down to about 8m around the fish farms (right) in order to get a realistic spreading and deposition close to the fish cages.

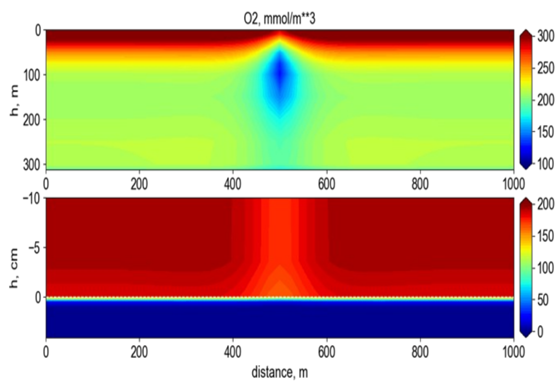

Figure 6: Modeled distributions along a 1000 m transect through the fish farm positioned at the center (500 m) of dissolved oxygen.

For the Management

We have developed a modeling tool that can be useful to assess the environmental footprint of the aquaculture industry. During 2018 we have started to develop a standardized procedure to evaluate the environmental consequences of production and furthermore to predict consequences of increased production.

Published Results/Planned Publications

- Publication in production: A model for prediction of eutrofication and sedimentation from fish cage farms
- A paper is under preparation presenting results with BROM for applications fishfarm discharges

Communicated Results

- Preliminary results from the depositional modelling was presented on a related project (SustainAqua) meeting with IMR in Bergen February 27. 2017
- Results presented at modeling workshop in Bergen November 15. 2017 with NIVA, Akvaplan-niva and Plymouth Marine Laboratory
- A presentation about results with BROM for applications fishfarm discharges will be held at the Goldschmidt 2018 conference
- A presentation of the sedimentation model will be held at the UK-FVCOM workshop in Plymouth UK

20.11.2018 (Hosted by Plymouth Marine Laboratory)

Interdisciplinary Cooperation

In MODEST we have a strong cooperation between physical and chemical oceanographers, and the results of the project depends on this inter-disciplinary cooperation. The cooperation works well and enables us to develop a product which is highly needed in the aquaculture industry. We do not have any negatives in this respect. The project also has a strong component of biology through the cooperation with other projects doing field work near fish farms. We only see this as positive, because interdisciplinary cooperation is the only way forward to reach the goal of the project.

Budget in accordance to results

The funding from the Fram Centre has made it possible to develop a sedimentation model suitable for organic waste from fish farms. This facilitated for the cooperation with industry, and we also received funding from CERMAQ to model the waste from the fish farms in Økssundet as shown in Figure 1-4.

Could results from the project be subject for any commercial utilization

Yes

If Yes

There is a need for tools that can estimate the carrying capacity of the coastal ocean to fish farming. The new standards for sea bed monitoring under marine cage farms (ISO 12878 and NS 9410, revised 2014) recommend the use of depositional models for prediction of the footprint of organic waste which is expected under marine cage farms. Furthermore, a considerable number of Norwegian salmon farms have during the years 2013 and 2014 voluntarily signed agreements with the Aquaculture Stewardship Council (ASC) and are obliged to follow the ASC standard for environmental monitoring. In this standard, predictive modelling of organic deposition under marine cage farms will become obligatory. The models developed within MODEST covers these needs, and these model tools will be commercially utilized.

Conclusions

a) For most cases studied so far the bulk mass of the organic waste from fish farms accumulates at the bottom close to the fish farm, and a further focus on high model resolution close to the nets is important. Furthermore, we assume that the effect of the fish farm itself on the current therefore plays a role in the depositional patterns, and we wish to develop model parametrizations to take this into account. An offline version of FABM has recently been developed, and implementing the sedimentation model in this way would reduce the need for cpu-hours for each scenario run.

b) The project shows good progress according to the original plan and we have developed/are developing new model techniques for use along the Norwegian coast. 1) We have developed "unstructured grid" ocean modelling for Norwegian coastal areas. This has large advantages along an irregular coastline because it makes it possible to vary the model resolution spatially through the model domain. 2) We have developed a model for sedimentation of organic waste from fish farms. 3) We have included the effect of resuspension in the model, which is important for the spreading at high-current locations. 4) We have coupled our unstructured-grid hydrodynamic model to a simplified ecosystem model (oxydep) for simulations of environmental effects in the water column and bottom sediments.