Project information

Project title

Development of MODel for prediction of Eutrofication and SedimenTation from fish cage farms (MODEST)

Year

2017

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)

60.5 N, 5.5 E; 68.0 N, 15.5 E

Participants

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Flagship

MIKON

Funding Source

Framsenteret

NFR

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. The Model is implemented for two fjord systems, Osterfjorden in Hordaland and Sagfjorden in Steigen. Osterfjorden is a deep and narrow fjord with limited exchange with the surrounding ocean, while Sagfjorden is well ventilated against Vestfjorden, and works well as a contrast to Osterfjorden.

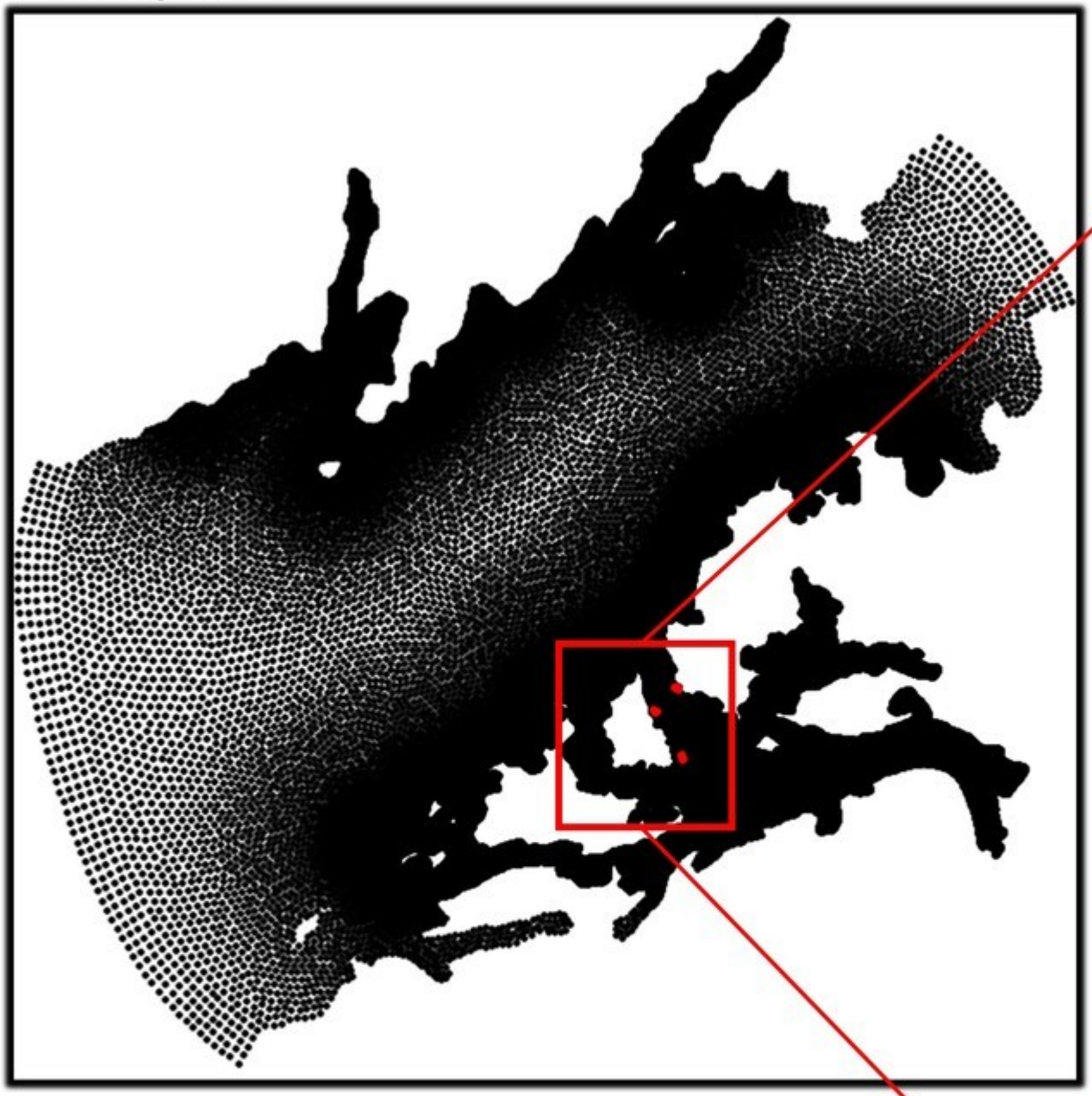
In 2017 much effort has been put into developing our own sedimentation model within the framework of FABM (Framework for Aquatic Biochemical Models, Bruggeman and Bolding, 2014) that is coupled to FVCOM. The tracer properties in the model is based on the results of a study by Bannister et al. (2016), which used a set of controlled experiments in a tank to determine the settling velocity of different fish faeces and were able to relate this to the size of the fish. In the sedimentation model, we assign a separate tracer for each

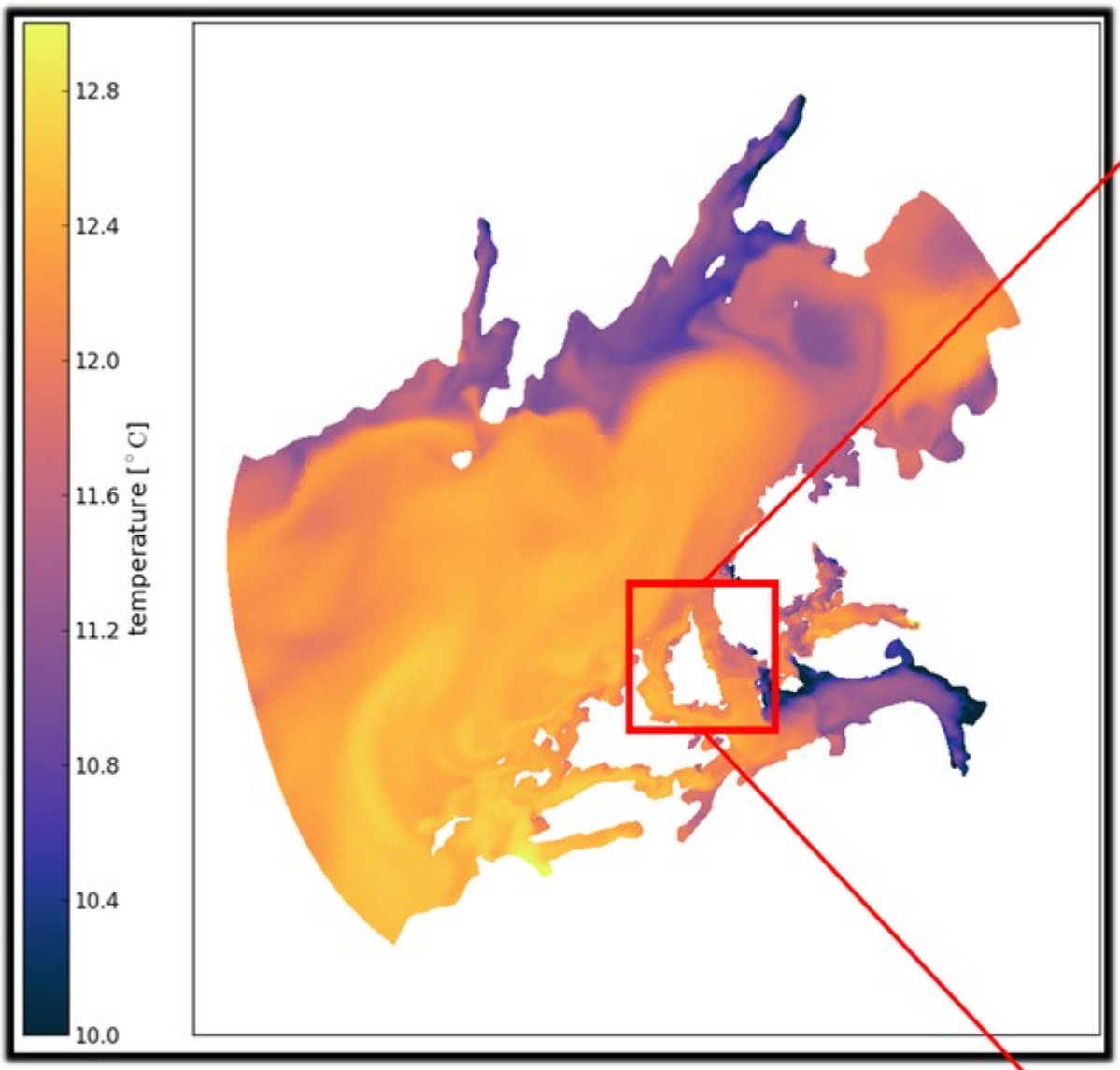
category of fish faeces (6 types) and feed spill (2 types), which each has a given rate of sinking based on Bannister et al. (2016). Further, we have incorporated the deposition process in the model. For tracers reaching the bottom layer in the model, further sinking will lead to deposition on the bottom. Figure 1 and figure 2 below show the model domains for Sagfjorden, and the release points for the three fish farms that were used to test the sedimentation model (figure 1). The 8 tracers were released with a time-varying flux at points representing each fish cage to simulate feeding. All tracers are then advected by the currents before they deposit at the bottom at distances dependent on the sinking rate. Figure 3 illustrates the mean total deposition in $g/m^2/day$ during September 2014 at two of the locations in Sagfjorden. FVCOM coupled with the new sedimentation model in FABM is a versatile tool that can now be set up at various locations along the coast and at locations inside narrow fjords with releases corresponding to realistic feeding cycles. Further work will be focused on including the effect of the fish farm itself on the currents in FVCOM, and to implement resuspension in the sedimentation model. Both these modifications will likely have a significant effect on deposition.

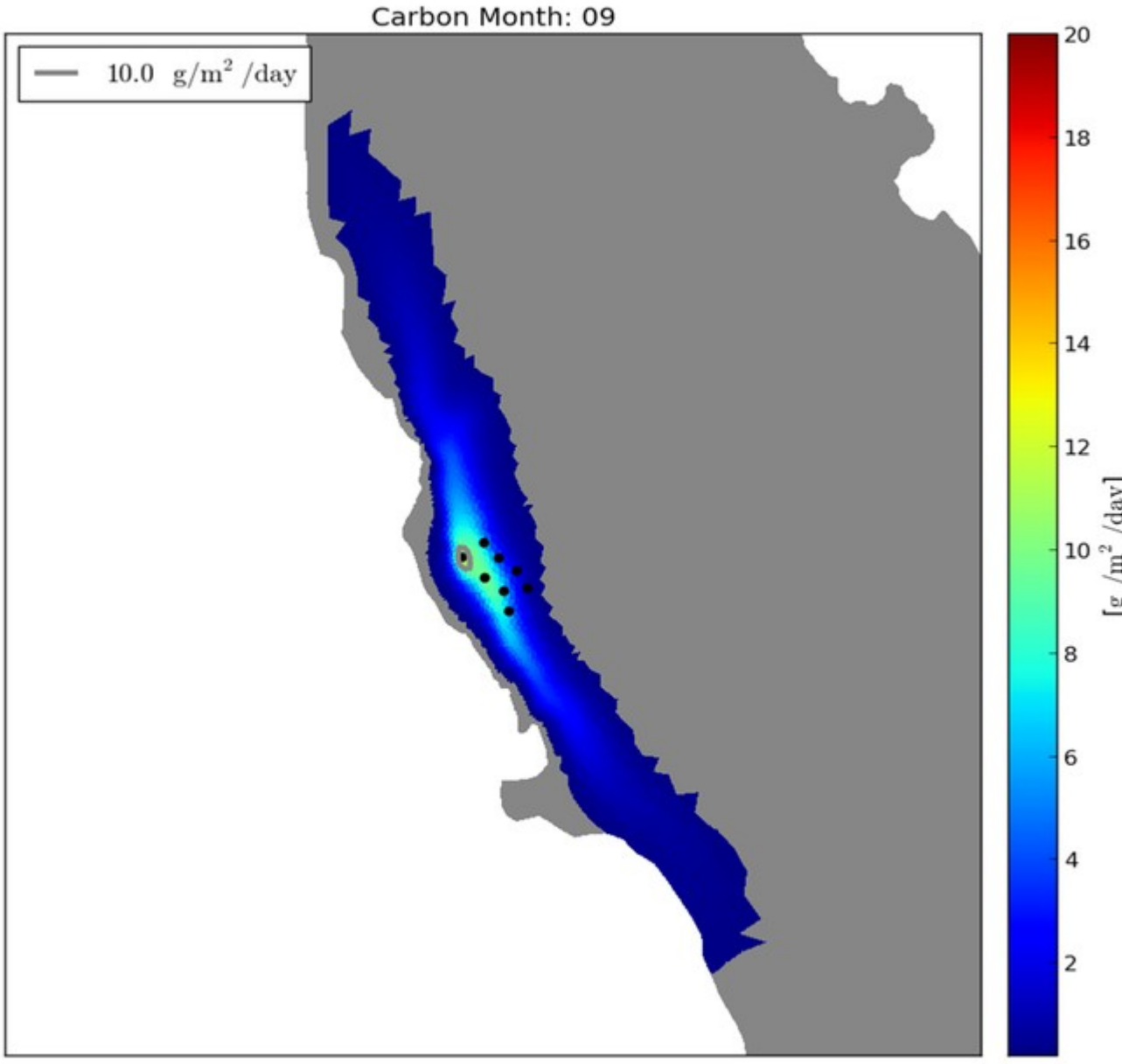
During 2017 at NIVA there was continued work on biogeochemical modules of FABM, and the coupling of OxyDep with a module representing the waste as particulate and/or dissolved matter was tested. The detailed biogeochemical O-N-P-Si-C-S-Fe-Mn model BROM (Yakushev et al., 2017) was re-coded and broken into separate modules (i.e. for transformation of Fe, Mn, S, calculation of pH, basic ecosystem model), that can be used as together and separately. BROM coupled with a 2 dimensional vertical benthic-pelagic transport model 2DBP was applied for an analysis of a fishfarm discharge and simulated interconnected changes in the water column and the sediments biogeochemistry.

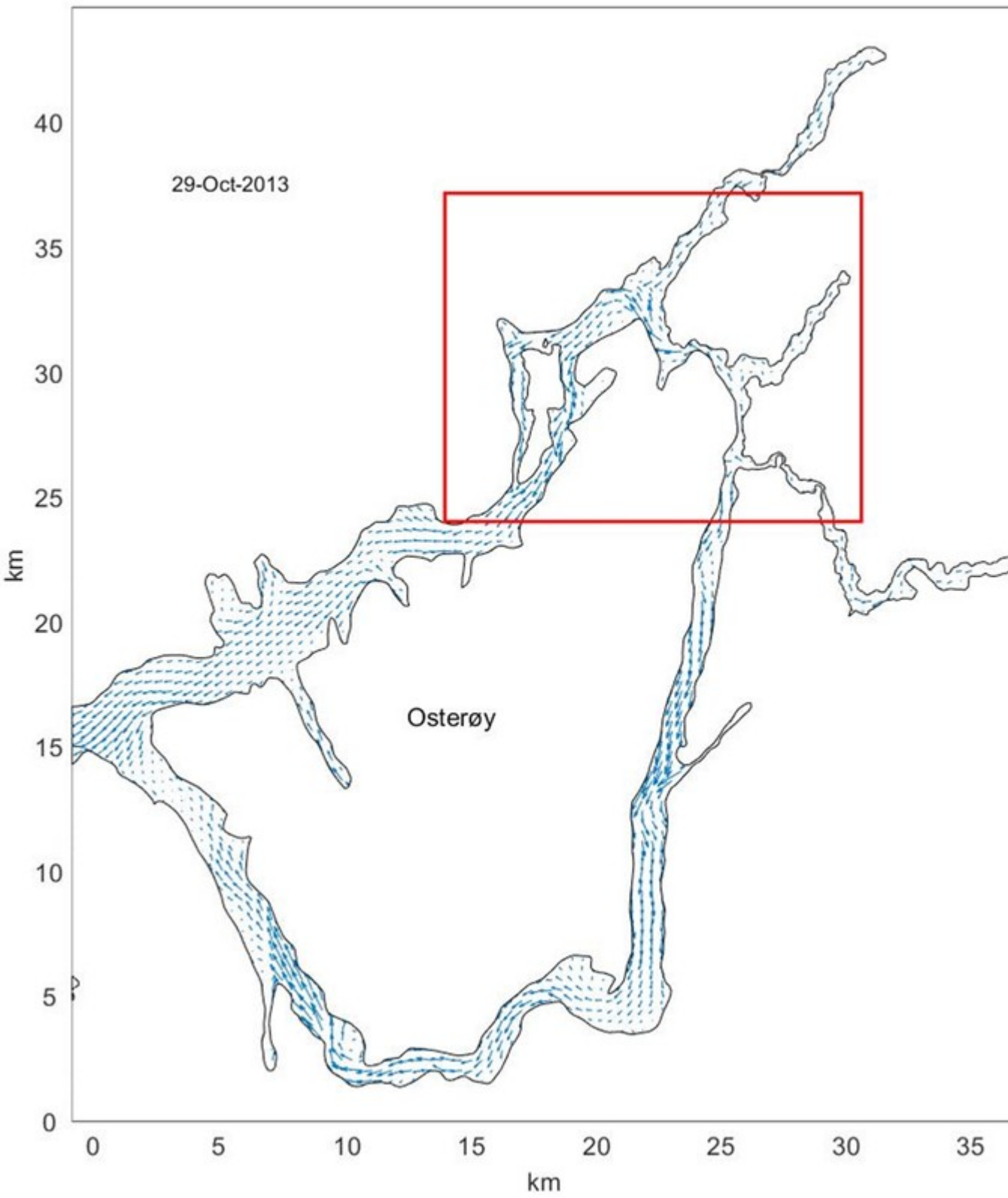
FVCOM has been set up for Osterfjorden, and the hydrodynamic model without tracers has been run and the results are being validated. An example of daily mean surface current can be seen in Figure 4, and an example of the surface temperature in Figure 5. During November and the December the plan is to couple FVCOM to the sedimentation model and OxyDep for this model domain.

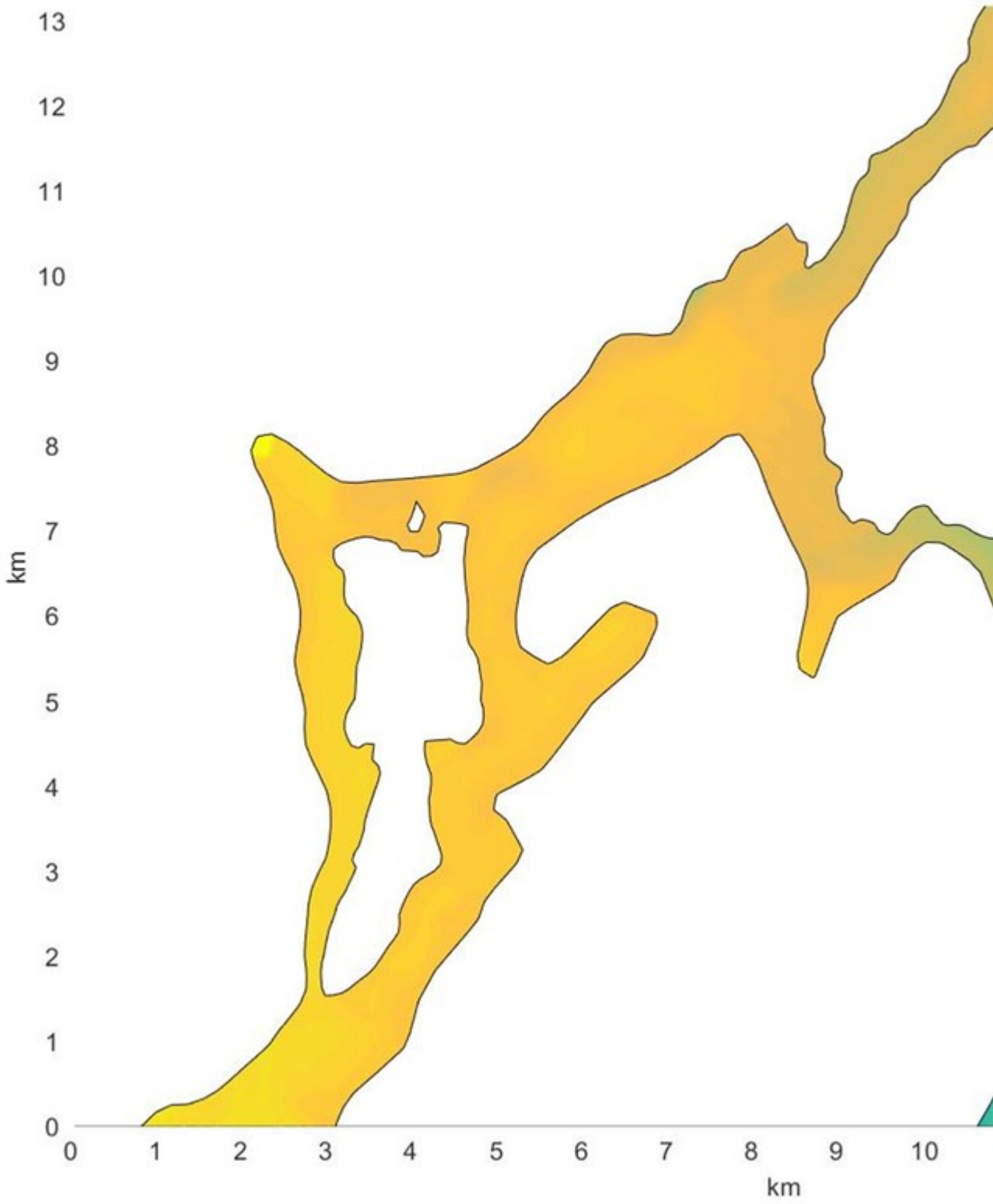
Vestfjorden




12.8
12.4
12.0
11.6
11.2
10.8
10.4
10.0
temperature [° C]


Carbon Month: 09
10.0 g/m^2 /day
20
18
16
14
12
10
8
6
4
2
[g /m^2 /day]


29-Oct-2013
Osterøy
km
km
0
5
10
15
20
25
30
35
40



References:

Bannister, R.J., I. A. Johnsen, P. K. Hansen, T. Kutti, L. Asplin, Near- and far-field dispersal modelling of organic waste from Atlantic salmon aquaculture in fjord systems, ICES Journal of Marine Science; doi:10.1093/icesjms/fsw027.

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Yakushev, E.V, E.I. Debolskaya, I.S. Kuznetsov, and A. Staalstrøm, Modelling of the Meromictic Fjord Hunnbunn (Norway) with an Oxygen Depletion Model (OxyDep), E.V. Yakushev (ed.), Chemical Structure of Pelagic Redox Interfaces: Observation and Modeling, Hdb Env Chem (2013) 22: 235–252, DOI 10.1007/698_2011_110, Springer-Verlag Berlin Heidelberg 2011, Published online: 20 July 2011

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For the Management

We have developed a modeling tool that can be useful to assess the environmental footprint of the aquaculture industry. As we continue to build experience with this, the goal is to develop a standardized procedure to evaluate the environmental consequences of production and furthermore to predict consequences of increased production.

Published Results/Planned Publications

- Planned publication: 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

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 2.

Could results from the project be subject for any commercial utilization

No

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) The results so far (see figure 3) indicate that bulk mass of the organic waste from fish farms accumulate 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. A process that should be incorporated into the sedimentation model is the effect of resuspension. There is current research at IMR that hopefully can contribute to giving reasonable empirical data that could be used in the model parametrizations of this process. 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 coupled our unstructured-grid hydrodynamic model to a simplified ecosystem model (oxydep) for simulations of environmental effects in the water column and bottom sediments.