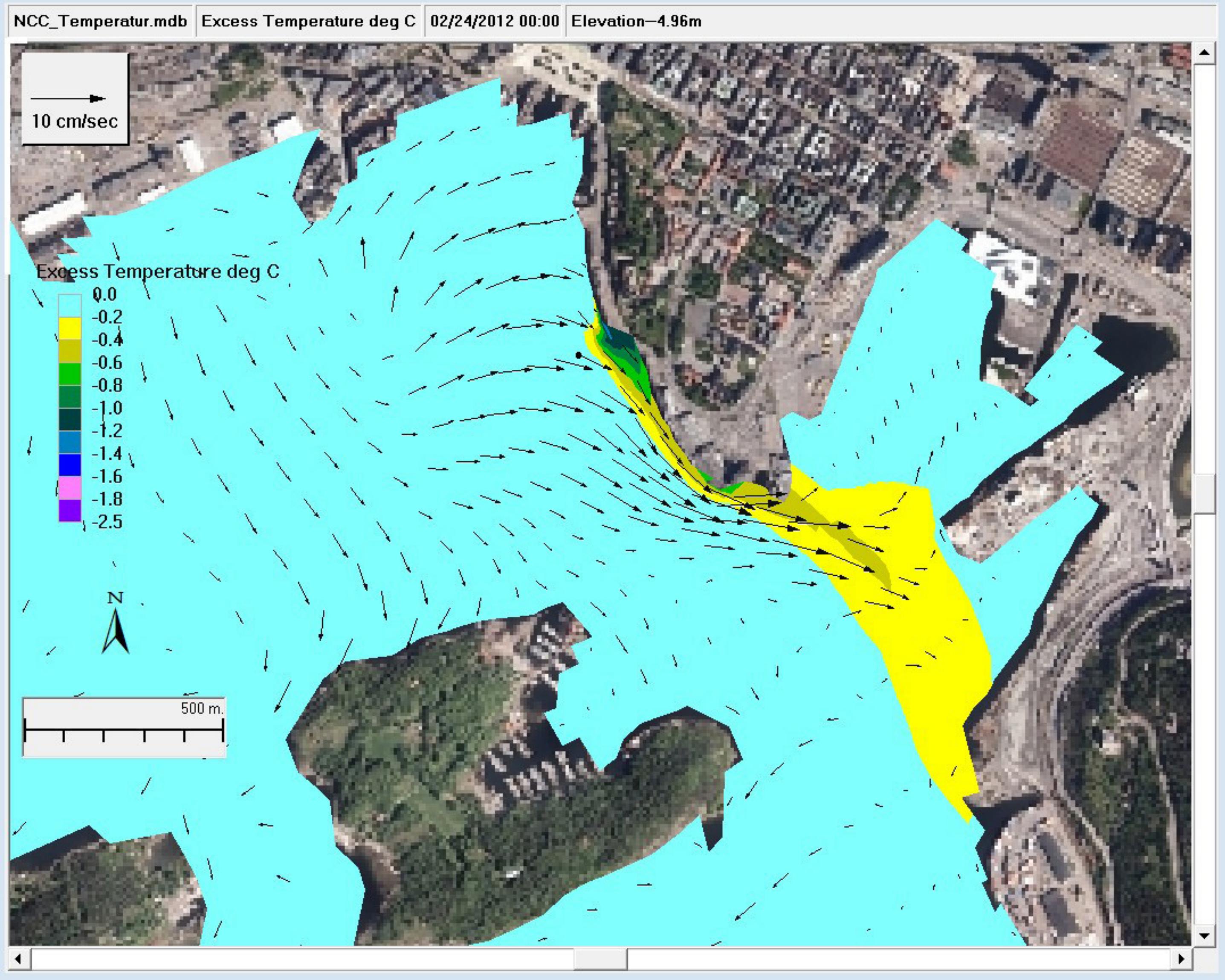
REPORT SNO 6671-2014

Discharge from NCC's snow melting barge at the Akerhuskaia
Reduced temperatures in Oslofjord



Norwegian Institute for Water Research
– an institute in the Environmental Research Alliance of Norway

REPORT

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Abstract

The objective of this work was to describe how discharged cold water from a snow melting barge at Oslo harbour reduces the temperatures in the fjord. It was of special interest to study how the discharged water might influence the temperature of the water intake. The results are obtained using the numerical model GEMSS. If the intake is localized 100 meter outwards the barge and deeper than 10 meter, the discharge does not practically influence the temperature in the intake water. The reduced temperatures in the intake water are less than natural changes during a day. Reduced vertical salinity difference from 5 ppt to 0.5 ppt between surface and 20 m does not change this conclusion. The discharge water is mainly spread beneath the surface and therefor in a minor degree leads to increased ice cover formation.

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1. Snøsmelteanlegg	1. Snow melting barge
2. Vanntemperatur	2. Water temperature
3. Numerisk modellering	3. Numerical modelling
4. Oslofjorden	4. Oslofjord

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Discharge from
NCC's snow melting barge at the Akershuskaia

Reduced temperatures in Oslofjord

Preface

This work is a part of NCC's BIA ("Brukerstyrt innovasjonsarena") project, financed by the Norwegian Research Council. NIVA's overall task in the project is to improve the knowledge on discharges from the barge. In this project, NIVA has conducted surveillance in the barge at specific sampling location in addition to monitoring of discharges from the barge, with special emphasize on persistent organic pollutants and heavy metals. During the monitoring, NIVA has used alternative sampling techniques like passive samplers and high volume water samplers, in addition to NCC's conventional monitoring program. A monitoring program, to be completed next year, has also started in the Inner Oslofjord. NIVA's tasks in the project are led by Sissel Brit Ranneklev.

The object of the work conducted in this report is to describe how discharged cold water (mixture of collected snow and ambient intake water) effect the temperatures in the influence area of the barge in the harbour.

This report is mainly made by Magdalena Kempa and Torulv Tjomsland. NCC by Hans L. Kevin has delivered the premises for the modelled scenarios and contributed with discussions during the work.

Oslo, 02.05.2014

Sissel B. Ranneklev

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Summary

NCC Construction has developed a snow-melting facility with the capacity to melt 500 cubic meters of snow per hour collected from the urban areas of Oslo during winter. Intake water above 0 °C from the Oslofjord is used to melt the snow. The melted mixture of snow and intake water in the barge flow through a double canal system, with areas for sedimentation, oil filters, micro filters and a lamella filter that removes particles of various sizes, and to some extend attached pollutants. Discharge of cold water may lead to a plume of colder water spreading around the facility during operation, since the mixture of snow and intake water is colder. The mobile melting facility is during operation located in Oslo at the Akershuskaia.

The objective of this project was to describe how the discharged water from the snow melting facility changes the water temperature in the harbour area. It was of special interest to study how the discharged water might influence the temperature of the water intake. It was also of interest to study alternative localization of the water intake for the melting facility.

The spreading of the discharged cold water was modelled by the 3-D hydrodynamic and water quality model package named GEMSS. Simulations of hydrodynamics and temperature were made with the melting facility continuously in operation during one month. The natural conditions were defined as observed during February 2012. The intake was localized 108 meter outwards from the barge, 24 meter below surface. The pumping rate was 6000 m^3/h (=1.667 m^3/s) with a temperature near 4 ^{o}C. After melting of the snow, water with a temperature of -2 ^{o}C was discharged from the bottom of the barge at a depth of 3.5 meter below surface.

The following description represents the maximum temperature change during the simulated month. On the surface the temperatures were reduced by less than 0.4 ^{o}C some hundred meters away from the barge. Near 5 meter below surface the temperatures became reduced by near 1 ^{o}C near the discharge point to less than 0.2 ^{o}C within one kilometer away. On 10 meter's depth and deeper, changes were less than 0.1 ^{o}C. The current direction was along the shore most of the time. The discharged cold water seldom moved outwards from the shore towards the intake.

Near the location of the intake the greatest temperature deviation was close to the discharge depth. The water always became less than 1 ^{o}C colder at 5 m depth. On the surface, the deviation seldom became larger than 0.2 ^{o}C. From 10 m and downwards the water temperatures became lowered by less than 0.1 ^{o}C.

One investigated scenario was related to the effect of decreased vertical stability. A scenario was prepared by the use of an observed profile by Helsinki, Finland. The salinity increased from near 0.5 ppt at the surface to 1.5 at 20 meter. For any practical use, the decreased vertical stability had less effect on the vertical distribution of colder water. Beneath 10 meter the water temperatures became lowered by less than 0.1 ^{o}C.

Conclusions

If the intake is localized 100 meter outwards from the melting facility and deeper than 10 meter, the discharge of cold water does not practically influence the temperature in the intake

water. The reduced temperatures in the intake water are less than expected natural fluctuations during a day. Reduced vertical salinity difference from 5 ppt to 0.5 ppt between surface and 20 m does not change this conclusion. The discharge water is mainly spread beneath the surface and therefor in a minor degree leads to increased ice cover formation.

1. Introduction

The removal of snow from Oslo's urban areas poses a major environmental challenge. Until recently, snow removed from major roads and from the city centre was removed by trucks and dumped in temporary landfills outside the city centre. This method was not only unsightly, it also meant that substances, such as solid particulate matter, oil residue and heavy metals, salt, contained in the snow, ended up contaminating the area around the landfill. It also meant employing considerable resources to transport and handle the excess snow.

NCC Construction has, in collaboration invented a snow-melting facility with the capacity to melt 500 cubic meters of snow per hour from the streets of Oslo during the winter. Snow from streets etc. is emptied into the melting facility, were water above 0 °C from the Oslofjord is used to melt the collected snow. The melted water in the barge then flow through double canals with areas for sedimentation, oil filters, micro filters and a lamella filters that removes particles of various sizes, and to some extend attached pollutants, before it drains to the sea.

The melting facility was put in operation in the winter 2011/2012 and has proved to be a very effective way of dealing with the removal of snow in the city.

(The above introduction is based on information from: http://www.oslo.kommune.no/english/environment/water/effective_measures_/article229485-65071.html)

1.1 Objective

The objective of this work was to describe how the discharged water from the snow melting facility changes the temperatures in the harbour area of Oslo. It was of special interest to study to what extent the discharged water might influence the temperature of the water intake. It was also of interest to study alternative localization of the water intake.

1.2 Area description

The Oslofjord is located in the south-eastern part of Norway. The length is about 100 km from its connection with Skagerrak in the south to the center of Oslo. The total area of the Inner Oslofjord is 190 km^2. Drainage area and mean freshwater inflow are ca. 1350 km^2 and ca. 30 m^3/s respectively.

The snow melting facility is localized on a barge by the harbour of Oslo down from the Akershus Castle and Fortress.

The water depths around the melting facility is less than 25 m within a radius of approx. 100 m, **Figure 1** and **Figure 2**.

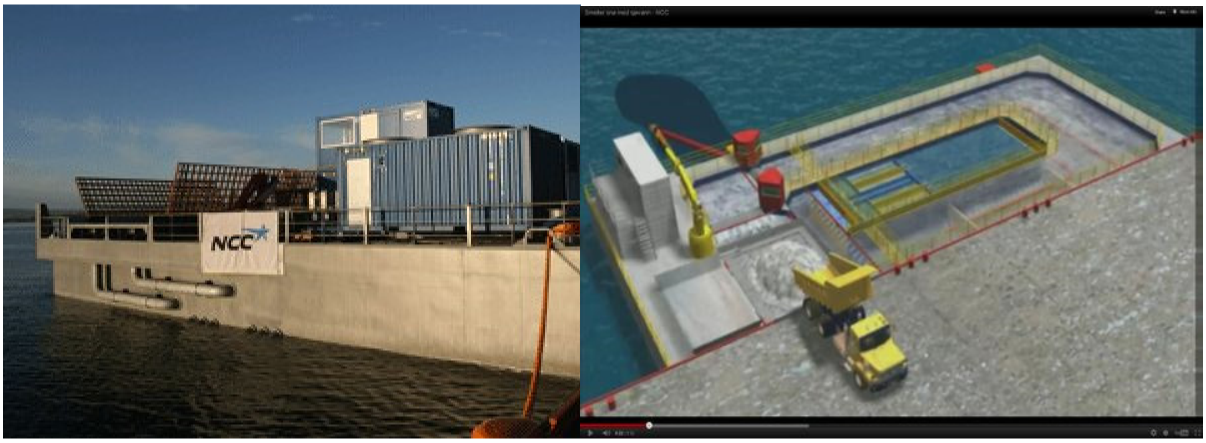


Figure 1. The snow melting facility is installed on a barge localized in the harbour of Oslo. (Source: www.oslo.kommune.no)

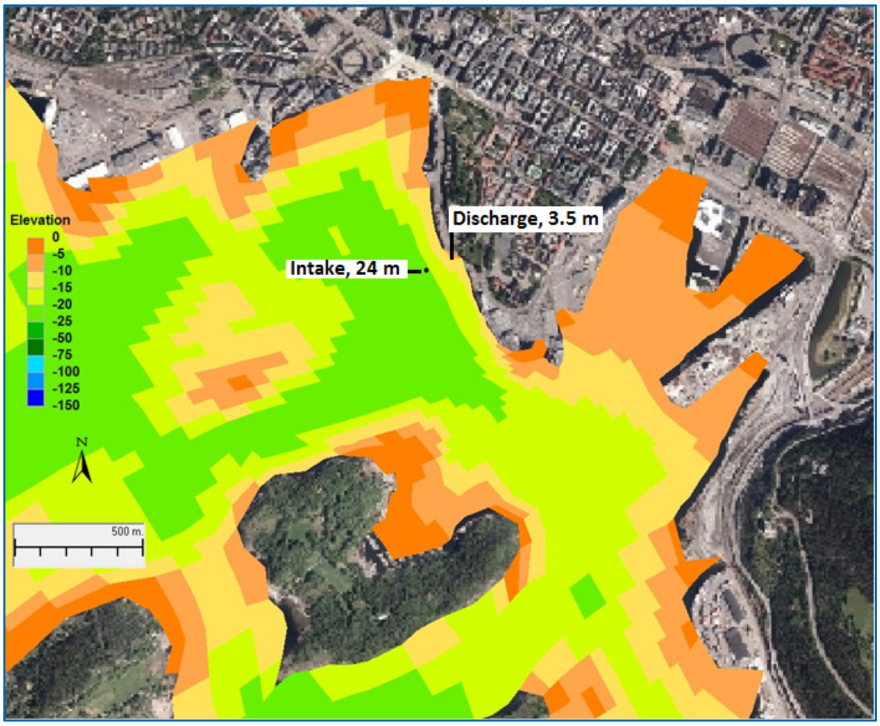


Figure 2. Bottom topography. An average depth is assigned to each cell in the modelling grid.

A 3-D model package named GEMSS (Generalized Environmental Modeling System for Surface waters) was used. The model package has been developed by ERM's Surface water Modeling Group in Exton, USA (http://gemss.com/index.html). The core of the package is a hydrodynamic model, with modules for sediment transport, water quality and others, which can be added when needed.

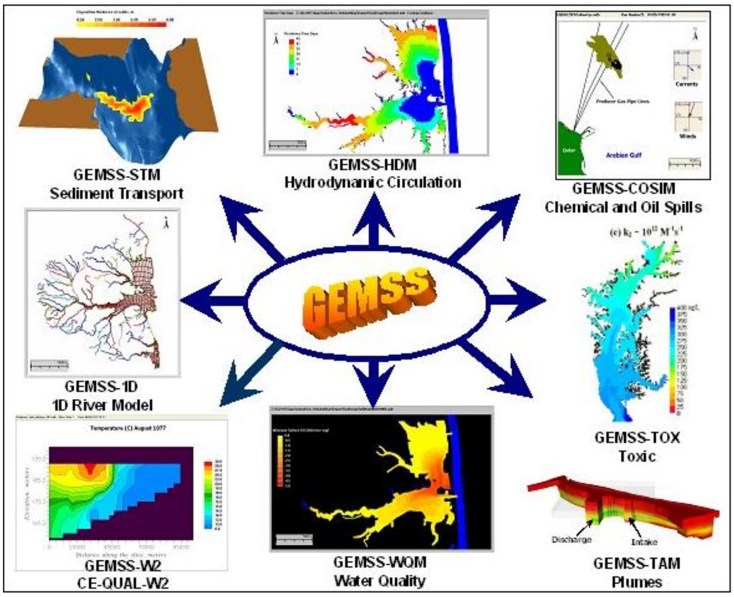


Figure 3. GEMSS is a package of models. The core of the package is a hydrodynamic model, with modules for sediment transport, water quality, etc., which can be added when needed.

2. Simulated temperature differences in the Inner Oslofjord due to operation of the snow melting facility

Simulations of hydrodynamics and temperature were done with the melting facility continuously in operation through one month. Assessment of the results from the modelling was focused on changes water temperature around the melting facility.

The fjord was divided in computational cells in the model set-up, **Figure 4**. For each computational cell water currents, temperature and salinity was calculated with conditions as in February 2012. The driving forces were climate (air temperature, dew point temperature, wind speed, wind direction, solar radiation and air pressure), water level changes/tide and water flow from rivers. The input data were downloaded from official governmental databases.

The meteorological conditions were rather normal and representative for winter conditions in Oslo, **Figure 5**-**Figure 7**. The main wind directions were from north and from south with speed that seldom exceeded 4 m/s. The air temperatures were slightly warmer than normal with periods with plus degrees.

The water temperatures increased from near zero at the surface to ca. 4 ^{o}C at 20 meters depth. The salinity increased from around 27 ppt at the surface to 32 ppt at 20 meter, **Figure 9**.

The tide led to changing water level with a period of 6 hour, **Figure 8**. The regular tidal fluctuations were some decimetre, but maximum difference during the February 2012 was 1.5 m.

Within 1 km from the barge, there are three rivers entering the Inner Oslofjord: Akerselva, Alna and Hovindbekken. Total mean water discharges were 4 m^3/s. The fresh water affects the water currents on a local scale; however the freshwater influence significantly the salinity/density profile.

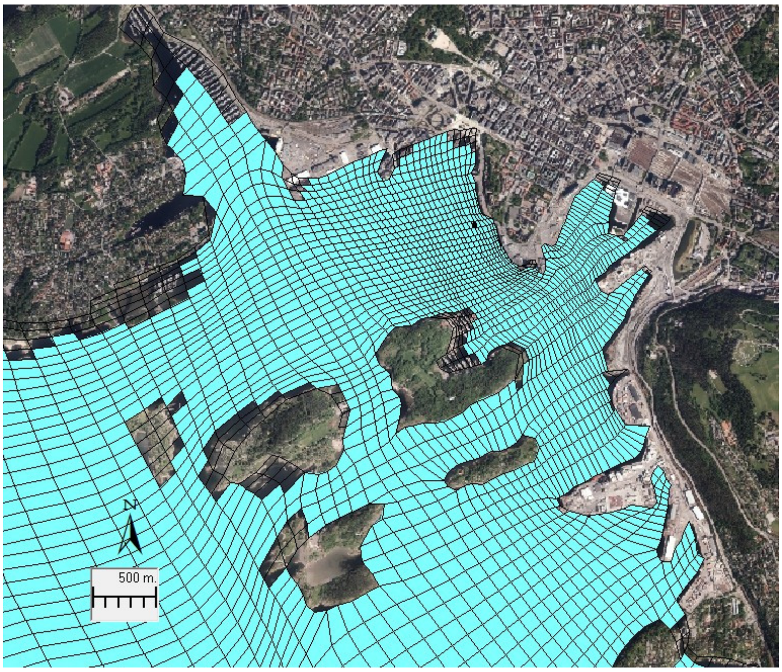


Figure 4. The fjord was divided in computational cells; horizontally as seen on the figure and vertically of horizontal planes with distance of one meter. The localization of the intake is marked with a point.

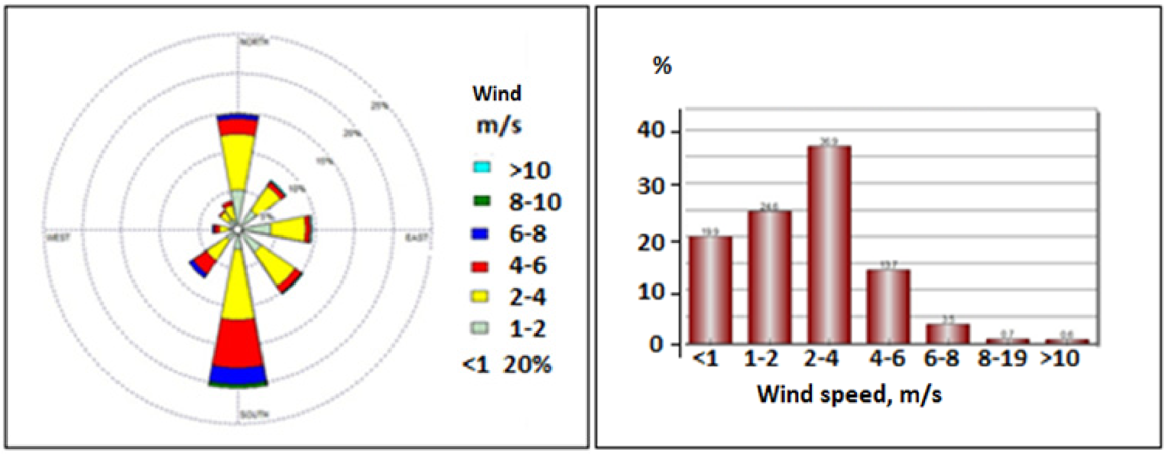


Figure 5. Oslo 2012. The main wind directions are along the fjord, from north and from south. The wind speed is seldom more than 6 m/s.

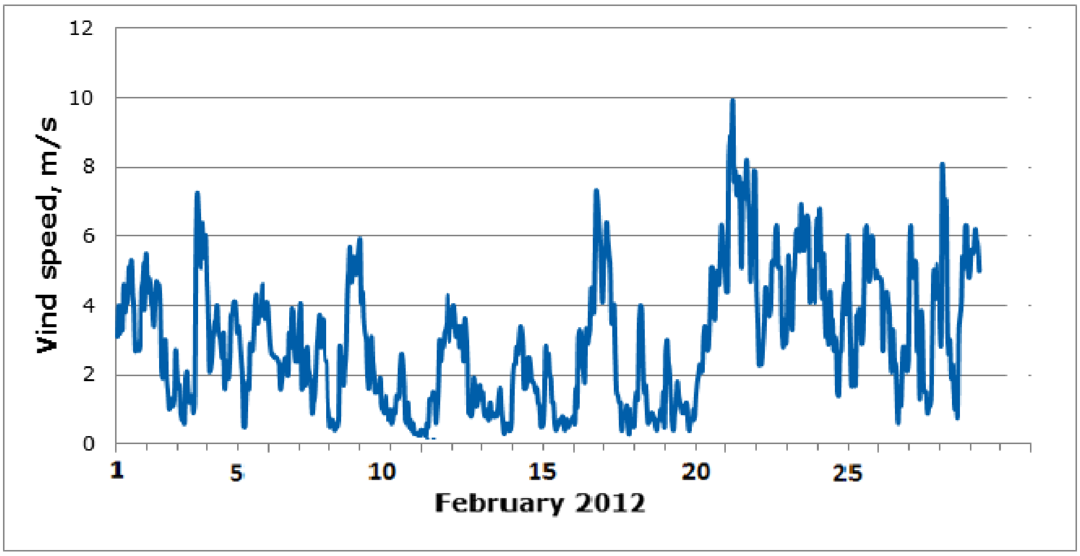


Figure 6. Wind speed during the simulated period.

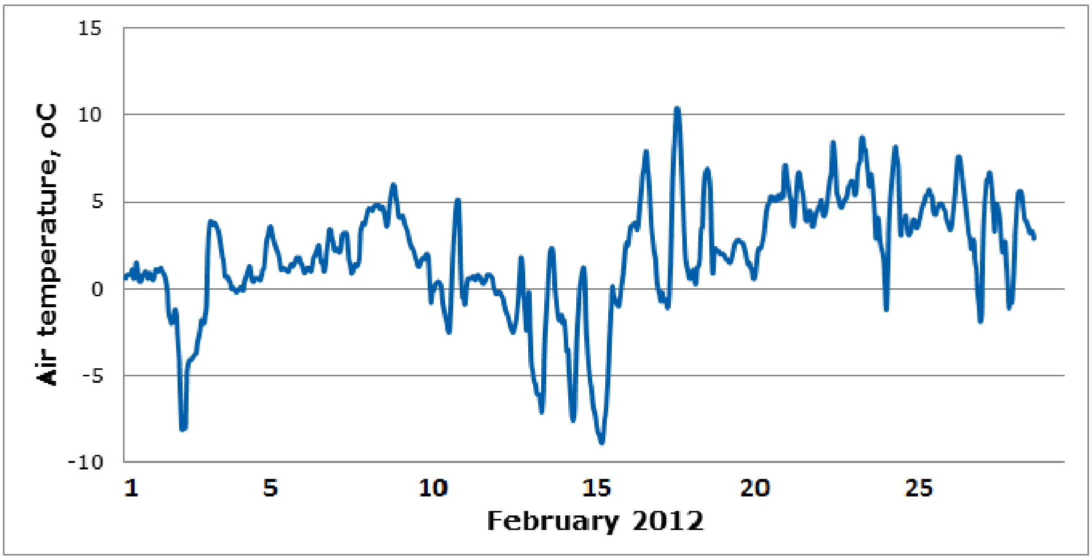


Figure 7. The air temperature during the simulated period.

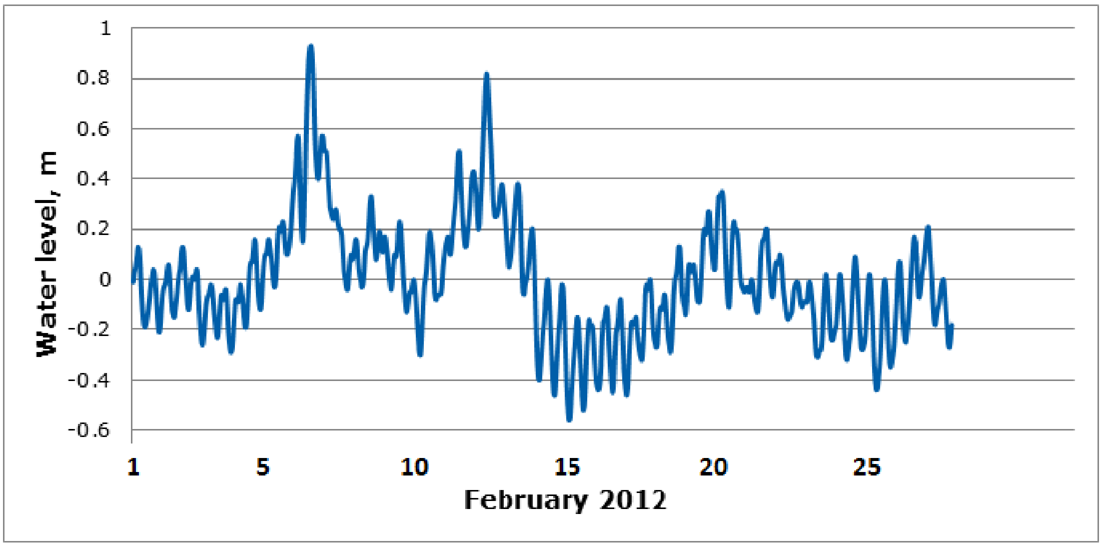


Figure 8. The tide led to changing water level with a period of 6 hour.

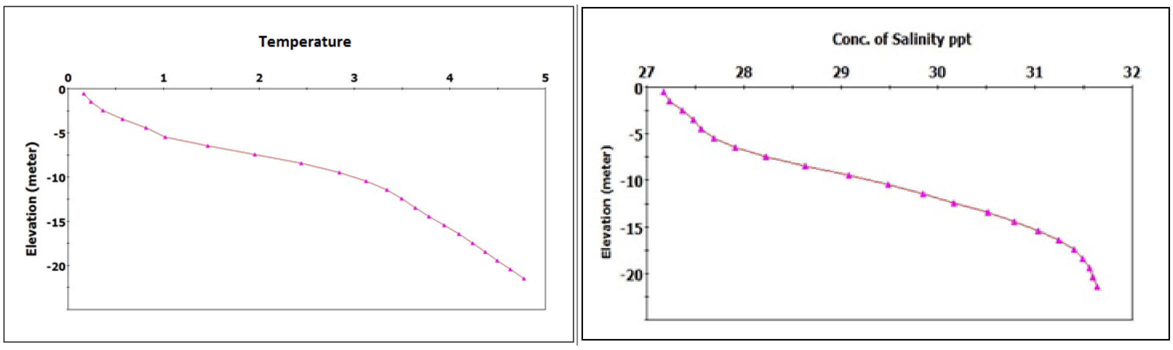


Figure 9. The water temperatures were changed from near zero at the surface to 4-5 °C at 20 meter's depth. The salinity decreased from around 27 ppt at the surface to 32 ppt at 20 meter.

Scenario summary:

- Continuously snow melting during one month with natural condition as of February 2012
- Intake: Depth 24 meter, 108 meter from land/barge
- Water pumped: 6000 m^3/h = 1.667 m^3/s
- Intake water temperature: near 4 °C
- Discharge localization: 3.5 m close to land (under the barge)
- Discharge water temperature: -2 °C

The results from the numerical modelling are presented as excess temperature, which is the difference between the temperatures in the fjord with and without discharge of the colder water from the barge.

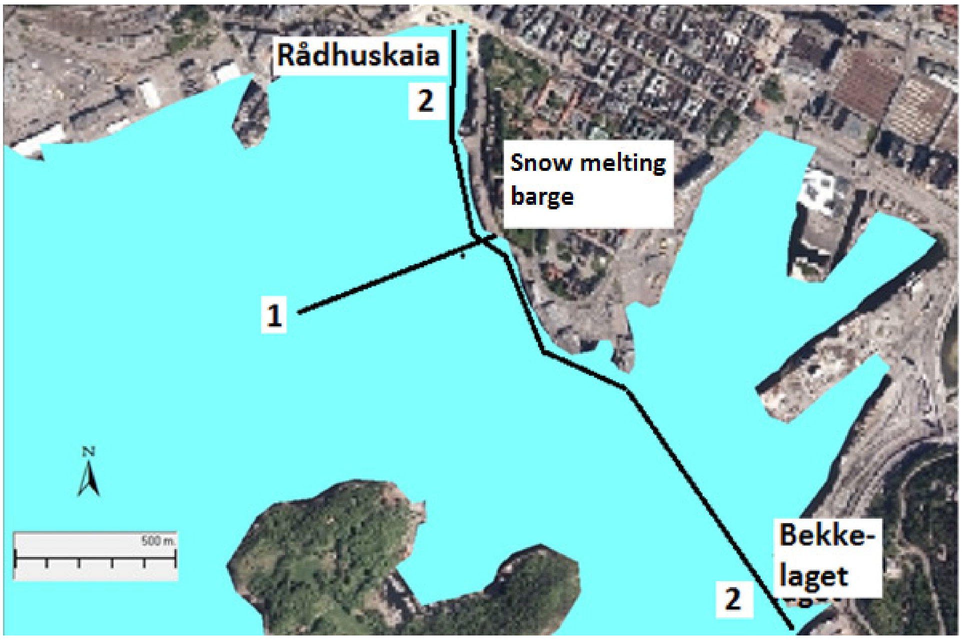
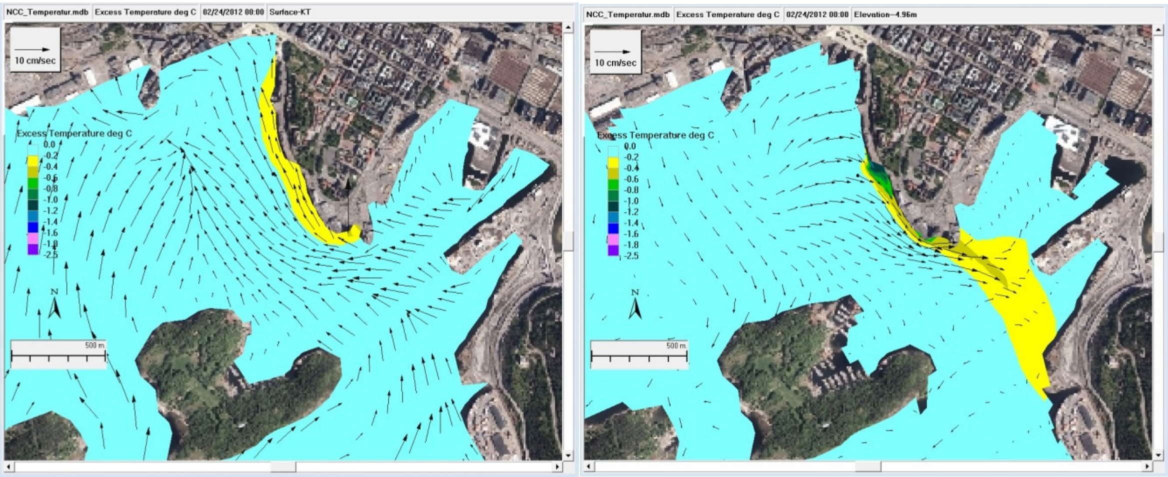


Figure 10. Cross sections used for presentation of modelling results in the following figures.

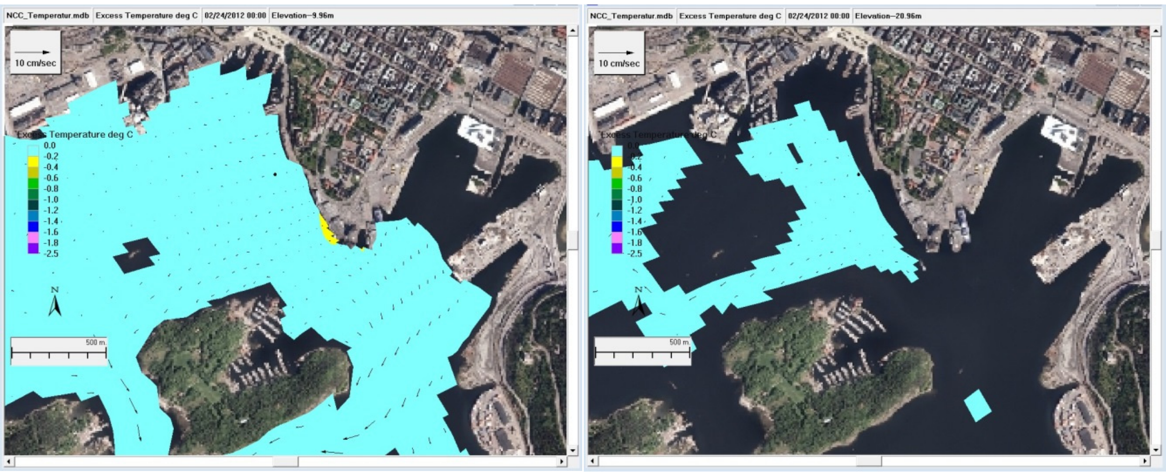
A typical situation is shown on
Figure 9. This distribution is rather like the simulated average temperature deviation during February 2012,
Figure 15. On the surface the temperatures were reduced by less than 0.4 ºC some hundred meters away from the barge. Near 5 meter below surface the temperatures became reduced from near 1 ºC by the discharge point to less than 0.2 ºC within one kilometer away. On 10 meter's depth and deeper, changes were below 0.2 ºC.

The deepest simulated distribution away from land towards the intake is shown on **Figure 13** and **Figure 14**. Temperatures were reduced by near 0.4 ºC down to 10 meter below surface.

Maximum simulated temperature deviations during February 2012 near the intake are shown on **Figure 16**. On the surface the temperatures were reduced by less than 0.4 ºC some hundred meters away from the barge. Near 5 meter below surface the temperatures became reduced by near 1 ºC near the discharge point to less than 0.2 ºC within one kilometer away. On 10 meter's depth and deeper, changes were below 0.1 ºC.

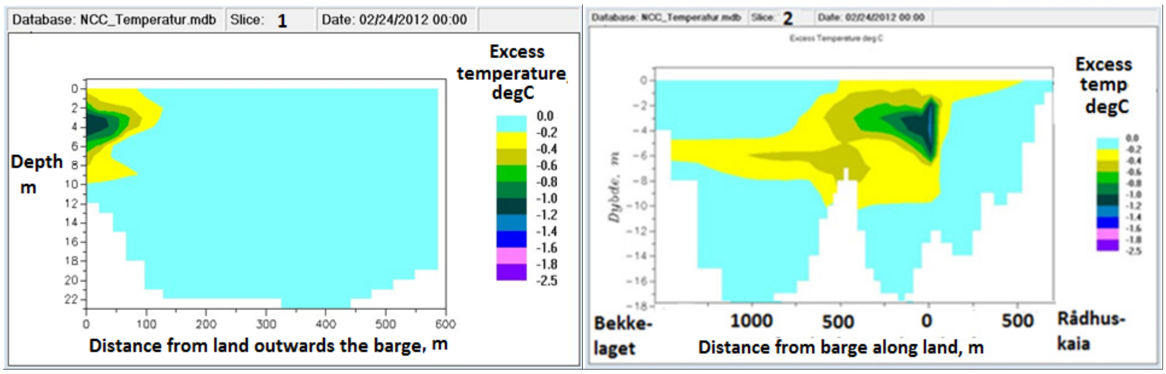


surface 5 m



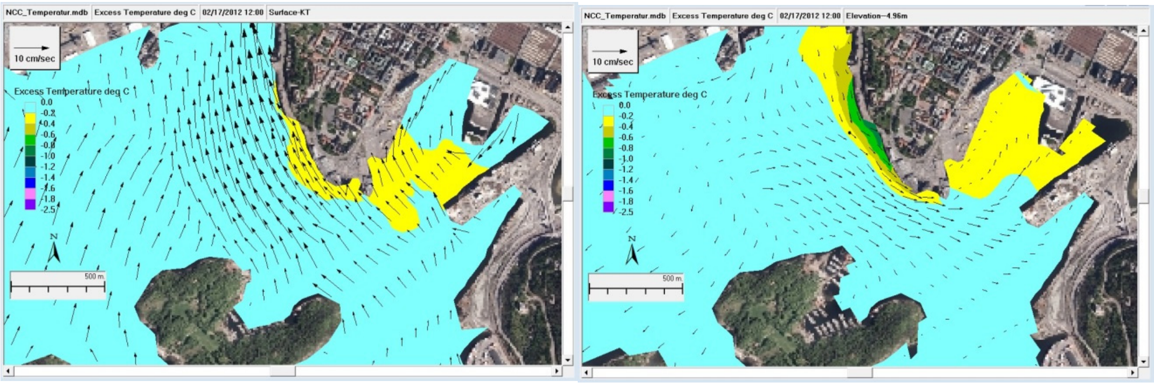
10 m 20 m

Figure 11. Example of a common distribution of water temperature at different water depths. The snow melting water was mainly spread along the shore. On the surface the water temperatures were reduced by less than 0.4 degree Celsius. Five meter below surface the temperatures were lowered from ca. 1 ºC near the outflow to less than 0.4 ºC 1 km away. Deeper than 10 meter below surface the deviations were less than 0.2 ºC.

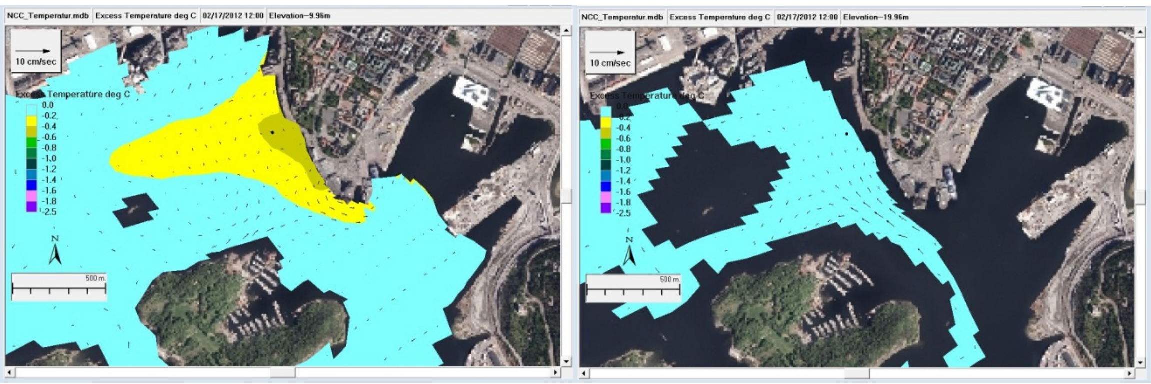


Perpendicular from shoreline ("1") Along shoreline ("2")

Figure 12. Example of a common temperature distribution of two cross sections (ref, fig. 10). The main temperature deviations were localized around 3-6 meter below surface.

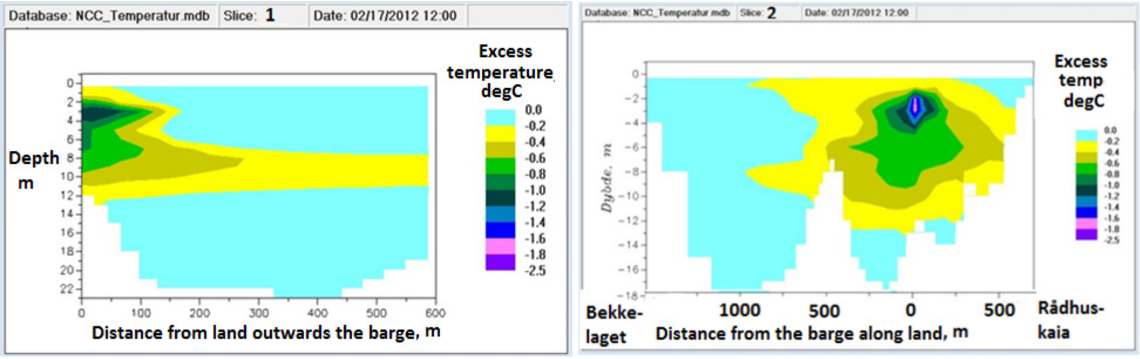


Surface 5 m



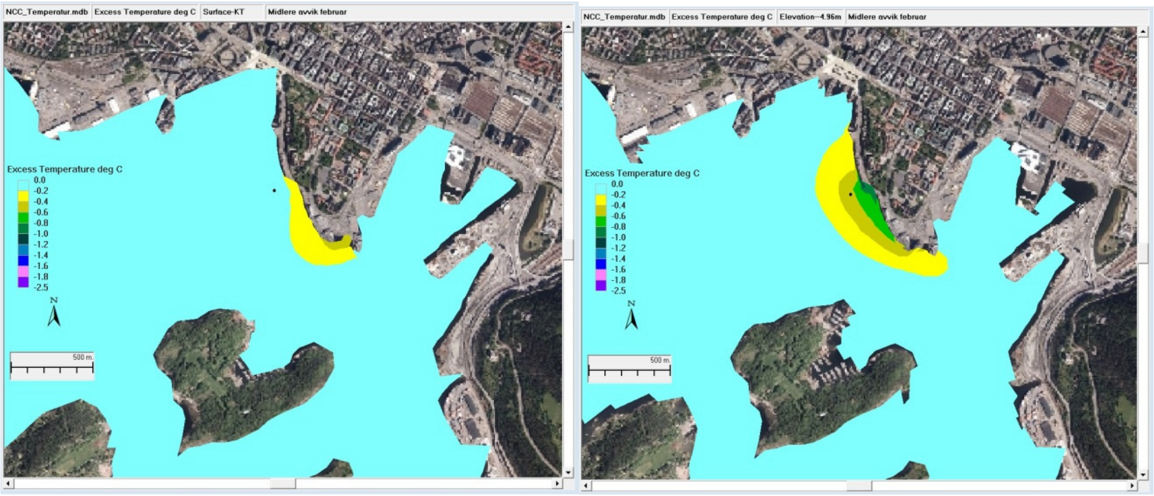
10 m 20 m

Figure 13. Example from the deepest simulated temperature distribution during the month with a great component perpendicular to land. Temperatures were reduced by near 0.4 °C down to 10 meter below surface.



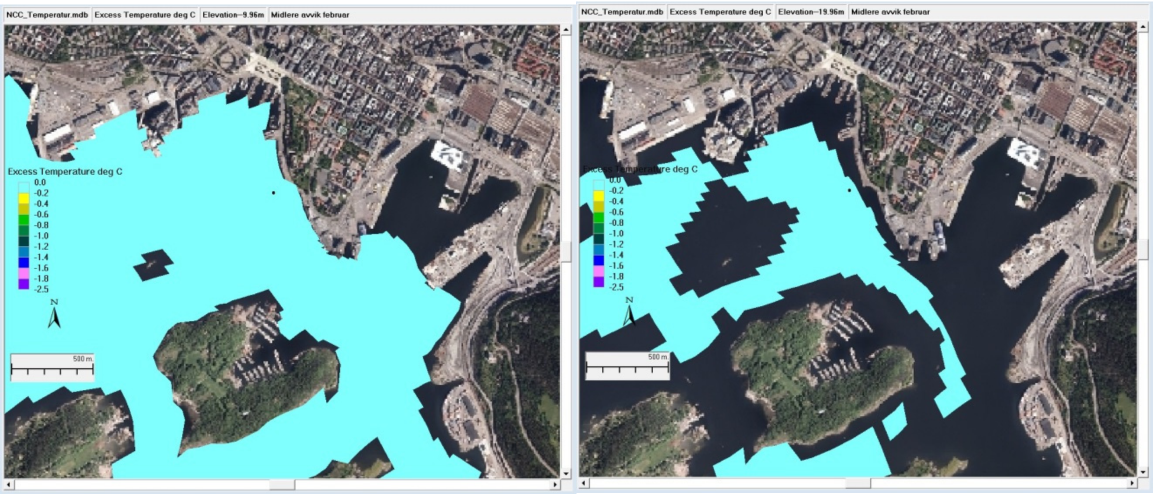
Perpendicular from shoreline ("1") Along shoreline ("2")

Figure 14. The deepest simulated distribution during February 2012 was around 10 meter



Surface

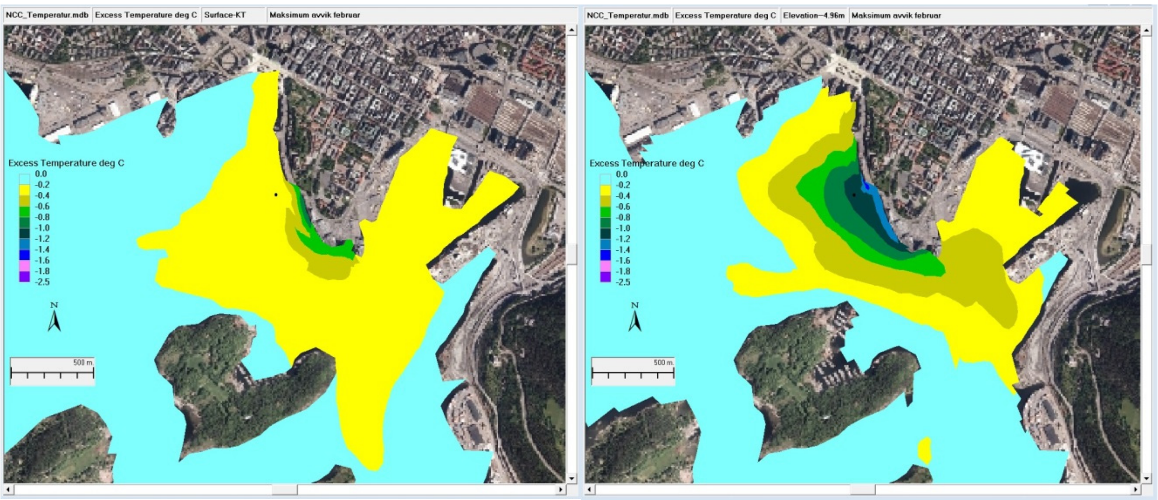
5 m



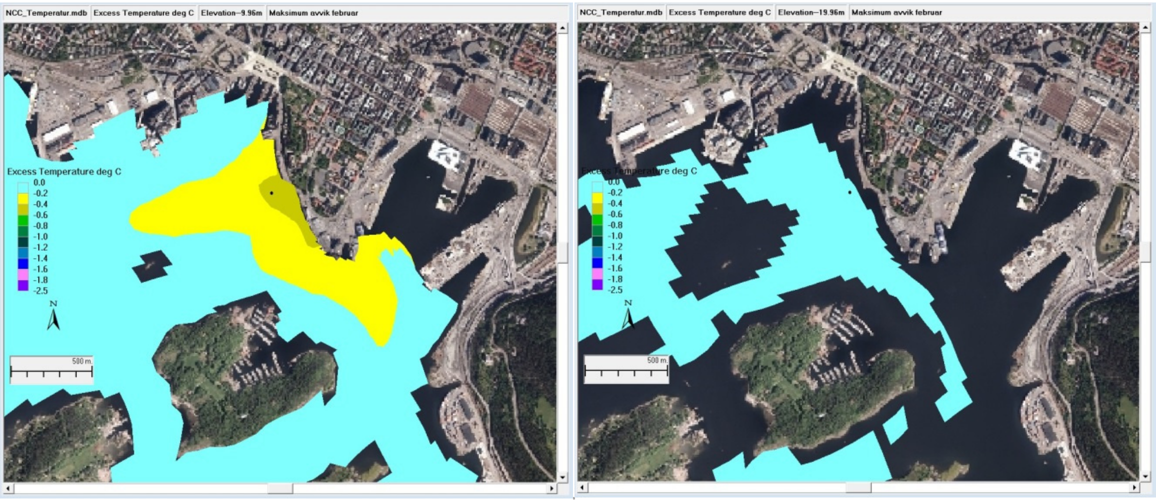
10 m

20 m

Figure 15. Simulated average temperature deviation during February 2012. On the surface the temperatures were reduced by less than 0.4 °C some hundred meters away from the barge. Near 5 meter below surface the temperatures became reduced from near 1 °C by the discharge point to less than 0.2 °C within one kilometer away. On 10 meter’s depth and deeper, changes were below 0.2 °C.



Surface 5 m



10 m 20 m

Figure 16. Maximum simulated temperature deviations during February 2012. On the surface the temperatures were reduced by less than 0.4 ºC some hundred meters away from the barge. Near 5 meter below surface the temperatures became reduced from near 1 ºC by the discharge point to less than 0.2 ºC within one kilometer away. On 10 meter's depth and deeper, changes were below 0.2 ºC.

Profile by the intake, 100 meter outwards from the barge is shown on

Figure 17. The greatest deviation due to the melt water discharge was near the discharge depth at 3m. At 5 m the water always became less than 1 ºC colder. On the surface the deviation seldom became more than 0.2 ºC. From 10 meter and downwards the water temperatures became lowered by less than 0.1 ºC.

The changed temperatures are less than natural changes during a month, may be with exception of the discharge zone 3-6 meter.

If the intake water had been taken from 10 meter depth, the melting efficiently would still not have been significantly changed due to the melting water. The intake water would become somewhat colder, which would have led to increased time to melt the snow. However the discharge temperature would still been unchanged, ca. -2 ºC. Consequently the curves of changed temperatures in **Figure 16** may be used even if the water is pumped from other depths. Reduced temperature would be expected to be less than 0.2 ºC at an eventually intake on 10 meter.

The temperature of the intake depth may change during the winter due to natural conditions. This will not significantly change the calculated temperature reduction presented as long as the water discharge is the same. The temperature change is proportional with the water discharge. If the water discharge is doubled, the corresponding temperature decrease also will be doubled or vice versa.

According to the simulations the water intake at 24 meter is practically not affected by the melt water discharge from the barge. The colder discharged water will not influence the temperature of the intake water and reduce the melting capacity. Intake at 10 meter will not change this conclusion.

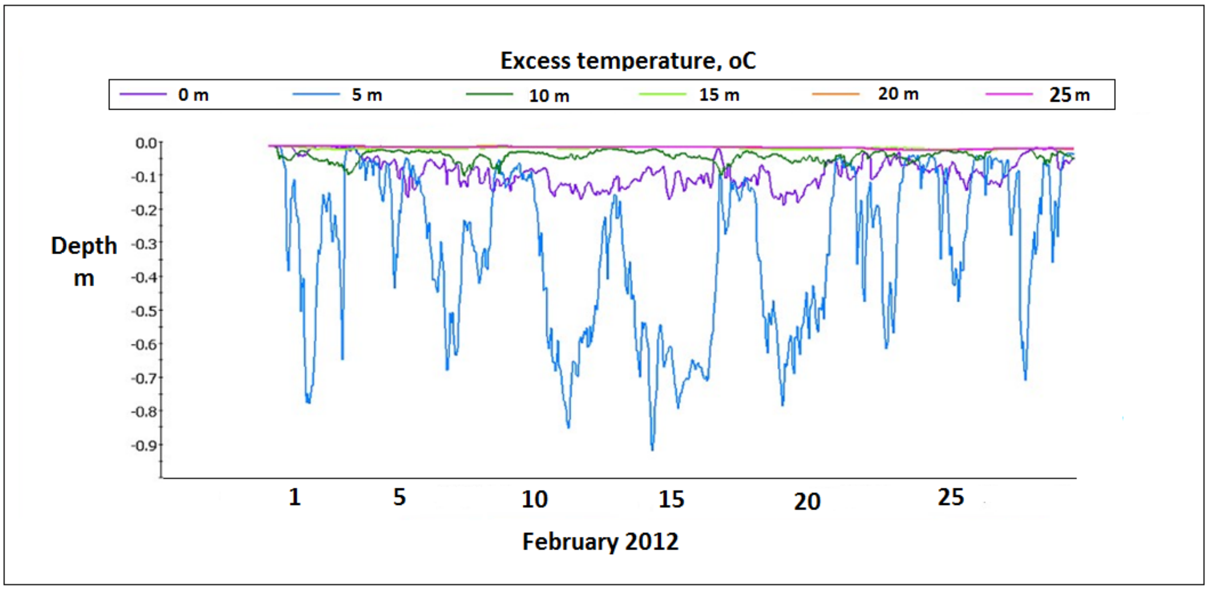


Figure 17. Profile by the intake, 100 meter outwards from the barge. The greatest deviation due to the melt water discharge was near the discharge depth at 3m. At 5 m the water always became less than 1 ºC colder. On the surface the deviation seldom became more than 0.2 ºC. From 10 meter and downwards the water temperatures became lowered by less than 0.1 ºC.

3. Changes in vertical stability and vertical water movements

Increased vertical density differences reduce vertical water movements. The vertical stability is strongly dependent of the vertically salinity differences.

In the scenarios the salinity by the harbour of Oslo increased from 27 ppt at the surface to 32 ppt at the intake depth at 24 meter. This profile efficiently prevented the melt water to mix with intake water. If the density/salinity gradients increase, the stability increase and the corresponding impact from the melt water decrease. No scenario is needed to test that.

Vice versa, if the salinity profile has a lower gradient, the vertical stability is reduced and melt water from above may impact the intake to greater extent. We prepared a scenario to study this phenomenon. The scenario was based on an observed profile from Helsinki, Finland.

The salinity increased from near 0.5 ppt at the surface to 1.5 at 20 meter. The corresponding temperatures increased were 0.4 and 2.5, **Figure 18**. The profile reflects great influence of fresh water from rivers. All other inputs to the scenario were the same as before.

Detailed studies of **Figure 19 - Figure 21** show slightly greater vertical dispersion of melt water than the corresponding scenarios with density profiles from the Oslofjord. For practical use, the results are equal. At the intake temperature due to melt water impact seldom became more than 0.2 ºC colder beneath 10 meter.

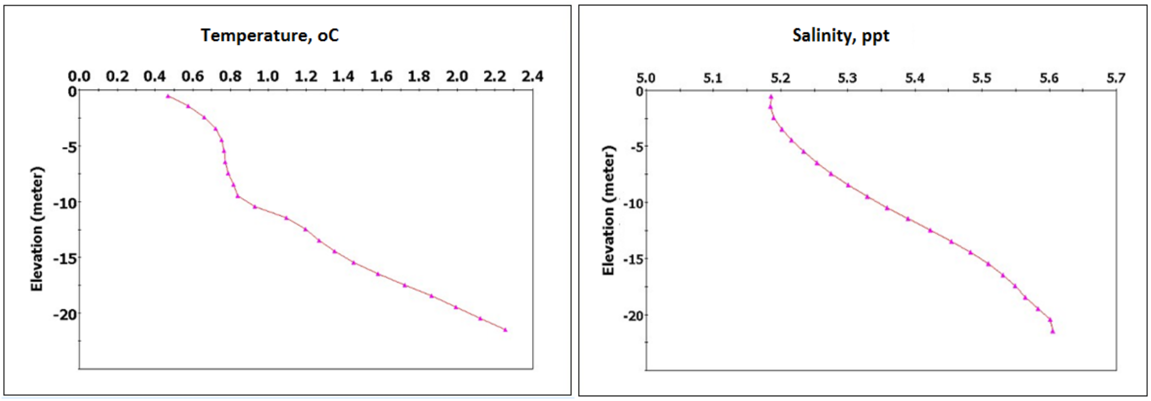


Figure 18. Depth profiles with small gradients of temperature and salinity. From Helsinki February 2012.

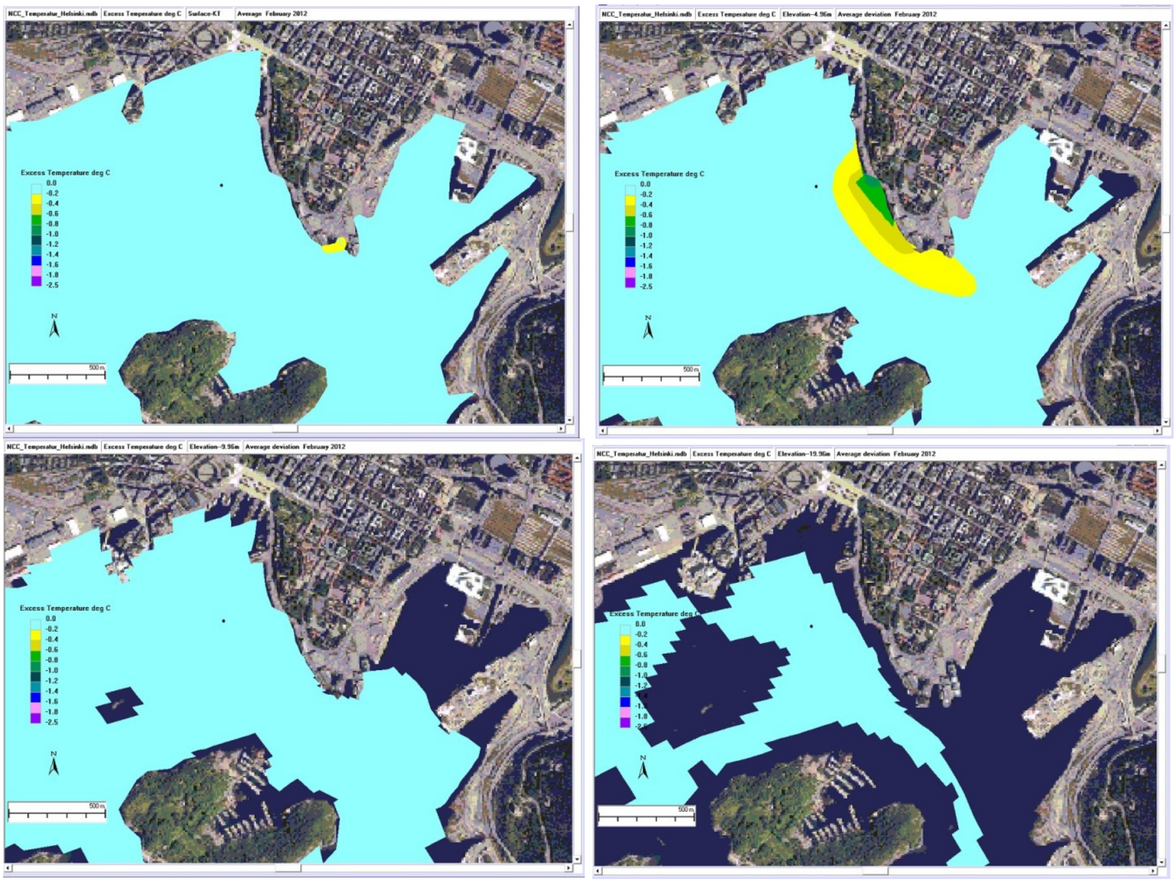


Figure 19. Average simulated temperature deviations during February 2012.

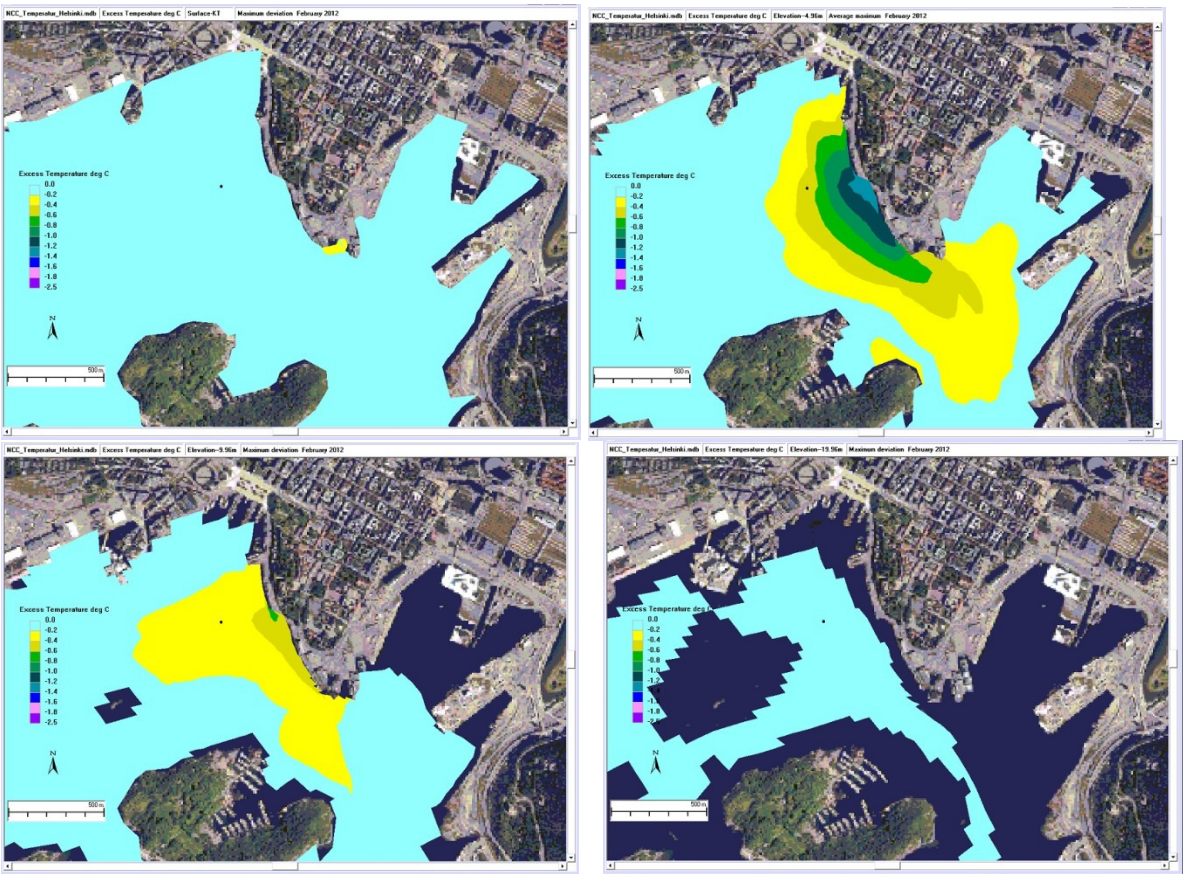


Figure 20. Maximum simulated temperature deviations during February 2012.

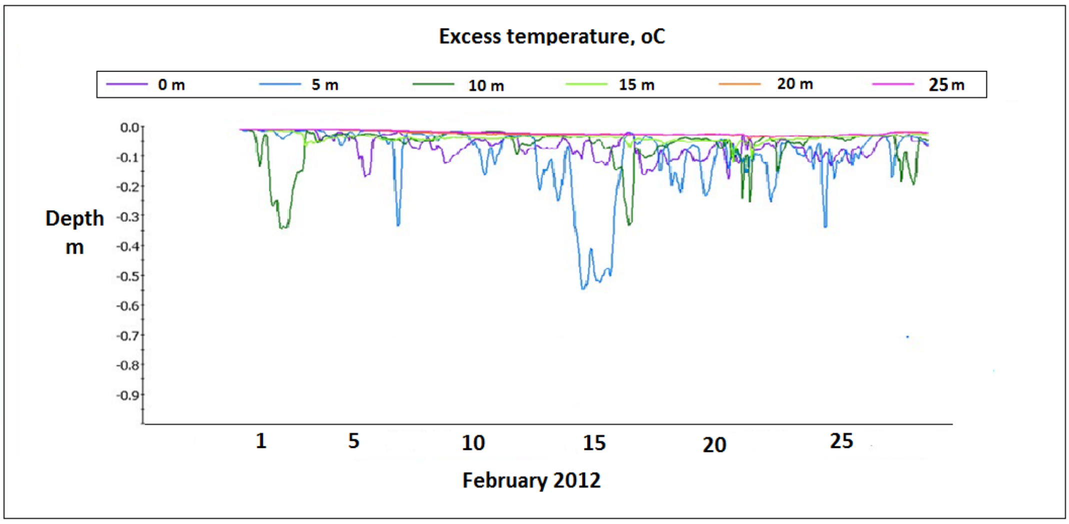


Figure 21. Profile of excess temperature by the intake, 100 meter outwards from the melting facility. The temperature due to melt water impact seldom became more than 0.2 ^{o}C colder beneath 10 m.

4. Discussion and conclusions

During the one month simulation period, the dominating directions of the water currents were along the shore. These directions reduced the influence at the intake located 100 meter outwards from the melting facility. The main wind directions were along the fjord, from north or from south. The wind speed was seldom more than 6 m/s. Also during calm periods, with just tide as a significant force, the same current pattern took place. Consequently this pattern should be representative also during period with ice cover with tide as the main force.

As the melt water most commonly were spread along the shore, it is obvious best to place the intake pipeline perpendicular outwards from the shore. However, according to the simulations even an intake along the shore would not be practically affected, at least not below 10 meter depth.

In the scenarios we applied continuous snow melting during one month. Normally maximum intensity is 20 hour per day during 5 days a week, which should led to less temperature deviations. As long as the natural flux of seawater due to the water currents is considerably greater than the melt water discharge, the temperature differences are close to proportional with the discharge. The discharge could have been considerable increased without influencing the water intake and thereby the melting process in a significant negative way.

Considerably reduced vertical stability due to less strong density gradients, as demonstrated in the by “Helsinki scenario”, did not change the temperature at the intake in practical terms. It seems as the dilution of the cold water effectively prevent serious temperature changes even in the presence of weak density gradients.

The density gradient mostly depends on salinity and to lesser extent on temperature. If the temperature difference between surface and intake are small, a situation where the temperature in the intake water is not sufficient to melt the snow may appear. That phenomenon is not an issue in this study.

The cold discharge water, with temperature around -2 °C, may lead to increased ice cover formation. In the scenarios this did not happened. The discharge water mostly was spread from 3 to 6 meter. The surface water was almost not affected.

Conclusions

If the intake is localized 100 meter outwards the barge and deeper than 10 meter, the discharge of cold melt water does not have any practical influence on the temperature of the intake water. The reduced temperatures in the intake water are less than natural fluctuations during a day. Reduced vertical salinity difference from 5 ppt to 0.5 ppt between surface and 20 m does not change this conclusion. The discharge water is mainly spread beneath the surface and therefor in a minor degree leads to increased ice cover.

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