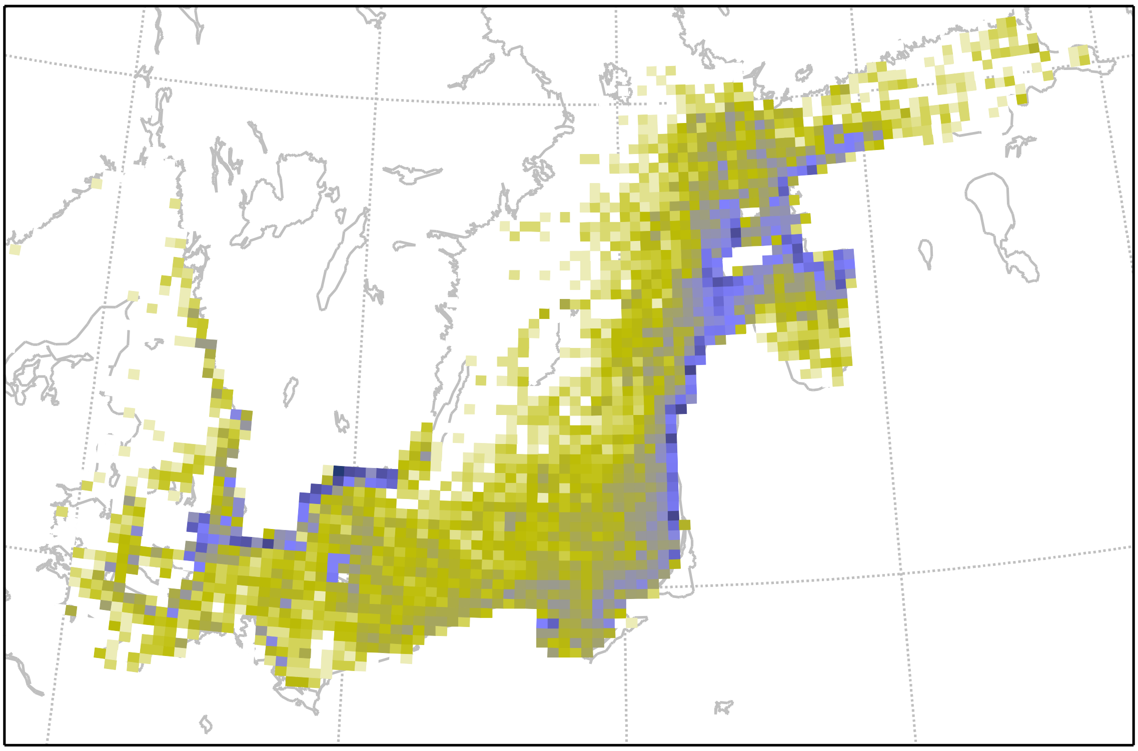
OCEANOGRAPHY No. 122

Invasive species in the Baltic Sea

A model study of plankton transport

Anders Höglund



Front:
Particle density one year after release from the port of Karlskrona.

ISSN: 0283-7714

OCEANOGRAPHY No 122

Invasive species in the Baltic Sea

A model study of plankton transport

Anders Höglund

Abstract

In this report, an ensemble of releases of passive particles at locations close to some selected ports around the Baltic Sea and Kattegat are modelled. The particles are transported with the currents. Maps of particle densities at 2, 4, 8, 16, 32 and 52 weeks after the release are presented.

The results indicate that many basins are narrow enough for the particles to cross from shore to shore within two weeks, e.g., in the Kattegat, Gulf of Finland and Kvarken. The results also show an asymmetry in the transport between different locations, which means that particles released from one location to another require substantially more time to reach the other location, if at all, than particles going in the opposite direction. Some potential barriers to transport are identified and discussed.

Sammanfattning

I den här rapporten modelleras ensembler av utsläpp av passiva partiklar från lokaler nära några utvalda hamnar runt Östersjön och Kattegatt. Partiklarna transporteras av strömmen. Kartor över partikeldensitet efter 2, 4, 8, 16, 32 och 52 veckor presenteras.

Resultaten visar att många bassänger är tillräckligt smala för att partiklar ska transporteras från ena sidan till den andra på mindre än två veckor, exempelvis Kattegatt, Finska viken och Kvarken. Resultaten uppvisar också en asymmetri i transporten mellan olika lokaler, vilket innebär att partiklar utsläppta vid en lokal kräver betydligt mer tid att nå en viss annan lokal, om den nås alls, än vad partiklar som går i motsatt riktning kräver. Några möjliga barriärer för transport identifieras och diskuteras.

Contents

1 Background

This report was commissioned and funded by the Swedish Transport Agency. They also provided the background description for this section.

Transfers of alien species from their natural habitats to new areas are considered by International Union for Conservation of Nature (IUCN) as one of the major threats to biodiversity. "The International Convention for the Control and Management of Ships' Ballast Water and Sediments" [5] (the BWM Convention) requires ships in international traffic to install technical equipment to prevent them from spreading marine species between different ports with their ballast water. In accordance with the BWM Convention, parties may grant exemptions from the requirements for ballast water management if a risk assessment demonstrates acceptably low risk.

The countries of the Baltic and North-East Atlantic regions have adopted the "Joint Harmonised Procedure for the contracting parties of OSPAR and HELCOM on the granting of exemptions under International Convention for the Control and Management of Ships' Ballast Water and sediments, Regulation A-4" [8] (JHP). The JHP includes a risk assessment approach that mainly considers the risk of transfer by ships based on the presence/absence of invasive "target species" in the ports of concern. HELCOM and OSPAR are currently working on the practical implementation as well as testing and updating of the JHP. At the same time, there are ongoing discussions on further concepts for risk assessment, "Same Risk Area" (SRA), introduced by Denmark and Interferry. This concept includes assessment of conditions for dispersal of species by natural means, based on the specifics of a certain sea area and the species specifics.

Alien species are organisms that have been transferred outside their natural distribution range by anthropogenic vectors such as ships ballast water. Primary introductions are the initial transfers of species, often over long distances or barriers, e.g. between continents or sea areas separated by landmasses. Once a species is introduced to a new area, secondary spread may take place by shipping or other vectors, or by natural means depending on wind, currents, connectivity and the species own ability to move.

In the context of exemptions from requirements for ballast water management in the Baltic Sea and The North Sea, it is the risk of secondary introductions of already established alien species that are of concern. In these regional seas many of the shipping routes are short and take place within limited sea areas. In these limited areas natural dispersal might be a factor to take into consideration in the overall risk assessments when evaluating the risk that individual ships pose.

The aim with this report is to contribute in the ongoing developments of risk assessment approach as well as provide support for risk evaluation with regards to natural dispersal of organisms.

2 Overview

The present study uses a model to simulate the Lagrangian transport of particles released from specific locations. The model results can be interpreted as the possible natural spreading of a species that uses the water as its main driver for expansion or secondary spreading, in case of an invasive species.

To account for different weather and current conditions, an ensemble of 108 runs is performed. The start of each simulation is evenly spread over three years, starting from 1 January 2010. This means that a new simulation begins approximately every ten days and each simulation runs for one year. This is done for each chosen release position.

The release positions are chosen to represent important ports in the Baltic Sea and the Kattegat. The positions have been suggested by the Swedish Transport Agency and complemented with a few more positions to get a better geographical coverage of the studied area. The positions and other geographical locations used in this report are shown in Figure 1.

The study focuses on connectivity by physical transport of generic passive particles, meaning that it is not species-specific and does not take into account any particular characteristics that a particular species might exhibit, e.g., the ability to swim vertically to exploit tides or sea-breezes in a systematic way [6].

3 General circulation

The wind in the studied area is mainly westerly[1] with a more southerly component in the north. Figure 2 depicts the 2010–2013 average modelled wind at 10 m above sea level. The wind forces the currents and creates waves. The waves mainly move in the direction of the wind while the currents have highly varying patterns.

The average surface current over the modelled time period is shown in Figure 3. The currents at any given time can, nevertheless, be very different from the average currents.

Many rivers enter the Baltic Sea and cause a net outflow of water. This becomes the dominating feature in narrower parts, especially in the Danish Straits but also in the Åland Sea.

Within each basin there is a counterclockwise current. This is very clear in the Bothnian Bay and the Bothnian Sea where there are no large islands or other geographical features to disturb this pattern. In places with more complex geographies where it is hard to see the counterclockwise feature, it still manifests in the direction of the coastal currents.

The Baltic Sea is stratified with high density saline water from about 70 meters depth and downward. The average circulation in the lower parts is an inflow from the

[1]For winds, a meteorological convention is used where the direction stated is the direction the wind is coming from. For currents a nautical convention is used where the direction stated is the direction the currents are going towards.

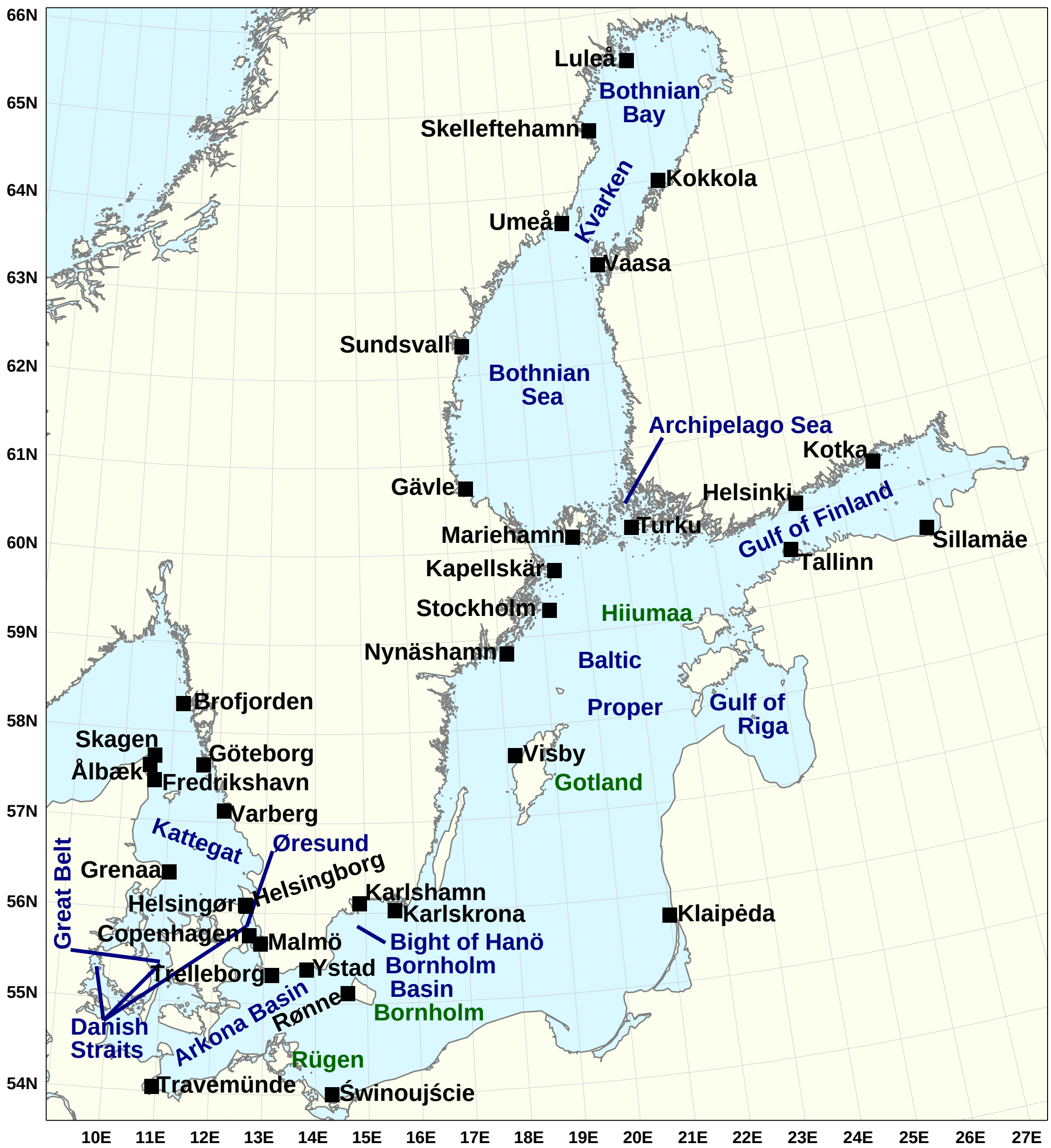


Figure 1: Geographical locations used in this report (black: release positions, blue: water, green: islands). The Baltic Proper extends to the south to, and including, the Arkona Basin.

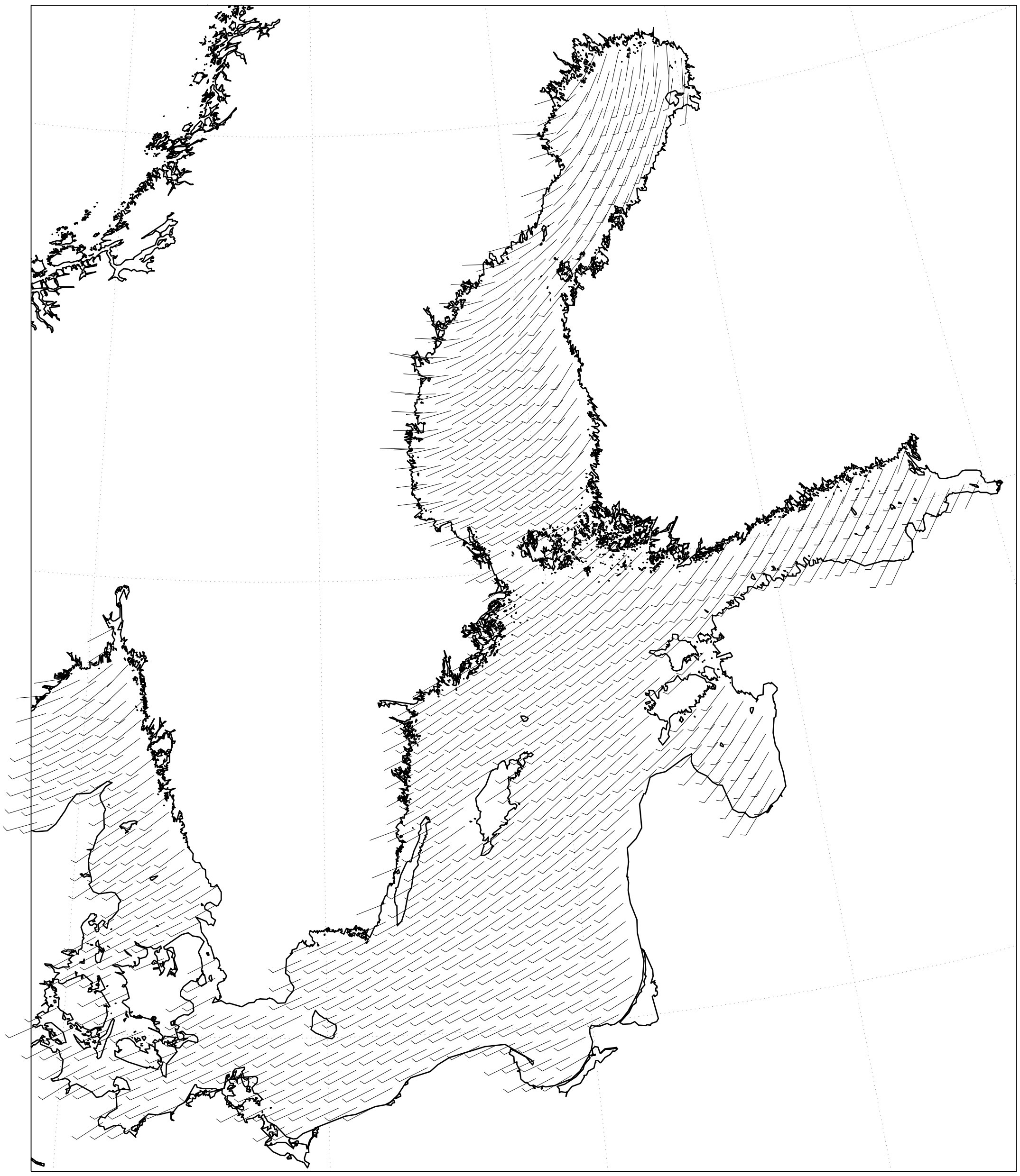


Figure 2: The average wind from Hirlam at 10 meter above sea level for the years 2010–2013.

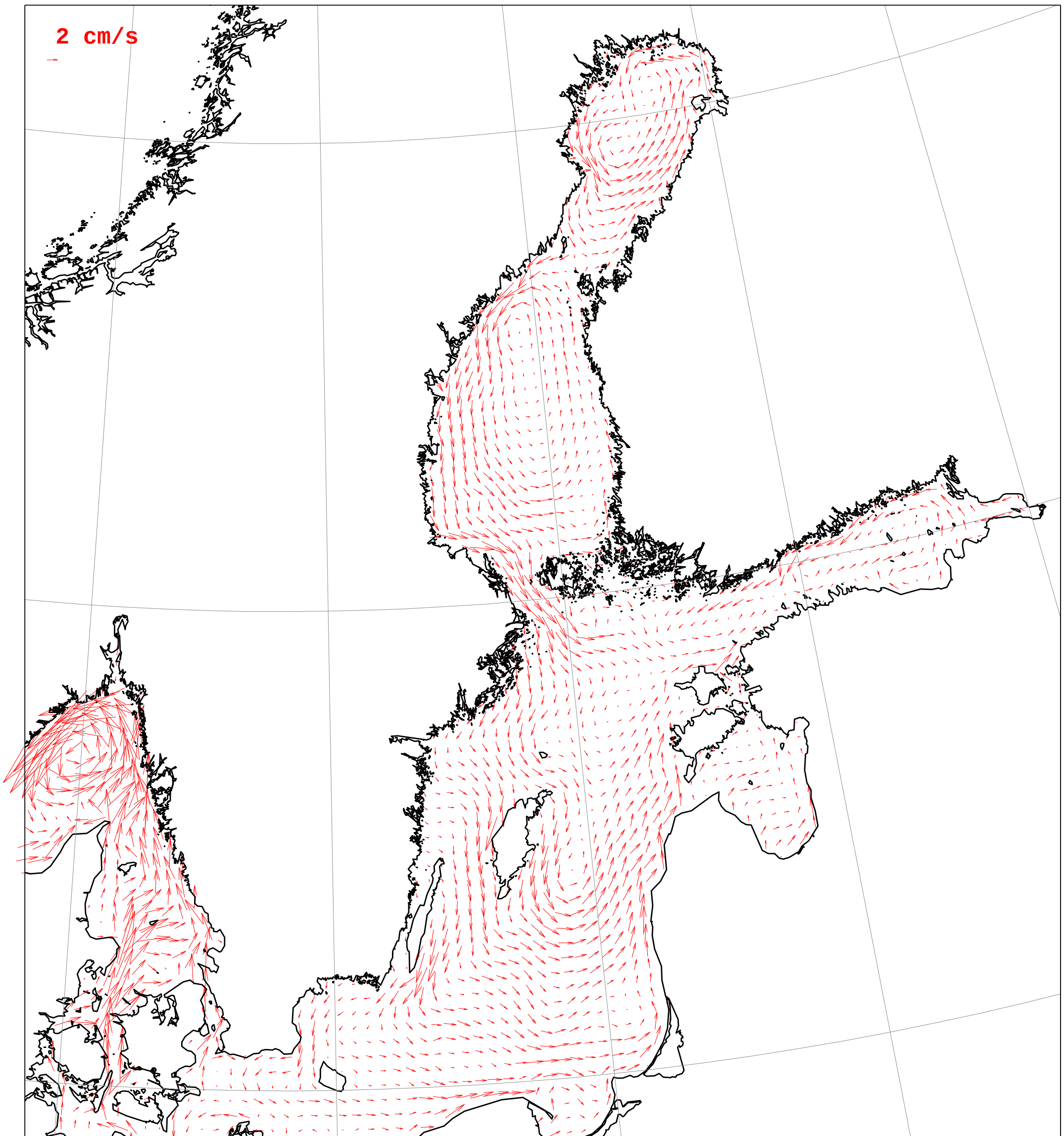


Figure 3: The average current in the top level in Hiromb for the years 2010–2013.

Danish Straits (further increasing the outflow at the surface) into the Baltic Proper going counterclockwise around the basin.

4 Methods

4.1 Model description

Seatrack Web [1] is an oil spill tracking system jointly developed by the Swedish Meteorological and Hydrological Institute (SMHI), the Defence Centre for Operational Oceanography (FCOO), the Federal Maritime and Hydrographic Agency (BSH) and the Finnish Meteorological Institute (FMI). For this study, we have used the model component of Seatrack Web: the Particle Dispersion Model (PADM), which moves Lagrangian particles in a velocity field. Its main purpose is oil spill tracking for which particles are given additional properties to simulate the behaviour of real oil, but it can also track other substances. Only those parts relevant to this study are described here.

Input to PADM (hereafter referred to as forcing) include currents, turbulence parameters, ice cover and wind. All parameters are taken from an ocean reanalysis [2] using the model Hiromb [4, 9] with 3 nautical mile resolution. The ocean reanalysis is forced by the atmosphere reanalysis EURO4M [3].

The wind is used to force a simple wave model based on local wind and fetch, i.e. the distance to the nearest coast in the direction the wind is coming from. The waves then create Stokes drift. With presence of ice, the Stokes drift is reduced linearly up to 70% ice concentration where the Stokes drift is zero.

Turbulence parameters add a random contribution to the velocity, which makes nearby particles diverge from each other to increase the spread.

The domain of PADM covers the Baltic Sea with a boundary in the North Sea at $2°53'20''$E and $59°31'0''$N. The coastline is rather detailed, containing more than 3 700 000 line segments. The forcing is extrapolated in locations outside of the oceanographic model grid, for example in bays.

Particles reaching the open boundary in the North Sea are inactivated and will not re-enter the calculation. Particles hitting other boundaries, such as a coastline, will not get stuck and may, if the direction of the forcing is such, leave the boundary again.

4.2 Simulations

The task was to simulate the spreading of plankton from selected ports. A list of ports was provided by the Swedish Transport Agency and has been complemented with a few more positions (see Table 1). It is beyond the current setup to properly model releases in ports. Archipelagos are also questionable since many islands are not included in the oceanographic circulation model providing the currents. Therefore, all locations presented in this report are found outside of the ports and also outside of any archipelagos.

Table 1: Selected ports for the simulations and chosen particle release positions.

Port/City	Position lat, long		Port/City	Position lat, long	
Brofjorden	58.290	11.180	Nynäshamn	58.810	18.155
Ålbæk	57.590	10.545	Stockholm	59.260	19.165
Skagen	57.695	10.626	Kapellskär	59.700	19.360
Göteborg	57.610	11.660	Mariehamn	60.055	19.830
Fredrikshavn	57.420	10.650	Helsinki	60.060	24.960
Varberg	57.105	12.125	Kotka	60.350	26.880
Grenaa	56.405	11.050	Tallinn	59.560	24.655
Helsingør	56.065	12.595	Sillamäe	59.480	27.730
Helsingborg	56.055	12.627	Gävle	60.700	17.475
Copenhagen	55.730	12.695	Turku	60.090	21.190
Malmö	55.640	12.915	Sundsvall	62.315	17.590
Travemünde	54.025	10.930	Vaasa	63.105	21.180
Trelleborg	55.290	13.150	Umeå	63.625	20.380
Ystad	55.360	13.825	Luleå	65.390	22.680
Rønne	55.095	14.620	Kokkola	63.970	23.025
Karlshamn	56.090	14.875	Skelleftehamn	64.650	21.390
Karlskrona	56.000	15.577			
Świnoujście	53.984	14.300			
Klaipėda	55.725	20.985			
Visby	57.660	18.180			

Each release consists of 500 particles arranged horizontally in rectangles of five times five particles in twenty vertical layers. The horizontal spacing is 0.005 degrees in the meridian direction (except for Helsingborg and Helsingør where 0.001 degrees is used due to the narrowness of the sound) and the same distance in meters in the zonal direction. The first vertical layer is 0.49 meters from the surface with a distance of 0.5 meters between each subsequent down to a depth of 9.99 meters.

Many species have a buoyancy or an ability to swim that would keep them in the upper layers. These effects are not directly included in the model but they are mimicked by turning off all vertical motion during the simulation. The currents are strongest close to the surface, which means that particles further down would not be transported as far as those near the surface.

For each release location, releases have been made at 108 different times, starting on 1 January 2010 and then on the 1st, 11th and 21st of each month over three years. This is done to ensure that different weather situations are included in the ensemble of simulations with realistic distribution of weather types. Each simulation runs for a full year with the location of the particles being recorded daily.

5 Results

Figures for the results can be found in Appendix A. In the following presentation, the figures are referred to by release location and time after release. Occasionally, the time reference is vague like "longer times scale" and may then refer to several figures for different times after release.

In the initial stages, the particles tend to spread out from the release location but not uniformly. The shape of the spread is characterised by the general circulation and wind pattern. The model results suggest that particles reaching the coastline tend to be retained near the coast, thus reducing the number of particles in the open water. This feature is not imposed by the model but is rather a result of the wave action that depends not only on the magnitude of the wind but also on the fetch (the distance in the wind direction to the closest coastline).

5.1 The Kattegat

(Brofjorden, Ålbæk, Skagen, Göteborg, Fredrikshavn, Varberg and Grenaa)

The Kattegat area is small enough for a release to cross from east to west in two weeks. The transport is stronger to the east than to the west though. In the north-south direction, the Danish Straits provides a natural barrier, which is strengthened by the general direction of the outgoing current from the Baltic Sea. From Grenaa, some particles penetrate the Great Belt already within two weeks.

Over time, most of what is released reaches either the North Sea or the Swedish or Norwegian coast.

5.2 Øresund

(Helsingør, Helsingborg, Copenhagen and Malmö)

From these release positions, the particles go both to the north into the Kattegat and south into the Arkona Basin. Particles from the two northerly positions, Helsingborg and Helsingør, spreads almost exclusively to the north and the behaviour is very similar to that of the release positions in the Kattegat area. The small portions of particles that go south reaches the entrance to the Gulf of Riga within a year.

From the two southerly release positions, Copenhagen and Malmö, a larger portion of the particles go to the south compared to the particles from the northerly release positions, even though the majority of the release goes north into the Kattegat. Within two weeks, small portions have reached the island of Rügen. Within 16 weeks, the entrance to the Gulf of Riga is reached, and within a year, the southern coast of the Gulf of Finland.

5.3 Arkona basin, Bornholm basin and southern Baltic Proper

(Travemünde, Trelleborg, Ystad, Rønne, Karlshamn, Karlskrona, Świnoujście, Klaipėda and Visby)

These release positions show a qualitatively similar behaviour but with a clear east-western component. Stations in the west export more through the Danish Straits than the eastern ones but they all export to the east as far as the inner parts of the Gulf of Finland.

Particles that go through the Danish Straits into the Kattegat have a higher tendency to follow the Swedish coast, but if there are large quantities, the particles will cover all of the Kattegat area.

Within two weeks, particles from Travemünde cover large parts of the Arkona Basin; from the positions of Ystad and Trelleborg the particles reach Øresund and the island of Rügen and Bornholm; from the positions of Karlshamn and Karlskrona, they fill the Bight of Hanö but do not reach the island of Bornholm; from the position of Rønne, they fill a large part of the eastern Arkona Basin and reach the Swedish coast but the German one; from the positions of Świnoujście and Klaipėda they follow the coast, mainly to the east and north, respectively; and from the position of Visby, they fill the area west of the island of Gotland and reach the coast of the Swedish main land.

Within one year, even particles from the western positions have reached the Gulf of Finland while those from the more eastern positions do so sooner. Particles from the position of Trelleborg reach the Kattegat area within four weeks, but releases from all the positions except Visby and Klaipėda have reached the Kattegat area within a year.

Particles from all positions have reached the position Klaipėda within eight weeks, except those from Travemünde and Trelleborg which do so within 16 weeks. Not even after one year have the particles from Klaipėda reached any of the other positions except Visby.

5.4 Central Baltic

(Nynäshamn, Stockholm, Kapellskär and Mariehamn)

Releases from these four positions behave very similarly. Within two weeks, all of them have reached the Archipelago Sea and the Swedish coast while none of them have reached the Estonian coast. Only particles from the two southerly positions, Nynäshamn and Stockholm, have reached the island of Gotland within two weeks. After around four weeks, particles from the four positions reach the Estonian island of Hiiumaa and later on the Estonian mainland as well.

Small amounts enter the southern part of the Bothnian Sea, but around week 16, particles from Kapellskär and Mariehamn start to enter the northern part of the Bothnian Sea along the Finnish coast, and around week 32 particles from the positions of Nynäshamn and Stockholm do the same.

After one year, particles from all four positions have reached the entrance to Øresund but none of them have reached the Kattegat area.

5.5 Gulf of Finland

(Helsinki, Kotka, Tallinn and Sillamäe)

The Gulf of Finland is narrow enough to be crossed in the north-south direction within two weeks, even in the wider parts in the east. It takes about four weeks to cover the Gulf of Finland in the west-east direction.

Even though particles from the positions closest to the entrance leave the Gulf of Finland already within two weeks, the concentration there remains high after one year.

After 32 weeks, particles from the two western positions enter the Bothnian Sea along the Finnish coast.

5.6 Bothnian Sea and Archipelago Sea

(Gävle, Turku, Sundsvall, Vasaa and Umeå)

The particles from Gävle and Turku reach Åland within two weeks but do not get across to the opposite mainland. The only part that is narrow enough to be crossed within two weeks is Kvarken, i.e. at Umeå and Vaasa. Particles from the positions of Gävle and Sundsvall reach Finland within four weeks.

Particles from Gävle enter the Baltic Proper within two weeks, particles from Sundsvall and Umeå within 16 weeks, and from Vaasa within 32 weeks. After one year, most of the Baltic Proper and Gulf of Finland are covered.

Within four weeks, particles from Umeå have entered the Bothnian Bay. Within eight weeks there are particles from Vaasa, within 16 weeks from Gävle and Sundsvall; and within one year from Turku.

5.7 Bothnian Bay

(Luleå, Kokkola and Skelleftehamn)

Particles from the position of Kokkola have reached the Swedish coast within two weeks, while particles from Luleå and Skelleftehamn have not reached the Finnish coast.

Particles from all three positions reach the area of Kvarken within two weeks but not until week 16 have any substantial amounts reached the Bothnian Sea. The concentrations in the Bothnian Bay remain high even after one year and only a few single particles reach the Baltic Proper.

6 Discussion

6.1 Model characteristics

This study is a general study of connectivity and does not examine particular species. Thus, important properties that affect vertical motion, e.g. buoyancy, is lacking in the input. One option would have been to let the particles follow the vertical motion of the water. This would bring many particles deeper where the currents are weaker. From a computational point of view, those particles would require as much resources as particles closer to the surface while contributing less to the information about connectivity. The rational decision is to lock the particles to a fixed depth but spread the initial depth enough to get representative results.

While this decision might be rational, it has consequences. Particles at deeper levels in the model cannot enter shallow areas. This might affect the statistics for positions like Copenhagen and Malmö where there is a sill at only seven meters depth blocking the transport to the south for about 30% of the released particles. In the same way, transport through archipelagos, where the depth is often very low, can also be affected, e.g. in the Archipelago Sea.

In addition, the currents at deeper levels might go in a different direction than the currents close to the surface, even though they may be weaker. This might cause the particles, if they could move vertically, to reach higher levels with strong currents in a different place, which would significantly affect a single release. It is, however, realistic to assume that this effect will not impact on the conclusions drawn by the statistical analysis of the large scenario ensemble.

Seatrack Web uses a rather detailed coastline that differs from the one in the oceanographic circulation model providing the currents. This means that the driving currents were extrapolated in some areas close to the coast and in bays. In other places there are peninsulas or islands which are not found in the oceanographic circulation model. Consequently, the currents close to the coast might be inconsistent with the coastline, e.g., by having currents passing straight through an island. To somewhat compensate for this, slip boundary conditions have been used, meaning that a particle that hits a coast is not inactivated but is allowed to slip along the coastline and later re-enter the calculation.

This has an impact on the transport through archipelagos. While the currents in reality would have guided the particle around the island, the modelled particle hits the island and is delayed by sliding along the coast until it can pass the island. On the other hand, if a particular species would settle as soon as it hits a coast, this method would overestimate the transport through archipelagos.

To minimise errors due to the archipelagos, the chosen starting positions are outside of any such areas, with the consequence that in some cases the release happens far from the actual port, e.g., Turku.

For some simulations in the ensemble, the initial wind and currents induce the transport towards the coast. If this happens where there is an archipelago, many particles will enter this area and it takes some time before they are free to be transported elsewhere again. Although this is a real possibility, it might raise some questions in the model results representation because the number of particles close to the release position remains high long into the simulation.

6.2 Biology

The biological factors were not considered in this study although they will have to be taken into account when extrapolating the results to a particular situation.

One of the key aspects is the life cycle of the species. Many species have a larval stage where they are subject to physical processes and where most of the results of this study could apply. However, some species might have different life cycles, different development times, different buoyancy and perhaps swimming capabilities and also different survival rates while being transported by the water.

In addition, changes in salinity, e.g. the sudden increase when passing the Danish Straits (see Figure 4), can have major consequences in the organisms' metabolic processes and for that reason alter the number of organisms (individuals or groups of individuals) that would actually be able to invade the areas concerned.

Many ports are for historical reasons located at river mouths, which are the main sources of fresh water into the Baltic Sea. For that reason, the river mouths are always areas with a significant salinity gradient that results in the existence of particular species in and outside the river. The transport of Ballast water between two different river mouths could spread a particular species that could not naturally spread between these areas due to the higher salinity in the water between them.

In summary, natural spreading in the Baltic Sea can be related to the bathymetry since it is directly related to the environmental conditions that larvae can find in a certain area. In deeper waters, larvae survival might be lower, as salinity gradients and lack of oxygen may be too intense to allow the development of these organisms.

This study is based on an ensemble of simulations evenly distributed over the seasons. The biology, however, is seasonally dependent as might be the currents and the wind. An extreme example of this can be found in the areas of the Baltic Sea that are covered by ice during the winter. The ice shields the water from the wind, thus giving a strong seasonal dependence.

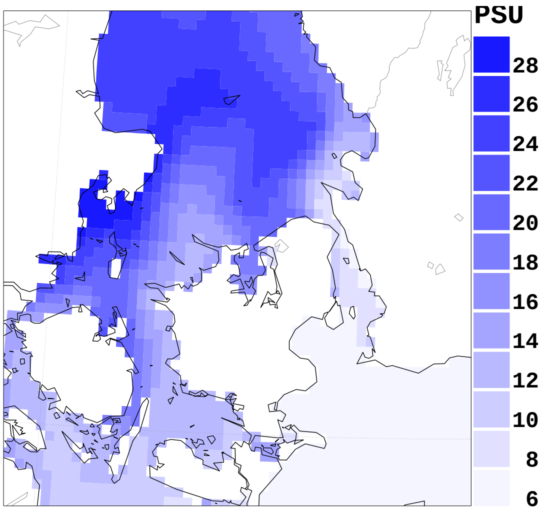


Figure 4: Surface salinity in the Danish Straits on 17 July 2010 according to the reanalysis data set used in this report.

6.3 Barriers and same risk areas

Some potential barriers can be identified by examining the transport of particles described in the results section. The most apparent one is the Danish Straits. It is hard to go southward through the strait while the currents naturally transports particles northward.

For the Gulf of Finland, it seems to be easier for the particles to enter than to leave. As there is no natural barrier, this is probably due to the dominant westerly wind direction, in spite of the net transport being out of the Gulf of Finland due to the water added by the rivers.

The passage from the Baltic Proper to the Bothnian Sea seems to be hard but possible. The net transport of currents is towards the south which creates a natural barrier. However, the role of the Archipelago Sea is not clear in this context due to model characteristics as discussed in Section 6.1.

Passing between Bothnian Bay and Bothnian Sea appears difficult but does not constitute an effective barrier over time in either direction.

Barriers will not be sharp boundaries. For instance, in the Danish Straits, particles from the positions in the Øresund spread both to the north and the south within the two week limit, and from the position of Grenaa, north of the Danish Straits, had particles reaching far into the Great Belt within two weeks. Unlike in rivers, currents at sea can go in any direction even when there are very dominant directions. The Danish Straits is such a place, where an amount of water equivalent to all the rivers ending in the Baltic Sea has to come through going north. Even so, from time to time there are southward currents. This suggests that the concept of same risk areas cannot be made into separate areas with sharp borders. However, even though a position can be chosen arbitrarily, the ports with commercial traffic are located at distinct places.

Further more, there are many places where the transport of particles is asymmetric. This suggest that the concept of a same risk area does not need to describe an area where all transport of ballast water is without restrictions, but could be directionally dependent. For instance, transporting ballast water south through the Danish Straits against the dominant direction implies a higher risk of introducing an invasive species than a transport in the opposite direction.

6.4 Related studies

Nordström [7] studies the spread of larva for the blue mussels Mytilus edulis and Mytilus trossulus. The life cycle is implemented and the spreading during the larval stage (that lasts for 21 days) is done with a connectivity model based on an ocean circulation model. The spreading is followed during 25 years with one iteration per year. The larvae are forced to stay in the top 6 meters of the ocean. If the final location is less than 12 meters deep they will settle and take part in the next iteration.

Many of the characteristics of the spreading are similar to the results of the present study. The spreading is faster in the counterclockwise direction along the coasts in each basin. It can cross narrow parts like the Gulf of Finland and Kvarken but must follow the coast in wider areas . It is easier to cross from the Øresund region to the German coast than to cross in the opposite direction.

There are also differences to the results reported in the present study. Spreading is for example easy from the Kattegat area into the Baltic Sea. This probably has to do with the iterative process where it is enough for some individuals to reach the Danish Straits to have a new release position in the next iteration. Using the results of our study and the two week limit, this would mean that iteration one can take particles from Gothenburg to Varberg, iteration two from Varberg to Helsingborg, iteration three from Helsingborg to Malmö and so on. Hence, this is only an apparent difference.

Another difference is that it seems to be easy for the larvae to pass through the Archipelago Sea. This is a shallow area where they are able to settle and reiterate from. The same explanation as for the Danish Straits can be applied. This is an area where the present study has many limitations, as discussed in section 6.1, and these limitations could also provide an explanation of the differences between the two studies.

References

[1] Ambjörn, C., Liunmgman, O., Mattsson, J. and Håkansson, B. *Seatrack Web: The HELCOM Tool for oil spill prediction and identification of illegal poluters.* In A. G. Kostianoy and O. Y. Lavrova (Eds.): *Oil pollution in the Baltic Sea.* Berlin Heidelberg, Springer-Verlag, 155-184, 2011.

[2] Axell, L. and Liu, Y. *Applications of 3-D ensemble variational data assimilation to a Baltic Sea reanalysis 1989-2013*, Tellus A, 68, 2016.

[3] Dahlgren, P., Kållberg, P., Landelius, T., and Undén, P., 2014. *EURO4M Project — Report, D 2.9 Comparison of the regional reanalyses products with newly developed and existing state-of-the art systems.* Technical report. Online at: http://www.euro4m.eu/Deliverables.html

[4] Funkquist, L., Kleine, E., 2007. *HIROMB: An introduction to HIROMB, an operational baroclinic model for the Baltic Sea*, Report Oceanography 37, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden, 2007.

[5] International Maritime Organisation, 2004. *International Convention for the Control and Management of Ships' Ballast Water and Sediments*, available at http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships'-Ballast-Water-and-Sediments-(BWM).aspx

[6] Moksnes, P.-O., Corell, H., Tryman, K., Hordoir, R. and Jonsson, P. R. Larval behavior and dispersal mechanisms in shore crab larvae (Carcinus maenas): *Local adaptations to different tidal environments?* Limnol. Oceanogr., 59(2), 588-602, 2014.

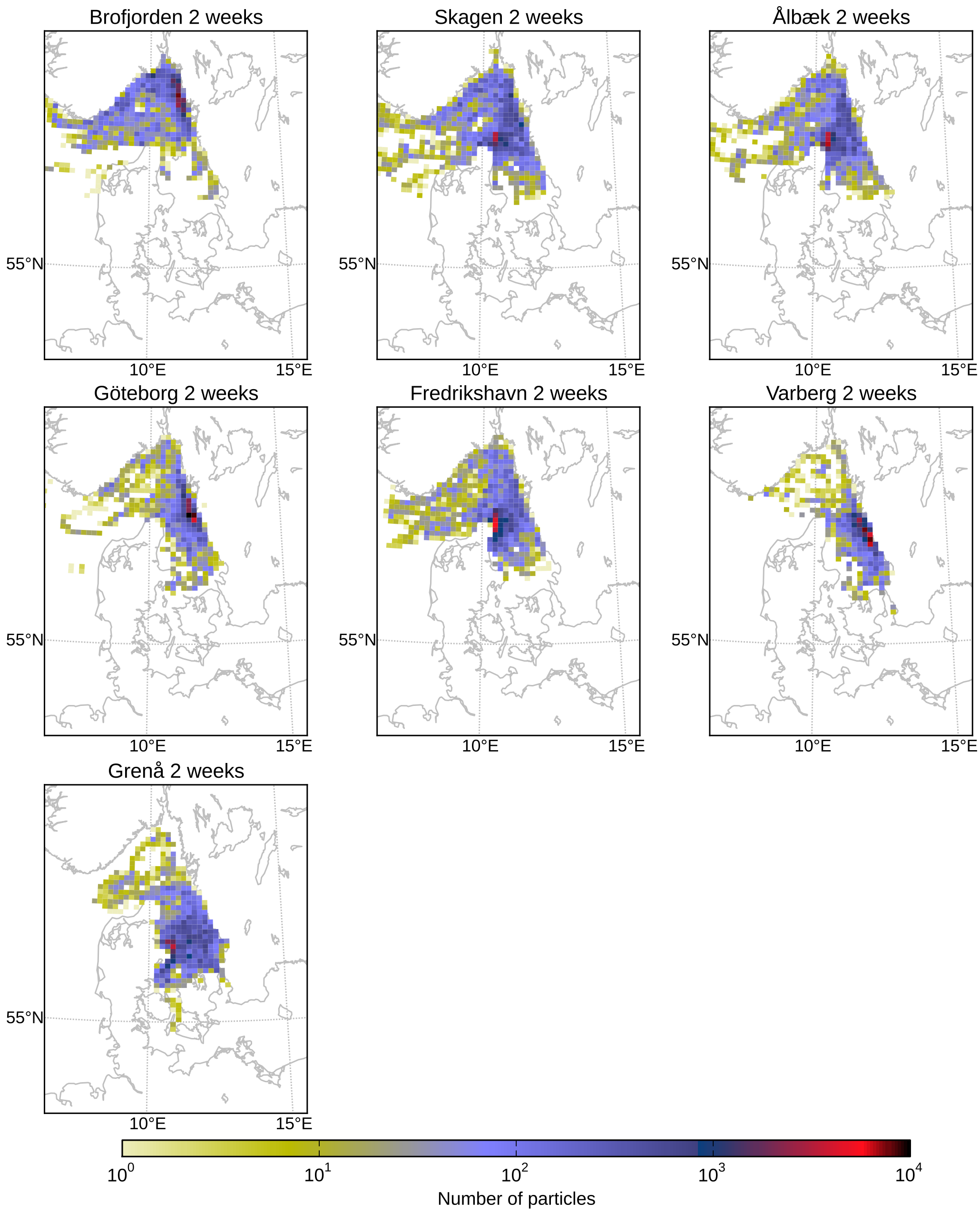
[7] Nordström, M., 2014. *Risk analysis of spread of introduced species in the Baltic Sea including Kattegat: A simulation of larval dispersal from major Baltic ports.* Master Thesis, University of Gothenburg, Gothenburg, Sweden, 2011.

[8] OSPAR Comission, 2013. *Joint Harmonised Procedure for the Contracting Parties of HELCOM and OSPAR on the granting of exemptions under International Convention for the Control and Management of Ships' Ballast Water and Sediments, Regulation A-4.* Available at http://www.ospar.org/documents?v=33060

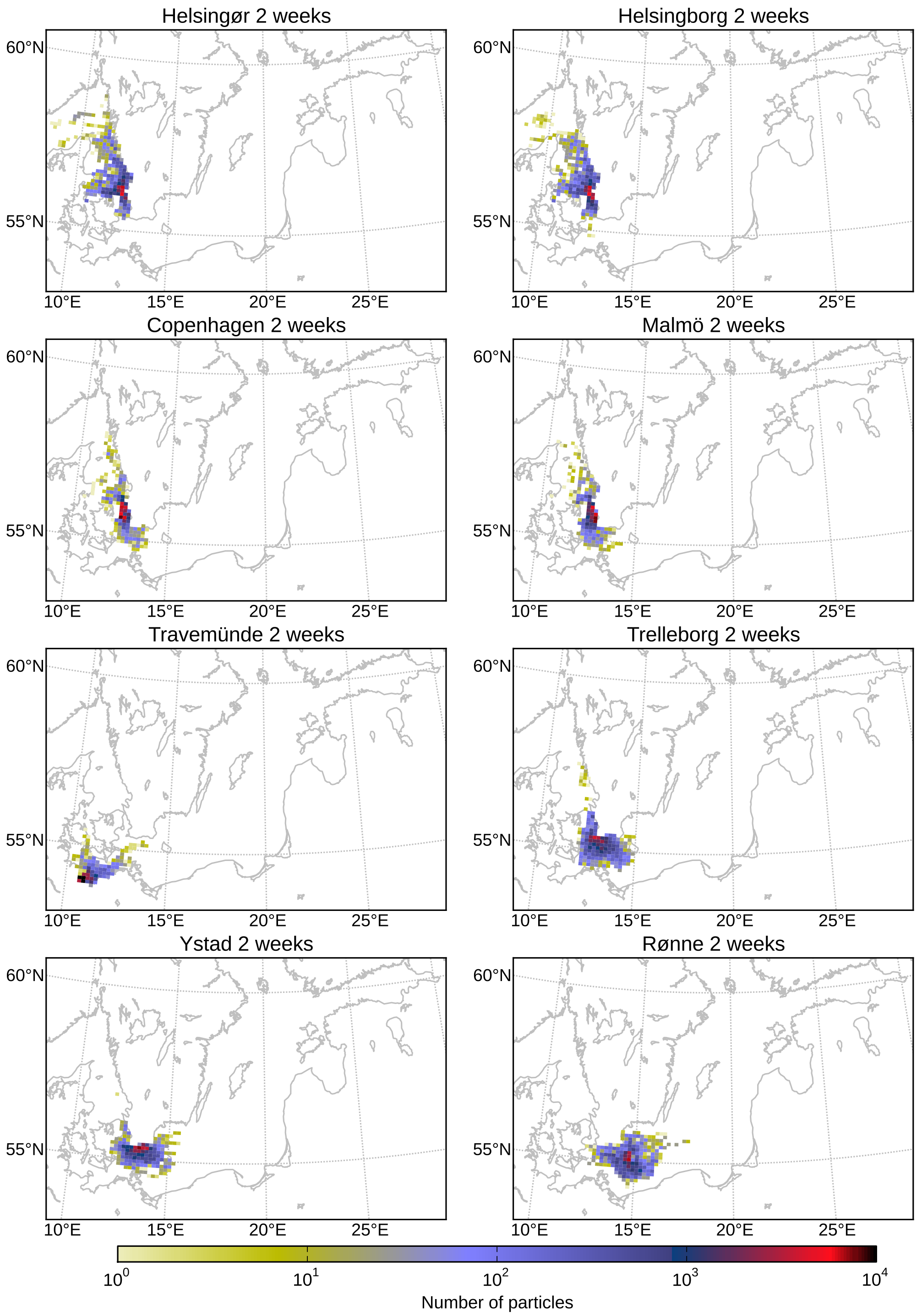
[9] Wilhelmsson, T., 2002. *Parallelization of the HIROMB ocean model*, Licentiate Thesis, Royal Institute of Technology, Stockholm, Sweden.

A Maps of outlets

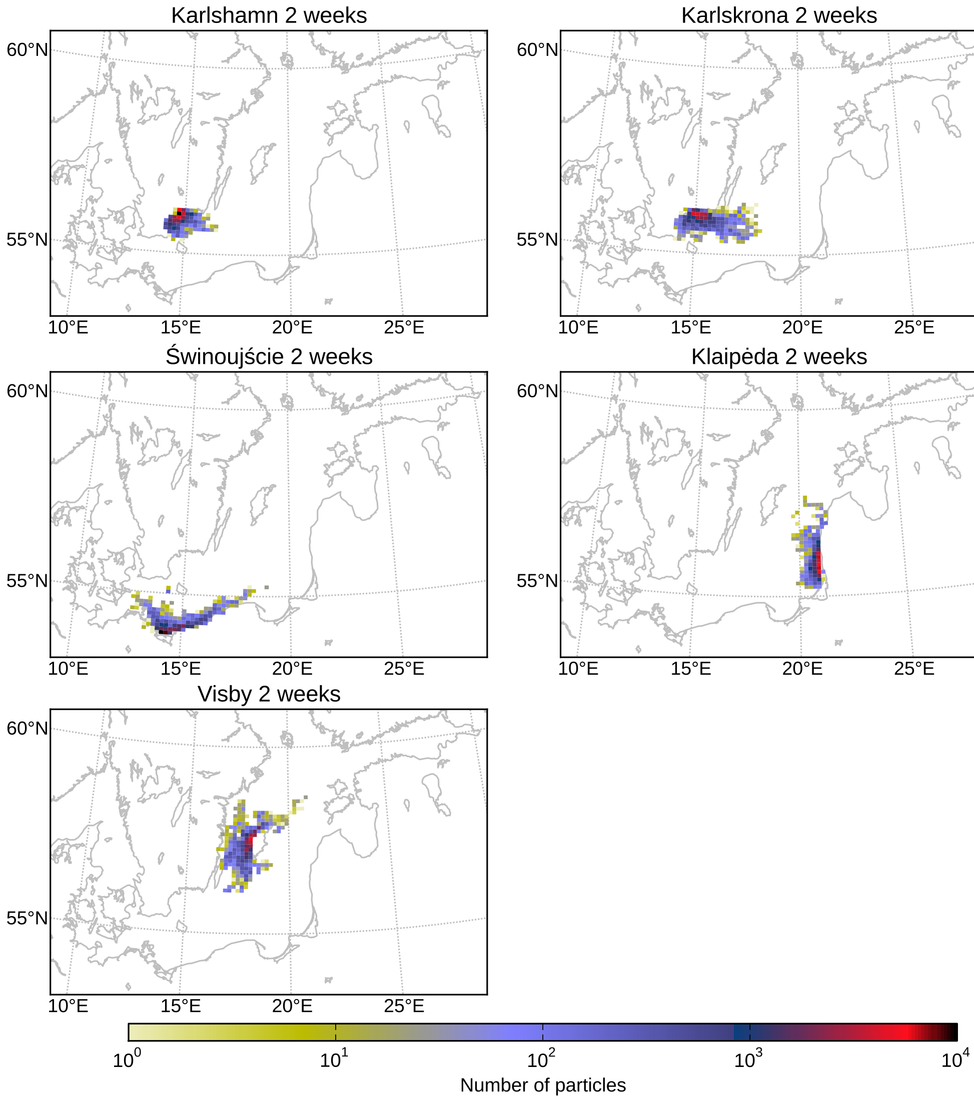
This appendix contains graphs of particles combined from all the runs for a given outlet position and time after release. The colour scale shows the number of particles in a box of 0.1 degrees in the meridian and 0.05 degrees in the zonal direction. Results after 2, 4, 8, 16 and 32 weeks and 1 year are shown.

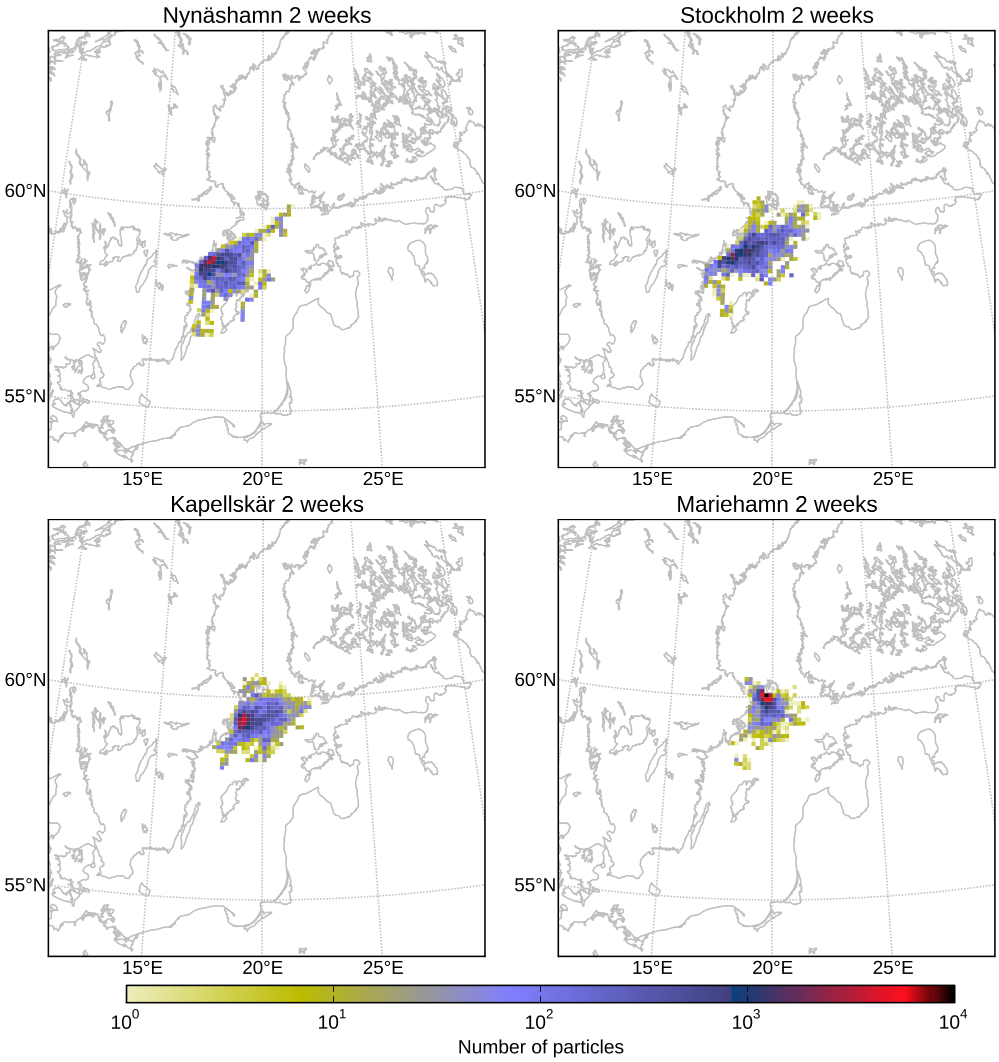


Brofjorden 2 weeks
Skagen 2 weeks
Ålbæk 2 weeks
Göteborg 2 weeks
Fredrikshavn 2 weeks
Varberg 2 weeks
Grenå 2 weeks
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles

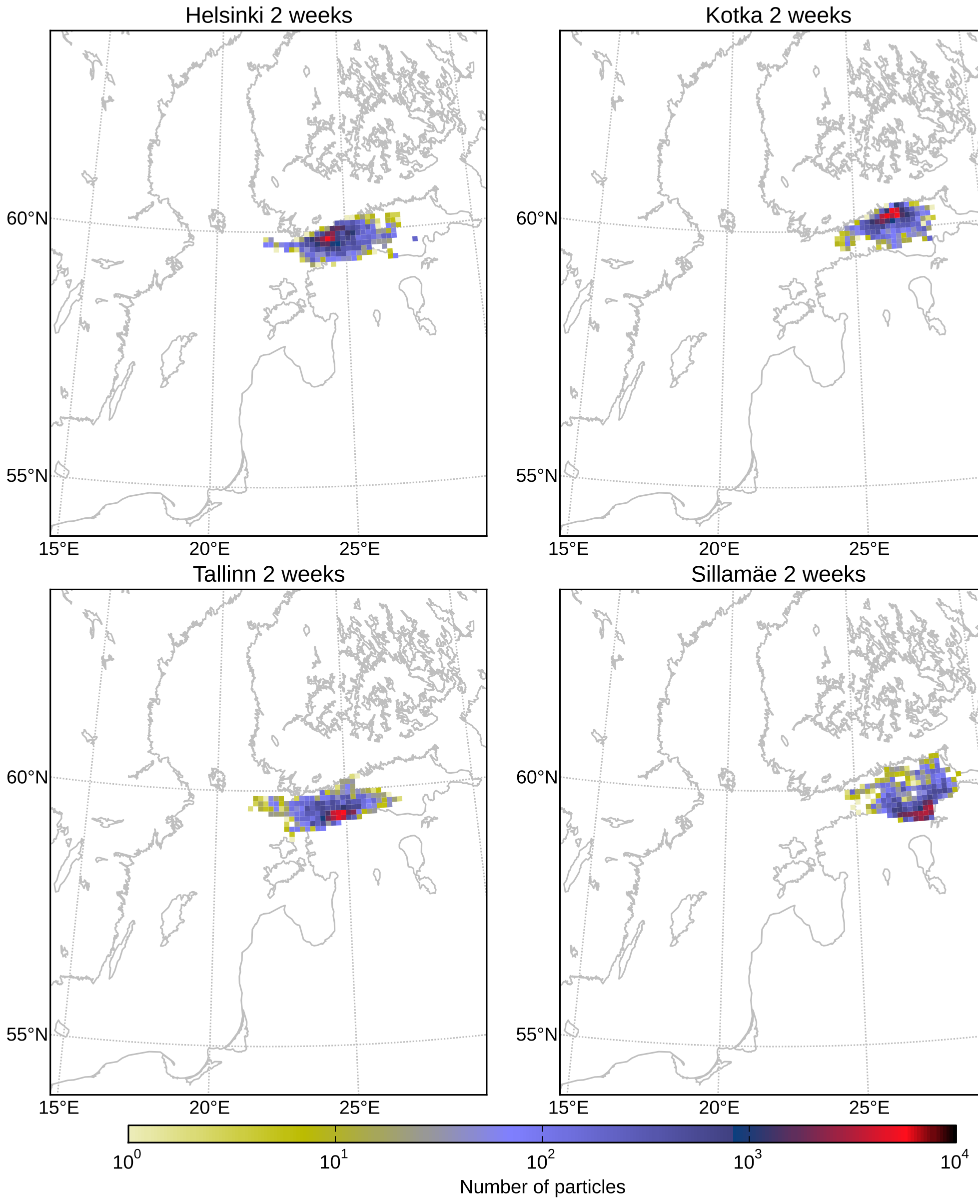


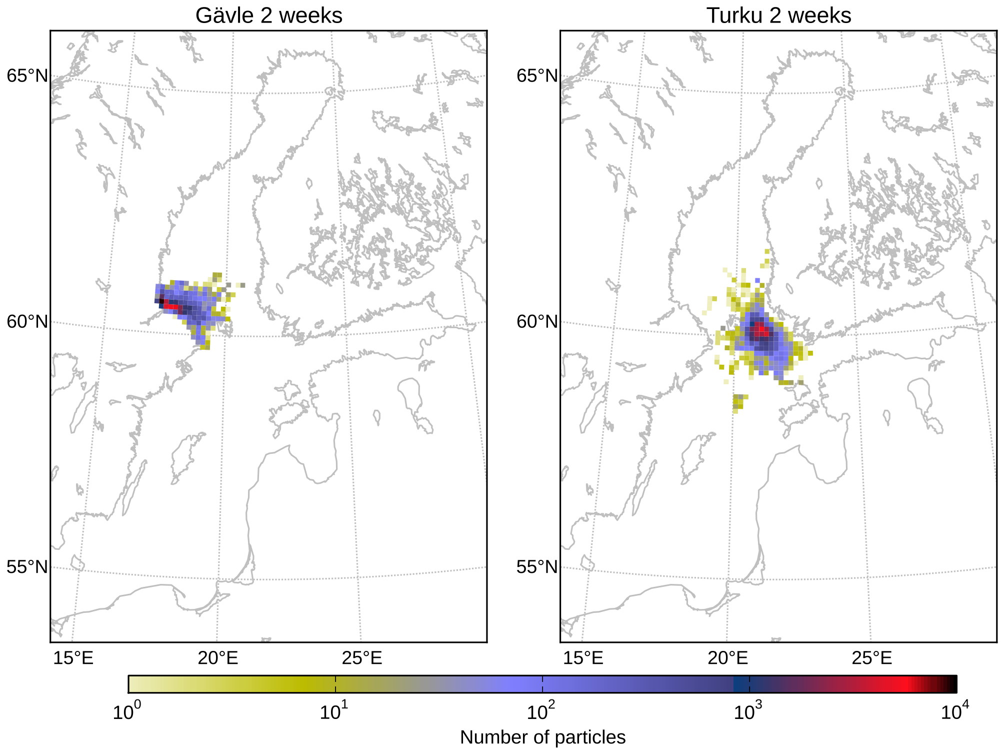
Helsingør 2 weeks
Helsingborg 2 weeks
Copenhagen 2 weeks
Malmö 2 weeks
Travemünde 2 weeks
Trelleborg 2 weeks
Ystad 2 weeks
Rønne 2 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

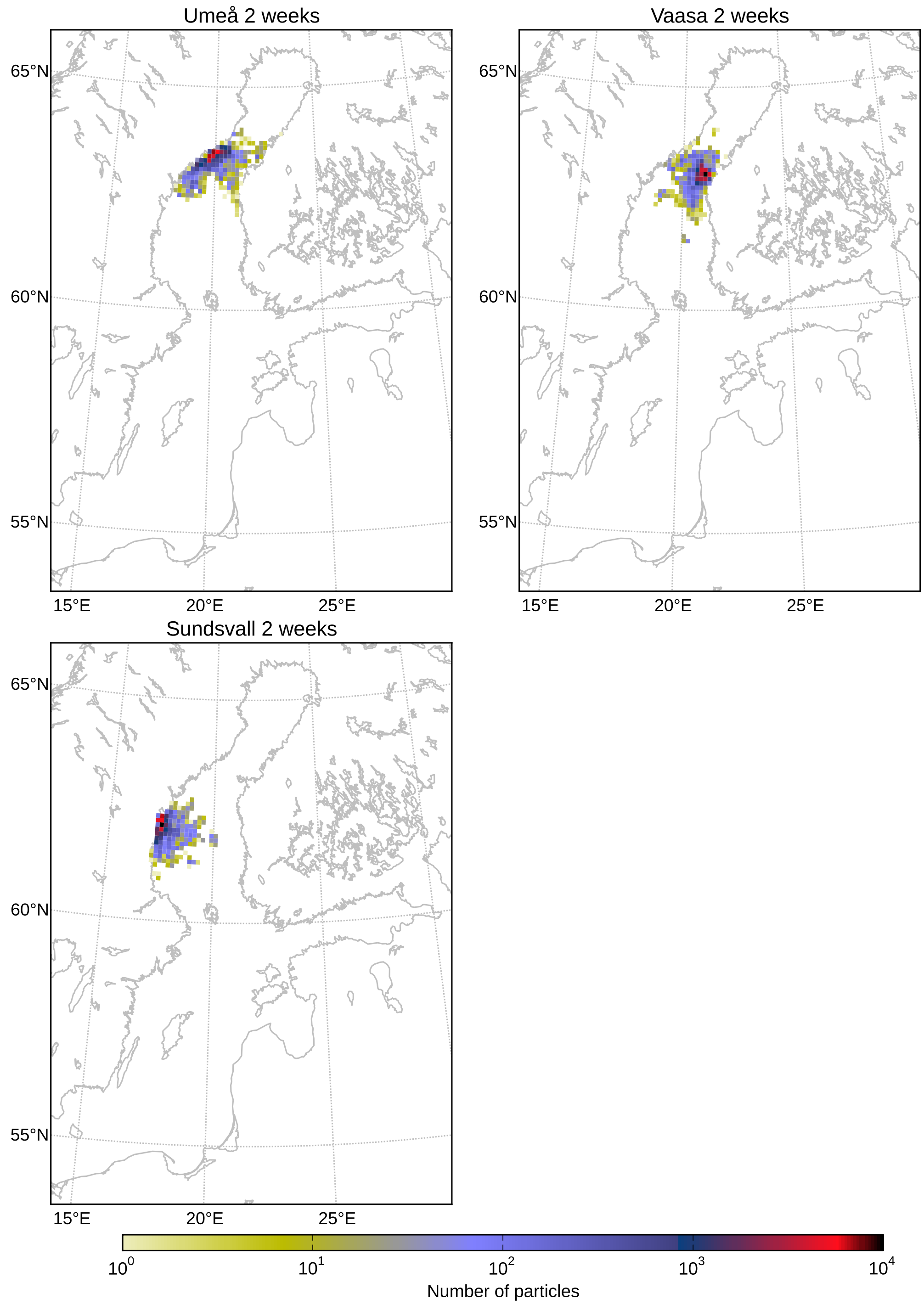

Karlshamn 2 weeks
Karlskrona 2 weeks
Świnoujście 2 weeks
Klaipėda 2 weeks
Visby 2 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

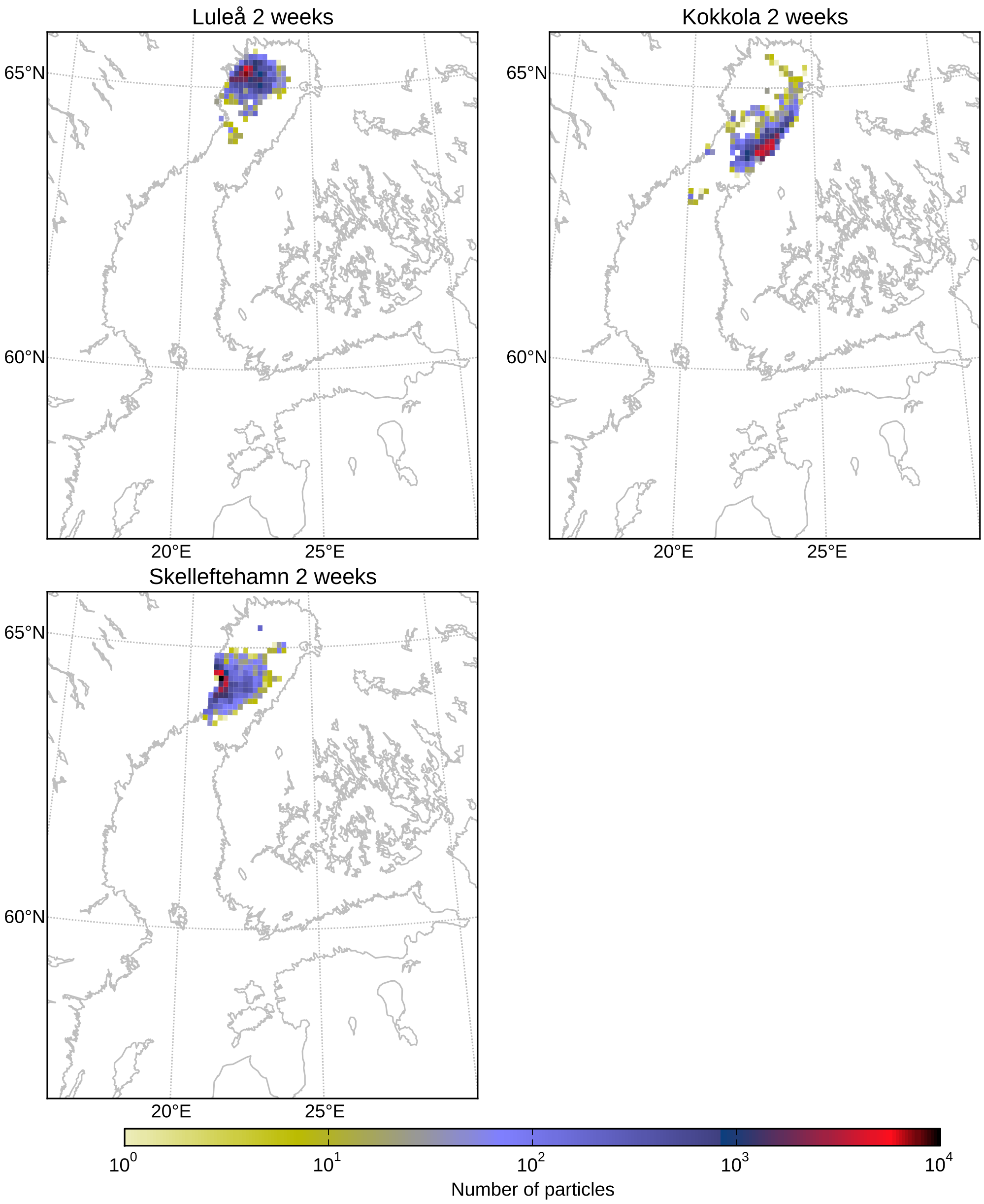


Nynäshamn 2 weeks
Stockholm 2 weeks
Kapellskär 2 weeks
Mariehamn 2 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

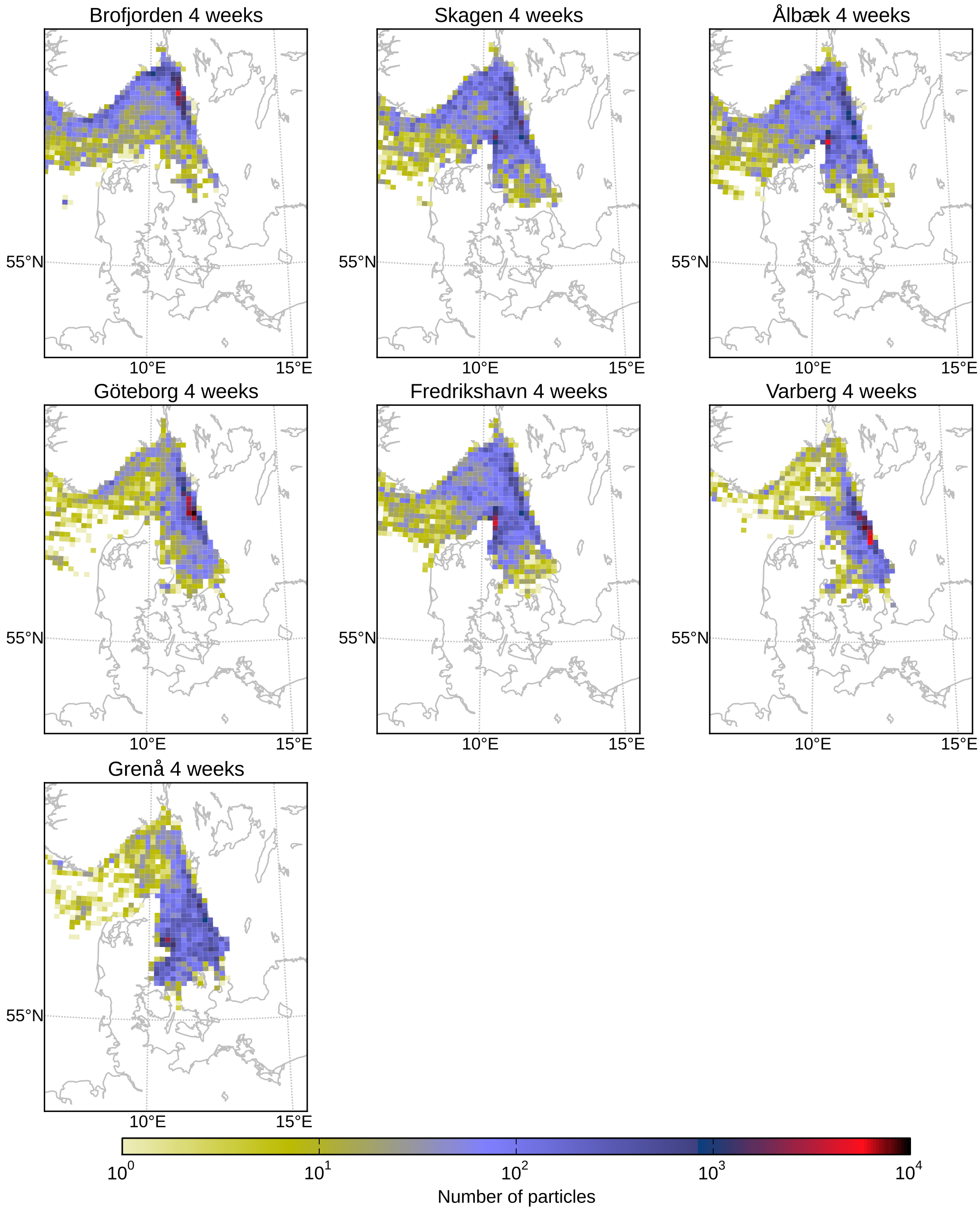

Helsinki 2 weeks
Kotka 2 weeks
Tallinn 2 weeks
Sillamäe 2 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

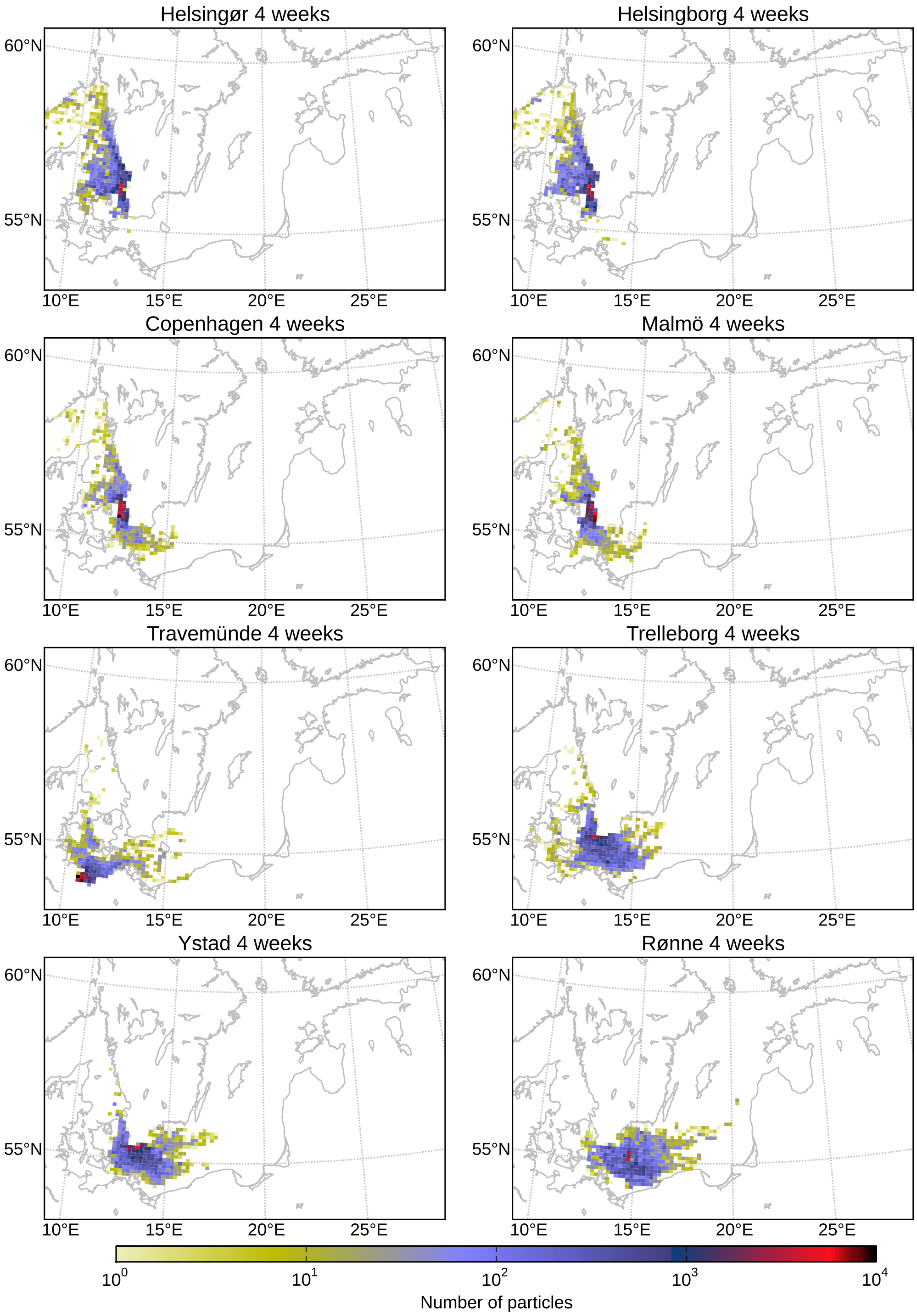

Gävle 2 weeks
Turku 2 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

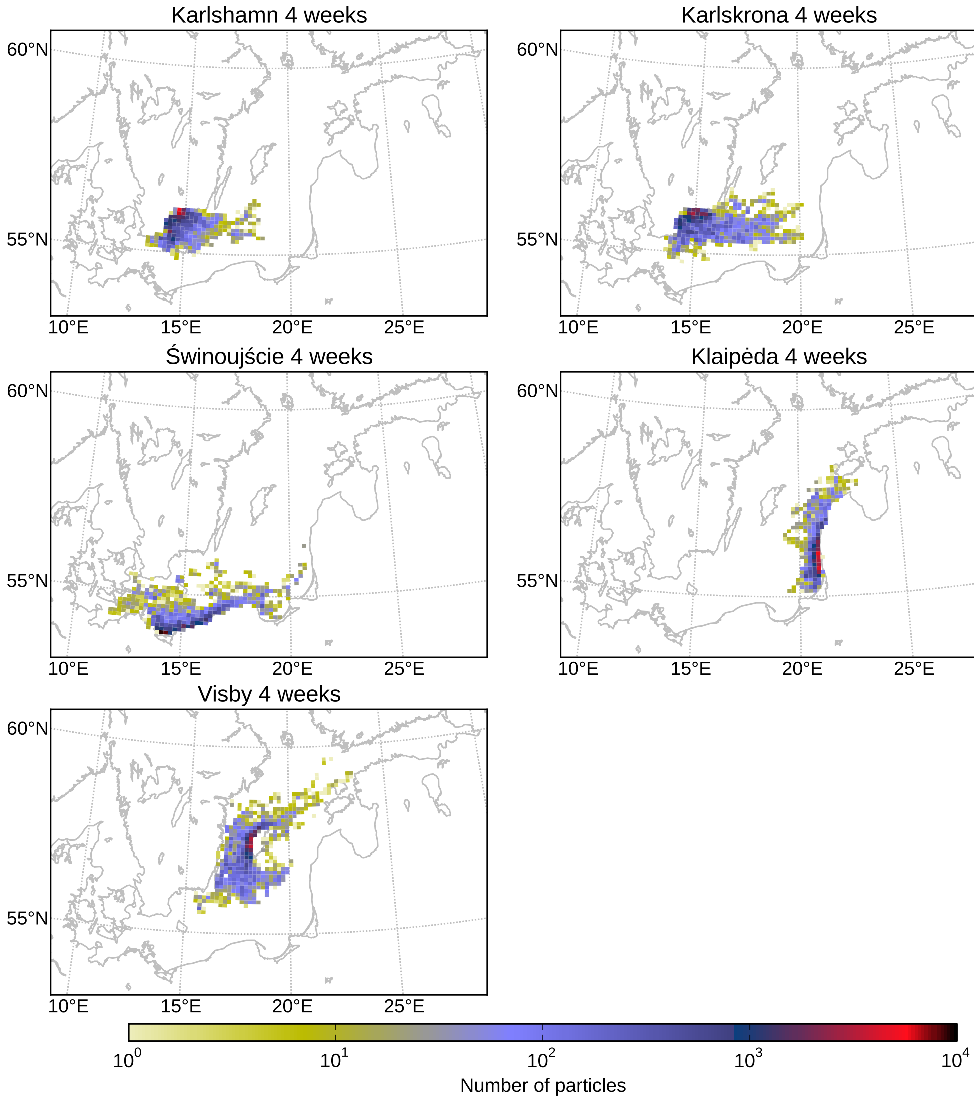

Umeå 2 weeks
Vaasa 2 weeks
Sundsvall 2 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

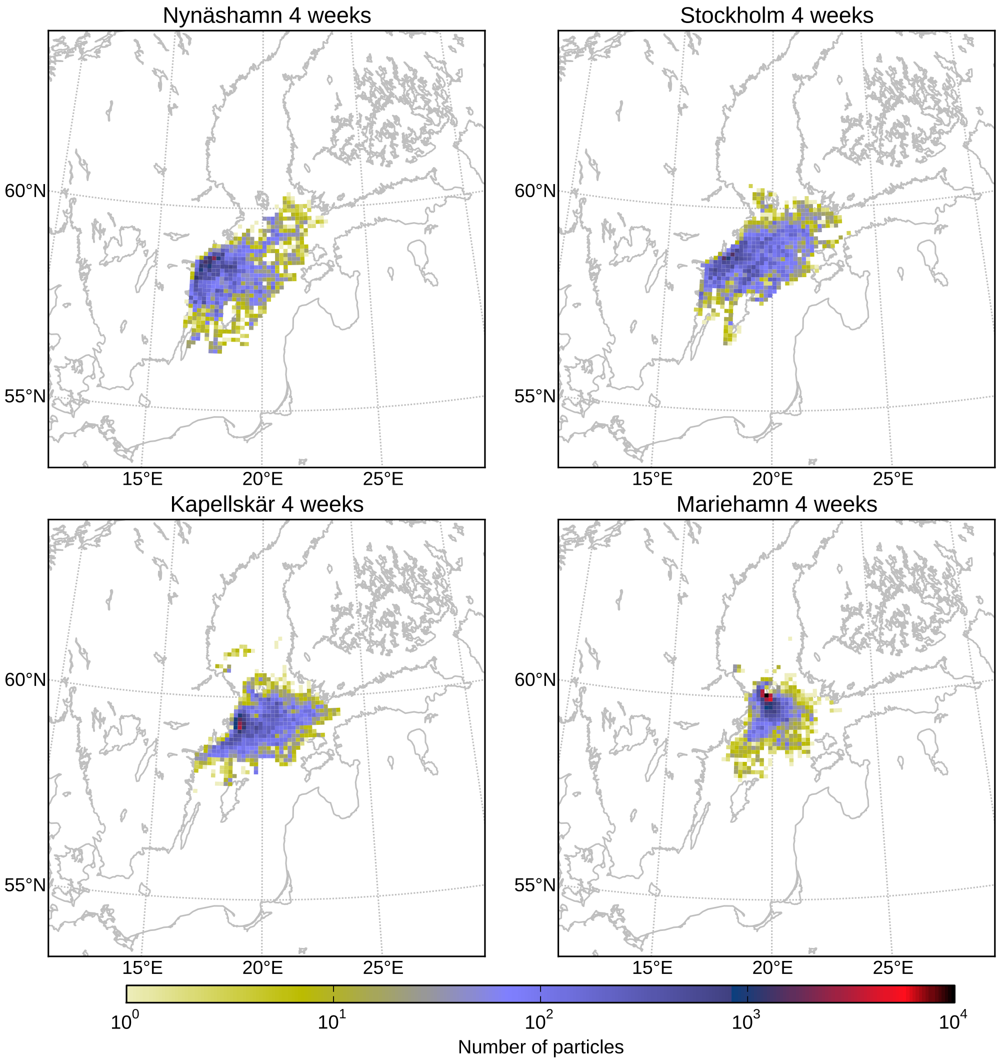


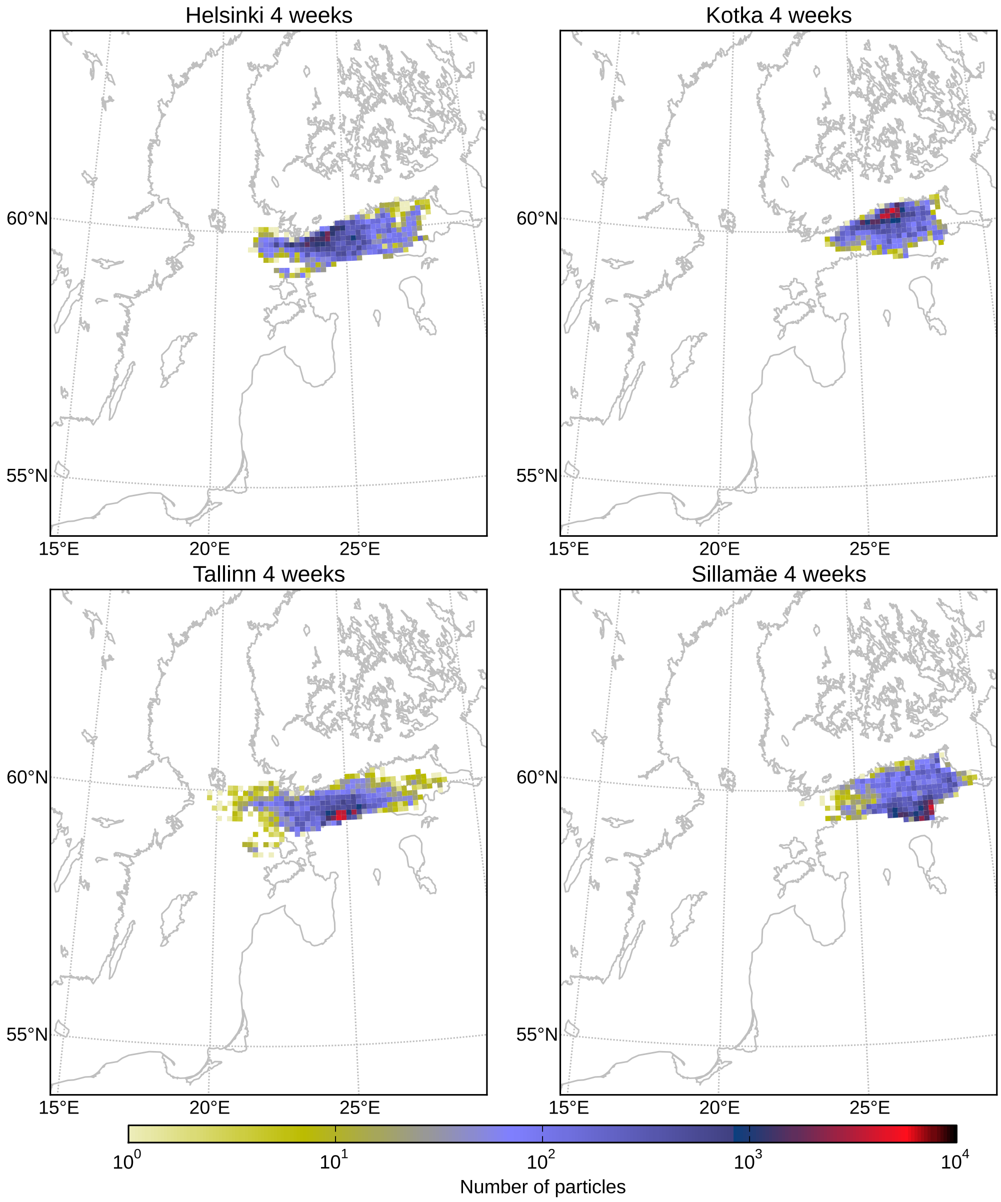
Luleå 2 weeks
Kokkola 2 weeks
Skelleftehamn 2 weeks
65°N
60°N
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

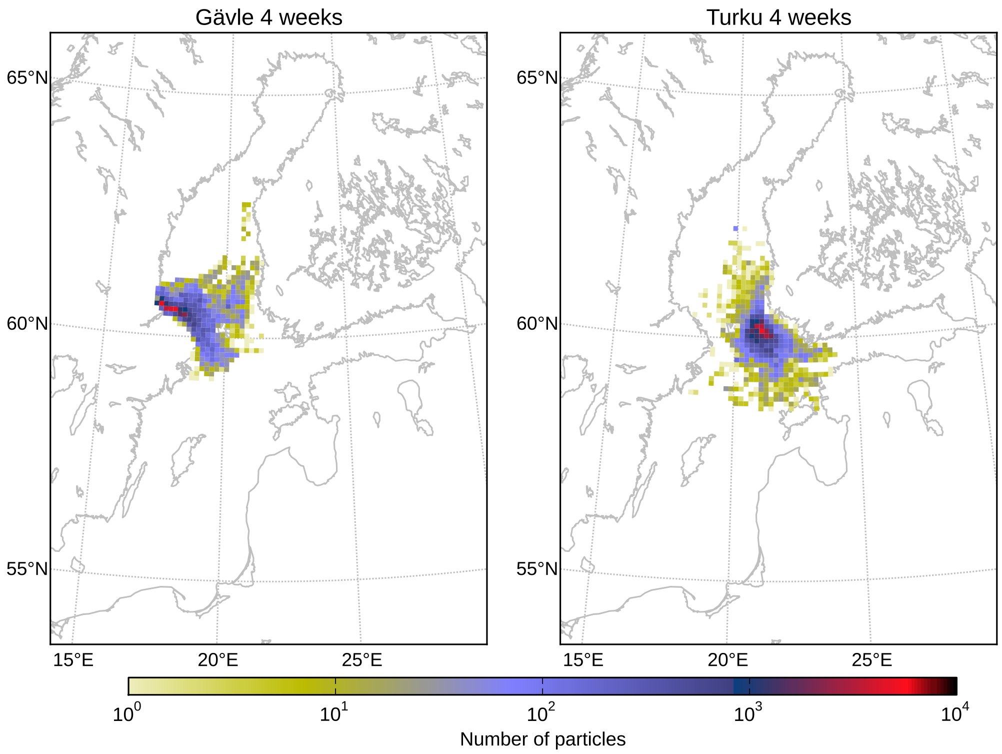

Brofjorden 4 weeks
Skagen 4 weeks
Ålbæk 4 weeks
Göteborg 4 weeks
Fredrikshavn 4 weeks
Varberg 4 weeks
Grenå 4 weeks
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles

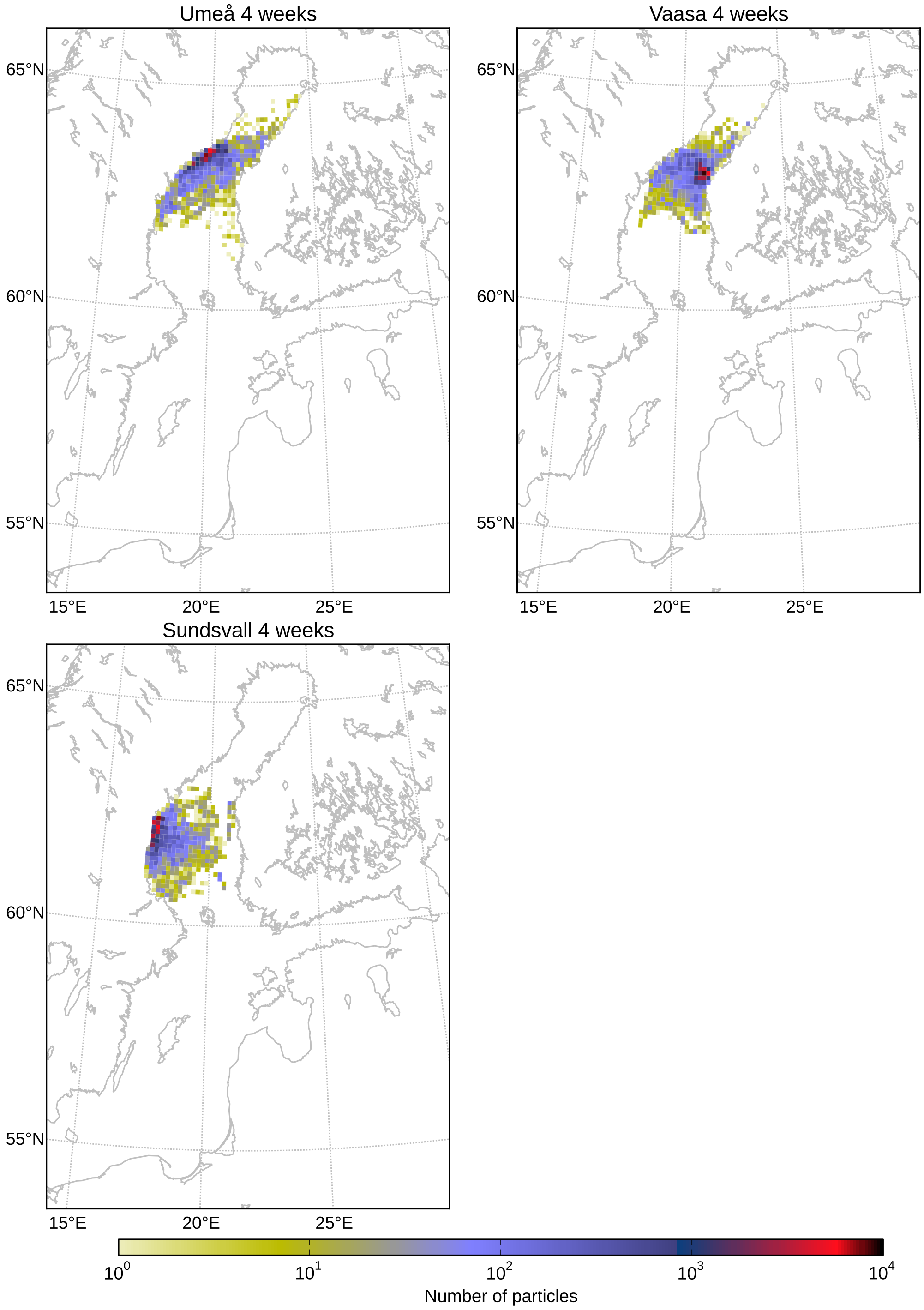

Helsingør 4 weeks
Helsingborg 4 weeks
Copenhagen 4 weeks
Malmö 4 weeks
Travemünde 4 weeks
Trelleborg 4 weeks
Ystad 4 weeks
Rønne 4 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

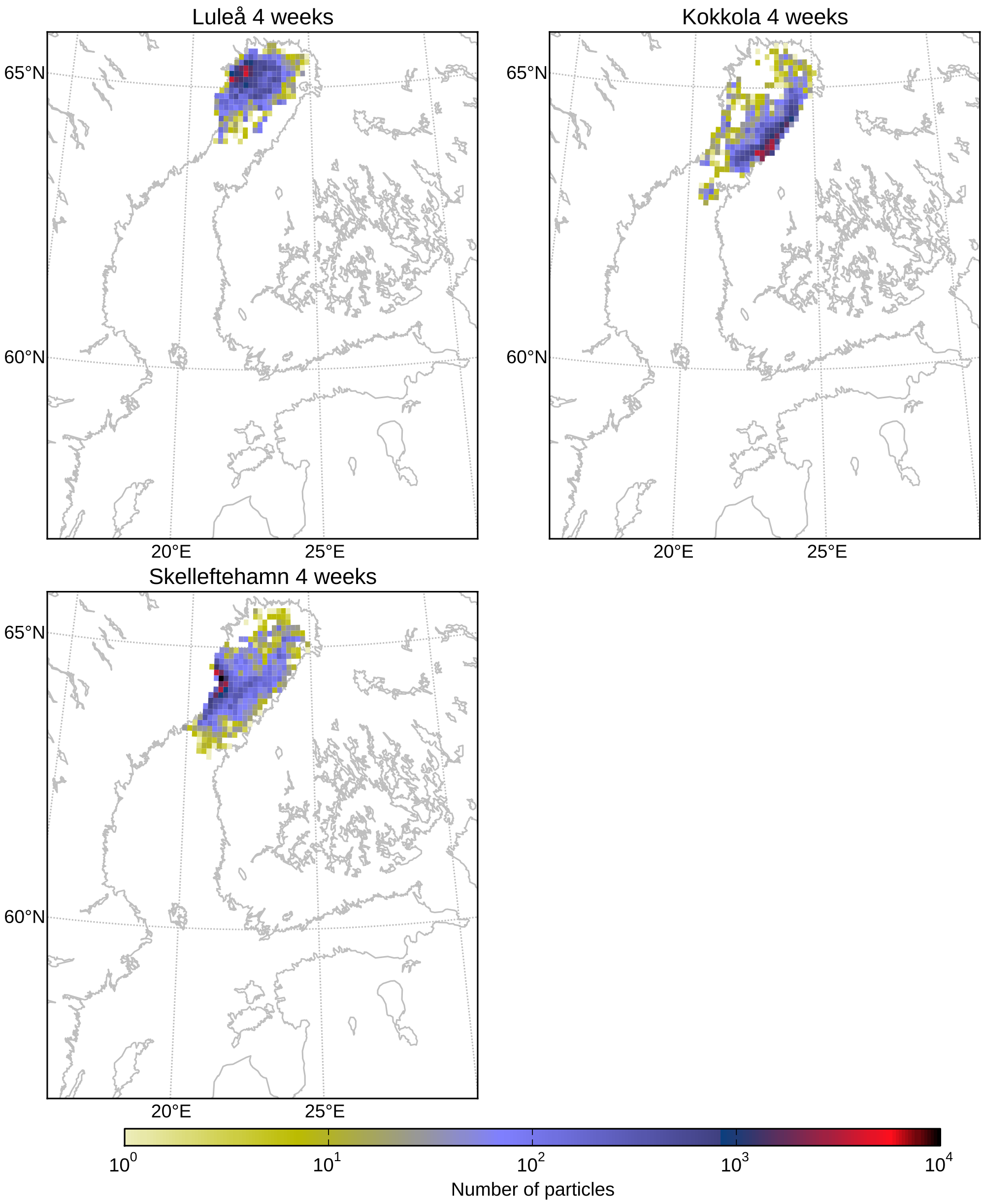

Karlshamn 4 weeks
Karlskrona 4 weeks
Świnoujście 4 weeks
Klaipėda 4 weeks
Visby 4 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

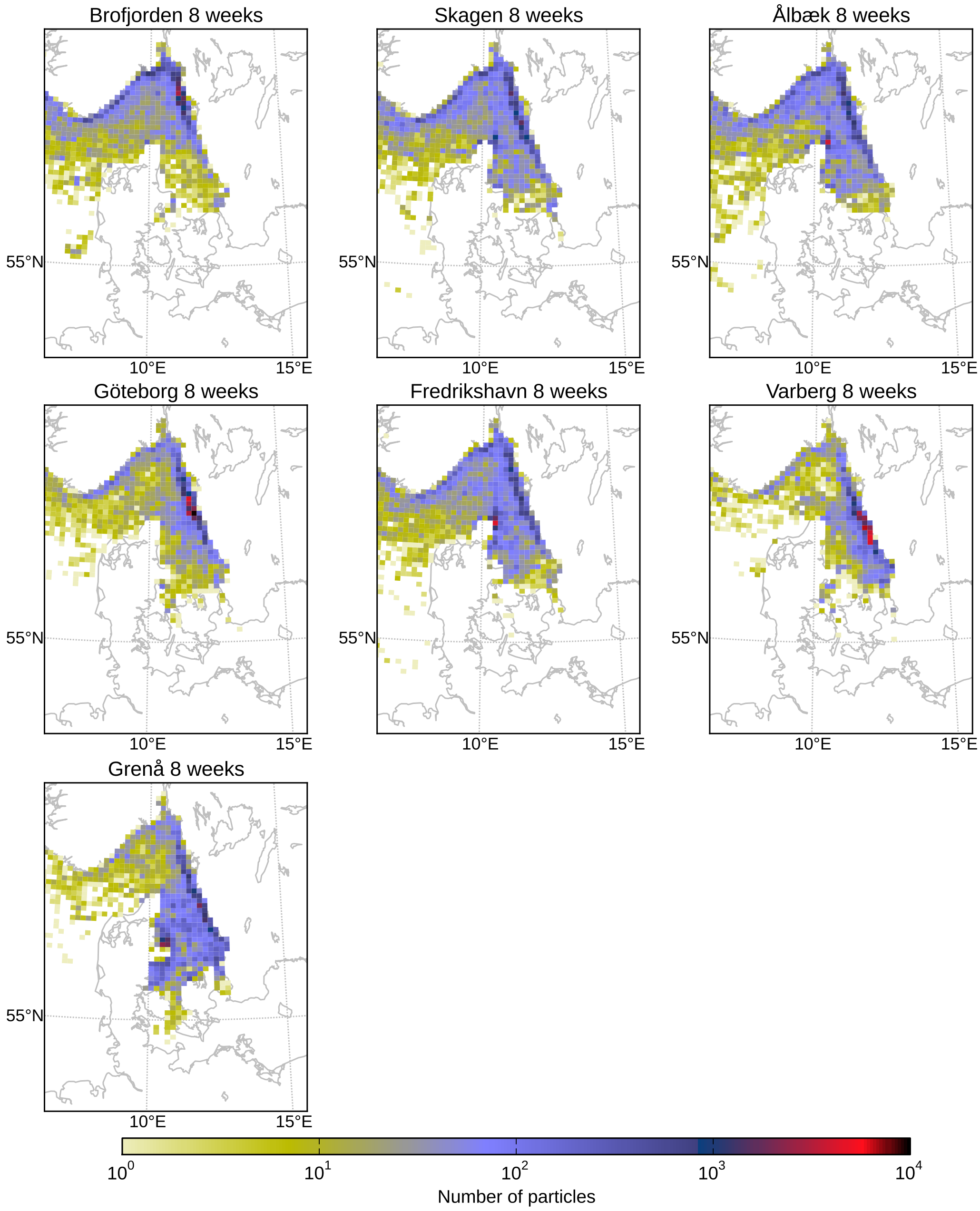

Nynäshamn 4 weeks
Stockholm 4 weeks
Kapellskär 4 weeks
Mariehamn 4 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Helsinki 4 weeks
Kotka 4 weeks
Tallinn 4 weeks
Sillamäe 4 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

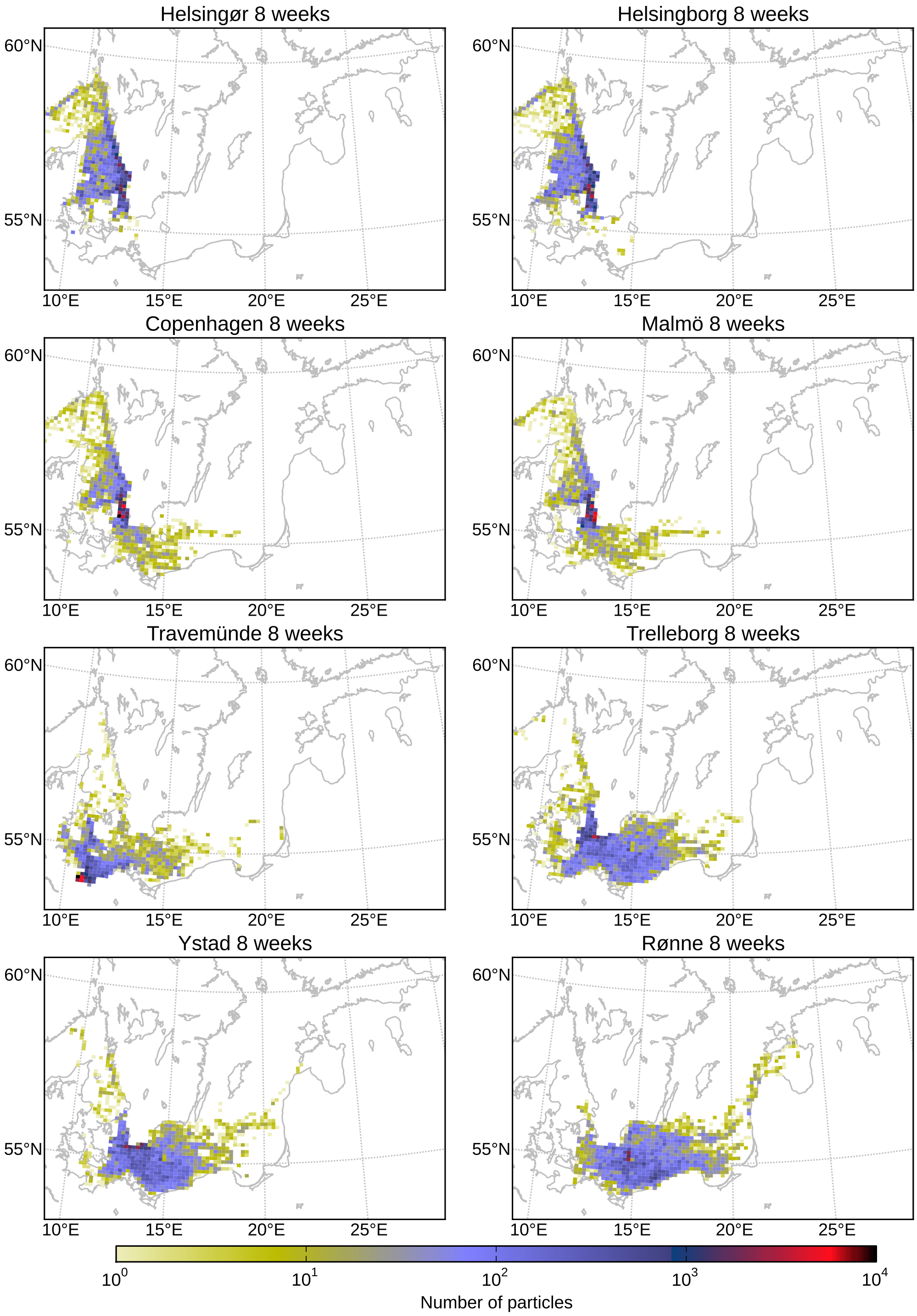

Gävle 4 weeks
Turku 4 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

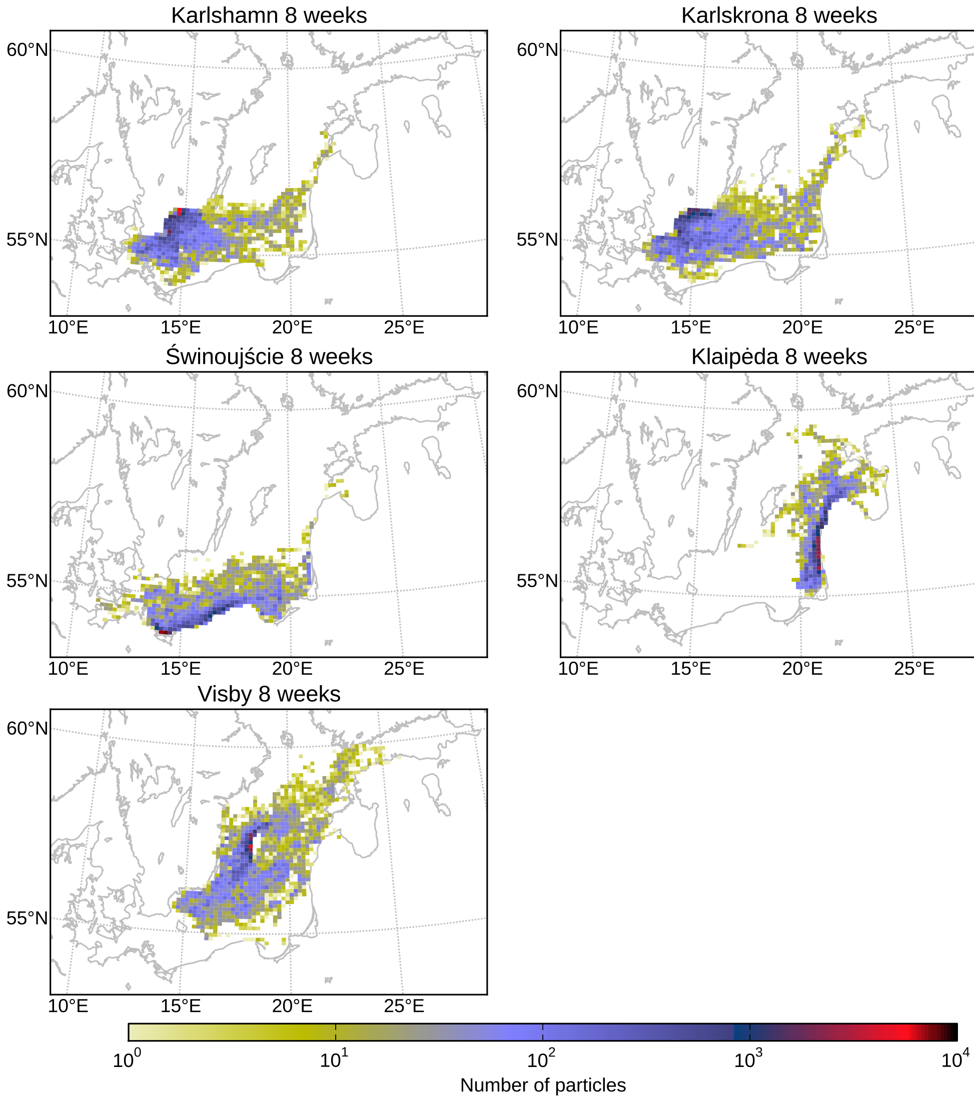

Umeå 4 weeks
Vaasa 4 weeks
Sundsvall 4 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

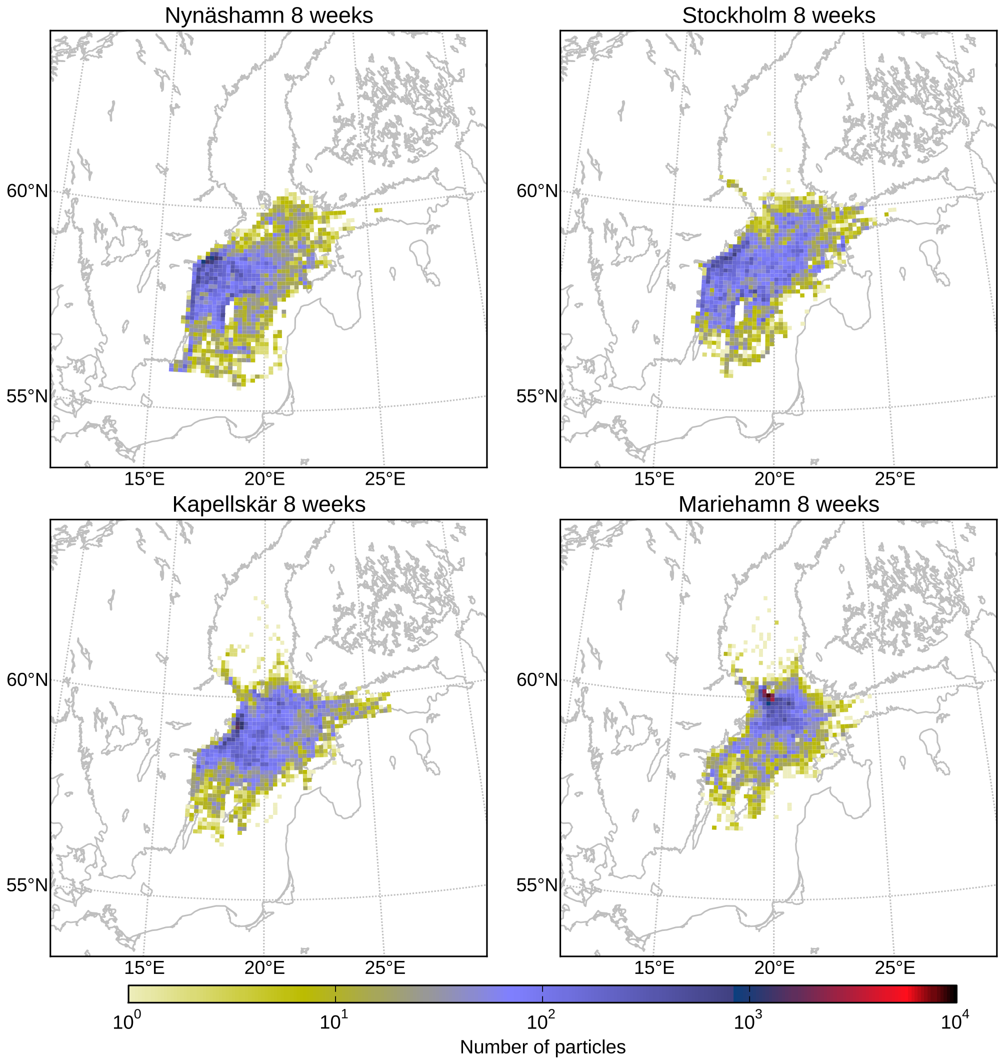

Luleå 4 weeks
Kokkola 4 weeks
Skelleftehamn 4 weeks
65°N
60°N
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

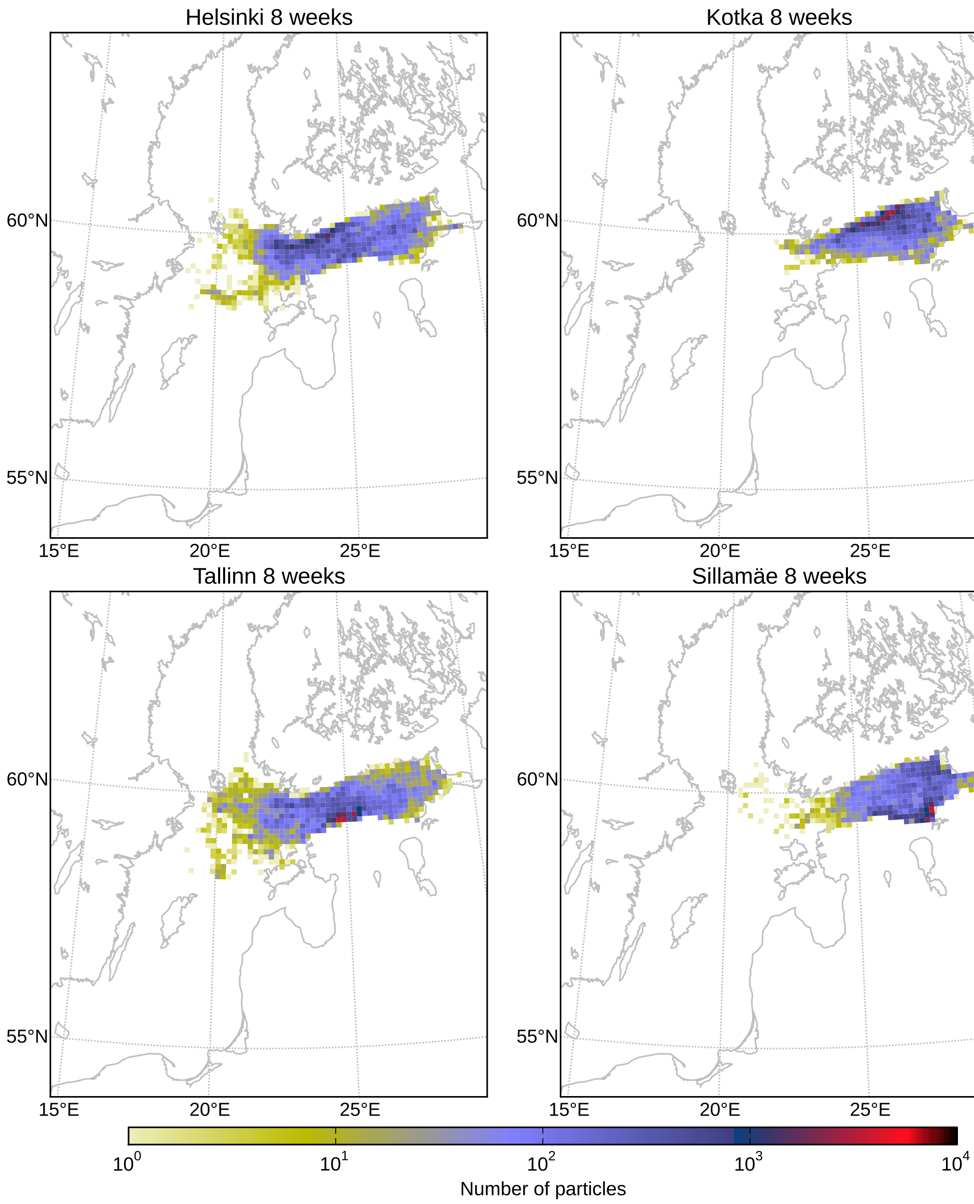


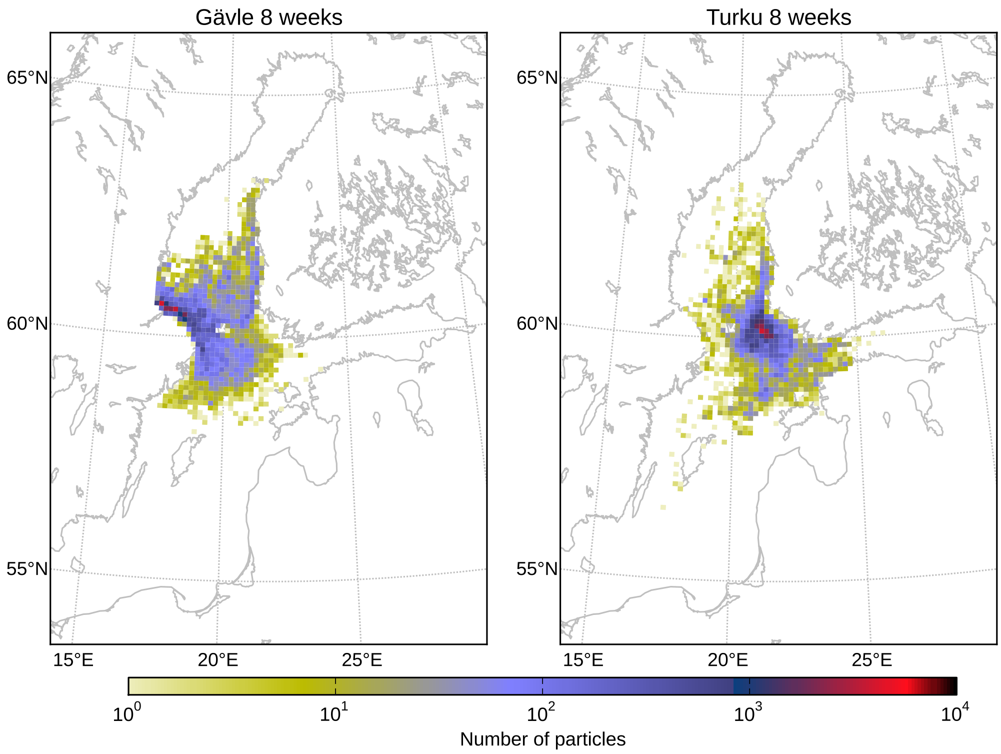
Brofjorden 8 weeks
Skagen 8 weeks
Ålbæk 8 weeks
Göteborg 8 weeks
Fredrikshavn 8 weeks
Varberg 8 weeks
Grenå 8 weeks
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles

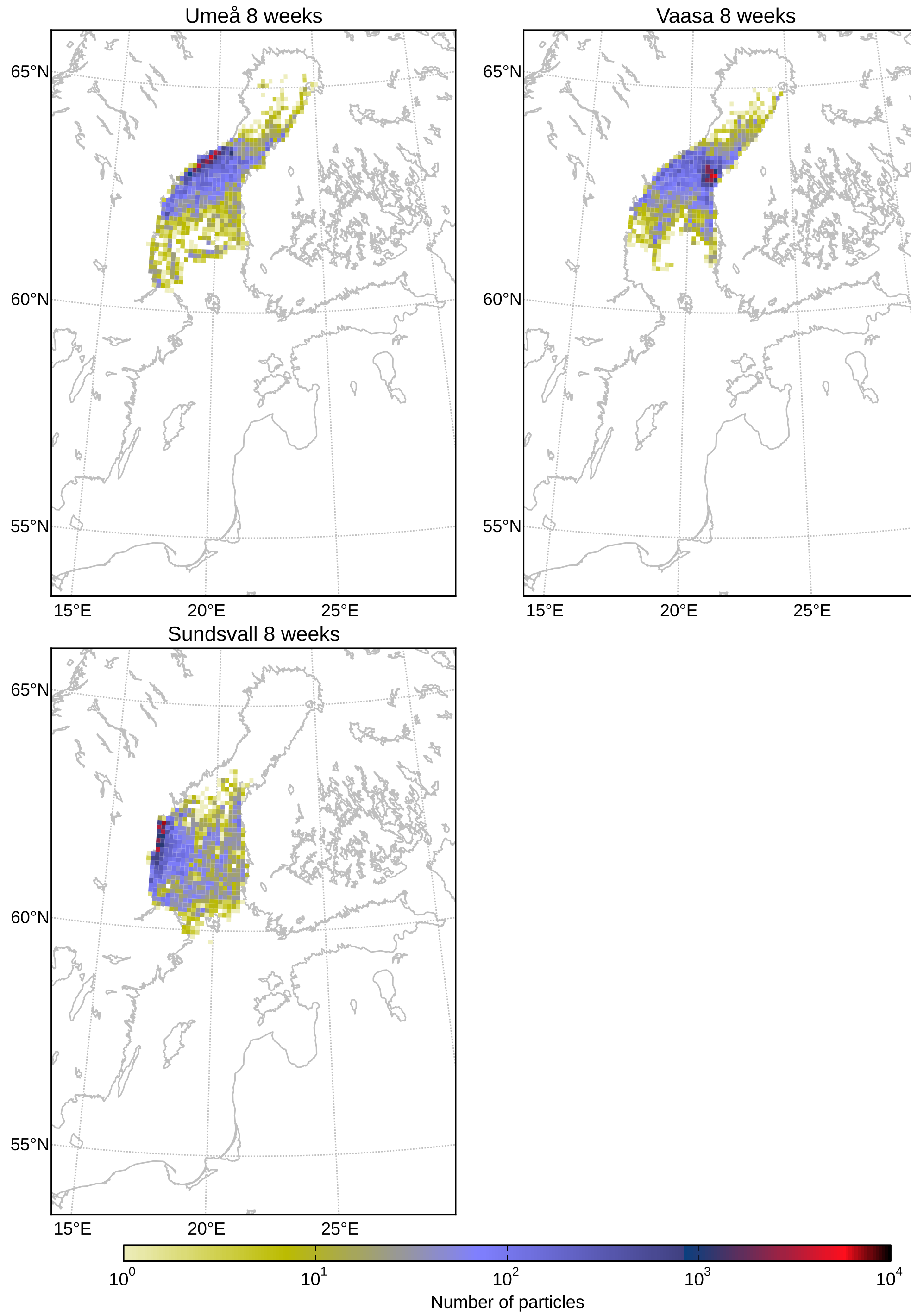

Helsingør 8 weeks
Helsingborg 8 weeks
Copenhagen 8 weeks
Malmö 8 weeks
Travemünde 8 weeks
Trelleborg 8 weeks
Ystad 8 weeks
Rønne 8 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

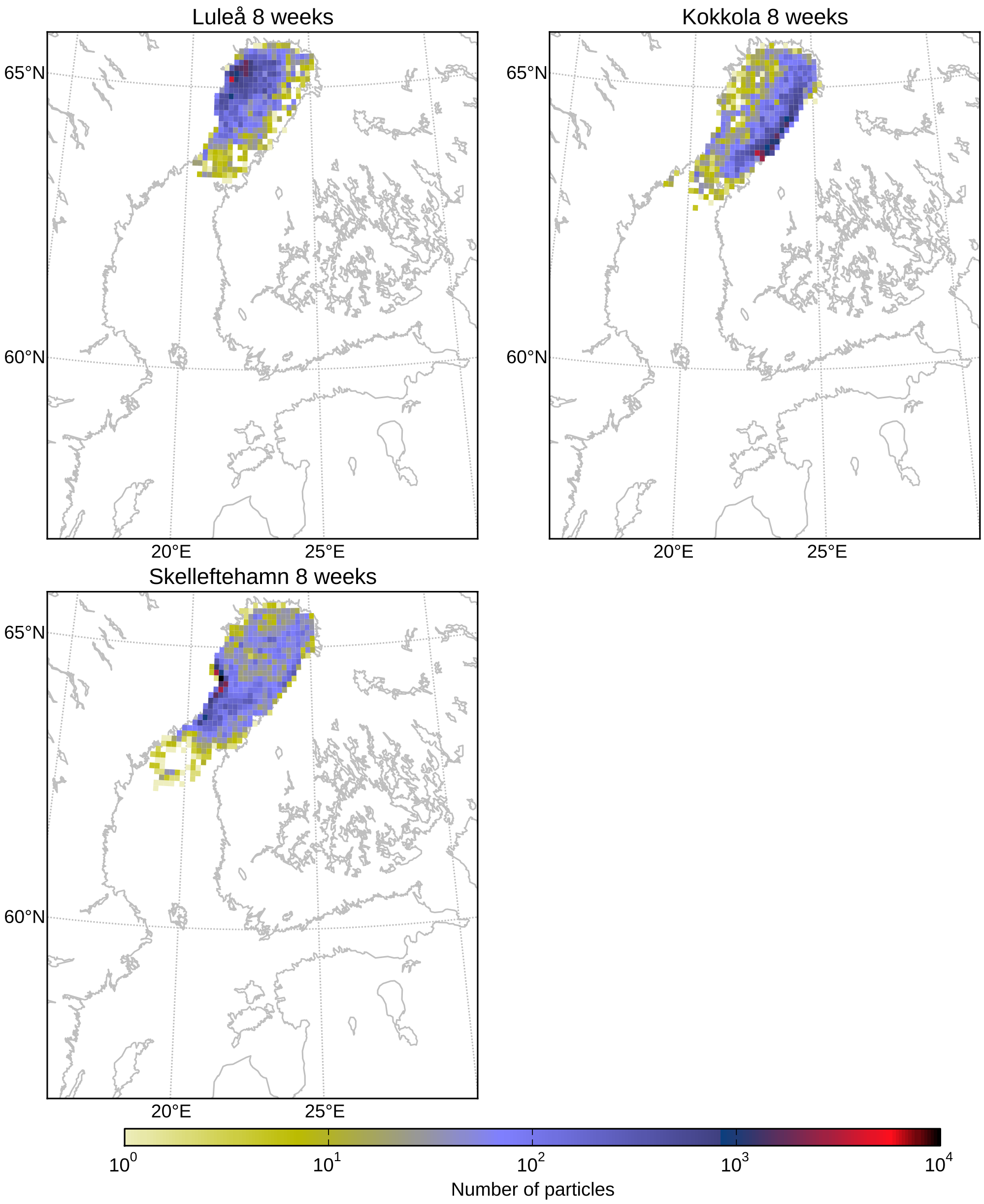

Karlshamn 8 weeks
Karlskrona 8 weeks
Świnoujście 8 weeks
Klaipėda 8 weeks
Visby 8 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Nynäshamn 8 weeks
Stockholm 8 weeks
Kapellskär 8 weeks
Mariehamn 8 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

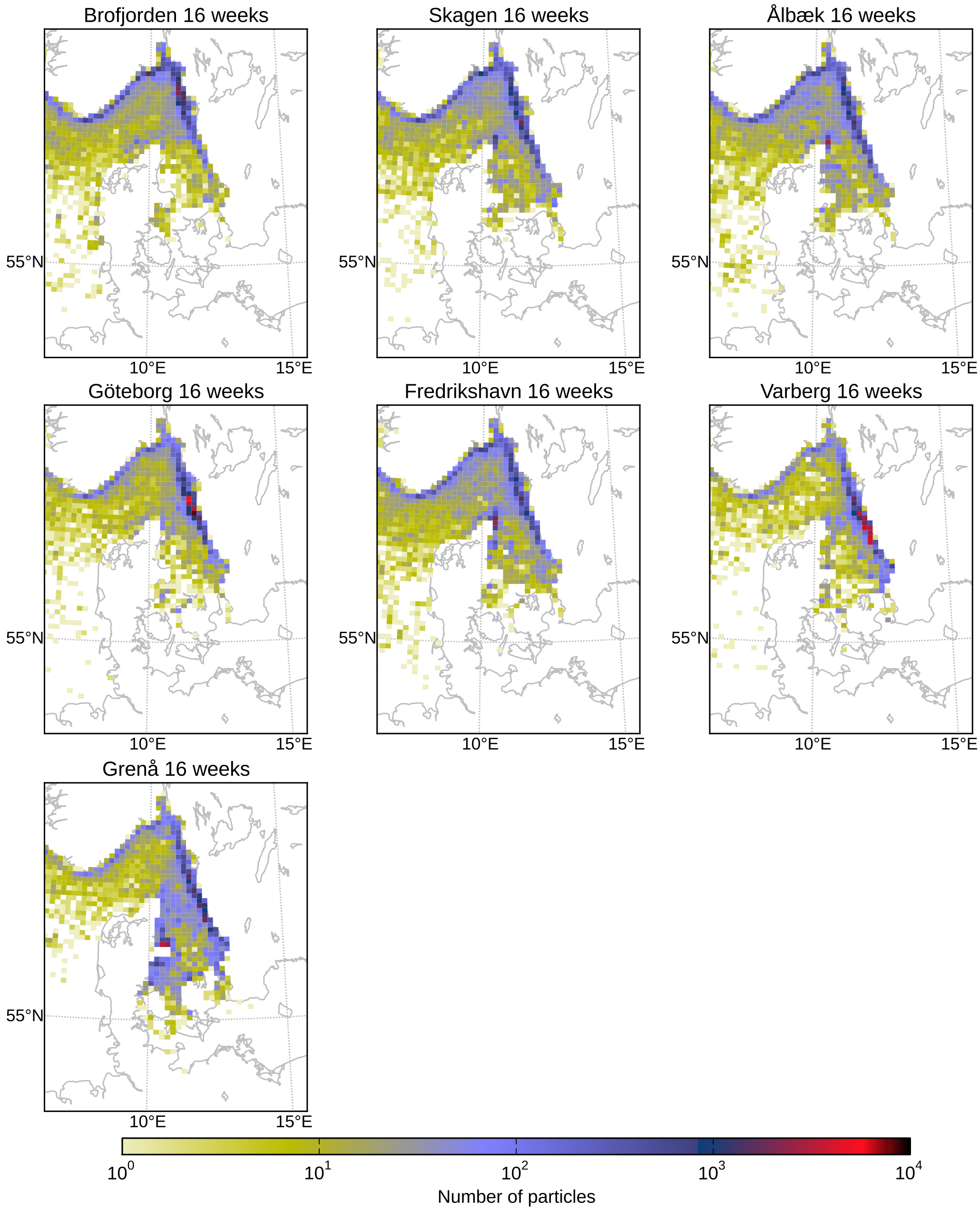

Helsinki 8 weeks
Kotka 8 weeks
Tallinn 8 weeks
Sillamäe 8 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

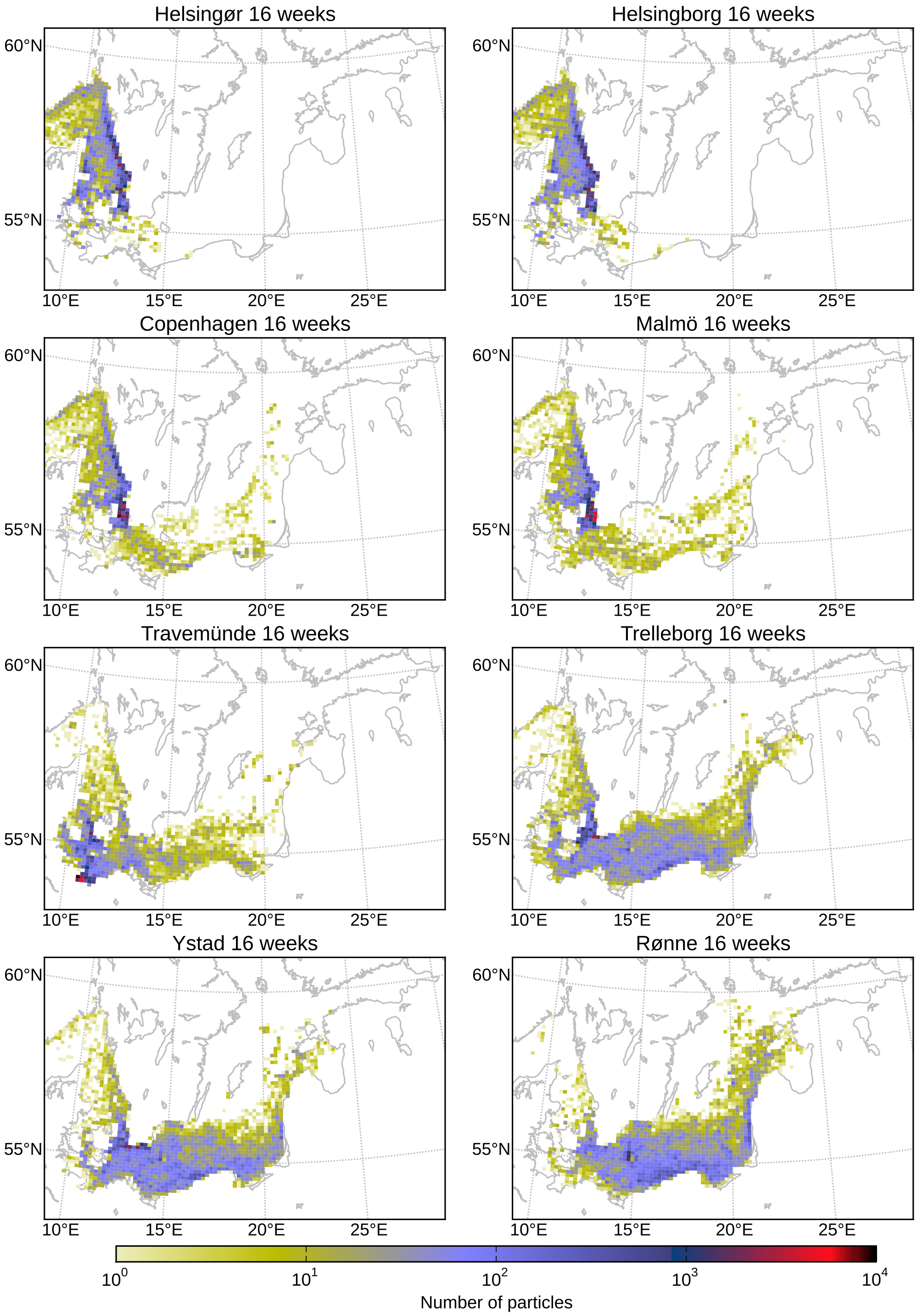

Gävle 8 weeks
Turku 8 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Umeå 8 weeks
Vaasa 8 weeks
Sundsvall 8 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

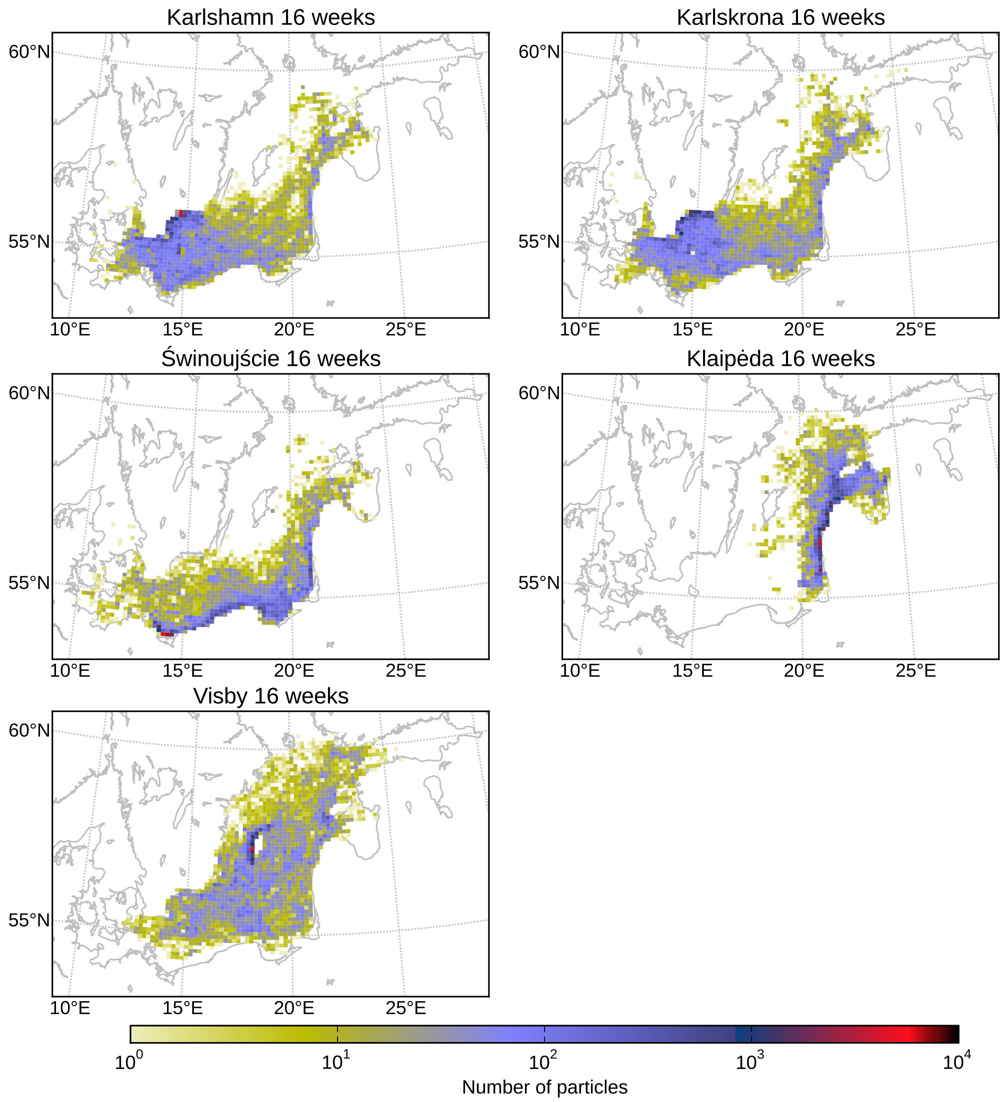


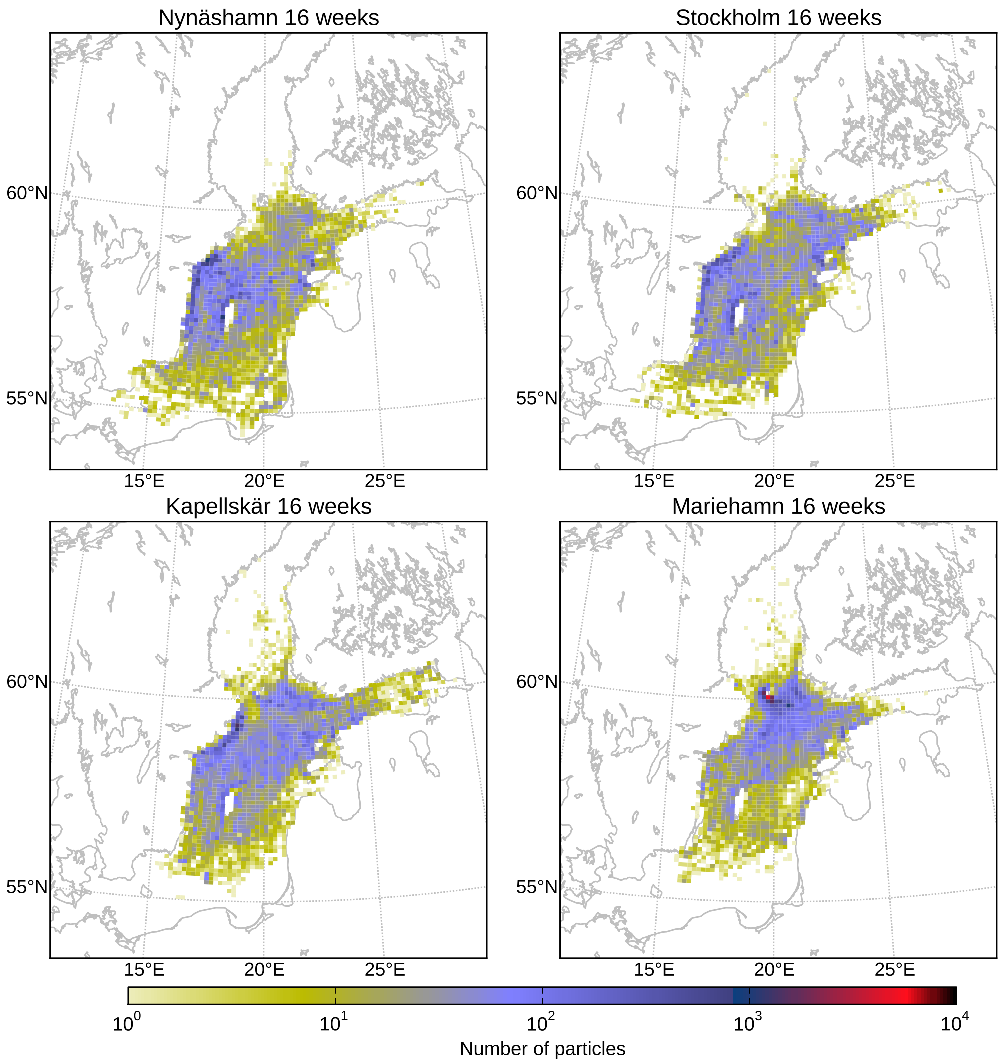
Luleå 8 weeks
Kokkola 8 weeks
Skelleftehamn 8 weeks
65°N
60°N
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

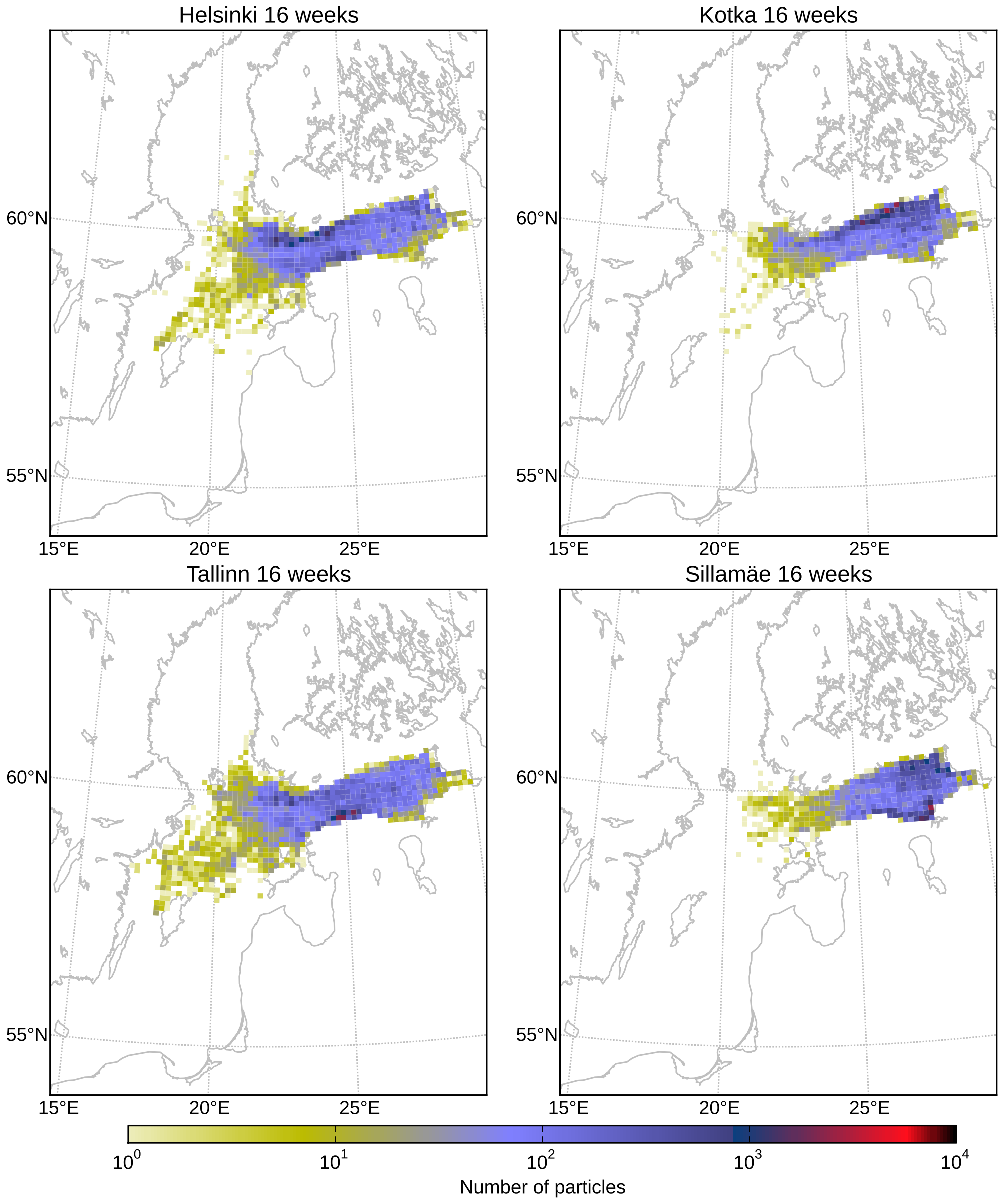

Brofjorden 16 weeks
Skagen 16 weeks
Ålbæk 16 weeks
Göteborg 16 weeks
Fredrikshavn 16 weeks
Varberg 16 weeks
Grenå 16 weeks
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles



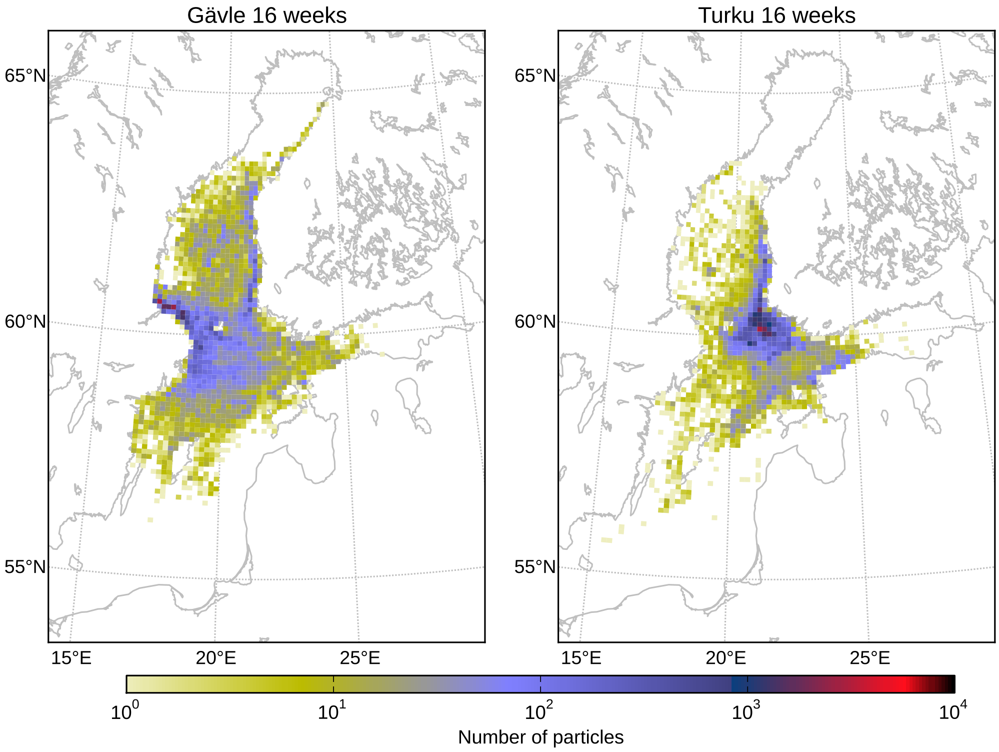
Helsingør 16 weeks
Helsingborg 16 weeks
Copenhagen 16 weeks
Malmö 16 weeks
Travemünde 16 weeks
Trelleborg 16 weeks
Ystad 16 weeks
Rønne 16 weeks
60°N
55°N
10°E
15°E
20°E
25°E
Number of particles


Karlshamn 16 weeks
Karlskrona 16 weeks
Świnoujście 16 weeks
Klaipėda 16 weeks
Visby 16 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

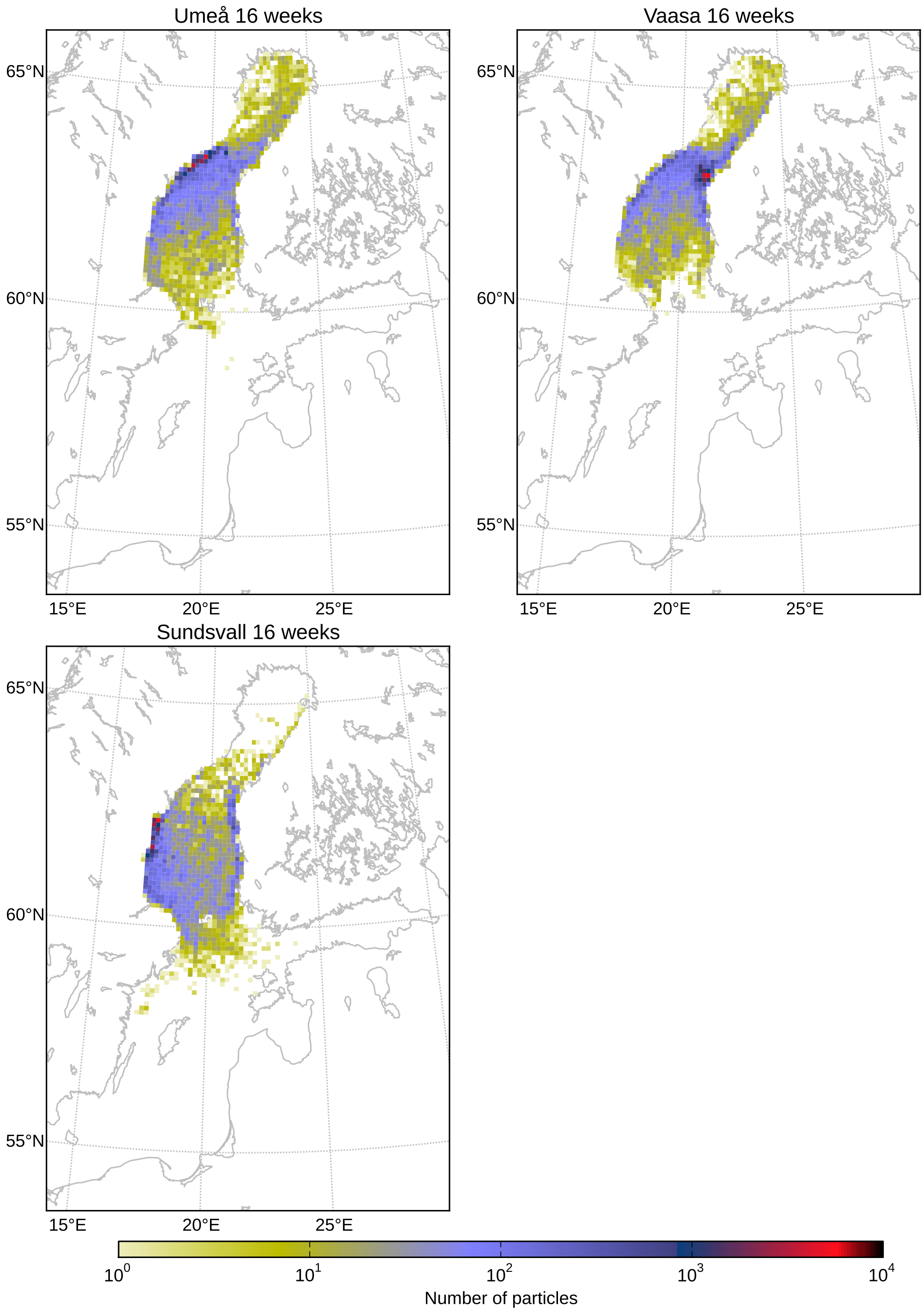

Nynäshamn 16 weeks
Stockholm 16 weeks
Kapellskär 16 weeks
Mariehamn 16 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



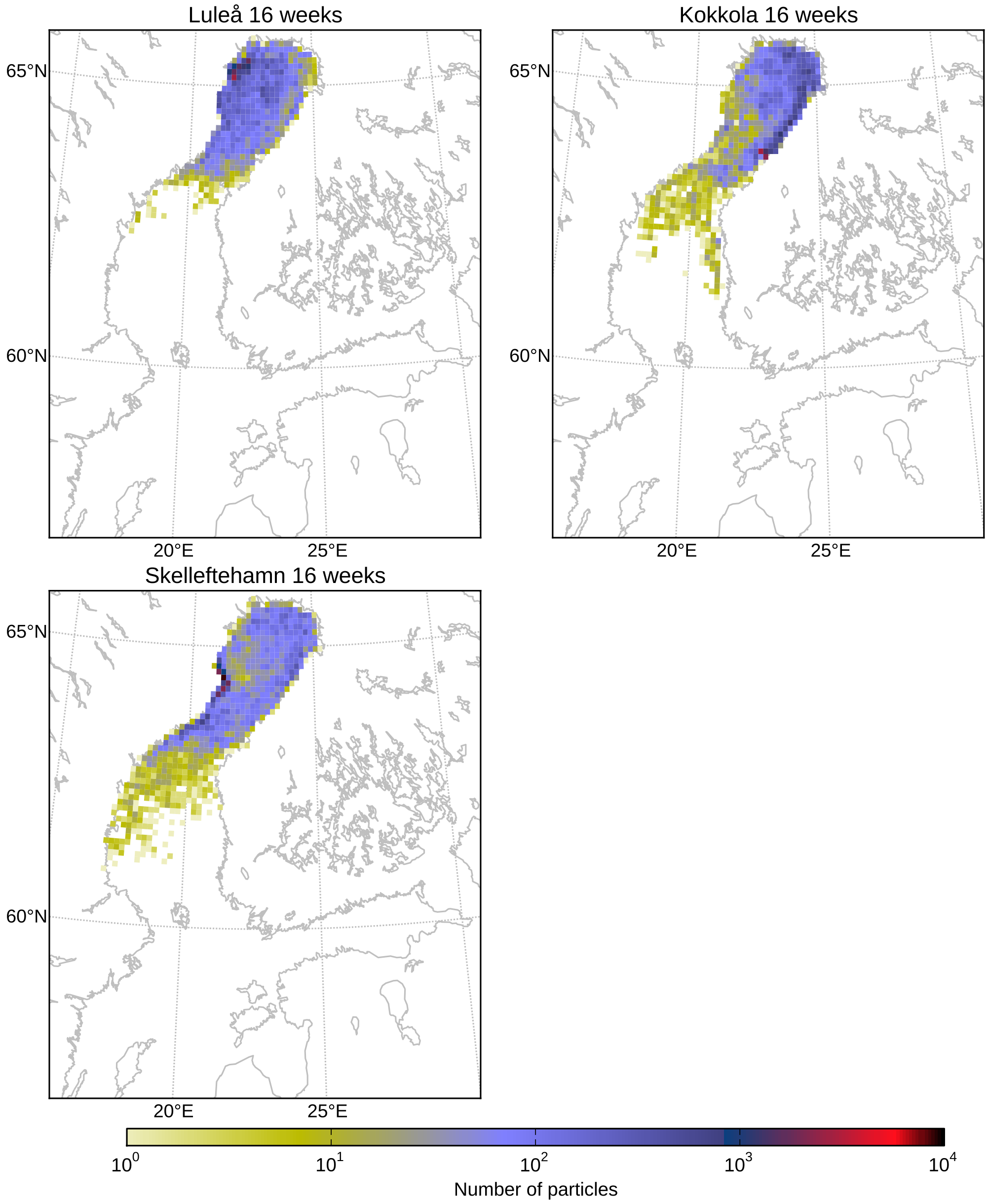
Helsinki 16 weeks
Kotka 16 weeks
Tallinn 16 weeks
Sillamäe 16 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

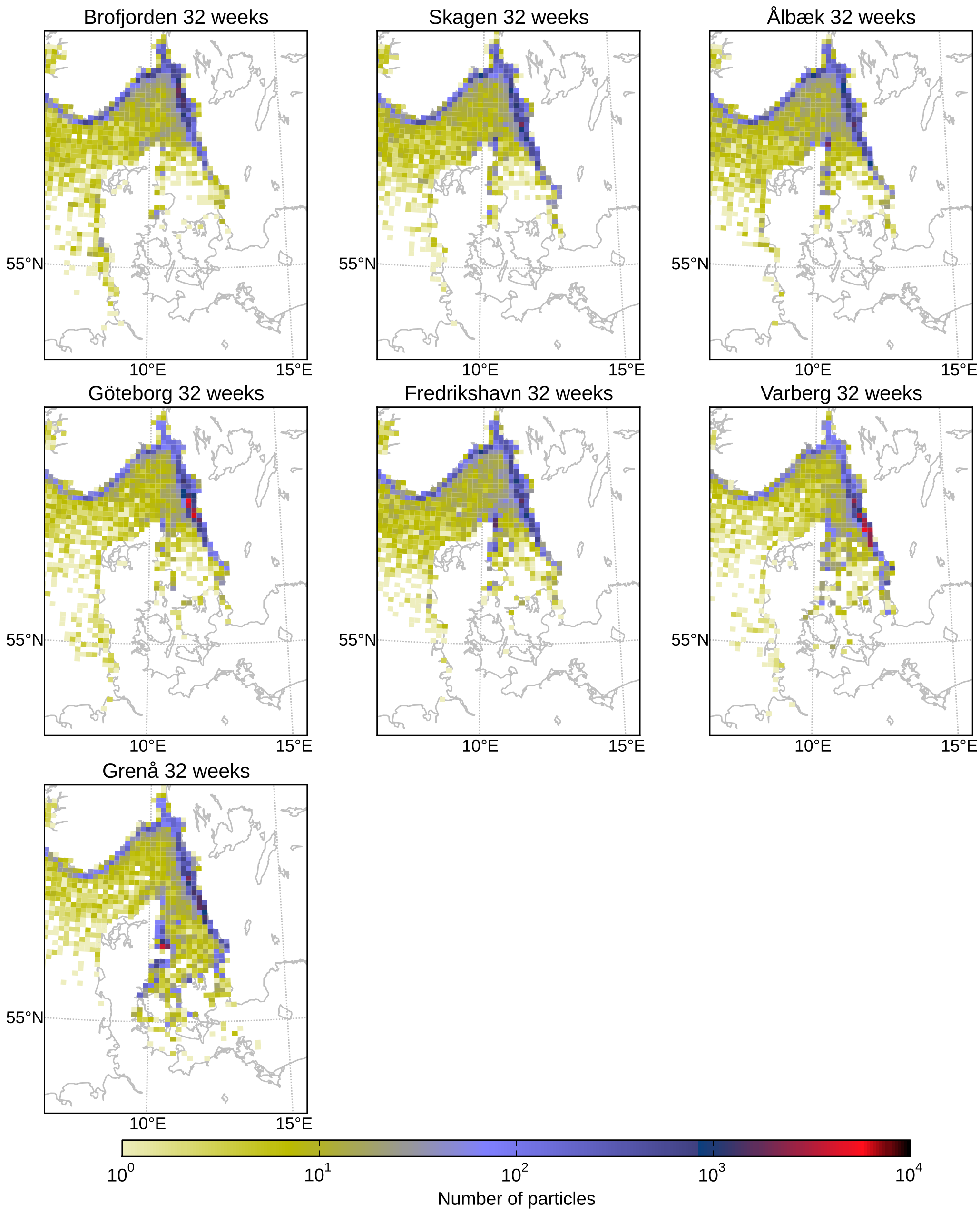


Gävle 16 weeks
Turku 16 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

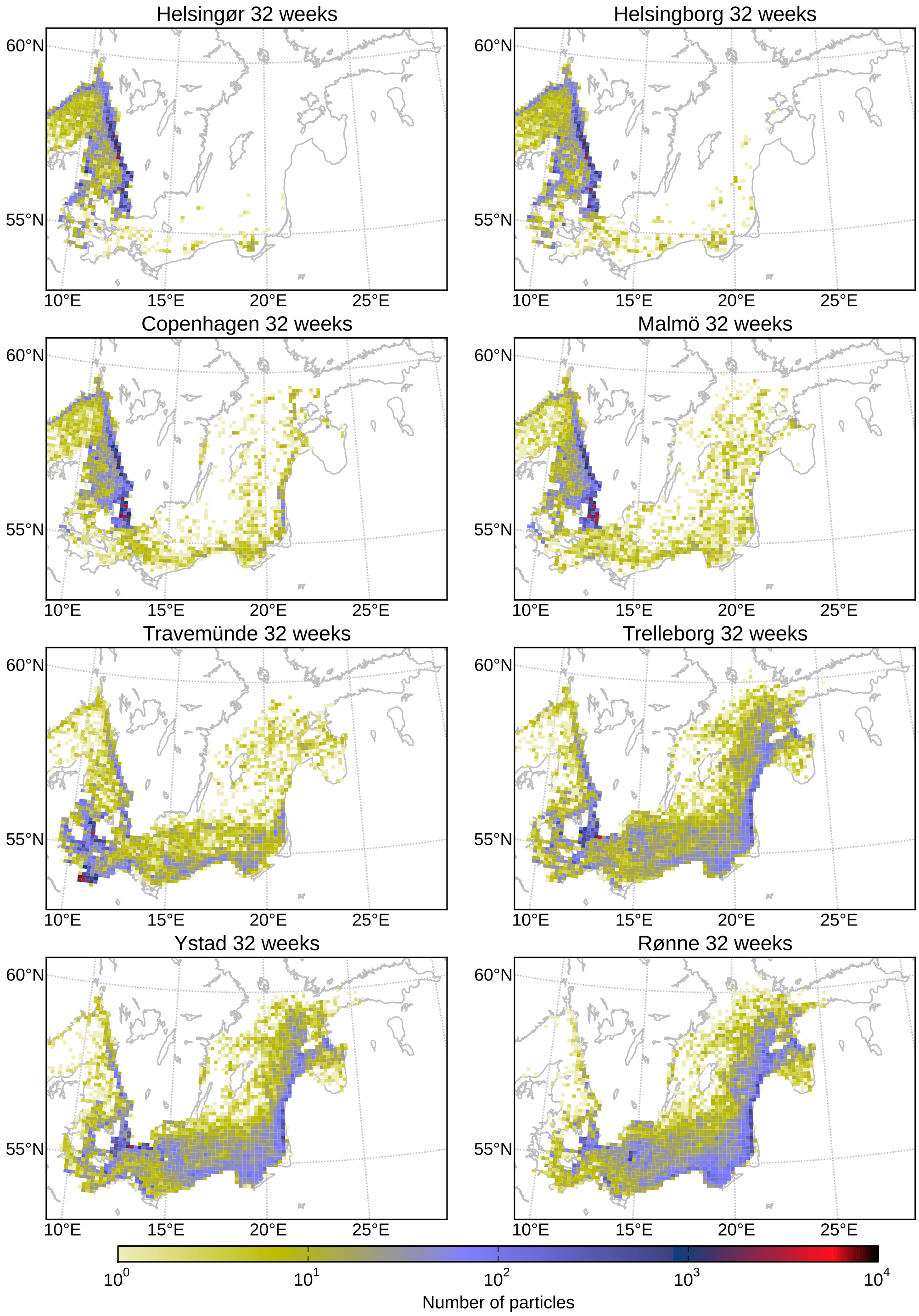


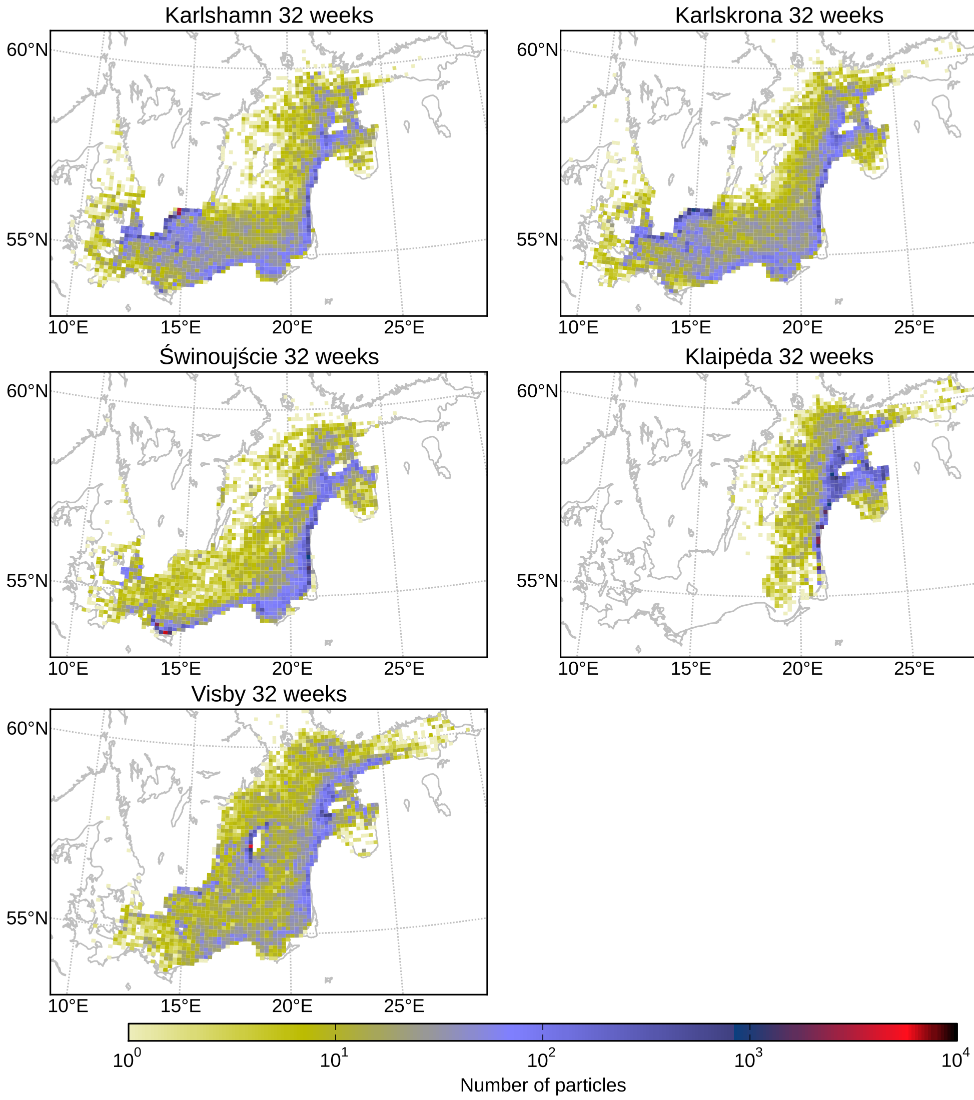
Umeå 16 weeks
Vaasa 16 weeks
Sundsvall 16 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

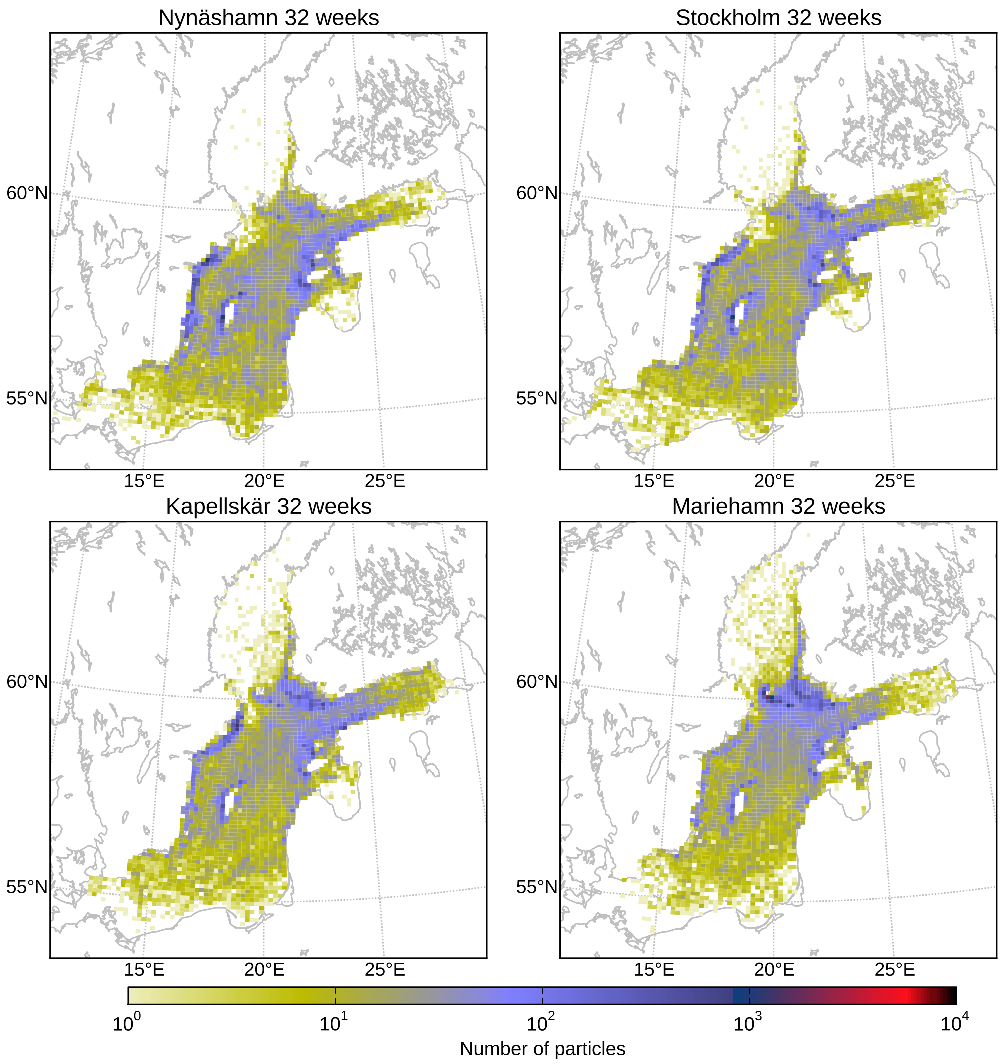

Luleå 16 weeks
Kokkola 16 weeks
Skelleftehamn 16 weeks
65°N
60°N
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



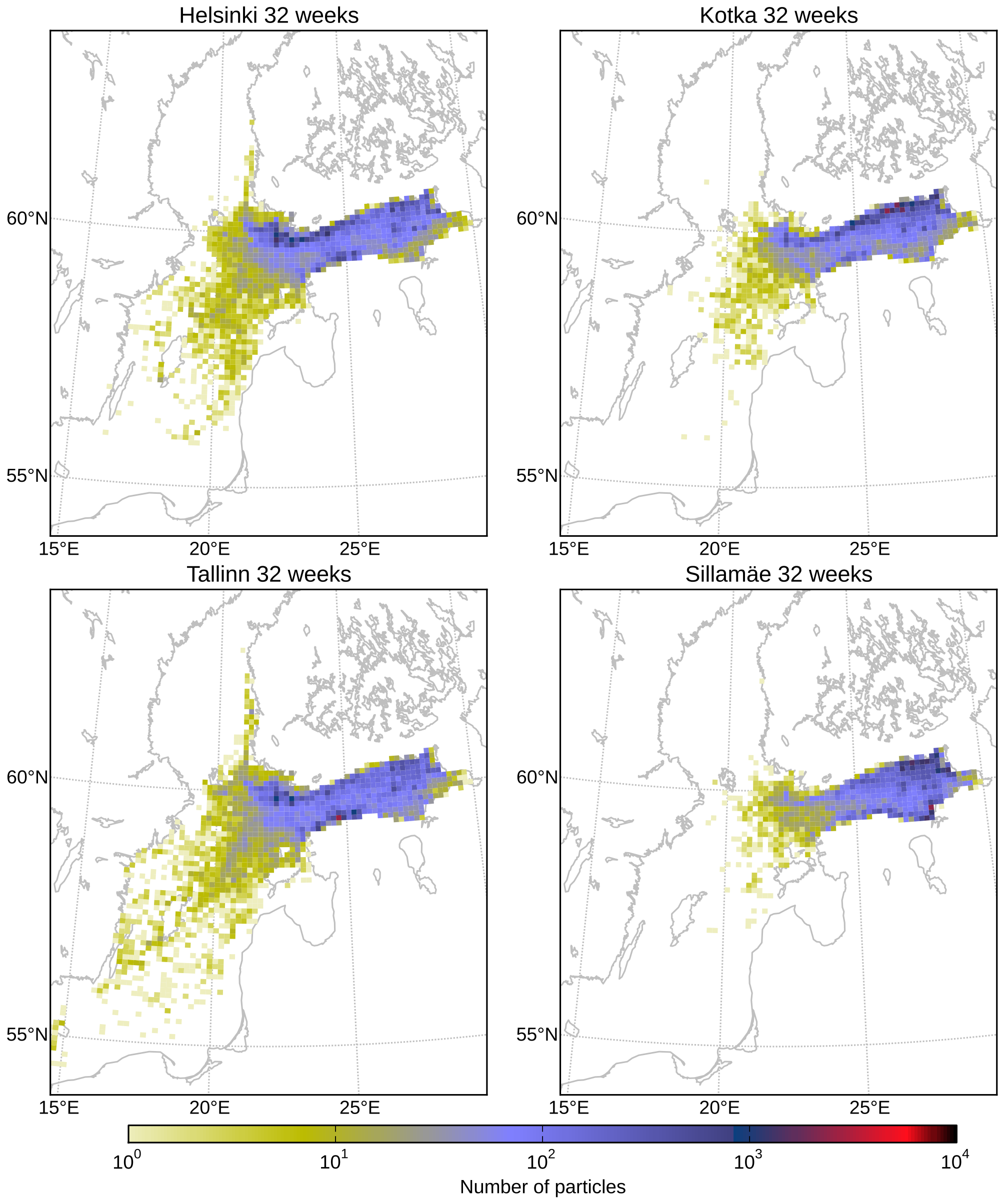
Brofjorden 32 weeks
Skagen 32 weeks
Ålbæk 32 weeks
Göteborg 32 weeks
Fredrikshavn 32 weeks
Varberg 32 weeks
Grenå 32 weeks
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Helsingør 32 weeks
Helsingborg 32 weeks
Copenhagen 32 weeks
Malmö 32 weeks
Travemünde 32 weeks
Trelleborg 32 weeks
Ystad 32 weeks
Rønne 32 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

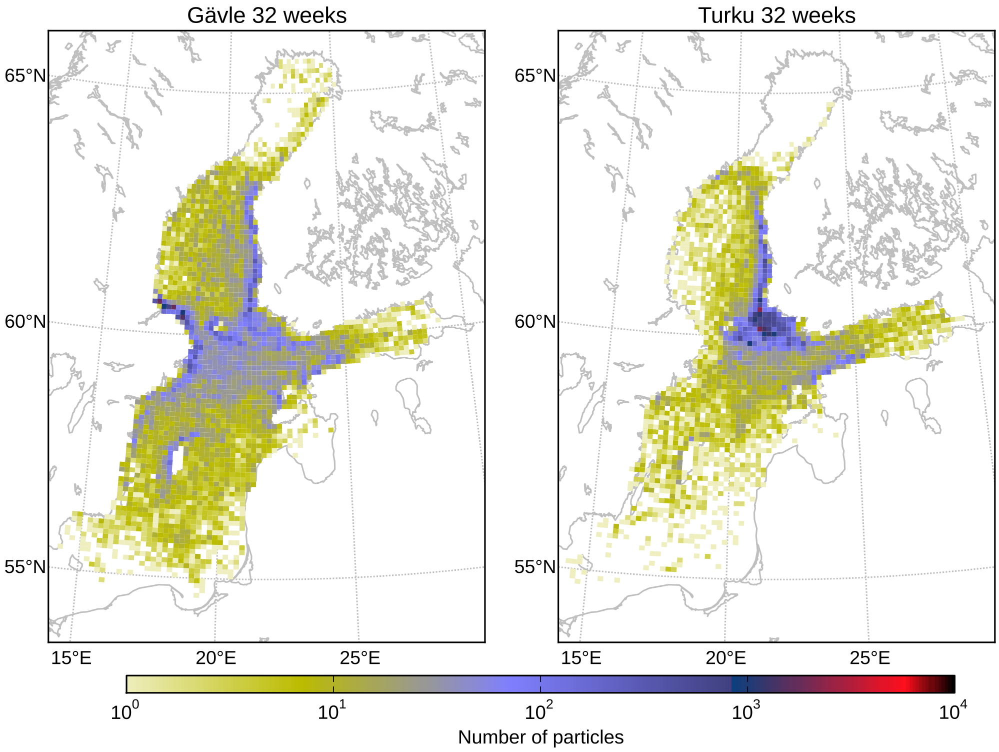

Karlshamn 32 weeks
Karlskrona 32 weeks
Świnoujście 32 weeks
Klaipėda 32 weeks
Visby 32 weeks
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



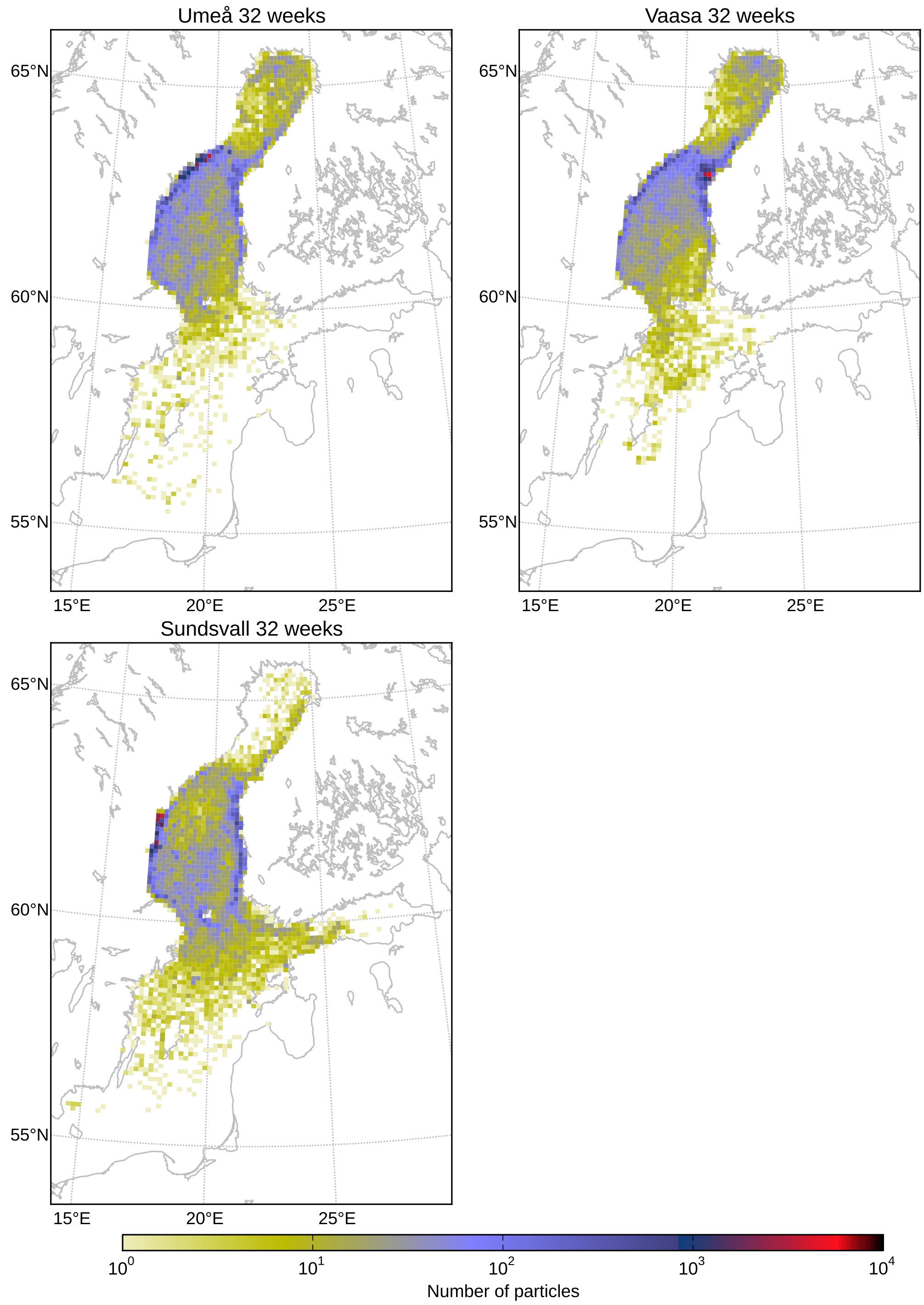
Nynäshamn 32 weeks
Stockholm 32 weeks
Kapellskär 32 weeks
Mariehamn 32 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



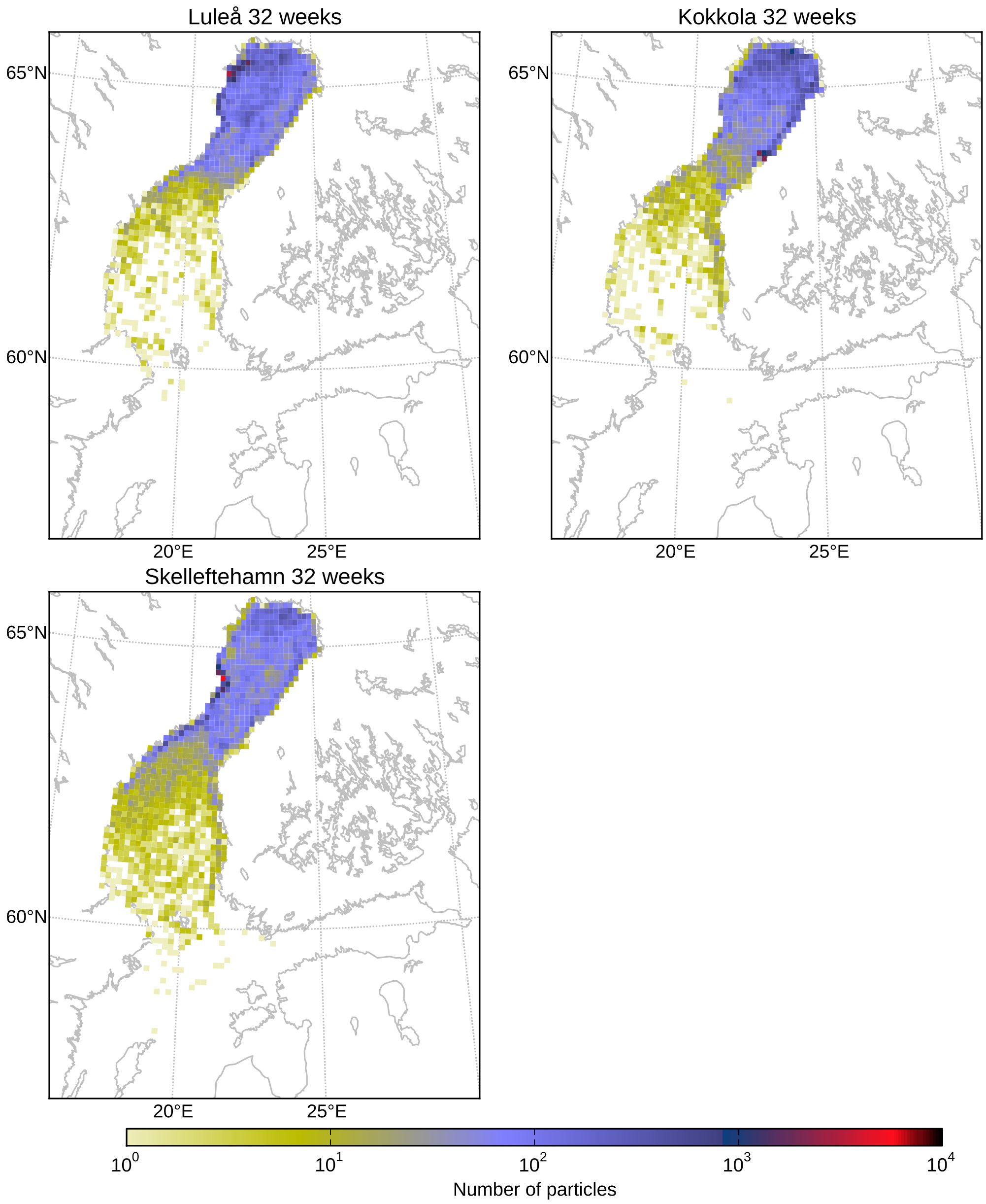
Helsinki 32 weeks
Kotka 32 weeks
Tallinn 32 weeks
Sillamäe 32 weeks
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

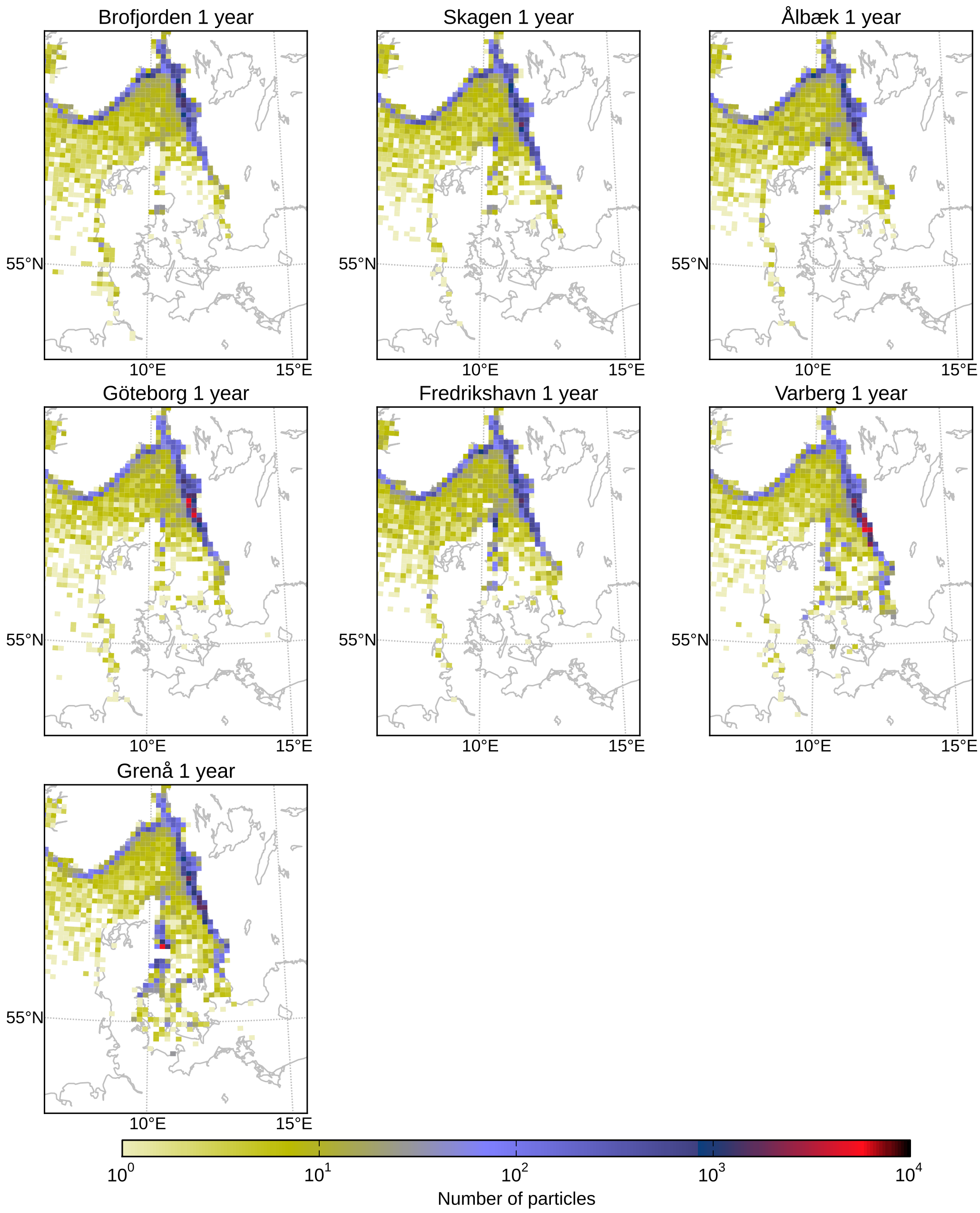


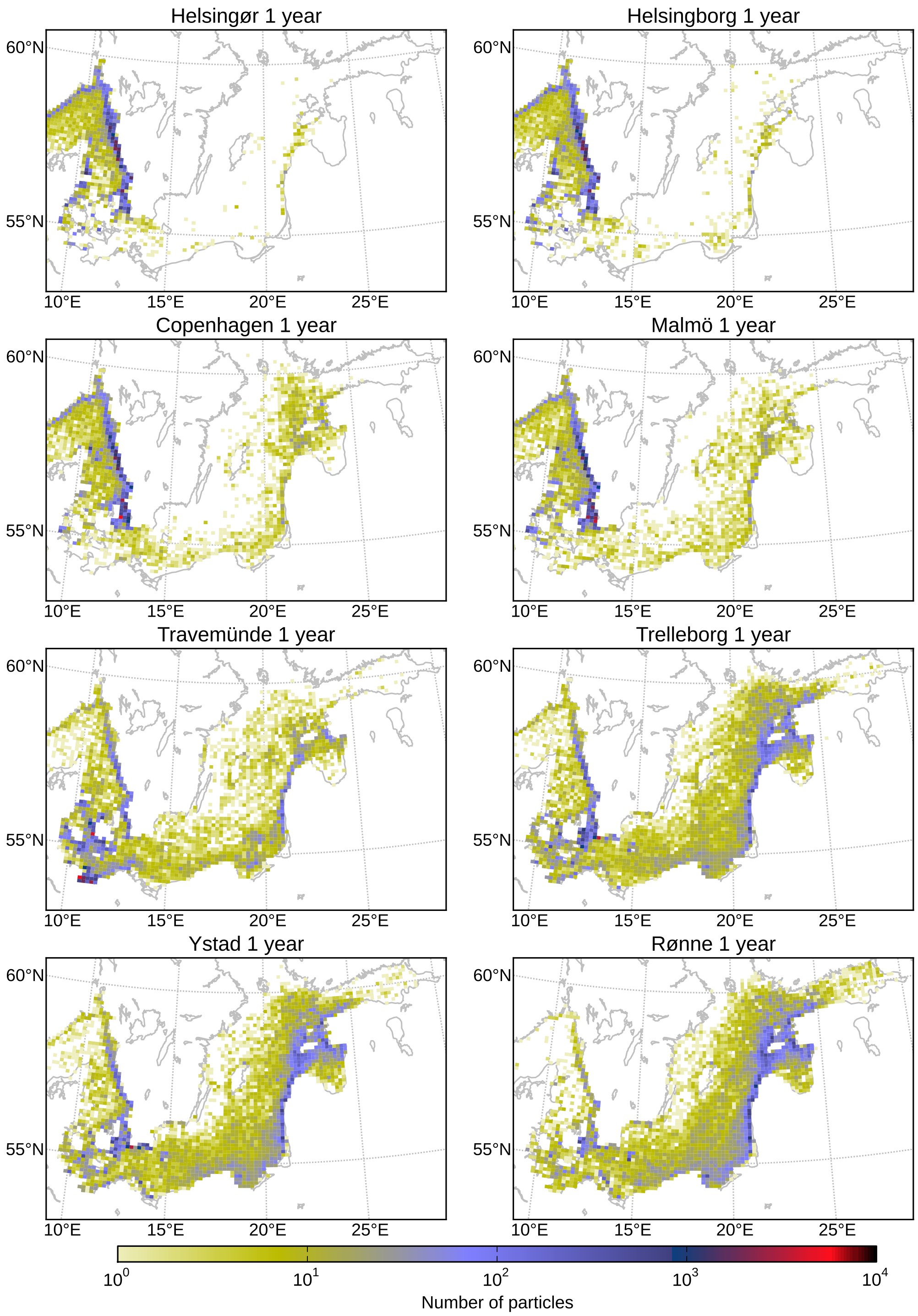
Gävle 32 weeks
Turku 32 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



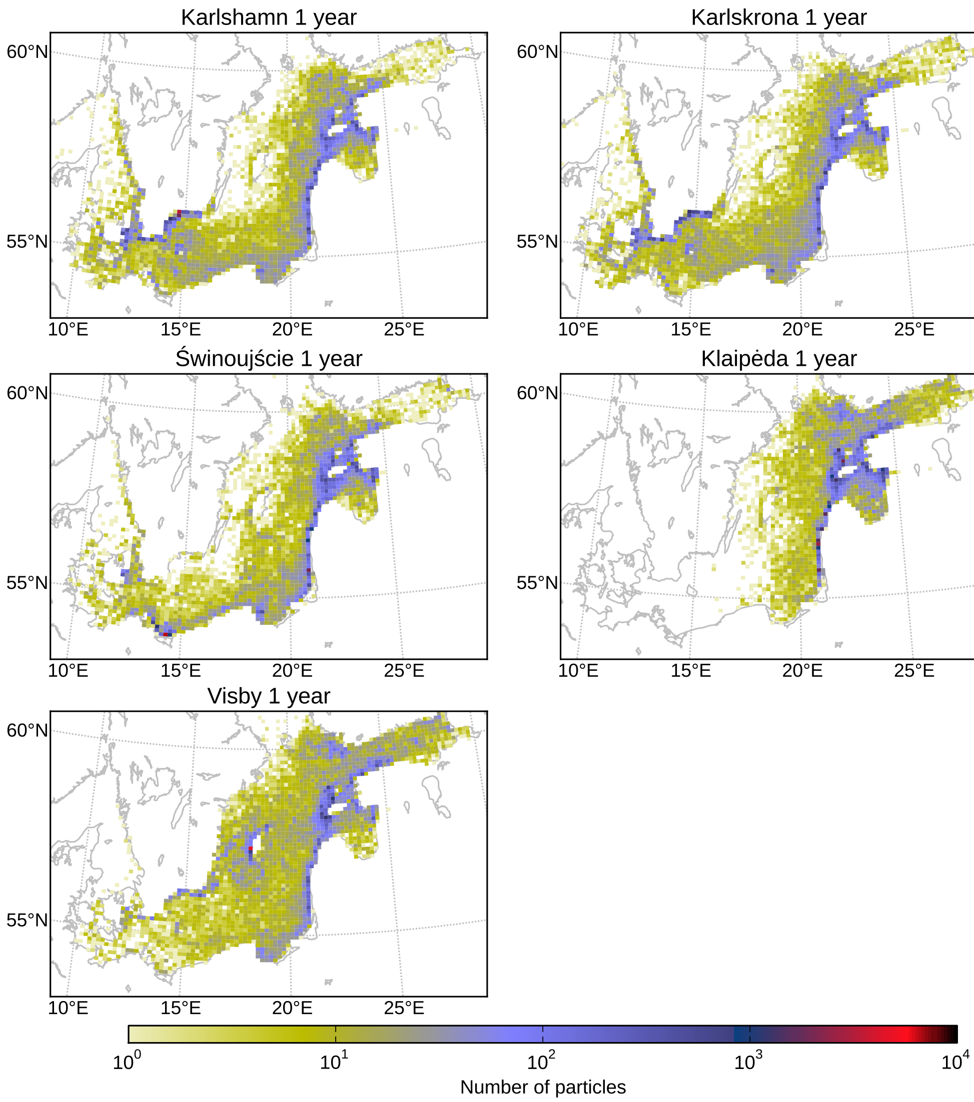
Umeå 32 weeks
Vaasa 32 weeks
Sundsvall 32 weeks
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Luleå 32 weeks
Kokkola 32 weeks
Skelleftehamn 32 weeks
65°N
60°N
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

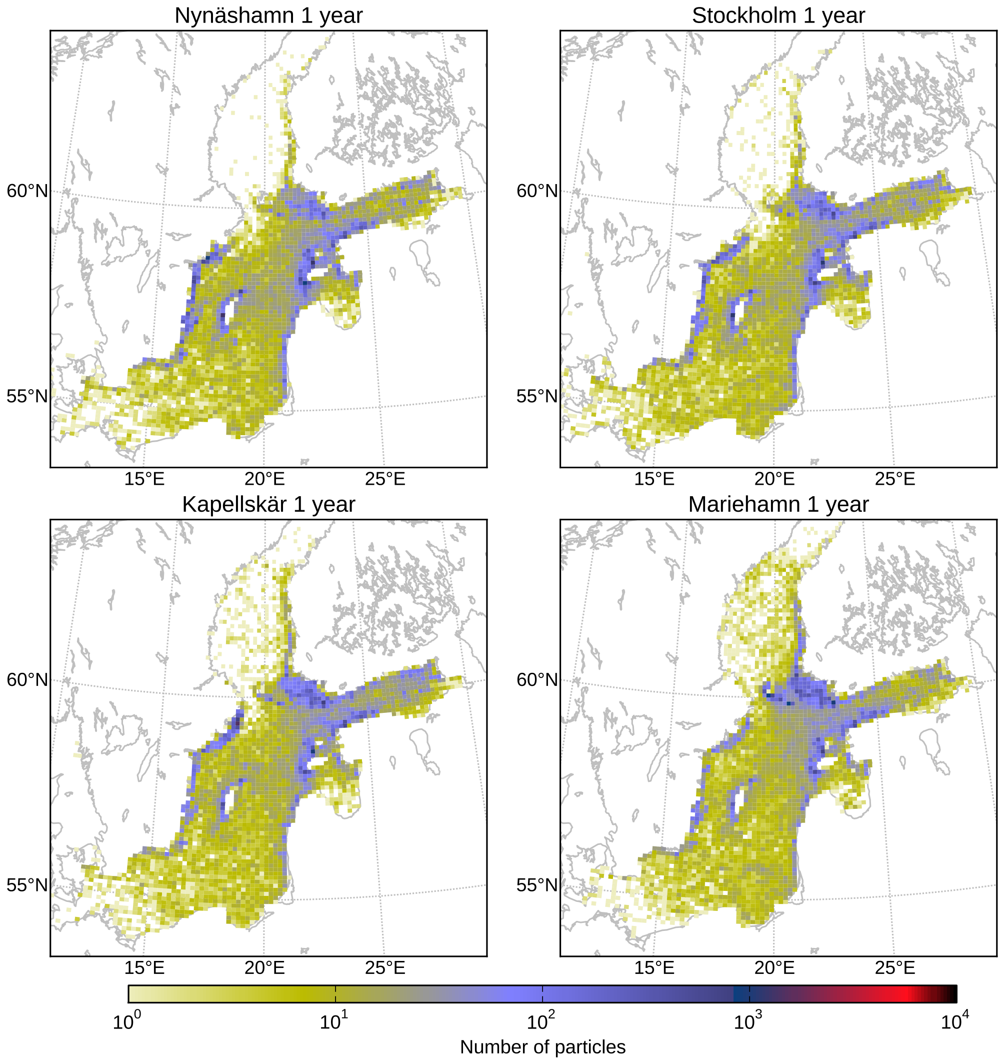

Brofjorden 1 year
Skagen 1 year
Ålbæk 1 year
Göteborg 1 year
Fredrikshavn 1 year
Varberg 1 year
Grenå 1 year
55°N
10°E
15°E
10^0
10^1
10^2
10^3
10^4
Number of particles

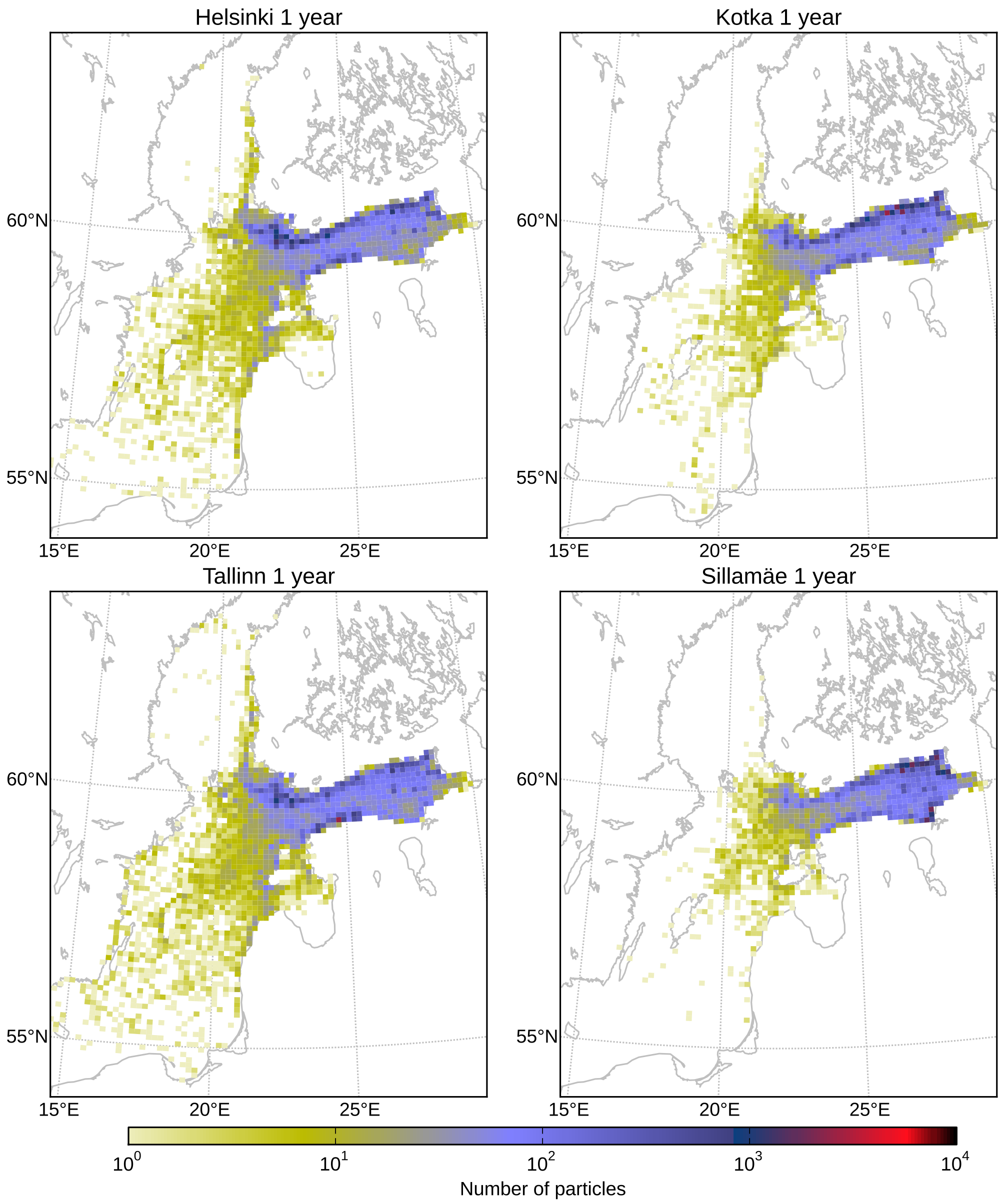


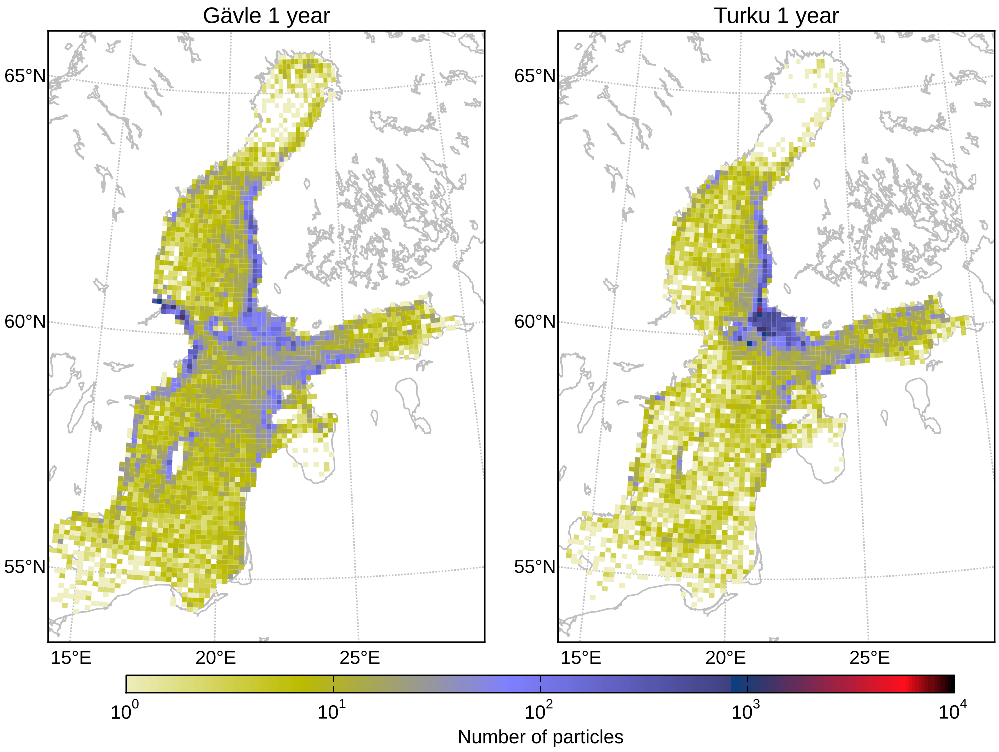
Helsingør 1 year
Helsingborg 1 year
Copenhagen 1 year
Malmö 1 year
Travemünde 1 year
Trelleborg 1 year
Ystad 1 year
Rønne 1 year
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



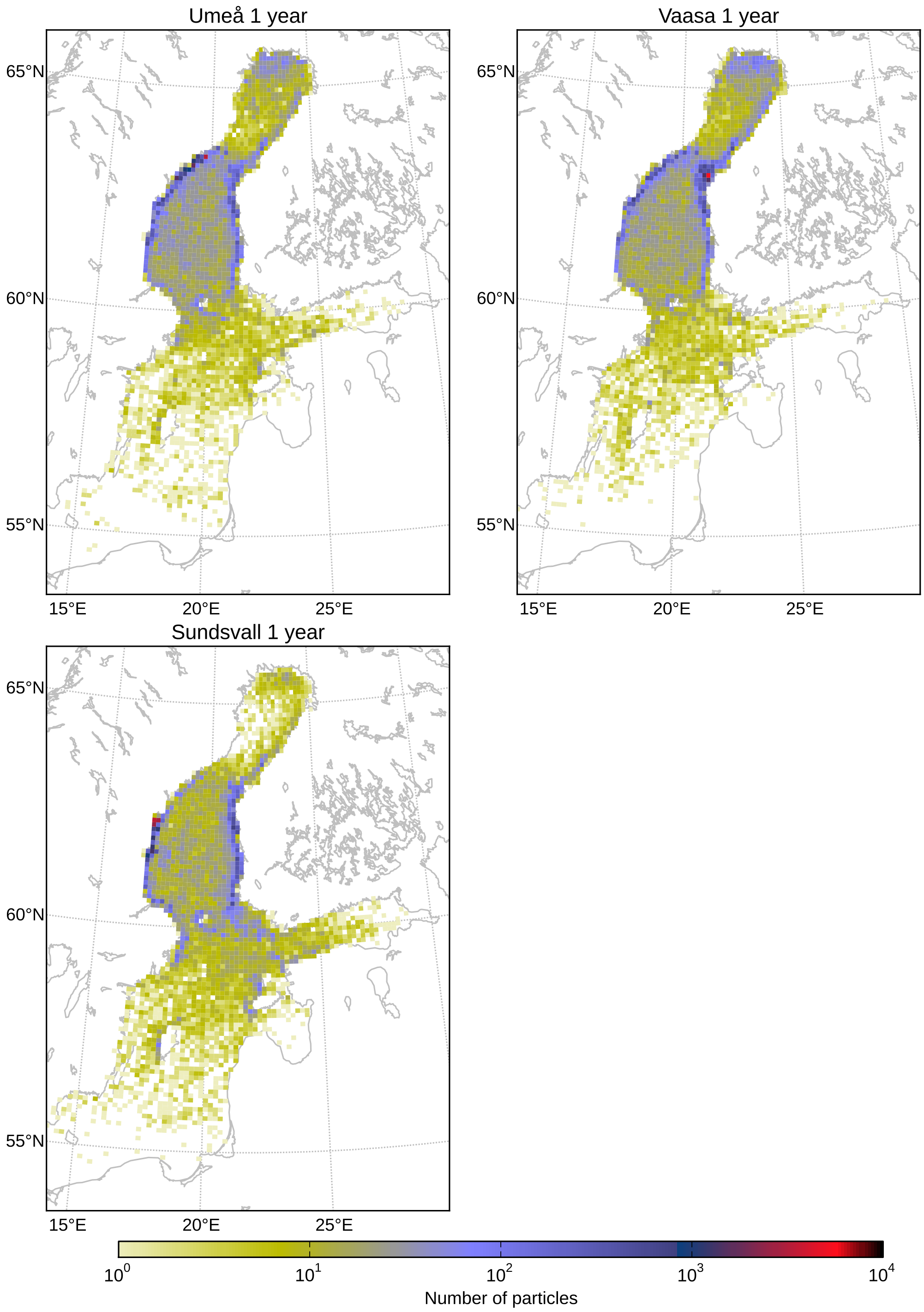
Karlshamn 1 year
Karlskrona 1 year
Świnoujście 1 year
Klaipėda 1 year
Visby 1 year
60°N
55°N
10°E
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles


Nynäshamn 1 year
Stockholm 1 year
Kapellskär 1 year
Mariehamn 1 year
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles

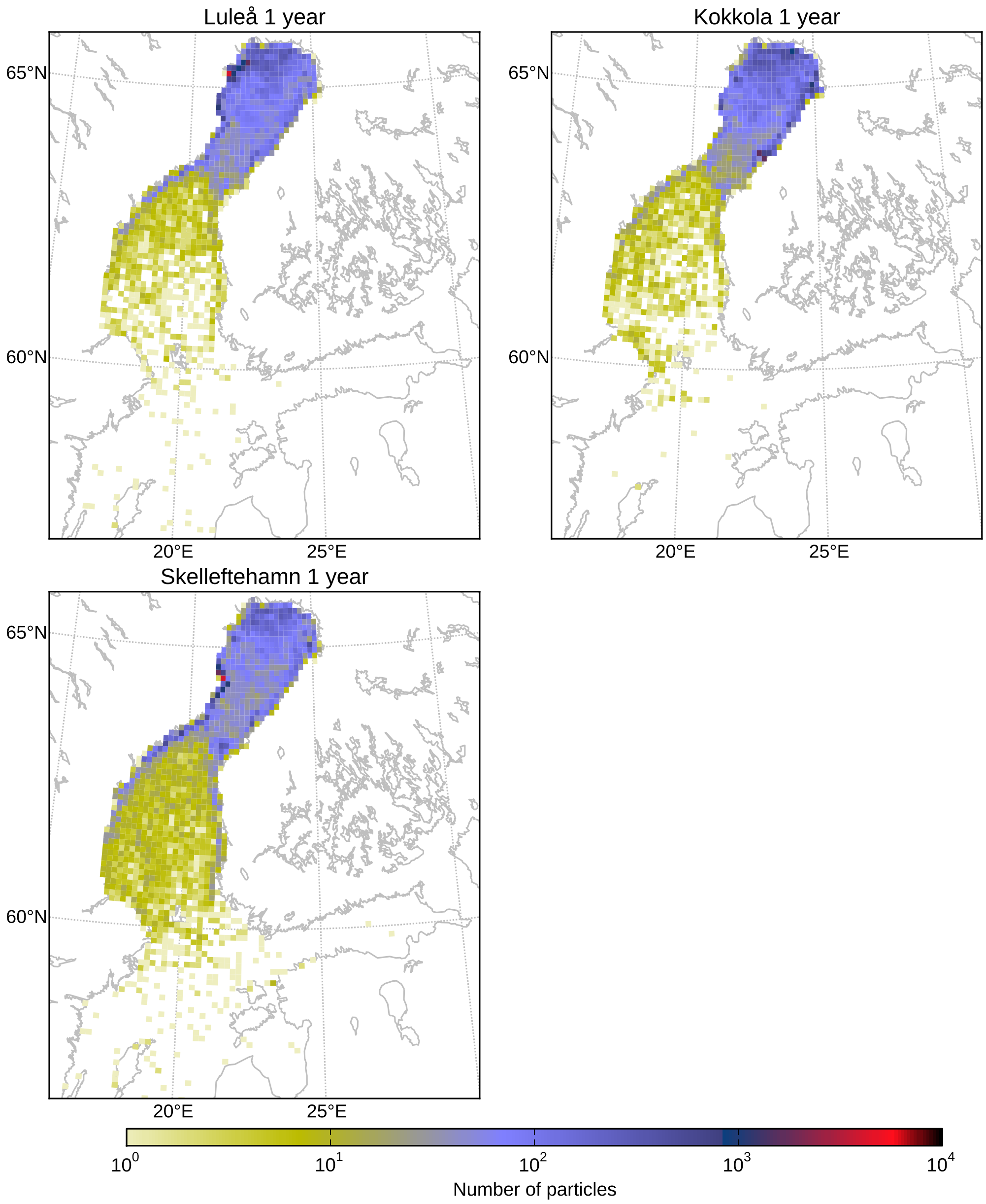

Helsinki 1 year
Kotka 1 year
Tallinn 1 year
Sillamäe 1 year
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



Gävle 1 year
Turku 1 year
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



Umeå 1 year
Vaasa 1 year
Sundsvall 1 year
65°N
60°N
55°N
15°E
20°E
25°E
10^0
10^1
10^2
10^3
10^4
Number of particles



Luleå 1 year
Kokkola 1 year
Skelleftehamn 1 year
65°N
60°N
20°E
25°E
Number of particles

SMHI Publications

SMHI publish seven report series. Three of these, the R-series, are intended for international readers and are in most cases written in English. For the others the Swedish language is used.

Name of the series	Published since
RMK (Report Meteorology and Climatology)	1974
RH (Report Hydrology)	1990
RO (Report Oceanography)	1986
METEOROLOGI	1985
HYDROLOGI	1985
OCEANOGRAFI	1985
KLIMATOLOGI	2009

Earlier issues published in serie OCEANOGRAFI:

1 Lennart Funkquist (1985)
En hydrodynamisk modell för spridnings- och cirkulationsberäkningar i Östersjön
Slutrapport.

2 Barry Broman och Carsten Pettersson. (1985)
Spridningsundersökningar i yttre fjärden Piteå.

3 Cecilia Ambjörn (1986).
Utbyggnad vid Malmö hamn; effekter för Lommabuktens vattenutbyte.

4 Jan Andersson och Robert Hillgren (1986).
SMHIs undersökningar i Öregrundsgrepen perioden 84/85.

5 Bo Juhlin (1986)
Oceanografiska observationer utmed svenska kusten med kustbevakningens fartyg 1985.

6 Barry Broman (1986)
Uppföljning av sjövärmepump i Lilla Värtan.

7 Bo Juhlin (1986)
15 års mätningar längs svenska kusten med kustbevakningen (1970 - 1985).

8 Jonny Svensson (1986)
Vågdata från svenska kustvatten 1985.

9 Barry Broman (1986)
Oceanografiska stationsnät - Svenskt Vattenarkiv.

10 ***Vakant – kommer ej att utnyttjas!***

11 Cecilia Ambjörn (1987)
Spridning av kylvatten från Öresundsverket

12 Bo Juhlin (1987)
Oceanografiska observationer utmed svenska kusten med kustbevakningens fartyg 1986.

13 Jan Andersson och Robert Hillgren (1987)
SMHIs undersökningar i Öregrundsgrepen 1986.

14 Jan-Erik Lundqvist (1987)
Impact of ice on Swedish offshore lighthouses. Ice drift conditions in the area at Sydostbrotten - ice season 1986/87.

15 SMHI/SNV (1987)
Fasta förbindelser över Öresund - utredning av effekter på vattenmiljön i Östersjön.

16 Cecilia Ambjörn och Kjell Wickström (1987)
Undersökning av vattenmiljön vid utfyllnaden av Kockums varvsbassäng.
Slutrapport för perioden
18 juni - 21 augusti 1987.

17 Erland Bergstrand (1987)
Östergötlands skärgård - Vattenmiljön.

18 Stig H. Fonselius (1987)
Kattegatt - havet i väster.

19 Erland Bergstrand (1987)
Recipientkontroll vid Breviksnäs fiskodling 1986.

20 Kjell Wickström (1987)
Bedömning av kylvattenrecipienten för ett kolkraftverk vid Oskarshamnsverket.

21 Cecilia Ambjörn (1987)
Förstudie av ett nordiskt modellsystem för kemikaliespridning i vatten.

22 Kjell Wickström (1988)
Vågdata från svenska kustvatten 1986.

23 Jonny Svensson, SMHI/National Swedish Environmental Protection Board (SNV) (1988)
A permanent traffic link across the Öresund channel - A study of the hydro-environmental effects in the Baltic Sea.

24 Jan Andersson och Robert Hillgren (1988)
SMHIs undersökningar utanför Forsmark 1987.

25 Carsten Peterson och Per-Olof Skoglund (1988)
Kylvattnet från Ringhals 1974-86.

26 Bo Juhlin (1988)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1987.

27 Bo Juhlin och Stefan Tobiasson (1988)
Recipientkontroll vid Breviksnäs fiskodling 1987.

28 Cecilia Ambjörn (1989)
Spridning och sedimentation av tippat lermaterial utanför Helsingborgs hamnområde.

29 Robert Hillgren (1989)
SMHIs undersökningar utanför Forsmark 1988.

30 Bo Juhlin (1989)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1988.

31 Erland Bergstrand och Stefan Tobiasson (1989)
Samordnade kustvattenkontrollen i Östergötland 1988.

32 Cecilia Ambjörn (1989)
Oceanografiska förhållanden i Brofjorden i samband med kylvattenutsläpp i Trommekilen.

33a Cecilia Ambjörn (1990)
Oceanografiska förhållanden utanför Vendelsöfjorden i samband med kylvatten-utsläpp.

33b Eleonor Marmefelt och Jonny Svensson (1990)
Numerical circulation models for the Skagerrak - Kattegat. Preparatory study.

34 Kjell Wickström (1990)
Oskarshamnsverket - kylvattenutsläpp i havet - slutrapport.

35 Bo Juhlin (1990)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1989.

36 Bertil Håkansson och Mats Moberg (1990)
Glommaälvens spridningsområde i nord-östra Skagerrak

37 Robert Hillgren (1990)
SMHIs undersökningar utanför Forsmark 1989.

38 Stig Fonselius (1990)
Skagerrak - the gateway to the North Sea

39 Stig Fonselius (1990)
Skagerrak - porten mot Nordsjön.

40 Cecilia Ambjörn och Kjell Wickström (1990)
Spridningsundersökningar i norra Kalmarsund för Mönsterås bruk.

41 Cecilia Ambjörn (1990)
Strömningsteknisk utredning avseende utbyggnad av gipsdeponi i Landskrona.

42 Cecilia Ambjörn, Torbjörn Grafström och Jan Andersson (1990)
Spridningsberäkningar - Klints Bank.

43 Kjell Wickström och Robert Hillgren (1990)
Spridningsberäkningar för EKA-NOBELs fabrik i Stockviksverken.

44 Jan Andersson (1990)
Brofjordens kraftstation - Kylvattenspridning i Hanneviken.

45 Gustaf Westring och Kjell Wickström (1990)
Spridningsberäkningar för Höganäs kommun.

46 Robert Hillgren och Jan Andersson (1991)
SMHIs undersökningar utanför Forsmark 1990.

47 Gustaf Westring (1991)
Brofjordens kraftstation - Kompletterande simulering och analys av kylvattenspridning i Trommekilen.

48 Gustaf Westring (1991)
Vågmätningar utanför Kristianopel - Slutrapport.

49 Bo Juhlin (1991)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1990.

50A Robert Hillgren och Jan Andersson (1992)
SMHIs undersökningar utanför Forsmark 1991.

50B Thomas Thompson, Lars Ulander, Bertil Håkansson, Bertil Brusmark, Anders Carlström, Anders Gustavsson, Eva Cronström och Olov Fäst (1992).
BEERS -92 Final edition

51 Bo Juhlin (1992)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1991.

52 Jonny Svensson och Sture Lindahl (1992)
Numerical circulation model for the Skagerrak - Kattegat.

53 Cecilia Ambjörn (1992)
Isproppsförebyggande muddring och dess inverkan på strömmarna i Torneälven.

54 Bo Juhlin (1992)
20 års mätningar längs svenska kusten med kustbevakningens fartyg (1970 - 1990).

55 Jan Andersson, Robert Hillgren och Gustaf Westring (1992)
Förstudie av strömmar, tidvatten och vattenstånd mellan Cebu och Leyte, Filippinerna.

56 Gustaf Westring, Jan Andersson, Henrik Lindh och Robert Axelsson (1993)
Forsmark - en temperaturstudie. Slutrapport.

57 Robert Hillgren och Jan Andersson (1993)
SMHIs undersökningar utanför Forsmark 1992.

58 Bo Juhlin (1993)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1992.

59 Gustaf Westring (1993)
Isförhållandena i svenska farvatten under normalperioden 1961-90.

60 Torbjörn Lindkvist (1994)
Havsområdesregister 1993.

61 Jan Andersson och Robert Hillgren (1994)
SMHIs undersökningar utanför Forsmark 1993.

62 Bo Juhlin (1994)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1993.

63 Gustaf Westring (1995)
Isförhållanden utmed Sveriges kust - isstatistik från svenska farleder och farvatten under normalperioderna 1931-60 och 1961-90.

64 Jan Andersson och Robert Hillgren (1995)
SMHIs undersökningar utanför Forsmark 1994.

65 Bo Juhlin (1995)
Oceanografiska observationer runt svenska kusten med kustbevakningens fartyg 1994.

66 Jan Andersson och Robert Hillgren (1996)
SMHIs undersökningar utanför Forsmark 1995.

67 Lennart Funkquist och Patrik Ljungemyr (1997)
Validation of HIROMB during 1995-96

68 Maja Brandt, Lars Edler och Lars Andersson (1998)
Översvämningar längs Oder och Wisla sommaren 1997 samt effekterna i Östersjön.

69 Jörgen Sahlberg SMHI och Håkan Olsson, Länsstyrelsen, Östergötland (2000).
Kustzonsmodell för norra Östergötlands skärgård.

70 Barry Broman (2001)
En vågatlas för svenska farvatten.
Ej publicerad

71 ***Vakant – kommer ej att utnyttjas!***

72 Fourth Workshop on Baltic Sea Ice Climate
Norrköping, Sweden 22-24 May, 2002
Conference Proceedings
Editors: Anders Omstedt and Lars Axell

73 Torbjörn Lindkvist, Daniel Björkert, Jenny Andersson, Anders Gyllander (2003)
Djupdata för havsområden 2003

74 Håkan Olsson, SMHI (2003)
Erik Årnefelt, Länsstyrelsen Östergötland
Kustzonssystemet i regional miljöanalys

75 Jonny Svensson och Eleonor Marmefelt (2003)
Utvärdering av kustzonsmodellen för norra Östergötlands och norra Bohusläns skärgårdar

76 Eleonor Marmefelt, Håkan Olsson, Helma Lindow och Jonny Svensson, Thalassos Computations (2004)
Integrerat kustzonssystem för Bohusläns skärgård

77 Philip Axe, Martin Hansson och Bertil Håkansson (2004)
The national monitoring programme in the Kattegat and Skagerrak

78 Lars Andersson, Nils Kajrup och Björn Sjöberg (2004)
Dimensionering av det nationella marina pelagialprogrammet

79 Jörgen Sahlberg (2005)
Randdata från öppet hav till kustzonsmodellerna (Exemplet södra Östergötland)

80 Eleonor Marmefelt, Håkan Olsson (2005)
Integrerat Kustzonssystem för Hallandskusten

81 Tobias Strömgren (2005)
Implementation of a Flux Corrected Transport scheme in the Rossby Centre Ocean model

82 Martin Hansson (2006)
Cyanobakterieblomningar i Östersjön, resultat från satellitövervakning 1997-2005

83 Kari Eilola, Jörgen Sahlberg (2006)
Model assessment of the predicted environmental consequences for OSPAR problem areas following nutrient reductions

84 Torbjörn Lindkvist, Helma Lindow (2006)
Fyrskeppsdata. Resultat och bearbetningsmetoder med exempel från Svenska Björn 1883 – 1892

85 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Baltic Proper

86 Elin Almroth, Kari Eilola, M. Skogen, H. Søiland and Ian Sehested Hansen (2007)
The year 2005. An environmental status report of the Skagerrak, Kattegat and North Sea

87 Eleonor Marmefelt, Jörgen Sahlberg och Marie Bergstrand (2007)
HOME Vatten i södra Östersjöns vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar

88 Pia Andersson (2007)
Ballast Water Exchange areas – Prospect of designating BWE areas in the Skagerrak and the Norwegian Trench

89 Anna Edman, Jörgen Sahlberg, Niclas Hjerdt, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenvikens vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar

90 Niclas Hjerdt, Jörgen Sahlberg, Eleonor Marmefelt och Karen Lundholm (2007)
HOME Vatten i Bottenhavets vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar

91 Elin Almroth, Morten Skogen, Ian Sehsted Hansen, Tapani Stipa, Susa Niiranen (2008)
The year 2006
An Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea
A demonstration Project

92 Pia Andersson editor and co-authors[1]
Bertil Håkansson[1], Johan Håkansson[1], Elisabeth Sahlsten[1], Jonathan Havenhand[2], Mike Thorndyke[2], Sam Dupont[2] *Swedish Meteorological and Hydrological Institute*[1] *Gothenburg University, Sven Lovén, Centre of Marine Sciences*[2] (2008)
Marine Acidification – On effects and monitoring of marine acidification in the seas surrounding Sweden

93 Jörgen Sahlberg, Eleonor Marmefelt, Maja Brandt, Niclas Hjerdt och Karen Lundholm (2008)
HOME Vatten i norra Östersjöns vattendistrikt. Integrerat modellsystem för vattenkvalitetsberäkningar.

94 David Lindstedt (2008)
Effekter av djupvattenomblandning i Östersjön – en modellstudie

95 Ingemar Cato[1], Bertil Håkansson[2], Ola Hallberg[1], Bernt Kjellin[1], Pia Andersson[2], Cecilia Erlandsson[1], Johan Nyberg[1], Philip Axe[2] (2008)
[1]*Geological Survey of Sweden (SGU)*
[2]*The Swedish Meteorological and Hydrological Institute (SMHI)*
A new approach to state the areas of oxygen deficits in the Baltic Sea

96 Kari Eilola, H.E. Markus Meier, Elin Almroth, Anders Höglund (2008)
Transports and budgets of oxygen and phosphorus in the Baltic Sea

97 Anders Höglund, H.E. Markus Meier, Barry Broman och Ekaterina Kriezi (2009)
Validation and correction of regionalised ERA-40 wind fields over the Baltic Sea using the Rossby Centre Atmosphere model RCA3.0

98 Jörgen Sahlberg (2009)
The Coastal Zone Model

99 Kari Eilola (2009)
On the dynamics of organic nutrients, nitrogen and phosphorus in the Baltic Sea

100 Kristin I. M. Andreasson (SMHI), Johan Wikner (UMSC), Berndt Abrahamsson (SMF), Chris Melrose (NOAA), Svante Nyberg (SMF) (2009)
Primary production measurements – an intercalibration during a cruise in the Kattegat and the Baltic Sea

101 K. Eilola, B. G. Gustafson, R. Hordoir, A. Höglund, I. Kuznetsov, H.E.M. Meier T. Neumann, O. P. Savchuk (2010)
Quality assessment of state-of-the-art coupled physical-biogeochemical models in hind cast simulations 1970-2005

102 Pia Andersson (2010)
Drivers of Marine Acidification in the Seas Surrounding Sweden

103 Jörgen Sahlberg, Hanna Gustavsson (2010)
HOME Vatten i Mälaren

104 K.V Karmanov., B.V Chubarenko, D. Domnin, A. Hansson (2010)
Attitude to climate changes in everyday management practice at the level of Kaliningrad region municipalities

105 Helén C. Andersson., Patrik Wallman, Chantal Donnelly (2010)
Visualization of hydrological, physical and biogeochemical modelling of the Baltic Sea using a GeoDome™

106 Maria Bergelo (2011)
Havsvattenståndets påverkan längs Sveriges kust – enkätsvar från kommuner, räddningstjänst, länsstyrelser och hamnar

107 H.E. Markus Meier, Kari Eilola (2011)
Future projections of ecological patterns in the Baltic Sea

108 Meier, H.E.M., Andersson, H., Dieterich, C., Eilola, K., Gustafsson, B., Höglund, A., Hordoir, R., Schimanke, S (2011)
Transient scenario simulations for the Baltic Sea Region during the 21st century

109 Ulrike Löptien, H.E. Markus Meier (2011)
Simulated distribution of colored dissolved organic matter in the Baltic Sea

110 K. Eilola[1], J. Hansen[4], H. E. M. Meier[1], K. Myrberg[5], V. A. Ryabchenko[3] and M. D. Skogen[2] (2011)
[1]Swedish Meteorological and Hydrological Institute, Sweden, [2] Institute of Marine Research, Norway, [3] St. Petersburg Branch, P.P.Shirshov Institute of Oceanology, Russia, [4] National Environmental Research Institute, Aarhus University, Denmark, [5]Finnish Environment Institute, Finland
Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea: A model study
Years 2001-2005

111 Semjon Schimanke, Erik Kjellström, Gustav Strandberg och Markus Meier (2011)
A regional climate simulation over the Baltic Sea region for the last Millennium

112 Meier, H. E. M., K. Eilola, B. G. Gustafsson, I. Kuznetsov, T. Neumann, and O. P.Savchuk,(2012)
Uncertainty assessment of projected ecological quality indicators in future climate

113 Karlson, B. Kronsell, J. Lindh, H. (2012)
Sea observations using FerryBox system on the ship TransPaper 2011 – oceanographic data in near real time. (Ej publicerad)

114 Domnina, Anastasia[1]. Chubarenko, Boris[1] (2012) *Atlantic Branch of P.P. Shirhov Institute of Oceanology of Russian Academy of Sciences, Kaliningrad, Russia.[1]*
"Discussion on the Vistula Lagoon regional development considering local consequences of climate changes Interim report on the ECOSUPPORT BONUS+project No. 08-05-92421.

115 K. Eilola[1], J.L.S. Hansen[4], H.E.M. Meier[1], M.S. Molchanov[3], V.A. Ryabchenko[3] and M.D.Skogen[2] (2013)
[1]Swedish Meteorological and Hydrological Institute,

Sweden. [2]Institute of Marine Research, Norway. [3]St. Petersburg Branch, P.P. Shirshov Institute of Oceanology, Russia. [4]Department of Bioscience, Aarhus University, Denmark
Eutrophication Status Report of the North Sea, Skagerrak, Kattegat and the Baltic Sea: A model study. Present and future climate

116 ***Vakant – kommer ej att utnyttjas!***

117 Kari Eilola[1], Elin Almroth-Rosell[1], Moa Edman[1], Tatjana Eremina[3], Janus Larsen[4], Urszula Janas[2], Arturas Razinkovas-Basiukas[6], Karen Timmermann[4], Letizia Tedesco[5], Ekaterina Voloshchuk[3] (2015)
[1]Swedish Meteorological and Hydrological Institute, Norrköping, Sweden. [2]Institute of Oceanography, Gdansk University, Poland. [3]Russian State Hydrometeorological University, Sankt-Petersburg, Russia. [4]Aarhus University, Roskilde, Denmark. [5]Finnish Environment Institute, Helsinki, Finland. [6]Coastal and Planning Research Institute, Klaipeda, Lithuania.
Model set-up at COCOA study sites

118 Helén C. Andersson, Lena Bram Eriksson, Niclas Hjerdt, Göran Lindström Ulrike Löptien och Johan Strömqvist. (2016)
Översikt av beräkningsmodeller för bedömning av fiskodlingars näringsämnesbelastning på sjöar, vattendrag, magasin och kustvatten

119 I. Kuznetsov, K. Eilola, C. Dieterich, R. Hordoir, L. Axell, A. Höglund, S. Schimanke. (2016)
Model study on the variability of ecosystem parameters in the Skagerrak - Kattegat area, effect of load reduction in the North Sea and possible effect of BSAP on Skagerrak - Kattegat area

120 Johannes Johansson, Martin Hansson (2016)
Slutrapport 2015 för uppdraget ”Databaslagring av historiska fys/kemdatafrån Stockholm Vatten ”Datavärdskapet Oceanografi och Marinbiologi

121 Arnold Andreasson, Patrik Strömberg, Maria Prager, Nils Nexelius (2016)
Automatisering av nationellt dataflöde till ICES genom skördning - en förstudie

Swedish Meteorological and Hydrological Institute
SE 601 76 NORRKÖPING
Phone +46 11-495 80 00 Telefax +46 11-495 80 01

ISSN 0283-7714