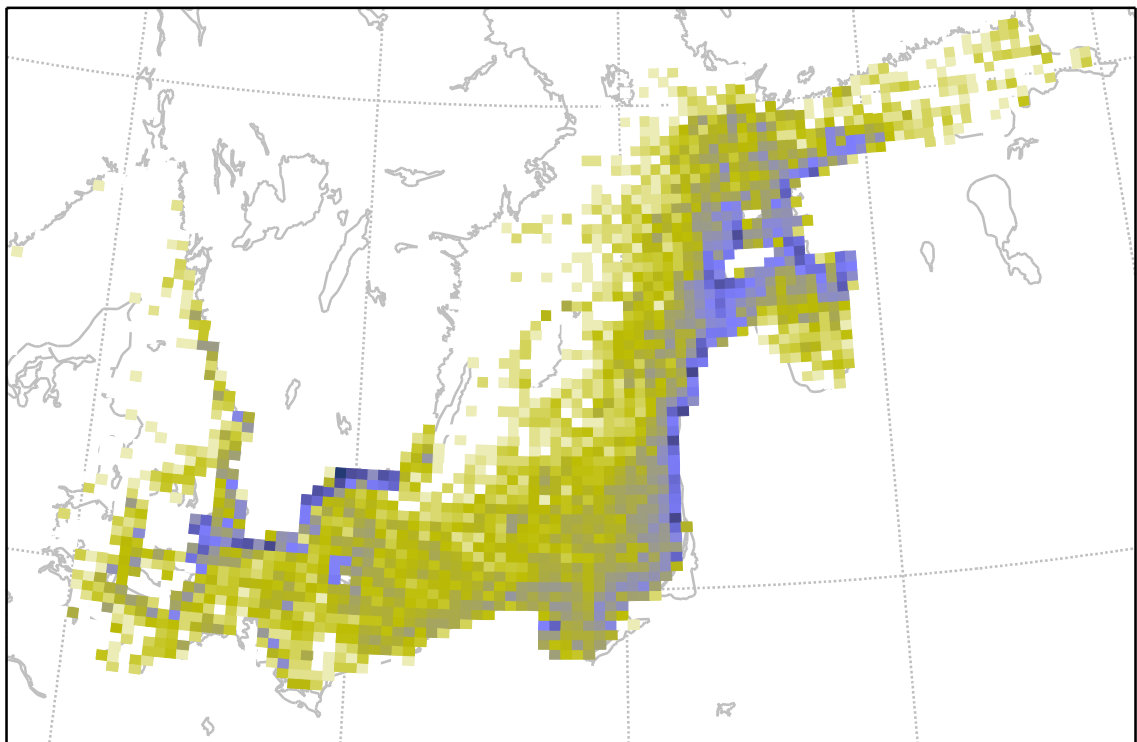


Invasive species in the Baltic Sea

A model study of plankton transport

Anders Höglund



Front:

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

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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.

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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 westerly¹ 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

¹For 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.

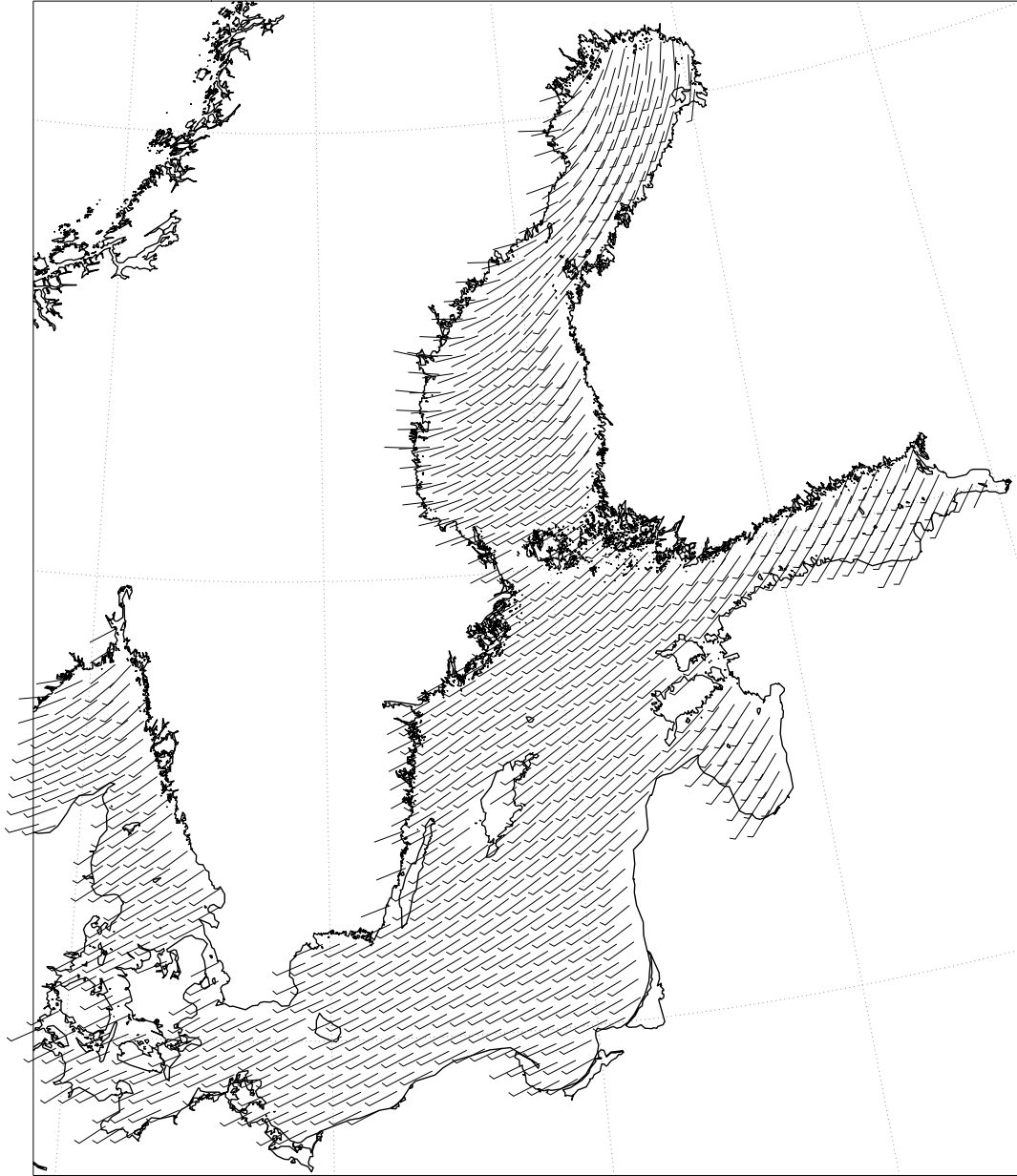


Figure 2: The average wind from Hirlam at 10 meter above sea level for the years 2010–2013.

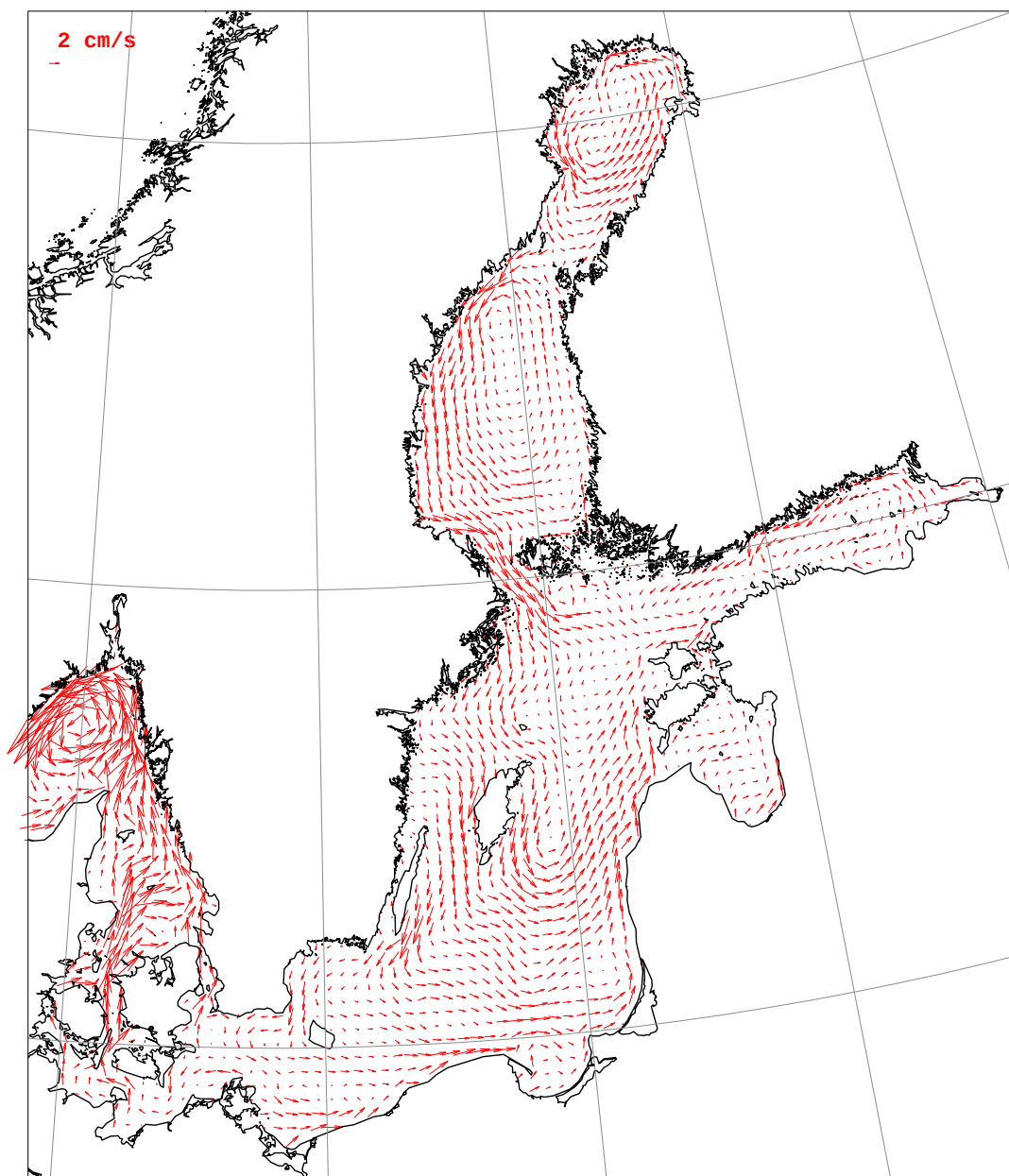


Figure 3: The average current in the top level in Hiromb for the years 2010–2013.

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 $2^{\circ}53'20''\text{E}$ and $59^{\circ}31'0''\text{N}$. 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.

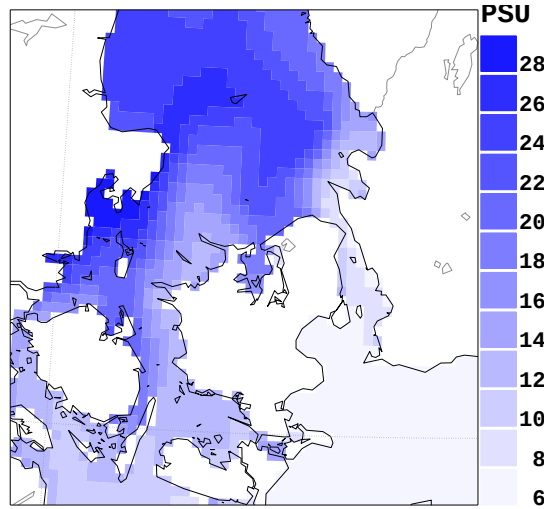


Figure 4: Surface salinity in the Danish Straits on 17 July 2010 according to the reanalysis data set used in this report.

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.

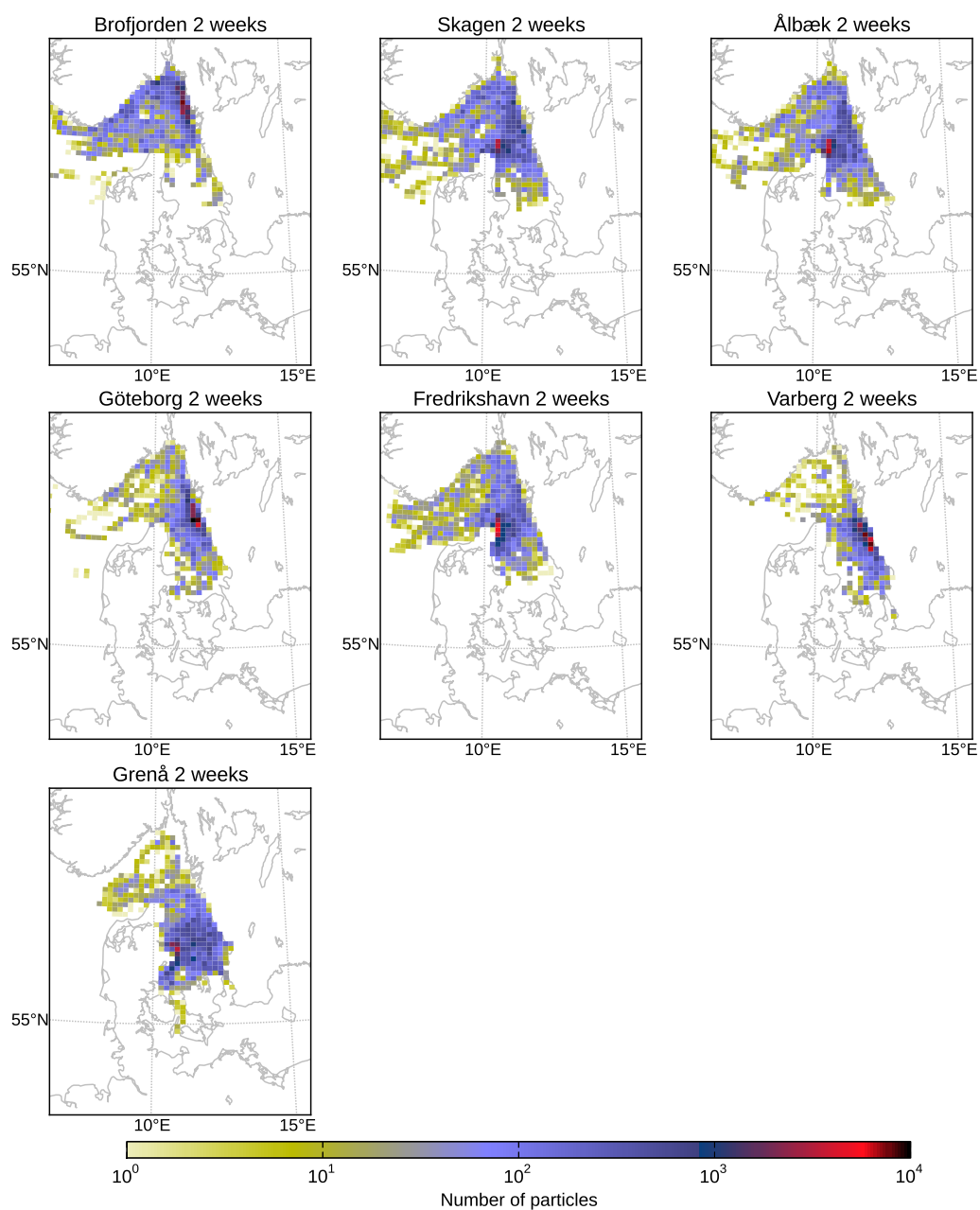
Another difference is that it seems to be easy for the larvae to pass through the Archipelago Sea. This is a shallow area where they are able to settle and reiterate from. The same explanation as for the Danish Straits can be applied. This is an area where the present study has many limitations, as discussed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

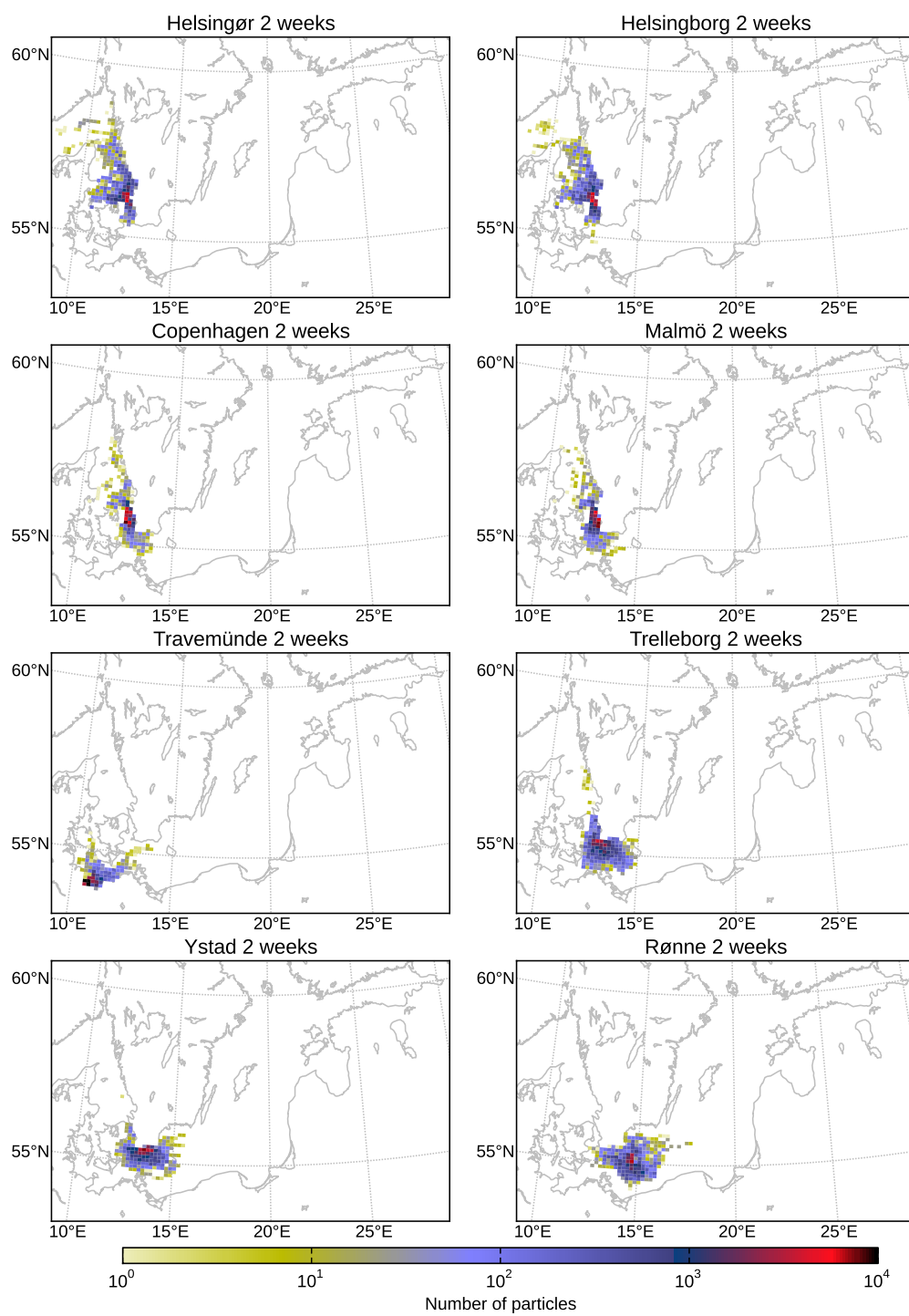
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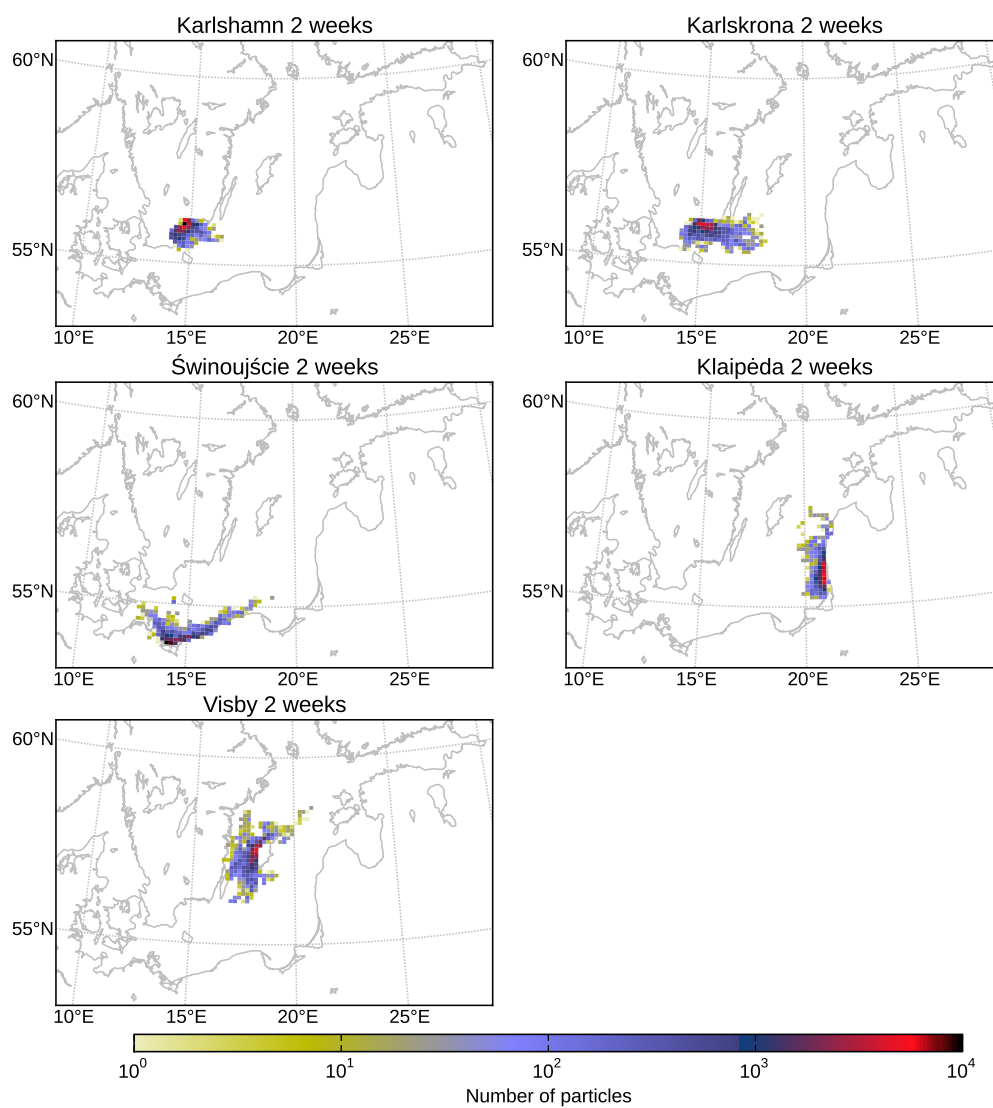
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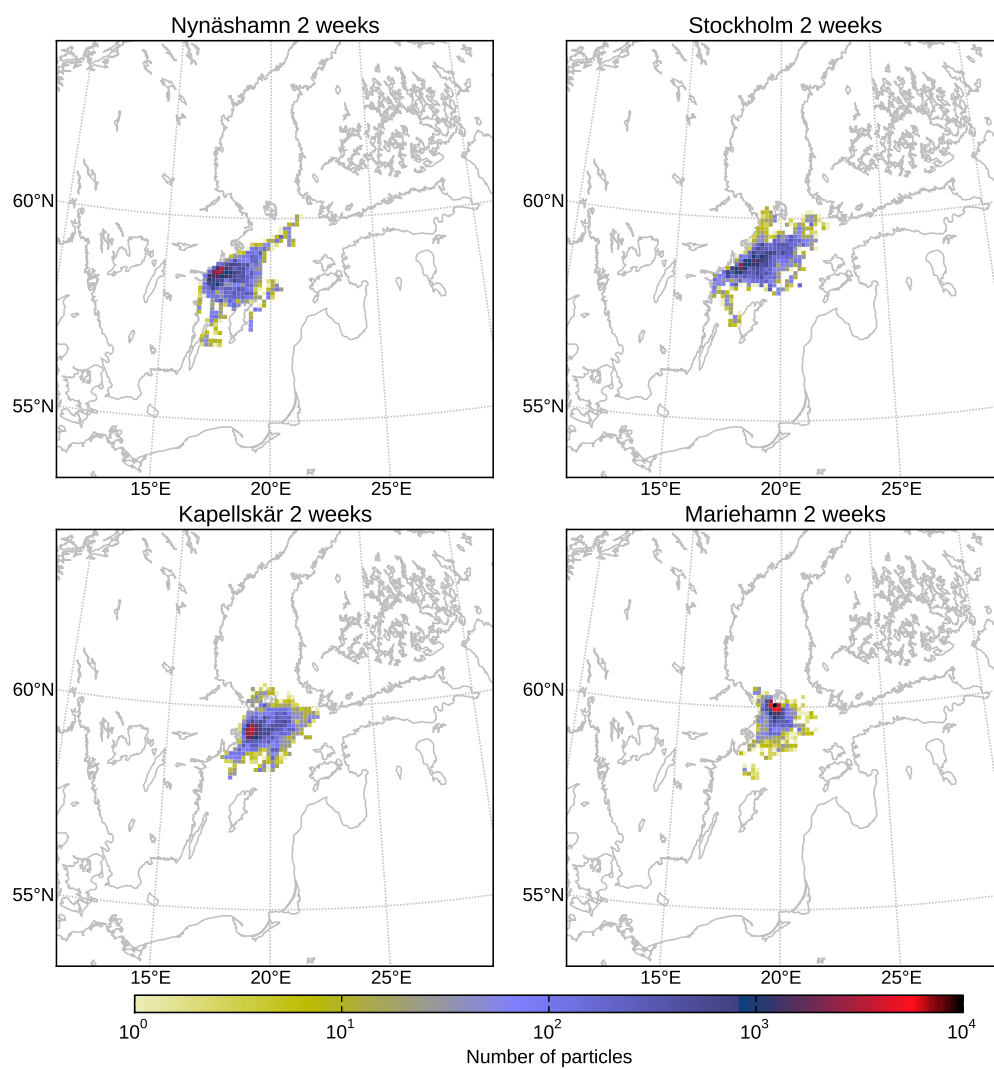
A Maps of outlets

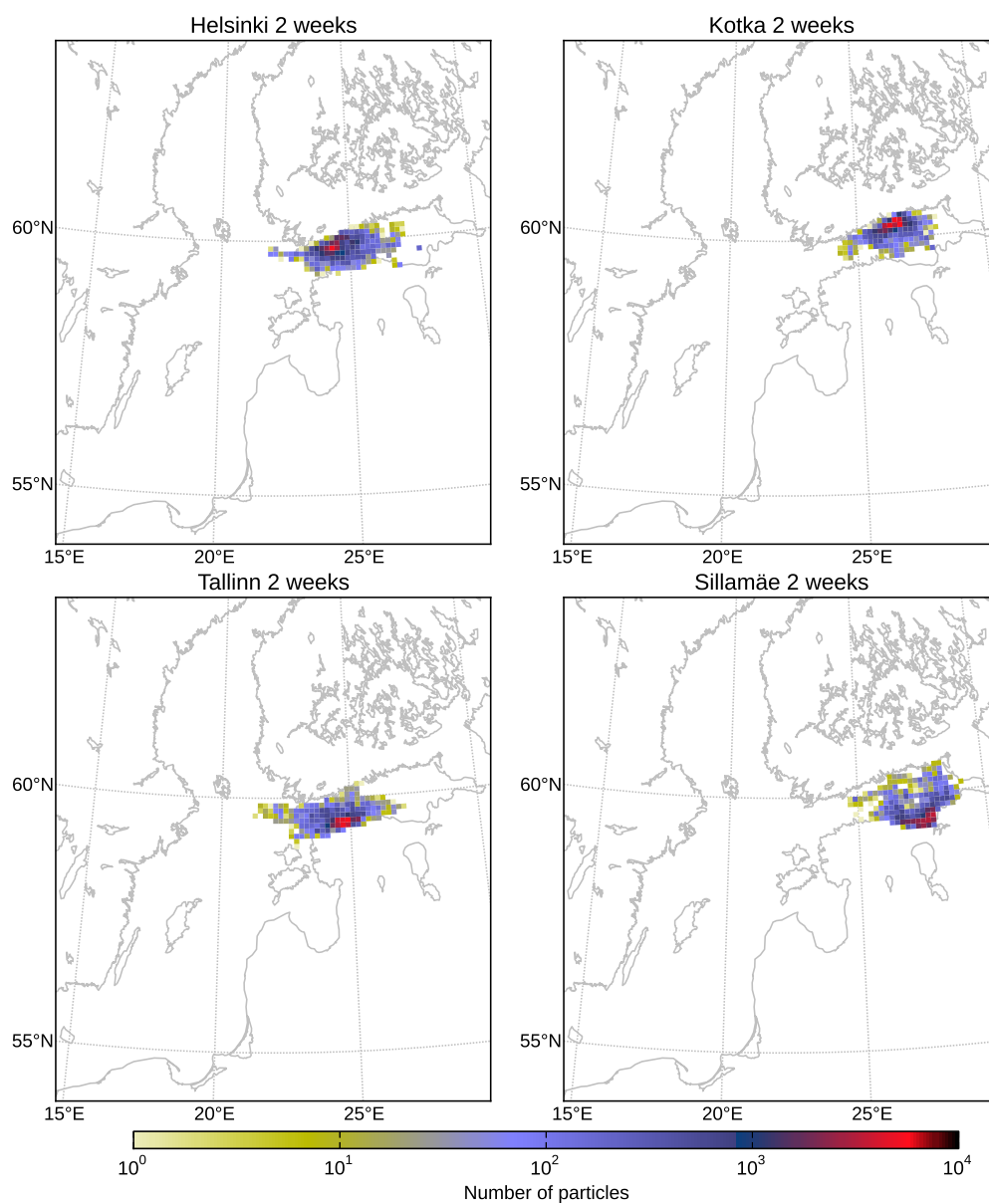
This appendix contains graphs of particles combined from all the runs for a given outlet position and time after release. The colour scale shows the number of particles in a box of 0.1 degrees in the meridian and 0.05 degrees in the zonal direction. Results after 2, 4, 8, 16 and 32 weeks and 1 year are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

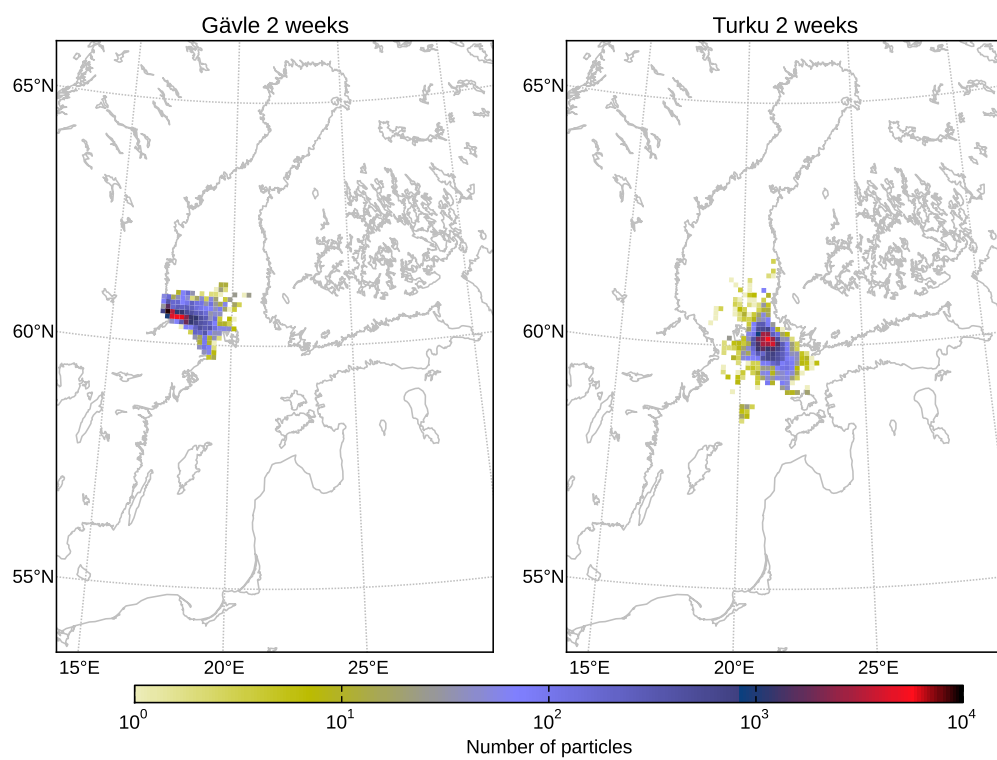


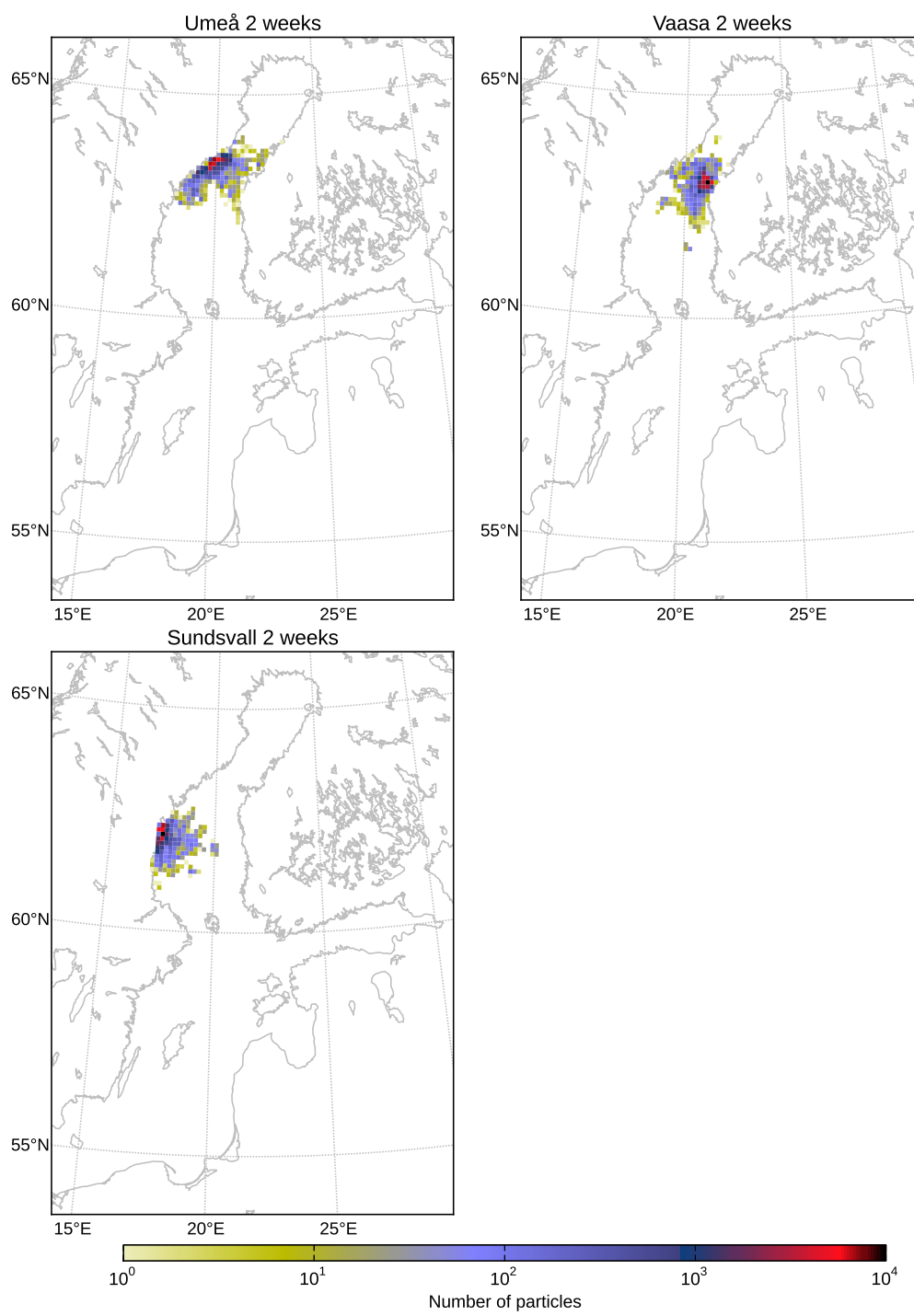


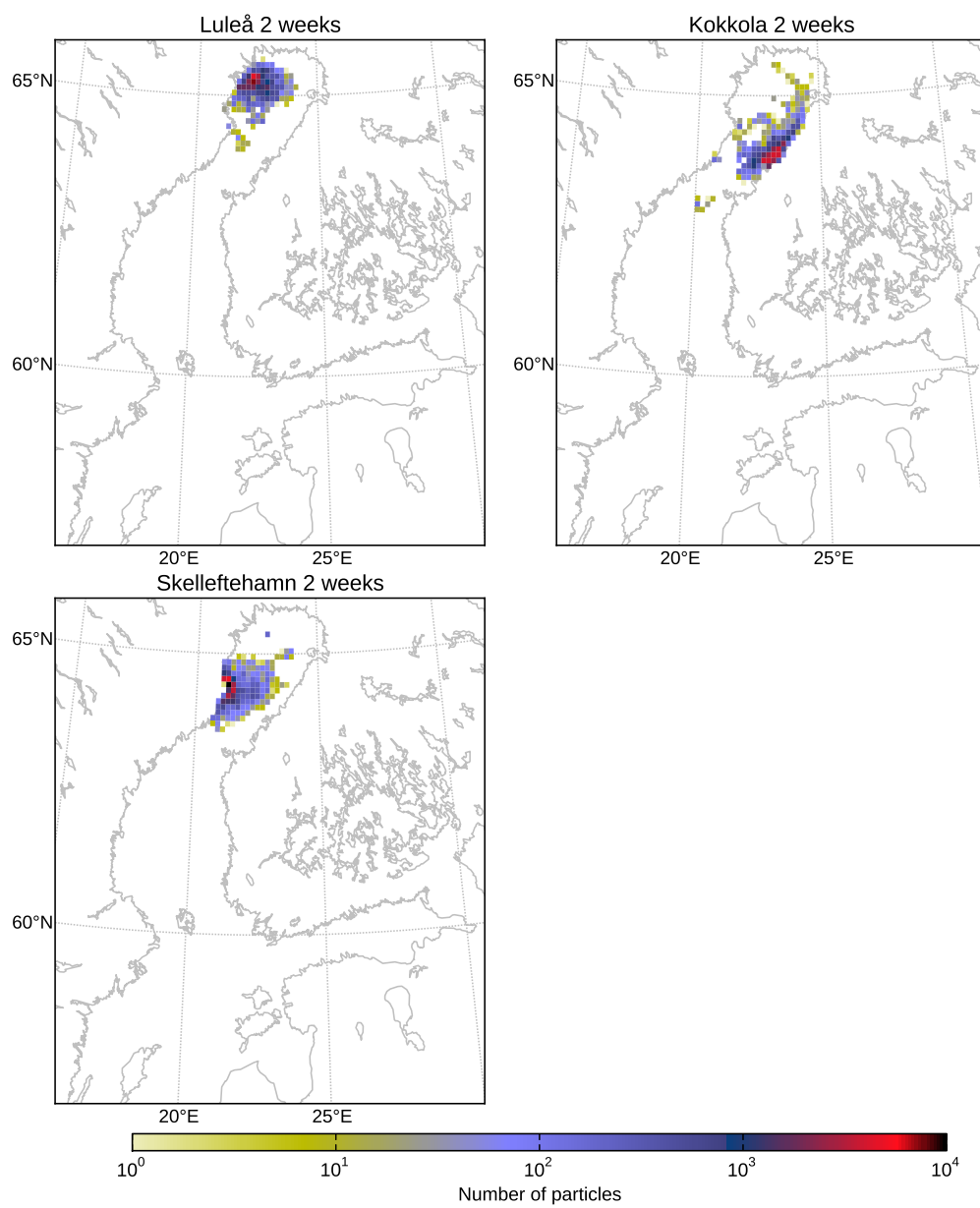


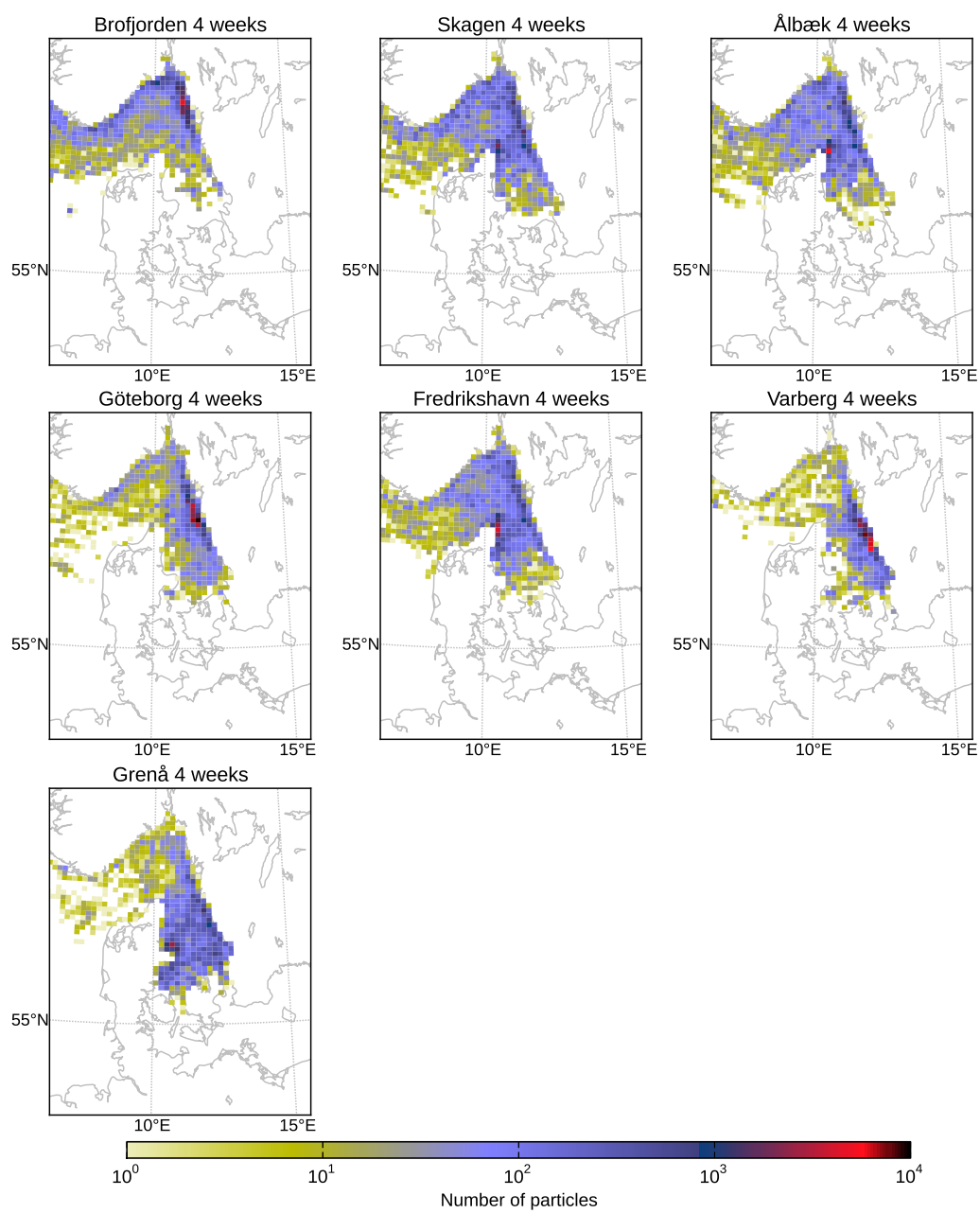


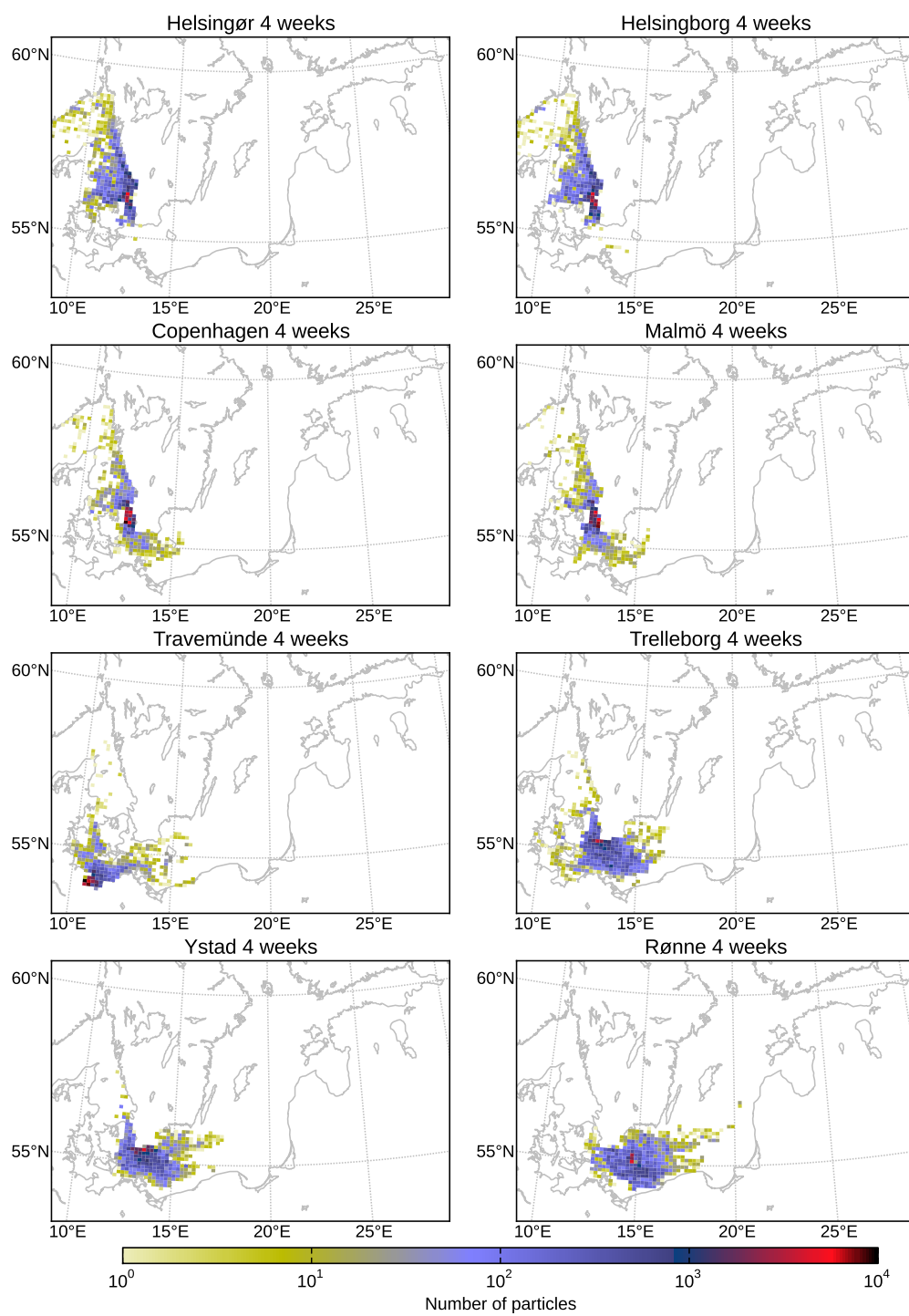


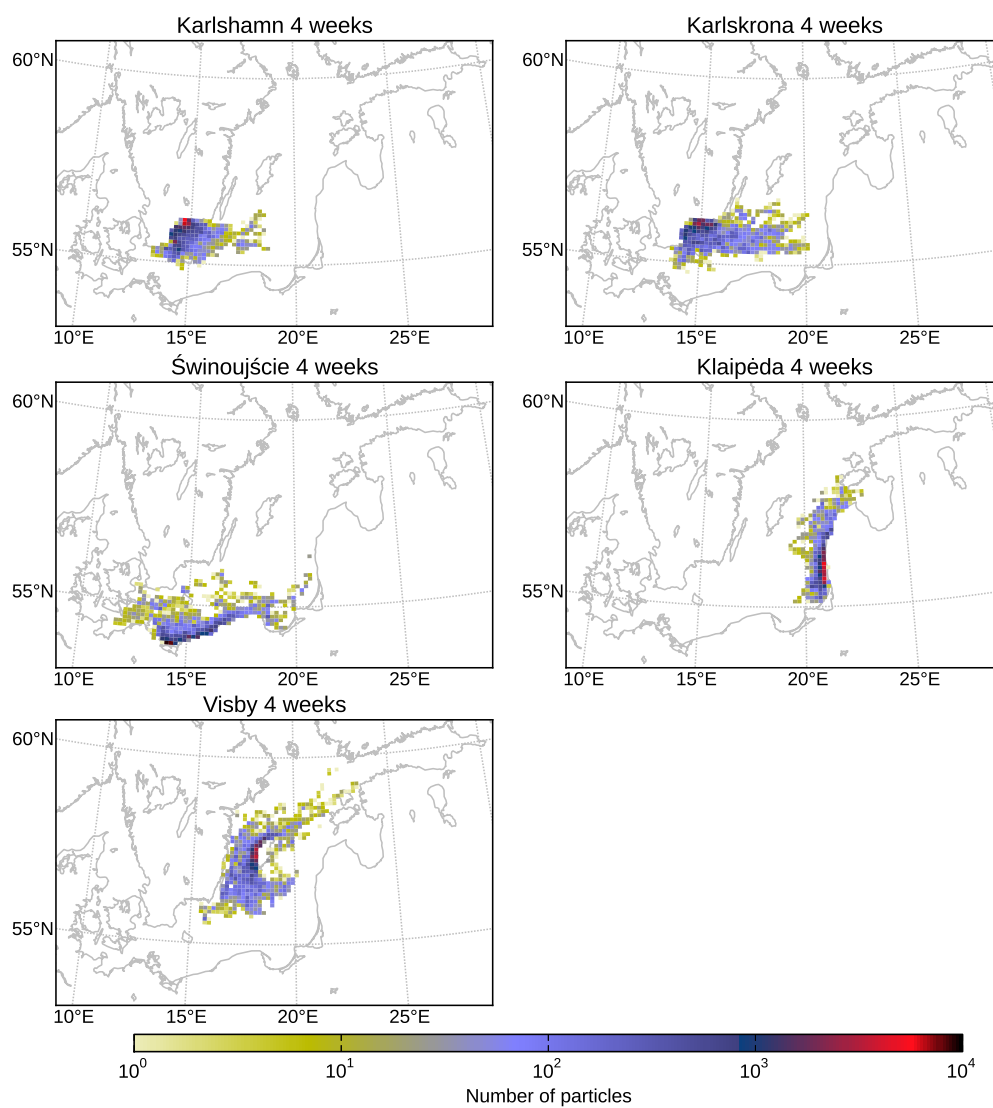


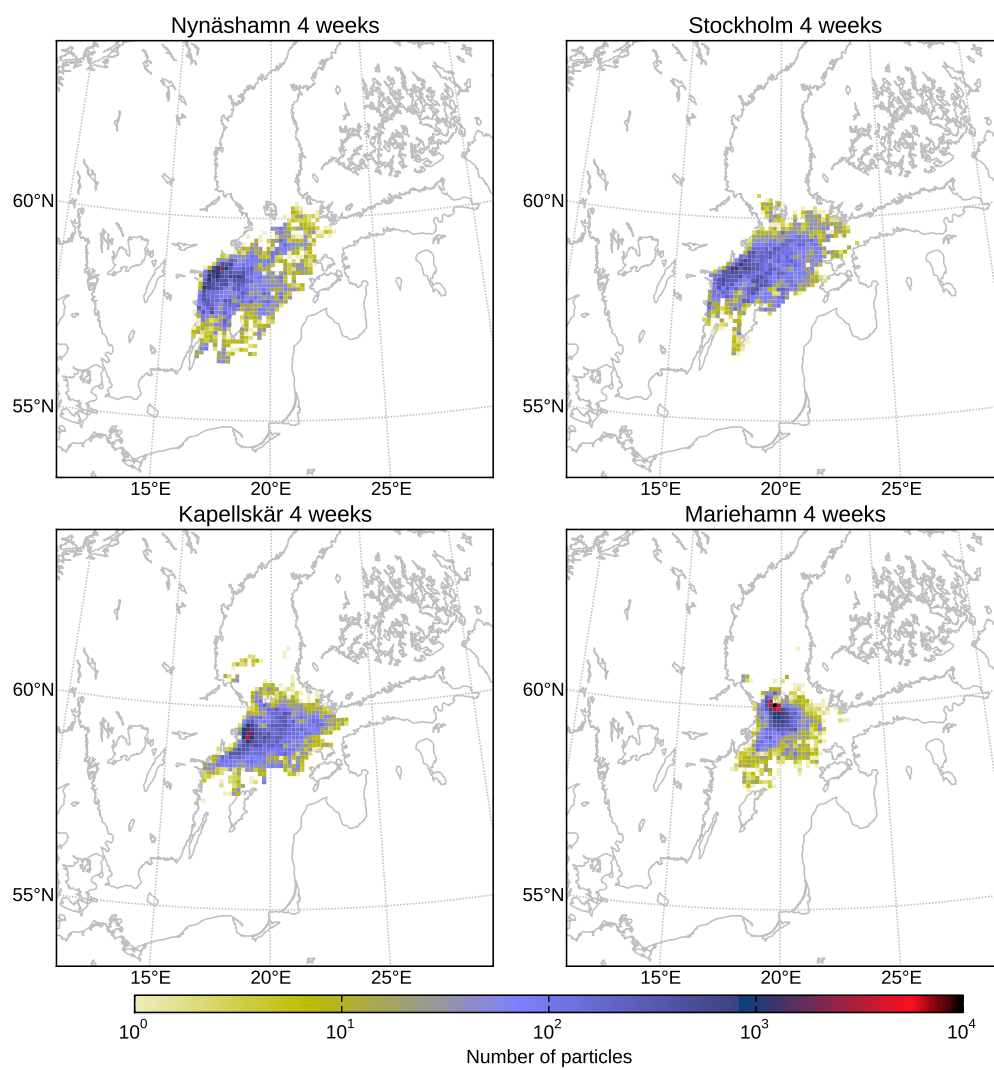


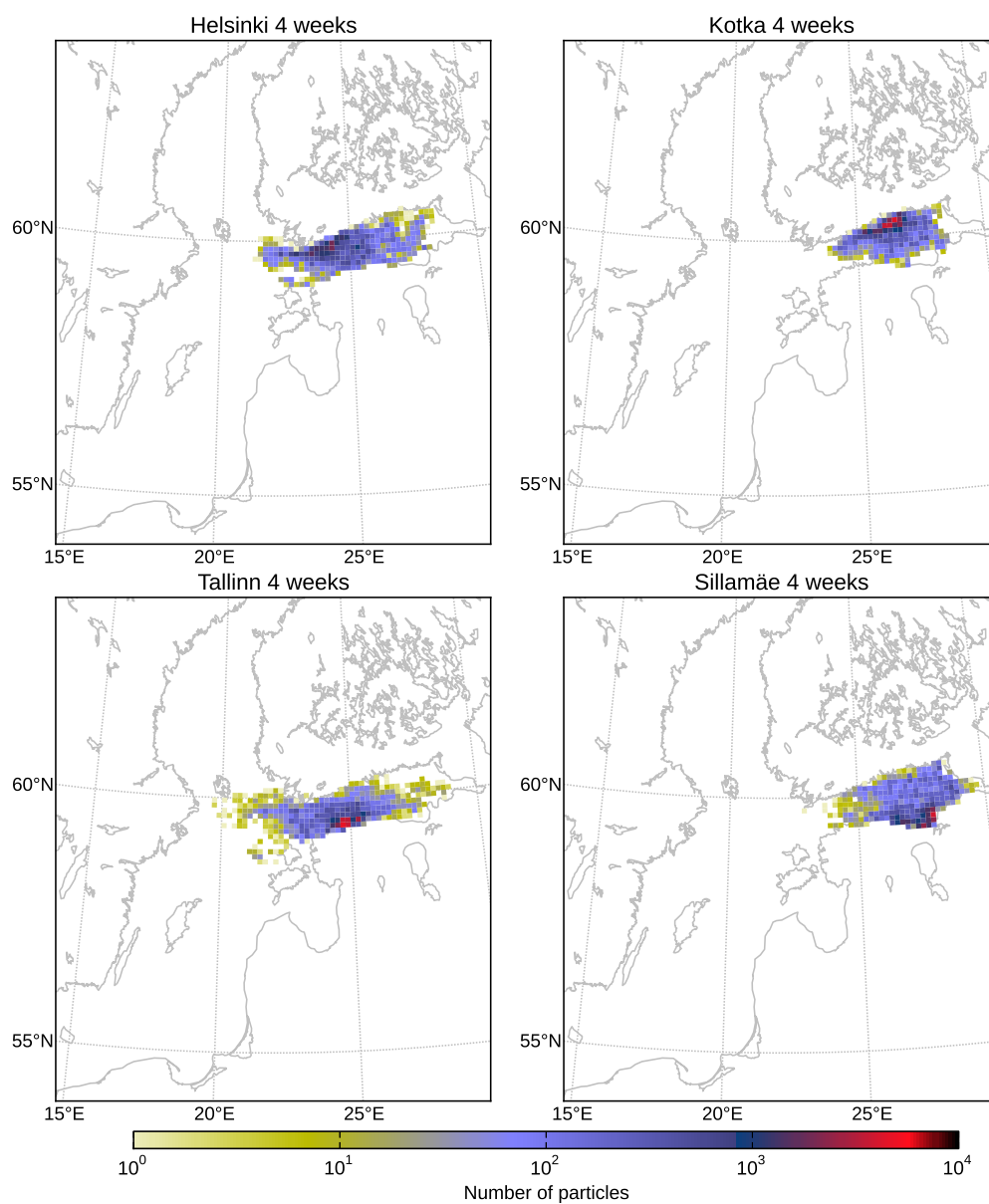


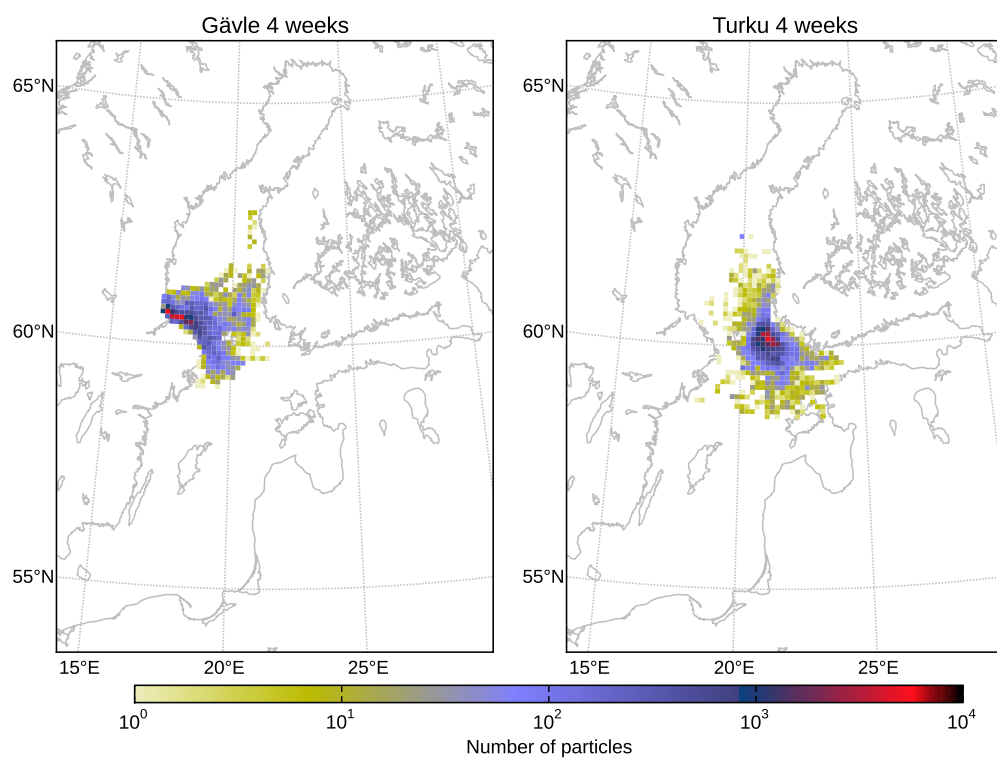


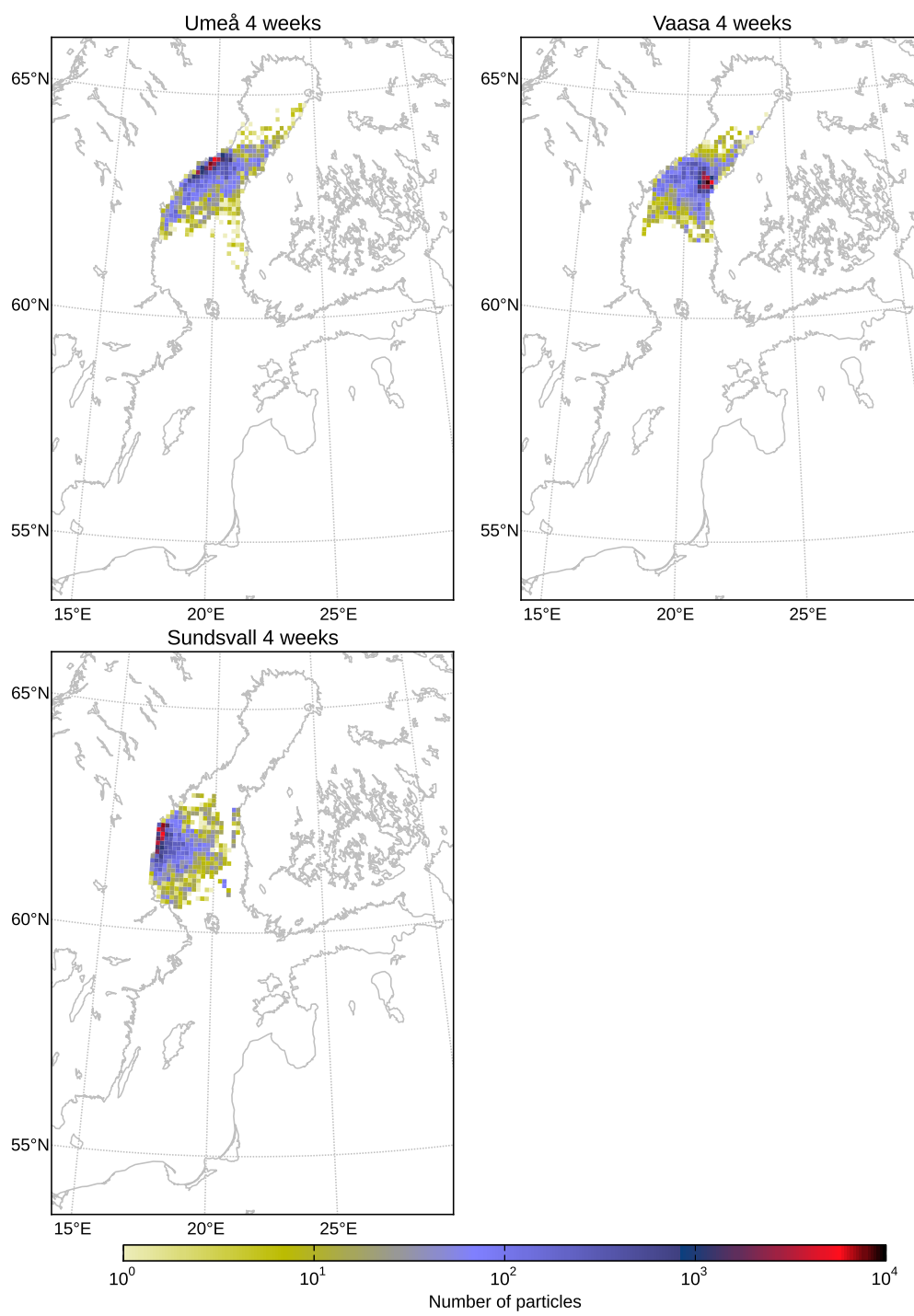


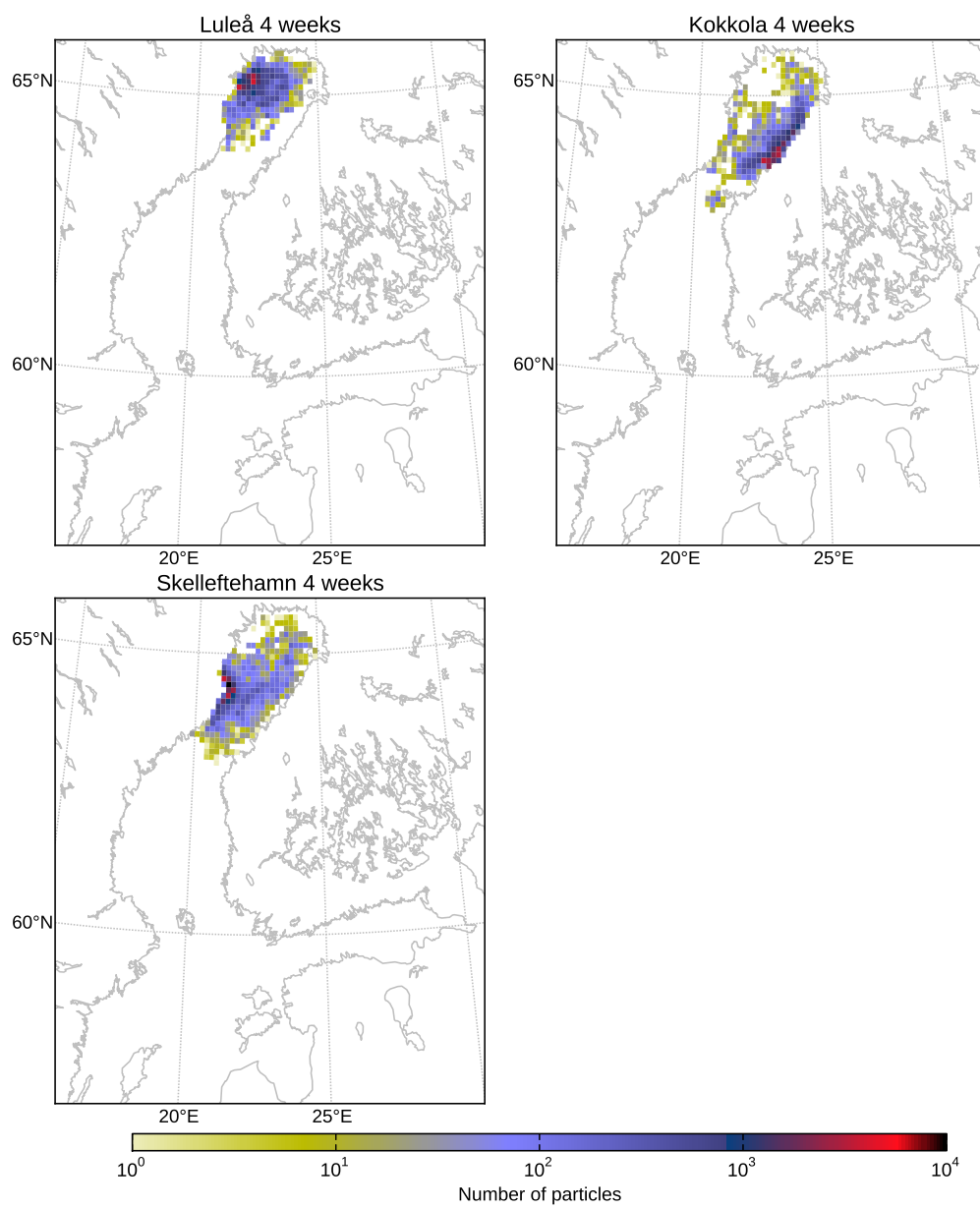


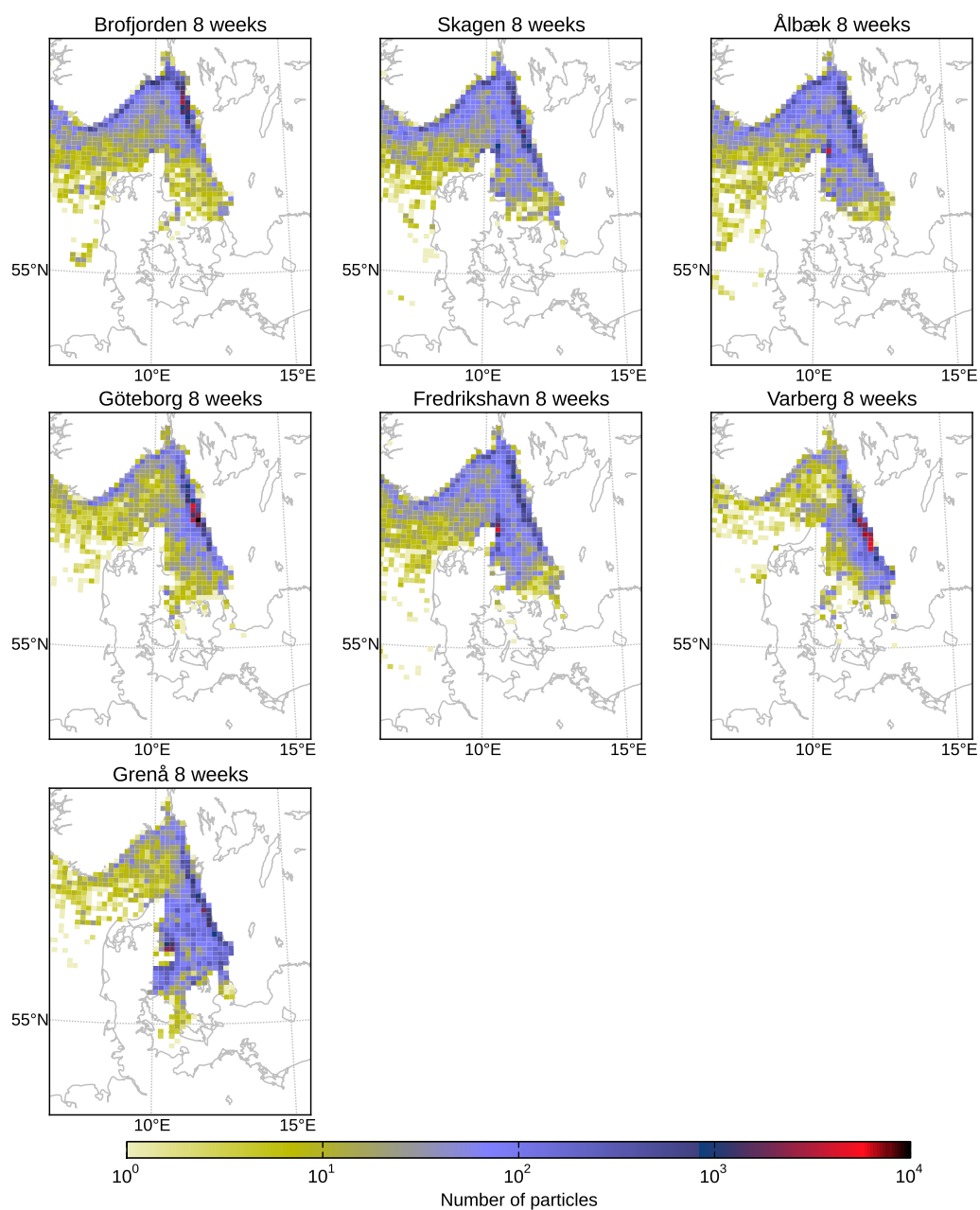


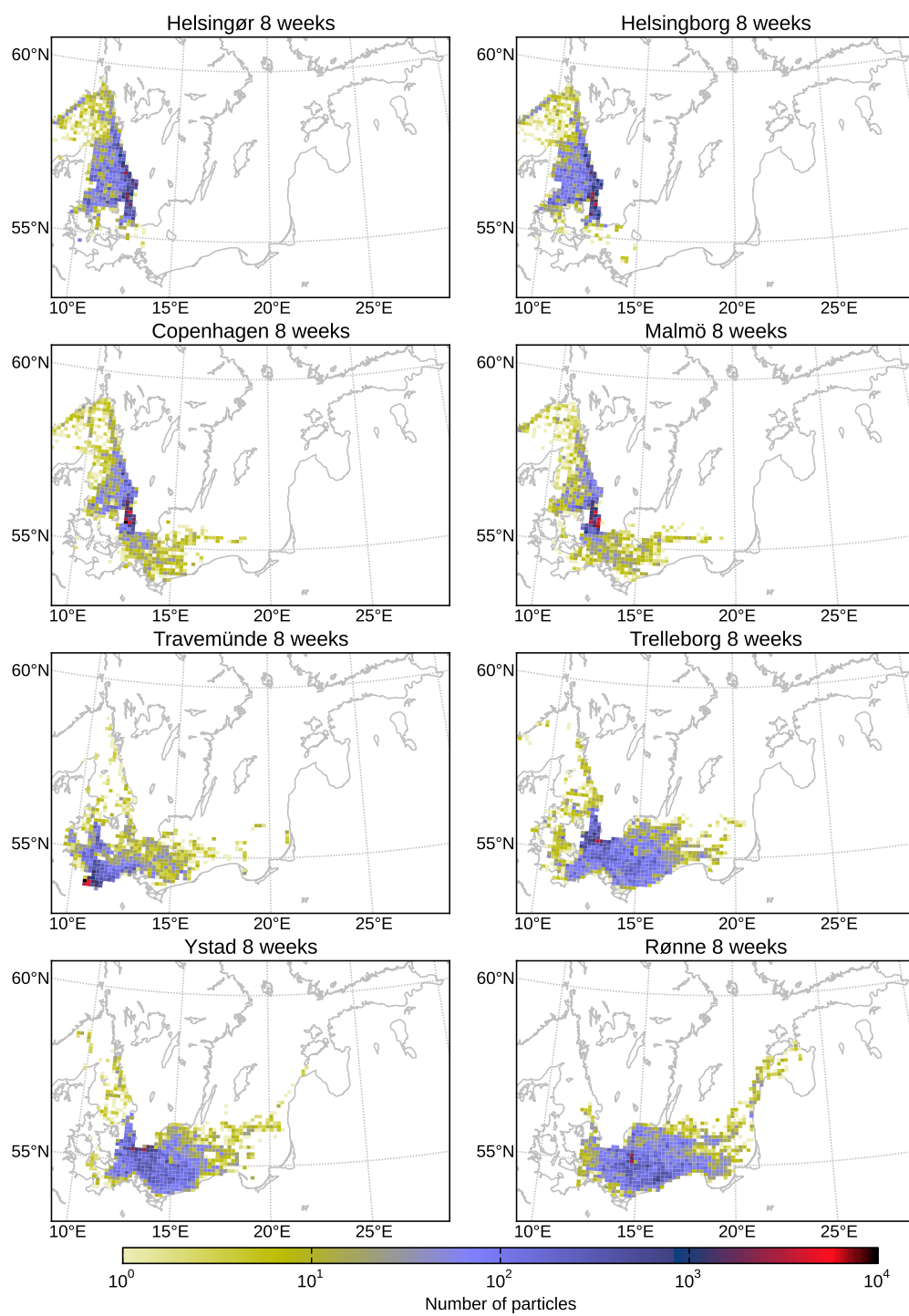


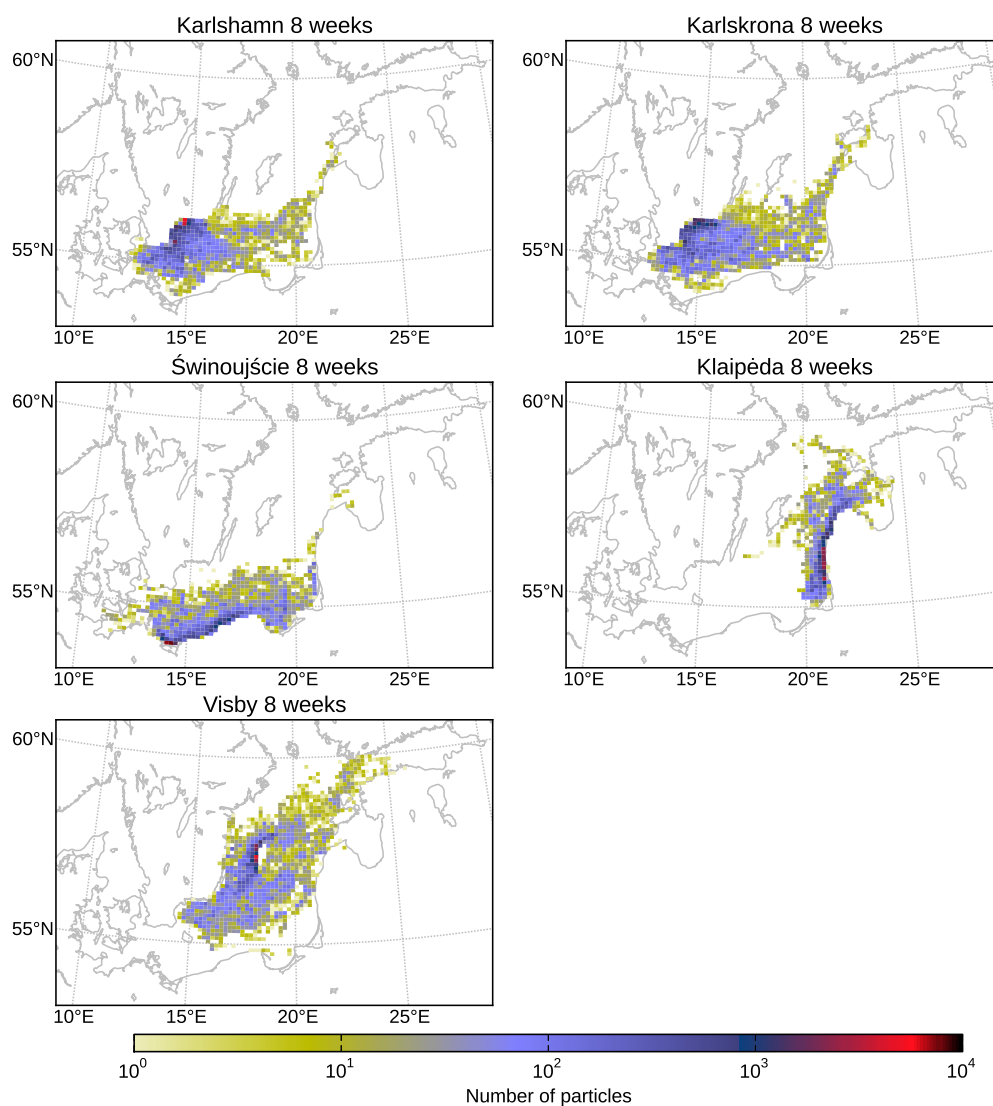


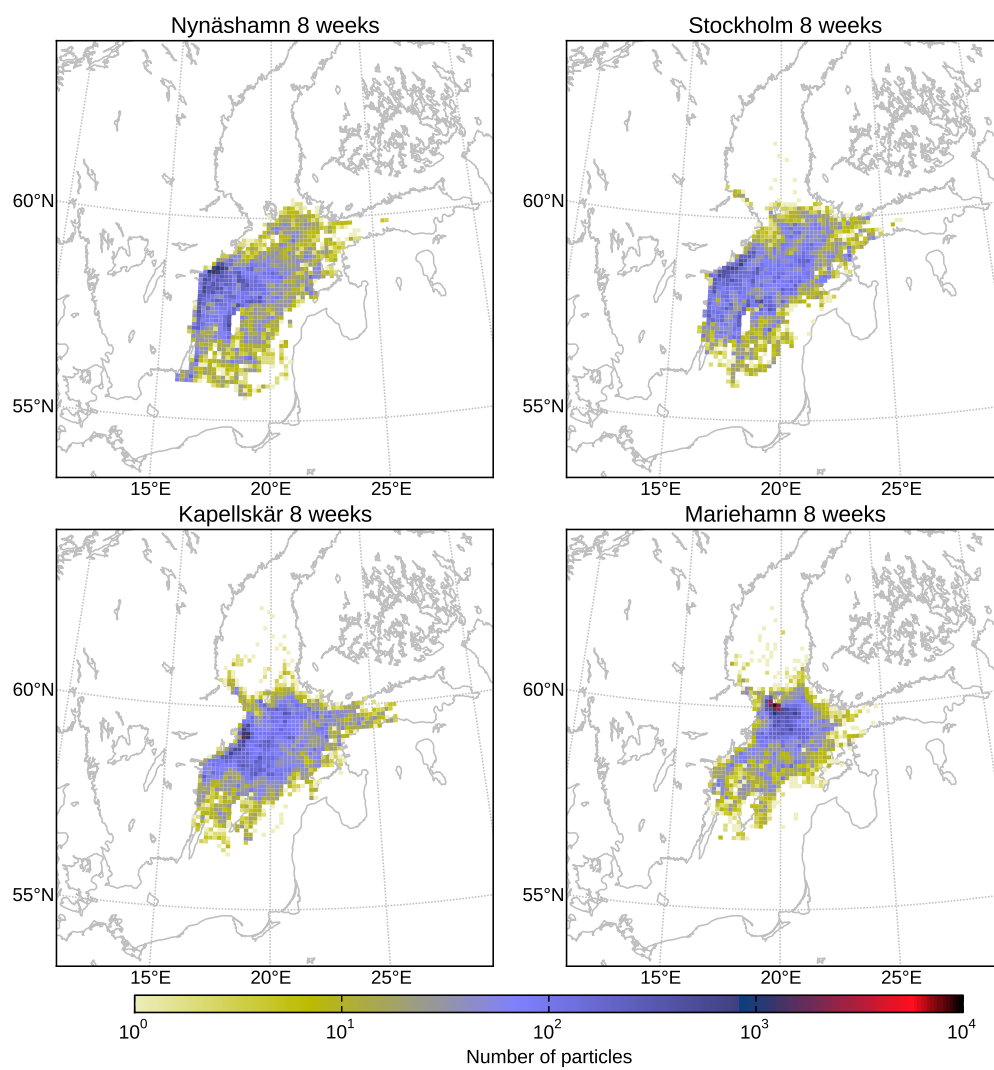


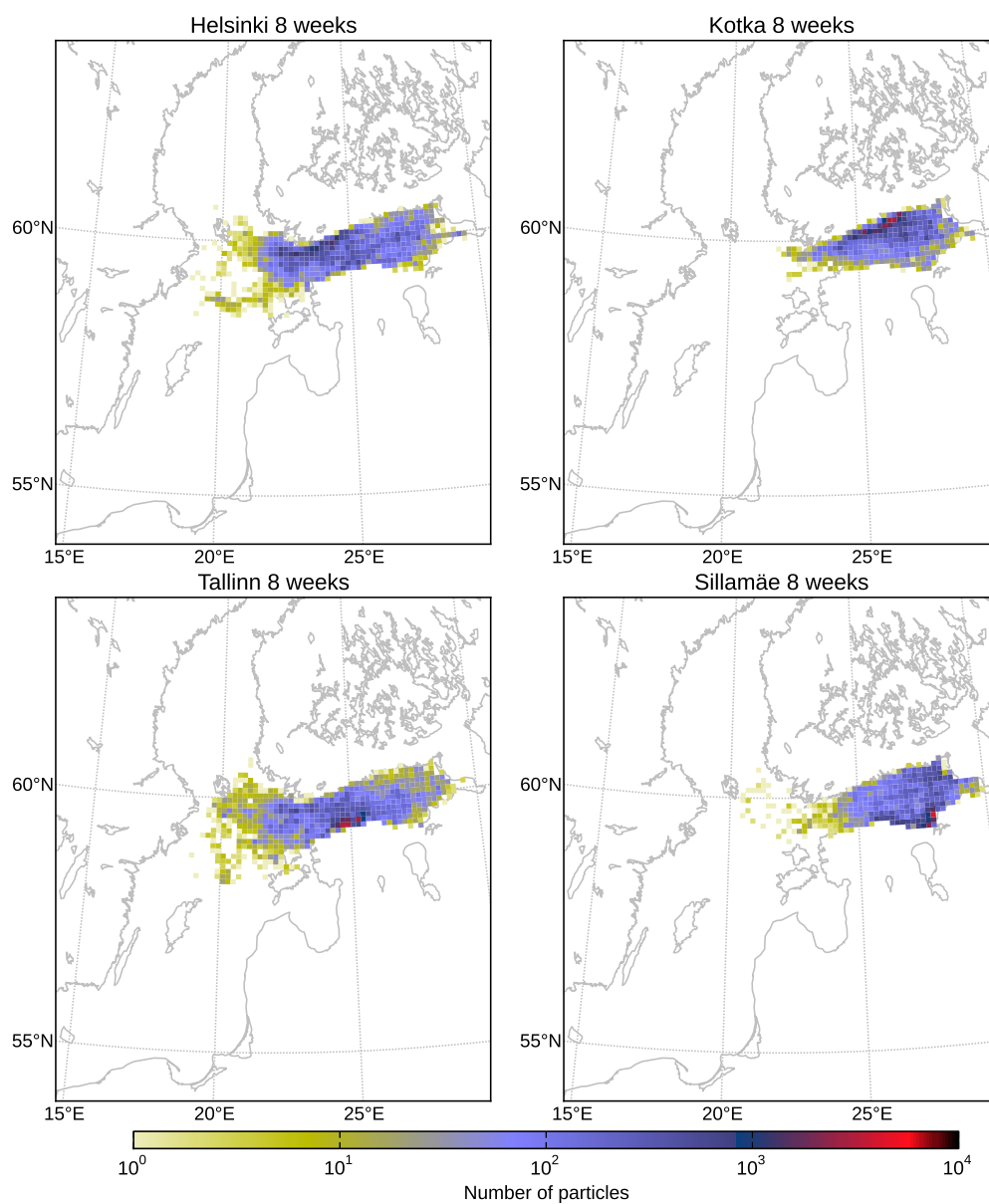


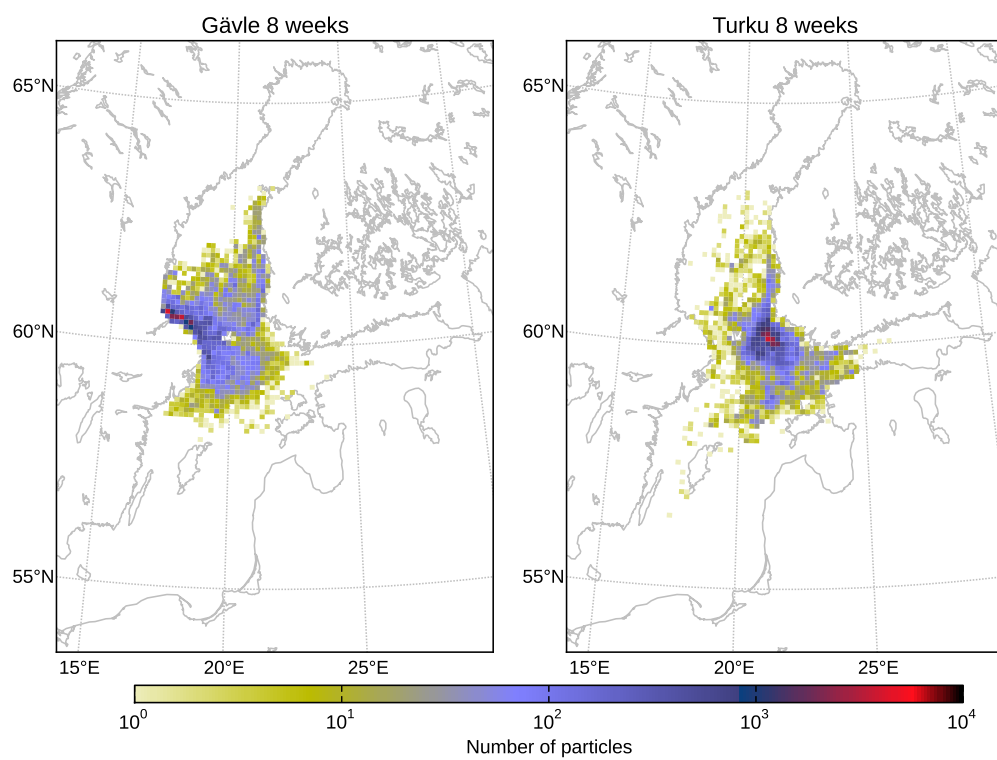


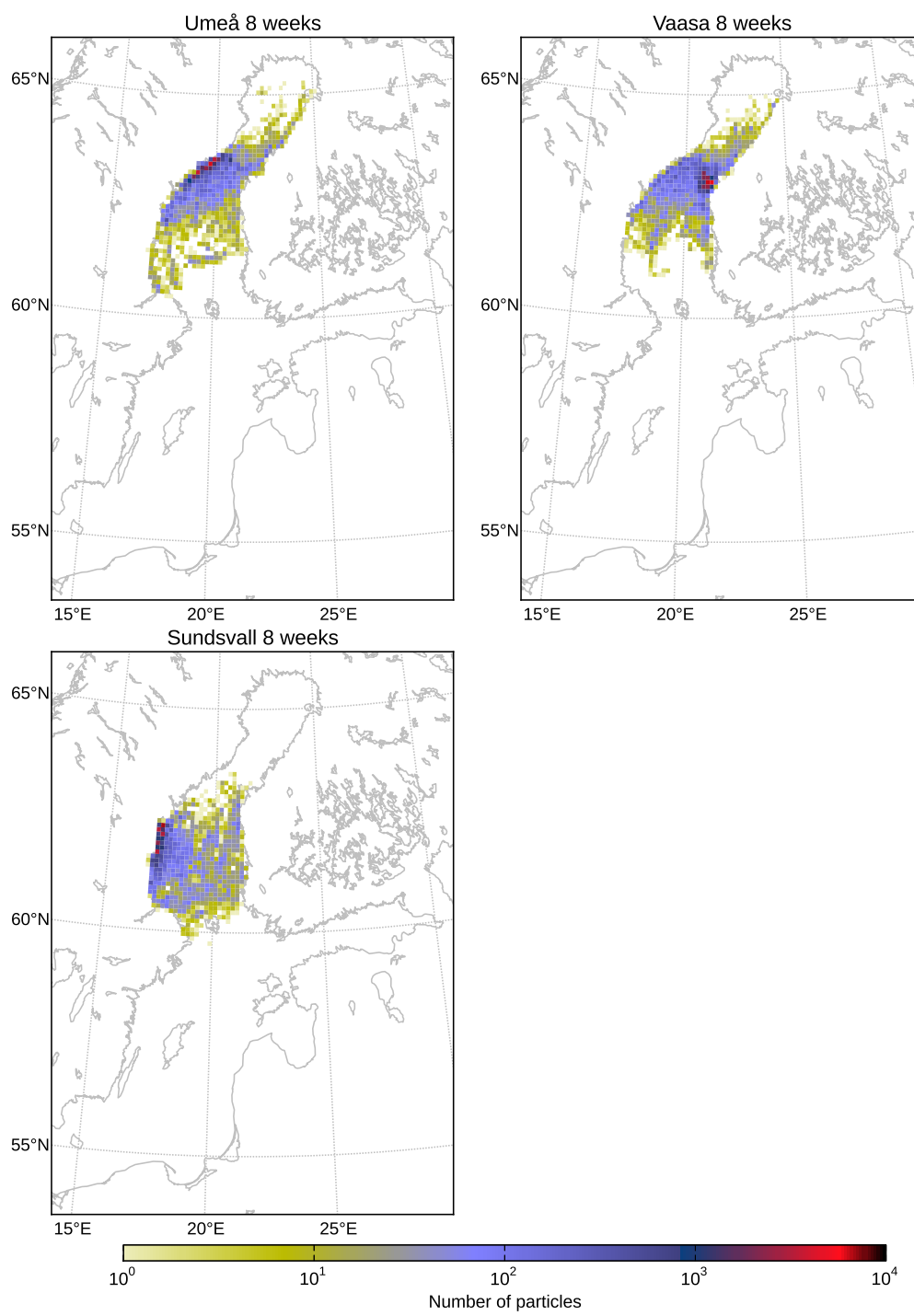


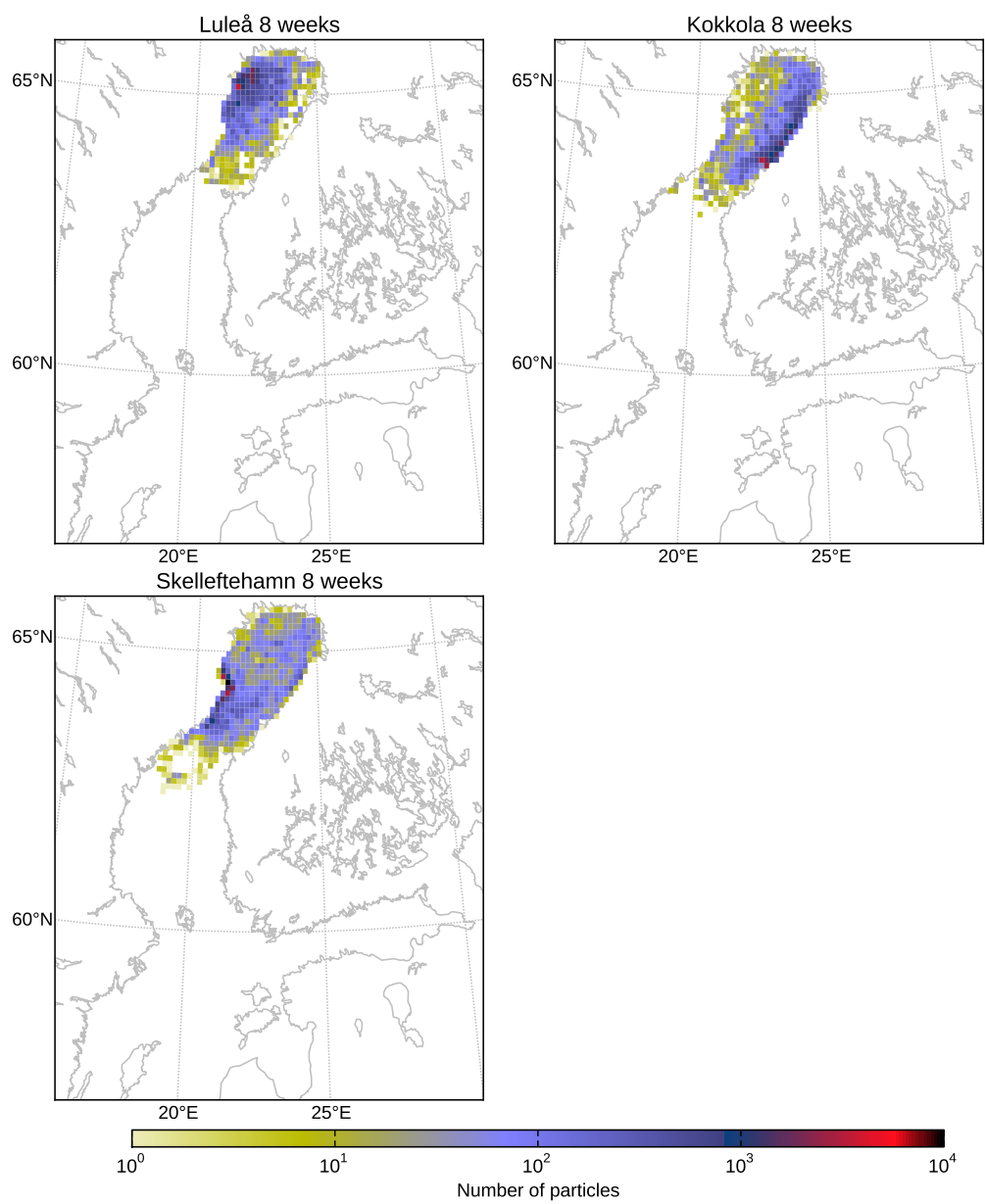


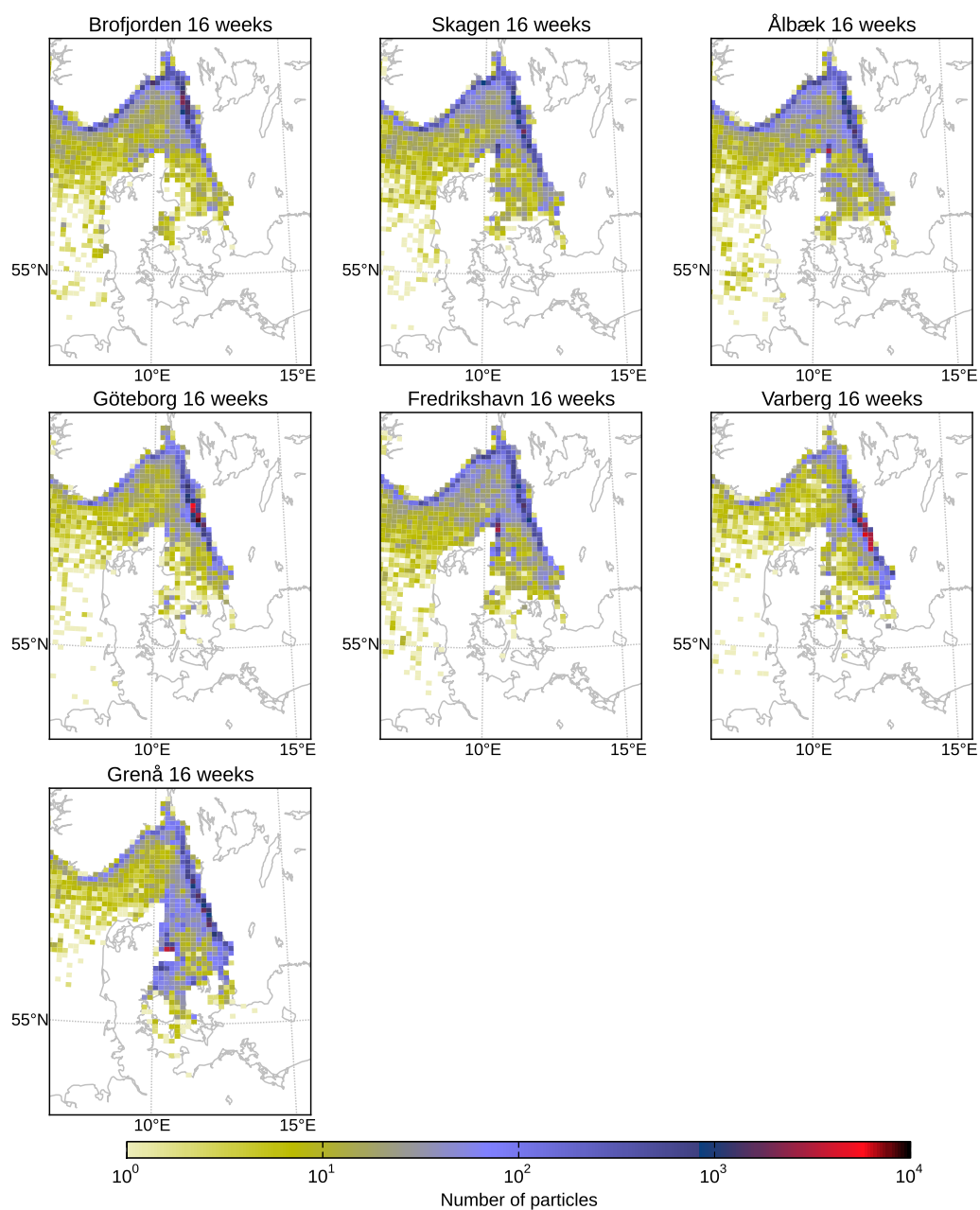


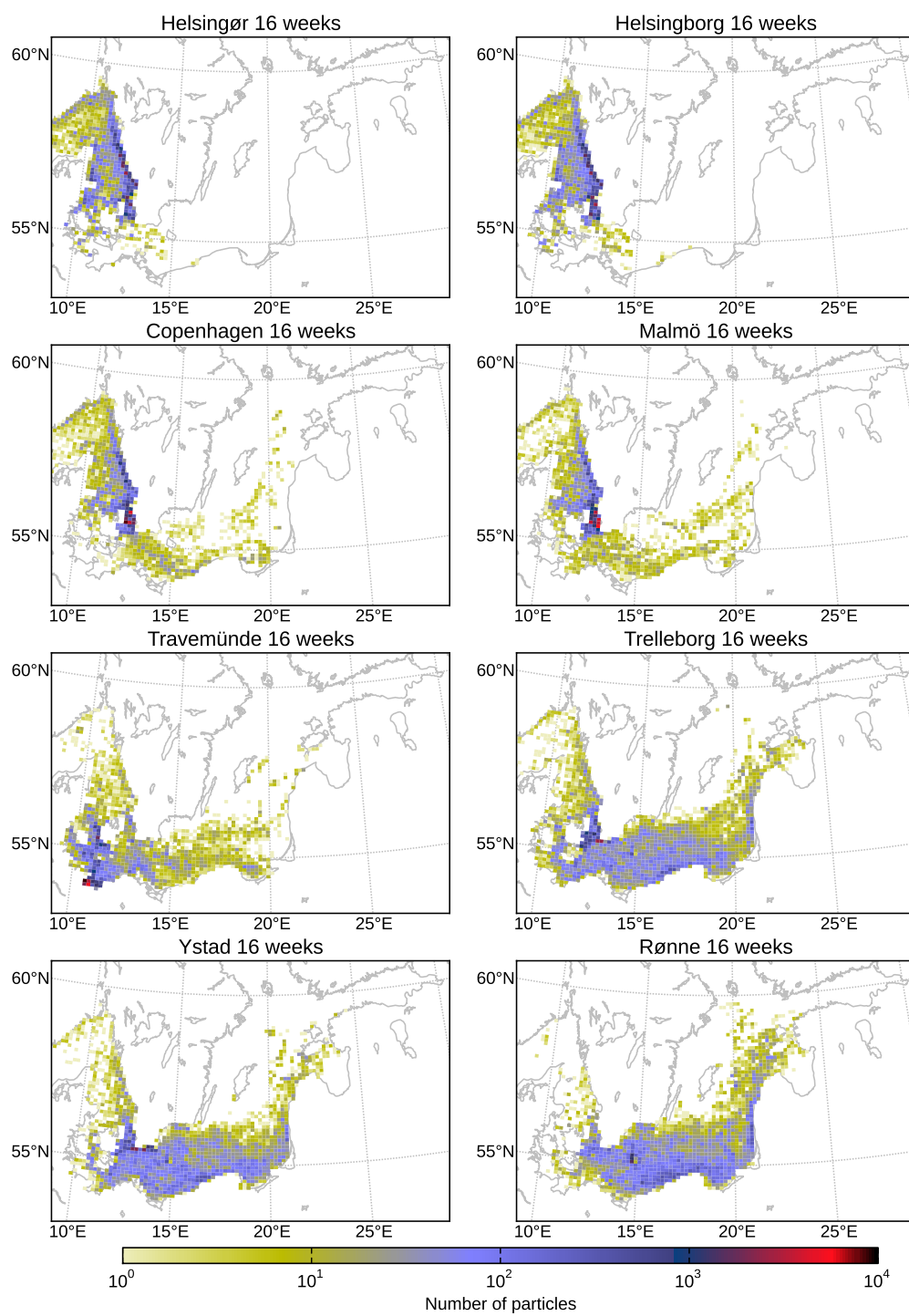


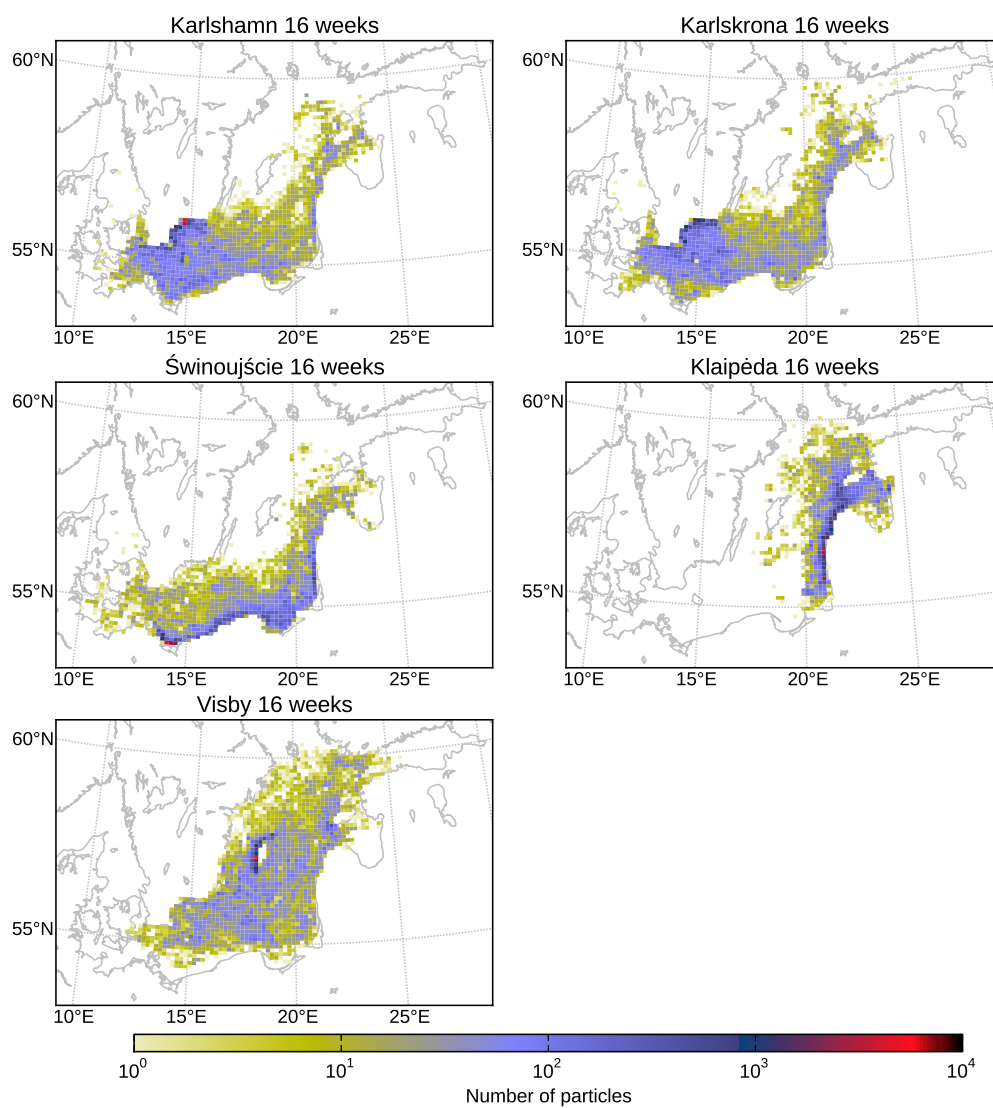


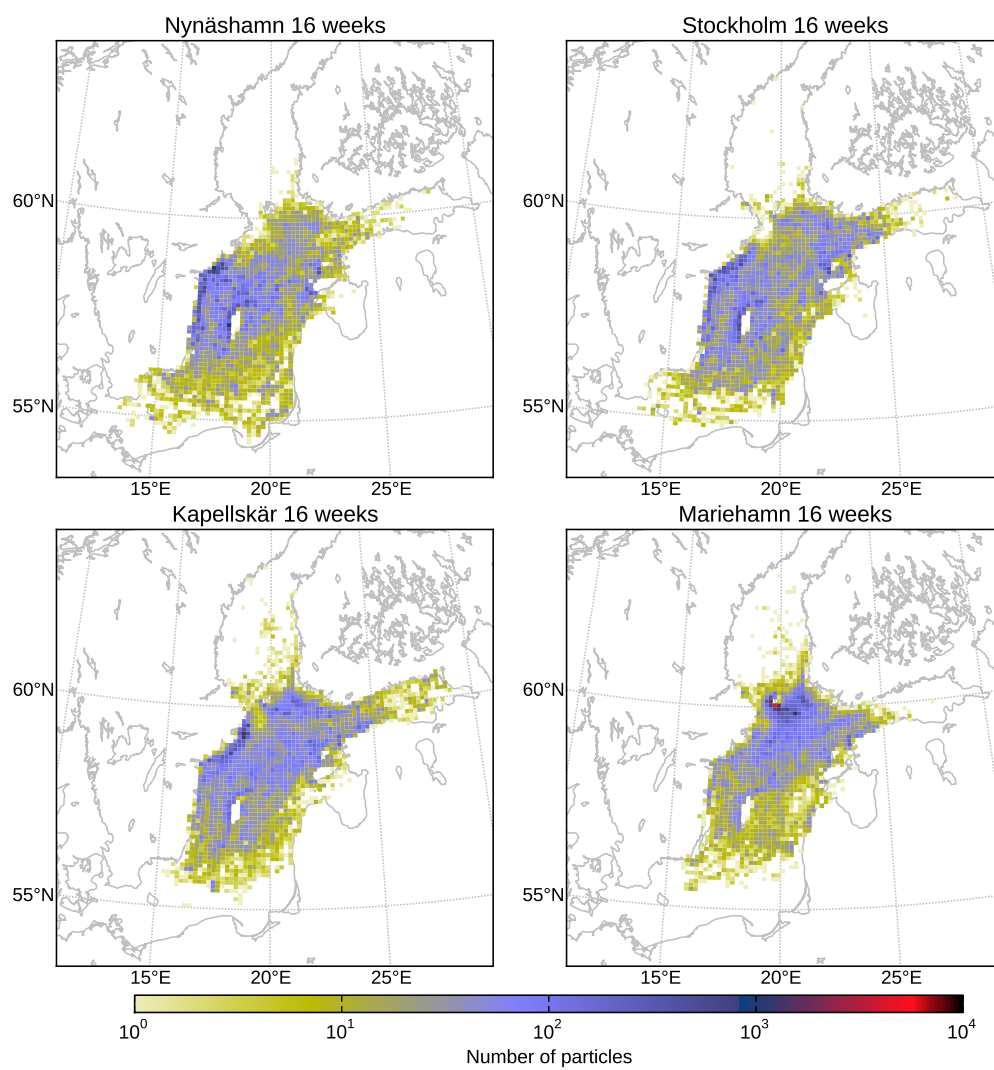


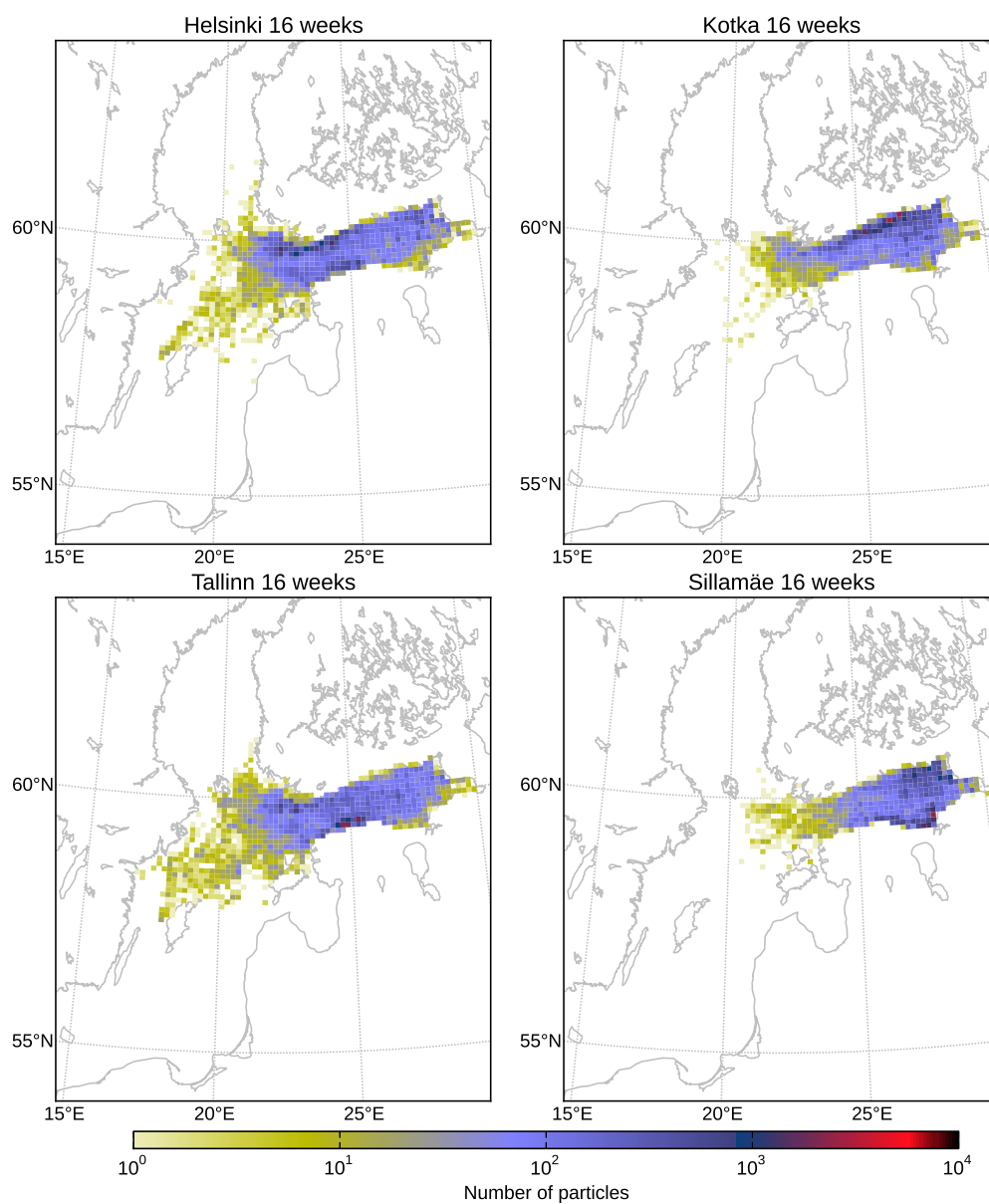


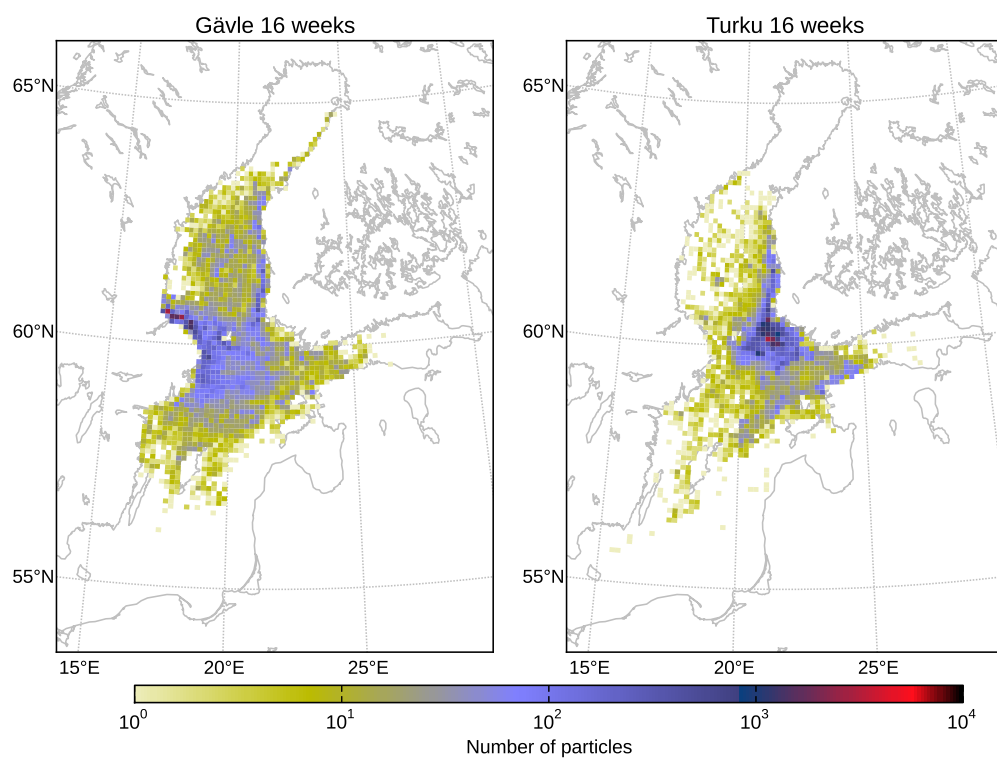


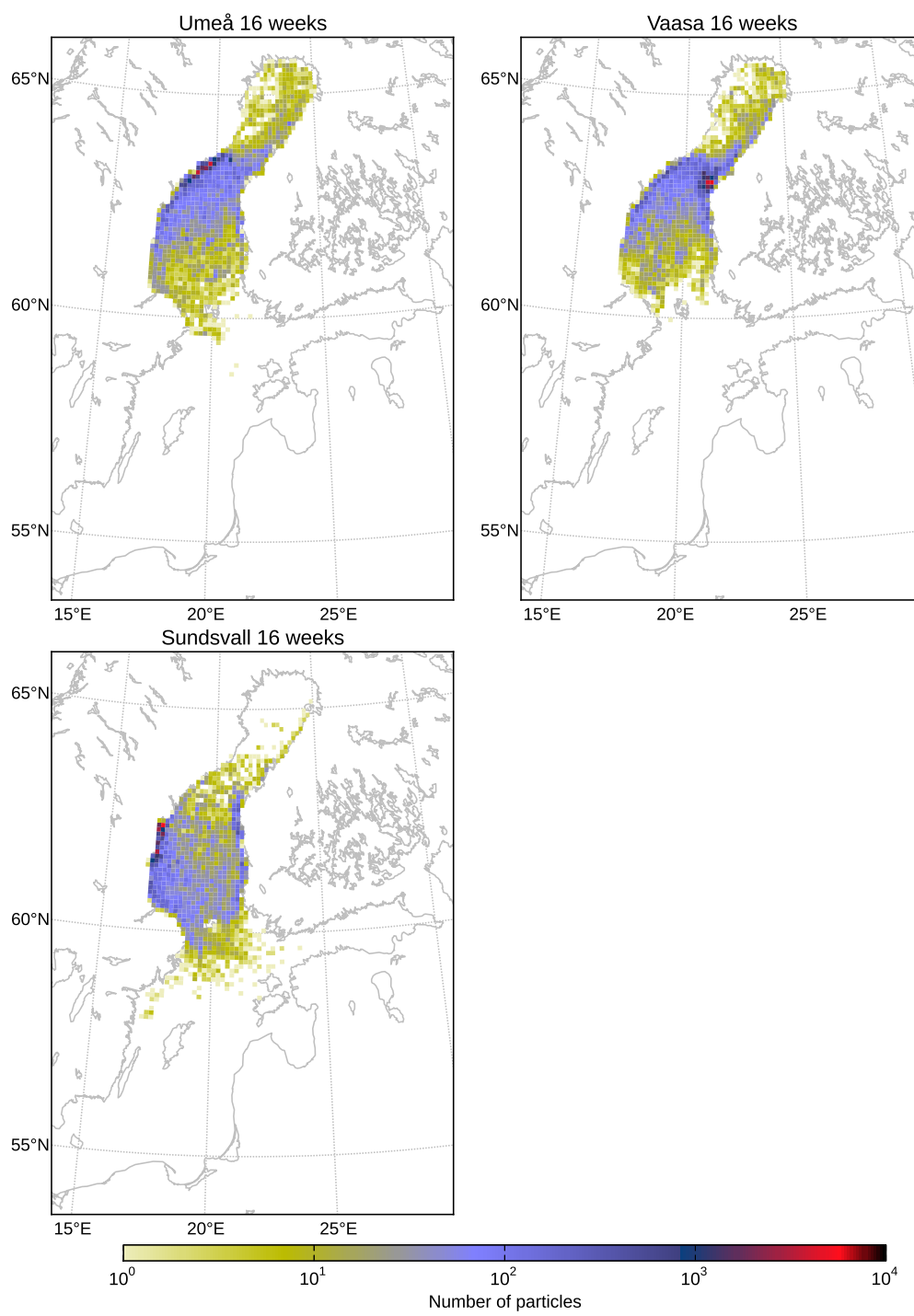


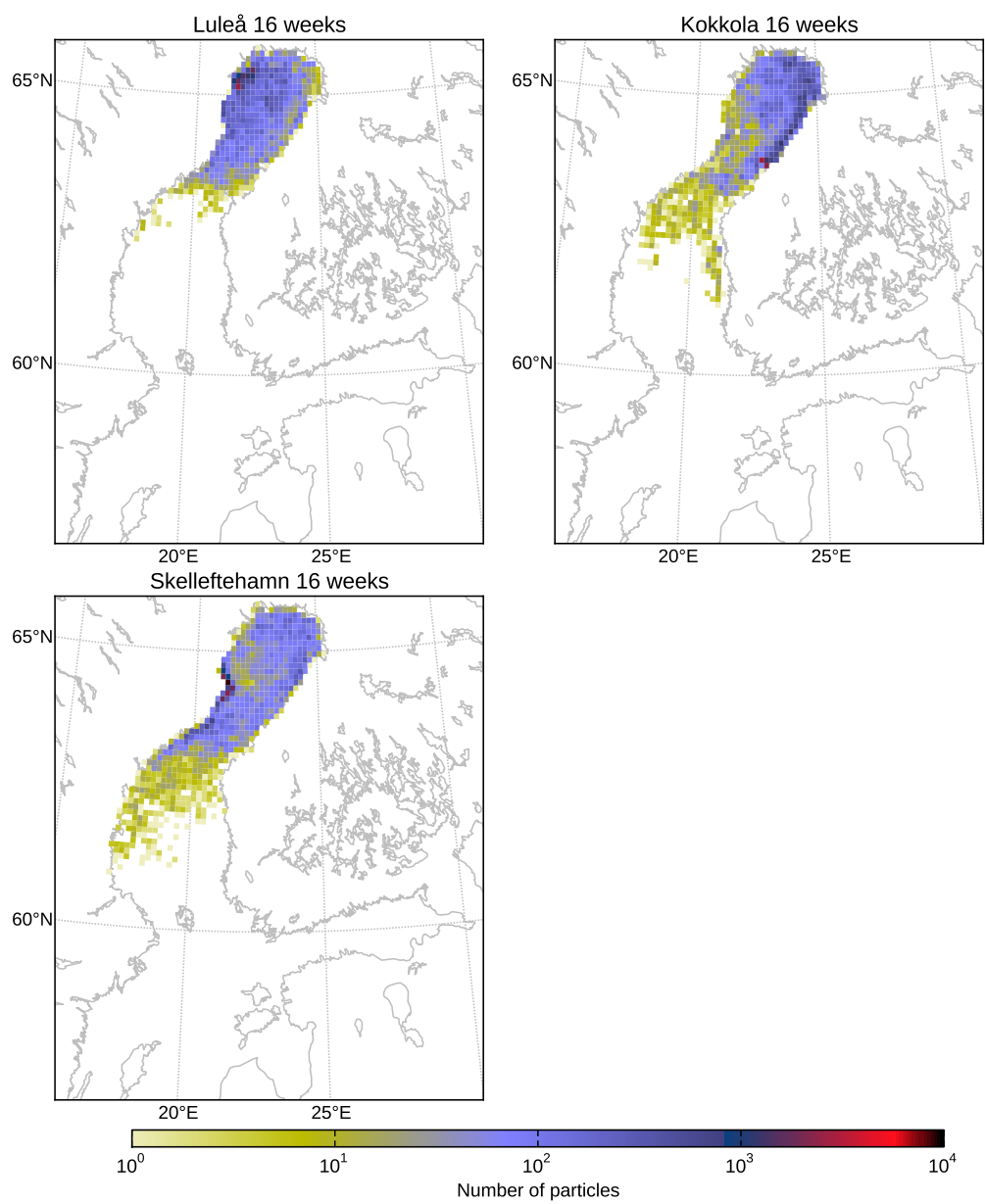


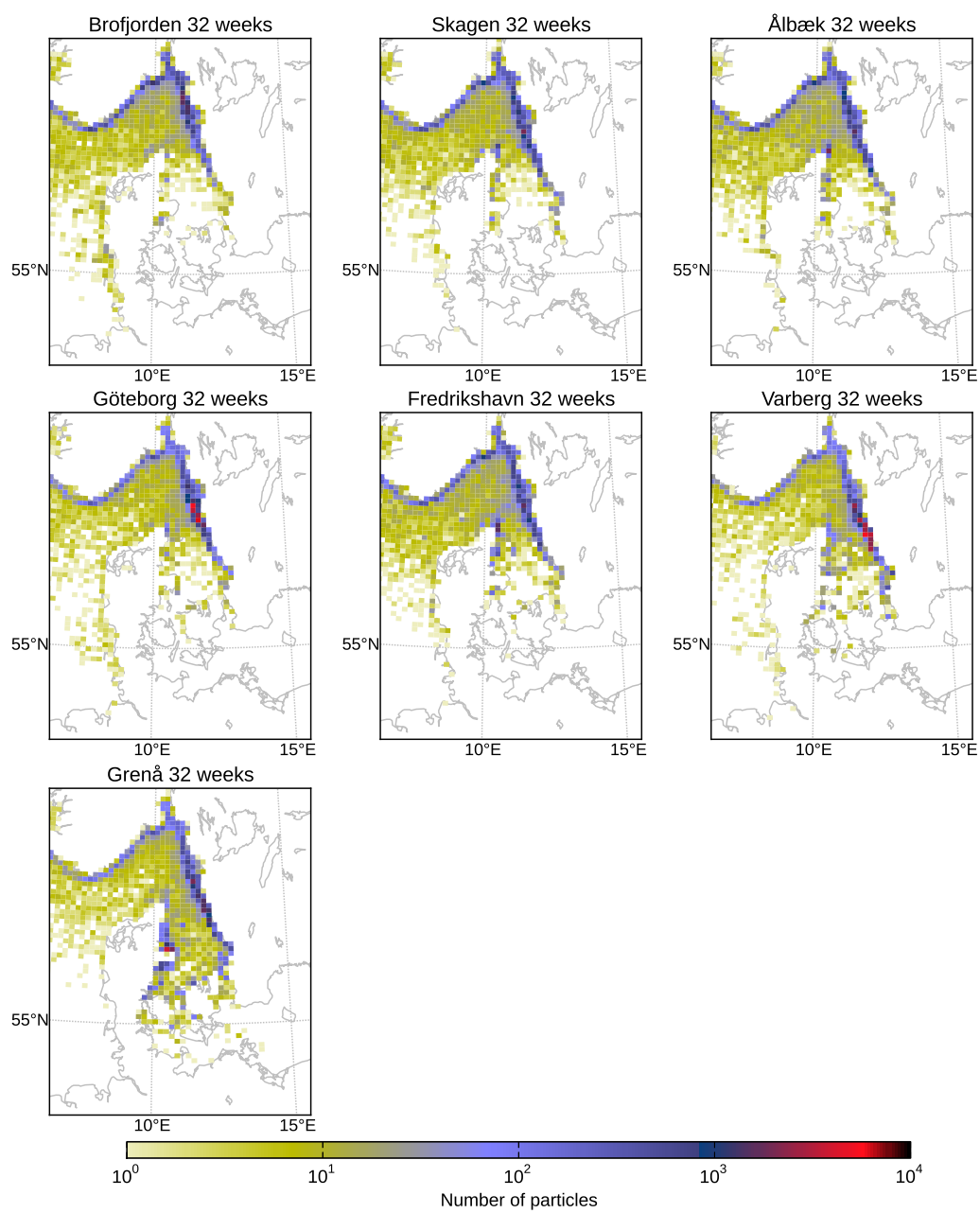


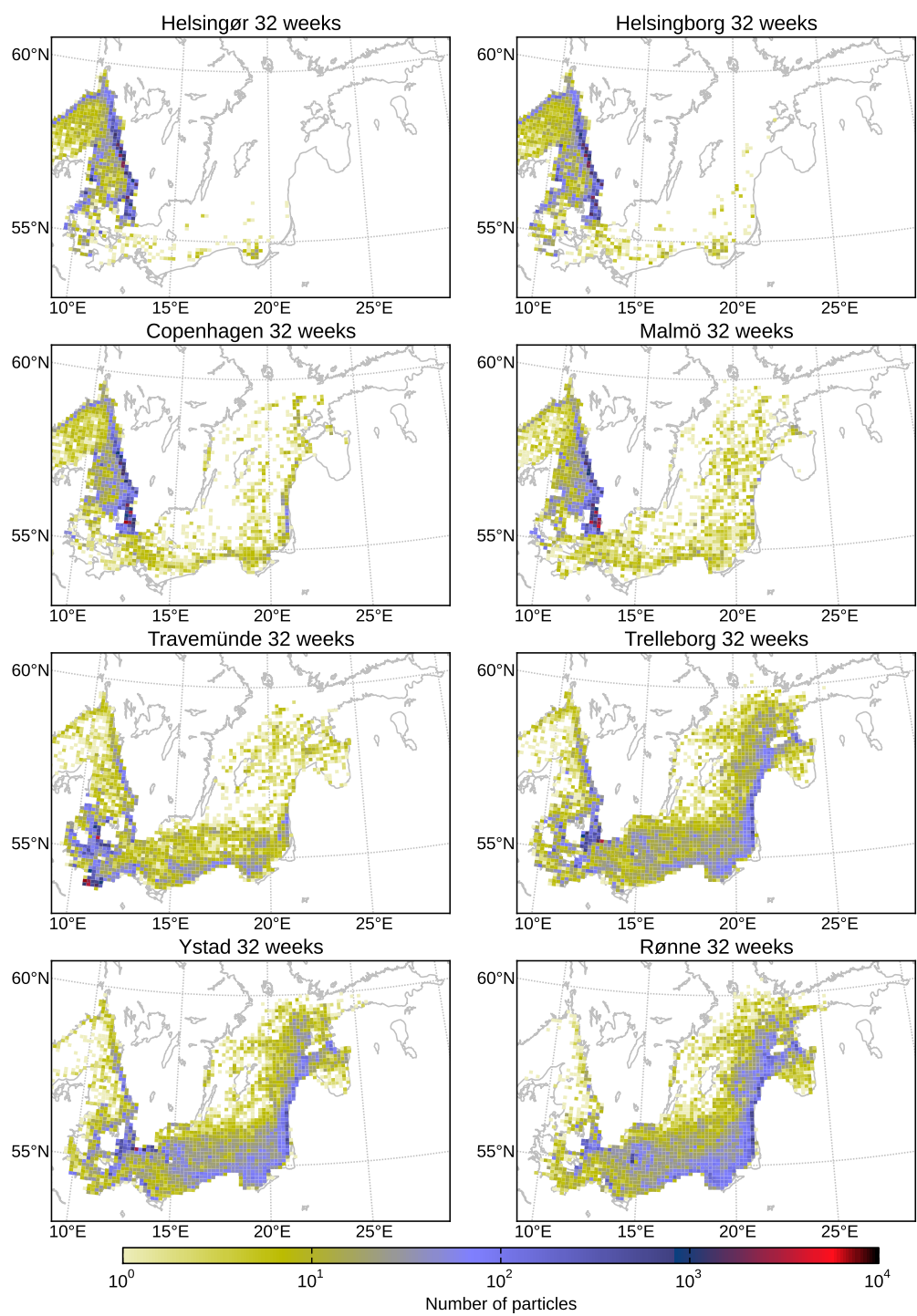


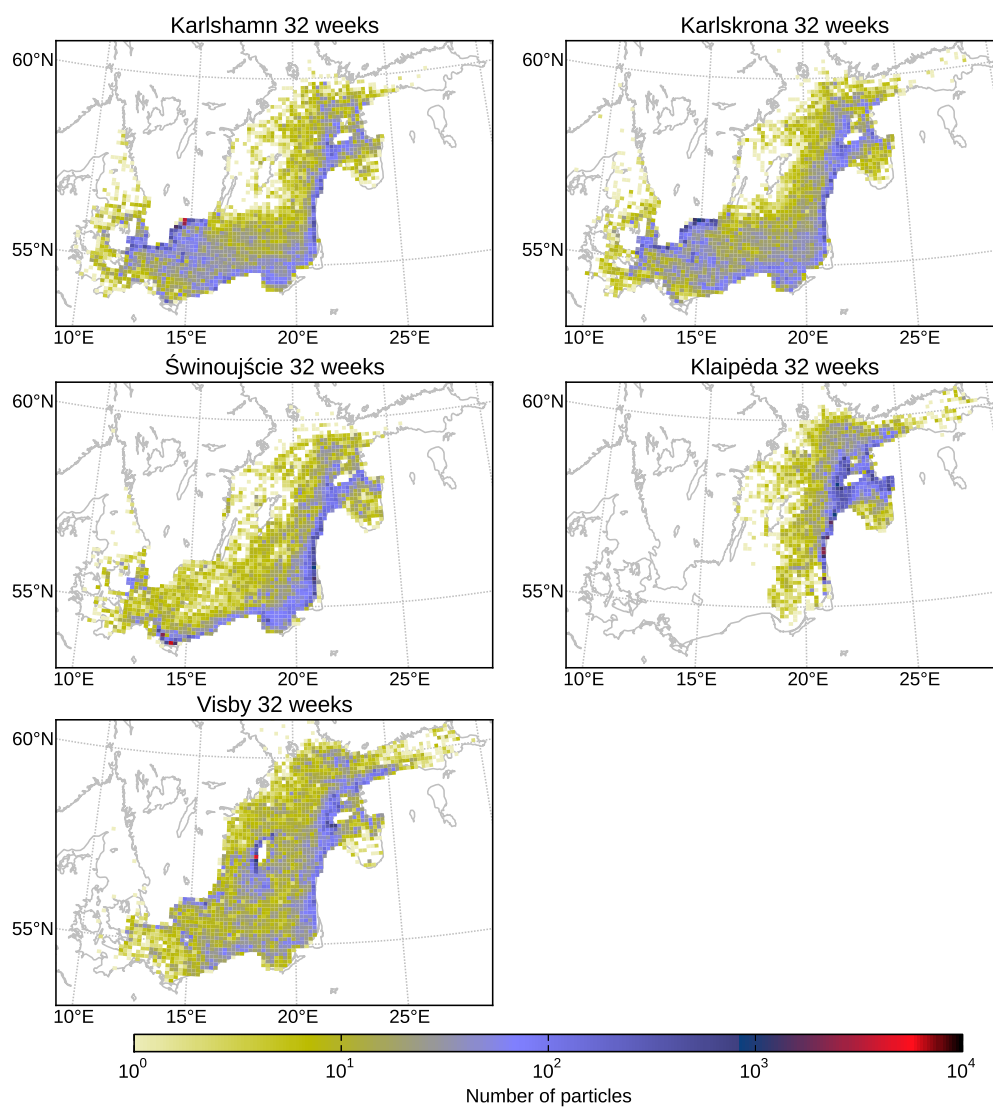


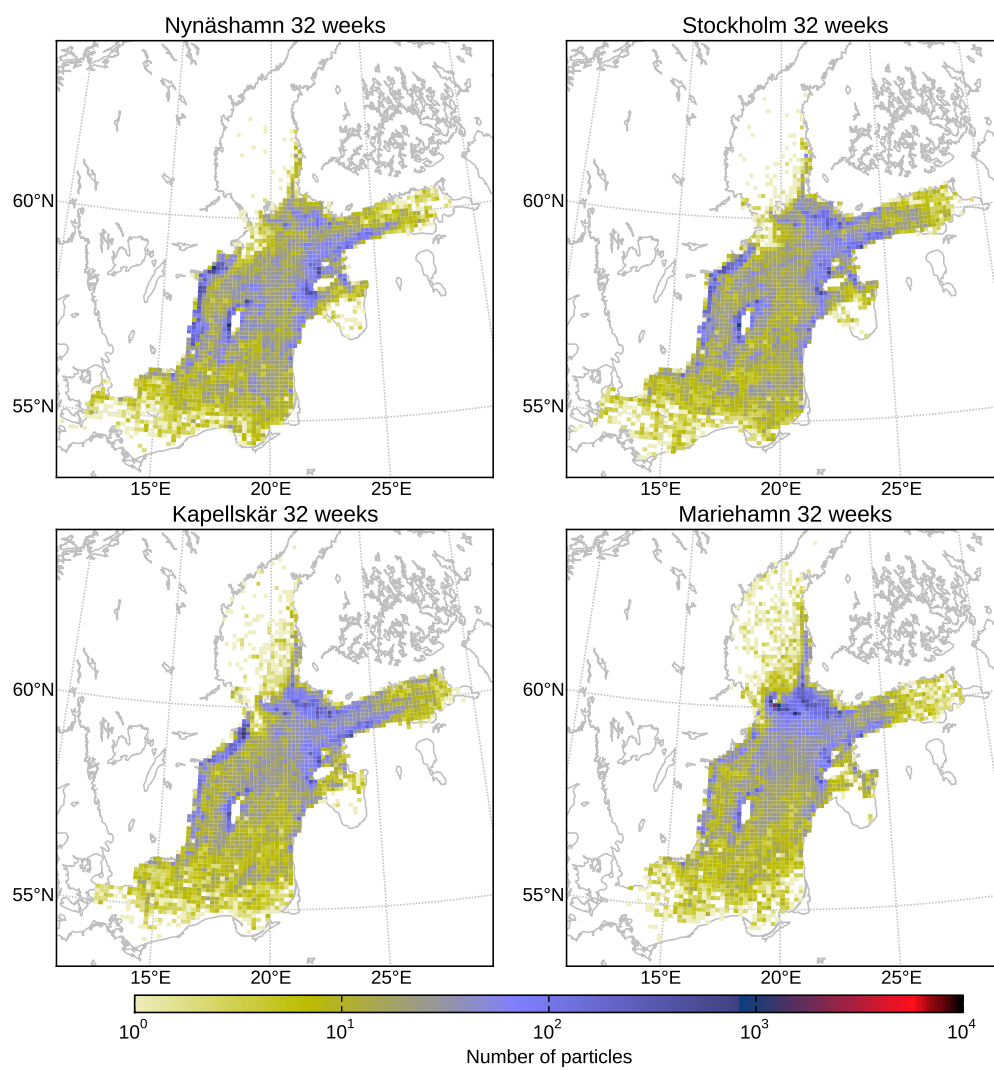


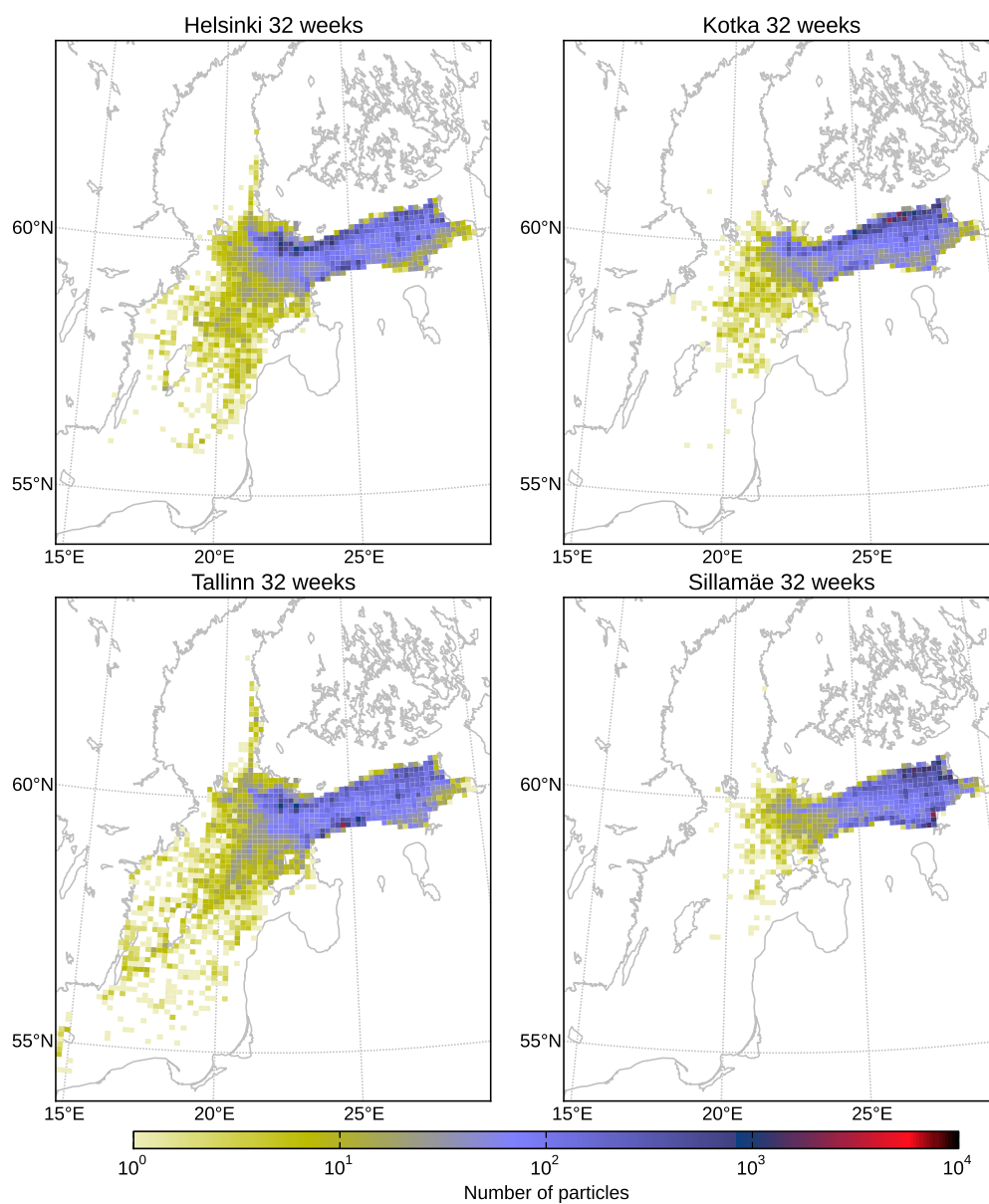


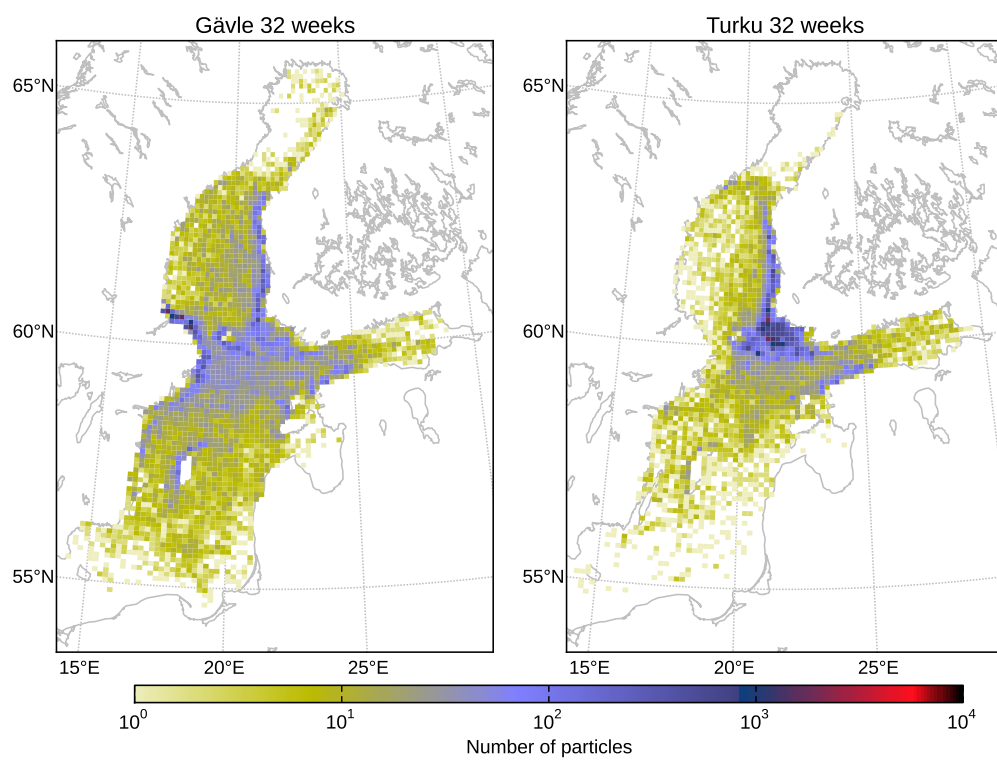


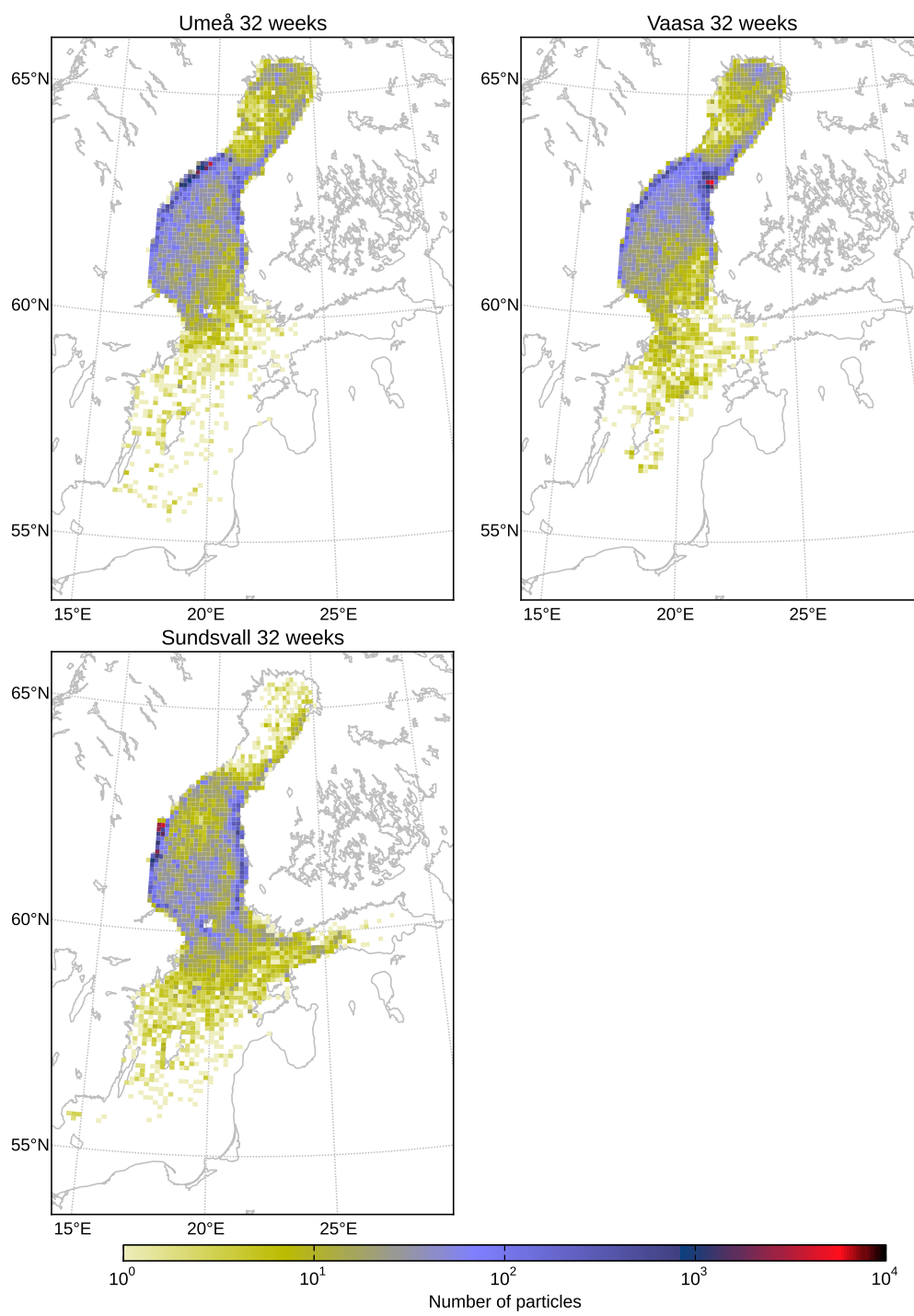


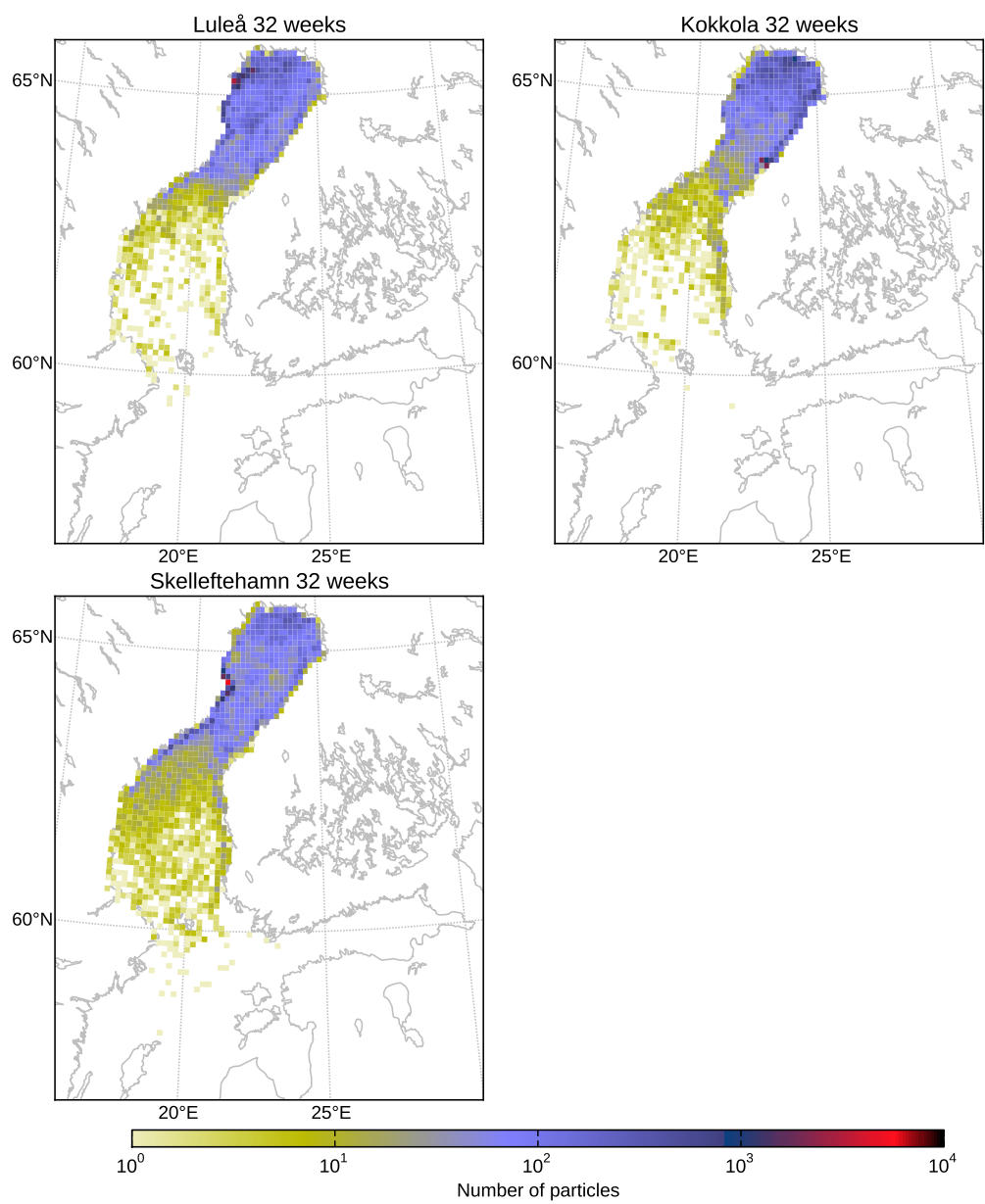


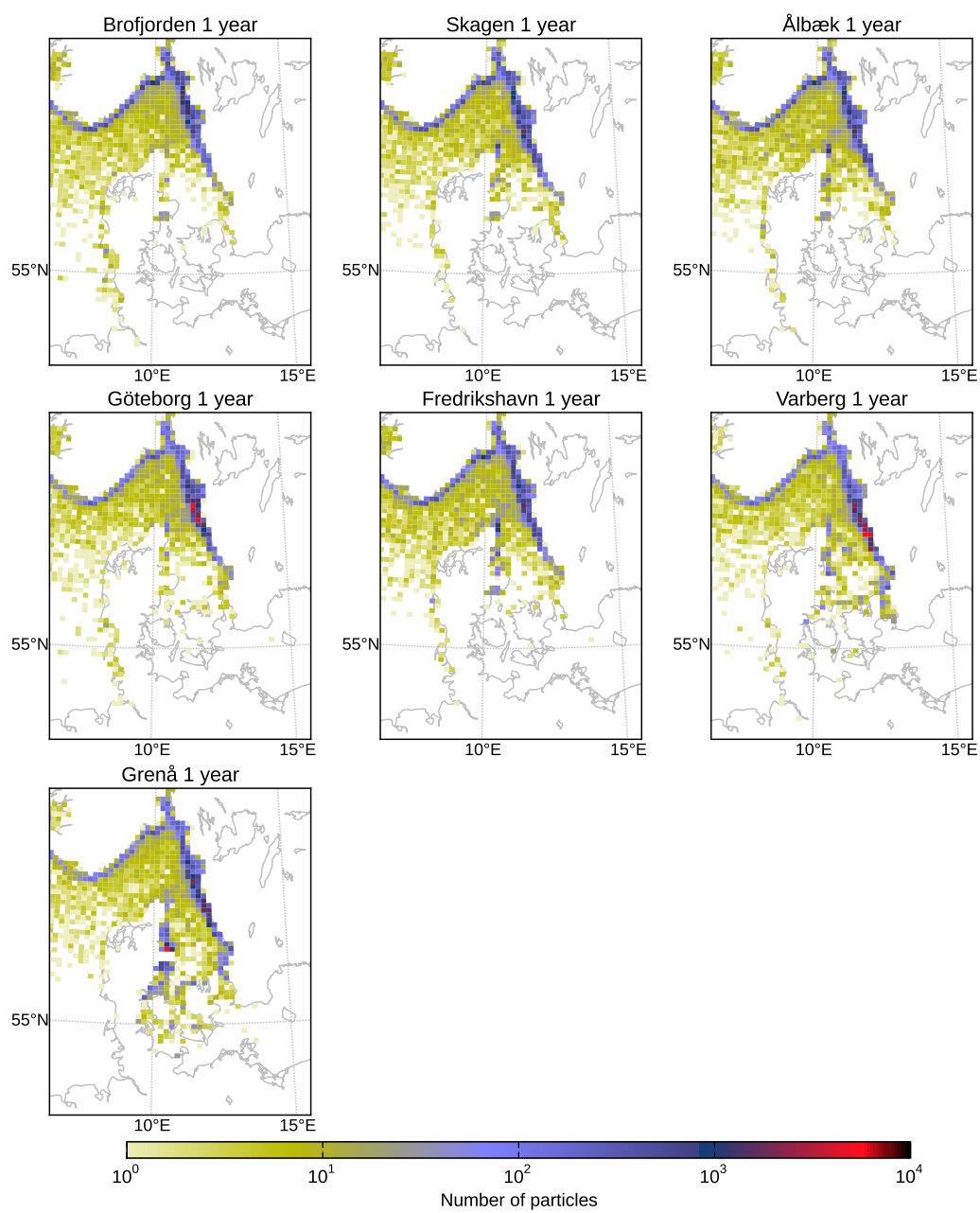


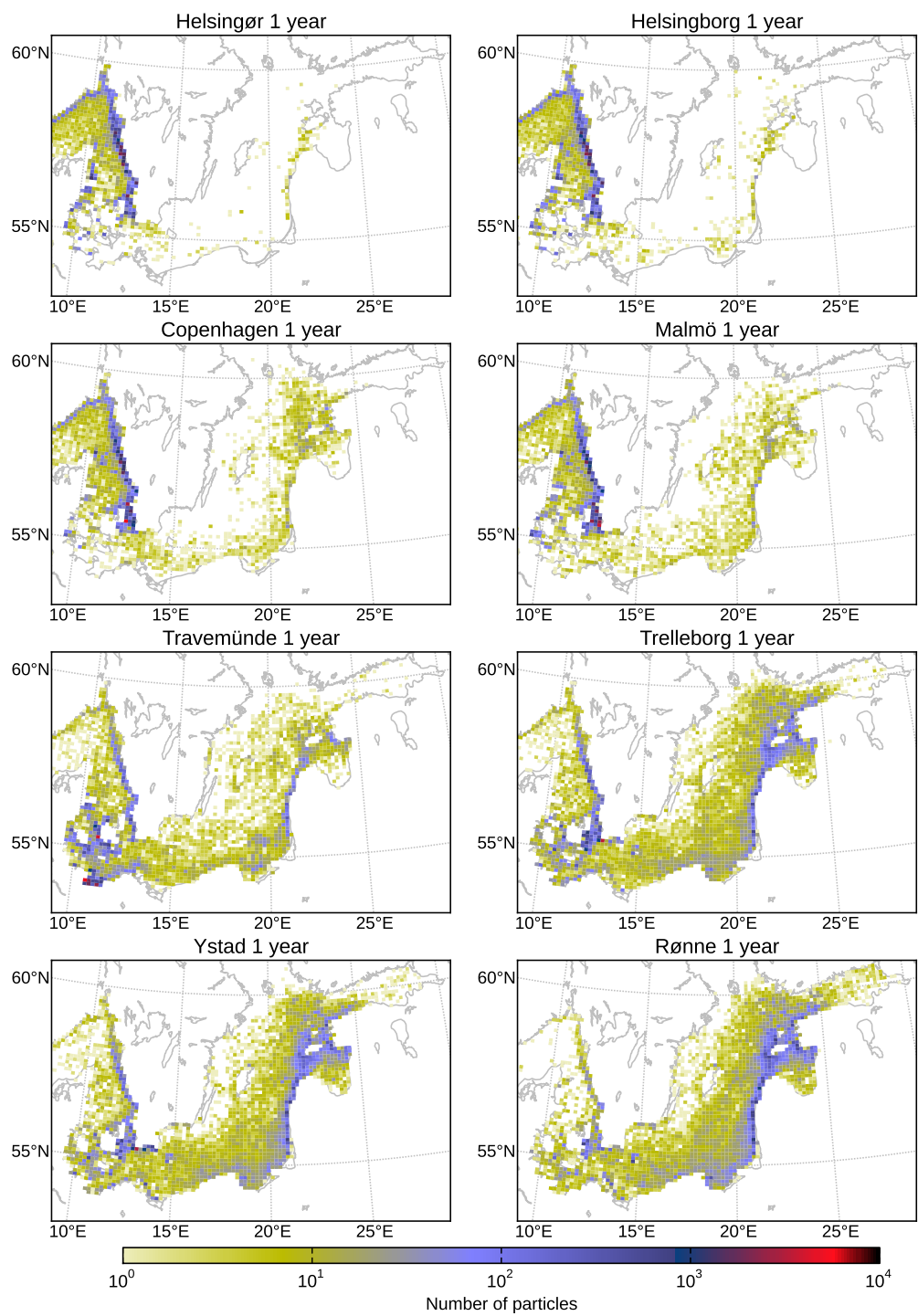


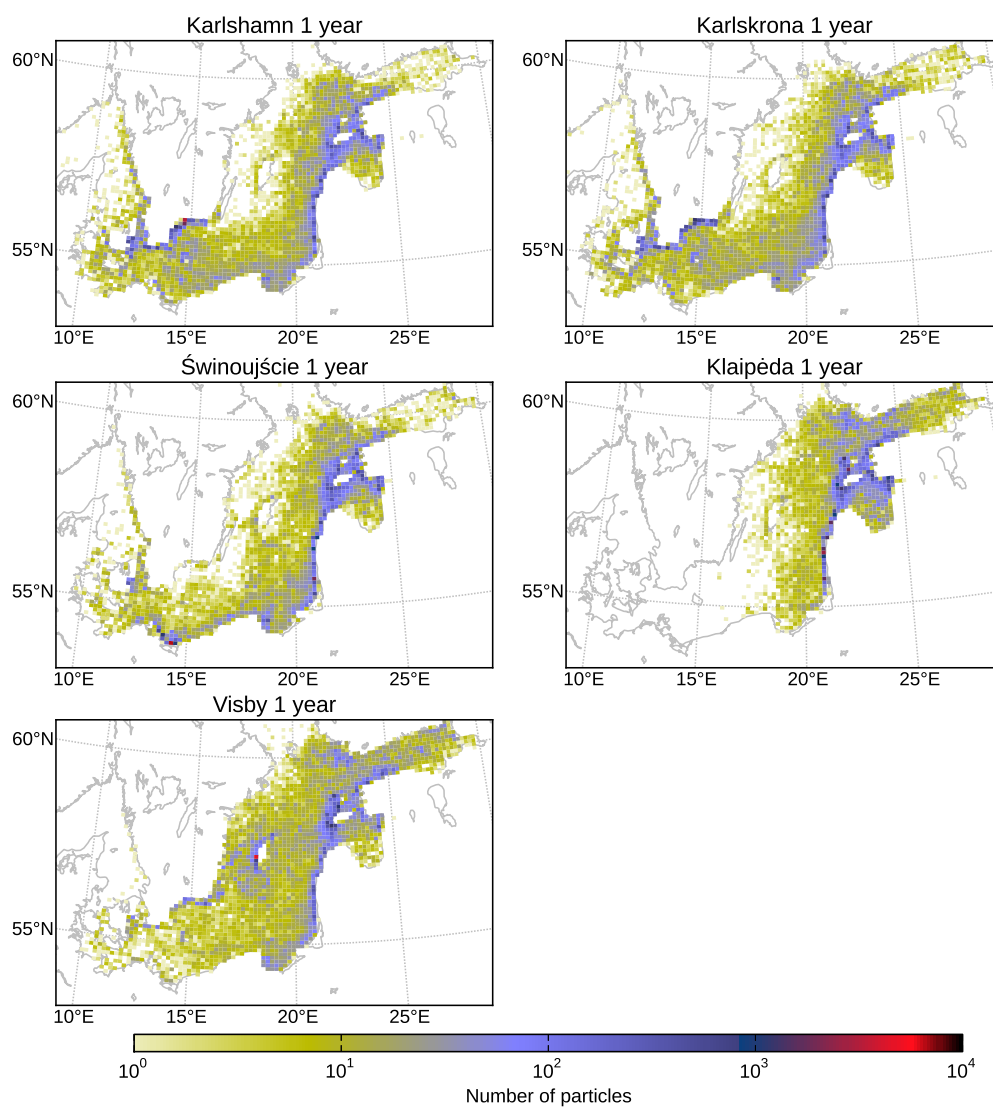


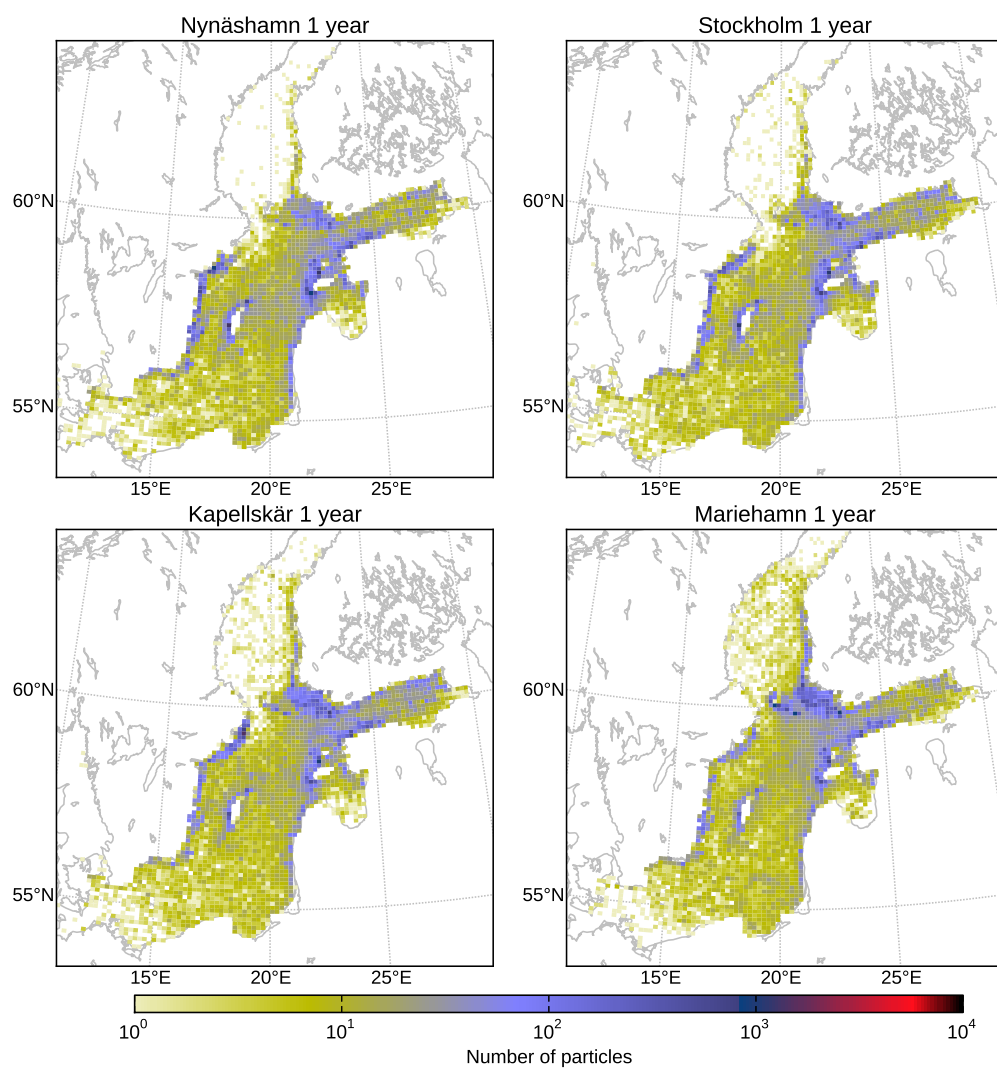


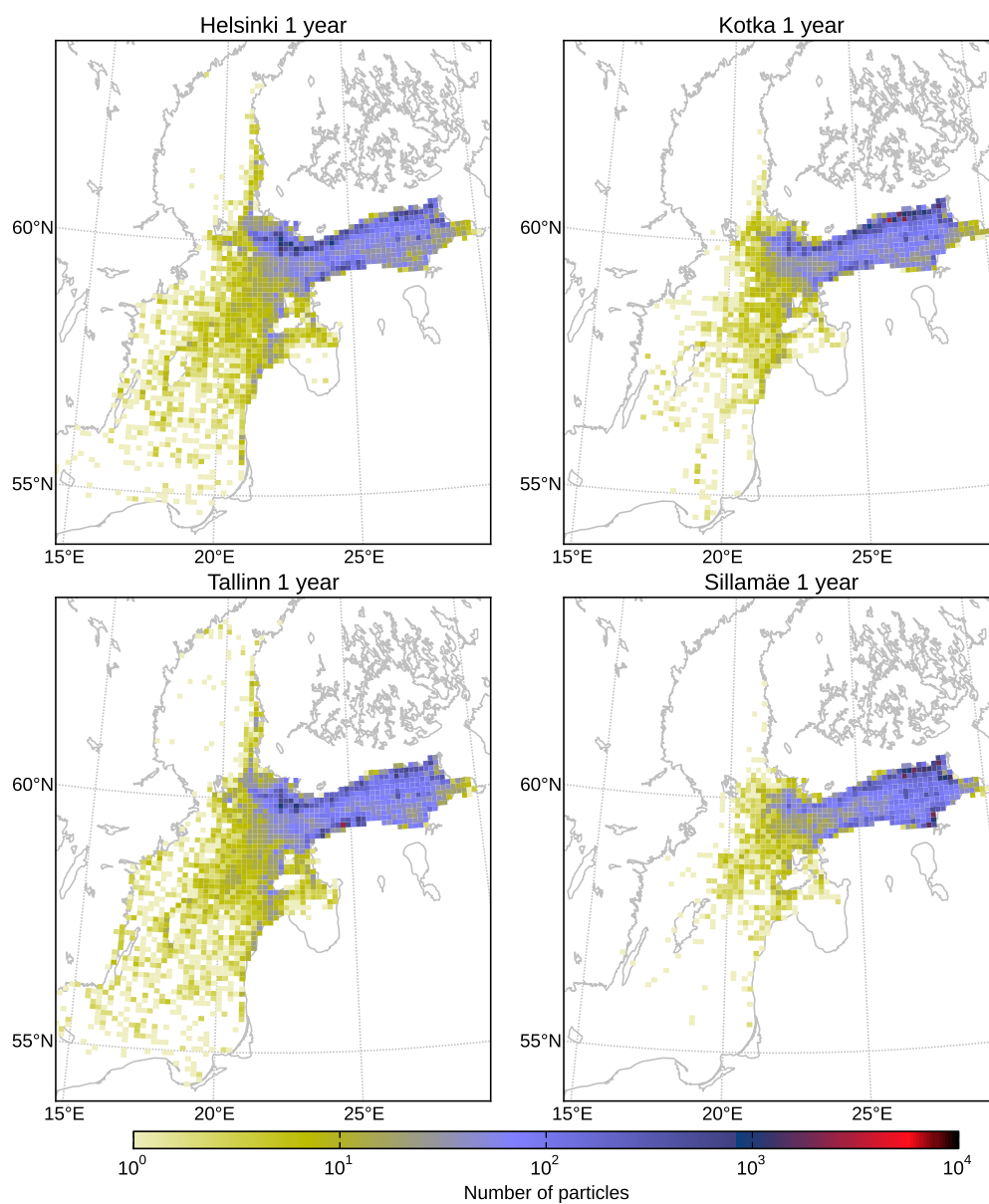


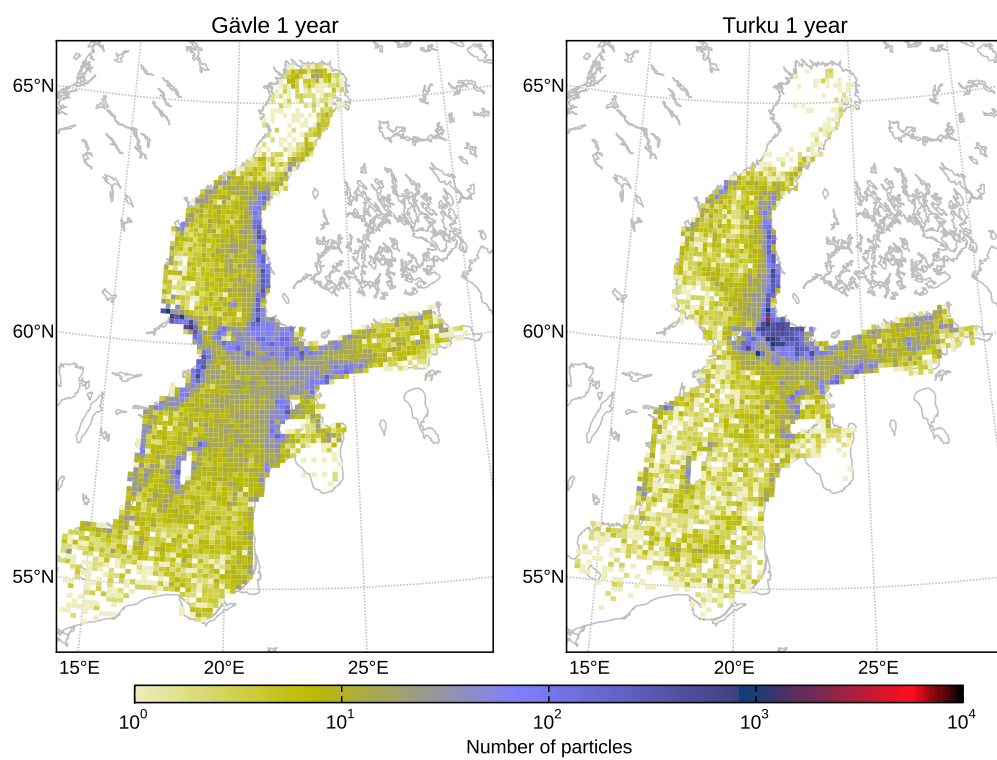


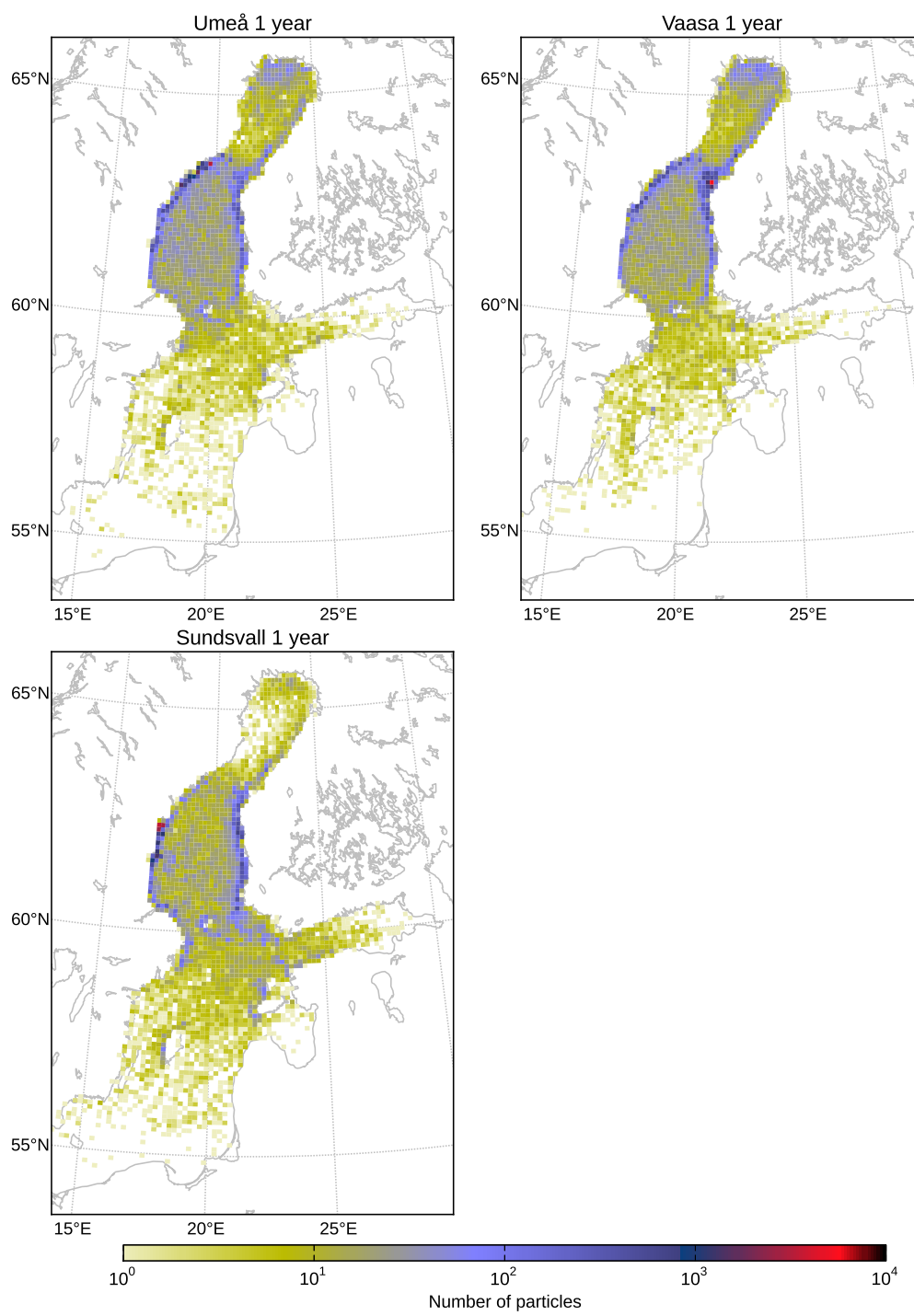


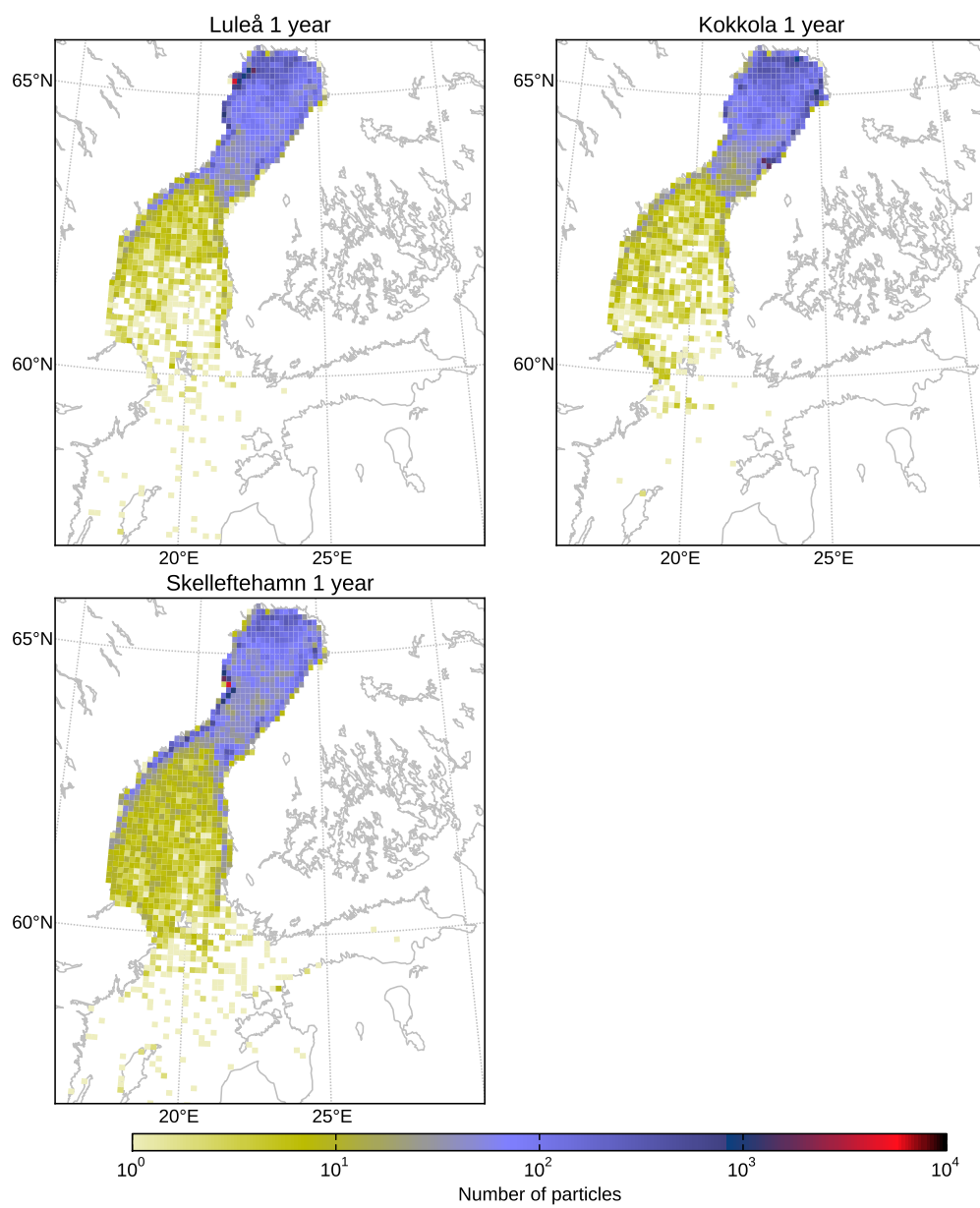












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