CLAIM

CLEANING LITTER BY DEVELOPING AND APPLYING INNOVATIVE METHODS IN EUROPEAN SEAS

Managing plastic litter in the marine environment with the help of ocean models

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Problems to be answered in CLAIM related to modelling

1. What are the spatiotemporal features of micro- and macroplastics in Baltic and Med. Sea?
2. Which important processes are behind the features?
3. Can we simulate these processes by using models?
4. Can we predict the heavily polluted areas?

Solutions:

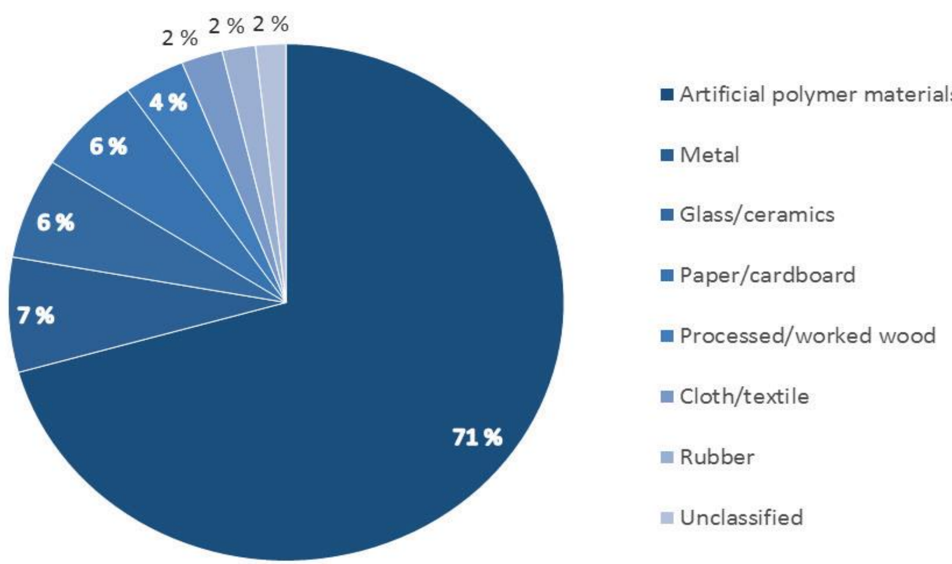
1. Comprehensive observations: historical data collection, cost-effective monitoring using ferrybox
2. Observation analysis
3. Developing proper modelling tools to perform realistic simulations of the drift of macro- and microplastics

Visible plastic litter: composition

- **Visible plastics**
  - 15% on beach
  - 15% in water
  - 70% at sea bottom
- **Danish & OSPAR monitoring results:**
  - 71% is plastic litter
  - Skagerrak is significantly higher than Baltic Sea and Inner Danish Waters

Table 3.1. Reference levels for amounts of litter items per survey (median numbers and range) registered from 100 m stretches on the five reference beaches each monitored three times in 2015.

	Baltic Sea and inner Danish waters			North Sea and Skagerrak	
Marine litter category	**Pomlenakke**	**Kofoeds Enge**	**Roskilde Bredning**	**Nymindegab**	**Skagen**
Plastic and polystyrene	17 (15-41)	65 (45-167)	31 (19-150)	188 (158-347)	2562 (1703-7813)
Rubber	3 (0-4)	2 (1-4)	2 (0-2)	25 (9-28)	68 (68-251)
Cloth	0 (0-5)	2 (0-3)	1 (0-3)	3 (0-6)	5 (0-31)
Glass and pottery	17 (11-21)	3 (0-4)	1 (0-1)	3 (1-6)	50 (28-67)
Sanitary waste	0 (0-1)	1 (1-4)	0 (0-0)	12 (4-12)	371 (245-767)
Medical waste	0 (0-0)	1 (0-1)	0 (0-1)	0 (0-1)	12 (6-28)
Paper and cardboard	1 (0-3)	5 (2-8)	1 (0-8)	3 (3-4)	5 (0-7)
Wood (machined)	2 (1-3)	8 (8-14)	9 (5-16)	16 (6-19)	29 (21-102)
Metal	2 (1-2)	4 (4-5)	1 (0-12)	2 (0-4)	19 (8-45)
Soild pollutants	0 (0-1)	0 (0-0)	0 (0-0)	2 (0-5)	16 (15-43)
Other materials	0 (0-0)	0 (0-2)	0 (0-0)	0 (0-2)	0 (0-0)
Total item numbers	**43 (35-73)**	**93 (67-204)**	**39 (31-193)**	**265 (191-413)**	**3102 (2146-9137)**



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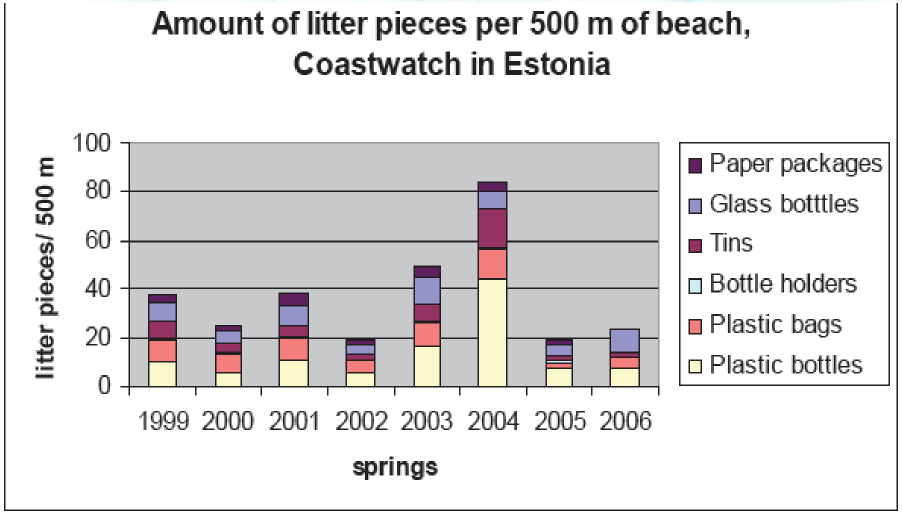
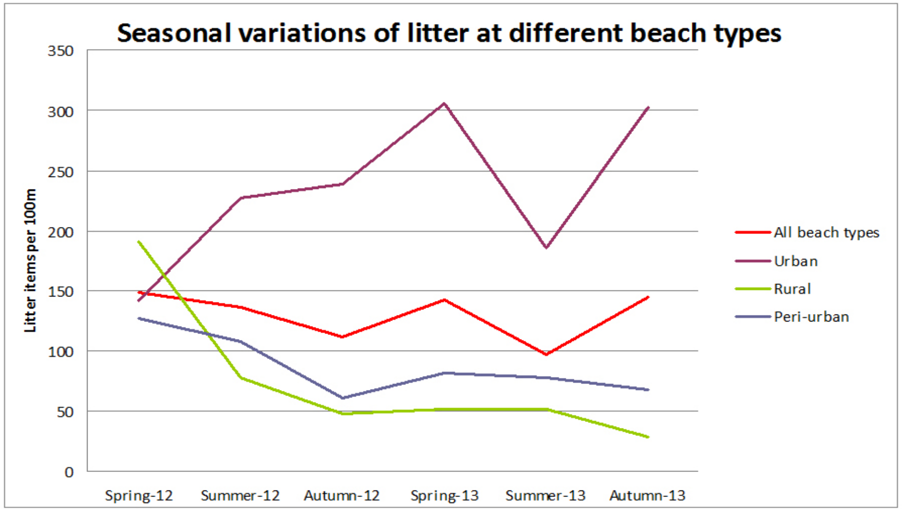
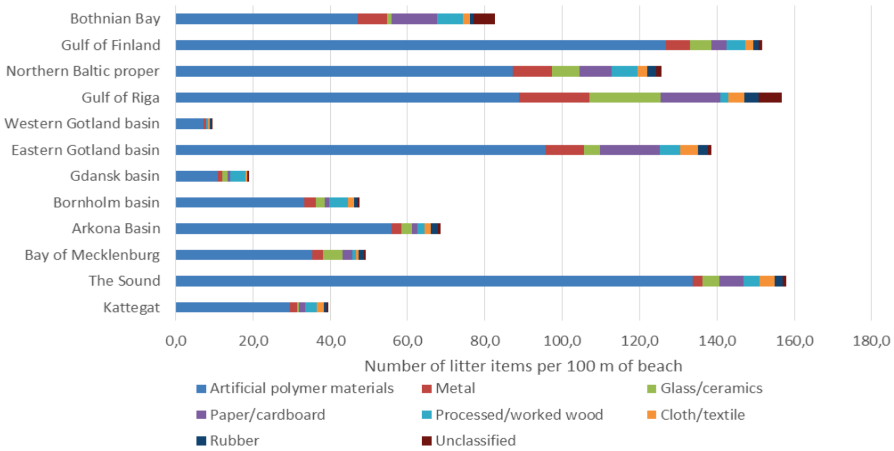
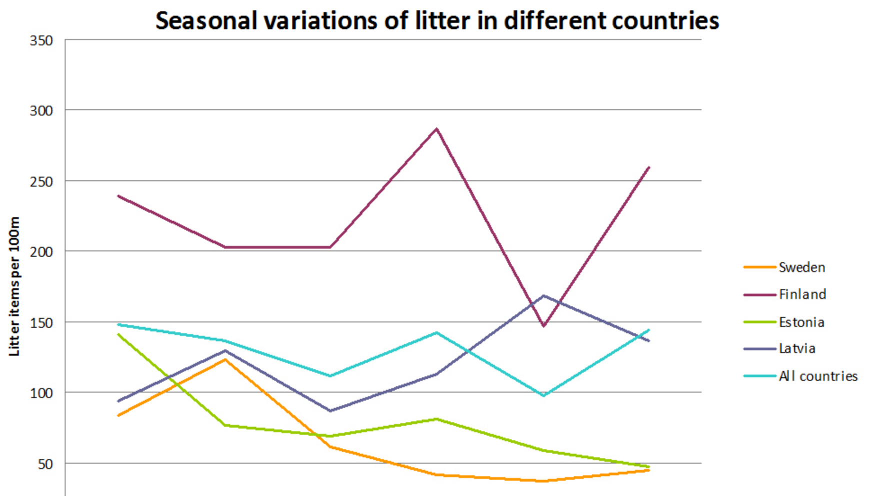
Beach litters: spatiotemporal distribution



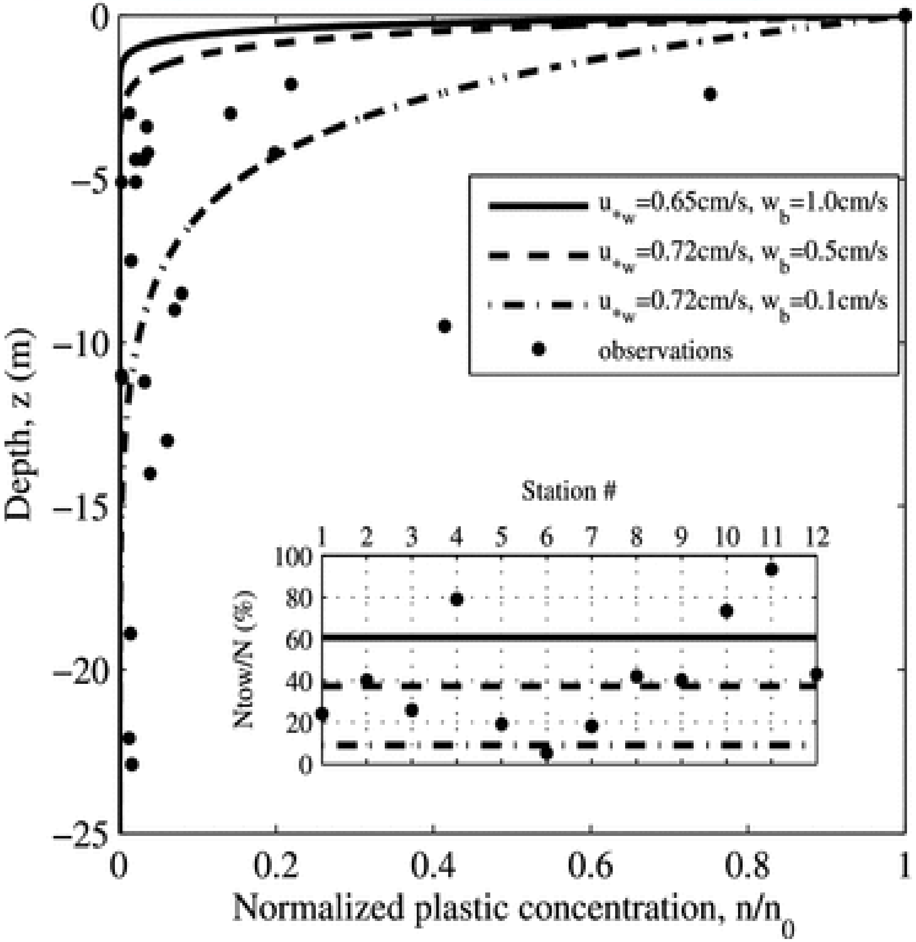




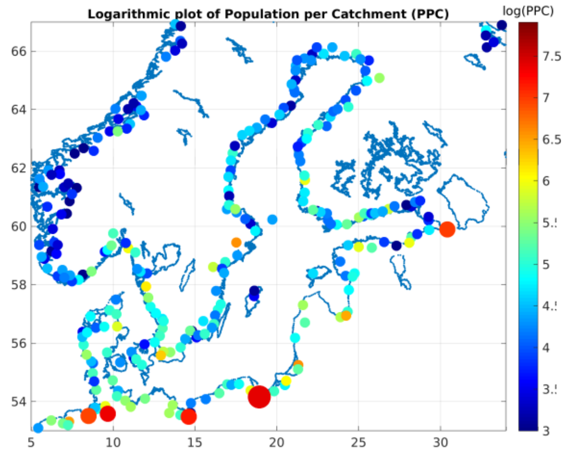


Microplastic litters

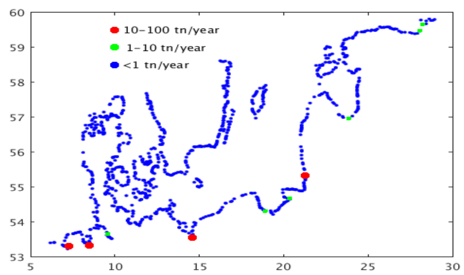
- **In the water column**
  - Surface concentration >> subsurface concentration
  - Almost no change in the past 30 years
- **In the sediment**
  - ~50-10^3 particles per kg in sediment, thousands of times higher than that in the surface
  - highly correlated to TOC in sediment

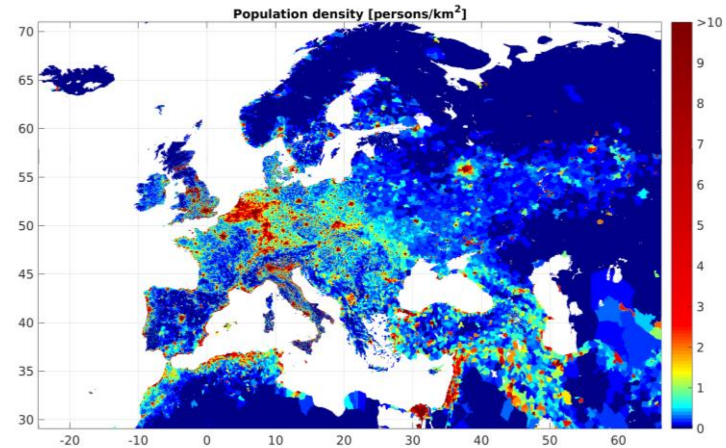


Source mapping in the Baltic Sea



Estimated Baltic Sea Input:
Magnusson & Wahlberg 2014





River inputs: Integrated population density over the area of the catchment (E-HYPE)

Inputs into the sea

- River inputs of miss-managed plastics
- Direct dicharge – coastal catchments (near coastal waste water treatment plants, hotels, marine traffic.

1. River Inputs: estimated from

- population density (person/km2)
- Plastic waste production in the catchment (kg/person/day)

2. Waste Water Treatment Plants: estimated from population/discharge and type of treatment

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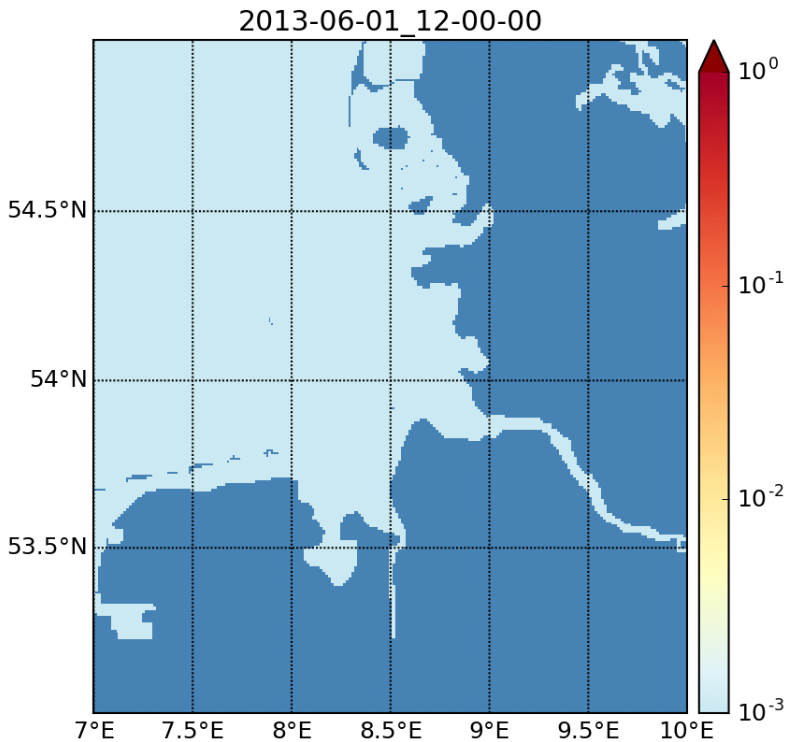
Modelling approach, Overview

In the Baltic Sea

Micro Plastics (≤5mm), DMI	Macro Plastics (>5mm), DTU-Aqua
Eulerian Passive tracers	Lagrangian Particles
Large number of particles with well defined properties (sinking, etc.)	Limited number of particles that might change their properties (degradation) and are allowed to interact with each other.
Modelling concentrations	Modelling particle trajectories
HBM	Individual Based model (IBM)
Key processes: • Small scale eddies & river plumes • On-shore or long-shore transport caused by waves • Biofouling • Resuspension • Vertical mixing	**Key processes**: • Direct wind forcing • Small scale eddies & river plumes • On-shore or long-shore transport caused by waves • Beaching (landing & re-activating)



Eulerian drifter experiment for the river Elbe.
Courtesy Thorger Brüning (BSH)

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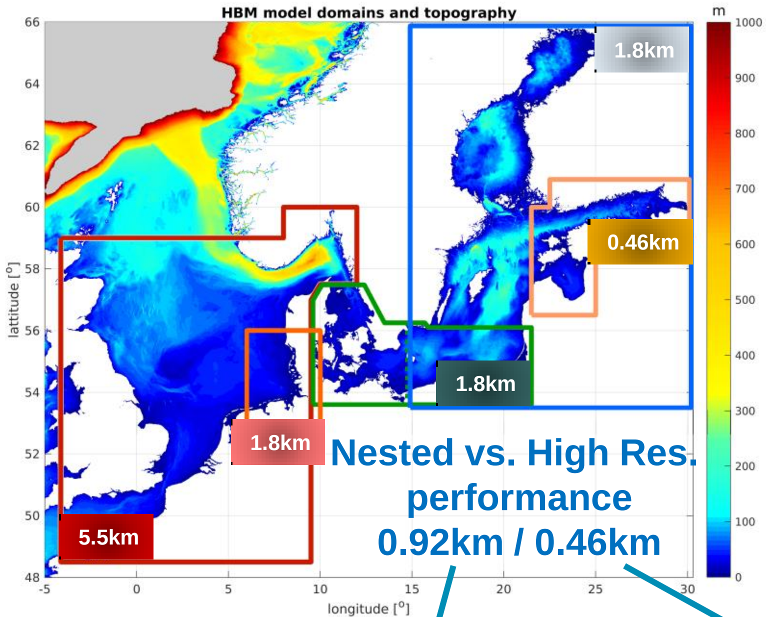
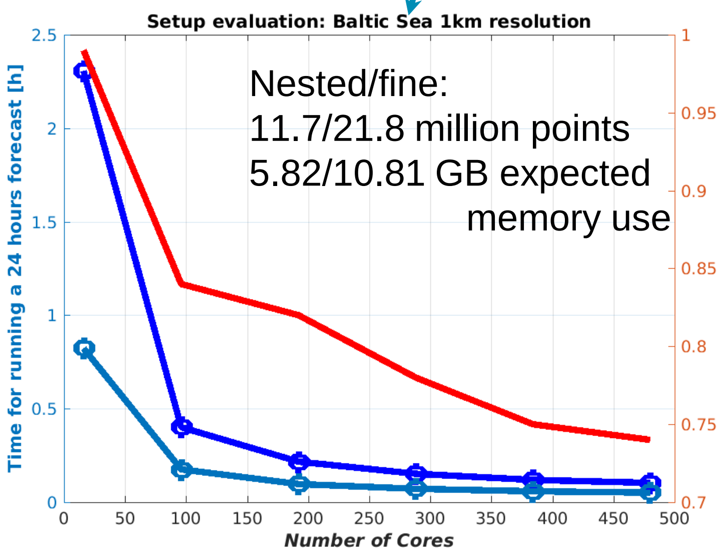
HBM's capabilities for running extensive set-ups

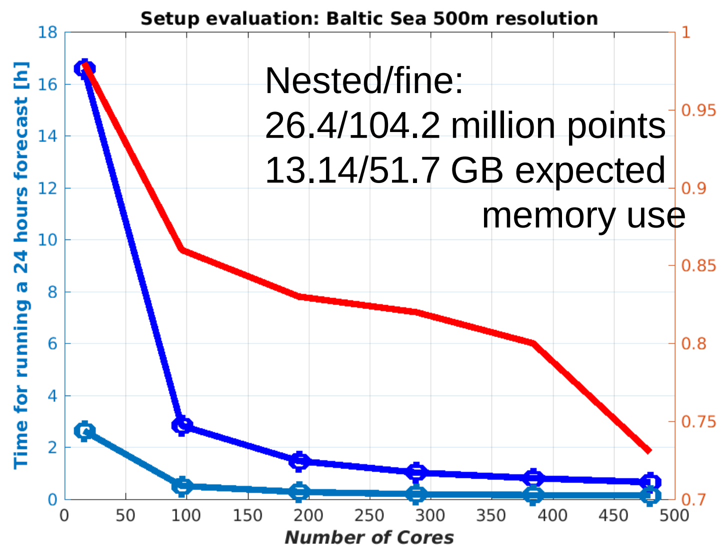


Nested vs. High Res. performance 0.92km / 0.46km

These results represent artificial test cases, coarse grid set-ups scaled up in resolution.

Realistic 0.92km BS setup requires 7-8min for a 24h run with 320 cores (20 nodes) on DMI's current HPC system.





Nesting efficiency (red): Ratio of *achived-to-potential* run time improvement

John Michalakes (NOAA)

Inter- and intera-basin water exchange

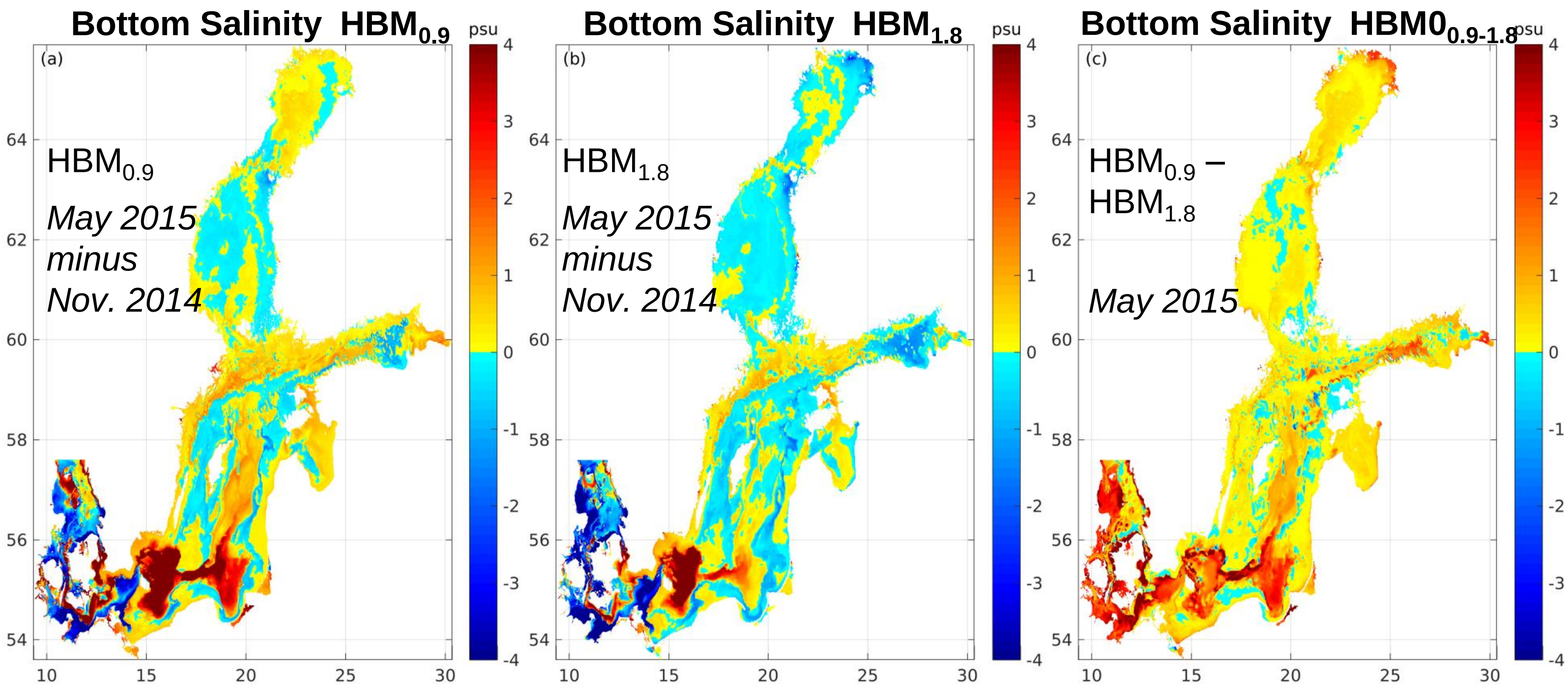


Fig. 1. Impact of model resolution on the Baltic inflow - bottom salinity difference (a) before and after the Major Inflow Event 2014/15 HBM0.9; (b) same as in (a) but for HBM1.8 (c) between HBM0.9 and HBM1.8 after the major inflow event (31-th May 2015).

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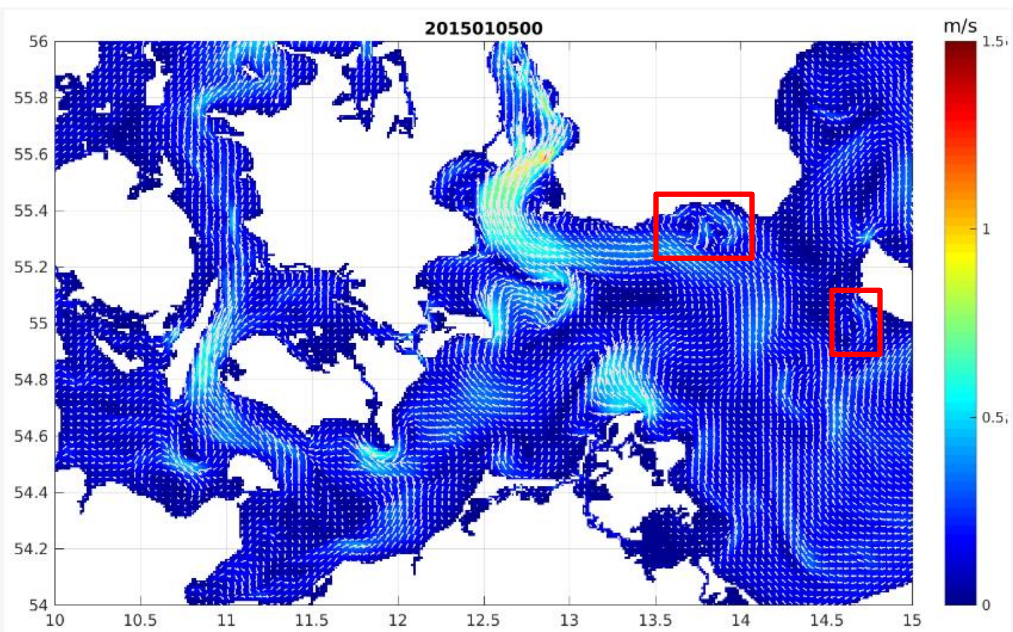
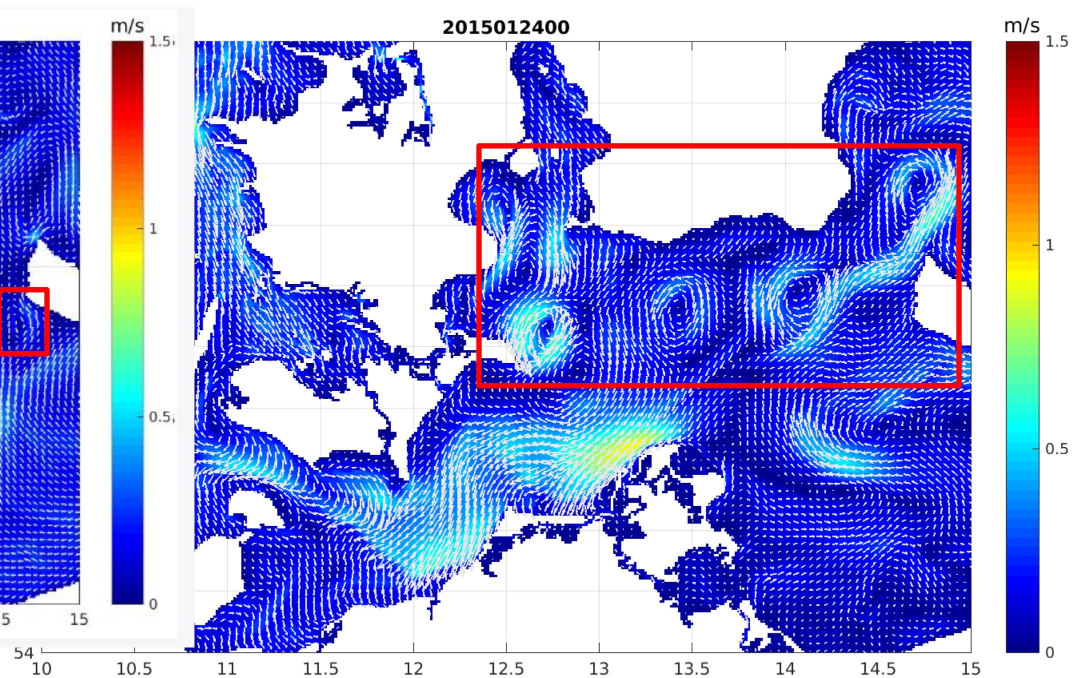
Meso-/submeso-scale eddies in a 0.9km reso. HBM

- Submesoscale eddies: <10km

Mesoscale eddies: ~20km size

- HBM model: 0.9km resolution, surface curent maps
- How many points are need to resolve an eddy? Min. 10 points



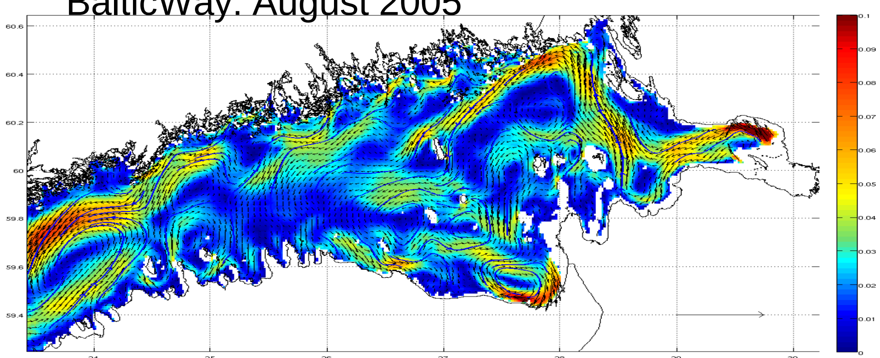


River Plume modelling

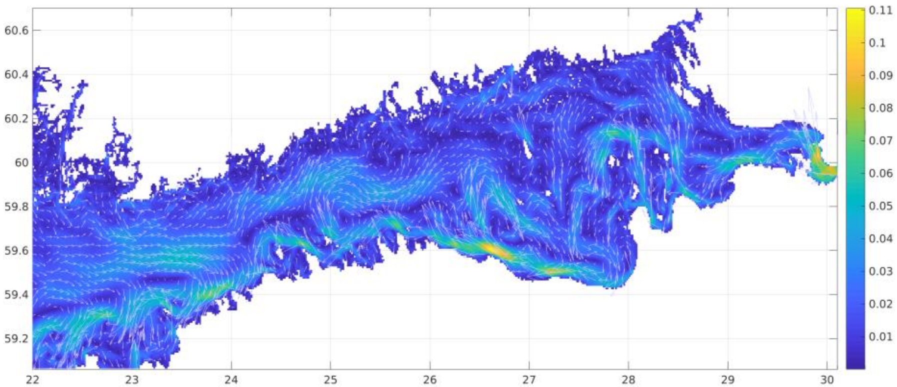
Improve river plume modelling, example Neva river.

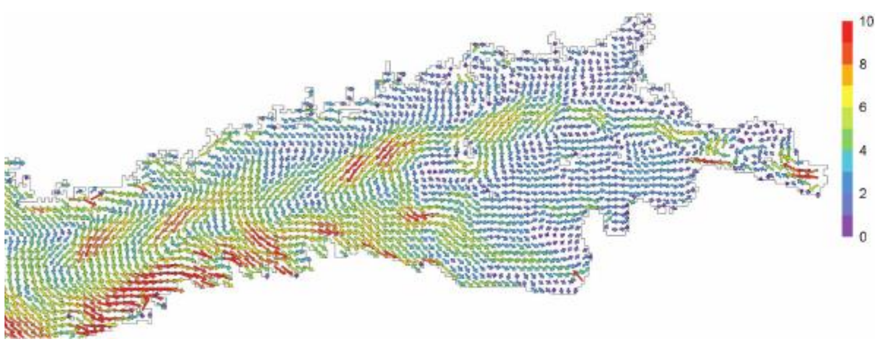
- Improve model bathymetry (BalticWay, ≈460m bathymetry)
- Model tuning – wind drag coefficient
- Extend model run to cover a longer period.

BalticWay: August 2005



Gulf of Finland
Annual mean sub-surface currents 2015 (2.5m depth)





5 years mean sub-surface mean currents, Oleg Andrejev ”Mean circulation and water exchange in the Gulf of Finland – A study based on three-dimensional modelling”

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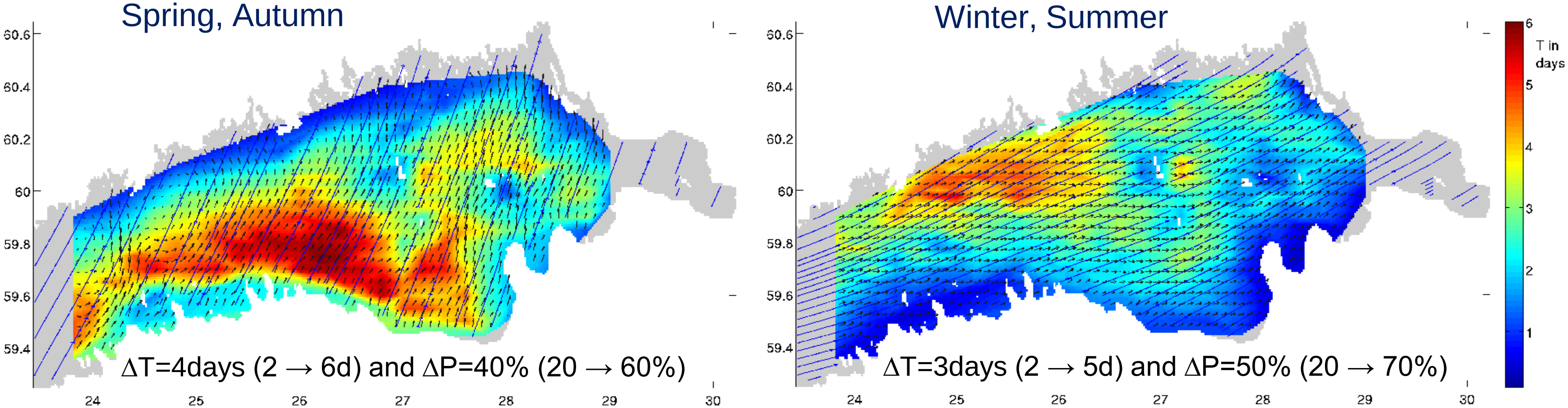
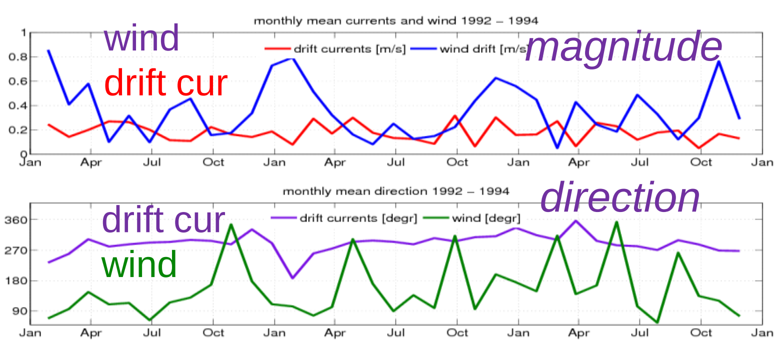
Challenge1: Wind forcing
Seasonal oil drift pattern in the Gulf of Finland

Oil residence time at sea (BalticWay project)





Wind forcing:

- *Oil drift model use a fraction of 3% to 3.5% of the wind speed in the direction of the wind.*
- *Wind forcing in spring/autumn/winter seasons is significantly stronger than forcing induced by currents.*

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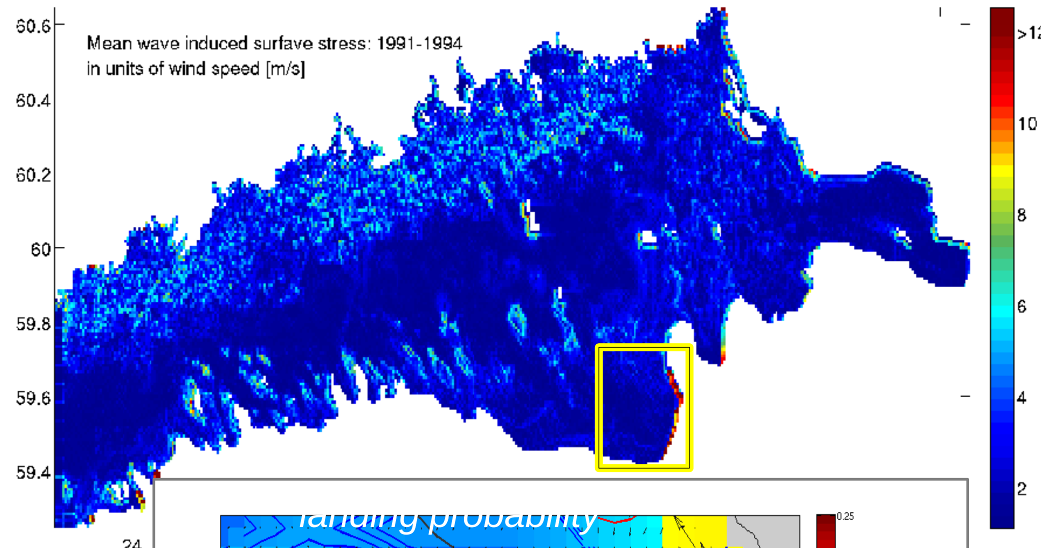
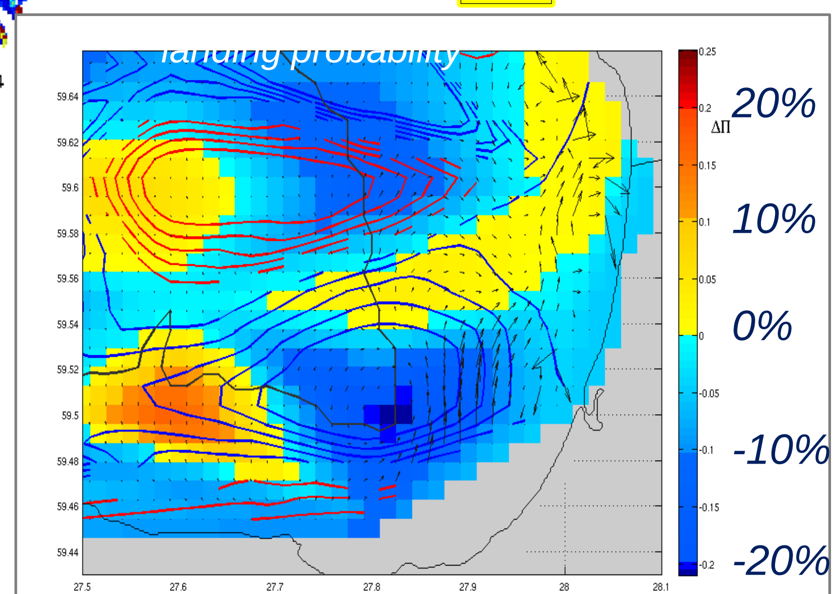
Challenge2: wave induced drift
Wave impacts on oil drift pattern

1. *Waves generate additional drift currents of locally up to 1 cm/s in the Gulf of Finland (2 cm/s during storms).*
2. *Wave induced oil drift increases onshore oil advection:*

- *Under average conditions (1992 annual mean) local wave induced oil residence time and landing probability differences of 5h to 7h and 10% have been modelled.*
- *During extreme events (storm surge 7-th to 12-th Jan. 2005) wave induced oil drift accounts for residence time differences of maximal 2 days.*





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Challenge3: Vertical dynamics of micro plastics, biofouling

(1.) Vertical Dynamics of micro plastics in the Baltic Sea

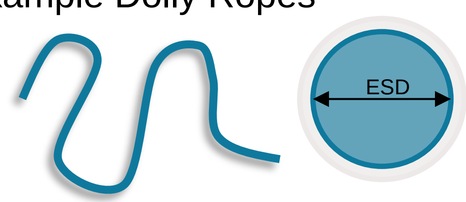
SPM, Suspended Particular Matter model:

- Includes sinking and wave dependent upwards mixing, as well as
- Sedimentation / resuspension / errosion of fine sediments at the sea bed.

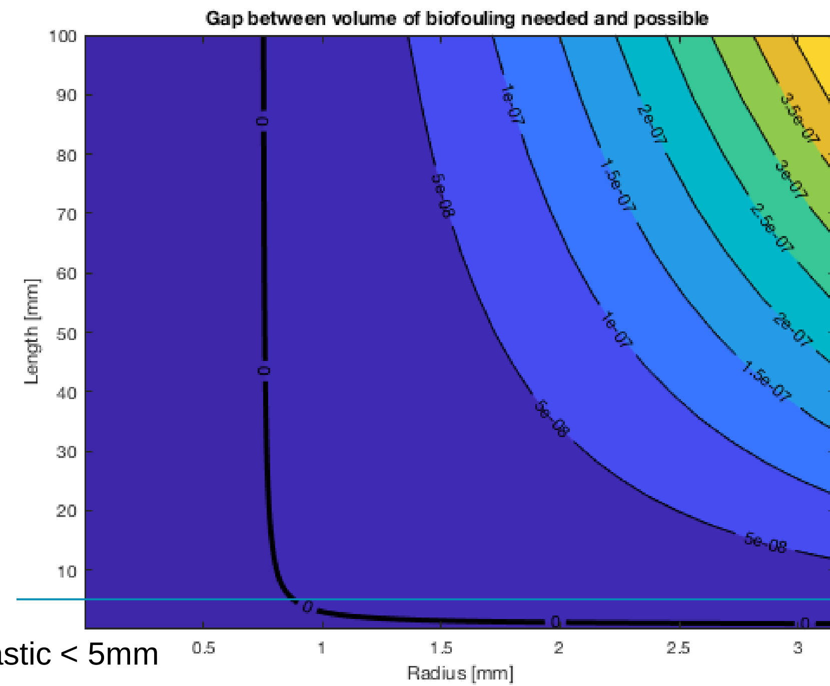
(2.) Biofouling:

- Most of the plastic ending up in the ocean is buoyant
- But less than 1% of the plastic pollution is found at the surface
- Biofouling is a size selective process that removes small plastic particles (<2.5mm) from the surface

Example Dolly Ropes



ESD: estimated spherical diameter



micro plastic < 5mm

Figure: Volume of biofouling required for sinking.
Explanation: Biofouling~surface, buoyancy~volume
Surface/Volume ratio increases with decreasing particle size.

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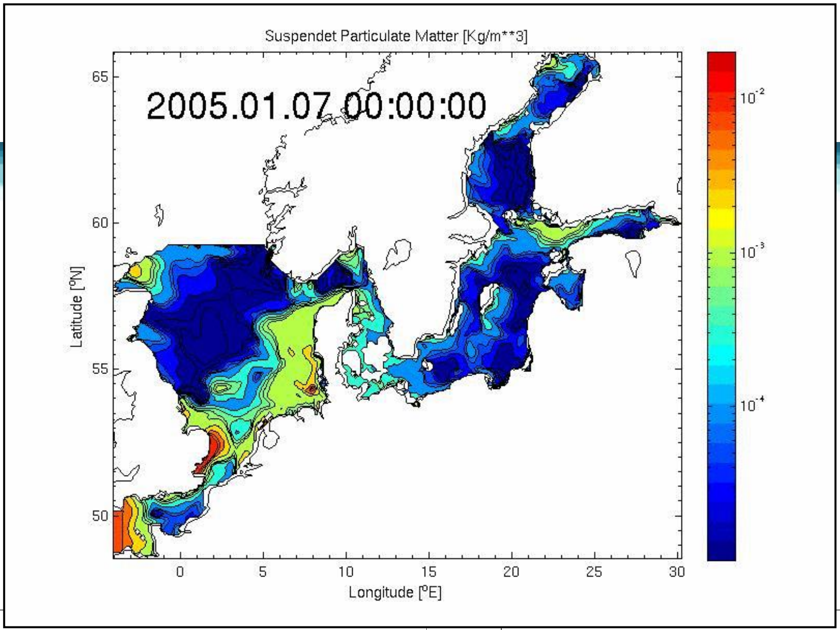
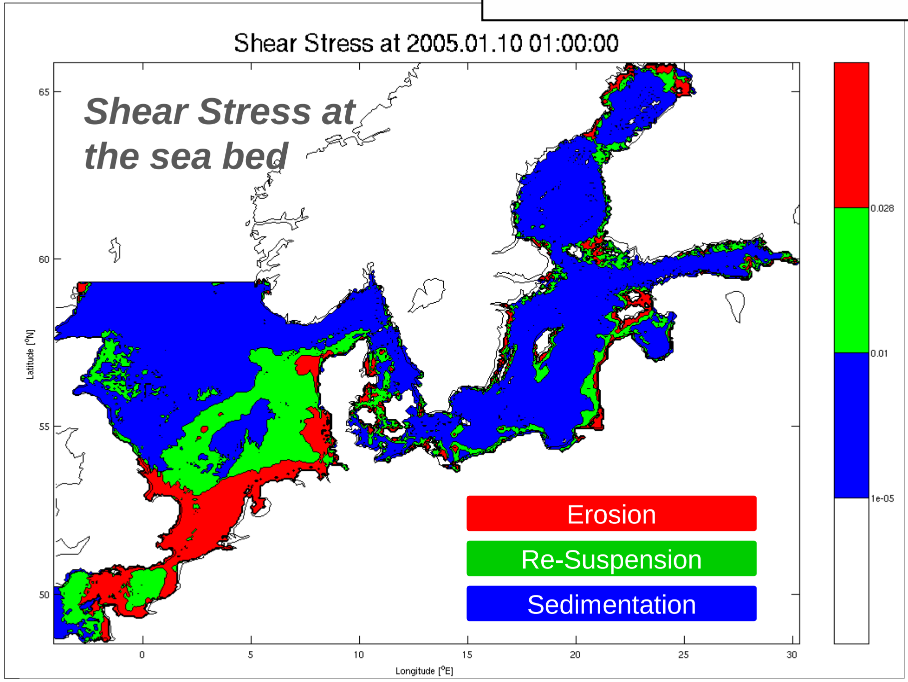
Sinking and upwards mixing of micro plastics

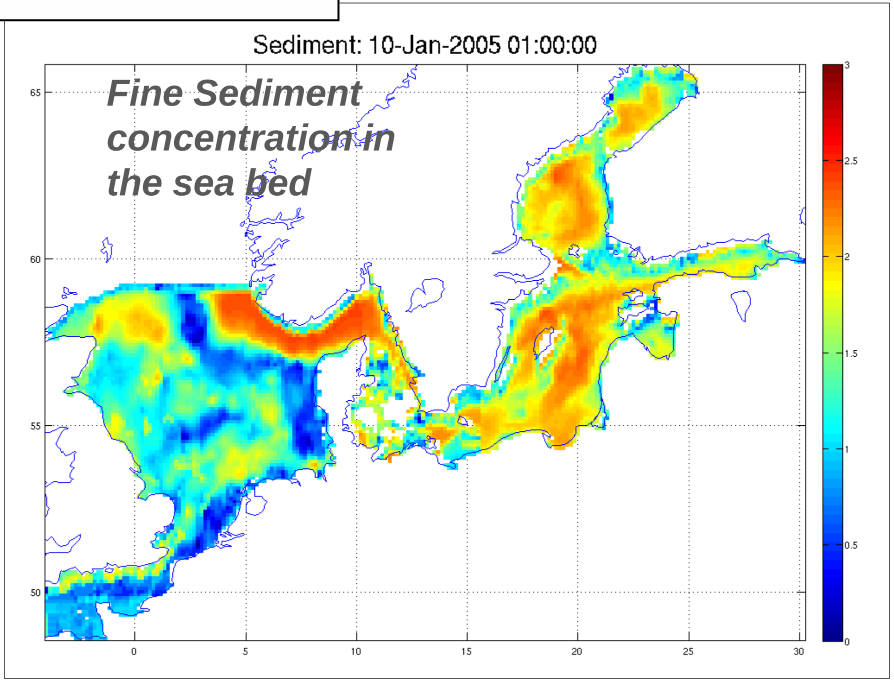
SPM model



3 SPM fractions:
$w_{sink}(f_1)=0.0001$ m/s
$w_{sink}(f_2)=0.00002$ m/s
$w_{sink}(f_3)=0.001$ m/s

Processes:
- Sinking versus mixing
- Advection
- Sedimentation
- Re-suspension
- Erosion
- Consumption
- Bioturbation



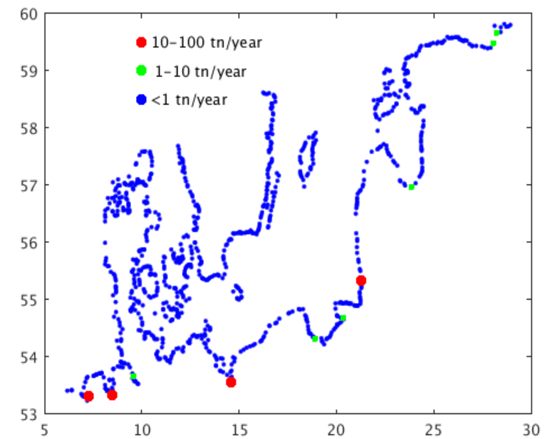


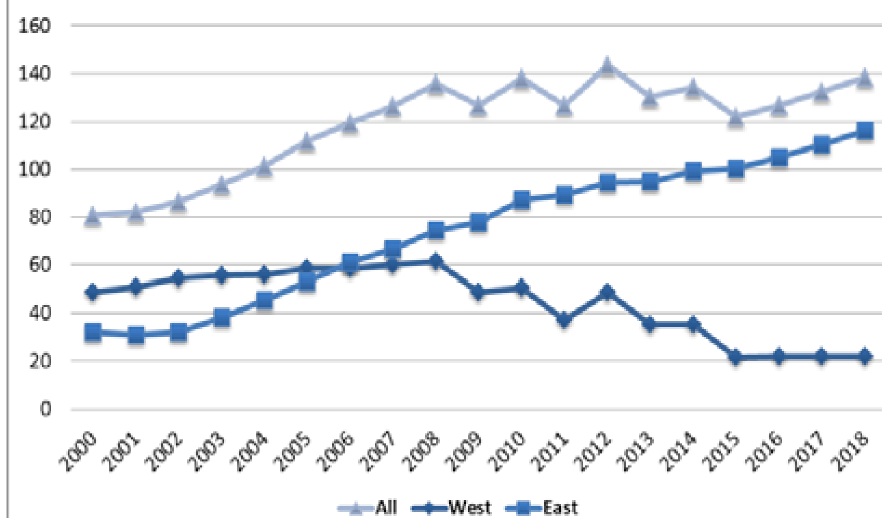
THANK YOU

QUESTIONS?

Source of microplastic litter

- Effluents from waste water treatment plants: (Magnusson & Wahlberg 2014)
  - Inlet water: 7,000–30,000 particles (>300 µm) and 60,000–80,000 particles (>20 µm) per cubic meter
  - Outlet water: 1–100 particles (>300 µm) and 1000–10000 particles (>20 µm) per cubic meter
- ~130 tons/yr of polyethylene particles from personal care products. 10-30% of them are released into the sea.
- 48% of marine litter in the Baltic Sea originates from household-related waste, while waste generated by recreational or tourism activities would add up to 33%





Use of microplastic particles in personal care products in the Baltic Sea catchment (Euromonitor 2015) in tons per year (*2014-2018 forecasts*)

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BalticWay: Oil drift model applications for safer fairways

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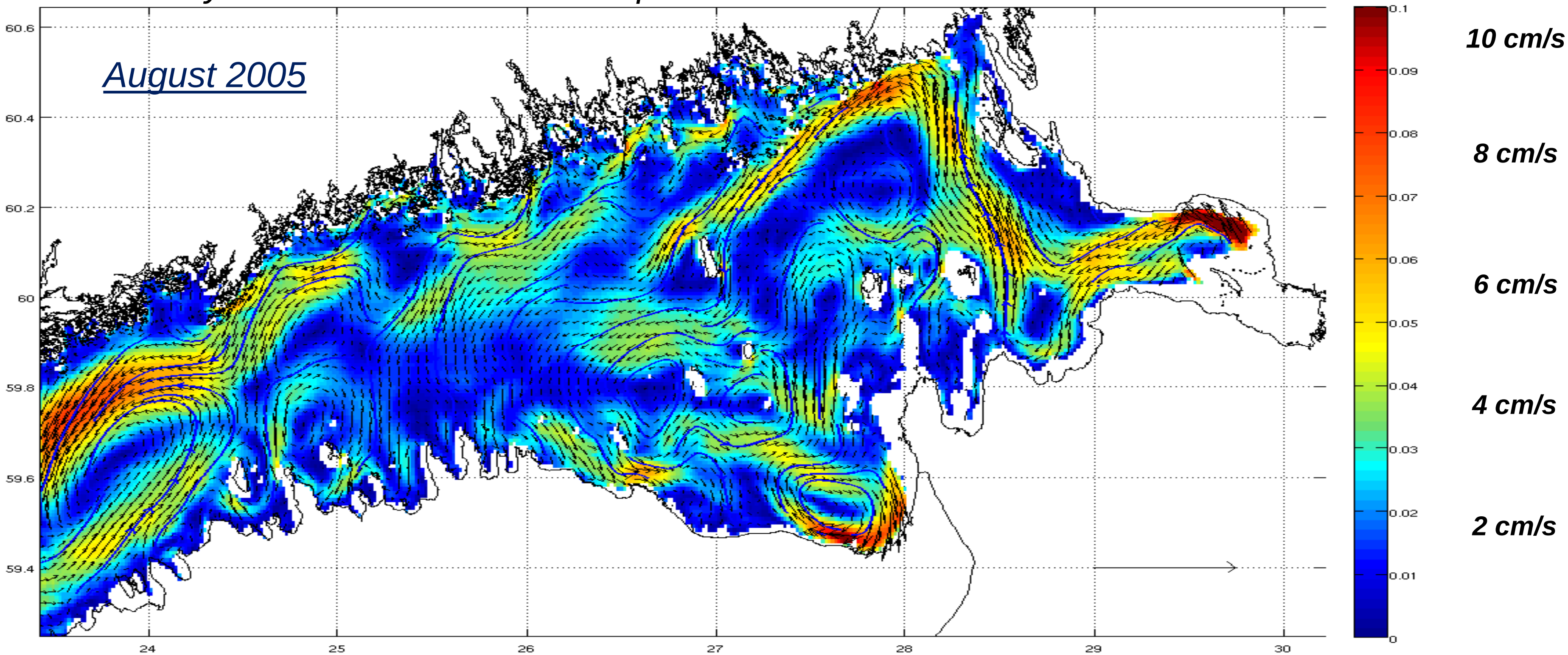
Monthly mean currents at 10m depth



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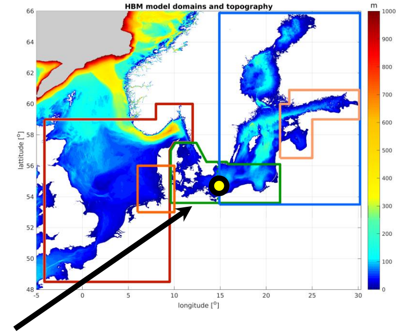
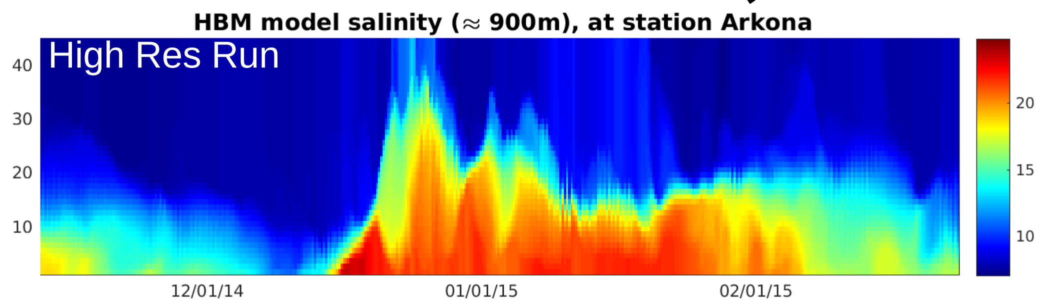
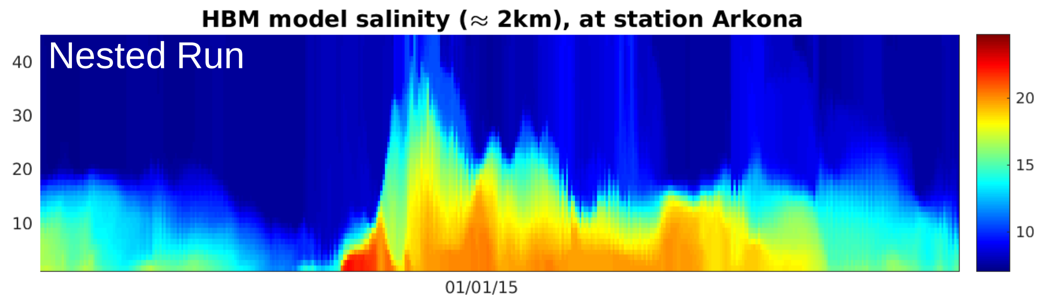
Baltic Sea inflow 2014/2015 at Arkona Station



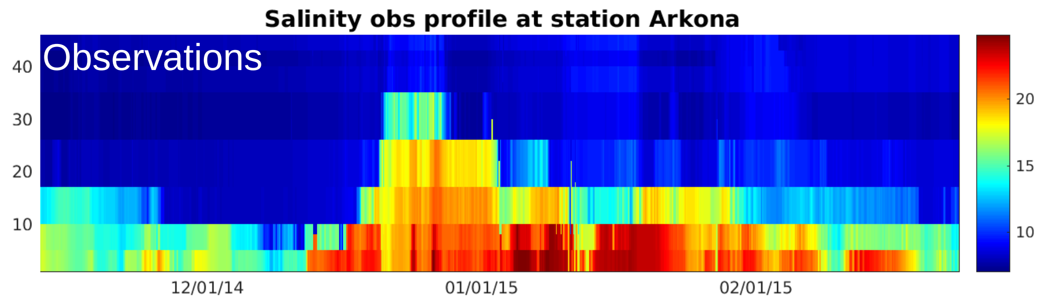
High Res Run:
Intensified salt water transport into the Baltic Sea.



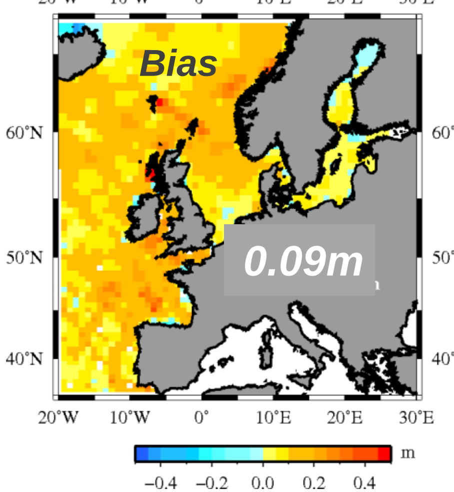
Nested Run:
The effect of the salt water intrusion is weaker, but all features are present.

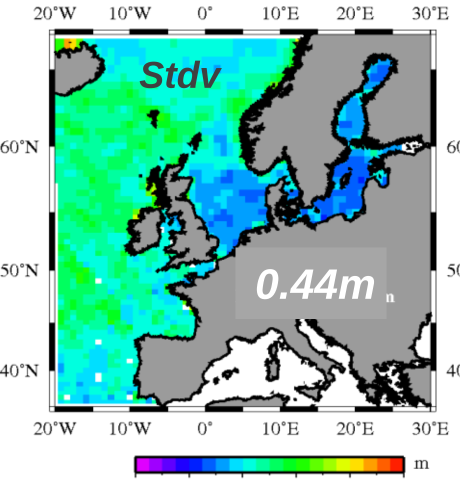


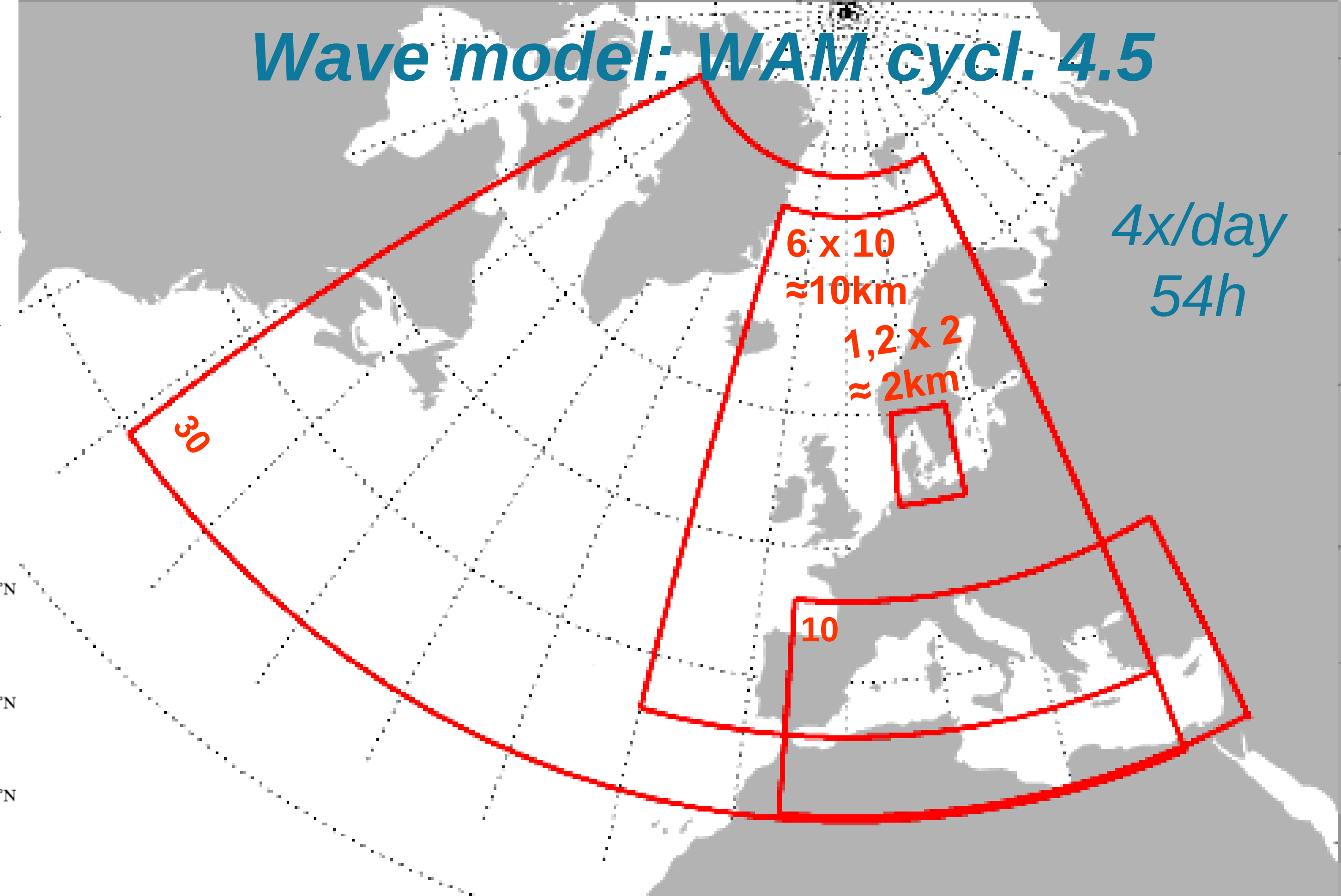
Observations:
Good agreement with model results

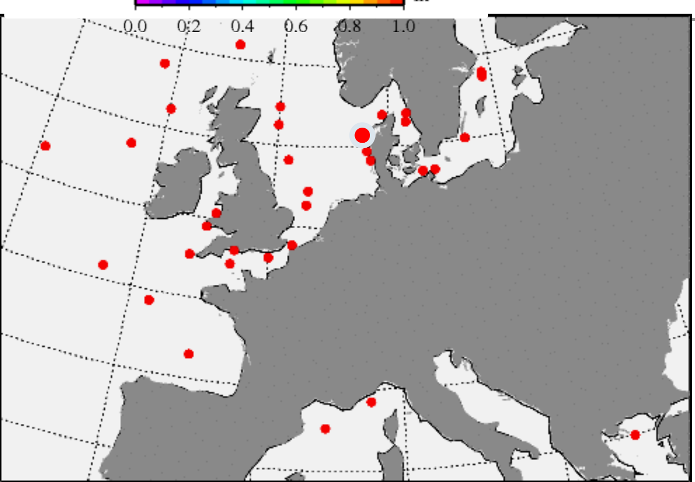


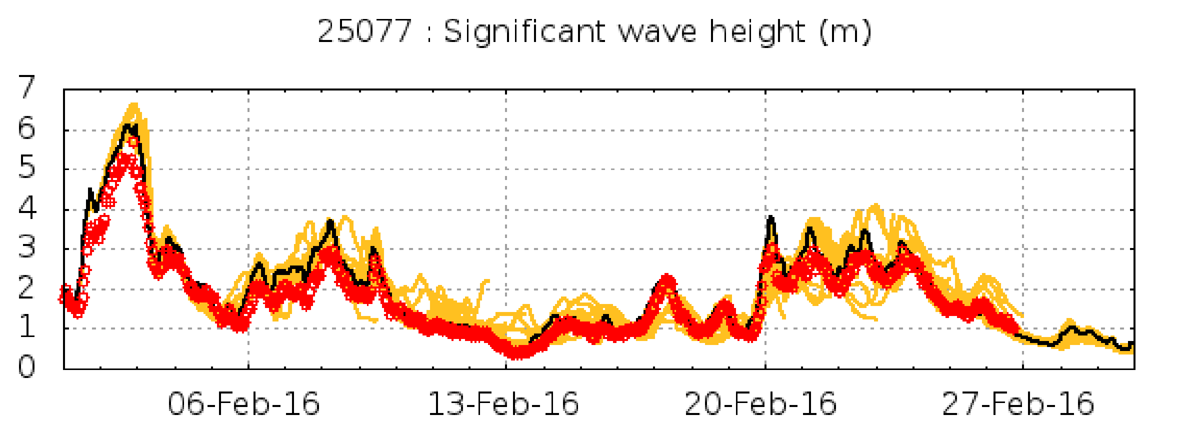
Wave model: WAM cycl. 4.5











Lagrangian modelling: DTU expertise and examples of work

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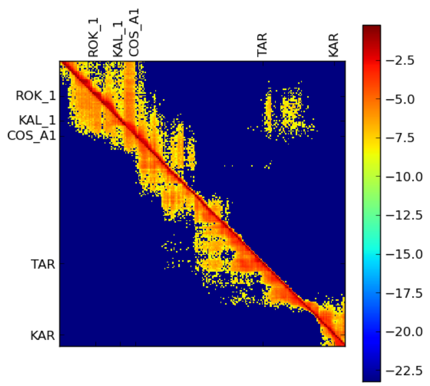
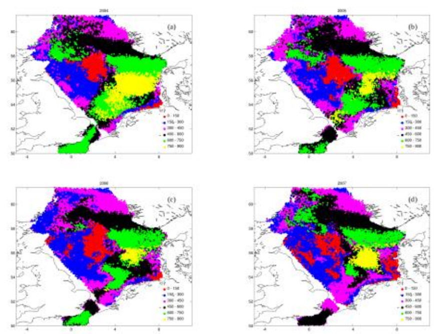
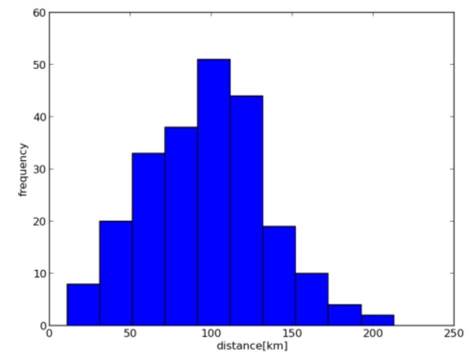
Expertise and background: DTU Aqua has a long experience in modelling organisms being transported by ocean currents and we develop software for doing this using different hindcast and real-time ocean currents data sets.



Coastal connectivity of the Black Sea based on Lagrangian modelling. Physical model: **BIMS-ECO**



Spatio-temporal variability of drift distance for cod larvae in the North Sea. Physical model: **NORWECOM**



Statistics of larval transport distance for plaice larvae in Kattegat. Physical model: **HBM-ERGOM**

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