Local scale oil spill modelling and risk assessment in seasonally ice covered seas

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Drive Folder with animations

Pollution mitigation concept

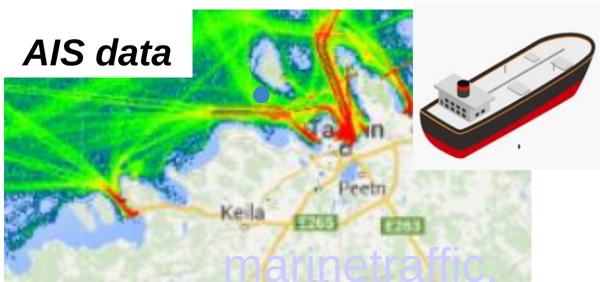
1

Oil spill Risk

= Probability *

Consequence

AIS data



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Output

Oil spill Location

Amount **1**

2

Transport and fate (models)

Currents, Ice (GETM)

Wind (HIRLAM)

Output

Trajectories (GITM)

Amount **2** ~ fate

3

SNEBA

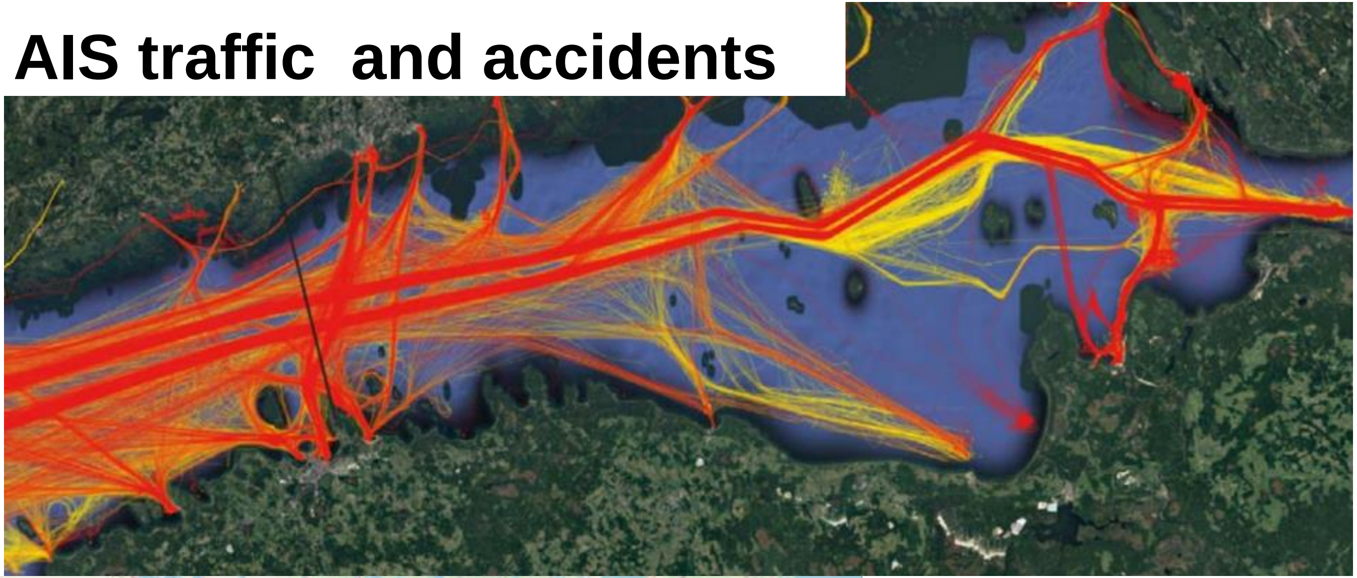
Assessment

- scenarios?
- vulnerability assessment
- response
- contam. Mitigation

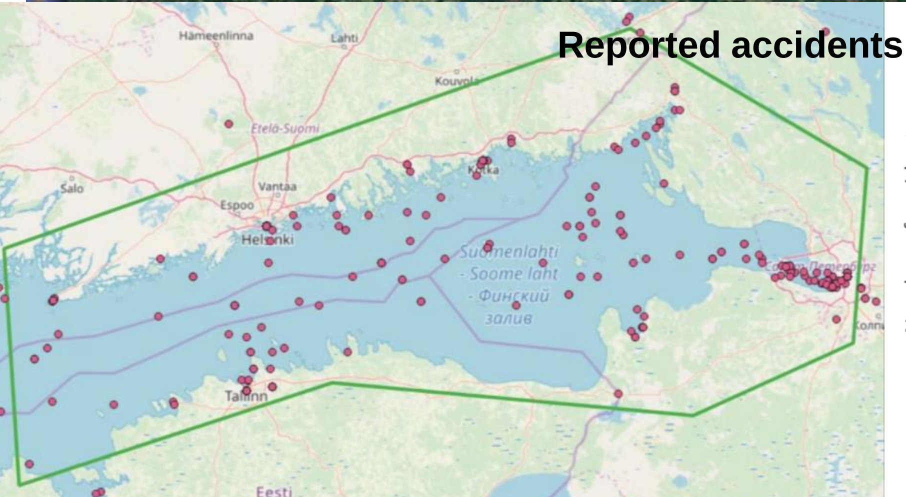
Output

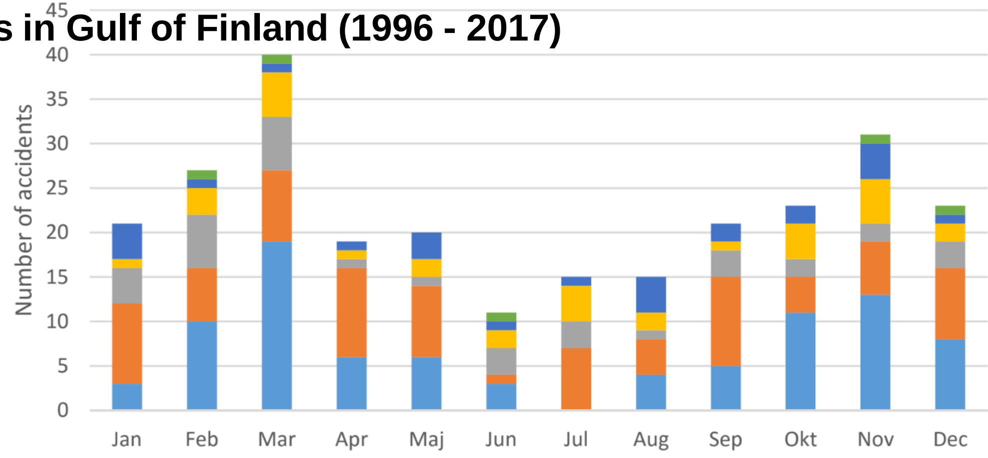
Action plan

AIS traffic and accidents



Reported accidents in Gulf of Finland (1996 - 2017)





Modelling Concept

Geophysical model

e.g SEATRACKWEB (NEMO-Nordic + PDAM)

- complex forcing F(t,x,y)
- 3D dynamics X_i(t,x,y,z)
- large domain

Forcing

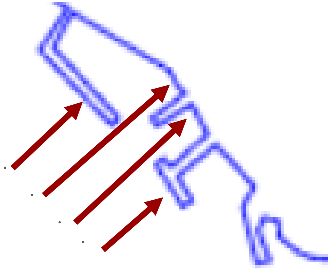
u,v

Enginering model

- simplified forcing $F_{const.}$,F(t)
- steady state
- limited area

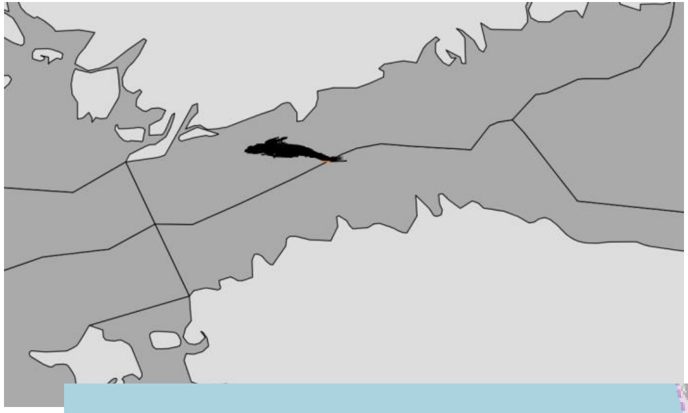
u,v

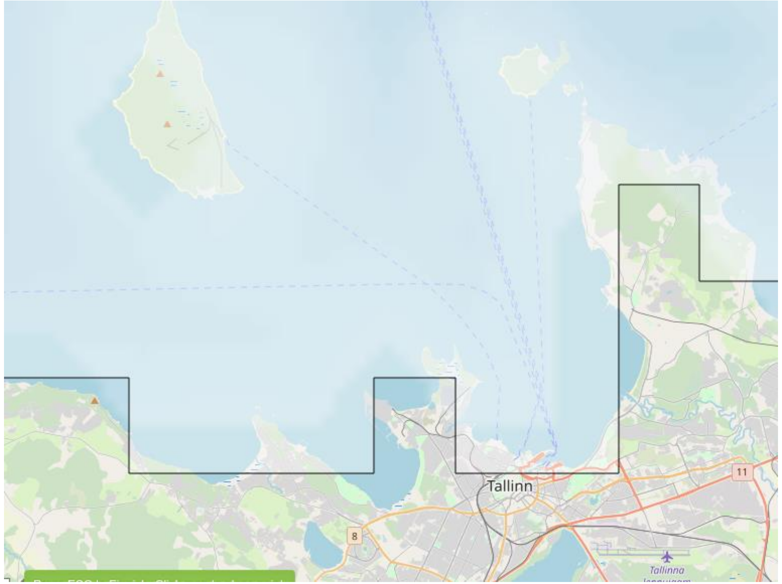
Forcing

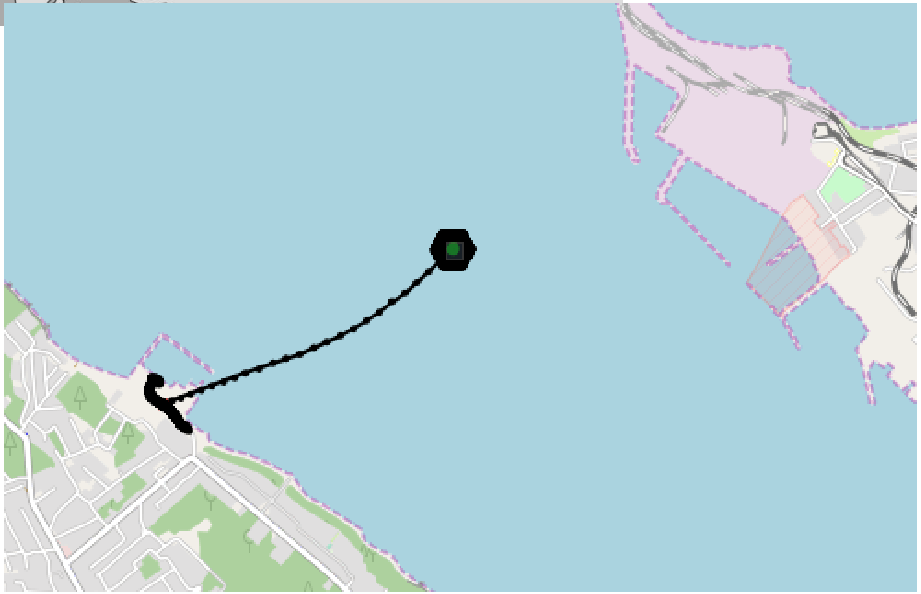


SeatrackWeb

Open sea oil spill







Model basics

General Individuals Transport Model

Lagrangian approach

Treat volume of oil as virtual particle

$$\partial_t C = -\nabla \cdot (\underline{u}\, C - \underline{K} \cdot \nabla C)$$

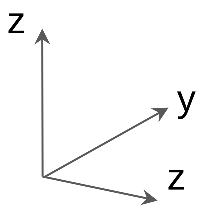
$$\nabla \cdot \underline{u} = 0$$

where **u** is the divergence free velocity field and **K** is the diffusivity, a symmetric and positive definite tensor. In the following only diagonal diffusivity tensors are considered with **K**h as horizontal and **K**z as vertical diffusivity.

$$d\underline{x}(t) = (\underline{u} + \nabla \cdot \underline{K})dt + \sqrt{2\underline{K}}\, d\underline{W}(t)$$

t2 t1

Particle n : x(t), y(t), z (t)



Particle Matrix - Lagrangian elementsd

Stores positions of particles, properties
Number of active particles in different

t1

N1	x	y	z	**ρ**	**ν**	age	m			
N2	x	y	z	**ρ**	**ν**	age	m			
...										
Nn1	x	y	z	**ρ**	**ν**	age	m			

t2

...										
Nn2	x	y	z	**ρ**	**ν**	age				

t3

…

Sinks and sources

<u>Removing particles</u>

- evaporation

- stranding

- sedimenting

- photolysis

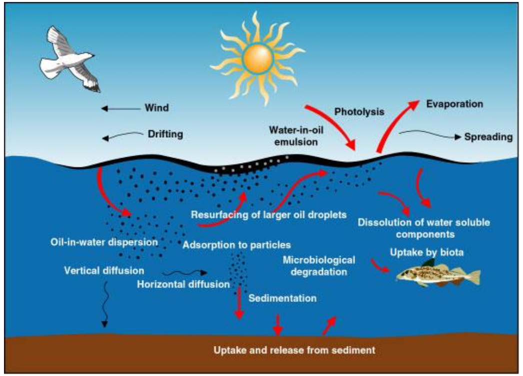
- use of dispersants

<u>Sources</u>

- initial release

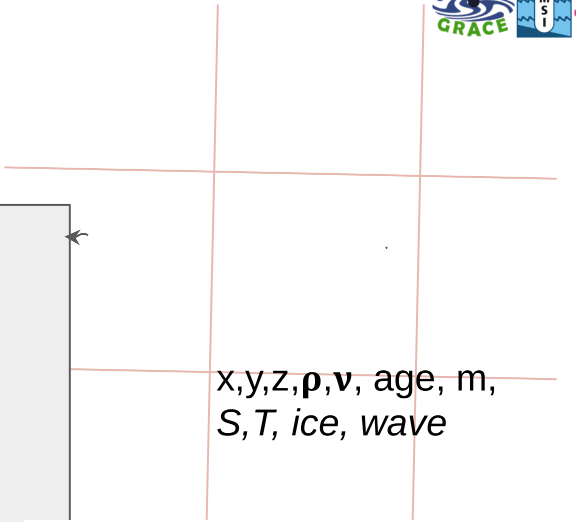
- continuous source

- (release stranded and sedimented particles)



Environment

N1	x	y	z	...	**vel**	***ice***	***wave***	***T***	***S***	...
N2	x	y	z	...	**vel**	***ice***	***wave***	***T***	***S***	...
...										
Nn1	x	y	z	...	**vel**	***ice***	***wave***	***T***	***S***	...



vel = f(ice,wave,...), **ν** = f(T, S) … etc.

Parallel computing is necessary.
M (particles ~ 1M, parameters ~ 20)
(no communication between particles - no MPI) !
Shared memory resources. Parallel I/O.

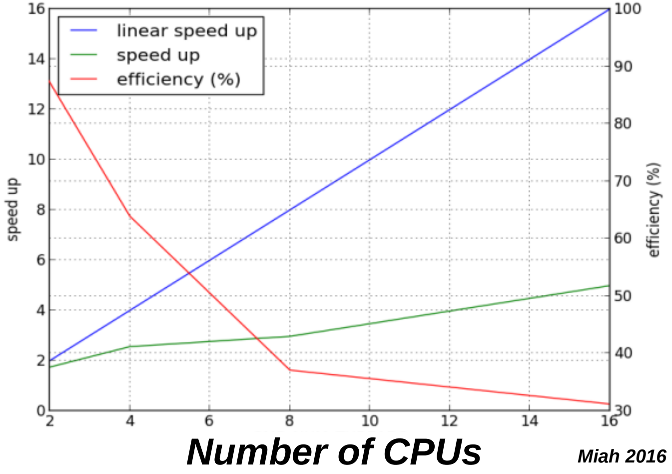
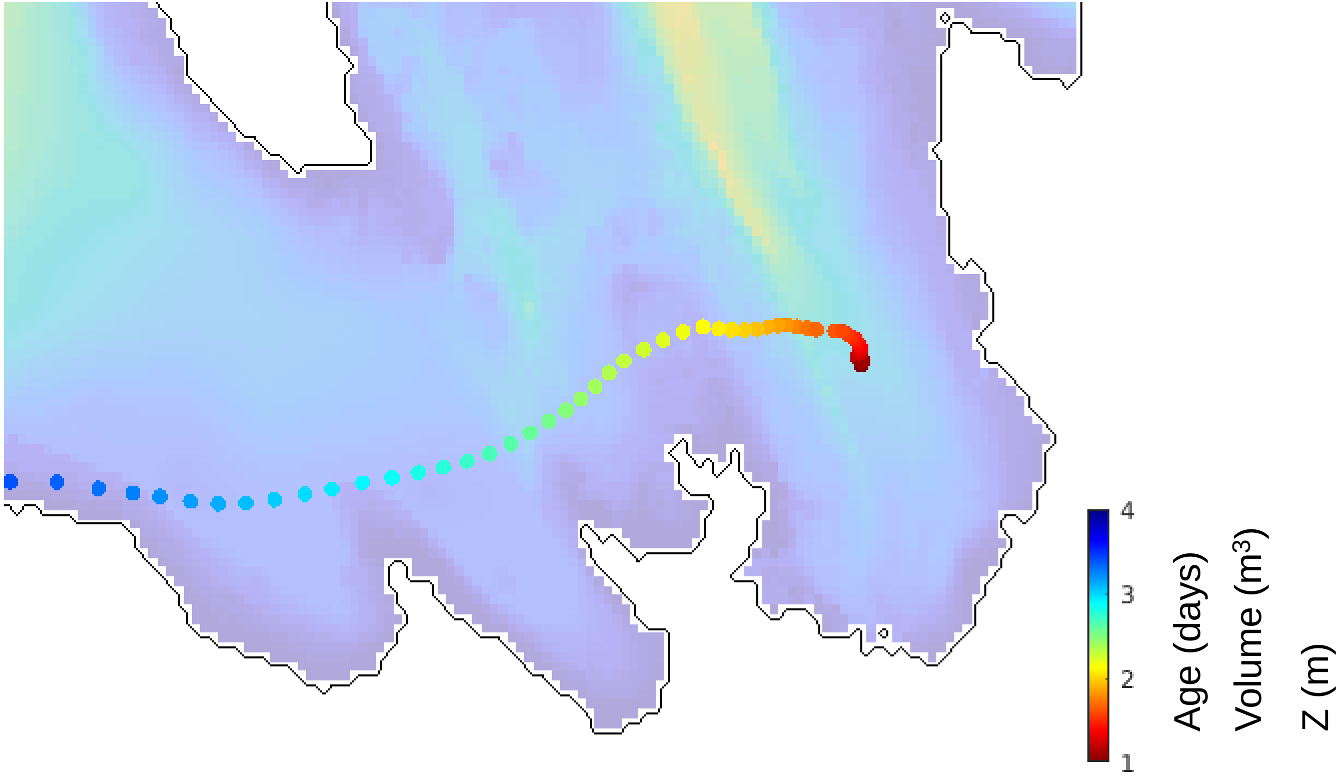


Figure 2: GITM Scalability

Case study - Tallinn Bay

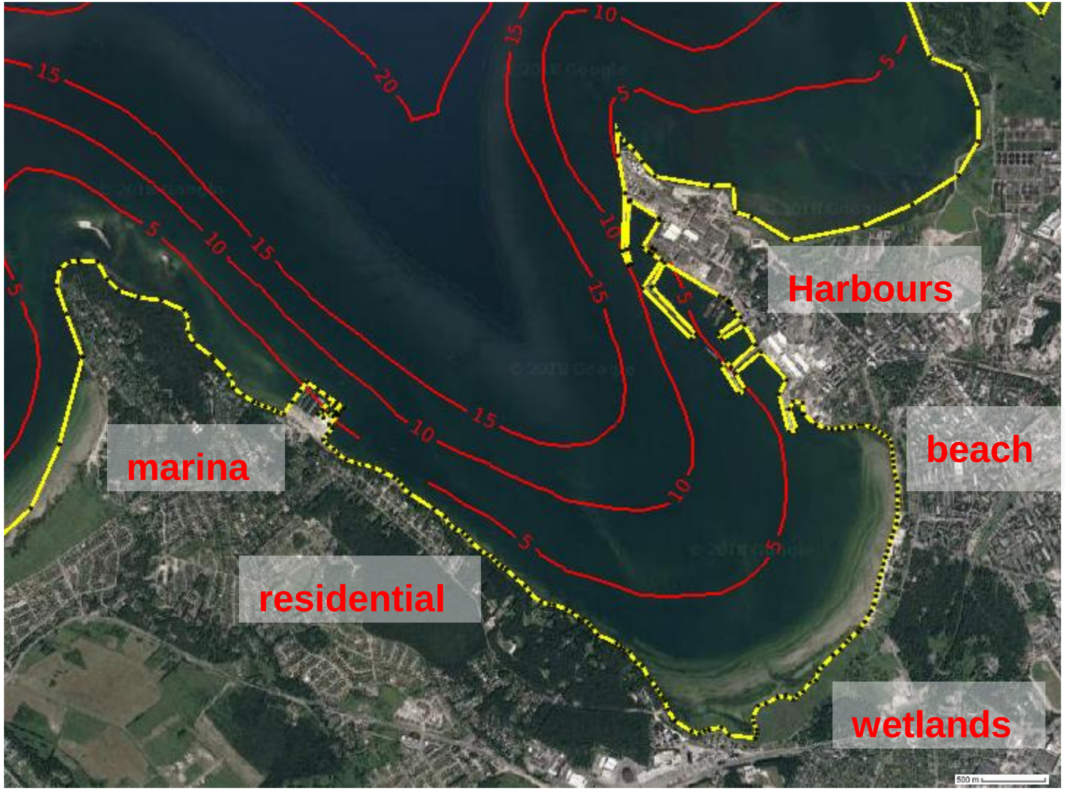


Particle related properties

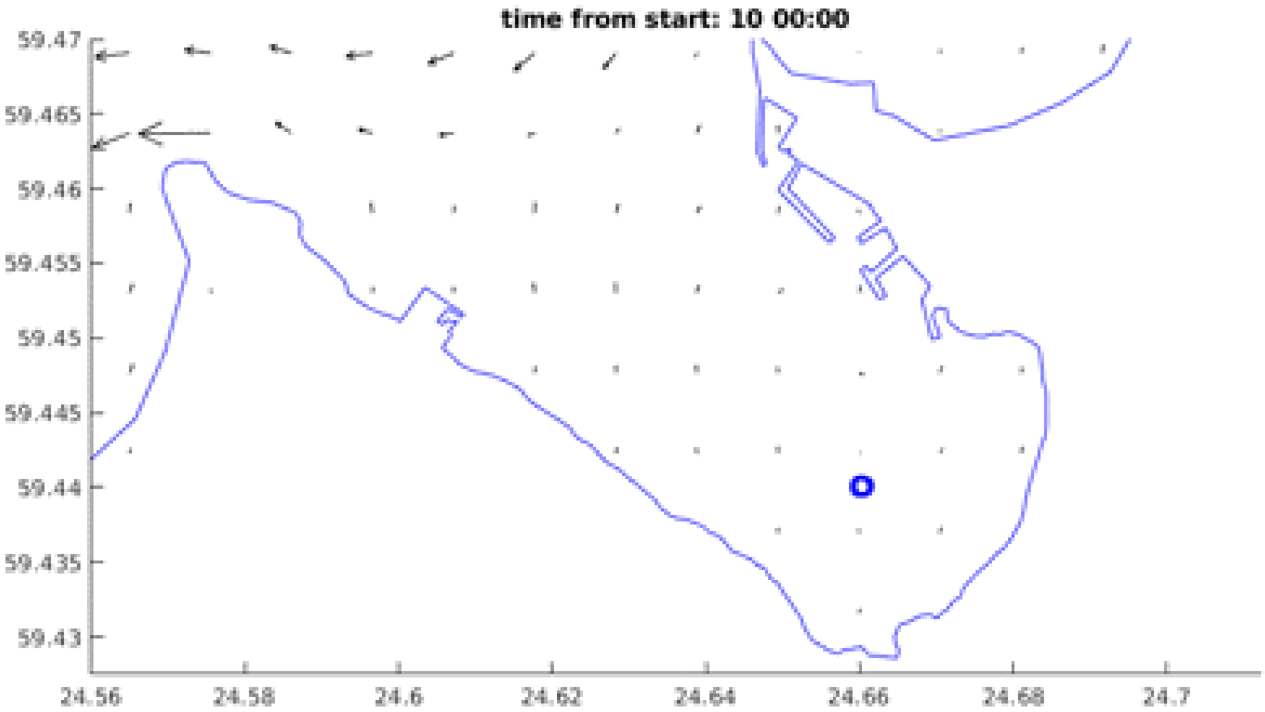
...

Test case - Kopli bay in Tallinn bay

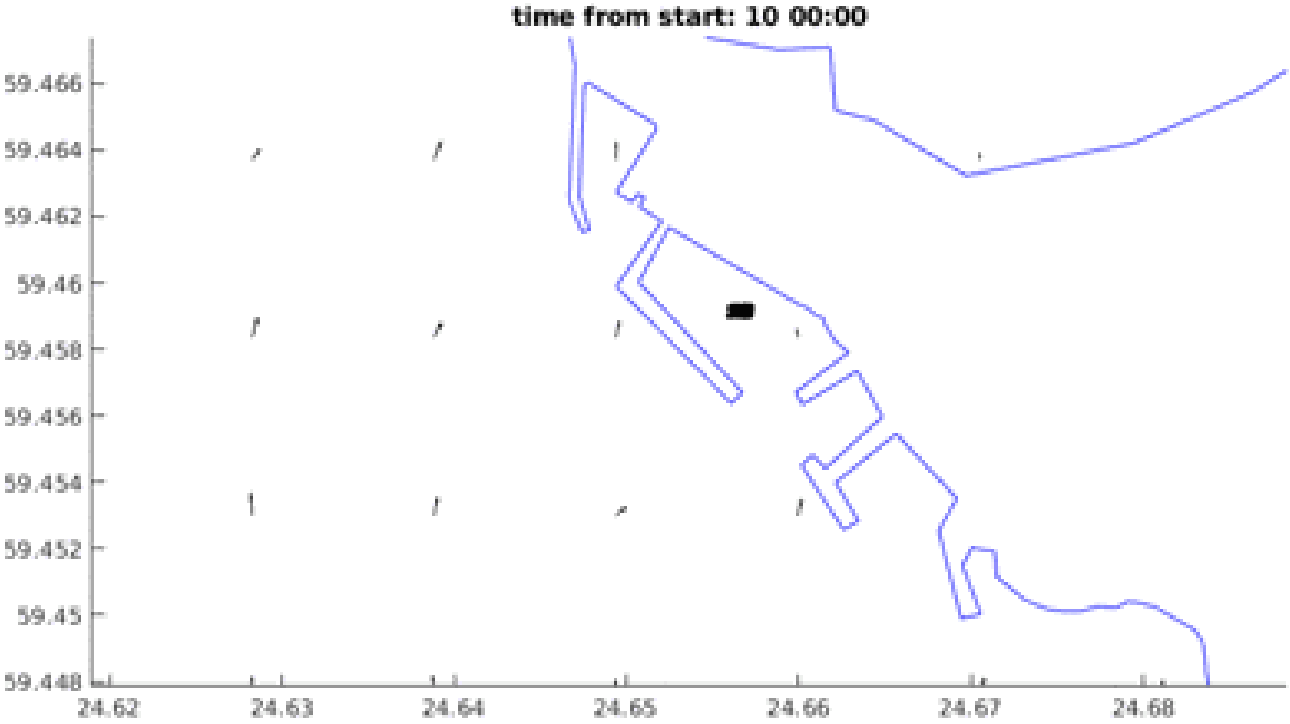
depth



Hitting quays and harbor constructions

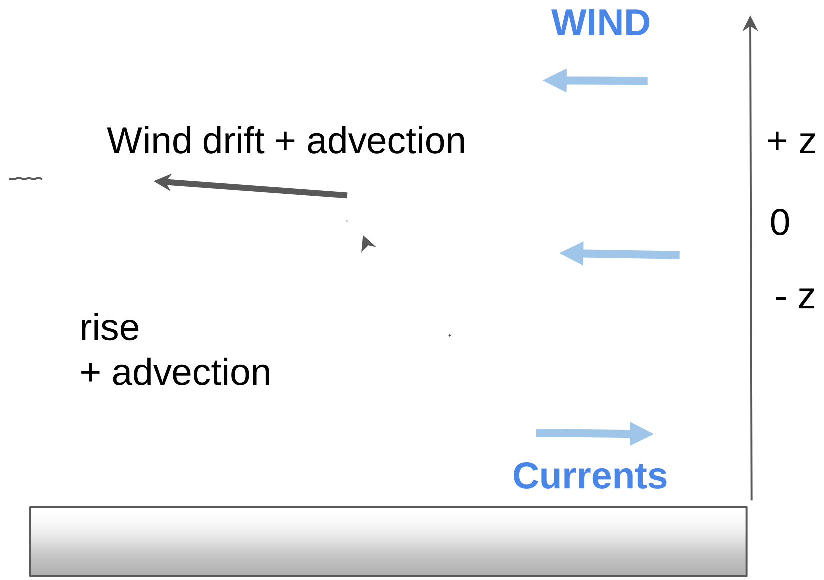


In-harbor oil spill

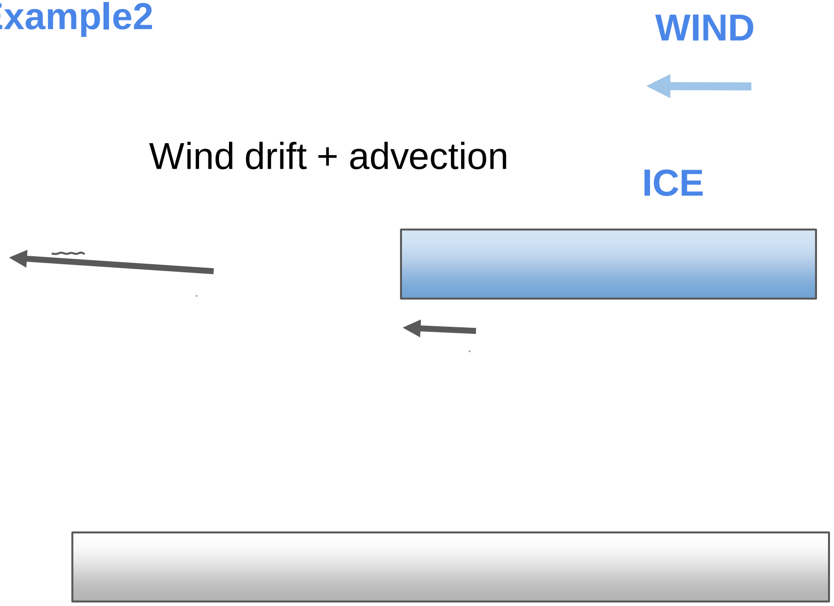


Processes & conditions

Example1



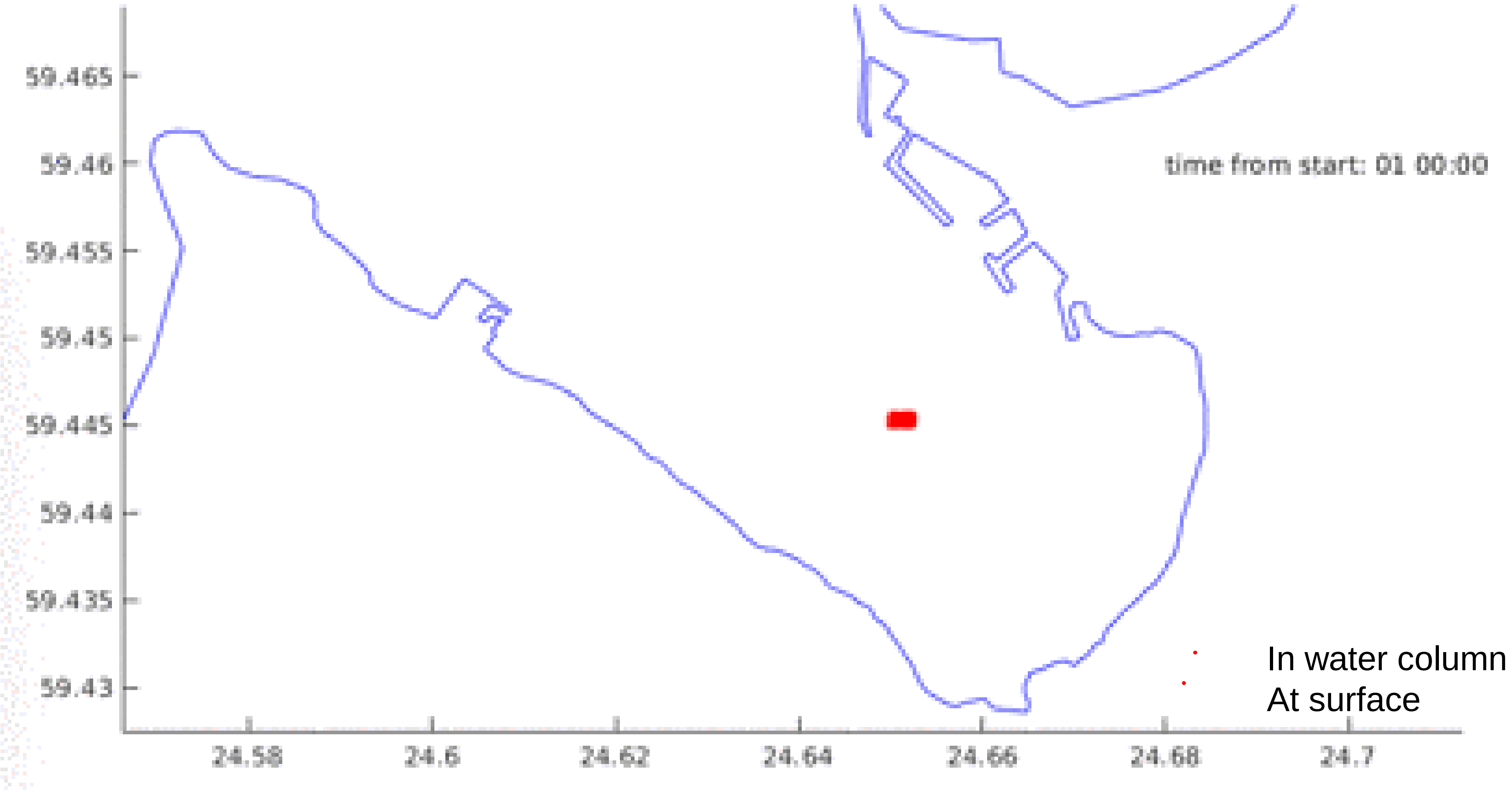
Example2



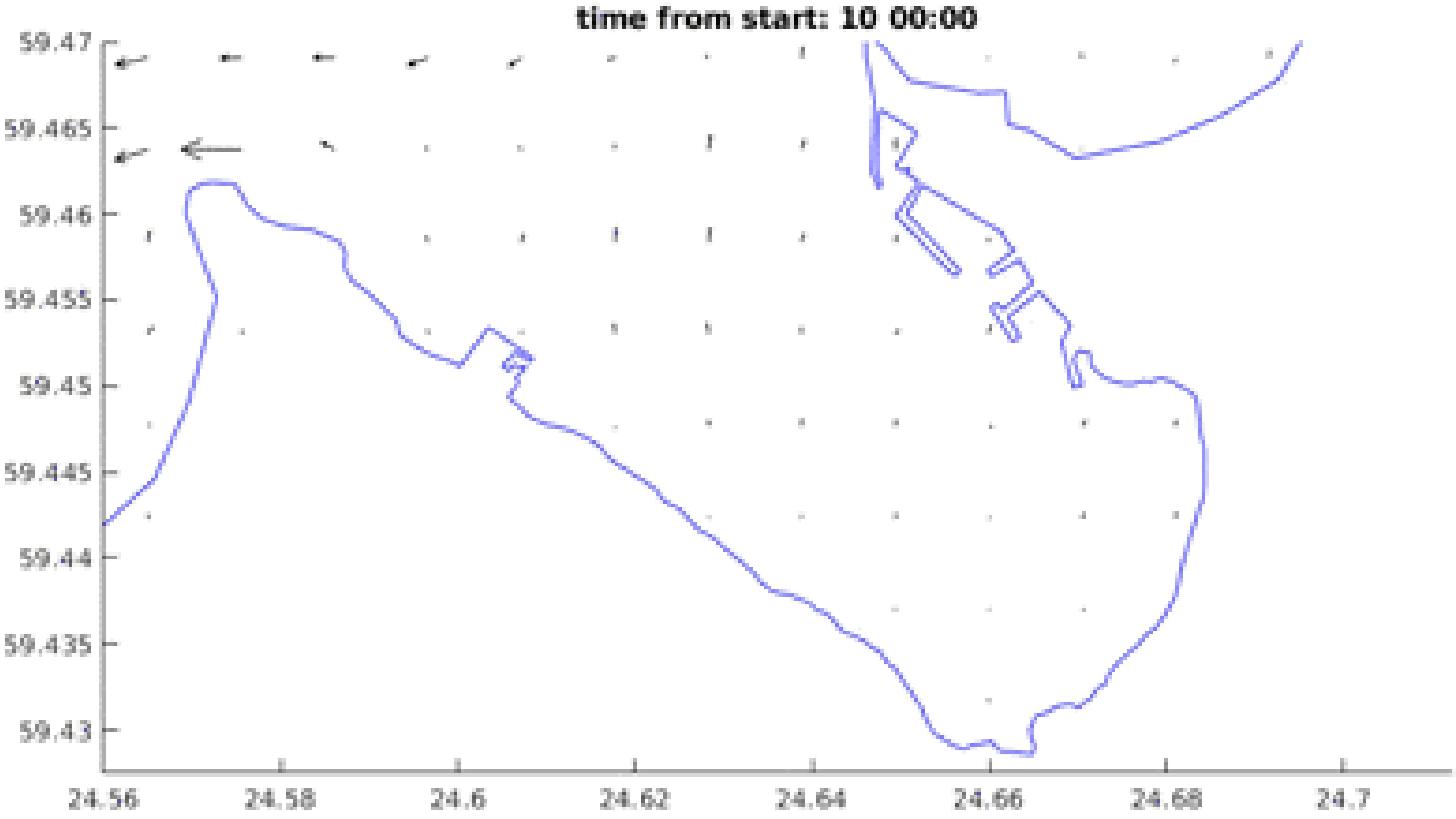
Based on density difference, particles are sinking or floating
Particles in water column are subject to diffusion and advection
Emerged particles are subject to the weathering effects like wind drift, evaporation, photolysis, etc...

In presence of Ice :
Drift with currents (slower velocity),
encapsulating, absorption … etc

Deep-water blowout

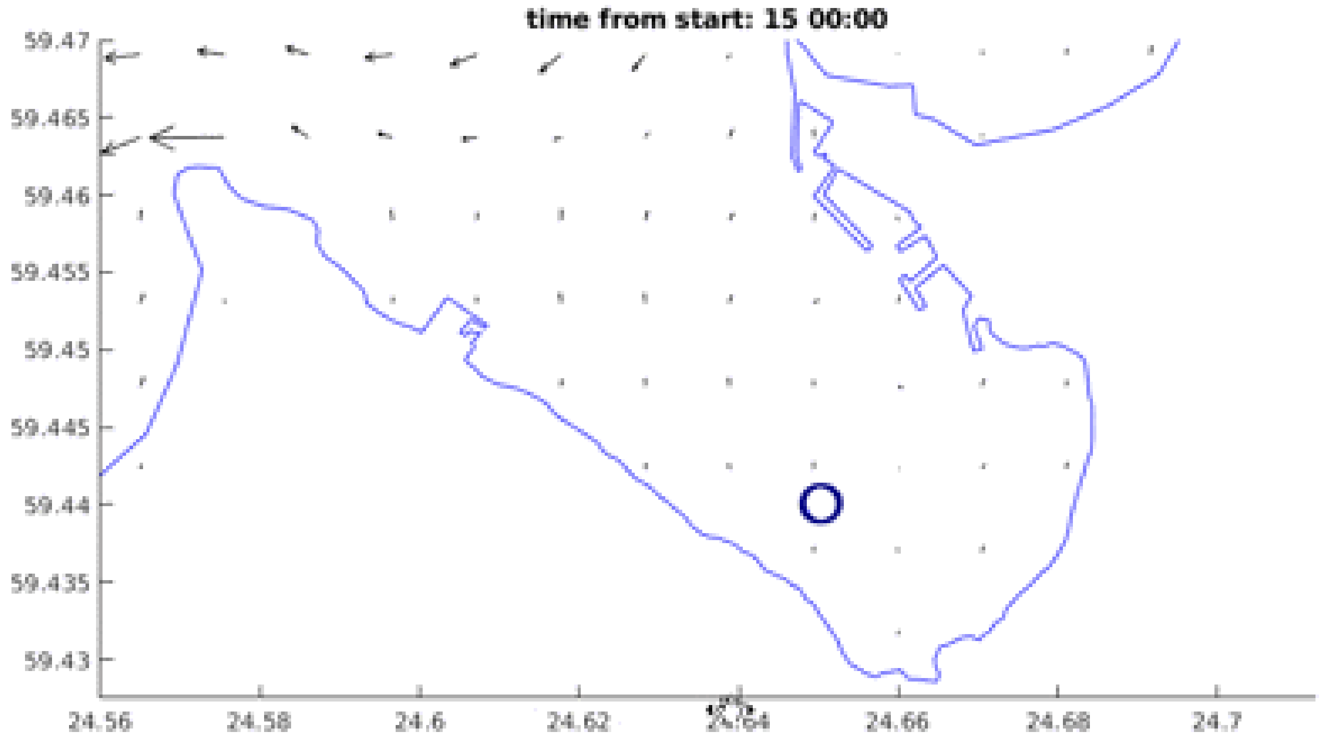


Continuous release

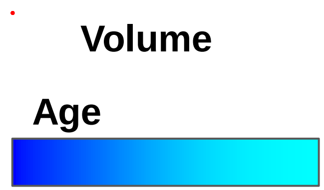


Deep-water blowout + Oil weathering changing particle properties

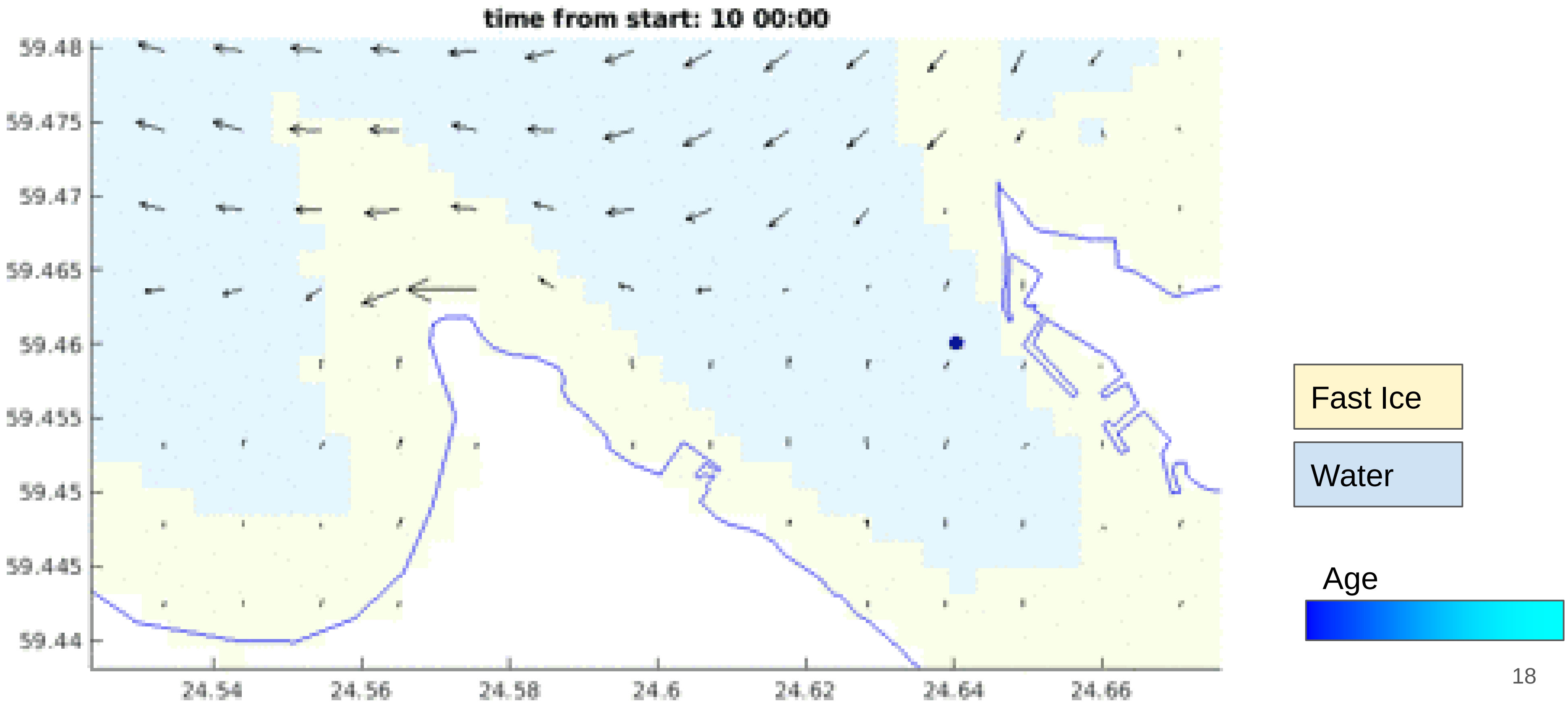
[Drive Folder](#) with animations



Evaporation
Volume of particle gradually decrease

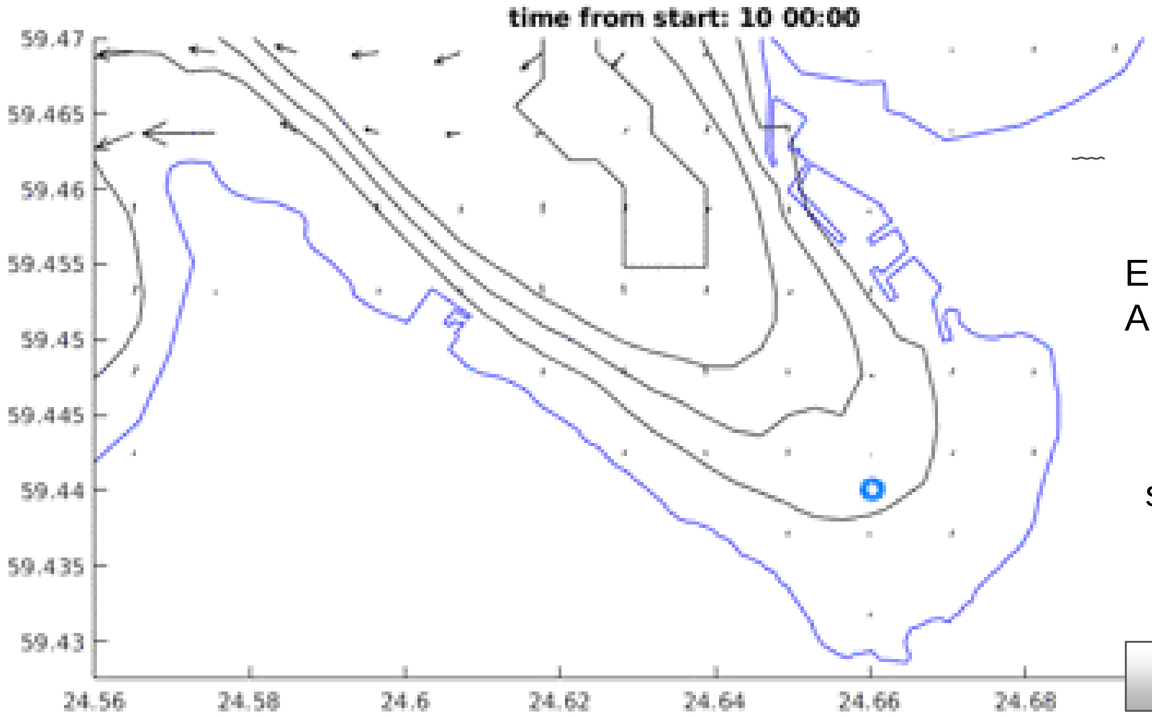


Ice trap



time from start: 10 00:00
59.48
59.475
59.47
59.465
59.46
59.455
59.45
59.445
59.44
24.54
24.56
24.58
24.6
24.62
24.64
24.66
Fast Ice
Water
Age

Settling / use of dispersant



1. Increase density, through environmental processes
2. Submerge
3. Sediment

Waves
SPM

Emulsification
Absorption

settling
+ sedimenting

Particle depth

Estimating polution area

Pollution mitigation concept

1

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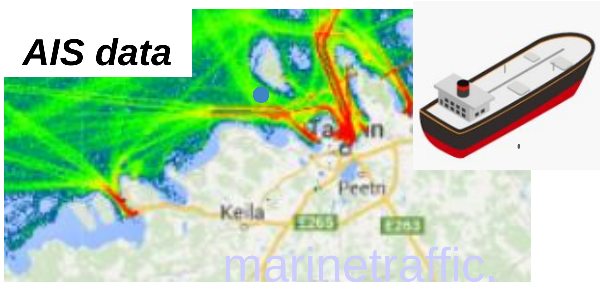

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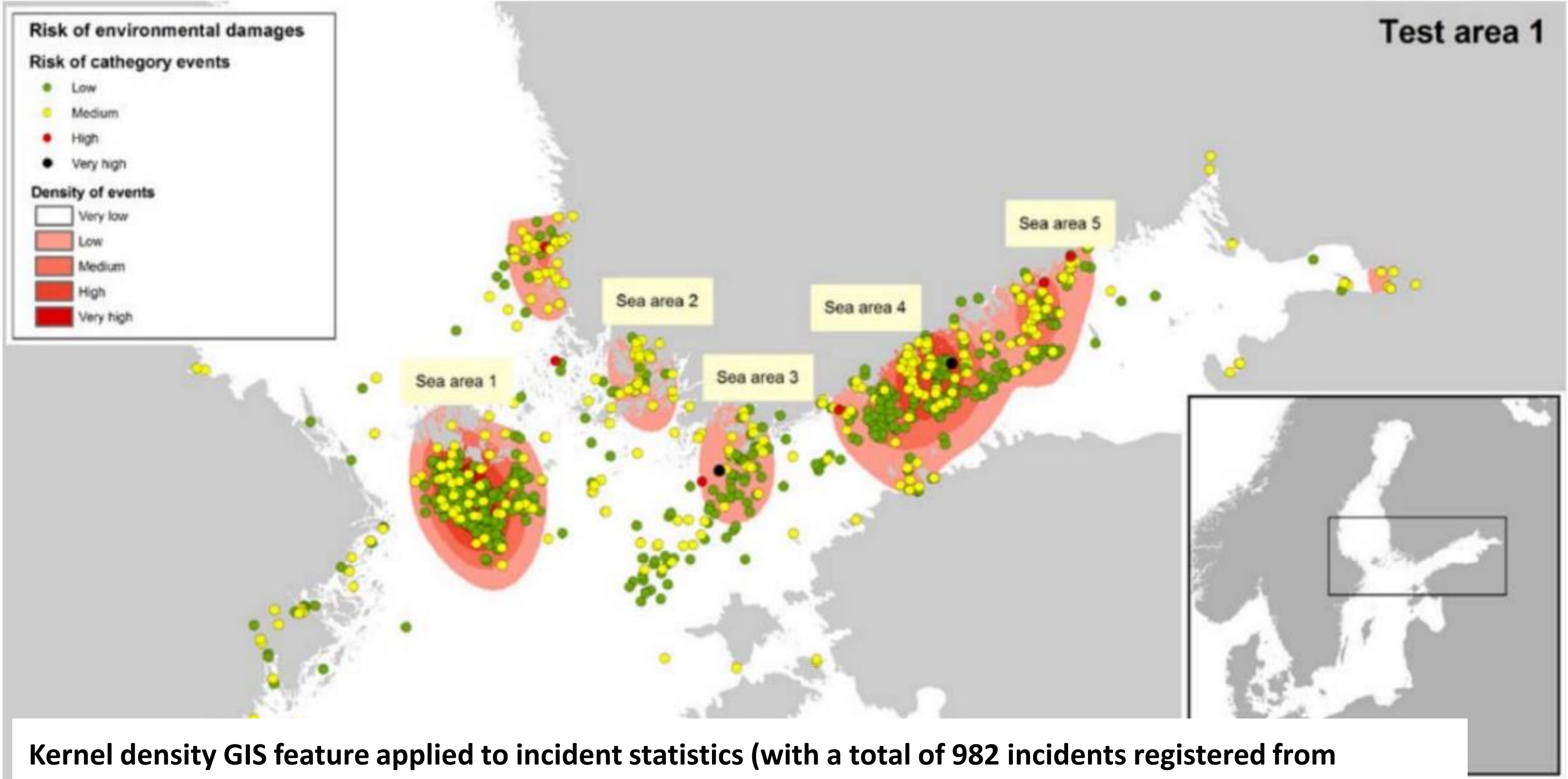

Kernel density GIS feature applied to incident statistics (with a total of 982 incidents registered from 2014-2016) for identification of accidental hotspot areas (OpenRisk, 2019).

THANK YOU!