Ecosystem Responses to Aquaculture Induced Stress (ECORAIS). Prosjekt nr 190474, 01.01.2009 - 31.12.2011

Fellesprosjekt for å undersøke hvordan utslipp fra matfiskanlegg for laks spres og påvirker omliggende miljø

- partikkeltransport
- omsetning og bunnpåvirkning
- vekst av alger og filtrerende organismer

Havforskningsinstituttet

NIVA

Uni Research (UiB)

Numerical simulation of organic waste dispersion from a marine fish cage

Alfatih Ali

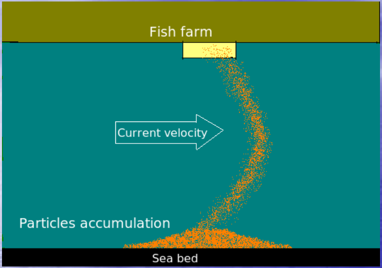
Uni Computing, Uni Research, University of Bergen

Joint work with:
Øyvind Thiem and Jarle Berntsen

HAVBRUK 2012

(ECORAIS)

Modelling particles movement



The particle tracking models consider three processes that influence the particle movement

1. Advection by the current velocity field
2. Random diffusion due to the turbulence that quickly changes in time
3. Vertical movement towards the sea bed (sinking) due to the particle weight

Random walk particle tracking model

- Lagrangian Stochastic Models (LSM)
- Impose w_s (Sinking)

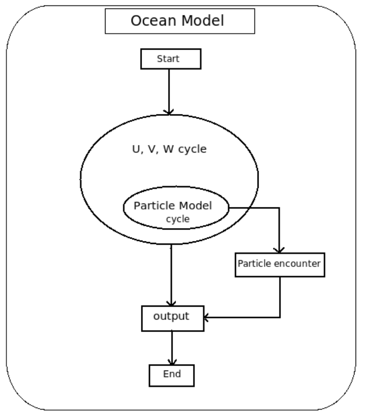
Particle tracking model

$$\begin{bmatrix} x(t_n) \\ y(t_n) \\ z(t_n) \end{bmatrix} = \begin{bmatrix} x(t_{n-1}) \\ y(t_{n-1}) \\ z(t_{n-1}) \end{bmatrix} + \begin{bmatrix} U(t_{n-1}) + \frac{\partial A_H}{\partial x} \\ V(t_{n-1}) + \frac{\partial A_H}{\partial y} \\ W(t_{n-1}) - w_s + \frac{\partial K_H}{\partial z} \end{bmatrix} \Delta t + \begin{bmatrix} \sqrt{2A_H}\gamma_1 \\ \sqrt{2A_H}\gamma_2 \\ \sqrt{2K_H}\gamma_3 \end{bmatrix} \sqrt{\Delta t}$$

Advantages of using particle tracking models:

- Offer the most cost-efficient technique for predicting the distribution of particulate waste
- Natural choice for predicting the dispersion of different size particles, rather than modelling tracer concentrations

Coupled particle-ocean model



At each time step

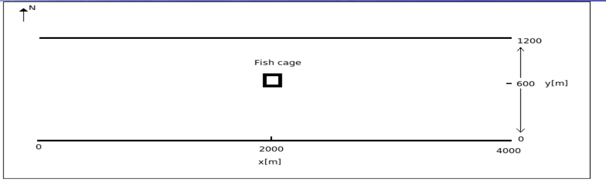
- Compute the local currents by the ocean model
- Then move all particles by the particle model
- Count as inactive if a particle reach the sea bed

Bergen Ocean Model (BOM)

- Numerical terrain-following 3D hydrodynamical model

Model domain and setup

- An idealized fjord with open western boundary
- Tidal current is the driving force
- Flat bottom with 100m as a constant depth



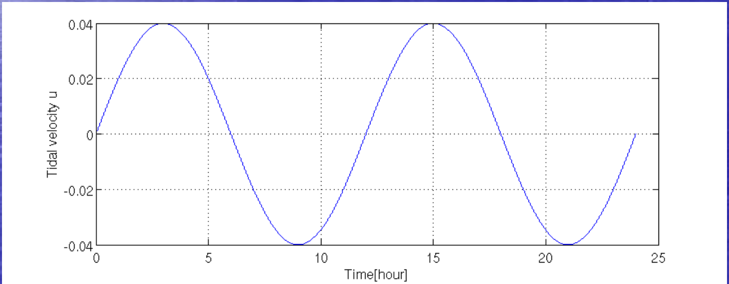
- Cage horizontal dimensions: (length$\times$width)[m]=100 $\times$ 100
- Continuous releasing of particles at depth of 5m for 24hours
- The initial horizontal position of a particle is chosen randomly with uniform distribution
- The sinking velocity w_s can be drawn randomly from a probability distribution

Tidal horizontal velocity u

Harmonic representation of the tidal velocity in x direction

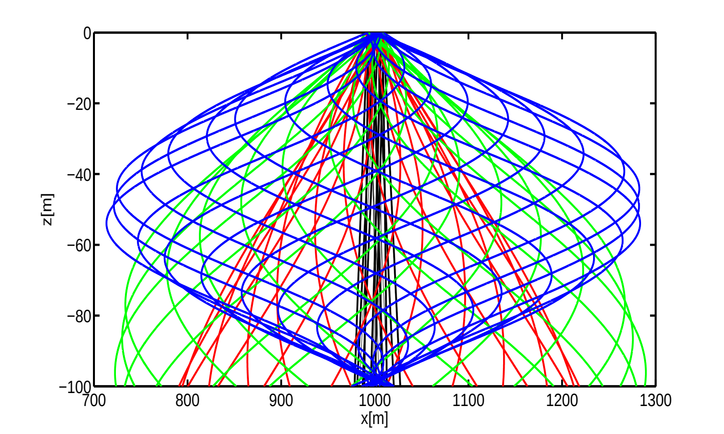
$$u = u_0 * cos(f * t - \phi)$$

- $f = \frac{360}{T}$ is tidal frequency ; $T = 12.4$ h is the tidal period
- u_0 donates the velocity amplitude and ϕ is the tidal phase



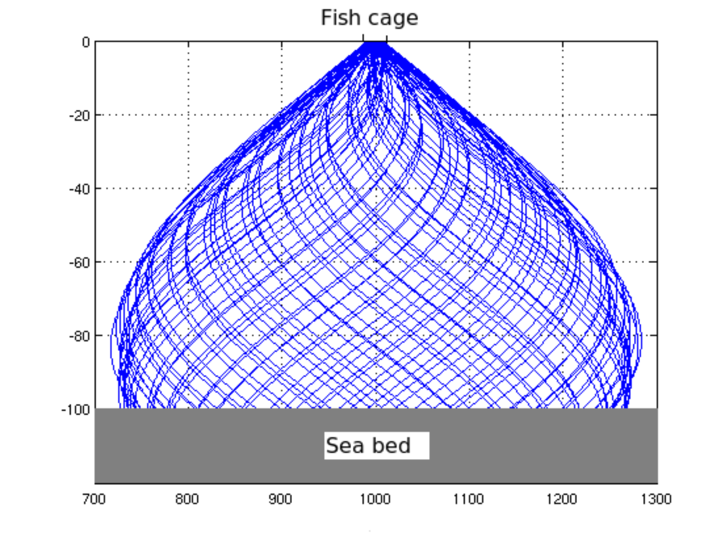
Sinking time ($\frac{H}{w_s}$) vs tidal period (T)

- Periodic spatial distribution of particle with respect to the sinking time

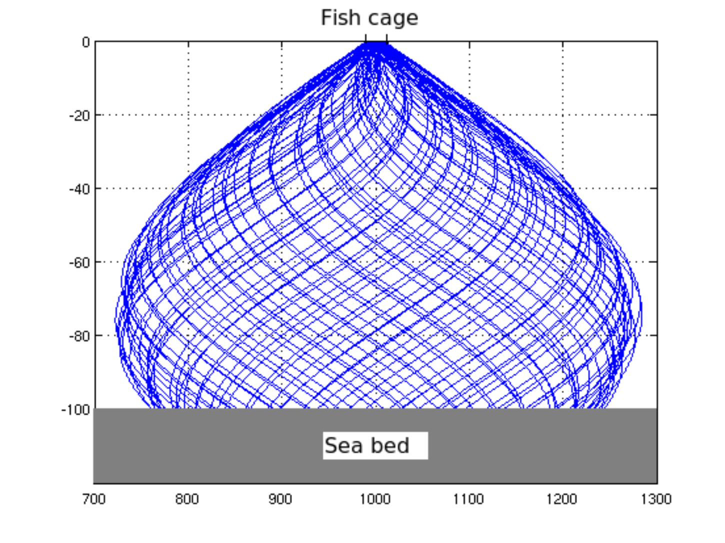


H/w_s (hours)	0.25	$0.25 + T/4$	$0.25 + T/2$	$0.25 + T$

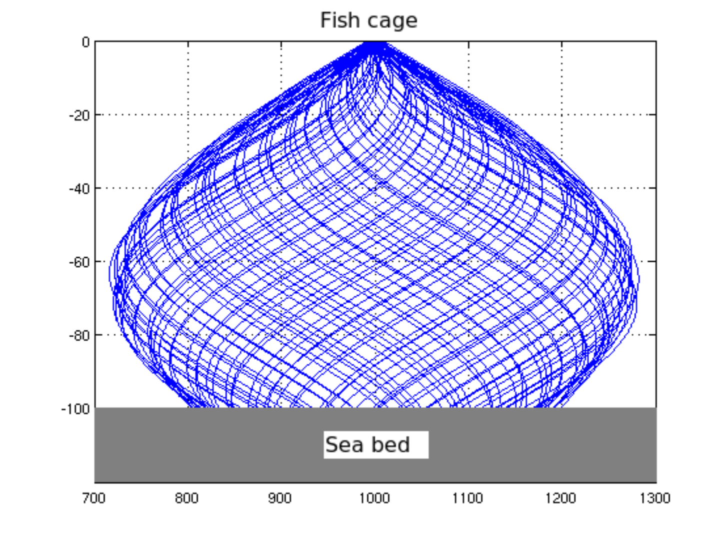
Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 07$ hours.



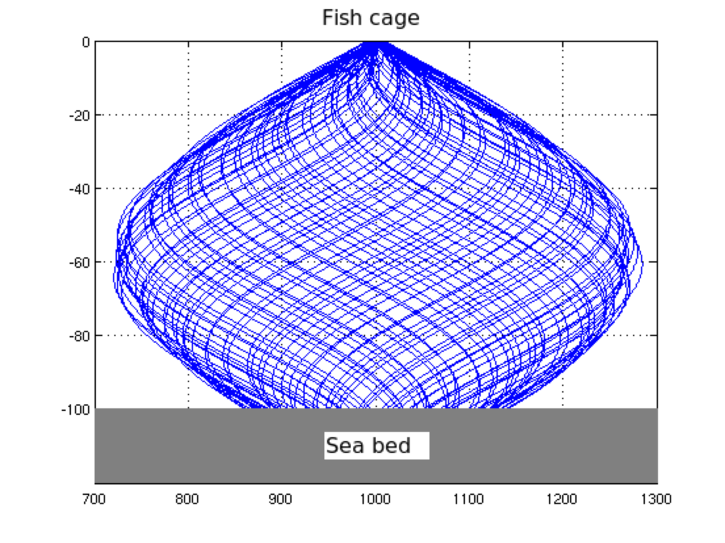
Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 08$ hours.



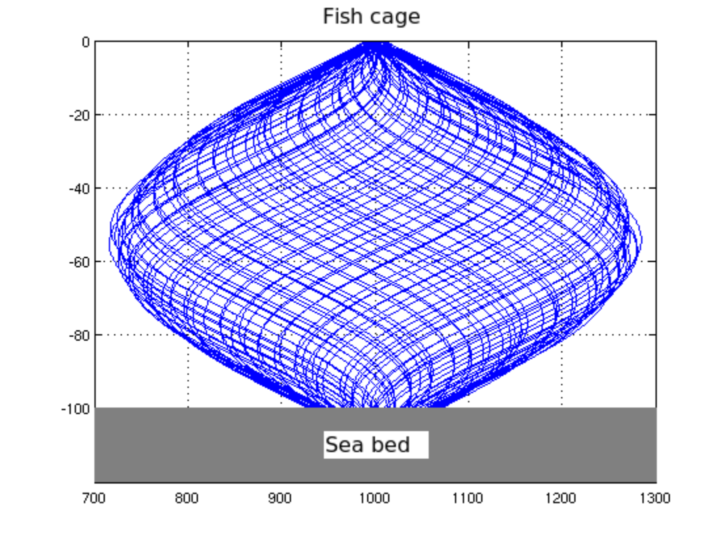
Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 09$ hours.



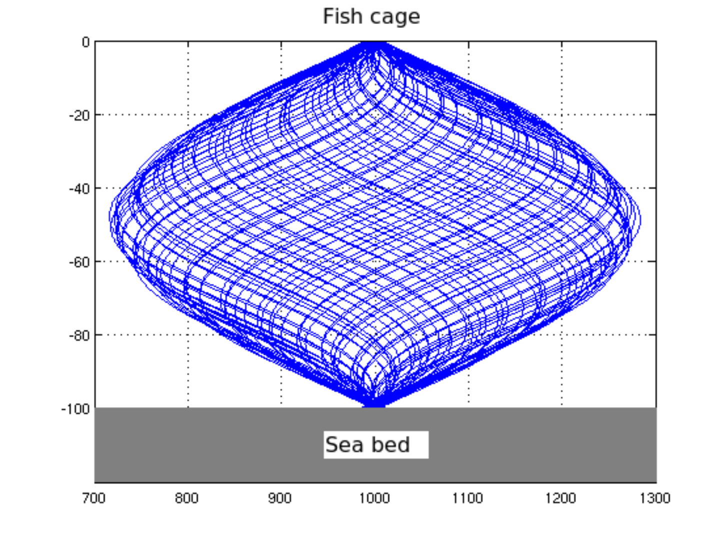
Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 10$ hours.



Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 11$ hours.

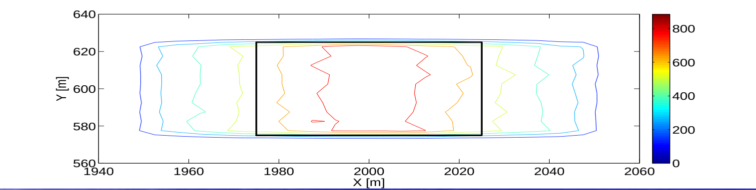


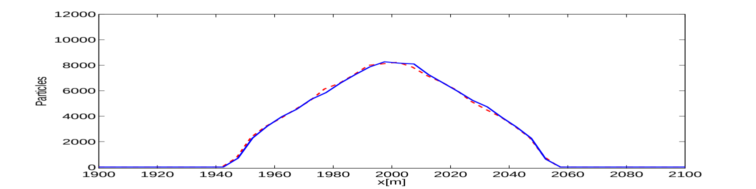
Sinking time: $\frac{H}{w_s} = \frac{100}{w_s} = 12$ hours.



One region of high accumulation

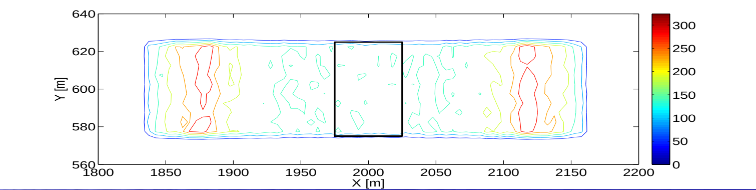
- A total of 1.1×10^5 particles are continuously released over two tidal cycles
- Constant settling velocity $w_s = 0.032\,\mathrm{m\,s^{-1}}$
- Tidal velocity amplitude $u_0 = 0.0098\,\mathrm{m\,s^{-1}}$
- The cage size is of $50 \times 50\,\mathrm{m}^2$

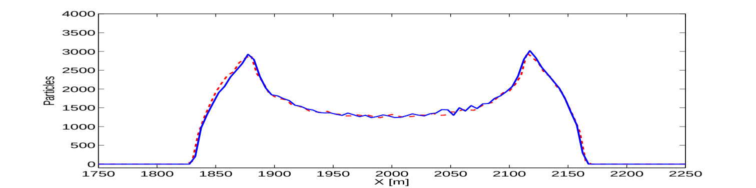




Two regions of high accumulation

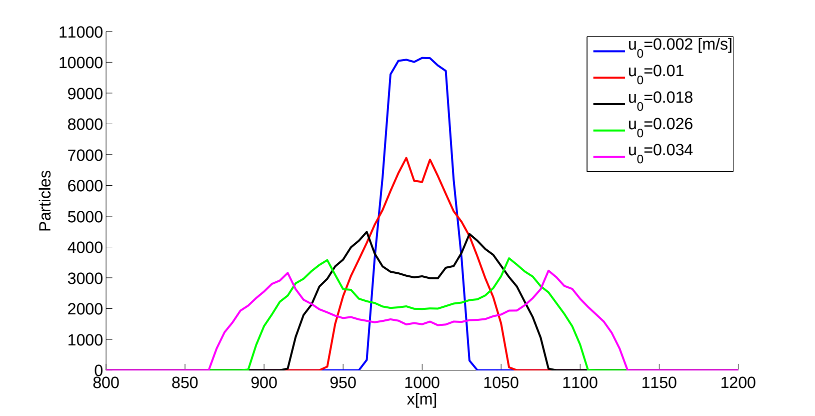
- A total of 1.1×10^5 particles are continuously released over two tidal cycles
- Constant settling velocity $w_s = 0.032\,\mathrm{m\,s^{-1}}$
- Tidal velocity amplitude $u_0 = 0.048\,\mathrm{m\,s^{-1}}$
- The cage size is of $50 \times 50\,\mathrm{m}^2$



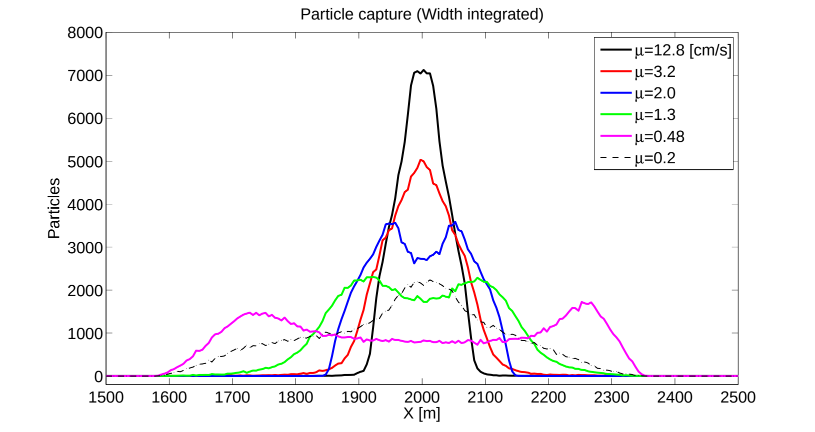


Sensitivity to the tide intensity u_0

Cage length: $b - a = 50$ centered at $x = 1000$, and $w_s = 0.032ms^{-1}$



Sensitivity to the settling velocity w_s

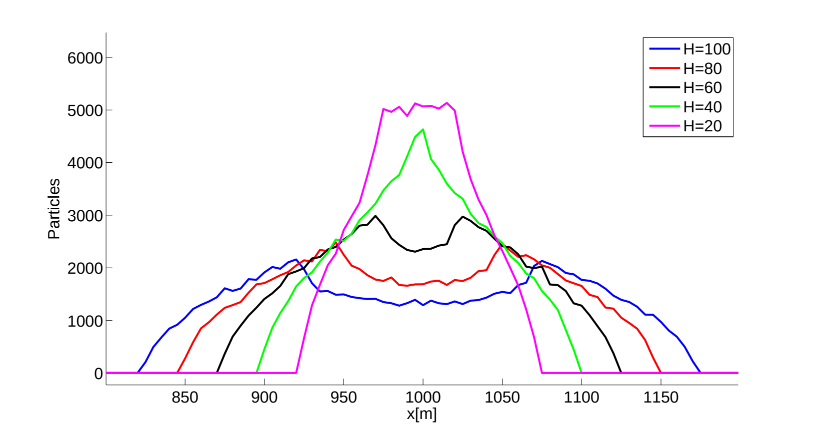


Particles accumulation over the sea bottom (width integrated)

Sensitivity to the water depth H

Cage length: $b - a$, $u_0 = 0.02, \; w_s = 0.12 \; ms^{-1}$

and $d_{max} \approx 18m$



Maximum accumulation region

The maximum concentration point depends on the cage size $(b - a)$ and the maximum distance $d_{max}(H, w_s, u_0)$:

- If $d_{max}(H, w_s, u_0) < \frac{b-a}{2} \Rightarrow$ one maximum concentration point just beneath the fish cage center
- If $d_{max}(H, w_s, u_0) > \frac{b-a}{2} \Rightarrow$ two maximum concentration points outside the fish cage area.

Summary

- Three dimensional particle tracking model is coupled to BOM and tested in an idealized fjord with tidal currents forcing
- The size and the shape of the waste footprint depend on the local current, water depth, particles settling velocity and the cage size
- Fish farm sites in deep water can have the highest waste concentration far a way from the farm area
- Increasing cage size increases the likelihood for that everything is ending up beneath the fish farm, and larger farms means larger biomasses which makes it even more polluted under the fish farm
- If the sinking time is close to the tidal period, everything will end up under the fish cage. This happens for fast-sinking particles
- For different topographies and forcing, site-dependent studies must be conducted

The end