Development of high-resolution coastal model around Hokkaido for fisheries science

-A study on passive transport of eggs, larvae and juveniles of walleye pollock-

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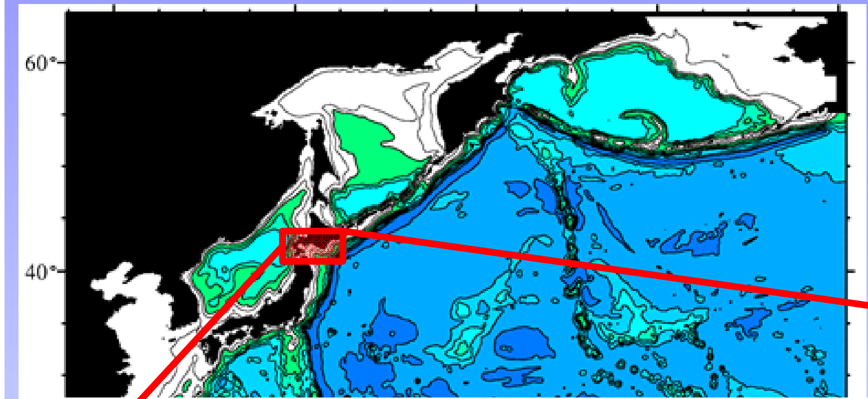
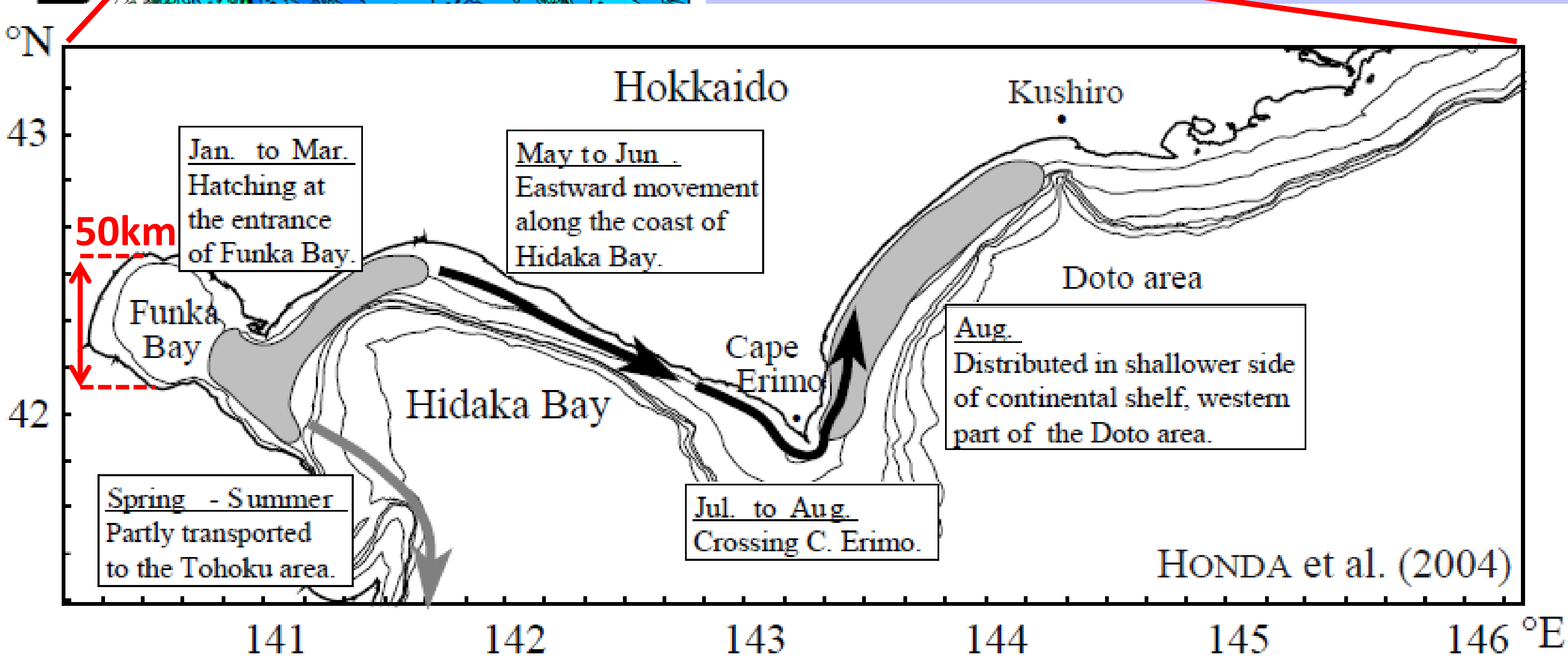
Early life history of Japanese Pacific walleye pollock, *Theragra chalcogramma*)

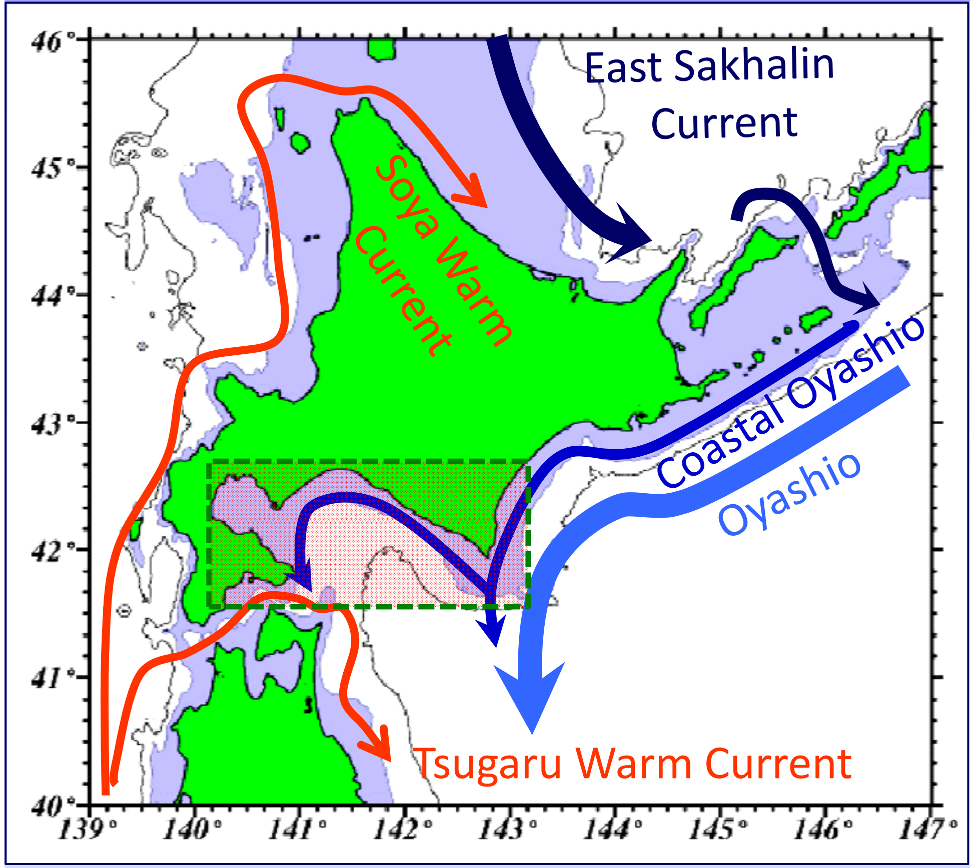




One of the favorable conditions for recruitment～remaining in Funka Bay

Oceanographic condition in winter (spawning season)

(1) The Coastal Oyashio current

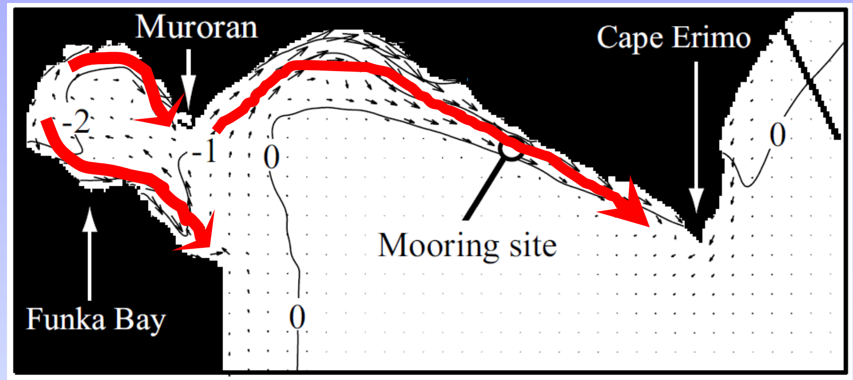


The Coastal Oyashio water

Low temperature (<2℃)

Low salinity (<33psu)

(2)Wind-driven current



+

= Superposition of

(1) The CO current &

(2) Wind-driven current

High-resolution model with grid sizes less than a few km is essential.

Purpose of this study

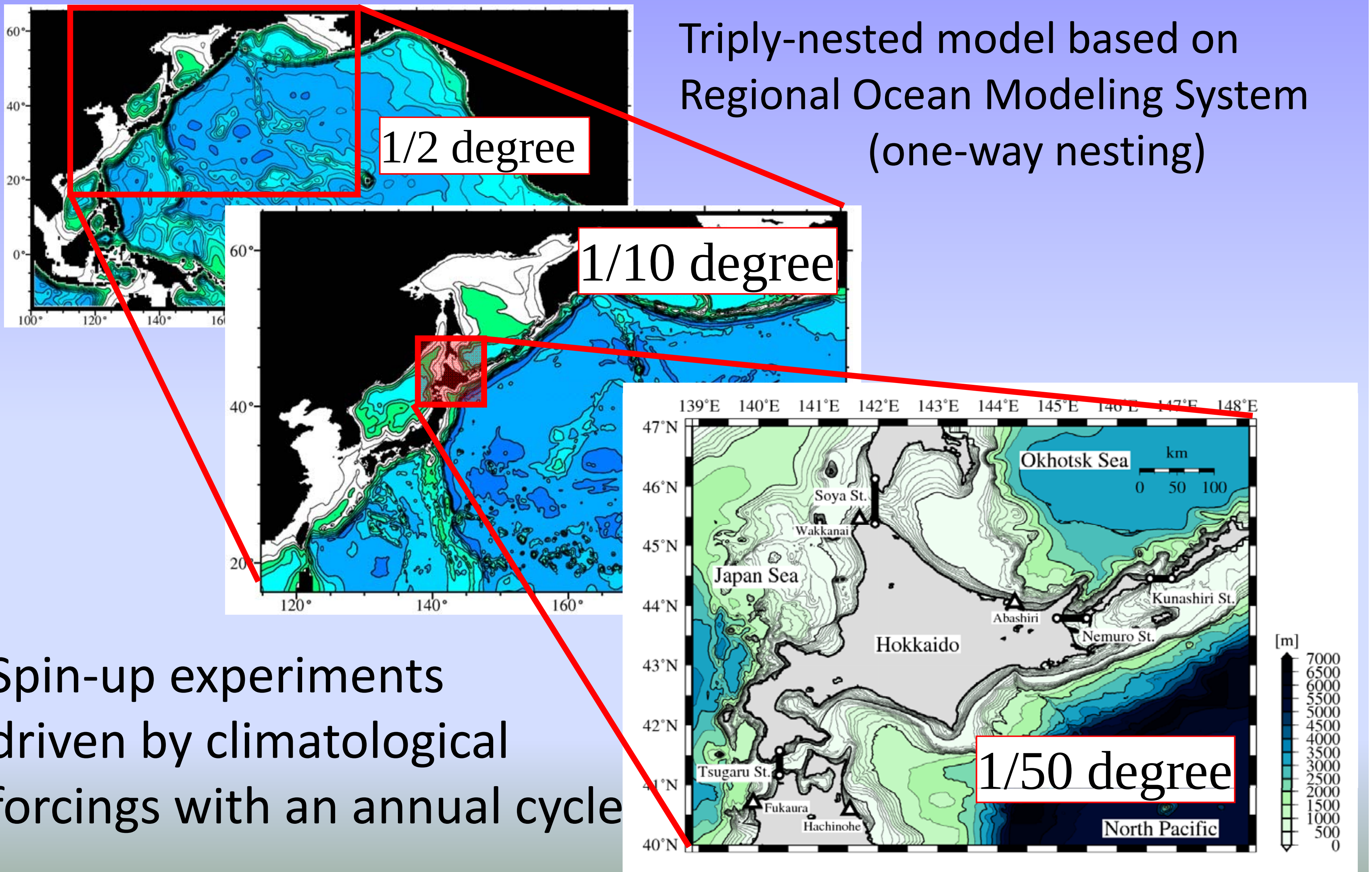
(1) To develop a high-resolution coastal model to simulate realistic oceanographic conditions around Funka Bay

(2) To examine effects of the high-resolution modeling on particle-tracking experiments (passive)

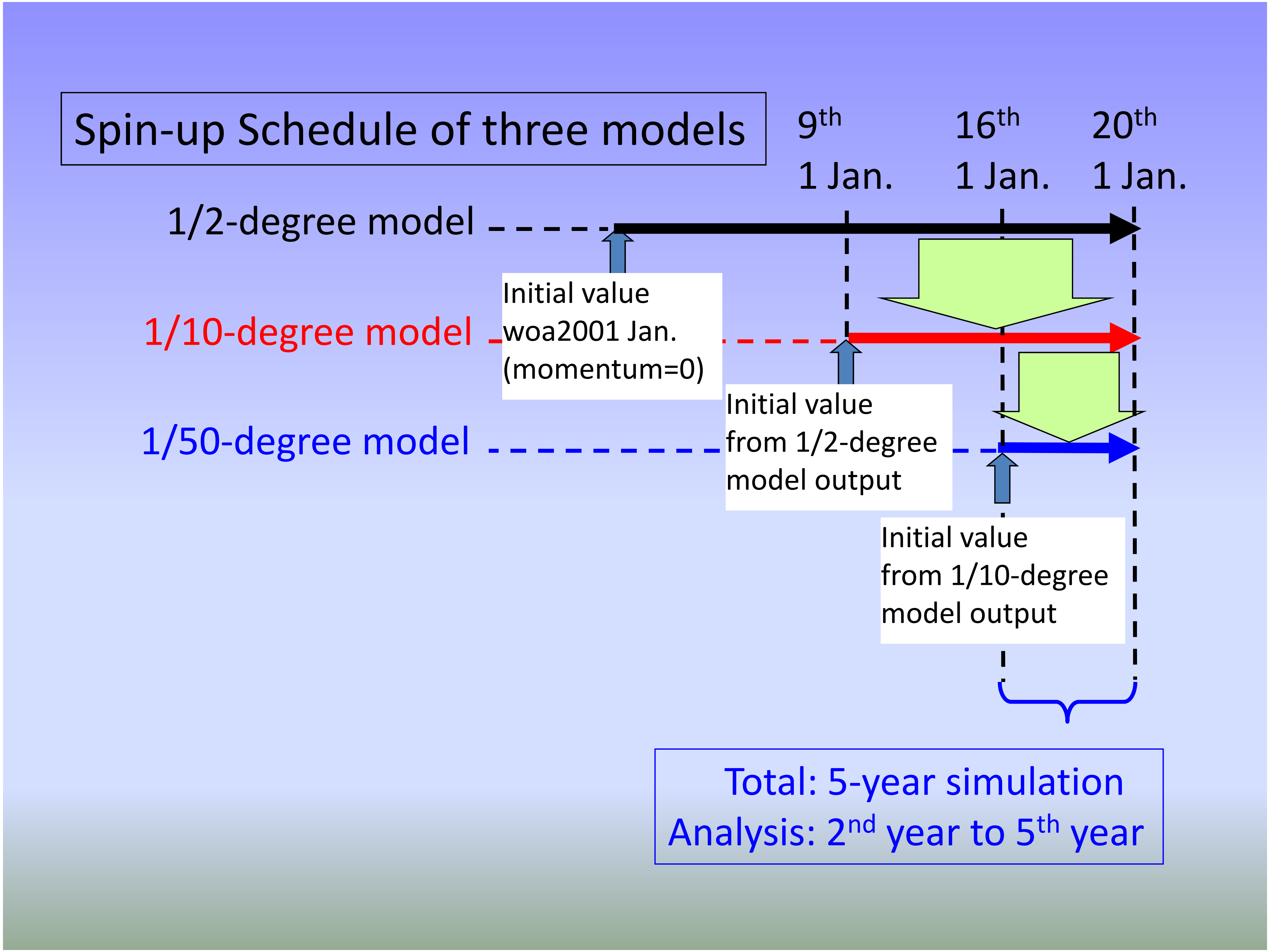
(3) To discuss buoyancy effects on vertical motion of the particles (non-passive)

Model Configuration

Triply-nested model based on Regional Ocean Modeling System (one-way nesting)



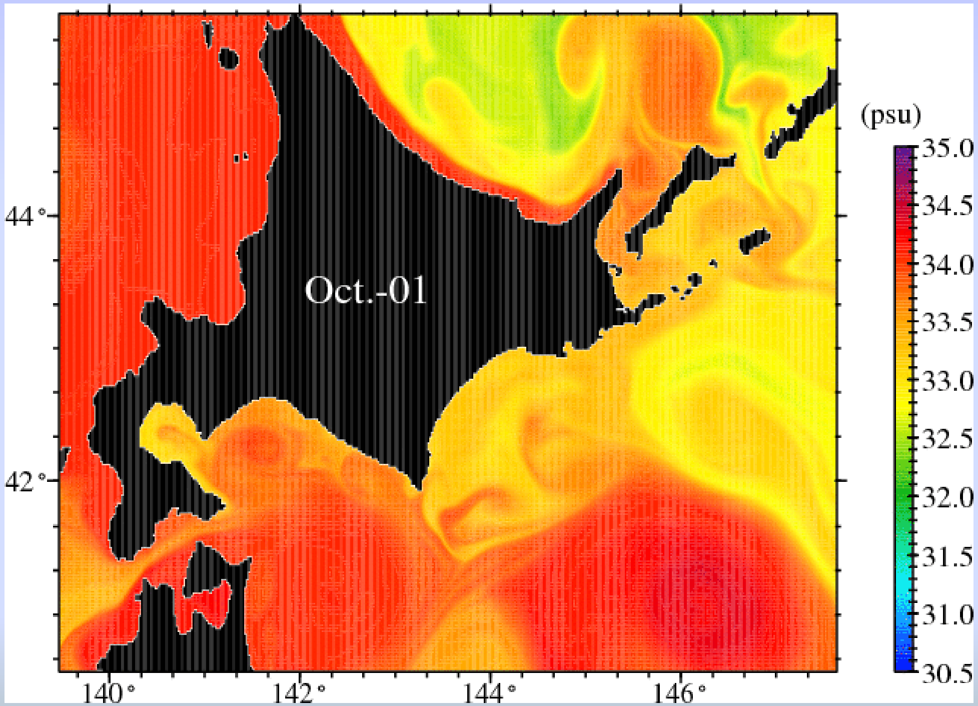
Spin-up experiments driven by climatological forcings with an annual cycle



Spin-up Schedule of three models
9th
1 Jan.
16th
1 Jan.
20th
1 Jan.
1/2-degree model
1/10-degree model
1/50-degree model
Initial value
woa2001 Jan.
(momentum=0)
Initial value
from 1/2-degree
model output
Initial value
from 1/10-degree
model output
Total: 5-year simulation
Analysis: 2nd year to 5th year

Seasonal variation simulated by the high-resolution model

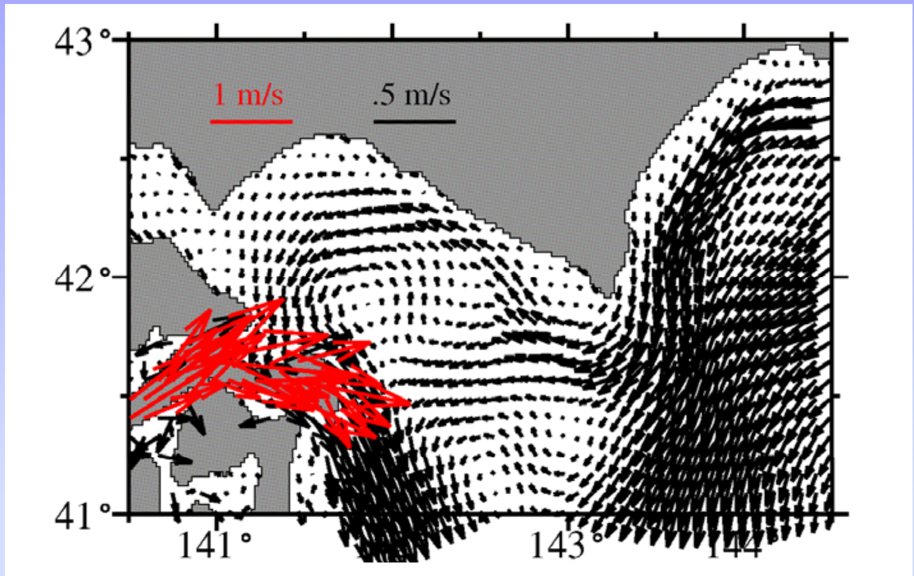
Sea surface salinity (4th October to 5th April)



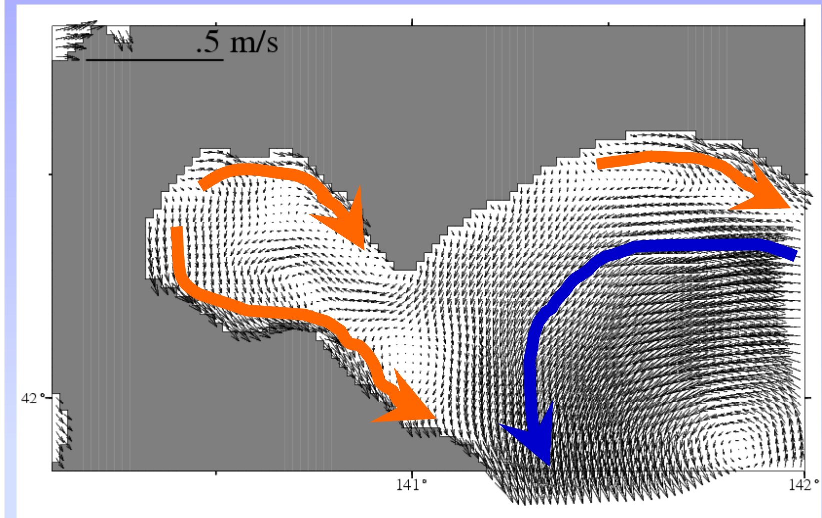
–Seasonal current at the sea surface–

Mean state (Jan. to Mar.)

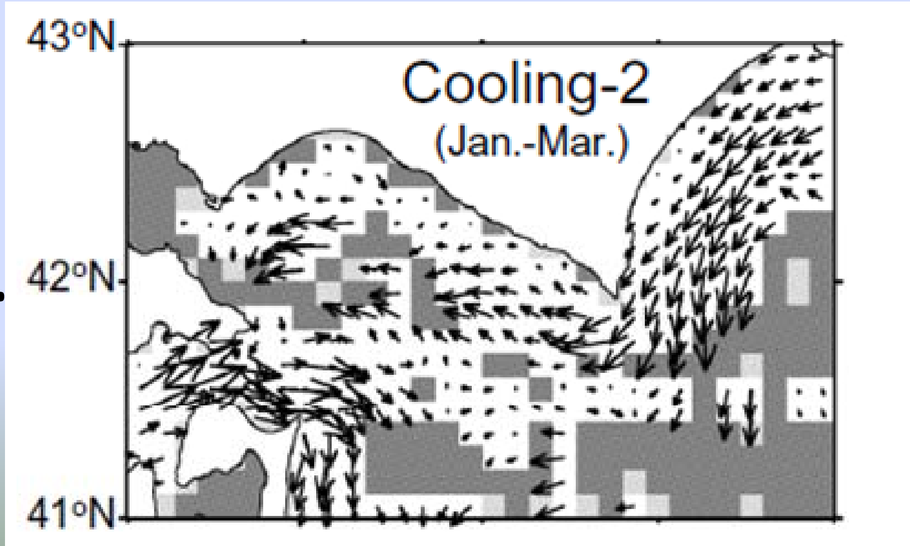
Sim.



simulation



OBS.



Typical currents

- Wind-driven current
- Coastal Oyashio current

Rosa et al. (2009)

Overview of Particle-Tracking Model

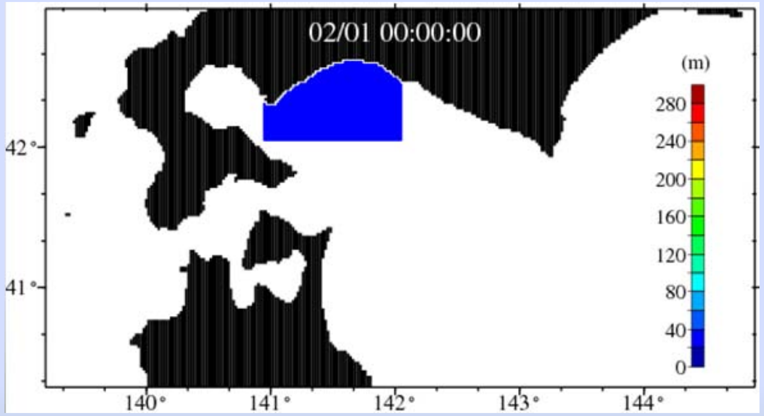
(LTRANS code is modified)

Equation:

$$\begin{cases} x_{n+1} = x_n + u_{\text{model}}\delta t \\ y_{n+1} = y_n + v_{\text{model}}\delta t \\ z_{n+1} = z_n + w_{\text{model}}\delta t \end{cases}$$

Turbulent diffusions are neglected for the basic case.

Initial Condition:

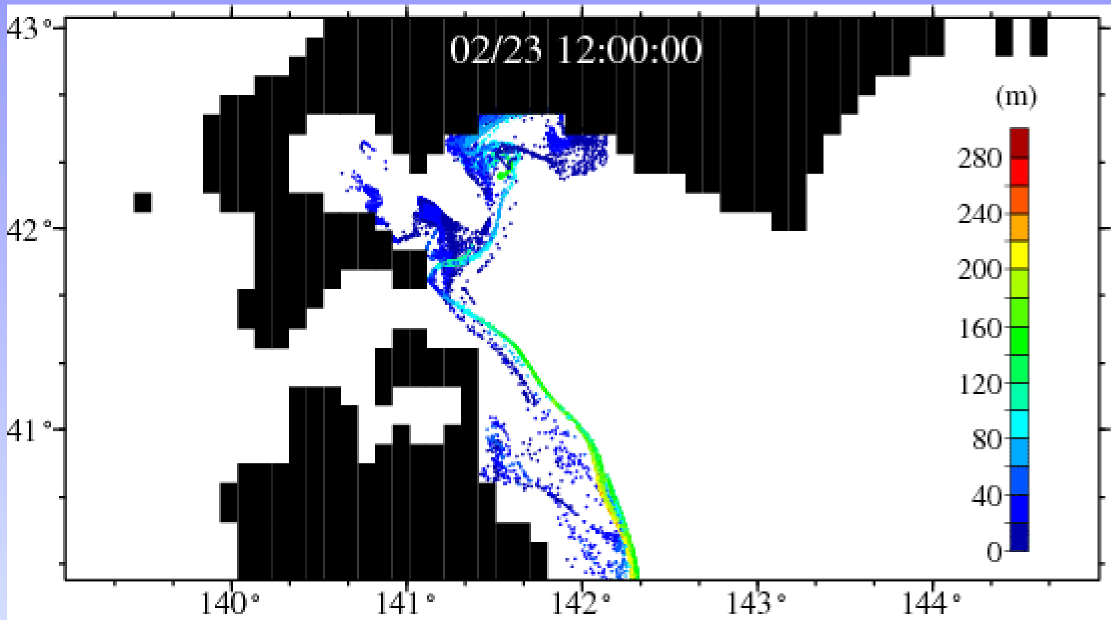


Initially, on 1 Feb., particles are set at the depth of 10m.

Particles are tracked for 2 months.

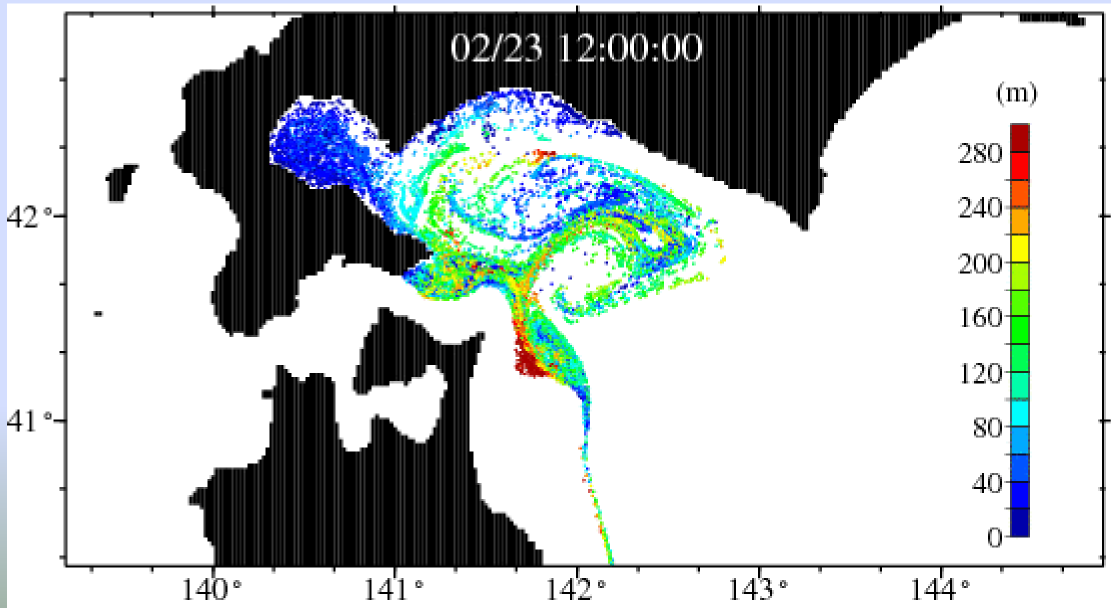
Impacts of high-resolution modeling

1/10-degree model

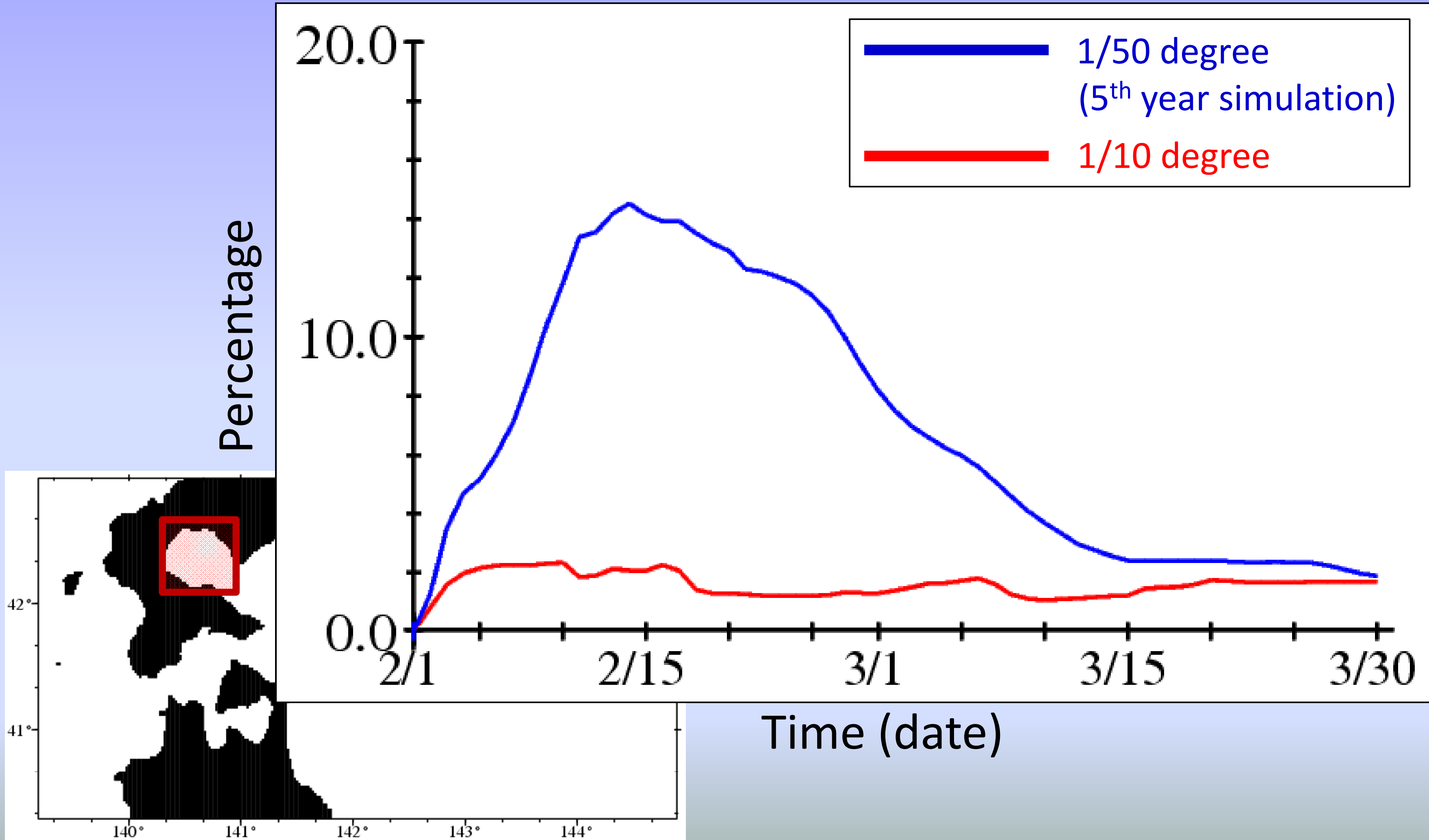


Same Forcings

1/50-degree model
(5th Feb. to Mar.)



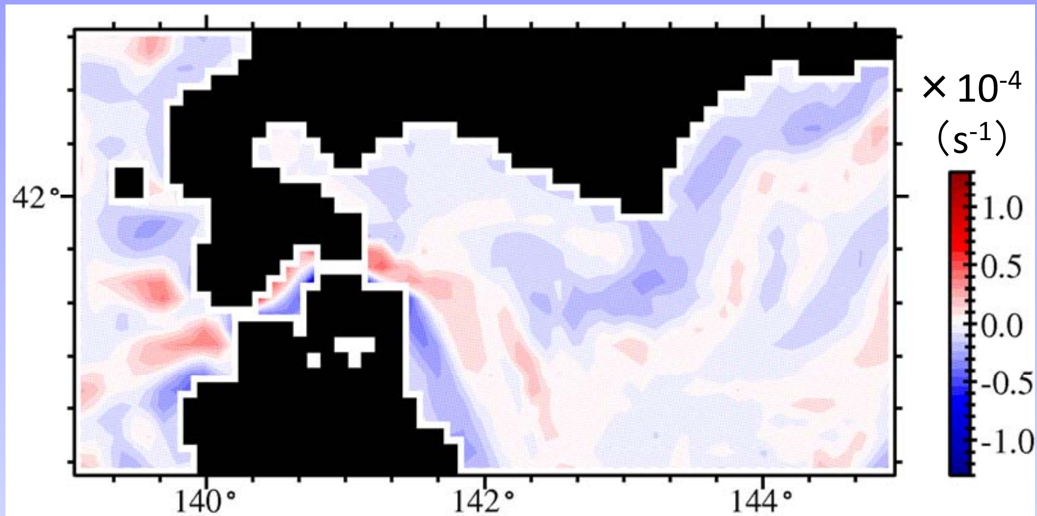
Ratio of particles within Funka Bay to released total particles



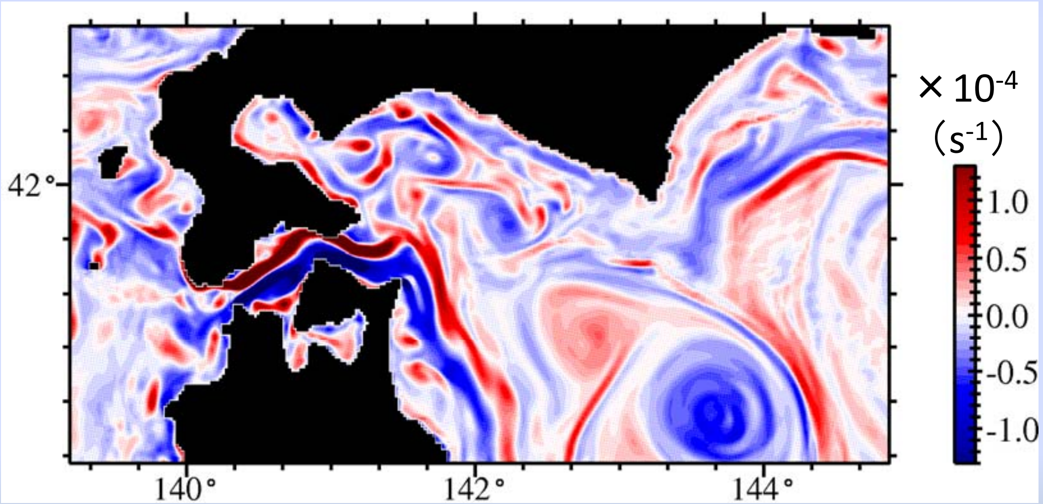
Relative vorticity at 10m on 1 Feb.

$$vorticity = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

1/10° model



1/50° model



Horizontal dispersion in the 1/50-degree model is enhanced by small-scale variability (~submesoscale variability)

Temporal change of egg density (Yamamoto et al., 2009))

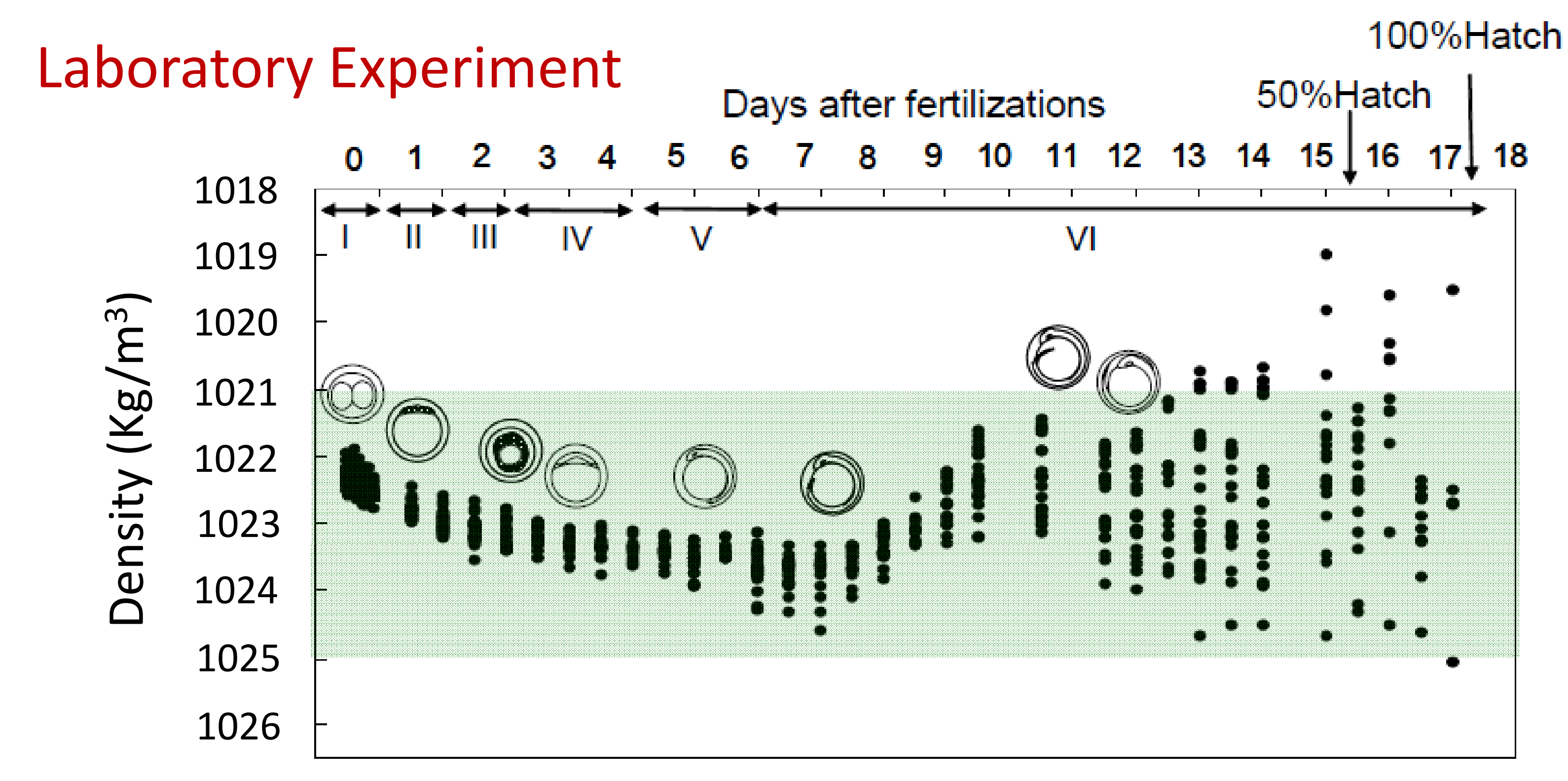


Fig. 2 The change in the density (σt) of the egg during development. Note the inverted *y* axis.

The density of egg = 1021-1025 Kg/m^3

The density of sea water within the mixed layer > 1026 Kg/m^3

→Buoyancy should be important for the vertical motion of particles.

The second particle-tracking experiment
Including buoyancy

$$\begin{cases} x_{n+1} = x_n + u_{\text{model}}\delta t \\ y_{n+1} = y_n + v_{\text{model}}\delta t \\ z_{n+1} = z_n + (w_{\text{model}} + w_{\text{buoyancy}})\delta t \end{cases}$$

Stokes' law (terminal velocity)

$$w_{\text{buoyancy}} = \frac{1}{18} g d^2 \frac{(\rho_{water} - \rho_{particle})}{\rho_{water}} \upsilon^{-1}$$

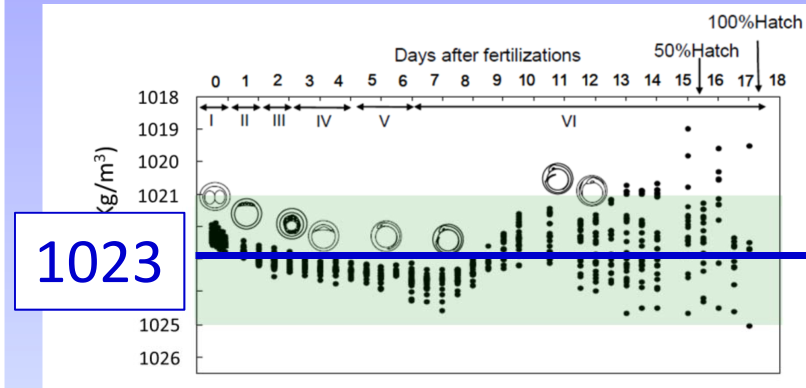


Fig. 2 The change in the density (σt) of the egg during development. Note the inverted y axis.

ρ_{egg} : density of particle (default = 1023 Kgm^{-3})

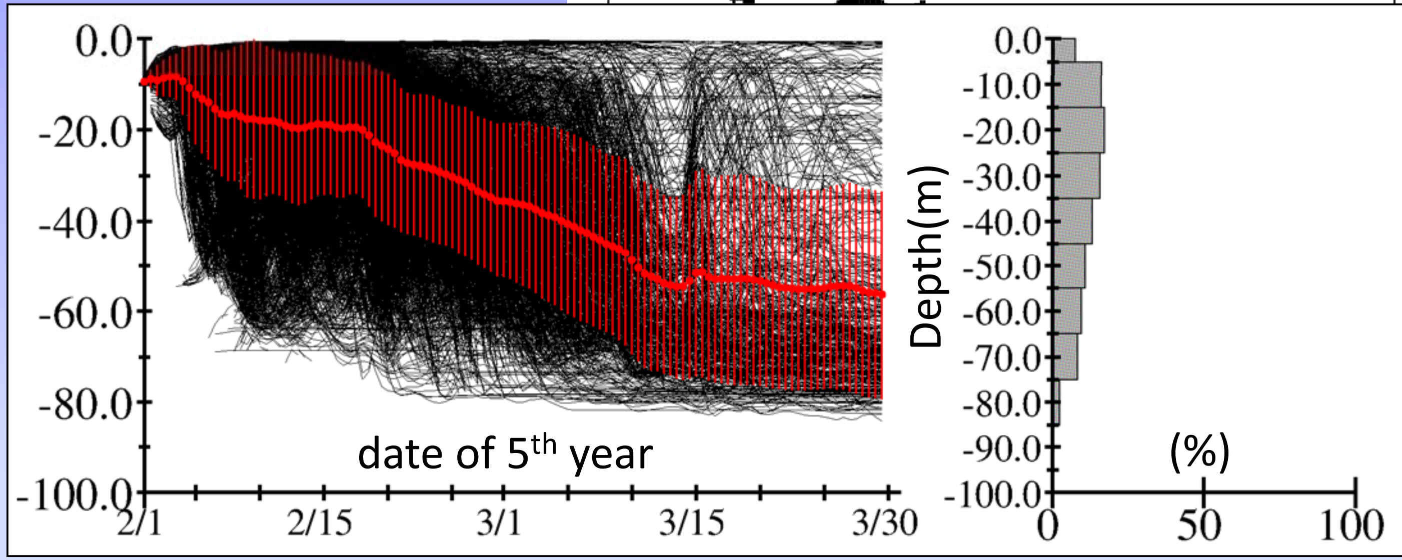
d : diameter of particle ($\sim 1.5 \times 10^{-3}\, m$)

υ : kinematic viscosity of water ($\sim 1.5 \times 10^{-6}$ m^{2}s^{-1})

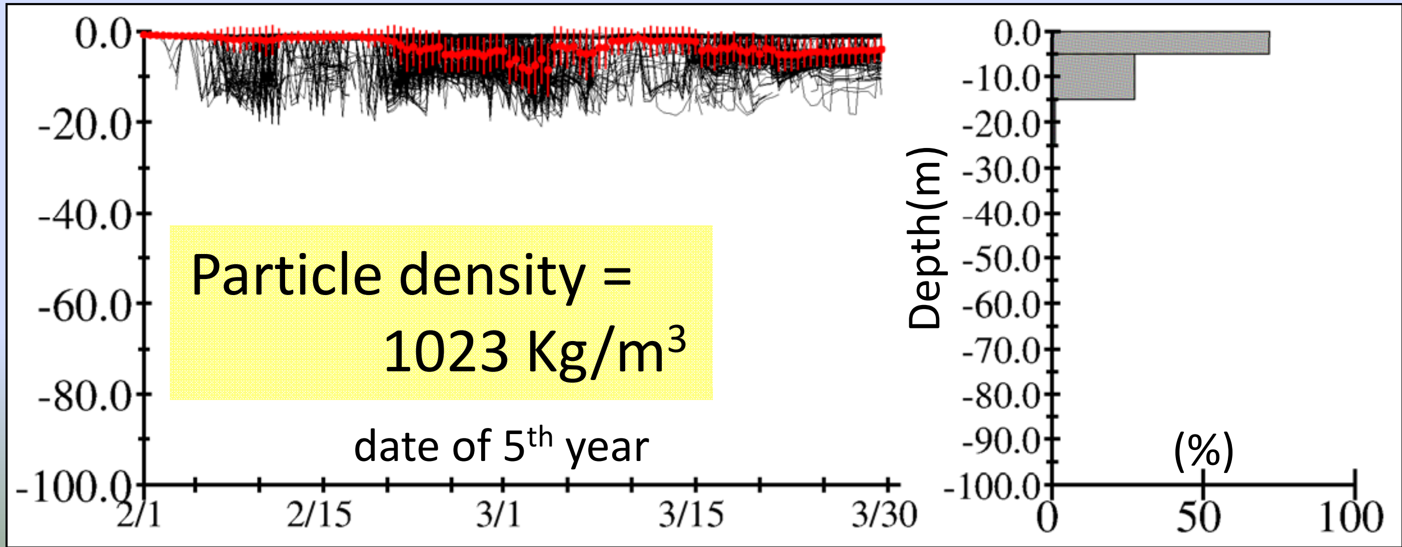
g : gravity acceleration($\sim$ 9.8ms^{-2})

Vertical position of particles within Funka Bay

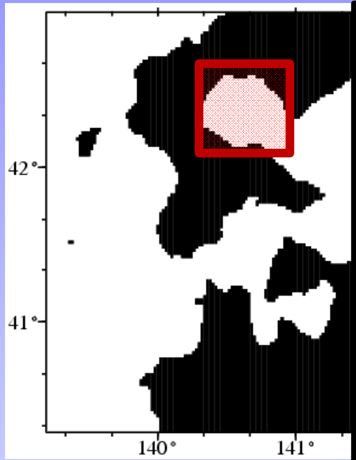
Passive
(no buoyancy)

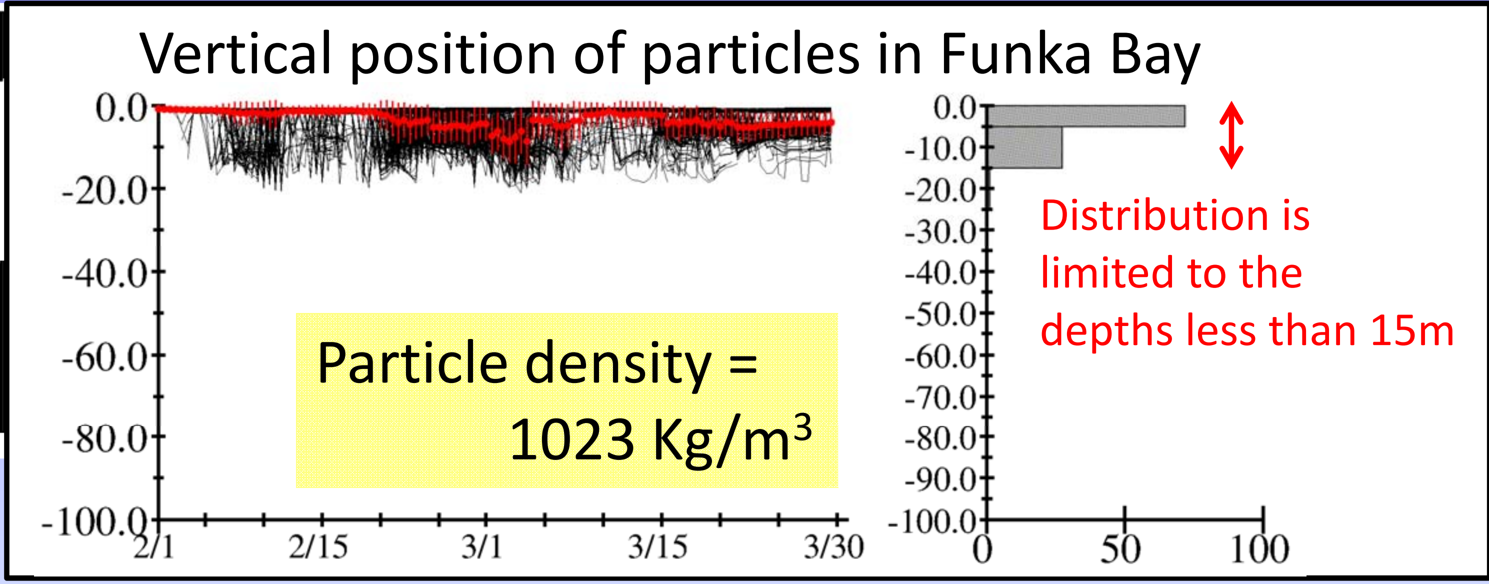


Particle
density
$=1023\ Kg/m^3$

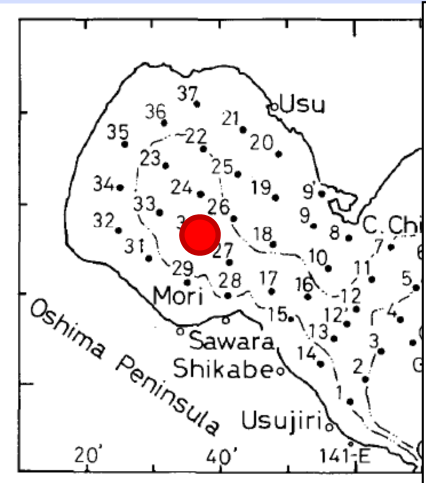


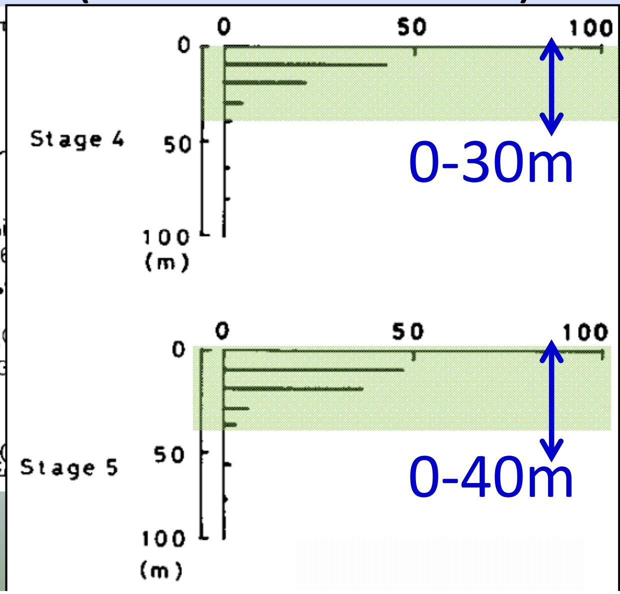
Comparison with observation



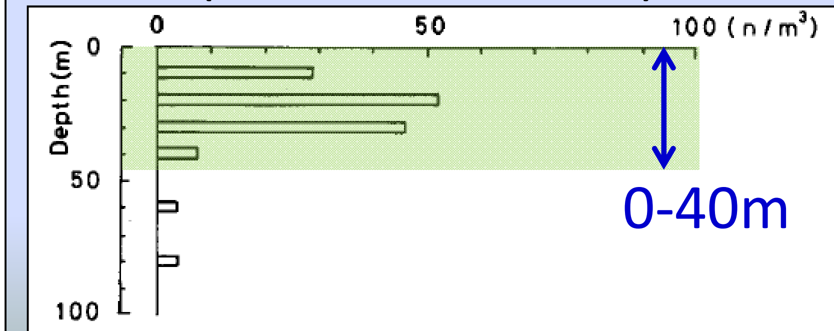


Eggs collected by MTD nets
(15-16 Mar. 1982)





Larvae collected by MTD nets
(15-16 Mar. 1982)



Nakatani (1988)

The third particle-tracking experiment
Including turbulent motion

$$\begin{cases} x_{n+1} = x_n + u_{\text{model}} \delta t \\ y_{n+1} = y_n + v_{\text{model}} \delta t \\ z_{n+1} = z_n + (w_{\text{model}} + w_{\text{buoyancy}}) \delta t + K'_V \delta t + R\sqrt{2r^{-1} K_V \delta t} \end{cases}$$

Stokes' law (terminal velocity)

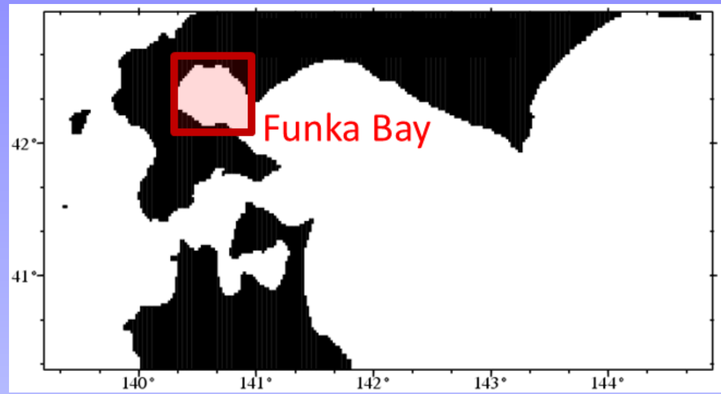
Corrected random walk Visser (1997)

K_V : vertical diffusivity derived from model

$K'_V = \partial K_V / \partial z$

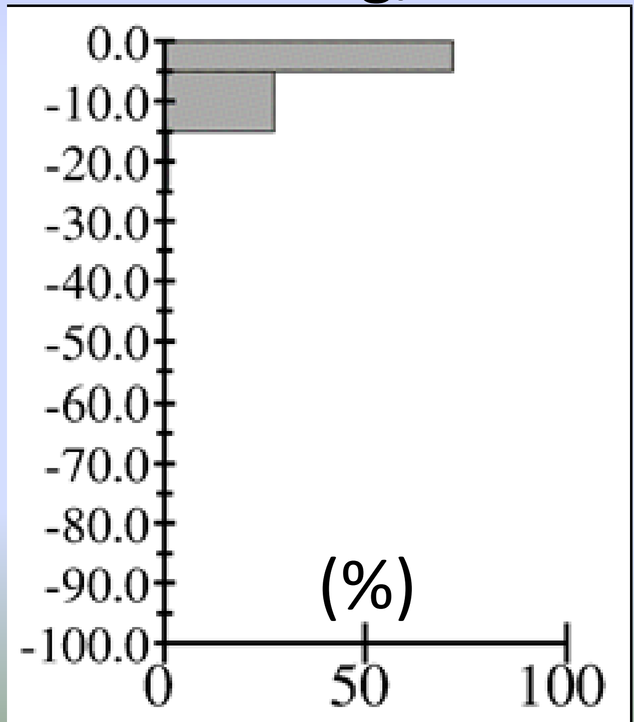
$R = \text{Random number (mean} = 0\text{, standard deviation} = r)$

Vertical position of particles within Funka Bay

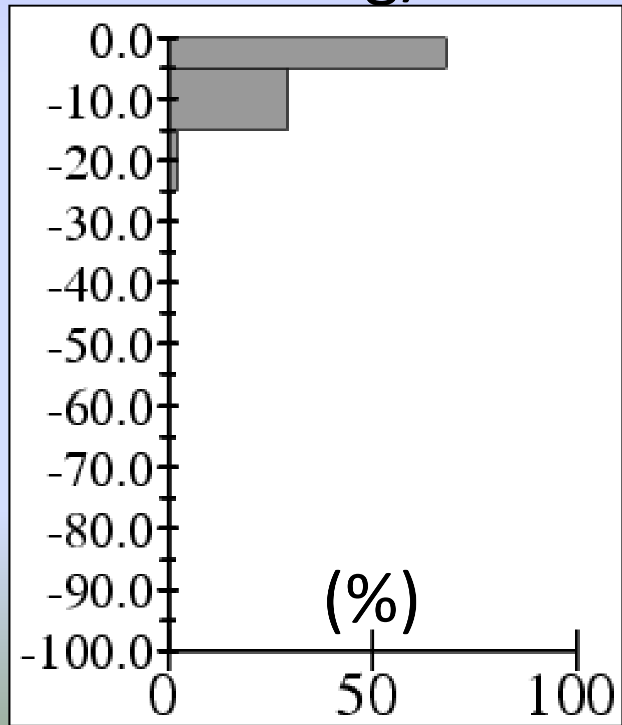


frequency distribution in March

Buoyancy
particle density
$=1023\ Kg/m^3$



Buoyancy plus turbulence
particle density
$=1023\ Kg/m^3$



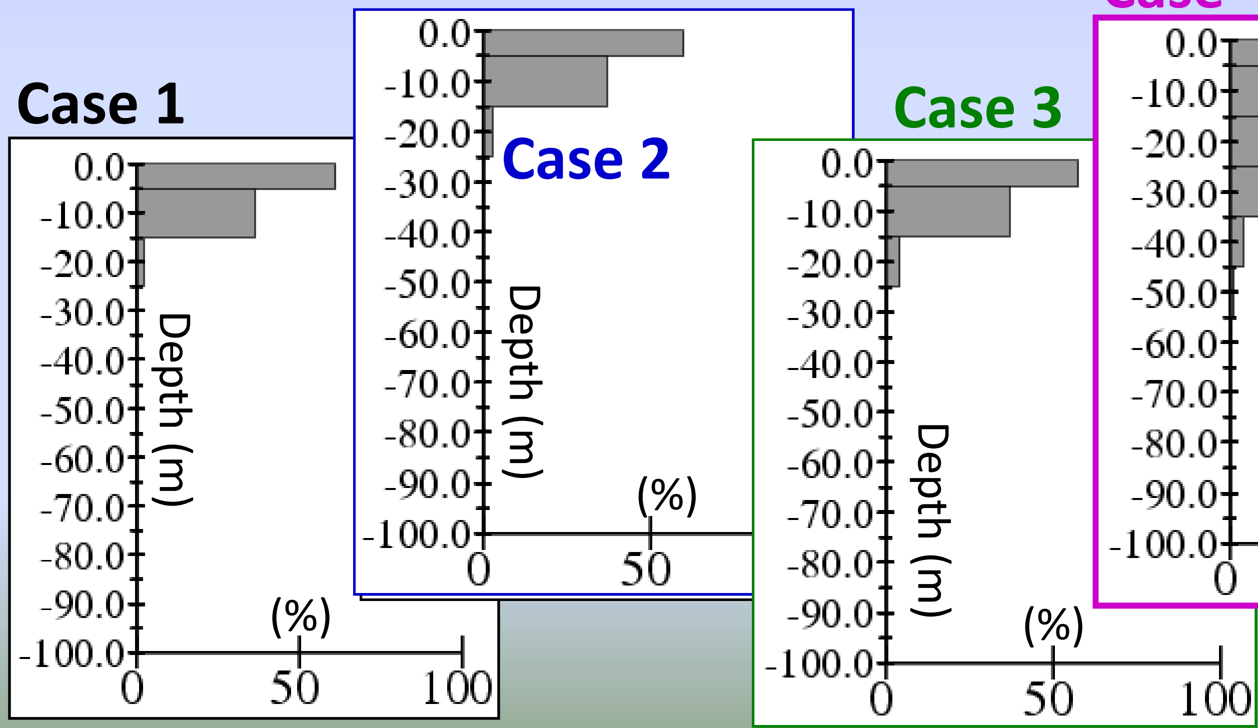
Sensitivity of vertical distribution to particle density

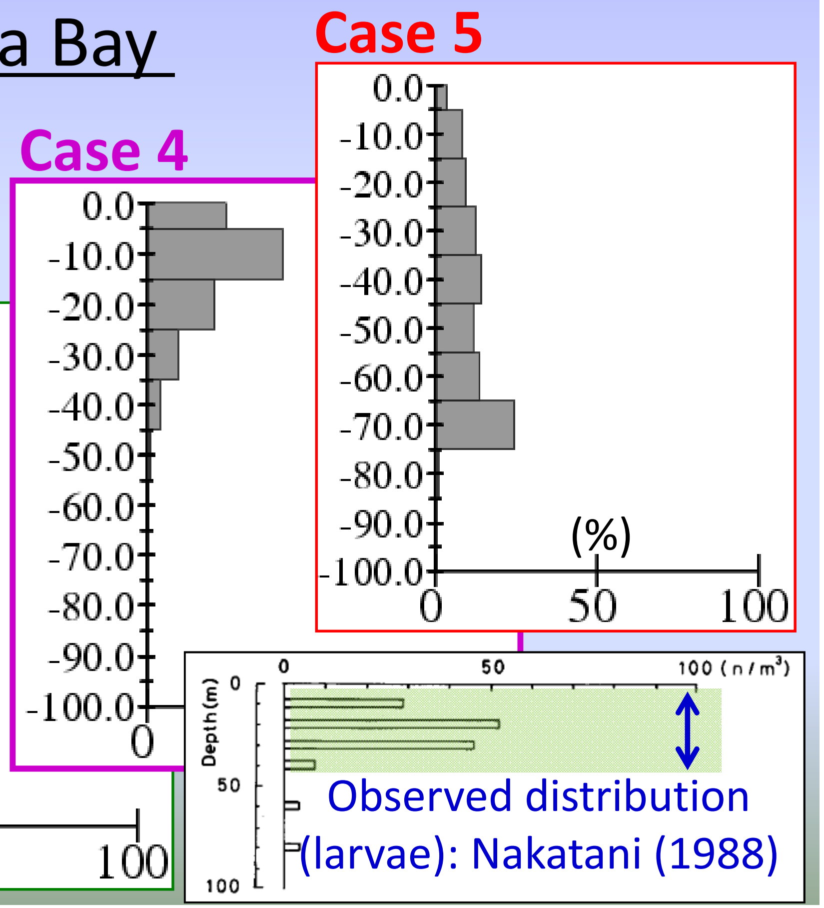
Case 1 : Turbulent motion + particle density = 1023.00 Kg/m^3
Case 2 : Turbulent motion + particle density = 1024.00 Kg/m^3
Case 3 : Turbulent motion + particle density = 1025.00 Kg/m^3
Case 4 : Turbulent motion + particle density = 1026.00 Kg/m^3
Case 5 : Turbulent motion + particle density = 1026.50 Kg/m^3

Cases 1–3: Laboratory Exp. range
Cases 4–5: Mixed layer density

Vertical position of particles in Funka Bay

(Frequency distribution in March)





Sensitivity of particles remaining in Funka Bay to the density

Case 0 : Default (completely passive)

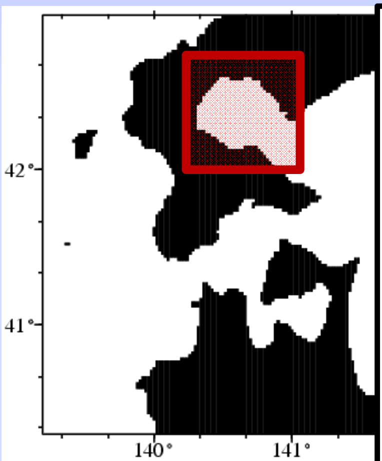
Case 1 : Turbulent motion + particle density = 1023.00 Kg/m^3

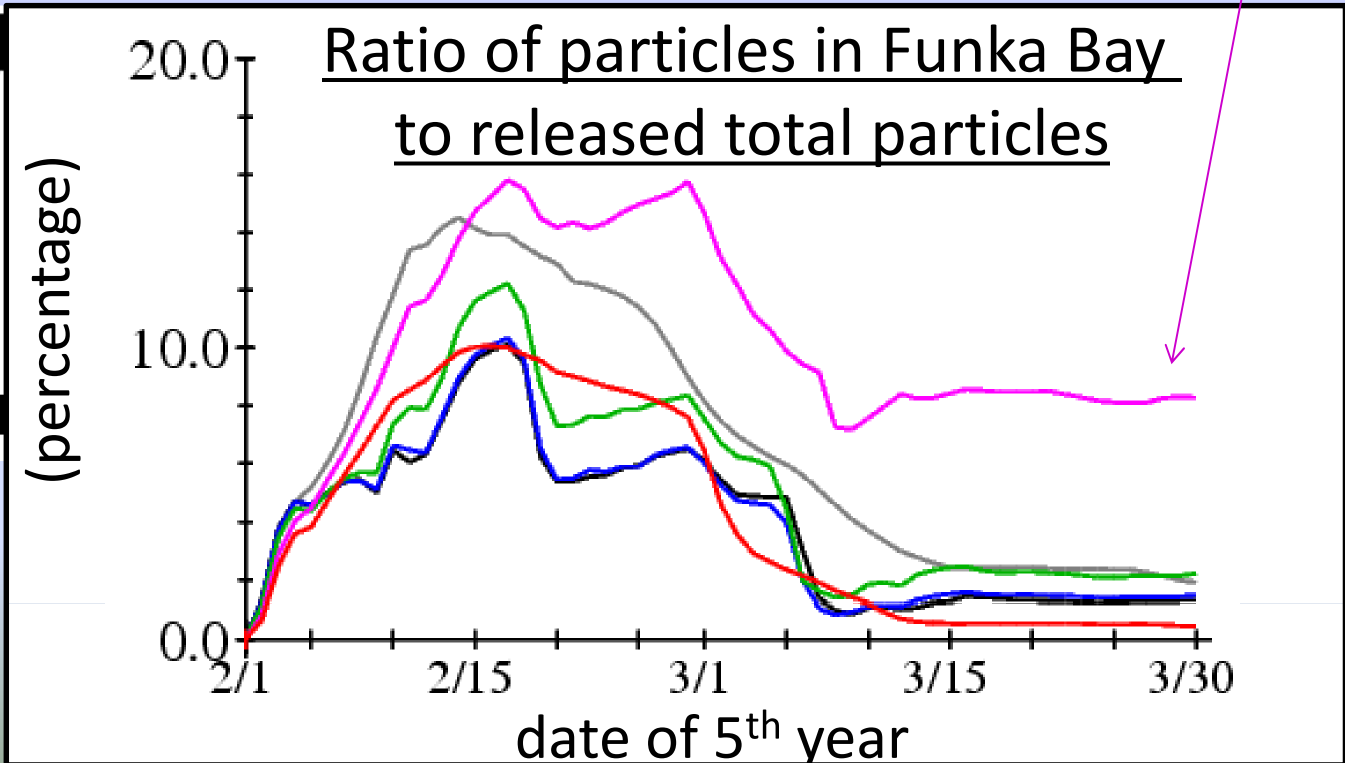
Case 2 : Turbulent motion + particle density = 1024.00 Kg/m^3

Case 3 : Turbulent motion + particle density = 1025.00 Kg/m^3

Case 4 : Turbulent motion + particle density = 1026.00 Kg/m^3

Case 5 : Turbulent motion + particle density = 1026.50 Kg/m^3





Conclusion

(1) Development of the 1/50-degree high-resolution model.

(2) Basic particle-tracking experiments showed
remarkable differences in particle behavior
between the 1/50- and 1/10-degree models.

- Behavior of particles transported into Funka Bay
- Horizontal dispersion
- Vertical movement

Buoyancy/density of eggs and larvae is essential.

(3) Sensitivity experiments suggested that
particles remaining in Funka Bay are very sensitive to
the density of eggs and larvae of walleye pollock.

Optimum density ~ 1026Kg/m^3

In future work

- We will compile historical field observation data
  to confirm the validity of the optimum density.

- We will perform particle-tracking experiments
  to clarify the causes of year-to-year variations
  in stock and recruitment of the walleye pollock
  after updating the model configuration.