Estimates of the shelf residence time using a 2-km resolution Japanese coastal model

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1. Introduction

Mean residence time of the sea water in the Japanese coastal seas
- is basic information for grasping and forecasting coastal seawater pollution and sea condition change.
- has been studied in several closed bays and inland seas:
  * 0.69 months in the Ise Bay
  * 6.4-14.7 months in the Seto Inland Sea (Unoki, 1993)
- is expected to vary depending on area, but there is no research that reveals the whole picture of its spatial variation.

Based on our 2-km resolution Japanese coastal model, we estimated the residence time over the entire coastal seas using two indices:
1. shelf water age
2. particle residence time

2. Model

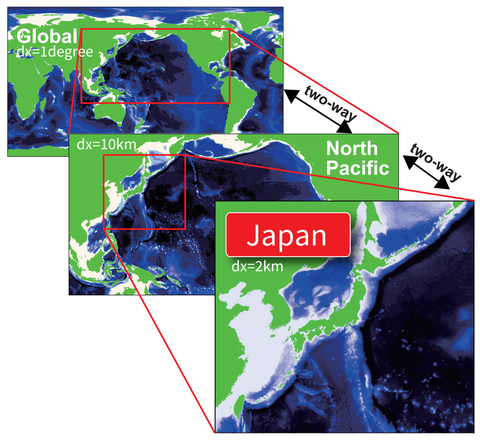


Fig. 1 Three models coupled by a two-way nesting scheme.

Table 1 Model specifications.

Model name	MRI.COM-JPN (Sakamoto et al. 2019, Ocean Dyn.)
area	117-160E, 20-52N
Numerical model	MRI.COM Ver.4.5
Grid coordinates	Vertical: free-surface z*, horizontal: latitude/longitude
Horizontal resolution	1/33° ×1/50° (approximately 2 km)
Vertical resolution	2-700m (60 layers, minimum water depth: 8 m)
Grid size	1423×1604×60
Tracer advection	SOM scheme (Prather 1986)
Horizontal mixing	Smagorinsky-like biharmonic viscosity and biharmonic diffusion
Turbulent vertical mixing	GLS scheme (Umlauf and Burchard 2003)
Background vertical diffusion	Decloedt and Luther (2010)
nesting	On-line two-way double nesting with water volume preservation
Lateral boundary	A North Pacific model
Surface forcing	Wind and SLP: JMA MSM dataset (hourly, dx=5 km) others: JRA55-do dataset (3 hourly, dx=~55 km)
River runoff	3986 rivers based on JMA Runoff Index (hourly)
tides	Main 8 constituents by theoretical equilibrium tide (Sakamoto et al. 2013)
inverse barometer effect	considered within the model
Sea ice	5-category sea ice with thermodynamics and elastic-viscous-plastic rheology
Numerical cost	4 days × FX-100 48 nodes / year

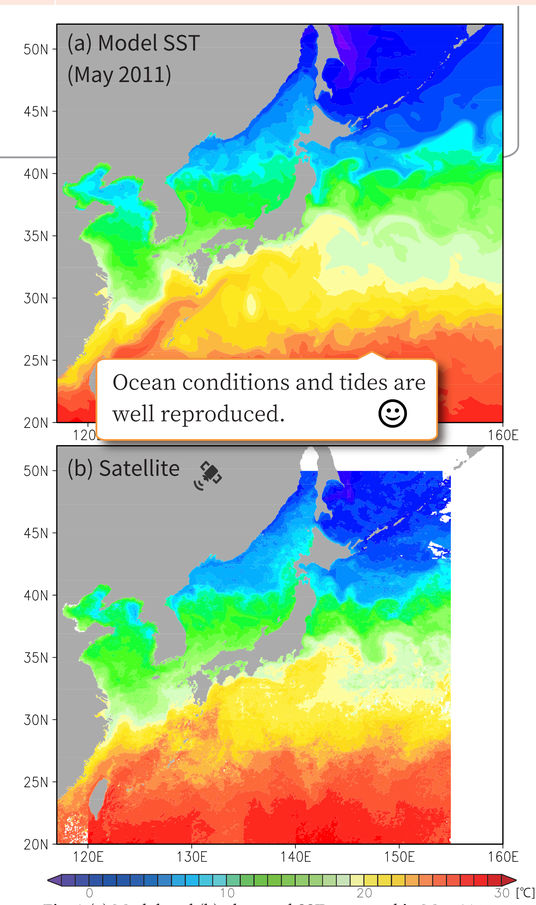


Fig. 2 (a) Model and (b) observed SST averaged in May 2011. (MODIS dataset: JAXA and Tokai Univ.)

3. Estimate by age tracer

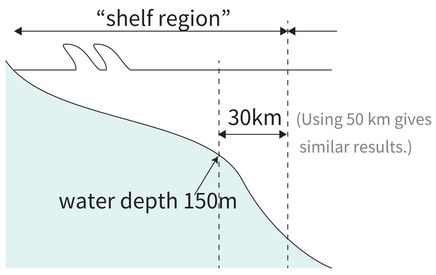
shelf water age

Nealy equilibrium value of age tracer, A, which gets older in the shelf regions

Experiment: Time evolution of age tracer, A, was calculated in the model as follows:

$$\frac{\partial A}{\partial t} = [\text{advection}] + [\text{diffusion}] + [\text{aging}]$$

- Initial value: 0.0
- Reset to 0.0 outside the shelf regions
- Lateral boundaries: two-way nesting with the parent model
- River runoff and precipitation: set 0.0
- Period: 8 years (2003-2011)



region	shelf water age
closed bays and Seto Inland Sea	100-450 days
Okhotsk Sea and San-in coasts	100-200 days
Kuroshio and Sanriku coasts	10-40 days
others	40-100 days

Downstream of continental shelf waters

Fig. 3 The shelf water age A. The surface value averaged from 2005 to 2011 is shown. The two white contours indicate 40 and 100 days.

4. Estimate by particle tracking (test)

particle residence time

Time required for particles placed along the coasts to be 50 km away

Experiment: Particle positions, **x**, were calculated in the model as follows:

$$\frac{\partial \boldsymbol{x}}{\partial t} = [\text{advection}] + [\text{random walk}]$$

Coefficient: 10[m²/s]
Results depend on this parameter.

- Initial position:
  Center of the first layer of the grids adjacent to the lands
- Number of particles:
  1 [/grid /day] * 6637 [grid] * 365 [day]
- Period: 3 years (2009-2011)

Results similar to the shelf water age are shown, except for
- nearly half of the age
- large in the Mikawa Bay
- not large (5-20 days) along the Okhotsk and San-in coasts.

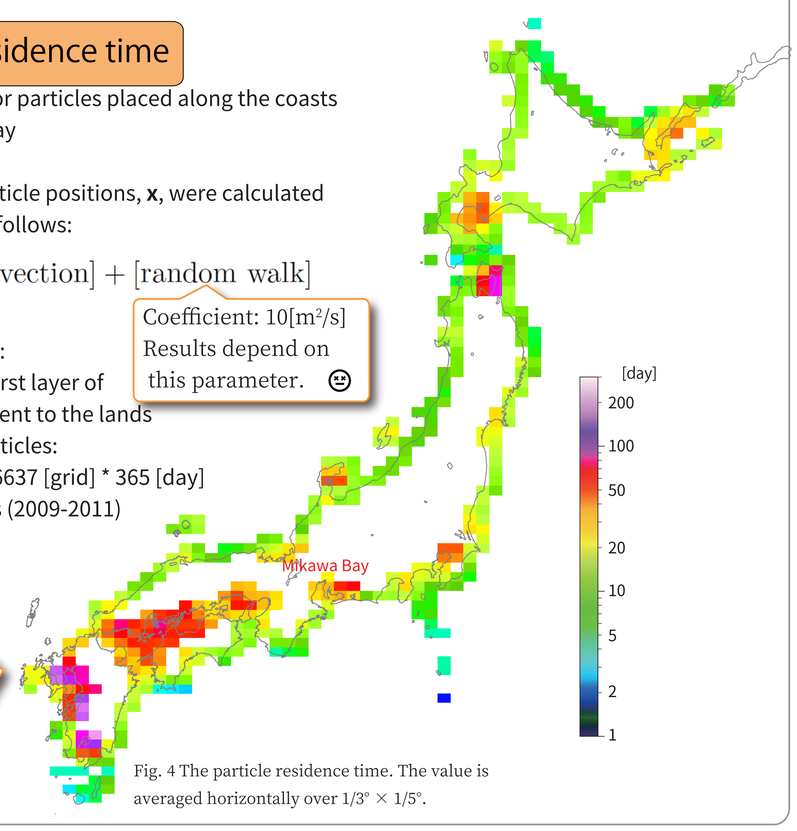


Fig. 4 The particle residence time. The value is averaged horizontally over 1/3° × 1/5°.