Evaluation of hydrodynamic effects on blue carbon dynamics in the Yatsushiro Sea

Bing XIONG[1], Naoki SAITO[1], Hiroto KOMORO[1], Shinichiro YANO[1], Keisuke NAKAYAMA[2], Katsuaki KOMAI[3], Kei YAJIMA[4]

(1) Kyushu University, Fukuoka, Japan
(2) Kobe University, Kobe, Japan
(3) Kitami Institute of Technology, Kitami, Japan
(4) Shimane University, Matsue, Japan

IAHR APD 22nd IAHR-APD CONGRESS 2020 IN SAPPORO

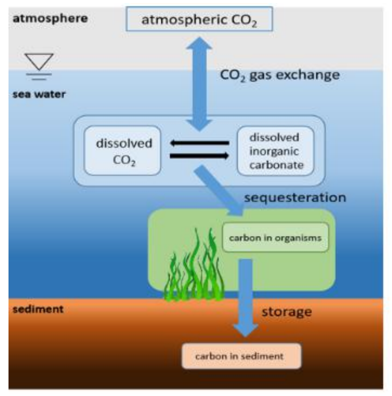
INTRODUCTION

Recent researches have highlighted a valuable role that coastal and marine ecosystems play in sequestering carbon dioxide (CO_2).

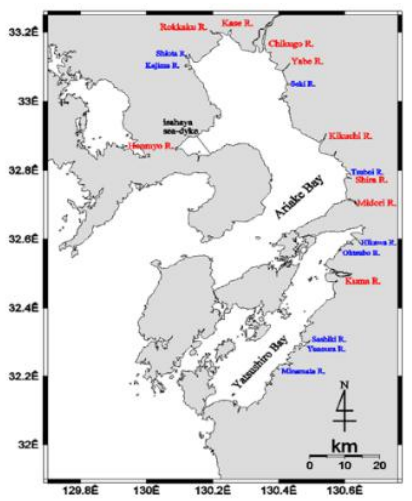
Carbon stored and sequestered in the coastal ecosystem is called "blue carbon" (Nellemann et al., 2009). It is clear that about 45 to 71% of blue carbon is absorbed by the shallow coastal waters.

Therefore, shallow coastal waters with vegetation such as seaweeds are considered to be significant sinks for carbon sequestration and storage.

In this study, we conducted the first field measurement of blue carbon dynamics in the Yatsushiro Sea, in order to analyze water quality parameters such as DIC and TA that have the greatest influence on pCO_2 in seawater. In addition, we tried to develop a 3D numerical model that can evaluate hydrodynamic effects, such as the effects of inflow from rivers and the Ariake Sea, which is connected to the Yatsushiro Sea by three very narrow channels, on the dynamics of DIC and TA in the bay.



Conceptual diagram of carbon sequestration and storage by living organisms in coastal waters



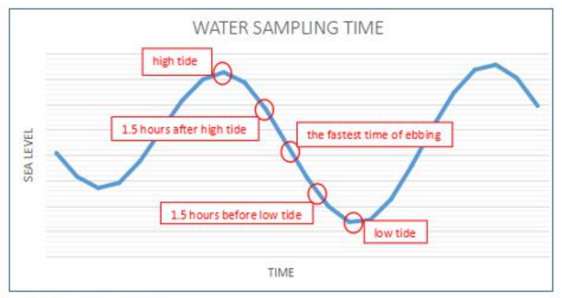
The Yatsushiro Sea and related rivers

FIELD MEASUREMENT

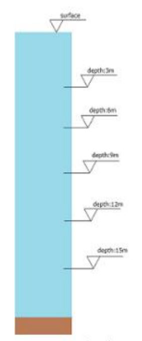
METHOD

- ❑Measurement time : August 26, 2018 (summer) December 7, 2018 (winter)
- ❑Measurement point : near the mouth of Kuma river.
- ❑CTD measurement : Manual operation with ProDSS (produced by YSI) every 20 minutes from the seawater surface to the seafloor. (salinity, temperature, depth)
- ❑Water sampling : Collect water 5 times from 6 layers (surface, 3m, 6m, 9m, 12m, 15m) each time. (TA, DIC)

The measurement point



Water sampling time



Water sampling layers

Results and discussion

The comparison between ΔDIC and ΔTA (calculated by using the measured value minus the value we estimated by end-member method which considered not affected by biological processes) obtained from this measurement and ones from the previous study (Tata et al., 2015) is shown in Table 1. As we can see, compared to seagrass meadow, ΔDIC shows similar values, but ΔTA is extremely low. Therefore, we can consider that DIC and TA measured at the measurement point are affected by both the photosynthesis of plants and the calcification of corals. However, although ΔDIC and ΔTA are calculated by considering the influence of the A-class river Kuma River that accounts for 60% of the whole catchment area inflow into the Yatsushiro Sea, we still need to evaluate whether other smaller rivers have obvious effects on DIC and TA measured in this study. In addition, because the measurement point is located near the strait between the Ariake Sea and the Yatsushiro Sea, the effects of the inflow of seawater from the Ariake Sea on the measured data must be considered as well. Thus, we can consider that the factors affecting DIC and TA at the point are both of hydrodynamic factors such as the seawater inflow from the Ariake Sea and the freshwater inflow from other small rivers, and biological factors such as the photosynthesis of seaweeds and phytoplankton and the calcification of corals. Next, we tried to develop a numerical model to evaluate the hydrodynamic factor's effects.

Table 1. Comparison between ΔDIC and ΔTA obtained from the measurement and ones from the previous study (Tata *et al.*, 2015)

	Measurement area	Ecosystem type	ΔDIC [μmol/kg]	ΔTA [μmol/kg]
This study	Yatsushiro sea (2018/8/26)	unknown	-118.1±15.0	-57.3±13.3
	Yatsushiro sea (2018/12/7)	unknown	-70.2±2.7	-58.8±2.4
Previous study (Tata et al.,)	Furen lagoon	seagrass meadow	-62.0±18.7	-29.1±22.6
	Komuke lagoon	seagrass meadow	-230.3±85.2	16.7±119.3
	Hashirimizu coast	seagrass meadow	-36.5±9.0	9.5±4.9
	Nojima coast	seagrass meadow	-311.7±206.2	-1.1±21.9
	Matsuwa mudflat	mudflat	8.9±101.0	44.9±48.8
	Banzu mudflat	mudflat	27.6±15.6	50.3±88.8
	Futtsu mudflat	mudflat	-85.6±108.7	-45.9±27.5
	Fukidogawa estuary	coral reef	17.5±14.9	-111.3±21.9
	Shiraho coast	coral reef	-48.4±177.7	-132.1±113.2

NUMERICAL MODEL

METHOD

❑In this study, a particle tracking model that calculates the amount of the inflow from the Ariake Sea and the rivers (flowing into the Yatsushiro Sea) was developed by applying D-WAQ PART (coupling hydrodynamics model by FLOW) module of Delft3D.

SETUP OF MODEL

Calculation A

- ❑Calculation object: The Ariake Sea
- ❑Release areas: 2 instantaneous release areas with radius of 4,250m and 5,000m
- ❑The initial concentration: 1.0kg/m^3
- ❑Release time:

		Tide time	Release time	Tide level (cm)
Spring tide	High tide	7/14 22:27	7/14 22:00	431
	Low tide	7/14 16:00	7/14 16:00	-7
Neap tide	High tide	7/21 15:46	7/21 16:00	303
	Low tide	7/21 21:43	7/21 22:00	179

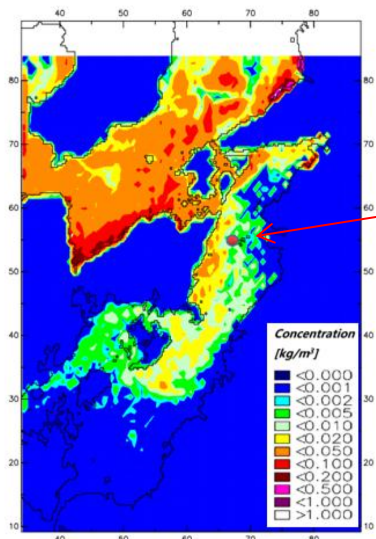
Calculation B

- ❑Calculation object:
  A-class: Kuma river
  B-class: Hikawa river, Ohtsubo river, Sashiki-Yunoura river, Minamata river
- ❑Release points: 5 continuous release points with radius of 1m
- ❑The initial concentration: 1.0kg/m^3
- ❑Release time: 2018/07/01 - 2018/09/01

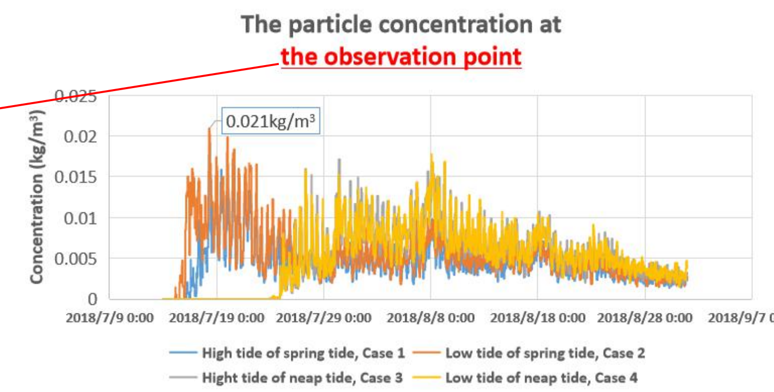
Results and discussion

Calculation A

In calculation A, the temporal variations in the particle concentration of seawater at the observation point for each release timing case were calculated, and we compared these results. We can see that the maximum peak of concentration is about 0.021 kg/m^3 at 8:00 on July 18, 2018, in case of the release at the low tide of spring tide. That means the largest effects of the inflow of seawater from the Ariake Sea can be evaluated as about 2%.

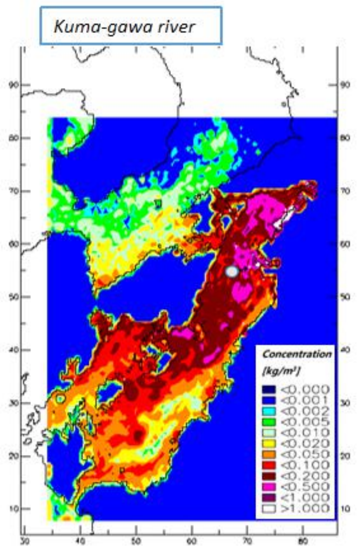


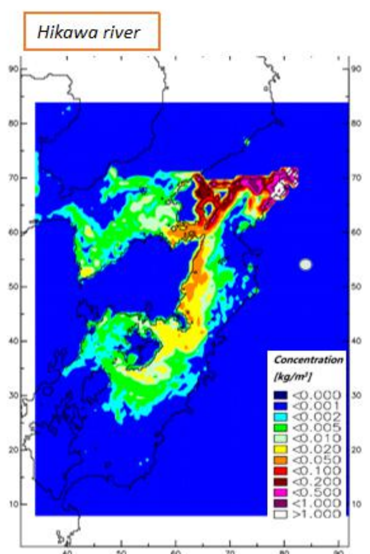
Particle concentration distribution

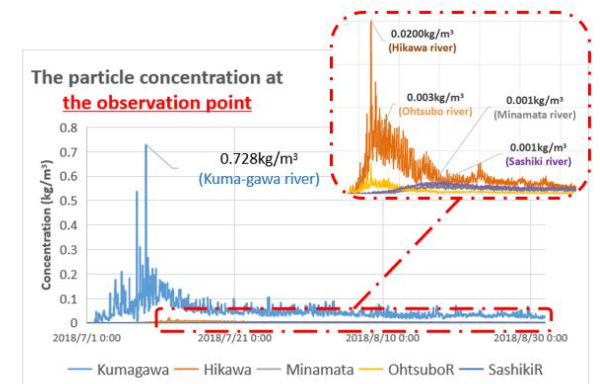


Calculation B

In the calculation B, the particle concentration variation of the riverine freshwater flowing at the observation point was calculated. We compared these results in cases of five rivers including the Kuma River case. We can see that the measurement point area was significantly affected by the freshwater from the Kuma River, and its maximum concentration of inflow reaches about 0.728 kg/m^3. Also, we calculated the effects of the inflow from the other four smaller rivers as shown in Table 2. We found that the inflow effects of the small rivers are totally accounted for about 3.54% of the value of the Kuma River. Therefore, it can be ignored. From these considerations, we can conclude that the hydrodynamic effect, namely, the inflows of the Ariake Sea seawater and freshwater of small rivers, on the pCO_2 dynamics is not significant in the area.







Comparison of the results of 5 rivers

Table 2. Maximum concentration of the freshwater of five rivers flowing into the Observation point

River name	Maximum of concentration (kg/m^3)	Ratio to Kuma R
Kuma R	0.728	100.00%
Hi R	0.020	2.75%
Minamata R	0.001	0.14%
Ohtsubo R	0.003	0.45%
Sashiki R	0.001	0.20%

CONCLUSION

We conducted field measurement of the blue carbon dynamics and hydrodynamic numerical simulation to investigate the physical effects in the Yatsushiro Sea. As a result of this study, we found out the followings: i) the value of ΔTA is extremely low comparing to the past study (Tata et al., 2015); ii) the largest effects of the inflow of seawater in the Ariake Sea can be evaluated as about 2%; and iii) the inflow effects of the small rivers are totally accounted for about 3.5% of the Kuma River. We can conclude that biological effects by photosynthesis of both seaweed and phytoplankton, and calcification of corals can be considered as a significant factor affecting the blue carbon dynamics in the bay.