Evaluation and prediction of the influences of ocean acidification to the subarctic coast

Takuto Yamaka[あ], Shintaro Takao[い], and Masahiko Fujii[あ]

[あ]Graduate School of Environmental Science, Hokkaido University

[い]National Institute for Polar Research

E-mail: mfujii@ees.hokudai.ac.jp

Anticipated economic loss caused by ocean acidification (OA)

- Decrease in mollusk catch in USA by 1.7 through 10 billion USD by the middle of 21st century
  (Cooley et al., 2009, Environ. Res. Lett.)

- Decrease in world's mollusk catch by 100 billion USD by the end of 21st century
  (Narita et al., 2012, Climatic Change)

- Decrease in calcifier catch in Japan by 5 billion through 20 billion USD by the end of 21st century
  (Fujii, 2018, Kaiyo monthly)

Evaluation and prediction of the influences of ocean acidification to the subarctic coast

Outline

1. Why subarctc?
2. Why coast?
3. Monitoring
4. Modeling
5. Summary

This study aims to clarify diurnal/seasonal variations of ocean acidification (OA) properties (i.e. pH and Ω) in the subarctic coast in Japan

1. Why subarctic?

- Vulnerable to OA, because of lower water temperature with higher CO_2 solubility

- Relatively high dependency of fisheries on calcifiers (see next slide)

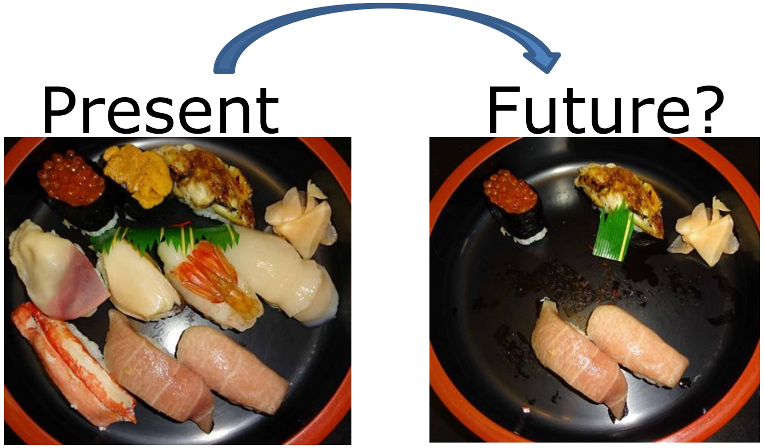
- Diurnal/seasonal variations of OA-related parameters (such as pH and Ω) have not yet well known, because of paucity of data in winter
when bad weather prevents us from observation

In Japan,

- one-fourth of total fish catch*
- half of calcifier catch**
- 60% of shellfish catch***

are from the subarctic (Hokkaido

→ Possible impacts of OA



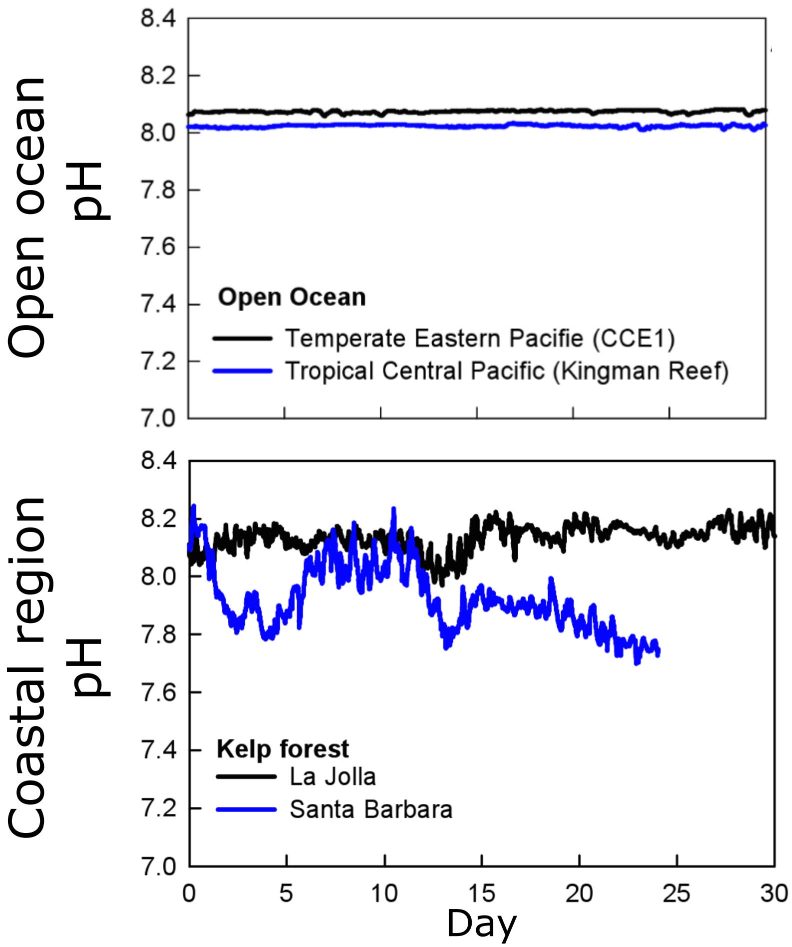
(https://www.ees.hokudai.ac.jp/carbon/mfujii/en/research/)

	Target species	Fish catch in Japan (J) (hundred million yen /yr)	Fish catch in Hokkaido (H) (hundred million yen / yr)	(H) / (J) (%)
Calcifiers	Shellfish	682	409	**60*** **
	Shrimps	219	36	16
	Crabs	193	47	24
	Sea urchins	74	52	71
	Krills	1	0	2
	Subtotal	1,169	544	**47** **
Non-calcifiers		6,662	1,475	22
Total		7,831	2,020	**26***

(農林水産省統計部　漁業・養殖業生産統計年報)

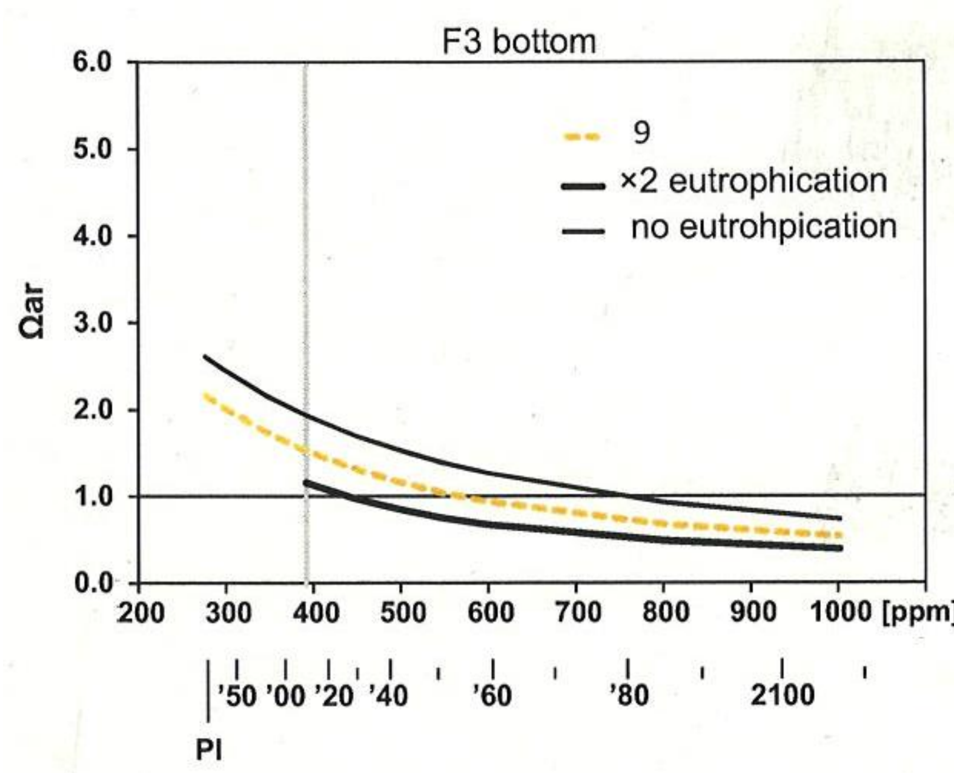
2. Why coast?

- Large diurnal/seasonal variation



(Hofmann et al., 2011, PLoS One)

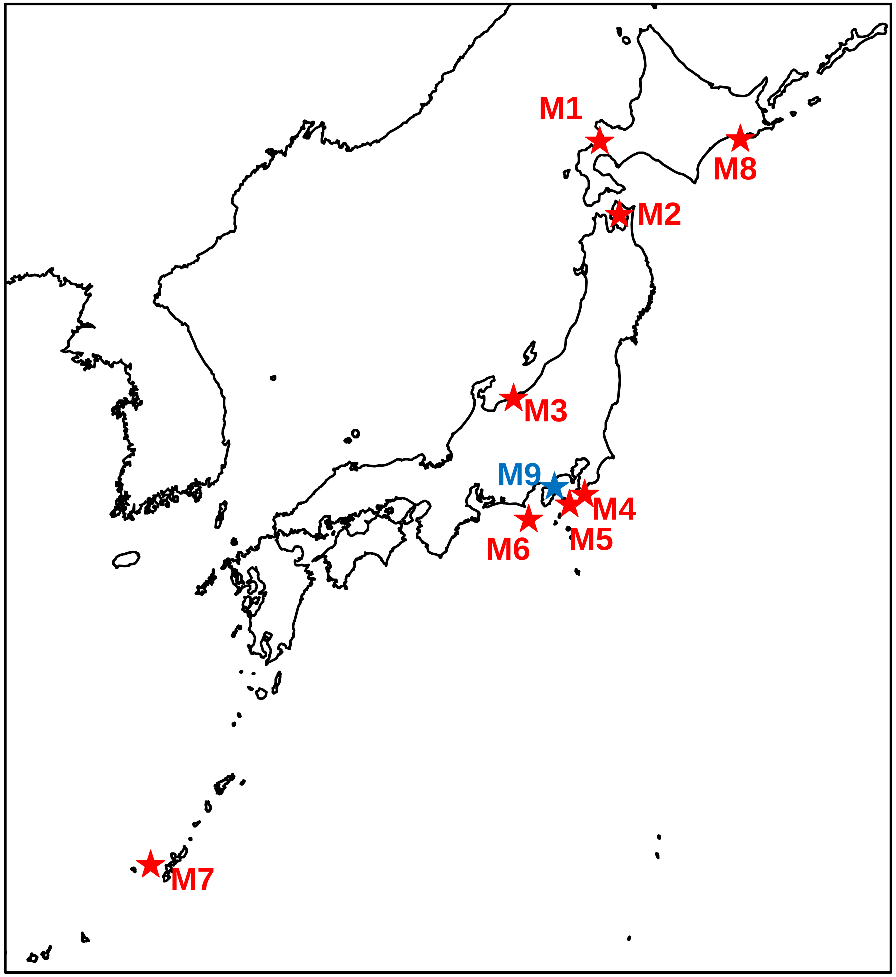
- Combined with other human impacts (e.g. eutrophication)



Simulated aragonite saturation state (Ωar) in the bottom of the central Tokyo Bay in September
(Yamamoto-Kawai, 2015, J. Oceanogr.)

3. Monitoring

Ongoing/past OA monitoring cites around Japan coast



M1: Oshoro Bay
[Hokkaido Univ./2013 - present]

M2: Tsugaru Straight
[JAMSTEC/2014 - present]

M3: Kashiwazaki Station
[MERI/1982 - present]

M4: Onjuku Station
[MERI/1982 - present]

M5: Tokyo Bay and Tateyama Bay
[TUMSAT/2011 - present]

M6: Shimoda Bay
[Tsukuba Univ./2011 - present]

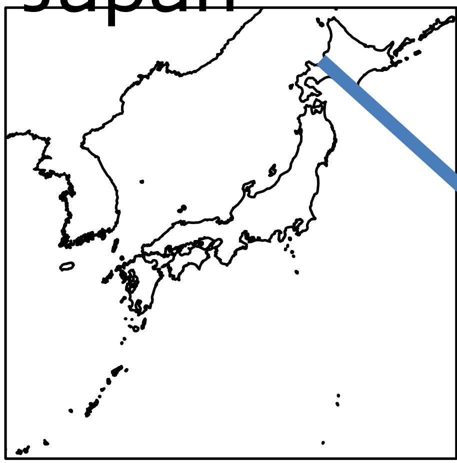
M7: Sesoko Island
[Ryukyu Univ./2000 - present]

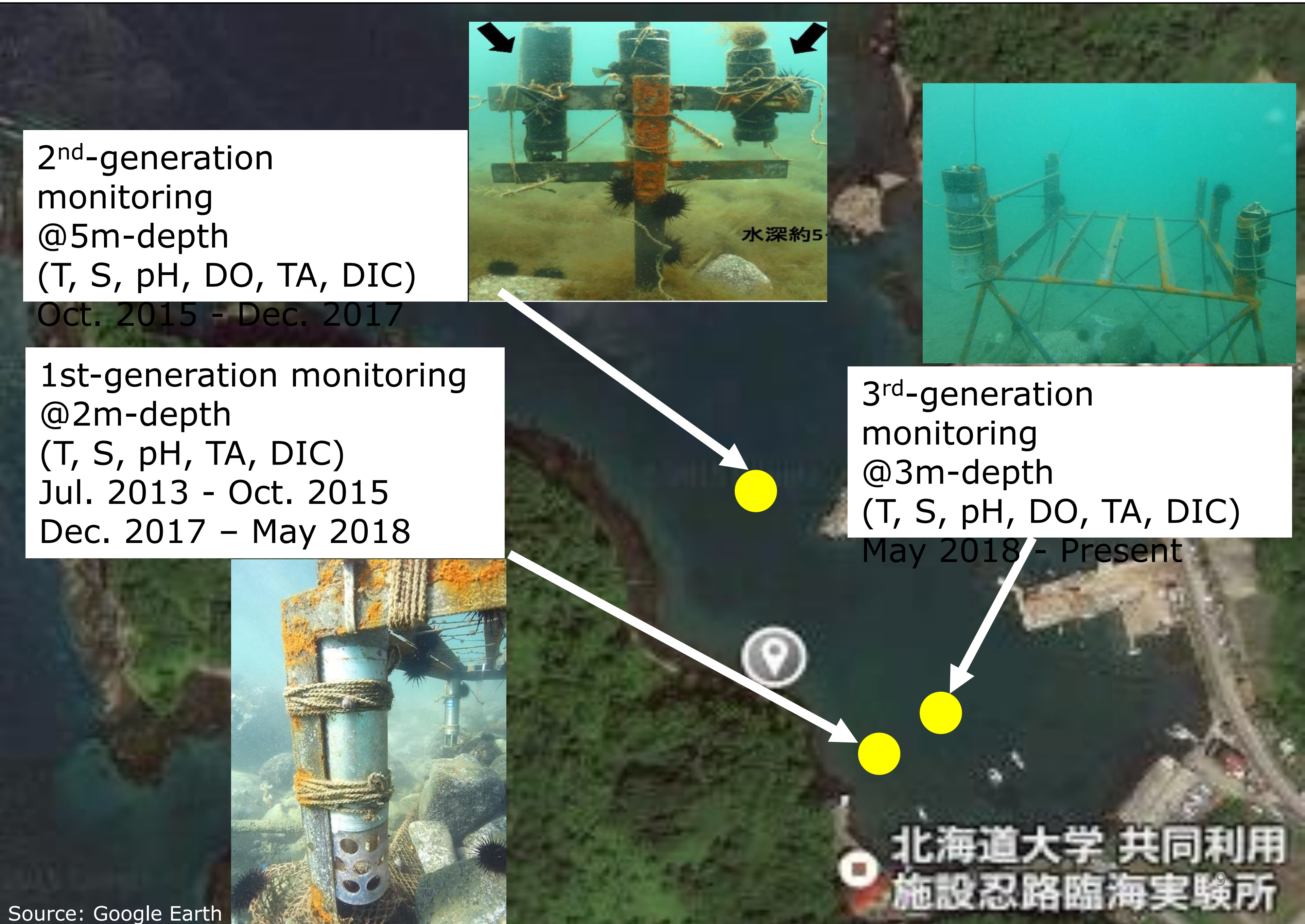
M8: Akkeshi Bay and Lake Akkeshi
[Hokkaido Univ./2014 - present]

M9: Arasaki Station
[FREA/2009 - 2011]

Source: Ono, T., M. Fujii, S. Takao, and Japan Ocean Acidification Network members, PICES 2017 Annual Meeting, Vladivostok, Russia, Sep. 22-Oct. 1, 2017

Oshoro Marine Station, Hokkaido University: A monitoring site in the subarctic coast in Japan




2nd-generation monitoring
@5m-depth
(T, S, pH, DO, TA, DIC)
Oct. 2015 - Dec. 2017
水深約5
1st-generation monitoring
@2m-depth
(T, S, pH, TA, DIC)
Jul. 2013 - Oct. 2015
Dec. 2017 – May 2018
3rd-generation monitoring
@3m-depth
(T, S, pH, DO, TA, DIC)
May 2018 - Present
北海道大学 共同利用施設忍路臨海実験所
Source: Google Earth

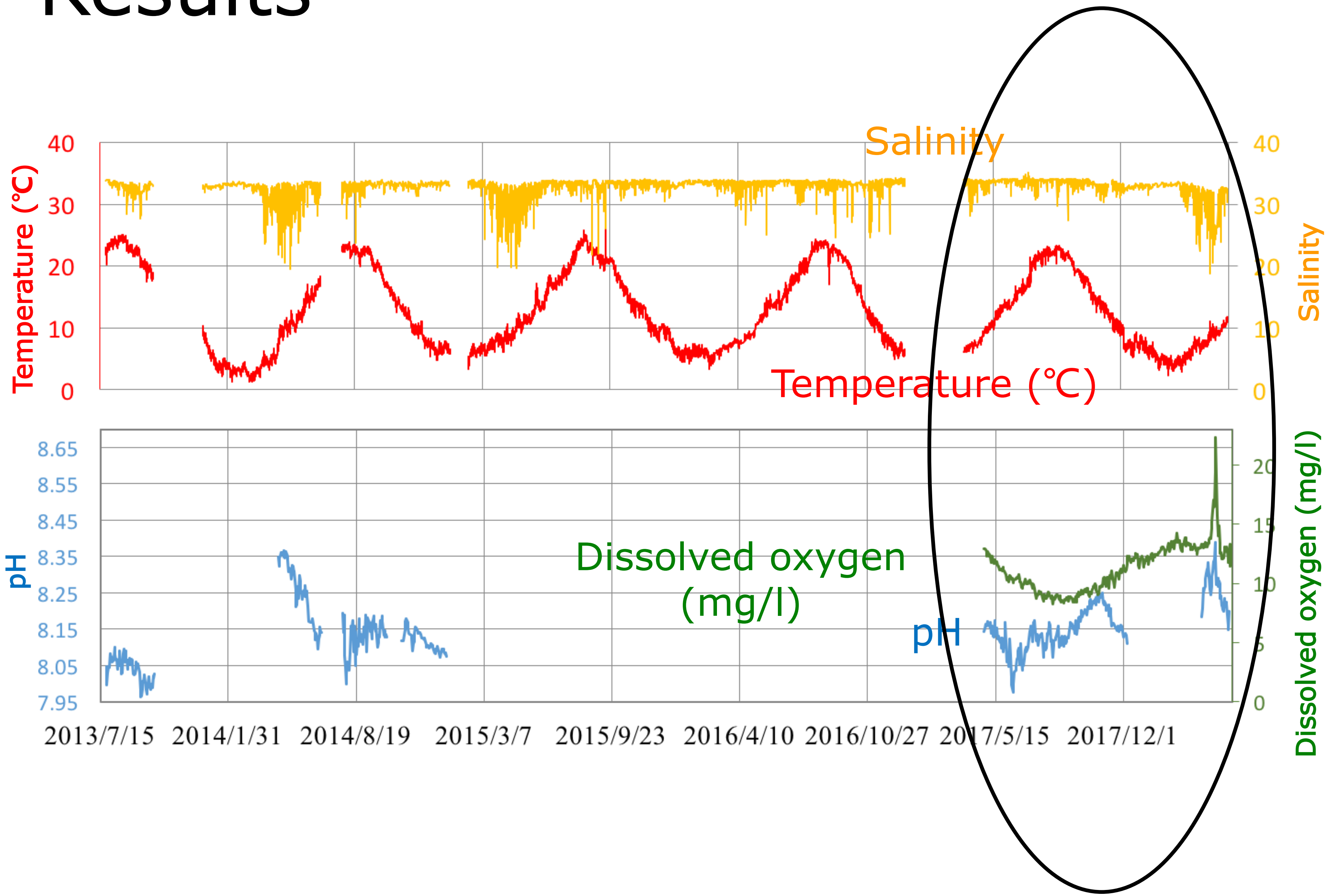
Monitoring

Parameter	Method	Sampling time
Temperature[1]	Sensor	Every hour
Salinity[1]		
pH[2]		
Dissolved oxygen (DO)[3]		
Dissolved inorganic carbon (DIC)	Water sample	Every 1-3 months
Total alkalinity (TA)		
Macronutrients		
pH & $CaCO_3$ saturation state (Ω)	CO_2SYS	

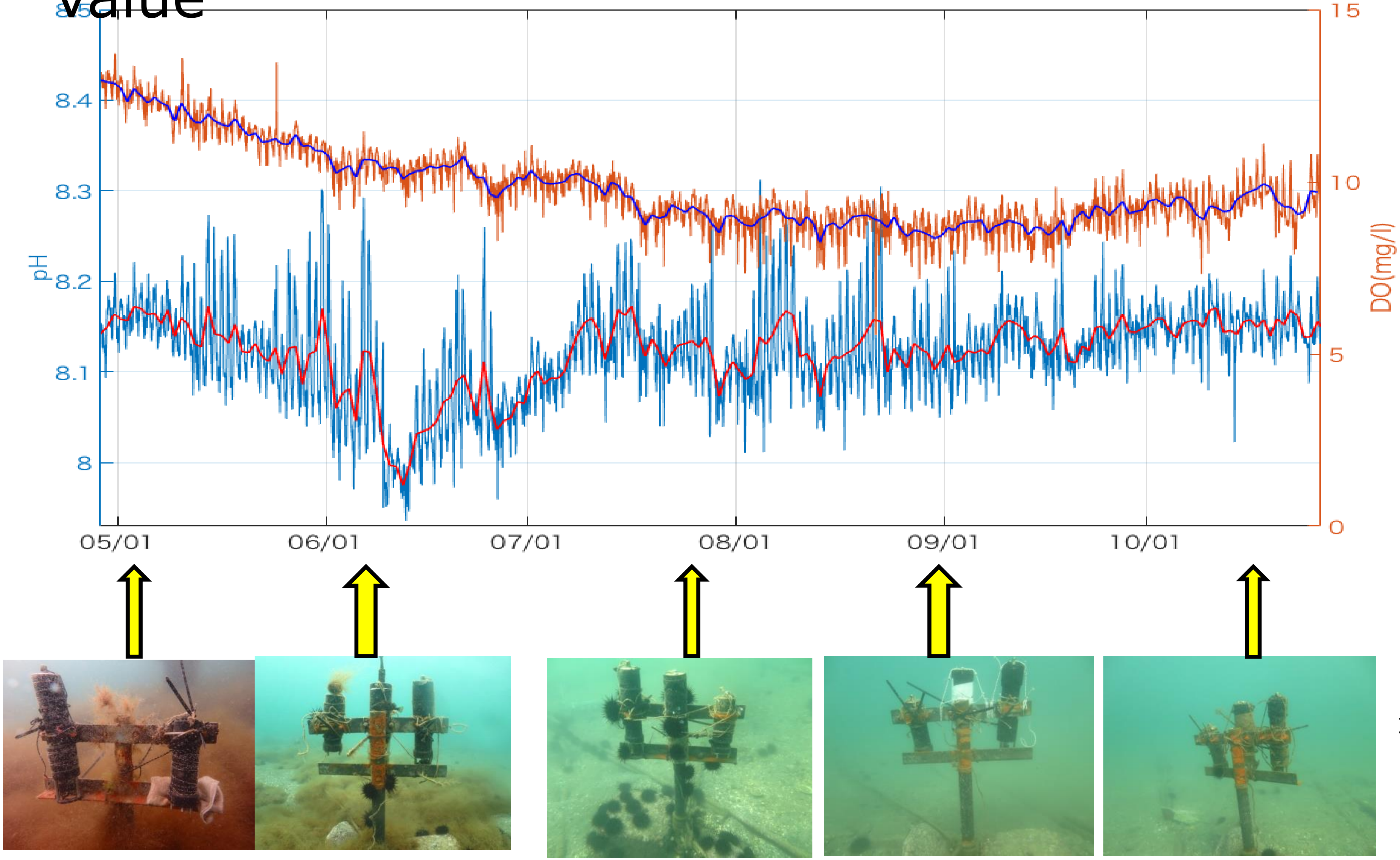
+ Hourly wind speed and precipitation (Japan Meteorological Agency)

[1]TS sensor (ACTW-USB, JFE Advantech)
[2]Glass electrode pH sensor (SP-11, Kimoto Electric)
[3]DO sensor (JFE Advantech)

Results


Salinity
Temperature (°C)
Salinity
Temperature (℃)
40
30
20
10
0
Dissolved oxygen (mg/l)
pH
pH
Dissolved oxygen (mg/l)
8.65
8.55
8.45
8.35
8.25
8.15
8.05
7.95
20
15
10
5
0
2013/7/15
2014/1/31
2014/8/19
2015/3/7
2015/9/23
2016/4/10
2016/10/27
2017/5/15
2017/12/1

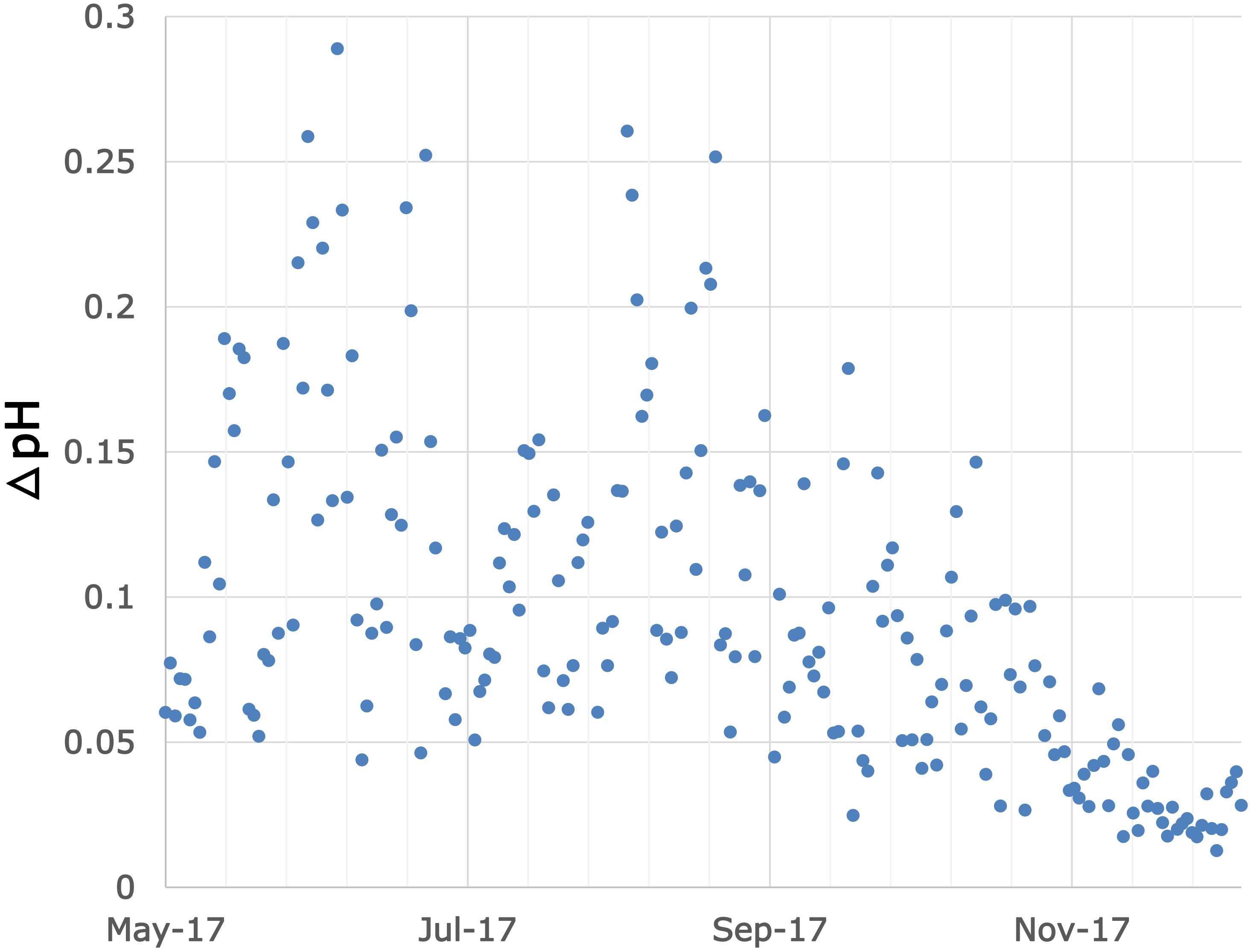
Diurnal and seasonal variation of pH and dissolved oxygen (DO) value



(Photo: Zen Tamura)

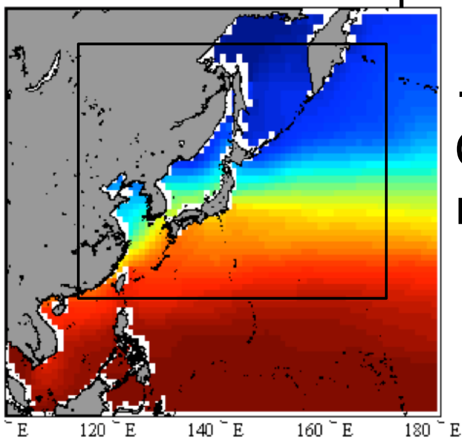
Diurnal variation of pH

(△pH = daily maximum pH – daily minimum pH)



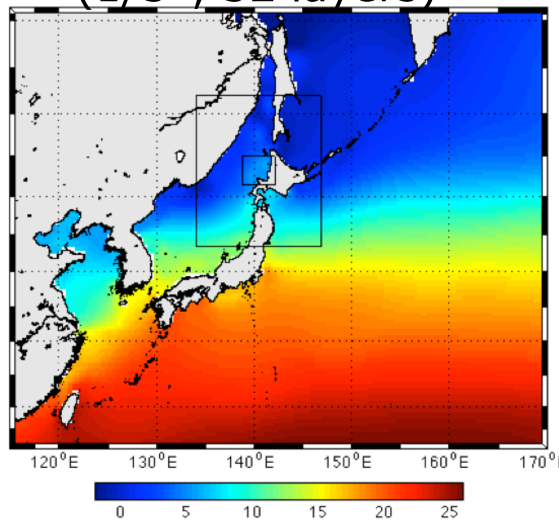
4. Modeling

Climatology or
climate model outputs (1°)



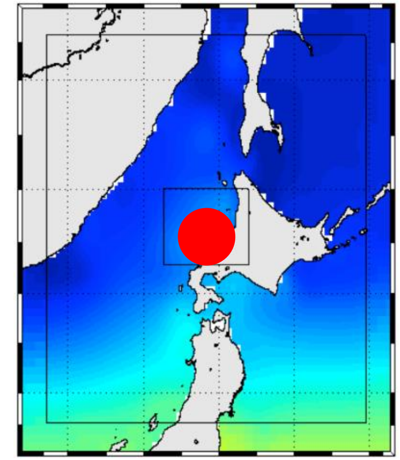
One-way
nesting

ROMS
(1/3°, 32 layers)



One-way
nesting

ROMS
(1/15°, 32 layers)



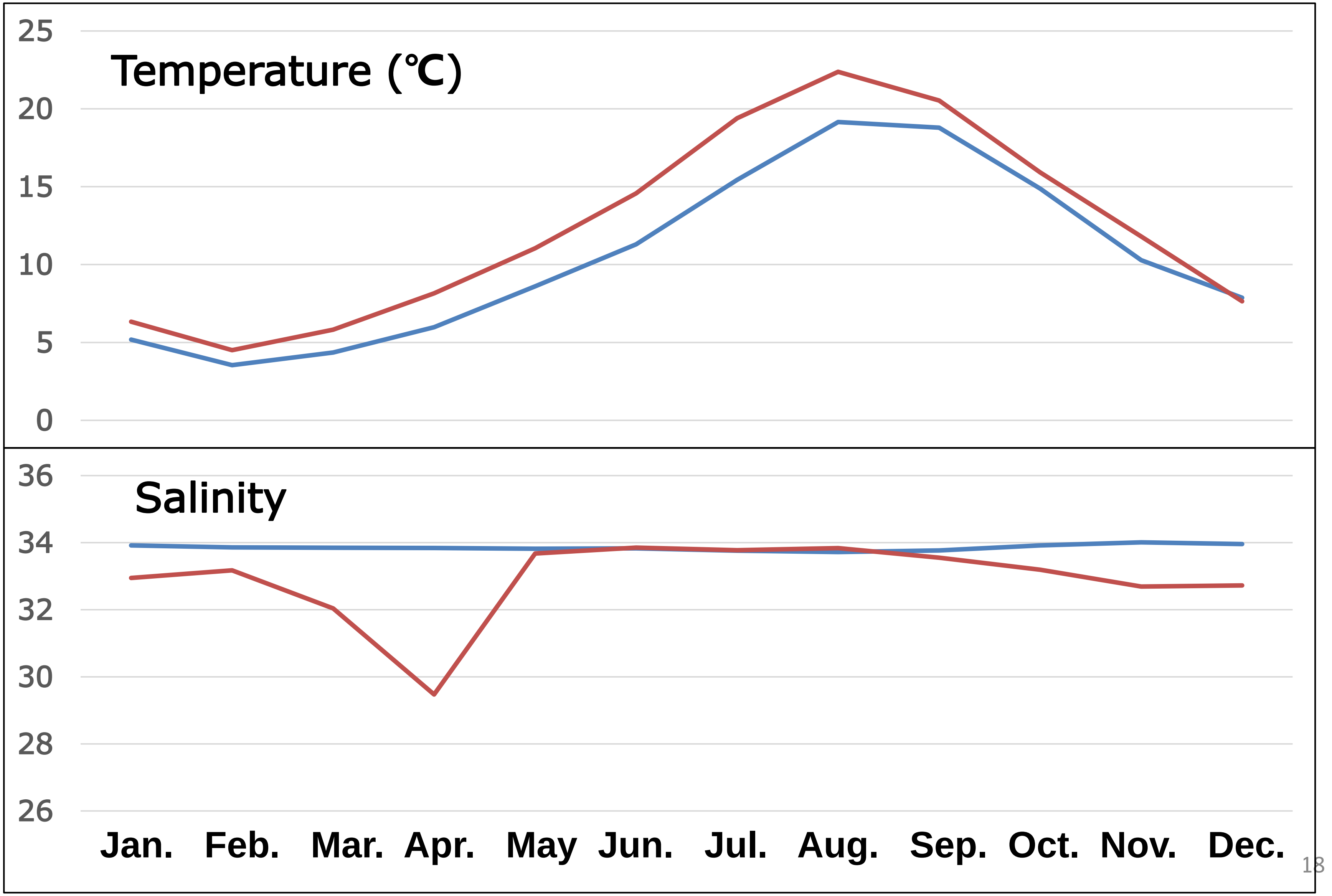
●: Oshoro Bay

Experimental design

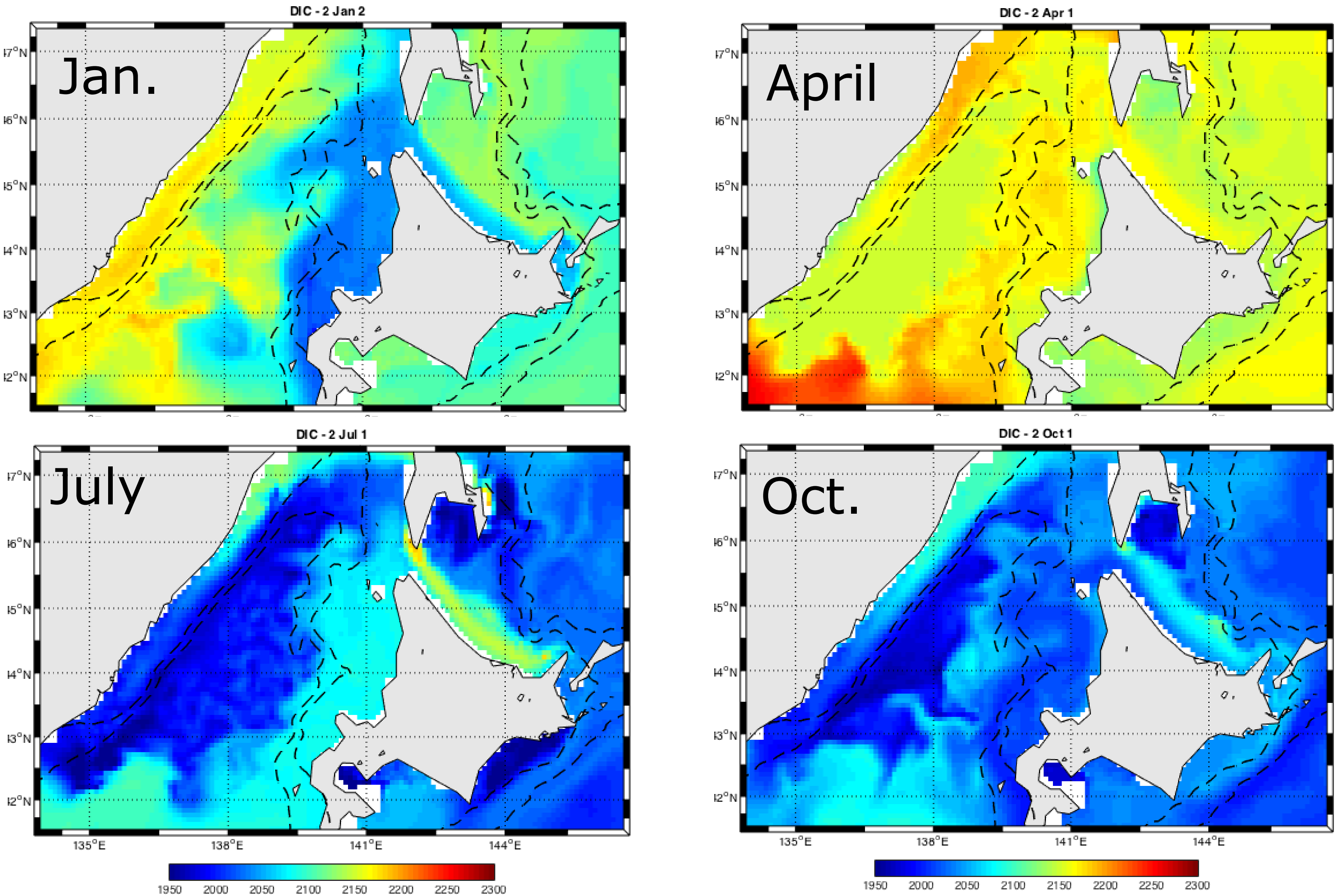
- Ocean model: Regional Ocean Model System (ROMS)-Agrif (Penven et al., 2006, Ocean Modelling)
- Bathymetry: Etopo1 (Amante and Eakins, 2009)
- Atmospheric forcing: COADS05 (Da Silva et al., 1994)
- Boundary and initial conditions
  - Physical factors: WOA09 (Locarnini et al., 2010; Antonov et al., 2010)
  - Biogeochemical factors: WOAPISCES (Goyet et al.,2000; Aumont and Bopp.,2006; Garcia et al.,2006)

Results

—— : Observation
—— : Model



Simulated dissolved inorganic carbon (μmol/l)



Summary

- First long-term OA monitoring site
  in the subarctic coast of Japan,
  but challenging…

- Large diurnal/seasonal variation of pH,
  mainly caused by biological production
  in spring/summer

- Model results well reproduce
  the observed physical and biological processes.
  Future projection is being in process

謝謝