Central Arctic Ocean Session @ Fall Pacific Arctic Group Meeting

Dec. 6, 2022

Arctic Challenge for Sustainability II

Arctic marine biogeochemical modeling in the ArCSII Project

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Arctic Challenge for Sustainability II

June 2020 ~ March 2025

Introduction

ArCSII Project

Ocean Research Program

Research and Public Data Production on the Arctic Marine Environment

（PI：Eiji Watanabe, JAMSTEC ／ co-PI：Hiromichi Ueno, Hokkaido University）

Portable Satellite

Sea Ice Camp

Sub-program 1

Ocean heat/freshwater transport and biogeochemical cycles in seasonal and multi-year sea-ice zones

Contribute to improvement of Earth System Models

Sub-program 2

Vulnerability and resilience of marine ecosystem in response to rapid sea-ice retreat

Contribute to ecosystem-based fishery management

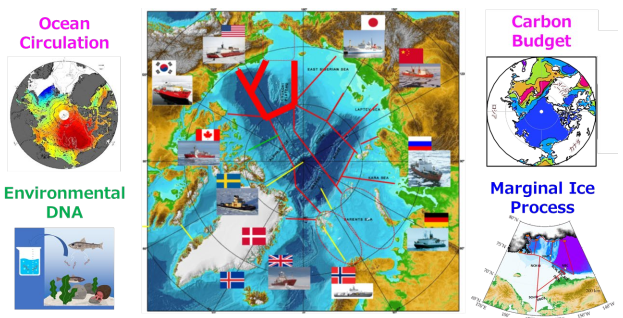
Sub-program 3

Air–sea (including waves) interactions related to sea ice

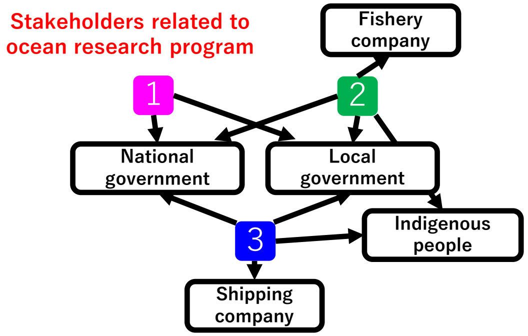
Contribute to safe and efficient sailing system

Collaboration with other research programs

- Carbon budget (RECCAP2 framework)
- Chemical process inside snow on sea ice
- Land–ocean interaction via river water inflow
- Sea condition in marginal ice zone
- Economical assessment of fishery resource
- Coastal marine ecosystem
- International law on marine research



Joint Research Cruise



【Intermediate Goals】

- ◆ Evaluation of riverine water impact on marine environment
- ◆ Production of satellite-based dynamic ocean height dataset
- ◆ Intercomparison of air–sea CO_2 flux datasets
- ◆ Production of satellite-based primary production dataset

【Final Goals】

- ◆ Production of ocean transport datasets
- ◆ Establishment of marine environmental DNA analysis
- ◆ Mapping of marine ecosystem vulnerability
- ◆ Clarification of local process in marginal ice zone

Modeling Themes

A) Resuspended Particle Transport

B) Riverine Geochemical Inflow

C) Ice Algae Model Intercomparison phase 2

Method

Pan-Arctic Sea Ice–Ocean Model

[COCO]

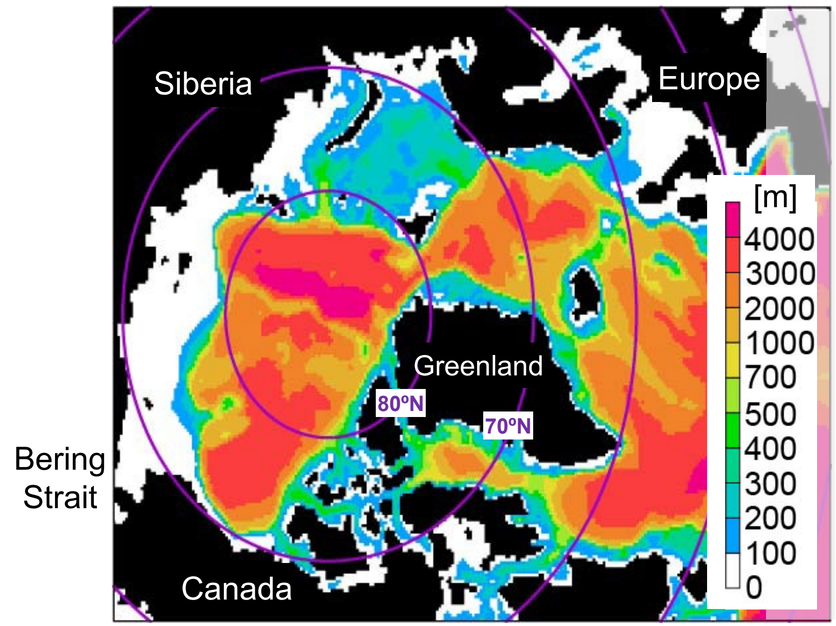
Center for Climate System Research Ocean Component Model version 4.9

Sea Ice Part
- 1 layer thermodynamics [Lipscomb et al., 2001]
- EVP rheology [Hunke and Duckwicz, 1997]
- 7 thickness category [Bitz et al., 2001]

Ocean Part
- free surface general circulation model
- UTOPIA/QUICKEST advection scheme
- turbulence closure scheme [Noh and Kim, 1999]

(for eddy-resolving configuration)
- Smagorinsky harmonic viscosity [Griffies, 2000]
- Enstrophy preserving scheme [Ishizaki and Motoi, 2001]

Model Bathymetry



Experimental Design
- A,B) NCEP/CFSR C) JRA55-do/CMIP6 atmos forcing
- A) AOMIP B) WATCH C) JRA55-do/CMIP6 river water discharge
- Pacific water inflow at Bering Strait
- Sponge layer in Atlantic side
- Passive tracer (Barrow Canyon, river mouth)

EARTH SIMULATOR

C) 1958–2100
143 yrs
B) 1979–2018
40 yrs
A) 2001–2020
18 yrs

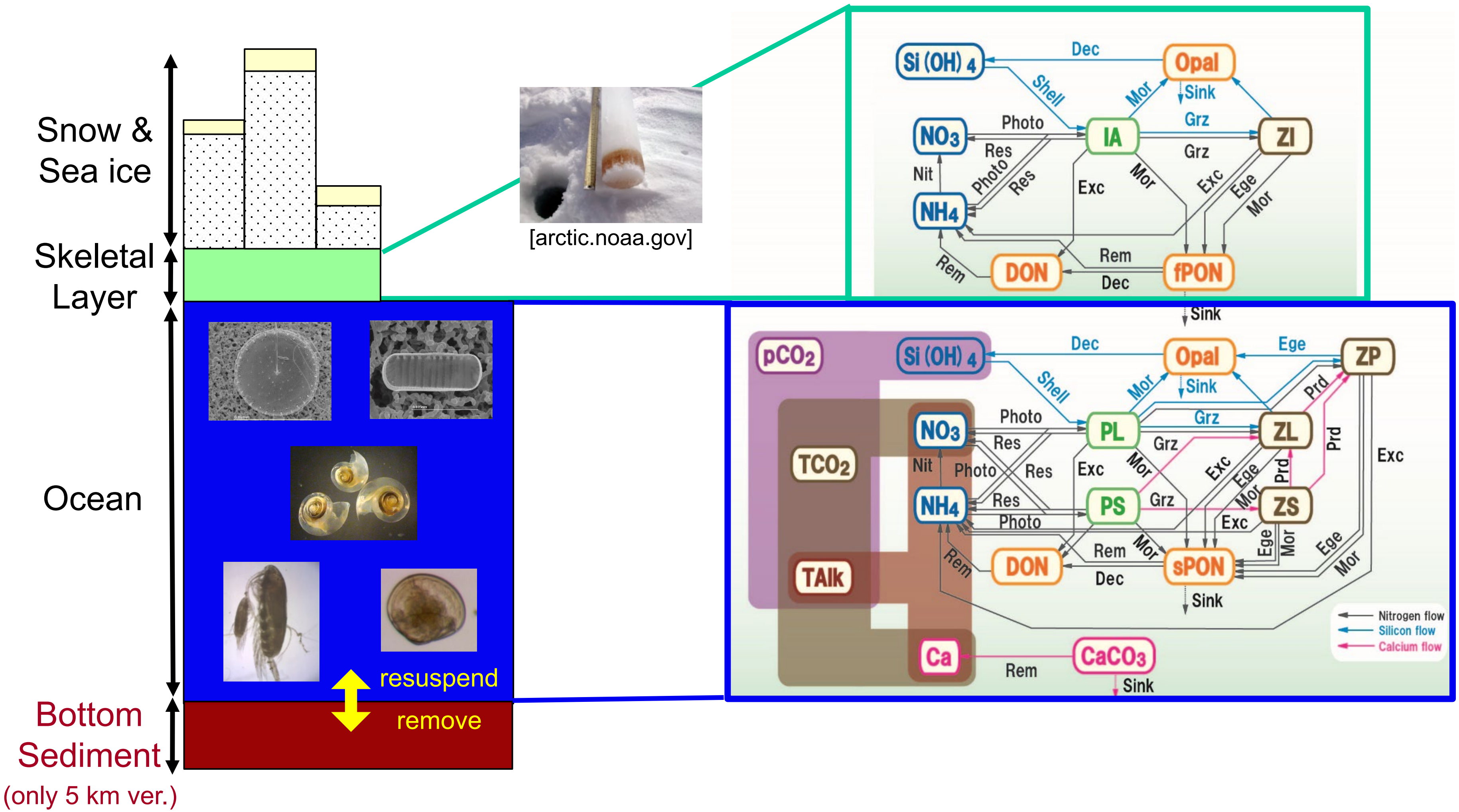
25 km
280 x 200 x 28 grids

5 km
1280 x 1024 x 42 grids

Method

Ice–Ocean Biogeochemical Model

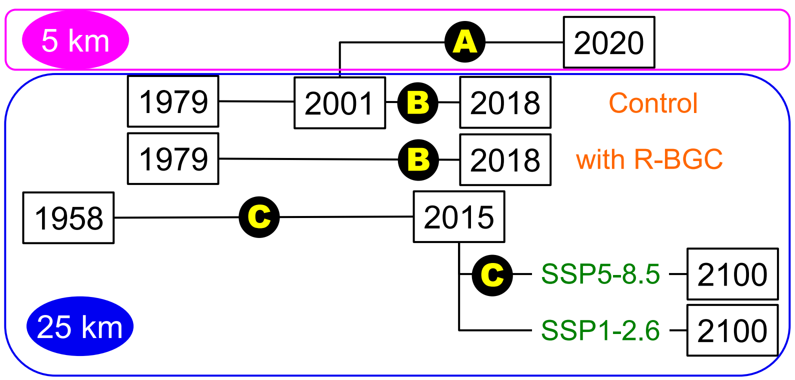
[Arctic NEMURO-C]



Method

Experiment List

Experiment Period



Atmospheric Forcing	Lateral Boundary Condition		
	T / S	Nitrate / Silicate	TA / DIC
CFSR	PHC	n. a.	n. a.
CFSR	PHC	WOA13	GLODAP-based
CFSR	PHC	WOA13	GLODAP-based
JRA55-do	WOA13	WOA13	GLODAP-based
EC / CM (585)	MIROC (585)	MIROC (585)	MIROC (585)
EC / CM (126)	MIROC (126)	MIROC (126)	MIROC (126)

EC: EC-Earth3 / CM: CMCC-ESM2 / MIROC: MIROC-ES2L

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Modeling Themes

A) Resuspended Particle Transport

B) Riverine Geochemical Inflow

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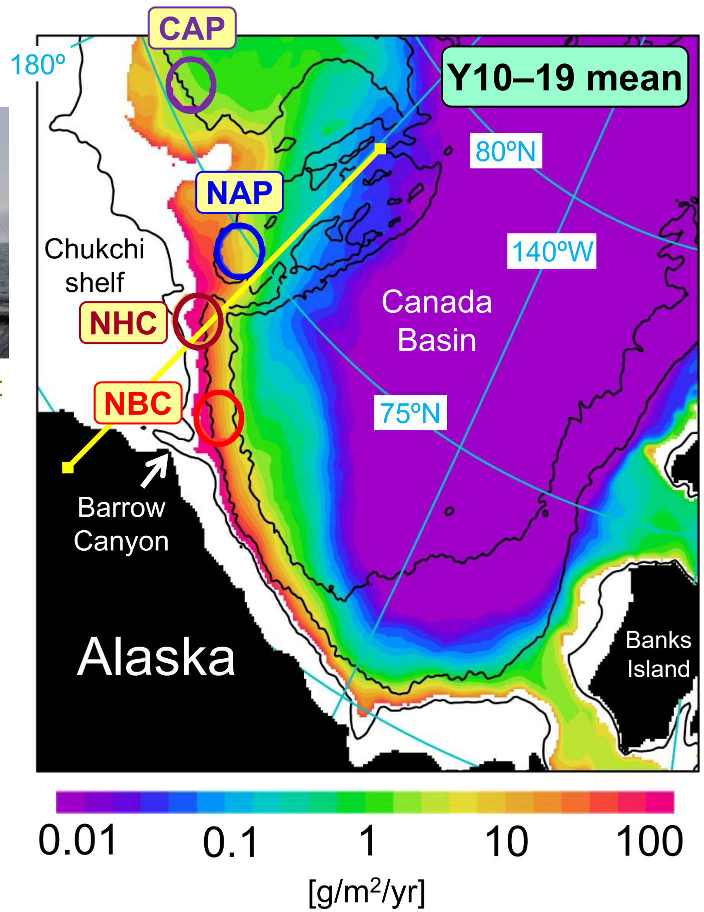
Watanabe, E., Onodera, J., Itoh, M., Mizobata, K. (2022)
Transport processes of seafloor sediment from the Chukchi shelf to the western Arctic basin. JGR Oceans, 127. doi:10.1029/2021JC017958

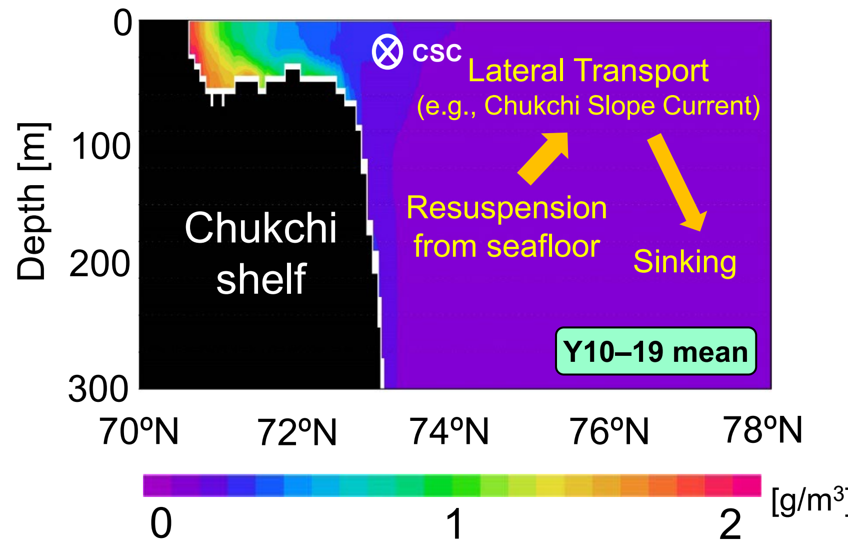
Sediment transport and its impact on carbon supply in western Arctic Ocean were examined by high-resolution modeling analyses

Sediment Trap Mooring

Sinking flux of resuspended sediment (200m)



Concentration of resuspended sediment



Watanabe et al. [2022, JGR Oceans]

Sediment transport from Chukchi shelf bottom contributes to a substantial part of carbon sink in western Arctic basin

Modeling Themes

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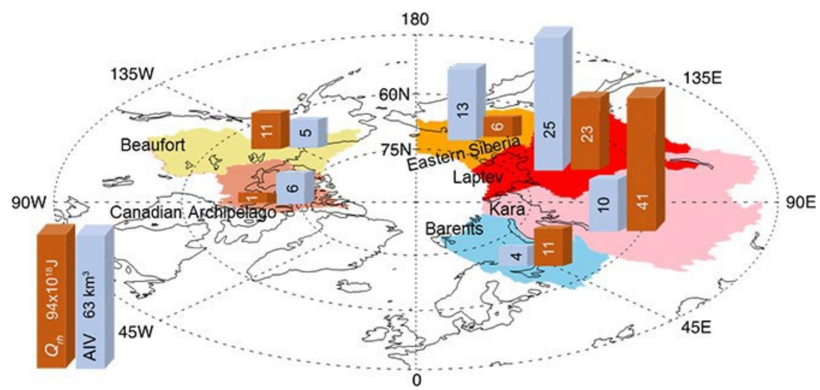
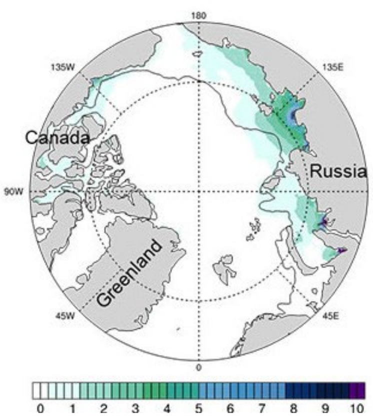
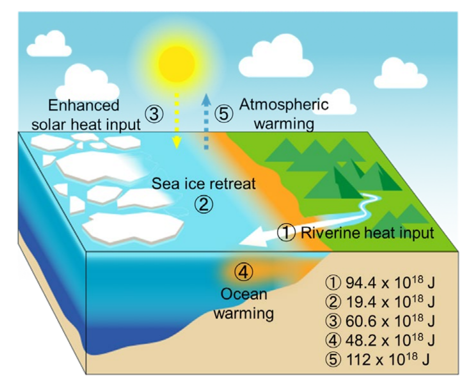
Riverine Heat Impact

Park et al. (2020) Increasing riverine heat influx triggers **Arctic sea-ice decline and oceanic and atmospheric warming**. *Science Advances*, *6*, *eabc4699*.



Riverine heat flux from land-surface model "CHANGE" was added to pan-Arctic sea ice–ocean model "COCO"



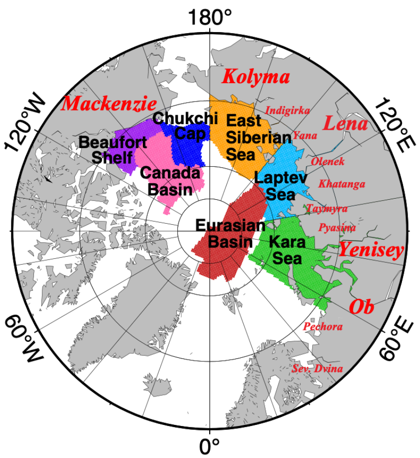


- Riverine heat impact on sea ice was quantitatively evaluated on the pan-Arctic and decadal scales
- Riverine heat input decreased annual mean sea-ice thickness by a maximum of more than 10%
- Atmospheric and ocean warming is amplified by ice-albedo feedback

Press release article is available on JAMSTEC website
"Increasing Riverine Heat Triggers the Arctic Warming"
[http://www.jamstec.go.jp/e/about/press_release/20201107/]

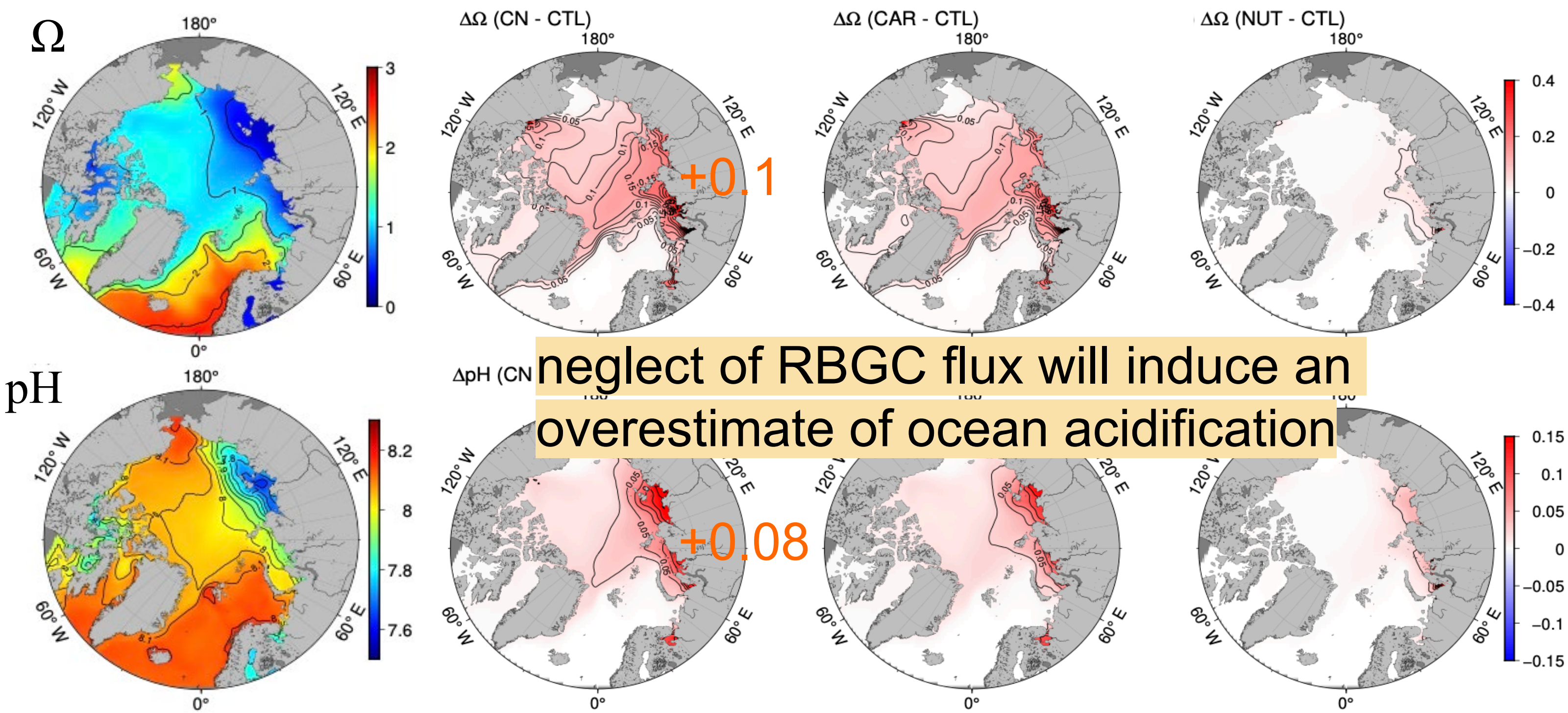
Impact of riverine nutrients and TA/DIC on various marine environments will be assessed as a next step

Riverine Biogeochemical Impact



- Arctic rivers' freshwater fluxes: land-surface model "CHANGE"
- Monthly climatology concentrations of nutrient (Nitrate, Silicate) and Carbon (TA, DIC) for 13 Arctic rivers: ArcticGRO program

Experiment ID	Freshwater Flux	Nutrient flux	Carbon Flux
Tracer Run (TRA)	Yes	-	-
Control Run (CTL)	Yes	-	-
Nutrient Run (NUT)	Yes	Yes	
Carbon Run (CAR)	Yes	-	Yes
Carbon+Nutrient Run (CN)	Yes	Yes	Yes



neglect of RBGC flux will induce an overestimate of ocean acidification

Modeling Themes

A) Resuspended Particle Transport

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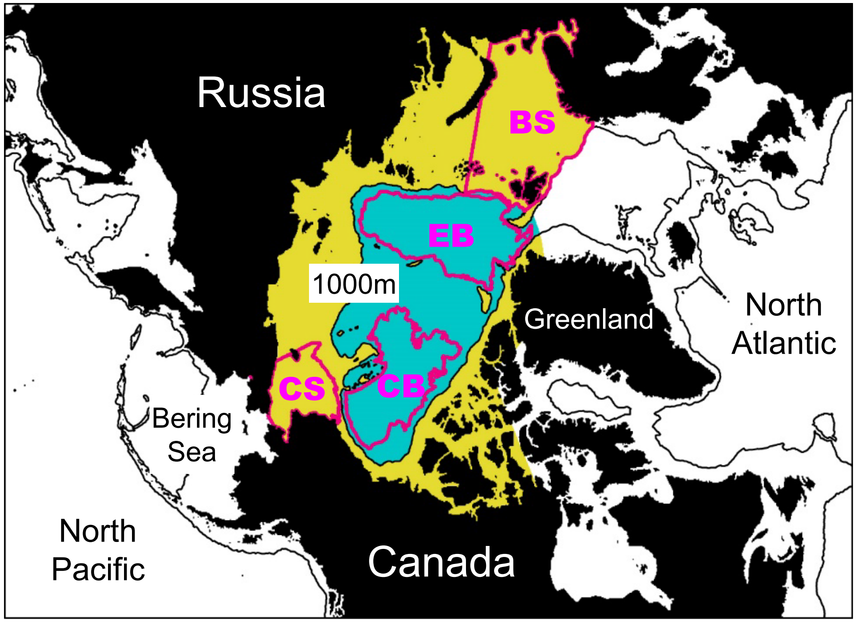
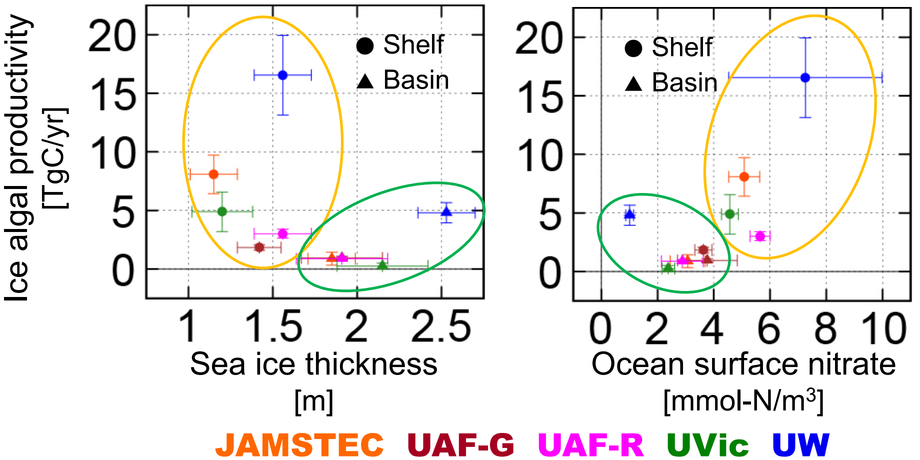
Ice Algal Productivity

Watanabe et al. (2019) Multi-model intercomparison of the pan-Arctic ice-algal productivity on seasonal, interannual (1980-2009), and decadal timescales, *JGR Oceans*





Uncertainties and controlling factors in several sub-regions are analyzed

- *Sharp shelf–basin contrast*
- *No significant decadal trend*
- *Stable habitat and enough light are both necessary for high PP*
- *Spring nitrate is a controlling factor*
- *Maximum growth rate parameter accounts for inter-model spread*

Dataset is available at Arctic Data Archive System (ADS)
"Primary productivity of sea-ice algae and the related variables in the Arctic Ocean simulated by five FAMOS models"
[https://ads.nipr.ac.jp/dataset/A20190924-001]

Method

IAMIP2

~ Ice Algae Model Intercomparison Project Phase 2 ~

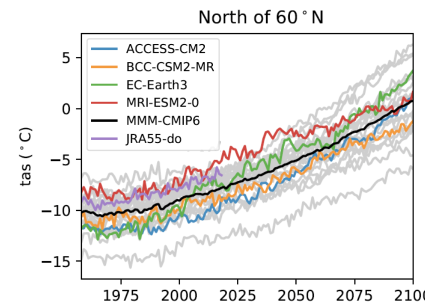
	UTAS	UAF-G	UAF-R	IOS	IOS	JAMSTEC
Model	**ACCESS-OM2**	**CESM**	**RASM**	**CanNEMO**	**NEMO-NAA**	**COCO-Arctic NEMURO**
Relevant CMIP6	ACCESS-ESM1.5 ACCESS-CM2	CESM2	CESM2	CanESM5	CanESM5	MIROC6
Ocean dynamics	MOM5.1	POP2	POP2	OPA	OPA	COCO4.9
Sea-ice dynamics	CICE5.1.2	CICE5.1.2	CICE5.1.2	LIM2	LIM2	COCO4.9
Ocean ecosystem	WOMBAT	Moore et al. [2013]	Moore et al. [2013]	CanOE	CanOE	Arctic NEMURO
Sea-ice ecosystem	Biogeochemistry of CICE	(Jin et al., 2006)	(Jin et al., 2006)	CSIB	CSIB	Arctic NEMURO
Spatial domain	Global	Global	Pan-Arctic	Global	Pan-Arctic	Pan-Arctic
Horizontal resolution	1º (1/4º, 1/10º)	1º	1/12º	1º	1/4º	1/4º
Reference	Kiss et al. [2020]	Jin et al. [2018]	Jin et al. [2018]	Swart et al. [2019]	Hayashida et al. [2019]	Watanabe et al. [2015]

6 models in Australia, U.S.A., Canada, and Japan

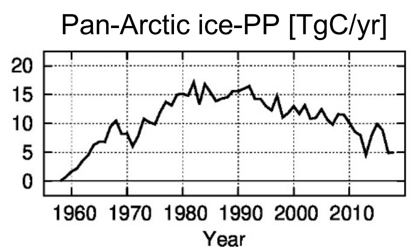
Experimental Design

1958 | 2015 | 2018 | 2100

Historical (JRA55-do)



Projection
(CMIP6 SSP5-8.5 / 1-2.6 output)

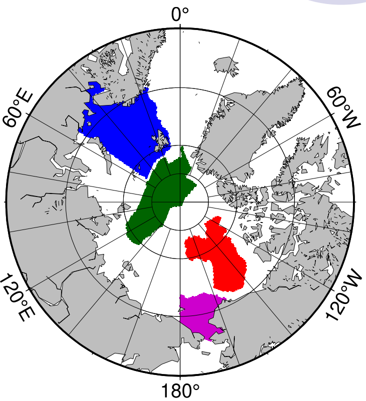


Exclusion
(same as projection except sea-ice ecosystem exclusion)

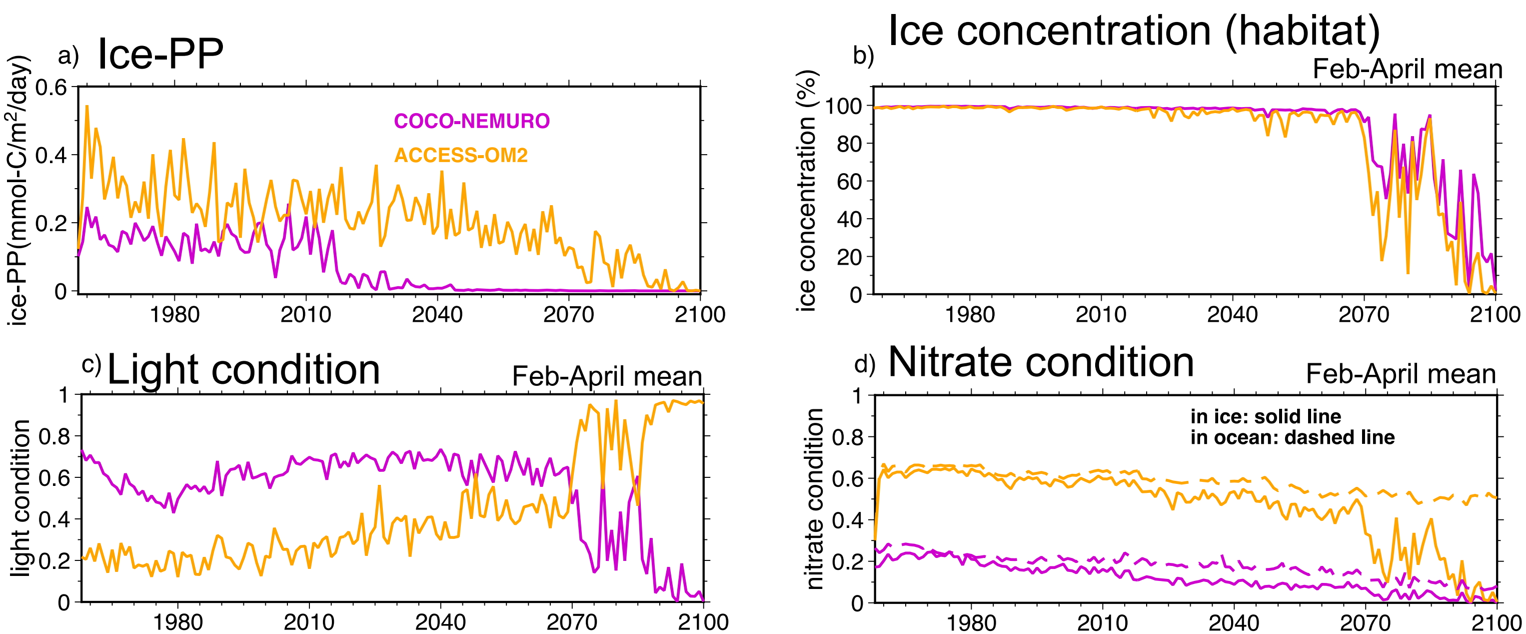
Control (JRA55-do Repeat Year Forcing from 1st May 1990 to 30th April 1991)

Hayashida et al. (2021) Ice Algae Model Intercomparison Project phase 2
Geoscientific Model Development

Model Intercomparison of Ice-algal Productivity



Ice algae and its controlling factors in the Chukchi Sea during 1958-2100, SSP5-8.5 for future projection



Future works

- Estimate the effects of terrestrial organic matter/permafrost thawing on Ocean Acidification and primary production in the different Arctic Seas
- Simulation using different atmospheric forcing datasets to compare ice-PP under various future climate conditions (scenarios SSP5-8.5/1-2.6)
- Multi-model intercomparison on seasonal, interannual, and decadal timescales of ice-PP among 3 Earth System Models and 2 regional models to estimate the uncertainties of different model behaviors (Hayashida et al., 2021)
- Quantify the impact of ice-PP on the Arctic primary production of phytoplankton and carbon cycle