Catastrophic reduction of sea-ice in the Arctic Ocean - its impact on the marine ecosystems in the polar region-

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Introduction

Phytoplankton responses on the sea-ice reduction

If sea-ice reduced in the Arctic Ocean…,

- Light

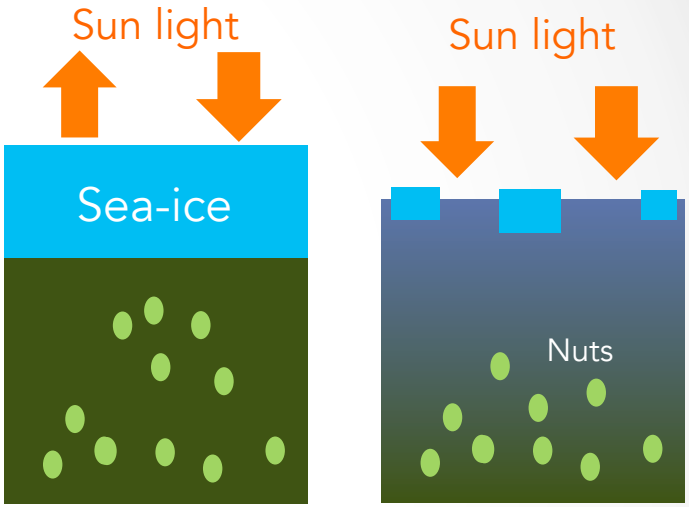
  Sea ice reduction contributes to the improvement of light condition in the sea water

- Temperature

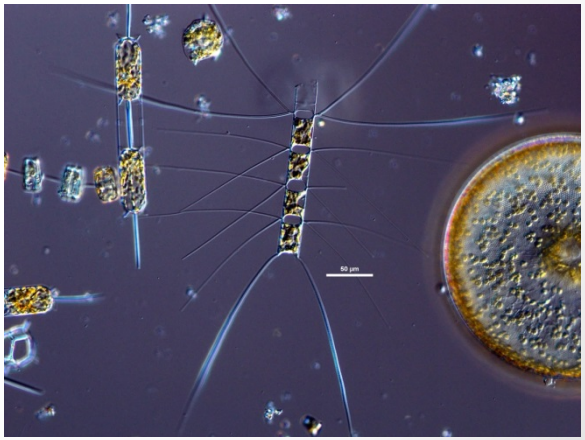
  Increasing the light promotes to be warm

- Nutrients

  Concentration of nutrients decrease by sea-ice melting. Light and fresh water prevents upwelling the nutrients from deep layer

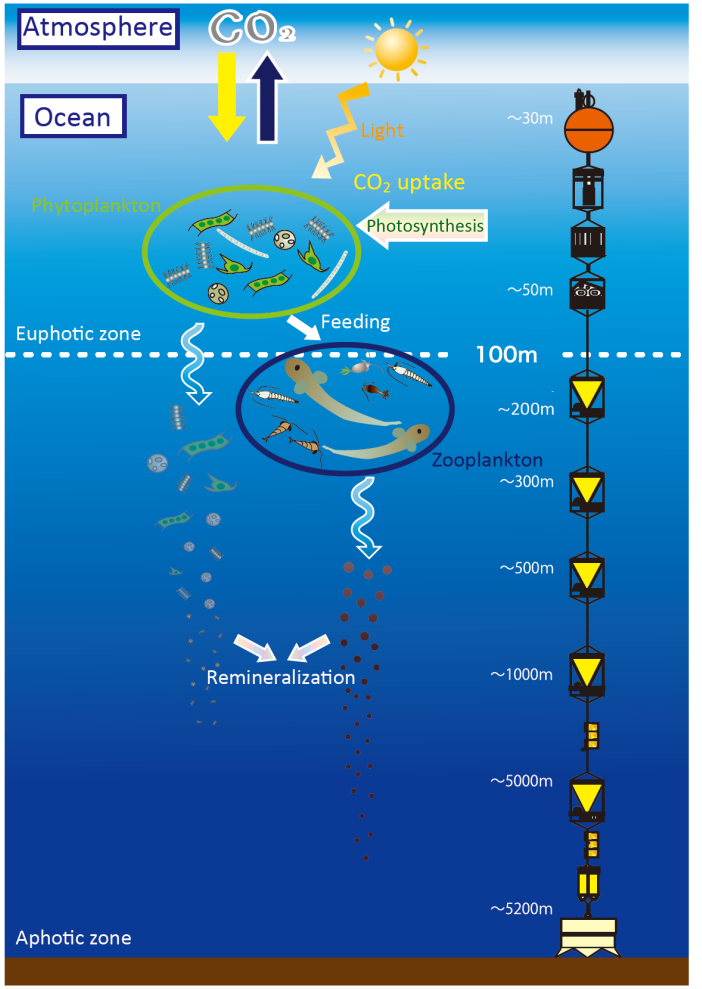


Does sea-ice reduction promote or prevent phytoplankton production?



Influence on biogeochemical cycle in the water

- Is biological pump accelerated?
- Does Arctic Ocean become a sink of atmospheric CO_2?



To understand the impact of sea-ice reduction on productivity and biogeochemical cycles

Limited biogeochemical observation research in the Arctic Ocean

Current climate model is insufficient to reconstruct the environment of the Arctic Ocean

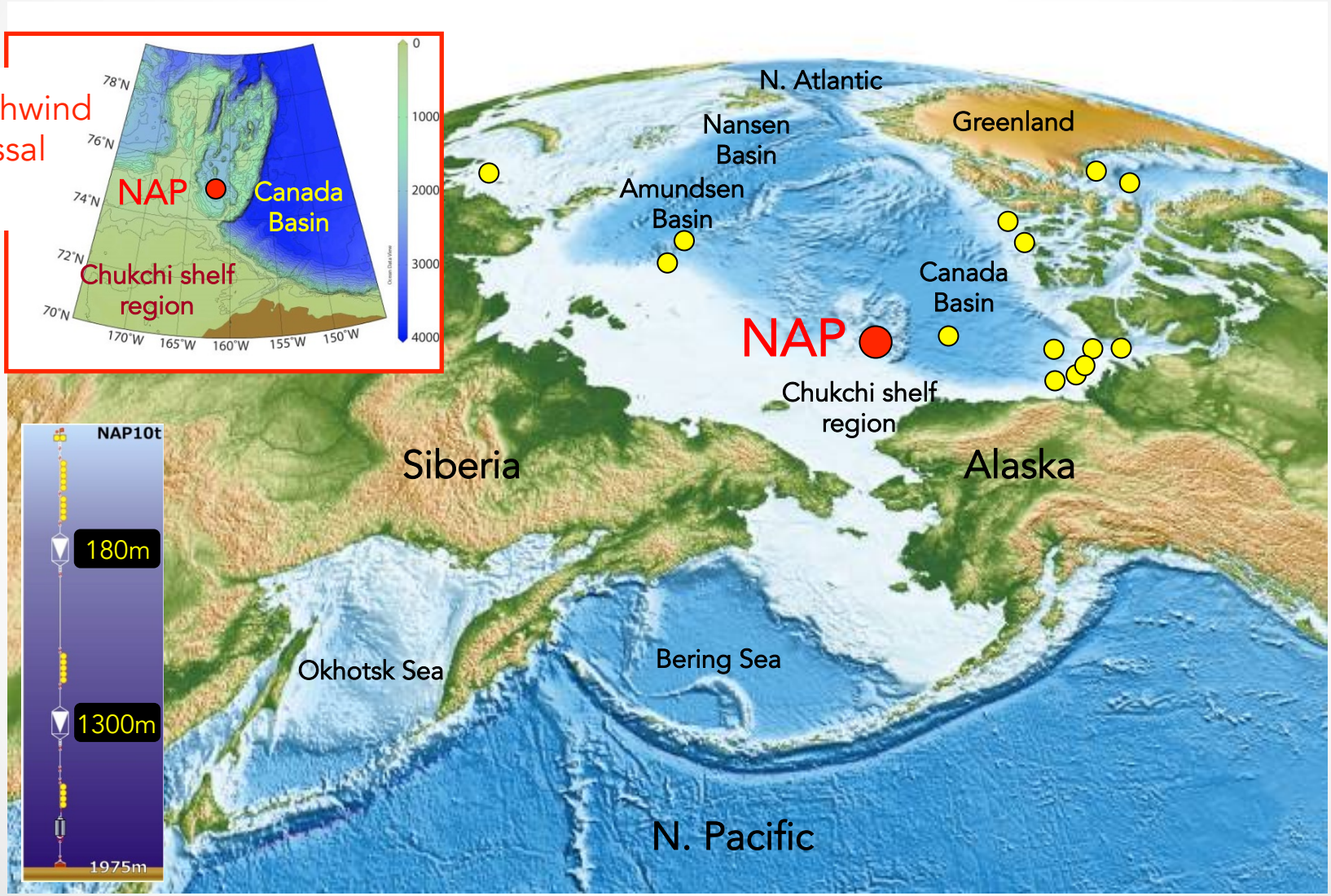
Collaboration study between observation and model to understand the temporal and spatial variability

R/V Mirai and Ice Breaker

Earth simulator

Sampling site and method

Observation area



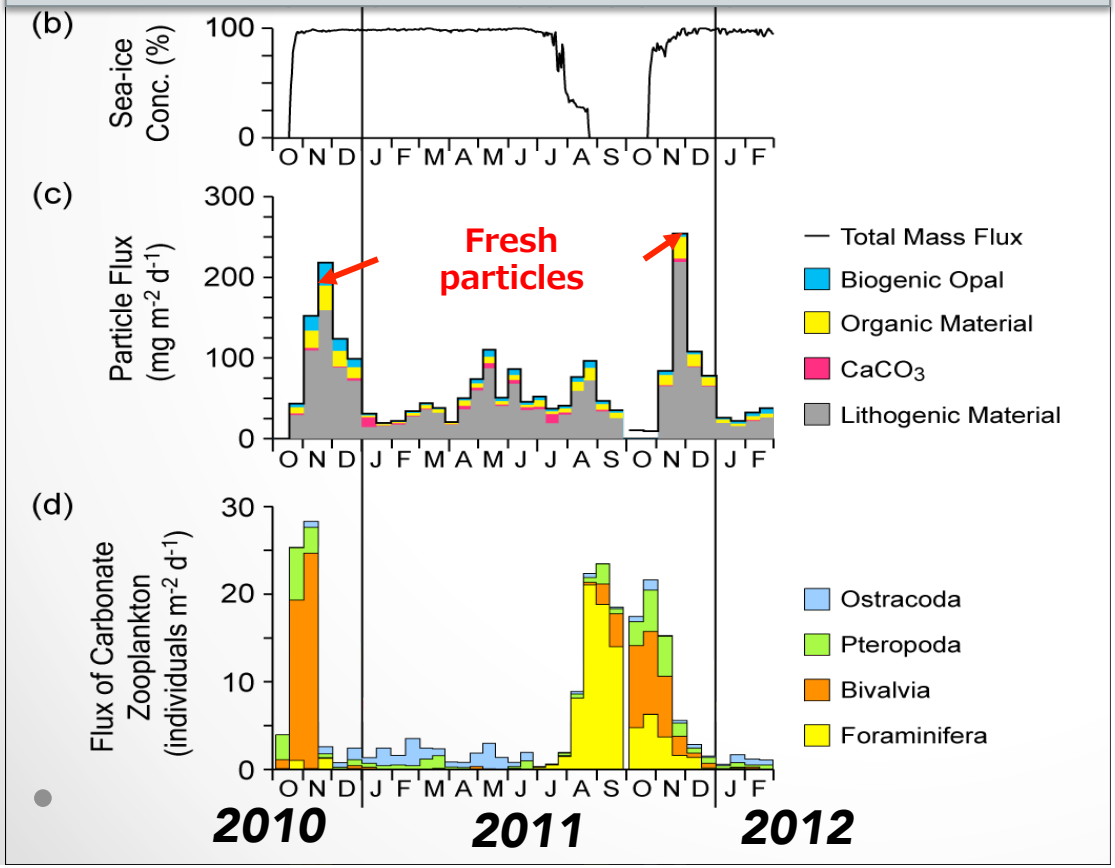
○ Previous sediment trap observation sites

Result

Biological particles collected by time series sediment trap system

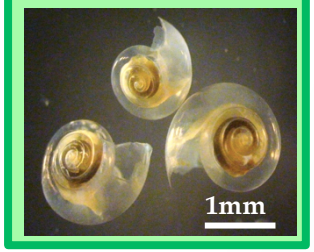
Result of biological fluxes

Flux was maximum in the beginning of winter and composed of quite old and fresh particles

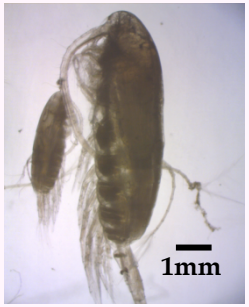


Fresh zooplankton from trap

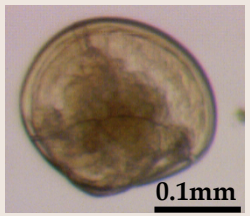
Pteropods



Copepods



Bivalves

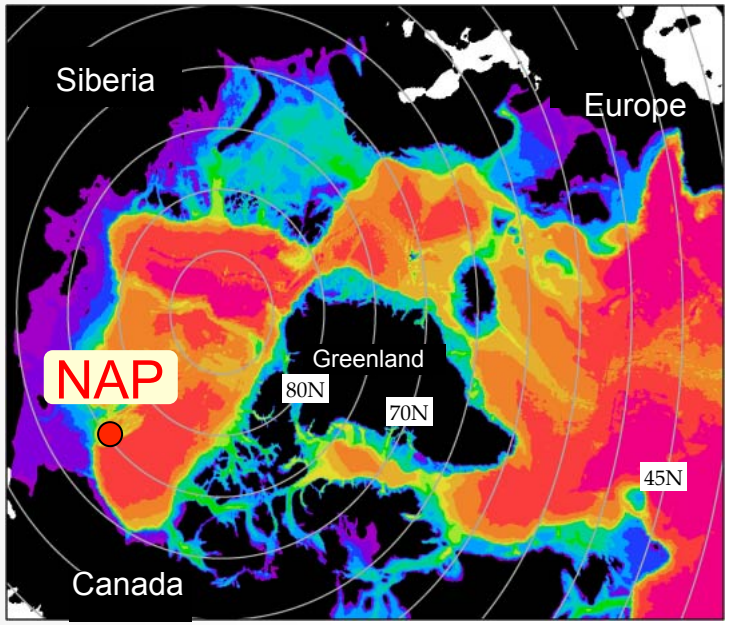


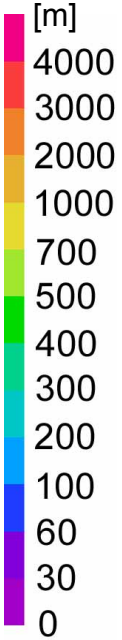
Method

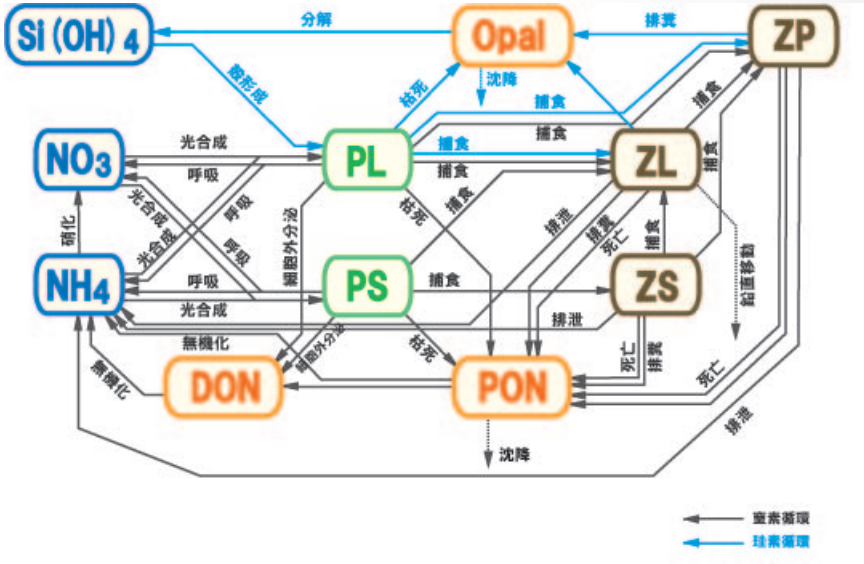
Arctic sea ice-ocean physics-ecosystem model

Sea ice-ocean physics model : COCO

Marine ecosystem model : NEMURO







Spin up (Atmospheric condition in 1979)

10 yrs integration

Annual variability exp. (Atmospheric condition during 1979-2012)

33 yrs integration

25km mesh

Seasonal variability exp. (Atmospheric condition in 2010)

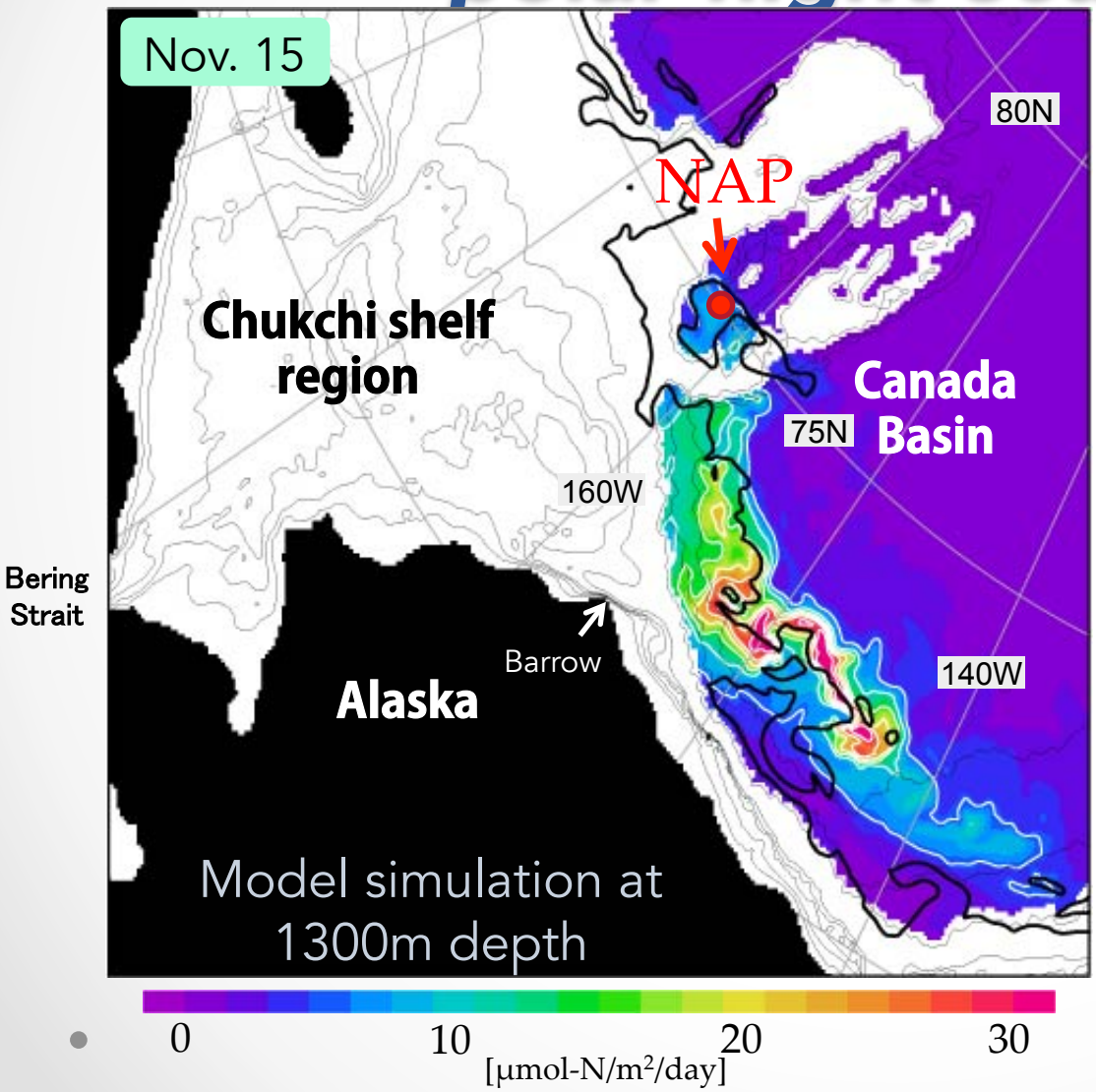
1 yr integration

5km mesh

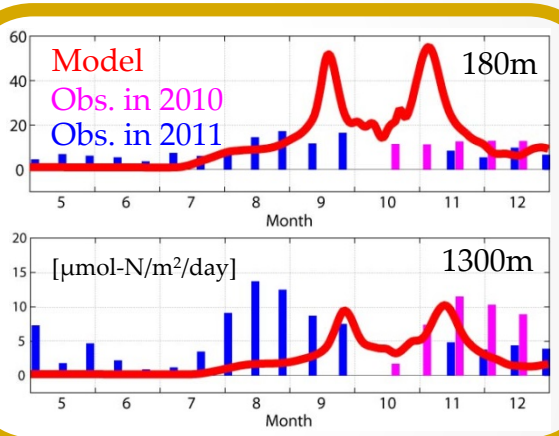
Simulation with 5 km mesh can provide eddy scale current, current along the complicated ocean floor and lower trophic level ecosystem

Enhanced biogenic particle fluxes into the deep layer at beginning of polar night season

Result



Comparison between model simulation and observation data of seasonal change in biogenic particle fluxes

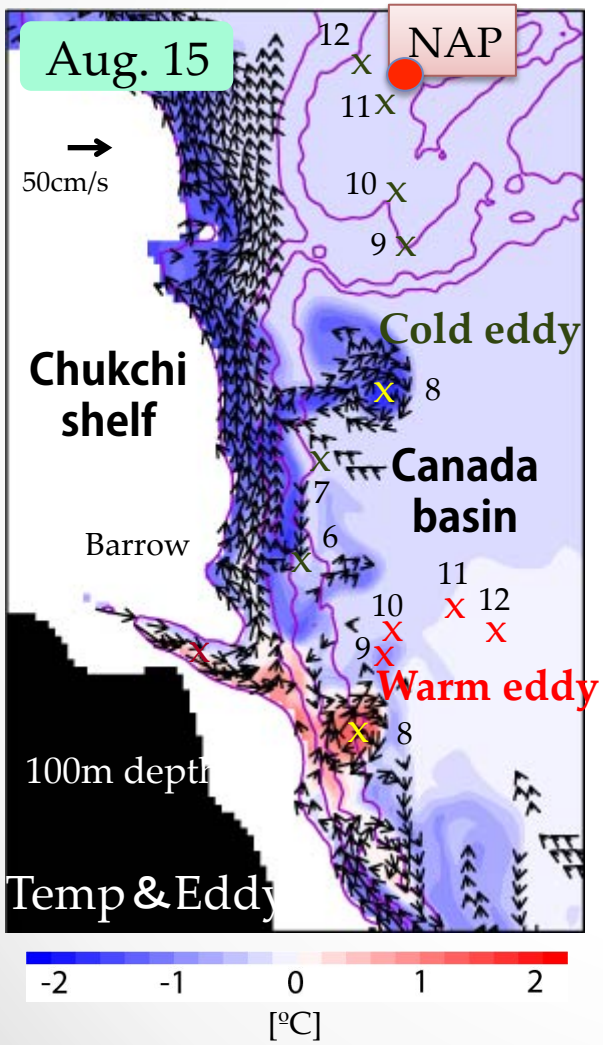


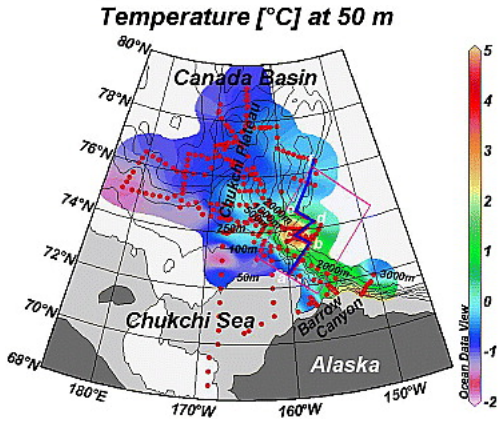
Model simulated biogenic particle fluxes……

- reconstructed the double peak observed in summer and autumn
- showed large settling in the southern part of Canada Basin

Meso scale eddy transports the shelf water and incubates the lower trophic level organisms

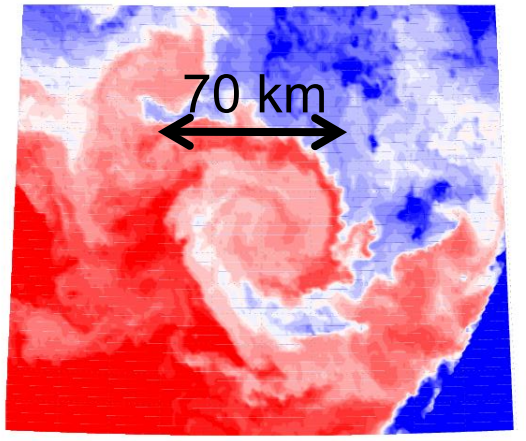
Result





Eddy observed in Oct, 2010 (R/V Mirai)

Nishino et al. [2011]



SST from MODIS satellite Sep, 2003

Watanabe [2011]

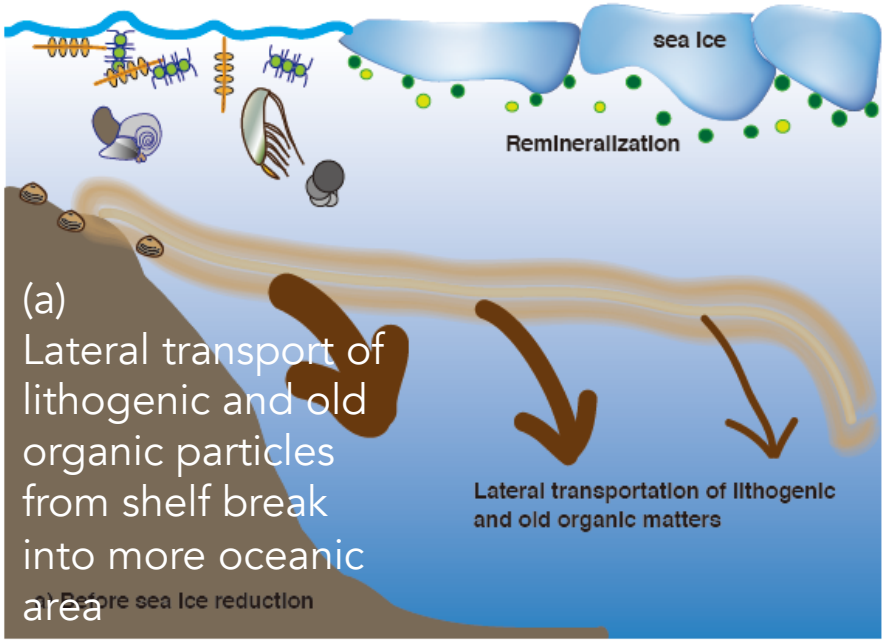
Eddy transports the water mass from the shelf break

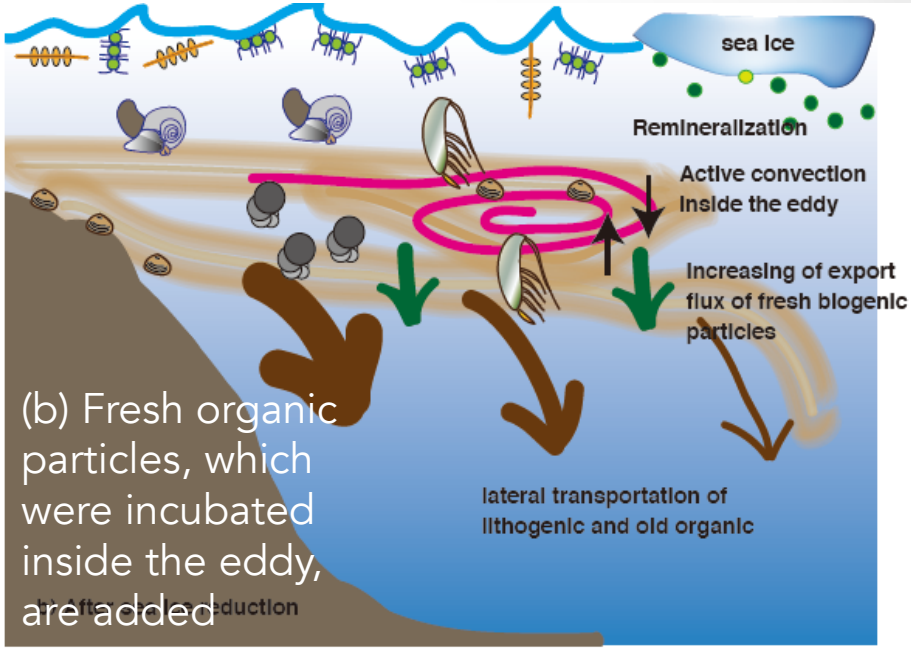
Turbulent mixing (inside the eddy) promotes nutrient input from subsurface to surface in the eddy-matured period

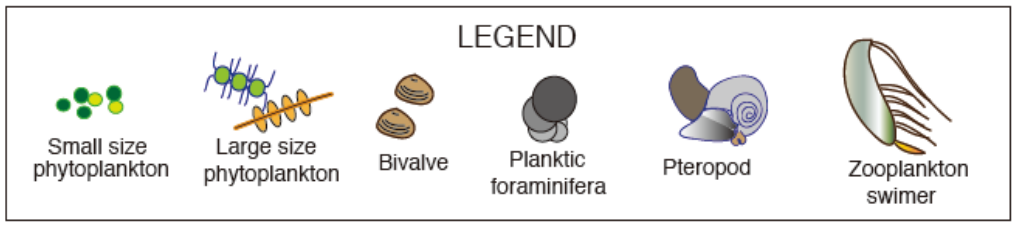
Biogenic particle flux would enhance depending on the timing and location of eddy occurrence

Result

Lower trophic ecosystem responses on the sea-ice reduction







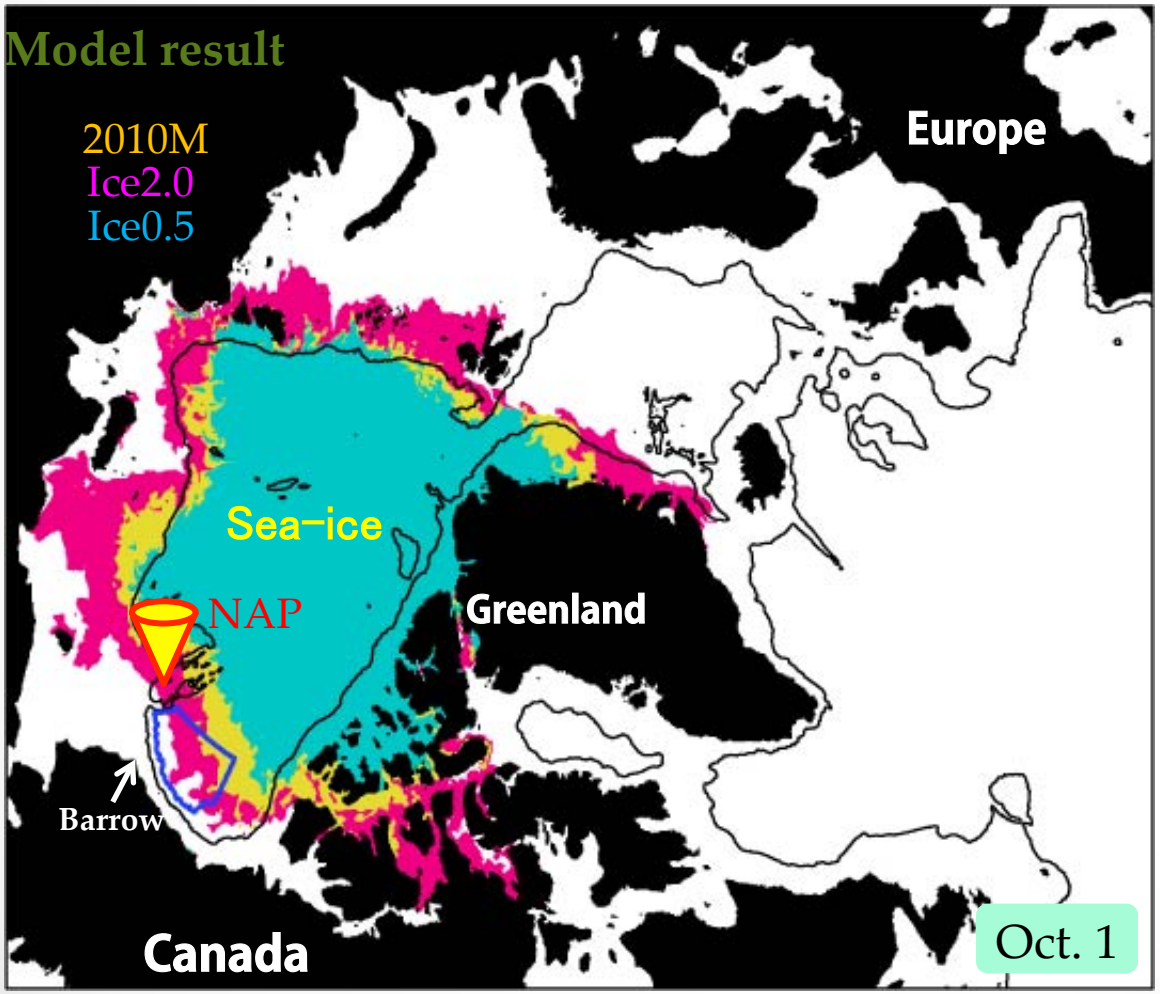
If sea ice edge moved back...

Accelerated eddy occurrence +
Enhanced current system

Promoted lower trophic level organisms production

Result

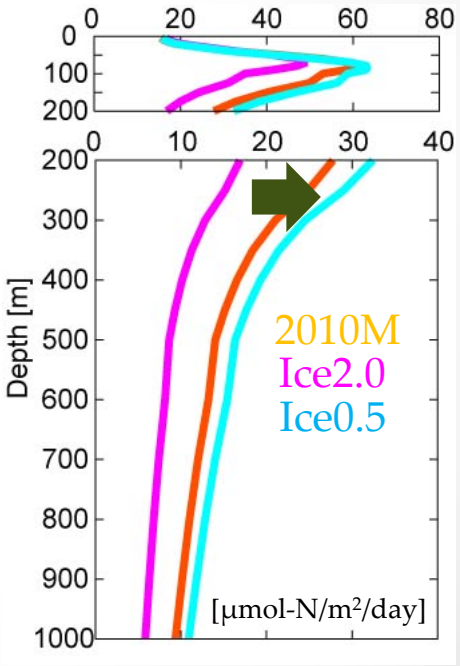
Comparison of model simulated organic nitrogen fluxes between 1990's and after 2005



Area: 140W−160W &75N−1000m depth contour

80% increase of eddy appearance

PON fluxes



Average flux on Nov. in the southern part of Canada Basin

Summary

- Time series sediment trap experiment and sea ice ocean physics-marine ecosystem model provided new findings regarding the lower trophic production Pacific side of Arctic Ocean.
- Maximum fluxes of biogenic particles appeared in the beginning of sea ice season. The shelf water transportation by meso scale eddies might be important.
- Biological pump associated with eddy occurrences would be enhanced in the Northwind abyssal plain, because eddy formation is considered to be more accelerated if no sea-ice condition expands in near future.

Watanabe et al., 2014 Nature Comm, doi: 10.1038/ncomms4950
Matsuno et al., 2013 J Plankton Res, 36, 490–502
Watanabe, E. 2013 Ocean Modelling, doi:10.1016/j.ocemod.2012.12.010
Watanabe et al., 2012 J Oceanogr 68, 703-718
Nishino et al., 2011 J Oceanogr 67, 305-314