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

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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
Observation area

Northwind Abyssal Plain

Previous sediment trap observation sites
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.
Arctic sea ice-ocean physics-ecosystem model

Sea ice-ocean physics model: COCO

Marine ecosystem model: NEMURO

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

Model simulated biogenic particle fluxes...
- reconstructed the double peak observed in summer and autumn
- showed large settling in the southern part of Canada Basin

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

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

**Eddy transporst 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.

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

Nishino et al. [2011]

SST from MODIS satellite Sep, 2003

Watanabe [2011]
Lower trophic ecosystem responses on the sea-ice reduction

(a) Lateral transport of lithogenic and old organic particles from shelf break into more oceanic area

(b) Fresh organic particles, which were incubated inside the eddy, are added

If sea ice edge moved back...

- Accelerated eddy occurrence
- Enhanced current system
- Promoted lower trophic level organisms production

LEGEND
- Small size phytoplankton
- Large size phytoplankton
- Bivalve
- Planktic foraminifera
- Pteropod
- Zooplankton swimmer
Comparison of model simulated organic nitrogen fluxes between 1990’s and after 2005

Model result

2010M  
Ice2.0  
Ice0.5

80% increase of eddy appearance

PON fluxes

80% increase of eddy appearance

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

2010M  
Ice2.0  
Ice0.5

Area: 140W–160W & 75N–1000m depth contour
• 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 et al., 2012 J Oceanogr 68, 703-718
Nishino et al., 2011 J Oceanogr 67, 305-314