PAG2015 21 Apr 2015

Observation, measurement and model techniques -Toward the understanding of biological response to Arctic change-

Naomi Harada (JAMSTEC)
J. Onodera, K. Kimoto, E. Watanabe, M. Kitamura, M. Itoh, T. Fujiki

To understand the temporal and spacial variability of biological response to Arctic change

R/V Mirai and Ice Breaker

ADCP

Sediment Trap with sensors

Miniaturized FRRF

Collaboration study between observation, laboratory experiment and model simulation

Micro-Focus X-ray Computing Tomography technique

Laboratory work

Sea ice-ocean-marine ecosystem coupled model

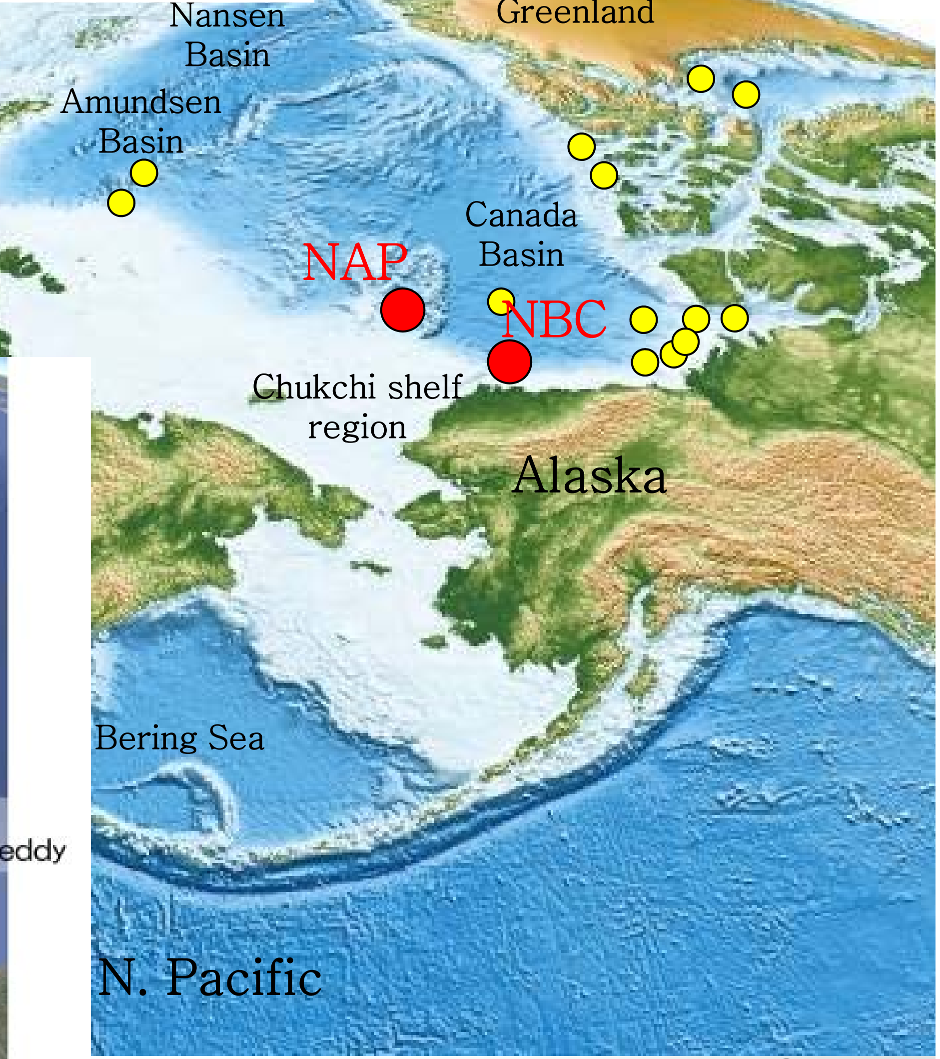
Earth simulator

Observation area

Sediment trap mooring sites

North of Barrow Canyon (73°N, 152.5°W, 3770m) 2015~

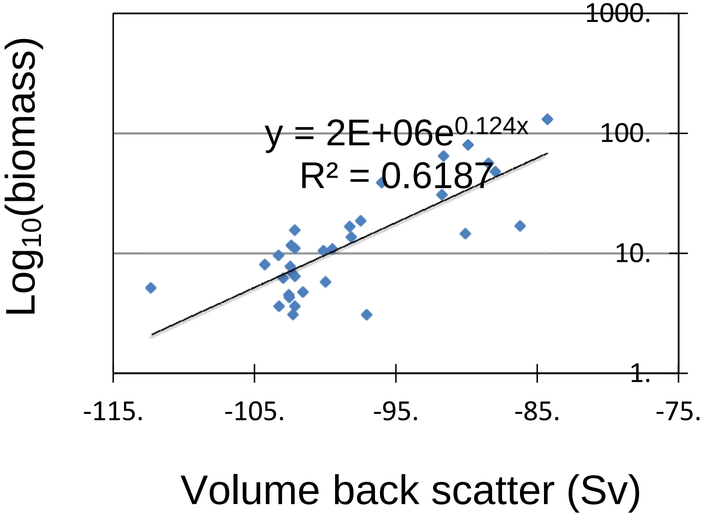
Northwind Abyssal Plain (75°N, 162°W, 1975m) 2010~

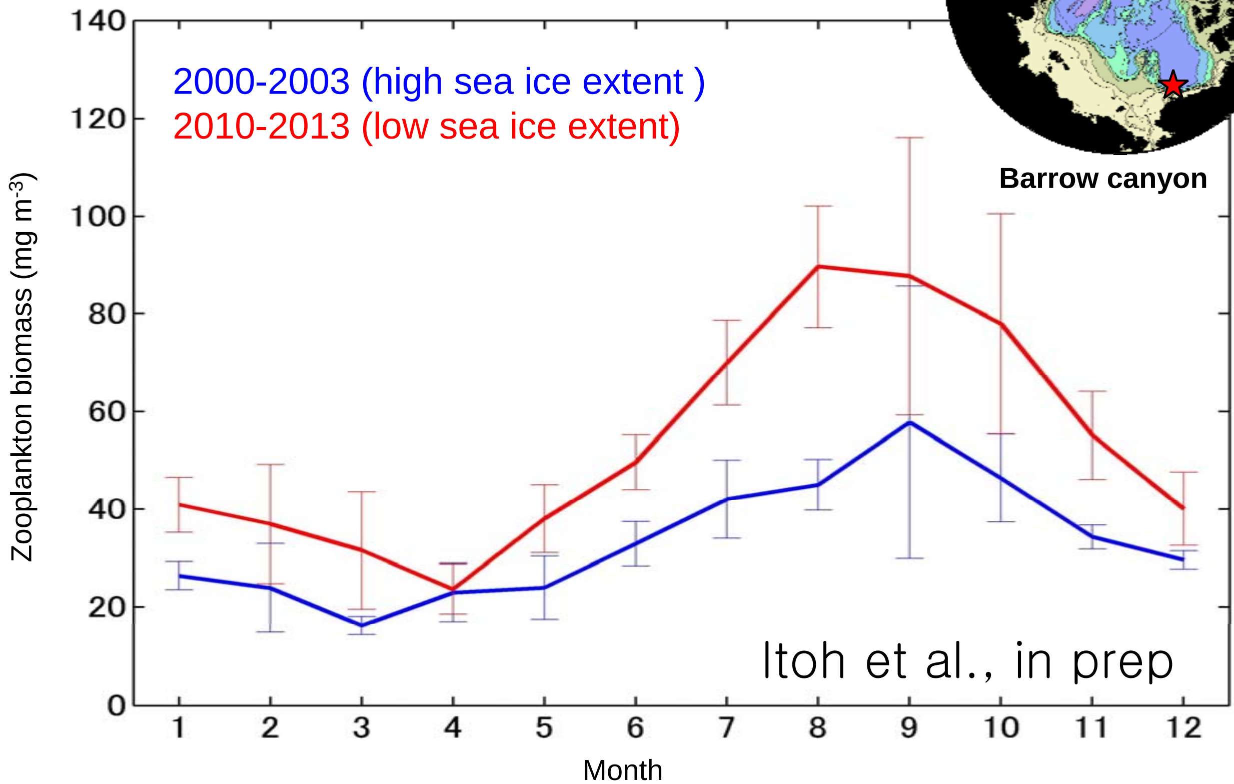


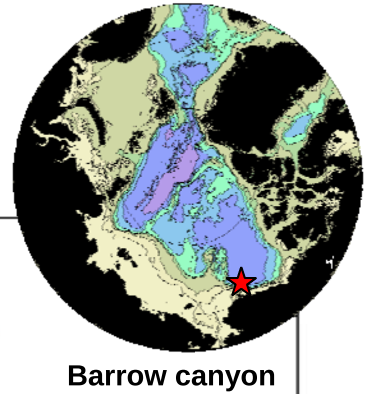
Previous sediment trap observation sites

Zooplankton biomass estimated by ADCP data

Sound scatters were well correlated with arctic zooplankton biomasses
Zooplankton biomasses were estimated using archived mooring ADCP data







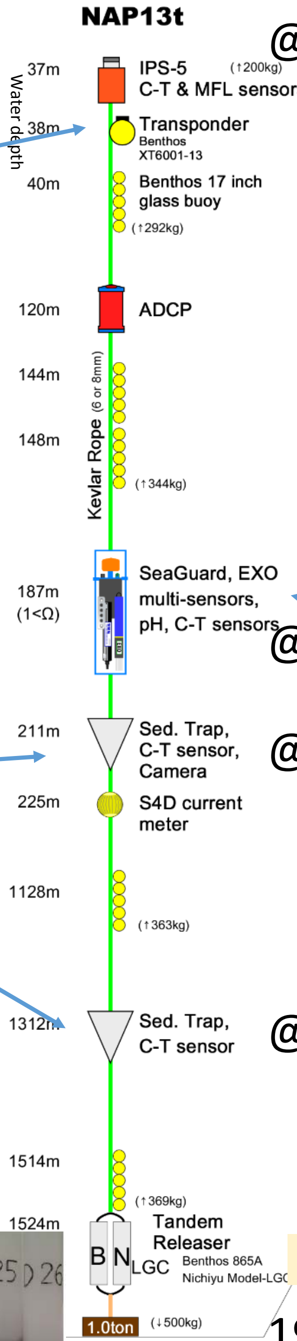
Comparison of seasonally composited zooplankton biomasses

Technical problem remained: inter calibration between plural ADCPs
Advantage: past zooplankton biomasses can be estimated without net samples

Time-series sediment trap mooring system (Oct. 2013-Sep. 2014)

Multi-wave length excitation fluorescence photometer

@ 38m



@ 37m

Ice profiling sonar

Sediment trap with 26 bottles (Oct. 2010-Sep.2014)

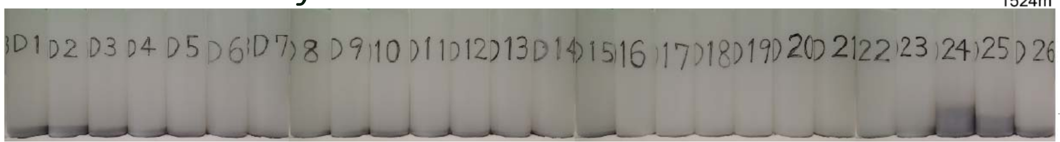
@ 170m

EXO advanced water quality monitoring platform

@ 200m

@ 1300m

10 days interval for each bottle

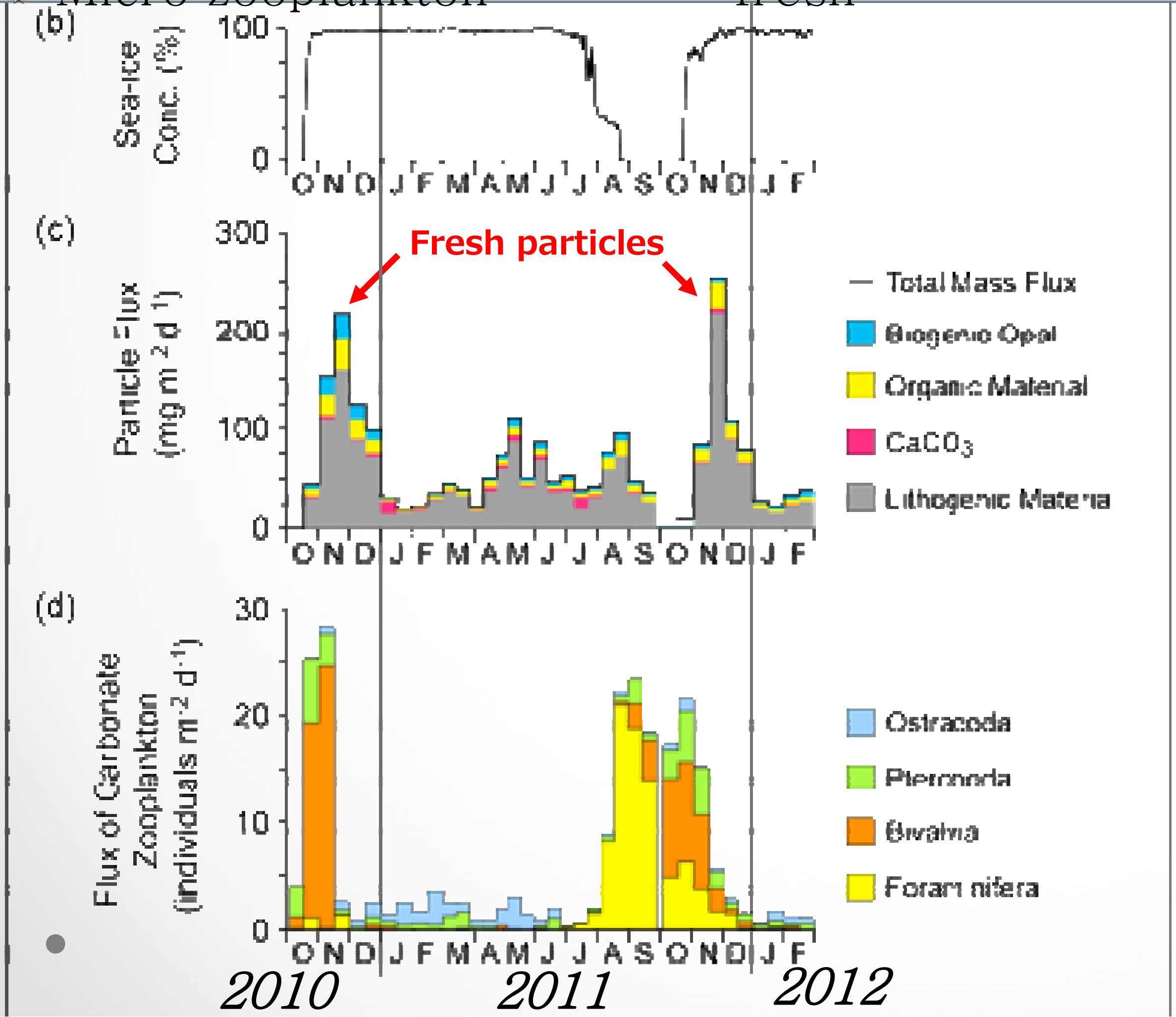


Battery Life: 2 years

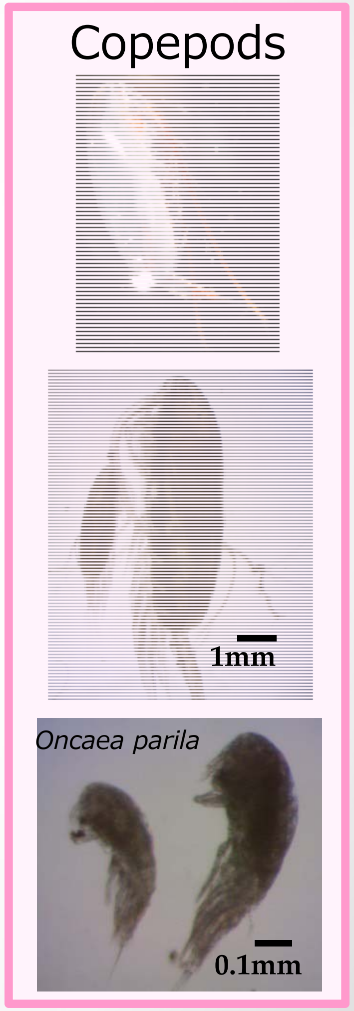
1975 m water depth

Seasonal change in particle fluxes

- Flux → maximum in the beginning of winter
- Major composition → lithogenic
- Biological particles → diatom dominant
- Micro zooplankton → fresh



Fresh zooplankton from trap

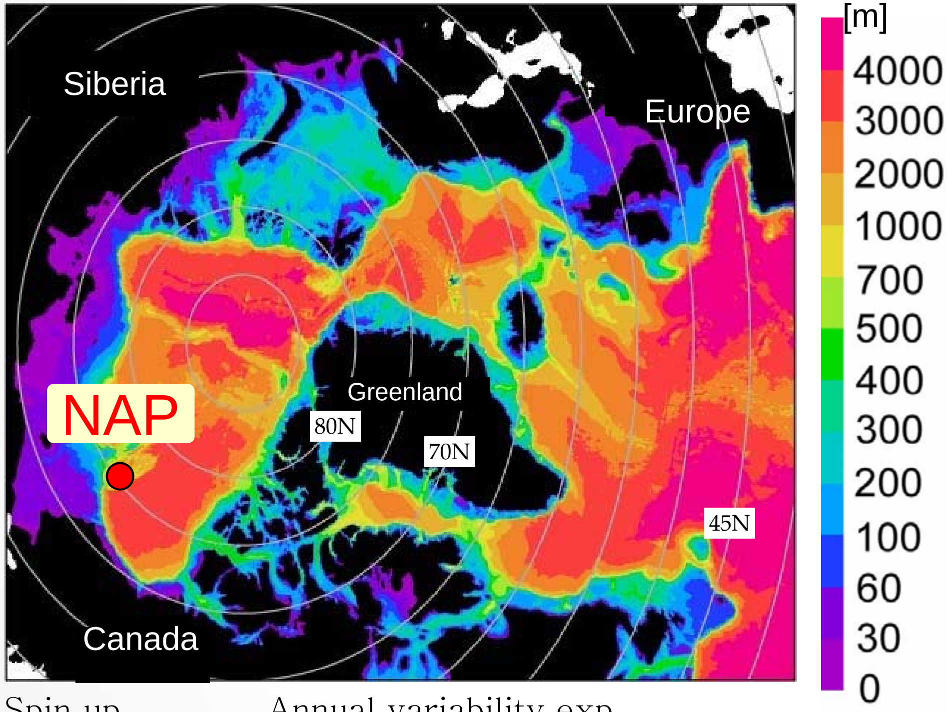


Onodera et al., 2015, Biogeosciences

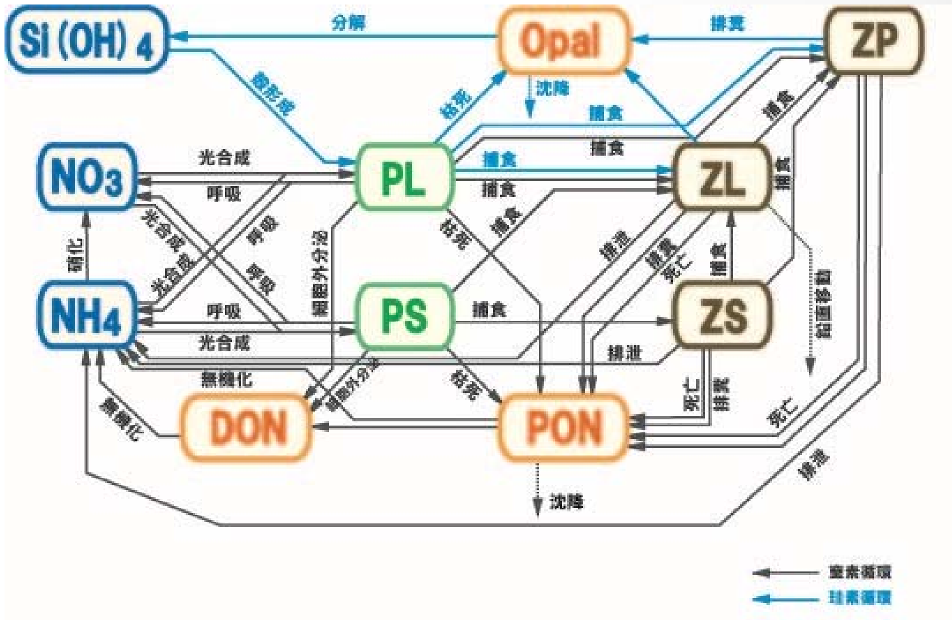
Arctic sea ice-ocean physics-ecosystem model

Sea ice-ocean physics model： COCO

Marine ecosystem model： NEMURO



Bering strait



Spin up (Atmospheric condition in 1979)

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

10 yrs integration

33 yrs integration

25km mesh

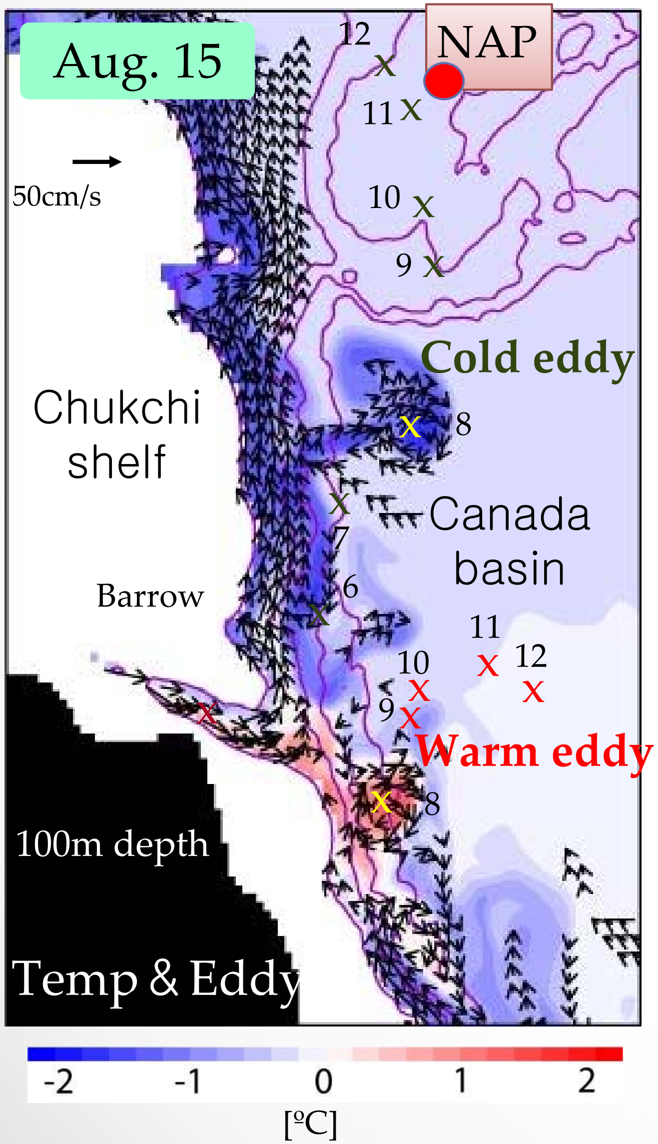
Seasonal variability exp. (Atmospheric condition in 2010)

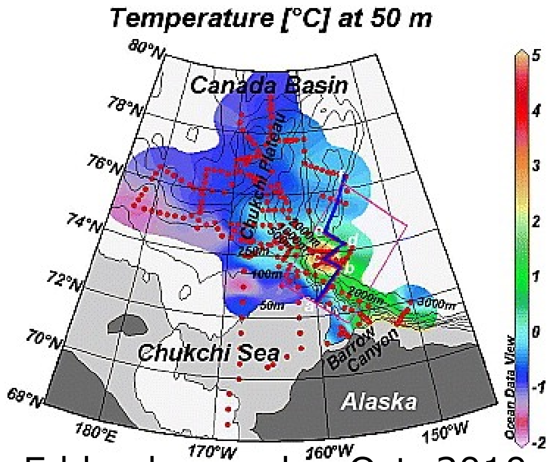
1 yr integration

5km mesh

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

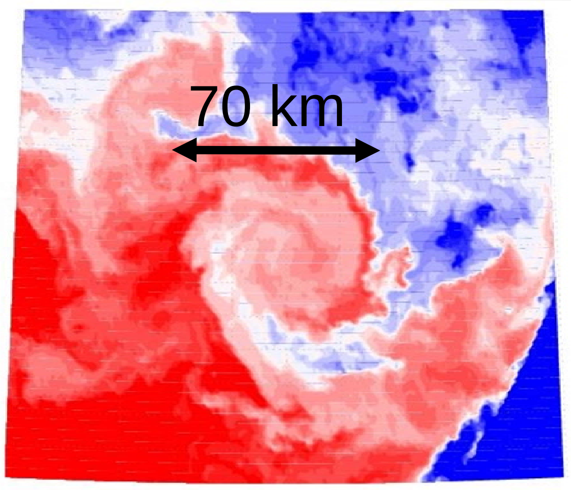
Meso scale eddy transports the shelf water and incubates the lower trophic level organisms





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

Nishino et al. [2011] GRL,
doi:10.1029/2011GL047885



SST from MODIS satellite
Sep, 2003

Watanabe [2011]

Eddy transports the water mass from the shelf break

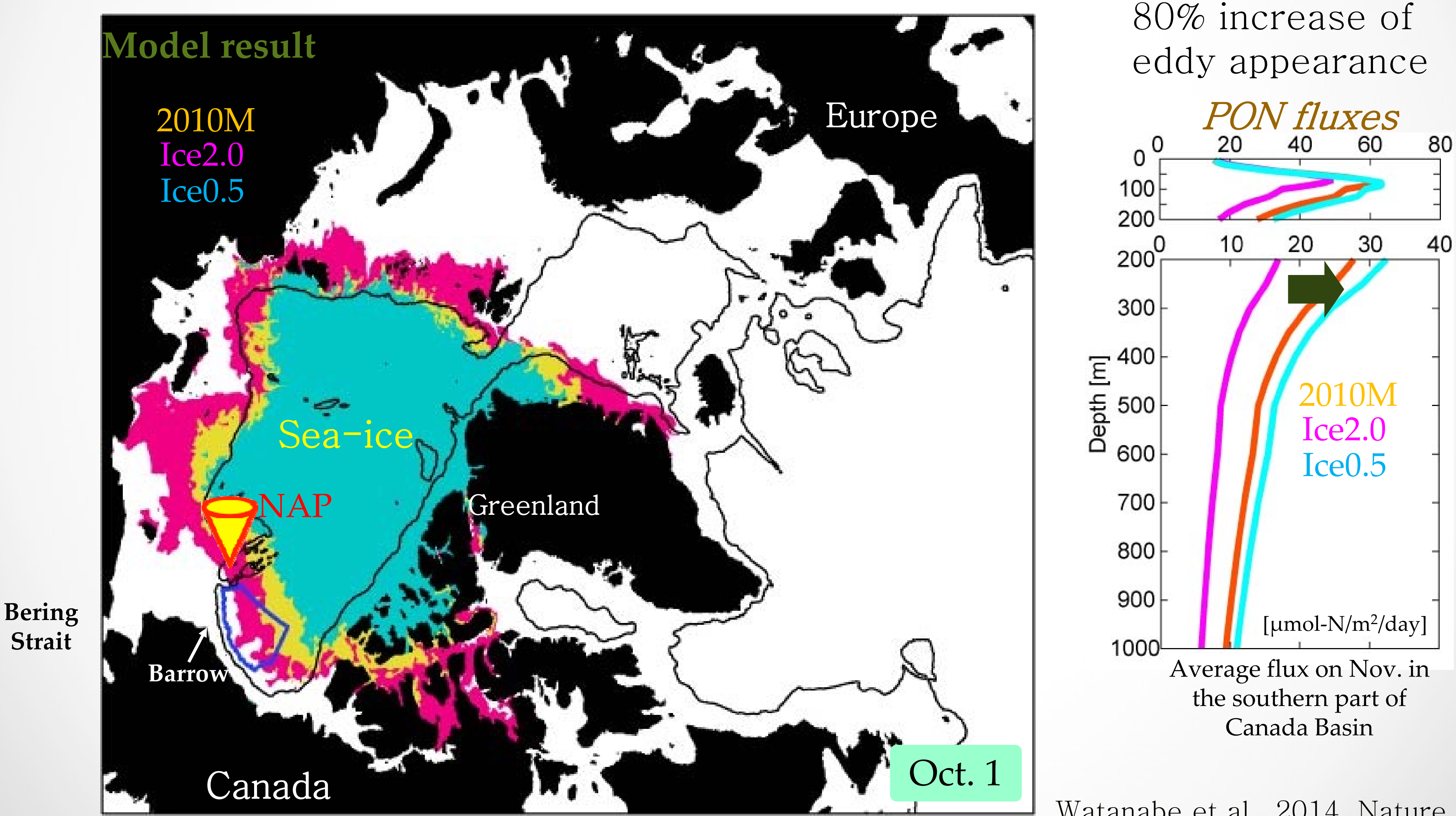
Turbulent mixing (inside the eddy) promotes
nutrient input from subsurface to surface
in the eddy-matured period

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

Watanabe et al., 2014, Nature Comm., doi: 10.1038/ncomms4950

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

80% increase of eddy appearance



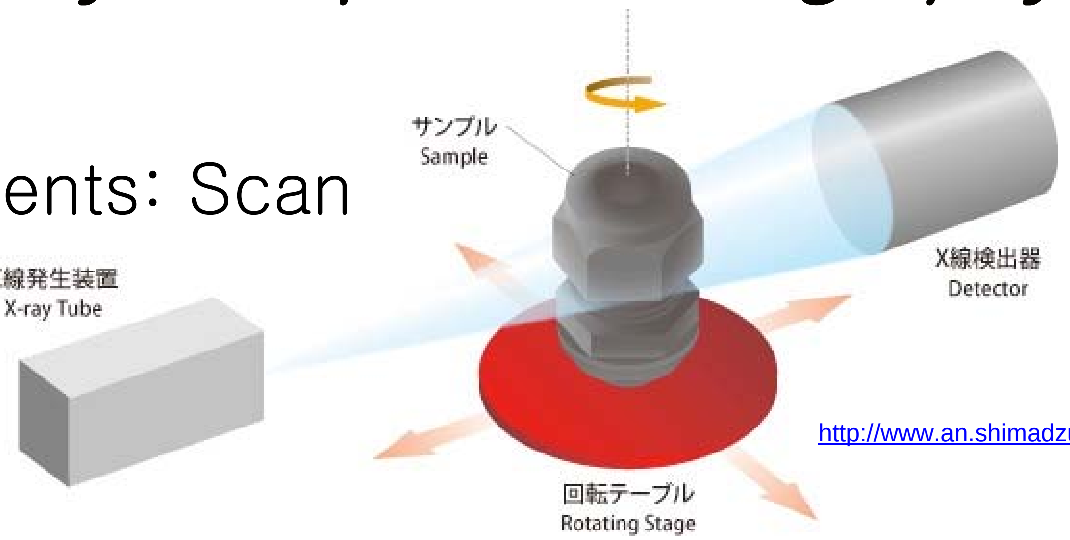
Average flux on Nov. in the southern part of Canada Basin

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

Watanabe et al., 2014, Nature Comm., doi: 10.1038/ncomms4950

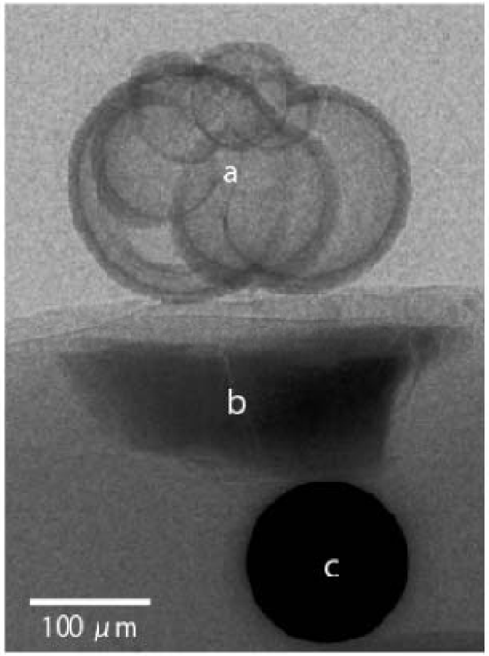
Micro X-ray Computer Tomography technique

Components: Scan



http://www.an.shimadzu.co.jp/ndi/products/x_ryct/x_ryct01.htm

Fluoroscopic image

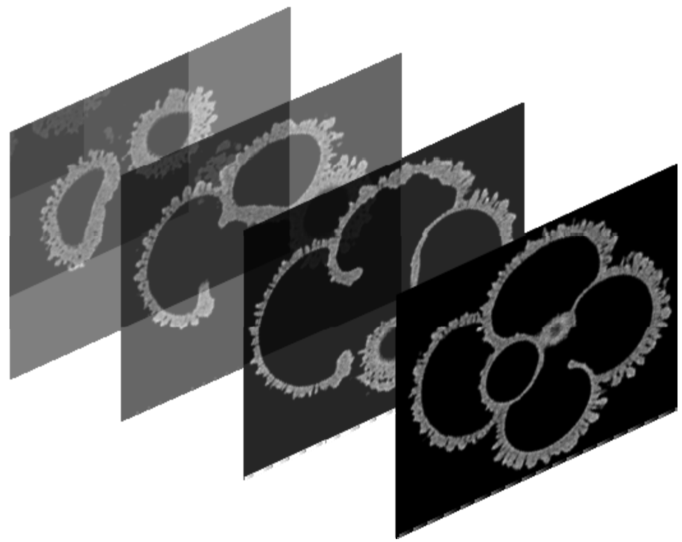


a. Specimen

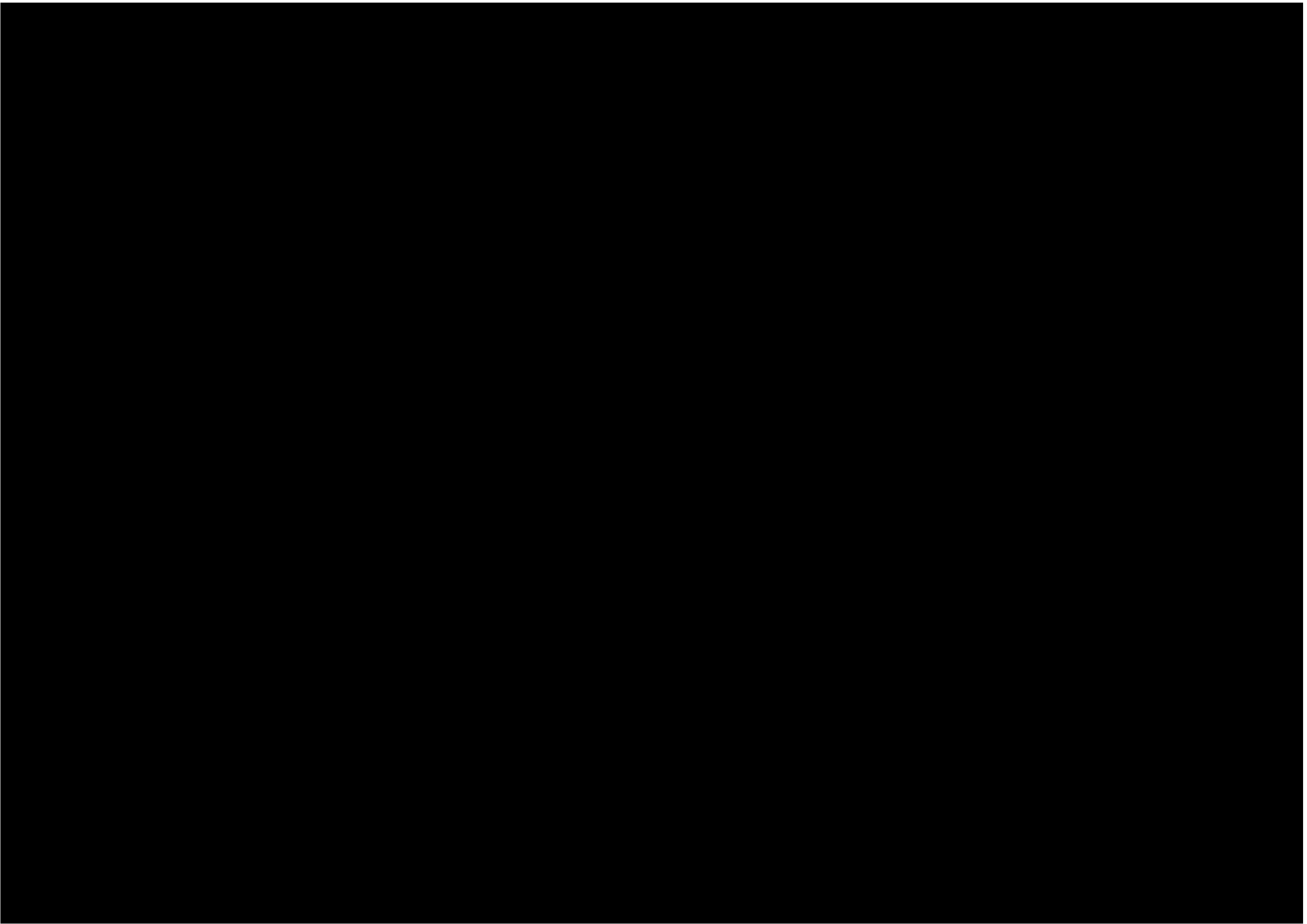
b. Standard material

c. Position maker

Stack & reconstruct



The special resolution of x-ray attention: 0.8 μm

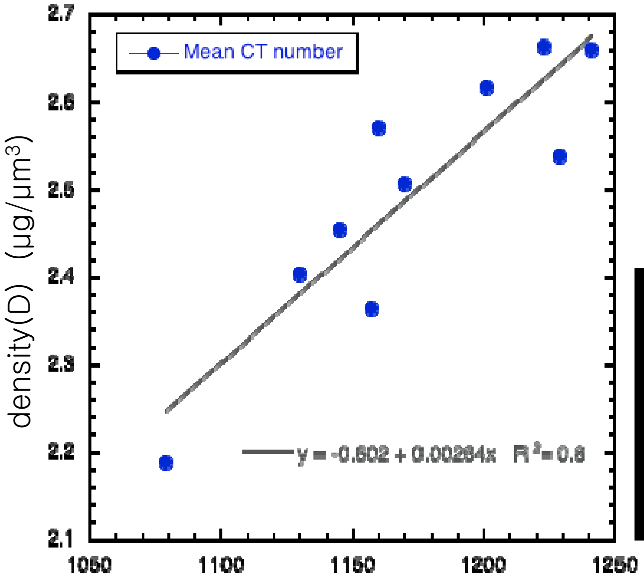


CT Number (proportional with density)

relative value of X-ray attenuation coefficient in each voxels on CT analysis

$$\text{CT Number} = \frac{\mu_{sample} - \mu_{air}}{\mu_{calcite} - \mu_{air}} \times 1000$$

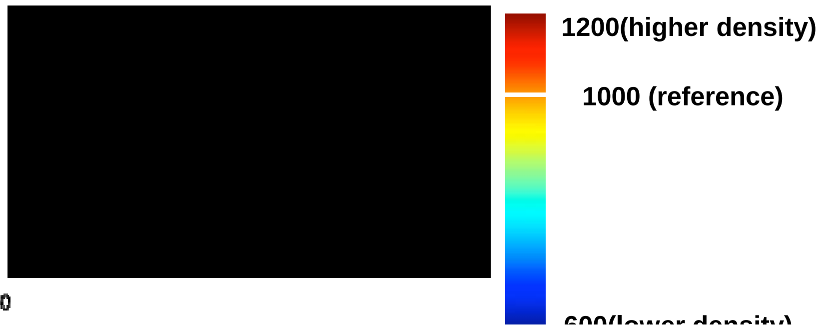
μ_{sample}: X-ray attenuation coefficient of samples
μ_{air}: X-ray attenuationcoefficient of the air
$\mu_{calcite}$: X-ray attenuation coefficient of calcite (standard material)

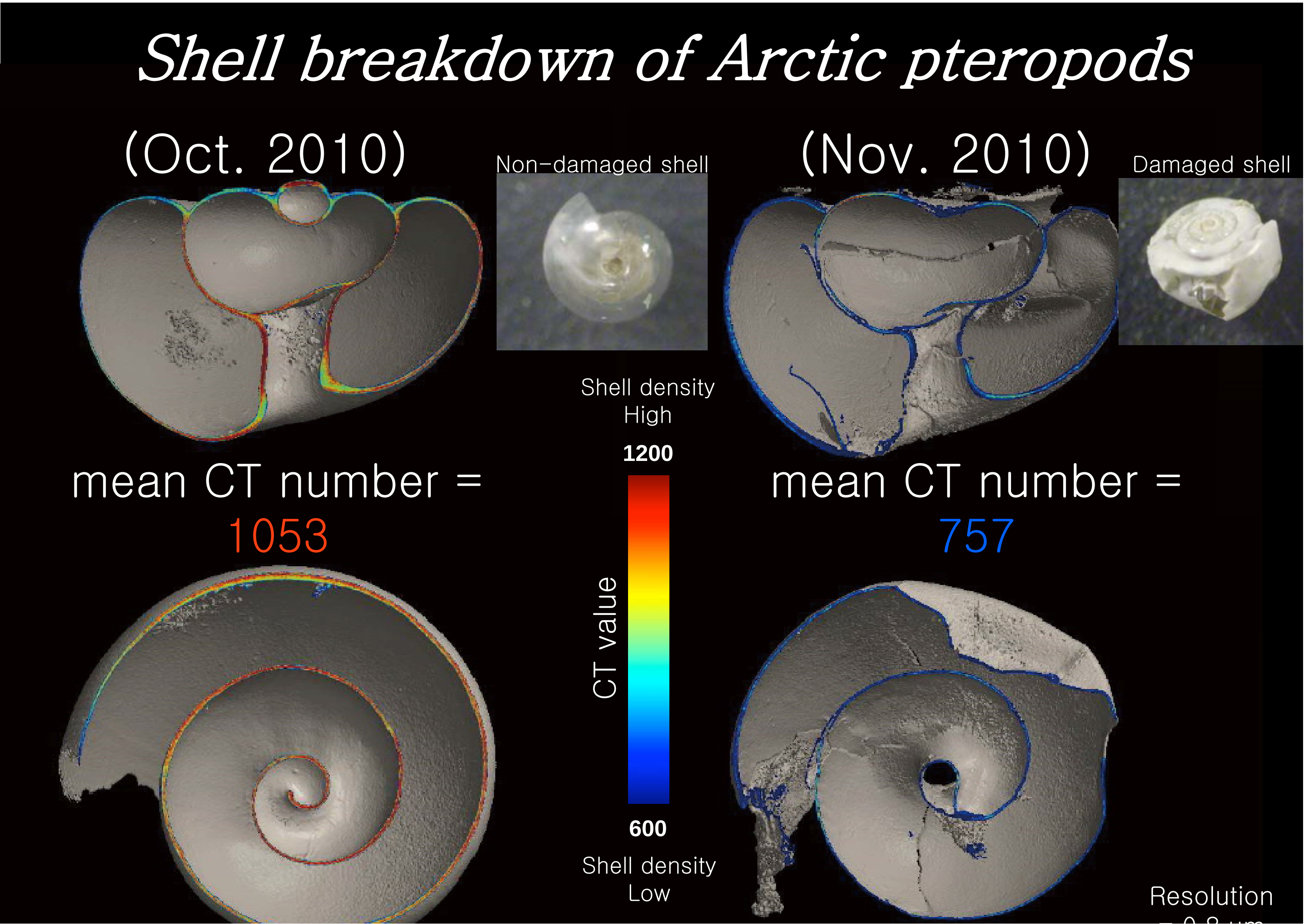


Density of calcite (D)
$D = 0.00264x - 0.602$ ($R^2 = 0.8$)

(x: mean CT value)

Shell volume: measured by micro XCT
$CaCO_3$ contents: analyzed by the HR-ICP-MS.





Shell breakdown of Arctic pteropods
(Oct. 2010)
Non-damaged shell
(Nov. 2010)
Damaged shell
Shell density
High
1200
CT value
600
Shell density
Low
mean CT number =
1053
mean CT number =
757
Resolution

Summary

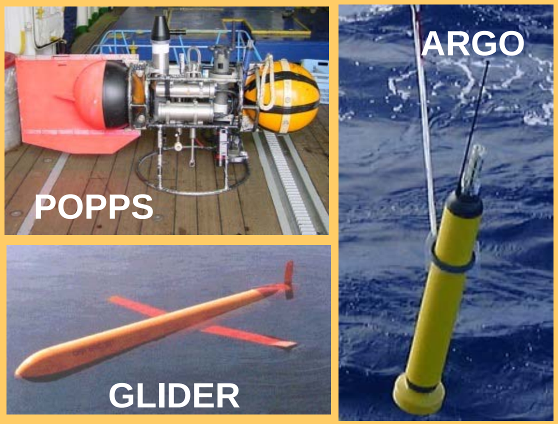
- Collaboration research between in-situ observation, sea-ice ocean physics-marine ecosystem model and laboratory work with new instruments have powerful potential to describe the relationship between environmental change and the biological response in the Arctic Ocean.
- For example, coupling work of time series sediment trap experiment and sea-ice ocean physics-marine ecosystem model provided new finding that the mesoscale eddy is a key process for enhancement of biological fluxes in the Arctic Ocean.
- Micro-Focus X-ray Computing Tomography technique has a potential to quantify the impact of ocean acidification for carbonate shell-bearing marine plankton.
- Regarding cost performance, temporal and spatial rising of data resolution, and quality control, further development of in-situ instruments is required to understand the Arctic change.

Development of Mini-fast repetition rate fluorometry (FRRF) (Diving Flash-14)

The FRRF can be used in autonomous platform systems (buoy moorings, drifters, and floats) for marine phytoplankton activity observations.

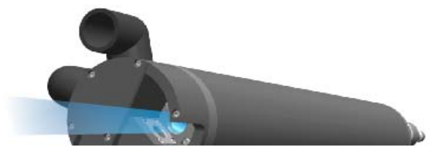
Challenges: down of size and cost
save electric power

Platform systems



Schedule (FY):

- 2014 bench-top type FRRF (performance verification)
- 2015 submersible type FRRF
- 2016～ load FRRF (POPPS) (field test)



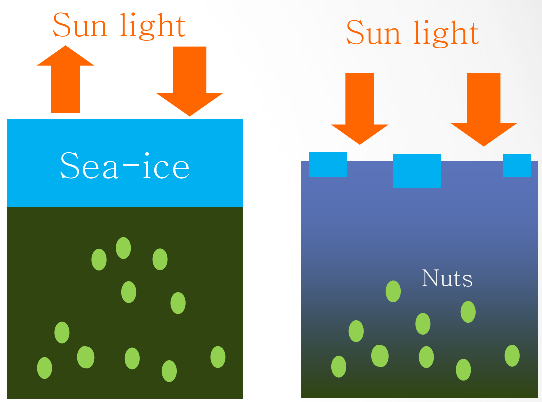
Phytoplankton responses to the sea-ice reduction

If sea-ice reduced in the Arctic Ocean…,

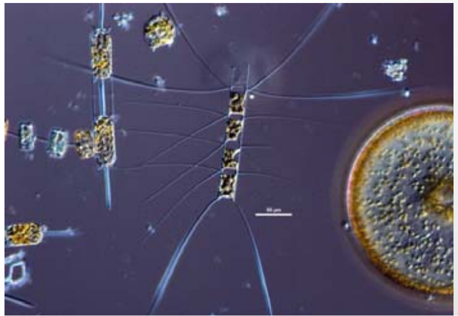
- Light
  Sea ice reduction contributes to the improvement of light condition in the sea water

- 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?



nite shell is sensitive to carbonate undersatu

Pteropods (sea snail)

Ω =1

Dissolution > Calcification

Station NAP13t – raw data
Multi-wave length excitation fluorescence photometer (Multi-Exciter)