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Biological hot spots emerging along the pathway of Pacific summer water in the western Beaufort Sea

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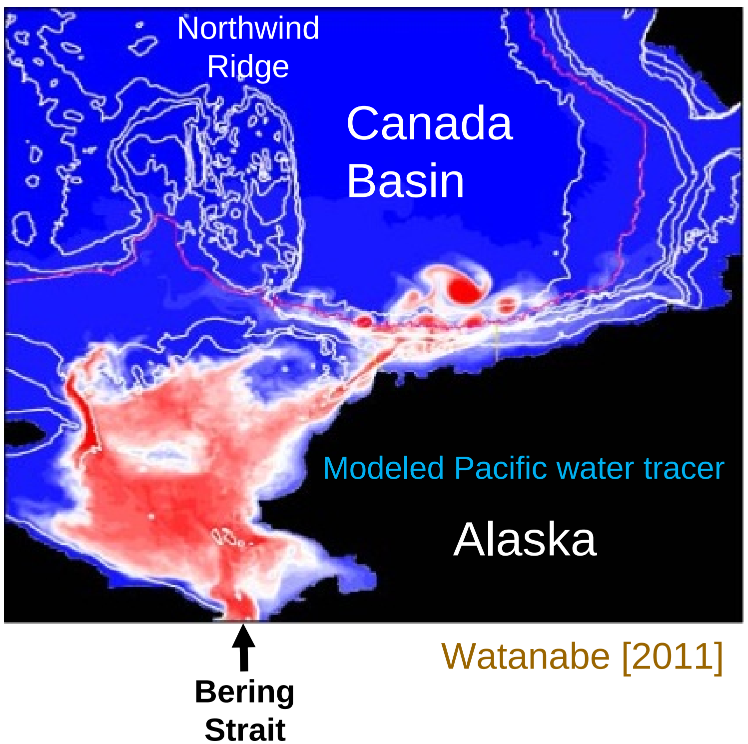
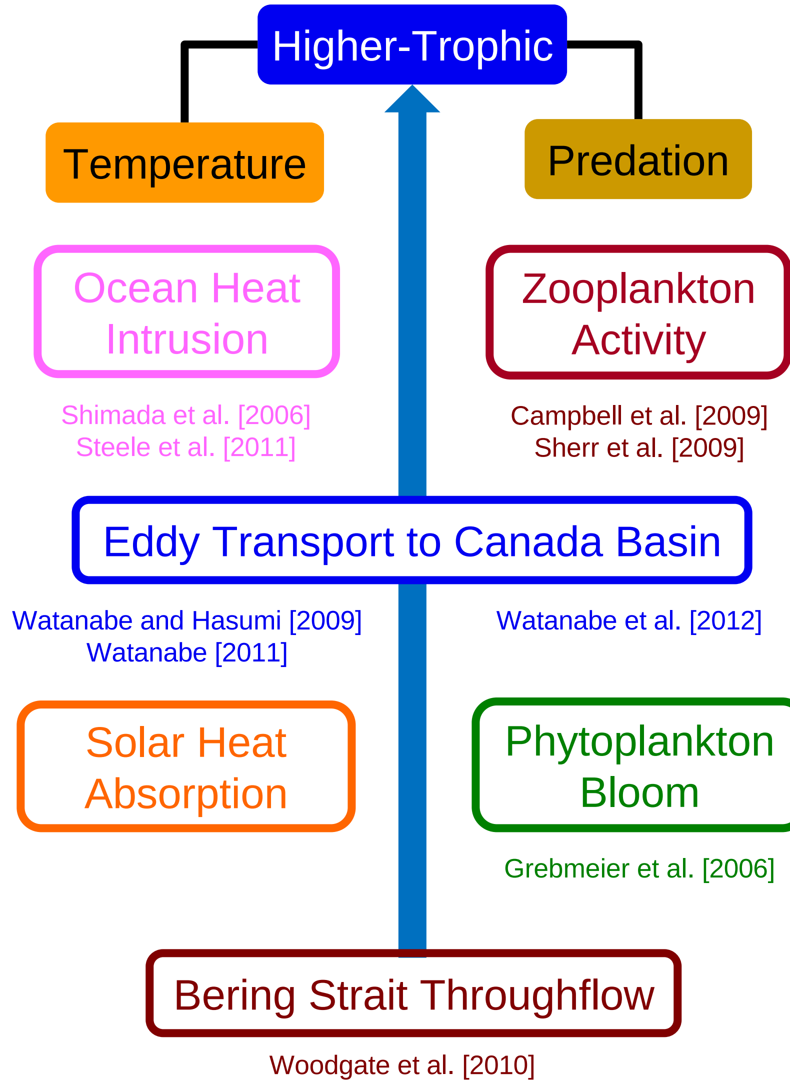
Role of Pacific Water Transport

Pacific water transport with heat
and biogeochemical materials
should be a key for basin ecosystem !



Watanabe [2011]

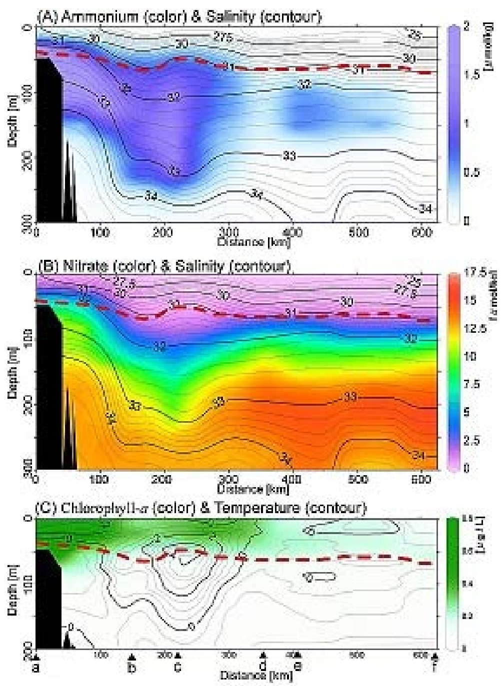
Does sea ice reduction enhance
biological activities in Arctic basin ?



Phytoplankton Response to Eddy Activities

Impact of ocean dynamics on Arctic marine ecosystem has a lot of uncertainties

Large warm Beaufort eddy is observed by R/V Mirai in 2010

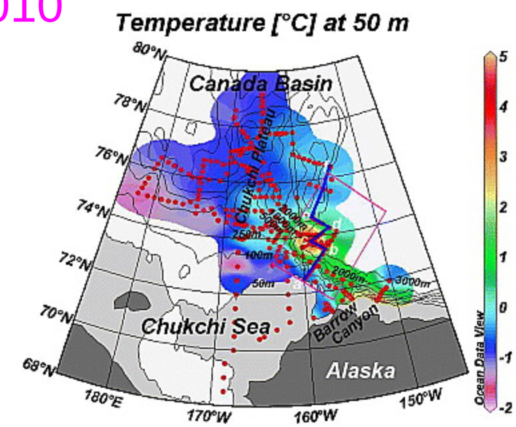


high-NH_4

low-NO_3

high-Chl

Nishino et al. [2011]



Locally high biomass
of phytoplankton

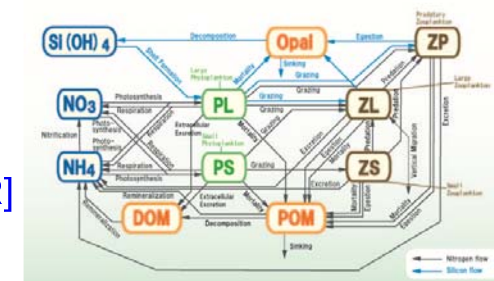
How do ocean dynamics such as
shelf-water transport, turbulent mixing,
upwelling produce biological hot spots ?

Primary productivity regulated by Beaufort shelf-break eddies
is addressed using an eddy-resolving ice-ocean model

Model and Experimental Design

NEMURO (North Pacific Ecosystem Model Used for Regional Oceanography)

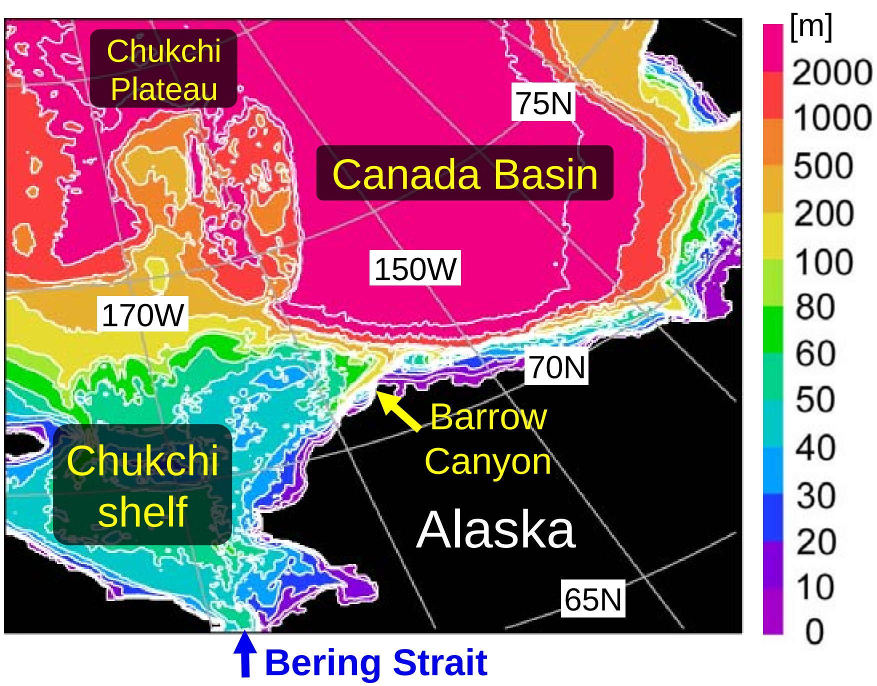
Reasonable performance in global and Arctic regions [Sumata et al., 2010 / Zhang et al., 2010]
- analysis of shelf process has been difficult due to coarser model resolution

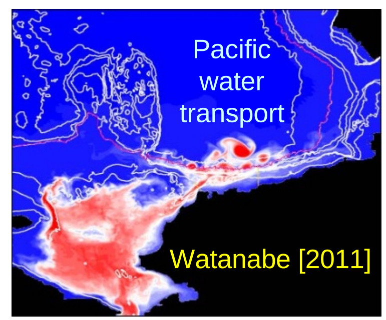


Kishi et al. [2007]

Coupled to physical ice-ocean model COCO (2.5 km ver.)
- Relationships of Beaufort shelf-break warm eddies with ice extent and wind were addressed [Watanabe and Hasumi, 2009, JPO / Watanabe, 2011, JGR]

NEMURO parameter values follow Arctic modeling of Zhang et al. [2010]



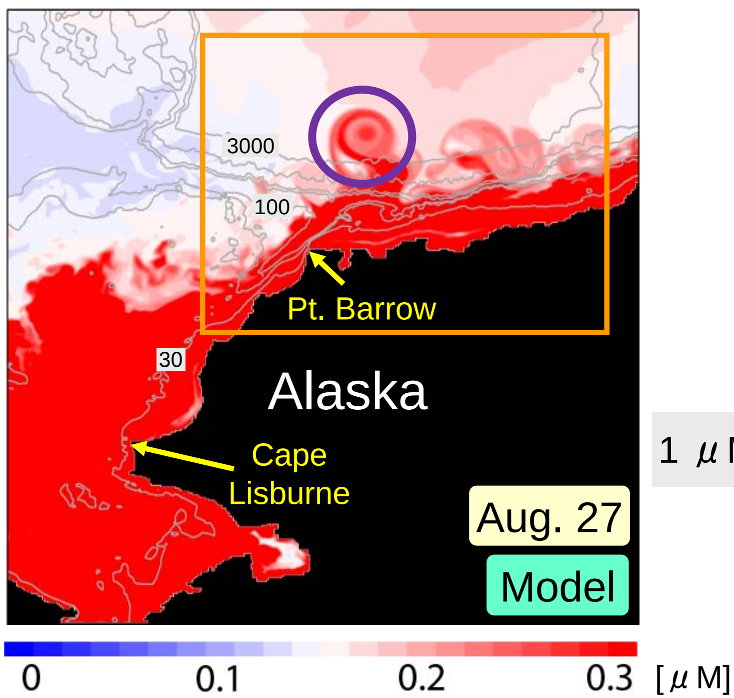


Integrated from March to November
- NCEP atmospheric forcing in 2003
- Pacific water inflow at Bering Strait
- Initial and lateral boundary condition of nitrate and silicate : WOA09

Result

Eddy-like Chlorophyll Features

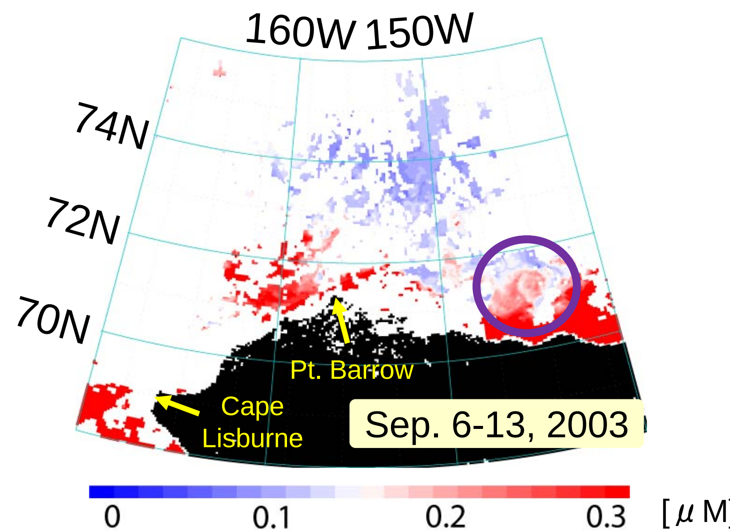
Swirling structures of phytoplankton biomass north of Point Barrow



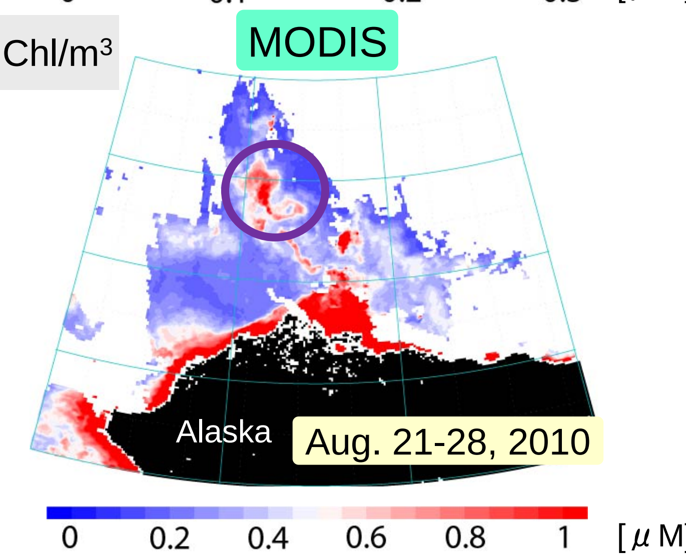
Model : 0.4 μM (~ 0.6 mgChl/m³)

OBS : 0.5 ~ 1.5 mgChl/m³

MODIS, Nishino et al. [2011]



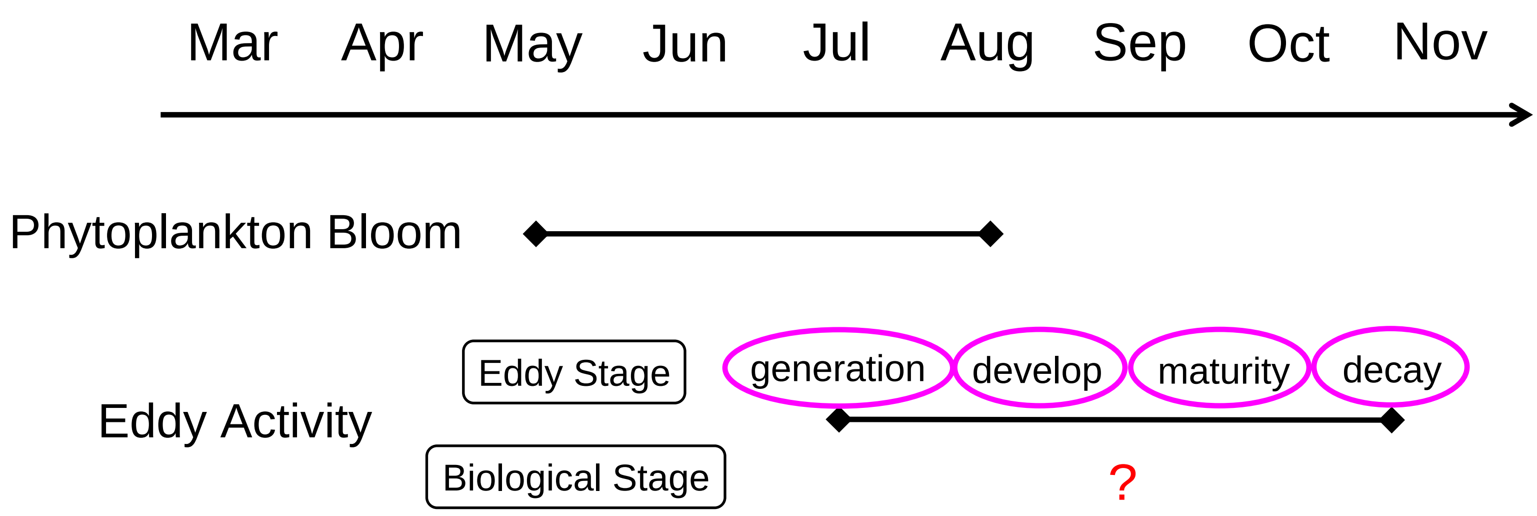
1 μM ~ 1.6 mgChl/m³



Result

Seasonal Transition of Bloom and Eddy

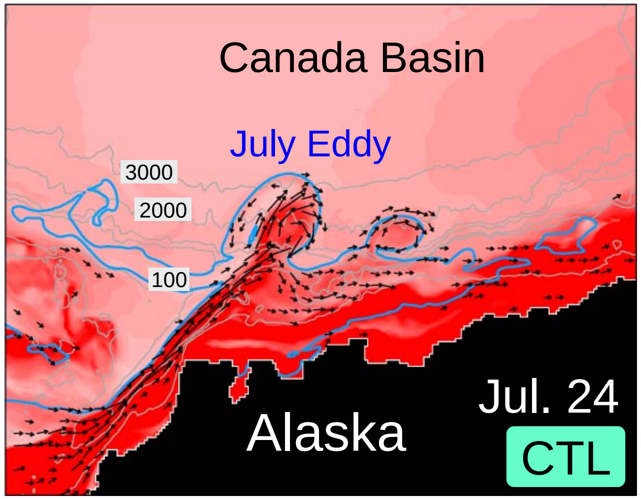
Phytoplankton bloom occurs following summertime sea ice retreat
Warm eddies are then generated north of Barrow Canyon after July

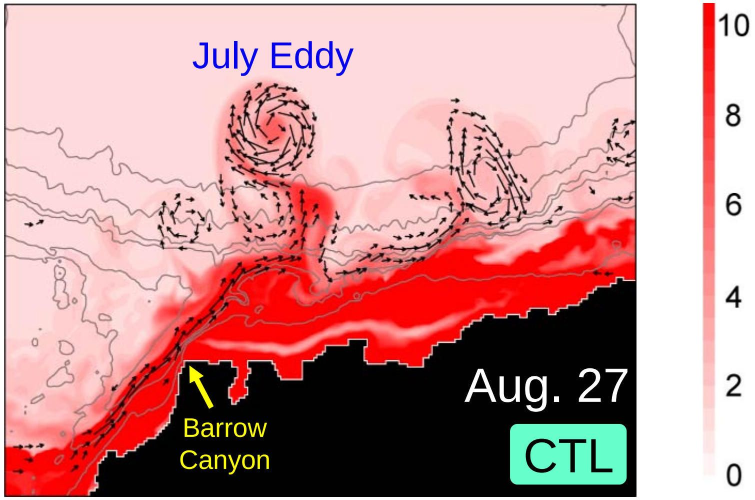


Eddy Generation and Development Stage

Primary productivity is tracked following life stages of shelf-break eddies

Surface gross primary production rate in Beaufort shelf-break region [10^{-2} μM/day]





Warm anti-cyclonic eddies are generated north of Barrow Canyon

Primary production continues at center of July Eddy moving offshore

Eddy-induced transport of shelf water with high primary productivity

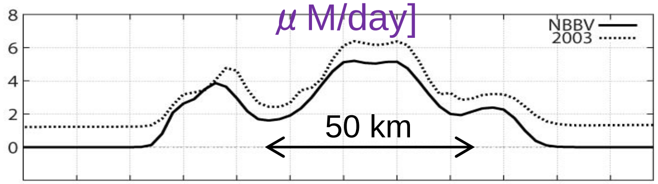
Shelf water is trapped along eddy edge via clockwise rotational flow

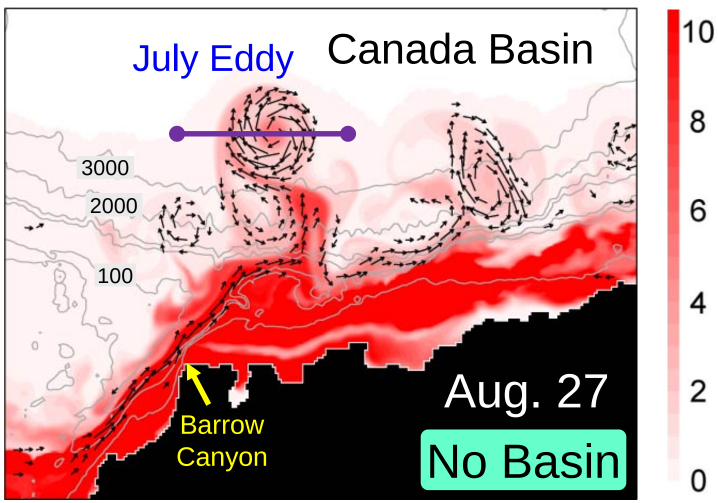
Result

Role of Shelf Water Transport

Relative importance of shelf-water transport on productivity is estimated

Primary production rate across July Eddy [10^{-2} μ M/day]





All NEMURO values are reset to zero in Canada Basin area on July 24

Similar spatial pattern with eddy-like structure is simulated

Water exchange with background basin environment is not an essential process

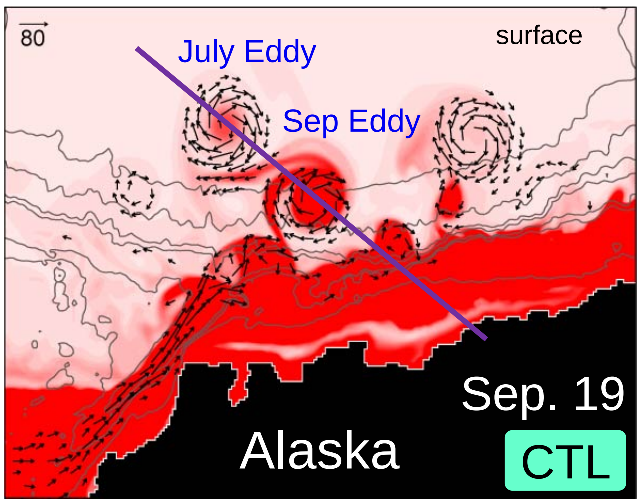
Primary productivity inside July Eddy is maintained by consuming residual of nutrient taken at initial eddy stage

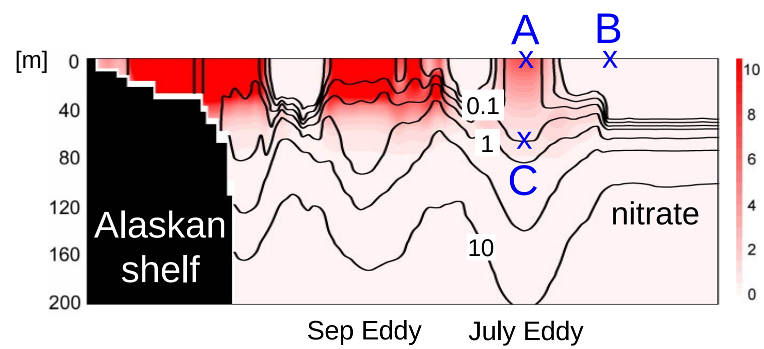
Result

Eddy Maturity Stage

Primary production is maintained even after offshore migration

Gross primary production rate [10^{-2} μM/day]





	Light	Nut	Temp	PP
A	High	High	High	High
B	High	Low	Low	Low
C	Low	High	High	Low

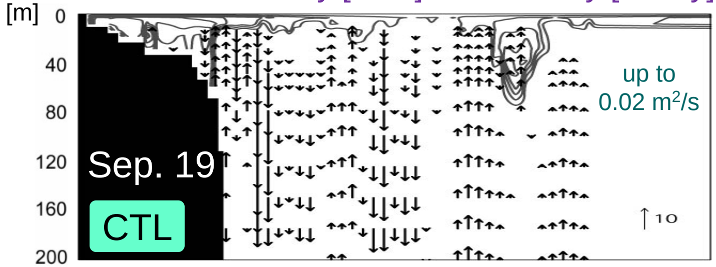
Surface central area of eddy is
a hot spot of primary production due to
enough light, nutrient, and warm condition

Role of Vertical Turbulent Mixing

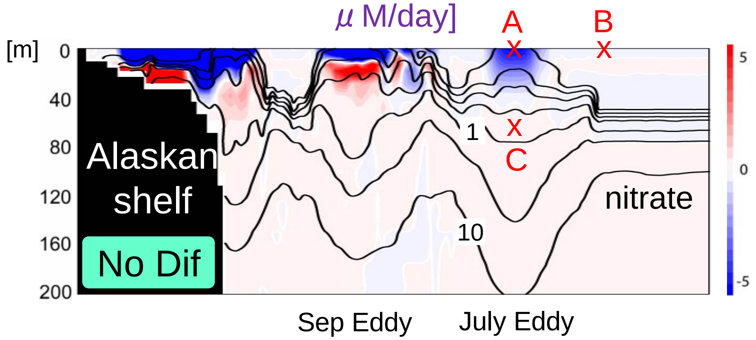
Relative importance of vertical mixing on productivity is estimated

Nutrient redistribution due to vertical diffusion is excluded from Aug. 27 to Sep. 19 in 2nd sensitivity experiment

Vertical diffusivity [m^2/s] and velocity [m/day]



Anomaly of primary production rate [10^{-2} μ M/day]



Vertical diffusion rate is the same order as tidal mixing around narrow straits

Less net upward nutrient flux accounts for reduction of surface primary productivity

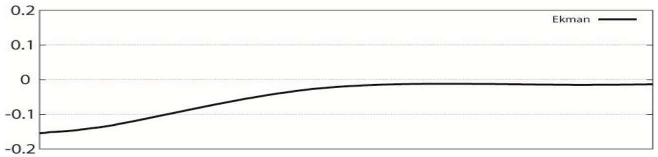
Vertical turbulent mixing of $O(10^{-2}\ m^2/s)$ drives exchange with underlying nutrient-rich water and enhances primary productivity inside eddies

Role of Vertical Flow

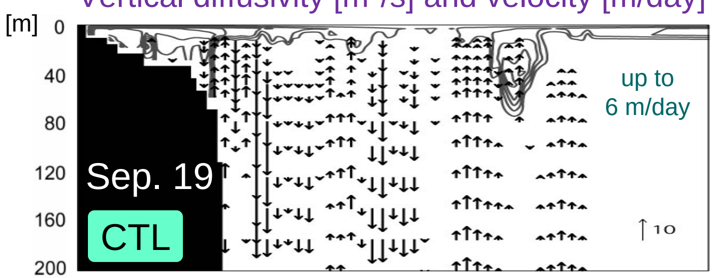
Relative importance of vertical flow on productivity is estimated

Nutrient redistribution due to vertical advection is excluded from Aug. 27 to Sep. 19 in 3rd sensitivity experiment

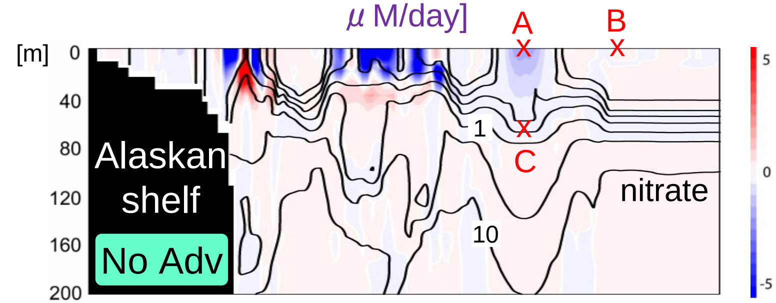
Wind-driven Ekman vertical velocity [m/day]



Vertical diffusivity [m^2/s] and velocity [m/day]



Anomaly of primary production rate [10^{-2} μ M/day]



Local upwelling/downwelling event of O(1 m/day) has just a minor contribution to primary productivity after eddy development

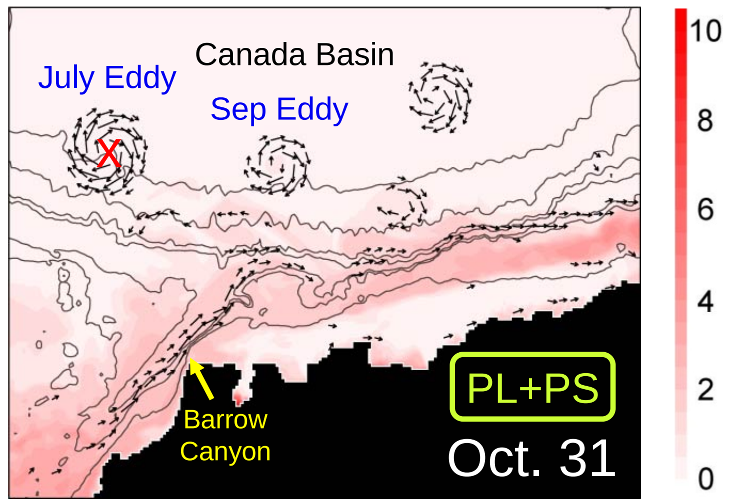
Result

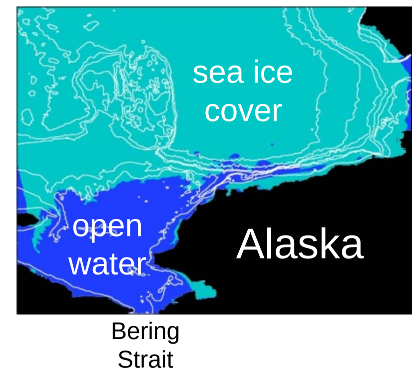
Eddy Decay Stage

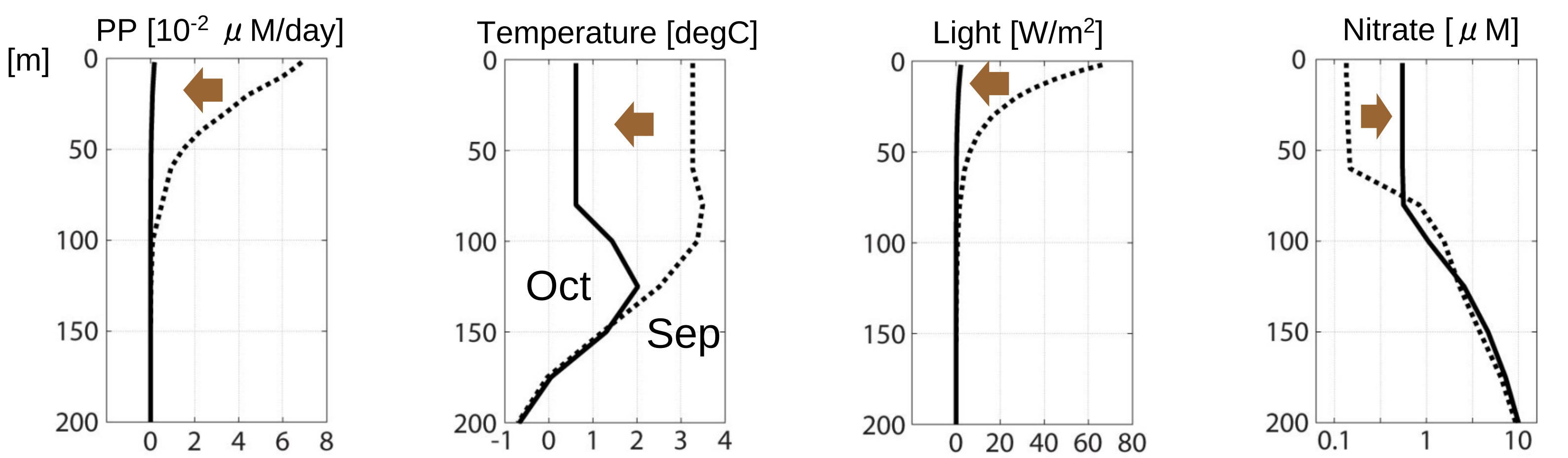
Surface gross primary production rate [10^{-2} μM/day]

Primary productivity is weakened in Oct.

Light limitation due to solar incidence ceases PP before sea ice freezing

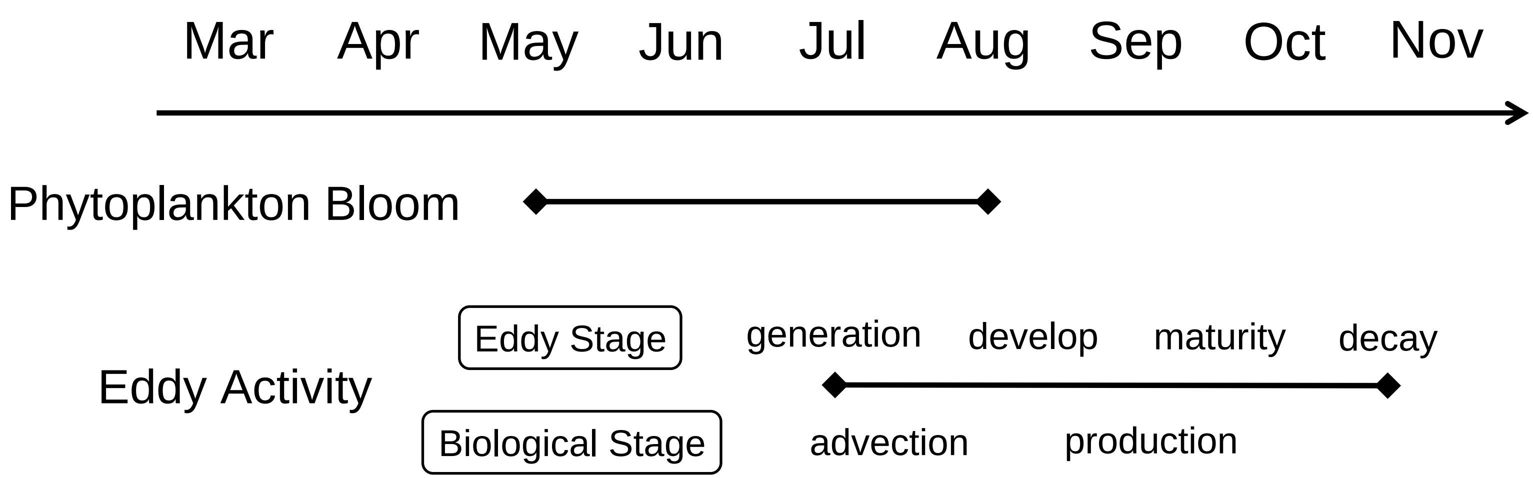






Summary and Suggestion

Modeled response of primary productivity to Beaufort shelf-break warm eddies is examined following eddy life stages

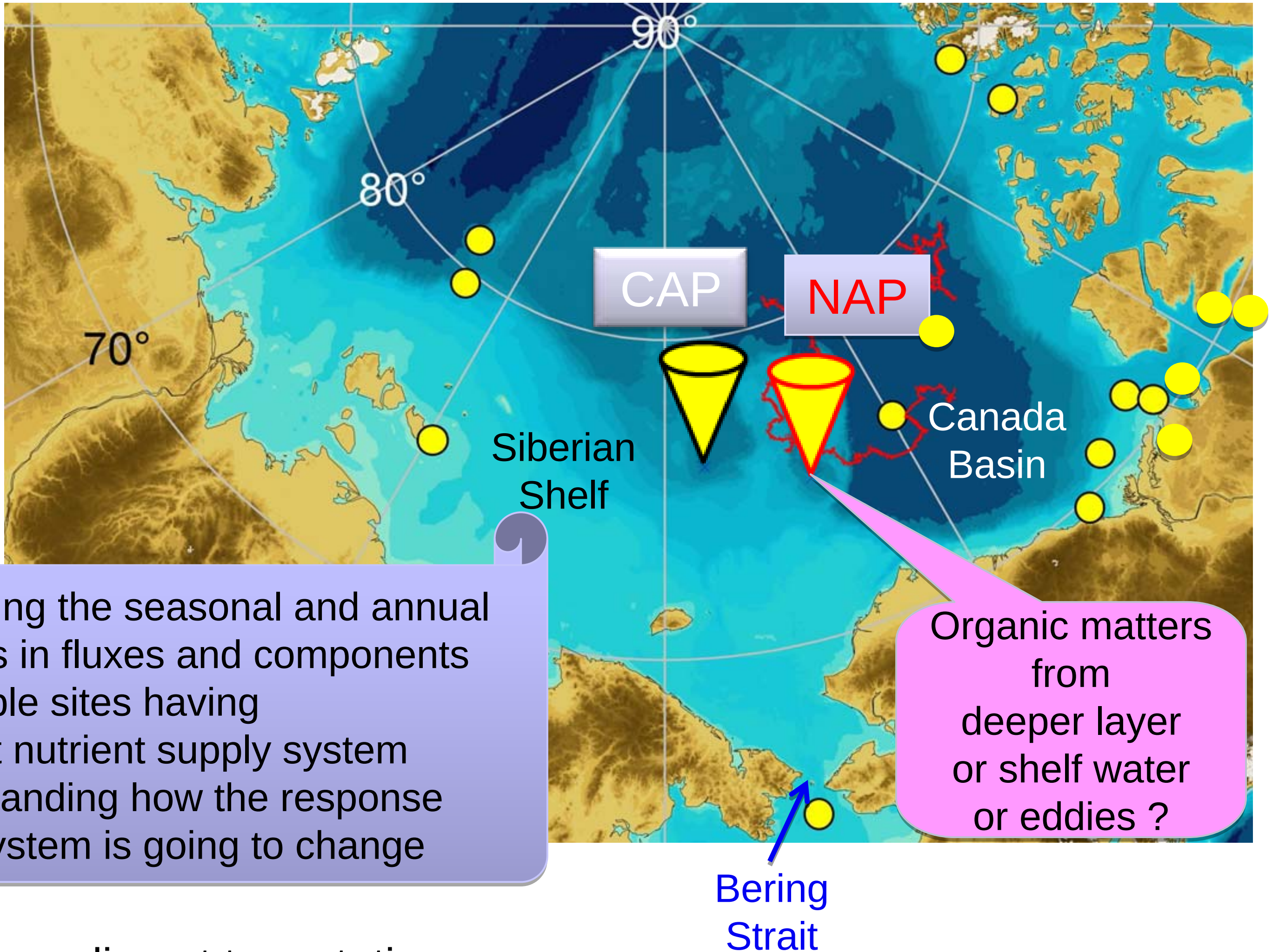


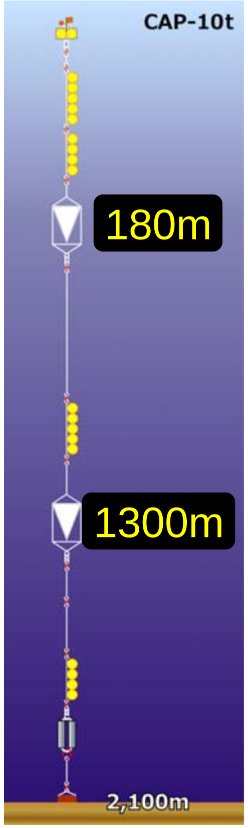
Time lag between phytoplankton bloom and eddy generation is an important index to determine biological regimes in Canada Basin

Earlier or longer shelf bloom would significantly change eddy-induced primary productivity in basin interior

Plan

Time Series Observation of Biogenic Flux





- Monitoring the seasonal and annual changes in fluxes and components at multiple sites having different nutrient supply system
- Understanding how the response of ecosystem is going to change

Previous sediment trap stations

Appendix

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