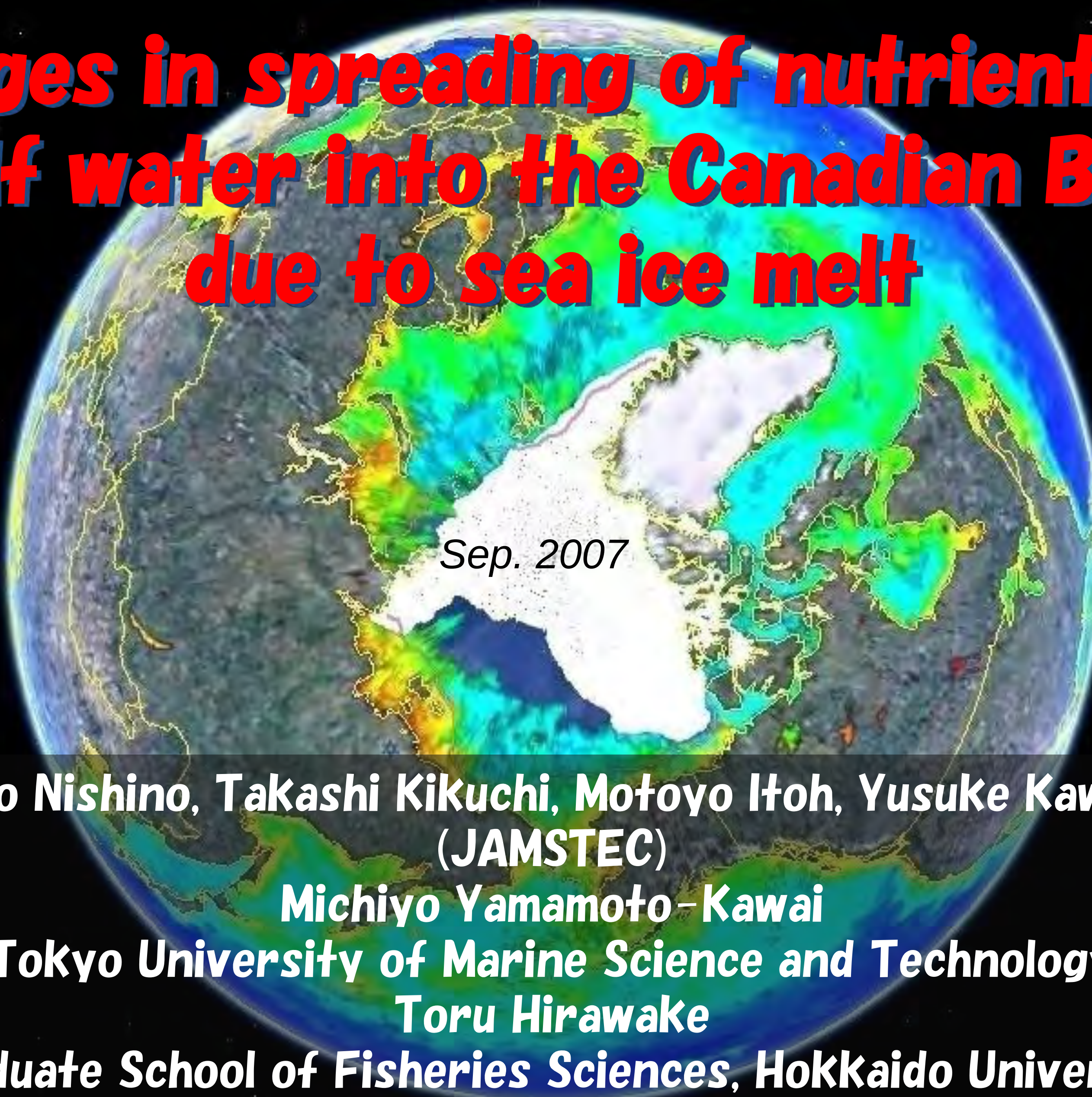
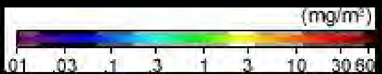
Changes in spreading of nutrient-rich shelf water into the Canadian Basin due to sea ice melt



Shigeto Nishino, Takashi Kikuchi, Motoyo Itoh, Yusuke Kawaguchi
(JAMSTEC)
Michiyo Yamamoto-Kawai
(Tokyo University of Marine Science and Technology)
Toru Hirawake
(Graduate School of Fisheries Sciences, Hokkaido University)



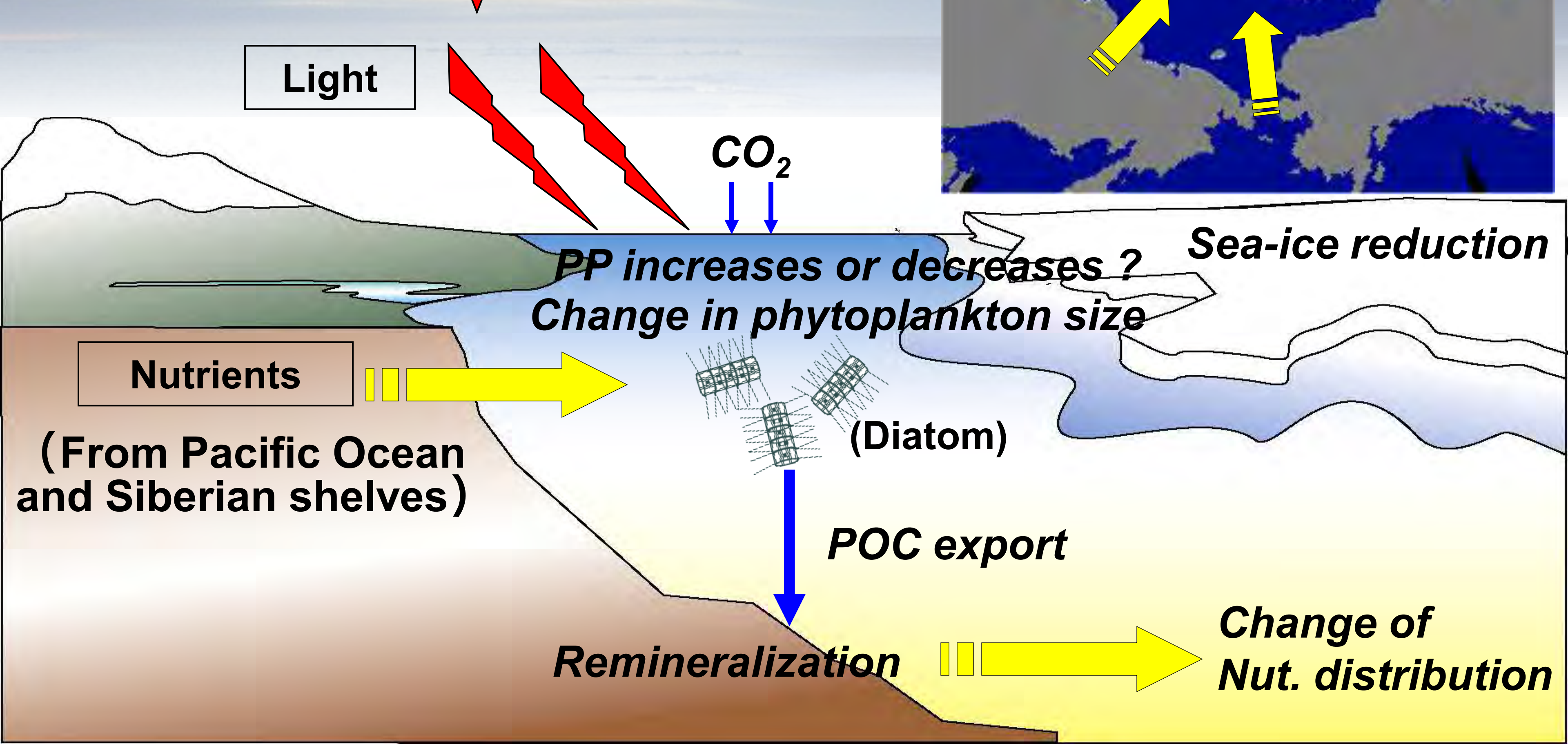
NASA Earth Observations
neo.sci.gsfc.nasa.gov

Papers

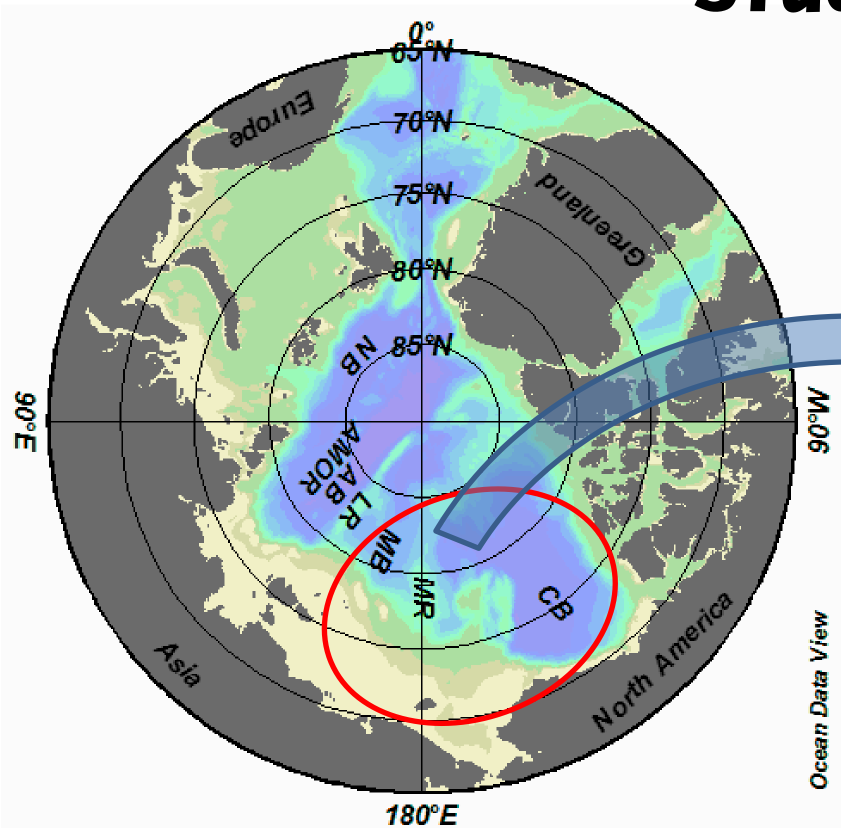
Nishino, S., T. Kikuchi, M. Yamamoto-Kawai, Y. Kawaguchi, T. Hirawake, and M. Itoh (2011), Enhancement/reduction of biological pump depends on ocean circulation in the sea-ice reduction regions of the Arctic Ocean, *J. Oceanogr*., accepted.

Nishino, S., M. Itoh, Y. Kawaguchi, T. Kikuchi, and M. Aoyama (2011), Impact of warm-core eddies on distributions of nutrients and phytoplankton in the Canada Basin, submitted to *Geophys*. *Res*. *Lett*.

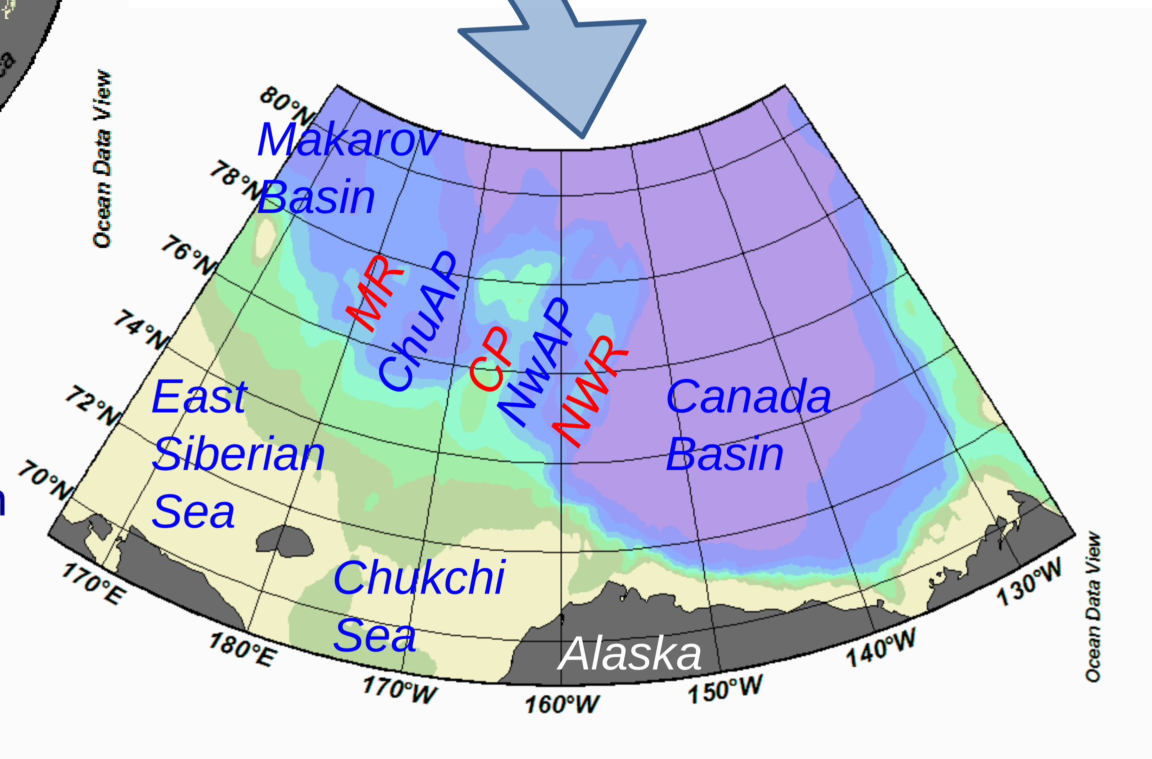
Biogeochemical responses to sea-ice reduction



Study area

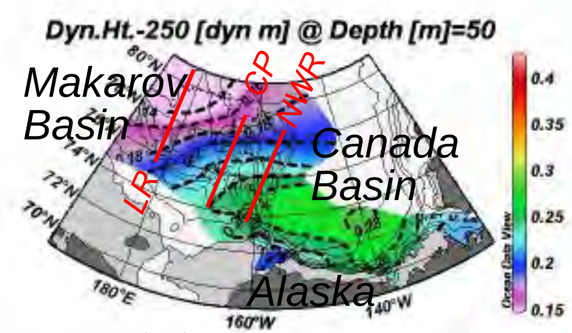


CB: Canada Basin
MR: Mendeleyev Ridge
MB: Makarov Basin
LR: Lomonosov Ridge
AB: Amundsen Basin
AMOR: Arctic Mid-Ocean Ridge
NB: Nansen Basin

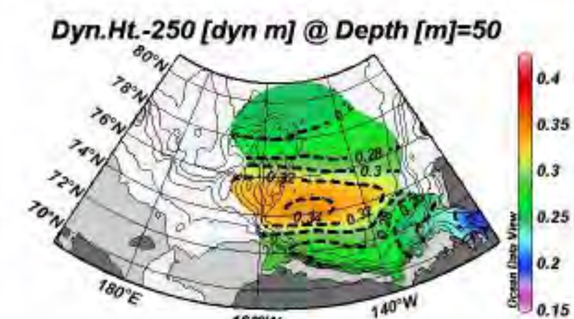


NWR: Northwind Ridge
NwAP: Northwind Abyssal Plain
CP: Chukchi Plateau
ChuAP: Chukchi Abyssal Plain
MR: Mendeleyev Ridge

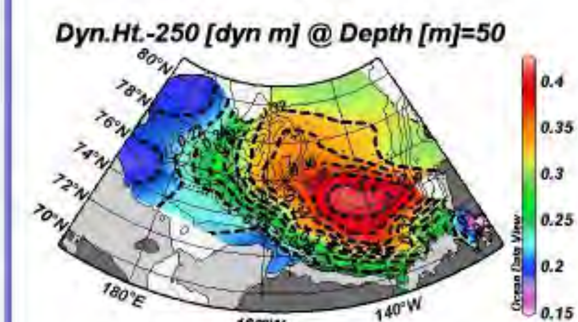
Dynamic height at 50m (relative to 250m) from 2002 to 2009



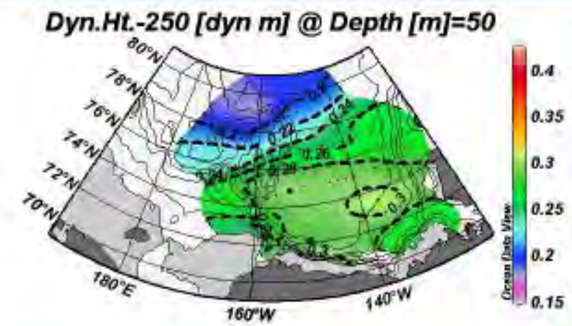
2002: Mirai + CBL



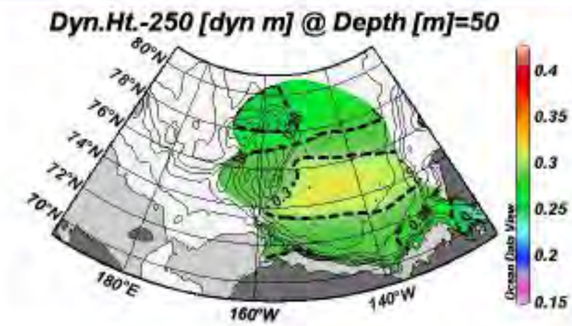
2005: JOIS/BGEP



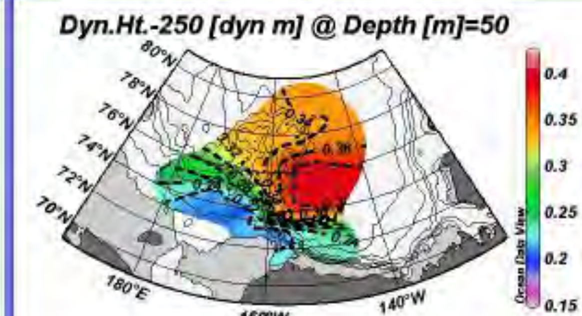
2008: Mirai + JOIS/BGEP



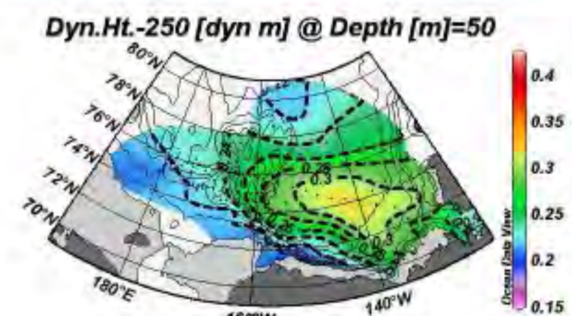
2003: JOIS/BGEP



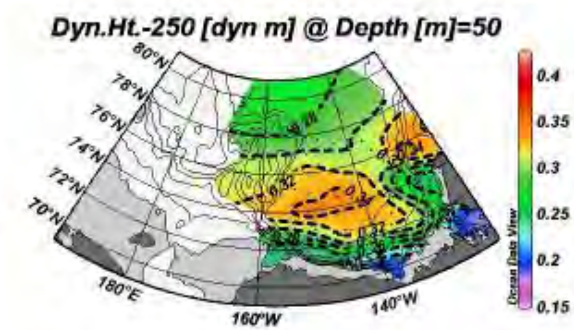
2006: JOIS/BGEP



2009: Mirai



2004: Mirai + JOIS/BGEP

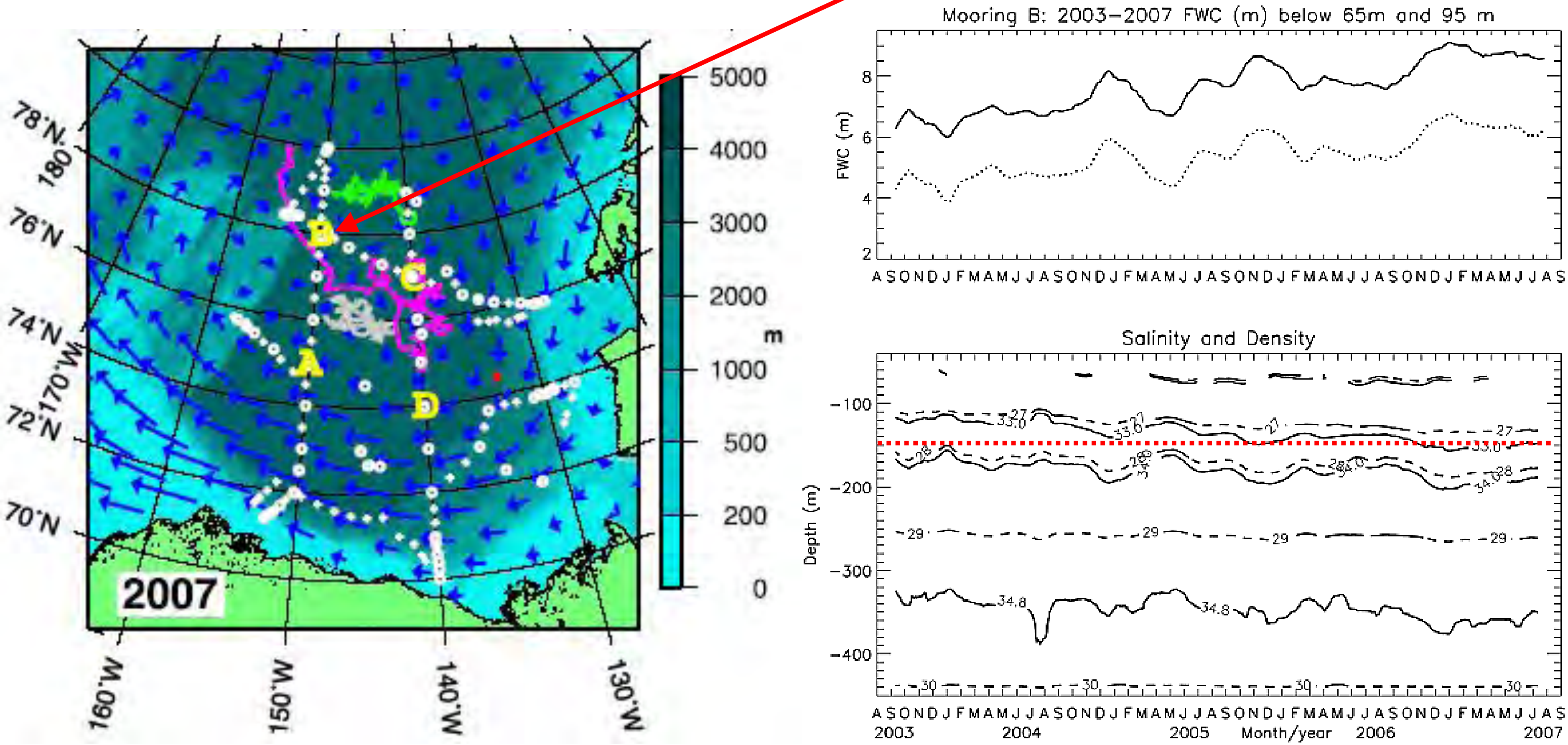


2007: JOIS/BGEP

Data: Mirai,
CBL,
JOIS/BGEP

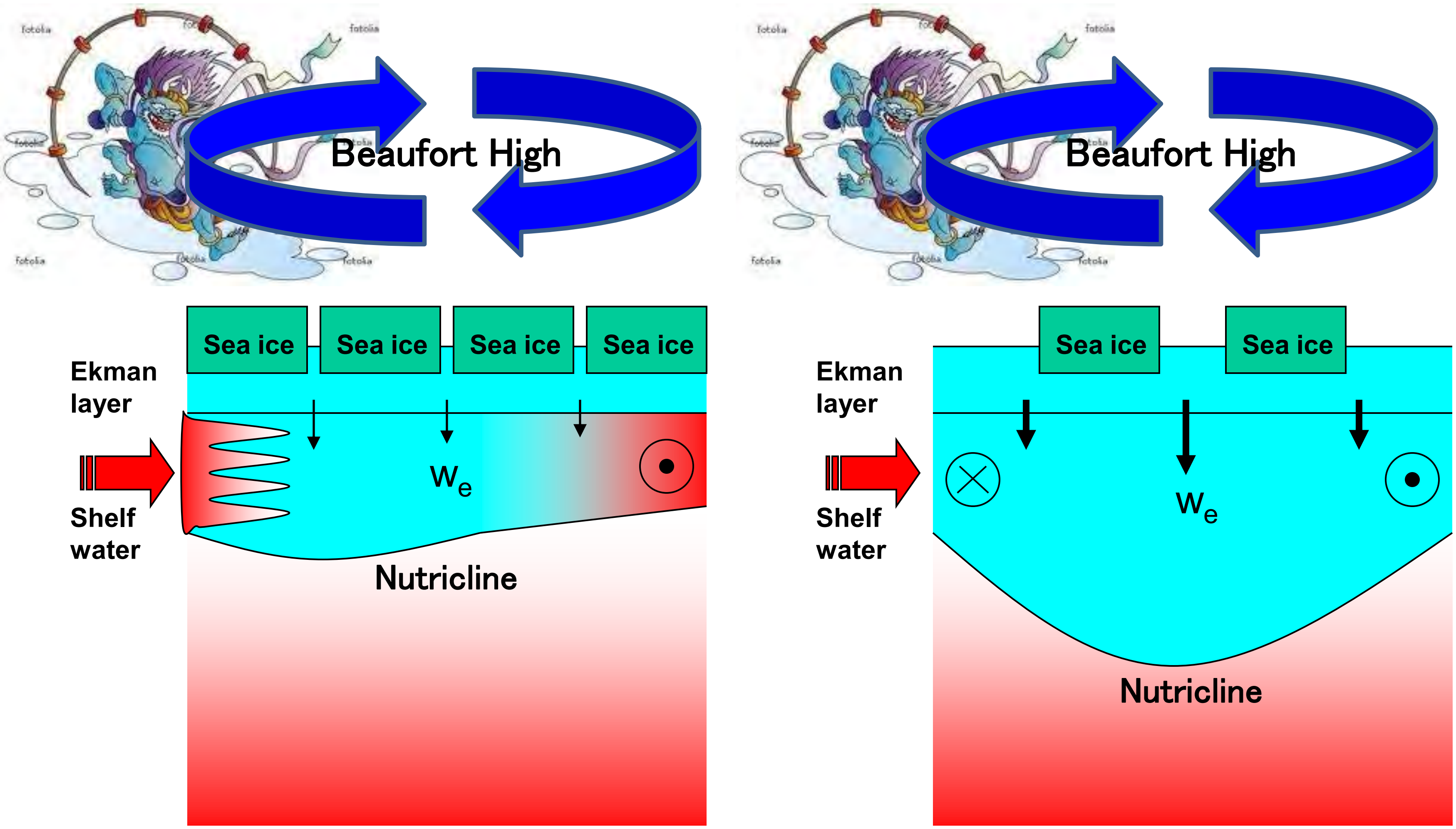
Changes in freshwater contents and isohaline (isopycnal) surfaces from 2003 to 2007

Mooring B (78° N, 150° W)



Proshutinsky *et al*. (2009)

Enhanced Beaufort Gyre, freshwater accumulation and deepening of nutricline

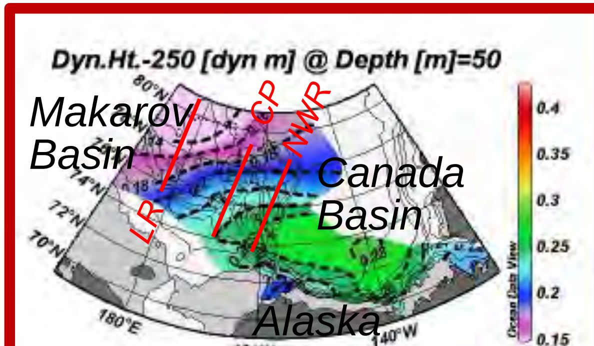


The early 2000s

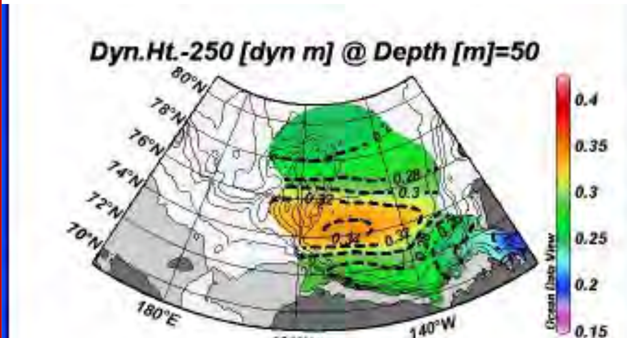
The late 2000s

Shimada *et al*. (2006), Yang (2009), McLaughlin and Carmack (2010)

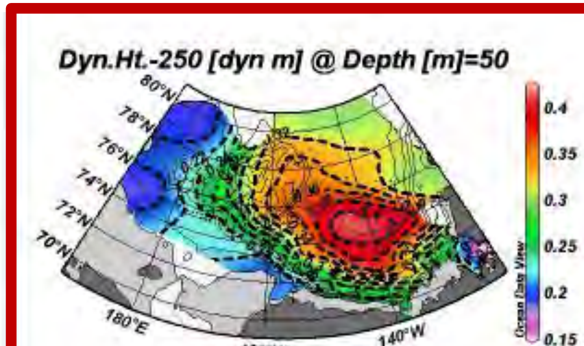
Dynamic height at 50m (relative to 250m) from 2002 to 2009



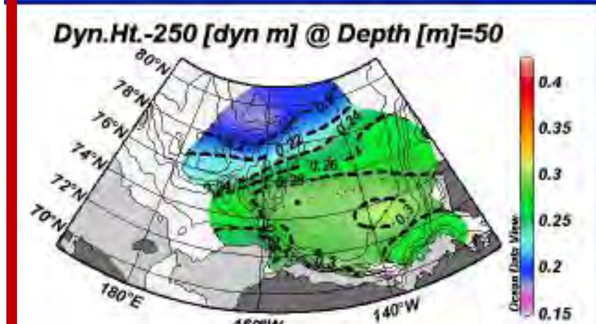
2002: Mirai + CBL



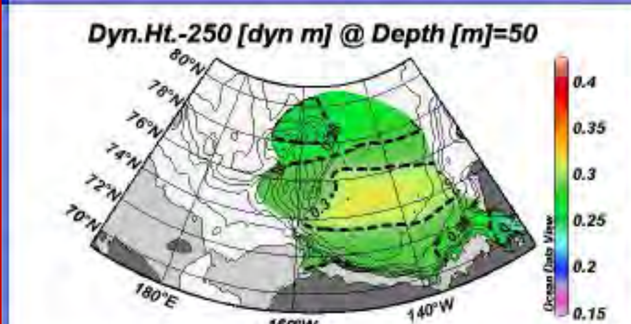
2005: JOIS/BGEP



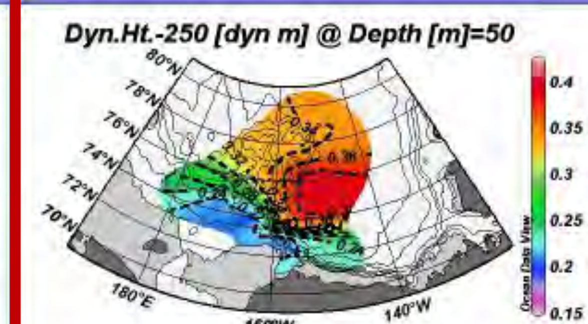
2008: Mirai + JOIS/BGEP



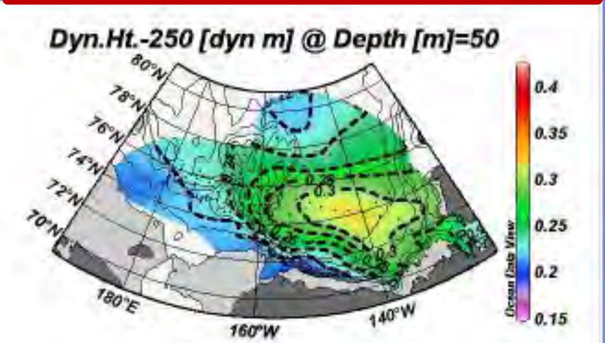
2003: JOIS/BGEP



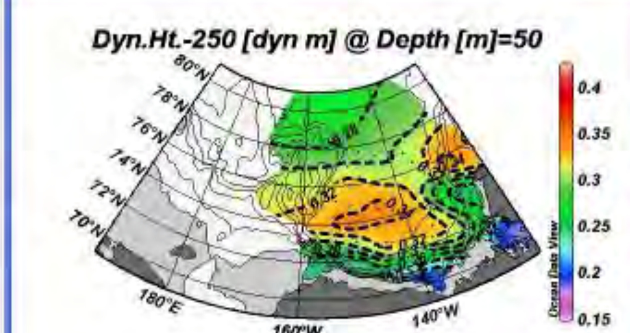
2006: JOIS/BGEP



2009: Mirai



2004: Mirai + JOIS/BGEP

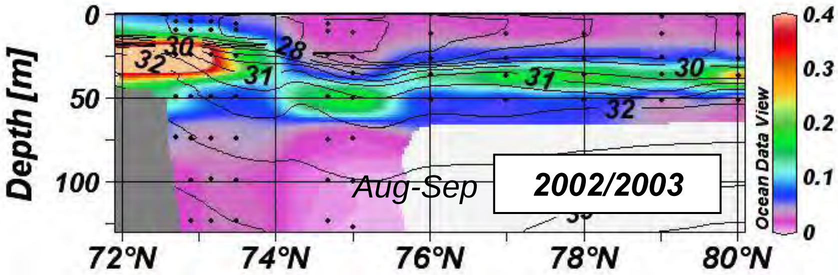


2007: JOIS/BGEP

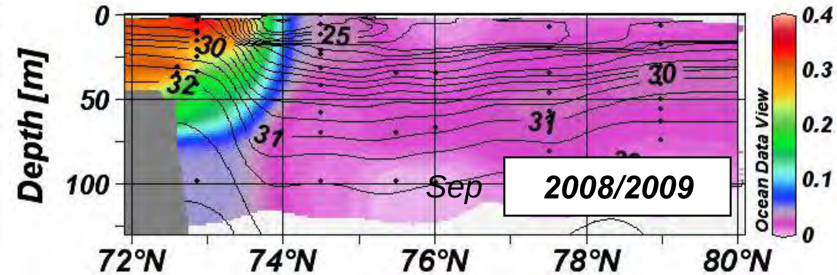
Data: Mirai,
CBL,
JOIS/BGEP

Changes in ocean circulation, nutrient and phytoplankton distributions

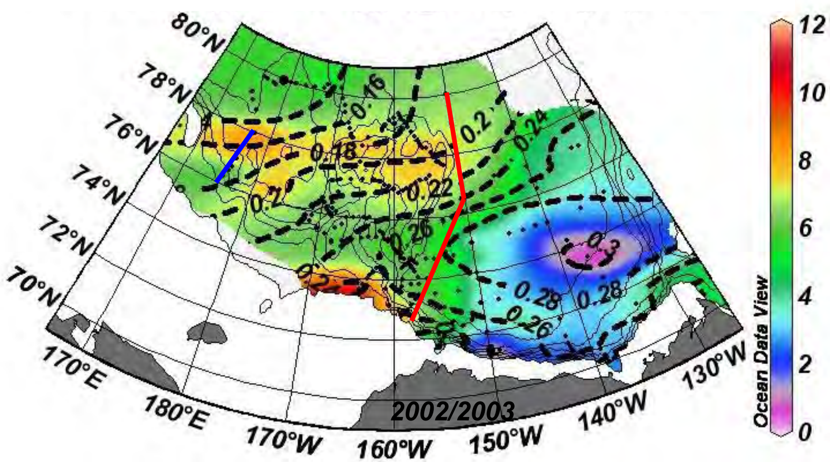
Chlorophyll a [µg/L] > 10 µm and salinity in 2002/2003



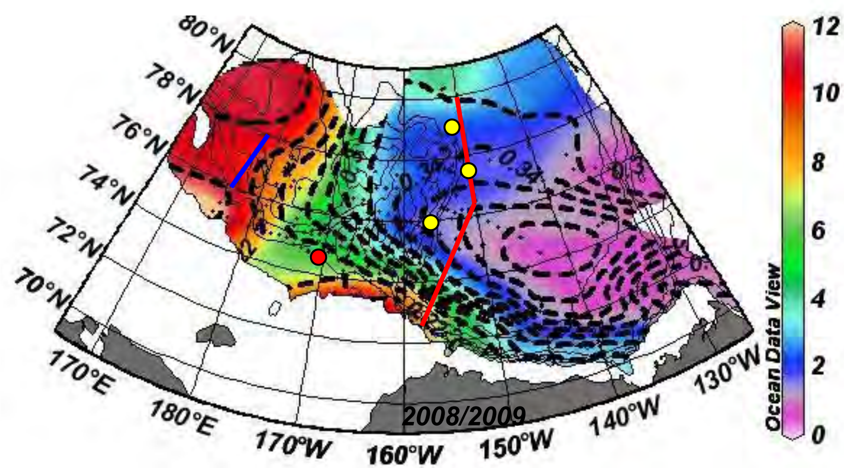
Chlorophyll a [µg/L] > 10 µm and salinity in 2008/2009



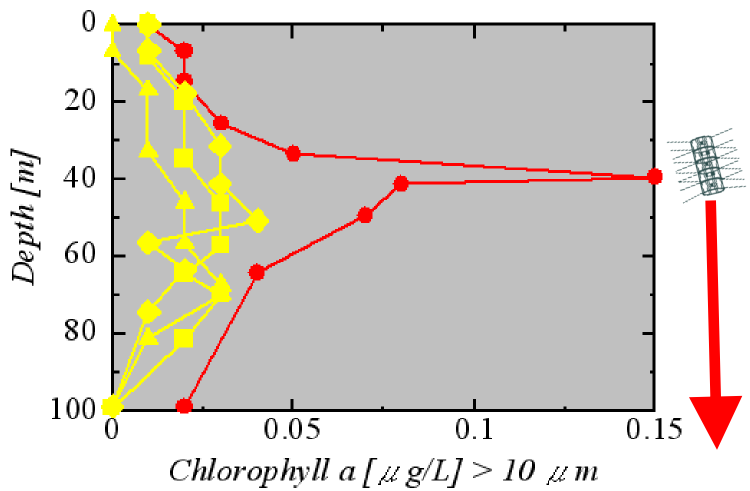
Dyn. Ht. [dyn m] and nitrate [µmol/kg] at 50 m in 2002/2003

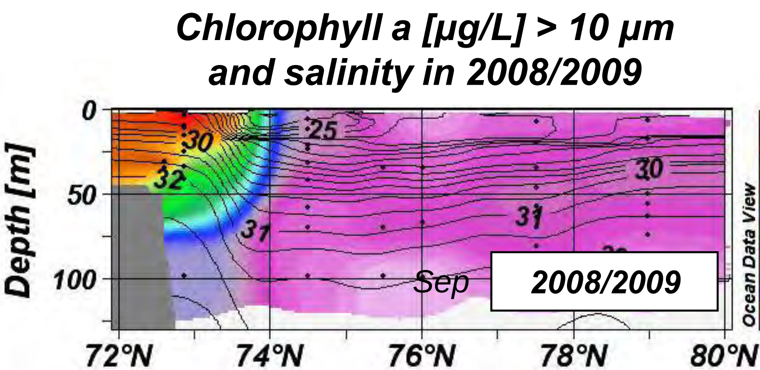


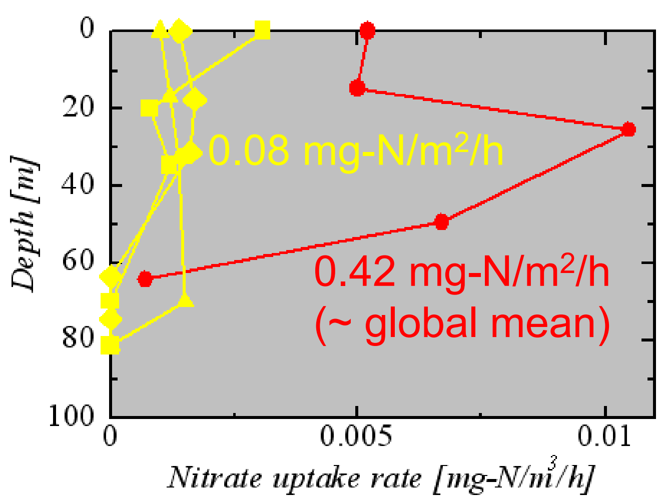
Dyn. Ht. [dyn m] and nitrate [µmol/kg] at 50 m in 2008/2009

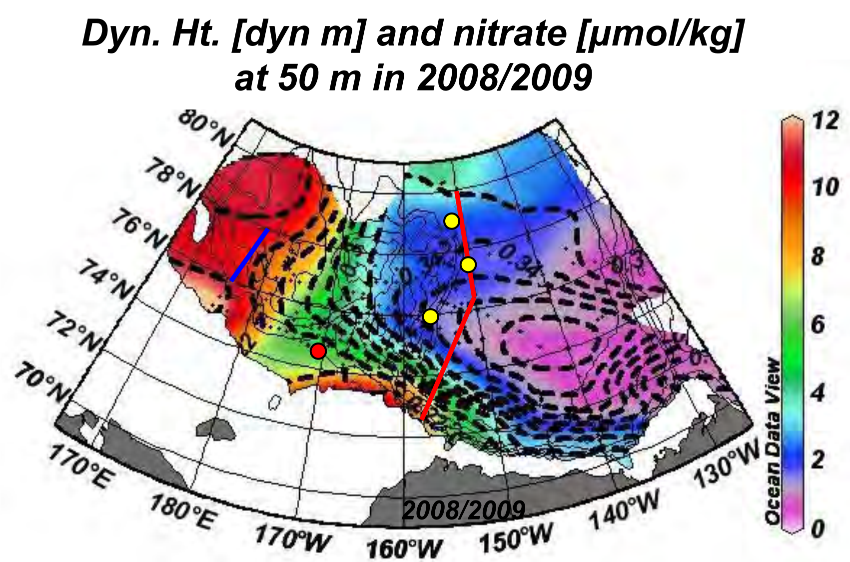


Differences in nitrate uptake rate between different locations of ocean circulation



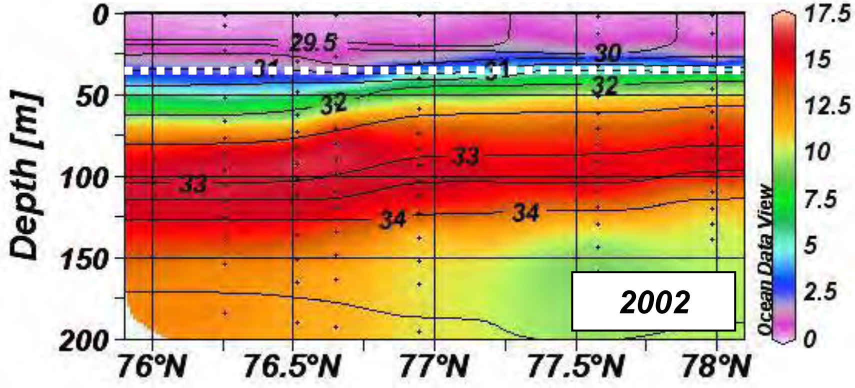




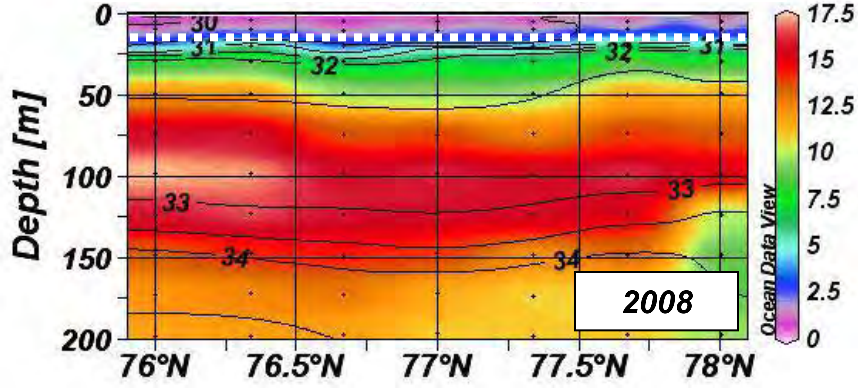


Changes in ocean circulation and nutrient distribution

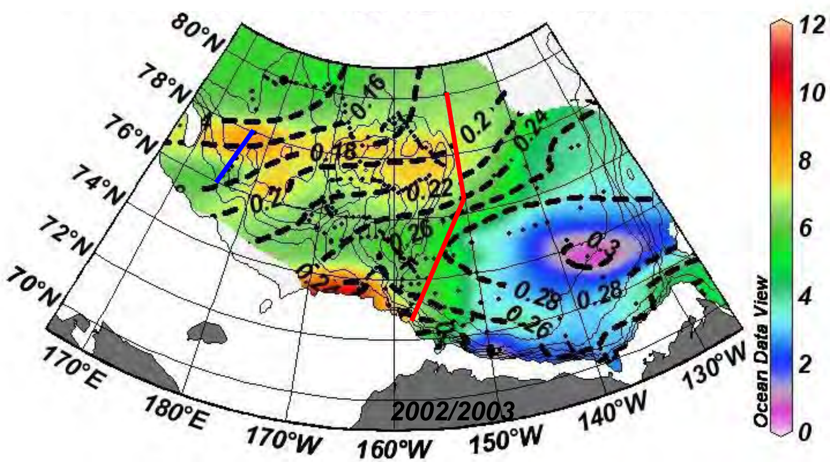
Nitrate [μmol/kg] and salinity in 2002



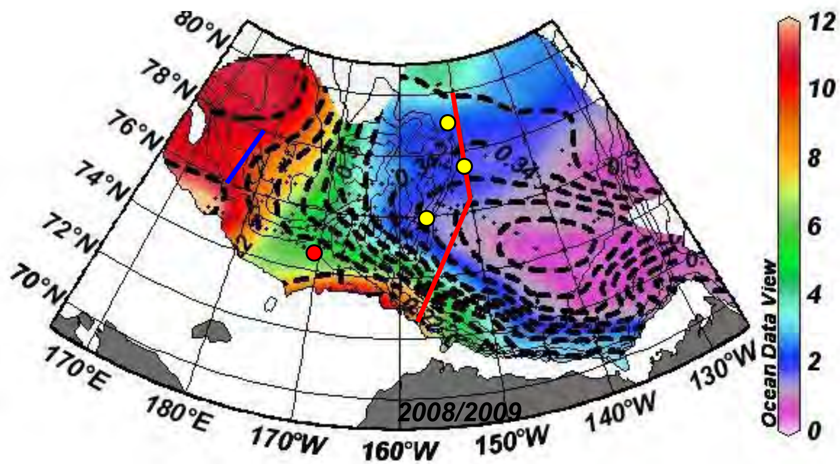
Nitrate [μmol/kg] and salinity in 2008



Dyn. Ht. [dyn m] and nitrate [μmol/kg] at 50 m in 2002/2003

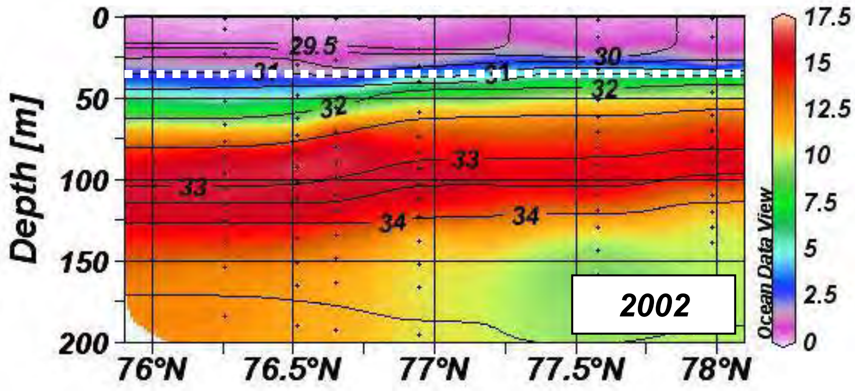


Dyn. Ht. [dyn m] and nitrate [μmol/kg] at 50 m in 2008/2009

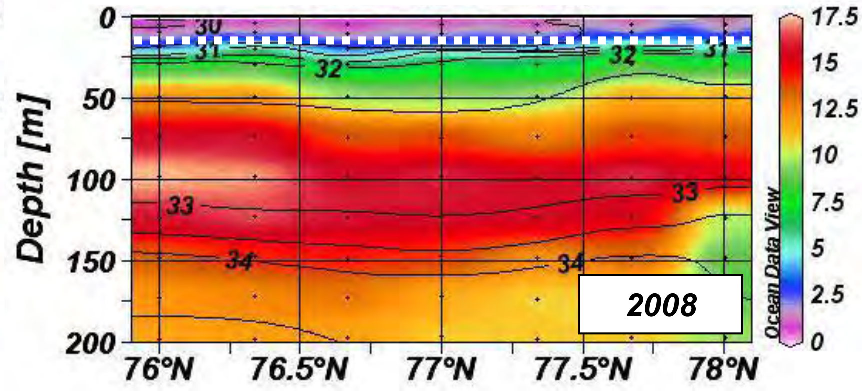


Shoaling of nutricline
due to input of large volume water mass

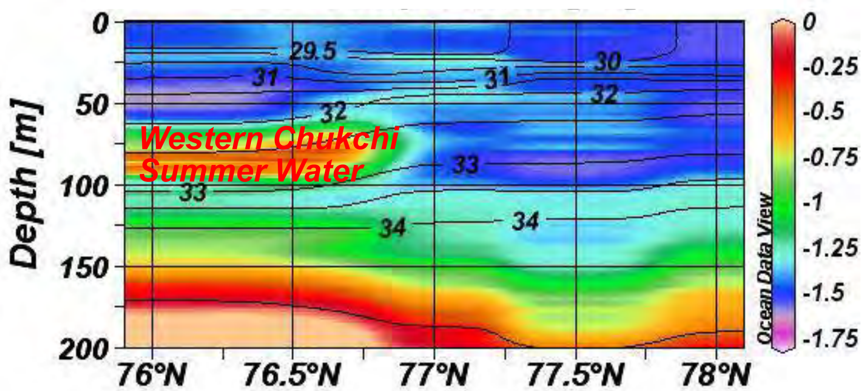
Nitrate [μmol/kg] and salinity in 2002



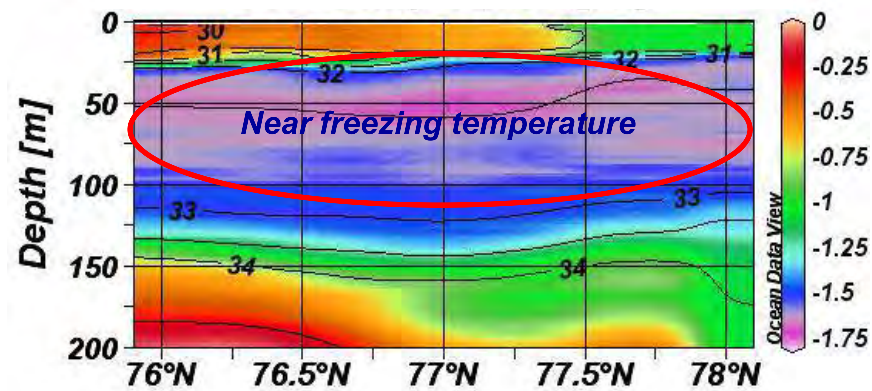
Nitrate [μmol/kg] and salinity in 2008



Temperature [ºC] and salinity in 2002



Temperature [ºC] and salinity in 2008



Spreading of Western Chukchi Summer Water into the Makarov Basins

Sea ice

Sea ice

Sea ice

Sea ice

Sea ice

Western Chukchi Summer Water

High nutrients, low DO&N*

Nutricline

T max

DO min

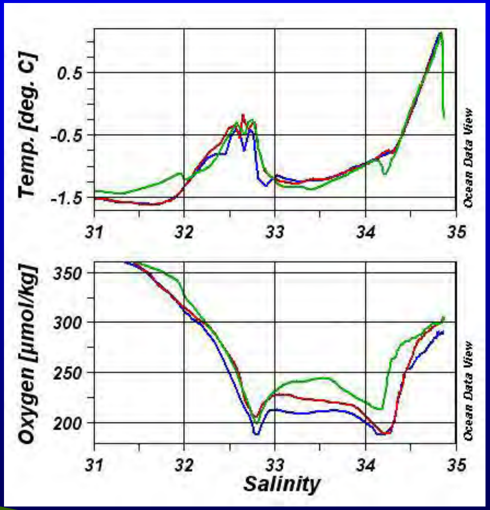
N* min (shelf origin)

Nishino *et al*. (2005)

Remineralization

Organic matter decomposition

Denitrification



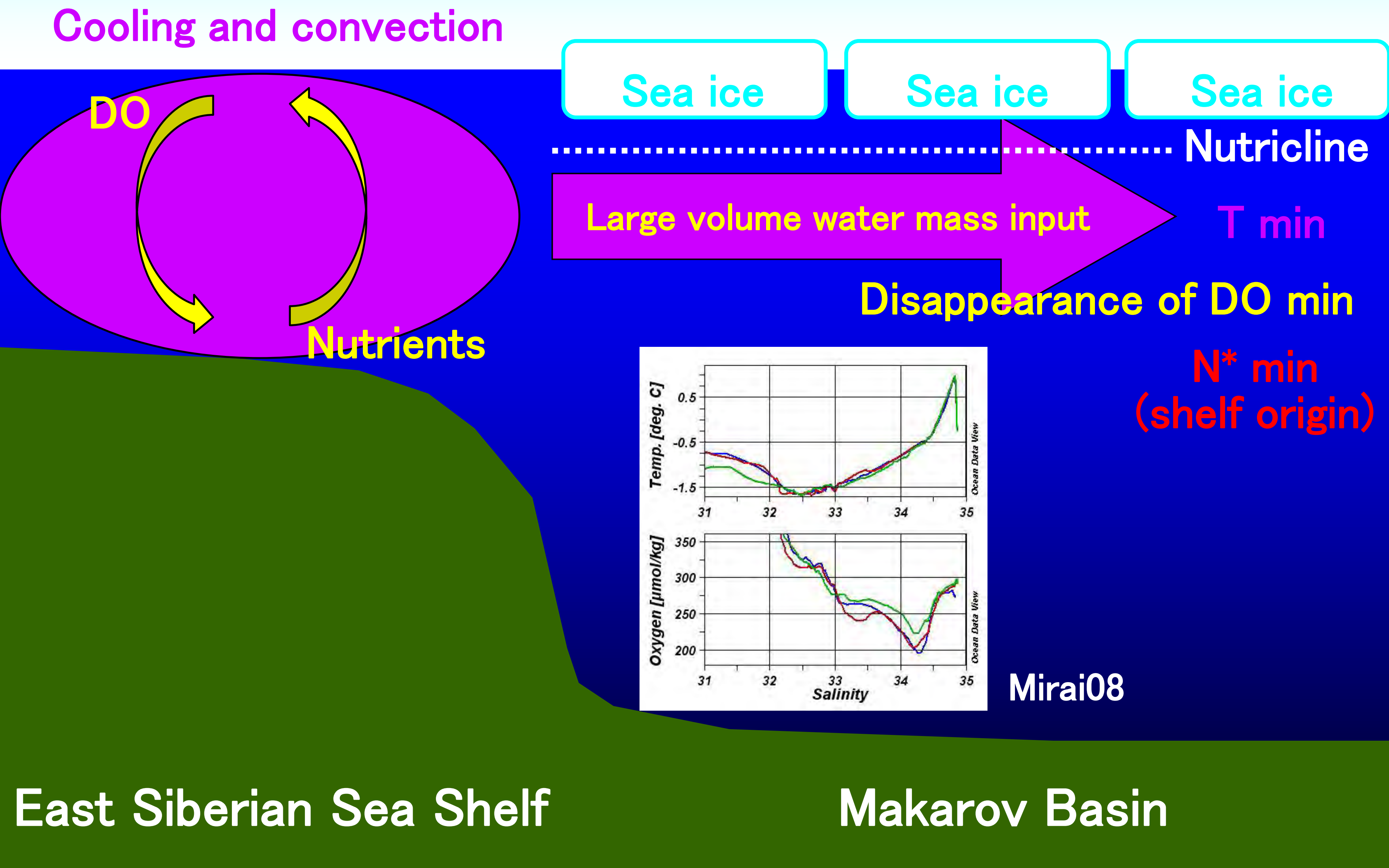
CBL02

East Siberian Sea Shelf

Makarov Basin

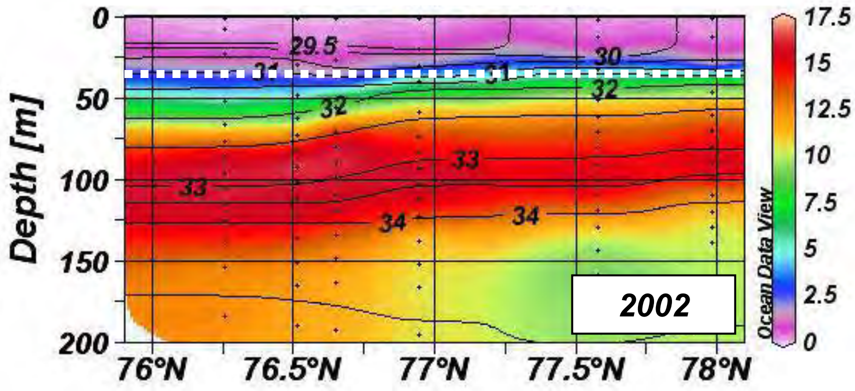
Formation of large volume water mass due to the delay in autumn freeze-up

Markus *et al.* (2009)

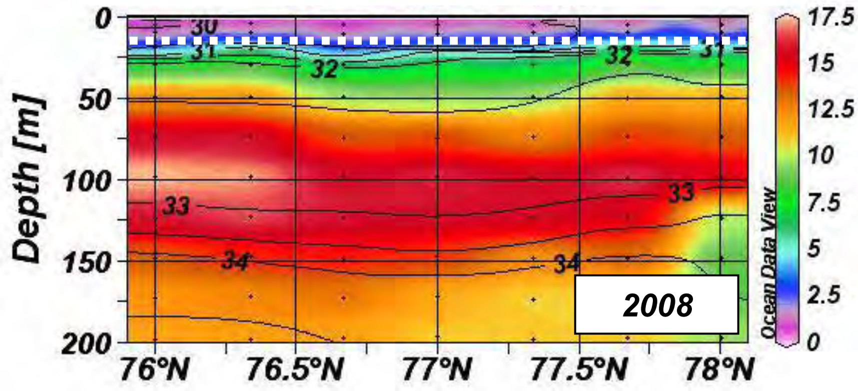


Wind stress curl ~ 0 over the Makarov Basin
Large volume shelf water input shallows the nutricline

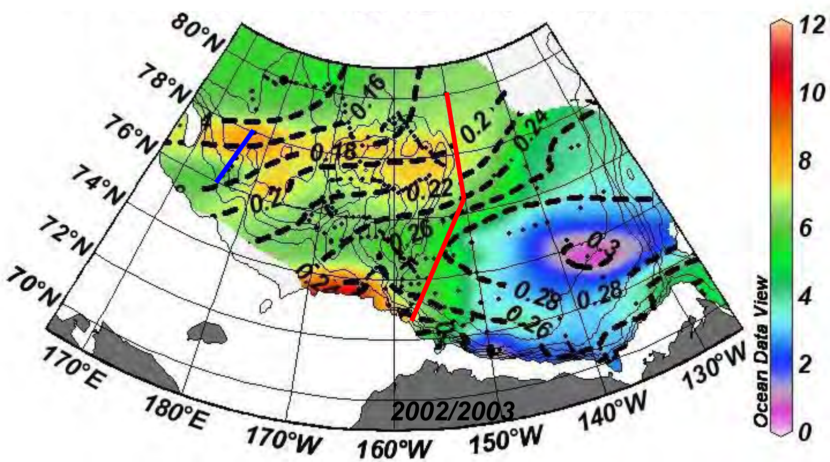
Nitrate [μmol/kg] and salinity in 2002



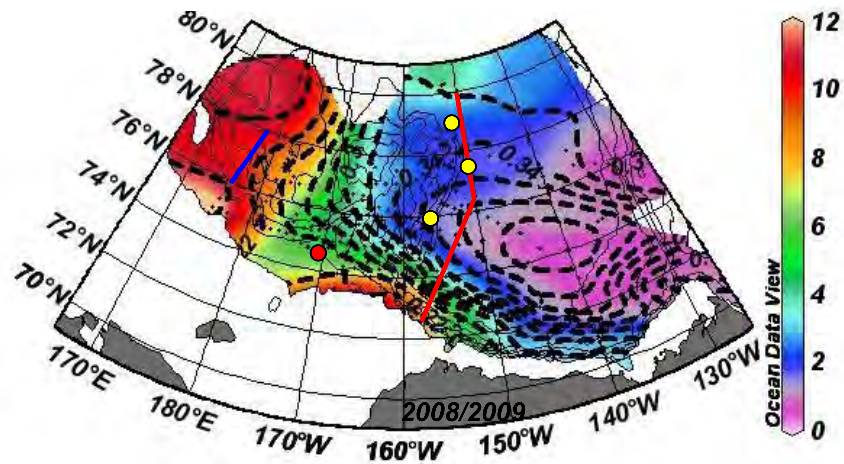
Nitrate [μmol/kg] and salinity in 2008



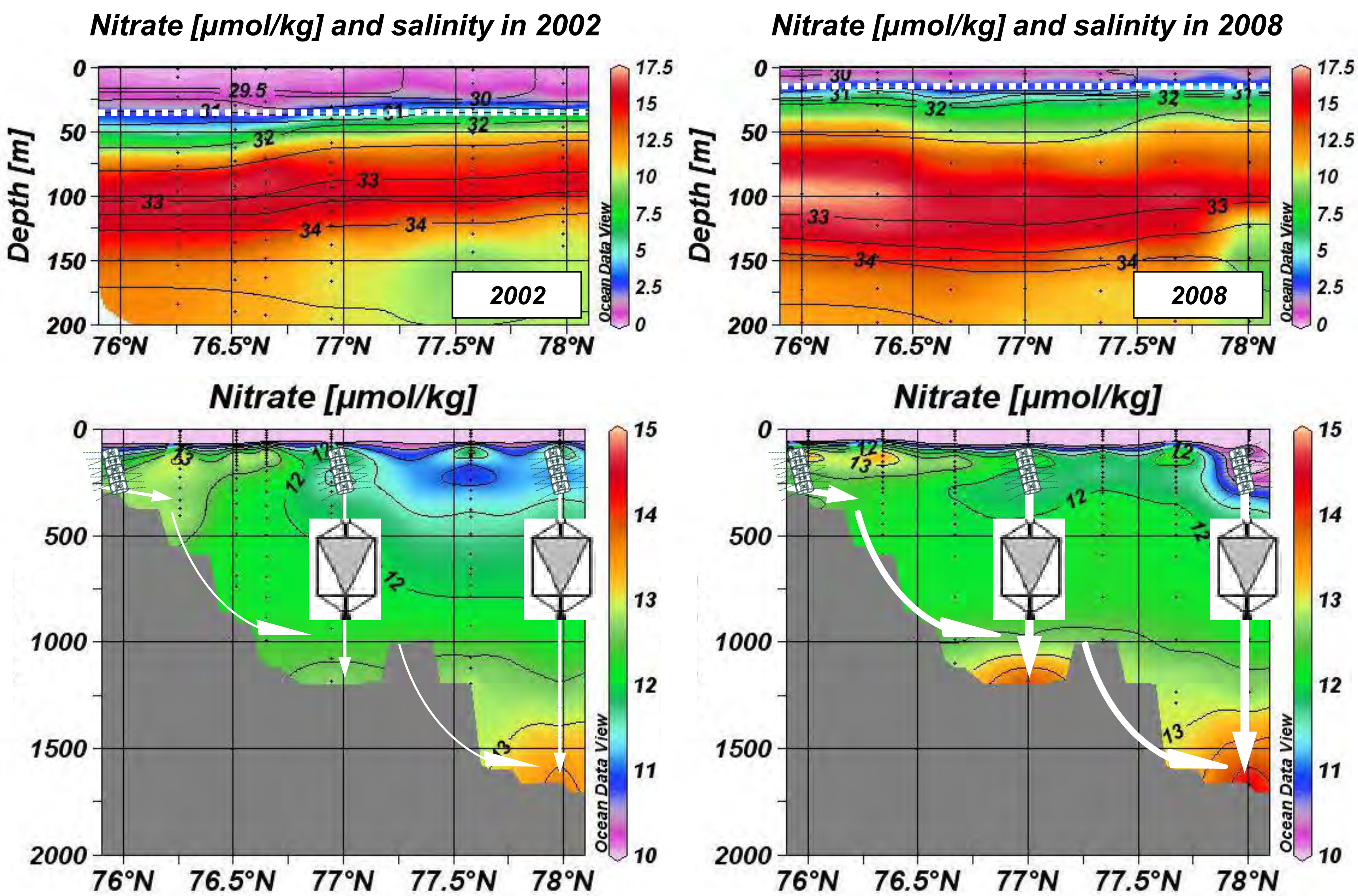
Dyn. Ht. [dyn m] and nitrate [μmol/kg] at 50 m in 2002/2003



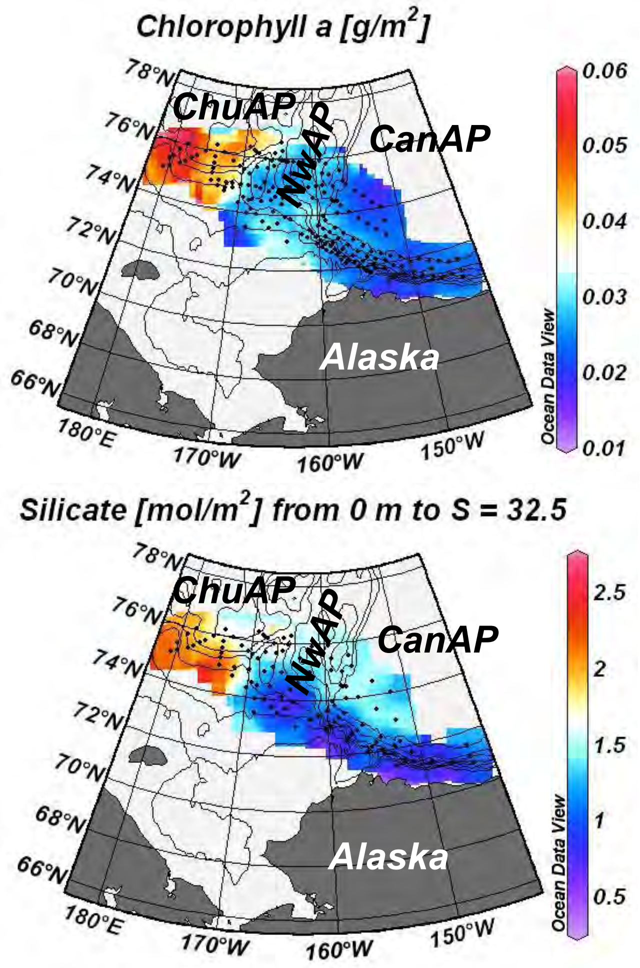
Dyn. Ht. [dyn m] and nitrate [μmol/kg] at 50 m in 2008/2009



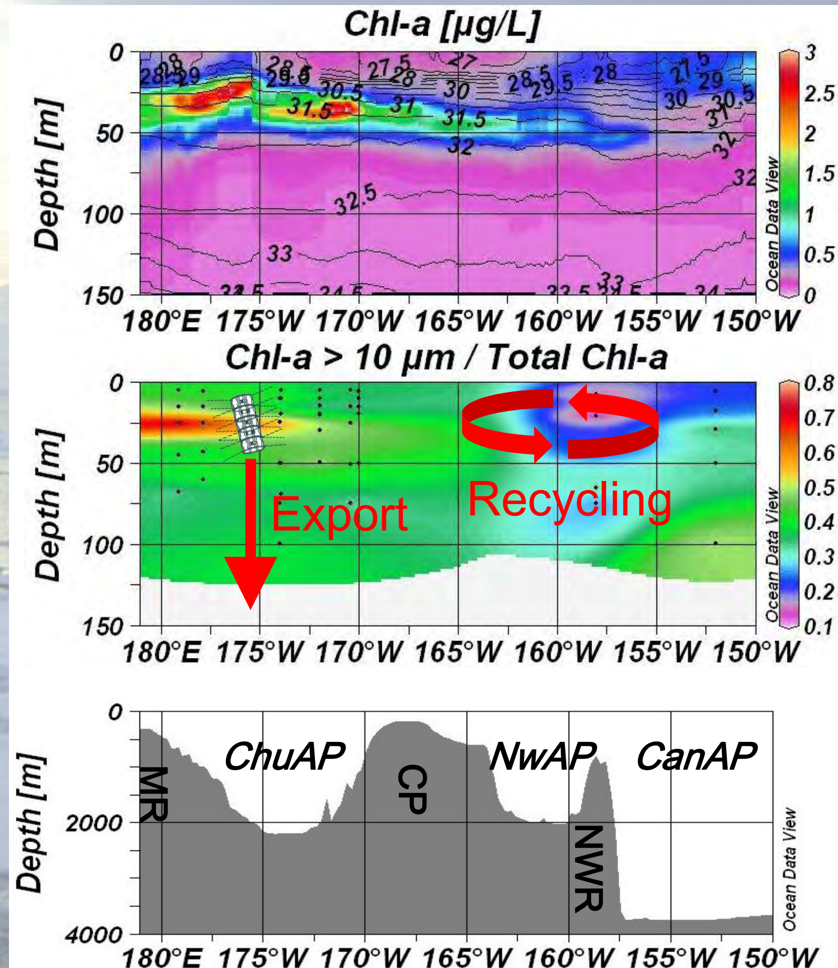
Shoaling of nutricline and sea ice loss increase the export production?



Phytoplankton biomass and nutrient distributions in the sea-ice reduction region of the Arctic Ocean

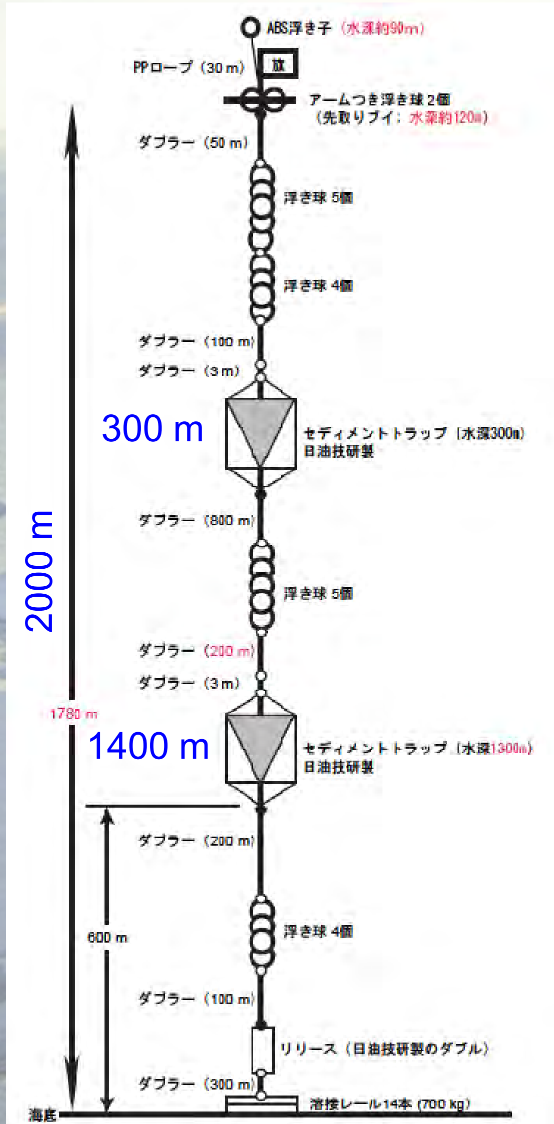


Vertical integration of chlorophyll *a* in the water column [g/m²] (top) and silicate from the sea surface to an isohaline surface of *S* = 32.5 [mol/m²] (bottom). Data are obtained from the R/V Mirai cruise in summer 2004. **Nishino *et al*. (2008)**

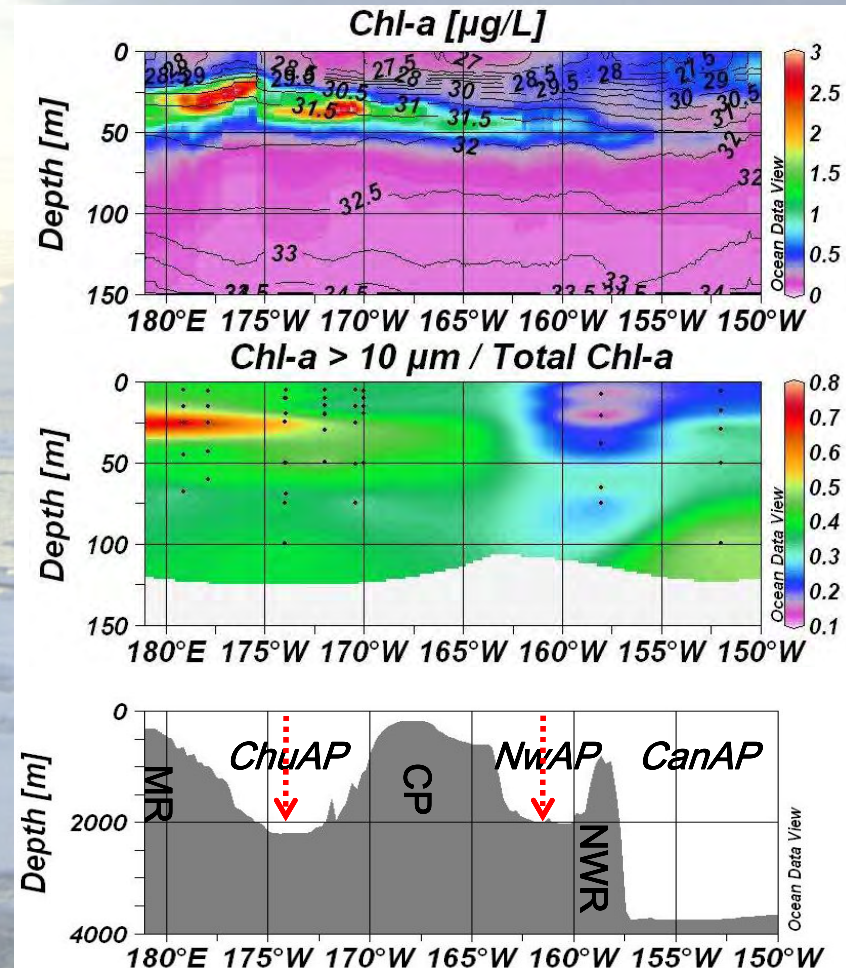


Vertical sections of chlorophyll *a* (top), fraction of chlorophyll *a* in phytoplankton larger than 10 μm to total chlorophyll *a* (middle), and bottom topography (bottom) via the Mendeleyev Ridge (MR), Chukchi Abyssal Plain (ChuAP), Chukchi Plateau (CP), Northwind Abyssal Plain (NwAP), Northwind Ridge (NWR), and Canada Abyssal Plain (CanAP). Data are from the R/V Mirai cruise in summer 2004. **Nishino *et al*. (2009)**

Sediment traps deployed in different locations of the ocean circulation



Harada (JAMSTEC)



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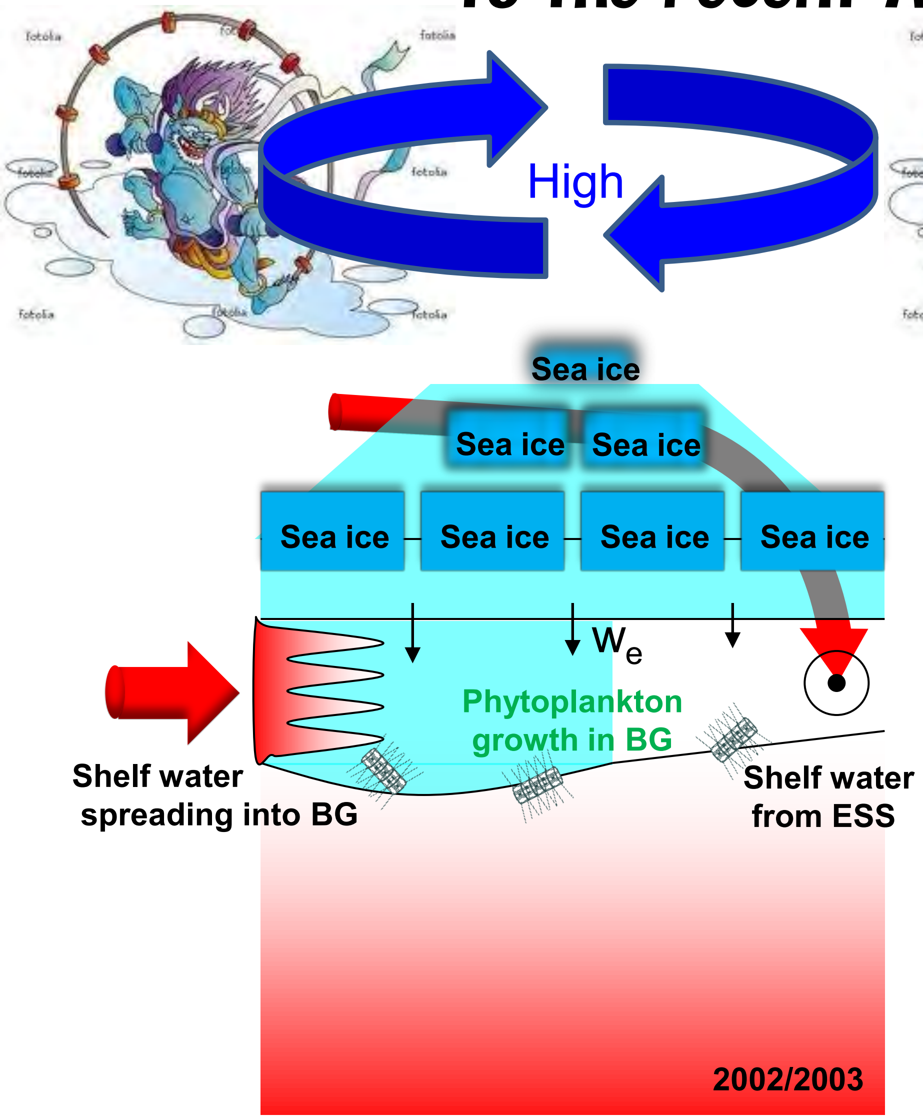
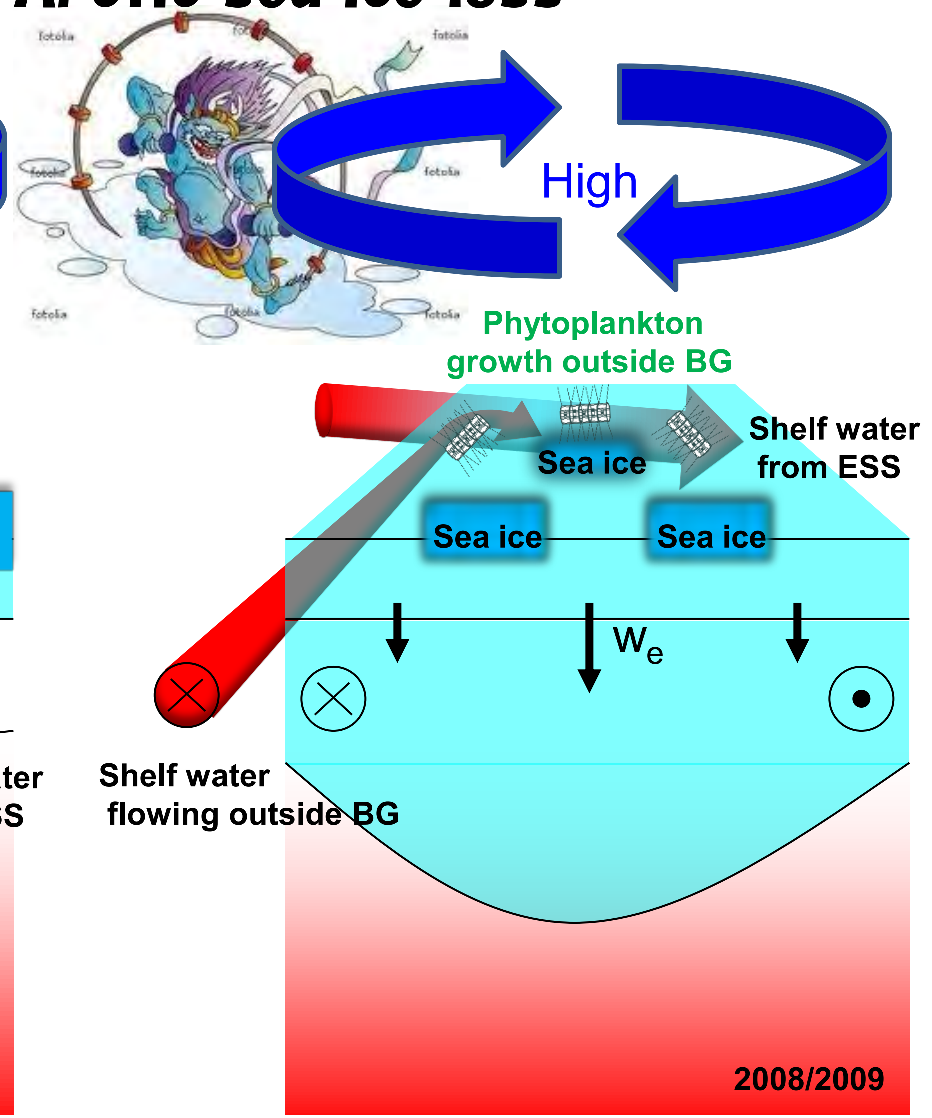
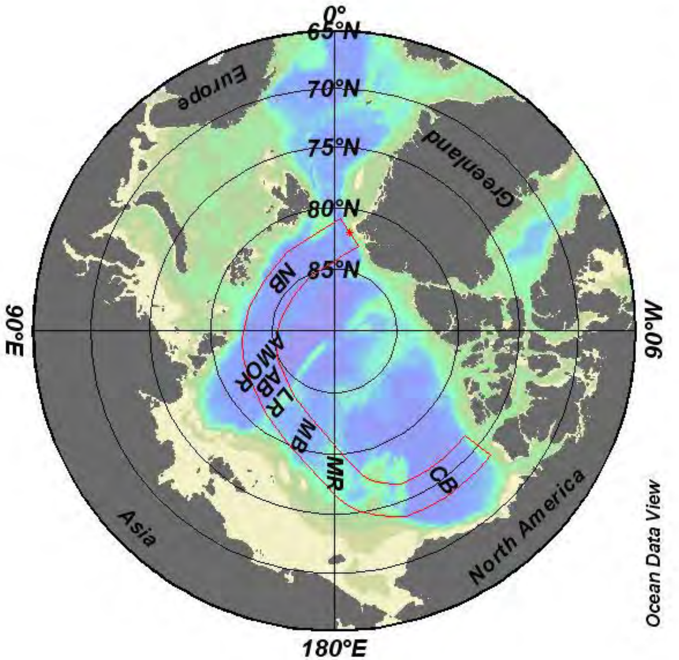
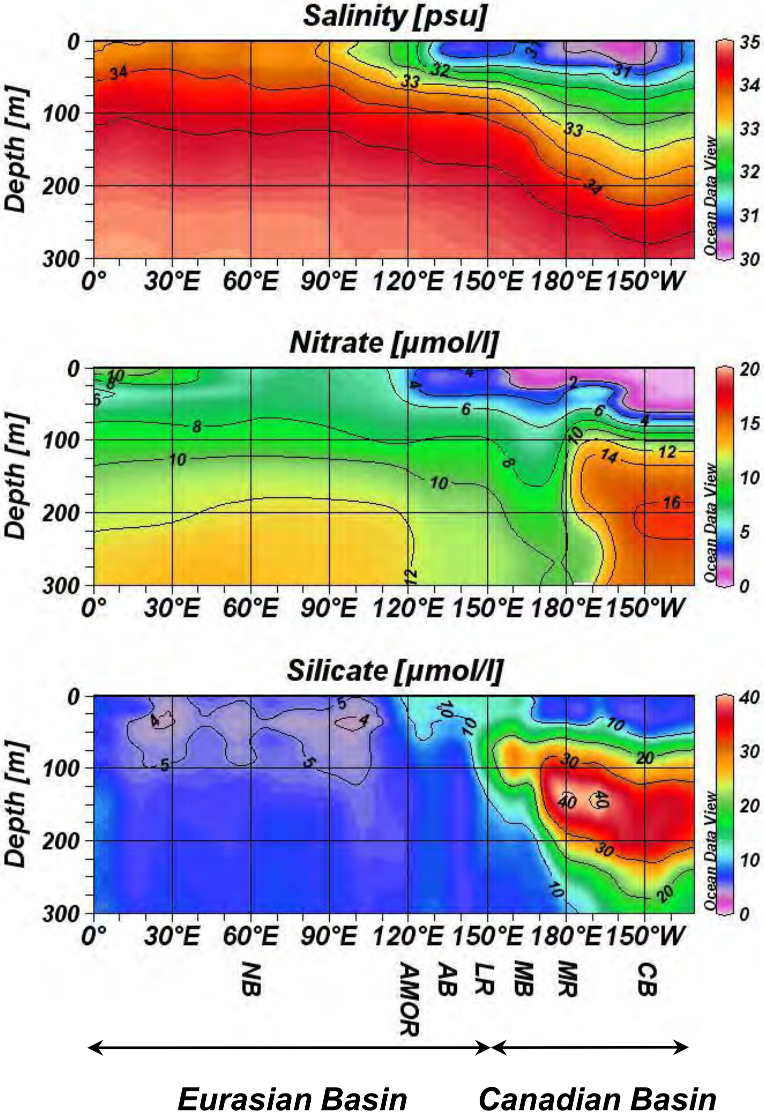
Summary of the responses of ocean circulation, nutrient supply, and phytoplankton distribution to the recent Arctic sea ice loss





Pan-Arctic prospects





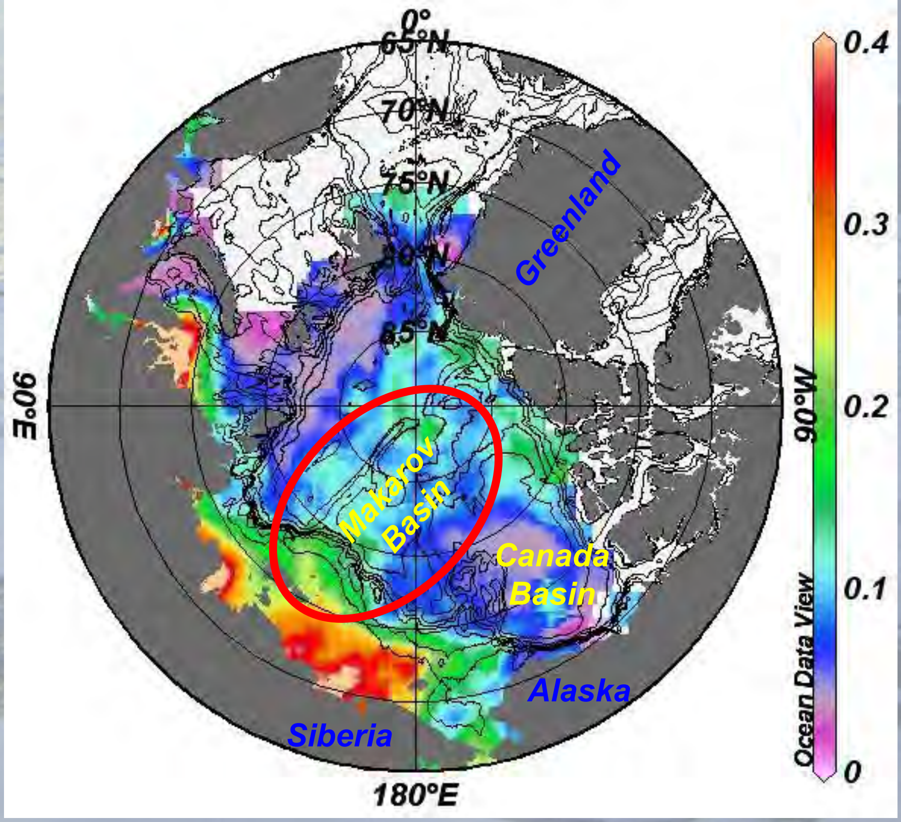
Data: EWG Arctic Ocean Atlas,
AARI-IARC Hydrochemical Atlas

R/V Mirai will go west!

<u>*Western Canada Basin & Makarov Basin*</u>

- Nut-rich shelf water
- Nut-rich Siberian river water
- Biological hot spot after the sea-ice melt
- Target area for the biogeochemical studies

Distribution of silicate integrated from the sea surface to a depth of 10 m [mol/m²]



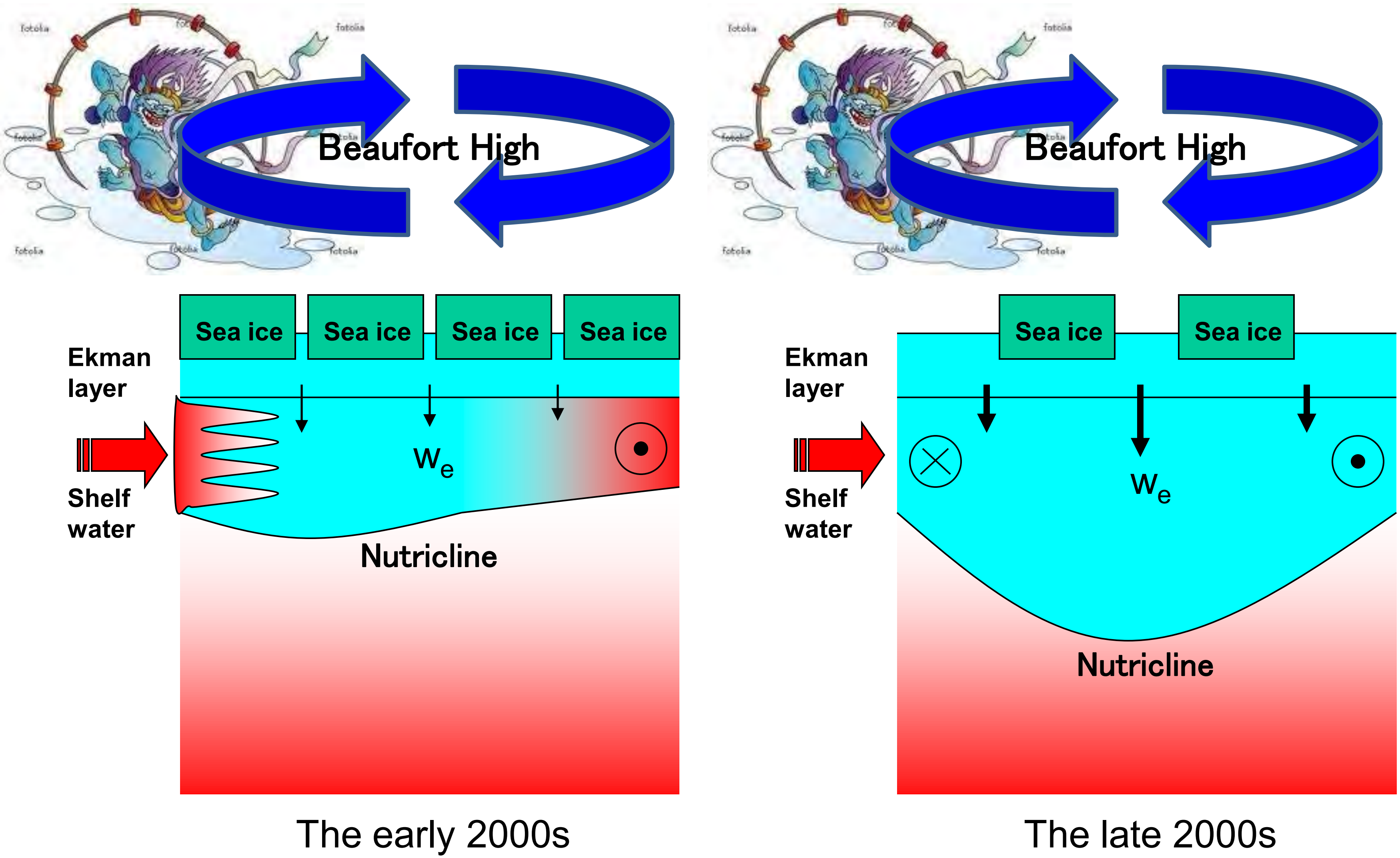
Data: AARI-IARC Hydrochemical Atlas

Papers

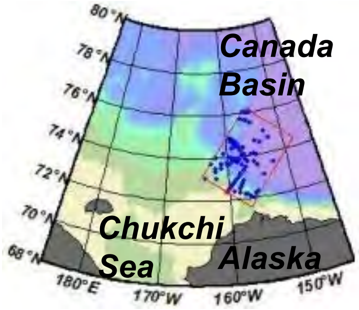
Nishino, S., T. Kikuchi, M. Yamamoto-Kawai, Y. Kawaguchi, T. Hirawake, and M. Itoh (2011), Enhancement/reduction of biological pump depends on ocean circulation in the sea-ice reduction regions of the Arctic Ocean, *J. Oceanogr*., accepted.

Nishino, S., M. Itoh, Y. Kawaguchi, T. Kikuchi, and M. Aoyama (2011), Impact of warm-core eddies on distributions of nutrients and phytoplankton in the Canada Basin, submitted to *Geophys*. *Res*. *Lett*.

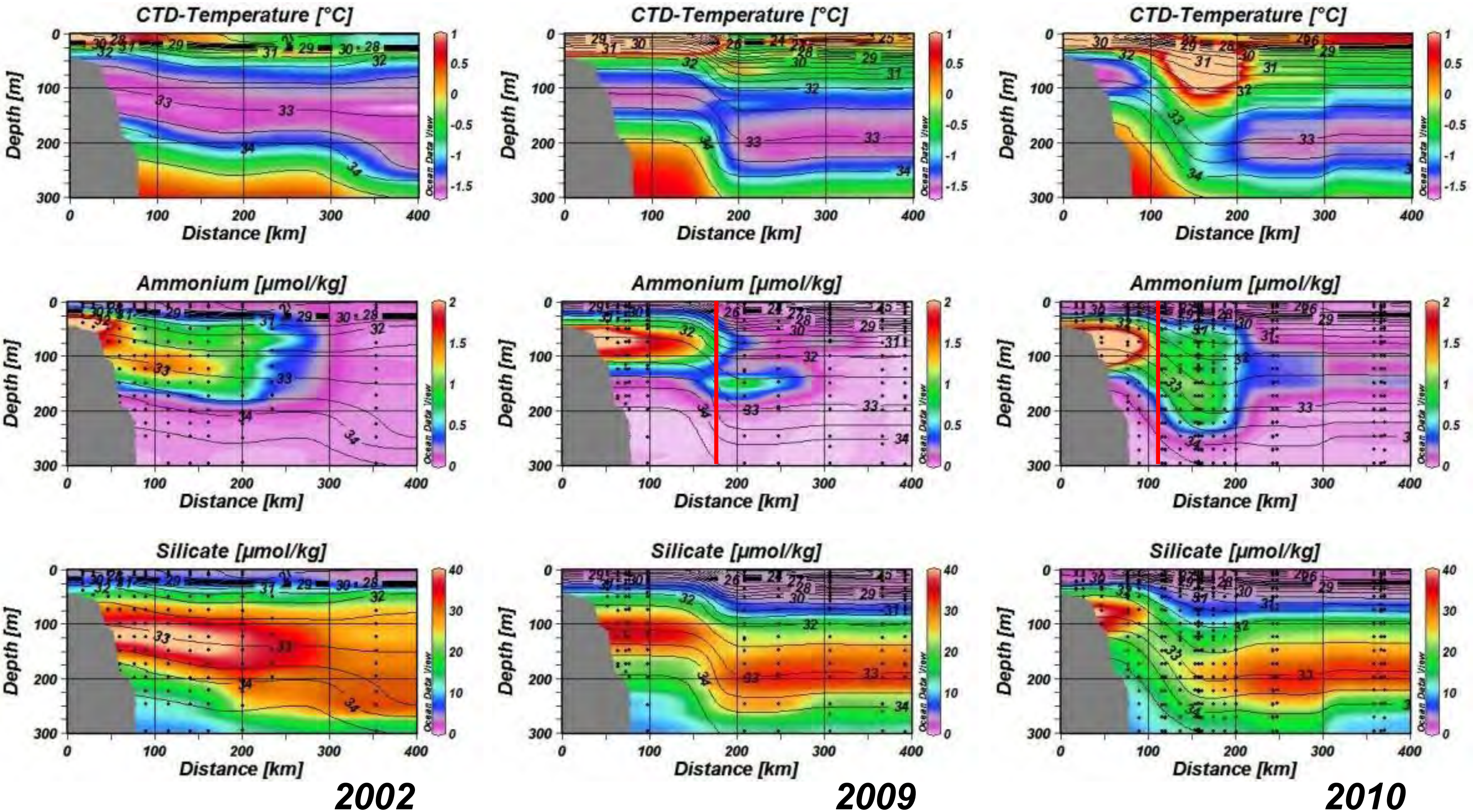
Enhanced Beaufort Gyre, freshwater accumulation and deepening of nutricline



Shimada *et al*. (2006), Yang (2009), McLaughlin and Carmack (2010)



Deepening of nutricline
Shelf-basin front
Eddy transporting shelf water



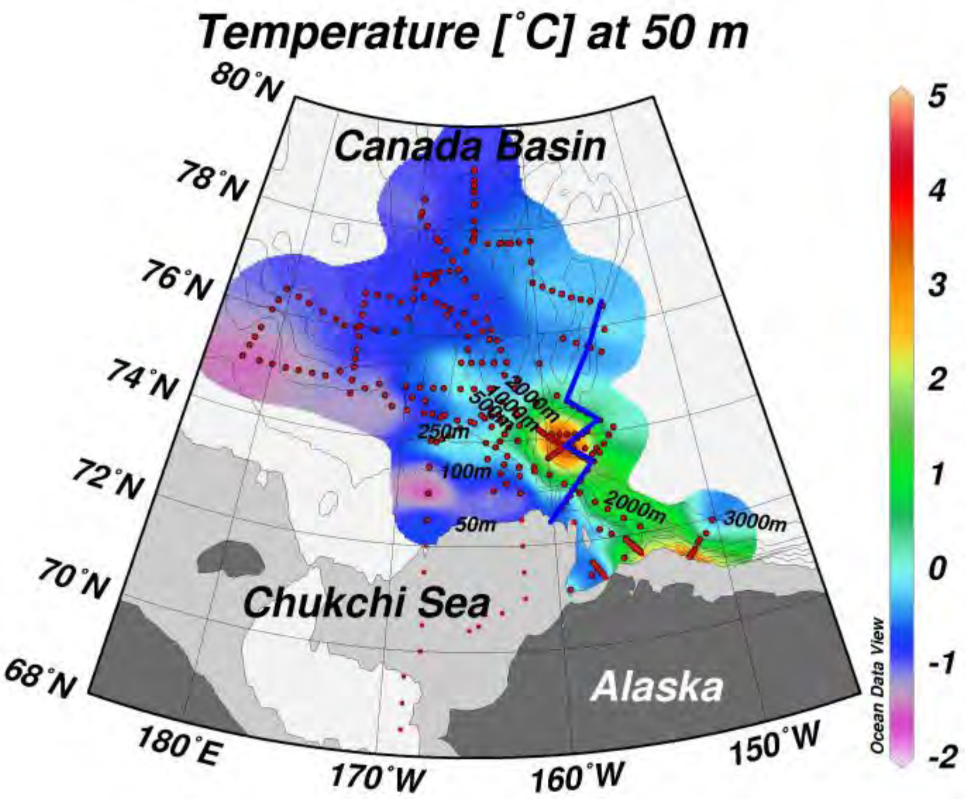
Large (~ 100 km) warm-core eddy from the R/V Mirai cruise in 2010

Previous studies

<u>Eddy transport of nutrients</u>

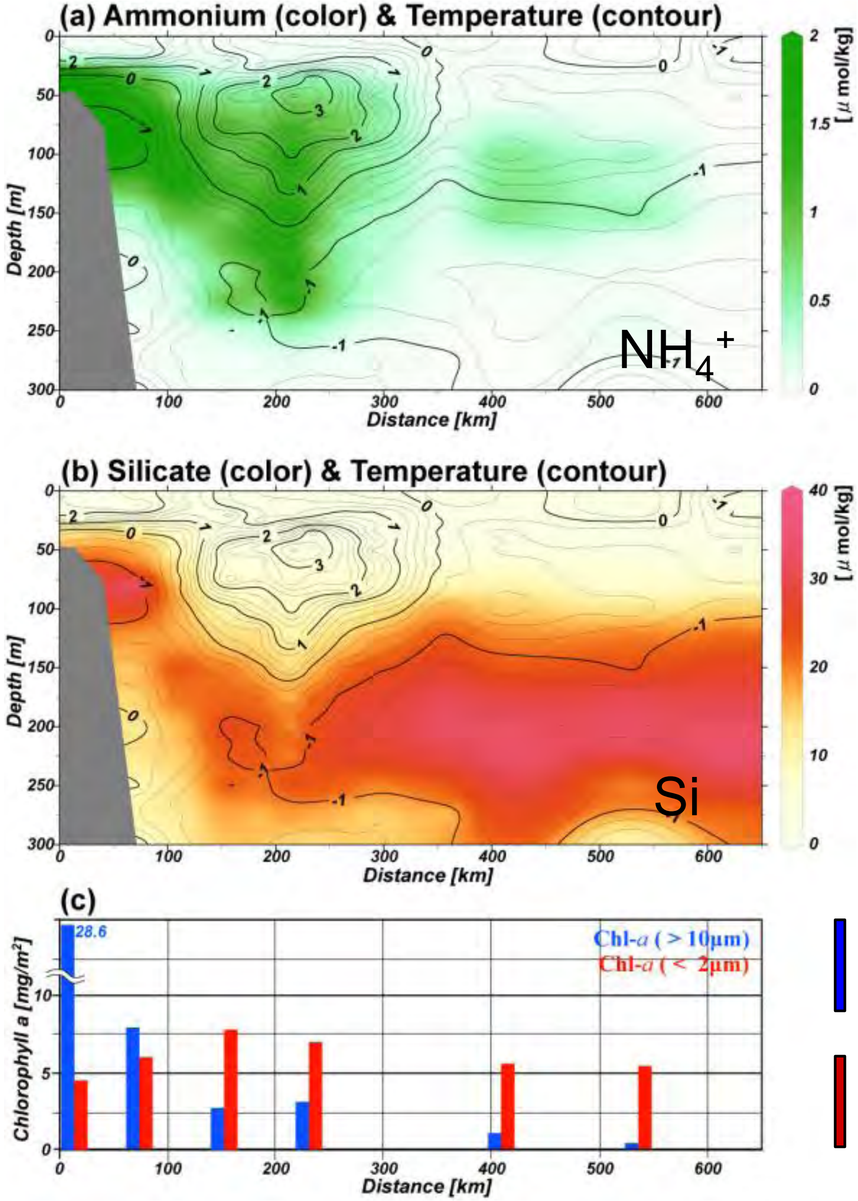
- Cold-core eddy
- 10-20 km in diameter
- Pacific-origin winter water
- Maintenance of nutrient max.

e.g., Mathis *et al*. (2007)



Nutrient transport by an eddy and its impacts to Arctic phytoplankton

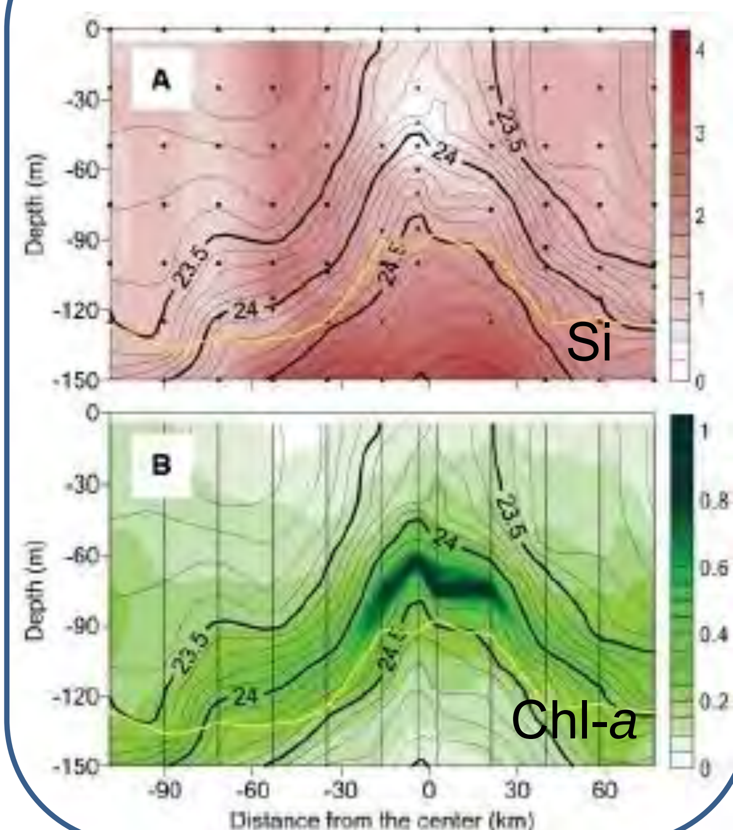
Arctic Ocean; Canada Basin



Chl-*a* (>10 μm)

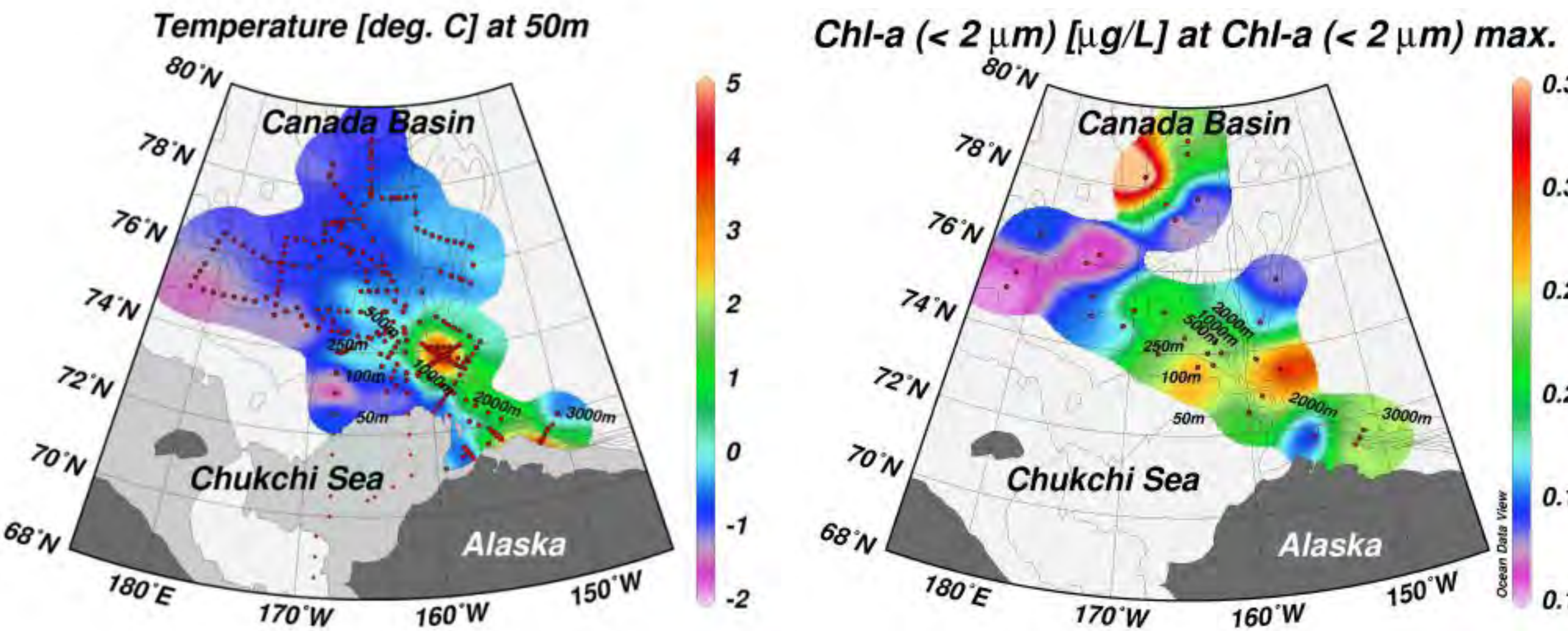
Chl-*a* (< 2 μm)

Subtropical Pacific Ocean

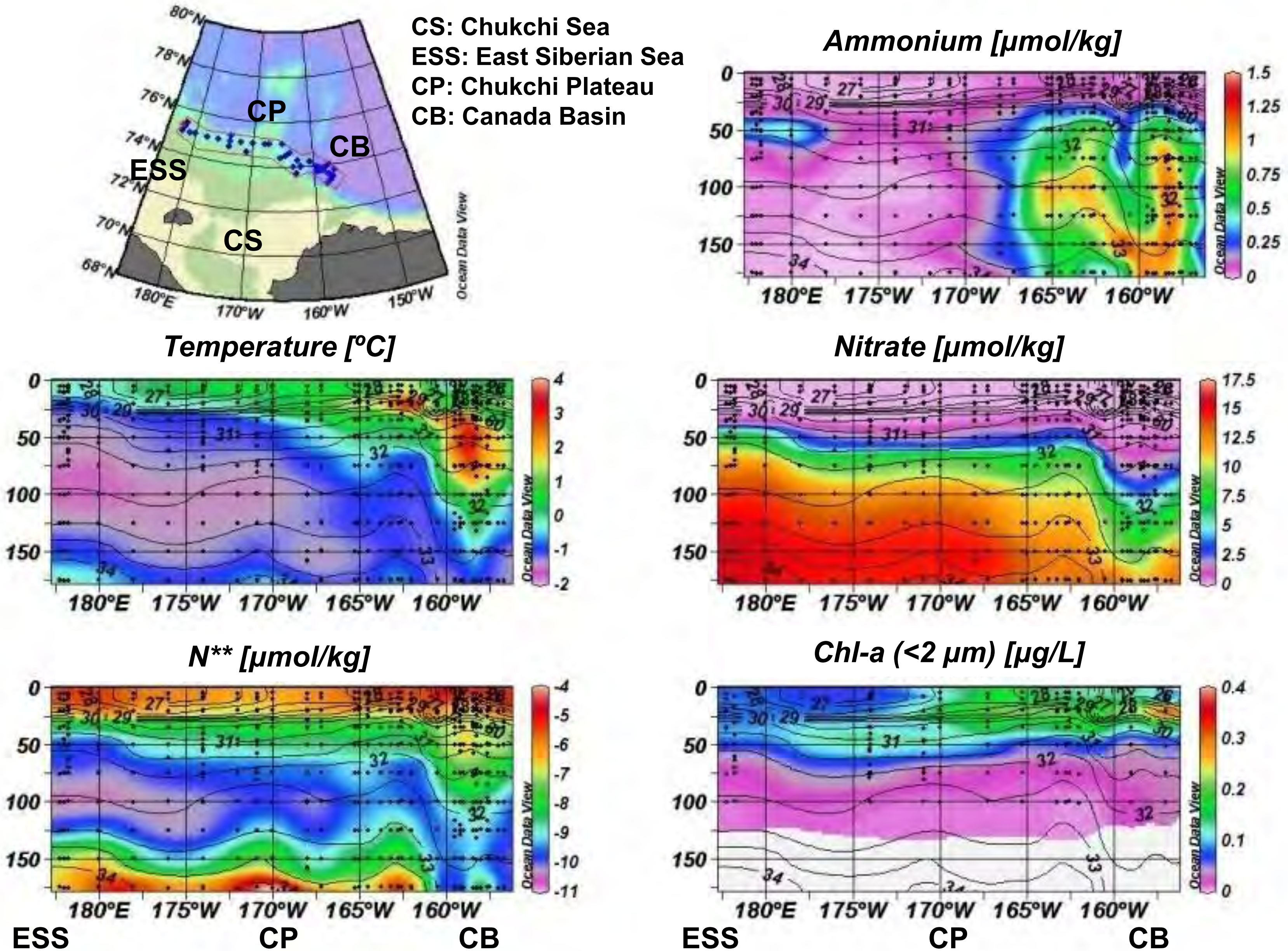


Benitez-Nelson *et al*. (2007)

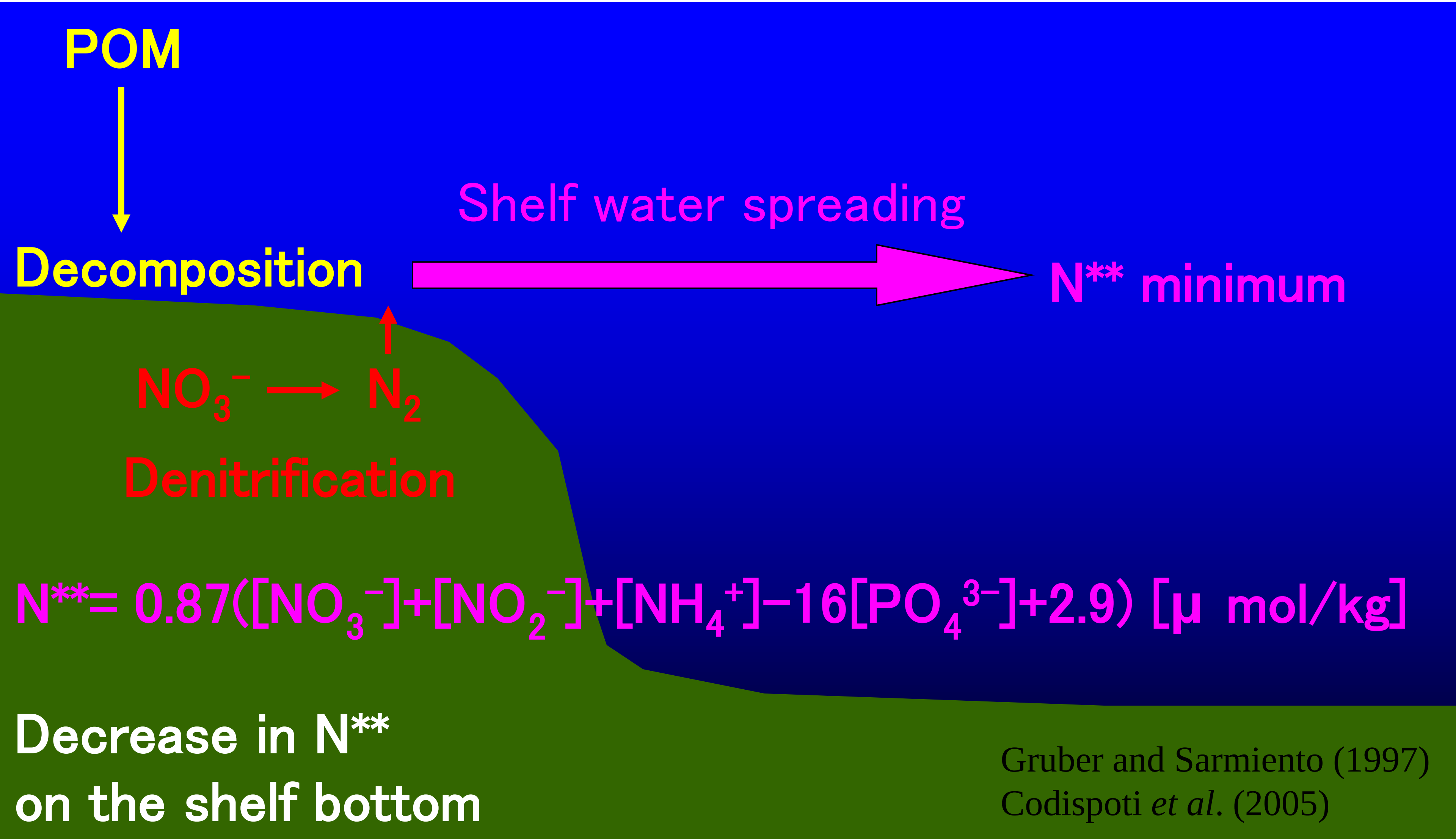
Warm-core eddy and small phytoplankton (< 2 μm) at its maximum



Water mass and small phytoplankton



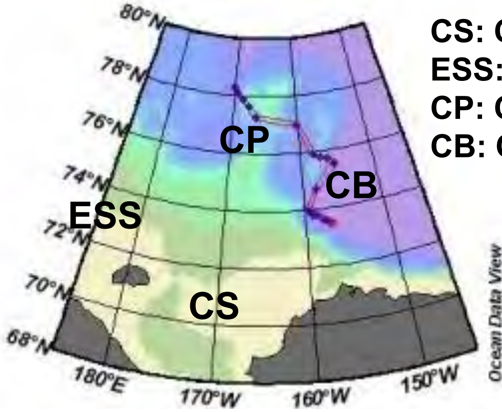
Tracer of the shelf water spreading → N**



$$N^{**} = 0.87([NO_3^-]+[NO_2^-]+[NH_4^+]-16[PO_4^{3-}]+2.9)\ [\mu\ mol/kg]$$

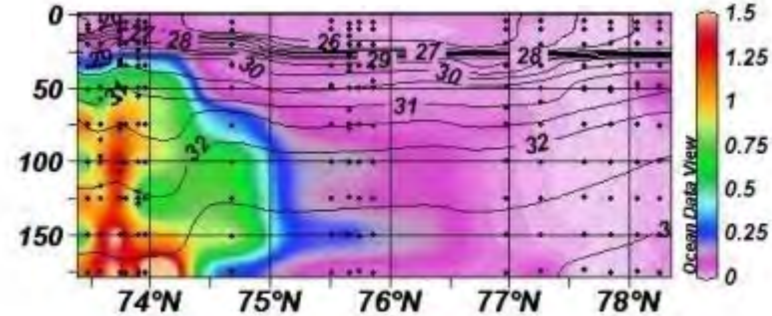
Gruber and Sarmiento (1997)
Codispoti *et al*. (2005)

Water mass and small phytoplankton

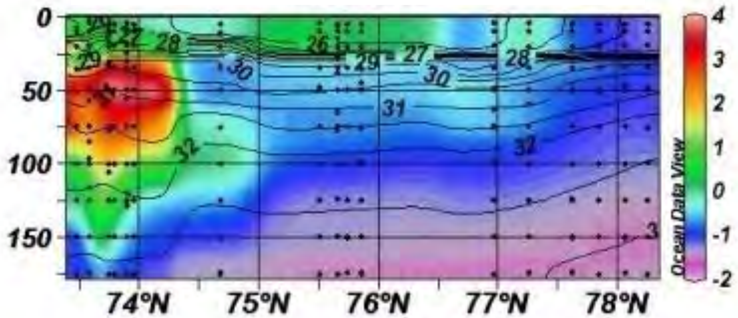


CS: Chukchi Sea
ESS: East Siberian Sea
CP: Chukchi Plateau
CB: Canada Basin

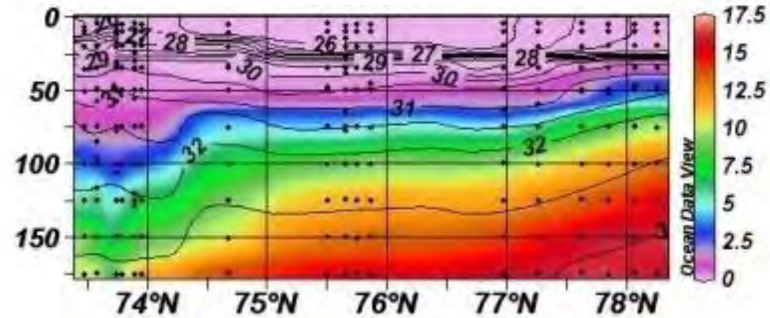
Ammonium [µmol/kg]



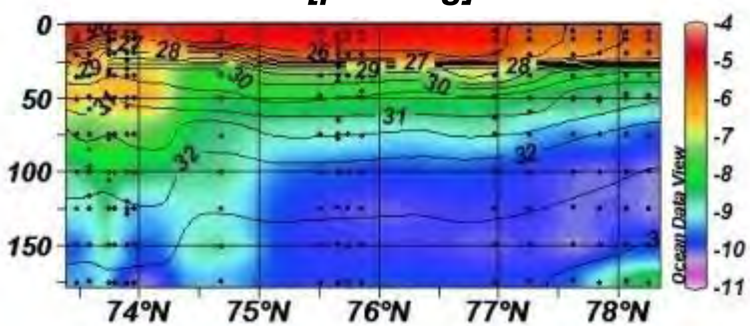
Temperature [ºC]



Nitrate [µmol/kg]

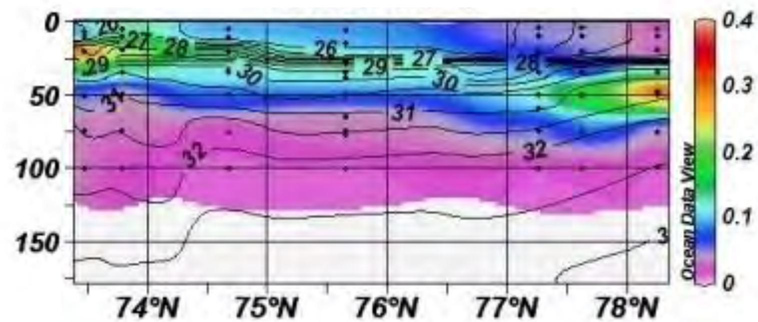


*N** [µmol/kg]*



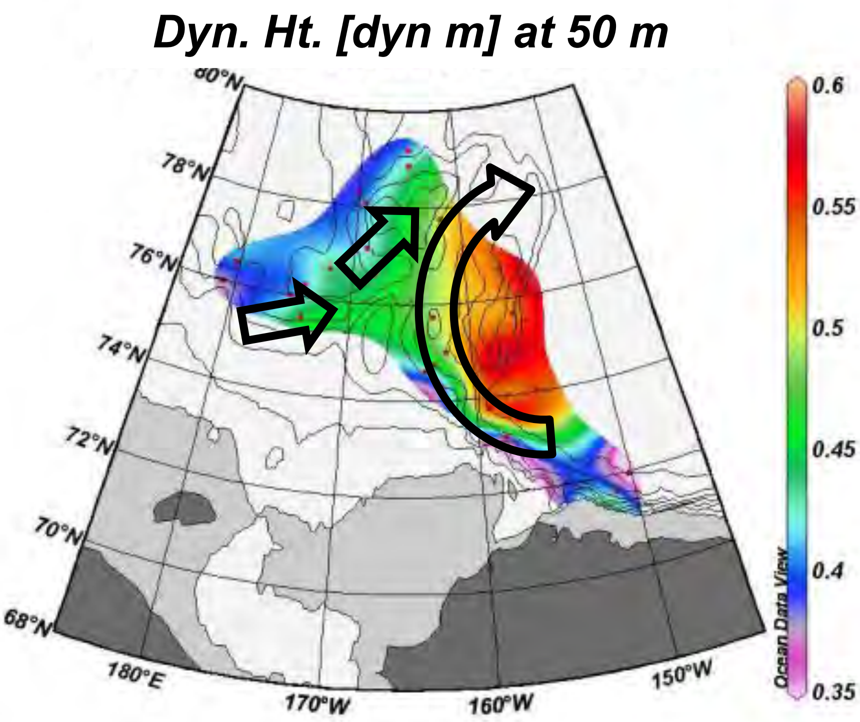
CB CP

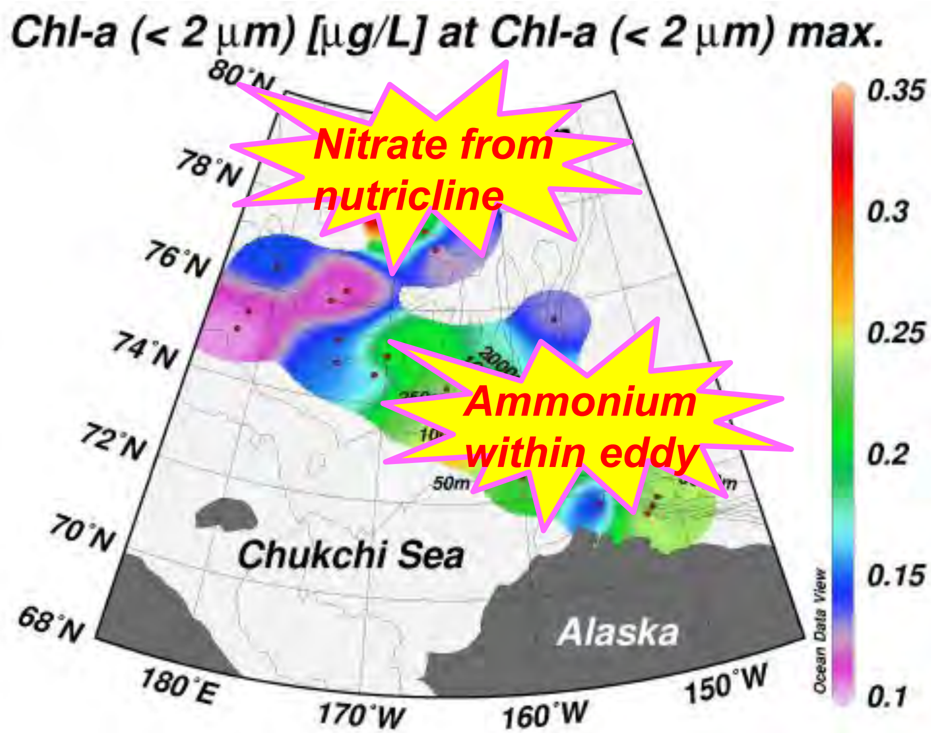
Chl-a (<2 µm) [µg/L]



CB CP

Ocean circulation and small phytoplankton





Summary of warm-core eddies

・Warm-core eddies of Pacific-origin summer water characterized by high ammonium and low silicate concentrations favor the growth of small phytoplankton in the Canada Basin of the Arctic Ocean.

・The nutrient contribution of these eddies to the euphotic zone would have increased recently because deepening of the nutricline in the Canada Basin has inhibited the nutrient supply from deep layers.

・The warm-core eddies would be a major nutrient (ammonium) provider to the euphotic zone over the Canada Basin, even if the nutricline is deeper than the euphotic zone.

・On the other hand, at the rim of the anticyclonic ocean Beaufort Gyre in the Canada Basin, the nutricline shallows. At the northern rim of the gyre distant from the shelf area, nitrate supplies from the shallow nutricline could sustain the phytoplankton production.