Phytoplankton production changes driven by physical forcing in the western Arctic Ocean

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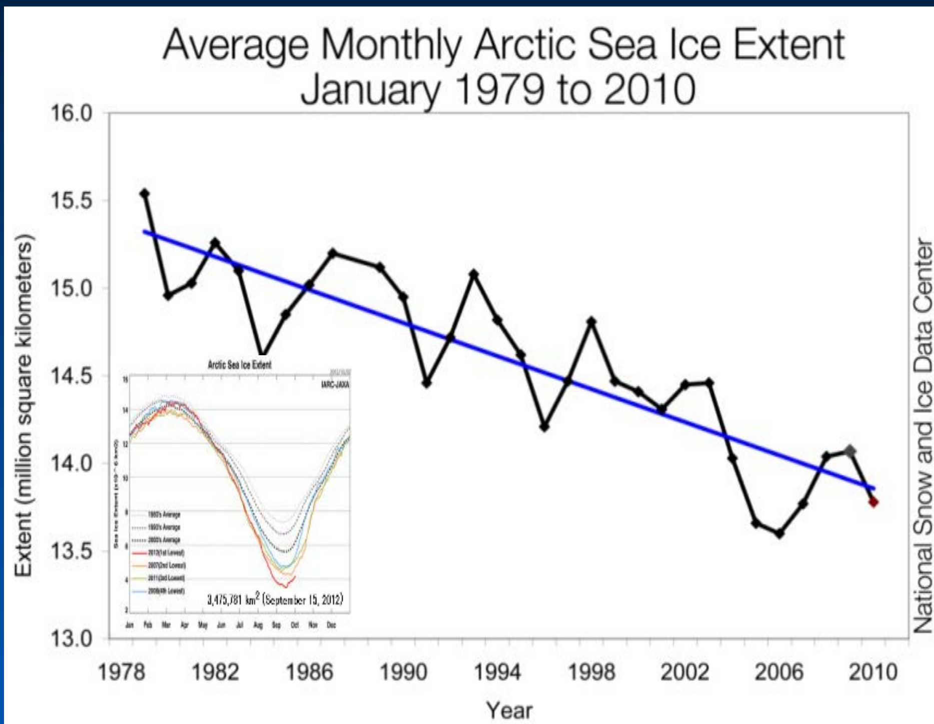
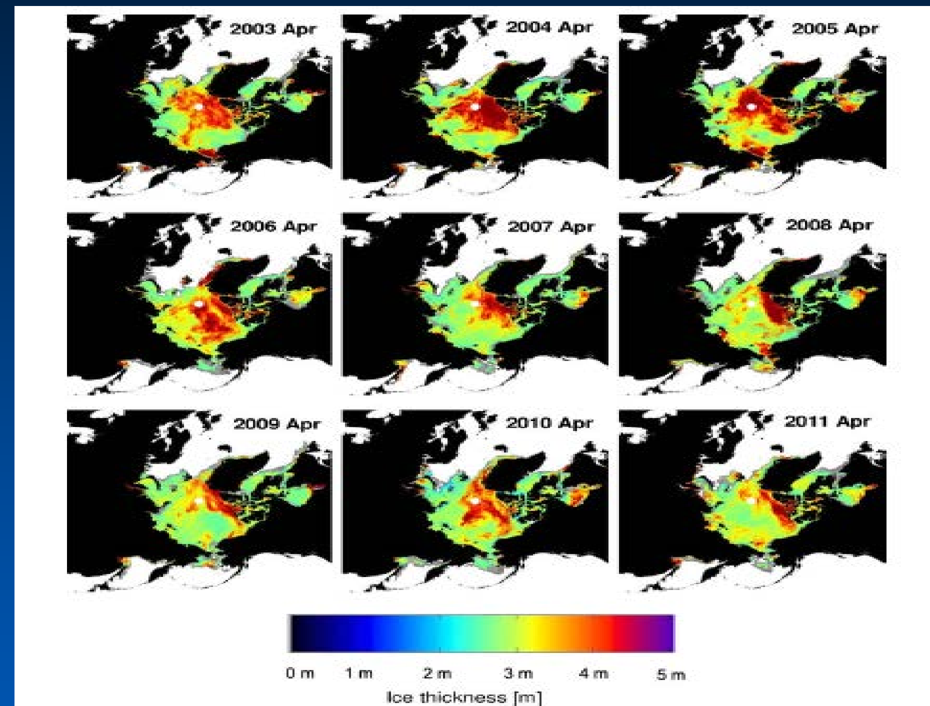
Introduction

Changes in Arctic sea ice cover



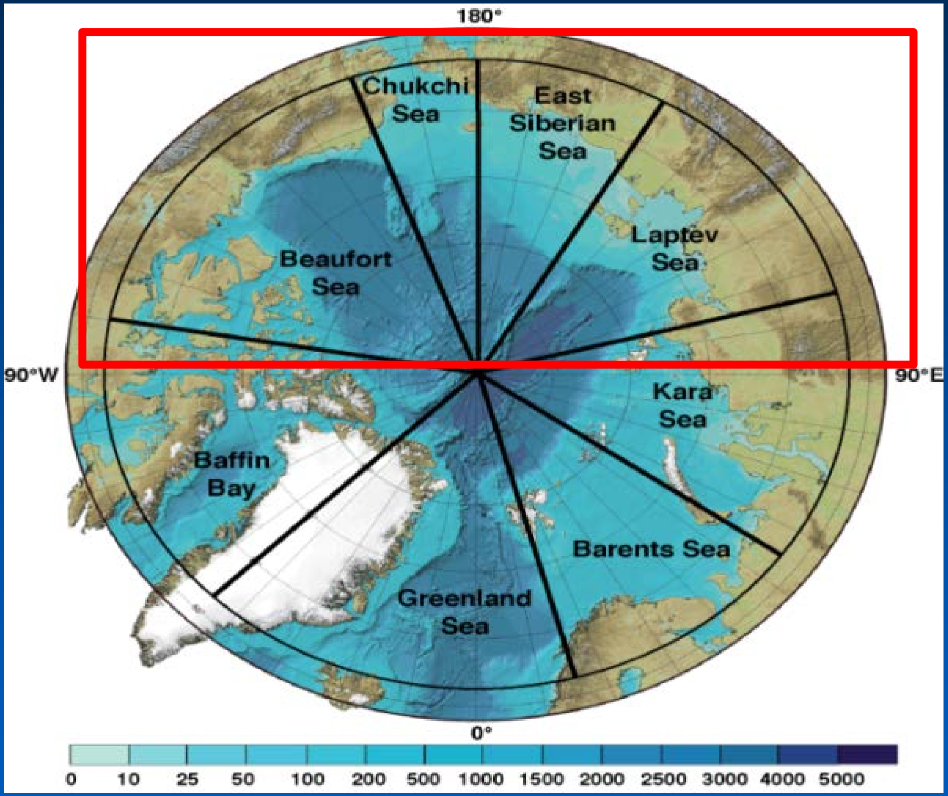


Krishfield et al. (2013)

- **Decreasing trend in summer sea ice cover**
- **Reductions in sea ice thickness**

Introduction

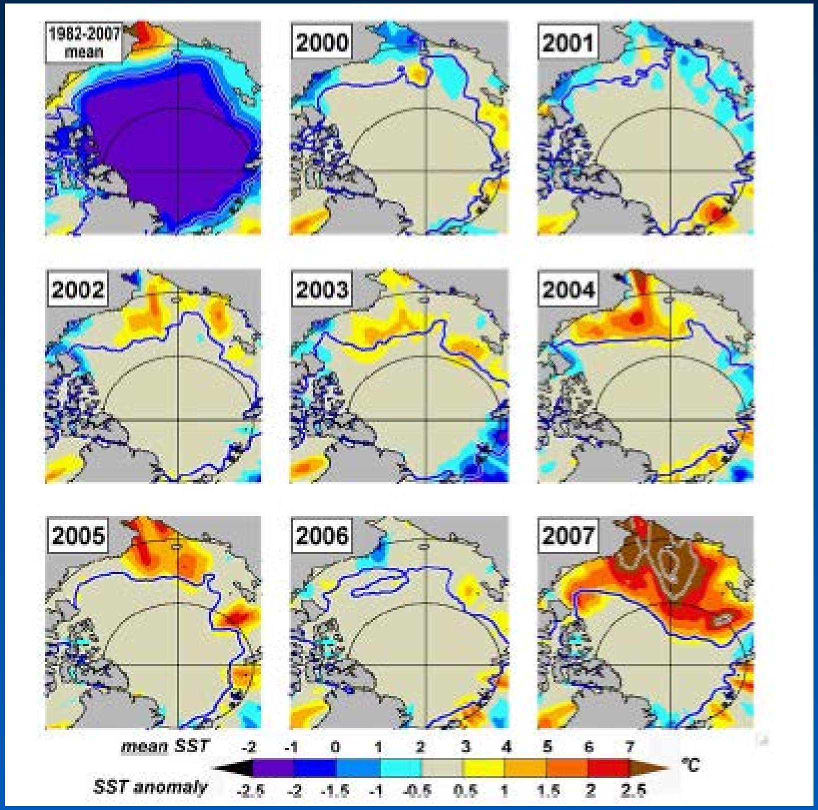
The largest sea ice loss in the western Arctic Ocean



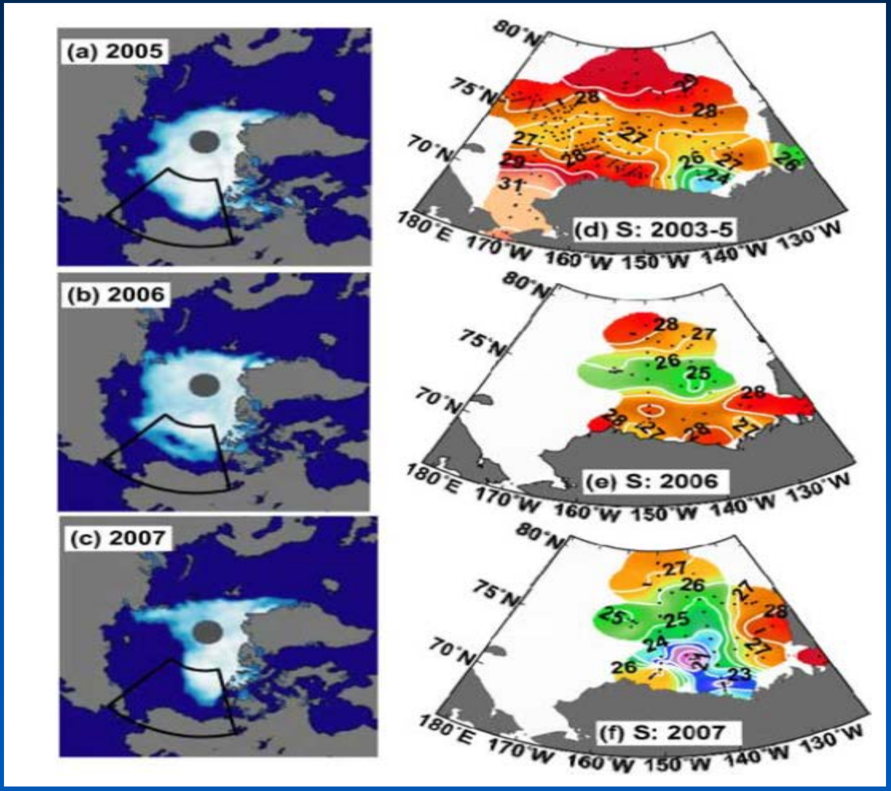
Arrigo and Dijken (2011)

Introduction

Arctic Ocean surface warming and freshening



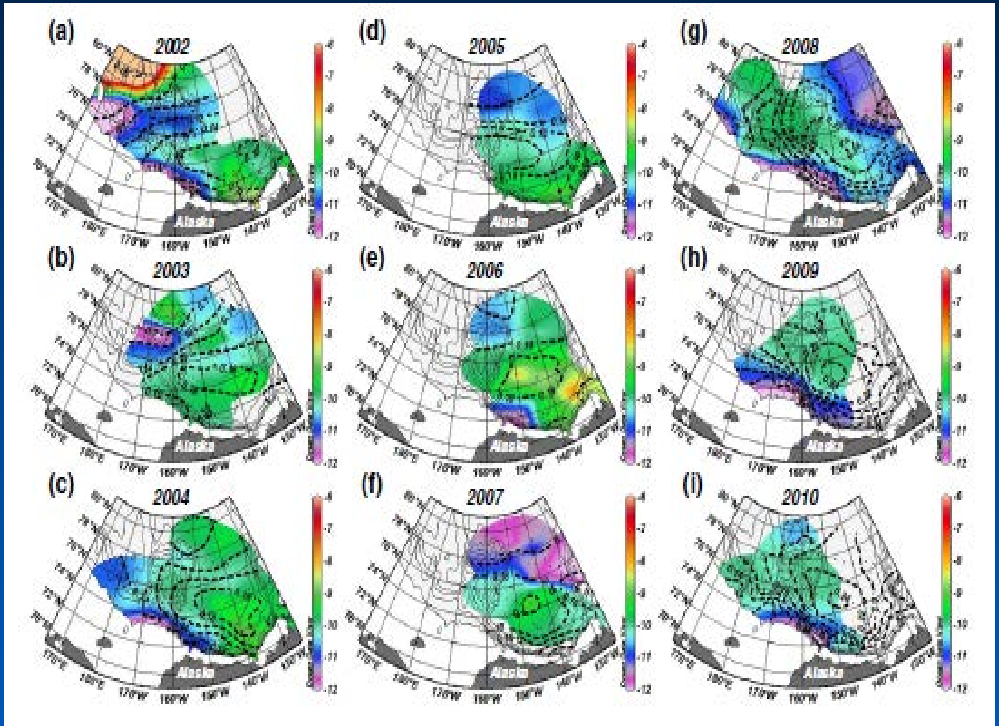
Steele et al. (2008)



Yamamoto-Kawai et al. (2009)

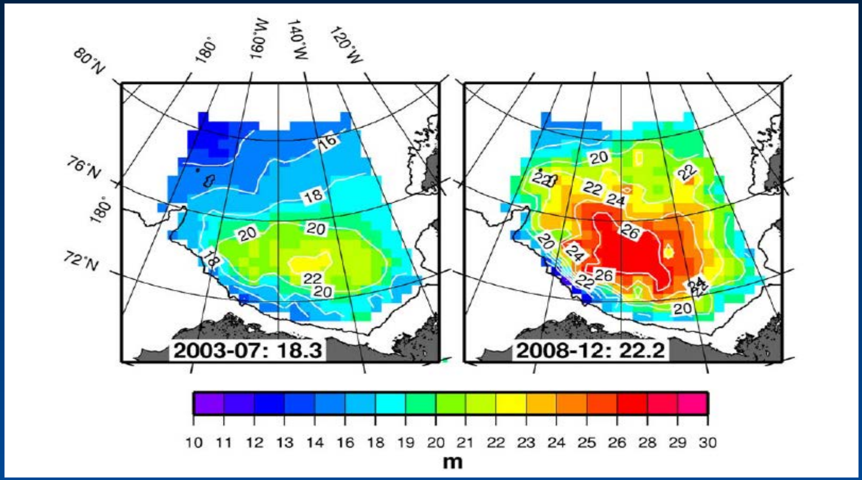
Introduction

Changes in Arctic physical environments



▲ A strong Beaufort Gyre

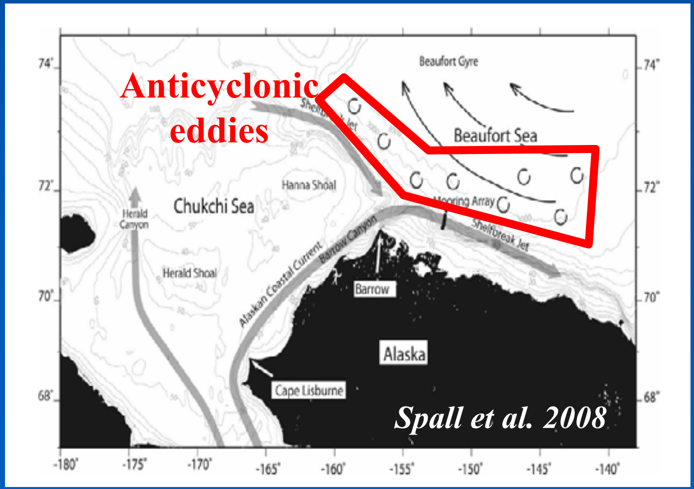
Nishino et al. 2013



Krishfield et al. (2013)

▲ Accumulation of surface freshwater within the Beaufort Gyre

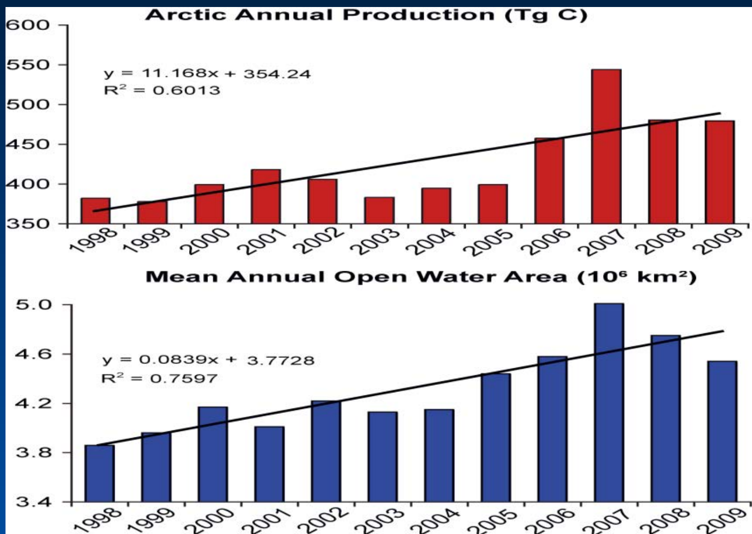
► Frequent of occurrence eddies



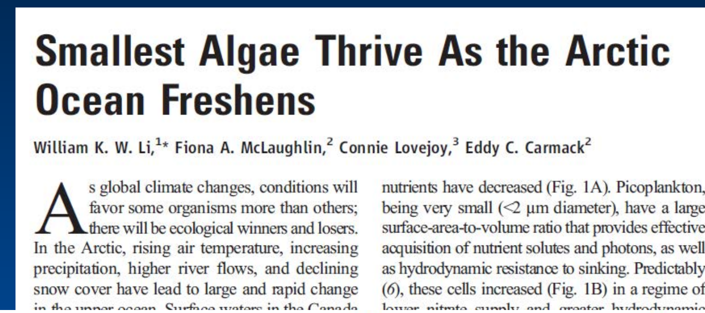
Spall et al. 2008

Introduction

Impacts of recent environmental changes on the phytoplankton



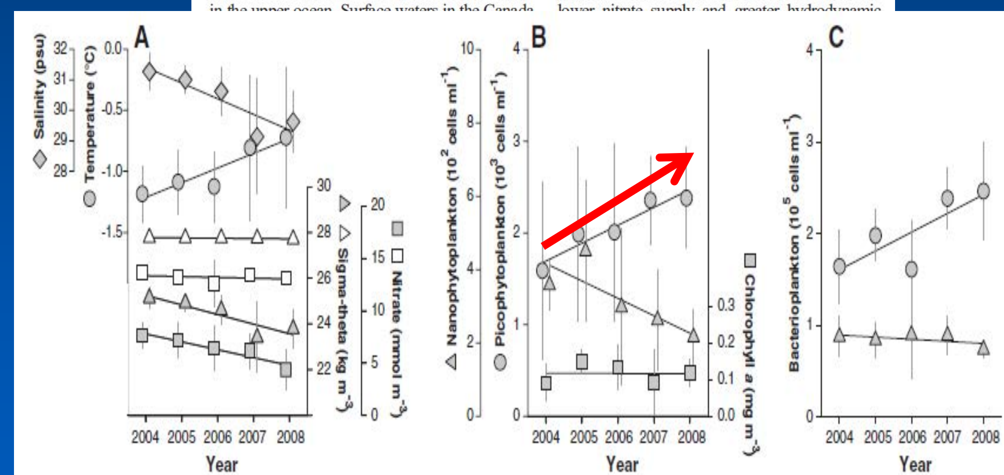
Arrigo and Dijken, (2011)


Smallest Algae Thrive As the Arctic Ocean Freshens

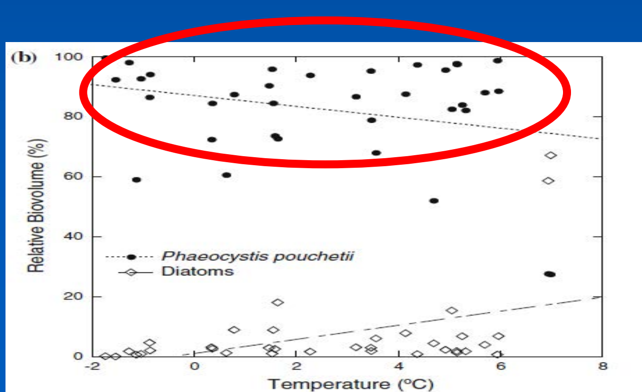
William K. W. Li,[1]* Fiona A. McLaughlin,[2] Connie Lovejoy,[3] Eddy C. Carmack[2]

As global climate changes, conditions will favor some organisms more than others; there will be ecological winners and losers. In the Arctic, rising air temperature, increasing precipitation, higher river flows, and declining snow cover have lead to large and rapid change in the upper ocean. Surface waters in the Canada ...

nutrients have decreased (Fig. 1A). Picoplankton, being very small (<2 µm diameter), have a large surface-area-to-volume ratio that provides effective acquisition of nutrient solutes and photons, as well as hydrodynamic resistance to sinking. Predictably (*6*), these cells increased (Fig. 1B) in a regime of lower nitrate supply and greater hydrodynamic ...



Li et al. (2009)

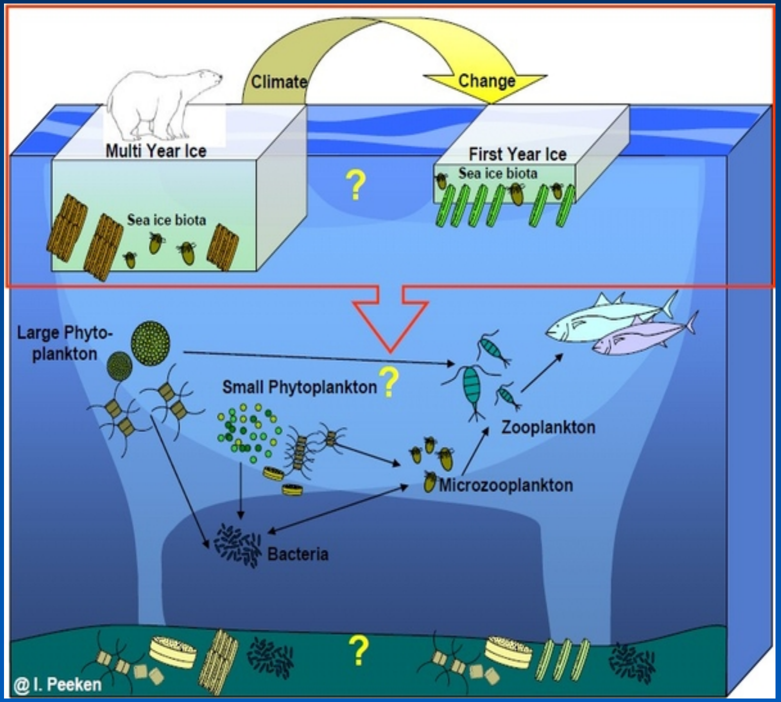


Lasternas and Agusti´(2010)

◀Exceptional dominance of the colonial form of *Phaeocystis pouchetii*

Research Questions

Given ongoing environmental changes in the Arctic Ocean….



http://www.awi.de/de/forschung/fachbereiche/biowissenschaften/polare_biologische_

- **How has primary production of phytoplankton changed driven by physical forcing?**
  - **Effects of freshwater inputs**
  - **Influence of eddies**

Materials and methods

Water samples from different light depths

Light Depth

100 % 50 % 30 % 12 % 5 % 1 %

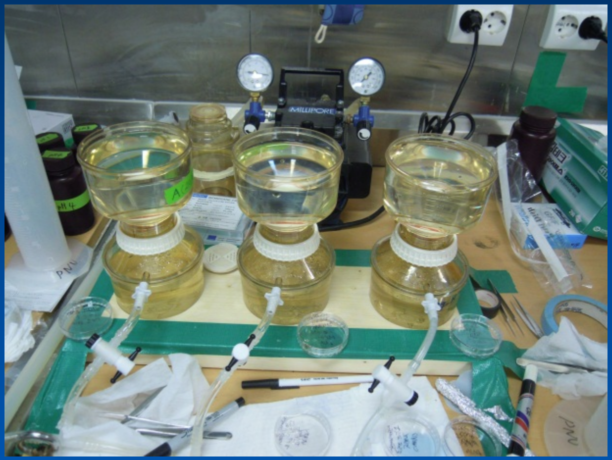
$^{15}NO_3$ + ^{13}C

$^{15}NH_4$ + ^{13}C

Materials and methods

In-situ Incubations & analysis

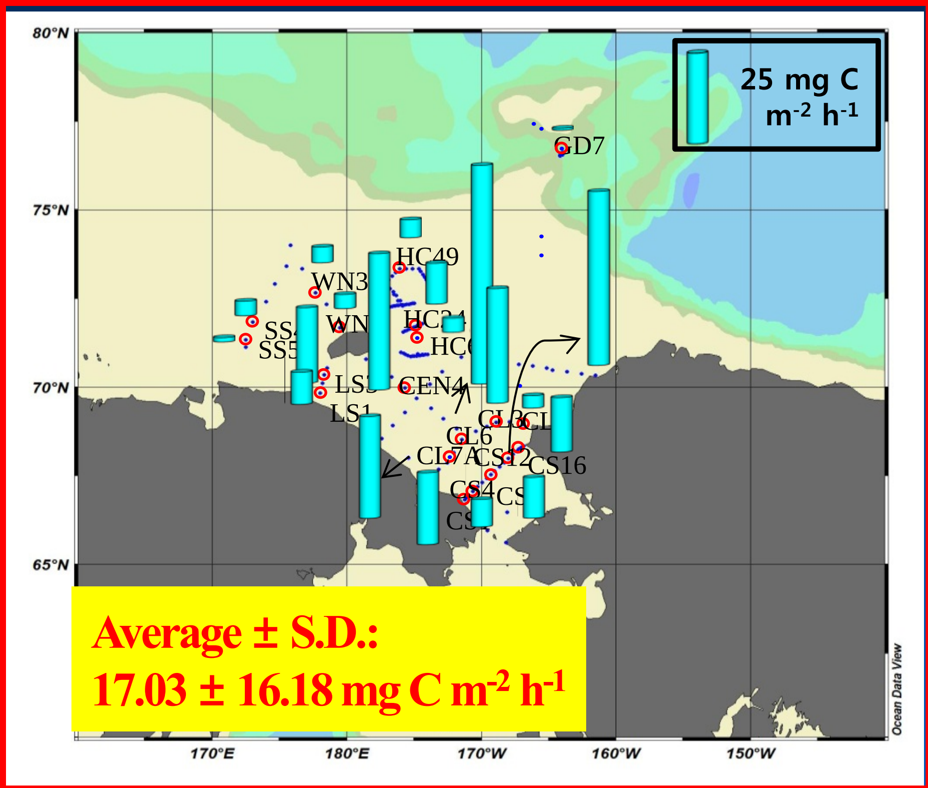
Incubation ⟶ **Filtering** ⟶ **Analysis**



Results and Discussion

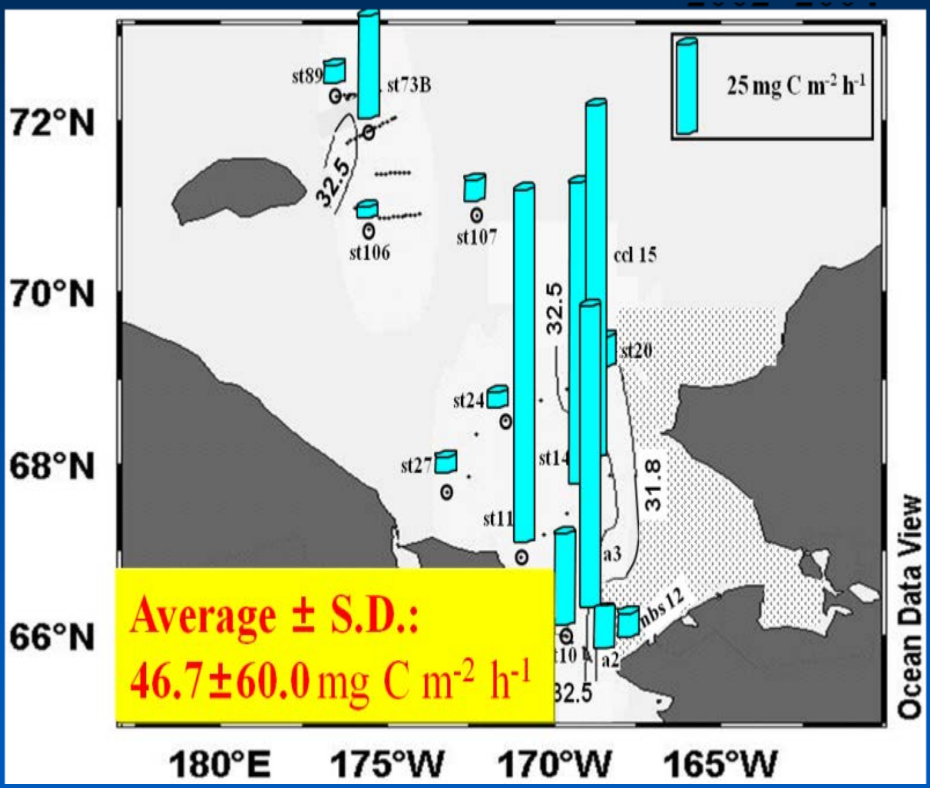
Comparison of recent primary production

2nd RUSALCA cruise (in 2009)



Yun et al. (2014)

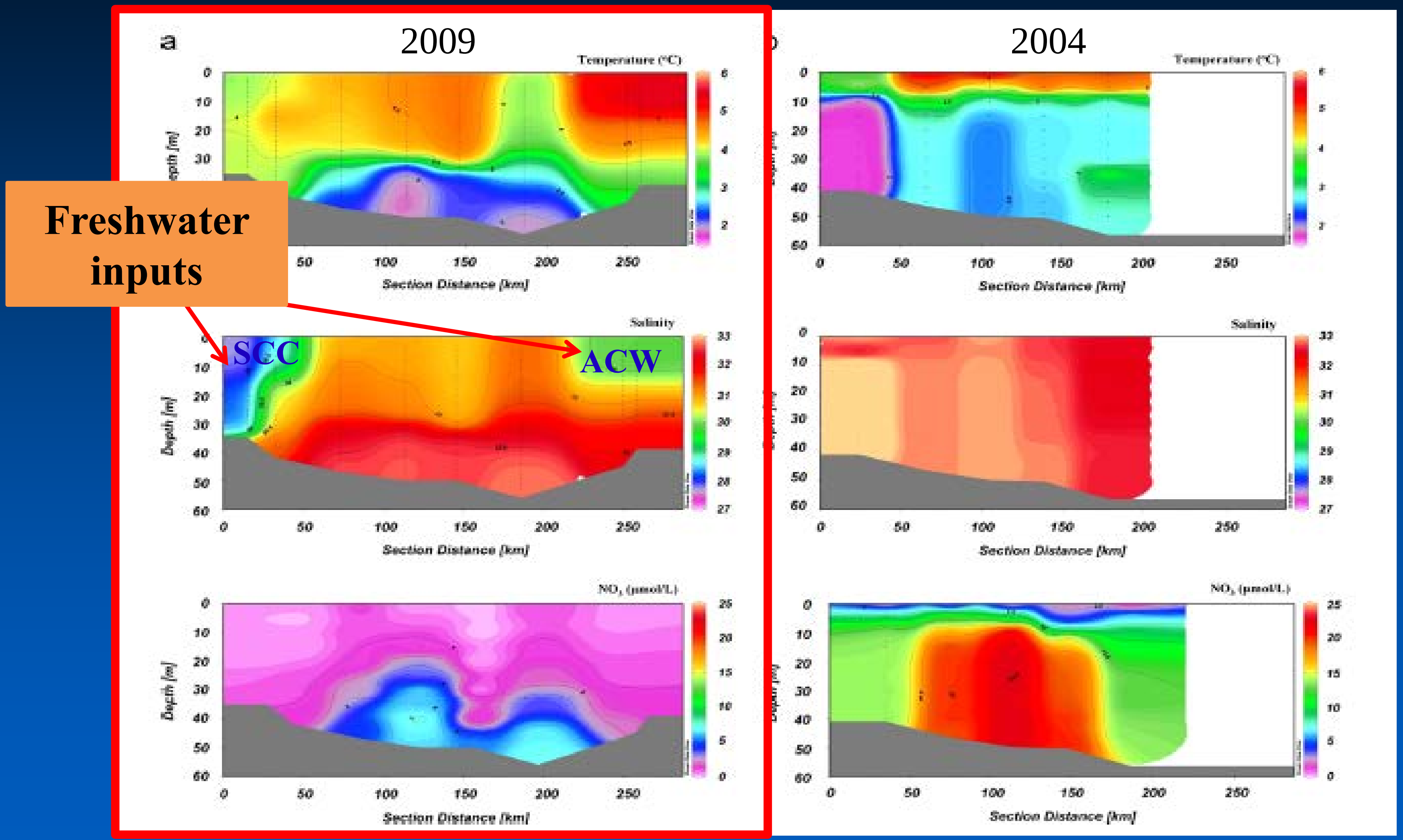
1st RUSALCA cruise (in 2004)



Lee et al. (2007)

Results and Discussion

A comparison of environmental factors in 2009 and 2004



Results and Discussion

A correlation analysis

	Surface Temperature	Bottom Temperature	Surface Salinity	Bottom Salinity	Surface Density	Bottom Density	Z_{eu}	Z_m	SI	SFL	NO_3	NH_4	Chlorophyll *a*	Carbon Production rate	Nitrate Production rate
Surface Temperature															
Bottom Temperature	0.611**														
Surface Salinity	0.735**	0.398													
Bottom Salinity	-0.466*	-0.236	0.000												
Surface Density	0.692**	0.364	0.998**	0.033											
Bottom Density	-0.600**	-0.281	-0.215	0.942**	-0.185										
Z_{eu}	-0.854**	-0.577**	-0.517*	0.684**	-0.479*	0.796**									
Z_m	0.223	0.046	0.045	-0.128	0.023	-0.016	-0.075								
SI	-0.826**	-0.535*	-0.894**	0.369	-0.879**	0.480*	0.691**	-0.184							
SFL	-0.248	0.153	-0.648**	-0.028	-0.678**	0.196	0.263	0.378	0.470*						
NO_3	-0.534*	-0.385	-0.139	0.351	-0.100	0.303	0.622**	-0.324	0.312	-0.179					
NH_4	-0.261	-0.040	0.060	0.566*	0.080	0.566*	0.447	-0.072	0.116	-0.041	0.434				
Chlorophyll *a*	0.304	0.087	0.536*	0.037	0.547*	-0.093	-0.182	0.173	-0.460*	-0.520*	-0.120	-0.243			
Carbon Production Rate	0.387	0.244	0.587**	-0.032	0.595**	-0.168	-0.306	0.115	-0.552*	-0.515*	-0.047	-0.107	0.795**		
Nitrate Production Rate	0.042	-0.326	0.345	0.203	0.363	0.104	0.170	-0.178	-0.174	-0.449	0.545*	0.541*	-0.091	-0.081	

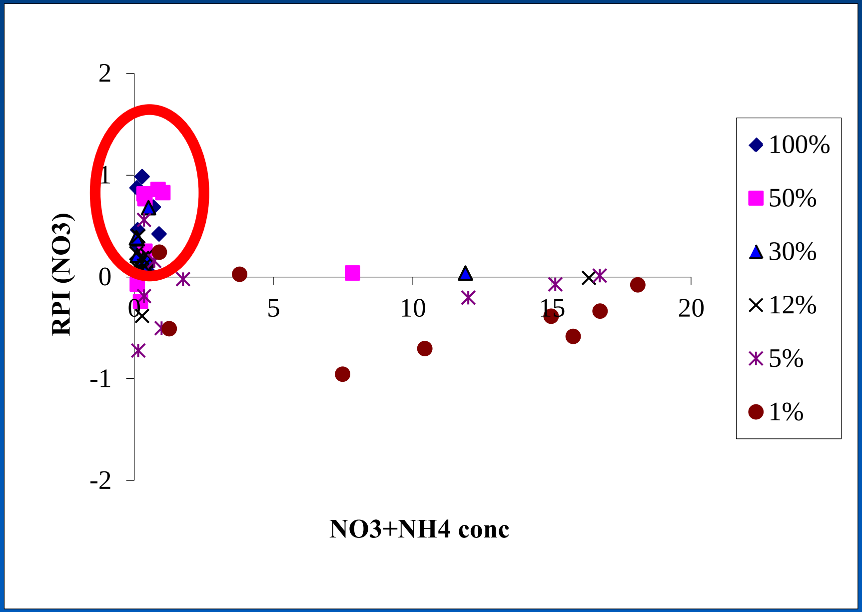
- **Chlorophyll a concentration and primary production were negatively affected by SI (Stratification Index) and SFL (Surface Freshwater Layer)**

Results and Discussion

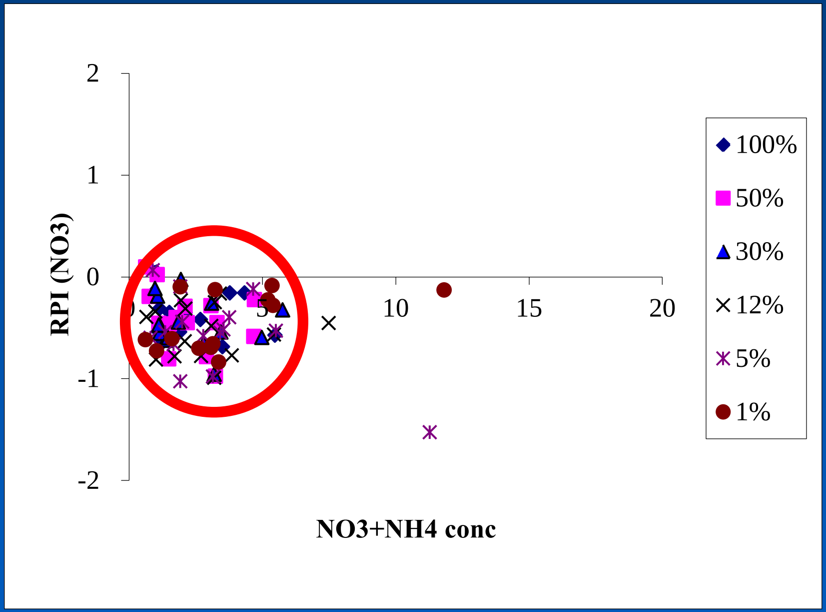
The utilization of different nitrogen source

- *The relative preference index (RPI) :* McCarthy et al. (1977)
- RPI_{NO3} > 1= NO_3^- preference, < 1= NO_3^- rejection, or NH_4^+ preference)

2004

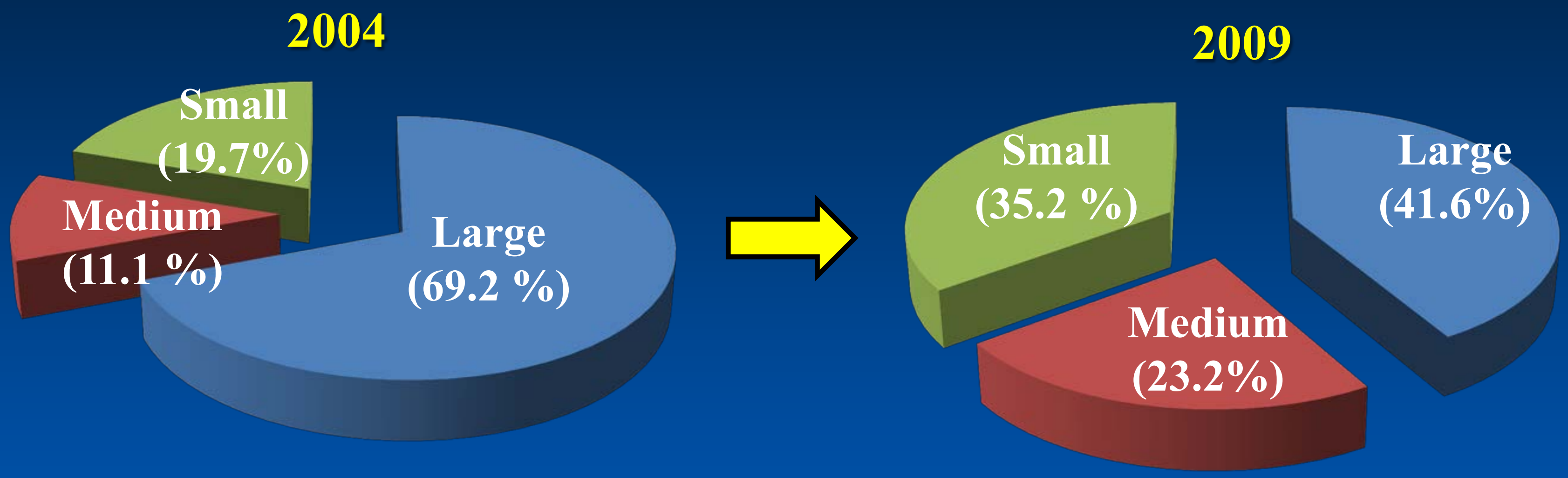


2009



Results and Discussion

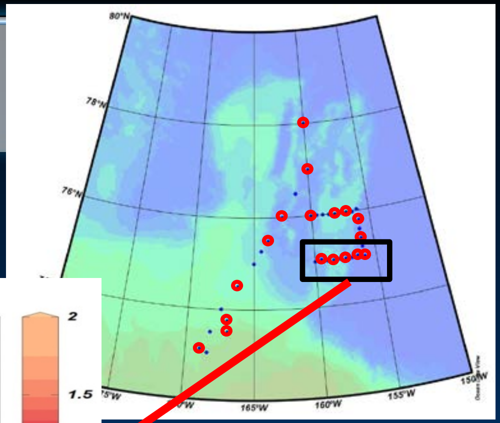
Phytoplankton biomass

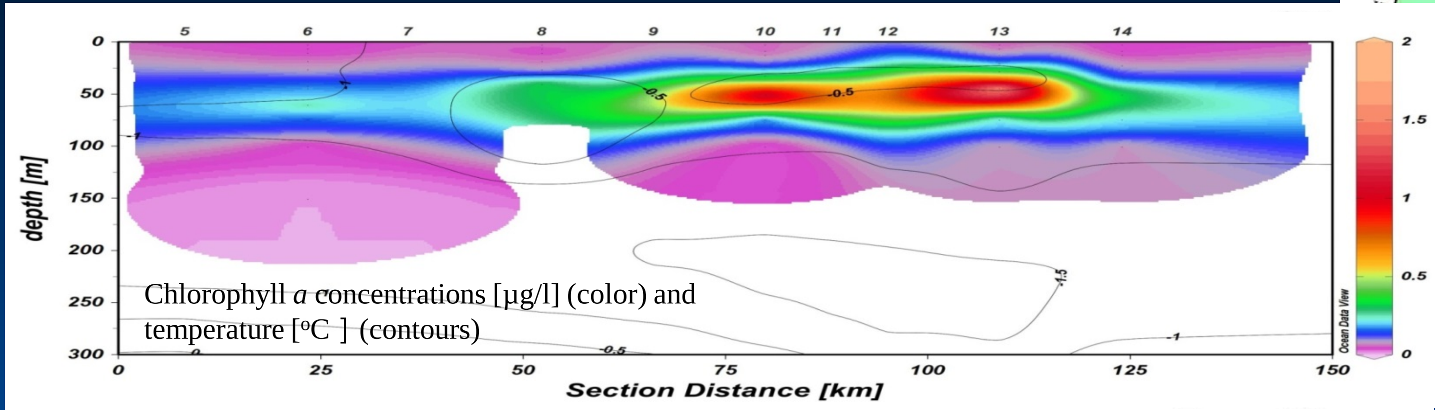


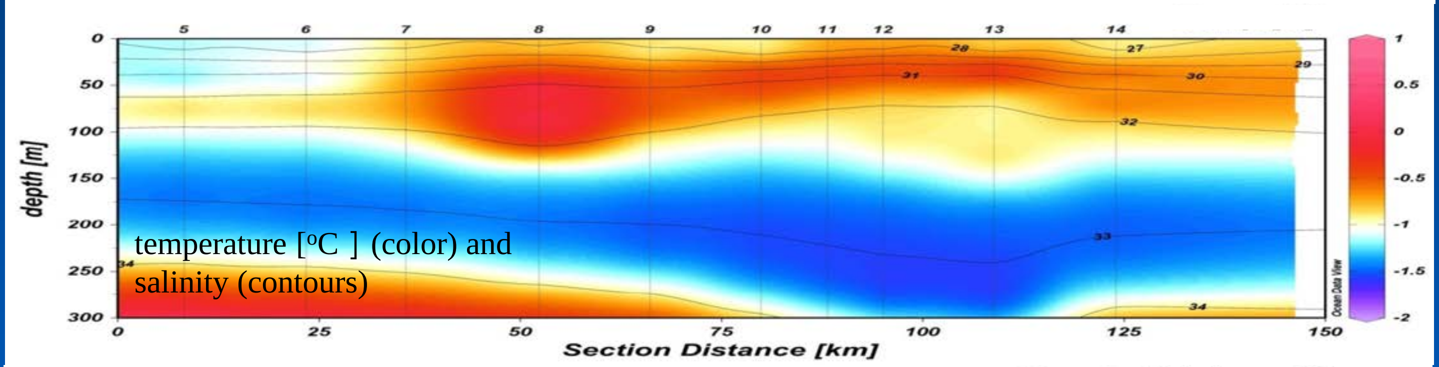
Small size phytoplankton increased!

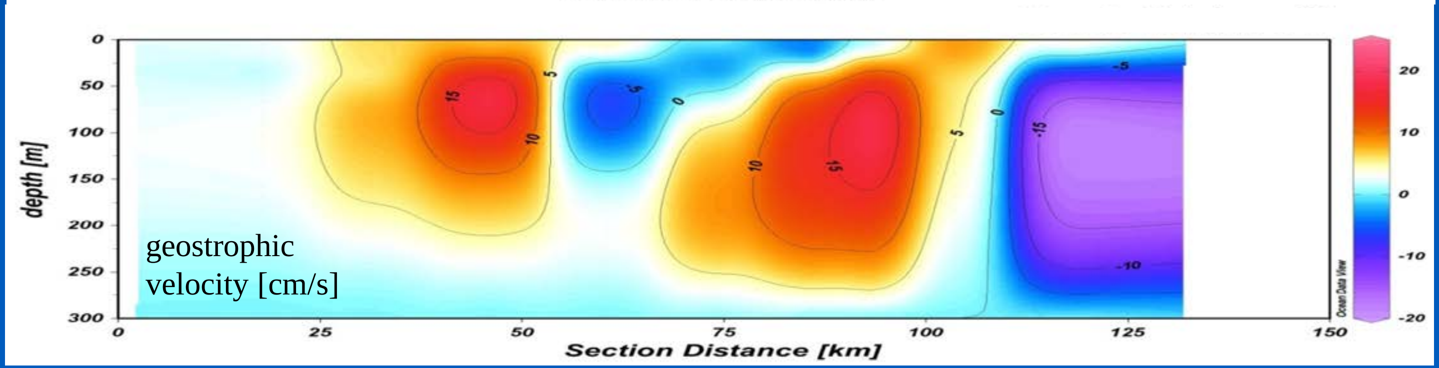
Results and Discussion

Exceptionally high regional phytoplankton biomass







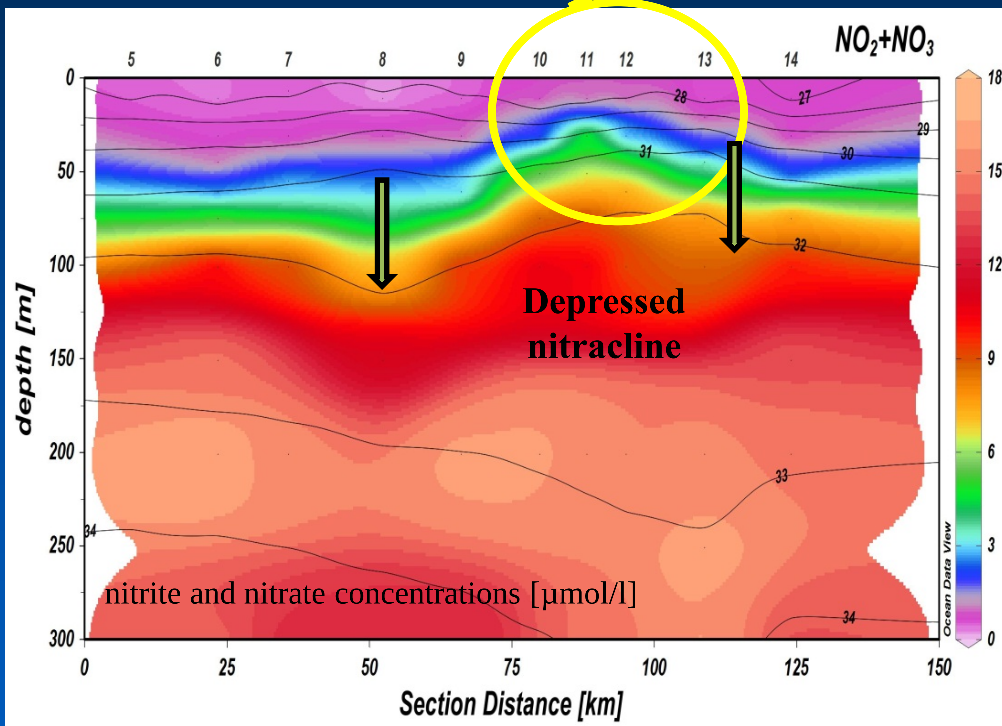


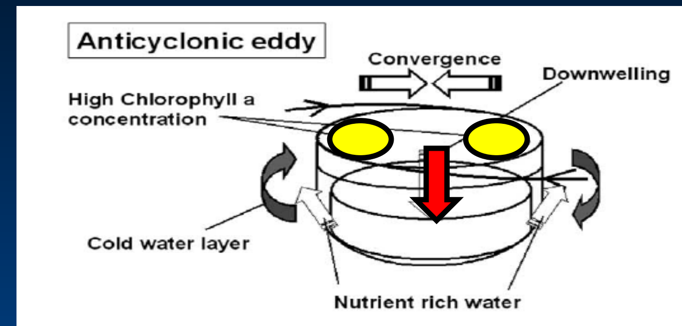
Anticyclonic warm-core eddies

Results and Discussion

The effects of warm-core eddy on the nitrate distribution

Shoaling of the nitracline





Mizobata et al. 2002

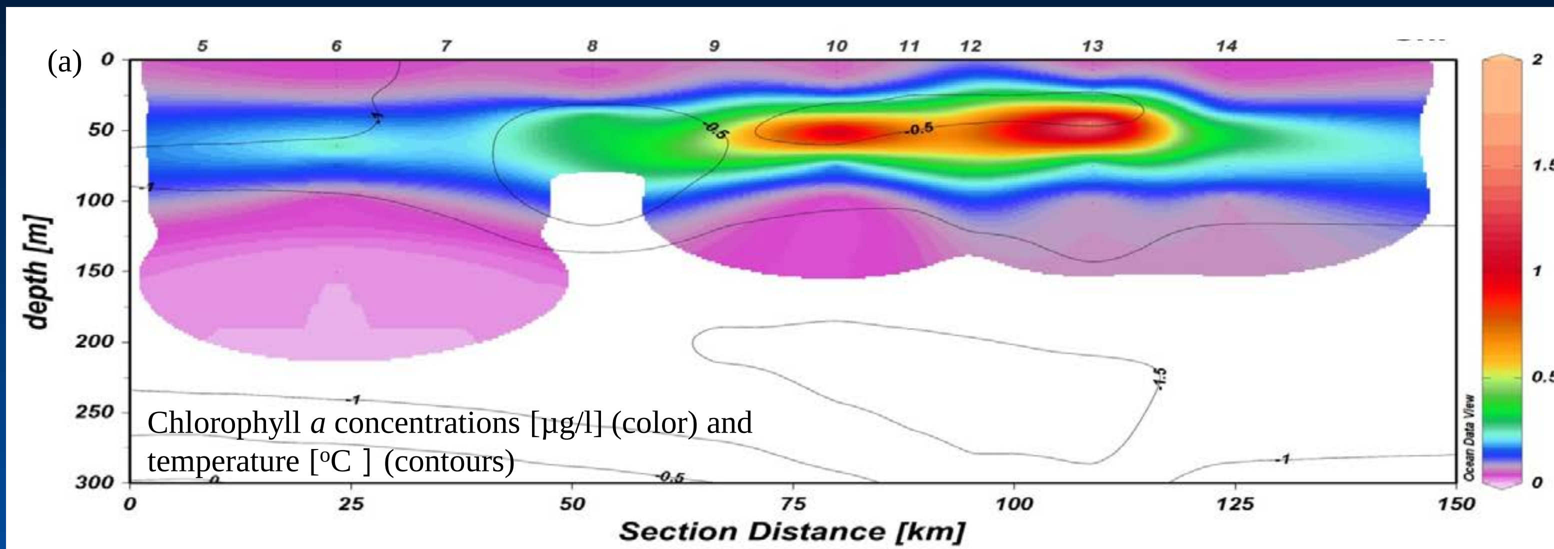
Nitrate upward flux

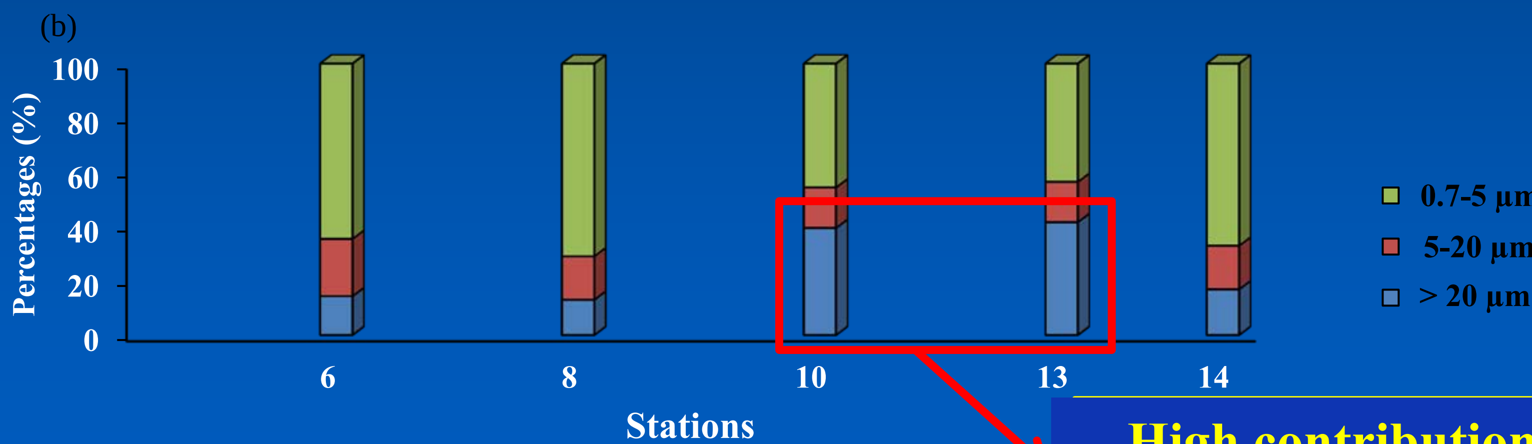
Station	Kz ($cm^2 s^{-1}$)	Fn ($\mu mol\ NO_3\ m^{-2}\ h^{-1}$)
6	0.49	0.70
8	0.37	5.99
10	0.41	***18.59***
13	0.28	***12.01***
14	0.35	2.64

Warm-core eddy caused more nitrate upward flux!

Results and Discussion

The effects of warm-core eddy on the phytoplankton biomass



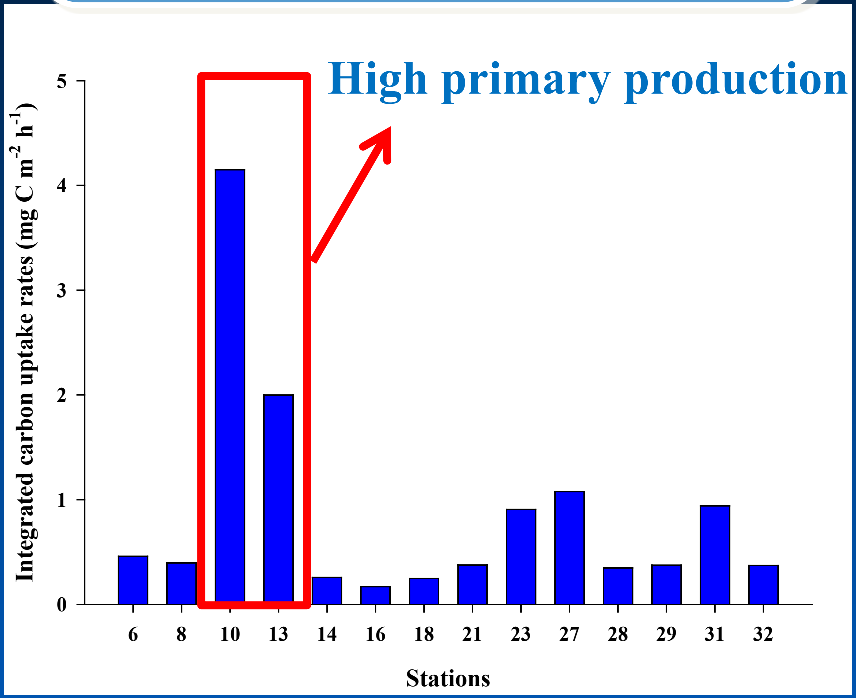


High contribution of large phytoplankton

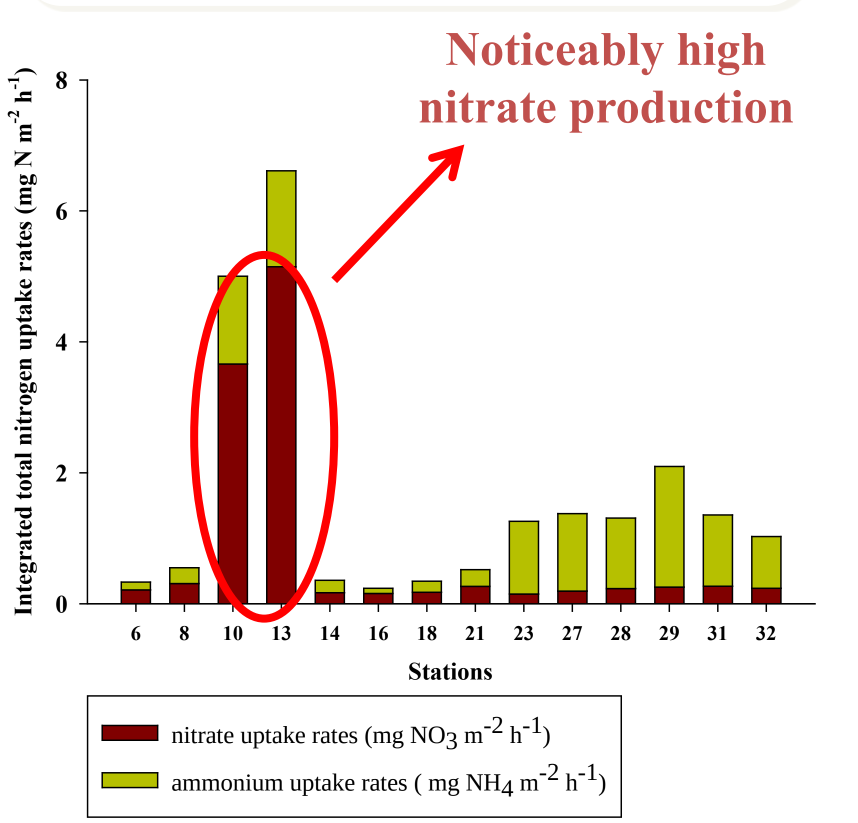
Results and Discussion

The effects of warm-core eddy on the phytoplankton production

Primary production



Nitrogen production



- **Warm-core eddies could lead to a significant increase in new production in the region.**

Summary and Conclusions

Given ongoing sea ice decline in the Artic Ocean:

- Effect of the freshwater inputs
  - Primary production were considerably reduced
    - Higher freshwater accumulation→ Increased stratification
  - Smaller size phytoplankton have increased

- Regional influence of warm-core eddies
  - An important role in the nitrate supply
  - A significant increase in primary/new production in the region.

- Therefore, the effects of physical forcing events (such as freshwater input and eddy) on the primary production need to be more examined to better understand changes of primary production under ongoing environmental changes in the Arctic Ocean.

Thank you for your attention.