HOKKAIDO UNIVERSITY

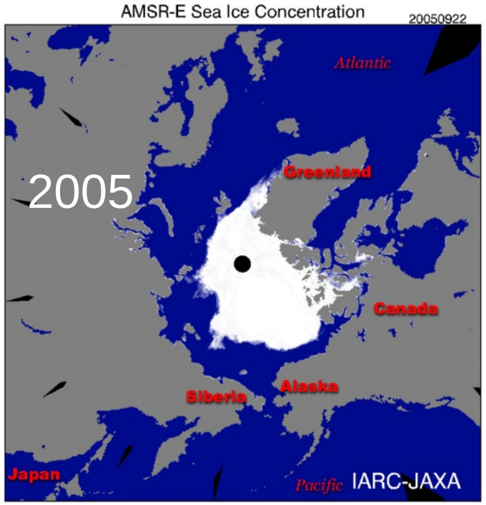
Optically derived primary production and size structure of phytoplankton in the polar oceans

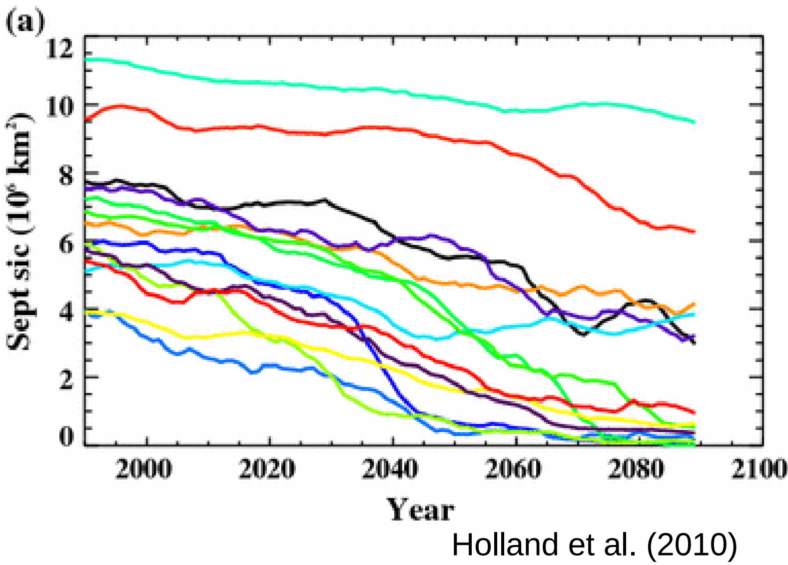
T . Hirawake, A. Fujiwara, S. Takao, K. Shinmyo and S-I. Saitoh

Laboratory of Marine Bioresource and Environment Sensing

May 23, 2011

Introduction





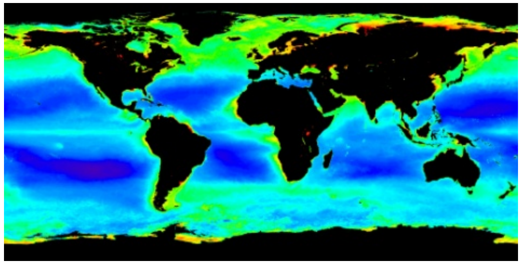
Holland et al. (2010)

Decline of sea ice affects light condition, nutrients and increase of freshwater, etc.

Change in primary productivity, phytoplankton size and group (eg. Pabi et al, 2008; Li et al, 2009)

Biological pump, structure of food web (eg. Nishino et al, 2010; Grebmeier et al, 2006)

Introduction



Satellite ocean color remote sensing data has been applied to study carbon cycles and marine ecosystem, even in the polar ocean.

Chlorophyll *a* (chl *a*) concentration is a main product of ocean color.

Uncertainty of chl *a* estimation in polar oceans

- **due to package effect in diatom dominant water = underestimation (eg. Mitchell, 1992, Hirawake et al, 2000)**

- **due to high absorption by colored dissolved organic matter (CDOM) in the Arctic Ocean = overestimation (eg. Cota et al. 2004)**

Introduction

Recent progress of in-water optical models (eg. Lee et al. 2004; Maritorena et al. 2001)

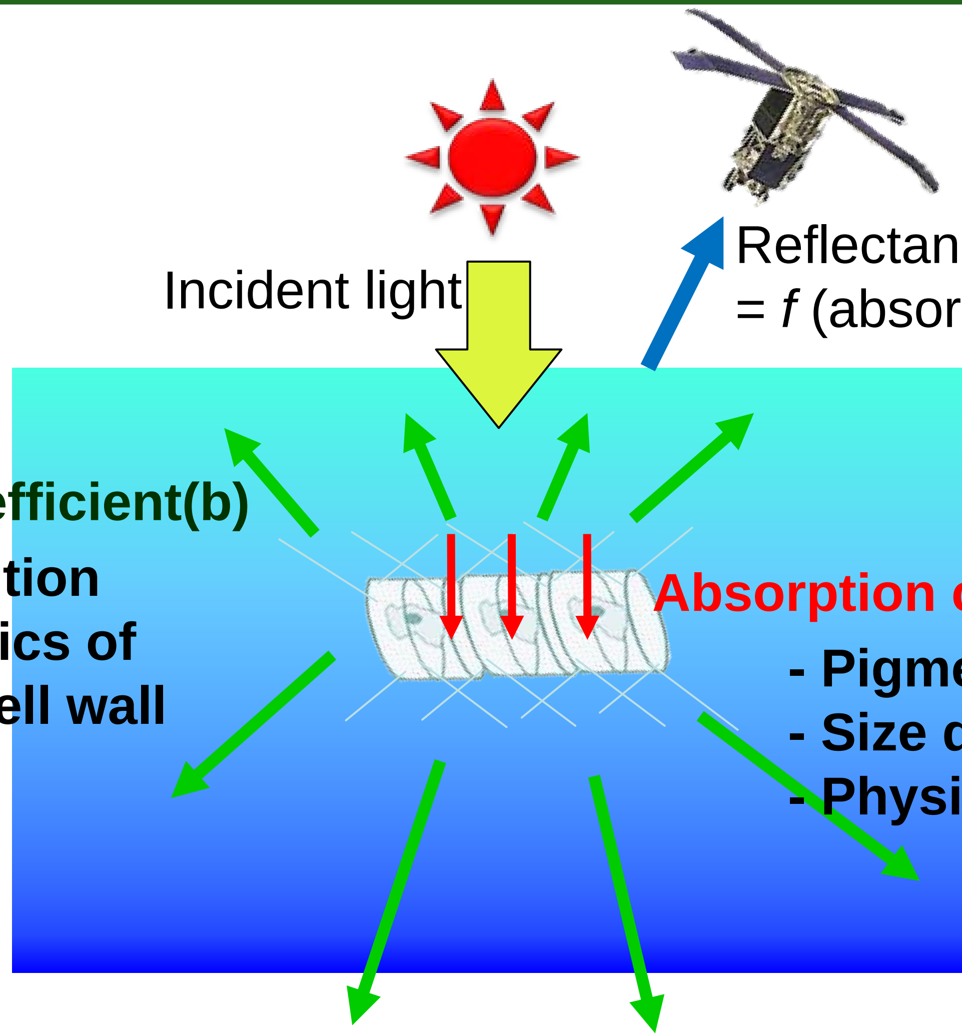
↓

Accurate estimation of Inherent optical properties (IOPs)

- **Light absorption coefficient of phytoplankton**
- **Light scattering coefficient of particles**

Introduction

IOPs



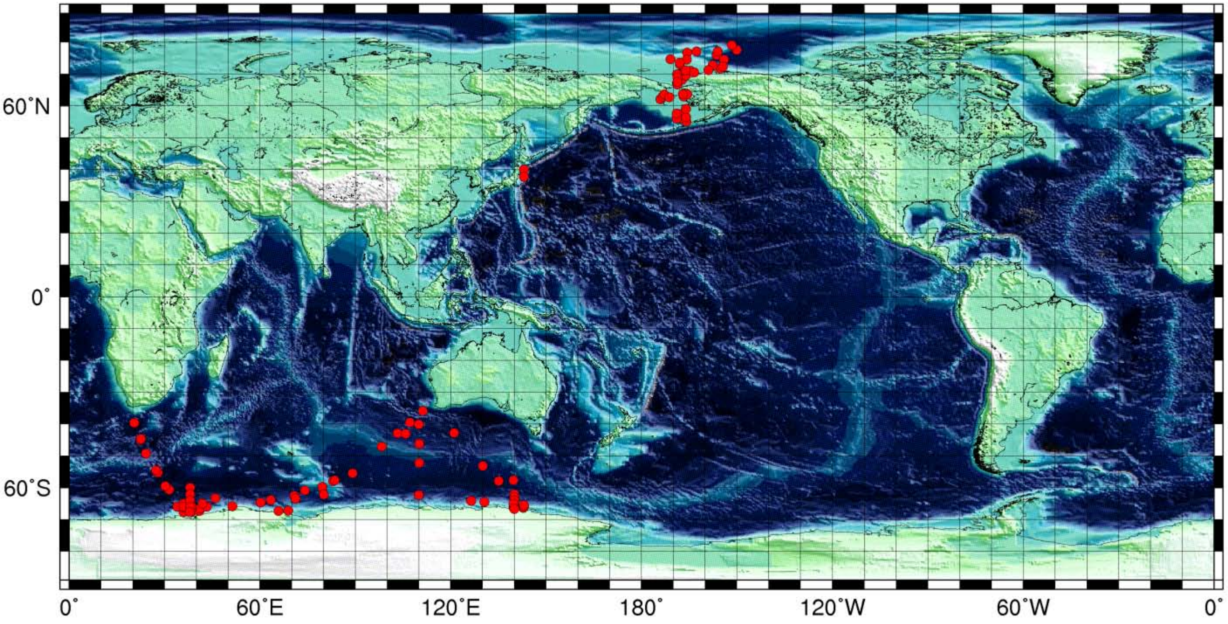
- Primary productivity and size structure are possible to be derived optically using IOPs.
- Use of IOPs instead of 'Chl a' is becoming increasingly accepted (eg. Shang et al 2011; Marra 2007; Lee et al 1996; Cullen 1982)

Objectives

- **To develop IOPs based models (algorithms) to derive primary productivity and phytoplankton size in the polar oceans.**
- **To apply the models to satellite ocean color data and assess those spatio-temporal variability.**

Materials and Methods

in situ optical measurements



- Primary productivity (^{13}C, 24h incubation)
- Absorption coefficient of phytoplankton (Glass fiber filter technique)
- Scattering coefficient of particles (VSF, HS6P)
- Pigments concentration (HPLC, fluorometry)
- PAR (LI-COR)
- Spectral radiation (PRR, SPMR, HyperPro)

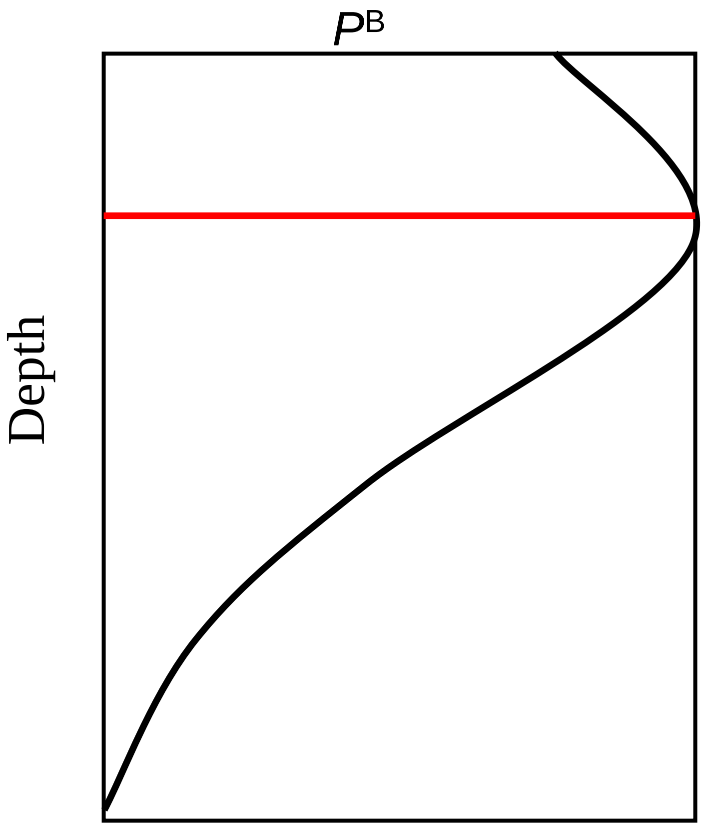
Data were collected in 2003-2009 mainly during IPY (2007-2009).

Absorption based primary production model (ABPM)

$f\,[\tilde{a}_{ph}(0\text{-})]$

$$PP_{eu} = P^{B}_{opt} \times Chl_{surf} \times Z_{eu} \times \frac{0.66125 \times E_0}{E_0 + 4.1} \times DL$$

VGPM (Behrenfeld & Falkowski, 1997)



Function of SST in VGPM

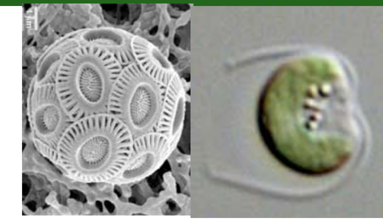
$P^{B}_{opt} \times Chl_{surf}$

$\tilde{a}_{ph}(0\text{-})$

Absorption coefficient at the sea surface

Chl *a* and SST were not used.

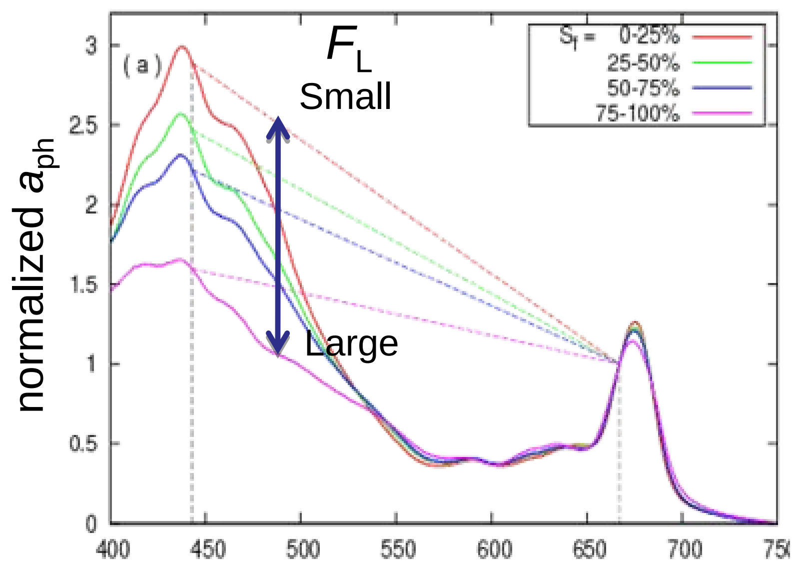
Phytoplankton size deriving model (SDM) (Arctic Ocean)



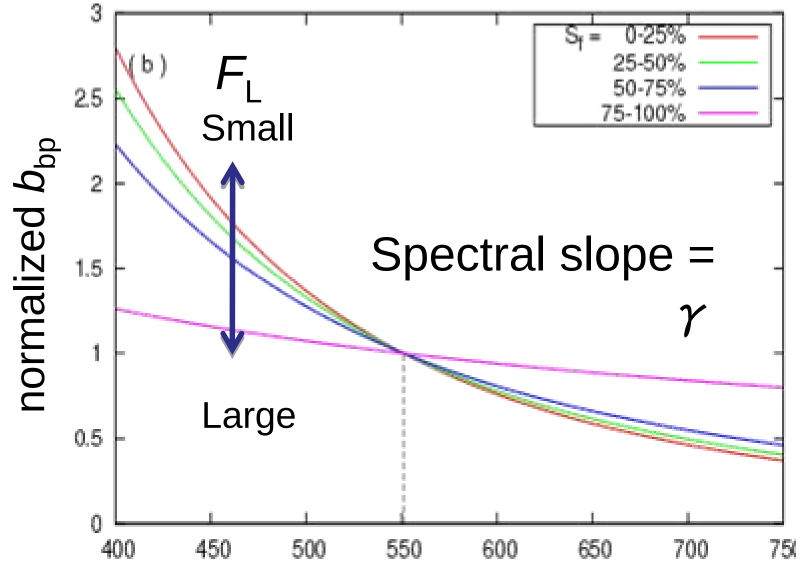
Phytoplankton size index: F_L = **Chla$_{>5\mu m}$ / Chla$_{total}$**

Contribution of larger sized (> 5µm cell) phytoplankton to total biomass

Absorption coefficient of phytoplankton

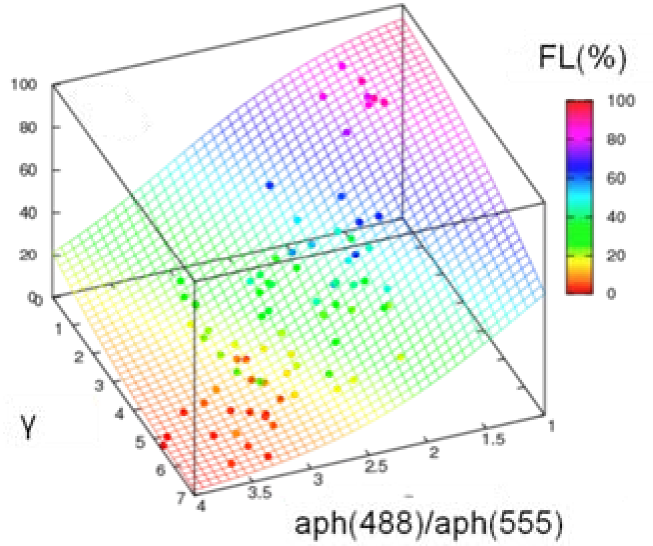


Scattering coefficient of particles



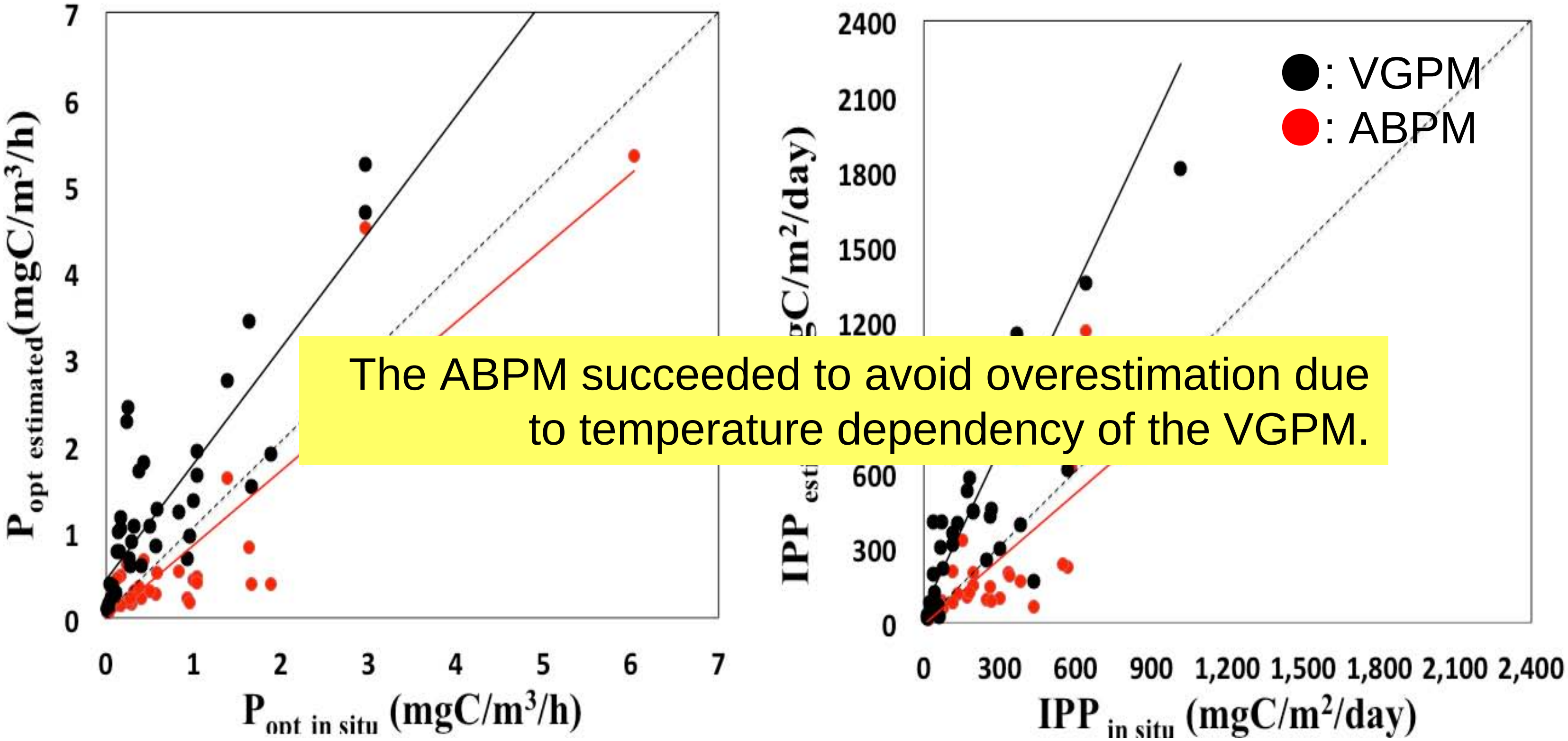
Fujiwara et al 2011, BGD

$$F_L = \frac{100}{1 + \exp[-(p \times a_{ph}(488)/a_{ph}(555) + q \times \gamma + r)]} \; [\%]$$



F_L was parameterized by ratio of absorption coefficients and spectral slope of backscattering, and fitted to multiple logistic model.

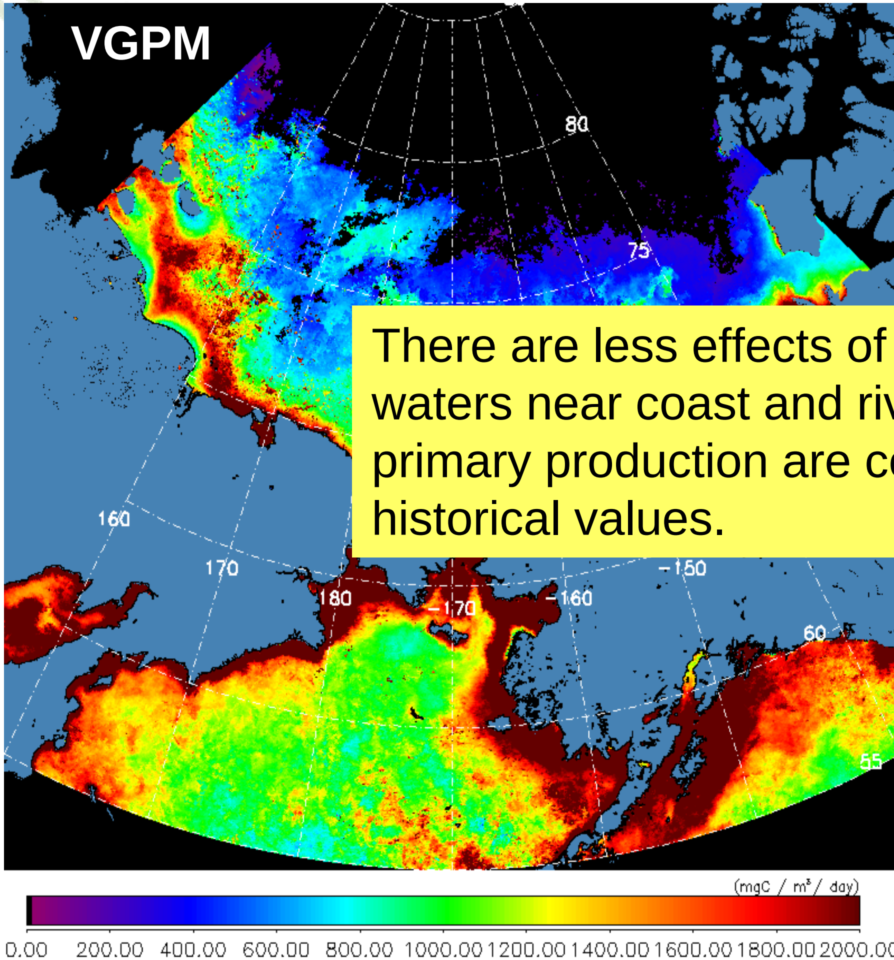
Results: Performance of absorption based primary production model (ABPM)

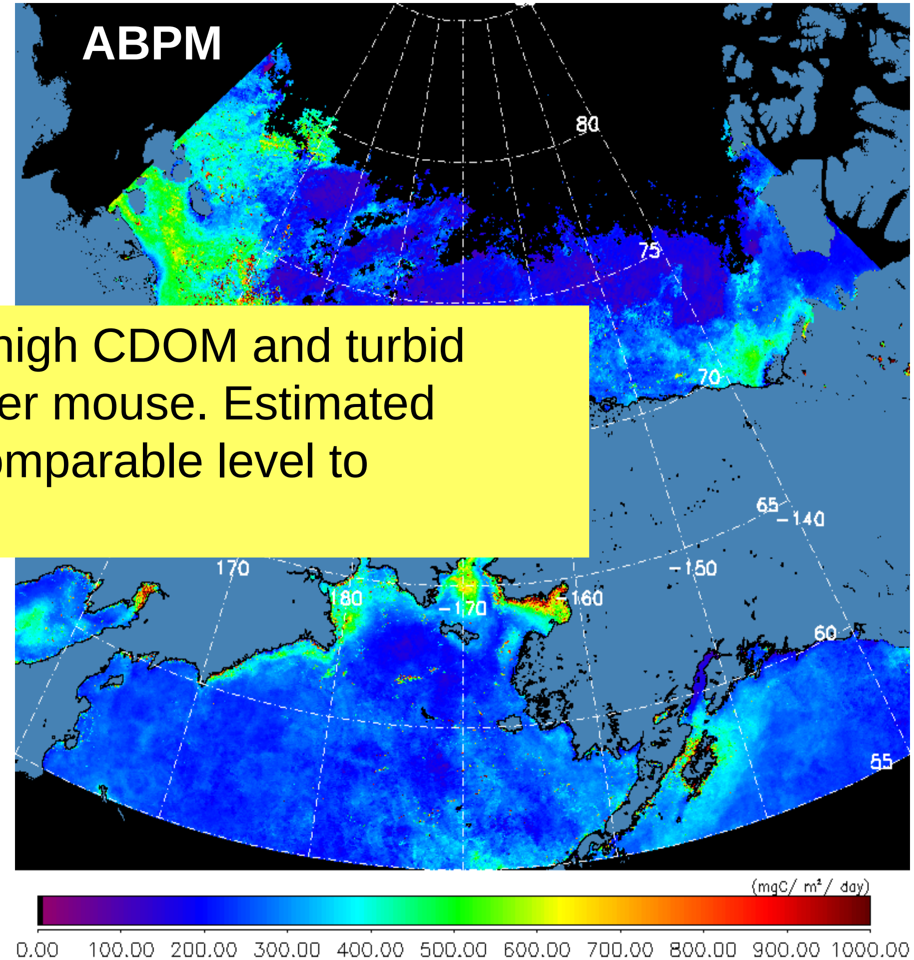


The ABPM succeeded to avoid overestimation due to temperature dependency of the VGPM.

	P_{opt}			IPP		
model	r^2	RMSE	slope	r^2	RMSE	slope
VGPM	0.732	0.381	1.339	0.482	0.199	2.142
ABPM	0.802	0.215	0.859	0.618	0.065	0.870

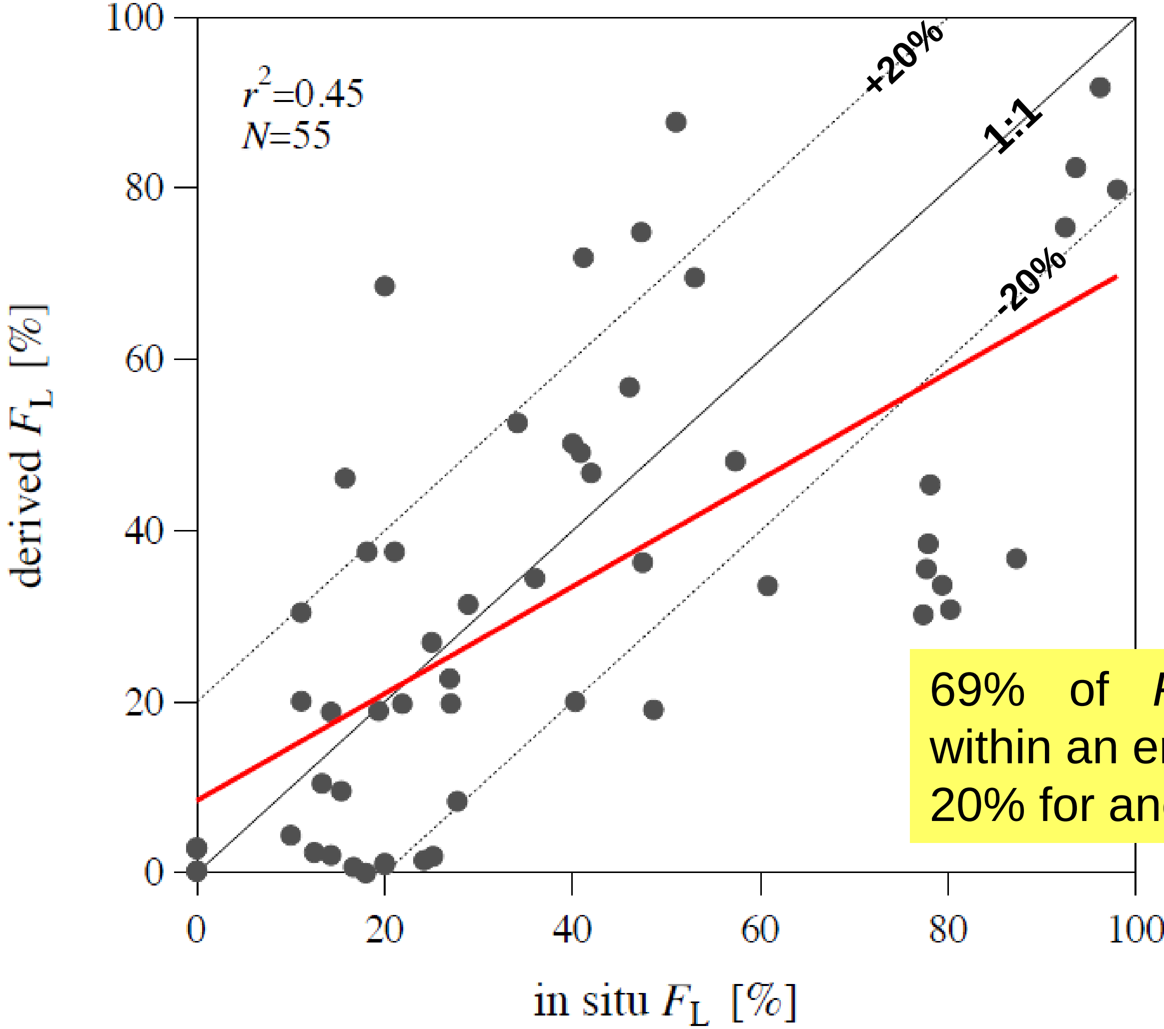
Results: Performance of absorption based primary production model (ABPM)





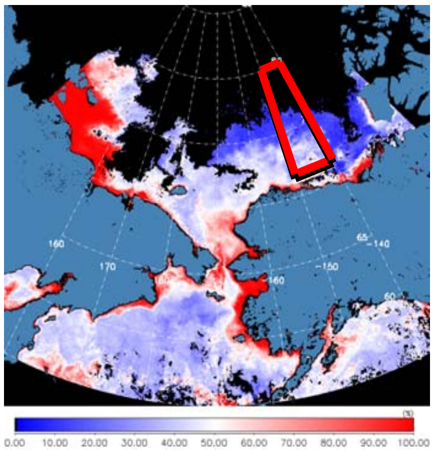
There are less effects of high CDOM and turbid waters near coast and river mouse. Estimated primary production are comparable level to historical values.

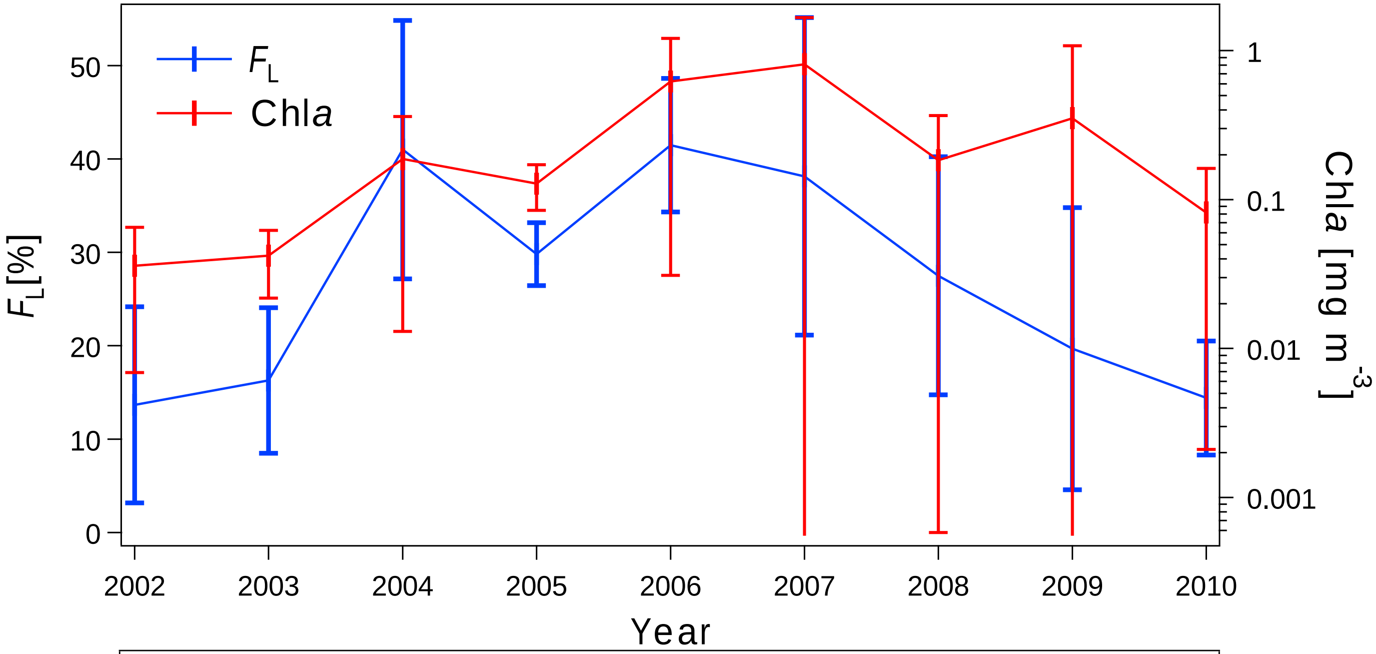
Results: Performance of phytoplankton size deriving model (SDM)

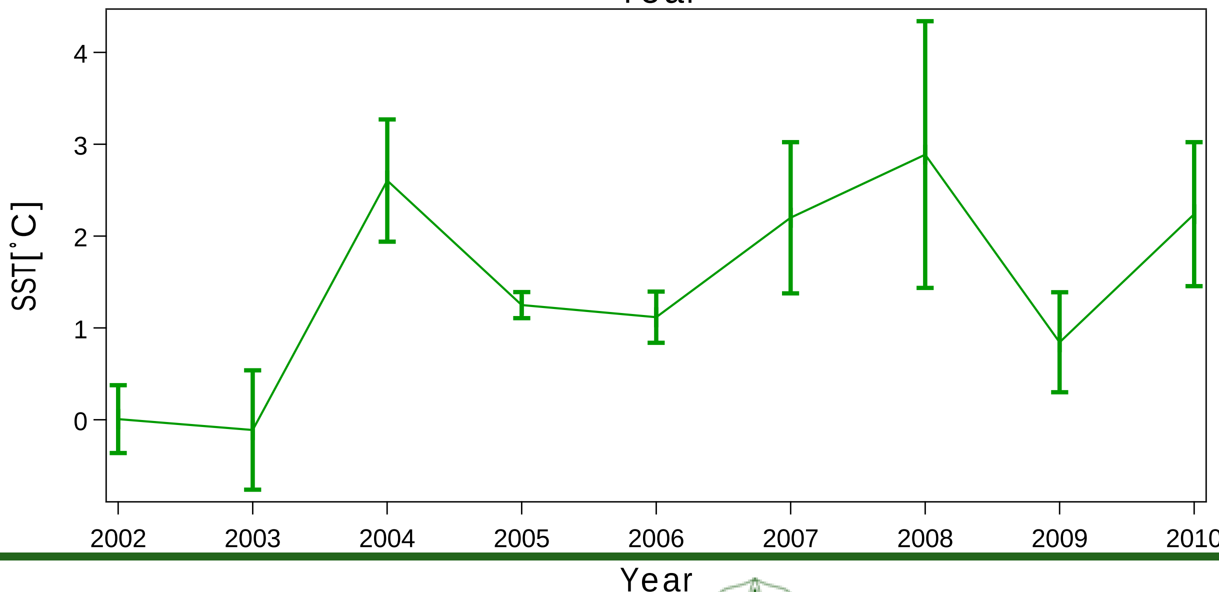


69% of F_L values are within an error range of +/-20% for another dataset.

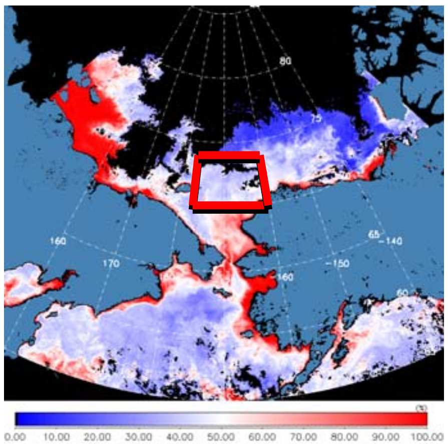
Canada Basin in August

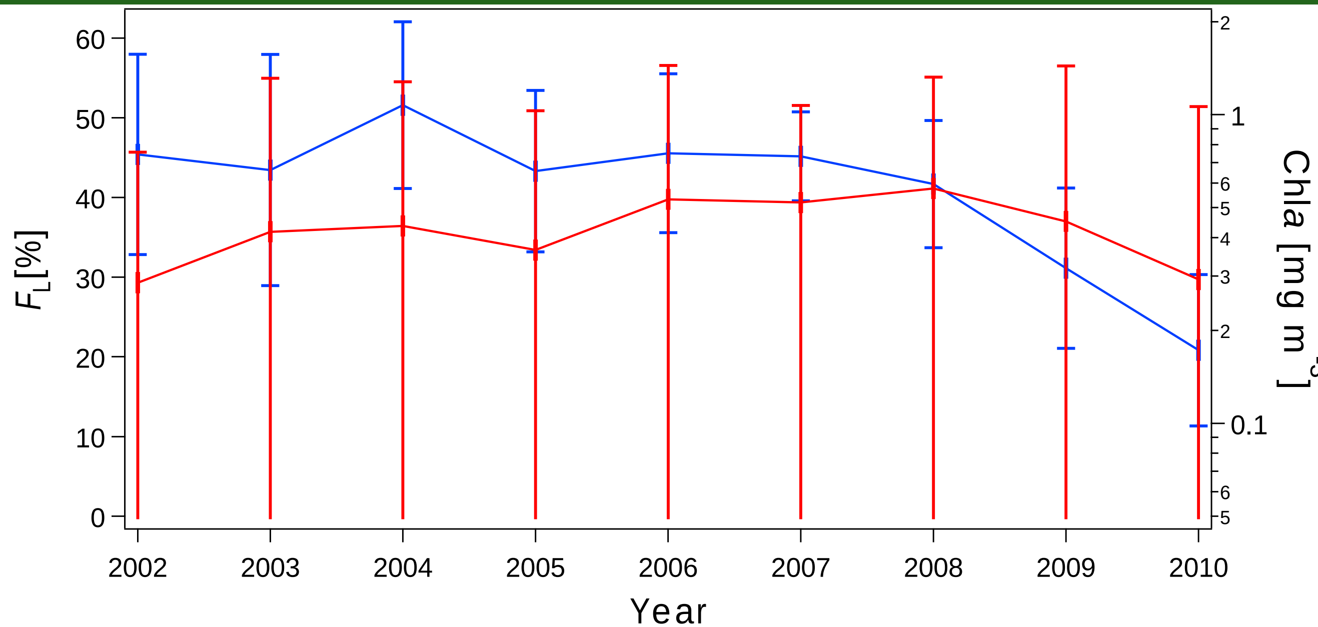


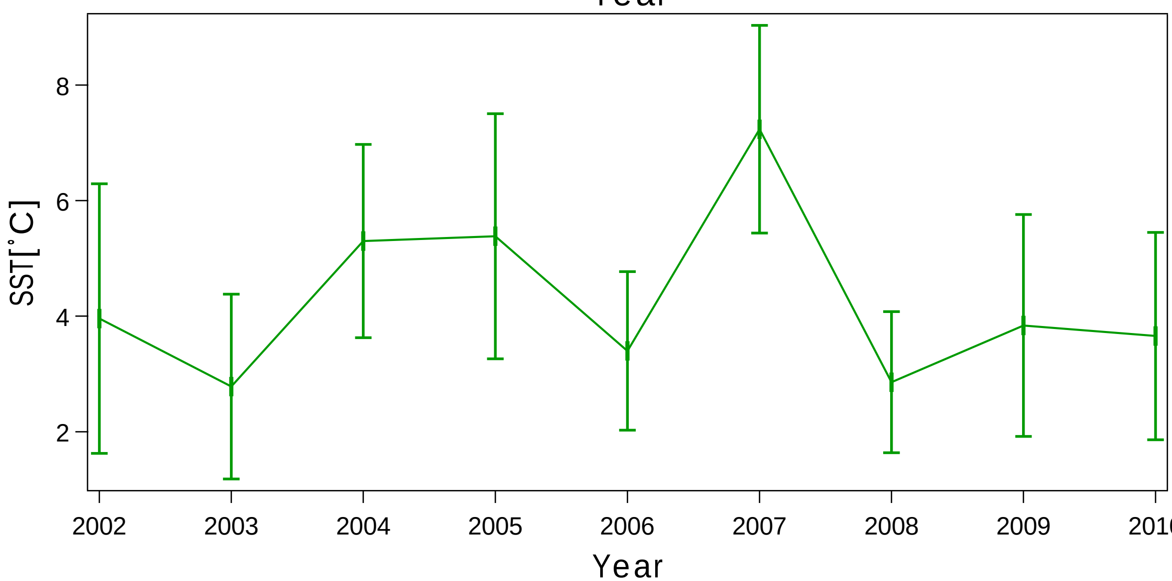




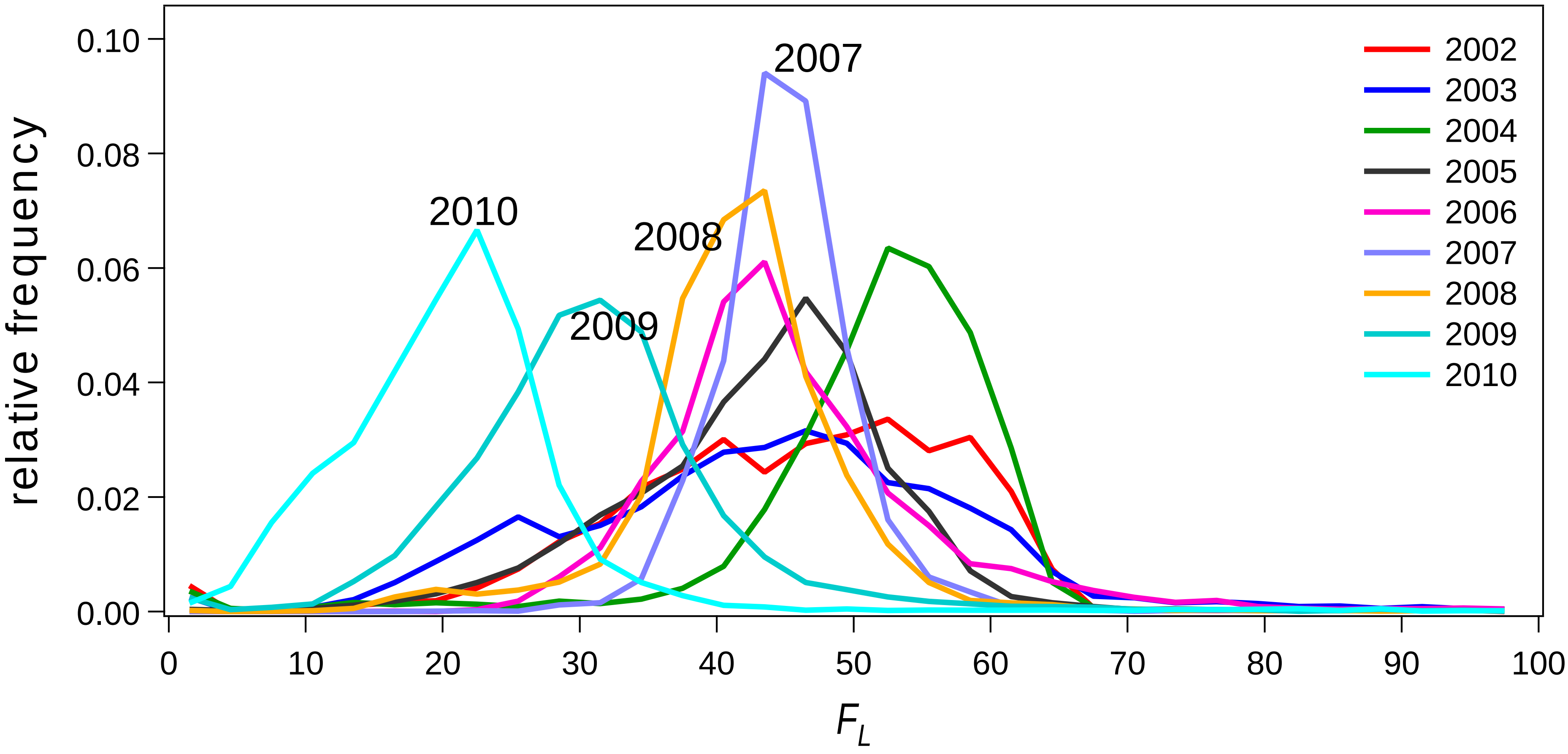
Northern Chukchi Shelf in August





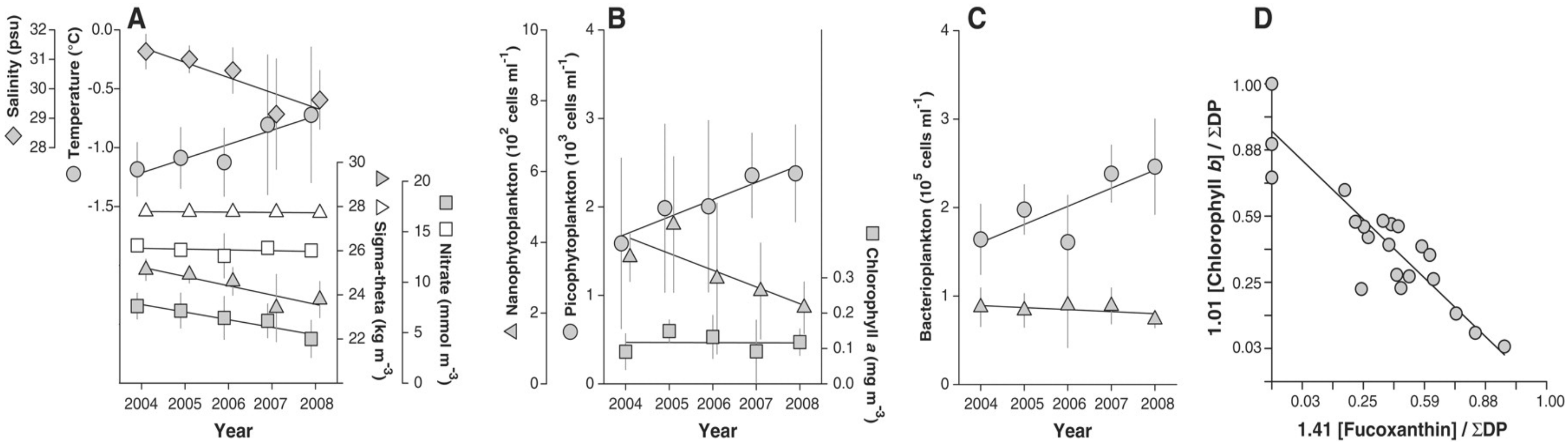


Histogram of F_L in the Northern Chukchi Shelf in August



Increase of small size phytoplankton community with warming and freshen

(Li et al., 2009: Science 326)



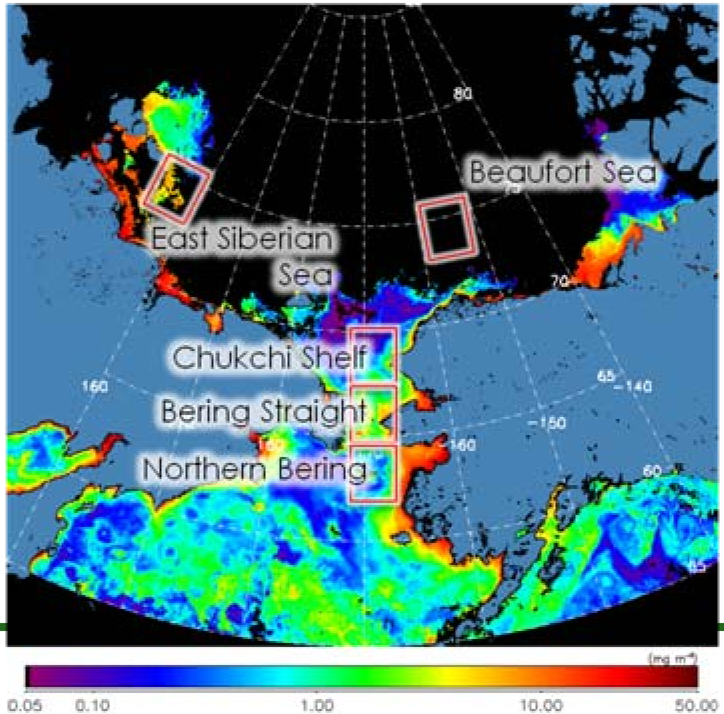
solid: upper ocean
open: deep ocean

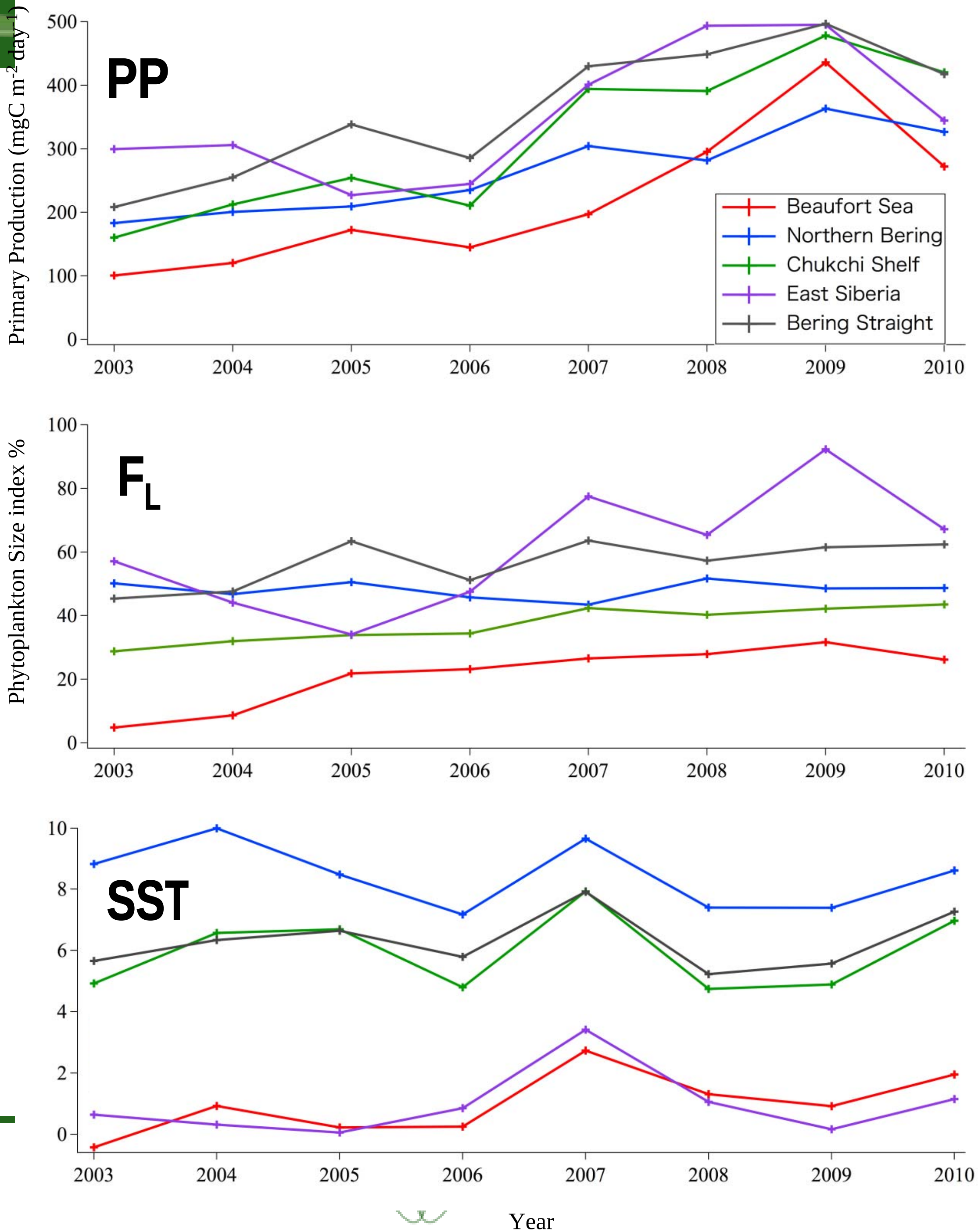
upper ocean

●: upper ocean
▲: deep ocean

Interannual variability in PP, FL & SST in September

- Significant increase in PP and size index (r^2=0.59, p<0.05)
- SST did not increase significantly.





Summary & conclusion

New models using IOPs showed good performance in the Arctic Ocean.

Smaller phytoplankton is increasing in August of recent years.

Both primary productivity and phytoplankton size in September increased.

These suggests increase in opportunities of phytoplankton grow in September due to less sea ice and resupply of nutrient by vertical mixing.