Assessment of the relationship between timing of sea-ice retreat and phytoplankton community size structure derived from remote sensing in the Bering and Chukchi Sea shelf region

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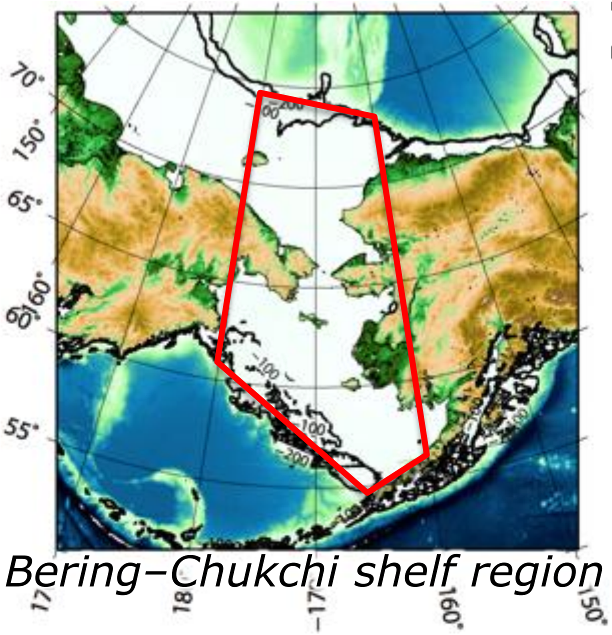
Introduction



Bering–Chukchi shelf region

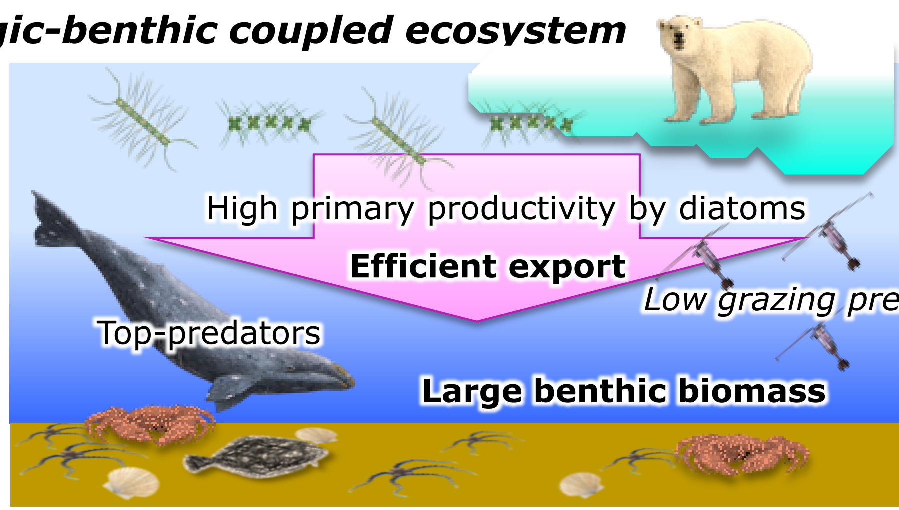
Study area:
Chukchi & Bering Seas shelf region
(160–180°W, depth < 100 m)

- Seasonal ice zone
- Complex water mass
- Shallow bottom depth
- Massive algal production during spring–summer
- Supports high benthic & grazers biomass
- Grazing field for higher trophic level animals

One of the most biologically productive sea in the world

(e.g. Coachman et al., 1975, Coachman, 1986, Springer and McRoy., 1993, Springer et al., 1996, Grebmeier, 2006)

Pelagic-benthic coupled ecosystem

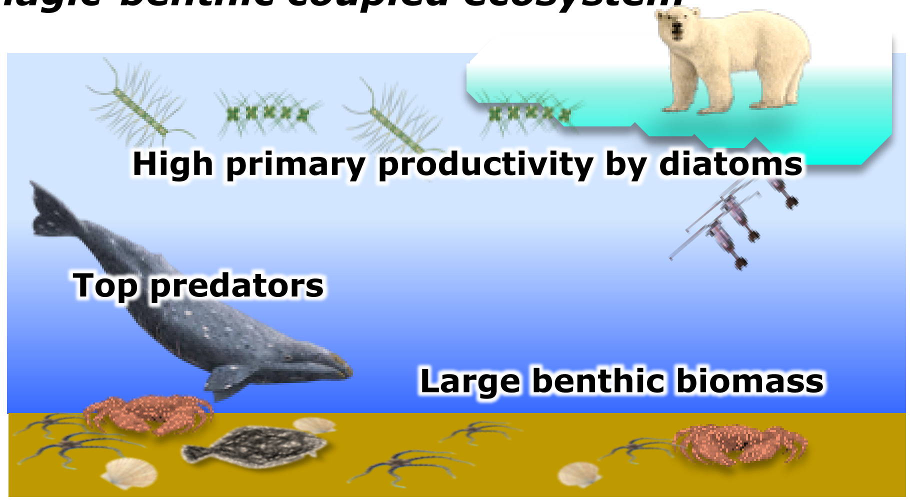


Introduction

Recent climate change

(e.g., change of sea-ice dynamics, ocean warming)

Pelagic-benthic coupled ecosystem



Ecosystem structure change??

Changes in ecosystem have been reported

- Northward shift in the species distribution in the Bering Sea (Grebmeier, 2011 & references)
- Increase of pelagic primary production in the Arctic Ocean (Arrigo et al., 2008; 2011)
- Less productive in the Beaufort Sea (Nishino et al. 2011)

- Further evaluation of impacts on the ecosystem is required
- <u>Ocean color remote sensing</u> can contribute to monitoring of spatio-temporal responses of phytoplankton to the environmental changes

Introduction

Timing of sea-ice retreat & phytoplankton bloom

- Contribute to bloom timing (e.g. Hunt et al. 2002, Perette et al. 2010)
- Important for recruitment of secondary producers (e.g. Hunt et al. 2002, 2011)
- the retreat and bloom timing are changing (Kahru et al. 2010, Ji et al. 2012)
- Retreat timing can alter summer time algal composition (Fujiwara et al. 2014)

Little is known about the Bering & Chukchi Sea shelf region (e.g. timing and magnitude)

Aims

The size & production are important factor for energy transport to higher trophic levels

- How phytoplankton community size structure responses to change of sea-ice retreat timing and related environmental variables??
- How the community size structure and the retreat timing affect annual primary production??

Materials & Methods

Development & application of new ocean color algorithms

- Ocean color remote sensing can be a powerful tool to assess spatio-temporal response of phytoplankton to climate change

⇔Arctic water is optically complex (Cota et al. 2003, Matsuoka et al. 2007, 2011, Naik et al. 2013)

- **Absorption based Primary productivity model (ABPM)**

  (Hirawake et al. 2011-PB, 2012-ICESJMS)

  →Estimates primary productivity optimized for the Pacific side Arctic waters

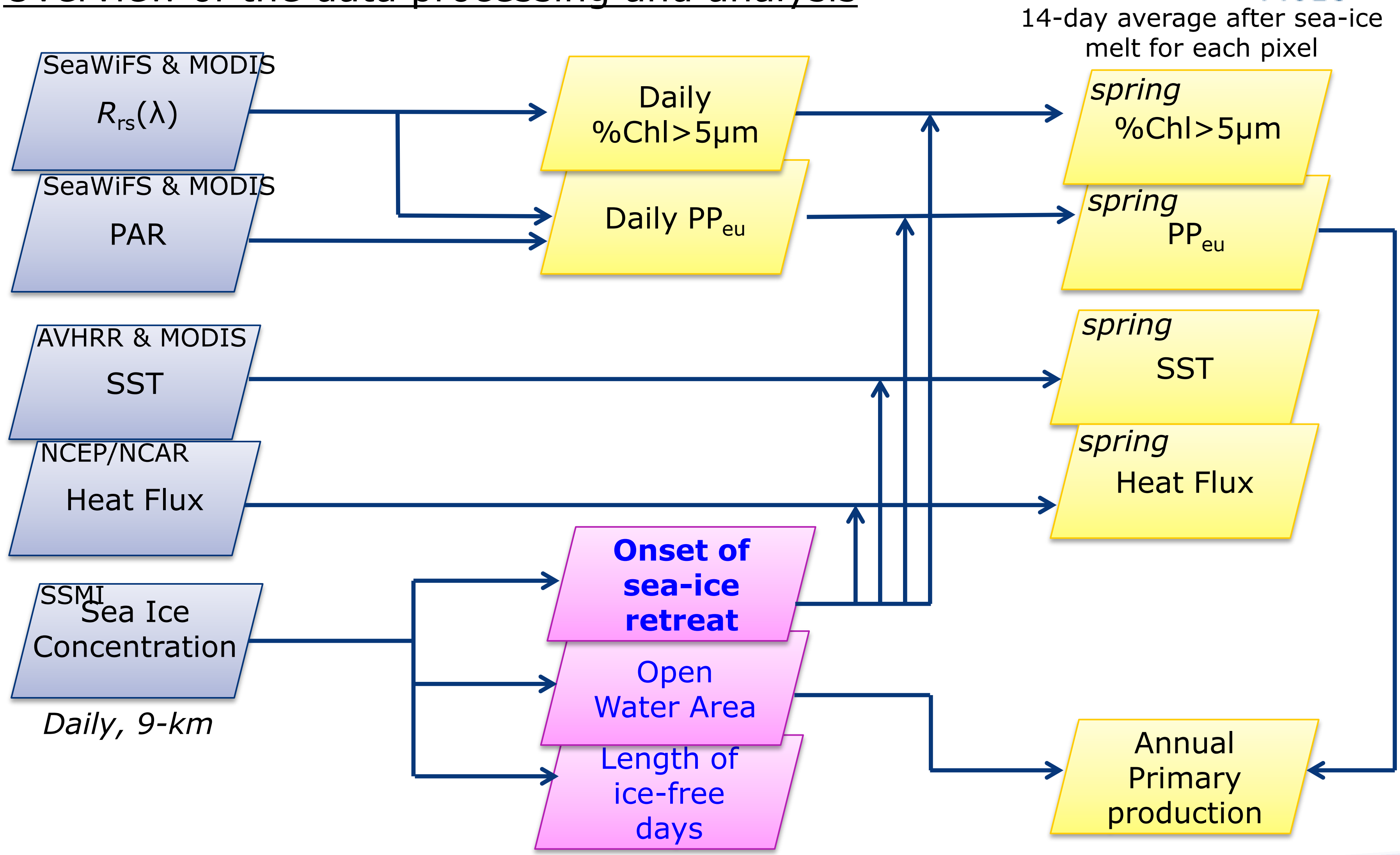
- **Size derivation model (SDM)**

  (Fujiwara et al. 2011-BG)

  →Estimates phytoplankton community size composition (**%Chla$_{>5\mu m}$**) for the western Arctic waters using optical properties (i.e. spectral absorption and backscattering)

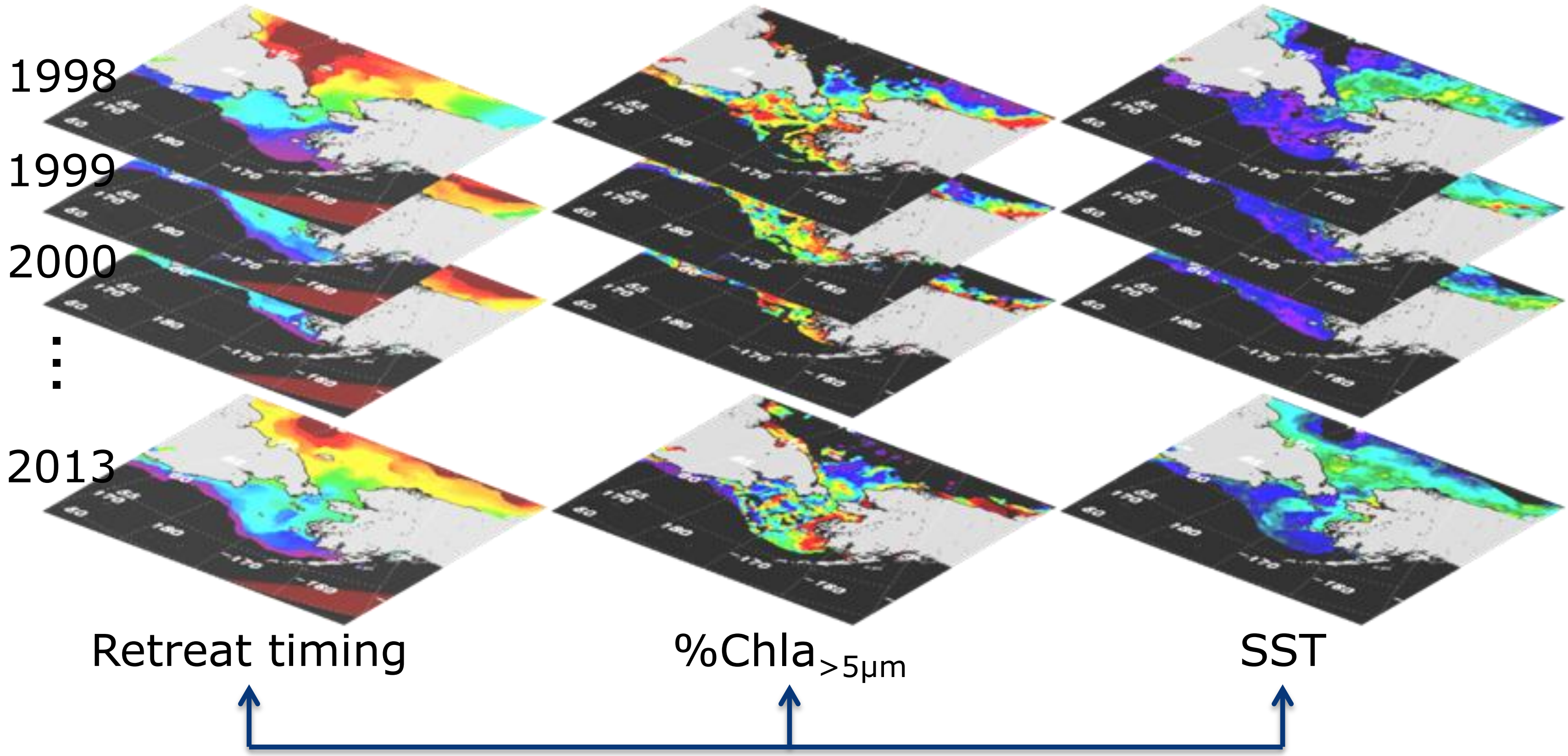
Materials & Methods

Overview of the data processing and analysis



Materials & Methods

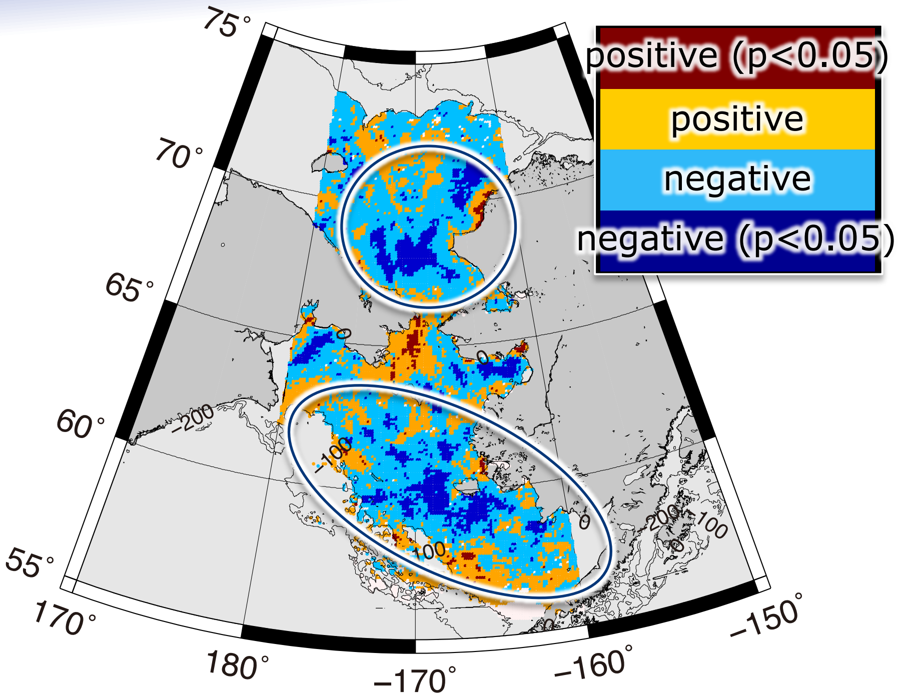
Spatial correlation analysis



Calculate rank-correlation coefficient for every one by one pixel between the 16-year time series of sea-ice retreat timing, phytoplankton variables and environmental variables

Assess how phytoplankton size & production vary with sea-ice retreat timing

Results & Discussion



Distribution of correlation coeff. (timing retreat vs %Chla$_{>5\mu m}$)

Distribution of negative correlation coefficient dominates (~70% of the area) in the shelf region (~18% was significant ($p<0.05$))

Earlier ice-retreat leads increase of larger phytoplankton (e.g. diatoms) after sea-ice retreat

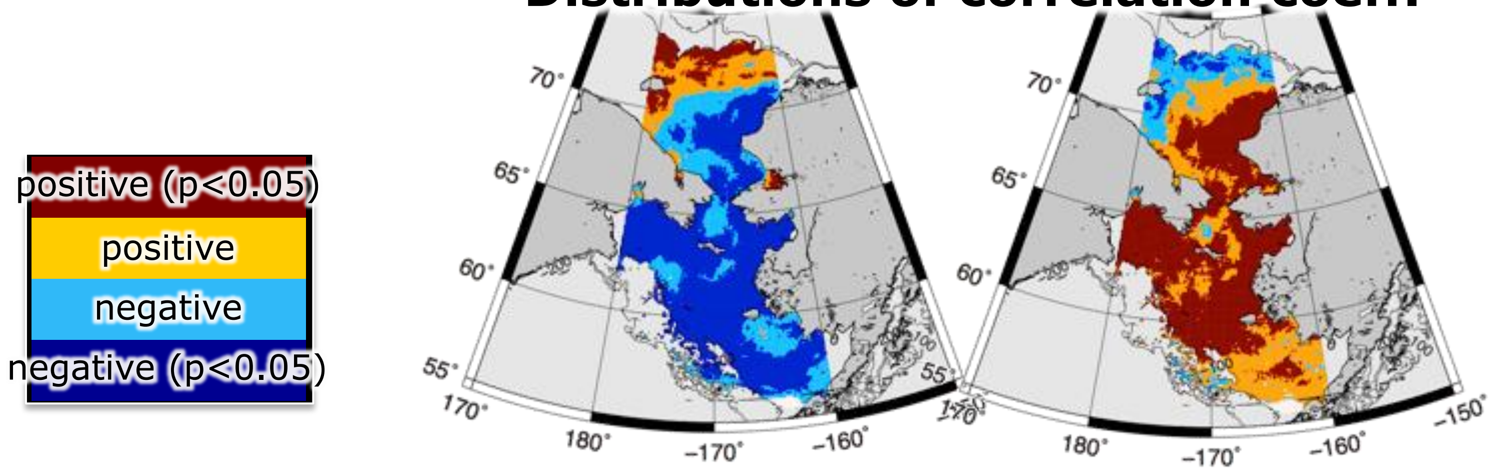
It is suggested that some control factors change corresponding to the sea-ice retreat timing

- Mechanism of Nutrient supply ??
- Under water light ??

Results & Discussion

Why earlier sea-ice retreat causes increase of larger phytoplankton??

Distributions of correlation coeff.



(timing retreat vs heatflux) (timing retreat vs SST)

Heat flux & SST: a proxy of stratification

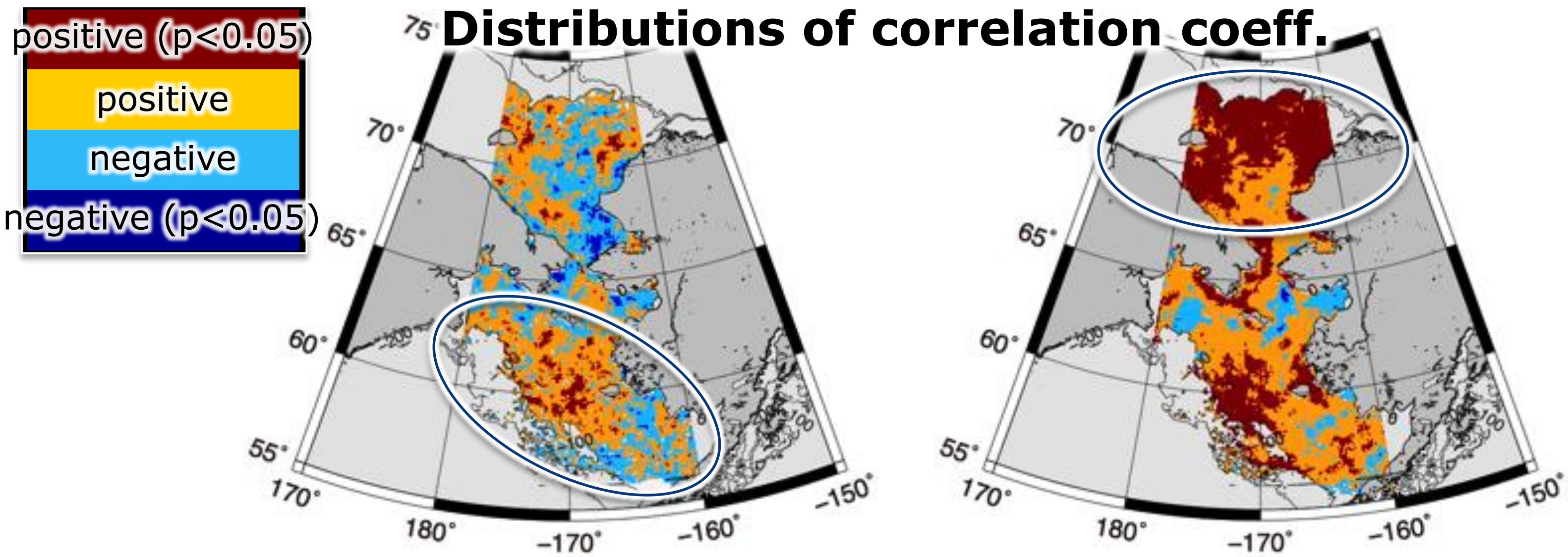
- 84% of the area showed negative ρ for heat flux, and positive ρ for SST (81%)
  ⇒Earlier sea-ice retreat causes colder SST and larger heat flux
  - i.e., The early retreat delays stratification due to less heat input, and vice versa (low air temperature & weak radiation during early melted season)
  - Continuous nutrient supply from below can be expected in the early retreat years during spring
- Under-ice bloom is likely to occur in the late retreat years
  - Sufficient light penetration into under ice can be expected in late retreat years (thin ice and strong radiation near summer solstice)
  - Utilization of nutrients by under-ice bloom <u>before open water bloom</u> in late retreat years

(Arrigo et al., 2012, Lowry et al. 2014)

Results & Discussion

What contributes to annual primary production in the shelf area??

Distributions of correlation coeff.

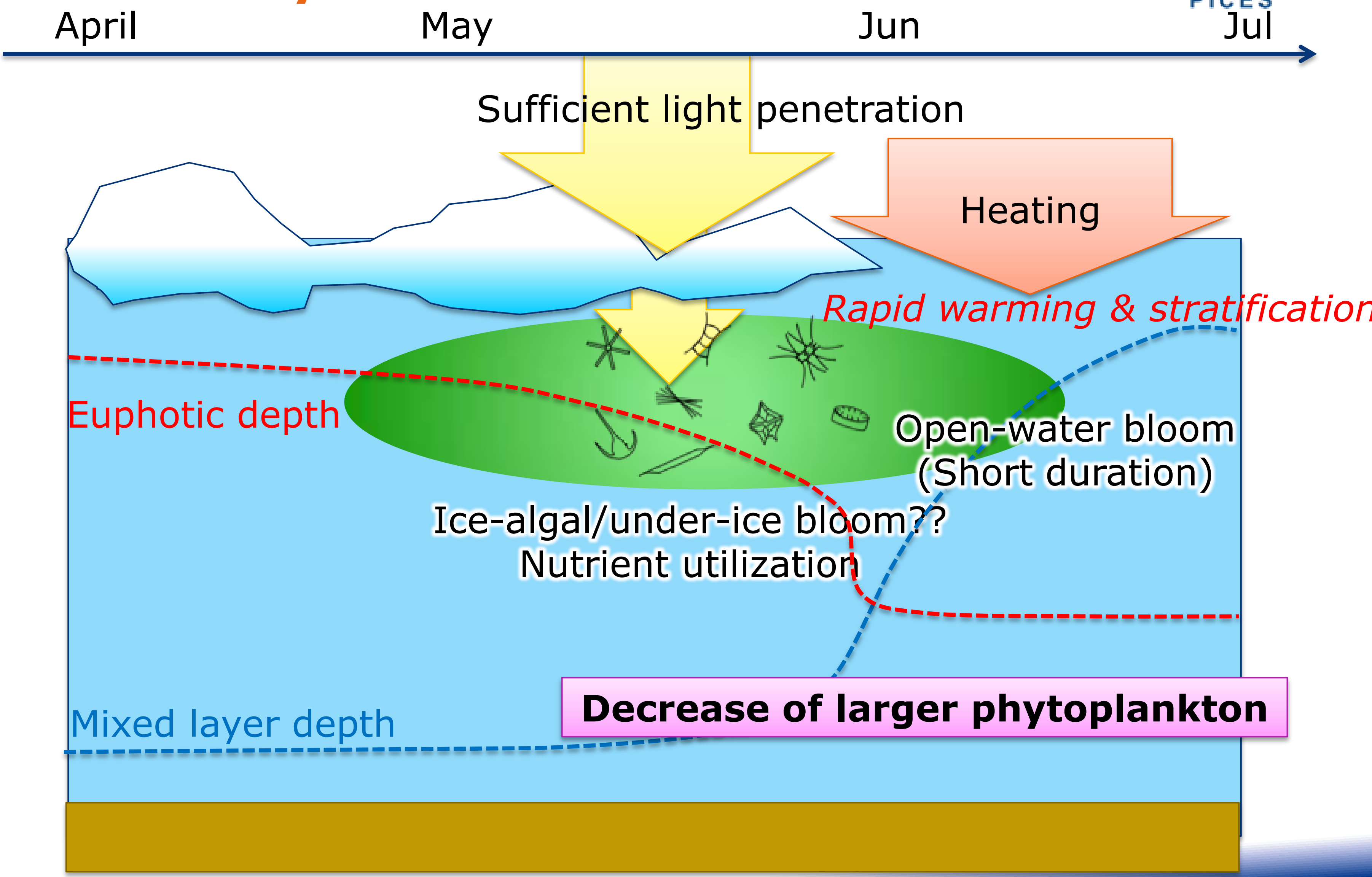


(%Chla$_{>5\mu m}$ vs APP) (length of open-water period vs APP)

- Open-water period controls APP especially in the northern part of the shelf
  (e.g., Arrigo et al. 2008, 2011, Pabi et al. 2008)
- Phytoplankton size composition (higher productivity of large groups) during spring is also important especially in the Bering Sea shelf region

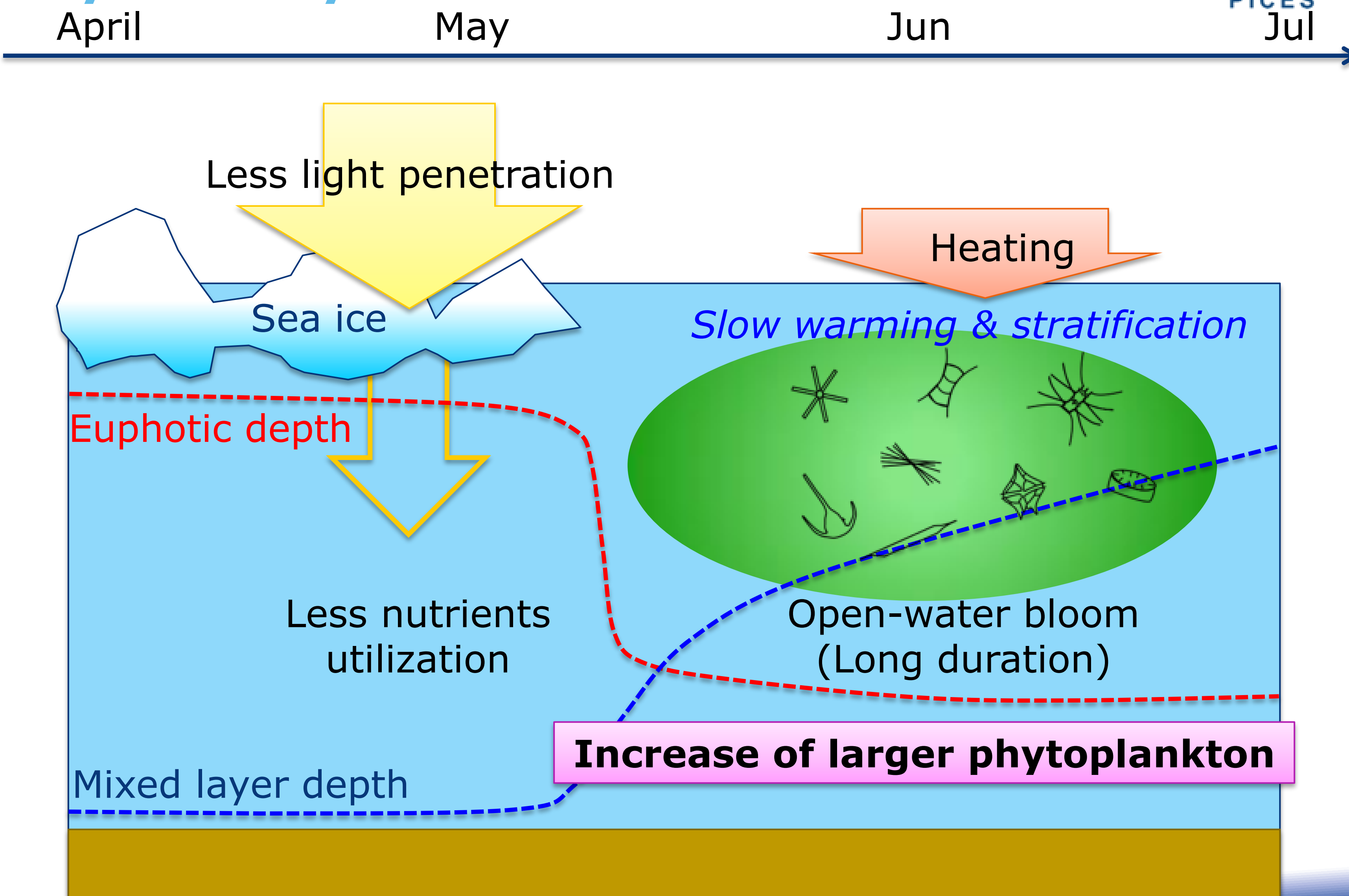
Summary

Late retreat years



Summary

Early retreat years



Conclusion & Future works

PICES

- Timing of sea-ice retreat contributes to phytoplankton community size composition during spring
  - Shoaling speed of mixed layer depth
  - Under-ice and/or ice-algal bloom ⇔ open-water bloom
- Not only the length of open-water period but also spring phytoplankton size structure (productivity) contribute to annual primary production especially in the southern part of the shelf area
- Remote sensing is a powerful tool to clarify spatial relationship between environmental and phytoplankton variables

Future works

- Evaluation of the bloom mechanism (in-situ observation / modeling)
- Assessment of the contribution to annual PP of summer and fall algal community and production (cf. Occurrence of fall bloom is increasing (Ardyna et al. 2014))
- How the timing & magnitude of the bloom affect higher trophic level organisms?? (Zooplankton, Fish larvae, Benthos..,)

Thank you for your attention!