Application of GCOM-C datasets to assess the responses of phytoplankton communities to recent environmental changes in the Pacific side Arctic Ocean

- Application study of new ocean color algorithms for GCOM-C (**Primary productivity** & **PFTs**)
- Case study for the Pacific side Arctic
- Time series study using SeaWiFS (1998–2007), MODIS (2002–) and should be expanded to GCOM-C (2016?–)

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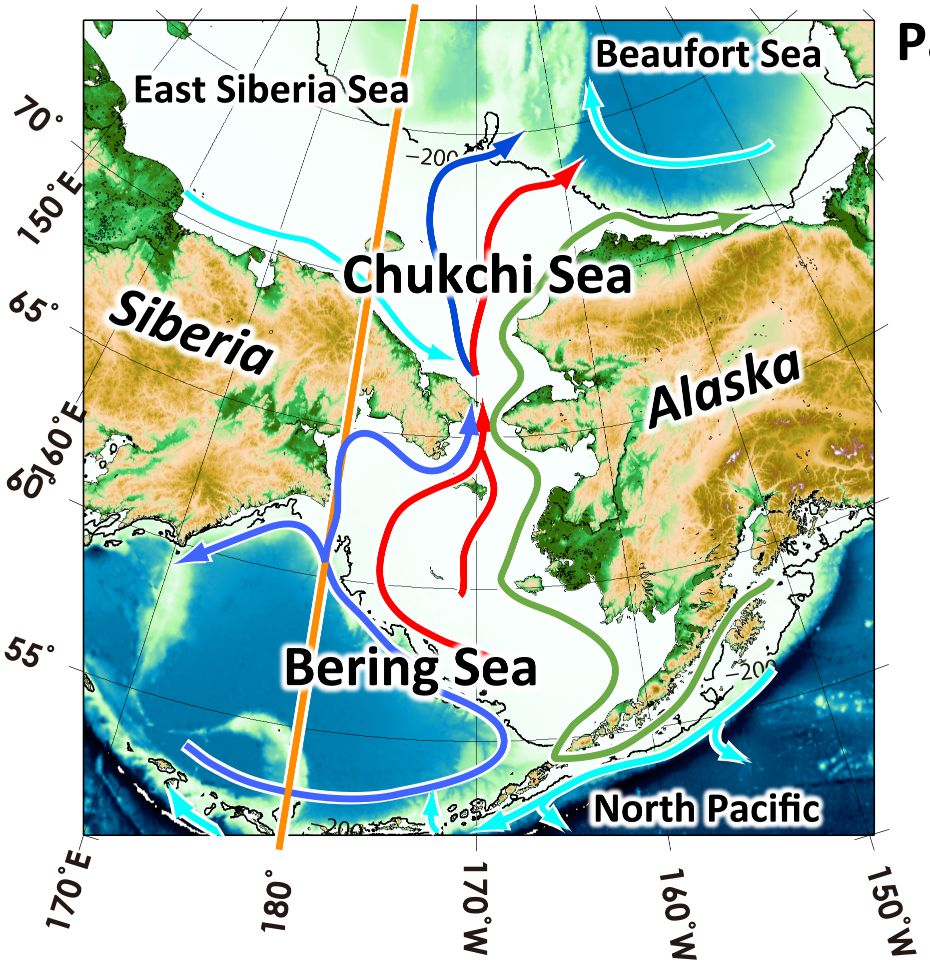
Pacific side Arctic Ocean



(Coachman et al., 1975, Coachman, 1986, Springer and McRoy., 1993)

Pacific Side Arctic (Western Arctic)

Chukchi & Bering Seas

(55°N–80°N、150–180°W)

3 dominant currents

- Anadyr Water
- Bering Shelf Water
- Alaska Coastal Water

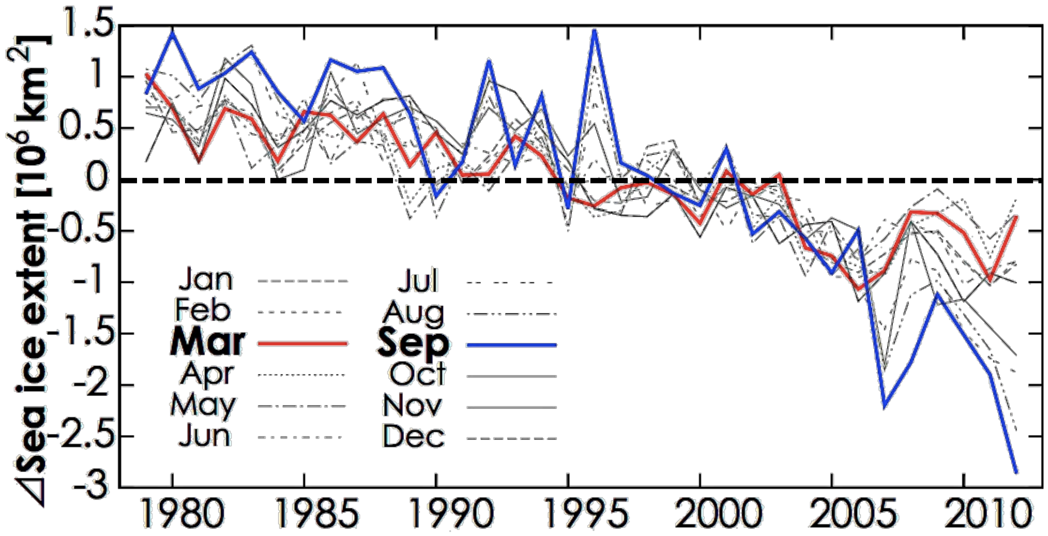
Seasonal Ice extent

Oct–Jun in the Chukchi Sea

Nov–May in the Bering Sea

One of the most biologically productive sea in the world

Recent decline in the Arctic sea-ice



1979–2012 (SMMR & SSMI)

- Dramatically declining in summer (37.5% decreased in Sep)

Changes in ecosystem have been reported

- Northward shift in the ecosystem in the Bering Sea (Grebmeier et al.,2006)
- Increase of pelagic primary production (Arrigo et al., 2008; 2011)

- Further evaluation of Impacts on the ecosystem is required
- Ocean color Remote sensing can contribute to monitoring of phytoplankton responses to the decrease of sea ice

Ocean Color Remote Sensing for the Arctic

- Why in the Arctic?
  - The arctic ecosystem is responsive and vulnerable to climate change
  - In-situ sampling by vessels is not easy because of the presence of sea-ice
  - There is a Lack of time series in in-situ data set
- Problems
  - Optical properties are unique (different from global properties)
  - Application of Global OC algorithms contain risks (Cota et al., 2003, Matsuoka et al., 2007)

✧ Improvement and optimization of the algorithms are needed

✧ An useful tool to monitor **phytoplankton production, biomass, community composition**

Importance of GCOM-C

- **Statistical evidence achieved from continuous time series data is crucial to predict the future Arctic ecosystem**
- **Multi-sensor analysis is important in the frequently cloud & ice covered polar waters**

Ocean Color Algorithms

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

  (Hirawake et al. 2011, 2012)

  →estimation of primary production optimized for the Pacific side Arctic waters

- **Size derivation model (SDM)**

  (Fujiwara et al. 2011)

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

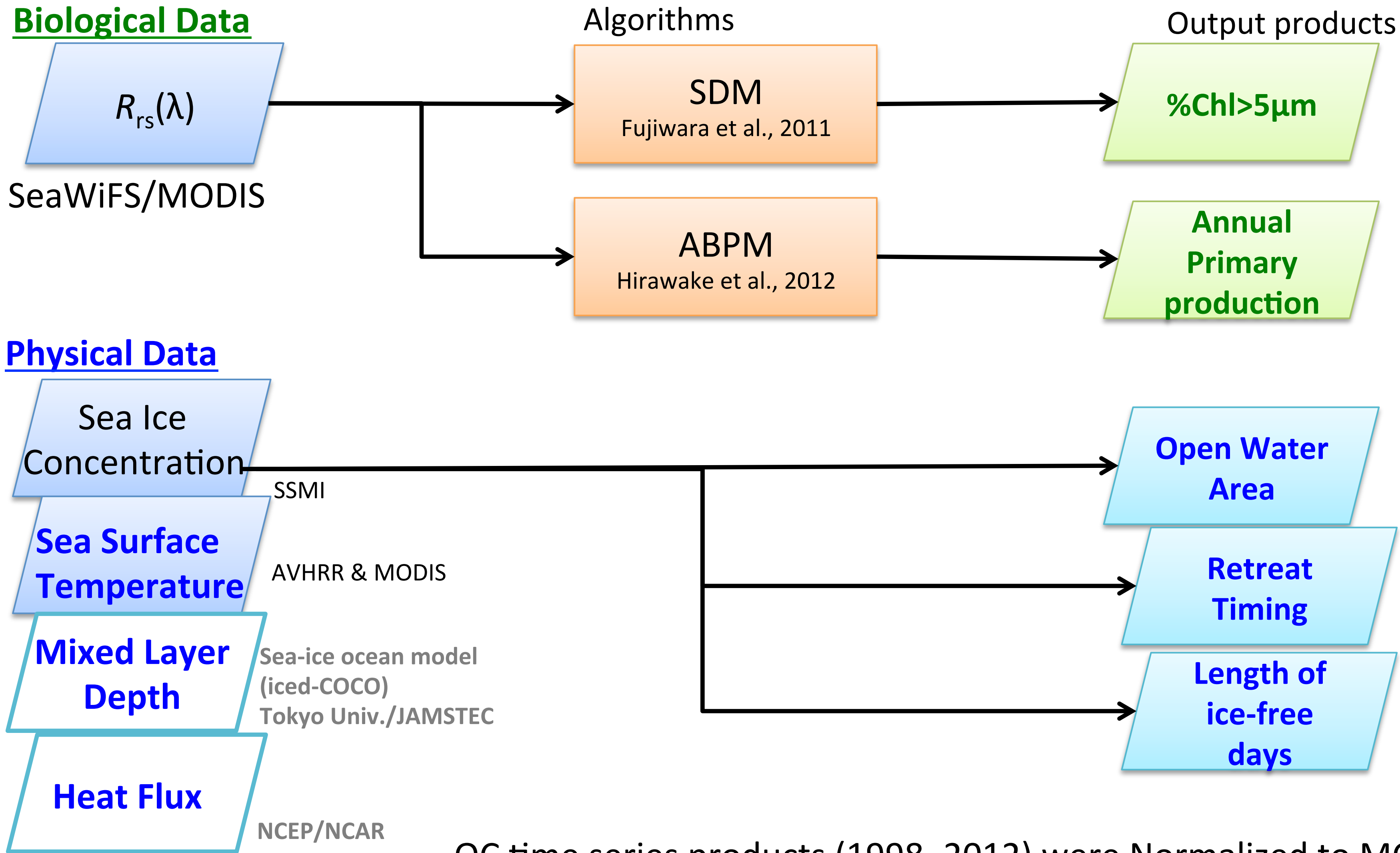
Evaluation & Improvement using in-situ dataset

→ Data obtained from 2 cruises in 2013 (under analysis)

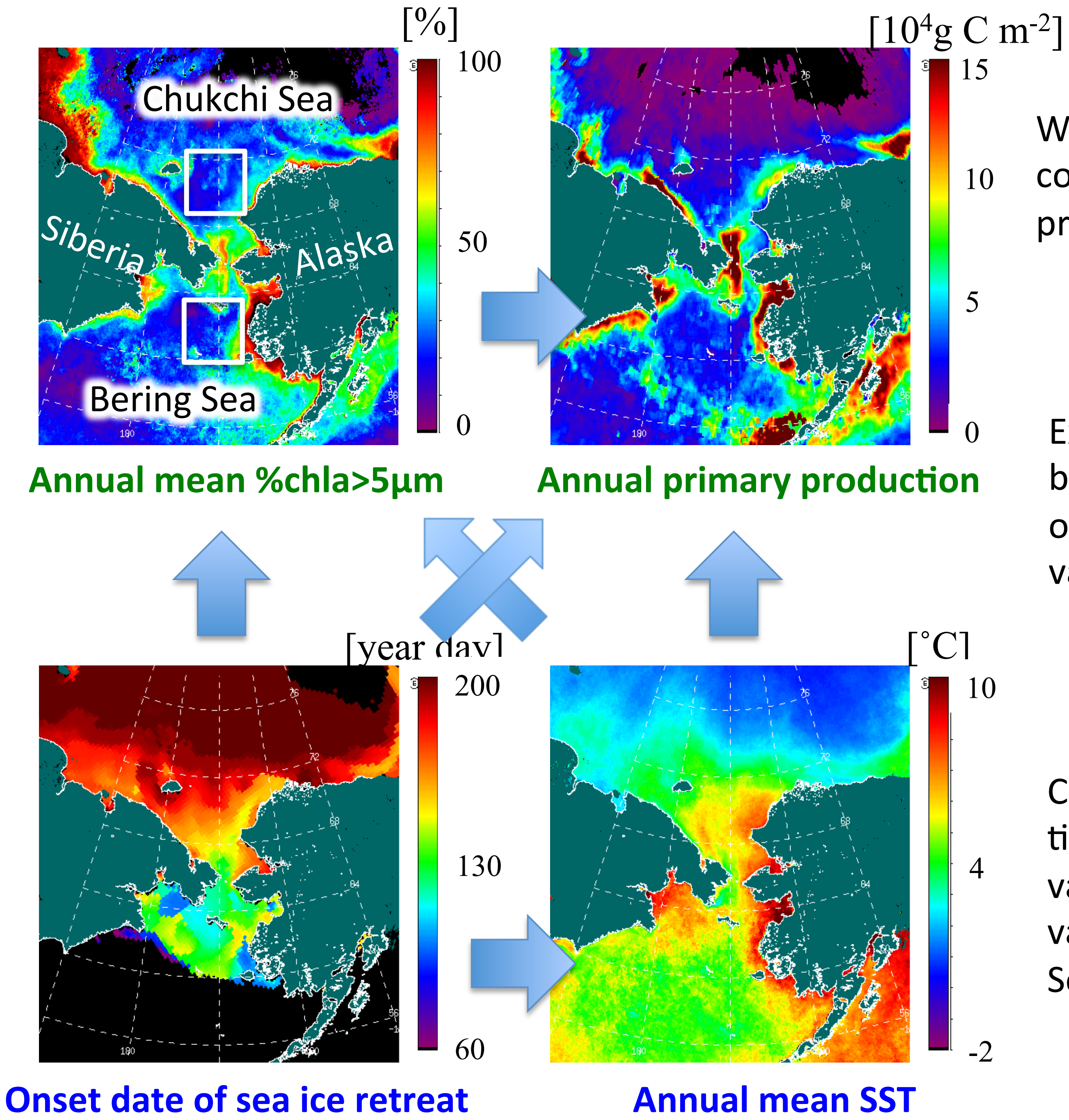
Objective and tasks

- to assess the responses of phytoplankton communities to recent environmental changes in the Pacific side Arctic Ocean
  1. Evaluate & improve current ocean color algorithms for the Arctic waters
  2. Apply the algorithms to long time series dataset
  3. Compare variability of ocean color products with environmental factors (e.g. sea ice, temperature, mixed layer depth)

Overview of the data processing and the analysis



OC time series products (1998–2012) were Normalized to MODIS

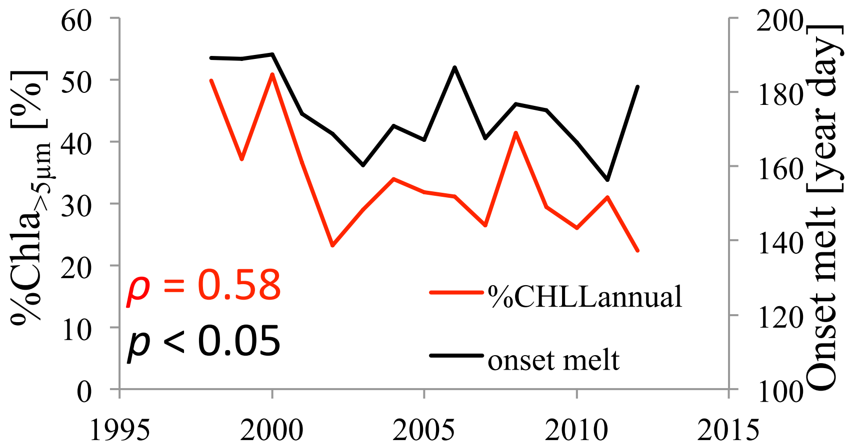


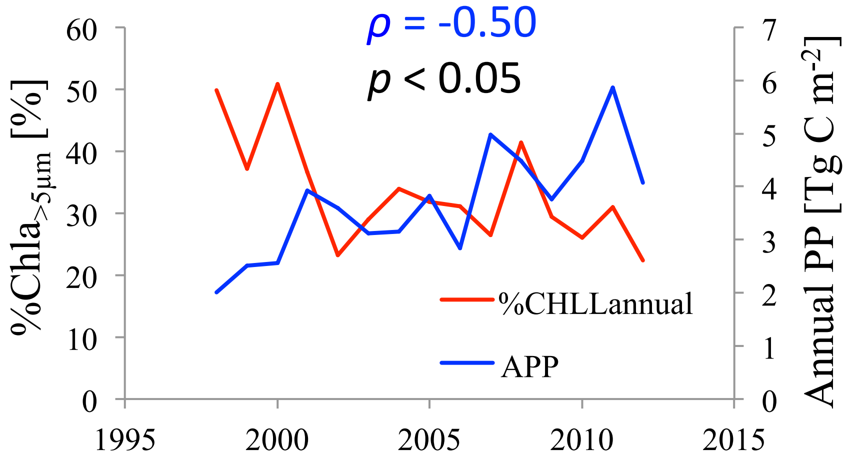
What controls phytoplankton community composition & primary production?

Examine the relationships between temporal variability of biological and physical variables

Correlation analysis between time series phytoplankton variables and physical variables for (1) the Chukchi Sea and (2) Bering Sea

Variability in the Chukchi Sea





%Chla>5µm has positively correlated with sea ice melt timing (& negative with SST)

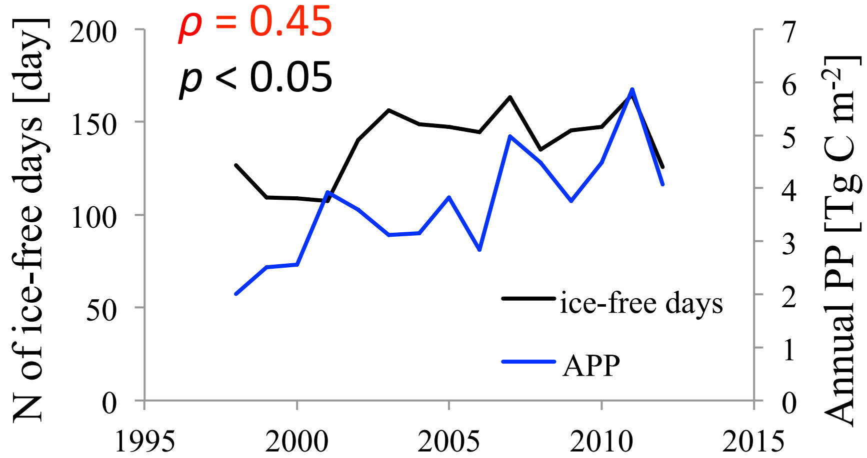
→Large phytoplankton decrease in early ice-retreat warm years

➔ reduction of nutrient supply due to thermal stratification?? (cf Doney et al., 2006)

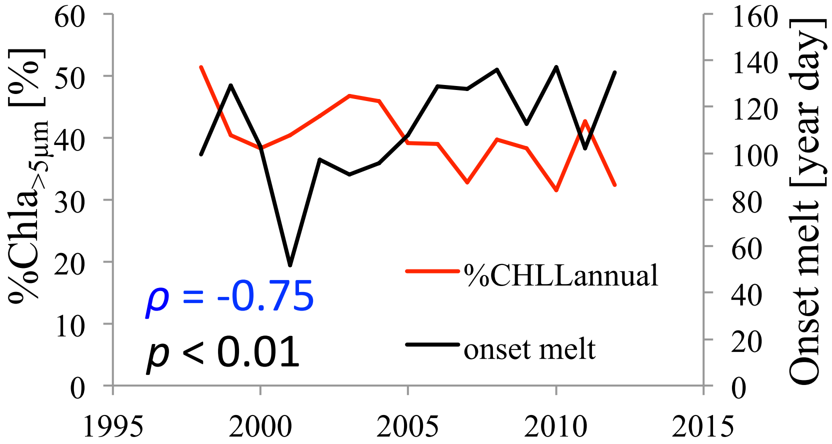
⇔%Chla>5µm has negatively correlated with APP (inconsistent with in-situ data)

APP showed positive correlation with number of ice-free days

Length of growing season is much important for APP



Variability in the Bering Sea



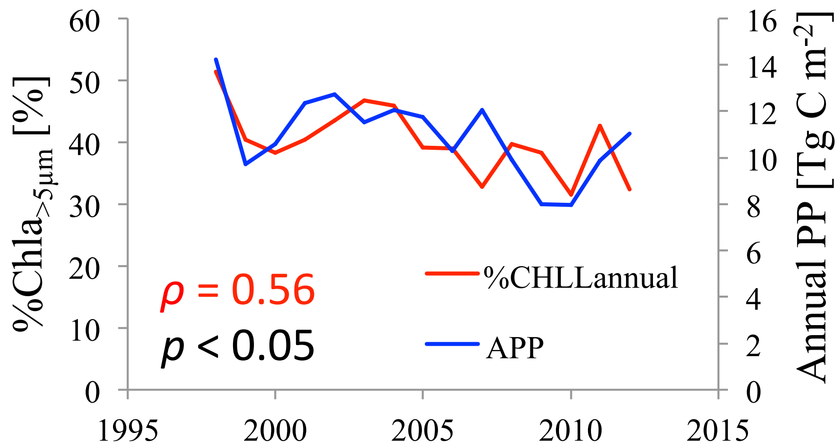
%Chla>5µm has negatively correlated with timing of sea ice retreat (co-occur with cold SST during spring *not shown*)

→Large phytoplankton decrease in cold spring years

Late ice retreat causes the formation of cold bottom water during summer
→ strong stratification denies nutrients supply from the bottom
(consistent with the trend of chla showed in Brown & Arrigo, 2013)

APP showed positive correlation with $\%Chla_{>5\mu m}$

Large sized (i.e. diatoms) contribute to variability of Annual Integrated PP



Summary 1

✧**Variability of phytoplankton size (%Chla>5μm)**

- Positive relationship with timing of sea ice retreat and negative with summer SST in **the Chukchi Sea**
  - →Large phytoplankton tend to decrease in early ice retreat years
  - ➔Thermal stratification co-occur with early ice retreat reduced nutrient supply (??)
- Negative relationship with the retreat timing & spring temperature in **the Bering Sea**
  - →Large phytoplankton tend to decrease in late ice retreat & cold years
  - ➔Cold bottom water co-occur with late ice retreat enhanced stratification and reduced nutrient supply from below (??)

Timing of sea ice retreat significantly contribute to the phytoplankton community size composition

➔**Further discussion using physical parameters is required**

(mixed layer depth, stratification index)

Summary 2

✧ **Variability of Annual primary production**

– Positive relationship with number of ice-free days in the Chukchi Sea (⇔negative with %$Chla_{>5\mu m}$)

➢ Growing area & season length is much important than phytoplankton community composition

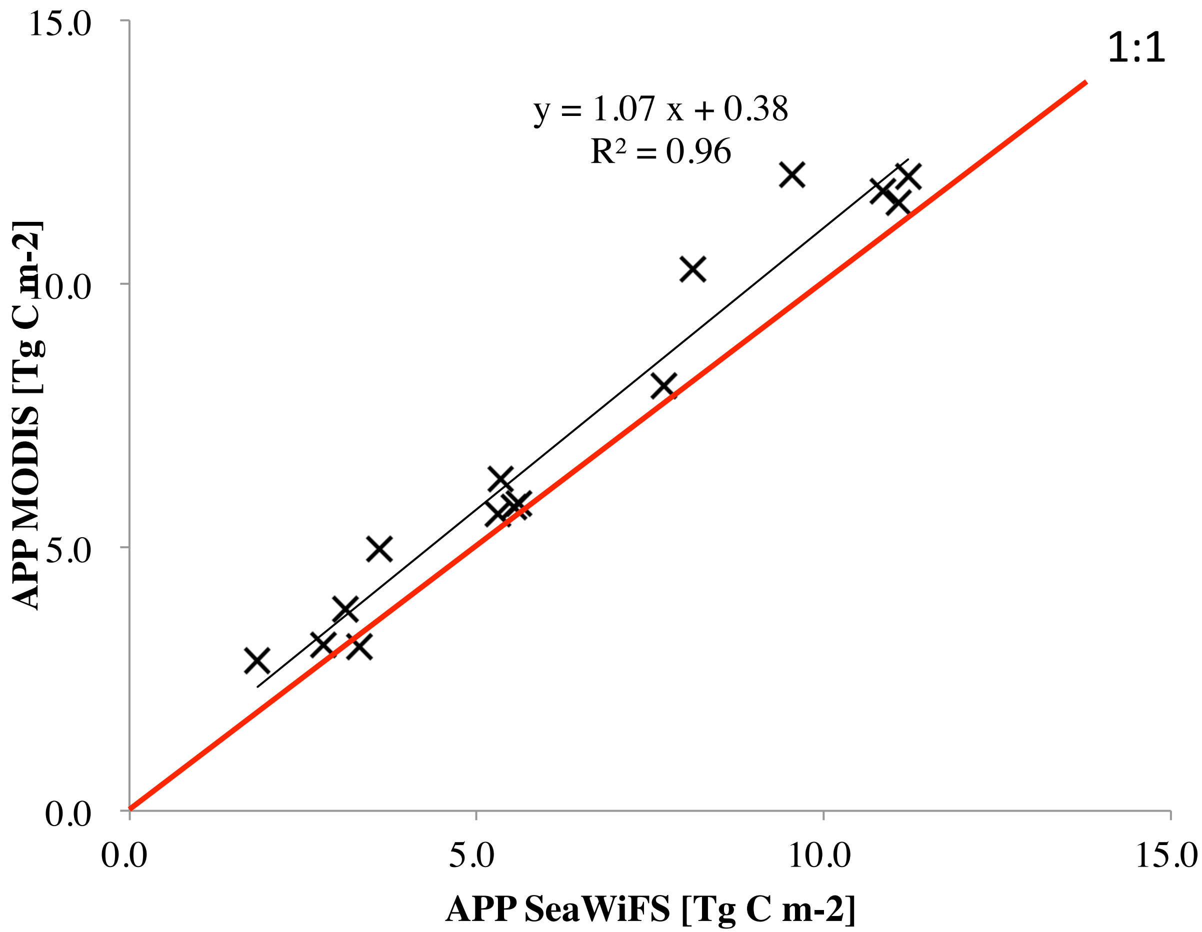
– Positive relationship with proportion of large phytoplankton (%Chla>5μm)

➢ Phytoplankton community composition is important factor for APP

Longer time series data will support the hypotheses and contribute to prediction of future ecosystem change

Progress of this study

- Dataset (satellite & models) [==========:70%]
  - Processing system has been prepared
  - Calculation of MLD or stratification index using COCO-model is required
- Dataset (in-situ) [==========:90%]
  - Analysis will be completed within a week
- Evaluation of Algorithms [==========:20%]
- Improvement of Algorithms [==========:20%]
  - In-situ Dataset is now under analysis
  - Expansion of target PFTs (size, groups e.g. diatoms)
- Application to the time series [==========:30%]
  - Timing of sea ice retreat is important factor to control phytoplankton assemblages
  - Further analysis & discussion are required comparing with environmental parameters (MLD, stratification index)
  - Setting of correction factor to standardize products between the sensors



Comparison of annual primary production calculated from SeaWiFS and MODIS for the Chukchi and Bering Seas

Validation of %Chla>5µm and PP

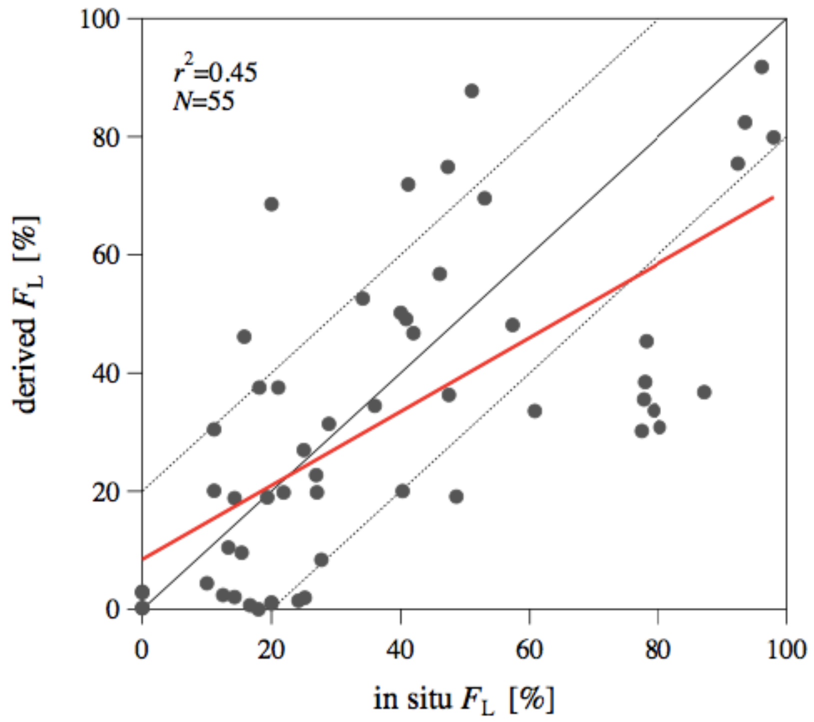


Fig. 3. Comparison of SDM-derived F_L and in situ F_L ($r^2 = 0.45$, $p < 0.0001$, RMSE = 22.7, $N = 55$). Solid red line represents the regression line (slope = 0.63, intercept = 8.46), the solid black line indicates the 1:1 line, and the dashed lines indicate the ±20 % F_L range with respect to the 1:1 line. 38 out of 55 validated data are correctly derived within ±20 % F_L range (success rate of 69 %).

Fujiwara et al. 2011BG

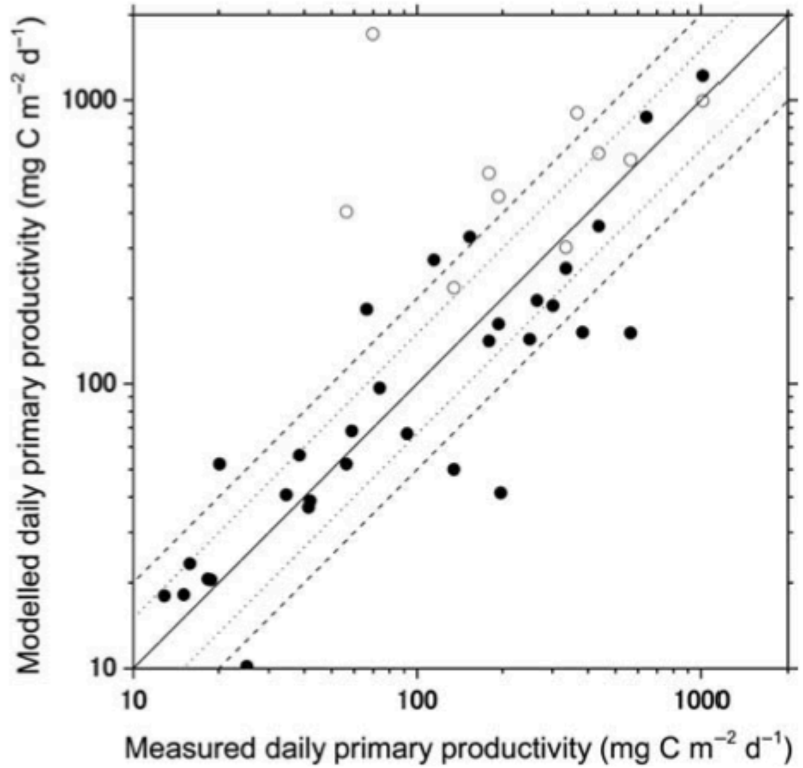


Figure 4. Comparison between measured and modelled daily primary productivity. Modelled data represented by solid circles were derived using *in situ* $R_{rs}(\lambda)$ determined by a spectroradiometer plus *in situ* PAR, and data represented by open circles were derived from MODIS $R_{rs}(\lambda)$.The solid line represents 1:1 agreement, and dashed and dotted lines represent factors of 2 and 1.5 relative errors.

Hirawake et al. 2012ICES-JMS

Comparison of %Chla>5µm and %Chla>20µm (microplankton)

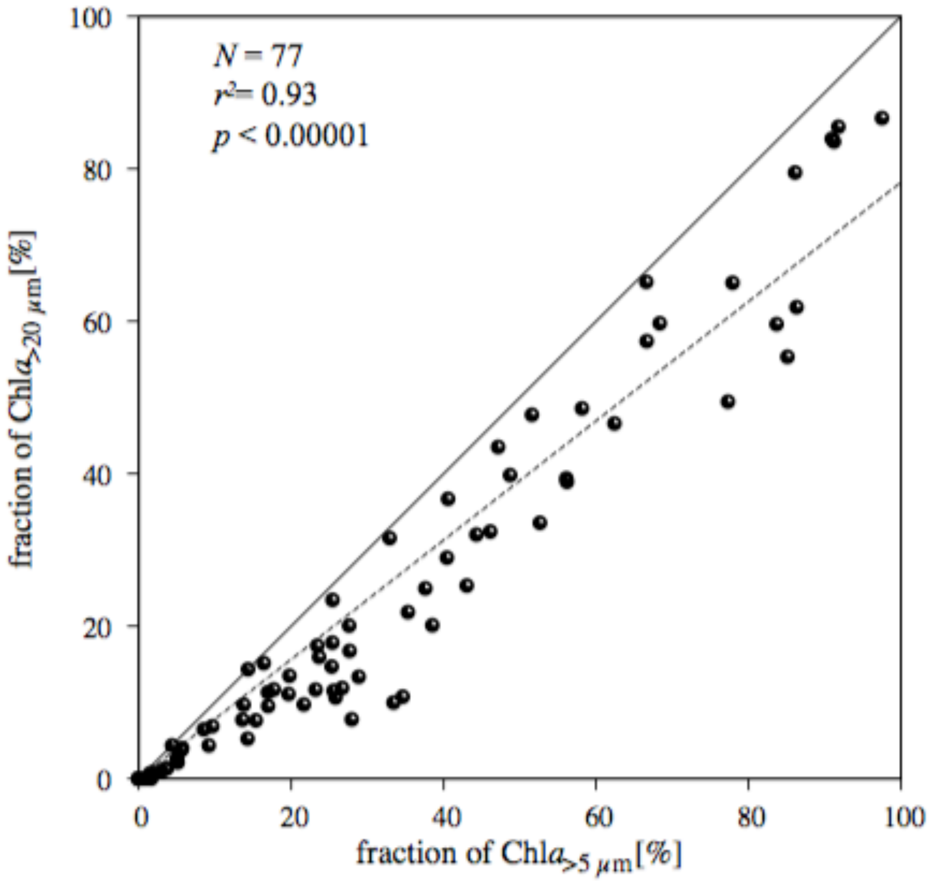
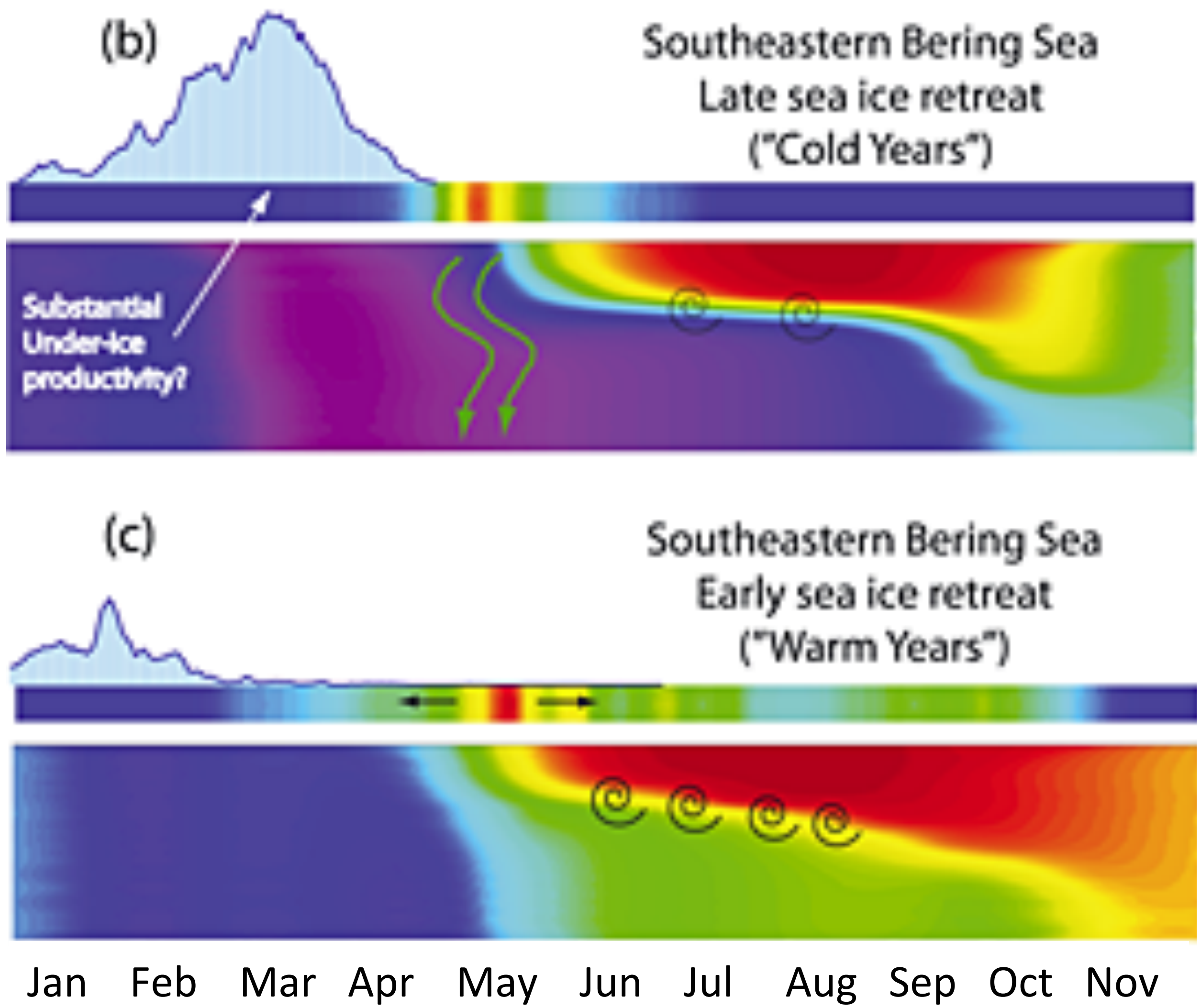


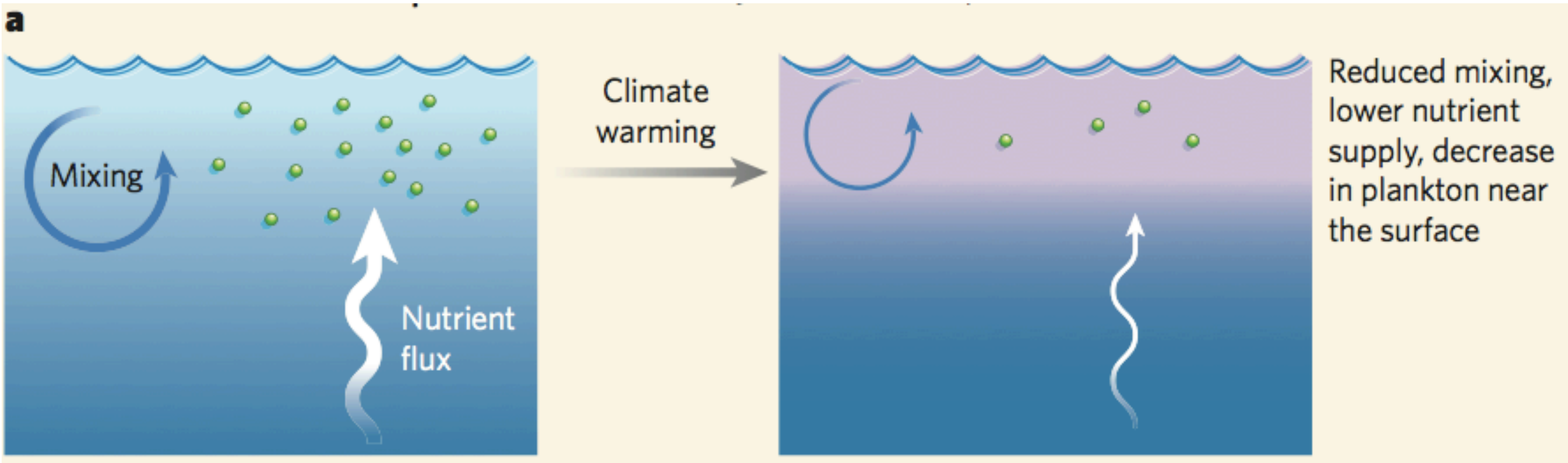
Figure 2.4. Comparison of contribution of Chl$a_{>5\mu m}$ to Chla_{total} and Chl$a_{>20\mu m}$ to Chla_{total}. Solid line indicates the 1:1 line and a dashed line indicates the regression line.

Formation of “Cold Pool” in the Bering Sea



Brown & Arrigo, 2013

Effect of thermal stratification on non-light limited sea in the warming world



Doney et al. (2006)