Satellite observations of phytoplankton bloom phenology in the Pacific Arctic

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Adequate monitoring of phytoplankton bloom phenology

As phytoplankton communities fluctuate over the course of days to weeks, traditional ship-based observations are suboptimal for monitoring time-series of phytoplankton biomass. Satellite remote sensing is a powerful and cost-effective tool for spatiotemporal monitoring of phytoplankton at high resolutions.

METHODS Retrieving phenology using a Gaussian function

Daily time series of satellite chla for 2003–2023 in seasonally ice-covered regions in the Pacific Arctic was modeled using a parametric Gaussian function. Spring bloom type was determined based on the resulting model coefficients.

RESULTS Timing of sea-ice retreat controls spring bloom

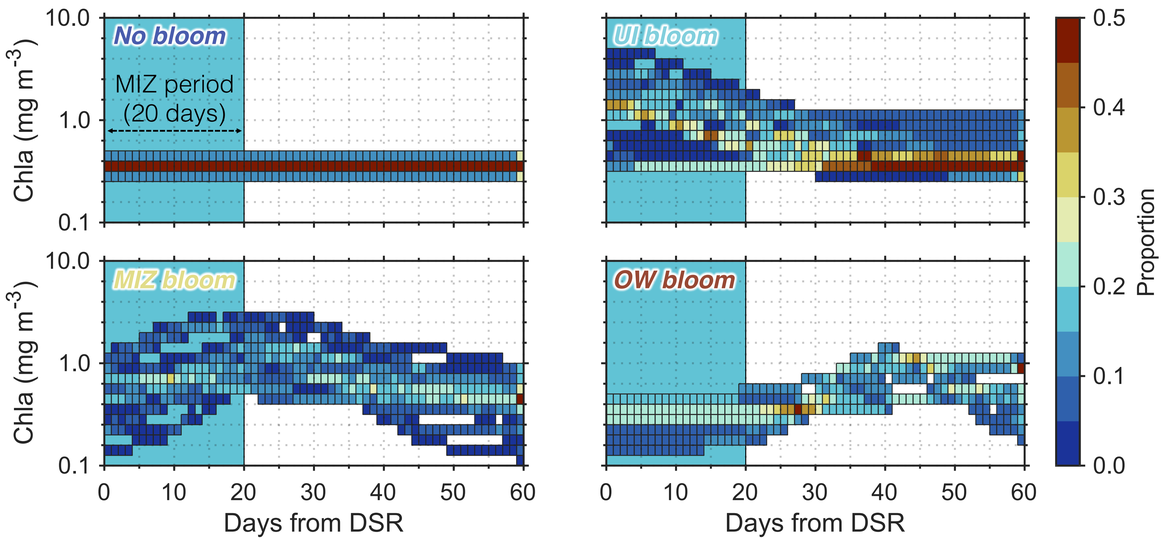
Our results demonstrated that the timing of sea-ice retreat largely determines spring bloom types: early and late sea-ice retreat supports open-water and under-ice blooms, respectively.

IMPLICATIONS Shifts toward less ice-associated blooms

The Pacific Arctic would be experiencing a shift from ice-coupled to less ice-associated blooms (i.e., MIZ and OW blooms). Such a shift in phytoplankton can cascade into higher trophic levels and, in turn, food webs and marine ecosystems in this region.

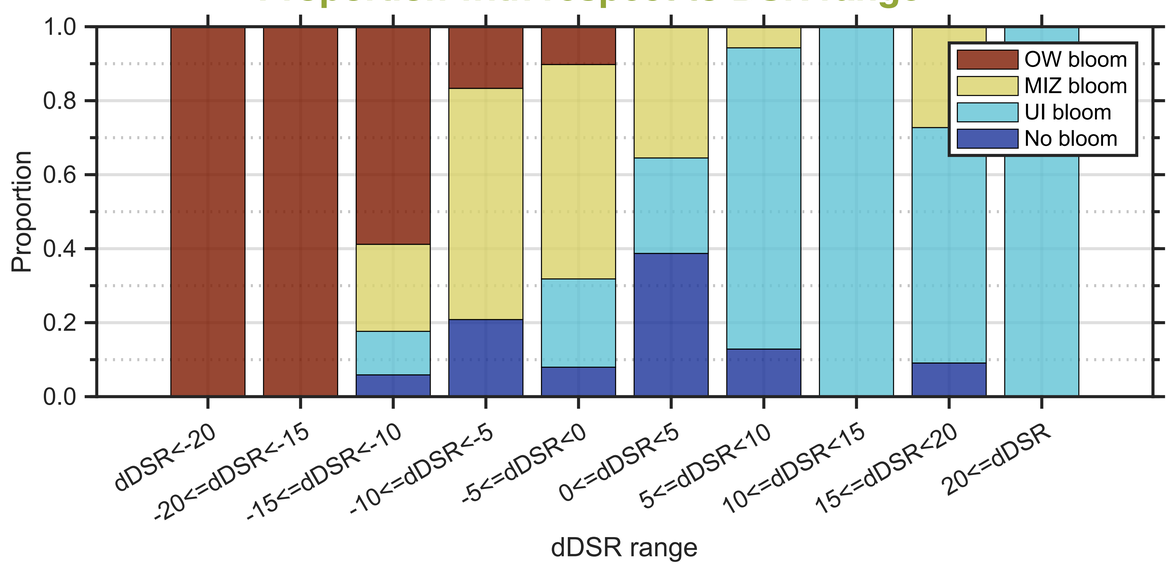
Spring phytoplankton bloom is shifting from ice-coupled to less ice-associated forms in the changing Pacific Arctic

Modeled chla time series



DSR: date of sea-ice retreat, defined as the first day of the year when sea-ice conc. is below 50%

Proportion with respect to DSR range

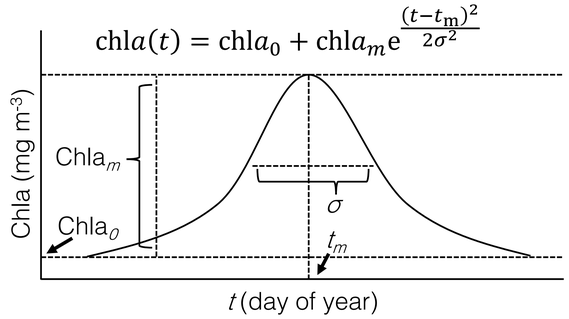


dDSR: anomaly of DSR for a given year at given location from average DSR (2003–2023)

Parametric Gaussian function

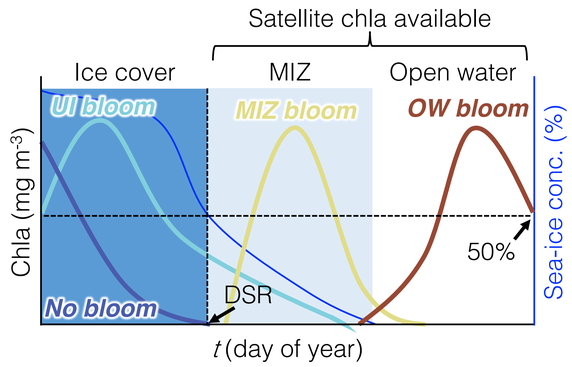
Seasonal development and decay of phytoplankton blooms can be captures with a parametric Gaussian function, which statistically retrieves phytoplankton bloom features, such as timing, amplitude, and duration of chla peak. One of the advantages is that this approach minimizes the effect of missing values by fitting the expected growth curve of phytoplankton biomass, whereas a conventional method employing the threshold would suffer from the cloud cover, resulting in large uncertainties in the estimation.

$$\mathrm{chl}a(t) = \mathrm{chl}a_0 + \mathrm{chl}a_m \mathrm{e}^{\frac{(t-t_\mathrm{m})^2}{2\sigma^2}}$$



Conceptual diagram of spring bloom types

Spring phytoplankton blooms are categorized based on the timing of the peak with reference to the date of sea-ice retreat (DSR) and marginal ice zone period. Bloom types defined here are as follows: No bloom, under-ice (UI) bloom, marginal ice zone (MIZ) bloom, and open water OW) bloom. Note that no bloom is assumed to be a post-bloom condition where phytoplankton blooms occur prior to ice retreat, suppressing the development of blooms after sea-ice retreat.



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