**Thesis title:** Classification of *Chattonella* spp. and *Skeletonema* spp. blooms in Ariake Sea based on backscattering index derived from two different ocean color satellites

（二つの海色衛星で求めた後方散乱指数による有明海のシャットネラとスケレトネマブルームの判別）

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## Summary:

Harmful algal bloom happened frequently in recent decades often affects the reflectance of water body by increasing phytoplankton pigments absorption and cellular backscattering. Algorithms have been developed on satellite sensors to understand the temporal-spatial distribution of blooms. However, presently there is no universal method applicable in many regions because of the difference in dominated phytoplankton and environmental conditions. In our research field, Ariake Sea, where is a highly productive and commercially-important semi-enclosed inland sea in Japan, phytoplankton blooms occur frequently. During summer raphidophyte *Chattonella* spp. and diatom *Skeletonema* spp. are the common harmful algal species which could alternate from one to another under favorable conditions. It is important to discriminate the harmful *Chattonella* spp. from diatom blooms for providing useful information for the coastal monitoring. In this study, methods to discriminate the two algal groups were explored based on their difference in inherent optical properties. New bio-optical methods were developed to differentiate *Chattonella* bloom from *Skeletonema* bloom and applied on multiple satellite images.

Chapter 2 investigated the optical difference between harmful species using Moderate Resolution Imaging Spectroradiometer (MODIS)-Aqua data, and a new bio-optical algorithm based on backscattering features has been developed to differentiate harmful raphidophyte blooms from diatom blooms. Using MODIS remote sensing reflectance R_rs(λ) data, bloom waters were first discriminated from other water types based on the positive value of distinct spectral shoulder at 645nm, SS(645), and the low magnitude of R_rs(555), to exclude the turbid water. Next, the higher cellular-specific backscattering coefficient of *Chattonella* bloom, estimated from MODIS data and quasi-analytical algorithm (QAA), was utilized to discriminate the bloom from *Skeletonema* bloom. A new index b_(bp-index) (555) was derived based on a semi-analytical bio-optical model to represent the backscattering of the two phytoplankton groups. Considering the magnitude difference in chlorophyll-a (Chl a) between the two bloom waters, Red Band Ratio (RBR) index, indicating Chl a fluorescence, was used with the b_(bp-index) (555) and effectively differentiated the two blooms. The method was successfully validated using other MODIS satellite data coincident with confirmed

bloom observations from local field surveys, and this method based on backscattering features could successfully discriminate *Chattonella* bloom from *Skeletonema* bloom.
In Chapter 3, the novel phytoplankton classification method was further modified and applied on the Geostationary Ocean Color Imager (GOCI) data with higher temporal and spatial resolution. First, the bloom detection method was further improved for the different bands of GOCI. Classification criteria for *Chattonella* bloom and *Skeletonema* bloom were determined based on a new index named Normalized Difference Red peak Index, NDRI, combining with SS (490). The usage of NDRI yield more satisfying classification results on GOCI images than RBR developed in Chapter 2, under the hourly varied fluorescence emission of the bloom waters. Diurnal changes of the bloom were successfully captured by the bloom detection method. Furthermore, strong correlations for each phytoplankton groups observed between NDRI and the GOCI b_(bp-index) (555), allowed *Chattonella* bloom to be discriminated from *Skeletonema* bloom. As a result, more than 80% of *Chattonella* spp. were classified from mixed population diatom bloom, not only *Skeletonema* bloom, correctly in the verification. Alternation of diatom and *Chattonella* blooms in July 2018 was clearly detected by the developed discrimination method.
This study has shown that use of their distinct backscattering properties is effective to classify *Chattonella* bloom from *Skeletonema* bloom. The novel developed method could be applied on different satellite imagery properly. The successful application of the classification approach could clearly present the temporal and spatial distribution of harmful blooms in Ariake Sea, which help us understand the factors influencing the changes of harmful blooms. It is likely that this approach may also be applied to other regions which share similar optical properties and harmful species with Ariake Sea.