Distinct sources of variability in the euphotic depth within the Arctic seas

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Growth of phytoplankton in the Arctic seas can be limited by insufficient light necessary for photosynthesis, and understanding the underwater light field plays an essential role in estimating carbon fixation by primary producers in the Arctic seas. However, sufficient in situ ocean observations in the Arctic seas necessary to reveal spatio-temporal variability of the underwater light field are not readily achievable due to its remote geography and harsh environment. As a result, satellite remote sensing is an indispensable technology for investigating the Arctic marine environment, as already proven by sea ice remote sensing. Towards a better understanding of the underwater light field and phytoplankton dynamics in the Arctic seas, the euphotic depth (Z_{eu}), defined as a water depth where Photosynthetically Active Radiation (PAR) at the sea surface attenuates down to its 1% intensity, is investigated using the ocean colour remote sensing data.

Firstly, an ocean colour inversion model was developed based on radiative transfer theory to estimate the euphotic depth. Independent validation of the satellite-derived euphotic depth showed Y = 1.23 X – 6.24 (N=28, r^2=0.68, p<0.01, RMSE=30.11) where Y and X indicate the euphotic depth derived from the satellite and measured in situ, respectively (Figure 1).

Secondly, monthly satellite data of the euphotic depth over the decade of 1998-2007 was analyzed to clarify seasonal and inter-annual variability of the euphotic depth in the Arctic seas. The analysis showed that the euphotic depth was relatively deeper at lower latitudes and shallower in higher latitudes during day-light seasons, being positively correlated with the solar altitude (Figure 2). As a result, it was found that planetary motion was dominating the variability of the euphotic depth in the Arctic seas. However, the euphotic depth in the Russian Arctic seas indicated a stronger influence from another source. The euphotic depth was deeper (shallower) when concentrations of colored dissolved organic matter (CDOM) and suspended hydrosols were lower (higher). As a result, anti-correlations between the euphotic depth and these biogeochemical properties of seawater were found in the Russian Arctic seas, resulting in the reduced positive correlation between the euphotic depth and solar altitude (Figure 2). Indeed, the ocean colour inversion model showed exceptionally high concentrations of CDOM and hydrosols in the Russian Arctic seas. Thus, the variability of the euphotic depth in the Russian Arctic seas was dominated by internal variability of the seawater rather than the planetary motion. Since CDOM reduces the euphotic depth by absorbing solar radiation including PAR, such a high CDOM concentration in the Russian Arctic may indirectly limit primary production, while the exceptionally high CDOM may also contribute to a rise of water temperature that can promote the primary production at the same time. Thus, possible counter-acting effects of CDOM on primary production were implied in the Russian Arctic seas.

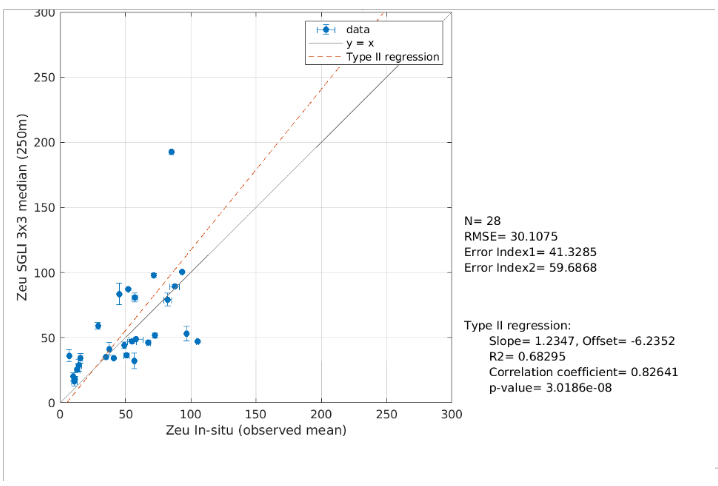

Figure 1. Validation of the satellite-derived euphotic depth.

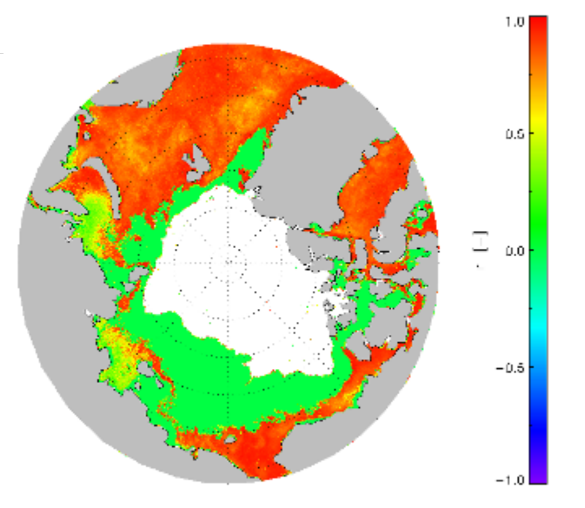

Figure 2. Correlation coefficient between the euphotic depth and solar