A role of vertical mixing on nutrient supply into the subsurface chlorophyll maximum in the East China Sea

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論 文 名　：A role of vertical mixing on nutrient supply into the subsurface chlorophyll maximum in the East China Sea
（東シナ海における亜表層クロロフィル極大層への栄養塩供給に対する鉛直混合の役割）

Title

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論 文 内 容 の 要 旨

Thesis Summary

In summer, Changjiang Diluted Water (CDW) expands over the shelf region of the northern East China Sea. Dilution of the low salinity water could be caused by vertical mixing through the halocline. Vertical mixing through the pycnocline can transport not only saline water, but also high nutrient water from deeper layers to the surface euphotic zone. It is therefore very important to quantitatively evaluate the vertical mixing to understand the process of primary production in the CDW region.

Far from the estuaries, the chlorophyll maximum is formed at subsurface and generally observed in shelf seas. Seasonal thermocline provides a physical barrier for a development of subsurface chlorophyll maximum (SCM) to transfer of nutrients and phytoplankton between the subsurface layer where light is abundant and the dark but nutrient-rich deep water.

In my thesis, I examine the vertical nutrient fluxes using the direct turbulence measurements which have rarely been reported in this region, and also evaluate their contribution to primary production which is determined with the simultaneous measurement in the same cruises. Our data revealed that chlorophyll abundance differed with the depth depends on the influence of the CDW. The nutrient supply from the lower layer is deduced from the relative positioning between the depths of nitracline and SCM. Based upon direct measurements of turbulence, we found that turbulent nutrient flux by vertical mixing considerably contributed to primary production around SCM in case of low N/P ratio, that is a ratio of nitrogen and phosphorus, through the snapshot measurements. Followed estimation using the time series showed a good consistency complementary to instant measurement. The thesis of contents is as follows:

First, I introduce the background and focus of my study in section 1.

In section 2, I describe the observations in general. Intensive measurements were conducted in the region southwest of Jeju Island during the period 2009–2011 including two time series measurements in each

year. The methods estimating vertical nutrient flux and primary production are also described in detail.

In section 3.1, I show the horizontal expansion of CDW which is considered as one of the main nutrient sources and describe the formation and depth of SCM relating to the influence of CDW.

In section 3.2, detailed investigations of the relative relationship between the depths of SCM and nitracline suggest that there were two patterns relating to the N/P ratio which could be considered as an indicator originating from different nutrient source. Comparing the depths of the nitracline and SCM, it is found that relatively deep SCMs were located just above the nitracline, where the N/P ratio within the nitracline was below 15, whereas relatively shallow SCMs were located within the nitracline, where the N/P ratio was above 20.

In section 3.3, the results of estimating vertical nutrient flux and primary production are described in detail. Turbulence measurements show that the vertical flux of nutrients with vertical mixing and its contribution to primary production in the vicinity of the SCM were large (small) where the N/P ratio was low (high). The former case indicates a significant nutrient input from the lower layer.

Meanwhile, large variability of vertical nutrient flux exaggerates their mean contribution to primary production in case of low N/P ratio. The snapshot measurement includes some uncertainty about representing daily mean flux, therefore, I try to evaluate the vertical nutrient flux by using the time series measurements in section 3.4. Due to the lack of nutrients data in the time series, I use the linear relationship between the temperature and nutrient concentrations below the nitracline. An estimation using the time series measurements lessened the variability of vertical nutrient flux as well as revealed a consistency about large contribution of vertical nutrient flux to primary production in case of low N/P ratio with the same pattern of snapshot measurements.

In section 4, I discuss on the cause of observed turbulence, another physical processes providing nutrient supply, uncertainties in the estimation of vertical nutrient flux and primary production, and consistency of vertical eddy diffusivity. Especially, statistical approach supported the significance of difference of vertical nutrient flux between the case of low and high N/P ratio, even allowing for the daily large variation of vertical eddy diffusivity.

Finally, in section 5, I conclude that, despite some uncertainties estimating vertical nutrient flux and primary production in the vicinity of SCM, the nutrient supply from lower layer associated with the vertical mixing contributes considerably to the maintenance of SCM.