Author's response to comments from Referee #1

First of all, we appreciate valuable comments from the referee.

Comment 1: Referee #1 mentioned "I regret say that this ms did not include novel finding nor important information for the progress in biogeosciences."

We acknowledge that our time series data is rather limited, and it would be ideal (and actually we plan) to deploy another mooring with enhanced sensor package and carry out field observations during the deployment period in future as the referee suggested. Nevertheless we think there are some important contributions of this study to the understanding of the spring bloom in this highly productive area,

- This is the first time series data taken in the area during the spring transition and undoubtedly we captured the spring bloom signal, thus providing opportunity to study the detailed temporal evolution of the spring bloom in relation to changes in physical properties such as fluctuations of isotherms and currents. And this revealed a new mechanism in triggering the spring bloom in the study area.

- Many processes have been proposed on the mechanisms of the onset of the spring bloom in the study area as we reviewed in the introduction part of the manuscript. The influence of the springtime advection of the East Sea Intermediate Water (ESIW), however, has never been thought of as another factor triggering the bloom. The observed data, though they are limited, clearly indicate the uplift of isotherms due to the advection of the ESIW, which is in turn related to the elevated level of the observed chlorophyll fluorescence, supporting our assertion that the springtime water mass advection is one of important factors for the onset of spring bloom in this area. (See also our response 3 to Comments 5 from Referee #2 below.) The Ulleung Basin of the East/Japan Sea is advection-dominated environment, and this study, at least, suggests that the advection is also important in biological processes rather than the previous arguments of the importance of the atmospheric forcing and/or the 1-diemnsional Sverdrup hypothesis which neglect the advection.

Comment 2: Problem of insufficient calibration

It is also true that we had only one well-matched in situ chlorophyll data to compare with the observed chlorophyll fluorescence, and virtually no data to investigate any variability in phytoplankton species.

As an indirect evidence of the measured chlorophyll fluorescence representing chlorophyll concentration, we estimate percent saturation of dissolved oxygen using the time series of dissolved oxygen and temperature at 30 m (Figure below). During the bloom period, dissolved oxygen was supersaturated with the degree of supersaturation up to 120 % indicating significant photosynthetic production of oxygen, and temporal variation of the percent saturation is well correlated with that of the chlorophyll fluorescence, both of which strongly suggest the observed high chlorophyll fluorescence represents the high chlorophyll concentration due to the spring bloom. We will add this figure to the manuscript when we revise it.

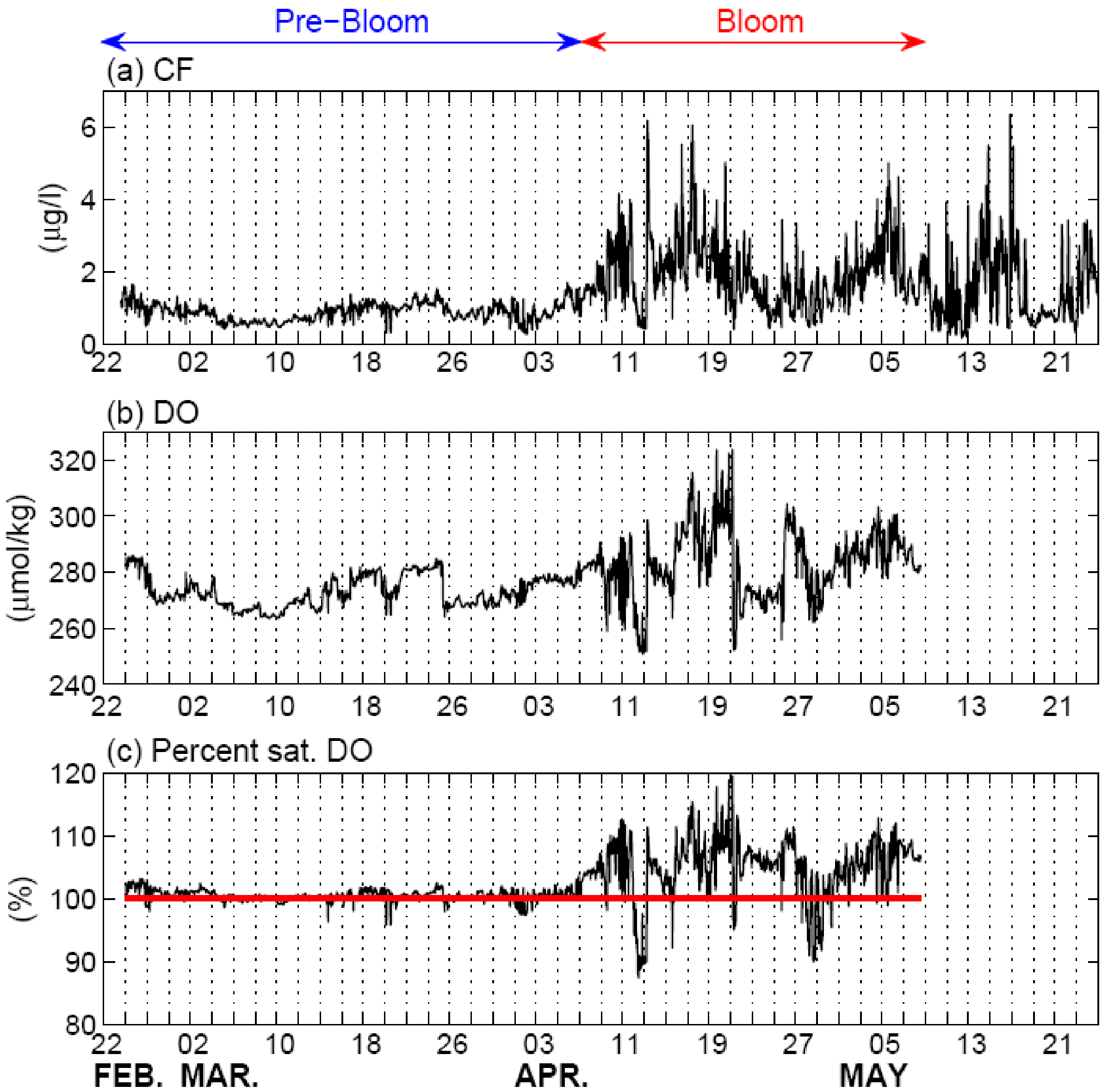

Figure. Time series of (a) chlorophyll fluorescence, (b) dissolved oxygen, and (c) percent saturation of dissolved oxygen at 30 m.

As referee #1 pointed out, we were not able to take any biological samples to identify dominant species during the buoy observation period. According to a recently published paper in BG, diatoms are the most dominant phytoplankton throughout the year, and especially, the subsurface chlorophyll maximum layer (20~30 m) corresponded to the depth of maximum contribution of diatoms (>90%) in May 2010 (Kwak et al., 2013). Species transition occurs from spring to summer with an increasing contribution of dinoflagellates and pelagophytes, and cyanobacteria contribution becomes high during the stratified season

(Kwak et al., 2013). Hence, we argue with a caution that the observed increase in the CF is due to the spring bloom rather than due to the phytoplankton species changes.

* J.H. Kwak, S.H. Lee, H.J. Park, E.J. Choi, H.D. Jeong, K.R. Kim, and C.K. Kang (2013) Monthly measured primary and new productivities in the Ulleung Basin as a biological "hot spot" in the East/Japan Sea. Biogeoscience, 10, 4405-4417.

Comment 3: Referee # 1 also mentioned the mechanisms of onset of the spring bloom are not fully investigated.

A key finding of the present study is that the advection of the ESIW is one of the important factors in triggering the spring bloom at least at the time of our observation. The other factors previously suggested by other studies may also contribute to the onset of the bloom, but our point is that the influence of the ESIW should also be considered in the Ulleung Basin. This factor has never been considered in the previous works.

Following points strongly suggest the ESIW intrusion occurred in spring at least at the time of the moored measurement in 2010.

(1) Previous studies documented the southward movement of ESIW from the formation region in the northern East/Japan Sea. Two pathways of the ESIW have been suggested, one route is along the western boundary of the East/Japan Sea carried southward by the coastal boundary current, North Korean Cold Current, and the other path of the ESIW toward the south is by subduction process that occurs along the subpolar front. All this information was included in the introduction, and we will add a couple of references on the seasonal and interannual variations of the ESIW.

(2) Temperature range of the ESIW is 1.0~5.0°C as we mentioned in the introduction. Thus the observed cold water with temperature less than 5°C below 50 m (Fig. 10) corresponds to the ESIW. It is obvious that the appearance of colder ESIW and the uplift of isotherms characterized the bloom period (Fig. 11).

(3) Temperature variation at 100 m in the study area from February to April at the time of buoy observation shows an unambiguous cooling in a wide area of the Ulleung Basin (Fig. 14(a)), and the climatological temperature variation at 100 m and 200 m (Fig. 15) corroborates the observed cooling in April, 2010. The cooling of the subsurface water would be due to either Ekman pumping or cold water advection or both. Mean wind stress curl during the pre-bloom and bloom periods differs by about 0.1×10^{-6} N/m^2 in the central UB, then the associated change in the Ekman pumping is about 3.6 m/month which cannot account for the observed shoaling of 5°C isotherm depth by 16.8 m in Table 1. (We will add this estimation to the discussion part.) Hence, we think the observed subsurface cooling resulted from the cold water (ESIW) intrusion.

(4) The observed subsurface temperature (e.g., at 100 m) at the buoy station was anomalously cold, which is also evidenced by the widespread cold anomalies at 100 m in April 2010 (Fig. 14b). The reason for this anomaly is beyond the scope of this paper, and we conjectured in the discussion that it may be associated with the strong negative phase of the Arctic Oscillation during the winter of 2009/2010 since 1950.

Comment 4: Referee #1 also said the contribution of internal tides to the onset of the spring bloom is speculation. We agree with that, and will remove this part in the revision. The observation clearly shows the enhanced internal tides during the bloom period (Table 1, Fig. 11), but it is not clear how this enhanced internal wave motions influence the low-frequency variation of the chlorophyll.