Interactive comment on "The potential effects of fresh water content on the primary production in the Chukchi Sea" by M. S. Yun et al.

Anonymous Referee #4

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General comments: This paper investigated the in situ primary production rates and their relation to various environmental variables in the Chukchi Sea including the Russian waters of the Arctic, where only the limited data are available. The authors pointed out that the primary production in the Chukchi Sea is mainly affected by nutrient concentrations and phytoplankton biomass, and the nutrient concentrations, and thus the primary production, are influenced by the freshwater content (FWC). This concept may be not new but seems to be verified from the present data and statistical analyses. In addition, the authors indicated a recent decrease in primary production from decades ago, although the primary production has large temporal and spatial variabilities. The authors suggested that a plausible reason for the recent low primary production could be due to the decreased concentrations of nutrients and chlorophyll. If possible, the authors should show the nutrient and chlorophyll data that are associated with the recent decrease in primary production. This point could be a new finding. This is an interesting paper that is in general clearly written and well-laid out. I recommend the paper for publication in Biogeosciences after some revisions.

Specific comments:

P. 13516, L. 11: The authors should explain why the reference salinity was selected as 34.8.

→ According to previous studies (Aagaard and Carmack, 1989; Carmack, 2000; Carmack et al., 2008; McPhee et al., 2009) in the Arctic Ocean, all freshwater fractions are computed relative to a salinity of 34.8. It has been considered as the mean salinity for the Arctic Ocean based on the compilations of Codispoti and Richards, 1968; Hanzlick and Aagaard, 1980; Gorshkov, 1983; Pfirman, 1985; Treshnikov, 1985; Macdonald et al. .1987. As the reviewer suggested, we explained why the reference salinity was selected as 34.8 (in line 130-132, page 8).

P. 13518, L. 18: The authors should explain why the upper 30m was selected to show the nutrient distribution.

→ In order to understanding the change of the primary production, the nutrient distribution (or inventory) within euphotic zone is very important. In this study, the mean depth of euphotic zone from the surface to 1% light depth was about 30m (in line 104-106, page 7). Thus, we showed the nutrient distribution in the upper 30m. As the reviewer suggested, we explained why the upper 30m was selected to show the nutrient distribution (in line 185, page 11).

P. 13519, L. 5: The authors should explain why the upper 30m was selected to show the chlorophyll distribution.

→ As the above-mentioned, the mean depth of euphotic zone from the surface to 1% light depth was about 30m (in line 104-106, page 7). Thus, we showed the chlorophyll distribution in upper 30m. As the reviewer suggested, we explained why the upper 30m was selected to show the chlorophyll distribution (in line 198-199, page 12).

P. 13519, L. 23 – P. 13520, L. 10: The authors should explain why the nitrate and ammonium production rates were measured. This explanation should be described in "Introduction". In addition, some discussion might be necessary. In the basin area, the nitrate (ammonium) production rates may be recognized as new (regenerated) production rates. But, in the shelf area, both the nitrate and ammonium are partly or mainly supplied from the sediments. In this case, what does the each rate mean?

→ This method could be useful for distinguish the relative importance of nitrate and ammonium as nitrogen sources for the cell and population (Dugdale and Goering, 1967). As the reviewer commented, we described why the nitrate and ammonium production rates were measured in "Materials and method" not "introduction" (in line 155-156, page 10), in order to better construction of the context.

→ Even though this study measured the nitrogen production rates, this study mainly focused on the recent changes of the primary production and major factors affecting it. Thus, we did not mention the detail discussion about the nitrogen production rates. However, we described the regional differences of the nitrogen production rates in section 4.1.

→ Generally, primary production in the coastal Arctic are principally supported by N inputs from the Pacific Ocean through the Bering Strait (Codispoti et al. 2005; Ortega-Retuerta et al. 2012). While there is likely a short-term pulse of nitrate uptake that corresponds with the spring bloom period (e.g. Martin et al. 2012), the remainder of the year is heavily dependent on ammonium and dissolved organic matter sources. The Chukchi Sea community is also more reliant on ammonium than nitrate. For example, this study showed the higher ammonium production rates compared to nitrate production rates (Fig. 6). However, the some stations within the western side of the Chukchi Sea had low dependence on regenerated nitrogen (i.e. ammonium) (Fig. 6). Even though a substantial sedimentary efflux of regenerated nutrients may occur in the shelf area, a thorough understanding of N uptake is needed to determine how the system is currently structured, and how it may react to changes in nutrient supply under the rapid changes observed and predicted in the Arctic Ocean.

P. 13519, L. 5: Siberian Coastal Water might result in the accumulation of freshwater in the western side of the southern Chukchi Sea (Fig. 7a). But, the sea ice meltwater is also a source of freshwater. Why did the authors discard the latter possibility?

→ As the reviewer suggested, sea ice meltwater could be also a source of freshwater. In fact, we encountered a considerable sea ice at some stations on the East Siberian shelf and around Wrangel Island during 2012 RUSALCA cruise. Thus, the accumulation of freshwater in the western side of the southern Chukchi Sea could be resulted from the inflow of the sea ice meltwater as well as the Siberian Coastal Water. As the reviewer commented, we added the possibility of inflow of the sea ice meltwater (in line 328, page 19). In addition, this study mainly focused on identify the variations of the total freshwater content (rather than distinguish of freshwater source) during three different RUSALCA cruises. In future, it will be needed to study about distinguish of the freshwater source and its effects on the biological system in the Chukchi Sea.

P. 13526, L. 25 – 26: Even if the measurements of primary production were performed in the same season (the mid-July and early August) both in the previous studies and Hill et al. (2005) or Lee et al. (2012, 2013), the sea ice condition might be different. For example, in the previous studies, the mid-July and early August might be just after the sea ice melt. In that case, the productivity would be large. The authors might be better to confirm the difference in the sea ice condition.

→ As the reviewer commented, the different sea ice condition (just after the sea ice melt or not) would affect the productivity. For example, Lee et al. (2012) found that the carbon uptake rates of phytoplankton in newly opened waters were higher than those in ice-free waters. However, we could not obtain the sea ice condition from previous studies (Hameedi, 1978; Korsak, 1992; Zeeman, 1992). Hill and Cota (2005), as the recent measurement, obtained the lower production rates than those in previous studies, even though primary production was measured during the initial ice breakup. Thus, the recent low rates of primary production might be reflected by decreasing trend than results of the difference in the sea ice condition. Even though we could not directly confirm the difference in the sea ice condition between previous studies and Hill and Cota (2005) or Lee et al. (2012, 2013), we mentioned the potential effects of the sea ice condition on the productivity (in line 356-357, page 21).

P. 13526, L. 28 – P. 13527, L. 2: If possible, the authors should show the nutrient and chlorophyll data. This point could be a new finding.

→ Data from Whitledge and Lee are including long-term field measurements from various programs since the 1980's in the BERPAC, ISHTAR, CHOEX and RUSALCA projects occurring in both the Russian and U.S. EEZ's (whereas, this study focused on recent change of the primary production and the potential effects of FWC on the primary production in the Chukchi Sea, mainly, based on three RUSALCA cruises). Based on these long-term measurements, significant decreases of 30-50% in nutrients and approximately 40% in integrated chlorophyll concentration have been observed in recent years in Bering Strait and the Chukchi Sea. As the reviewer suggested, it will be needed to show the nutrient and chlorophyll data to support our explanation for decreased primary production in the Chukchi Sea. However, unfortunately, this data is in preparation for other journal. If possible, we will involve as citing this data after it published.