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 #3

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This is a short paper that describes results of primary production measurements in the Chukchi Sea. Since it adds scarce data on direct productivity measurements, it is potentially a valuable addition, but in its current state, the manuscript is not a particularly successful presentation. If it is taken for granted that less saline waters in the Chukchi Sea have lower nutrient concentrations, and therefore lower production, freshwater content has an influence on productivity, but this is not new information by itself. The manuscript also lacks a lot of the historical and recent references on nutrient and chlorophyll distributions on the Chukchi shelf as well as any references to the recent RUSALCA special issue. The productivity measurements reported are also probably biased by the late summer sampling time frame, so comparisons to other productivity measurements are incomplete without careful consideration of the influence of seasonality and location of sampling—high productivity in the Chukchi Sea is rather localized, so conclusions about changes in productivity merit caution. Finally the manuscript uses the findings of increased freshwater fluxes through Bering Strait and its possible influence on productivity as a starting point, but does not separate those influences from freshwater that can be present from Siberian Coastal Current contributions in some years, as well as the increasing influence of melted sea ice on freshwater content. The changes in freshwater content of the Canada Basin are also raised, but these increases in freshwater are driven by additional atmospheric processes in addition to the Bering Strait inflow.

Some specific editorial suggestions:

Page 13513. Line 10 suggest replacing "revealed" with "documented"

→ We changed "revealed" to "documented" (in line 53, page 4).

Page 13514. Line 10 Probably worthwhile to add a reference to the RUSALCA special

issue (Oceanography Vol. 28(3), and the description of the program: Oceanography 28(3):18–23, http://dx.doi.org/10.5670/oceanog.2015.54 INTRODUCTION TO THE SPECIAL ISSUE. Russian-American Long-term Census of the Arctic: RUSALCA, K. Crane and A. Ostrovskiy

→ We added the description of "RUSALCA program" (in line 77-80, page 5).

Page 13516, Section 2.3, Fresh water content. Freshwater is derived from both melted sea ice and runoff, but this equation provides no means of separating the two. The manuscript seems to be a confused conflation of the two sources of freshwater. The introductory discussion of Woodgate et al 2012 is based upon a finding that freshwater fluxes from runoff have increased over the past decade and the reference to Li et al. is based upon a finding of an increase in melted sea ice having an impact on freshwater content and thereby affecting phytoplankton cell size.

→ As the reviewer mentioned, the source of the freshwater could be divided sea ice meltwater and river runoff. In fact, some previous studies evaluated the contributions of the each source in the regions of the Canada Basin (Yamamoto-Kawai et al., 2005; Nishino et al., 2013). However, this study mainly focused on identify the quantitative change of total freshwater (rather than distinguish of freshwater source) during three 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.

Line 11: This implies that a salinity of 34.8 was reached at some depth for all stations. I don't think this is true.

→ As the reviewer mentioned, all stations were not reached to a salinity of 34.8. However, we use a reference salinity of 34.8 following Aagaard and Carmack (1989) to computing freshwater since it has been considered as the mean salinity for the Arctic Ocean. We added this in section 2.3 (in line 130-132, page 8).

Line 13. This is really the Russian Exclusive Economic Zone (200 miles), not territorial waters, which extend only 12 miles from shore.

→ Yes, the water depths of the study area are generally shallow, as shown in Table 1.

However, we sampled as about 5 m interval in order to obtain high resolution value in the vertical distribution of the nutrient. Thus, we could obtain water samples for nutrient analysis from 5 to 9 depths (in line 135-136, page 9).

Lines 13-16. There were annual cruises of the RUSALCA program that serviced moorings, so the numbering scheme, if kept, should refer to the 2004, 2009 and 2012 cruises as process cruises. The annual cruises would then use a different numbering scheme.

→ As the reviewer commented, the annual cruises used a different numbering scheme. In order to prevent confusion, we changed "1st", "2nd", and "3rd" RUSALCA to "2004", "2009", and "2012" RUSALCA (in line 20, page 2; in line 83-86, page 6; in line 97, page 6).

Page 13518 Line 8-9. There really isn't an east-west comparison. To the southwest, the freshest waters were observed, and salinity increased to the northeast.

→ We changed this sentence (in line 175-176, page 11).

Line 18. It is stated that the nutrient concentrations in the upper 30 m of water are shown on Figure 3, but Figure 3 actually appears to show integrated distributions.

→ As the reviewer mentioned, figure 3 showed the distributions of the integrated nutrient concentrations in the upper 30 m. We changed this sentence (in line 185-186, page 11).

Lines 19-21. These are inventories of nutrients, not concentrations.

→ These are integrated concentrations from surface to upper 30 m. Thus, we added this (in line 185-186, page 11).

Page 13524, Line 28. Since the East Siberian Shelf and Chukchi shelf are quite shallow, as well as broad, I do not follow what mechanism is being invoked for replenishment of nutrients from deep waters (e.g. Canada Basin). In most of the study area, nutrients are supplied from the south (e.g. Bering Sea).

→ As the reviewer mentioned, the nutrient replenishment from deep water could be not

case for Chukchi Sea shelf. Actually, the high amounts of the nutrients in the Chukchi Sea are depending on horizontal supply through the Bering Strait or supply of regenerated nutrients from sediments. Thus, we added this (e.g. Canada Basin) since this mechanism has to be applied to deep basin region (in line 334, page 20).

Page 13526, Line 1-2. Stating that there is a declining trend in productivity without acknowledging that it is in large part seasonally dependent is misleading. A similar relationship could very well be apparent if plotted against day of year instead of year. A more careful analysis would be to plot each productivity measurement versus day of the year rather than combine all the measurements on any single cruise. The seasonal signal could very well be lost if you average all measurements taken over a two month period. As it is, the Figure 10 caption states that the RUSALCA 2012 collections were made from 27 August to 16 September, but Table 1 indicates that the date range for productivity experiments was actually 30 September to 14 September. The dates of productivity measurements should be shown on the figure, not the cruise duration dates.

→ We agree the reviewer's comment. However, we mentioned the possibility of the seasonal and inter-annual variability in the primary productivity (in line 369-370, page 22). Based on some reasons, we concluded the recent low primary production might be reflected by decreasing trend rather than results of seasonal and inter-annual variations (in line 369-382, page 22).

→ As the reviewer suggested, it would be detail analysis if plotted against day of the year. However, the number of in situ PP measurement data (during cruise period) is very limited because of logistic problems during the cruise and thus it makes more difficult to compare against day among different cruises. Thus, we could not help combining all the measurements during each cruise.

→ As the reviewer suggested, we changed the figure caption as the dates of in situ productivity measurements.

Lines 11-26. This could serve as a basis for the seasonal discussion that is really needed to address whether productivity is declining, but I don't think this is really enough. We

need to see individual productivity measurements by date, and it would also help to put them in the context of where they were located (nutrient-poor vs. nutrient-rich locations).

→ As the reviewer comment, it will be really needed to address by including the date or detailed sampling location, in order to clearly identify seasonal variation. However, as we mentioned above, the in situ PP data is very scarce and the data number or sampling location are very limited due to logistic problems. In addition, the most Arctic cruises were designed for multidisciplinary studies, as well as biological measurements. Thus, we could not help combining all the measurements during each cruise.

Figure 2, 3, 4, 7 The station points where these data were collected should be made larger so it is clear what the basis for the color gradations are. In each of the captions it is stated that these are integrated data "up to 30 m", but it would make more sense to say "down to 30 m." For Figure 3 (integrated nutrients), I think this sort of presentation is misleading. There will be almost no nutrients in surface waters, and in the case of ammonium, the source of that nutrient is likely the sediments. Therefore integrating to 30 m doesn't really tell the reader much about the distribution of ammonium, and integrating for nitrate without taking into account where the chlorophyll peak is in the water column is not providing the information that is most valuable for understanding productivity. For Figure 4, areas of high chlorophyll biomass in the central southern Chukchi Sea are readily apparent, but these areas of high biomass are already well known.

→ We changed to the larger station point.

→ We changed "up to 30 m" to "integrated from surface to upper 30 m" (page 33).

→ Even though we did not show the vertical distribution of the nutrient in this study, we could identify that the nutrient concentrations in the surface water were considerably different depending on stations (For example, the nitrate concentrations in the surface waters of the some stations such as CL5, CL5A, and CL6 were exceeded 5 μM). In addition, the integrated nutrients over euphotic zone could provide the information about ambient concentrations, even though the regenerated nutrient came from sediments. For that reason, we'd like to compare the integrated nutrient values and PP

values over the euphotic zone. As the reviewer's commented, we would need to show vertical profile between the nutrient and PP, in order to more understanding the effects of nutrients on the primary production rates, in future.

→ As the reviewer mentioned, it is known that the central southern Chukchi Sea has high chlorophyll biomass. However, the phytoplankton biomass in the central southern Chukchi Sea in 2009 was considerably lower than that in 2012, mainly, because of an inflow of the cold and fresh Siberian Coastal Current from the western sides of the southern Chukchi Sea. Therefore, it is important to identify the significant changes in the phytoplankton biomass, even though this region has been considered as high biomass region.

Figure 9. I don't follow why these derived parameters are used (freshwater content and integrated nutrients). Why not plot salinity versus nutrients for all bottle samples? The results, either way would not be surprising. Much previous work describing nutrient distributions in the Chukchi Sea has documented the positive correlation between salinity and nutrient concentration, and the spatial separation of water masses. I don't really think this adds much new information. Also, the figure caption refers to nutrient concentrations, but since these are integrated data presented on square meter basis, so these data are not properly concentrations, but rather inventories, and when there is so much vertical variability in the water column, computing inventories really doesn't make as much sense as determining the depth of the nutricline in relation to available light.

→ As we mentioned in section 2.4 (in line 135-136, page 8-9), the water samples for nutrient analysis were collected only from 5 to 9 depths at stations. Since this is discrete samples, the comparison with salinity in the corresponding depth would cause biased result. Thus, we compared the nutrient inventories in the upper ocean with FWC, which is reflecting vertical distribution of salinity.

→ Even though much previous work describing nutrient distributions in the Chukchi Sea has documented the positive correlation between salinity and nutrient concentration, we could provide more information about the effects of FWC on the PP based on the relationships among FWC, nutrients, and PP.

→ We clearly described where the integrated concentration came from (in all figure captions) (page 33).

Figure 10, remove date of 31 September

→ We removed date of 31 September.