19 January 2015

**Reply to the interactive comment by Referee #1 on "Diatom flux reflects water-mass conditions on the southern Northwind Abyssal Plain, Arctic Ocean" by J. Onodera et al.**

General comments

This paper presents a time-series of diatom fluxes obtained from October 2010 through September 2012 using sediment traps moored at Station NAP. Increases in diatomfluxes were observed in November-December in 2010 and 2011 (dominated by resting spores), and in August 2011 (dominated by the sea-ice associated diatom Fossula arctica). Nearly no fluxes were observed from March to September 2012. The authors suggest a significant influence of mesoscale eddies developing along the Chukchi Sea shelf break and transporting shelf-origin material to the basin during periods of increased fluxes, while they suggest that the period of very low fluxes reflected the influx of oligotrophic water originating from the central Canada Basin.

This paper presents the same results than another paper from the same authors (Watanabe et al. 2014 in Nature Communications) except for the additional presentation of the diatom fluxes. Although it may be interesting to present these diatom fluxes, the paper provides the same interpretation than what is already published in Watanabe et al. However, a curious difference between the 2 papers is the presentation in the currently-reviewed paper of export fluxes obtained from March to September 2012 that were absent from the Watanabe et al. paper.

Overall, the authors argue that mesoscale eddies have an important role for shelf basin interactions but they have proof of the occurrence of an eddy only for November-December 2010. More information is needed on the actual hydrographic conditions observed from October 2010 to September 2012 to support these statements (not only based on a model). The authors could use satellite ice maps to investigate the presence of eddies (during summer) and could also use satellite data for backtracking and contrasting the origin of sea ice in 2011 and 2012. Such results may help support their conclusions.

Author's reply

The critical comments and suggestions by referee #1 were useful to improve the manuscript. Based on the suggestion by the referee #1, we newly prepared the information on the sea-ice motion in the western Arctic Ocean for the study period. The additional sea-ice data and previous our interpretation on diatom flux at Station NAP are not contradict as shown below specific comments. The difference of this paper from Watanabe et al (2014) was described in Introduction. We hope the revised manuscript is acceptable for referee #1.

Specific comments

Abstract

-We studied time-series fluxes of diatom particles and their relationship to hydrographic variations from 4 October 2010 through 18 September 2012 using bottom-tethered sediment trap moorings deployed at Station NAP (75 N, 162 W; 1975m water depth) in the western Arctic Ocean.

I think it is misleading to mention that you studied diatom fluxes in relation to hydrographic variations as no in-situ measurements of hydrographic conditions were collected or presented. Also, please specify that there are 2 traps deployed and mention their deployment depths in the Abstract.

The sentences were revised as "We studied time-series fluxes of diatom particles and their relationship to simulated hydrographic variations from 4 October 2010 through 18 September 2012 using bottom-tethered sediment trap moorings with two sediment traps deployed at 180 m and 1300 m depths at Station NAP (75°N, 162°W; 1975-m water depth) in the western Arctic Ocean."

Introduction

-The sea-ice decrease and related oceanographic changes, such as increases in water temperature...

The relationship between a decrease in sea ice and an increase in water temperature is not as straightforward as the authors describe here. Please clarify if the following statement regarding enhanced primary production is related to a decrease in sea ice or an increase in temperature and support with appropriate references.

This sentence was removed during the re-organization of sentences in the introduction.

-...recent environmental changes have influenced the diatom flora and diatom productivity (e.g. Arrigo et al., 2008, 2012; Lowry et al., 2014)

It is not appropriate to cite these papers to discuss diatom flora and productivity as these studies present satellite-derived results and do not mention diatoms. It is not possible to distinguish the type of phytoplankton associated with chl a measurements obtained from remote sensing.

The sentence and references were revised as follows. "Diatoms are one of the dominant phytoplankton in the Chukchi Sea (Sukhanova et al., 2009; Coupel et al., 2012; Joo et al., 2012; Laney and Sosik, 2014), and the recent environmental changes have influenced the diatom flora and phytoplankton phenology (Arrigo et al., 2012; Ardyna et al., 2014)."

-In the cryopelagic Canada Basin, where the major primary producer is picoplankton, the biogenic particle flux into the deep sea has been quite low (Honjo et al., 2010). Please provide values and contrast them with other regions of the Arctic Ocean.

In the re-organization of Introduction section, the sentence was rewritten as follows. "In the cryopelagic Canada Basin, where the major primary producer is picoplankton, the biogenic particles are remineralized in the upper water column and particulate organic carbon (POC) supplied into the deep sea are essentially composed of allochthonous old carbon (Honjo et al., 2010)." The POC values in the cryopelagic Canada Basin (Honjo et al., 2010) and at Station NAP (Watanabe et al., 2014) were added in the introduction.

-The decrease in sea-ice cover results in the intensification of the Beaufort Gyre (McPhee, 2013). . .

This sentence suggests that the decrease in sea ice cover leads to the intensification of the Beaufort Gyre when in fact the geostrophic current intensification appears to have played a significant role in the recent disappearance of old ice in the Canada Basin (McPhee, 2013). McPhee states that the intensification of the Beaufort Gyre seems to be the result of atmospheric forcing and not of a decrease in sea ice cover. This statement must be clarified.

As the referee #1 pointed out, the description regarding McPhee (2013) was incorrect. The sentence was partially removed and was rewritten as "The decrease in sea-ice cover results in deepening of the nutricline in the central part of the Beaufort Gyre (McLaughlin and Carmack, 2010; Nishino et al., 2011a), …"

-. . .and deepening of the nutricline (Nishino et al., 2011a). . .

Actually, Nishino et al. state that a decrease in sea ice may either enhance or reduce the biological pump (deeper or shallower nutricline) depending on ocean circulation. So again, this statement is not accurate and the literature is not cited appropriately.

The deepening of the nutricline is estimated in the central part of the Beaufort Gyre. According to Nishino et al. (2011), shallower nutricline will be observed in the edge part of the gyre. The description “deepening of the nutricline” is revised as “deepening of the nutricline in the central part of the Beaufort Gyre”.

-. . .whereas there has been no year-round monitoring study of settling particles except for that by Watanabe et al. (2014).

This should be reformulated as results presented in this study are in large part the same as presented in the Watanabe et al. paper.

This part was rewritten as follows: “Based on the first year-round monitoring of settling particle flux in the southern Northwind Abyssal Plain by Watanabe et al. (2014), it was suggested that the large amount of settling biogenic and lithogenic particles in November-December 2010 was transported from the Chukchi Sea shelf by the westward advection of cold eddy which developed around the off Barrow Canyon in early summer 2010.”

-The only previous report on a time-series of diatom fluxes in the basin of the Arctic Ocean is that by Zernova et al. (2000). . .

Although the deep Fram Strait is not a central basin, it would be worth mentioning that long-term diatom fluxes were also reported by Bauerfeind et al. (2009) at the HAUSGARTEN observatory.

Based on the suggestion, Bauerfeind et al. (2009) was newly included in the Introduction.

Material and Methods

-Because the moored sediment trap array at Station NAP did not include equipment to measure current velocity, temperature, or salinity (i.e., acoustic Doppler current profiler [ADCP] or conductivity–temperature–depth [CTD] sensors). . .

If there were no equipment to measure temperature, how come water temperatures recorded at the shallow trap are presented in the Results and figure 2? The pressure and temperature sensor mentioned in the Results section must be described in the Material and Methods section.

Temperature and pressure sensors have been mounted on the sediment trap. Water temperature at moored trap depth presented in text and Fig 2 is based on the monitoring data by these sensors. The sentences were revised as follows. “The deployed sediment trap mounts pressure and temperature sensors. Because the moored sediment trap array at Station NAP did not include equipment to measure current velocity, and salinity, …”

Results

There is still a large amount of sea ice algae collected in the upper trap when there is no more ice at the end of August and in September 2011. As the ice recedes towards the north, could it be that these ice algae fluxes actually reflect lateral advection from the north?

The sea ice-related diatom *Fossula arctica*, which was dominant in summer 2011, is observed as not only an attached form to sea ice but also as a plankton (Cramer, 1999). In addition to our diatom data, occurrence of the Pacific water copepods in the summer 2011 also suggests the temporal input of shelf waters into the studied region. Although we do not have the *in situ* observation data on primary productivity and plankton biocoenosis at Station NAP in summer 2011, high diatom productivity supported by the advected nutrient-rich shelf waters and high flux of settling diatoms are estimated with the simulated hydrographic situation of summer 2011.

-*Melosira arctica*, which was commonly observed at Station LOMO2 (Zernova et al., 2000) and under summer sea ice in the Amundsen and Nansen basins (Boetius et al., 2013), was rarely observed in the studied samples...

*Melosira arctica* was not commonly observed under sea ice by Boetius et al. in the Amundsen and Nansen Basins, it was rather commonly observed on the deep seafloor of the Arctic basins. Also, even if *Melosira arctica* was rarely observed, information should be provided regarding how much and when.

It would also be interesting to present the proportion of intact cells vs resting spores, which could potentially inform on the origin of the ice algae (and ice).

The description was corrected based on the comment and additional paper (Lallande et al. 2009). Because the abundance of *Melorira arctica* was very low in this study, the occurrence notice of *M. arctica* was plotted in Figure 3c and 3d. The flux data of *M. arcitica* is included in supplementary data table. Unfortunately, I did not distinguish the intact cells from all encountered diatoms during the cell counting work for all samples.

Discussion

-In contrast to the situation in 2011, the limited influence of shelf-origin sea-ice and shelf waters around Station NAP in 2012. . .

Here it is implied that the ice does not have the same origin in 2011 and 2012, while sea ice concentration was similar for both years. Again, the origin of the ice could be further discussed using backtracking with satellite data. The authors should make a distinction between water and ice origin.

The additional figures (Figs. 5 and 6) representing sea ice flow by satellite and our model was prepared. Regarding to the addition of new figures, text in the method section was revised. We think that the additional data and our interpretation on settling diatom fluxes are not contradict. Previous Figures 5 and 6 were re-numbered as Figures 7 and 8, respectively.

A statement made in the Introduction: . . .the intensification of sea-surface circulation resulting from the sea-ice decline promotes lateral shelf–basin interactions (Nishino et al., 2011b; Watanabe and Hasumi, 2009)...

If a decline in sea ice results in an intensification of circulation promoting lateral shelf basin interactions, then a larger lateral advection of matter due to more frequent eddies should have been recorded in 2012 due to the record low ice extent. The authors should discuss the fact that their results in 2012 contradict their introductory statement.

The increasing eddy formation by sea-ice decrease is clary observed in decadal time scale. In the intra- and interannual time scale as discussed in this paper, eddy formation also reflects a condition of wind systems. As far as we see the simulated hydrographic condition, the eddy-induced lateral transport of shelf materials to Station NAP is the event of early winter. It is considered that the advected shelf materials transported by eddies do not directly influence to the summer diatom flux. In schematic view point, the eddy track is observed along the edge of the Beaufort Gyre. However, Station NAP in summer 2012 was within the Beaufort Gyre rather than the edge of gyre, and we may not clearly detect the eddy's influence in the settling particles at Station NAP in October-December 2012. The studied period of this paper ends in early September 2012, and the following samples are under the analysis from last month. The results from October 2012 will be shown in another paper in future. In addition, our co-author Dr. Eiji Watanabe is working on the physical oceanographic study in detail now. The confirmation of eddy formation along the shelf break of western Arctic Ocean in summer 2012 and the relationship with decreased sea-ice condition are the out of objectives in this paper, but will be presented in other papers.

Also, as the eddy-induced biological pump would be enhanced by sea ice retreat, how can you explain that the model showed the presence of a drifting anti-cyclonic cold eddy in October-December 2010 only but not in 2011 or 2012?

Although the model experiment for eddy advection at Station NAP was conducted for the hydrographic situation only in November-December 2010 because of limited super computer resource, eddy occurrence and westward advection along the edge of Beaufort Gyre is commonly figured. As the cause of particle flux maxima in November-December of 2010 and 2011, westward advection of eddies originated from off the Barrow Canyon are the strongest candidate to explain the results. Another mooring at Station NAP from October 2013 to September 2014 has deployed current meter and other equipment such as CTD and chlorophyll sensors. Further discussion on the material advection will be proceeded in near future.

Finally, there is a distinct important physical event occurring in July 2012 (recorded from the pressure-temperature sensor) that is not discussed in the manuscript. The authors should explain what caused the trap to go deeper and into warmer waters. A similar event also appears to have occurred in May 2012.

This physical event had been mentioned in the last part of section 3.1 "Oceanographic features and mooring conditions". The temporal deepening of bottom-tethered trap usually reflect a tilted mooring by strong lateral current. Because deployment of current meter with sediment trap started from the next deployment after October 2012 we do not have the certain evidence on this event. Just as one possibility, cyclones in the Arctic Ocean for July 2012 might be influenced to the temporal hydrographic change around the study area. Although the deepening of shallow trap in May 2012 was minor compared to that in July 2012, the increase of water temperature at shallow trap depth suggests the shallowing boundary of the Pacific and the Atlantic water layers. The event in May 2012 was shortly mentioned in the revised manuscript. The cyclone in May 2012 shortly passed over Station NAP, which might cause the temporal upwelling of the Atlantic water.