Interactive comment on "Inter-shelf nutrient transport from the East China Sea as a major nutrient source supporting winter primary production on the northeast South China Sea shelf" by A. Han et al.

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Response to Anonymous Referee #2

General Comments:
Han et al. studied the nutrient transport between the shelves of the two major marginal seas of mainland China, the East China Sea (ECS) and the northeast South China Sea (SCS). Based on combining results from field data and modeled volume transport rates, they estimated a DIN flux of 1430±260 mol/s from ECS to SCS via Taiwan Strait, about 6 fold higher than that from the Pearl River. They argued that the along-shelf nutrient transport was the major driver for primary production in the northeast South China Sea. These results are interesting to oceanographic community and potentially important for local marine environmental protections and managements. However, after carefully reading the manuscript, I found there were several issues in their analyses (please refer to my specific comments for detail). Given the large uncertainty of the flux estimate and the limited area of the CCC in the sampling section, the impact of inter-shelf nutrient flux of CCC on primary production in the northeast SCS may be overestimated. Given these concerns, I have to suggest a major revision of the paper before publication.

[Response] We thank the reviewer's overall positive comments towards the importance of this study. And we have fully taken comments into consideration during our revision of the manuscript. We have also been aware that the present estimate of the inter-shelf nutrient fluxes is subject to uncertainties. The uncertainties were obviously associated with both the nutrient concentrations and volume transport.

Firstly, as clearly stated in the original MS, DIN concentrations in the TWS segment were ~ 8.9-13.1 μmol L^{-1} in the two winter seasons (2008 and 2009). Previous results from field observations were also shown for comparison. Average nitrate in the TWS (from ~ 24.2^{o}N, 118.5^{o}E to ~ 26.2^{o}N, 120.4^{o}E) ranges ~ 13.0-15.0 μmol L^{-1} in January 2003 (Chen, 2008; Naik and Chen, 2008). Average nitrate concentration in the northern TWS (~ 25.3^{o}N, 120.0^{o}E) decreased from ~ 14.0 μmol L^{-1} in the surface to ~ 4.0 μmol L^{-1} in the bottom in March 1997 (Liu et al., 2000). In addition, DIN concentrations in the southern TWS (~ 24.4^{o}N, 118.7 ^{o}E) were ~ 7.7-20.1 μmol L^{-1} in November 2008 (Yan, 2011). Taken together, there was no noticeable inter-winter variation in DIN concentrations in the CCC of the TWS segment. Moreover, considering that there was no significant vertical gradient for stations with water depth <30 m and was considerably stratification for stations with water depth >30 m, it is reasonable to use the average depth-integrated concentration of ~ 11.0±2.0 μmol L^{-1} to represent the DIN level in the CCC of the TWS segment.

Secondly, as stated in the MS, we summarized that the southward T_T ranged from ~ 0.05 to ~ 0.23 Sv based on different observational results of current field. For example, two sets of time series along-strait current volume transport T_T in the western TWS in 1999 and 2001, and other previous published data (Liang et al. 2003; Fu et al., 1991; Pan et al., 2012). Considering that the field observations in the TWS were generally short-term, and especially with limited spatial and temporal coverage, we adopted a climatological numerical model to simulate the current velocity across the TWS in the entire winter (December, January and February). Considering the modeled velocity essentially decreased from ~ 0.3 m s^{-1} in the nearshore area to 0.1 m s^{-1} in the offshore region within CCC, which was validated by previous sb-ADCP measurements surveyed around a similar location (Liang et al., 2003), the integrated T_T of 0.13±0.09 Sv was reasonable to represent the winter CCC T_T level in the TWS.

We also point out that this study highlights, as being well taken by Reviewer 1, the importance of long range nutrient transport between two of the major shelf systems, and to support the primary productivity in the NSCS in winter which is oligotrophic otherwise. We also contend that such nutrient transport might also be significant in other shelf settings, the process of which has not been widely recognized.

Finally, we have fully considered the concerns from the Reviewer and have further estimated the uncertainties in our flux estimation, which have been added to our revision of the MS.

Specific Comments:

1. Page 3897, Lines 1-9: It would be interesting to plot the T/S diagram for all the water masses discussed in the area, which would strengthen the argument of water mixing scenario they proposed.

[Response] The comment has been taken. We have plotted the T-S diagram superimposed with the data of DIN:PO_4 (Figure 2.1). The T-S diagram clearly demonstrated the water masses in the region of survey.

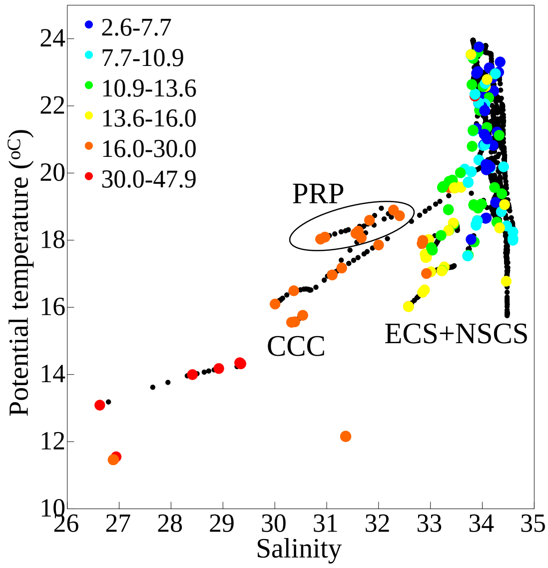

Figure 2.1. Potential temperature (θ, ^{o}C)-Salinity diagram superimposed with the data of DIN:PO_4. Black circles represent the potential temperature and salinity. Color circles are the DIN:PO_4 ratio for samples collected on the ECS and the NSCS shelf through the TWS in winter 2008 (Pearl River plume: PRP; China Coastal Current: CCC).

2. Page 3898, Lines 3-6: Low chlorophyll but high nutrients in the surface of ECS than SCS (Fig. 2c-e) during the cruises may not be simply attributed to low temperature. Comparing the mean sea surface temperature (Fig.1a) and sea surface chlorophyll (Fig.7a) from satellite data, one can easily find that high chlorophyll in the ECS with lower temperature compared to northeast SCS.

[Response] The comment has been taken. We have revised it into "Low Chl *a* in the ECS in winter is believed to be primarily attributable to the low temperature that limits the phytoplankton growth although limited light penetration in winter could alternatively play a role (Gong et al., 2003).".

As we clearly stated in the MS that the satellite-derived Chl *a* concentration may be subject to large errors in the nearshore regions due to the impact from the high suspended particle concentration (Kiyomoto et al., 2001; Liu et al., 2007), which were not adopted for discussion in the present study. We used the *in situ* observation to study the sea surface chlorophyll in the ECS nearshore.

3. Page 3899, Lines 1-14: The comparison of the transect data of ECS (Fig.3) and SCS (Fig.4) is interesting and may need further discussion. Could the difference of chlorophyll in the outer shelves of Transect PN and Transect 2 come from other factors influencing the growth efficiency of phytoplankton such as iron limitation or light limitation?

[Response] The comment has been taken, and we have added more description and further discussion in the revised MS.

First, temperature on the NSCS shelf was much higher than that of the ECS. Gong et al. (2003) have demonstrated that the temperature was one of the most important factors limiting the algae growth on the ECS shelf.

Second, we made a comparison between the distributions of total suspended materials (TSM) along Transect PN on the ECS shelf and Transect 2 on the NSCS shelf in winter 2008, which showed much higher levels of TSM in ECS (Figure 2.2). High TSM may obviously influence the light penetration depth and potentially impact on the phytoplankton growth on the ECS shelf.

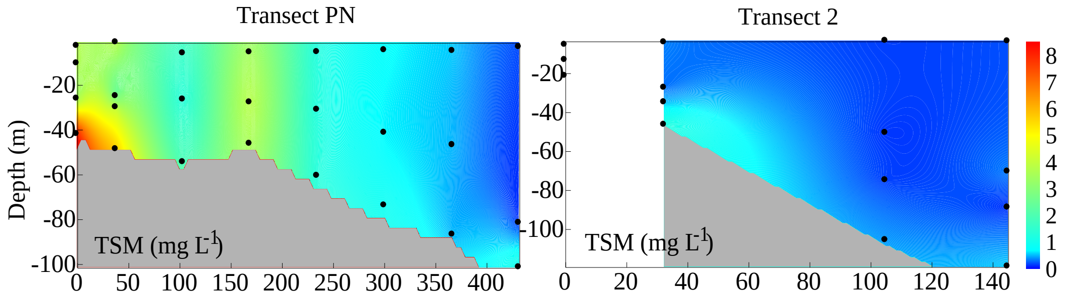

Figure 2.2. Transectional distributions of turbidity in Transect PN on the ECS shelf and in Transect A on the NSCS shelf in winter 2008.

Finally, although we cannot exclude iron limitation for the growth of phytoplankton in the ECS, and indeed, limited studies have revealed that addition of dust, or iron and other nutrients into an on-deck mesocosm incubation system (onboard a cruise to the Yellow Sea and East China Sea) promotes primary productivity (H. Gao, Personal Communication), we are not at a position to examine the potential of iron limitation in ECS. Moreover, in a comparative view, ECS has clearly more abundant iron input sources from for example, atmospheric deposition and larger river input as compared to the NSCS.

4. Page 3901, Line 14: biological consumption will lead to increase but not decrease of the N:P ratio in the water columns in this particular case. For example, N:P ratio of 50:1 in source water (100 uM of DIN, 2 uM of DIP) will be changed to a ratio of 84:1 (84 uM of DIN, 1 uM of DIP) after Redfield biological removal of 16 uM of DIN and 1 uM of DIP.

[Response] The comment has been taken. We have revised it into "The rapid reduction of the DIN:PO_4 ratio from the Changjiang to the CCC might primarily be induced by the mixing with the ambient seawater with low DIN:PO_4 ratios, as well as the biological process (Chai et al., 2006; Zhang et al., 2007; Lui and Chen, 2011; Han et al., 2012).".

5. Page 3901, Lines 16-28: Discussion of the varying DIN:SRP ratios for different

waters (Fig.6) should be compared to water-mass analyses (T/S diagram).

[Response] The comment has been taken, and we have plotted a Potential temperature (θ, ^{o}C)-Salinity diagram superimposed with the data of DIN:PO_4 in the revised MS (Figure 2.1). The different DIN:SRP ratios in different water masses are now clearly shown in the figure (please refer to Response 1).

6. Page 3902, Lines 21-24: "almost comparable to" should be changed to "higher than"

[Response] Agreed.

7. Page 3902, Lines 25-28: According to Fig.1a-b, the influence of CCC is only limited to the inner shelf of the northeast SCS (<50m isobaths). However, the field data of Transect 2 (Fig.4f) suggested that chlorophyll is also high in the upper layers of the northeast SCS (~145 km away from the coast). Apparently, the high biomass there was not due to the mixing of CCC and SCS as the chlorophyll is much lower in the outer shelf (~105 km from the coast). I expect the diapycnal diffusion fluxes of nutrients would be important there, which however are not quantified in the paper. The authors should address this issue in the revised manuscript.

[Response] The reviewer is right. We fully agreed that the CCC should not be able to influence the offshore regions such as the far field in Transect 2. However, the values of the Chl *a* in the upper layers of the northern SCS was comparable with that in the outer shelf, as being shown in the Figure 2.3 with the values of Chl *a* added.

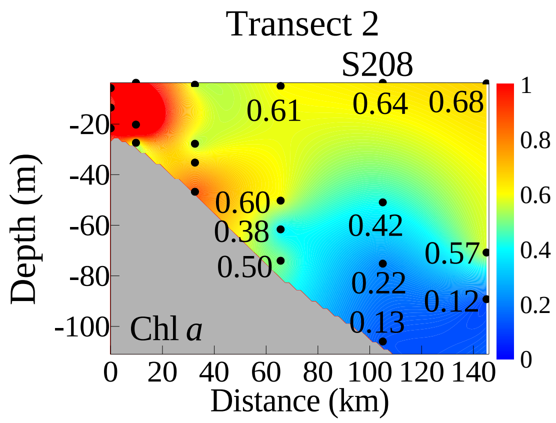

Figure 2.3. Transectional distribution of Chl *a* (mg m^{-3}) in Transect 2 on the NSCS shelf in winter 2008

Secondly, we also thank that the Reviewer pointed out the potential importance of diapycnal diffusion in contributing nutrients from subsurface in winter. We note however, that the seawater was well mixed on the NSCS shelf in winter. Taking Station 208 as an example, the diaphynal diffusion flux was estimated to be as low as 0.37 mmol m^{-2} d^{-1}. As it will take > one year for the diapycnal diffusion to meet the

DIN inventory, the contribution from diaphycnal diffusion to supply nutrients should not be significant.

8. Page 3903, Line 20-25: The calculation of net southward total-volume-transport rates (-0.23 Sv and -0.07 Sv) may not be appropriate given the large error-bars (±0.37Sv and ±0.24 Sv). The author should conduct significant test for the associated data.

[Response] The transport volume here is the time average value during the period. The so-called "error bars" of ±0.26 Sv, ±0.11 Sv, ±0.14 Sv, and ±0.10 Sv are the standard deviations from the mean values reflecting the strong variability of currents rather than merely "error".

In winter 1999, T_T varied from -1.08 to 0.50 Sv. If we average all the negative values (or southward transport), the number would be -0.35±0.26 Sv. Similarly, the average of all positive values (or northward transport) would be 0.12±0.11 Sv. Net T_T was therefore southward, with a value of 0.23 Sv and a standard deviation of 0.28 Sv. While, in winter 2001, T_T had lower values ranging from -0.59 to 0.43 Sv. Based on the average negative value of -0.19±0.14 Sv and the positive value of 0.13±0.10 Sv, net T_T was also southward, being 0.07±0.17 Sv.

9. Page 3903-3905, Section 4.1.1 and 4.1.2: It is quite confusing here since the authors compare net $\mathrm{T_T}$ and southward $\mathrm{T_T}$ at the same time. The direction of current velocity in the two stations varied frequently through the time-series (Fig.8) suggesting a periodic injection of the high-nutrient CCC water to the west TWS. Therefore, I think it may better to estimate TT by using just the southward value but not the net value (southward minus northward) since only southward transport will bring nutrients to the SCS.

[Response] Sorry for the confusion. As stated above, the net/integrated T_T derived from the field observation was southward. We adopted the *in situ* results and previous reports to validate the model result, which was consistently southward. We have clarified the description of T_T as suggested.

We also point out that water flow fluctuated and the nutrients transport was not only southward but also northward. Such fluctuation may be caused by the northeast monsoon relaxation or diverse monsoon (Jan and Chao, 2003; Wu and Hsin, 2005; Lin et al., 2005; Pan et al., 2012). It will be much more reasonable to use the net/integrated (averaged southward value minus averaged northward value) volume transport for the estimation of the CCC transport, which represented the total volume transport in the wintertime.

10. Page 3905, Line 16: The author should provide the error-bar for the estimated T_T of 0.13 Sv for CCC in TWS.

[Response] We have revised the MS as suggested. The model was simulated for twenty years during which the model reaches quasi-steady state. We adopted model derived winter (December, January and February) data from the last three years to calculate the average winter transport. The averaged southward CCC volume was 0.13 Sv, and the standard deviation for three winter seasons is 0.09 Sv.

11. Page 3905, Line 20: The flux estimate of ~1430±260 mol/s is incorrect. The author should also include the error bar of TT in the calculations. For example, if we use the observed southward TT of 0.14±0.09 Sv (Page 3904, Line 11), then the flux is (11.0±2.0 uM) ïC´ t' (0.14±0.09 Sv) = 1540±1450 mol/s.

[Response] Thanks for the important suggestions. We have recalculated the nutrient flux as suggested by including the error bar of T_T, as well as the error of DIN concentration. The nutrient flux was ~1430±1024 mol s^{-1}, based on the volume transport of 0.13±0.09 Sv and the DIN concentration of 11.0±2.0 μmol L^{-1}.

12. Page 3905, Lines 26: The authors should discuss the source of uncertainty to their flux estimate of CCC before comparing it to nutrient fluxes from Changjiang and Pearl River.

[Response] We have addressed this issue in our Response to the Specific Comment 10, and have revised the MS accordingly. "The uncertainty sources to the nutrients flux estimate of CCC are associated with the concentration of nutrients in the CCC and the CCC volume transport.".

13. Page 3906, Section 4.3: The estimates of CCC-supported new and primary productions are misleading here. Statistical analyses are needed here in order to provide an unbiased estimate. The authors also need to consider error propagation in their calculations.

[Response] As stated in the above Responses 11 and 12, we considered the uncertainty/error propagation of the nutrient flux estimation, and recalculated the DIN flux of ~ 1430±1024 mol s^{-1}. Finally, we recalculated the production of ~ $8.84 \pm 6.33 \times 10^{11}$ gC being fixed on the NESCS shelf. The errors for the carbon production are based on the error propagation from the uncertainties of DIN concentration and volume transport. The statement has been added in the revised MS.

14. Page 3906, Line 23: It is inappropriate to express approximate estimates as "~>58±10%" and "~38±7–24±4%". I would suggest change them to "~58%" and "38-24%". On the other hand, the values of 58±10% , 38±7%, and 24±4% are pretty conservative numbers, while the total area of the NESCS shelf is only a rough calculated number. How much can we trust these estimates?

[Response] We double checked and have recalculated the shelf area shallower than ≤100 m based on the bathymetry of the numerical model (Figure 2.4). The area is ~ 8.8×10^4 km^2 and we can quantify the percentage of CCC-supported carbon to new production and primary production on the NESCS shelf was 74-33% and 22-14%, respectively.

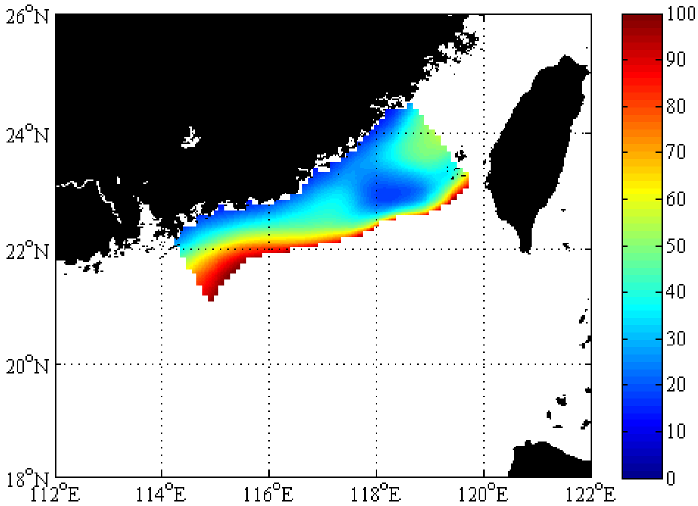

Figure 2.4. Shelf area shallower than ≤100 m on the NESCS shelf based on the bathymetry of the numerical model.

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