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Ocean Science Discussions

Interactive comment on "Modeling the effects of size on patch dynamics of an inert tracer" *by* P. Xiu and F. Chai

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Reply to Referee #2 Comments

Thank you so much for the valuable comments. For conveniences, we have repeated the referee's comments and followed by our responses.

This paper performs several numerical experiments, where a patch of dye of different sizes are introduced into a flow field and the fate of the patch is examined. The dilution of the patches appear to follow theoretical dispersion, but the timescales appear different depending on the initial size of the patch. The bottom line is that bigger patches take longer to disappear and maintain higher values for longer - so could have more impact in, for instance, iron fertilization experiments. I think a version of the paper is

worth publishing, however I have some serious queries about the consequences of some of the definitions (such as "disappear") and a concern that there is no attempt to see how normalizing the results with the total amount of dye introduced would impact the inferences.

Main concerns: 1) the definition of "disappearance" of the patch is given when the dye drops to 0.1. How would a different definition change your results (e.g. Laws 1/e)? In fact the dye never disappears, but becomes increasingly diluted. What would happen if you used a specific value rather than a ratio as the definition (see 2 below). If this dye was iron and introduced at 2nM, would its impact be totally gone if it "disappeared" (i.e. 0.2nM) as given by the definition here. I suspect not - so absolute values are still relevant here.

Response: Thanks for pointing this out. First, Fig. 1 shows the time evolution of the area within the contour c=1/e. Note that the consequence of defining the patch to be 1/e is that the region with tracer concentration lower than 1/e are treated as ambient waters. The reason why we only see the decreasing phase in Fig. 1 is probably caused by the high concentration (1/e) in the ambient waters. However, in the iron enrichment experiments, the ambient waters always stay iron-limited. Therefore, 1/e is too high for our experiments. Second, as indicated by Law et al. (2006), they use m/e to indicate patch center but m/7.5 to represent total patch area. Also in Lee et al. (2009), they also use a value of m/e3 to represent an area which encompasses about 95% of the total tracer load. Fig.2 shows a comparison between 0.1 and 0.05. , the values for 0.1 patch are a little different from the 0.05 patch, but we still can see that the rate is initial size dependent, which is the focus of this study. But we also can't just choose the zero contour line as the tracer patch, because it's not consistent with iron enrichment situation and the area of zero contour line will keep increasing during the time evolution. Also, since our experiment is only taken for one year, if we choose a relatively low value like 0.01, we will not see the decreasing phase within one-year study. Thus, 0.1 is chosen from our many trial experiments not only to represent the real iron enrichment experiment but also to elucidate the impact due to initial patch sizes.

2) larger patches have larger amounts of dye added. Is there some way to normalize your results with this in some way? For instance would the same amount (mass) of dye added in a smaller patch take as long to "disappear", if the definition of "disappear" was based on on an actual rather than relative value. I think an additional experiments (or diagnostics) to see the impact of total amount of dye on the results is warranted to address this question. This is especially true given that the authors motivate these experiments by iron fertilization experiments.

Response: Yes, larger patches have larger amounts. By using the normalization, we can compare the results from different initial patch sizes. During the iron enrichment, people might be more interested in the iron concentration but not the total iron load within the area, because phytoplankton growth could be strongly stimulated only when the iron concentration reaches a certain value. If we consider the iron concentration limit to be 0.1 (assumption), then the only difference among different patches at the initial stage is their sizes. Also, by doing so we make sure that the area defined by 0.1 in large patches is larger than small ones. However, if we put the same amount tracer into different patches, larger patches will have lower concentration, then we can't guarantee that the area defined by 0.1 in large patch is larger than small ones. We know adding a certain amount is especially true in iron enrichment experiments but the focus of this study is to elucidate the impact due to different initial patch sizes.

3) even given the above, the authors should be careful on extrapolating their results to iron fertilization experiments - this is after all a passive tracer that they are looking at here, and the timescales of the biological uptake may change the dispersion results significantly. There are few statements in the text that mention this limitation: I think more should be mentioned in this regard in abstract and conclusions.

Response: Thanks for the suggestion. We have added the followings in the manuscript,

around page 15, line 9:

"We understand that only physical processes are included in this study, however, biogeochemical processes may change the behavior of patch dilution significantly (Neufeld et al., 2002; Elliott and Chu, 2003)."

4) nothing is mentioned about the (smaller) scales that are missed by the physical model. It would be good to mention that your model does not capture all the scales and speculate on what is being missed as a consequence.

Response: We have added the followings in the manuscript, around page 13, line 16:

"The difference between these two cases is probably caused by the different physical environment, such as surface wind, current, and diffusion effect, as well as some small-scale processes like waves and turbulence that are missed by our physical model."

Some details:

1737 line 1-3: I think you mean that "impact of patch size" was not investigated. As written here you suggest that influence on phytoplankton bloom and carbon cycling was not investigated - and that is obviously not correct.

Response: We changed this sentence, around page 3, line 9:

"The impact of patch size on phytoplankton bloom and carbon cycling were not fully assessed."

1737 line 7-10: I think the biology could have an order 1 impact – if the biological timescale is quicker than the advection and diffusion timescale, then I think this statement is incorrect.

Response: The biology may have a certain impact on the patch reshaping, but physical processes should be the primary process that controls the movement of the patch.

1737 line 14-17: It would be nice to have a brief explanation of why the growth goes in these two stages.

Response: Thanks for the suggestion. We have modified this part as follows, around page 3, line 19:

“For the physical processes controlling a surface patch, there are generally three stages of dispersion, because different control mechanisms are found on different length scale the patch (Garrett, 1983). The first stage is a linear growth with time at a rate proportional to small-scale diffusivity; the second stage begins when the patch reaches a length scale large enough for the stirring by shear flow that advects the patch into long streaks with an exponential growth rate with time; when the length scale of the patch is longer than that of the eddies, the third stage begins, in which surface area begins to increase linearly again.”

1737 line 19: I think you mean "first" not "second" stage here?

Response: We mean the second. In order to make it clear, we modified as follows, around page 4, line 4:

“For all of the iron enrichment experiments, the iron patches usually start with a scale of $\sim$1000m and most of the observed patches are at their second stage (Abraham et al., 2000; Ledwell et al., 1998). The third stage of the patch can be observed if only the experiment lasts long enough (Sundermeyer and Price, 1998).”

1738 line 16: Since nutrients are not addressed in this article, K(N*-N) seems a bit confusing.

Response: We have removed the nutrient description.

1739 line 13-14: Why do you say "IT is very similar to SF6". In what manner (inert)?

Response: Yes, IT has the inert property, which is complete conservative. We compare IT with SF6 because this study is motivated by the iron enrichment, though they are not totally the same. SF6 decays through air-sea exchange.

1739 line 22: What happens if you use 1/e instead?

Response: see the first response

1739 line24-25: How was this fitting technique done?

Response: We use nonlinear minimization technique to fit measured surface tracer concentration C with Gaussian equation. In general, we provide σx, σy and N with initial values, then we get an estimate of C. Keep changing σx, σy and N values until the estimated C equals the measured C. Then σx, σy and N will be the value we are looking for. Of course, there are a lot of minimization algorithms we can use to optimize the entire process, like Quasi-Newton method and Conjugate gradient method.

1739: line 25: remove "that"

Response: Thanks, we have removed “that”.

1742 line 17: "While note..." is an awkward sentence. Also, I think you need more clarification in this regard through out the paper.

Response: Thanks for pointing this out. We modified that as follows, around page 10, line 14:

“The discrepancy might be caused by the lack of biological activities in our model, which could affect patch dynamics significantly.”

1744 line 8-15: Similar results would probably also be true if you had used different locations instead of different initialization time. Given this, it suggests you need to be more emphatic that exact times calculated here are not important, but rather the sequence of dispersion.

Response: Indeed, we also did some experiments for the same time but in different locations, and the results are similar. We have added the followings, around page 13, line 10:

“The b2 values from exponential regression are also found to be correlated linearly with the initial patch size (see Fig. 5 for the 2004 case), implying that the relationship between dilution rate and initial patch size is independent of the modelling time, though the magnitudes in 2005 case are slightly different from the 2004 case.”

1745 line 14: "larger patches have more nutrients". I think you mean more "iron" – this sentence is not clear.

Response: Sorry we did not make it clear. We mean larger patches have more nutrients but have lower dilution rate, thus with the same duration of iron fertilization, the larger patches could produce broader spatial extent and longer lasting phytoplankton bloom than smaller patches.

Figures: the axis labels (numbers and words) are much too small.

Response: We have modified all the figures to make it clear.

Figure captions:

Fig.1. Variation of surface patch area with time for 2004 case. The patch in this figure is defined as c=1/e.

Fig.2. Variation of the dilution rate with time. The left figure is for the patch that is defined as concentration higher than 0.1; the right figure is defined as higher than 0.05.

Interactive comment on Ocean Sci. Discuss., 6, 1735, 2009.

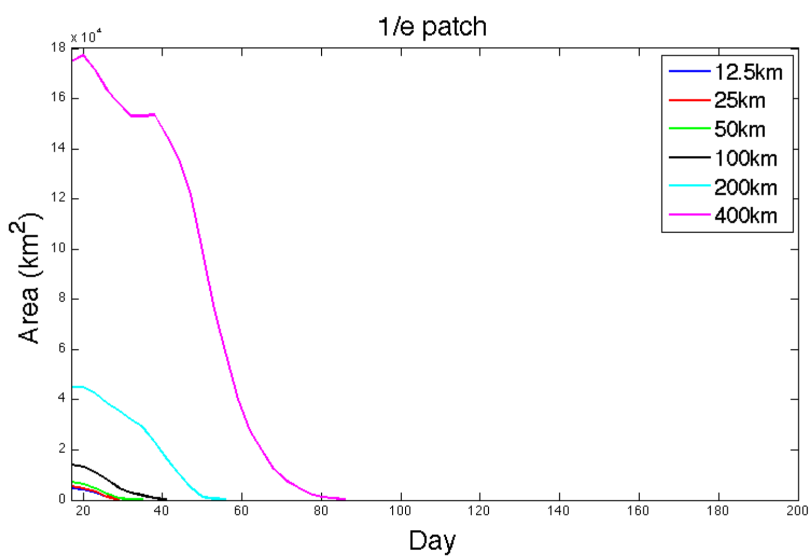

Fig. 1.

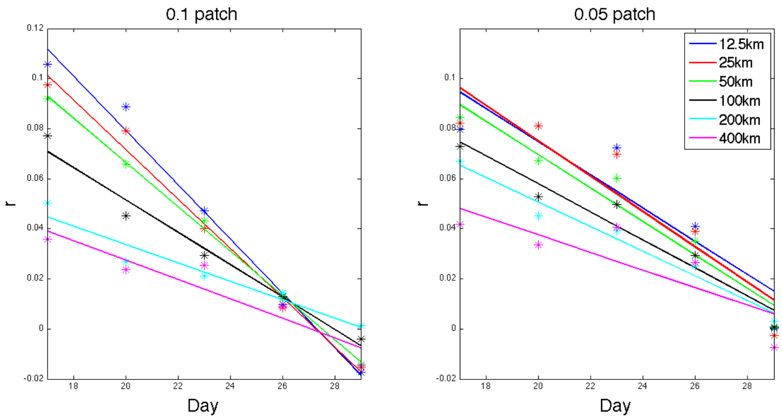

Fig. 2.