Sunda Shelf Seas: flushing rates and residence times

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Response to Reviewer #2

We'd like to thank the reviewer for the comments. We will reply to all comments in the following. Our response is in blue colour.

General comments: The MS is well written and I found it pleasant to read. The MS tries to compute the flushing times and residence times in the Sunda Shelf Seas and its adjacent marginal seas. The models applied are state of the art, and I cannot really complain about this. However, I found it a little strange that the authors decided not to include tides in the application. I can understand the problems resulting from the use of z-levels. However, transferring all the tidal mixing efficiency to the horizontal diffusion is for me not the solution of the problem. Probably a thicker surface layer would have been a better choice.

In the manuscript, we inserted some more text about the treatment of tides and tidal mixing. Tidal mixing is roughly included by increasing the factors in the calculation of horizontal and vertical exchange coefficients, which – in turn – increases the turbulent exchange of momentum, salt, temperature. So, it is roughly included in the hydrodynamical model simulations. The amount of increase is calibrated by means of observed data.

The above neglect of tides in the model is also the cause of all other problems. When the authors apply the lagrangian model, they neglect turbulent diffusion and only use advective velocities. Unfortunately, the tidal mixing effects have been transferred to the turbulent diffusion, and therefore horizontal velocities used for the lagrangian model do not have any effect of tides included.

As mentioned above, even in the Lagrangian model simulations, the mixing effect of tides on the velocities themselves is included, because the higher vertical and horizontal mixing coefficients effected the velocities already in the hydrodynamical model. It is intentionally not included in the transport of the tracers, because we used the traditional definition of residence times (Maier-Reimer, 1973; Prandle, 1984), which solely depends on advective transports.

Authors find this out when comparing flushing times with lagrangian computed residence times: the latter are much higher than the flushing times. Clearly using monthly averaged velocities for the lagrangian simulations does not help with these problems. Using these velocities is like using residual velocities, normally much lower than actual velocities. I think the use of immediate velocities would be a much better choice.

This is exactly what we intend to do: use of residual velocities. Use of instantaneously velocities would increase both renewal parameters.

In our article, we are interested in the exchange of the water body itself but not in the dilution of a substance in it. Using a Eulerian instead of a Lagrangian model would even introduce numerical diffusion. However, we are not interested in diffusive but only pure advective processes.

We added also some more explanation why we used decadal monthly averaged velocities for both methods: to obtain a better idea about the hydrodynamic role of the seasons.

Another critic is the fact that they do not use an Eulerian evaluation of the residence times. Since they already have a model it would be easy to this kind of evaluation. See for example Cucco et al. (Ecological Modelling, 2009) for the combined use of lagrangian and Eulerian model applications.

Cucco et al. (2009) and Umgiesser et al. (2014) published some very nice and interesting work. However, they just used another tool. We decided to use the Lagrangian model with our hydrodynamical model results. As mentioned before, we used the traditional formulation taking only advection into account and not the advanced one as Cucco et al. (2009) and Umgiesser et al (2014).We think that the Lagrangian approach is even better for this matter because of the numerical diffusion within the Eurlerian scheme.

866, 3-8: this is a very simplistic approach. Normally you use this approach if you only have discharge data, but no numerical model. We know that this kind of computation always produces flushing times which are much lower than realistic renewal times (see for example Umgiesser et al., 2014, JGR). So why do you use this approach?

Indeed, we used this approach only to give an idea about the order of these differences you mentioned.

866 ,11: receive -> obtain Thank you, we replaced it.

868, 9-15: now this is strange. You say you do not need to account for tides, because you simulate them through higher diffusion in the areas of high tidal mixing. Now, this is already an approach I am not completely satisfied with. However, now, for the lagrangian model, you decide to only use advection and no diffusion (no turbulent mixing). So, for the lagrangian simulations you completely neglect tidal mixing. Therefore, what I would expect is that your lagrangian derived residence or transit times are too high than they would be with tidal mixing included. Neglecting diffusion here is not a secondary effect, as it might be when neglecting non linear effects in the momentum equation, but a first order effect. This is a glitch that has to be resolved.

As mentioned already, tidal mixing is neglected in the tracer model to stick to the traditional residence time definition.

869, 1-2: you use constant velocities for the computation of the residence times. Now this sounds strange to me, because the averaged velocities are nothing than residual velocities, which normally are much lower than real immediate velocities. Again this changes the values of the computed residence times.

Exchange of water body is not accelerated by tidal currents as they usually flow forth and back only.

And when you compute fluxes over the open boundaries, do you still use averaged velocities or velocities coming out directly from the model. In the first case your flushing times will be way too high.

Yes, for the cross-sectional transports, the same averaged velocities are taken. In case of taking instantaneous velocities, we would gain even faster exchange since this is calculated only from inflowing transports being much higher if tidal movement is included.

869, 3: with these horizontal velocities. . . So I was right, you use the averaged values of the velocities. Therefore, your computed Q is wrong.

In our case, we think the computed Q is more realistic as it uses an average throughflow and not the much higher tidal inflow, which mostly causes a periodic in- and outflow and does not contribute to the long-term exchange of the water.

874, 16: so again my question. What fluxes do you use for the computation of the flushing rates: daily or monthly fluxes? Results are clearly depending on this decision.

Yes, results depend ion this, because the daily fluxes are quite much varying within a month or season because of the variability of the current system. We used monthly averages to get the idea of the role of the seasons regarding the exchange of water.

875, 15: well, only if the mixing efficiency would be 1. Again this is shown in Umgiesser et al., 2014, JGR. However, here you only consider advection, and for the lagrangian simulation do not consider tidal mixing, I guess that your mixing efficiency would be much lower than 1.

Yes, we agree. Since we do not consider mixing, mixing efficiency would be much smaller than 1. This is the reason, why some areas, especially coastal areas, show very long residence times (Figs. 7 and 8). And this is what is interesting when investigating also internal biogeochemical processes at certain locations.

875, 28: well this is not surprising to me. It all depends on the set up of the simulations.

Here, we think it is rather a result of the current system depending on the specific characteristics of the very different regions.