Title: Effect of double diffusion processes in the deep ocean on the distribution and dynamics of particulate and dissolved matter: a case study in Tyrrhenian Sea
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First, I would like to thank the authors for their detailed responses and for clarifying several points. The manuscript has been improved in several ways. For the most important: inclusion of additional examples of the influence of staircases on the particle retention process from profiles other than the initial two, better description and explanation of some of the processes with new relevant references, improved part 4.3 with a detailed view of the diffusive fluxes over the water column at station 9 instead of just one depth level.

My main point in the first review was the lack of strong evidence of the retention process of particles by staircases. The additional examples (Figs. 9 – 11) provide close-up views of the details at three steps on profiles that were not shown before. Does the revised version convince me? Unfortunately, I would say, not really, and I will explain why below.

I do understand the comments that measurements at meter scale (the scale of the steps/interfaces) of BAC, large particle abundances, … are not easy at all, and that there is a strong natural variability at small scales, that sensors have limited response time and noise, …

Several times, I have tried to convince myself that, what I observe (with the help of your text) in the figures clearly shows that staircases alter the “normal” (without staircases) behavior of particle settling. It’s clear that the profiles are different since one has a sequence of steps and layers in your data (even if it’s a bit noisier for some variables), the other shows a more usual gradual vertical gradients, as you mention. But my key question is: do the data show an anomaly in particle distribution, nutrient production or AOU, when there are staircases compared to when there are no staircases? And I’m still puzzled when I try to reconcile what I see in the data with your claim that clear evidences exist for particle retention process by staircases.

For example, the discussion of the two large-scale profiles (#9 and 20) falls short of the argument of an aggregation-retention process, which is the main focus of your paper. I don’t know what to conclude at the end of line 356. Yes, staircases are also visible for oxygen, nitrate, small particles concentrations, and somewhat less so for large particle abundance. You end the short section with a comment about the Junge index decreasing more in the case of staircases, but, how should I interpret that?

Conversely, I could argue that the concentration of small particles decreases more when there are no staircases (no stairs. :0.447 → 0.440, with stairs: 0.448 → 0.4435). I would expect the opposite if steps act as a “barrier” with aggregation of fine particles. Moreover, I could also argue that there is about the same abundance of large particles between the two profiles at 2000 m, that is after having crossed all the interfaces of the staircases (i.e. no excess of the large particle production when there are staircases, as I would expect with retention-aggregation). The large particle profiles are difficult to compare, because at the origin, at 600 m, the abundance is not the same. The profiles do not start with the same ‘initial’ conditions. Therefore, what I just wrote 2 lines above about the decrease in large particles is biased, as well as what you wrote on lines 355-356: it is difficult to interpret the decrease rates in large particles with depth since the starting points are not the same (for large particles, and thus, for the

Junge index). The proximity of the anticyclone may bias the no-staircase profile as marine production in the euphotic zone strongly depends on the vorticity field (e.g. Belkin et al. 2022, 10.5194/os-18-693-2022). This adds another degree of complexity to the staircases-nostaircase comparison.

Fine particles: should decrease more with staircases (consumed by aggregation)
Large particles: should decrease less with staircases (produced by aggregation)
Thus Jungle index (fine/large) should decrease more with stairs, but the starting point in terms of fine and large particle abundance should be the same at shallow depth (above the first step of the staircase structure) for the comparison to be meaningful.

Finally, we are left with the possible impact of staircases with the three close-up examples of steps (Figs. 9 – 11). The discussion of these figures ends up on l. 486 – 487, with the statement that the observed variations provide ‘strong evidence’ that staircases have a significant influence on particle abundance and size distribution. I agree that these figures show that staircases alter the distribution of the finest particles seen by the transmissiometer, the oxygen and the nitrate concentrations. This is easily seen when I compare the interface gradient with the upper and lower mixed layer from off the interface in these examples. For large particles (UVP measurements by particle size), there is not much evidence, point-to-point measurements show a large noise, noise that is as large as what the authors are trying to estimate. And therefore, I do not agree with the statement: l. 481, ‘an increase is evident for the largest particles’ (largest class seen by the UVP). Then follows a useful paragraph on the retention-aggregation process with references.

My conclusion is that the close-up views on these three interfaces do not show any clear evidence of retention-aggregation process, the main topic of the paper according to the abstract. They only show that mixed layers homogenize the distribution of fine particles (and nitrate, O2), and that in between, there are more or less large interfaces connecting the two mixed layers, as one would expect if one creates two successive mixed layers from an initially smooth constant gradient of properties. Unfortunately, this has nothing to do with proving the existence of a retention-aggregation process in this case of small density gradients across the interfaces.

To get such a proof, you have to show that staircases remove more fine particles and produce more large particles than you would observe in a region without staircases. This is very hard to do as the real ocean is not a controlled lab experiment where the initial conditions are the same. Given the large variability in your examples of interfaces, I would suggest doing a statistical study among all interfaces of the staircases observed in your entire data set (not just a pick-up of very few examples). For example, you could statistically study what happens within mixed layers on the one hand, and across interfaces on the other hand (sign, intensity of gradients, variability inside the mixed layer and inside interfaces), try to relate things to some parameters (dependence on the amplitude of the interface density gradient, …) and try to contrast these statistics with what is observed for the set of profiles without staircases and for the same depth ranges. You might find some undeniable statistical evidence of a retention-aggregation process. You could also look at the whole staircase structure of each profile, and try to relate whole depth variations in the abundance of fine and large particles, to the number of interfaces in the profiles, the cumulated thickness of interfaces, the intensity of the sum of the density gradients, … compare that with the ‘typical’ variations observed when there is no staircase and see if something clear emerges…. From my point of view and given the oceanic natural and instrumental variability, you cannot avoid such a statistical study to support unquestionably your conclusions about the aggregation-retention process, the main subject of your study.

Other comments:

l. 261 – 269: water masses acronyms have already been defined on page 3. No need to repeat.

Fig. 2: add TIW on the subplots

l.276: ‘The antcicylonic eddy…’: first time it is mentioned, change for ‘An anticlyclonic eddy...’
l. 277 – 280 : You can also mention the signature of the cyclonic eddy to the west of the anitcylone on the property distribution.

l. 288: ‘The cyclonic eddy…’, to be more accurate, I ‘d write ‘The southern edge of the cyclonic eddy’ given Fig. 3a. The center is sensibly further North.

Fig. 3a: add station numbers

Fig. 4. To me, not essential. Could be removed if you need room for other figures.

l. 317: To better locate immediately the turbid tongue, add : (sta. #19 – 20).

l. 424 and following: In your data, staircases largely disappear under the anticyclone, not just on the periphery (although the section does not cross the core). There is no such removal of staircases in the vicinity of the cyclone to the west. Another possibility for eroding staircases, with a contrasting behavior between cyclones and anticyclones, comes from the focusing of near inertial internal waves and associated enhanced velocity shear and mixing in anticyclones (e.g. Fer et al., 2018 : The dissipation of kinetic energy in the Lofoten Basin Eddy, J. Phys. Ocean. 48, pp. 1299-1316. Doi :10.1175/JPO-D-17-0244.1).

Section 4.2, l. 451 – 455: This is the first time you mention the particle size spectrum and its slope (?) , while no such spectrum is shown in the study. It’s a bit confusing. I guess you are simply referring to the Junge index that was discussed before, which is a very rough proxy of what a real spectrum would be. I don’t think the wording ‘spectrum’ has to be used in this study. The whole discussion can be done using the simpler Junge index that you show and discuss.

l. 454: ‘deep scattering layer’, why scattering? Meaning in this context?

l. 468 – 469 : ‘macroscale’ and ‘microscale’ are unfortunate in this context. Usually, in physical oceanography, vertical large-scale = O(>100 m), finescale (1 m – 10 m), microscale (1cm – 10 cm).

l. 474: the largest thickness among the three examples reaches ~150 m.

Fig. 9 – 11 : indicate what is the red line (mean, median, …)

l. 578 – 579 : homogenize writing of unit exponents

Fig. 12: Thanks for this useful figure. Is the divergence in nitrate fluxes between two interfaces compensated for by nitrate production? If yes, does the number make sense in terms of nitrate production by processes?