Response to the comments of the Ref. 2

The manuscript presents a reproduction of an important quasi-decadal mechanism that drives thermohaline oscillations in the Adriatic-Ionian region. I appreciate such a novel approach using tank experiments, which tries to provide the underlying physics that has (still) several possible explanations - this research is important to put proper weight on them (internal forcing vs. wind-stress curl) Therefore, I strongly recommend publication of the manuscript. Still, some issues should be cleared and corrected (also agreeing with comments of Anonymous Referee #1):

- Lines 94-106. It might be more appropriate to have this at the beginning of Section 2 (as an introduction, before Section 2.1), as justifying the applied methodology.

As suggested by the referee, the text between lines 94 and 106 (see below) was moved after the second paragraph of Section 2.1. :

"We distinguish the slope and central deep (flat bottom) areas in the tank that are equivalent to the continental slope and deep zone of the northern Ionian basin, respectively (Fig. 1). We compare the potential vorticity evolution in each area as related to the dense water flow. The two areas are presumably controlled by different processes of the vorticity generation. In the central area (flat bottom) the upper layer squeezing, due to the downslope sinking of the dense water to the lower layer, generates the upper layer anticyclonic vorticity. In the slope area, the upper layer stretching due to the downslope water flow results in the generation of the cyclonic vorticity. The lower layer on the slope is subject to squeezing and anticyclonic vorticity generation as related to the formation of the dense water flow parallel to isobaths."

- Fig. 1. It might be good to increase the font of the smallest labels, they can be hardly read in such a composite figure.

This is done and the old Fig. 1 in the revised text becomes Fig. 2 (see below).

- Section 2.1 or elsewhere. I am wondering how the scaling between the tank simulation and the real Ionian Sea has been done for (turbulent) diffusion? I see no comments on that in the text, while I believe that it might be worth to discuss somewhere. Also, please add and discuss any other limitation or approximation of the tank experiments which are relevant for the presented experiments.

We have introduced Appendix A (see text below) where we address the scaling of the turbulent diffusion and comparison between the laboratory experiments and the Ionian Sea.

"Appendix A:

Turbulent diffusion could be estimated both in the central deep and the slope domain. In both areas the turbulent diffusivity can be associated with a stratified shear layer. The turbulent energy *of a typical eddy of size L in this shear layer is of the order $E_t \sim (\varepsilon L)^{2/3}$, with ε being the dissipation rate in $m^2\ s^{-1}$, whereas the energy associated with buoyancy and shear is $E_b \sim (NL)^2$ and $E_s \sim (L\ \partial u/\partial z)^2$, respectively. Here $N^2 = -g\rho^{-1}(\partial\rho/\partial z)$ is the Brunt-Väisälä frequency and ∂u/∂z is the vertical shear.*

Balancing turbulent and forcing components yields a buoyancy length (i.e., the Ozmidov length scale) $L_o = (\varepsilon N^{-3})^{1/2}$ and a shear length $L_s = (\varepsilon <\partial u/\partial z>^{-3})^{1/2}$. This latter scale was defined initially by Corrsin (1958) as the smallest scale at which anisotropy effects resulting from a large-scale shear are carried out by the turbulent cascade.

For low Richardson numbers the effect of shear dominates the effect of buoyancy therefore, the relevant quantity to define the mixing scale is shear, while for large Richardson numbers the relevant quantity is the Brunt-Väisälä frequency N. The smaller of these lengths limits the typical eddy size.

Odier et al. (2012) proposed an approach based on the Prandtl mixing length model with a characteristic mixing length L_m to relate the turbulent eddy diffusivity v_t to the velocity fluctuations and gradients in a stratified shear layer. They showed that L_m was proportional to L_s so that the turbulent diffusivity v_t can be evaluated using:

$$v_t \sim L_s^2 <\frac{\partial u}{\partial z}>.$$

In the tank experiments we estimate $\varepsilon \approx O(10^{-4}\ m^2\ s^{-3})$ from the PIV measurements, $N=0.1\ s^{-1}$, and $<\partial u/\partial z> \approx O(1\ s^{-1})$. Introducing these values in the above expressions we obtain for $L_o \approx 0.3$ m and for $L_s \approx 0.01$ m. Hence, the eddy length scale is determined by shear since $L_s < L_o$, so that our estimate gives $v_t \sim 10^{-4}\ m^2\ s^{-1}$ for the tank experiments. Using a velocity scale, the Nof speed $U = 0.1\ m\ s^{-1}$ and the vertical scale of the gravity current of $h = 0.05$ m, the normalized turbulent diffusivity is $v_t(Uh)^{-1} \sim 0.02$. We also expect that at higher Richardson numbers, as typical in the ocean, the length scale will be determined by buoyancy, since $L_o < L_s$ so our oceanic estimate may be slightly higher. Parameterizations in ocean models (Lane-Serff and Baines, 2000) have used values in the range $0.032 < v_t < 0.70\ m^2\ s^{-1}$ for typical overflow scenarios. Critical to extrapolating to oceanic conditions is a systematic exploration of the dependence of the mixing lengths on turbulence intensity and on the degree of stratification as measured by the Richardson number.

Lane-Serff and Baines (2000) also proposed a relation to evaluate turbulent diffusivity based on scales that are easier to extrapolate for oceanic overflows, which reads:

$$v_t = (4k^2 Q f^2)(g' s^2)^{-1},$$

where Q is the injected volume transport of the gravity current and k is taken to be 2.5×10^{-3} (a typical value for oceanographic flows, e.g., Lane-Serff 1993, 1995; Bombosch and Jenkins 1995). The value of the Adriatic outflow into the Ionian Sea $Q \approx 10^5\ m^3\ s^{-1}$, along with $f = 10^{-4}\ s^{-1}$, $g' = 0.003\ m\ s^{-2}$ and $s = 0.02$ give $v_t \approx 0.02\ m^2\ s^{-1}$. Rare in situ observations of upper ocean turbulent mixing, stratification and currents in the Adriatic Sea resulted in the estimates of the eddy diffusivity in the central part of the basin (Peters and Orlić, 2005). The values are however smaller than those presented above due to weak shear and strong stratification combined with large Richardson numbers. Using $U = 0.1\ m\ s^{-1}$ as a typical *velocity scale and a typical vertical length scale of the overflow of h = 200 m, one obtains a normalized turbulent diffusivity of* $\nu_t\,(Uh)^{-1} \approx 0.001$ *for the real flow conditions in the Ionian Sea, which is smaller than the laboratory value (0.02). Note that if the above expression of Lane-Serff and Baines (2000) for the oceanic environment is applied to the laboratory experiments, the value of the constant k should be adapted to larger values, since the Reynolds number is smaller in the experimental conditions than in the real ocean (see Lane-Serff 1993, 1995; Bombosch and Jenkins 1995)."*

1) Bombosch, A. and Jenkins A. : Modeling the formation and deposition of frazil ice beneath the Filchner–Ronne Ice Shelf. J. Geophys. Res., 100, 6983–6992, 1995.
2) Corrsin S. : Local isotropy in turbulent shear flow, National Advisory Committee for Aeronautics RM 58B11, 1958.
3) Lane-Serff, G. F. : On drag-limited gravity currents.,Deep-Sea Res. I, 40, 1699–1702, 1993.
4) Lane-Serff, G. F. : On meltwater under ice-shelves, J. Geophys. Res., 100, 6961–6965, 1995.
5) Lane-Serff, G. F. and P. G. Baines: Eddy formation by overflows in stratified water. J. Phys. Ocean., 30, 327–337, 2000.
6) Odier, P., Chen J. and R. E. Ecke: Understanding and modeling turbulent fluxes and entrainment in a gravity current, Phys. D: Nonlin. Phen., 10.1016/j.physd.2011.07.010, 2012.
7) Peters, H. and M. Orlić: Turbulent mixing in the springtime central Adriatic Sea. Geofizika, 22, 1-19, 2005."

- Figure 2 caption. Please add the area or the location for which density and MLD is presented (at the very centre, Cp3 ?)

The location of the sensor used to measure density is presented in the new Fig. 1 (see the diamond symbol at the panel b) and specified in the new Fig. 2 as follows:

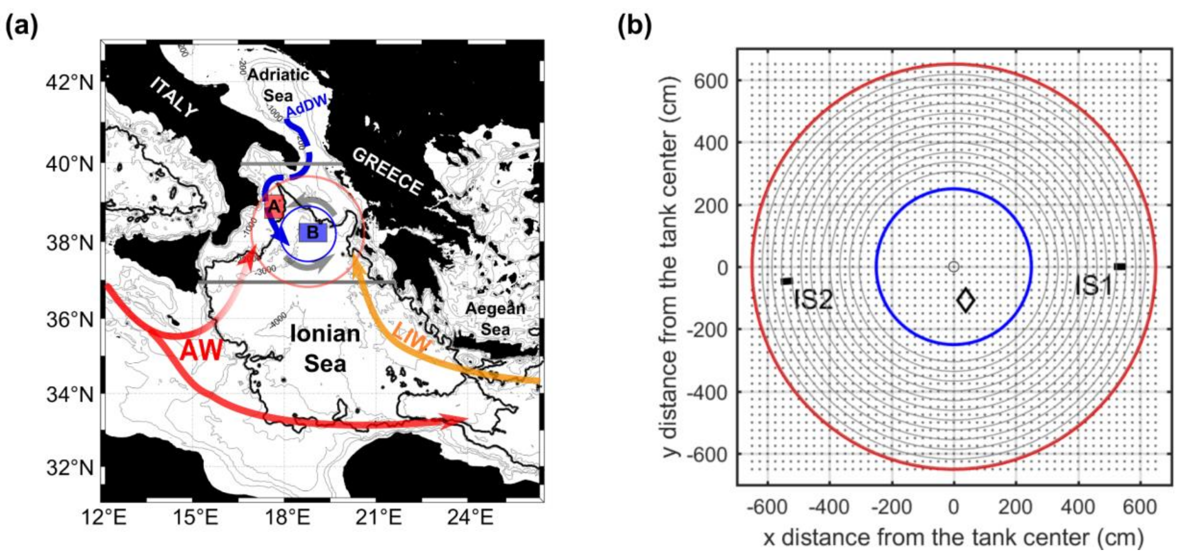

Figure 1: (a) Map of the study area in the Ionian basin with a simplified circulation scheme, which changes according to the BiOS regime. Gray horizontal lines indicate the geographical limits within which the mean vorticities above and below the 2200 m isobath were calculated. Rectangles A and B indicate the areas where density data (CMEMS reanalysis) were averaged. Concentric rings represent the simplified laboratory tank scheme. Acronyms: AW = Atlantic Water, LIW = Levantine Intermediate Water, AdDW = Adriatic Deep Water; (b) Top view of the tank: the slope area is between the red and blue circles, the deep flat-bottom area is inside the blue ring. Dense water injectors are placed at IS1 and IS2. A diamond near the center shows the location of the Cp3 profiler. Concentric gray rings indicate intersections of the laser sheet levels with the slope. Gray dots indicate regular x-y grid nodes for the tank velocity field (subsampled every 5 nodes for clarity). The map in (a) was created from the bathymetry data ETOPO2v2, NOAA, World Data Service for Geophysics, Boulder, June 2006, doi: 10.7289/V5J1012Q) using the MATLAB software.

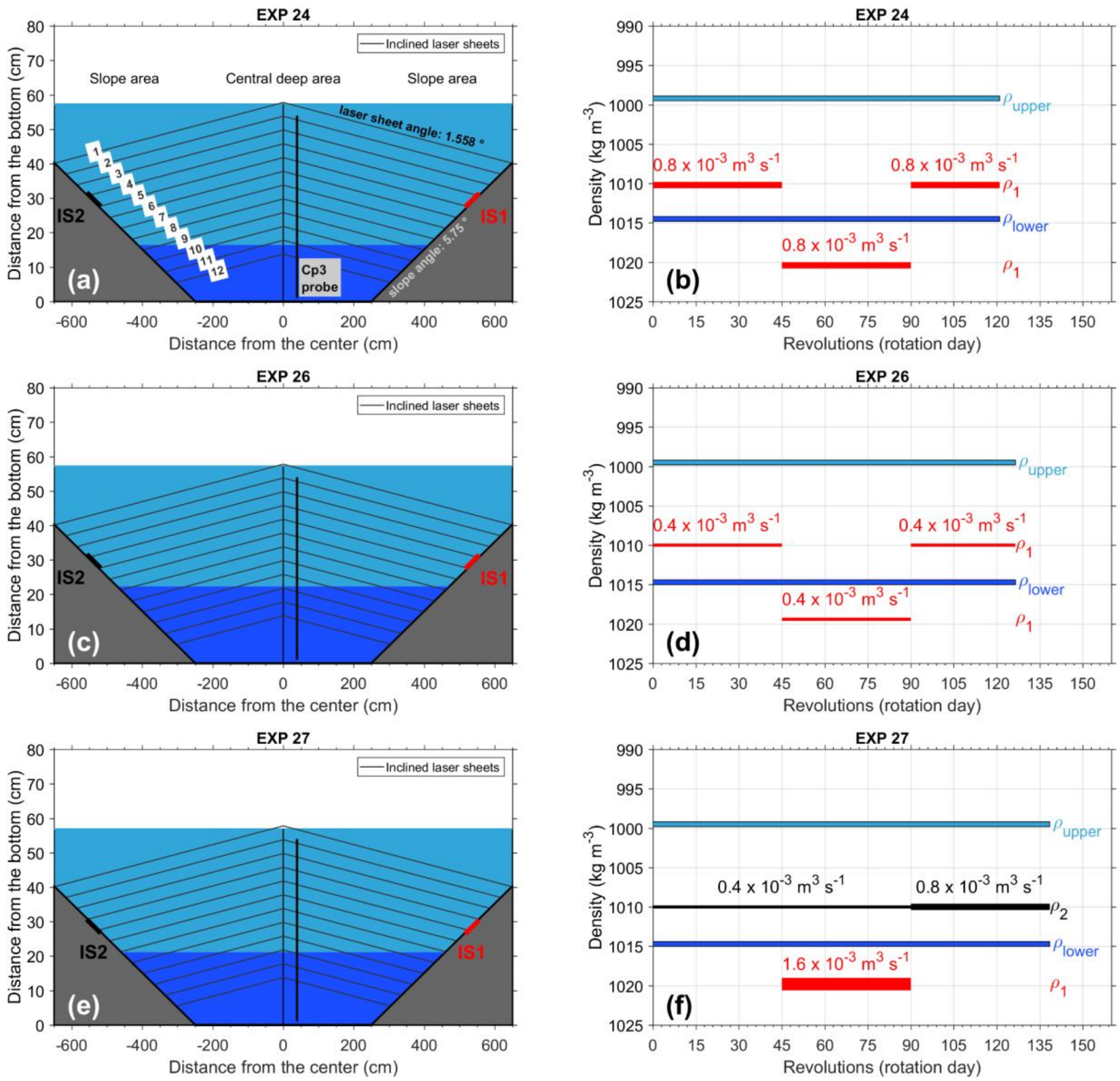

Figure 2: Scheme of the rotating tank (not to scale) and density configuration for the three experiments discussed in the paper, EXP 24, EXP 26, and EXP 27. Cross sectional view with central deep and slope areas, and injectors IS1 and IS2 (a, c, e); a vertical bar near the center of the tank indicates location of the vertical profiler Cp3; blue/cyan patches refer to the lower/upper

layers; numbers from 1 to 12 indicate inclined laser sheet levels. Initial density (blue/cyan bars) in the lower/upper layers along with density and discharge rates of the injected water (b, d, e); red/black bars correspond to IS1/IS2; the thickness of the bars corresponds to discharge rates during various phases (for details see Tables 1 and 2). Only in EXP 27 were both injectors active.

- Line 377. Densities of 2010 and 2015 kg/m3 (?)

Sorry for the mistake, corrected into 1010 and 1015.

- Fig. 9. There are two (b) marks in the figure - please correct.

In a new version of the manuscript the mistake was corrected (See new Fig. 10).

- Lines 434-436. Why did you took 2200 m as the borderline between the slope and the flat central region? Just by looking in the topography 3000 m looks more appropriate for me (plus moving lower boundary line more to the south). Please justify your choice.

We took the 2200 m isobath as the limit between the slope area and the open sea after several attempts with other choices and noticed that, essentially, different isobaths show similar features. We finally end up with taking 2200 m since in that case the number of points for both open-sea and slope areas and the number of vorticity points are similar, and the statistical significance of the average vorticity is equally representative.

- Line 566. If you have doi, you don't need to provide the direct link to the reference.

- Line 572. Missing "doi:"

- References. Please unify: doi or DOI or https://doi.org/... and add missing doi numbers for all references (for these which have them).

- References. Please unify: short or full journal names.

The references were corrected accordingly in a new version of the manuscript.