We thank the referee for carefully reviewing this manuscript and providing helpful feedback, which has greatly improved the manuscript and clarified the text. We address all issues raised in their comments below and incorporate the revised changes into the manuscript. The Reviewer comments are included below in black, and our responses to their comments are in blue. The line numbers in the responses refer to the marked-up manuscript; modified text is presented in red in the marked-up version. The modified manuscript text is pasted with the corresponding comment and presented below as *italic text*.

RC2

This is an observations based paper addressing the detachment of the P/AG water from the continental shelf into the water column as it encounters a change in the bathymetric slope, in the Gulf of Oman. The paper is well written, the figures are of very good quality and clearly show the detachment and the mixing of P/AG. In particular, the PAG water fraction (Fig 2h) clearly summarizes the findings : the P/AG flows as a very shallow bottom current as long as the shelf is no deeper than about 100m. After a rapid drop in the bathymetry, from 100m to about 300m, the P/AG current detaches from the bottom, entrains surrounding water and thickens. The connection with the detachment and the benthic life is very instructive.

Thank you for the summary of the paper and for commending its quality and significance.

My only concern is on the authors claim that the reason of the detachment is the bathymetric roughness. I find this statement insufficiently supported. The detachment is also concomitant with the slope increase, which could be another cause of detachment. At some point the authors seem to suggest it too, l.162 "*the abrupt bathymetric shift serves as the initial trigger for flow transformation*". To me, the paper would be as valuable without this claim of roughness as the controller. This would require to change the title. By the way, from Fig2, it seems that the roughness is not due to small hills but to narrow deep cracks. I believe this makes a difference, especially in terms of form drag, a process invoked by the authors, but also in terms of boundary layer stability.

Thank you for this valid and constructive point. We updated the manuscript and modified "controls" for the roughness to "modulates", in addition to integrating the roughness with Thorpe-scale proxies for further support. We also updated the manuscript to reflect that the abrupt bathymetric step is the primary trigger of outflow transformation, supported by a CTD-derived critical velocity (c_i). c_i indicates a transition from near-critical or supercritical to subcritical flow consistent with a hydraulic-jump-like adjustment. Bathymetric roughness then modulates the subsequent thickening, overturning, entrainment, and dilution across the unstable shelf. Double diffusion (salt fingering at the plume base) is placed as a secondary, background contributor to interface erosion, and mesoscale and internal-wave processes are acknowledged as additional contributors that cannot be separated quantitatively with the present dataset. The dynamical interpretation is now based on the same integrated set of hydrographic and bathymetric indicators, together with a CTD-derived critical velocity (c_i). Please check the new Methods section of "*2.2.2 CTD-derived fine-structure and overturn-proxies*", lines 129-169 (quoted above), and the new Results section of "*3.3 CTD-derived Thorpe-scale and diffusivity proxies*", lines 215-240, quoted below:

"***3.3 CTD-derived Thorpe-scale and diffusivity proxies***

The gridded Thorpe-scale section (Fig. 3a) shows that CTD-resolved density overturning is spatially heterogeneous along the P/AG outflow transect. Over the stable shelf, where the P/AG plume is thin and bottom-attached, L_T values are generally low, indicating limited accepted overturning within the compact plume. Toward the stable-to-unstable shelf transition (Fig. 3a, at station 32), L_T increases coinciding with the zone where the plume thickness curve shows rapid thickening (Fig. 3c) and where the high-P/AGw_f core begins to weaken (Fig. 2h). Across the rough unstable shelf, elevated L_T extend through a broader part of the plume and its upper interface, consistent with stronger vertical reordering of density in the same sector where salinity, temperature, oxygen, and pH decrease downstream.

The Thorpe-scale-derived diffusivity proxy, $K_\rho^{(T)}$, section (Fig. 3b) shows a similar distribution along the transect. Low $K_\rho^{(T)}$ over the stable shelf reflects the limited number and magnitude of accepted overturns in the thin attached plume. Higher $K_\rho^{(T)}$ values occur mainly near the bathymetric transition and across the unstable shelf, where the plume-thickness curve indicates rapid expansion of the P/AG layer (Fig. 3c) and the P/AGw_f section shows progressive dilution of the plume core (Fig. 2h). These enhanced diffusivity-proxy patches indicate locations where CTD fine structure records stronger overturning and vertical exchange within the transforming outflow.

Comparison with the along-transect h_r/H curve (Fig. 3d) shows that the strongest Thorpe-derived signals occur where seabed roughness becomes large relative to the local P/AG plume thickness (Fig. 3a, b, and d). In the stable shelf sector, low h_r/H, small plume thickness, and weak Thorpe-derived signals are consistent with a compact, bottom-attached plume. Immediately after the bathymetric transition, h_r/H increases as roughness elements become comparable to the plume thickness, while the L_T and $K_\rho^{(T)}$ sections show enhanced patchiness within and above the plume. Farther across the unstable shelf, the combined pattern of high or variable h_r/H, plume thickening, elevated L_T, enhanced $K_\rho^{(T)}$, P/AGw$_f$ decay, reduced oxygen, and increased turbidity supports localized roughness-modulated overturning and dilution of the P/AG plume.".

Please also check the new Discussion related to this part (in Sect. 4.1), lines 361-389, quoted below:

"*The Thorpe-scale analysis provides a quantitative hydrographic basis for interpreting the fine structure and step-like density profiles observed along the P/AG outflow pathway. Elevated L_T and $K_\rho^{(T)}$ occur preferentially near the stable-to-unstable shelf transition and across the rough bathymetry, where the P/AG plume thickens, the P/AGw$_f$ core weakens, and the sharp upper-interface N^2 maximum is eroded. L_T and $K_\rho^{(T)}$ estimates are not direct microstructure measurements, and their interpretation is constrained by standard CTD-overturn quality-control requirements and by the known uncertainty of overturn-based estimates near rough topography (Galbraith and Kelley, 1996; Gargett and Garner, 2008; Jalali et al., 2017). Nevertheless, their spatial coincidence with high h_r/H, plume thickening, P/AGw$_f$ decay, turbidity enhancement, oxygen reduction, and weakening of the upper plume interface supports the interpretation that bathymetric roughness modulates localized overturning and dilution of the P/AG plume. This relationship is strongest where the hydrographic overturn proxies coincide with the bathymetric transition and rough seabed sectors, whereas isolated overturns outside the plume or away from rough terrain are interpreted more cautiously because they may also reflect internal-wave activity, mesoscale intrusion, or double-diffusive layering.*

Double diffusion is intrinsic to the P/AG outflow: its warm, salty core overlies cooler, fresher deep water, favouring salt fingering at the base of the plume, consistent with salt fingering reported beneath P/AG water further downstream in the Sea of Oman (Font et al., 2024) and in the Arabian Sea (L'Hégaret et al., 2021; Turner, 1967). Because double diffusion operates within statically *stable stratification ($N^2>0$) and transfers heat and salt across the plume's interfaces without producing density inversions, the salt-fingering and diffusive-convection regimes (Fig. 2f) are dynamically distinct from the overturning detected by the Thorpe scale (Fig. 3a,b). Double diffusion contributes to the slow, along-path erosion of the plume's salinity, temperature, and oxygen contrasts, whereas the abrupt transformation at the bathymetric step is driven by hydraulic adjustment and overturning. In the hierarchy of processes acting on the outflow it is therefore a secondary, background contributor to interface erosion, rather than the primary driver of the step-localised transformation. The Turner angle diagnoses only susceptibility to double diffusion, not its flux, which, having a lower effective diffusivity and a different mixing efficiency than shear-driven turbulence, is not captured by $K_\rho^{(T)}$ and cannot be quantified without microstructure data.*".

The title has also been revised to "*Hydrographic Transformation of the Persian/Arabian Gulf Outflow over Rough Shelf Bathymetry in the Gulf of Oman*".

Minor remark.

Fig 3d: the colorbar for the bathymetry seems inconsistent with Fig1 and Fig2 : e.g. mooring #5 seems to go as deep as 400m (Fig 1 and 2) but looks to go only down to ~-150m on Fig. 3.

Thank you for this comment. We are sorry for this misunderstanding; since "Depth" is not explicit in this figure and does not represent the seafloor depths, we changed it to "Upper depth of the outflow (m)" and removed the map of "Lower depth of the outflow" (Based on a comment from RC1). Please check updated Figure 4e.