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 and presented below in the responses as *italic text*.

RC1

Title: Shelf Bathymetric Roughness Controls Mixing of the Persian/Arabian Gulf Outflow and Arabian Sea OMZ Ventilation Author(s): Iteration: Initial submission

The manuscript is based on a dataset of 50 CTD casts collected recently in July 2025. The major result is presented in Figure 2, which nicely illustrates the depth stabilization and the erosion of the core of the P/AG outflow in terms of salinity, temperature, dissolved oxygen, pH, and turbidity, as it progresses through the Sea of Oman, along the continental shelf. Figure 3 complements Figure 2 by depicting the properties of the bottom waters. Despite the highly informative nature of these two figures, the study struggles to provide convincing dynamic elements to better understand the origin of the property erosion (as suggested by the article's title). The study also suffers from the absence of current measurements (LADCP and ship-ADCP), which would provide additional dynamic insights into the flow, such as hydraulic constraints—mentioned but not quantified, for example, with a Froude number—or the intensity of shear, which is also cited but not quantified.

We thank the respected referee for the time and effort in evaluating our manuscript, and for this important comment. We agree that the manuscript does not provide direct estimates of current velocity, bottom stress, turbulent dissipation, observed Froude number, or measured vertical shear. The reason for that is the unavailability of LADCP or shipboard ADCP measurements. We have therefore revised the manuscript to avoid implying that these quantities were directly observed.

We also agree that the original version over-relied on hydrographic sections without sufficiently quantifying the dynamical susceptibility of the plume. However, in the revised version, we added CTD-derived proxies, computed from the available dataset. These proxies include the Thorpe scale and the Thorpe-scale-derived diapycnal diffusivity (new Figure 3), along with further explanation and correlation with the roughness-to-plume-thickness ratio, h_r/H. We also added a CTD-derived critical velocity, $c_i = \sqrt{(g'H)}$, to place the plume-thickness variations in a hydraulic context. c_i is presented as an indicative, hydrographically derived speed scale rather than a directly observed Froude number, and is compared only with the range of outflow speeds reported in previous studies (revised Methods, Sect. 2.2.2, and Discussion, Sect. 4.1). These additions are explained in detail in the subsequent comments.

The manuscript title focuses on the control of the outflow by the topographic roughness. One would therefore expect an article explaining the dynamics of the flow along the slope. However, after reading, the only diagnostic addressing this aspect concerns the parameter h_r/H, where h_r is a roughness height and H is the thickness of the outflow. It is unclear how h_r is precisely calculated; I assume that, here, it simply refers to the height of the submarine micro-relief that dots certain parts of the continental slope (if so, based on which bathymetric datasets (multibeam?), at what resolution, what are the limitations, what about the horizontal length scales, …?). As in many other outflows, the gravity-driven flow accelerating along the first significant slopes (here, depths > 170 m) is likely the primary source of erosion (Froude > 1, strong current shear at outflow/ambient fluid, instabilities and mixing). This deep-ward flow is quickly counteracted by the Earth's rotation on one hand and bottom friction on the other. No element in this article describe this dynamics and we don't know whether the selected path for Fig. 2 section (white line on Fig. 1) is along the outflow pathway or if it is more or less across its pathway. We don't even know how rough the bathymetry is (vertical scales, horizontal scales, isolated vs continuous roughness, separation distance between isolated small topographic bumps, …) while such parameters are among the key parameters for inferring the relationship between roughness and mixing (e.g. Özgökmen and Fischer, 2008, as referenced in the text).

Thank you for this detailed and constructive comment. We addressed the concerns raised in this comment as follows.

- We revised the title to better reflect the study's observational basis and reduce the expectation that it fully addresses the dynamical analysis of the overflow. Here is the new title: "*Hydrographic Transformation of the Persian/Arabian Gulf Outflow over Rough Shelf Bathymetry in the Gulf of Oman*".

- We agree that the roughness-to-plume-thickness ratio (h_r/H) was not enough for the dynamical interpretation of the outflow. We also agree that it wasn't explained how it was calculated. Therefore, to address this matter, we updated the manuscript so that the dynamical interpretation is now based on integrating hydrographic and bathymetric indicators, including plume thickness, P/AGw$_f$ decay, salinity and oxygen reduction, N^2 structure, Turner angle, turbidity, h_r/H, and CTD-derived Thorpe-scale proxies, together with a CTD-derived critical velocity (c_i). We also added a detailed explanation of how the h_r/H was calculated. We also clarified that h_r/H is a geometric plume-roughness interaction index, not a direct measure of form drag, shear, bottom stress, or turbulent dissipation. Please check the new Methods section of "2.2.2 CTD-derived fine-structure and overturn-proxies", lines 129-169, quoted below:

"2.2.2 CTD-derived fine-structure and overturn-proxies

Because neither ADCP/LADCP current measurements nor turbulence microstructure profiles are available, hydrographic overturn proxies were used to quantify relative mixing intensity from the CTD density fine structure. The Thorpe length scale (L_T), also called the Thorpe overturn scale (Thorpe, 1977), represents the root-mean-square vertical displacement required to reorder an unstable CTD density profile into a statically stable profile. Physically, L_T is the vertical size of CTD-resolved density overturning. Larger L_T indicates greater vertical reordering of water parcels and therefore stronger overturning evidence in the CTD profile (Galbraith and Kelley, 1996; Gargett and Garner, 2008; Jalali et al., 2017; Park et al., 2014).

The Thorpe analysis was performed on the CTD data and each used density profile was quality-controlled following Park et al. (2014) and Gargett and Garner (2008), retaining only vertically coherent, well-resolved overturns. The Thorpe-derived diapycnal diffusivity proxy ($K_\rho^{(T)}$) was also calculated as $K_\rho^{(T)} = 0.64\Gamma L_T^2 N$, obtained by combining the Dillon-type relation $L_O = 0.8L_T$ with the Osborn diffusivity relation $K_\rho = \Gamma\epsilon/N^2$ (Dillon, 1982; Osborn, 1980; Ozmidov, 1965; Thorpe, 1977). A mixing efficiency $\Gamma = 0.2$ was assumed. The values of Thorpe scale proxies are interpreted as relative indicators of mixing hotspots rather than absolute turbulence measurements (Fig. 3).

Bathymetric roughness was quantified from the multibeam-derived bathymetric profile extracted along the CTD section. The resolution of the bathymetric grid, hence the bathymetric profile, is 10 m. For each along-section location, we calculated an effective local roughness amplitude, h_r, as *one half of the bathymetric relief within a moving window of ±1 km: $h_r = 0.5(D_{max} – D_{min})$, where D_{max} and D_{min} are the maximum and minimum depths within the window. The full window length is therefore 2 km. The roughness-to-plume-thickness ratio was then calculated as: h_r/H where H is the local P/AG plume thickness. This ratio is used here as a geometric relative roughness-height index, analogous to the roughness-height to current-depth ratios used in laboratory and numerical gravity-current studies, where obstacle or roughness height is normalized by the thickness of the dense current (Cenedese et al., 2018; Maggi et al., 2022; Ottolenghi et al., 2017; Özgökmen and Fischer, 2008). h_r/H is not a direct measurement of form drag, velocity shear, bottom stress, or turbulent dissipation; it is interpreted as a geometric plume-roughness interaction proxy and is evaluated together with CTD-derived plume thickening, P/AGw_f decay, N^2 structure, turbidity, and overturn-based mixing proxies.*

To place the plume-thickness variations in a hydraulic context, we computed a critical velocity, $c_i = \sqrt{(g'H)}$, the along-section speed at which the Froude number of the bottom-attached layer, $Fr = U/\sqrt{(g'H)}$, equals unity. Here $g' = g\,\Delta\rho/\rho0$ is the reduced gravity from the density contrast between the P/AG plume and the overlying ambient water, and H is the local plume thickness. c_i equals the phase speed of long internal (interfacial) gravity waves on the bottom layer: where an actual current exceeds c_i the flow is supercritical ($Fr > 1$), and where it is slower the flow is subcritical ($Fr < 1$). Because current measurements are unavailable, c_i is not an observed Froude number but a hydrographically derived speed scale that can be compared with independent current estimates from the literature. c_i depends on both g' and H and therefore increases partly as a consequence of downstream plume thickening; it is interpreted as consistent with, rather than proof of, a change in hydraulic state.".

- We agree that gravity-driven acceleration, hydraulic state, rotation, and bottom friction are key components of dense outflow dynamics. However, the present dataset cannot directly quantify these processes. We also agree that gravity-driven downslope and along-margin flow is the fundamental background mechanism for P/AG outflow. The manuscript already describes the P/AG water as a dense near-bottom flow exiting the Strait of Hormuz, entraining ambient water, and spreading along the Gulf of Oman margin, whereas the bathymetric roughness is interpreted as a local modulator of plume thickening, overturning susceptibility, entrainment, dilution, and detachment. Mesoscale activity, internal waves, bottom friction, and double-diffusive processes are acknowledged in the discussion as additional possible contributors that cannot be separated quantitatively from this dataset alone.

- We also agree that the Figure 2 transect should not be described as a measured flowline. In the revised manuscript, we described the CTD section as traversing the hydrographically inferred P/AG plume corridor, based on near-bottom salinity, P/AGw_f, plume thickness, and bathymetric steering. Please check the updated caption of Figure 2, quoted below:

  "***Figure 2: An NNW-SSE CTD transect (along the hydrographically inferred P/AG plume corridor; the white line in Fig. 1a) showing P/AG outflow and its relation to the seafloor irregularities.*** *The parameters include salinity (a), turbidity (b), temperature (c), Brunt–Väisälä frequency (d), dissolved oxygen (e), Turner angle (f), pH (g), and P/AGw_f (h). i) Along-transect thickness of the P/AG outflow core and main plume. j) The local seabed roughness relative to the height and plume thickness (h_r/H), plotted with the plume thickness. a-g are superimposed by P/AGw_f contours, whereas h is superimposed by density contours. SF stands for salt fingering; DS, doubly stable; DC, diffusive convection; US, unstable.*"

The h_r/H parameter is used merely used to suggest that mixing is possible due to the presence, in certain parts of the region, of small relief features where h_r/H > 1, which could potentially generate form drag and wake turbulence. Fair enough, but no quantitative evidence confirms an increase in turbulence in these areas. The article mentions the occurrence of local instabilities in vertical density profiles and portions of profiles that are homogeneous. Perhaps the authors could use this as a starting point to diagnose mixing more precisely and determine whether profiles with strong local instabilities correspond to areas where h_r/H > 1 (or downstream of these obstacles) ? The inclusion of historical datasets with current measurements should have been part of the study to complement and improve the description and quantification of flow dynamics and turbulence, thereby aligning more closely with the title.

Thank you for this detailed and constructive comment.

- We agree that the roughness-to-plume-thickness ratio (hr/H) was not enough for the dynamical interpretation of the outflow. As set out in our response to the previous comment, 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 in the above response.

- Regarding historical current measurements, we agree that they are useful for regional context. We therefore do not use these non-synoptic historical currents to compute a precise local Froude number, shear, or bottom stress for the July 2025 section, as that would imply a precision the data do not support. Instead, in the revised manuscript we compare our CTD-derived critical velocity (c_i) only against the range of previously reported outflow speeds, as an indicative hydraulic context, and we stress that this comparison is non-synoptic and not a direct measurement of hydraulic state (Sect. 4.1).

Conclusion: The article primarily describes the erosion of the hydrological characteristics of the P/AG outflow plume and its detachment from the topography during its depth stabilization phase. On these descriptive aspects, the article is well-written and easy to read. Some points need clarification. It is also well-supported by appropriate references to past studies. Nevertheless, it fails to address the essential questions implied by the title: If we were to establish a hierarchy of the most important erosion processes referenced in the study, which are the most significant?

• Hydraulic constraints due to bathymetry (Froude > 1, strong shear)?
• The localized presence of small submarine reliefs (h_r/H > 1) associated with turbulence?
• Double-diffusive phenomena?
• Intrusions by mesoscale processes and slope current instability?
• ...

To answer these questions, the study must be taken further by using the CTD profiles more extensively, incorporating historical data, or leveraging numerical model outputs. In its current version the manuscript falls short of the expectations from the attractive title. It is very descriptive but lacks of tangible quantification of key parameters.

Thank you for this detailed and constructive comment. We agree that the revised manuscript should present a clearer hierarchy of processes. In the revised manuscript this hierarchy is made explicit. The abrupt bathymetric step is identified as the primary trigger of the transformation, supported by a CTD-derived critical velocity (c_i) that 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. As noted above, 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.*"

Annotated manuscript comments:

Without any measurements of flow (current) properties, vorticity and mixing, it is difficult to conclude anything on the bathymetric control with the simple h_r/H diagnostics. Of course, btahymertic irregularities may enhance mixing (as stated in the text), but, it is higlhy probable that cascading along the slope (depth >170 m from your nice FiG. 2), influence of mesoscale acitivity along the shelf break, internal wave activity, ... strongly contribute to erode the outflowing waters.

Thank you for this comment. We revised "controls" to "modulates" and explicitly stated that h_r/H is a geometric proxy and integrated it with Thorpe-scale proxies for further support. In addition, following the reviewer's point that downslope cascading, mesoscale activity, and internal-wave processes probably contribute to the erosion, the revised manuscript now attributes the initial transformation to hydraulic adjustment at the bathymetric step (supported by the CTD-derived critical velocity, c_i), treats roughness as a modulator rather than the sole control, and explicitly acknowledges cascading, mesoscale intrusion, and internal-wave activity as additional contributors that cannot be separated with the present dataset (Sect. 4.1). It should also be noted that the bathymetric step in this area does not represent the shelf break, where this continental shelf is subdivided geologically into stable (with smooth bathymetry) and unstable (with rough bathymetry, as well as other geological structures) shelf domains based on Abdelmaksoud et al. (2026, In Review).

Abdelmaksoud, A., Al-Suwaidi, A., Ali, M., Aldhanhani, O., Sreenivasan, S., and Steuber, T., 2026. Geological Controls on the Distribution of Pockmarks and Gas Seeps along the Northeastern Arabian Margin, Marine Geoscience and Energy Resources, In Review.

51 cyan dots on map Fig 1a = 51 CTD stations ?

Thank you for this comment. We modified the text to "*51 Conductivity–Temperature–Depth (CTD)*", please check line 93.

After processing, what is the final vertical resolution? What are the acuuracies and relative uncertainties on your output variables? Do some variables were further adjusted with bottle sampling? (S, O2, pH ?)

Thank you for this comment. We mentioned about the used sampling and that no bottle sampling was used for adjustments. Please check lines 97-99, quoted below:

"*The original CTD sampling was used for all parameters for subsequent analysis and plotting, except for N^2 and Turner angle, for which 2 m binning was used. No bottle sampling was used for adjusting the measurements.*"

IODW, IOCW: undefined before

We defined the abbreviations at first use. Please check lines 109-111, quoted below:

"*Indian Ocean Deep Water (IODW), ………… for Indian Ocean Central Water (IOCW)*"

missing: Fig. 1a: white line denotes the CTD section of Fig. 2

We added "*The white line denotes the CTD section of Fig. 2.*" to the caption of Figure 1.

cyan dots with CTD station number?

We added "*(cyan dots with station numbers)*" to the caption of Figure 1.

"Turner angle (Tu) and Brunt–Väisälä frequency (N^2) were calculated.": How are they calculated?

Thank you for this comment. We thank the reviewer for noting this omission; the calculation of Turner angle and Brunt-Väisälä frequency was not described in the submitted manuscript. We added a detailed explanation about how we calculated these parameters. Please check lines 119-128 quoted below:

"*Practical Salinity and in situ temperature were first converted to SA and CT using TEOS-10 Gibbs SeaWater MATLAB toolbox. Turner angle (Tu) and Brunt-Väisälä frequency squared (N^2) were then calculated using the TEOS-10 functions from individual binned CTD downcasts before horizontal interpolation. This avoids creating artificial inversions from section gridding. The calculated Tu values were classified into four regimes: statically unstable, $|Tu|>90°$; diffusive convection, $-90°<Tu<-45°$; doubly stable, $-45°\leq Tu\leq 45°$; and salt fingering, $45°<Tu<90°$ (Fig. 2).*

These classes were used for the Turner-angle section. Positive N^2 indicates stable stratification, whereas negative N^2 indicates static instability or density overturning. The N^2 values returned at midpoint pressures were interpolated back onto the profile depth grid used for section plotting (McDougall et al., 2009; McDougall and Barker, 2011; Roquet et al., 2015; Ruddick, 1983)."

Line 114 "flat bathymetry": over a flat and shaloow bathymery (z<130 m ?)

We modified the sentence as recommended. Please check lines 191-192, quoted below:

"*over relatively flat and shallow bathymetry (depths <130 m) of the stable shelf*".

Lines 115-116 "Over the shelf of the Arabian Plate": provide the depth range to better guide the reader: (130 m < z < 370 m).

We added a depth range as suggested. Please check line 193, quoted below:

"*Over the unstable shelf (depths of 130-370 m), which is…….*"

Lines 117-118 "over the lower shelf and upper slope": (z > 370 m)?

We added the corresponding depth. Please check line 195, quoted below:

"*(depths >370 m)*"

Line 119 "What is meant by "corresponds to bathymetric constraints"?"

We modified the sentence to avoid misunderstanding. Please check lines 196-197, quoted below:

"*The western shallowest occurrence of the outflow is at ~110 m depth.*"

Does the selected transect follow the core? For example, there is a discontinuity in the salinity maximum between stations 42 and 35 as compared with sta. (43, 42) and (31, 28)

Thank you for the valid question. In the revised manuscript, we described the CTD section as traversing the hydrographically inferred P/AG plume corridor, based on near-bottom salinity, P/AGw_f, plume thickness, and bathymetric steering. Please check the updated caption of Figure 2.

Line 125 "hr/H": If 'r' is not a subscript, it should be defined.

We corrected "h_r" throughout the manuscript.

Line 126 "(Fig. 2j)": How is defined roughness height? What should we conclude from 2j?

We defined how h_r/H is calculated. Please check lines 145-158 of the Methods section (Sect. 2.2.2), quoted in our response to the second comment above.

We also added a description for the h_r/H figure in the Results. Please check lines 177-179, quoted below:

"*The roughness-to-plume-thickness ratio (h_r/H) is used as a measure of the dynamical interaction between the P/AG outflow plume and the seabed. The h_r/H increases to >1 immediately after the bathymetric step (Fig. 3d, near station 32 southwards).*".

Please also check lines 232-240 of the Results section (Sect. 3.3), quoted in our response to the Conclusion comment above.

Line 128 "(Fig. 3e-f)": 1- Why do we have a minimum in salinity, minimum in temperature, minimum in dissolved O2 in the two regions defined by stations (33, 35, 46, 38, 37) and by stations (2, 10, 11, 52) ? (note: my station numbers are guessed from fig. 1 and may not be fully exact). Could they be lenses of nearby offshore water advected towards the shelf?

Thank you for this comment. We added explanations for these localized patches in the Results (Sect. 3.4) and Discussion (Sect.), quoted below:

Lines 249-252:

"Superimposed on this downstream decline are two localized patches of reduced near-bottom P/AGw_f, accompanied by lower salinity, temperature and oxygen, one in the north (near station 36) and one to the southwest (Fig. 4a–d). In both, the outflow signal persists near the seabed but is locally weakened rather than absent."

Lines 343-360:

"*The two near-bottom low-P/AGw_f patches around stations 36 and 11 (Fig. S1) are interpreted as localized lateral interleaving of ambient, lower-P/AG water into the near-bottom outflow layer. On the σ0 = 26 isopycnal, which removes the effect of plume thickness and depth, the P/AGw_f field shows a lateral structure (Fig. S1), indicating interfingering of P/AG-rich and P/AG-poor water across the shelf. Such interleaving is expected at the margins of the boundary plume, where mesoscale and submesoscale stirring can peel P/AG water from the boundary and draws ambient water inward (L'Hégaret et al., 2016; Vic et al., 2015). Because the survey is non-synoptic, a partly* *transient origin, such as plume meandering on sub-seasonal timescales (Pous et al., 2004a, b), cannot be excluded. Internal tides are well documented in the Gulf of Oman, with generation attributed to tidal flow across the shelf break off the Musandam Peninsula (Small and Martin, 2002) and to steep topography within the Strait of Hormuz (Subeesh et al., 2025); moored records further southeast on the Al-Batinah shelf show a predominantly diurnal, shoreward-propagating internal tide of largely remote origin (Bruss et al., 2026). Reported pycnocline displacements are of order 10–25 m, so internal tides can displace a density interface on diurnal to semidiurnal timescales. Because each station represents a single snapshot, aliasing of the internal-tide phase may contribute to the observed patchiness, although the present data cannot separate this from mesoscale and submesoscale stirring. The patches are therefore not attributed to the seabed erosional features, and there is no evidence that they represent local detachment of the outflow."*

Figure 2 caption: Here, reference, the white line of Fig.1a

Thank you. We added "*the white line in Fig. 1a*" as a location reference in caption of Figure 2.

Line 144: For a non-specialist, could you indicate what is/are the most contraining factors that favor 4c vs 4d cmmunities: is it the ground type ? temperature ? oxygen ? ...

Thank you for your question. The observed shift likely reflects substrate type, sediment cover, near-bed energy, oxygen availability, and food-particle delivery.

Figure 3: 1- Why is the number of CTD stations smaller than on Fig. 1 ?
2- Colorbar labeled 'Depth' on panels d) and e) are not explicit. You could use 'upper depth of outflow core' for d) and "lower depth of outflow core' if my understanding is correct. The difference between e) and d) gives the thickness panel f).

1- Thank you for this note. Three stations were mistakenly omitted from the parameter maps. We regenerated the maps to ensure the missing stations are included.

2- We have changed "Depth" in Figure 4e to "Upper depth of the outflow (m)" and removed the map of "Lower depth of the outflow".

Line 165 "geometric/hydraulic adjustment": What is the dynamical meaning of these terms?

We replaced this with "*hydrographic and geometric adjustment,*" defined as plume thickening, interface erosion, and detachment, as we don't have measurements for the real dynamical changes.

Fig. 4b: give the meaning of vertical blue arrows off the shelf, blue circle arrows and yellow arrows.

A legend has been added to Fig. 5b to show the meaning of these symbols.

Line 183 "hr": h_r -> r subscript

We corrected "h_r" throughout the manuscript.

Line 192-193 "with the top of the outflow water moving towards shallower depths": Not sure to exactly understand: do you mean that the upper part of the outflow flows more or less following constant f/h, which contrast with the lower part of the outflow, which, due to bottom drag, goes on crossing f/h contours?

Thank you for this point. We rewrote the sentence to avoid misunderstanding. Please check lines 319-320, quoted below:

"*with its top occurring higher in the water column, i.e., towards shallower depths*".

We do not invoke f/h behavior, as we do not have velocity data.

Lines 201-202 "where the pronounced N2 maximum at the upper plume interface disappears": To help the reading and navigating between text and figures, and it would be helpful to reference here Fig. 2d and cite the stations where it appears (sta. 31, 35 ?).
This applies to others figures where you could cite targeted station numbers and depths to clearly locate what your text describes.

Thank you. We added corresponding depths and stations throughout the Results and Discussion when referring to specific features in the figures for more clarity. Here are some examples; line 329, "*(Fig. 2d, at station 46 southward to station 32 and at 100-150 m depths)*", line 330, "*(Fig. 2d, at station 29 and around 150 m depth)*", lines 335-336, "*(Fig. 2d, at stations 16, 07, and 06 at 100-150 m depths)*".

Lines 204-205 "the gradual re-establishment of moderate N2 suggests formation of a new, weaker and broader interface": I do not see where this new interface is located farther offshore. Here again, as for other figures and comments in the text, more guidelines need to be provided to the reader.

We added corresponding depths and stations for clarification. Please lines 335-336, "*(Fig. 2d, at stations 16, 07, and 06 at 100-150 m depths)*".

Line 212 "and the value is reduced to less than 0.3": I would replace Fig. 3d and 3e that show the depth of top and bottom outflow (property maps and the overflow thickness are self-sufficient), by a map of P/AGwf to illustrate its decrease along the Omani margin.

We removed the bottom depth of the outflow map and added a P/AGw_f map (Fig. 4d).

Lines 221-231: This would nicely fit in (or complement) the introduction, such as Pous et al. reference, Prasad et al. reference, with a bit more details about what those studies revealed and what yours bring as new insights.

Thank you for this comment. We moved this paragraph to the Introduction. Please check lines 63-73, quoted below:

"*Previous hydrographic and ADCP observations show that, after exiting the Strait of Hormuz, P/AG water cascades down the continental slope and spreads along the Gulf of Oman margin (Pous et al., 2004). Along the Omani coast, the outflow core occurs at a depth of 200 m with a potential density range of 25.5 – 27 kg/m^3 (Font et al., 2024). Climatological and historical analyses indicate that P/AG water typically equilibrates between approximately 200 and 350 m (Prasad et al., 2001; Swift and Bower, 2003). Observations off Oman document that the P/AG outflow pathway and thermohaline properties vary with the mesoscale field, which can eject boundary water offshore through near-shelf dipoles and lee eddies (L'Hégaret et al., 2015). High-resolution simulations and process analyses demonstrate that remotely generated mesoscale eddies interact with the steep slope to generate frictional boundary layers and submesoscale vortices that peel P/AG water from the boundary, thereby enhancing lateral dispersion and dilution (Vic et al., 2015).*"

Section "4.2 Oxygen modification along the P/AG outflow path and its impact on the Arabian Sea-OMZ": This subsection is mostly a review of past studies.

Thank you for this comment. We modified and summarized this subsection, then merged it with "4.4 Climate sensitivity…. Subsection, with a new subsection heading "*4.3 Implications for OMZ ventilation and climate sensitivity of the P/AG outflow*". The new subsection presents the regional implications of the study, including the oxygen ventilation of the OMZ and climate sensitivity of the outflow. Please check updated subsection 4.3, quoted below:

"*P/AG outflow brings high-oxygen waters from the Arabian Gulf to the Arabian Sea-OMZ, thereby ventilating the OMZ. Glider observations off Oman directly demonstrate that P/AG water supplies oxygen to the OMZ at intermediate depths, quantifying its ventilation contribution along the slope (Font et al., 2024). Modeling further indicates that changes in Gulf properties can modulate OMZ intensity by altering the density and ventilation potential of exported P/AG water (Lachkar, 2019). Downstream changes in the oxygen content and pH of the outflow water show consistent dilution and oxygen loss along the continental shelf. Layer fine structure and step-like profiles along transects indicate active mixing above the seafloor. These results provide a high-resolution continuous mapping of P/AG outflow* O_2 *modification along the continental shelf, linking local mixing intensity to the outflow's potential to ventilate the upper oxycline of the Arabian Sea. The spatial correspondence between P/AG outflow persistence and elevated near-bottom oxygen levels suggests that the upper oxycline is effectively ventilated. Where the shelf-trapped P/AG water layer is strongest and most persistent, near-bottom oxygen is elevated relative to adjacent waters, indicating effective ventilation near the upper oxycline depths (Font et al., 2024; Swift and Bower, 2003). Downstream maps show progressive oxygen reduction along the outflow pathway basinwards, reflecting dilution and consumption (Fig. 5). As mixing intensity varies across the stable-unstable shelf boundary, depending on seafloor roughness, the magnitude and spatial footprint of P/AG outflow ventilation depend on local thickness, attachment state, and mixing intensity.*

The attachment–detachment thresholds documented here imply that the P/AG outflow's pathway is sensitive to moderate shifts in source-water density, which depends strongly on the Gulf surface temperature and evaporation. Warming in the P/AG would reduce outflow density, alter lift-off depths, modify downstream oxygen delivery, and potentially reorganize benthic zonation along the margin, indicating a climatically sensitive mechanism. Interannual to decadal changes in evaporation and heat content modulate the density contrast across the Strait of Hormuz and, by extension, the strength and properties of the exported outflow (Campos et al., 2020)."

Lines 240-241 “Layer fine structure and step-like profiles along transects indicate active mixing above the seafloor”: Could you use the finestructure of your specific hydrological dataset to quantify and map mixing intensity and hotpots?

Thank you for this comment. We added CTD-derived Thorpe scale proxies and interpreted them along with the roughness-to-plume-thickness ratio, as well as the new P/AGw_f map, to support the mixing interpretation and its spatial distribution. Please check the new subsections of Methods (*2.2.2 CTD-derived fine-structure and overturn-proxies*”) and Results “*3.3 CTD-derived Thorpe-scale and diffusivity proxies*”, in addition to lines 361-389 of the Discussion, quoted above.

Line 251 “(Fig. 6)”: Fig. 6 ??? missing

That was mistakenly written; we have corrected it to “*(Fig. 5)*”. Please check line 318.

Line 257 “strong near-bed shear”: Do you have any measurements of these strong bottom-intensified shears to show?

As we don’t have any shear measurements, we modified “strong near-bed shear” to “*conditions consistent with an energetic near-bed boundary layer*” to avoid implying that we measured the shear.

Section “4.4 Implications for climate sensitivity of the P/AG outflow”: OK, why not, but there are extrapolations not shown by your study. So a bit useless here.

Thank you for this comment. We modified and summarized this subsection, then merged it with “4.2 Oxygen modification along the P/AG outflow path and its impact on the Arabian Sea-OMZ” Subsection, with a new subsection heading “*4.3 Implications for OMZ ventilation and climate sensitivity of the P/AG outflow*”. The new subsection presents the regional implications of the study, including the oxygen ventilation of the OMZ and climate sensitivity of the outflow. The revised subsection 4.3 is quoted in our response to the comment on Sect. 4.2 above.