Response to the comments of referee #2 on "Determining the depth and pumping speed of the equatorial Ekman layer from surface drifter trajectories" (egusphere-2025-089) by Paldor and De-Leon

We thank the referee for accolades in his general comments: "…This is a well-conceived and straightforward study that highlights new aspects of equatorial Ekman dynamics." and "Overall, the manuscript is well written and suitable for publication…". We also appreciate the extensive list of references included in the review and used in the greatly expanded revised version (and for which an acknowledgement was added to the manuscript).

Our detailed response to the referee's particular comments are detailed bellow with the comment in black and our response in blue. The comments are listed as in the referee's list i.e. each comment is denoted by the line number of the original draft to which it relates.

L54: Minimum potential. More information would be helpful here to make this understandable without referring directly to Paldor (2024).

A more detailed explanation of the essential theoretical background of the theory developed in Paldor (2004) now appears in the Introduction and in Sec. 2a (see L60-67, L117-132 and new Fig. 1). We feel that the repetition of previously published material (especially when published with open access) in a leading journal (Phys. Fluids) is a highly subjective issue.

L101: Did you check for drifters that lost their drouges? Should be noted.

No. A comment reflecting this appears in L168-169

L103: Typically, there is substantial meridional wind, particularly in the equatorial Atlantic. How do you account for this effect? With the selection criteria used, a significant bias could be introduced, as only drifters associated with specific non-Ekman dynamics—such as tropical instability waves, Yanai waves, or meridional wind forcing—are considered. A way to test for such a bias would be to calculate the mean meridional drifter velocity as a function of latitude. It would be interesting to see how this quantity compares to the meridional velocities derived from Ekman theory.

We agree: There can be many reasons why the simple theory adapted in the manuscript should not apply to the drifter observations. However, "the proof is in the pudding" and the robust estimates derived from the application of the theory where H varies by about 10% and W by 50% speak for themselves.

L111: I do not understand this sentence. Please clarify. What does it mean? L is 2° or is L approaching y(0)? Or do you mean if y(0) approches L=2°? Is the erratic behavior a consequence of meridional wind forcing?

Sentence extended and rephrased and the new sentence in L160-162 explains the point more clearly.

L113: Criterion for selection of drifters. Would it be a better criterion to consider the strength of the meridional wind, i.e., to only use drifters in cases of weak meridional wind? Additionally, what is the initial velocity of the drifters—for example, is it influenced by meridional wind forcing or, more importantly, by tropical instability waves, Yanai waves, etc.? Drifters could be deployed under different conditions.

Clearly, the conditions that prevailed when a particular drifter was launched affect its trajectory but since these conditions are not known we assume that all forces but the zonal wind stress (the value of which is negative even in the decadal mean) average out to zero for the hundreds of trajectories calculated for drifters that were launched in a period of over 40 years. Similarly, for lack of data, and as explained in Paldor (2004), the initial velocities are assumed to be 0 which agrees with the over 6-hour gap between launch time and first fix by a satellite. The important forcing of meridional wind stress can be incorporated in the dynamical theory but not as part of the present work in which the Paldor (2024) theory is applied to observations.

L140: Result of the Ekman layer depth. There must be a strong bias in the mean since you specifically neglect drifters that do not flow in the expected direction or that cross the equator. As a result, you include all drifters that may be driven by other motions away from the equator but exclude those drifting toward it.

That is correct. The theory is relevant to poleward moving drifters forced by zonal wind-stress. Thus, the "bias" alluded to in this comment is a virtue that suits the present application (see also our response to reviewer's comment L103) - the motion due to other types of forcing should be neglected.

What would be the equatorial divergence if calculated from all drifters, i.e., the mean meridional velocity averaged along the equator at different latitudes (3°, 4°, 5°)? If there is a difference, how could it be explained?

The suggested analysis was carried out in Poulain (1993) by transforming the Lagrangian data to Eulerian fields after averaging the values of v in prescribed spatial bins. In the Lagrangian formulation, employed here, $\frac{\partial v}{\partial y}$ only determines the shape of the projection of the 4Dimensional solution curve onto the (v, y) plane but does not imply horizontal divergence as in the Eulerian form. In contrast, the novelty of the present work is the use of Lagrangian Eq. (3) directly to circumvent the transformation from Lagrangian to Eulerian formulations. As was shown in Paldor (2024), in the Lagrangian formulation mass (height) conservation is determined by $\frac{\partial y(t)}{\partial y(0)}$. A discussion of this point now appears in L248-253.

L141: Can this be called oscillation free. How do you subtract the oscillation from the drifter velocity? To my understanding this would require the knowledge of the initial velocity.

Our method is based on the realization that the period of oscillation is (significantly) shorter than the period over which the trajectories are calculated so the oscillations are averaged out. This is explained now in L231-240.

L142: The derived velocity corresponds to the velocity at the depth of the drifters' drogue. What assumptions do you make about the vertical structure of the Ekman velocity? Would it be useful to also consider Argo drift velocities, which represent surface velocity, to calculate mean meridional velocities? This could provide an estimate of the vertical structure of the Ekman flow near the equator.

The simplified Lagrangian theory cannot be expected to decipher the 3Dimensional structure of the velocity field. As is evident from our calculations it does a reasonable job in fitting the meridional motion to drifter trajectories, which is probably due to the fact that the cation of the wind stress decays with depth so the averaged velocity over the entire 45 m deep layer is determined primarily by the velocity at the top 15 meters sampled by the drifters.

L147: I think one of the main results is the dependence of the derived vertical velocity on the meridional scale, which could also explain many previous estimates (see references below). This aspect should be given more emphasis

Thank you. The point (that agrees with the results obtained by Poulain93) is now discussed in L241-248.