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Interactive comment on "Water masses and mixing processes in the Southern Caribbean upwelling system off Colombia" *by* Marco Correa-Ramirez et al.

Anonymous Referee #2

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Water masses and mixing processes in the Southern Caribbean upwelling system off Colombia by Marco Correa-Ramirez, Ángel Rodriguez-Santana, Constanza Ricaurte-Villota, and Jorge Paramo

Using more than 100 salinity and temperature profiles off the Colombian coast, the authors investigate the Southern Caribbean Upwelling System, particularly the path and role of the Subtropical Underwater. There is basic knowledge on the SCUS, but little is known on transports, mixing rates, fluxes, which all are of interest for the biogeochemical impact of the SCUS, and could be used to compare to Eastern Boundary Upwelling Systems and to learn on upwelling systems in general. So the subject of

the manuscript is an interesting research question and suitable for this journal. The authors propose the Caribbean Coastal Undercurrent, which transports SUW, to be stronger than previously thought (a mean of 0.4m/s), and being the main feed of upwelling water to the SCUS. They deduce high diapycnal turbulent mixing rates throughout the water column in the SCUS (of order 10-3 m2/s), and conclude that the saline SUW gets modified by mixing with fresher waters on its way along the Western and Southern Caribbean Coast, before being upwelled.

Evaluating the manuscript, the data base seems not sufficient, spatially and in parameters, to unravel the processes outside and inside the study region, which are the base of the authors' conclusions. For example, the concluded very high turbulent mixing rates are based only on Thorpe scale analysis of the CTD profiles, with unfortunately no ground truthing possible. The very high speed of the CaCU is based only on the Mercator model output. This hampers the ability of the data set to be the foundation for the ambitious goal to describe water mass changes, transport paths, mixing impact, particularly when the findings are unexpected like here (unexpected strong undercurrent, unexpected strong diapycnal mixing and salt flux, unexpected path of the SUW feeding the upwelling). Missing to support the proposed scenario is data on salinity and mixing in the PCG, how to consolidate mixing and salinity development along the CaCU/SUW off the Colombian coast, evidence that the pathway of SUW from the Central Caribbean towards upwelling is negligible compared to the CaCU pathway. Besides, there are several critical points, and some method aspects that need to be shown (see below). However, I see possibilities if focussing the paper on the SUW salinity balance in the region of the observational data base. Estimates of current velocity and vertical mixing (after a rough calculation based on 0.2m/s CaCU speed and Fig.4 values) support a salinity loss of 0.1 or 0.2 by vertical mixing along the path of the CaCU off Colombia. Together with estimates of CaCU transport and Ekman transport, some plausible value range for horizontal mixing, and given consistency with the salinity field, a salinity budget could lead to an estimate which pathway contributes how much to the upwelling. Given that such information can be inferred for the SCUS, the paper could also seek answers what is different to EBUS in dynamical processes affecting biogeochemistry (and why).

This would however be a considerable change of focus ('The subsurface salinity maximum in the Southern Caribbean upwelling system off Colombia'?) and considerable additional work, so that I recommend not to give major revision, but reject and encourage submission of a refocused study. I would appreciate if the existing observational data could be published and used, particularly if the strong mixing can be verified.

Specific comments:

Given the high turbulent mixing inferred is real, salt finger influence seems negligible, therefore I would recommend to give it less space in the paper, as it has very minor impact on mixing and salt fluxes (<10-2 g/kg m/d for the lower boundary of the SUW, not quantified for the upper boundary, Fig.3).

The inferred high turbulent mixing is entirely based on the Thorpe scale analysis. As there is no ground truthing possible, and the reported K = 10-3 throughout the water column seems very high to me, it seems necessary to give the Thorpe scale analysis a more prominent space in the paper. Make used CTD data accessible/visible, show profiles, show that instabilities and overturns are discernible above sensor noise and salinity spikes, show some estimate of uncertainty based on the CTD sampling rate, the lowering velocity, the postprocessing of CTD data. With the high stratification of N2 above 10-4, LT of 0.2m would have to be discerned with confidence from 0.6m, in order to discern K = 10-4 from 10-3. At a lowering rate of 1m/s this usually means 5 to 15 raw values of the CTD sensors along a typical overturn. For my feeling, this makes Thorpe scale analysis hard under these stratification conditions. This should clearly be addressed, and shown that issues can be solved by the chosen processing, in order to convincingly lay down the high diapycnal mixing rate is no artefact.

I would recommend not to speculate about the impact on nutrient fluxes, as there is no information on the nutrient field at all. Maybe a sentence in the Discussion, what

nutrient fluxes to the mixed layer a diffusion coefficient of K = 10-3 would cause in typical oligotrophic ocean regions (there should be some information around on nutrient gradients below the mixed layer for the tropical Atlantic and the Caribbean).

The salinity maps seem to contradict the authors' conclusion that the fresher CaCU feeds the upwelling, and that there's no direct feed from the North: Fig.7 shows increasing salinity along the path of the CaCU, particularly when the CaCU is strong in January to March, and as the map follows the vertical salinity maximum, this increasing salinity cannot be caused by vertical mixing.

Looking at the model currents (Figs.6 and 8), it seems the CaCU rather has its maximum at 0.4m/s, not its average as is stated in the abstract and other places. From Fig.8 I would maybe read an average of about 0.2m/s (0.1m/s at Guajira), which would then also fit the observed current velocities in Andrade et al. (2003), who show current sections with core velocities of up to 0.4m/s (their Fig.3) and lower currents at Guajira (their Fig.4).

Lines 90-109: Plase clarify what CTD was used on AMP cruises. What were conditions, lowering rates, processing, accuracies? (Seems particularly important for the CTD data role in Thorpe scale analysis)

L140: There is a discrepancy between Ksf defined in equation 3 and respective values shown in Fig 3. (Equation 3 as it is would not allow Ksf<3*10-5). If Ksf is meant to be the surplus mixing effect of salt fingering, Kinf should probably not be in equation 3.

L149ff: Please specify and show how you applied the data processing (threshold values chosen, identification of overturns...), and verified that the chosen processing works successfully.

L185-187: Please show evidence/references/analysis of defined regions, to support the reported 0.2 difference. The search for reasons is good for the discussion.

L223-224: N2 alone is not sufficient to evaluate the susceptibility to shear instability.

L235: Flux is not inherently dependent on total exposure time to mixing. Perhaps you had in mind the salinity budget of SUW, and refer to the total salt transport off SUW during the time it is following the CaCU. This budget is in fact worth looking at, I believe (see general comments above).

L246: Fig.5 (model based sections of S and T) should be rethought. In the present form of presentation it allows no real comparison to observations (maybe do a difference plot?), and it allows no conclusion how realistic the model circulation may be (maybe compare the density fields?)

L254: What does MSE mean (also later in the text)?

L262-268: Please specify if Fig.6 is for a single model year or a climatological seasonal cycle.

L270: probably 'eastward' is meant

L288-290: There is a discrepancy here between the 'could suggest' for some of the main points of the paper, and the certainty with which these conclusions are stated in L418 and in the Conclusion.

L333-337: The last paragraph of subsection 3.2 contains current velocity values of maybe a factor 10 too high, compared to the model output they refer to. In conclusion as well.

L376: The T-S-Diagram shows high variability in SUW salinity, between 36.8 and 37.1. From previous figures I could not see that it is a reduction of salinity from West to East, but it rather seems to show that SUW in the upwelling is variable between 'diluted' and 'Central Caribbean' SUW, and contains all mixtures of the two.

L426: Please support the large distances for the CaCU path. From the maps it seems like 1000 to 1500km in total. Months of the reported salt flux from SUW to adjacent waters at a mixing rate of 10-3 m2/s would mean several psu salinity change.

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