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Comment on egusphere-2022-1245

Anonymous Referee #1

Referee comment on "Joint observation-model mixed-layer heat and salt budgets in the eastern tropical Atlantic" by Roy Dorgeless Ngakala et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-1245-RC1, 2022

We thank the anonymous reviewer #1 for these constructive comments to improve our manuscript. We also appreciate the recommended papers on the importance of tropical instability waves (TIWs) in the eastern equatorial Atlantic heat budget, which we found useful. Below, we have tried to provide responses (blue text) to the reviewer's comments (black text), and we hope that the revised manuscript will satisfy the reviewer.

My most serious concern is that there is no discussion of the importance of tropical instability waves in the heat balance of the eastern equatorial Atlantic. The effect of TIWs is hidden in the lateral diffusion term (D-sub-L) as well as in the vertical turbulent diffusion term (because of the effects of TIWs on vertical shear, e.g. Heukamp et al., 2022). These important processes are not discussed at all and yet there is a long history of describing their role in the near equatorial heat balance (e.g., Weisberg and Weingartner, 1988; Grodsky et al, 2005; Lee et al, 2014; and many more). I'm guessing the authors have ignored this issue because TIWs have periods of ~30 days whereas PREFCLIM is a monthly climatology (although its temporal resolution is never specified-see below). Thus, PREFCLIM does not resolve TIWs. However, the model has no such limitation in terms of temporal resolution. The model is used to assess what is lost in terms of the effects of sub-mesoscale variability in computing the surface layer heat balance from PREFCLIM. The model can be used in a very similar way to assess the effects of mesoscale TIWs that are not resolved by PREFCLIM.

Response 1:

We agree on the importance of tropical instability waves (TIWs) in the heat budget in the equatorial Atlantic region, although it was not addressed in the submitted manuscript. As mentioned by the reviewer, there are many studies, either based on observations (Grodsky et al., 2005; Lee et al., 2014; Heukamp et al., 2022) or models (Jochum et al., 2004, 2005; Peter et al., 2006) , describing the role of TIWs in the tropical Atlantic. In the equatorial Atlantic, the TIWs are mostly found slightly north of the equator, outside of the Gulf of Guinea between 30°W and 10°W (Olivier et al., 2020; Tuchen et al., 2022). The role often attributed to TIWs in the mixed-layer heat budget is warming by horizontal advection and cooling by vertical mixing of the equatorial cold tongue (Jochum et al., 2004; Grodsky et al., 2005; Peter et al., 2006). On the one hand, horizontal advection due to TIWs will bring warm water from the eastern basin across the South Equatorial Current (SEC), thus warm the cold tongue water (Foltz, 2003; Peter et al., 2006; Tuchen et al., 2022). On the other hand, TIWs will amplify the vertical shear between the equatorial current system, thus enhance the vertical mixing between the warm surface water and the cold subsurface water, and consequently enhancing the surface cooling (Jochum et al., 2005; Heukamp et al., 2022). In our study, we did not focused on TIWs and, unfortunately, could not isolate advection at specific timescales due to the unavailability of daily simulation outputs. Indeed, we exploit here monthly outputs from a simulation produced a few years ago, do not have computational time available at the moment in our laboratory to rerun the simulation to produce daily outputs, and wonder if it would be worth the carbon cost. Nonetheless, our subsampling method allows to isolate submesocale variability. As mentioned by the reviewer, the effect of TIWs can be hidden in the lateral diffusion term computed from models. However, comparing two simulations at low (1° spatial resolution) and high (0.25° spatial resolution) resolutions to study the effect of TIWs in the heat budget, Jochum et al. (2005) showed that, at low resolution, the effect of TIWs is included in the strong lateral diffusion term, while at high resolution, the effect of TIWs is included in the heat advection term and the lateral diffusion term is much weaker. Indeed, in our high-resolution (0.25° like Jochum et al. 2005) simulation, the lateral diffusion term is generally much weaker than the horizontal advection term in the mixed-layer heat budget (compare Figure R1.1a and Figure R1.2.a below), including in the TIW region. Also the positive difference between online and offline advection, particularly strong in the TIW region (Figure R.1.2), strongly supports the idea that the TIWs contribution is transferred from the horizontal diffusion term to the horizontal advection term when increasing resolution, which more generally allows to explicit resolve smaller scales. TIWs also contribute to vertical diffusion, as underlined by the reviewer, which explain why this process is particularly strong in the TIWs region (Figure R1.1b), but it is still strong farther east in the equatorial part of the Gulf of Guinea due to the current shear associated with the EUC (Jouanno et al., 2011). Although we do not expect any significant contribution of TIWs in our boxes where the seasonal budgets are presented, as these boxes are outside of the TIWs region, we now added in the paper some discussion about the role of TIWs when presenting regional maps including the TIW region and discussing the processes involved in our equatorial box (see lines 106-113 "page 4", lines 532-538 "pages 29-30", lines 562-564 "page 30", and line 567-568 "page 30" in revised manuscript).

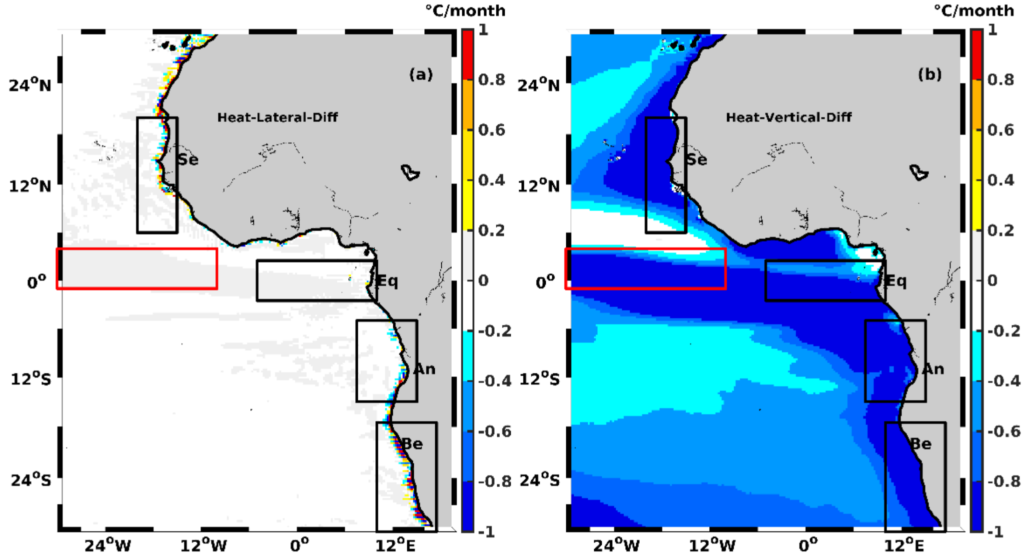

Figure R1.1: Mean lateral (a) and vertical (b) heat diffusions from NEMO model at original 0.25° resolution. The black rectangles correspond to our 4 regions of study. The red rectangle represents the TIWs box as used by Tuchen et al. (2022).

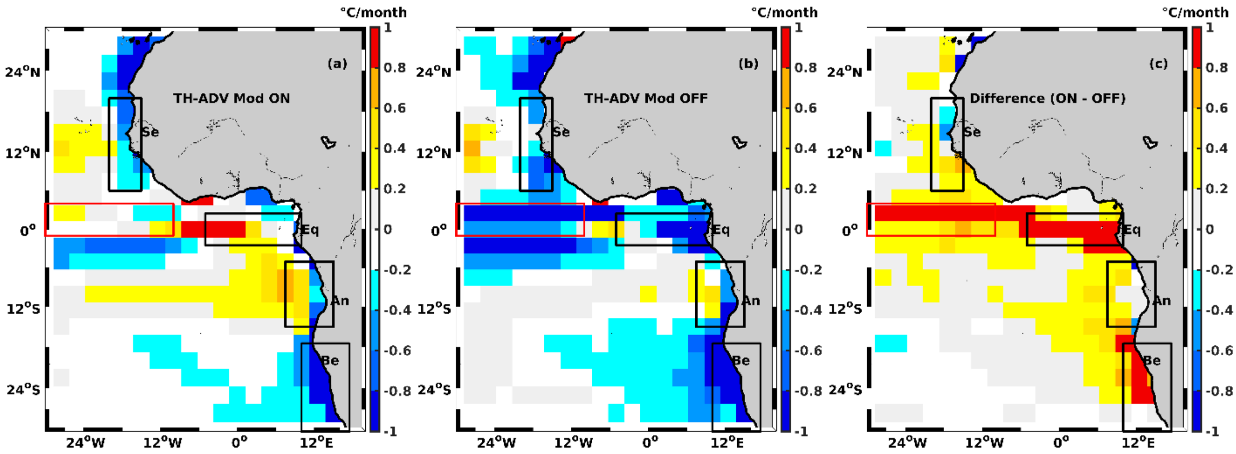

Figure R1.2: Mean horizontal heat advection from model: online re-sampled at 2.5° resolution (a), offline (b) and their difference (c). The black rectangles correspond to the 4 regions of study. The red rectangle represents the TIWs box as used in Tuchen et al. (2022).

Introduction. Somewhere around lines 50-70, the paper by Scannell and McPhaden (2018) should be cited and discussed.

Response 2:

As recommended by the reviewer, we have introduced this article from line 69 in the revised manuscript as follows:

"The dominance of the surface heat flux is highlighted by a recent study based on PIRATA buoy data off the equator, in particular at the 6°S,8°E position. At this latitude, seasonal variations in SST governed by solar flux and latent heat flux are shown to be associated with the meridional migration of the ITCZ and the formation of low-level marine stratocumulus , (Scannell and McPhaden 2018) ." (See lines 69-72 "page 3").

And we briefly discussed this , Scannell and McPhaden (2018) paper from line 552 as follows:

"**Recently, Scannell and McPhaden (2018) also confirmed the role of turbulent vertical mixing from a PIRATA buoy located at the southeastern edge of the ACT**." (See lines 552-553 "page 30").

And from line 571 as follows:

"**Competition between the shortwave flux and the latent heat flux is also mentioned in (Scannell and McPhaden, 2018). Although at the 6°S,8°E position, the horizontal advection remains weak in their study**. (See Lines 571-572 "page 31")"

Line 85. The PIRATA acronym should be defined and a reference provided (e.g. Bourles et al, 2019).

response 3:

The reference (Bourlès et al., 2019) is added after the acronym PIRATA in the revised version (See line 135 "page 5").

Section 2.1.1. The temporal resolution of PREFCLIM is not specified. What is it?

response 4:

The temporal resolution (monthly) of PREFCLIM is now specified in the Observations subsection (See line 131 "page 5").

Figure 3. The Angola and Equatorial boxes contain areas of very high variability and very low variability. Presumably, the areal averages are therefore representative of much smaller regions within the boxes where the variability is high. This bias should be noted and discussed.

Response 5:

We thank the reviewer for this remark and did sensitivity tests on the boxes, by decomposing each one into two boxes (figures R1.3 & R1.4 below). For the equatorial box, except for the observed shift in the salinity tendency in March in the western half (2.5°S-2.5°N, 5°W-2°E) compared to the eastern half (2.5°S-2.5°N, 2°E-10°E) and the full box (2.5°S-2.5°N, 5°W-10°E), we note the same seasonal variations in SSS, related salinity tendency, and associated dominant processes. However, the magnitude of the individual processes increase toward the east with the salinity stratification of due to the contribution of the rivers. After decomposing the Angola box (15°S-5°S, 7.5°E-15°E) into its northern half (10°S-5°S, 7.5°E-15°E) and southern half (15°S-10°S, 7.5°E-15°E), we observe that the seasonal variations in the mixed-layer salt budget are all nearly identical but with different intensity for each process involved. Due to this relatively small sensitivity of the salt budget to the box boundaries, although the Angola and Equator boxes consist of areas of high and low variability in SSS, we decided to keep these boxes for consistency between mixed-layer heat/salt budgets. The selection of the boxes, which cover regions with particularly low mean SST/SSS and/or strong SST/SSS variability, is necessarily a trade-off. We therefore noted and discussed this bias as follows in the revised version (see lines 265-270 "page 12", lines 455-457 "page 24", and lines 474-476 "page 24").

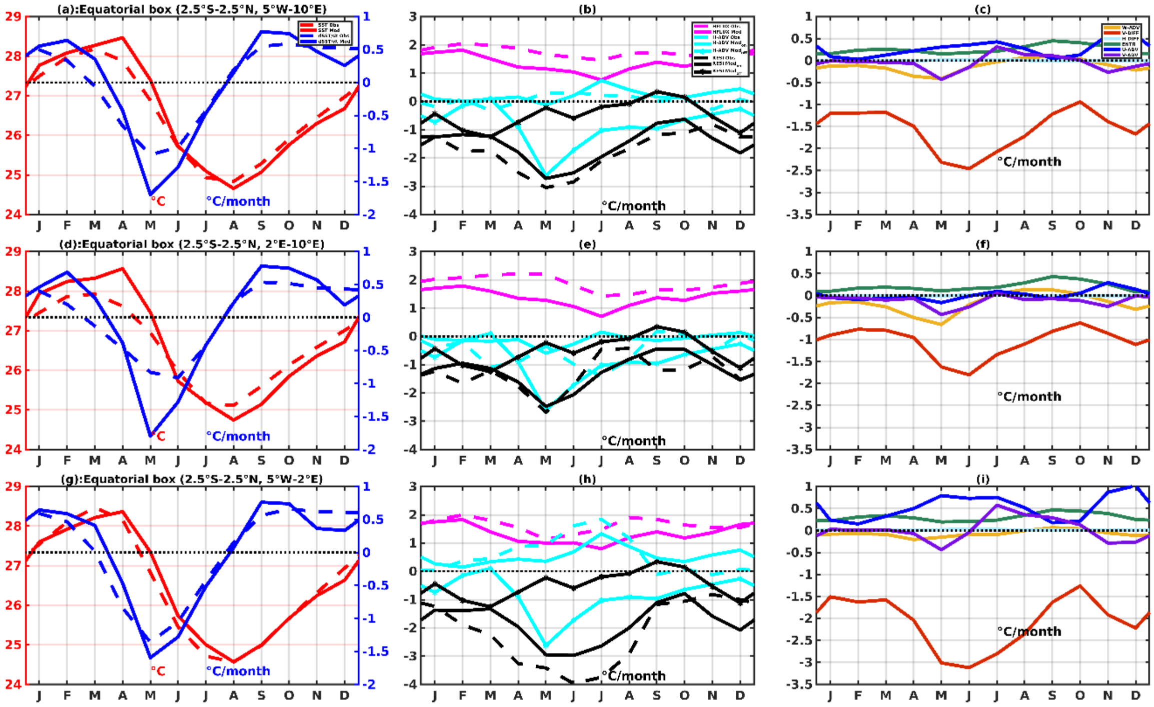

Figure R1.3: Seasonal mixed-layer salt budget terms from observations (dashed line) and model (full line and full dotted line for pseudo-residual associated with offline advection) in the equatorial box used in the paper (top row), its eastern half (middle row) and western half (bottom row). SSS in PSU and tendency terms in PSU per month.

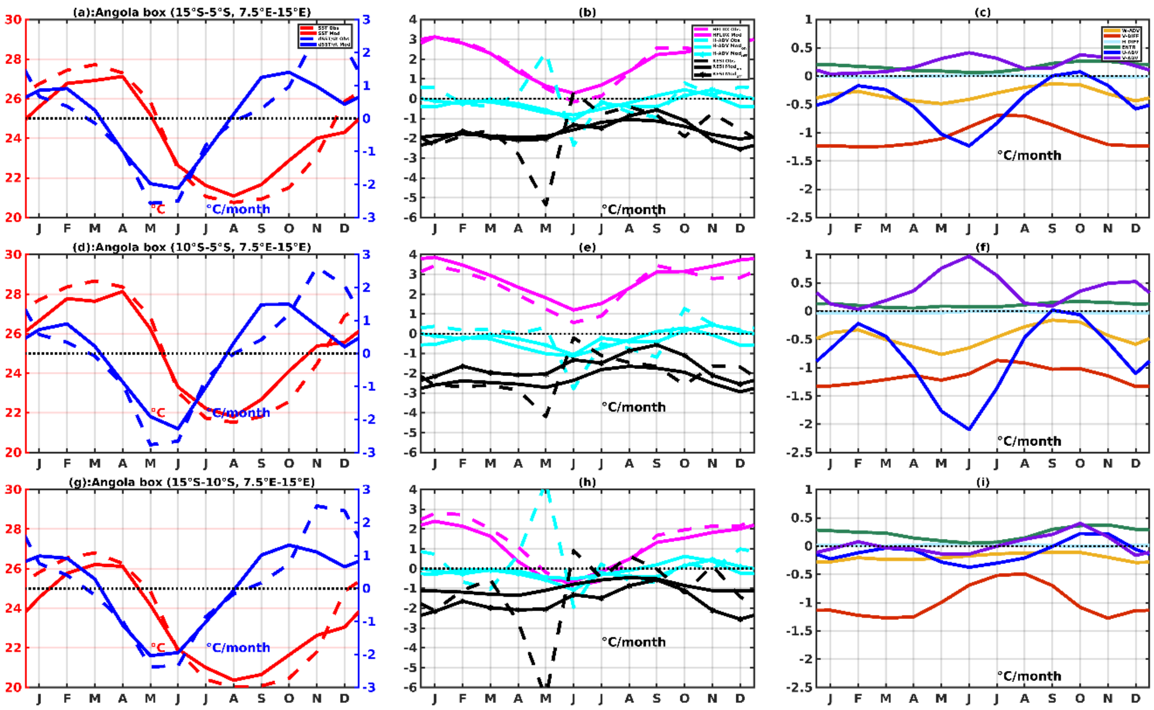

Figure R1.4: Seasonal mixed-layer salt budget terms from observations (dashed line) and model (full line and full dotted line for pseudo-residual associated with offline advection) in the Angola box used in the paper (top row), its northern half (middle row) and southern half (bottom row). SSS in PSU and tendency terms in PSU per month.

Line 275. What are the implications of the off-line advection correlating better with The Lagrangian estimate of advection? Similar question regarding statement in lines 298-99 comparing offline/online to PREFCLIM.

Response 6:

Lagrangian advection terms in PREFCLIM were obtained from the estimated velocities at each point along the drifters and floats trajectories combined with the corresponding high-resolution hydrographic climatology, then gridded. We expected that online advection could compare better to Lagrangian advection than offline advection due to the finer resolution relative to the float trajectories. However, we get the opposite result. This is probably explained by the fact that float trajectories are not homogeneous, and by the low spatial coverage of floats in the Gulf of Guinea, as now noted (see lines 300-301 "page 13"). In addition, we could also expect the offline advection to compare better with PREFCLIM "Gridded advection" than the online advection at the seasonal time scale, as it was the case for the spatial comparison (Fig. 4e-g), again showing that non-linear terms cannot be properly captured by observations. However, note that this is not verified in all cases, and this disagreement can probably be associated with the temporal coverage of the in situ observations as discussed in the last section of the manuscript (see lines 650-653 "page 33").

Figures 5 and 8. I do not see full dotted lines in these figures.

Response 7:

Improved versions of these figure are now provided.

The Rath and Dengler (2016) reference seems incomplete.

Response 8:

Rath et al. (2016) is in fact complete, as can be checked by following the doi link: https://doi.pangaea.de/10.1594/PANGAEA.868927. This is a dataset, which explains why there is no journal title.

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