

Atmos. Chem. Phys. Discuss., referee comment RC2
<https://doi.org/10.5194/acp-2022-615-RC2>, 2022
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Comment on acp-2022-615

Anonymous Referee #2

Referee comment on "Boundary layer moisture variability at the Atmospheric Radiation Measurement (ARM) Eastern North Atlantic observatory during marine conditions" by Maria P. Cadeddu et al., Atmos. Chem. Phys. Discuss.,
<https://doi.org/10.5194/acp-2022-615-RC2>, 2022

This paper analyses the variability of boundary layer moisture at the ARM ENA site using ground-based observations and ERA5 reanalysis data. The authors compute mixed-layer water budgets at monthly timescales and analyze the respective contributions of the different terms, and then assess mesoscale moisture variability on sub-daily timescales and their relationships to updrafts, liquid water path and precipitation. The analyses seem sound, and the paper is well written and quite easy to follow. My major concerns are that (i) many assumptions are not justified or discussed, (ii) I did not understand if the authors just focus on stratocumulus or also shallow cumulus conditions, (iii) the story and sequence of analyses is hard to anticipate, and the novelty and connection among different sections is not really clear, and (iv) uncertainties are not systematically quantified.

These comments, along with some more minor comments, are addressed in more detail below.

Major comments:

1. Justification & discussion of assumptions: For many of the assumptions made here, I miss a justification or discussion. For example, are the boundary layers analyzed really well-mixed up to the boundary layer top? For stratocumulus conditions I'd assume this is the case, but for decoupled shallow cumulus conditions, only the sub-cloud layer is well mixed. (See also comment 2 regarding the cloud regimes below). Could the authors demonstrate the well-mixedness of their boundary layers, and discuss how different cloud regimes might affect the budgets?

I understand that ERA5 data is necessary to complement the observations, but did the authors check whether the moisture profiles are consistent with the radiosonde and Raman lidar profiles? E.g., are the moisture profiles consistent enough that ERA5 can be used to compute the gradient? Even if this can be checked only for a limited data sample, it would greatly increase confidence in the approach. Similarly, for the local tendency and the PBL heights, could the Raman lidar profiles be used to check the hourly variability and a potential diurnal cycle in the terms that would be missed with the twice daily radiosondes?

2. Cloud regimes: As alluded to in Sec. 1 and 2, both stratocumulus and shallow cumulus conditions are frequent at ENA. But these cloud regimes are associated with coupled vs. uncoupled boundary layers, which is a relevant difference for this study. Except for Sec. 5, which clearly addresses stratocumulus conditions, only in L147 a cloud criterion is mentioned: "In the following discussion only boundary layer clouds with cloud fraction from the ceilometer greater than 0.99 were selected (total of 3580 hours)." So does this mean that the entire discussion of the budgets focuses on stratocumulus conditions with ~100% cloud cover? And does the 0.99 threshold refer to hourly values? Please clarify, and discuss more prominently.

3. Story, structure of the paper and novelty: I found it hard to anticipate the story and the structure of the paper from the abstract and the introduction. For example, Sec. 3.1 on the cloud adiabaticity seems rather peripheral and came quite unexpectedly. And at first, I expected just an analysis of the water vapor budget, and then I realize the paper focuses on the total water budget, and also constrains the mass budget. So it would have helped me if the story of the paper was clearer and if the reader's expectation was a bit more guided.

In a similar spirit, I missed the coherence and connections between the different Sections. How do the monthly mixed-layer budget analyses connect to the analyses of the mesoscale variability? Could you construct mixed-layer budgets also on shorter timescales to connect to the monthly budgets and understand how the terms contribute differently at different timescales?

I would also recommend the authors to highlight more explicitly what is new in the paper. How does the novel retrieval used, which better separates cloud and drizzle contributions to TLWP, affect the robustness of your analyses and conclusions? What are the novel insights gained with the ENA data here compared to previous ML budgets? In L541 it is mentioned that 'the results presented herein are useful for future observational and modeling studies on low clouds conducted at the ARM ENA site', but can you be a bit more explicit?

4. Uncertainty quantification: I missed a quantification of the uncertainty of the different terms in equations (1) and (3). Also, can you briefly say in L133 how the uncertainties of the retrievals are estimated?

Minor comments:

- Retrievals section 2.3: I think this section could be written a bit more concisely. From one paragraph to the other, it seems to jump from one algorithm (with unfamiliar acronym for me) to another. Also, I think it could be worthwhile to present the comparison of SPARCL and MWRRET (L141 onwards) in an appendix, not to depart from the main story of the paper too much.
- Use of commas: I missed a lot of commas throughout the manuscript, e.g.:
 - L113: were derived, cases that
 - L134: For ten selected cases of weakly precipitating marine stratocumulus clouds, vertical profiles of water
 - L143: Traditionally, the total liquid water path retrieved by radiometers is assumed to represent the cloud water path. However, in the presence
 - ... Please check the entire manuscript carefully.
- References: I'm not sure which program (if any) the authors use for the references, but it's not consistent and sometimes erroneous. E.g. Zhou and Bretherton 2019 is cited differently in L381 and L432. Also, the reference 'Shultz and Stevens, 2018 is not correct (L379), or (Zheng et al. Lamer et al. 2019; ...) in L44. Please improve throughout the manuscript.
- L276: I understand that strong precipitation rates can introduce strong peaks, but this is the intermittent nature of rain, and I guess not a measurement error. Can you understand from your data how such strong precipitation rates are locally balanced? It would be very interesting to analyze this.
- L308: please specify what kind of filter is applied here.
- L343: "The seasonality of the large-scale advection term is also the factor that determines the seasonality of the overall budget." --> Please clarify how you get to this statement. From Fig. 7 it seems that the seasonality in the LHF or precipitation terms is also very large.
- L345ff: Does the magnitude of the monthly residuals depend on how much data was used per month? I.e. if only a few days of data could be used, it might not be surprising that the monthly budgets don't balance well. Please clarify.
- L389: How do you interpolate 10-min profiles over 1 minute? Do you downsample the data?
- Figures:
 - 11: Please specify what normalized height refers to in the right panel
 - 12: the figures are far too small and can hardly be read..
- L511: I do not understand this sentence, please clarify: "The lower mid-tropospheric humidity during the winter months, together with turbulence (Ghate et al. 2021) point towards turbulence being the primary controlling factor rather than water vapor in determining cloudiness in the region."
- L532: "Moist and dry patches present differences in vertical velocity with dry regions displaying more frequent downdrafts than moist regions immediately below the cloud base." i□ from Fig. 12 I'd say the opposite, please clarify.

Typographical suggestions:

L45: that that the water ...

L229 / L263: the total water mixing ratio is once written in normal and once in bold font – please harmonize.

L234: please use proper math formulation for the averaging brackets.

L279: maybe add after `... the entrainment rate (**see Sec. 4.2**)`

L303: ...balanced by local change in the boundary layer **height** (?)

L321: large-scale turbulence --> do you mean subsidence instead of turbulence? And previously, largescale was written without `-`, please make it consistent.

L322: that what reported --> than what was reported ..

L514: hear --> heat