21 March 2026

Dear Editor,

We thank both reviewers for their thoughtful and constructive evaluations of our manuscript. All suggested changes have been implemented in the revised manuscript. Below we respond to each point.

Thank you and best regards,

Anna Lea Albright on behalf of all authors

Reviewer 1

General Comments

Reviewer: The authors present a new approach to estimate air specific humidity (qa) over convective oceanic regions by exploiting the physical connection between cloud base height and near-surface relative humidity in oceanic regions where optically-thick clouds do not prevent lidar sampling. In my view the manuscript is well structured and detailed. Overall, the authors introduced the need for a specific humidity estimate from cloud base height observations, they described their methodology and results in detail. They addressed the benefits and limitations of the method they introduced in a satisfactory manner.

If I would add something to the discussion it would be the relation to wind speed and how it affects in-situ and satellite retrievals directly or indirectly, given that the wind speed is an essential meteorological parameter for estimating latent heat flux.

Comment 1 — Lines 30–41: COARE and exchange coefficient differences

Reviewer: The authors most likely refer to the COARE3.5 bulk algorithm which is one (though widely used) of many bulk algorithms to estimate latent heat flux. I think it should be noted here that the variations in the definition of the exchange coefficient can lead to latent heat flux estimates that differ by more than 2Wm-2 especially at very low (<2m/s) and at high wind speeds (>17m/s). Also, the atmospheric stability is very important which is introduced into the stability functions in the form of z/L (where z is the measurement height and L is the Monin-Obukhov length) and is affected by the humidity estimate. The z/L could be used in a similar manner as the Buoyancy flux in Figure 1.

Response: Thank you. The revised text now explicitly notes that COARE is referenced as a representative bulk algorithm among several formulations, and that different bulk parameterizations yield different fluxes under identical inputs, especially under extreme wind conditions. We clarify that near-surface humidity affects latent heat flux (i) directly through Δq, and (ii) indirectly through stability-dependent transfer coefficients (Monin–Obukhov similarity, expressed via z/L). We also note that even with improved q_a, flux uncertainties remain in low-wind (gustiness-dominated) and high-wind regimes.

Revised text added: "We refer to COARE as a representative bulk algorithm but note that different bulk formulations and transfer-coefficient parameterizations can yield differing latent heat flux estimates for identical bulk inputs, particularly under very low- and very high-wind conditions. Thus, uncertainties in q_a influence flux estimates directly through Δq and indirectly through stability-dependent transfer coefficients. The surface moisture fluxes can therefore be reasonably well determined given knowledge of the specific humidity of the near-surface air, $q_\ra,$ the saturation specific humidity at the surface temperature and pressure, $q_\rs,$ as well as the near-surface winds, $|U|$."

Comment 2 — Lines 249–251: Cool-skin correction

Reviewer: The consideration of the cool skin effect is essential in estimating specific humidity and latent heat flux. Just for reference, the developers of COARE just released a new treatment of the cool skin (https://doi.org/10.1029/2025JC023539). Omitting adjusting for the cool skin can lead to mean changes higher than 6Wm-2 (Cronin et al. 2019, doi: 10.3389/fmars.2019.00430), provided that the bulk formula applied "expects" the skin temperature as input. In this case the authors consider a representative value, but for the operational product I think that a computational approach should be considered (cool skin, warm layer adjustments to the bulk sea surface temperature).

Response: We have clarified that consistent use of skin vs. bulk SST depends on the bulk algorithm, added citations to Cronin et al. (2019) and the updated COARE cool-skin treatment (Fairall et al. 2026), and noted that an operational implementation should include physically based cool-skin and warm-layer corrections.

We have first edited the paragraph starting line 263: “Fig.~\ref{fig:temperature_offset}a shows the time evolution of sea-surface temperatures measured by the port thermosalinograph (depth \SI{5}{m}) and near-surface air temperatures measured at \SI{28.3}{m}. The seawater measurements are expected to be biased warm relative to the true skin temperature due to the cool-skin effect, typically \SIrange{0.1}{0.3}{K} \citep{Fairall1996, Yan2024}. As expected, nearly all (97\%) of the 47{,}512 measurements show the ocean is warmer than the overlying air, consistent with unstable and convective conditions. The median and mean temperature differences are 1.0 and \SI{1.1}{K}, respectively. Because the relevant temperature for surface fluxes is the sea-surface \textit{skin} temperature, we take it to be \SI{0.3}{K} cooler than the measured bulk temperature, yielding a representative offset of $\Delta_a T = \SI{1.3}{K}$. This fixed offset is applied to the sea-surface temperatures corresponding to each radiosonde launch."

We have then added the following new paragraph: "Because bulk flux algorithms may be formulated to use either a skin temperature or a bulk (foundation) temperature as input, consistent treatment of cool-skin and warm-layer effects is important when translating $\Delta_a T$ into latent heat flux estimates. Omitting a cool-skin adjustment can lead to mean latent heat flux differences exceeding \SI{6}{W\,m^{-2}} when the bulk formulation expects a skin temperature \citep{cronin2019air}. Recent updates to the COARE framework include an updated treatment of the cool skin effect \citep{fairall2026updated}. While we adopt a fixed representative offset here for consistency and simplicity, we note that an operational implementation of the present retrieval would benefit from coupling the humidity estimate to a physically based cool-skin and warm-layer correction scheme."

Comment 3 — Line 293: Air–sea temperature difference variability

Reviewer: "Because the air–sea temperature difference varies only modestly across most of the global ocean, it can be estimated statistically." Though the statement can be true on monthly mean and basin-scale it has significant limitations e.g. in western boundary currents, upwelling zones and frontal regions where the variability is large to name one. In addition statistical methods complement rather than replace direct measurements if we want to achieve target accuracies (2-5Wm-2 on daily/annual time scales) for surface turbulent fluxes. Note also that the accuracy for relative humidity would be 0.5-1% under common conditions, with critical challenges at very low wind speeds (up to 3% for u<3ms-1).

Response: Thank you, we have revised this part. We now explicitly note these regional limitations and emphasize that statistical approaches complement rather than replace direct measurements and physical corrections.

Revised text: "The air--sea temperature difference varies only modestly over much of the open ocean on monthly and basin scales, and it can therefore often be estimated statistically; however, this assumption breaks down in regions of strong gradients such as western boundary currents, upwelling zones, and frontal regions, where variability is large and direct observations or physically based corrections remain important."

Comment 4 — Lines 301–306: Outlook and wind-speed regime limitations

Reviewer: The authors claim that one of the goals for the method application is to establish large scale latent heat flux climatologies. What I am missing from this outlook is the relation to the exchange coefficient (discussed in the introduction briefly) and thus the wind speed. Especially, the estimation of latent heat flux is challenging at very low and high wind speeds. At very low wind speeds many bulk formulae including COARE include a convective gustiness term in order to allow for convergence. My suggestion would be to add some discussion about the limitations (or not) of the introduced method at low wind speeds.

Response: We have now added a paragraph explicitly addressing gustiness corrections at low wind speeds, sea-state and spray effects at high wind speeds, and the need to assess retrieval value within specific wind regimes.

Revised text added: "Finally, we note that improving \(q_{\mathrm{a}}\) addresses only one, albeit dominant, term in Eq.~\eqref{eq:bulk_flux_eq}. For latent heat flux applications, residual uncertainties will remain associated with wind speed retrievals and with the wind- and stability-dependence of the exchange coefficient, C. In particular, low-wind conditions require special treatment in many bulk algorithms (e.g., convective gustiness terms), and high-wind conditions can involve additional processes (e.g., sea state and spray) that affect transfer coefficients. Thus, the value added by a cloud base–constrained humidity estimate should be assessed jointly with wind-speed regime and the chosen bulk parameterization when developing and evaluating flux climatologies."

Technical corrections

Line 51. "*Gentemann et al. (2020) detail approaches to this problem*" should be something like "Gentemann et al. (2020) provides detailed approaches to this problem"?

Thank you, we have rewritten as "Various approaches to this problem are described in \citet{gentemann2020fluxsat}."

Line 171, add a comma after "Similarly, …"

Corrected.

Figure 4 caption add comma after first parenthesis: "…cloud base height, h (using the first, major peak of the distribution), from R/V Meteor (n=171, dark blue), and BCO (n=118, medium blue) measurements…"

Corrected, thank you.