

REPLY TO MINOR CORRECTION REVIEWER 1

We warmly thank the referee for the comment regarding the role of humidity.

We believe that the confusion on this point likely arises from the wording used to define LHF_therm and LHF_therm_U, which has now been revised in lines 196-214. We therefore clarify this aspect in detail below.

Following the notation of the article, variables with the subscript “LR” denote smoothed fields, obtained by applying a low-pass Gaussian filter with a cutoff length of 250 km to the original model variables. The subscript “HR” denotes reconstructed fields obtained using the coupling coefficients and the downscaling algorithm (Eq. 2 of the article).

To compute LHF_therm we use the smoothed surface wind (U_{LR}), whereas SST and air temperature are modified adding the SST correction (ΔSST , Eq. 3 of the article). Air temperature is therefore not fully downscaled in this dataset, in order to keep the air–sea temperature vertical imbalance at its smoothed value. We note, however, that the results do not change significantly if air temperature is fully downscaled using Eq. 3 and the SST-air temperature coupling coefficient s_t , suggesting a weak contribution of fine-scale air-temperature variations. For this reason, we do not explicitly assess the LHF sensitivity to air-temperature changes in this study.

In addition, the saturation specific humidity used in LHF_therm is computed from the Clausius-Clapeyron relation using SST_HR: $qsat(SST_{HR})$. Importantly, in LHF_therm the specific humidity is not maintained at its “smoothed” value. Instead, what is kept fixed at its “smoothed” value in LHF_therm is relative humidity (RH). Hence, the specific humidity used in LHF_therm (q_{therm}) is the one reconstructed from RH_LR and $qsat(SST_{HR})$.

By contrast, to compute LHF_LR, all variables controlling the latent heat flux are smoothed using the low-pass Gaussian filter (250 km cutoff length).

In summary:

$$LHF_{therm} = LHF(U_{LR}, q_{therm}, T_{LR} + \Delta SST, qsat(SST_{HR}))$$

$$LHF_{LR} = LHF(U_{LR}, q_{LR}, T_{LR}, qsat(SST_{LR}))$$

As a consequence, the difference $LHF_{therm} - LHF_{LR}$ represents LHF variations solely linked to the mesoscale SST anomalies, while relative humidity (not specific humidity) and surface winds are kept at their smoothed values. This is what we refer to in the text as “thermodynamic contribution”. This point has been made more explicit in the revised manuscript (lines 196–205).

Finally, LHF_therm-U differs from LHF_therm only through the surface winds, which are downscaled:

$$LHF_{therm-U} = LHF(U_{HR}, q_{therm}, T_{LR} + \Delta SST, qsat(SST_{HR}))$$

Hence, $LHF_{therm-U} - LHF_{LR}$ represents LHF variations arising from the thermodynamic contribution together with the component of the dynamic contribution associated with mesoscale SST-induced variations in surface winds.

As a result, we believe that our Fig. 5 is not directly comparable to Fig. 11 of Small et al. (2019), which presents a decomposition of the latent heat flux bulk formula (their Eq. 2). We assume that the first three terms shown in their Fig. 11 correspond to what the reviewer refers to as the “standard linearization of LHF.” For example, the term in Eq. 2 of Small et al. (2019) describing LHF anomalies associated with changes in specific humidity at constant surface winds contributes only weakly (their Fig. 11c), whereas an apparently much larger contribution is inferred from our Fig. 5 when comparing $LHF_{therm-U} - LHF_{LR}$ and $LHF_{HR} - LHF_{LR}$.

However, the large contribution in our regressions does not arise from large variations in specific humidity itself. Rather, it reflects the fact that, at the mesoscale, q does not follow Clausius–Clapeyron scaling with SST, leading to enhanced undersaturation and associated changes in relative humidity. Indeed, if we were to perform a regression of $LHF_q - LHF_{LR}$ against ΔSST , where LHF_q is obtained by downscaling all variables except q —the resulting regression line would be nearly flat (slope close to zero), owing to the small magnitude of Δq (i.e., the weak specific-humidity coupling coefficient shown in our Fig. 4).

Therefore, rather than concluding that weak mesoscale variations of q with SST directly drive the fine-scale LHF sensitivity to SST, we argue that it is the undersaturation imbalances (i.e. relative humidity changes) induced by the departure of q from Clausius–Clapeyron scaling that are responsible for the LHF variations. This interpretation has been clarified in the revised manuscript when analysing Fig. 7 (lines 451–457) and explicitly reiterated in the conclusions (Section 5, lines 570–585).

In addition, the anomalies in Eq. 2 of Small et al. (2019) (denoted by primes) are defined in the time domain relative to a monthly climatology, whereas our anomalies are derived using a combination of spatial and temporal filters applied over two specific months. This methodological difference likely affects the spatial scales represented in each analysis and further complicates a direct comparison between the two studies.

Finally, regarding the interdependence between variables, the reviewer is correct that this is not accounted for in our framework. This is an explicit assumption of the downscaling algorithm. While we acknowledge this as a limitation, previous studies using the same approach have demonstrated improved LHF estimates. Its simplicity and demonstrated performance motivated its use here. We now explicitly acknowledge this assumption in the manuscript and cite Small et al. (2019) accordingly (lines 190–195 of the revised version).

