

Parameterizing the meso-scale enhancement of
oceanic surface turbulent fluxes: a
physical-statistical approach
Supplementary material

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1 ”Antilles” numerical domain analysis

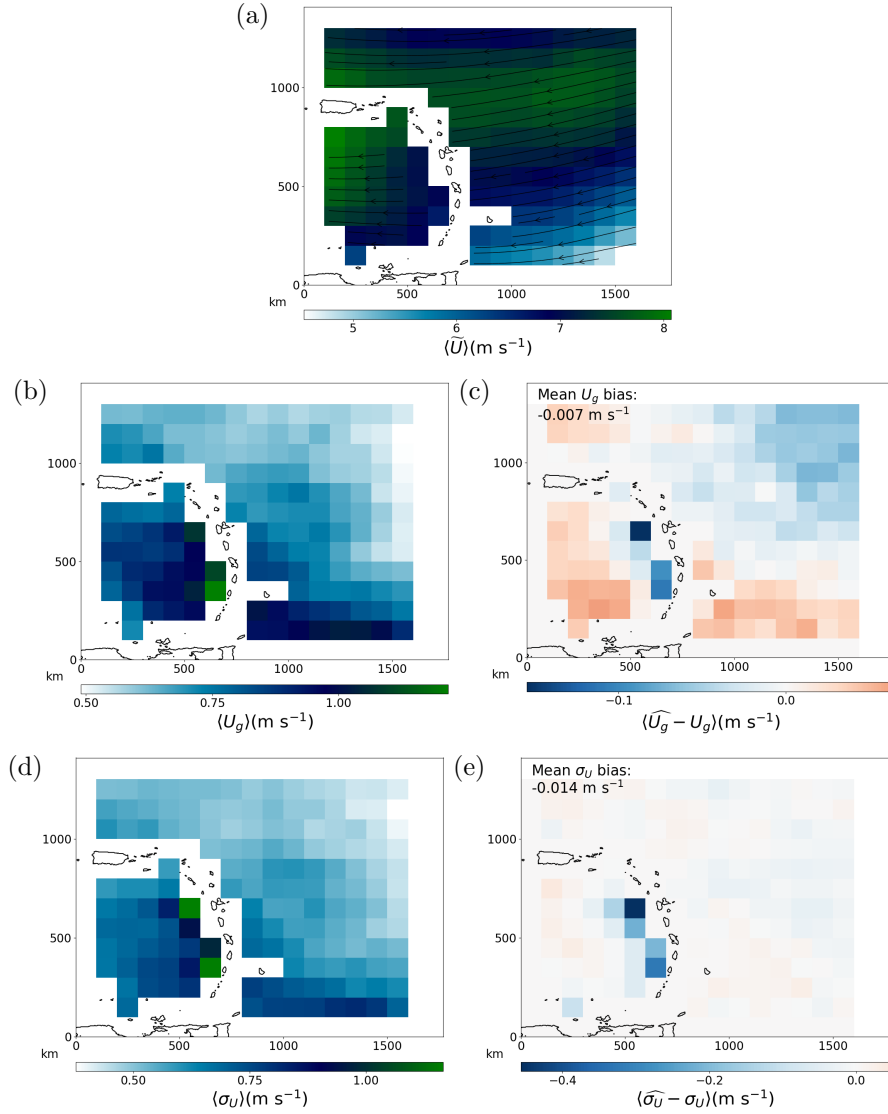


Figure S1: One month average on the $\text{GCM}_{\text{Antilles}}$ domain ($E_{\text{test,Ant.}}$ dataset) of: (a) the GCM-resolved wind speed $\langle \tilde{U} \rangle$; (b) the reference gustiness velocity U_g ; (c) the present U_g parameterization bias; (d) the reference meso-scale wind speed standard deviation σ_U and (e) the present σ_U parameterization bias.

2 Predictor distribution

The distribution of each predictor is provided in this Supplementary Material in order to make it possible comparison with the predictors that may be used in GCMs for any implementation of the proposed parameterization.

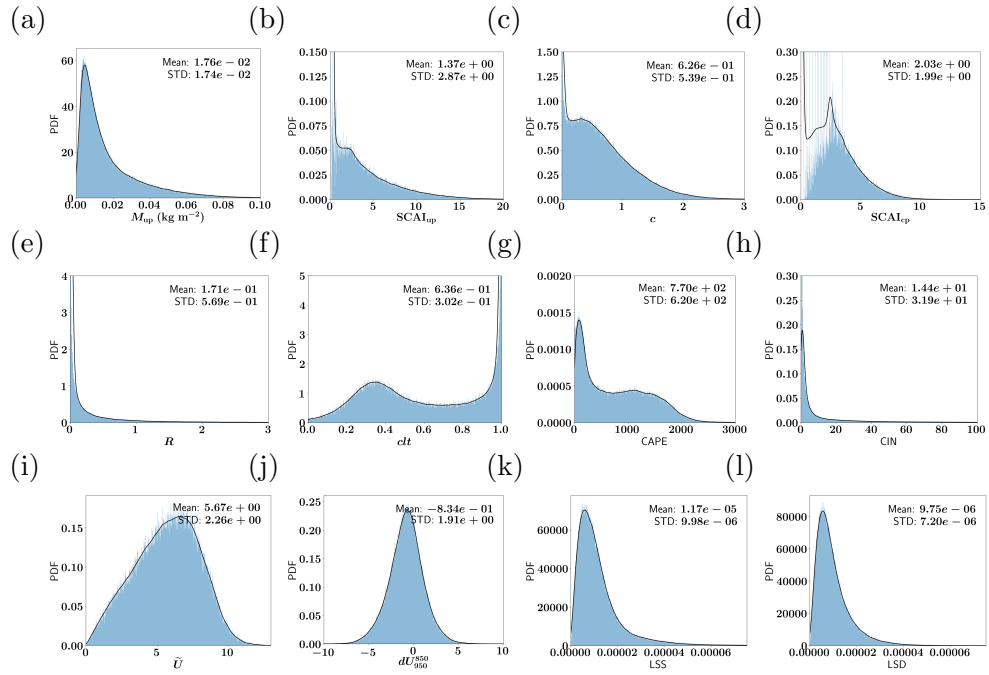


Figure S2: Probability density function of each potential predictors based on the $\mathcal{D}_{Indien}^{All}$ dataset.

3 Statistical model for the meso-scale wind speed variance

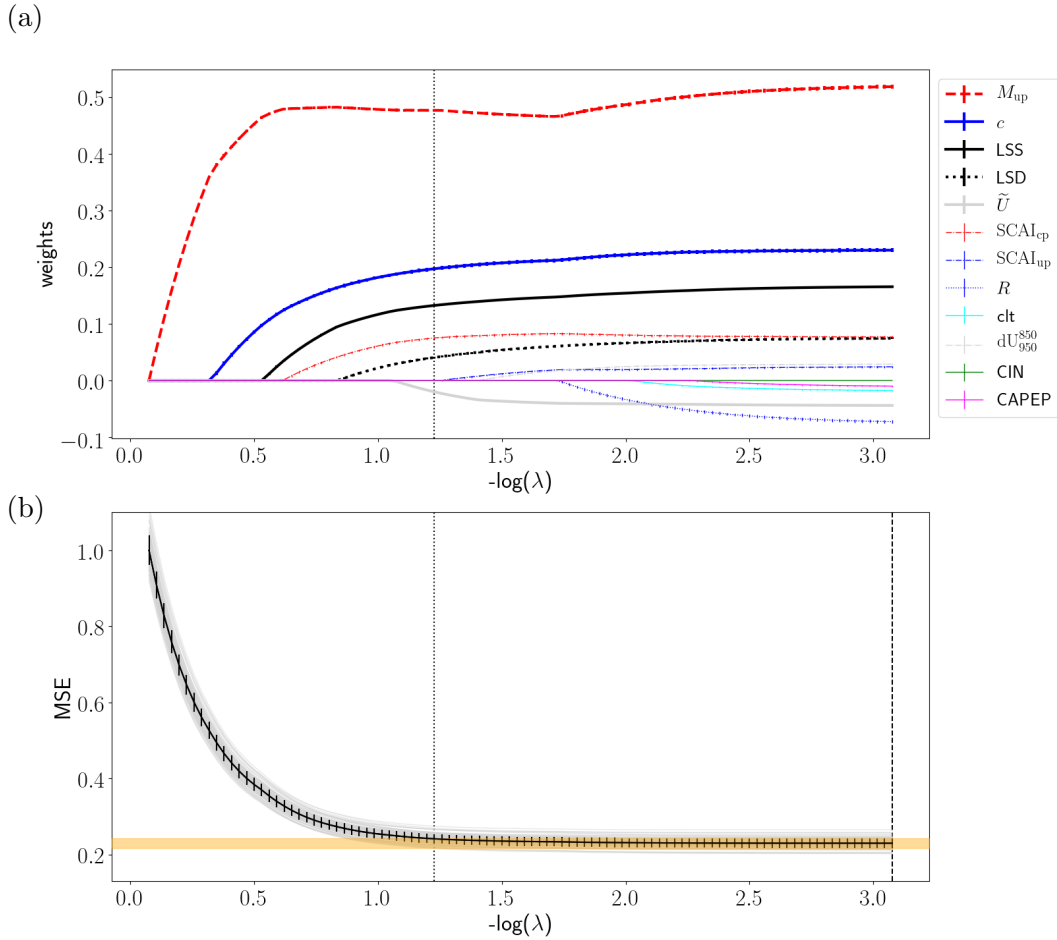


Figure S3: LASSO path and K -fold cross validation for the σ_U model. (a) evolution of the LASSO path for each predictor with the degree of penalization λ . Error bars on each path: variability ($10\times$ the standard deviation) of the coefficient for a given λ . Vertical dotted line: optimum λ selected by the cross validation. (b) gray lines: evolution of MSE with λ for each fold. Red line and error bars: mean and \pm one standard deviation. Vertical dashed line: λ of the minimum average MSE; orange shadowing: amplitude of \pm one standard deviation around the minimum average MSE; vertical dotted line: largest λ at which the average MSE reaches the \pm one standard deviation around the minimum average MSE (“one-standard-deviation rule”).

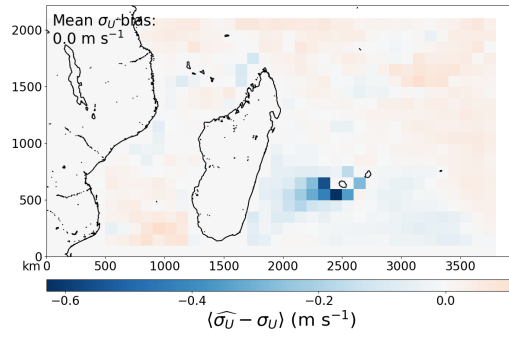


Figure S4: Monthly average map of σ_U parameterization bias tested on the entire $E_{\text{tot.,Ind.}}$ dataset

4 Wind speed gustiness parameterizations inter comparison

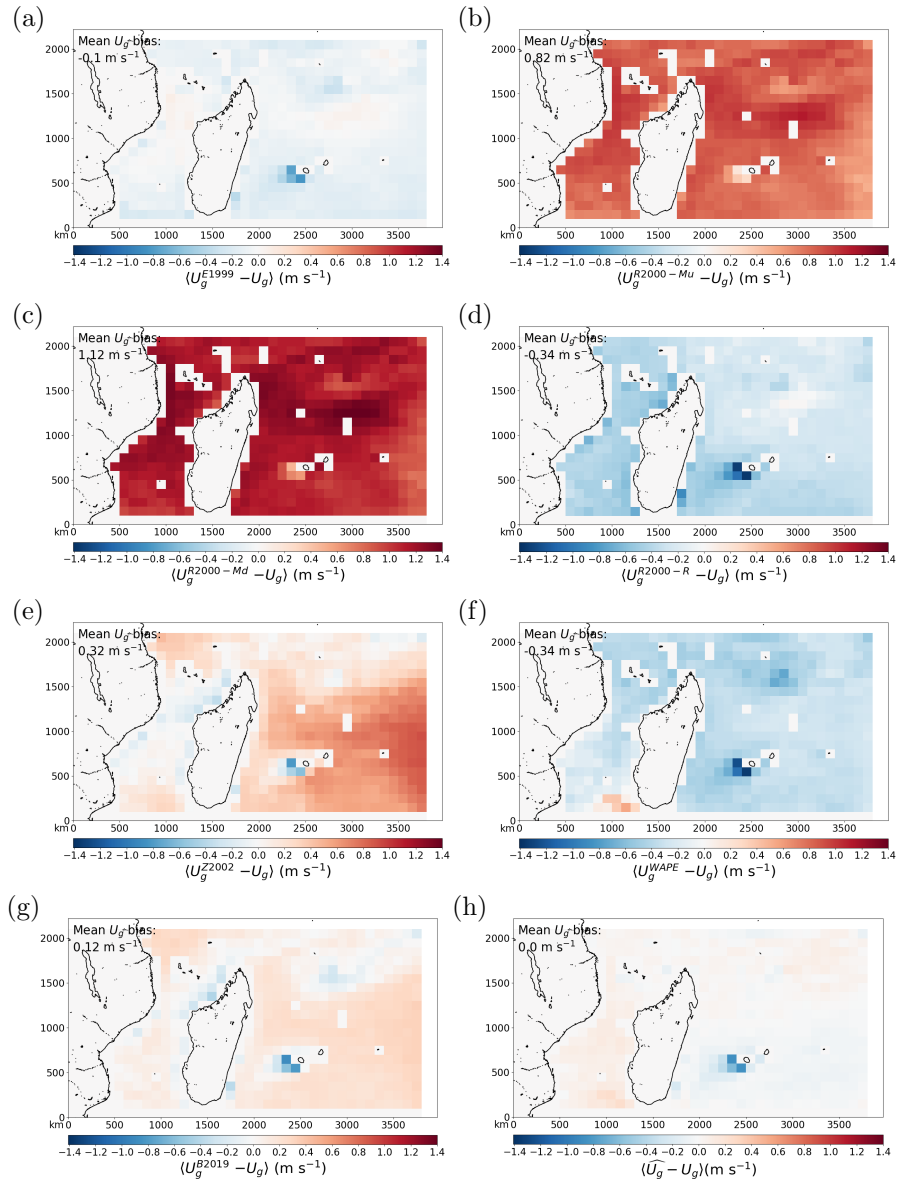


Figure S5: One month average of the U_g bias for all the previously published parameterizations: Emanuel and Živković-Rothman (1999) (re-tuned, *E1999*), Redelsperger et al. (2000) (*R2000 – Mu*, *R2000 – Md* and *R2000 – R*), Zeng et al. (2002) (*Z2002*), Hourdin et al. (2012) (re-tuned, *WAPE*), Bessac et al. (2019) (*B2019*) and the present parameterization (\widehat{U}_g).

5 Parameterizations inter comparison in term of surface fluxes

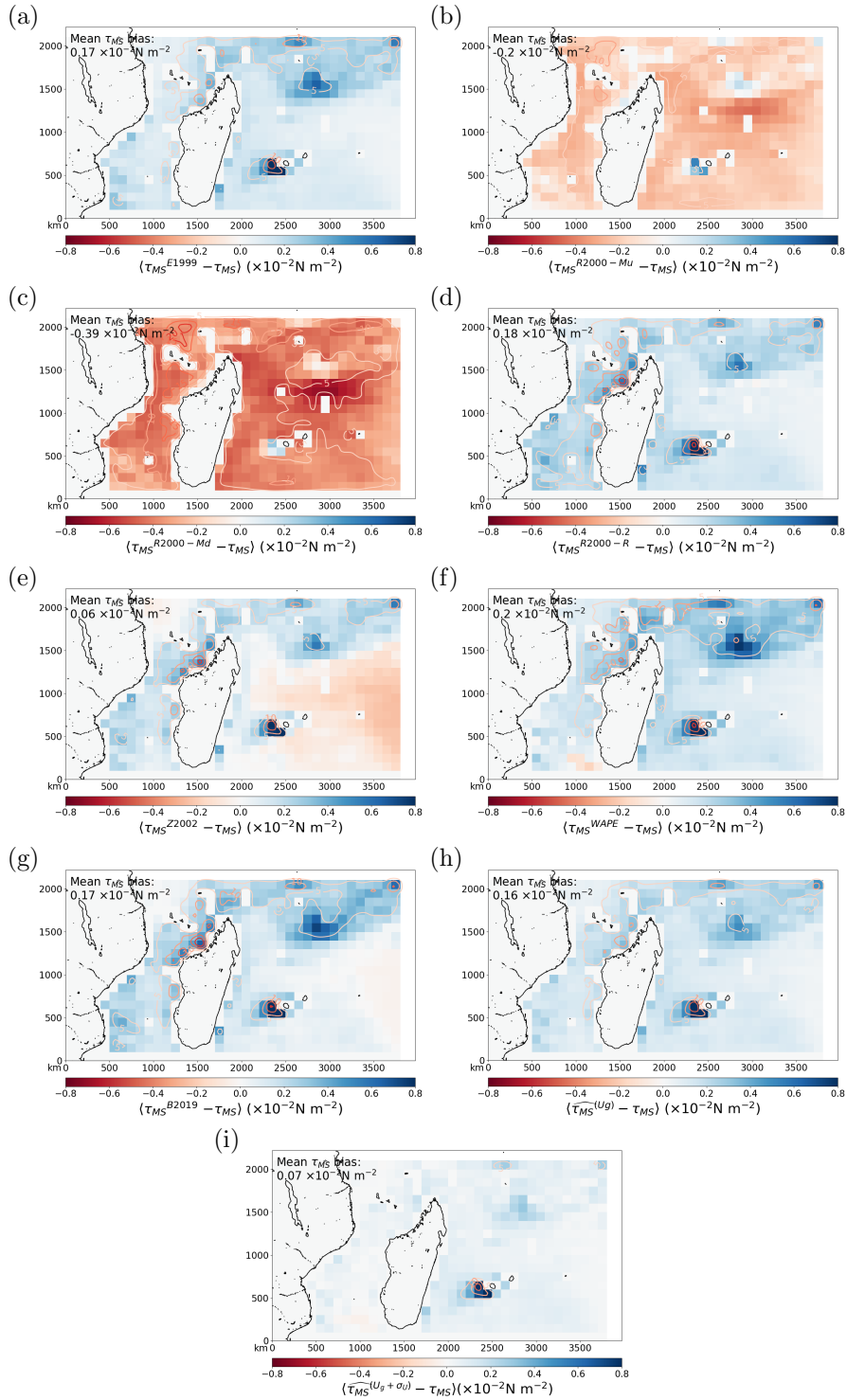


Figure S6: Same as Figure S1 but for the momentum flux residual bias. Note that $\widehat{\tau}_{MS}^{(U_g)}$ considers only the U_g parameterization while $\widehat{\tau}_{MS}^{(U_g + \sigma_U)}$ considers both the present U_g and σ_U parameterization.

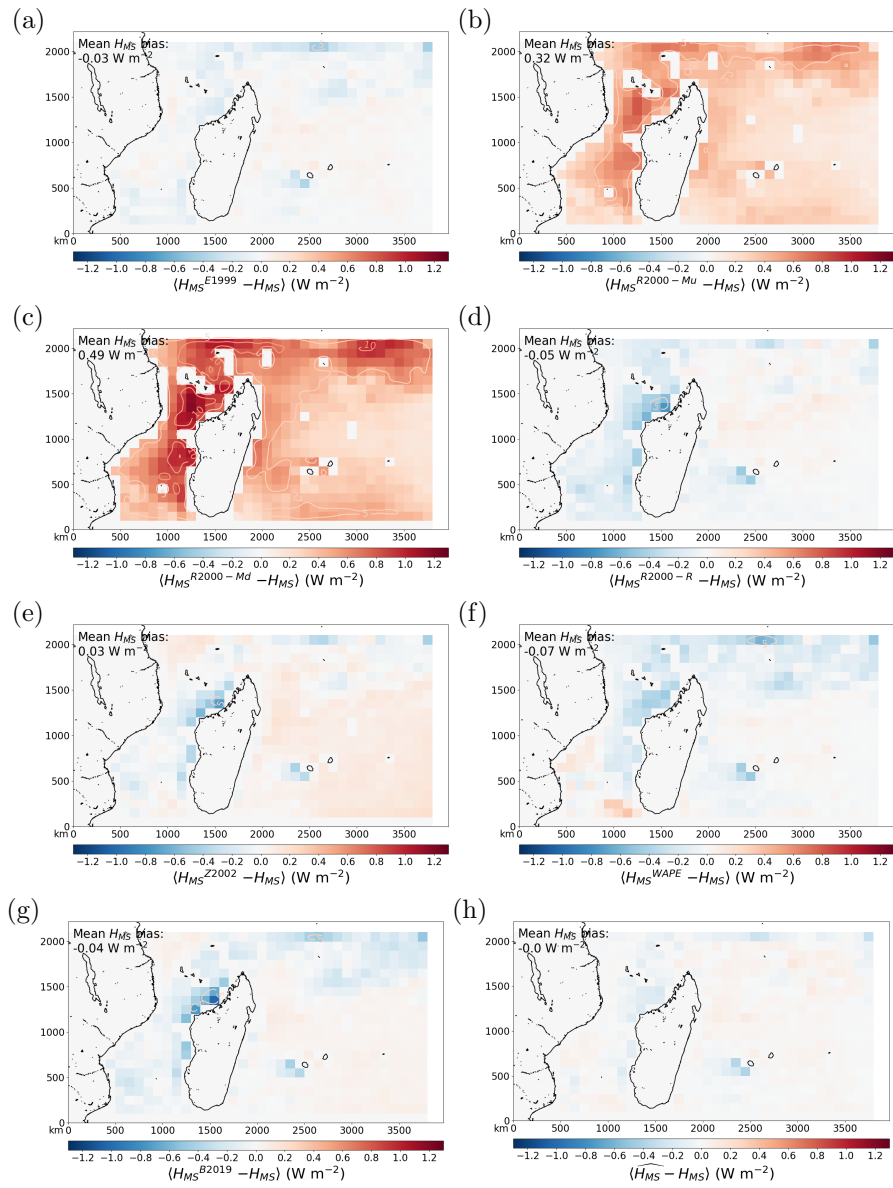


Figure S7: Same as Figure S1 but for the sensible heat flux.

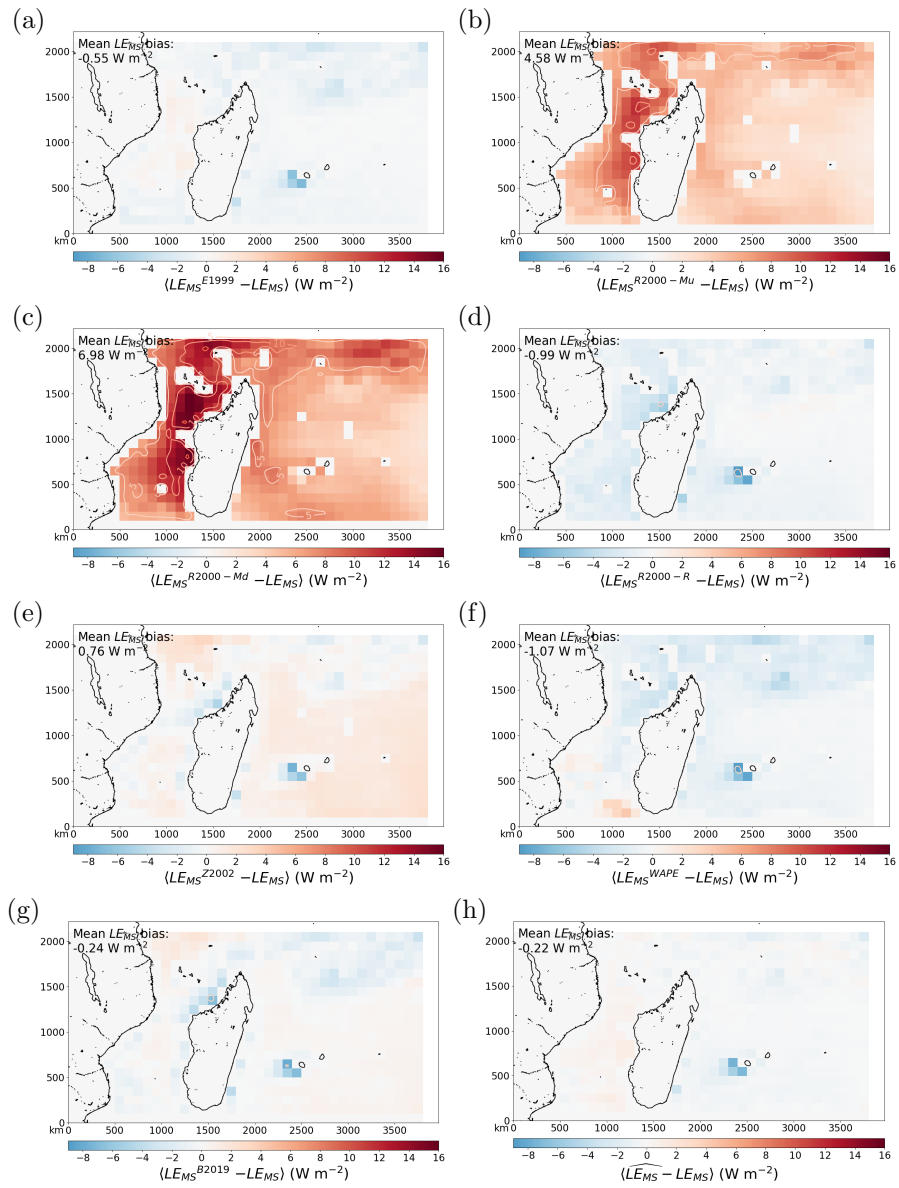


Figure S8: Same as Figure S1 but for the latent heat flux.

6 Proposed parameterizations involving fewer predictors

6.1 Simpler parameterization for U_g

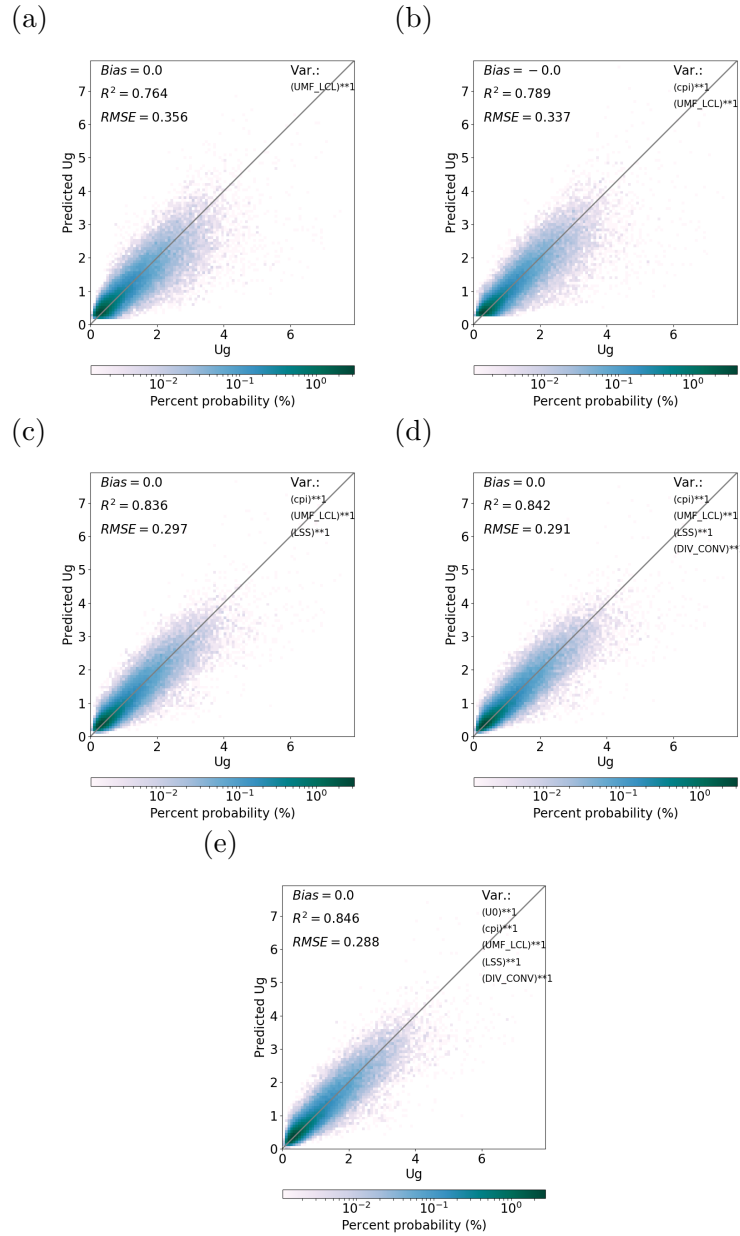


Figure S9: Joint probability distribution of predicted and reference U_g for model from 1 to 5 predictors (a to e).

6.2 Simpler parameterization for σ_U

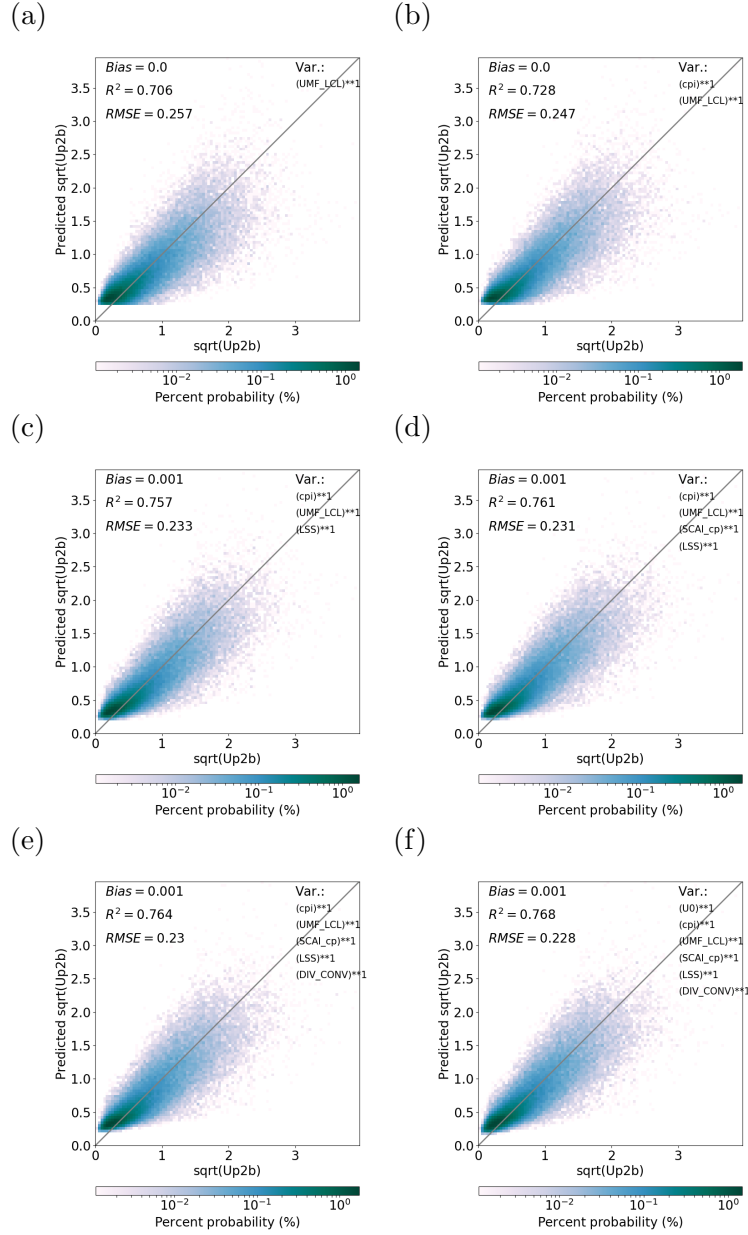


Figure S10: Joint probability distribution of predicted and reference σ_U for model from 1 to 6 predictors (a to f).

7 Parameterization of δU

This section briefly discuss the parameterization of δU , equivalently to the parameterization of Bessac et al. (2019) with their parameter $n=1$.

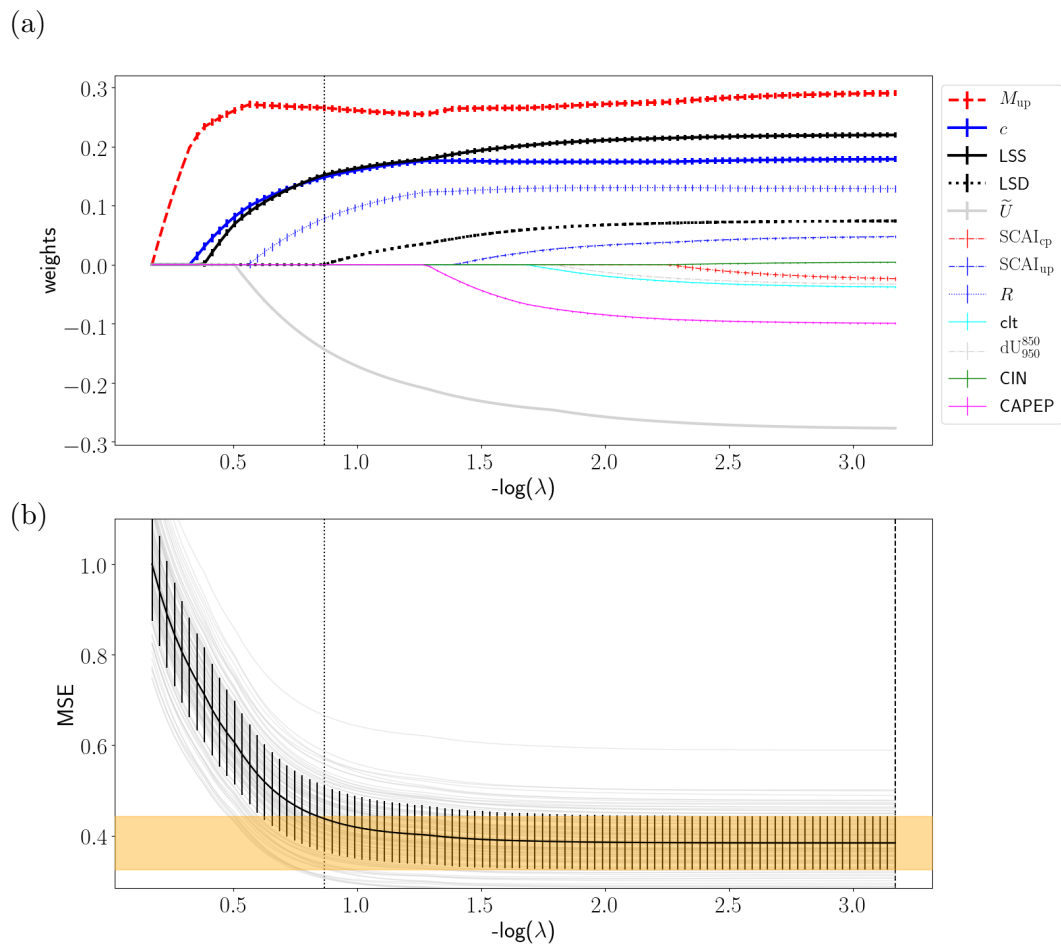


Figure S11: Same as Figure S3 but for the δU model.

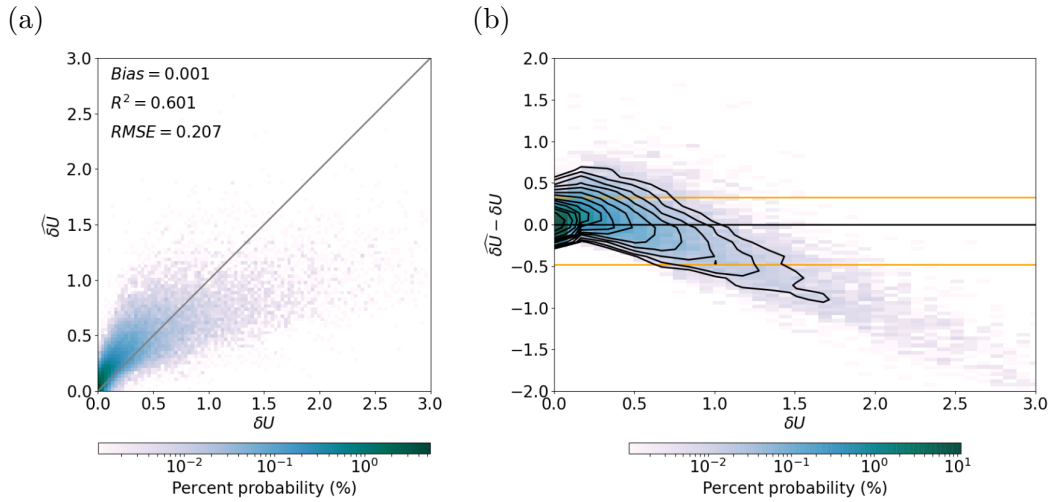


Figure S12: Joint probability distribution (a) between the parameterized wind speed difference $\widehat{\delta U}$ and its targeted reference δU and (b) between the parameterization residual $\widehat{\delta U} - \delta U$ and the reference δU . On panel (b), contours are equally spaced by 0.29 in the logarithmic space starting from 1.3×10^{-6} , and the two horizontal orange lines indicate the 2nd and 98th percentiles of the residual distribution. Only the testing dataset $\mathcal{D}_{Indien}^{\text{Test}}$ is used here.

8 Link between M_{up} and c

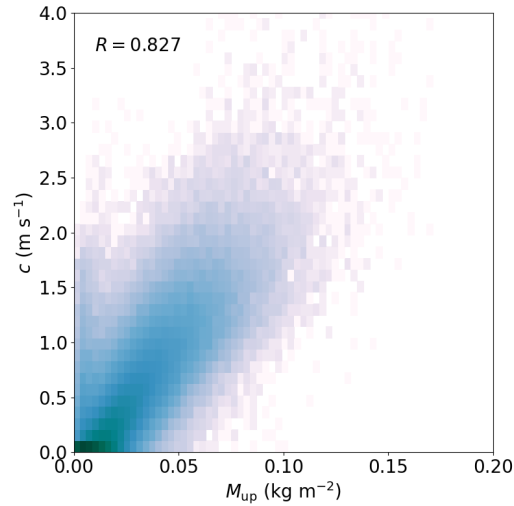


Figure S13: Joint probability distribution between the updraft mass flux M_{up} and the cold pool spreading velocity c .

References

- Bessac J, Monahan AH, Christensen HM, Weitzel N (2019) Stochastic parameterization of subgrid-scale velocity enhancement of sea surface fluxes. *Monthly Weather Review* 147(5):1447–1469, DOI 10.1175/mwr-d-18-0384.1
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