Latent heat flux coupling to the small-scale ocean

Pablo Fernández*[1], Sabrina Speich[1], Agostino N. Meroni[2], Matteo Borgnino[2], Fabien Desbiolles[2,3] and Claudia Pasquero[2,4]

[1] Département de Geosciences, École Normale Supérieure / Laboratoire de Météorologie Dynamique, 75005 Paris, France.
[2] Department of Earth and Environmental Sciences, University of Milano – Bicocca, Milan Italy.
[3] CIMA Research Foundation, Savona Italy.
[4] Institute of Atmospheric Sciences and Climate, Consiglio Nazionale delle Ricerche (ISAC – CNR), Turin, Italy.

*pablo.fernandez@lmd.ipsl.fr

Introduction

Our ability to compute latent heat flux (LHF) is subject to many shortcomings. Some of them are related to the lack of temperature and humidity observational coverage [1] while others rely on the uncertainties of the parameterisations used in models to compute LHF [2]. There is a large body of evidence which suggests that LHF is largely affected by mesoscale and submesoscale activity in numerous parts of the World Ocean ([3] and [4]) and that it feeds back into the atmosphere [5]. Hence, this study aims to improve our understanding of the interaction mechanisms between the upper ocean and the marine atmospheric boundary layer (MABL) focusing on sea-surface temperature (SST) and sea-surface salinity (SSS) by means of reanalysis, models, satellite and in-situ observations.

Motivation

Improving the representation of small-scale nonlinear ocean-atmosphere interactions in climate models by innovative joint observing and modelling approaches.

How?

- **Understanding driving mechanisms.**
- **Process parameterisation and modelling approaches.**

Model

- Focus on the boreal winter season in the EUREC⁴A-OA region (5°-17°N, 60°-51°W).
- **Goal:** Study the impacts of small-scale SST features in LHF.
- We propose a first-order SST-based linear downscaling algorithm.

$$\psi_{HR} = \psi + \alpha_\psi \Delta SST$$

$$\Delta SST = (SST_{MUR} - < SST_{MUR} >) - (SST_X - < SST_X >)$$

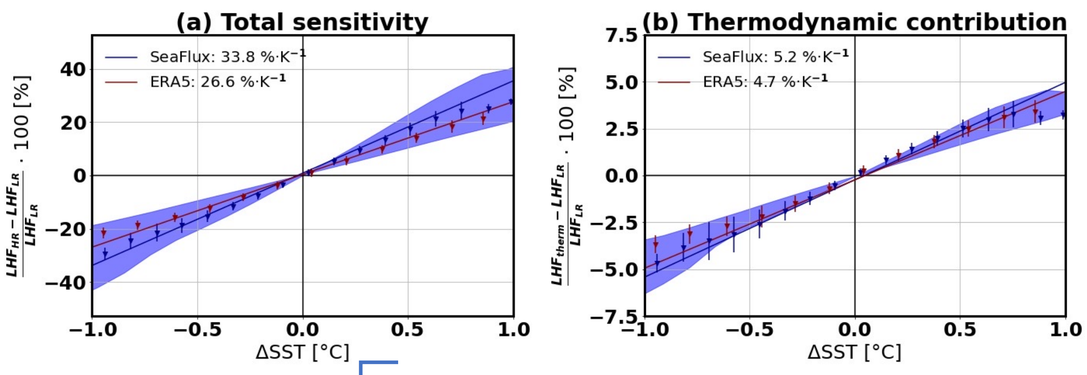
$$\alpha_\psi = \frac{\partial \psi'}{\partial SST'}$$

Coupling coefficients

Angle brackets denote area-weighted means over the EUREC⁴A-OA region.

LHF sensitivity to SST

LHF sensitivity to SST quantifies the LHF variation per °C of SST increase. In the EUREC⁴A-OA region we find it to represent around **33% LHF increase per °C of SST** .



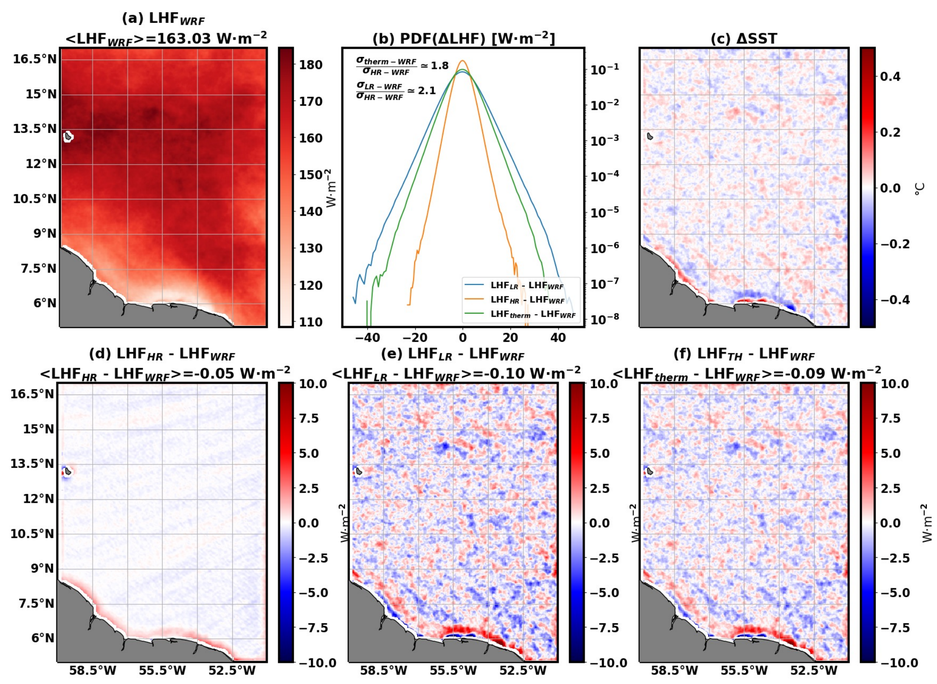
Two contributions

Dynamic: As a consequence of the thickening or shallowing of the marine atmospheric boundary layer. It accounts roughly for 28%·°C^{-1} and **is only present when the small-scale coupling is considered.**

Thermodynamic: As a result of the water vapour saturation pressure-SST relation. it represents 5%·°C^{-1} approximately.

Validation using WRF output

We compare the downscaled LHFs with LHF_{WRF}. The latter is computed applying COARE3.5 [2] to the original WRF variables.



LHF_{therm} - LHF_{WRF}

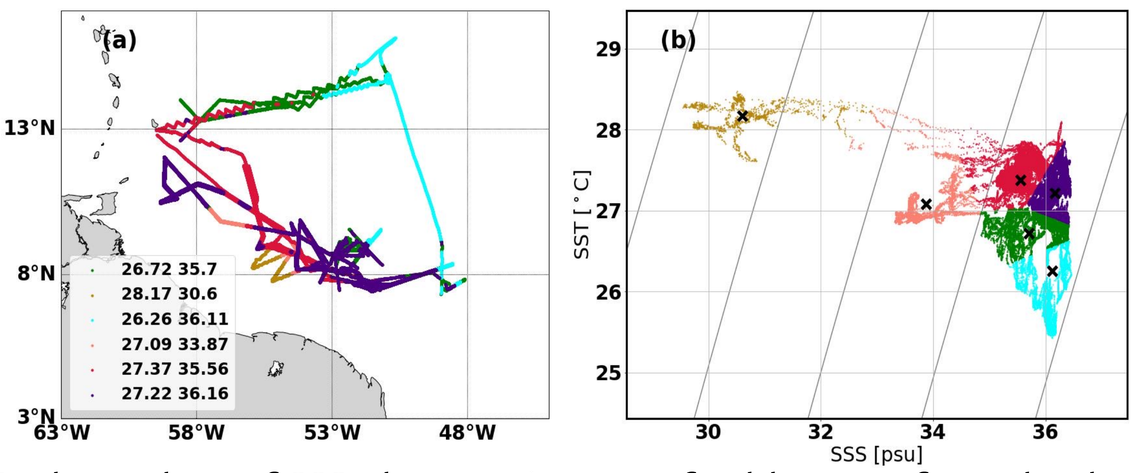
LHF_{LR} - LHF_{WRF}

LHF_{HR} – LHF_{WRF}

The downscaling approach ameliorates by a factor of two (roughly) our LHF estimates in the region providing confidence in the results.

Ocean mixed layer stratification and LHF

Watermass identification using Saildrone data



Amazon plume

Eddy stirring

Transition

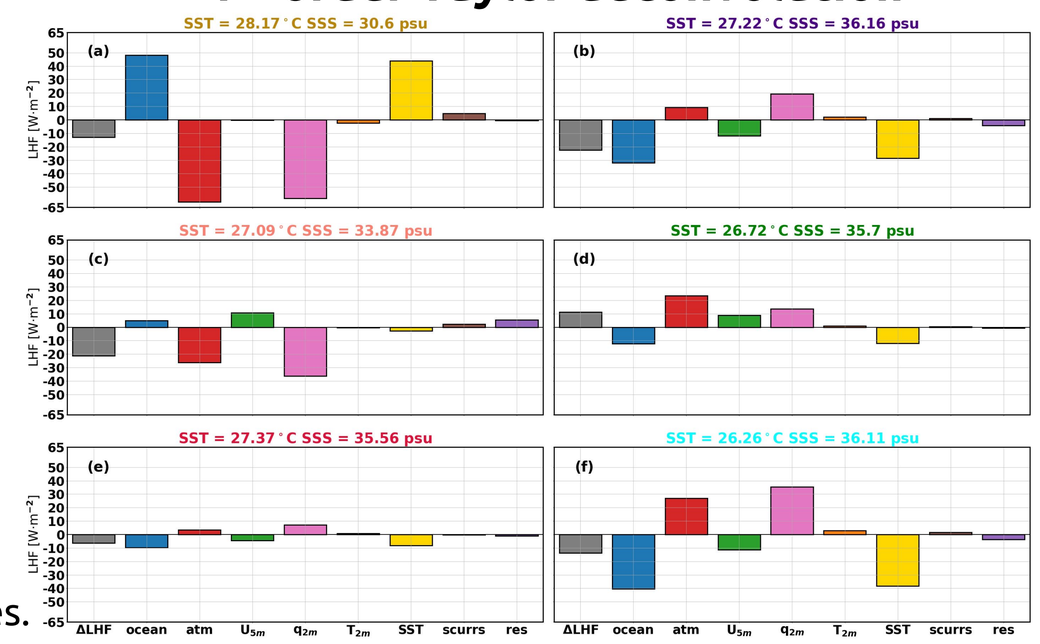
Retroflection

Tradewind alley

Open ocean

For low values of SSS, the entrainment of cold waters from the deep ocean is inhibited and the heating rate of the mixed-layer increases. This results in an increase in LHF. We observe the opposite → increase in q_{2m} → atmospheric profiles.

1st-order Taylor deconvolution



Shortcomings and next steps

1. How can we relate LHF to the mixed layer energy budget? Processes involved?
2. How important is the diurnal cycle signal on in-situ data measurements → MSSA.
3. Need to study the MABL structure → lidar data and radiosoundings.

Knowledge on how small-scale SST structures affect LHF suffices to ameliorate our LHF estimations but a more detailed analysis of other surface variables is necessary to understand the ocean – MABL linkages modulating LHF.

References

[1] Cronin M. *et al*, Front. Mar. Sci. 6, 430 (2019).

[2] Edson J. B. *et al.*, Jour. Phys. Ocean 44(9), 1589 (2013).

[3] Frenger I. *et al.*, Nat. Geo. 6, 608-612 (2013).

[4] Xu H. *et al.*, Jour. Clim. 24 4959-4972 (2011).

[5] Pasquero C. *et al.*, Geo. Re. Lett. 48 e2020GL091185 (2021).