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Quantification and parametrization of the impact of subgrid-scale variability on air-sea surface fluxes

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The Monin Obukov Similarity Theory (MOST) is widely used to compute surface fluxes from observations (when direct flux measurements are not available) or in atmospheric models (using data at the first model level and at the surface). This is a fundamentally 1-D approach, which supposes that atmospheric and surface fields are horizontally homogeneous in the targeted area (e.g., a model grid cell). Convection activity, from the boundary-layer scale to the deep-convection scale, generates variability in atmospheric parameters which remains generally unresolved in most state-of-the-art GCMs (horizontal resolution from tens to hundreds of kilometers). When present, these unresolved scales invalidate the MOST applicability and can lead to an underestimate of surface fluxes in GCMs, which can reach 20%. In this work, we focus on the subgrid scales related to the occurrence of deep-convection.
A few authors have proposed a correction to GCM fluxes by adding a gustiness velocity to the bulk formula. This requires several assumptions, which are not always fully verified. Here, we tackle this problem by setting-up a numerical "a priori" approach, which provides a better quantification and understanding of the sub-grid variability of surface atmospheric fields and their impact on surface fluxes. Subgrid GCM scales related to deep convection are explicitly provided by a Cloud Resolving Model (CRM – here the operational AROME model used at Météo-France), confirming that GCM flux biases are mainly driven by subgrid variability of the surface wind. However, we highlight that setting the mean fluxes as the fluxes computed from mean parameters, as it is usually done, may lead to potential errors that are further quantified.
Concerning the gustiness velocity, we propose a new parametrization based on the deep-convection activity through a multivariate linear regression using the cold pool and updraft mass-flux intensities. This parametrization leads to a decrease of all mean flux biases down to less than 7% (compared to 17% for the momentum flux, 13% for the heat flux and 7% for the latent heat flux, using existing parametrizations).