



## **Surface thermal heterogeneities, dispersive fluxes and the conundrum of unaccounted statistical spatial inhomogeneities**

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The use of Numerical Weather Prediction (NWP) models is ubiquitous in our daily lives, whether to decide what to wear, to plan for the weekend, invest on wind turbines, decide strategies for food security or to forecast atmosphere-driven natural disasters, to name a few. Currently, intrinsic to most NWP models is the assumption of spatial homogeneity at kilometer to sub-kilometer scales when, for example, classic similarity scaling relationships are applied to account for unresolved near-surface momentum, heat and mass exchanges. While advances in computation (and computing) are enabling finer grid resolutions in NWP, representing land-atmosphere exchange processes at the lower boundary remains a challenge (regardless of the numerical resolution but not independent from it). This is partially a result of the fact that land-surface heterogeneity exists at all spatial scales and its variability does not ‘average’ out with decreasing scales. Such variability need not rapidly blend away from the boundary and thereby impacts the spatial distribution of fluxes throughout the near-surface region of the atmosphere.

While, the effects of spatial surface heterogeneities have long been minimized under the assumption of an existing blending length-scale, in this work evidence is presented of the consequential effect of such surface heterogeneities. Specifically, canonical experiments based on in-situ measurements and high-resolution numerical simulations quantify the effect of surface thermal heterogeneities on an otherwise homogeneous planar surface. Therefore, such near-canonical case describes inhomogeneous scalar transport in an otherwise planar homogeneous flow when thermal stratification is weak or absent. In this work, the interaction between the characteristic length scales of the surface heterogeneities, and the scales of resolved fluid dynamics transport is further unraveled. Dispersive fluxes naturally appear as a means to account for unresolved, and time-lasting advection fluxes generated by a-priori unresolved spatial thermal heterogeneities. Results illustrate that dispersive fluxes can represent as much as 40% of the total resolved advection flux under weak wind conditions, and remain relevant under strong winds. Furthermore, results of this work appear not to only be relevant in the treatment of unresolved heterogeneities in NWP models, but also in understanding the unresolved problem of surface energy budget closure.