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Signature of coalescence during scalar mixing in heterogeneous flow fields

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Stretching of fluid elements by a heterogeneous flow field, such as the flow through a porous media or geophysical flows such as atmospheric or oceanic vortices, is known to enhance mixing rates of scalar fields[1]. While the mechanisms leading to the elongation of material lines are well understood, predicting mixing rates still remains a challenge particularly when there is a reconnection (or aggregation) between several parts of the mixing interface, leading, at large mixing time, to a so-called coalescence regime[1][2]. In this presentation, we numerically study this coalescence dynamics through scalar transport in two different flow fields, the Rankine vortex and Stokes flow through a periodic bead pack[3]. The former is typical of large-scale turbulent flows [4] whereas the second is generic of small-scale laminar flows in porous media [5]. Both flows show a net elongation of the mixing interfaces, although at very different rates. To solve the transport problem in these flows, we use a Lagrangian method (the diffusive strip method[6]). This method allows us to reconstruct, at high resolution, the scalar concentration fields and to compute the evolution of the distribution of concentrations levels, scalar dissipation rate and scalar power spectrum in time. The signature of coalescence is clearly observed in both flows and we assess the influence of coalescence on the difference in mixing behaviour for the two flows. We finally discuss how coalescence may affect the reaction kinetics of mixing-limited reactive flows. The analysis proposed sheds light on fundamental aspects of transport and mixing in earth surface and subsurface flows.

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