DYNAMICS OF MULTIPLE POINT-SOURCE REACTIVE SCALARS IN SIMPLE VORTEX FLOWS

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We investigate a new class of reactive advection-diffusion problems motivated by an ecological mixing process (see [1] and references therein). The problem class involves the spatial and temporal dynamics of two reactive scalars that each originate as distinct point sources in an otherwise pristine fluid. Although the scalars are passive, spatial correlations develop between the two as a result of structure in the velocity field. The result is a significant enhancement in reaction rates due to instantaneous processes that are not predicted by time-averaged approaches.

We use analytical and numerical methods to determine reaction rates for the case of two scalars stirred by a single two-dimensional vortex in a variety of geometrical configurations. The numerical modeling is accomplished via a Lagrangian particle-tracking approach (see, for example, [2]). We show that the aggregate second-order reaction rate in the low-concentration limit is enhanced and accelerated by the instantaneous stirring processes, relative to the rate predicted by an equivalent eddy diffusivity. The peak reaction rate grows as $\mathrm{P}^{1/3}$, and the time to reach the peak decreases as $\mathrm{P}^{-2/3}$, where P is the Péclet number. We also use numerical methods to investigate reactions rates for finite-concentration cases, and for two-dimensional flows with chaotic vortex interactions (as reviewed by [3]).

References

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