Fluid mechanics of persistence: Mixtures, clouds and the importance of rare events

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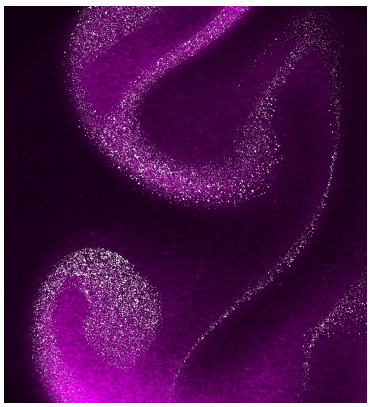
Numerous phenomena in the tangible world are not governed by a mean but rather by significant deviations from it. For instance, odors are perceived through yet unmixed parcels of carrying fluid situated far from the source; Delayed spray evaporation facilitates long-distance disease transmission from human exhalations; Uncontrolled agricultural spraying results in field contamination; Airborne fungal spores, akin to pollens, ashes, or sand particles, are transported intact over extended distances, traversing oceans; The Earth's iron-rich core originates from unmixed planetesimals impacting its surface. These are just a few examples among many.



Persistent liquid droplets of acetone in a stirred field of their vapor, mixing in air.

At the core of all these phenomena lie the principles of fluid mixing. These principles explain why stirring motions in nature, exceptionally and paradoxically, *delay* diffusive uniformization. Their relevance will be emphasized in the aforementioned examples and demonstrated through several experiments. In fact, exceptions are the norm.

The outline of the five lectures will be[†]

1. Elementary principles of mixing: stretching enhanced difusion and mixing times
2. Random flows and the lognormal route to uniformity
3. Slow zones, cascade bypass and persistence
4. Sprays and aerosols: the elegant, but often misleading *d-squared* law
5. Evaporation of dense sprays: origin of the persistence and its consequences

[†]Relevant references are: VILLERMAUX, E. Mixing versus Stirring. *Annu. Rev. Fluid Mech.* **51** , 245–73 (2019), DE RIVAS, A. AND VILLERMAUX, E. Dense spray evaporations as a mixing process. *Phys. Rev. Fluids* **1**, (1), 014201 (2016), VILLERMAUX, E., MOUTTE, A., AMIELH, M. AND MEUNIER, P. Fine structure of the vapor field in evaporating dense sprays. *Phys. Rev. Fluids* **2**, (7), 074501 (2017), MEUNIER, P. & VILLERMAUX, E.. The diffuselet concept for scalar mixing. *J. Fluid Mech.,* **951**, A33, 1–42 (2022).