Correlations between scalar and vorticity reduce 2D mixing

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Invariants play a major role in the study of turbulence and turbulent mixing. The correlation $Q = \langle \omega\phi \rangle$ between a passive scalar ϕ and the vorticity ω of the flow is an invariant of the two-dimensional Euler equations advecting a passive scalar. The question we address in the present investigation is : "how does this correlation affect the mixing rate".

We first consider mixing in a Galerkin truncated Euler system, i.e., the dynamics of a finite number of Fourier modes advecting a passive scalar. This system allows rigorous treatment by equilibrium statistical mechanics. The results point to the importance of Q and the initial energy distribution for mixing. For most initial conditions it is shown that a strong correlation Q results in bad mixing.

To investigate the dynamics, we use a recently developed numerical method [1] to investigate the non-truncated Euler and advection equations. Simulations (See Fig. 1) confirm the insights from statistical mechanics : the initial correlation Q is of major importance for mixing [2] and strong initial correlations dramatically reduce the mixing rate. Implications are discussed for the generation of helicity in anisotropic turbulence [3], a system which turns out to be directly related to 2D mixing.

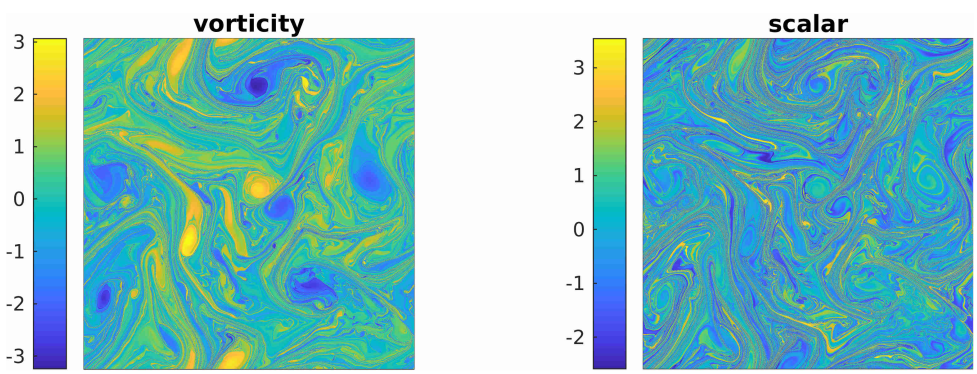

Figure 1. Vorticity and scalar field, computed using the characteristic mapping method. Initial correlations between the fields are conserved and will strongly affect the mixing rate.

Références

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