Transport by 2D turbulence : Vortex-gas theory vs. scale-invariant inverse cascade

Julie Meunier[1], Basile Gallet[1]

Université Paris-Saclay, CNRS, CEA, Service de Physique de l'Etat Condensé, 91191, Gif-sur-Yvette, France.
julie.meunier@cea.fr

The scale-invariant inverse energy cascade is a hallmark of 2D turbulence [1], with its theoretical energy spectrum observed in both Direct Numerical Simulations (DNS) and laboratory experiments [2]. Under such scale-invariance assumption, the effective diffusivity of a 2D turbulent flow is dimensionally controlled by the energy flux and the friction coefficient only [3,4]. Surprisingly, however, we show that such scaling predictions are invalidated by numerical solutions of the 2D Navier-Stokes equation forced at intermediate wavenumber and damped by weak linear or quadratic drag (Fig 1). We derive alternate scaling-laws for the effective diffusivity based on the emergence of intense, isolated vortices causing spatially inhomogeneous frictional dissipation localized within the small vortex cores. The predictions quantitatively match DNS data. This study points to a universal large-scale organization of 2D turbulent flows in physical space, bridging standard 2D Navier-Stokes turbulence with large-scale geophysical turbulence.

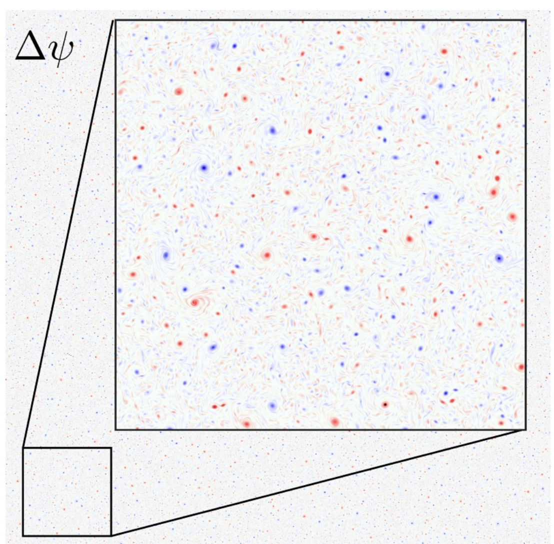

Figure 1. Coherent vortices in a snapshot of the vorticity field $\Delta\psi$ for a 8192×8192 simulation of 2D turbulence forced at intermediate wavenumber with weak quadratic drag.

Références

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