Spontaneous suppression of inverse energy cascade in instability-driven 2D turbulence

Benjamin Favier[1], Adrian van Kan[2], Keith Julien[3], Edgar Knobloch[2]

[1] Aix Marseille Univ, CNRS, Centrale Marseille, IRPHE, Marseille, France
[2] Department of Physics, University of California at Berkeley, Berkeley, CA 94720, USA
[3] Department of Applied Mathematics, University of Colorado, Boulder, CO 80309, USA
benjamin.favier@univ-amu.fr

Instabilities of fluid flows often generate turbulence. Using extensive direct numerical simulations, we study homogeneous two-dimensional turbulence driven by a wavenumber-localised instability superposed on stochastic forcing, in contrast to previous studies generally focusing on a purely stochastic and state-independent forcing [1].

As the contribution of the instability forcing increases, the system undergoes at least two transitions. Below a first threshold, a regular large-scale vortex condensate forms. Above this threshold, shielded vortices (SVs) emerge within the condensate. These vortices are tripolar and are characterised by an outer ring and a core having opposite vorticity sign. At the instability strength increases, the condensate breaks down, and a gas of weakly interacting vortices with broken symmetry spontaneously emerges, characterised by preponderance of vortices of one sign only and quasi-suppressed inerse energy cascade. The latter transition is shown to depend on the damping mechanism necessary to reach a steady state in such a system. Bistability is observed between the condensate and mixed SV-condensate states.

The number density of SVs in the broken symmetry state slowly increases via a random nucleation process. After a very long transient, yet another transition towards a perfect hexagonal lattice of vortices is observed, reminiscent of solutions obtained in active matter models such as the Toner-Tu model [2]. Our findings provide new evidence for a strong dependence of two-dimensional turbulence phenomenology on the forcing [3].

References

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