Two-dimensional turbulence with local interactions: statistics of the condensate

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Two-dimensional turbulence can self-organize through an out-of-equilibrium process of energy accumulation at large scales. The resulting large, coherent flow is termed a condensate. We examine the condensate arising in the large-scale quasi-geostrophic equation (Fig. 1(a)), a two-dimensional model with local dynamics never before studied in this regime. We obtain analytical results for the mean flow (Fig. 1(b-c)) and the two-point, second-order correlation functions, and validate them against direct numerical simulations. The condensate state requires parity+time-reversal symmetry breaking and our results show distinct mechanisms determining the even and odd correlators under this symmetry. These mechanisms appear to be universal across different two-dimensional flows. At the same time, we find a dramatic influence of the local nature of the dynamics on the condensate state. Regions where the condensate is strong have depleted fluxes towards small scales and a vanishing small-scale dissipation. We explain these observations by the presence of a spatial flux, mediated by the mean flow, which we show to exactly balance injection.

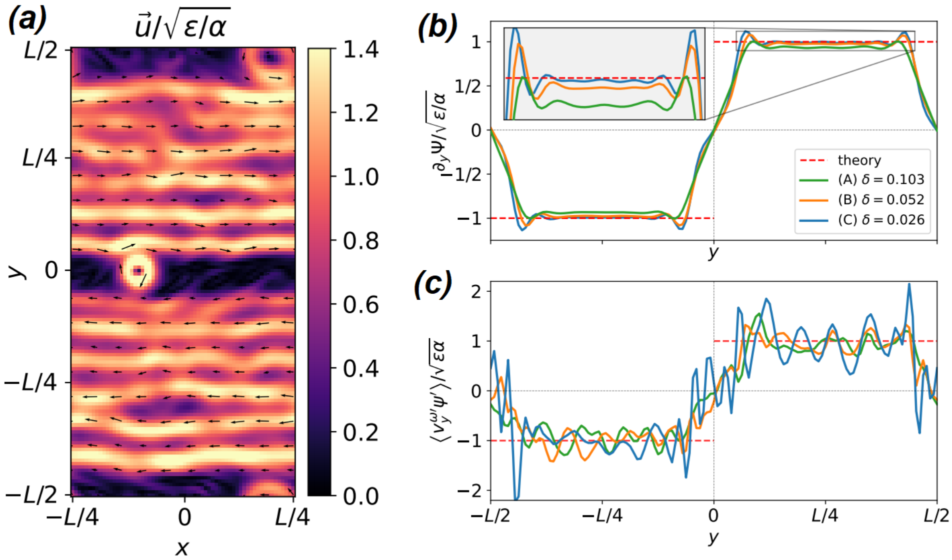

Figure 1: Direct numerical simulations: (a) Velocity field of the jet condensate in a periodic, rectangular box. (b) Horizontal velocity profile $\partial_y \Psi$; (b) Mass flux $\langle v_y^{\omega\prime} \psi' \rangle$; In plots (b-c) the dashed line corresponds to the analytical prediction and δ is the ratio of the rate of dissipation compared to the eddy-turnover time at the box scale

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