Transitions to condensate formation in two-dimensional turbulence and thin rotating fluid layers

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Two-dimensional (2d) and quasi-2d flows occur at macro- and mesoscale in a variety of physical systems. Examples include stratified layers in Earth's atmosphere and the ocean, soap films and more recently also in dense bacterial suspensions, where the collective motion of microswimmers induces patterns of mesoscale vortices. A characteristic feature of turbulence in 2d and thin fluid layers is the occurrence of an inverse energy cascade. In case of weak Rayleigh damping the inverse energy cascade results in the formation of large-scale coherent structures, so-called condensates, which can take the form of jets or large-scale vortices. With a view towards atmospheric physics, we study the formation of the condensate in a rotating thin layer with free-slip boundary conditions as function of the amplitude of the forcing, and we compare with results obtained in strictly 2d domains.

Direct numerical simulations show that the condensate in the thin rotating layer appears in a first-order non-equilibrium phase transition, with rare transitions occurring towards and away from the condensate state. In contrast, condensate formation 2d can proceed by means of either a first or a second-order non-equilibrium phase transition, depending on the type of driving.

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