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Emergence of scaling properties in momentum-scalar coupling turbulence: Exploring interplay of multiphysics mechanisms

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Momentum-scalar coupling turbulence, such as buoyancy-driven turbulence and electrohydrodynamic (EHD) turbulence, involves the transportation of multicomponent scalars under the strong interplay of multiphysics. For instance, in the atmosphere, the temperature gradient can induce buoyancy, driving the flow to form thermal convection. At the same time, electric body force can be generated on droplets, dust, and moisture gradients through spatial electric fields, resulting in air flow into EHD turbulence. Additionally, charged species move and create electric current, leading to Lorentz force due to the magnetic field of the earth, which may induce magnetohydrodynamic (MHD) turbulence. These physical mechanisms generate the diverse phenomena on our beautiful planet. This study theoretically explores how multiphysical mechanisms interplay, governing the cascades of turbulent kinetic energy and multicomponent scalars. Some new scaling properties, which differ from those predicted in buoyancy-driven turbulence, EHD, and MHD, emerge when two mechanisms and scalar components exist simultaneously. The quad-cascade processes of such turbulent systems are again validated. Unfortunately, when three or more mechanisms are taken into account at the same time, the problem becomes unattainable to close. This research endeavors to shed light on the diverse observation in momentum-scalar coupling turbulence across various scenarios.