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Anisotropic turbulence, waves and zonal jets in two-dimensional turbulence with a β-effect

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A universal regime of two-dimensional turbulence on the surface of a rotating sphere, the so-called zonostrophic regime, has been discovered in computer simulations and then found on the giant planets of the Solar System, in the terrestrial oceans, and in the laboratory (the Grenoble experiment). The universality of this regime has never been thoroughly investigated and, thus, has been questioned in some studies. We have investigated this issue in a series of long-term simulations of two-dimensional turbulence on the surface of a rotating sphere that explored a wide range of scenarios with various parameter combinations. We have found that there exist four distinct flow regimes one of which is the zonostrophic regime. A criterion for the existence of the zonostrophic regime has been formulated. This criterion is fulfilled for the circulations on the outer planets and in the terrestrial oceans as well as for the Grenoble experiment. The flow field features linear Rossby waves and nonlinear nondispersive waves that have never been studied. We have analyzed these waves and showed that they play an important role in formation of the zonostrophic regime.