Spatial and spectral dynamics of turbulence spectra

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Abstract

The theory of evolution of drift wave turbulence spectra with special emphasis on turbulence spreading will be discussed. We begin by considering basic physical processes that lead to nonlinear evolution of the probability distribution function in space, as well as in scale. We argue that the primary means by which the turbulence evolves from regions where it is excited into regions where it is dissipated is via nonlinear mode-coupling processes. This is the same process that controls evolution in the usual Kolmogorov picture, in which the turbulence evolves by cascading from the scales at which it is excited, towards where it is dissipated. Therefore, we show that these two processes of spreading and cascade are inherently linked. Different models that aim to describe different aspects of this generic phenomenon are discussed. Basic implications of such models and the underlying assumptions will be analyzed. The ”ballistic front” solution, which is a common output of these models, will be discussed. Also, the analogy to the evolution of the particle distribution function (ala’ Boltzmann’s equation) is introduced and we show that the nonlinear bi-evolution of the spectrum based on a Markovian closure approximation of two-scale dynamics conserves energy and satisfies a simple Boltzmann H-theorem. Thus, a Chapman-Enskog approach to the calculation of spatial evolution of the turbulence is possible. In addition, we take account of the fact that spatial evolution of turbulence results in self-consistent evolution of background gradient profiles that drives the turbulence in the first place, and so leads to avalanches. Finally, we relate spatial coupling and evolution to potential vorticity (PV) homogenization, which we also discuss as a useful, unifying concept in drift wave turbulence.