Layering in dissipative drift wave turbulence

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Hasegawa-Wakatani system with a proper treatment of zonal modes, provide the minimal non-trivial model of plasma turbulence. Being a reduced model with various simplifying assumptions describing the nonlinear evolution of dissipative drift waves with a non-adiabatic electron response from parallel ressistivity, it is a minimal model. While at the same time, as it provides a linear instability mechanism on top of drift wave propagation and allows flow self-organization through potential veroticity (PV) evolution with a background PV gradient, leading to zonal flow formation and self-regulation resulting eventually in a PV staircase profile, it is a non-trivial model. Here we will discuss the detailed mechanisms of layering in PV evolution in the context of the Hasegawa-Wakatani model interpreting it mainly as a beta-plane model with nonlinear PV inversion represented by the continuity equation. Considering the electron response, we note that a critical transition scale appears such that larger scales are adiabatic and smaller scales are hydrodynamic. This allows us to define a zonostrophy parameter, indicating the relative strengths of the zonal flows to eddies. One can use the different spatial scales implied by the balances between various time scales in order to estimate wave-number spectra in different limits, resulting in the usual Kraichnan-Kolmogorov results, but mainly with forward energy cascade in the hydrodynamic limit, but a different spectrum based on a balance with a hybrid time scale for the adiabatic limit.