Statistics of optimal perturbations in quasigeostrophic turbulence

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Abstract

Optimal perturbations are initial conditions that optimize some measure of linear growth about a background flow. Many investigators, starting with Kelvin and Orr from a century ago, have suggested that optimal perturbations play an important role in turbulence. An outstanding question regarding optimal perturbations is whether they are excited in statistically steady turbulence at a rate necessary for them to play a significant role. This question does not seem to have been addressed rigorously in the published literature. Numerical experiments based on a two-layer quasigeostrophic model were undertook to resolve this question. It turns out that a certain class of optimals, called instantaneous optimals, substantially clarify the analysis. The experiments revealed that a surprisingly a large fraction of energy is concentrated in the leading and trailing instantaneous optimals. However, the actual energy tendency of the nonlinear system turns out to be a small residual between the tendency of a few growing and a few decaying optimals. This result suggests that the simple picture in which turbulence is maintained by random excitation of optimal perturbations is fundamentally incomplete.