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A fluctuation relation for the probability of energy backscatter[1]
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We simulate the large scales of an inviscid turbulent flow in a triply periodic box using a dynamic Smagorinsky model for the sub-grid stresses. The flow, which is forced to constant kinetic energy, is fully reversible and can develop a sustained inverse energy cascade. However, due to the large number of degrees freedom, the probability of spontaneous mean inverse energy flux is negligible. In order to quantify the probability of inverse energy cascades, we test a local fluctuation relation of the form $\log P(A) = -c(V,t)A$, where $P(A) = p(|C_s|_{V,t} = A)/p(|C_s|_{V,t} = -A)$, p is probability, and $|C_s|_{V,t}$ is the average of the least-squared dynamic model coefficient over volume V and time t. This is confirmed when C_s is averaged over sufficiently large domains and long times, and c is found to depend linearly on V and t. In the limit in which $V^{1/3}$ is of the order of the integral scale and t is of the order of the eddy-turnover time, we recover a global fluctuation relation that predicts a negligible probability of a sustained inverse energy cascade. For smaller V and t, the local fluctuation relation provides useful predictions on the occurrence of local energy backscatter.

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