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Local and nonlocal pressure Hessian effects in real and synthetic fluid turbulence

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The Lagrangian dynamics of the velocity gradient tensor A in isotropic and homogeneous turbulence depend on the joint action of the self-streching term and the pressure Hessian. Existing closures for pressure effects in terms of A are unable to reproduce one important statistical role played by the anisotropic part of the pressure Hessian, namely the redistribution of the probabilities towards enstrophy production dominated regions. As a step towards elucidating the required properties of closures, we study several synthetic velocity fields and how well they reproduce anisotropic pressure effects. It is found that synthetic (i) Gaussian, (ii) Multifractal and (iii) Minimal Turnover Lagrangian Map (MTLM) incompressible velocity fields reproduce many features of real pressure fields that are obtained from numerical simulations of the Navier Stokes equations, including the redistribution towards enstrophy-production regions. The synthetic fields include both spatially local, and nonlocal, anisotropic pressure effects. However, we show that the local effects appear to be the most important ones: by assuming that the pressure Hessian is local in space, an expression in terms of the Hessian of the second invariant Q of the velocity gradient tensor can be obtained. This term is found to be well correlated with the true pressure Hessian both in terms of eigenvalue magnitudes and eigenvector alignments.

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