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Nonlinear optimal large-scale structures in turbulent channel flow

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Coherent structures in turbulent shear flows take the form of packets of hairpin vortices reaching the outer region of the boundary layer along with streaks of different size, going from the near-wall to the outer region. The latter can be explained by the linear transient growth of the perturbations of the mean turbulent profile. Whereas, the former are recently found to be optimally-growing only in the presence of nonlinear effects, as ascertained for a turbulent channel flow at a low friction Reynolds number. The present work aims at investigating whether large-scale streaks can be optimally-growing in a nonlinear framework for a turbulent channel flow. Changing the friction Reynolds number from 180 to 590, the nonlinear optimal perturbation tends towards more robust large-scale streaks and vortical structures of smaller size. These streaks are generated by a coherent large-scale lift-up mechanism, acting as a source term in the energy balance, inducing a positive turbulent kinetic energy production at the outer scale. This indicates that the outer energy production peak arising between the two considered Reynolds numbers can be associated with the growth of optimal large-scale streaks, which represent a robust feature of turbulent channel flows.

Keywords: Nonlinear optimization, coherent structures, turbulent shear flows, hairpin vortices, large-scale streaks

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