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Cause-and-effect of Linear Mechanisms in Wall Turbulence
NAVID CONSTANTINOU, Australian National University, ADRIN LOZANO-DURN, Stanford University, MARIOS-ANDREAS NIKOLAIDIS, National and Kapodistrian University of Athens, MICHAEL KARP, Stanford University — A crucial element in closing the loop in the self-sustaining cycle in wall turbulence is the energy transfer from the large-scale mean flow to the turbulent fluctuations. There is consensus that this energy transfer is attributed to linear processes, but the mechanism by which this transfer occurs has been a subject of heated debates. Different scenarios stem from linear stability theory and comprise, among others, exponential instabilities, neutral modes, transient growth from non-normal operators, and parametric instabilities from temporal mean-flow variations. Here, we assess the role of the various linear mechanisms potentially responsible for the energy transfer from the streamwise-averaged mean-flow, $U(y, z, t)$, to the fluctuating velocities, $u'(x, y, z, t)$. We use cause-and-effect analysis based on interventions: manipulation of the causing variable leads to changes in the effect. Our main conclusion is that the dominant process responsible for this energy transfer is transient growth of fluctuations. Transient growth alone is able to sustain realistic wall turbulence. Furthermore, we demonstrate that the self-sustaining cycle of turbulence persists when either exponential instabilities, neutral modes, and parametric instabilities of the mean flow are suppressed.

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