SCALING AND SPATIO-TEMPORAL CONSTRAINTS OF THE MINIMAL SEED IN BOUNDARY-LAYER FLOWS

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Bypass transition to turbulence is a very sensitive phenomenon, whose accurate prediction can have important repercussions in aeronautical design. Even formulated as an initial value problem, a causal explanation for the seemingly random occurrence of turbulent spots remains yet incomplete. The initial condition energetically closest to the laminar state, while just able to cause transition to turbulence, is called minimal seed [1]. This elegant concept was initially introduced for parallel shear flows, where a given geometry and Reynolds number entirely define the minimal seed. Such a picture is challenged in spatially developing flows [2]. Using nonlinear adjoint optimisation, we show how the resulting minimal seed in spatially developing boundary layer flows depends explicitly on three optimisation parameters: the inlet Reynolds number at the start of the computational domain, the horizon time and the dimensions of the computational domain. Our results suggest a new scaling for the energy of the minimal seed with the Reynolds number, other parameters being held constant. We analyse the physical structure of the minimal seed for several Reynolds numbers by classifying patterns of high and low streamwise velocity perturbations. Both Orr and lift-up mechanisms can be singled out during the temporal evolution of the minimal seeds. We then show that shorter optimisation times result in suboptimal transition.

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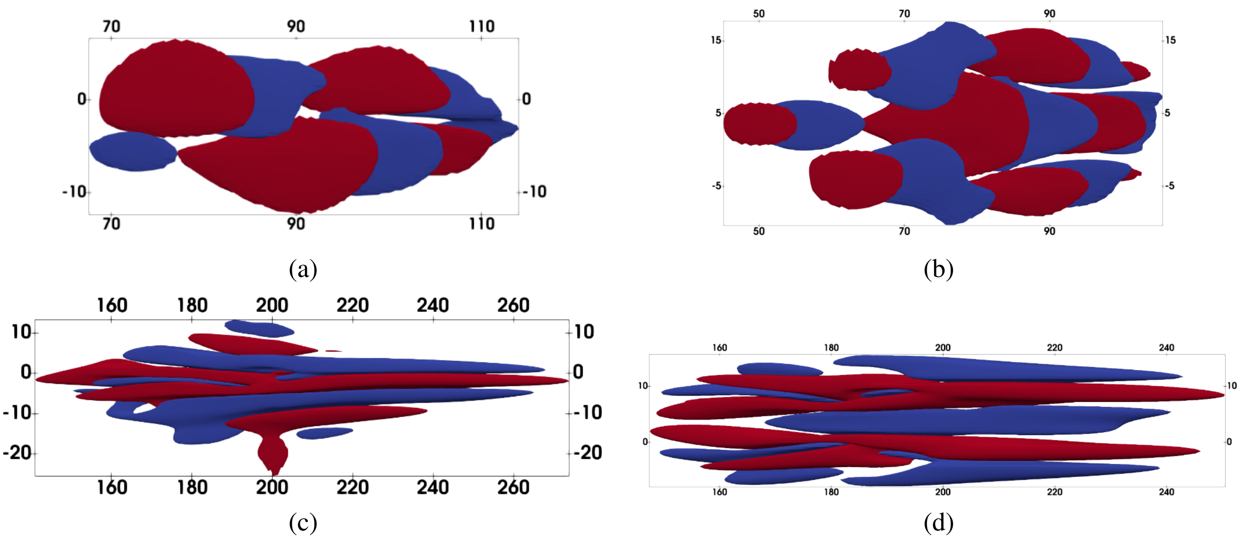

Figure 1. Streamwise perturbation velocity (blue for negative; red for positive) for (a,b) optimal disturbances above the minimal seed in the set-up described in [2]. (a) $E_0 = 1.7 \times 10^{-2}$, $Re_{\delta^*} = 275$ (b) $E_0 = 3.0 \times 10^{-2}$, $Re_{\delta^*} = 395.98$. (c,d) Evolution of perturbations (a,b) at $t = 200$

References

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