# Laminarisation and turbulence enhancement of non-uniform body force influenced flows

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Turbulence changes strongly when subjected to near wall non-uniform body forces. When the body forces are applied in the same direction as the flow, turbulence is strongly weakened and can even laminarise. This has been seen in various flow control techniques[1] and is also a dominant mechanism in the heat transfer deterioration in some cooling systems (particularly in the nuclear energy sector). Conversely for body forces which oppose the flow, turbulence is enhanced. We use a combination of Linear Stability Analysis (LSA) and Direct Numerical Simulations (DNS) to better understand the mechanisms which cause both laminarisation and turbulence enhancement.

In particular we attempt to unify the behaviour of body force influenced transient growth (obtained from LSA) at different scales with the anisotropic structure of turbulence observed in DNS (Fig.1). In contrast to some recently developed understanding, we show that in such laminarising flows, the transient growth relating to the near wall structures is actually increased, hence explaining the increased dominance of streaks relative to the other turbulence components. Since we know the flow laminarises we then deduce that other components of the regeneration cycle must be weakened to compensate for the streak generation.

Another angle to explain body force induced laminarisation was introduced by He et al.[2] where the key changes in turbulence are attributed to an increased/decreased *'apparent Reynolds number'* corresponding to a flow with an equal pressure gradient but without body forces. The only difference between these two flows is seemingly limited to enhanced/weakened near wall streaks. We highlight the similarities and differences in transient growth between the body force influenced flows and their apparent Reynolds number flows at different scales. It is found that transient growth at larger wavelengths are similar, however at smaller wavelengths, corresponding to structures in the near wall cycle, transient growth varies strongly. There are some clear parallels between this behaviour and the observed DNS behaviour described above.

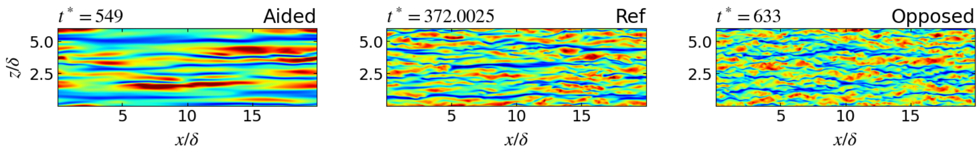


Figure 1: Streamwise streaks normalised by turbulent kinetic energy $\frac{u'}{\sqrt{k}}$.

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[1] Kuhnen et al., *Nature Physics.* **14**, 386 (2018).

[2] He et al., *J. Fluid Mech.* **809**, 31 (2016).