The effect of the quiescent core of turbulent channel flows on the wall skin friction via Renard-Deck decomposition

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The quiescent core in a turbulent channel flow is a region with high and relatively uniform velocity magnitude. In the quiescent core, the turbulent intensity is relatively lower than other regions of the flow, and it is defined to be bounded by the contour lines of the instantaneous streamwise velocity at 95% of the mean centreline velocity (U_{CL}) [1]. This study focuses on the impact of the quiescent core of a turbulent channel flow on the local mean wall skin friction coefficient. To investigate this, the Renard-Deck (RD) decomposition[2] of the turbulent production term is used. The RD-decomposition is a theoretical decomposition of the mean skin friction coefficient based on the mean kinetic energy budget in the streamwise direction. For a turbulent channel flow, it is given as,

$$C_f = \underbrace{\frac{2}{U_b^3}\int_0^h \nu \left(\frac{\partial \langle u \rangle}{\partial y}\right)^2 \mathrm{d}y}_{C_{f,a}} + \underbrace{\frac{2}{U_b^3}\int_0^h -\langle u'v' \rangle \frac{\partial \langle u \rangle}{\partial y}\, \mathrm{d}y}_{C_{f,b}}, \tag{1}$$

where h represents half channel height, U_b represents bulk velocity, $\langle \square \rangle$ represents averaged quantities, and $\square'$ represents fluctuating quantities. The $C_{f,a}$ term of the RD-decomposition shows the contribution of the mean velocity gradient to the wall skin friction coefficient, and the $C_{f,b}$ term represents the contribution of the turbulent production.

The impact of the quiescent core in turbulent channel flows on the $C_{f,b}$ term of the RD-decomposition is studied using conditional statistics based on velocity fields obtained through direct numerical simulation (DNS) of a turbulent channel flow at $Re_\tau = 2{,}300$. At each streamwise and spanwise location, the extent of the quiescent core is determined by the 0.95 U_{CL} contour line nearest to the core center, as illustrated in Figure 1. The conditional $C_{f,b}$ term is subsequently computed based on two criteria: a) the presence of a core region, and b) the distance between the core boundary and the wall being higher or lower than the mean distance. This paper will present the analysis of these results.

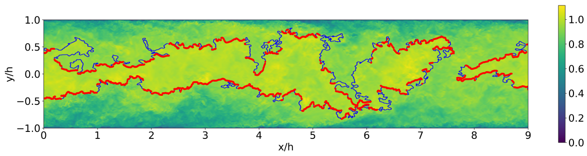

Figure 1: Example instantaneous streamwise velocity field normalised by mean centreline velocity, U_{CL}. Blue: contour of 0.95 U_{CL}. Red: the extent of the quiescent core

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[1] Kwon et al., *J. Fluid Mech.* **751**, 228 - 254 (2014).

[2] Nicolas Renard and Sébastien Deck, *J. Fluid Mech.* **790**, 339 - 367 (2016).