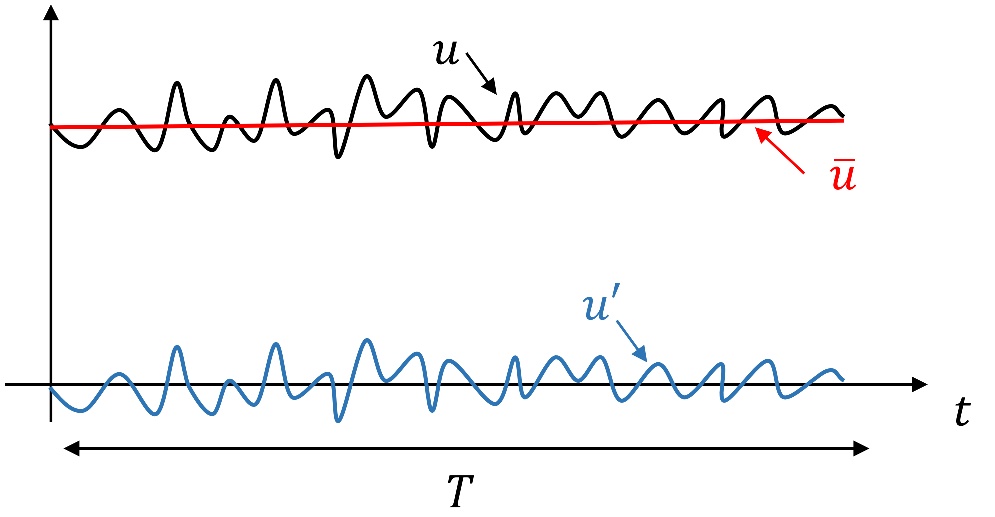
Exercise 10.

- $u = \bar{u} + u'$ Instantaneous velocity
  - $\bar{u}$ Time-average velocity (mean velocity)
  - u' Velocity fluctuation



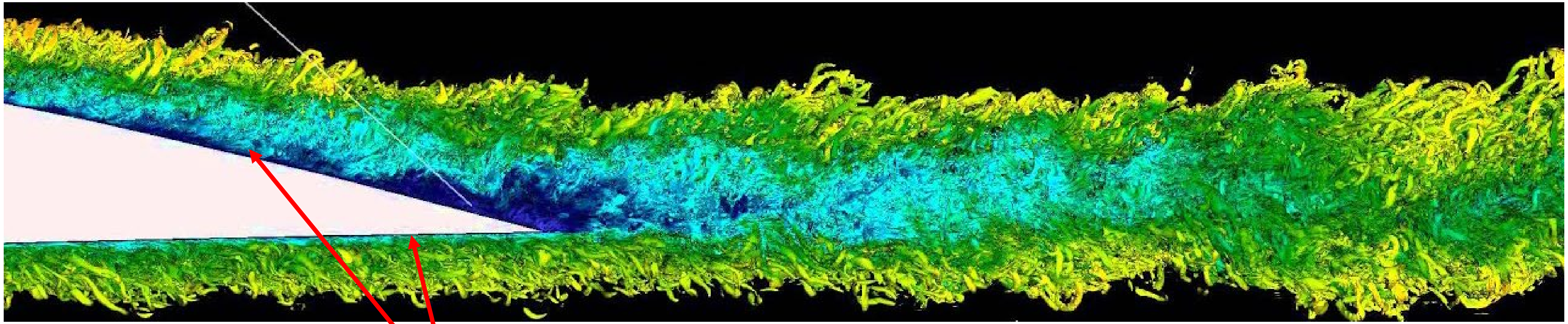
- u^* Friction velocity

- $u^+ = \frac{\bar{u}}{u^*}$ Normalised velocity

- $y^+ = \frac{yu^*}{\nu}$ Normalised wall distance

- $\overline{u'v'}$ Time-average turbulent fluctuations

Exercise 10.



Boundary layer

Exercise 10.

- Wall Shear stress in the fluid (near the wall)

$$\tau_{\mathrm{w}} = \mu \frac{\partial \bar{u}}{\partial y} - \rho \overline{u'v'} = \tau_{\mathrm{lam}} + \tau_{\mathrm{turb}}$$ Eq. (6.23) or (4.19)

- The laminar shear stress:
  - Due to gradients in the mean velocity field
  - Shear stress arise since fluid particles move with varying mean velocities

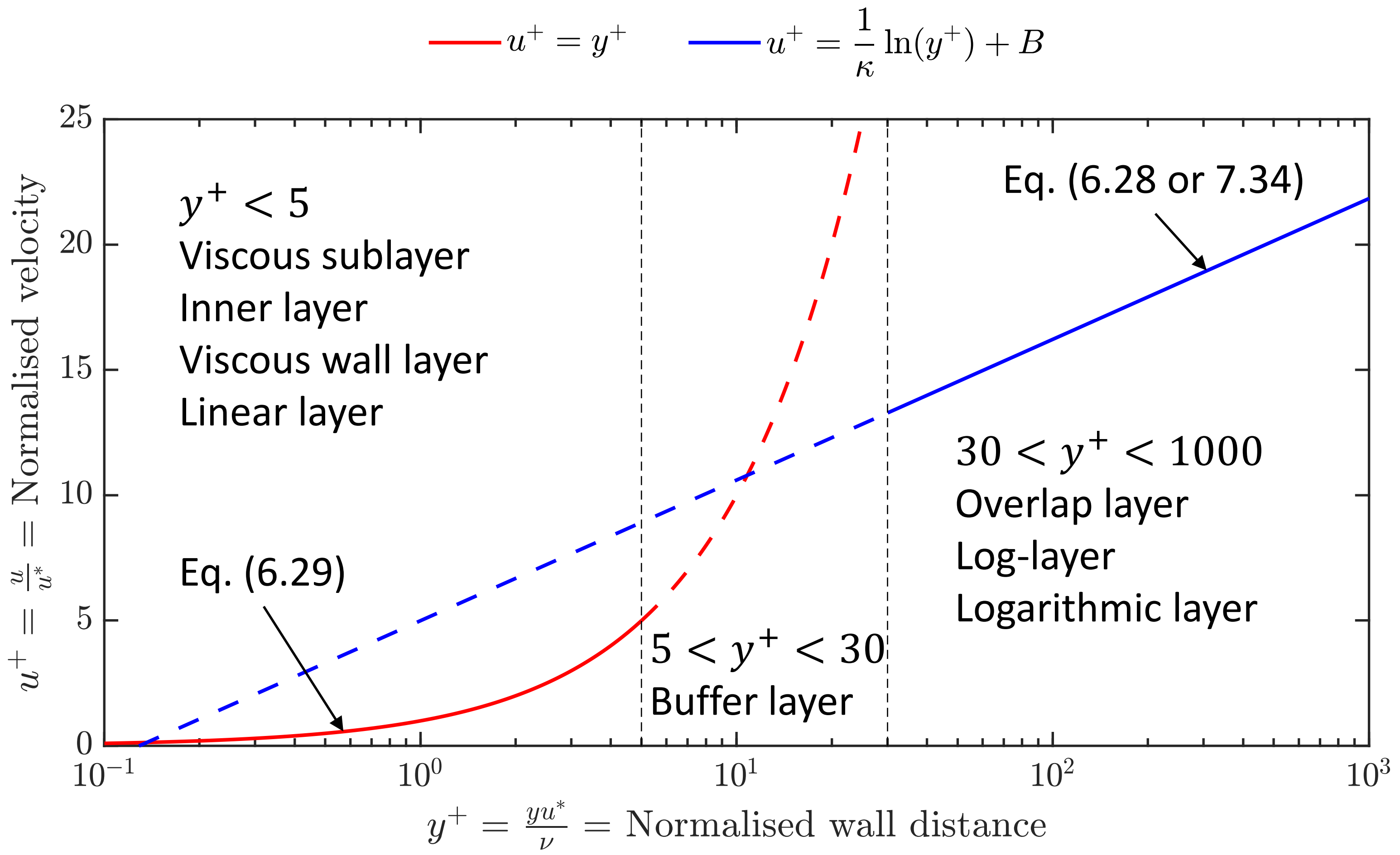
- Turbulent shear stress:
  - Shear forces between fluid particles caused by fluctuations)
  - u', v', w' are zero at the wall (no-slip)

- Wall shear stress modelled with

$$\tau_{\mathrm{w}} = \rho {u^*}^2$$ Eq. (6.25)

Exercise 10.

- $y^+ < 5$ (Sublayer)
  - τ_{lam} dominant
  - $u^+ = y^+$
- $5 < y^+ < 30$ (Buffer)
  - No exact model
- $30 < y^+ < 1000$ (Log)
  - $\tau_{\text{lam}} + \tau_{\text{turb}}$
  - $u^+ = \frac{1}{\kappa} \ln y^+ + B$
- $1000 < y^+$ (Outer)
  - τ_{turb} dominant



Exercise 10.

- https://www.youtube.com/watch?v=e1TbkLIDWys
  - Flow of wall boundary layer