Friction velocity

Friction velocity u_* is a scaling parameter for the fluctuating component of velocity in turbulent flow in the surface layer. These fluctuating velocity components are also known as eddy velocities.

u_* is equal to the square root of the surface stress τ divided by air density. Surface stress is air density times the vertical fluxes of horizontal momentum. Mathematically, these are represented:

In two-dimensions:

$$u_* = \sqrt{\frac{\tau}{\rho}} \quad \text{where} \quad \tau = \rho\{\,(\overline{u'w'})^2 + (\overline{v'w'})^2\,\}^{1/2} \quad , \quad \text{hence } u_* = \{\,(\overline{u'w'})^2 + (\overline{v'w'})^2\,\}^{1/4}$$

In one-dimension (for example, along the x axis):

$$u_* = \sqrt{\frac{\tau}{\rho}} \quad \text{where} \quad \tau = \rho\overline{u'w'} \quad , \quad \text{hence } u_* = \sqrt{\overline{u'w'}}$$

The surface stress can be observed by special instruments that directly observe the drag at the surface, since $\overline{u'w'} = -C_D|\vec{V}|\bar{u}$ and $\overline{v'w'} = -C_D|\vec{V}|\bar{v}$. Or, the eddy velocities can be measured by fast response turbulence instruments that can measure the wind fluctuations, from which then a time average for the stress terms is performed.

A rough rule of thumb is that the ratio $u_*/|\vec{V}|$ is about 0.03 to 0.1, where the wind speed is at 10 m., which is the World Meteorological Organization (WMO) standard. u_*has typical values ranging from about 0.05 ms^{-1} in light winds to about 1 ms^{-1} in strong winds.

Physically, the term “friction velocity” was derived based on the observation that the root-mean-square of the wind is proportional to the vertical shear of the wind near a boundary. Hence, it is also sometimes called the shear velocity. This definition then provides a boundary condition to help derive the logarithmic wind profile.