5.8 Dimensionless Gradients

We can simplify term IV of the dimensionless TKE equation (5.7a) by choosing a coordinate system aligned with the mean wind, assuming horizontal homogeneity, neglecting subsidence, and using the definition that $u_*^2 = -(\overline{u'w'})_s$:

$$\text{Term IV} = \frac{-k\,z}{u_*}\frac{\partial \overline{U}}{\partial z}$$

Based on this dimensionless term, we can define a ***dimensionless wind shear***, ϕ_M, by

$$\phi_M = \frac{k\,z}{u_*}\frac{\partial \overline{U}}{\partial z} \tag{5.8a}$$

This parameter is primarily useful for studies of surface-layer wind profiles and momentum fluxes. In chapter 9 we will use ϕ_M in similarity theory to estimate momentum flux (as given by u_*) from the local mean wind shear. This is particularly valuable because it is easy to measure mean wind speeds at a variety of heights in the surface layer, but much more difficult and expensive to measure the eddy correlations such as $\overline{u'w'}$.

By analogy, a ***dimensionless lapse rate***, ϕ_H, and a ***dimensionless humidity gradient***, ϕ_E , can be defined:

$$\phi_H = \frac{k\,z}{\theta_*^{SL}}\frac{\partial \overline{\theta}}{\partial z} \tag{5.8b}$$

$$\phi_E = \frac{k\,z}{q_*^{SL}}\frac{\partial \overline{q}}{\partial z} \tag{5.8c}$$

These dimensionless gradients are equally as valuable as the dimensionless shear, because using similarity theory we can estimate the surface layer heat flux and moisture flux from simple measurements of lapse rate and moisture gradient, respectively.