The Surface Layer (from Holton 5.3.5)

Maintained entirely by vertical momentum transfer by turbulence.

Friction velocity, u_*:

$$\boxed{u_*^2 \equiv \overline{(u'w')_s}}$$

where wind near surface is parallel to x-coordinate.

$|\overline{(u'w')_s}| \sim 0.1\ m^2 s^{-2}$, $\boxed{\text{so } u_* \sim 0.3\ m\ s^{-1}}$.

Variation of $\overline{u'w'}$ with ht near sfc.

Scale analysis ~~of~~ in midlatitudes of

$$\frac{D\bar{u}}{Dt} = -\frac{1}{\rho_0}\frac{\partial \bar{p}}{\partial x} + f\bar{v} - \frac{\partial \overline{u'w'}}{\partial z} \qquad (5.16)$$

10^{-4}	10^{-3}	10^{-3}	$m\ s^{-2}$
$\frac{U^2}{L}$	$\frac{\delta P}{\rho L}$	$f_0 U$	

$f_0 = 2\Omega \sin\varphi_0 \sim 10^{-4}\ s^{-1}$

$\delta P/\rho \sim 10^3\ m^2 s^{-2}$

$U \sim 10\ m\ s^{-1}$

$L \sim 10^6\ m$

For balance, must have

$$\frac{\partial \overline{u'w'}}{\partial z} = \frac{\delta(u_*^2)}{\delta z} \lesssim 10^{-3}\ m\ s^{-2}$$

For $\delta z = 10 m$, $\delta(u_*^2) \lesssim 10^{-2}\ m^2 s^{-2}$.

This is $\lesssim 10\%$ of $\overline{(u'w')_s} \sim 0.1\ m^2 s^{-2}$.

$\boxed{\text{So } u_* \text{ is approx. constant near sfc.}}$

Log wind profile (Holton, 5.3.5)

Parameterize $\overline{(u'w')}_s$ ~~###~~ as

$$K_m \frac{\partial \bar{u}}{\partial z} = u_*^2 ,$$

mixing length model:

$$K_m = l^2 \left| \frac{\partial \bar{u}}{\partial z} \right| .$$

Near surface,

$$l = kz, \qquad k = \text{(von Karman) const.} = 0.4$$

so

$$K_m = (kz)^2 \left| \frac{\partial \bar{u}}{\partial z} \right| , \quad \text{and}$$

$$\boxed{\frac{\partial \bar{u}}{\partial z} = \frac{u_*}{kz}, \quad \text{and} \quad K_m = u_* kz ,}$$

Integrate dz to get log wind profile.

$$\boxed{\bar{u}(z) = \frac{u_*}{k} \log(z/z_0)}$$

$\boxed{z_0 = \text{roughness length, chosen so } \bar{u}(z_0) = 0.}$

Obtain u_* from u measured at several heights:

Arya Fig 10.4 is an example.

$$\bar{u}(z) = \frac{u_*}{k} \log(z/z_0) = \frac{u_*}{k}(\log z - \log z_0)$$

$$= \frac{u_*}{k} \log z + c$$

Plot of $\bar{u}(z)$ vs $\log z$: line w/ slope $\frac{u_*}{k}$.

When $z = z_0$, $\bar{u}(z) = 0$, so z_0 is height for which line intersects $u = 0$.

Numerical: $\bar{u}$ at 2 hts z_1, z_2

$$\bar{u}(z_1) = \frac{u_*}{k} \log(z_1/z_0)$$

$$\bar{u}(z_2) = \frac{u_*}{k} \log(z_2/z_0)$$

$$u_2 - u_1 = \frac{u_*}{k} \log(z_2/z_1).$$ Solve for u_*.

Obtain z_0:

If $u_1 = 0$, then $z_1 = z_0$, so

$$u_2 = \frac{u_*}{k} \log(z_2/z_0).$$ Solve for z_0.

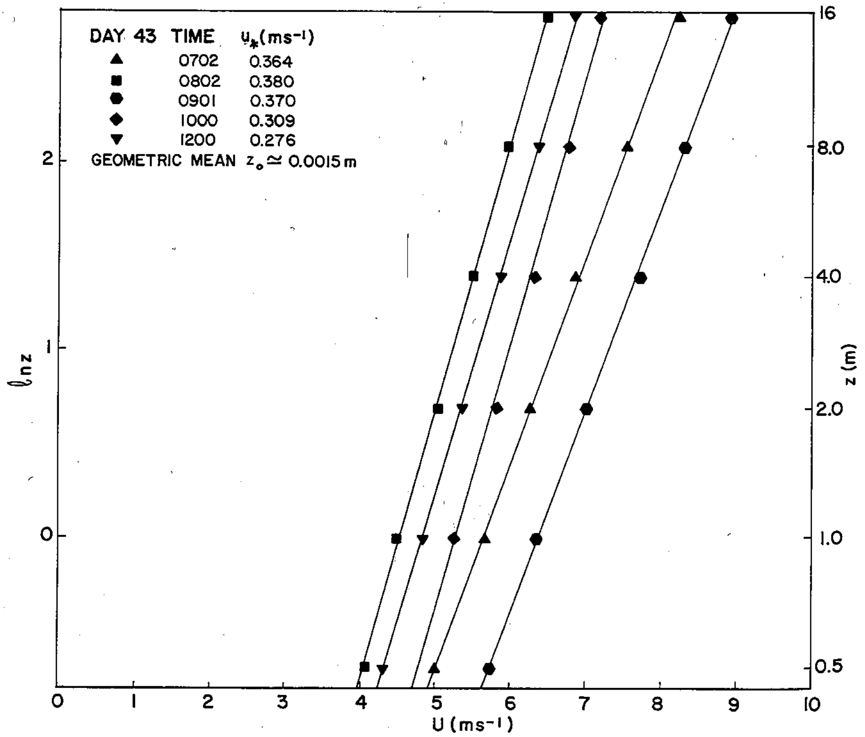

Fig. 10.4 Comparison of the observed wind profiles in the neutral surface layer of day 43 of the Wangara Experiment with the log law [Eq. (10.6)] (solid lines). [Data from Clarke *et al.* (1971).]

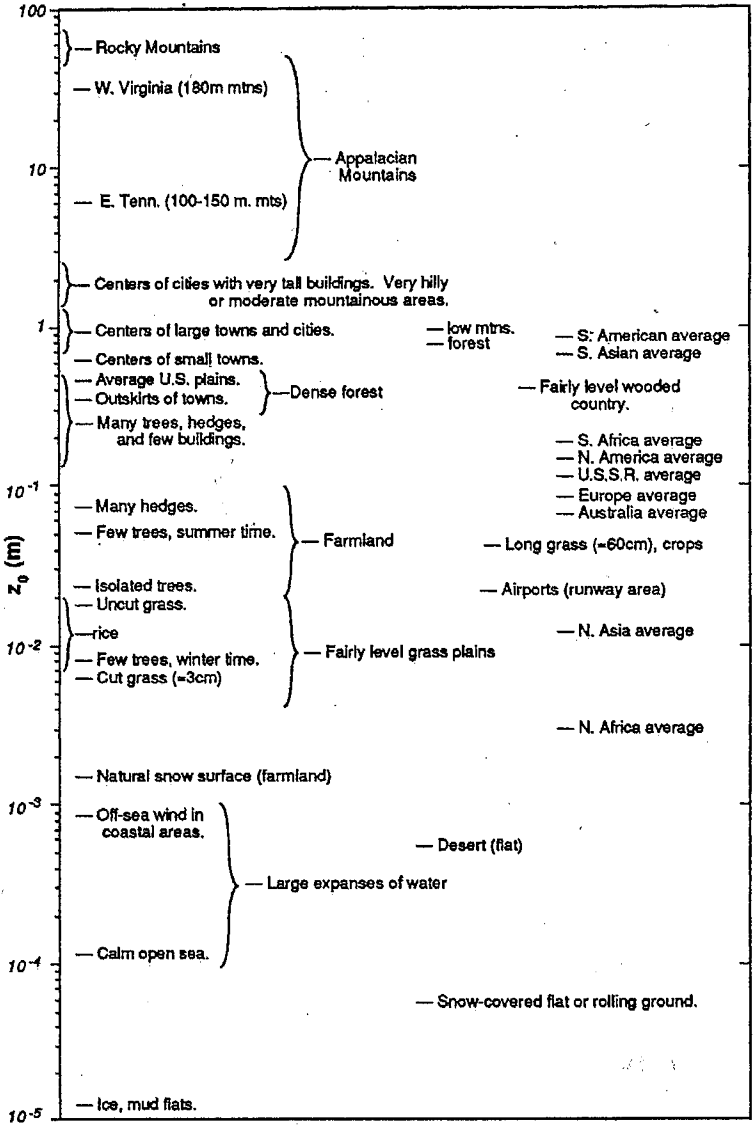

Fig. 9.6 Aerodynamic roughness lengths for typical terrain types. (After Garratt 1977, Smedman-Högström & Högström 1978, Kondo & Yamazawa 1986, Thompson 1978, Napo 1977, and Hicks 1975).