Find u_* and z_0 from the following wind profile measurements made during statically neutral conditions at sunset:

z (m)	$\bar{u}$ (m/s)
1	4.6
3	6.0
10	7.6
30	9.0

Answer:
$u_* = 0.52$ m/s, $z_0 = 0.028$ m. To calculate u_*, apply the log wind profile

$$u = u_*/k \log(z/z_0),$$

at any two heights z_1 and z_2 to obtain

$$u(z_2) - u(z_1) = u_*/k \log(z_2/z_1),$$

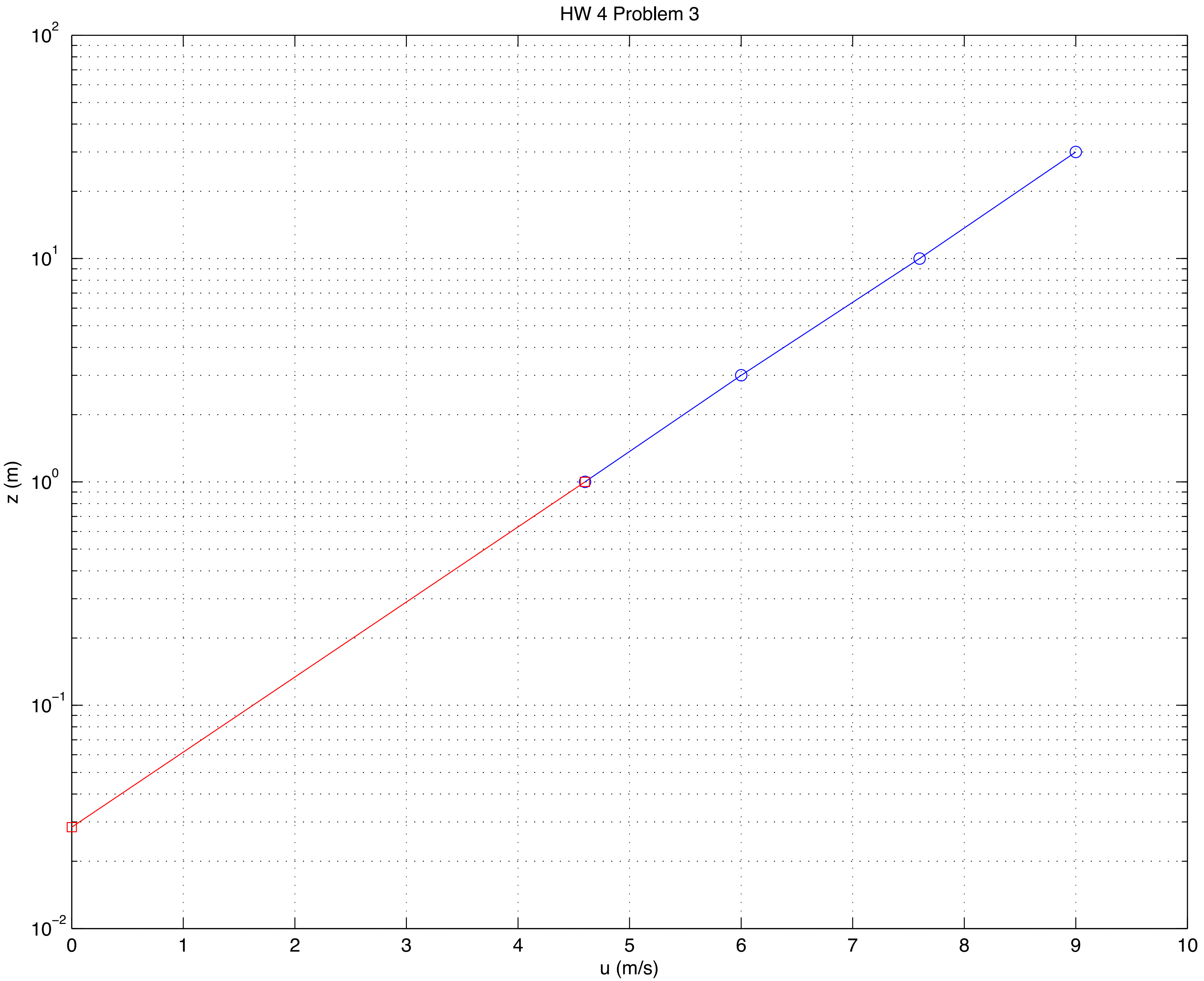
then solve for u_*:

$$u_* = k \frac{u(z_2) - u(z_1)}{\log(z_2/z_1)}.$$

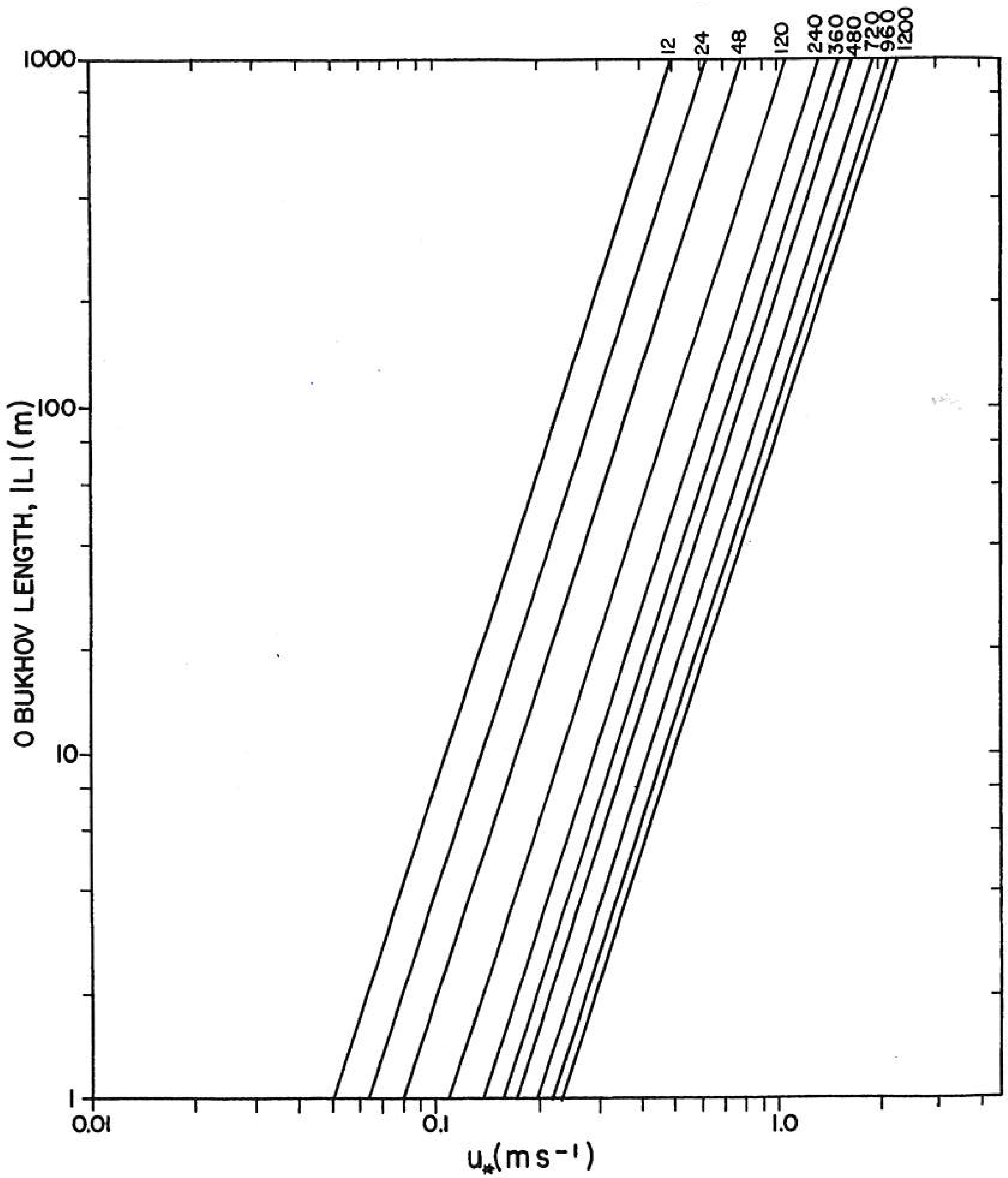
To calculate z_0, solve the log wind profile at any height z for z_0:

$$z_0 = z \exp(-ku(z)/u_*).$$

The graphical solution method is to plot the wind profile u versus $\log z$, then extrapolate the profile to $u = 0$. The height at which $u =$ is z_0.



Monin-Obukhov length as a function of friction velocity and surface heat flux



Wind and thermodynamic profiles

$$\psi_m(\zeta) = \int_0^{\zeta} [1 - \phi_m(\zeta')] d\zeta' / \zeta'$$

$$= \begin{cases} \ln\left(\left(\frac{1+x^2}{2}\right)\left(\frac{1+x}{2}\right)^2\right) - 2\tan^{-1}x + \frac{\pi}{2}, & \text{for } -2 < \zeta < 0 \text{ (unstable)} \\ -\beta\zeta, & \text{for } 0 \le \zeta \text{ (stable)} \end{cases}$$

$$\psi_h(\zeta) = \int_0^{\zeta} [1 - \phi_h(\zeta')] d\zeta' / \zeta'$$

$$= \begin{cases} 2\ln\left(\frac{1+x^2}{2}\right), & \text{for } -2 < \zeta < 0 \text{ (unstable)} \\ -\beta\zeta, & \text{for } 0 \le \zeta \text{ (stable)} \end{cases}$$

Similarity Functions

$$(kz/u_*)(\partial\overline{u}/\partial z) = \phi_m(\zeta)$$

$$(kz/\overline{\theta}_*)(\partial\overline{\theta}/\partial z) = \phi_h(\zeta)$$

$$K_m = -\overline{u'w'} \,/\, (\partial\overline{u}/\partial z) = u_*^{\,2}/(\phi_m(\zeta)\, u_*/kz) = ku_*z \,/\, \phi_m(\zeta)$$

$$K_h = -\overline{w'\theta'} \,/\, (\partial\overline{\theta}/\partial z) = u_*\theta_*/(\phi_h(\zeta)\, \theta_*/kz) = ku_*z \,/\, \phi_h(\zeta)$$

$$\begin{aligned}
\mathrm{Ri} &= (-d\overline{b}/dz) \,/\, (d\overline{u}/dz)^2 \\
&= (\overline{w'b'}_0 \,/K_h)/\, (\,\overline{u'w'}_0/K_m)^2 \\
&= (B_0\phi_h(\zeta) \,/ku_*z) \,/\, (u_*^{\,2}\phi_m(\zeta)/ku_*z))^2 \\
&= \zeta\phi_h/\phi_m^{\,2}
\end{aligned}$$

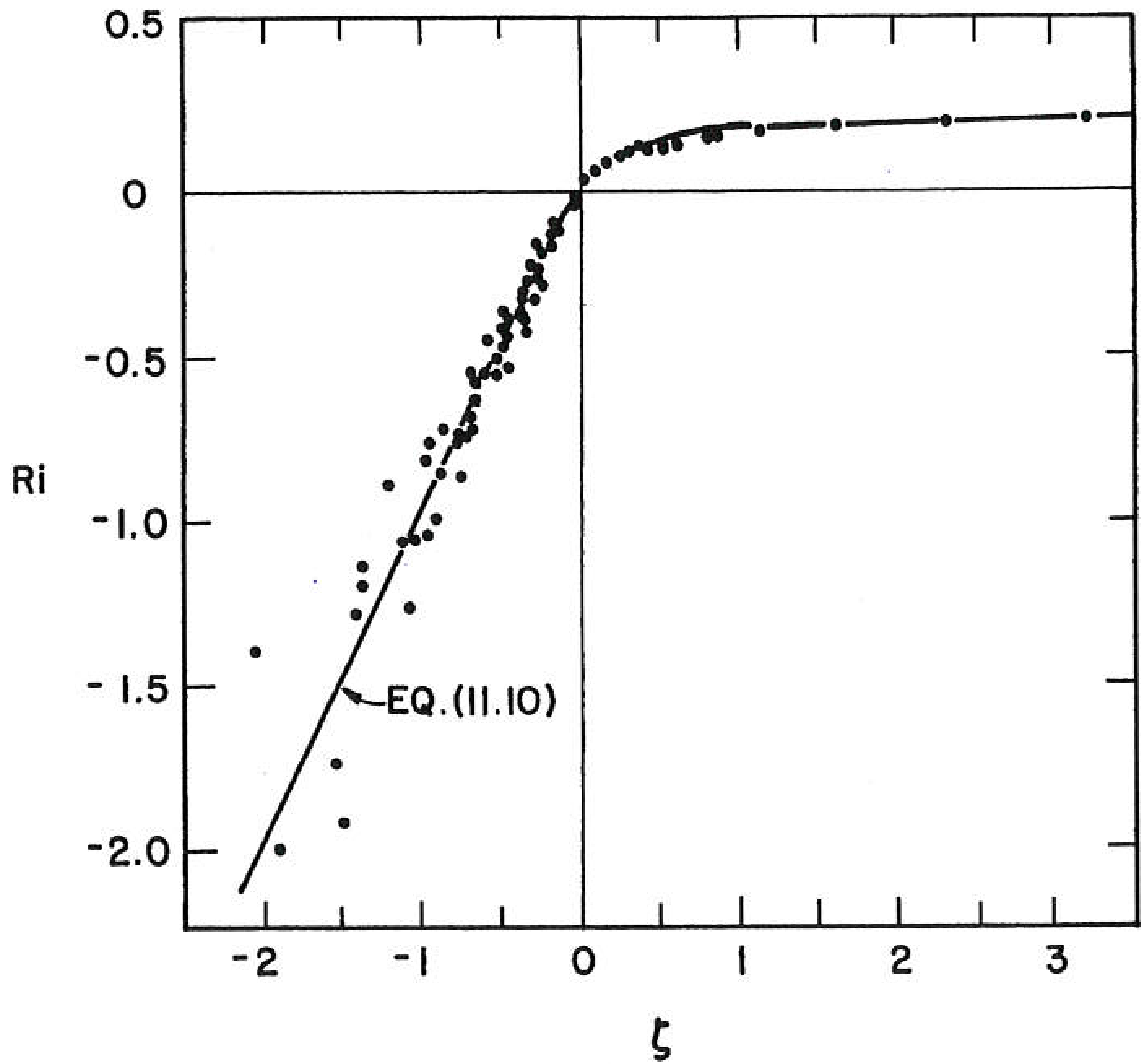


Figure 11.4 The Richardson number as a function of the M–O stability parameters. Equation (11.10) (—) is compared with Kansas data. [After Businger *et al.* (1971).]

Bulk aerodynamic coefficients for non-neutral conditions

$$C_D = \frac{k^2}{\left[\ln(z/z_0) - \psi_m(z/L)\right]^2}$$

$$C_H = \frac{k^2}{\left[\ln(z/z_{T0}) - \psi_m(z/L)\right]\left[\ln(z/z_{T0}) - \psi_h(z/L)\right]}$$

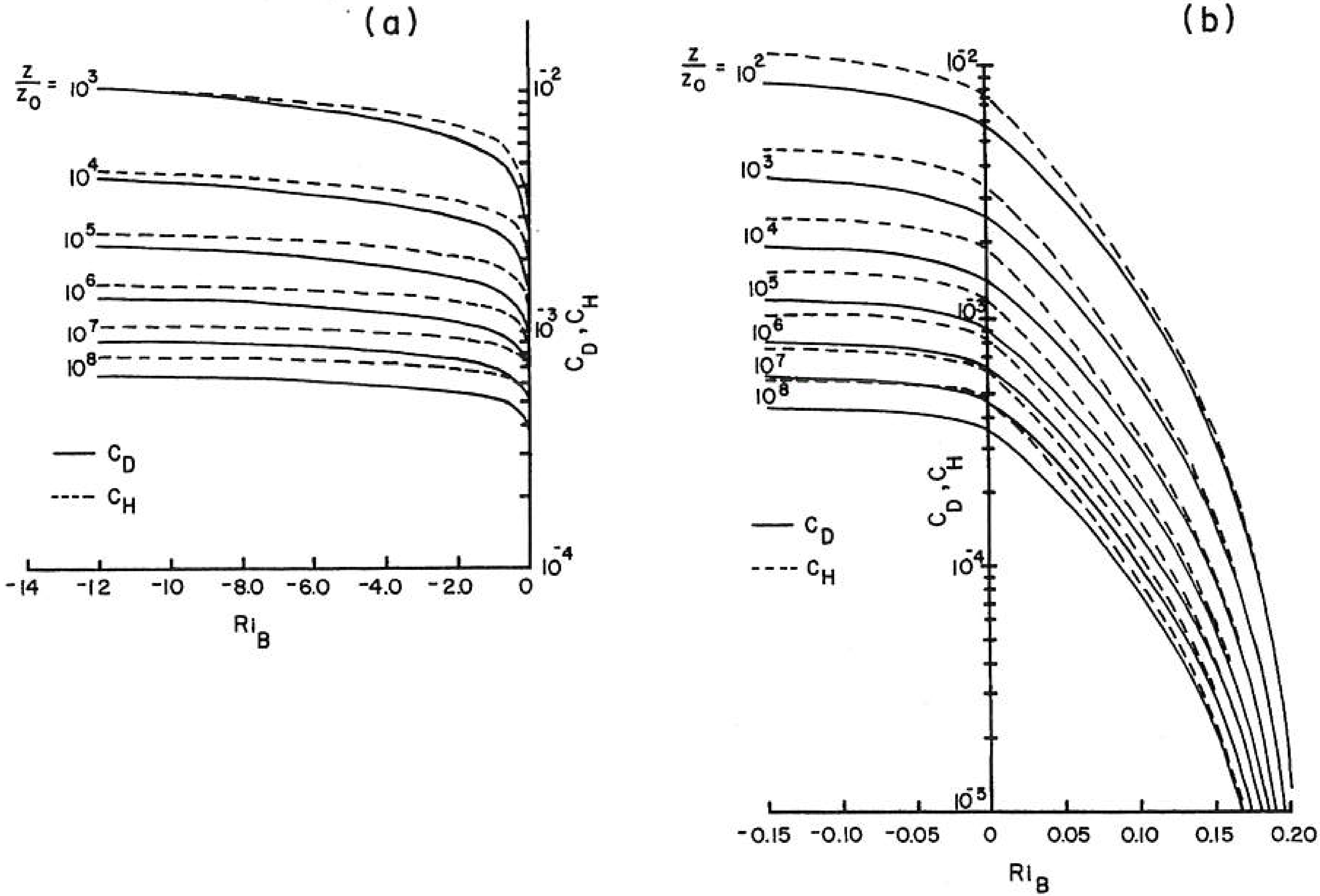


Figure 11.6 Variation of surface drag and heat transfer coefficients with surface roughness and the bulk Richardson number for (a) unstable conditions, and (b) near-neutral and stable conditions. [After Arya (1977).]