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MIXING HEIGHT IN UNSTABLE CONDITIONS: MEASUREMENTS AND PARAMETERIZATIONS

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In air pollution meteorology, the height of the subsidence inversion, Z_i, is a required parameter. This mixing height is needed because it provides the vertical extent for the airborne effluents to be dispersed. According to the Offshore and Coastal Dispersion (OCD) model, unstable conditions prevail when the Obukhov stability length (-L) is less than 25 m. This phenomenon occurs mainly in the afternoon during the peak of superadiabatic lapse rate. Because the routine timing of twice daily rawinsoundings by the National Weather Service are 00 and 12 UTC, direct measurements of Z_i over the U.S. mainland are not available. On the other hand, during an emergency, Z_i is needed whether one has direct measurement or not. The purpose of this study is to provide such a formula for rapid estimation of Z_i.

According to Panofsky et al. (1977),

$$\frac{\sigma_w}{u_*} = a\left(1 + \frac{3z}{(-L)}\right)^b \qquad (1)$$

where σ_w is the standard deviation of the vertical velocity, u_* is the friction velocity, z is the height, -L is the Obukhov length and a and b can be determined from measurement.

According to Arya (1999), for unstable and convective conditions,

$$\frac{\sigma_u}{w_*} = \frac{\sigma_v}{w_*} = \frac{\sigma_w}{w_*} \qquad (2)$$

where $\sigma_{u,v}$ are the standard deviation of horizontal velocity and w_* is the convective velocity. Therefore, we postulate here for operational applications that from Eqs. (1) and (2),

$$\frac{\sigma_u}{u_*} = a\left(1 + \frac{3z}{(-L)}\right)^b \qquad (3)$$

On the basis of the data sets provided in Panofsky et al. (1977), Eq. (3) does exist where $a \approx 2.2$, $b = 0.53$, and $R^2 = 0.82$.

Note that for neutral conditions $\sigma_u = 2.4u_*$ (see Panofsky and Dutton, 1984, p. 377), thus we further postulate from Eq. (3) and Figure 1 that

$$\frac{\sigma_u}{u_*} = 2.4\left(1 + \frac{3z}{(-L)}\right)^{1/2} \qquad (4)$$

Now, according to Kaimal and Finnigan (1994)

$$\frac{\sigma_u^2}{u_*^2} = 4 + 0.6\left(\frac{Z_i}{(-L)}\right)^{2/3} \qquad (5)$$

Santoso and Stull (2001) have provided the data necessary to verify that Eqs. (4) and (5) are essentially equal as shown in Figure 2. Therefore, Eqs. (4) and (5) can be reduced to

$$\frac{Z_i}{|L|} = \left[2.9 + \frac{288}{|L|}\right]^{3/2} \qquad (6)$$

This is the equation we suggest for operational use.

To further verify Eq. (6), Figs. (3) and (4) are provided for over land and over water cases. The data used in Fig. 3 are based on Stull (1994) and in Fig. 4 on Panofsky et al. (1977), Wyngaard et al. (1978), and Chou et al. (1986). On the basis of the above analysis, it is suggested that Eq. (6) be used for operational applications.

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References

Arya, S. P., 1999: Air Pollution Meteorology and Dispersion. Oxford Univ. Press, 310 pp.

Chou, S.-H., D. Atlas, and E.-N. Yeh, 1986: Turbulence in a convective marine atmospheric boundary layer. *J. Atmos. Sci.*, **43**, 547-564.

Kaimal, J. C., and J. J. Finnigan, 1994: Atmospheric Boundary Layer Flows. Oxford Univ. Press, 289 pp.

Panofsky, H. A., H. Tennekes, D. H. Lenschow, and J. C. Wyngaard, 1977: The characteristics of turbulent velocity components in the surface layer under convective conditions. *Boundary-Layer Meteorol.*, **11**, 355-361.

Panofsky, H. A., and J. A. Dutton, 1984: Atmospheric Turbulence. John Wiley & Sons, 397 pp.

Santoso, E., and R. Stull, 2001: Similarity equations for wind and temperature profiles in the radix layer, at the bottom of the convective boundary layer. *J. Atmos. Sci.*, **58**, 1446-1464.

Stull, R., 1994: A convective transport theory for surface fluxes. *J. Atmos. Sci.*, **51**, 3-22.

Wyngaard, J. C., W. T. Pennell, D. H. Lenschow, and M. A. LeMone, 1978: The temperature-humidity covariance budget in the convective boundary layer. *J. Atmos. Sci.*, **35**, 47-58.

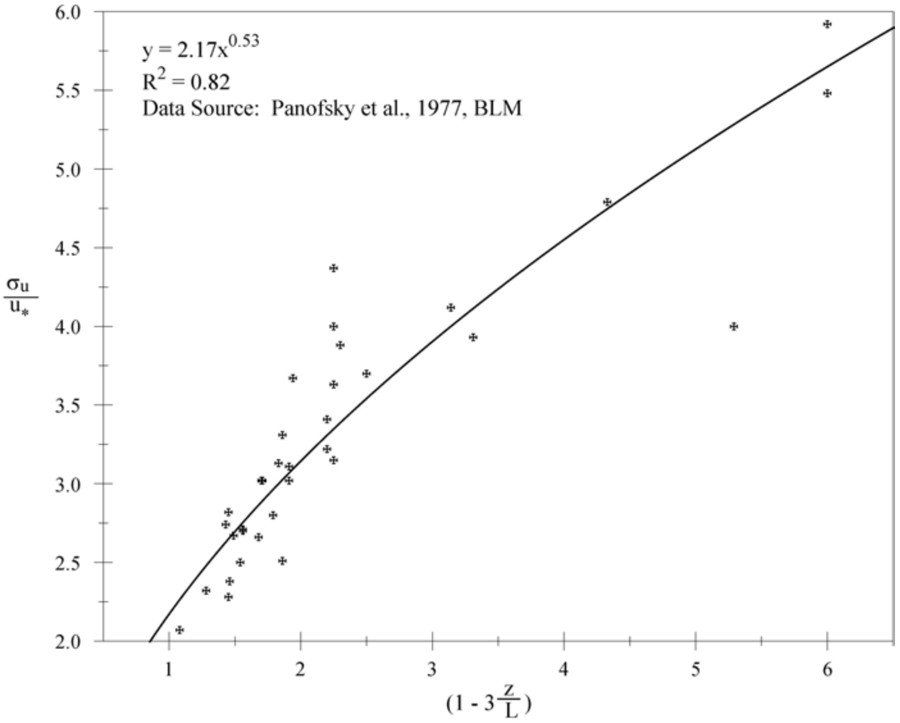

Figure 1. Evidence to support Eq. (1).

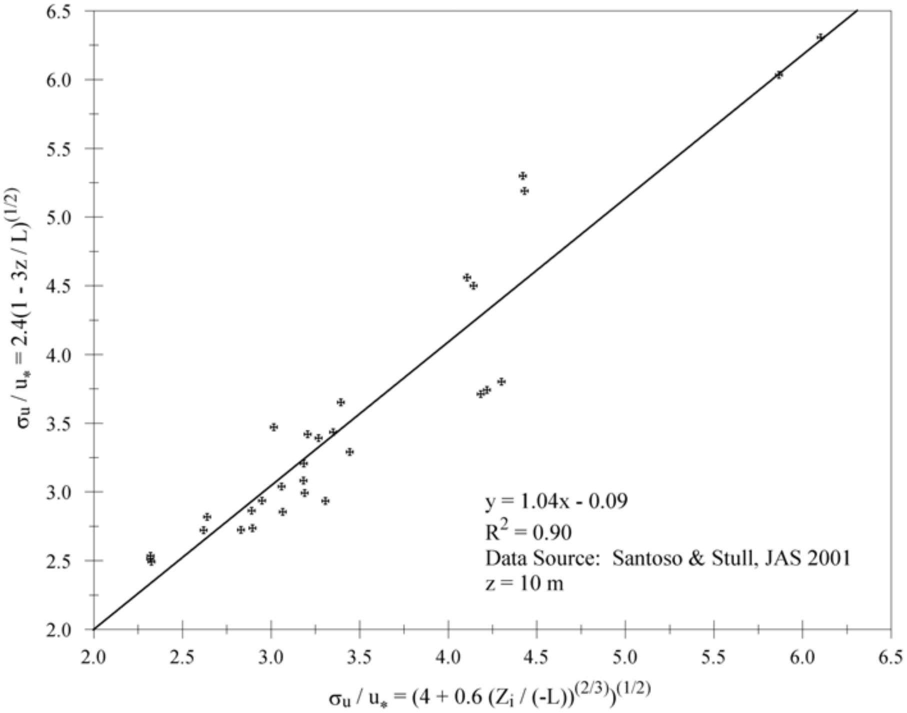

Figure 2. Evidence to support that Eqs. (4) and (5) are nearly equal.

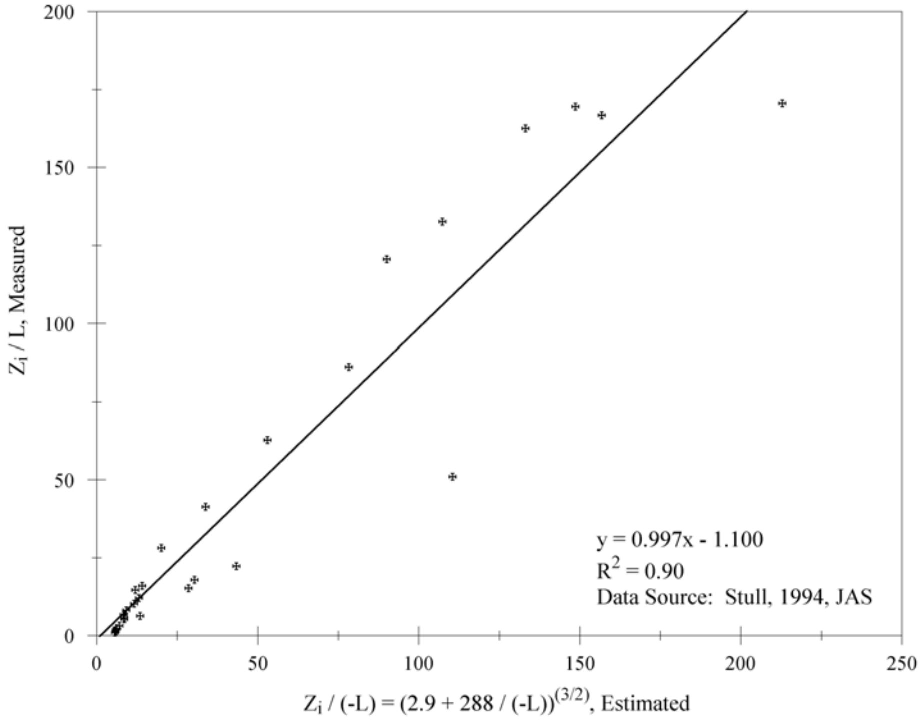

Figure 3. Verification of Eq. (6) on land.

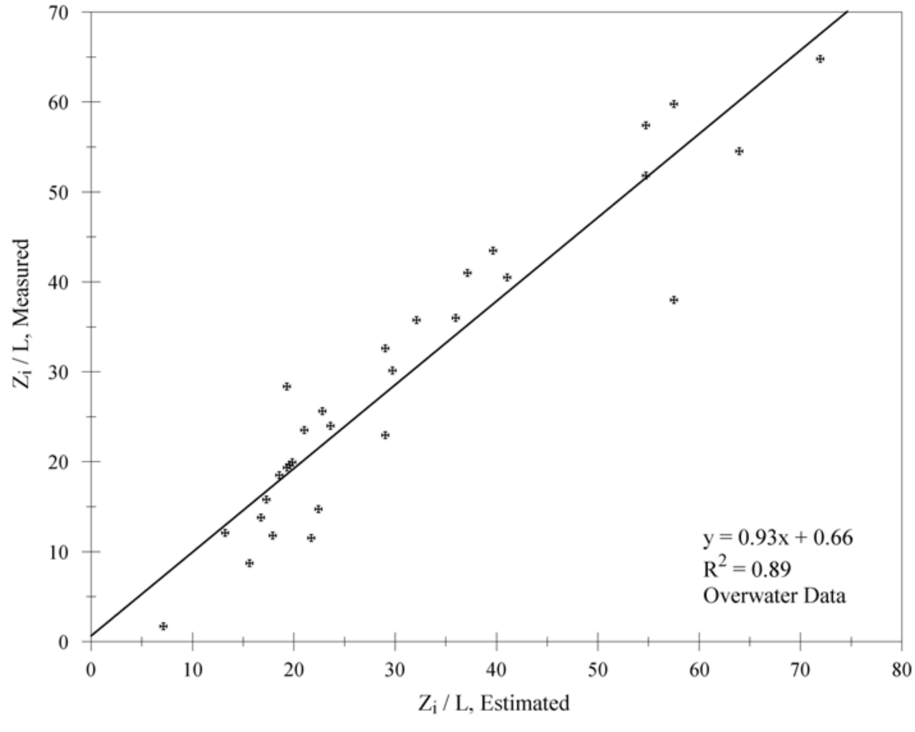

Figure 4. Verification of Eq. (6) over water.