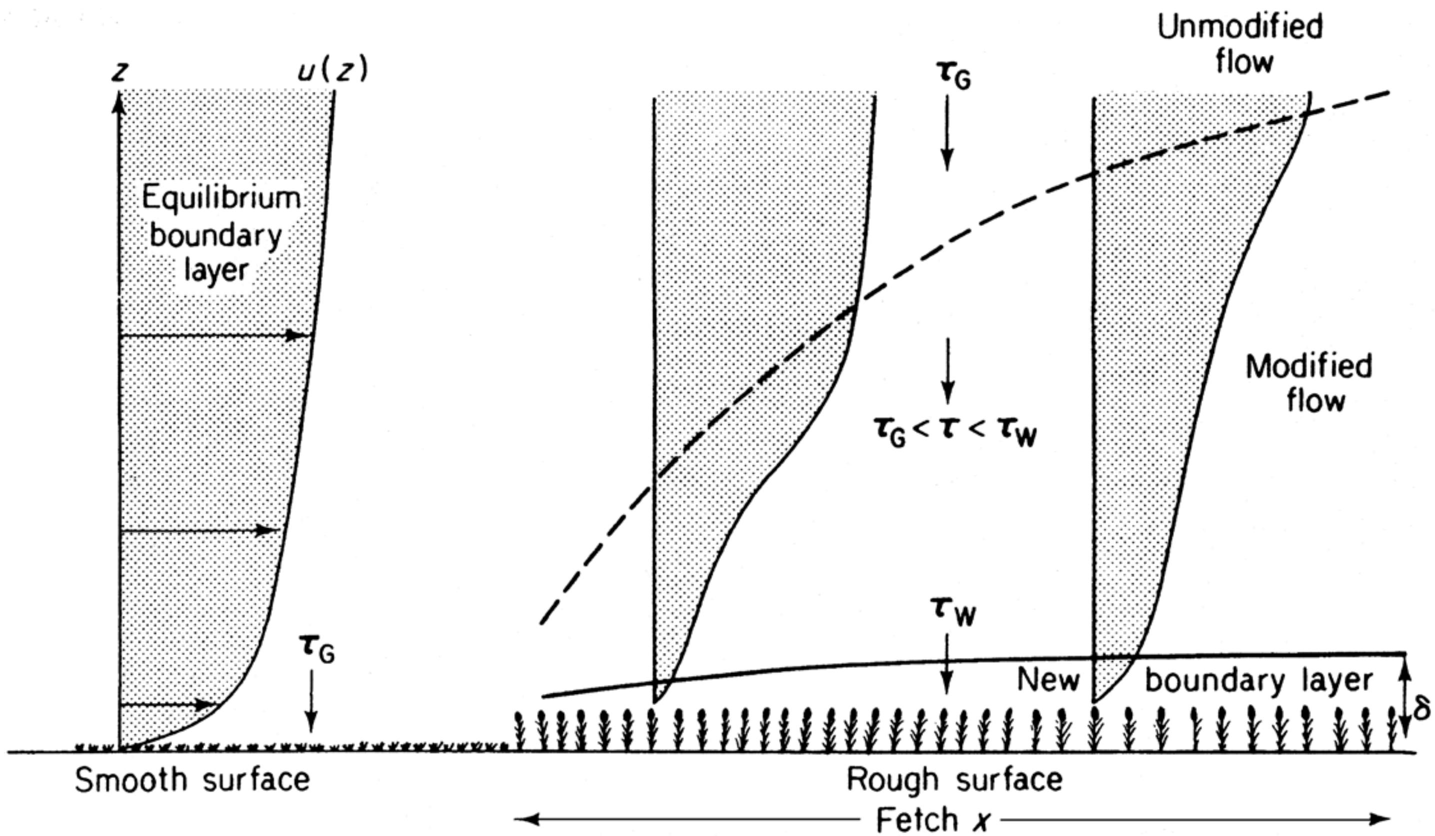

Figure 16.1 Development of a new equilibrium boundary layer when air moves from a relatively smooth to a rougher surface. The ratio of the vertical to the horizontal scale is about 20:1. The broken line is the boundary between unmodified flow in which the vertical momentum flux is $\boldsymbol{\tau}_G$ and modified flow in which the flux is between $\boldsymbol{\tau}_G$ and $\boldsymbol{\tau}_W$. The flux is $\boldsymbol{\tau}_W$ below the new boundary layer height δ.

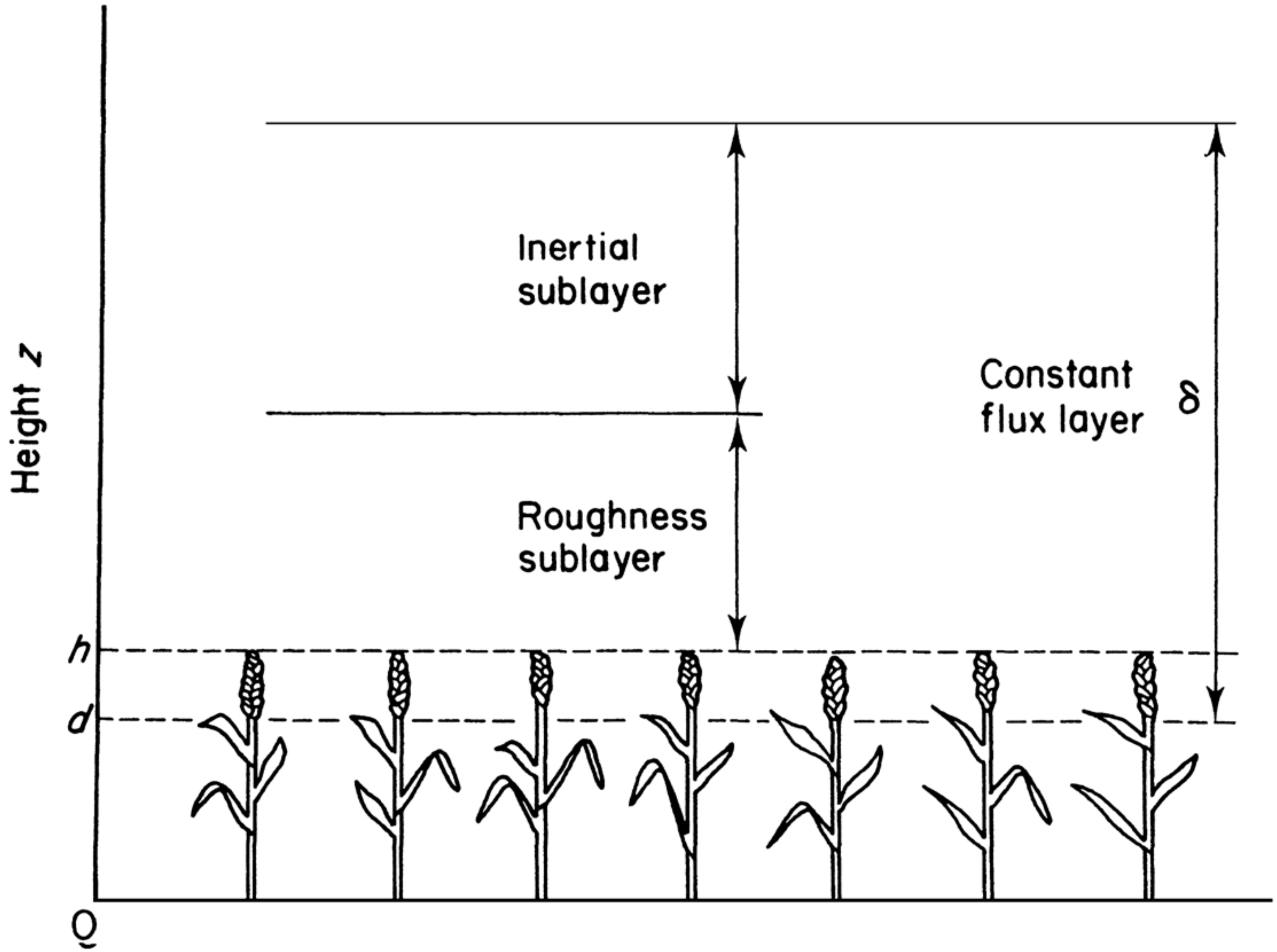

Figure 16.2 The constant flux layer and its sublayers. The depth δ is about 15% of the surface boundary layer.

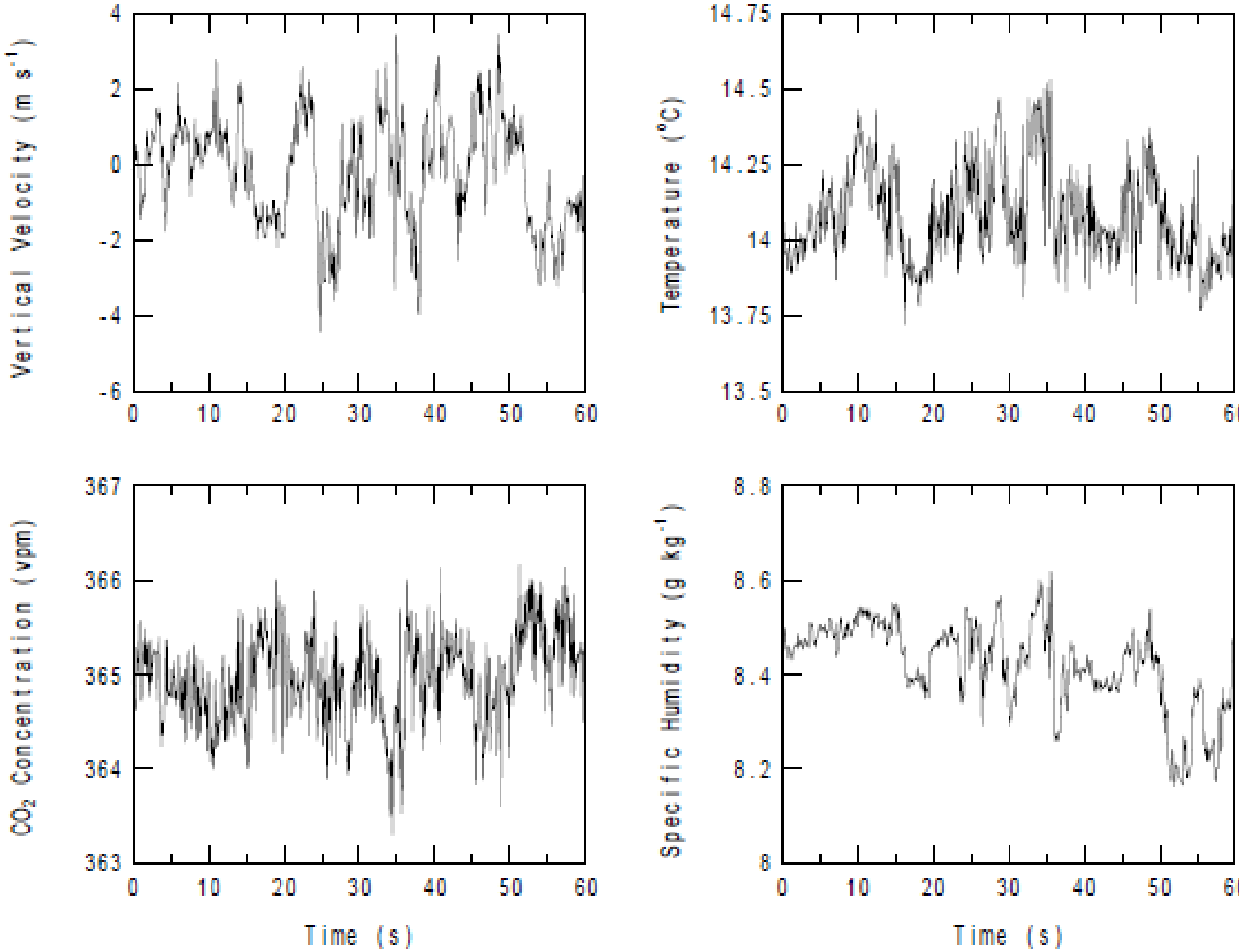

Figure 16.3 Fluctuations in vertical windspeed, temperature, carbon dioxide concentration and specific humidity measured over a pine forest in Oregon. (Data courtesy of Dean Vickers and Larry Mahrt.)

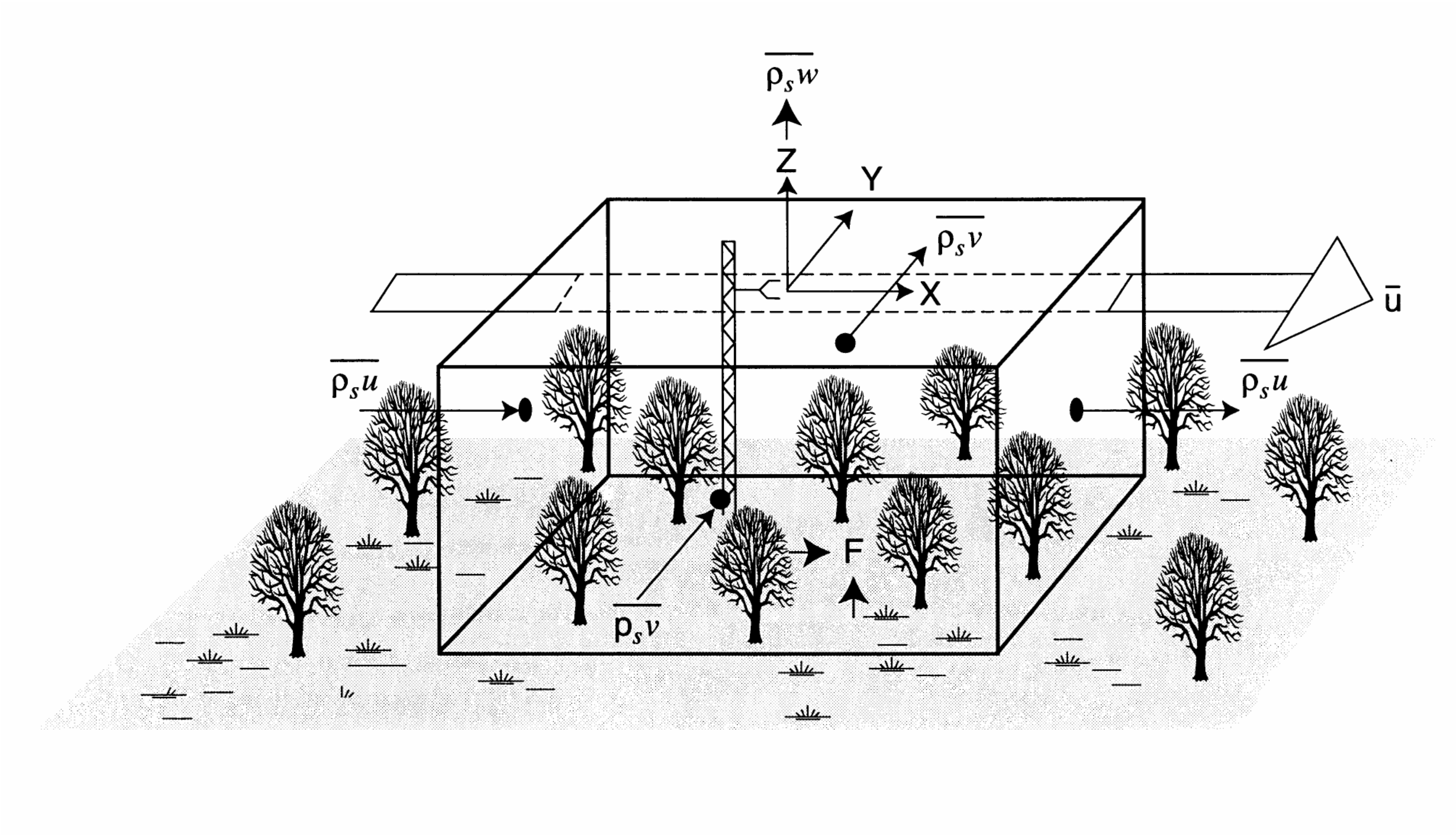

Figure 16.4 Flux relationships in and above a uniform, horizontal forest. The coordinate axes are aligned with the mean wind vector, which is parallel to the ground. In the absence of horizontal advection and storage in the sample volume, the vertical flux measured by instruments above the forest on a tower is identical to the flux from the soil and vegetation (after Finnigan et al.,2003).

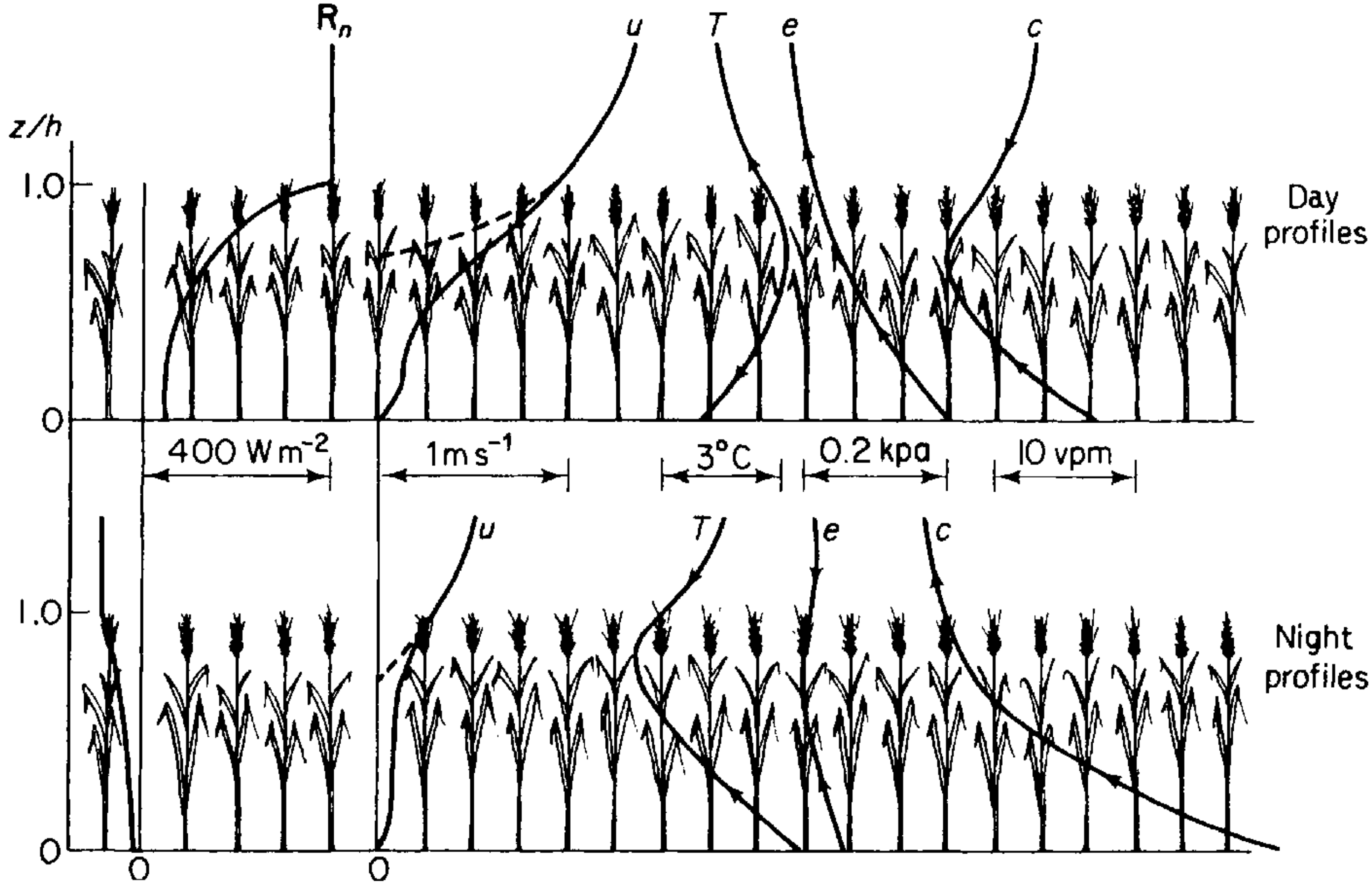

Figure 16.5 Idealized profiles of net radiation *(*$\mathbf{R}_n$*)*, horizontal windspeed *(u)*, air temperature *(T)*, vapor pressure *(e)*, and CO_2 concentration *(c)* in a field crop growing to a height *h,* plotted as a function of *z/h*. The pecked wind profiles represent an extrapolation of the logarithmic relation between *u* and *(z − d)* above the canopy (see pp. 302–303).

Table 16.1 Characteristic values of Roughness Length, z_0, for a range of natural surfaces (from Campbell and Norman, 1998)

Type of surface	z_0 (m)
Ice	0.001
Open water	0.002–0.006
Bare soil (untilled)	0.005–0.020
(tilled)	0.002–0.006
Grass 0.01 m high	0.001
0.1 m high	0.023
0.5 m high	0.05–0.07
Wheat 1 m high	0.10–0.16
Coniferous forest	1.0

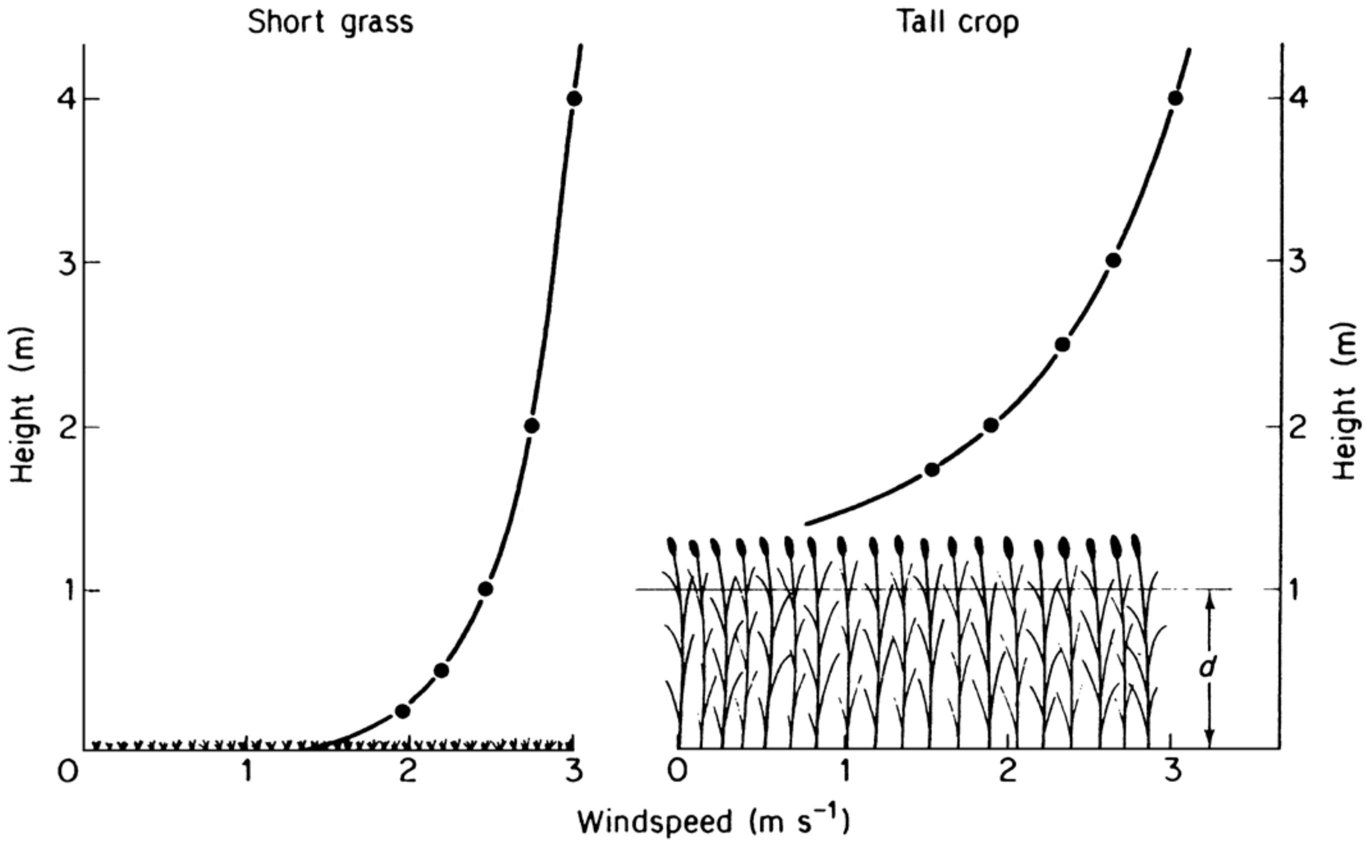

Figure 16.6 Profiles of mean horizontal windspeed over short grass and a moderately tall crop when windspeed at 4 m above the ground is 3 m s^{-1}. The filled circles represent hypothetical measurements from sets of anemometers.

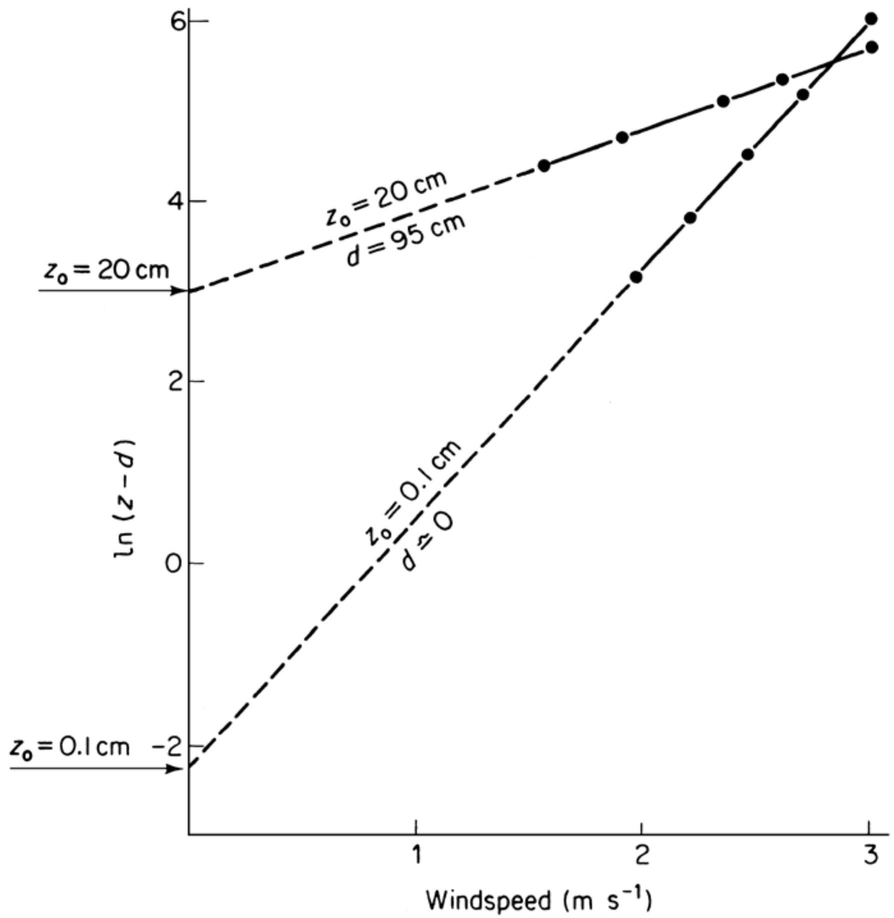

Figure 16.7 Relationships between windspeed and ln *(z−d)* for the wind profiles in Figure 16.6.

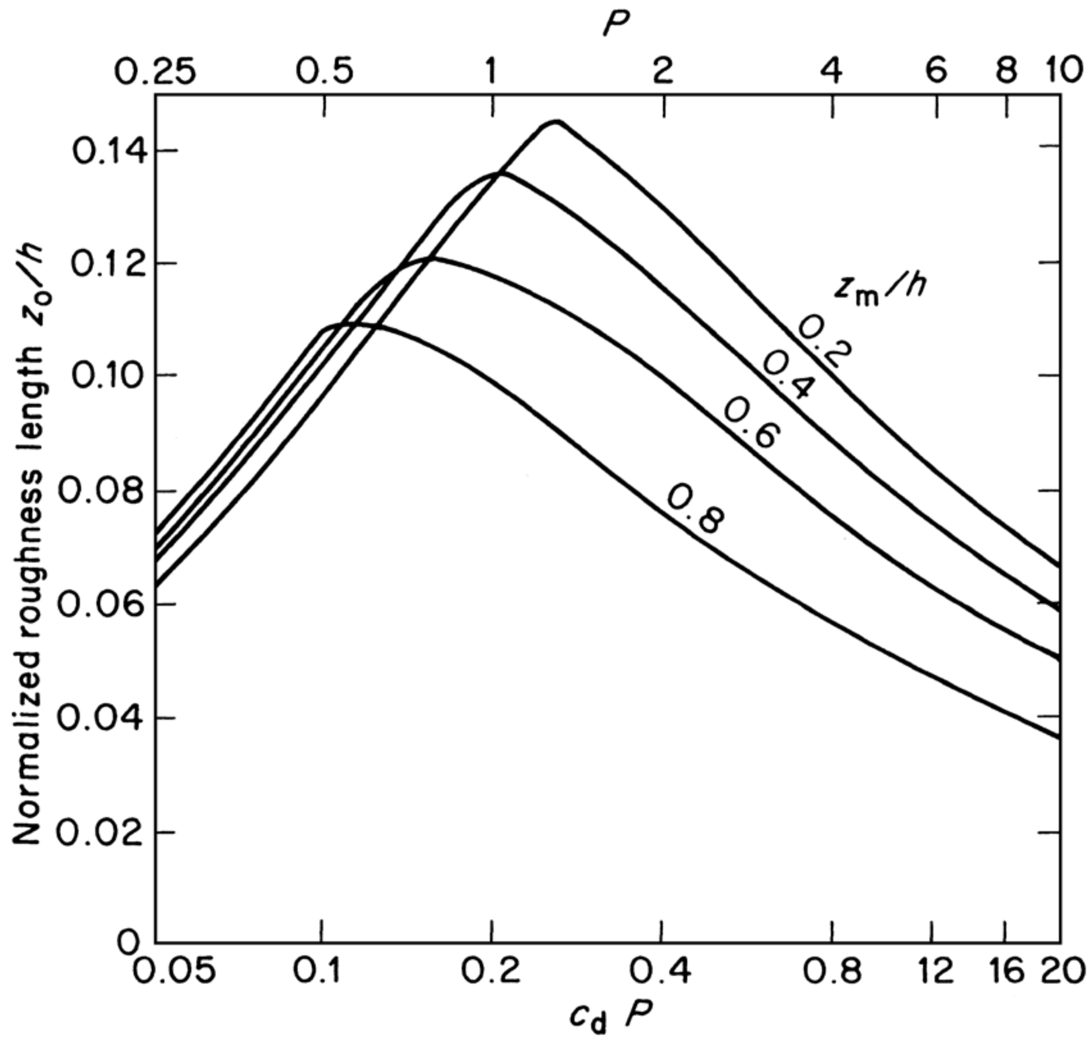

Figure 16.8 Normalized roughness length as a function of $c_d P$ (and against *P* assuming that $c_d = 0.2$). Curves are labeled according to the height at which foliage density reaches a maximum (from Shaw and Pereira, 1982).

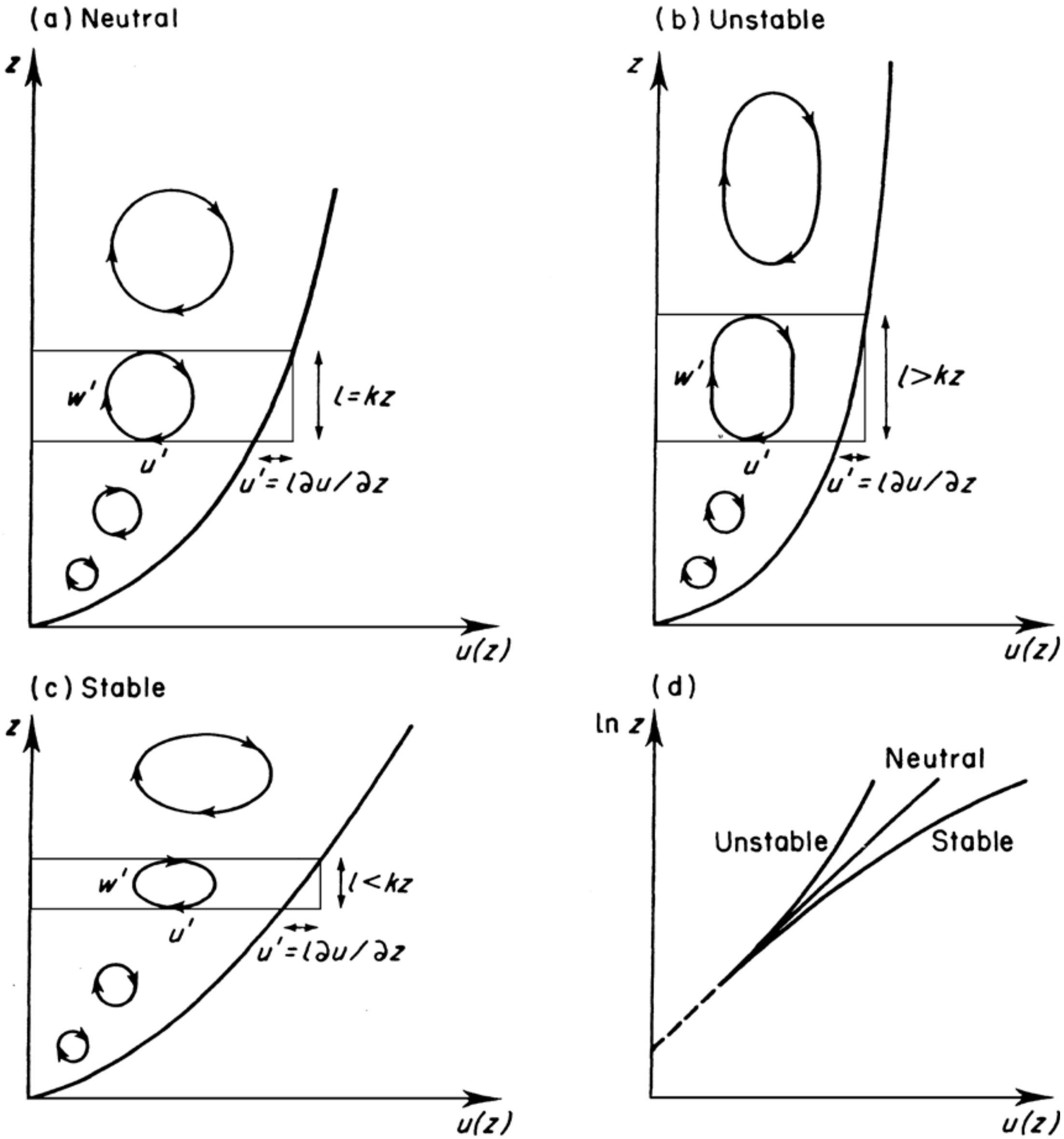

Figure 16.9 Windspeed profiles and simplified eddy structures characteristic of the three basic stability states (neutral, unstable and stable in air flow near the ground. Panel (d) illustrates the profiles of windspeed plotted against a logarithmic scale of height *z* (from Thom, 1975).

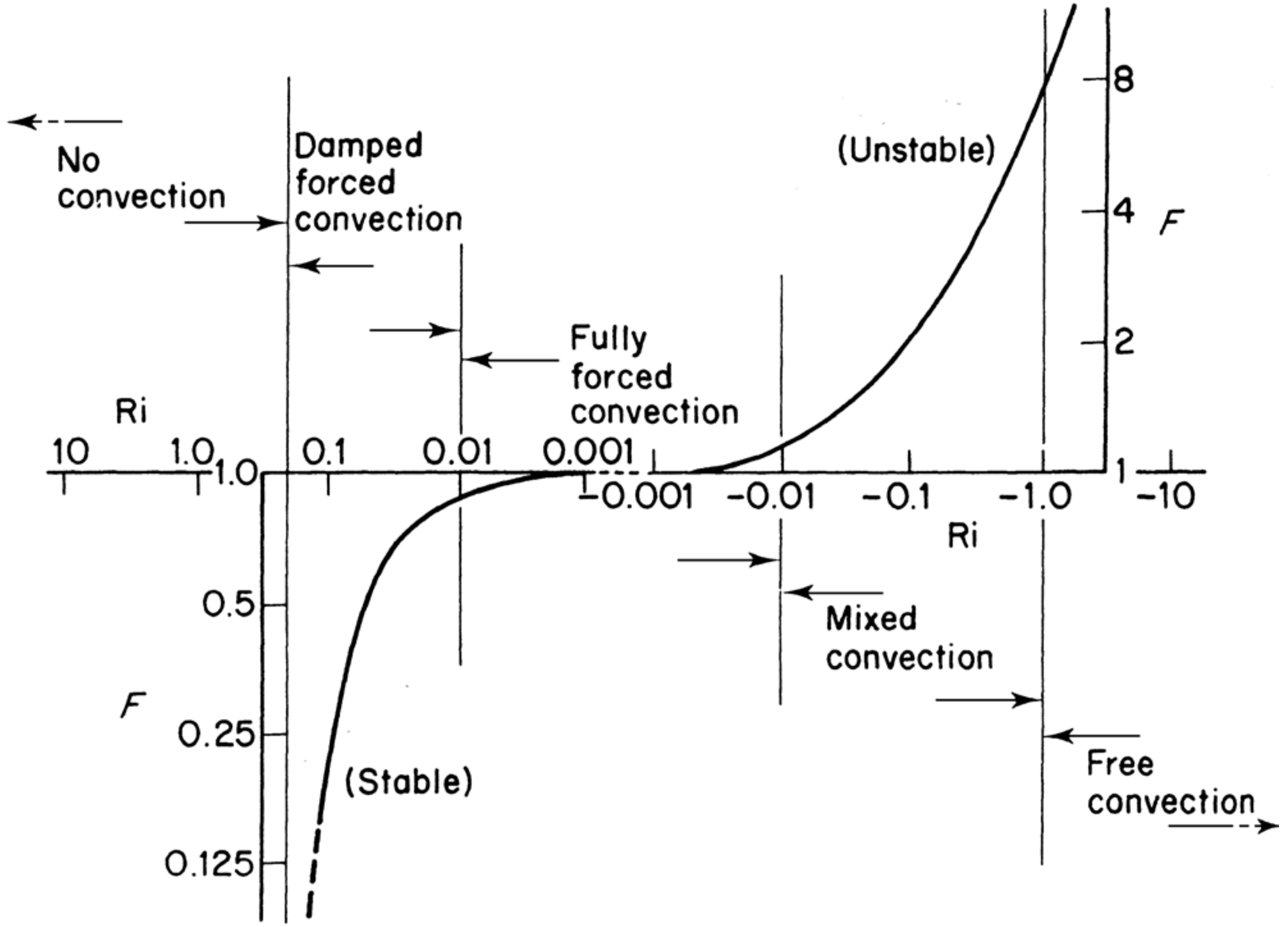

Figure 16.10 The "stability factor" *F* plotted logarithmically against the Richardson number Ri. Fluxes calculated in non-neutral conditions, using profile-gradient equations valid for neutral conditions, must be multiplied by *F*. The curves for stable and unstable conditions are calculated from Eqs. (16.44) and (16.45), respectively. (From Thom, 1975)

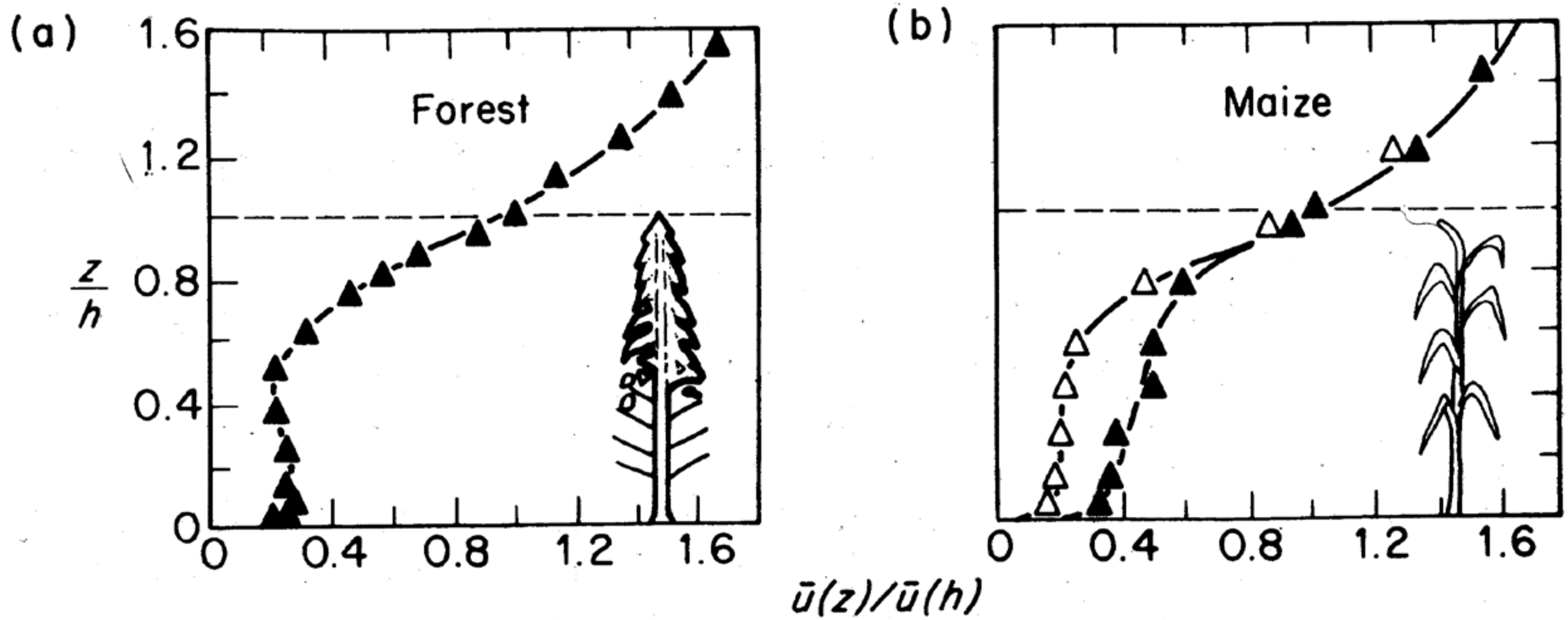

Figure 16.11 (a) Profile of mean horizontal windspeed in a pine forest canopy *(h* = 16 m); data averaged from 18 very-near-neutral 1-h runs. (b) Profiles of mean windspeed in a maize canopy *(h* = 2.1 m*)* during periods of light wind (mean *u(h)* = 0.88 m s^{-1}) and strong wind (mean *u(h)* = 2.66 m s^{-1}) (from Raupach and Thom, 1981).