ESS5203.03 - Turbulence and Diffusion in the Atmospheric Boundary-Layer: Winter 2020

Turbulence & Diffusion in Canopies:

See Foken, Micrometeorology, Ch 3; Kaimal & Finnigan, Atmospheric Boundary Layer Flows, Ch 3

1) Flow profiles within and above the canopy

Roughness and Displacement Height:

$u(z) = \frac{u_*}{\kappa} \ln\left(\frac{z-d}{z_0}\right)$, Similar for θ and q, without the bluff-body effect.

The Roughness Sublayer (height = z_*)

$$\overline{u'w'} = -\frac{\kappa z}{\phi_*\left(\frac{z}{z_*}\right)\phi_m\left(\frac{z}{L}\right)}\frac{du}{dz}, \quad \overline{w'T'} = -\frac{\alpha_0 \kappa z}{\phi_*\left(\frac{z}{z_*}\right)\phi_H\left(\frac{z}{L}\right)}\frac{dT}{dz}, \quad \overline{w'q'} = -\frac{\alpha_{0E} \kappa z}{\phi_*\left(\frac{z}{z_*}\right)\phi_E\left(\frac{z}{L}\right)}\frac{dq}{dz}$$

$$\phi_*\left(\frac{z}{z_*}\right) = \exp\left[-0.7\left(1 - \frac{z}{z_*}\right)\right]$$

Flow within the Canopy

$$u(z) = u(h_c)\exp\left(\alpha\left(\frac{z}{h_c} - 1\right)\right), \quad \alpha = \frac{0.2\ \mathrm{LAI}\ h_c}{l_m}$$

2) Failure of *K*-Theory within the Canopy

Momentum Balance

$$\frac{D}{Dt}\langle\overline{u}\rangle = 0 = -\frac{\partial}{\partial z}\langle\overline{u'w'}\rangle - \frac{\partial}{\partial z}\langle\overline{u}''\overline{w}''\rangle - \frac{\langle\overline{D}\rangle(z)}{\rho}, \qquad u_*^2 \neq K\frac{du}{dz}$$

Near-Field / Far-Field Theory $K_f = R\left(\frac{\tau}{T_L}\right)K_z$

Counter-Gradient Turbulence, Turbulent and Coherent Structures, Bursts and Sweeps, Canopy Decoupling