$C_p = 29.3\ J/mol\,C$ $\hat{\rho} = 44.6 \frac{P}{101.3} \frac{273}{T}$

$\hat{\rho}\, c_p = 1200\ J/m^3 C$ @ 20°C + SLP

Temp	$T(z) = T_0 - \frac{H}{0.4 \hat{\rho} c_p u^*} \ln\left(\frac{z-d}{z_H}\right)$
$\omega = \pi/12$	Diurnal Temp. Func. $\Gamma(t) = 0.44 - 0.46 \sin(\omega t + 0.9) + 0.11 \sin(2\omega t + 0.9)$
$0 < t \le 5$	$T(t) = T_{x,i-1}\Gamma(t) + T_{n,i}[1-\Gamma(t)]$ thermal time $\tau = \sum_{i=1}^{n}\left(\frac{T_{x,i} - T_{n,i}}{2} - T_b\right)\Delta$
$5 < t \le 14$	$T(t) = T_{x,i}\Gamma(t) + T_{n,i}[1-\Gamma(t)]$
$14 < t < 24$	$T(t) = T_{x,i}\Gamma(t) + T_{n,i+1}[1-\Gamma(t)]$
	$T(z,t) = T_{ave} + A(0)\exp(-z/D)\sin(\omega(t-8) - z/D)$ time dependence in soil
	$T(z) = T_{ave} + A(0)\exp(-z/D)$ range of temp. at a given depth
Gas Conc.	$\rho_j = n_j M_j / V$ $C_j = n_j / n_{air}$ $\rho_j V = n_j R T$ $C_j = p_j / p_{air}$ $p_a = 101.3 \exp(-A/8200)$ A: altitude
	$e_s = 0.611\,kPa \exp\left(\frac{17.502\,T}{240.97°C + T}\right)$ Vapor Deficit: $D = e_s(T_a) - e_a$ $e_s(T_d) = e_a$ saturation
	$T_d = \frac{c \ln \frac{e_a}{a}}{b - \ln\frac{e_a}{a}}$
H_2O in organisms	$C_{vs} = h_{rs}\frac{e_s(T_s)}{p_a} = h_{rs} C_v(T_s)$
Wind	$I_m = \left(\frac{4uh}{\pi L_t}\right)^{1/2}$ for canopy $I_m = \left(\frac{6w^2 h}{\pi L_t}\right)^{1/3}$ w: leaf width $a = \left(\frac{0.2 L_t h}{I_m}\right)^{1/2}$ Lt: LAI h: canopy hgt
	$u(z) = \frac{u^*}{0.4}\ln\left(\frac{z-d}{z_m}\right)$ $d = 0.65h$ $z_m = 0.1h$ above canopies
	$u(z) = u(h)\exp\left[a\left(\frac{z}{h} - 1\right)\right]$ a: attenuation coef. within canopy
Heat/Mass Transport	Fick's Law for Diffusive Transport $F_j = -D_j \frac{d\rho_j}{dz} = g_j(C_{js} - C_{ja}) = \frac{C_{js} - C_{ja}}{r_j}$ like Evaporation
	Fourier's Law for Heat Transport $H = -k \frac{dT}{dz}$
	Darcy's Law for fluid flow in a porous medium $J_w = -K(\psi)\frac{d\psi}{dz}$
	$H = -\hat{\rho} c_p D_H \frac{dT}{dz} = g_H c_p (T_s - T_a) = \frac{c_p(T_s - T_a)}{r_H}$
	Series → $r_H = r_{Ha} + r_{Hs} \ldots$ $g_H = 1/(1/g_{Ha} + 1/g_{Hs} \ldots)$
	Parallel → $g_{Ha} + g_{Hs} = g_H$ $r_H = 1/(1/r_{Ha} + 1/r_{Hs} \ldots)$
Conductance for Heat/Mass transfer	$g_j = \hat{\rho} D_j / \Delta z = \frac{\hat{\rho} D_j}{z_s \ln \frac{z_a}{z_s}}$ z_s: radius of exchange sfc. z_a = distance from axis
	$D_j(T,p_a) = D_j(STP)_{20°C} \frac{101.3}{p}\left(\frac{T}{293.16}\right)^{1.75}$
	$\tau = -\hat{\rho}\overline{u'w'} = K_M \hat{\rho} \frac{du}{dz}$ $K_j = 0.4 u^* (z-d)(1/\phi_j)$
	$H = \hat{\rho} c_p \overline{w'T'} = -K_H \hat{\rho} c_p \frac{dT}{dz}$ $z_H = z_V = 0.2 z_m$
	$E = \hat{\rho}\,\overline{w'C_v'} = -K_V \hat{\rho} \frac{dC_v}{dz}$

$Re = ud/\nu$ $\quad Gr = \frac{g d^3 \Delta T}{T \nu^2}$ $\quad Pr = \nu / D_H$ $\quad Sc = \nu / D_j$ $\quad Nu = \frac{g_H d}{\hat{\rho} D_H}$

Forced

$g_H = 0.664 \hat{\rho} D_H Re^{1/2} Pr^{1/3} / d$ or replace $Pr^{1/3}$ w/ $Sc^{1/3}$ for g_j

$g_{Ha} = 0.135 (u/d)^{1/2}$

Gr/Re² small

Free convection & no wind $\quad g_{Ha} = 0.05 \left(\frac{T_s - T_a}{d}\right)^{1/4}$

d: rectangular plate / cylinder w/ axis parallel & d is length of axis in flow → d

circular disk → w $\quad d = 0.81 w$

0.04 m ← leaf shape → w $\quad d = 0.72 w$ $\quad w$ = max. leaf width

sphere or cylinder axis perpendicular → d $\quad d$ = diameter

animal shape $\quad d = V^{1/3}$ $\quad V$ = vol. animal

Heat Flow in Soil

$K = k / \rho_s c_s$ $\quad T(0,t) = T_{ave} + A(0) \sin[\omega(t - t_0)]$

$D = \sqrt{2K/\omega}$ $\quad T(z,t) = T_{ave} + A(0) \exp(-z/D) \sin[\omega(t - t_0) - z/D]$

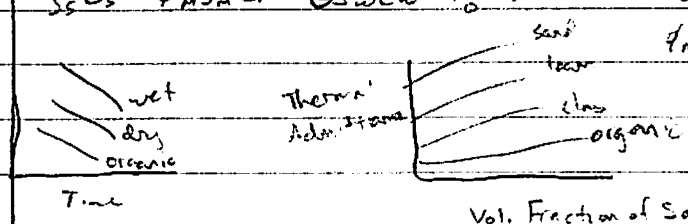
$G_{(0,t)} = \frac{\sqrt{2} A(0) k \sin[\omega(t - t_0) + \pi/4]}{D}$ $\rightarrow \sqrt{2} D \rho_s c_s A(0)$

$\sqrt{2} k / D = \mu \sqrt{\omega}$ $\quad + \quad \sqrt{2} D \rho_s c_s = 2\mu / \sqrt{\omega}$ $\quad \mu = (k \rho_s c_s)^{1/2}$

$\rho_s c_s = \phi_m \rho_m c_m + \theta \rho_w c_w + \phi_o \rho_o c_o$ $\quad \theta$ = water content

$\phi_m + \phi_o$ mineral & organic vol. fraction

Soil Heat Conductance



Water Flow in Soil

$K(\psi_m) = K_s (\psi_e / \psi_m)^{2 + 3/b}$ $\quad K(\theta) = K_s (\theta / \theta_s)^{2b+3}$

$\psi_m = \psi_e (\theta / \theta_s)^{-b} \rightarrow \theta = \theta_s (\psi_e / \psi)^{1/b}$ $\quad A_w = (\theta_c - \theta_{pwp})$ depth of wet

Infiltration Rate $\quad J_{wi} = \left(\frac{\rho_w \Delta\theta K_{ave} (\psi_{mi} - \psi_{mf})}{2t}\right)^{1/2}$ $\quad$ from $\theta = \theta_s (\psi_e / \psi_m)$

Cumulative Infiltration $\quad I_w = (2 \rho_w \Delta\theta K_{avg} (\psi_{mi} - \psi_{mf}) t)^{1/2} + g K_{ave} t$

$\psi_{mf} = \frac{2b+3}{b+3} \psi_e$ $\quad \Delta\theta = \frac{(\theta_i + \theta_f)}{2} - \theta_o$ $\quad f$ = wetting front $\quad o$ = initial $\quad i$ = infiltration boundary ≥ θ_s

$K_{ave} = [(K_s)(K(\psi_{mf}))]^{1/2}$ $\quad \rho_w = 1 \times 10^3$ kg/m³ $\quad \psi_m = -33$ field capacity

$A_w = \theta - \theta_{pwp} / \theta_{fc} - \theta_{pwp}$ $\quad \psi_m = 1500$ pwp

$U_p = E_{pmax} [1 - (1 + 1.37 A_w)^{-b}]$

$Z_f = \left(\frac{2 K_{avg} (\psi_{mi} - \psi_{mf}) t}{\rho_w \Delta\theta}\right)^{1/2}$ $\quad \theta = d/D$ $\quad d_{initial} = \theta_o D$

new $\theta = \frac{d_{final}}{D}$ $\quad d_{final} = d_{initial}$ + rain

$P + I - R - ET = D + \Delta W$ $\quad P - R = \Delta W$

P: amt. of rain, $\Delta W = I_w$