CE 560 Advanced Hydrology sept 15

Evaporation [weather. wsu. edu]

liquid water - water vapor

* energy supply
* advection component

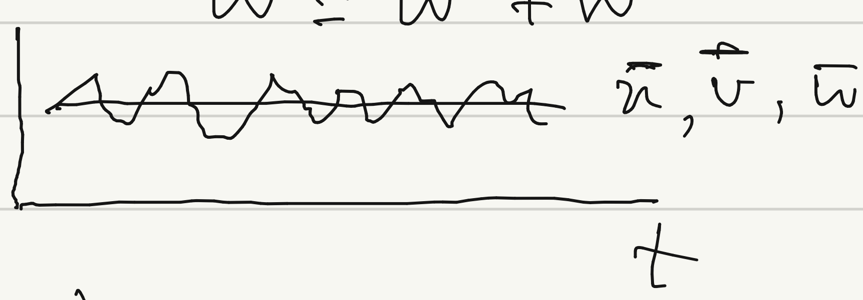
3 methods 1) mass transfer

2) energy budget

3) water budget

1) Mass transfer

$u = \bar{u} + u'$
$v = \bar{v} + v'$
$w = \bar{w} + w'$



variance $\alpha = \frac{1}{n} \sum (x - \bar{x})^2$

covariance $(x, y) = \frac{1}{n} \sum [(x - \bar{x})(y - \bar{y})]$

$\text{cov}(w, q) = \frac{1}{n} \sum (w')(q')$

measurements : 15 ~ 30 min frequency

flux tower => "covariance method"

in a stable atmosphere

$E = \rho \, \overline{q' w'}$

Bulk transfer approximation

Bulk transfer approximation

$$E = C_e \rho \bar{u}_2 (\bar{q}_s - \bar{q}_2)$$

$C_e \Rightarrow$ vapor transfer coefficient

$\bar{u}_2 \Rightarrow$ mean wind speed at $z = z_2$

$\bar{q}_s \Rightarrow$ specific humidity at water surface

$$q_s = q_s^* (T_s)$$

$q_2 \Rightarrow q$ at z_2

C_e is constant $\sim 1.2 * 10^{-3}$

$\underline{\underline{\text{if}}}$ z_0, z_{0v} are constant
→ neutral conditions

✓ eqn 4.4 $C_e =$

mass transfer equation : empirical way

need wind speed, water surface temp,
humidity of air

$$E = \underbrace{f_e(u)}_{\text{wind function}} \underbrace{(\bar{e}_s - \bar{e}_2)}_{\text{vapor pressure deficit}}$$

e vapor pressure $\qquad q = 0.622 \dfrac{e}{p}$

1822 Stelling $E = (a + b\bar{u})(\bar{e}_s - \bar{e}_z)$

- Mean profile methods

in ch 2 : 2.50, 2.51, 2.52

u_*, H, E

measurements : $\bar{q}$, $\bar{u}$, $\bar{T}$

Bowen Ratio $B_o = \frac{H}{L_e E}$

$$B_o = \frac{c_p(\bar{\vartheta}_1 - \bar{\vartheta}_2)}{L_e(\bar{q}_1 - \bar{q}_2)}$$

ϑ : potential temp

eqn 2.23

$= T\left(\frac{P_0}{P}\right)^{R_d/c_p}$

$E = \ldots$ eqn 2.36

$H = \ldots$ eqn 2.38

$$E = \frac{H(\bar{q}_1 - \bar{q}_2)}{c_p(\bar{\vartheta}_1 - \bar{\vartheta}_2)}$$

2) Energy formulations

$$R_n - L_e E - H + L_p F_p - G + A_h = \frac{\partial W}{\partial t}$$

simplify $R_n - G = H + L_e E$ $\frac{W}{m^2}$

here $L_e E + H = Q_n$

if $L_e = 2.466 * 10^6$ J/kg , $1 \frac{W}{m^2} \simeq 1.07 \frac{kg}{m^2}/mo$

$\rho_w = 1000$ kg/m³ $\Rightarrow 1$ mm/mo

$H_e = H/L_e$

depth units $E + H_e = Q_{ne}$

$Q_{ne} = Q_n/L_e$

Because we cannot reliably measure H

$\Rightarrow$ indirect methods $\quad B_o = \frac{H}{L_e E}$

$$L_e E = \frac{Q_n}{1+B_o} \quad \text{OR} \quad H = \frac{B_o Q_n}{1+B_o}$$

$$E = \frac{Q_{ne}}{1+B_o} \quad \text{OR} \quad H_e = \frac{B_o Q_{ne}}{1+B_o}$$

EBBR : energy budget bowen ratio

accurate if B_o is small

$B_o = -1$ solutions in text

$\Rightarrow$ Penman (1948) $\Rightarrow$ combined method