Using ARM Cloud Radar Data to Study Cloud-Top Entrainment Processes in Continental Stratocumulus

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Entrainment Parameterizations-- Entrainment Zone TKE Budget

OTTO ZEMAN AND H. TENNEKES   JAS 1977

$$0 = \frac{g}{T}\left(\overline{\theta_v' w'}\right)_i - \frac{\partial}{\partial z}\left(\overline{ew'} + \overline{p'w'}/\rho\right) - \varepsilon_i$$

| Bouyancy | Transport +Pressure | Dissipation |

$$w_e \Delta\theta_v = -\frac{\partial}{\partial z}\left(\overline{ew'} + \overline{p'w'}/\rho\right) - \varepsilon_i$$

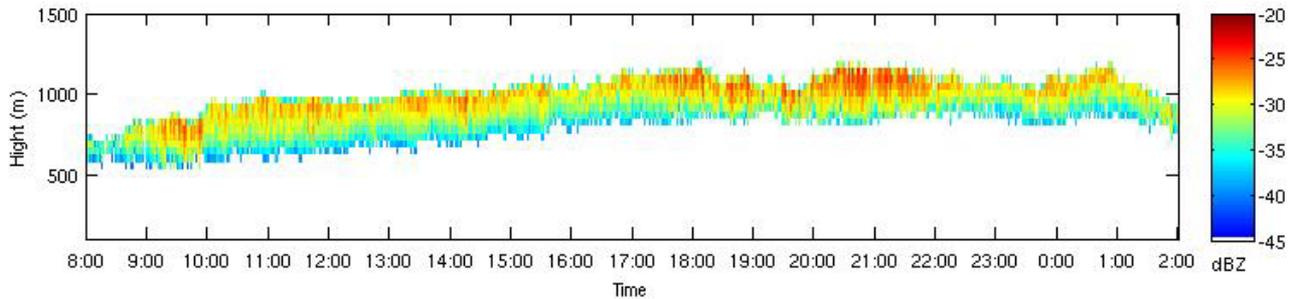$$C_F \,{\sigma_w^3}\big/{h}$$

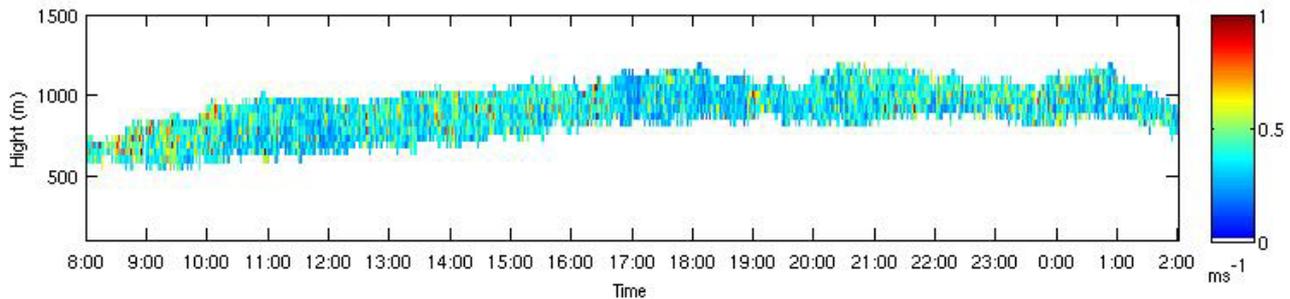$$w_e = \frac{C_F \,{\sigma_w^3}\big/{h} - \varepsilon_i}{\Delta\theta_v}$$

$$w_e = w_{ee} - w_{ed}$$

18H, Lamont, OK,
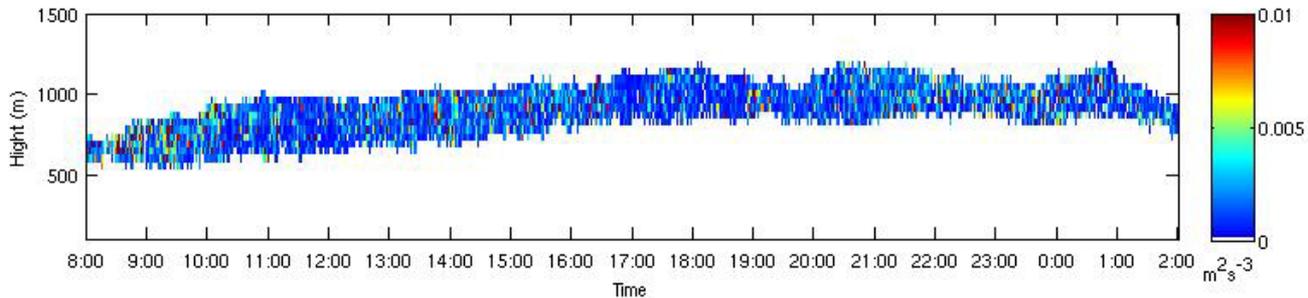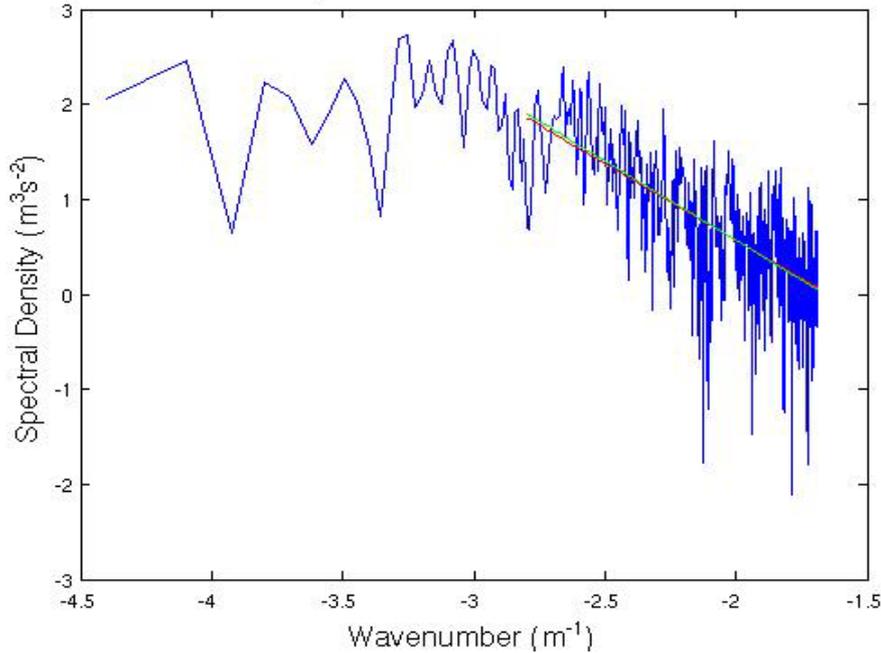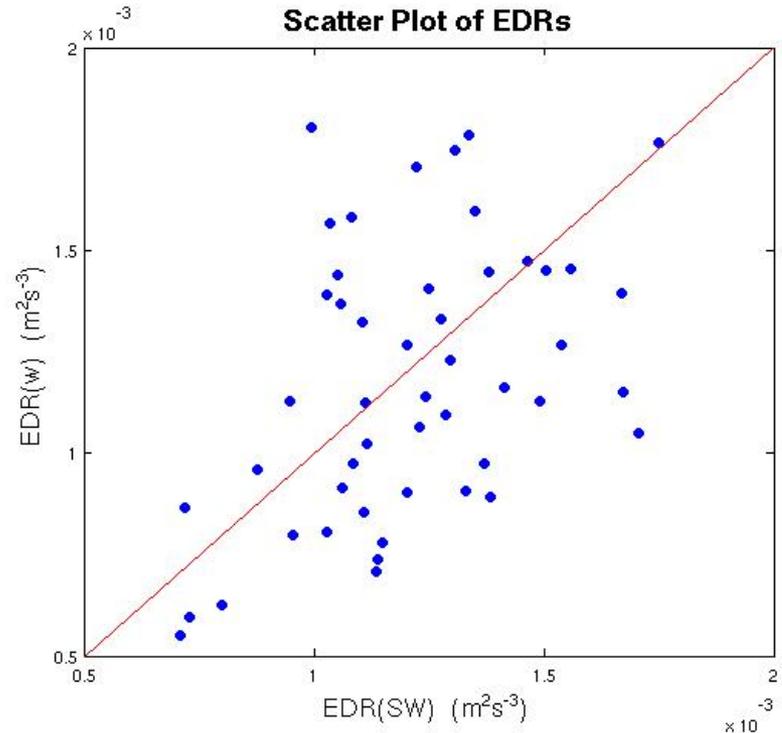## 08:00 03/25/2005 – 02:00 03/26/2005

EDR(w) and EDR(SW)

Power Spectra 20050325 11:00-12:00

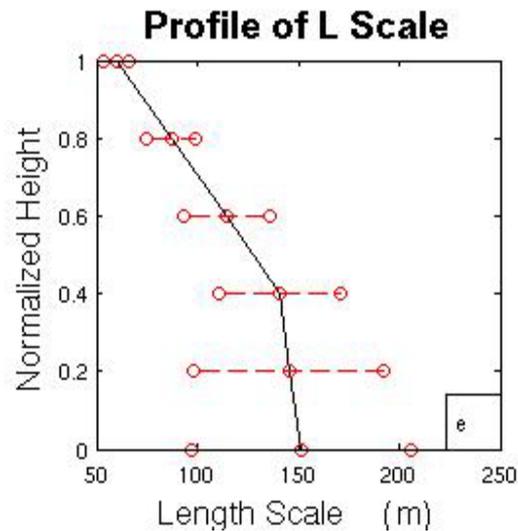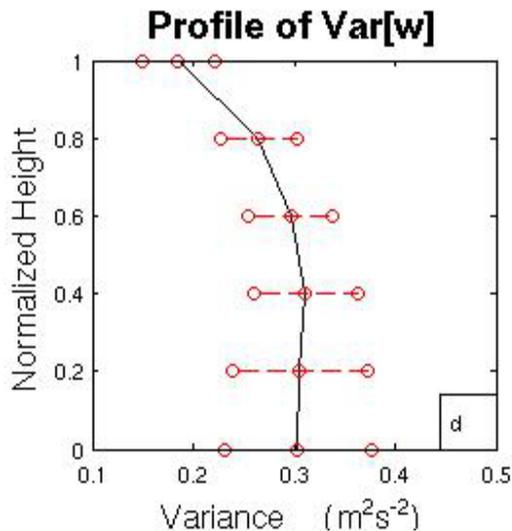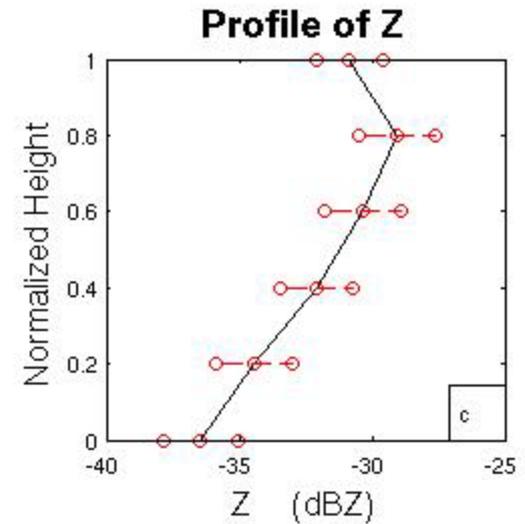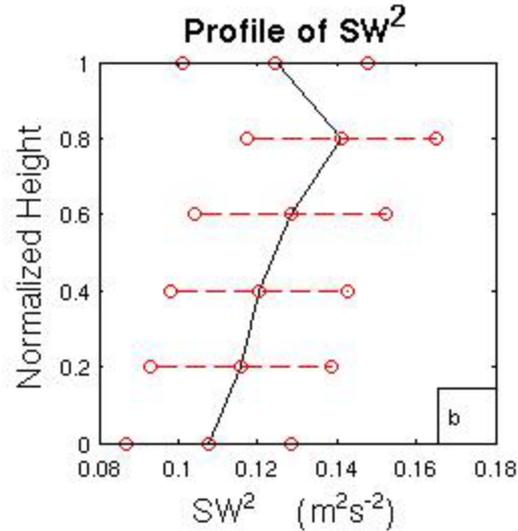$$\varepsilon = \frac{1}{\delta}\left[\frac{\hat{\sigma}_t^2}{1.35\alpha\left(1-\gamma^2/15\right)}\right]^{3/2}$$

Scatter Plot of EDRs
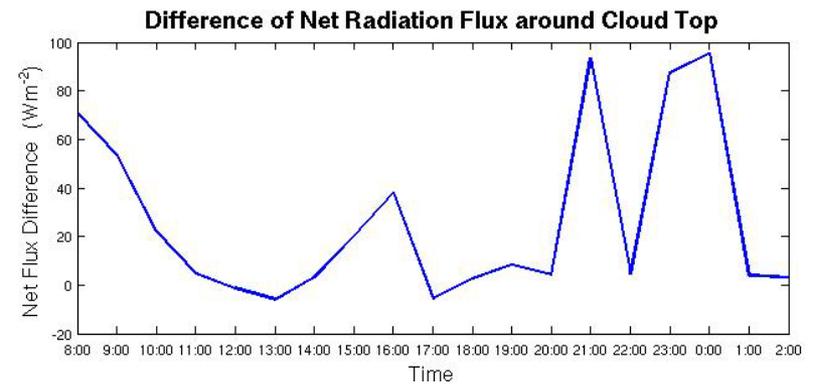
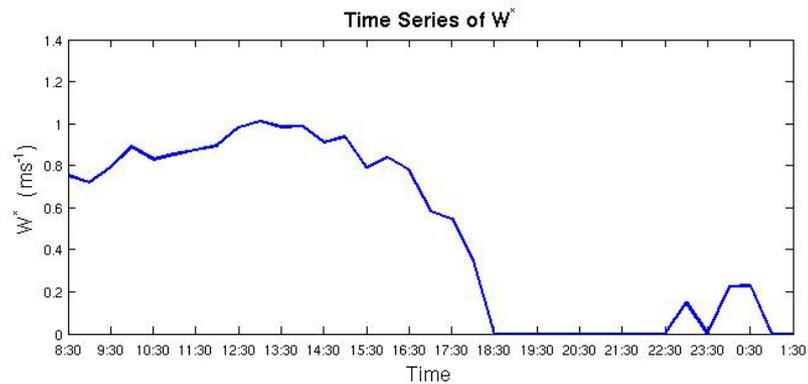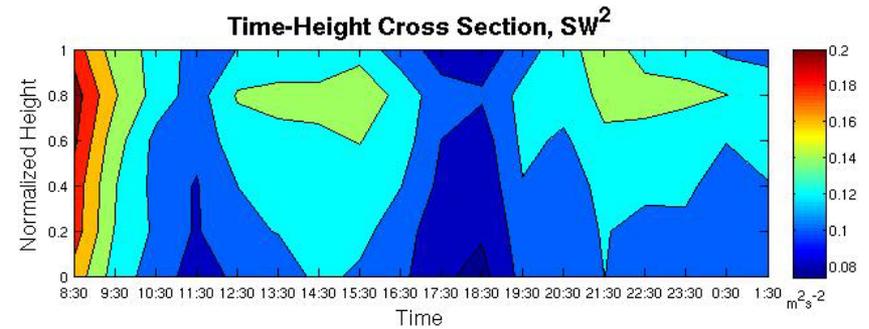$$S(k) = a\varepsilon^{\frac{2}{3}}k^{-\frac{5}{3}}$$
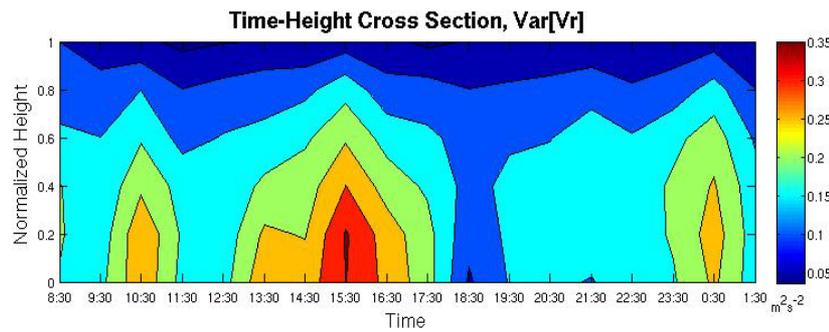
18H Profiles, EDR, SW², Z, Var[w], l_w
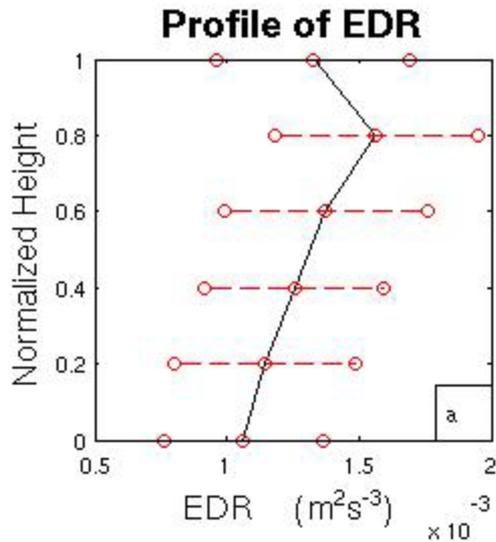
Vertical integral length scale

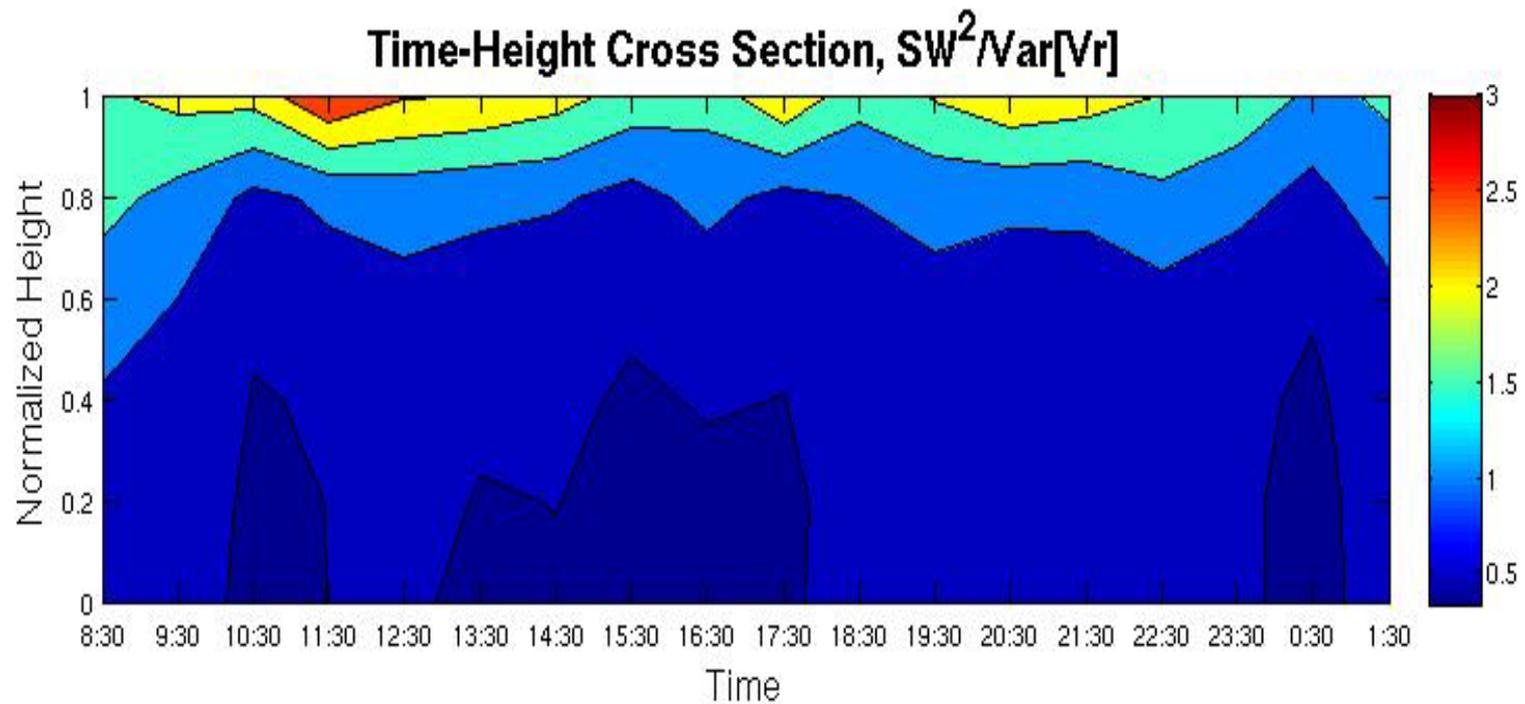$$l_w = \frac{\sigma_w^{3/2}}{\bar{\varepsilon}}$$

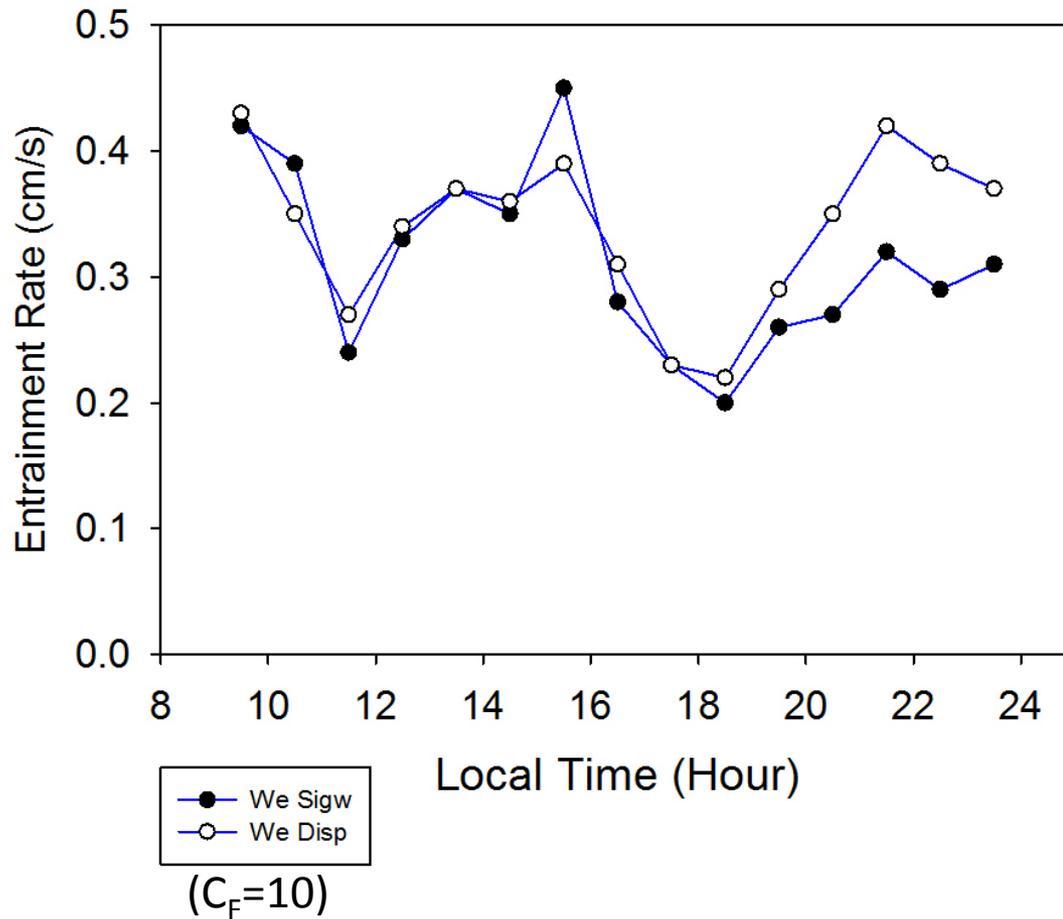# Resolved and Unresolved Turbulence
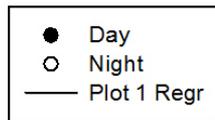
Resolved and Unresolved Turbulence
SW^2/Var[Vr]

Time-Height Cross Section, SW^2/Var[Vr]

Entrainment Rates

$$w_e = \frac{C_F \, \sigma_w^3 / h - \varepsilon_i}{\Delta \theta_v}$$

$(C_F = 10)$

$$\varepsilon_i = C_D \sigma_w^3 / \ell_i$$

$$w_{e\sigma} \Big/ w_{e\varepsilon} = \frac{C_F \ell_i}{C_D h} \propto \frac{\ell_i}{h}$$

Day
Ratio: 1.16

Night
Ratio: 0.62

Ent Rate Var (cm/s)

Ent Rate -- Disp (cm/s)

● Day
○ Night
— Plot 1 Regr
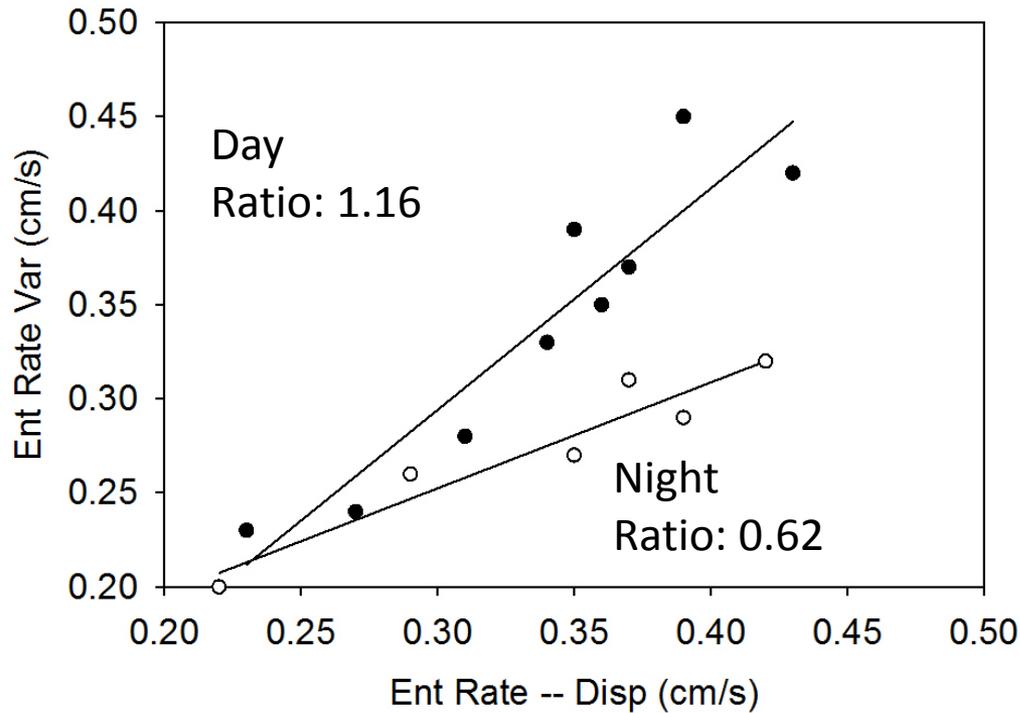
$$w_e = \frac{C_F \sigma_w^3 \Big/ h - \varepsilon_i}{\Delta\theta_v} = \frac{C_F' \sigma_w^3 \Big/ h_i}{\Delta\theta_v} = \frac{C_D' \varepsilon_i / \ell_i}{\Delta\theta_v}$$

Summary

- Entrainment rates are proportional to quantities that can be derived from Doppler radar observations (Verification?)

    - Fine angular resolution of MMCR limits the contribution of cross beam wind and the impact of T_c to SW
    - EDR calculated from SW agrees with that calculated from Var[w]
    - Additional observations?

- Dissipation term important in the TKE budget in entrainment zone but depends on scales that vary with turbulence structure

- Implications for Modeling?
    - Parameterization
    - LES