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

Flux Measurements:

See Kaimal and Finnigin, Ch. 6. and LiCor reference guide:
http://www.licor.com/env/pdf/eddy_covariance/ECbook2013.pdf

1) Eddy Covariance Principals

   Co-variance of the time series
   Reynolds stress: $\overline{u'w'}$, Heat flux (raw): $\overline{w'\theta'}$, Moisture flux: $\overline{w'q'}$, Tracer gas flux: $\overline{\chi'\rho'w'}$
   Reynolds decomposition of $F = \overline{\rho w \chi}$ to give $F = \overline{\rho}\,\overline{w'\chi'}$.

2) Trace Gas or Aerosol Measurements

   Infrared gas analyzers, Radiation spectra, Beer-Lambert Law
   Optical sensors, Ionization, Particle Charging

3) Other Methods

   Profile Method: $F = -K\frac{d\rho}{dz}$, where $K = \kappa u_* z/\Phi$
   Relaxed Eddy Accumulation

4) Sonic Anemometers (*u*, *v*, *w*, *T*)

   See: Schotland (1955) The measurement of wind velocity by sonic means, *J. Meteor.*, 12, 386-390.
   and: http://www.apptech.com/history-of-sonic-technology.html for some history by Kaimal.

   The speed of sound in air $C = \sqrt{\frac{\gamma R T_v}{m}}$. Measure *C* in the *w* direction and solve for T_v .

   The velocity is determined as $V_d = \frac{d}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right) = \frac{d\Delta t}{2t^2}$.

   Footprint: $CNF(x) = \exp\left(-\frac{U(z-d)}{u_*\kappa\, x}\right)$

5) Measurement Corrections

Time delay (cross-correlation), Detrending (stationarity), Frequency response

Rotation in *z*, *y*, *x*: (See Wilczak et al., Boundary-Layer Meteorology, 2001)
Align to mean wind ($\overline{v} = 0$); level anemometer to ground ($\overline{w} = 0$); 3rd rotation ($\overline{w'v'} = 0$).
$u_1 = u_m \cos\theta + v_m \sin\theta$, and $v_1 = -u_m \sin\theta + v_m \cos\theta$, where $\theta = \tan^{-1}(\overline{v_m}/\overline{u_m})$
$u_2 = u_1 \cos\phi + w_1 \sin\phi$, and $w_2 = -u_1 \sin\phi + w_1 \cos\phi$, where $\phi = \tan^{-1}(\overline{w_1}/\overline{u_1})$

Webb Correction

$$F_c = \overline{\rho_d w's'} = \overline{w'q'_c} + \mu \frac{E}{\overline{\rho_d}} \frac{\overline{q_c}}{1+\mu \frac{\overline{\rho_v}}{\overline{\rho_d}}} + \frac{H}{\overline{\rho} C_p} \frac{\overline{q_c}}{\overline{T_a}} - (1+\mu \frac{\overline{\rho_v}}{\overline{\rho_d}}) \frac{\overline{w'P'}}{\overline{P}} \overline{q_c}$$