Key Lessens in Eddy-Covariance Measurements

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Outline

- Re-visit of mass balance (advection)
- Density + advection corrections
- Coordinate (rotation)
- Averaging time length (low frequency)
- Co-spectral correction (high frequency)
- The friction velocity (u_*) criterion
- Gap filling method
- Sensor height (vertical flux divergence, footprint)

Lee 1998 Agricultural and Forest Meteorology, 91, 39-49

$$\mathrm{NEE} = \int_0^{z_r} \frac{\partial \bar{c}}{\partial t} \mathrm{d}z + \left(\overline{w'c'}\right)_r + \bar{w}_r \left(\bar{c}_r - \frac{1}{z_r} \int_0^{z_r} \bar{c} \mathrm{d}z \right)$$

Storage **EC-Flux** **Mean Vertical Advection**

- **Re-visit of mass budget equation**
  continuity equation
- **Consideration of contribution by vertical mean advection**
- **A 1-D linear regression to estimate mean vertical velocity**

Paw U et al. 2000 Boundary-Layer Meteorology, 97, 487-511

$$\bar{\rho}\frac{\partial \bar{s}}{\partial t} + \bar{s}\frac{\partial}{\partial z}\left[\frac{\bar{\rho}}{\bar{T}}(1+\mu\sigma)\overline{(w'T')} + \mu\overline{(w'\rho_v')}\right] + \bar{w}\bar{\rho}\frac{\partial \bar{s}}{\partial z} + \frac{\partial\overline{(w'\rho_c')}}{\partial z} = \bar{S}_c$$

Storage

Air Density Flux Term From Continuity

Mean Vertical Advection

EC-Flux

$$\mu \equiv \frac{m_a}{m_v} \quad \text{and} \quad \sigma \equiv \frac{\bar{\rho}_v}{\bar{\rho}}$$

- **Incorporation of both air density flux and advection**
- **A 2-D planar fit method to estimate the mean vertical velocity**

Paw U et al. 2000

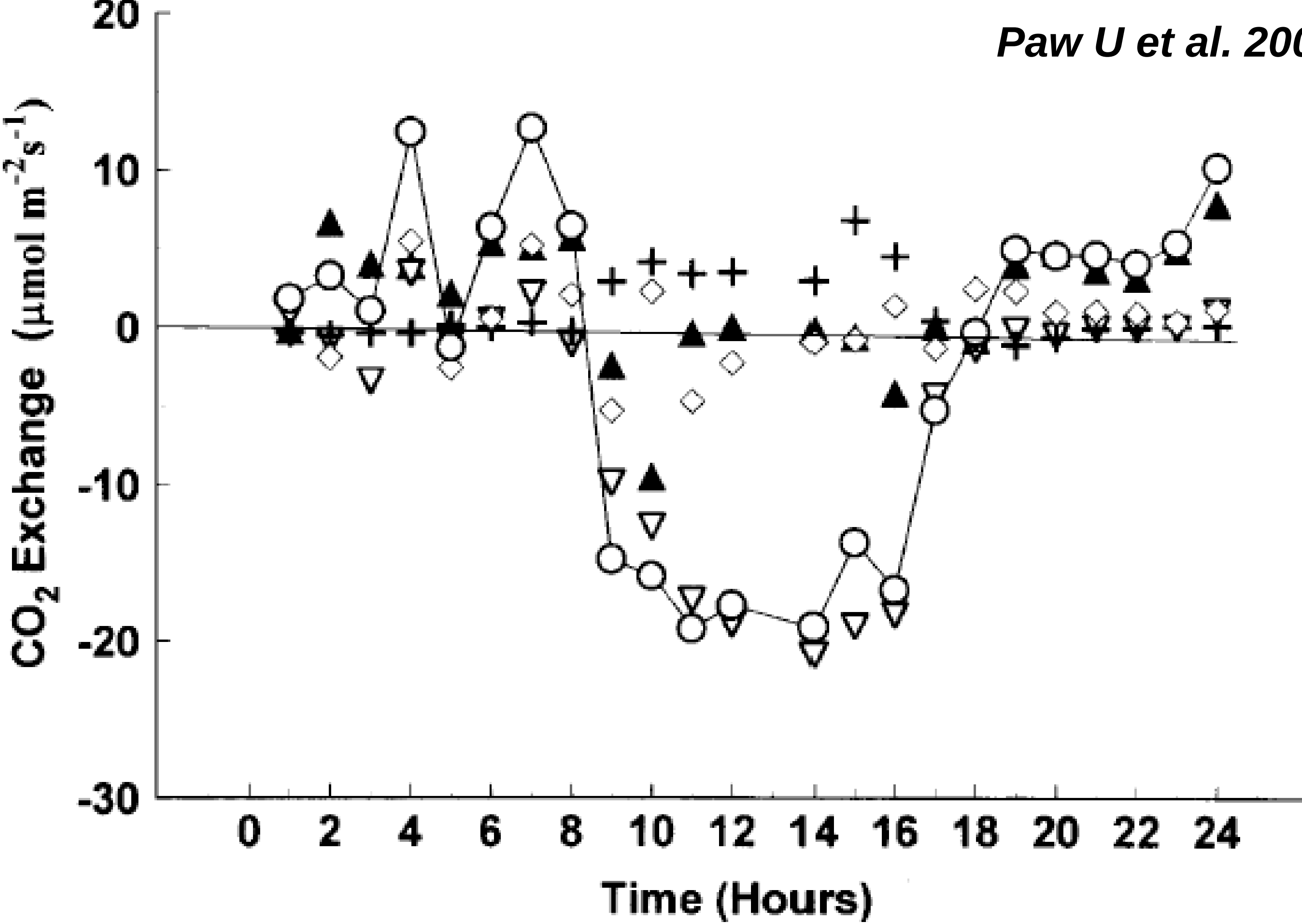


Figure 8. Components of the net ecosystem exchange (NEE) of CO_2 over a deciduous forest, day 293. The circles represent the NEE, the inverted open triangles, the eddy covariance, the solid triangles, the vertical advection, the diamonds, the transient storage term, and the pluses, the Webb et al. (1980) correction.

Finnigan 1999 Agricultural and Forest Meteorology, 97, 55-64

that the appropriate analysis framework for constructing such budgets is unavoidably two- or three-dimensional because 2
and 3D mean velocity fields always induce streamwise variation in the eddy fluxes of scalars.

that in such flow fields it is generally incorrect to assume that the vertical component of advection $\bar{w}\partial\bar{c}/\partial z$ is everywhe
much larger than the horizontal component $\bar{u}\partial\bar{c}/\partial x$ The vertical component can only provide a good measure of tot
advective flux divergence in the special circumstance where the tower is located beneath the vertical stagnation streamline
a recirculating flow. By referring to a linear model of scalar transport over a hill we show that the relationship betwe
$\bar{u}\partial\bar{c}/\partial x$ and $\bar{w}\partial\bar{c}/\partial z$ is entirely dependent on particular flow conditions and that, in general, $\bar{w}\partial\bar{c}/\partial z$ cannot even be used
provide a bound on the magnitude of total advection.

that for measurements at heights small compared to the horizontal scale of the advective flow, the horizontal gradient
turbulent flux $\partial\overline{u'c'}/\partial x$ can probably be neglected relative to its vertical equivalent $\partial\overline{w'c'}/\partial z$ and,

by using simple hydrodynamic models of 2D flows it can be shown that the vertical gradient of mean vertical velocity
approximately constant over tower heights small compared to the horizontal scale of the advective flow.

Coordinate - Rotation

$$\hat{w} = \bar{w} + a(\phi) + b(\phi)\hat{u}$$

Lee 1998

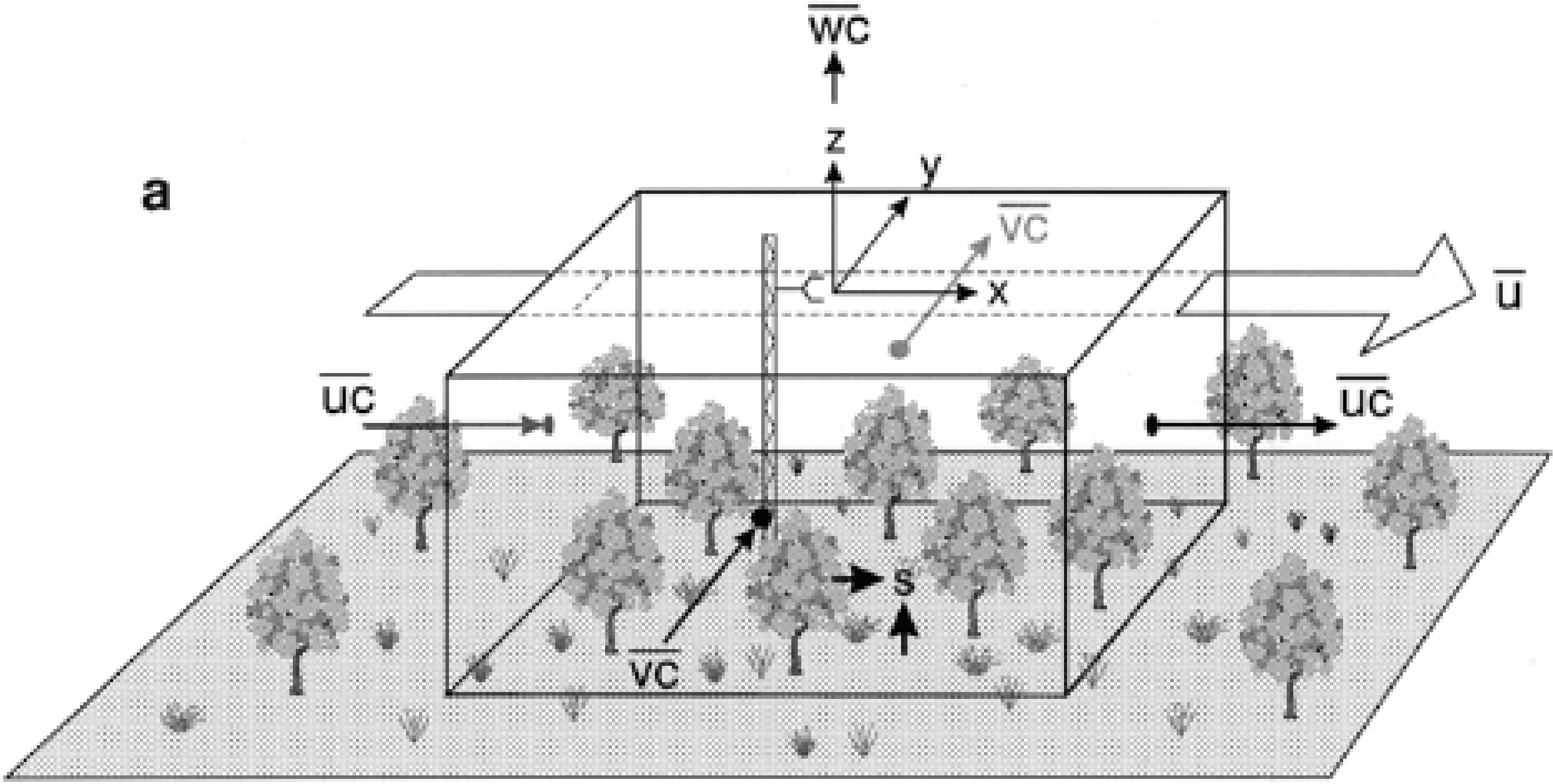
Ensemble average of vertical rotation angle as a function of azimuth

For example: Baldocchi 2000 Finnigan 2003, Su et al. 2004

2-D Planar Fit Method

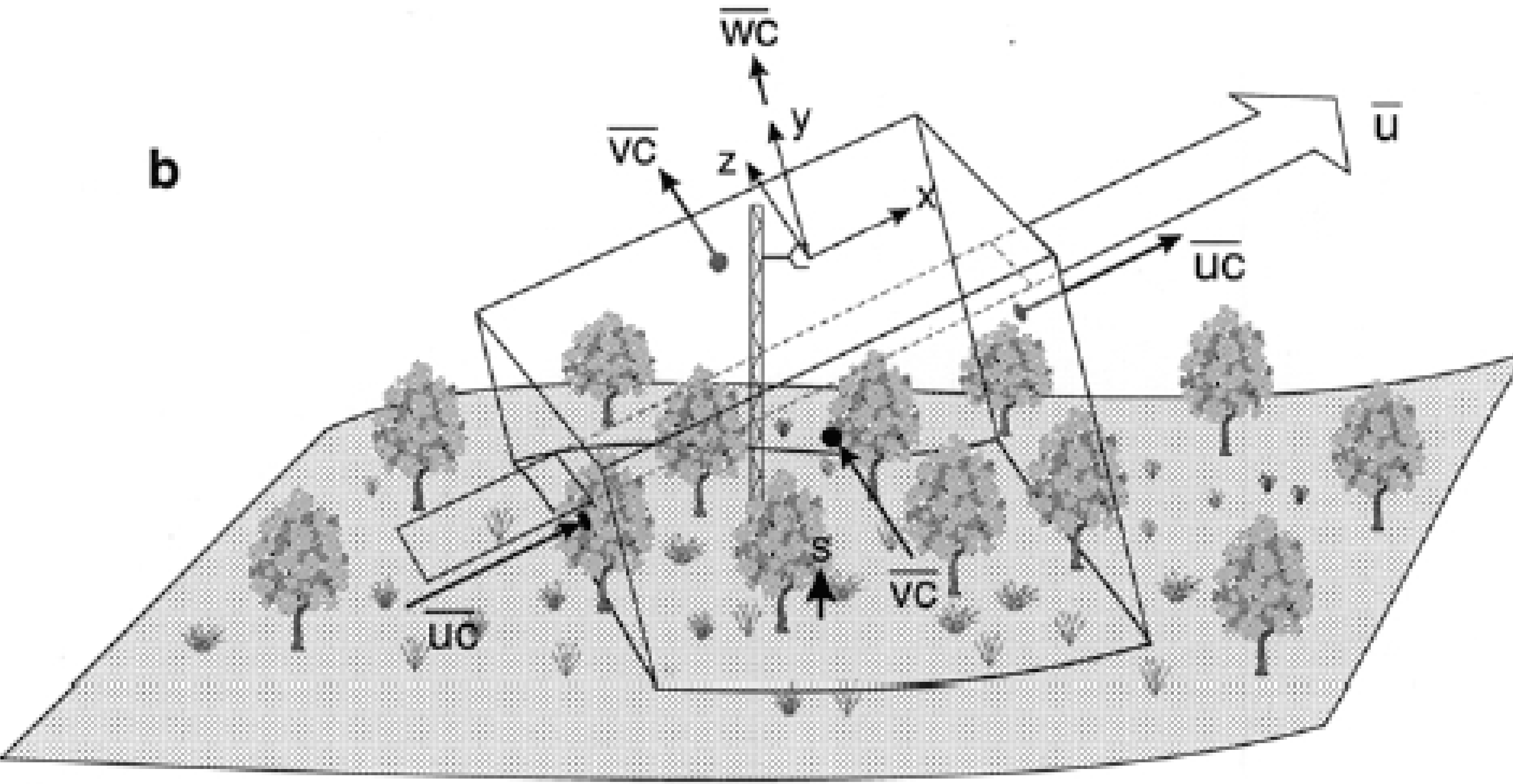
Paw U et al. 2000
Wilczak et al. 2001

Flat Terrain

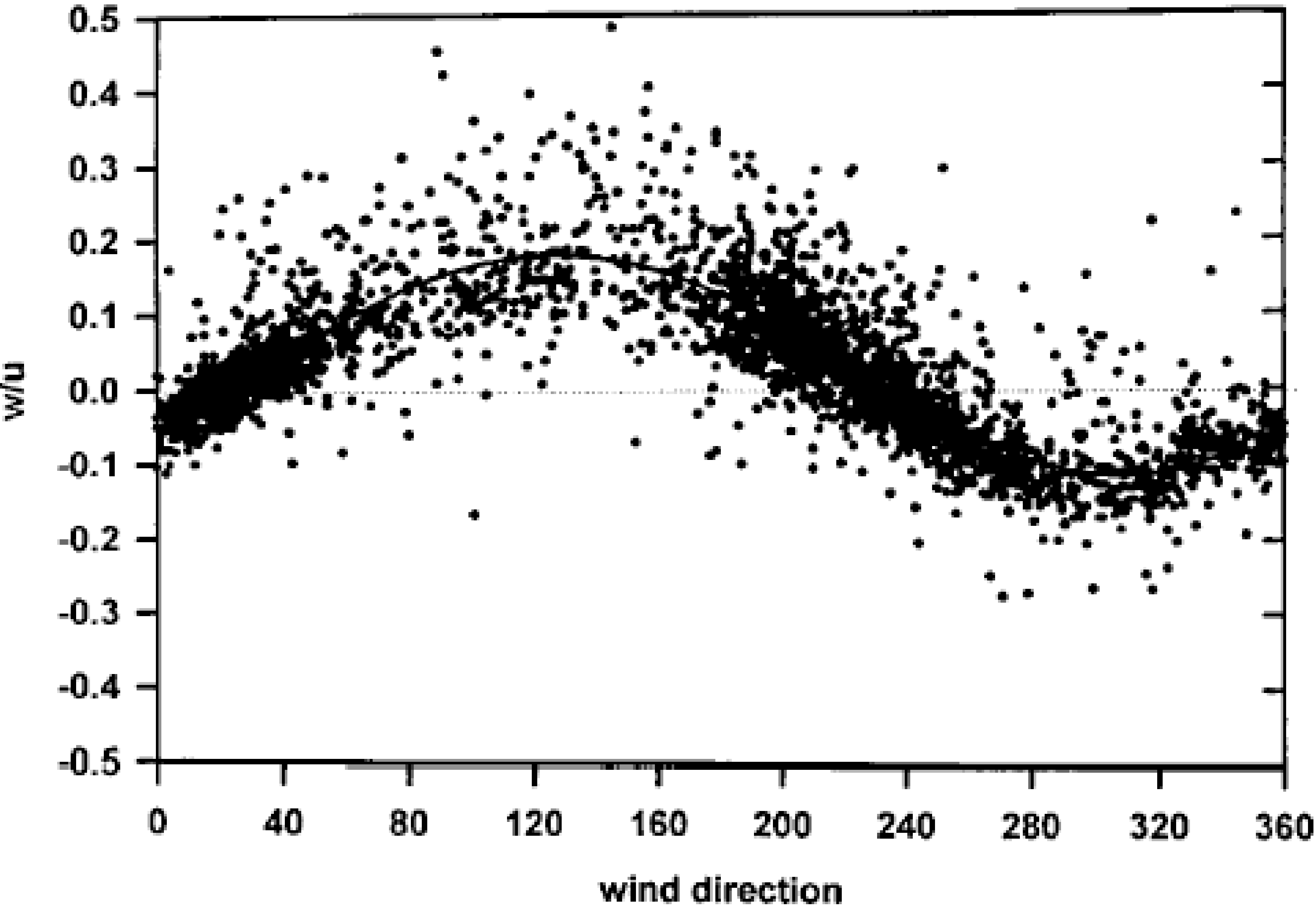


Finnigan et al. 2003 Boundary-Layer Meteorology

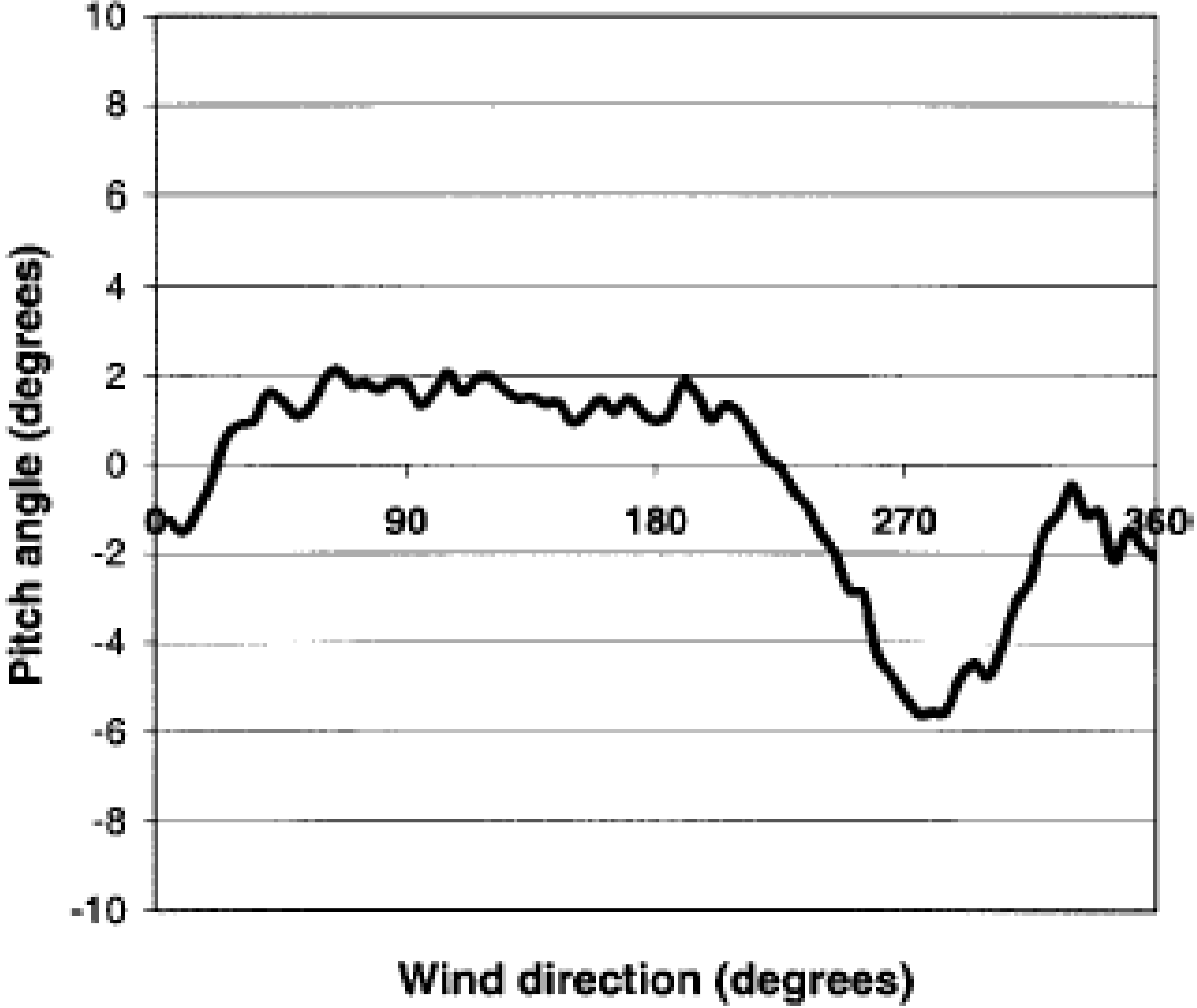
Non-flat or Complex Terrain



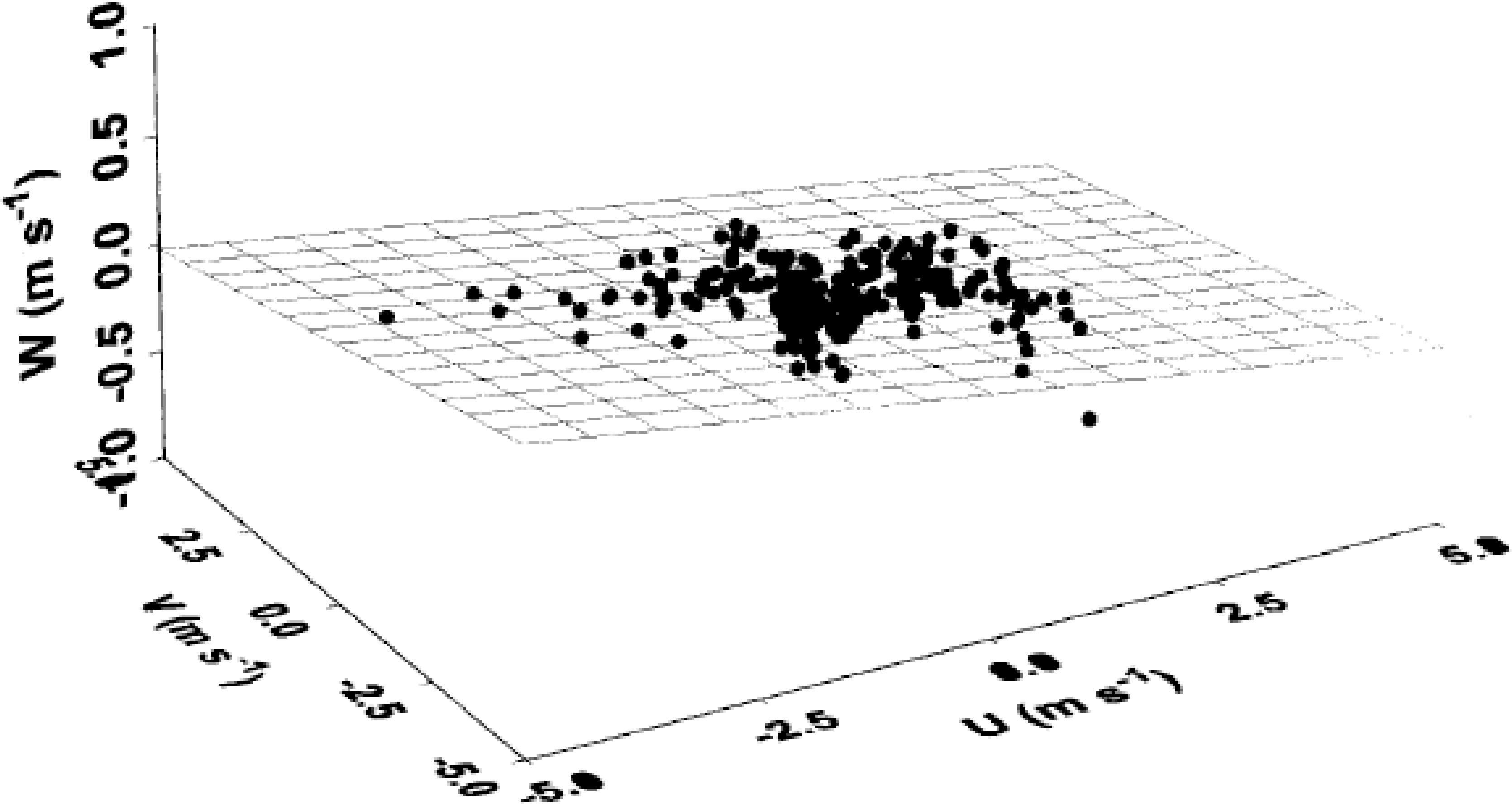
Finnigan et al. 2003 Boundary-Layer Meteorology



Baldocchi et al. 2000

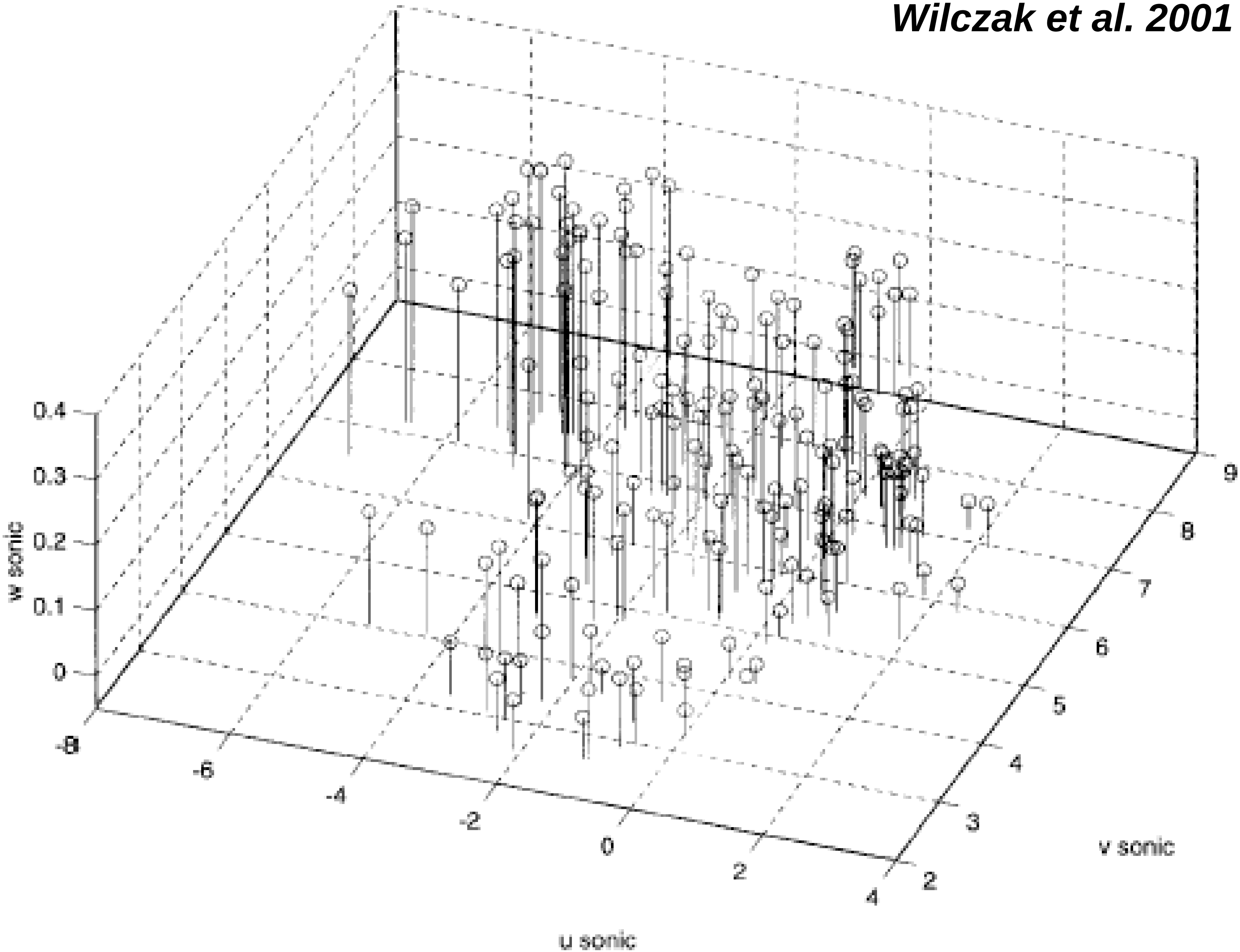


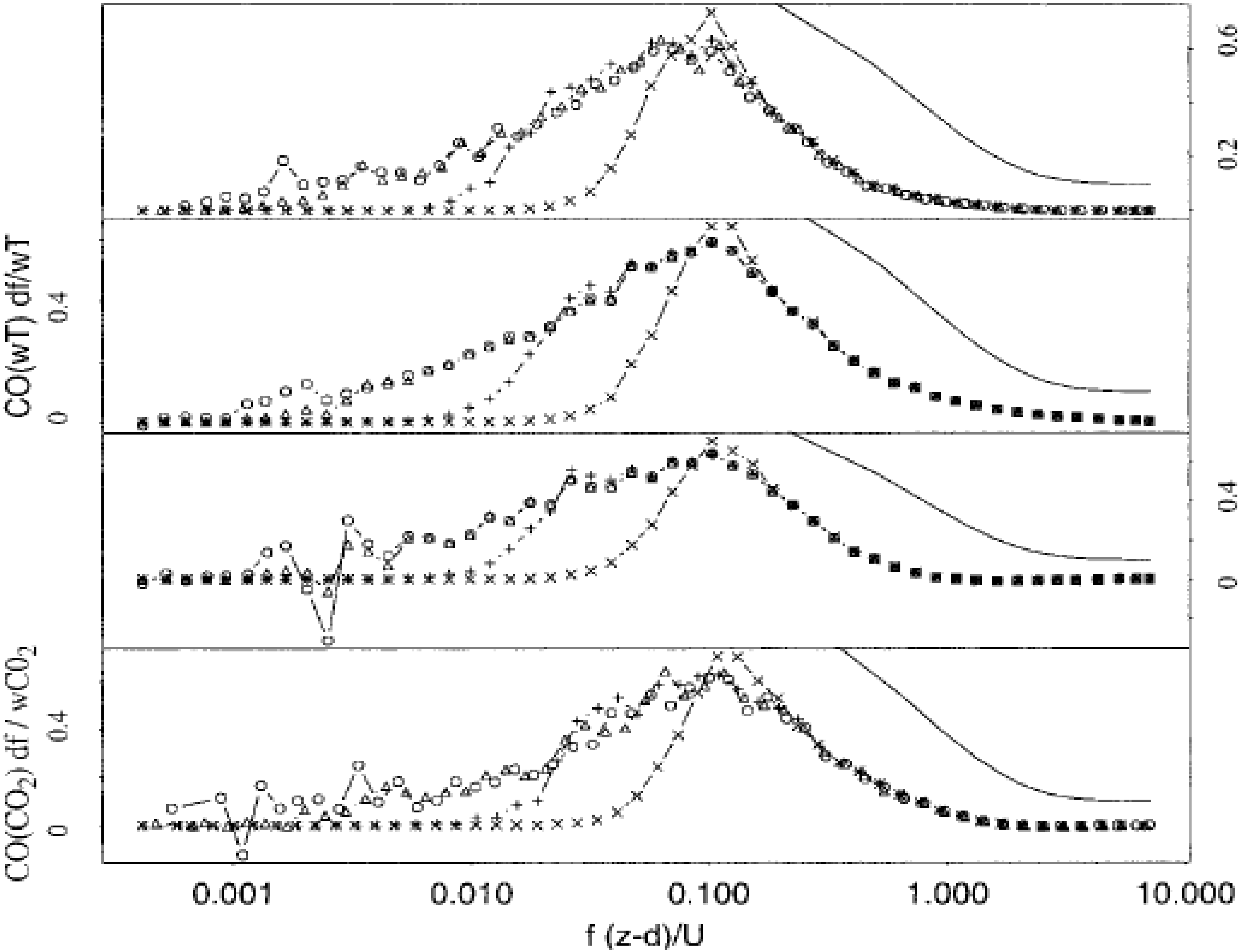
Finnigan et al. 2003 Boundary-Layer Meteorology w = -0.099998 -0.059016*u -0.043260*v



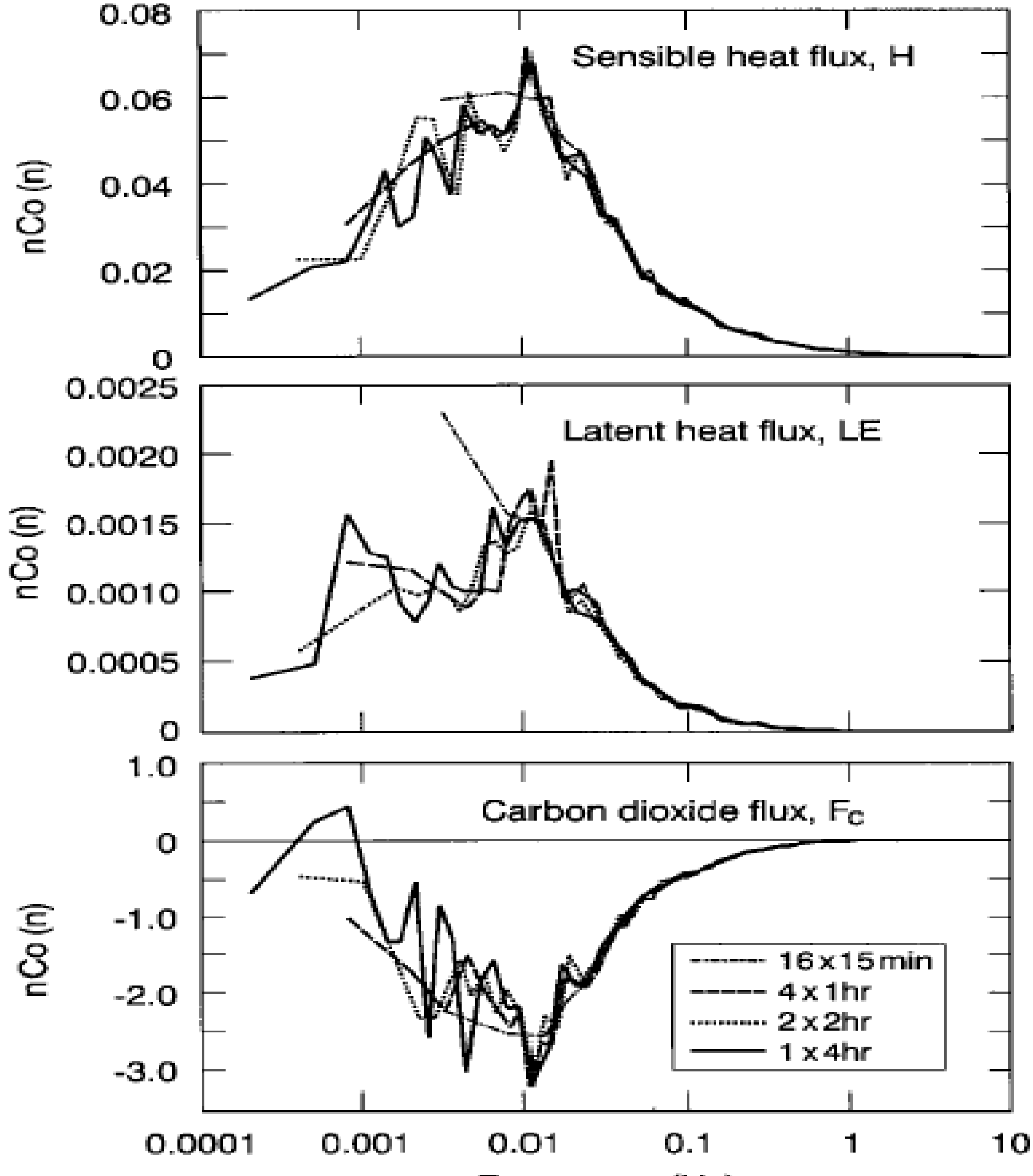
Paw U et al. 2000

Wilczak et al. 2001

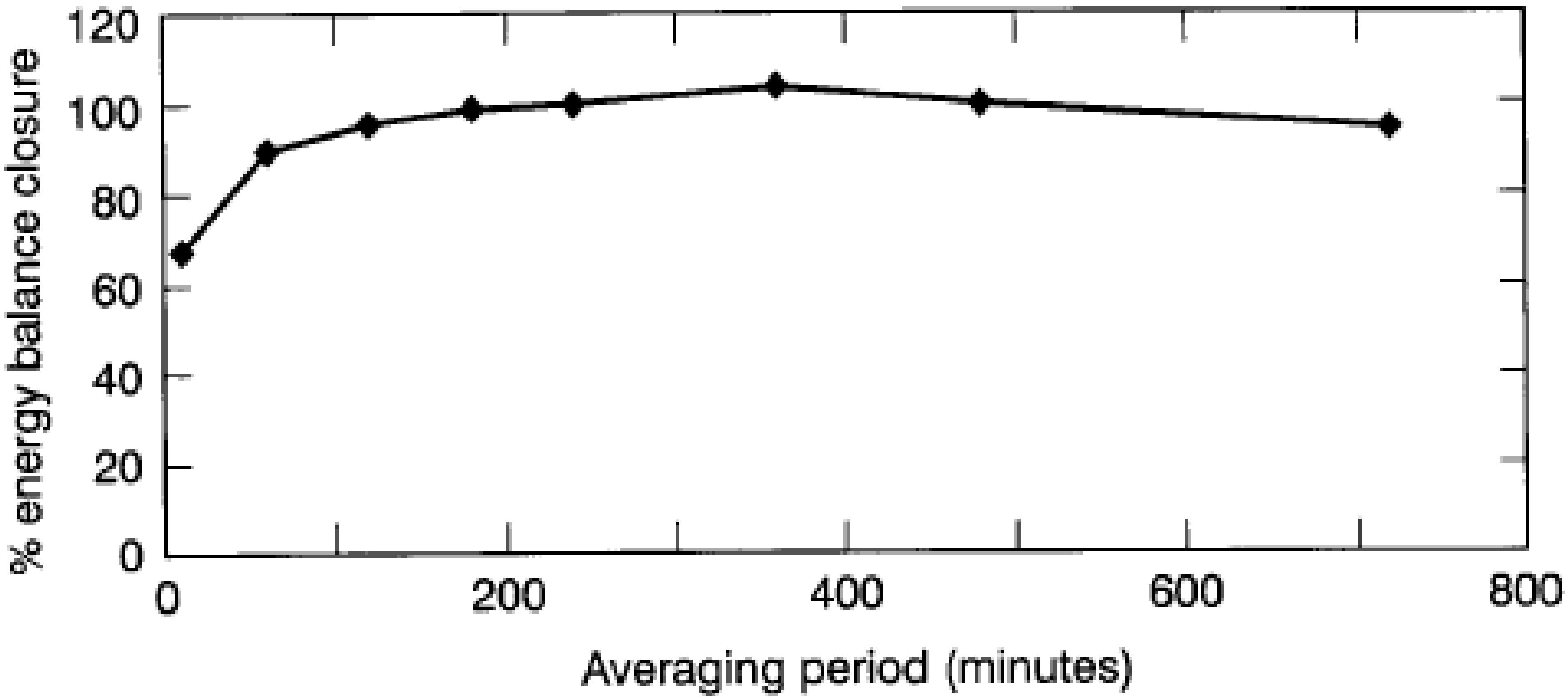




Sakai 2001 Journal of Applied Meteorology, 40, 2178-2192

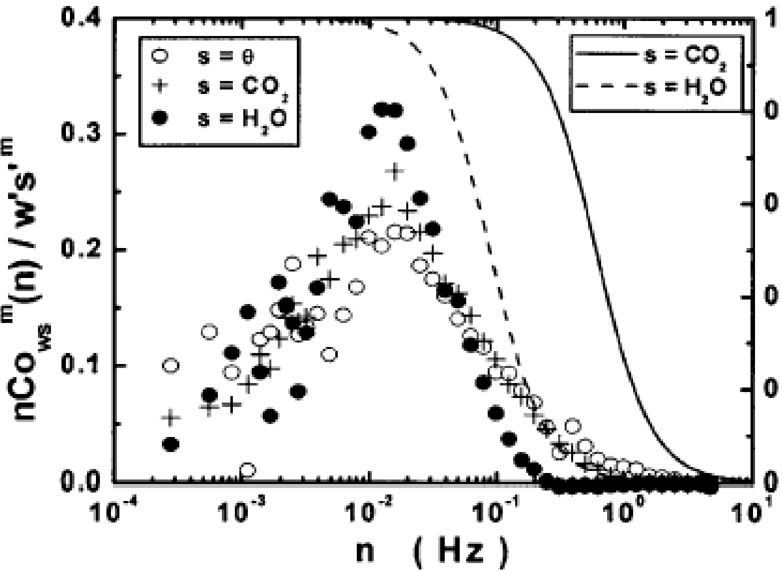


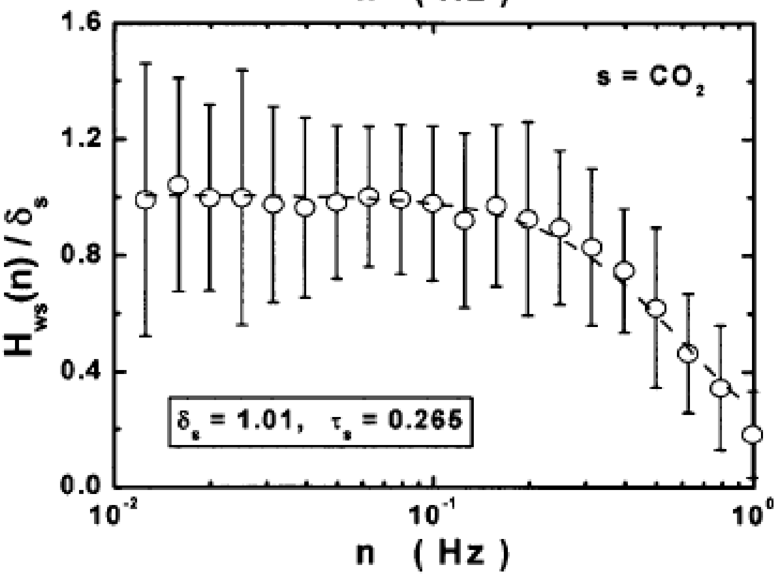
Finnigan et al. 2003 Boundary-Layer Meteorology, 107, 1-48

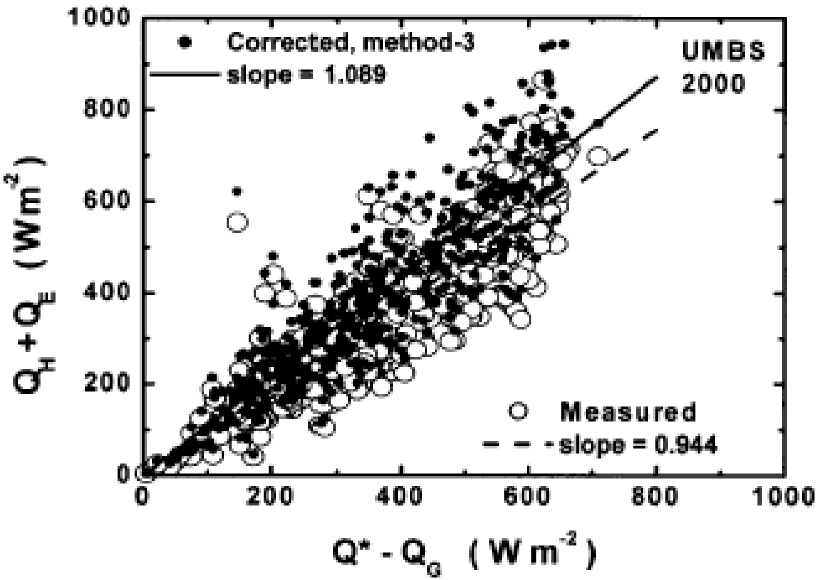


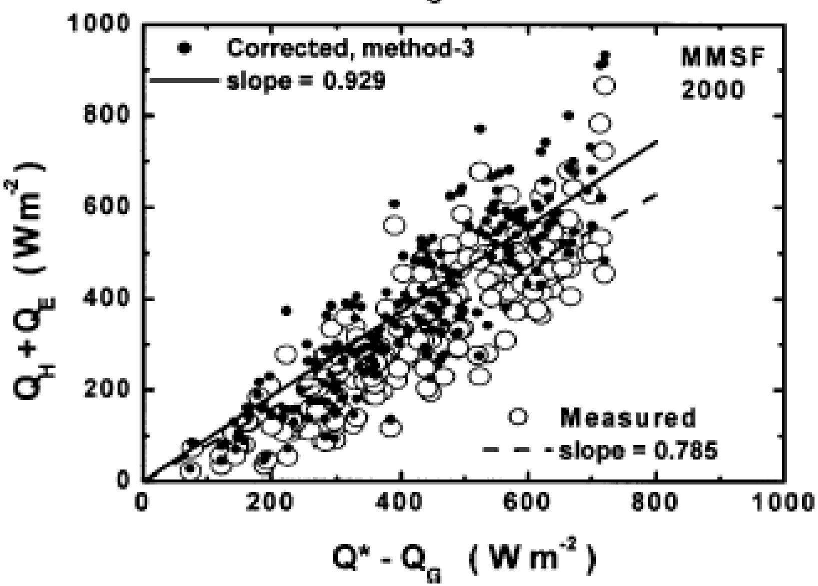
Finnigan et al. 2003 Boundary-Layer Meteorology, 107, 1-48

Co-spectral Correction (*Su et al. 2004*)

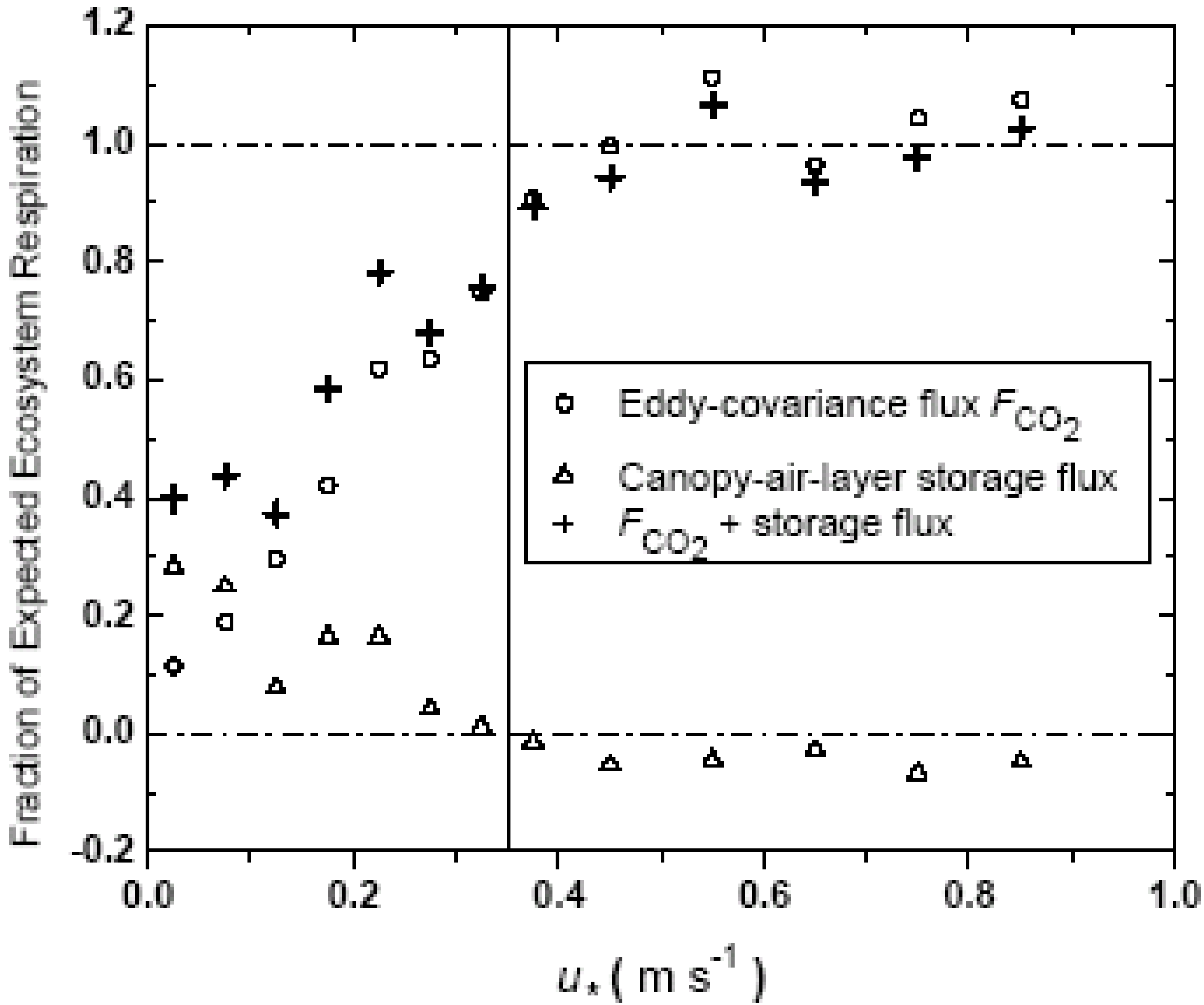






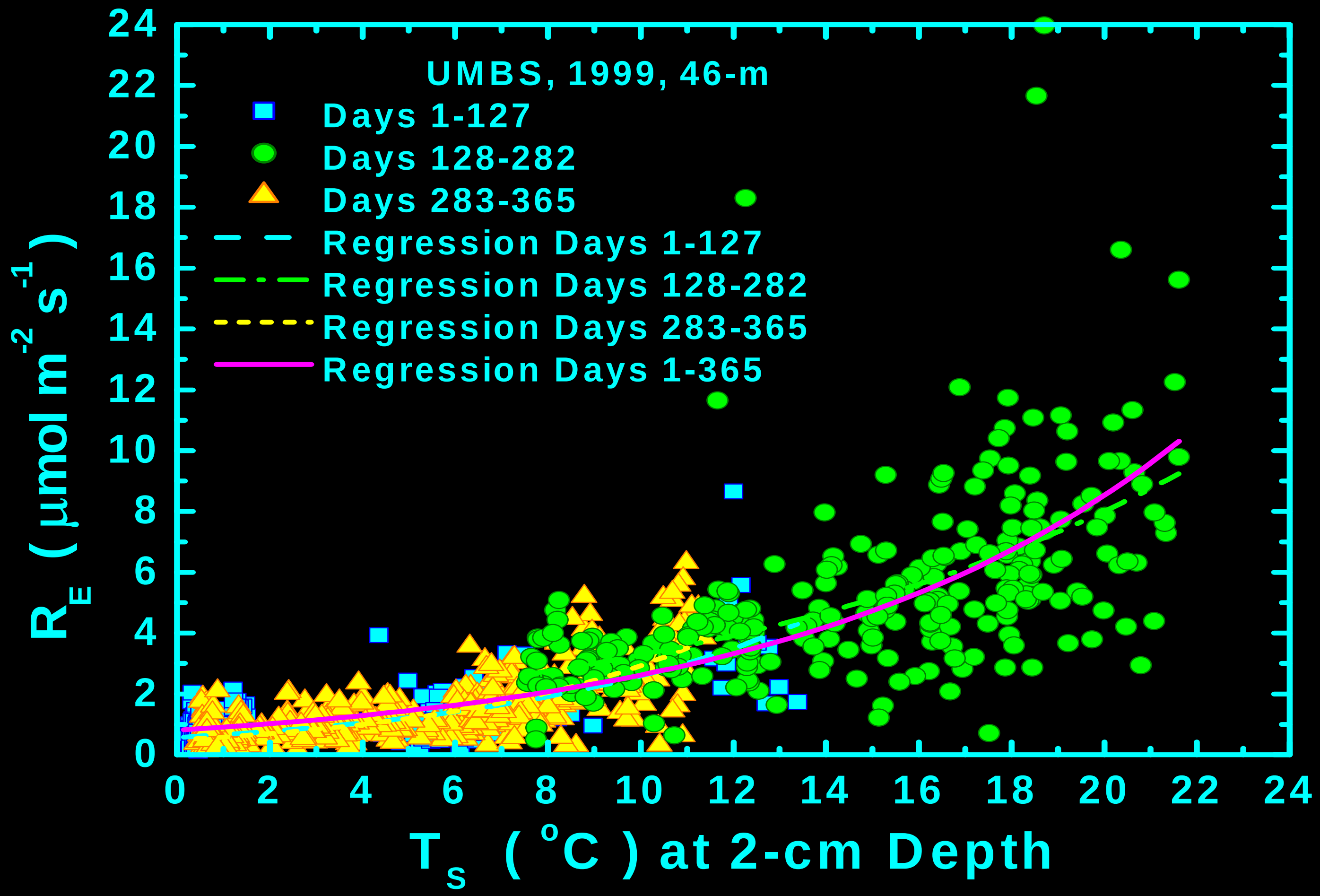


The friction velocity (u_*) criterion



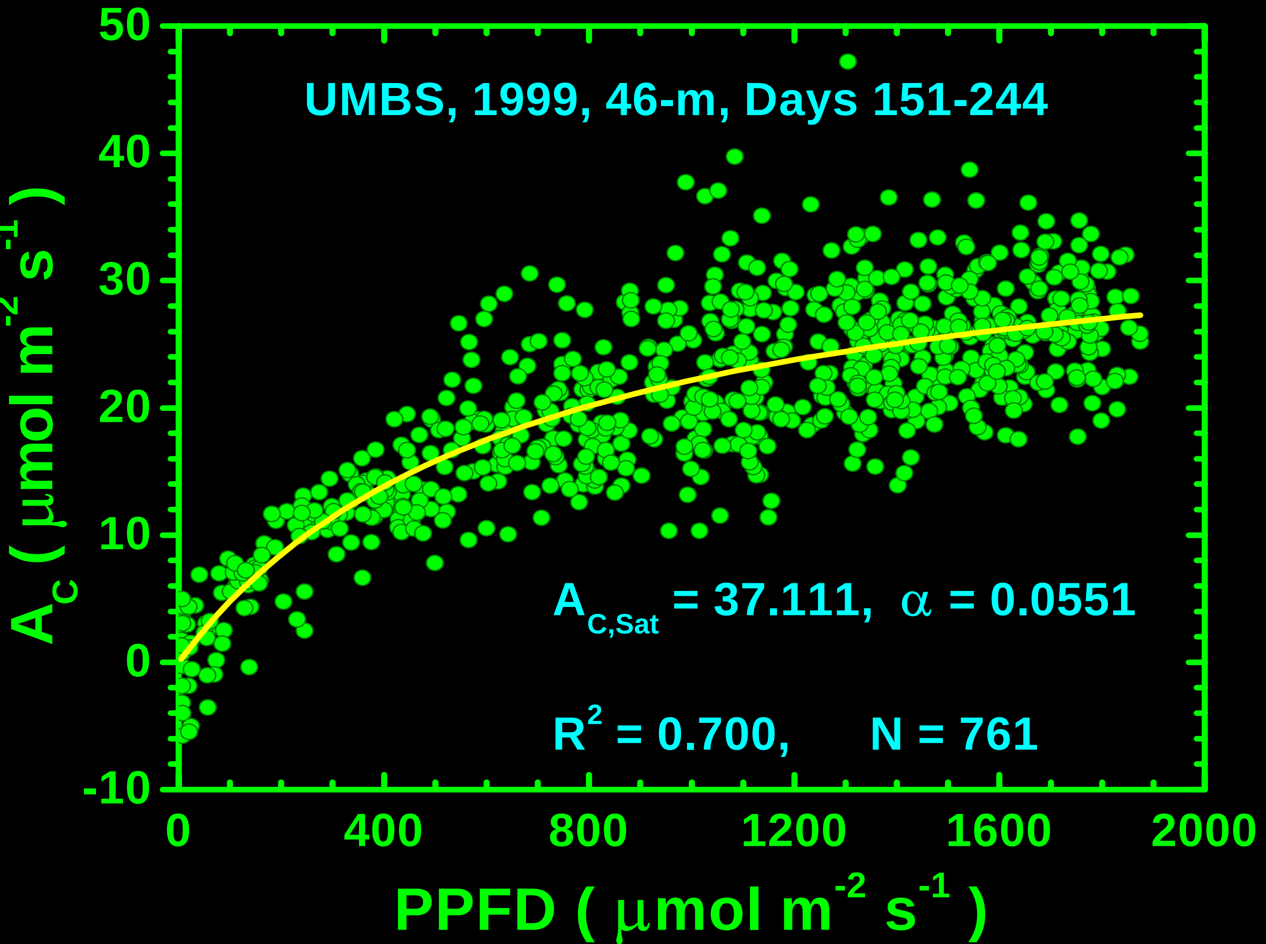
Forest Ecosystem Respiration — Soil Temperature Relationship

$$R_E = a \cdot \exp(b \cdot T_S)$$

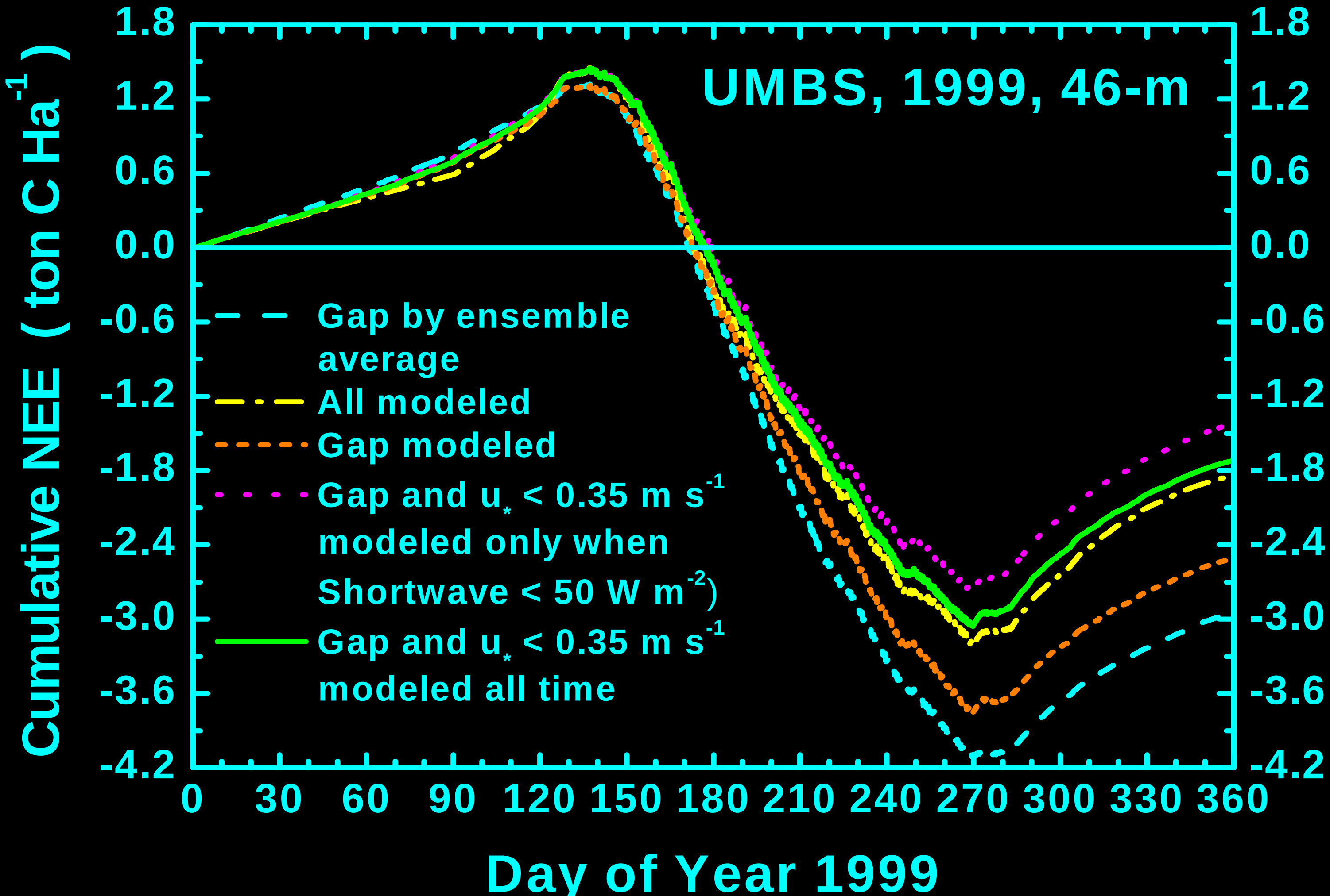


Light-Response at the Whole Forest Canopy Scale

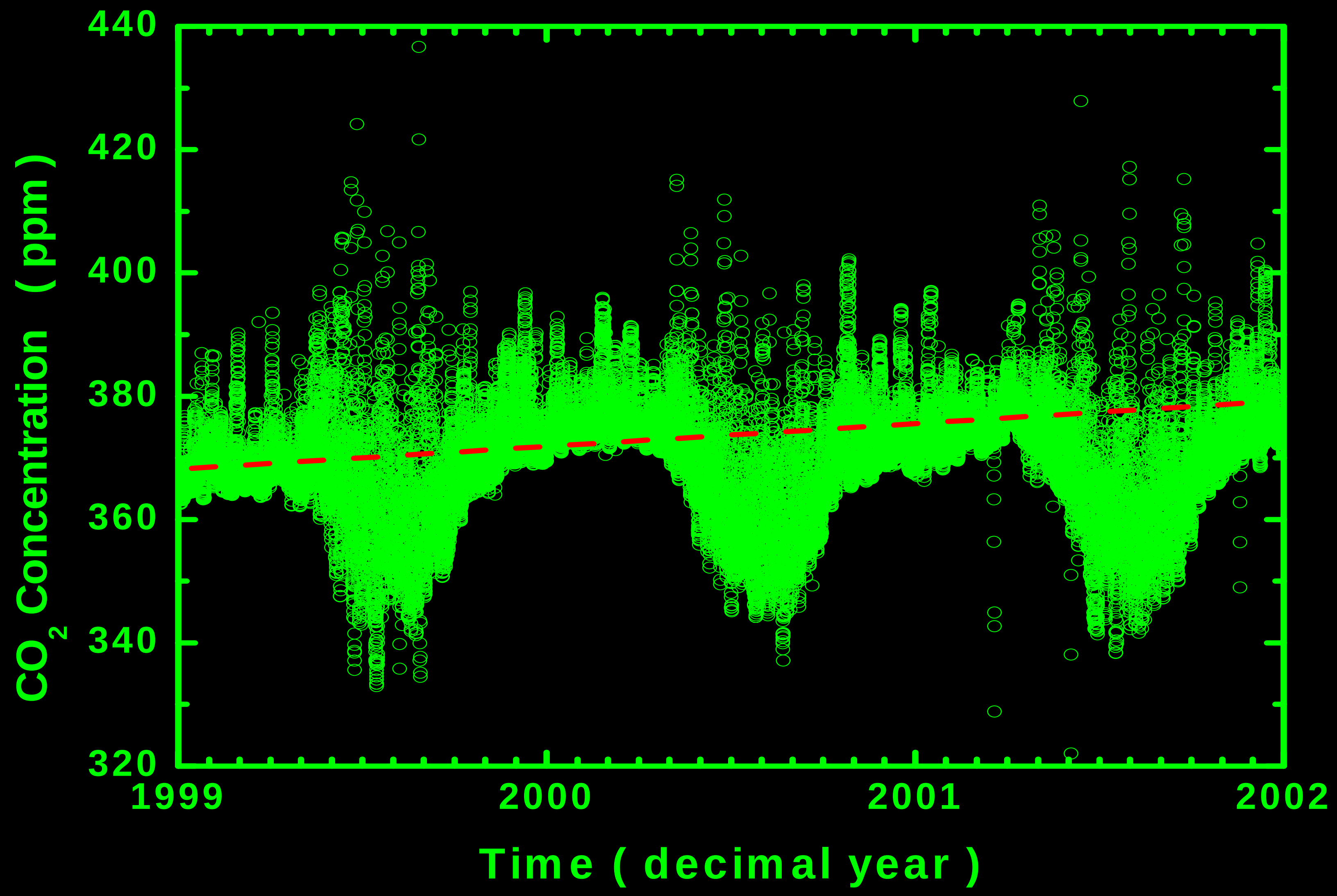
$$F_C = -A_C + R_E = -\frac{\alpha \cdot A_{C,Sat} \cdot PPFD}{A_{C,Sat} + \alpha \cdot PPFD} + R_E$$



Effect of Different Gap-Filling Methods on Annual NEE



Temporal Variation of CO_2 Concentration over UMBS Forest



Temporal Variation of CO_2 Flux over UMBS Forest