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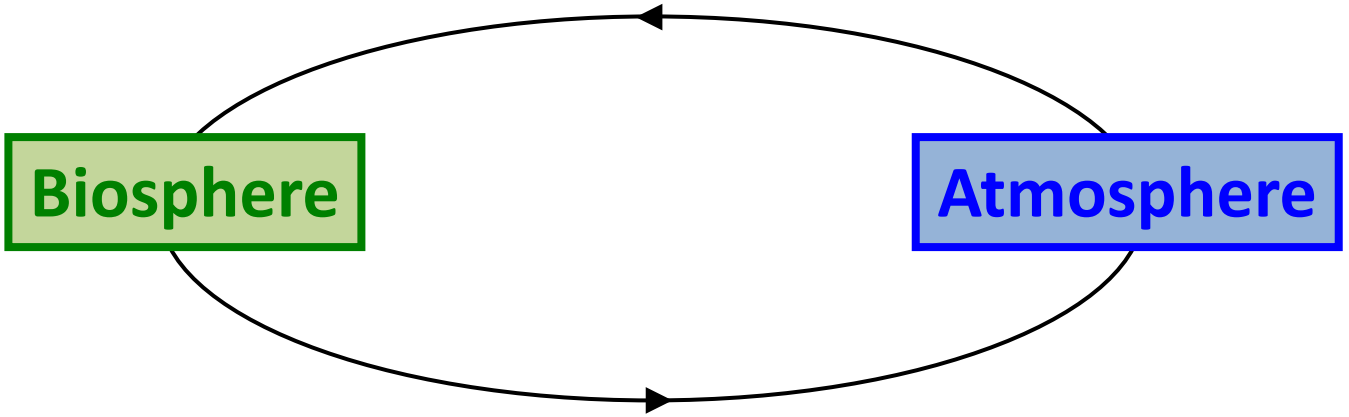
Microbes at the Interface of Land-Atmosphere Interactions

Biosphere-atmosphere exchange by means of micrometeorological methods

Georg Wohlfahrt, University of Innsbruck

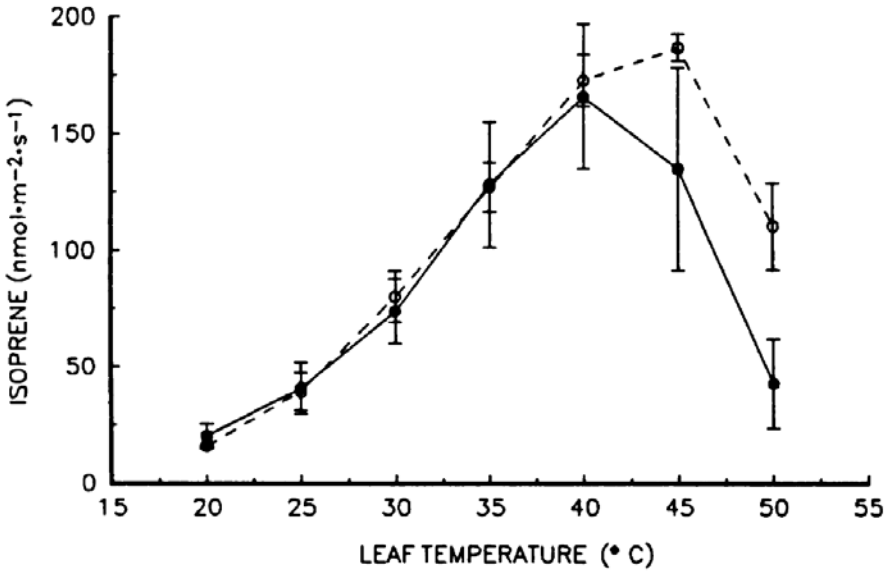
Bozen/Bolzano, 19. March 2016

Biometeorology is an interdisciplinary science which investigates the interactions between atmospheric processes and living organisms – plants, microbes, animals und humans.

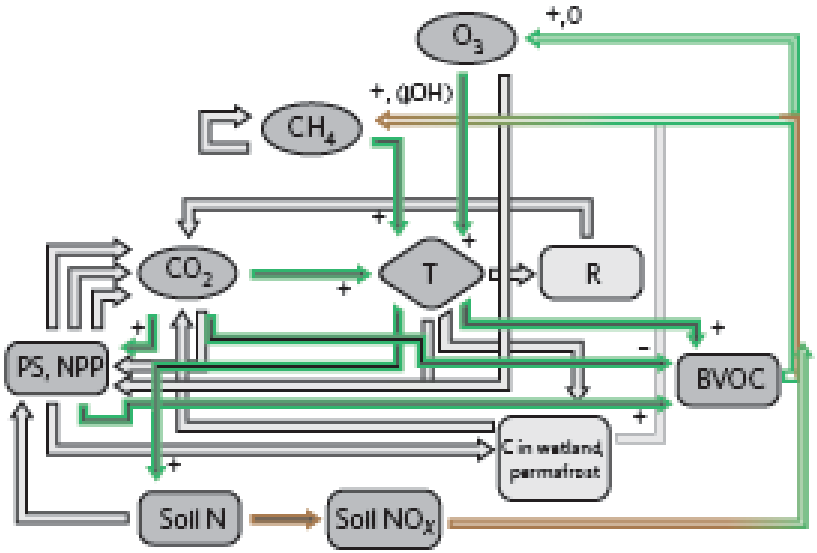


Example: BVOC

BVOC … biogenic volatile organic compounds

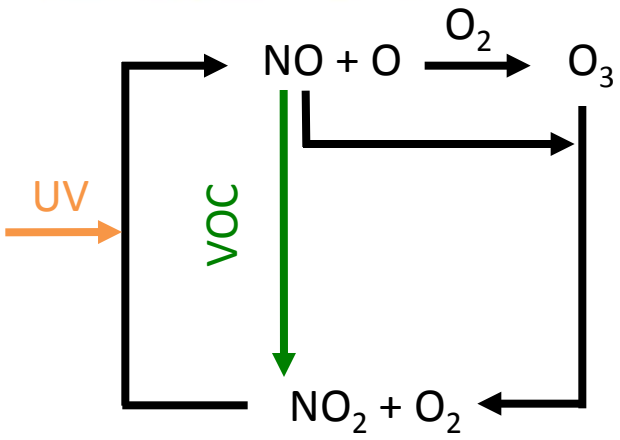


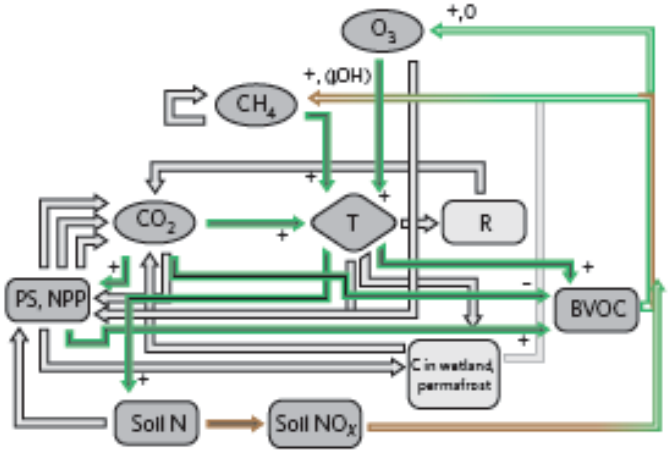
Monson et al. (1992)



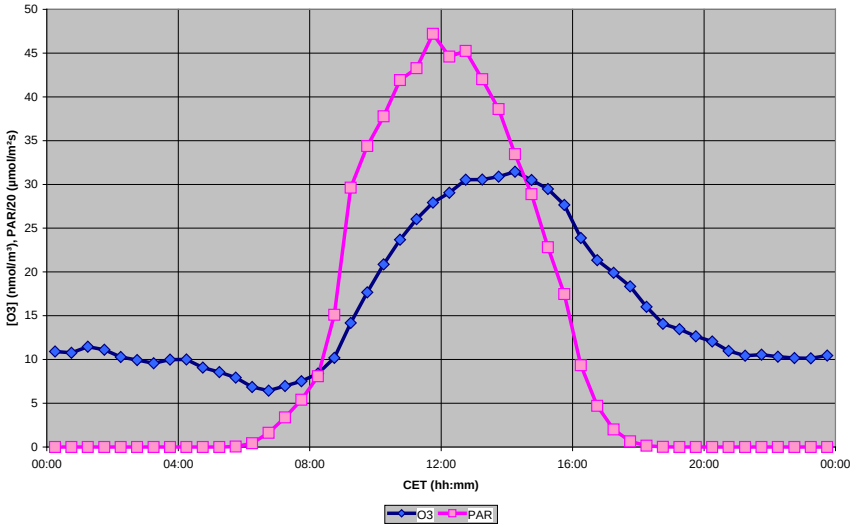
Arneth et al. (2010)

Example: BVOC





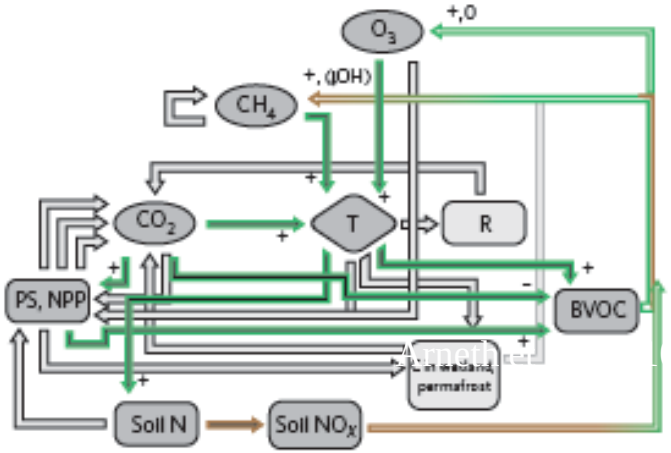
Arneth et al. (2010)



Without VOC hardly any net production of ozone.
This equilibrium is broken in the presence of reactive VOC, leading to the net formation of ozone.

Example: BVOC

OH – the atmospheric „detergent“
(Paul Crutzen)



Sinks for OH:

$$OH + CO \rightarrow CO_2 + H$$

$$OH + CH_4 \rightarrow CO + products$$

$$OH + C_5H_8 \rightarrow 2.5CO + products$$

$$O_3 + OH \rightarrow HO_2 + O_2$$

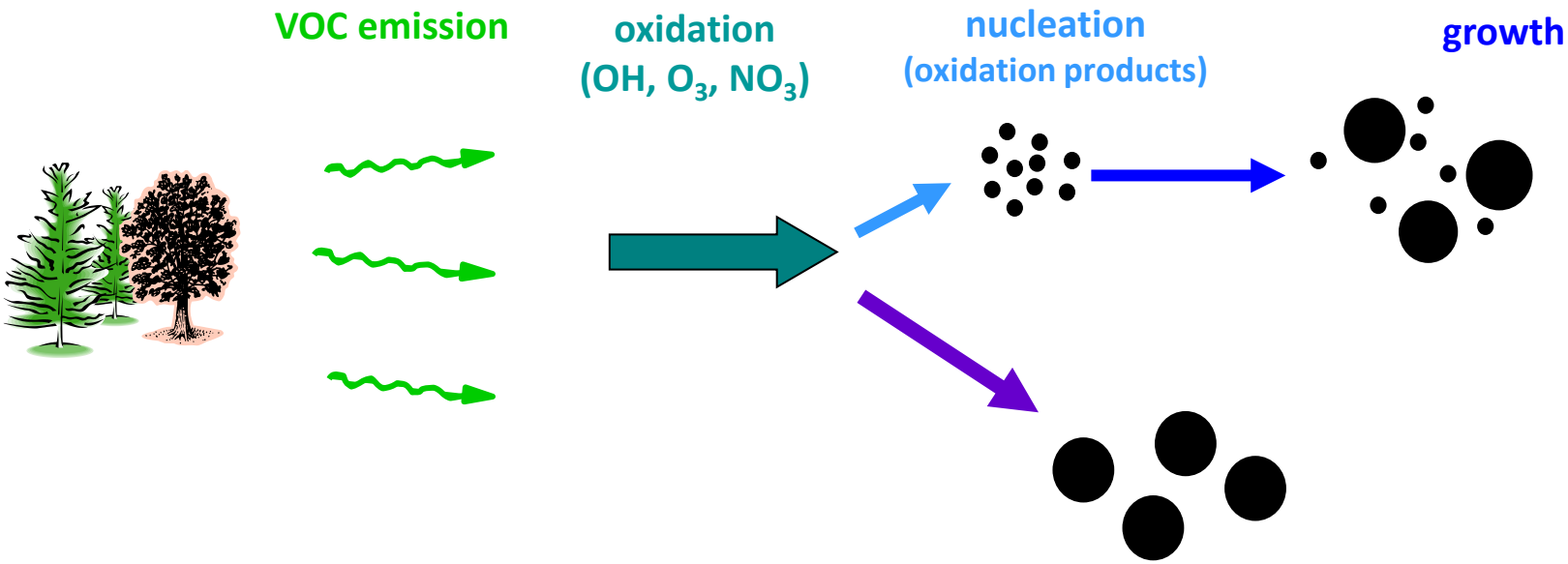
$$OH + H_2O_2 \rightarrow HO_2 + H_2O$$

$$OH + HO_2 \rightarrow H_2O + O_2$$

$$OH + NO_2 \rightarrow HNO_3$$

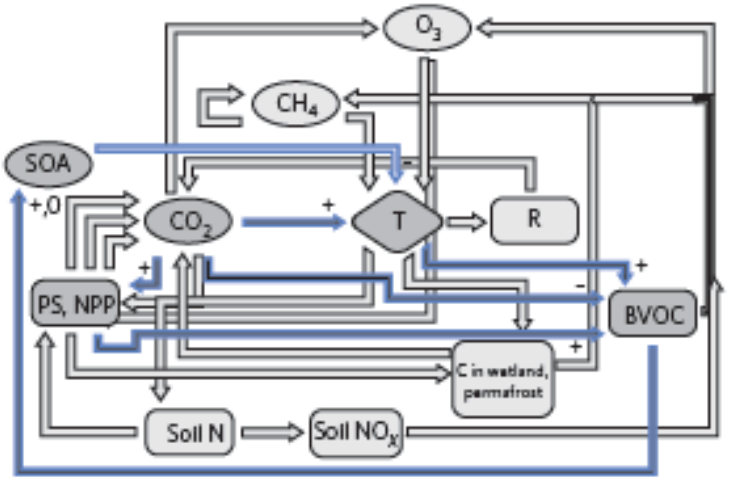
VOCs, e.g. isoprene (C_5H_8), react with OH. As a result less OH is available for destruction of methane (CH_4), causing an increase in its atmospheric lifetime and more warming.

Example: BVOC



after C. Heald (Colorado State Univ.)

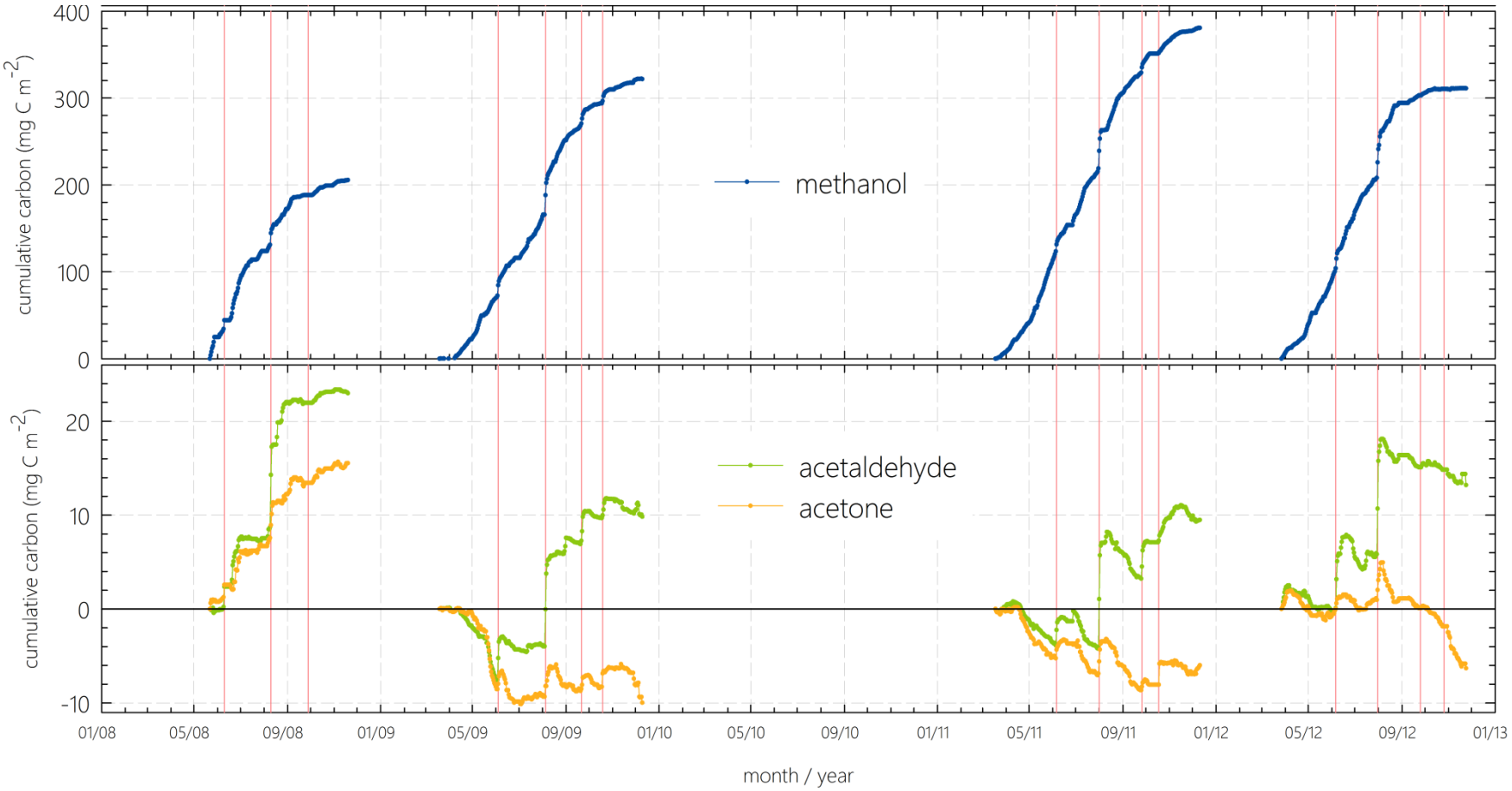
Example: BVOC



Arneth et al. (2010)

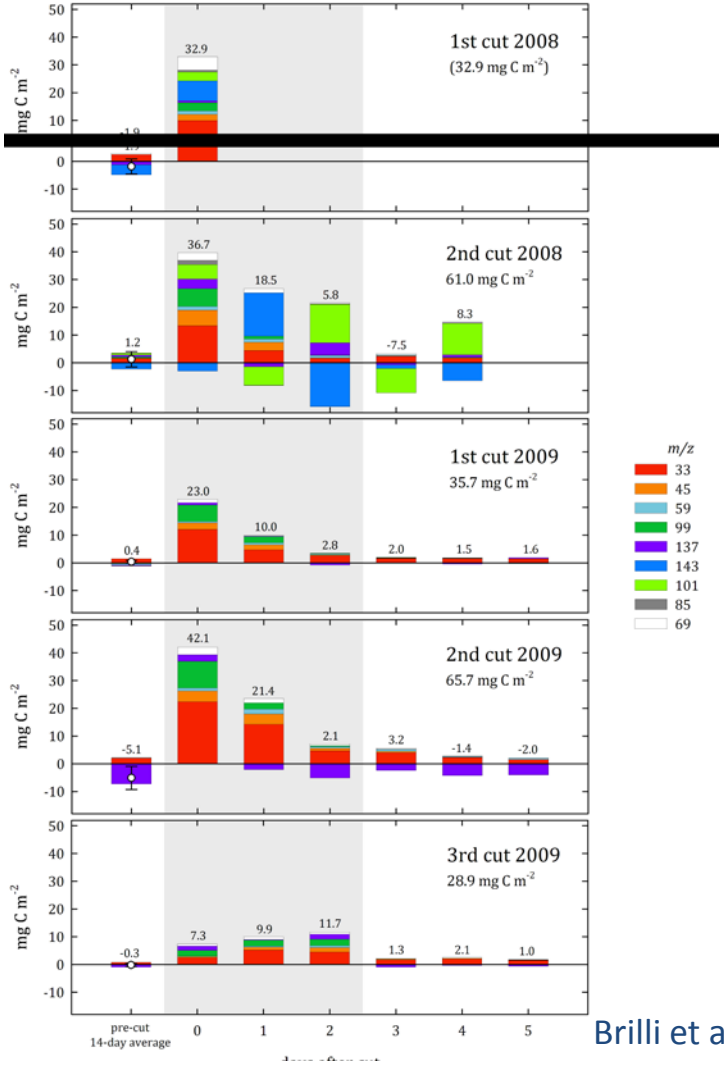
Biogenic volatile organic compounds are important precursors for the production of secondary organic aerosols (SOA), which affect climate through changes of the planetary albedo and precipitation.

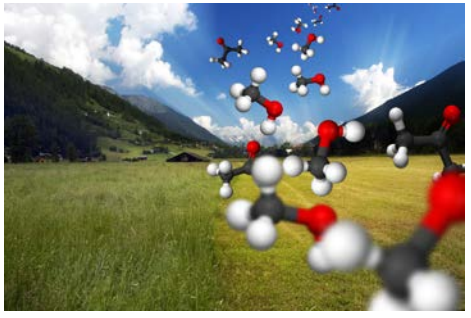
Example: BVOC

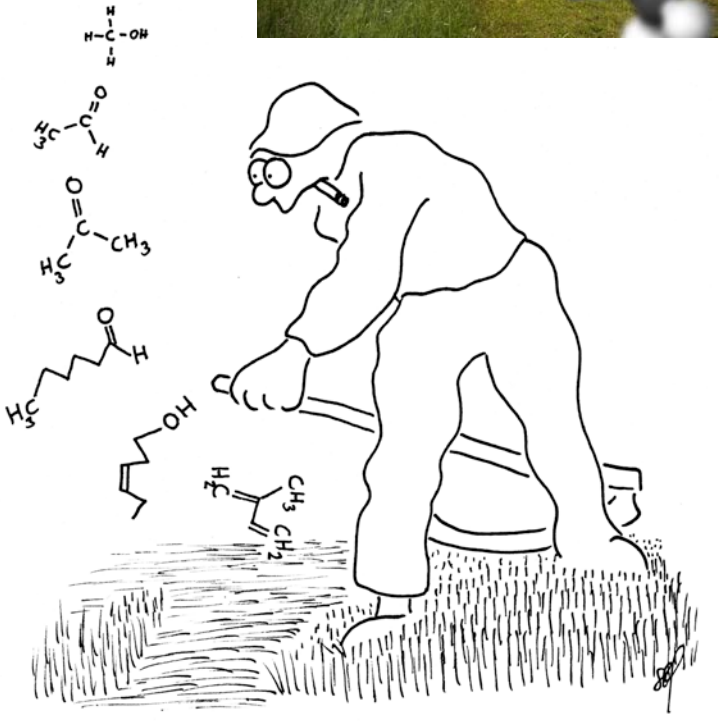


Hörtnagl et al. (2011, 2014)

Example: BVOC







Brilli et al. (2012)

Eddy covariance

Net rd flux

Height above ground (m)

w‘<0

c‘<0

w‘<0

Concentration

Concentration

Eddy covariance

The covariance

$$S_{XY} = \frac{1}{n-1}\sum_{i=1}^{n}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right) \approx \overline{X'Y'}$$

The flux

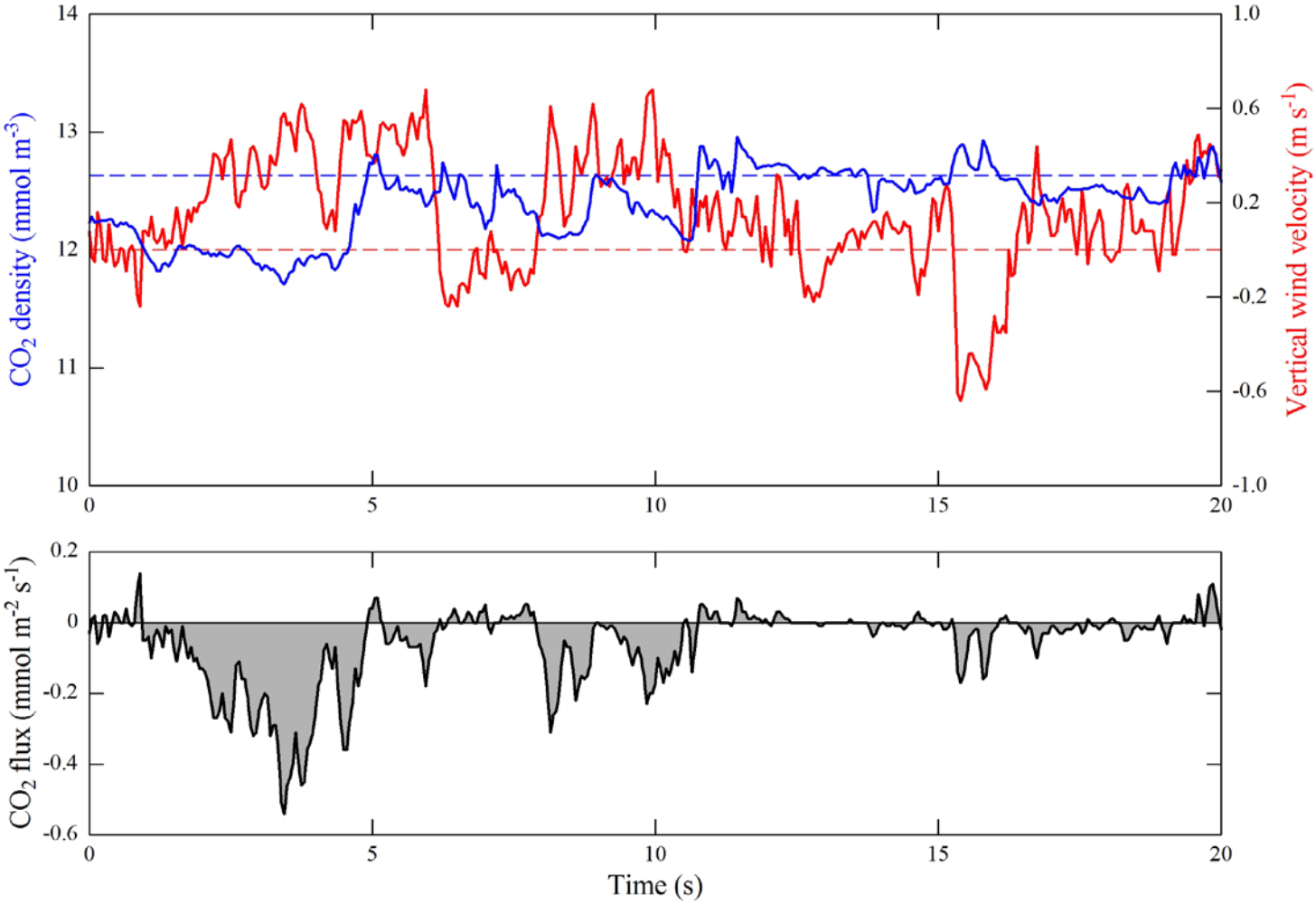
$$F_x = \overline{w'\rho_x'}$$

w … vertical wind velocity (m s^{-1})

ρ_x … density of scalar x (e.g. g m^{-3})

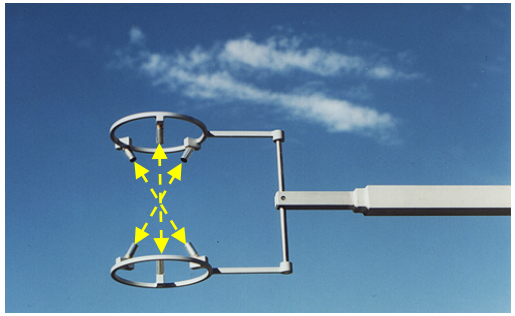
F_x … flux of scalar x (e.g. g m^{-2} s^{-1})

Eddy covariance



Eddy covariance

Wind speed components: sonic anemometer



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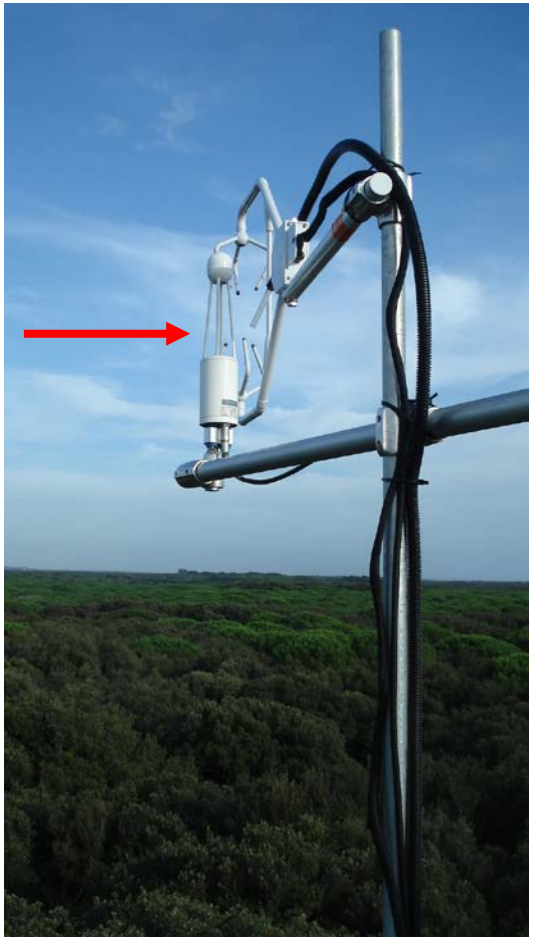
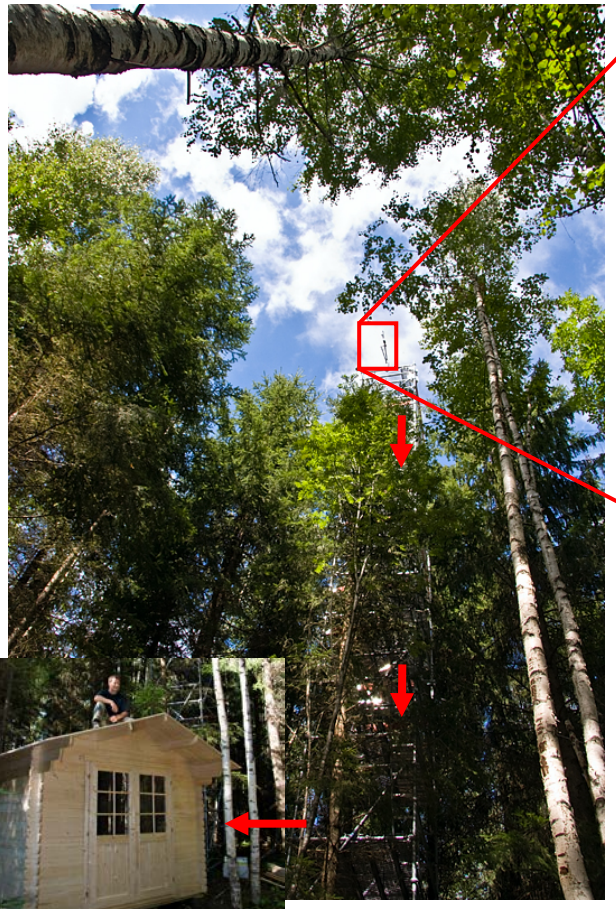
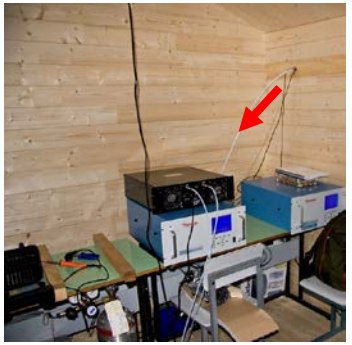
Eddy covariance

Open-path design



Closed-path design





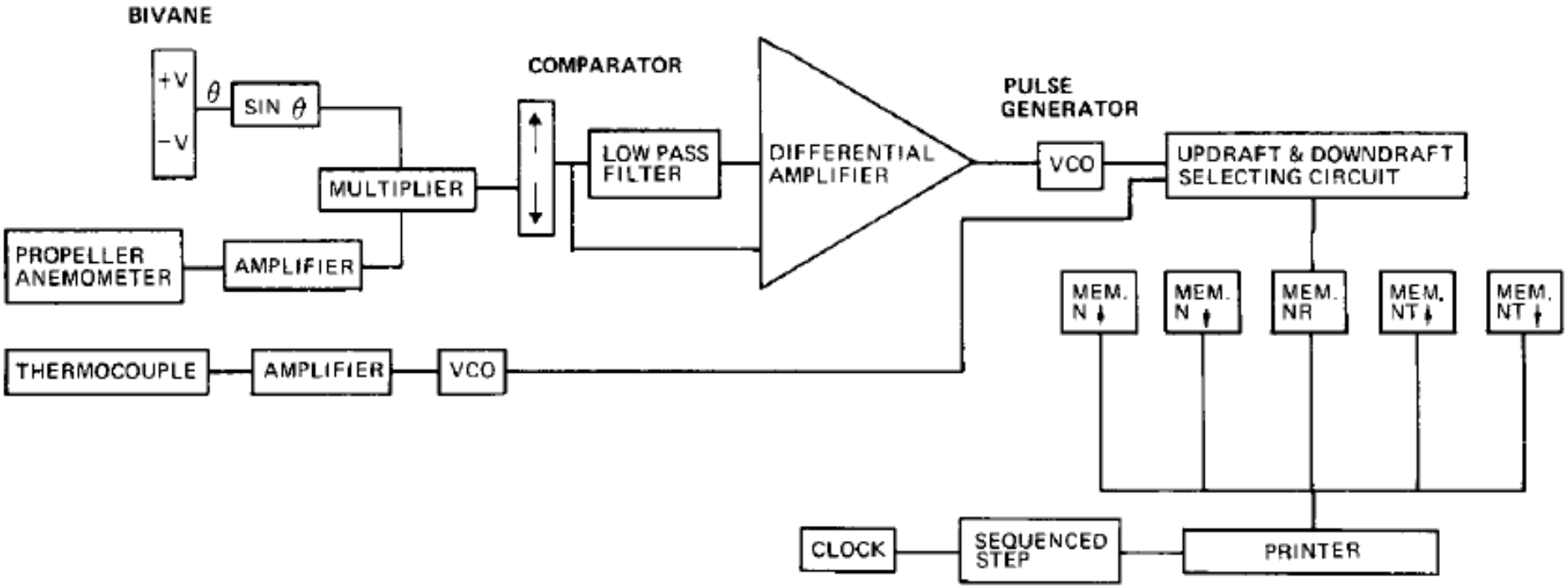
Relaxed eddy accumulation

Eddy accumulation (Desjardins 1977)

$$\overline{w'\chi'} = \overline{w^{+}\chi} + \overline{w^{-}\chi}$$

… in other words: up- and down-draft air is sampled in two reservoirs with the flow rate proportional to the magnitude of the vertical wind speed

Relaxed eddy accumulation



Desjardins (1977)

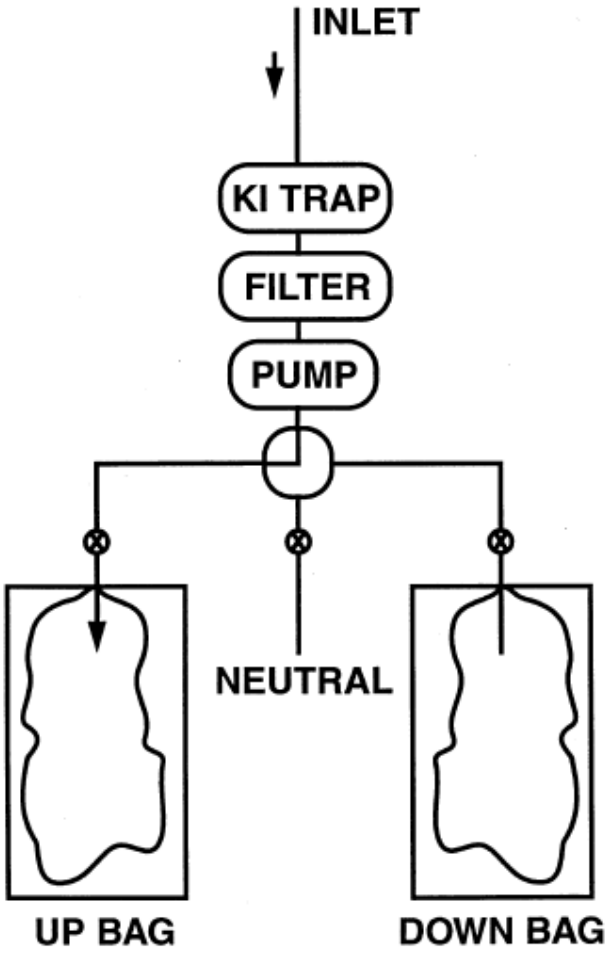
Relaxed eddy accumulation

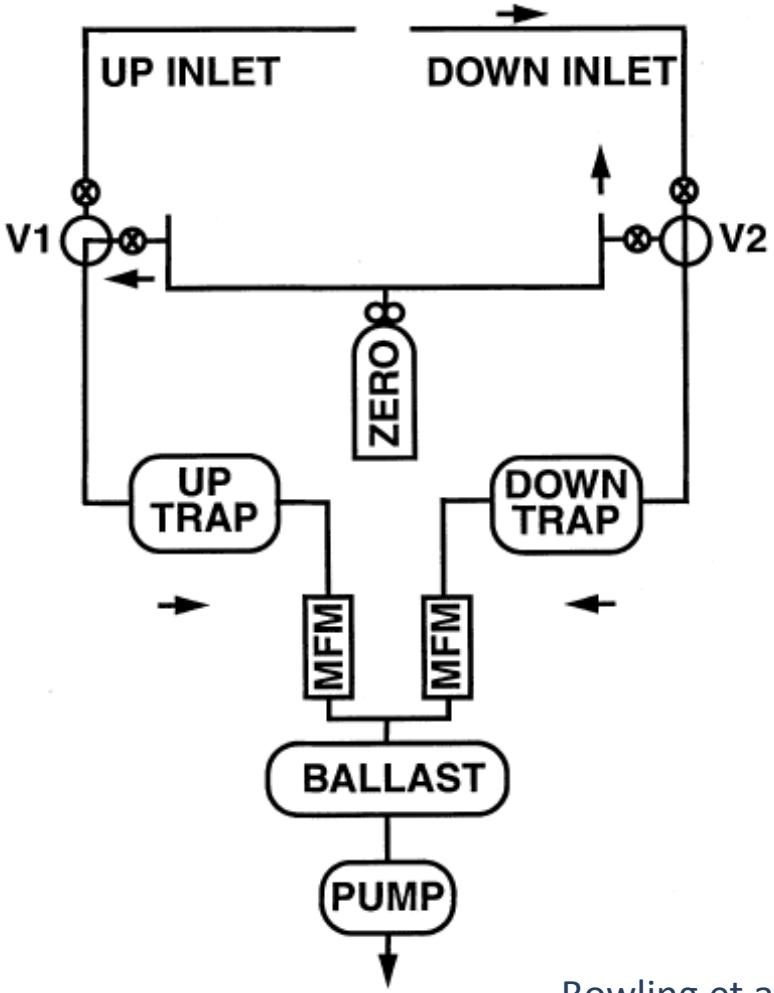
Relaxed eddy accumulation (Businger & Oncley 1990)

$$\overline{w'\chi'} = b(\zeta)\sigma_w\left(\overline{\chi^+} - \overline{\chi^-}\right)$$

… in other words: up- and down-draft air is sampled in two reservoirs depending on the sign of the vertical wind speed using a constant flow rate

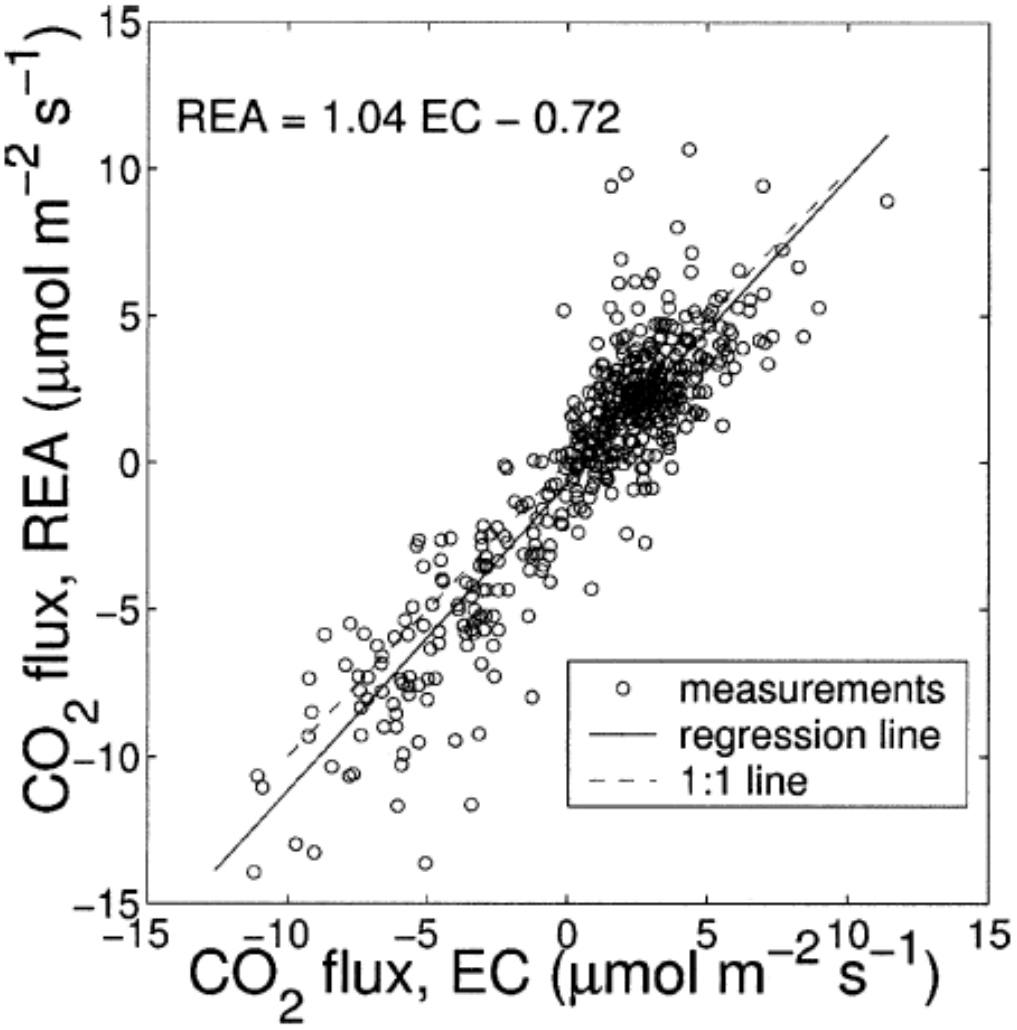
Relaxed eddy accumulation





Bowling et al. (1998)

Relaxed eddy accumulation



Gaman et al. (2004)

Modified Bowen-ratio

K-Theory

$$F_x = -K_x \rho \frac{d\chi_x}{dz}$$

- ρ … molar density of air (mol m^{-3})
- K_x … eddy diffusivity for scalar x (m^2 s^{-1})
- χ_x … dry mole fraction of scalar x (e.g. mmol mol^{-3})
- z … height above ground (m)
- F_x … flux of scalar x (e.g. mmol m^{-2} s^{-1})

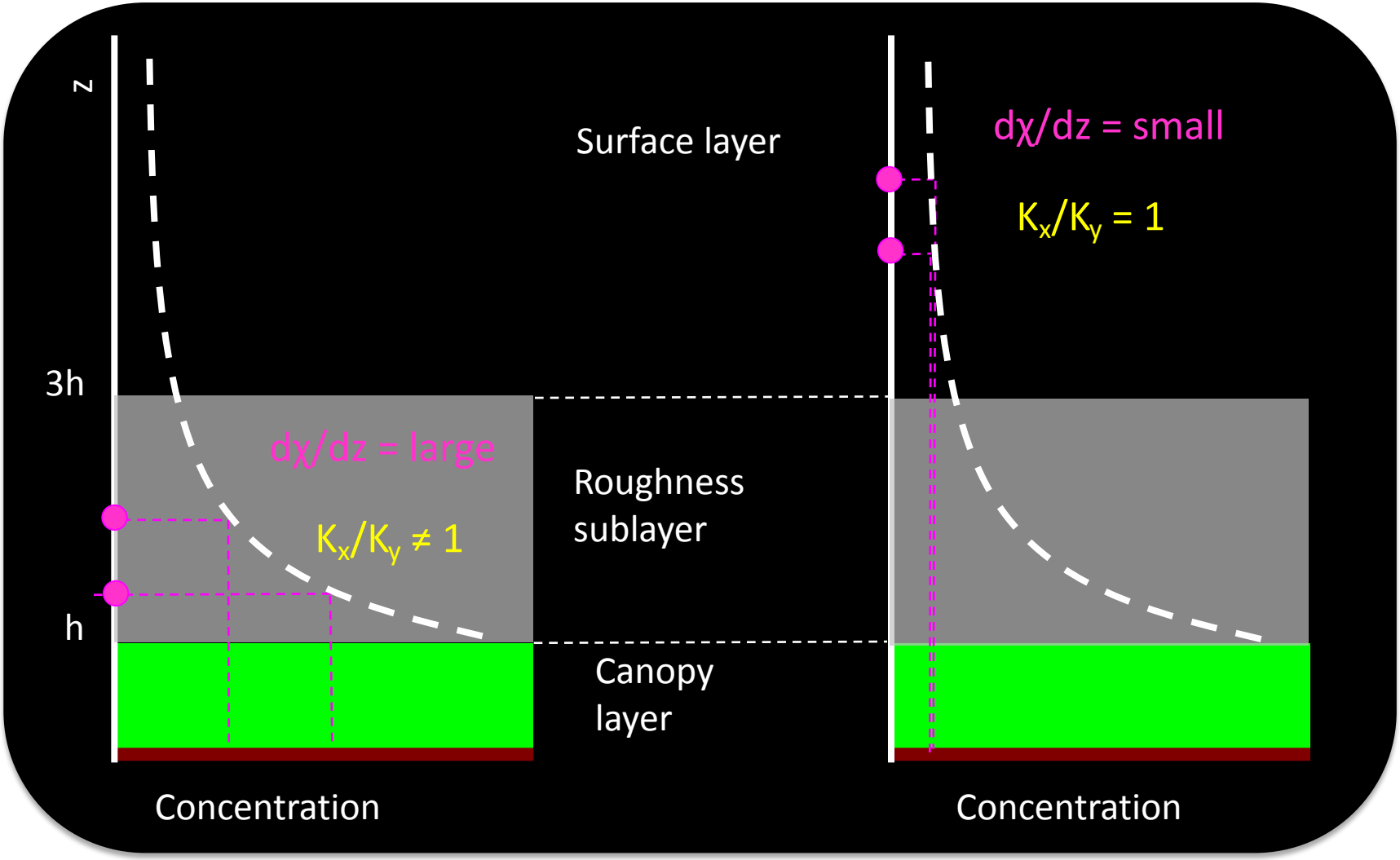
Modified Bowen-ratio

$$K_x = -\frac{F_x}{\rho}\frac{dz}{d\chi_x}$$

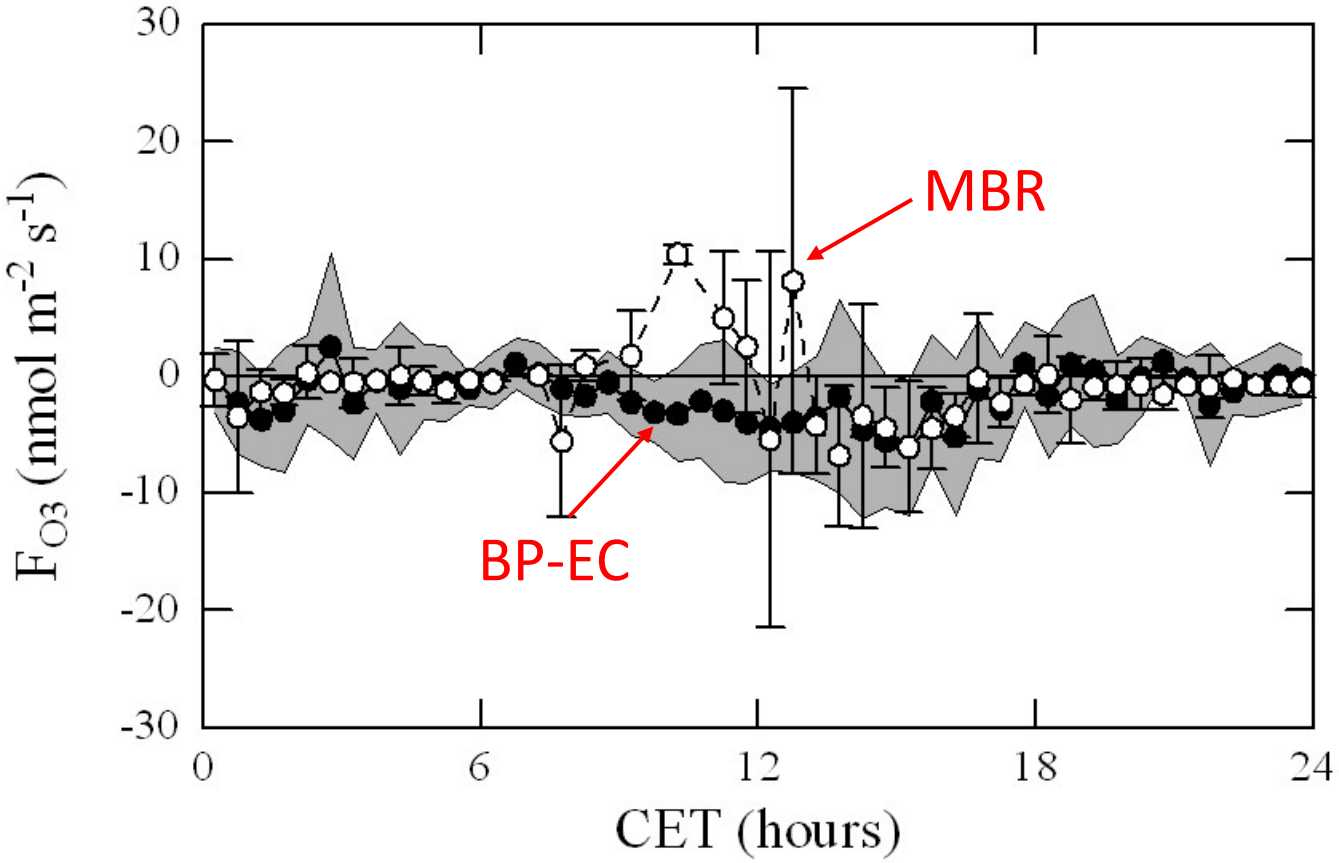
invoking scalar similarity:

$$F_y = -K_x \rho \frac{d\chi_y}{dz}$$

Modified Bowen-ratio



Modified Bowen-ratio



Take home messages

- Micrometeorological methods are rooted in theory describing turbulent transport of momentum, mass and energy. The most direct method is the eddy covariance technique.
- The theory can be adapted to the limitations imposed by scalar sensor design (time response, sample processing, …) – this goes along with a less direct measurement and increased uncertainty.
- For microbial fluxes, the feasibility of gradient, MBR and REA methods has been demonstrated – can we do eddy covariance?