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Bundesministerium
für Bildung
und Forschung

TERENO
TERRESTRIAL ENVIRONMENTAL OBSERVATORIES

JÜLICH
FORSCHUNGSZENTRUM

Searching for Sinks and Sources in Land-Atmosphere Fluxes of CO_2 and H_2O

Anne Klosterhalfen

Maria P. Gonzáles Dugo, Jan Elbers, Cor Jacobs, Matthias Mauder, Arnold Moene, Patrizia Ney, Corinna Rebmann, Mario Ramos Rodríguez, Marius Schmidt, Rainer Steinbrecher, Christoph Thomas, Harry Vereecken, Alexander Graf

September 26th, 2017 | TERENO Workshop

Mitglied der Helmholtz-Gemeinschaft

EDDY COVARIANCE METHOD

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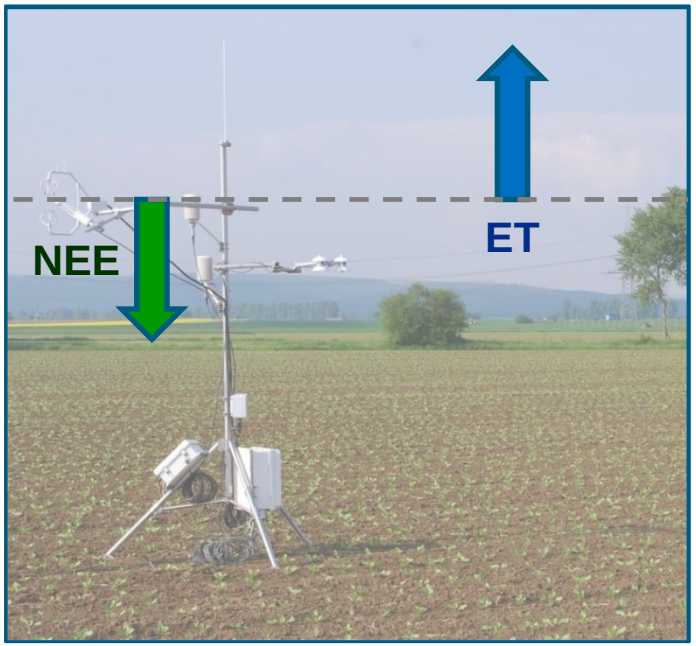

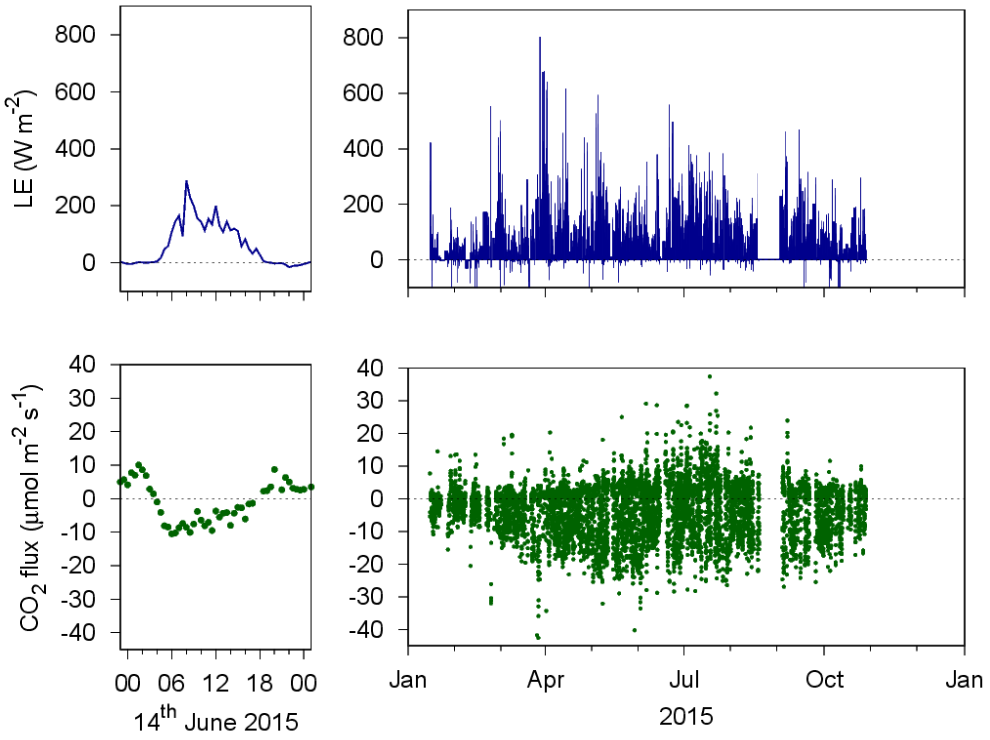

$$F_c = \overline{\rho}\,\overline{c'w'} = \overline{\rho}\,\frac{1}{N-1}\sum_{k=0}^{N-1}[(w_k - \bar{w})(c_k - \bar{c})]$$

NEE: net ecosystem exchange
ET: evapotranspiration

F_c: vertical CO_2 flux (kg m^{-2} s^{-1})
ρ: density of air (kg m^{-3})
N: number of measurements per interval
w: vertical wind (m s^{-1})
c: specific CO_2 concentration (kg kg^{-1} dry air)

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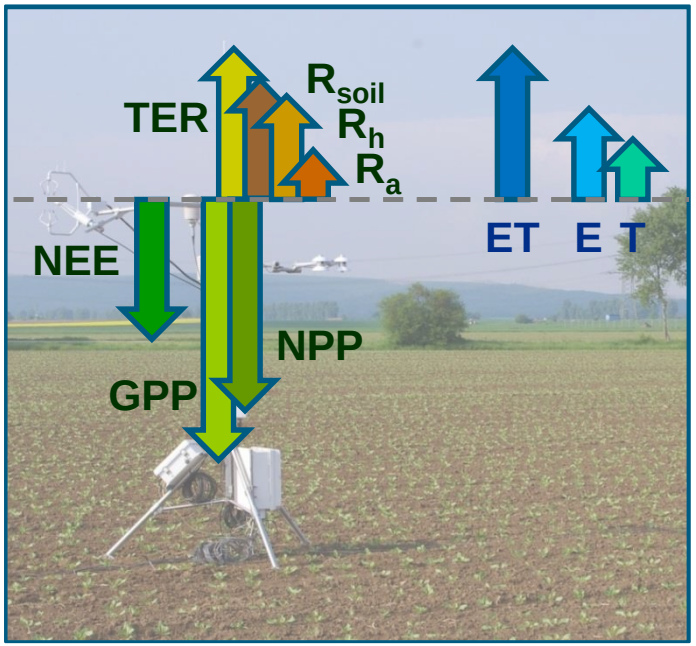

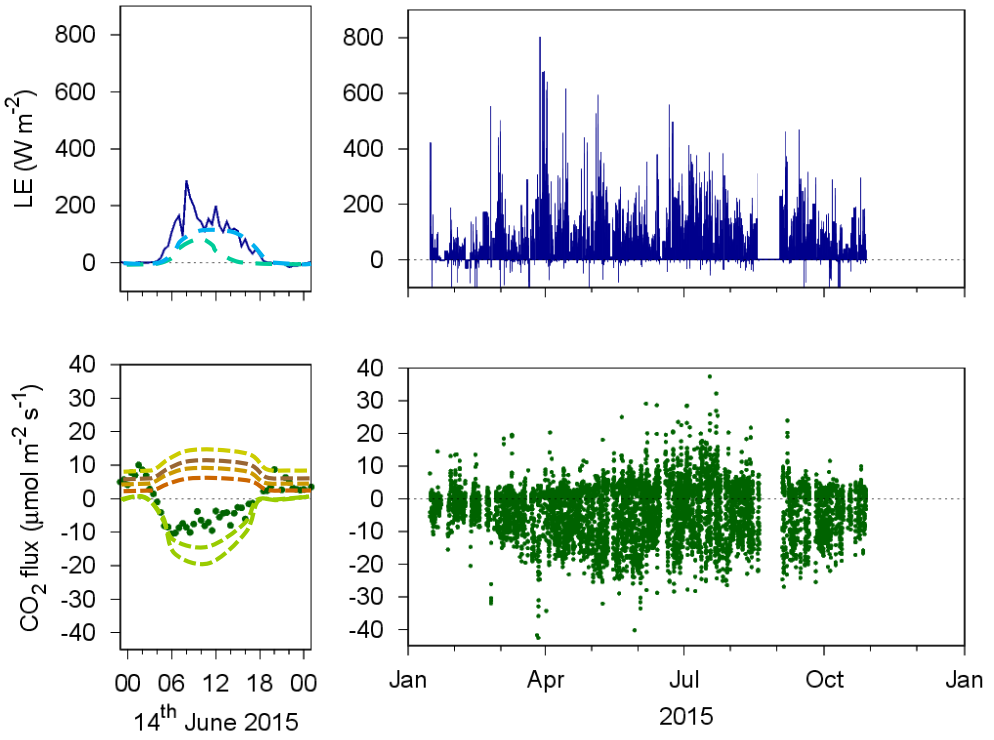

→ Source Partitioning Methods

NEE: net ecosystem exchange
GPP: gross primary production
NPP: net primary production
TER: total ecosystem respiration
R_{soil}: soil respiration
R_h: respiration by heterotrophs
R_a: respiration by autotrophs

ET: evapotranspiration
E: evaporation
T: transpiration

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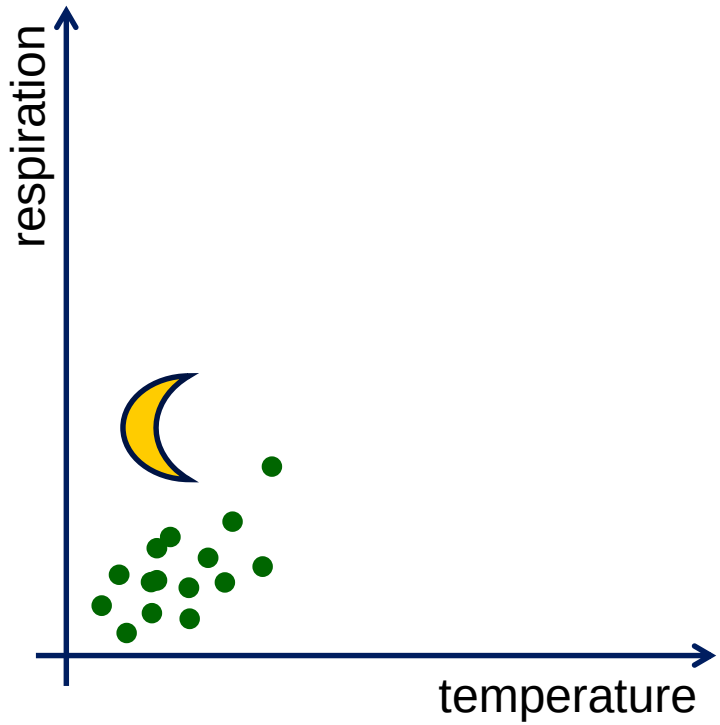
DATA-DRIVEN APPROACH

- e.g., after **REICHSTEIN et al. 2005**, *Glob Change Biol 11, 1424-1439*

→ non-linear regressions (physical driver)



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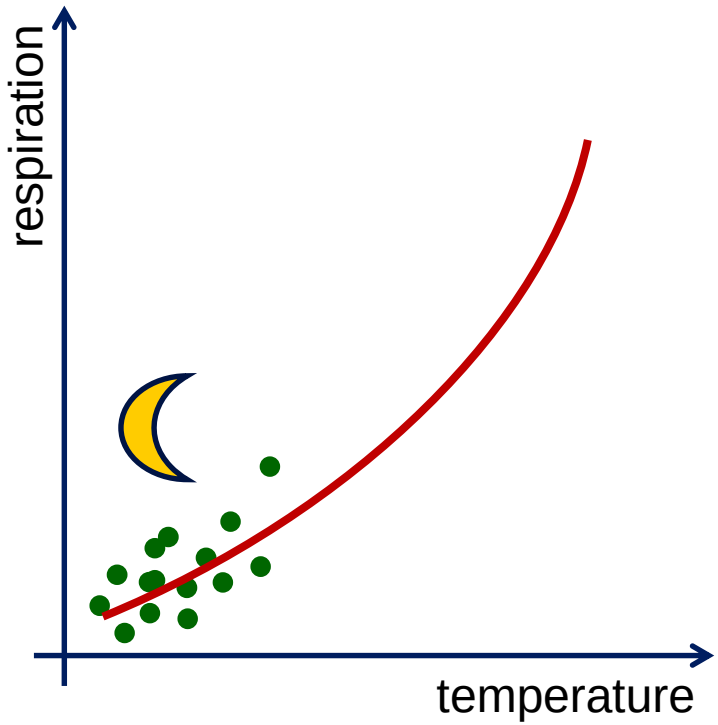

ARRHENIUS (1889) equation
after LLOYD & TAYLOR (1994)

$$TER = R_{10}\, exp\left[E_0\left(\frac{1}{283.15 - T_0} - \frac{1}{T_a - T_0}\right)\right]$$

R_{10}: base respiration at reference temperature
E_0: temperature sensitivity parameter
T_0: constant, 227.13 K
T_a: air temperature

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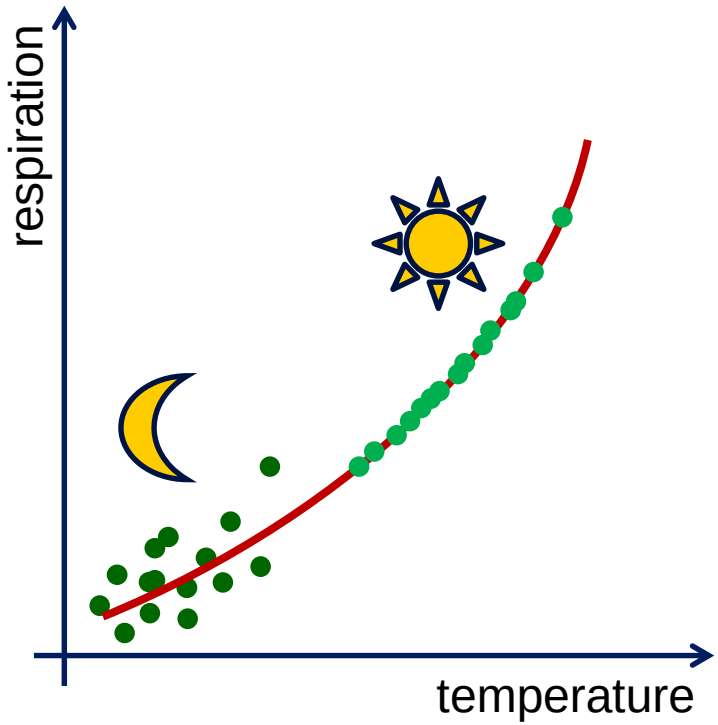

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GPP = NEE - TER

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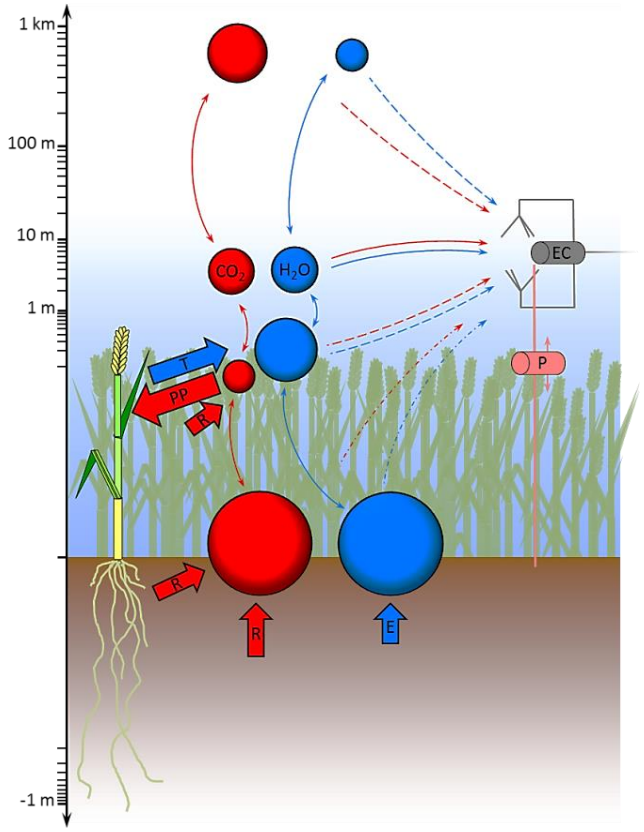
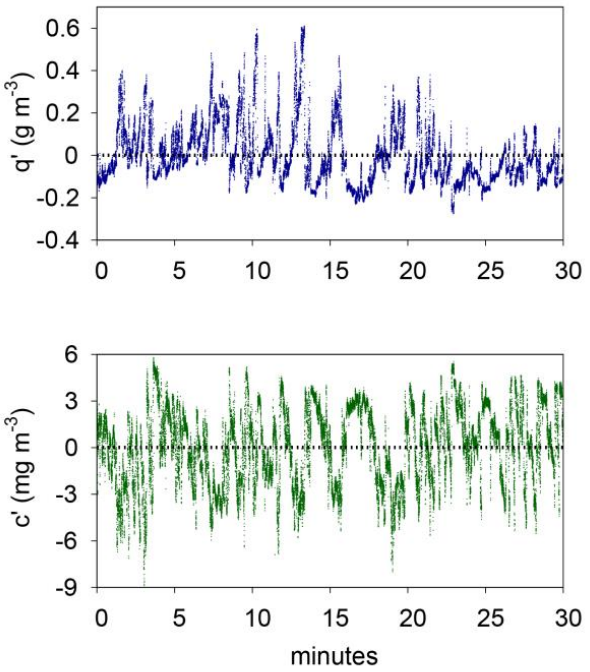
DATA-DRIVEN APPROACH - SK10

- after **SCANLON & KUSTAS 2010**, *Agr Forest Meteorol 150, 89-99* (SK10)

→ flux-variance similarity theory





H_2O

CO_2

Wüstebach, 14.06.2015, 12:00 p.m. (UTC).

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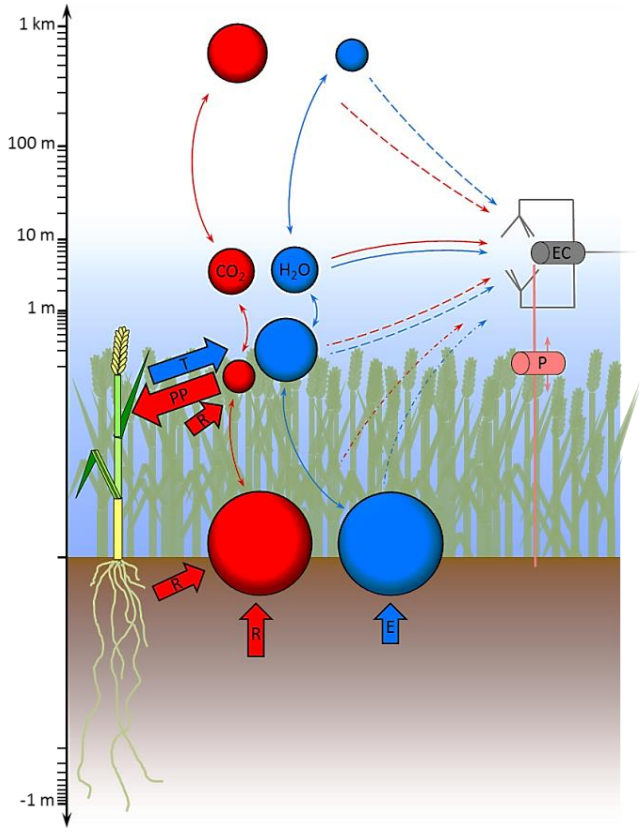

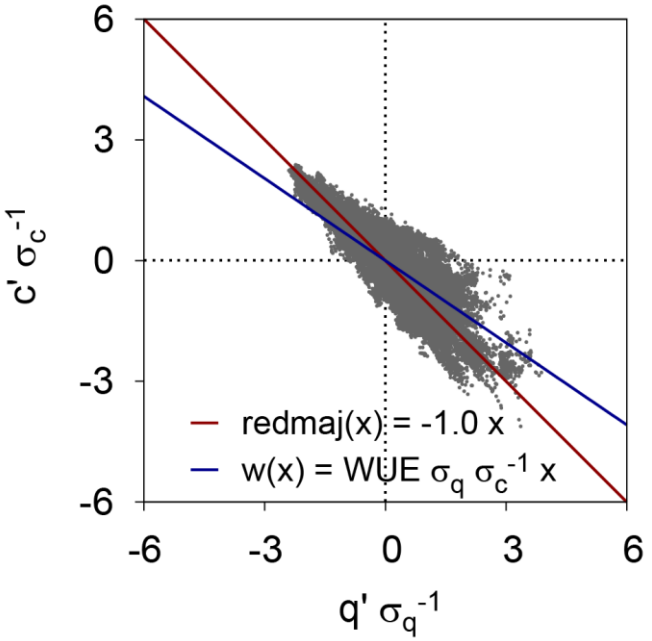

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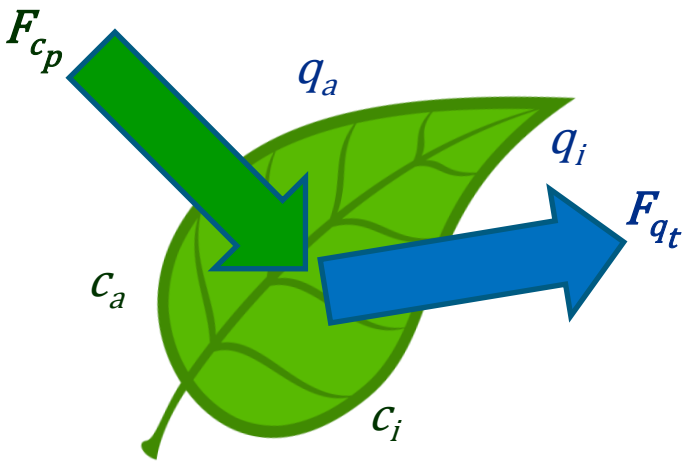
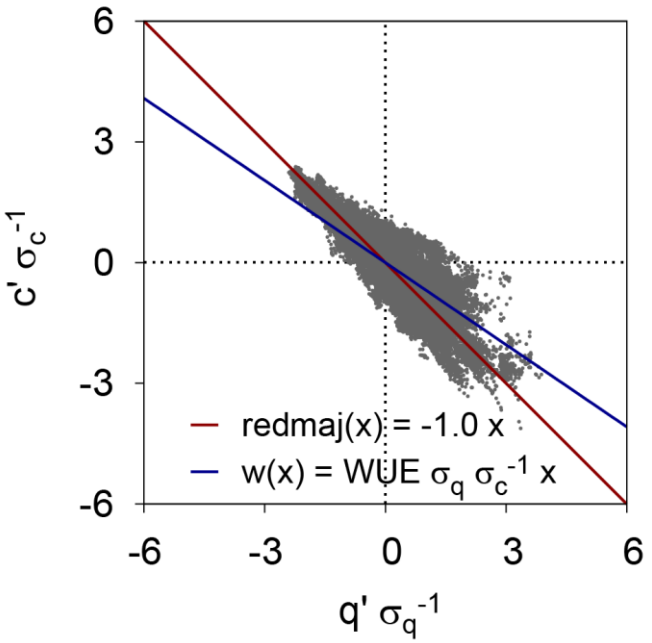
Water use efficiency on leaf-level





$$WUE = \frac{F_{c_p}}{F_{q_t}} = \frac{g_c \cdot (c_i - c_a)}{g_w \cdot (q_i - q_a)}$$

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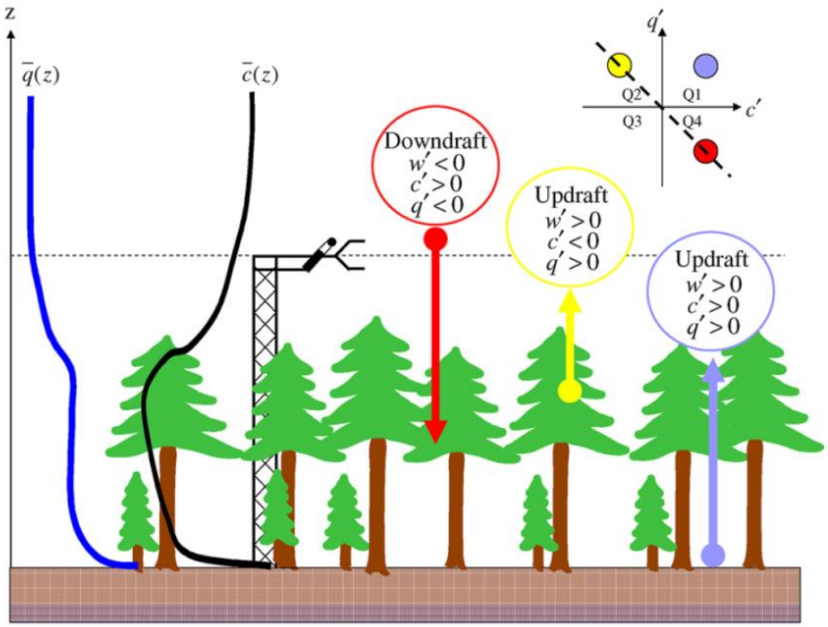
DATA-DRIVEN APPROACH – TH08

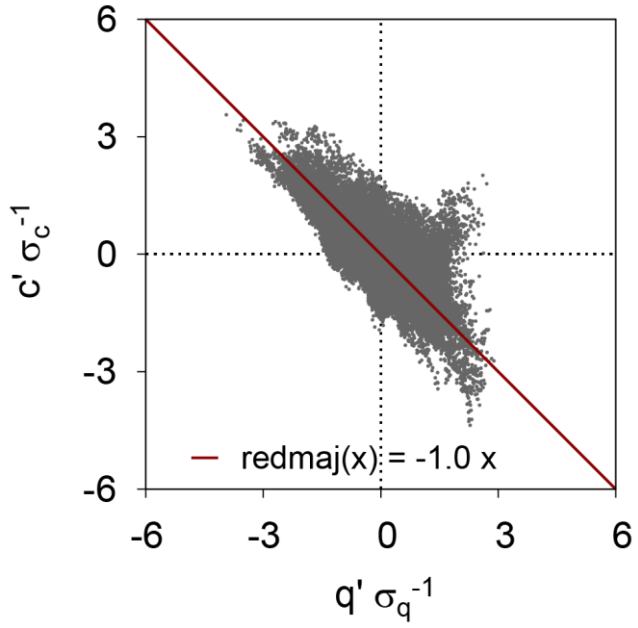
- after **THOMAS et al. 2008**, *Agr Forest Meteorol 148, 1210-1229* (TH08)

→ estimation of subcanopy respiration

→ conditional sampling methods



THOMAS et al. 2008, Fig. 1, 1213.



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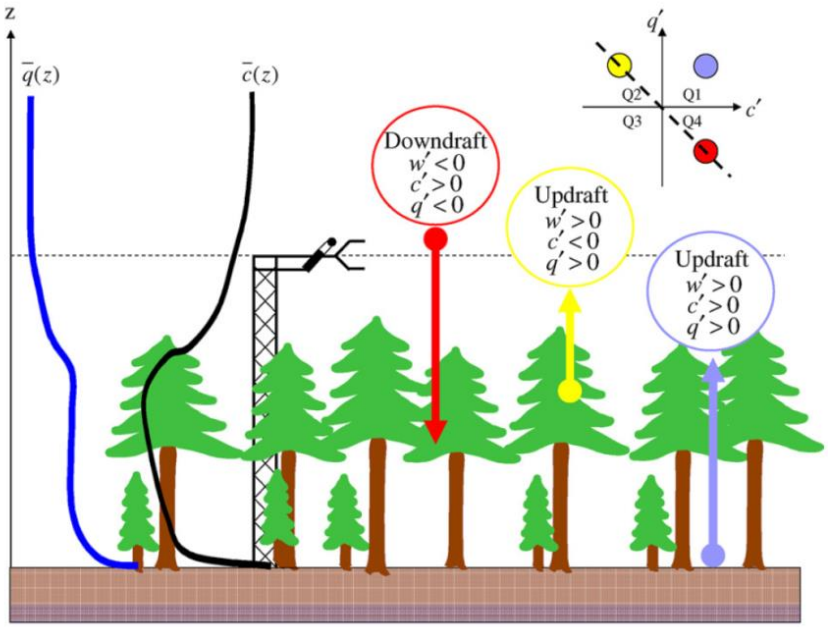

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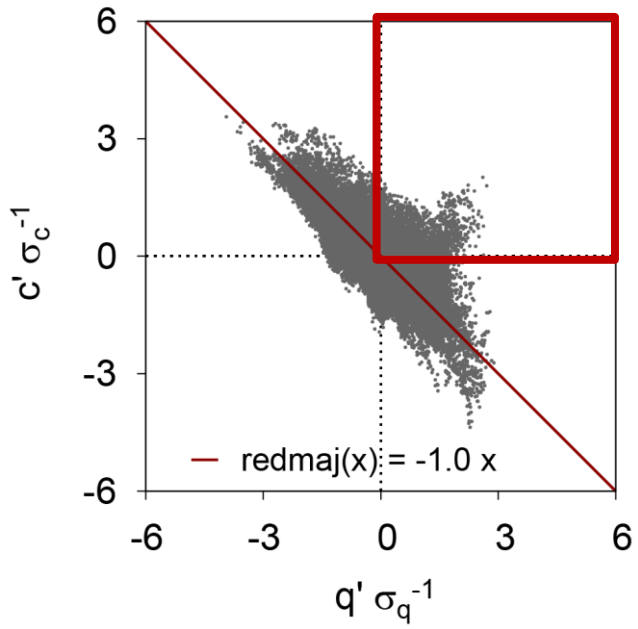

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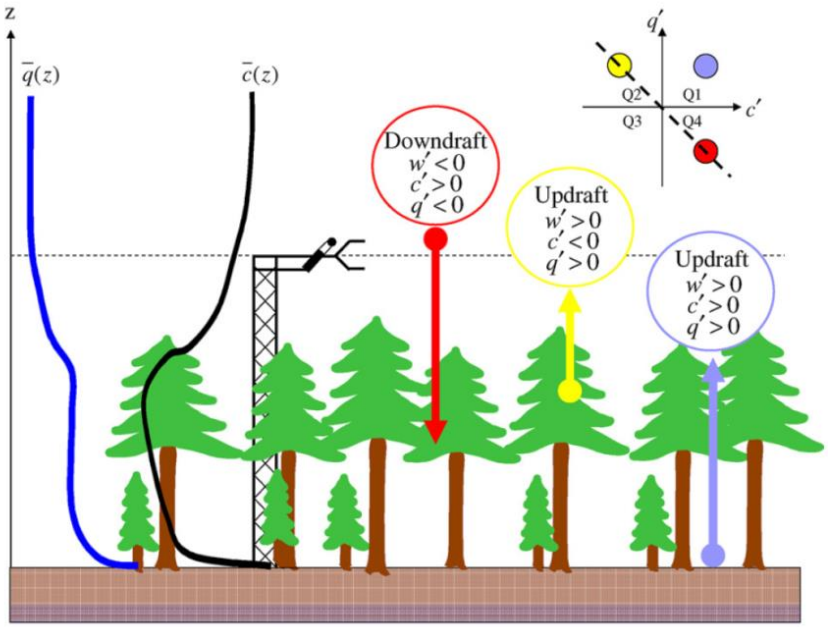

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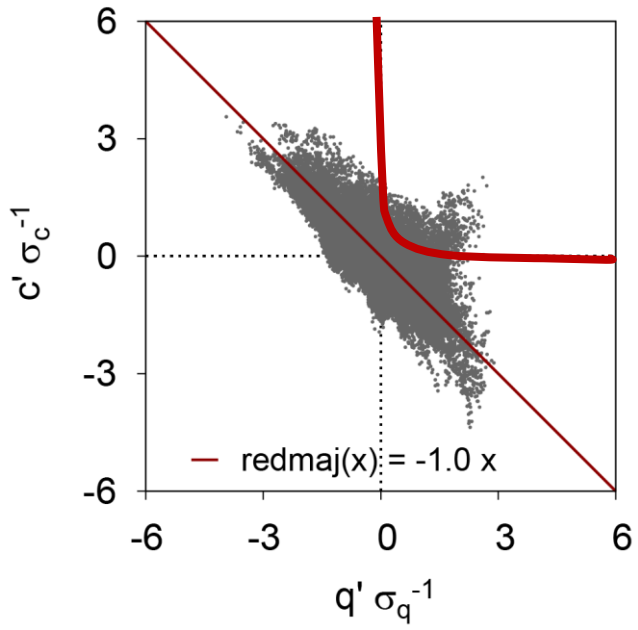

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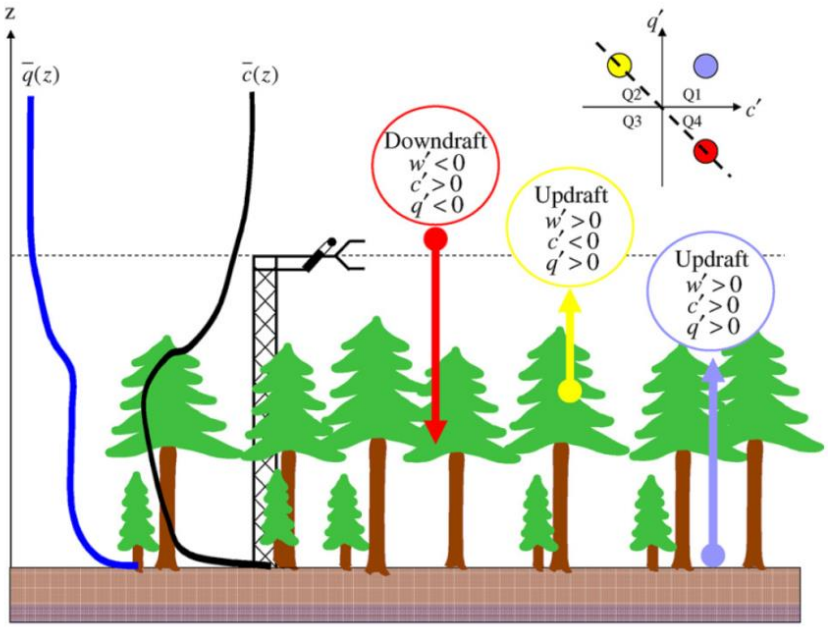

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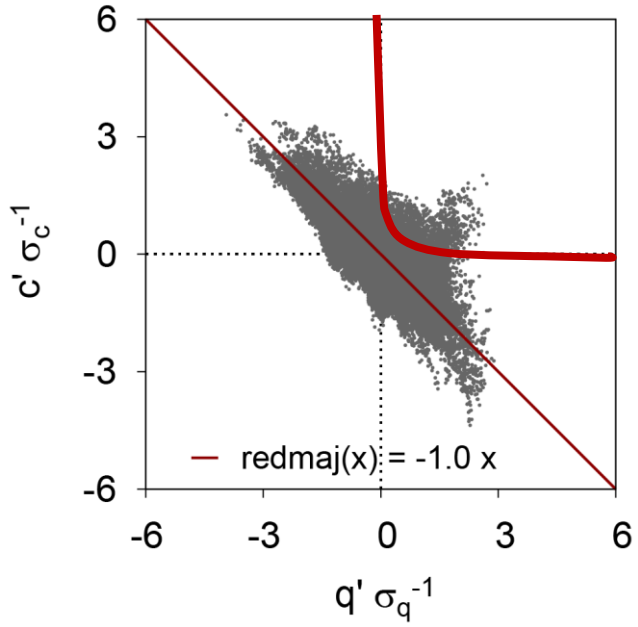

- average of covariances
- relaxed eddy accumulation

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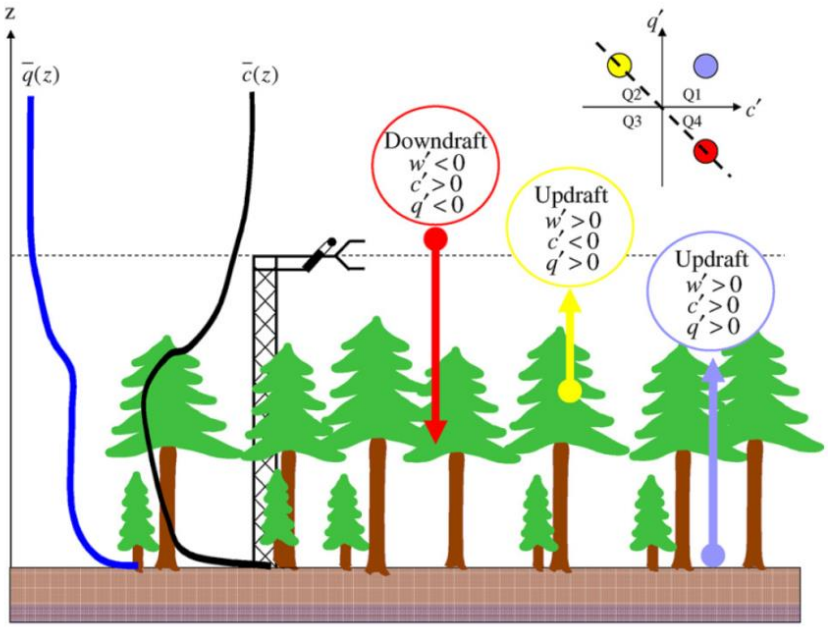

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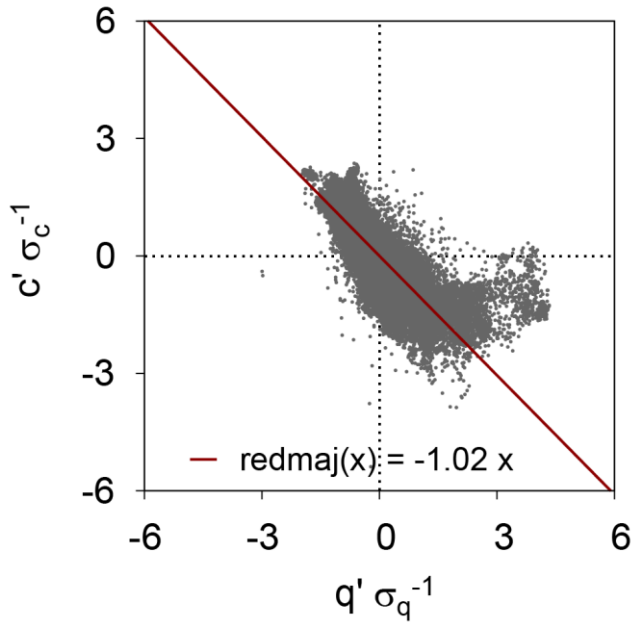

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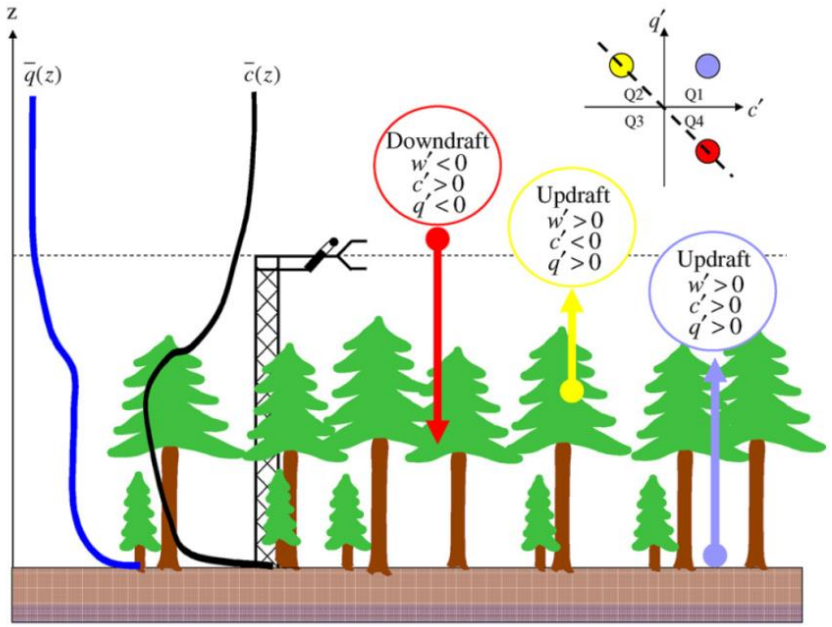

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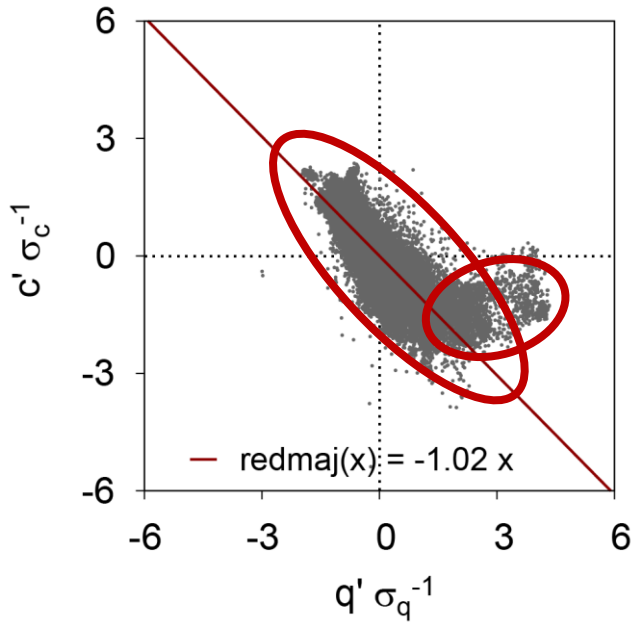

- average of covariances
- relaxed eddy accumulation

- Gaussian Mixture Model for clustering

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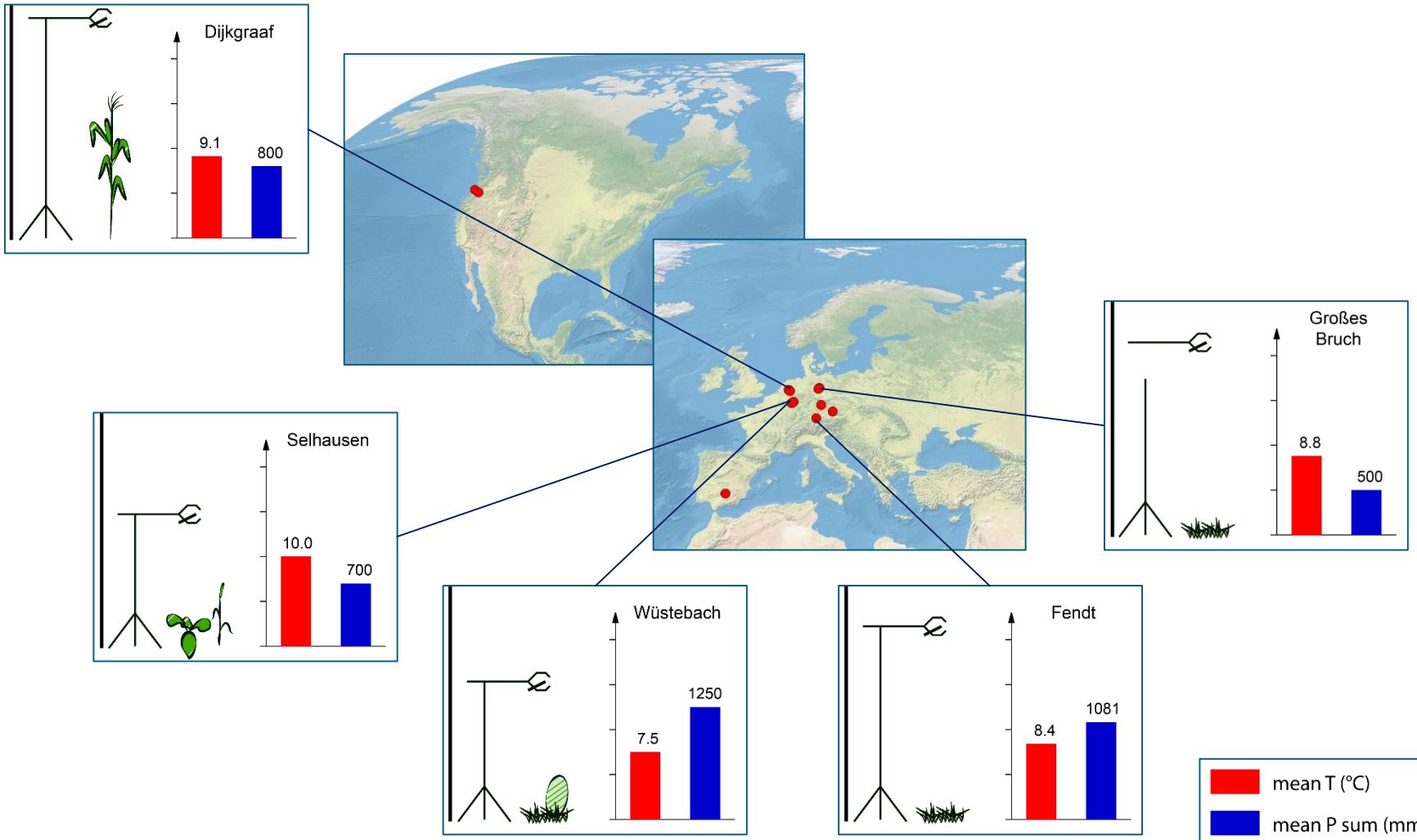
STUDY SITES



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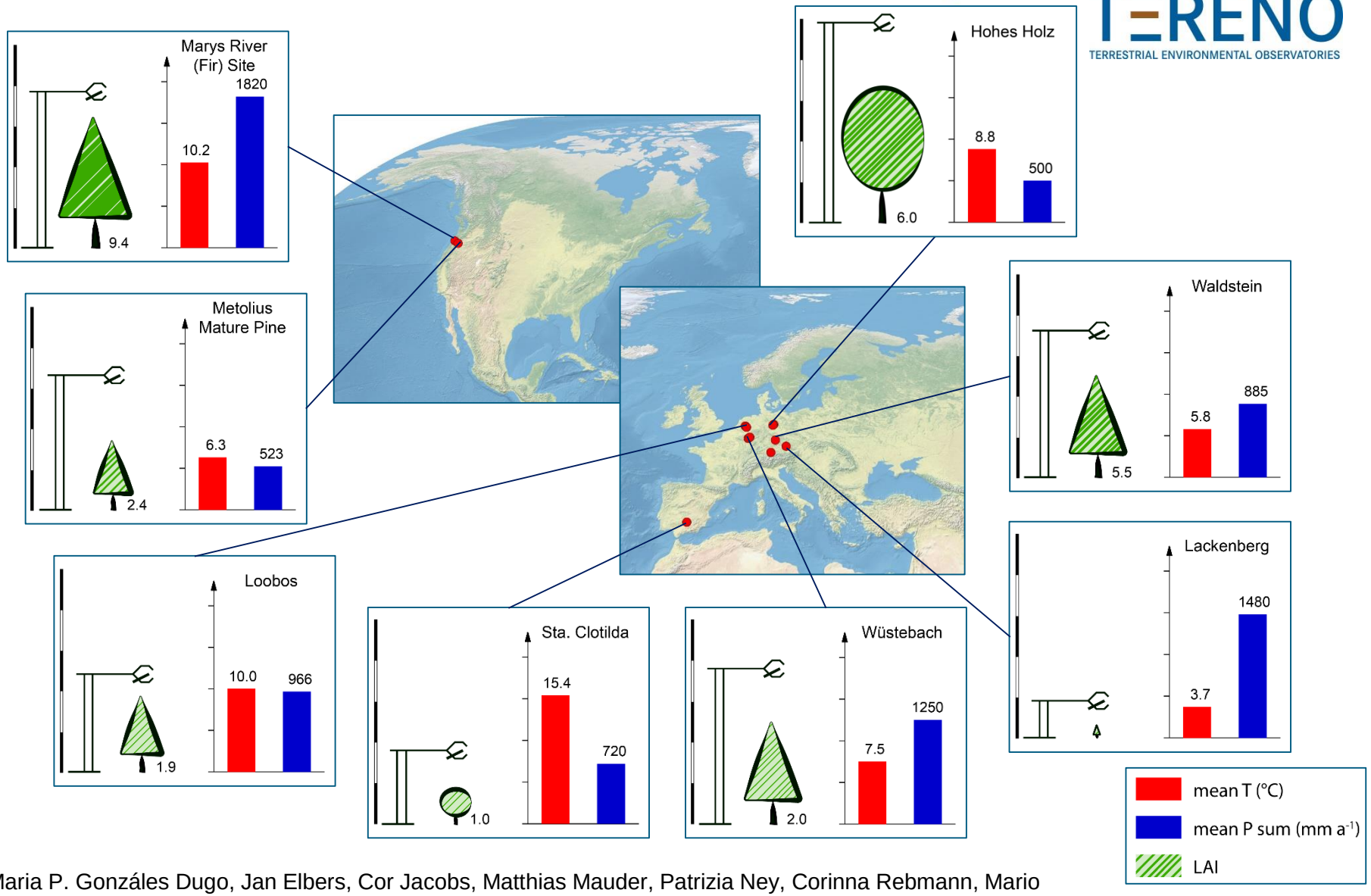

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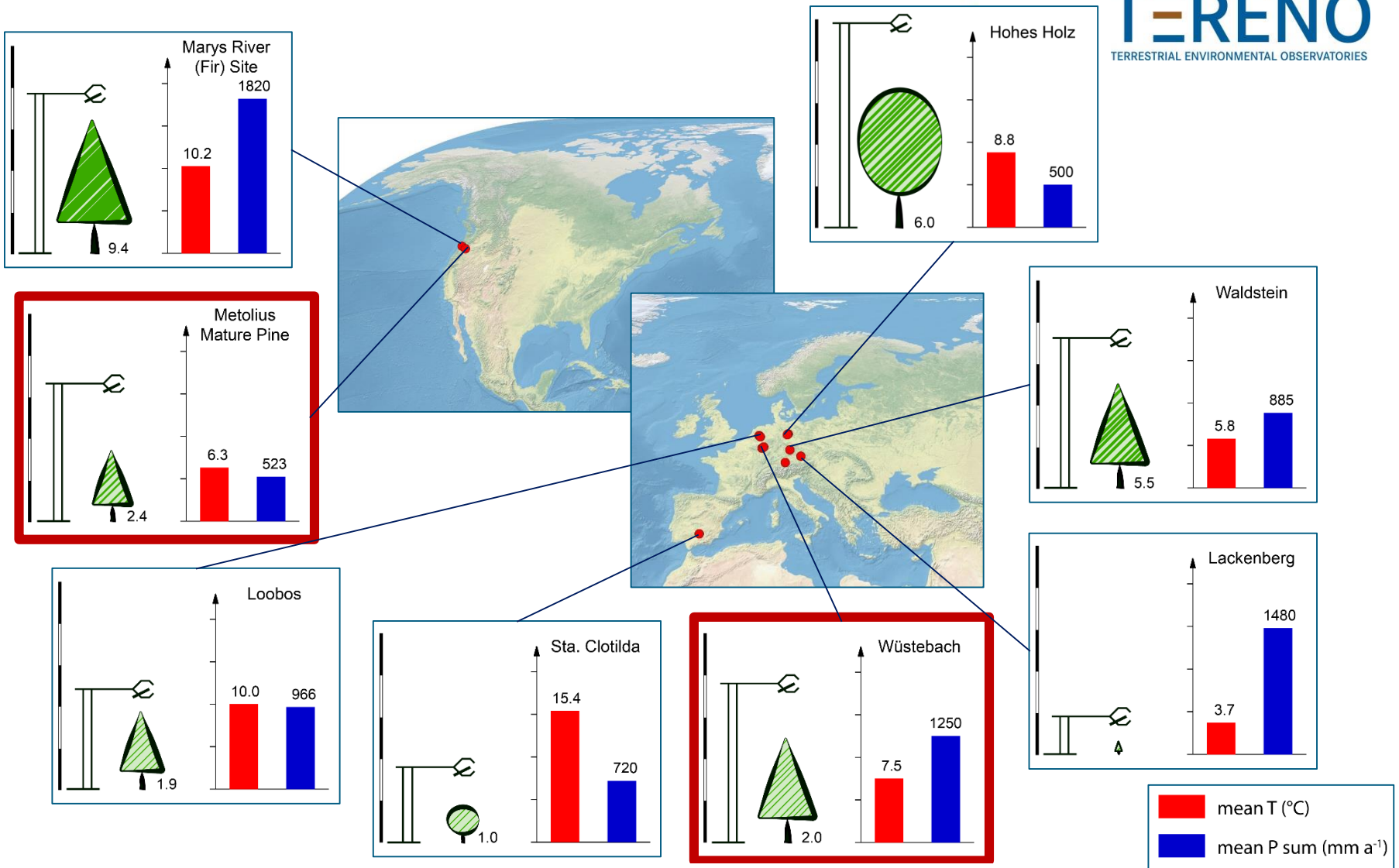

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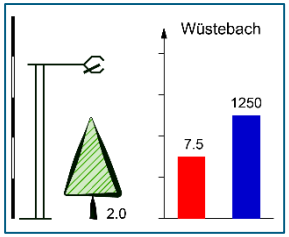
WÜSTEBACH



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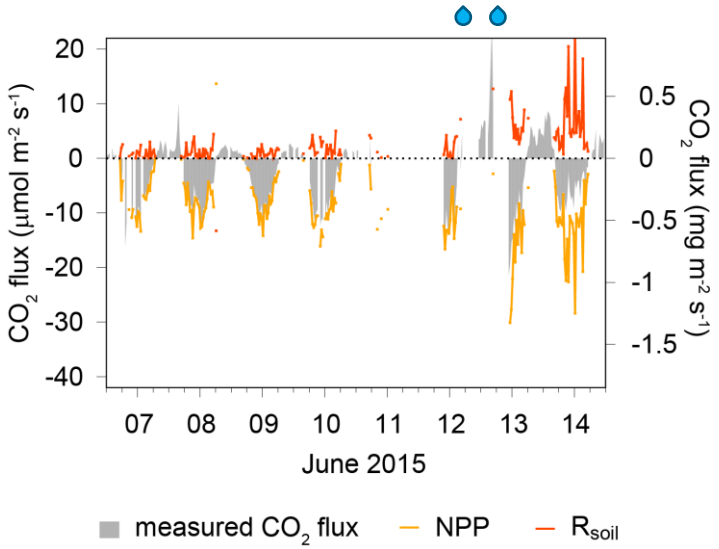
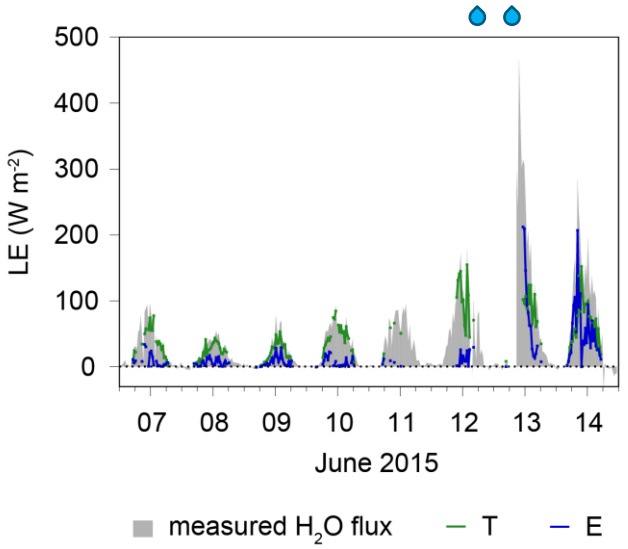
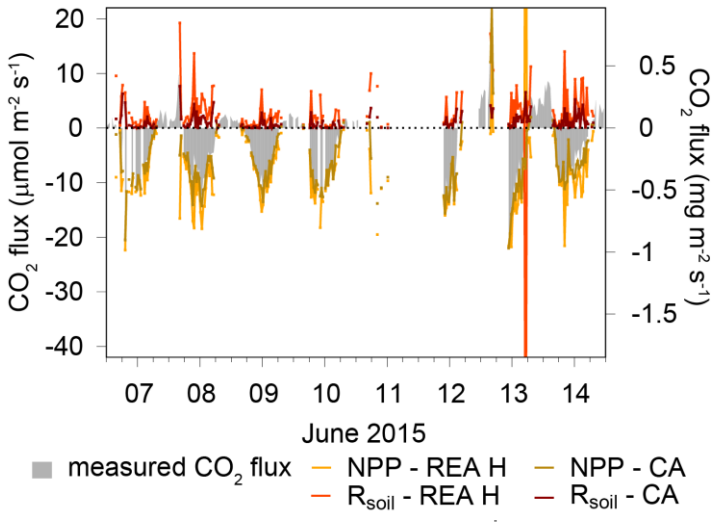
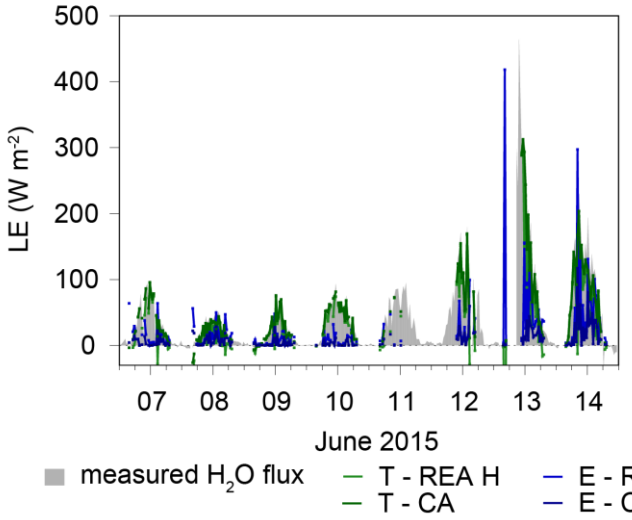




SK10





TH08

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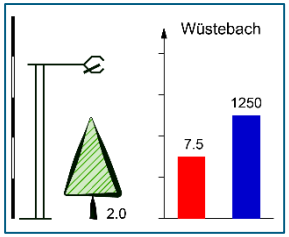
WÜSTEBACH



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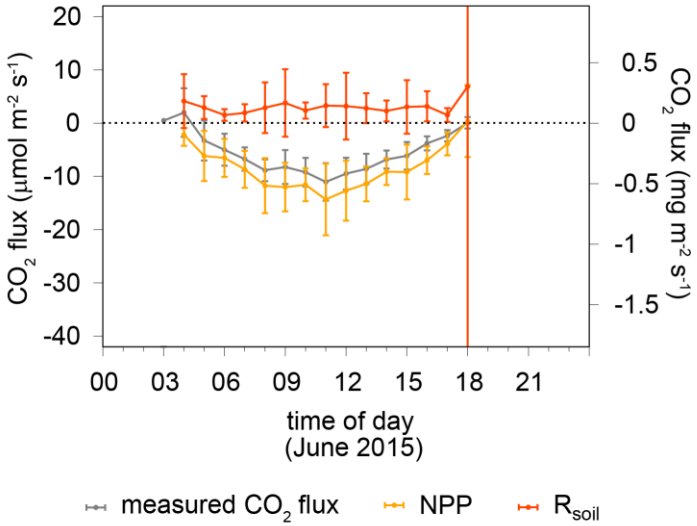

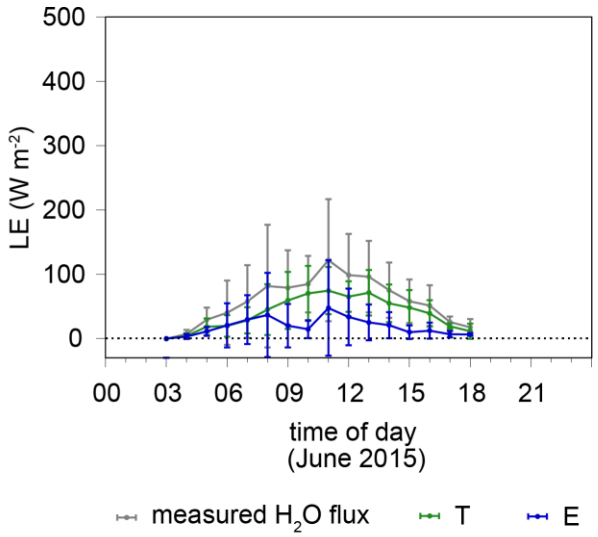

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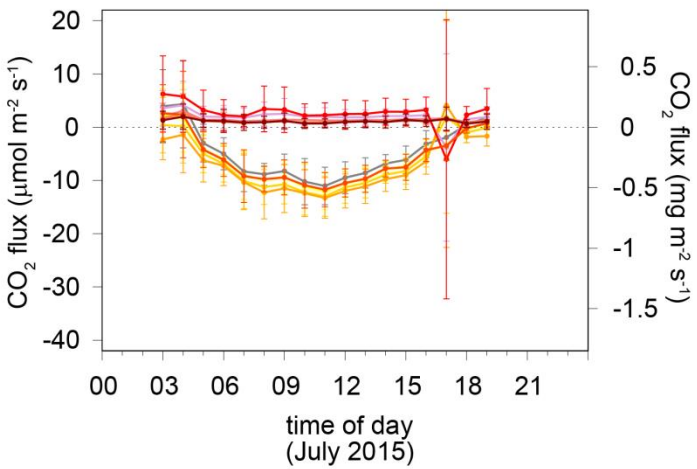

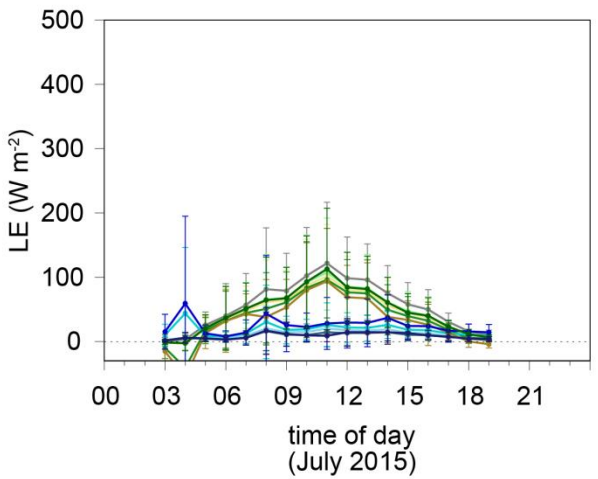

TH08

measured flux EC EC H REA REA H CA

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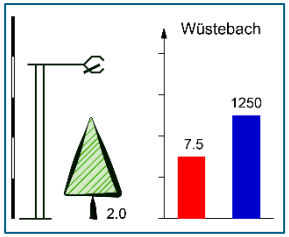
WÜSTEBACH



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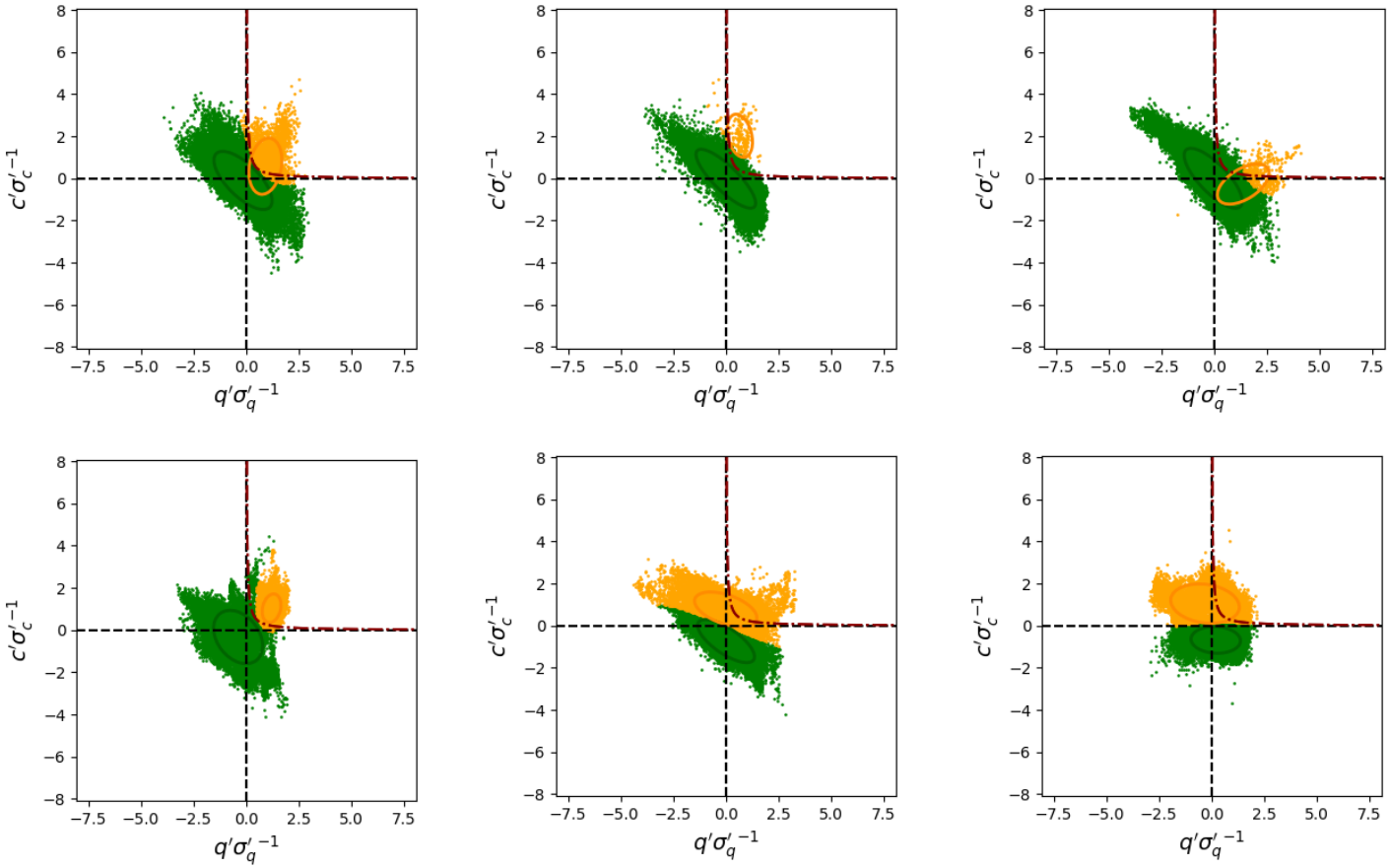
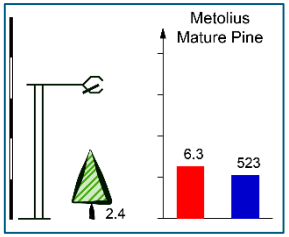
TH08 - Gaussian Mixture Model for Clustering



METOLIUS MATURE PINE



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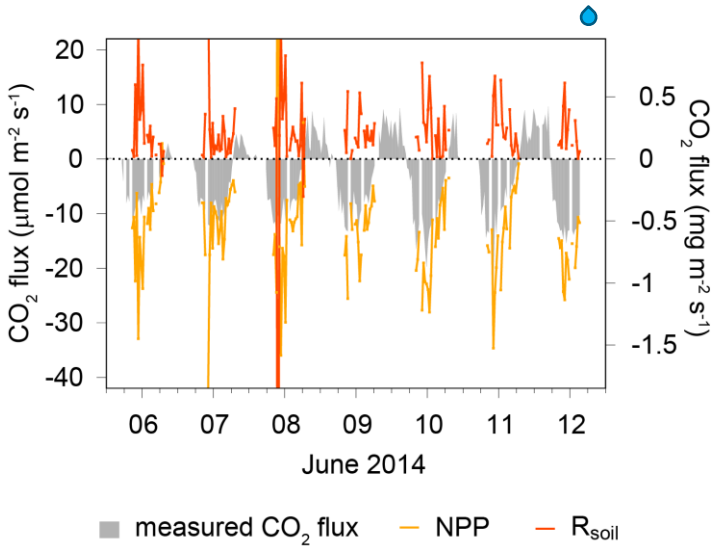
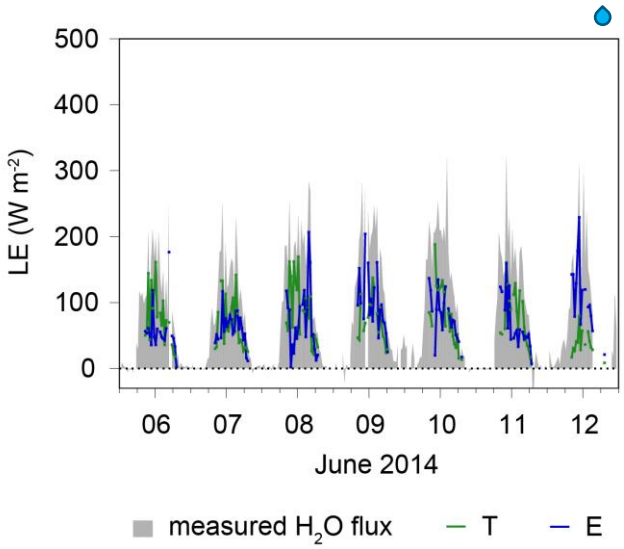
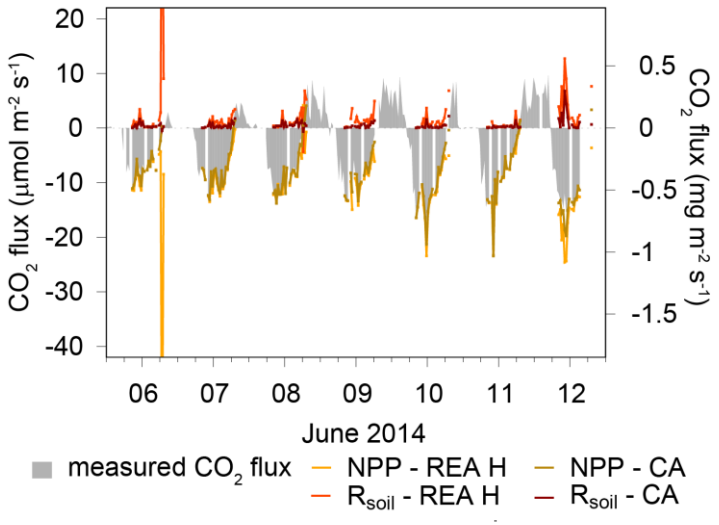
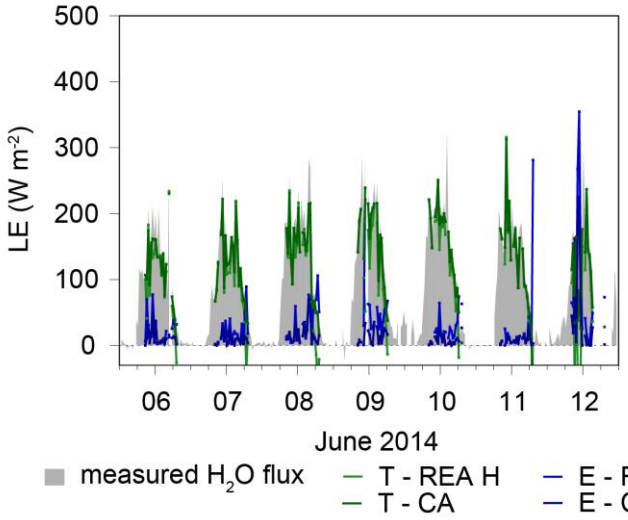




SK10

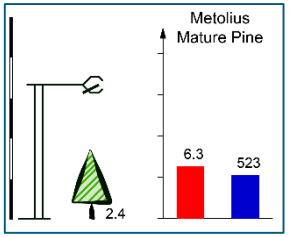




TH08

Mitglied der Helmholtz-Gemeinschaft

METOLIUS MATURE PINE



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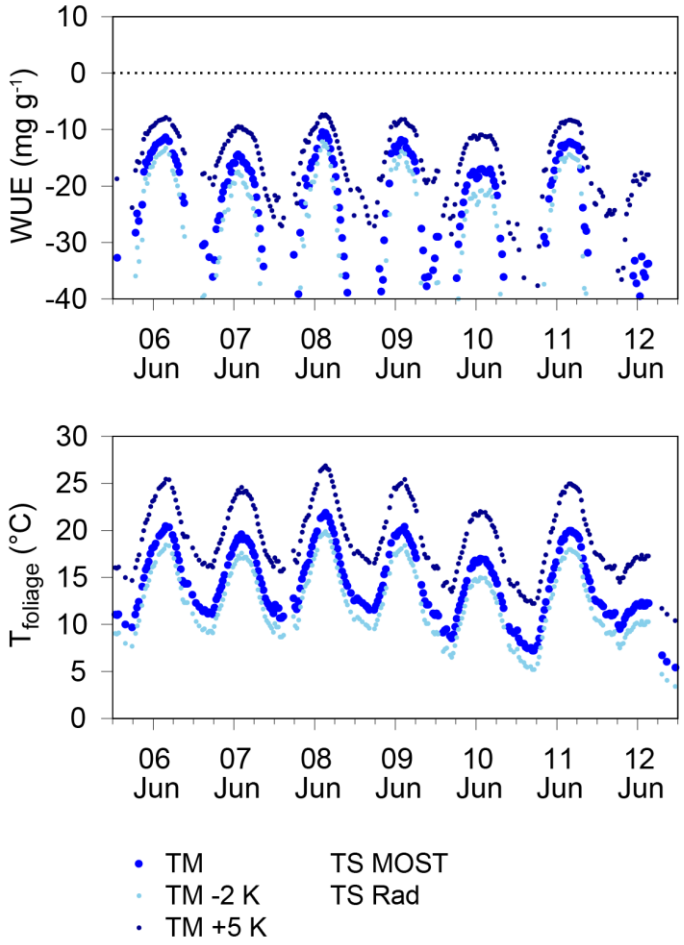


$$WUE = \frac{F_{c_p}}{F_{q_t}} = \frac{g_c \cdot (c_i - c_a)}{g_w \cdot (q_i - q_a)}$$

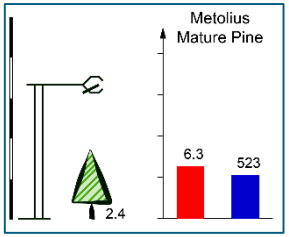
SK10

estimation of q_i based on
100% relative humidity at foliage temperature

1. T_L = mean T_{air}
2. T_L = mean T_{air} - 2 K
3. T_L = mean T_{air} + 5 K
4. $T_L(z)$ = mean $T_{air} + \frac{H}{k\,\hat{\rho}\,c_p\,u^*}\left(\ln\left(\frac{z-d}{z_0}\right) - \psi_H\right)$
5. $T_L = \sqrt[4]{\frac{\phi_L}{\varepsilon\,\sigma}}$

Mitglied der Helmholtz-Gemeinschaft

METOLIUS MATURE PINE



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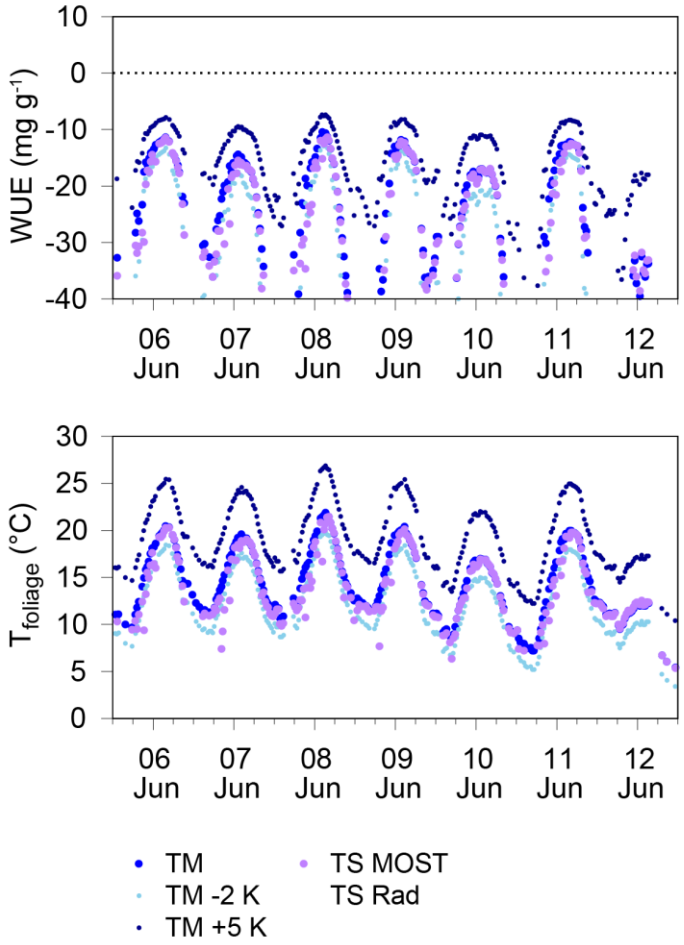

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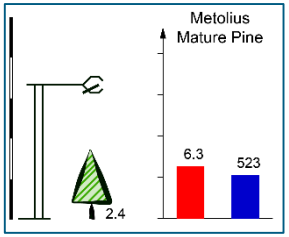

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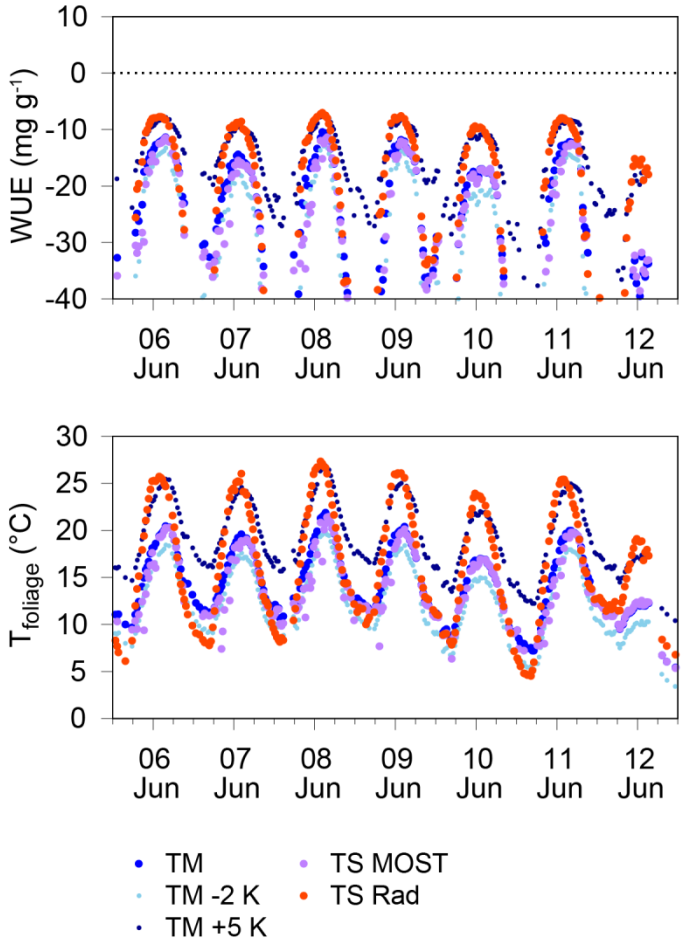

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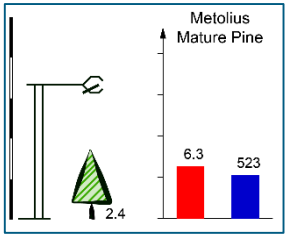

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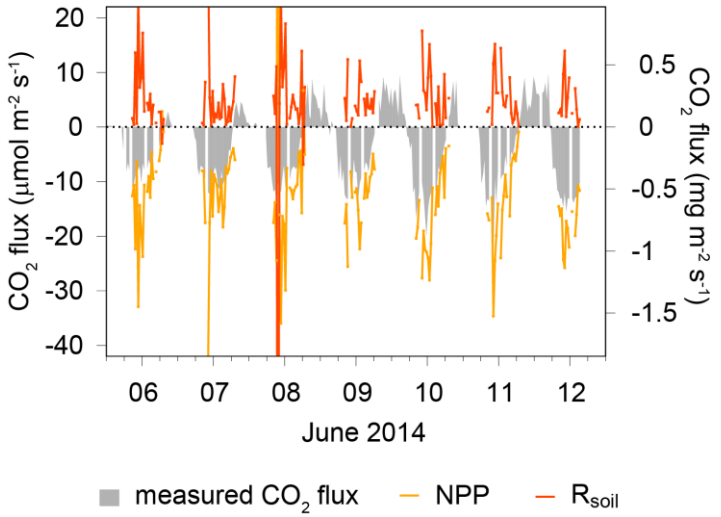
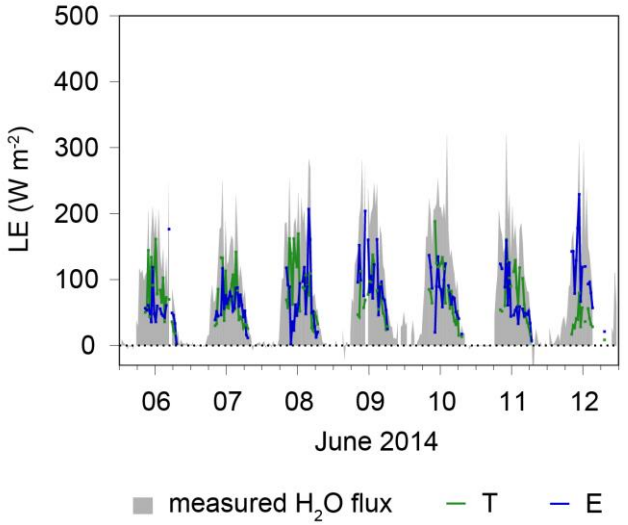
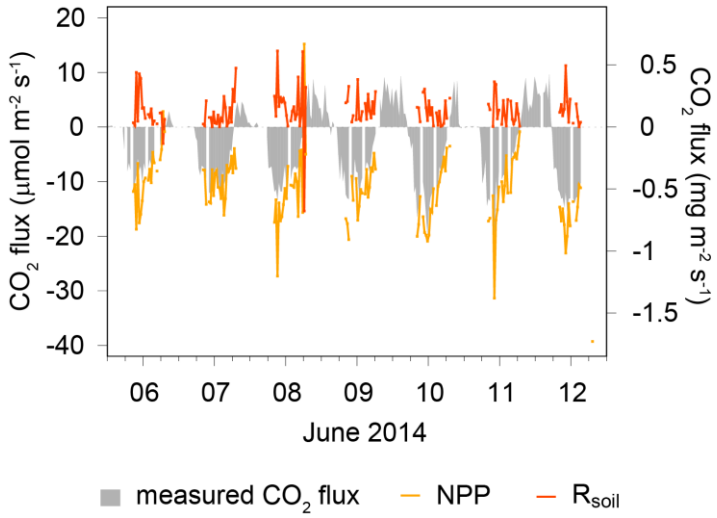
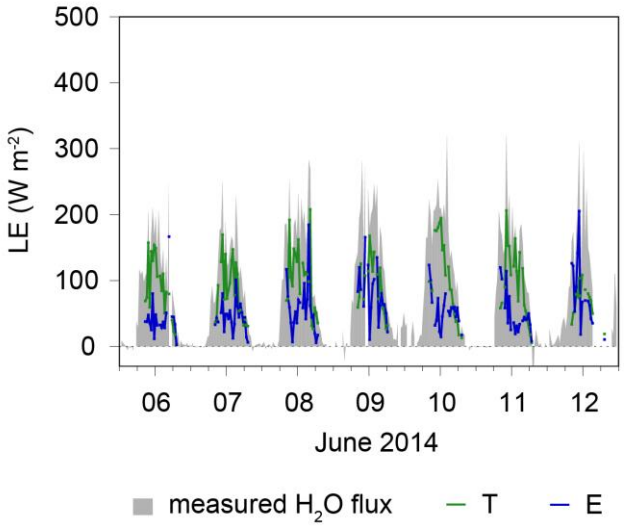




SK10

$T_L = T_{air}$





$$T_L = \sqrt[4]{\frac{\phi_L}{\varepsilon\,\sigma}}$$

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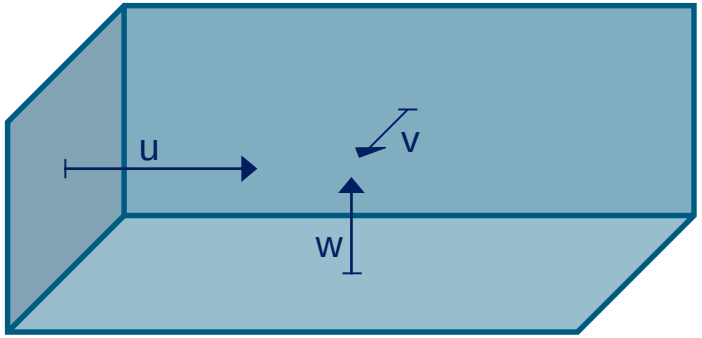
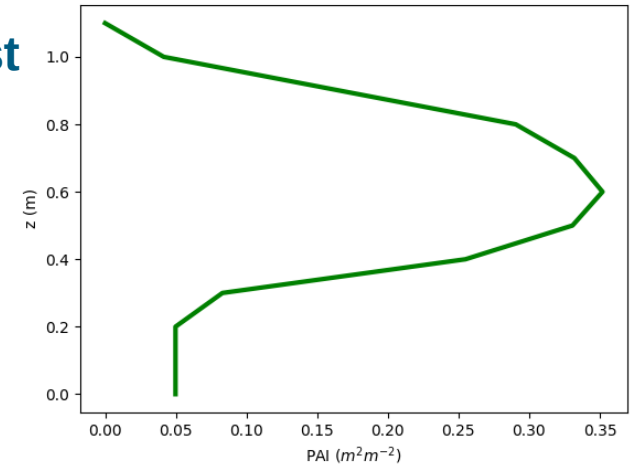
LARGE-EDDY SIMULATIONS

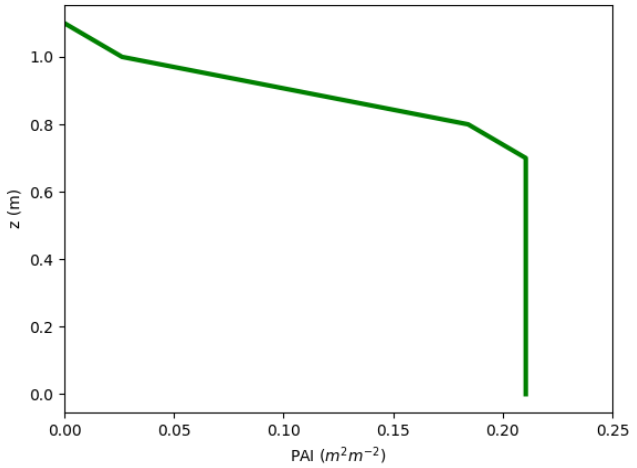
- Dutch Atmospheric Large-Eddy Simulation (DALES)
  HEUS et al. 2010, OUWERSLOOT et al. 2016
- domain size: 72 x 36 x 32 m^3
- resolution: 0.1 m x 0.1 m x 0.1 m
- canopy height: 1 m
- PAI: 2 m^2 m^{-2}
- scalar sources: 10 in canopy,
  1 soil surface
- runtime: 3000 s + 600 s sampling



forest



crop



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LARGE-EDDY SIMULATIONS

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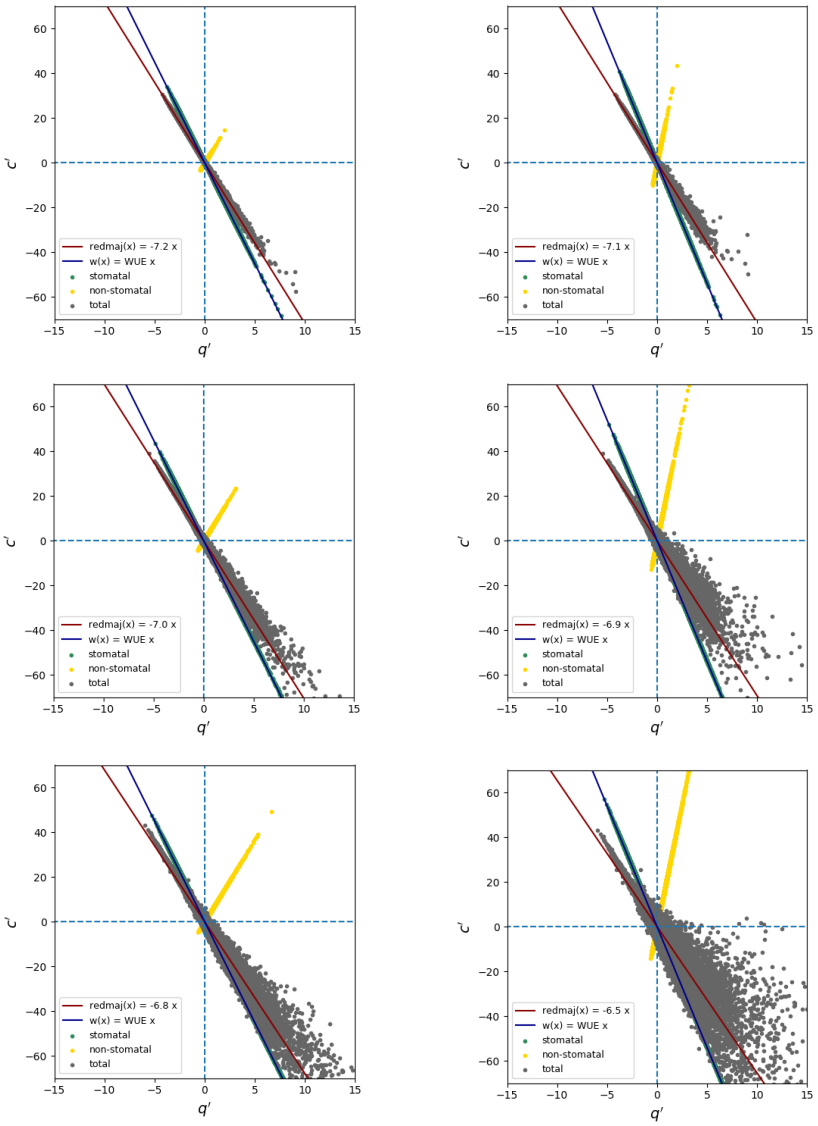

5 m

2.5 m

1.5 m

low CO_2 soil source

high CO_2 soil source

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OUTLOOK

- Further application and comparison of SK10 and TH08
- Sensitivity Analysis (input WUE for SK10)
- Usage of ensemble of approaches
- Application of SK10 and TH08 on ‘virtual’ LES data
- Comparison of crop and forest canopy in LES
- Comparison of various source distribution in canopy
- When do SK10 and TH08 perform well? What are the conditions and circumstances?
- How do canopy density, measurement height and turbulence influence the source partitioning results?

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