Technische Universität Braunschweig

INSTITUTE OF GEOECOLOGY
Climatology and
Environmental Meteorology

Quantification of the surface-atmosphere exchange of energy and carbon dioxide of an extensive urban green roof by eddy covariance measurements

Structure

- Introduction
- Study area and measurement setup
- Meteorological characterization
- Data quality
- Data
- Conclusions

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Relevance/Motivation

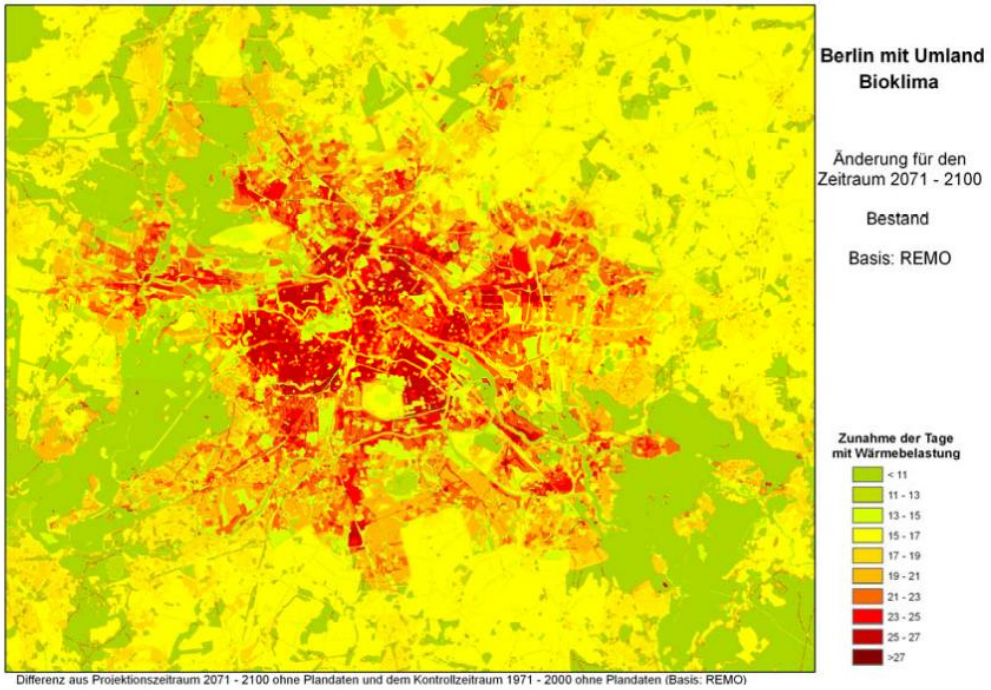
→ **IPCC AR5: „warming is unequivocal“**

→ Specific set of problems in cities

Increase of days with heat stress per year:

Berlin: 27
Environs: 17

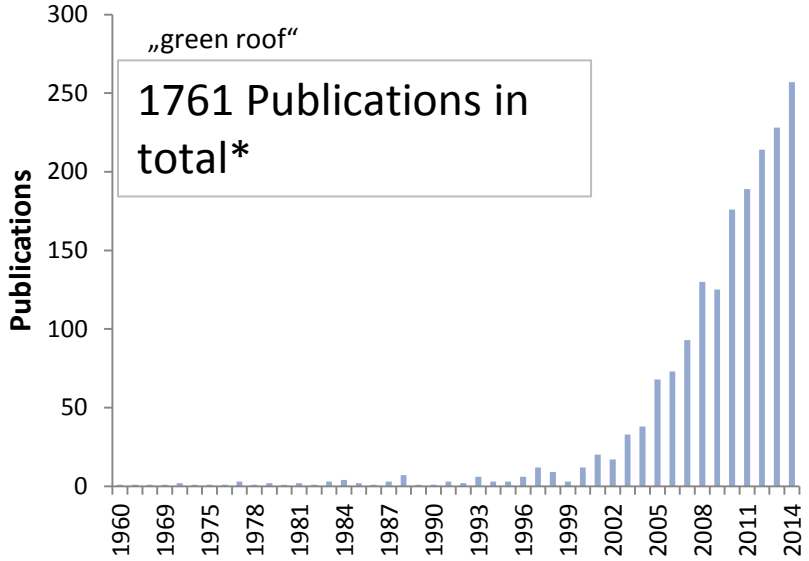
- More frequent and intense heat waves (Li & Bou-Zeid 2013).
- Green roofs as one measure for climate proof adaptation in cities.
- No competition of space in contrast to other vegetation types.

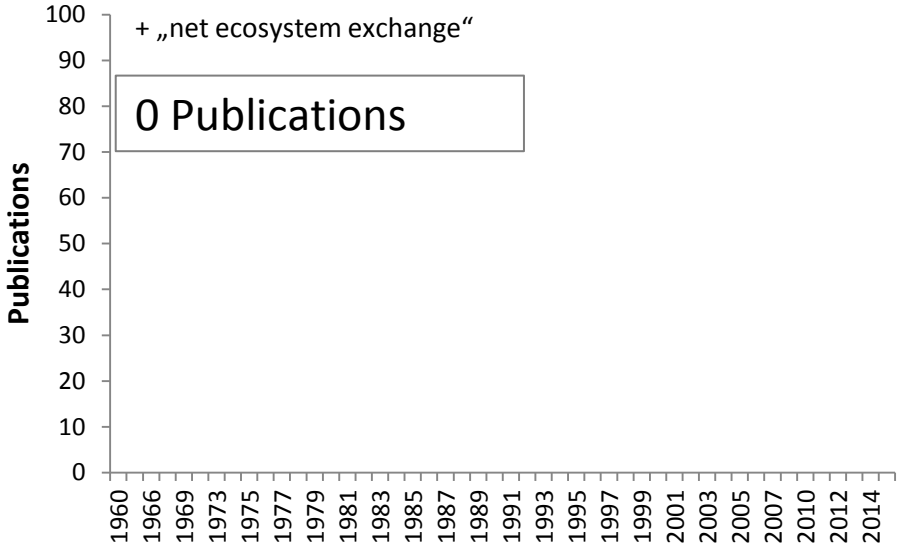


Behrens & Grätz 2010

Relevance/Motivation

- Literature shows that green roofs are sinks for heat and carbon – but empirical quantifications are scarce.
- Quantify the annual variation of the energy balance and net ecosystem exchange of carbon by the state of the art method: eddy covariance.
- Generate a continuous time series (14 months) of data for modelling purposes and to enhance process understanding.





*based on a scopus database search analysis. Terms were searched in title, abstract and keywords.

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Study area

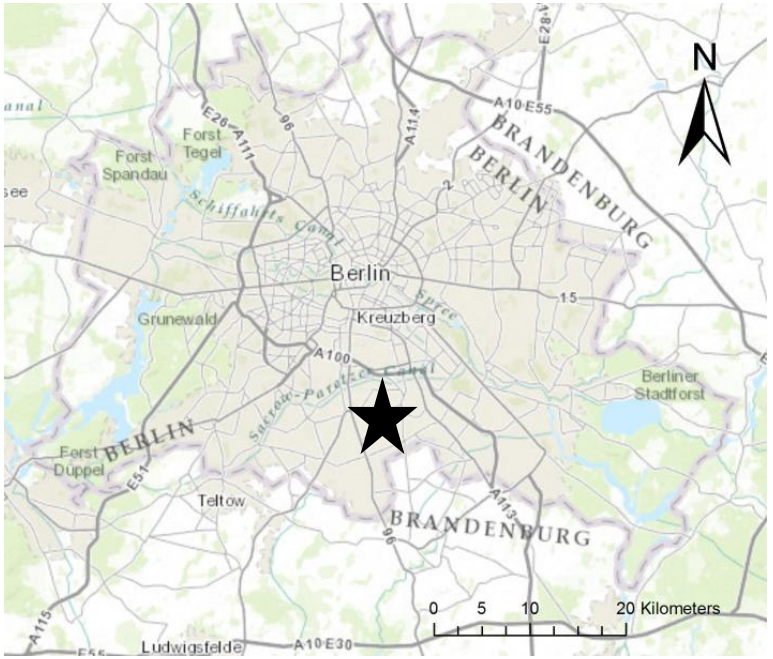

Fig.1: Topographic map of Berlin and surroundings (Esri).

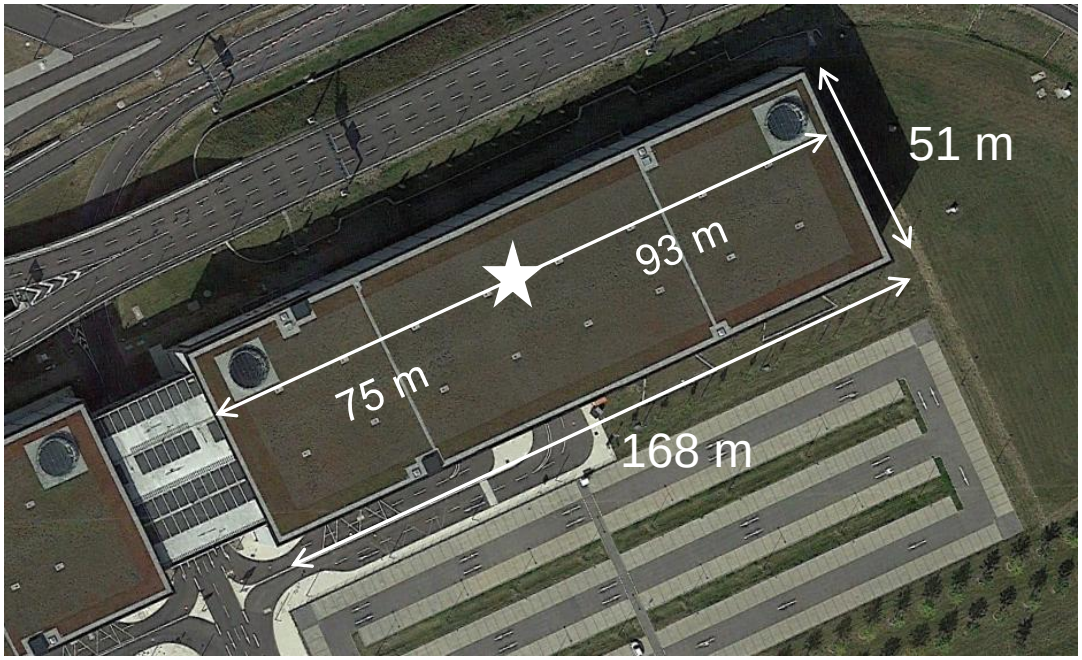

Fig.2: Roof dimensions and fetch for SSW and NEE.

Car Park P7 BER
Schönefeld
Size: ca. 8.600 m²
Year of construction: 2012
Sedum vegetation and herbacious plants

Assets:
- No balustrade
- No roof windows
- No heating emissions
- Permeable facade

Measurement setup

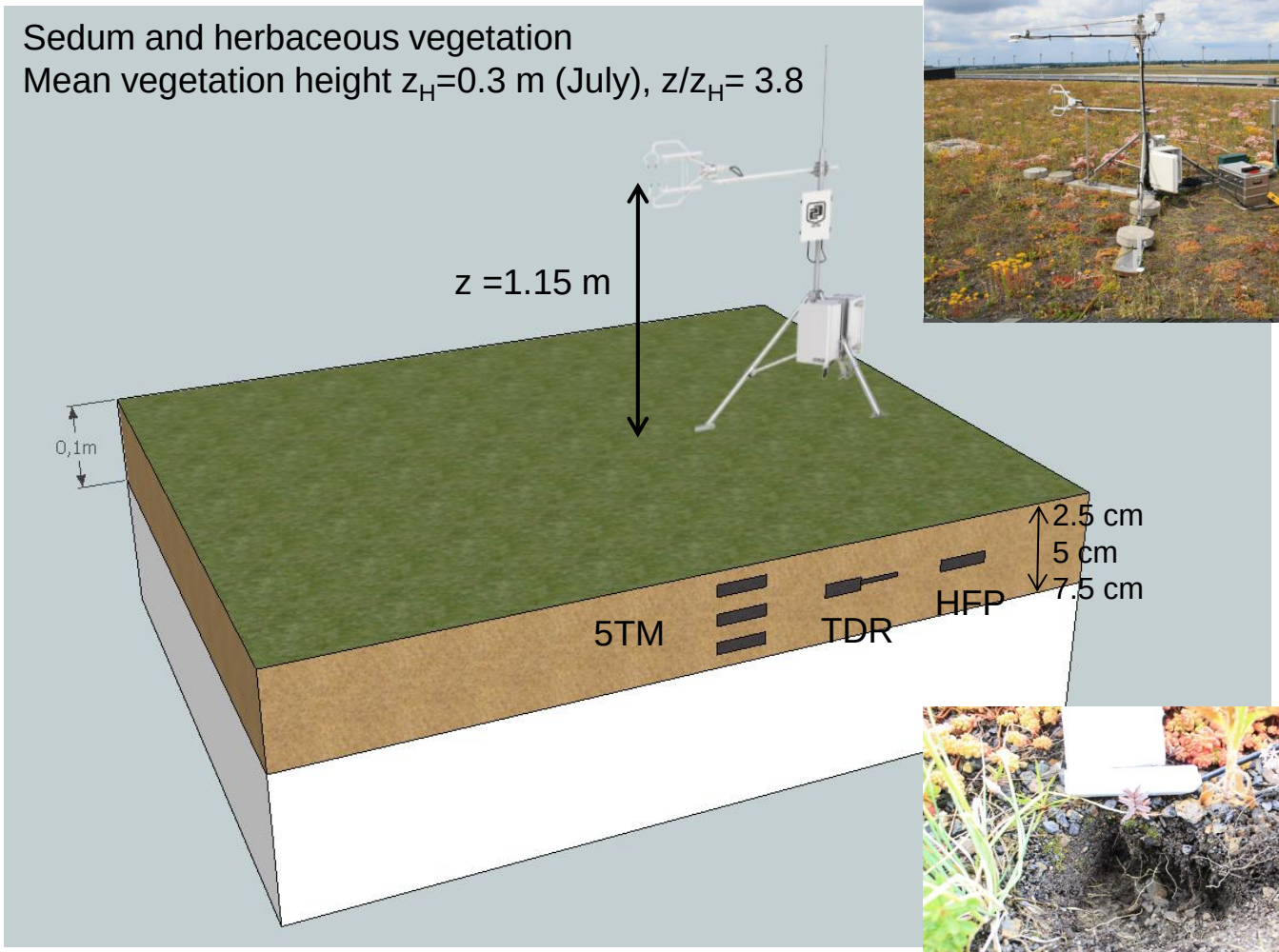

Fig.3: Measurement setup at the extensive green roof at BER airport.

Meteorological characterization

Measurement period: June 2014 until end of August 2015

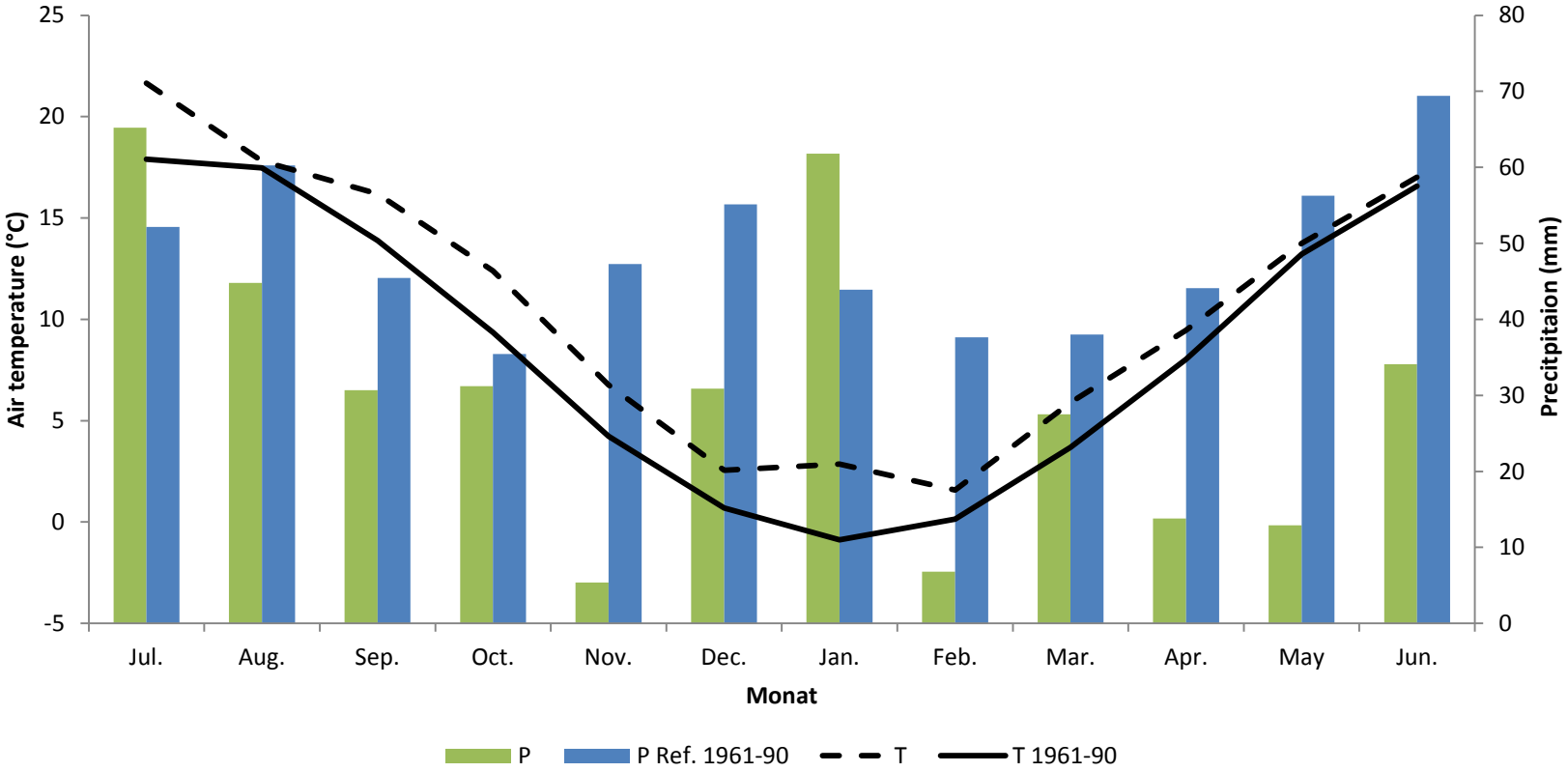

Fig.4: Precipitation and air temperature during the measurement period compared to the reference period 1961-1990.

- Precipitation: 62 % of the longterm mean (Potsdam), last 3 month only 36 %
- Air temperature: 2 °C higher

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Wind regime and footprint

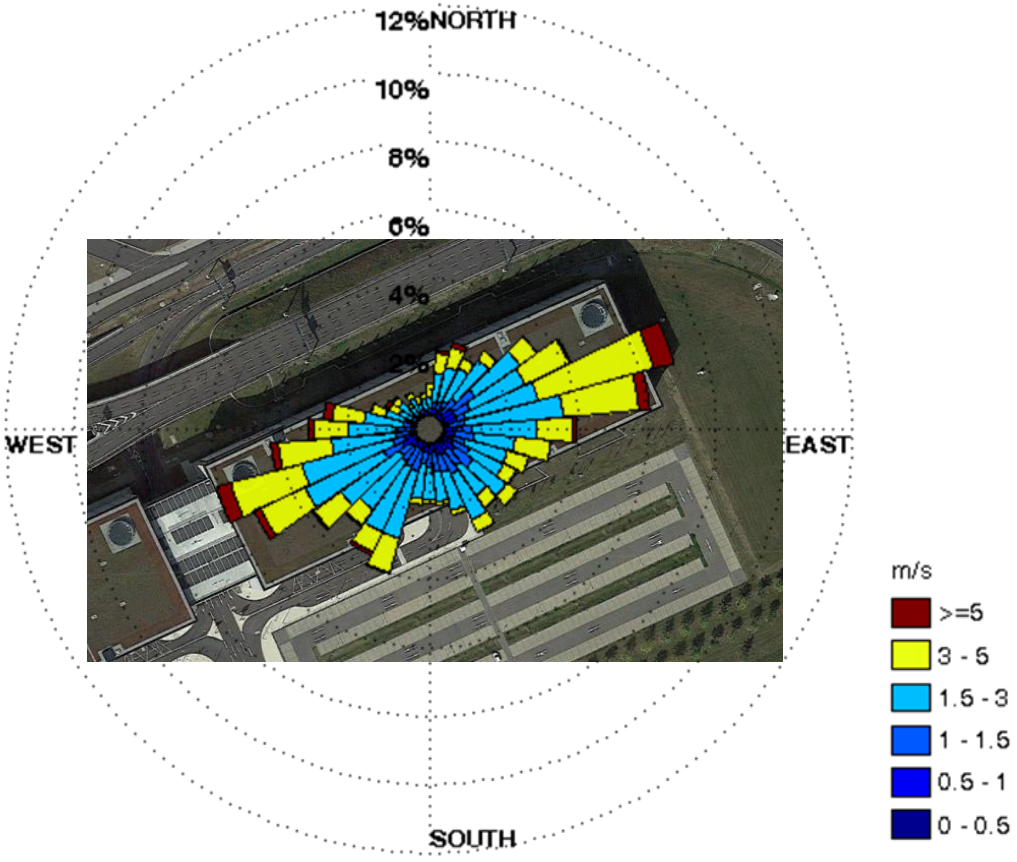

Fig.5: Wind regime from Jul.2014 to Jun. 2015 with wind speed classes of 0 to >= 5 m s^{-1}.

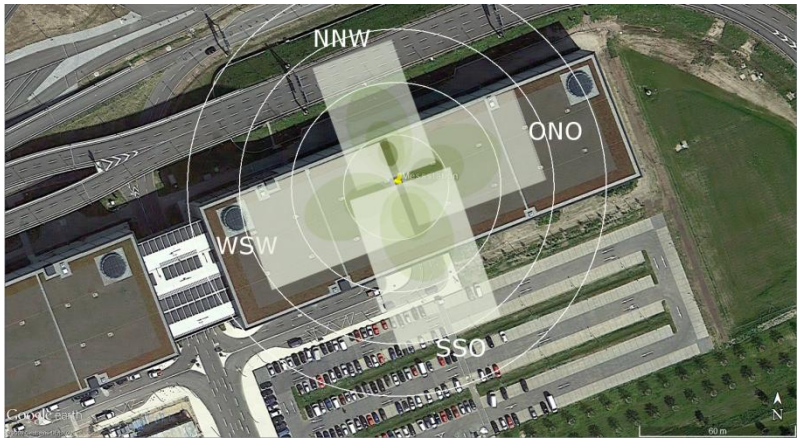

Fig.6: Simulated footprint under neutral atmospheric conditions (-0,05 < ζ < 0,05) according to Schmid (1994) (input data: Jul. 2014 – Dec. 2014).

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Data quality

- Data flags for quality assurance
- Steady state test and test on developed turbulent conditions

➢ high data availability

➢ good site for EC measurements

➢ Flags 1-6 for data analyses

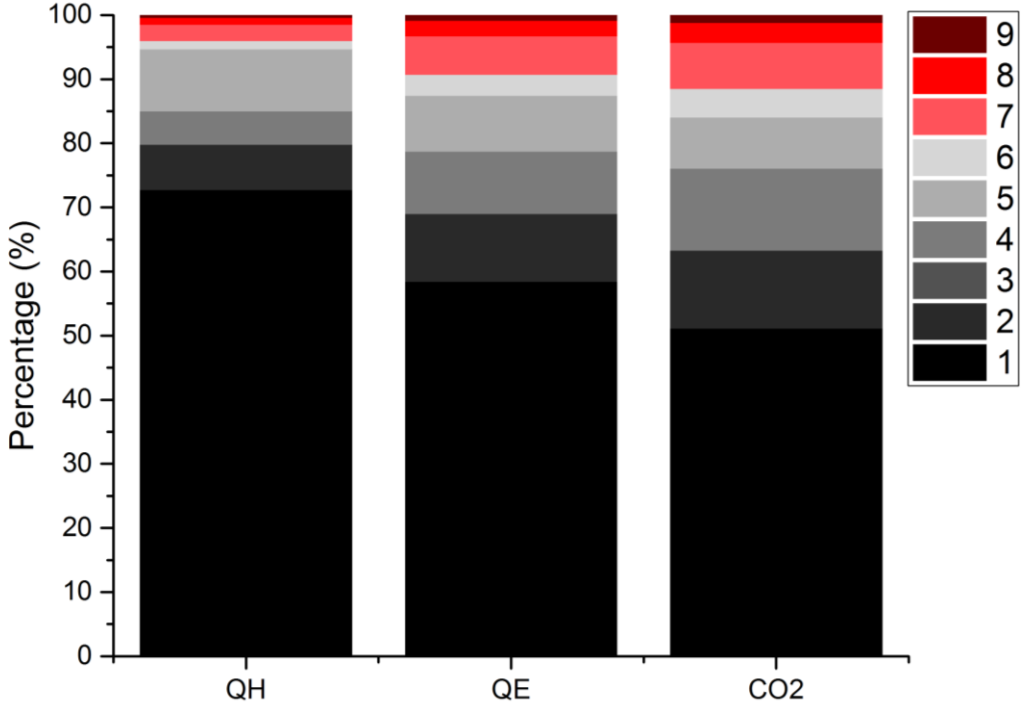

Fig. 7: Percentage distribution of data quality flags according to Foken et al. (2004) for Q_H, Q_E and CO_2 flux between 01.07.2014 and 31.12.2014. Flags 1 and 2 = „For fundamental research“; Flags 3 – 6 = „For general use“; Flags 7-9 = „Not reliable data“.

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Seasonal variation of energy fluxes

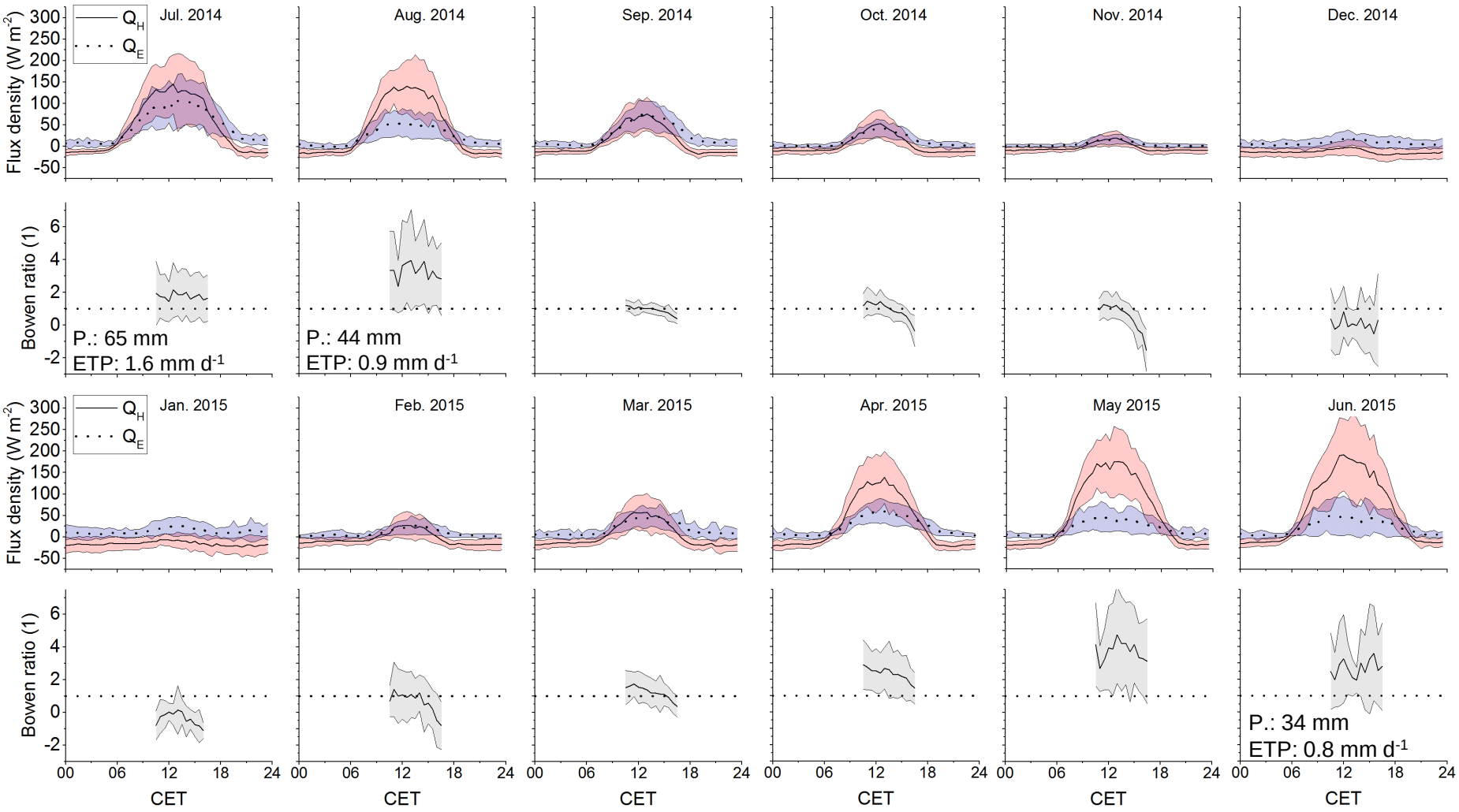


Fig.8: Mean diurnal variation of Q_H, Q_E and Bowen ratio B_O for each month from July 2014 to June 2015.

Q_E – Periods without precipitation

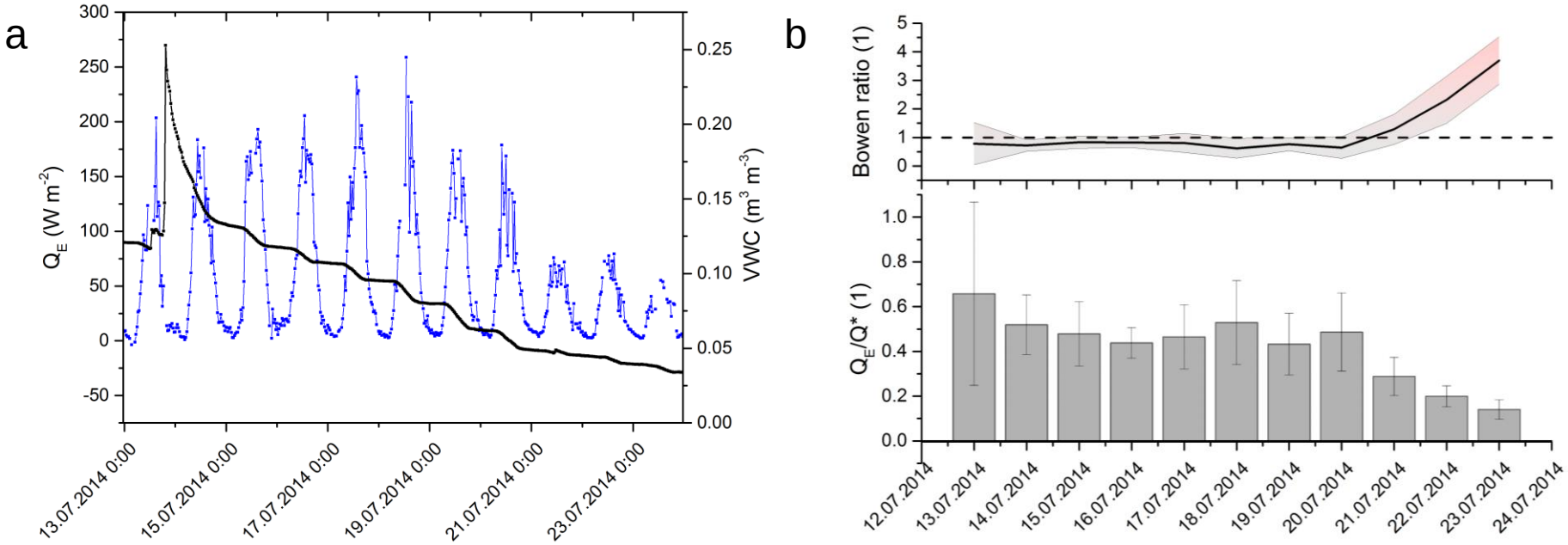


Fig.9: Course of Q_E and volumetric water capacity (VWC) (a), Q_E/Q^* ratio and Bowen ratio (b) during a 10- day period without precipitation.

Seasonal variation of CO_2-Fluxes

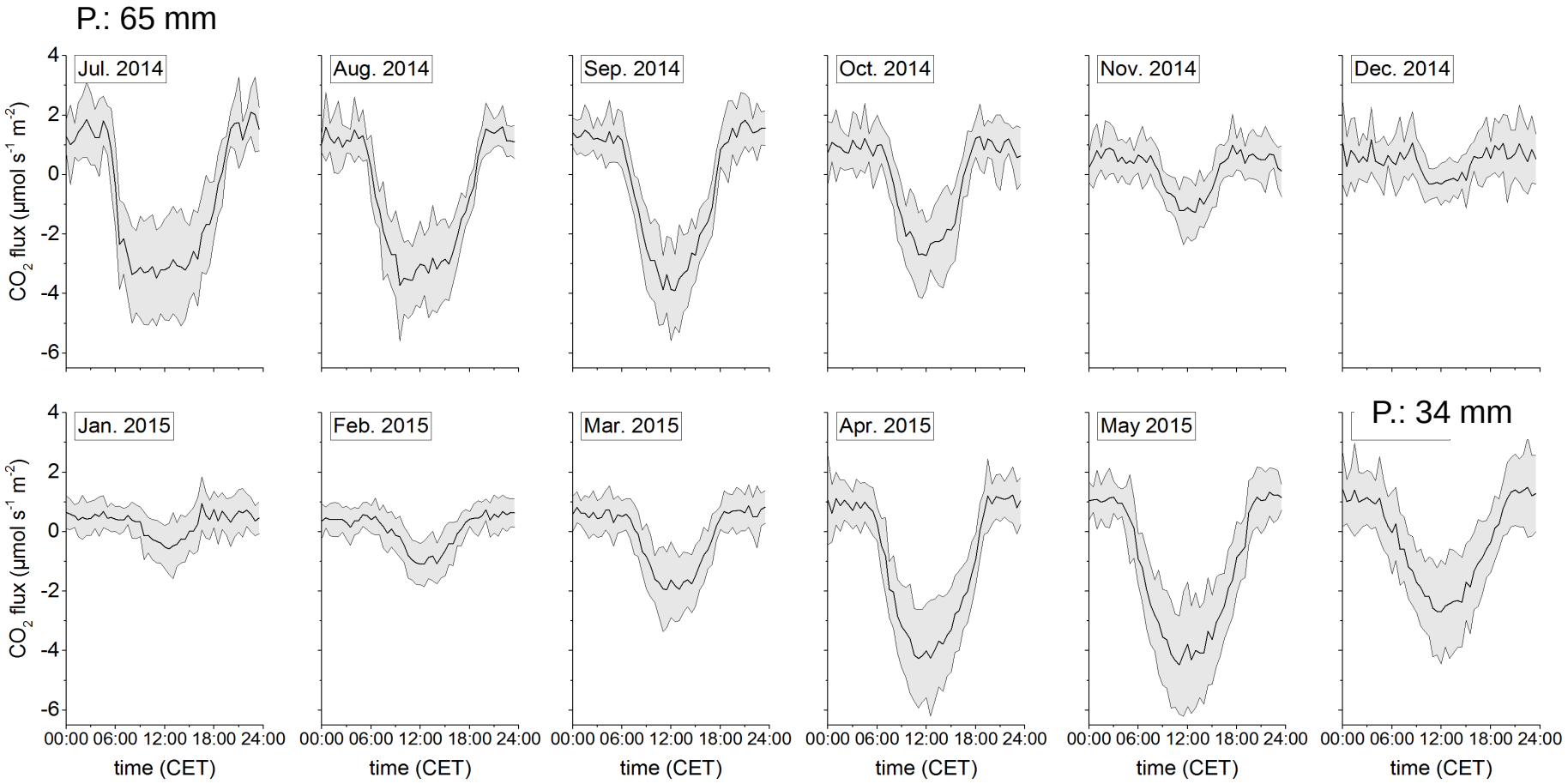
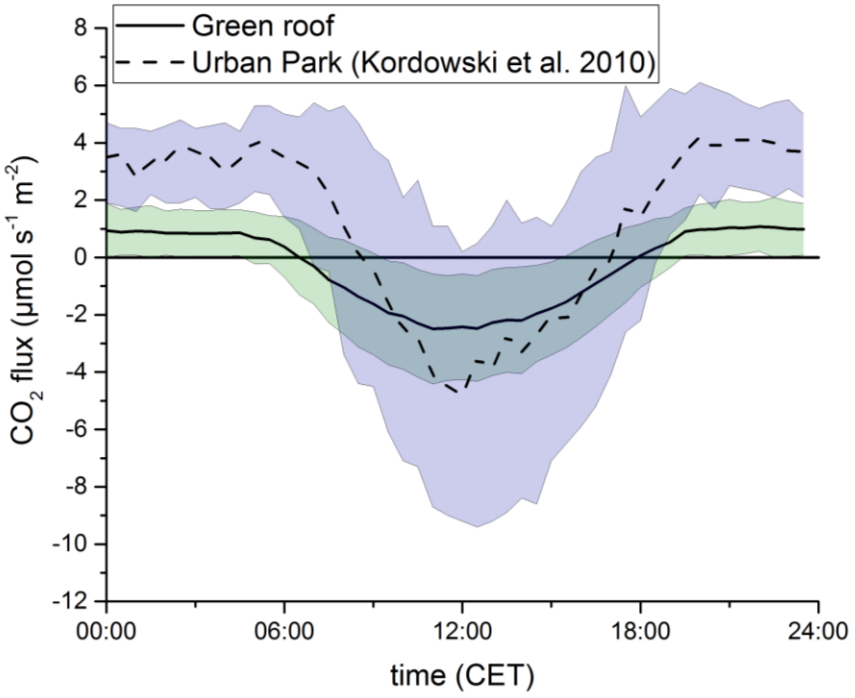


Fig.10: Mean diurnal variation of CO_2-Fluxes for each month from July 2014 to June 2015.

- Mean flux: -0.36 µmol s^{-1} m^{-2}

Comparison with published CO_2-Fluxes

12 Months



July

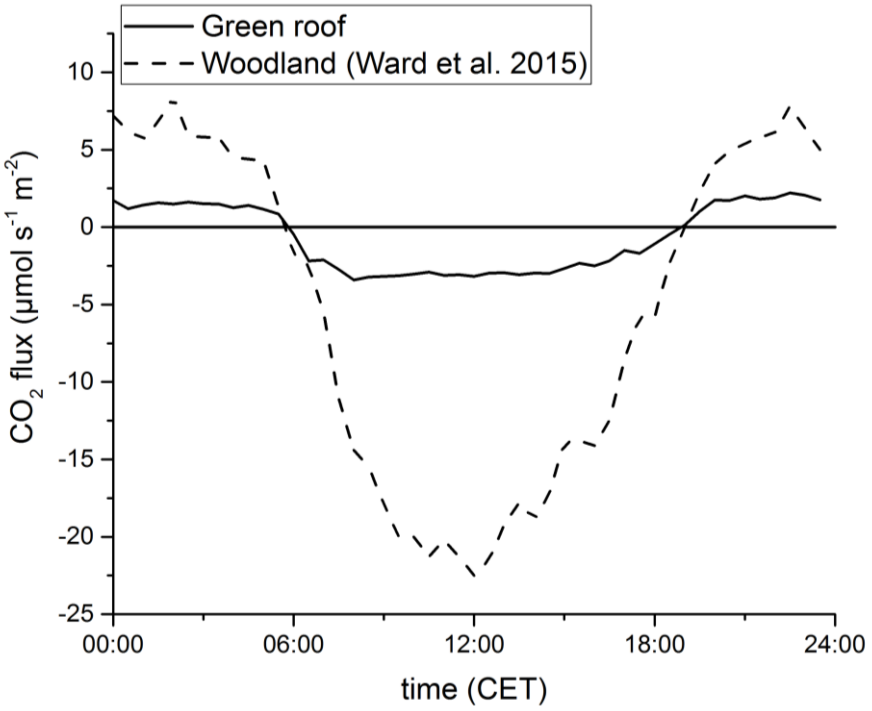


Fig.11: Comparison of CO_2-Fluxes at the green roof BER with published values of Kordowski and Kuttler (2010) and Ward et al. (2015).

Summary/Conclusions

- First measured annual variation of the energy balance of an extensive green roof by eddy-covariance.
- Energy balance is dominated by Q_H in summer months.
- Q_E reduced by about 80 % at the end of a dry period and Bo-ratio increases from 0.8 to 3.6.
- Bowen ratio may significantly be lowered by irrigation.
- CO_2-Fluxes (not gap-filled) indicate that the extensive green roof is a net sink for carbon.
- Comparisons show that the carbon uptake at the green roof is lower at daytime than in urban parks and urban woodland but respiration is also lower.
- Measurements continue until end of August 2015, data analysis is in preliminary state.

Unrotated vertical wind velocity