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
Environ: 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

Car Park P7 BER
Schönefeld
Size: ca. 8,600 m²
Year of construction: 2012
Sedum vegetation and herbacious plants

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

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

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

Sedum and herbaceous vegetation
Mean vegetation height $z_H=0.3$ m (July), $z/z_H=3.8$

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

Measurement period: June 2014 until end of August 2015

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

**Fig.4**: Precipitation and air temperature during the measurement period compared to the reference period 1961-1990.
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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 $\geq 5$ m s$^{-1}$.

**Fig.6**: Simulated footprint under neutral atmospheric conditions ($-0.05 < \zeta < 0.05$) 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

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

![Graph showing unrotated vertical wind velocity against wind direction.](image-url)