Nocturnal boundary layer budgets of carbon dioxide enabled by unmanned aircraft

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Measuring air-land interactions at night

Stable stratification at night ...

- ... makes Eddy Covariance measurements difficult or impossible
- ... but enables nocturnal boundary layer (NBL) budgets [1,2]

Limitations of common NBL budget realisations

- Tall towers: low number of instrumented towers available, typically no more than 3-5 inlet heights
- Small towers: height of NBL and CO$_2$ distribution needs to be estimated
- Tethered balloons: relatively large logistical effort, limited maximum height
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Small unmanned aircraft equipped with miniaturised analysers can overcome these limitations
COCAP – a COmpact Carbon dioxide analyser for Airborne Platforms

- Measured quantities:
  - \( x_{\text{CO}_2} \) (dry air mole fraction of \( \text{CO}_2 \))
  - Ambient temperature
  - Relative humidity
  - Air pressure
- Self-contained
- 42x14x14 cm\(^3\), 1 kg, 8 W

Kunz et al., Atmos. Meas. Tech., 2018
The ScaleX 2016 campaign in Fendt

- Aim of ScaleX: closing gaps in observation of biogeochemical cycles
- Fendt site: rural area, mostly grassland
Formation of the nocturnal boundary layer

Fendt site, Germany, 6 July 2016
Sunset at 19:16 (all times UTC)
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Comparison to Eddy Covariance measurements

Kunz et al., in preparation
Effect of air displacement on measurements
Effect of air displacement by multicopter

Fendt site, 7 July 2016, 22:15 LT

![Graphs showing the effect of air displacement by a multicopter on temperature and CO2 concentration](image)
Effect of air displacement by multicopter

Fendt site, 8 July 2016, 00:15 LT

$v$ in m.s$^{-1}$

$\theta_v$ in °C

$z = 10$ m

$\chi_{CO2}$ in μmol.mol$^{-1}$
Sensitivity of flux estimates to error sources

![Graph showing sensitivity of flux estimates to error sources. The graph plots flux (F) in μg·m⁻²·s⁻¹ against various error sources for Night 1 and Night 2. The graph includes data points for different scenarios, such as No change, z+2m, z-2m, xCO₂+3ppm, and xCO₂-3ppm, with and without 9m mast. The graph also shows the mean and NBL budgets.]
Conclusions

- NBL budgets yield constraints of surface-atmosphere exchange under stable conditions
- Unmanned aircraft carrying miniature analysers greatly simplify the NBL budget method
- Effects of air displacement by multicopter can be kept within acceptable limits
Thank you for your attention!