Eddy covariance measurements of CO_2 and CH_4 fluxes over a boreal river

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Aki Vähä, T. Vesala, S. Guseva, A. Lindroth, A. Lorke, S. MacIntyre, A. Ojala, I. Mammarella

UNIVERSITY OF HELSINKI

INAR
INSTITUTE FOR ATMOSPHERIC AND EARTH SYSTEM RESEARCH

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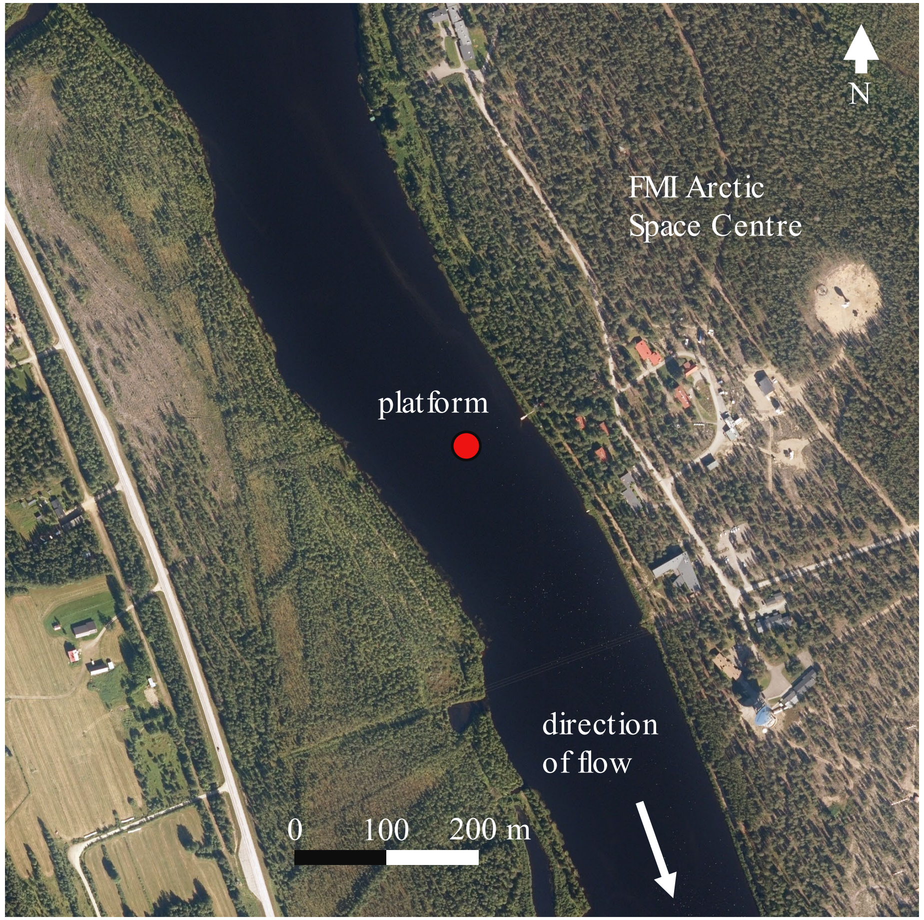
Background: Greenhouse gas fluxes over rivers

- Considerable outgassing of carbon from rivers, not just passive carbon-transporting pipes
- Unknowns:
  - Magnitude of fluxes
  - Drivers of fluxes in different-sized rivers
  - Nighttime fluxes
- Lack of previous EC measurements: only one study of a boreal river (Huotari et al. 2013)
- Goal: to measure and quantify greenhouse gas fluxes and the physical processes that control them on the River Kitinen in northern Finland
- Four-month campaign in 2018

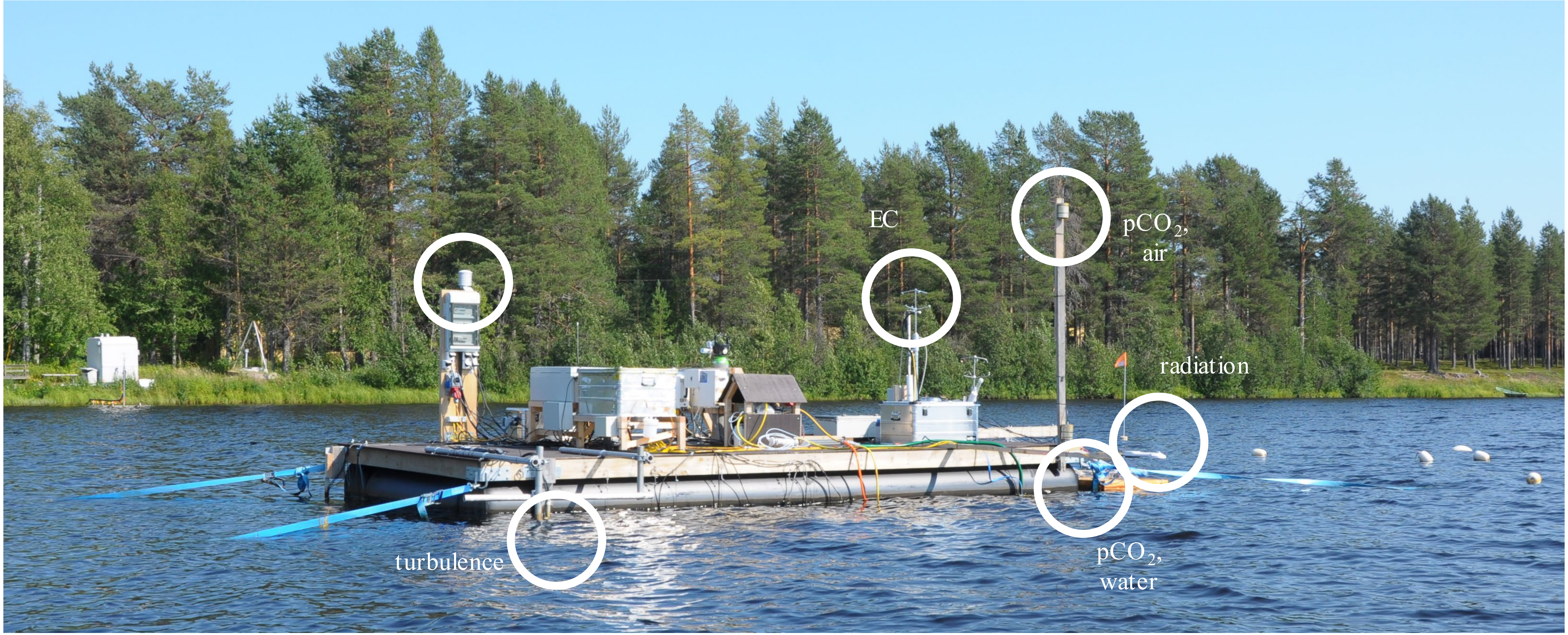
Site of measurements



Site of measurements

- Köppen climate classification Dfc (northern boreal)
- 67.37 N, 26.62 E, 173 m above sea level
- River Kitinen
  - length 235 km
  - catchment area 7 672 km^2
  - width at the experiment site 180 m
  - mean yearly discharge (10 km downstream) 103 m^3/s
- Heavily regulated river: seven hydropower plants, power plant 11 km both up and downstream from the experiment site
- Water current completely controlled by the power plants

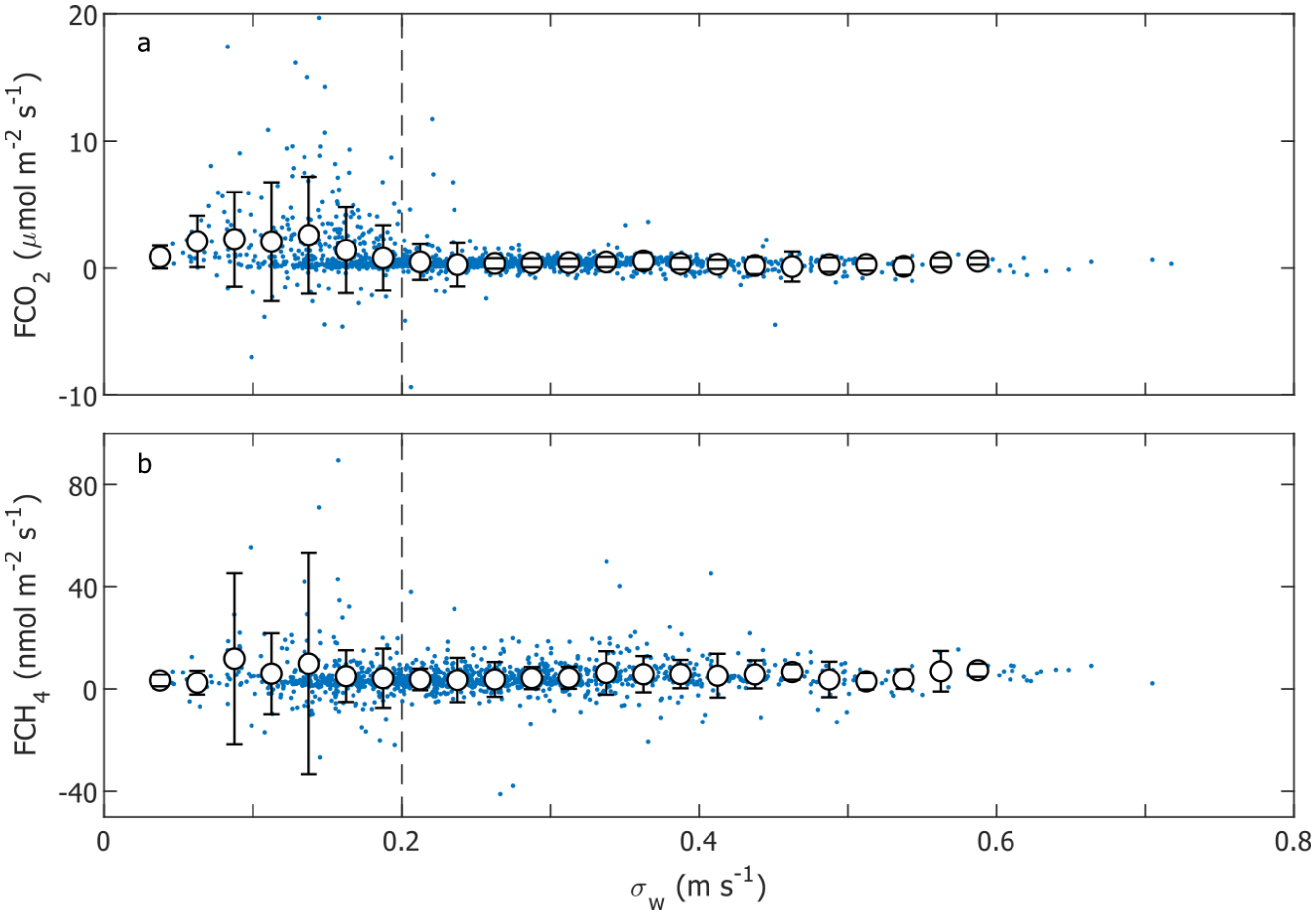
Platform



Eddy covariance measurements

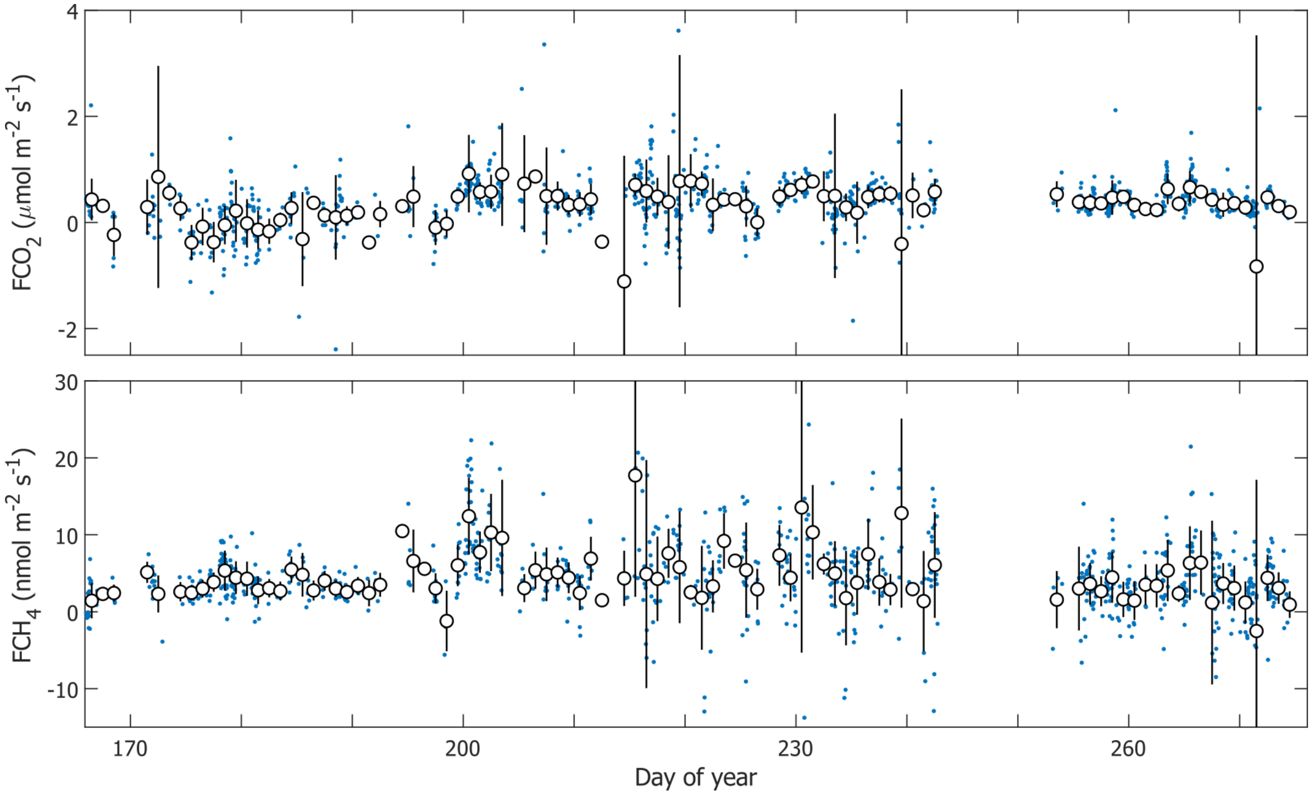
- METEK uSonic-3, Li-Cor LI7200RS (enclosed-path)
- Normal data processing workflow
- Data screening: skewness & kurtosis of w and c, flux stationarity, minimum σ_w threshold, wind direction using footprint analysis (Kljun et al. 2014)
- 27 % of CO_2 fluxes and 23 % of CH_4 fluxes were retained after data screening
    - σ_w threshold and wind direction most prominent

σ_w filtering



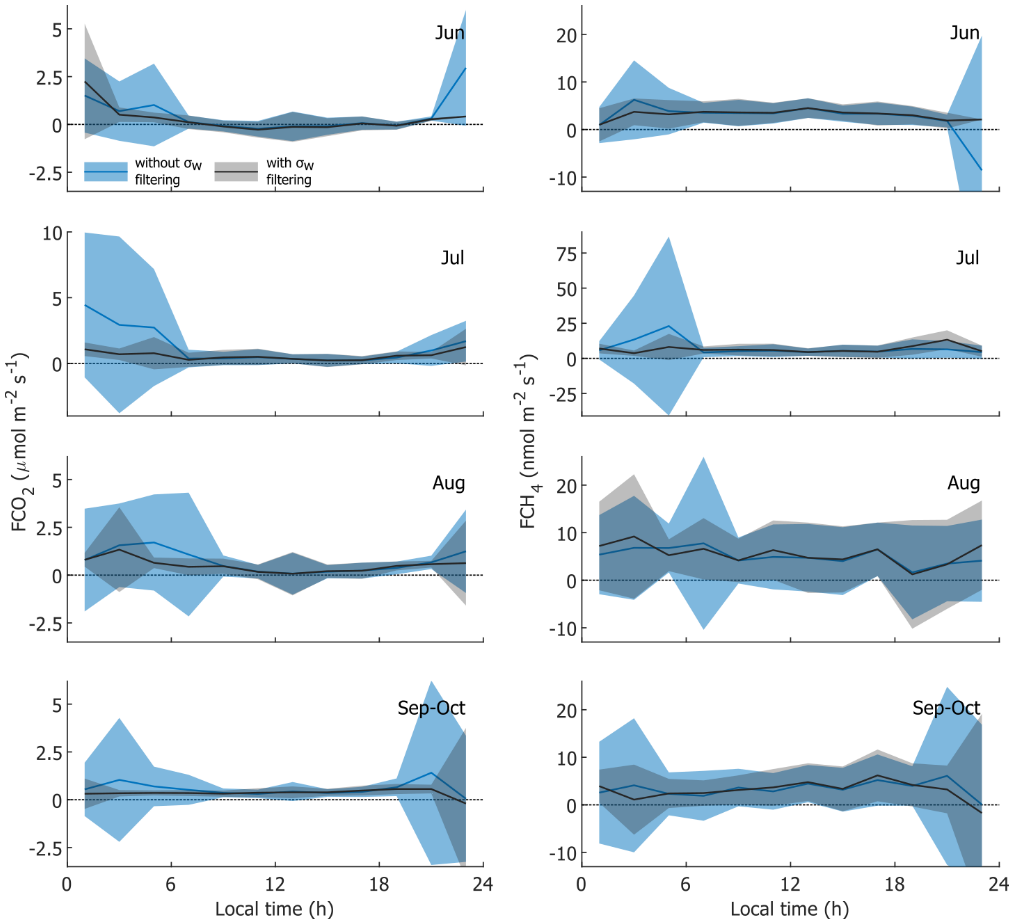
- σ_w threshold at where the variability becomes independent on σ_w
- Same threshold for both FCO_2 and FCH_4

CO_2 and CH_4 fluxes and their variability



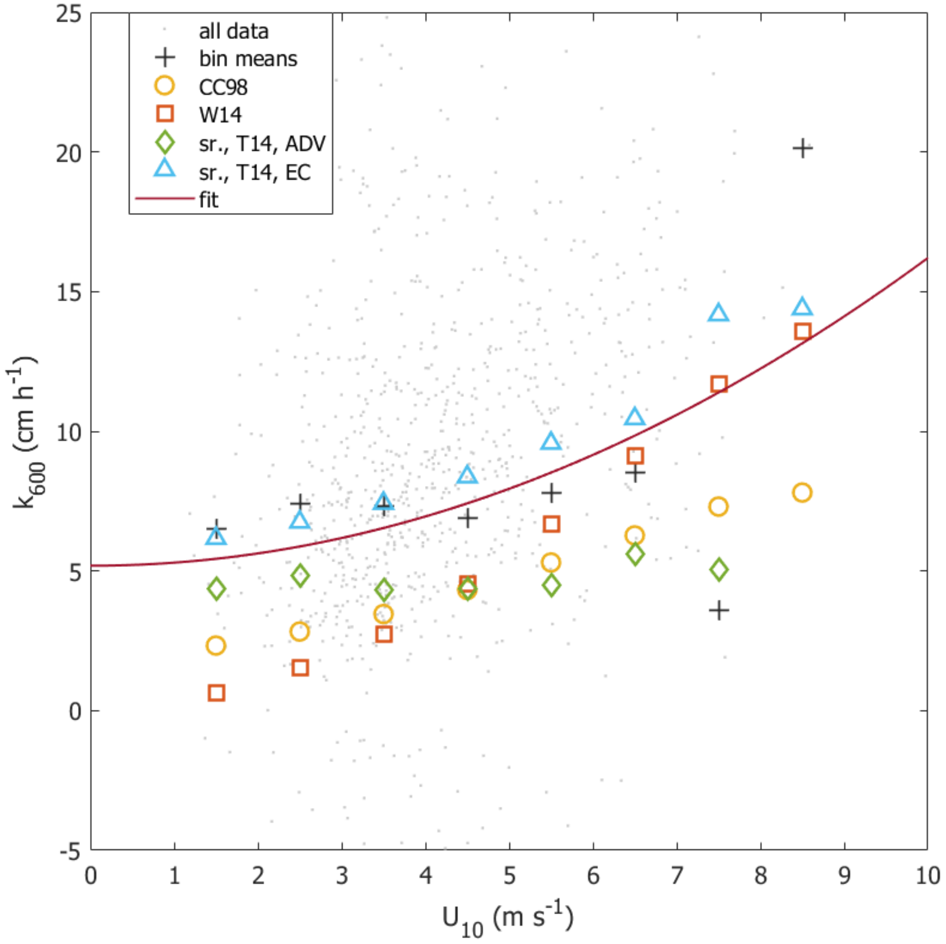
- Fluxes were generally small and relative flux variability large
- Highest FCO_2 (0.49 ± 0.98 μmol m^{-2} s^{-1}) and FCH_4 (5.5 ± 7.9 nmol m^{-2} s^{-1}) in August
- Occasional negative FCO_2 in June opposite to the measured ΔpCO_2

Diurnal cycle in the fluxes and the nighttime flux problem



- Nighttime CO_2 fluxes were higher, large variability in all fluxes
- σ_w filtering decreases the $F$$CO_2$ difference: suggests that the large nocturnal fluxes do not represent the surface exchange
- However, data coverage only 10–15 % during night
- Negative CO_2 fluxes in daytime in June

Gas transfer velocity and wind speed



- Models:
    - Cole & Caraco (1998): $k_{600} = (2.07 + 0.215U_{10}^{1.7})(\frac{Sc}{600})^{-0.5}$
    - Wanninkhof (2014): $k_{600} = 0.251U_{10}^{2}(\frac{Sc}{600})^{-0.5}$
    - Zappa et al. (2007) (surface renewal): $k_{600} = c(\varepsilon\nu)^{1/4}Sc^{-1/2}$
    - Line fit: $k_{600} = 0.11 \cdot U_{10}^{2} + 5.2$
- Non-zero intercept is required
- Buoyancy flux is required (also Guseva et al. 2021: often dominant during low wind)

Conclusions

- EC measurements can and should be conducted on rivers but data could be scarce
- Continuous measurements are needed to capture nocturnal fluxes
- The effect of the buoyancy flux on the gas transfer cannot be neglected

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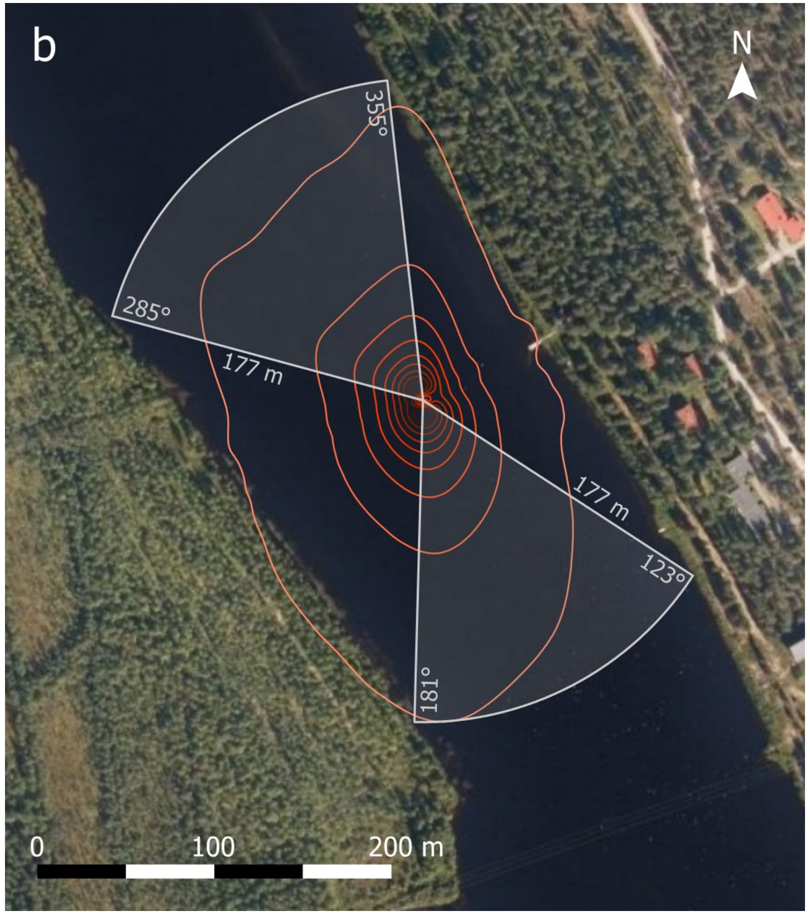
Thank you! Questions?

Extra: footprint analysis



- Kljun et al. (2015) footprint model
- Footprint underestimated at the river bank directions
- Accepted wind sectors where the maximum distance to 90 % line (177 m) intersects the river banks