Optimizing chambers for stream carbon dioxide evasion estimates; results of a controlled flume experiment

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Introduction

- Inland waters were recently discovered as a relevant player in the global carbon cycle, especially the more turbulent one are responsible of a globally large biogeochemical flux occurring across the air-water boundary.
- Quantification of CO2 degassing in headwater streams requires the estimation of the flux across air-water interface, among the many variables, of the gas exchange velocity (k).
- The k is currently estimated via different methods all of which is associated to high uncertainty.
- Here we report an analysis, supported via experimental data, of i) two differently designed chamber and of ii) two methods available to interpret the chamber data.

Floating chambers and CO_2 sensors

SE-0020
CM-0026

- Chamber methodology (CO_2 sensor: K33 ELG by SenseAir)
- Chamber types *Flexible Foil* *Standard*

… sealing design

Study setup

Configurations analysed

Table 2: Summary of the configurations setup used at the EcoCatch Flumes of the Lunz Mesocosm Infrastructure.

	Configuration	Discharge $[l\,s^{-1}]$	Flow velocity $[m\,s^{-1}]$	Travel Time $[s]$	Slope [‰]
a	R6Q1	2.74	0.083	421	0.5
b	R6Q2	5.50	0.126	278	0.5
c	R4Q2	5.63	0.202	173	2.5
d	R4Q3	7.04	0.261	134	2.5

Total of 4 slope/discharge combinations.

→ Influence of the **slope** (b-c);
→ Influence of the **discharge** (a-b), (c-d).

Sampling description

- "Anchored" (i.e. "Steady")

Fixed in a point (long-term deployments)

- "Drifting"

Free to follow the current (measurements last up to the travel time of the chamber in the flume)

- Post-process calibration (set to 400ppm initial value)

(This procedure does not affect k estimated via the anchored chamber)

Methods (1)

Method # 1

I. Linear model

II. CO2 water is needed (derived from steady chambers)

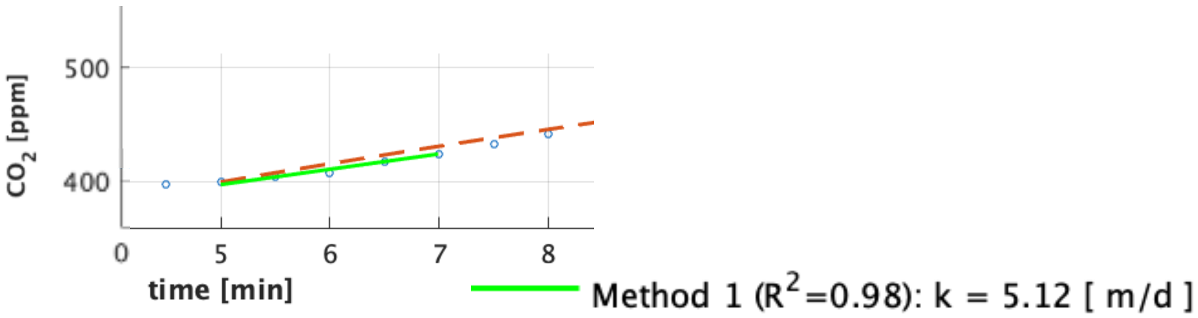
III. Applicable to both steady and drifting observations (in theory)

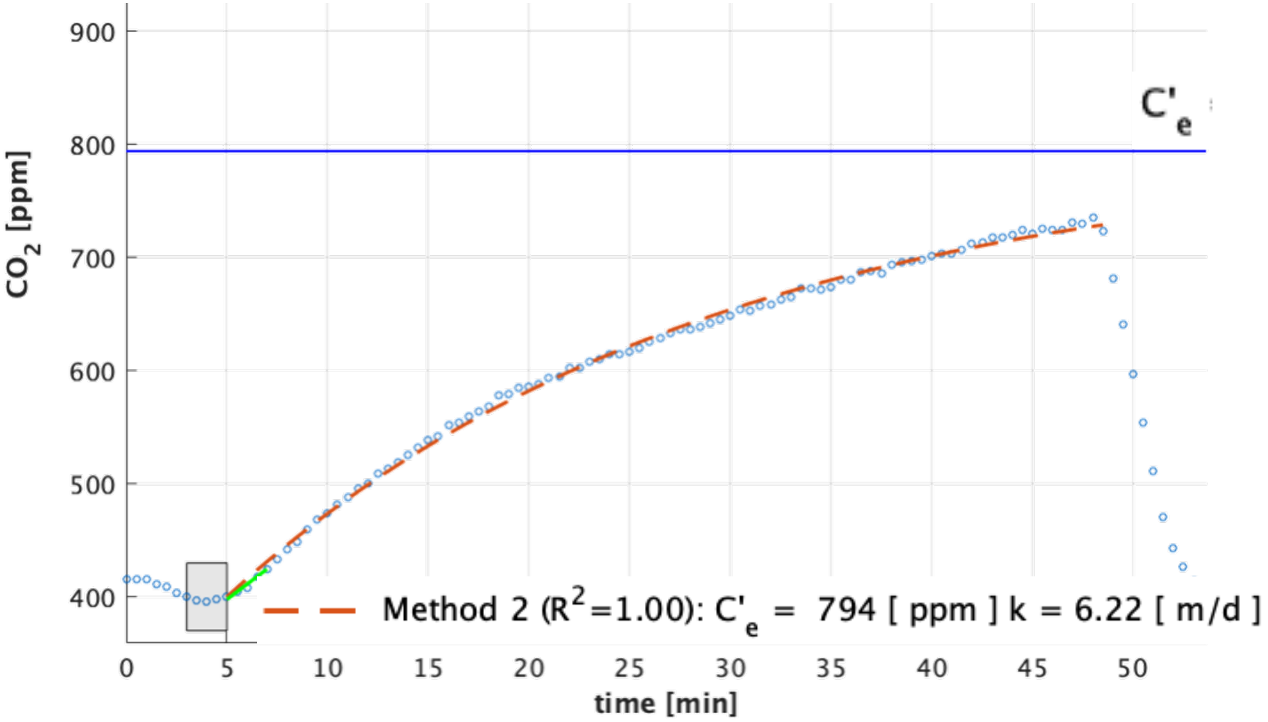
Method # 2

I. Exponential model (both k and C02 water are estimated)

II. Applicable only to steady deployments

III. Very robust (simultaneous measure of k and CO2 water, estimate on a lot of data)





Methods (2)

Standardization to k600

→ results independent on <u>temperature</u> and <u>gas</u> type

(temperature data not available, estimated based on daily temperature expression)

$$k_{600} = k\left(\frac{600}{SC_{CO_2}}\right)^{-n} \qquad SC_{CO_2} = 1742 - 91.24\,T_w + 2.208\,T_w^2 - 0.0219\,T_w^3$$

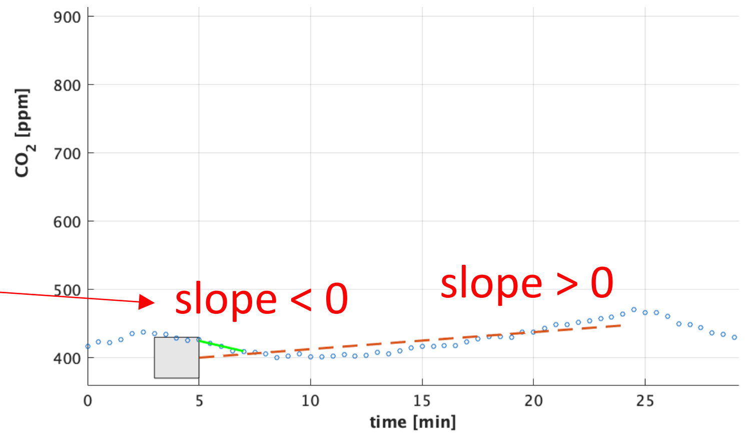
Generalized Likelihood Uncertainty Estimate, "GLUE"

→ assessing <u>uncertainties</u>

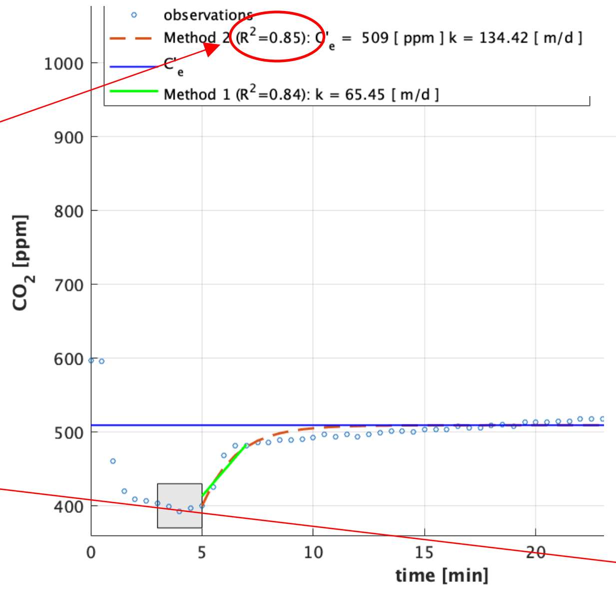
- <u>Random generation</u> of (k, Ce) couples and test on <u>R-squared</u>;
- Posterior bi-variate Probability Density Functions of k and Ce

Notes on data quality check

1. Increasing monotonous trend



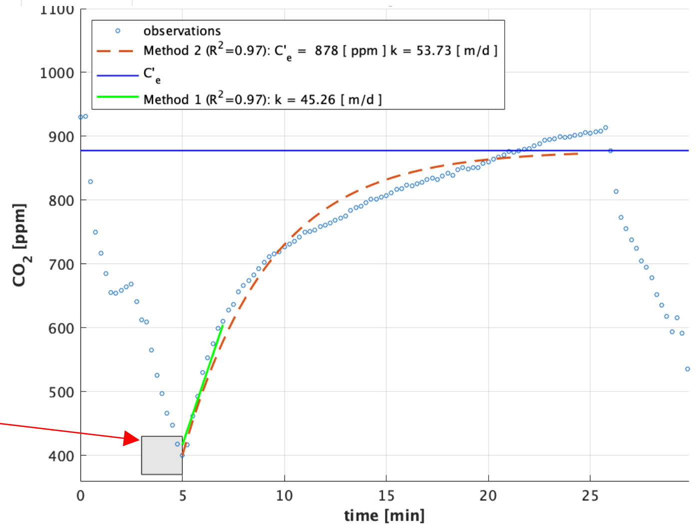
2. Ce = 400 ÷ 2000 ppm



3. R-squared > 0.98

4. 2 minutes of constant CO2

   (equilibration with air guaranteed)



Results and Discussion (1)

STEADY

Configuration	$\mu_{k600,\,Std}$ $[m\,d^{-1}]$	$cv_{k600,\,Std}$ [/]	$\mu_{k600,\,FF}$ $[m\,d^{-1}]$	$cv_{k600,\,FF}$ [/]
a	5.5 (3)	0.33	4.7 (1)	-
b	9.8 (2)	0.59	10.8 (3)	0.30
c	9.8 (5)	0.64	21.5 (1)	-
d	13.2 (3)	0.71	31.3 (2)	0.35

0.55 0.24

DRIFTING

9.46 17.2

Configuration	$\mu_{k600,\,Std}$ $[m\,d^{-1}]$	$cv_{k600,\,Std}$ [/]	$\mu_{k600,\,FF}$ $[m\,d^{-1}]$	$cv_{k600,\,FF}$ [/]
a	4.0 (3)	0.74	-	-
b	5.1 (2)	0.17	6.8 (2)	0.17
c	20.1 (6)	0.76	21.9 (2)	0.15
d	8.21 (4)	0.47	27.8 (1)	-

1) **higher values** of k600 from FF chamber with respect to Std chamber, despite the lower Turbulence Kinetic Energy (ADV method) induced by the FF chamber.

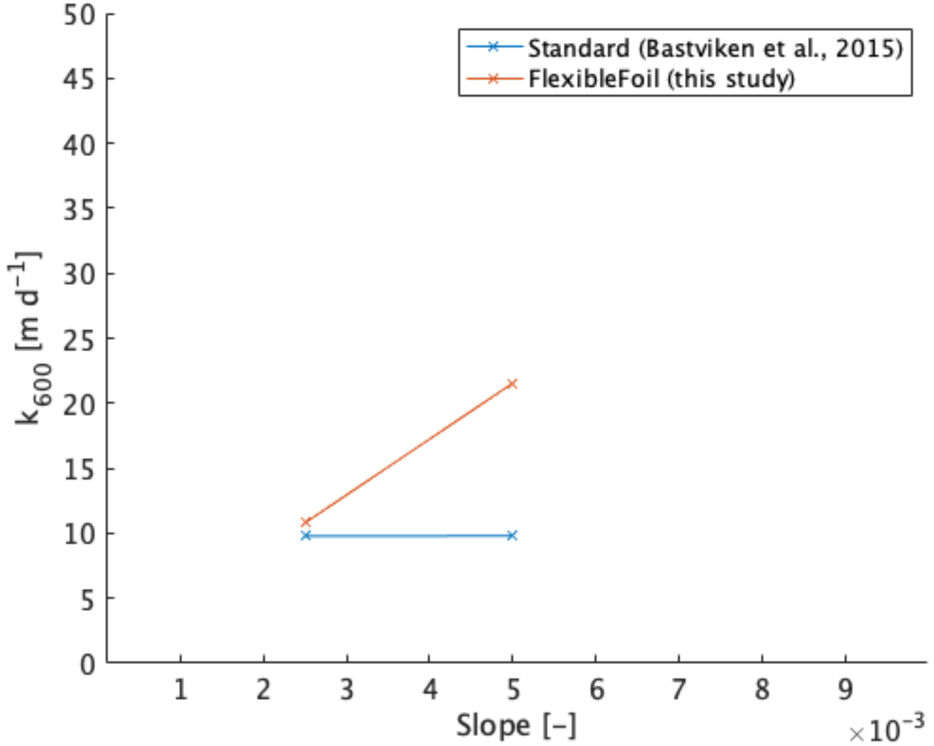
→ Mean k600 [m d^{-1}]:
FF = 17.2
Std = 9.46

2) **higher variability** for Std chamber
with respect to FF chamber.

→ Mean Coefficient of Variation:
FF = 0.24
Std = 0.55

Results and Discussion (2):
SLOPE

STEADY



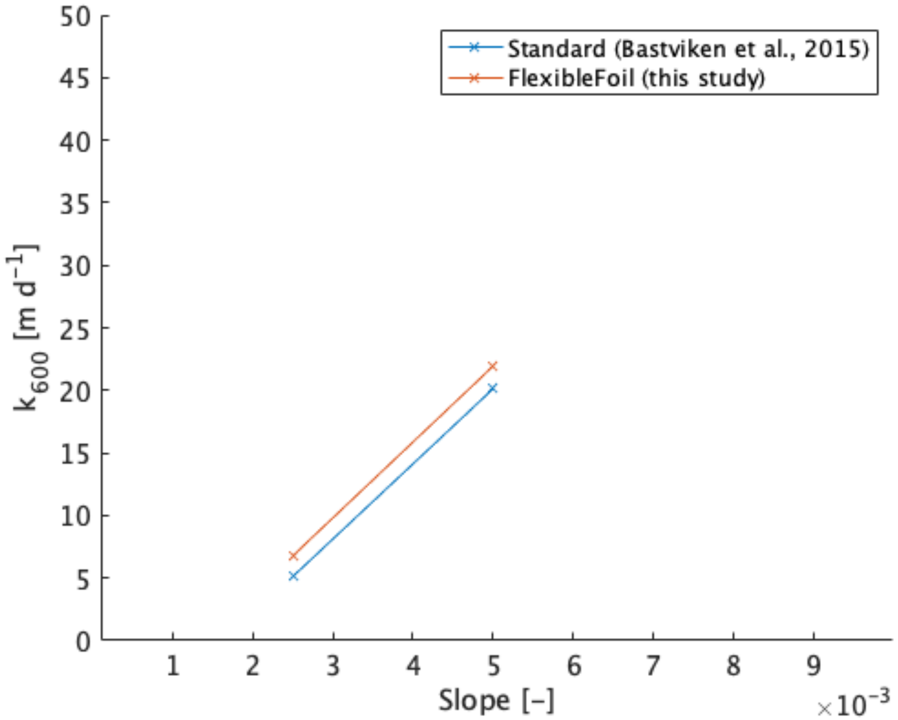
- FF:

Increasing slope, k600 increases

- Std:

k600 not influenced by slope

DRIFTING



- FF:

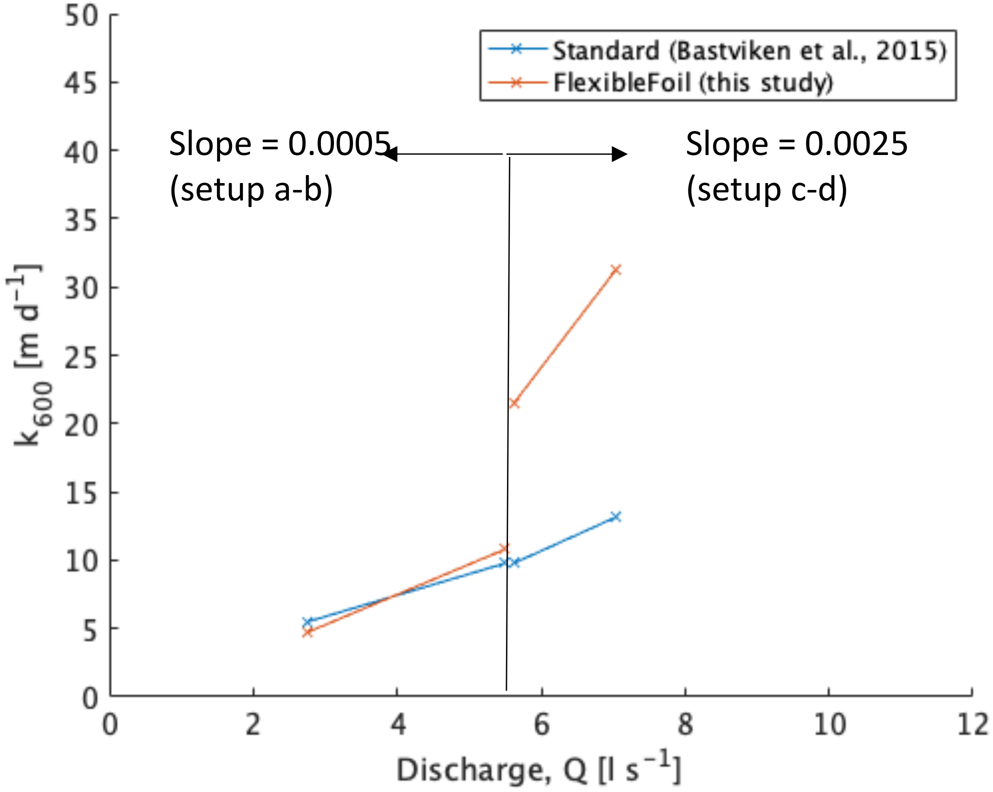
Increasing slope, k600 increases

- Std:

Increasing slope, k600 increases

Results and Discussion (3):
DISCHARGE

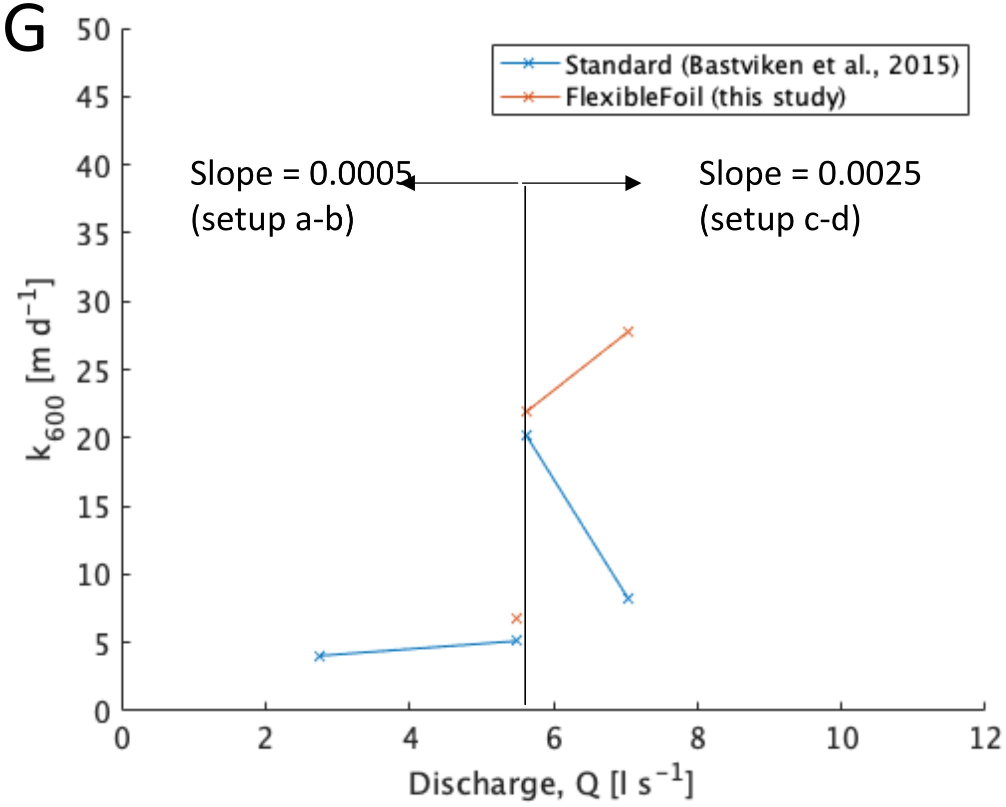
STEADY



- FF and Std:

Increasing discharge, k600 increases (similar trend for lowest slope, different trend for highest slope).

DRIFTING



- FF:

Increasing discharge, k600 increases (available only for the highest slope).

- Std:

Increasing Q, k600 slightly increases (low slope);
Increasing Q, k600 decreases (high slope).

Results and Discussion (4):

TURBULENCE

Energy dissipation rate vs. k600

(Velocity*gravity*slope)

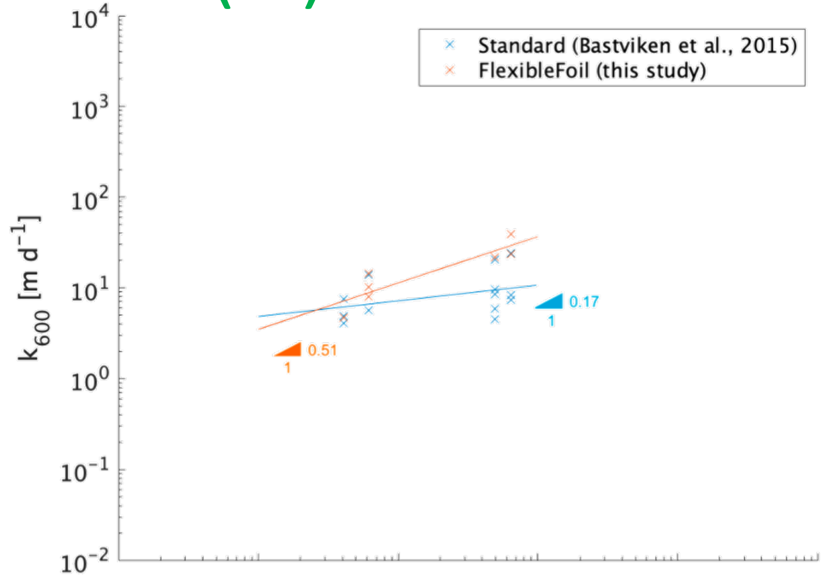
- FF and Std:

increasing εD, k600 increases …

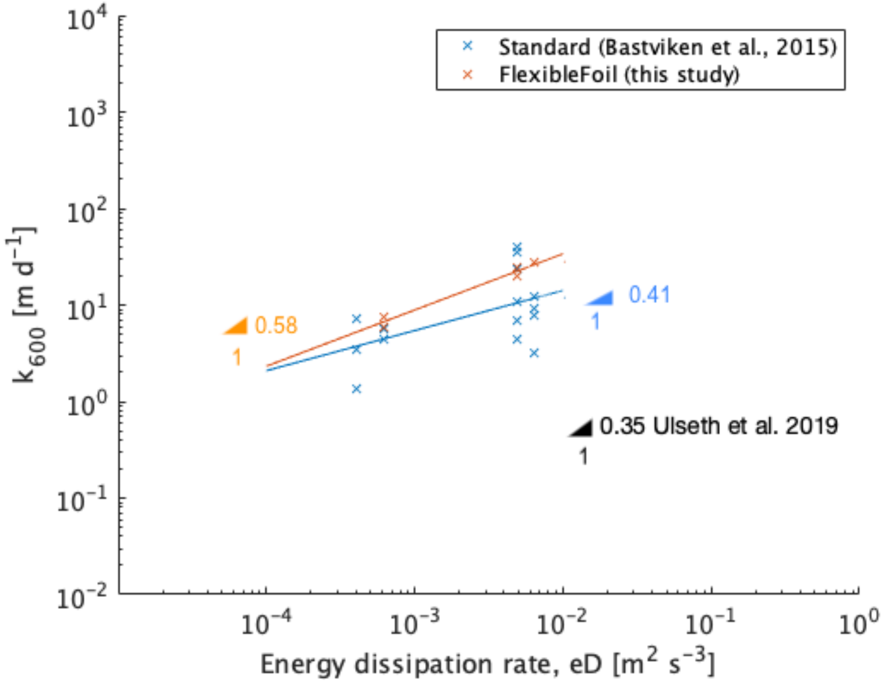
… with different slopes,

… slopes differ from Ulseth et al, 2019 but the data fall in the 95% CI supporting the truthfulness of the chamber data

Steady



Drifting



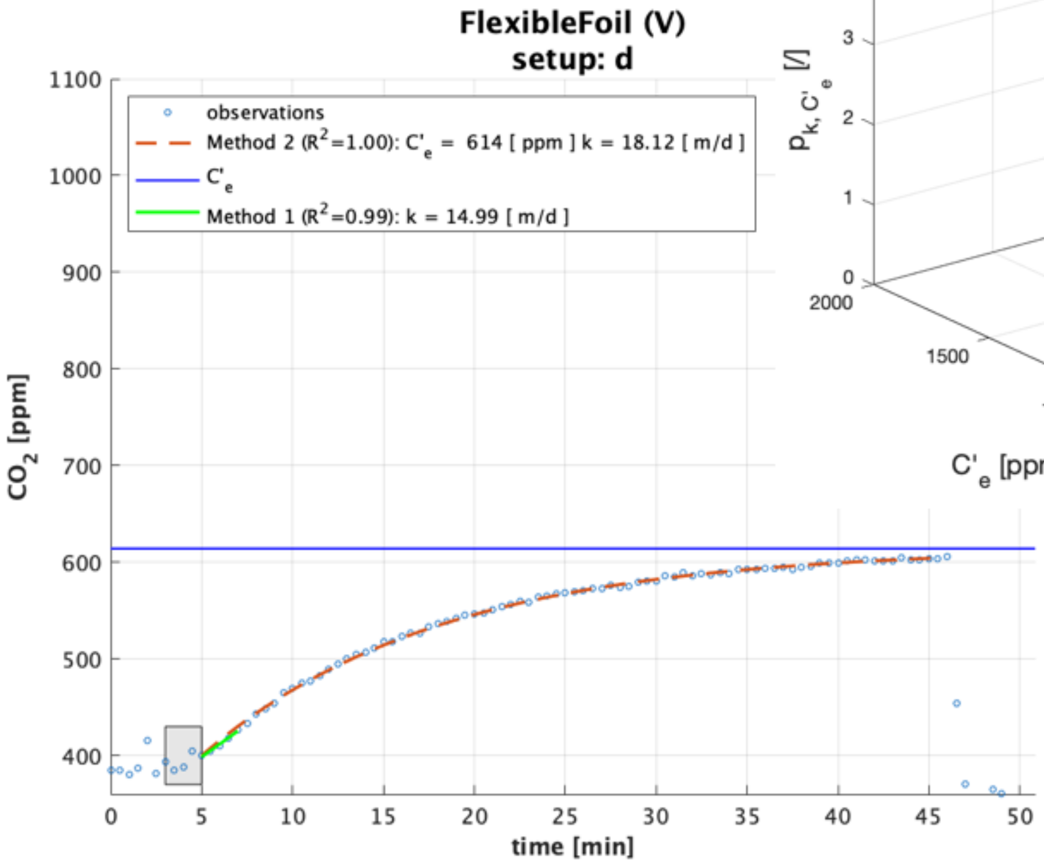
Result and Discussion (5)

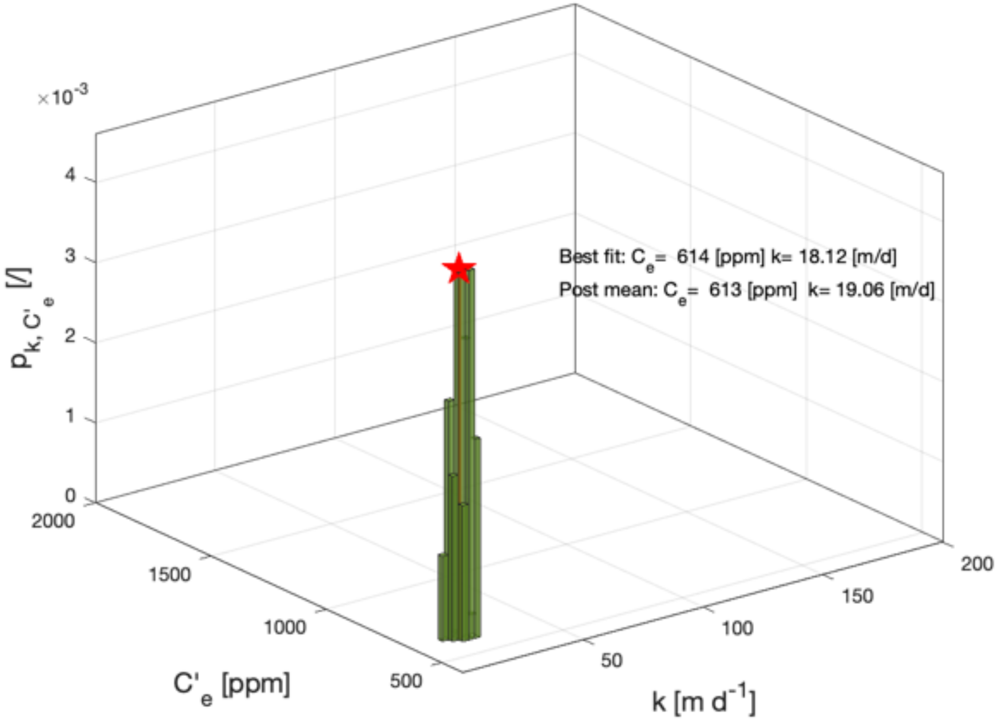
- Generalized Likelihood Uncertainty Estimation, “GLUE”

Posterior bi-variate distribution peaked on the best fit couple

…

not always





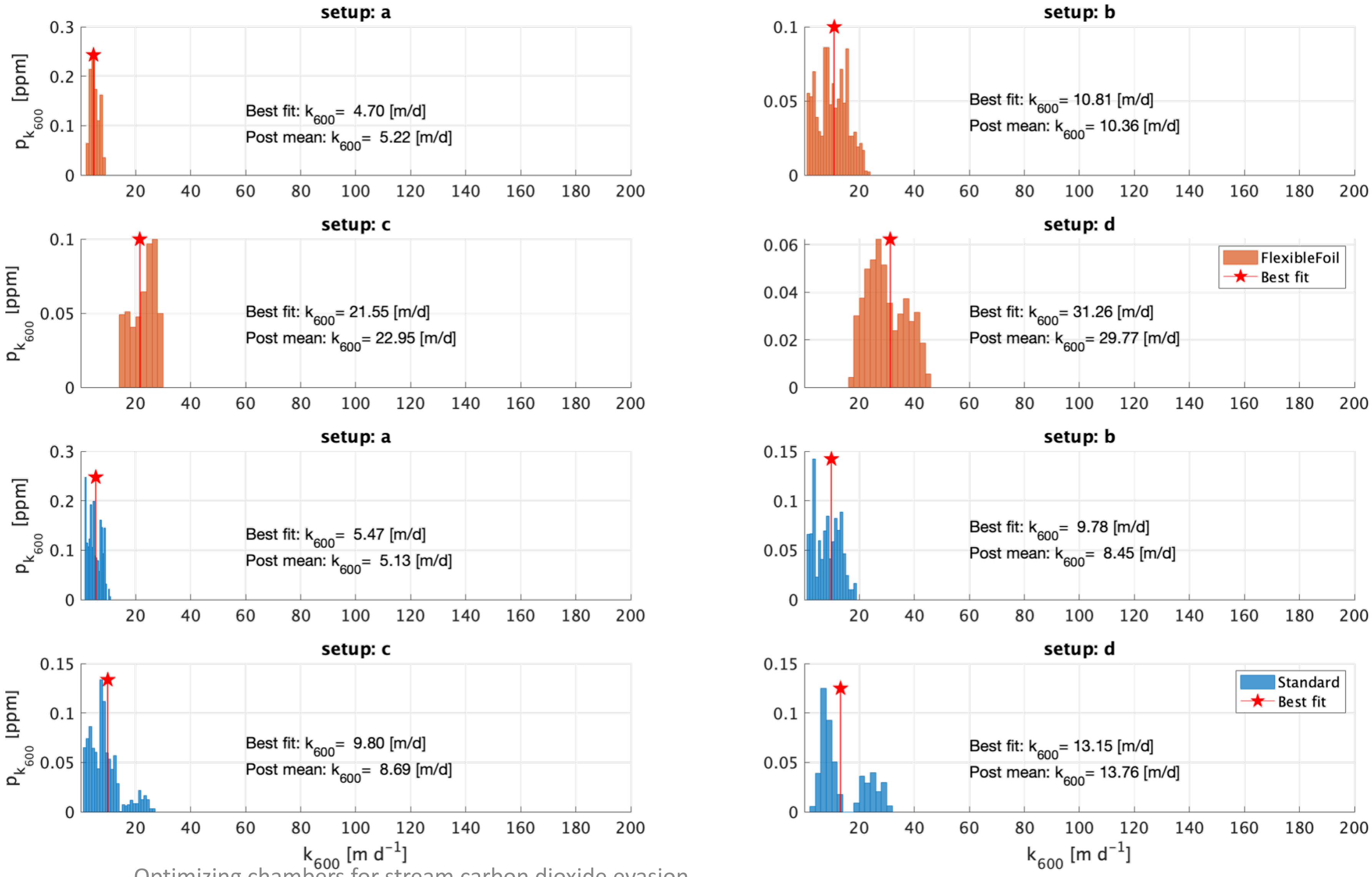
Results and Discussion (6)

- Overall assessment via the GLUE

best fit = Posterior mean

Bi-modal trend for *c* and *d* for the Std chamber;

→ FF gives a reasonable fitting also for Std chamber



Summary

- The Model (1) applied to the entire saturation curve is more robust than the most common linear method (2);
- k600 from FF >> k600 from Std for high k600 (despite lower TKE!);
- FF: consistent patterns (steady vs drift, influence of Q and slope);
- Std: not consistent;
- Relatively small uncertainty in the fitting (peaked post pdfs of k);
- When k600(Std) ≠ k600(FF), k600(FF) best fit is representative also for the Std;
- The chamber might influence the estimate of k600: which is the most reliable? Need comparisons….