Evaluating stream CO_2 outgassing via drifting and anchored flux chambers in a controlled flume experiment

Vingiani, F.[1], Durighetto, N.[1], Klaus, M.[2], Schelker, J.[3,4], Labasque[5], T., Botter., G.[1]

[1]Department of Civil, Environmental and Architectural Engineering, University of Padua, 35131 Padua, Italy

[2]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden

[3]Department of Limnology and Oceanography, University of Vienna, 1090 Vienna, Austria

[4]WasserCluster Lunz GmbH, 3293 Lunz am See, Austria

[5]Géosciences Rennes, Université de Rennes 1, 35042 Rennes, France

EGU General Assembly 2021

Article available online

Published on Biogeosciences 02/2021.

Introduction

Inland waters play a relevant role in the global carbon cycle (Battin et al., 2009; Raymond et al., 2013; Hotchkiss et al., 2015; Marx et al., 2017):

- headwater catchments (significant surface + high per area evasion fluxes)

How to compute the water-atmosphere fluxes (Φ_{atm}) in headwater catchments?

Fick's First law of diffusion:

$$\Phi_{atm} = k(C_e - C_0)$$

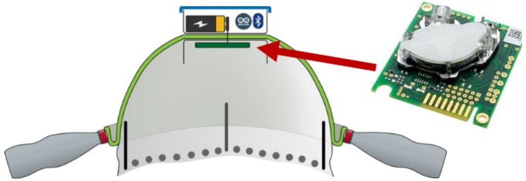
With

k **gas exchange velocity, ?**

C_e **water concentration, ?**

C_0 atmosphere concentration.

CHAMBER METHOD:



Direct point measurements of k and C_e …
extrapolation of gas fluxes along the entire stream.

Research Questions

Chamber method:

recently **widespread** (e.g. Lorke et al., 2015; Sawakuchi et al., 2017; Rosentreter et al., 2017; Jeffrey et al., 2018; Boodoo et al., 2019) but we **lack**:

- rigorous **comparison** among **designs** and **deployments**,
- **uncertainty** of **k** estimates from chamber data.

Aims:

1) **Improvements** of **k reliability** via a **novel** experimental **design**?

2) Procedure to **interpret** the **k**-chamber data **accounting** for parameters **uncertainty**?

Instrument and Methods

Chamber design:

1) Standard (Bastviken et al., 2015)

2) Flexible Foil (this study)

Deployment modes:

1) **Drifting**: free to follow the current

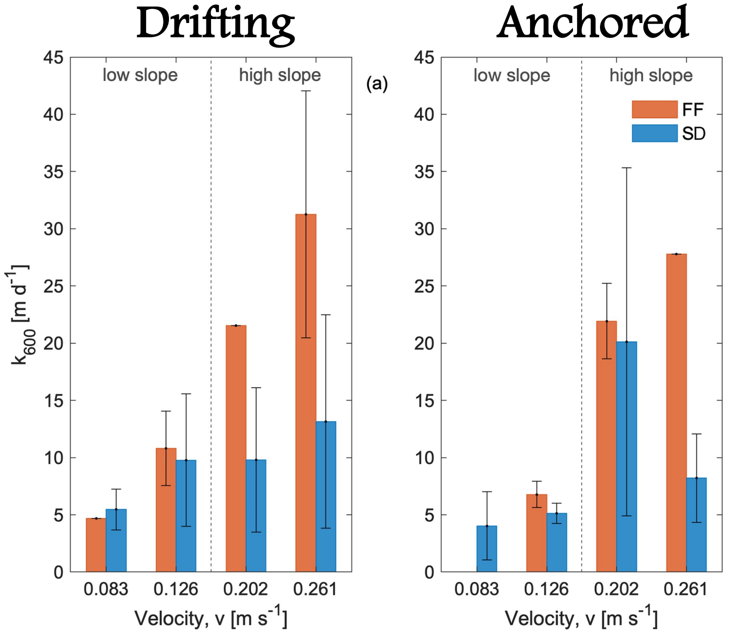
2) **Anchored**: fixed in a point

4 different experimental flumes with different **energy configurations** (ADV based-estimates):

$$1.5\times10^{-3} < \varepsilon < 1\times10^{-1}\,m^2\,s^{-3}$$

Configuration	Discharge ($L\,s^{-1}$)	Flow velocity ($m\,s^{-1}$)	Travel time (s)	Slope (%)
1	2.74	0.083	421	0.05
2	5.50	0.126	278	0.05
3	5.63	0.202	173	0.25
4	7.04	0.261	134	0.25

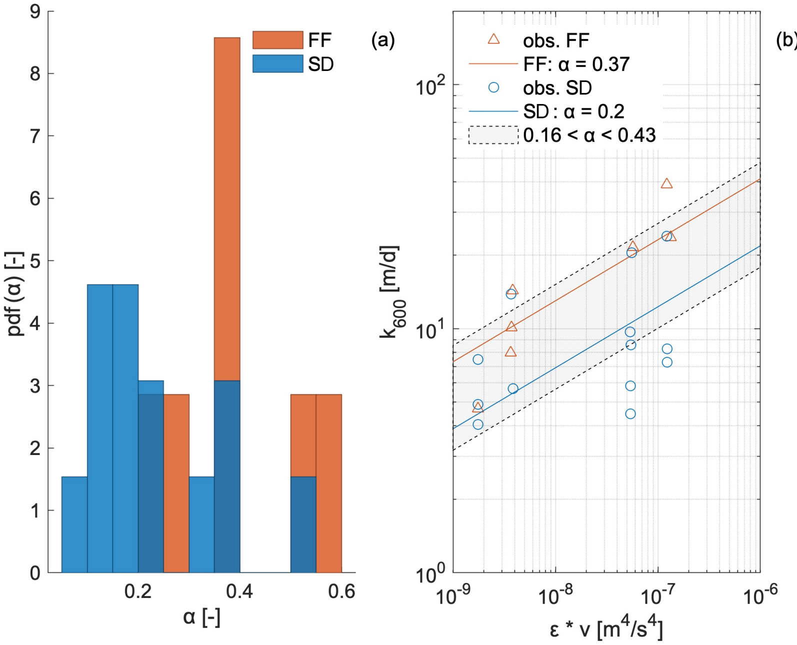
Results & Discussion



k_{600} = 4~31.3 m d^{-1} (40 deployments)

- $k_{600,\ FF} > k_{600,\ SD}$
- $\overline{cv}_{k600,\ FF} < \overline{cv}_{k600,\ SD}$

Literature comparison:
Surface Renewal Model (SNM) (Zappa et al., 2003) ~ $k \propto \varepsilon$ (from ADV)

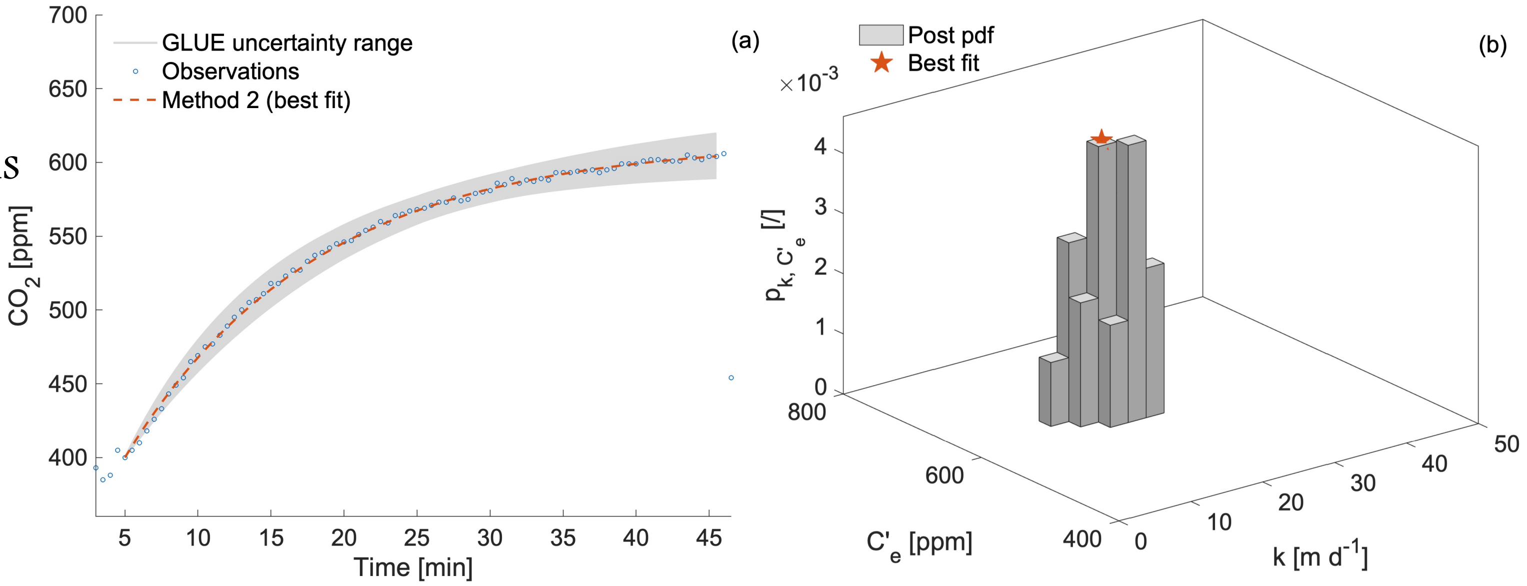


Results & Discussion

Generalized Likelihood Uncertainty Estimation **(GLUE)** procedure:

=> Posterior probability bi-variate density function for 2 model parameters ***k*** and ***C'_e***

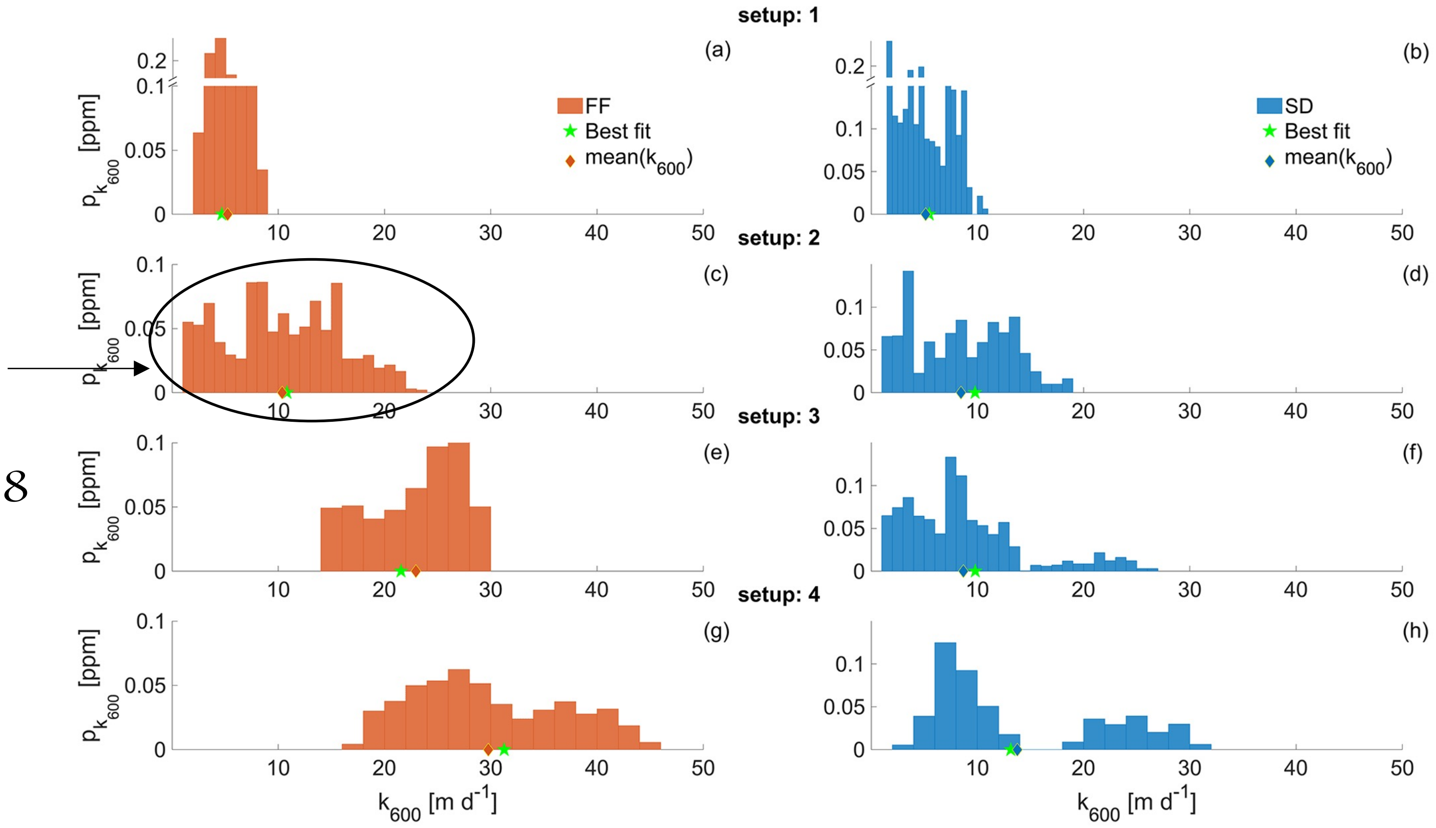
Each deployment is associated to a **range** of **parameters** values (NSE ≥0.98).



Results & Discussion

Overall GLUE uncertainty applied to **anchored** deployments:

k_{600} values from all the runs for a given setup and chamber NSE ≥0.98



Conclusions

- **k** ∝ **ε** (SRM)

- Flexibility: 😃 **FF** | 😟 **SD**

- **GLUE** (uncertainty analysis): function(design, deployments, energy)

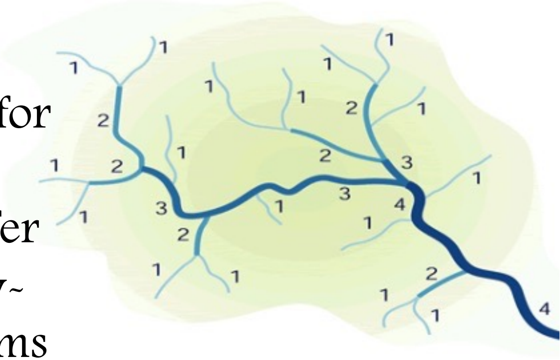
  Deployment modes: 😃 **anchored** | 😟 **drifting**

  Chamber design: 😃 **FF** | 😟 **SD**

Flexible Foil chamber + **anchored** mode …

+ **GLUE** analysis

⇒ useful tool for evaluating mass transfer rates in low-order streams



References

Bastviken, D., Sundgren, I., Natchimuthu, S., Reyier, H., and Gål- falk, M.: Technical Note: Cost-efficient approaches to measure carbon dioxide (CO2) fluxes and concentrations in terrestrial and aquatic environments using mini loggers, Biogeosciences, 12, 3849–3859, https://doi.org/10.5194/bg-12-3849-2015, 2015.

Battin, T. J., Luyssaert, S., Kaplan, L. A., Aufdenkampe, A. K., Richter, A., and Tranvik, L. J.: The boundless carbon cycle, Nat. Geosci., 2, 598–600, https://doi.org/10.1038/ngeo618, 2009.

Boodoo, K. S., Schelker, J., Trauth, N., Battin, T. J., and Schmidt, C.: Sources and variability of CO2 in a prealpine stream gravel bar, Hydrol. Process., 33, 2279–2299, https://doi.org/10.1002/hyp.13450, 2019.

Hotchkiss, E. R., Hall Jr, R. O., Sponseller, R. A., Butman, D., Klaminder, J., Laudon, H., Rosvall, M., and Karlsson, J.: Sources of and processes controlling CO2 emissions change with the size of streams and rivers, Nat. Geosci., 8, 696–699, https://doi.org/10.1038/ngeo2507, 2015.

Jeffrey, L. C., Maher, D. T., Santos, I. R., Call, M., Reading, M. J., Holloway, C., and Tait, D. R.: The spatial and temporal drivers of pCO2, pCH4 and gas transfer velocity within a subtropical estuary, Estuar. Coast Shelf, 208, 83–95, https://doi.org/10.1016/j.ecss.2018.04.022, 2018.

Lorke, A., Bodmer, P., Noss, C., Alshboul, Z., Koschorreck, M., Somlai-Haase, C., Bastviken, D., Flury, S., McGinnis, D. F., Maeck, A., Müller, D., and Premke, K.: Technical note: drifting versus anchored flux chambers for measuring greenhouse gas emissions from running waters, Biogeosciences, 12, 7013–7024, https://doi.org/10.5194/bg-12-7013-2015, 2015.

Marx, A., Dusek, J., Jankovec, J., Sanda, M., Vogel, T., van Geldern, R., Hartmann, J., and Barth, J. A. C.: A re- view of CO2 and associated carbon dynamics in headwater streams: A global perspective, Rev. Geophys., 55, 560–585, https://doi.org/10.1002/2016RG000547, 2017.

Raymond, P. A., Hartmann, J., Lauerwald, R., Sobek, S., McDonald, C., Hoover, M., Butman, D., Striegl, R., Mayorga, E., Humborg, C., Kortelainen, P., Dürr, H., Meybeck, M., Ciais, P., and Guth, P.: Global carbon dioxide emissions from inland waters, Nature, 503, 355–359, https://doi.org/10.1038/nature12760, 2013.

Rosentreter, J. A., Maher, D. T., Ho, D. T., Call, M., Barr, J. G., and Eyre, B. D.: Spatial and temporal variability of CO2 and CH4 gas transfer velocities and quantification of the CH4 microbubble flux in mangrove dominated estuaries, Limnol. Oceanogr., 62, 561–578, https://doi.org/10.1002/lno.10444, 2017. Zappa, C. J., Raymond, P. A., Terray, E. A., and McGillis, W. R.: Variation in surface turbulence and the gas transfer velocity over a tidal cycle in a macro-tidal estuary, Estuaries, 26, 1401–1415, https://doi.org/10.1007/BF02803649, 2003.

Sawakuchi, H. O., Neu, V., Ward, N. D., Barros, M. d. L. C., Valerio, A. M., Gagne-Maynard, W., Cunha, A. C., Less, D. F. S., Diniz, J. E. M., Brito, D. C., Krusche, A. V., and Richey, J. E.: Carbon Dioxide Emissions along the Lower Amazon River, Front. Mar. Sci., 4, 76, https://doi.org/10.3389/fmars.2017.00076, 2017.

Zappa, C. J., Raymond, P. A., Terray, E. A., and McGillis, W. R.: Variation in surface turbulence and the gas transfer velocity over a tidal cycle in a macro-tidal estuary, Estuaries, 26, 1401–1415, https://doi.org/10.1007/BF02803649, 2003.