The role of stream heterogeneity in gas emissions from headwater streams

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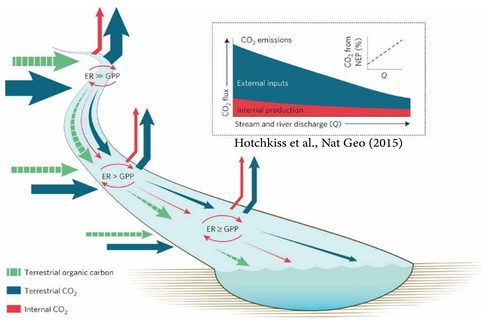
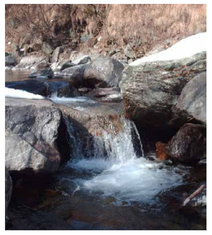
01 - INTRODUCTION

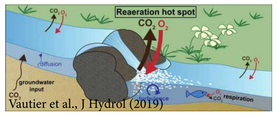
CO2 degassing from streams depends on flow properties (slope, water velocity) and gas concentration in water. Headwater streams combine high concentrations with high energy flows, therefore they are emission hotspots.



Hotchkiss et al., Nat Geo (2015)

But mountain streams are characterized by a pronounced internal heterogeneity, often resulting into cascades and step-pool formations.





Vautier et al., J Hydrol (2019)

02 - RESEARCH QUESTION

Is degassing driven by average flow properties or localized hydraulic discontinuities?

FOR MORE INFORMATION SEE

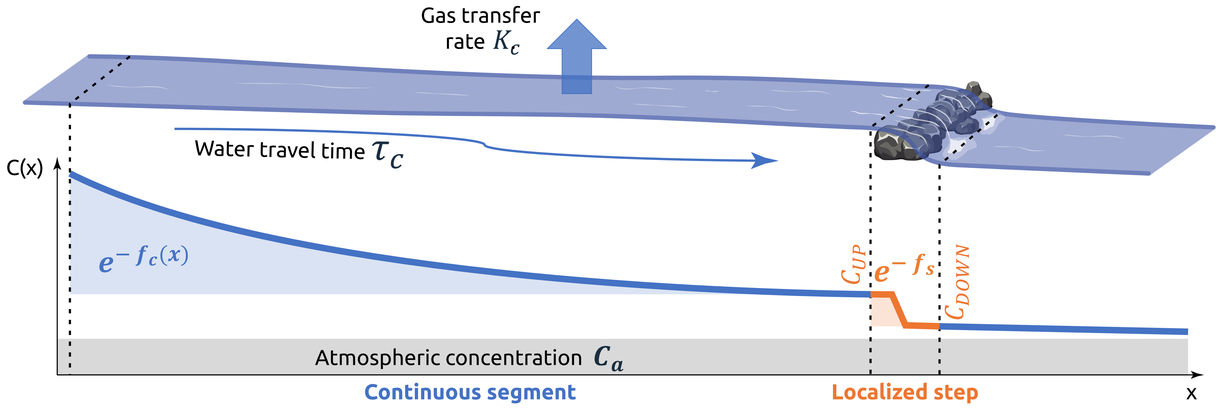
G. Botter, A. Carozzani, P. Peruzzo & N. Durighetto. Steps dominate gas evasion from a mountain headwater stream. Nature Communications 13, 7803 (2022).

G. Botter, P. Peruzzo & N. Durighetto. Heterogeneity matters: aggregation bias of gas transfer velocity vs energy dissipation rate relations in streams. Geophysical research letters 48, 17 (2021).

03 - QUANTIFYING GAS EVASION RATE

Stream reach: a sequence of continuous segments and localized steps. How is gas evasion quantified?

	CONTINUOUS SEGMENT		LOCALIZED STEP	
Gas transfer rate	K_c	**Standard method**	???	Not available
Damping factor	$f_c = K_c\,\tau_c$	**Proposed method**	$f_s = \ln\left(\frac{C_{DOWN} - C_a}{C_{UP} - C_a}\right)$	Damping factor



04 - EXPERIMENTAL EVIDENCES

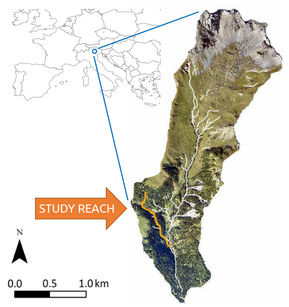
Study site:

Location	Northern Italy
Reach length	1.36 km
Mean slope	14 %
Flowrate	0.2 - 3 L/s

Water pCO2 was measured up and downstream a number of steps and a reference segment, under different hydrologic conditions, using a Pro Oceanus MiniCO2 sonde.

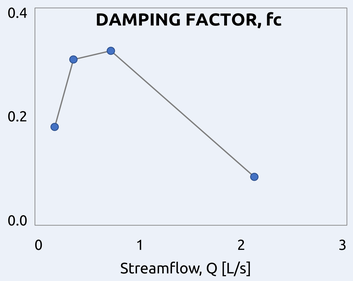
Monitored reach	13 m
Plastic film	No biofilm production
Clean stones	Natural turbulence

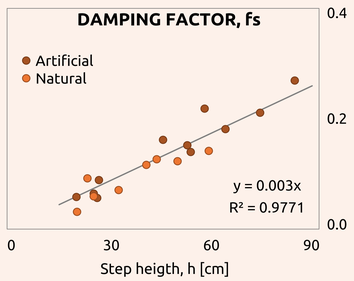
Total steps	271
Monitored steps	19
Step height	20 - 90 cm



Non-monotonic relation between fc and streamflow.

Maximum degassing for intermediate streamflows.



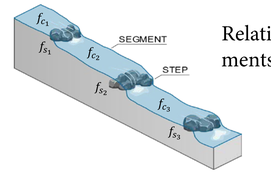


Linear relation between fs and step height.

Does not depend on geometry and streamflow.

05 - DOMINANCE RATIO:

CONTINUOUS SEGMENTS vs LOCALIZED STEPS



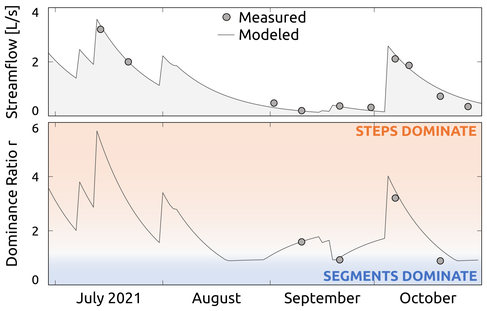
Relative contribution of segments and steps to outgassing.

$$r = \frac{f_{s_1} + f_{s_2} + f_{s_3}}{f_{c_1} + f_{c_2} + f_{c_3}}$$

$r < 1$	$r \approx 1$	$r \gg 1$
SEGMENTS DOMINATE OUTGASSING	COMPARABLE CONTRIBUTION	STEPS DOMINATE OUTGASSING

Measured dominance ratio r:

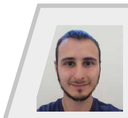
Min	Average	Max
0.9	2.4	4.0



06 - CONCLUSIONS

Local steps dominate outgassing 85% of the time!

Large scale estimations of CO2 emissions from streams and rivers should take local losses into account.



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