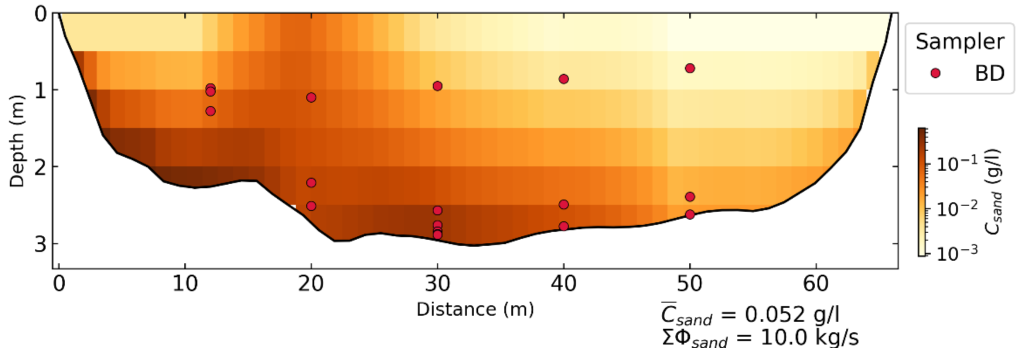
Using a hydroacoustic method to establish continuous time series of suspended sand concentration and grain size in the Isère River, France

Jessica Laible, Benoît Camenen, Jérôme Le Coz, Guillaume Dramais, Gilles Pierrefeu, François Lauters

Suspended sand

- Important spatial and temporal gradients
- Physical sampling time- and cost-consuming
- Difficult to measure continuously concentration and grain size



Use a hydroacoustic method to establish time series of suspended sand concentration and grain size

Isère River, France

HADCPs

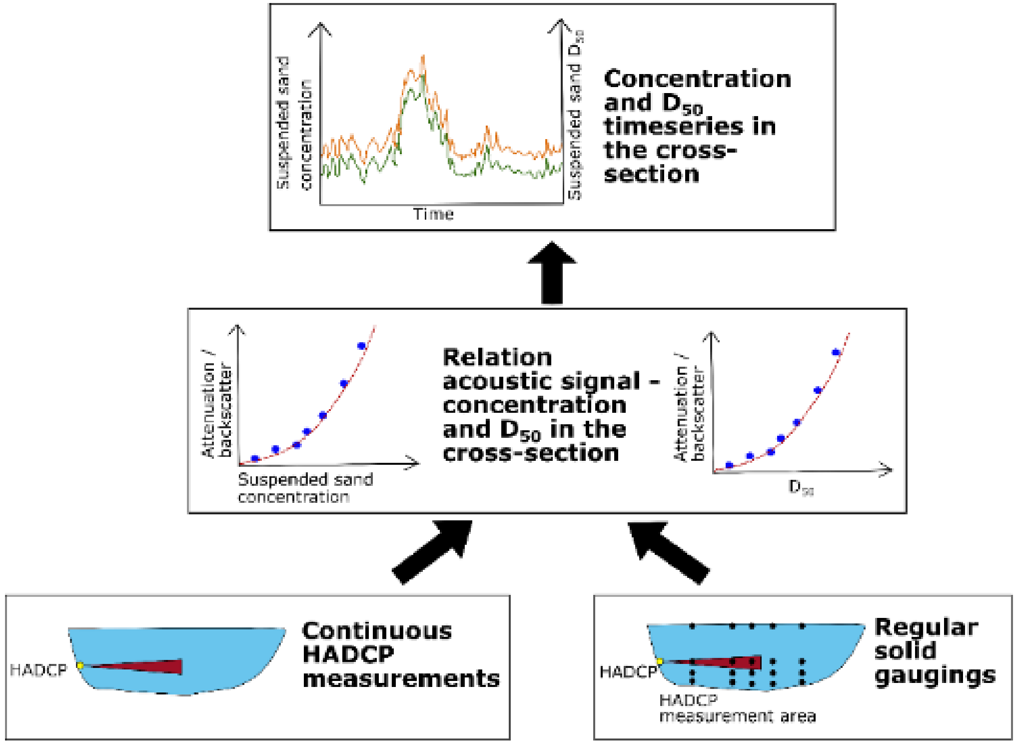
Outstanding Student & PhD candidate Presentation contest

Sharing is encouraged

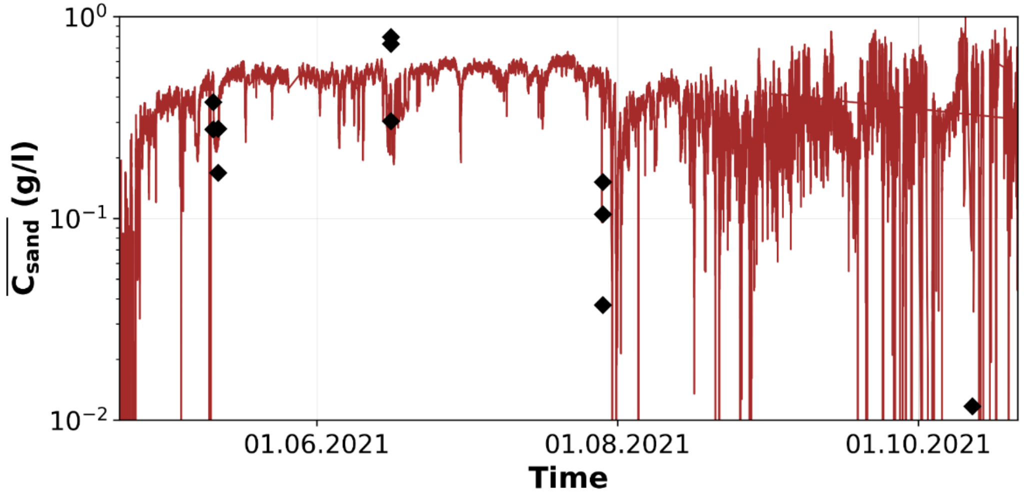
GM3.2 / PICO3a.3

Using a hydroacoustic method to establish continuous time series of suspended sand concentration and grain size in the Isère River, France

Methodology



Time serie of suspended sand



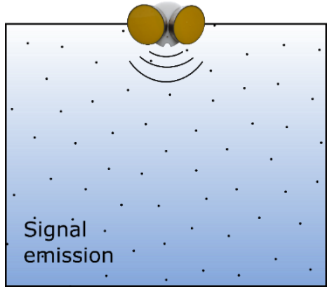
→ Preliminary establishment of concentration and grain size time series

→ Improvements of methodology necessary

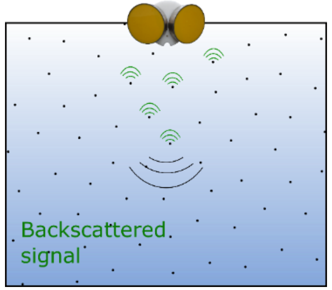
Laible, J., Camenen, B., Le Coz, J., Dramais, G., Pierrefeu, G., Lauters, F.

Theory

Active sonar

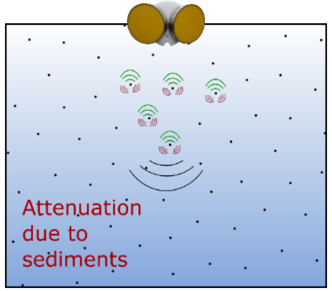


- Based on the principle of sonar and the Doppler effect



Backscatter B

- Dominated by sand
- If $S = \frac{c_{fines}}{c_{sand}}$ is high: contribution of fine sediments, too

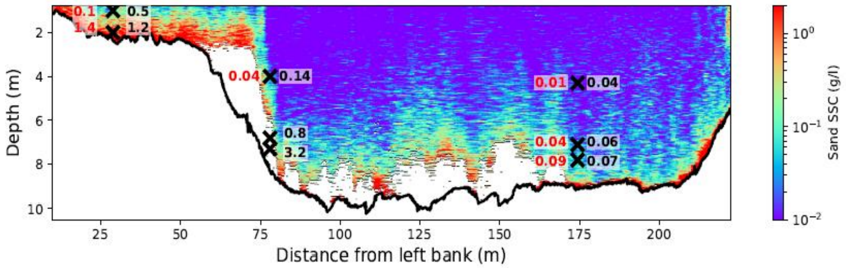


Attenuation (α)

- Geometric distribution in space, viscosity of water (α_W) and due to sediments $(\boldsymbol{\alpha_{Sed}})$
- Dominated by fine sediments and high concentrations

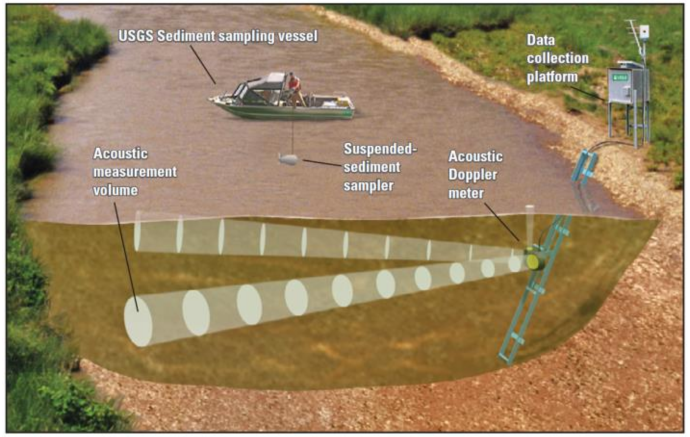
Deployment of Acoustic Doppler Current Profilers (ADCPs)

Vertical deployment:
High spatial, but low temporal resolution



Vergne et al., (2019)

Horizontal deployment:
Horizontal Acoustic Doppler Current Profilers (**HADCP**s)
High temporal, lower spatial resolution
→ Applied in this study

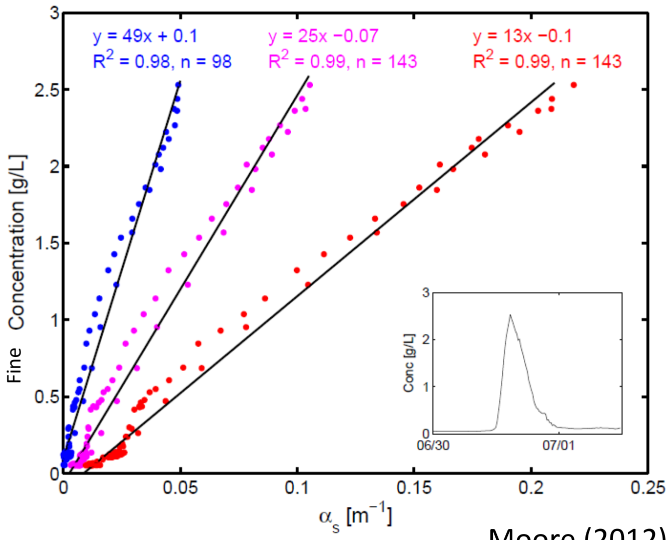


Landers et al., (2016)

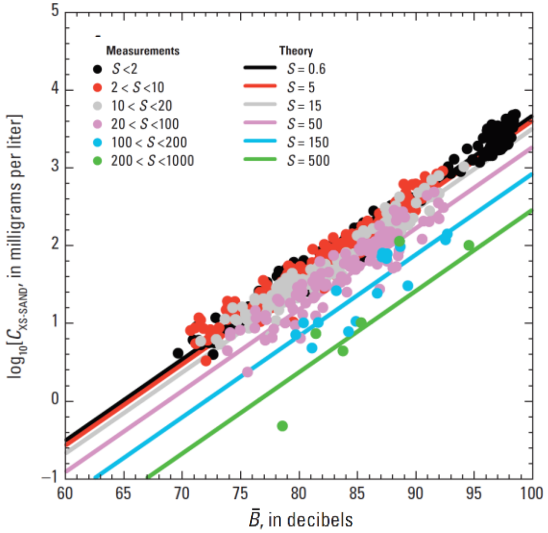
Theory: Use α_{sed} and $\bar{B}$ to estimate the concentration and grain size

Concentration

Relate α_{sed} with the concentration of silt-clay sediments and $\bar{B}$ with the concentration of sand



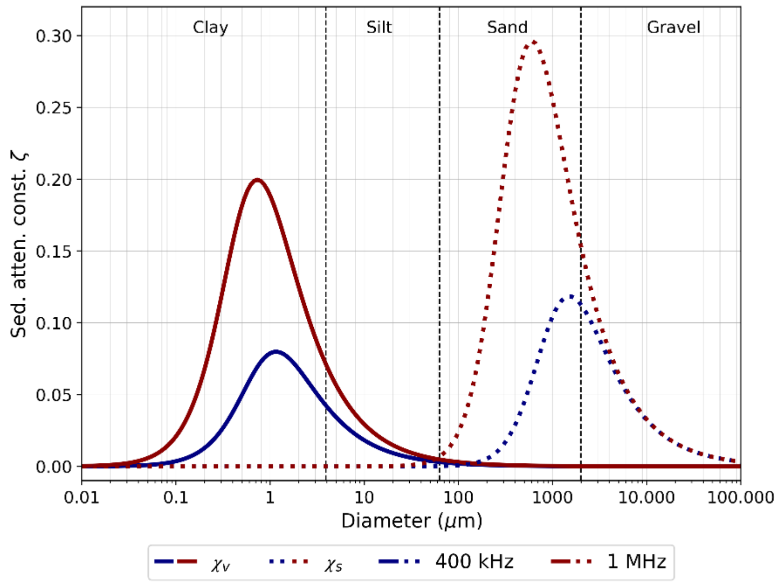
Moore (2012)



Topping & Wright (2016)

Grain size

Attenuation caused by a particle depends on its size



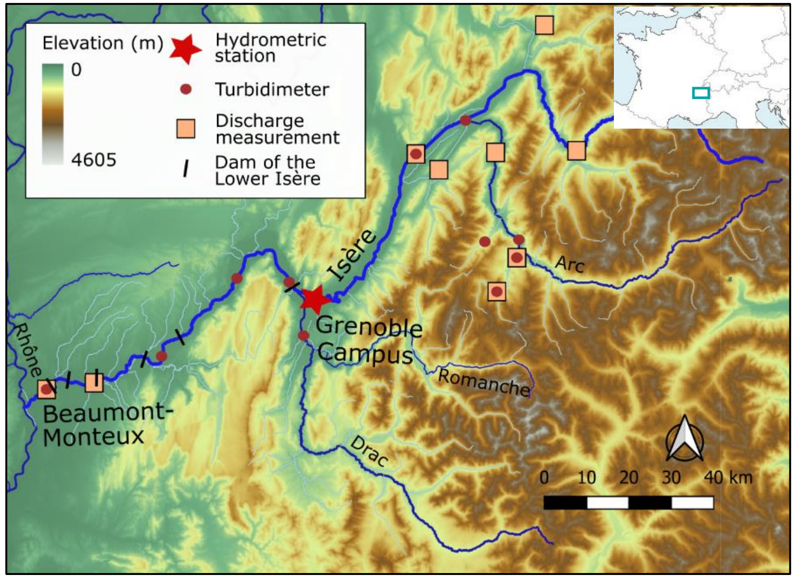
Study area: Isère River

- French Alpine River
- Rich in suspended sediment, particularly sand
- Highly engineered (dikes, dams for hydro-power generation)

→ Requires sediment management and knowledge on the suspended sand concentration and grain size

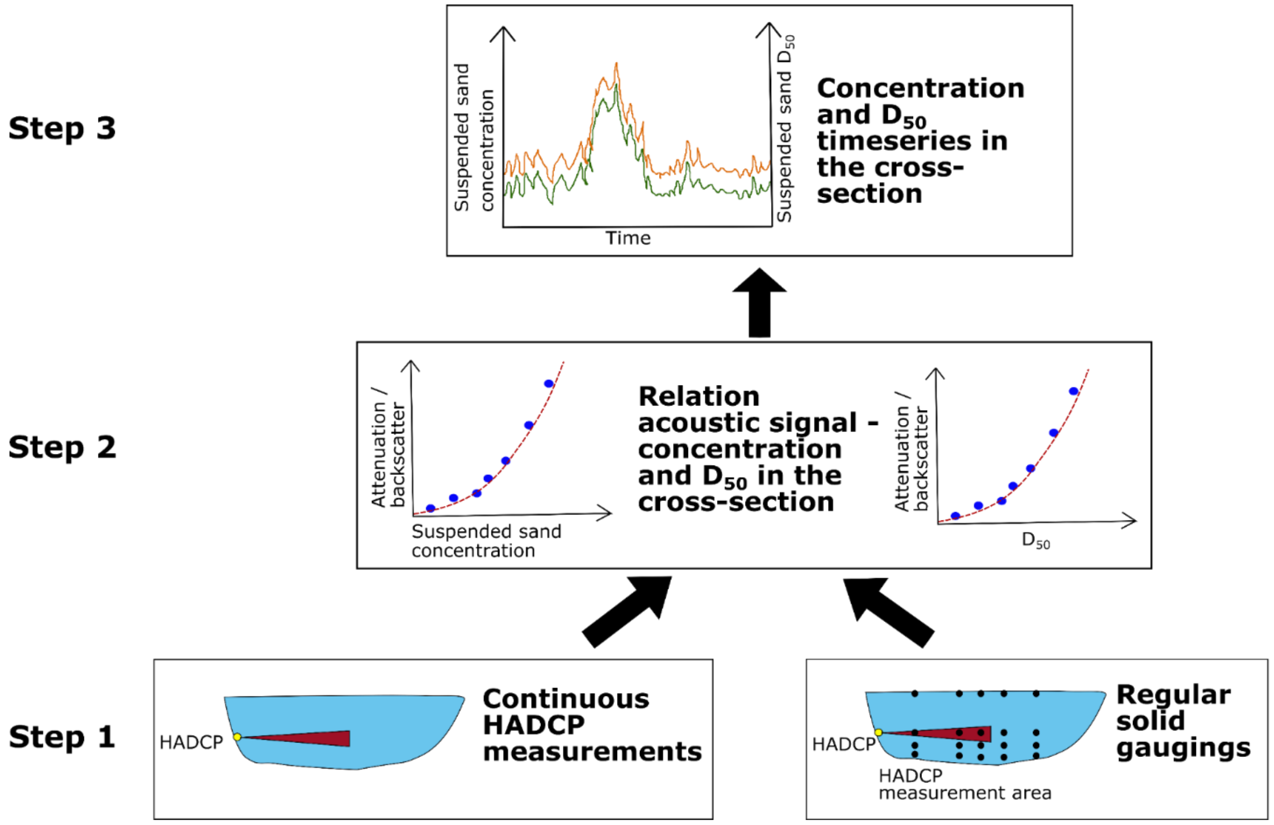
Sampling at Grenoble Campus

Dam flush, Beaumont-Monteux



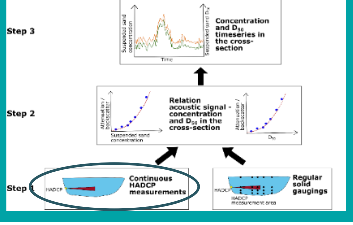
Data: IGN

Applying a bi-frequential method

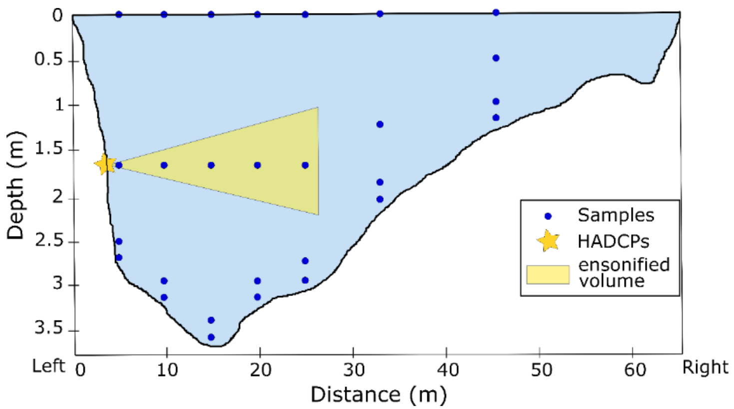


Following Topping & Wright (2016)

Step 1: Continuous HADCP measurements

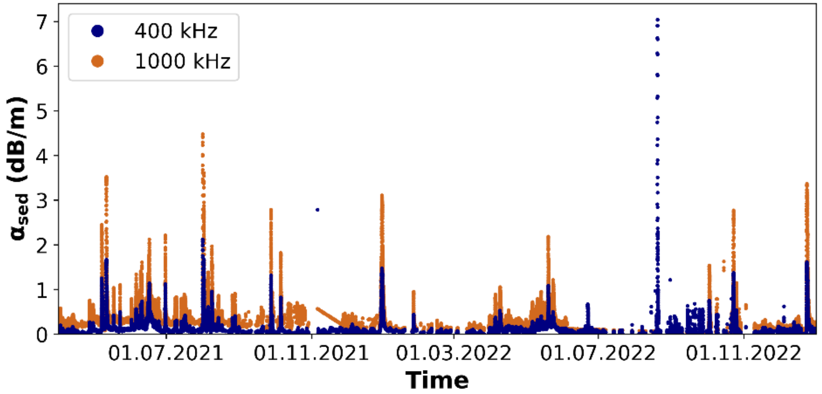


- 400 and 1000 kHz ADCPs
- Measurements every 10 min

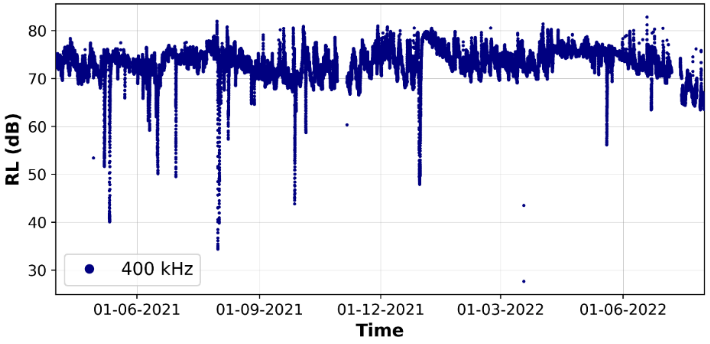


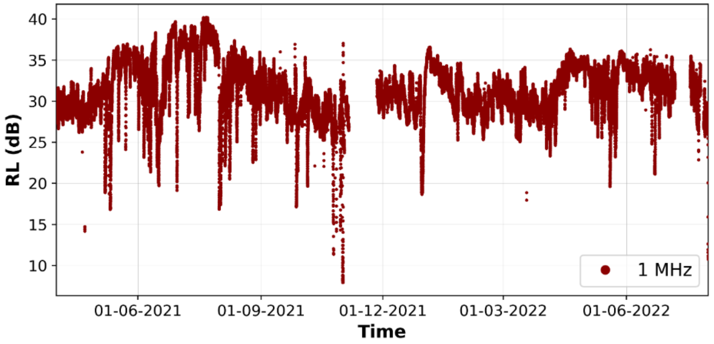
Determination of α_{sed} and $\overline{B}$

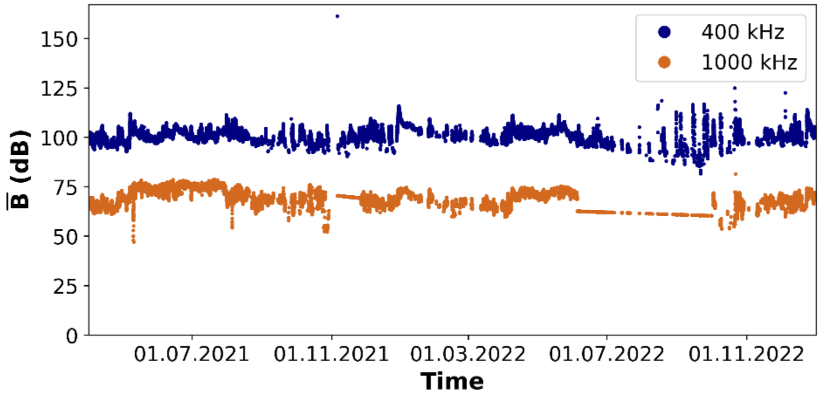
- Establishment of time series for both frequencies and α_{sed} and $\overline{B}$



Raw data

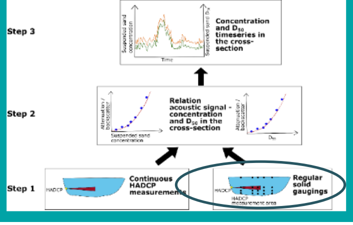






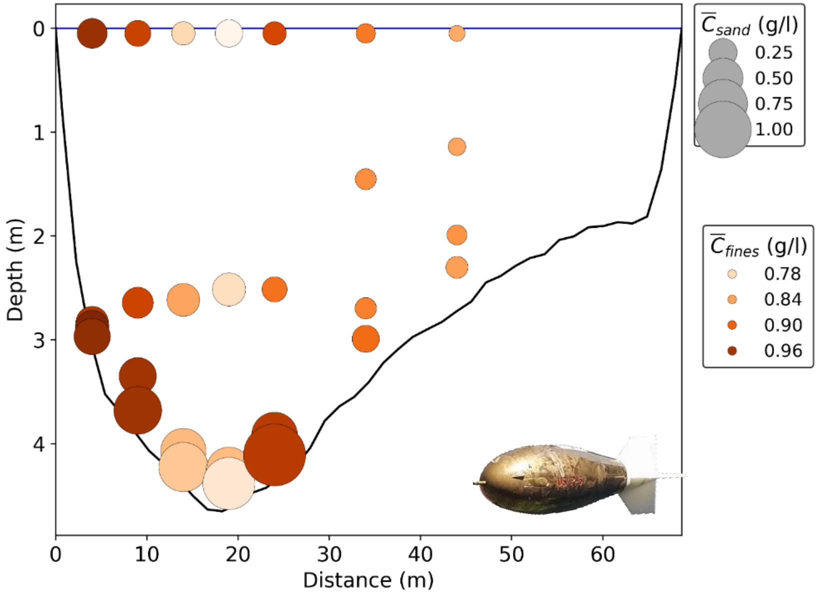
More information on the signal treatment

Step 1: Regular solid gaugings



Point sampling using US-P6, US-P72 and the Delft bottle

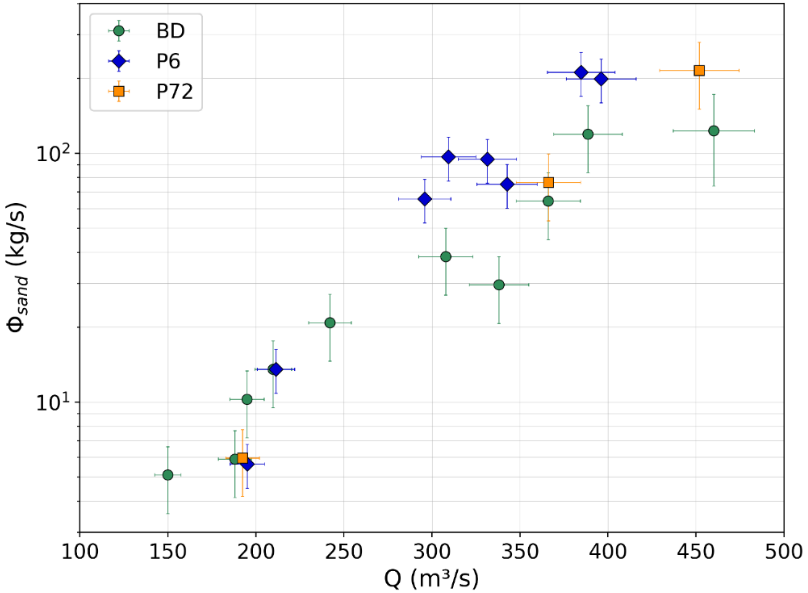
Information per sample:
→ Sand and fine sediment concentration
→ Grain size distribution



Dramais, G., **Laible, J.**, Le Coz, J., Calmel, B., Camenen, B., Topping, D.J., Santini, W., Pierrefeu, G. Methodology for River suspended-sand discharge-computation with uncertainty estimation, using water samples and high-resolution ADCP measurements (in prep)

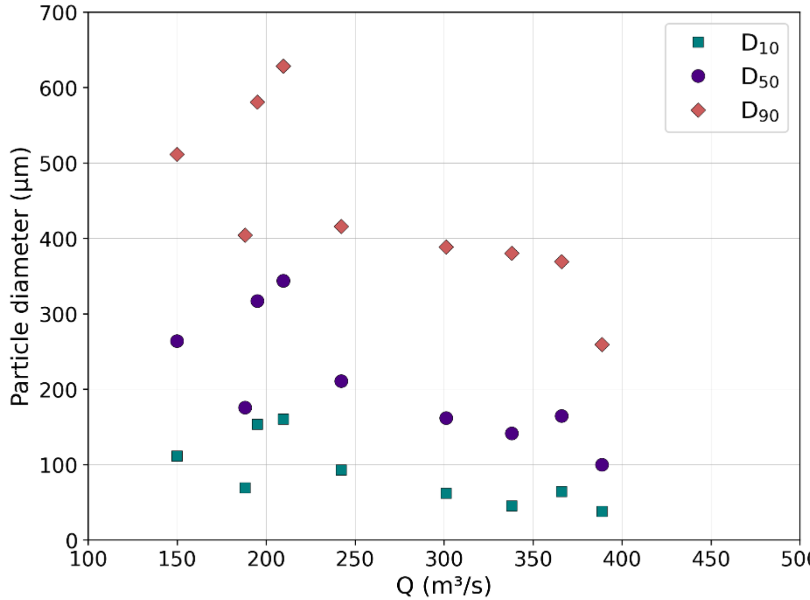
Mean cross-sectional suspended sand concentration & total sand flux

→ Vertical and lateral integration



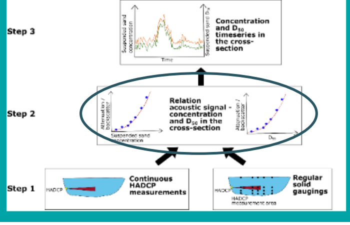
Mean cross-sectional sand grain size distribution

→ Following ISO 4363



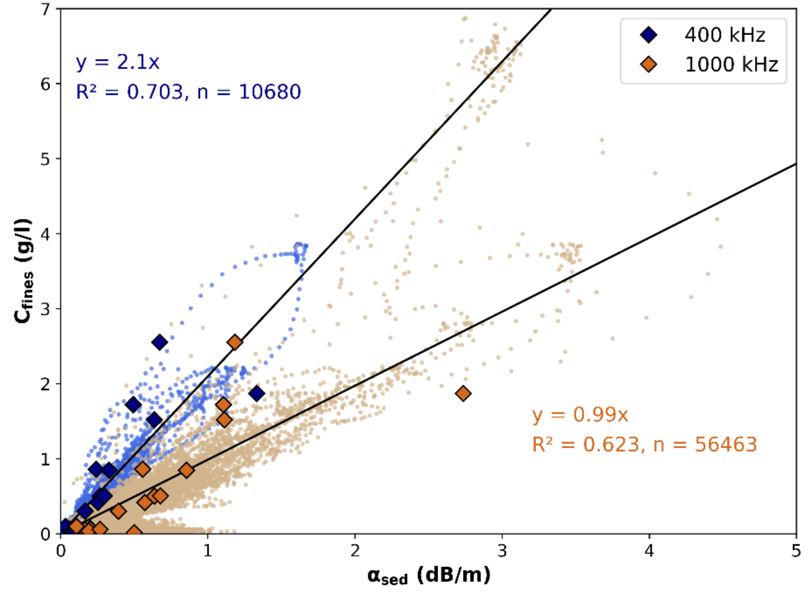
Laible, J., Camenen, B., Le Coz, J., Pierrefeu, G., Mourier, B., Lauters, F., & Dramais, G. (2023). Comparison of grain size distribution measurements of sand-silt mixtures using laser diffraction systems. *Journal of Soils and Sediments*, 1-16

Step 2: Relate acoustic signal & concentration and grain size in the cross section



Relating C_{fines} with α_{sed}

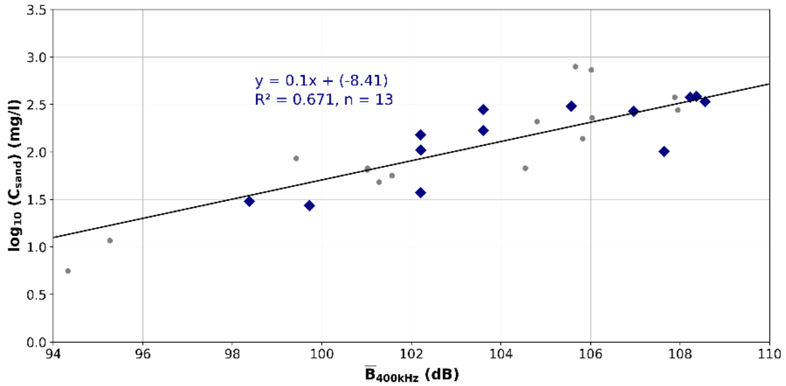
C_{fines} measured by US P6, US P72 and turbidity
α_{sed} dominated by fine sediments

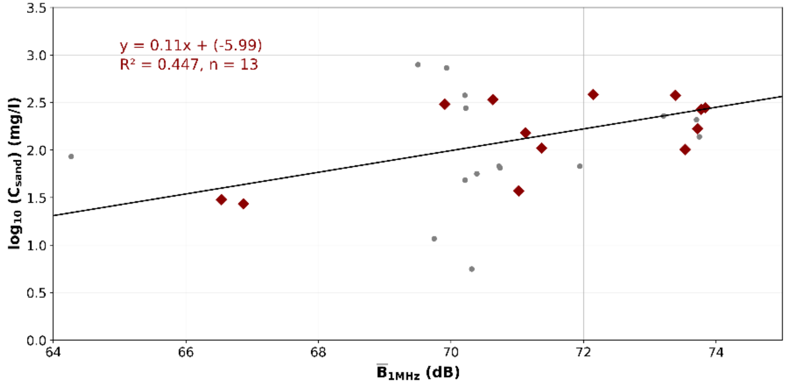


Relating C_{sand} with $\overline{B}$

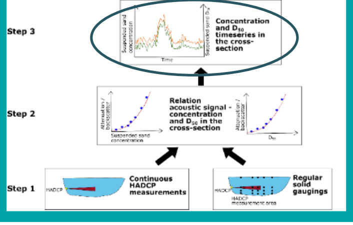
$\overline{B}$ dominated by sands, but also influenced by high concentrations of fine sediments

→ Use only gaugings where $S = \frac{C_{fines}}{C_{sand}} < 2$ and D_{50} close (± 50 µm) to the reference D_{50} = 200 µm

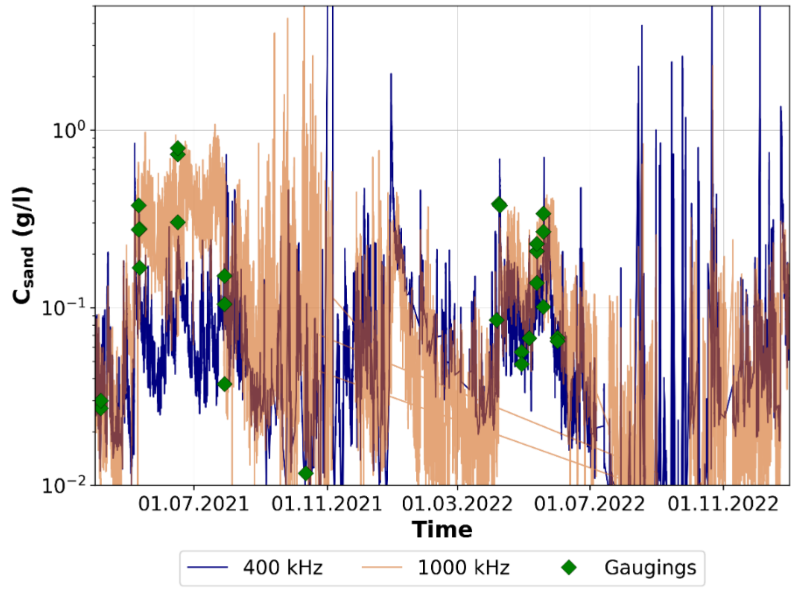




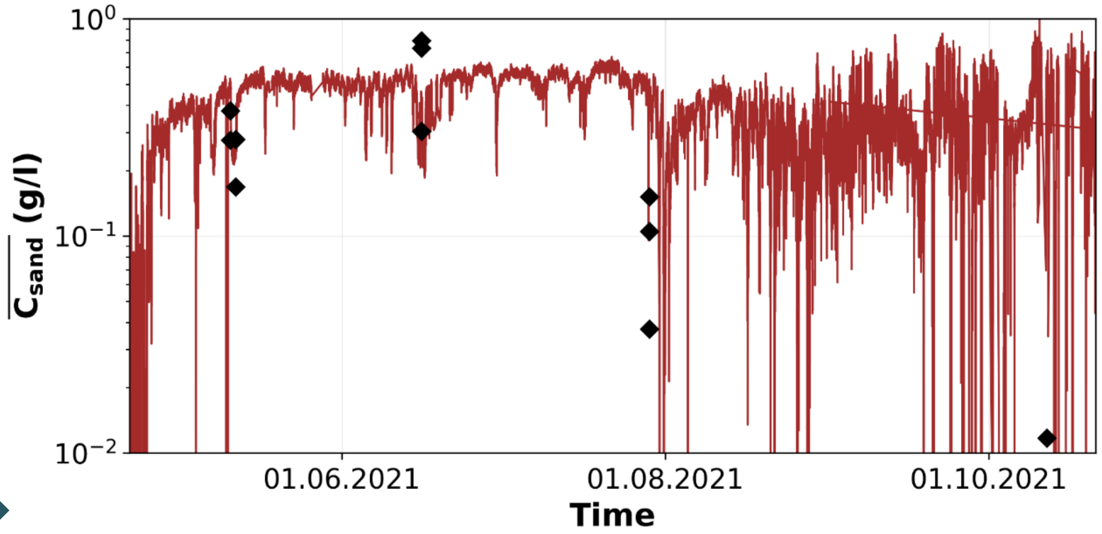
Step 3: Establish sand concentration and grain size timeseries

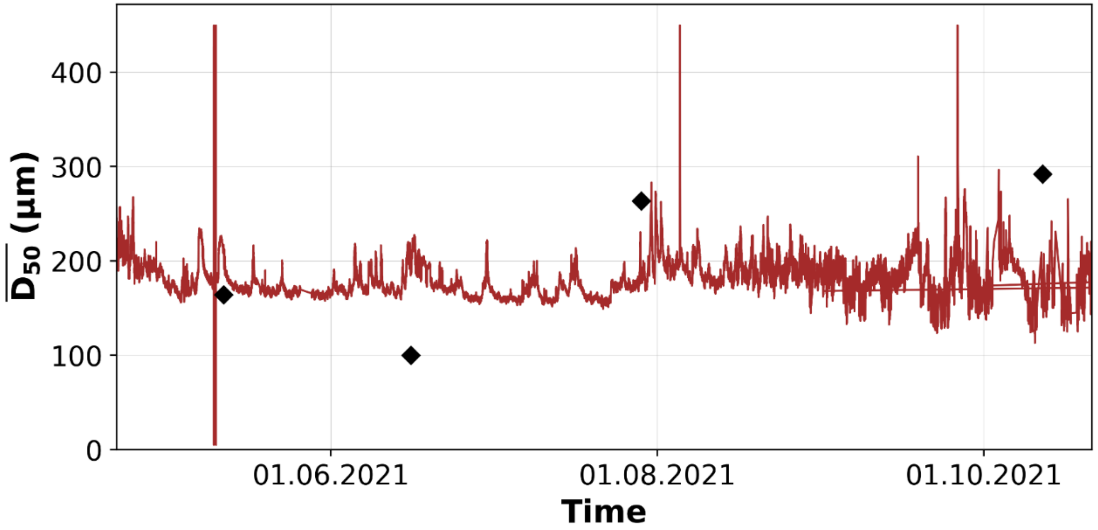


Intermediate step: Single-frequency estimates of the sand concentration



Combine both frequencies based on theory





Conclusion & perspectives

Conclusion

- Continuous deployment of 2 HADCPs for 18 months
- 21 solid gaugings under various hydro-sedimentary conditions
- Good relations between the concentration of fine sediments and α_{sed} as well as the concentration of sand and $\bar{B}$
- Time series need to be improved

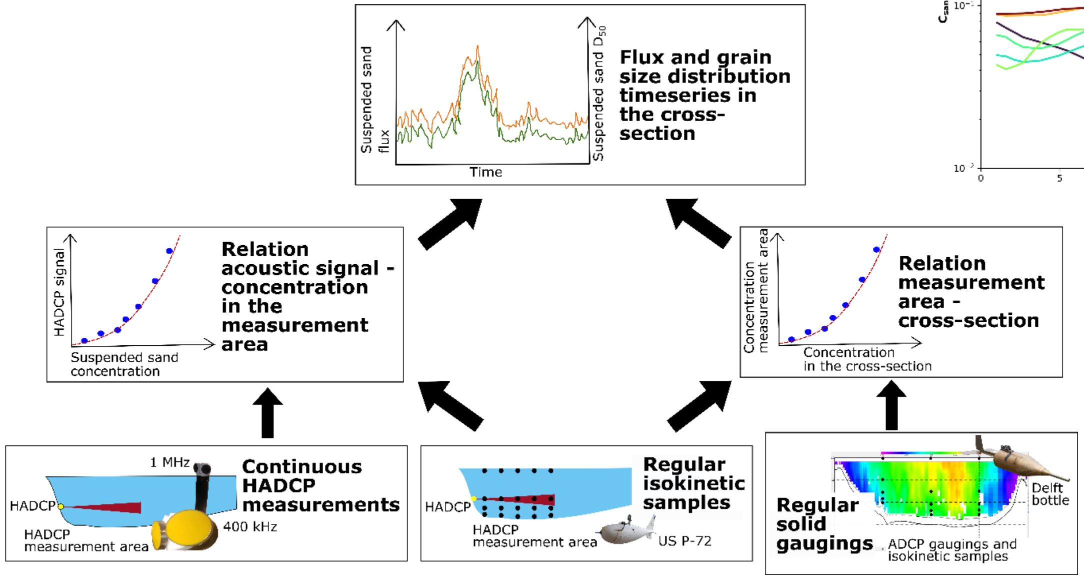
Perspectives

- Introduce physical approach by relating measurements within the acoustic beam

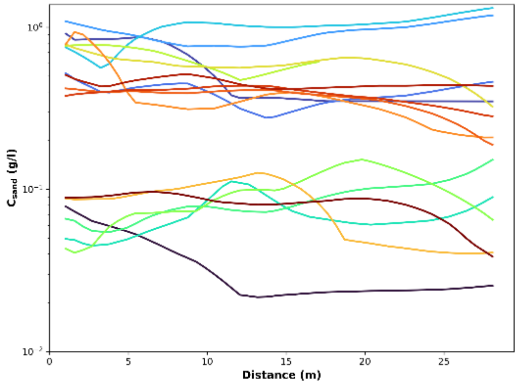
Step 3

Step 2

Step 1



Variation of C_{sand} along the beam



Do you have questions, remarks or a PostDoc offer?

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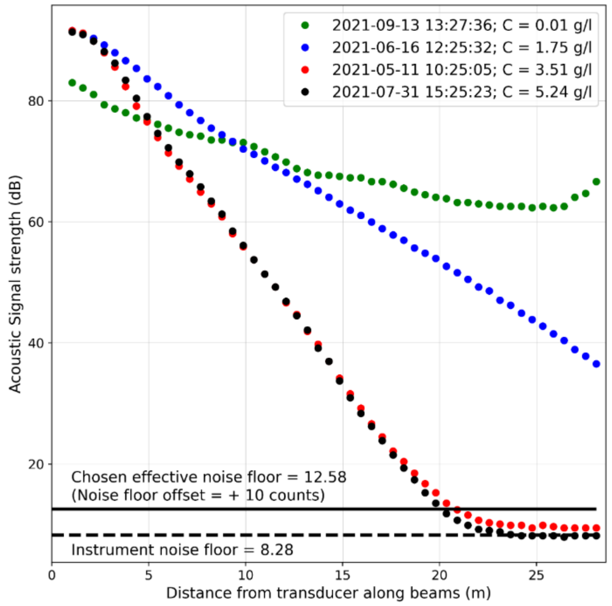
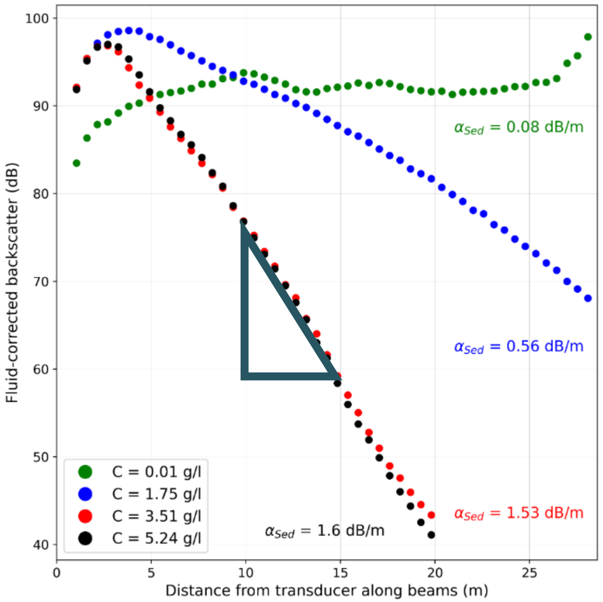
Calculate α_{Sed} et $\bar{B}$

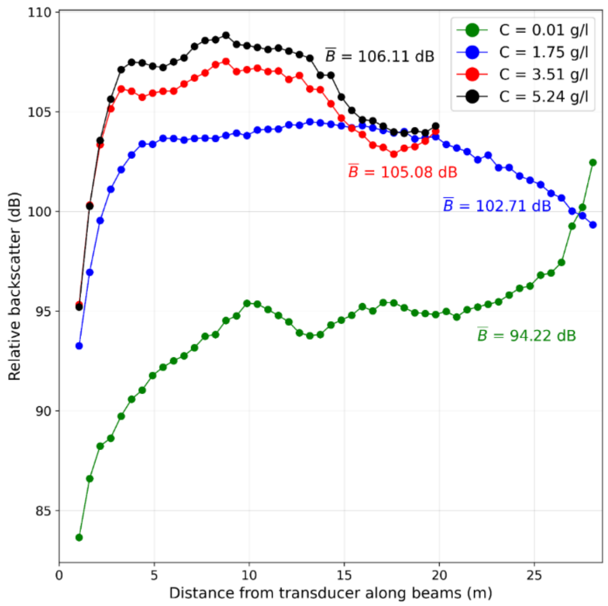
Measured intensity (I_{RL})



$$\alpha_{Sed} = -\frac{1}{2} slope$$



$\bar{B}$



$$FCB = I_{RL} + 20\, log_{10}(r) + 2\alpha_w r$$

$$B = FCB + 2\alpha_{Sed} r$$

FCB = Fluid-corrected backscatter
r = Distance to transducer
α_w = Coefficient of absorption for acoustic energy in water
α_{Sed} = Sediment attenuation coefficient
B = Backscatter
$\bar{B}$ = Beam-averaged backscatter

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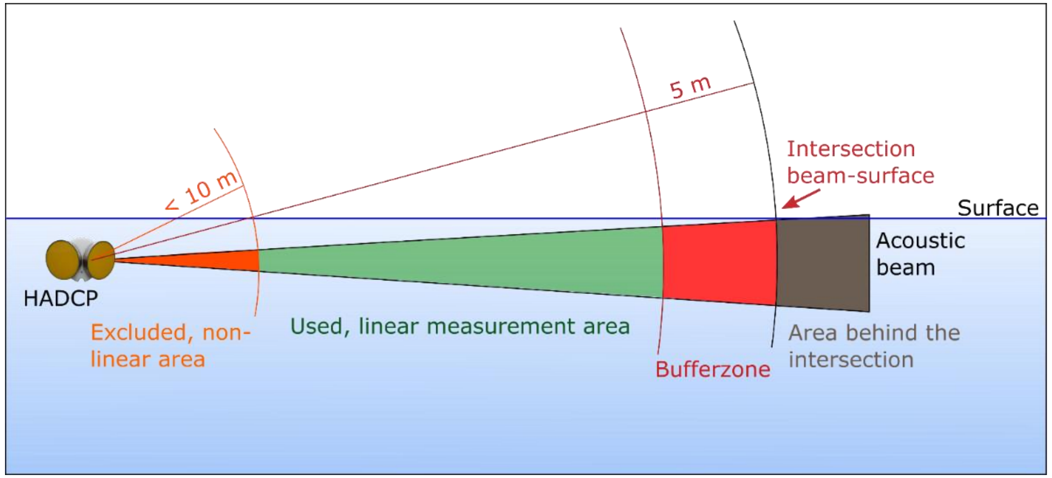
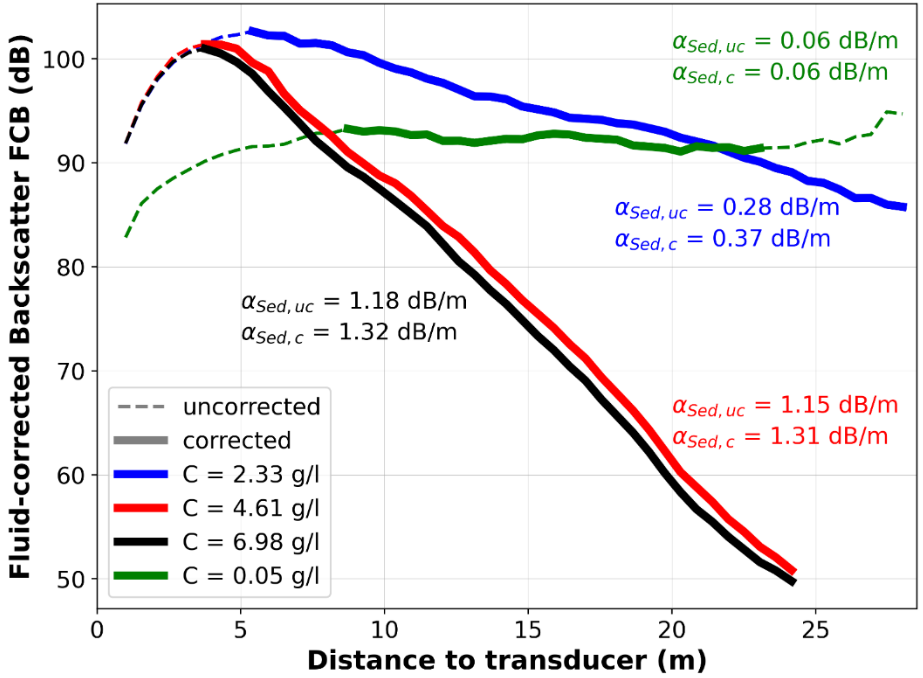
Correct for interference

Instead of using the total beam:

1) Application of a bufferzone in front of the intersection
2) Exclude the non-linear area close to the transducer





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