Bedload monitoring of rivers with hydrophone technique

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The description of a river is often based on its noise
Luka and the fire of life - Salman Rushdie (2000)
L'eau, quand elle coule, n'est jamais silencieuse. Les ruisseaux babillent (babble), les cours d'eau gazouillent (tweet) et un fleuve plus grand et plus large raconte des choses plus profondes et plus complexes. Les grands fleuves s'expriment sur une fréquence très basse, trop basse pour l'oreille humaine, même pour l'oreille des chiens qui sont incapables de saisir les mots qu'ils prononcent; le Fleuve du Temps racontait ses histoires sur la plus basse de toutes les fréquences, et seule une oreille d'éléphant pouvait en percevoir les chants.
Niroot Puttapipat

The description of a river is often based on its noise

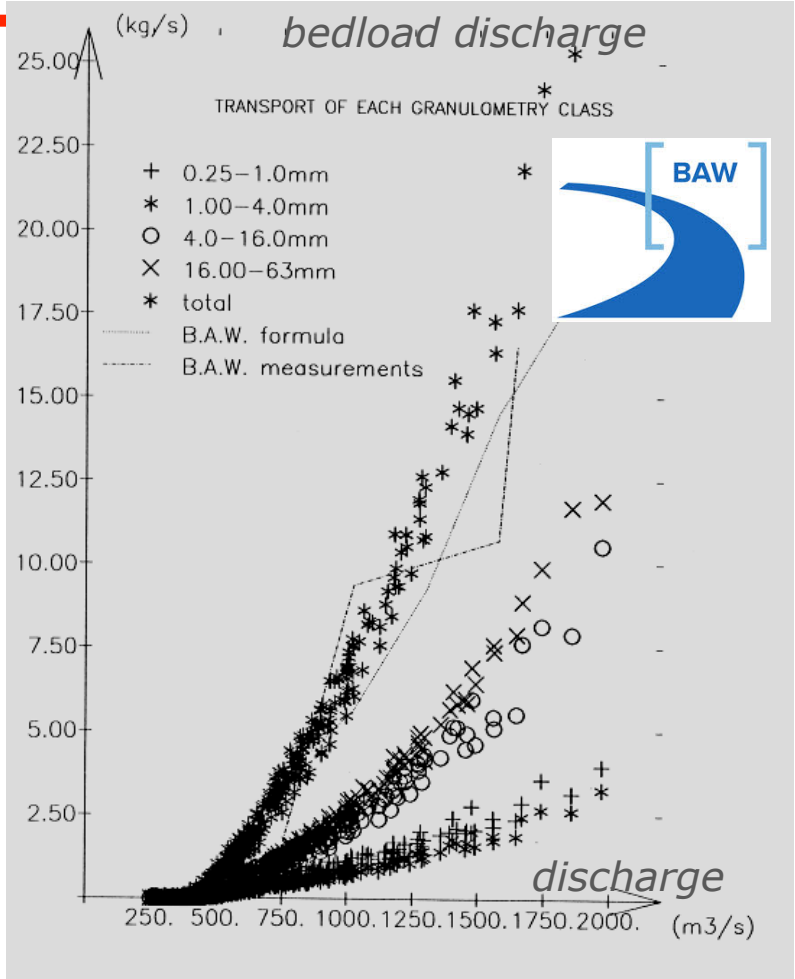
Baudolino - Umberto Ecco (2000, trad. **Jean-Noël Schiffano**)

Là, par une fente, presque une blessure entre deux monts, on voyait le Sambatyon prendre sa source : un bouillonnement d'arène, un gargouillement *(gurgling)* de tuf, un égouttement *(dripping)* de boue, un cliquètement *(clicking noise)* d'éclats, un grondement *(rumble)* de limon qui s'encaillotte, un débordement de mottes, une pluie d'argiles peu à peu se transformaient en un flux plus constant qui débutait son voyage vers quelque immense océan de sable.

Carte d'Ebstorf (vers 1300)

Measurements are needed for diagnosis, modelling, training …

GH about sediment budget application to modelling:
« estimate sediment load in case there are no measurements »



- **ex. 1 : calibration of a morphological model of the Danube River**
  - grains size differences and hidding effects are most important near *beginning of transport*

Measurements are needed for diagnosis, modelling, training …

- **ex. 2 : estimation of the annual sediment load**

  … and its longitudinal gradient

le pont des Molettes à Montmélian

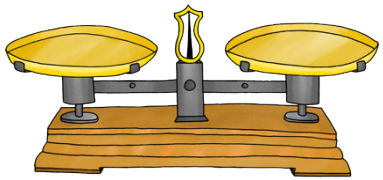
Bed load mesurements are difficult, hasardous, expensive…

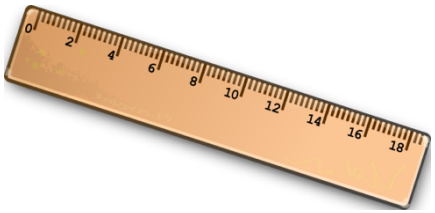
Helley-Smith exercices in a mountain creek

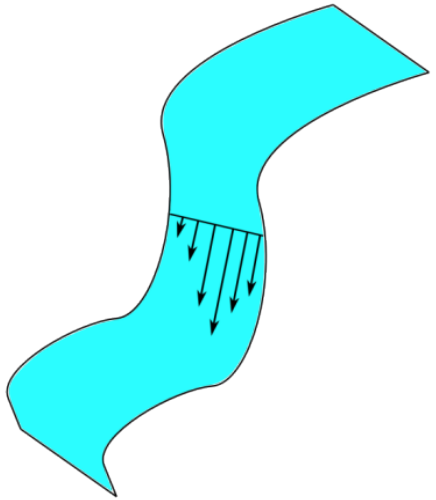
Arc River during flushing operations - June 2011

But what do we need in term of data ?

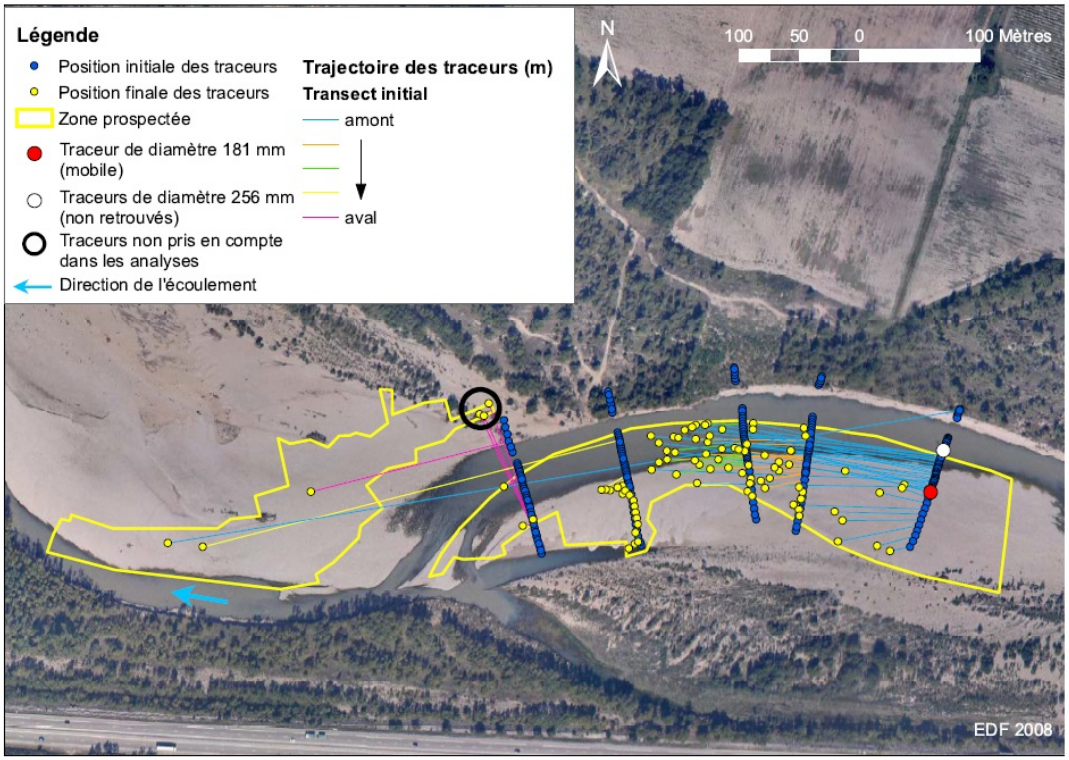
1. When ? Critical discharge ? Rythms ?
2. How much (solid discharge) ?
3. What ? Grain size ? Transport type ?
4. Where ? within the river, within the X-section







many techniques are available for bed load measurement



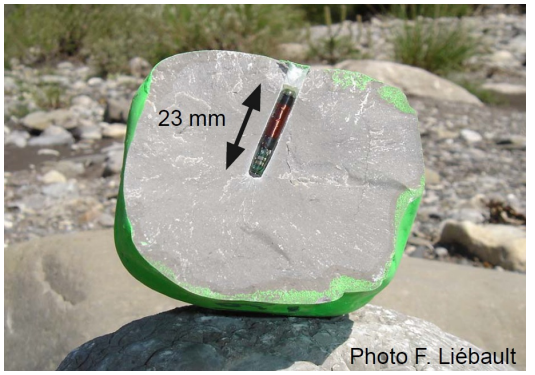
The dispersion of radiotracers on a bar of the Durance R. by a flood - 16/06/2010
Recovery rate 41%
(Chapuis – 2012)

◆ **example :**

radiotracers

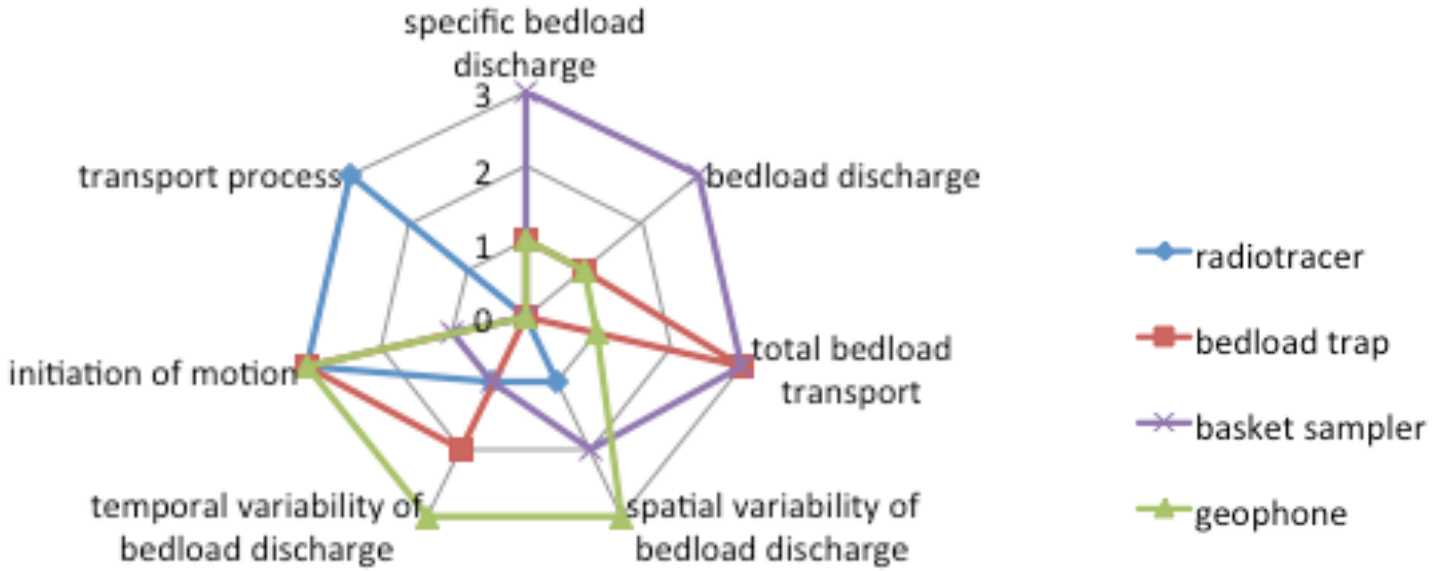
mechanisms of transport,

spatial variability



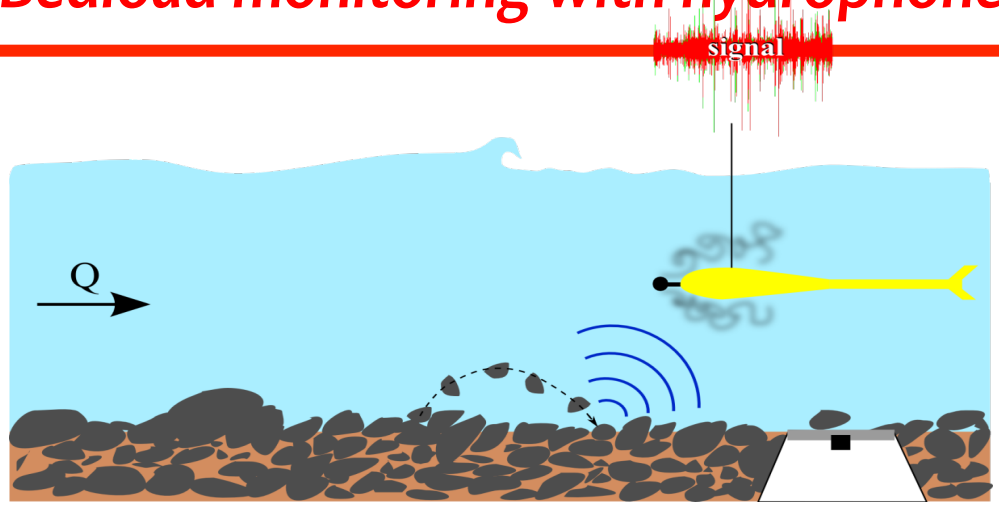
many techniques are available for bed load measurement

from H. Habersack



each one is adapted, but for different goals

Bedload monitoring with hydrophone technique



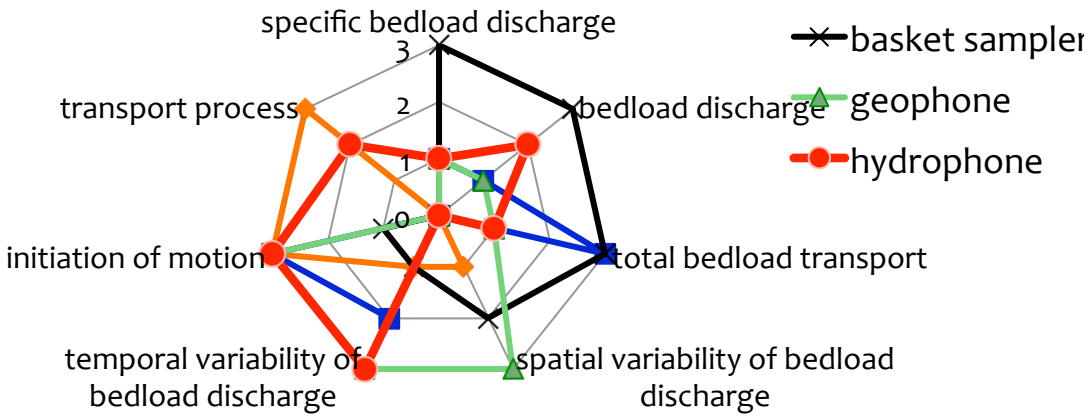
characteristics:

+++ Continuous mesurement

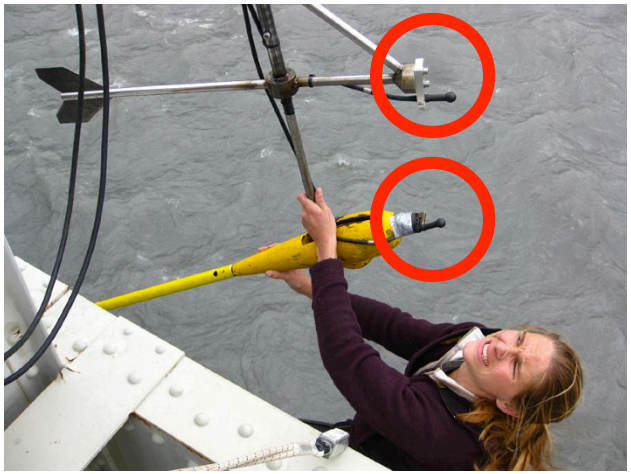
++ feasible during floods

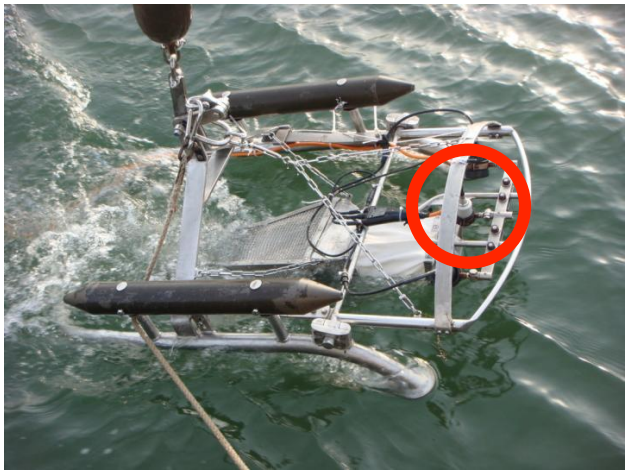
+ - space integrative

- - indirect measurement ,
needs theoretical development



hydrophone setup





dipped in the water
- ↖ from the bank
- ← on the sampler
- ↑ from a bridge

bedload trap

sill with geophone plates

on the bottom →

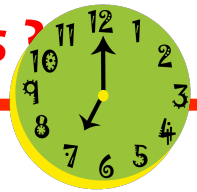
small and large rivers

Salman Rushdie:

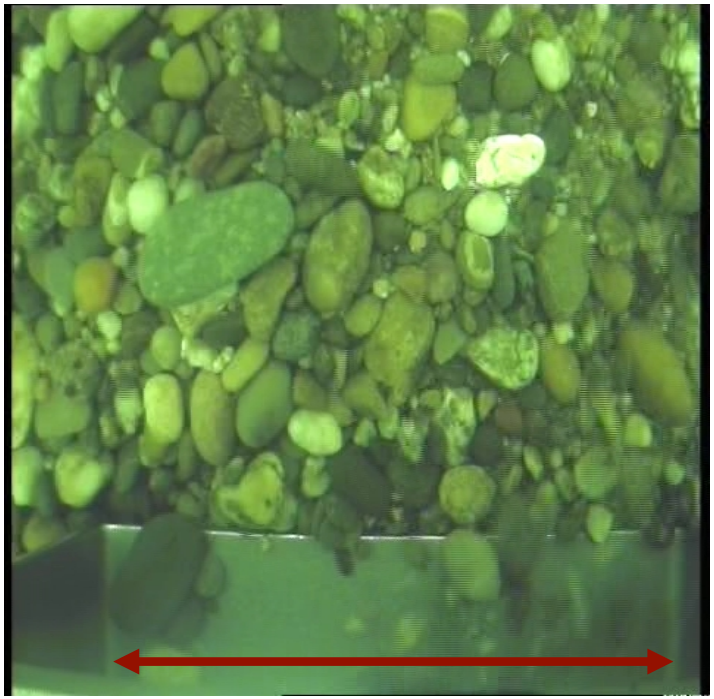
- ***creeks babble***
- ***small rivers tweet***
- ***large rivers use low frequencies***

BOKU eDF bfg Bundesanstalt für Gewässerkunde irstea

1. When ? Critical discharge ? Rythms ?



bfg Bundesanstalt für Gewässerkunde



16 cm

Video at the entrance of the sampler

from Thomas Geay PhD Thesis

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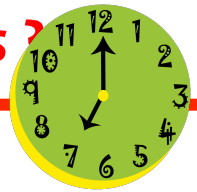

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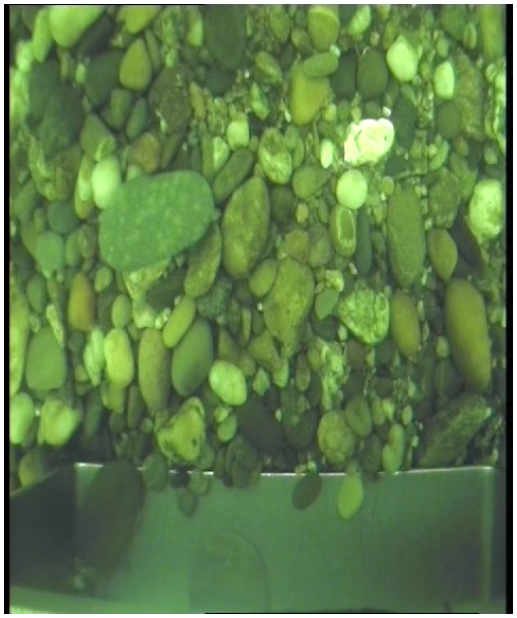
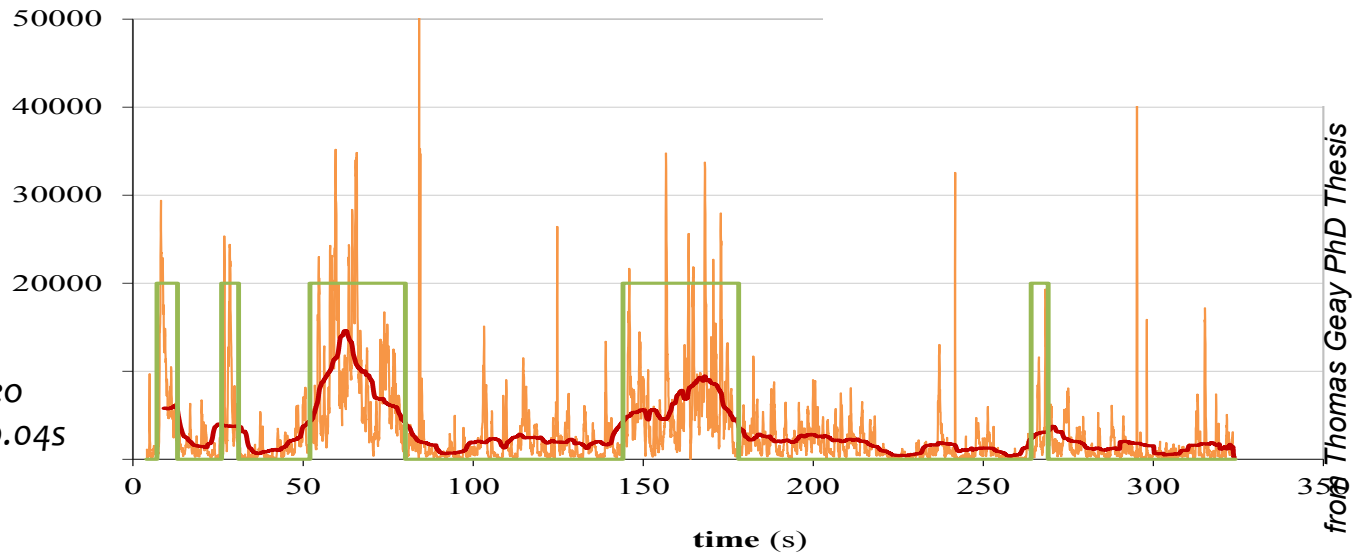
Rhine River at Leimersheim





particle movement from the video

- *number of pixels during 0.04s*
- *moving average (10s)*
- *visual estimation*

from Thomas Geay PhD Thesis

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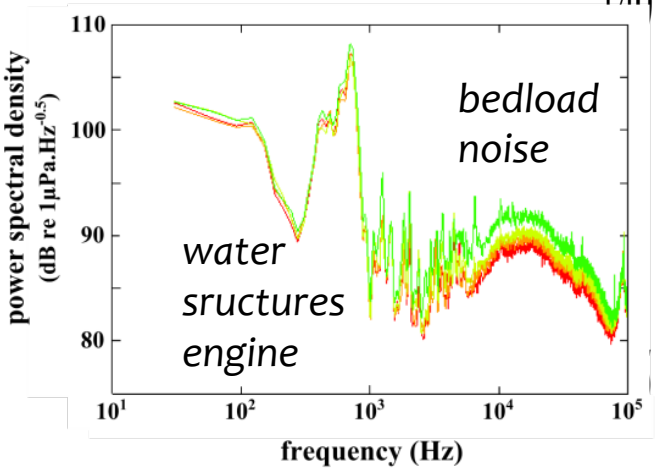
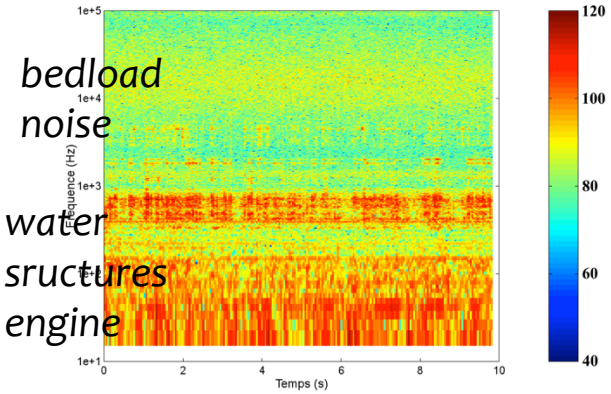
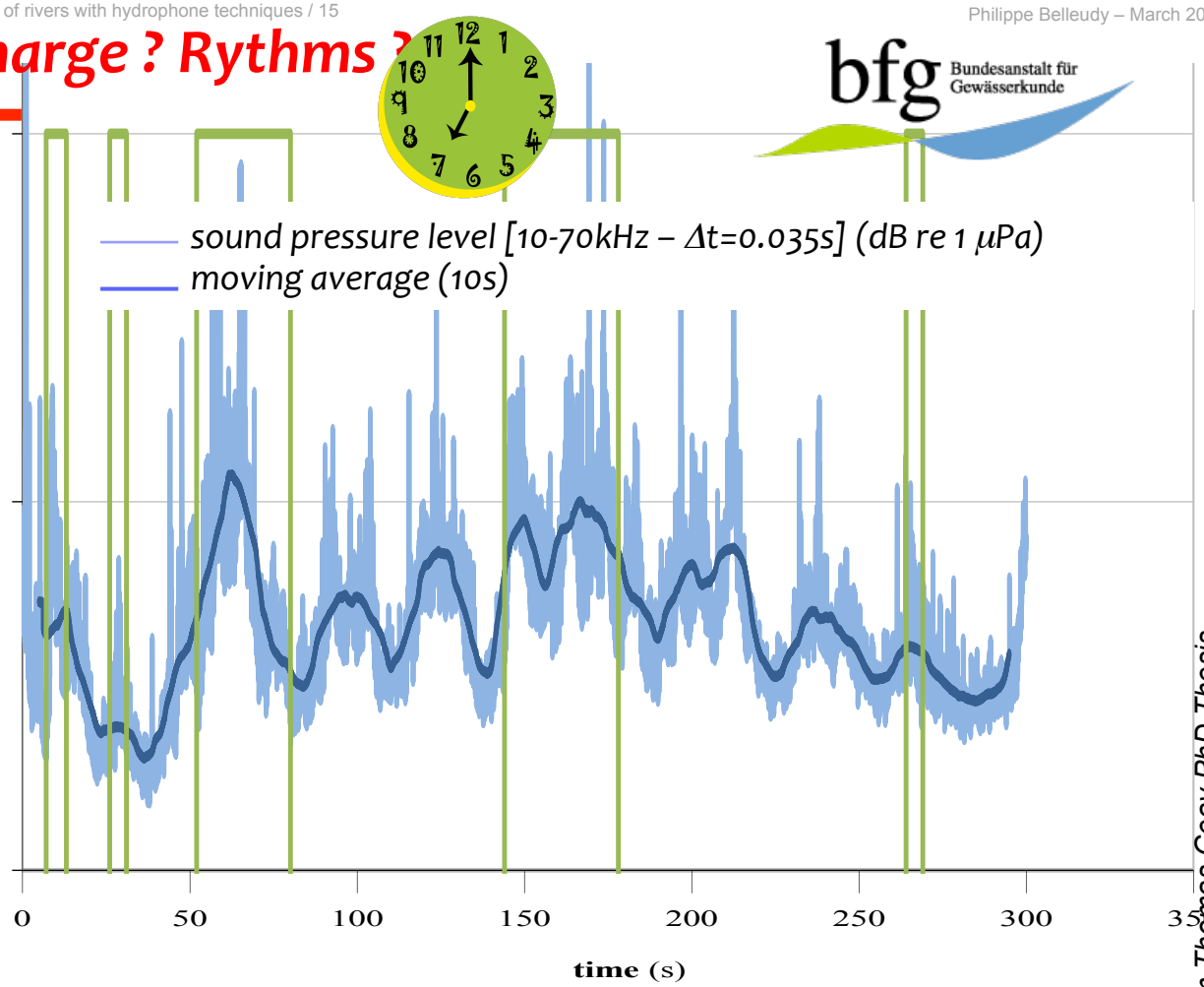






from Thomas Geay PhD Thesis

1. When ? Critical discharge ? Rythms ?

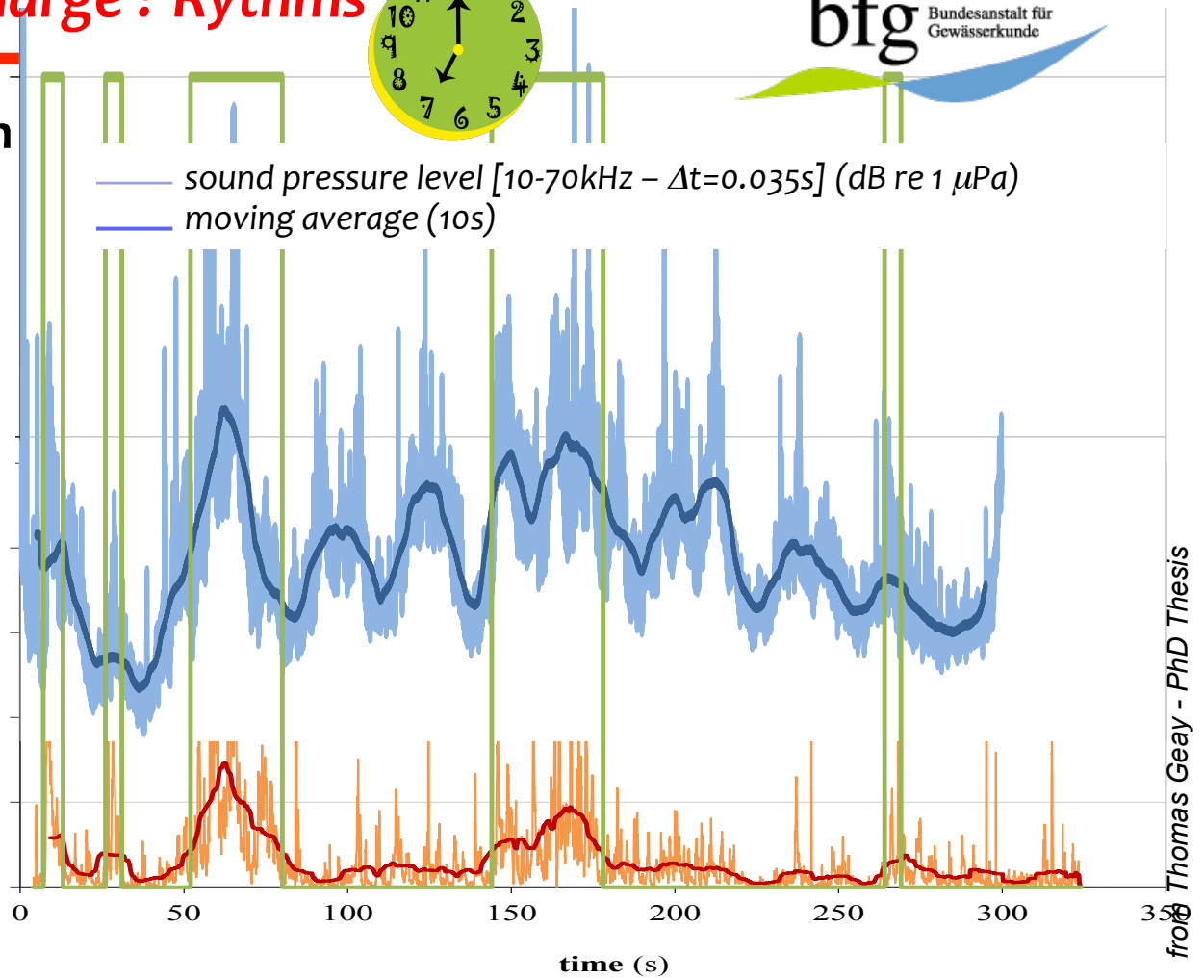
140

Rhine River at Leimersheim

➔ detection of the beginning of transport

➔ seems to be integrative of a large surface of bed

➔ comparison/calibration needed



particle movement from the video
- *number of pixels during 0.04s*
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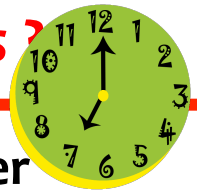
- *visual estimation*

from Thomas Geay - PhD Thesis

1. When ? Critical discharge ? Rythms ?

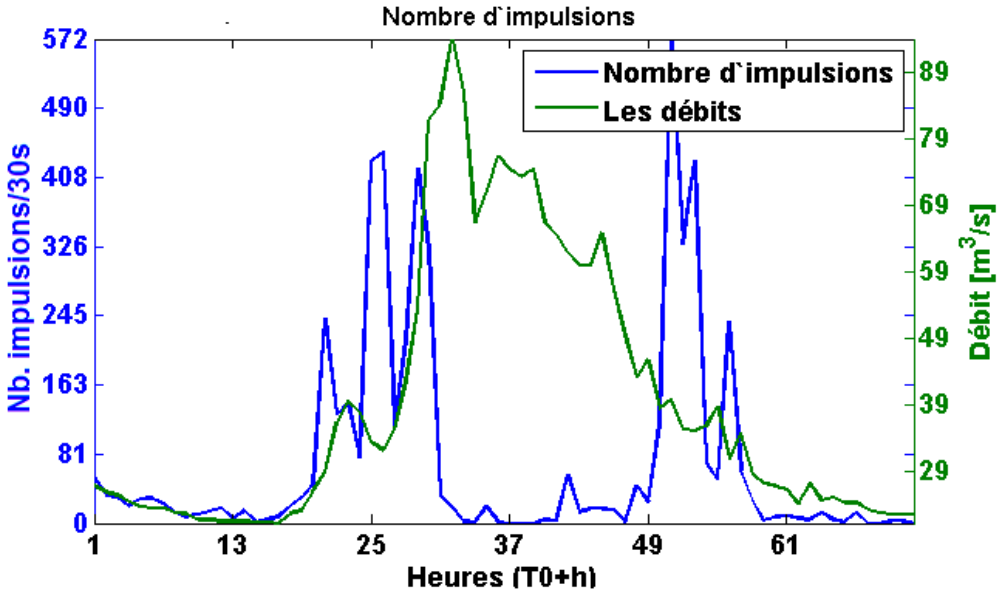


Vénéon River

flood : 12-14 August 2014

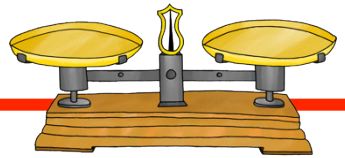
Pulses of SPL above threshold during 30s of signal.

in the frequency range > 1kHz

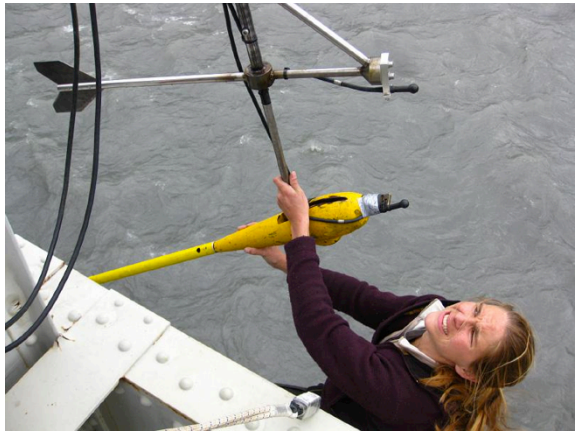


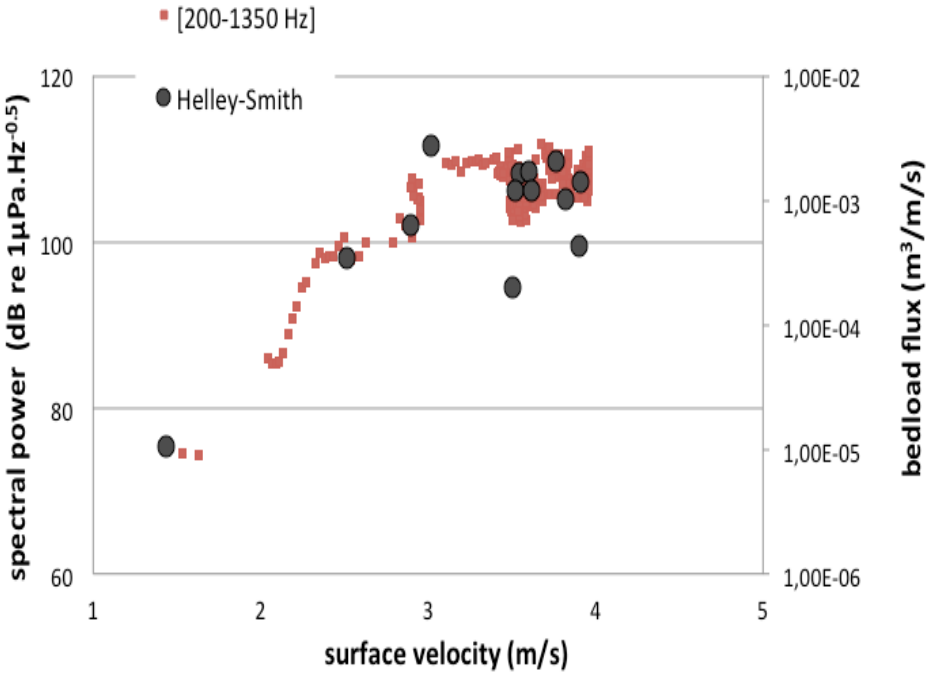
from Teodor Petrut - PhD Thesis

2. How much (solid discharge) ?



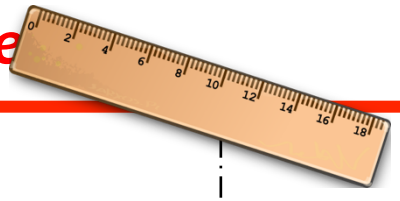
Arc River (Savoie) during flushing operations



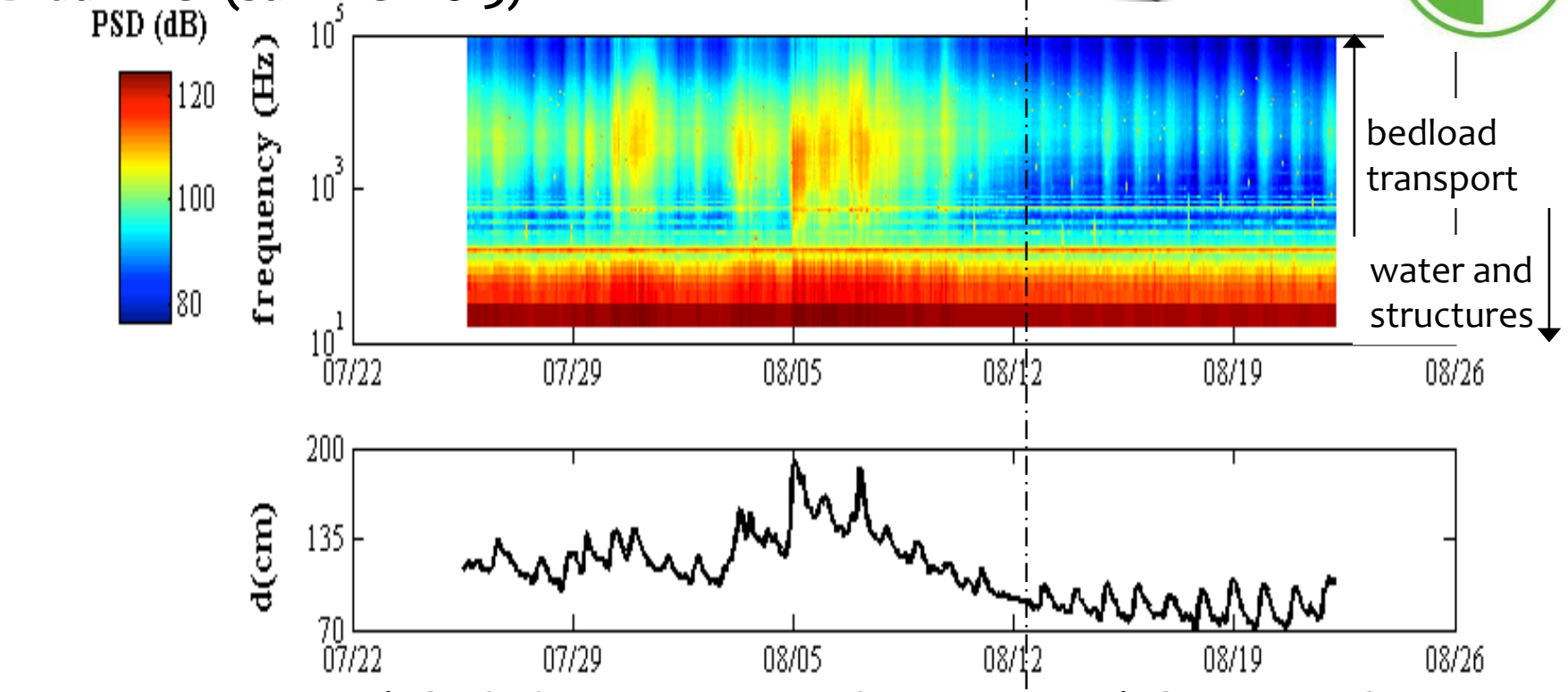


➔ need for comparison/calibration

3. What ? Grain size ? Transport type



Drau River (summer 2013)

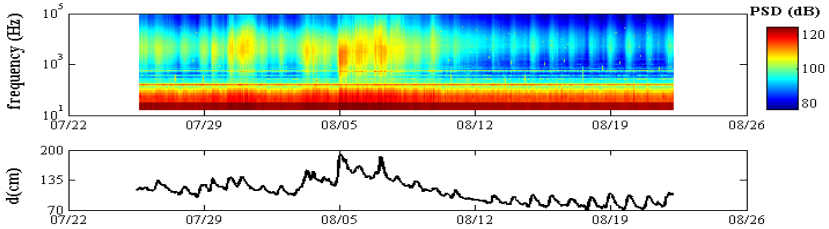


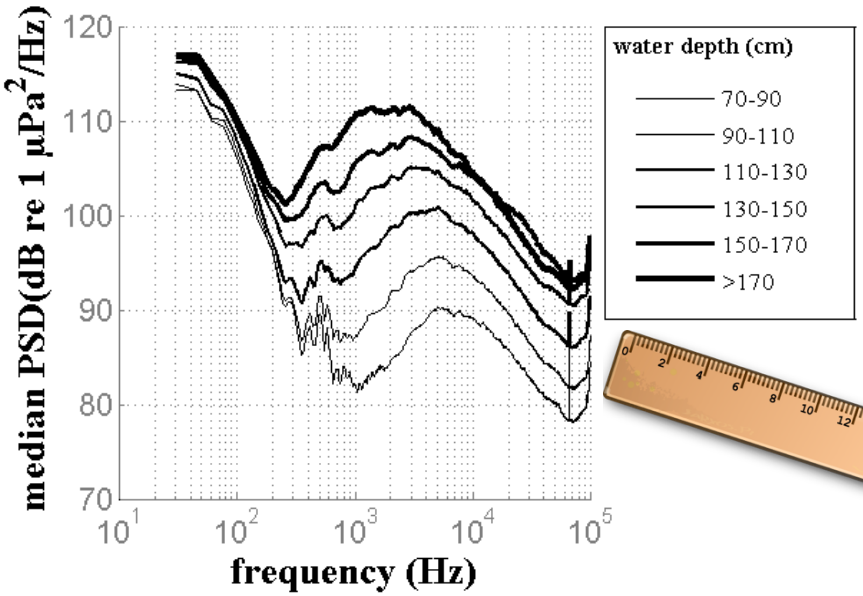
period A: high waters – snow melt + rain

period B: snow melt, daily variations

Geay et al. (in prep)

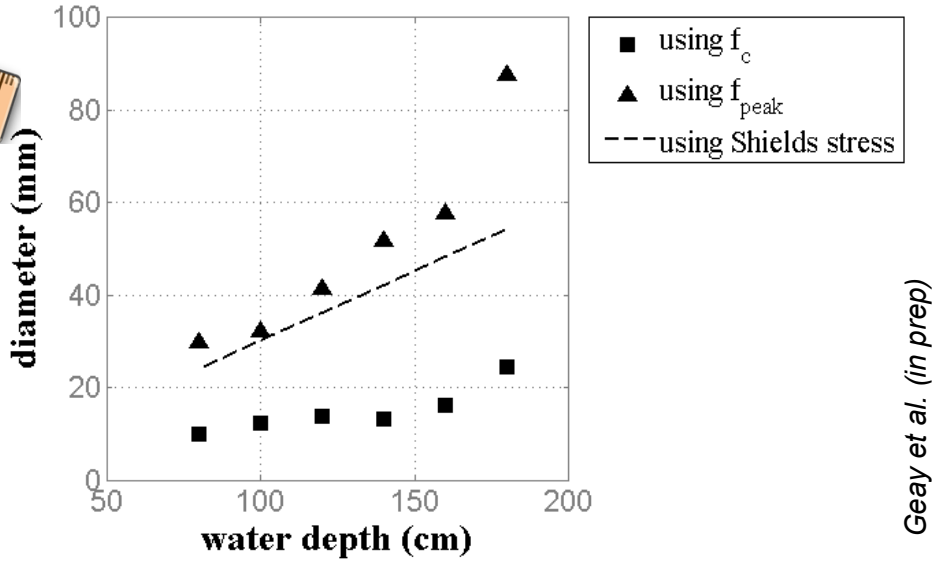
3. What ? Grain size ? Transport type





← Bedload dominant frequency depends on water depth (and discharge)

Bedload frequencies may be related to particle diameters diameters using empirical Thorne's laws and critical Shields stress →



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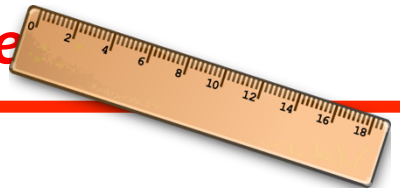
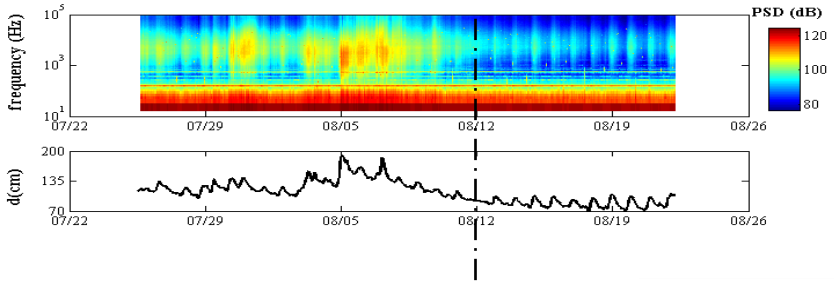
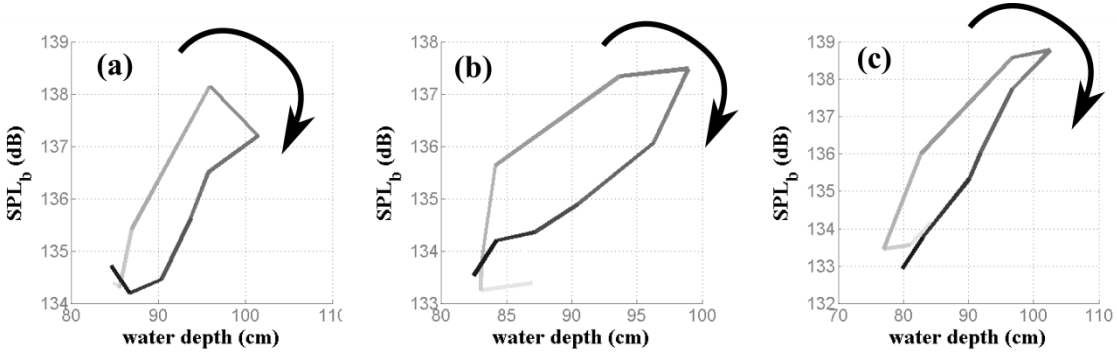


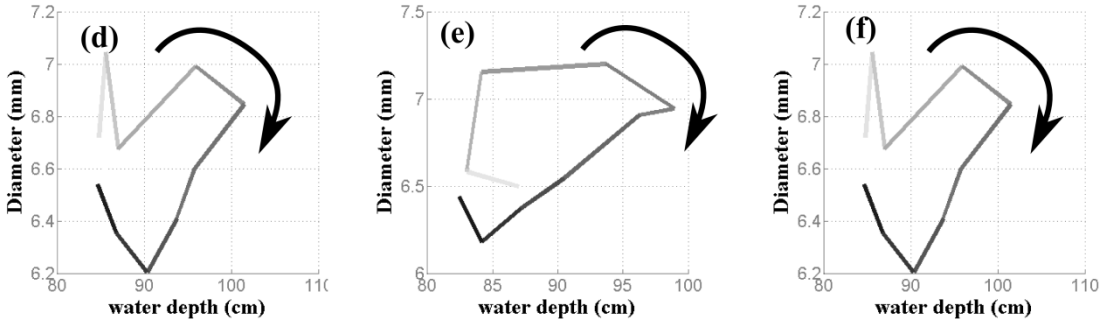


period B: snow melt, daily variations

Daily variations of SPL_b (dB re 1µPa) vs. water depth (cm) during 3 daily cycles →

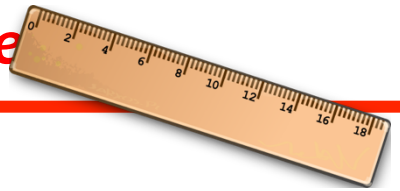


Daily variations of estimated bedload diameters (mm) vs. water depth (cm) during 3 daily cycles →

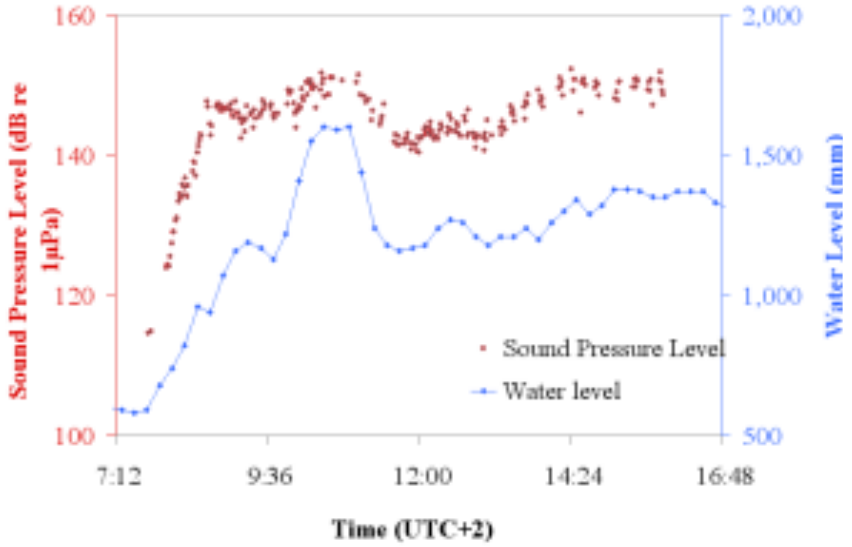


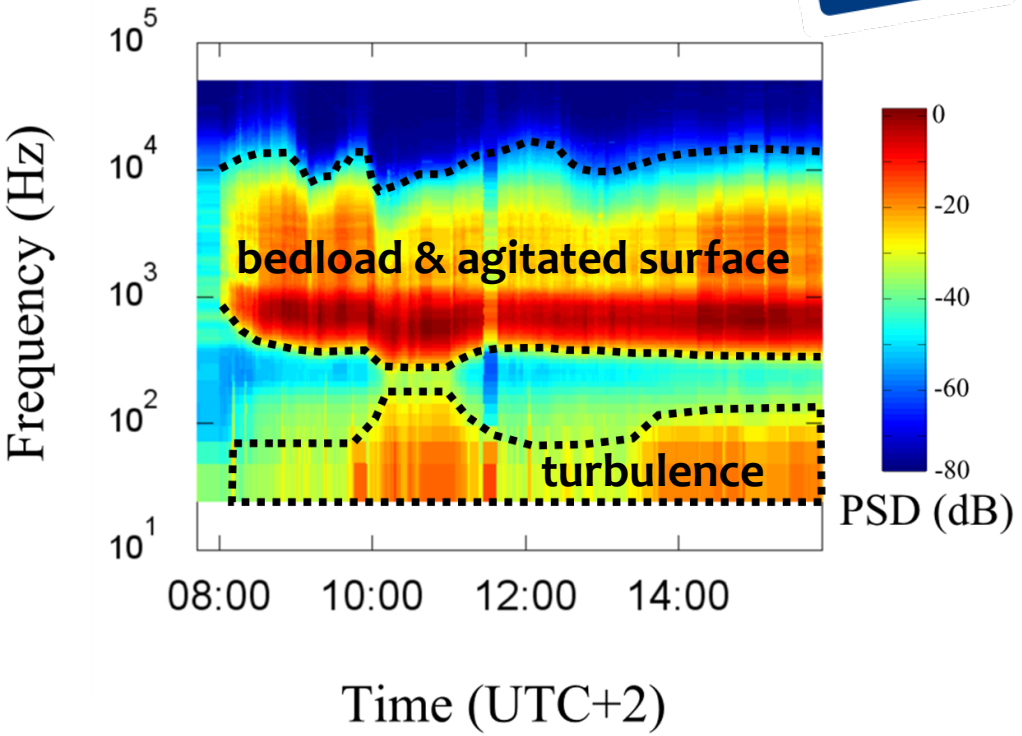
Geay et al. (in prep)

3. What ? Grain size ? Transport type



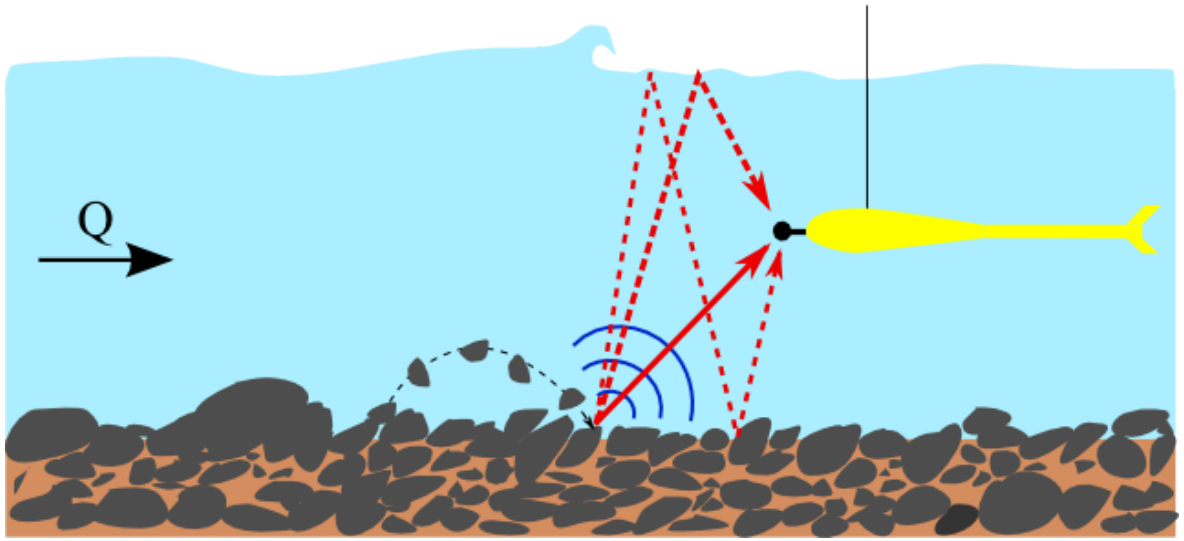
Arc River (Savoie) during flushing operations



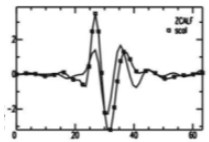


one could see coarser particles during peak flow…

Acoustic wave guide

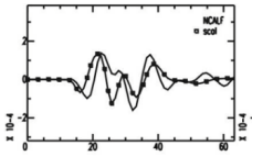


source



transfer function
f(range, depth, freq)

receive



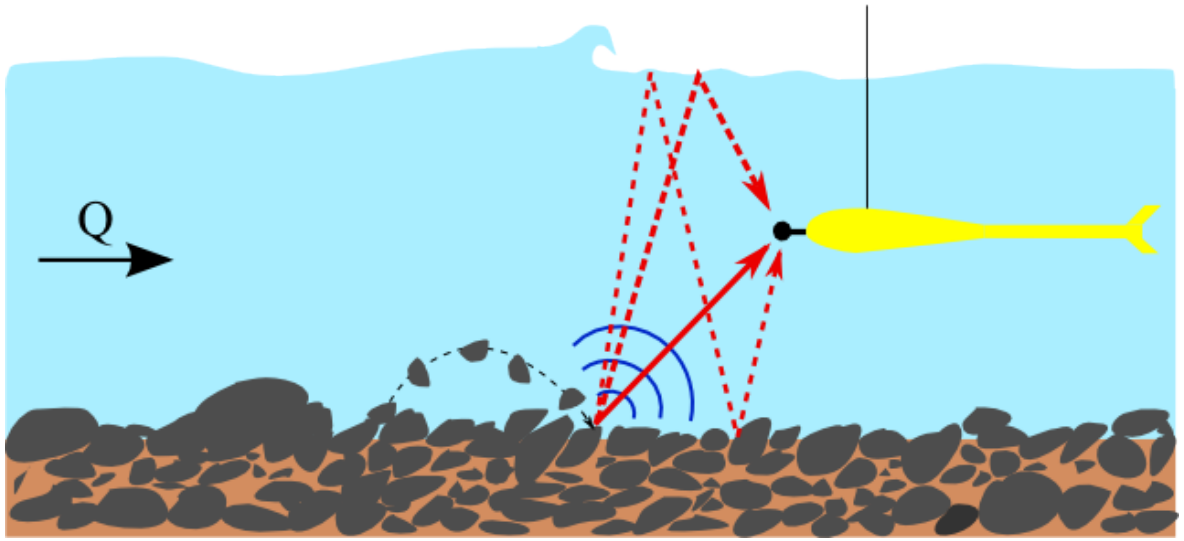
Acoustic wave guide

Pekeris model

Air

Water, c_1

Bottom, c_2



$$f_{cutoff} = \frac{C_1 C_2}{4D\sqrt{C_2^{\,2} - C_1^{\,2}}}$$

water depth (m)

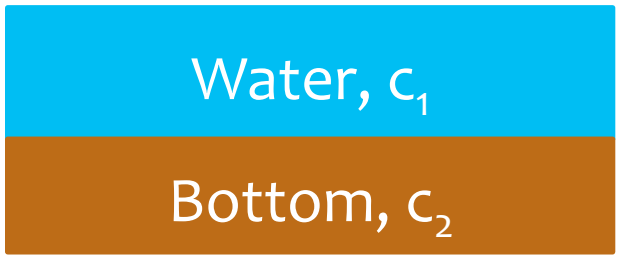
sound speed in sediment (ms^{-1})

sound speed in water (ms^{-1})

➔ only high frequencies can propagate

3. What ? Grain size ? Transport type ?

Arc River (Savoie) during flushing operations



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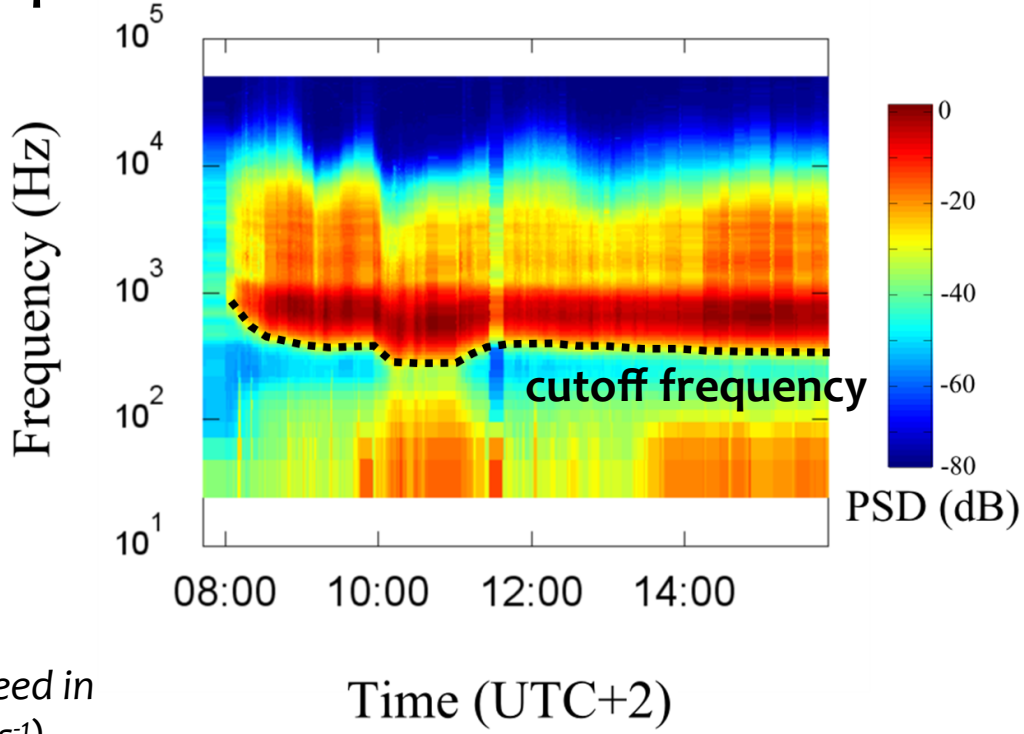
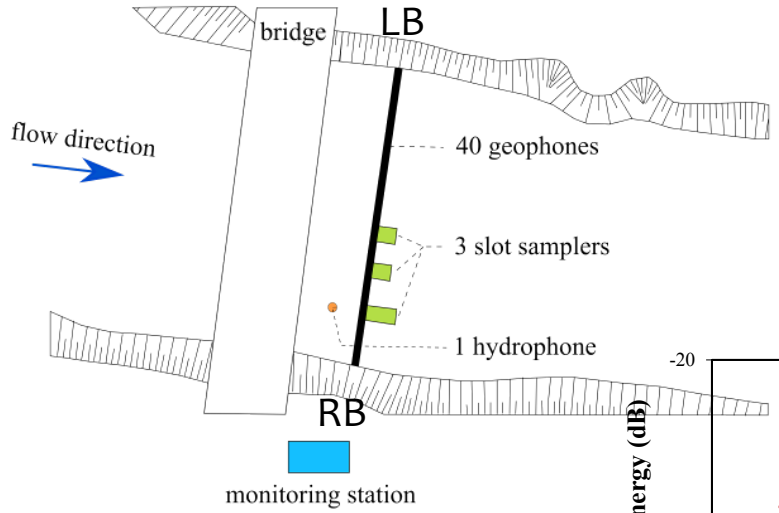
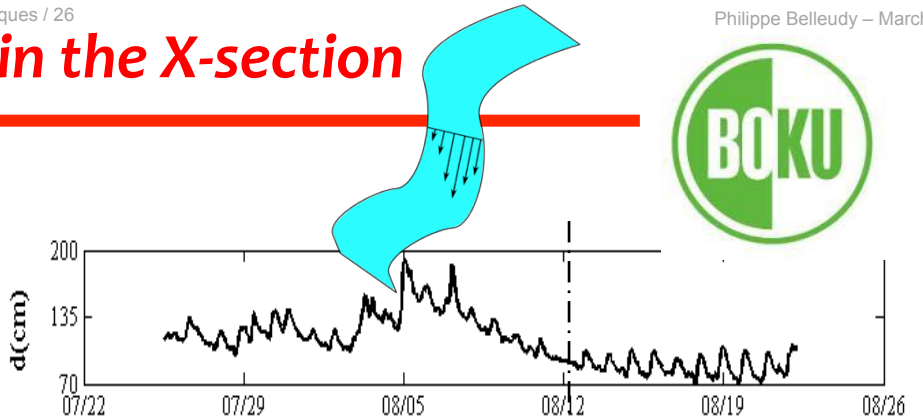


4. Where ? within the river, within the X-section

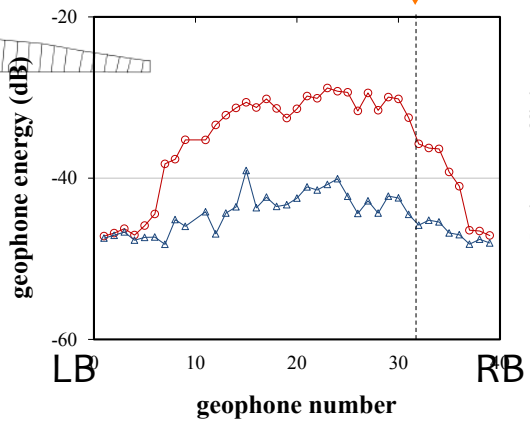
Drau River (summer 2013)

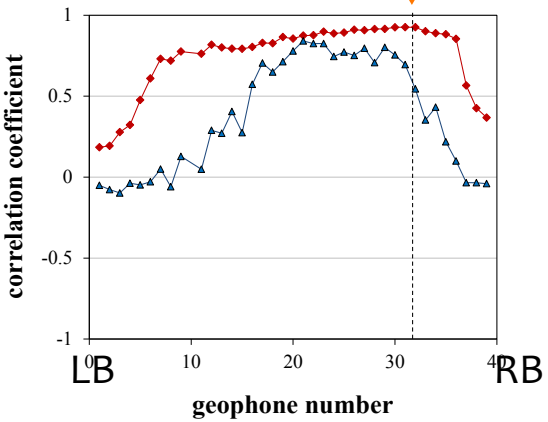




period A **period B**

hydrophone location *hydrophone location*





___ period B:
snow melt, daily variations

_____ period A:
high waters – snow melt + rain

→ hydrophone is integrative of a large portion of the X-section

from Thomas Geay PhD Thesis

Bedload monitoring with hydrophone : summary & conclusions

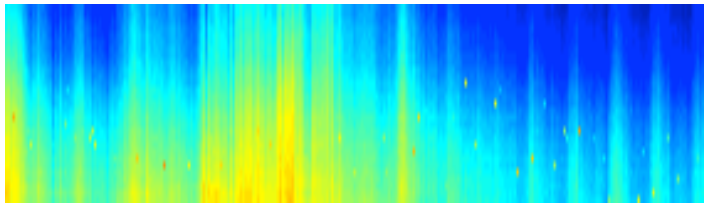
- **the soundscape is a combination of different sources of noise and of propagation properties**
- **needs adapted signal analysis methods**

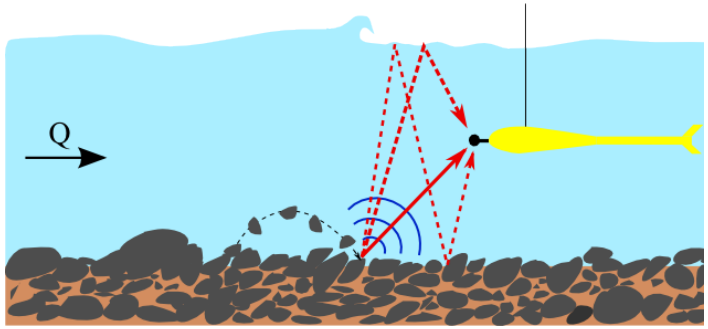
  time-frequency analysis, statistical analysis, correlation betwenn several hydrophones, etc.
- **needs calibration**

- **continuous / integrative / easy to deploy / cheap**

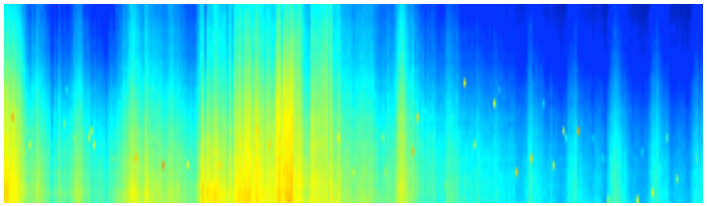
  a good alternative for large rivers

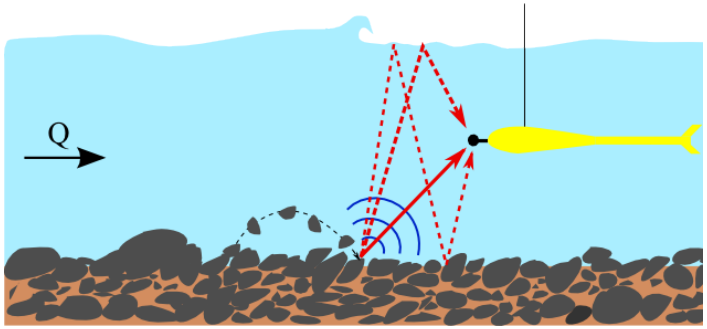
- **operational for monitoring if bedload continuity through dams**





thank you for your attention





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