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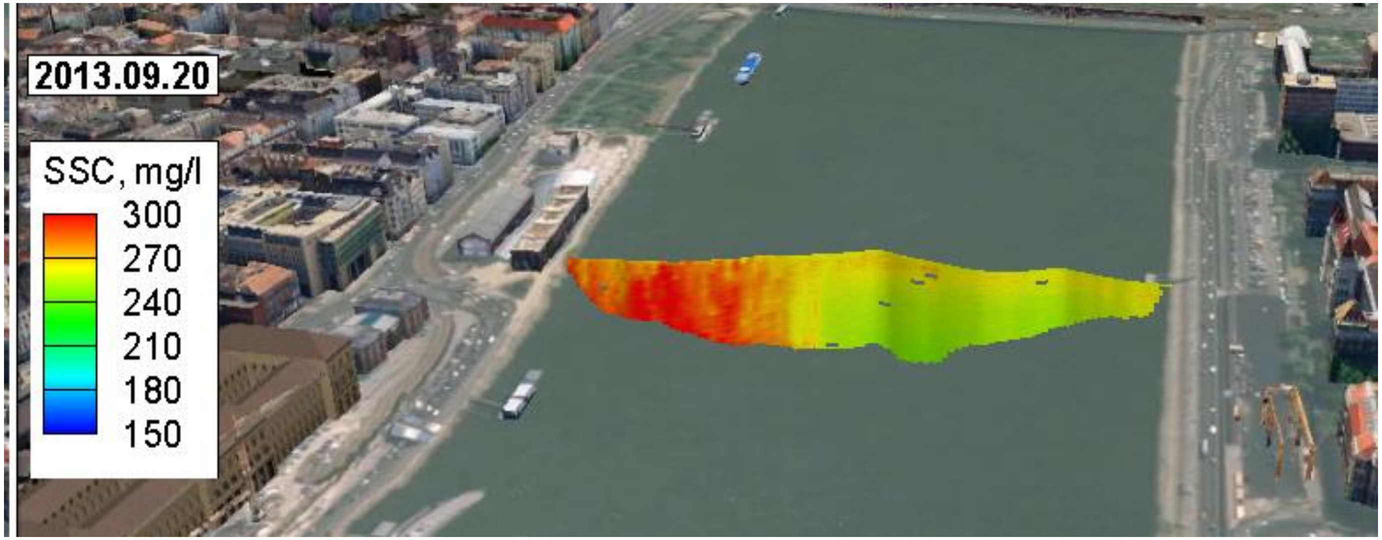
Sediment Monitoring Workshop
DanubeSediment project

Good practices in suspended sediment monitoring: Concurrent expeditionary calibration measurements. Laboratory analysis methods

Budapest, 18.04.2018.

Why do we need calibration?

- Goal → Relationship between point concentration and sediment load
- Inhomogeneous cross-sectional distribution of suspended sediment



$C_{bank} \neq C_{mean}$

Procedure of sediment load estimation

Turbidity

↓

Concentration close to the sensor ← Probe characteristic $s_k = a\ s_s$; Probe factor $k_s = s_k / s_s$

↓

Mean concentration ← Cross-sectional characteristic $s_m = a\ s_k$

↓

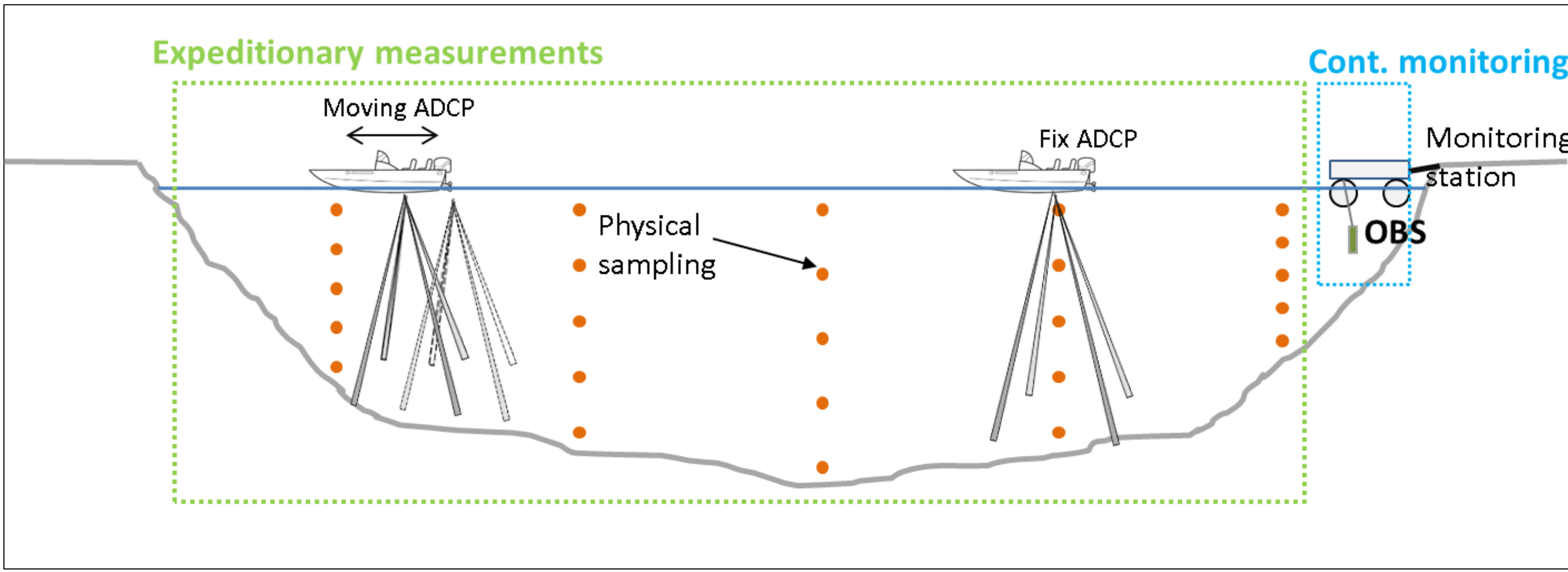
Suspended sediment transport ← Discharge $Q_s = s_m\ Q$

↓

Suspended sediment load ← Time $V_s = \int_{t_1}^{t_2} Q_s(t)\ dt$

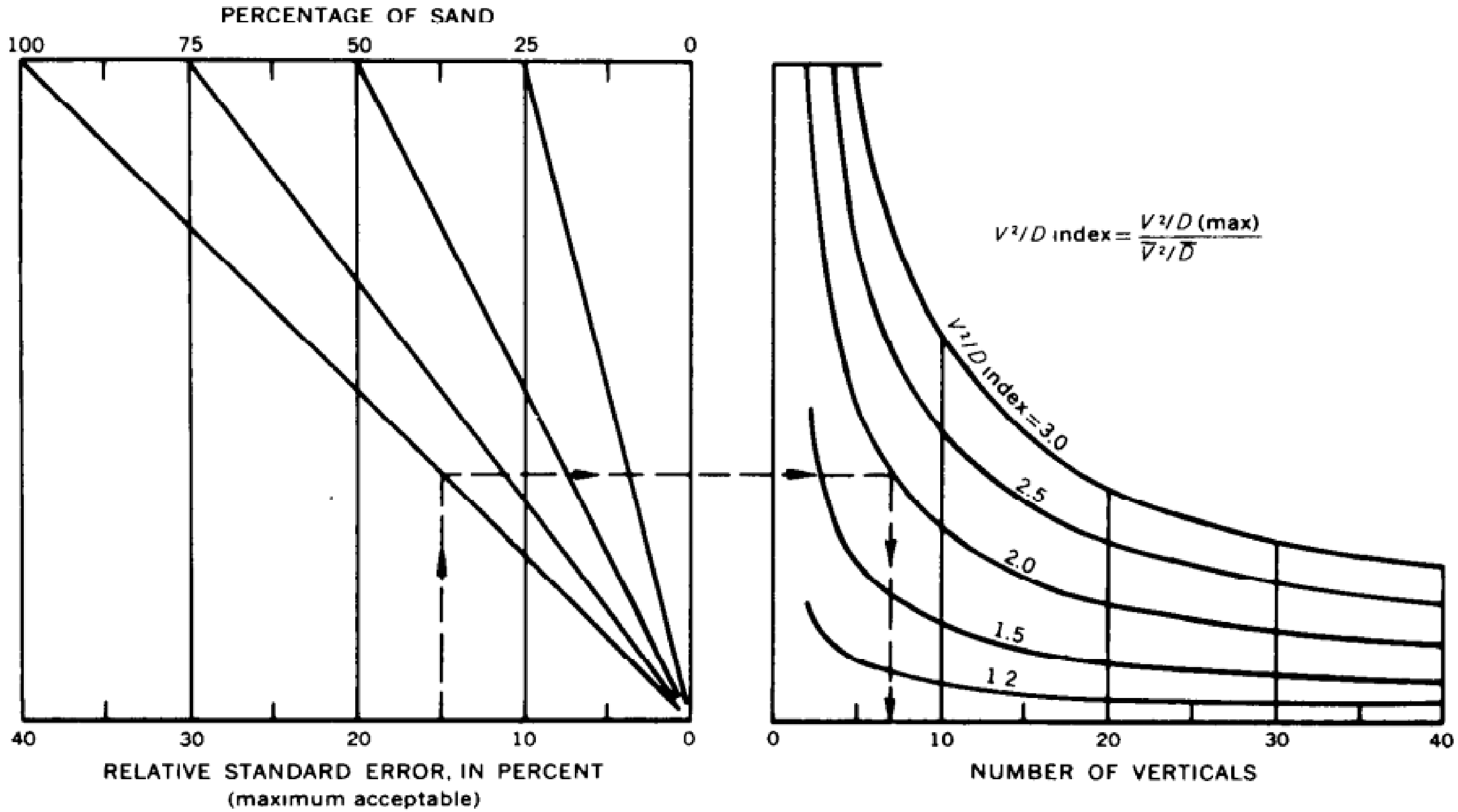
Multipoint sampling – HOW?

- Flow velocity measurements
- Sediment sampling



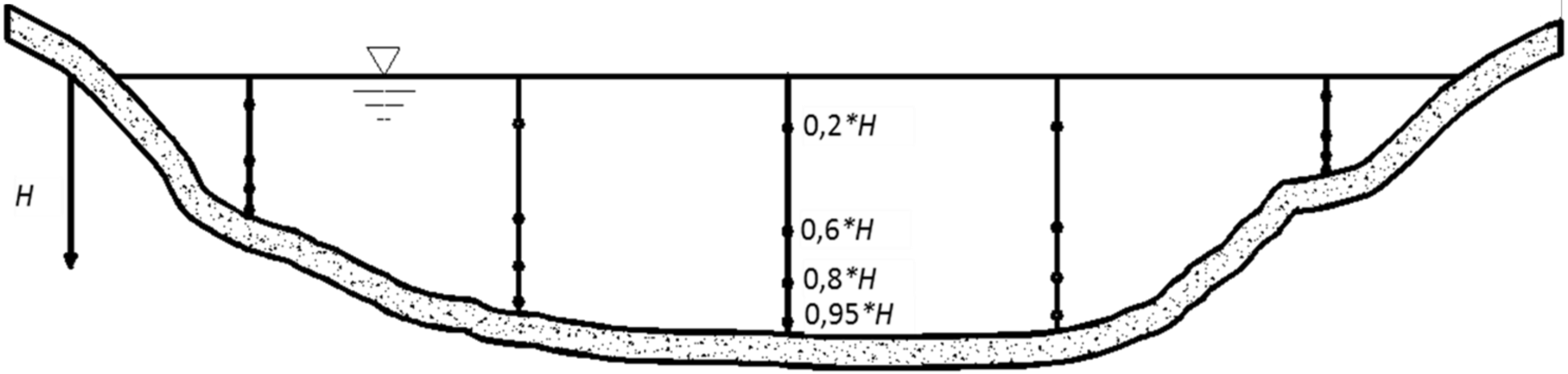
Multipoint sampling –
HOW MANY VERTICALS?

- 5-10 verticals along the transect
- 5-10 points along a vertical
- Preparatory survey of typical concentration distribution is needed



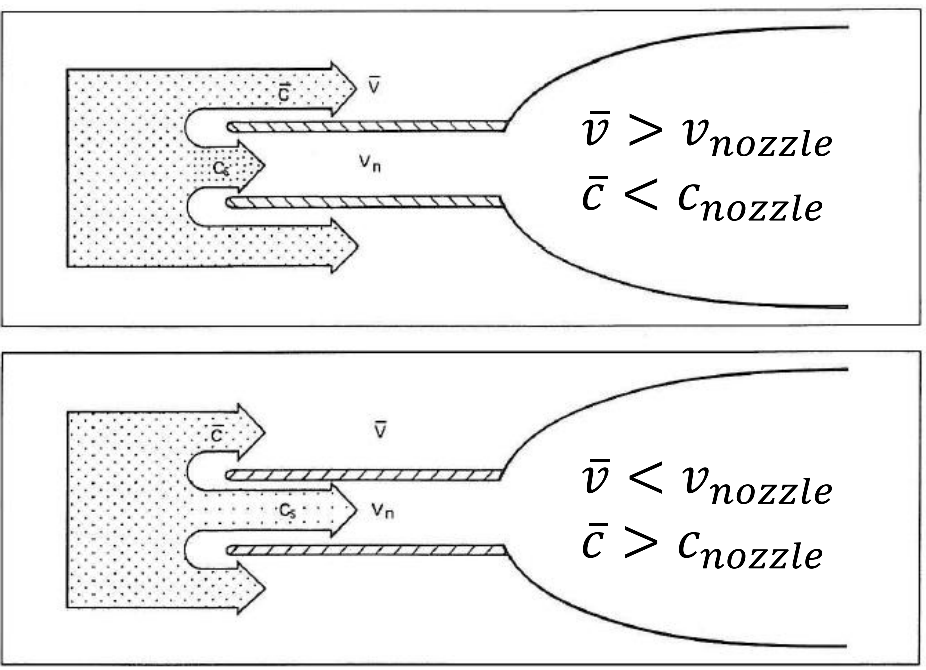
Multipoint sampling – HOW MANY POINTS?

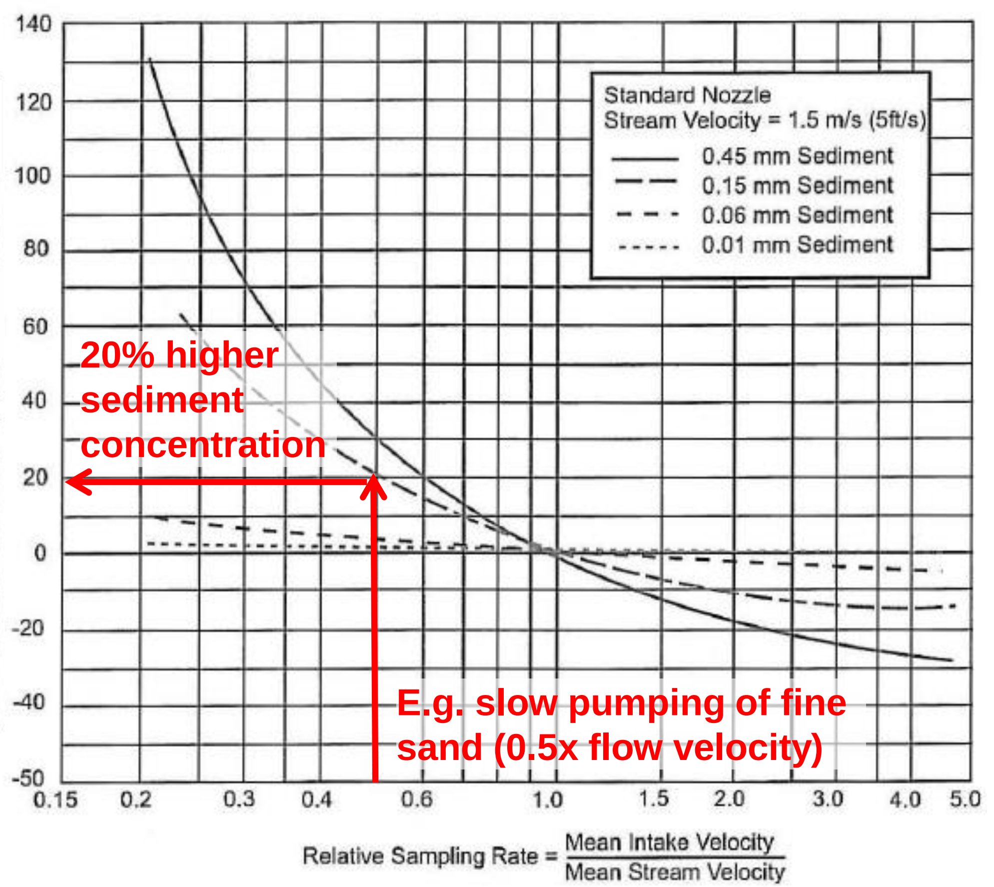
- Distribution of sampling points along the vertical
    - 5-pointed method: 0.05×H, 0.20×H, 0.60×H, 0.80×H, 0.95×H
    - 4-pointed method: 0.20×H, 0.60×H, 0.80×H, 0.95×H
    - 3-pointed method: 0.20×H, 0.60×H, 0.80×H



Isokinetic sampling – IMPORTANT?

- Error of non-isokinetic sampling





Instruments

- Flow velocity measurements – acoustic methods
  - **Profile – Acoustic Doppler Current Profiler**
  - Point – Acoustic Doppler Velocimetry

- Typical features:
  - 3D flow velocity vectors along verticals
  - Bin size: 25 cm
  - Ping rate: 2 Hz
  - Flow velocity range: 0.3-4 m/s
  - GPS and /or Bottom Tracking

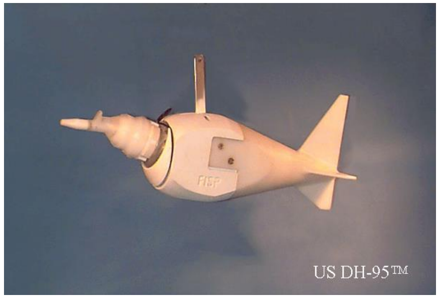
Instruments

- Flow velocity measurements – acoustic methods
  - Profile – Acoustic Doppler Current Profiler
  - **Point – Acoustic Doppler Velocimetry**

- Typical features:
  - 3D flow velocity vectors in the measurement point
  - Ping rate: 1-64 Hz
  - Flow velocity range: 0.01-7 m/s
  - Pressure sensor
  - Compass

Instruments

- Sediment sampling (Isokinetic samplers)
  - **Depth-integrated samplers**
  - Point-integrated samplers



Instruments

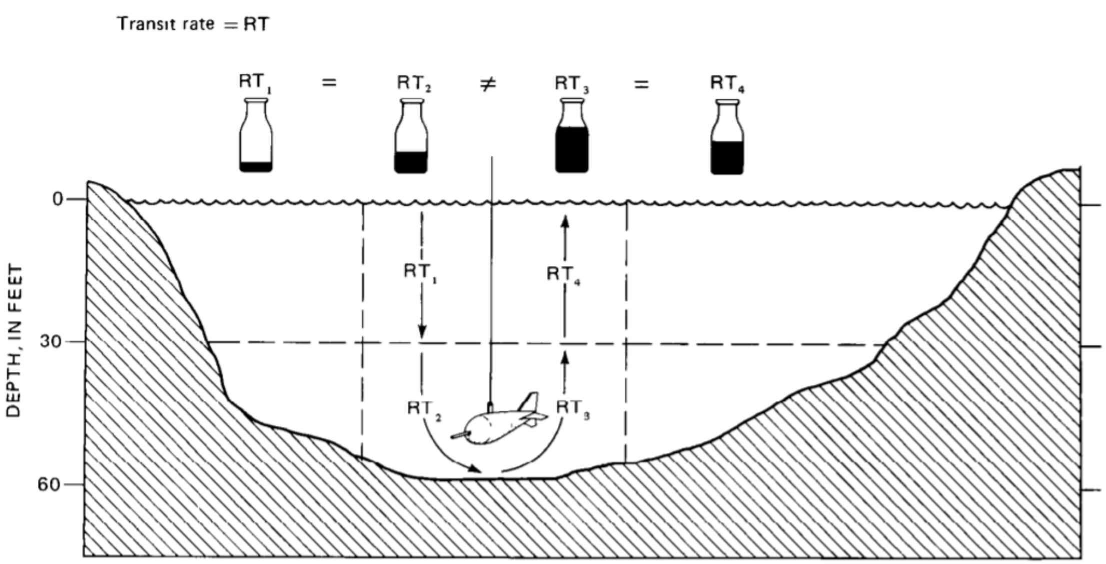
- Sediment sampling (Isokinetic point-integrated sampler)
  - **e.g. US P-61-A1**
  - Well-tested device
  - ~47 kg
  - V = 730 ml
  - Max 4 m/s flow velocity

  - Instrument description:
    https://water.usgs.gov/fisp/docs/Instructions_US_P-61-A1_030115.pdf

Instruments

- Depth-integrated (DI) vs. point-integrated (PI) sampling

  - DI requires less time
  - No vertical variation of SSC can be assessed with DI
  - Good performance of transit rate at DI is crucial (not constant along a vertical and not constant along a transect)



Edwards, T.K. & Glysson, G.D. 1999. *Field Methods for Measurement of Fluvial Sediment*. Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 3, Applications of Hydraulics, Chapter C2.

Performing the measurements - BRIDGE

- Parallel flow measurement and sediment sampling
- e.g. ADV + US P-61-A1
- Carriage, generator, PC, automatic reel, frame
- Sampling time (depends on local flow velocity, volume of sampler), e.g.:

$$T(\text{sec}) = 0{,}0561 \cdot \frac{\text{sample volume (ml)}}{\text{flow velocity}\left(\frac{\text{m}}{\text{s}}\right)}$$

Performing the measurements - VESSEL

- Parallel flow measurement and sediment sampling
- e.g. ADCP + US P-61-A1
- vessel, mounting, PC, reel



Performing the measurements - VESSEL

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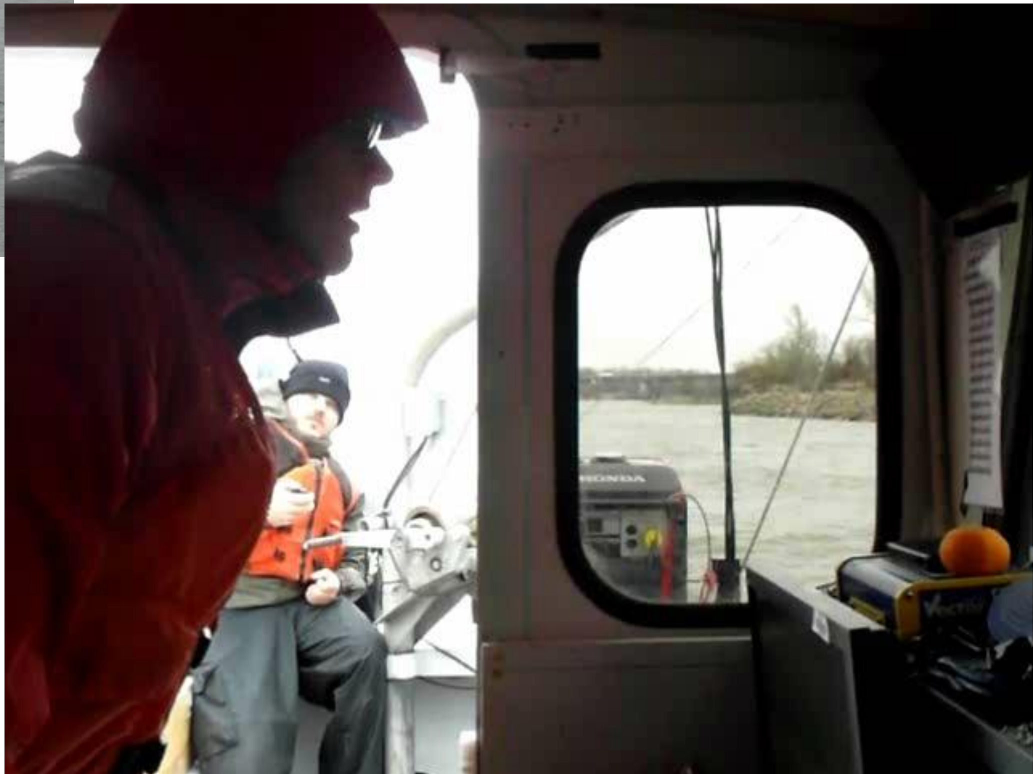
- Example: US Corps of Engineers



Measurement protocol

- Example from a recent project (SEDDON – AT-HU Interreg)

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Suspended sediment measurement

Measurement method:	Meas. protocol number:
Sampling device:	Date:
Velocimeter:	Related file name:
River:	Project:
Rkm:	Country:
Gauging station:	Water dir.:

Team:

Type of measurement: Bridge / Vessel-mounted / Roped / ....

Related measurements: flow velocity, discharge, bed load, ...

Horizontal and vertical positioning system/method:

Cross-section of reference point:

Distance of ref. point from bank (left/right) .... m Cross-sect. width .... m

Gauging st.: .... (upstream)

	Stage	Discharge	Water temp.	Turbidity	Time
Start:	.... cm	.... m^3s^{-1}	.... °C	.... mg l^{-1}	.... h
End:	.... cm	.... m^3s^{-1}	.... °C	.... mg l^{-1}	.... h

Gauging st.: .... (downstream)

	Stage	Discharge	Water temp.	Turbidity	Time
Start:	.... cm	.... m^3s^{-1}	.... °C	.... mg l^{-1}	.... h
End:	.... cm	.... m^3s^{-1}	.... °C	.... mg l^{-1}	.... h

Comments:

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Measurement protocol

- Example from a recent project (SEDDON – AT-HU Interreg)

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Suspended sediment measurement

Measurement method:		Meas. protocol number:
Date:	Team:	
River:	Project:	Comments:
Rkm:	Country:	
Station:	Water dir.:	

Sample number/ID	Distance from bank (left/right)	Water depth	Depth of sample	Sampling period	Time of sampling	Flow velocity / file name	Turbidity	Stage	Comments (navigation, volume of sample, ...)
	(m)	(m)	(m)	(sec)	(hh:mm)	(m s^{-1})	(mg l^{-1})	(cm)	

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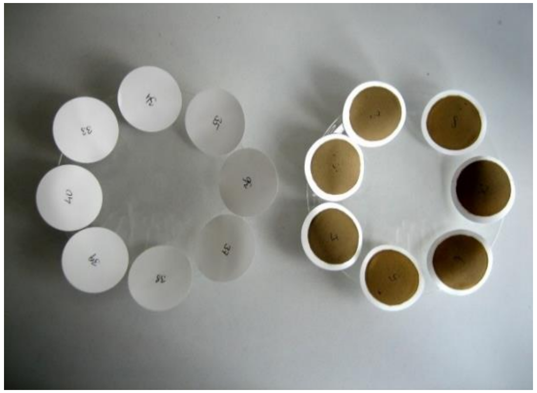
Laboratory analysis – direct analysis

- Several protocols, e.g. BMLFUW (2008, 2017)
- Final result: SSC of the sample in M/L^3, e.g. [mg/l]
- Main steps:
    - Drying of membrane filter (of 0.45 µm pores) at 105° C until constant weight, after the drying the filter is placed in a desiccator, to let the filter cool down
    - Mass of the plate and filter is measured (m_a)
    - Membrane filter is placed into the filtering device.
    - Sample is poured into the filtering device and its volume is measured precisely (V_p).
    - After filtering, the membrane filter is dried at 105° C until constant weight, after the drying the filter is placed in a desiccator, to let the filter cool down
    - Plate and membrane filter is weighted again (m_b).
    - Dry matter content is: $m_T = m_b - m_a$ [mg].
    - SSC = m_T / V_p [mg/l].



BMLFUW (ed.) (2008): Schwebstoffe im Fließgewässer – Leitfaden zur Erfassung des Schwebstofftransportes. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Austria, Vienna.

Laboratory analysis – laser diffraction method

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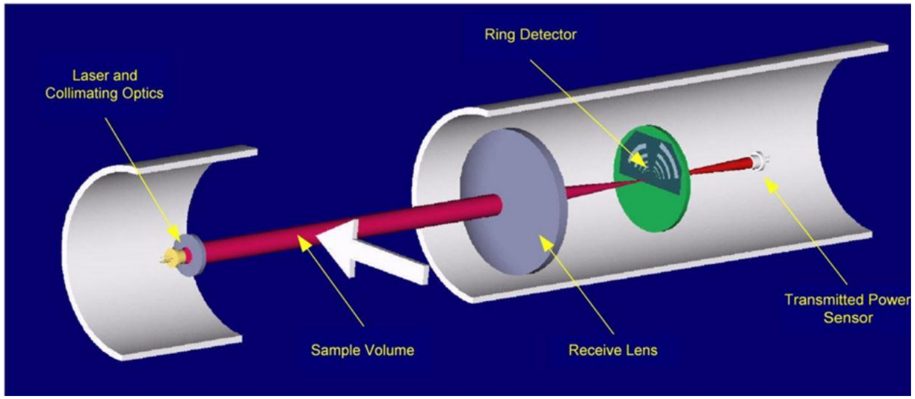
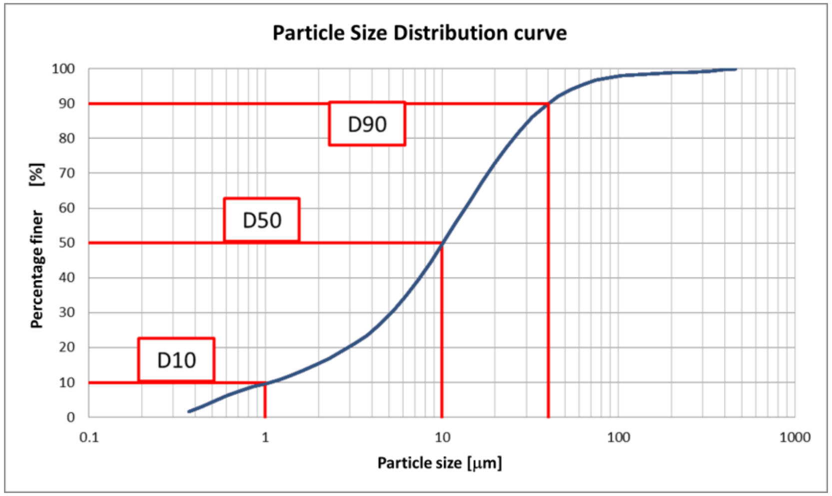
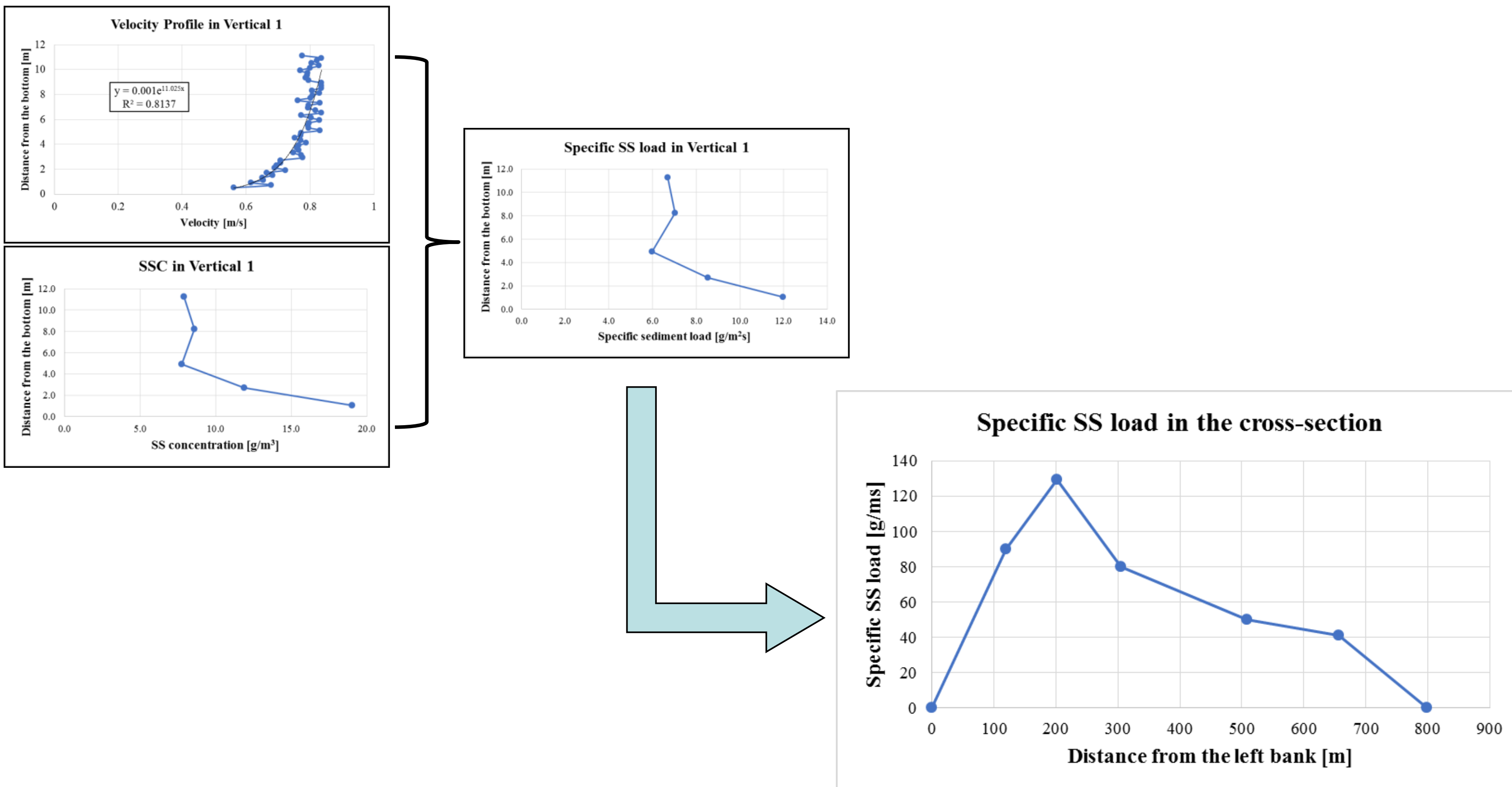
- LISST-Portable
  - Laser In-Situ Scattering and Transmissometry
  - Analyzes water samples using the laser diffraction method
  - 44 rings providing a Particle Size Distribution (PSD) in 44 size classes between 0.34-500 µm
  - Volume concentration is given
  - Recommended SSC range: 30-1900 mg/l (dilution if higher)
  - Fast, provides PSD, can be even used in the field





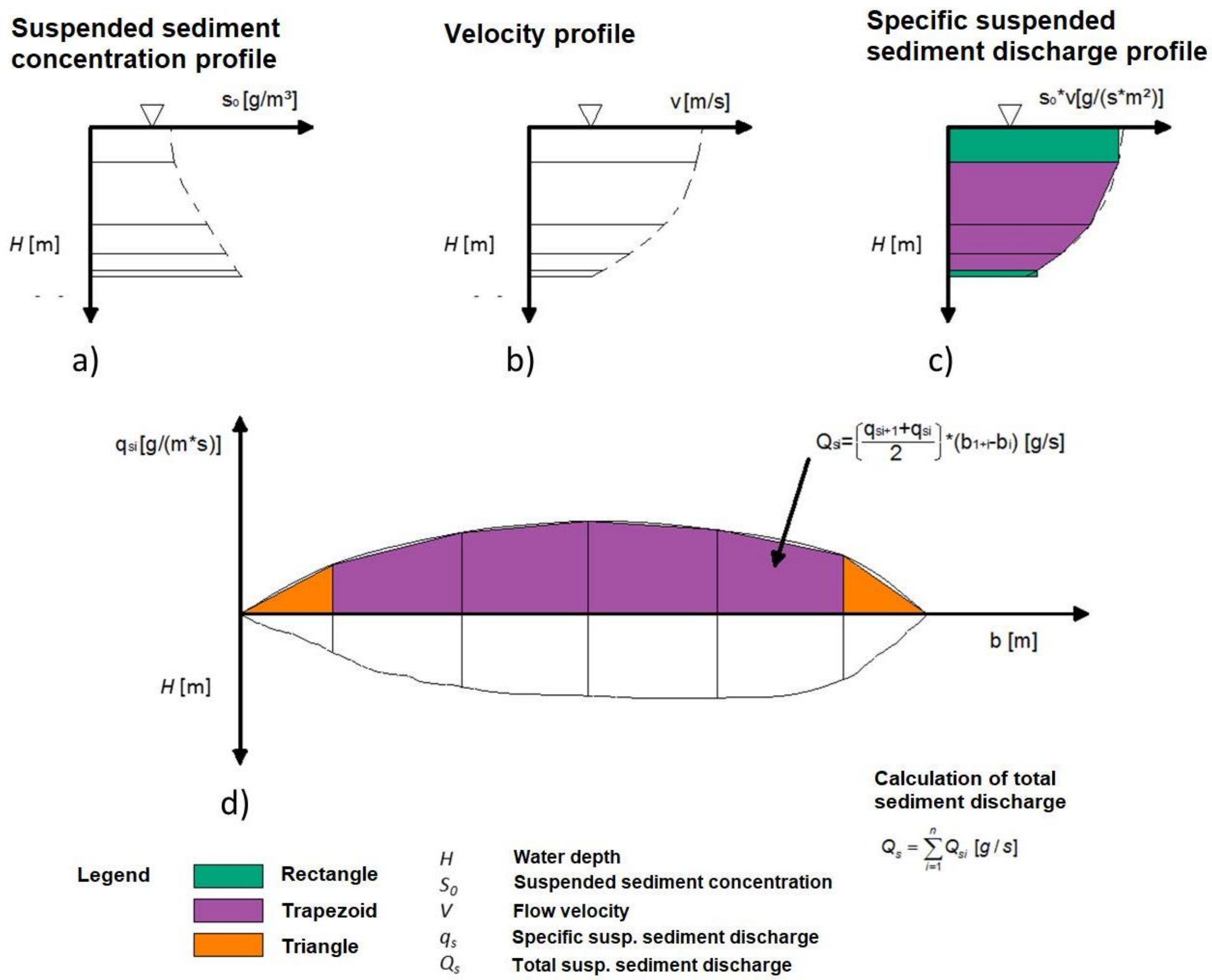
Estimation of sediment load

- Calculation of cross-sectional distribution of specific sediment discharge:



Estimation of sediment load

- Calculation scheme (BMLFUW, 2008)



Procedure of sediment load estimation

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Turbidity

Probe characteristic $s_k = a\ s_s$

Probe factor $k_s = s_k / s_s$

Sensor calibration

Concentration close to the sensor

Cross-sectional characteristic

$s_m = a\ s_k$

Cross-sectional calibration

Mean concentration

Discharge $Q_s = s_m\ Q$

Suspended sediment transport

Time $V_s = \int_{t_1}^{t_2} Q_s(t)\ dt$

Suspended sediment load

Calibration procedure

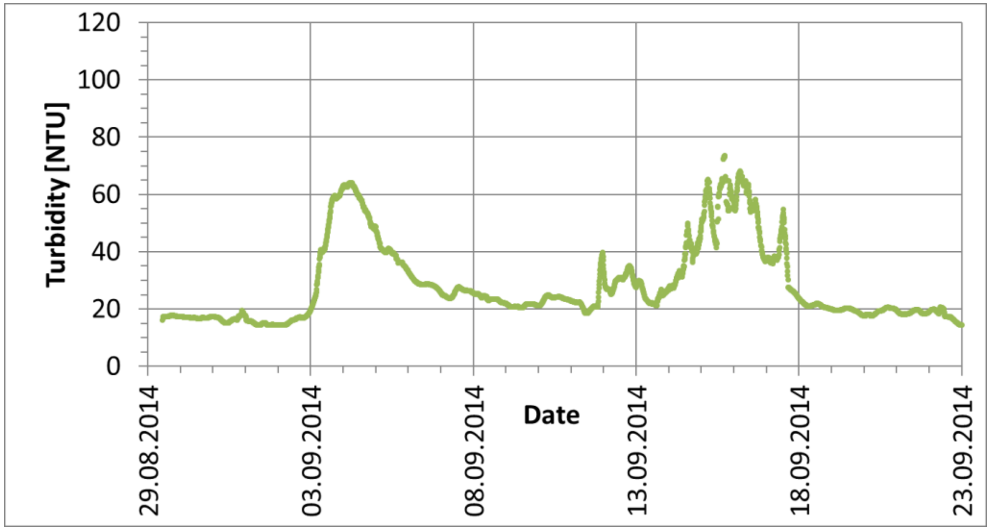
Turbidity

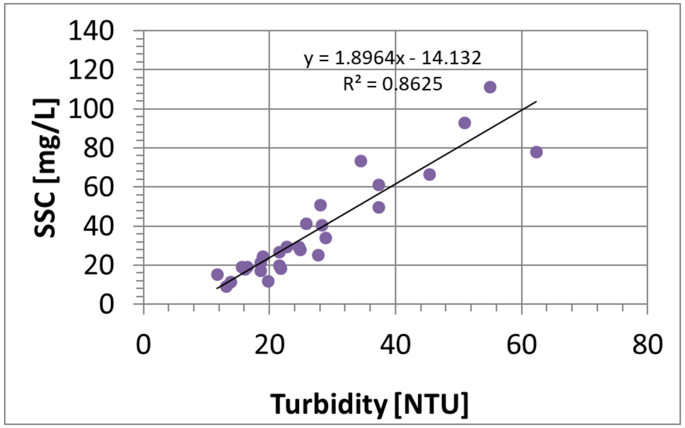
Concentration close to the sensor

Mean concentration

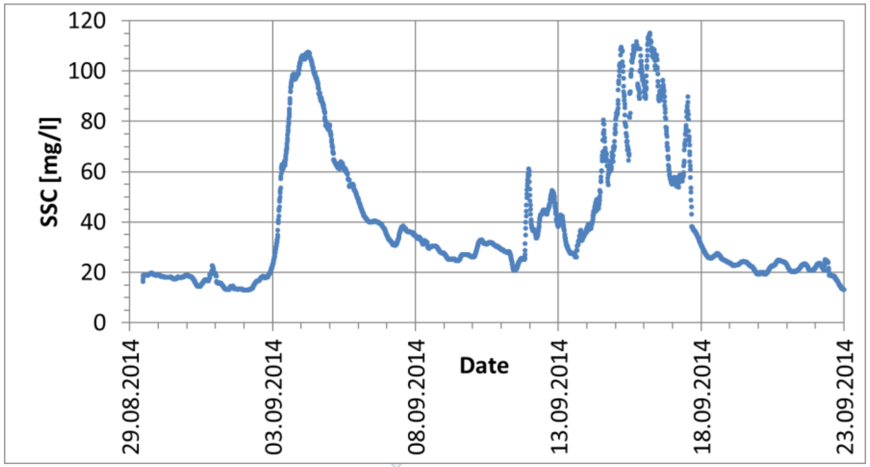
Suspended sediment transport

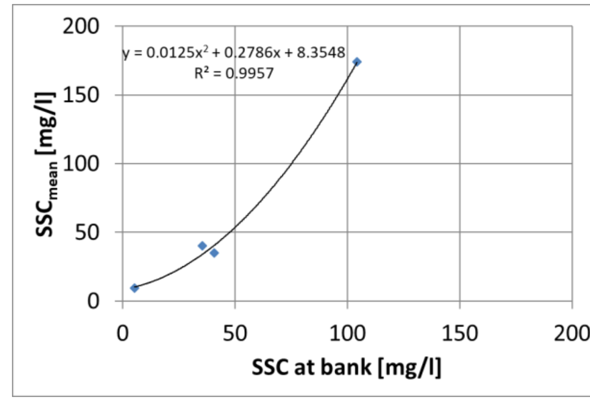
Suspended sediment load





Calibration procedure



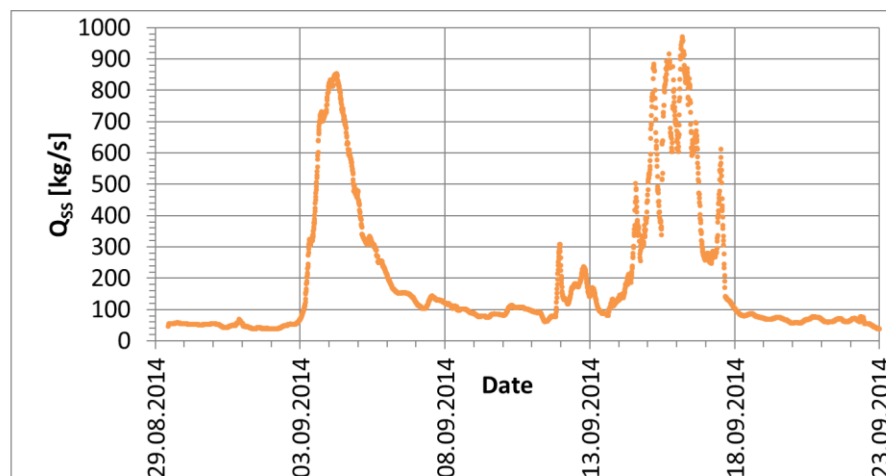


Concentration close to the sensor

Mean concentration

Suspended sediment transport

Suspended sediment load



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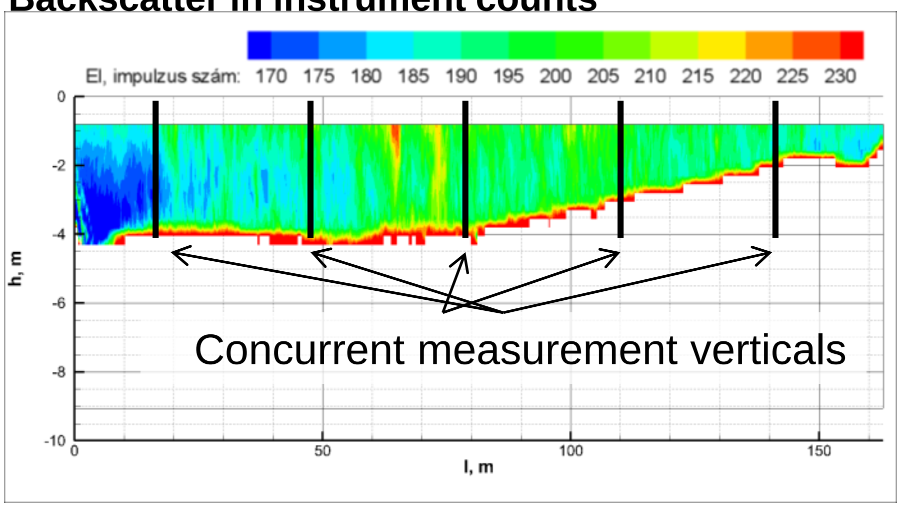
ADCP based SS load estimation

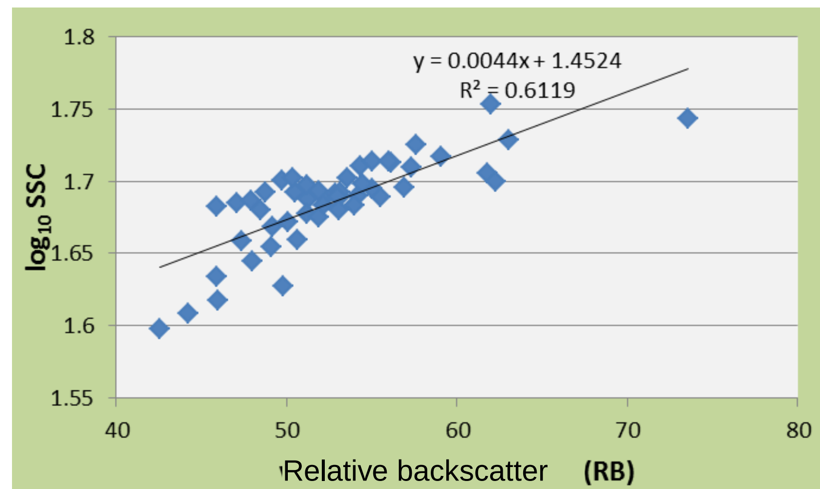
- Relationship between SSC and the so called relative backscatter (pl. *Gartner, 2004*):

$$SSC = 10^{(A+B\cdot RB)}$$

SSC	Suspended Solid Concentration
RB	Relative Backscatter
A and *B*	constants, to be calibrated

Backscatter in instrument counts





Gartner, J. W. 2004. Estimating suspended solids concentrations from backscatter intensity measured by acoustic Doppler current profiler in San Francisco Bay, California. *Marine Geology* 211 (2004) pp. 169-187 doi:10.1016/j.margeo. 2004.07.001.

ADCP based SS load estimation

Theoretical background

$$RB = RL + 2 \cdot TL$$

Reverberation level

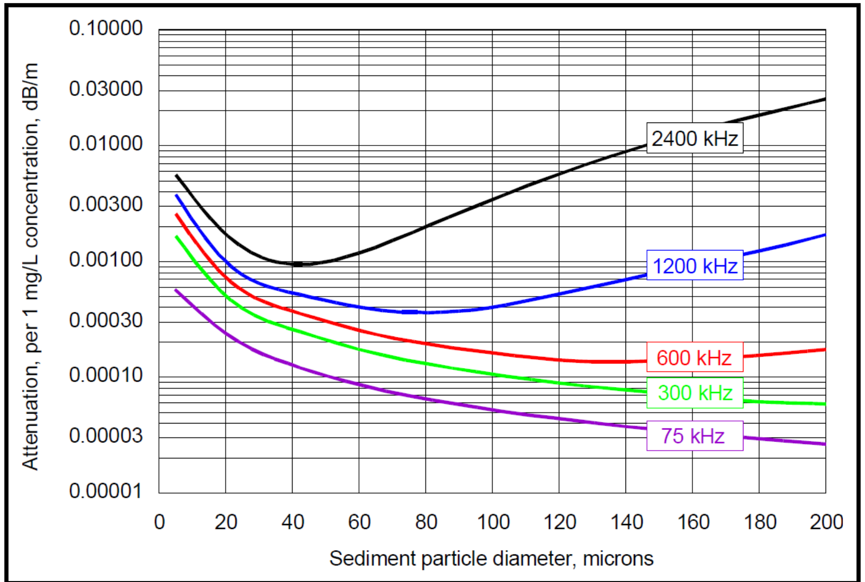
$$RL = K_c (E - E_r)$$

K_c	received signal strength indicator scale factor	*known or estimated*
E	measured echo strength (in counts)	*measured*
E_r	reference level for echo intensity (in counts),	*measured*

Transmission losses

$$TL = 10 \cdot \log(R) + \alpha \cdot R$$

R	slant range from transducer head	*measured*
α	absorption of energy by water and attenuation from suspended sediments *estimated*	

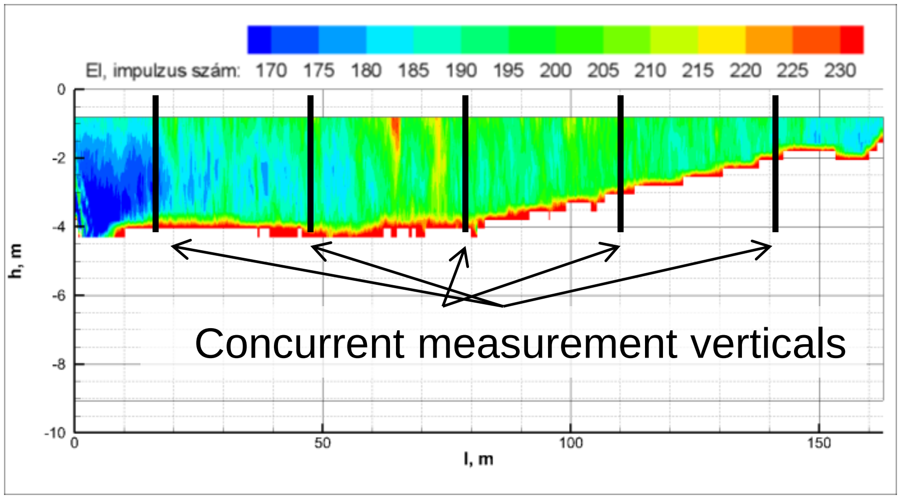


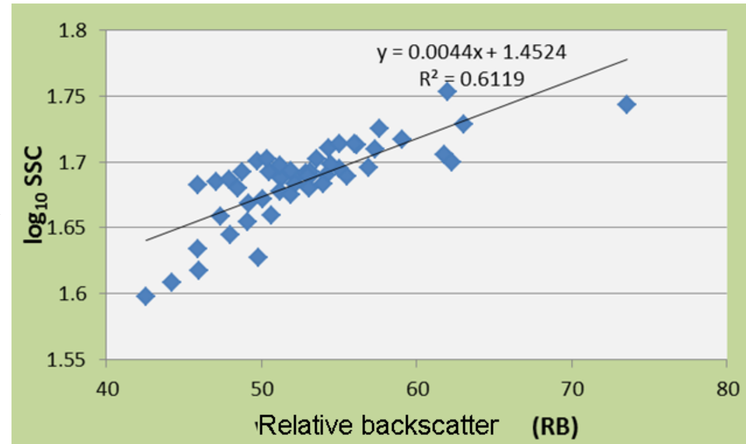
Applied relationship

$$SSC = 10^{A + B \cdot (K_c (E - E_r) + 2(10 \cdot \log(R) + \alpha \cdot R))}$$

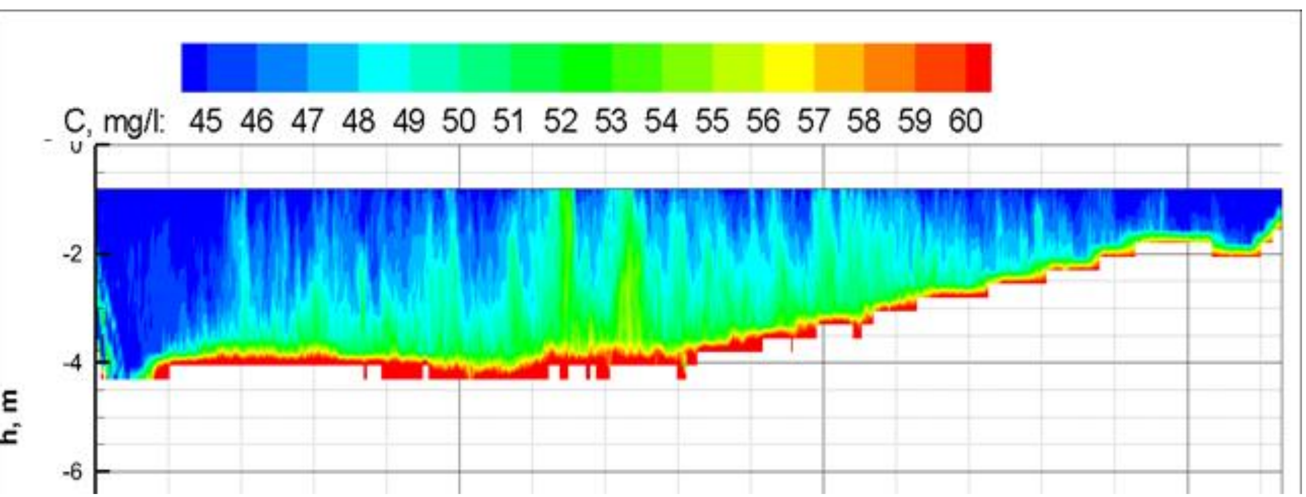
ADCP based SS load estimation

Backscatter in instrument counts



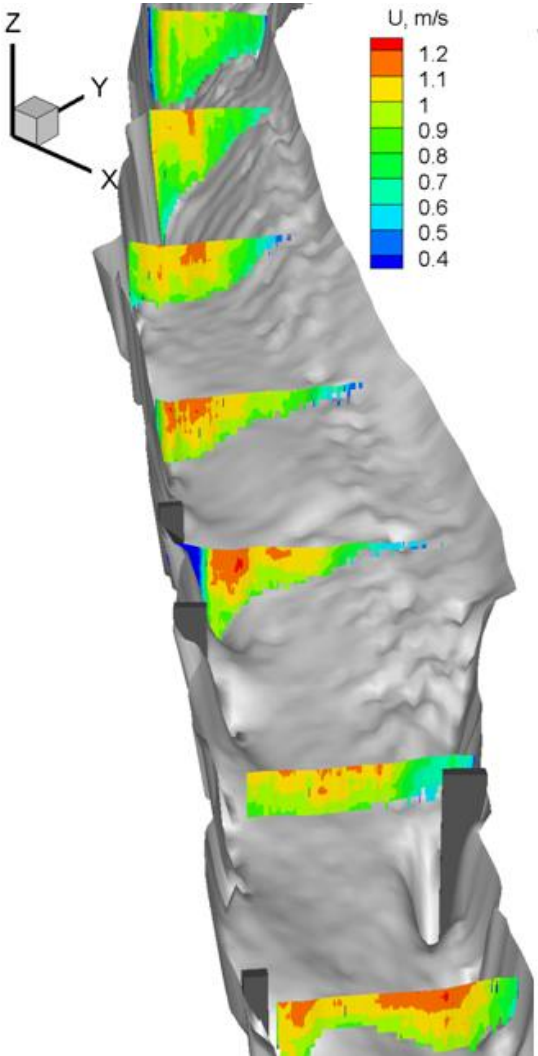


$$SSC = 10^{(A+B \cdot RB)}$$

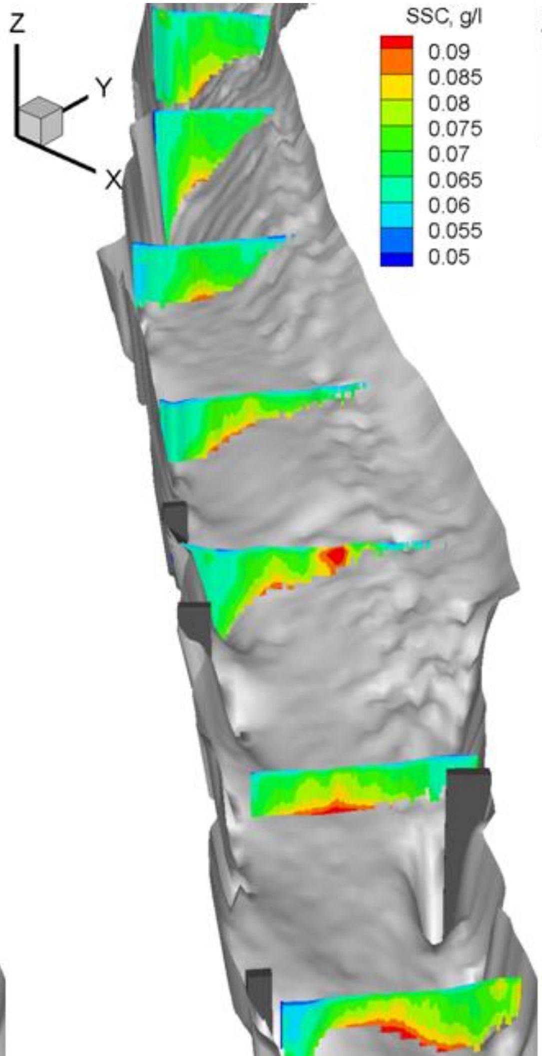


ADCP based SS load estimation

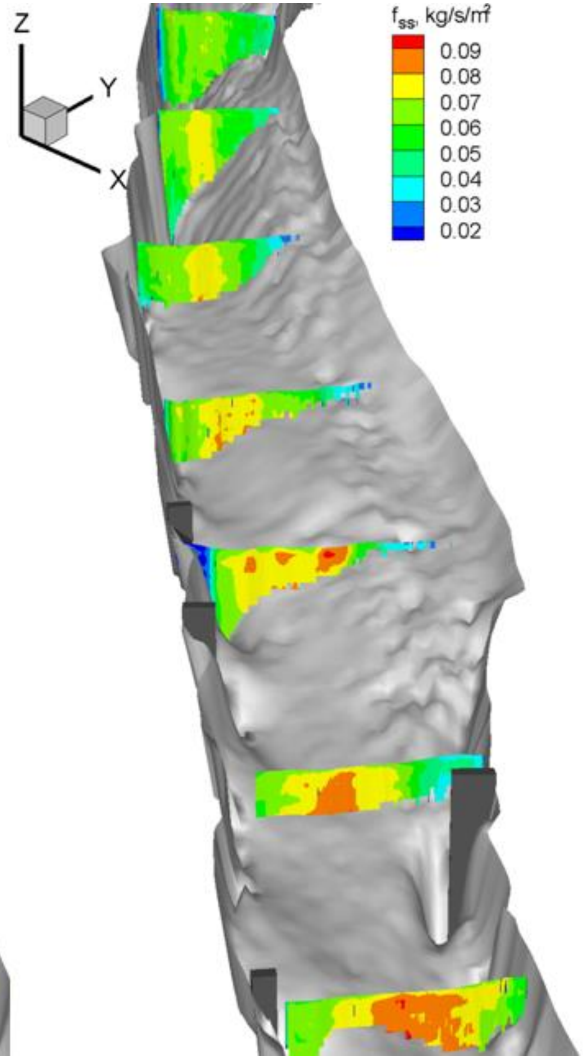
Flow velocity



SSC



Specific sediment discharge



ADCP based SS load estimation

- Needs calibration each time (as of now)
- No extra effort is needed is ADCP is used for measurements
- SSC estimation method is developed, even commercial software are available (e.g. ViSea from AquaVision, already used in GE, AT, HU, RS)
- Provides detailed cross-sectional distribution of SSC and can be extended to reach scale
- Supports the better distribution of sampling points for a more accurate cross-section measurement
- Results can contribute to more detailed numerical model validation

Comments

- Time demand of multipoint measurement: ~1 day/section
- Heavy sampler requires stable vessel
- Manpower: 3-4
- Indicative costs:
  - ADCP: ~30K EUR
  - OBS: ~5K EUR
  - US-P61-A1 + reel: ~12K EUR
  - LISST-Portable: ~32K EUR

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→ Good practices in BL monitoring