River sediment transport monitoring by means of H-ADCP:

attenuation to backscatter ratio (ABR) method to enable the long term monitoring of suspended sediment concentration (SSC) subjected to changes of suspended matter quality

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Introduction

The suspended sediment concentration (SSC) together with flow discharge and water level are crucial data for the understanding of fluvial processes.

The time resolution and the period of field measuring are relevant to actually investigate hydro-geological processes and eventually track sediment source and fate along the river basin. Therefore, the application of the Acoustic Doppler Current Profile integrated in a monitoring station and horizontally pointing (H-ADCP) the streamflow from side, is herein presented which enables the continuous and long term monitoring of these three parameters.

The Devoll river (Albania) at Kokel bridge (arrow in the left box) where a H-ADCP monitoring station was installed (right) and has been measuring since beginning 2016.

SSC estimation from H-ADCP profiling: method novelty

The inversion of the sonar equation (i.e., the passing from acoustic backscatter to sediment concentration) is the main issue when using ADCP profiling for SSC assessment. This inversion is usually achieved by means of a calibration procedure in the field that is prone to seasonal and sites specific changes (e.g., sediment lithology change). This changes hinder the long term monitoring of SSC by means of acoustic methods.

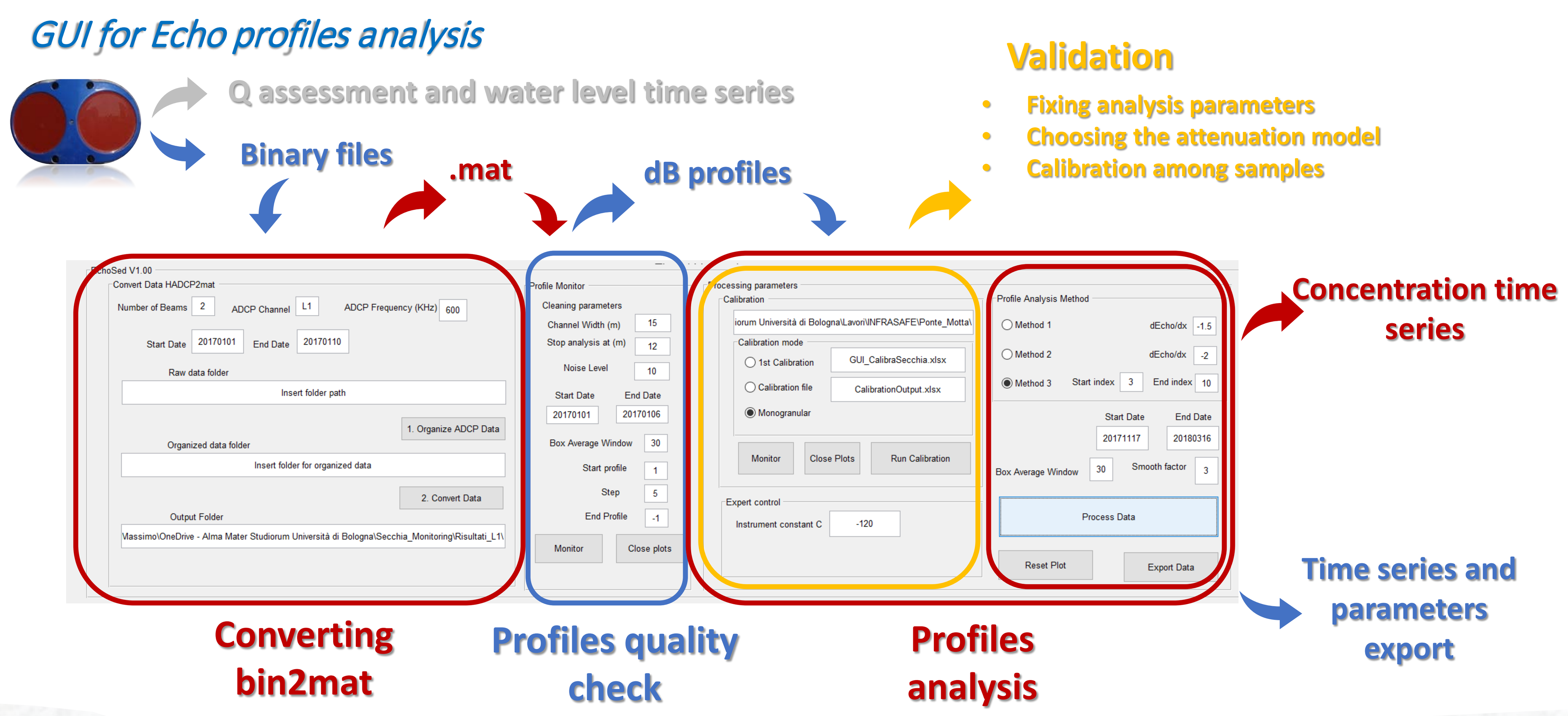
Herein the sound attenuation (α_s in Appendix) and its ratio over the corresponding backscatter (ABR) at a given frequency are applied to eventually estimate the suspended sediment concentration (M_s in Appendix) for very long periods and in two different case studies: the Devoll river that is a mountain stream in Albania and the Secchia river in the Italian lowland of the Po River.

The using of ABR adds a relevant information that accounts for instrument sensitivity (reflected by ζ_s in Appendix) change due to the variation of suspended matter quality in the long period and passing from low level to flood event.

The Secchia river (Italy) at Motta bridge with an outline H-ADCP profiling (left). Instrument installation at bridge pier (right) during dry period.

A Graphical User Interface for ABR-method application

The raw dataset from H-ADCP is exploited for the monitoring of water level, flow discharge and SSC. These hydrological parameters are made available in a single graphical suit that facilitates the analysis of recorded echo profiles with the H-ADCP and the collected water-sediment samples to eventually validate the ABR-method. **The outcomes of this GUI are the validated relation of instrument sensitivity ζ_s vs. ABR and the time series of SSC** and the other parameters (to be implemented soon).

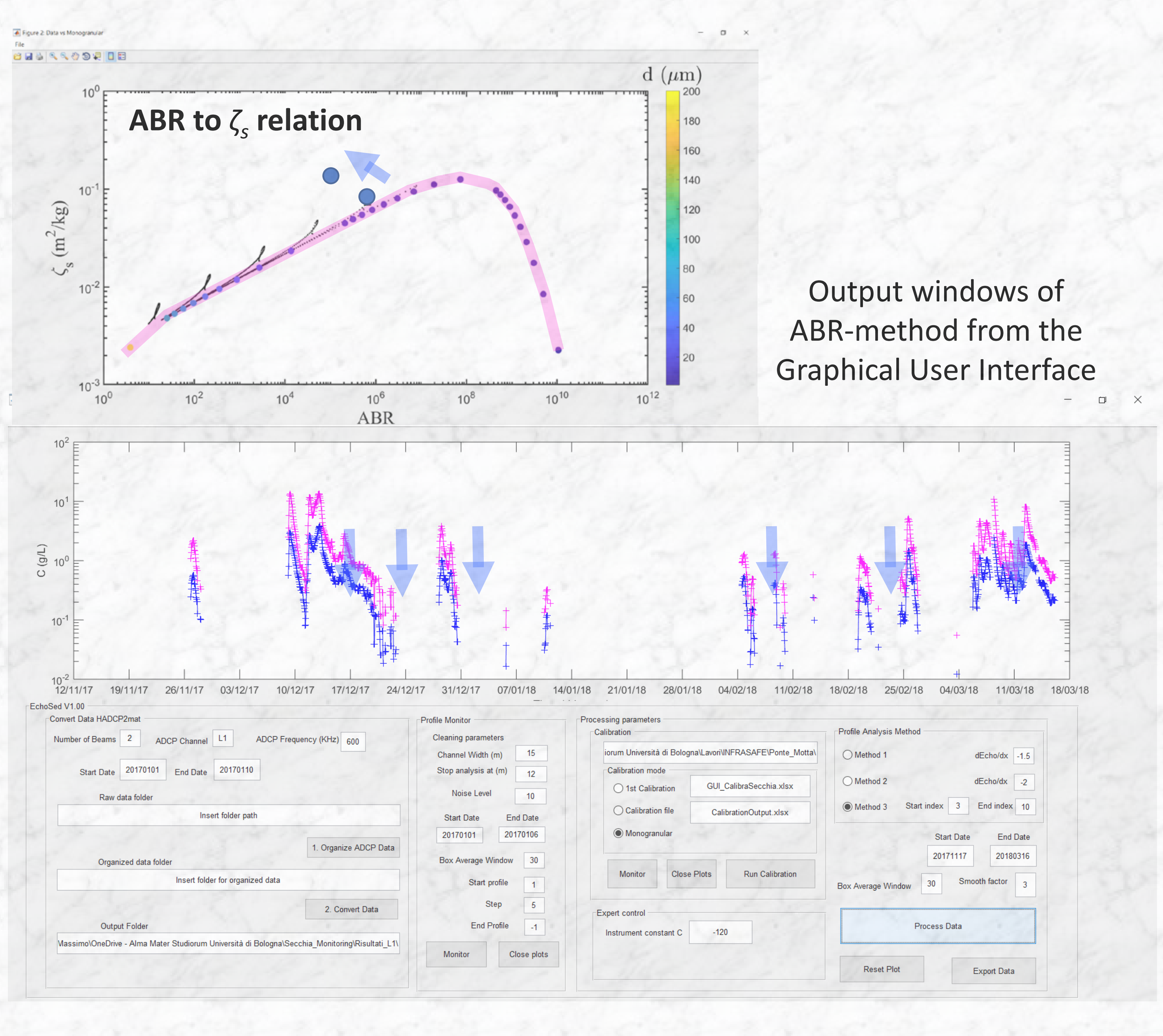


Appendix: the used form of the sonar equation embeds the assumption that the gradient of sediment concentration is negligible along the horizontal alignment; I_{db} is the **acoustic intensity** measured in dB, α_s is the sound **attenuation due to suspended sediment** , i.e. the **normalized attenuation coefficient** ζ_s times the **mass concentration** M_s, r is the **ranging distance** (the horizontal ranging) and α_w is the attenuation due to clear water (modelled with formulas from the literature).

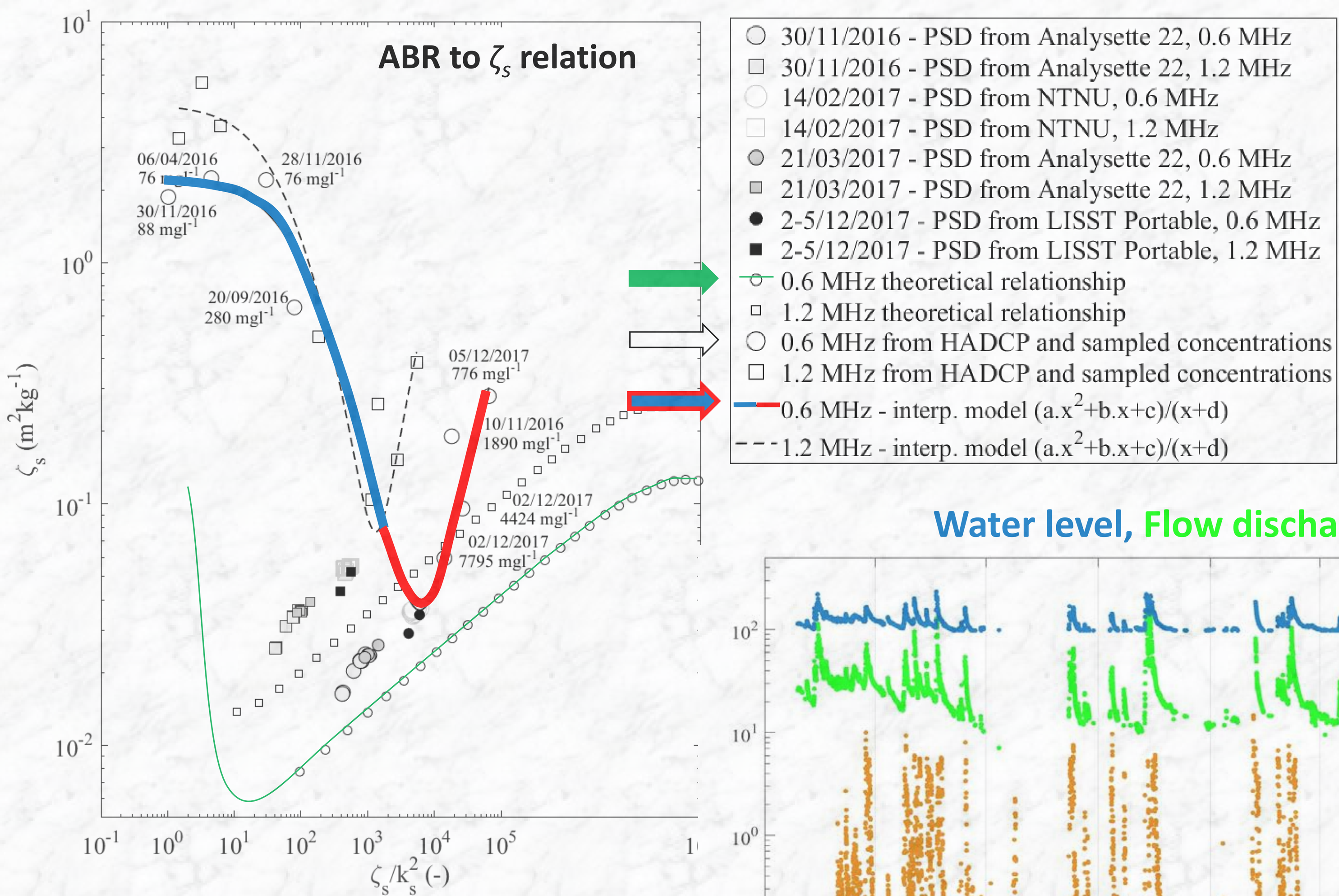
$$\alpha_s = \zeta_s \cdot M_s = -\alpha_w - \frac{1}{2r} - \frac{1}{40\log(e)}\frac{dI_{dB}}{dr}$$

ζ_s is a function of ABR rather than a calibration parameter

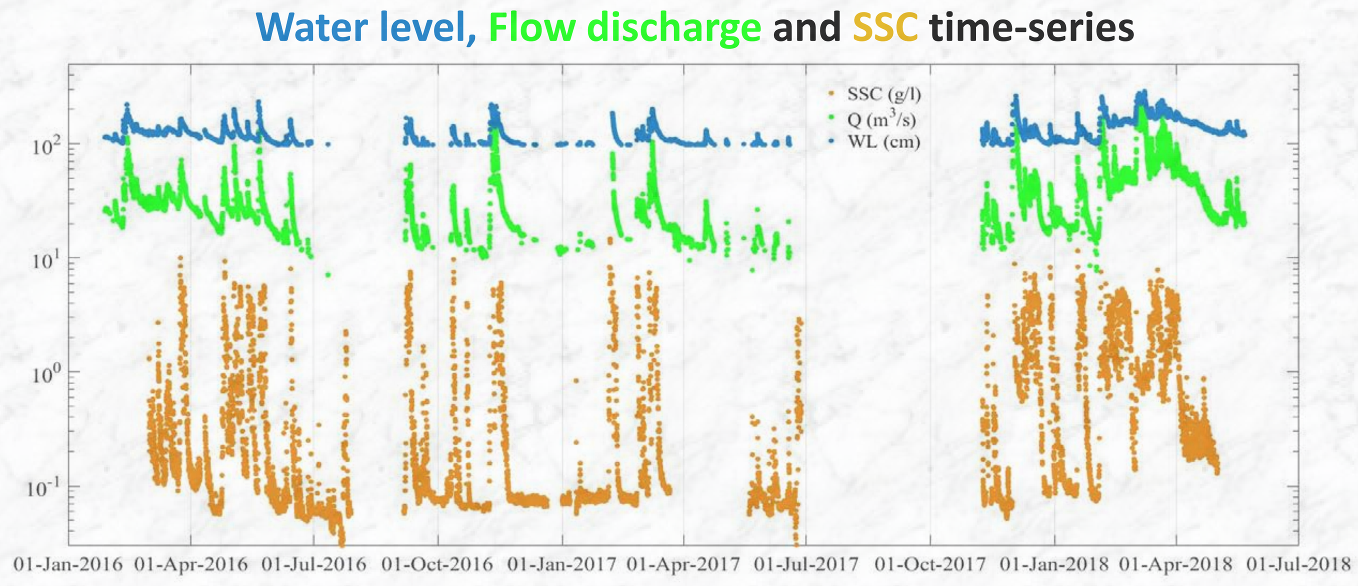
Results



The observed change in ζ_s during a five days flood event at the Secchia river (above) and corresponding correction applied to SSC time series (below)



A full validation of the ABR-method over a three years dataset (left) and corresponding time series monitored at the Devoll river (below)



Conclusions

The ABR-method to calculate the suspended sediment concentration from the echo profiled by H-ADCPs was applied at the Kokel and at Motta monitoring stations in the Devoll (Albania) and Secchia (Italy) rivers, respectively. This method is based on the measurements of attenuation and backscattering strength along an horizontal range that provides the ABR in addition to the sound attenuation, given the assumption of homogenous concentration along the horizontally aligned acoustic beam. The ABR is converted into instrument sensitivity (i.e., ζ_s coefficient) by means of semi-empirical relationship which needs to be validated. This relationship made possible to continuously correct the inversion of the sonar equation (see Appendix) by changing ζ_s before the assessing of SSC, that increases the reliability of acoustically derived SSC time series especially in case of long term monitoring.