Suspended sediment estimative through an ADCP analysis – Study Case: Taquari River, Pantanal, Brazil

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ABSTRACT – In general fluvial systems are used for different objectives – energy production, water supply, navigation, etc. Many impacts are associated to its use and one of them are the excessive sediment production or erosion, which can change the water system morphology, causing several impacts to the environment. Therefore, the sediments must be monitored and quantified, to understand its dynamics and behavior in the environment. It is a known fact that the sediment quantifications are expensive and time-consuming and because of these problems, the use of surrogate technologies to measure suspended and bedload has been stimulated. The presented study aims to show preliminary results regarding the use of ADCP (Acoustic Doppler Current Profiler) to estimate suspended sediment concentration in the water column. For this were consider results from field campaigns at the *Taquari* River, an important river from the Alto Paraguay Basin, in the Pantanal Biome, known as the largest freshwater wetland system in the world.

Keywords – suspended, sediment, ADCP.

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1 - INTRODUCTION

All over the world the fluvial systems are used for different objectives – water supply, electricity, transport, intensive soil use in agriculture, urbanization, among others. One of the impacts caused by the use of these systems is the production of the sediment in the basin.

Because of its importance for the environment, the sediments must be monitored and quantified. Many researchers are working on the use of surrogate technologies as acoustics and optical devices (e.g. acoustic doppler current profiler - ADCP, Laser In-Situ Scattering and Transmissometry - Lisst, Turbidimeters, etc.) to measure suspended and bedload and to estimate particle distribution – Guerrero et. al (2011, 2012 and 2016) and Baranya and Józsa (2013).

As cited by Wood (2017), surrogate technology can be a cost-effective component of a long-term sediment monitoring program. But, once it started and a regression model is developed between surrogate data and suspended sediment concentration, samples can be collected less frequently, reducing long-term operation and maintenance costs.

Sediment surrogates also allow the estimation of sediment when it is unsafe to sample the stream. In addition, it includes high spatial and temporal resolution with continuum measurement along the cross-section, making it easier to measure and to analyze data when compared to conventional methods.

Throughout of this study will be presented the correlation between the corrected signal from acoustic measurements, made with the ADCP-M9 from Sontek, and suspended solid concentration measured with conventional methods at a cross-section at Taquari River.

2 - MATERIALS AND METHODS

The presented study is part of a partnership between Federal University of Mato Grosso do Sul (UFMS), Superficial Water Resource Monitoring Group – represented by the Post-Graduate Program in Environmental Technologies (PPGTA) and Group of the Research Project for the Monitoring of Surface Water Resources and Federal University of Parana (UFPR), represented by the Post-Graduate Program in Water Resources and Environmental Engineering (PPGERHA) and the Technological Institute of Infrastructure and Transport (ITTI).

2.1 - Study Area

The Taquari River is an important river from the Alto Paraguay Basin, in the Pantanal Biome, the largest freshwater wetland system in the world, with a high diversity of flora and fauna. Its importance suggests a very careful treatment and any scientific contribution can be helpful in the ecosystem maintenance.

According to Galdino et. al (2006), the Taquari River springs between Serra da Saudade and Serra de Maracaju, at Mato Grosso State. It is the main river from the Alto Taquari Basin (ATB) and one of the biggest tributaries of Alto Paraguai Basin (APB). The river is commonly known by its intense sediment dynamics with high erosion and transport capacities.

Figure 1 shows the ATB location at Mato Grosso and Mato Grosso do Sul State (Brazil) and the location of the cross-section in the Taquari River before its confluence with Coxim River, at Coxim city, in a place where the stream lines can be consider aligned and the flux permanent and uniform.

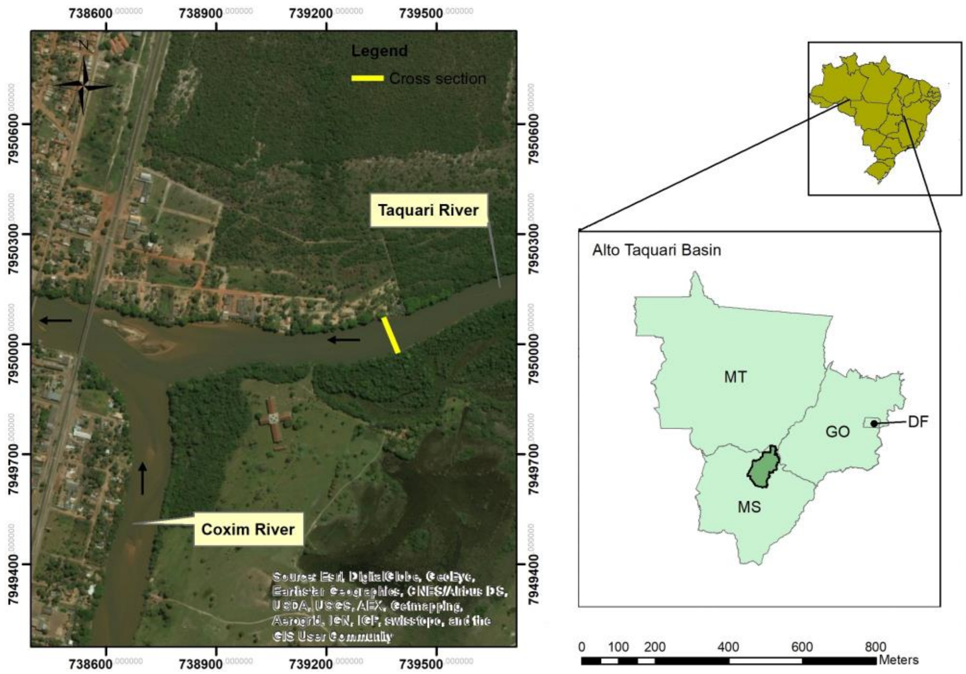
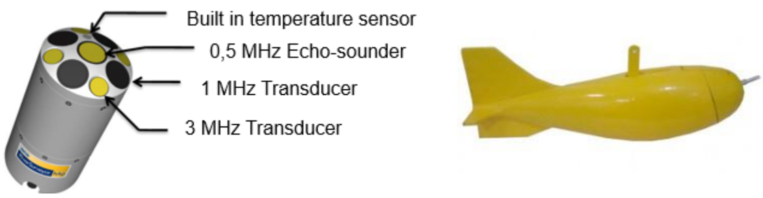


Figure 1 – Spatial context of the sediment collection cross section.

2.2 - Field Campaign and Lab Analysis

The data were obtained throughout 5 field campaigns (2017-03-09, 2017-03-20, 2017-04-21, 2017-05-26 and 2017-06-27). During these campaigns, measurements were taken with the ADCP and water sampling in order to obtain the SSC – suspended sediment concentration. The used devices and tools were an *(a)* **ADP-M9 from Sontek®**, Figure 2a and *(b)* **USD-49 Water Sampler**, Figure 2b, which is a hand-line suspended sediment sampler with about 27.5 kg. The sampler can be lowered and raised, hand over hand, with a flexible suspension line.

During the campaigns were conducted measurements with the ADP-M9, setup for a Smart Pulse frequency mode, where the frequency is automatically chosen by the device based on the depth.



(a) (b)

Figure 2 - (a) ADP-M9 from Sontek® and (b) USD-49 Water Sampler

First were taken measurements along of the cross-section, to obtain the discharge. Since Taquari River has a strong bedload, was also taken a total of 6 static verticals, in every campaign, to correct the obtained velocities and avoid discharge's super-estimation when using the bottom track positioning. The 6 verticals were chosen based on the results of the *Hidrossedimentos 3.1* tool, developed by Agricultural and Rural Extension Research Company from Santa Catarina State (EPAGRI -SC), and was divided according to the equal discharge increment (EDI).

The water sampling was taken together with the static ADCP measurements, to obtain a correlation between the received signal from ADCP and the SSC. All the 6 samples (400 mL per sample), were mixed in order to obtain one representative sample from the whole cross-section.

After each field campaign, in the lab, for granulometry and suspended sediment concentration determination, the procedure was based on the sieving of the largest grains (sand) according to the American Geophysical Union classification, considering a sieve granulometry as: 2.0, 1.0, 0.5, 0.25, 0.125 and 0.0063 mm. For the finest grains (silt and clay) the adopted procedure followed the procedures described in CSQA (1999), where the method is determined by sediment concentration: if it is between 300 and 5 000 ppm, the particle selection is done by a gravitational method where the fractions are divided according its sedimentation at a specific time; if the concentration is between 3,000 and 10,000 it is used the pipetting method.

2.3 - Data Processing

First the measured acoustic data was corrected for temperature, conductivity, salinity and sound velocity, using a CTD data in the **RiverSurveyor®** Software, provided by the manufacturer. Then, the exported data was processed in a Matlab programing language environment.

The algorithm was written to extract and correct the Signal to Noise Ratio (SNR) and correlate it with sediment concentration data.

As the acoustic waves go further from the transducer, the wave signal is becoming weaker due the geometry spread of the sound wave, water absorption and sediment attenuation. All of these factors can be mathematically translated into models that can be described by sediment, hydrodynamics and devices characteristics. Equation 1 shows the applied equation, where SNR_{mean} is the mean of the 4 beams of the ADCP along of each vertical, $20log_{10}(\psi R)$ is the spread attenuation, $2R\alpha_w$ is the water absorption and $2R\alpha_s$ is the sediment attenuation term.

$$Corrected\ Signal = SNR_{mean} + 20log_{10}(\psi R) + 2R\alpha_w + 2R\alpha_s \quad (1)$$

where the coefficient ψ is a correction factor related to the effect of spherical spreading, close to the transducer, *R* is the slant range from the transducer head to the measured ADCP cell (bin), α_w is the absorption energy by the water and α_s is the attenuation from suspended sediment.

The models applied in this study are based on the models presented by Guerrero et. al (2011) – for water absorption and by Guerrero et. al (2016) for sediment attenuation.

After the corrections it is possible to obtain an adjusted curve from the form presents at Equation 2, that correlate the sediment-corrected backscatter *(SCB)* in *dB* with the Log_{10} of suspended sediment concentration *(SSC)* in *mg/L*.

$$log_{10}(SSC) = a.SCB + b \quad (2)$$

where *a* and *b* are the angular and linear coefficient of the adjusted curve.

3 - RESULTS AND DISCUSSIONS

The data collected from the campaigns are shown in the Figure 3, where it is possible to observe that although, in general, the discharge fluctuations were followed by regular SSC fluctuations, they are not strongly correlated. For example, in the first two campaigns the discharge was similar in the two days, but the fluctuation in the SSC was greater.

Another interesting situation happened in the 4th campaign (2017-05-26), where although the discharge was near the average, the SSC had the highest value observed for the whole series. This can be explained through an analysis of the data from *Cachoeira Polvora* Pluviometric Station (790389.11; 8007665.89) from National Water Agency (*ANA*). According to this, during the days May 24th and 25th the amount of rain registered was about 70% of the total rain observed for the entire month.

With this information and taking into account that the precipitation it is not uniform in the whole basin, we can conclude that this amount of rain in only two days is enough to increase the soil loss in the upstream part and as consequence increasing the sediment concentration in the water column.

Figure 4 shows the correlation between SSC and the corrected backscatter, where the fitted curve has returned a correlation coefficient of 0.64 (co-variance=1.36). This result was obtained according to the methodology presented by Guerrero (2011) and Guerrero (2016).

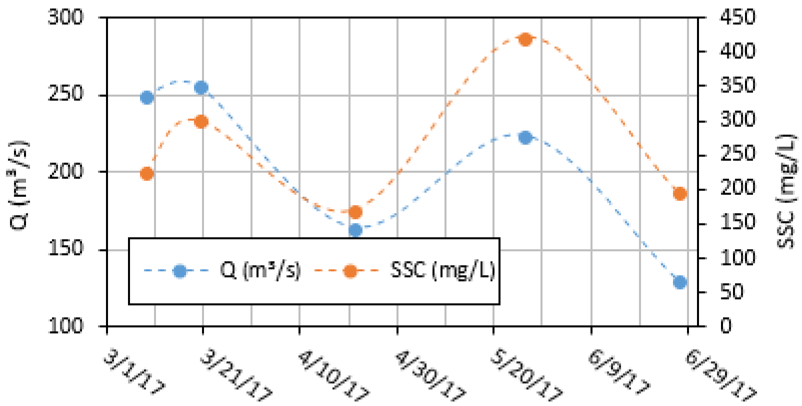


Figure 3 – Mean discharge and mean sediment concentration during the field campaigns

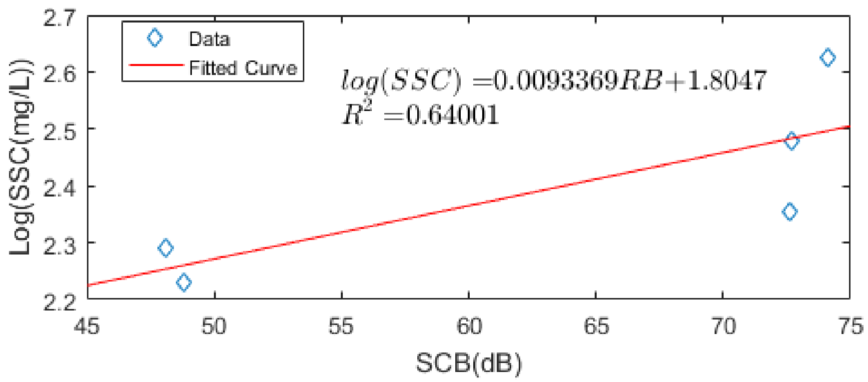


Figure 4 – SSC x SCB correlation curve

All the results consider the Sontek (2016) criteria for the backscatter near the borders, it means that there is an area close to the surface, margins and bottom that are not evaluate, due the noise produced by the wave propagations. Since the measurements were done considering the smart-pulse mode enabled (where the device choses the best frequency) it wasn't possible to plot the total suspended solids distribution throughout the cross-section considering each cell, instead, was plotted the mean values for one entired section

Figure 5 presents the mean flow velocity, where it is possible to observe that according with the theoretical models, the velocities are lower near the bank and bigger in the deepest part. Figure 6 shows two blocks of SSC, these blocks where divided considering the flow velocity presented in Figure 5. As we can observe, considering the mean values for the cross-section, the results agreed with the theory where is expected the highest concentration values in the highest flow velocities (in the middle of the channel) and lower SSC values near the bank, where the flow velocity is lower.

A detailed analysis regarding to the SSC throughout the cross-section could be done if the measurements were taking with a fixed frequency.

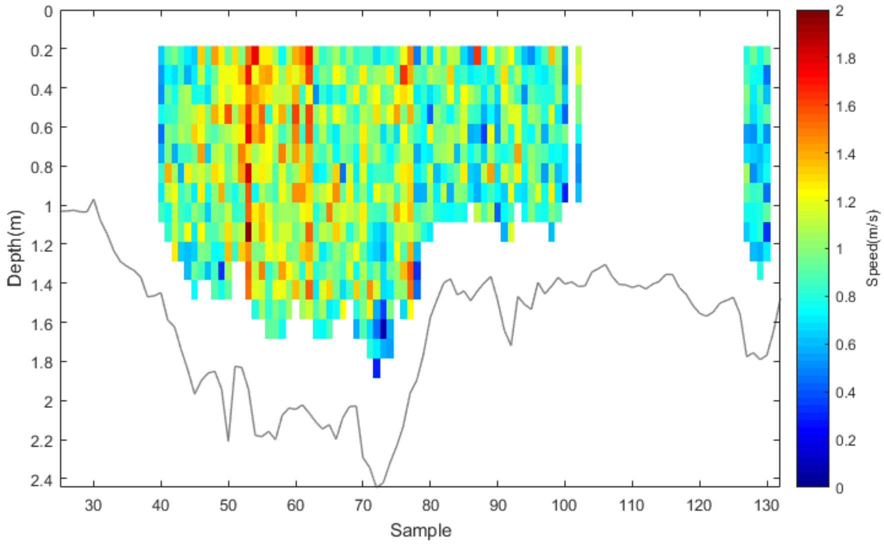


Figure 5 – Flow Velocity

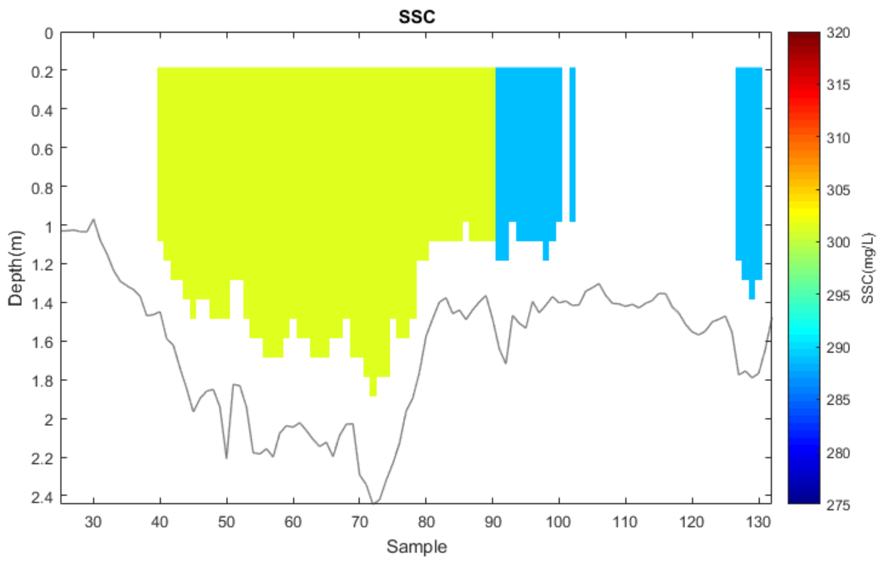


Figure 6 – Suspended Sediment Concentration from ADCP Backscatter Correction

4 - CONCLUSIONS

Regarding surrogate technology application to sediment estimative, a lot still must to be done, since the development of field methods, the coherence in lab procedure and the development of models that can be used to correlate the acoustic signal with the amount of sediment.

The use of ADCP has many advantages over the conventional methods, the high resolution throughout the cross-section, the viability of measurements during extreme events and the simplicity to obtain the data are good examples. But as any other tool it has some disadvantages, the equipment costs, the need of a trained team, limitations regarding the frequency, many uncertainties related to the use of the models and many parameters regarding the sediment characteristics must to be determinate.

The fact is, it is really important to study new technologies that can help us to improve our measurements and monitoring plans, and it does not mean that, the use of ADCP or other technologies are going to replace the conventional methods in the field or in the lab, but it means that both technologies combined can help us to improve the data quality and at the same time it can help us understand and explain the associated phenomena.

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