

ADcp Measurements of Suspended Sediment Fluxes in Banat Rivers, Romania

Eugenia Rotaru¹, Jérôme Le Coz², Radu Drobot³, Mary-Jeanne Adler¹, Guillaume Dramais²

¹National Institute of Hydrology and Water Management
Bucharest, ROMANIA

²Cemagref, Hydrology-Hydraulics Research Unit
Lyon, FRANCE

³UTCB, Hydrotechnics Faculty
Bucharest, ROMANIA

Abstract

Acoustic Doppler current profilers (aDcp) are increasingly used to perform river discharge measurements. Water velocity profiles are computed from the Doppler frequency shift measured between emitted and received ultrasonic signals. The intensity of the sound backscattered by suspended solids depends on water (temperature, absorption coefficient, etc.), aDcp (frequency, beam spreading, etc.) and particle (size, concentration, absorption coefficient, etc.) hydroacoustic properties. The field tests reported here mainly aim at comparing suspended sediment concentration and flux values provided by aDcp and conventional procedures routinely followed by the Romanian hydrometric network.

Test measurements have been performed at two hydrometric stations in the Banat Basin, Western Romania. We used a Teledyne RDI WorkHorse Rio Grande 1200 kHz aDcp mounted on a tethered board. First, stationary aDcp profiles were acquired simultaneously and close to bottle sampling verticals. These linked measurements were later used to calibrate hydroacoustic parameters and convert backscatter profiles to concentration profiles. This calibration step and further analysis were supported by the Sediview commercial software (DRL Software, UK).

Several successive aDcp transects were acquired across both hydrometric sections of Faget, on the Bega river, and Lugoj, on the Timiș river. Due to shallow water depths and technical restrictions, linked concentration measurements were not possible at Faget, but discharge measurements are in good agreement. In the Lugoj study case, sediment calibration was carried out and concentration contours show some contrast throughout the cross-section. Water discharge and sediment mean concentration and flux are similar to the values provided by standard measurements (respectively about 35 m³/s, 85 mg/l and 3 kg/s). Further experiments are required to evaluate more accurately the potential of the aDcp method, especially in wide and deep river cross-sections and during floods.

Keywords: suspended sediment, aDcp, river discharge measurement, hydrometry

Introduction

Suspended load represents a huge majority of solid fluxes in most rivers. It strongly conditions their quality (e.g. nutrient or pollutant transfer) and their morphology (e.g. deposits, vegetalization, bank and substrate texture). However fine sediment transport in suspension has been less often studied than bed load transport.

For tens of years, the National Romanian Hydrometric Network has been monitoring suspended solid fluxes thanks to velocity measurements and direct water sampling, according to official procedures for data acquisition and processing (Diaconu, 1997).

Among all the different methods for suspended load measurement, acoustic technologies seem to be the most promising (Wren and al., 2000): they are non intrusive and they can simultaneously provide bed topography, 3D velocity field, suspended solid concentration (SSC), and sometimes grain size distribution (cf. e.g. (Thorne and Hanes, 2002)).

For the last fifteen years, acoustic Doppler current profilers (aDcp) have been increasingly used to measure river discharge in France as well as in many countries. aDcp's emit ultrasonic signals in the

water and listen to echoes backscattered by suspended particles. The Doppler frequency shift is used to compute instantaneous water velocity profiles, then total discharge through a cross-section. The intensity of the backscattered signal actually reflects particle properties, in particular their concentration and size.

The aDcp potential for suspended sediment flux measurements in rivers was soon recognized (Reichel and Nachtnebel, 1994), but very few comparisons with classical sampling estimates have been reported (Filizola and Guyot, 2004). This paper reports our first attempts to compare suspended sediment concentrations and fluxes measured by aDcp and conventional techniques in two Banat rivers: the Timiș and the Bega rivers, Western Romania.

Study sites

The Timiș-Bega catchment

The Timiș-Bega river basin is found in the Banat province located in the South-Western part of Romania. They present two district water courses: the Bega river is a tributary of the Tisa river with which it unites beyond the border in Serbia; the Timiș river is a tributary of the Danube. The whole catchment area is 8,035 km².

The density of the hydrographical network is 0.32 km/km² for the Bega river and 0.33 km/km² for the Timiș river. The hydrometric network contains 30 hydrometric stations among which 12 stations are equipped for suspended-sediment load monitoring (Fig. 1).

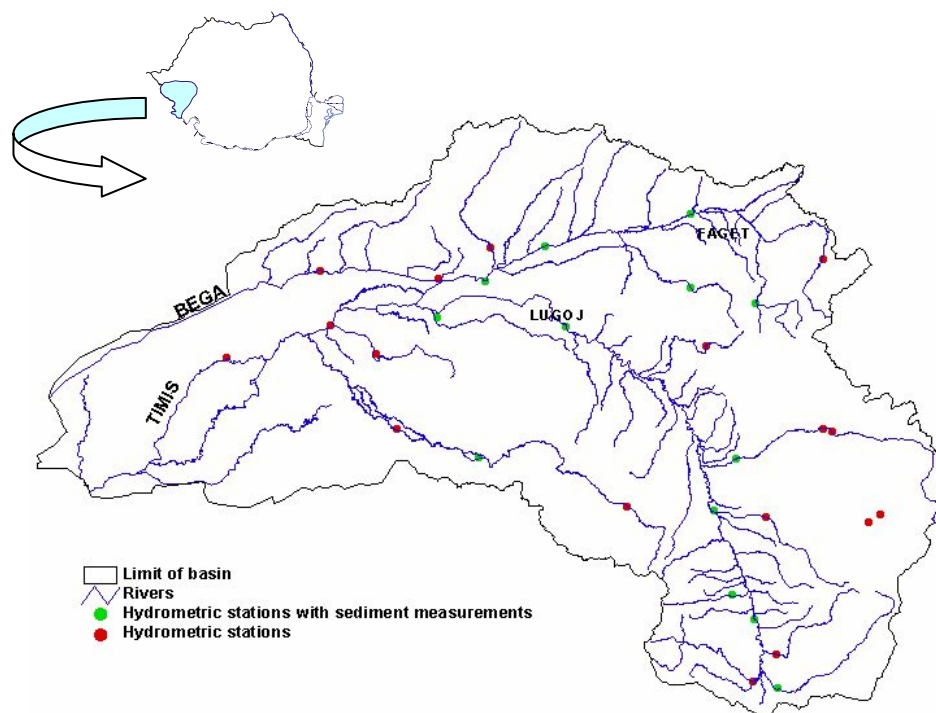


Figure 1. Timiș-Bega catchment and hydrometric network

The Lugoj and Faget hydrometric stations

Both analyzed hydrometric stations present some interesting and contrasted characteristics for suspended sediment investigations (Table 1):

- At Lugoj - Timiș hydrometric station, the measuring section is 68 meters wide during maximum flow and 50 meters wide during low flow, and the Bega river at Faget hydrometric station has a cross section of 34 m during maximum flow and 20 m during low flow
- Liquid discharge time series $Q(t)$ linked with suspended sediment discharge time series $Q_{SM}(t)$ are respectively about 25 year long in Faget and 44 year long in Lugoj
- Both sub-basins are homogenous in terms of suspended sediment production: 121 tons/year/km² at Lugoj and 65 tons/year/km² at Faget (Galéa et al. 2004)
- The river beds have been recalibrated which ensures an efficient sediment transfer towards downstream and limits the deposit areas
- Both rivers show significant turbidity and the mean annual discharge at Lugoj is 16 m³/s with a 19.5 kg/s corresponding sediment flux ($Q = 6.67$ m³/s and $Q_{SM}=1.86$ kg/s at Faget)

Table 1 Characteristics of the experimental areas

River	Hydrometric station	Elevation m	Surface km ²	Length m	River slope m/km	Basin slope m/km	green lands	Vegetative cover		
								crops	forests	others
Bega	Faget	470	474	42.6	188	199	22.5	1	73	3.5
Timiș	Lugoj	666	2706	114	11	258	32	3.5	62	2.5

Material and methods

Conventional hydrometric tools

In Romania, speed measurements are carried out by means of the current meter. It overtakes the movement energy of the water through a propeller which the faster the water flows, the faster rotates. The current meter is used at depths higher than the diameter of the propeller and at greater speeds than the start speed (which characterizes the sensibility of the current meter). The water speed in a point can be determined with the help of the current meter, knowing the number n of revolutions of the blade in a t time interval and the revolution, using the current meter dragging chart $v = f(n)$. The main components of the current meter are: the rotor, the body and the direction empennage.

In both hydrometric stations, water level is automatically recorded and converted to discharge time series through the local rating curve.

Depth-integrated sediment measurements are organized at the gauging stations within the hydrometrical network with the purpose of knowing the alluvial deposits quantities and their runoff regime. Procedures are based on water sampling from standard points at known depths on verticals established along the cross-section.

Sediment samplers (Fig. 2) are bottle-shaped containers made of glass with a given capacity and various adapted accessories in order to keep the sediment sample properties unchanged. The most frequent sediment samplers used in the hydrological network are: a bottle with distributors, simple bottles and the tacheo-sampler, whose main characteristics is the filling time.

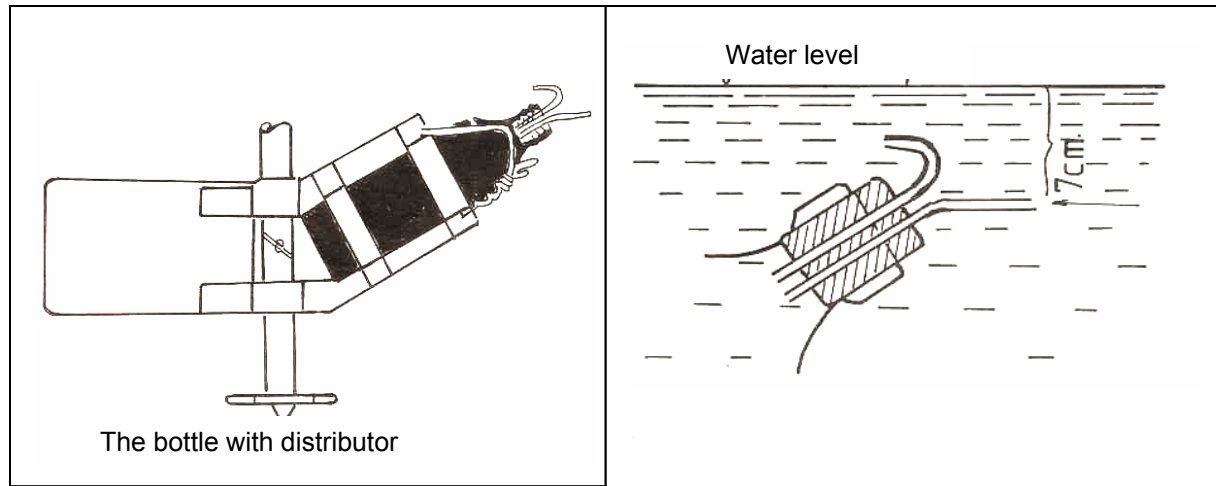


Figure 2. Sediment samplers – surface sampling

In order to establish the depth-integrated sediment discharges, sediment concentrations ρ in the sampling points must be calculated. Each water sample is filtered, dried and weighed. Then suspended sediment concentrations for each point are determined using the following relation:

$$\rho = \frac{G}{V} \left[\frac{g}{m^3} \right] \quad (1)$$

G = weight of the sediments in sample
 V = volume of the sample

Then unit sediment discharges in the sampling points are given by:

$$\alpha = \rho \cdot v \left[\frac{g}{s \cdot m^2} \right] \quad (2)$$

- α - unit sediment discharge in the sampling point
- ρ - concentration in the sampling point
- v - water velocity in the sampling point

aDcp deployment and linked measurements

For the present study, we used a Teledyne RDI WorkHorse Rio Grande 1200 kHz aDcp installed on a small buoyant board. Remote communication with the aDcp was ensured by radio modems and a laptop. The aDcp first refused to communicate through the radio modems. So we had to wake it up by plugging it to the computer directly, then going on with the radio modems, as also reported by (Oberg et al., 2005). No additional positioning system (such as tachometer survey or DGPS) was used besides the aDcp bottom tracking. In both cases, no apparent sign indicated any significant bed motion.

At Faget, as the cross-section was narrow (about 12 m) and as velocities were quite high (about 0.61 m/s), the aDcp was maintained by tight ropes by one operator on each bank. Measuring “water mode” 1 (WM1, broadband default mode) gave poor results with a lot of bad current data. As the cross-section was shallow (maximum depth about 0.9 m), we used “water mode” 8 (WM8) which gave reasonably dispersed velocity data in 10 cm-high bins. The blanking zone was 20 cm high.

At Lugoj, as the Timiș river is quite wide (about 55 m) and velocities quite low (about 0.31 m/s), the aDcp was pulled from the historical Austro-Hungarian bridge from one side to the other. As the maximum depth was about 4 m, we used water mode 1 and water bin size 25 cm-high. The blanking zone was 35 cm high. Standard measurements (water sampling and velocity point measurements) were performed by the Lugoj hydrological station staff simultaneously with the aDcp deployment. On 3 verticals, several water samples were linked with aDcp vertical profiles (Fig. 3).

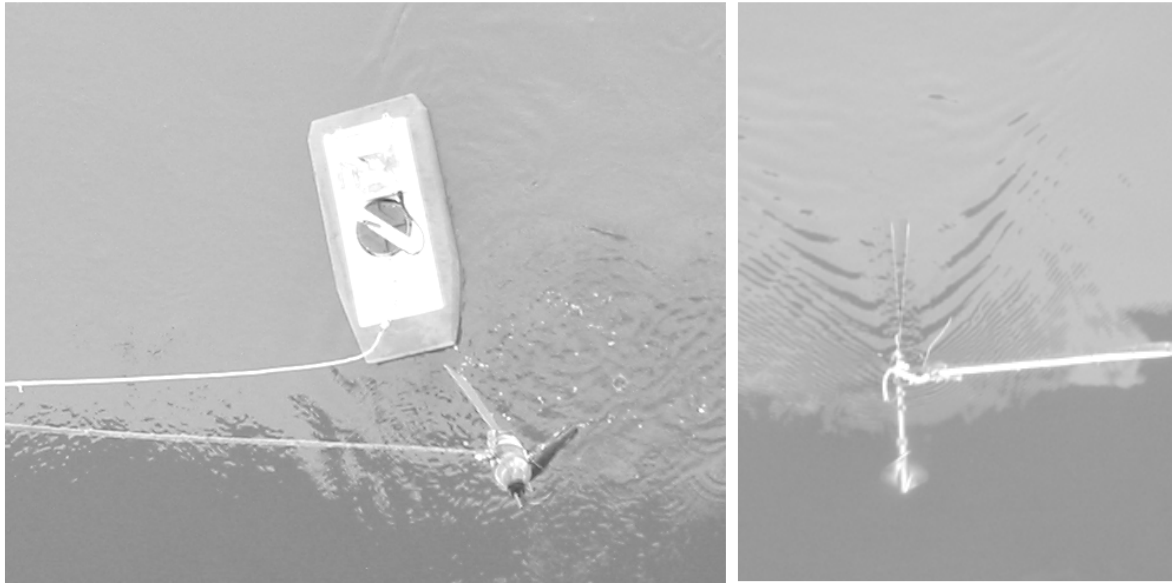


Figure 3. Linked measurements at Lugoj
ADCP and water sampler (left) – current-meter (right)

River discharge computation tools

In Romania, the most frequent method used in assessing liquid discharge is the **grapho-mechanical method**. This method needs the drawing of the transversal profile and the hydrographs in every vertical. Then through the planimetry of the hydrograph surface, multiplied with the river width unit (e.g. 1 meter), the elementary discharge q in every vertical is determined; this is expressed in m^3/s and on linear meter. With q values from every vertical of speed, it is constructed over the water line the repartition a transverse areas diagram of repartition of q sizes on the width of the river. Planimetry of the surface of the q curve and using the proper curves the discharge that flows through the section is determined.

Bareme is French software developed by the Ministry of Ecology and Sustainable Development (Bareme, 2006). It has been specially designed to meet the requirements of river water discharge measurement, according to the velocity-area method. The software uses the field measurements to compute water discharges and stage-discharge curves for a given gauging station. Information is stored in a data base. This tool is widely used in France by hydrometric teams such as the regional environmental agencies (DIREN).

The RDI **WinRiver1.06** software is usually used to process RDI ADCP data in order to compute discharge following to the so-called moving-vessel equation:

$$\delta q(z, t) = [\vec{u}_w(z, t) \times \vec{u}_b(t)] \cdot \vec{k} \delta z \delta t \quad (3)$$

which means that the elementary water flux $\delta q(z, t)$ through a bin measured at (z, t) is equal to the dot product of the unit vertical vector \vec{k} by the cross-product of the water-velocity vector $\vec{u}_w(z, t)$ by the vessel-velocity vector $\vec{u}_b(t)$. The vessel velocity is measured the same way as water velocity from Doppler analysis of dedicated bottom-tracking pulses, assuming that the bottom material has no movement.

The discrete integration of equation (3) over the whole part of the cross-section where water velocities can be measured leads to the “measured discharge” value. Then discharges in the top/bottom layers of the section where velocities can’t be measured are estimated by fitting a 1/6 power law on measured vertical profiles. Edge discharges are estimated too, according to a ratio extrapolation method (Simpson, 2001). Putting all these partial discharges together gives the “total discharge” through the cross-section. The total to measured discharge ratio was typically 38% and 72% for the 10 and 7 crossings at Faget and Lugoj respectively.

Total discharges were also computed with **Sediview3.2** in a similar way and with the same computation parameters. The main difference is the way each software interpolates lost current data from neighbour values.

Romanian procedures for suspended-load measurements

Two calculation methods can be used for the complete measurements, according to the velocity and turbidity field patterns and according to measurement and calculation tools.

- **The analytic method** consists in establishing the partial sediment discharges. The calculation operations are the following:

- Determine the mean unit sediment discharges α_m [kg/m²/s] at one vertical, according to the water depth h:

- h = 15-20 cm: $\alpha_m = \alpha_{0.6h} = \rho_{0.6h} \cdot V_{0.6h}$
- h = 21-40 cm: $\alpha_m = (\alpha_{\text{surface}} + \alpha_{\text{bottom}})/2$
- h = 41-80 cm: $\alpha_m = (\alpha_{0.2h} + 2\alpha_{0.6h} + \alpha_{0.8h})/4$
- h > 80 cm: $\alpha_m = (\alpha_{\text{surface}} + 3\alpha_{0.2h} + 3\alpha_{0.6h} + 2\alpha_{0.8h} + \alpha_{\text{bottom}})/10$

- Establish the mean unit sediment discharges between two successive verticals (X, Y):

$$\alpha_m(X, Y) = \frac{\alpha_m^X + \alpha_m^Y}{2} \quad (4)$$

- Establish the partial sediment discharges:

$$Q_{SM}(X, Y) = \Omega(X, Y) \cdot \alpha_m(X, Y) \quad (5)$$

- $Q_{SM}(X, Y)$ - partial sediment discharge transported between the 2 verticals
- $\Omega(X, Y)$ - sediment partial surface between the 2 verticals
- $\alpha(X, Y)$ - unit mean sediment discharge between the 2 verticals

- Establish the total depth-integrated sediment discharge as the sum of the partial sediment discharges:

$$Q_{SM} = \sum Q_{SM}(X, Y) \quad (6)$$

- Determine the cross-section mean concentration:

$$\rho_m = \frac{Q_{SM}}{Q} \quad (7)$$

- Q_{SM} - sediment discharge [kg/s]
- Q - total water discharge [m³/s]

- **The grapho-mechanical method**

Calculation steps are similar to the methodology used for the determination of water discharges:

- draw the cross-section profile;
- calculate the velocity and concentration fields and α_m on the vertical;
- determine the unit v_m , ρ_m , α_m on the verticals;
- determine the value of Q_{SM} through the cross-section.

Calibration of acoustic backscatter data

Theoretical relationships can be derived to describe the way the acoustic signal is backscattered by suspended particles in water. Thus the mass SSC according to range $M(r)$ can be written as (DRL, 2003; Holdaway et al., 1999; Thorne and Hanes, 2002) :

$$M(r) = (K \langle P_{rms} \rangle r)^2 \langle a_s \rangle \rho_s / \langle f \rangle^2 * \exp(4r(\alpha_w + \alpha_s)) \quad (8)$$

where K is a constant linked to the acoustic device, P_{rms} is the random mean square backscattered pressure, a_s the grain mean radius, ρ_s the sediment density, f a shape function representing particle

acoustic properties, α_w (resp. α_s) the attenuation coefficient of water (resp. sediments), and $\langle . \rangle$ the average on allinsonified particles.

Unlike multifrequency acoustic backscatter devices (e.g. (Taylor et al., 1998)), monofrequency profilers can't provide simultaneous information on sediment concentration and grain size distribution (Reichel and Nachtnebel, 1994). At a given concentration indeed, backscatter intensity is maximum for a mean particle radius a given by (SonTek, 1997):

$$ka = 1 \quad \text{i.e.} \quad a = C / 2\pi v \quad (9)$$

with k the sound wave number, v the ultrasonic wave frequency, C the speed of sound in water (typically 1,500 m/s). The smallest particles contributing to the aDcp echo have a mean radius of $a=0.05/k$ typically. Consequently, backscatter conversion into particle concentration basically depends on grain size fluctuations (Gartner, 2004; Kostaschuk et al., 2005).

The commercial software Sediview (DRL Software, UK) has been used to calibrate and post-process aDcp data. Designed for RDI aDcp's, Sediview is based on a simplified expression of equation 8 (DRL, 2003), and offers tools to calibrate hydro-acoustic parameters from direct SSC measurements (water samples in the present study) linked with aDcp profiles.

Some encouraging methodological tests had been performed by the *Cemagref* on a 12-m deep Rhône river cross-section near Lyon (Drevet, 2004). These tests had helped in the definition of field procedure guidelines for aDcp calibration. At least six water samples must be taken as close as possible to the measuring aDcp, while precise sampling depths and aDcp ensemble (i.e. vertical profile) numbers must be noted. The water samples should cover contrasted ranges of depth and concentration. In particular, samples from the acoustic far field (below 1.8 m deep for a 1,200 kHz aDcp) are required. Additional turbidity and/or grain size measurements can also be used for calibration (this was not the case here).

Comparison of results

Water discharge measurements

The hydrometric cross-section Lugoj – Timiș is divided into a large and a small active channels by the bridge pier. In the main channel, maximum depth reaches about 4 m. The secondary channel is only 2 m-deep. The distribution of velocity point measurements is presented on Fig. 4 (Bareme software output). The corresponding distribution of velocity intensities from an aDcp transect is presented on Fig. 5 (WinRiver1.06 software output).

The equivalent outputs for the hydrometric station Faget – Bega are shown on Fig. 6. Standard measurements were performed at the usual hydrometric cross-section from a bridge, whereas aDcp transects were performed about 100 m downstream, on a smaller section with higher velocities.

Table 2 shows the detail of aDcp results for all the successive crossings in both locations. Discharge estimates don't seem particularly dispersed: the standard deviation to mean ratio is 6.3% and 4.8% at Lugoj and Faget respectively. However Lugoj aDcp discharges show a clear decrease with time, in association with decreasing bulk velocities (defined as the discharge to area ratios). This trend is confirmed by the discharge time series simultaneously recorded at the automatic gauging station (Fig. 7). Successive aDcp discharges are in very good agreement with the local rating curve, even if the last transects seem to slightly underestimate discharges.

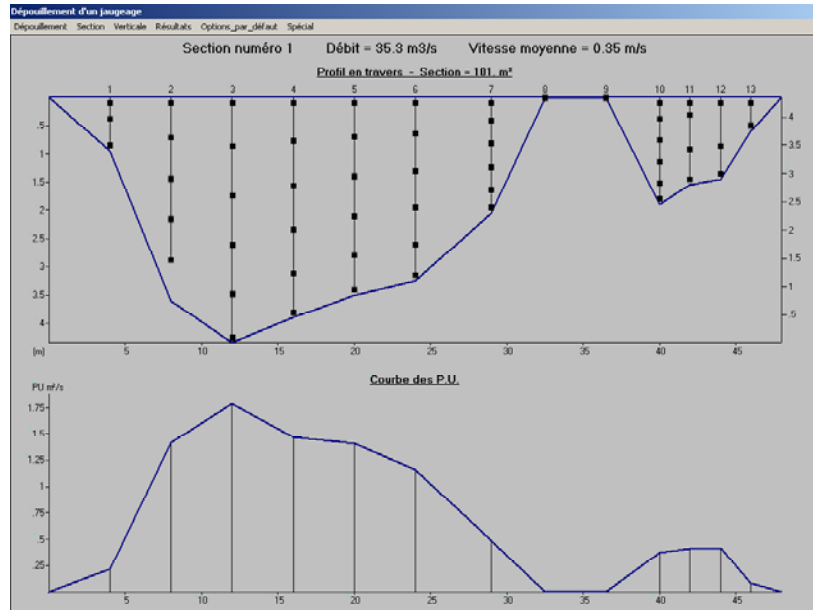


Figure 4. Discharge computation with French software Bareme – Lugoj
Measurement points in the cross-section (top); corresponding unit discharges (down)

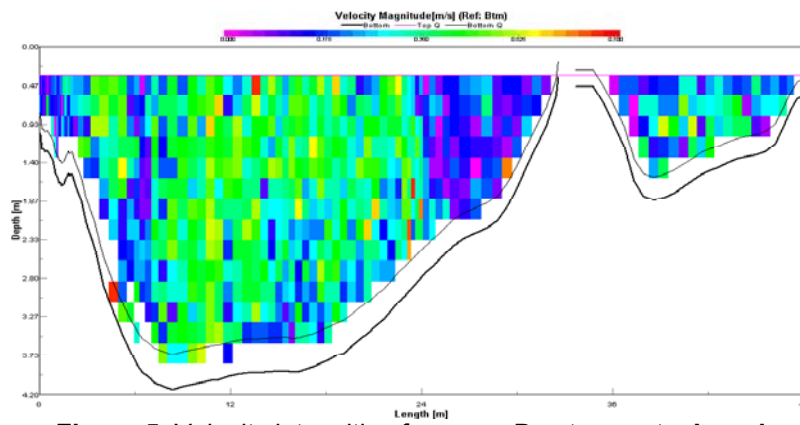


Figure 5. Velocity intensities from an aDcp transect – Lugoj

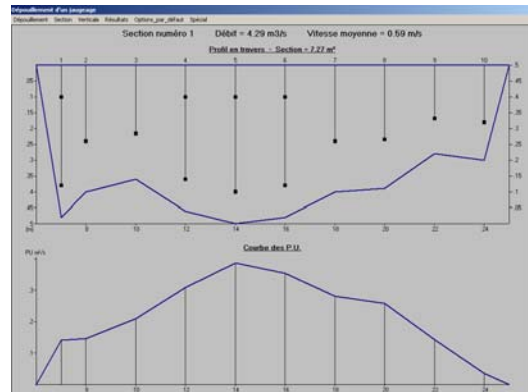
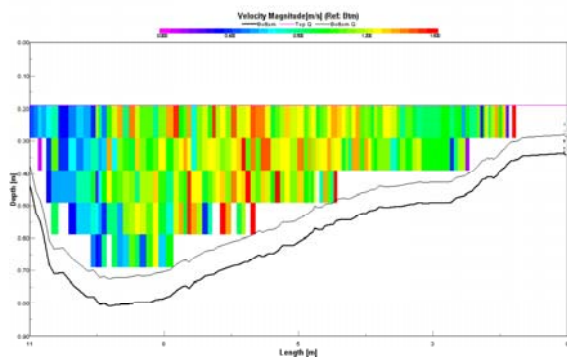


Figure 6. Same outputs as Fig. 4 and 5 – Faget

Table 2 ADcp discharge measurements processed by WR1.06 (2005, September 7th)

<i>Location</i>	<i>Time (UT+3)</i>	Discharge (m ³ /s)	Area (m ²)	Bulk velocity (m/s)
Lugoj	12:02	33.51	118.89	0.308
	12:08	32.30	124.37	0.260
	12:41	31.38	117.19	0.268
	12:45	32.43	130.24	0.249
	13:23	30.23	123.79	0.244
	13:27	28.07	113.07	0.248
	13:32	29.17	124.35	0.235
Faget	17:43	4.05	4.65	0.871
	17:46	4.21	5.18	0.813
	17:48	3.96	4.65	0.851
	17:54	4.40	5.08	0.866
	17:56	3.93	5.39	0.730
	18:00	4.36	4.56	0.954
	18:03	4.04	4.72	0.856
	18:07	4.24	4.46	0.951
	18:15	4.21	4.55	0.924
	18:20	3.79	4.16	0.912

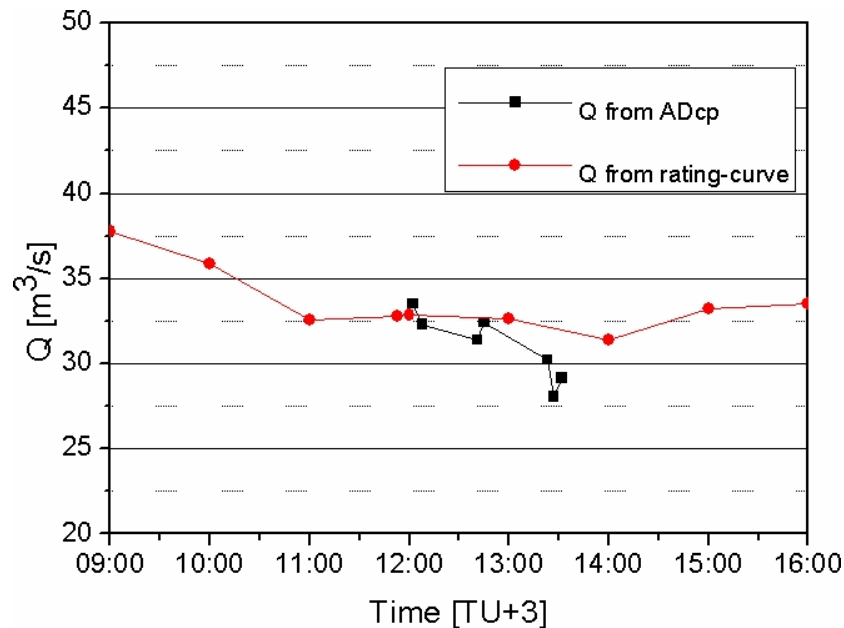
**Figure 7.** Discharges from aDcp and the local rating-curve - **Lugoj**

Table 4 sums up discharge, area and bulk velocity estimates from standard measurements and aDcp transect averaging. As expected, the same point velocity and depth data give quite the same results. Slight differences may be due to the different interpolation and integration methods. A detailed comparison of both discharge computation methods is beyond the scope of this paper.

Mean aDcp discharge at Faget agree well with standard measurements even if cross-sections were quite different, point velocity data not refined and the aDcp-measured to total discharge ratio quite low (38%). At Lugoj however, the discrepancy between the mean aDcp discharge (about 31 m³/s) and the standard discharge (about 35 m³/s) is beyond the usually reported uncertainty (5%). As hydraulic conditions were significantly unsteady, it can't be decided whether differences arise from measurement methods. Indeed standard velocity point measurements started almost 1:30 before the

first aDcp transect and lasted from 10:00 to 12:30 approximately with interruptions due to linked sampling measurements.

Backscatter calibration

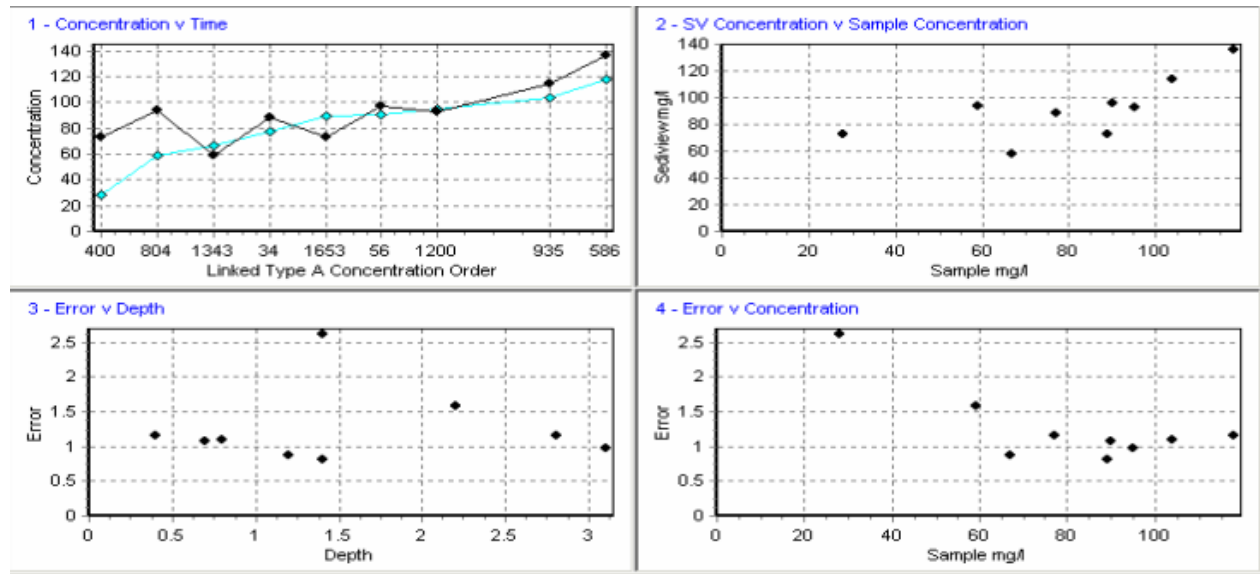
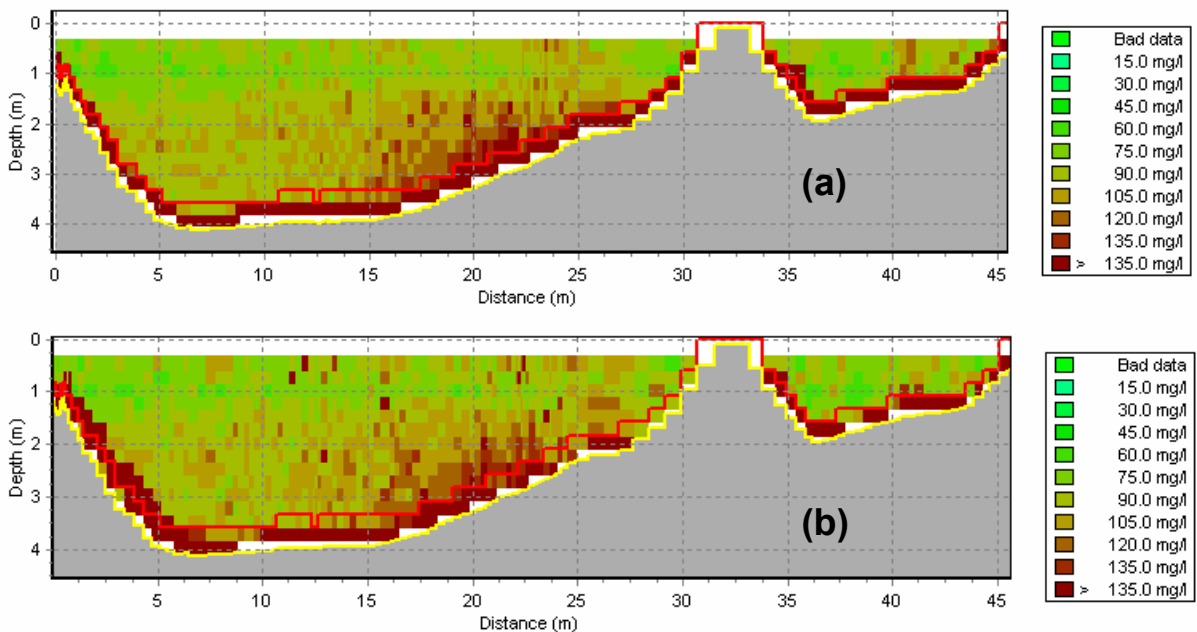


Figure 8. Sediview concentration calibration – Lugoj

As shown on Fig. 8, 9 water samples linked with aDcp profiles were available for the calibration of hydro-acoustic parameters. Black dots represent 4-beam averaged concentrations from aDcp data and blue dots represent concentrations from water samples. Graphs 1 and 4 show that calibration is quite acceptable (error ratio close to 1) except for the lowest two concentration samples (error ratios of 1.5 and 2.5). Graph 3 shows that there is no clear error trend with depth if the 2.5 error point is discarded. The far-field backscatter (below 1.8 m) was calibrated first, but only 3 samples were available, which is quite few. Then the near-field backscatter (above 1.8 m) was calibrated, essentially through a parameter standing for the effective transducer diameter.



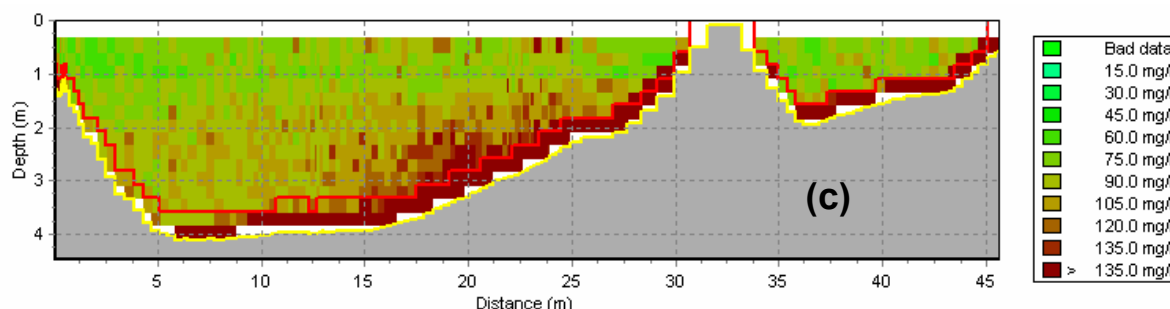


Figure 9. Concentration contour plots after backscatter calibration (SV32)
(a) averaging beams 1&2; (b) beam 3; (c) beam 4

Fig. 9 shows an example of cross-section concentration maps calibrated from 1 aDcp transect (10:41).

Graph (a) reports concentrations from the average backscatter of aDcp beams 1 and 2, whereas graphs (b) and (c) report concentrations from beam 3 and 4 respectively. As the aDcp was moved with an overall constant heading, the opposite beams 3 and 4 were constantly pointing towards the left and right banks respectively. The opposite beams 1 and 2 were pointing upstream and downstream respectively. In bins close to the bed, side-lobe echoes may corrupt aDcp velocity data and result in large aberrant backscatter values.

Normally side-lobe corrupted bins are situated below the red line, in a small bottom layer. The height of this layer is 6% of the water depth for a 20° beam angle aDcp. Biased-high concentrations below the side-lobe line (a) are not used in the flux computation. But if the bank is steep, the bank-pointing beam can present corrupted bins above the side-lobe line (b) and (c). These data can be edited and corrected manually in SV32 even if their contribution to total flux estimates is limited. The 4-beam averaged concentrations are taken into account in the flux computation.

But as shown by Fig. 9 (b) and (c), they are not representative of high suspended load values near the bottom. Furthermore, it can be deduced that higher concentrations in the right part of the main channel are real and not a side-lobe artifact. Indeed these persistent patterns affect each set of data for each beam and each crossing. Moreover these higher concentration values are realistic (about 0.120 kg/m³) whereas side-lobe biased concentrations are up to 0.600 kg/m³ and even more. This high suspended load area is not associated with particularly high velocities but perhaps to pier-driven turbulence downstream the bridge. Our data suggest that there can be a significant turbidity contrast across the section even at low-flow conditions. This contrast is difficult to observe on dispersed point concentration data from direct sampling.

Suspended solid discharge measurements

As the aDcp provides simultaneous current and concentration data, it is possible to compute the total sediment flux and the mean suspended-solid concentration (as the flux to discharge ratio). Results are shown on Table 3.

Table 3 Suspended sediment aDcp data processed by SV32 (2005, September 7th)

<i>Location</i>	<i>Time (UT+3)</i>	SV Discharge (m ³ /s)	Flux (kg/s)	Mean concentration (kg/m ³)
Lugoj	12:02	32.45	2.86	0.088
Lugoj	12:08	32.53	2.86	0.088
Lugoj	12:41	30.87	2.64	0.085
Lugoj	12:45	30.82	2.67	0.087
Lugoj	13:23	28.48	1.67	0.059
Lugoj	13:27	27.91	2.41	0.086
Lugoj	13:32	27.74	2.54	0.092

The estimated mean concentration is quite constant from the 7 aDcp transects, except for the 13:23 transect. SV discharges and fluxes were computed with the same interpolation and computation parameters as for WR. Slight differences are mainly due to the way each software interpolates bad current data. However, there may be a computational problem with this transect, because SV and WR water discharges are quite different (-5.8%). Once discarded this aberrant transect, the average concentration is 0.088 kg/m^3 and the standard deviation is 0.002 kg/m^3 (dispersion coefficient 2.3%).

As a consequence of unsteady hydraulic conditions during the measurement time span, estimated sediment fluxes decreased following the observed water discharge decrease. Discarding the aberrant 11:23 transects again, the average flux is 2.66 kg/s and the standard deviation is 0.18 kg/s (dispersion coefficient 6.8%).

A summary of integrated measurements from each method is presented on Table 4. Water discharge and sediment flux estimates are generally in acceptable agreement, even if slight discrepancies occur at Lugoij. Differences don't seem to stem from concentration calibration errors, but rather mainly from the dispersion of water discharge values (discussed above).

Table 4 Comparison of aDcp and standard measurements (2005, September 7th)

<i>Location</i>	<i>Method</i>	Discharge (m^3/s)	Area (m^2)	Bulk velocity (m/s)	Flux (kg/s)	Mean concentration (kg/m^3)
Lugoij	Standard (SH Lugoij)	34.7	112	0.31	2.96	0.085
Lugoij	ADcp (average)	31.01	122	0.25	2.66	0.088
Lugoij	Standard (Bareme)	35.3	101	0.35	-	-
Faget	Standard (SH Lugoij)	4.76	7.8	0.61	0.35	0.074
Faget	ADcp (average)	4.12	4.74	0.87	-	-
Faget	Standard (Bareme)	4.29	7.27	0.59	-	-

These results are quite promising but they should be completed by tests during hydrological events with quasi-steady state conditions and contrasted discharge values. At least two error sources should be investigated as regards the concentration calibration accuracy and sensitivity. As time-integrated water samples were taken, the number of pings averaged to make an aDcp ensemble (WP) should be set so that the ensemble duration be the same order of magnitude as the sampling duration. In addition, grain size analysis from different campaigns would be useful to quantify the calibration sensitivity to grain size distribution.

Perspectives

Beyond river discharge measurement, the aDcp can be a useful tool for suspended solid flux estimate, in particular through wide cross-sections. As acoustic backscatter intensities must be converted into suspended particle concentrations, simultaneous water sampling remain necessary in most cases in order to get quantitative flux estimates. Validation tests and especially comparisons with standard methods are still very scarce and poorly documented in rivers.

These first results are promising. Despite unsteady hydrodynamic conditions, water and suspended sediment fluxes computed from aDcp data and standard procedures are in acceptable agreement. However further field test measurements are necessary to ensure the reliability of the acoustic method and in particular its sensitivity to grain properties. Some field procedure improvements will help for a more accurate data post-processing. More appropriate aDcp configuration and deployment should tend to avoid corrupted data. In addition, sediment analysis, especially grain size distribution, would help to define typical hydro-acoustic parameters for a given hydrometric section.

Acknowledgements

This work was supported by the *Cemagref* (Lyon), INHGA (Bucharest) and UTCB (Bucharest). Funding for the acquisition of the aDcp was provided by the *Cemagref*, Région Rhône-Alpes (programme « *Modifications anthropiques des flux sédimentaires des cours d'eau, réponses des écosystèmes aquatiques et actions de restauration* »), and the *Programme National de Recherche en Hydrologie* (ACI ECCO PNRH, « *étude du fonctionnement hydro-sédimentaire des annexes fluviales* »). We are grateful to Mircea Ghinescu, Andreea Ghinescu & others and to the Lugoij hydrologic station staff (Georgeta Petconi and collaborators) for their precious help and friendly welcome.

References

- Bareme, 2006. "Guide de l'utilisateur, version 5.8", Direction Régionale de l'Environnement Rhône-Alpes, 90 p. (in French).
- Diaconu, C., 1997. *Instructiuni pentru statiile si serviciile hidrologice. Debite de apa si aluviuni.* Institutul National de Meteorologie si Hidrologie, Bucharest (in Romanian).
- Drevet, C., 2004. *Mise en place d'un protocole expérimental de mesure de taux de MES par ADCP. Modélisation de la confluence lône de Ricotti / rivière d'Ain.*, Cemagref, Lyon (in French).
- DRL, 2003. *DRL-Sediview software user manual V3*, DRL Software Ltd.
- Filizola, N. and Guyot, J.L., 2004. The use of Doppler technology for suspended sediment discharge determination in the river Amazon. *Hydrological Sciences Journal*, 49(1): 143-153.
- Galéa, G., Ramez, P., Adler, M.-J., Rotaru, E., 2004. *Modélisation statistique des apports de MES associés au régime des crues d'un sous-bassin du Timiș-Bega (Roumanie). Statistical modelling of the wash load associated with the flood regime in a sub-basin of the Timis-Bega Rivers (Romania).* *Revue des sciences de l'eau*, 17(4):471-488 (in French).
- 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: 169-187.
- Holdaway, G.P., Thorne, P.D., Flatt, D., Jones, S.E. and Prandle, D., 1999. Comparison between ADCP and transmissometer measurements of suspended sediment concentration. *Continental Shelf Research*, 19: 421-441.
- Kostaschuk, R., Best, J., Villard, P., Peakall, J. and Franklin, M., 2005. Measuring flow velocity and sediment transport with an acoustic doppler current profiler. *Geomorphology*, 68: 25-37.
- Oberg, K.A., Morlock, S.E. and Caldwell, W.S., 2005. *Quality-assurance plan for discharge measurements using acoustic Doppler current profilers.* 2005-5183, USGS.
- Reichel, G. and Nachtnebel, H.P., 1994. Suspended sediment monitoring in a fluvial environment: advantages and limitations applying an acoustic Doppler current profiler. *Water Research*, 28(4): 751-761.
- Simpson, M.R., 2001. *Discharge measurements using a broad-band acoustic Doppler current profiler*, USGS, Sacramento, California.
- SonTek, 1997. *SonTek Doppler current meters - Using signal strength data to monitor suspended sediment concentration.*
- Taylor, J.A. et al., 1998. Three-dimensional sediment transport measurements by acoustics (tridisma). *Proc. Oceans conf.*, 2: 1108-1114.
- Thorne, P.D. and Hanes, D.M., 2002. A review of acoustic measurement of small-scale sediment processes. *Continental Shelf Research*, 22(4): 603-632.
- Wren, D.G., Barkdoll, B.D., Kuhnle, R.A. and Derrow, R.W., 2000. Field techniques for suspended-sediment measurement. *Journal of Hydraulic Engineering*, 126(2): 97-104.