

## **Amazon suspended sediment yield measurements using an Acoustic Doppler Current Profiler (ADCP): first results**

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**Abstract** The Acoustic Doppler Current Profiler (ADCP) is an instrument that has been used for years with success on the sea, but little experience exists for big rivers. For the first time in Brazil, this kind of instrument was used for continuous purposes, in the discharge measurement of Amazonian rivers. To date, there has been little information on the relation between the Total Suspended Sediment (*TSS*) concentration obtained by standard methods and the ADCP received signal intensity (echo), as a means of estimating the sediment flow. In this paper we try to obtain some results with this relation. We found that it is possible to identify the contributions of the tributaries to the main stream in terms of *TSS* and to know how the *TSS* cycle works during a year in a section and maybe regionally.

### **Medición de los flujos de sedimentos con perfilador de velocidad a efecto doppler (ADCP): primeros resultados en la cuenca Amazónica**

**Resumen** El ADCP es un medidor acústico de corriente a Efecto Doppler; es una herramienta utilizada desde varios años en oceanografía para realizar perfiles de velocidad horizontal y vertical. Su utilización en los grandes ríos es todavía reciente. En Brasil, este equipo está utilizado de forma continua en el marco del proyecto HiBAm en la cuenca amazónica. Hasta ahora, pocas informaciones existían entre las concentraciones en sólidos suspendidos (SS) medidas según el método clásico y la intensidad del señal del ADCP. Esta relación es estudiada en este trabajo para (o en el objeto de) estimar los flujos de sedimentos de los grandes ríos a partir del ADCP. Los resultados muestran una variabilidad de esta relación  $SS = f(\text{Intensidad})$  al nivel del un ciclo hidrológico, y también de un río a un otro.

## **INTRODUCTION**

The National Department of Water and Electrical Energy of Brazil (DNAEE) has developed, within its attributions, a program of hydroclimatological study in the Amazon basin. This study is articulated as a research program with the Brazilian National Council of Scientific and Technological Development (CNPq) and ORSTOM, the French Institute for Research and Development in Cooperation. In this research program—Hydrology of the Amazon basin (HiBAm)—campaigns of discharge measurements have been made. In order to do these measurements, an instrument that makes use of the Doppler effect to calculate water discharge has been used. The device, named ADCP, has shown excellent results. Discharge

measurements have been made in the gauging stations of DNAEE in the Amazon Basin, to gauge, among other things, the existing rating curves, for which the ADCP has shown itself to be very efficient (Guyot *et al.*, 1995).

This instrument transmits sound waves through water. The particles carried by the water at different depths reflect the sound back to the device, which detects the echo through its sensors. The return of the sound reflected by the particles at different depths allows the sensors to also recognize different depths. That enables the instrument to build a vertical profile of the water column (RDI, 1989). The movement of particles in the water causes variations in the echo frequency. The ADCP measures these variations—the Doppler effect—as a function of the depth in order to obtain the speed of the water current in up to 128 different positions in the water column. Knowing the speed of the water, the area of the measuring section and the depth of the section, a computer program specially developed by RD Instruments for the ADCP calculates the total water discharge in the measuring section. The ADCP has other very useful characteristics because it gives a profile of the intensity of the echo of the suspended material in the water. This makes it possible to know

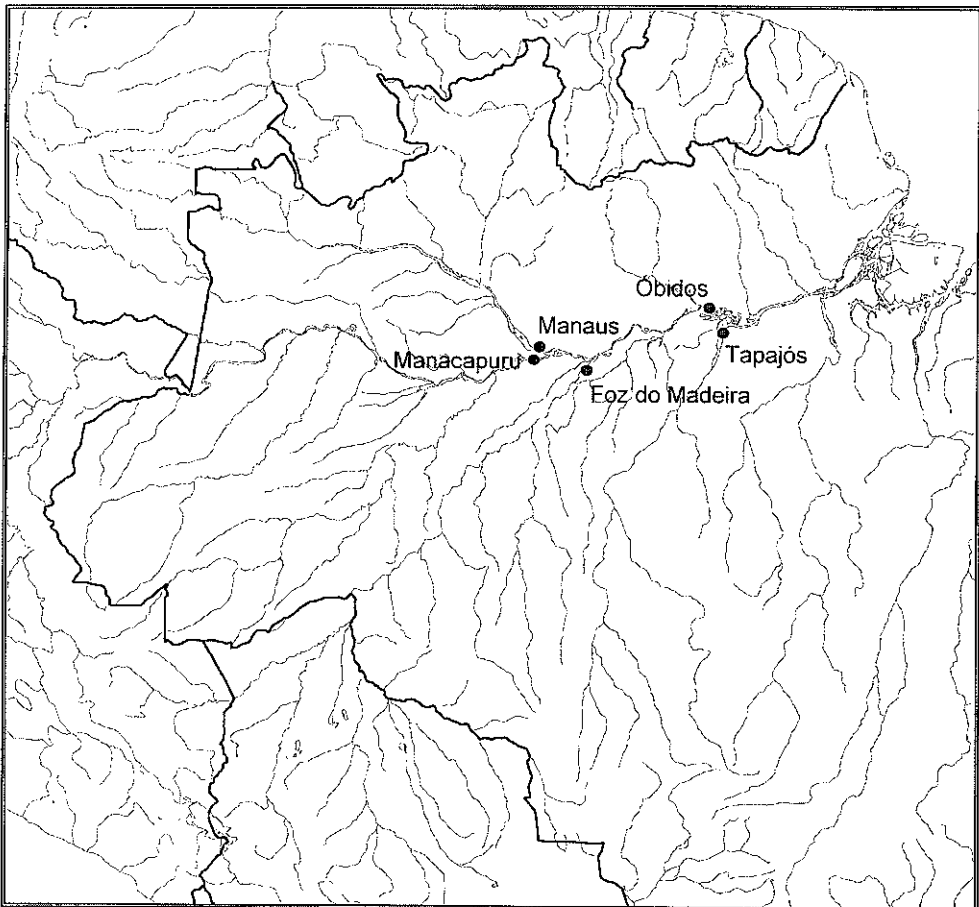


Fig. 1 Map indicating the location of the sampling stations.

the distribution of the suspended sediments in the section, which is the object of this study. Investigation was made of the relation between the data of the suspended sediment,  $TSS$  ( $mg\ l^{-1}$ ), sampled with a conventional sampler at different depths in the studied sections, and the data of intensity of echo (dB), reflected by the suspended material, registered by the ADCP at different places:

$$TSS = f(I)$$

where  $I$  = ADCP intensity. This relation will allow a more precise calculation of the flow of sediments in the measuring section. The first results indicate a strong correlation between the data, in the sense that each river has its own relation, establishing graphically very distinct groups of points. There are also relations in the section that vary with time.

### THE $TSS = f(I)$ RELATION

In this study, strategically positioned stations in the basin were chosen (Fig. 1). With this, it was possible to study the relation  $TSS = f(I)$  and its variation in time at each station, as well as a regional variation, verifying different patterns for different rivers. Three campaigns of discharge measurements were made during 1995. However, only the stretch between Manacapuru in the Solimões River and Santarém where the Amazon and Tapajós rivers meet, was repeated more than once. The most important tributaries of the Amazon River are in this stretch (Solimões, Negro,

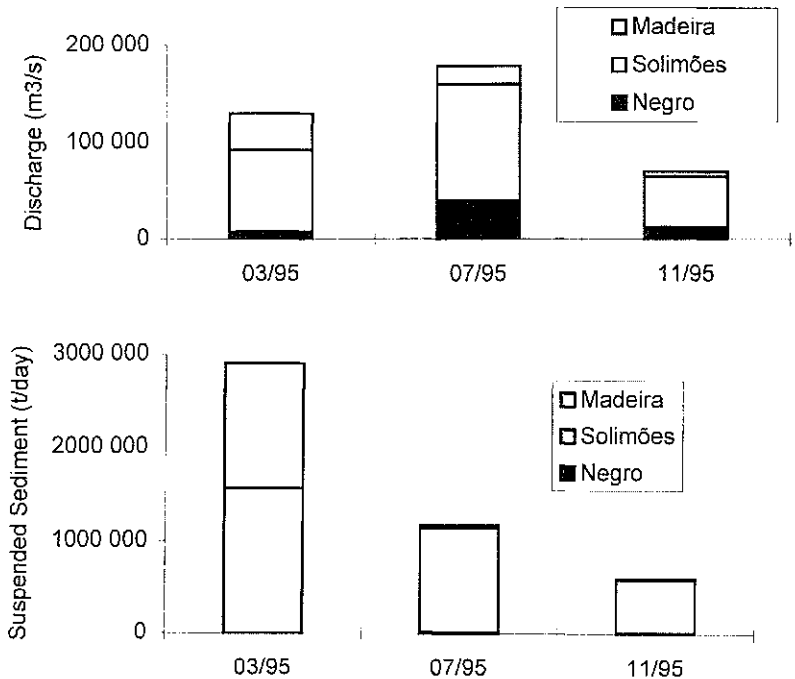
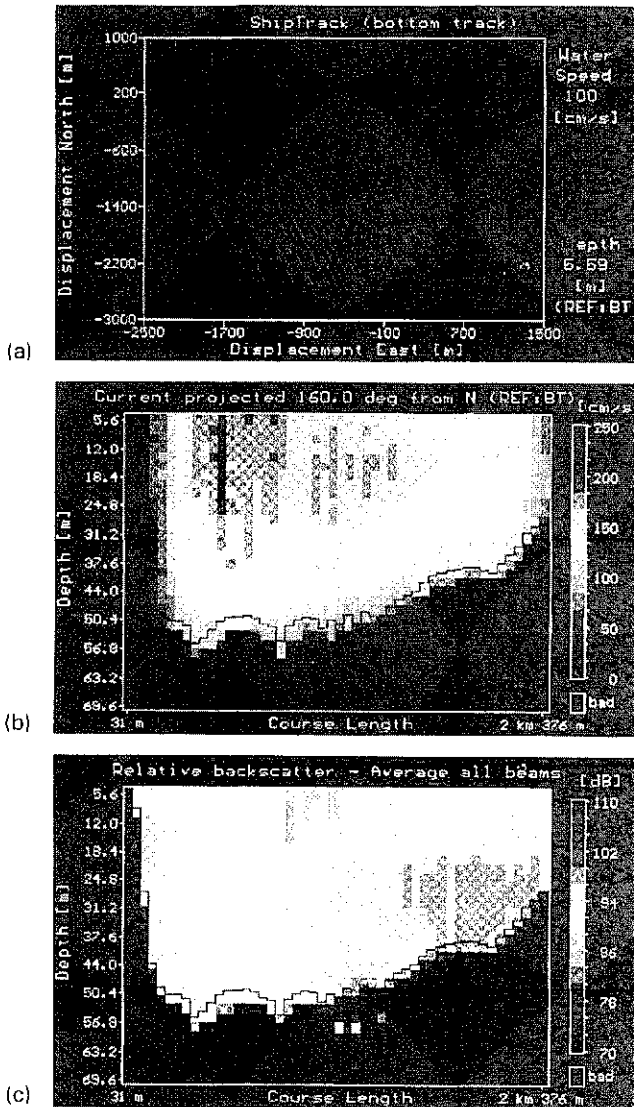


Fig. 2 Origin of water and suspended sediment yield of the Amazon River in Óbidos.

Madeira and Tapajós), which is why the stations of this stretch were taken as objects of this study. In the chosen rivers, besides the importance in terms of amount of water, the importance in terms of amount of suspended sediments was considered. The clear and black water rivers (Negro and Tapajós) transport a lot less suspended sediments than the white water rivers (Solimões/Amazon and Madeira), responsible for almost all the load of suspended sediments in the Amazon River in Óbidos (96.9% in March 1995, 97.7% in July 1995 and 95.6% in November 1995—see Fig. 2). Furthermore, the white water rivers are characteristically of Andean origin



**Fig. 3** ADCP graphics, Amazon River at Óbidos (24 March 1995;  $157\,380\text{ m}^3\text{ s}^{-1}$ ): (a) track of the boat and speed intensity lines ( $\text{cm s}^{-1}$ ); (b) vertical profile of the speed distribution in the section ( $\text{cm s}^{-1}$ ); and (c) vertical profile of the backscatter intensity distribution in the section (dB).

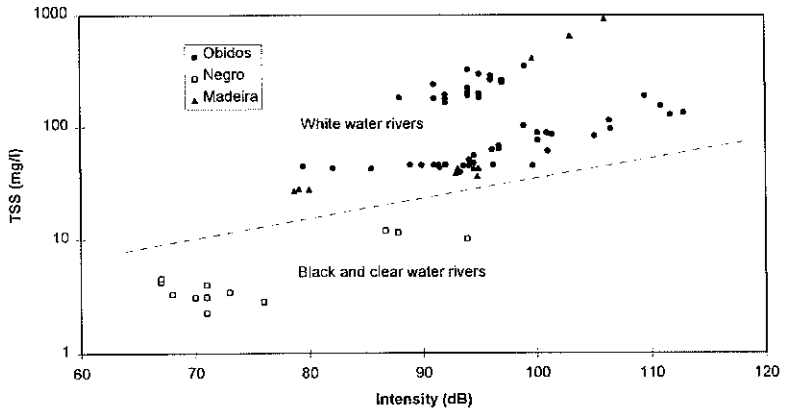


Fig. 4 Distinction between white water rivers and black/clear water rivers.

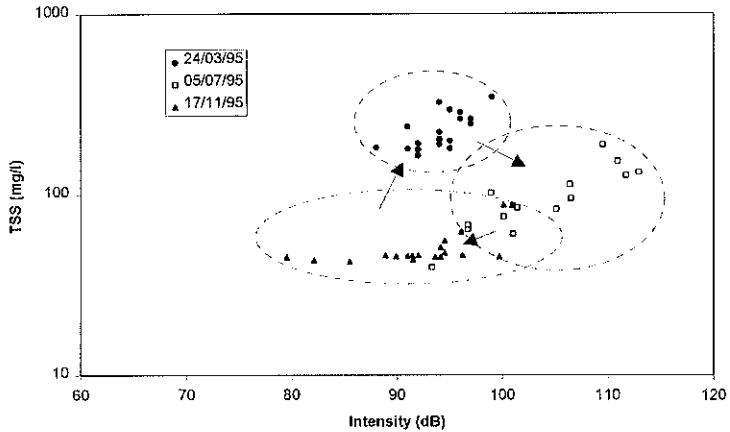
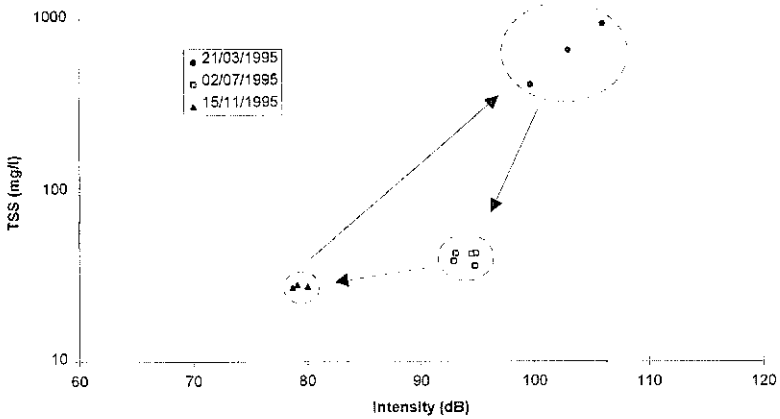


Fig. 5 "Loop" observed from data of different measuring campaigns at Óbidos (Amazon River).

and the black and clear water rivers have their origin in the Guianese and Brazilian shields (Sioli, 1975; Meade *et al.*, 1985; Meade, 1994).

In spite of three measuring and sampling campaigns having gone through all the chosen places, only a few stations showed enough data to enable a deeper study. As far as the ADCP graphic goes, it was possible to verify a standard behaviour in what is related to the sediment flow in the chosen sections (Fig. 3). However, when the relation  $TSS = f(I)$  was considered, graphically distinct groups of points were registered (Fig. 4). These groups are different not only in one station, when its variation is analysed in the hydrologic cycle, but also when stations are compared with reference to different types of waters (black, clear or white).

When the space variation of the TSS relation is considered, a notable distinction between the white water rivers (Andean rivers) and the clear and black water ones (from the shields) is verified. Figure 4 elucidates this observation. In the same Figure, it is also possible to observe a variation with time. When the Andean rivers



**Fig. 6** Indication of a “loop”, observed from data of different measuring campaigns, in the Madeira River at river mouth.

are considered, two families of points show themselves to be very distinct, one corresponding to the measuring campaign of March 1995, with more TSS and the other within the period of time when the two other campaigns took place: July 1995 and November 1995. It all indicates that the same happens to the other rivers (black and clear water).

When the data of only one station (Óbidos) were analysed, it was possible to verify the existence of a loop. That allows the affirmation that there are variations of the  $TSS = f(I)$  relation not only from one river to another, but also in only one station when taken over a period of time. This variation seems to be wider in the tributaries of the main course, such as the Madeira River, for example (Figs 5 and 6).

## CONCLUSION

It is still too early to affirm the existence of only one  $TSS = f(I)$  relation. On the contrary, it all points to the existence of various relations at different levels, that is, not only for the comparison between rivers of different origins, but also for the global time variation and concerning only one station. It is necessary to move towards a more profound study of these relations. Collecting more information in the next campaigns of the HiBAm program will enable a better detailing of the initial observations.

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