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► **To cite this version:**

Thomas Geay, Jonathan Laronne, Philippe Belleudy, Bernard Mercier, Catherine Coulaud, et al.. Passive acoustic monitoring of bedload in large gravel bed rivers. International Workshop on Monitoring Bedload and Debris-Flows in Mountain Basins, Oct 2012, Bolzano, Italy. 2012. hal-01671598

**HAL Id: hal-01671598**

**<https://hal.science/hal-01671598>**

Submitted on 22 Dec 2017

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# Passive acoustic monitoring of bedload in large gravel bed rivers

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This research is supported by the project **GESTRANS** (ANR-09-RISK-004)



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International Workshop on Monitoring Bedload and Debris Flows 10-12 October 2012, Bolzano

## The dilemma of bedload monitoring in large gravel bed rivers

To understand mountain gravel bed river morphodynamics, bedload flux needs to be studied and determined. The use of standard techniques to measure bedload discharge involves problems of accuracy, reproducibility and efficiency. This is true of physical methods such as basket samplers. Geophones are being used successfully to monitor bedload in small mountain gravel bed rivers. ADCP is being developed to monitor gravel bedload in large rivers (Rennie et al., 2004) with limited use in flood conditions. Therefore, other surrogate bedload monitoring techniques require development for large gravel bed rivers and floods.

Hydrophones sense acoustic waves generated by the river environment, including noise (turbulence in the river and around the hydrophone, the agitating water surface, direct impacts on the hydrophone) and sound generated by bedload motion. Acoustic information in the river environment derives from its propagation from these sources toward the monitoring system (Fig. 1).

Our objective is to assess the ability of a hydrophone to monitor bedload transport in large gravel bed rivers. This is demonstrated by measurements on the large Rhine, the Arc en Maurienne during flushing and the instrumented Drau Rivers. Only the total acoustic energy is exemplified in this presentation.

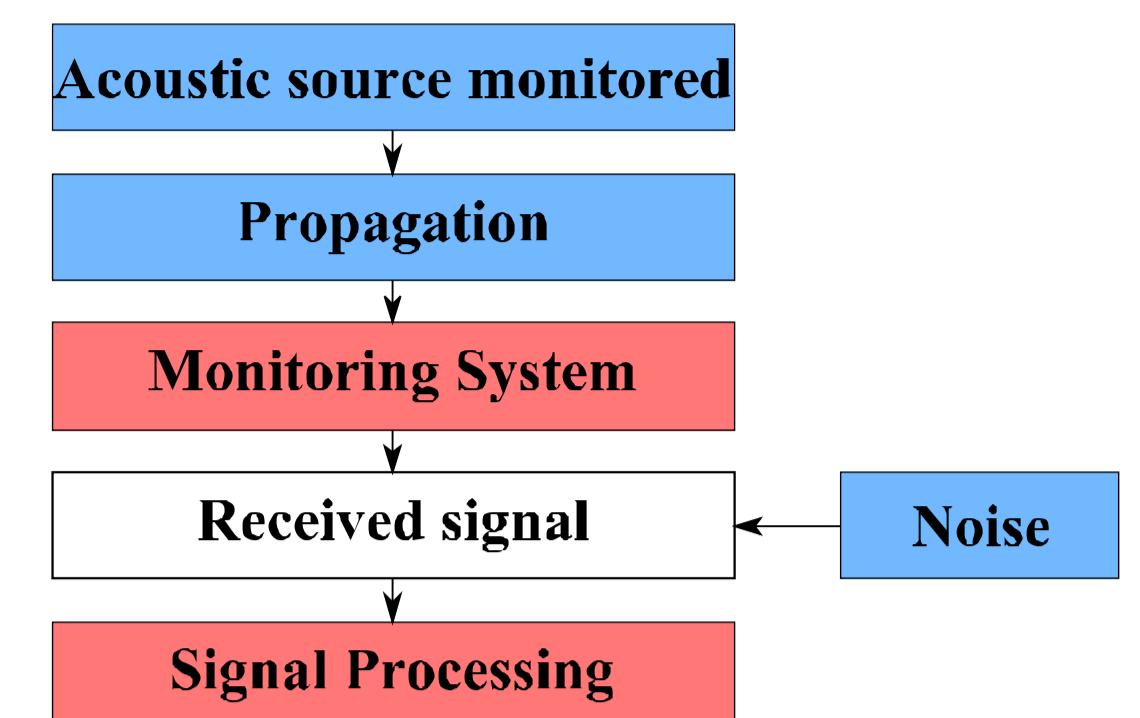


Fig.1. Schematic diagram of a passive acoustic measurement

The **Rhine River** is one of the major European waterways. Gravel is continuously supplied to avert degradation due to hydroelectric dam construction. Requiring bedload measurements, hydrophone monitoring may prove to be an alternative to standard sampling.



Fig. 2. Routine "MessSchiff" boat used for monitoring sediment. In the 300 m wide Koblenz cross-section of the Rhine, Germany.

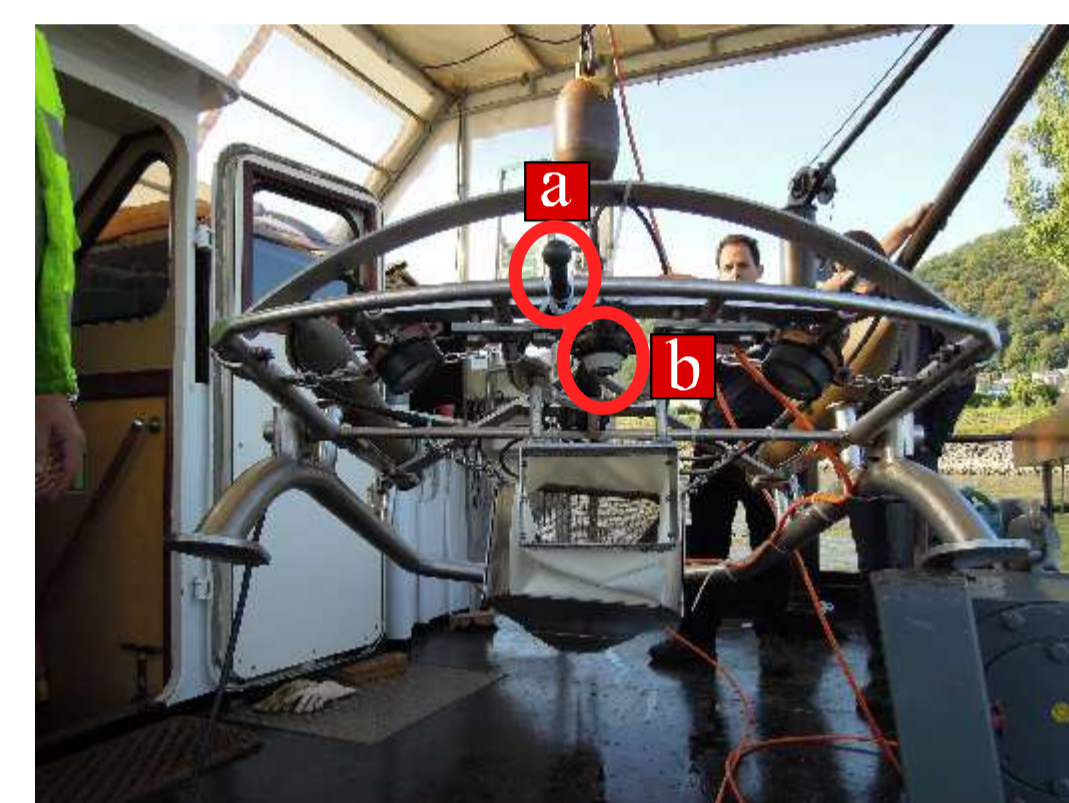


Fig. 3. Hydrophone (a) and video camera (b) mounted on the BfG 30 cm bedload sampler.

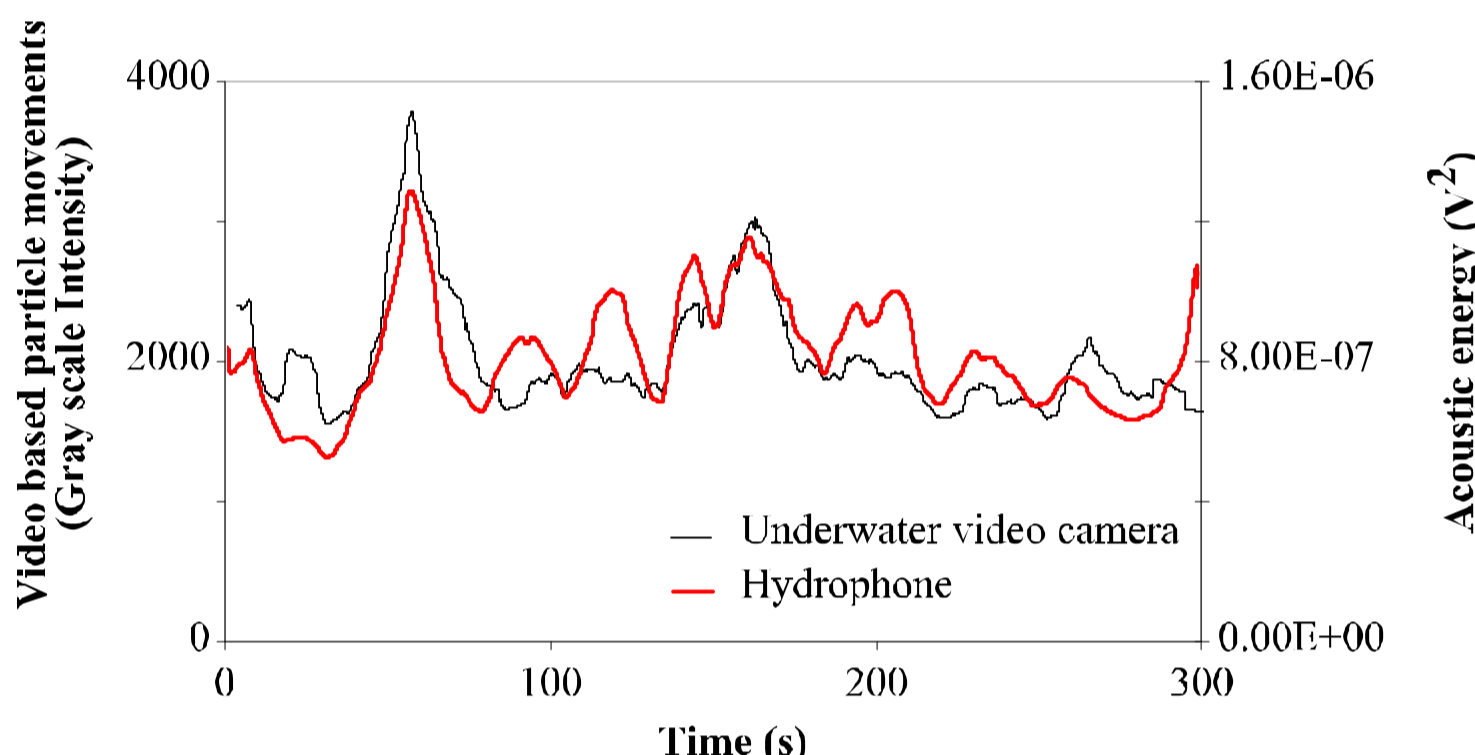


Fig. 4. Simultaneous measurements of hydrophone and underwater camera-based gravel movements.



Fig. 5. River bed gravel captured by video camera.

The **Arc en Maurienne River** undergoes annual sediment flushing operations. Bedload was monitored using a hydrophone from a bridge (Fig. 6) and a Helley-Smith (H-S) sampler (Fig. 7) as well as from the bank (Fig. 8-9). Due to H-S sampling inefficiency and large spatial variations in bedload flux, the correlation is not high (Fig. 7).



Fig. 6. Hydrophone deployment with sounding weight from a bridge on the Arc en Maurienne River.



Fig. 8. Hydrophone deployment on a rigid structure from the bank of the Arc en Maurienne River.

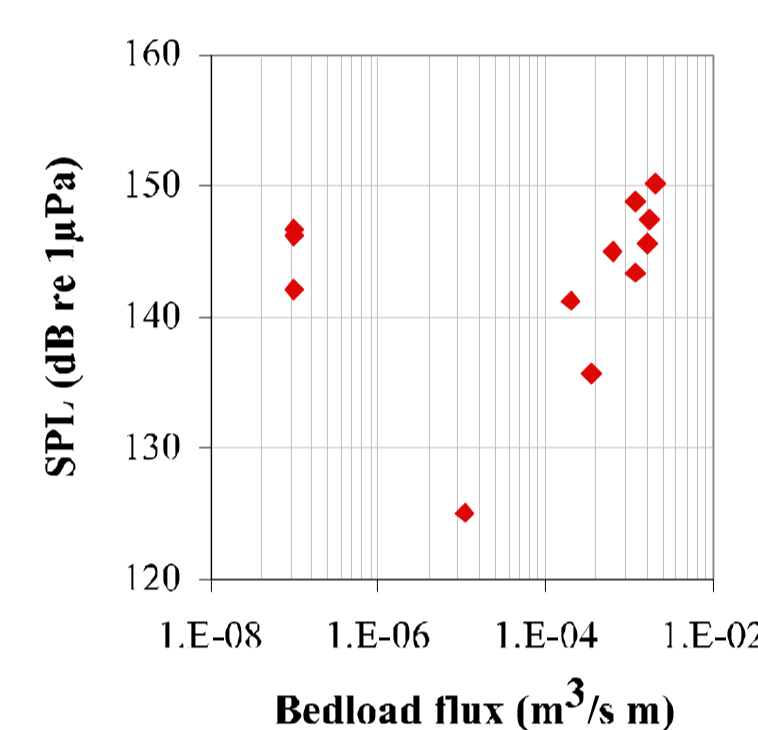


Fig. 7. Sound Pressure Levels (SPL) and H-S based volumetric bedload discharge during flushing operation in June 2012.

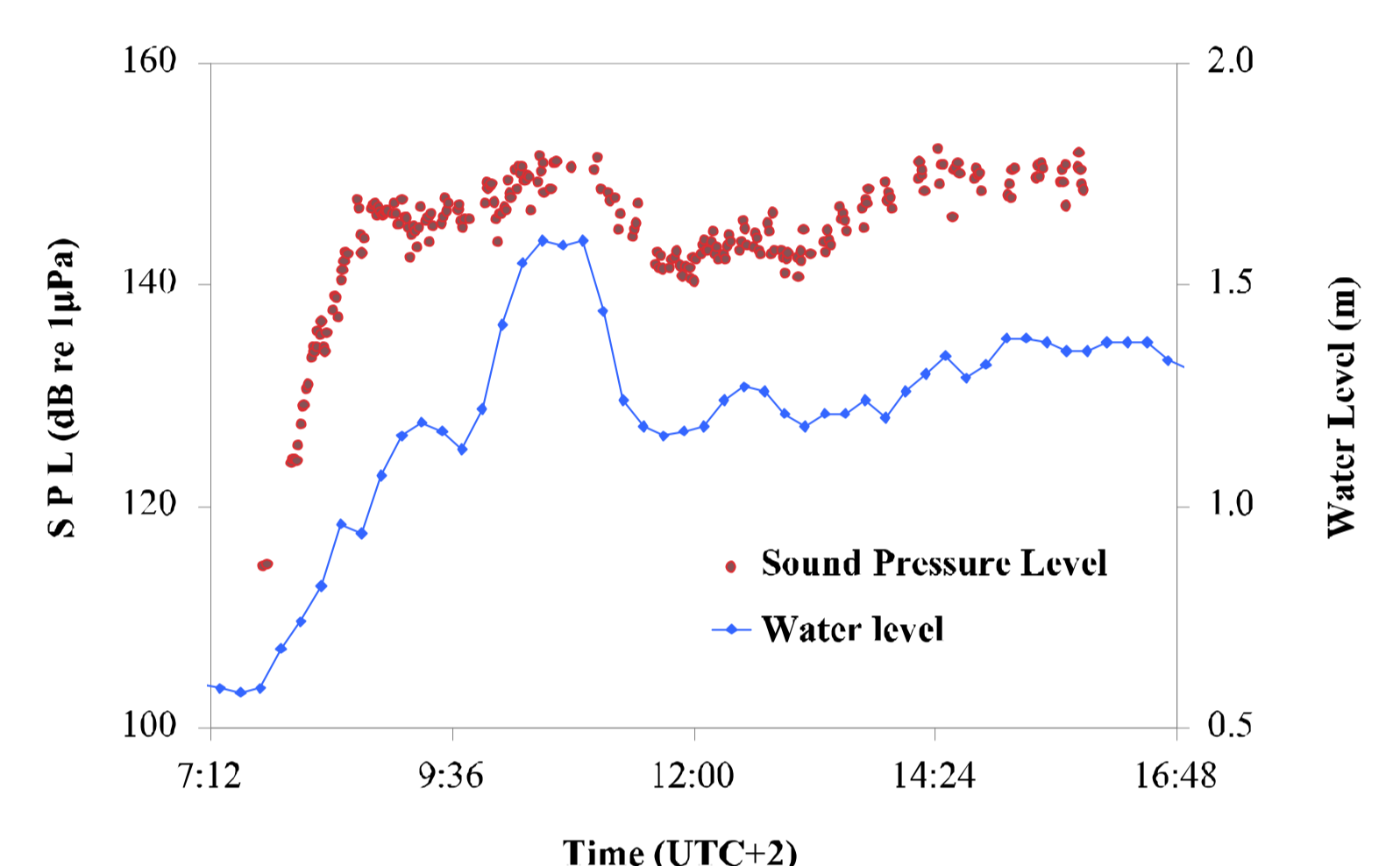
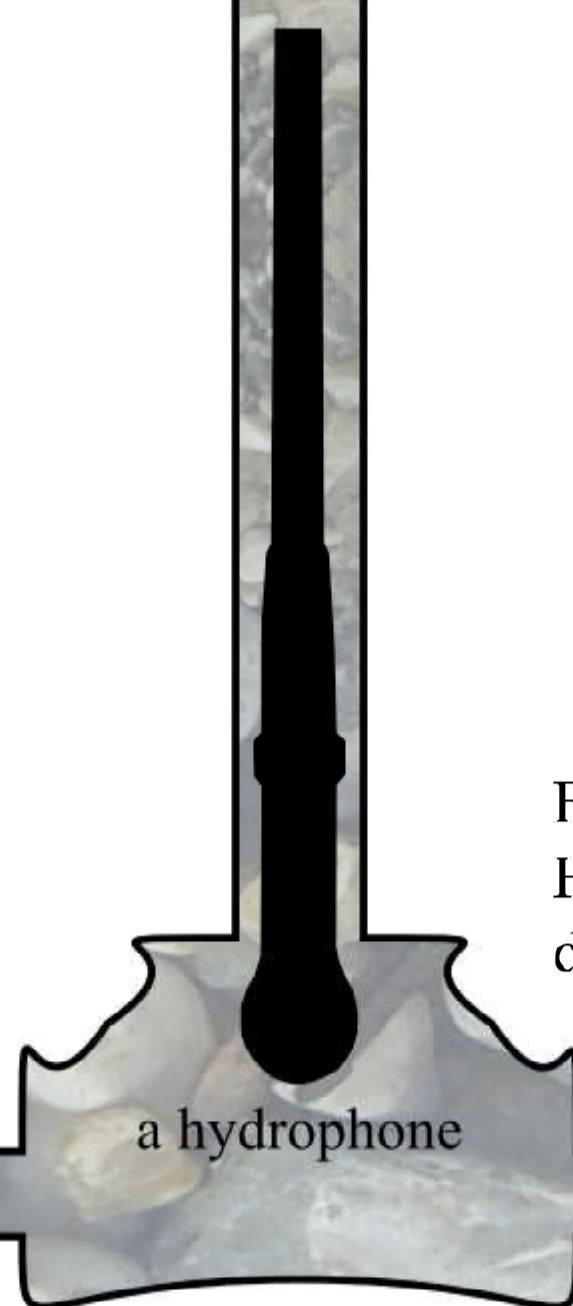


Fig. 9. Sound Pressure Levels (SPL) and water level monitored during flushing operation in June 2012.



a hydrophone

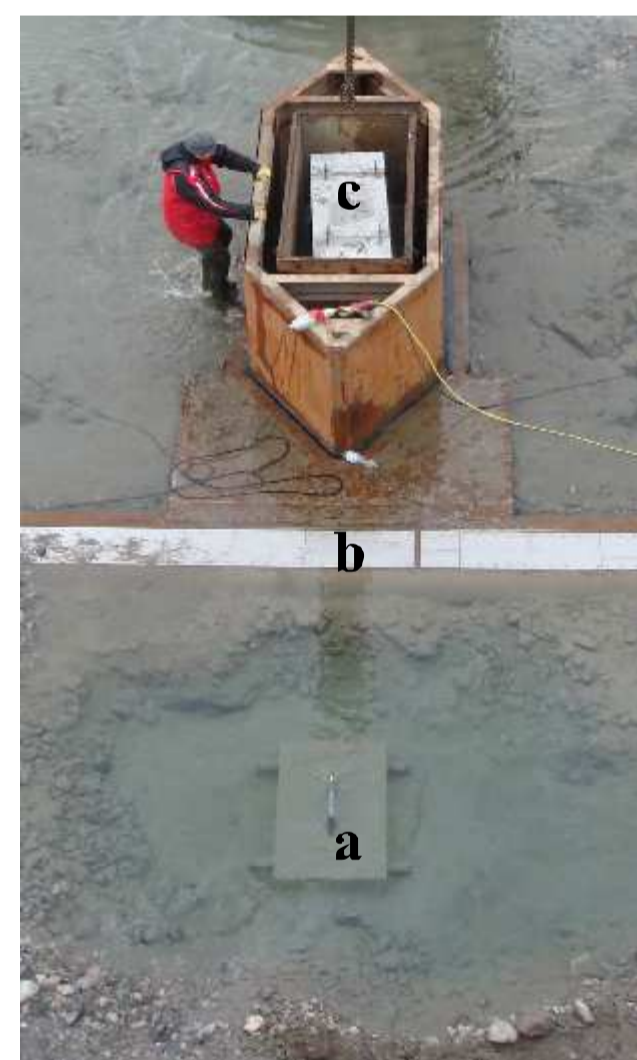


Fig. 10. Hydrophone (a) fixed on Drau River bed, in proximity to geophone 32 (b) and a liftable continuous Reid bedload slot sampler (c).

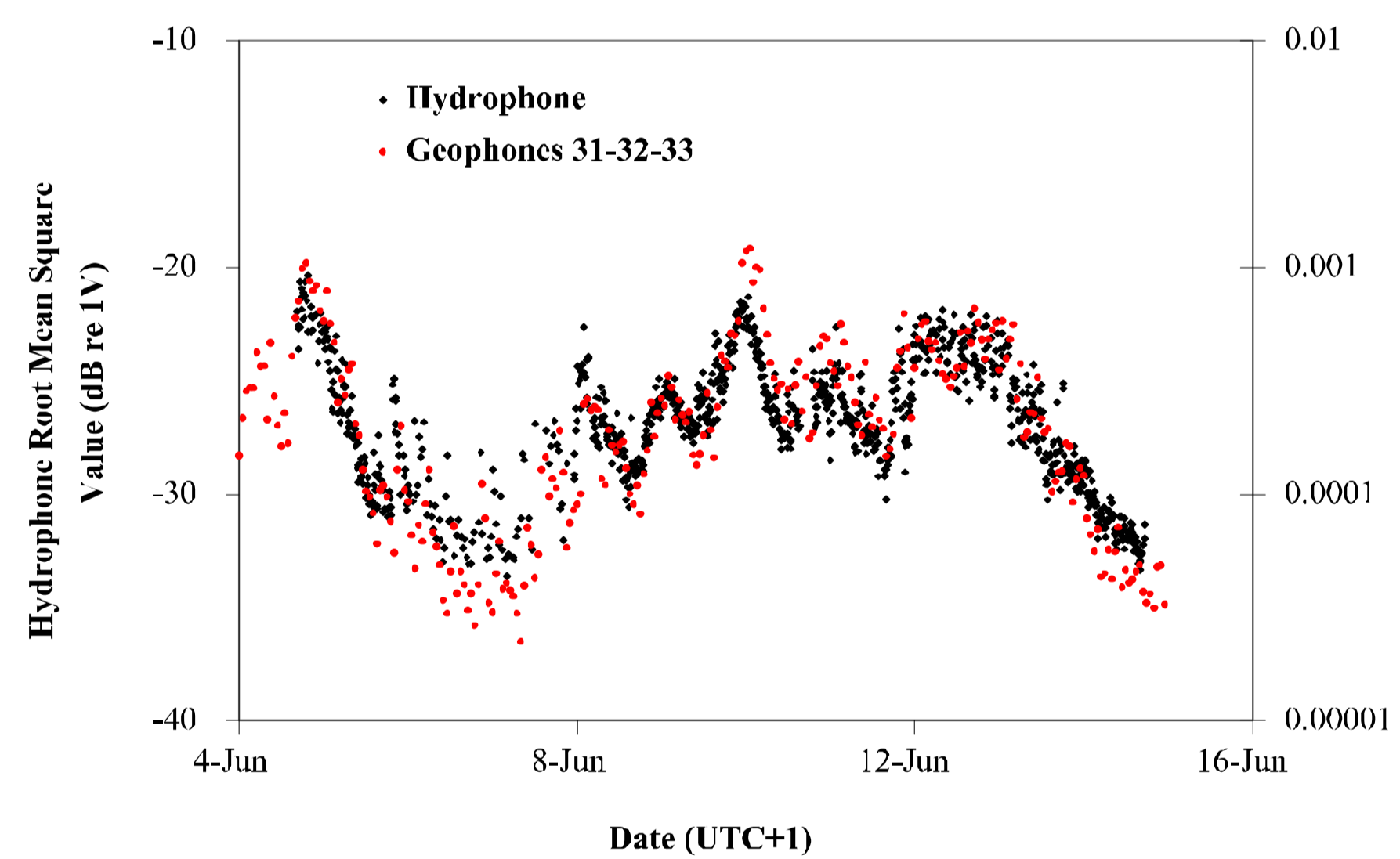


Fig. 11. Temporal variation of total acoustic power (hydrophone) and total energy averaged for the 3 nearest geophones integrated over 1 hour, June 2012.

Continuous bedload monitoring on the large gravel bed **Drau River** since 1992 includes 40 cross-sectional located geophones, 3 Reid type slot samplers and a variety of other sediment and hydrometric equipment. A fixed-bed hydrophone has recently been deployed between geophone 32 and the liftable Reid slot sampler (Fig. 10). Both the geophones and the hydrophone operate continuously (Fig. 11) and appear to correlate well (Fig. 12).

The geophone has been shown to be highly correlated to slot-based bedload fluxes (Strahlhofer, 2010).

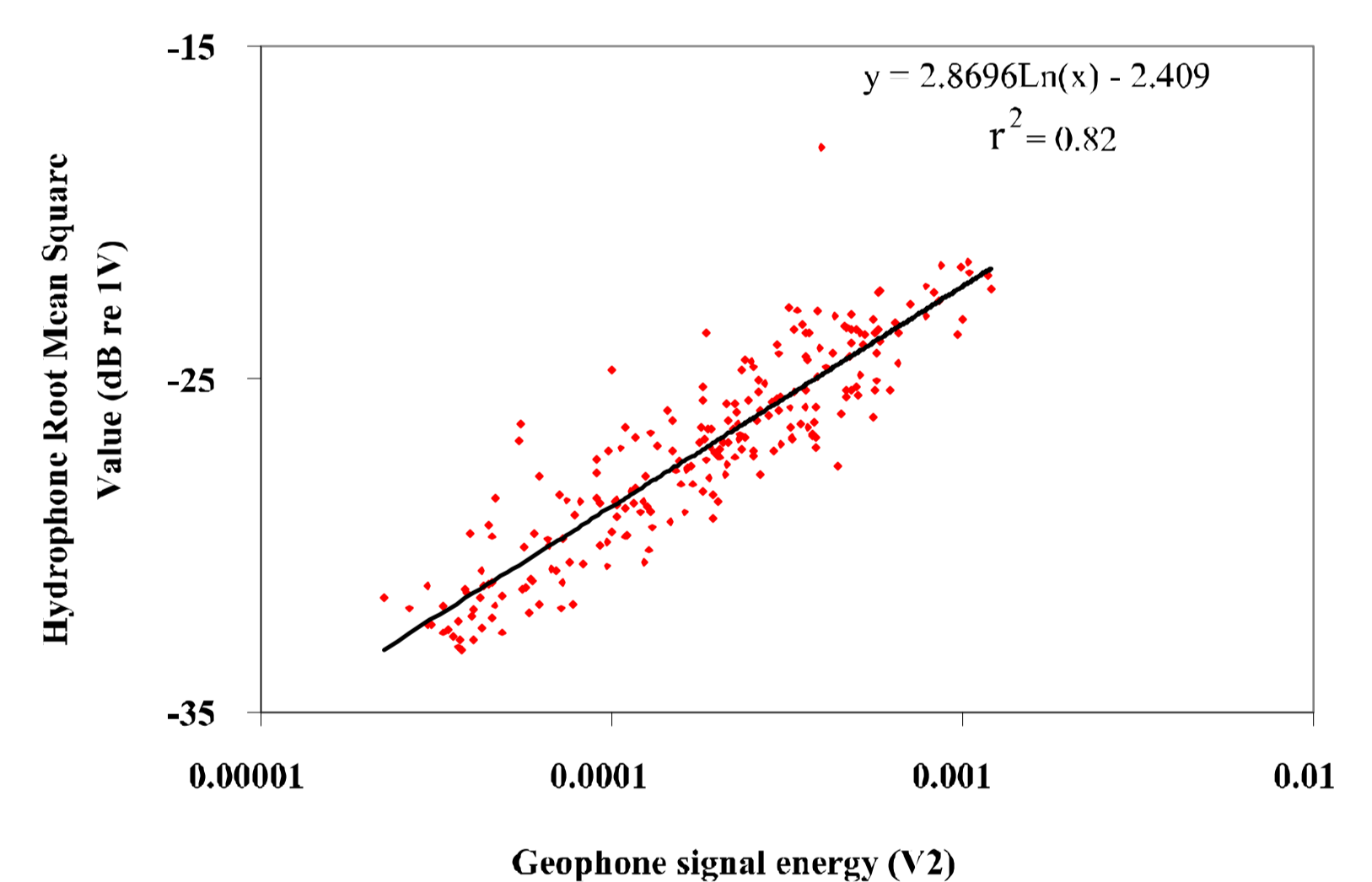


Fig. 12. Co-variation of total acoustic power (hydrophone) and total energy averaged for the 3 nearest geophones integrated over 1 hour, June 2012.

## Discussion & Summary

Because it has been shown that passive acoustic signals (Swiss geophones) due direct bedload impacts are well correlated to physically monitored bedload discharge (Rickenmann & McArdell, 2008; Lukas, 2010), our hydrophone measurements, which are highly correlated to the Drau River geophone signals, demonstrate the applicability of hydrophones for bedload monitoring in large gravel bed rivers. This proof of concept has been utilized to continuously monitor bedload under flood conditions using a fixed location hydrophone on the bank of the Arc en Maurienne River. Furthermore, initial results on the use of hydrophone to monitor low bedload discharge of fine-grained sediment in the Rhine River are promising.

Unlike monitoring of bedload transport due to direct impingement, the use of a hydrophone requires characterization of more complex acoustic signals and methods to process these. For instance, the signals arising from a bankward position differ from those monitored in mid-section. On the Arc en Maurienne, the entire frequency response differs with the bank-ward position having lower received energy; signals in mid-river are more energetic and noisy, particularly below 200 Hz (Fig. 13).

Our ongoing research involves further study of the energetic Soundscape of large gravel rivers and signal processing techniques to identify noises with the objective to filter them. A second direction is dedicated to the study of acoustic propagation processes in this environment. We expect to present results of this continuing study in the 2013 Zurich Workshop.

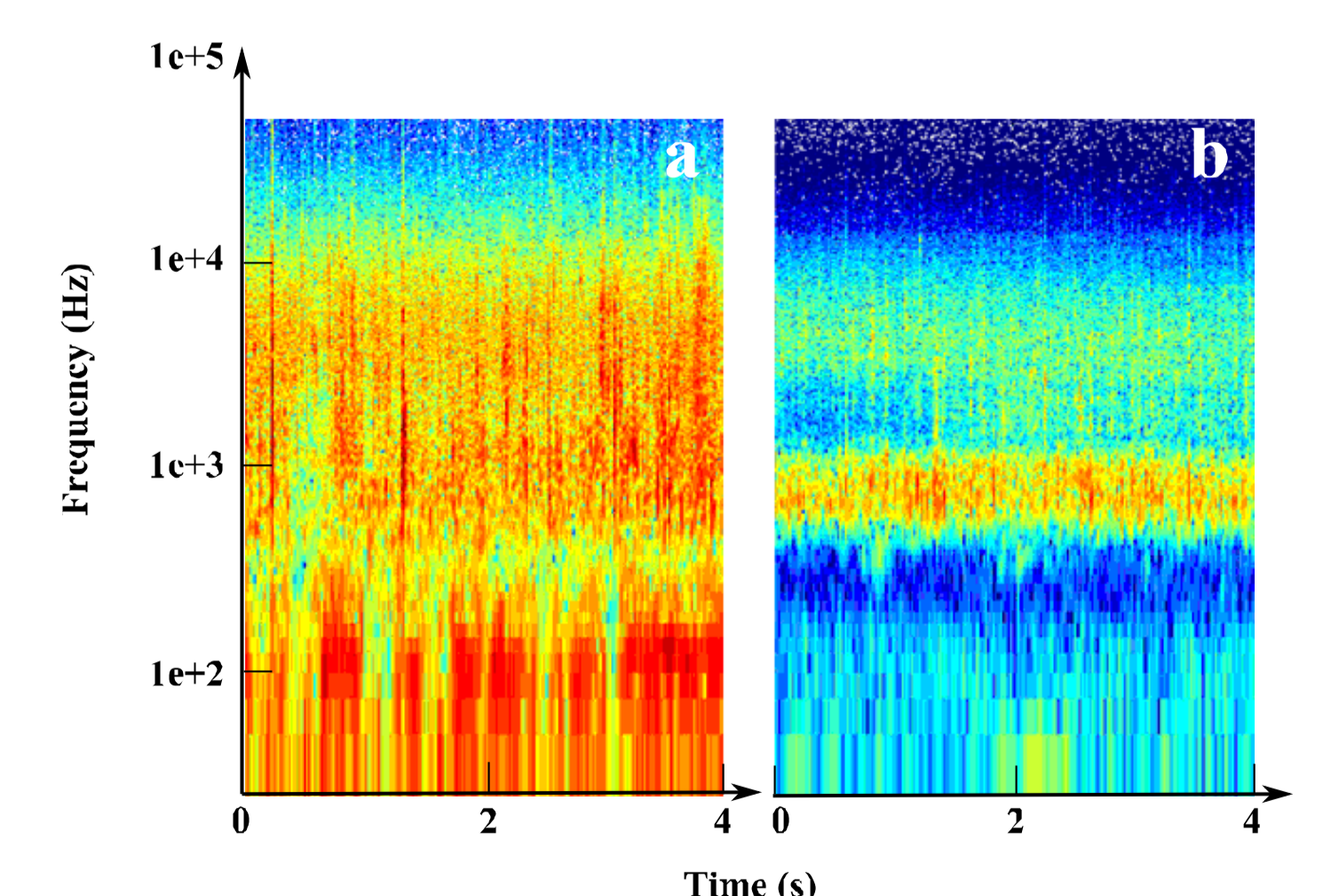


Fig. 13. Spectrograms of acoustic responses from hydrophones in Arc en Maurienne, June 2012 during flushing operation: bridge mounted (a) and fixed position bank mounted (b).

## References

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