Title : Development of innovative tools and methods for monitoring discharge in mountain rivers

Laboratory : Institut des Géosciences de l'Environnement, Grenoble

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Duration : 5 or 6 months

Level : M1 or M2

Context :

Numerous applications require the monitoring of river discharge, both in the operational field (e.g. flood and drought warning systems, water resource management, hydroelectric production) and in the academic field (e.g. hydrological modelling, fluxes of water and associated matter). However, flow monitoring is not trivial. Historically, flow monitoring has been carried out at hydrometric stations by continuously monitoring the water level and transforming the water level into discharge using the stage-discharge rating curve, which is established from a set of gaugings, possibly complemented by hydraulic modelling. This conventional approach is still the most widely used today, even though it is relatively expensive to set up and maintain over time, as it requires a lot of human resources, particularly qualified personnel for gauging and bathymetric surveys. These factors are also limiting factors nowadays as scientific and societal issues (e.g. Valencia disaster, 29/10/2024) are calling for more discharge data, particularly in small rivers of headwater catchments (<100 km²) where data is lacking and satellite remote sensing cannot provide any information.

In the case of mountain rivers, conventional hydrometric stations have other disadvantages: 1) exposure of personnel to hydrometeorological risks, 2) exposure of equipment installed in the water, which may be lost or damaged during high water, 3) morphological changes caused by erosion processes and sediment deposition in the riverbed, which modify the stage-discharge rating curve and may even render this approach inoperative if the changes are too frequent.

To overcome these limitations, we are developing a new method for monitoring discharge in mountain rivers. Our approach is based on non-contact instruments (Nord et al., 2020): fixed H-V radars to monitor water level and surface velocity at high resolution (~10 min), supplemented by imagery to measure the surface velocity field during floods (10 s video sequence every 30 min). Nord et al (under review) have shown that it is possible to establish a proportional relationship between the maximum surface velocity (Vs,max) and the mean velocity in the section, also known as the cross sectional velocity (Umean). This relationship is insensitive to morphological changes and could constitute an intrinsic property of the section. Furthermore, the location of Vs,max is stable despite morphological changes. It is therefore proposed that the surface velocity radar should be positioned vertically above Vs,max in the section of interest. Nord et al. (in revision) restrict the conditions of application of this approach to steep (> 1%) and channelled rivers, linear and uniform sections with quasi-1D velocities. The authors have also shown that it is possible to detect the precise moments of morphological change by plotting the two radar-derived variables (water level and surface velocity) against each other. A discontinuity appears in the relationship between the two variables when a morphological change occurs. A relationship can be assigned to each stable bathymetric period between the water level and the the wetted section area, on the basis of manual topo-bathymetric surveys. Ultimately, the discharge is calculated at each time step (~10 min) by multiplying the flow velocity (derived from Vs,max and therefore from the velocity radar) and the wetted section area. This method still needs to be tested against reference data to be fully validated.

If the method presented reveals effective, it will minimise the need for gauging. To further reduce the need for a field operator, it would be necessary to automate the topo-bathymetric survey of the section of interest. To date, there is no mature monitoring technique that can accomplish this task, particularly during floods. On the other hand, since base flows are generally low in steep rivers (~slope greater than 1%) outside flood periods and most of the riverbed is exposed to the air at low water, much of the topography of the section can be directly measured by techniques such as stereo LSPIV or LiDAR (Stumpf et al., 2016; Picard et al., 2019). We propose to use a LiDAR near infrared lasermeter rotated from a fixed point above the water and to progressively re-construct the topography of the emerged part of the section as the water level decreases.

As part of the Equipex + TERRA FORMA project, the IGE is developing a low-cost, low-tech, hydrometric station based on non-intrusive techniques. Off-the-shelf sensors from industry have been selected: radar for water level, radar for surface velocity and LiDAR near infrared lasermeter for topography. The specifications, technology review and purchase of the sensors have been completed. The V radar is currently being integrated on an Arduino microcontroller (Guyard et al., 2024). In addition, the LiDAR has been mounted on a rotating device to monitor the topography of the emerged part of the river section from a fixed point above the water. An initial prototype was developed and data was acquired during a test phase at the station on the Sonnant d'Uriage. This station was also used to compare different surface velocity measurement techniques (3 commercial velocity radar models, a Vortex micro-station using imagery). During the autumn of 2024, a period of testing of the 'low cost' velocity radar integrated into a 'low tech' microcontroller is underway at the Doménon station in Domène (managed by the DREAL 38) to evaluate the behaviour of this sensor for monitoring river velocities in comparison with reference measurements (commercial radar and camera).

Objectives : The objectives will be chosen from the following list in relation to the candidate:

1) Qualify the velocity data from the intercomparison carried out on the Sonnant d'Uriage.

2) Evaluate the performance of the 'low cost' radar sensor for monitoring water surface ve locities.

3) Develop a methodology for reconstructing topo-bathymetry using near infrared LiDAR based on data acquired in situ.

4) Carry out laboratory channel tests to determine the effect of water surface roughness, water thickness and turbidity on the penetration of the near infrared LiDAR signal into the water.

Required skills: As the internship is focused on the analysis of large datasets, it is necessary to be comfortable with at least one programming tool (R, Python, or MATLAB). A basic knowledge of hydrology is desirable.

Application: Send a CV and cover letter by email to the supervisors.

Bibliography:

Guyard, H., Rousseau, C., Nord, G. (2024). Station hydrométrique : un radar de vitesse de surface low-tech, Ateliers Expérimentation et Instrumentation AEI-2024, Rennes, France, 25-28 juin.

Nord, G., Michielin, Y., Biron, R., Esteves, M., Freche, G., Geay, T., et al. (2020). An autonomous low-power instrument platform for monitoring water and solid discharges in mesoscale rivers. Geoscientific Instrumentation, Methods and Data Systems, 9(1), 41–67. https://doi.org/10.5194/gi-9-41-2020.

Nord, G., Safdar, S., Hasanyar, M., Eze K.O., Biron R., Freche G., Denis H., Legout C., Hauet A., Esteves M. (in revision in Water Resources Research). Streamflow monitoring at high temporal resolution based on non-contact instruments and manually surveyed bathymetry in a river prone to bathymetric shifts.

Picard, G., Arnaud, L., Caneill, R., Lefebvre, E., & Lamare, M. (2019). Observation of the process of snow accumulation on the Antarctic Plateau by time lapse laser scanning. The Cryosphere, 13(7), 1983–1999. https://doi.org/10.5194/tc-13-1983-2019.

Stumpf, A., Augereau, E., Delacourt, C., & Bonnier, J. (2016). Photogrammetric discharge monitoring of small tropical mountain rivers : A case study at Rivière des Pluies, Réunion Island : PHOTOGRAMMETRIC DISCHARGE MONITORING. Water Resources Research, 52(6), 4550–4570. https://doi.org/10.1002/2015WR018292.