# Long term high frequency sediment observatory in an alpine catchment (Arc-Isère Rivers, French Alps)

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## Abstract

The present dataset is related to the Arc-Isère long-term environmental research part of the Rhône Basin Long Term Environmental Research Observatory. This alpine watershed located in the French Alps is characterized by high Suspended Particulate Matter (SPM) in very anthropogenized valleys. Suspended Sediment Concentrations (SSC) naturally observed in the river are very high, ranging from a few tens of milligrams per litre at low flow to tens of grams per litre during major natural hydrological events (floods, debris flows) or river dam hydraulic flushes. One research objective related to this site aims at better understanding the SSC dynamics along the river using a system of nested watersheds (Arvan, Arc, and Isère) in order to access to both temporal and spatial dynamics. Studies using this dataset are on the quantification of fine sediment fluxes but also on the related morphological changes due to fine sediment deposition or resuspension. Additionally, the observatory database can support studies on contaminants (either dissolved or particulate contaminant). Six hydro sedimentary stations monitor SSC with high frequency via turbidity sensors associated to automatic samplers. Discharge is measured via classical water level measurements and a rating curve. The oldest station (Grenoble-campus) started recording data from 2006 while others hydro-sedimentary stations were built from 2009 to 2011. Data are available in an online data website called “Base de Données des Observatoires en Hydrologie" (Hydrological observatory database, https://bdoh.irstea.fr/ARC-ISERE/) with DOI references for each site. The hydrological and sediment transport time series are stored, managed and made available to a wide community in order to be used at their full extent. This database is used as a data exchange tool for both scientists and operational end-users and as an online tool to compute integrated fluxes.

Keywords: long term observatory; database; suspended sediment concentration; turbidity, water discharge, sediment fluxes, Alpine rivers.

## Objectives and site description

The Arc-Isère observatory is located in the French Alps in the eastern part of France (longitude 5.7689497 / latitude 45.1974416). These alpine rivers carry large amounts of fine sediments, typically yielded by erosive badland sub-catchments such as in the Arvan river system. The bed river sediment material consists of a mixture of coarse (gravel and cobble) and fine (sand, silt and clay) particles that can interact together. The Arc and Isère rivers were significantly modified due to anthropogenic changes such as dykes linked to the construction of motorways and railways, numerous hydroelectric infrastructures (diversions, dams), and river mining. It resulted in the formation of system of alternate gravel bars within a constraint river (Jaballah et al., 2015). Anthropogenic modifications such as mountain land restoration works, regression of pastoralism activities, infrastructure constructions (levees, groynes, bridges, etc.), dam management activities or sediment mining significantly modified the relative quantity of the different types of transported sediments. Nowadays, there is a general lack of coarse particle input, and so a relative excess of fine particles. The resulting unbalanced system led to an erosion of the main channel, an aggradation and fixation of gravel bars due to massive fine sediment deposits and riparian vegetation growth (Jourdain et al., 2020);

Main scientific objectives linked to this river system are related to:

- The characterization of deposition and erosion of fine sediments over gravel bars along alpine rivers;
- The assessment of the exchanges of fine sediments between flow and bed matrix (infiltration, exfiltration);
- The understanding of the spatial and temporal variations of fine sediment transport including sand in the river system;

- The quantification of the forcing effects of bar morphology, hydrology, sediment supply, riparian vegetation on fine sediment dynamics
- The study of the particulate dynamics contaminants

The Arc-Isère river system is a reference site of the ZABR (Zone Atelier du Bassin du Rhône [Rhône Basin Long Term Environmental Research Observatory], http://www.graie.org/zabr/index.htm that has been monitored for more than 15 years (Mano et al., 2009; Némery et al., 2013; Antoine et al., 2020). Six hydro-sedimentary stations (see Figure 1) have been set in a system of nested watersheds (Arvan, Arc and Isère watersheds), and produce continuous data for both water discharge and sediment concentration (operated by INRAE, IGE). The network is completed by stations operated by operational partners (EDF, DREAL Rhône-Alpes Auvergne). All the actors work in synergy, for example in choosing the location of the stations, in order to better investigate the whole watershed.

The three rivers have distinct characteristics (see Table 1): the Arvan River is a steep mountain torrent, very responsive to precipitation and events in its watershed including daily snow melt. The Arc River is a mountain river with an average slope of 1% where we can find several river dams. Regular dam flushes are operated (yearly if no significant flood occurs), that deeply affects sediment transport. Lastly, the Isère River is a larger piedmont river where gravel bars are affected by vegetation spreading, and so where flood risk is a significant issue. The Arc and the Arvan watersheds are very erosive yielding a significant production of suspended particulate matter (SPM), which is transported along the river system and can possibly settle temporarily over gravel bars or within dam reservoirs.

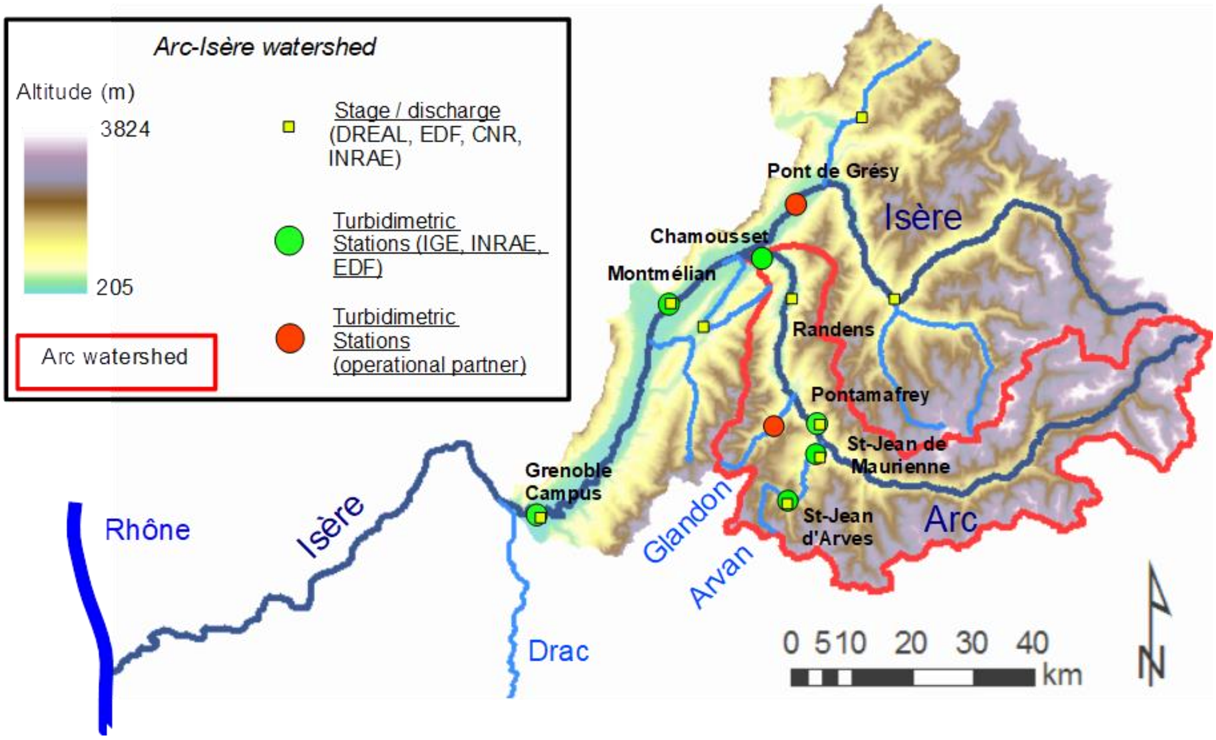


*Figure 1 : Location of hydro-sedimentary stations on Arc – Isère watershed*

Table 1: Suspended sediment fluxes (SSF) on the Arc-Isère watershed (https://dx.doi.org/10.17180/OBS.ARC-ISERE)

| **Station / river** | **Start year** | **Watershed area (km²)** | **Annual average SSF (kt)** | **Specific SSF (t/km²)** |
|---|---|---|---|---|
| Saint Jean d'Arves / Arvan | 2010 | 58 | 50.3 | 867 |
| St Jean de Maurienne/ Arvan | 2009 | 222 | 250 | 1126 |
| Pontamafrey / Arc | 2009 | 1510 | 515 † | 341 † |
| Chamousset / Arc | 2011 | 2000 | 1200 † | 600 † |
| Montmélian / Isère | 2010 | 4840 | 1500 | 310 |
| Grenoble - Campus / Isère | 2006 | 5720 | 1440 | 251 |

† Because of hydropower plants and water diversions, fluxes at Pontamafrey and at Chamousset are underevaluated and overevaluated, respectively.

Description of hydro-sedimentary stations

Water discharge and suspended sediment concentrations (SSC) are measured on each station. Data are recorded with time steps varying from two to thirty minutes. Times steps are adapted to accurately describe natural variations of these parameters.

Continuous flow rates are obtained from a water level measurement recorded continuously on a datalogger. Using different gauging methods on each station (see Table 2), rating curve are built applying either a classical stage/discharge relation or the index velocity method coupling to a stage/area relation with an average velocity (Thollet et al., 2017). Additional gaugings are regularly done to complete and check the rating curves.

Table 2: Main characteristics on flow discharge measurements

| Station / river | Frequency (min) | Range (min-max in $m^3/s$) | Owner | Technology | Gauging methods | Data availability / percentage |
|---|---|---|---|---|---|---|
| Saint Jean d'Arves ‡ / Arvan | 6 | 0.4-35 | DREAL Rhône-Alpes | Pressure and Radar sensors. Video measurements for flood events | Current meter, water surface velocity with radar | 2010-2015 93% |
| St Jean de Maurienne/ Arvan | 2 | 0.2-80 | INRAE | Stage & velocity radar sensors Sommer RQ24 | Current meter, water surface velocity with radar | 2010-2018 73% |
| Pontamafrey / Arc | 6 | 1.6-356 | EDF | Pressure sensor Hydrologic LPN8 | Current meter, ADCP | 2011-2020 97% |
| Chamousset / Arc | 6 | 2.6-427 | DREAL Rhône-Alpes | Stage & velocity radar sensors Sommer RQ30 | Gauging truck, ADCP, water surface velocity with radar | 2011-2019 98% |
| Montmélian / Isère | 6 | 26-780 | DREAL Rhône-Alpes | Pressure sensor | Gauging truck, ADCP | 2009-2015 ‡‡ 99% |
| Grenoble – Campus / Isère | 30 | 33-866 | IGE & EDF | Pressure sensor OTT PLS 0-10 m | Gauging via cableways, ADCP | 2005-2019 99% |

‡ The station moved 5 km upstream in 2019 because of the installation of a new hydraulic power station

‡‡ Only water level from 2015 to 2019. Flow discharge will be soon available for 2020.

SSC is measured indirectly from a turbidimeter signal (see Table 3). Hach Lange SC100 or SC200 transmitters are used in addition with numerical Solitax SC probes, all equipped with mechanical cleaning system (wiper). The sensor uses the infrared scattered light method but the answer of an optical turbidimeter signal depends on sediment characteristics in the water. Therefore, it is necessary for each site and each sensor to establish a calibration curve linking turbidity to SSC on a large range of concentrations. The relation SSC = f(turbidity) is always linear with a single segment. This is done by sampling water with ISCO 3700 or Sigma SD900 automatic samplers controlled by the turbidimeter or to the datalogger. Each sample is then vacuum-filtered at the laboratory to determine SCC (Standard NF EN 872, ISO 4365, 2005); a special attention was recently made to exclude sands from the analysis (Dramais et al., 2018).

Scientific questions of the Arc-Isère Observatory being mostly oriented towards suspended sediment fluxes, a particular effort has been made into quantifying uncertainties of turbidimetric measurement and associated variables. Taking into account the error of the sensor, the calibration curve and the samples analysis, uncertainties on high frequency SSC data series are very variable, generally between 10 to 20% (Navratil et al, 2011; Arnaud et al 2013). More precisely, on the Isère River calculated uncertainties reach 20% for SSC below 1 g/L and 8% for SSC above 2 g/L (Némery et al 2010). Because the turbidimeter is sensitive to the variation in size of suspended particles (Thollet, 2014), the established relationship turbidity/SSC can be very unstable for stations that are relatively close to sediment production areas, for example on the Arvan River or on the Arc River at Pontamafrey. We also observed on these stations a seasonal effect according to hydrological event types (storm events, snow melt, flood events, low water discharges). At Pontamafrey, depending on the event type, the coefficient varies between 0.8 and 1.6. In contrast, on the Isère River at Grenoble, the grain sorting through to the flow propagation yields a more stable grain size distribution and so a more stable relationship.

Table 3: Main characteristics on sedimentary measurements

| **Station / river** | Frequency (min) | Range (min-max in g/L) | Owner | Technology (Turbidimeter – Datalogger – Sampler) | Data availability / percentage |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Saint Jean d'Arves‡ / Arvan | 2 | 0-114 | INRAE | Hach Lange SC100 & Solitax 0-150 g/L – Ott Duosens – Automatic sampler Sigma SD900 | 2010-2020 53% |
| St Jean de Maurienne/ Arvan | 2 | 0-132 | INRAE | Hach Lange SC100 & Solitax 0-150 g/L – Ott Logosens– Automatic sampler Sigma SD900 | 2009-2018 76% |
| Pontamafrey / Arc | 2 | 0-137.6 | INRAE / EDF | Hach Lange SC100 & Solitax 0-150 g/L – Ott NetDL- Automatic sampler ISCO 3700 | 2009-2020 95% |
| Chamousset / Arc | 2 | 0-83.5 | INRAE / EDF | Hach Lange SC100 & Solitax 0-150 g/L – Ott NetDL - Automatic sampler ISCO 3700 | 2011-2020 91% |
| Montmélian / Isère | 60 | 0-31.4 | EDF | Hach Lange SC100 & Solitax 0-50 g/L – Ott NetDL - Automatic sampler ISCO 3700 | 2009-2019 67% |
| Grenoble - Campus / Isère | 30 | 0-46.9 | IGE / EDF | Hach Lange SC200 & Solitax 0-50 g/L - Campbell Scientific CR1000 - Automatic sampler ISCO 3700 | 2006-2019 99% |

‡ The turbidity sensor at Arvan amont is wintered to prevent from freezing. Only 1/2 of the year is taken into account. Winter flows are assumed to be negligible.

Data processing and online storage

Raw data is processed manually and individually for each station, using specific softwares from French hydrometric services, spreadsheets and homemade R programs. The expertise consists of suppressing duplicated data, correcting data drifts, deleting aberrant points, identifying data lacks, etc. It takes into account all the observations (maintenances and events which could affect the data values, level control points by reading on staff gauge) made by technical staff and written in a follow-up notebook every time they come to the station. A quality level code is associated to each data values. It aims at helping end users to better understand the accuracy of the dataset related to the metrology and the corrections made during the data processing. The possible values for quality codes are valid, doubtful, estimated, no code (because of no traceability for example) and for the case of no data the code is either gap (no measurement) or invalid (irrelevant measurement that was removed).

The time series are made available on a public online database, available in French and English, named "Base de Données des Observatoires en Hydrologie (BDOH)" (Branger et al, 2014) for Database of Hydrologic observatories (https://bdoh.irstea.fr/ARC-ISERE/) with a DOI reference

(10.17180/OBS.ARC-ISERE). This database gives access to homogeneous data that can be used by all scientists and it provides to the public a large view on what is done on the observatory. BDOH features data-management oriented functionalities, such as detection of duplicate or inconsistent data, rating curve management for stage to flow discharge or turbidity to SCC conversions, automatic calculations of derived data including integrated fluxes and reporting tools. For all users, functionalities include time-series visualization with color distinction to take into account quality codes, stations and parameters technical specifications. Identified users can select and freely download the data they are interested in with functionalities like time step interpolations, average calculation and so on. Data are exported as flat text files that contain all the necessary metadata (producer, variable, unit, time zone, conversion laws) and can be processed by any software (Excel, R, Matlab, etc).

Currently 37 users are identified on the Arc-Isère observatory and since the database was created in 2013, an average of 70 downloads is made every year for scientific and operational end-users works using these data.

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