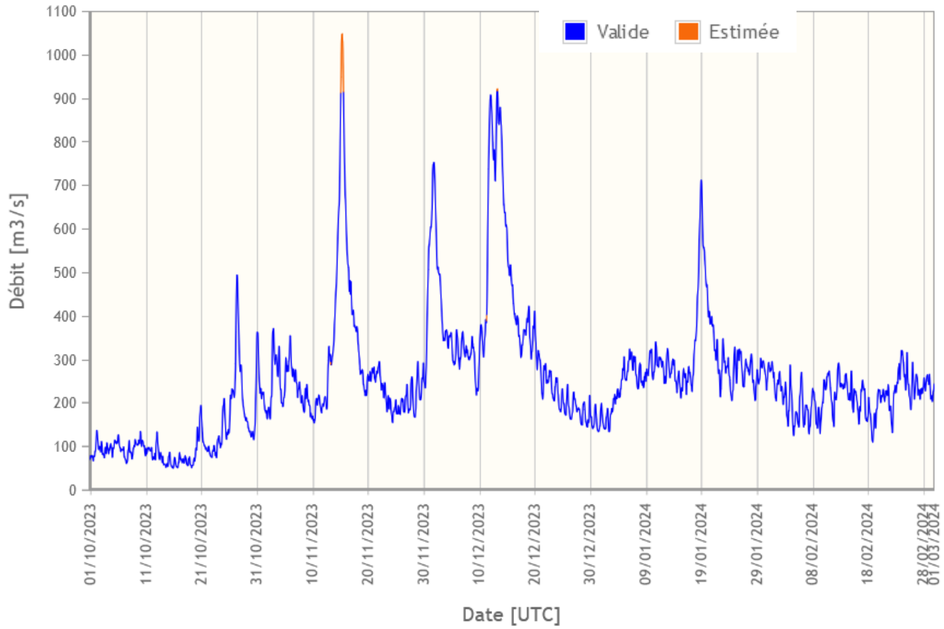
New rating curve for the Isère River at Grenoble-Campus: using in-situ measurements in a Bayesian approach

Séminaire IGE - 6/12/24 - A. Hauet & C. Rousseau

16/11/23 ADCP gauging at Grenoble-Campus station



Discharge time-serie of the Isère at Grenoble-campus autumn - winter 2023-2024. Source : BDOH

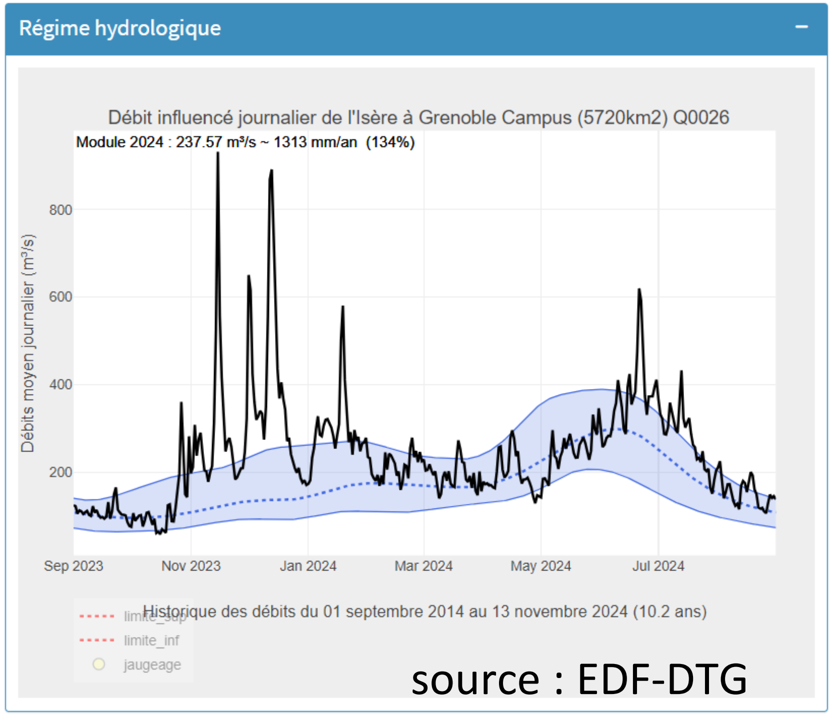
New rating curve for the Isère River at Grenoble-Campus: using in-situ measurements in a Bayesian approach

Outline

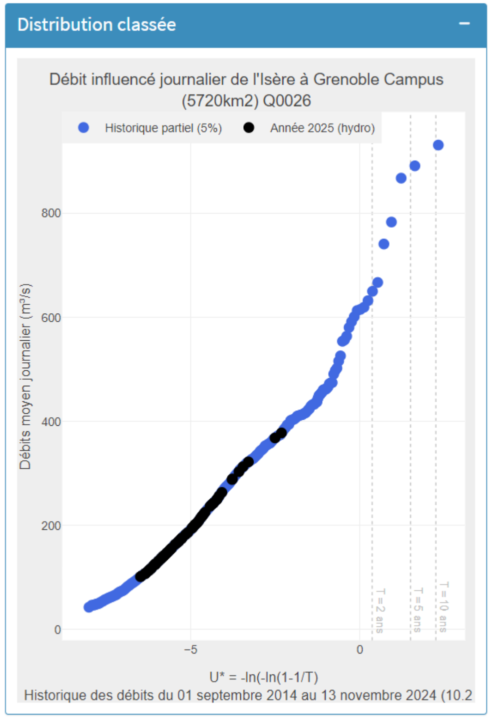
- Discharge time-series : for who and for what ?
- Establishing streamflow series & Stage-Discharge rating curves
- Grenoble-Campus station
- Problem encountered following the floods of winter 2023-2024
- Rating-curve using BaRatin
- Application to Isère at Grenoble-Campus station : data and hydraulic modelling
- Analysis of the new curve
- Conclusions and Perspectives

Discharge time-series : for who and for what ?

- Continuous time-series of discharge Q(t) are needed for a lot of applications
  - Computation descriptive statistics of the water resource
    - Mean annual flow, flow regime, return-period of events…
    - To define a regulatory framework for water uses → Environmental flow downstream dams > 1/20th of the mean-annual flow
    - Sizing of structures → embankment dams must resist to a 10,000 years return period flood



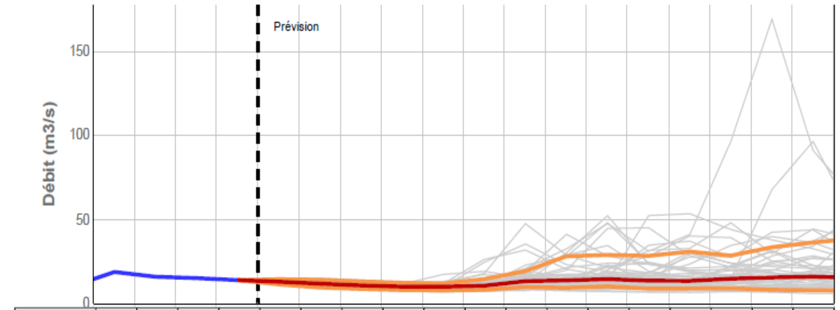
source : EDF-DTG



Discharge time-series : for who and for what ?

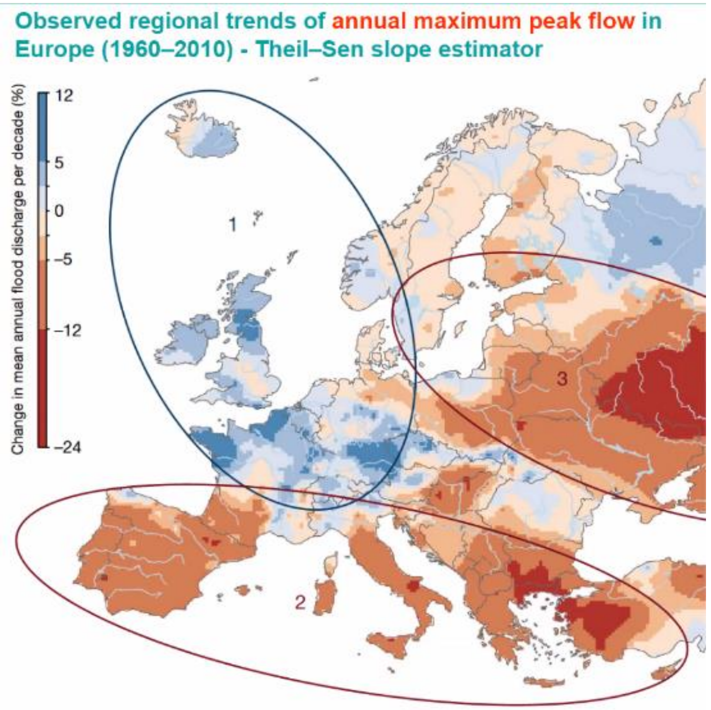
- Continuous time-series of discharge Q(t) are needed for a lot of applications
  - Calibration / validation of hydrological models
    - Forecasting models for warning of floods or droughts
    - Optimization of the production of electricity
    - Study of the impact of climate-change

☑ **Prévisions probabilistes de débits journaliers** source : EDF-DTG



Q (m³/s)	dim 10/11	lun 11/11	mar 12/11	mer 13/11	jeu 14/11	ven 15/11	sam 16/11	dim 17/11	lun 18/11	mar 19/11	mer 20/11	jeu 21/11	ven 22/11	sam 23/11	dim 24/11	lun 25/11	mar 26/11	mer 27/11
Q10	-	-	-	-	11	9.3	8.4	7.8	7.6	7.9	9.6	9.1	10	8.6	8.7	8.8	7.9	7.6
Qobs/Qexp	19	16	15	14	13	12	11	9.8	9.7	10	13	14	14	13	13	14	15	16
Q90	-	-	-	-	14	14	13	12	12	14	19	28	29	28	31	28	33	36

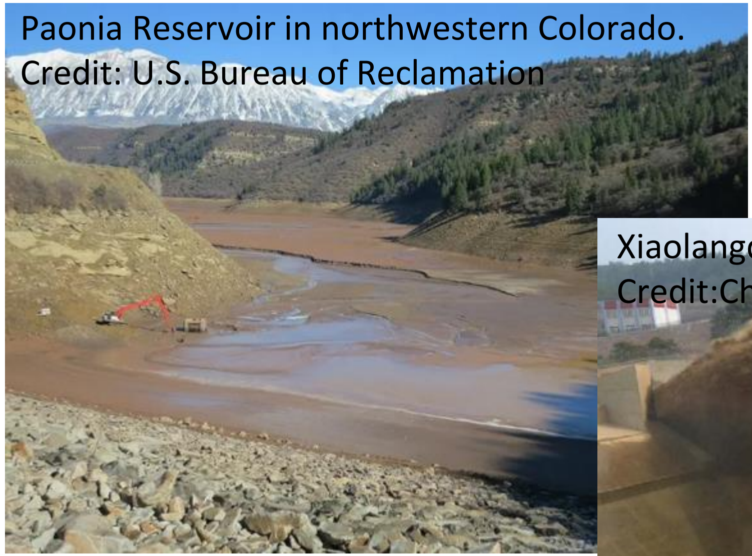
Damaged cars are seen along a road on the outskirts of Valencia on October 31, 2024. Eva Manez/Reuters



Blöschl *et al.*, *Nature* (2019)

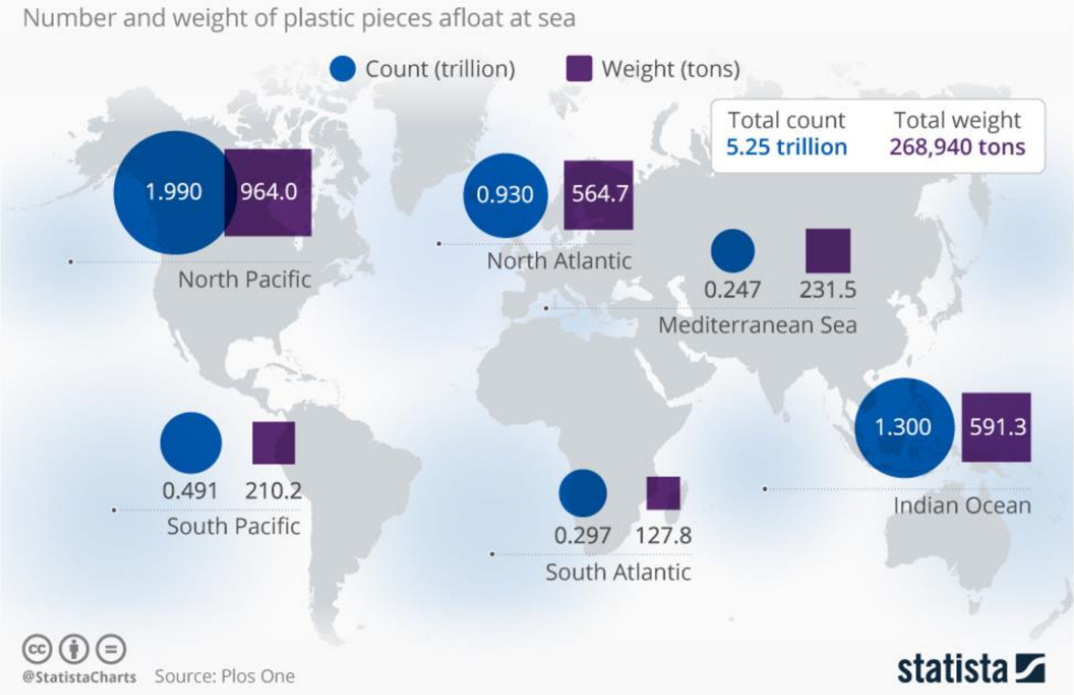
Discharge time-series : for who and for what ?

- Continuous time-series of discharge Q(t) are needed for a lot of applications
  - Computation of the watershed fluxes
    - Sediment
    - Nutriments, contaminants, plastics…



Paonia Reservoir in northwestern Colorado.
Credit: U.S. Bureau of Reclamation

Xiaolangdi Dam on China’s Yellow River.
Credit:China Photo Press.

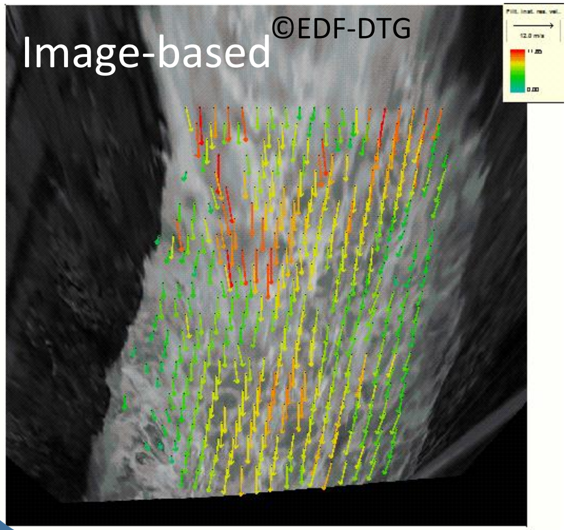


Establishing streamflow series

- Punctual measurement of discharge can be realized
  - So-called “gaugings”
  - A large variety of gauging methods

Intrusive methods

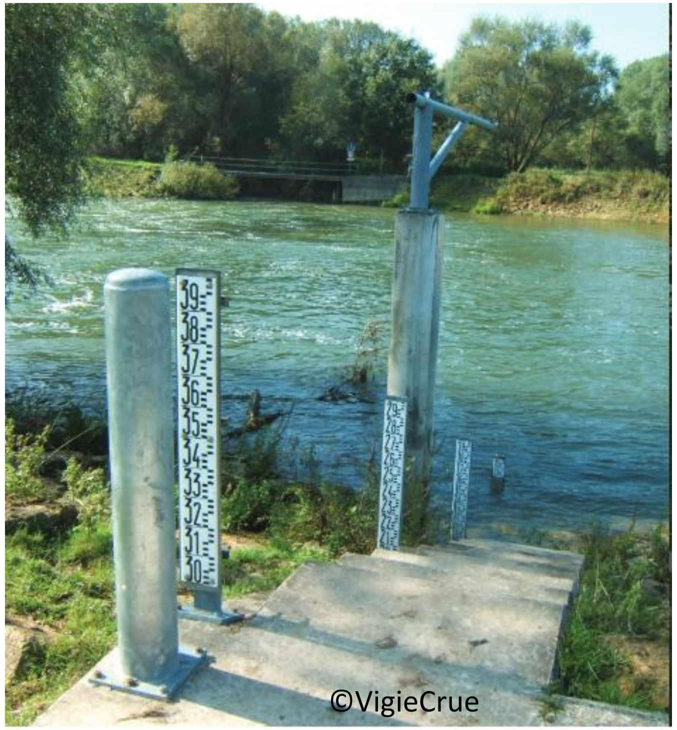
Non-intrusive methods

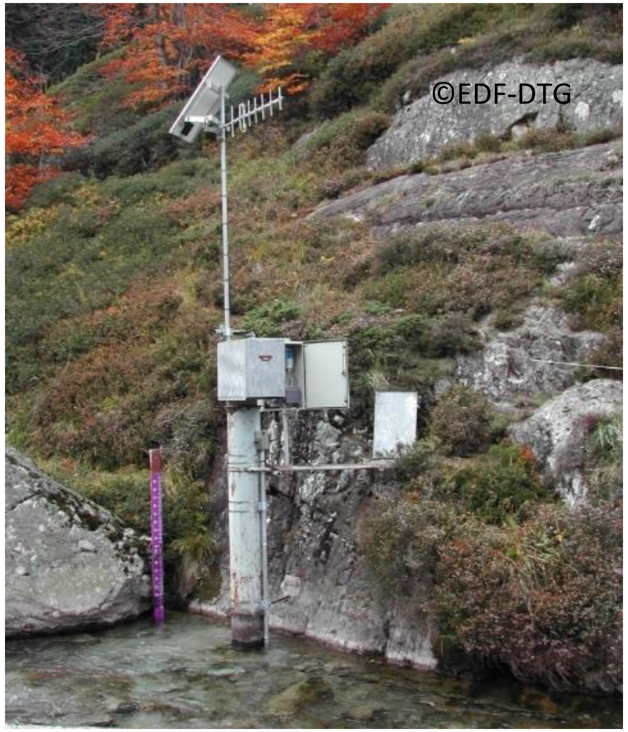


Establishing streamflow series

- Discharge cannot be directly measured continuously and in real-time
- Idea:
  1. Measuring a parameter
     - Which is a good proxy of the discharge
     - Easy to measure precisely, in real time and continuously

  } Water stage (h) !



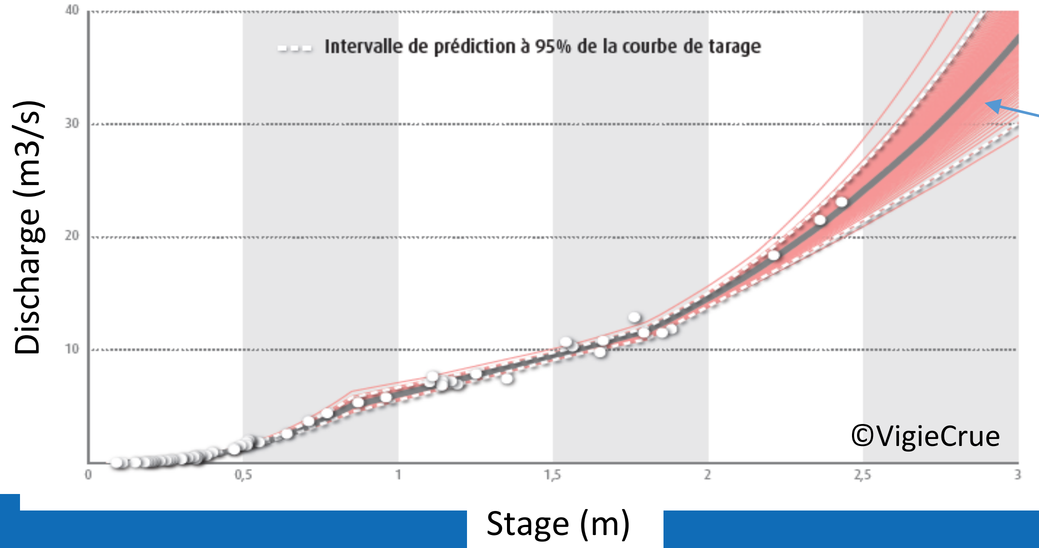


Establishing streamflow series

- Discharge cannot be directly measured continuously and in real-time
- Idea:
  1. Measuring a parameter
     - Which is a good proxy of the discharge
     - Easy to measure precisely, in real time and continuously

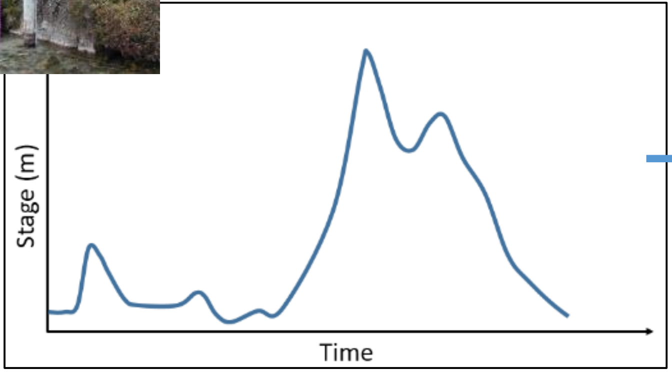
     → Water stage (h) !
  2. Computing the discharge from the water stage $Q = f(h)$
     - Using a hydraulic model of varying complexity
     - Calibrated on a set of gaugings for a large range of h/Q

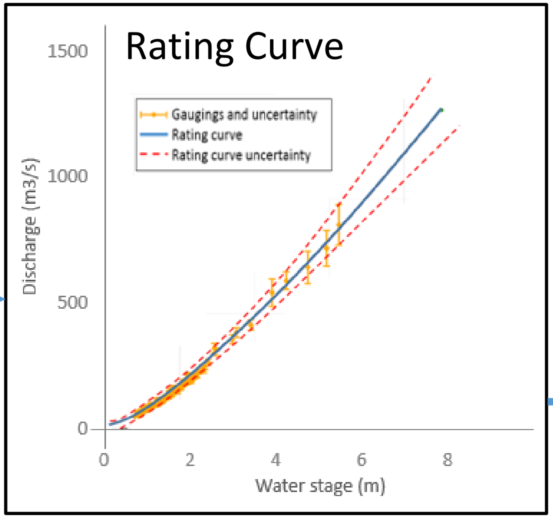
     → Rating curve → stage-discharge relationship



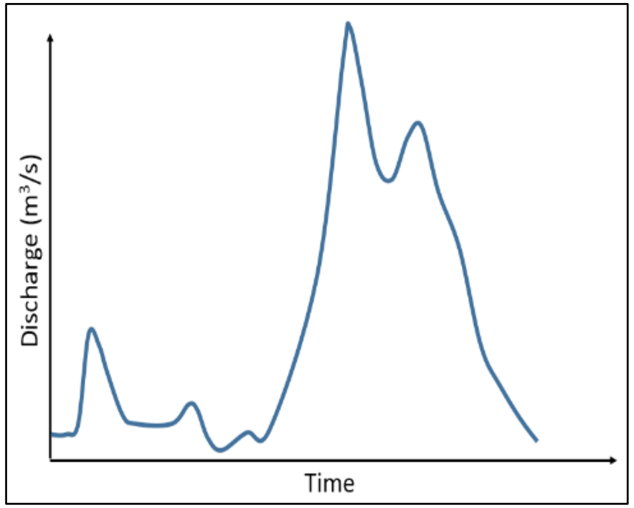
Establishing streamflow series

Continuous measurement of water stage





Streamflow time serie



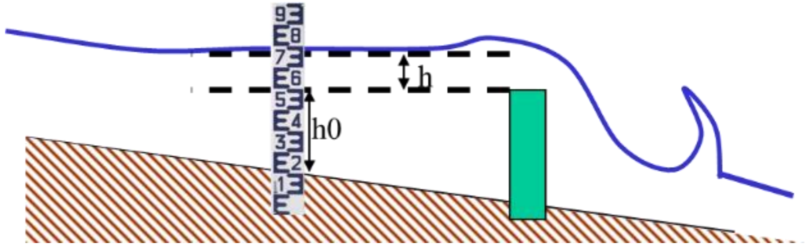
Gaugings

Stage-Discharge rating curves

- **Hydraulic controls** shape the rating curve
  - Physical properties of a channel which determine the relationship between stage and discharge at a location in the channel (World Meteorological Organization, 2012)

Section control

- Natural or artificial geometric singularity → Fall (critical flow)
- Upstream water level ~ horizontal
- Torricelli → $Q = \mu * B * h * \sqrt{2gh}$ → $Q = a * h^{3/2}$

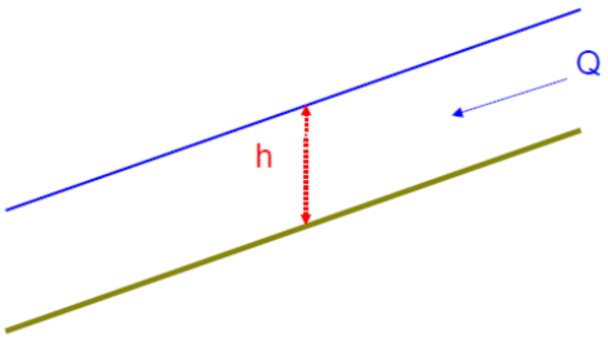


Stage-Discharge rating curves

- **Hydraulic controls** shape the rating curve
  - Physical properties of a channel which determine the relationship between stage and discharge at a location in the channel (World Meteorological Organization, 2012)

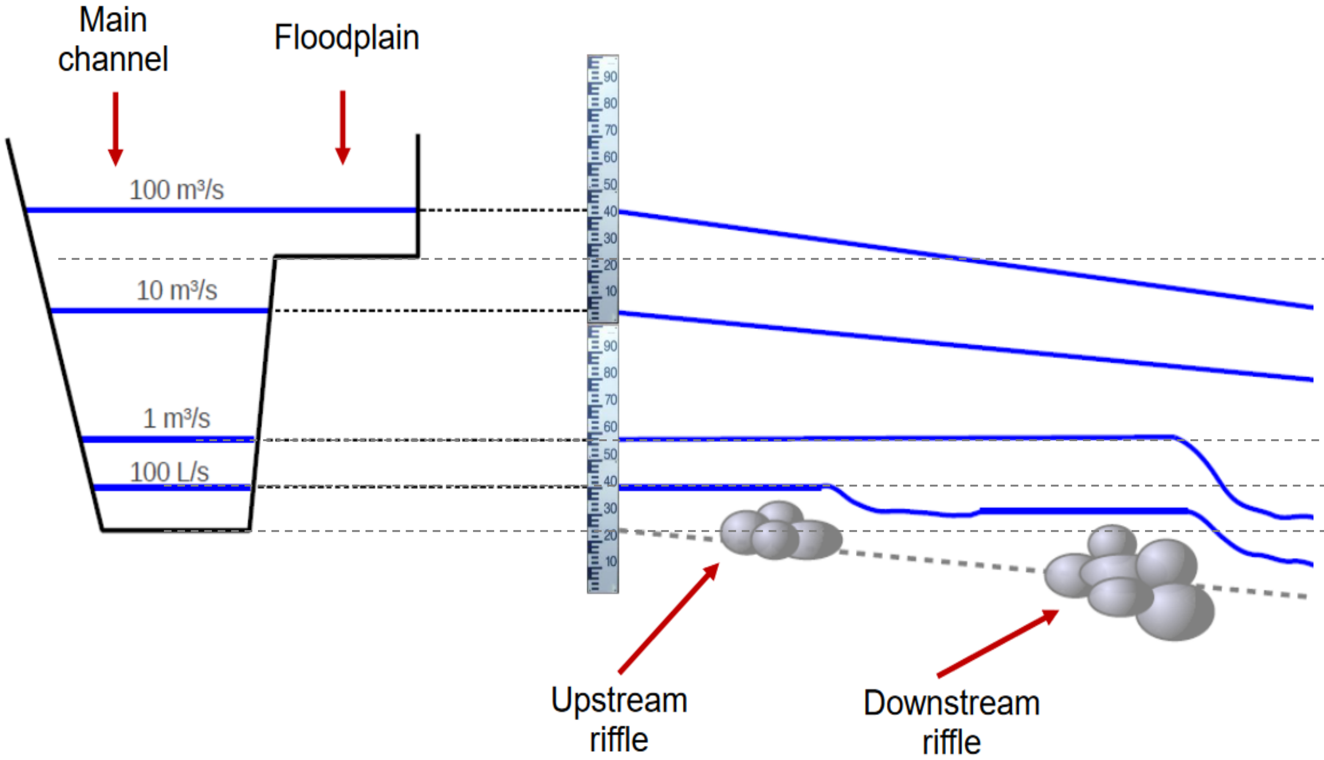
Channel control

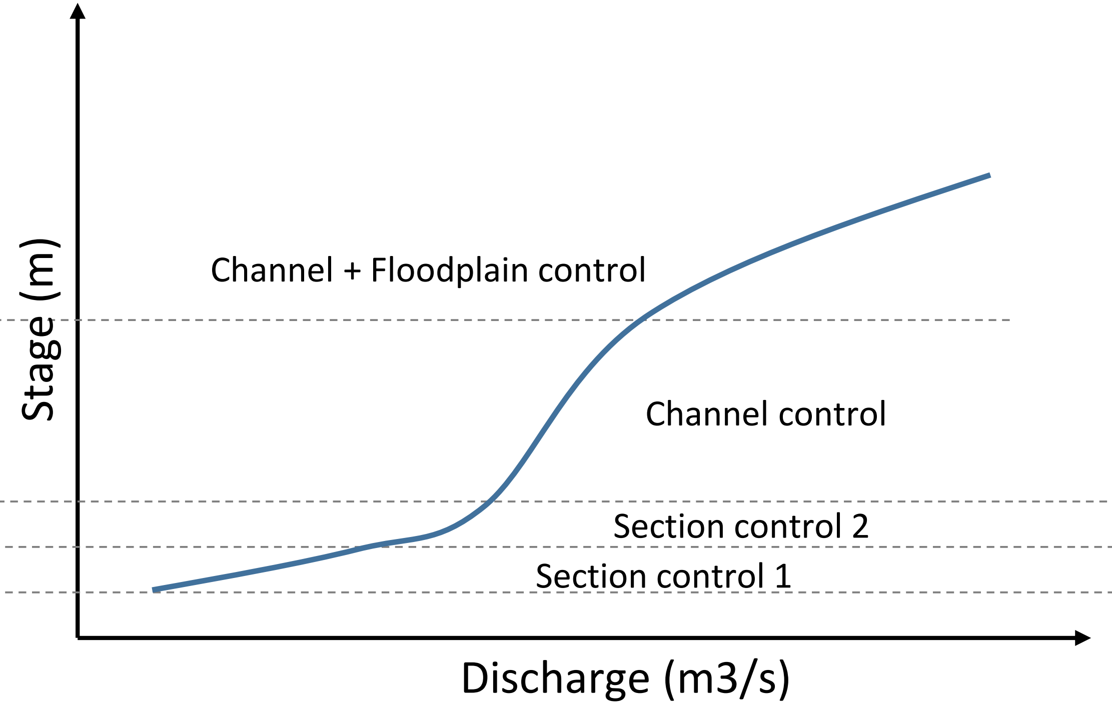
- Quasi steady and uniform flow
- Water level ≈ parallel to the riverbed
- Manning-Strickler → $Q = KAR_h^{2/3}S_f^{1/2}$ → $Q = a * h^{5/3}$



Stage-Discharge rating curves

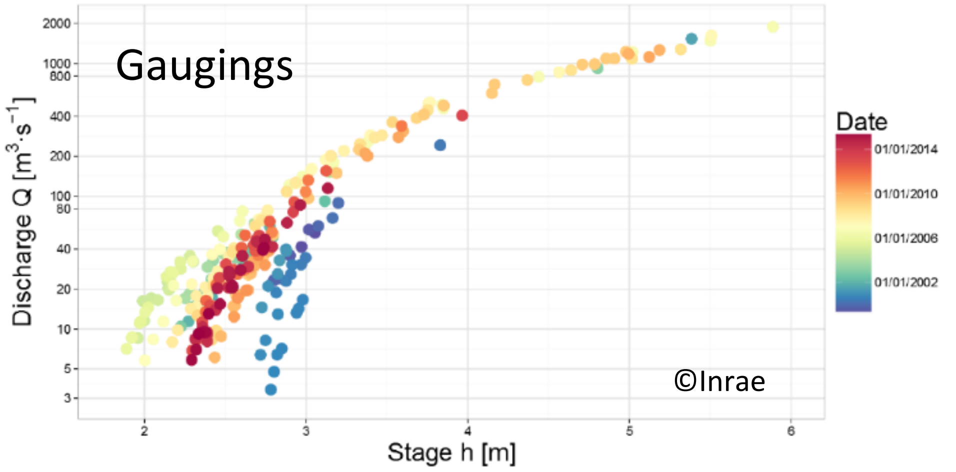
- **Hydraulic controls** shape the rating curve
  - Depending on the water level, differing controls may appear or disappear
  - Several controls may add up



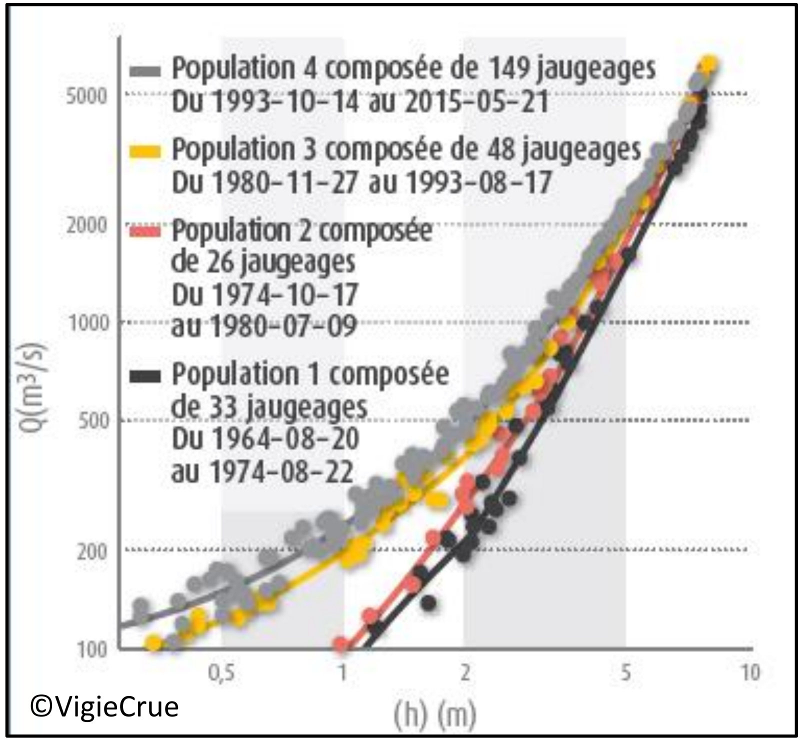


Stage-Discharge rating curves

- **Hydraulic controls** shape the rating curve
  - Change in the morphology of the control → rating-curve shift
  - Management of temporal variability by a succession of “static” rating curves
    - Supposed to represent a state of hydraulic control over a given period

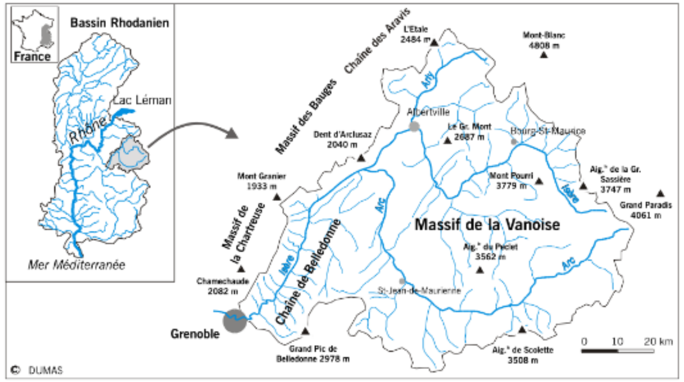


The Wairau River at Barnett’s Bank, New Zealand

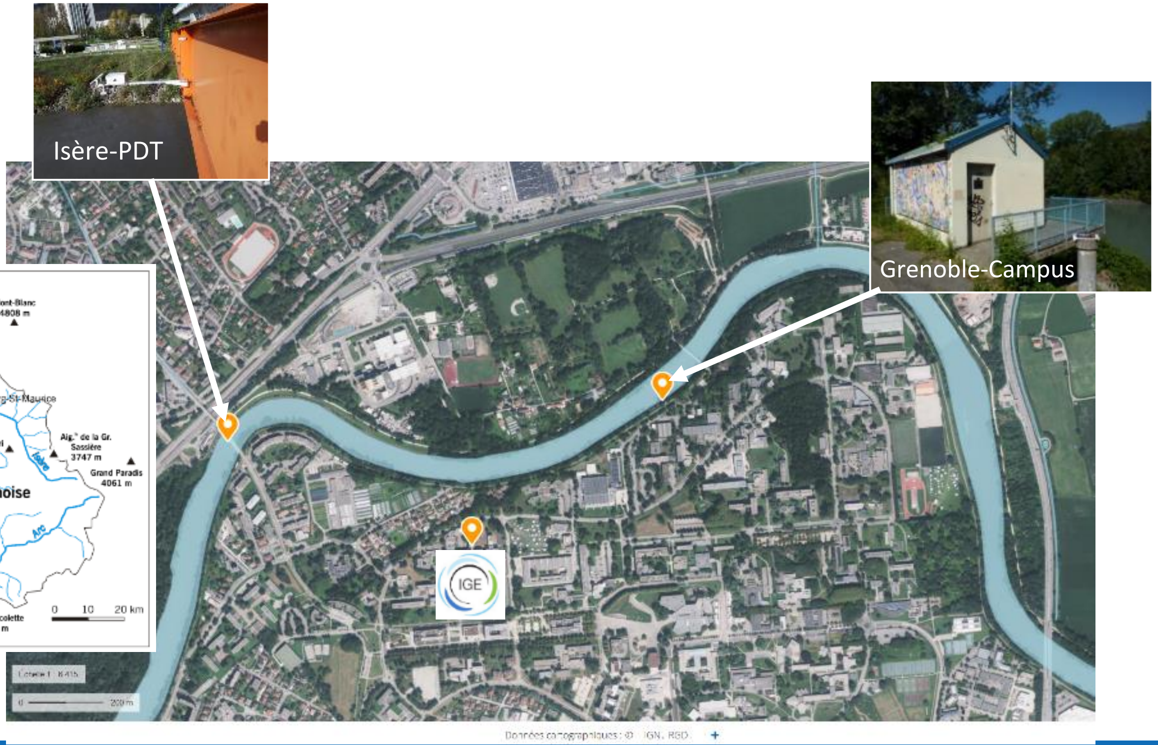


Grenoble-Campus station

- Commissioning in 1992, funding by EDF, Grenoble-INP ENSHMG P. Bois (now ENSE3), Pôle Grenoblois d'Etudes et de Recherche sur les Risques Naturels (PGRN, now PARN).
- Location : Grenoble campus, Gières, France
- Manager : Grenoble INP Ense3, Obs-Eau platform (Ense3, Phitem, IGE)
  - Scientific manager : Julien Némery / Technical manager : Christophe Rousseau, with the help of IGE technical department (ST)
- Attachment : ZABR Arc-Isère
- River concerned: Isère river, tributary of the Rhône
- Watershed at Grenoble-campus :
  - Area : 5570 km², 70% at more than 1000 m altitude
  - Main tributaries : Arc and Arly
  - mean annual discharge : 175 m³/s
  - Significant influence of human activities (hydroelectric dams, dikes)

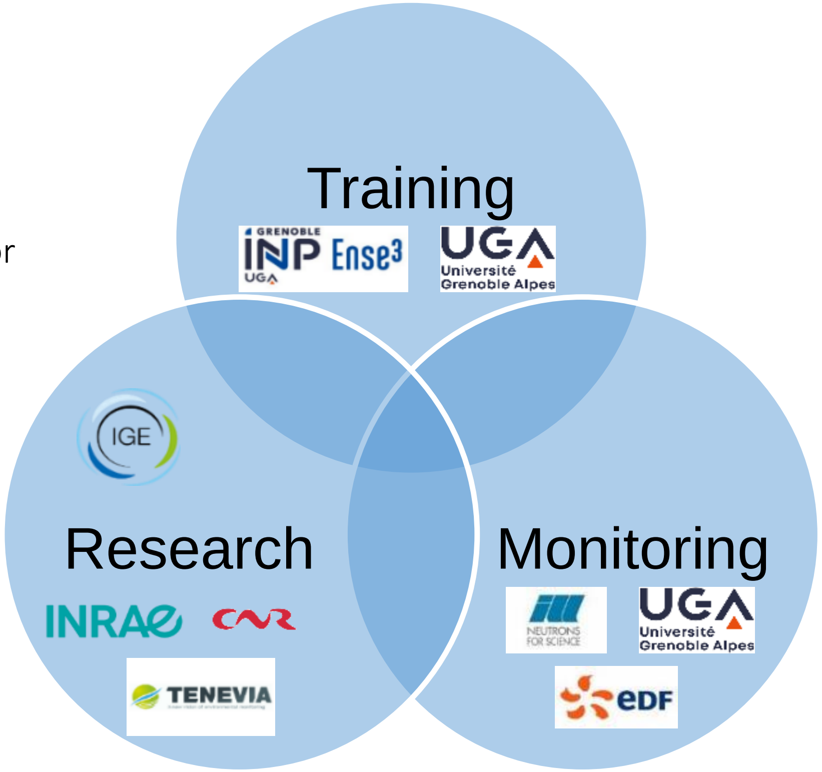


Dumas (2004)



Grenoble-Campus station

- Objectives
  - Training :
    - practical work on large rivers flow measurements, data for education (Grenoble-INP Ense3, UGA Phitem)
  - Monitoring :
    - campus flood protection system (ENSE3 + UGA DAD)
    - hydrometric measurements for St Egrève dam management (EDF)
    - regulatory measures during Isère and Arc dam flushings (EDF-DTG)
    - regulatory control of the effects of the release of cooling water from the ILL neutron reactor (Institut Laue-Langevin)
  - Research & development :
    - long term high frequency sediment observatory (IGE, INRAE & EDF-DTG)
    - development of sand transport measurement technology (EDF-DTG, CNR, INRAE Lyon)
    - determination of flow rate by surface velocities measurements using images (IGE, Ténévia)



Grenoble-Campus station

- Continuous measurements: level, temperature, conductivity, turbidity, pH, O2
- Calculated measurements: flow, Suspended Sediments Concentration (SSC), hydraulic slope (with the Isère-PDT station located downstream),
- Main station equipment:
  - Main supply, network
  - Limnimetric scale
  - Hydrometric cable ferry (EDF-DTG)
  - Campbell Scientific CR1000 datalogger
  - OTT sensors PLS (level) and PLS-C (level, temperature, conductivity)
  - Hach SolitaxTurbidity probe (EDF-DTG partnership)
  - ISCO Sampler
  - Hach pH and conductivity probes (ILL partnership)
  - Axis network camera
  - Sontek M9 and RDI Rio Grande ADCP

Level sensor to clean !

Access door to measuring tubes

ADCP pulled by cable ferry

Limnimétric scale

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Grenoble-Campus station

- Continuous measurements: level, temperature, conductivity, turbidity, pH, O2
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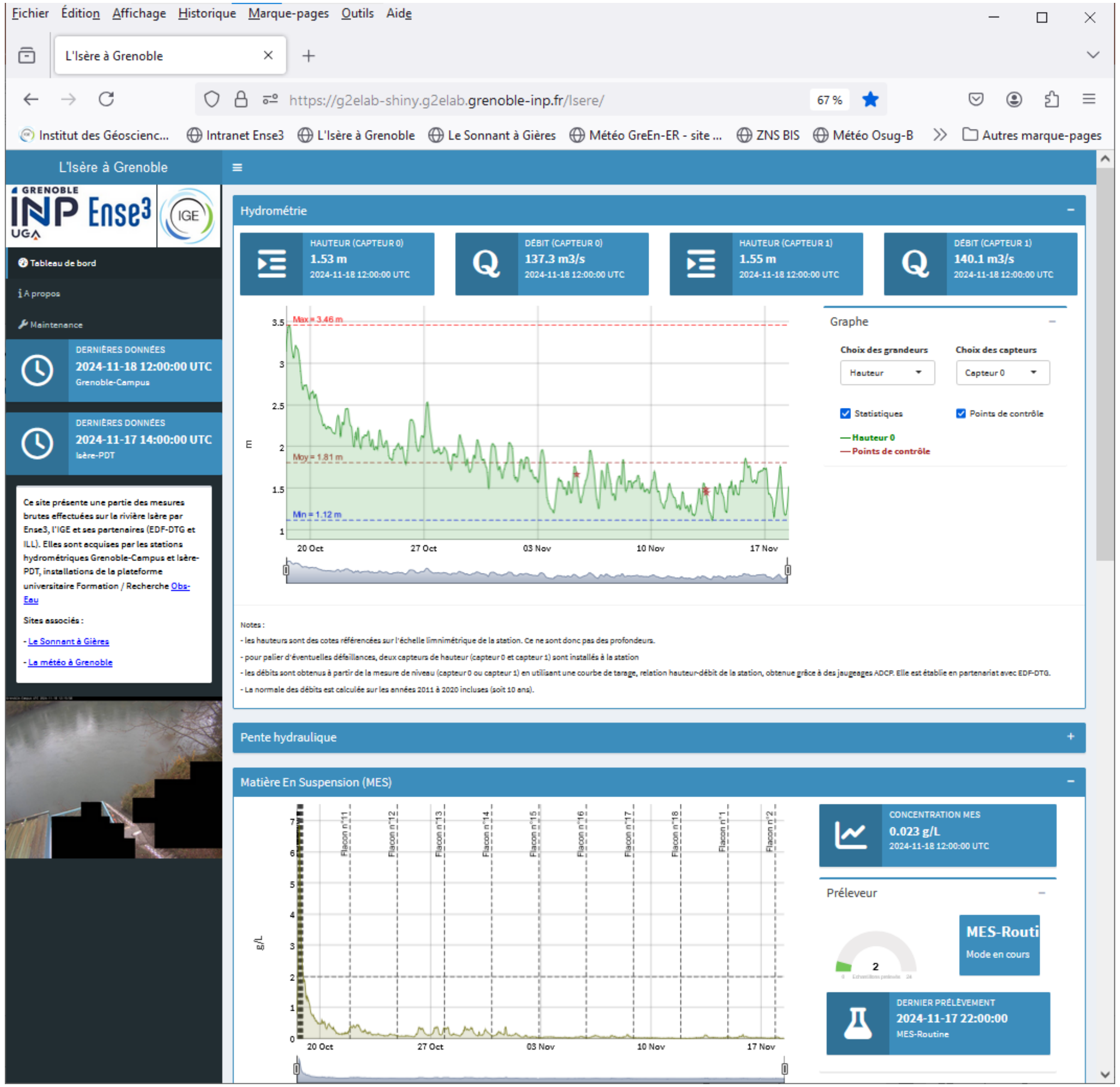
  - Hach pH and conductivity probes (ILL partnership)
  - Axis network camera
  - Sontek M9 and RDI Rio Grande ADCP
- Raw data website (last month) : https://g2elab-shiny.g2elab.grenoble-inp.fr/Isere/



Grenoble-Campus station 3/3

- Continuous measurements: level, temperature, conductivity, turbidity, pH, O2
- Calculated measurements: flow, Suspended Sediments Concentration (SSC), hydraulic slope (with the Isère-PDT station located downstream),
- Main station equipment:
  - Main supply, network
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  - Hydrometric cable ferry (EDF-DTG)
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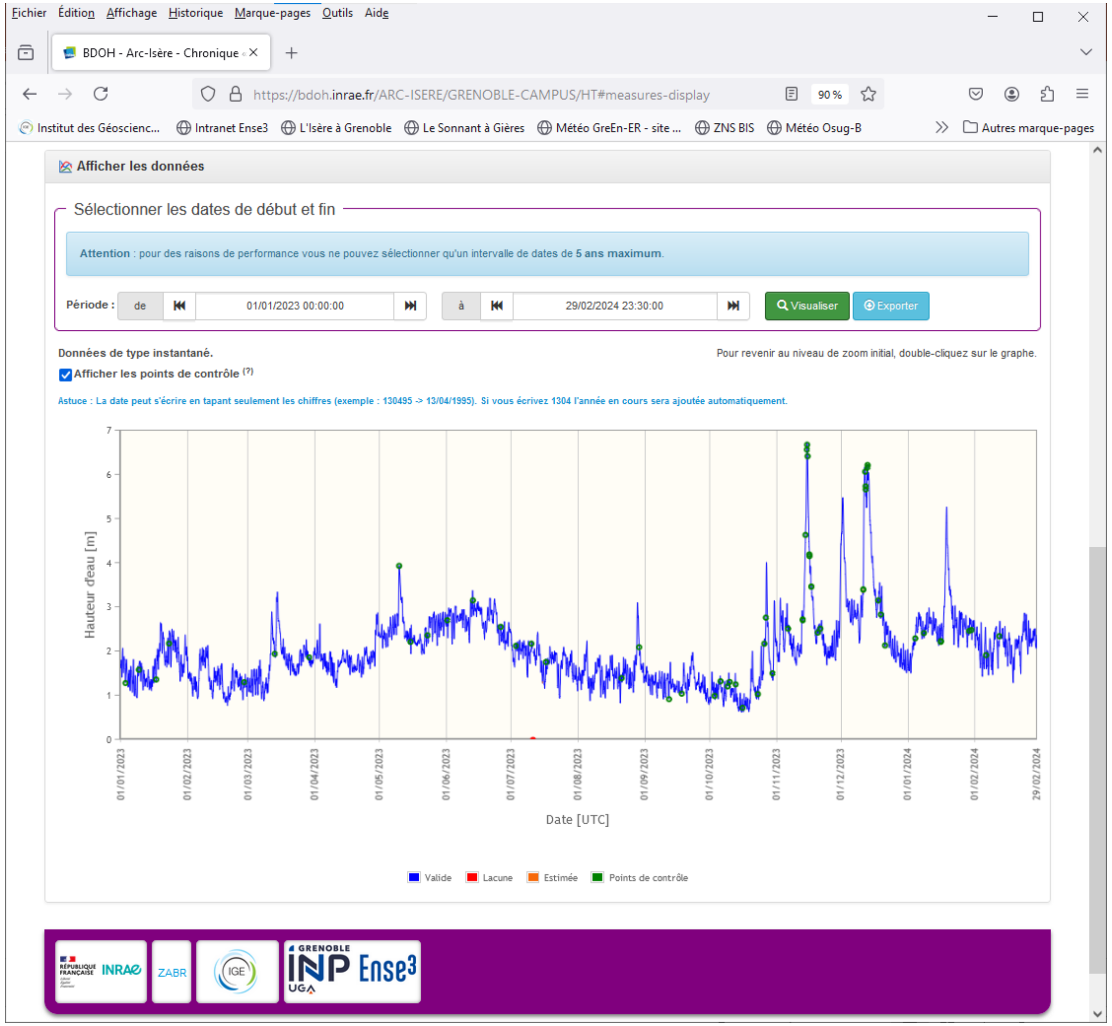
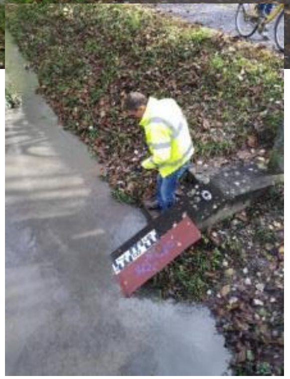
  - Hach pH and conductivity probes (ILL partnership)
  - Axis network camera
  - Sontek M9 and RDI Rio Grande ADCP
- Raw data website (last month) : https://g2elab-shiny.g2elab.grenoble-inp.fr/Isere/
- Processed data website : https://bdoh.inrae.fr/ARC-ISERE/station/GRENOBLE-CAMPUS

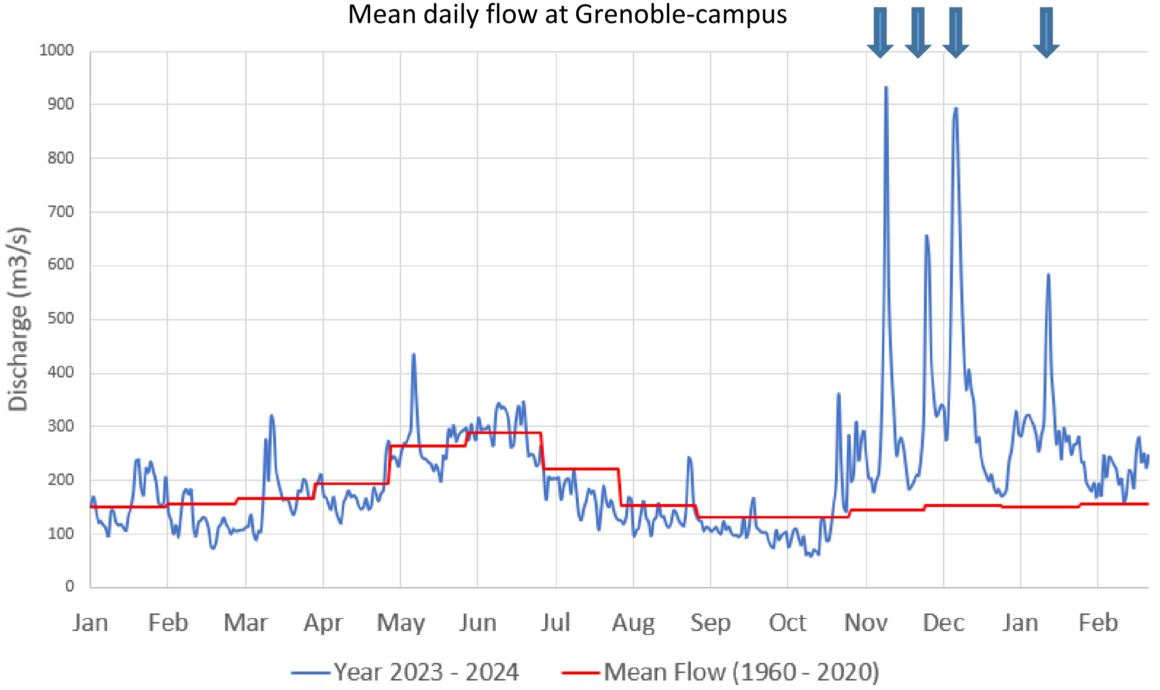


Winter 2023-2024 floods

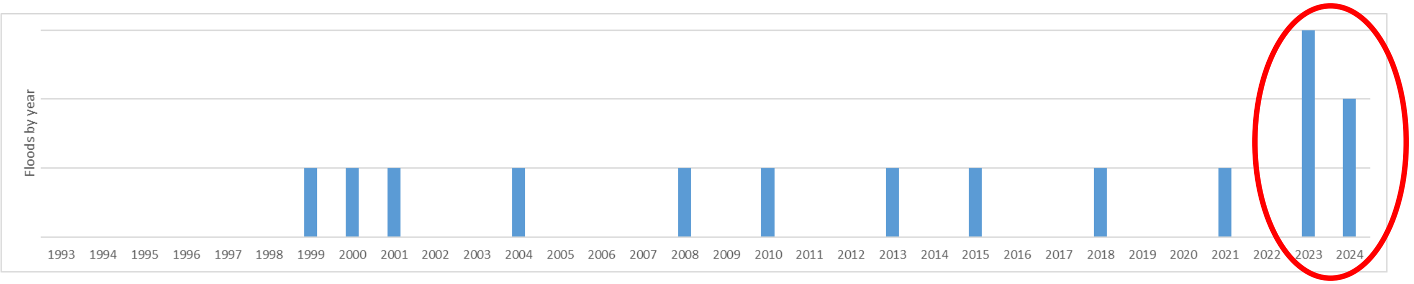
- An exceptional 2023 – 2024 winter :
  - 4 successive floods
  - including the largest flood observed over the last 30 years.



Date	H (m)	Q (m3/s)	Type
15/11/2023	6,71	1047	vicennale
22/03/2001	6,36	938	décennale
13/12/2023	6,21	921	décennale
02/05/2015	6,27	866	quinquennale
31/05/2010	6,27	866	quinquennale
30/05/2008	6,13	840	quinquennale
15/05/1999	5,84	829	quinquennale
16/10/2000	5,80	821	quinquennale
05/01/2018	5,63	787	quinquennale
01/12/2023	5,46	752	quinquennale
13/01/2004	5,23	708	biennale
19/01/2024	5,25	711	biennale
30/12/2021	5,08	680	biennale
21/06/2024	5,17	677	biennale
21/06/2013	5,12	664	biennale



15 largest floods observed at the station between 01/01/95 and 01/12/2024



Winter 2023-2024 floods

- 2 gaugings realized by IGE-Ense3 at very high flows:
  - 12/12/2023 13:00 → h=5,69m ; Q= 791 m^3/s ± 7%
  - 13/12/2023 10h25 → h=6,17m ; Q= 923 m^3/s ± 9%
- Using an ADCP SonTek M9 **+ GPS Hemisphere**
  - Mounted on a board; Deployed with a rope from the Passerelle de l'île d'Amour
- Measurements in difficult conditions:
  - High velocities & Lots of floating debris (big tree trunks !)
  - High sediment load that perturbates the acoustic waves → GPS helps a lot
  - Unsteady flows → quick measurement needed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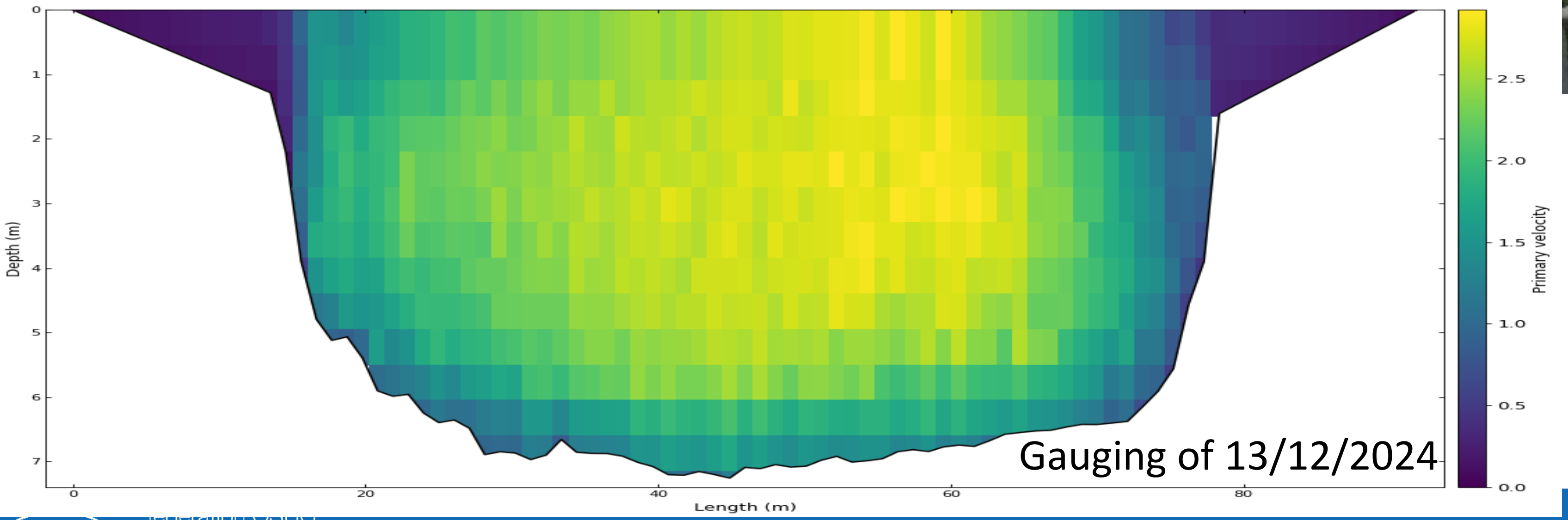
Crue de l'Isère : Coup double pour des jaugeages records

Les hydrologues de l'IGE étaient sur le pont cette semaine pour mesurer des débits exceptionnels de l'Isère à 800 m3/s le mardi 12 décembre et 928 m3/s le mercredi 13 décembre (crue légèrement inférieure à la crue vicennale définie comme de période de retour 20 ans). Les valeurs normales à cette époque de l'année sont habituellement comprises entre 130 et 160 m3/s. Ces mesures extrêmes ont été faites avec un ADCP (Acoustic Doppler Current Profiler) au niveau de la passerelle d… en amont immédiat de la station de mesure Grenoble-Campus instrumentée pour le suivi en continu des hauteurs d'eau et de la turbidité … (pH, conductivité, O2, et température).

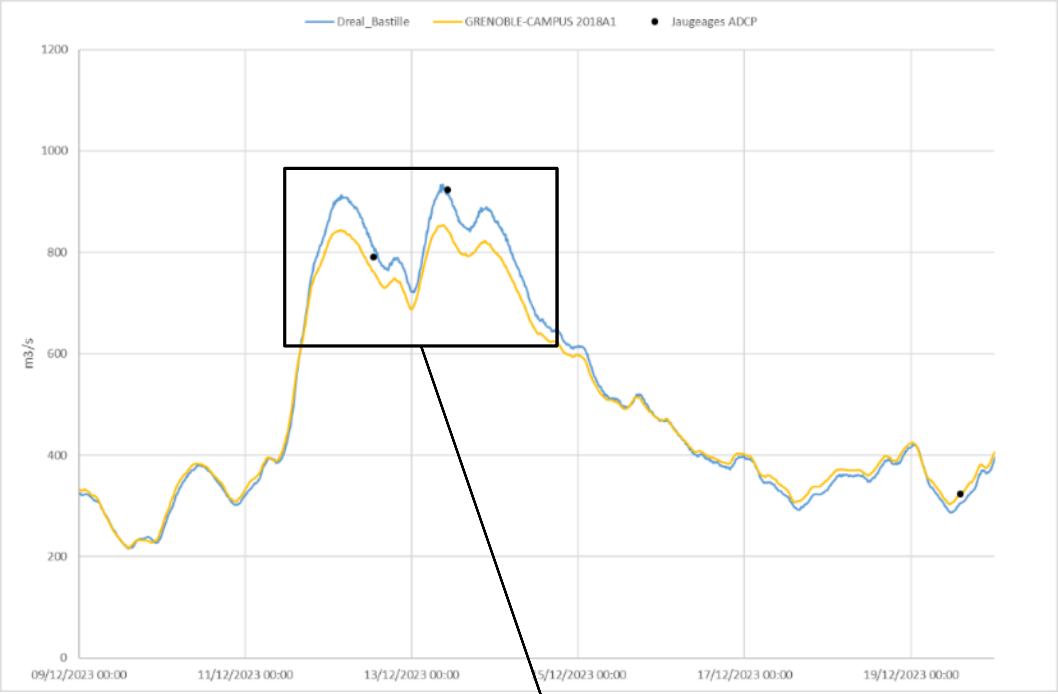


Gauging of 13/12/2024

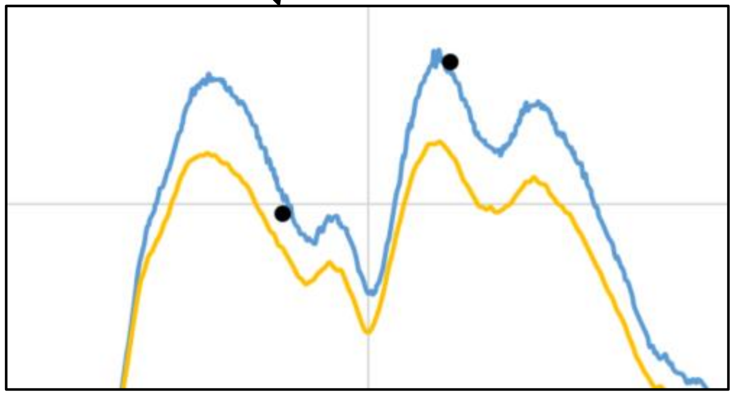
Largest discharge ever measured at the station !

Problem encountered at Grenoble-Campus following the floods of winter 2023-2024

Finding: deviations for high flow rates
- comparing with DREAL Bastille station values
- comparing with ADCP gaugings
→ The current rating curve (2018A1) is called into question for high flow rates



Crue des 12 & 13/12/23



Gaugings (ENSE3-IGE)				Grenoble-Bastille Station (DREAL)		Grenoble-Campus Station - 2018A1 (EDF-DTG – ENSE3 – IGE)	
Date heure UTC	H (m)	Q (m^3/s)	Incertitude	Date heure UTC	Q (m^3/s)	Date heure UTC	Q (m^3/s)
12/12/2023 13:00	5,69	**791**	7,2% 734-848	12/12/2023 12:52	**812**	12/12/2023 13:00	**762**
13/12/2023 10:25	6,17	**923**	8,8% 842-1004	13/12/2023 10:30	**913**	13/12/2023 10:30	**842**

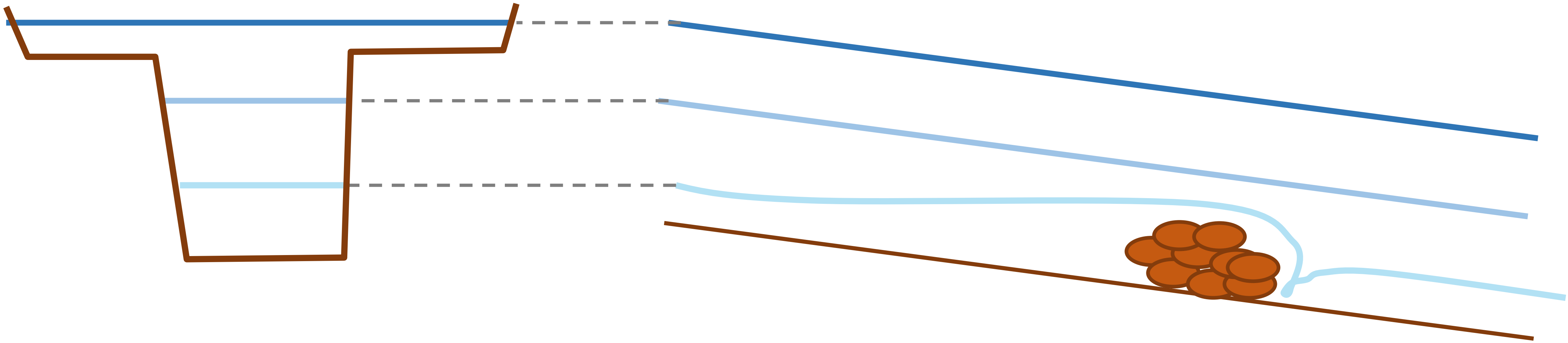
Comparison of values during the 12 & 13/12/23 flood

Rating-curve using BaRatin

- **BaRatin : Bayesian Rating-curves**
  - Free and open-source software developed by Inrae Lyon (Le Coz et al., 2014)
  1. User describes the hydraulic controls of the site
     - Channel control or Section control
     - How they appear / disappear / add up

     depending on the water level

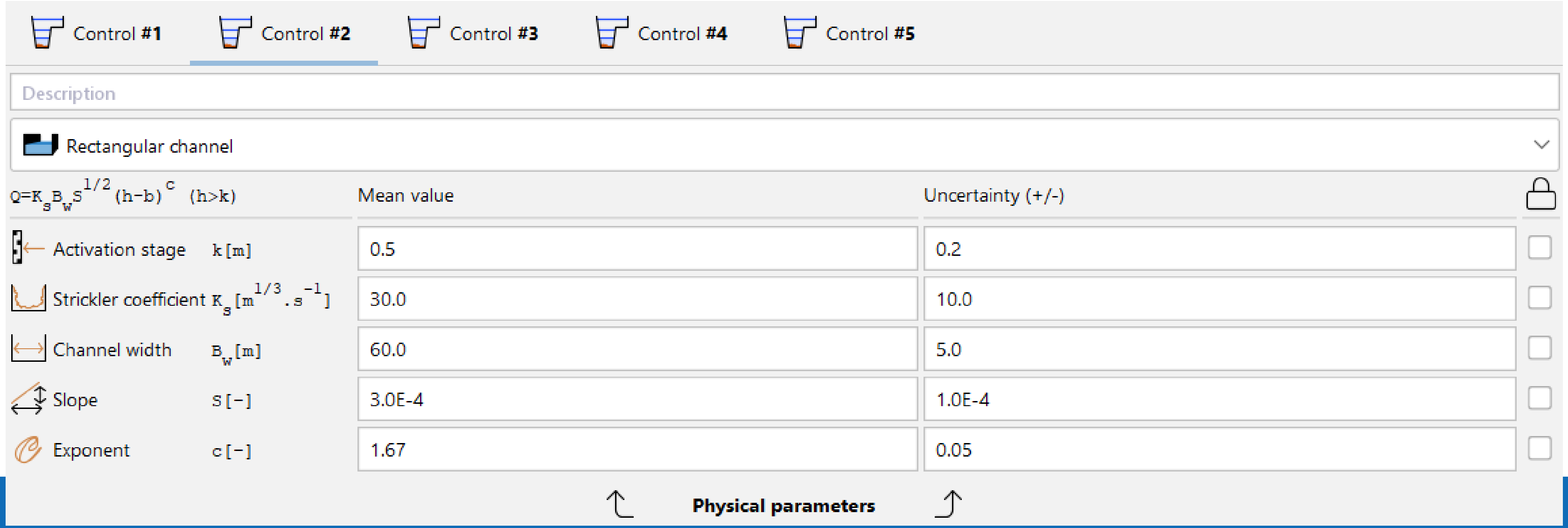
	Contrôle n°1	Contrôle n°2	Contrôle n°3
Segment n°3 (Haut)	☐	☑	☑
Segment n°2	☐	☑	
Segment n°1 (Bas)	☑		



Rating-curve using BaRatin

BaRatin
Bayesian Rating Curves

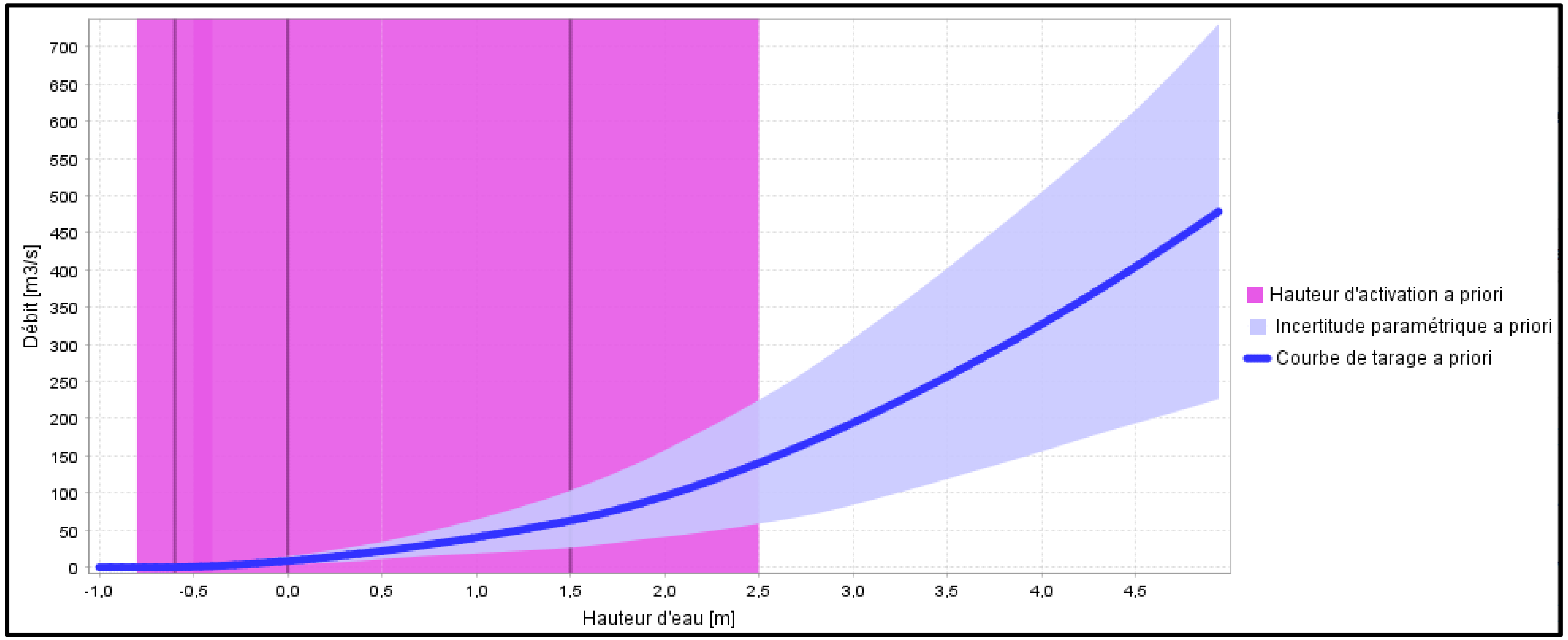
- **BaRatin : Ba**yesian **Ratin**g-curves
  - Free and open-source software developed by Inrae Lyon (Le Coz et al., 2014)
  1. User describes the hydraulic controls of the site
  2. For each hydraulic control, user provides "a priori" knowledge of parameters
     - Channel Control → $Q = K * B * S^{1/2} * h^c$
       - Strickler friction coefficient K; Stream width B; Stream slope S; Coeff c (≈5/3); Activation stage
     - Section control → $Q = \mu * B * \sqrt{2g} * h^c$
       - Weir coefficient μ; weir width B; Coeff c (≈3/2); Activation stage
     - Central value + Normal distribution uncertainty



Rating-curve using BaRatin

BaRatin
Bayesian Rating Curves

- **BaRatin :** Bayesian Rating-curves
  - Free and open-source software developed by Inrae Lyon (Le Coz et al., 2014)
  1. User describes the hydraulic controls of the site
  2. For each hydraulic control, user provides “a priori” knowledge of parameters
  3. The prior rating curve and it’s prior uncertainty are computed
     - Using the user’s priors only
     - Large uncertainties



Rating-curve using BaRatin

BaRatin
Bayesian Rating Curves

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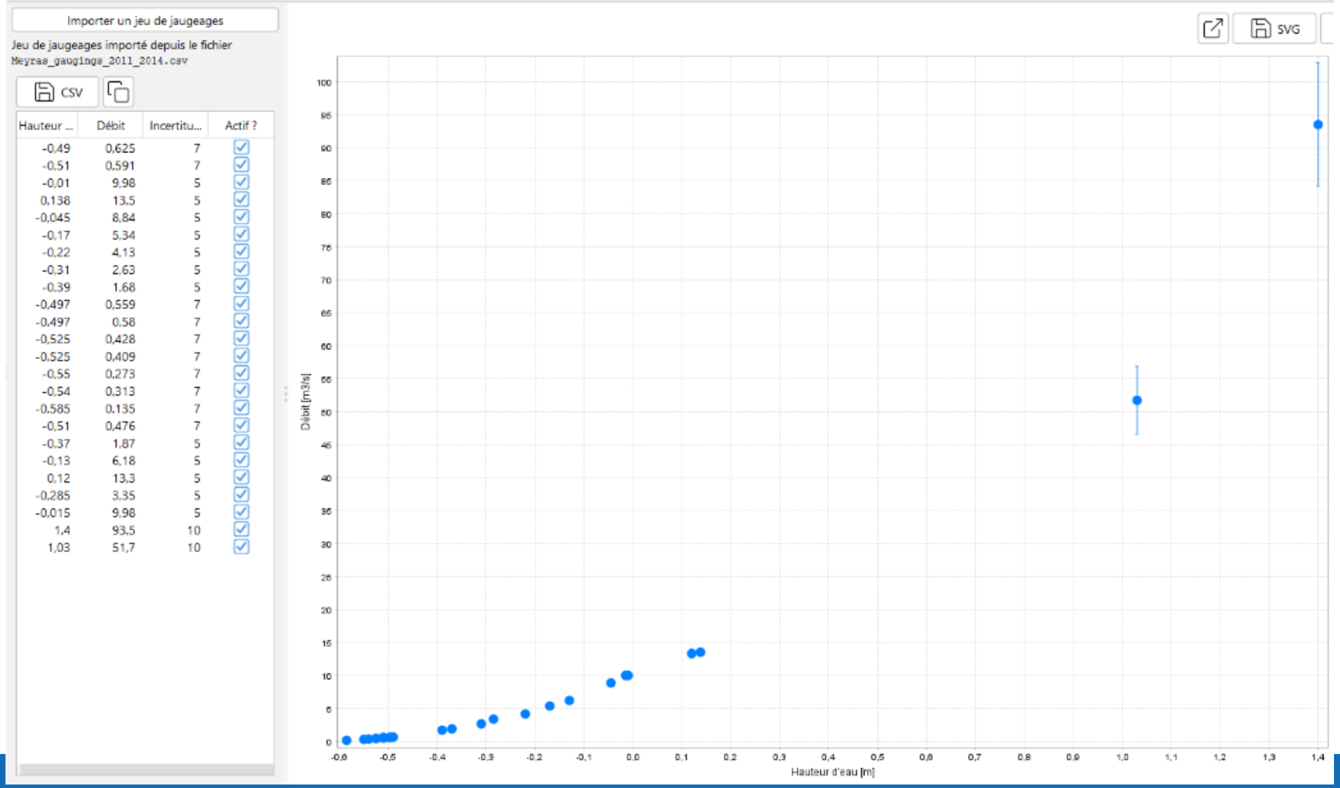
- **BaRatin :** Bayesian Rating-curves
  - Free and open-source software developed by Inrae Lyon (Le Coz et al., 2014)

1. User describes the hydraulic controls of the site
2. For each hydraulic control, user provides “a priori” knowledge of parameters
3. The prior rating curve and it’s prior uncertainty are computed
4. User provides a set of gaugings
   - With their uncertainty



Hauteur ...	Débit	Incertitu...	Actif ?
-0,49	0,625	7	☑
-0,51	0,591	7	☑
-0,01	9,98	5	☑
0,138	13,5	5	☑
-0,045	8,84	5	☑
-0,17	5,34	5	☑
-0,22	4,13	5	☑
-0,31	2,63	5	☑
-0,39	1,68	5	☑
-0,497	0,559	7	☑
-0,497	0,58	7	☑
-0,525	0,428	7	☑
-0,525	0,409	7	☑
-0,55	0,273	7	☑
-0,54	0,313	7	☑
-0,585	0,135	7	☑
-0,51	0,476	7	☑
-0,37	1,87	5	☑
-0,13	6,18	5	☑
0,12	13,3	5	☑
-0,285	3,35	5	☑
-0,015	9,98	5	☑
1,4	93,5	10	☑
1,03	51,7	10	☑

Rating-curve using BaRatin

BaRatin
Bayesian Rating Curves

- **BaRatin :** Bayesian Rating-curves
  - Free and open-source software developed by Inrae Lyon (Le Coz et al., 2014)
  1. User describes the hydraulic controls of the site
  2. For each hydraulic control, user provides “a priori” knowledge of parameters
  3. The prior rating curve and it’s prior uncertainty are computed
  4. User provides a set of gaugings
  5. Bayesian black magic happens !
     - Posterior distribution of each parameters computed using Bayes theorem
     - From prior distribution / using the gaugings

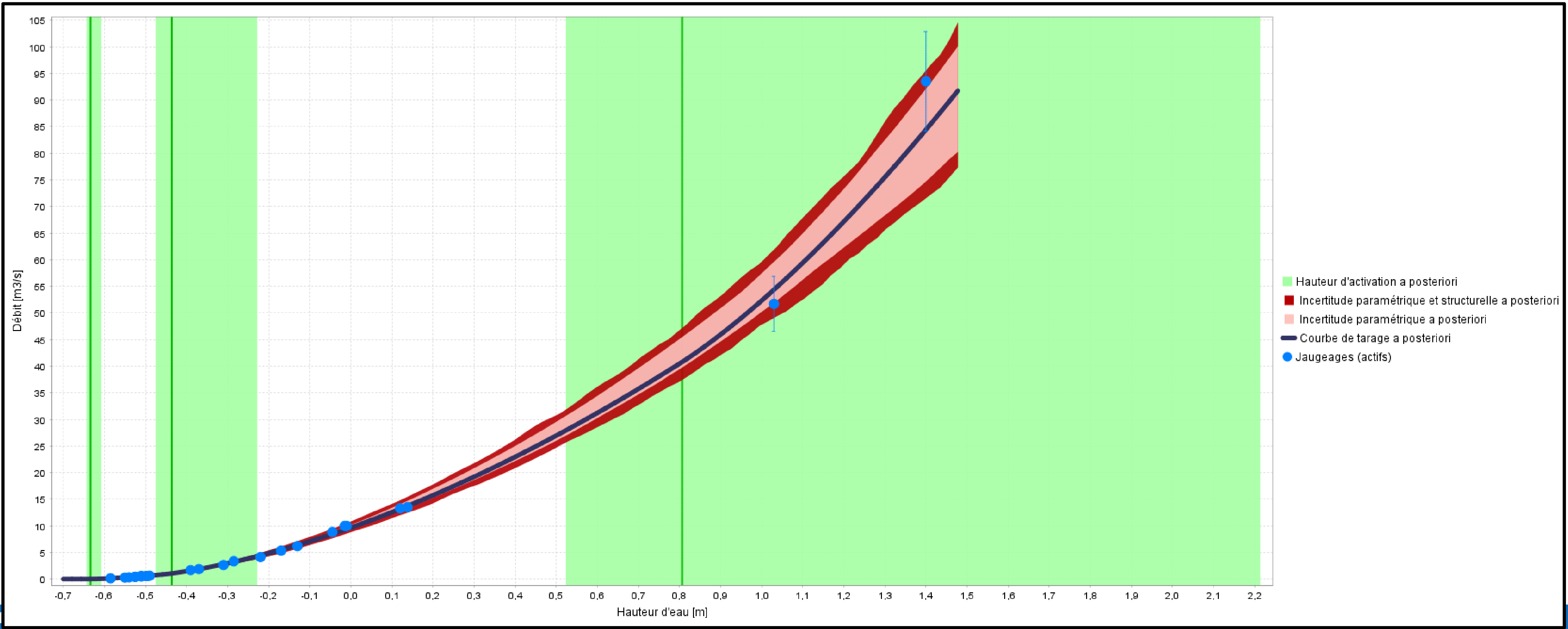
Reverend Thomas Bayes (1702-1761)

Posterior distribution $$p(\boldsymbol{\theta}|\boldsymbol{y}) = \frac{\overbrace{p(\boldsymbol{y}|\boldsymbol{\theta})}^{\text{likelihood}} \times \overbrace{p(\boldsymbol{\theta})}^{\text{prior}}}{\underbrace{\int p(\boldsymbol{y}|\boldsymbol{\nu}) \times p(\boldsymbol{\nu})d\boldsymbol{\nu}}_{\text{normalization constant}}}$$

y → gaugings
θ → parameters

Rating-curve using BaRatin

- Posterior rating curve
  - Bayesian analysis using Priors on the parameters & Gaugings
  - Most probable Rating Curve + it's uncertainty

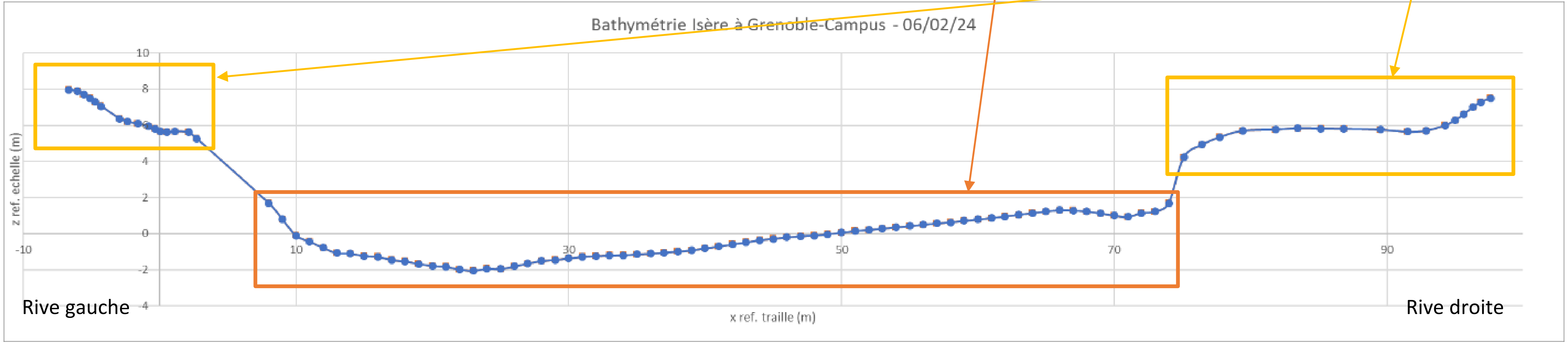


Application to Isère at Grenoble-Campus station : data for hydraulic modelling

•Bathymetry

Measured on the same day at ADCP for the submerged part and theodolite for the surface part then reconstitution of the section

→ informations on geometry and sizes



Section bathymetry reconstruction

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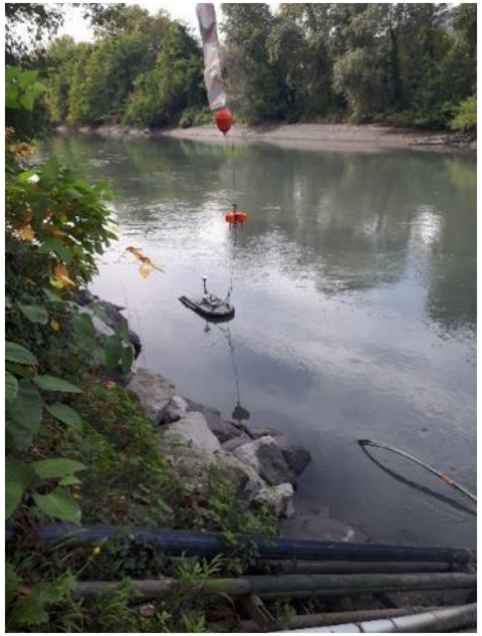
Application to Isère at Grenoble-Campus station : data for hydraulic modelling

- Observation of the river banks



→ Strickler coefficient estimation (Ks) :

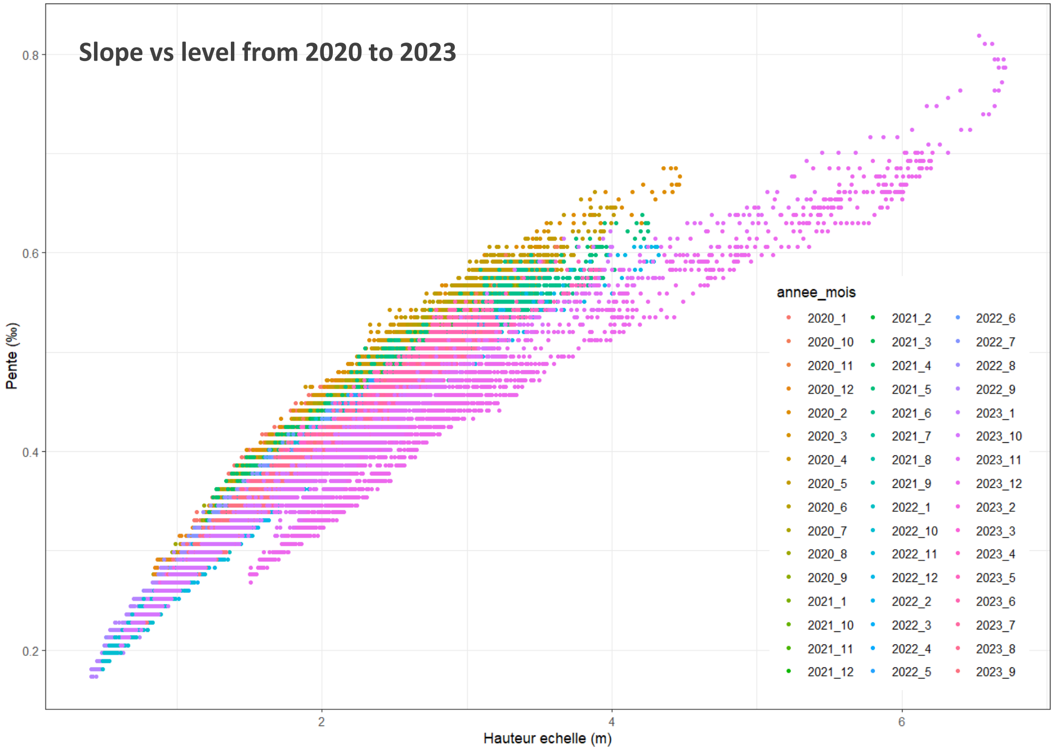
Level H (m)	river banks	Ks estimate ($m^{1/3}/s$)	uncertainty (+/-) ($m^{1/3}/s$)
5 < H	Lawn and some tree trunks	20	5
2 < H < 5	Dense vegetation*	10	5
0,5 < H < 2	Without vegetation, shingle	30	10

*depends on the season

Application to Isère at Grenoble-Campus station : data for hydraulic modelling

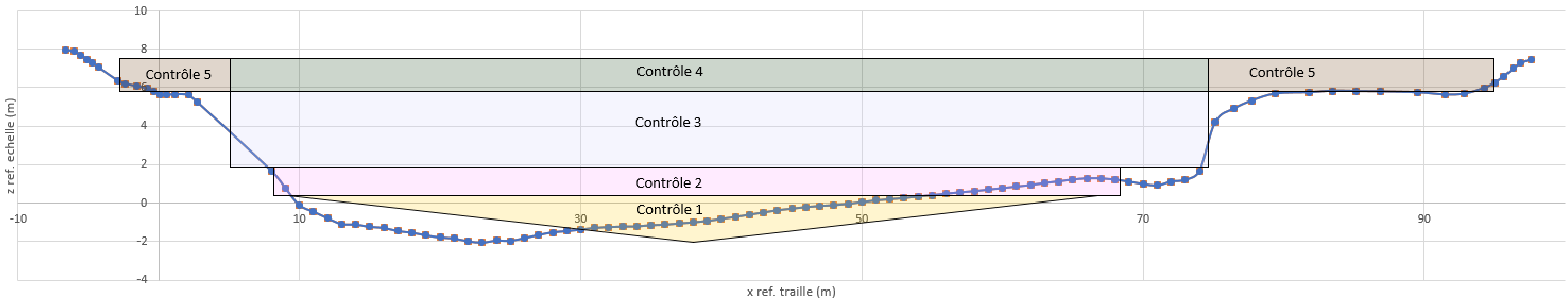
•Slope

- Continuous measurements have been available between the Grenoble-Campus and Isère-PDT stations since 2020
- The slope depends on the discharge



Application to the Isère at Grenoble-Campus station : hydraulic modelling

- matrix assumption of hydraulic controls



	Contrôle n°**1**	Contrôle n°**2**	Contrôle n°**3**	Contrôle n°**4**	Contrôle n°**5**
Segment n°**5** (Haut)	☐	☐	☐	☑	☑
Segment n°**4**	☐	☐	☐	☑	
Segment n°**3**	☐	☐	☑		
Segment n°**2**	☐	☑			
Segment n°**1** (Bas)	☑				

Contrôle	Type	Hauteur Activation (m)	Incertitude (m)
5	Chenal rectangulaire	5,51	+/- 0,5
4	Chenal rectangulaire	5,5	+/- 0,5
3	Chenal rectangulaire	2,0	+/- 0,5
2	Chenal rectangulaire	0,5	+/- 0,2
1	Déversoir triangulaire	-2,0	+/- 0,1

Uncertain but can't be verified

Application to Isère at Grenoble-Campus station : hydraulic modelling

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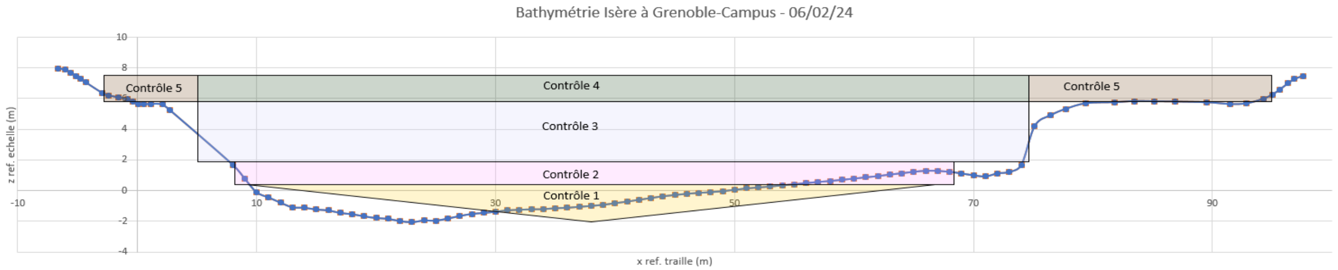
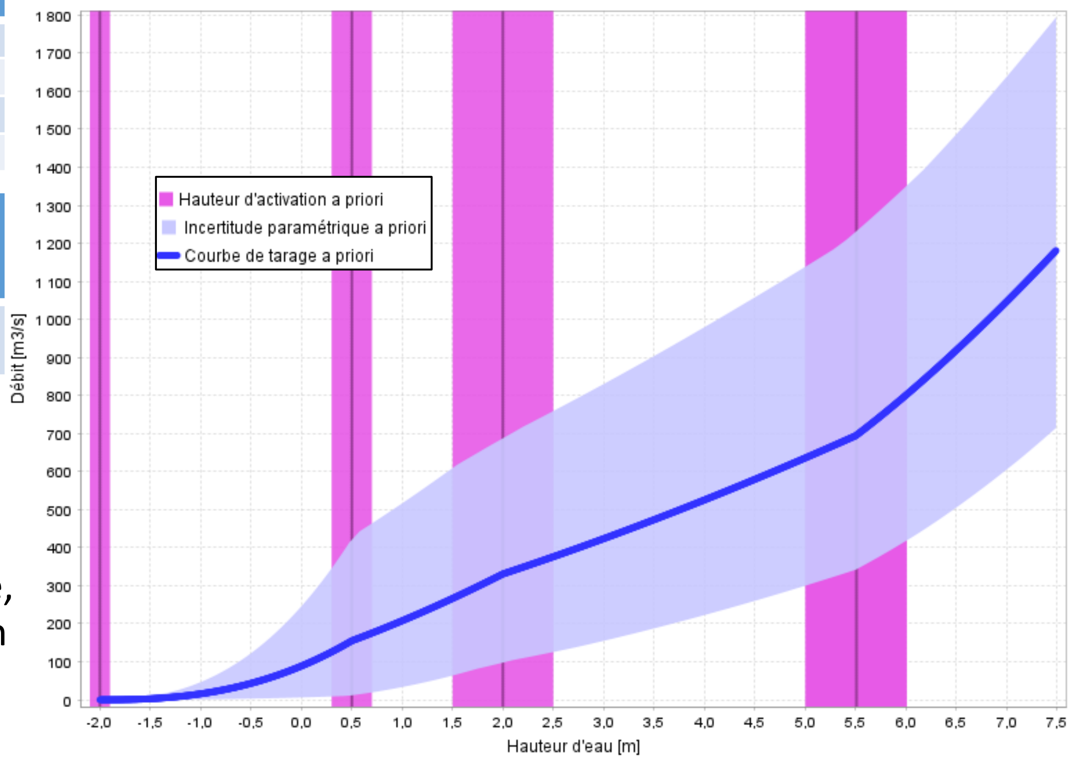


Hydraulic controls settings

Contrôle	Type	Hauteur Activation k (m)	Coef. De Strickler K_s ($m^{1/3}.s^{-1}$)	Largeur du chenal B_w (m)	Pente du chenal S (S.U. 10^{-4})	Exposant C (S.U.)
5	Chenal rectangulaire	5,51 +/- 0,5	20 +/-5	29 +/-5	7 +/-1	1,67 +/-0,05
4	Chenal rectangulaire	5,5 +/- 0,5	20 +/-5	69 +/-5	7 +/-1	1,67 +/-0,05
3	Chenal rectangulaire	2,0 +/- 0,5	10 +/-5	69 +/-5	5 +/-2	1,67 +/-0,05
2	Chenal rectangulaire	0,5 +/- 0,2	30 +/-10	60 +/-5	3 +/-1	1,67 +/-0,05

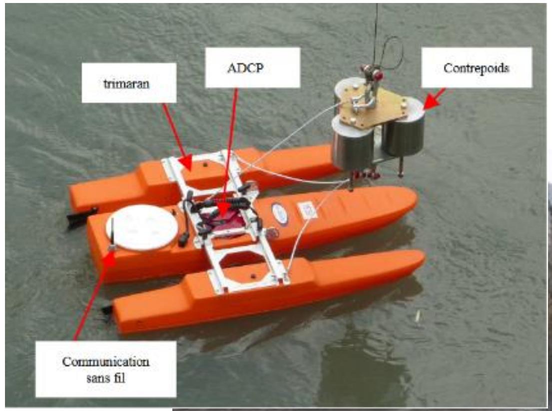
Contrôle	Type	Hauteur Activation k (m)	Coefficient d'ouvrage C_t (S.U.)	Angle v (°)	Acc. de pesanteur g ($m.s^{-2}$)	Exposant c (S.U.)
1	Déversoir triangulaire	-2,0 +/- 0,1	0,31 +/-0,05	170 +/-20	9,81 +/-0,01	2,5 +/-0,05



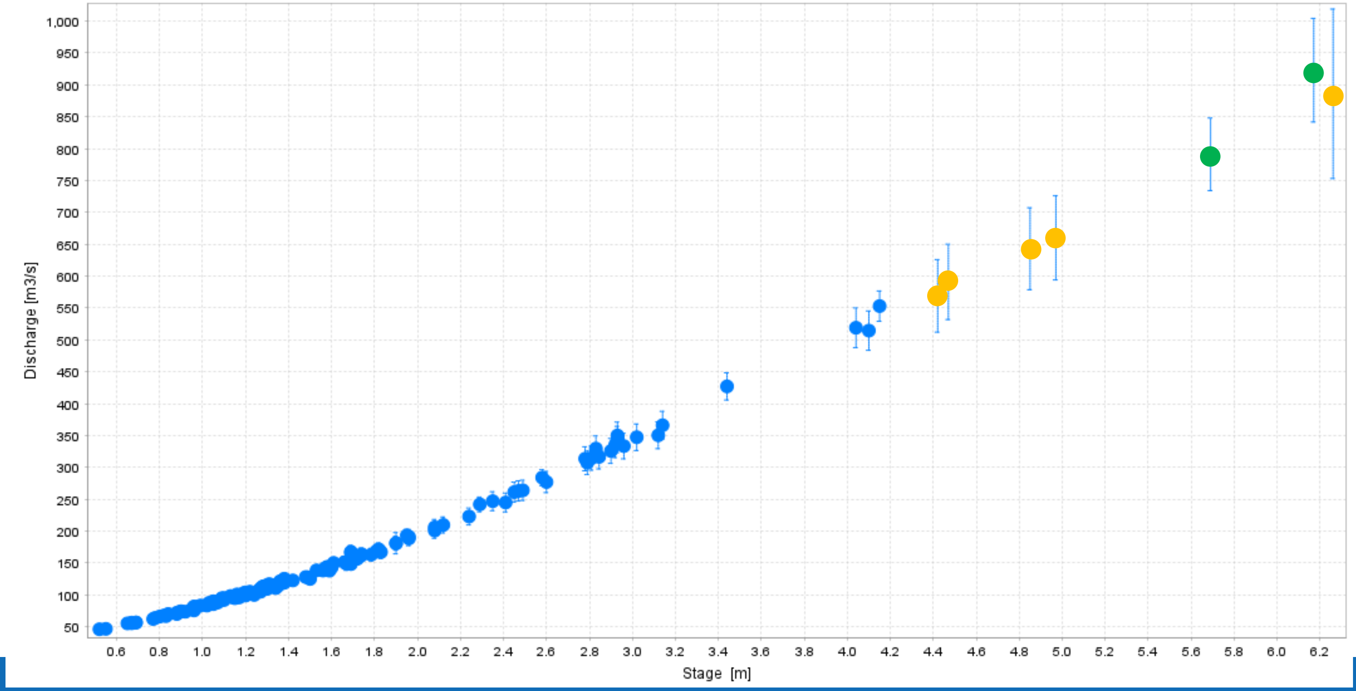
computation of the prior rating curve, solely based on hydraulic information and not using any gauging

BaRatin for Isère@Campus

- Set of gaugings:
  - All the gaugings since the rating shift of 2018
    - 146 gaugings realized by ADCP ! (mostly done during Ense3 trainings)
    - Including the 2 high flow gaugings of December 2023 (IGE – Ense3)
  - 5 older high-flow gaugings (EDF + IGE + Ense3):



Date	h (m)	Q (m3/s)	Uncertainty (%)	Method
27/06/1994	4,97	660	10,0	Current-meter
23/06/1995	4,42	569	10	Current-meter
23/03/2001	4,47	591	10	Current-meter
31/05/2010	6,26	886	15	Current-meter
04/05/2015	4,85	643	10	ADCP



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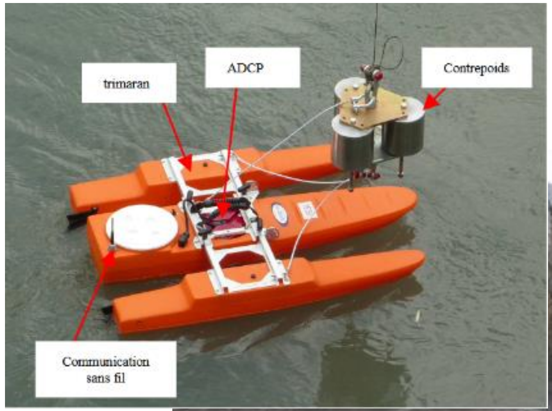

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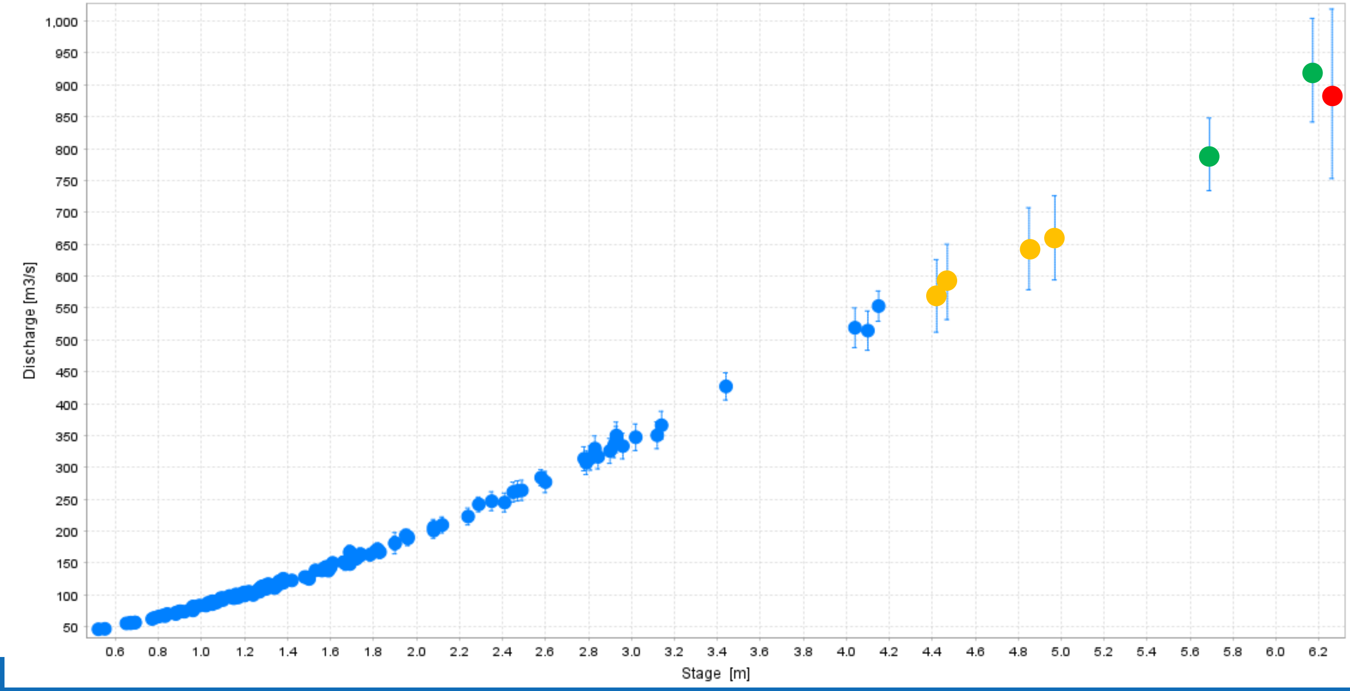
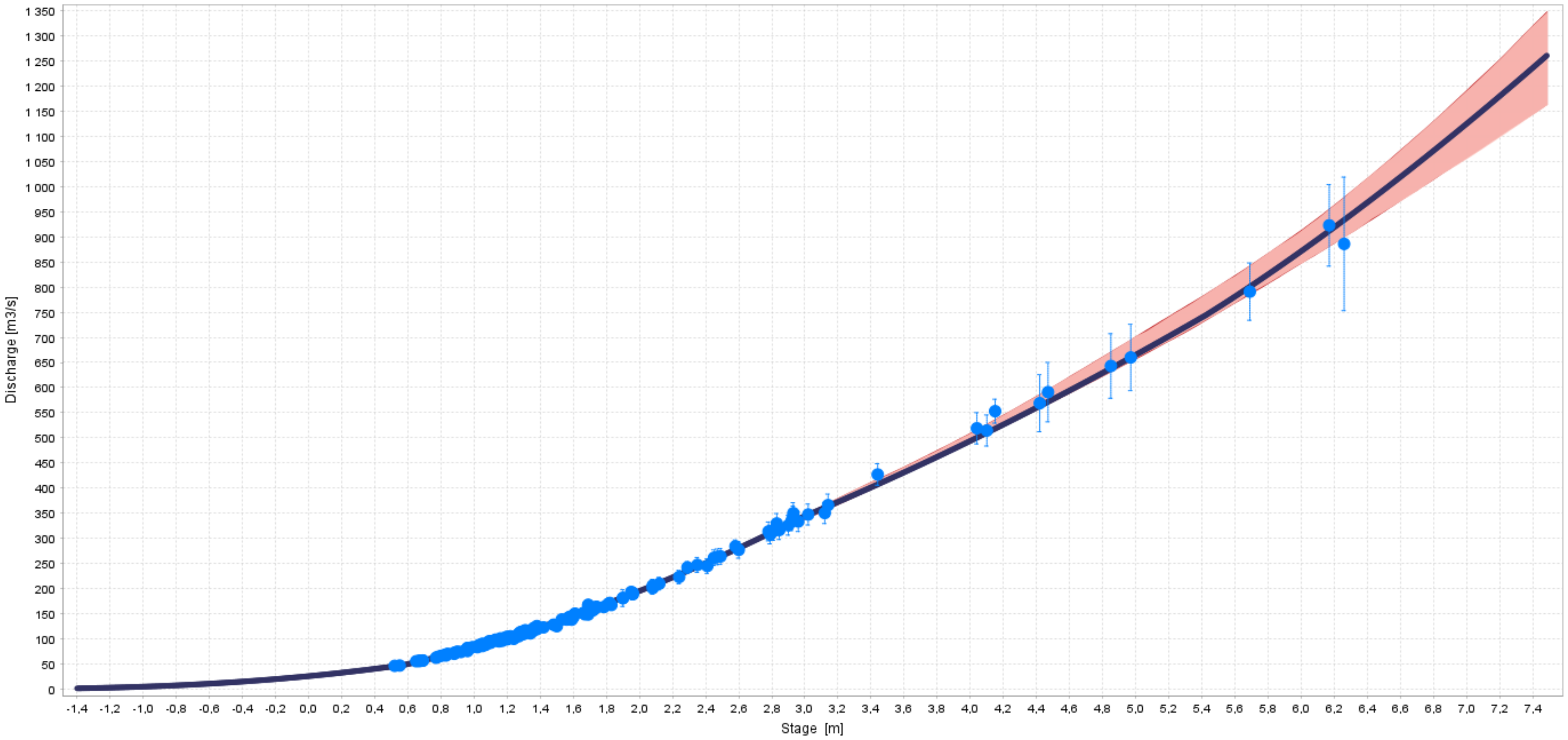
31/05/2010	**6,26**	**886**	**15**	**Current-meter**
04/05/2015	4,85	643	10	ADCP

Difficult conditions → downgraded gauging protocol → high uncertainty

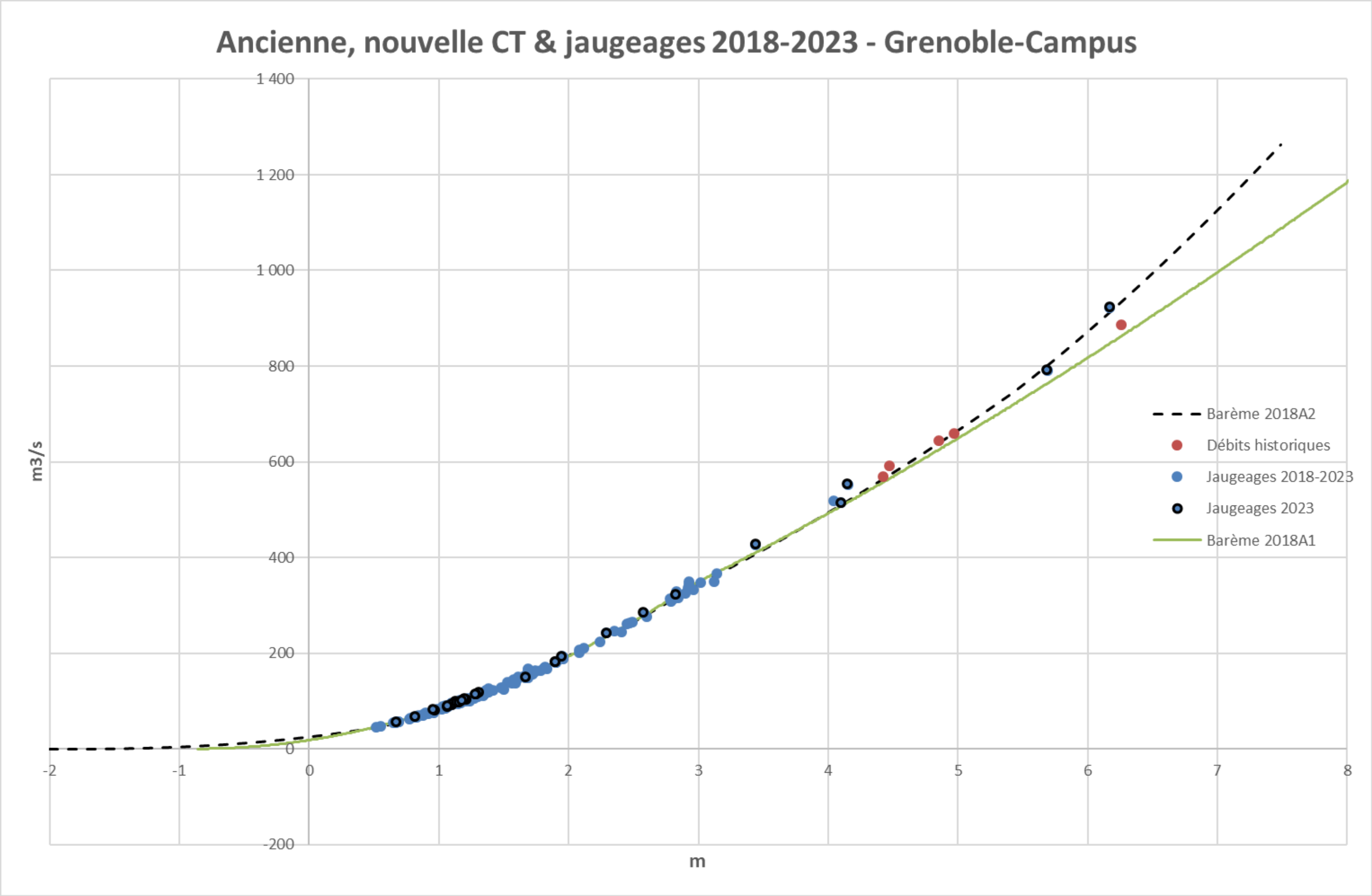


BaRatin for Isère@Campus

- Posterior rating curve:
  - Fits really nicely to the gaugings
  - Deviates from the highest but more uncertain gauging
  - Has a very low uncertainty
    - +/- 5% a low discharge
    - +/- 1% at medium discharge
    - +/- 8% at high discharge



Analysis of the new curve : comparison with the old curve

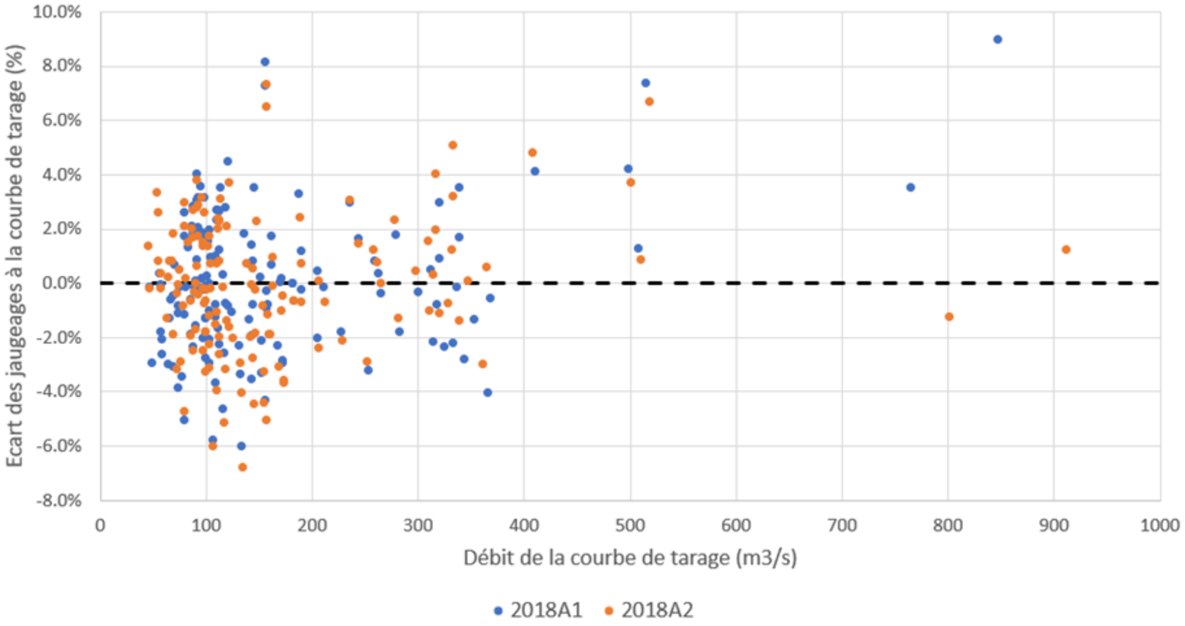


comparison with the previous curve 2018A1 :
H < 4 m, similar to the prvious curve
H > 4 m, higher flow rates for the same water level

Analysis of the new curve : comparison with the old curve

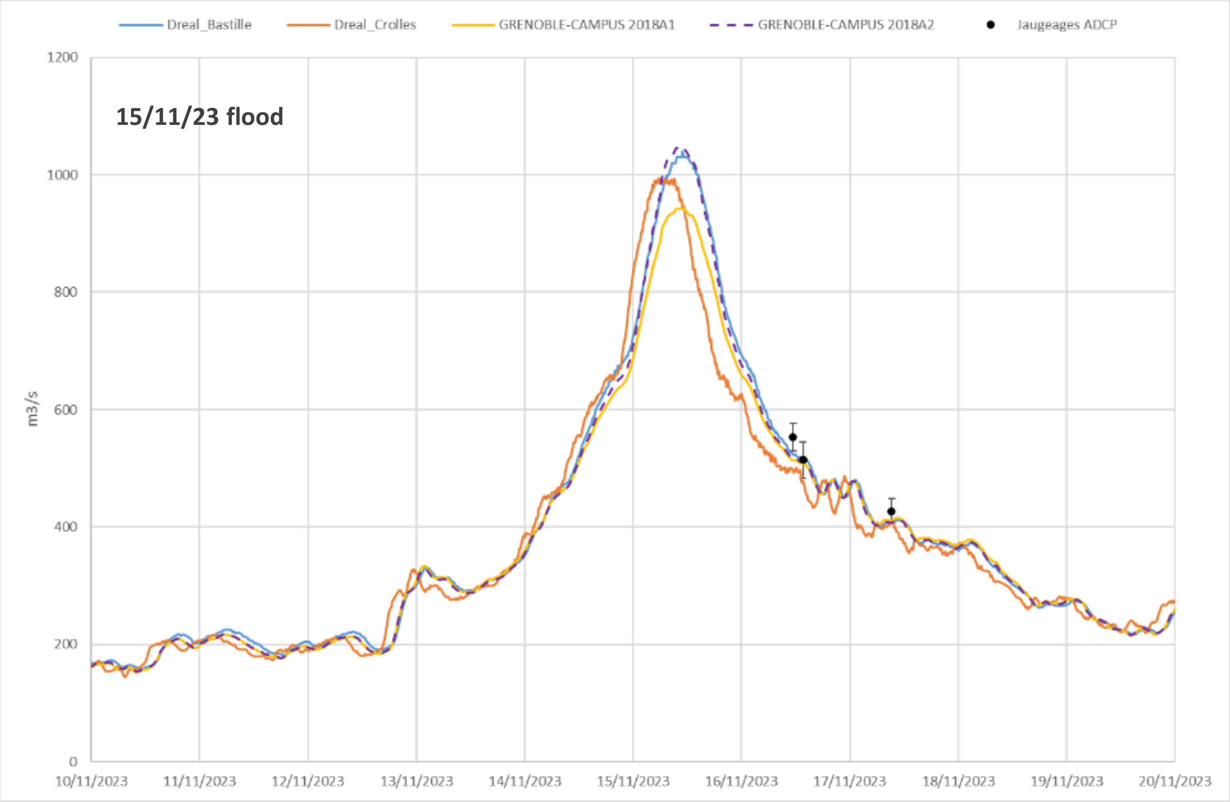
	Jaugeage IGE Ense3			Grenoble-Bastille DREAL		Grenoble-Campus Ense3 - IGE				
Date heure UTC	H (m)	Q (m³/s)	Incertitude	Date heure UTC	Q (m³/s)	Date heure UTC	H (m)	Q 2018A1 (m³/s)	Q 2018A2 (m³/s)	Incertitude 2018A2 (m³/s)
12/12/2023 13:00	5,69	791	7,2%	12/12/2023 12:52	812	12/12/2023 13:00	5,68	762	799	783-840
13/12/2023 10:25	6,17	923	8,8%	13/12/2023 10:30	913	13/12/2023 10:30	6,14	842	905	876-947
19/12/2023 14:15	2,83	323	4,5%	19/12/2023 14:00	304	19/12/2023 14:00	2,84	322	318	314-323

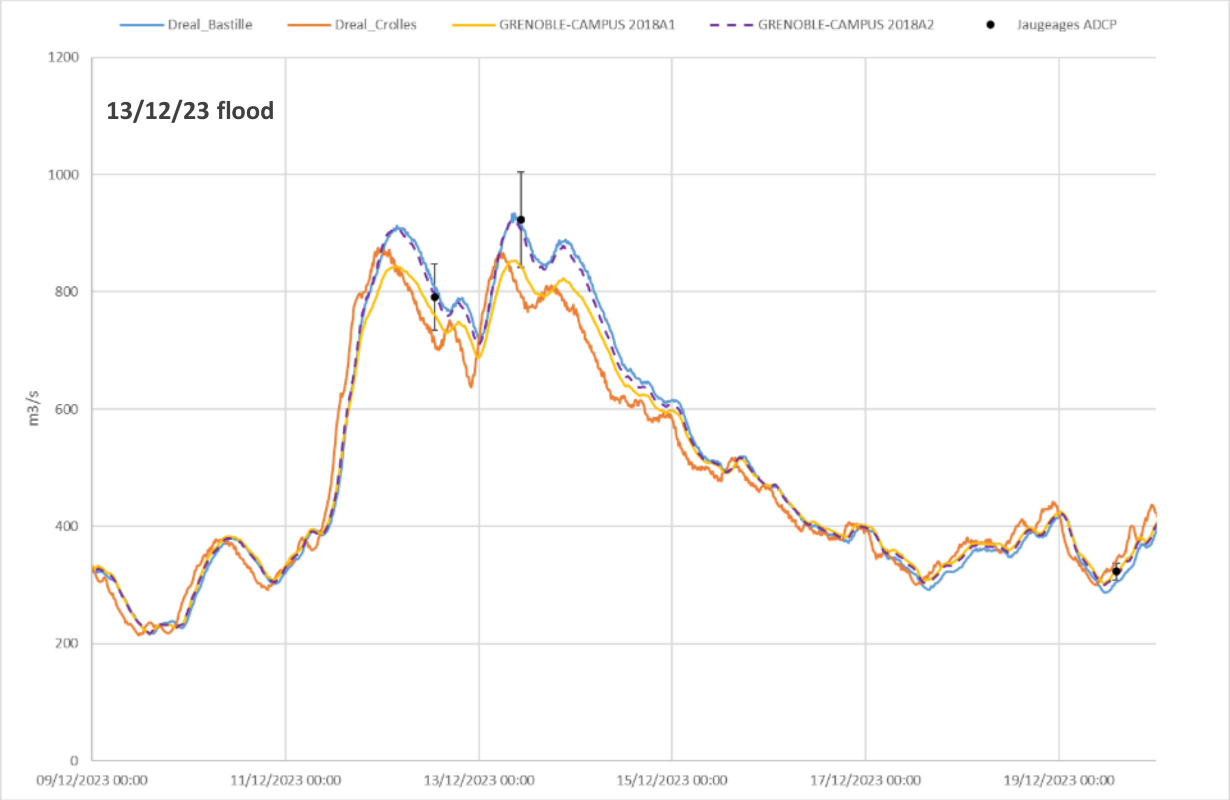
12/12/23 ADCP gauging



→ a better match between gauging and new curve-estimated values

Analysis of the new curve : flood hydrograms comparison with other stations



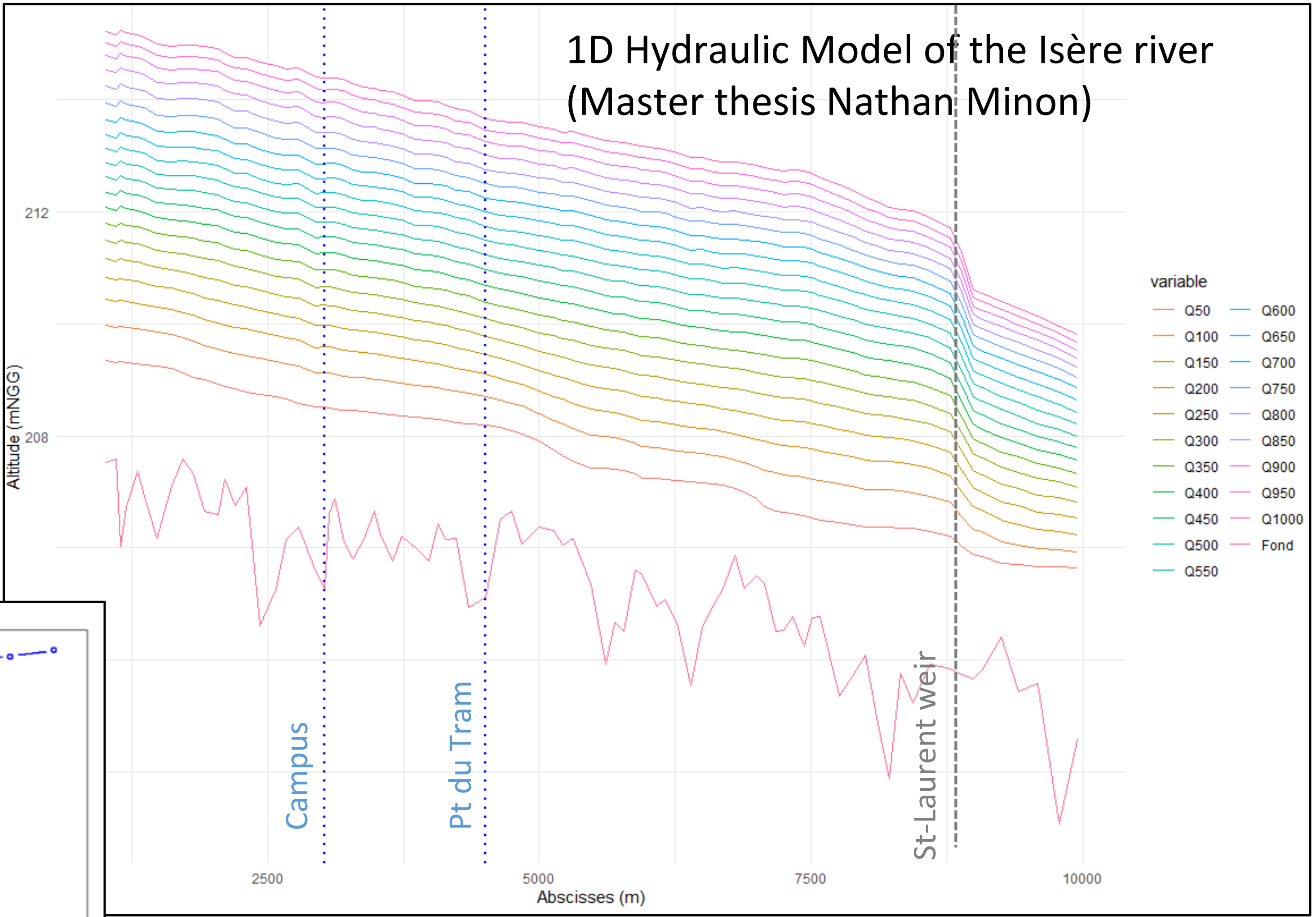


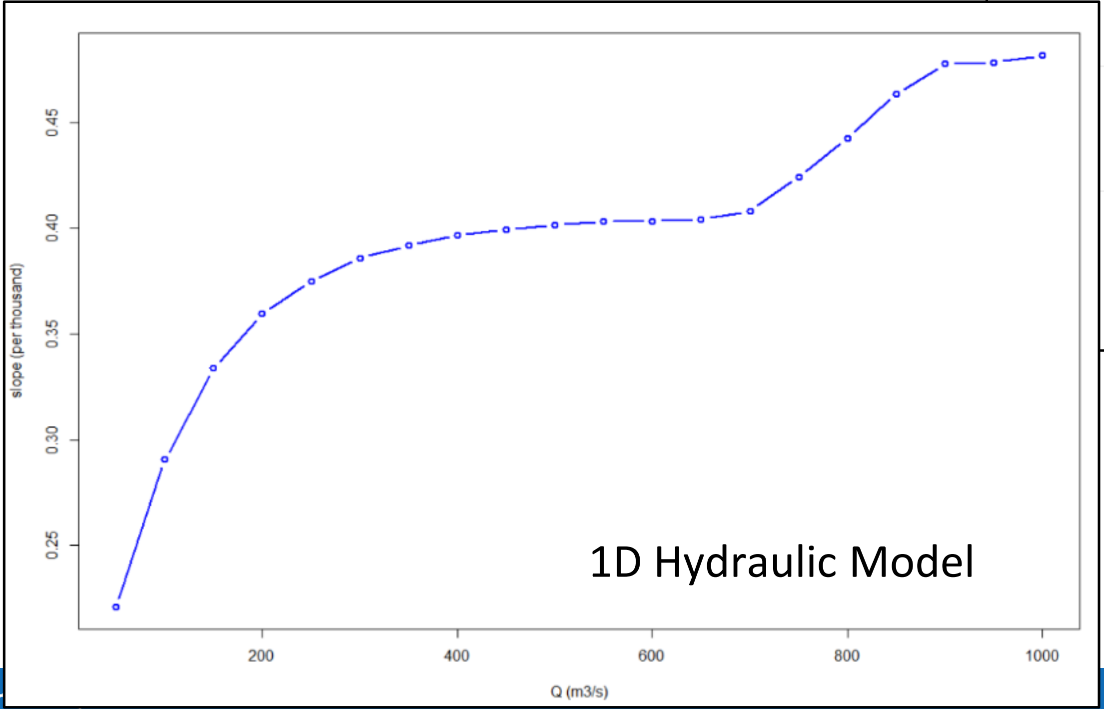
→ a good consistency with DREAL measurements

Conclusions

- Isère@Campus
  - Stable hydraulic controls
  - A large amount of gaugings
  - But a quite complex rating curve !!
    - Several hydraulic controls
    - Change of the slope with the stage

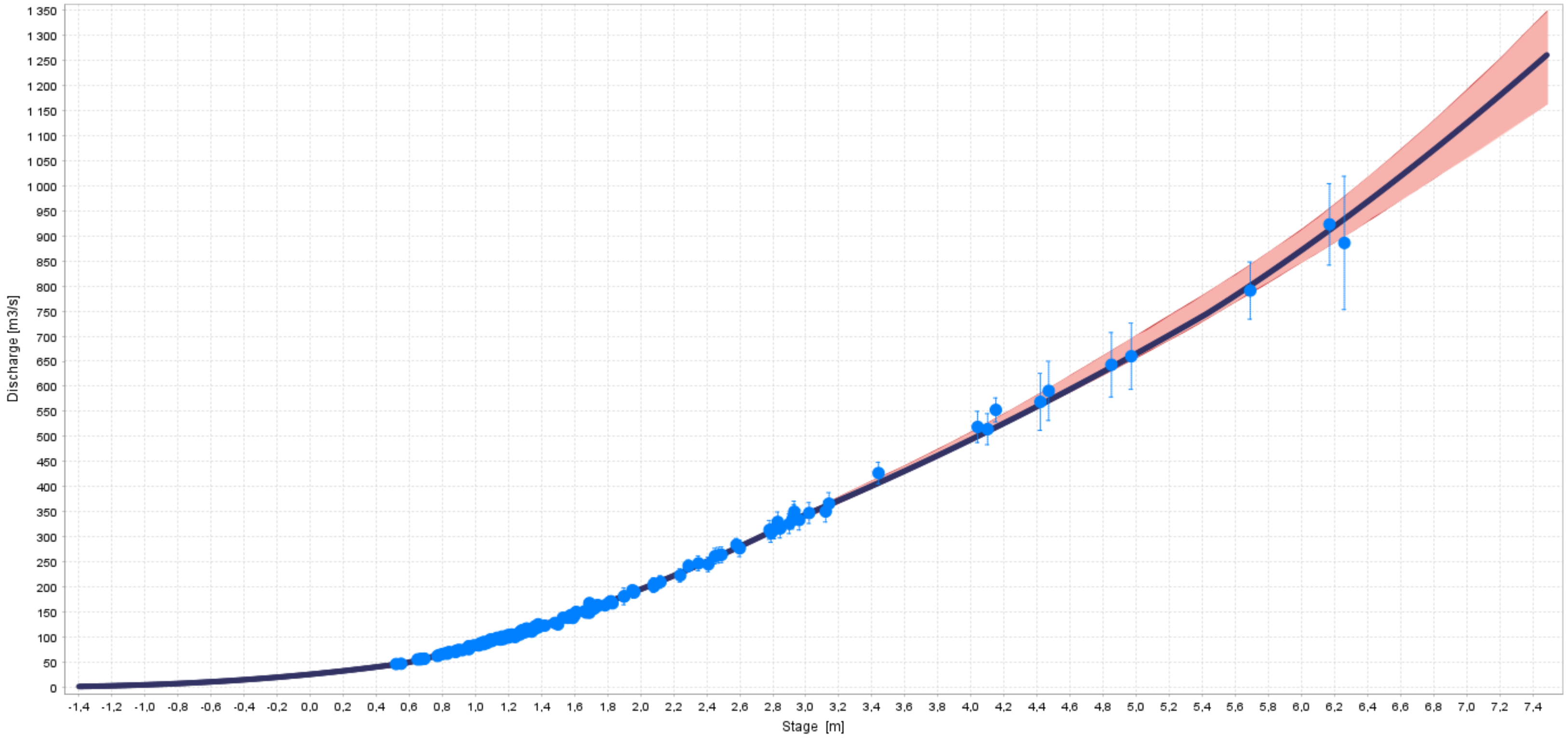
1D Hydraulic Model of the Isère river
(Master thesis Nathan Minon)





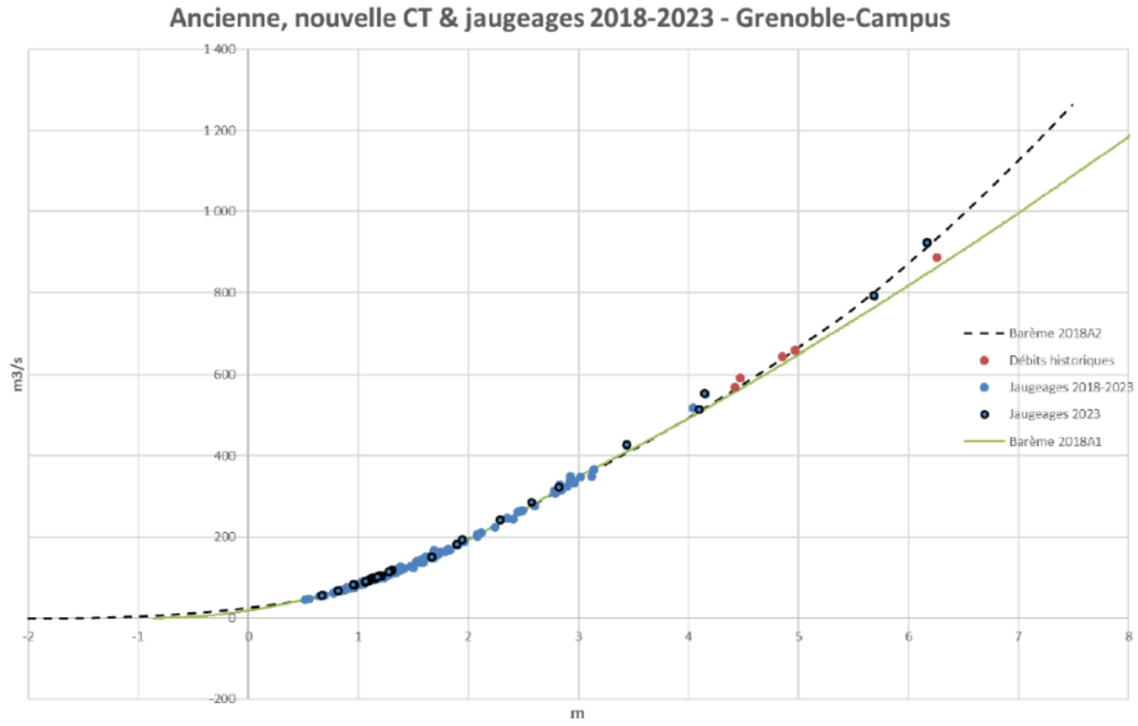
Conclusions

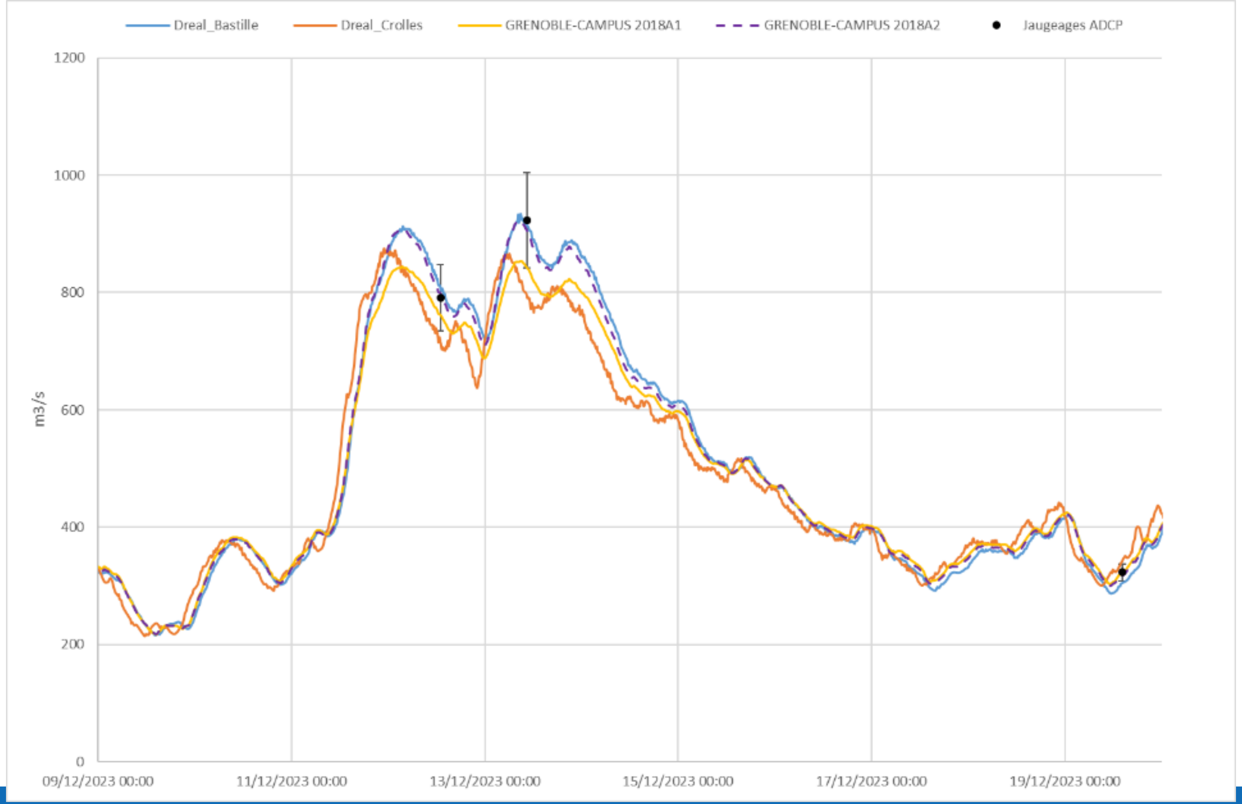
- A new rating curve and it's uncertainty
  - Computed with BaRatin
  - Thanks to 2 high flow gaugings in December 2023 → ADCP + GPS Tracking
  - Considering the slope variation



Conclusions

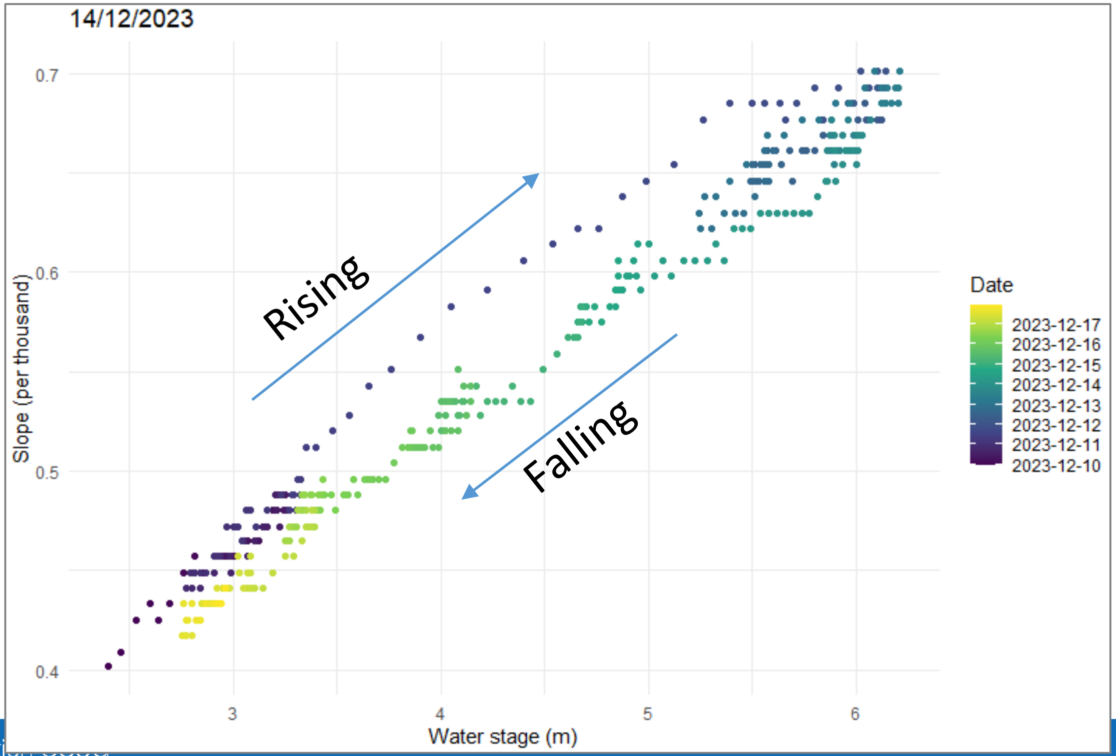
- A new rating curve significantly different from the previous one for the high flows
  - For Q > 500 m^3/s
  - Recalculation of the historical series since 2018
  - More consistent with the neighboring stations

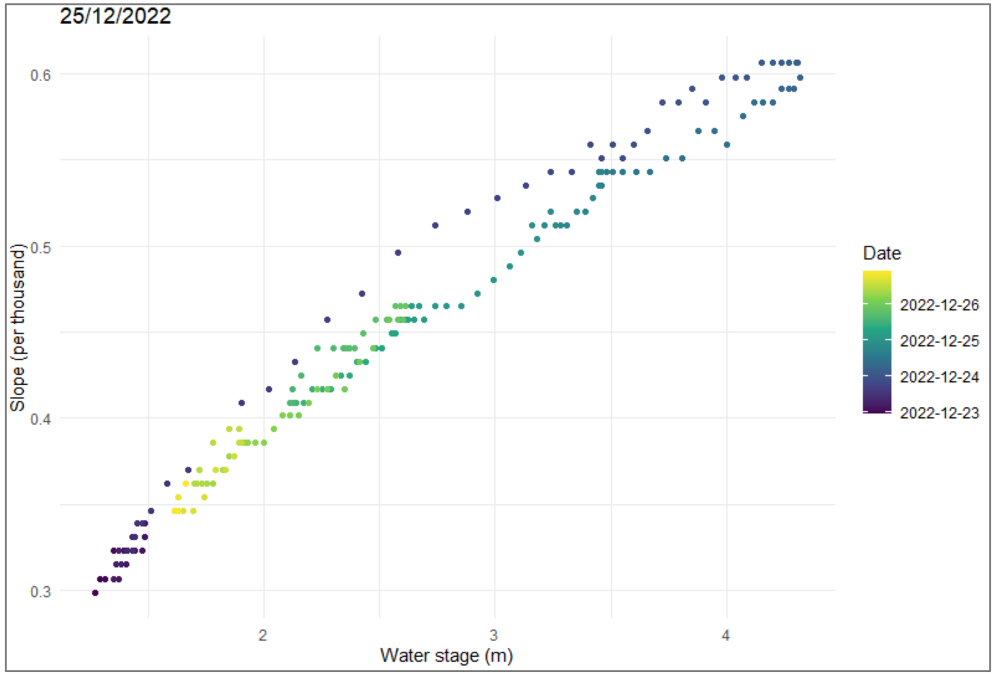


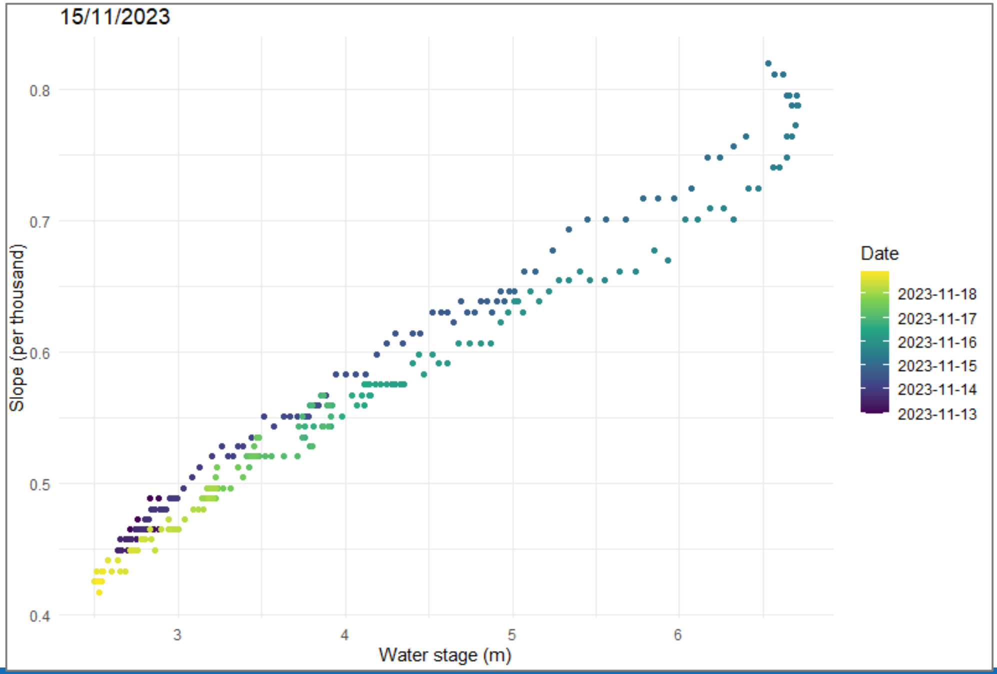


Perspectives

- A probably even more complex rating-curve….
  - Hysteresis effect ??
  - Impact on the stage-discharge relationship ?
    - Work in 2025 with a visiting researcher, Marian Muste, IIHR, Univ of Iowa
  - To be integrated in a new version of BaRatin
    - In which the slope can be expressed as an equation of the stage and time







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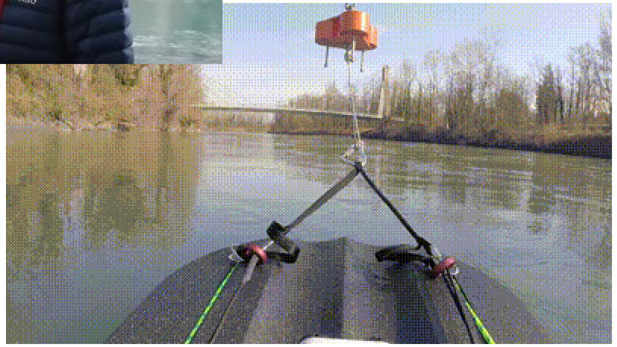
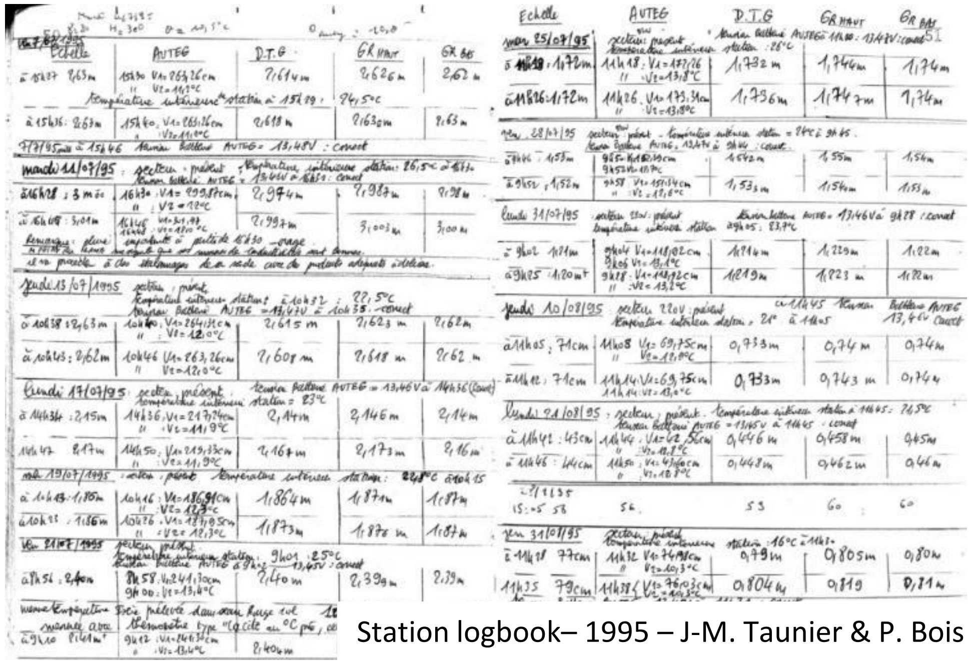
- Long term discharge series = long term field work
  - And a lot of people involved ! Special thanks to them !
    - And to the hundreds of students that conducted so many gaugings !



Philippe Bois, 1994



Station logbook– 1995 – J-M. Taunier & P. Bois