Quantifying the Uncertainty in Discharge Data Using Hydraulic Knowledge and Gaugings with their Uncertainty: the BaRatin approach

Benjamin Renard, Jérôme Le Coz, L. Bonnifait, F. Branger, R. Le Boursicaud, I Horner, Valentin Mansanarez, M. Lang, Sylvain Vigneau

▶ **To cite this version:**

Benjamin Renard, Jérôme Le Coz, L. Bonnifait, F. Branger, R. Le Boursicaud, et al.. Quantifying the Uncertainty in Discharge Data Using Hydraulic Knowledge and Gaugings with their Uncertainty: the BaRatin approach. AGU Fall Meeting, Dec 2014, San Francisco, United States. pp.1, 2014. hal-02600782

HAL Id: hal-02600782
https://hal.inrae.fr/hal-02600782

Submitted on 16 May 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Quantifying the Uncertainty in Discharge Data Using Hydraulic Knowledge and Gaugings with their Uncertainty: the BaRatin* approach

Renard, B., Le Coz, J., Bonnifait[+], L., Branger, F., Le Boursicaud, R., Horner, I., Mansanarez, V., Lang, M., Vigneau, S.

Hydrology-Hydraulics, Irstea Lyon-Villeurbanne, France. benjamin.renard@irstea.fr

[+] *Now at Cerema Trappes, France*

The Original BaRatin Recipe

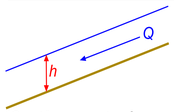
* *Bayesian Rating Curve*

irstea

Cerema

The basics

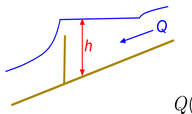
Channel control



Simplified Manning-Strickler

$$Q(h) = KB\sqrt{J}(h-h_0)^{\frac{5}{3}}$$

Section control



rectangular weir

$$Q(h) = CB\sqrt{2g}(h-h_0)^{\frac{3}{2}}$$

triangular weir

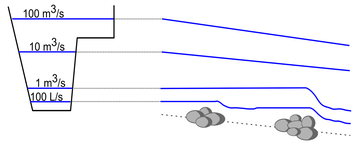
$$Q(h) = C\tan\left(\tfrac{\alpha}{2}\right)\sqrt{2g}(h-h_0)^{\frac{5}{2}}$$

General formula

$$Q(h) = a(h-b)^c$$

Formalisation of the rating curve *(unknown quantities in pink)*

Activation / deactivation of hydraulic controls



The hydraulic control matrix

	control 1 riffle1	control 2 riffle 2	control 3 main channel	control 4 floodplain	
segment 1					κ_0
segment 2					κ_1
segment 3					κ_2
segment 4					κ_3
					κ_4

Transition stages

Domain of validity

A versatile rating curve equation

$$Q(h) = \sum_{r=1}^{N_{segment}} \left(\mathbf{1}_{[\kappa_{r-1};\kappa_r]}(h) \times \sum_{j=1}^{N_{control}} M(r,j) \times a_j \, (h - b_j)^{c_j} \right)$$

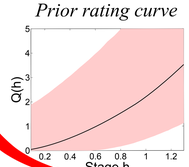
computed by continuity for $j > 1$

$$= f(h;\boldsymbol{\theta}), \text{ where } \boldsymbol{\theta} = (a_1, b_1, c_1, \kappa_1, a_2, c_2, ..., a_{N_{control}}, c_{N_{control}})$$

Ingredient 1: Hydraulics

Bob Manning likes this

Prior rating curve



Bayesian Inference

The blender: Bayes theorem

Combines hydraulic information (prior) and information from gaugings with uncertainty (likelihood)

$$post(\boldsymbol{\theta}, \gamma_1, \gamma_2 | \widetilde{Q}, \widetilde{H}) \propto$$
$$prior(\boldsymbol{\theta}, \gamma_1, \gamma_2) \times$$
$$lkh(\widetilde{Q} | \boldsymbol{\theta}, \gamma_1, \gamma_2, \widetilde{H})$$

MCMC sampling

Tom Bayes likes this

Ingredient 2: Statistics

Nobody likes this

Data: gauging and their uncertainty

$$(\widetilde{H}_i, u_{H_i}, \widetilde{Q}_i, u_{Q_i})_{i=1:N}$$

- $\widetilde{H}_i$: Observed stage
- $\widetilde{Q}_i$: Observed discharge
- u_{H_i}: Uncertainty in observed stage. Stage error $\sim \mathcal{N}(0, u_{H_i})$. Often assumed to be negligible
- u_{Q_i}: Uncertainty in observed discharge. Assumed to be known. Discharge error $\sim \mathcal{N}(0, u_{Q_i})$

Order of magnitude of standard discharge uncertainty for a few gauging methods

ADCP	Velocity-area (current-meter)	Tracer dilution	Surface velocity (radar)	Surface velocity (video)
2.5-5%	3.5-7.5%	1.5-5%	5-10%	5-10%

Statistical model

Linking the rating curve with gaugings

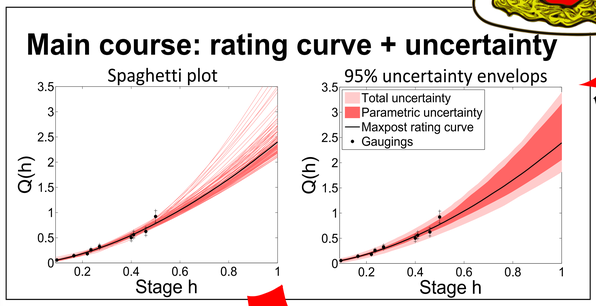
Remnant structural error $\sim \mathcal{N}(0, \sigma_f)$, $\sigma_f = \gamma_1 + \gamma_2 f(\widetilde{H}_i; \boldsymbol{\theta})$

Gauging error $\sim \mathcal{N}(0, u_{Q_i})$

$$\widetilde{Q}_i = f(\widetilde{H}_i; \boldsymbol{\theta}) + \epsilon_i^f + \epsilon_i^Q$$

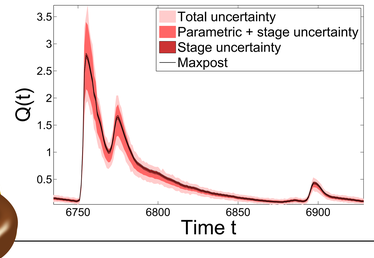
Total error $\sim \mathcal{N}\left(0, \sqrt{\sigma_f^2 + u_{Q_i}^2}\right)$

Main course: rating curve + uncertainty



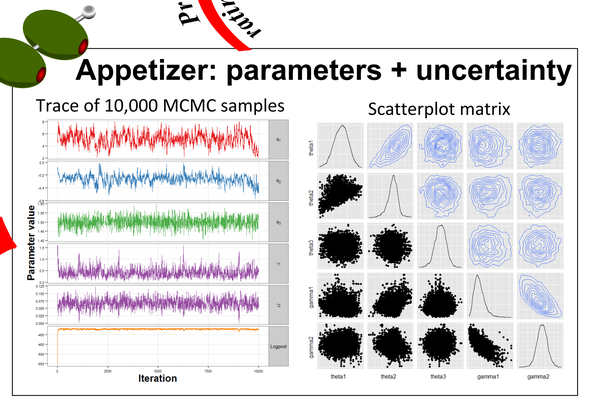
Propagate an uncertain limnigraph

Dessert: hydrograph + uncertainty



Propagate through rating curve equation

Appetizer: parameters + uncertainty



Software tool: BaRatinAGE

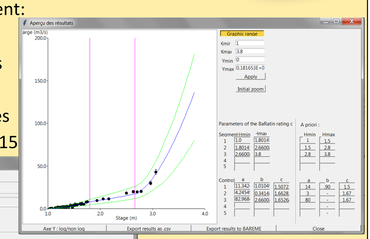
BaRatin Advanced Graphical Environment

V1.3 freely available (windows platform)

Just send an email to baratin.dev@lists.irstea.fr

V2.0 currently under development:

- ✓ multi-platform
- ✓ propagation to hydrographs
- ✓ improved graphical outputs
- ✓ more import/export facilities
- ✓ expected release: end of 2015



Ask for a demo!

Conclusion & perspectives

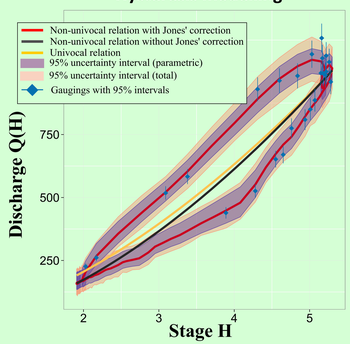
Main properties of BaRatin

- A versatile rating curve equation elicited by a hydraulic analysis
- Uses informative priors from hydraulic knowledge
- Acknowledges uncertainty in gaugings
- Uncertainty in rating curve and all derived quantities (hydrographs)
- Uncertainty decomposition (stage / parametric / structural)

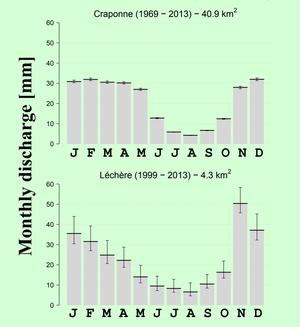
Current and future research

- Inclusion of uncertainty in gauged stages needs further appraisal
- Non-univocal rating curves: hysteresis, vegetation, rating shifts, etc.
- Model for remnant structural error: alternatives?
- Random vs. systematic errors and their impact on derived quantities (e.g. daily / monthly / annual discharge)
- Impact of discharge uncertainty on water balance analyses
- Impact of discharge uncertainty on hydrologic modelling

Hysteresis modelling



Impact of rating curve uncertainty on interannual monthly discharge



Le Coz, Renard, Bonnifait, Branger, Le Boursicaud, **2014**. Combining hydraulic knowledge and uncertain gaugings in the estimation of hydrometric rating curves: A Bayesian approach. *J. Hydrol.*, **509**: 573-587.