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

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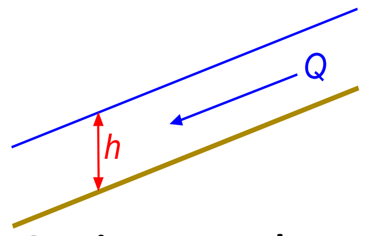
The Original BaRatin Recipe

* *Bayesian Rating Curve*

Ingredient 1: Hydraulics

The basics

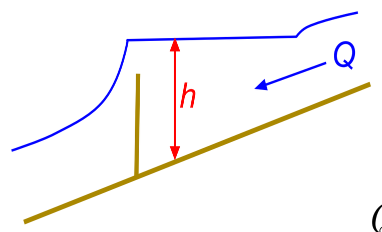
Channel control



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

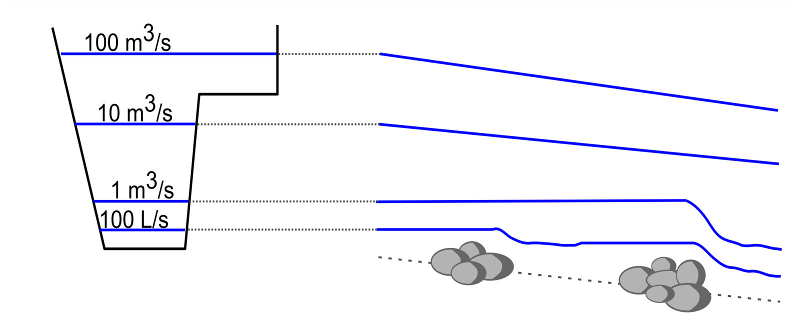
$Q(h) = C\tan\left(\frac{\alpha}{2}\right)\sqrt{2g}(h-h_0)^{\frac{5}{2}}$

General formula

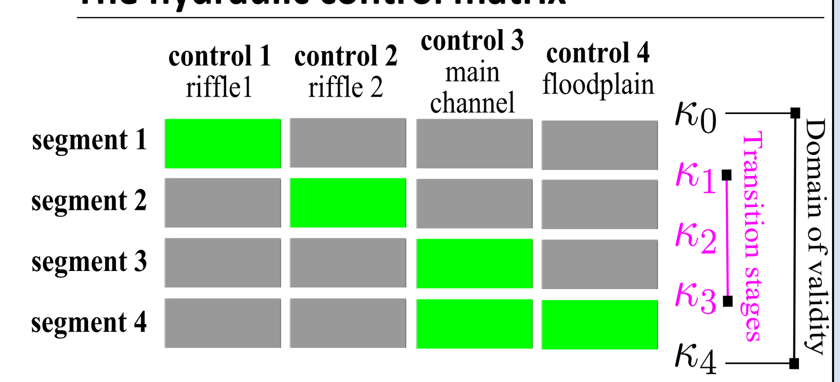
$Q(h) = a(h-b)^c$

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

Activation / deactivation of hydraulic controls



The hydraulic control matrix

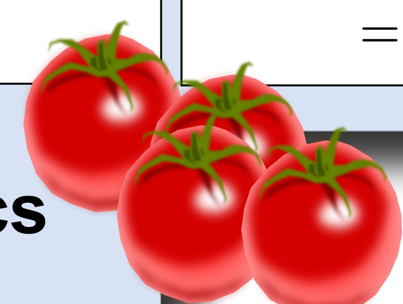


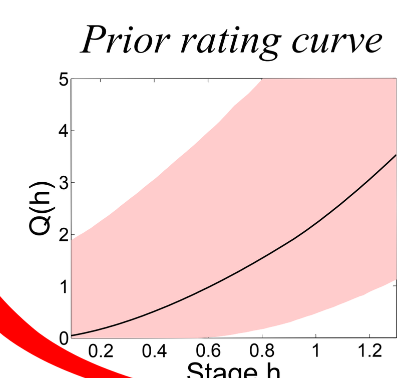
A versatile rating curve equation

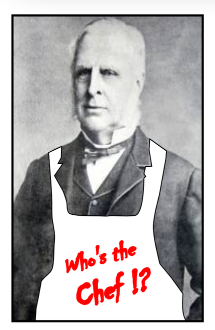
$$Q(h) = \sum_{r=1}^{N_{segment}} \left(\mathbf{1}_{[\kappa_{r-1};\kappa_r]}(h) \times \sum_{j=1}^{N_{control}} M(r,j) \times a_j\,(h-b_j)^{c_j} \right)$$

computed by continuity for $j > 1$

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







Bob Manning likes this

Bayesian Inference

The blender: Bayes theorem

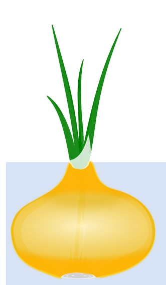
Combines hydraulic information (prior) and information from gaugings with uncertainty (likelihood)

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

MCMC sampling

Tom Bayes likes this

Ingredient 2: Statistics



Nobody likes this

Data: gaugings and their uncertainty

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

Observed stage

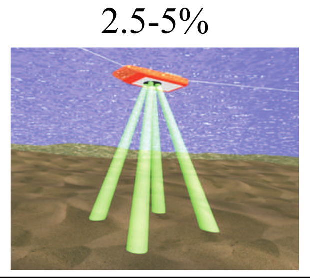
Observed discharge

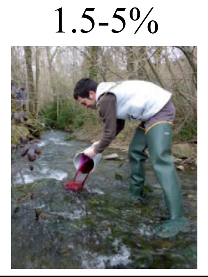
Uncertainty in observed stage
Stage error $\sim \mathcal{N}(0, u_{H_i})$
Often assumed to be negligible

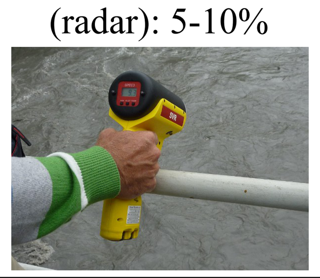
Uncertainty in observed discharge
Assumed to be known
Discharge error $\sim \mathcal{N}(0, u_{Q_i})$

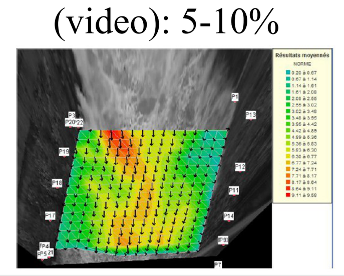
Order of magnitude of standard discharge uncertainty for a few gauging methods

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

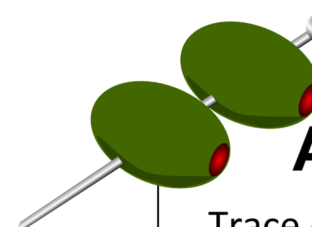
Remnant structural error
$\sim \mathcal{N}(0, \sigma_f)$
$\sigma_f = \gamma_1 + \gamma_2 f(\widetilde{H}_i; \boldsymbol{\theta})$

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

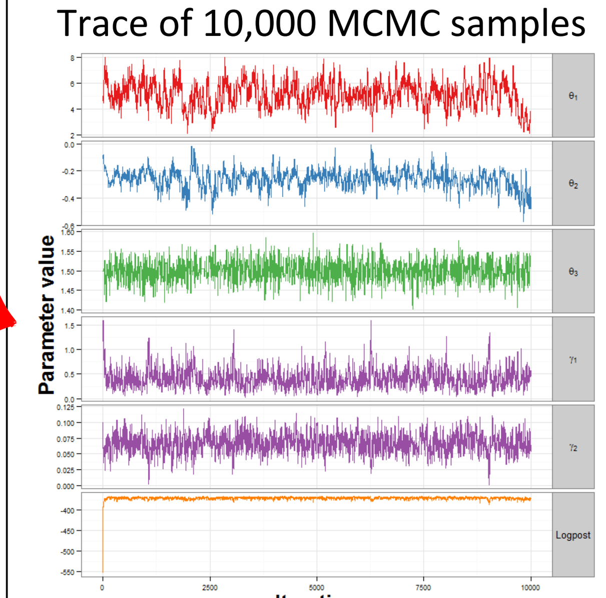
$$\widetilde{Q}_i = f(\widetilde{H}_i; \boldsymbol{\theta}) + \epsilon_i^f + \epsilon_i^Q$$

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

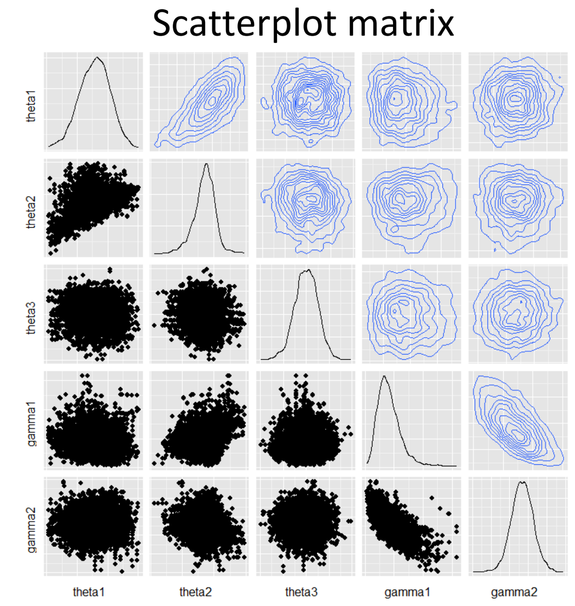
Appetizer: parameters + uncertainty



Trace of 10,000 MCMC samples

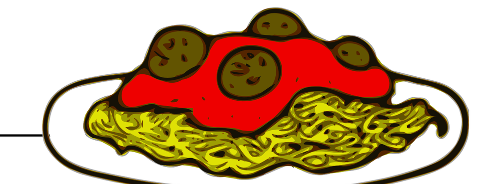


Scatterplot matrix

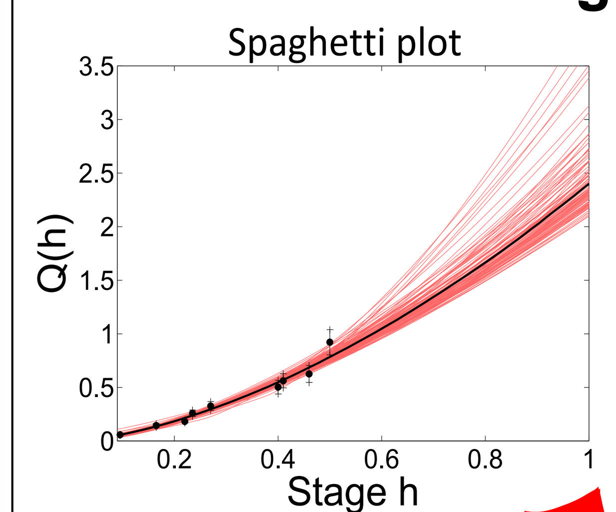


Propagate through rating curve equation

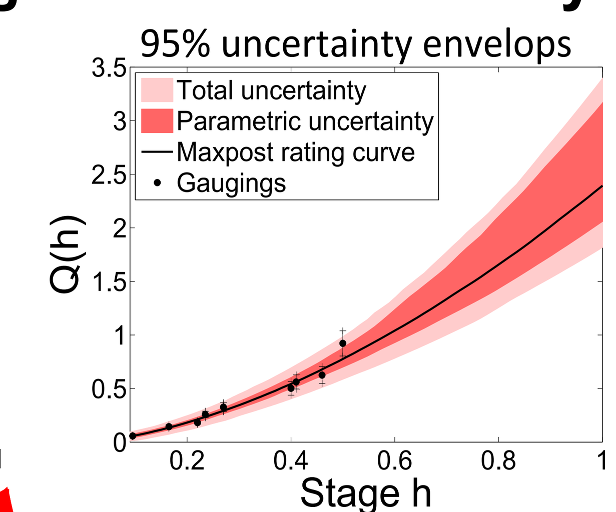
Main course: rating curve + uncertainty



Spaghetti plot

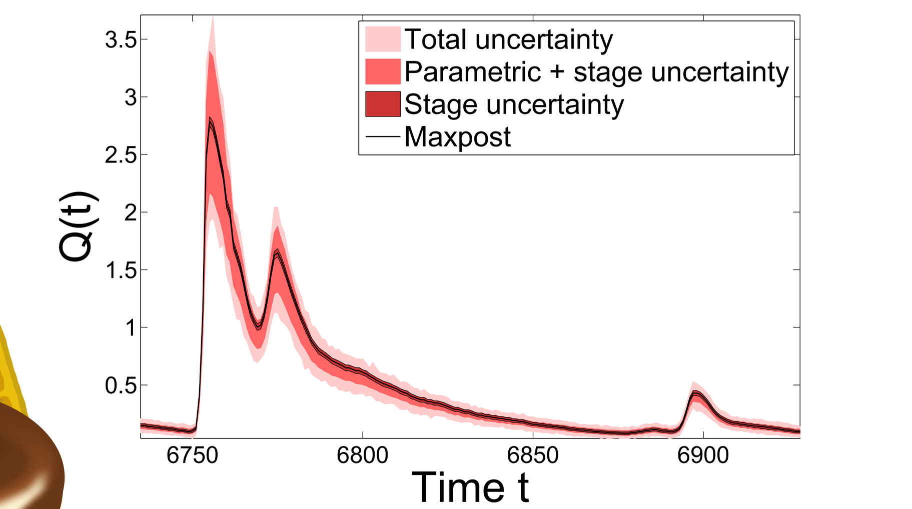


95% uncertainty envelops



Propagate an uncertain limnigraph

Dessert: hydrograph + uncertainty



Software tool: BaRatinAGE

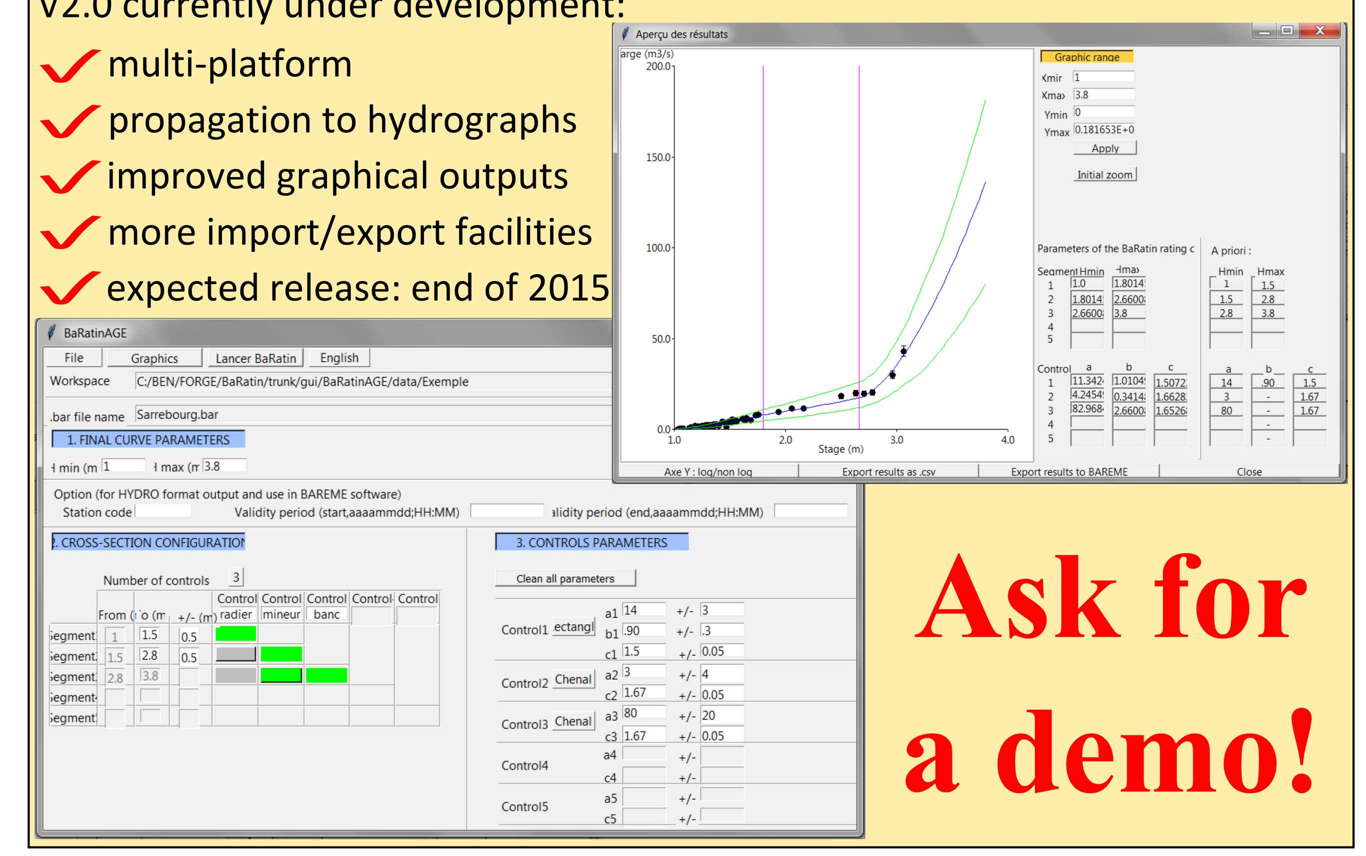
BaRatin Advanced Graphical Environment

V1.3 freely available (windows platform)

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

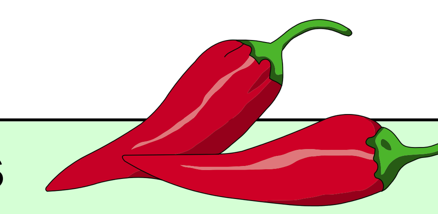
V2.0 currently under development:

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



Ask for a demo!

Conclusion & perspectives



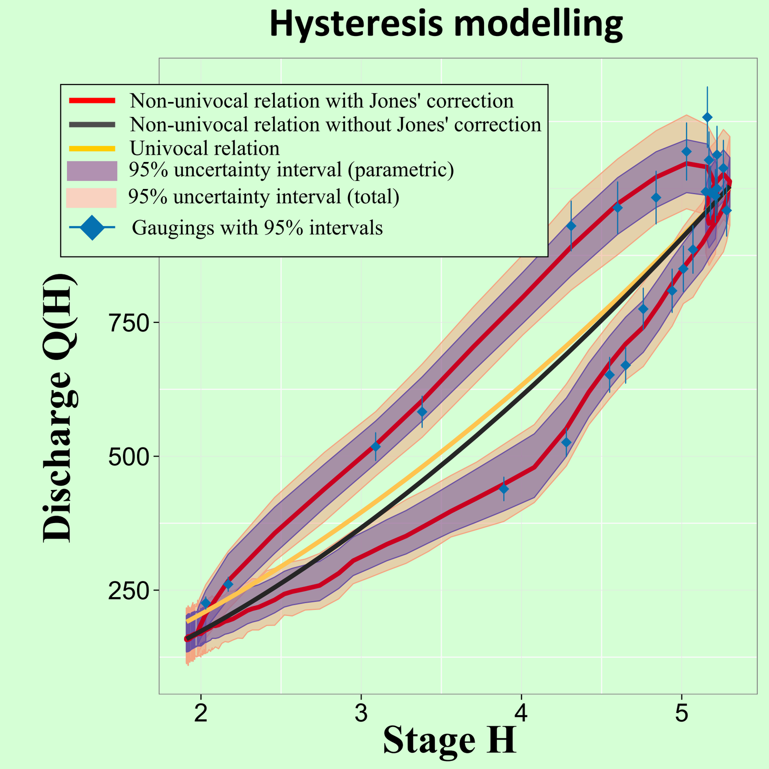
Main properties of BaRatin

- 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)

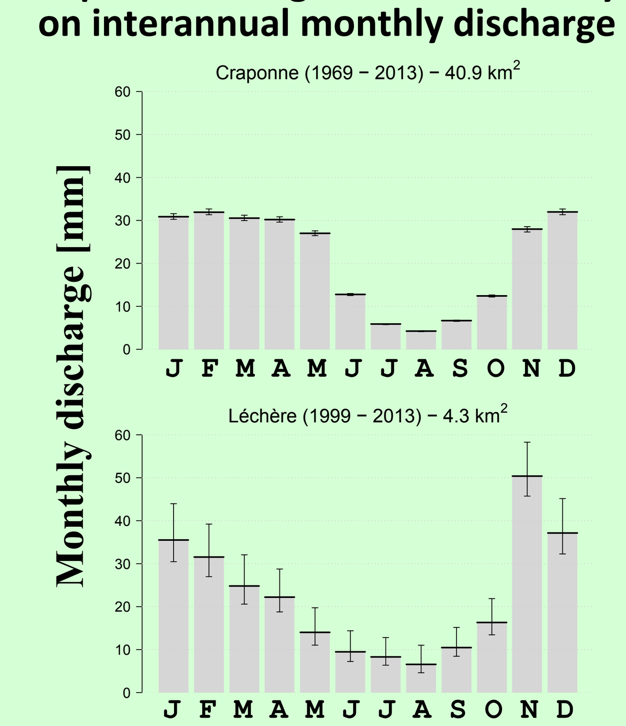
Current and future research

- 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.