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

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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



* Bayesian Rating Curve

The basics

Channel control
Simplified Manning-Strickler
 $Q(h) = KB\sqrt{J}(h - h_0)^{5/3}$

Section control
rectangular weir
 $Q(h) = CB\sqrt{2g}(h - h_0)^{3/2}$
triangular weir
 $Q(h) = C \tan(\frac{\alpha}{2})\sqrt{2g}(h - h_0)^{3/2}$

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

Formalisation of the rating curve (unknown quantities in pink)

Activation / deactivation of hydraulic controls

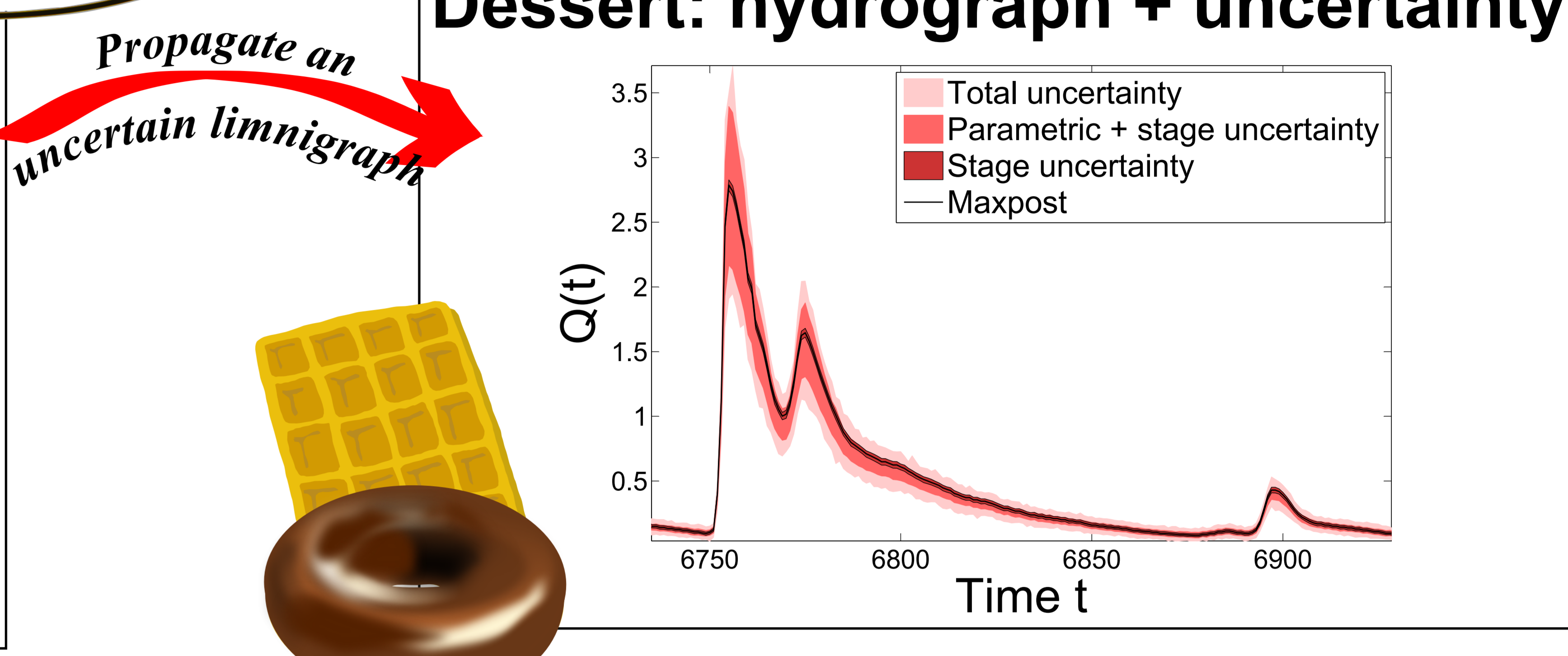
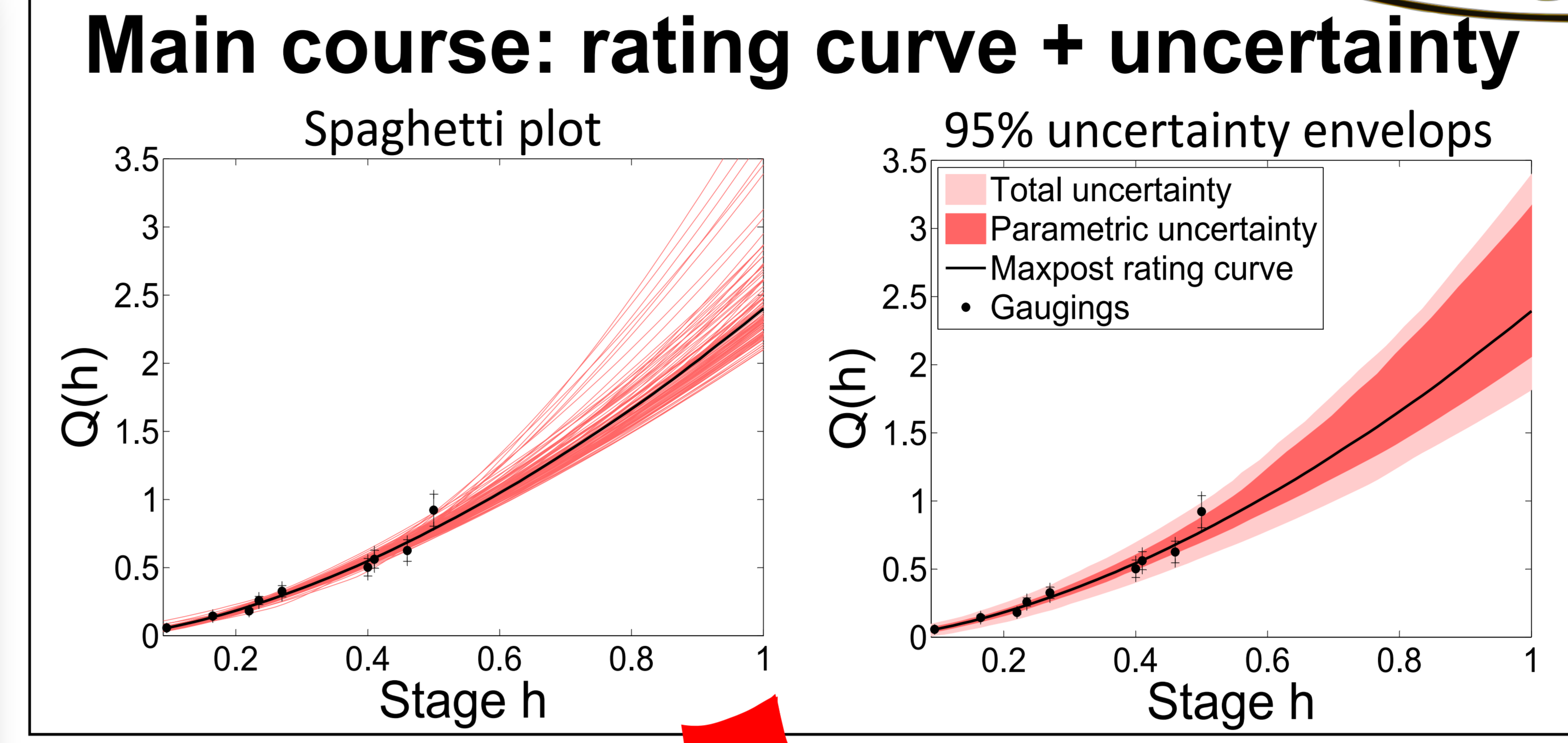
The hydraulic control matrix

	control 1 riffle 1	control 2 riffle 2	control 3 main channel	control 4 floodplain	K_0
segment 1	█	█	█	█	K_1 K_2 K_3 K_4 Transition stages Domain of validity
segment 2	█	█	█	█	
segment 3	█	█	█	█	
segment 4	█	█	█	█	

A versatile rating curve equation

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

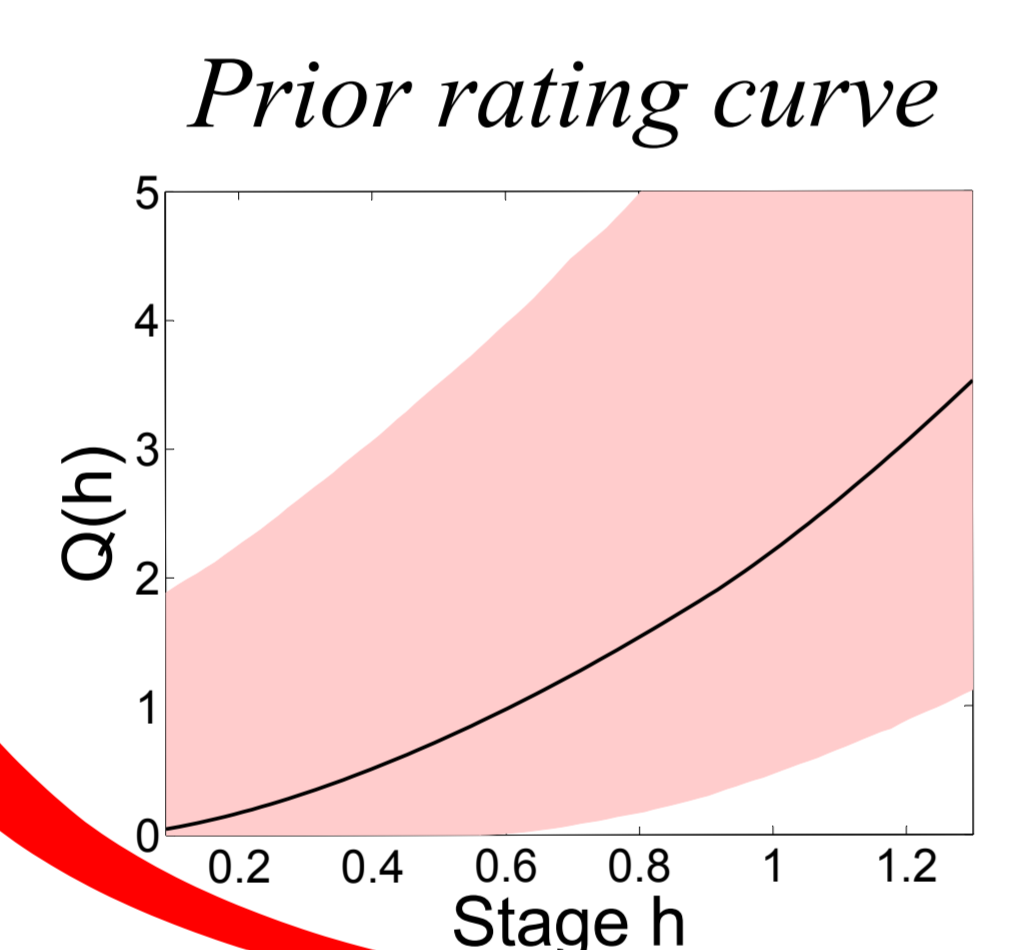
computed by continuity for $j > 1$

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


Ingredient 1: Hydraulics



Bob Manning likes this



Bayesian Inference

The blender: Bayes theorem

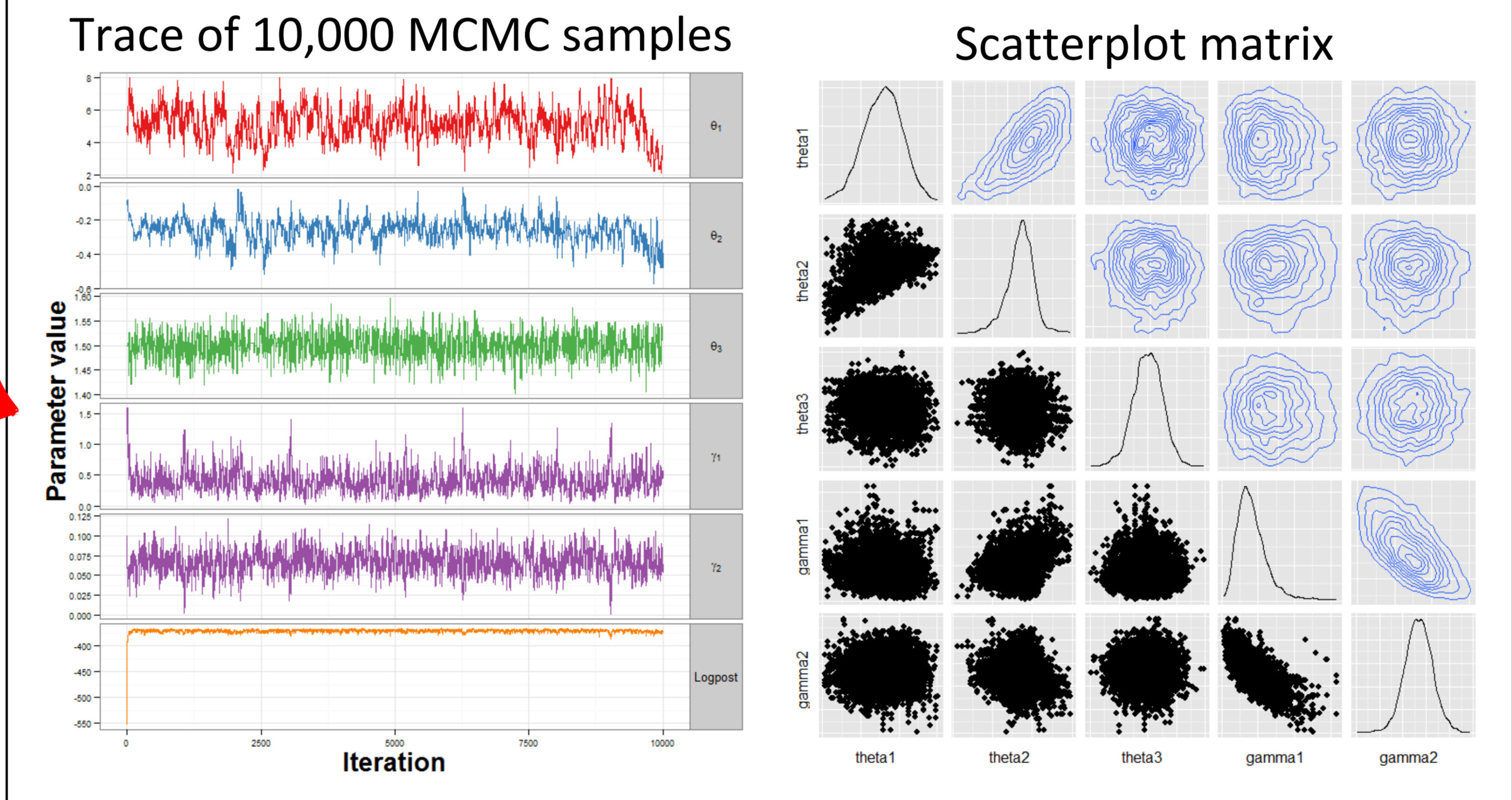
Combines hydraulic information (prior) and information from gaugings with uncertainty (likelihood)

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

MCMC sampling

Tom Bayes likes this

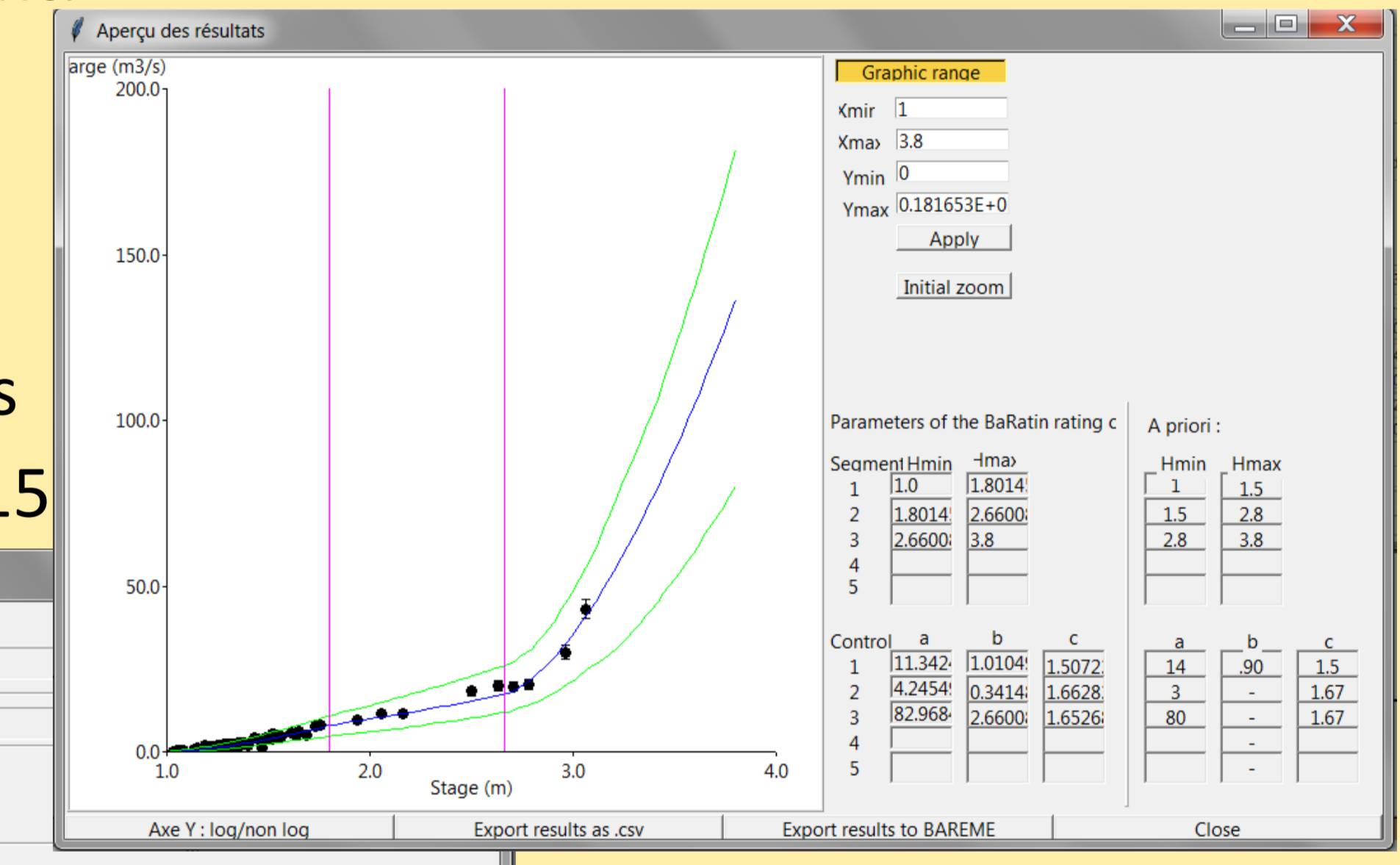
Appetizer: parameters + uncertainty



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!

Ingredient 2: Statistics

Nobody likes this

Data: gaugings and their uncertainty

Observed stage (\tilde{H}_i, u_{H_i}) , Observed discharge (\tilde{Q}_i, u_{Q_i}) , $i=1:N$

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

Linking the rating curve with gaugings

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

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

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

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

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

