The OpenTURNS uncertainty quantification library

Michaël Baudin [1] Julien Schueller [2]

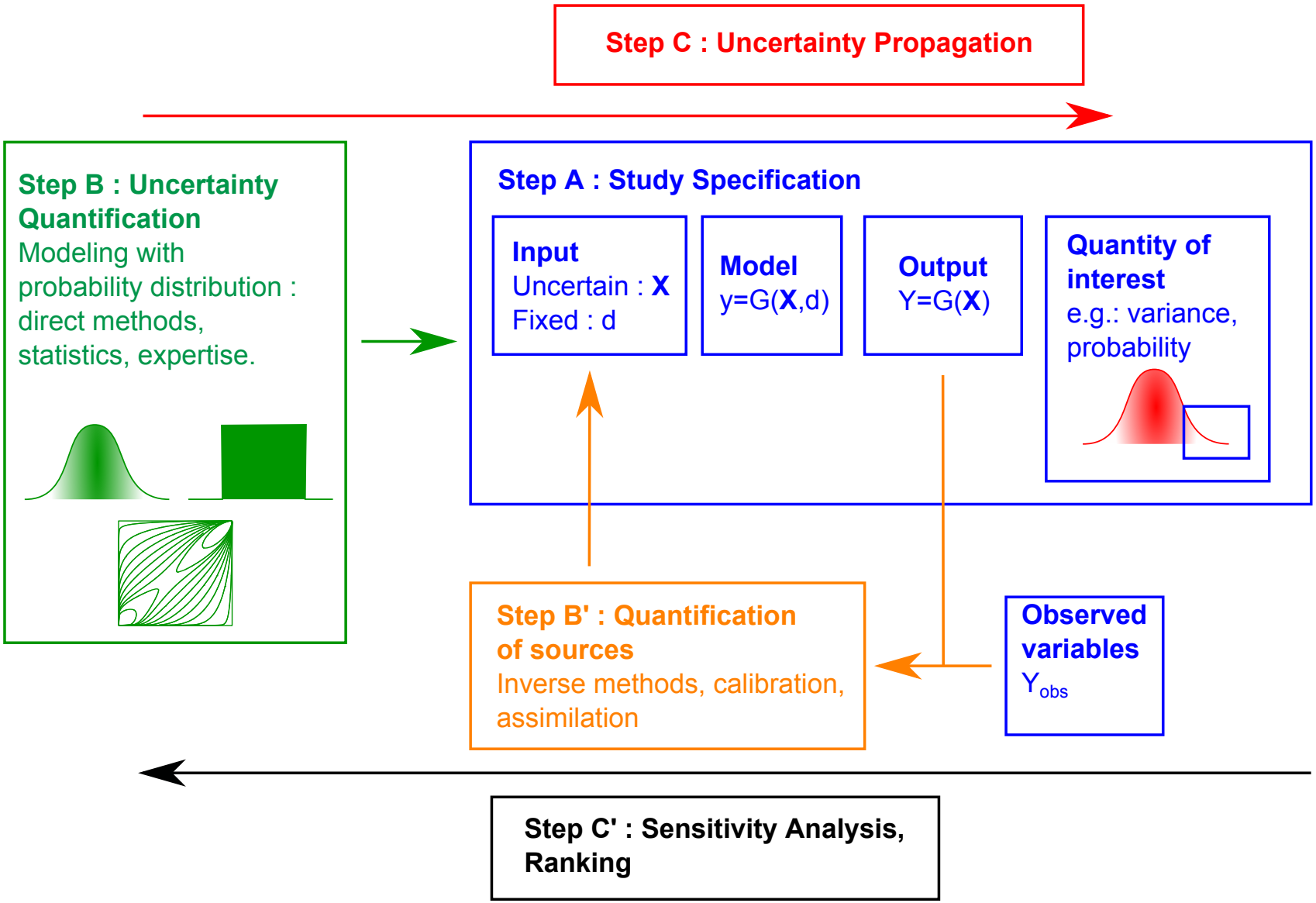
[1]EDF R&D. 6, quai Watier, 78401, Chatou Cedex - France, michael.baudin@edf.fr

[2]Phimeca Engineering. 18/20 boulevard de Reuilly, 75012 Paris - France, schueller@phimeca.com

EuroSciPy 2017, Erlangen, Germany

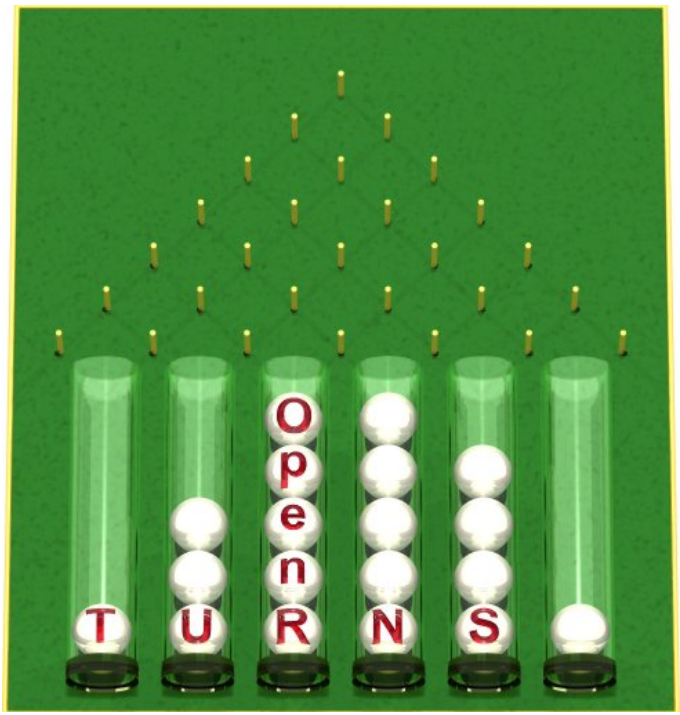
Contents

Uncertainty Quantification Methodology



OpenTURNS

- Uncertainty quantification, uncertainty propagation, sensitivity analysis and metamodeling
- Partners : EDF, Phiméca, Airbus, IMACS
- www.openturns.org
- Licence LGPL
- Linux, Windows



OpenTURNS

Overview :

- First release: 2007
- technical committee (including 4 developers), steering committee
- Users: mainly in France
- Number of users: ≈ 1000 (10900 Conda downloads in 2016-2017)
- Size of the project (2017): 5420 files, 680 classes, 158k sloc
- Documentation: theoric, API, developer

Features overview 1/2

Data analysis:

- Visual analysis
- (Non)parametric estimation
- Distribution fitting tests
- Bayesian calibration

Probabilistic modeling:

- Dependence modeling: Copulas
- Univariate & multivariate distributions
- Process: ARMA, Gaussian

Features overview 2/2

Meta modeling:

- Gaussian process regression (Kriging)
- Spectral methods: Functional chaos expansion, Karhunen-Loeve, low-rank tensors

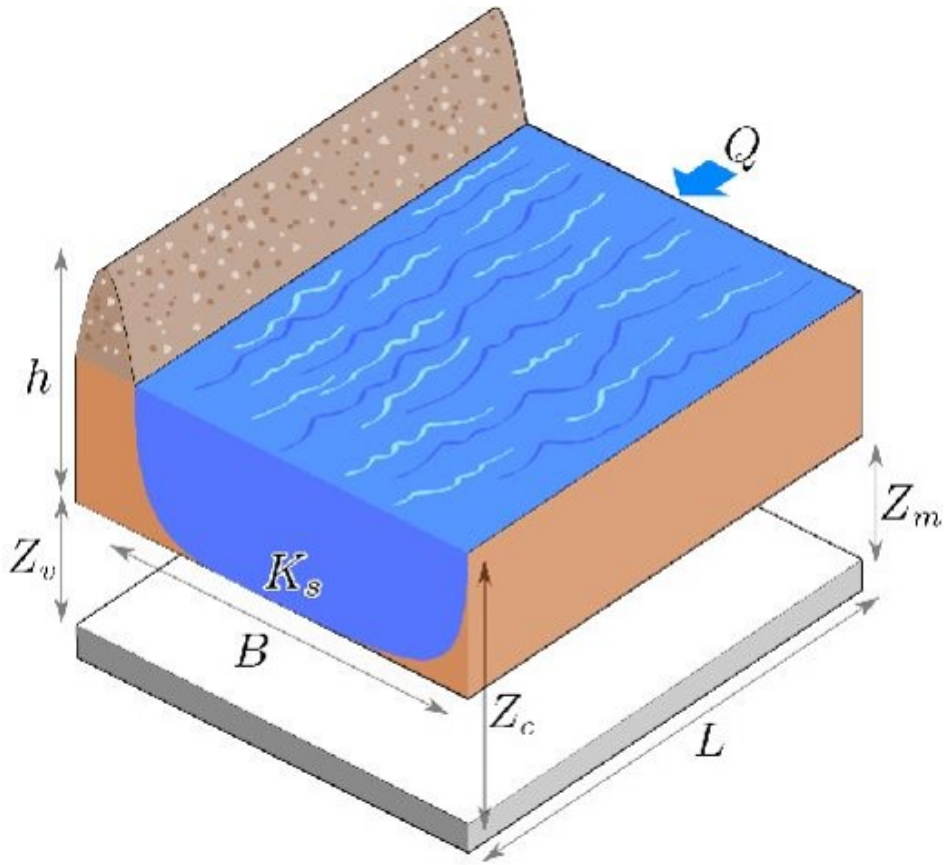
Reliability, sensitivity:

- Monte Carlo, LHS, low-discrepancy sequences
- Variance reduction methods: importance sampling, subset sampling
- Approximation methods: FORM, SORM
- Indices: Spearman, Sobol, ANCOVA

Flood example 1/5

The flood model of a river compares the water level to the dike height:

$$S = \left(\frac{Q}{Ks \times 300 \times \sqrt{(Zm - Zv)/5000}} \right)^{3/5} + Zv - 55.5 - 3$$



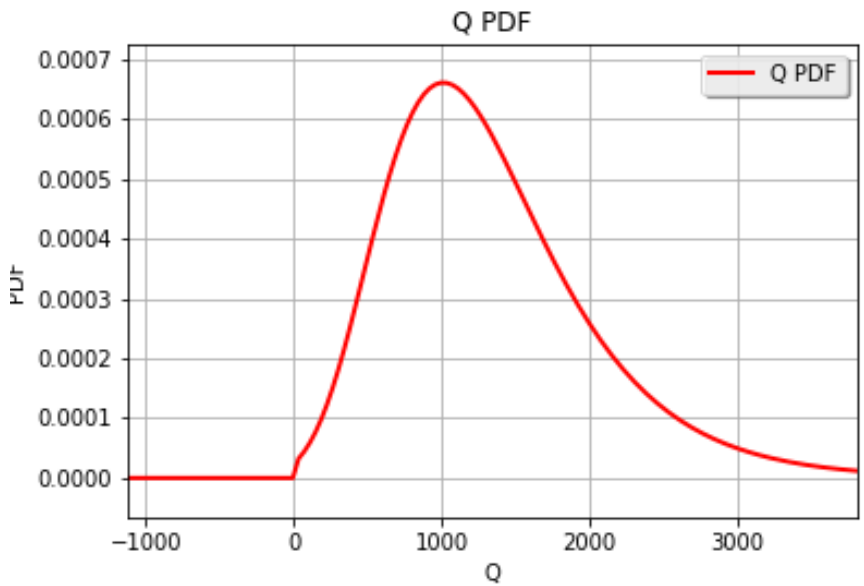
Flood example 2/5

- Q $\sim$ Gumbel(alpha=0.00179, beta=1013), flow rate $[m^3 s^{-1}]$
- Ks $\sim$ Normal(mu=30.0, sigma=7.5), strickler $[m^{1/3} s^{-1}]$
- Zv $\sim$ Uniform(a=49, b=51), downstream depth [m]
- Zm $\sim$ Uniform(a=54, b=56), upstream depth [m]

Failure occurs when S is positive, lets estimate $P_f = \mathbb{P}(S(\underline{X}) > 0)$.

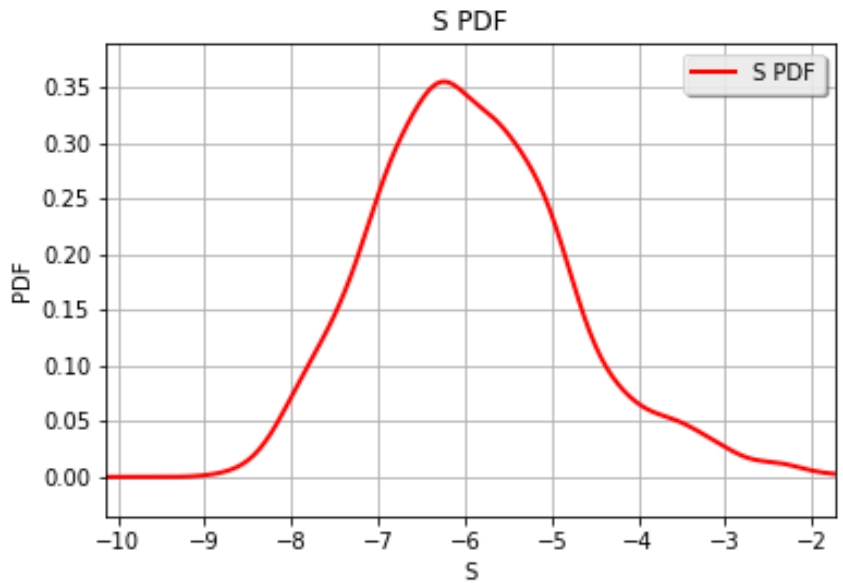
Flood example 3/5

```
# Probabilistic model
Q = ot.Gumbel(1./558., 1013.)
Ks = ot.Normal(30.0, 7.5)
Zv = ot.Uniform(49.0, 51.0)
Zm = ot.Uniform(54.0, 56.0)
copula = ot.IndependentCopula(4)
dist = ot.ComposedDistribution([Q, Ks, Zv, Zm], copula)
```



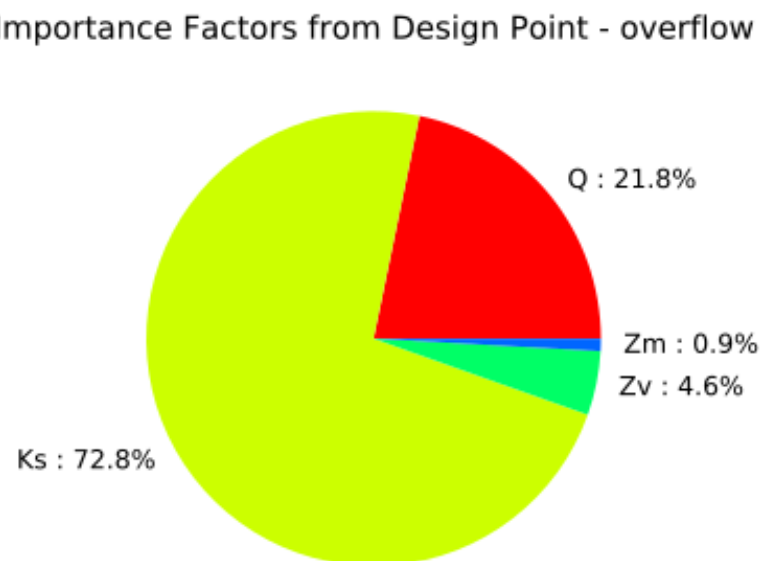
Flood example 4/5

```
# Random variable S=G(Q,Ks,Zv,Zm)
rv = ot.RandomVector(dist)
f = ot.SymbolicFunction(['Q', 'Ks', 'Zv', 'Zm'],
  ['(Q/(Ks*300.*sqrt((Zm-Zv)/5000)))^(3.0/5.0)+Zv-55.5-3.'])
S = ot.CompositeRandomVector(f, rv)
```



Flood example 5/5

```
# Compute P(S>0) using First Order Reliability Method algorithm
event = ot.Event(S, ot.Greater(), 0.0) # event S>0
optimAlgo = ot.Cobyla()
algo = ot.FORM(optimAlgo, event, dist.getMean())
algo.run()
result = algo.getResult()
print('Pf=', result.getEventProbability()) # P(S>0)=0.00053
result.drawImportanceFactors()
```



Architecture

- C++ core / SWIG Python bindings
- BLAS / LibXml2 / TBB / muParser / NLopt
- Packaging: Debian, Conda, Windows
- Compilation: cmake
- Documentation: Sphinx
- Repository: https://github.com/openturns

Modules

- otrobopt: Robust optimization module
- otfmi: FMI models manipulation
- otsvm: SVM classifiers, metamodels
- otagrum: Bayesian networks module
- otwrapy: wrap external simulation codes
- ...

Contributions welcome!

END

Thank you for your attention!
Any questions?

Bibliography

- Airbus, EDF, Phimeca Engineering, IMACS. OpenTURNS, a scientific library usable as a Python module dedicated to the treatment of uncertainties, www.openturns.org.
- Airbus, EDF, Phimeca Engineering, IMACS. Documentation of OpenTURNS, version 1.9. http://openturns.github.io/openturns/1.9/contents.html
- Michaël Baudin, Anne Dutfoy, Bertrand Iooss, and Anne-Laure Popelin. OpenTURNS: An Industrial Software for Uncertainty Quantification in Simulation, Handbook of Uncertainty Quantification, pages 1-38. Springer International Publishing, 2016
- Open TELEMAC-MASCARET. Electricité de france, Sogreah, Hydraulic Research Wallingford, Centre d'Etudes Techniques Maritimes et Fluviales, Bundesanstalt fur Wasserbau, and Daresbury Laboratory. www.opentelemac.org.