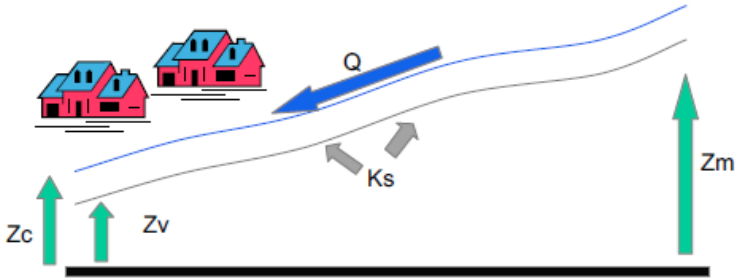
DEALING WITH IMPERFECT KNOWLEDGE IN NATURAL HAZARD ASSESSMENTS:

Beyond classical probabilities and challenges

Jeremy Rohmer, French geological survey BRGM, j.rohmer@brgm.fr

An illustrative example

Probabilistic flood risk assessment [1]



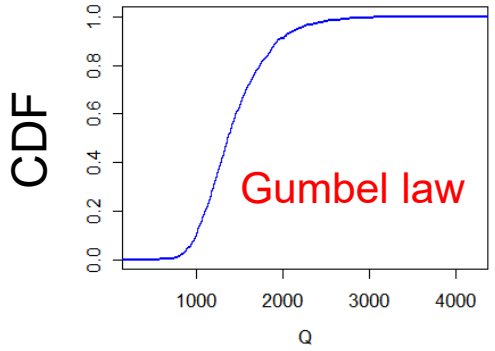
Flood model

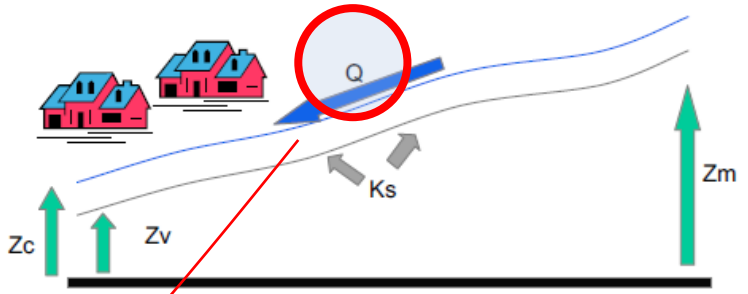
[1] Adapted from Iooss et al. (2005)

Probabilistic flood risk assessment [1]

Modelling the uncertain knowledge using probability

River flow rate Q [m3/s]





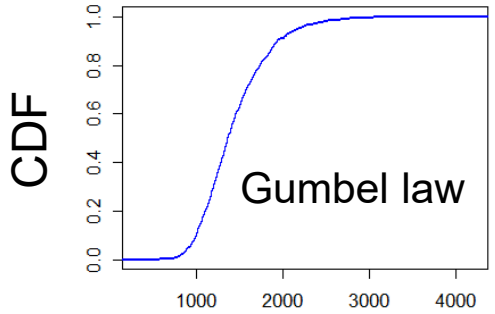
Flood model

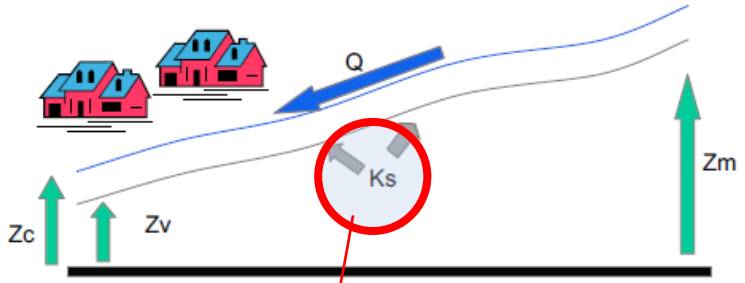
[1] Adapted from Iooss et al. (2005)

Probabilistic flood risk assessment [1]

Modelling the uncertain knowledge using probability

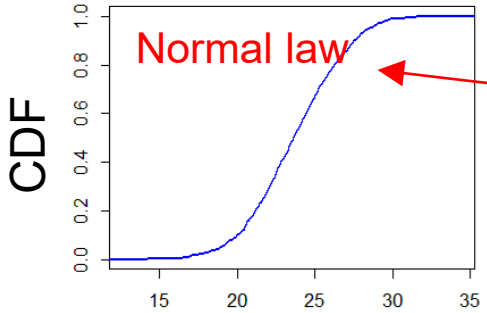
River flow rate Q [m3/s]





Flood model

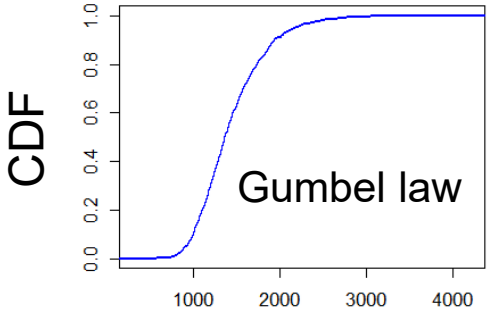
Friction coeff. Ks



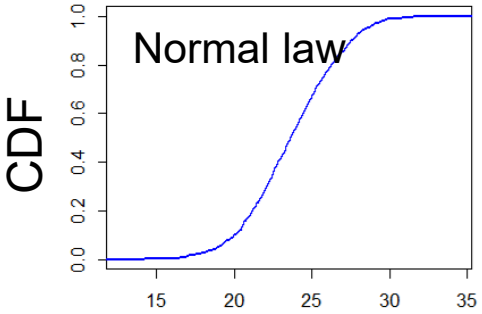
[1] Adapted from Iooss et al. (2005)

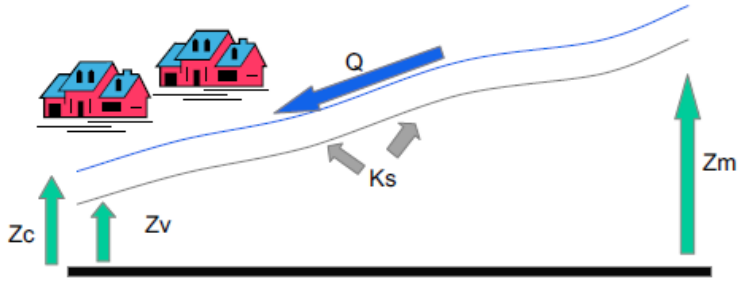
Probabilistic flood risk assessment [1]

River flow rate Q [m3/s]



Friction coeff. Ks

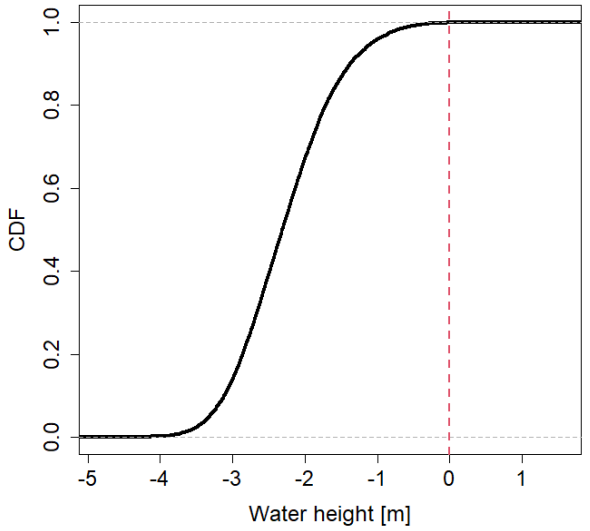




Flood model

Uncertainty propagation via Monte-Carlo Sampling

Probability law of water height

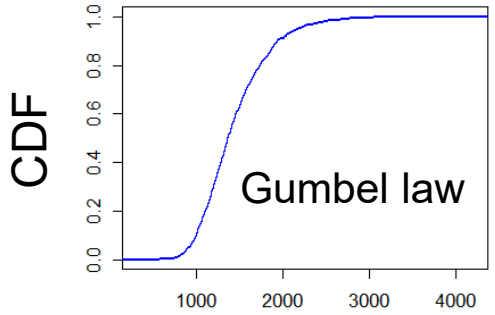


[1] Adapted from looss et al. (2005)

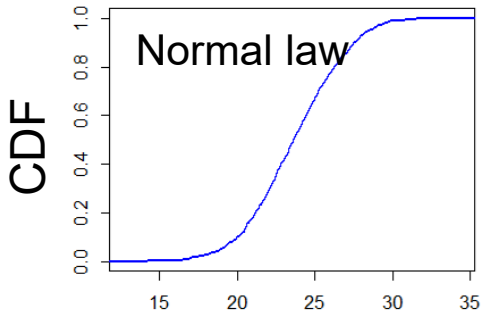
Probabilistic flood risk assessment [1]

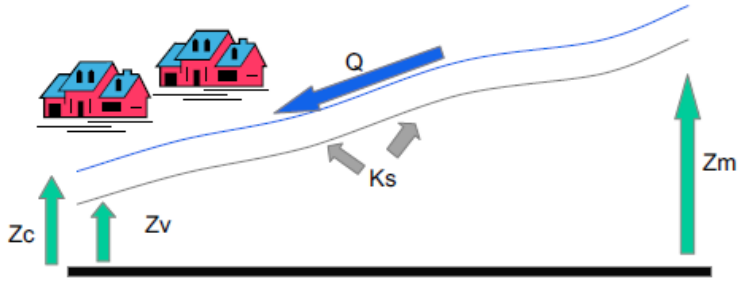
Probability of flooding Pf ~ 0.2%

River flow rate Q [m3/s]



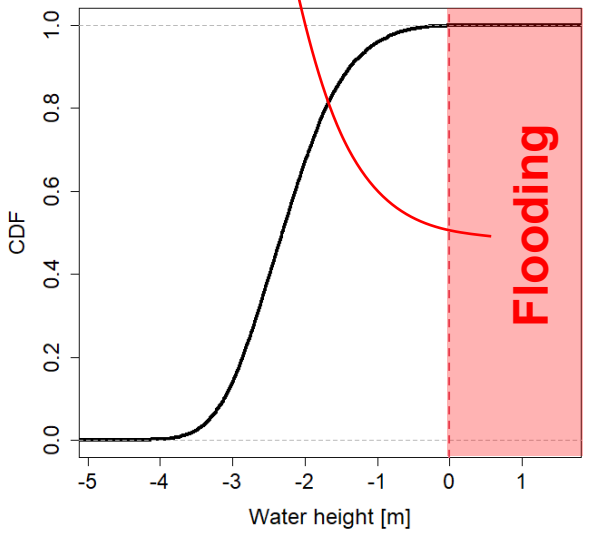
Friction coeff. Ks





Flood model

Probability law of water height

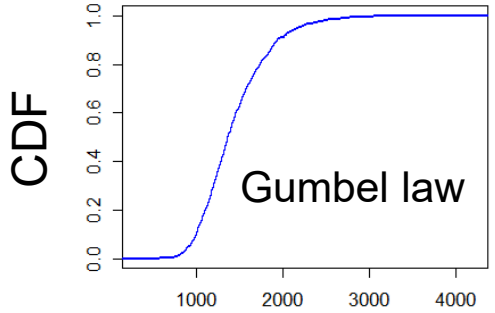


[1] Adapted from Iooss et al. (2005)

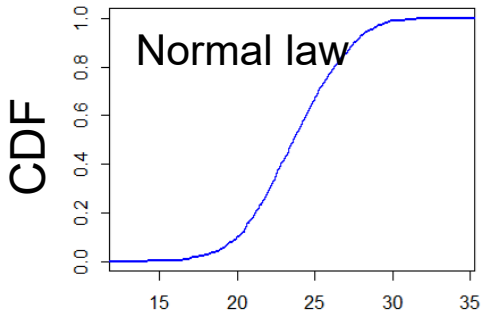
This value does not reflect the difficulties with the Heterogeneous and Imperfect Data

Probability of flooding Pf ~ 0.2%

River flow rate Q [m3/s]



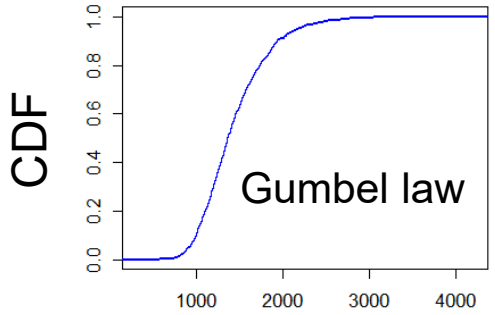
Friction coeff. Ks



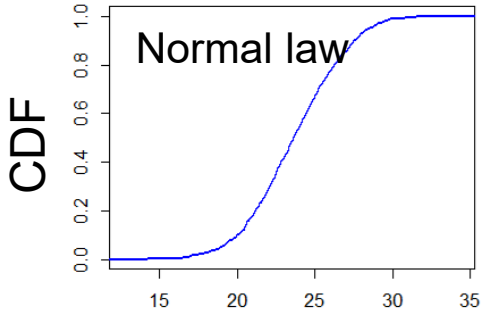
This value does not reflect the difficulties with the Heterogeneous and Imperfect Data

Probability of flooding Pf ~ 0.2%

River flow rate Q [m3/s]

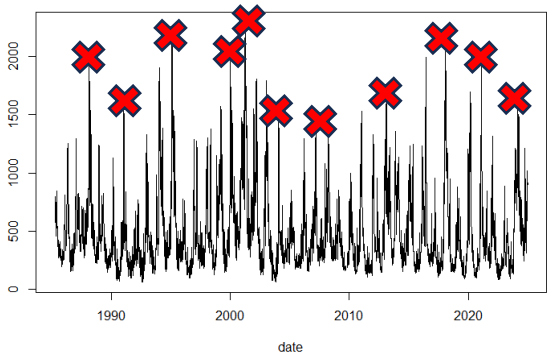


Friction coeff. Ks



Selected and fitted using many observations

Time series of measured Q

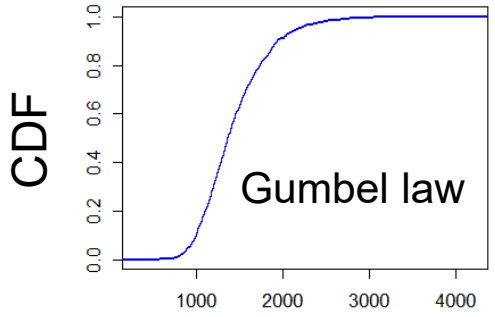


Randomness drives uncertainty

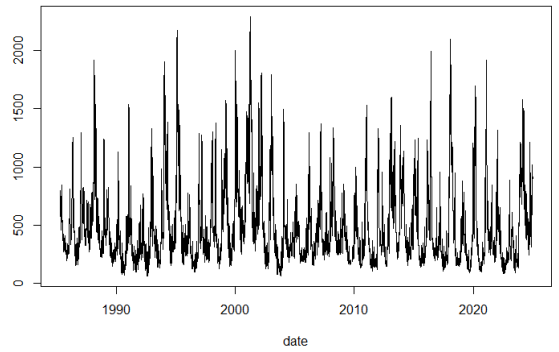
This value does not reflect the difficulties with the Heterogeneous and Imperfect Data

Probability of flooding Pf ~ 0.2%

River flow rate Q [m3/s]

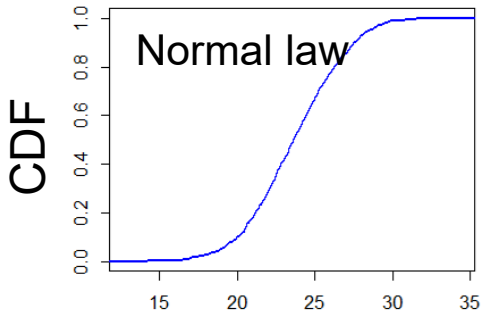


Time series of measured Q



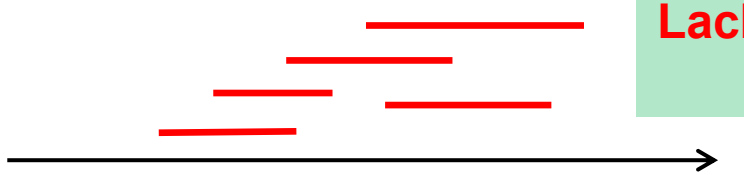
Randomness drives uncertainty

Friction coeff. Ks



Selected and fitted using only 5 observations

…with imprecision…

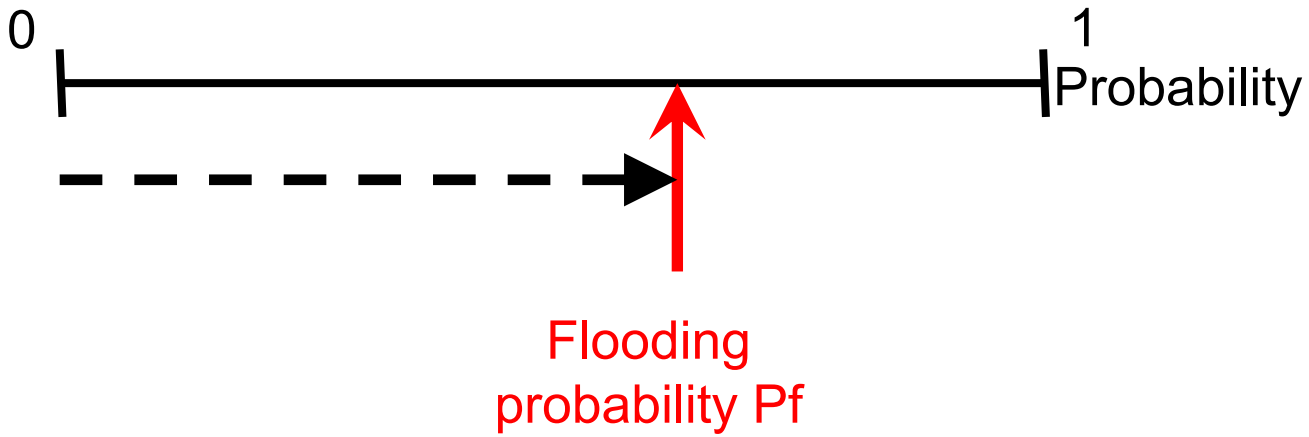


…and completed by expert oipnions…

Lack of knowledge drives uncertainty

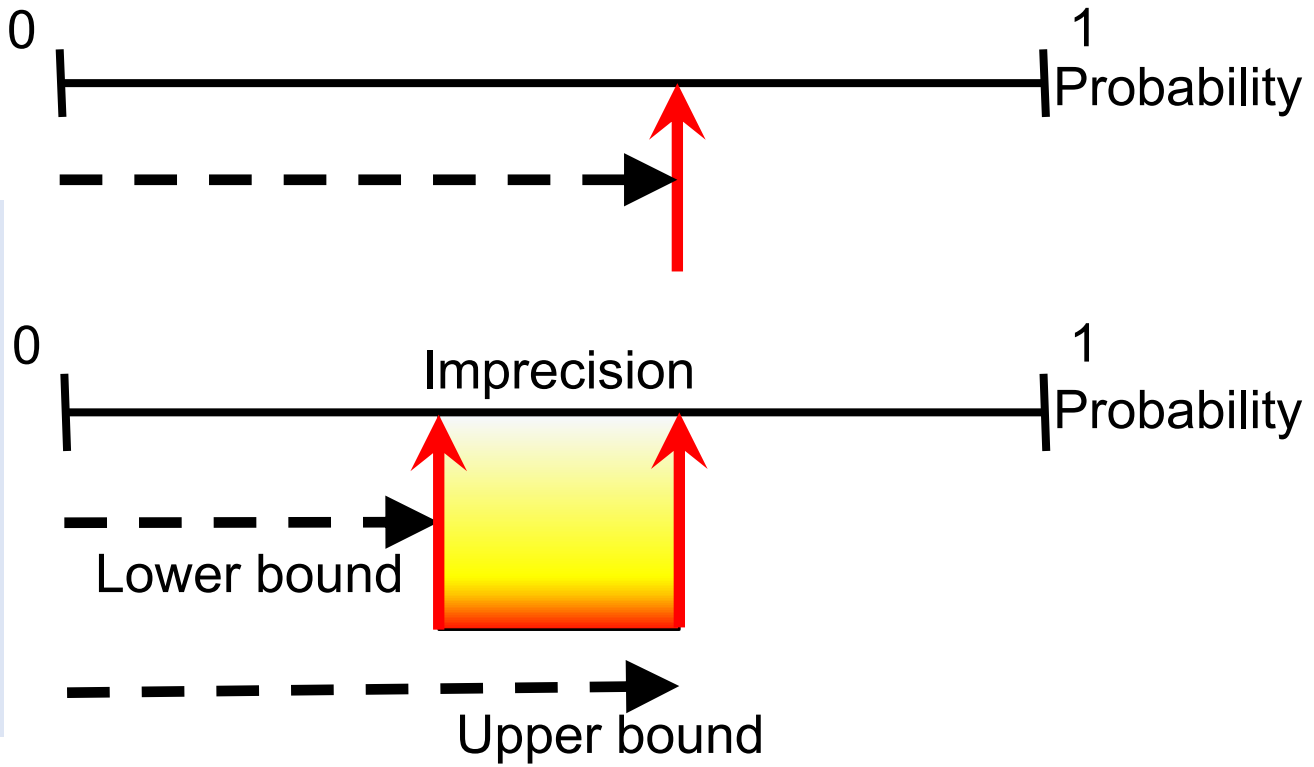
Need for flexibility for modelling knowledge with Heterogeneous and Imperfect Data

Widely used framework

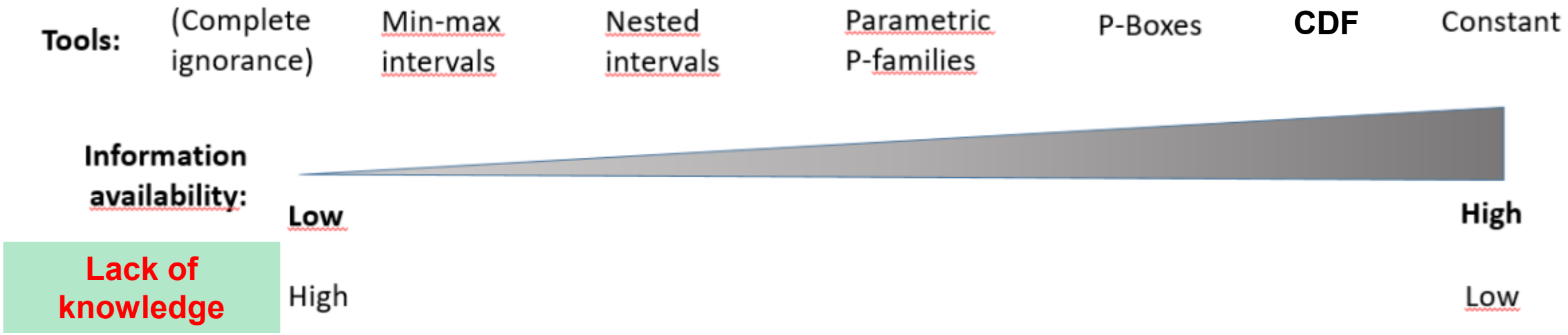


Need for flexibility for modelling knowledge with Heterogeneous and Imperfect Data

Use a pair of lower and upper probability measures



Need for flexible tools for modelling knowledge with Heterogeneous and Imperfect Data



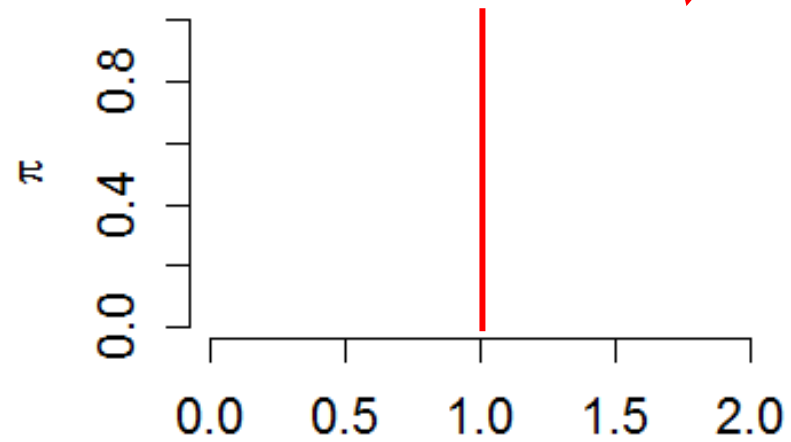
Adapted from Guyonnet et al., 2025, Science of the Total Environment

Need for flexible tools for modelling knowledge with Heterogeneous and Imperfect Data

Tools: (Complete ignorance) | Min-max intervals | Nested intervals | Parametric P-families | P-Boxes | **CDF** | Constant

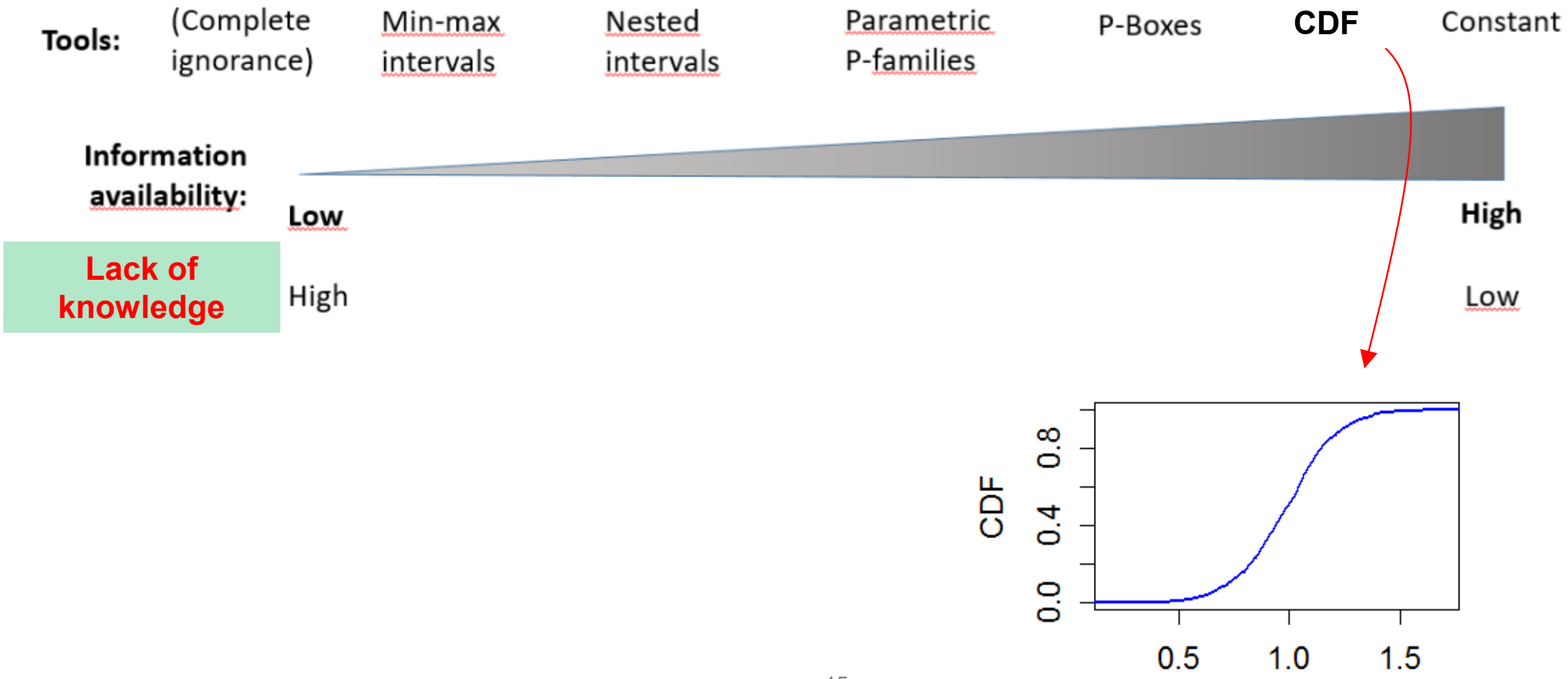
Information availability: **Low** → **High**

Lack of knowledge: High → Low



Adapted from Guyonnet et al., 2025, Science of the Total Environment

Need for flexible tools for modelling knowledge with Heterogeneous and Imperfect Data



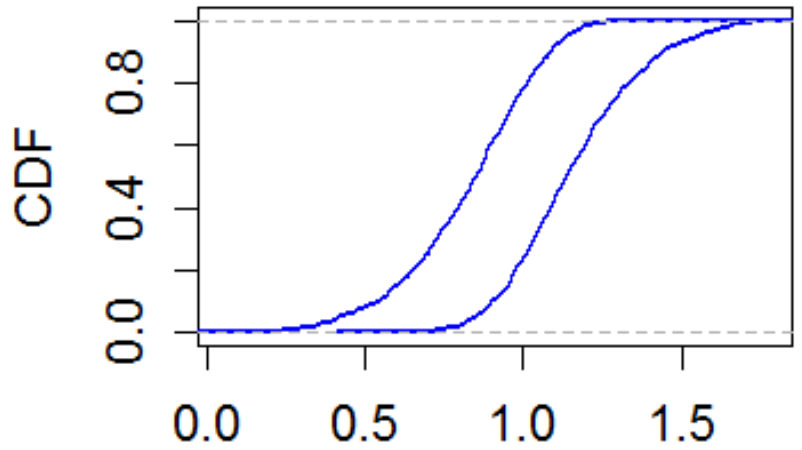
Adapted from Guyonnet et al., 2025, Science of the Total Environment

Need for flexible tools for modelling knowledge with Heterogeneous and Imperfect Data

Tools: (Complete ignorance) | Min-max intervals | Nested intervals | Parametric P-families | P-Boxes | **CDF** | Constant

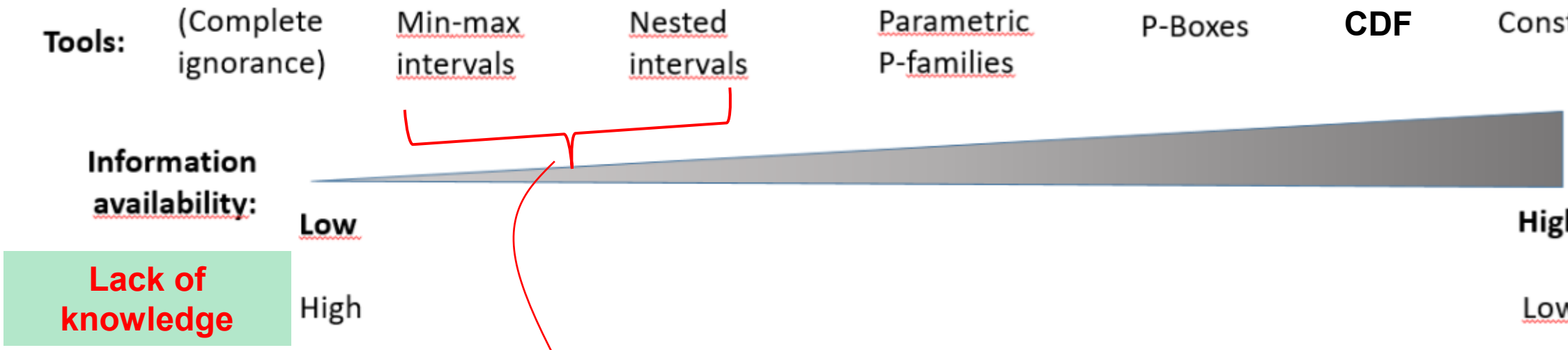
Information availability: **Low** → **High**

Lack of knowledge: High → Low

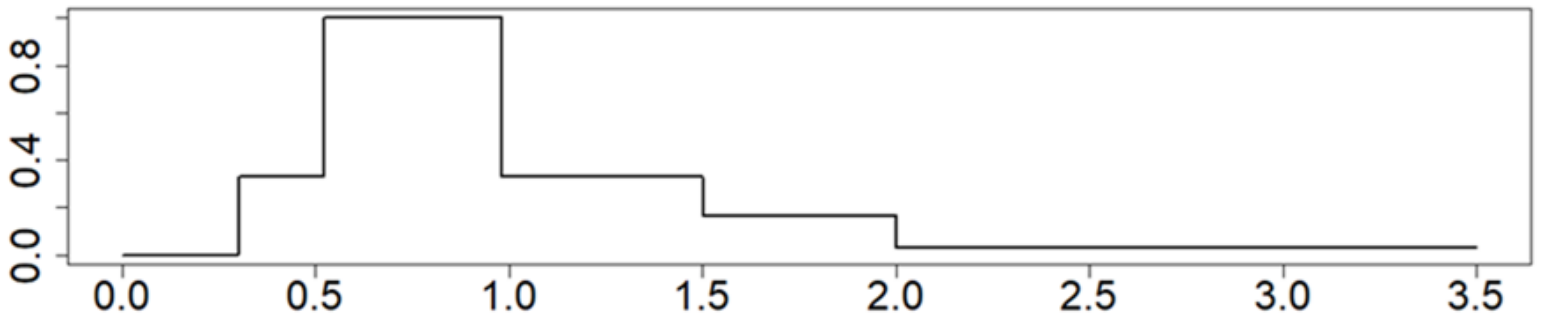


[1] Ferson et al. (2003); [2] Baudrit et al., 2007

Need for flexible tools for modelling knowledge with Heterogeneous and Imperfect Data



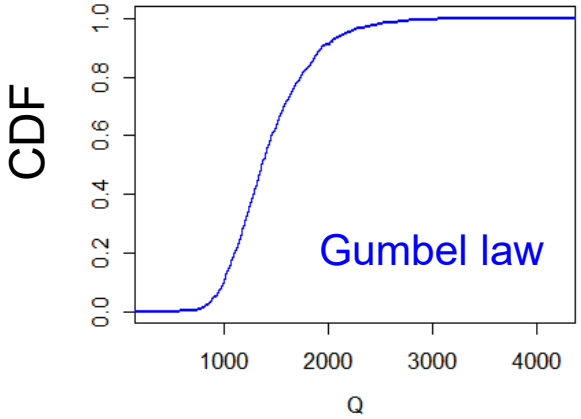
Distribution of possibility [1]



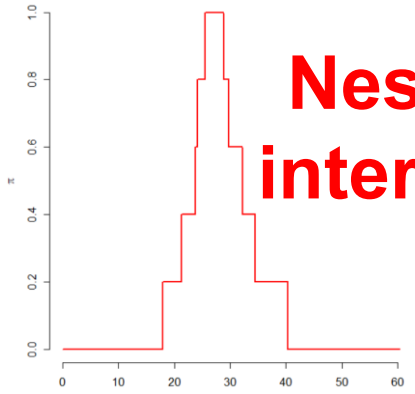
[1] Dubois & Prade (1988)

Hybrid probabilistic flood risk assessment [1]

River flow rate Q [m3/s]



Friction coeff. Ks

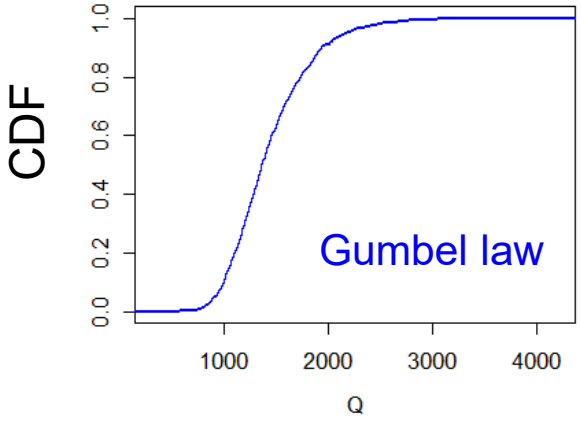


Nested intervals

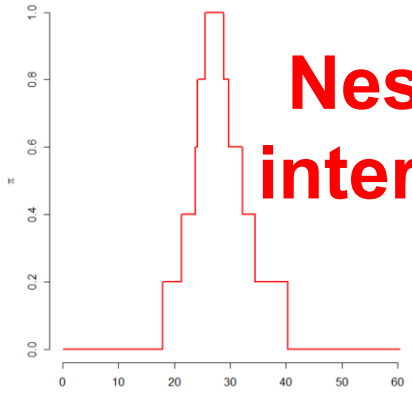
[1] Baudrit et al. 2005

Hybrid probabilistic flood risk assessment [1]

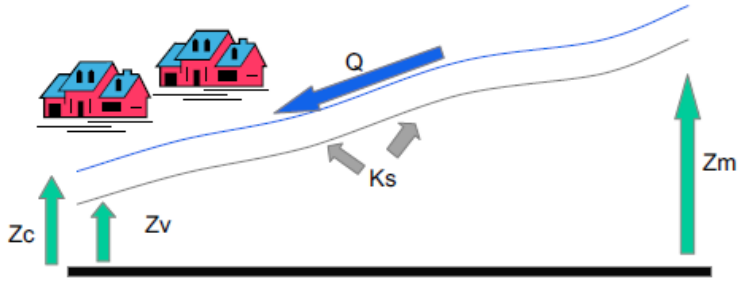
River flow rate Q [m3/s]



Friction coeff. Ks

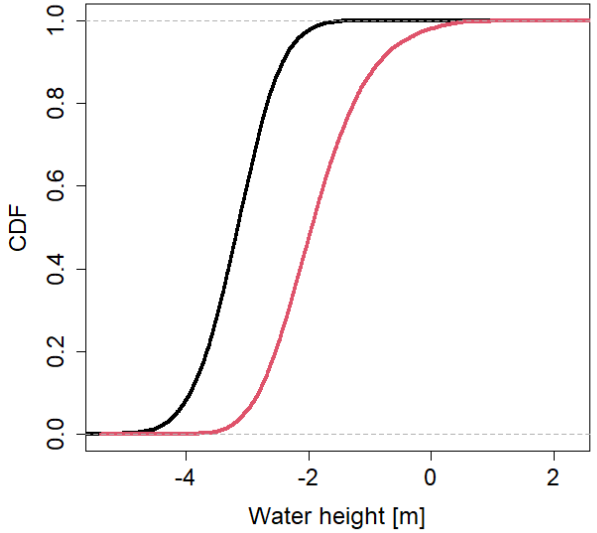


Nested intervals



Flood model

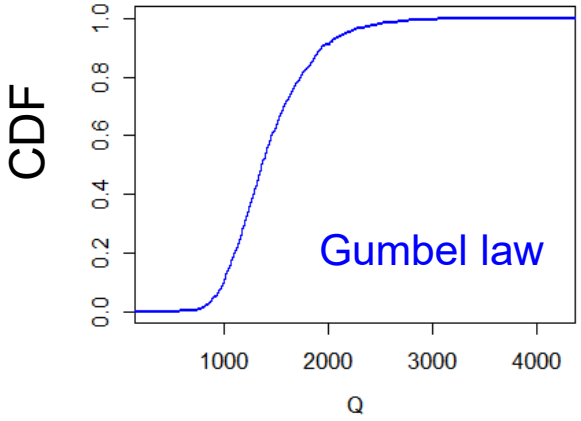
Uncertainty propagation via Monte-Carlo Sampling and interval computation



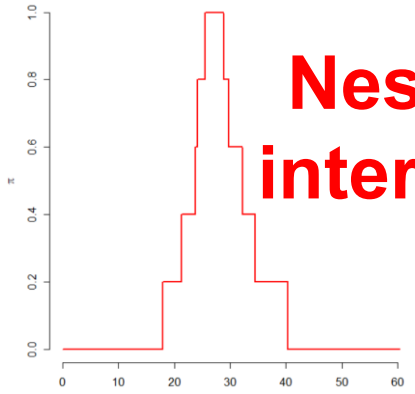
[1] Baudrit et al. 2005

Hybrid probabilistic flood risk assessment [1]

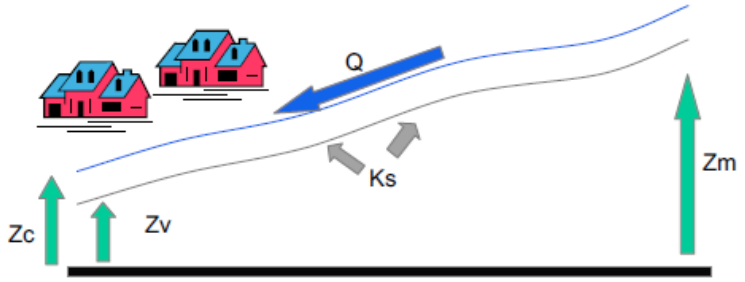
River flow rate Q [m3/s]



Friction coeff. Ks

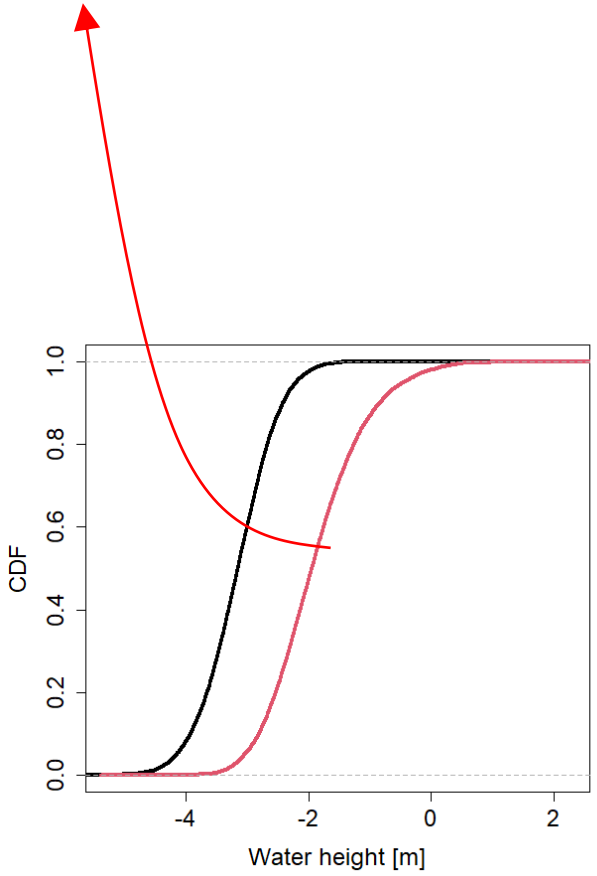


Nested intervals



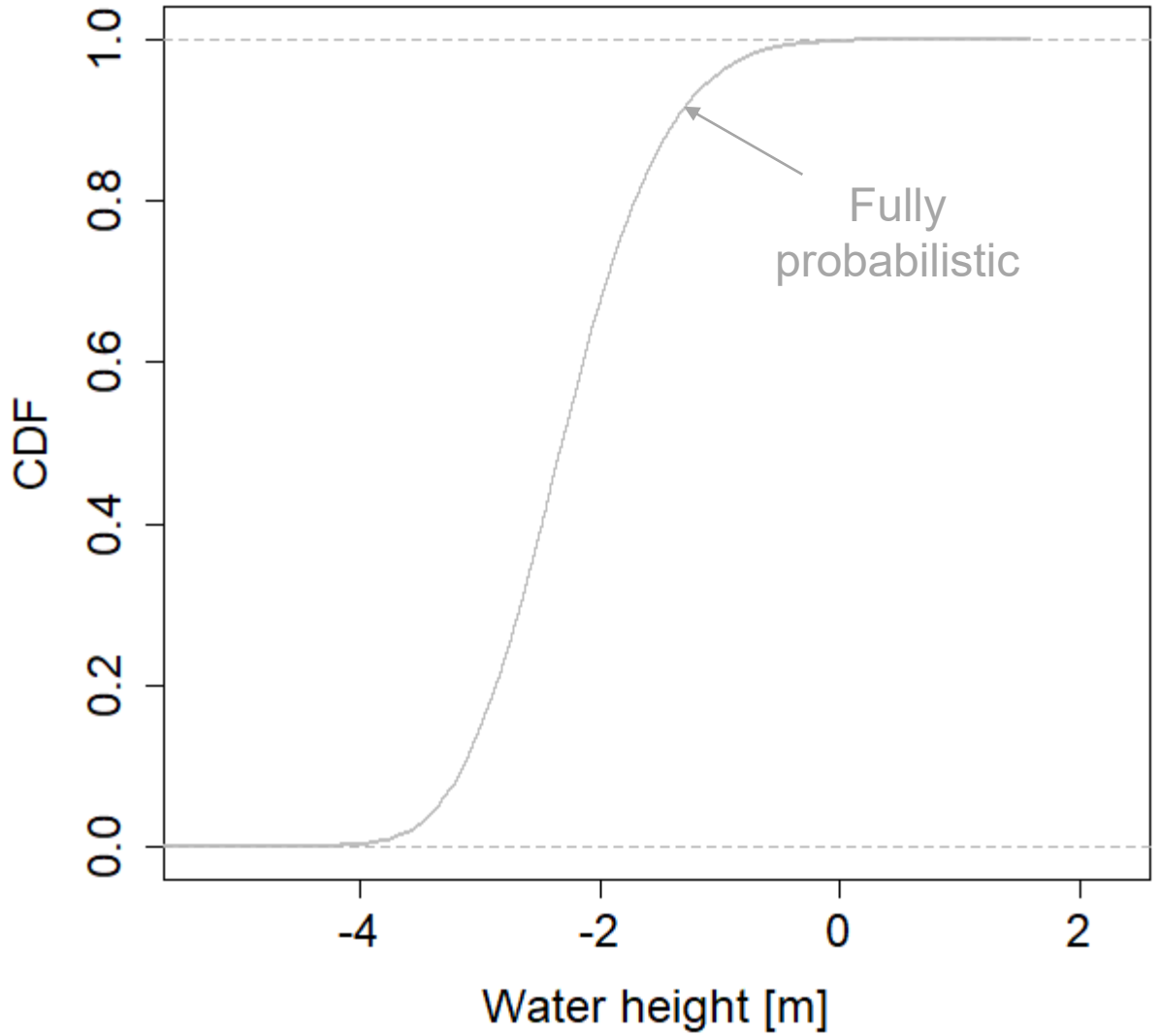
Flood model

Pair of probability laws

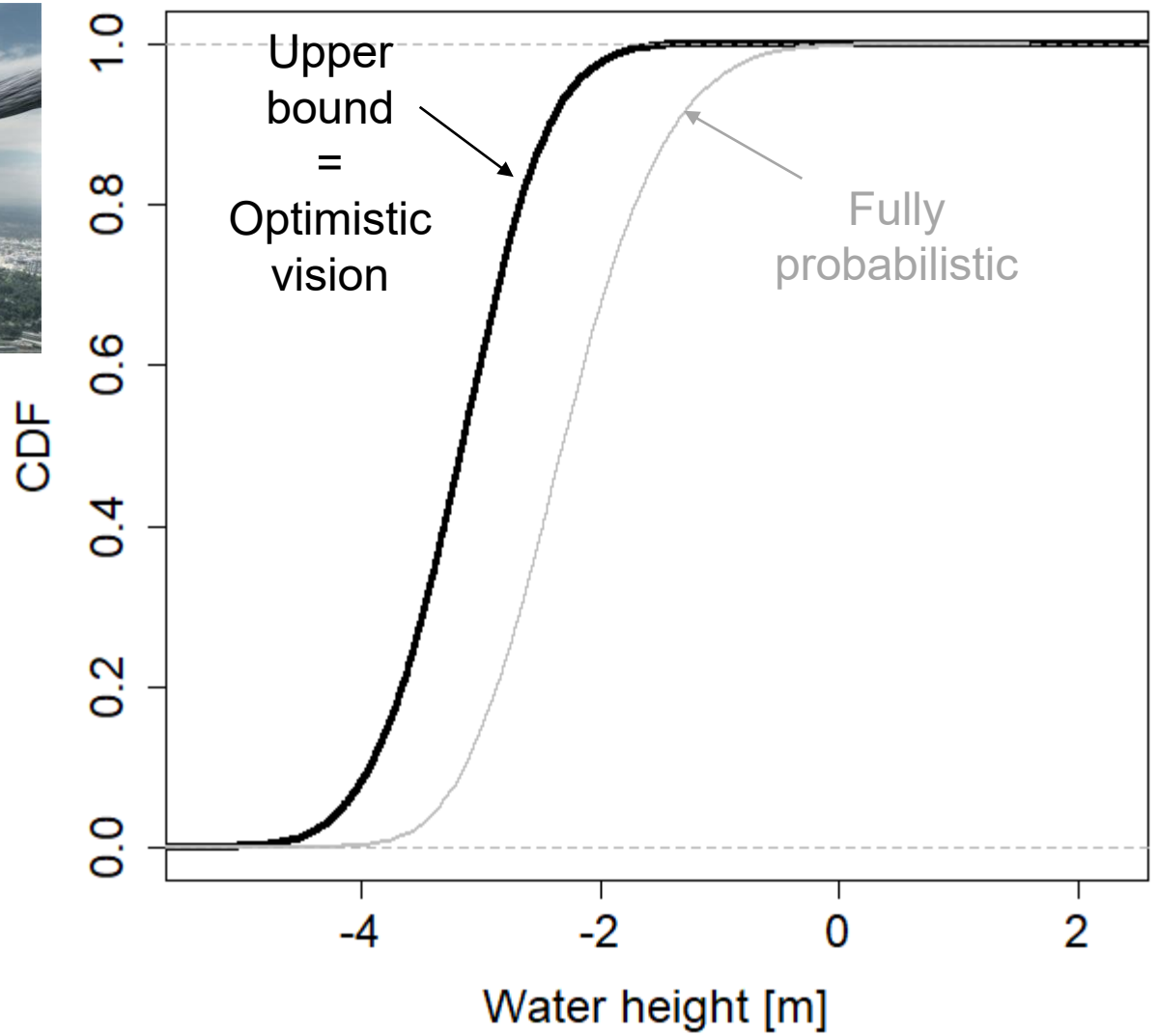


[1] Baudrit et al. 2005

An alternative viewpoint to ‘classical’ probability

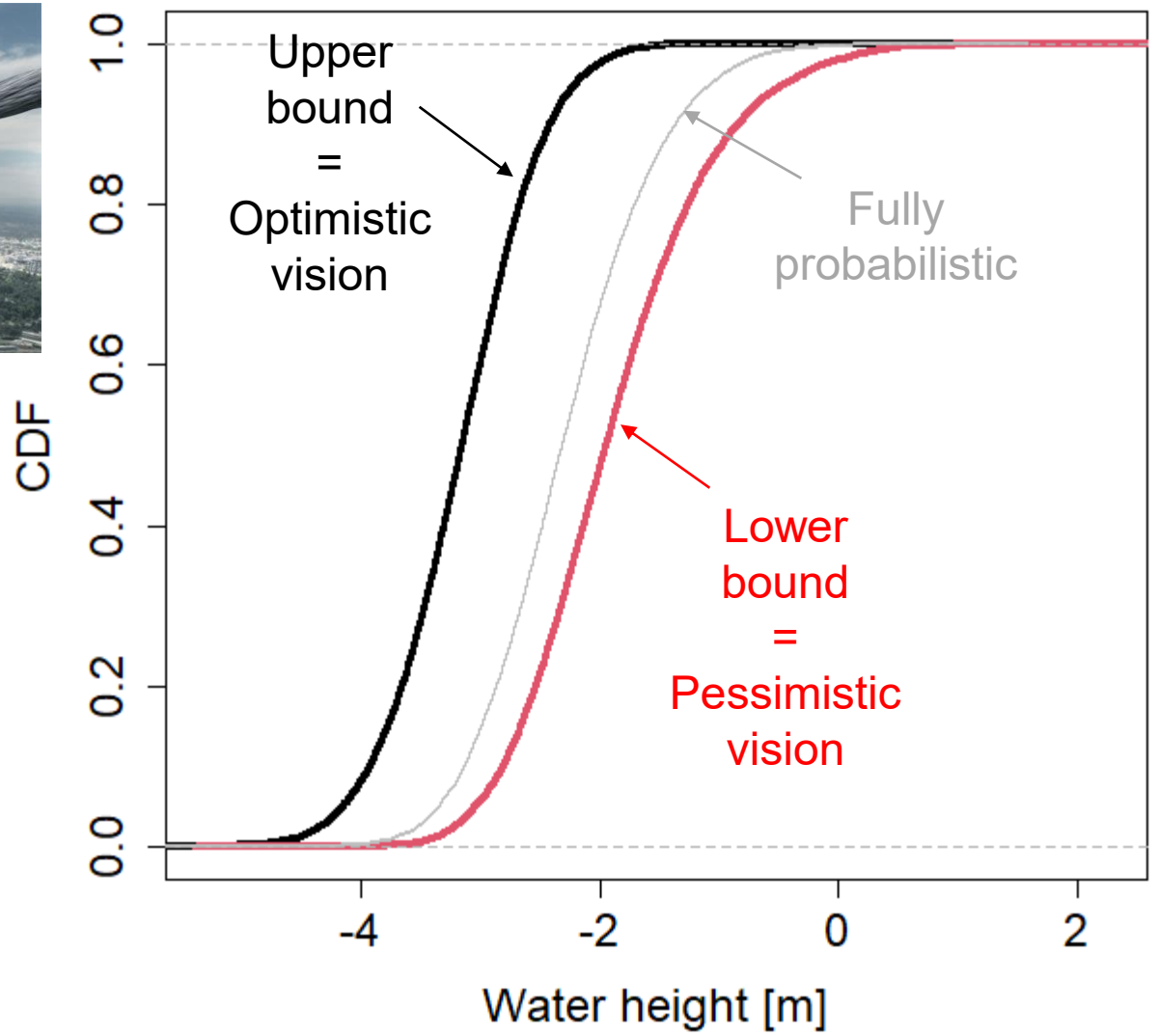


An alternative viewpoint to ‘classical’ probability



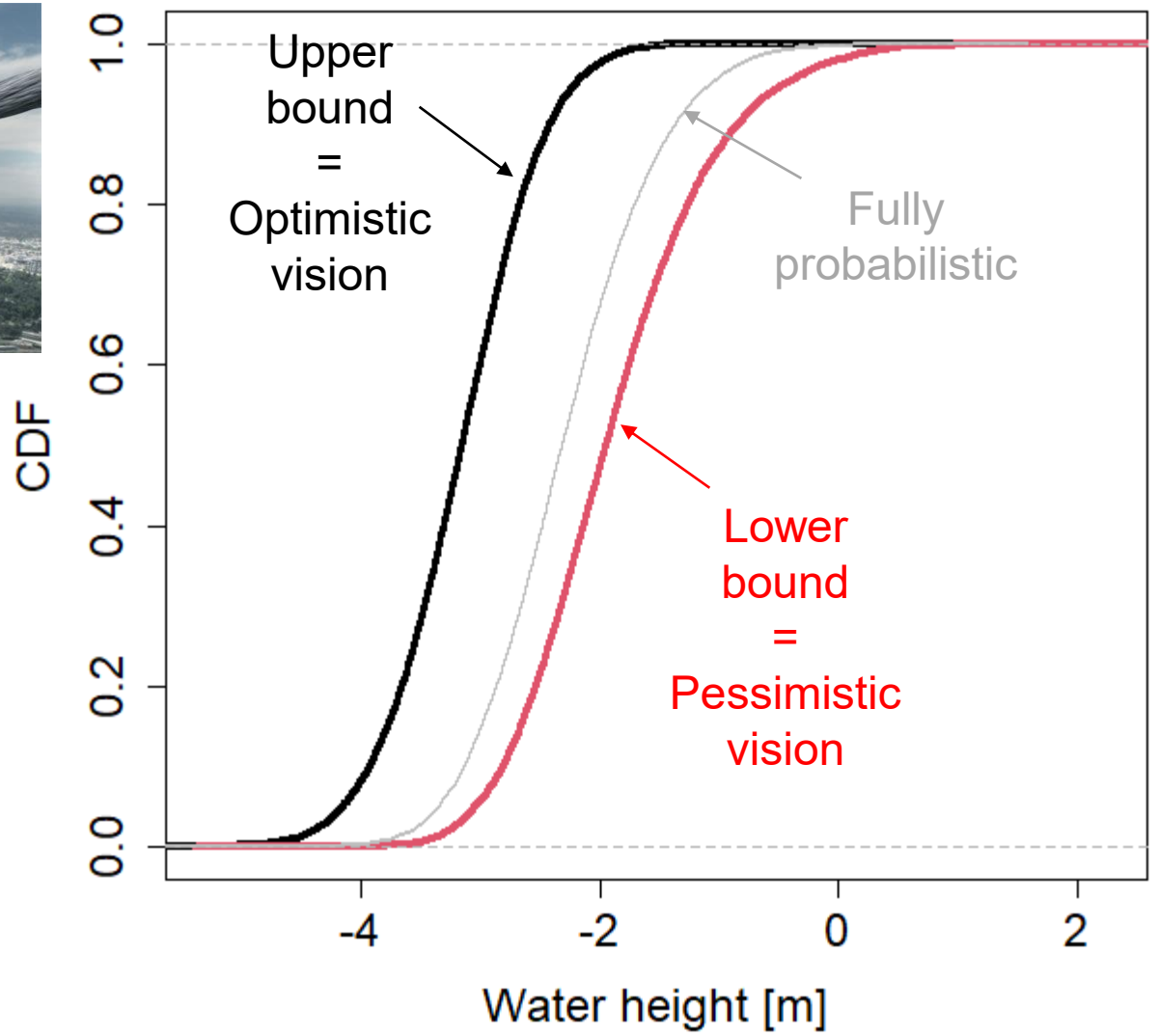
http://danschawbel.com/blog/how-our-risk-averse-society-kills-creativity/
http://savvybuck.com/2014/07/10/how-to-build-your-risk-tolerance-when-investing/

An alternative viewpoint to ‘classical’ probability



http://danschawbel.com/blog/how-our-risk-averse-society-kills-creativity/
http://savvybuck.com/2014/07/10/how-to-build-your-risk-tolerance-when-investing/

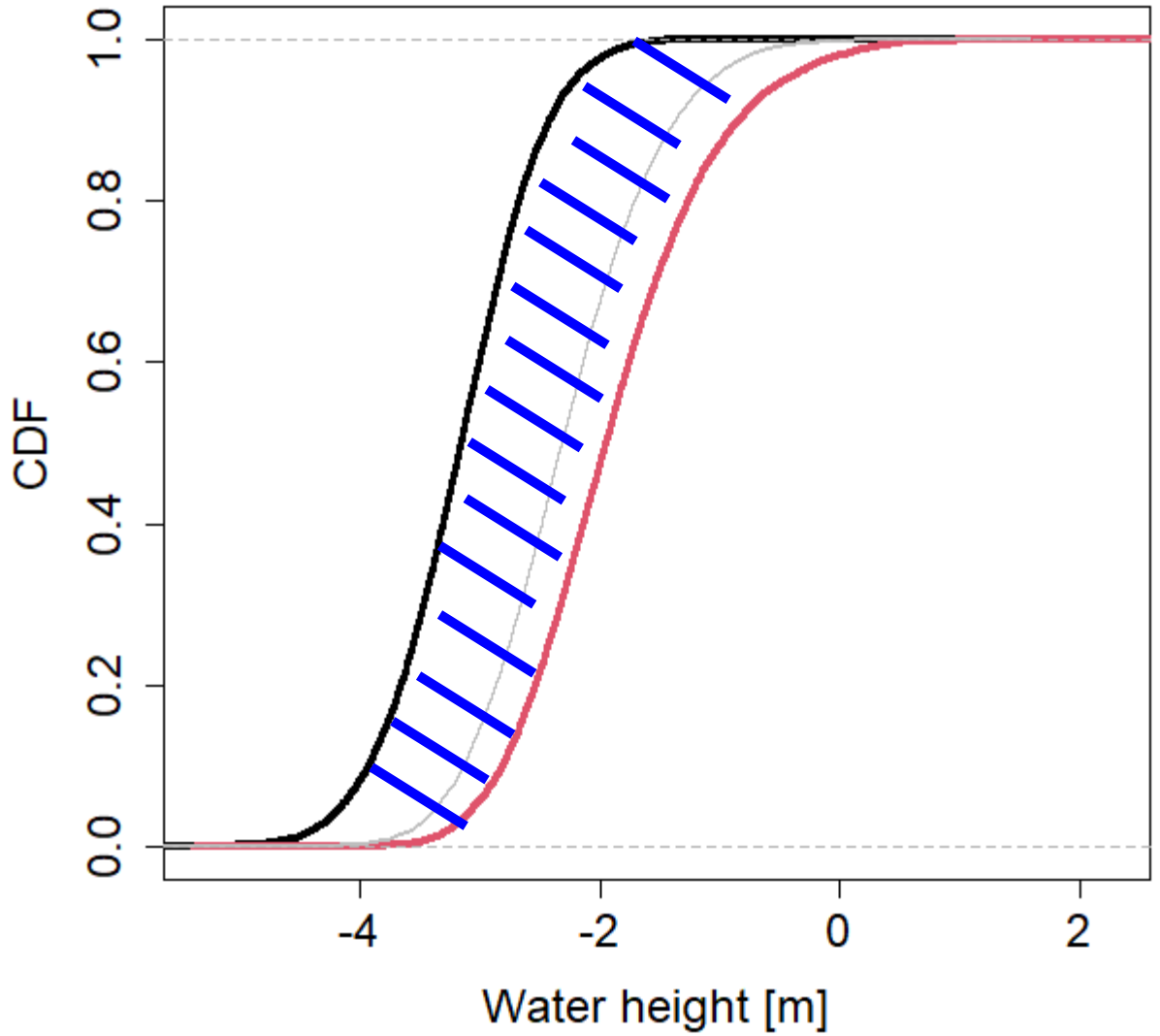
An alternative viewpoint to ‘classical’ probability



Nuance by bounding the fully probabilistic result

http://danschawbel.com/blog/how-our-risk-averse-society-kills-creativity/
http://savvybuck.com/2014/07/10/how-to-build-your-risk-tolerance-when-investing/

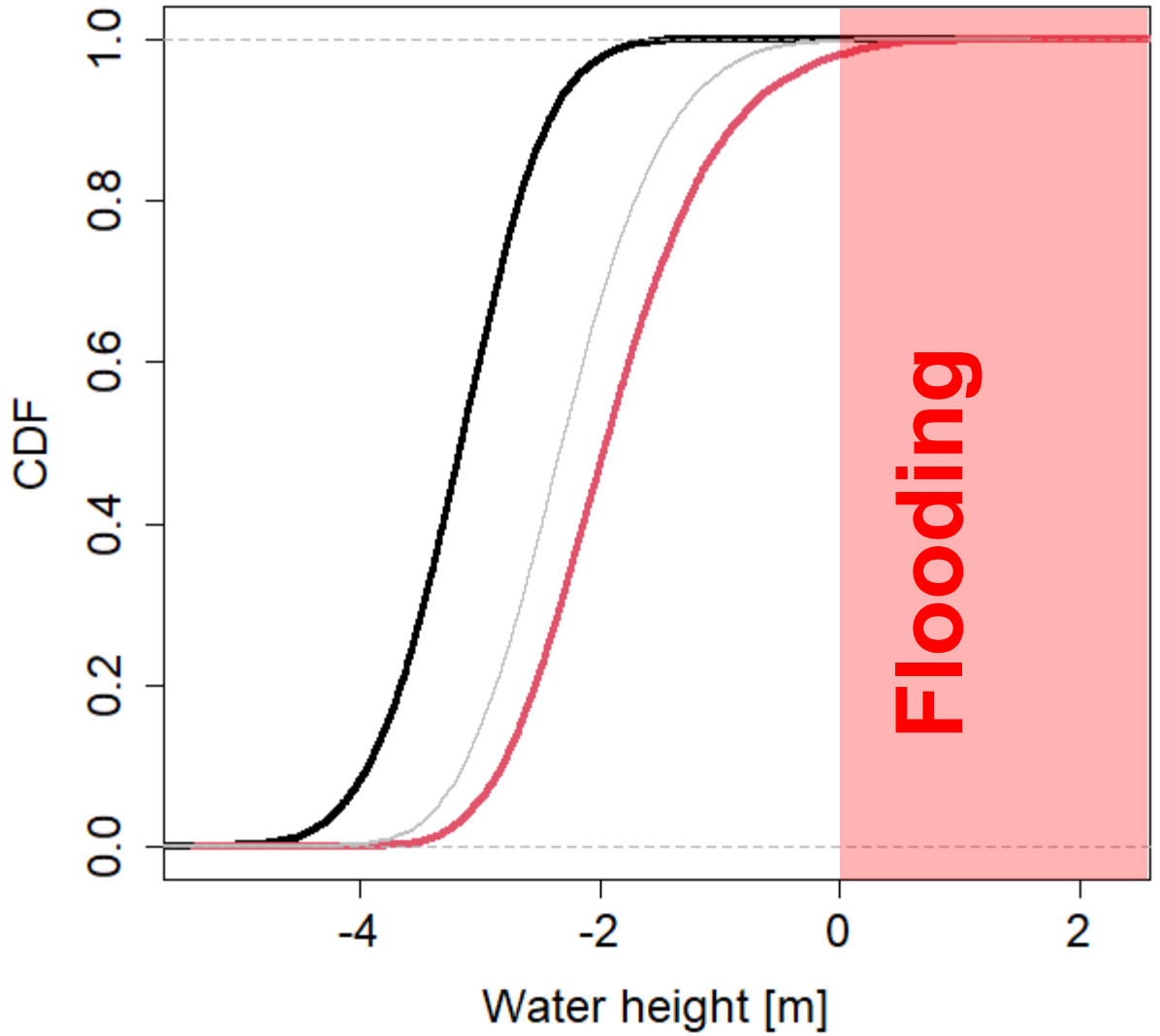
An alternative viewpoint to ‘classical’ probability



Gap = measure of lack of knowledge

Fully probabilistic:
Pf ~0.2%

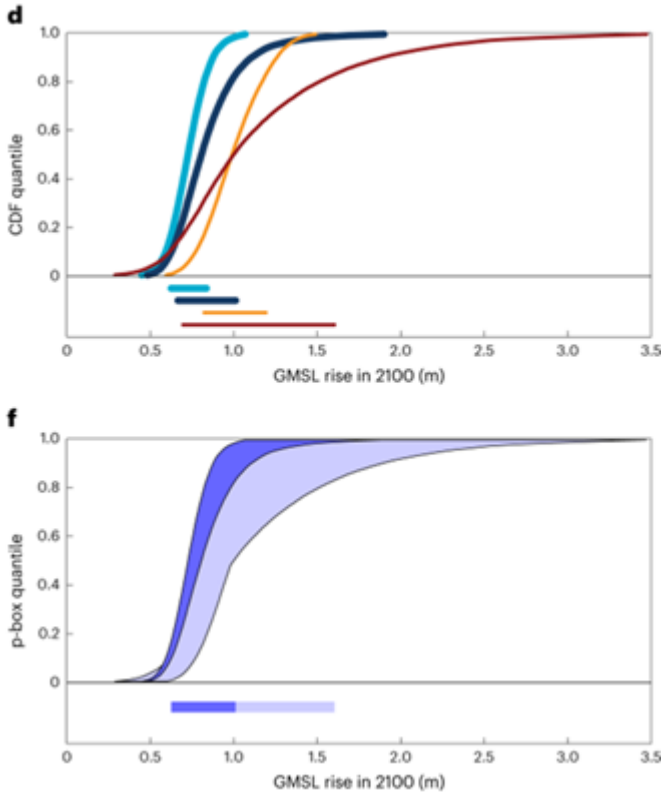
Hybrid probabilistic:
Pf betw. 0 and 2%



Show transparantely the difficulties in processing heterogeneous and imprecise data

Not a rare case…

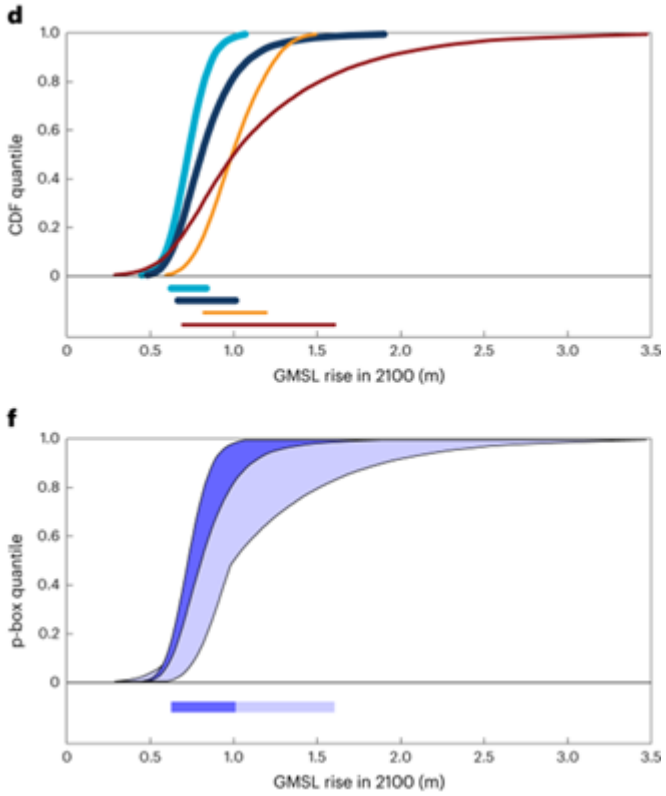
Probabilistic projection for climate change impact assessment [1,2]



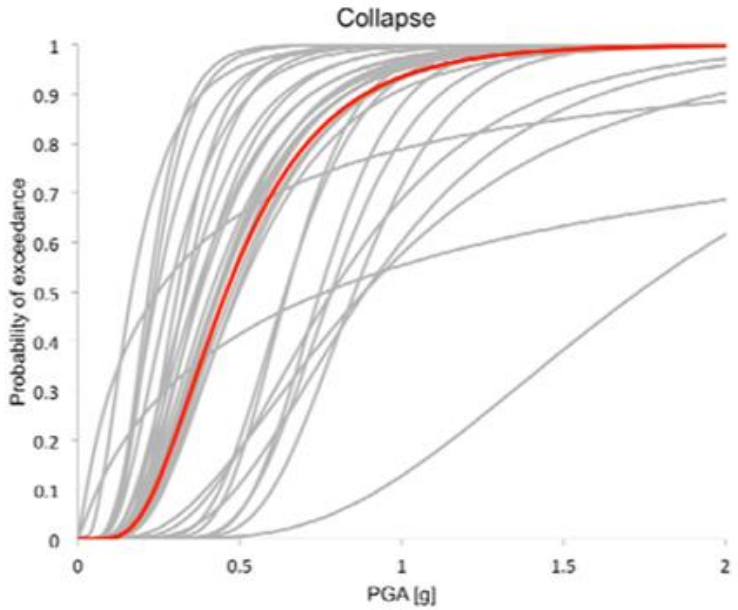
[1] Kopp et al., 2023, [2] IPCC AR6 report, [3] SINER-G FP7 report, [4] Guyonnet et al. 2024

Not a rare case…

Probabilistic projection for climate change impact assessment [1,2]



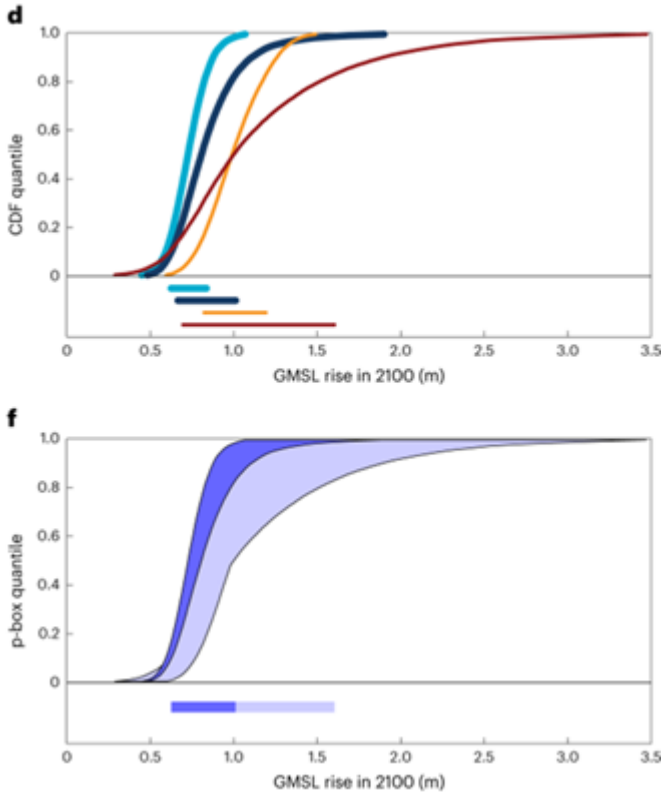
Probabilistic fragility curve for earthquake risk assessment [3]



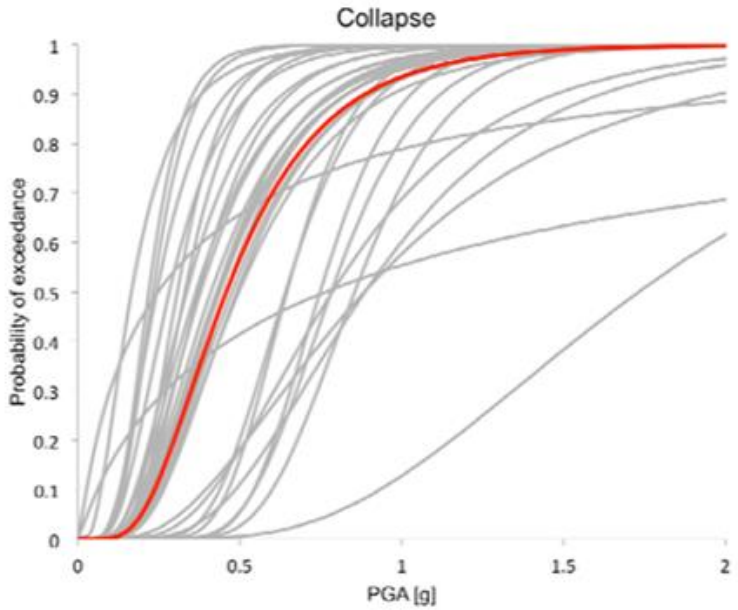
[1] Kopp et al., 2023, [2] IPCC AR6 report, [3] SINER-G FP7 report, [4] Guyonnet et al. 2024

Not a rare case…

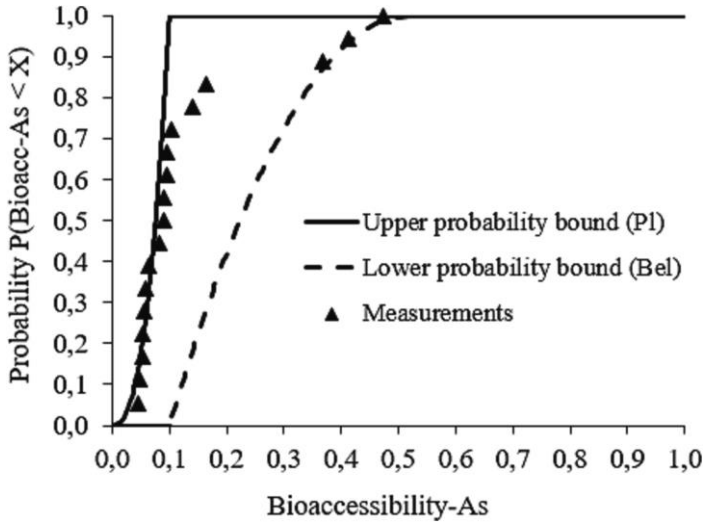
Probabilistic projection for climate change impact assessment [1,2]



Probabilistic fragility curve for earthquake risk assessment [3]



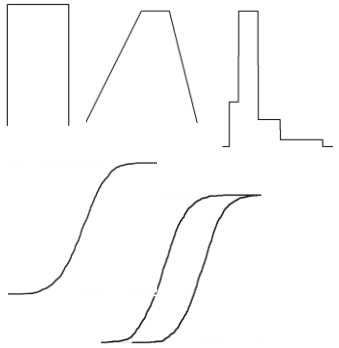
Heterogeneous and Imprecise measurements for soil pollution [4]



[1] Kopp et al., 2023, [2] IPCC AR6 report, [3] SINER-G FP7 report, [4] Guyonnet et al. 2024

In practice… an R package for hybrid probabilistic analysis

more info here

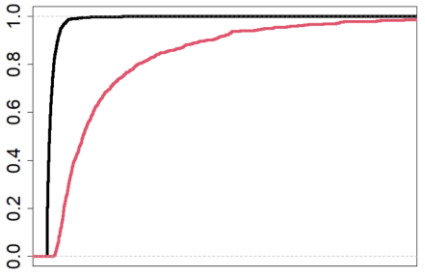


Knowledge modelling

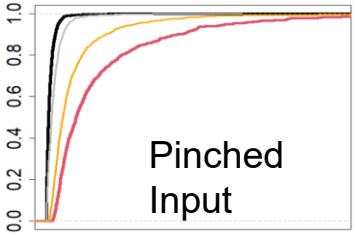
Step 1

Step 2

Hybrid propagation



hyriskR

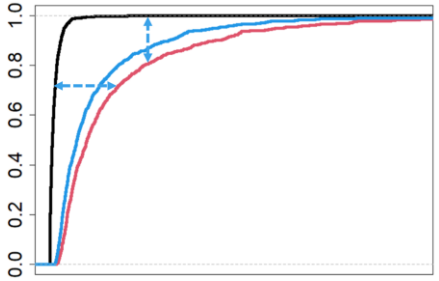


Sensitivity Analysis

Step 4

Step 3

Support decision making

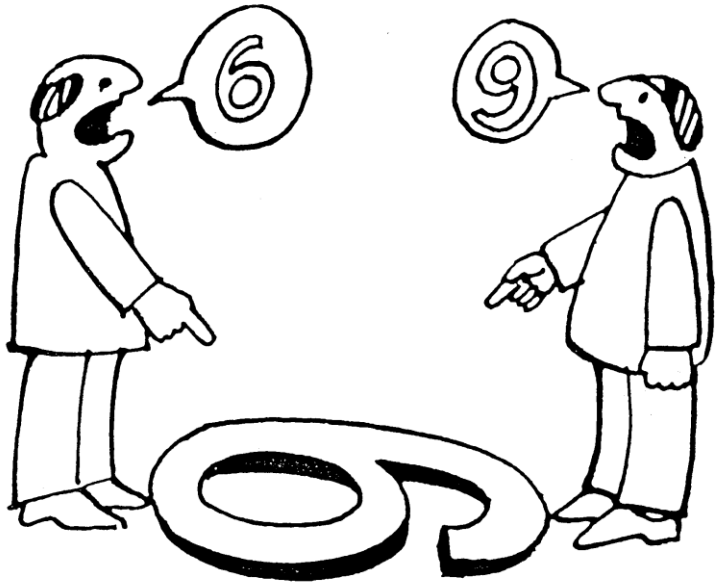


anrhouses.github.io/hyriskR

Take home messages

Faced with heteregeneous and imprecise data, uncertainty quantification has rarely a single answer

Embrace multiple perspective!



Need for flexible knowledge modeling tools!

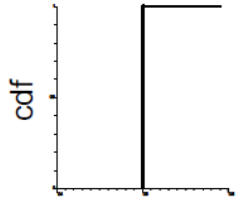
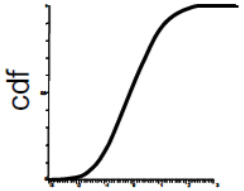
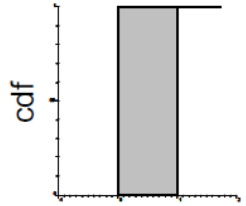
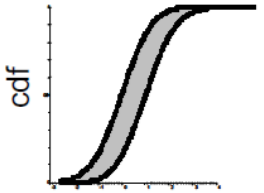
	Deterministic	Probabilistic
Precise	 Precise Scalar	 Precise Distribution
Imprecise	 Interval	 Probability-box

Figure 2: Dimensions of uncertainty

Aughenbaugh & Paredis (2006)

THANK YOU FOR YOUR ATTENTION !

Contact: Jérémy Rohmer*
*j.rohmer@brgm.fr

We acknowledge financial funding by ANR-HOUSES (grant number: **ANR-22-CE56-0006**)
https://anrhouses.github.io/