Brief Introduction on Global Sensitivity Analysis (GSA) and the SAFE Toolbox for GSA

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What is Sensitivity Analysis? and why shall we use it?

Sensitivity analysis (SA) is:

set of mathematical techniques which investigate how uncertainty in the output of a numerical model can be attributed to variations of its input factors.

Benefits:

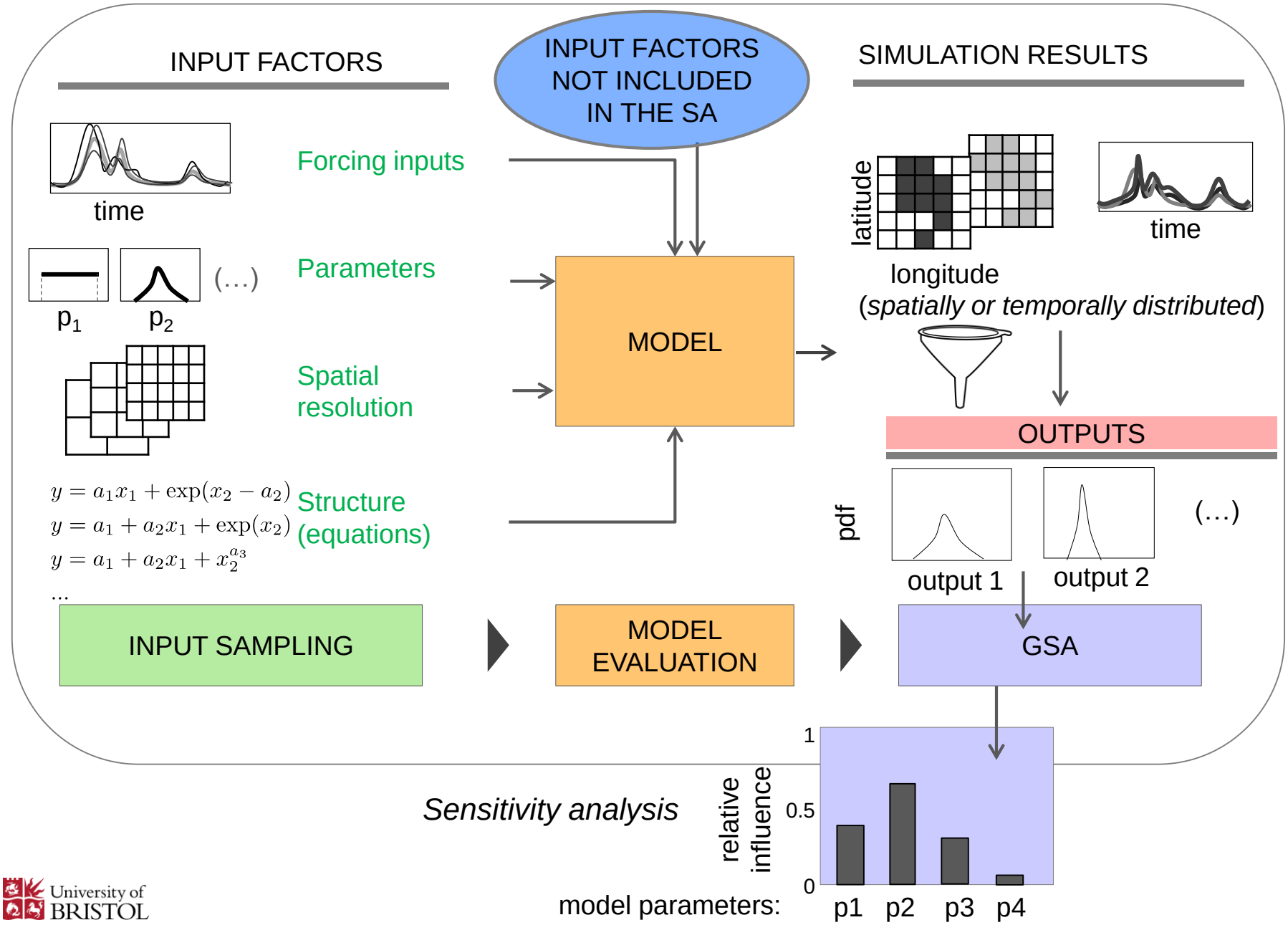
1. **Better understanding of the model**
   Evaluation of model behaviour beyond default set-up

2. **Model "sanity check"**
   Does the model meet the expectations (model validation)

3. **Prioritize investments for uncertainty reduction**
   Identify sensitive parameters for computer-intensive calibration, acquisition of new data, etc.

4. **More transparent and robust decisions**
   Understand main impacts of uncertainty on modeling outcome and thus on decisions

How Global Sensitivity Analysis works



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Workflows can be used to transfer knowledge on model use and GSA use

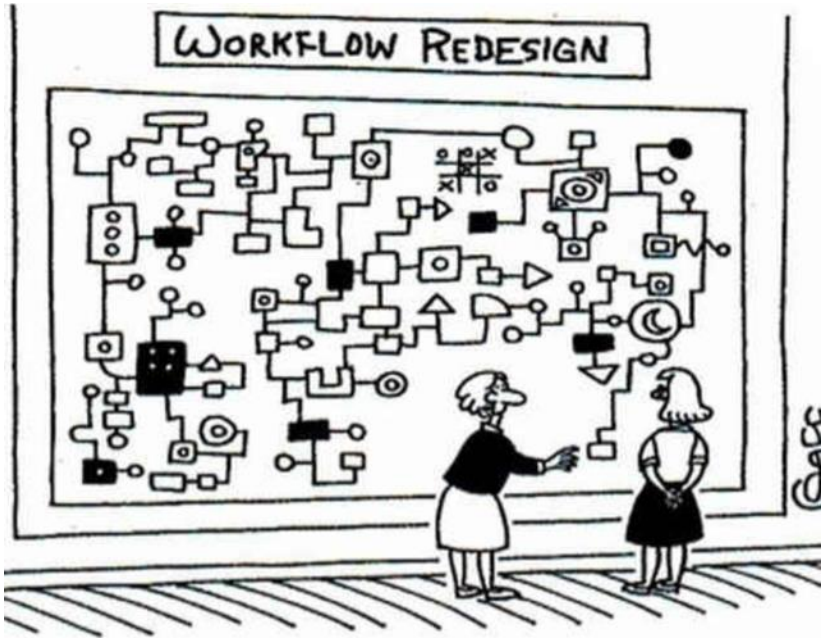
Workflows as a way to transfer expertise, help the reproducibility of results and the automatization of routines for model and GSA use.

Often workflows exist only in the users head.

Workflows should include **guidance** on:

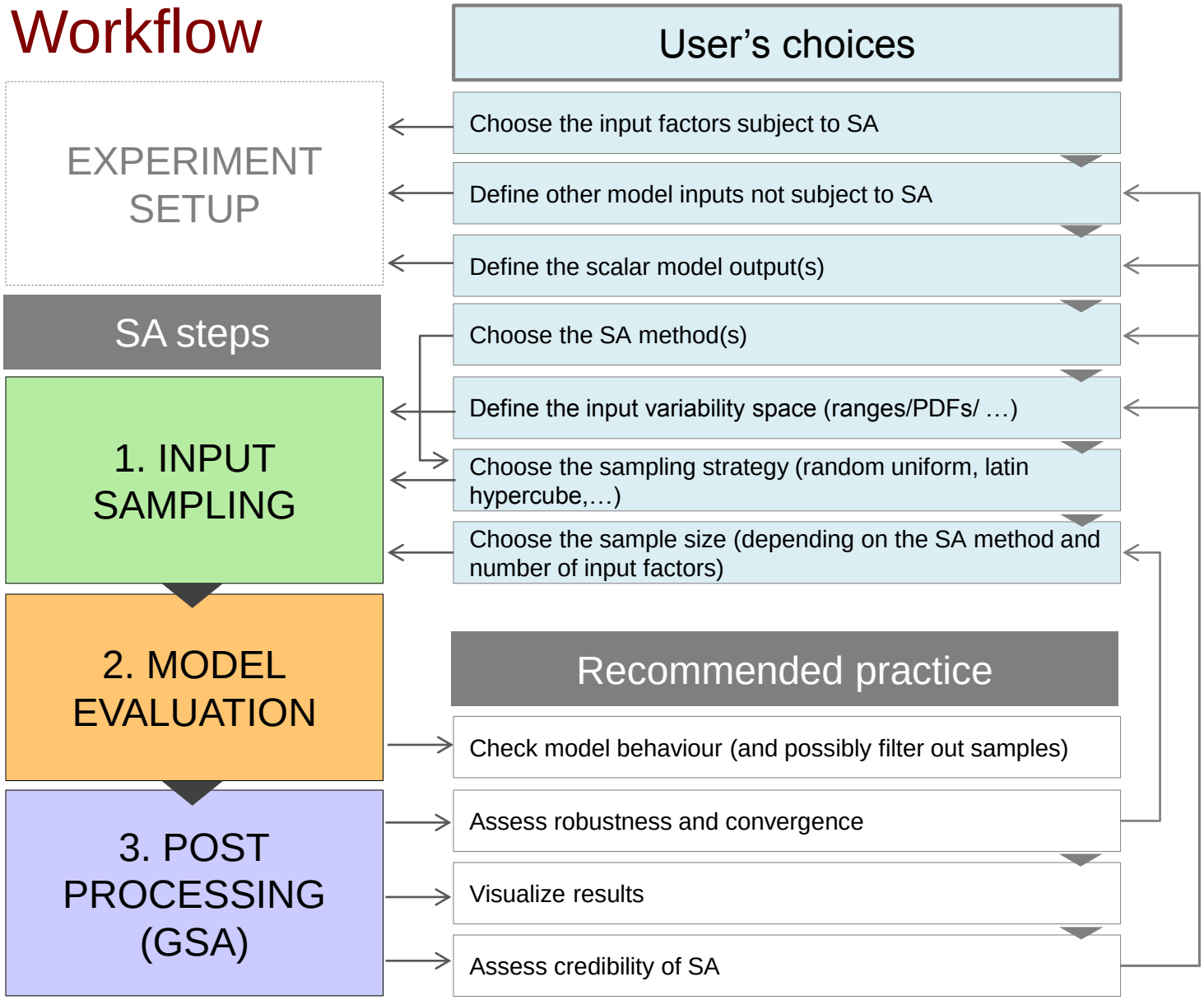
:: how to **produce GSA results**, and

:: how to **interpret** these results.

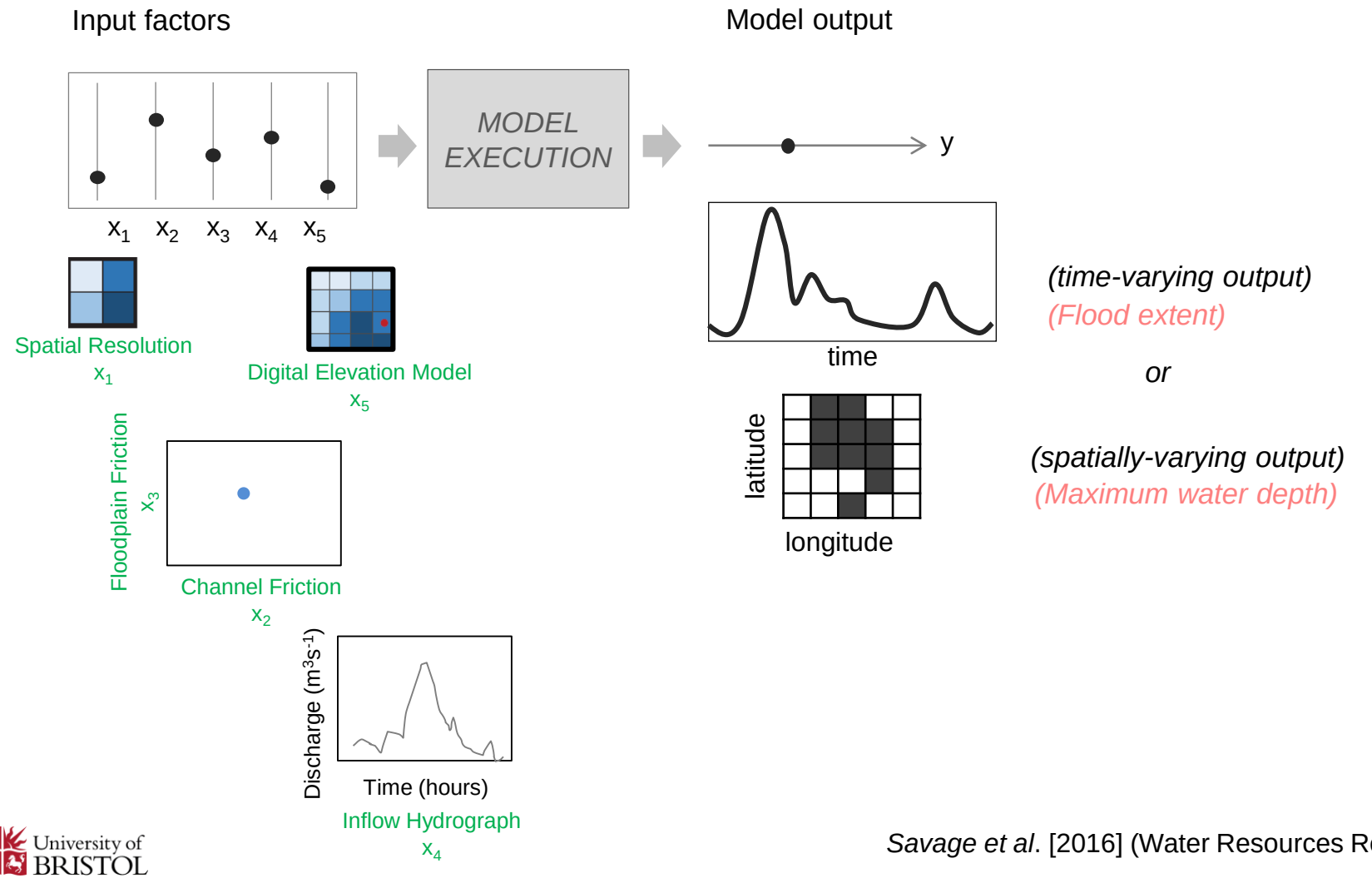


"And this is where our workflow redesign team went insane."

GSA Workflow

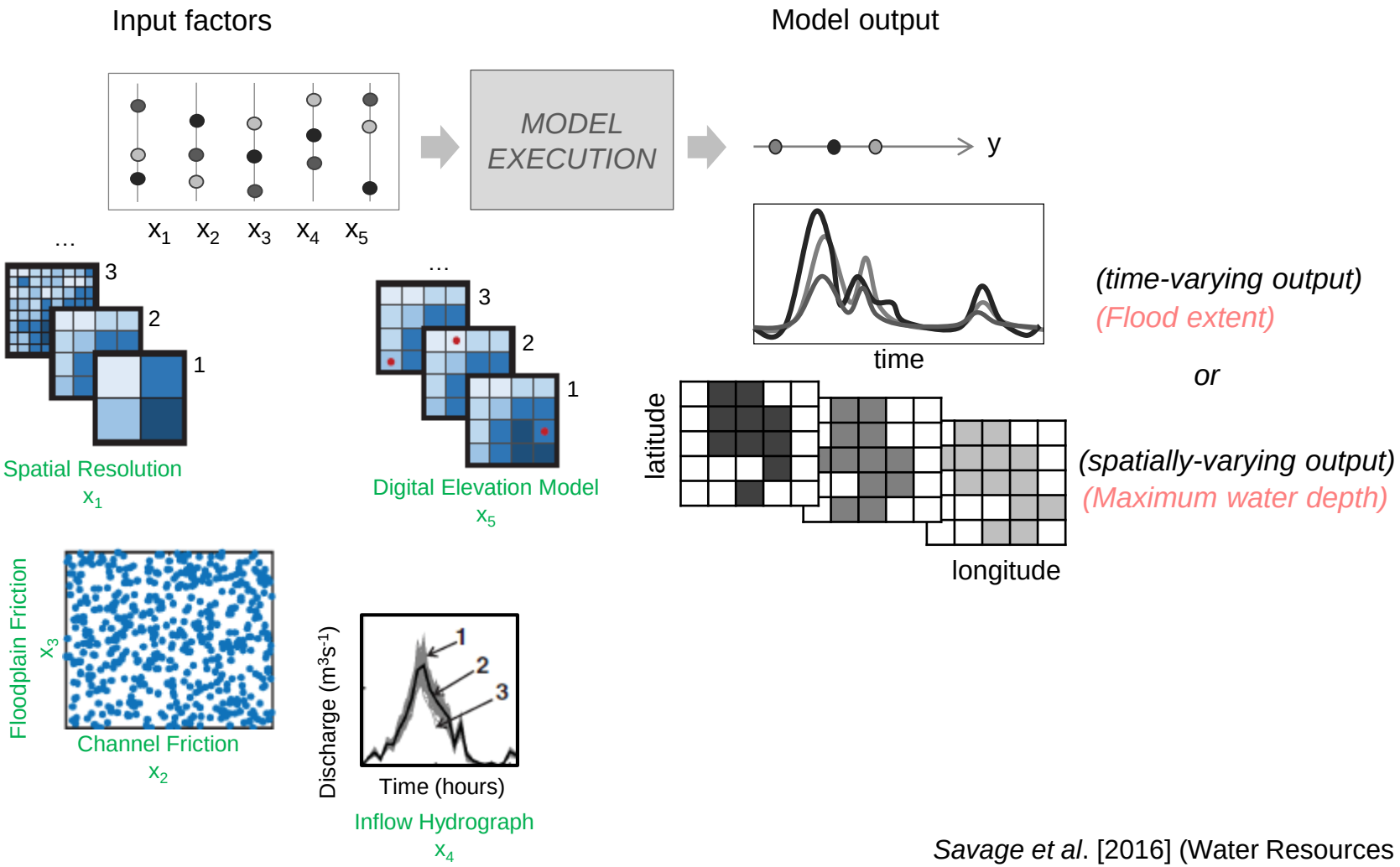


What would be the input factors and outputs in a flood inundation model?



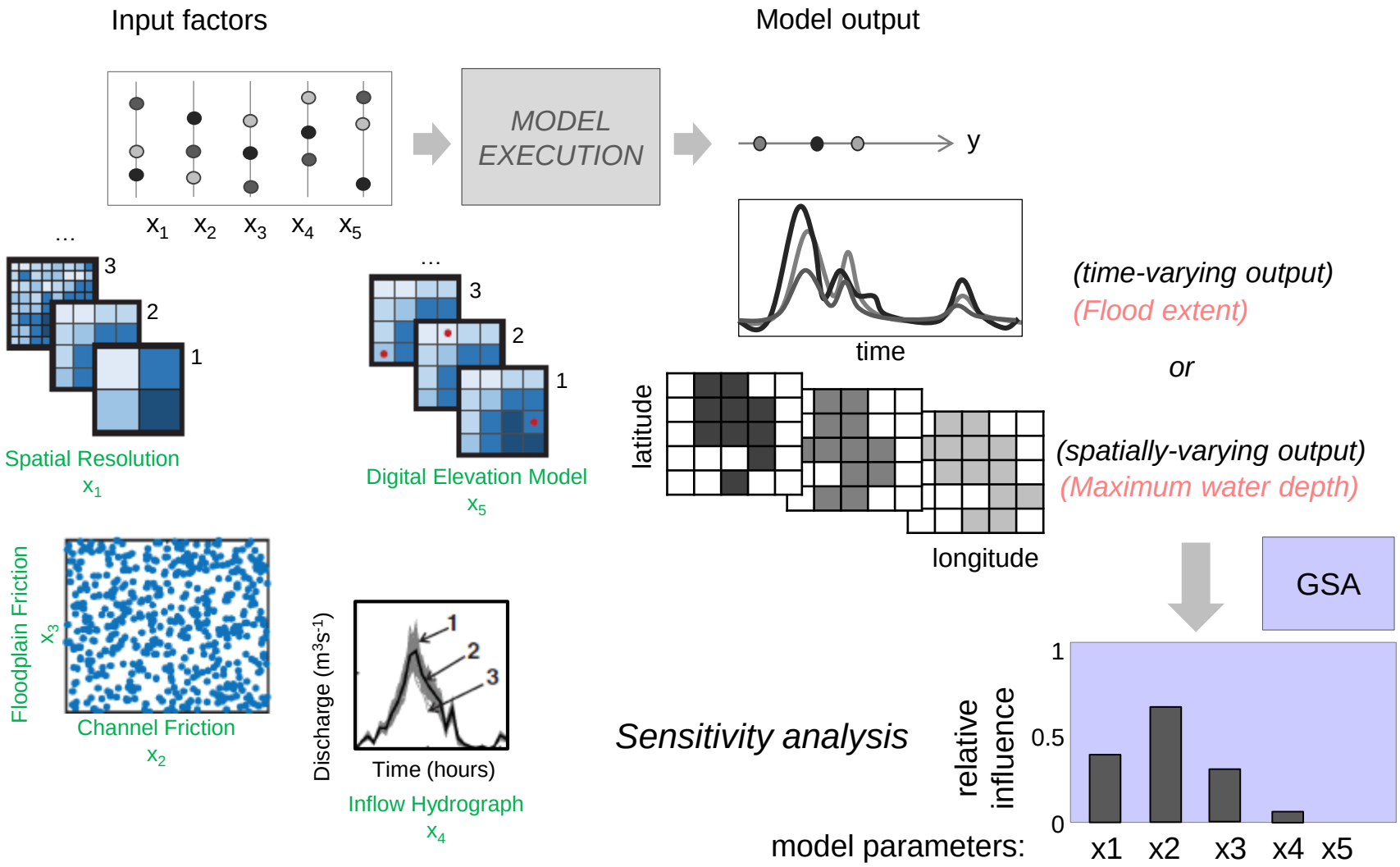
Savage et al. [2016] (Water Resources Research)

SA would perturb the input factors… which changes the outputs



Savage et al. [2016] (Water Resources Research)

…and then estimate Sensitivity Indices



Difference between calibration and SA

The ‘calibration’ question:

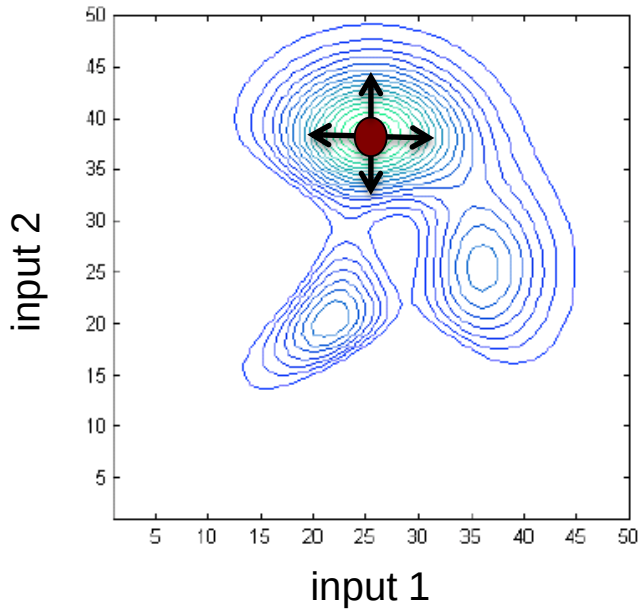
What is *the right* (or *a reasonable*) choice for the input factors (i.e. produce a sensible model output)?

The ‘sensitivity’ question:

How much varying each input factor contributes to variability of the model output?

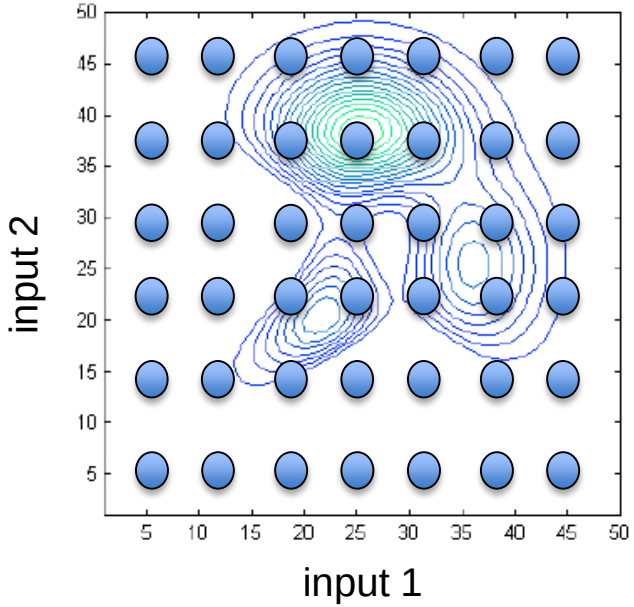
Local vs Global approaches to SA

Local methods analyze sensitivity around some point in the factor space.



Local methods require a good ‘baseline’ or ‘nominal point’

Global methods attempt to analyze variability across the full factor space.

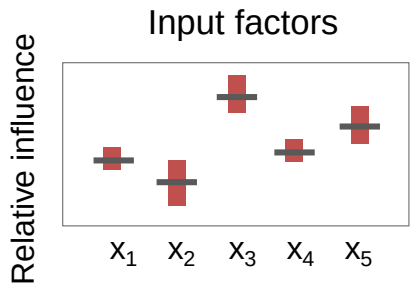


Global methods require a good definition of the space you are going to sample

Possible objectives of SA

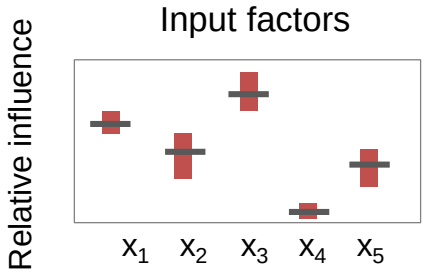
Ranking

Which input factors have more influence on the model's response?



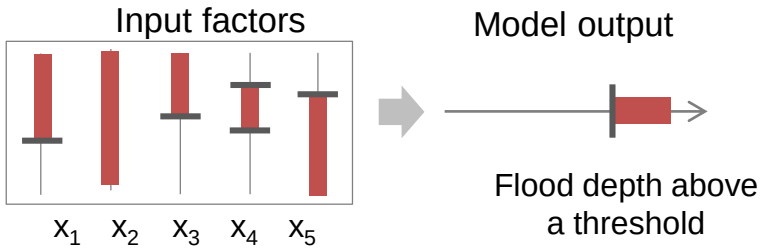
Screening

Is there any input factor that has negligible influence on the model's response?

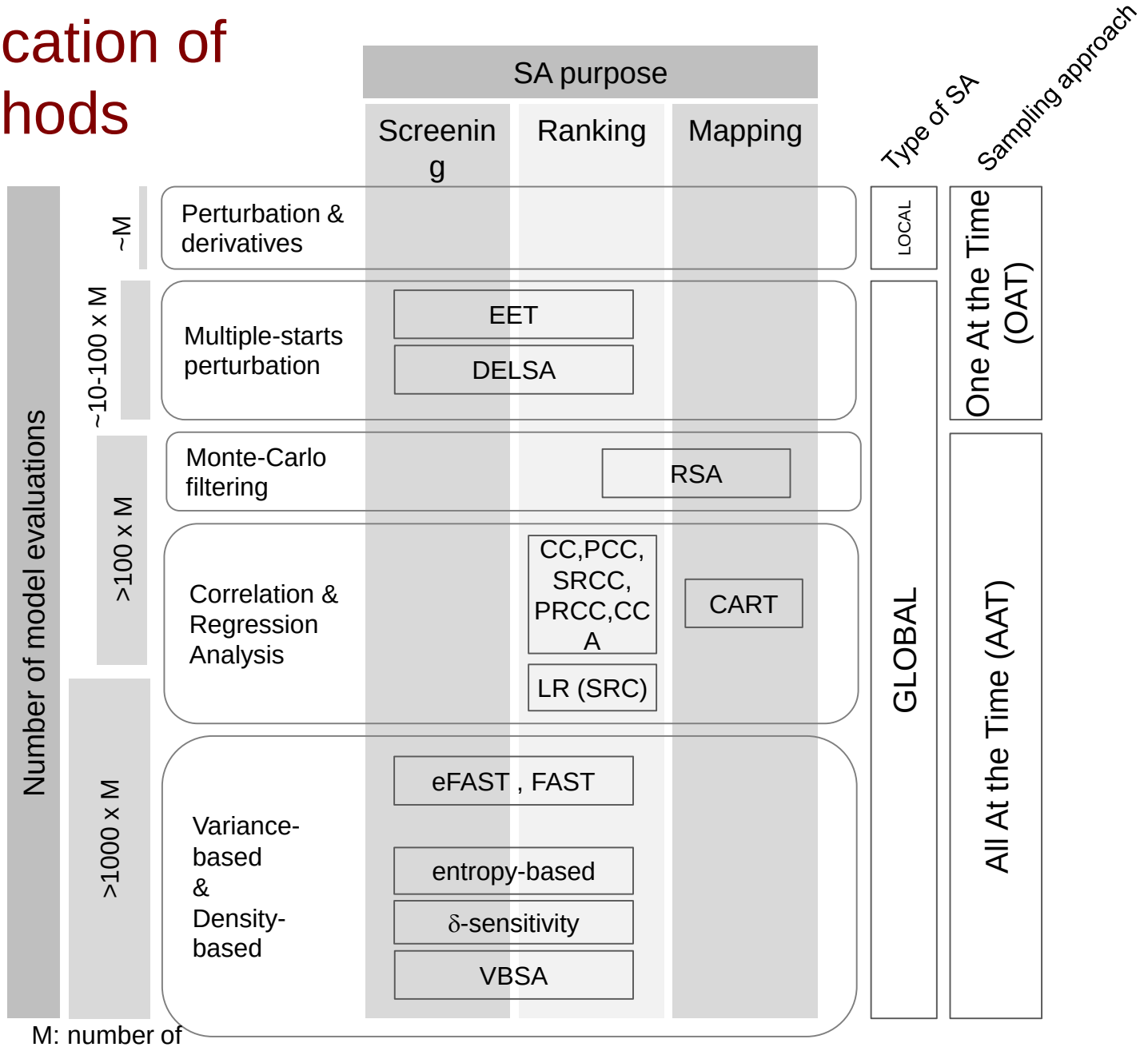


Mapping

Are there subranges of the input factors that map into "significant" (e.g. extreme) output values?

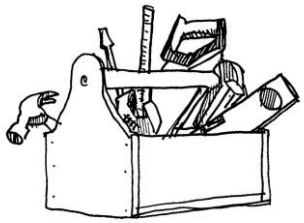


Classification of SA methods



M: number of input factors

SAFE (Sensitivity Analysis For Everybody) Toolbox



:: Developed in 2014 by Pianosi *et al.* during NERC-funded CREDIBLE project (2013-201)

www.safetoolbox.info

:: Over 1300 users in academia in 50+ countries

:: Works under Matlab (R version is also available)

:: Flexible, **modular** structure, easy to integrate with models running outside Matlab, R

:: Many **visualisation** functions

:: Commented code and **workflows**

Most Downloaded Environmental Modelling & Software Articles

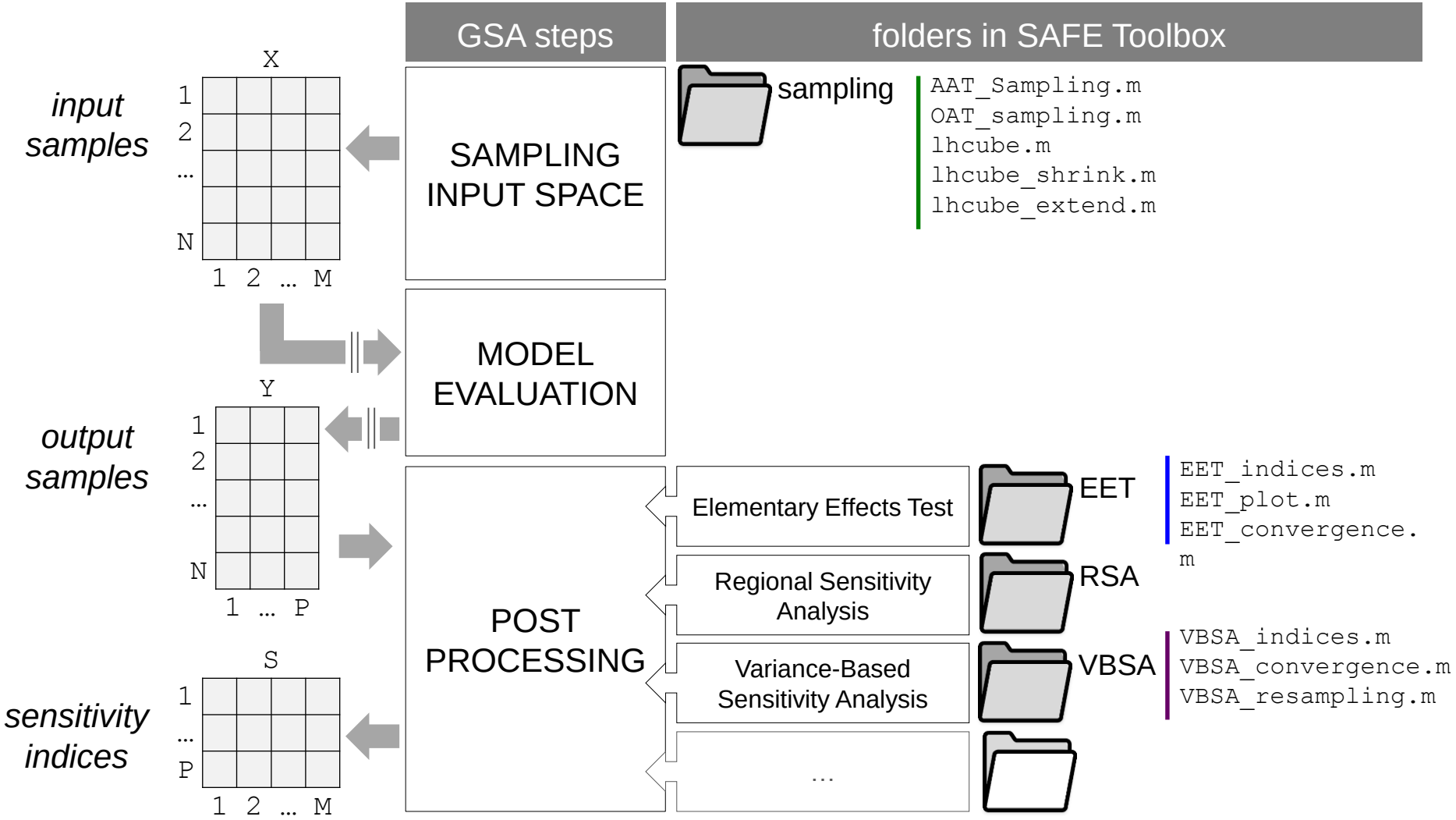
The most downloaded articles from Environmental Modelling & Software in the last 90 days.

A Matlab toolbox for Global Sensitivity Analysis

August 2015

Francesca Pianosi | Fanny Sarrazin | Thorsten Wagener

The modular structure of SAFE



References and additional material

Website to download SAFE:

https://www.safetoolbox.info/

Introductory paper to SAFE (open access paper):

https://www.sciencedirect.com/science/article/pii/S1364815215001188

A review of available methods and workflows for Sensitivity Analysis (open access paper):

https://www.sciencedirect.com/science/article/pii/S1364815216300287

Example application to handle the issue of epistemic uncertainty (due to climate change) in landslide hazard modelling:

https://www.nat-hazards-earth-syst-sci.net/17/225/2017/nhess-17-225-2017-discussion.html

Appendix

Insurance case study

Pricing model (Individual Account Rater)

Experience model based on a frequency-severity approach

It produces a price recommendation for the premium to charge for a new risk to a given company to cover from all classes of business

Collaboration with XL Catlin actuary

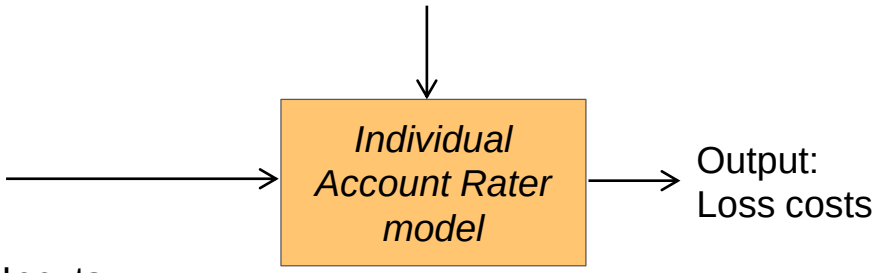
Objective of case study:

Investigating where to focus efforts to reduce uncertainty when reviewing the model

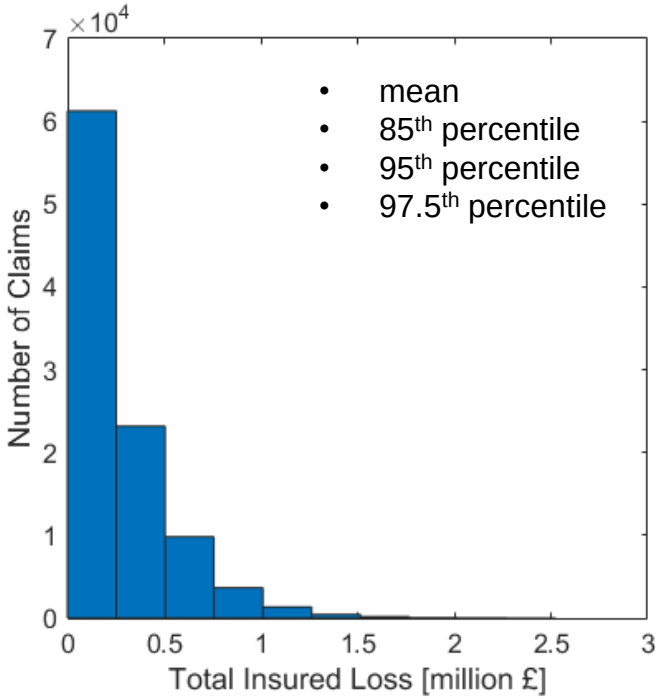
Simplified current workflow of Pricing Model (Individual Account Rater)

Pricing model

Fixed Parameters
p1. Frequency Trend
p2. Severity Trend
p3. Exposure Trend
p4. Development Pattern



Inputs
i1. Claim data
i2. Exposure data
i3. Cover data
i4. Portfolio and market data



Simplified future workflow of Pricing Model (Individual Account Rater)

Pricing model

Sampling of parameters

Varying Parameters
p1. Frequency Trend
p2. Severity Trend
p3. Exposure Trend
p4. Development Pattern

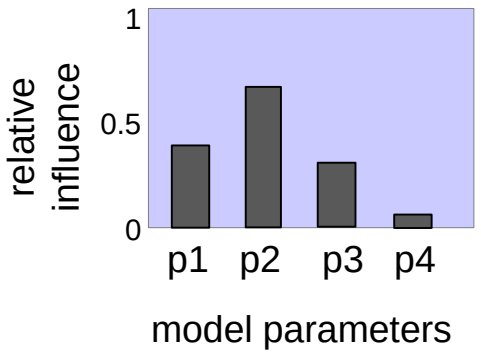
Individual Account Rater model

Stochastic component

Output:
Loss costs

Inputs
i1. Claim data
i2. Exposure data
i3. Cover data
i4. Portfolio and market data

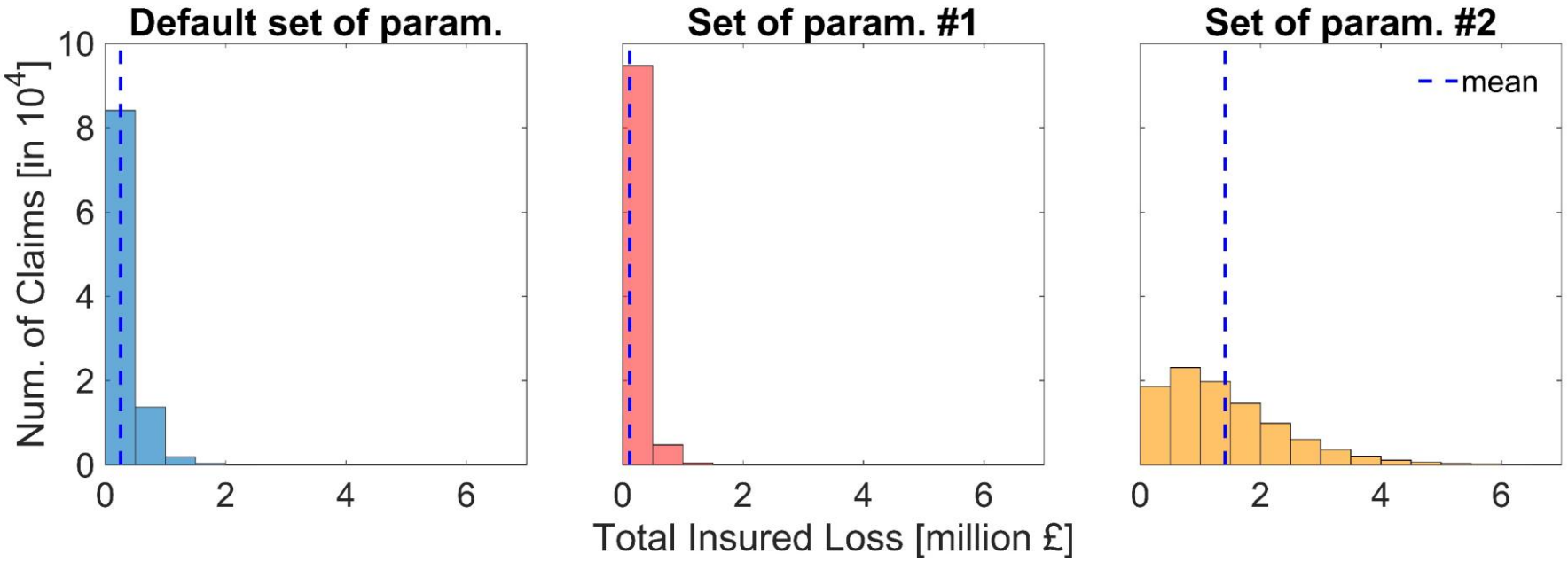
Sensitivity analysis



1 INPUT SAMPLING → 2 MODEL EVALUATION → 3 POST PROCESSING

Results

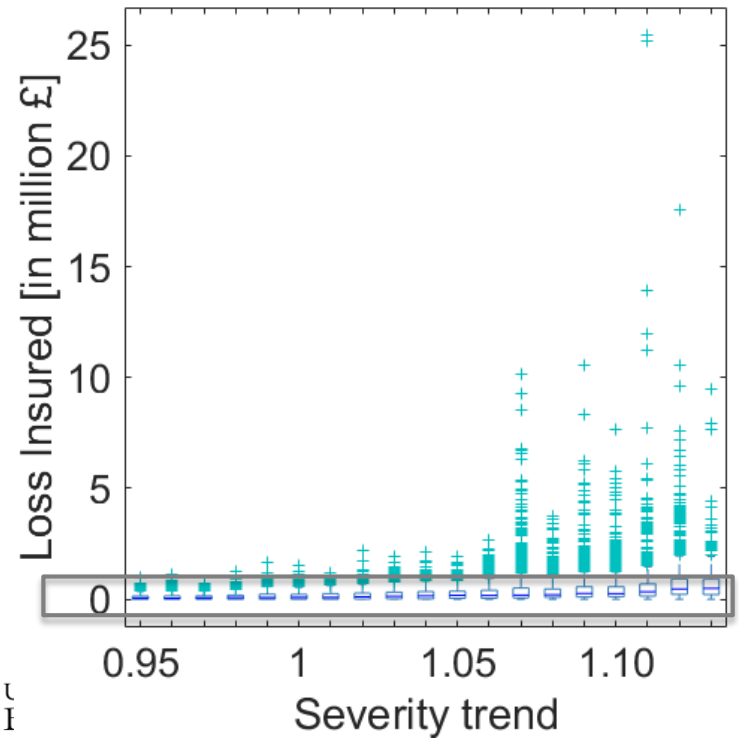
1. Understand model behaviour beyond default set-up

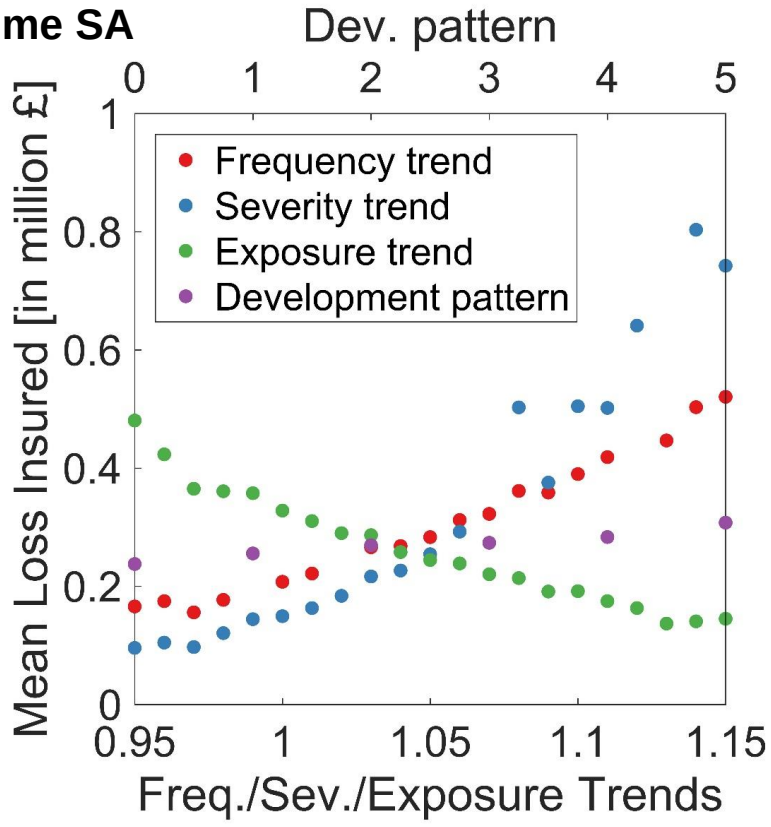


Results

1. Understand model behaviour beyond default set-up
2. Understand main impacts of uncertainty on modeling outcome and thus on decisions

One At the Time SA



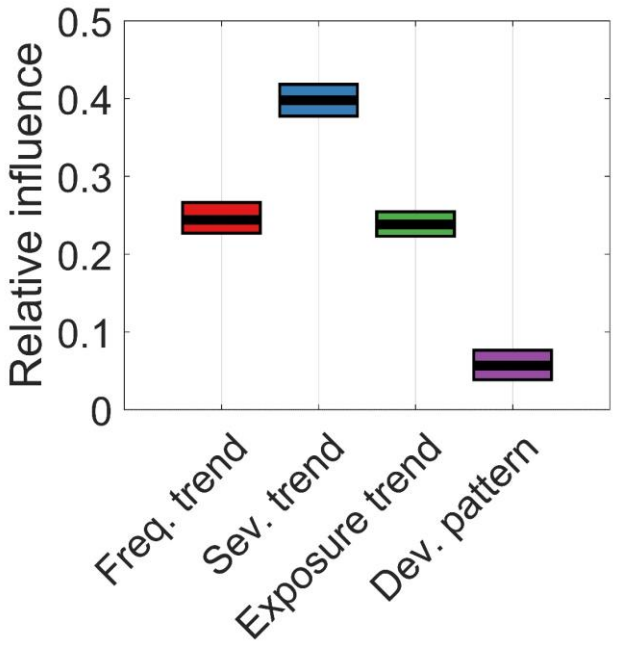


Results

1. Understand model behaviour beyond default set-up
2. Understand main impacts of uncertainty on modeling outcome and thus on decisions
3. Understand where to prioritize investment for uncertainty reduction

   → acquire data to better estimate severity trend

All At the Time SA



Results

1. Understand model behaviour beyond default set-up
2. Understand main impacts of uncertainty on modeling outcome and thus on decisions
3. Understand where to prioritize investment for uncertainty reduction
   → acquire data to better estimate severity trend
4. “Sanity check”
   → does the model meet the expectations?
   (a way to validate your model)

All At the Time SA