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

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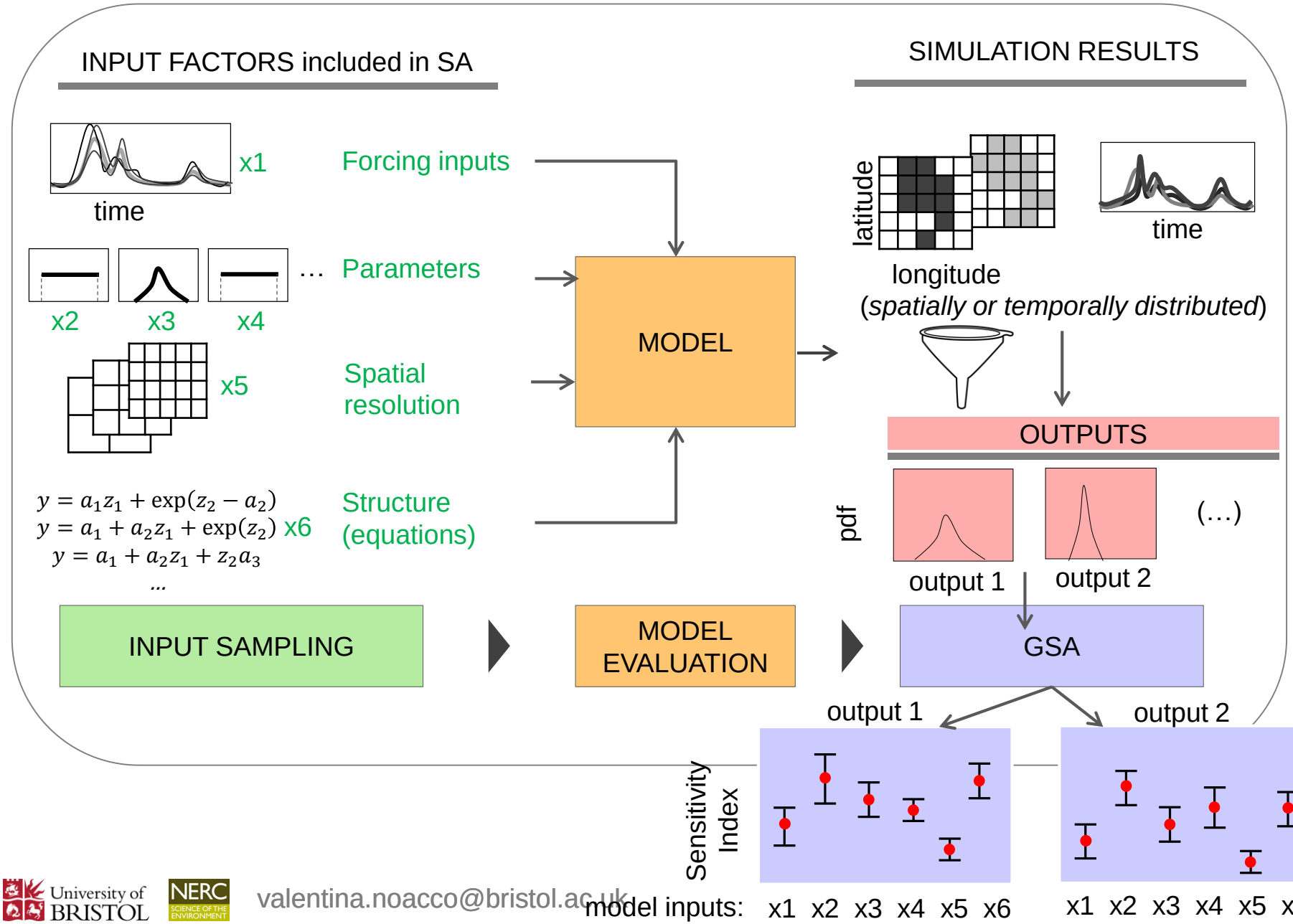
How Global Sensitivity Analysis works



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We aim to transfer GSA to practitioners and integrate it in their modelling workflows

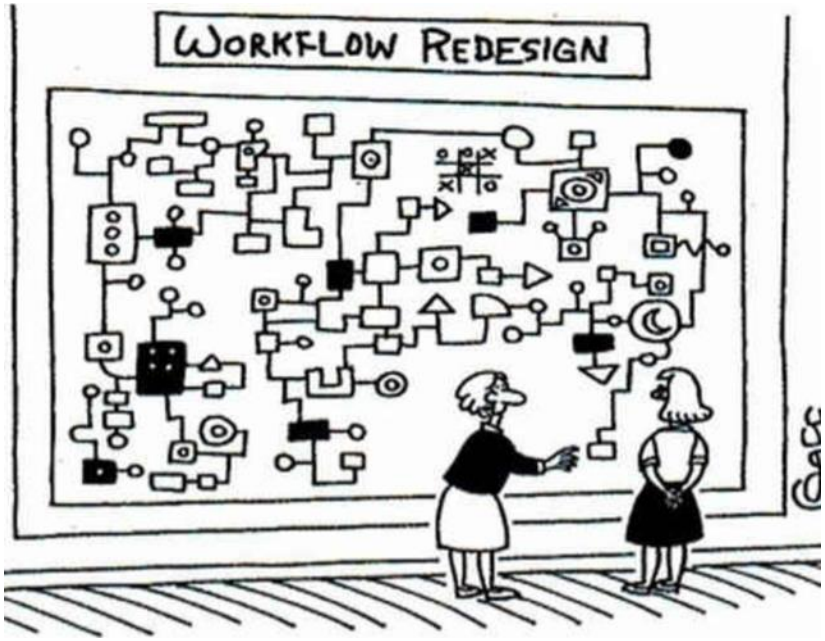
We want to use workflows as a way to transfer expertise.

Often workflows exist only in the users head.

Workflows we produced include **guidance** on:

- how to **produce GSA results**, and
- how to **interpret** these results.

To this end we have developed an R markdown script to guide in the application and interpretation of SA for models which run in R or Excel.



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

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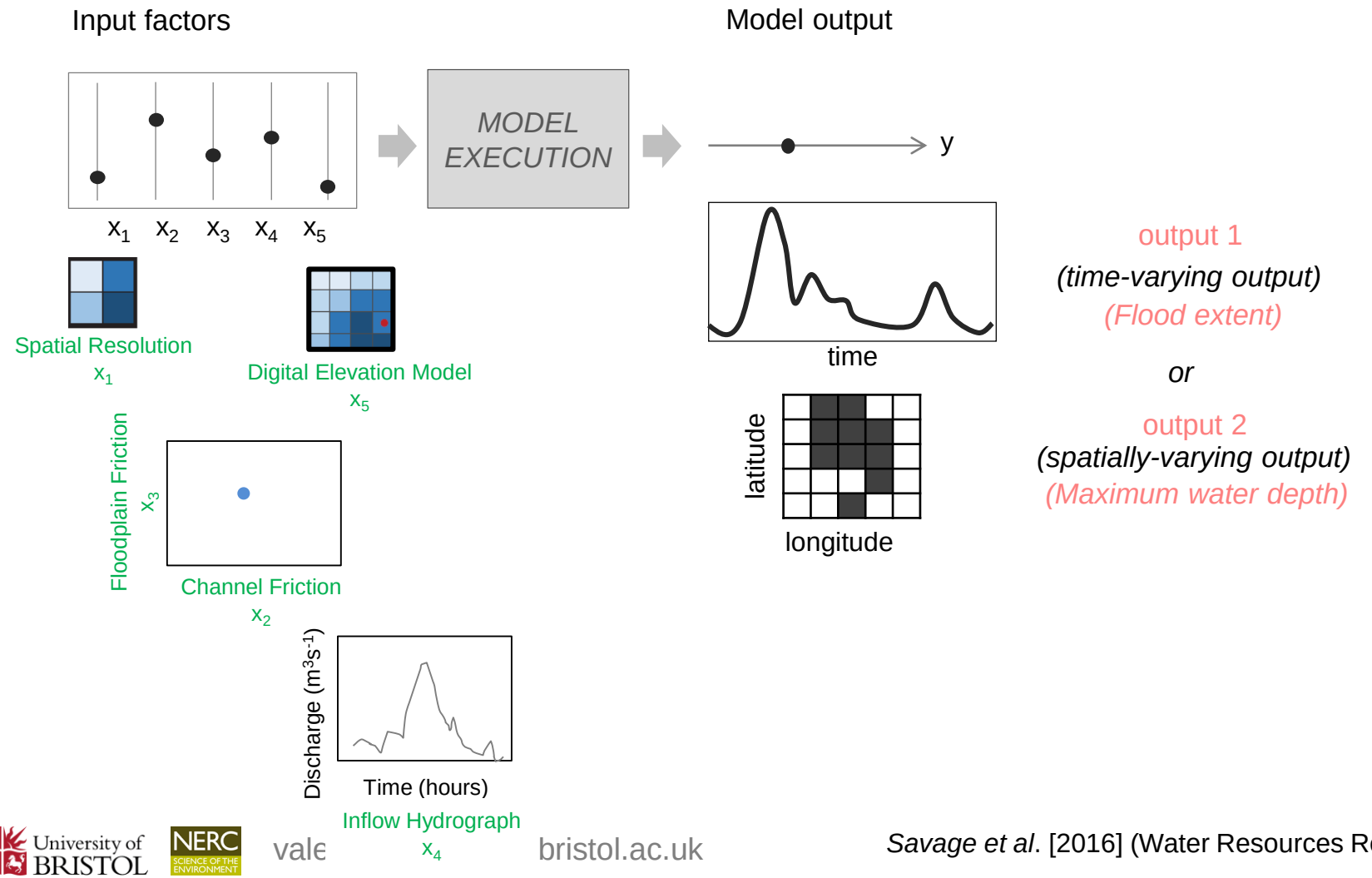
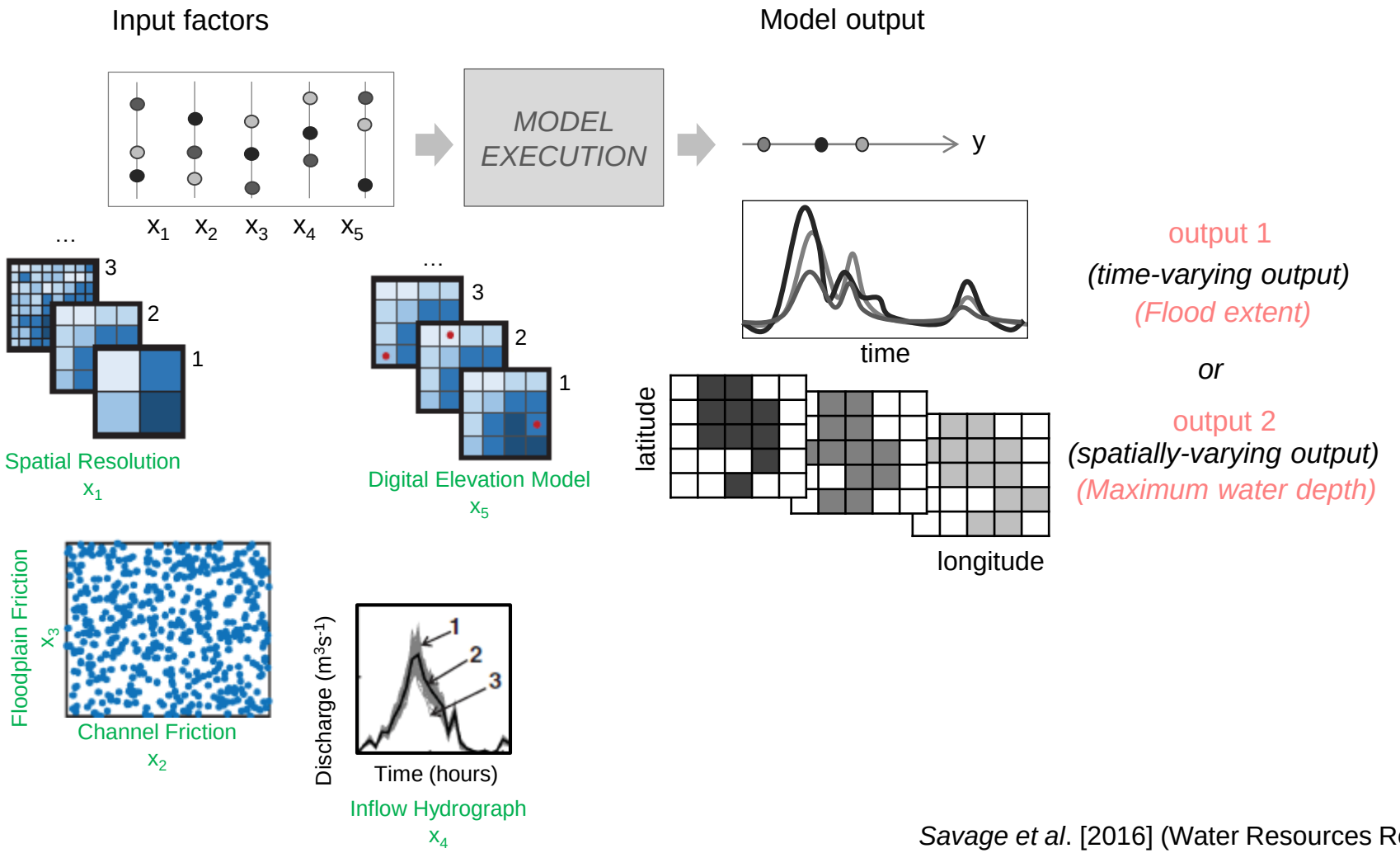
What would be the input factors and outputs in a flood inundation model?



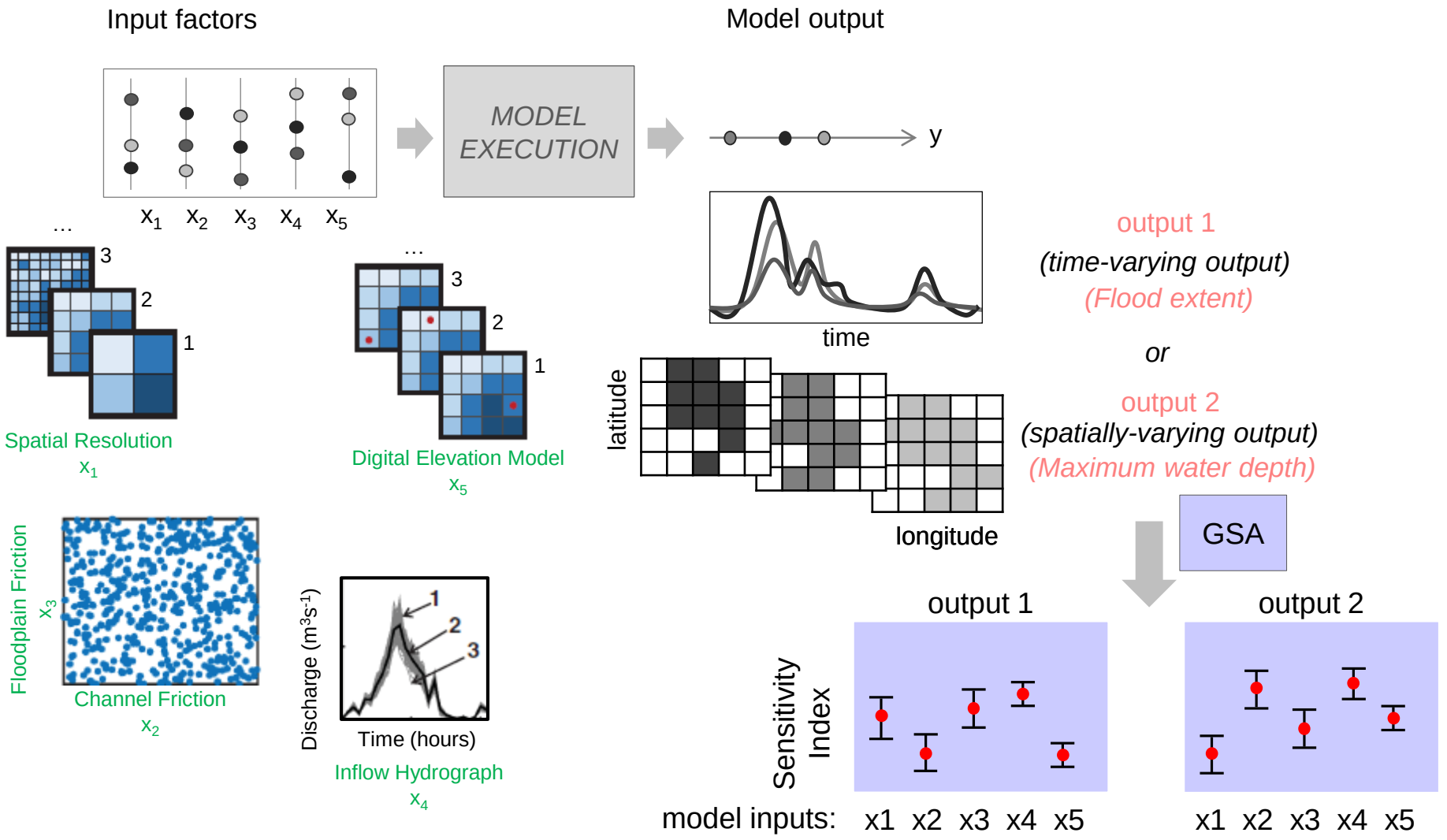
Savage et al. [2016] (Water Resources Research)

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:

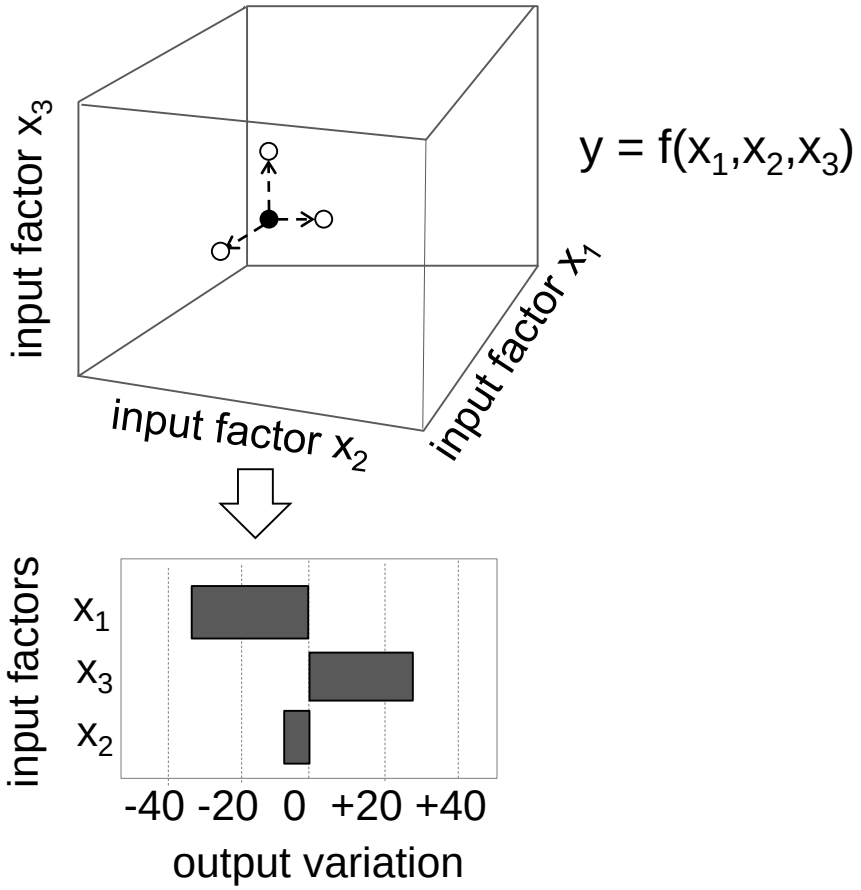
What is *the right* (or *a reasonable*) choice for the input factors (i.e. produce a sensible model output)?

The ‘sensitivity’ question:

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

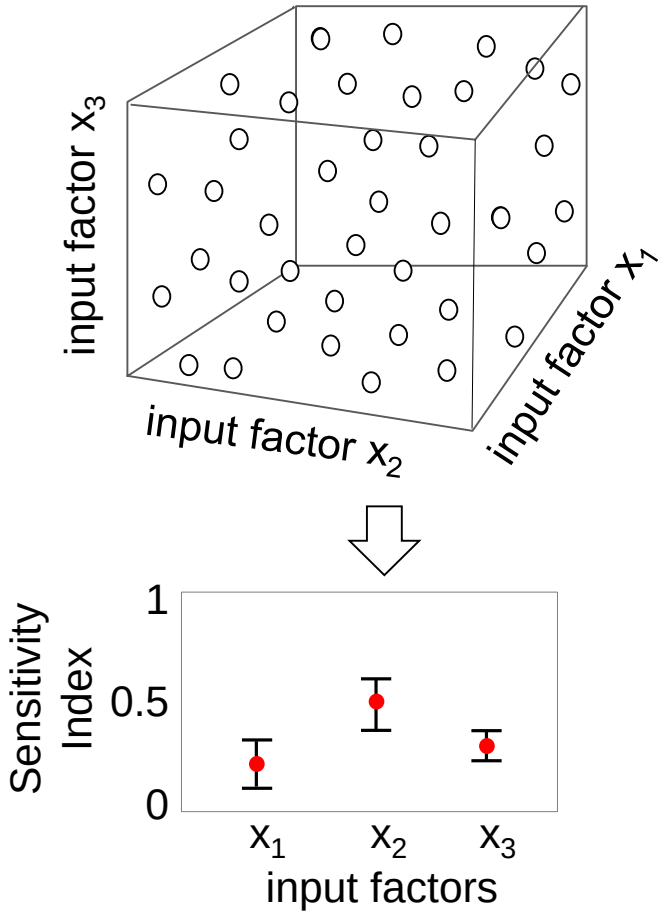
Local vs Global approaches to SA

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.

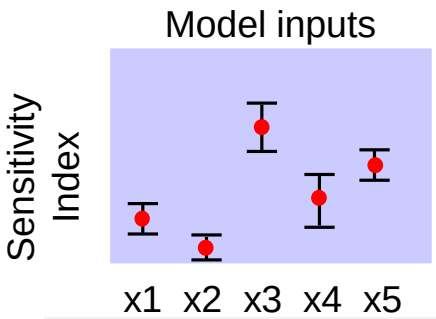


Global methods require a good definition of the space you are going to sample

SA allows to achieve different objectives

Ranking

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

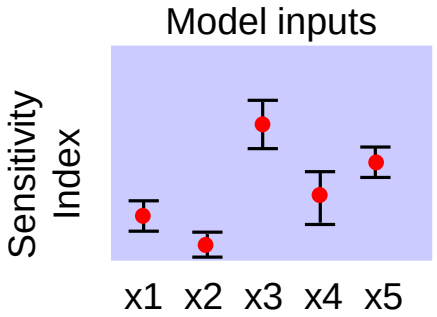


Then possible SA methods:
- Regional Sensitivity Analysis
- Elementary Effects
- Variance Based

→ $x_3 > x_5 > x_4 > x_1 > x_2$

Screening

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

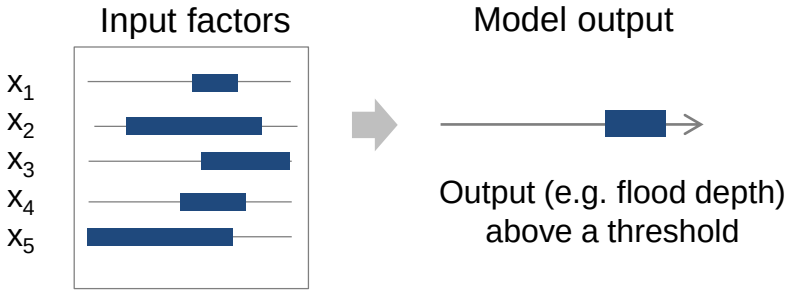


Then possible SA methods:
- Elementary Effects
- Variance Based

→ x_4 non influential

Mapping

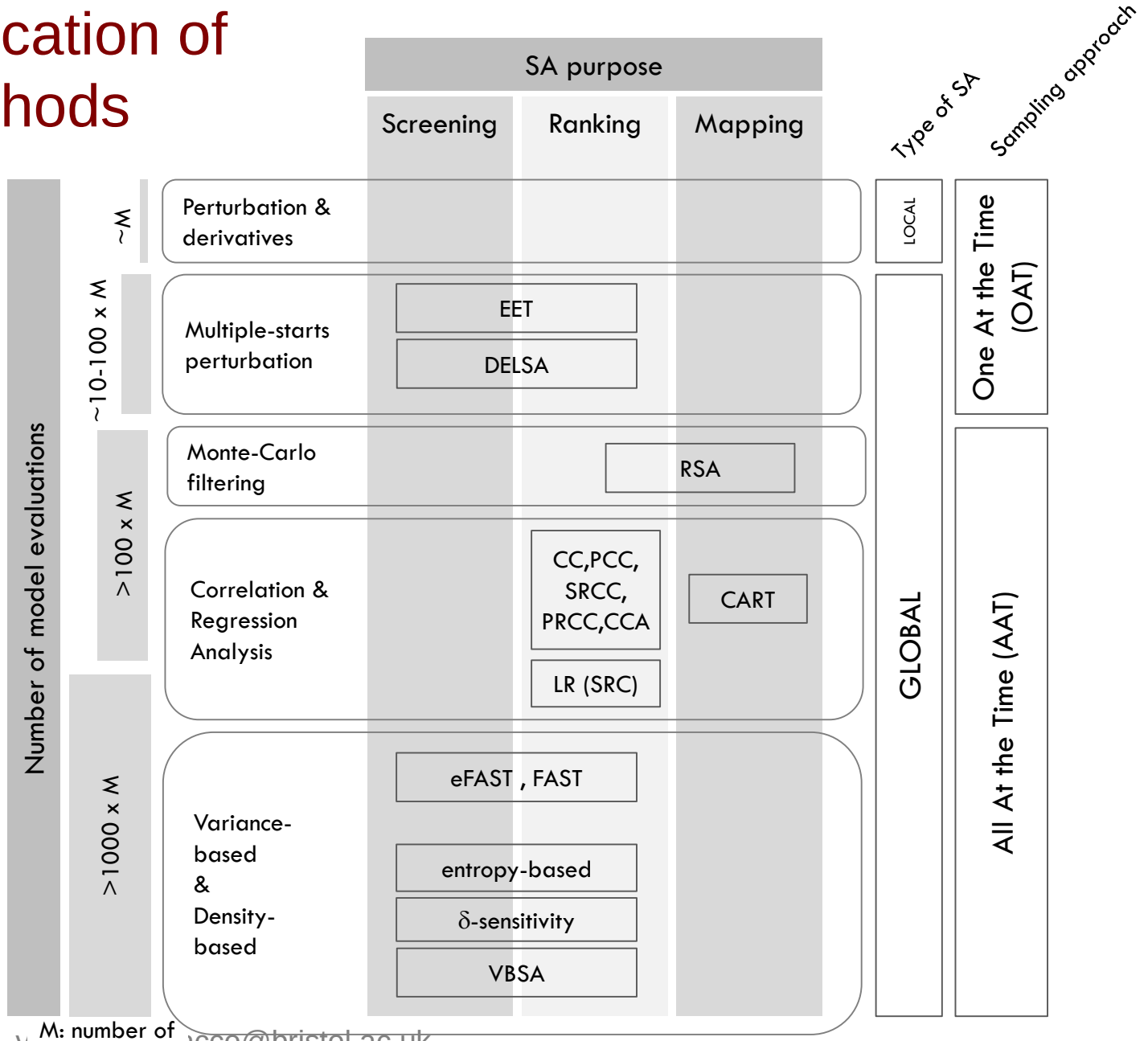
Are there subranges of the input factors that map into "significant" (e.g. extreme) output values?



Then possible SA methods:
- Regional Sensitivity Analysis
- Classification and Regression Trees

→ specific subranges of the inputs give a flood depth above a threshold

Classification of SA methods



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SAFE (Sensitivity Analysis For Everybody) Toolbox

- Developed in 2014 by Pianosi *et al.*

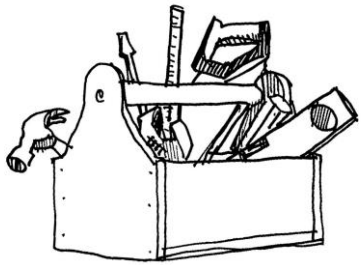
A Matlab toolbox for Global Sensitivity Analysis

August 2015

Francesca Pianosi | Fanny Sarrazin | Thorsten Wagener

- Over 1300 users in academia and industry in 50+ countries

- Developed in R and Matlab (Python version under way)



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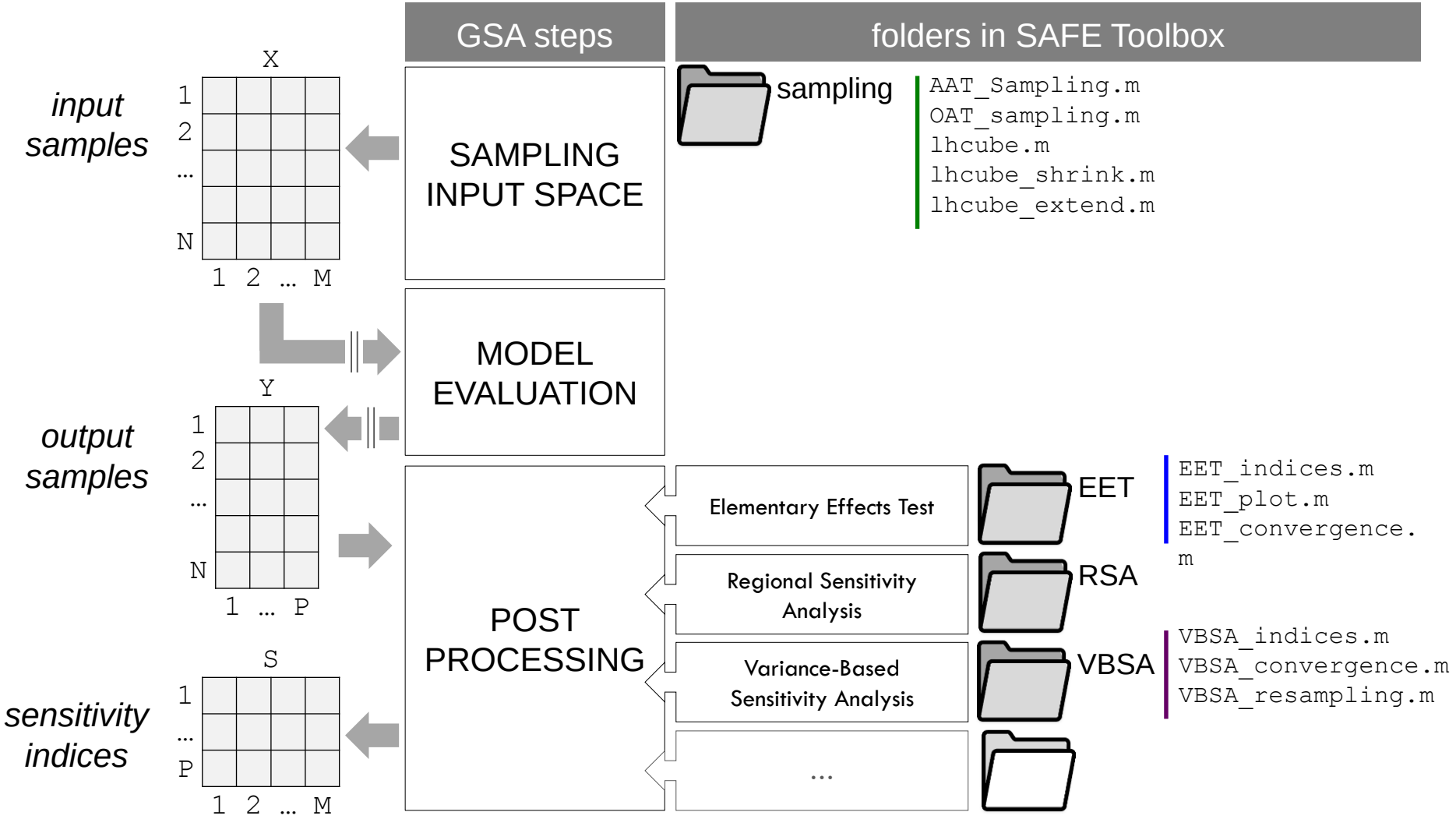
The modular structure of SAFE



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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 based on past losses experience.

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

Objective of case study:

Identify where to focus efforts to reduce uncertainty when reviewing the model (i.e. ranking).

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Simplified schematic of pricing model

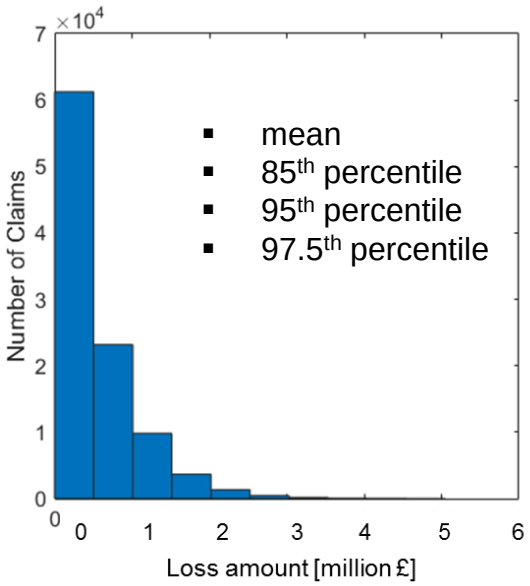
x1. Frequency Trend
x2. Severity Trend
x3. Exposure Trend
x4. Development Pattern

Claim data
Exposure data
Cover data
Portfolio and market data

Pricing model

Output:
Loss amount

Choice of distribution of inputs



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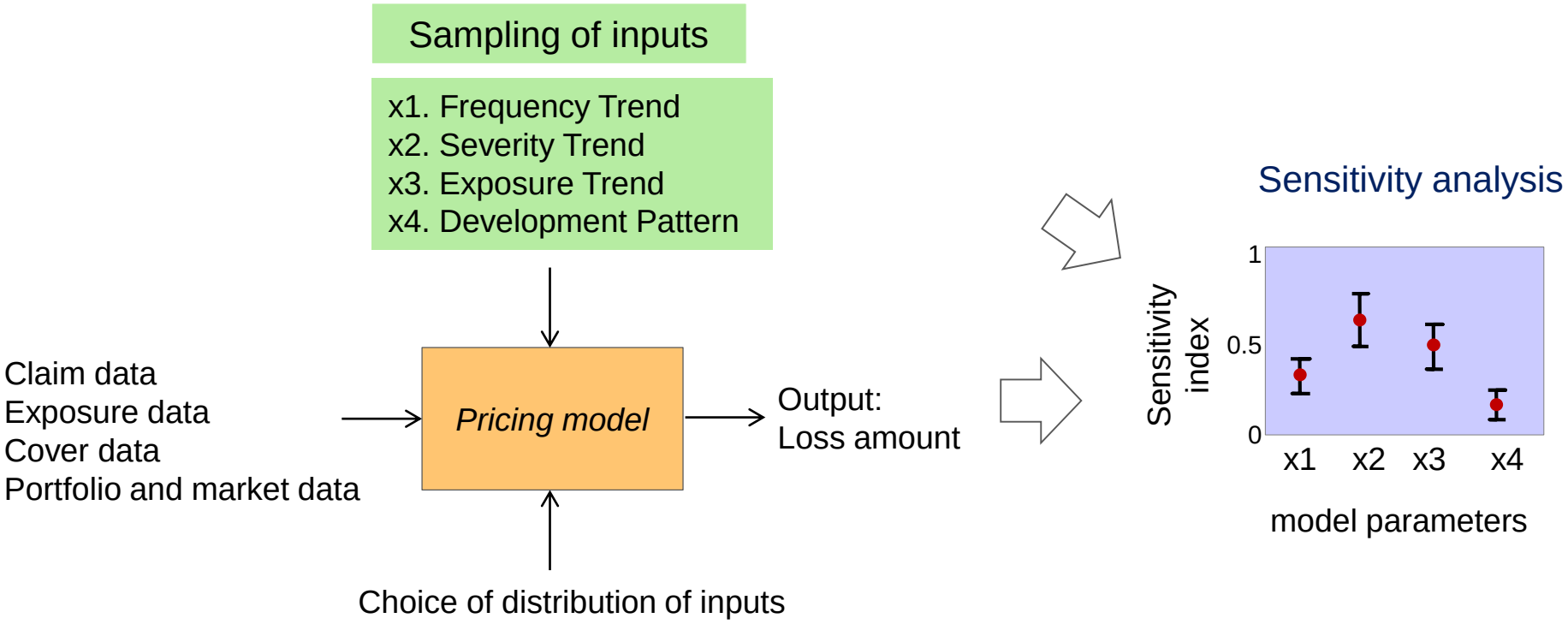
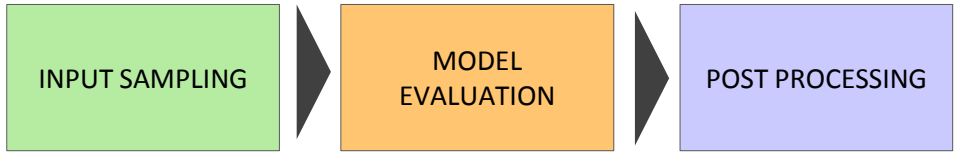
Simplified schematic of pricing model with GSA





Results

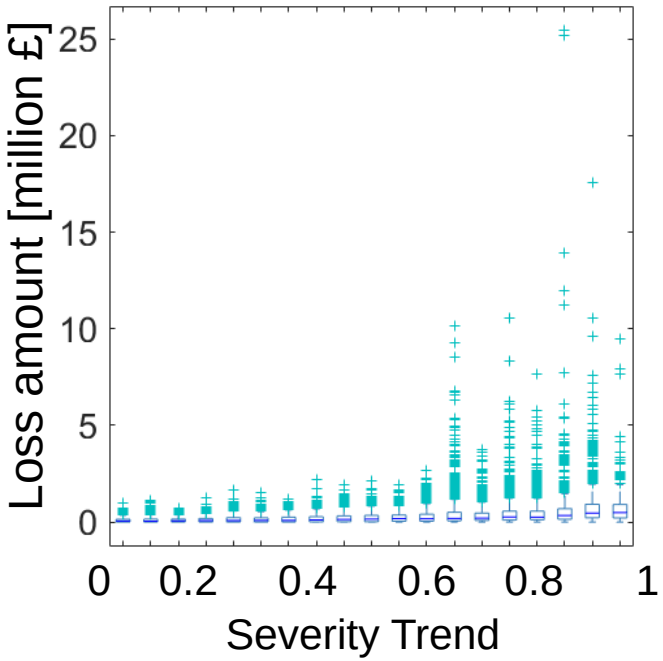
Summary:

- Most influential inputs vary depending on the line of business, therefore this analysis helps to focus efforts to reduce uncertainty and enables to better communicate and outline to the underwriter the uncertainty in the model results due to the assumptions being used.

- Varying the inputs within their credible range sensibly increases the variability of the model output, this should be taken into account while making decisions regarding the premium to charge to a client.

- There are some unexpected behaviours in how the output responds to changing input values, this highlights areas where to focus when reviewing a policy (addressing these issues could improve the model).

Varying the inputs within their credible range sensibly increases the variability of the model output



Benefit:

More transparent and robust decisions

Understand main impacts of uncertainty on modeling outcome and thus on decisions

➢ This analysis enables to better communicate and outline to the underwriter the uncertainty in the model results due to the assumptions being used.

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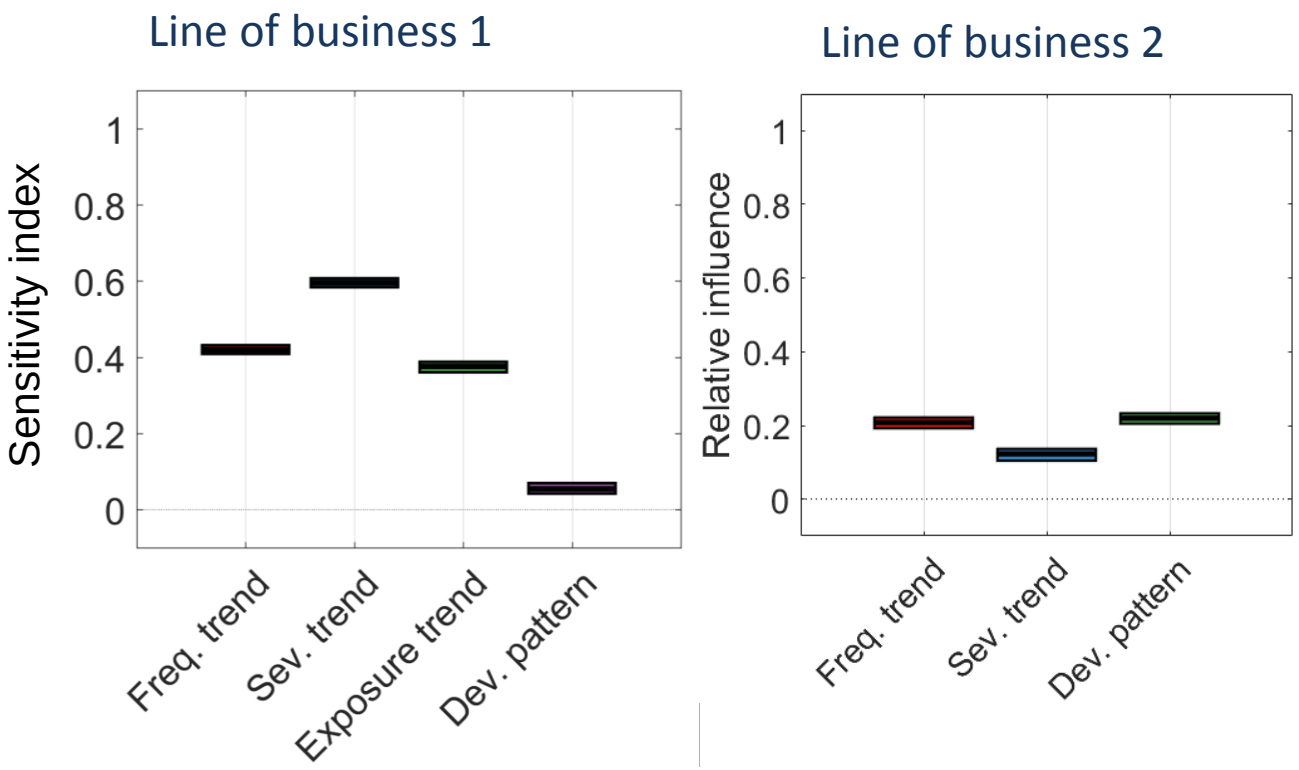
Most influential inputs vary depending on the line of business



Benefit:

Prioritize investments for uncertainty reduction

Identify sensitive inputs for computer-intensive calibration, acquisition of new data, etc.

- We should focus on different inputs to reduce uncertainty depending on the line of business. These inputs could be better estimated from portfolio data of businesses of similar nature.

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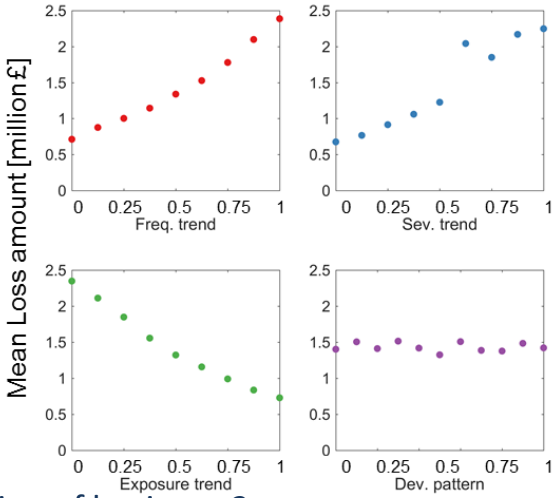
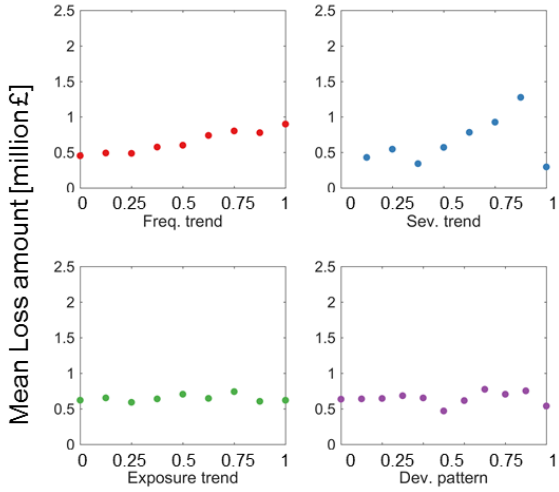
There are some unexpected behaviours in how the output responds to changing input values

Line of business 1



✓ Frequency trend and Severity Trend were expected to increase output losses and vice versa for Exposure trend.

Line of business 3



✗ Severity trend has an incoherent behaviour for some values.

➢ this highlights areas where to focus when reviewing a policy, where addressing these issues could improve the model.

Benefit:

Sanity check" of the model

Does the model meet the expectations (model validation)

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