ETH zürich

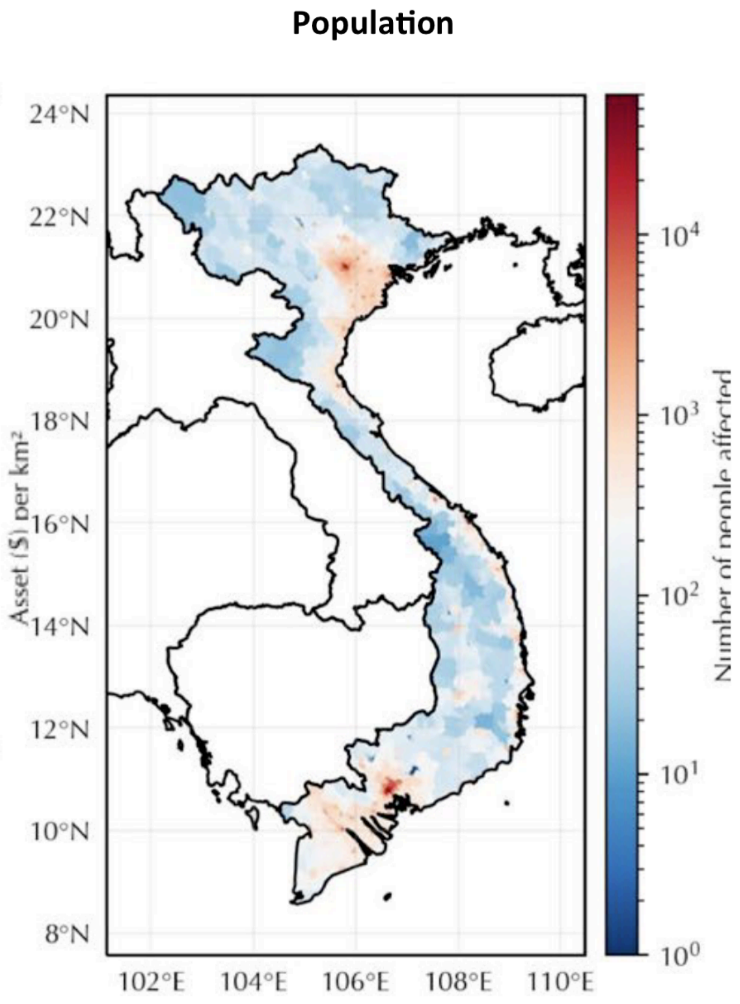
Weather and Climate Risks

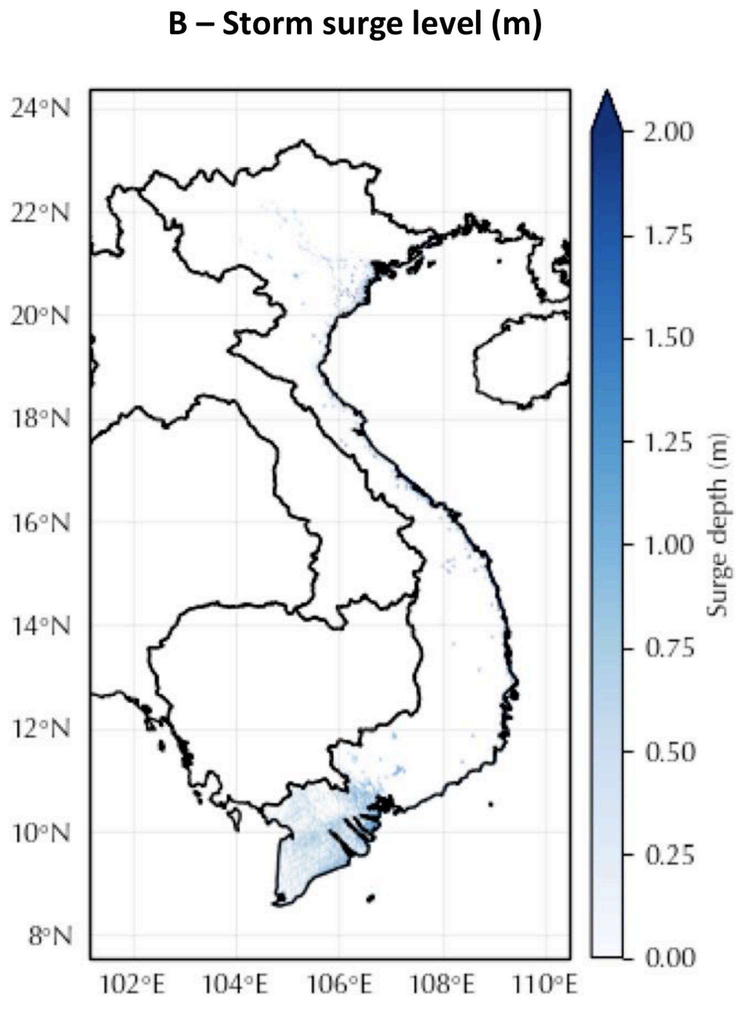
CLIMADA
Economics of Climate Adaptation

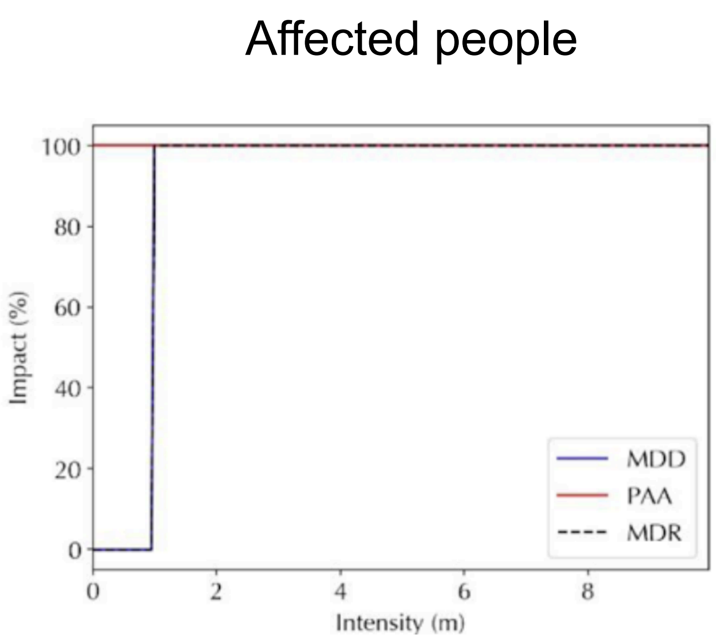
Uncertainty and sensitivity analysis for climate impact assessment and adaptation options appraisal modeling with CLIMADA

Cross-sectoral ISIMIP and PROCLIAS Workshop
16-19 May 2022
Chahan Kropf

Example - storm surge in Vietnam : Input variables





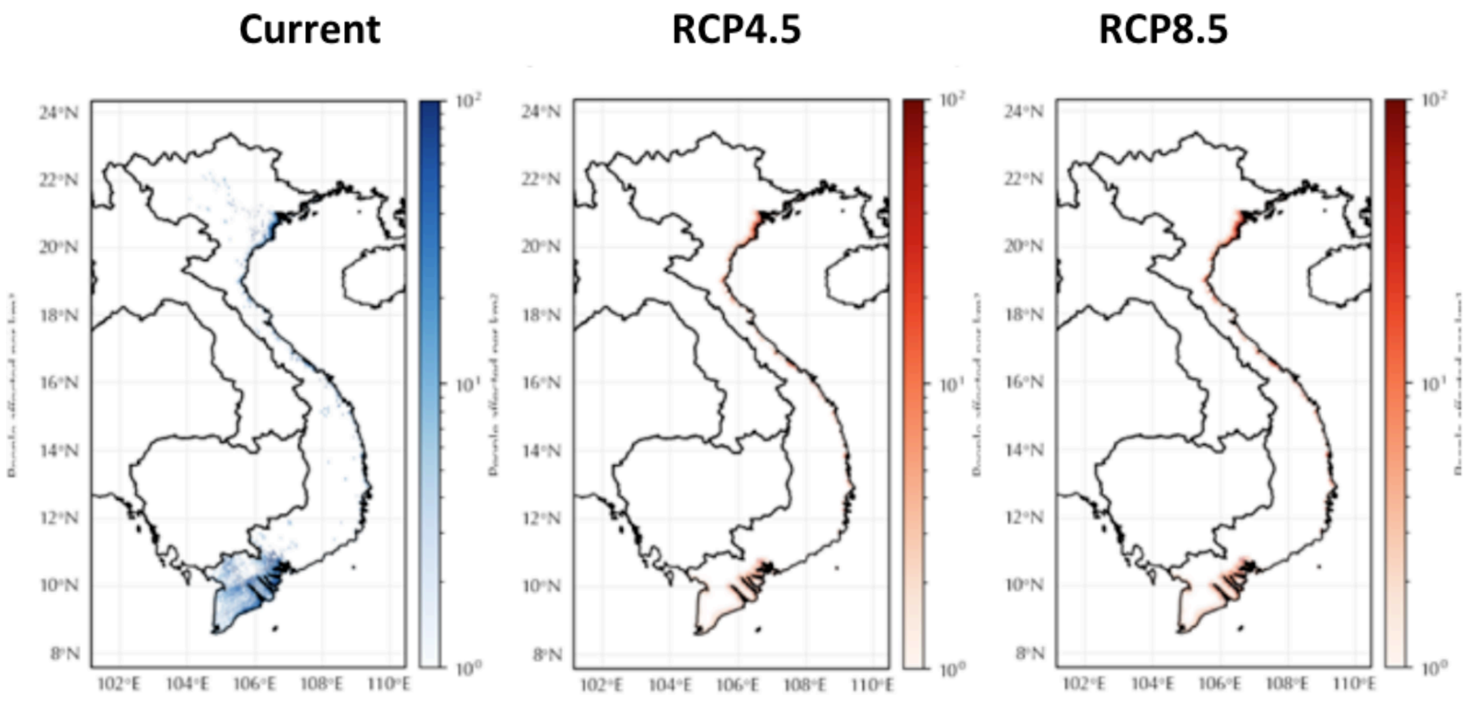


>10000 events

ETH zürich

Example - storm surge in Vietnam : Impact

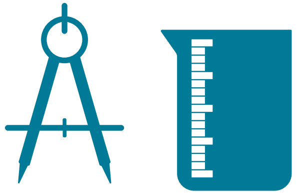
- Tropical cyclone induced surge
- Current 2020 scenario and additional damage in the future 2050 scenarios under RCP4.5 and RCP8.5.
- Population growth, climate change, sea level rise



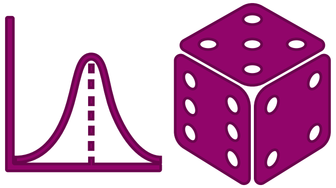
- Average annual impact: 1.94Mio. +1.08Mio. +2.16Mio.

Uncertainty

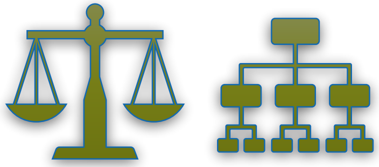
“Uncertainties” in risk models



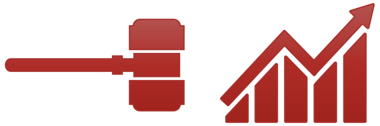
- **Epistemic:** “imperfect understanding of the system”[1]



- **Aleatoric:** “uncertain due to system properties”[1]



- **Predictive:** “different model specifications might seem equally plausible and it is unclear how to best represent the target system for a specific purpose.”[1]



- **Normative:** “uncertainty about value itself”[2] and “uncertainties about how to decide and how to act”[3]

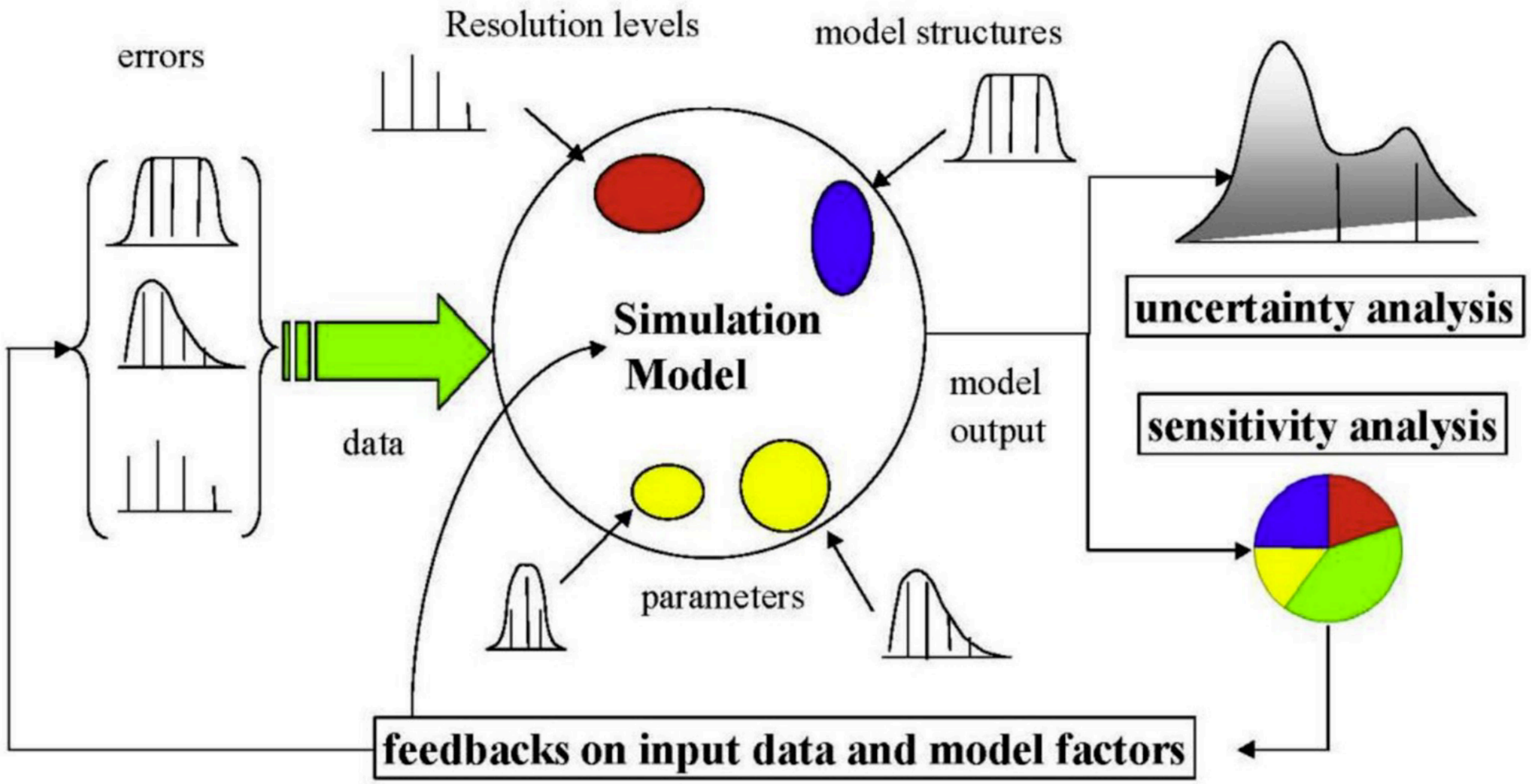
1- DOI:10.1016/j.envsoft.2020.104754 3- DOI:10.1093/acprof:oso/9780199964482.003.0003 3. https://doi.org/10.1017/S0266267121000201

Quantitative? Not all

- Depends on
  - **case study**
  - **purpose**
- **Subset** of uncertainties
- General treatment with **argument analysis framework**[1]

1- In prepatation: Analyzing Uncertainties in Climate Risk Assessment and Adaptation Options Appraisal with a Four-Phase Analytical Framework

Quantitative: uncertainty and sensitivity analysis with quasi-Monte-Carlo sampling



Taken from: DOI:10.1016/j.envsoft.2019.01.012

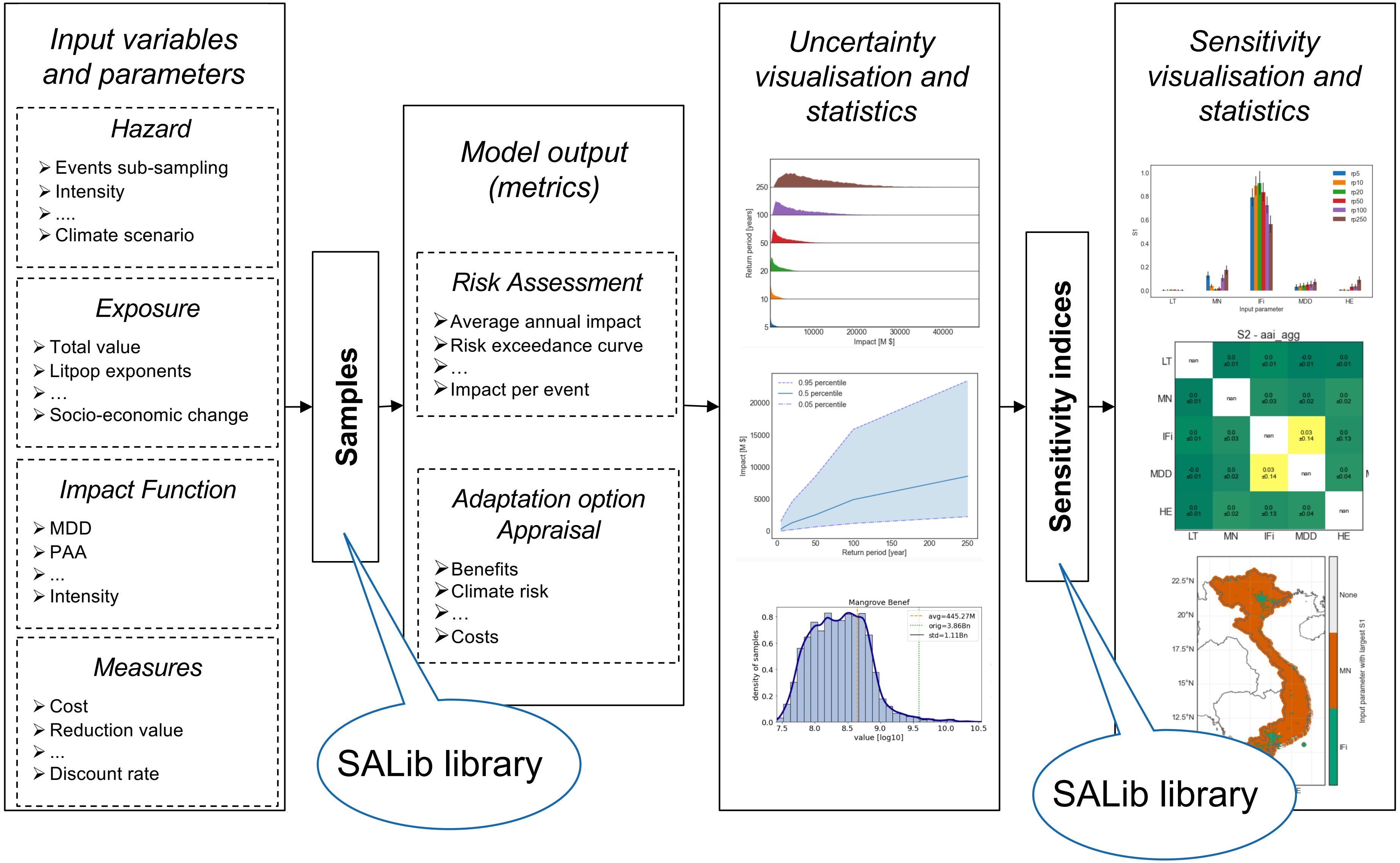
ETH zürich

CLIMADA
Economics of Climate Adaptation

unsequa module

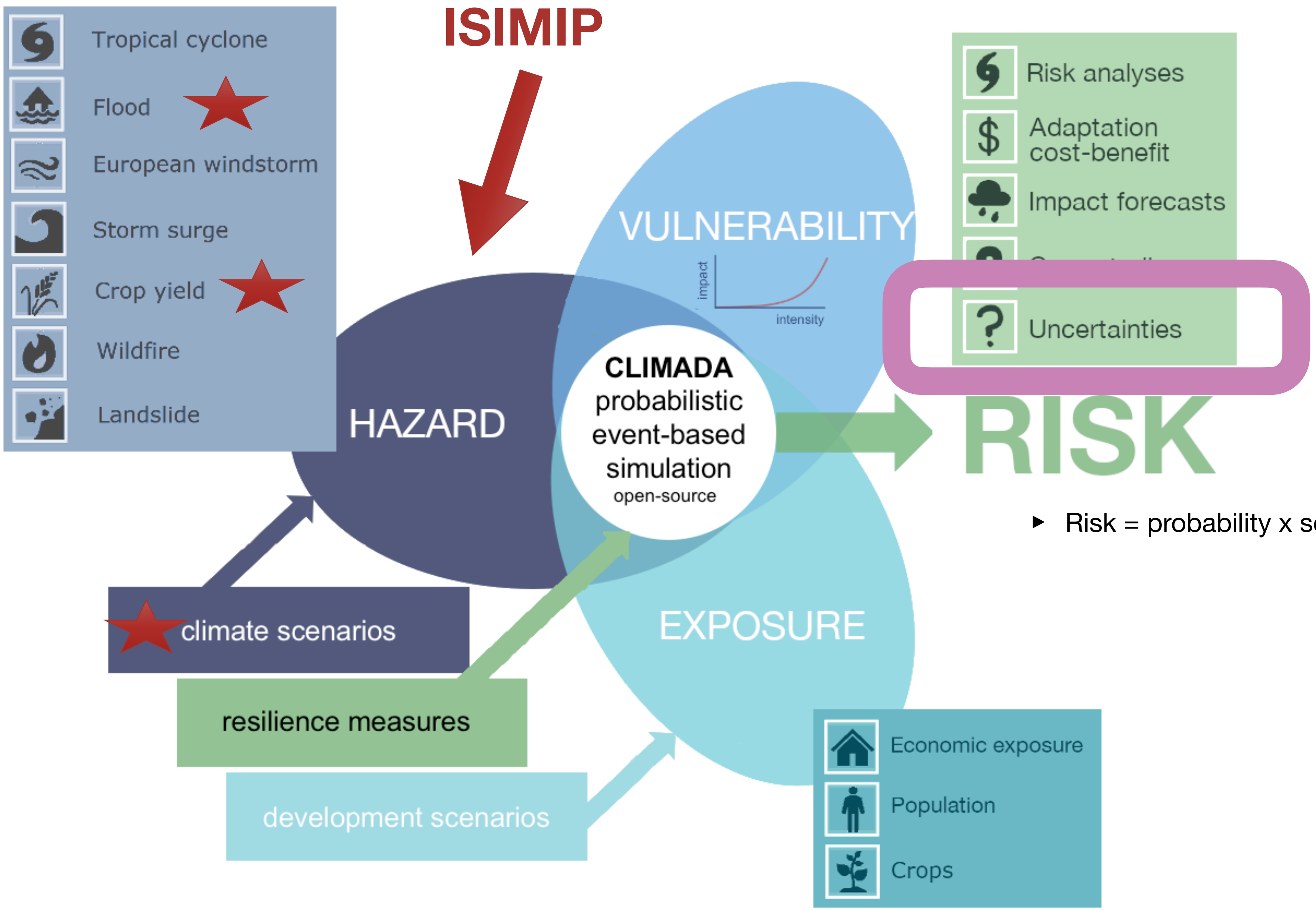
Module for uncertainty and sensitivity quantification in CLIMADA

unsequa (uncertainty sensitivity quantification) module



Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

CLIMADA v3.1.2

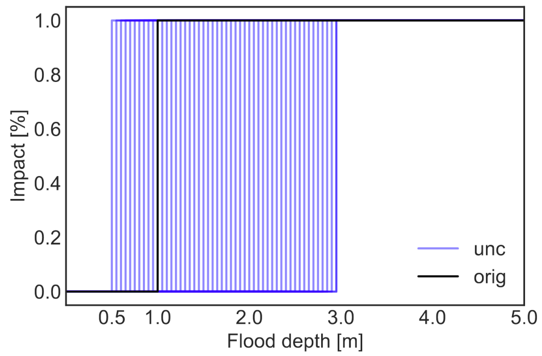


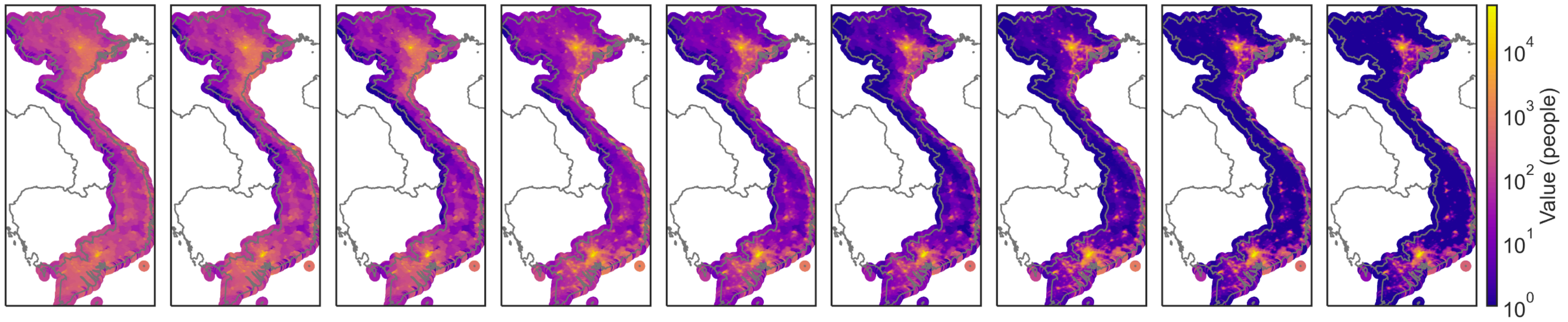
- Risk = probability x severity

ETH zürich

Case study: Vietnam storm surge current risk

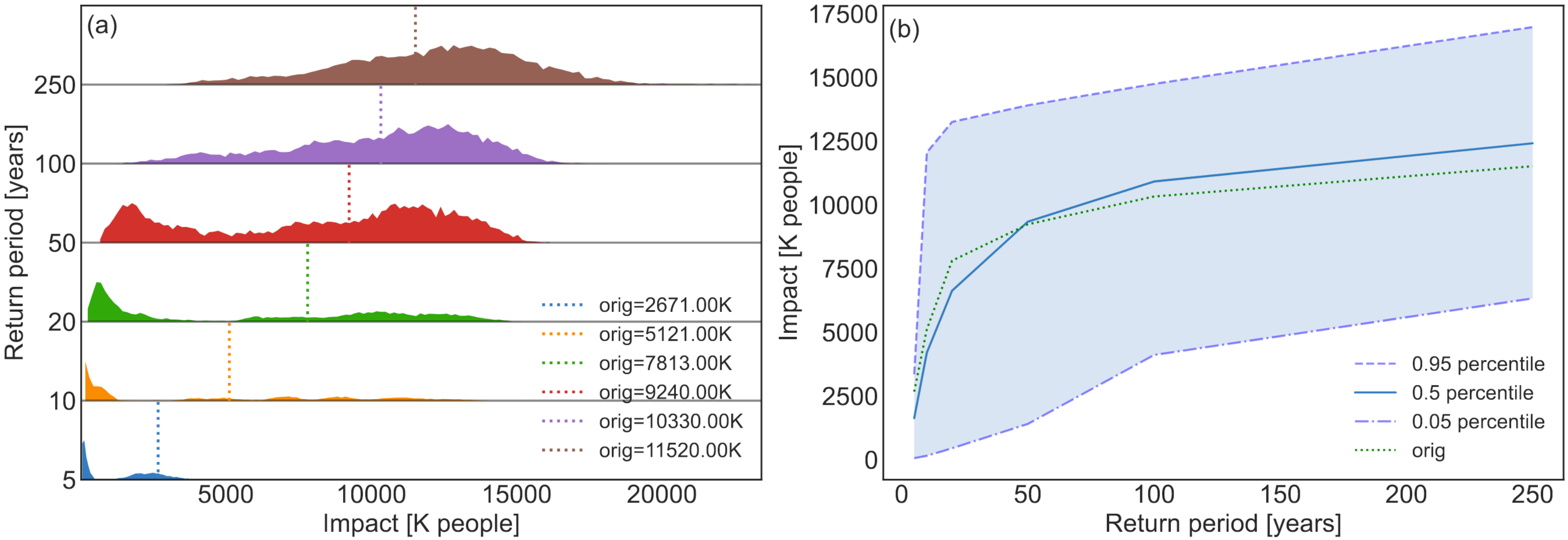
Risk assessment				
Exposures	total value	T	truncated Gaussian multiplicative	clip:[0.9, 1.1] ; $\mu : 1, \sigma : 0.05$
	spatial distribution	L	LitPop layers exponents	$m \in (0, 0.5, 1); n \in (0.75, 1, 1.25)$
Hazard	event set bootstrapping	H	re-sampling the event set with replacement	
Impact function	threshold shift	S	uniform range	[0.5m, 3.0m]





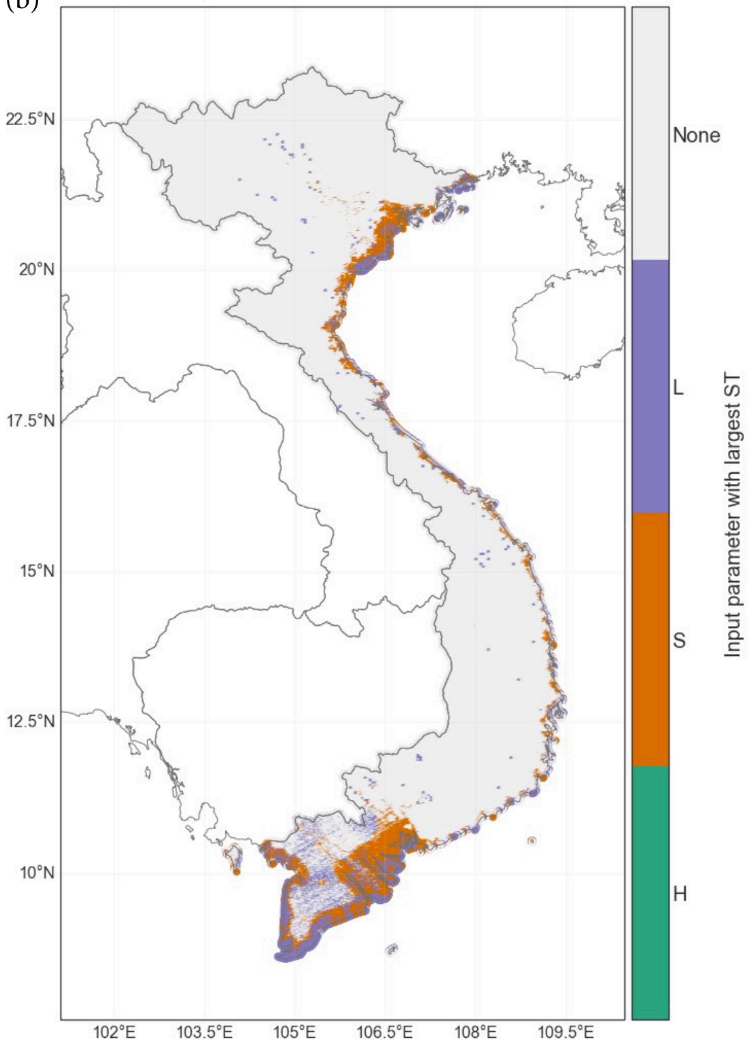
Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Impact uncertainty

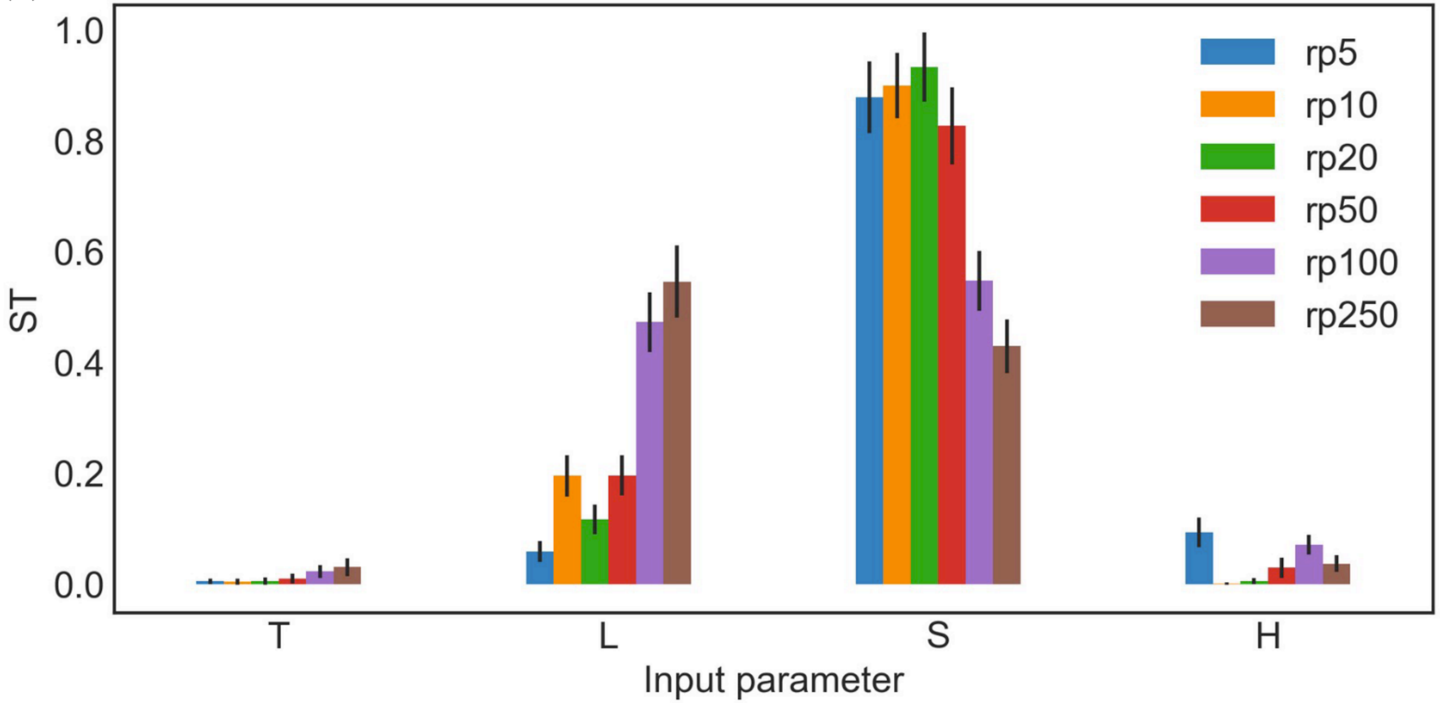


Sensitivity

(b)

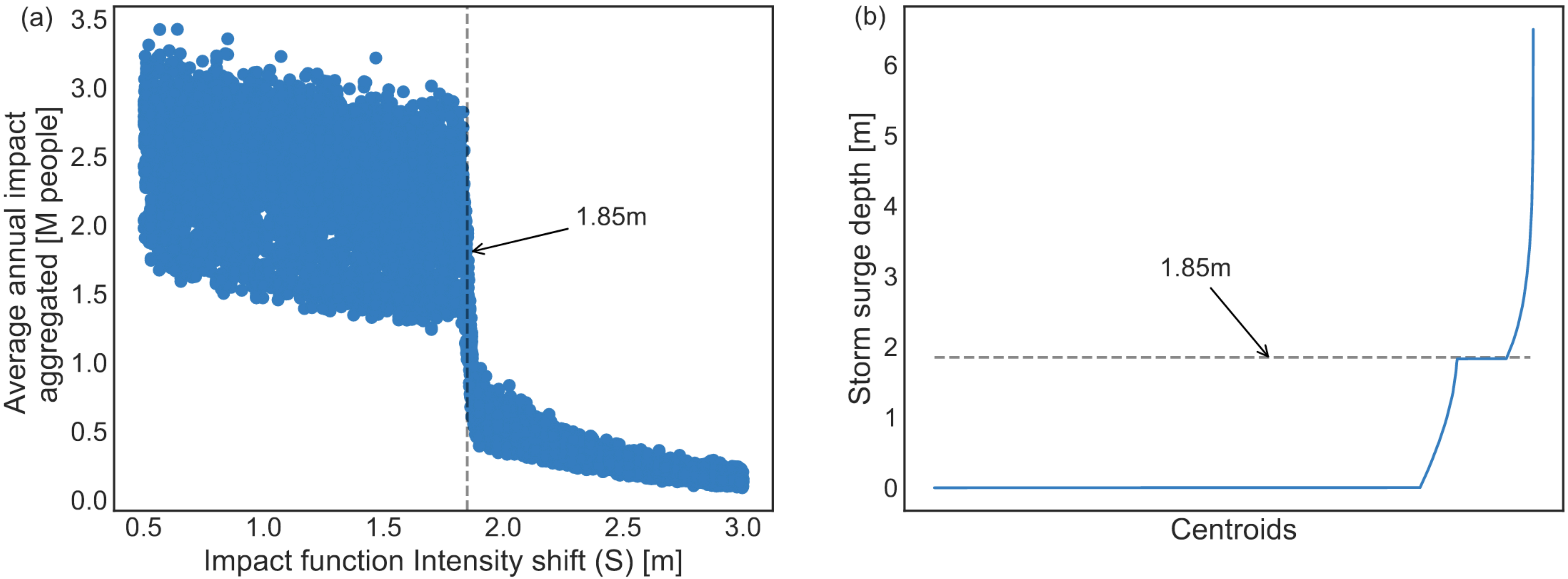


(c)



Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Bi-modal distribution



Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

ISIMIP ?

Conclusion

Caution on Uncertainty Quantification

- Be vary of false certainty from uncertainty!
- You need to have a good idea of the uncertainty of the uncertainty.

- For **ISIMIP**-data, good **uncertaint**y estimates are sometimes **missing**
- How to treat **ensembles** combining different models, different scenarios?
  - "Equi-probably" ensemble of opportunity?
- Uncertainty requires **more than** hazard model.
- Uncertainty of **modelling choices** are rarely reported

Thank you!

Kropf, C. M., Ciullo, A., Otth, L., Meiler, S., Rana, A., Schmid, E., McCaughey, J. W., and Bresch, D. N.: Uncertainty and sensitivity analysis for probabilistic weather and climate risk modelling: an implementation in CLIMADA v.3.1.0, 1–32, https://doi.org/10.5194/gmd-2021-437, 2022.

ETH zürich

CLIMADA
Economics of Climate Adaptation

Supplementary slides

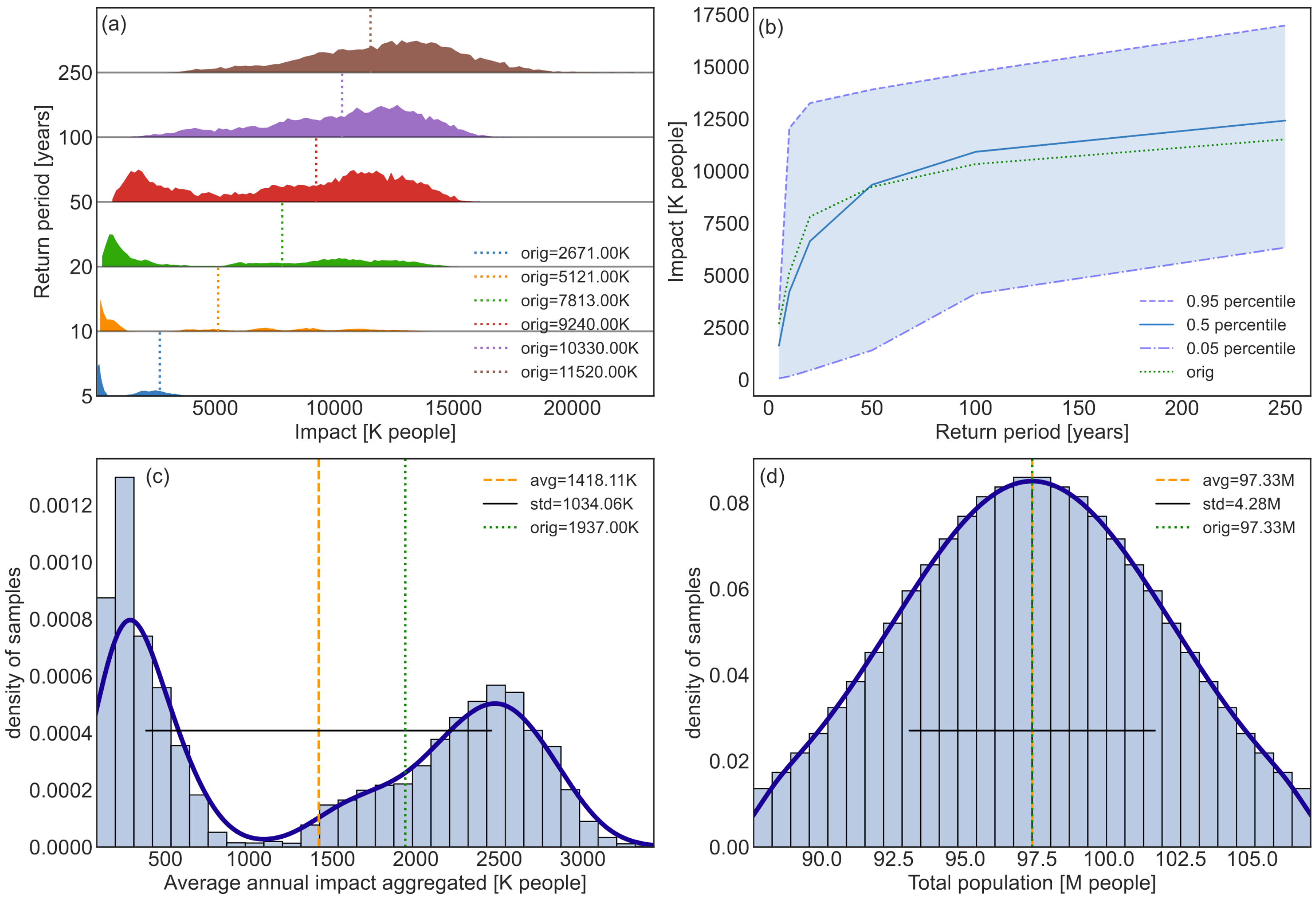
Uncertainty vs Sensitivity analysis

- **Uncertainty**: distribution of output metric due to a distribution of input variables/parameters

- **Sensitivity**: attribution of the output metric variation to the input variable/parameters

    - **NOT**: attribution of contribution to output metric from input variable/parameter

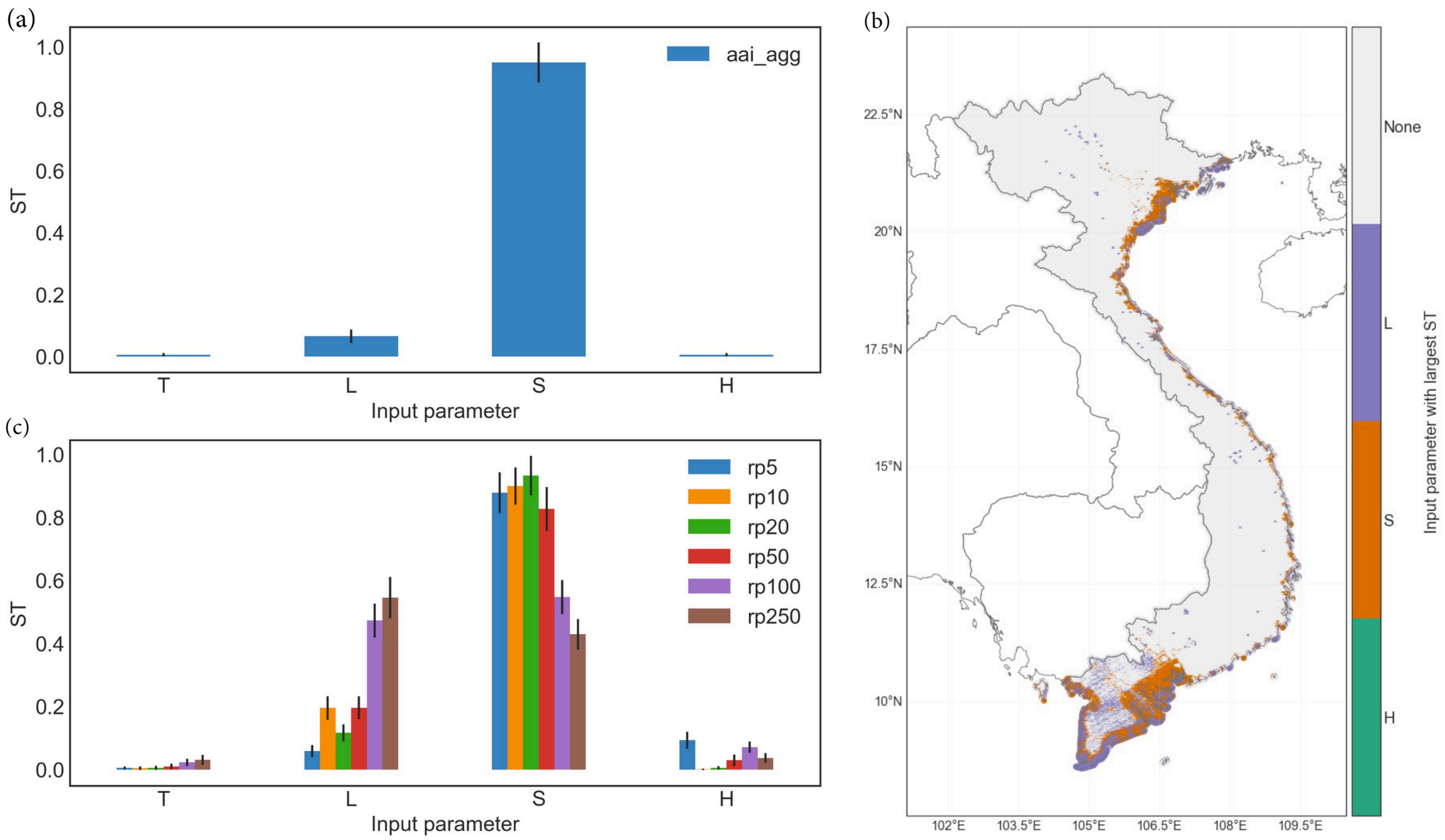
Impact uncertainty



ETH zürich

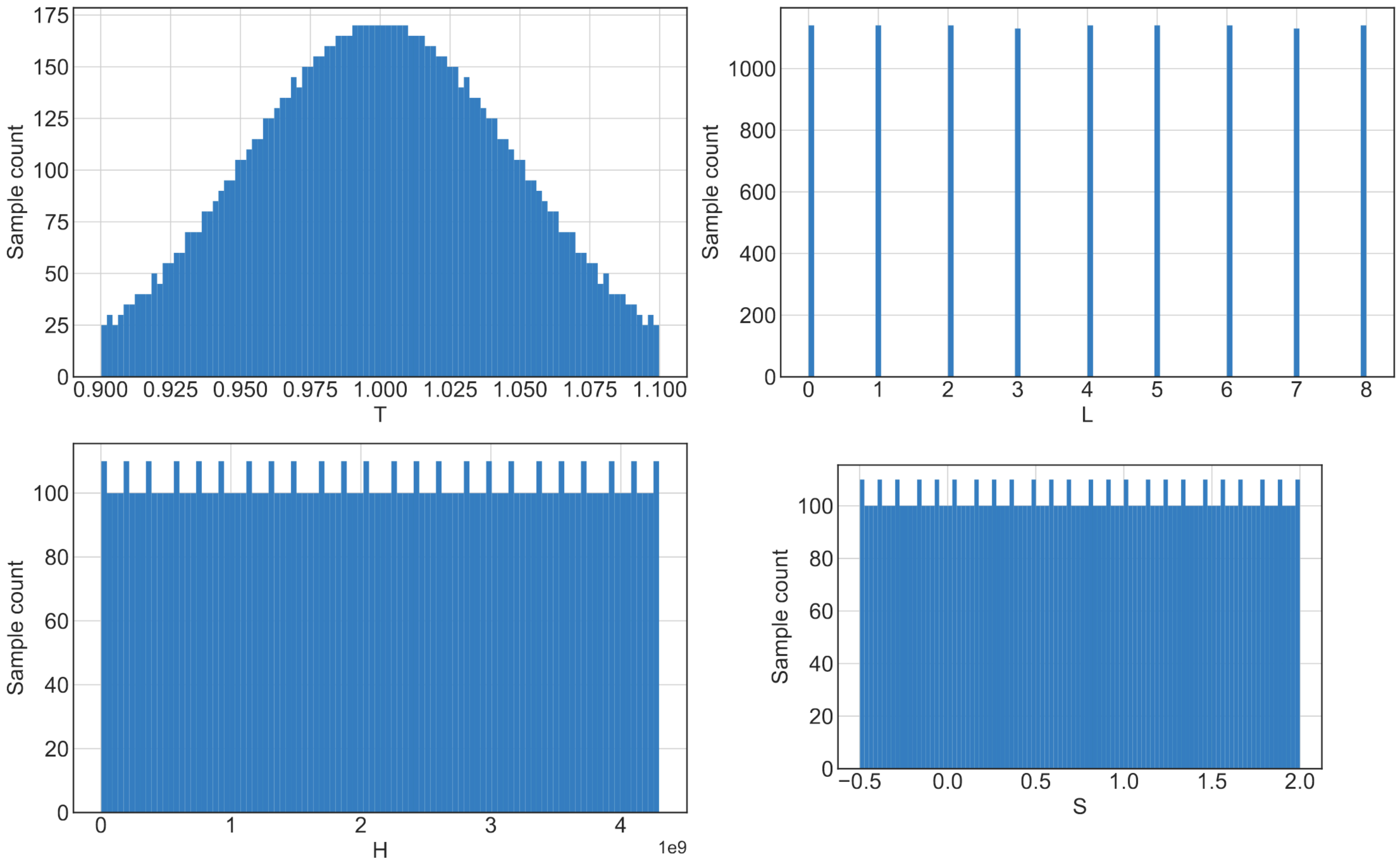
Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Sensitivity



Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Global sampling with Sobol sequence

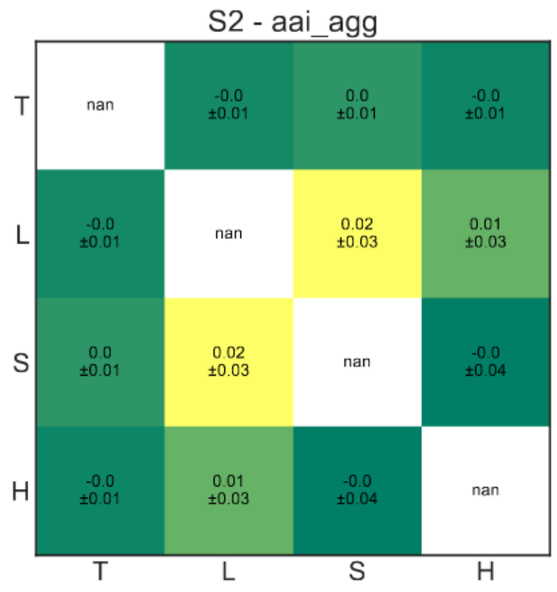


Exposures	total value	T
	spatial distribution	L
Hazard	event set bootstrapping	H
Impact function	threshold shift	S

Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Summary

- Unsequa module for uncertainty and sensitivity analysis of climate risk
- Fully integrated and flexible
- Several helper methods for quick and easy analysis
- All input variables can have uncertainty
- Quasi-Monte Carlo sampling from SALib library
- Sensitivity analysis from SALib library
- Future development: allow for the use of surrogate model



Kropf, C. M., Ciullo, A., Otth, L., Meiler, S., Rana, A., Schmid, E., McCaughey, J. W., and Bresch, D. N.: Uncertainty and sensitivity analysis for probabilistic weather and climate risk modelling: an implementation in CLIMADA v.3.1.0, 1–32, https://doi.org/10.5194/gmd-2021-437, 2022.

Global vs local sampling

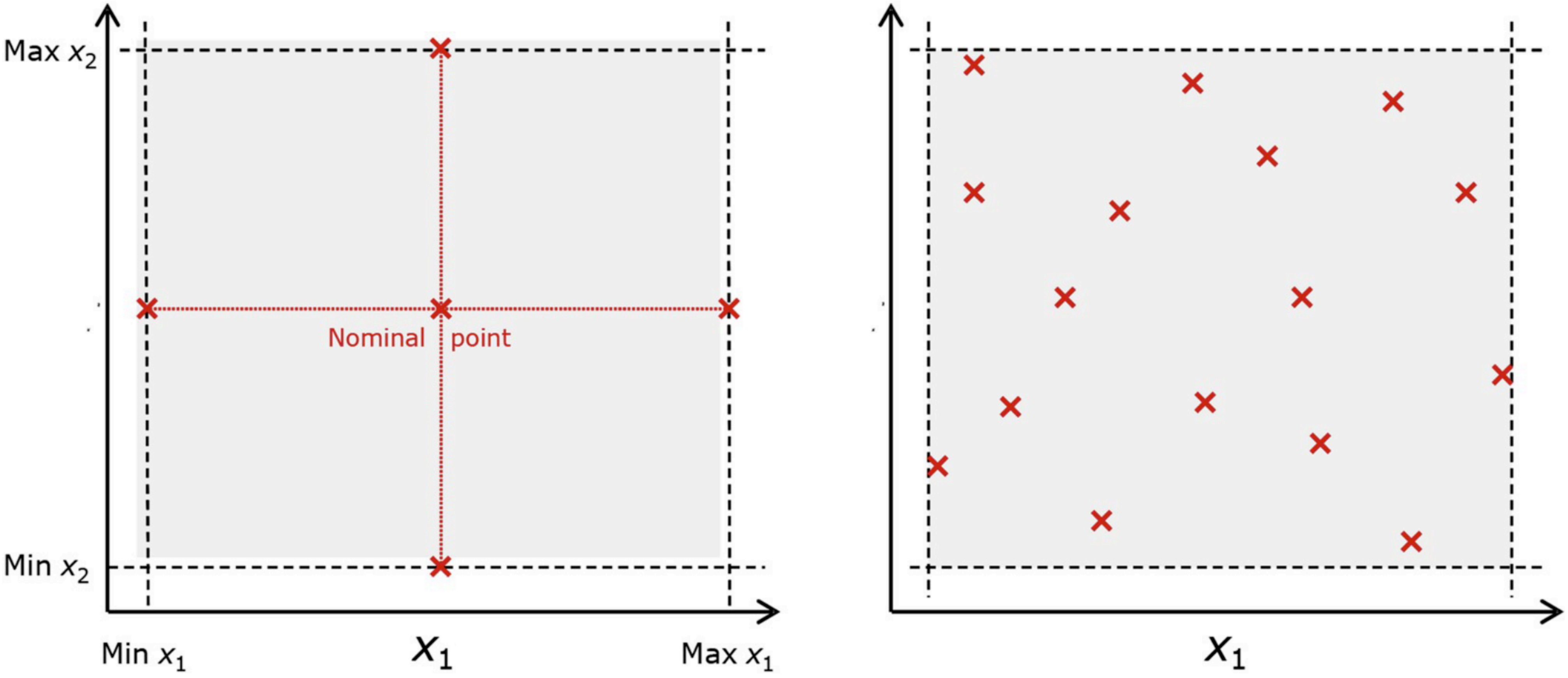
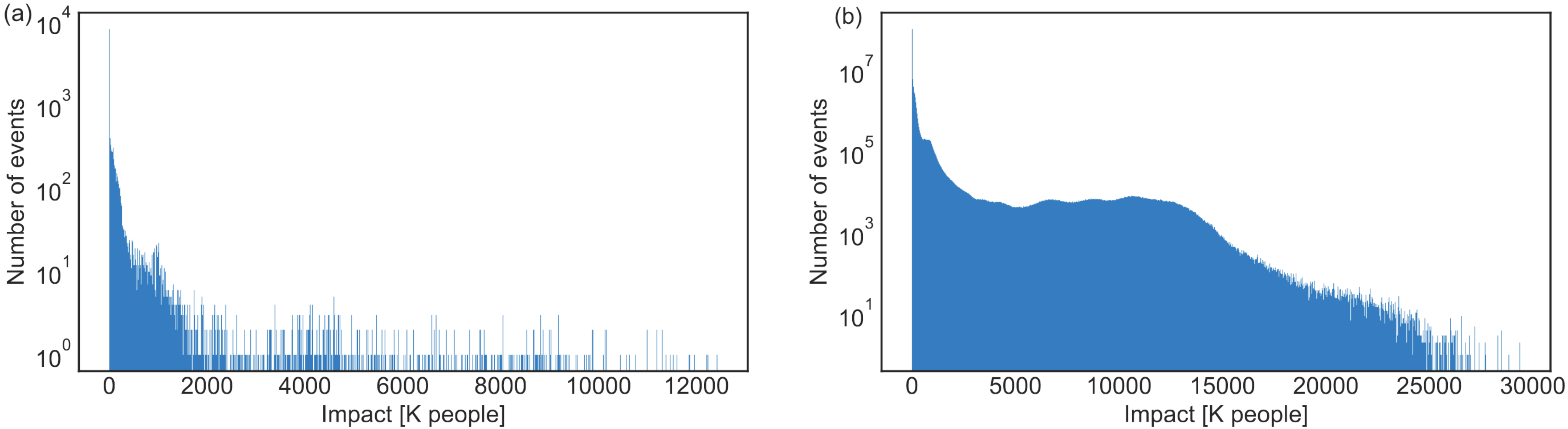


Fig. 2. OAT design (left) contrasted against global design (right).

- For non-linear models (like CLIMADA), always use Global sampling

Taken from: DOI:10.1016/j.envsoft.2019.01.012

Impact over all events form sampling



Taken from: https://gmd.copernicus.org/preprints/gmd-2021-437/

Core impact computation

- Exposures value at given location : $E(x)$
- Intensity of hazard event epsilon at modelled location $\tilde{x}$ closest to x : $h_\epsilon(\tilde{x})$
- Frequency (probability) of event : ν_ϵ
- Impact function of exposures at location x : $f(E(x)) = f_x$
- Impact matrix:

$$I_{\epsilon,x} = f_x(h_\epsilon(\tilde{x}))E(x)$$

Impact and risk metrics

- Impact at event

$$I_\epsilon = \sum_x I_{\epsilon,x}$$

- Expected average impact at exposures

$$\overline{I}_x = \sum_\epsilon I_{\epsilon,x}\nu_\epsilon$$

- Average impact over all exposures and all events (total annual expected risk)

$$\overline{R} = \sum_{\epsilon,x} I_{\epsilon,x} \cdot \nu_\epsilon$$