Horizon2020
Insurance

Flood recurrence under climate change: A probabilistic flood risk assessment of the Danube basin

EGU online, 7 May 2020

PIK

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GFZ
Helmholtz Centre
POTSDAM

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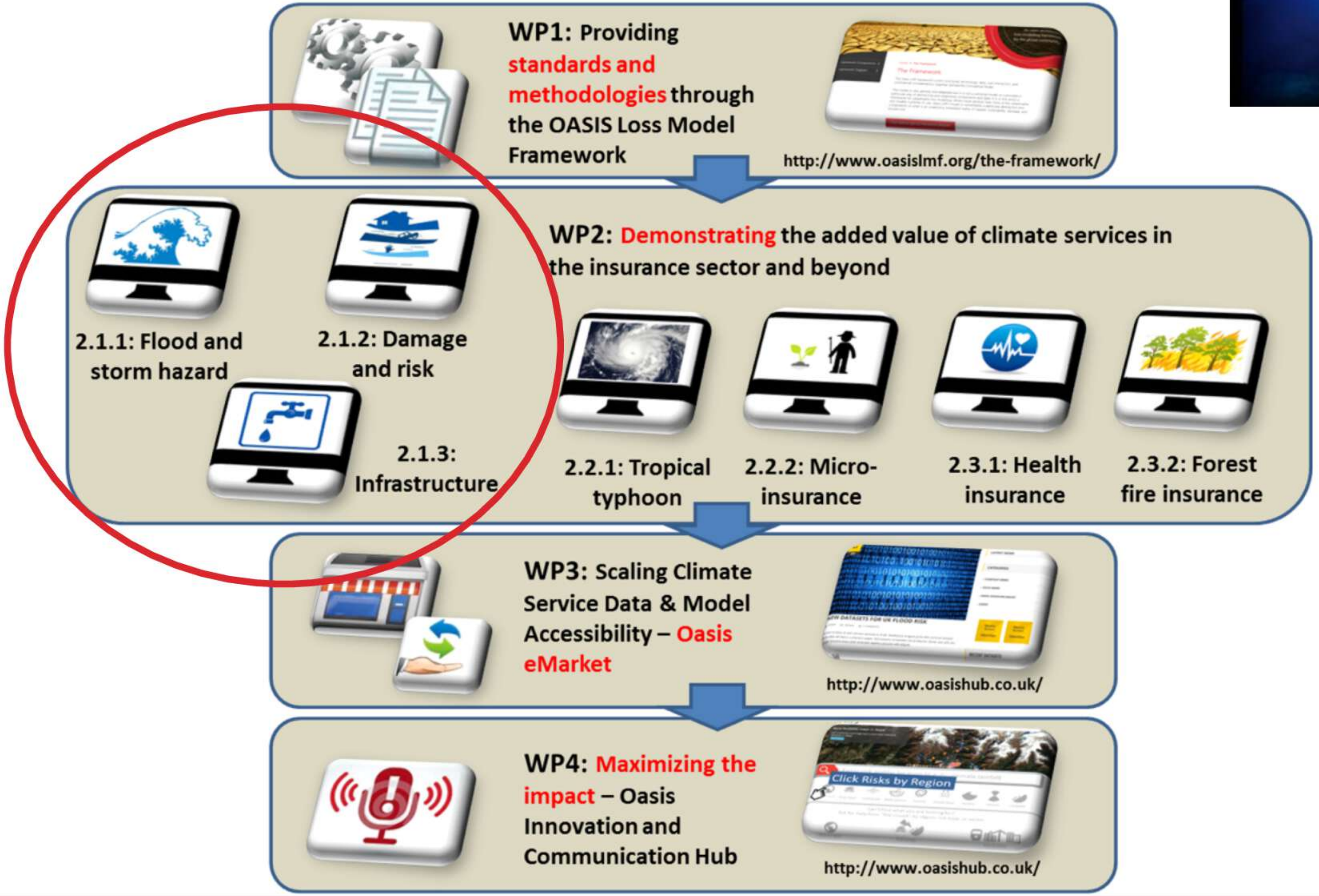
DTU

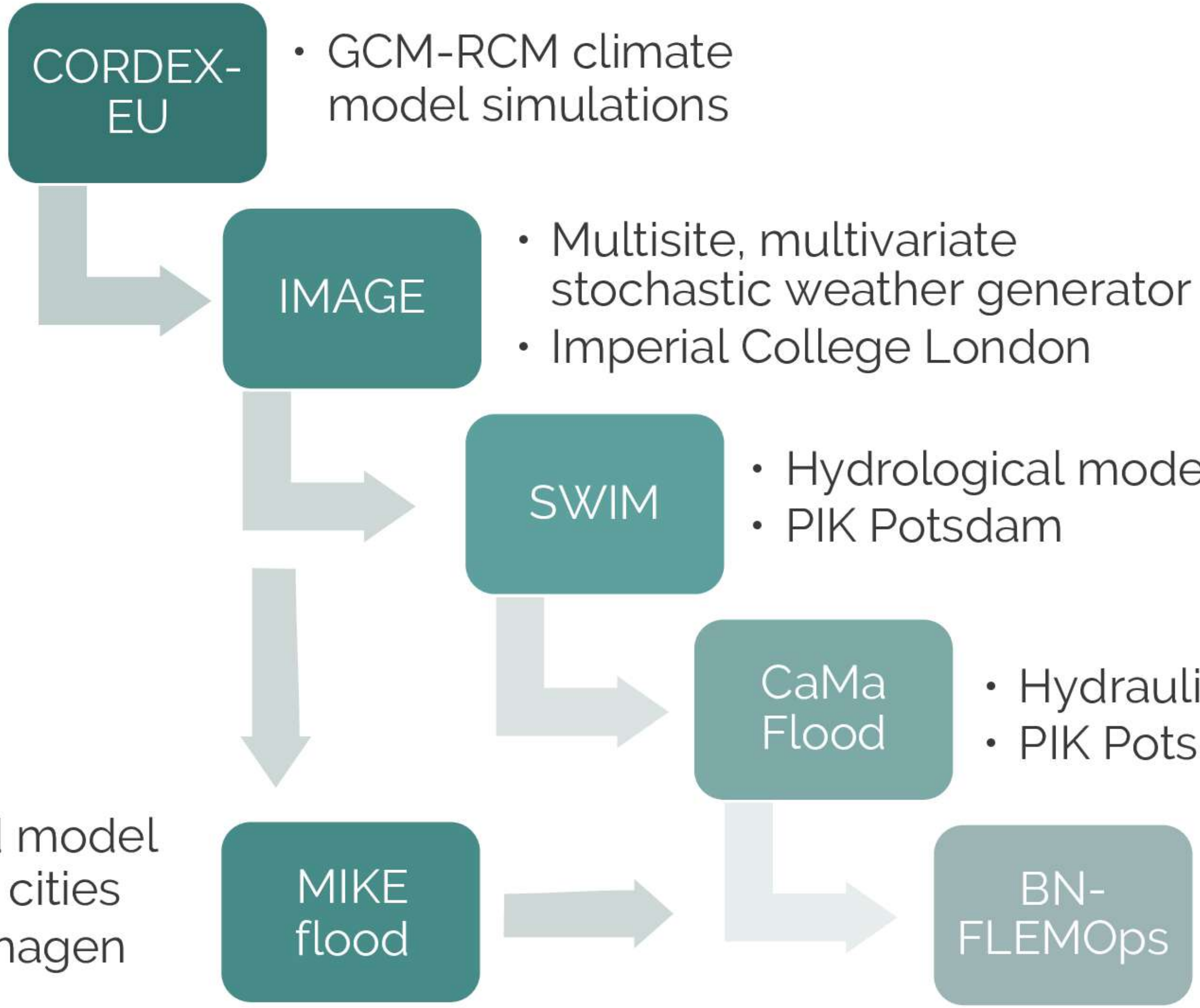
Martin Drews

This project has received funding from the European Commission’s, Horizon 2020 research and innovation programme under Grant Agreement number: 730381 — H2020_Insurance

H2020 Insurance – project background



Model chain



CORDEX-EU
- GCM-RCM climate model simulations

IMAGE
- Multisite, multivariate stochastic weather generator
- Imperial College London

SWIM
- Hydrological model
- PIK Potsdam

CaMa Flood
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Partners:

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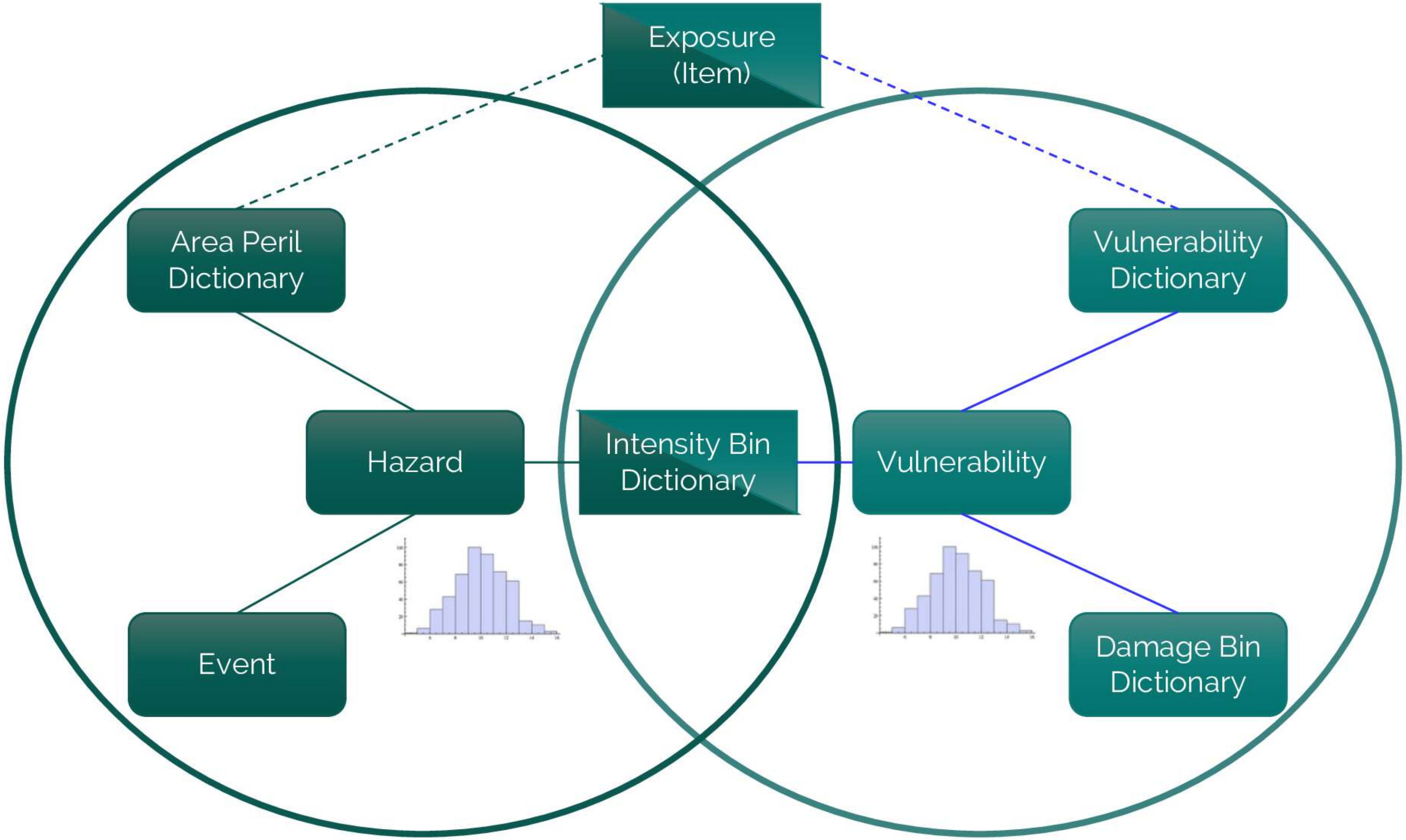
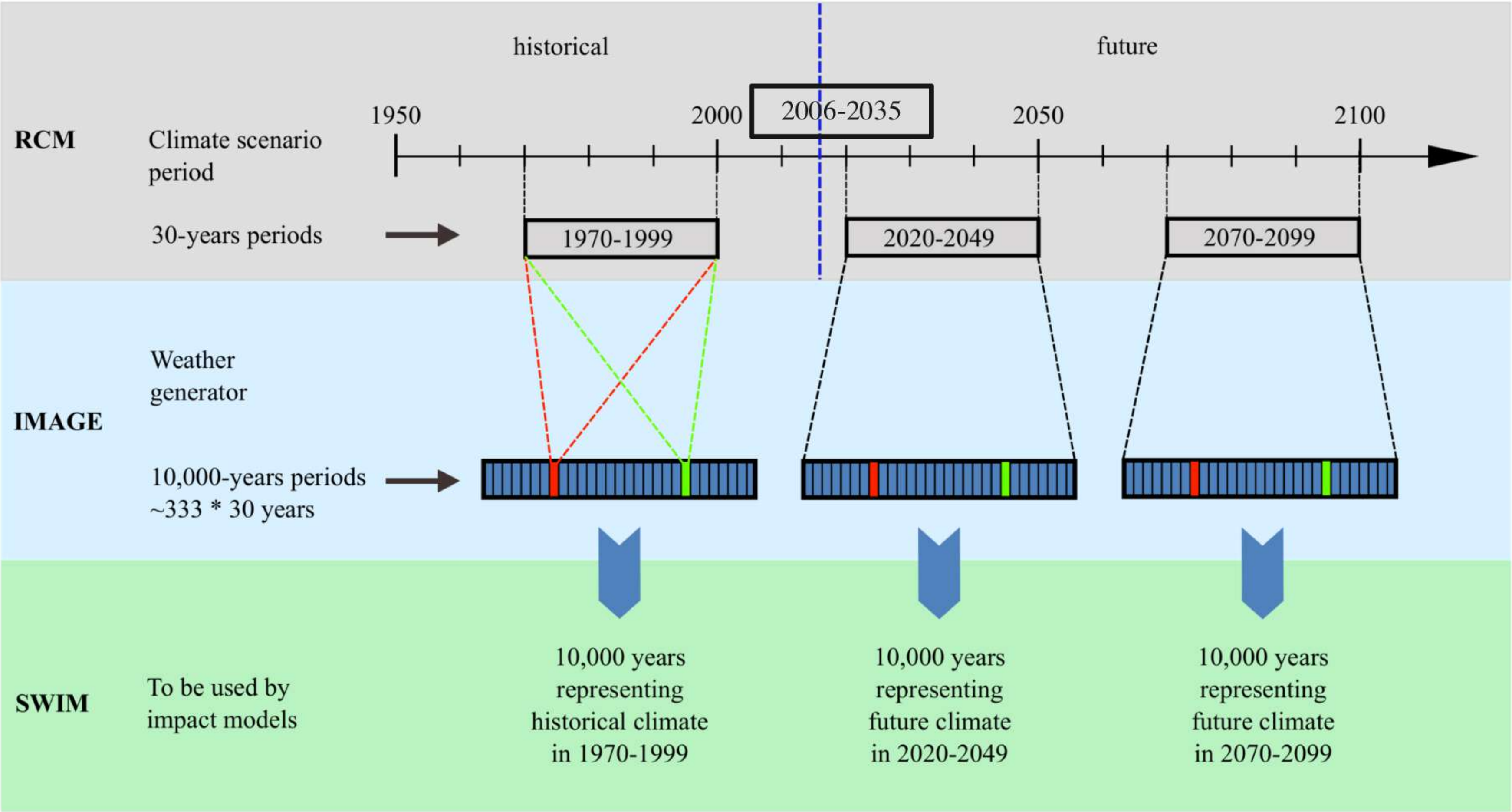
- Genillard & Co
- Pannon Pro
- Uni. Novi Sad
- Insurance sector

OASIS LMF enabled



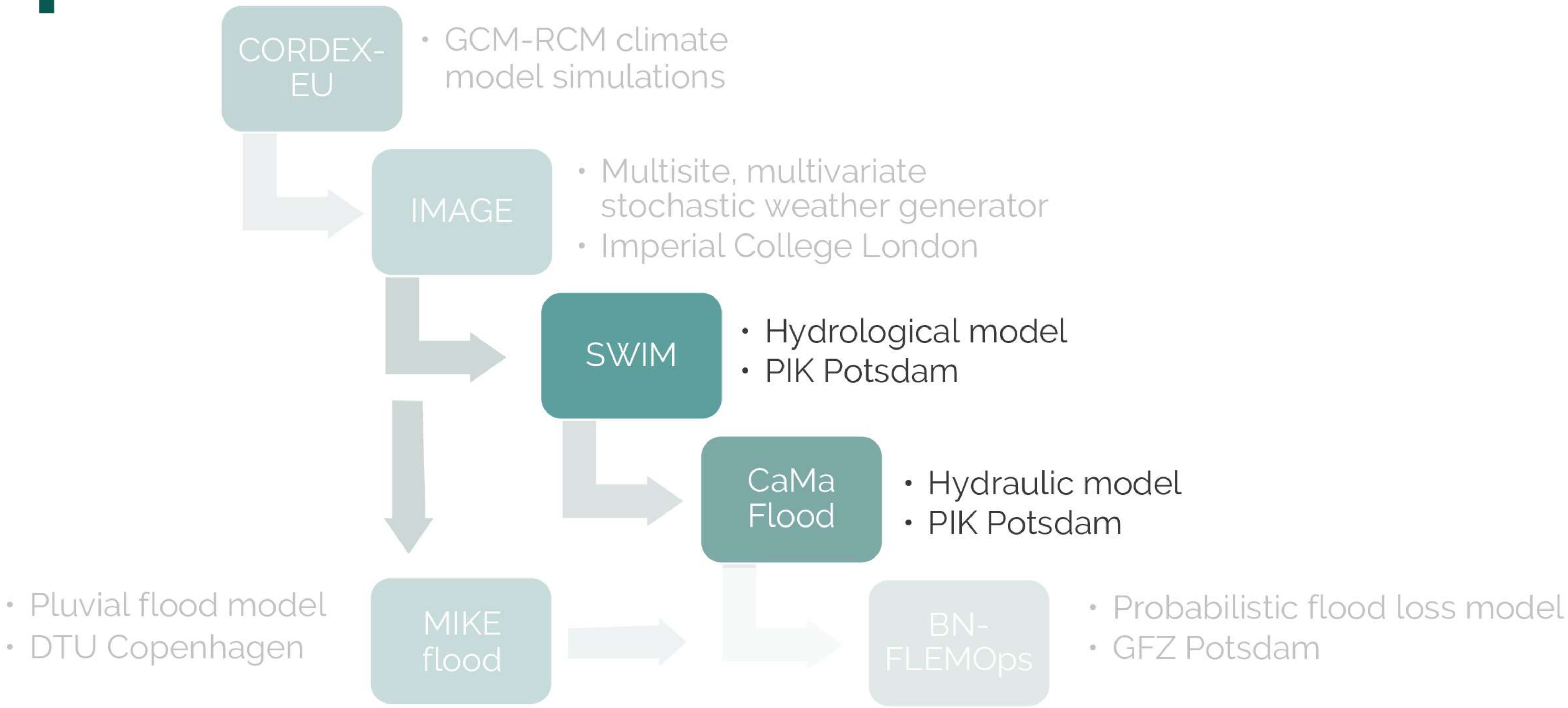
Generation of stochastic meteorological event sets

- 4 regional climate models (CORDEX-EU)
- 2 climate scenarios (RCP-4.5 & 8.5)
- Historical reference climate (1971-2000), current climate (2006-35) and two future periods (2020-49, 2070-99)



1. Fluvial flood hazard modelling

Model chain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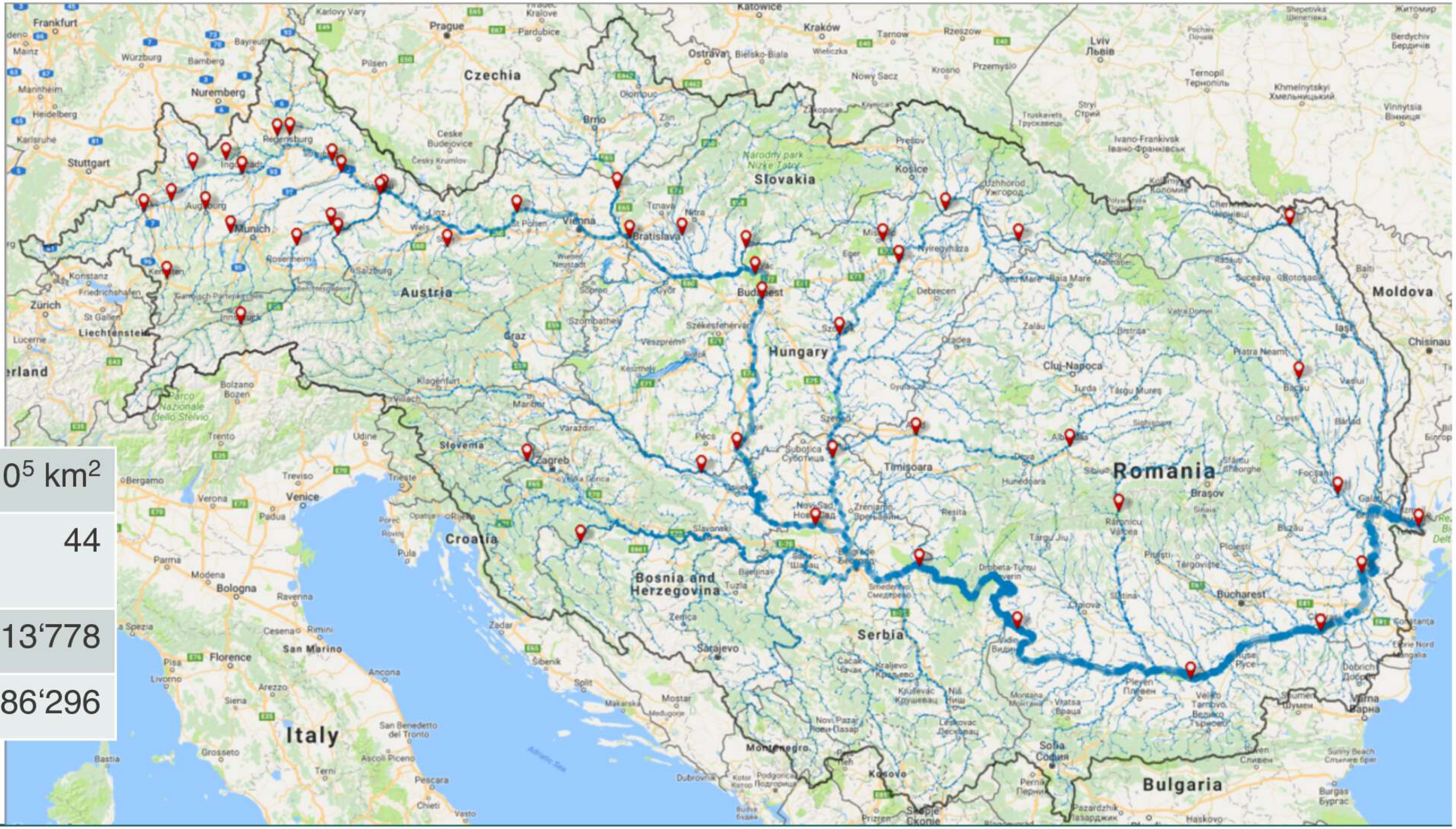
Model domain

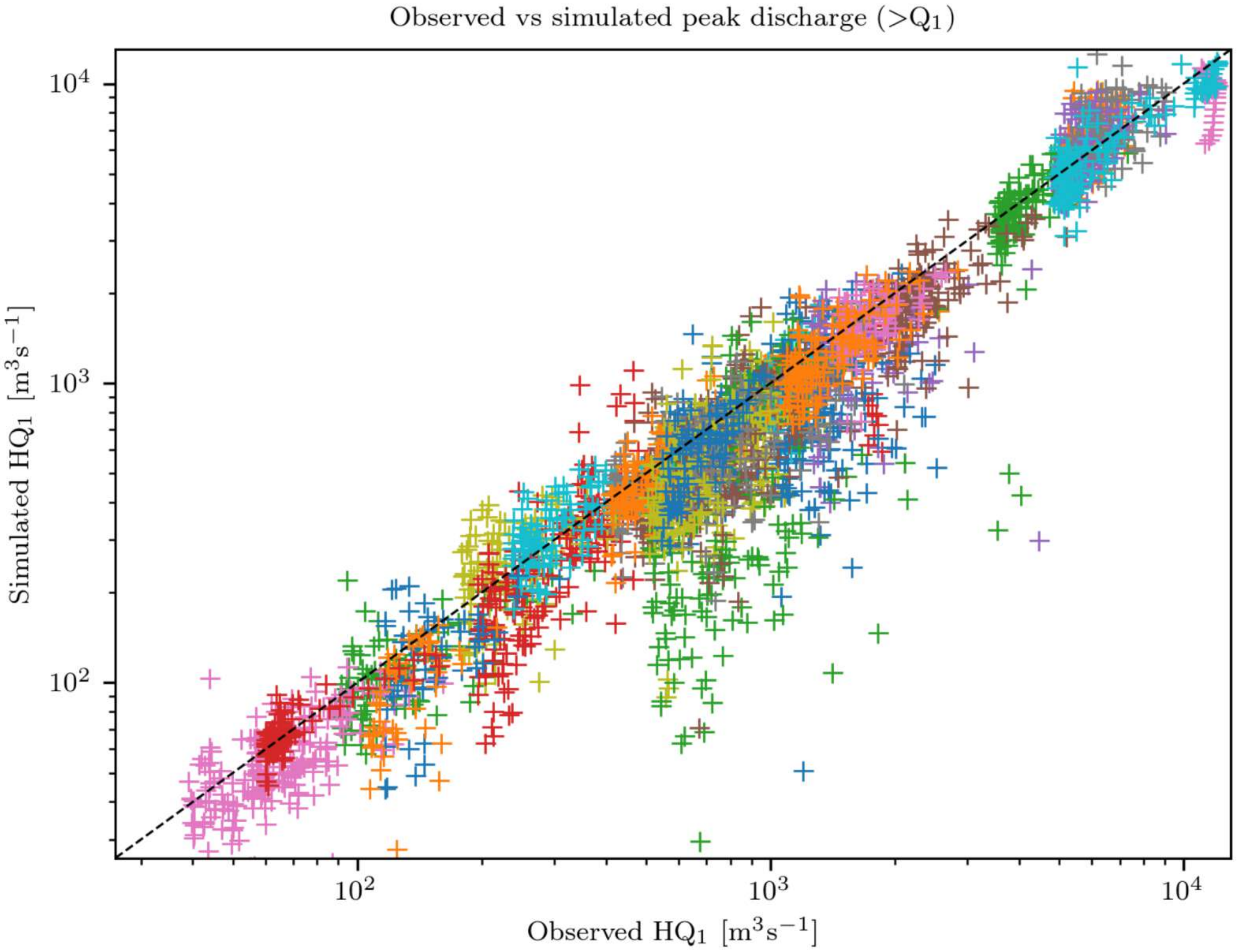
SWIM hydrological model



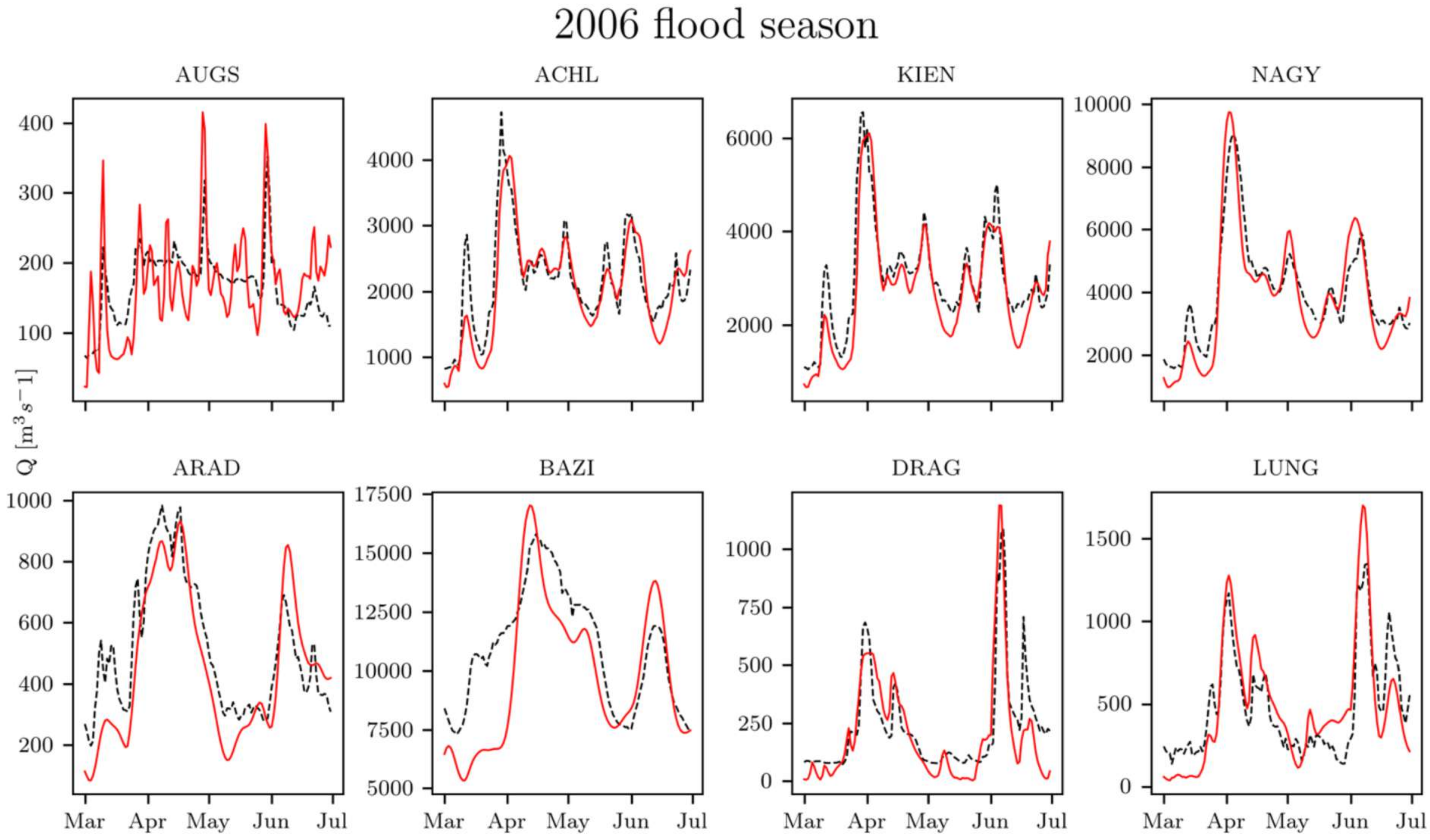
Area	$8x10^5$ km^2
Validation stations	44
Subbasins	13‘778
Hydrotopes	186‘296

Model calibration and validation

- Observations at 44 gauging stations
- Multi-objective, evolutionary Pareto optimisation
- Variable observation data availability
- Historic events
- Catchment ET compared to MODIS

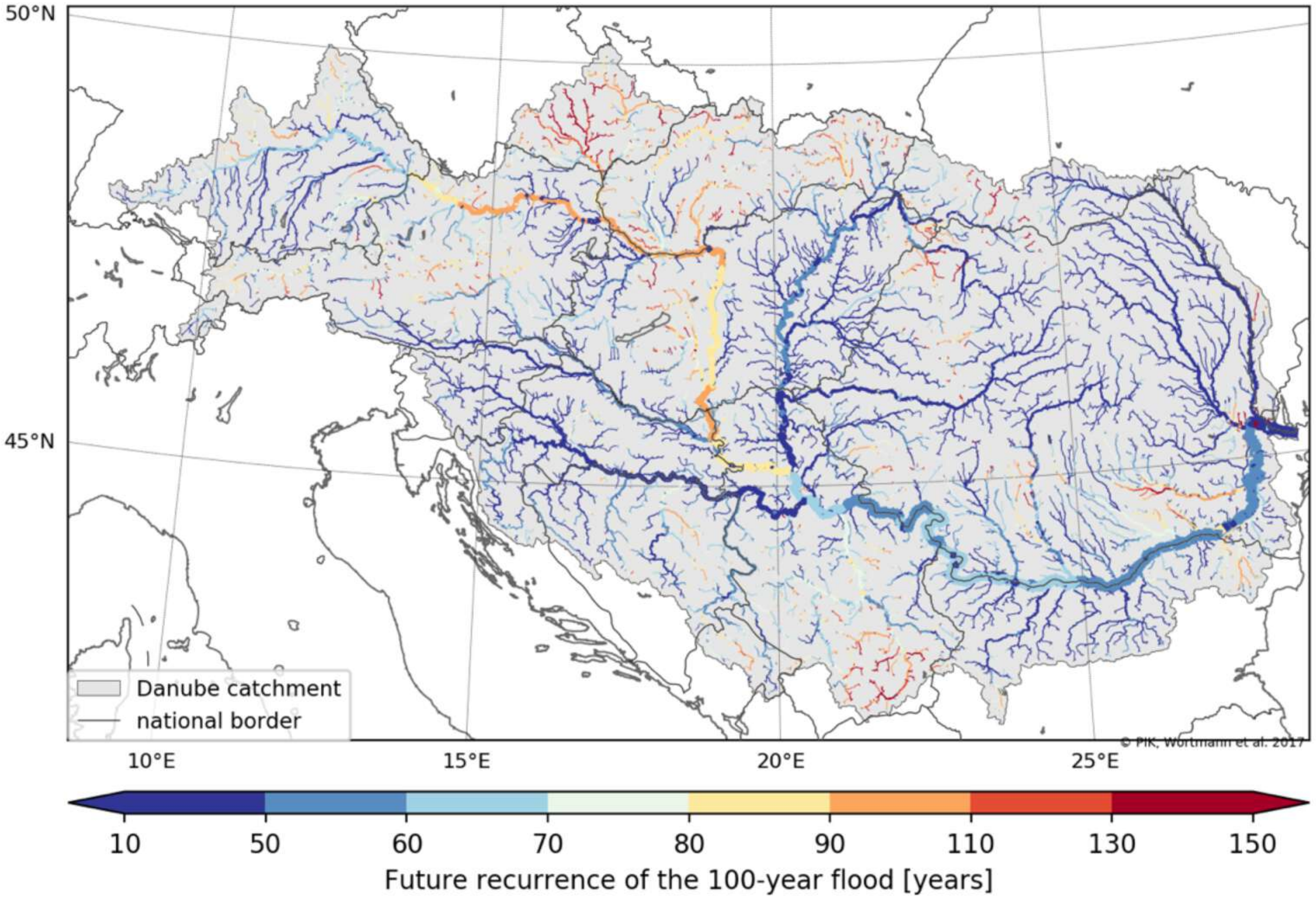


Model validation

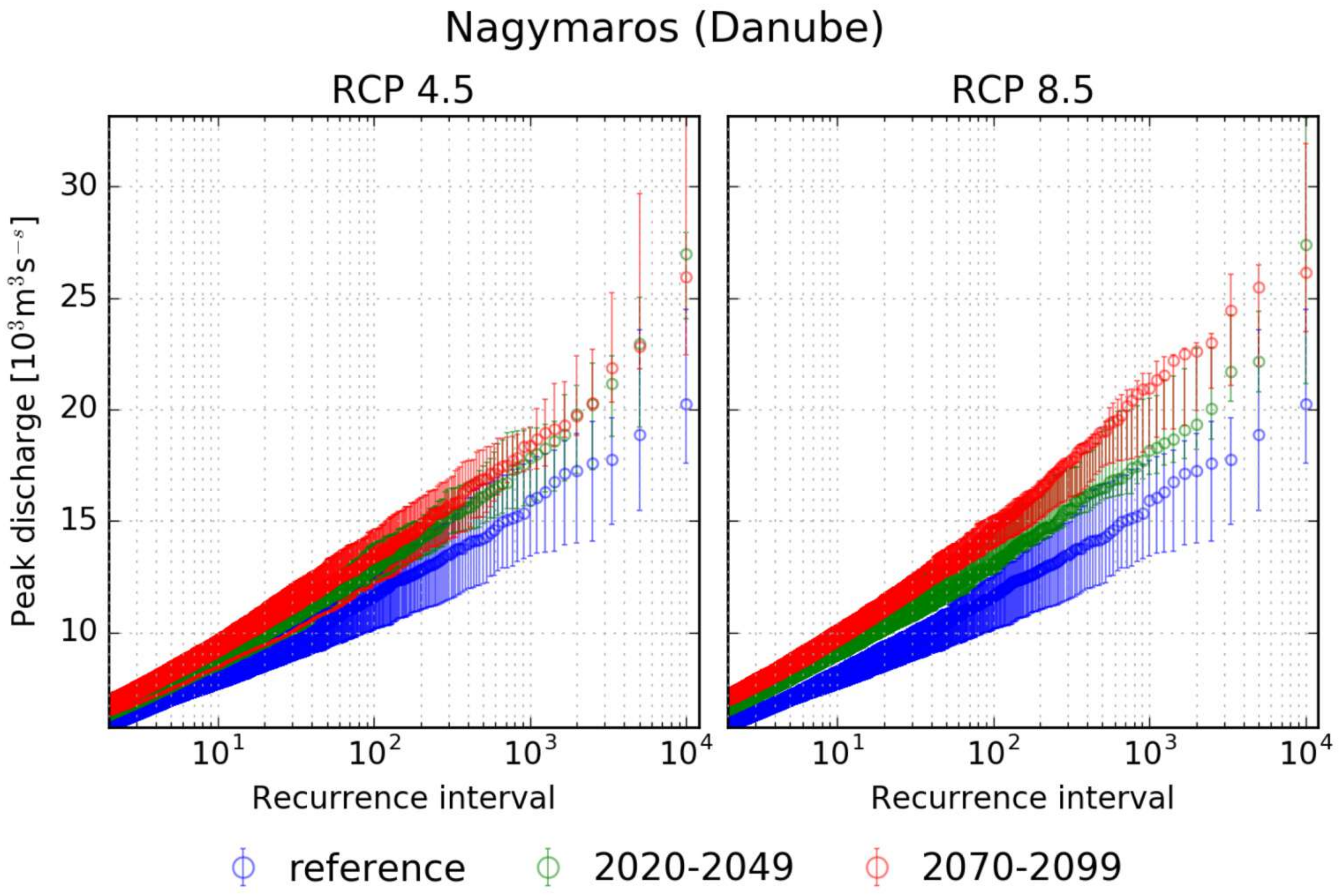


Changes from reference period until 2006-2035

Future reoccurrence of the 100-year flood

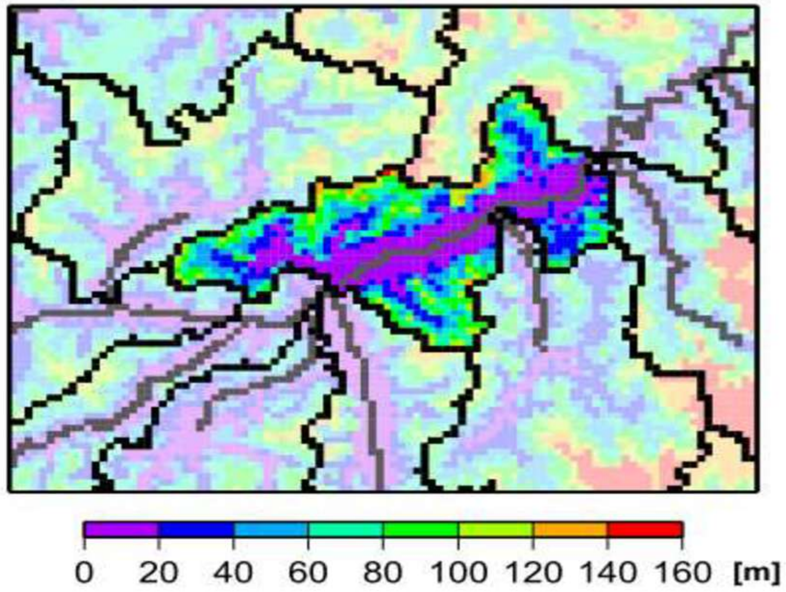


Future peak discharge
Budapest, Hungary

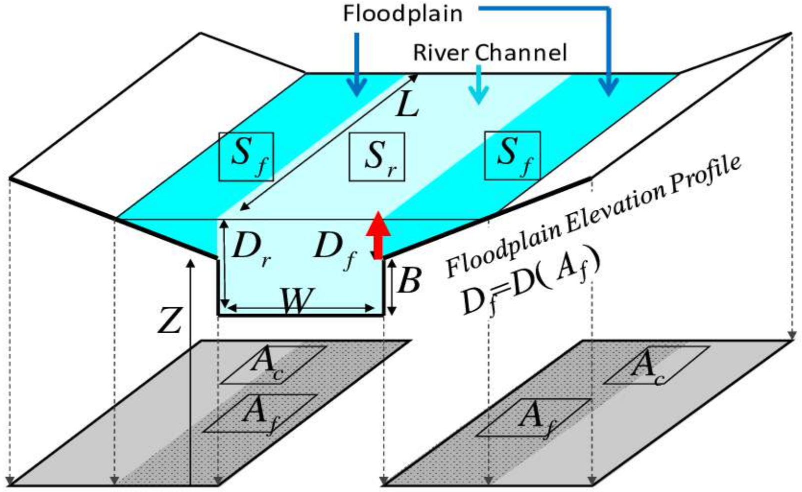


CaMa Flood hydrodynamic modelling

- Global semi-distributed hydrodynamic model
- Here adapted to predefined, high-resolution subbasins of the hydrological model
- Efficient computation at larger domains and stochastic event sets
- Driven by daily runoff
- Shallow water momentum equation approximated to a local inertial form
- 1.5D results are imposed on a high-res DEM
- Considerable preprocessing of elevation data necessary to fit them to assumptions



DEM’s height above river channel (FLDDIF)

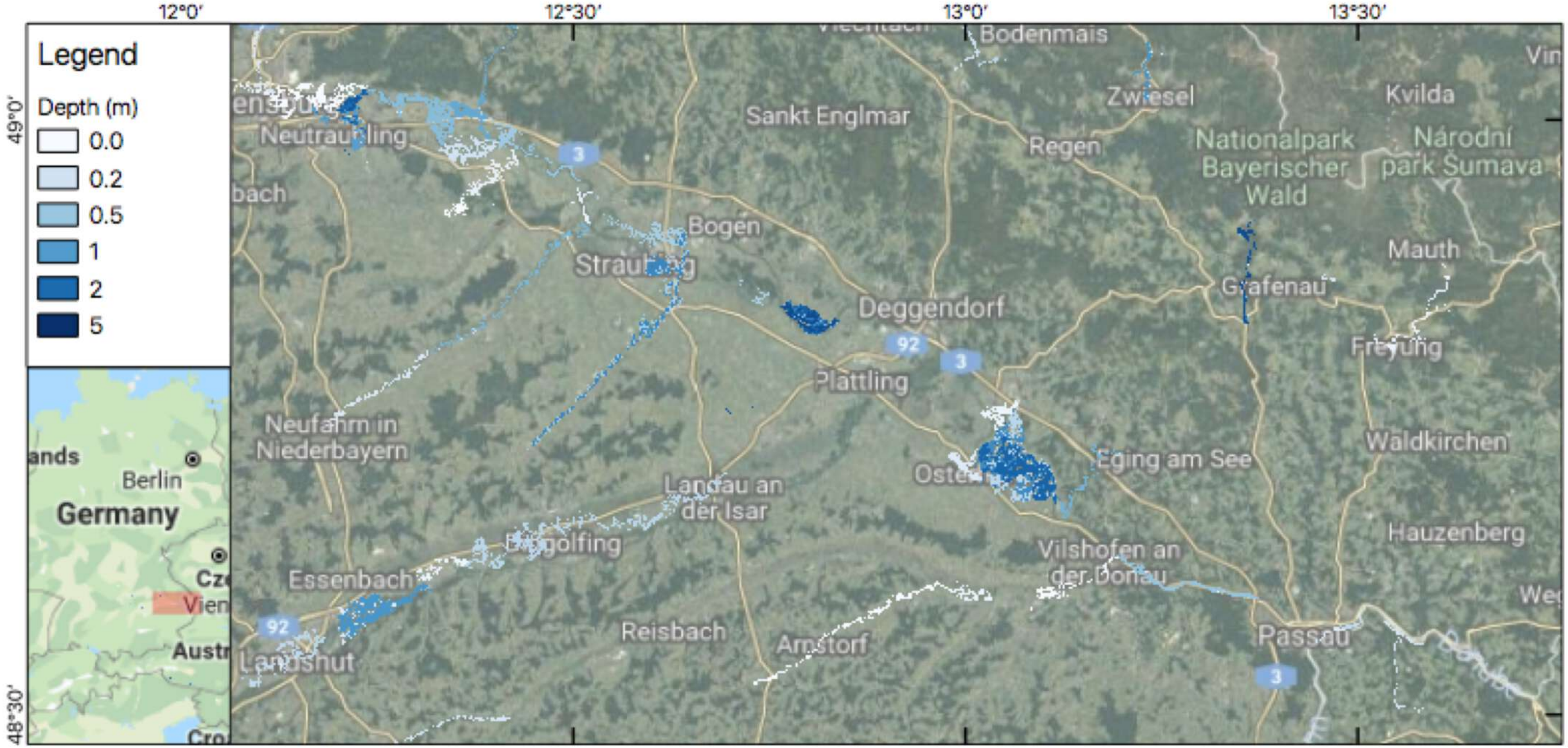


Water depth above river channel (FLDDPH)

Yamazaki et al., 2012; 2014

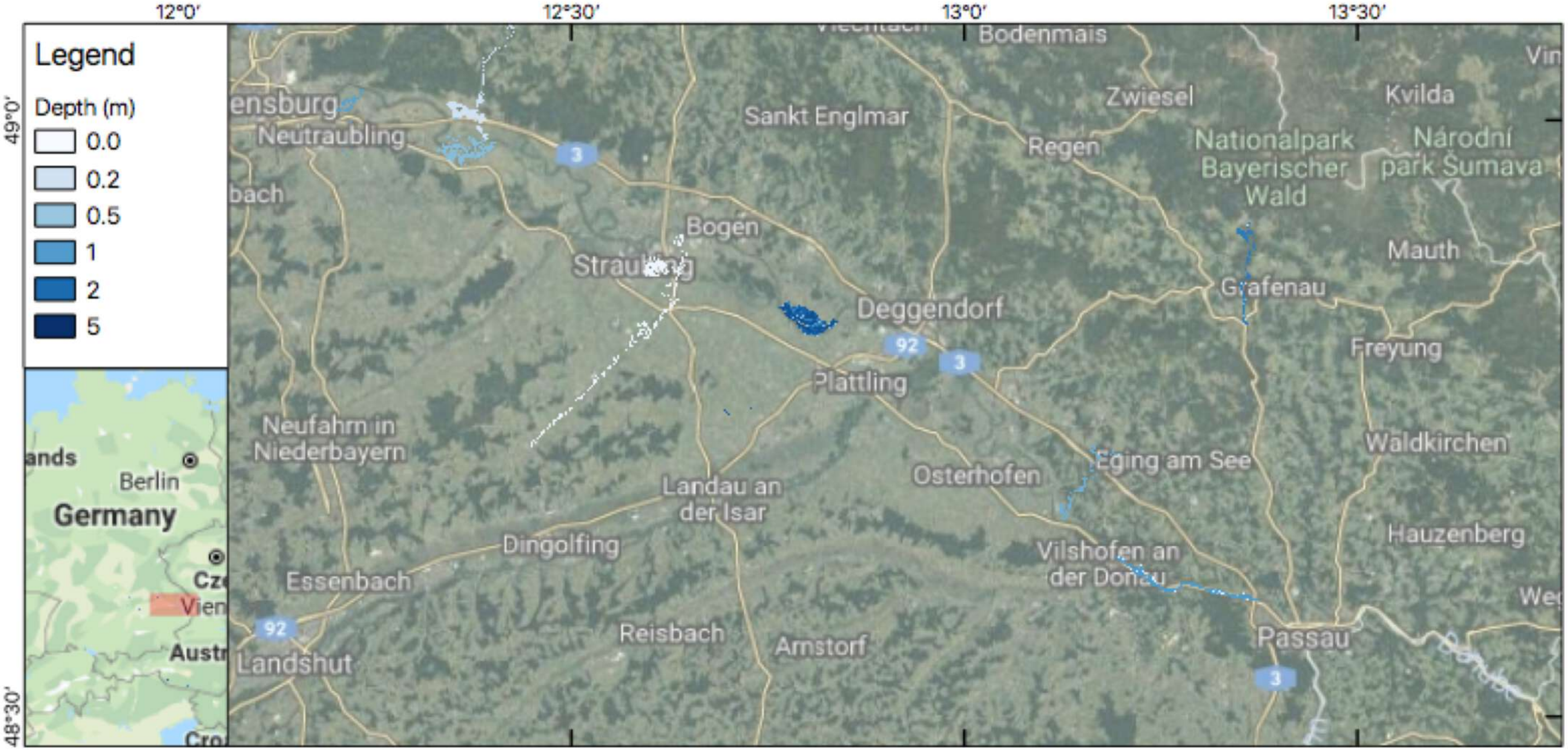
Simulation without levees

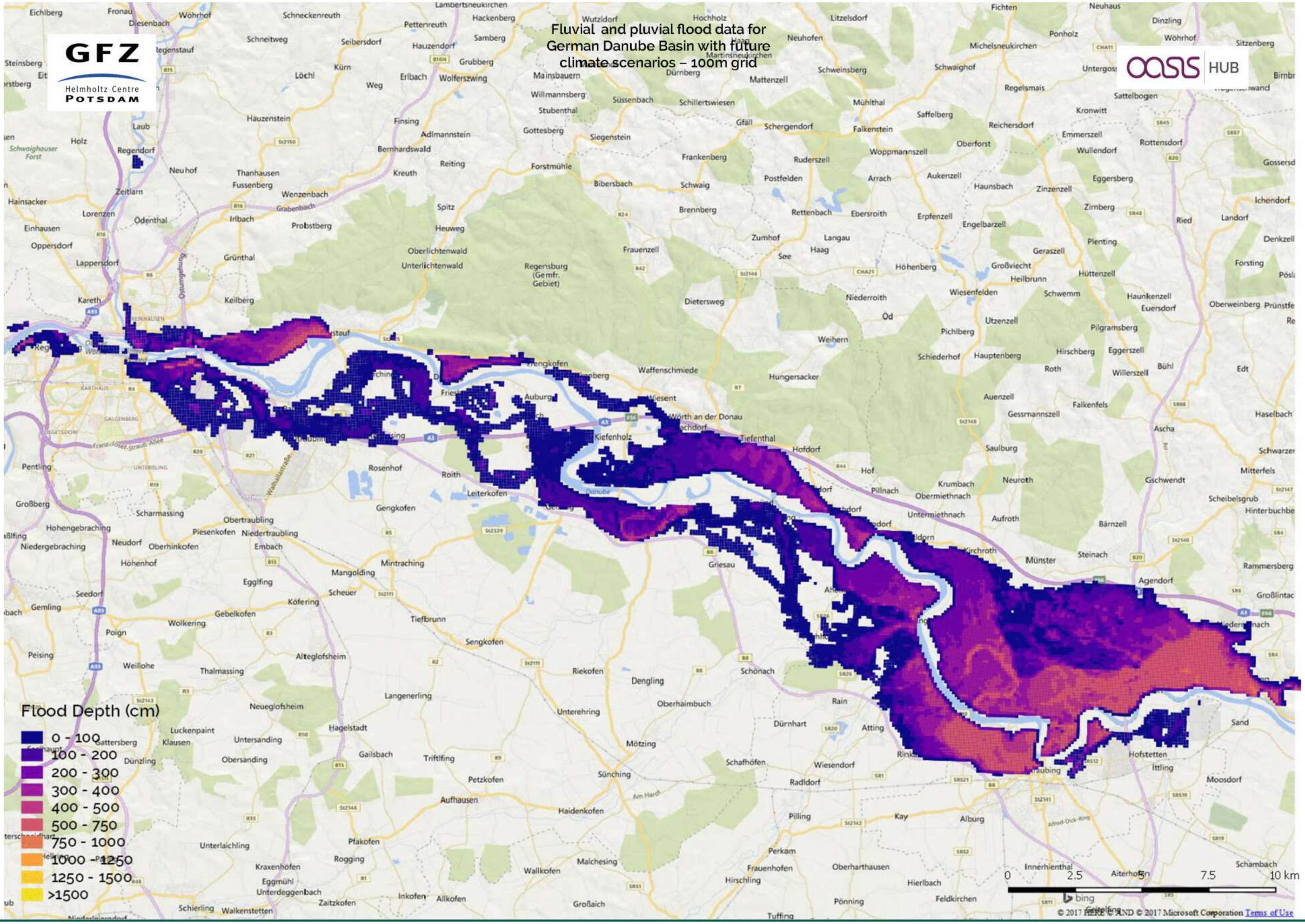
Bavaria, Germany, 2006



Simulation with levees

Bavaria, Germany, 2006

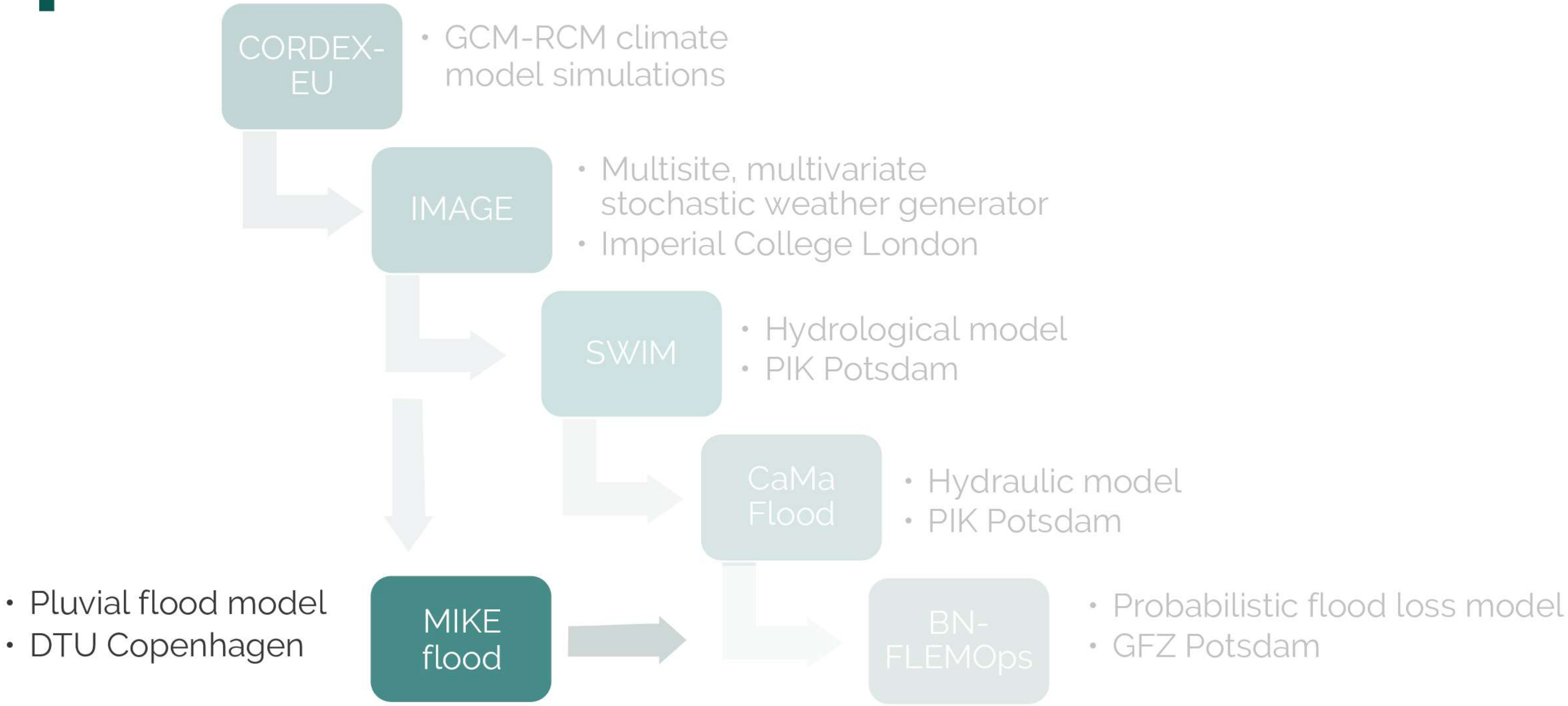




Schröter, K. *et al.* Flood inundation depth maps Danube catchment. (2017). doi:10.5880/GFZ.5.4.2017.003

2. Pluvial flood hazard modelling

Model chain



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Pluvial hazard model - methodology

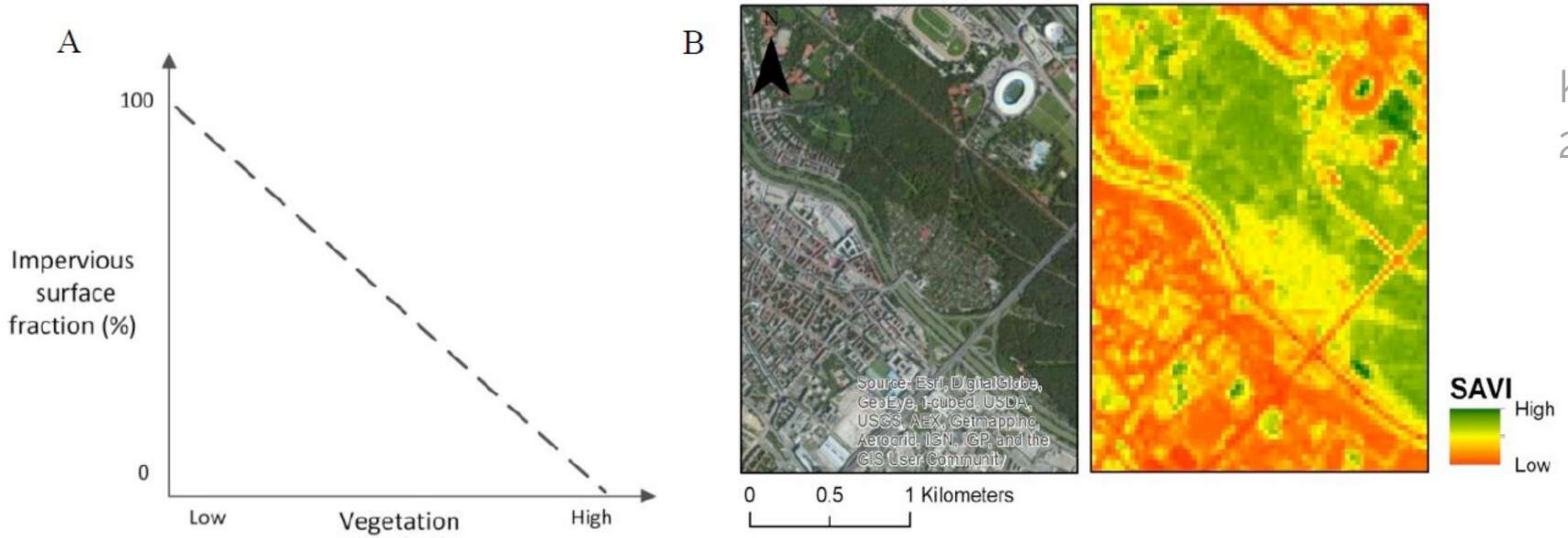
- 2D urban-scale flood model (MIKE by DHI)
- EU-DEM (25-m) Digital Elevation Model (or finer)
- Urban land cover based on high resolution remote sensing estimates (e.g. Sentinel-2)
- Infiltration based on international soil data base
- Conceptual simulation of urban drainage system

- Rainfall events modelled by "Chicago" design storms (IDF)
- Climate projections based on output from Climate Module

2D Model setup

- MIKE flood model
- Inputs: precipitation, DEM, infiltration, land cover
- Conceptual urban drainage system
- Urban surface from remote sensing

Urban surface from remote sensing



Kaspersen et al. 2017

	France	Austria	Denmark	France
	Strasbourg	Vienna	Odense	Nice
1984	41.4 %	42.2 %	29.1 %	38.1 %
2014	53.0 %	53.5 %	36.6 %	44.7 %
Change	11.6 %	11.3 %	7.5 %	6.6 %

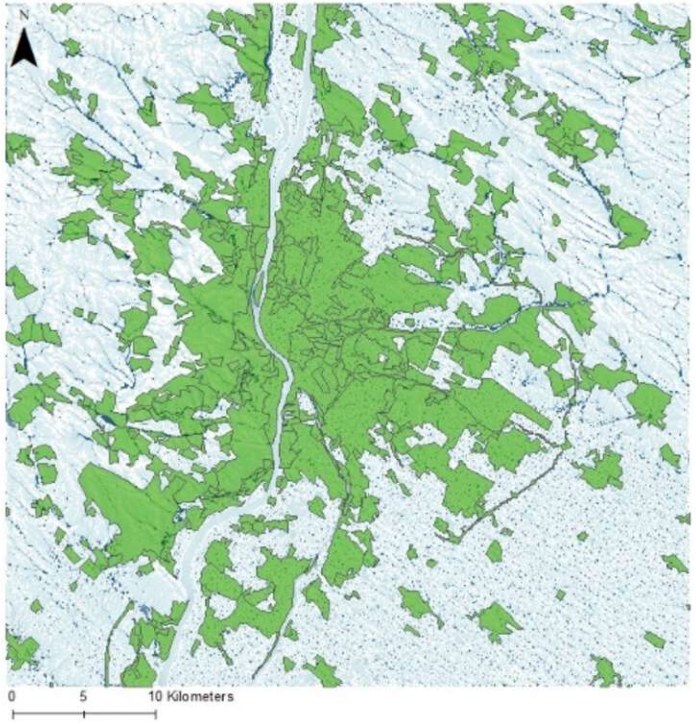
Table 1: Impervious surface fractions and changes therein during 1984-2014 (2013-2015). Imperviousness is calculated for the area covered by the urban classes in the CORINE 2012 Land Cover Inventory (CORINE, 2012).

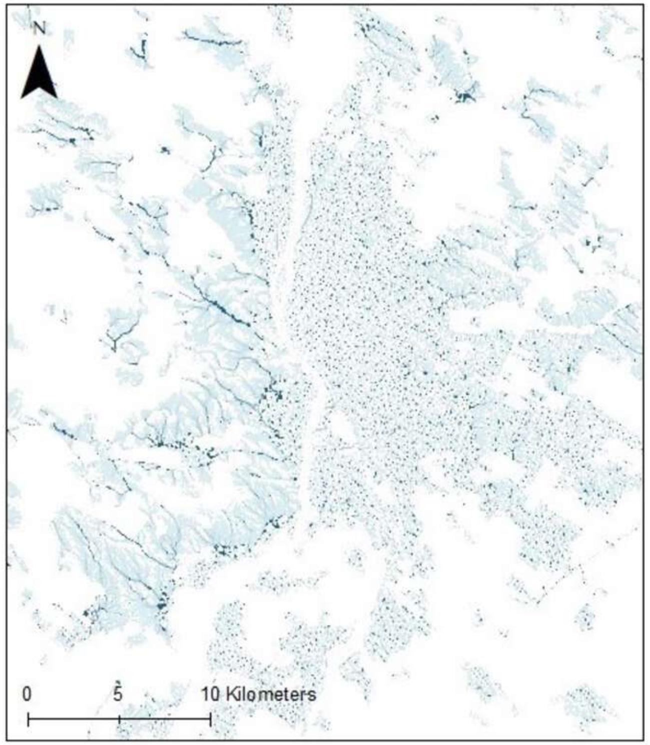
Validation of Budapest model

- Historical rain: 23 May 2017
- Current climate: RP2, RP10, RP20, RP50, RP100

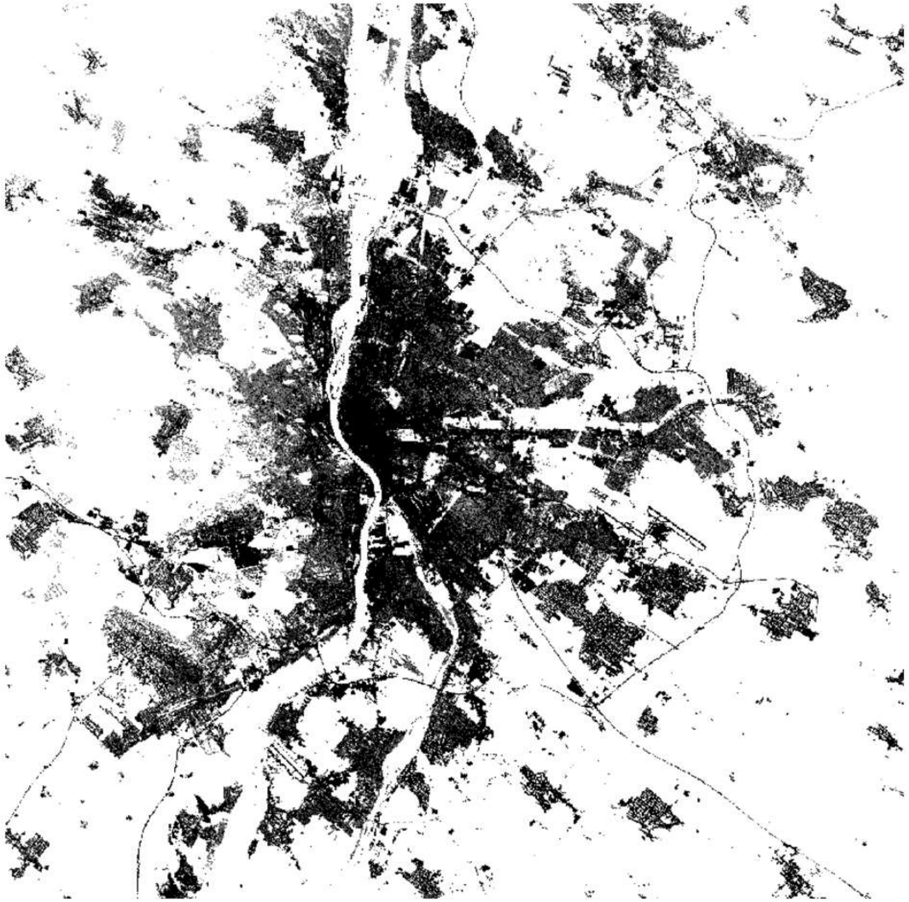
- Validation carried out in collaboration with Tibor Racz from Budapest Sewage Works
- Results are available from Oasis Hub

Budapest model domain





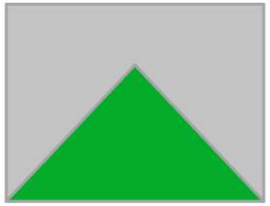
Infiltration from pervious surfaces



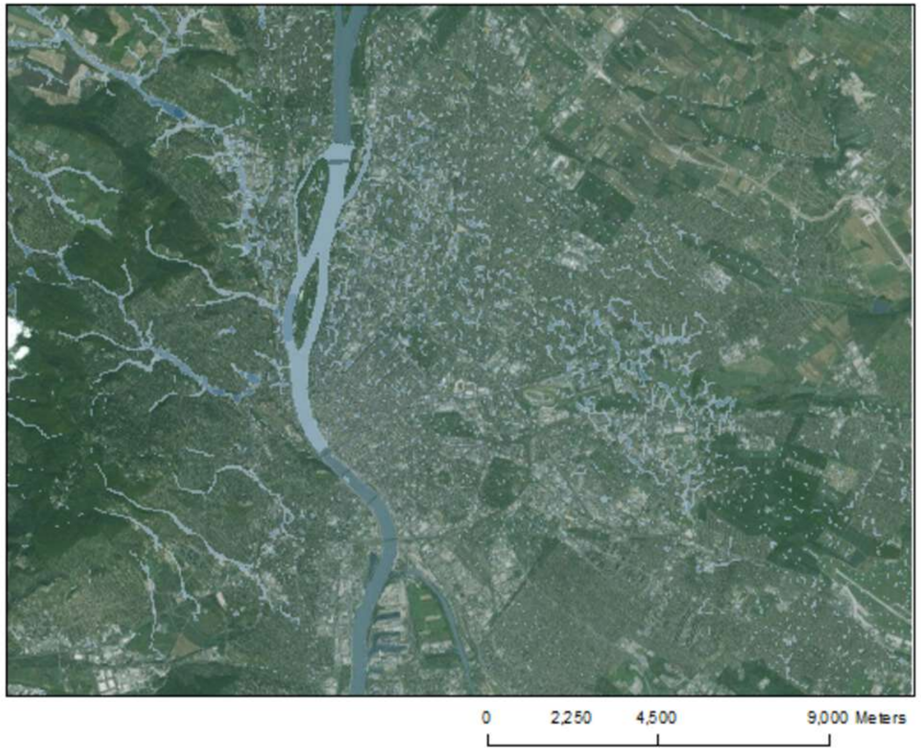
- The infiltration is modelled as constant in time and varying in space
- The infiltration capacity in each pixel depends on the soil characteristics, the slope and the impervious surface fraction

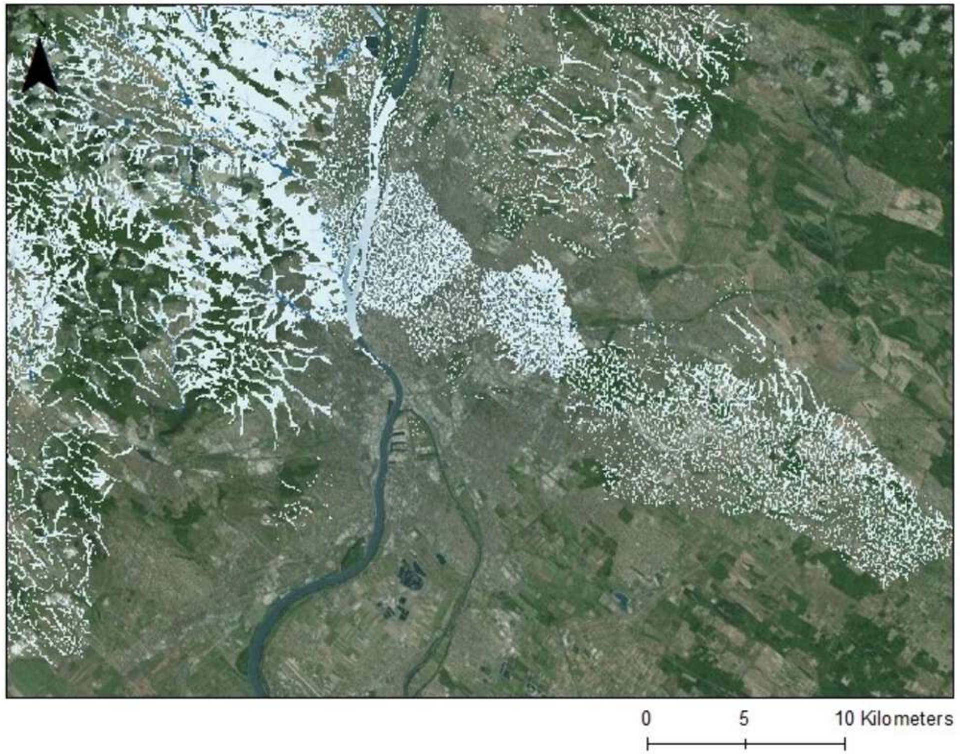
Conceptual drainage system model

- Design criteria in Budapest:
  - 10-100-year rainfall event (main pipes)
  - 1-4-year rainfall event (smaller pipes)
  - Issues with man-holes being blocked may reduce capacity
- Calibrating for a 2-year rainfall event (low end)
  - Varying the local sewer capacities from 0 to 3000 mm/day (125 mm/hour/pixel)
  - Varies with the fraction of imperviousness
- Surface water cannot flow into the river due to the flood defences – only via the drainage system



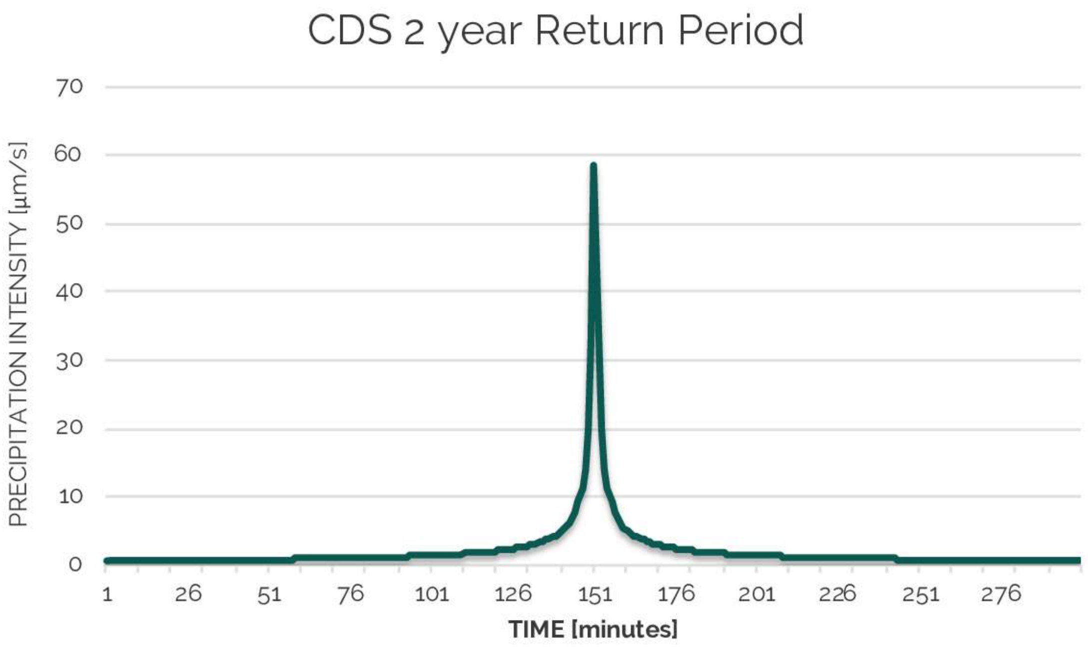
Cloudburst in Budapest 23rd May 2017

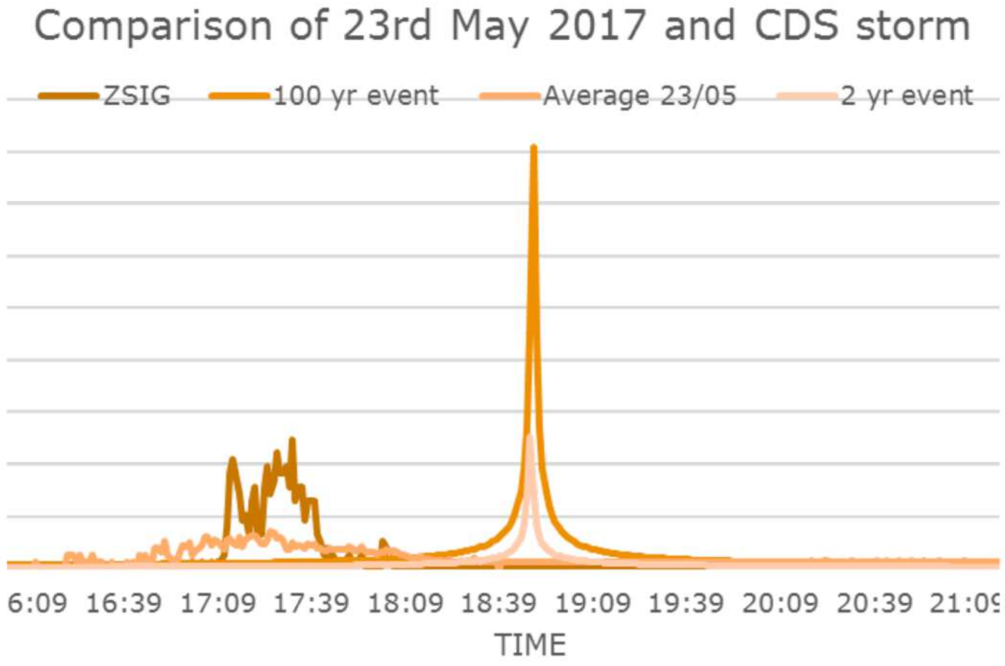




Limited flooding in the city centre

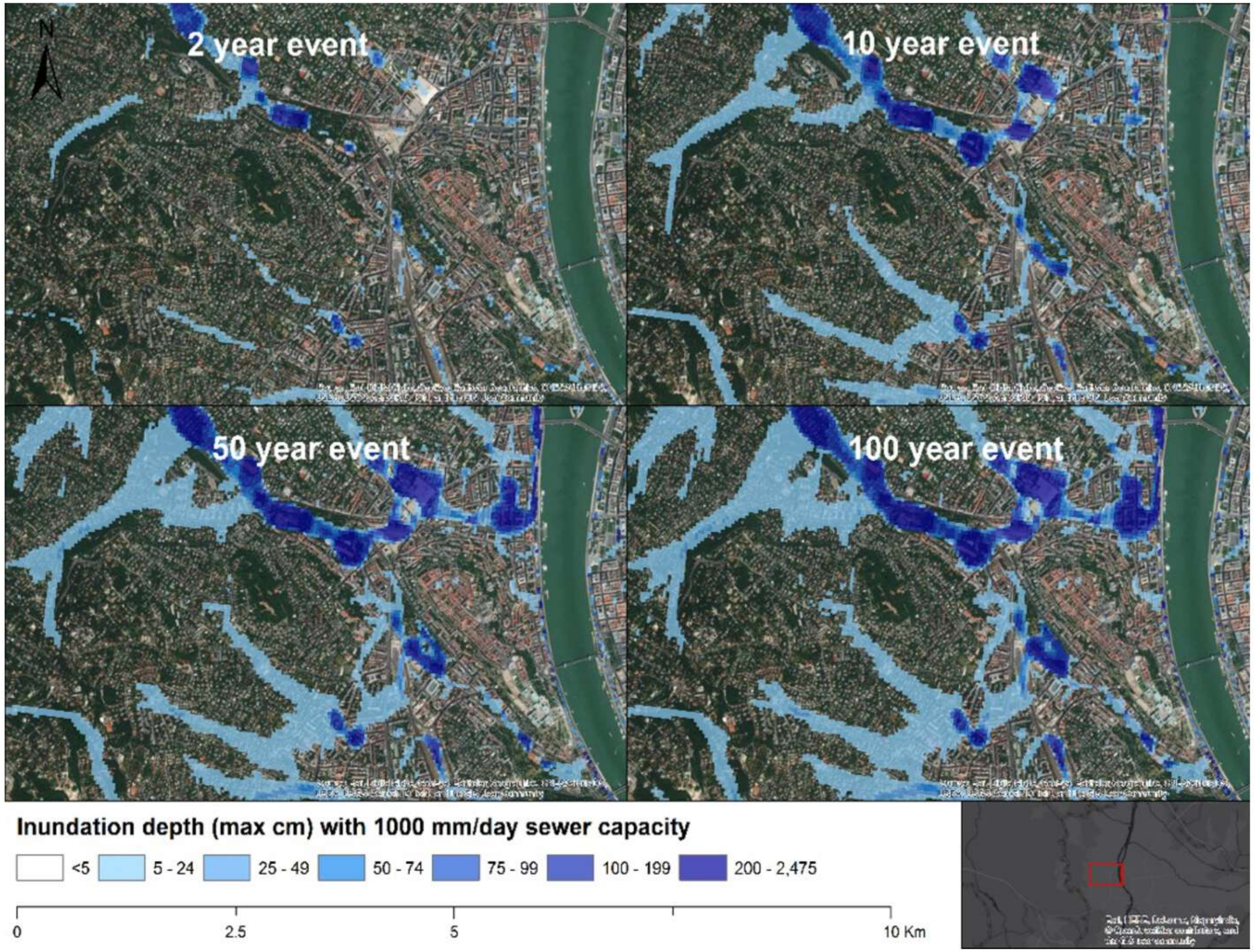
Cloudburst in Budapest 23rd May 2017



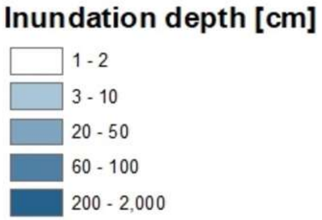


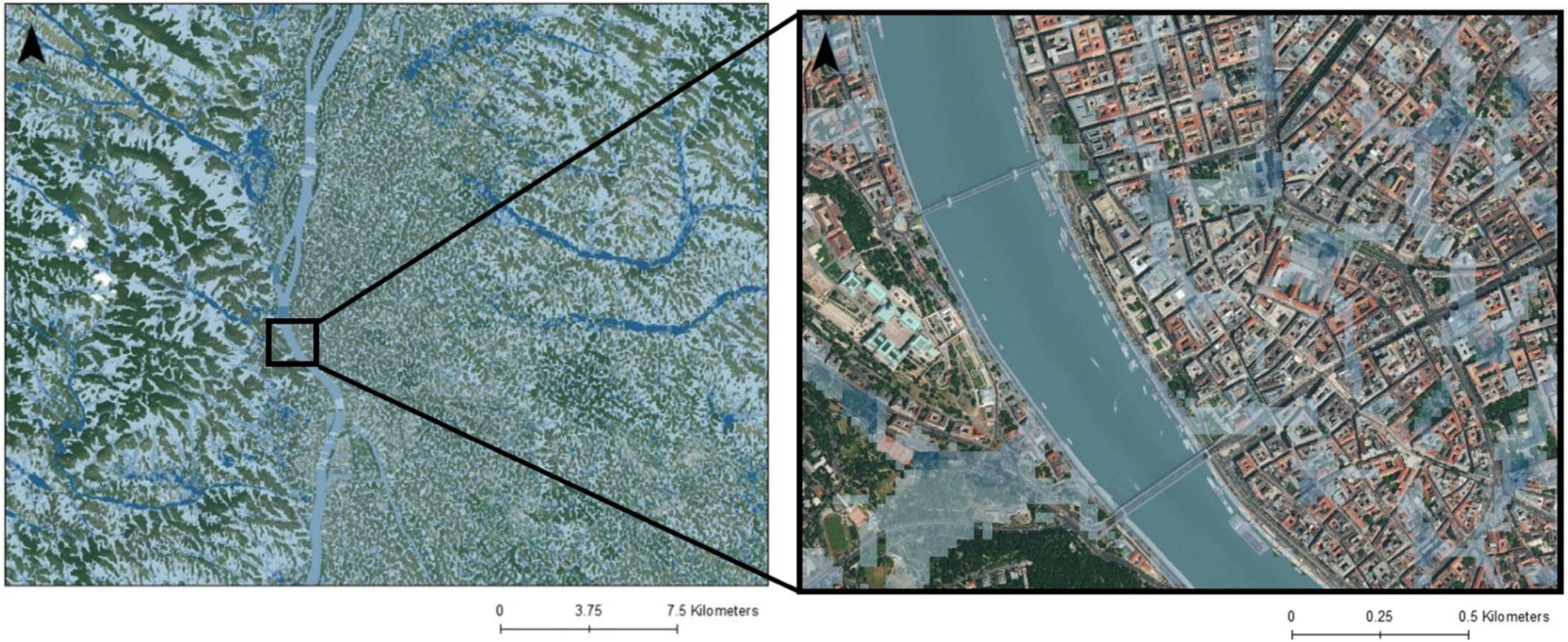
The station ZSIG measured the highest amount of rainfall (73mm) – which is more than a 2-yr event (43mm), but less than a 100yr event (123mm).

Simulations for Budapest (present climate)



Details: 100-year event





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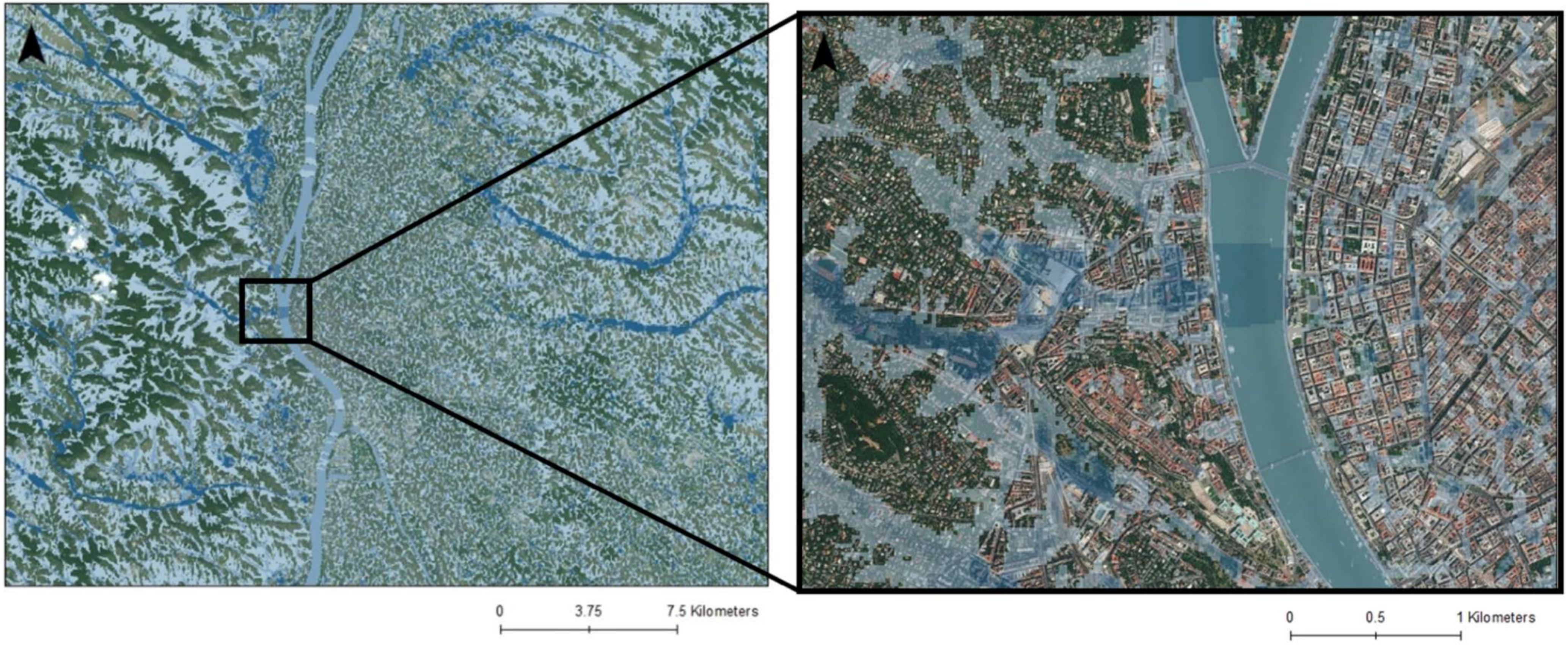

3. Fluvial Flood Loss Model

Overview

CORDEX-EU
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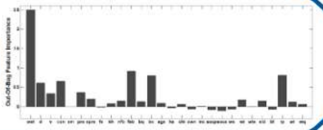
- Insurance sector

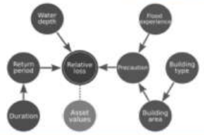
Approach to Model development

1 Empirical data — Post flood event survey data (4368)

2 Variable importance — Relevant variables for flood loss prediction



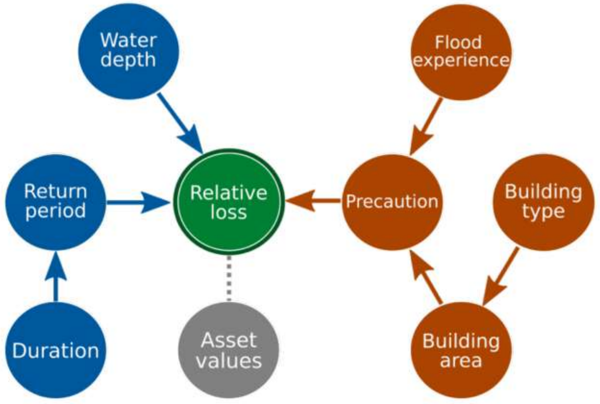
3 Bayesian network — Structure from data and expert knowledge



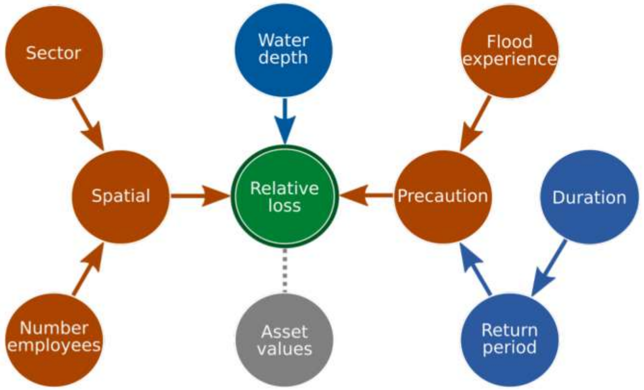
4 Scale transfer — European proxy data for model application

OASIS lmf implementation

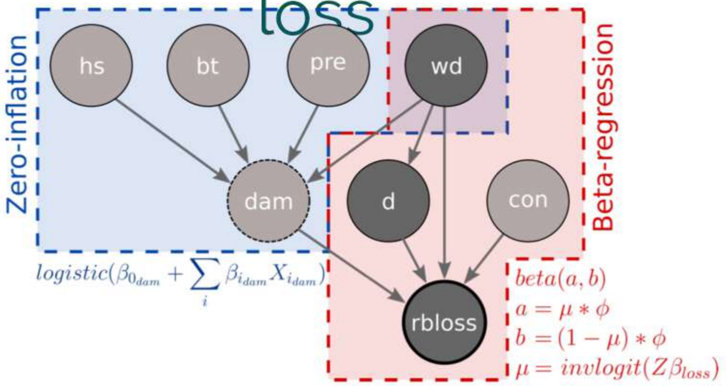
Residential fluvial flood loss



Commercial fluvial flood loss



Residential pluvial flood loss



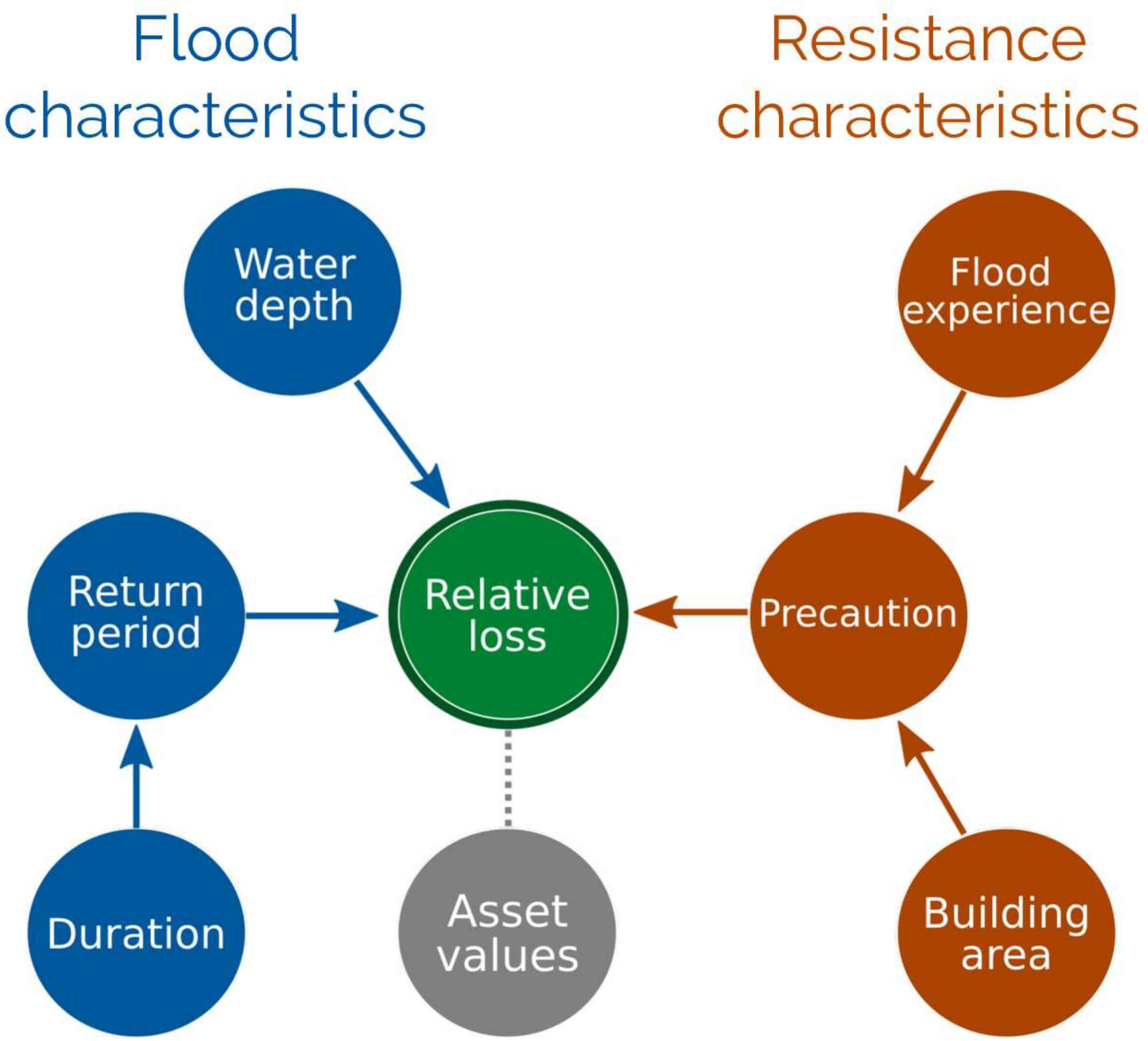
OASIS LOSS MODELLING FRAMEWORK

Model features & structure

BN-FLEMOps

The **B**ayesian **N**etwork – **F**lood **L**oss **E**stimation **Mo**del for the **p**rivate **s**ector

- Multi-variable
- Probabilistic
- For the private sector (buildings)
- Transferable in location and scale
- Predictions also with incomplete data



Probabilistic loss estimation

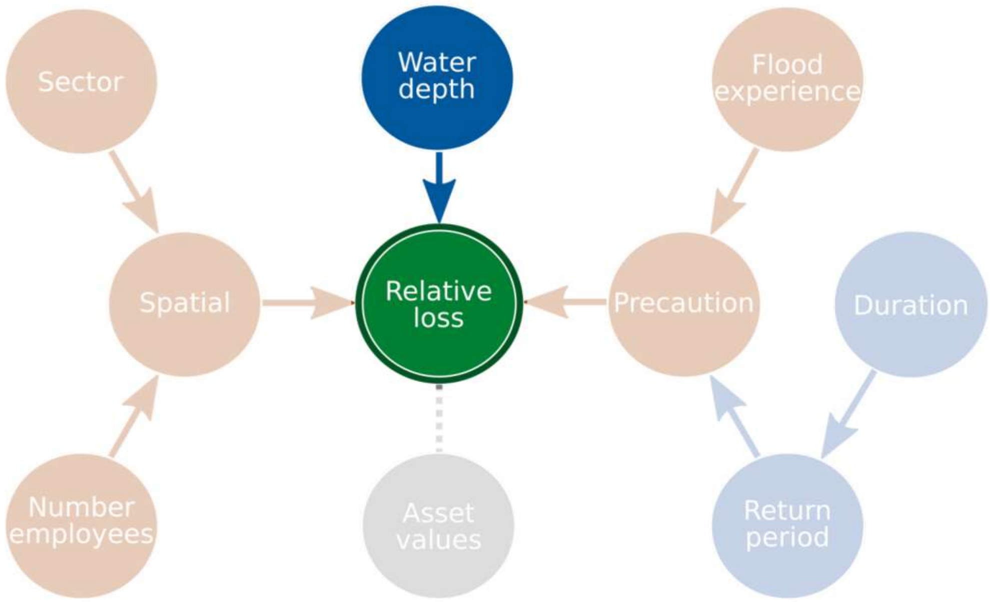
Inference from observed values

$$P(X_i, \ldots, X_n) = \prod_{i=1}^{n} P(X_i | \text{parents}(X_i))$$

Water depth → **Relative loss**

class	P(wd)
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	0.0
7	1.0
8	0.0
9	0.0
10	0.0

class	P(wd, rloss)
1	0.001
2	0.005
3	0.013
4	0.022
5	0.034
6	0.156
7	0.683
8	0.051
9	0.025
10	0.010



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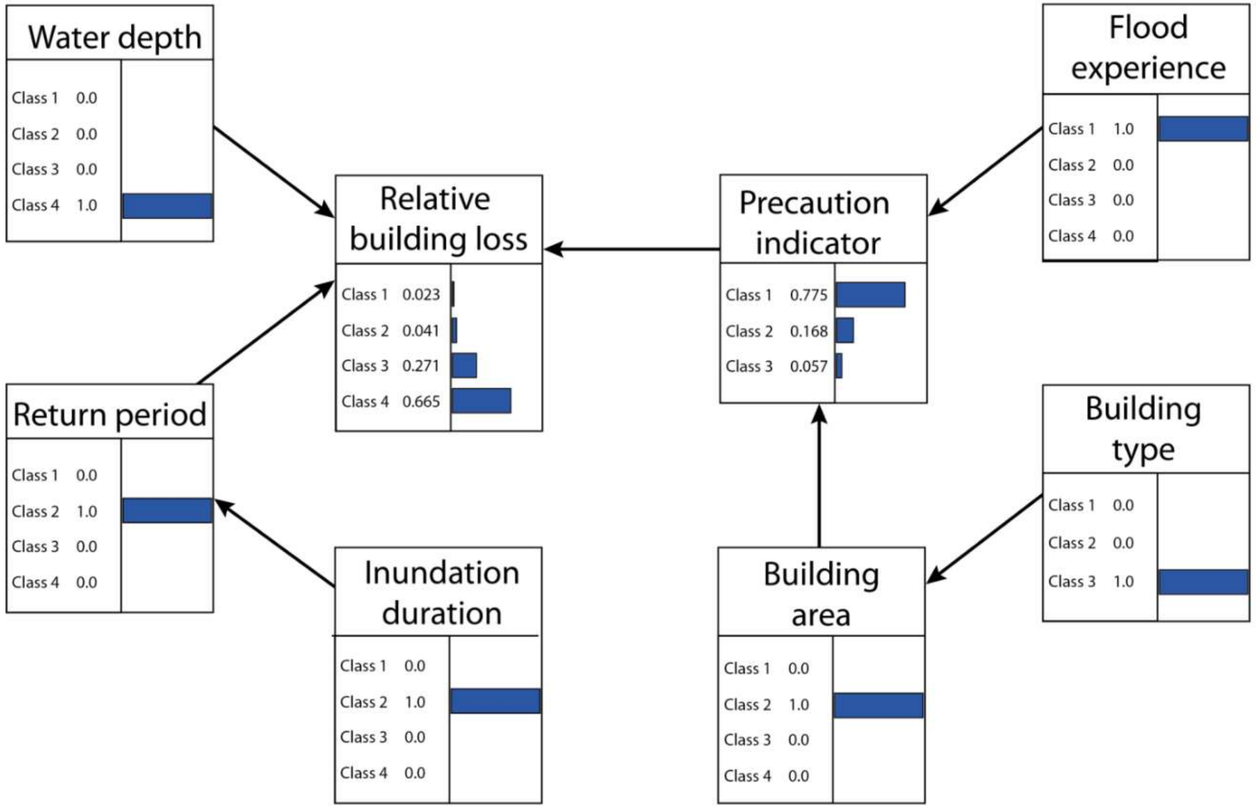


Model data sources

European proxies

Hydraulic Model

- Water depth
- Return period
- Duration

Asset Values

- European Asset Map
- Assets per land use class

Open Building Maps

- Building footprint
- Building location

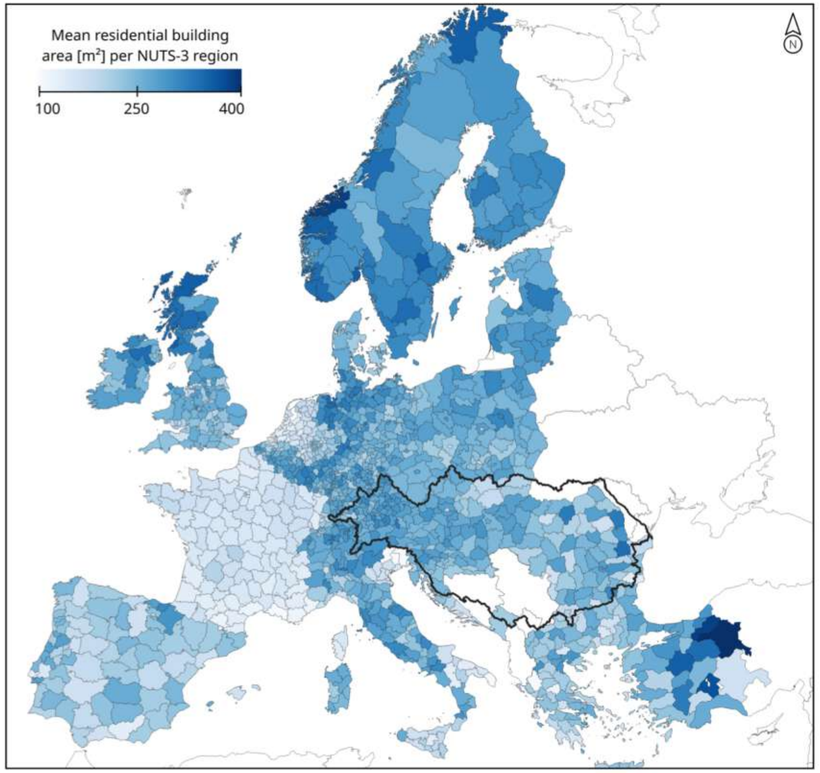
DFO Catalogue

- Flood experience
- Flood events of the past 25 years

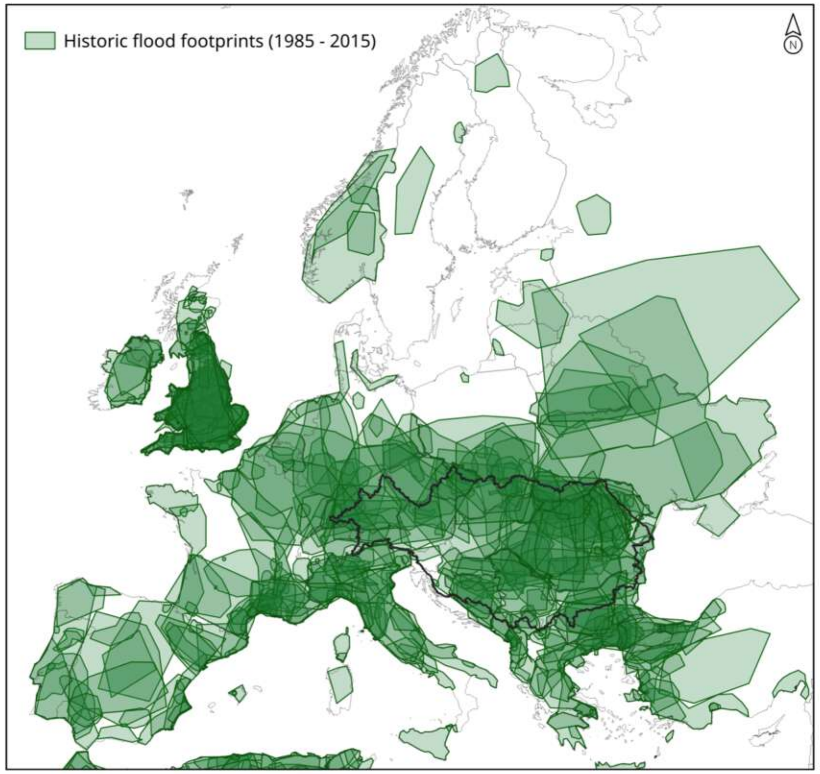
Model data sources

European proxies

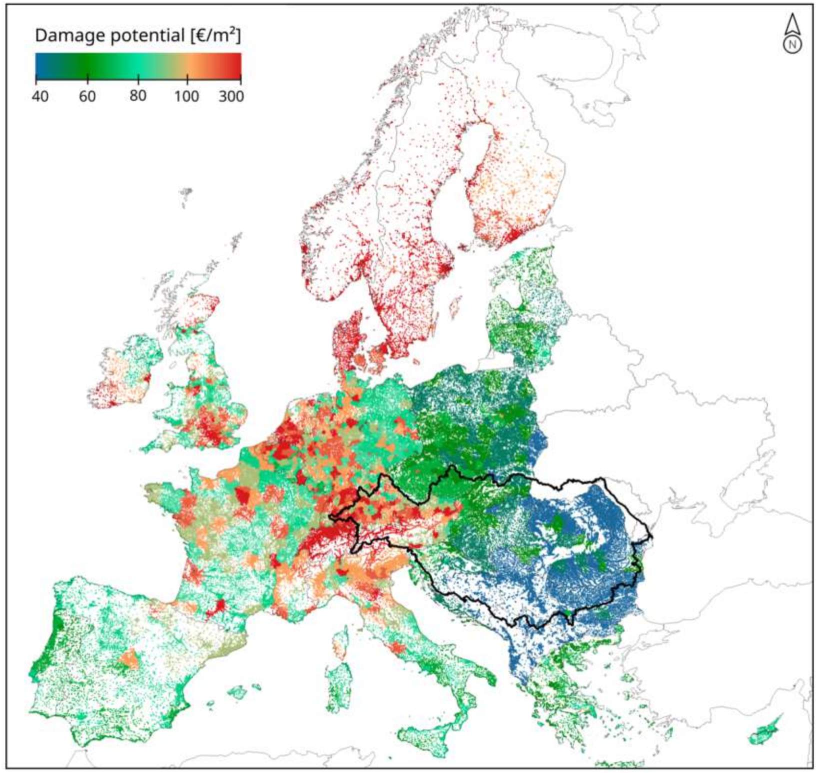
Building area



Flood experience



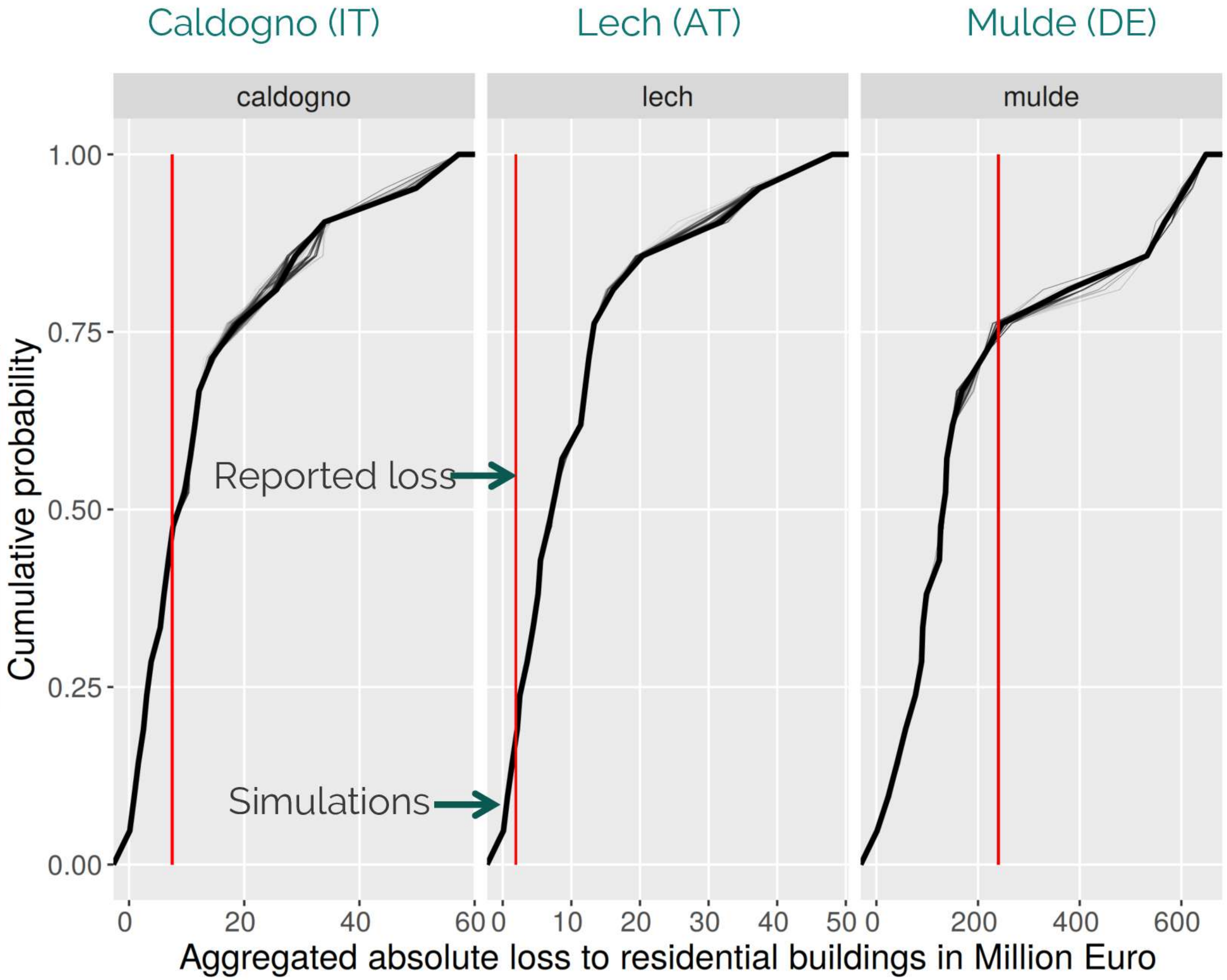
Assets



Model validation

Comparison with reported loss

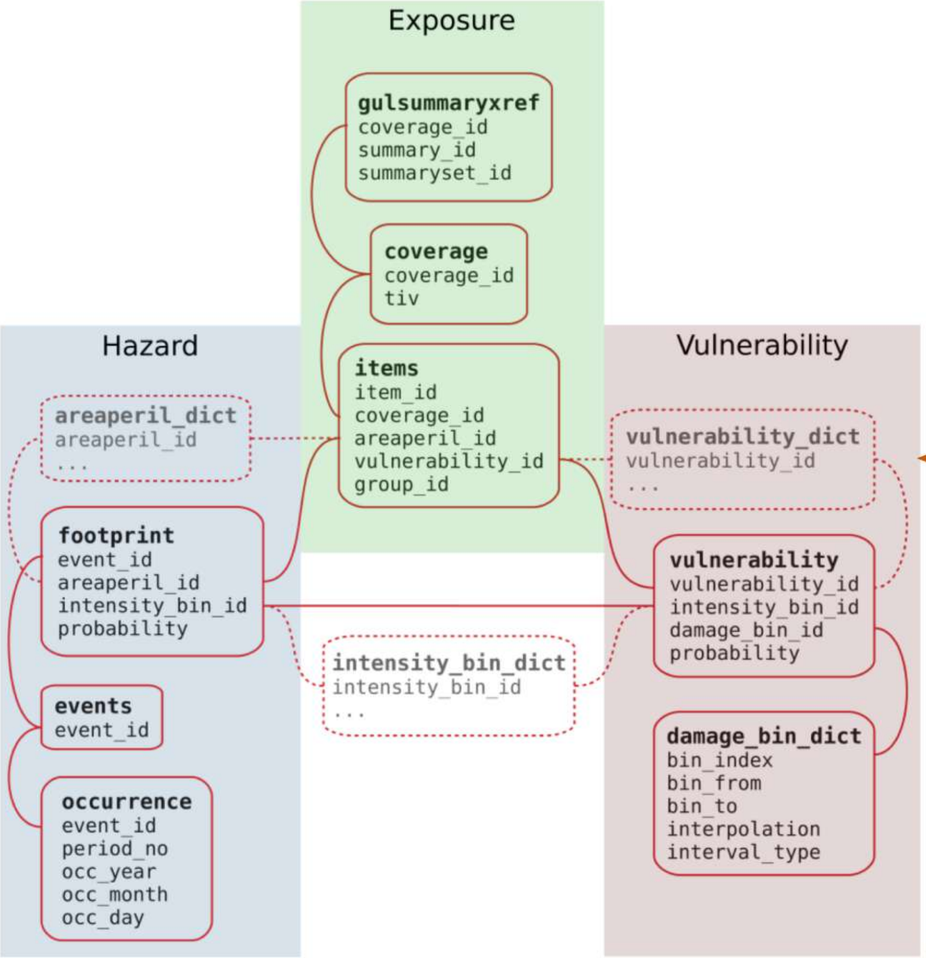
	Caldogno	Lech	Mulde
Reported loss (Mio €)	7.5	1.9	240
Simulated loss (Mio €)	9.6 (3.8; 18.8)	7.8 (3.6; 13.3)	136.0 (89.0; 248.2)

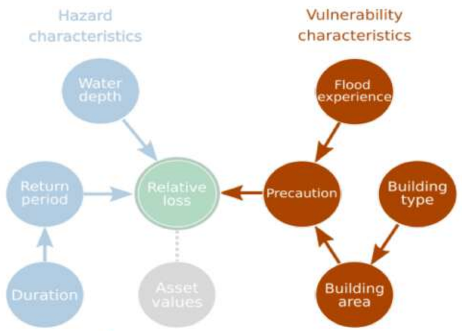


Lüdtke et al. 2019 (WRR)

Implementation to OASIS lmf

Standardized table formats



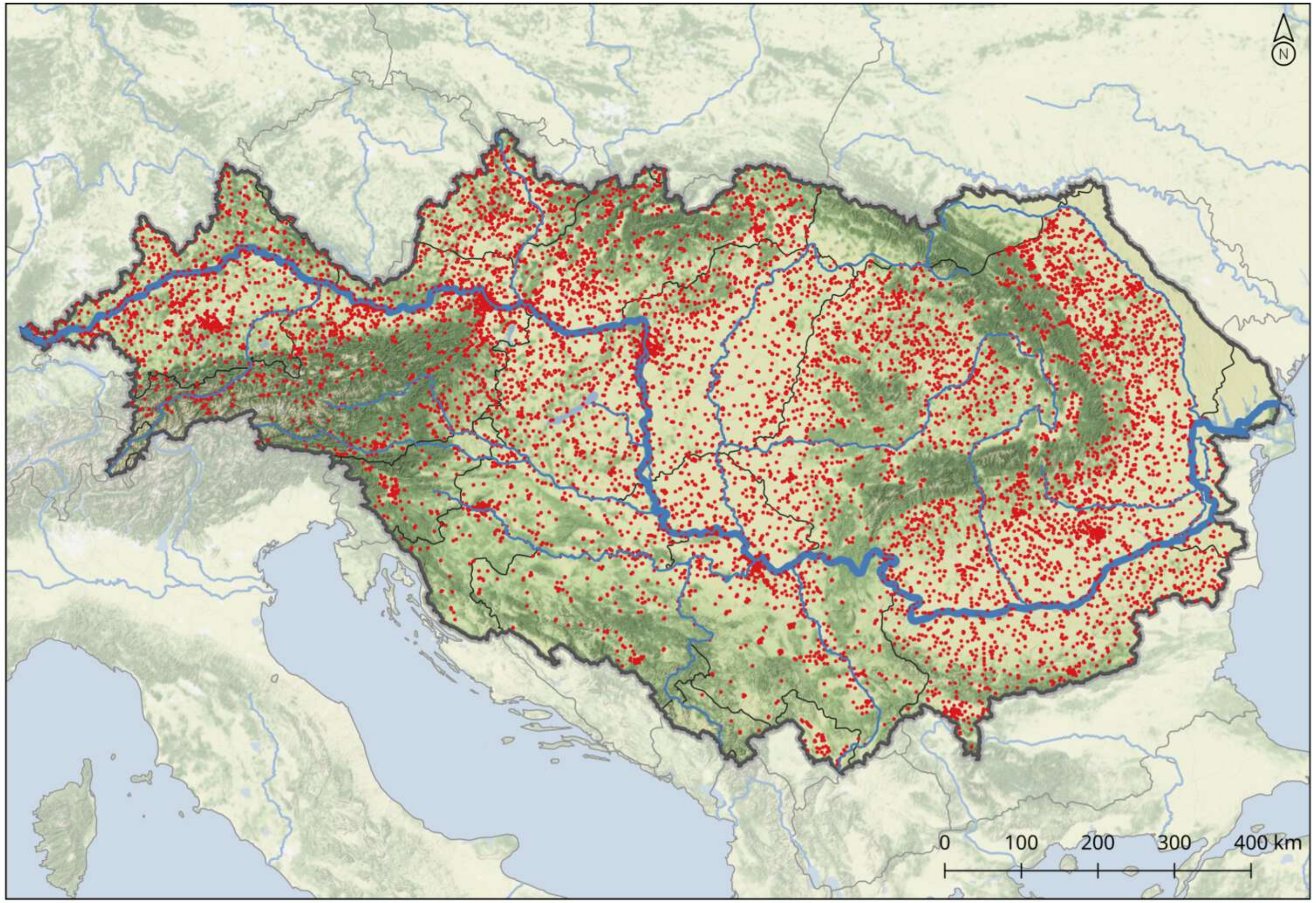


vulnerability.csv

vulnerability_id	pre_range	fe_range	ba_range	bt_range
1	0	NA	NA	NA
2	1	NA	NA	NA
3	2	NA	NA	NA
4	NA	0	[8-158)	NA
5	NA	1	[8-158)	NA
6	NA	2	[8-158)	NA
...	...	...	...	...

Testportfolio residential sector Danube region

- Random sample of 10.000 virtual objects from the Danube region
- Residential assets based on CORINE Land use Land cover
- Exposure 460 M. EUR



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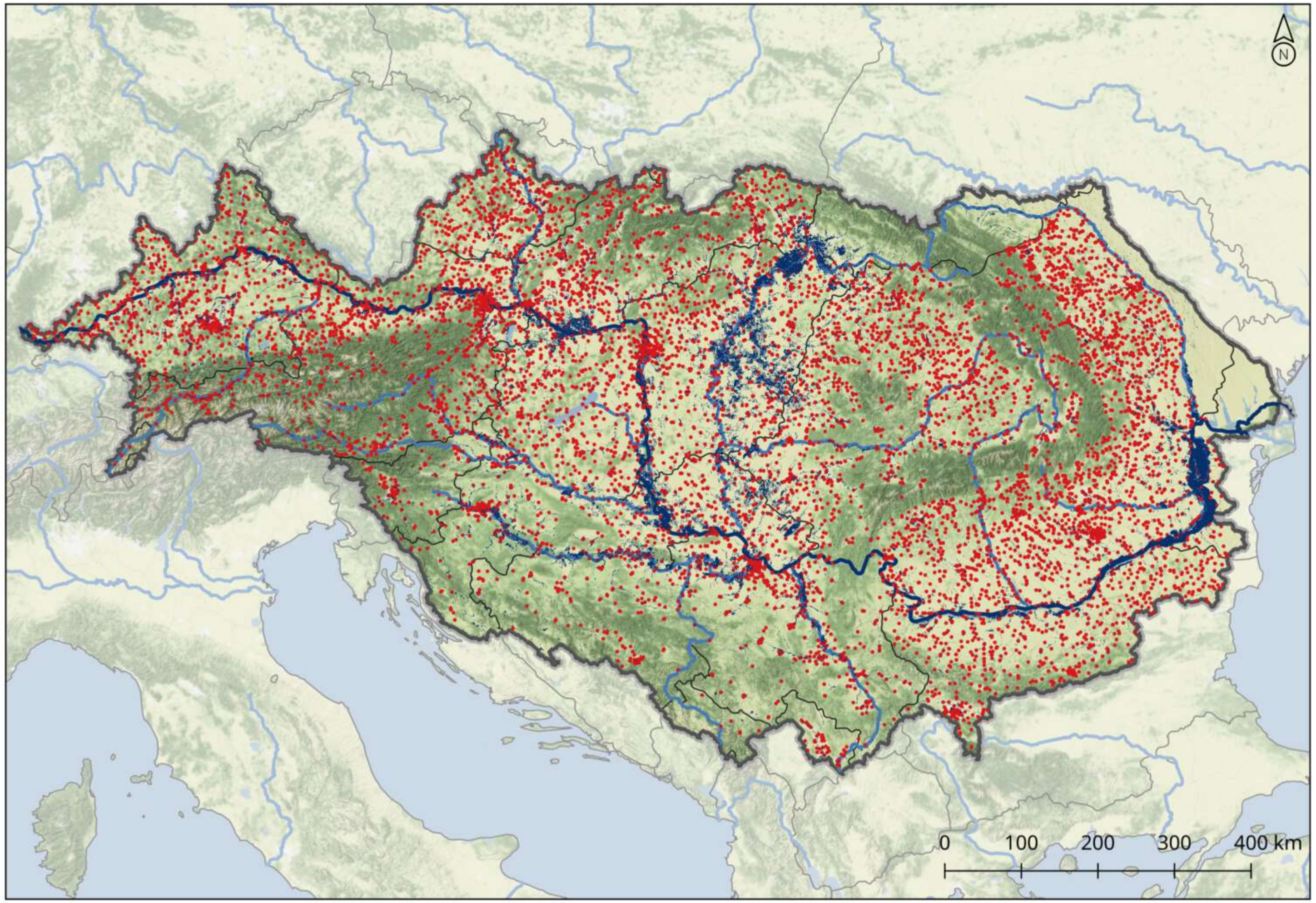
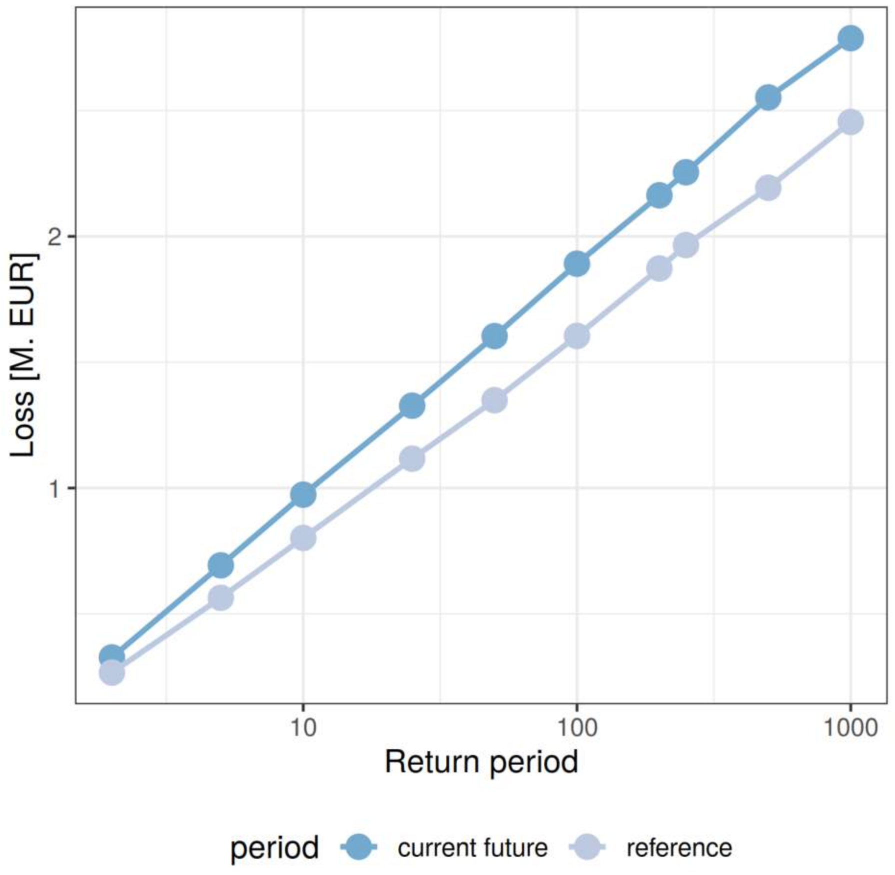


Results Testportfolio – aggregate exceedence probability

Numerically integrated mean



Ref-period
Exposure value = 27,708,840 EUR
Annual average loss (ref) = 514,525 ± 392,591 EUR

Current future
Exposure value = 29,387,632 EUR
Annual average loss (ref) = 638,317 ± 480,162 EUR

Oasis Oasisui

LOSS MODELLING FRAMEWORK

User Interface

Analysis

Dashboard

Analyses table

Show 5 entries

Search:

ID	Name	Portfolio Name	Model Version	Supplier	Created	Modified	Status Detailed	Status
17	demo run	demo	FUTUREDANUBE, version 1	H2020	2019-11-15 14:31:19	2019-11-15 14:36:52	run completed	
16	test default	Test Bud 250	FUTUREDANUBE, version 1	H2020	2019-11-15 12:25:02	2019-11-15 12:28:27	run completed	
15	test 1970	Test Bud 250	FUTUREDANUBE, version 1	H2020	2019-11-15 12:21:27	2019-11-15 12:22:17	run completed	
14	Danube 10000 location future present	Technical Review 10000 Location	FUTUREDANUBE, version 1	H2020	2019-11-15 12:02:57	2019-11-15 12:17:31	run completed	
13	Danube 10000 location reference	Technical Review 10000 Location	FUTUREDANUBE, version 1	H2020	2019-11-15 11:52:29	2019-11-15 12:15:51	run completed	
A	A	Al	All	A	Al	Al	A	Al

Showing 1 to 5 of 17 entries

Previous 1 2 3 4 Next

Dashboard of Analyses Outputs | Delete Analysis | Export to csv

Analysis

Dashboard

Selected Analysis: 14 "Danube 10000 location future present"

Go to Configure Output

Summary | Plots | Files

Inputs

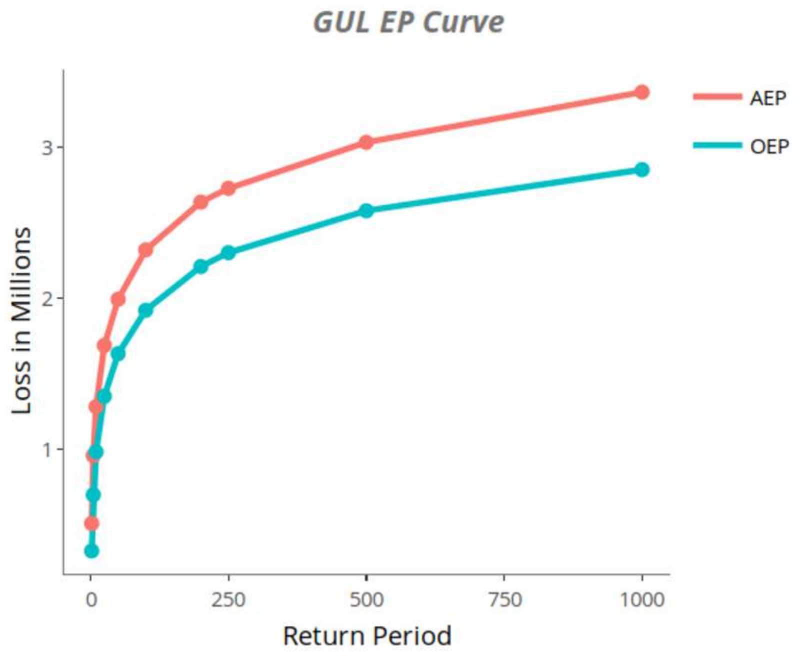
	Specification	Value
1	exposure location count	10,000
2	exposure TIV gul (Analytical)	29,387,632
3	exposure TIV gul (Sample)	29,387,632

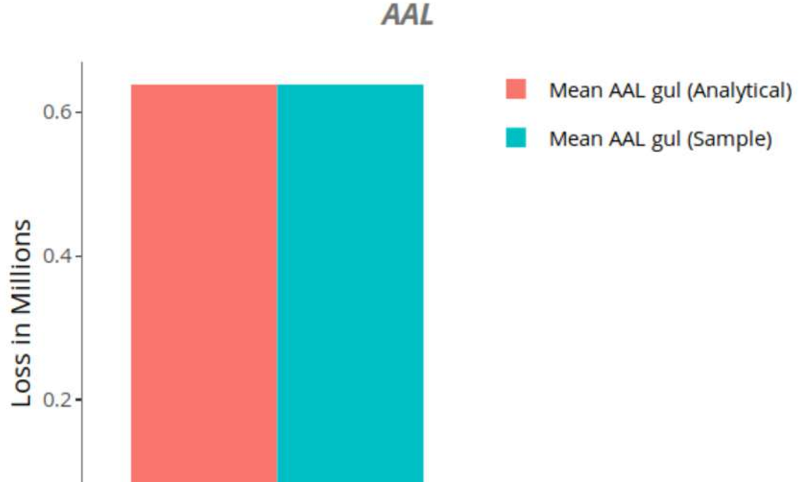
Parameters

	Specification	Value
1	return period file	TRUE
2	event set	2006_2035
3	event occurrence id	rcp85_2006_2035
4	peril pluvialflood	TRUE
5	peril fluvialflood	TRUE

Outputs

	Specification	Value
1	Mean AAL gul (Analytical)	638,168
2	Mean AAL gul (Sample)	638,317





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Oasis-HUB:

https://oasishub.co/organization/gfz-potsdam

https://oasishub.co/organization/pik

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