Impact Based Forecasting of Urban Flooding

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Our definition of forecasting

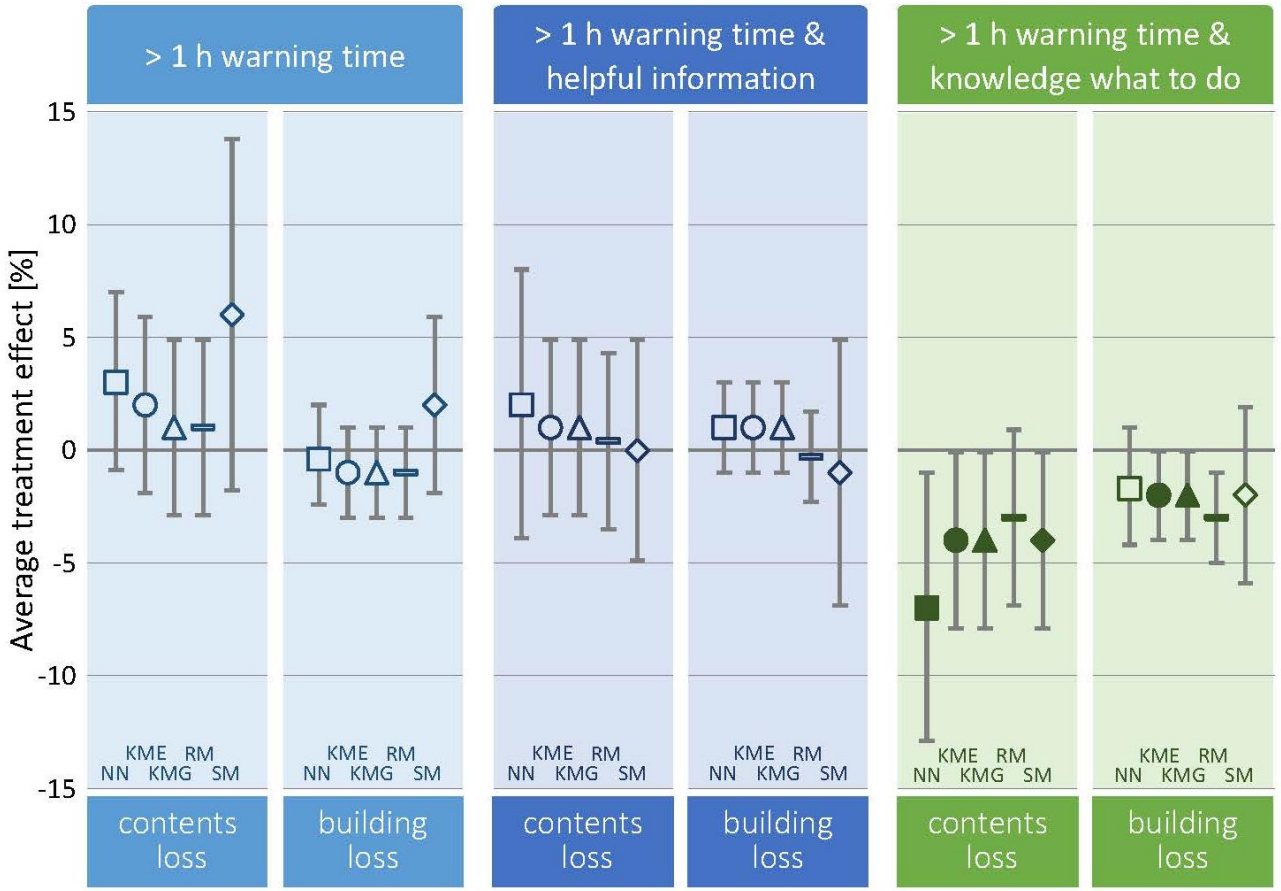
Provision of timely information to improve management in emergency phase, i.e. shortly before, during and after hazardous event.

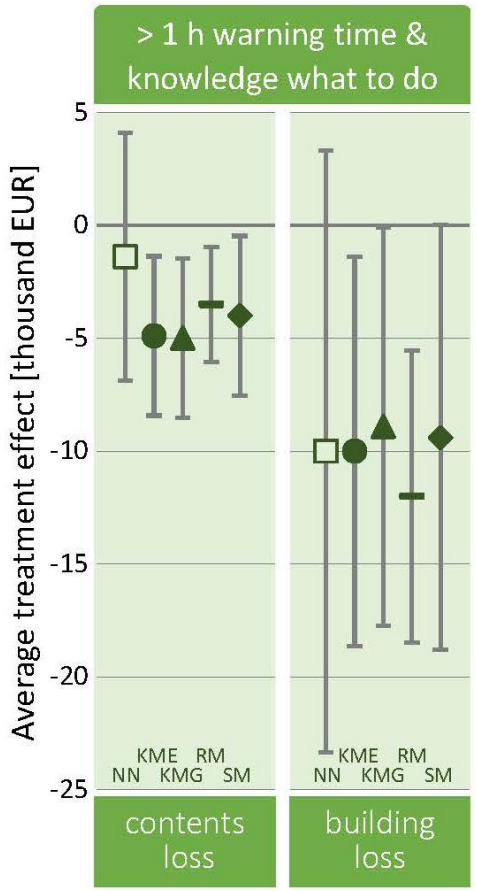
Forecasts as essential element of **early warning systems**, defined by UNISDR (2009) as …

"… *the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss*".

Forecasting reduces loss - but people need to know what to do

Average treatment effects





Kreibich et al. 2021 BAMS

Matching methods:
NN: nearest-neighbor matching
KME: kernel matching (Epanechnikov)
KMG: kernel matching (Gaussian)
RM: radius matching
SM: stratification matching.

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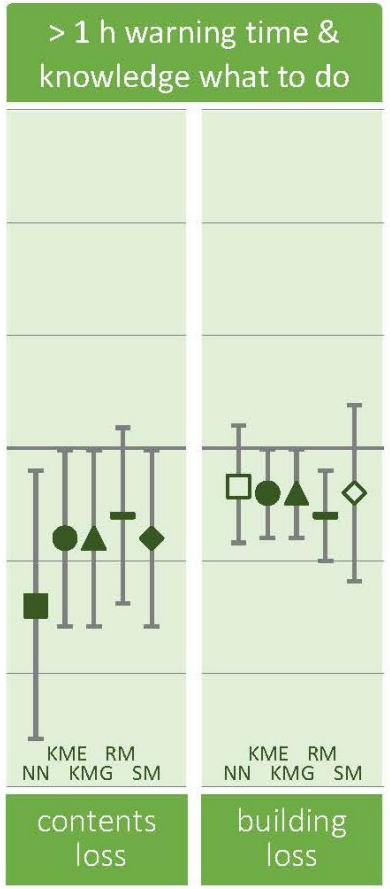
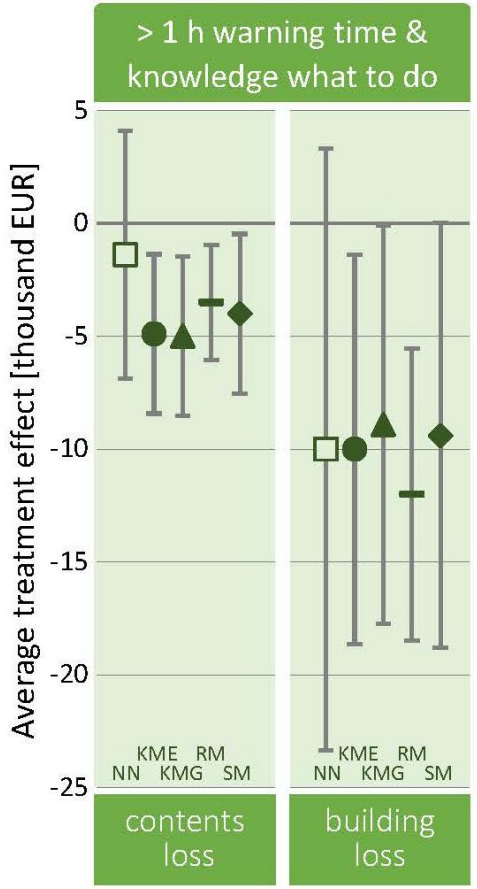
Average treatment effects

Summary:

Average reduction contents loss:
4 percentage points
3,800 €
Average contents loss ratio 21%
Absolute contents loss 17,000 €

Average reduction building loss:
2 percentage points
10,000 €
Average building loss ratio 11%
Absolute building loss 48,000 €





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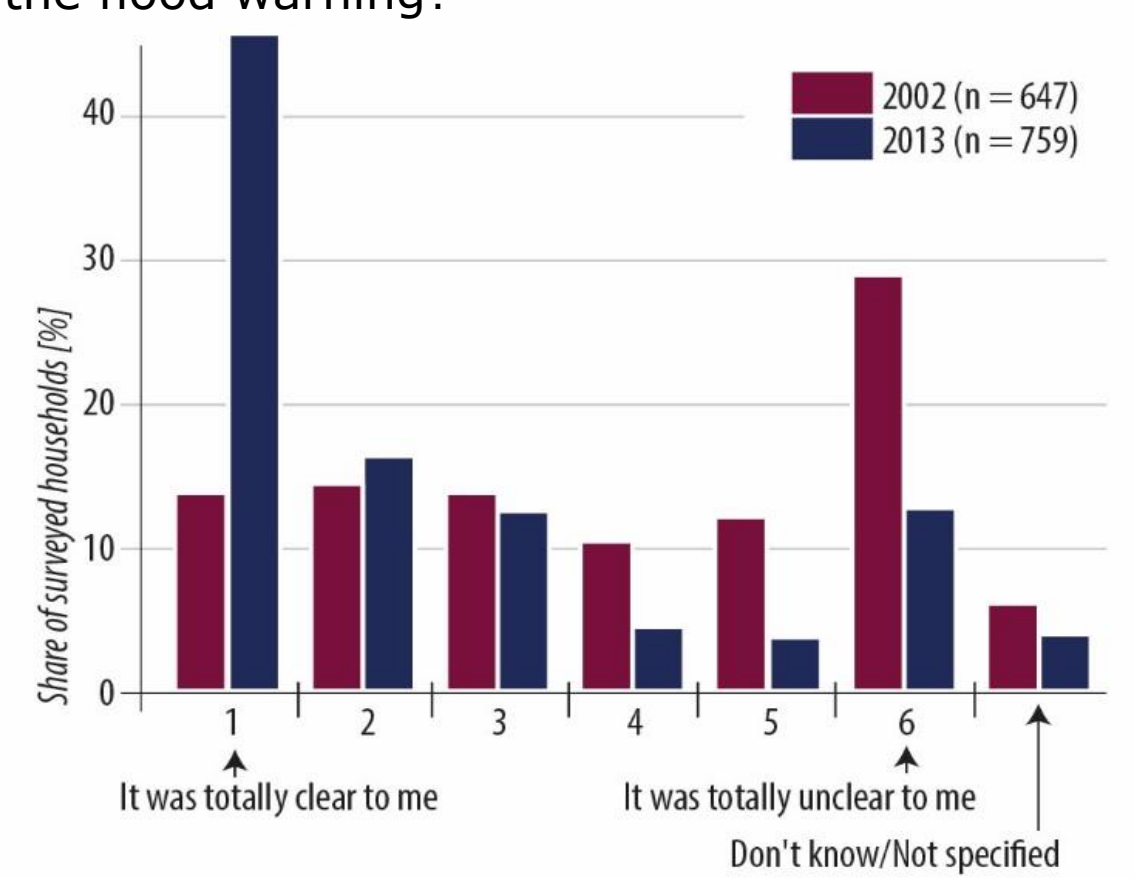
Example: 2002 & 2013 floods, Germany

Did you know what to do when you received the flood warning?



Event	Hydrological severity	Affected share of river system	Share of residents who received warning	Loss [billion €]
2002	35	19%	74%	15
2013	75	45%	95%	7

Kreibich et al. 2017 NHESS

Forecasting reduces loss - but people need to know what to do

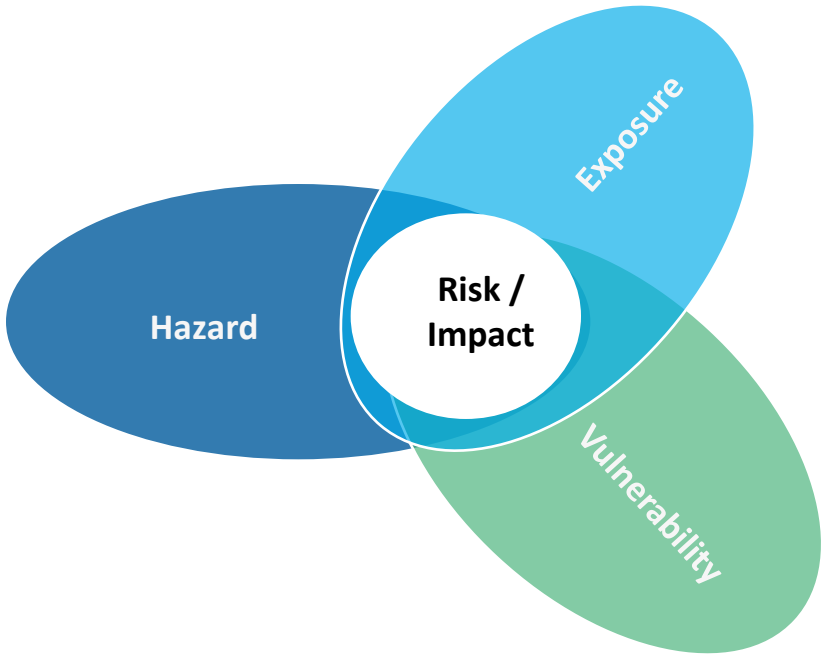
Which factors are associated with people being more likely to know what to do when they receive a flood warning?

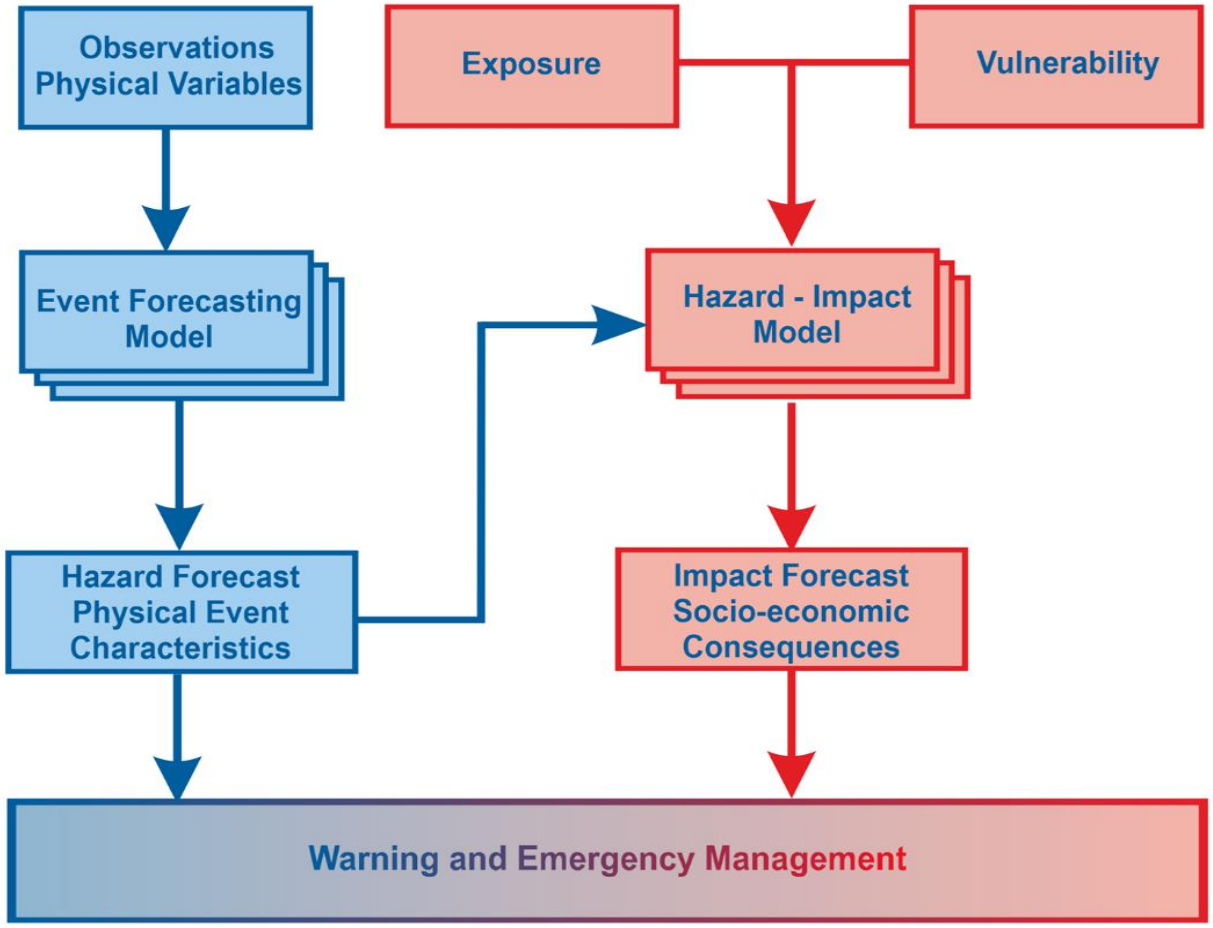
	Parameter estimate	Marginal effect
Age of the interviewed person	0.006** (0.003)	0.001** (0.0006)
Knowledge of flood hazard	0.73*** (0.12)	0.16*** (0.02)
Flood experience indicator	0.86*** (0.09)	0.18*** (0.02)
Perception of efficiency of private precautions	0.51*** (0.08)	0.11*** (0.02)
Some precautionary measures undertaken	0.8*** (0.09)	0.18*** (0.02)
Many precautionary measures undertaken	1.26*** (0.11)	0.29*** (0.02)
Indicator of flood warning information	1.35*** (0.1)	0.27*** (0.02)
Official warning through authorities	0.4*** (0.09)	0.09*** (0.02)
Constant	−3.72*** (0.19)	

Kreibich et al. 2021 BAMS

Impact forecasting

Risk = Probability x Damage = $f(H, E, V)$
(UNISDR, 2009 , IPCC, 2012)





Impact (or impact-based) forecasts and warnings:

- Extends hazard forecasting, translating hazard characteristics into impacts.
- Include information on affected elements at risk and, if possible, their vulnerability.

Additional complexities when extending hazard forecasts to impact forecasts

Rhine floods in Cologne

December 1993:

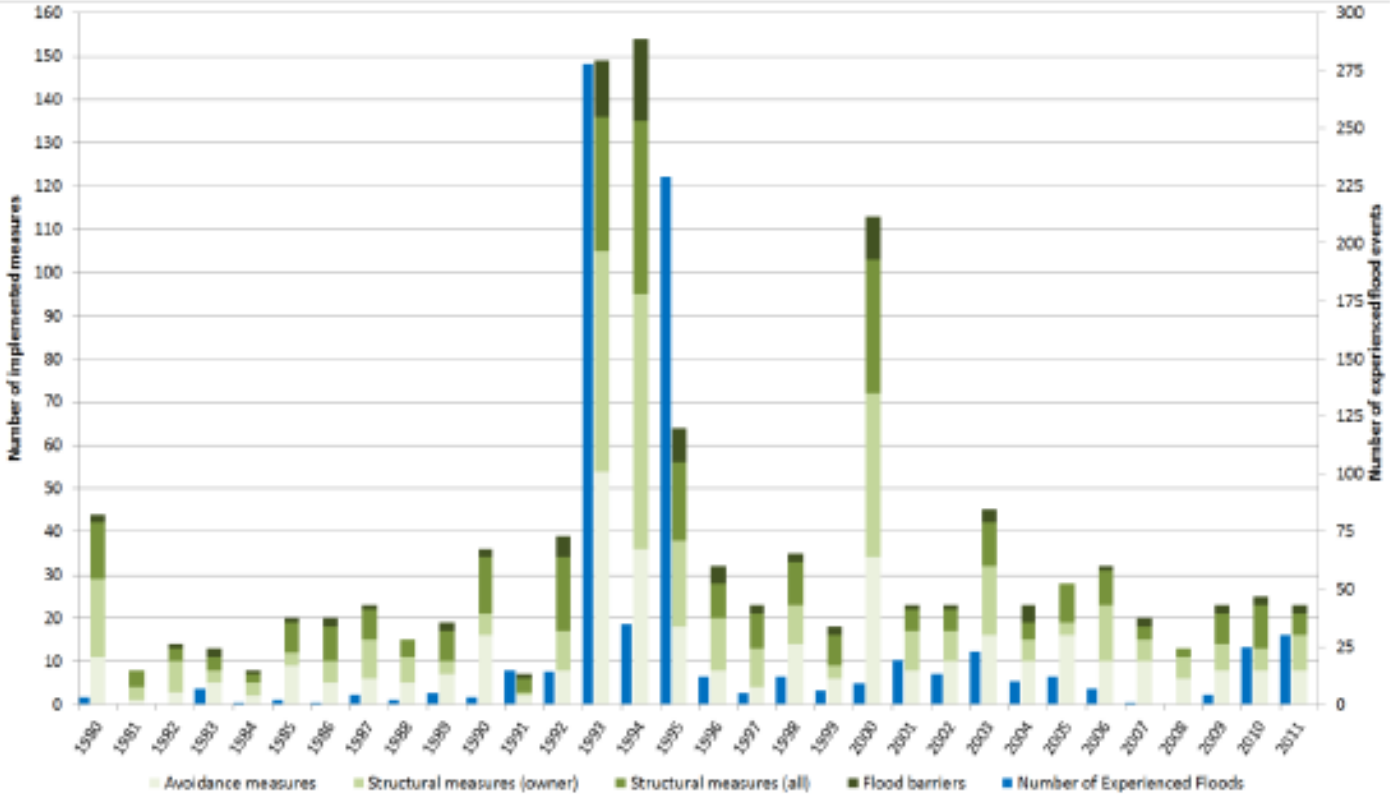
- Water level gauge Cologne: 10.63 m
- Damage: 70 Mio €

January 1995:

- Water level gauge Cologne: 10.69 m
- Damage: 35 Mio €

Implementation of flood mitigation measures

by flood-prone households along the German part of the Rhine (Bubeck et al. 2012, NHESS)

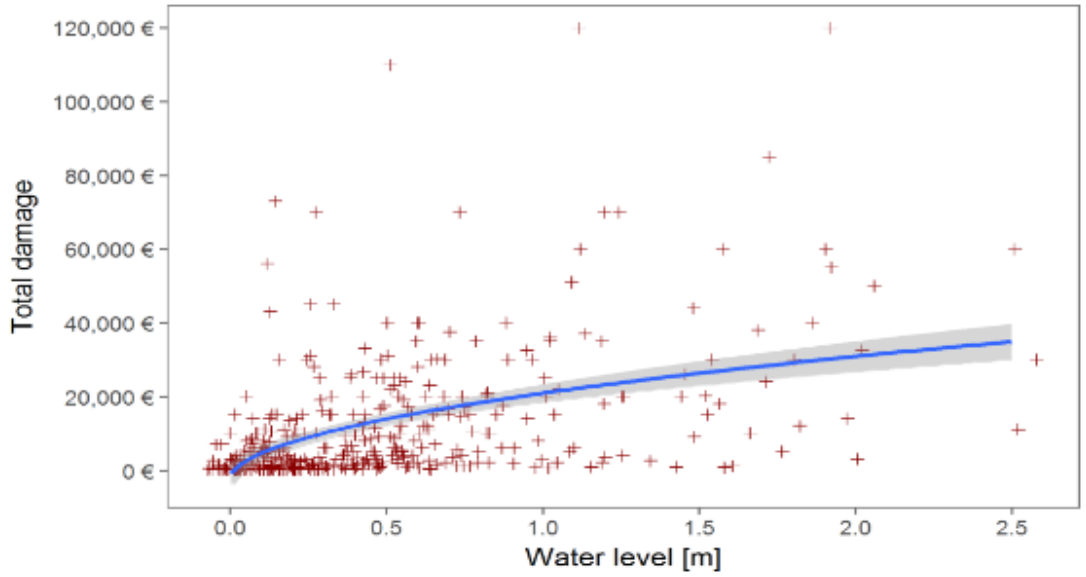


Impact modeling is lagging behind

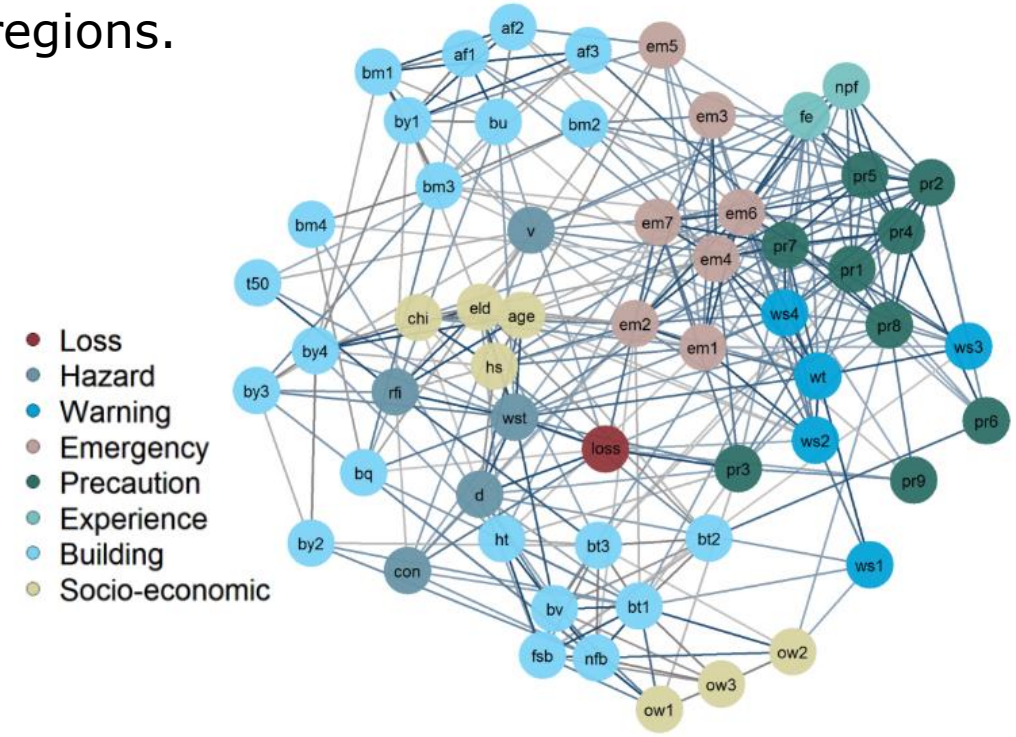
Often, **very simple (deterministic) approaches** used for impact modeling in terms of process representation and complexity compared to hazard modeling.

Impact models usually **derived from post-event damage and loss observations**. Several factors hinder their development, including:

- Rarity of damaging loss events,
- Lack of systematic collection of damage & loss data,
- Difficulties in transfer of impact models across regions.



Depth-damage curve for estimating flood damage to certain type of residential buildings in Germany



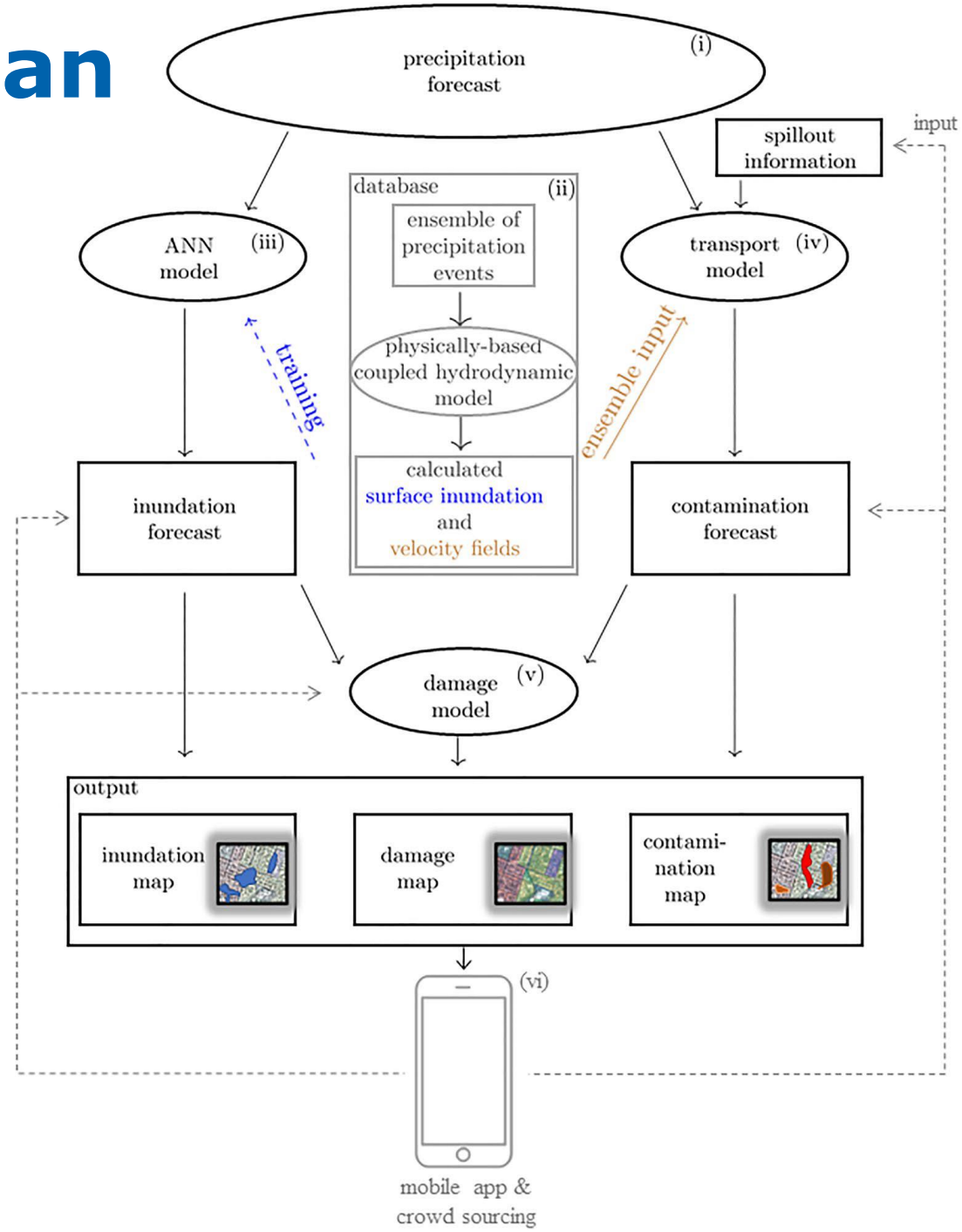
Damage-influencing factors for flood damage to buildings, derived from post-flood surveys (Rözer et al. 2019 Earth's Future)

Impact forecasting of urban flooding

Hazard forecasting: mostly limited to severe weather warnings incl. expected maximum rainfall intensity on district level.

Impact forecasting model chain:

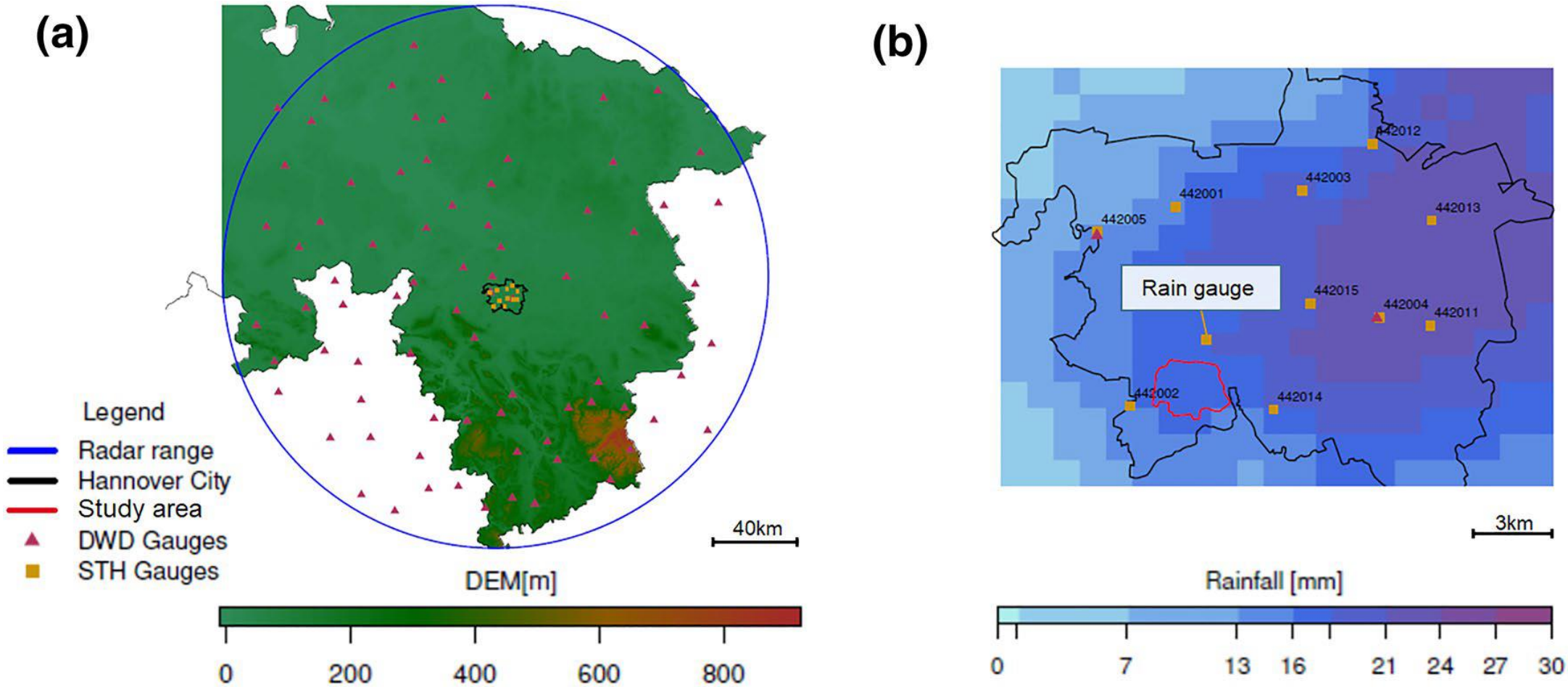
- Rainfall forecast model
- Inundation model
- Contaminant transport model
- Residential building damage model



Impact forecasting of urban flooding

Rözer et al., 2021, Earth's Future

Rainfall forecast model: Station and radar rainfall measurements; forecast model to track spatio-temporal development of storm cell; reliable forecasts up to 30 min.



The rainfall data used for the estimation of the rainfall field at 1 km^2 and 5 min resolution and the location of the study area
(a) the overall study area for the forecast model and
(b) the close up view of the city of Hannover and the rainfall volume accumulated for 30 min for the convective event on June 22, 2017.

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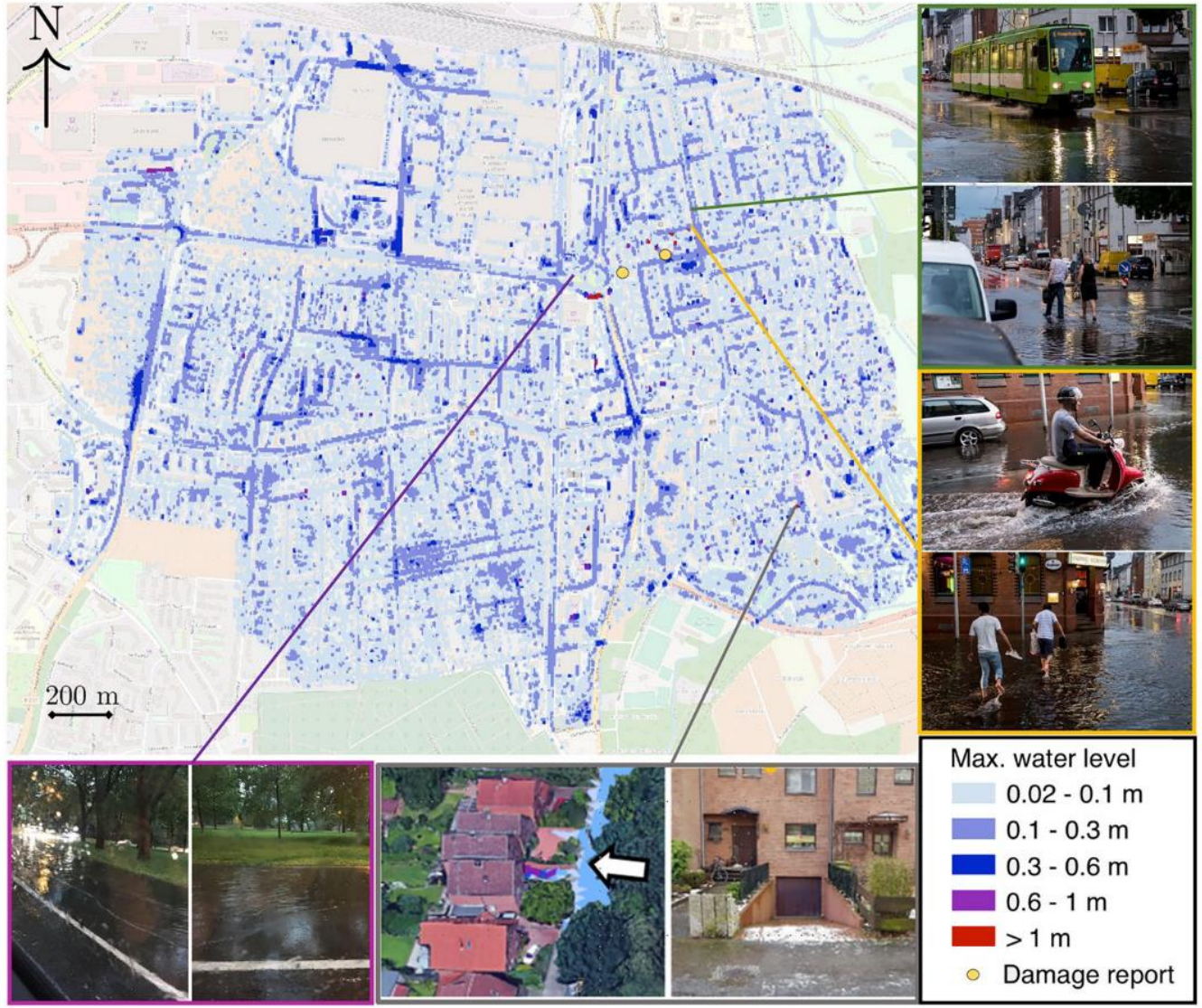
Inundation model: ANN model using database of pre-calculated scenarios; based on coupled hydrodynamic models for urban surface flow and subsurface pipe network.



Hindcast of pluvial flood on June 22, 2017 in Hannover, Germany. Comparison of ANN-predicted maximum water levels and press photographs.

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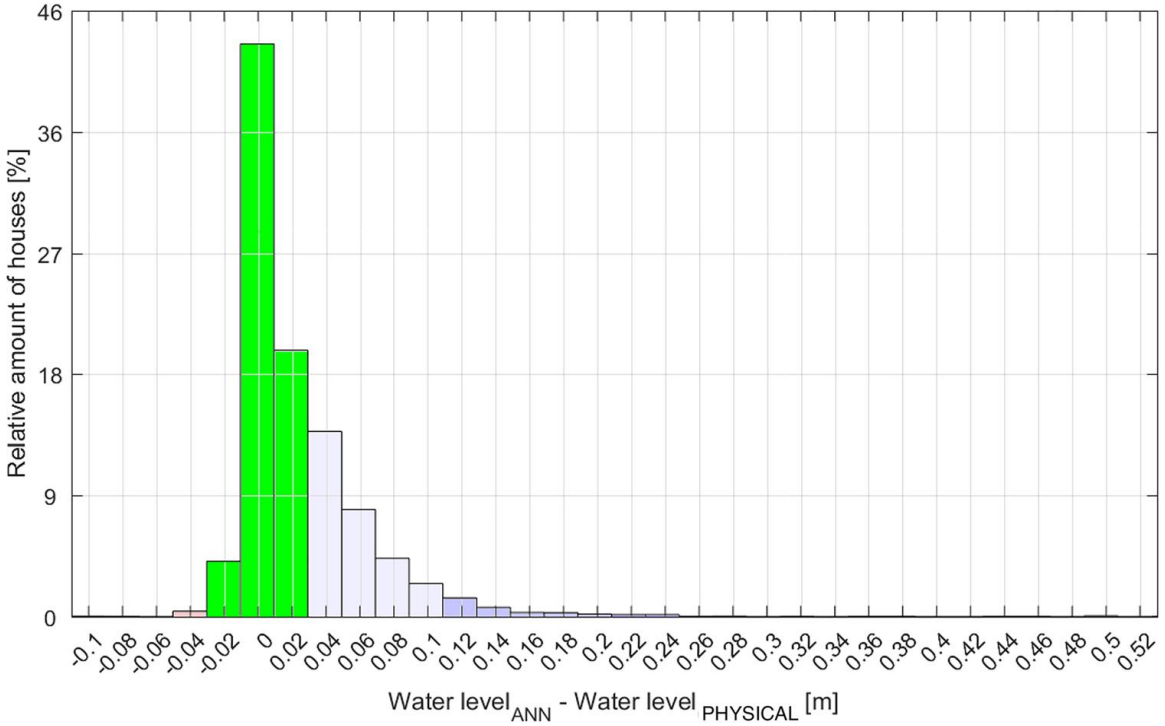
Rözer et al., 2021, Earth's Future

Spatial distribution of deviation of maximum water levels directly at the houses between ANN and the results from the physically based model



Histogram of deviation of maximum water levels directly at the houses between ANN and the results from the physically based model

Impact forecasting of urban flooding

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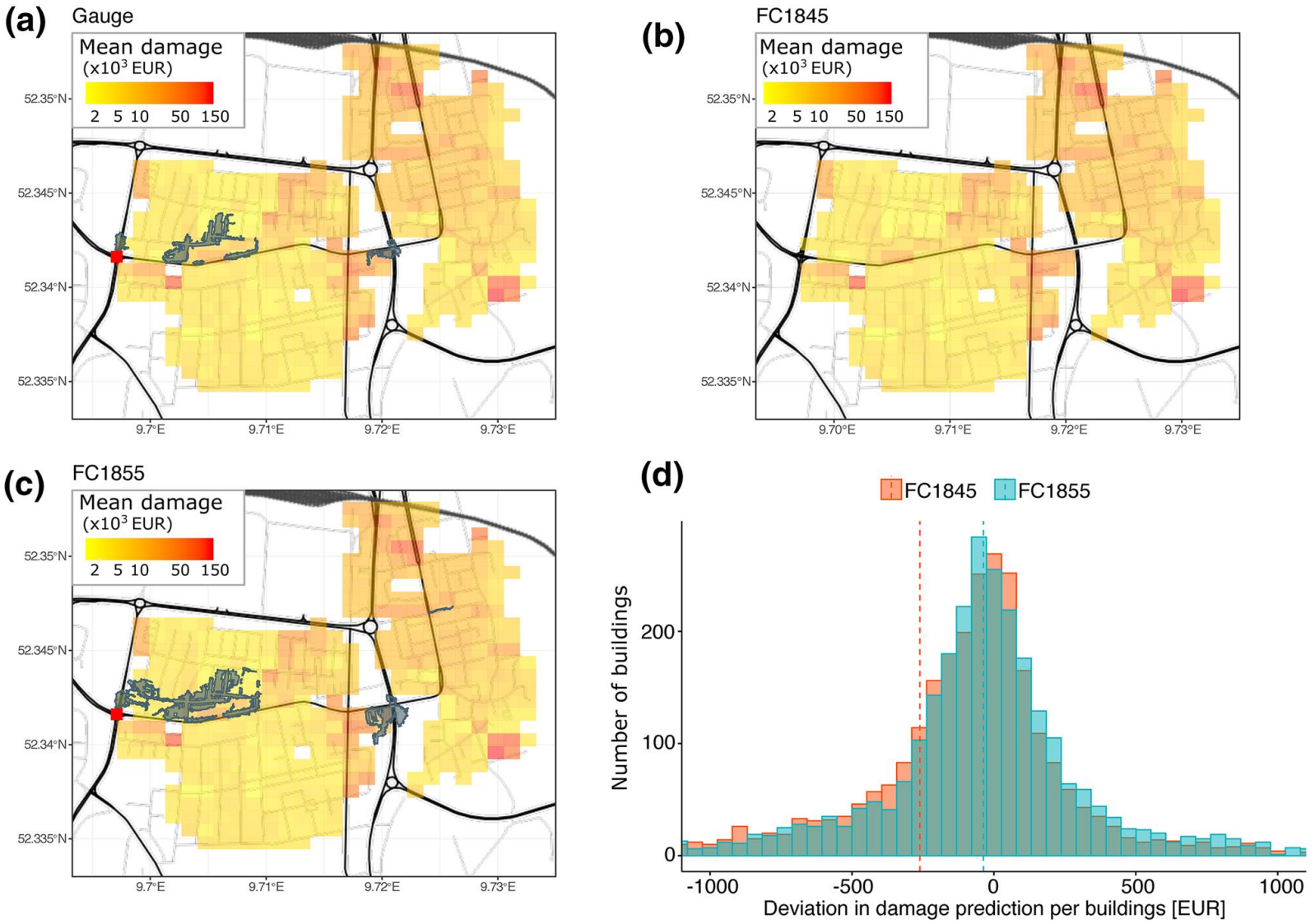

Residential building damage model: Probabilistic Bayesian model based on empirical damage data

Spatial distribution of mean damage to residential buildings using inundation input from ANN model based on rainfall gauge (a), rainfall forecast at 18:45 (b) and rainfall forecast at 18:55 (c)

Discussion & Conclusion

- New possibilities for emergency management
- Assumed benefits of impact forecasting hardly been tested
- Consider social systems & human behaviour
- Complexity and dynamics in exposure and vulnerability
- Impact uncertainty to be better addressed and communicated
- Harmonize risk assessment and emergency-oriented impact estimation
- New challenges/opportunities for communication and decision making
- Leverage to foster interdisciplinary work

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