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Operational flood impact forecasting with *RIM2D* for improved disaster management

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Section 4.4 Hydrology

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Flood 2021 in Western Germany – the triggering event

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- Most costly event in history (30 billion € relief fund, 7 billion € insured loss)
- Death toll > 180 in Germany, 230 in Europe

Causes?

Among others:

- Lack of spatially explicit early warnings of flood severity
- No information about affected areas and flood impact (inundation areas, flood depths, flow velocities)

→ Wrong decisions in disaster management

Flood 2021 in Western Germany – the triggering event

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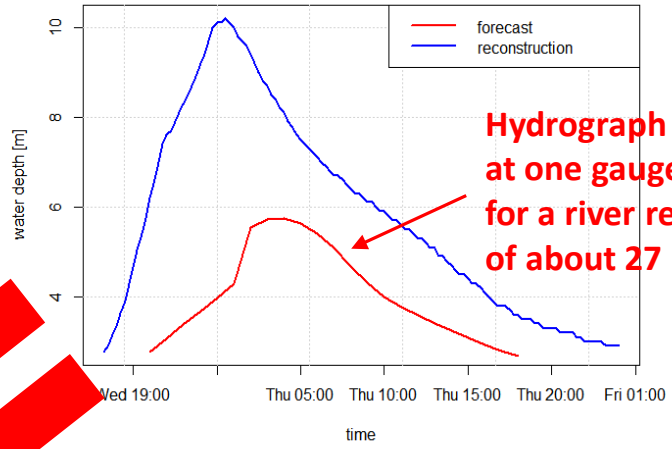
Available information for disaster management

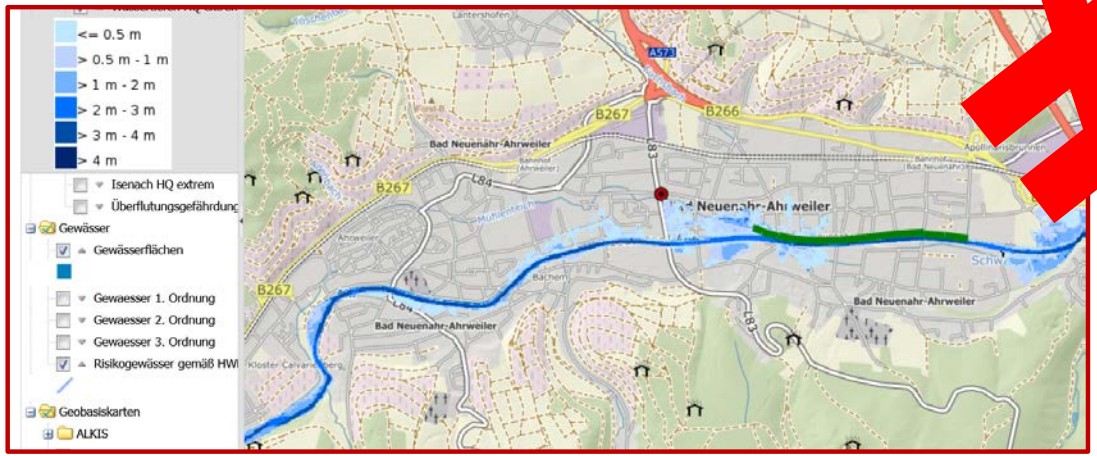
→ Need for spatially explicit flood forecasts

1. Flood forecast



Hydrograph at one gauge for a river reach of about 27 km

2. Flood hazard maps (HQ100, HQextreme)



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RIM2D – a raster-based hydraulic model for simulating fluvial and pluvial floods

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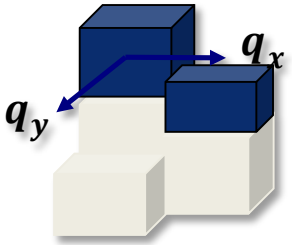
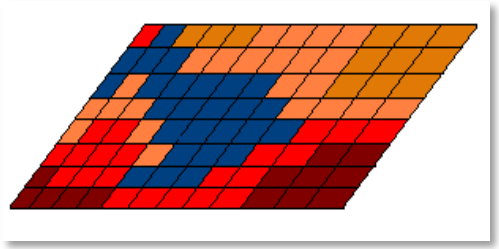
RIM2D

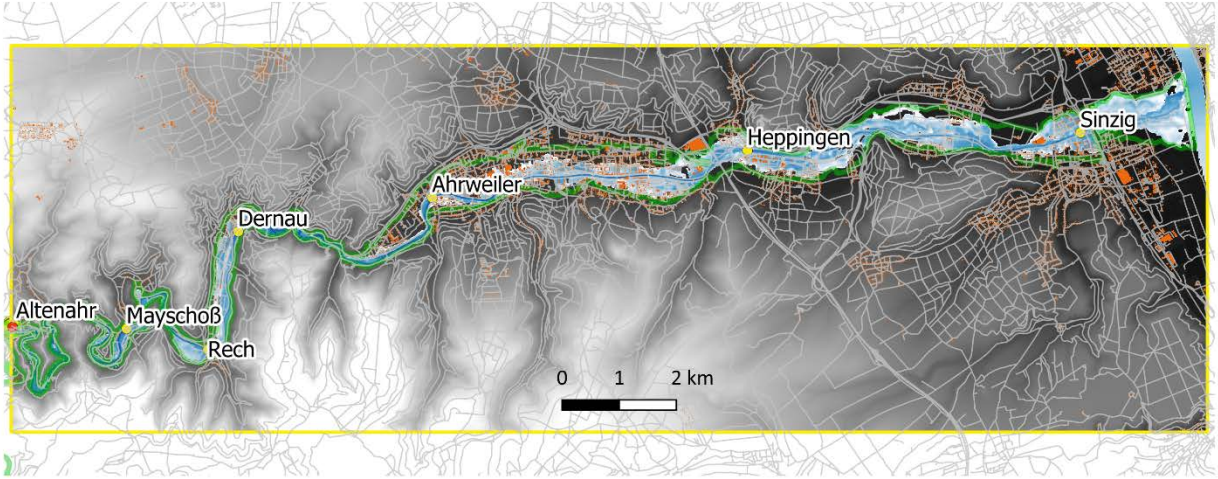
- Raster-based 2D hydraulic model
- Mathematical foundation as Lisflood-FP[1,2] (simplified SWEs)
- Massively parallelized on **GPUs** with CUDA Fortran
- Capacity-based simulation of **sewer system** (drainage from sealed surfaces and roofs in mm/h)
- Capacity-based **infiltration** from un-sealed surfaces (infiltration rate in mm/h)





[1]Bates, P. D., Horritt, M. S., and Fewtrell, T. J.: A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling, Journal of Hydrology, 387, 33-45, 10.1016/j.jhydrol.2010.03.027, 2010.
[2]Almeida, G. A. M. d., Bates, P., Freer, J. E., and Souvignet, M.: Improving the stability of a simple formulation of the shallow water equations for 2-D flood modeling, Water Resources Research, 48, W05528, doi:10.1029/2011WR011570, 2012.

a) Simulated maximum water depths derived from flood forecast

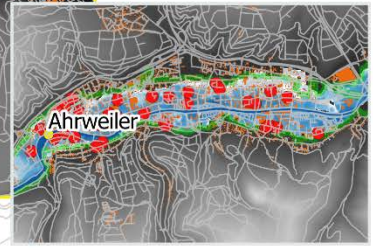


Flood July 2021 simulated max. inundation depth [m]
- 0.10
- 0.30
- 0.60
- 1.00
- 1.50
- 3.00
- 4.00
- 12.00
- mapped inundation

OSM
- building
- roads

DEM 10m
- 22
- 400
- water marks

b) Simulated maximum water depths derived from reconstructed water levels Altenahr



Maximum water depths

(10 m raster resolution)

Event duration

54000 sec (15 h)

Simulation time

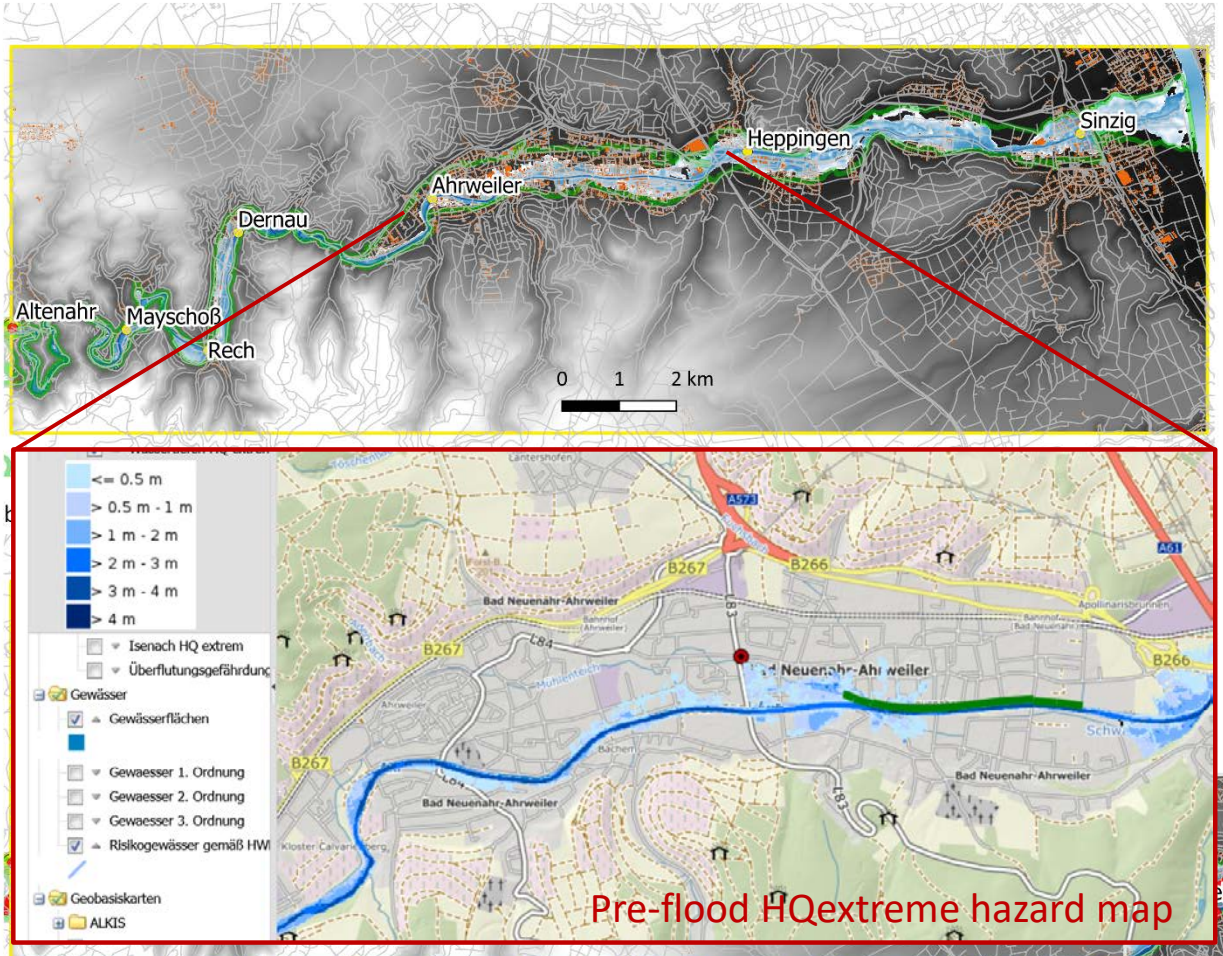
400 sec (~ 7 min)

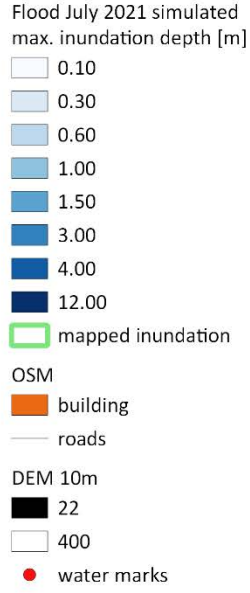
= 0.78% of event

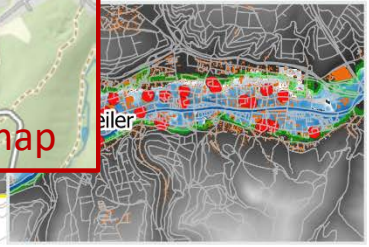
Validation:

- Critical Success Index : 0.845
- Bias: 0.09 m
- RMSE: 0.3 m

a) Simulated maximum water depths derived from flood forecast







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RIM2D – Ein generalisiertes rasterbasiertes hydraulisches Modell zur Simulation von fluvialen und pluvialen Hochwassern

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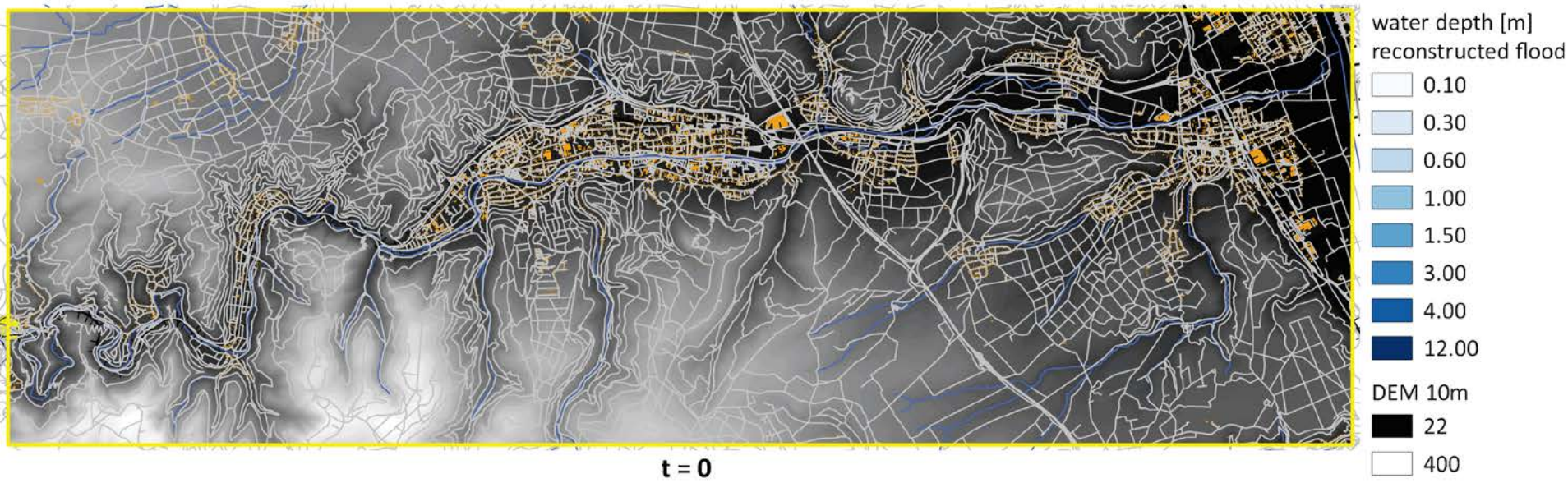
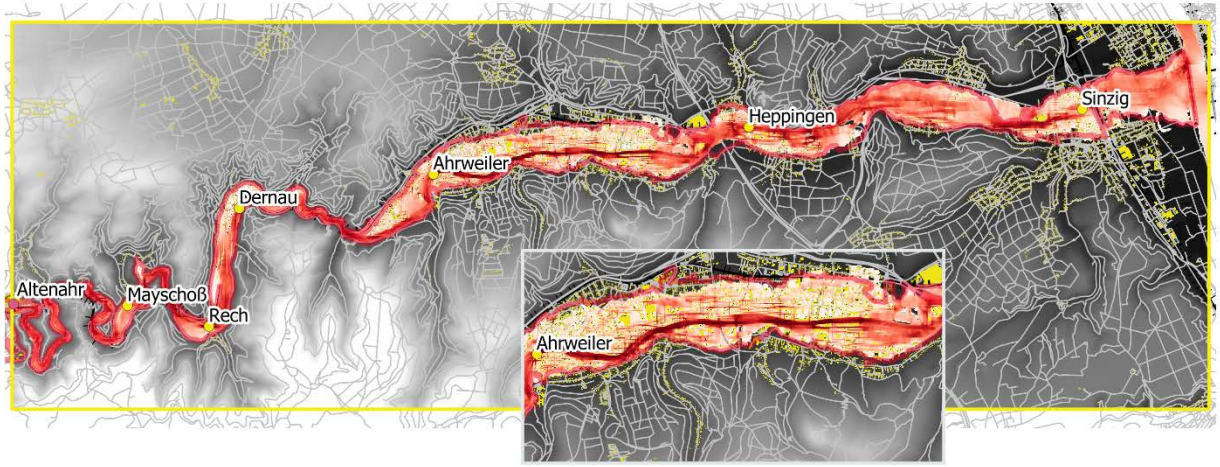
Flood dynamics → arrival of flood peak



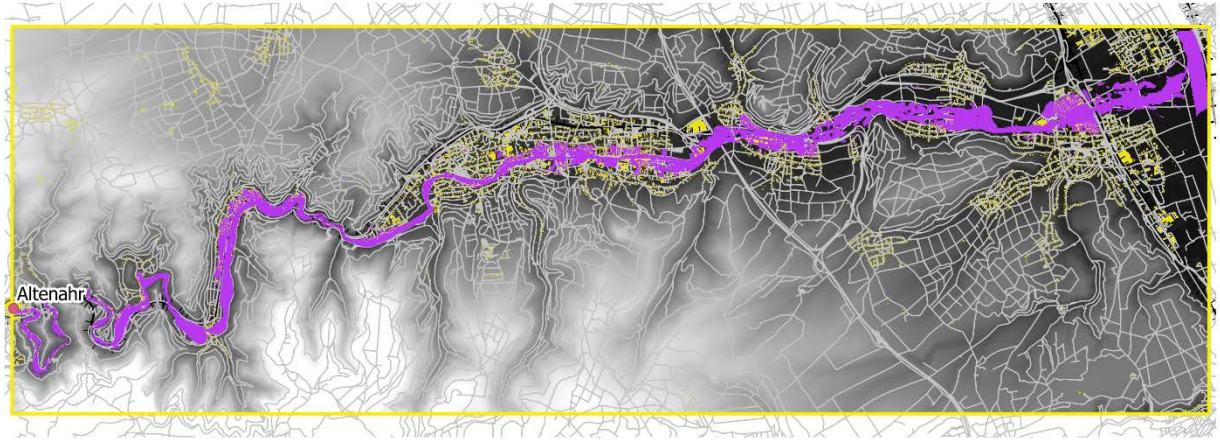
a) Simulated maximum flow velocities based on the reconstructed hydrograph Altenahr



Flood 2021 reconstructed
Max. velocity [m/s]
0.00
0.50
1.00
2.00
3.00
5.00
OSM
building
roads
DEM 10m
22.6756
406.592

Maximum flow velocities

b) Human moment instability acc. to Jonkman & Penning-Rowsell (2008)



human instability
instable
QSM
buildings
OSM roads
DEM 10m
22.6756
406.592

Derived impact forecasting:

Human instability

Car instability

Building damages

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RIM*urban* – Ein generalisiertes Modell zur Abschätzung von Hochwasserrisiken durch Starkregen

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Summary

RIM2D offers

- Simple model setup based on readily available spatial data
- Fast hydraulic flood simulation with the potential for use in **operational flood forecasting** and **better informed disaster management**

Outlook

- Pluvial floods in cities can be simulated as well, considering urban drainage and infiltration

Many thanks for the attention!

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Apel, H., S. Vorogushyn, and B. Merz (2022), Brief communication - Impact Forecasting Could Substantially Improve the Emergency Management of Deadly Floods: Case Study July 2021 floods in Germany, Nat. Hazards Earth Syst. Sci. Discuss., 2022, 1-10, doi: 10.5194/nhess-2022-33.