FLOOD MODELLING IN COASTAL URBAN AREAS
-
The Effect of Horizontal Resolution and Building Representation

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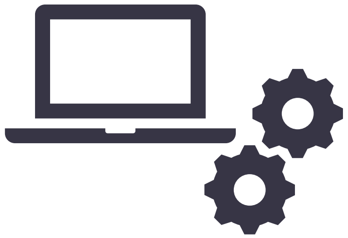
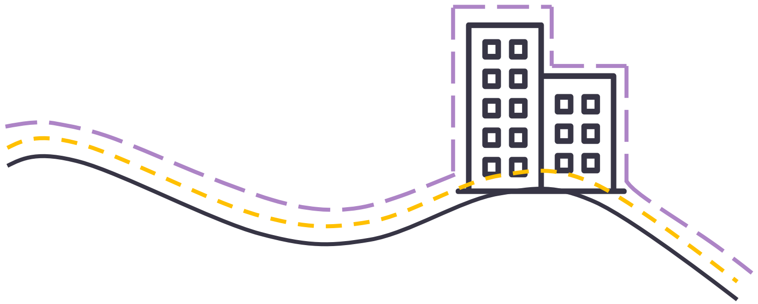
Coastal urban areas…

- …face growing risks to **storm surge flooding,** making **adaptation planning** and **detailed** and **rapid flood assessments** essential for coastal cities
- **Urban areas** are complex environments with many features and structures
- **Modelling of urban areas** requires detailed representation of the surface

Hydrodynamic modelling of urban areas





- **Hydrodynamic models** [at high resolutions] are computationally demanding
- Few studies have assessed which resolution suitable in **urban coastal settings** using **complex** hydrodynamic models [e.g., Le Gal et al., 2023; Ozdemir et al., 2019]

- **Buildings** are often not included in underlying topography
- Methods to include buildings mostly assessed for **river flooding** and using models of **reduced physics** [e.g., Bellos and Tsakiris, 2015; Iliadis et al., 2024]

Find balance between accuracy and efficiency and best practice methods for modelling complex urban areas

Objectives

Provide insights into more efficient hydrodynamic model set-ups in urban areas

Quantify effect of resolution on flood characteristics

Quantify effect of buildings as structures on flood characteristics

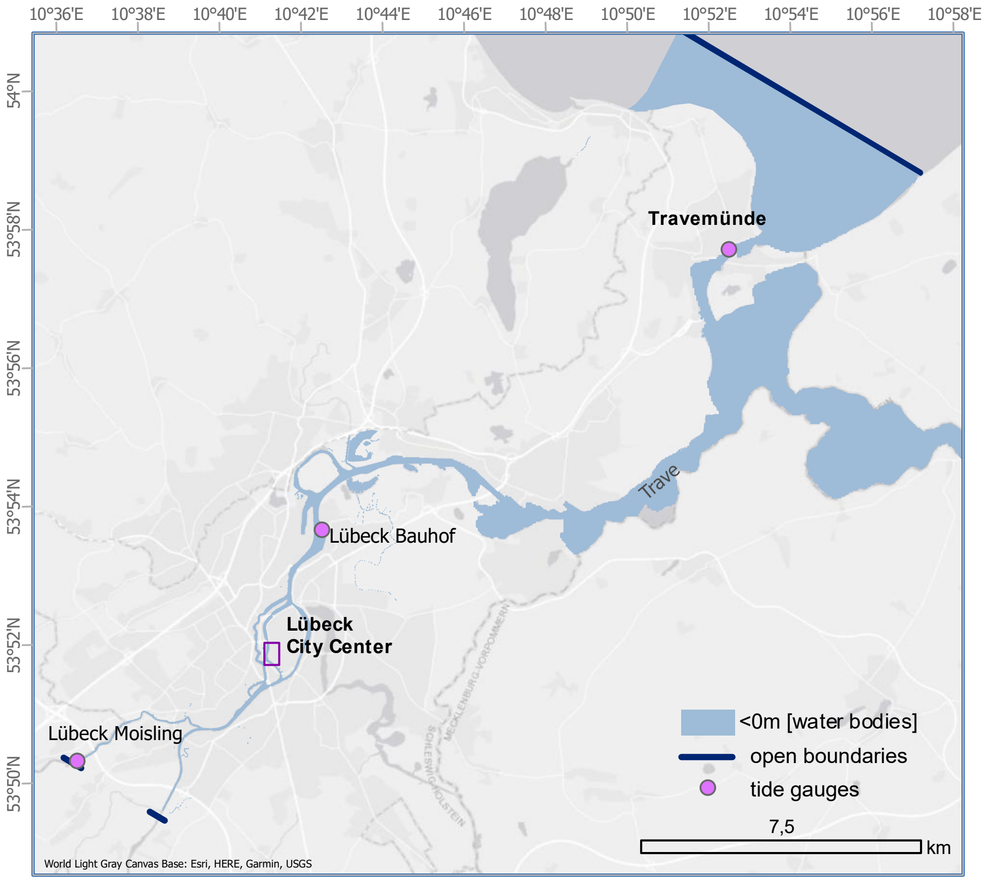
Validate simulated flood extent and flood depth

Storm Babet [German Baltic Sea]

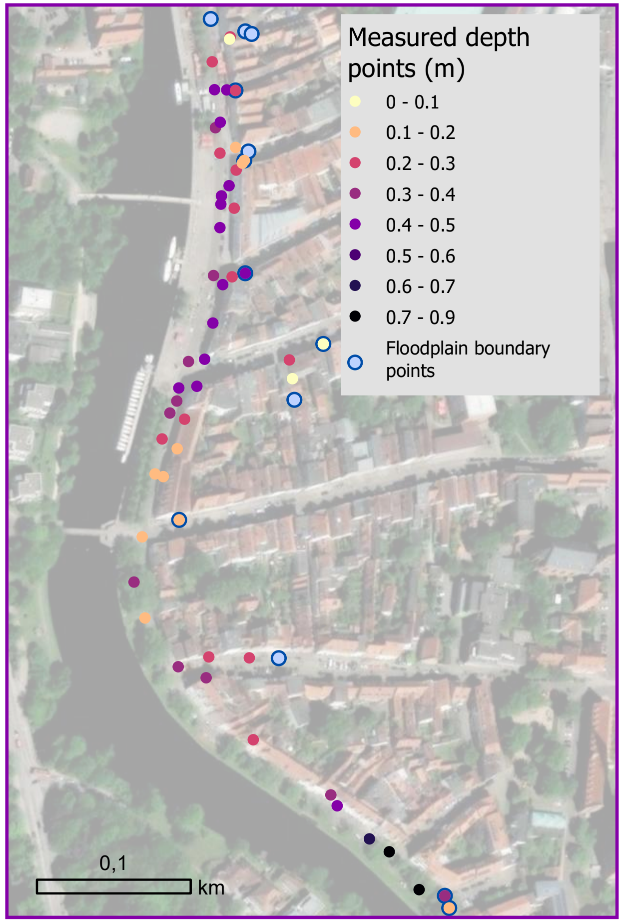
19th – 21st October 2023
Caused damages of up to 200 million € along the coast of Schleswig-Holstein [NDR,2023]

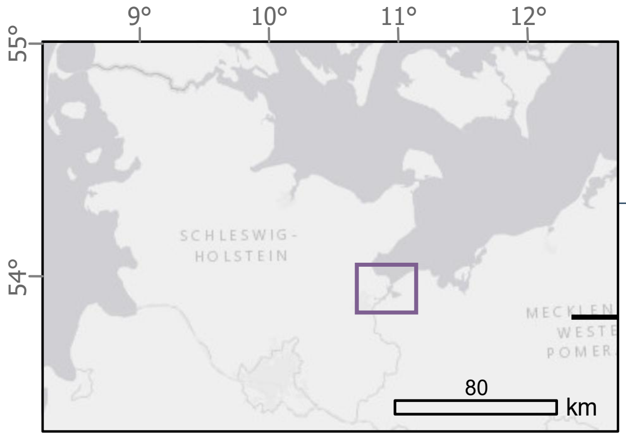
Lübeck: peak WLs of 1.78 m
[20/10/23, ~08:00 pm]

Flood measurements in Lübeck during storm Babet



Flood depth and extent measurements





Hydrodynamic Model [Delft3D] Lübeck

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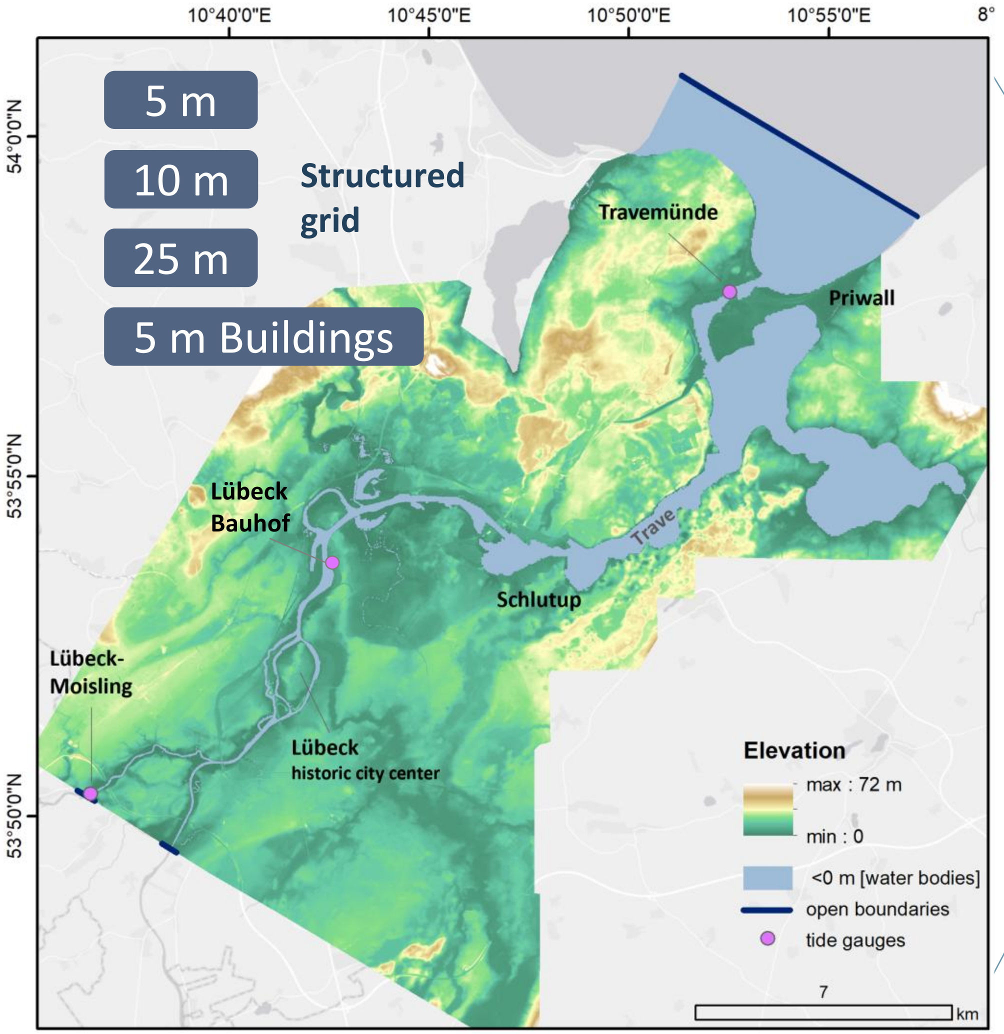
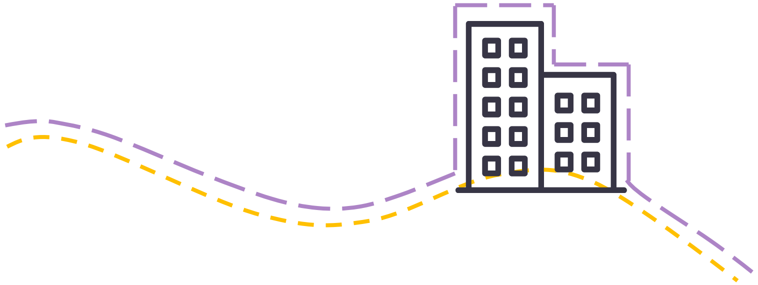


Performance of flood characteristics*

* Flood extent and depth

Overall flood characteristics

ESLs hydrographs [MacPherson et al., 2019]
Storm surge 2023 = 1.78 m
200-year event = 2.55 m



Effect of horizontal resolution

Storm Babet | 5m | 10m | 25m resolutions

a) Model performance

b) Comparison of overall flood characteristics

Model Performance

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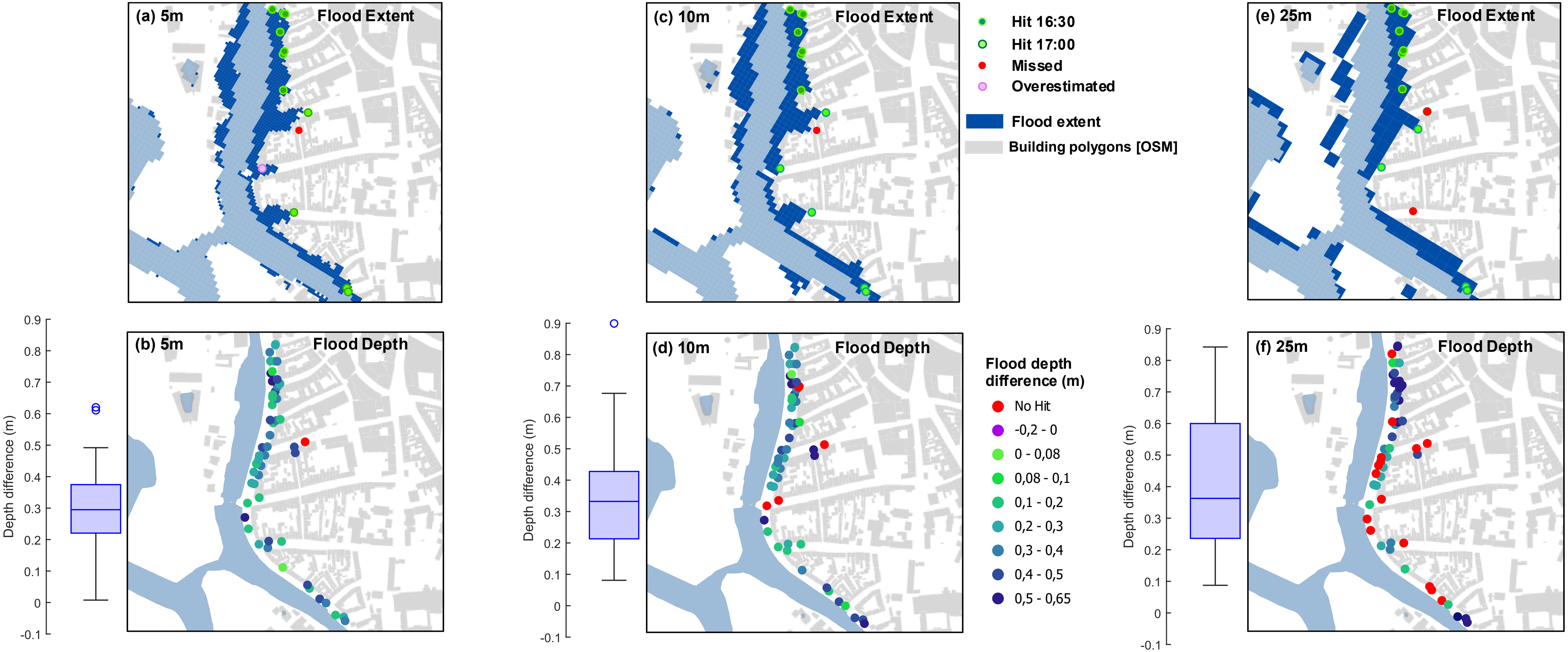
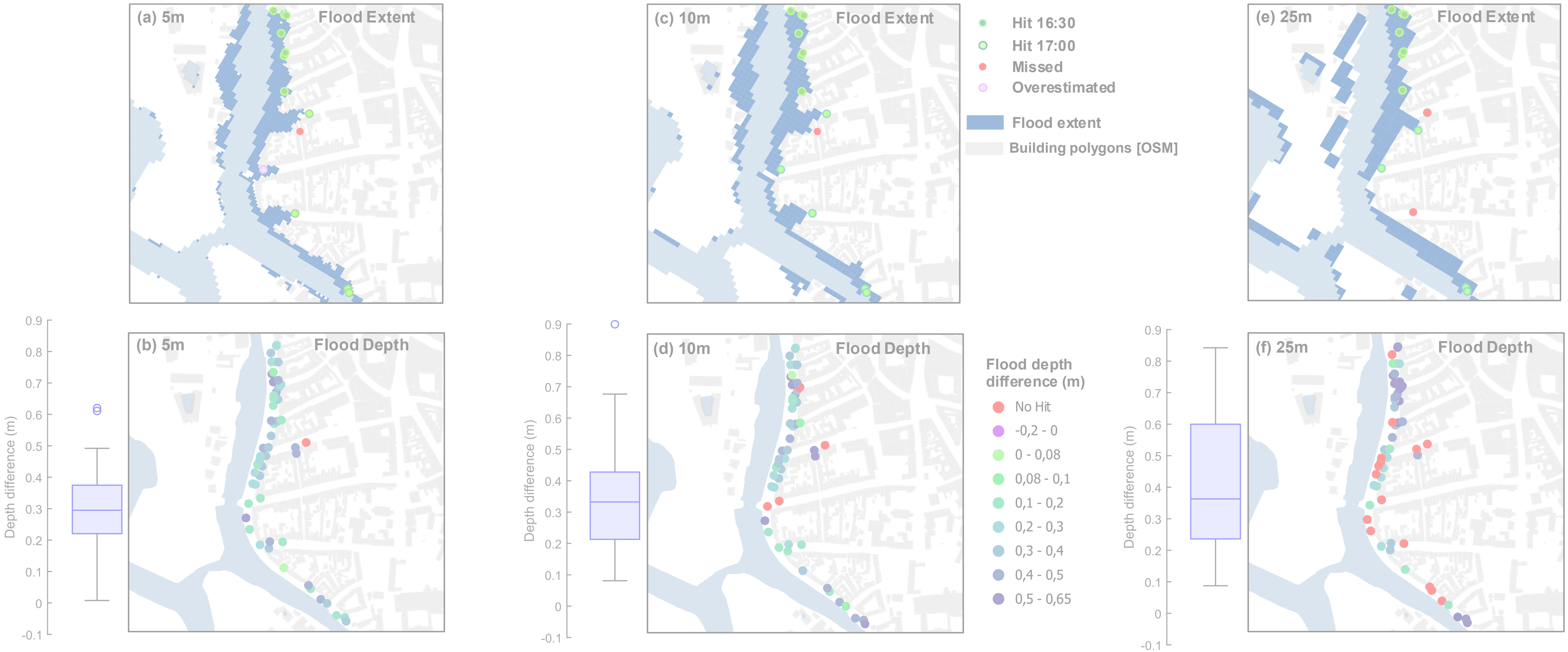


RMSE = 0.37 m

RMSE = 0.37 m

RMSE = 0.46 m

Good and similar representation of flood characteristics at **5 m** and **10 m** resolutions



RMSE = 0.37 m

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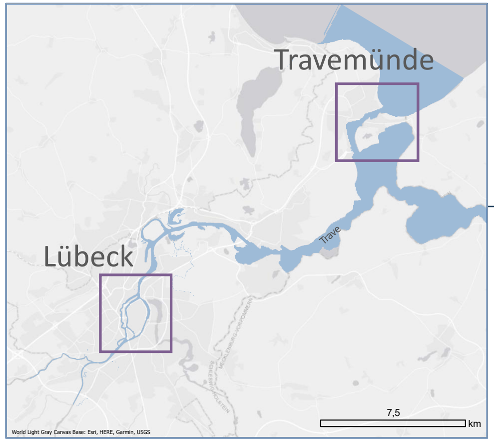

Overall comparison of flood characteristics

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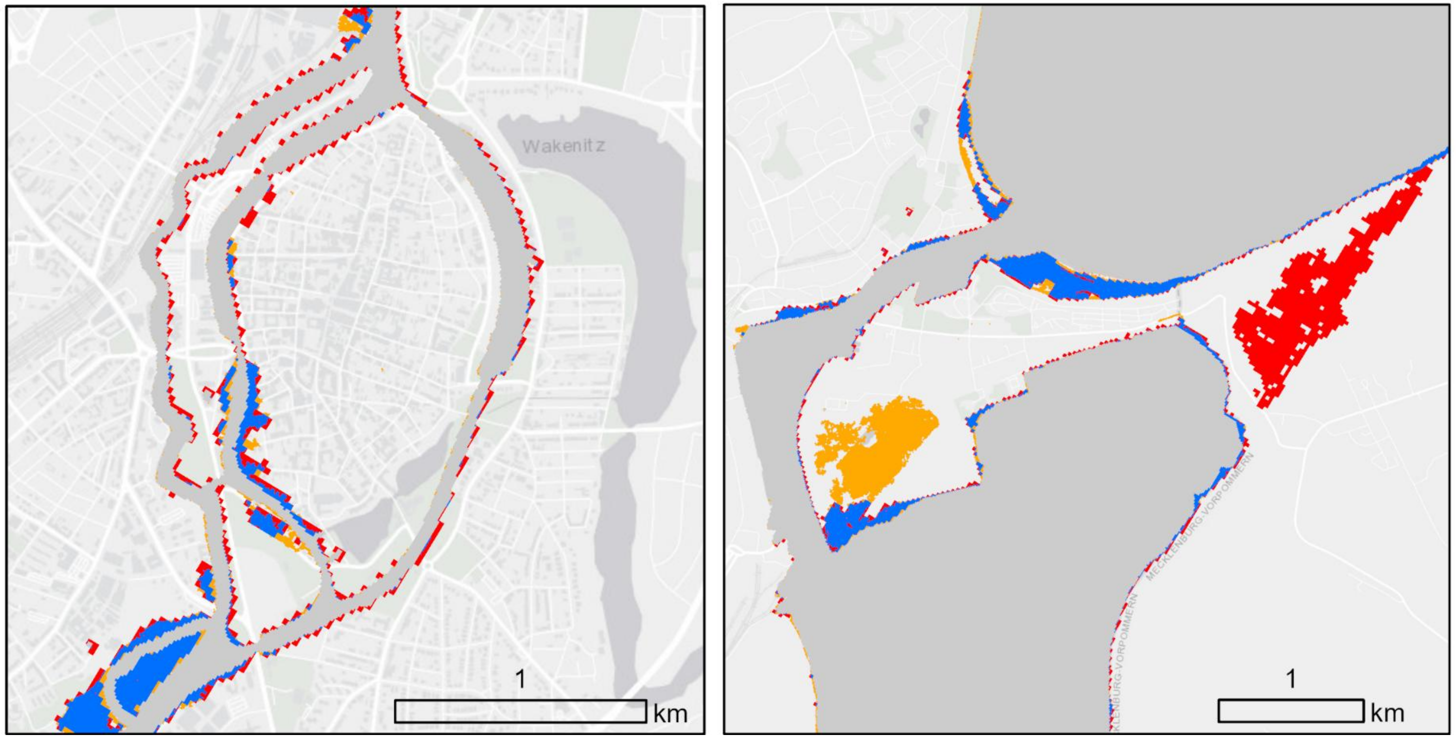
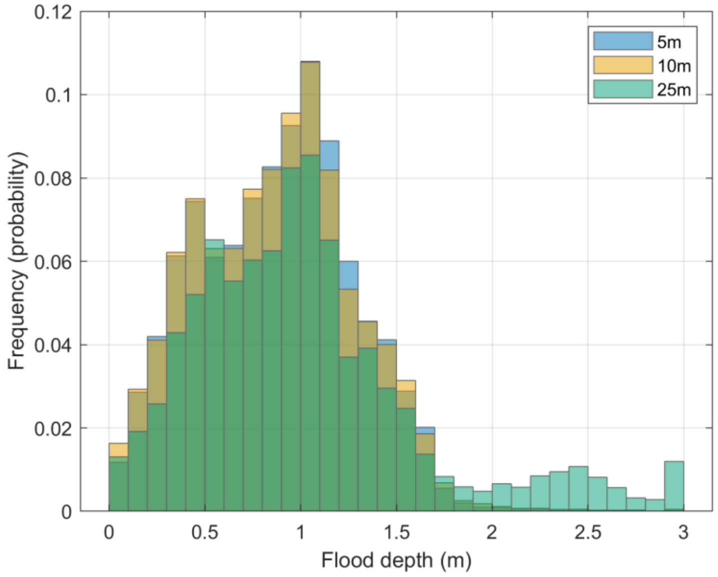
5 m vs. 25 m: 13.6 % difference



Overestimated in 25 Underestimated in 25 m Flooded in both

Threshold resolution to accurately represent flooding?



5 m vs. 10 m

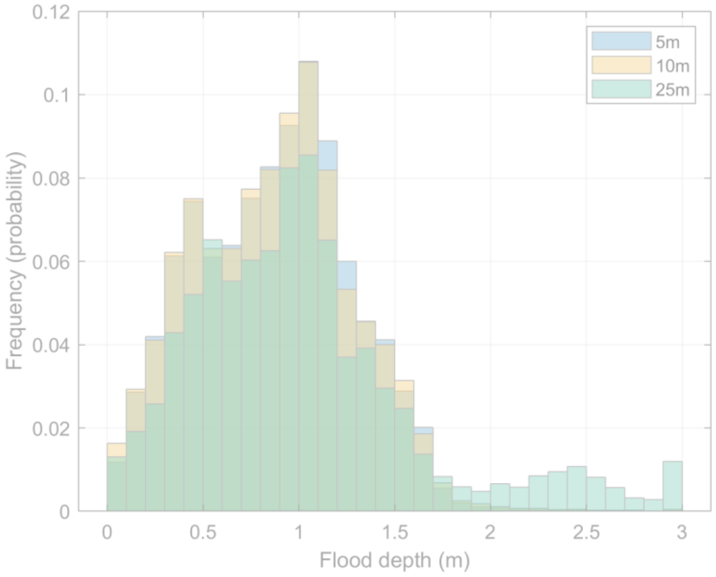
~1 cm difference in mean flood depths

The **10 m** resolution provides a good balance between accuracy and efficiency

Runtime of 10 m resolution 6x faster than 5 m

5 m vs. 10 m

Overestimated in 10 Underestimated in 10 Covered in both



5 m vs. 10 m

~1 cm difference in mean flood depths

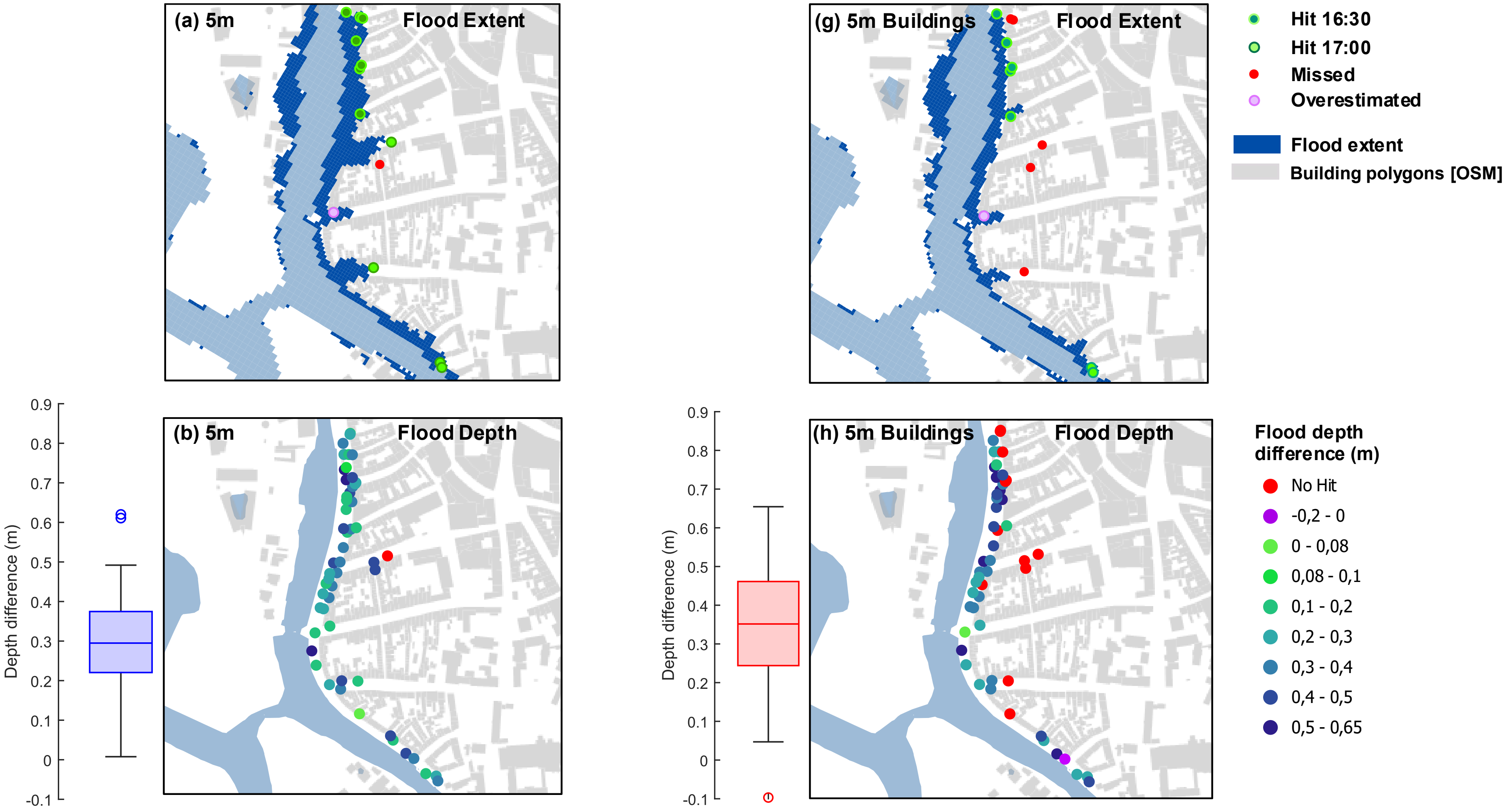
Effect of building representation

Storm Babet | 200-year event | 5 m

a) Model performance

b) Comparison of overall flood characteristics for both events

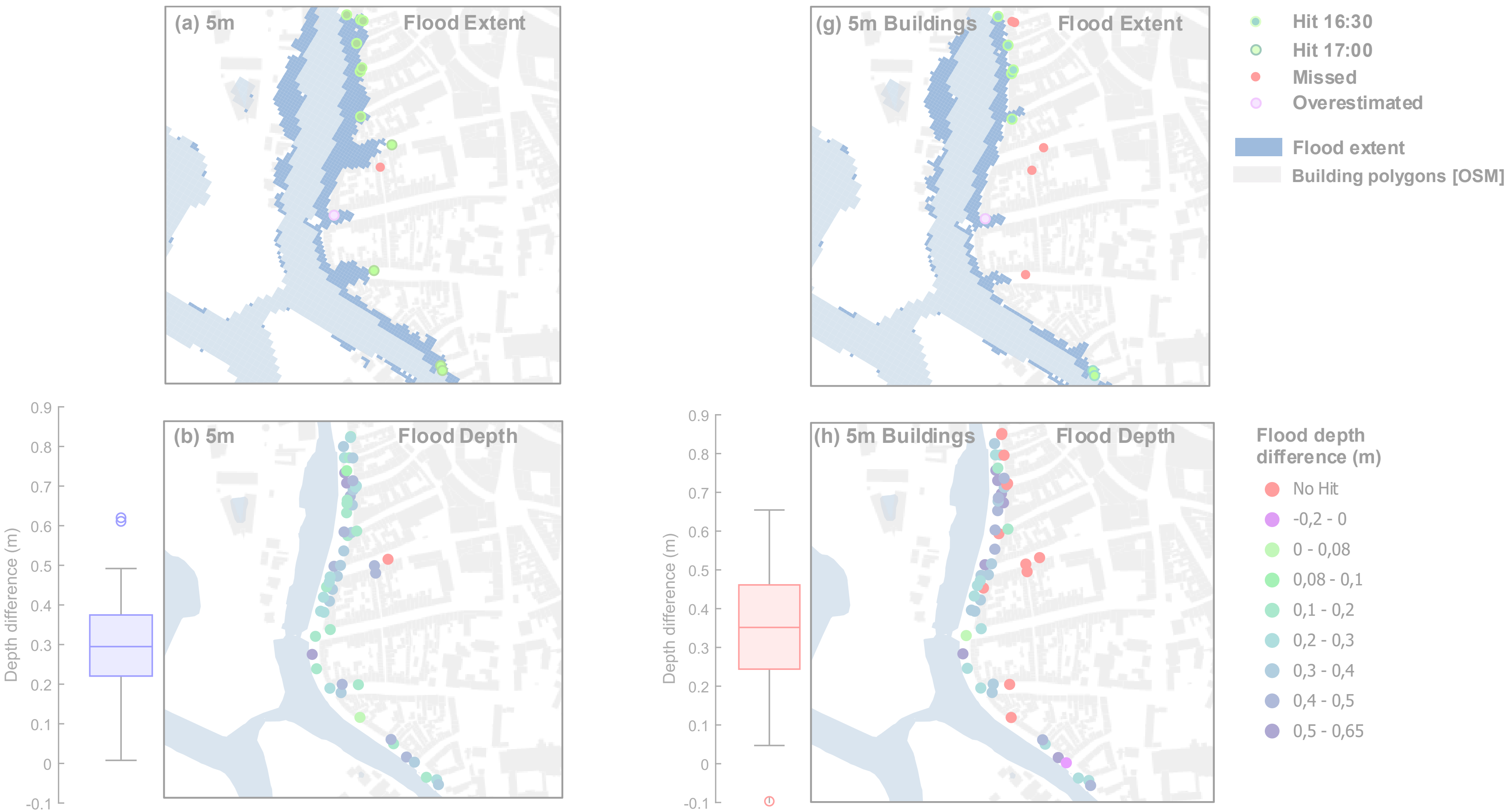
Model Performance



RMSE = 0.37 m

RMSE = 0.42 m

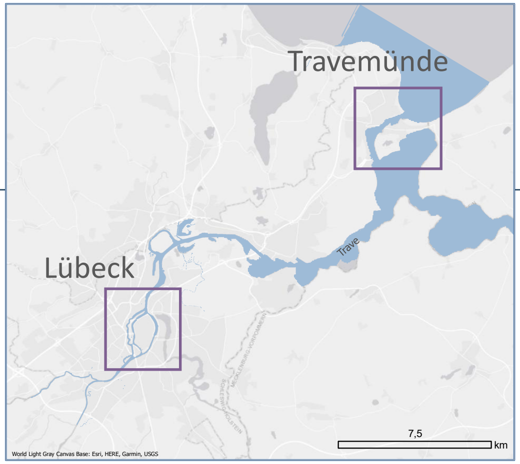
Buildings lead to a **decrease in representation** of simulated flood characteristics and to smaller flood extents



RMSE = 0.37 m

RMSE = 0.42 m

Overall comparison of flood extents



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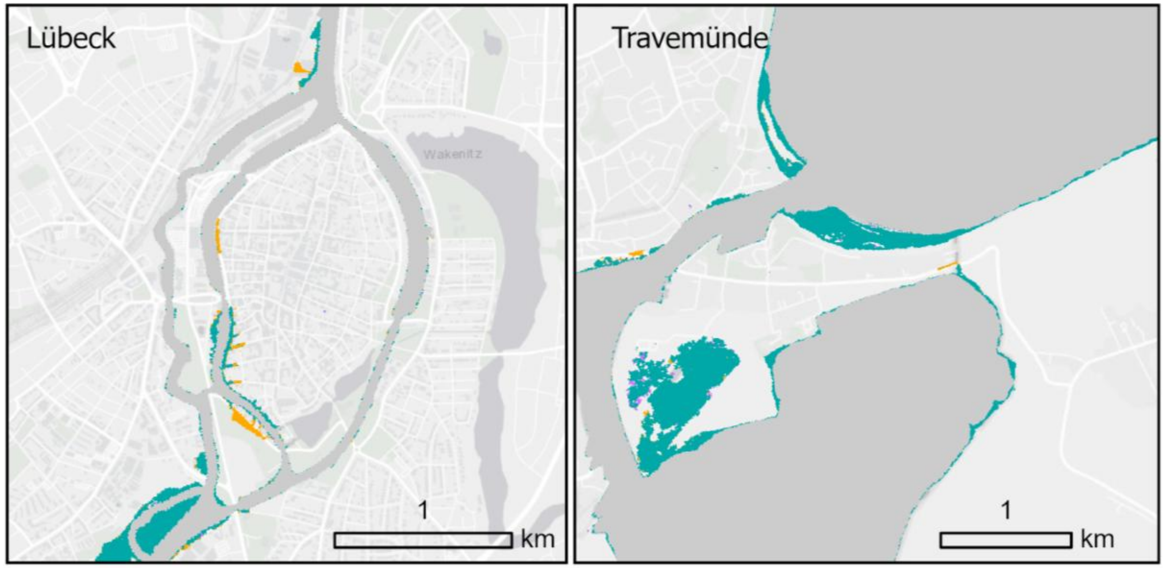
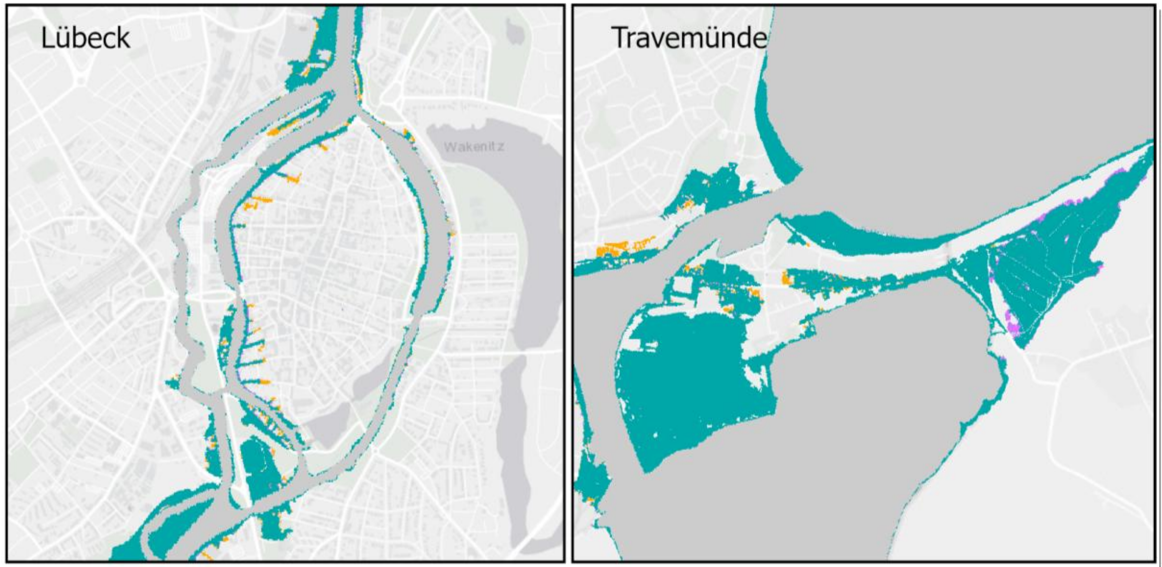
Differences
Flood extent: 0.6 %
Flood depth (mean): 2 cm

Storm Babet 2023



Differences
Flood extent: 1.1 %
Flood depth (mean): 3 cm

200-year event



Only „No Buildings“ | Only „Buildings“ | Flooded in both

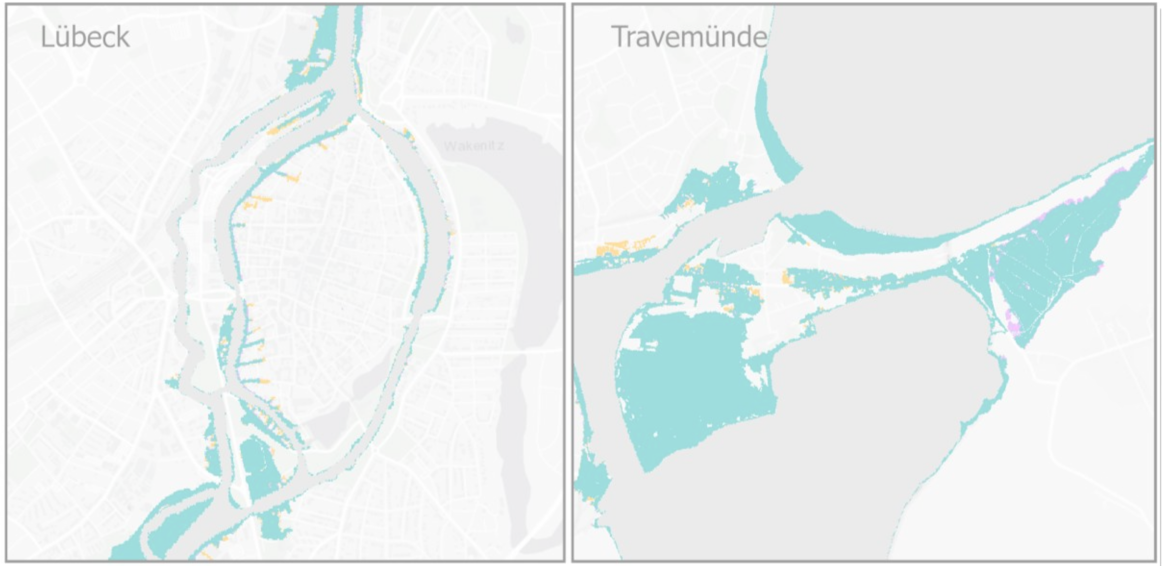
Accurately representing buildings requires **higher resolutions**, as buildings in a 5 m resolution **block** narrow streets…

Differences
Flood extent: 0.6 %
Flood depth (mean): 2 cm

Storm Babet 2023

Differences
Flood extent: 1.1 %
Flood depth (mean): 3 cm

200-year event



Hit   No Buildings   Buildings

Conclusions

Intermediate resolutions (~ 10 m) provide a **good balance** between accuracy and efficiency

Useful for **comprehensive** flood risk assessments or **real-time modelling**

In combination with **high resolutions**, buildings as structures may be suitable for questions that require a **high level of detail**

E.g., flood damage estimates at the building level

On land validation data are essential to assess representations of flood characteristics

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Research Group

Thank you !

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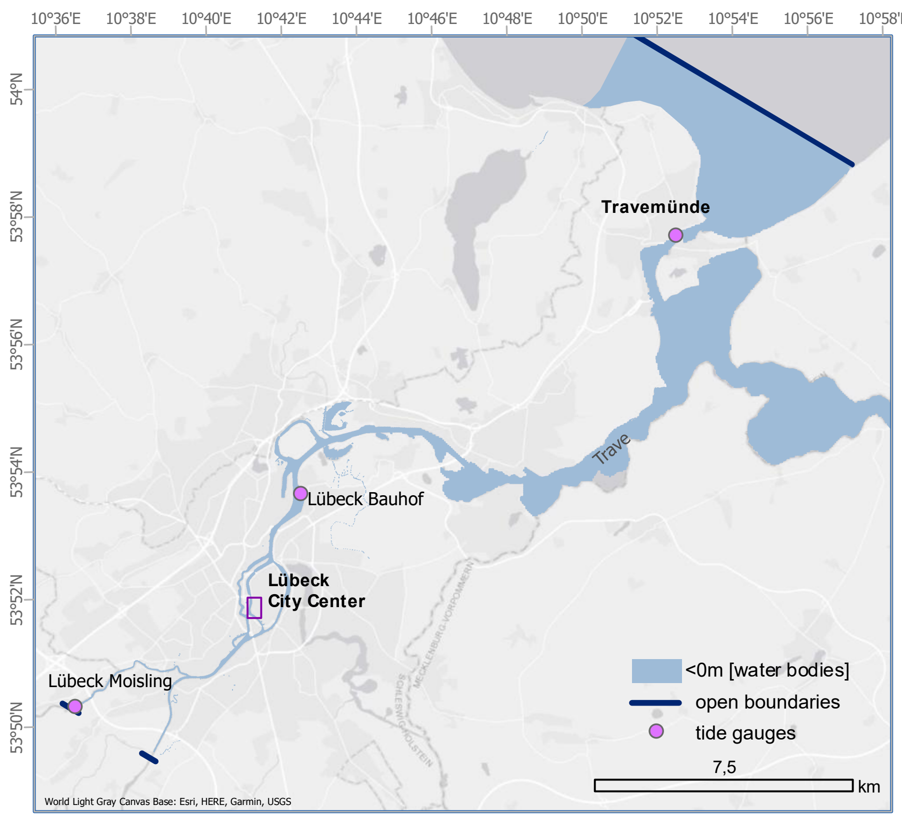
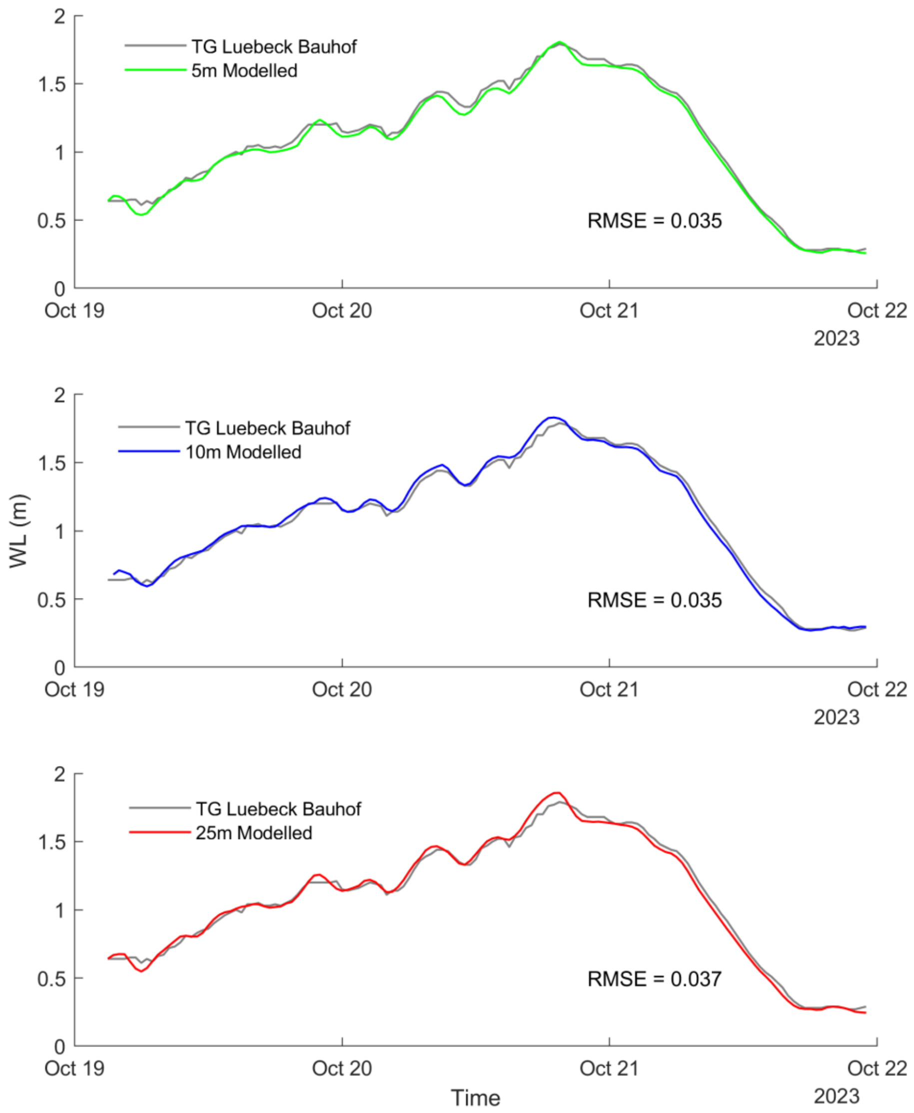
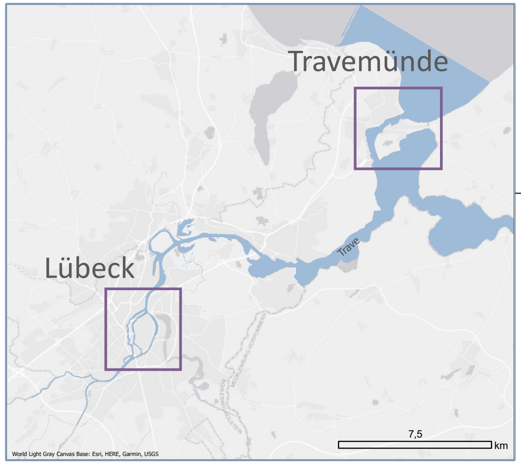
Appendix | Validation at tide gauge







Overall flood depth

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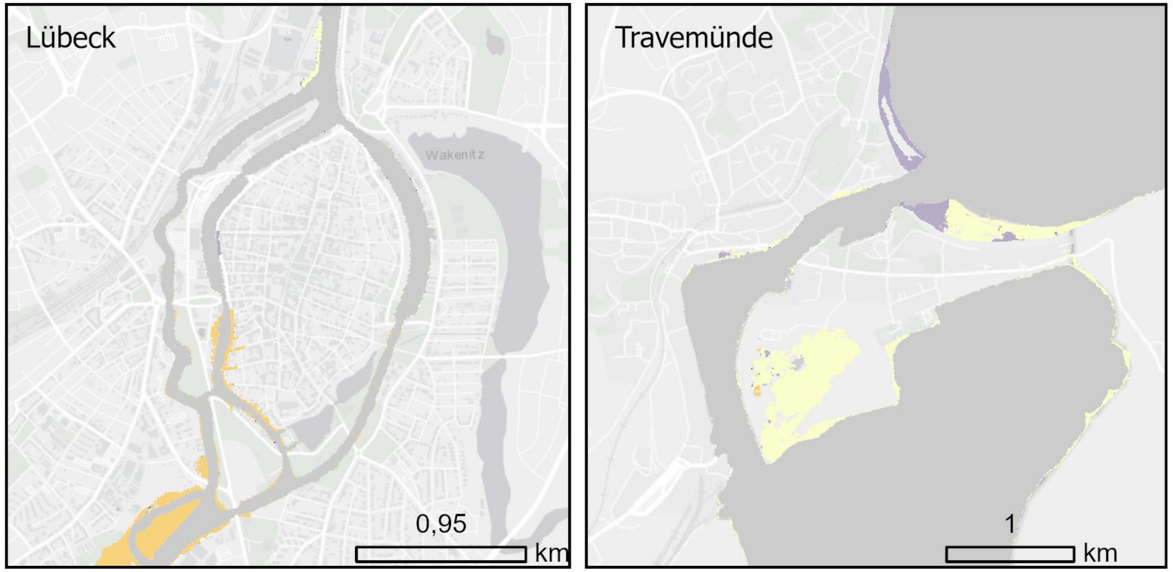
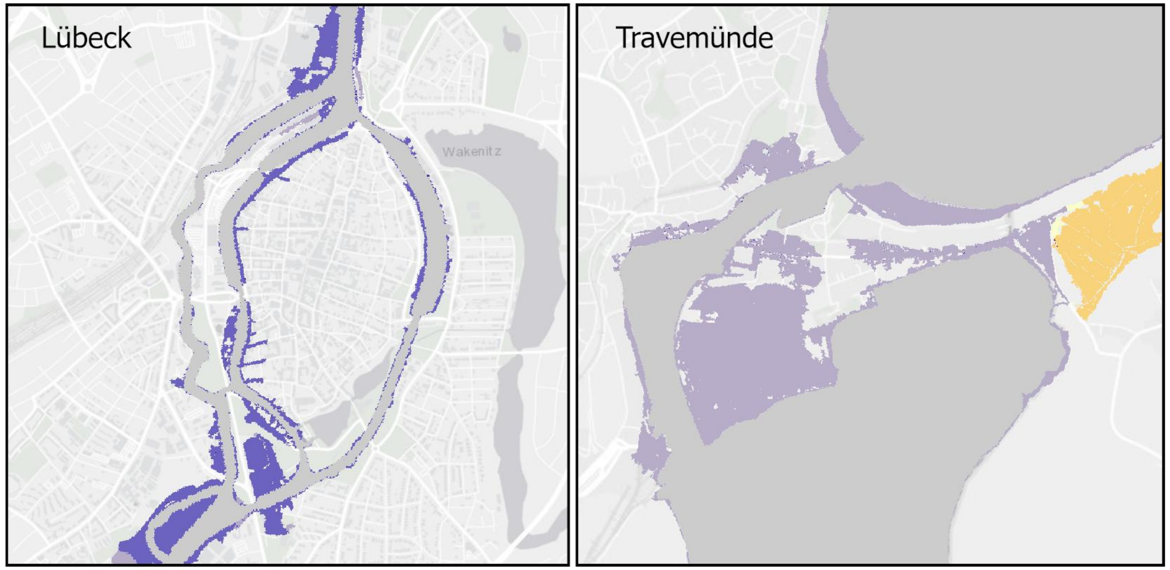
Storm Babet



No Buildings - Buildings

- -0.2 - -0.1
- -0.1- -0.07
- -0.07- -0.05
- -0.05- -0.01
- -0.01- 0
- 0- 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.5

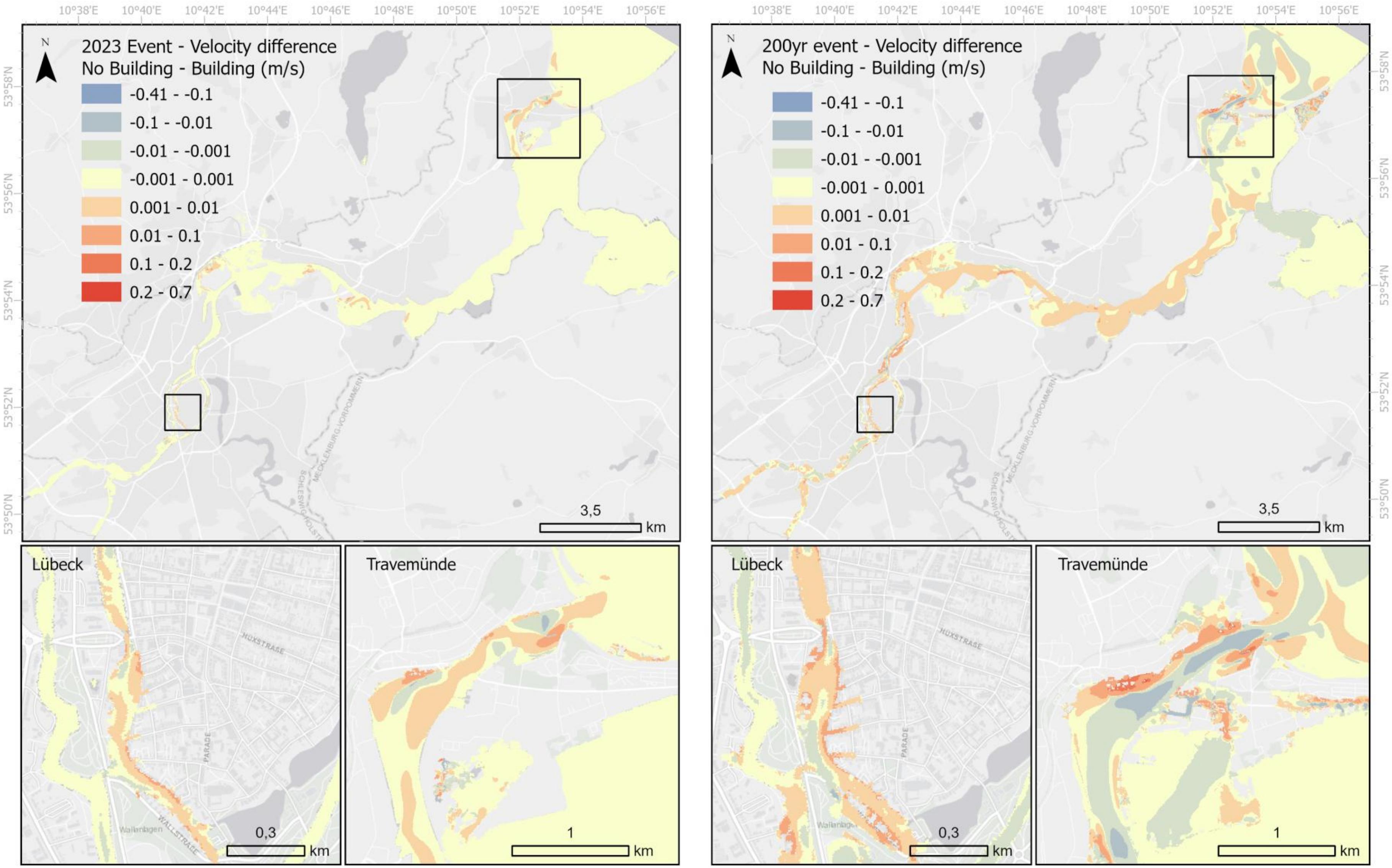
200-year event



No Buildings - Buildings

- -1 - -0.5
- -0.5- -0.3
- -0.3- -0.2
- -0.2- -0.1
- -0.1- 0
- 0- 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5

Flow velocity



Comprehensive flood assessments

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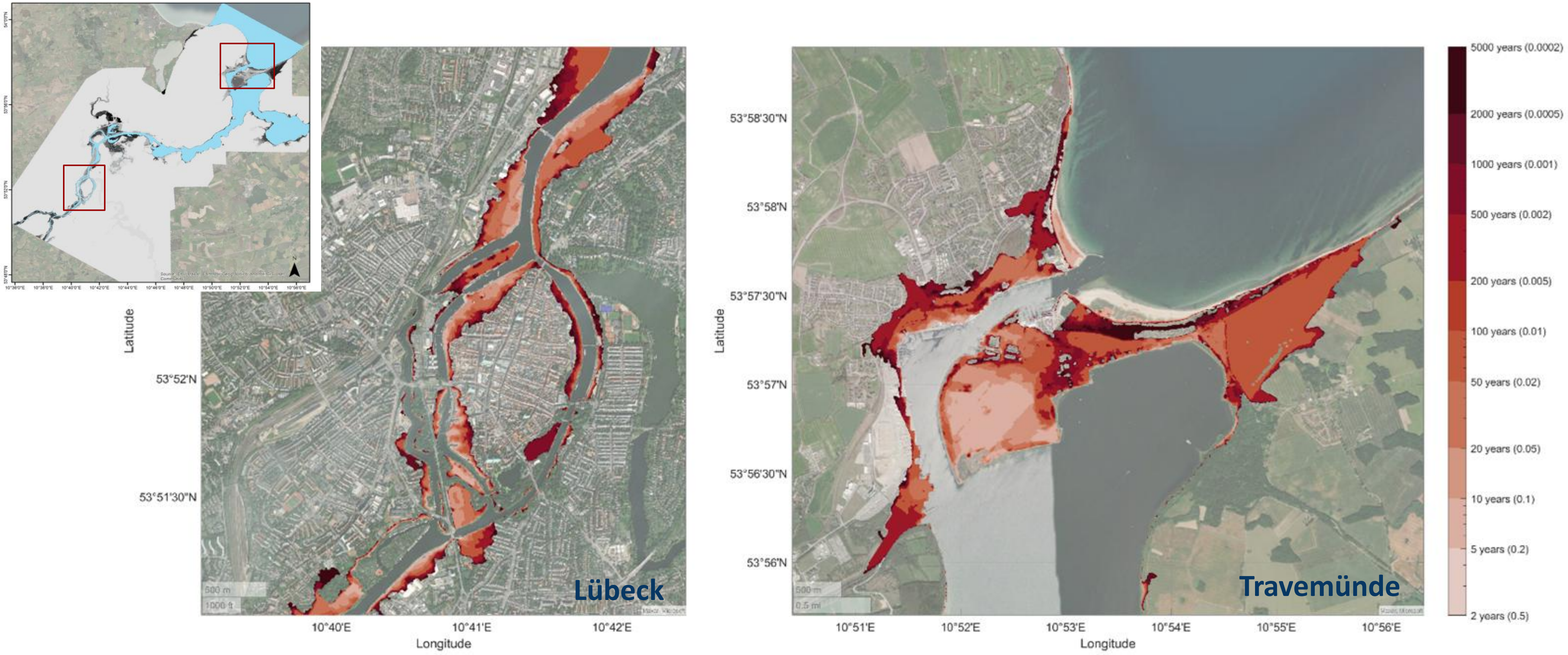
We simulate flooding from 37 ESLs [1.6-3.4 m] covering **return periods** of ~4-3650 years [**111 events**].



Effects of a barrier on flood extents

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