Understanding the impact of varying geometry level of detail in multi-direction urban RANS simulations tailored for urban air-mobility viability.

Akshay Patil & Clara García-Sánchez

3DGeoinformation Research Group, Faculty of Architecture & the Built Environment,

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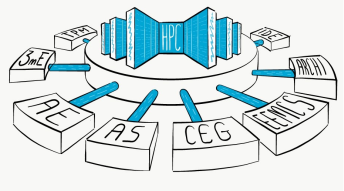
Funded by
the European Union

This Project has received funding from the European Union's HORIZON Research and Innovation Programme under Grant Agreement number 101096698



Carbon Footprint Statement

This work used the DelftBlue supercomputer and had an estimated footprint of 1051kg CO_2-equivalent (at least if not higher) using the Green Algorithms (http://calculator.green-algorithms.org/). This is equivalent to taking 0.65 flight(s) from New York (U.S.) to Melbourne (Australia).

Motivation

+

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- Car-centric built environment
  - SO_x & NO_x concentration worsen (*Wolf et al. 2020*)
- EU Response: Lower CO_2 acceptable limits (*Fit for 55, Council of the EU 28/03/2023*)
- Vertical extensions – Wind loading concern

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Potential (Partial) Solution?

UAV's as alternatives to last-mile transit (*Elsayed & Mohamed, 2020; Lemardelé et al. 2021; Cui et al., 2024*)

Research Focus

Challenges*

- Turbulent flow in urban built environments
  - Large dependent parameter space
  - Flow response is complex

$$Q = \mathcal{L}(\wp_i)$$

$$\wp_i \sim \mathcal{O}(10^1)$$

*To list a few

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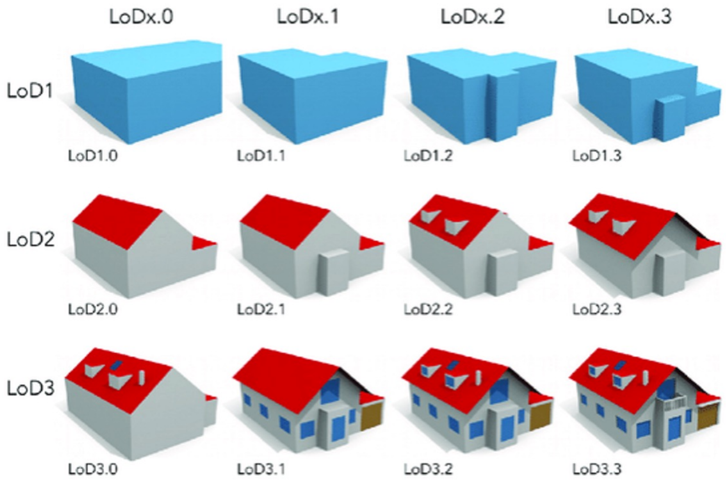

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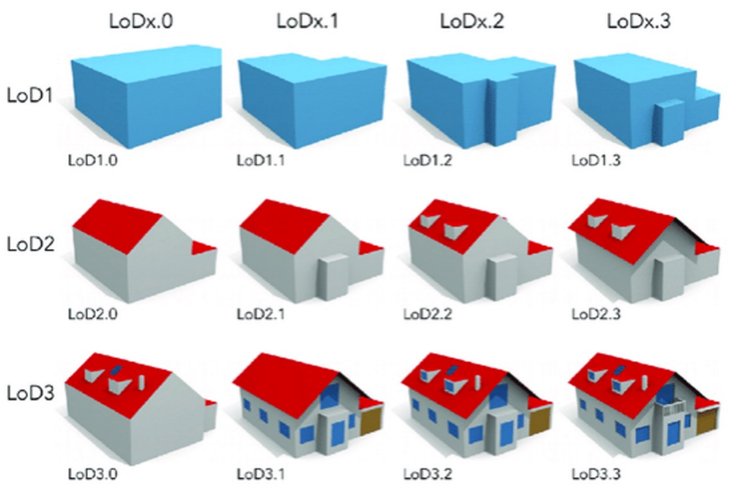

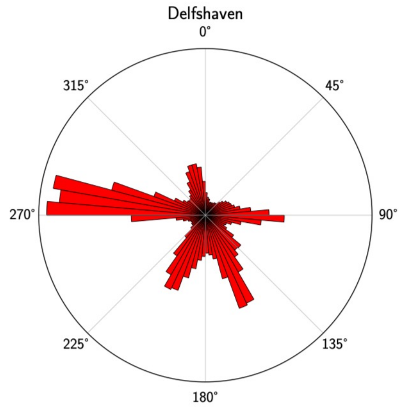

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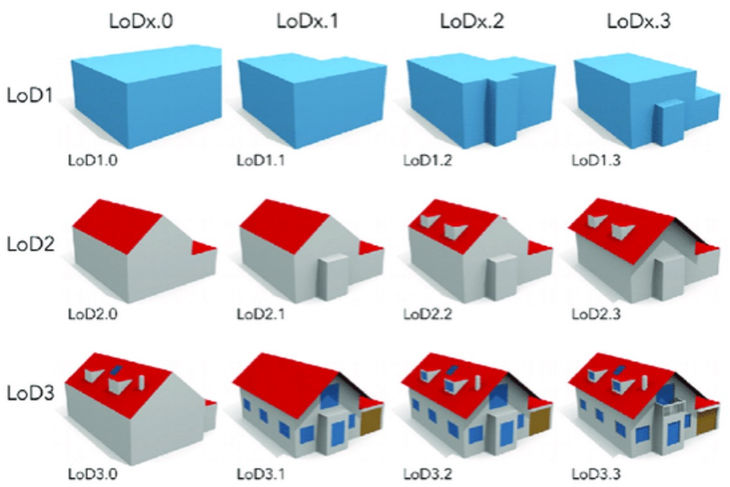

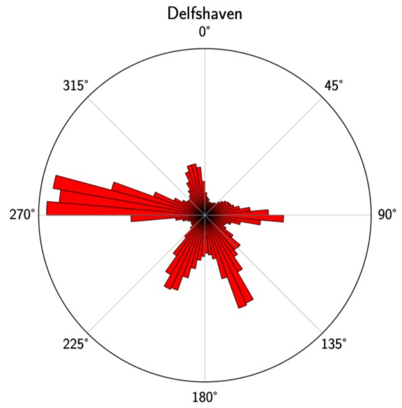

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Reynolds-Averaged Navier-Stokes framework

- Neutral Boundary Layer

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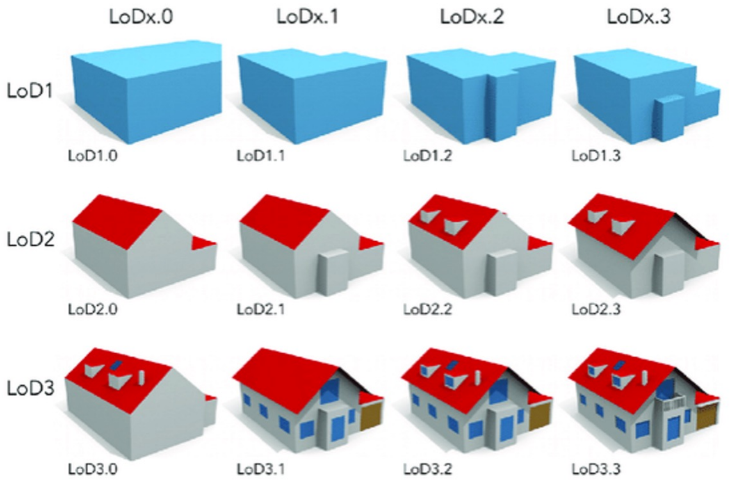

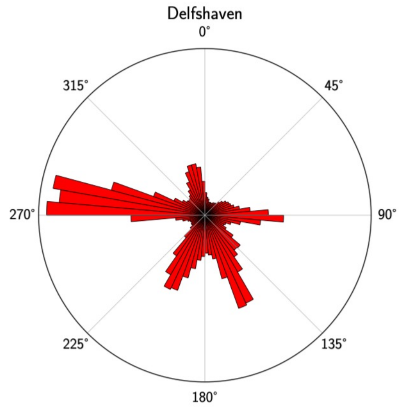

Understand and quantify the hydrodynamic response as a function of building resolution and wind incidence

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Steady-State RANS equations – Finite Volume + SIMPLE

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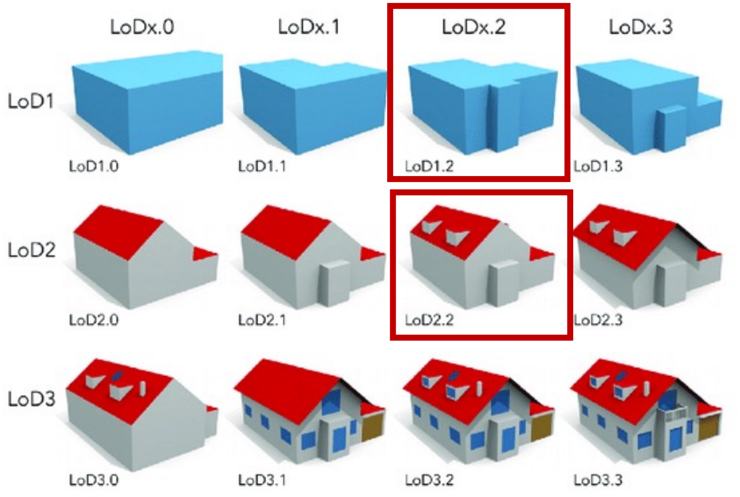

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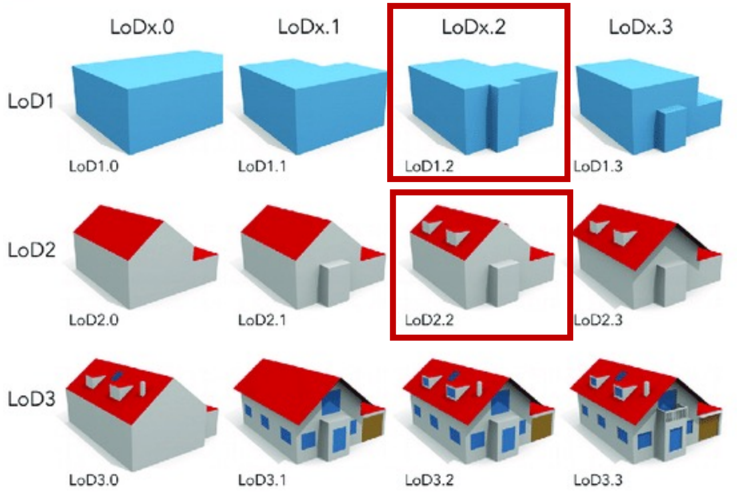

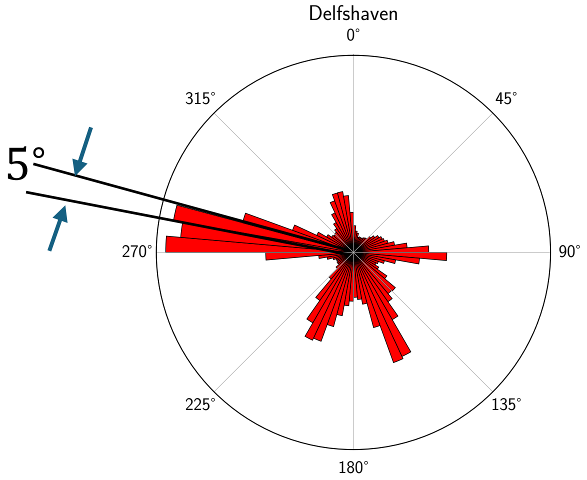

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- Two equation closure (K-Epsilon)
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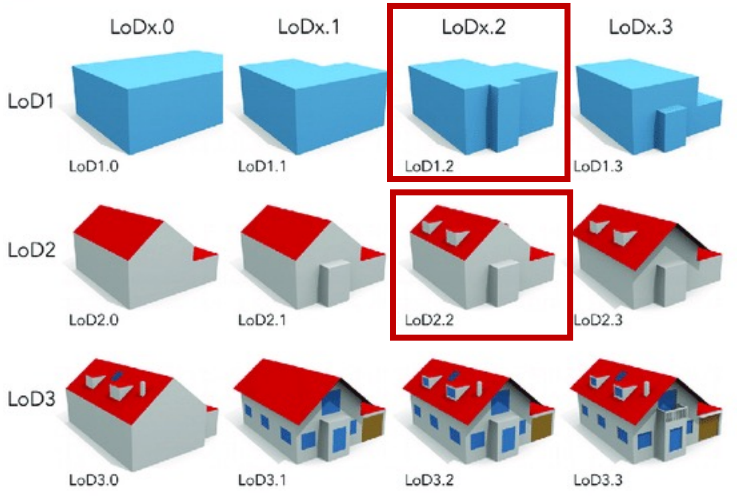
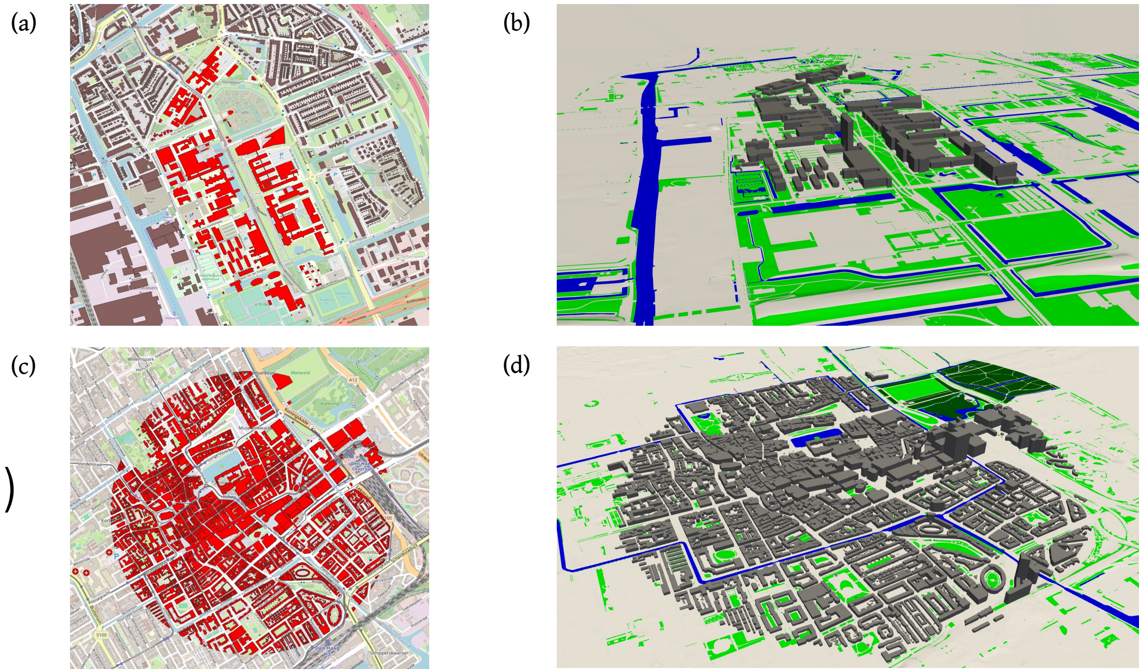
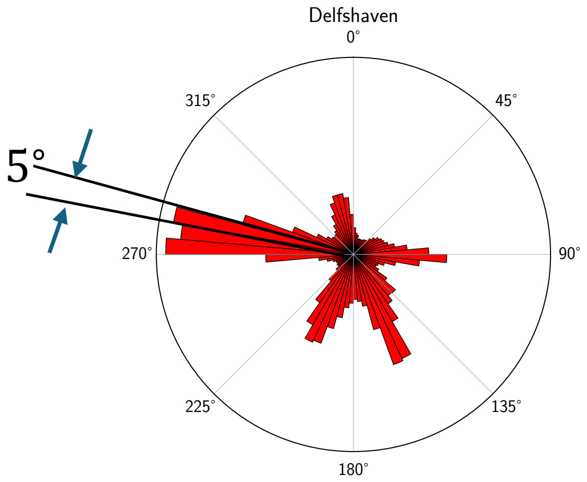


TU Delft Campus



Den Haag (The Hauge)



Building reconstruction using City4CFD (Pađen et al., 2022)

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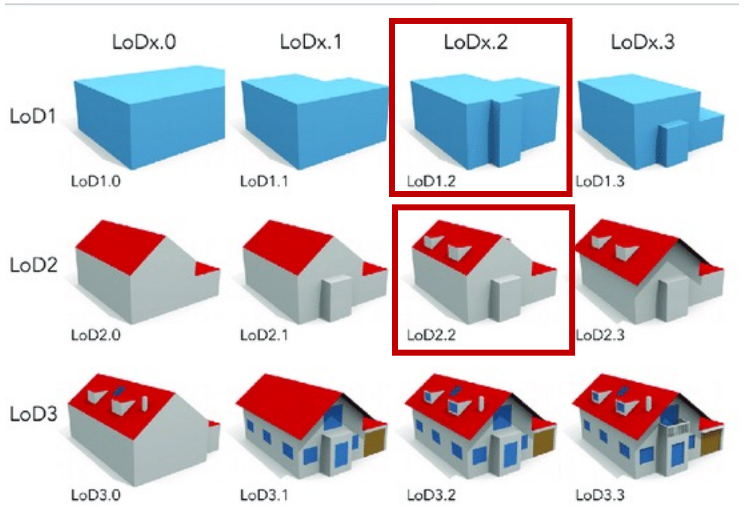
- Total of 4 x 72 = 288 simulations



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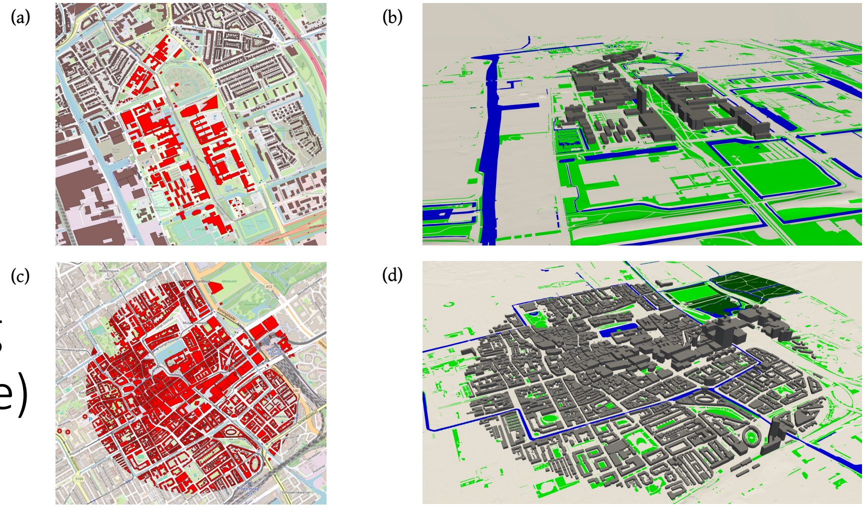

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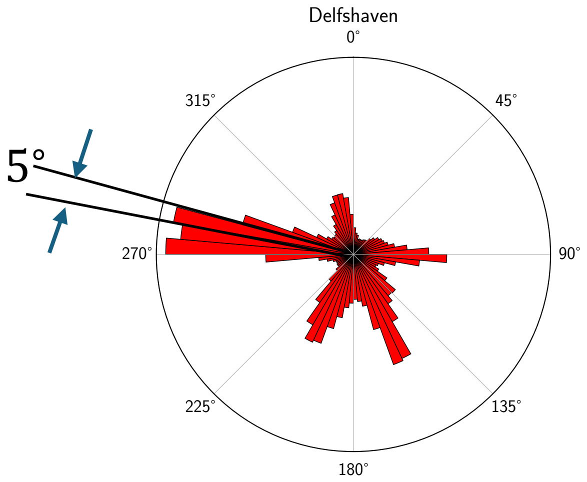

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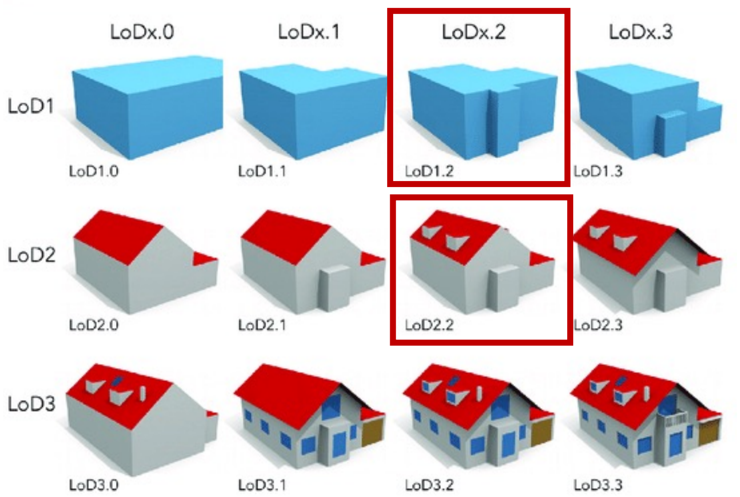
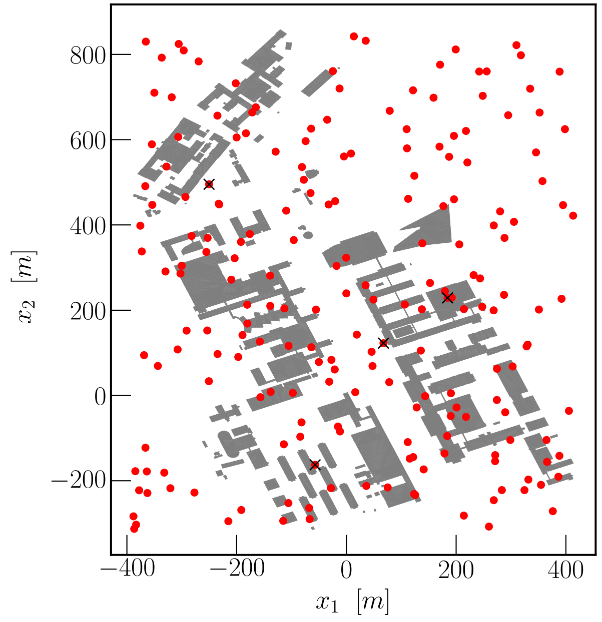
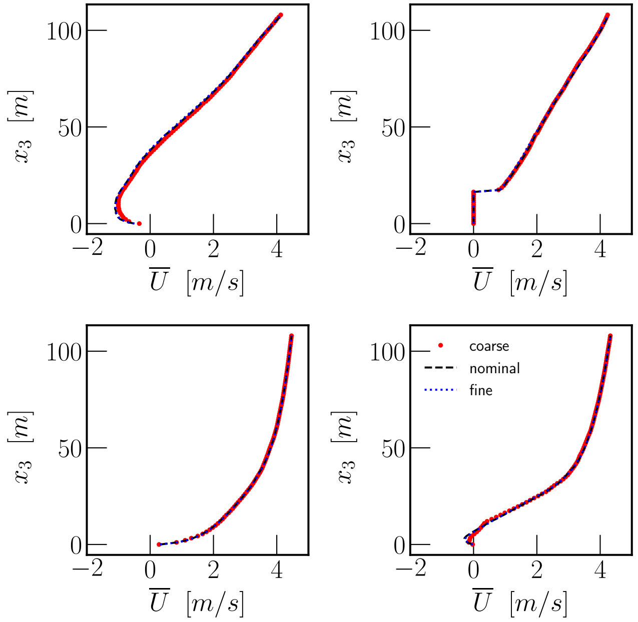
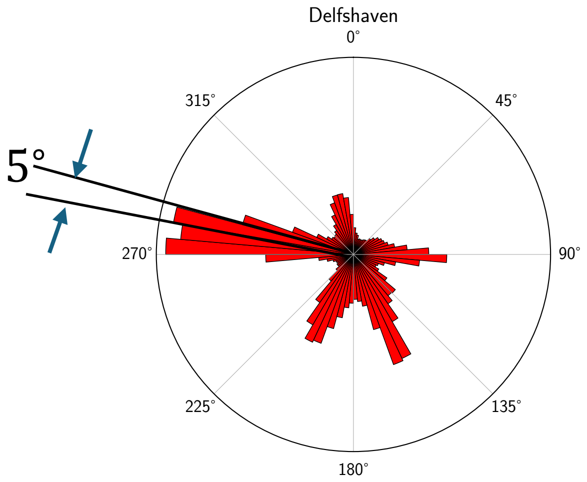




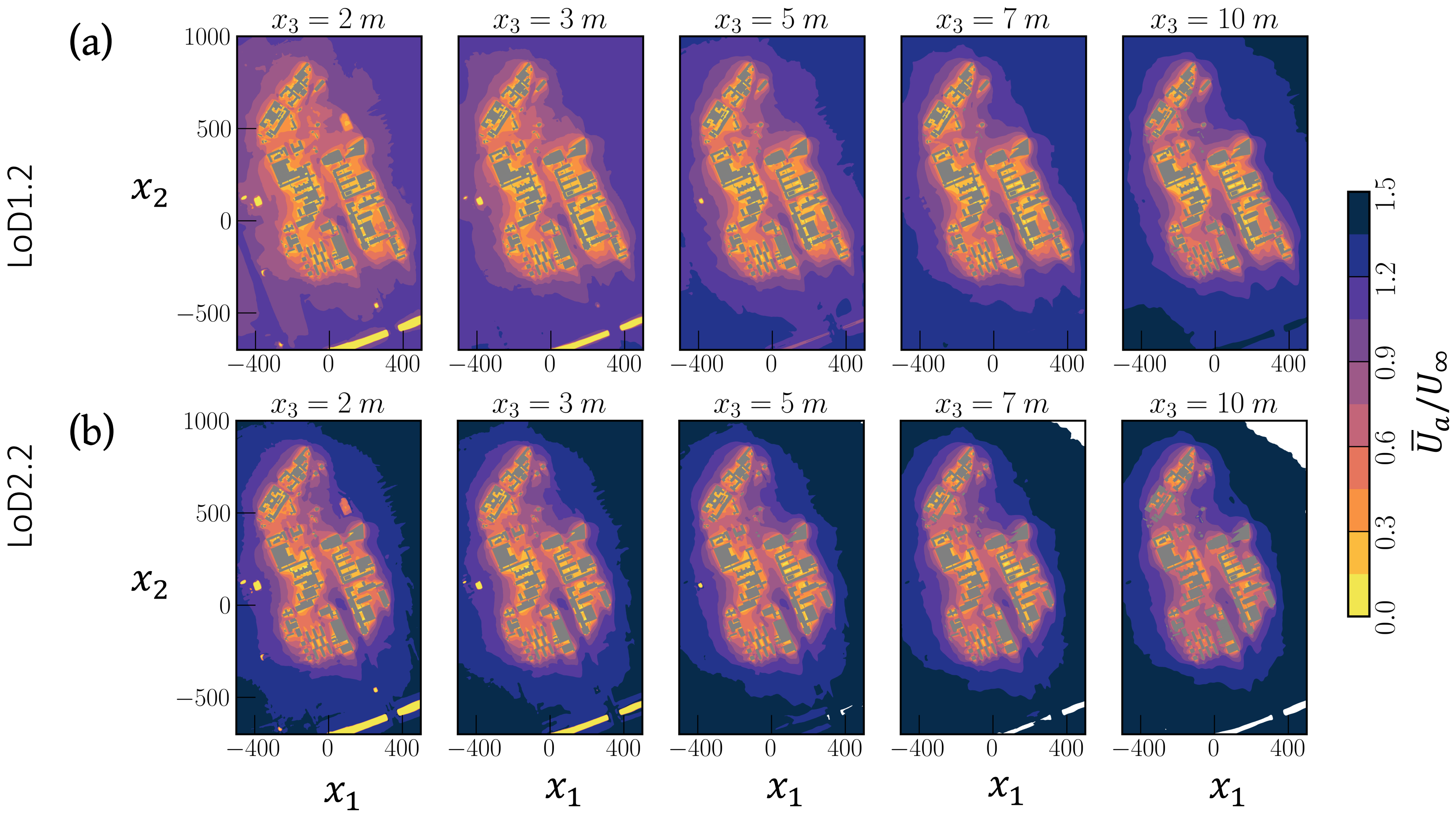




Results: Average Velocity

Case: TU Delft campus

$$\overline{U_a} = \frac{1}{N_\theta} \Sigma_{i=1}^{i=N_\theta} w_i |U_i|$$



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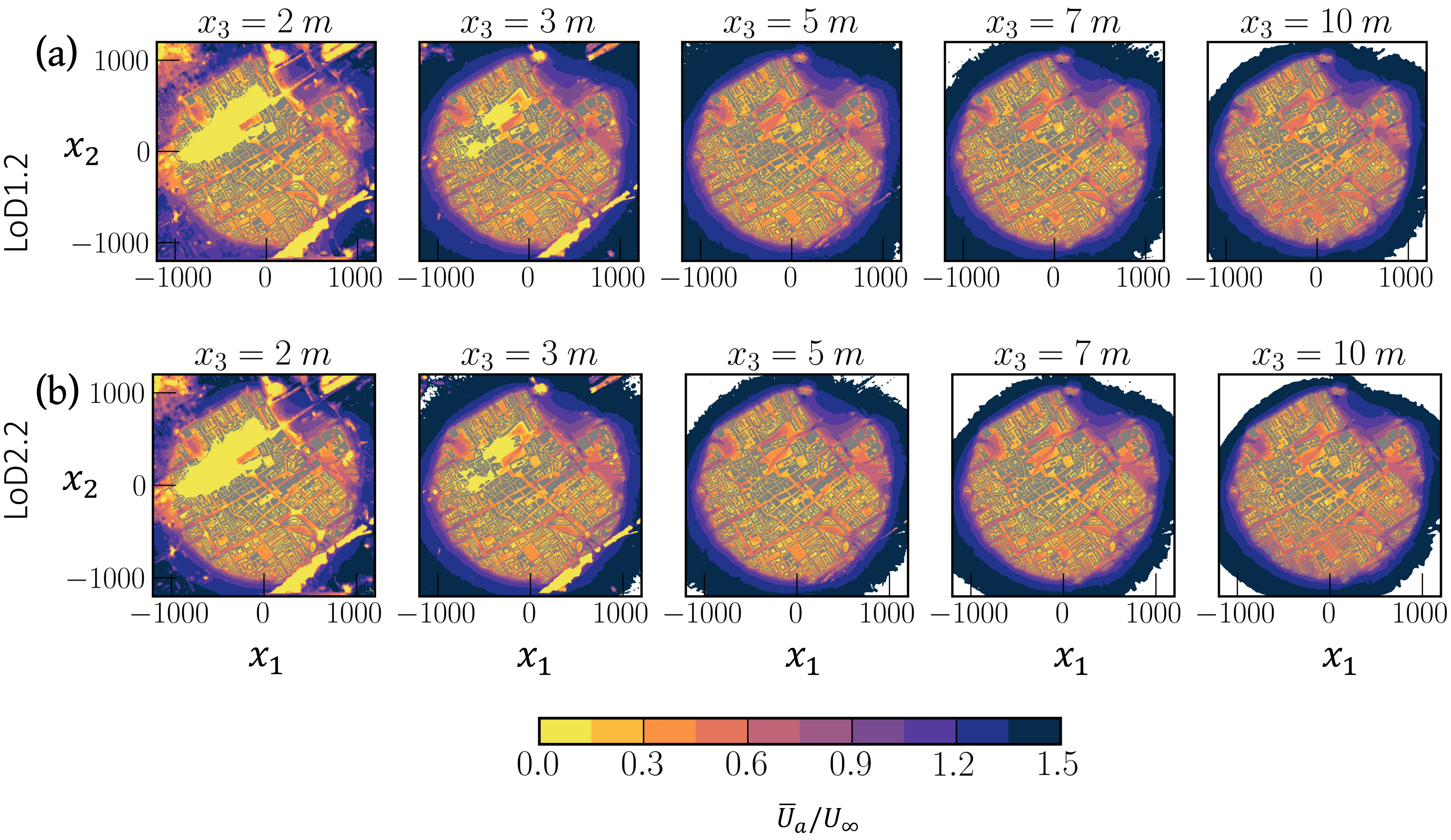

Results: Risk Map

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$$P_r \equiv P(U^* > \alpha \cap k^* > \beta)$$

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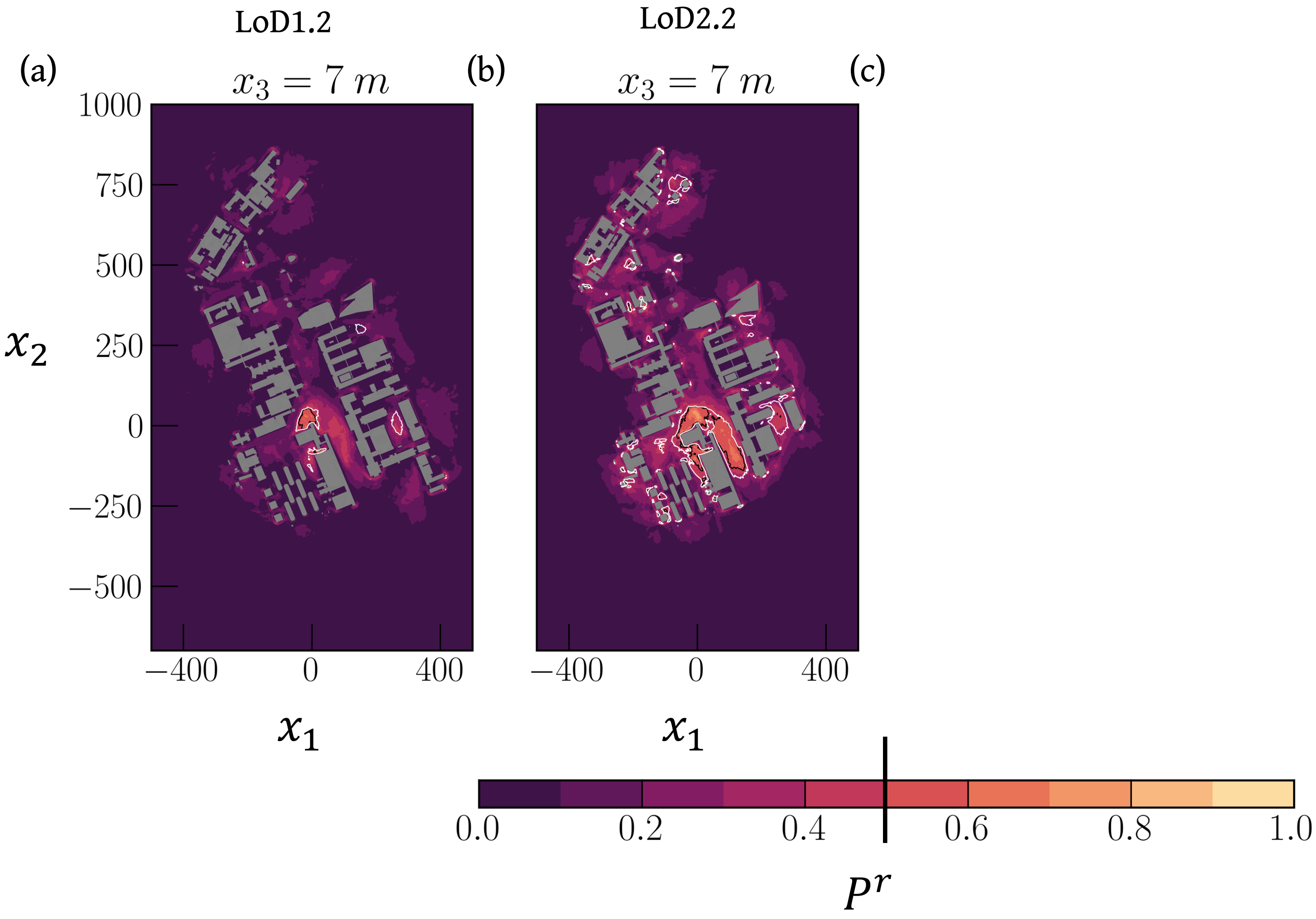

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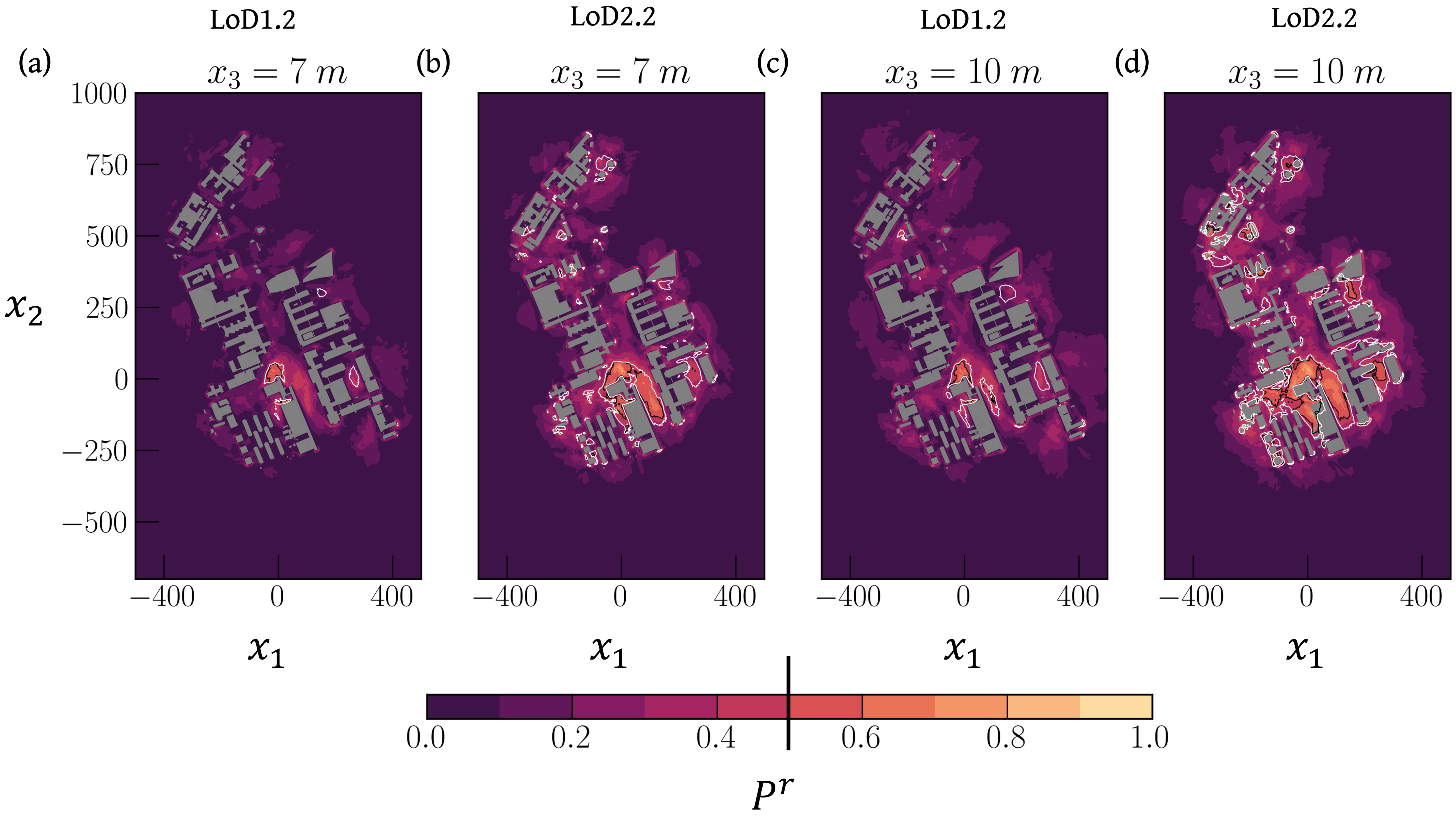

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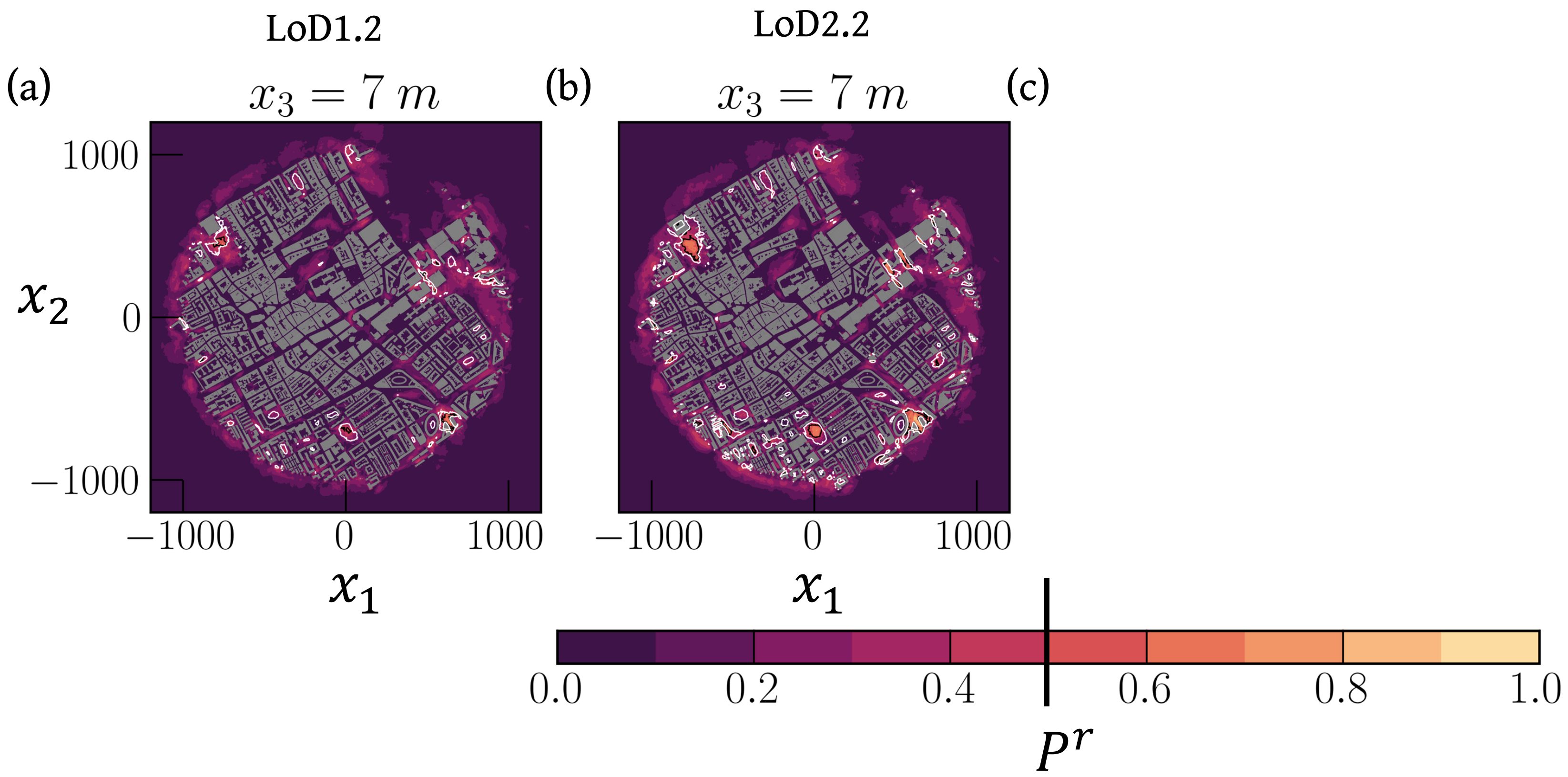

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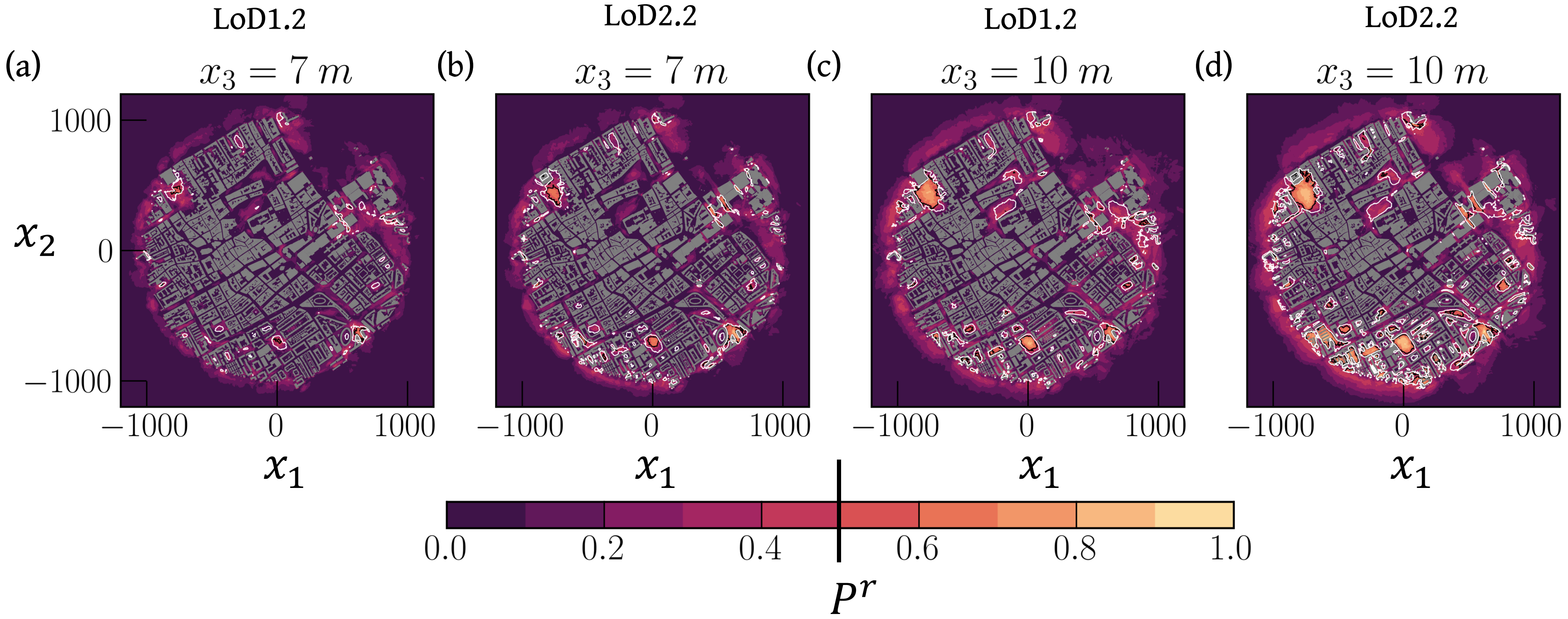

Results: Angular Resolution - Sensitivity

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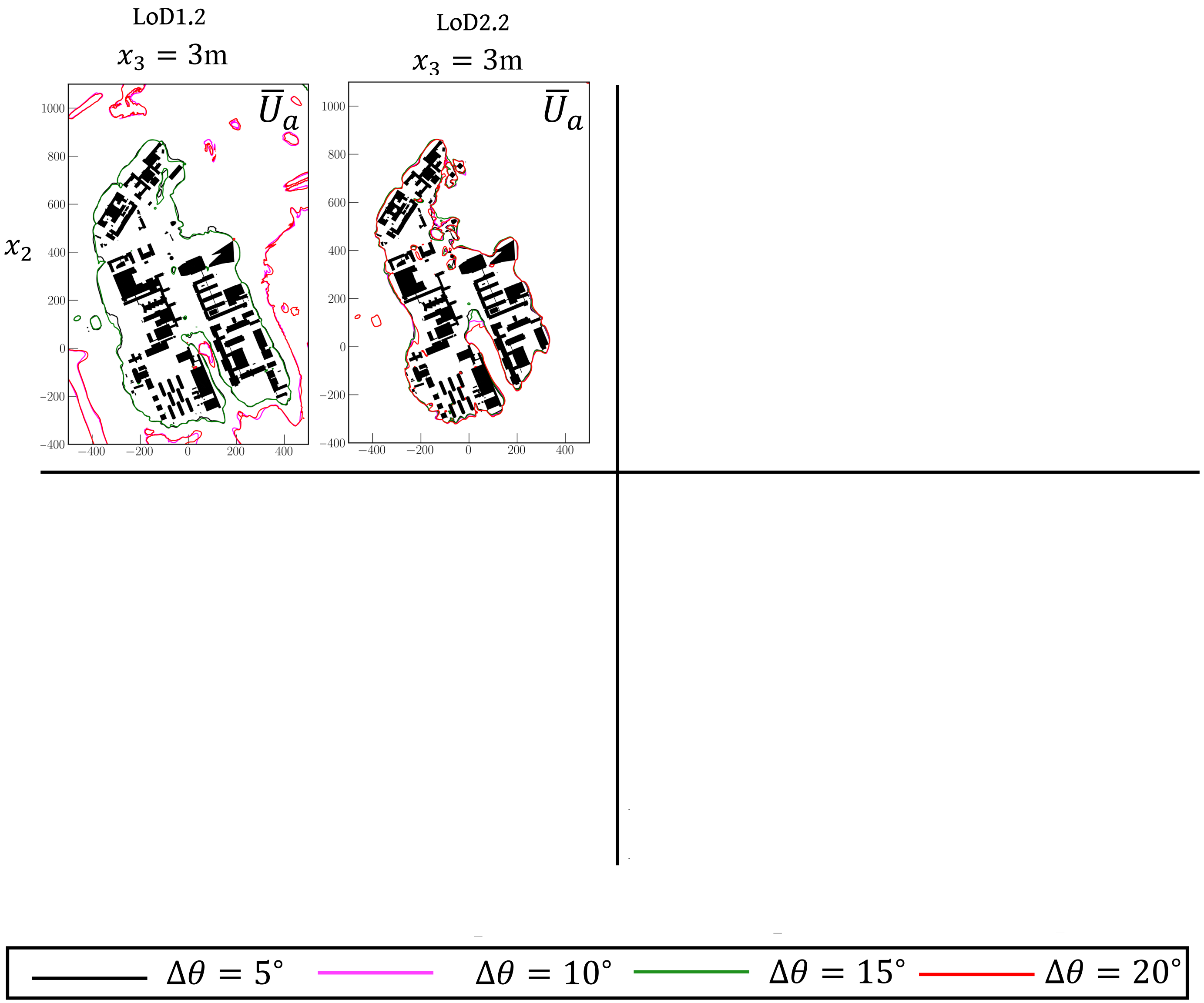

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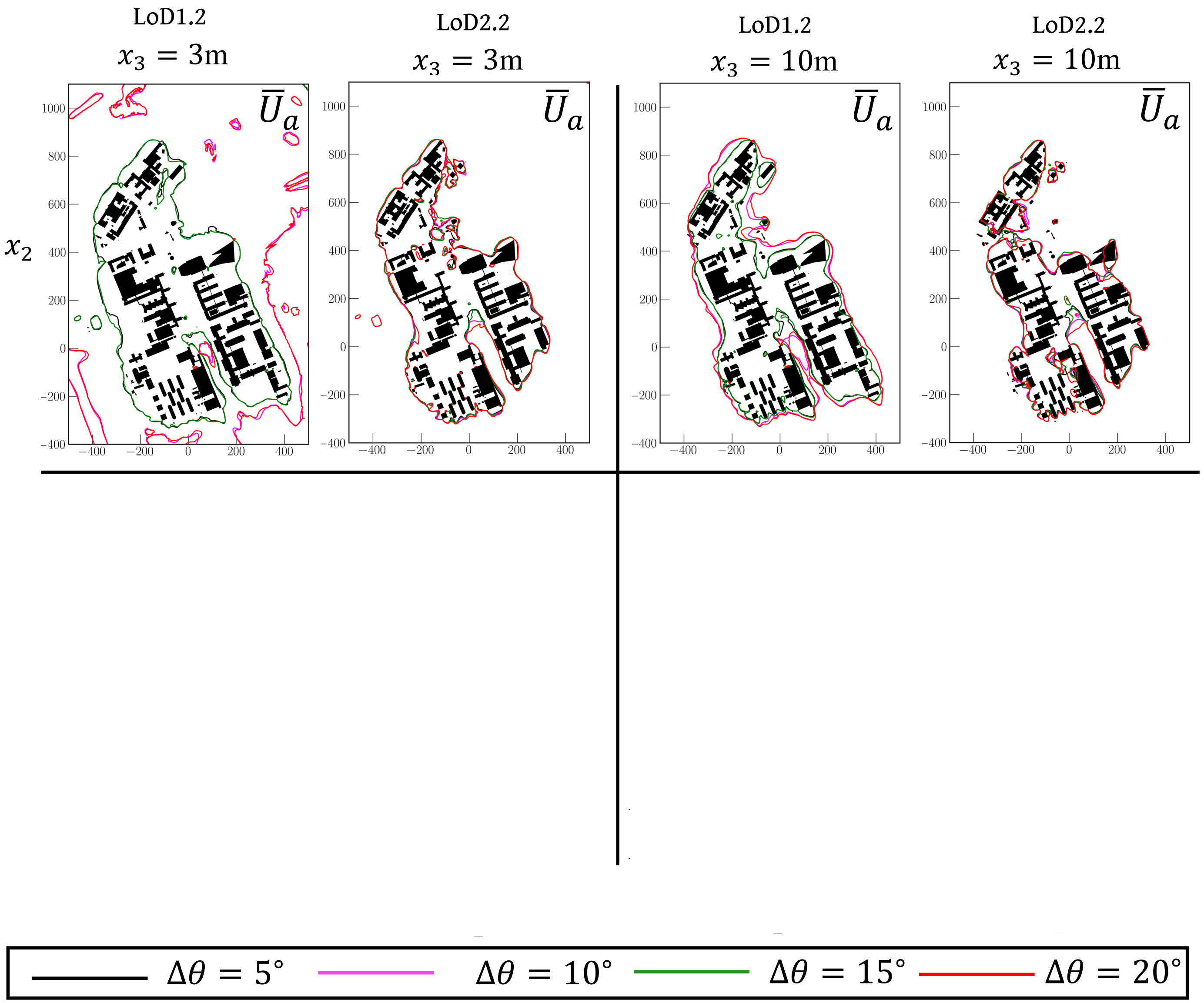

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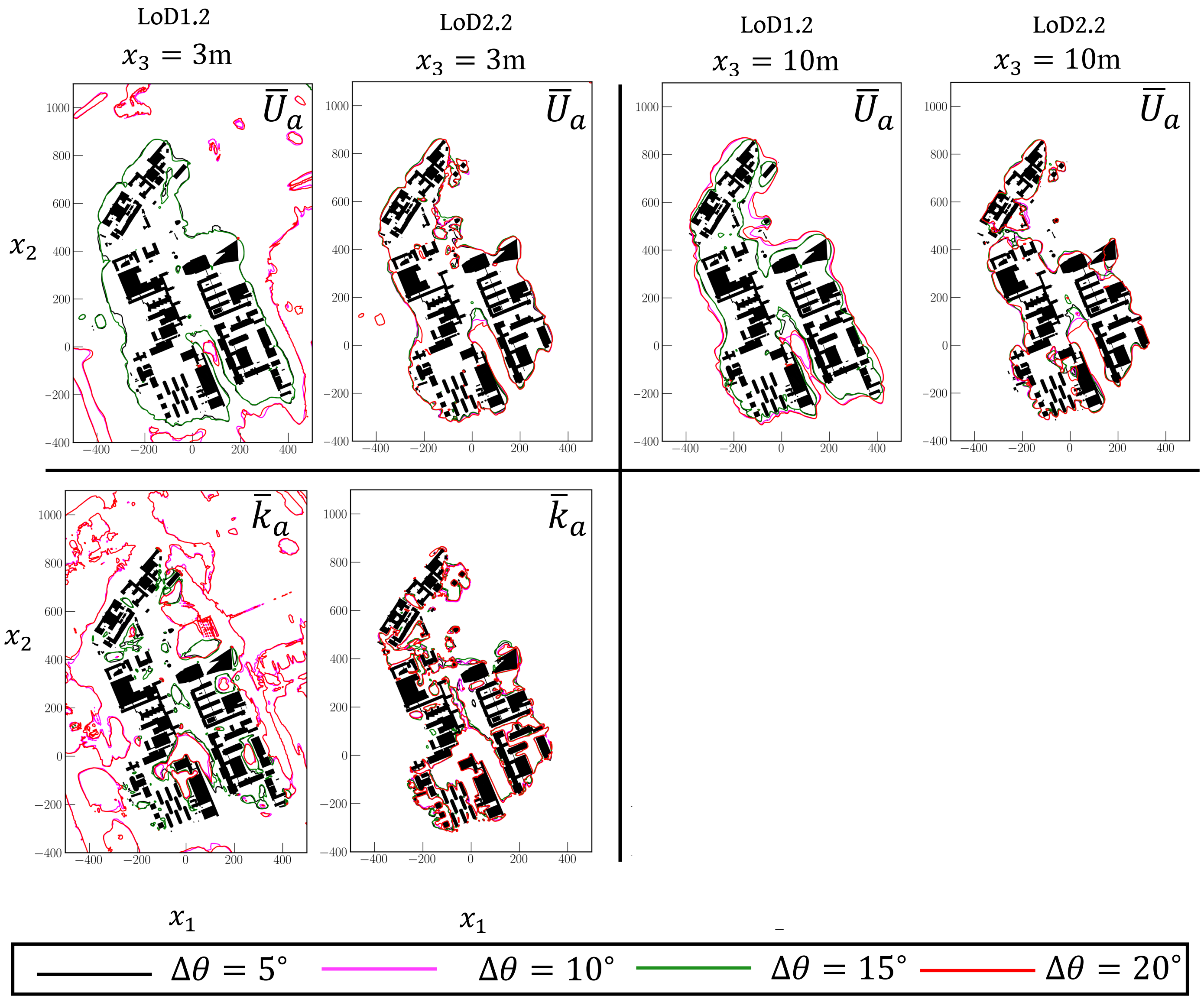

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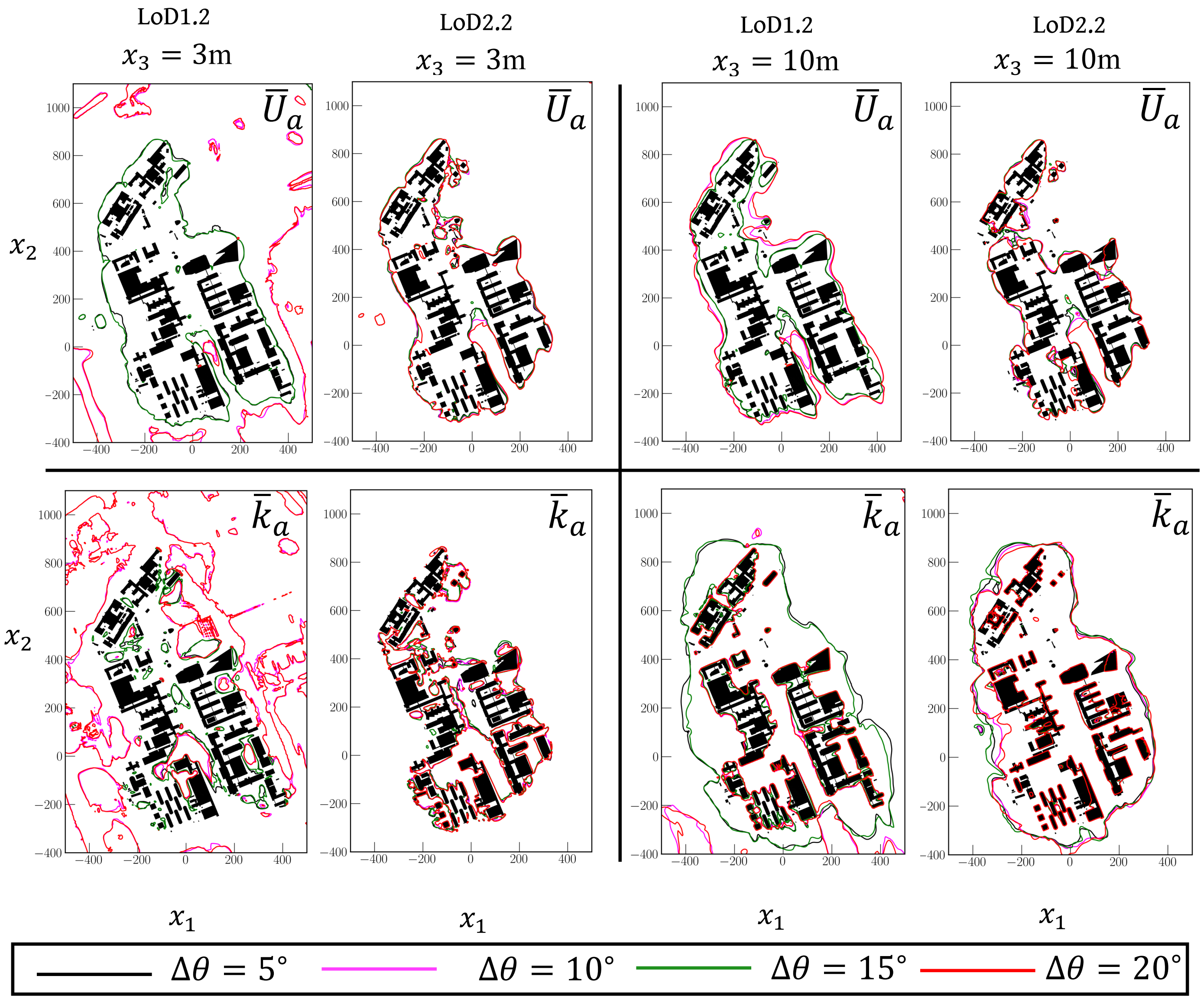

Conclusions

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  - Industry-standard LoD 1.2 massively underpredicts the risk
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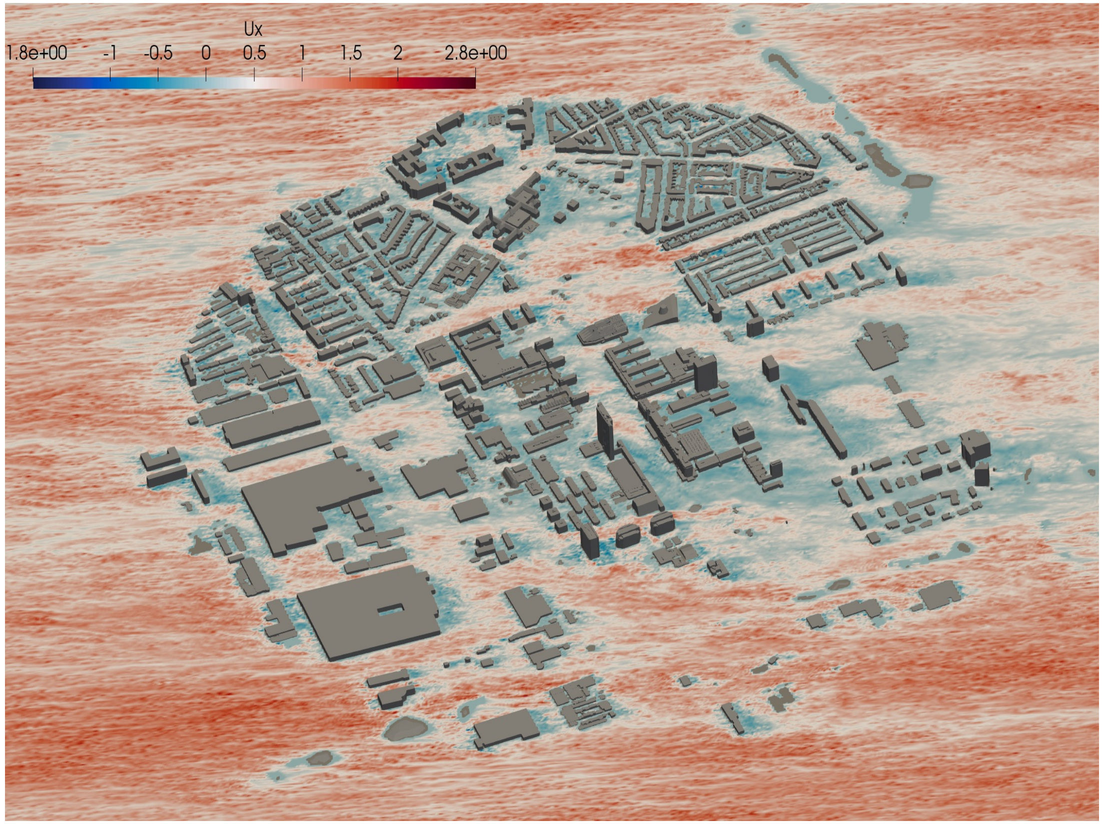
Future Work

- Baseline 1-degree resolution dataset for validity checks
- Multi-fidelity method for at-scale or reduced-scale computational framework



Thank you!