Refining Urban Wind and Pollutant Dispersion Modelling: From Airborne Lidar Data to CFD Models

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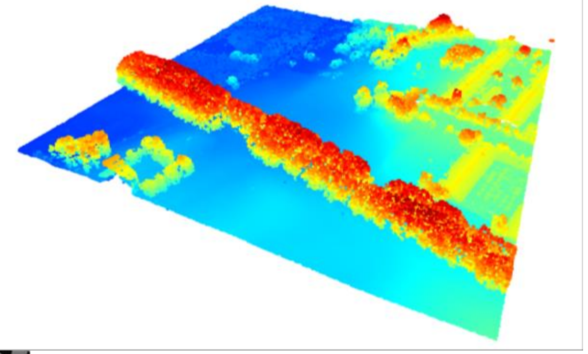
Outline

- Introduction & Objective
- Building reconstruction
- CFD Simulations (RANS)
- Wind Scanner Campaign (Validation)
- Initial Results
- Conclusions and Outlook

DTU Risø Campus

Point Cloud Data



URD Dispersion Model

Introduction & Objective

Predicting both high-resolution wind patterns and atmospheric dispersion of pollutants is challenging in urban areas due to the complexity of the urban canopy.

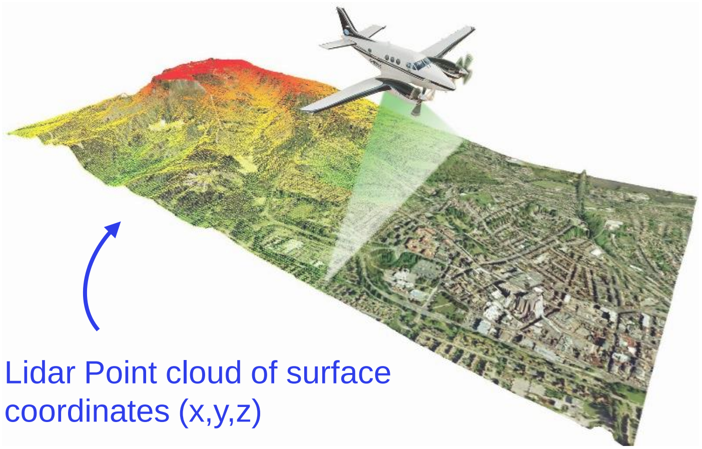
Challenges:

- Difficulty in obtaining realistic urban geometry for flow models
- Need for a fine computational grid to capture building details and cover urban flow scales
- Lack of validation data matching model capabilities

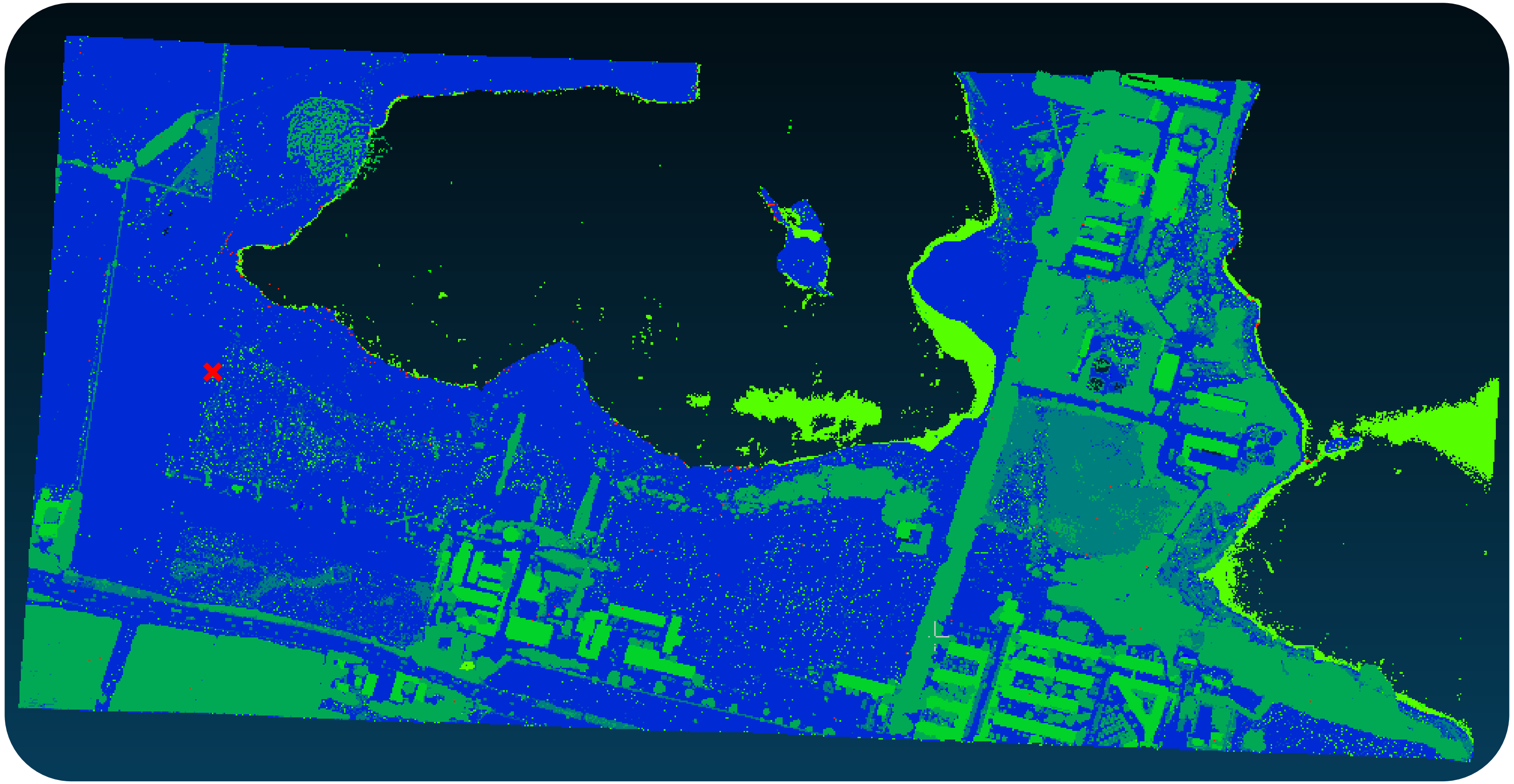
Objective:

- Single house study to investigate the challenges and establish validation for our CFD and dispersion simulations

Airborne Lidar data



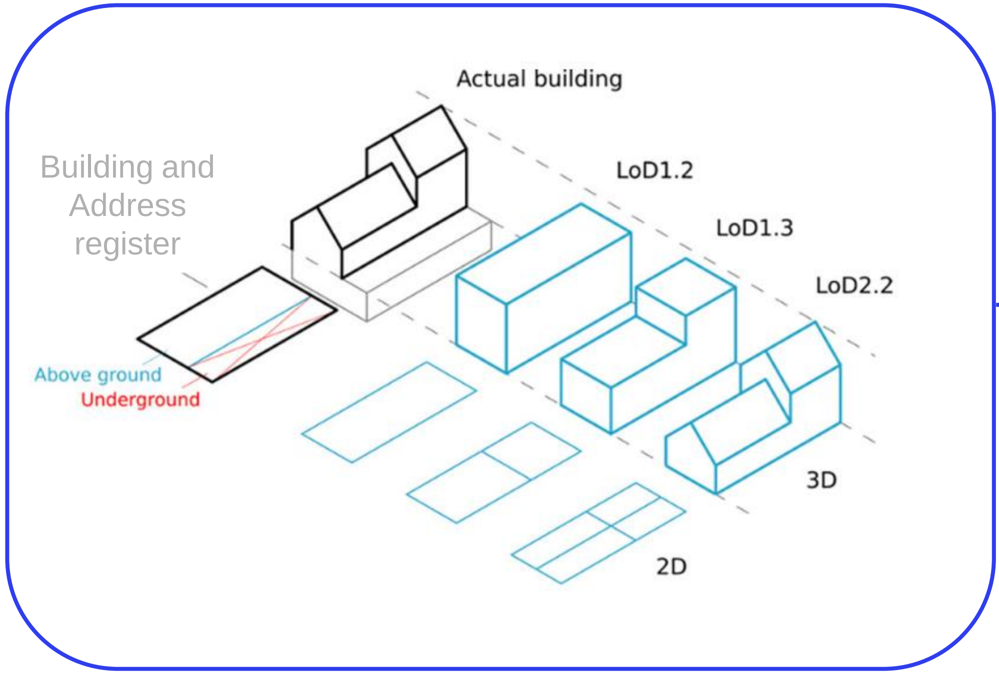
Lidar Point cloud of surface coordinates (x,y,z)

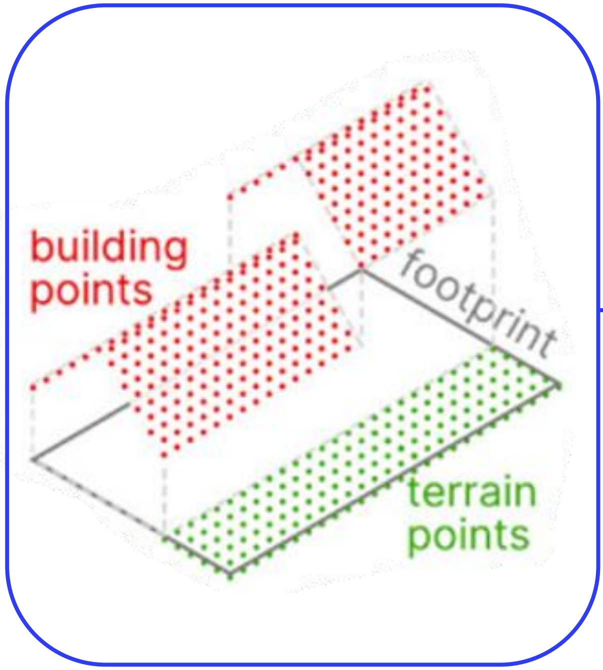


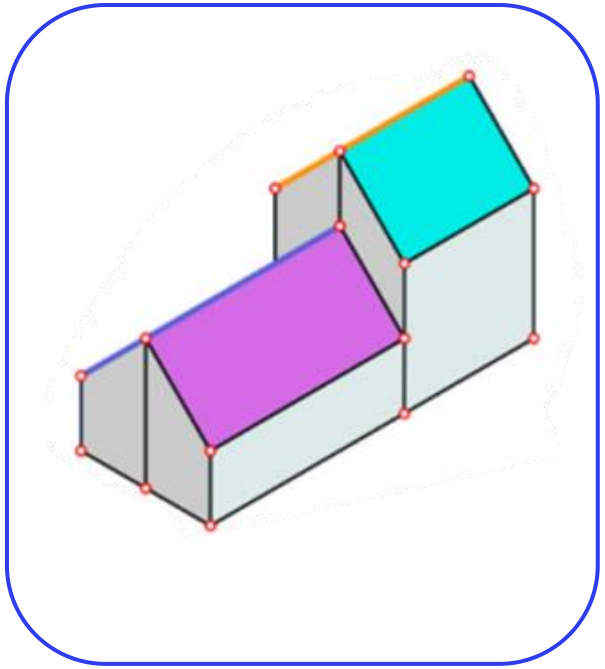
Airborne Lidar System:

- Laser scanner, an IMU (Inertial Measurement Unit), and a GPS (Global Positioning System) attached to airplane

Geoflow TU Delft - Highly realistic 3D reconstruction



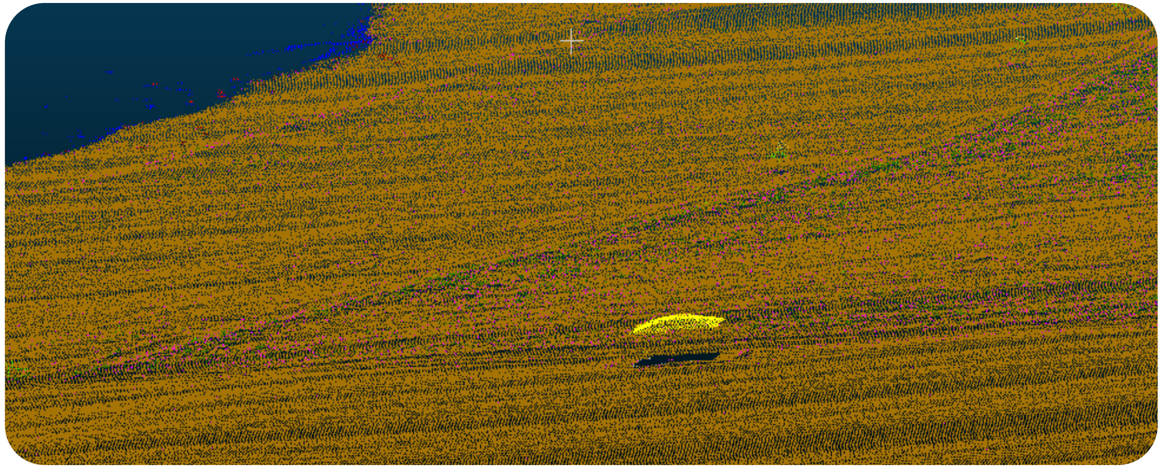


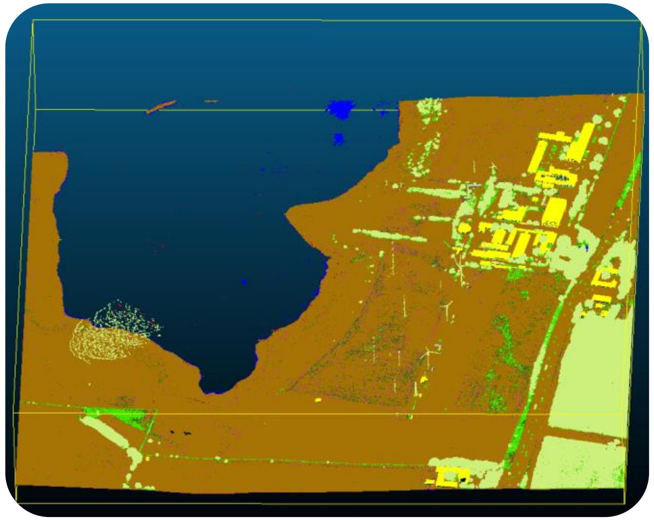


R. Peters, B. Dukai, S. Vitalis, J. van Liempt, and J. Stoter. (2022). Automated 3D Reconstruction of LoD2 and LoD1 Models for All 10 Million Buildings of the Netherlands. Photogrammetric Engineering and Remote Sensing, 88(3), 165–170.

Single building reconstruction

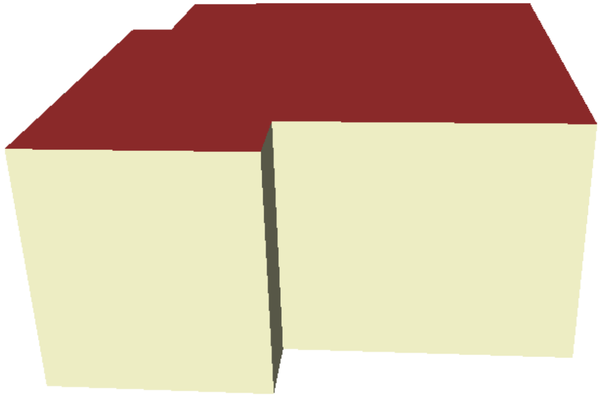
Airbone Lidar Pointcloud



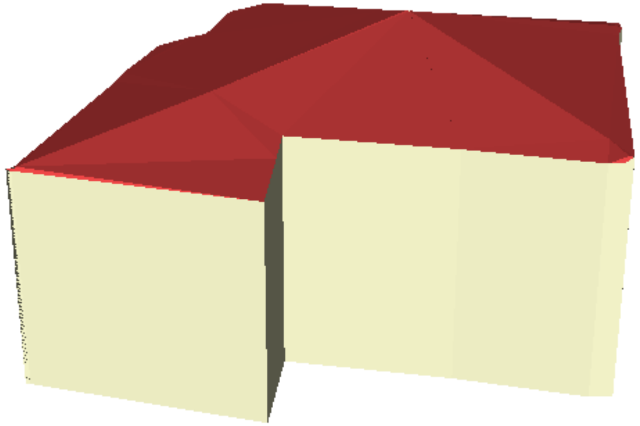


~20 min to process a 1km^2 pointcloud area in 3 LoDs

LoD 1.2



LoD 2.2

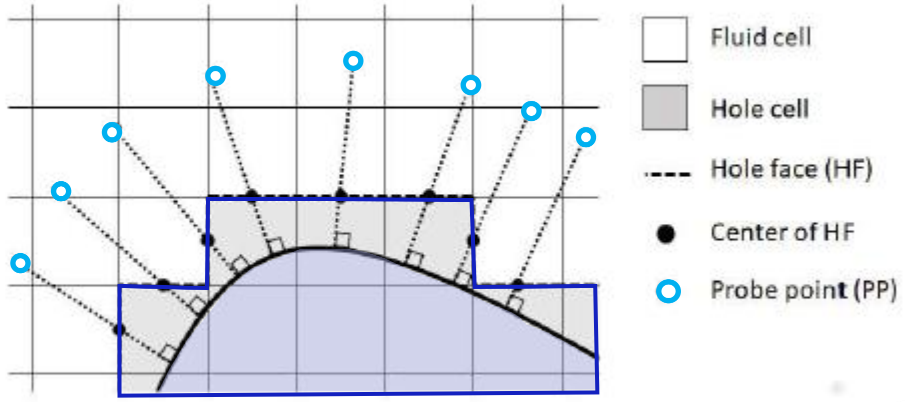


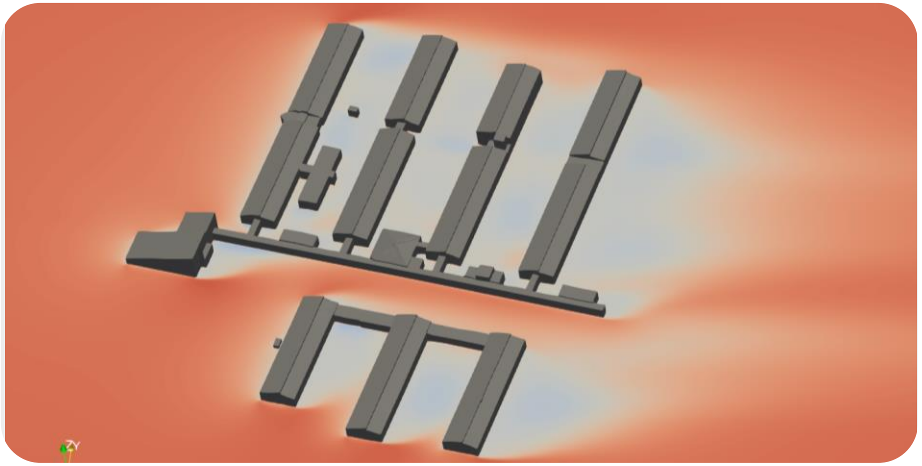
Georeferenced building footprint

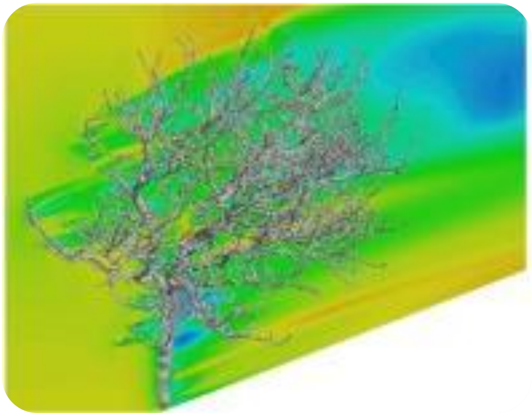
Immersed Boundary Method (Troldborg et al., 2021)

A method for CFD to represent surfaces on non-conforming grids in EllipSys3D (RANS):

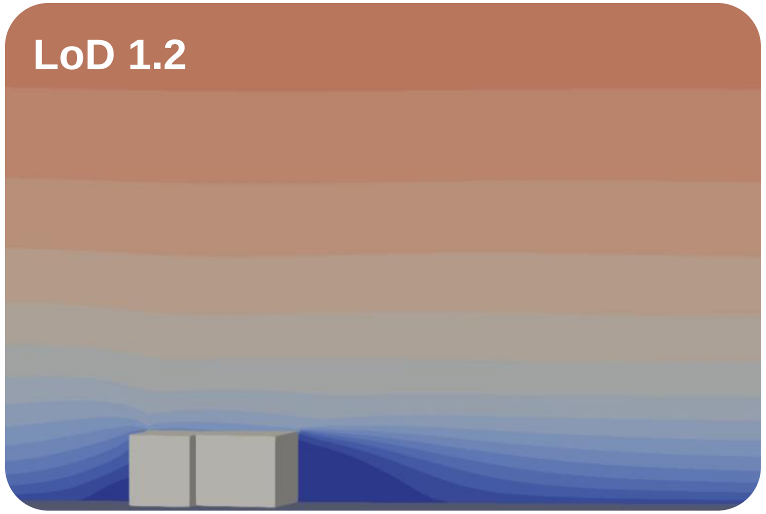
- IB → watertight surface composed of unstructured triangles
- Cut hole in background CFD grid; enclosing the IB
- Impose boundary conditions for all governing equations on the hole faces (HFs)
- Flow not solved inside object/hole
- Probe points (PPs) defined at a distance from the IB

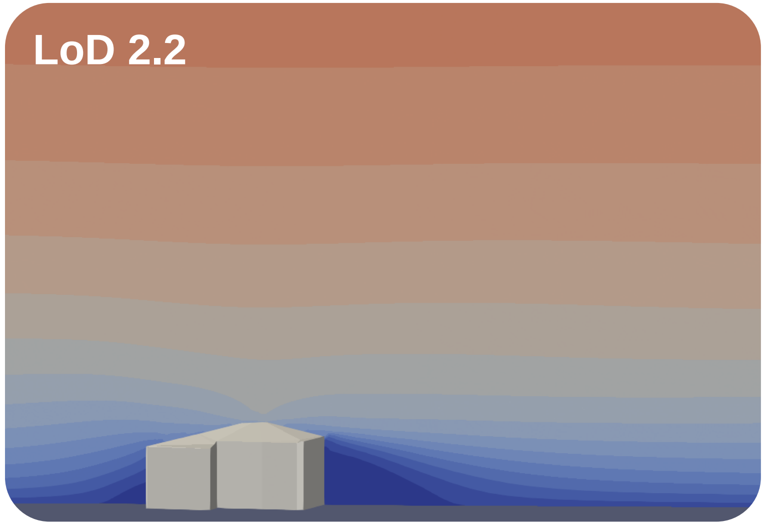


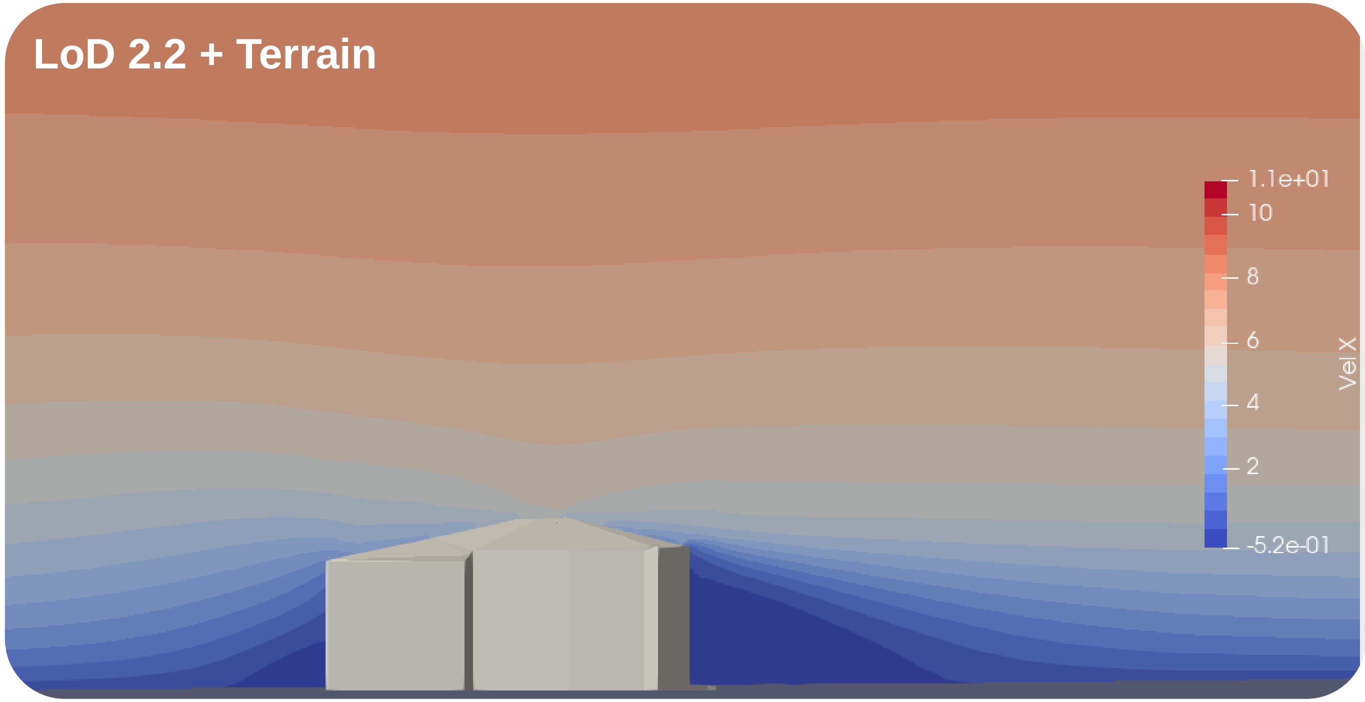




Simulation results – EllipSys3D RANS



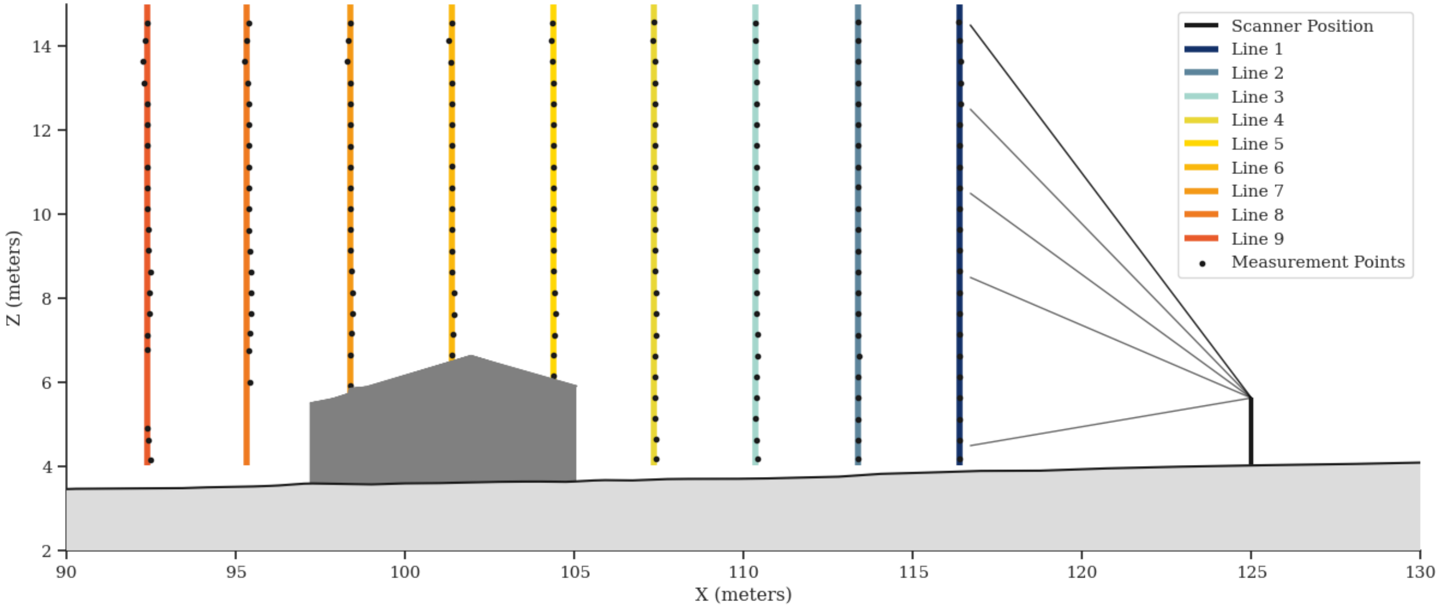




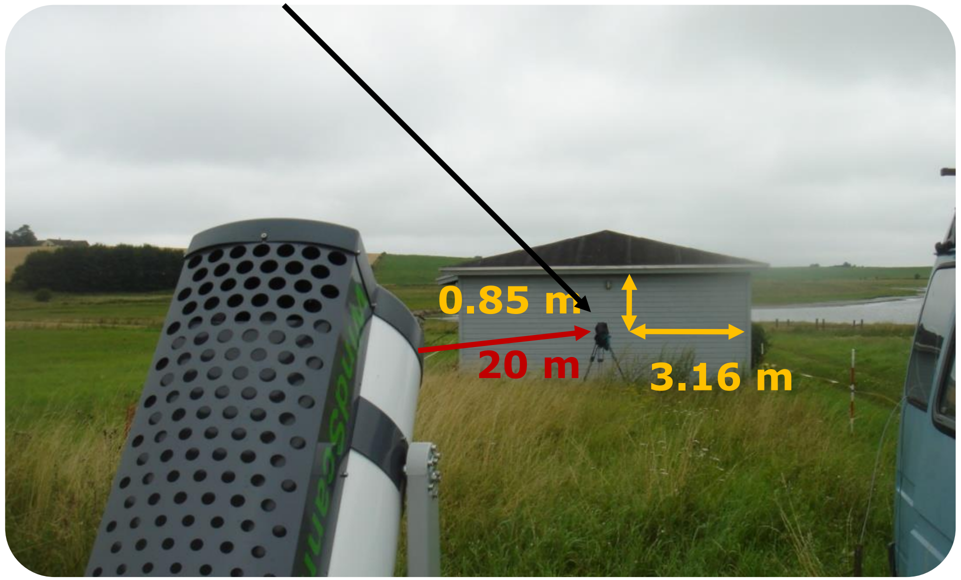
	LoD 1.2	LoD 2.2	LoD 2.2 + Terrain
Fx [N]	232.231	185.6319	243.5852
Fy [N]	-13.88692	-10.84574	-15.27790

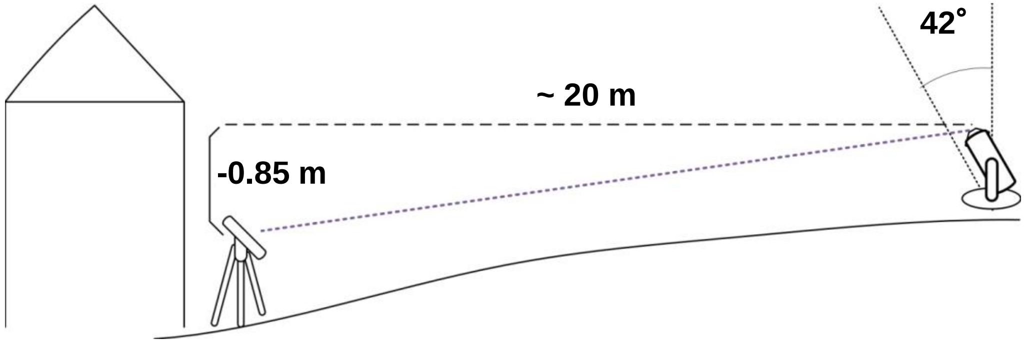
Wind Scanner Campaign

- Experiment took place in summer 2011
- DTU short-range Wind Scanner
- Continuous Wave Lidar with a sampling frequency ~390 Hz
- Line scanning pattern:

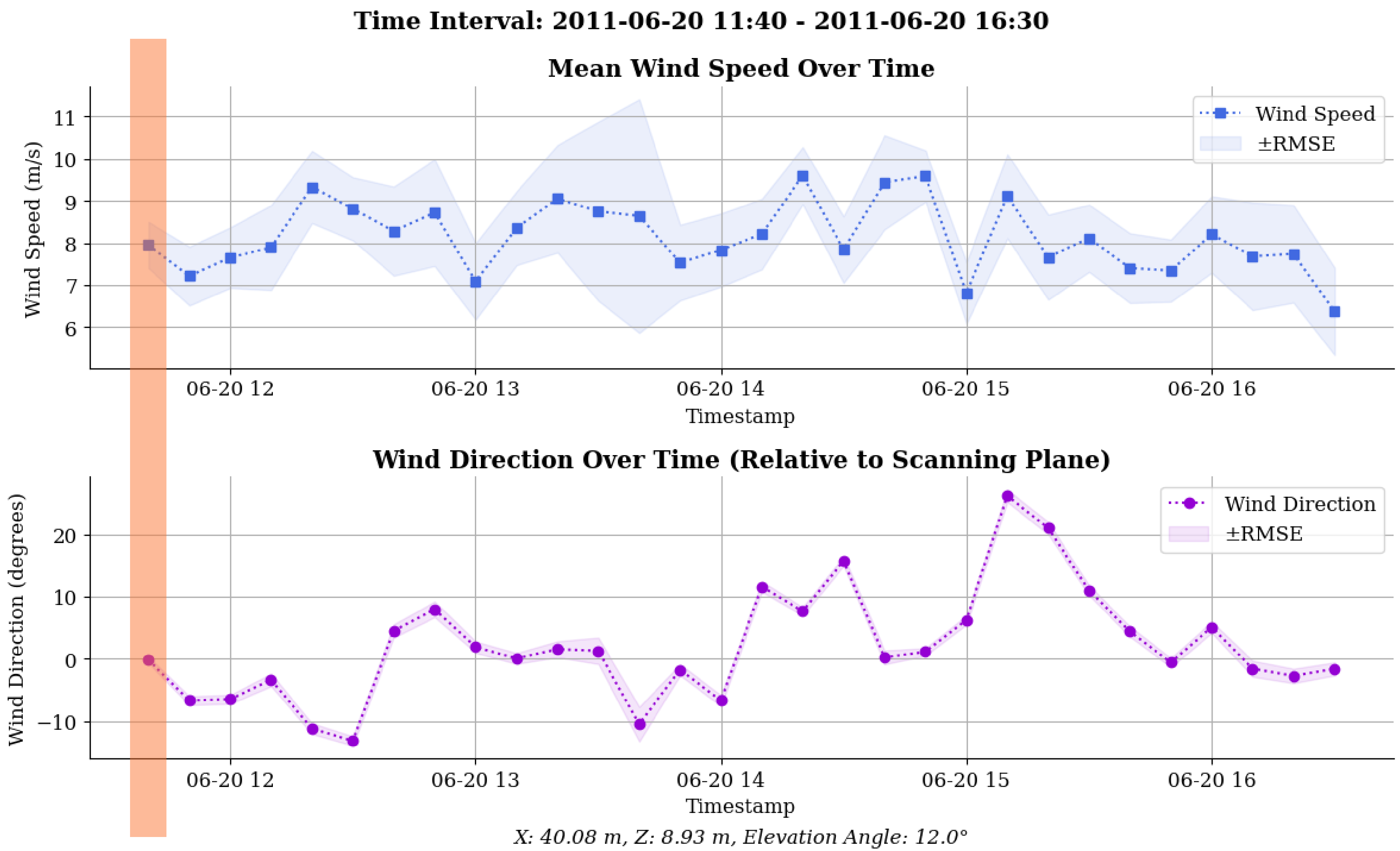


Solid moving target





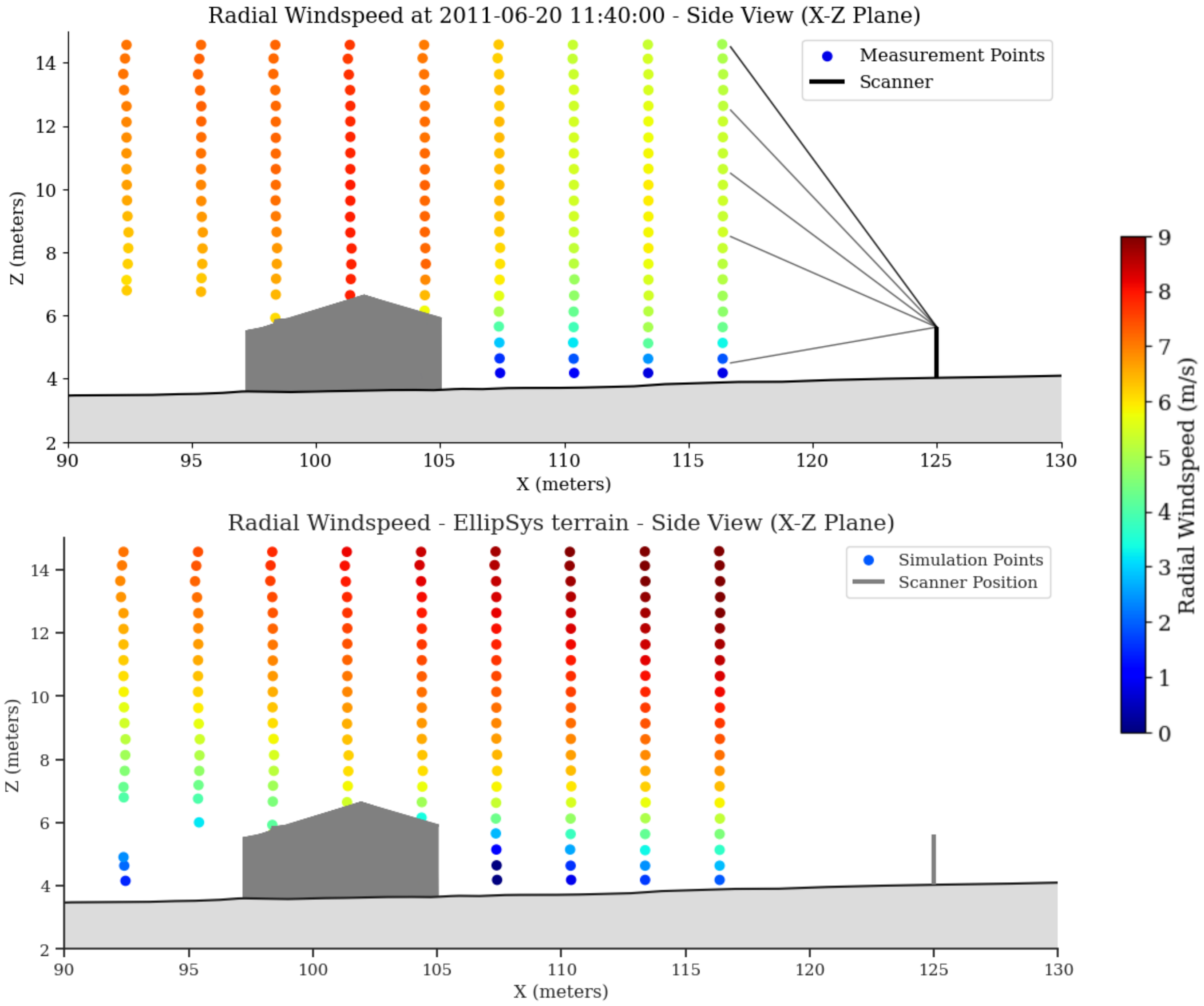
Wind Conditions



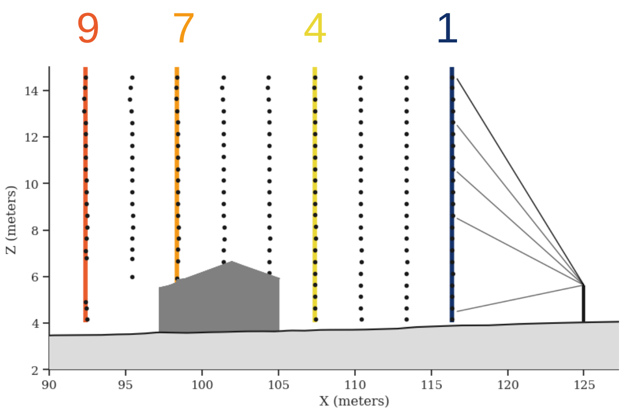
Comparison of Radial Windspeeds

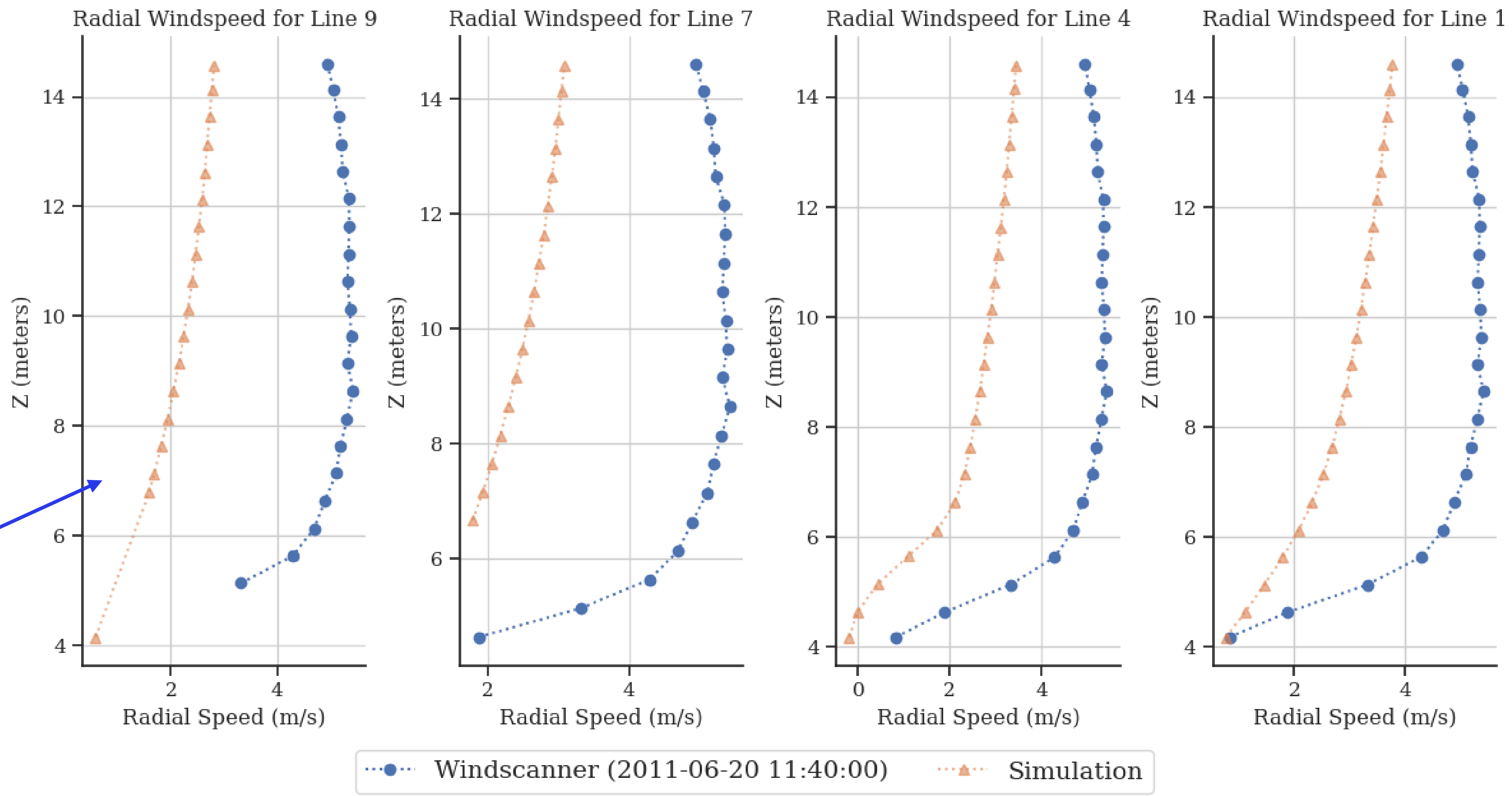
Wind Scanner

RANS Simulation



First comparison of Wind profiles





Mismatch in inflow

Conclusion & Outlook

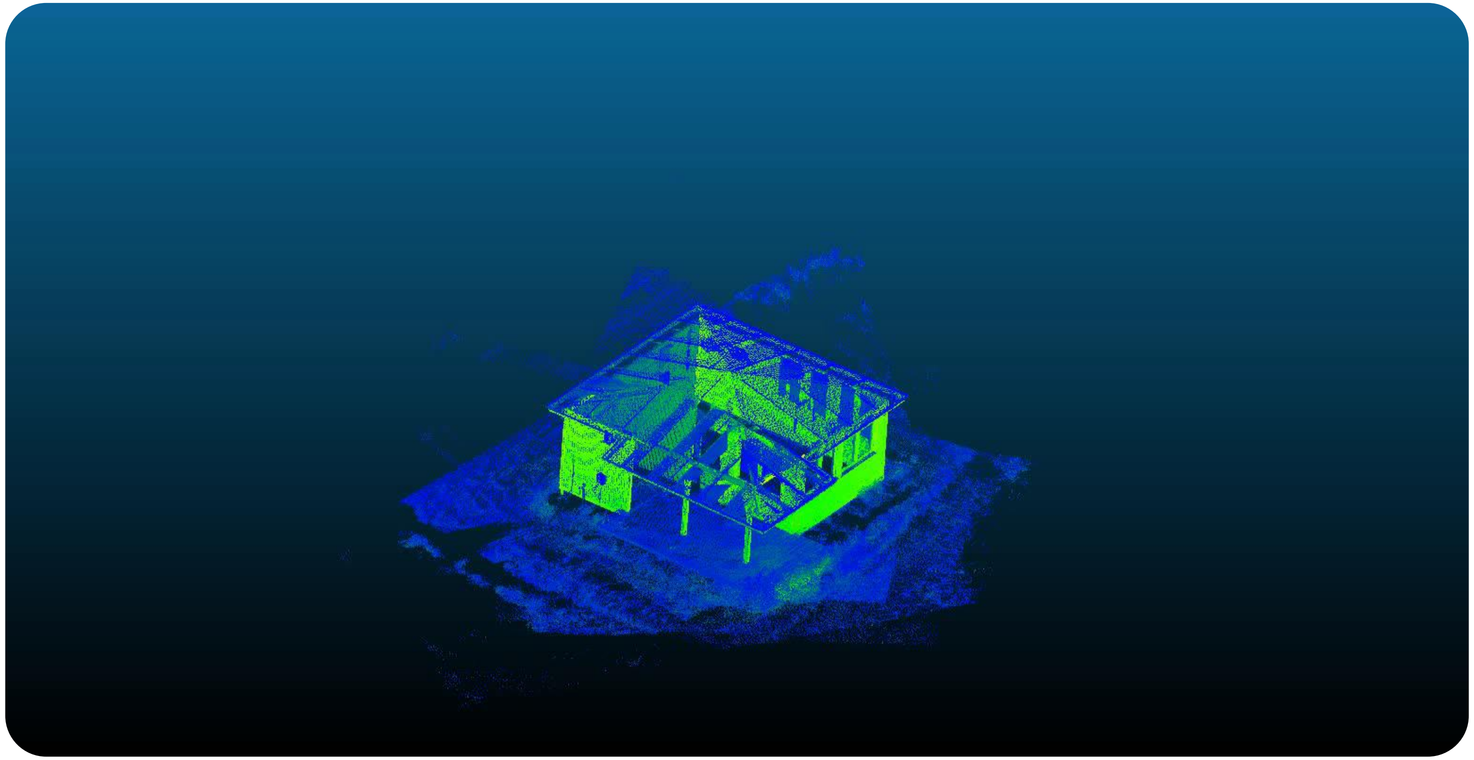
- Rapid technological development of airborne lidar technology has led to radically improved accuracy and realism in 3D digital surface models of urban areas
- Make real and model worlds match: Achieve this with detailed building reconstruction and high-resolution Wind Scanner data

Take-home Message: Our work shows new possibilities in accurately modeling urban environments, which is crucial for various applications of local scale dispersion and flow modeling.

Future Work:

- Matching inflow conditions for better comparative analysis
- Further processing of Wind Scanner data to compare Turbulent Kinetic Energy (TKE)
- Conducting a tracer experiment to validate our CFD dispersion simulation ☺

Thank you for your attention!



Further Questions?
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References

- R. Peters, B. Dukai, S. Vitalis, J. van Liempt, and J. Stoter. (2022). Automated 3D Reconstruction of LoD2 and LoD1 Models for All 10 Million Buildings of the Netherlands. Photogrammetric Engineering and Remote Sensing, 88(3), 165–170..
- Troldborg, N., Sørensen, N. N., & Zahle, F. (2022). Immersed boundary method for the incompressible Reynolds Averaged Navier–Stokes equations. Computers and Fluids, 237, [105340]. https://doi.org/10.1016/j.compfluid.2022.105340