A dual-model analysis toward a harmonised CFD approach for urban air quality: Case study of Milan, Italy

23rd International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes

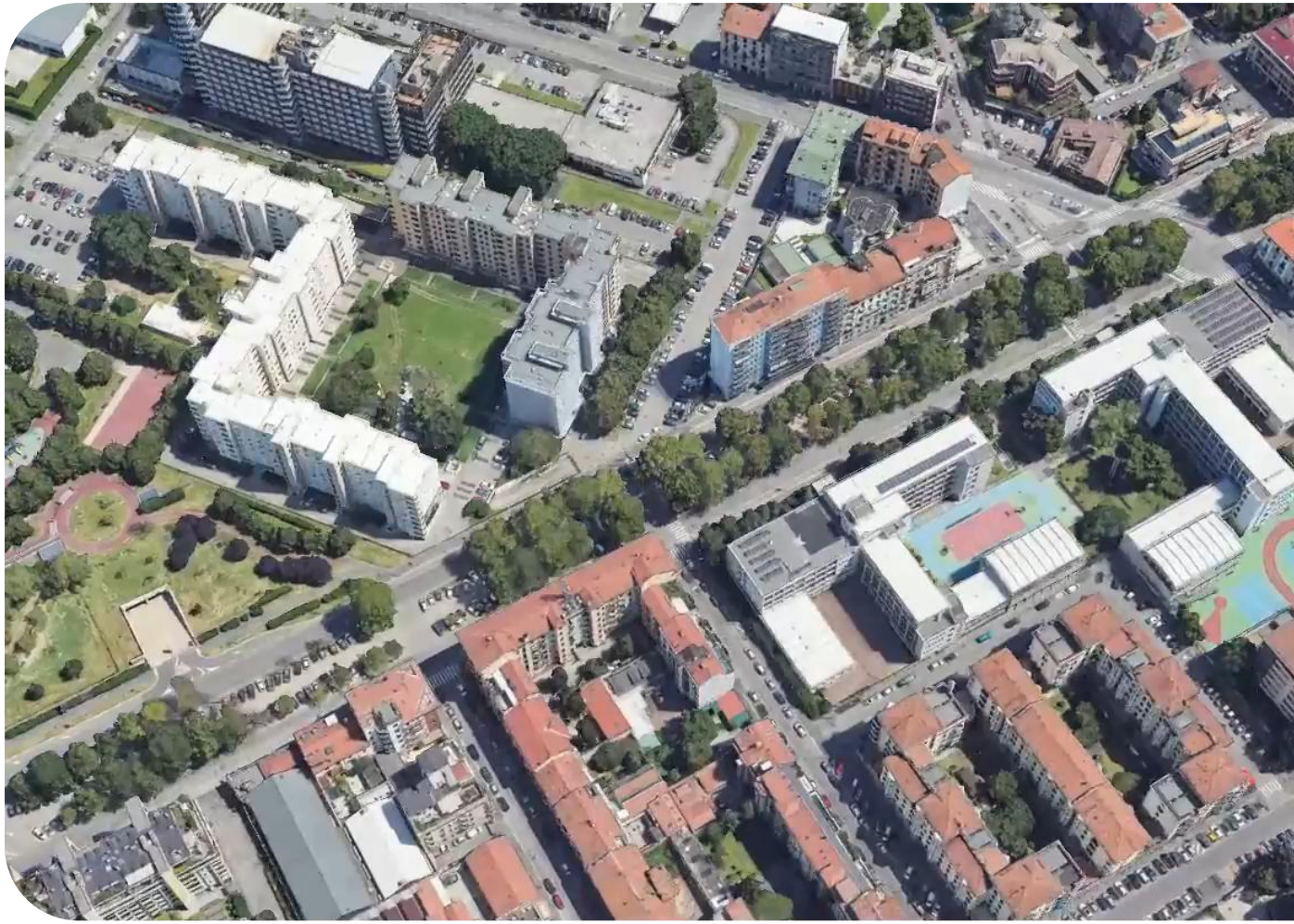
16-19 September 2025
Hamburg, Germany

Diogo Nascimento*[a)c)], Nicola Luciano [b)], Andrea Piccoli [b)], Domenico Toscano [b)], Guido Pirovano [b)], Diogo Lopes [a)], Jorge Sousa [c)], Myriam Lopes [a)], Ana Isabel Miranda [a)], Carlos Borrego [a)],Vera Rodrigues [a)]

[a)] CESAM – Centre for Environmental and Marine Studies & Department of Environment and Planning, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal;
[b)] RSE - Ricerca sul Sistema Energetico, via Rubattino 54, Milan, 20134, Italy;
[c)] VITO - Flemish Institute for Technological Research, Boeretang 200, 2400 Mol, Belgium;

Contents

- Introduction
- Case Study Overview
- Methodology
- Results
- Discussion
- Implications for Practice
- Conclusion



Introduction and Objective

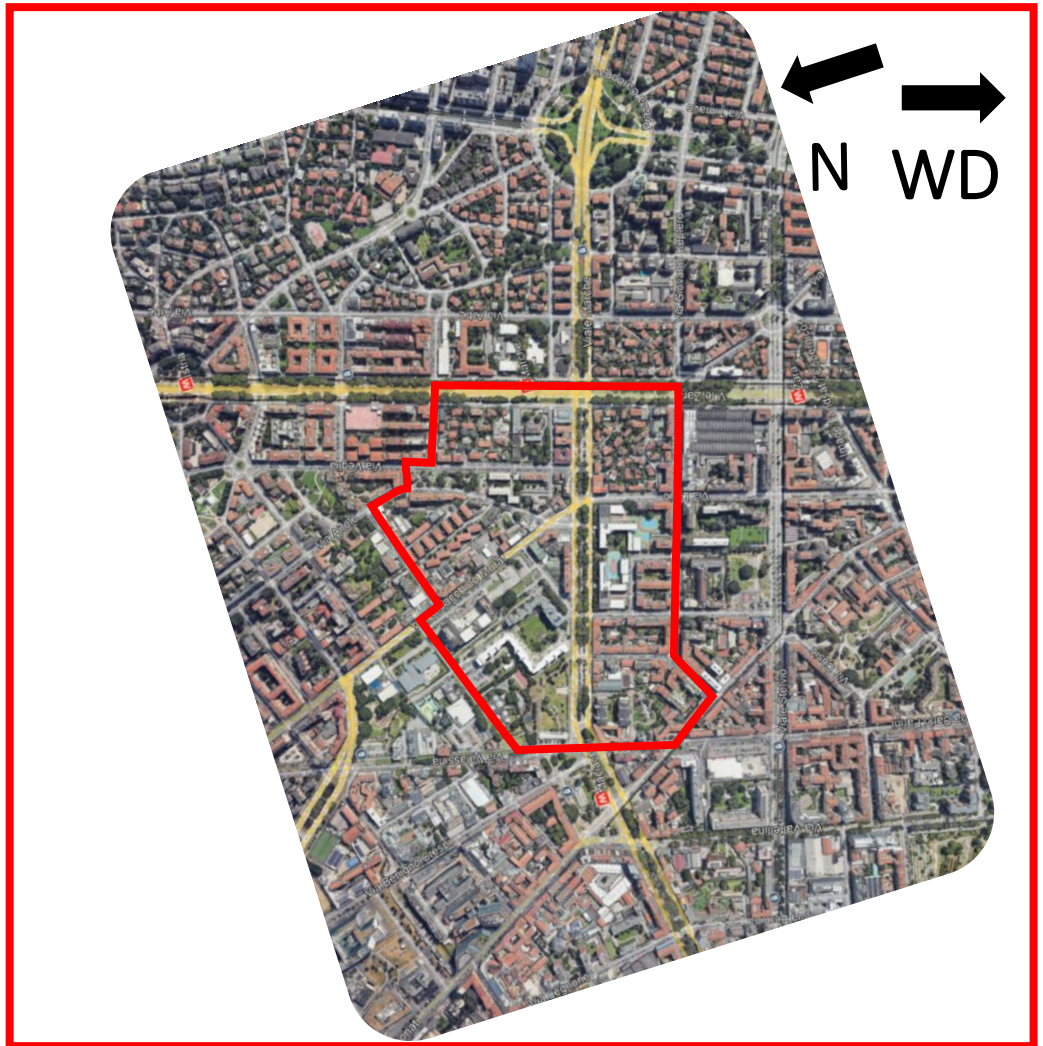
- CFD models are standards to simulate urban air pollution.
- Inconsistencies between models and modelling approaches pose challenges for harmonisation and reproducibility.
- OpenFOAM and ANSYS Fluent are the most commonly used CFD tools.

- How different are the results for two of the most common used CFD models?
- How hard it is to setup/replicate the same results in both models?

Methodology

- Interest area approx: 700m x 800m
- Square domain length = 2250m
- H_{max} = 50 m
- ≈ 10.7M Cells

Same Urban Geometry



Methodology

Same simulation conditions

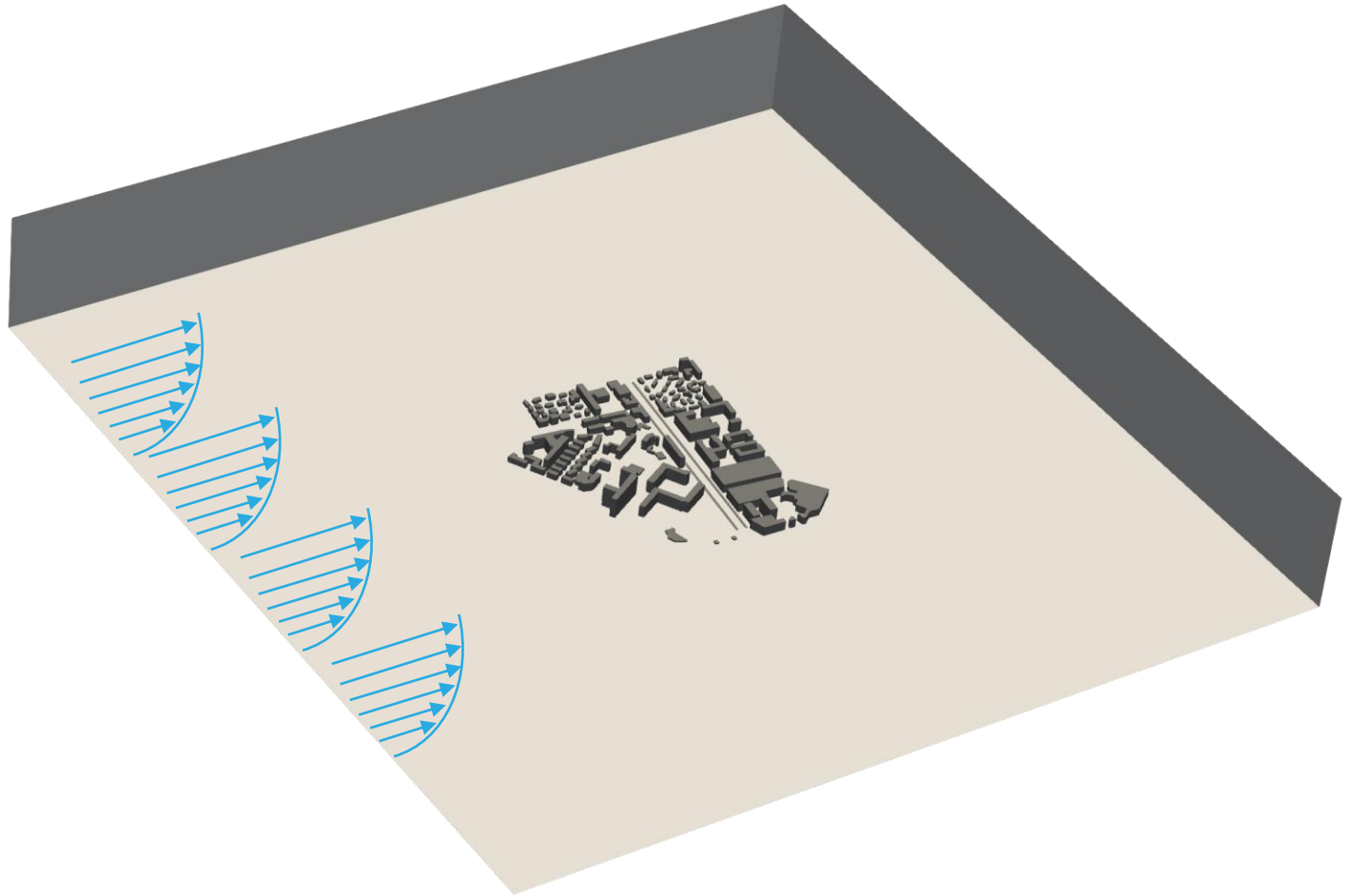
- Pressure-based steady solver
- Simple algorithm
- Realizable k-ε turbulence model
- Second order schemes

$$U = \frac{u_*}{\kappa} ln \frac{(z+z_0)}{z_0}$$

$$k = \frac{u_*^2}{\sqrt{C_\mu}} \sqrt{C_1 \ln\left(\frac{z+z_0}{z_0}\right) + C_2}$$

$$\epsilon = \frac{u_*^3}{\kappa(z+z_0)} \sqrt{C_1 \ln\left(\frac{z+z_0}{z_0}\right) + C_2}$$

Uref	2.66 [m/s]
Zref	10 [m]
Z0	0.65 [m]
C1	0.0
C2	1.0



Methodology

Same simulation conditions

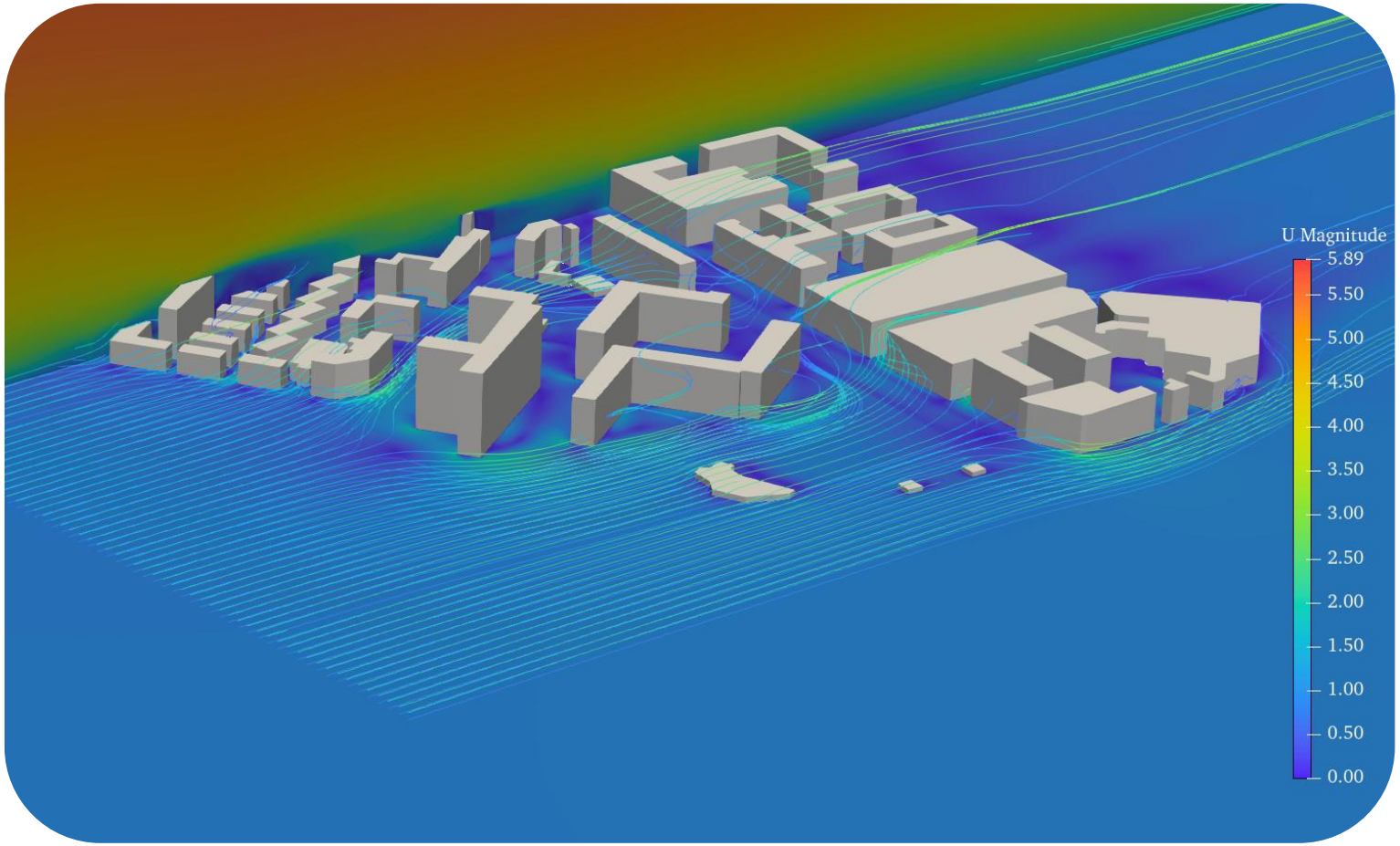
- Pressure-based steady solver
- Realizable k-ε turbulence model
- Second order schemes

$$U = \frac{u_*}{\kappa} ln \frac{(z+z_0)}{z_0}$$

$$k = \frac{u_*^2}{\sqrt{C_\mu}} \sqrt{C_1 \ln\left(\frac{z+z_0}{z_0}\right) + C_2}$$

$$\epsilon = \frac{u_*^3}{\kappa(z+z_0)} \sqrt{C_1 \ln\left(\frac{z+z_0}{z_0}\right) + C_2}$$

Uref	2.66 [m/s]
Zref	10 [m]
Z0	0.65 [m]
C1	0.0
C2	1.0



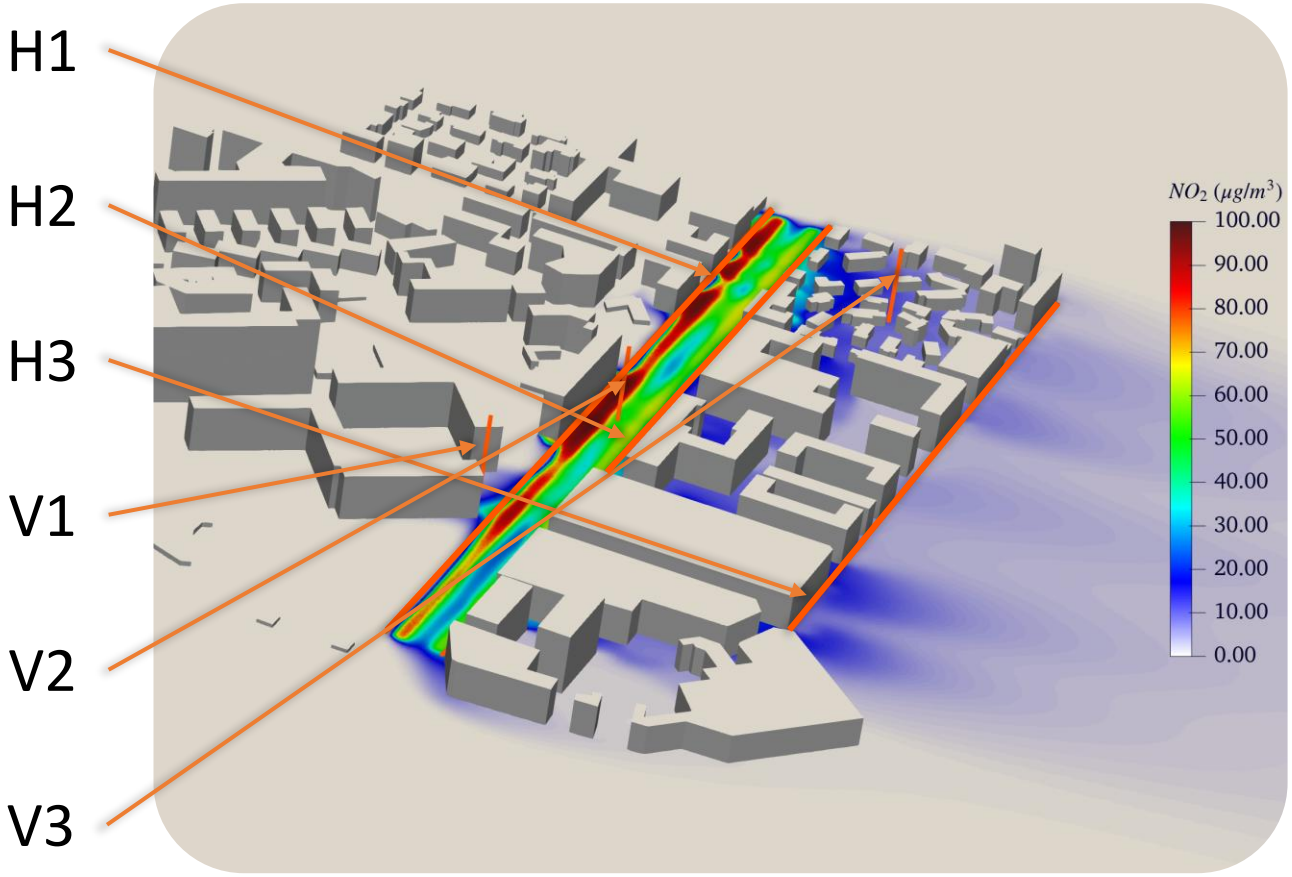
Methodology

Same Pollutant

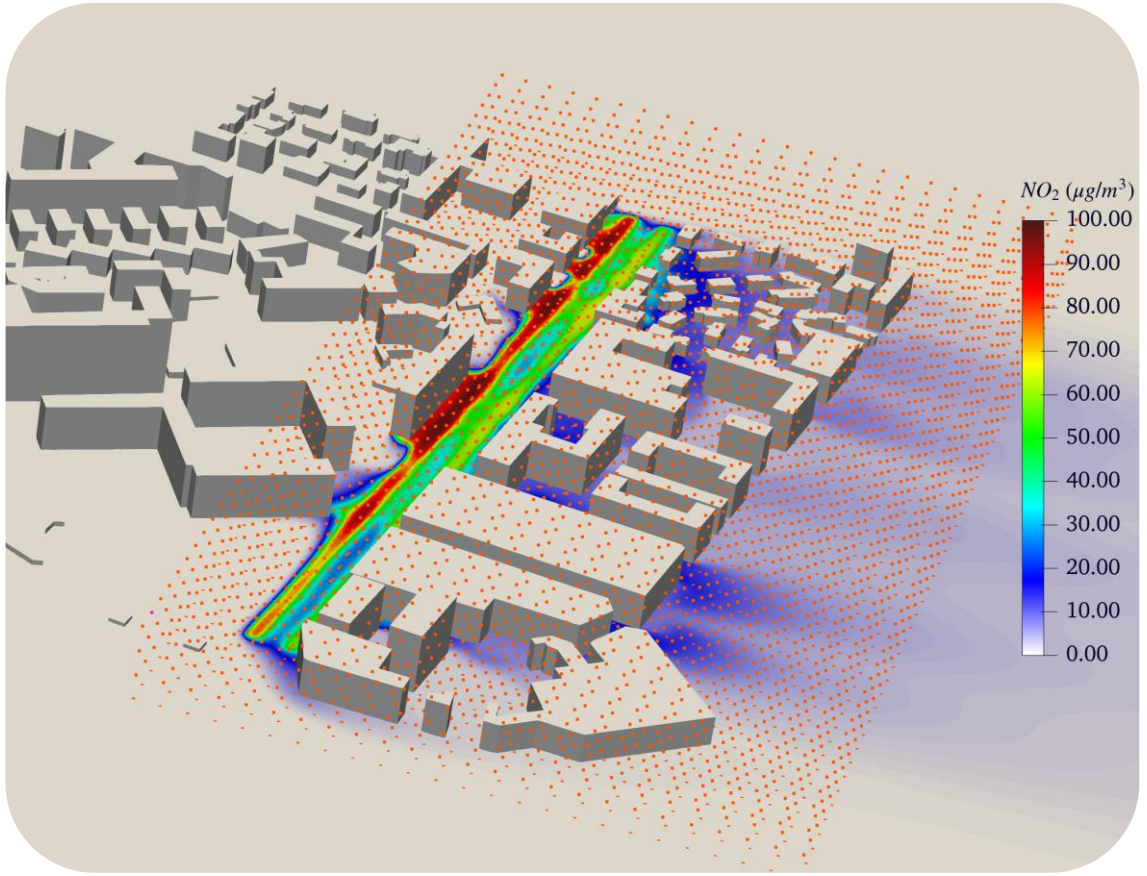
- Passive scalar transport approach;
- Nitrogen Oxides (NO_X), modelled as mass-equivalent NO_2;
- No chemical reactions considered;
- Two pollutant source locations:
  - North link → 3.61×10^{-4} kg
  - South link → 2.45×10^{-4} kg

Methodology

Same sample locations



Horizontal plots are at 1m height



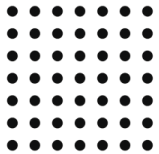
4337 points sampled

Methodology

Same Urban Geometry

Same Simulation conditions

Same Pollutant



Same Comparizon locations

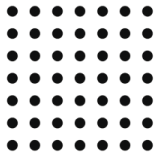
What's different?
Different Models and Meshes

Methodology

Same Urban Geometry

Same Simulation conditions

Same Pollutant



Same Comparizon locations

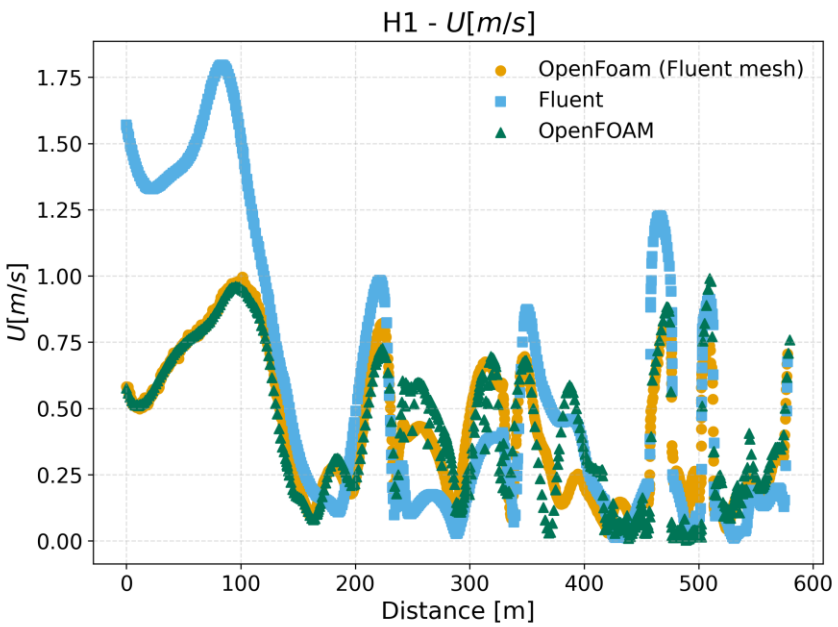
What's different? Different Models and Meshes

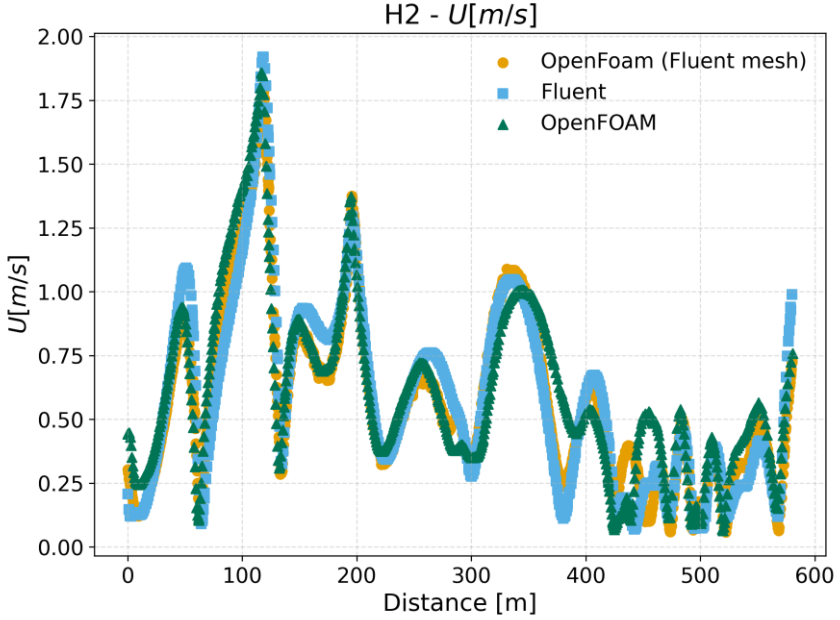
CASE A
Mesh + Simulation
Ansys FLUENT

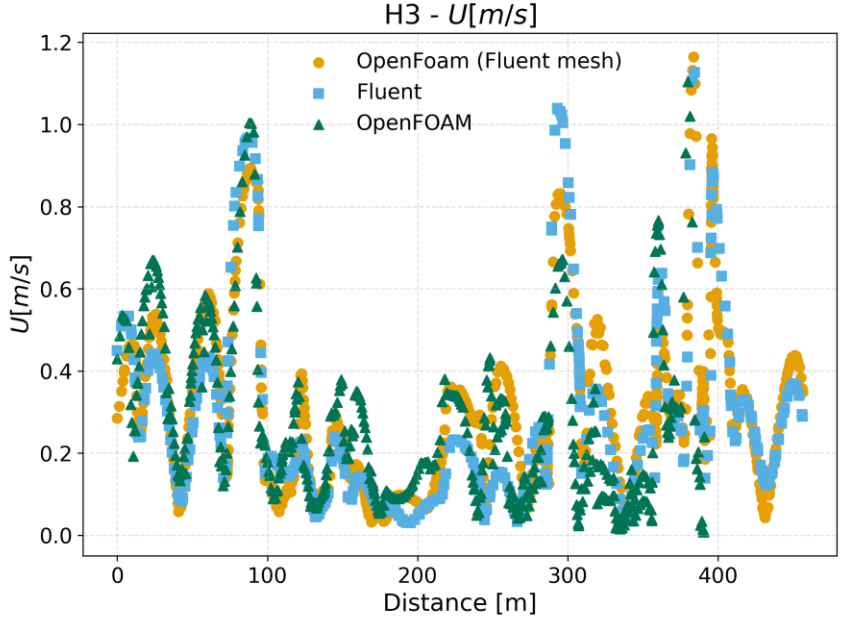
CASE B
Mesh + Simulation
Ansys FLUENT OpenFOAM

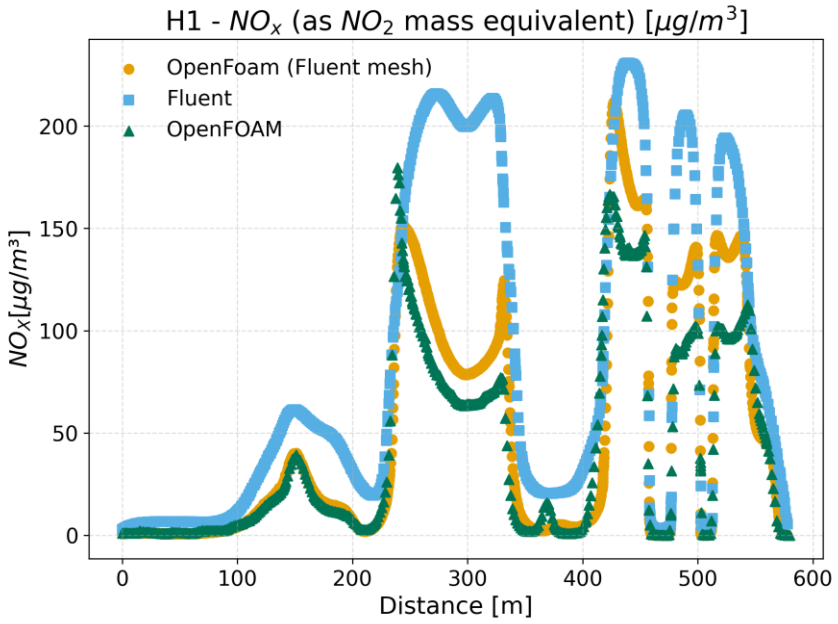
CASE C
Mesh + Simulation
OpenFOAM

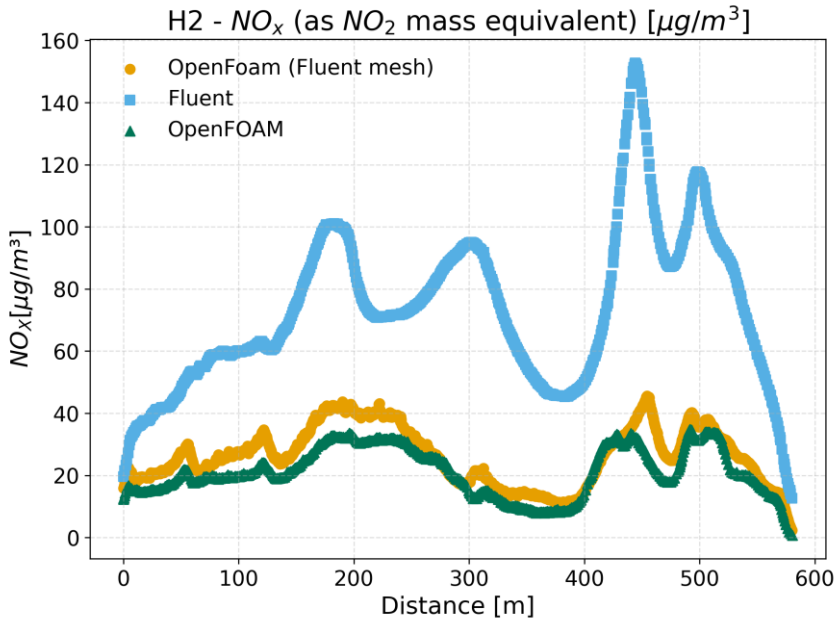
Results | horizontal line samples

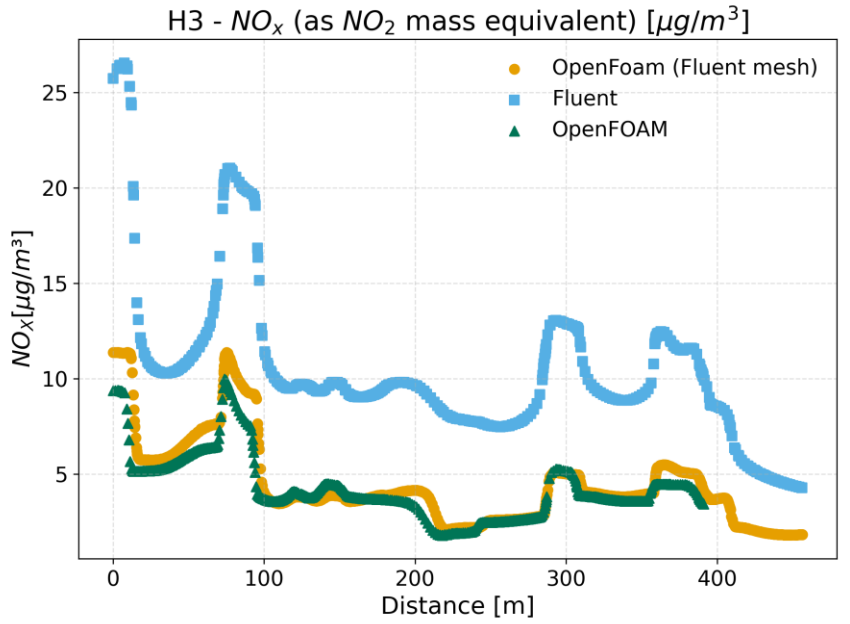




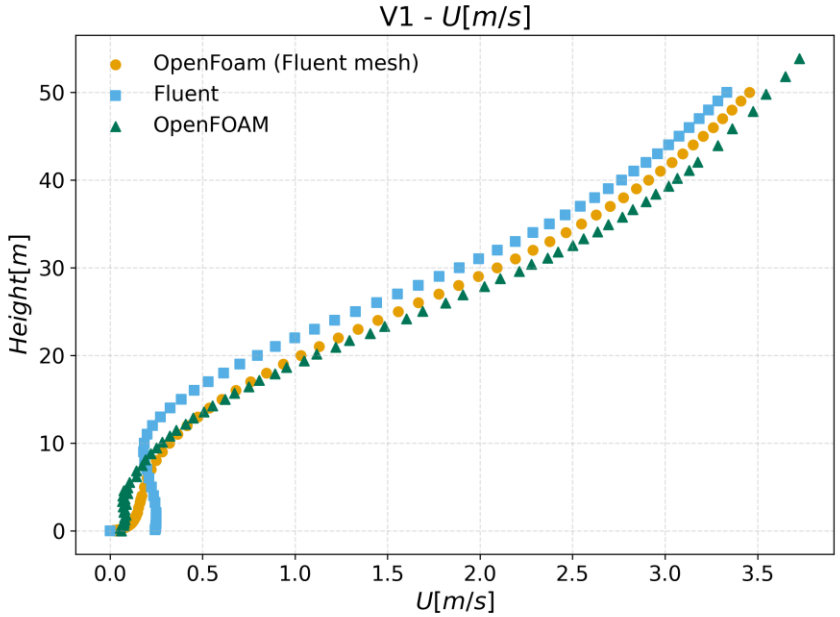


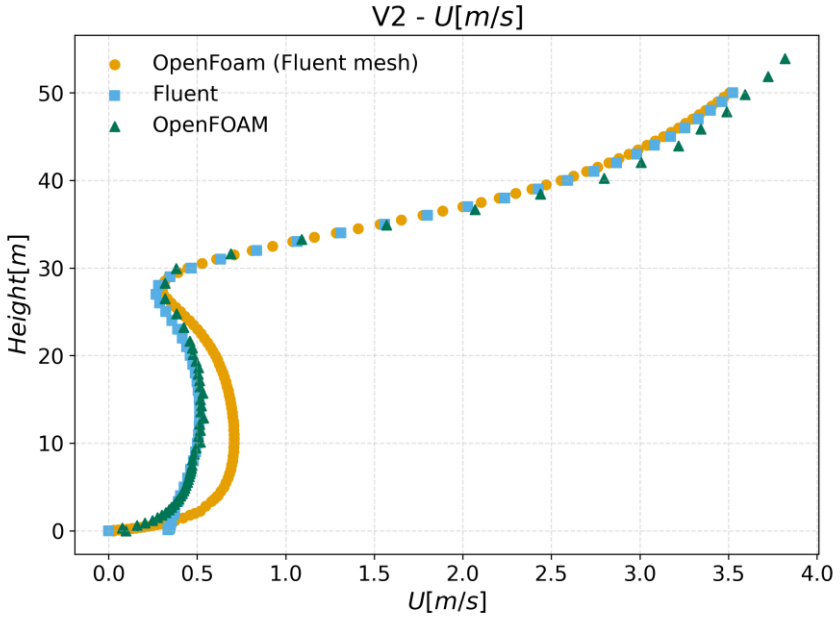


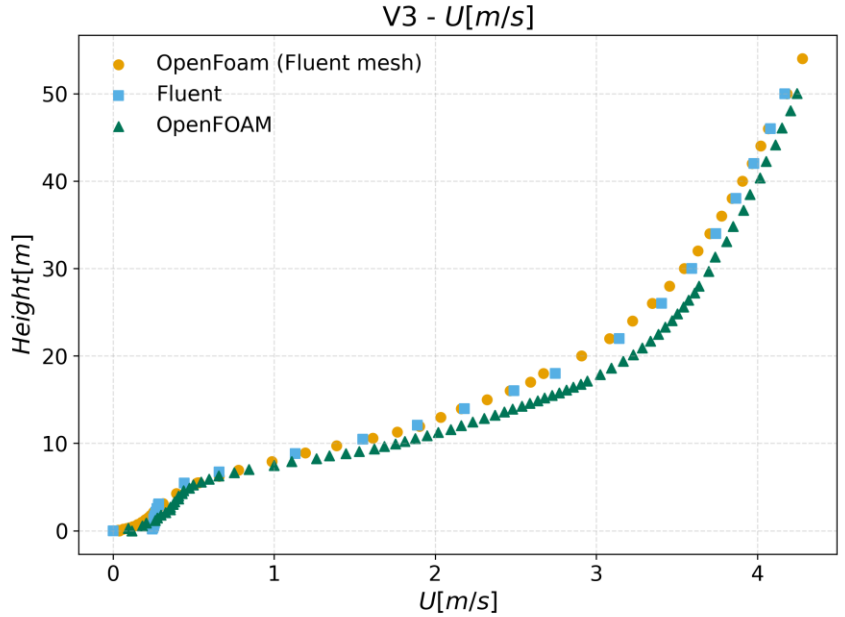


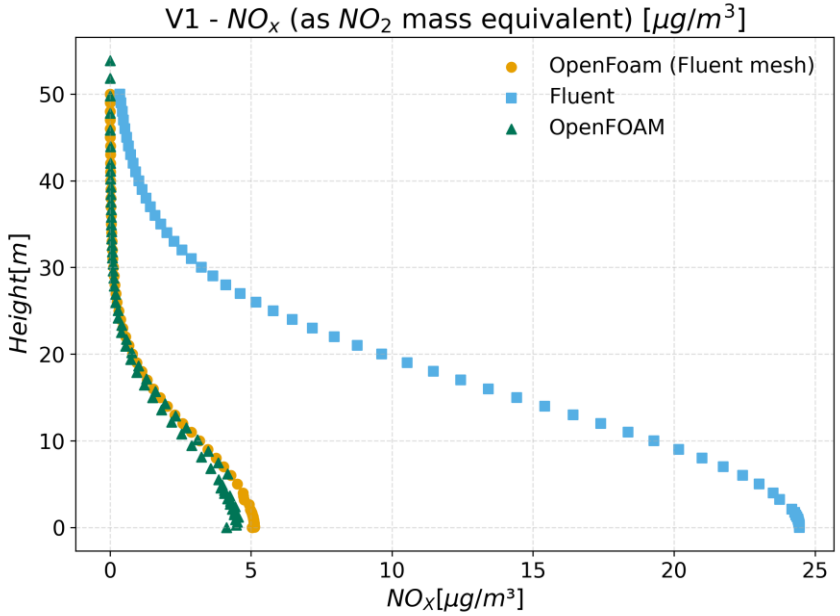


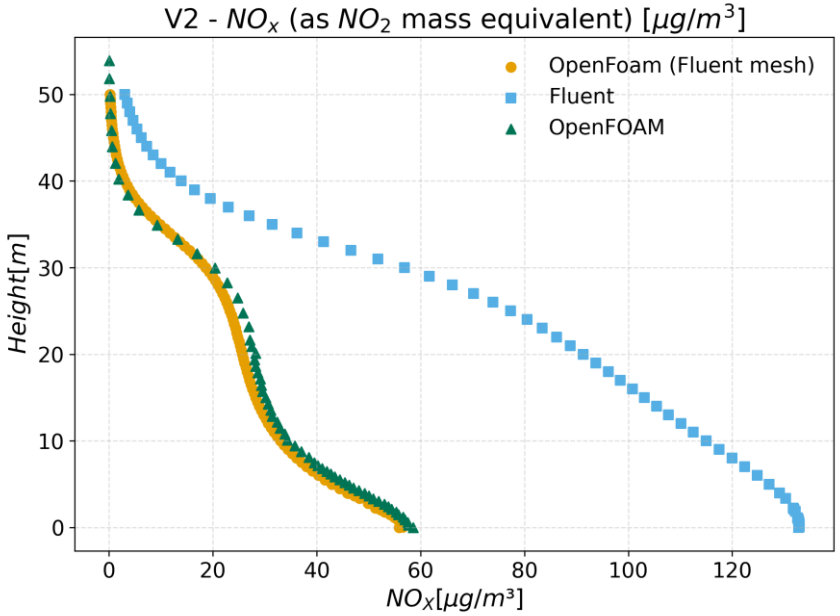
Results | vertical line samples

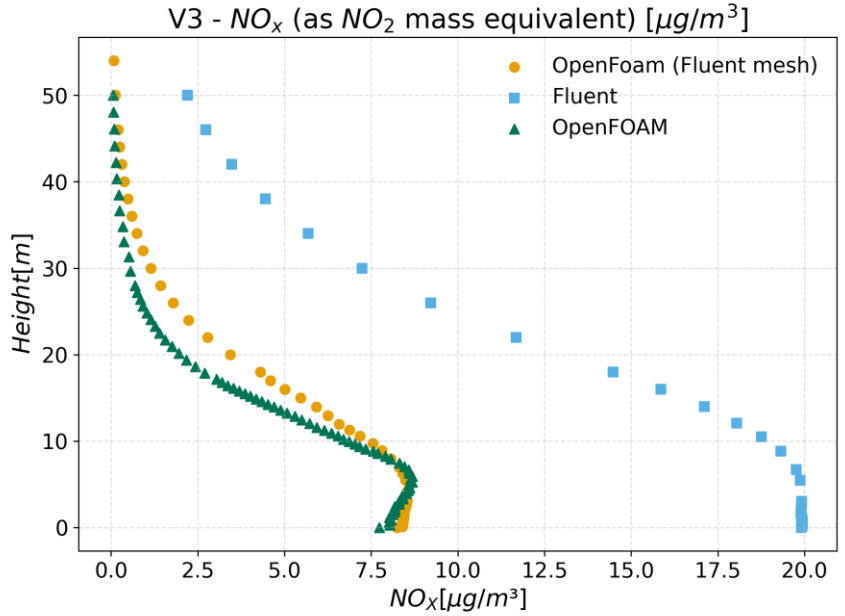












Results | point samples

U [m/s]	RMSE	MAE	R^2	Pearson r	
A vs B	0.35	0.16	0.93	0.97	Good agreement. Differences are solver-related.
B vs C	***0.14***	***0.10***	***0.99***	***0.99***	Results match. Meshing software denotes no differences.
A vs C	0.38	0.22	0.91	0.96	Larger deviations from combined solver + mesh.

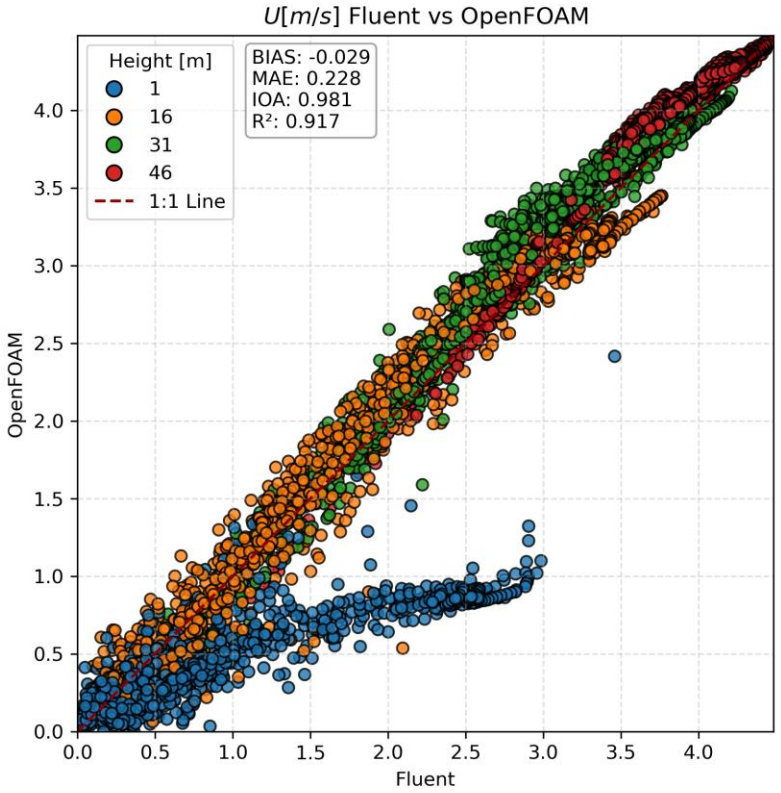
NO_2 [µg/m³]	RMSE	MAE	R^2	Pearson r	
A vs B	15.58	5.25	0.65	0.92	Moderate agreement.
B vs C	***2.84***	***0.59***	***0.93***	***0.96***	Good agreement. Meshing software denotes no differences.
A vs C	12.67	5.65	0.57	0.88	Larger deviations.

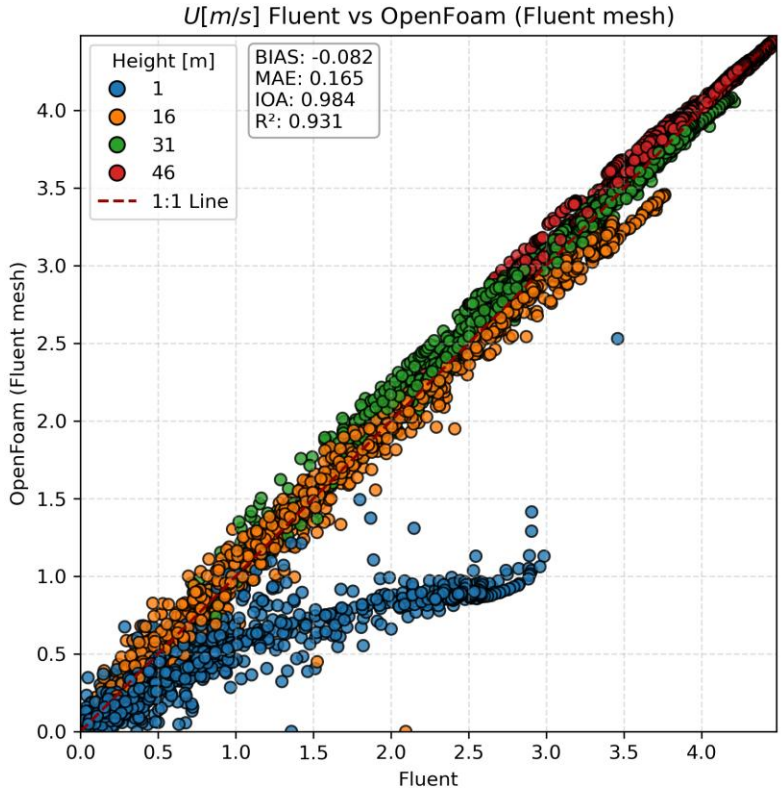
CASE A
Mesh + Simulation
Ansys FLUENT

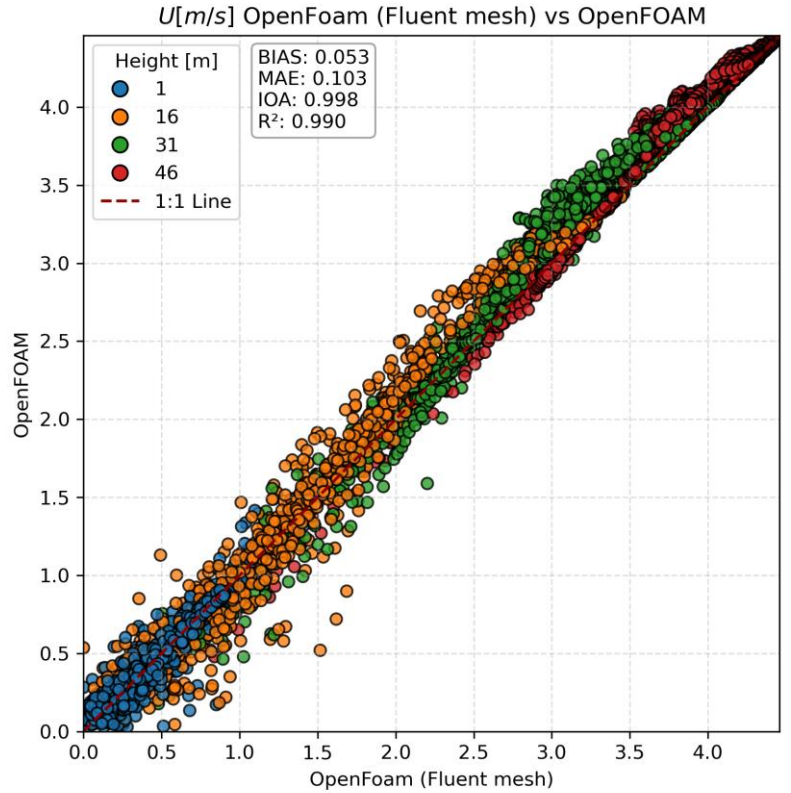
CASE B
Mesh + Simulation
Ansys FLUENT
OpenFOAM

CASE C
Mesh + Simulation
OpenFOAM

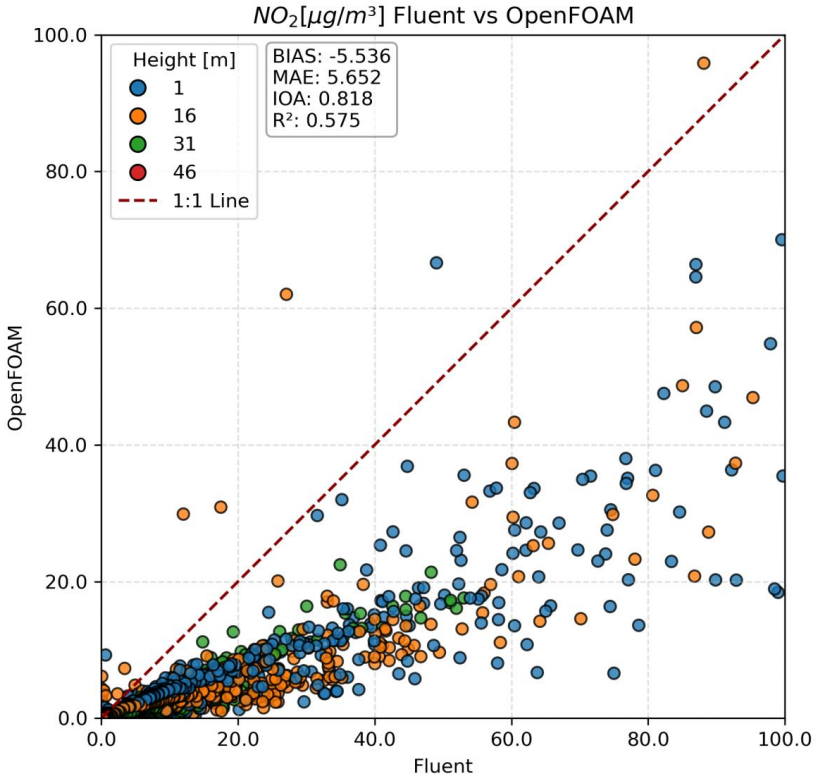
Results | point samples | velocity

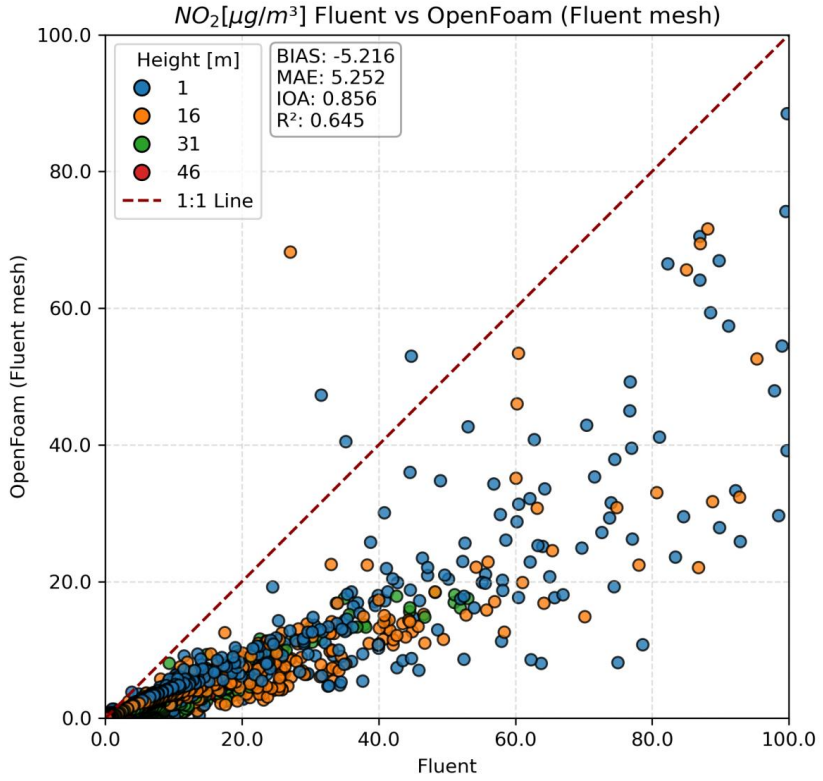


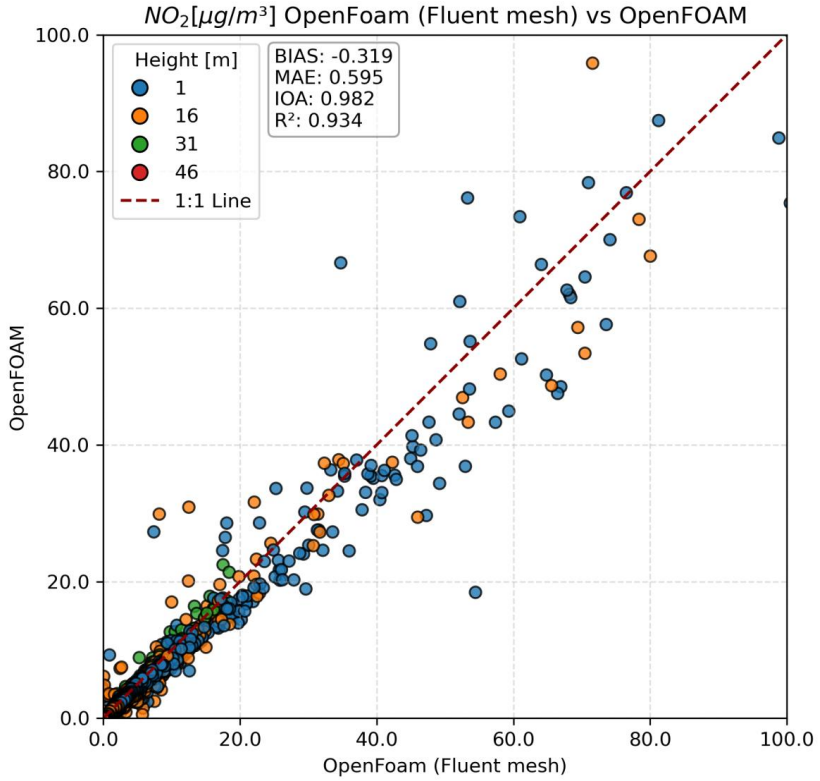




Results | point samples | NO_2







Discussion | Conclusions

- Validation against measurements, is essential to ensure accuracy, reliability, and applicability.
- No vegetation was considered.
- Both Fluent and OpenFOAM demonstrate consistent results under similar methodological setups.
- Solver/Software-specific differences exist, and outputs should be interpreted carefully when informing real-world decisions.

Implications for Practice

- Awareness of solver-specific variability is important for practitioners translating CFD outputs into policy or design.
- Demonstrated consistency across tools supports continued confidence in CFD as a basis for urban air quality assessments.
- Harmonisation Supports Progress

Thank you for your attention!

23rd International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes

16-19 September 2025
Hamburg, Germany

HARMO

Diogo Nascimento[*a)c)], Nicola Luciano[b)], Andrea Piccoli [b)], Domenico Toscano [b)], Guido Pirovano [b)], Diogo Lopes [a)], Jorge Sousa[c)], Myriam Lopes [a)], Ana Isabel Miranda [a)], Carlos Borrego [a)],Vera Rodrigues [a)]

[a)] CESAM – Centre for Environmental and Marine Studies & Department of Environment and Planning, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal;
[b)] RSE - Ricerca sul Sistema Energetico, via Rubattino 54, Milan, 20134, Italy;
[c)] VITO - Flemish Institute for Technological Research, Boeretang 200, 2400 Mol, Belgium;

This research was funded by FCT – Fundação para a Ciência e a Tecnologia I.P. through the FCT PhD Scholarship 2024.00422.BD, the OptWire project (PTDC/EEI-TEL/2697/2021), and CESAM (UID/50006 + LA/P/0094/2020). Funding was provided through national resources, with additional co-funding from the FEDER, as part of the PT2020 Partnership Agreement, Compete 2020, and Portugal 2030.

REPÚBLICA PORTUGUESA | EDUCAÇÃO, CIÊNCIA E INOVAÇÃO
fct Fundação para a Ciência e a Tecnologia
OptWire Optical Wireless Communications Enabled by AI
PESSOAS 2030
PORTUGAL 2030
Cofinanciado pela União Europeia

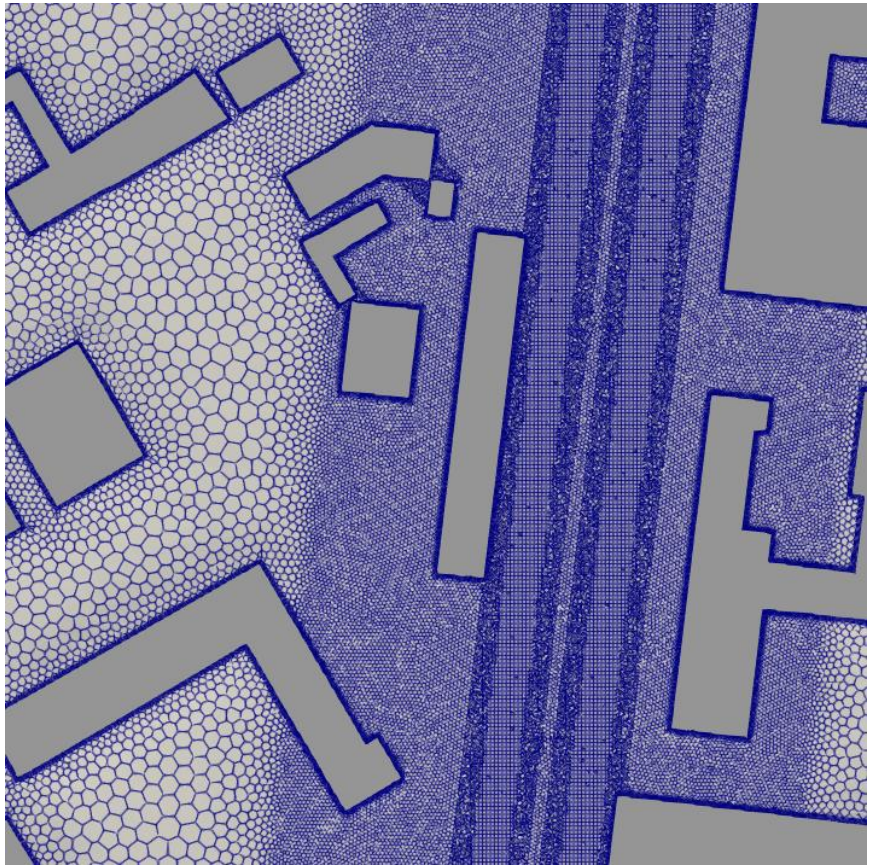
Methodology | What's different?

EXTRA SLIDES

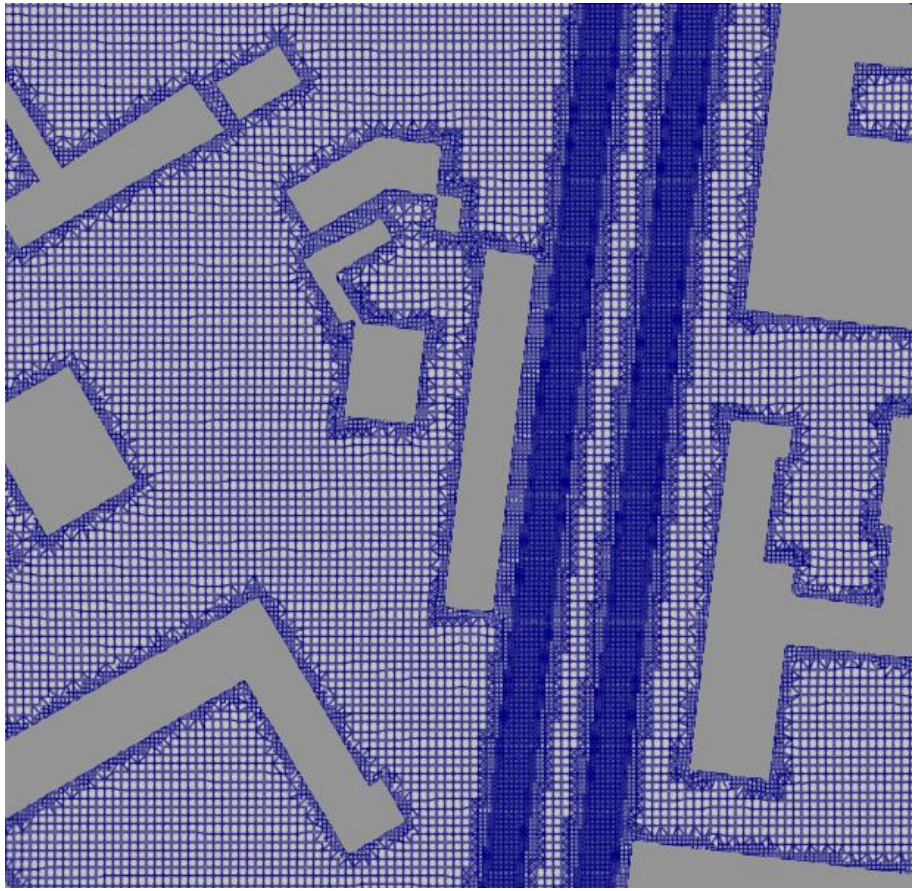
HARMO

Mesh differences

CASE A + CASE B



CASE C



CASE A
Mesh + Simulation

Ansys FLUENT

CASE B
Mesh + Simulation

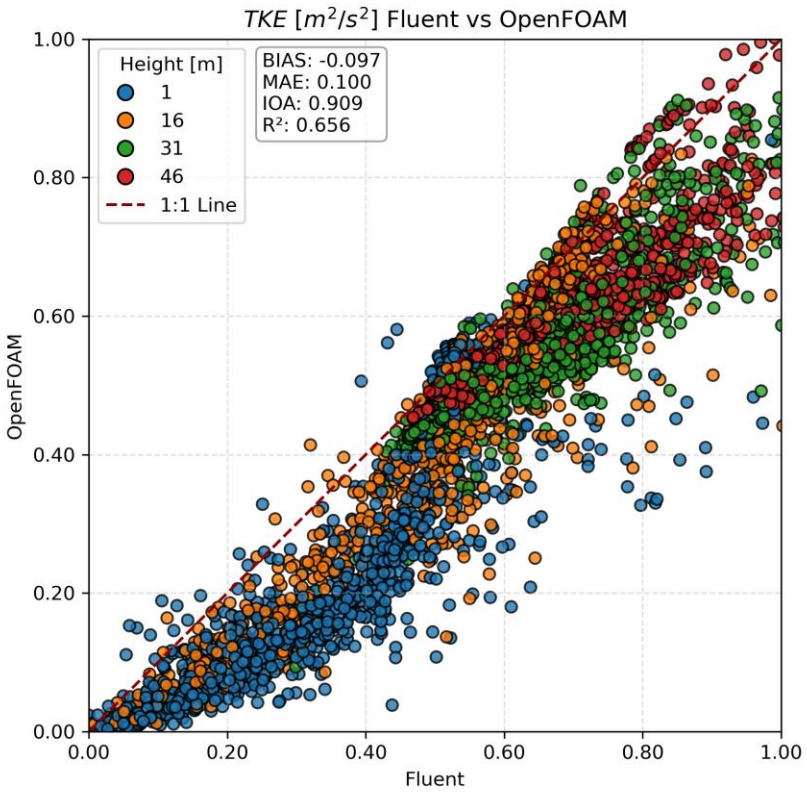
Ansys FLUENT OpenFOAM

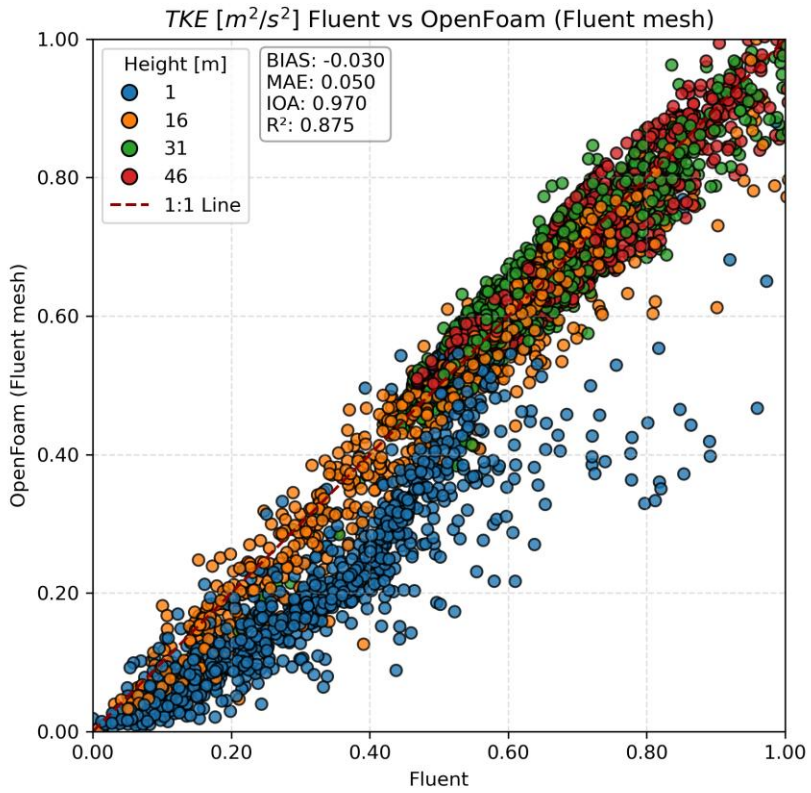
CASE C
Mesh + Simulation

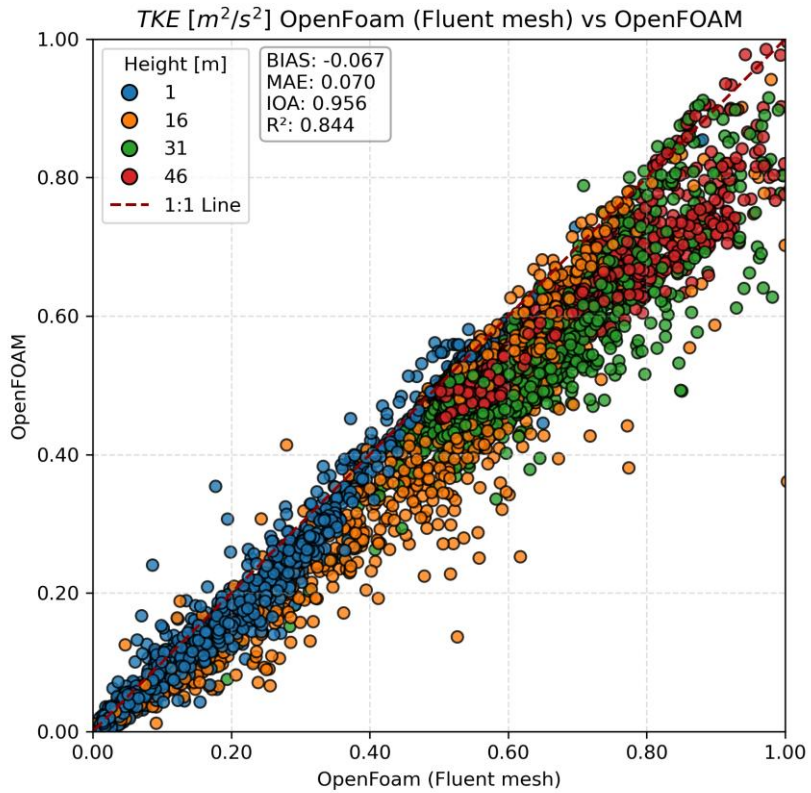
OpenFOAM

Results | point samples | TKE

EXTRA SLIDES





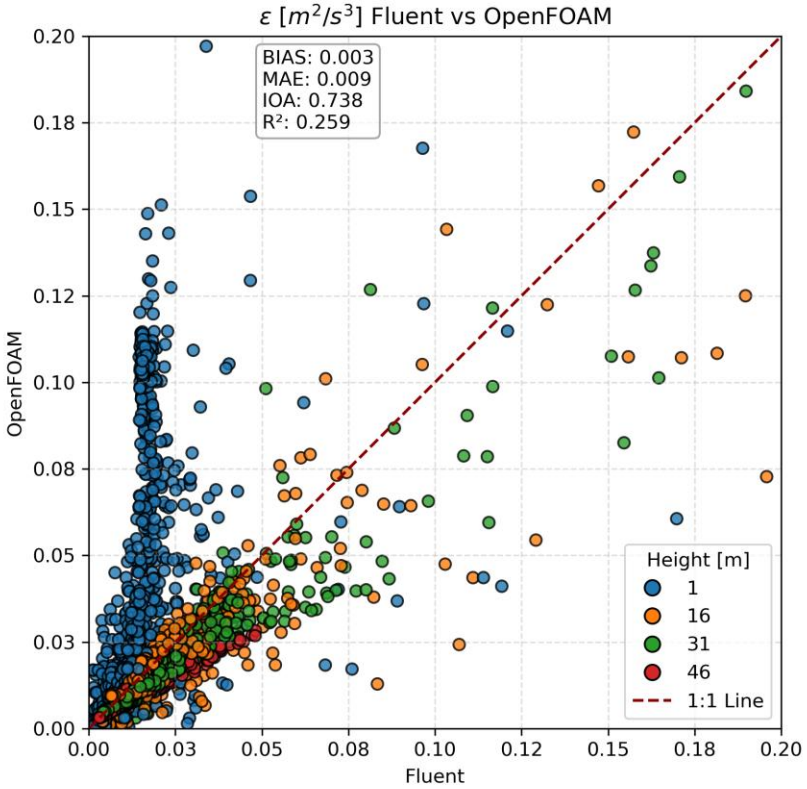


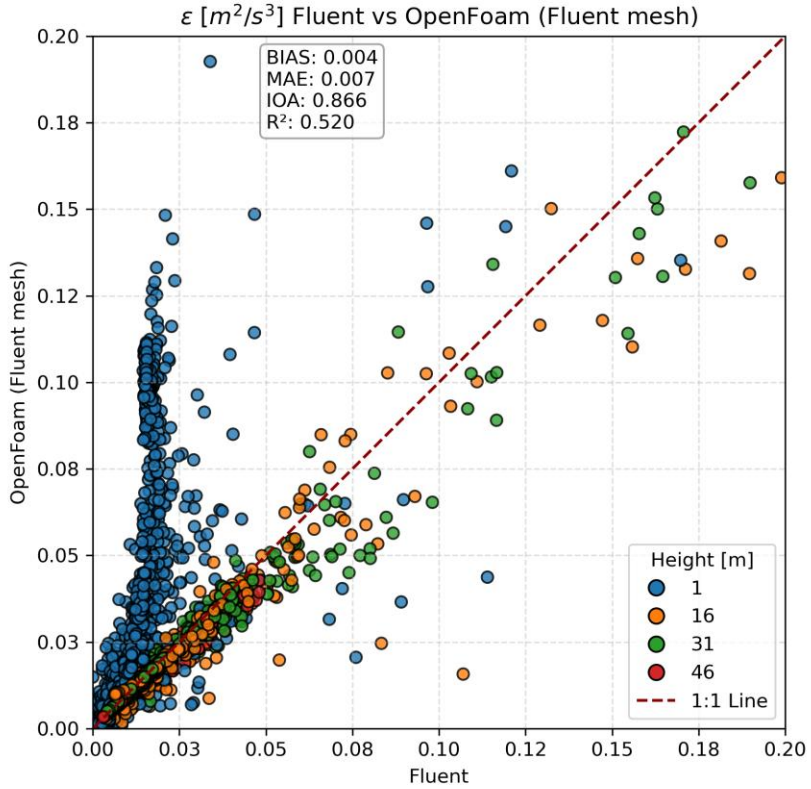
TKE [m²/s²]	RMSE	MAE	R^2	Pearson r
A vs B	0.08	***0.05***	0.87	0.94
B vs C	***0.01***	0.07	***0.84***	***0.96***
A vs C	0.13	0.09	0.66	0.91

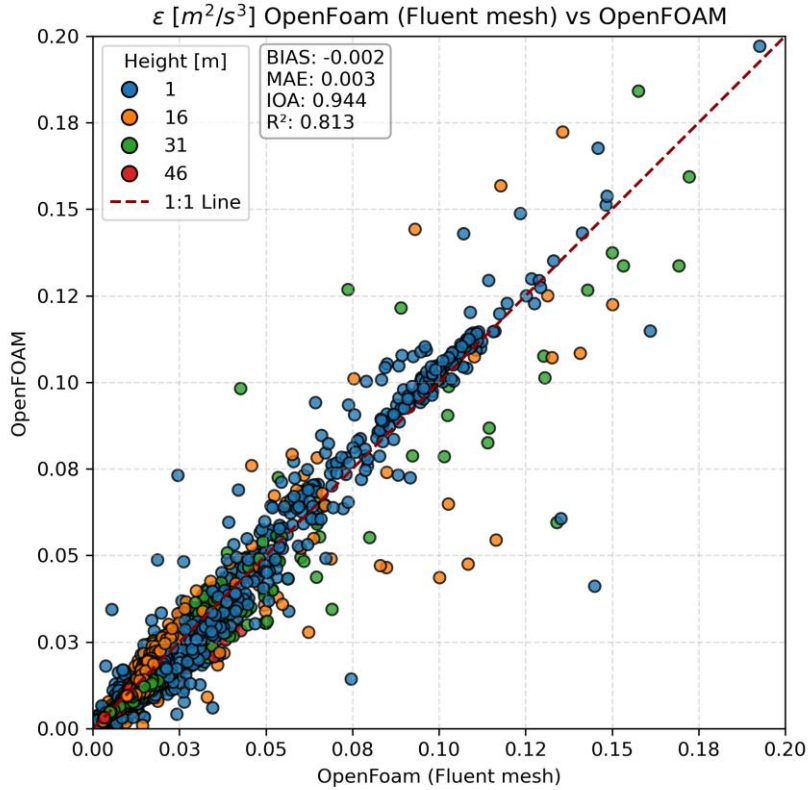
Results | point samples | Turbulent energy dissipation

EXTRA SLIDES

HARMO



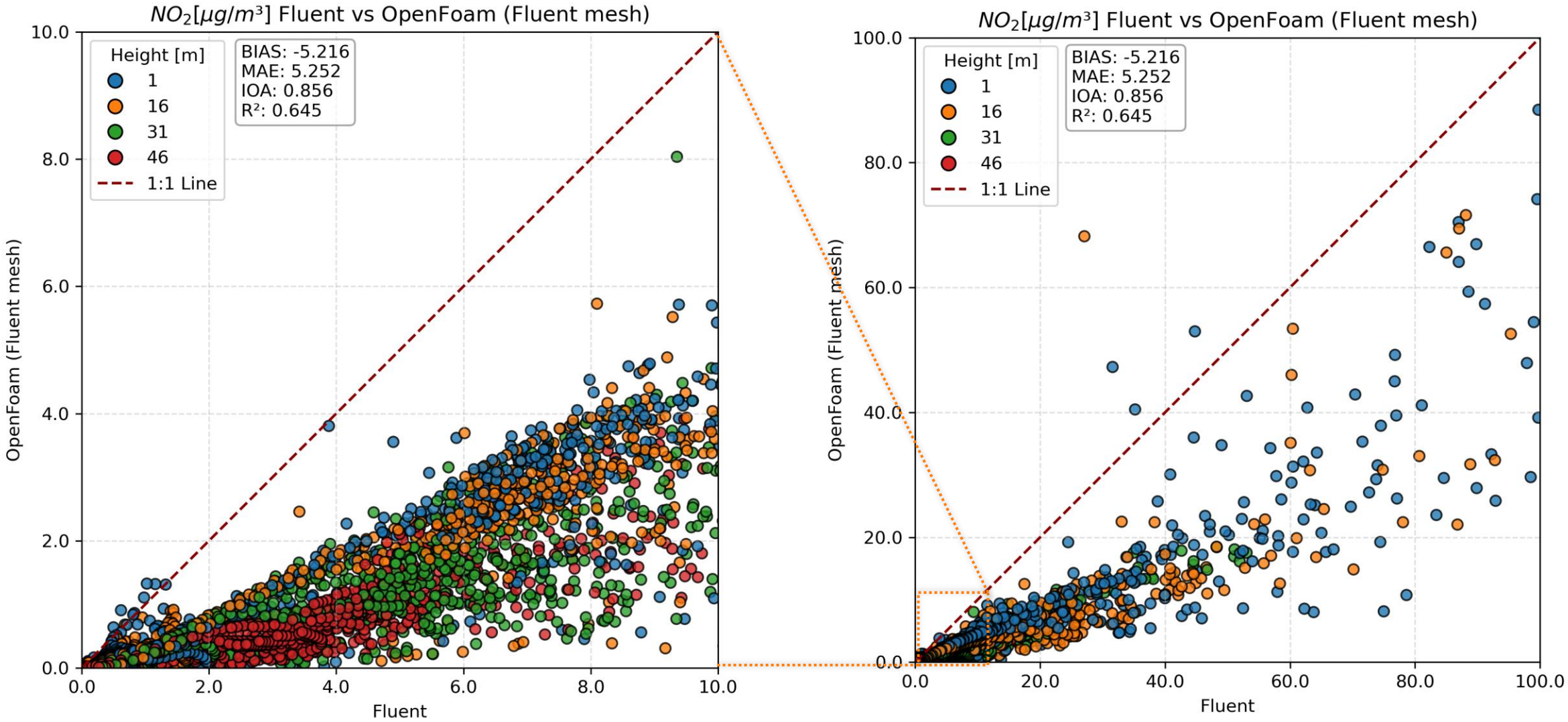




TKE [m²/s²]	RMSE	MAE	R^2	Pearson r
A vs B	0.02	0.007	0.52	0.77
B vs C	***0.01***	***0.003***	***0.81***	***0.90***
A vs C	0.03	0.009	0.25	0.58

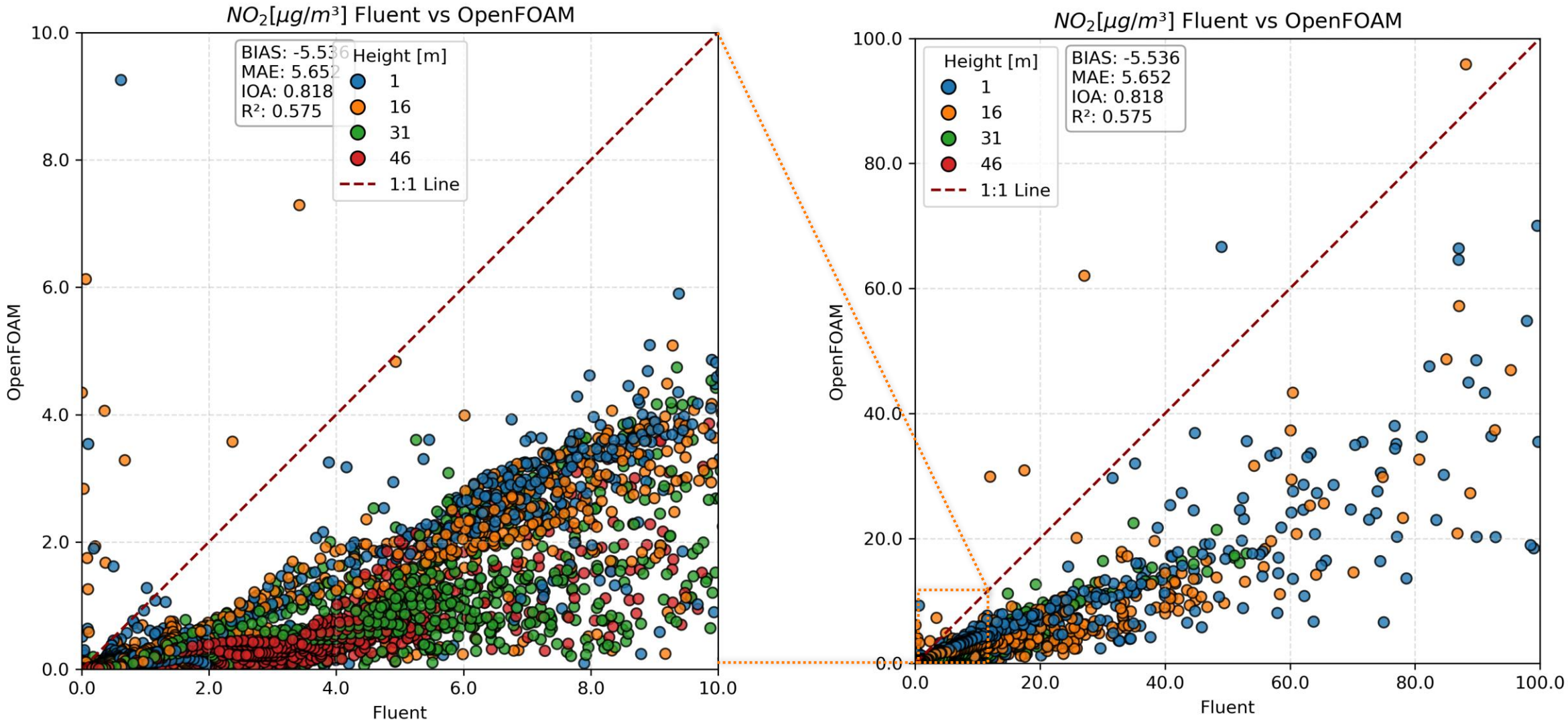
Results | point samples | NO_2

EXTRA SLIDES



Results | point samples | NO_2

EXTRA SLIDES



Results | point samples | NO_2

EXTRA SLIDES