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CFD and wind tunnel modelling of green infrastructures effects on air quality

In Porto's urban area

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HARMO18

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CESAM
Centre for Environmental and Marine Studies
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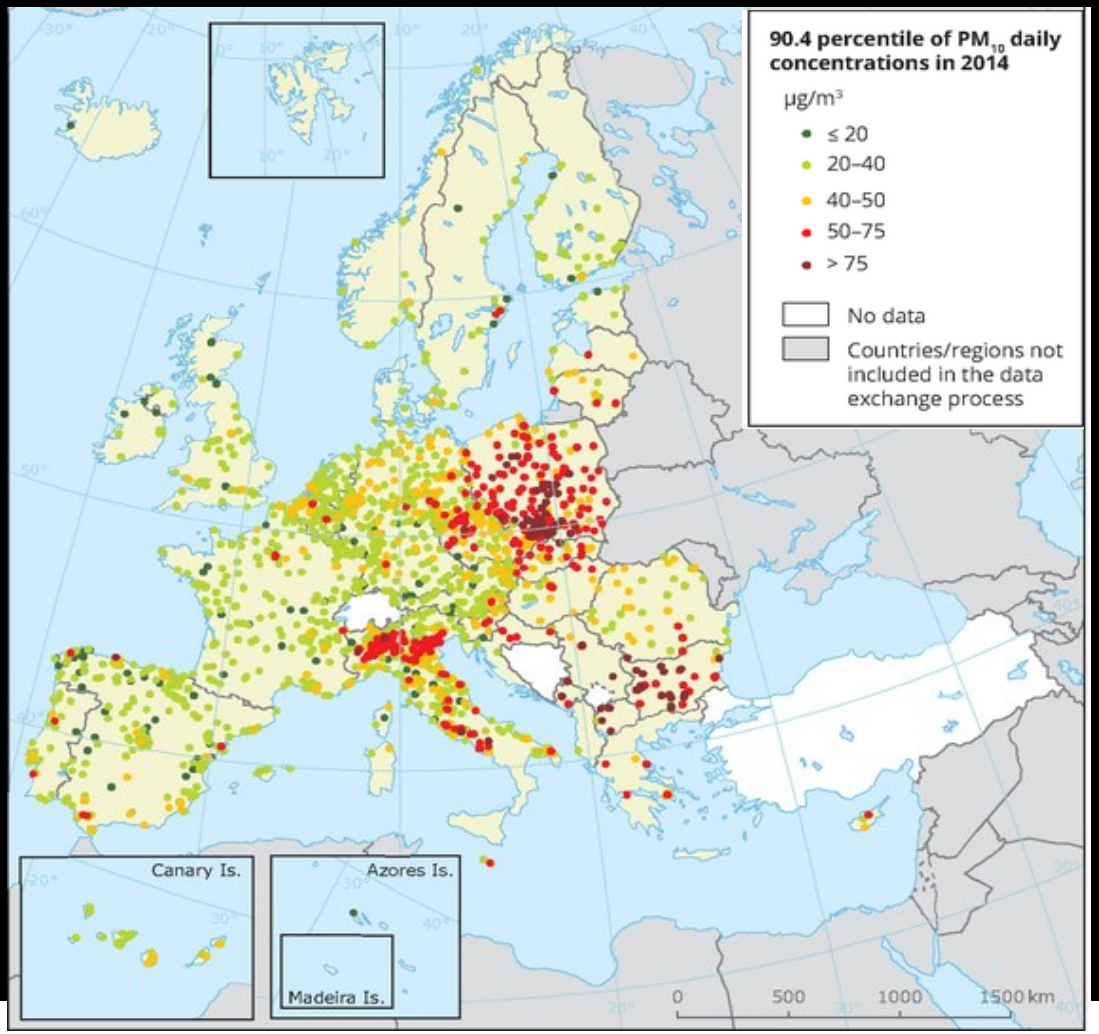
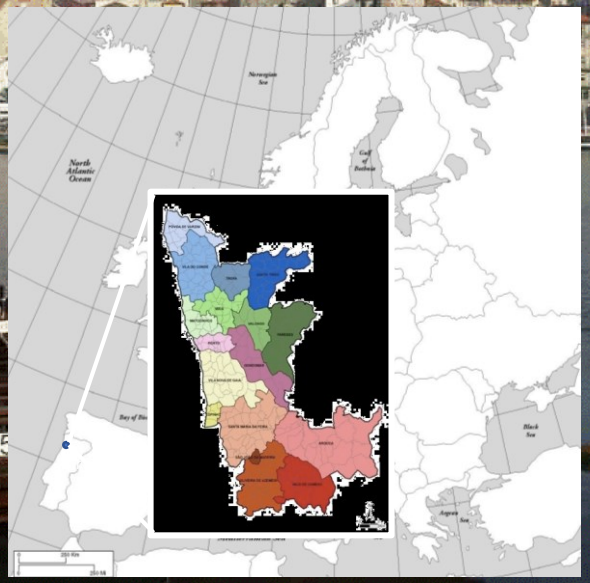
Motivation

Urban areas sustainability is alarmingly threatened by **air pollution**





Case study: Porto urban area

Air pollution episodes

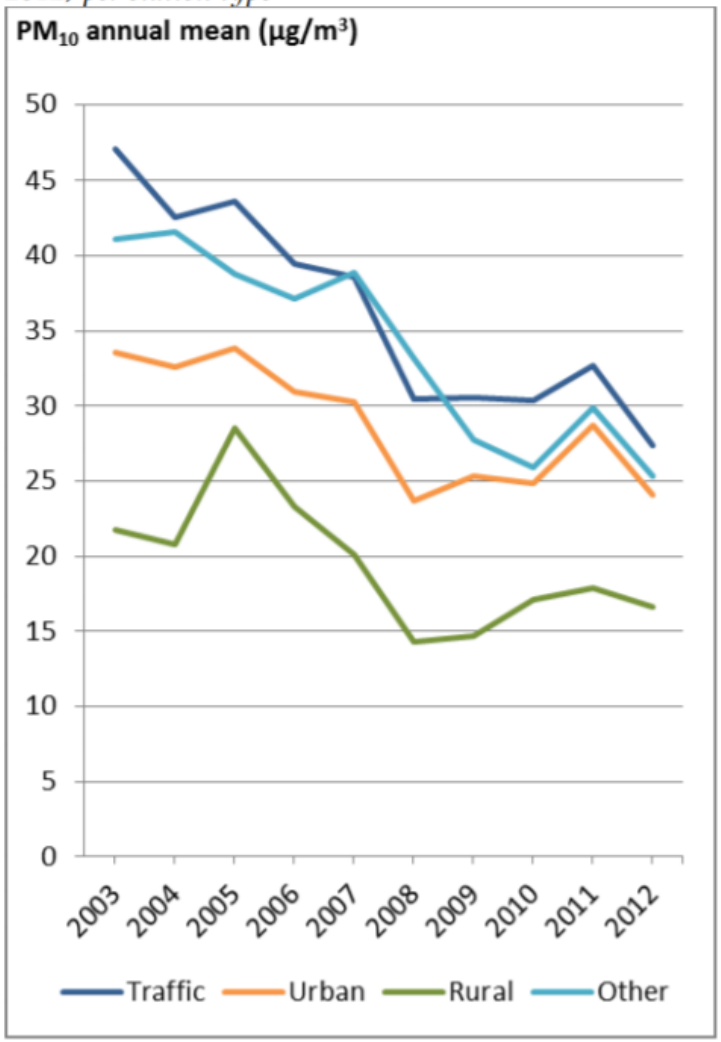
Porto urban agglomeration

– several exceedances –

26 PM10 exceedances in 2010

Impacts on human health

Changes in annual mean concentrations of PM_{10} (2003-2012) per station type



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Urban atmospheric quality, climate change and resilience

Green infrastructures effects on flow dynamics

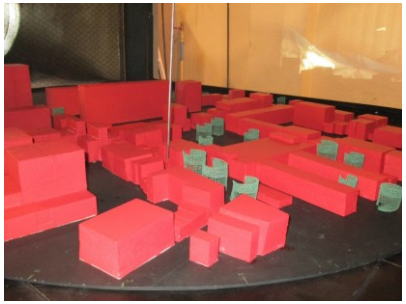
- Meteorology
- Urban elements geometry
- Computational domain
- Grid resolution

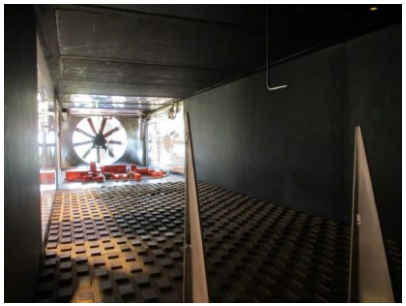
- **3D wind field**
- Emission rate
- Emission configuration

RANS model extended k-ε turbulence closure

Lagrangian approach

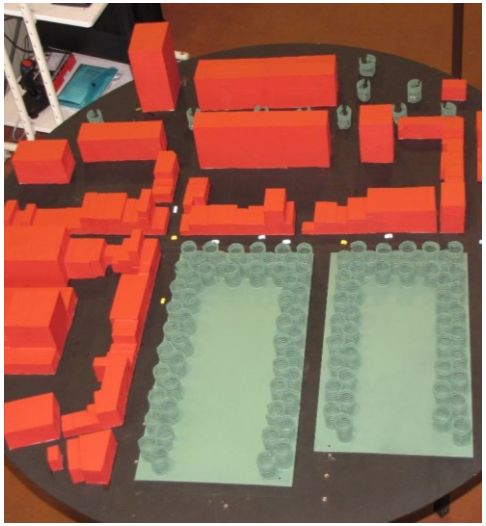
CFD model VADIS





Physical simulations wind tunnel

- Atmospheric boundary layer simulation
- Neutral stability conditions
- Wind tunnel test section of 6.5 m x 1.5 m x 1 m
- Turbulence generators and roughness elements
- Hot-wire anemometer (TSI IFA-300)
- Mock up scale 1:250

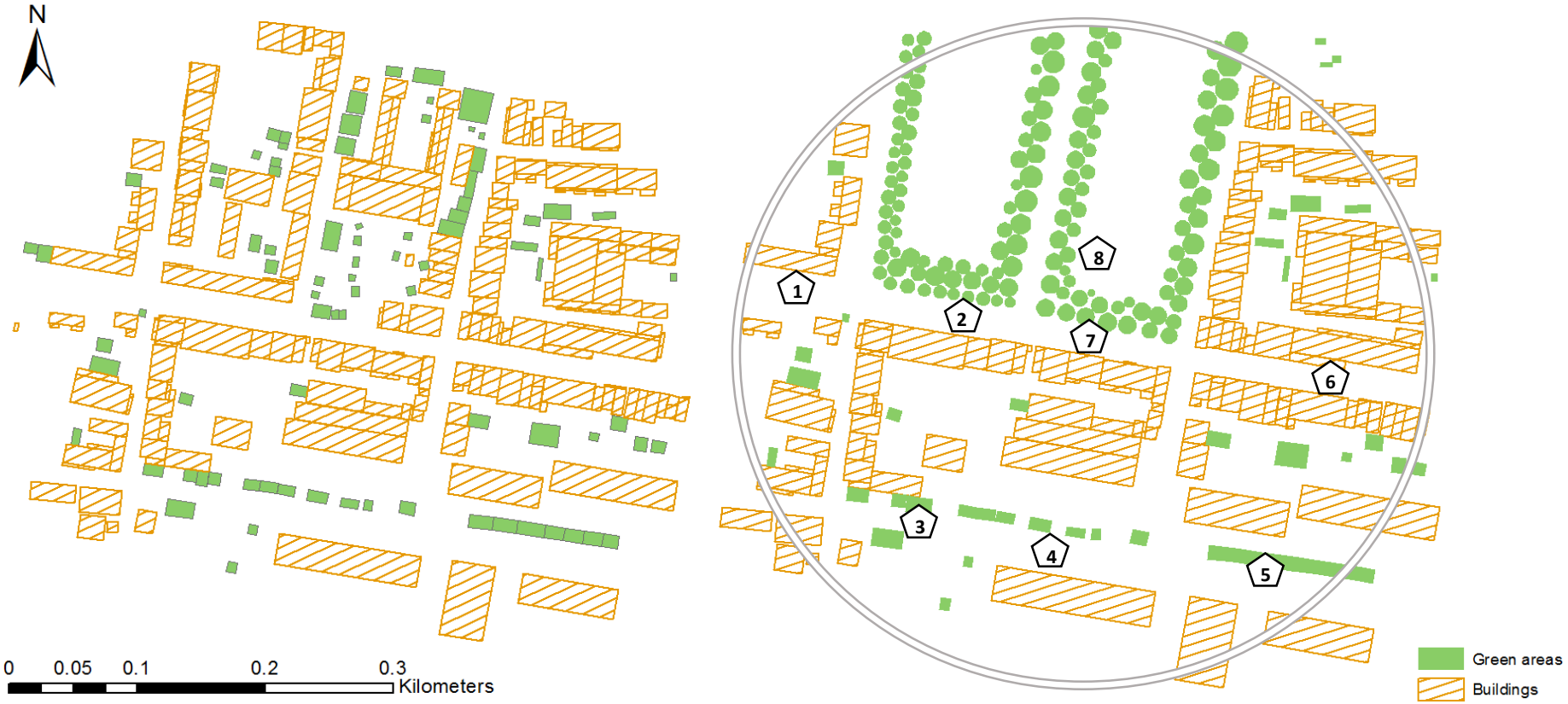


Physical simulations

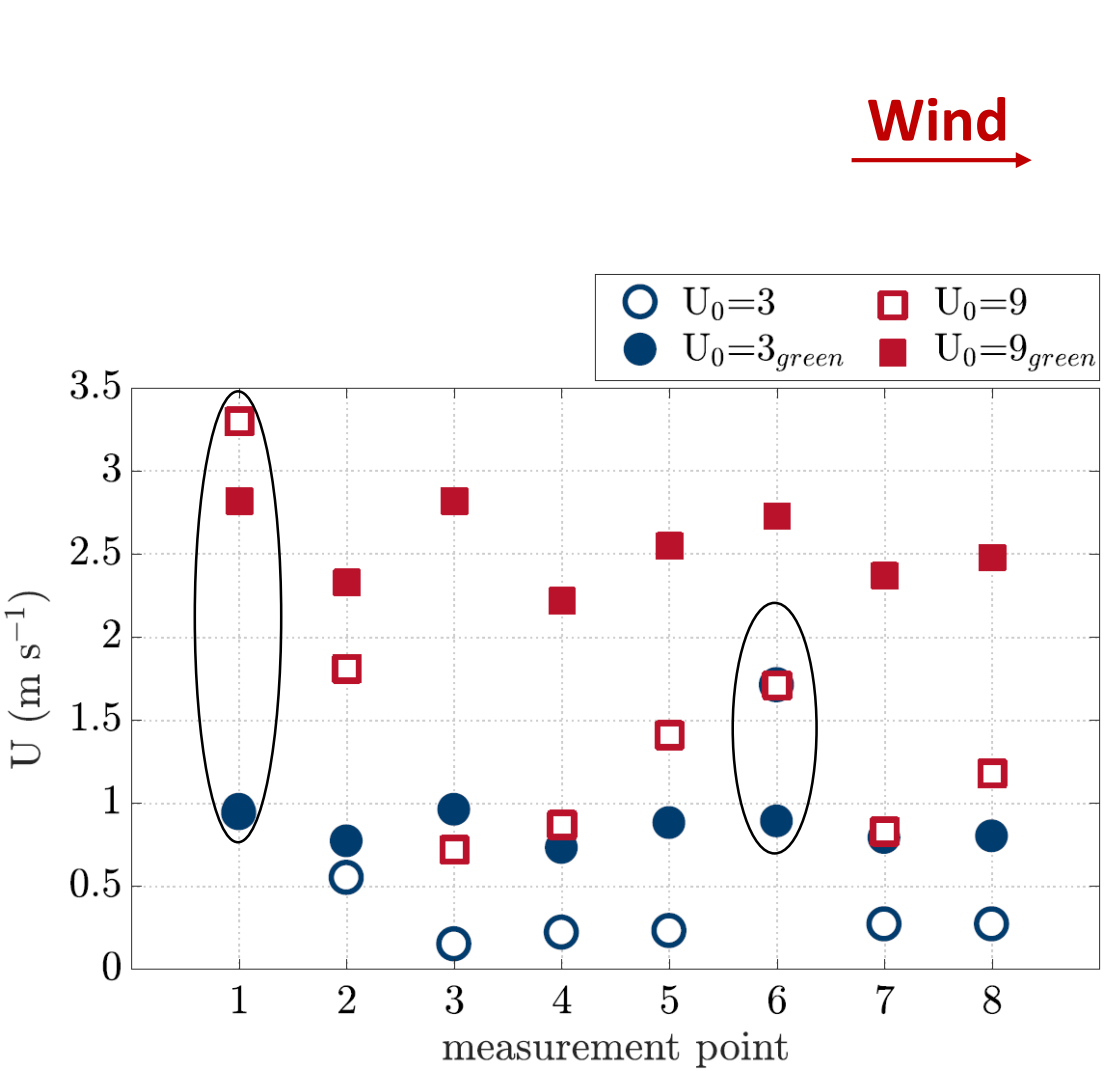
- Inflow wind speed: 3, 6 and 9 m s^{-1}
- Inflow wind direction:

  North, West and Southeast
- **replacement of built-up by green areas**

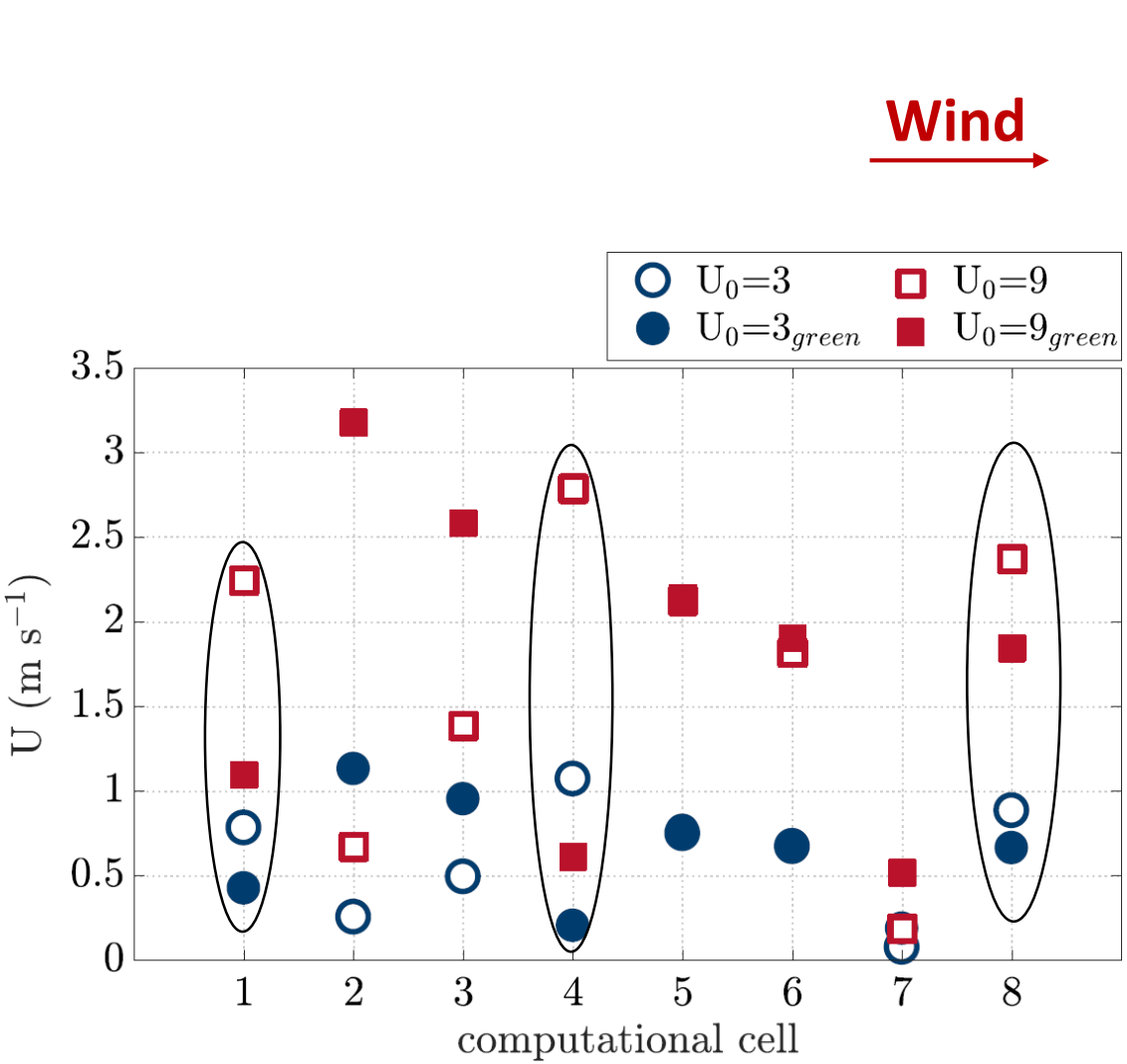
Computational domain



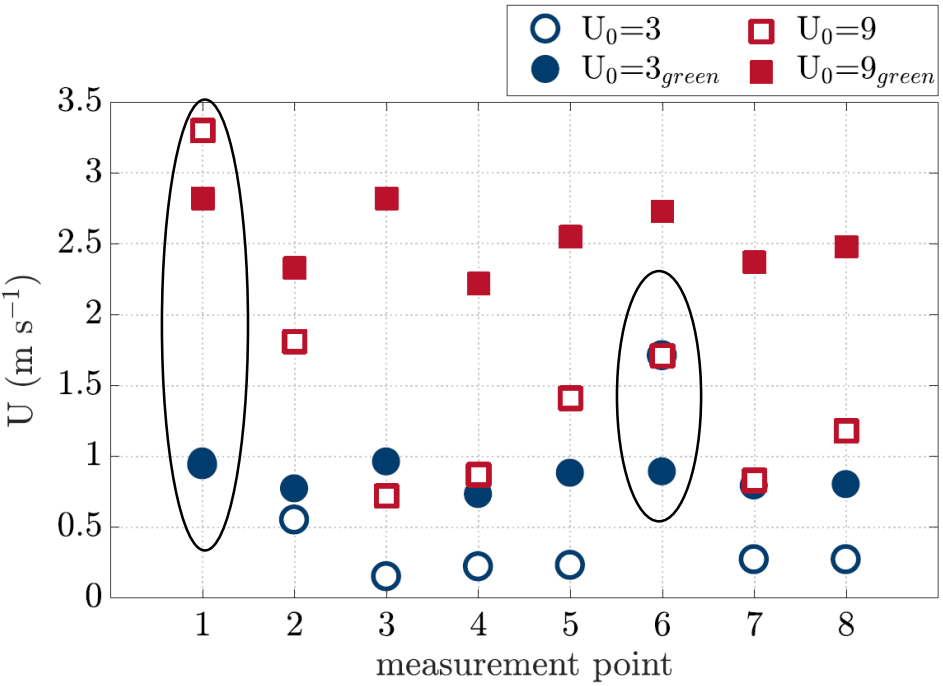
CFD and wind tunnel results

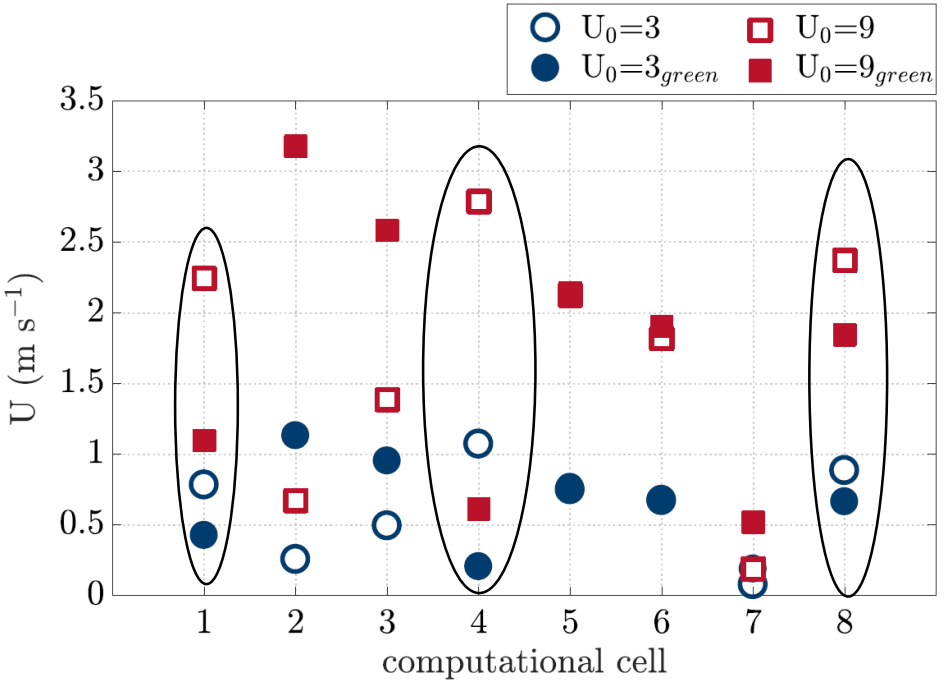


CFD and wind tunnel results



CFD and wind tunnel results

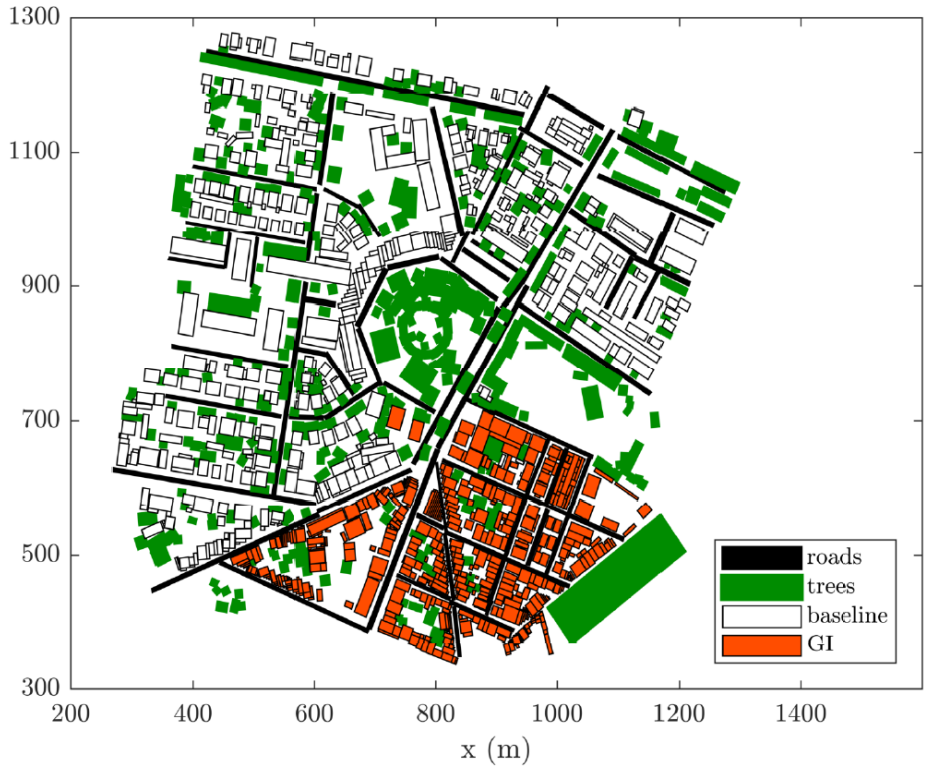




- RMSE for the baseline scenario: 0.5, 0.9 and 1.0 m s^{-1}
- **RMSE for the green scenario: 0.6, 1.3 and 1.4 m s^{-1}**

Green infrastructures effects on air quality

Computational domain

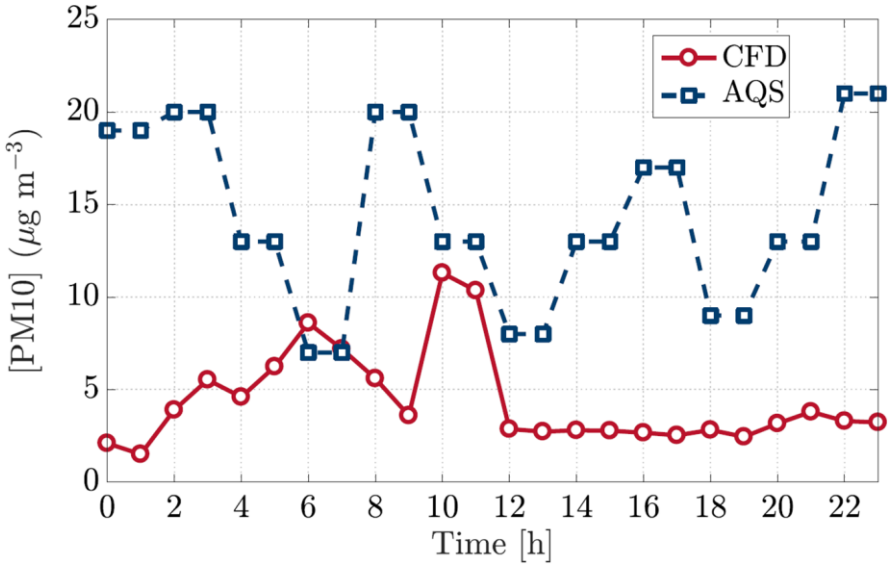


CFD model performance

- PM10 concentrations point out an underestimation by the CFD model

- Hourly PM10 concentrations are below the legal limit value (**2008/50/EC Directive**) of **50 µg m^{-3}**

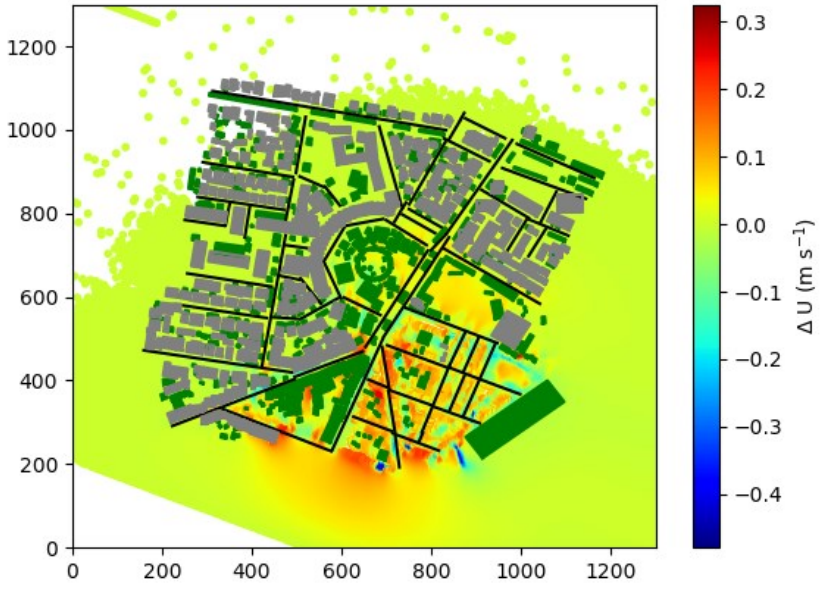
– **daily average value**



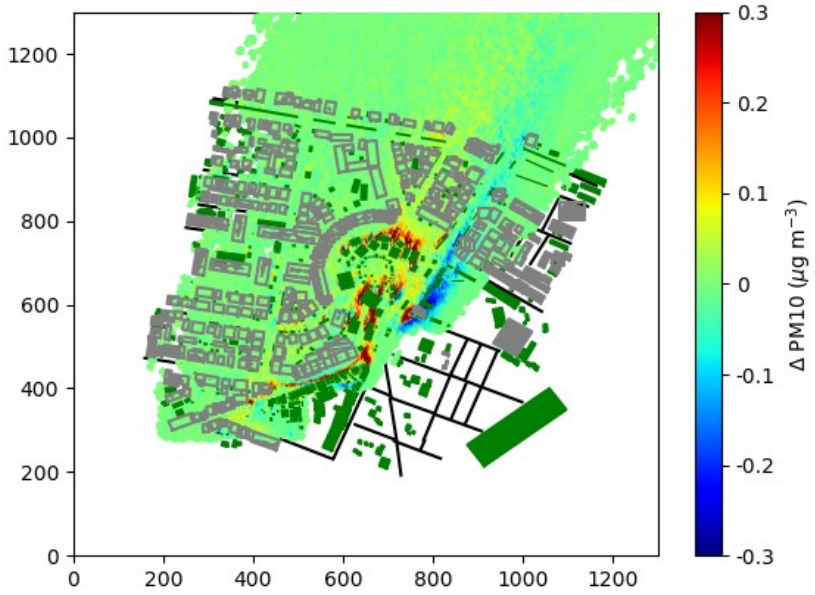
Assessment the effectiveness of Green Infrastructures

Effects of GI…

… on flow dynamics



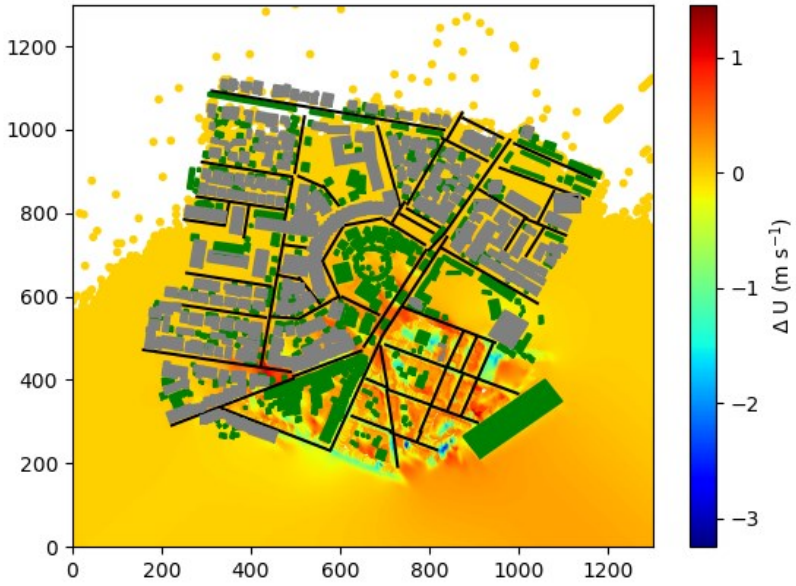
… on PM10 dispersion



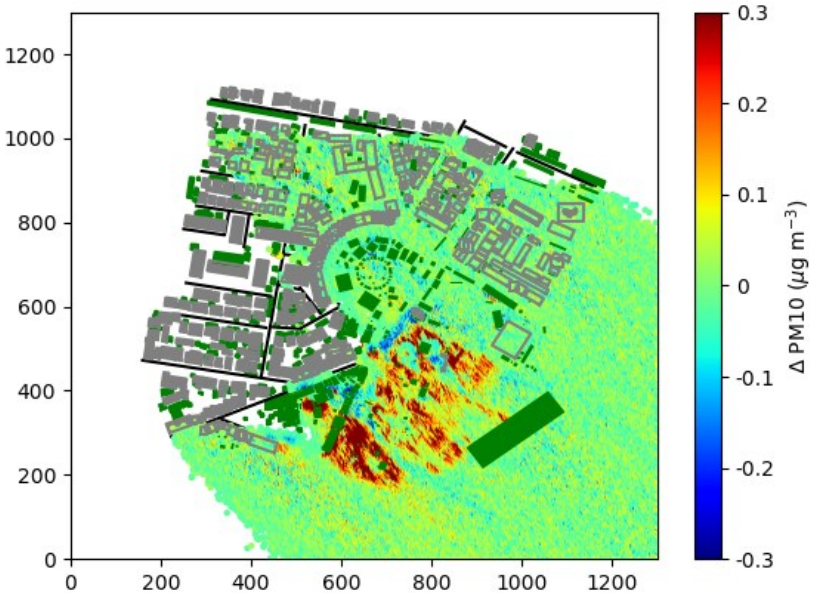
… at 4 a.m.

Effects of GI…

… on flow dynamics



… on PM10 dispersion



… at 8 a.m.

Conclusions

- **Air quality may be improved by the presence of GI in Porto's urban area**

PM10 concentration fields depend on the:

- meteorological conditions
- configuration of the local urban area
- presence of green infrastructures
- emissions from road traffic

Increase of Porto's urban area resilience

Harmonisation Regulatory Purposes

Common tools:

- To foster urban microclimate and pollutants dispersion patterns knowledge
- To assess GI effects on air quality
- To establish a set of guidelines to be disseminated to stakeholders and decision makers
- To promote important social, environmental and economic benefits

The **combination of these different tools** contributes to the development of an **effective procedure** for the characterization of the **turbulent flow dynamics and pollutants dispersion patterns** in urban areas

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Thank you!

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