Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

CALIOPE-Urban v1.0: Coupling R-LINE with a mesoscale air quality modelling system for urban air quality forecasts over Barcelona city (Spain)

Jaime Benavides[1], Michelle Snyder[2], Marc Guevara[1], Carlos Pérez García-Pando[1], Albert Soret[1], Fulvio Amato[3], Xavier Querol[3] and ***Oriol Jorba***[1]

[1] Earth Sciences Department, Barcelona Supercomputing Center, Barcelona, Spain
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28/6/2019

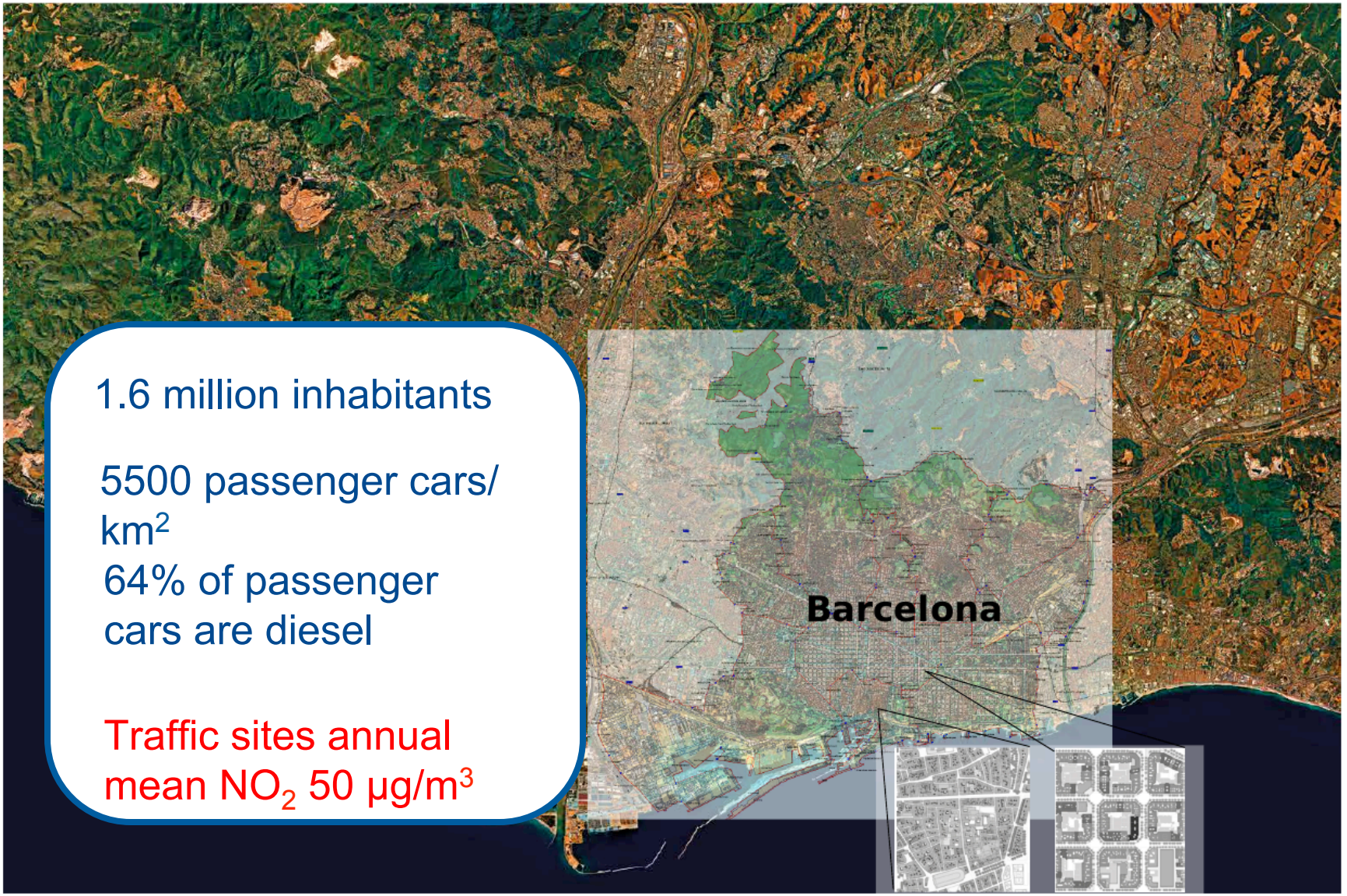
2nd Street-in-Grid (SinG) Modeling Symposium
Champs-sur-Marne, France, June 24 – 28, 2019

Outline

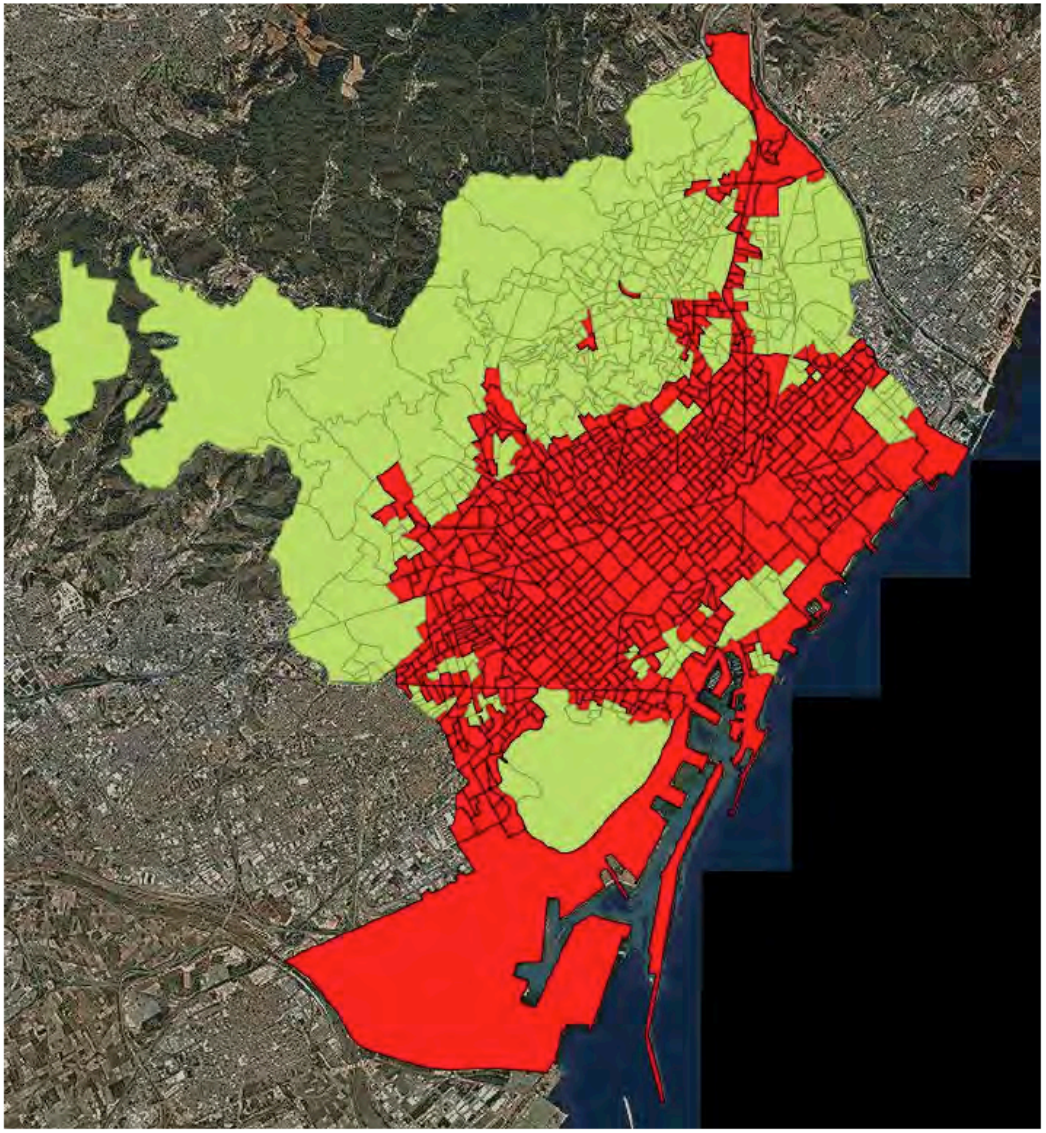
- CALIOPE-Urban v1.0: overview and evaluation for NO_2

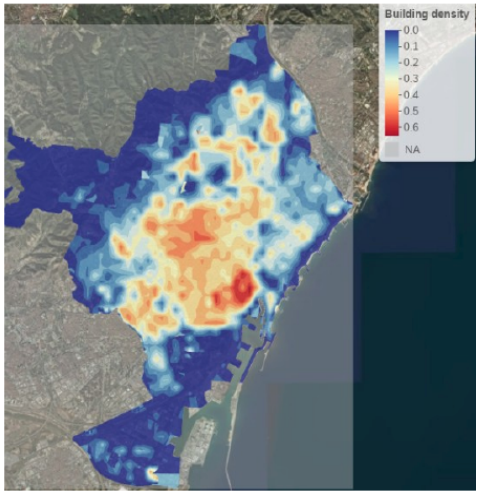
- Local traffic contribution to black carbon horizontal and vertical profiles using CALIOPE-Urban v1.0

Barcelona


1.6 million inhabitants
5500 passenger cars/ km2
64% of passenger cars are diesel
Traffic sites annual mean NO2 50 µg/m3
Barcelona
Ciutat Vella
Eixample

Motivation - NO_2 a health issue





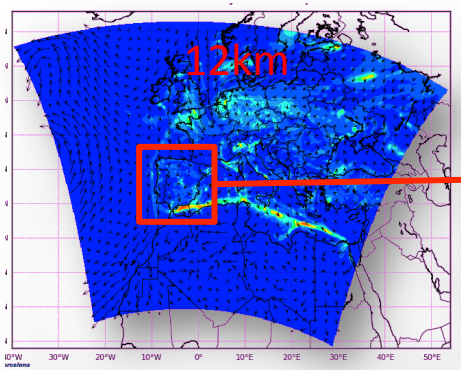
Potential exposure of the population to the annual mean NO_2 concentration for 2016

< 40 µg/m³

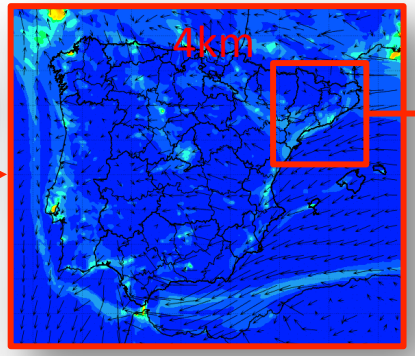
> 40 µg/m³

Barcelona Public health Agency (2017)

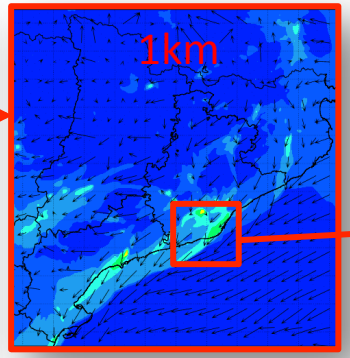
CALIOPE: Air Quality Forecasting System for Spain



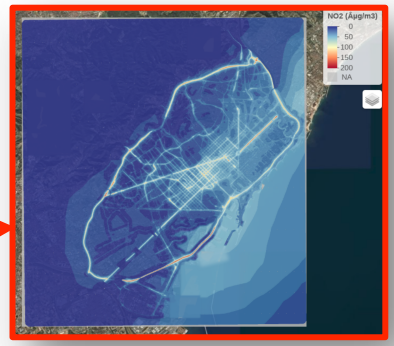
Pay et al. (2011; 2012 AE)



Baldasano et al. (2012 AE)



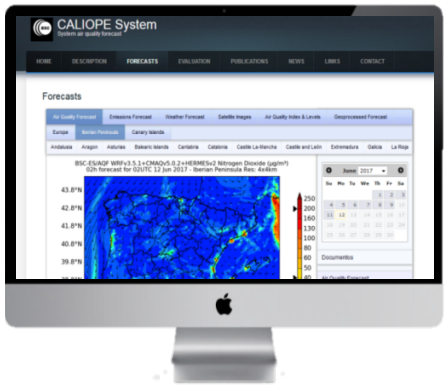
Pay et al. (2014 GMD)

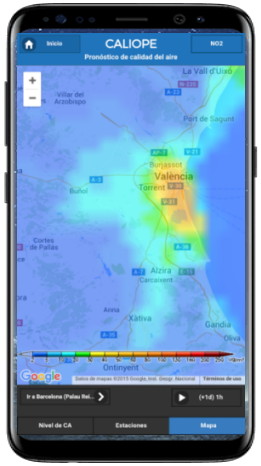


Benavides et al. (2019 GMD)

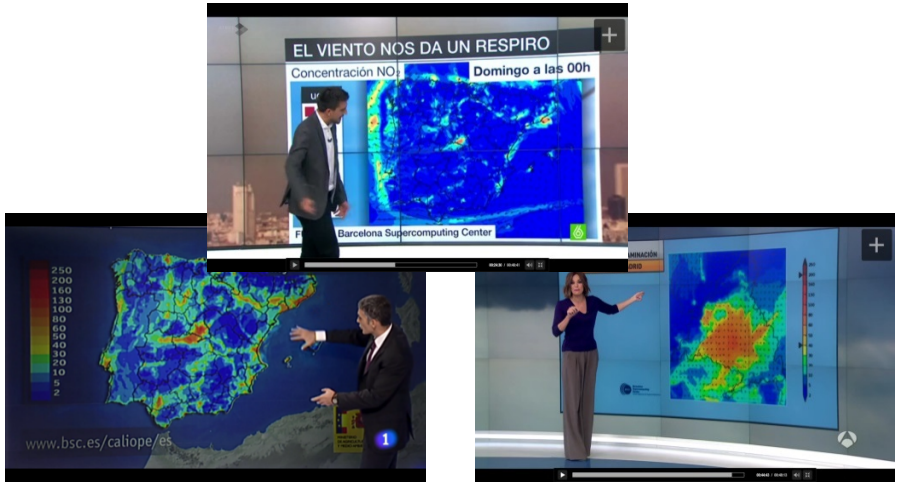
Multiscale models from regional to local scales

Web / App

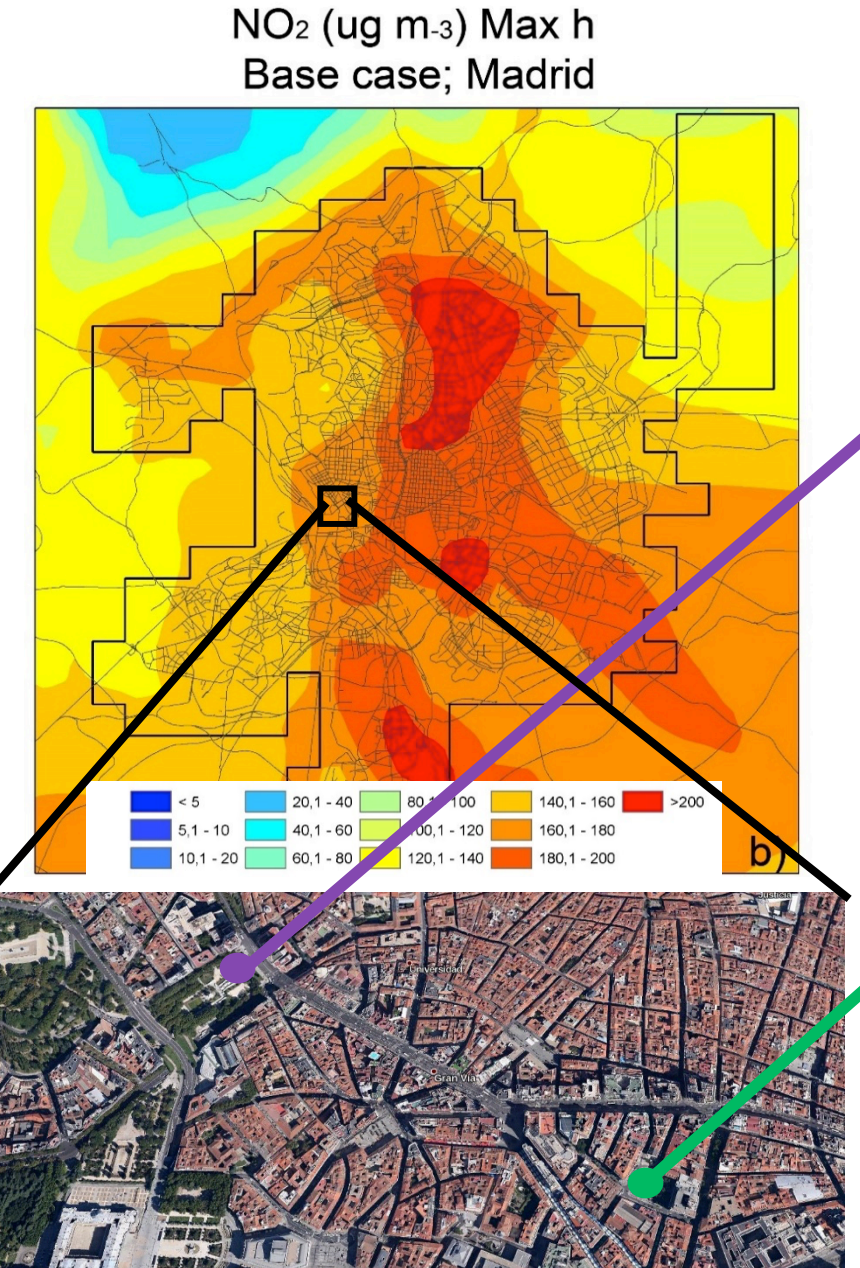




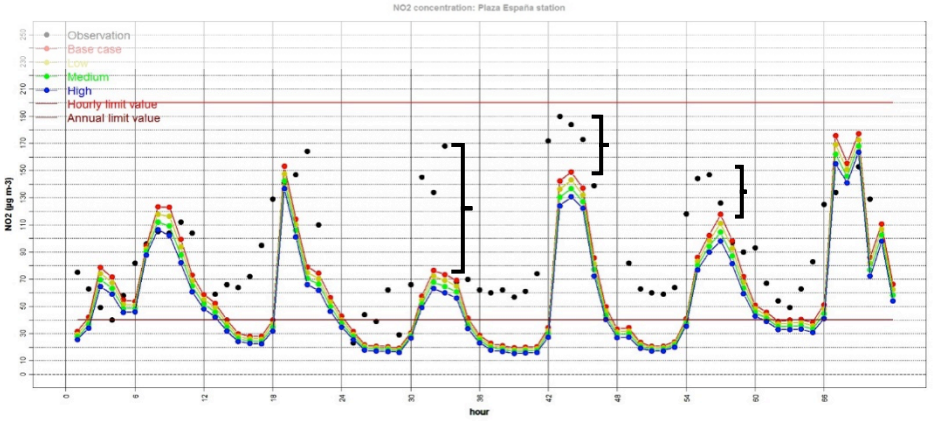
In the media



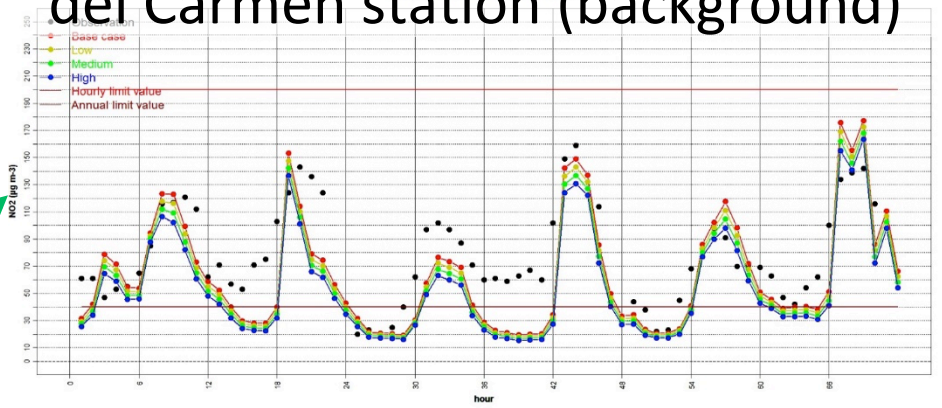
Problem definition



NO_2 hourly concentration. Plaza de España station (traffic)



NO_2 hourly concentration. Plaza del Carmen station (background)

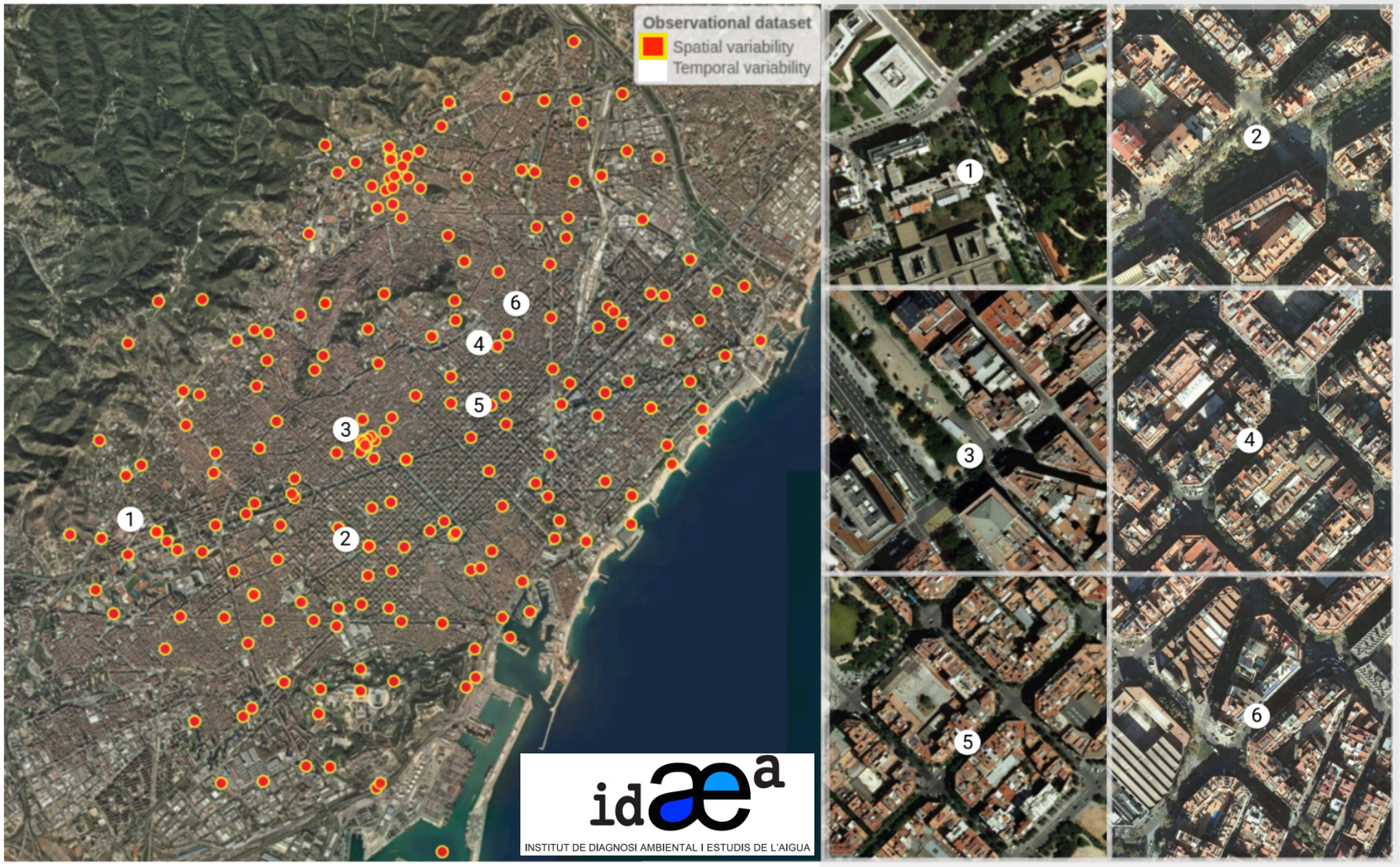


Soret et al. (2014)

Objective

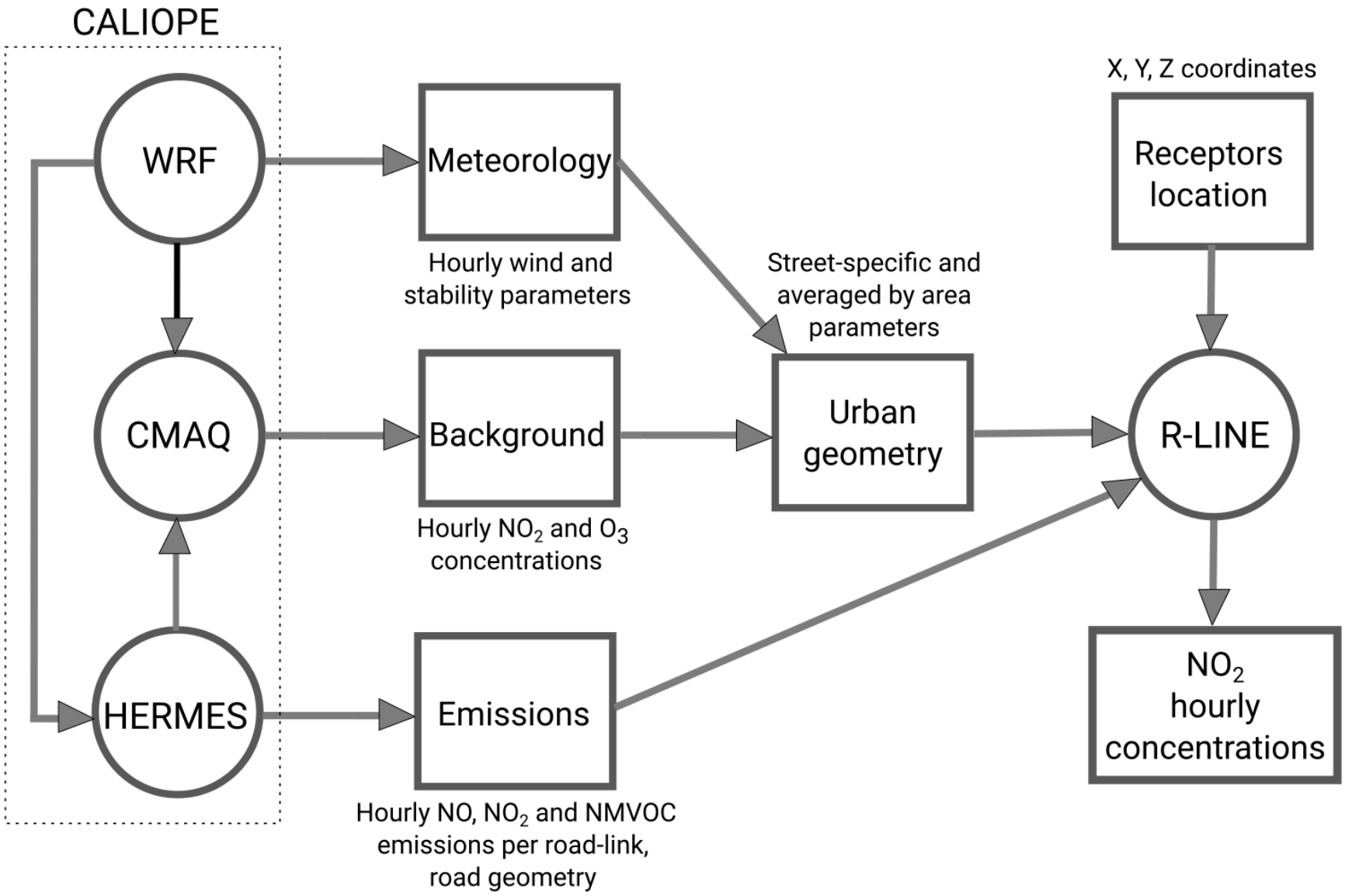
- Simulate more accurate NO_2 concentrations at street-scale level.
- Use valuable information from a mesoscale model (i.e., meteorology and air quality) forecast.
- Give a more realistic estimate of NO_2 spatial distribution and temporal variability across the city for regulatory purposues.

Observational data



Temporal: Air quality measures on April-May 2013 (Amato et al., 2014)
Spatial: 212 passive dosimeters for two weeks on Feb-March 2017

Methodology

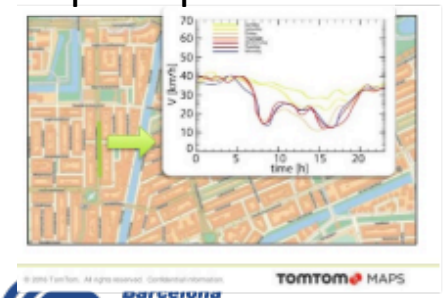


HERMES - Traffic emissions

Traffic flow data

Fleet composition

Speed profiles



Emission factors

Geosci. Model Dev., 12, 1885–1907, 2019
https://doi.org/10.5194/gmd-12-1885-2019

Geoscientific Model Development
Open Access
EGU

HERMESv3, a stand-alone multi-scale atmospheric emission modelling framework – Part 1: global and regional module

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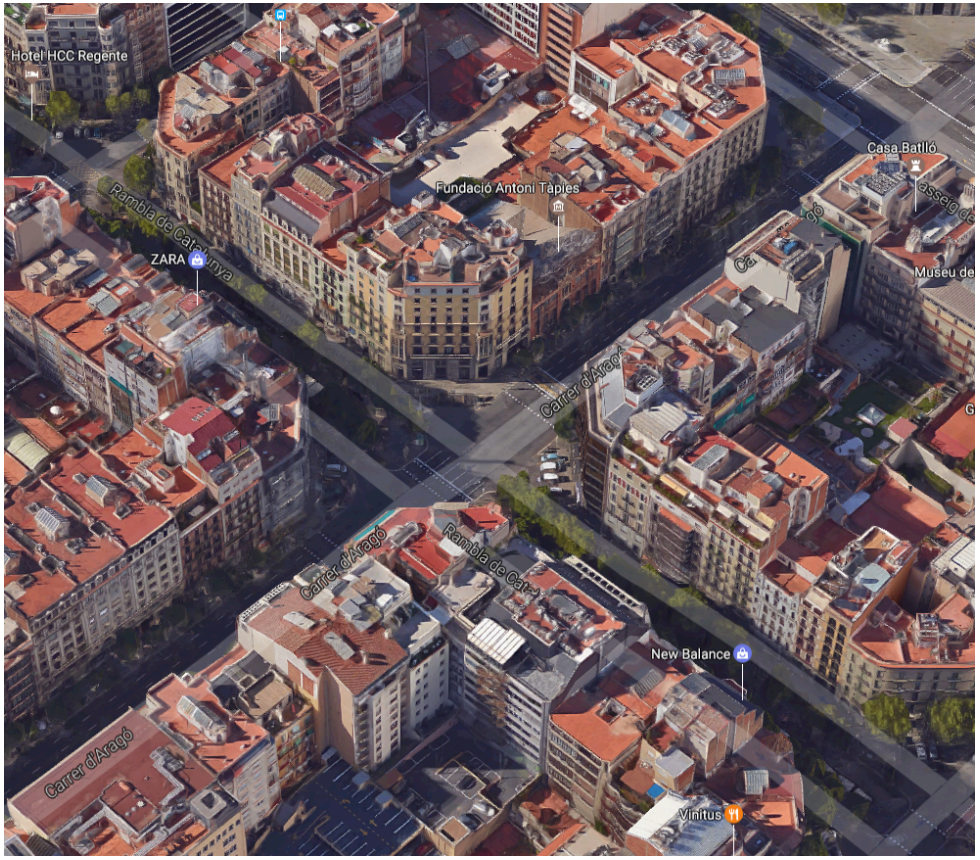
R-LINE

R-LINE world view
open terrain, one meteorological input

Barcelona reality
complex terrain, each street specific meteorological patterns

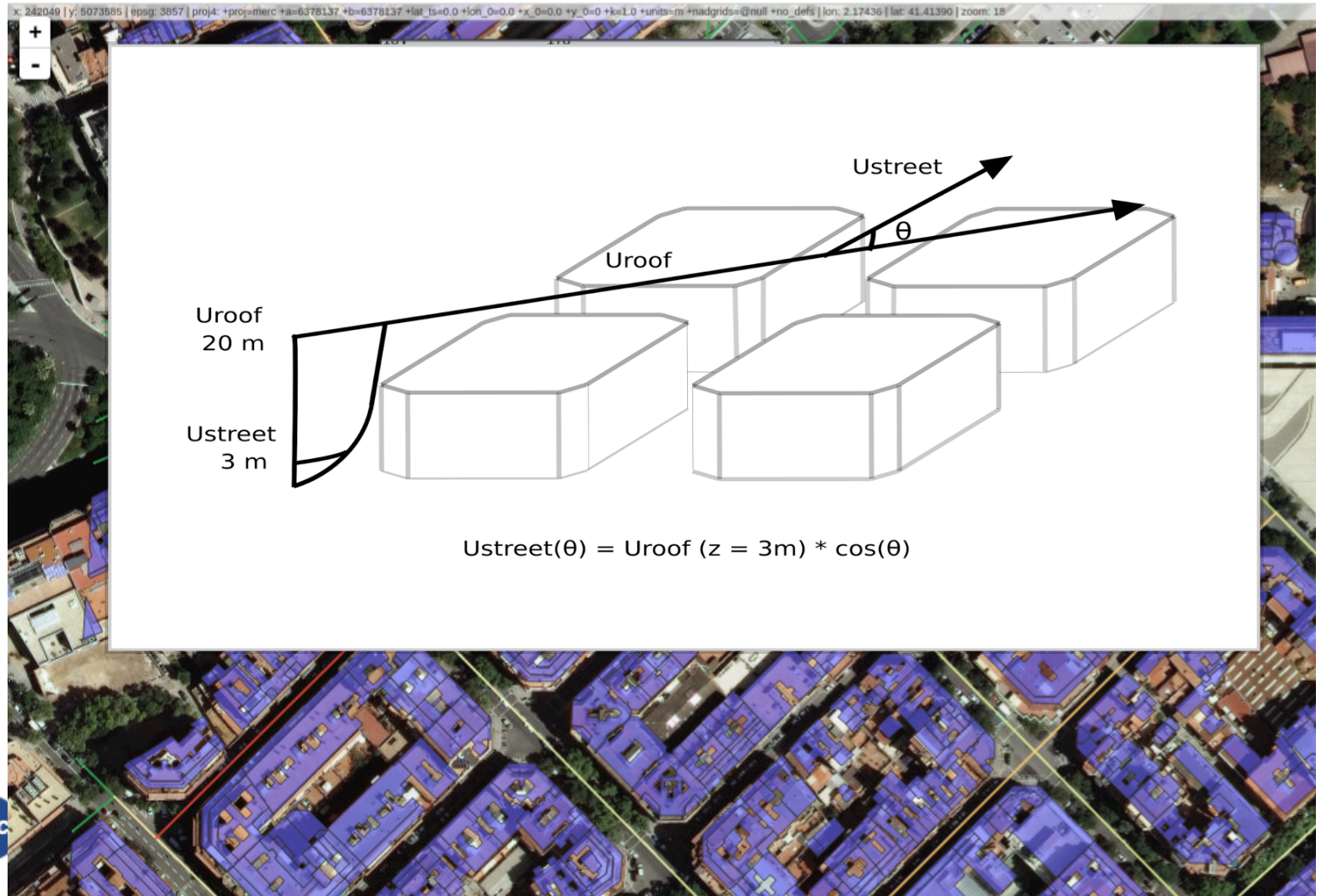


Adapting R-LINE meteorology to Barcelona

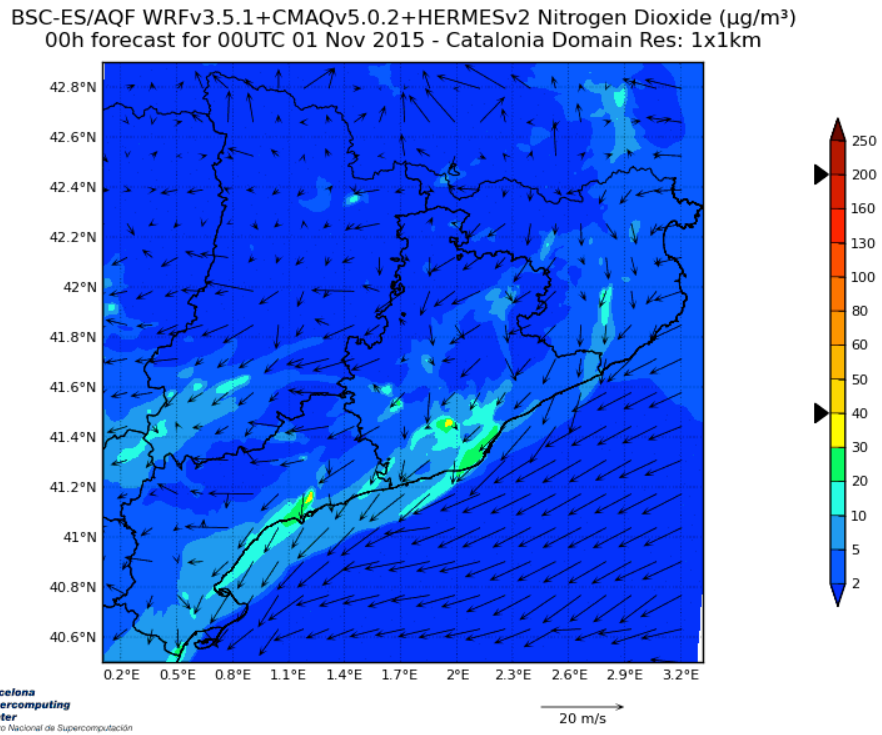
1. Roughness length

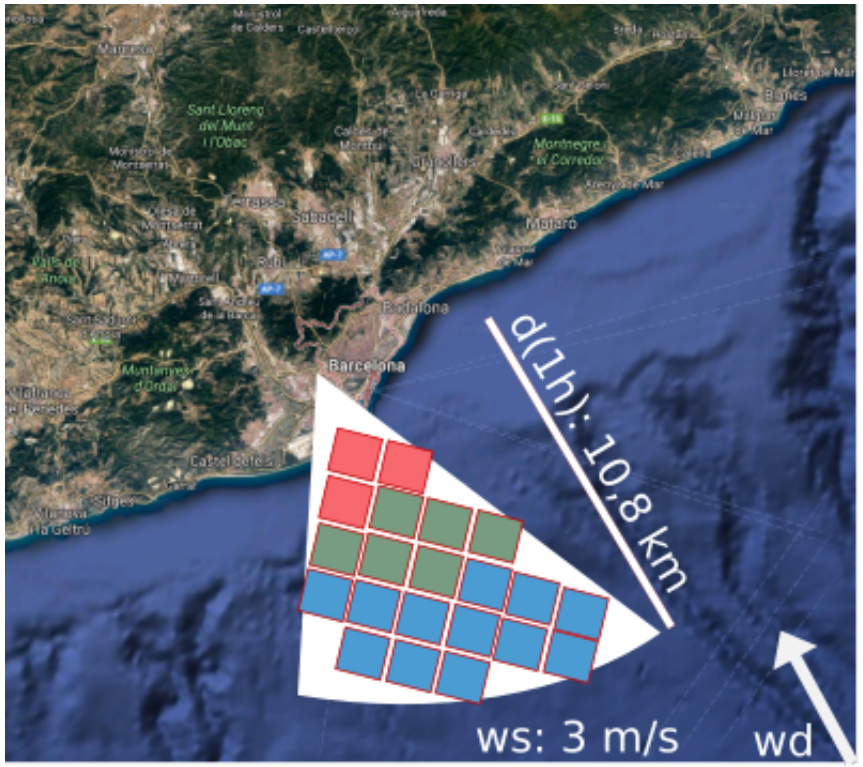
2. atmospheric stability parameters

3. Adjust meteorology



Upwind urban background scheme





High spatial (1x1 km^2) and temporal resolution (1h) over Barcelona

Select concentrations from CMAQ depending on the wind speed and direction provided by WRF. Inspired by Berkowicz (2000)

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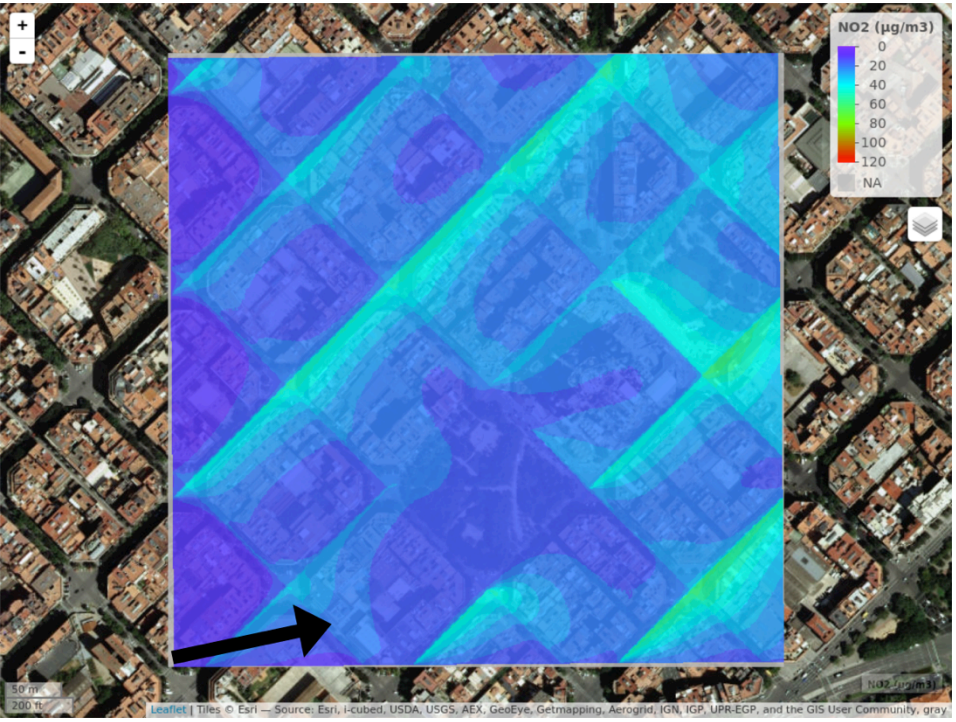
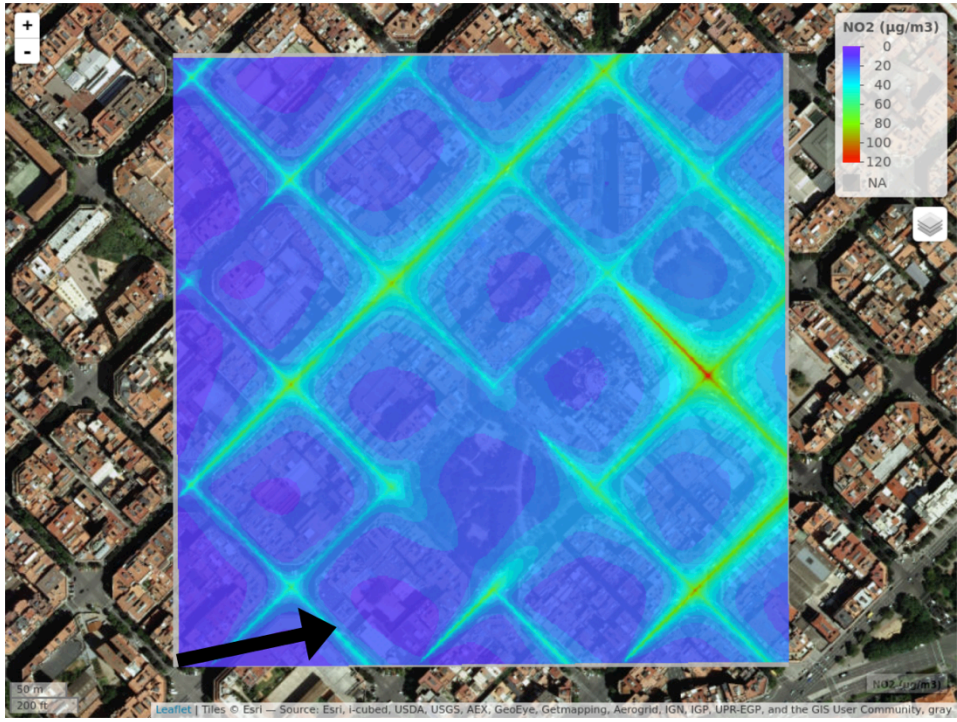
R-LINE for Barcelona

Open terrain
R-LINE (Snyder et al. 2013)



Channelled winds
R-LINE Street

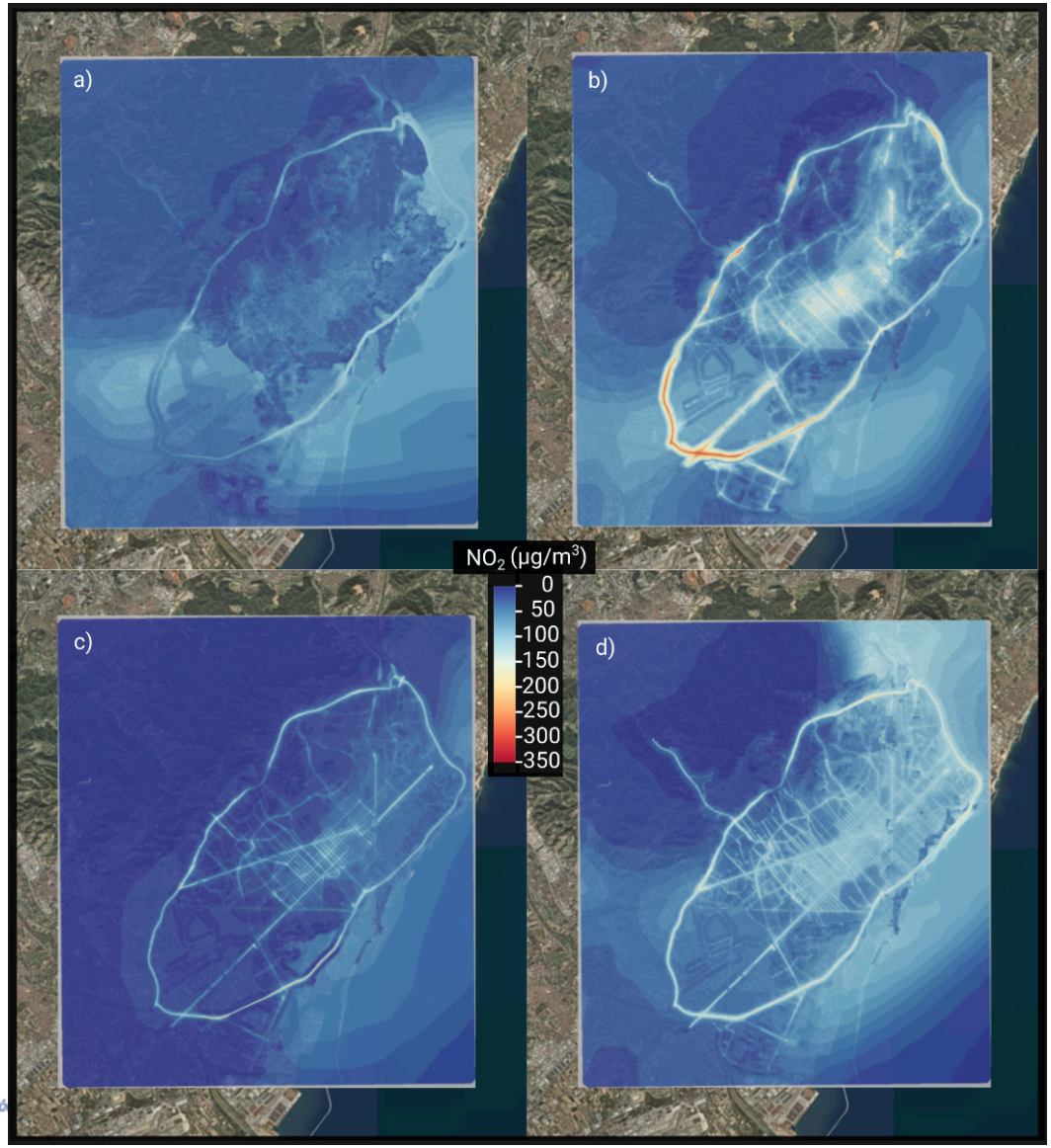


Results

Barcelona NO_2 concentrations on 4/11/2013 at 10 m x 10 m

O UTC

7 UTC



12 UTC

18 UTC

Average diurnal cycle evaluation

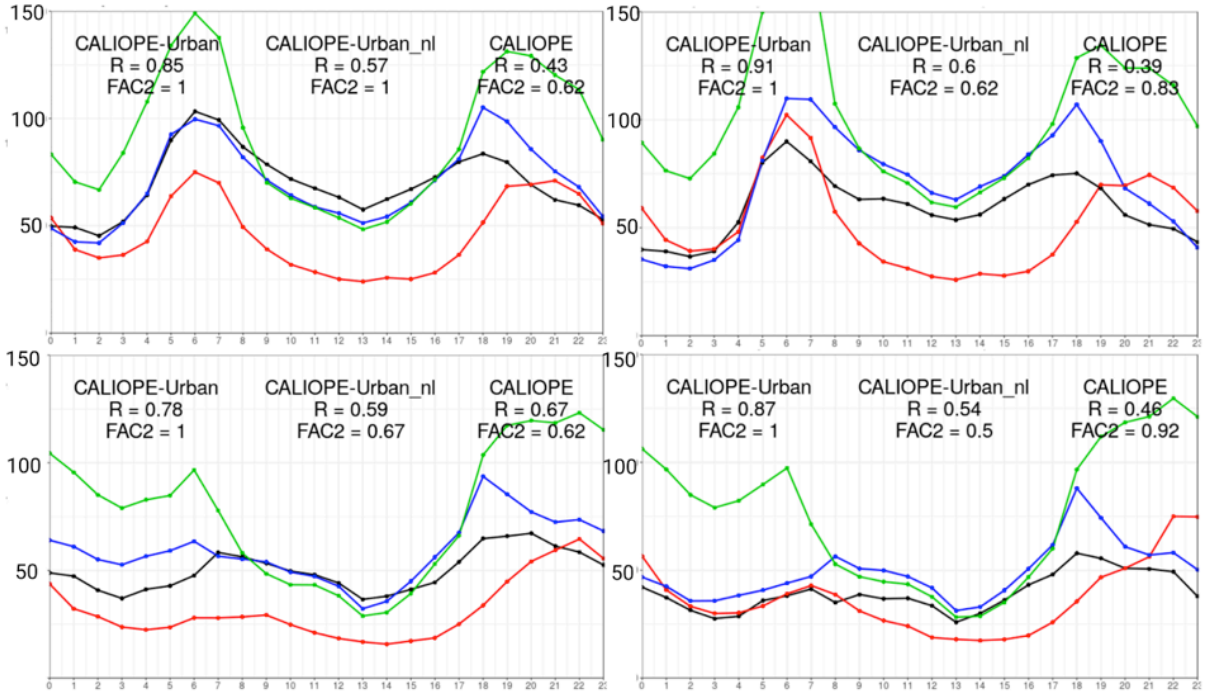
Valencia Street 445

Eixample

Weekday

Weekend

NO_2 ($\mu g/m^3$)

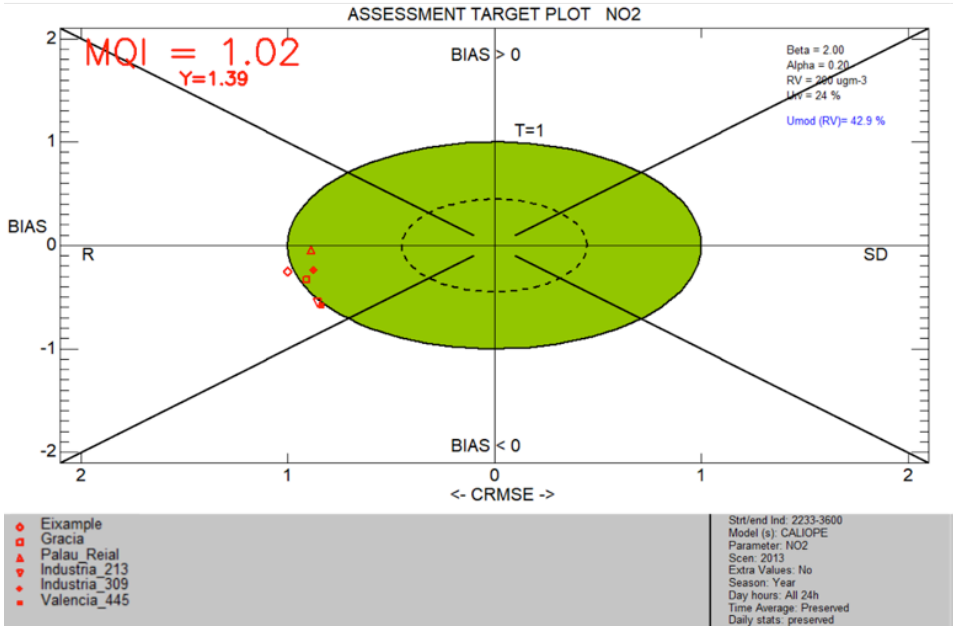


Observations CALIOPE-Urban CALIOPE-Urban-nl CALIOPE

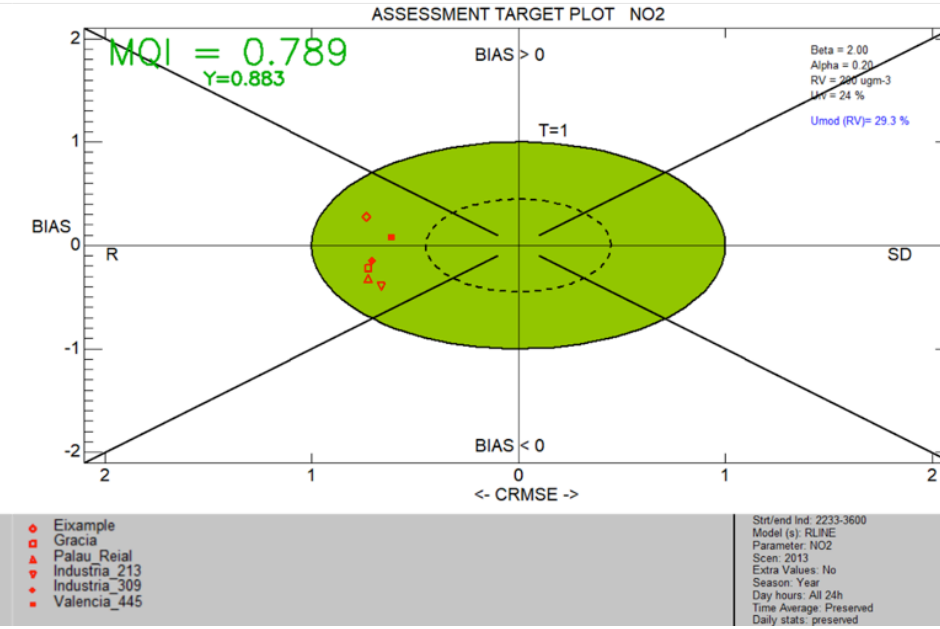
European model quality objective

MQI values below 1 (i.e. green shading area) are considered to comply with the model quality objective

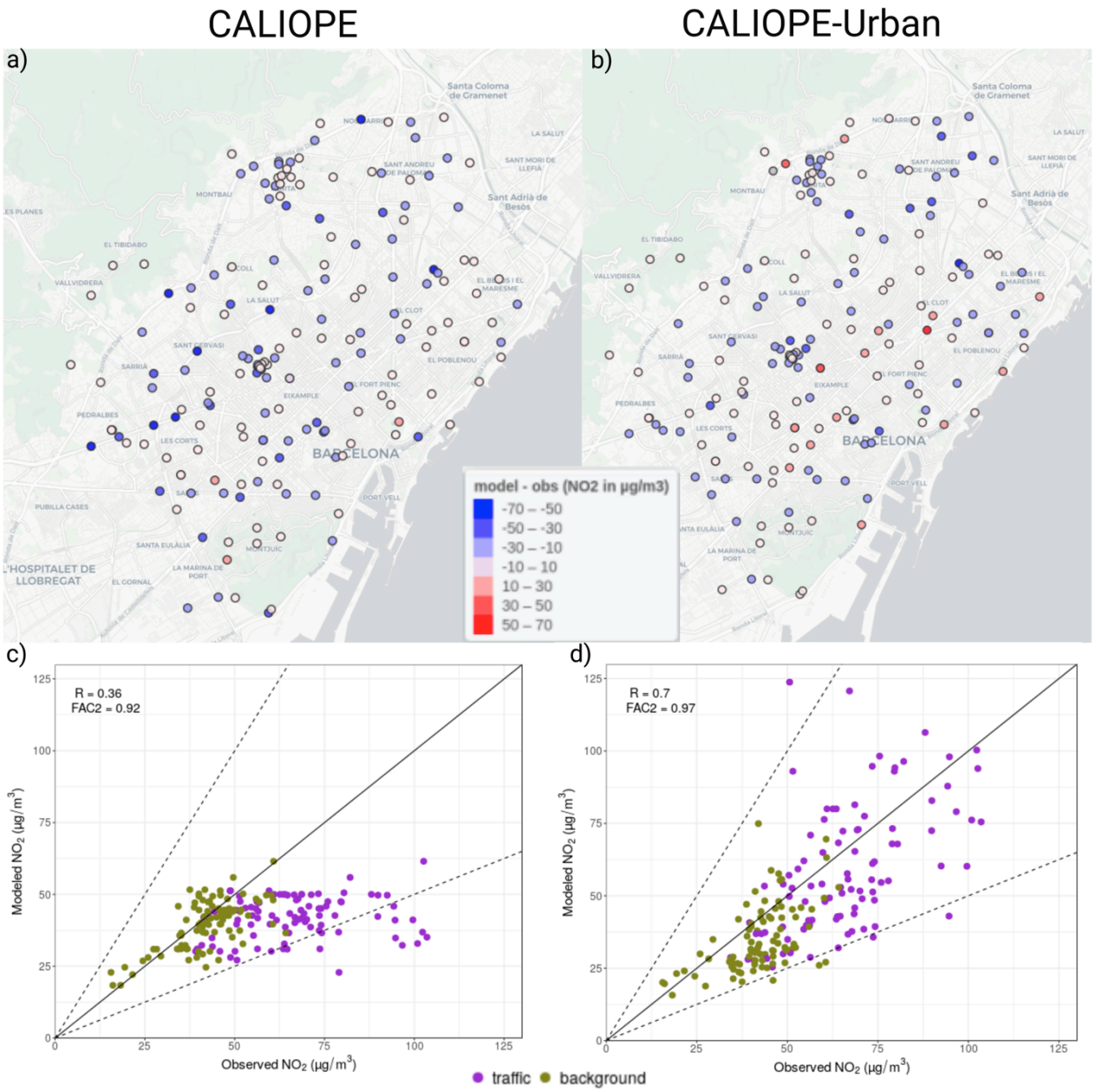
CALIOPE



CALIOPE-Urban



Spatial evaluation



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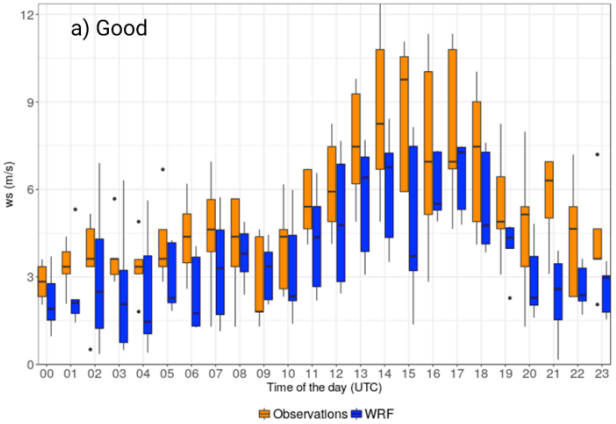
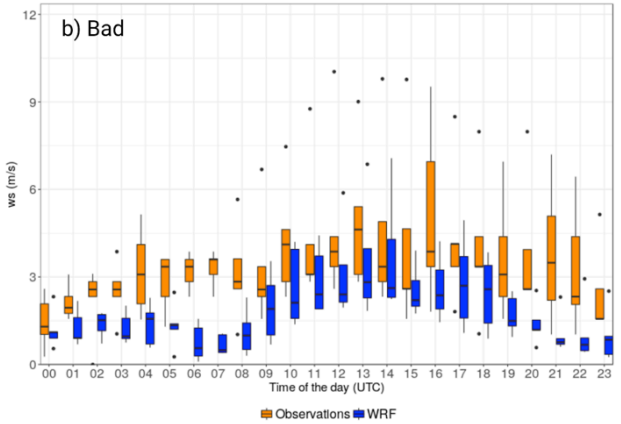
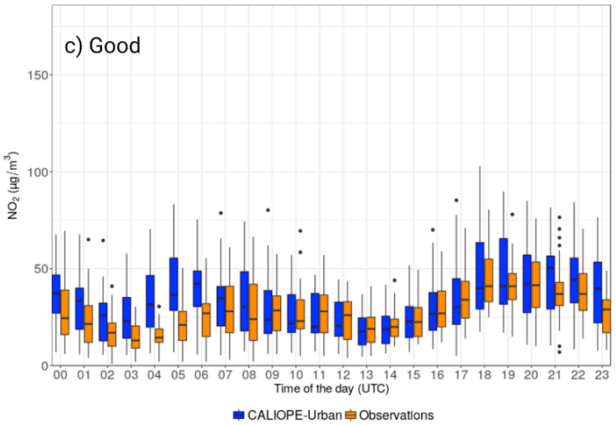
Major sources of uncertainty

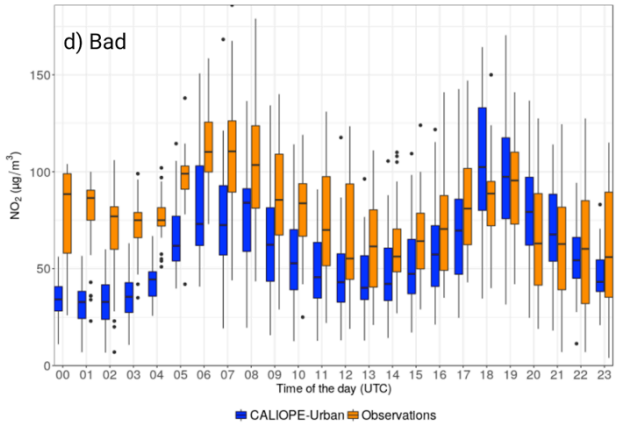
Wind speed at BCN airport *vs* WRF



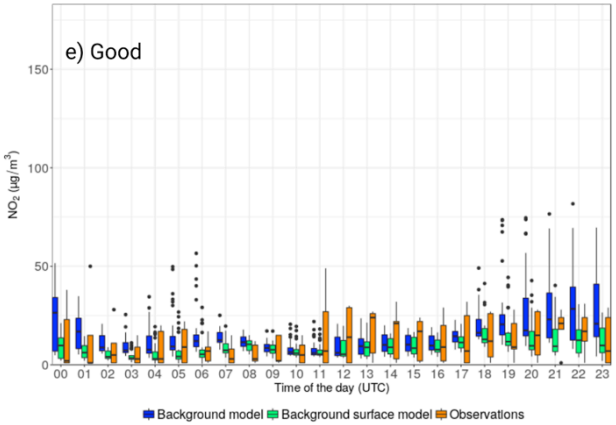


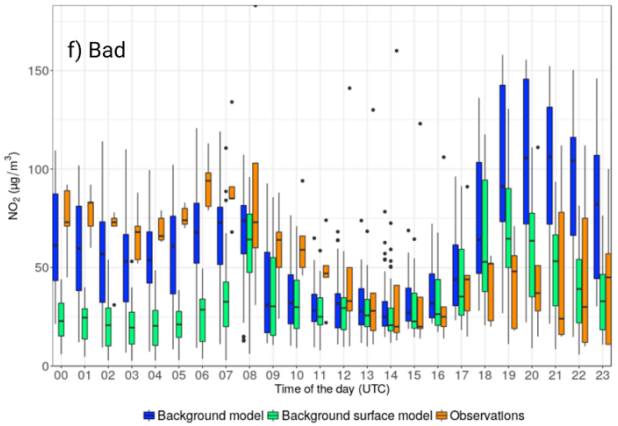
NO_2 concentrations at the six urban sites *vs* CALIOPE-Urban





NO_2 concentrations at a background urban site *vs* model background NO_2 estimate





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Conclusions

- CALIOPE-Urban methodology adapts dynamically to street conditions by coupling the meteorology and background using street-specific surface roughness based on urban geometry.

- CALIOPE-Urban agrees better with hourly-resolution observations than CALIOPE at the five traffic sites evaluated, where the contribution of local emissions predominates.

- CALIOPE-Urban performs better than CALIOPE at the dosimeters located close to traffic because R-LINE explicitly resolves road traffic emission dispersion simulating the high gradients of NO_2.

- We find larger CALIOPE-Urban errors under stable conditions with light winds and low PBL height, and a significant sensitivity to background concentrations.

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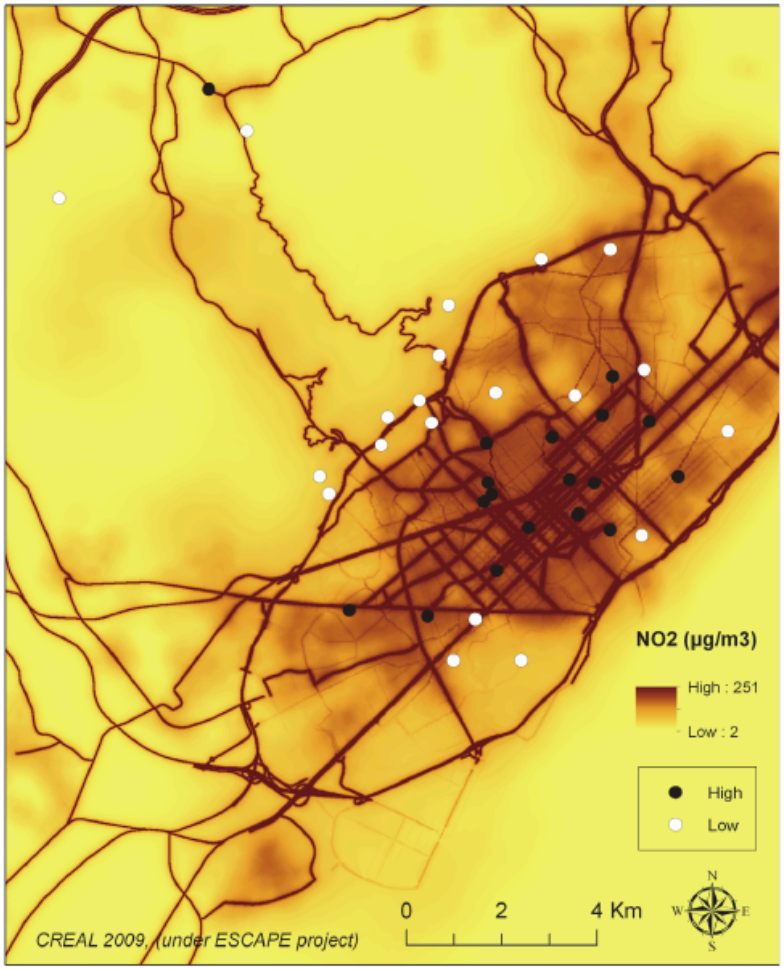
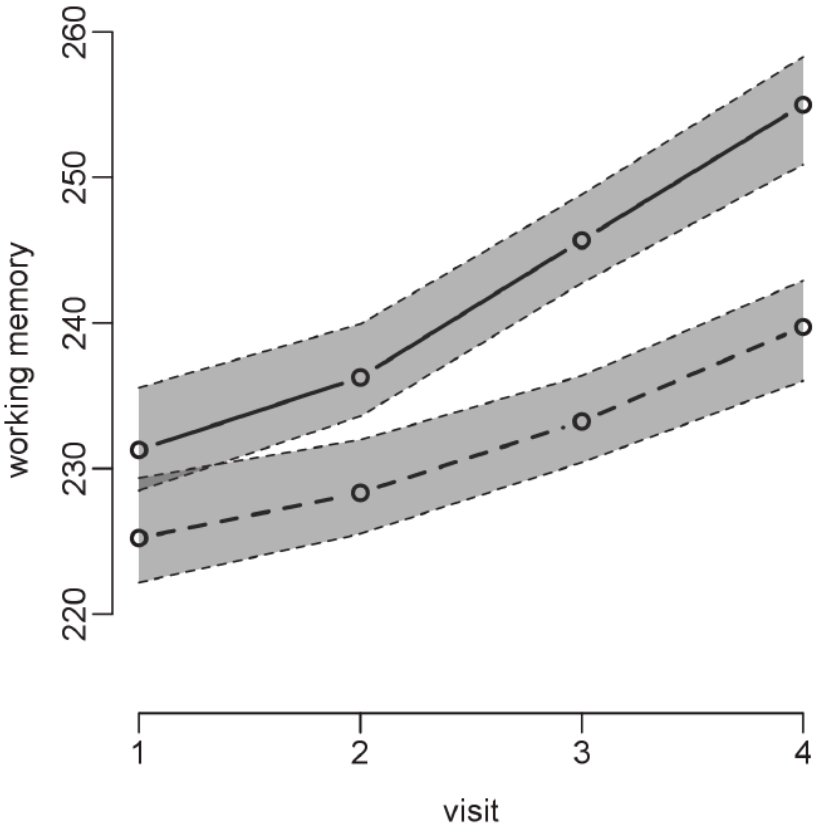
Local traffic contribution to black carbon horizontal and vertical profiles in compact urban areas

Jaime Benavides[1], Michelle Snyder[2], Marc Guevara[1], Carlos Pérez García-Pando[1], Albert Soret[1], Fulvio Amato[3], Xavier Querol[3] and ***Oriol Jorba***[1]

[1] Earth Sciences Department, Barcelona Supercomputing Center, Barcelona, Spain
[2] Institute for the Environment, The University of North Carolina, Chapel Hill, NC, USA
[3] Institute of Environmental Assessment and Water Research, IDAEA-CSIC, Barcelona, Spain

Traffic pollution spatial gradients matter



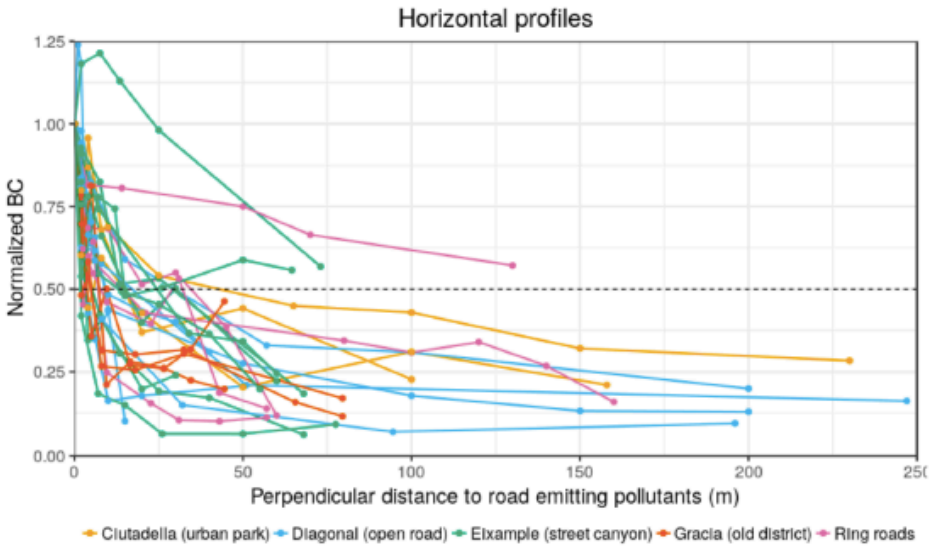


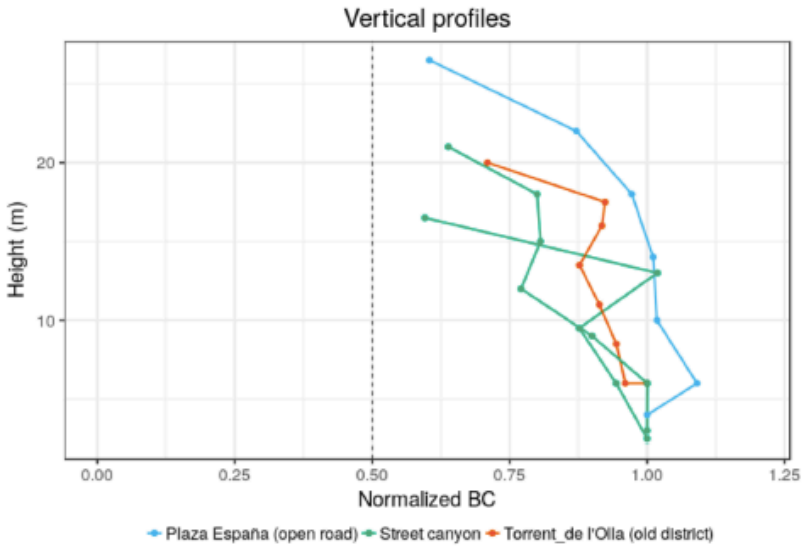
Children attending schools with higher traffic-related air pollution had a **smaller** improvement in **cognitive development**. J. Sunyer et al. (2015)

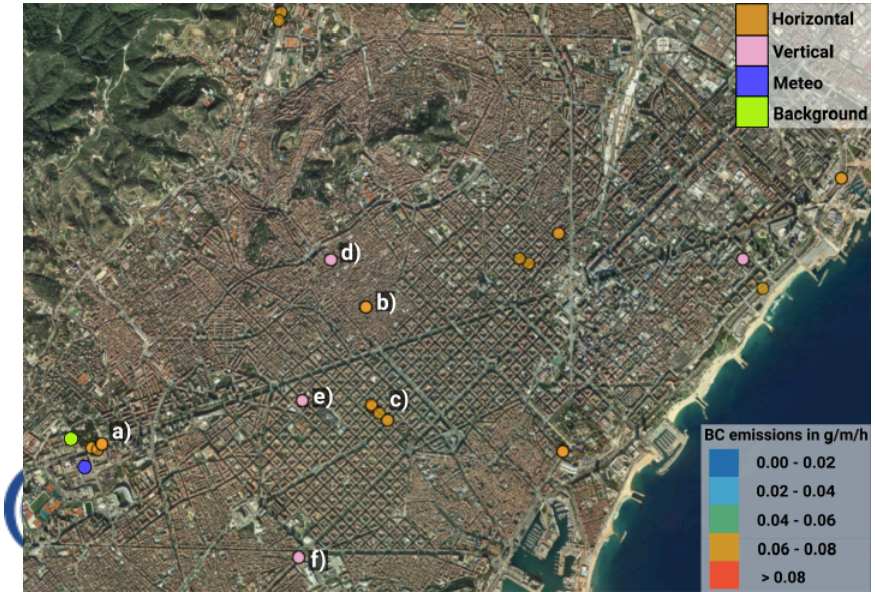
Objective

- Quantify the local and nearby traffic contribution to Black Carbon (BC) concentrations at street level.
- Assess CALIOPE-Urban v1.0 reproducing horizontal and vertical decay of BC concentrations.

Observed horizontal and vertical BC profiles by distance to road in different areas of the city





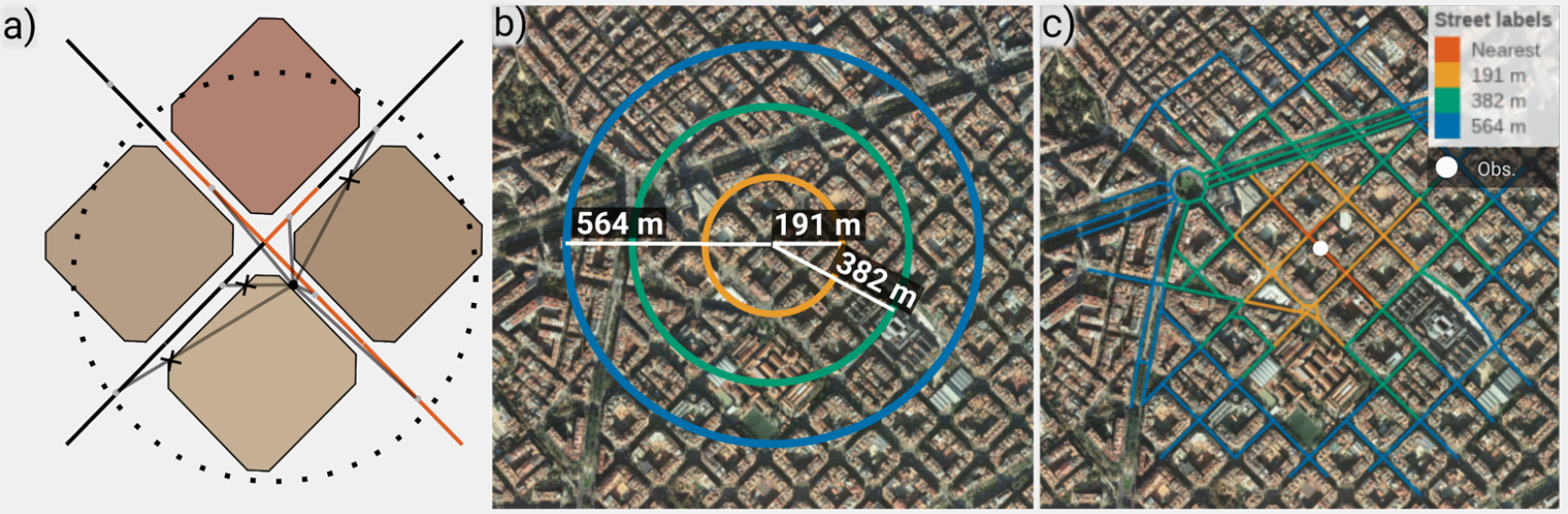


Observations described in Amato et al. (2019)

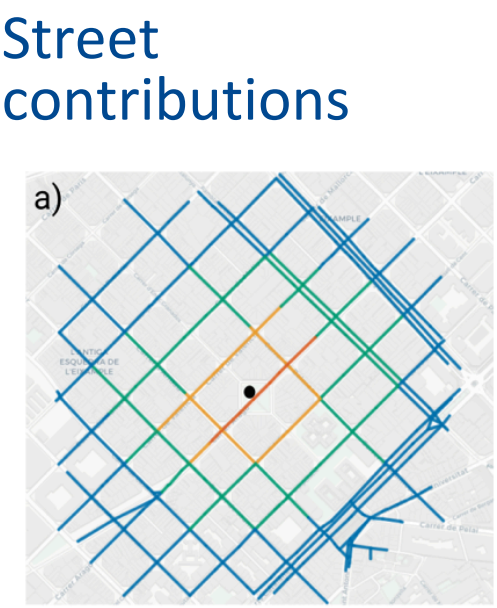
- Horizontal: more than 50% decay within initial 50 m with steep decay in first 5 m.
- Vertical: decay below 75% above 15 m height.

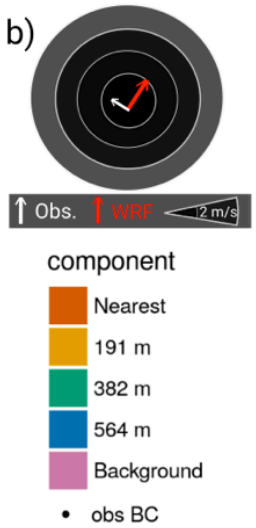
Methodology

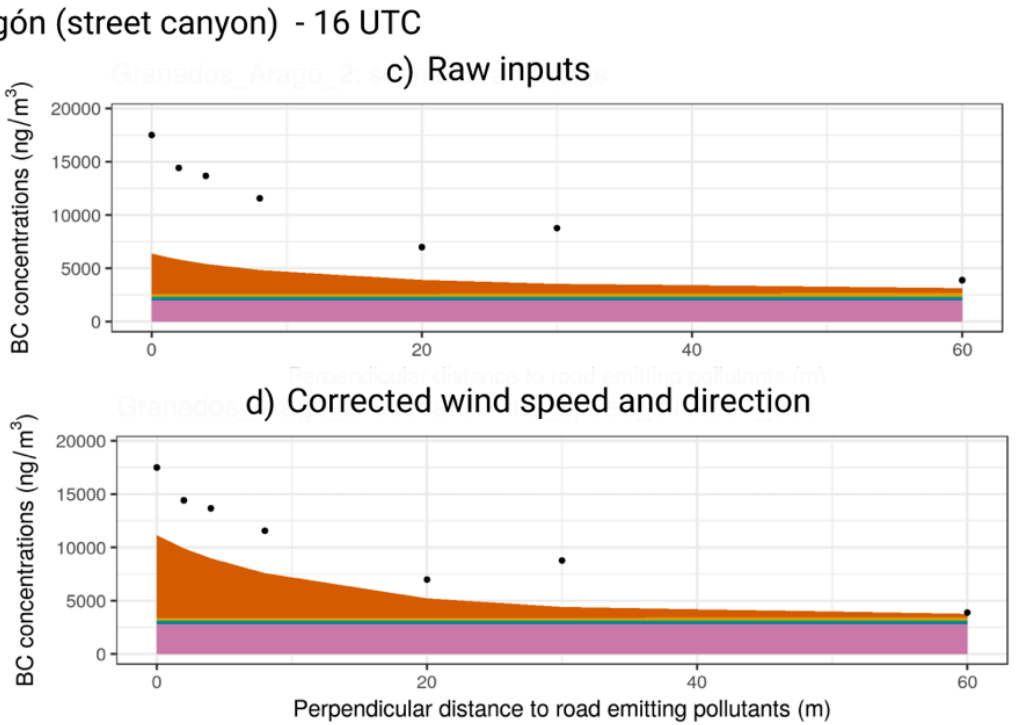
Tagging



Street contributions

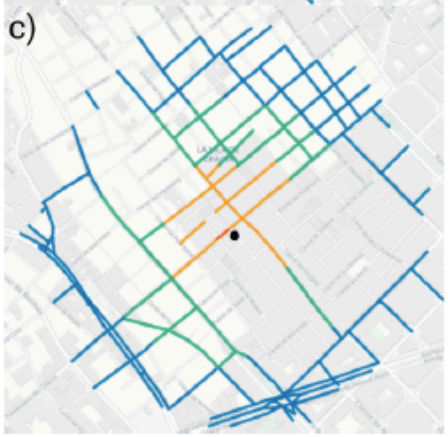


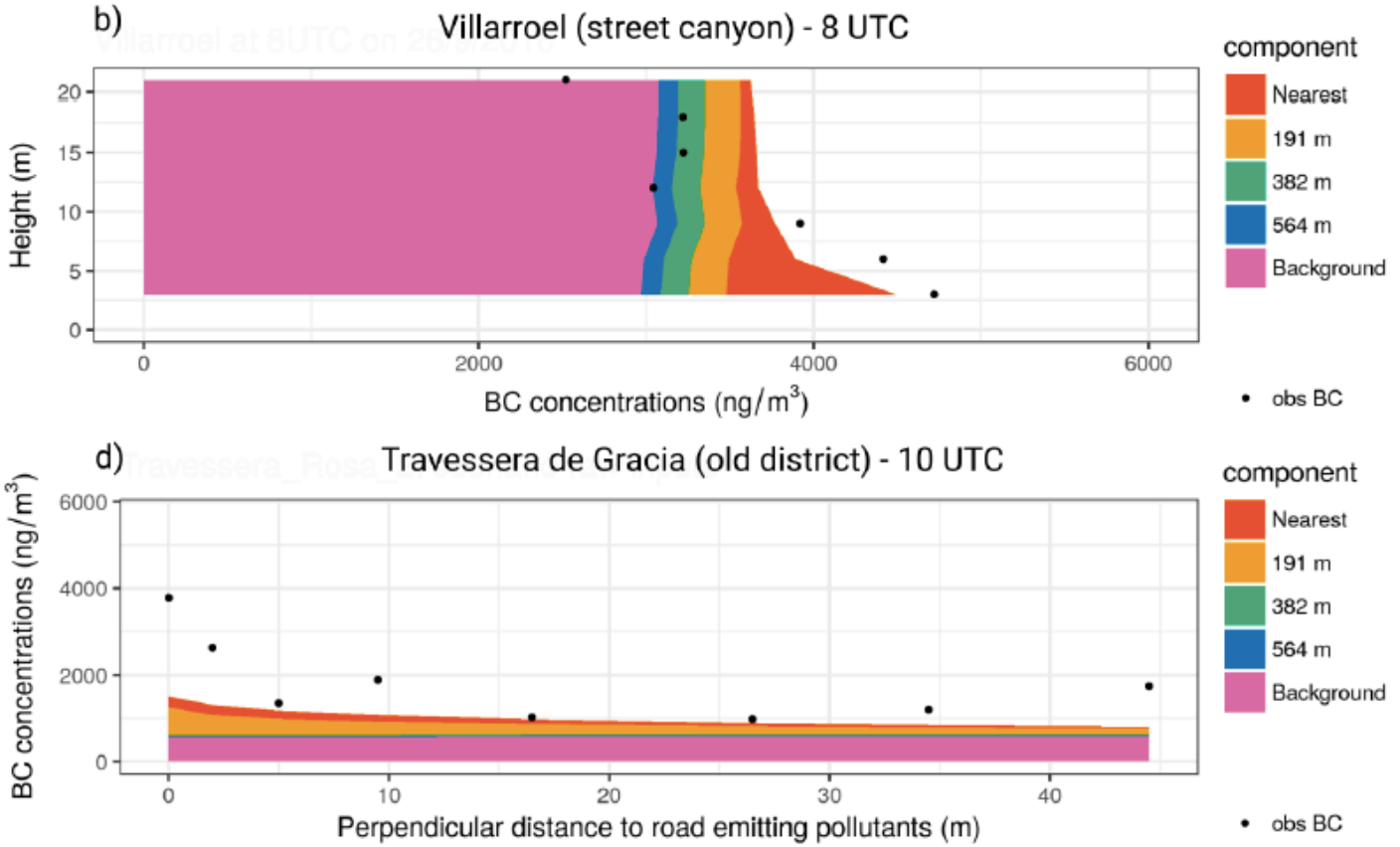




CALIOPE-Urban v1.0 model

Results





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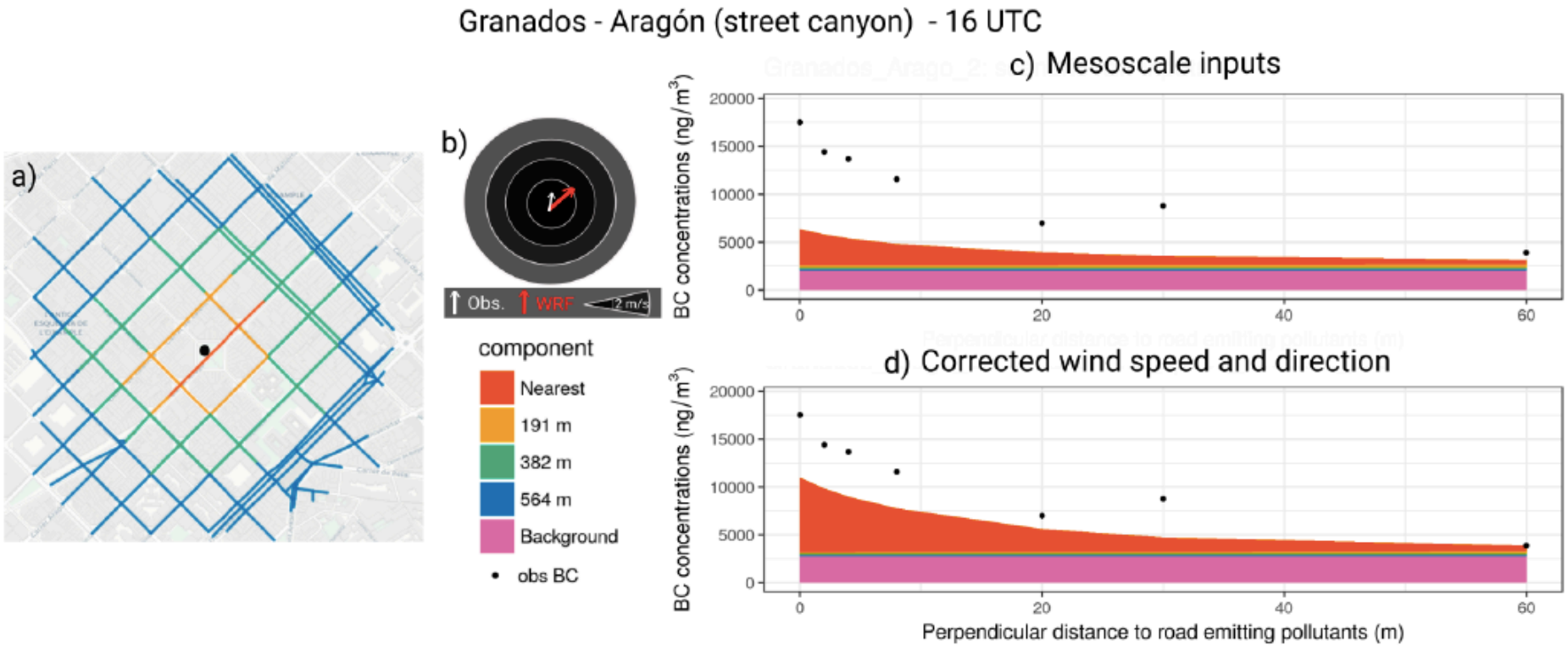
Sensitivity to meteorological inputs



Conclusions

- Strong decay observed in horizontal profiles the first 5 -10 m very difficult to capture, much better agreement beyond.
- High BC concentrations observed and modeled along the vertical profiles with small decay until the top of the building heights are reached.
- Strong sensitivity of CALIOPE-Urban v1.0 to meteorological inputs.
- Tagging results show complex behavior depending on the local features of the city (e.g., street morphology, emissions).
- CALIOPE-Urban v1.0 can not explain observed BC concentrations only considering local traffic emissions, the background contribution is very high.

Thank you!

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Acknowledgments

- Grants CGL2013-46736-R, CGL2016-75725-R and COMRDI15-1-0011-04 of the Spanish Government.
- J. Benavides PhD work is funded with the grant BES-2014-070637 from the FPI Programme by the Spanish Ministry of the Economy and Competitiveness.
- J. Benavides developed part of this work as research visitor at the Institute for the Environment at UNC funded with the mobility grant EEBB-I-17-12296 by the same Ministry.
- IDAEA-CSIC acknowledges the Barcelona City Council for the support to the experimental campaign.

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