EUMETSAT

Funded by the European Union

Destination Earth

IMPLEMENTED BY EUMETSAT esa ECMWF

Dust in Barcelona

Urban-scale air pollution model using Data Lake's Near-Data Computing

CIMNE

EXCELENCIA SEVERO OCHOA

Pere-Andreu Ubach, Ignasi de Pouplana, Laurence Sigler, Salva Latorre, Guillermo Casas, Claudio Zinggerling
ubach@cimne.upc.edu

Destination Earth Use Cases in the Data Lake Workshop
October 2024

Use Case Description and Objective

Synthesis of the Use Case. Motivation

Brief introduction to the use case

Air pollution in urban areas is a major concern for all relevant institutions as it is linked to adverse health effects.

PM_{10} particles (coarse, ~10μm) represent a significant health threat. They are derived both from human activity such as vehicular traffic, and from natural sources such as dust storms.

What are you trying to achieve?

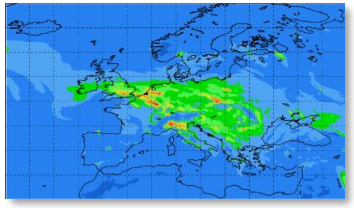
A numerical framework for modelling the transport of PM_{10} or other suspended particles at the street level, covering large urban areas. The numerical model runs on DEDL infrastructure and uses its framework to connect to various sources of federated data.

Expected outputs:

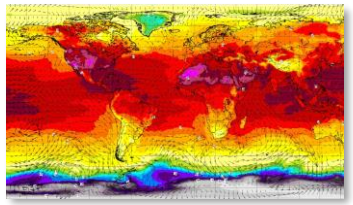
- Wind velocity over Barcelona
- Concentration of PM_{10} over Barcelona

Use Case Technical Implementation

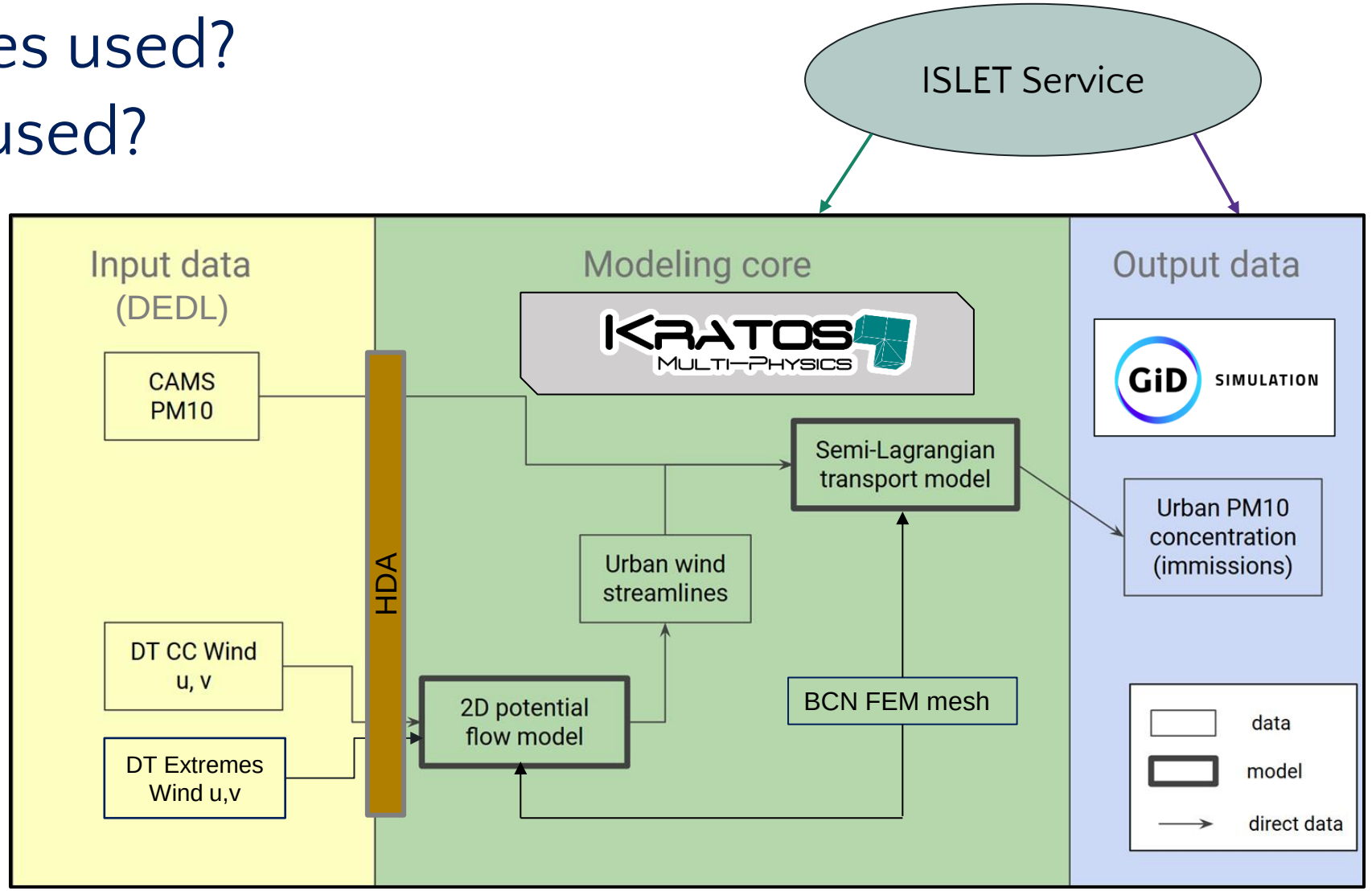
How are services used?
What data are used?



European Air Quality Forecasts
PM_{10} particulate matter

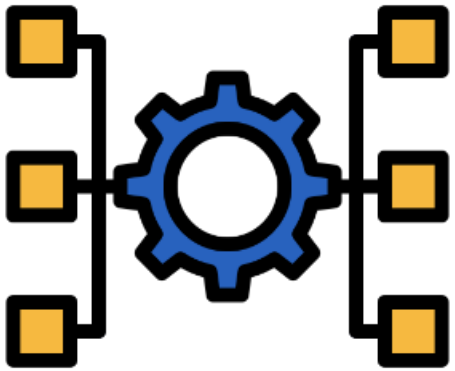


DT: Climate Change Adaptation / Extremes
2m temperature and 30m
wind forecast (u/v)



Use Case Technical Implementation

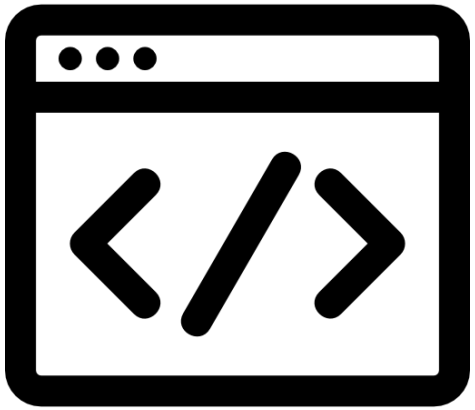
General methodology



1. Selection of data from DEDL
   - STAC search/selection of relevant datasets via HDA-PyStac
   - Retrieval of datasets (HDA-PyStac)
   - ETL of datasets on VM via Python (on Islet VM)
2. Modeling via Kratos Multiphysics framework on Islet VM

Use Case Technical Implementation

STAC search, retrieval and ETL scripts



DEDL_HDA_pystac_get.py (collection, dataset)

- Executes STAC selects on the two (3) collections
- Downloads datasets to S3 bucket (mount point)
- Converts wind data to csv (clips to bounding)

grib_select.py (grib, lat, lon)

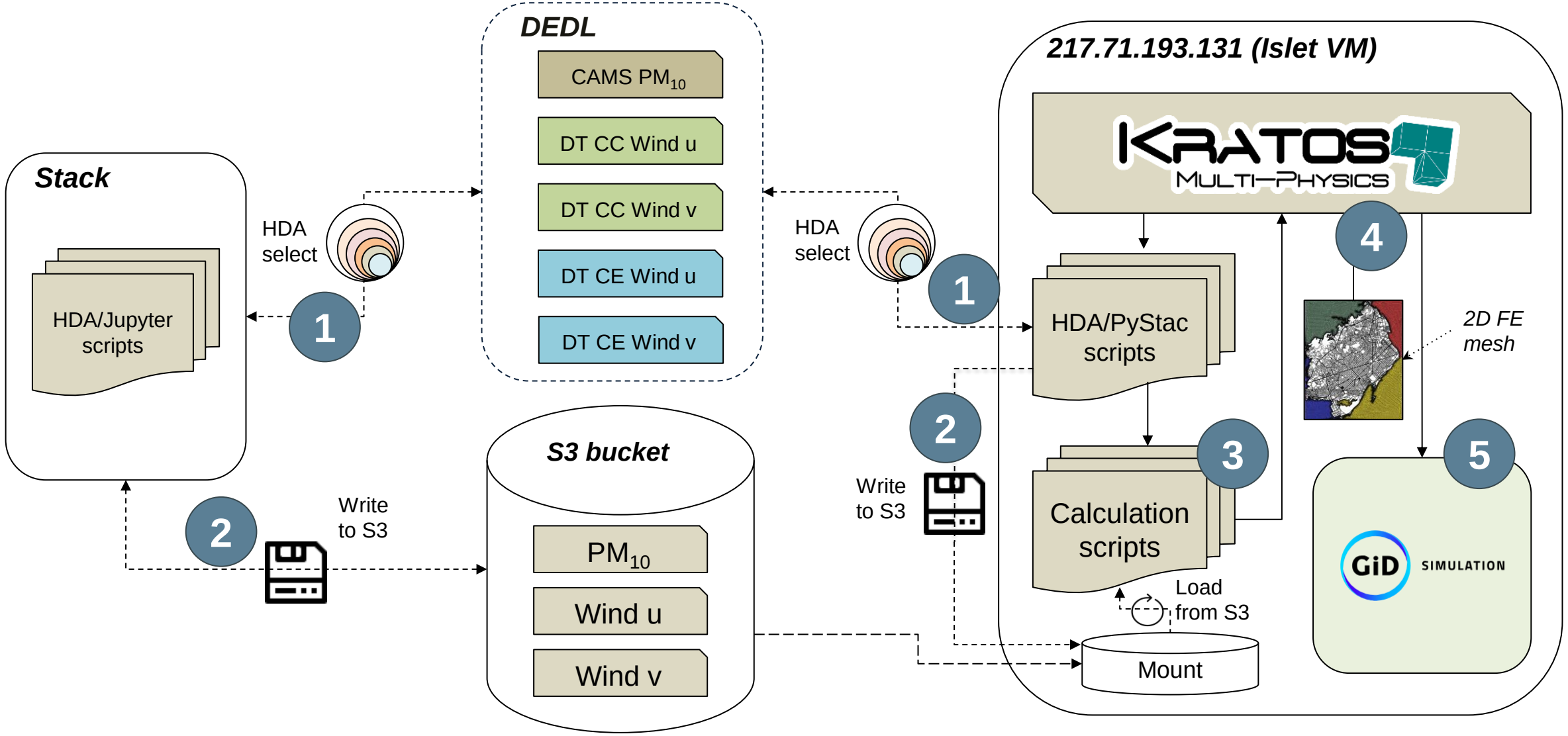
- Retrieves PM_{10} data from grib by lat/lon coordinate within the bounding – each corresponds to a point on the FE mesh

calculate_exterior_averages.py (csv)

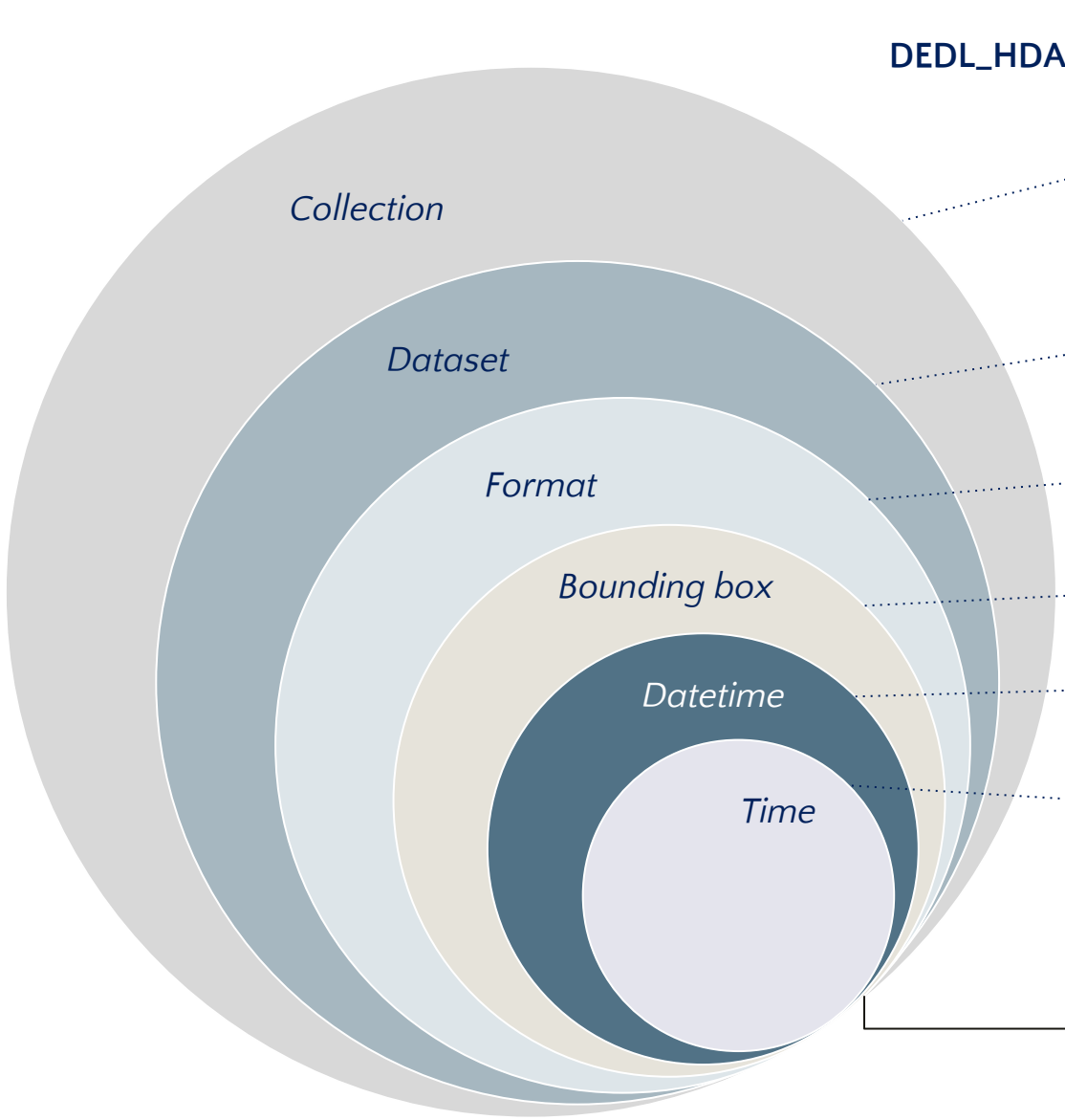
- Farfield generation: reads wind csv (x2) and calculates average values for exterior points of the bounding –
- Generates lists of farfield (averages) by hour

Use Case Technical Implementation

Overview of use case architecture



Use Case Technical Implementation - HDA



DEDL_HDA_pystac_get.py

DAT.DT_CLIMATE_ADAPTATION
or
DAT.DT_CLIMATE_EXTREMES
or
CAMS_EUROPE_AIR_QUALITY_FORECASTS

165 (u) and 166 (v)
or
particulate_matter_10um

grib

1.554252,40.94932,2.762153,41.858645

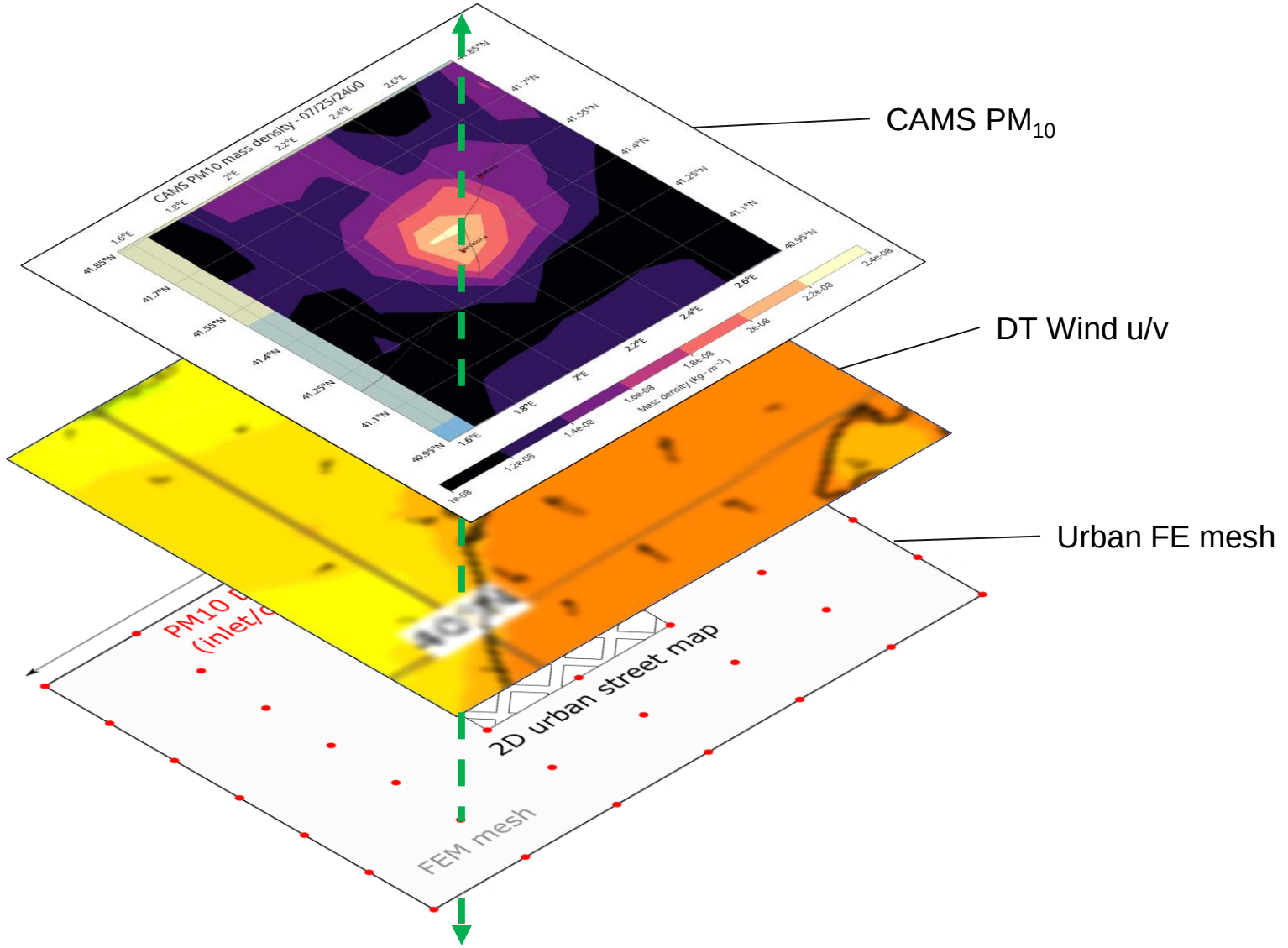
Clipping to a bounding box is under development for wind datasets

date_plus_3_days
or
date

0-24
or
0-72

STAC item – wind (x2) for download

General methodology – interpolation of points in DEDL datasets



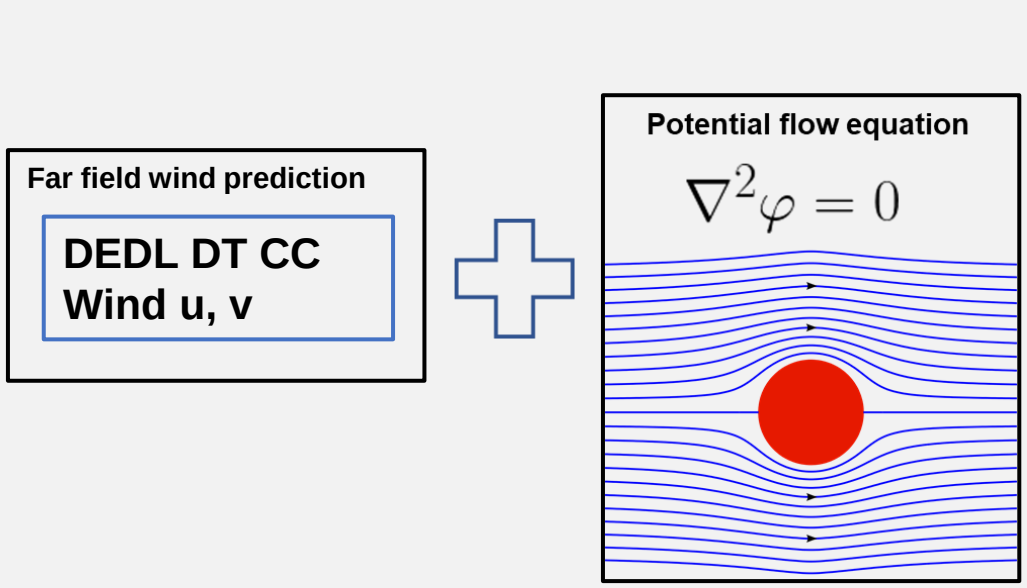
grib_select.py

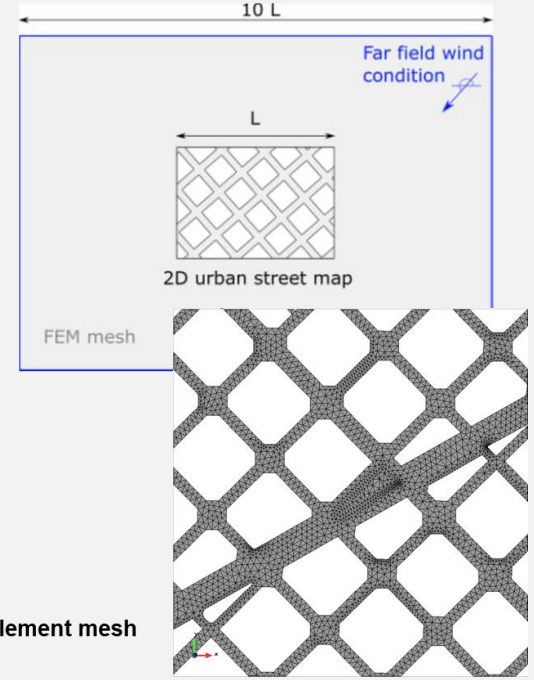
for each lat/lon in the datasets, interpolation to the corresponding node in the model mesh

Use Case Technical Implementation

Modeling methodology (in a nutshell)

1. Estimate wind speed and direction over the streets of a urban area at 3.5 m height





Finite element mesh

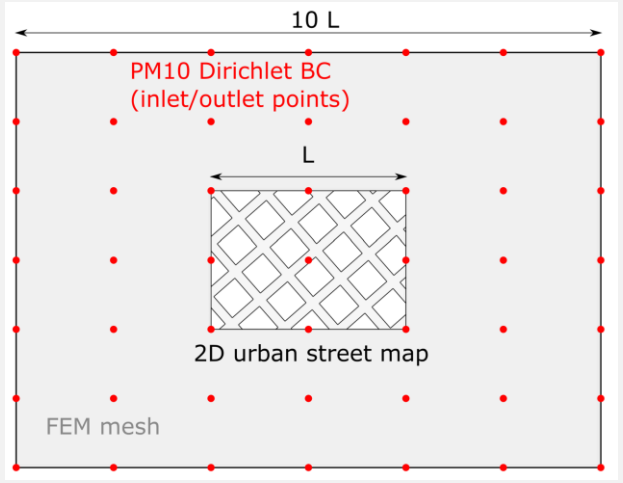
De-Pouplana, I., Latorre, S., Masó, M., Alonso, C., Pérez, E., Guinart, X., ... & Oñate, E. (2023). A prototype of a micro-scale model for the distribution of NO2 in urban areas. *Atmospheric Pollution Research*, 14(2), 101668.

Use Case Technical Implementation

Modeling methodology (in a nutshell)

2. Transport pollutant over the streets

Transient advection-diffusion-absorption equation

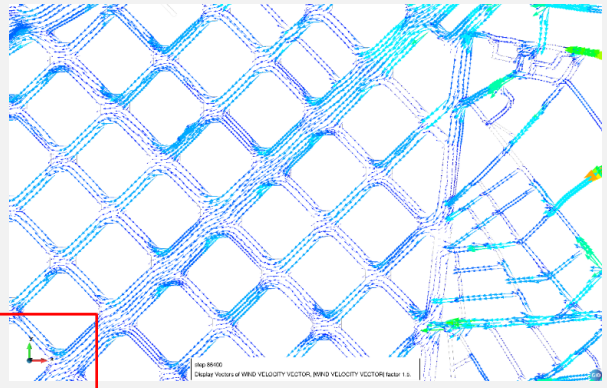


$$\frac{D\phi}{Dt} - \nabla^T \boldsymbol{D} \nabla \phi + s\phi + Q = 0$$

$$\frac{D\boldsymbol{x}}{Dt} = \boldsymbol{v}$$

Advective terms

φ: Concentration of pollutant
$\boldsymbol{v}$: Wind velocity at 3.5 m height



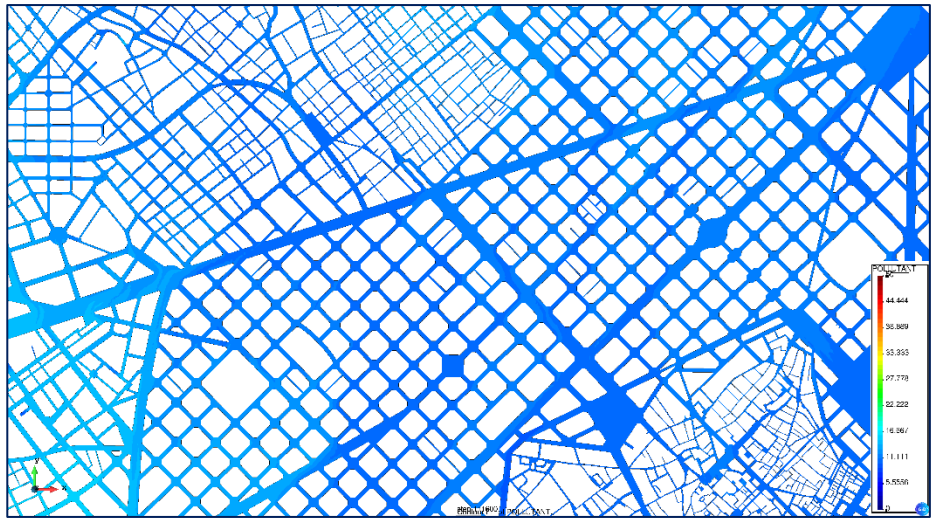
DEDL CAMS PM_{10}

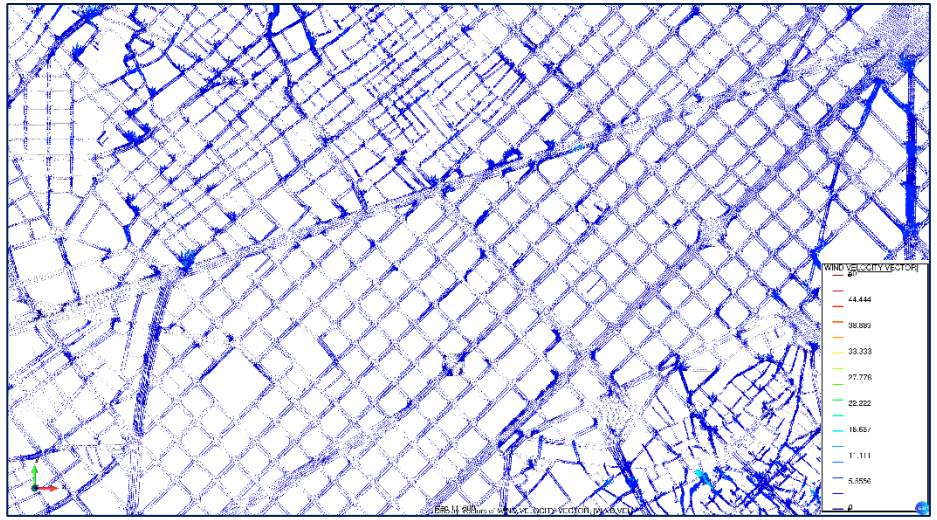
Puigferrat, A., Masó, M., De-Pouplana, I., Casas, G., & Oñate, E. (2021). Semi-Lagrangian formulation for the advection–diffusion–absorption equation. *Computer methods in applied mechanics and engineering*, 380, 113807.

Current Status

Today's use case maturity and achievements

- A simplified physical model is already implemented and running on realistic size domains.
- Data is downloaded, converted and used in the model, all within the DEDL infrastructure. Download issues are preventing further testing.
- Visualization of contour fills of wind velocity and pollutant concentration over the domain is achieved using GiD.
- Time evolution of wind velocity and pollutant is plotted using matplotlib.





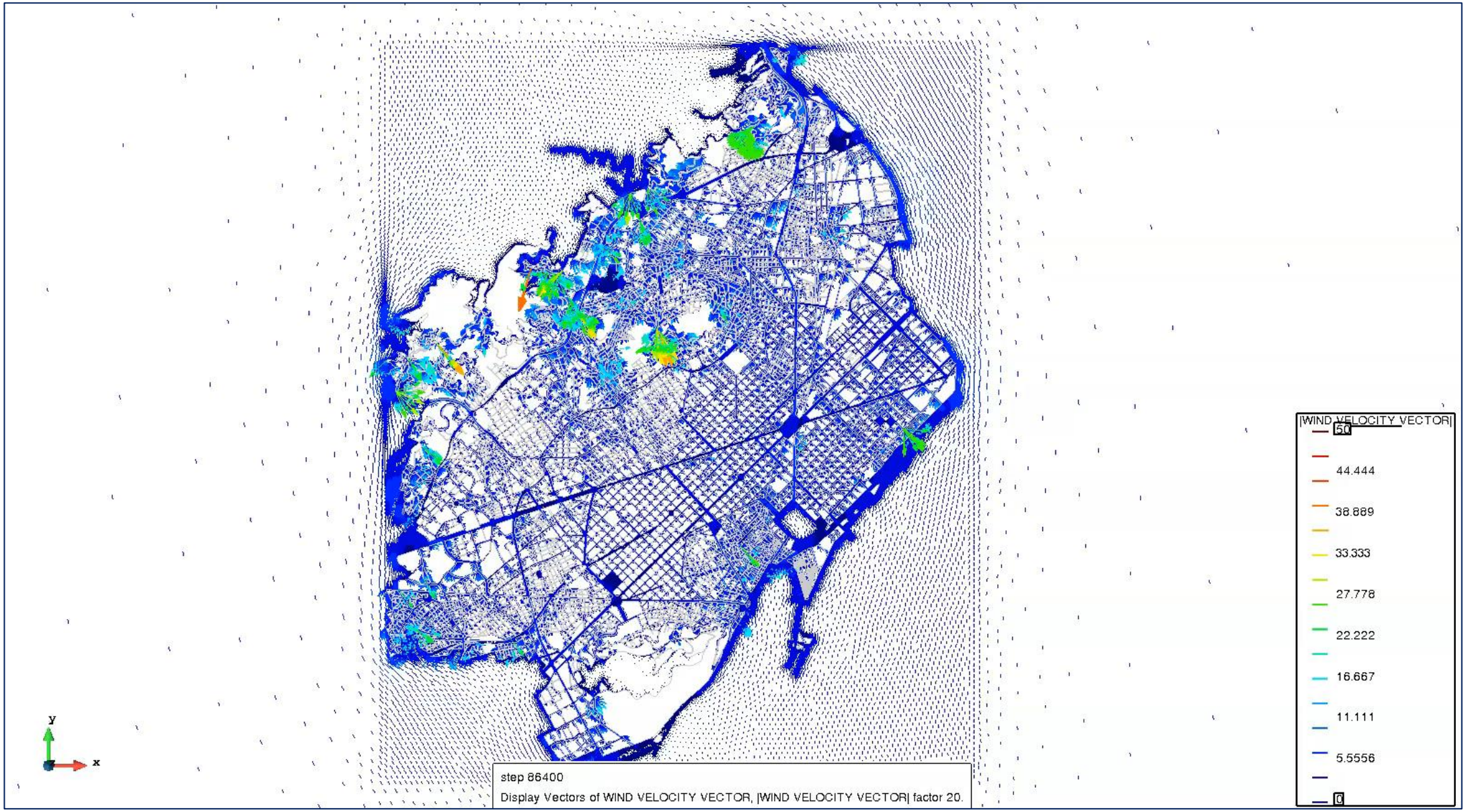
Results

2D FEM mesh of Barcelona

1,067,153 3-noded triangles

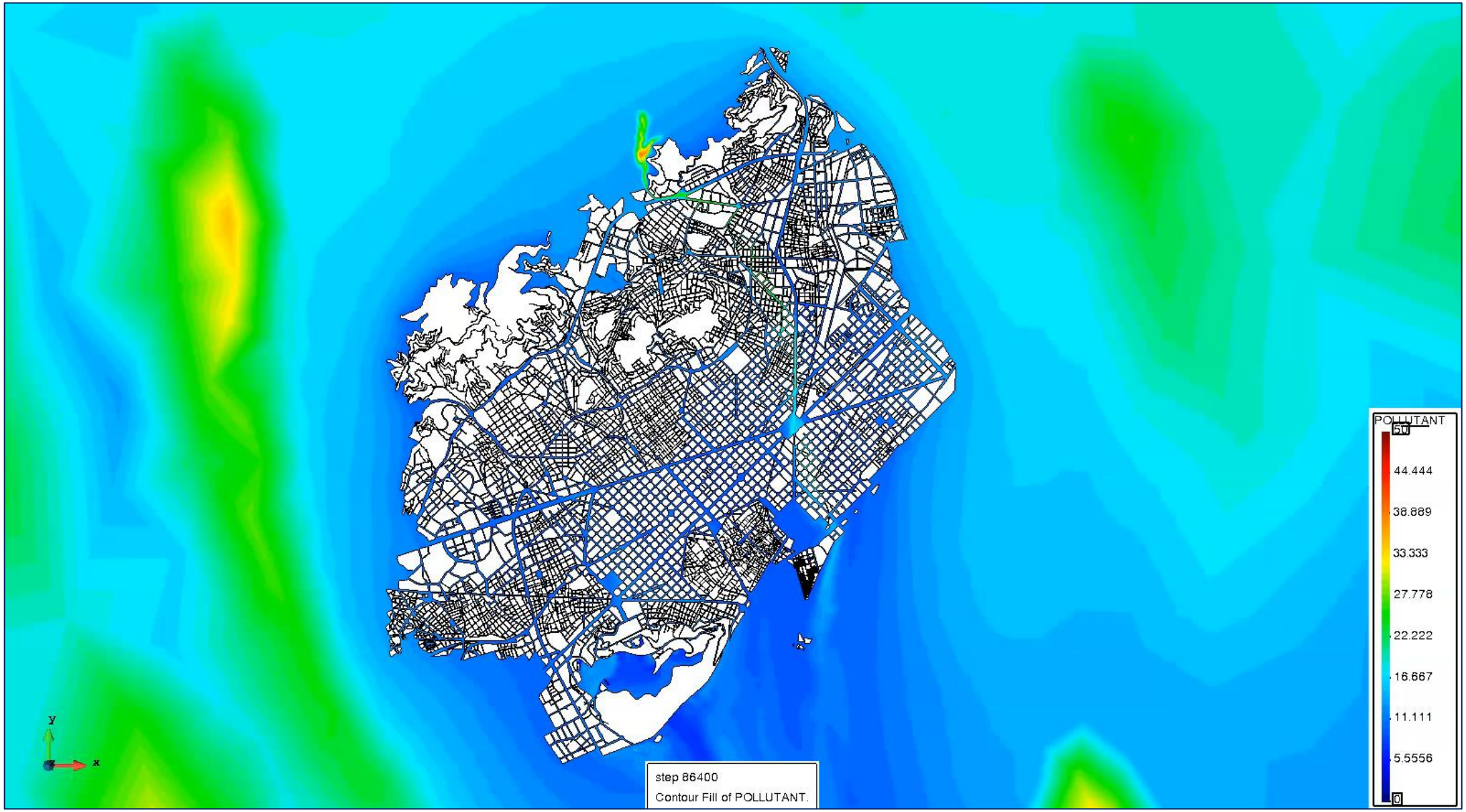
Results

Wind u/v
10m (Km/h)



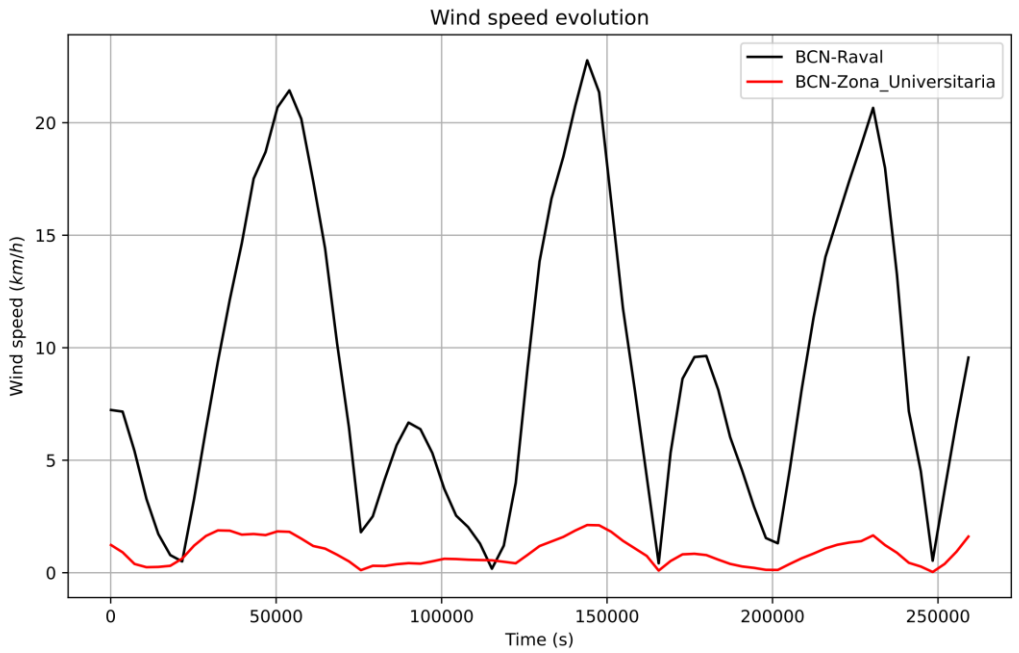
Results

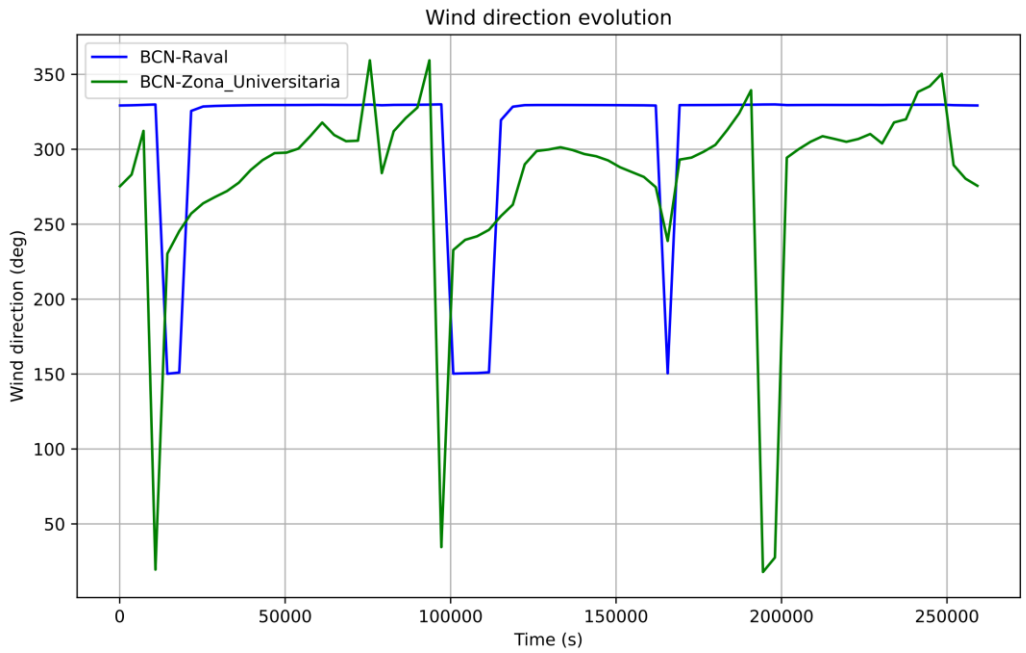
PM_{10} concentration ($\mu g/m^3$)



Results

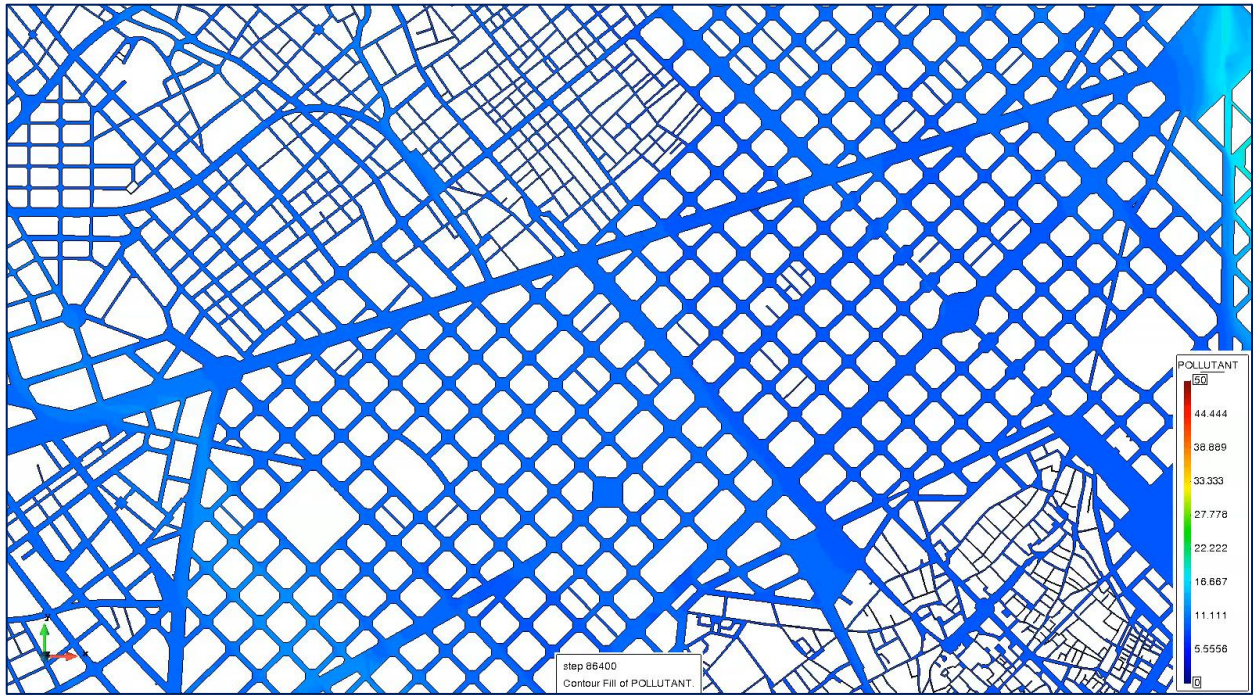
Wind speed and direction evolution in time at two points in the city. These points correspond to existing meteorological stations for future validation.

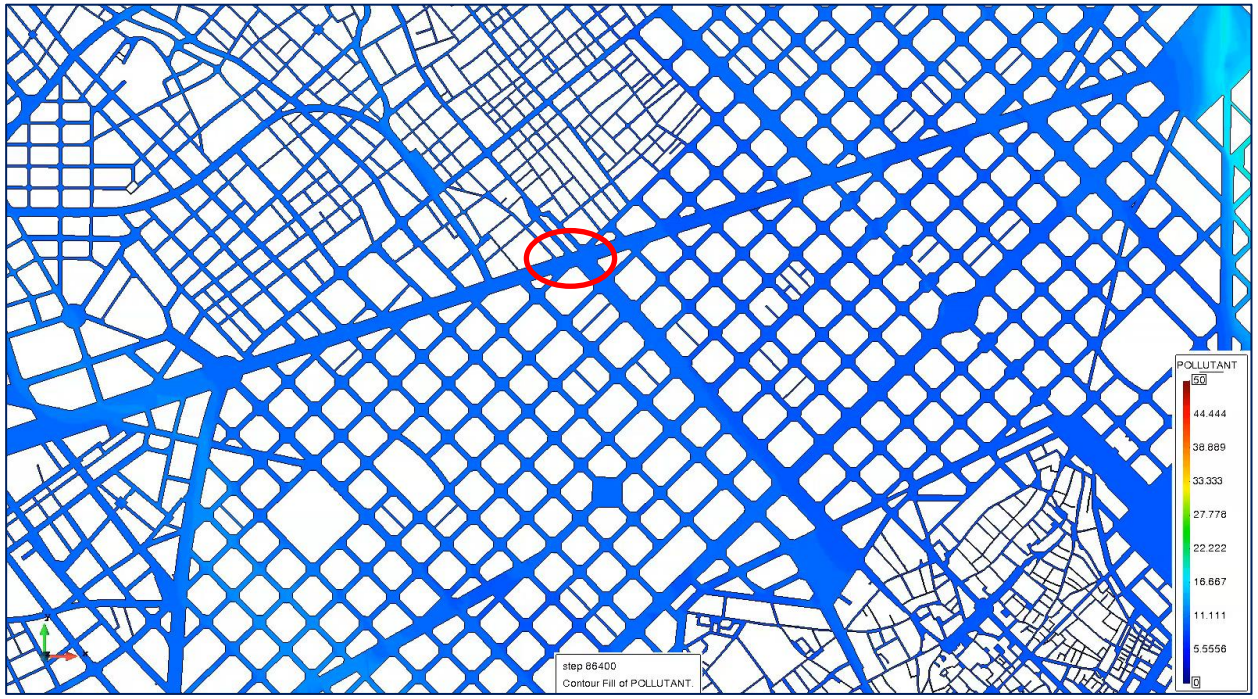




Results

Pollutant concentration (μg/m^3) from DEDL datasets (left) and from DEDL with added local event (right).

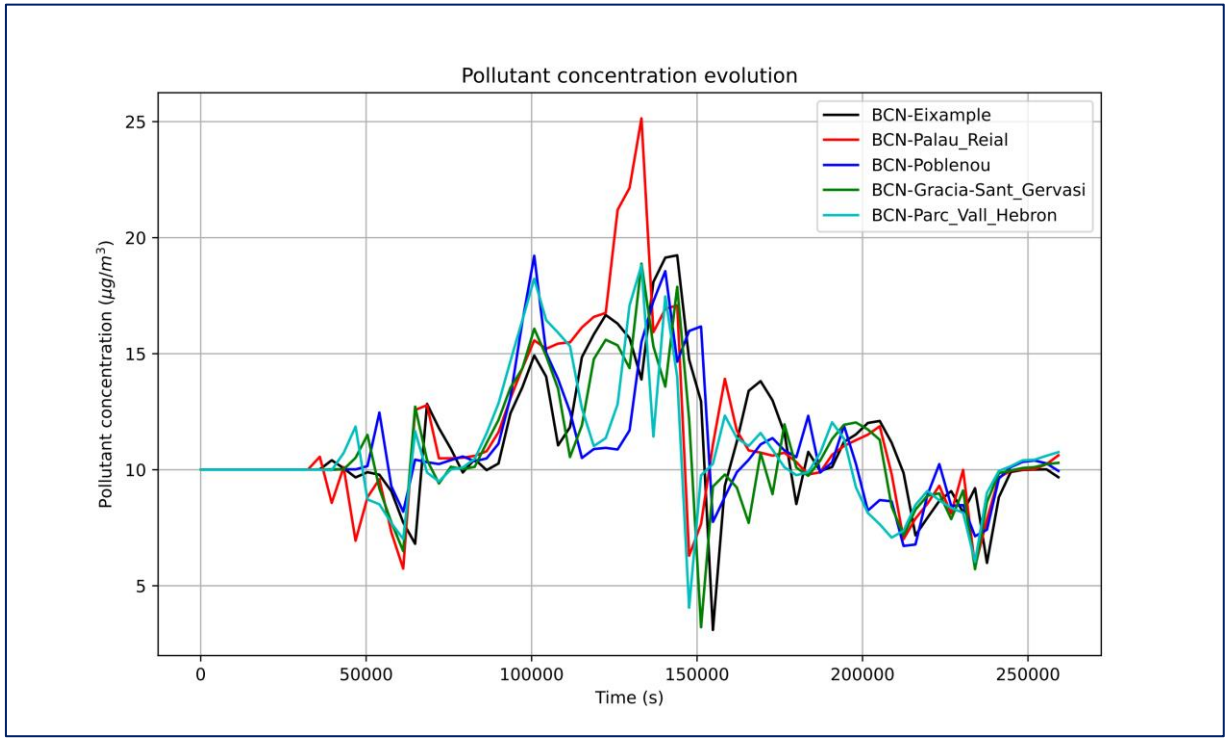


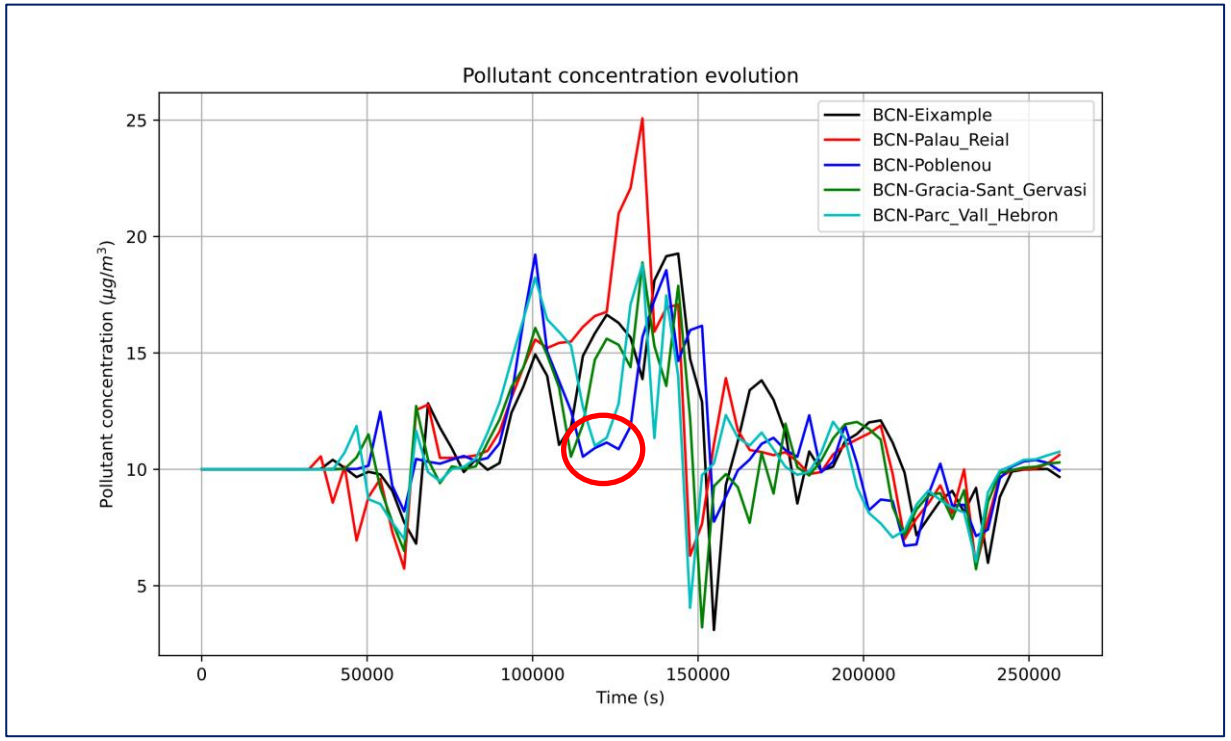


We added an artificial pollutant concentration spike for 12 hours at *Pg.Gràcia - Av.Diagonal* intersection.

Results

Pollutant concentration evolution in time at five points in the city. These points correspond to existing pollutant measuring stations for future validation.
DEDL datasets (left) and DEDL with added local event (right).

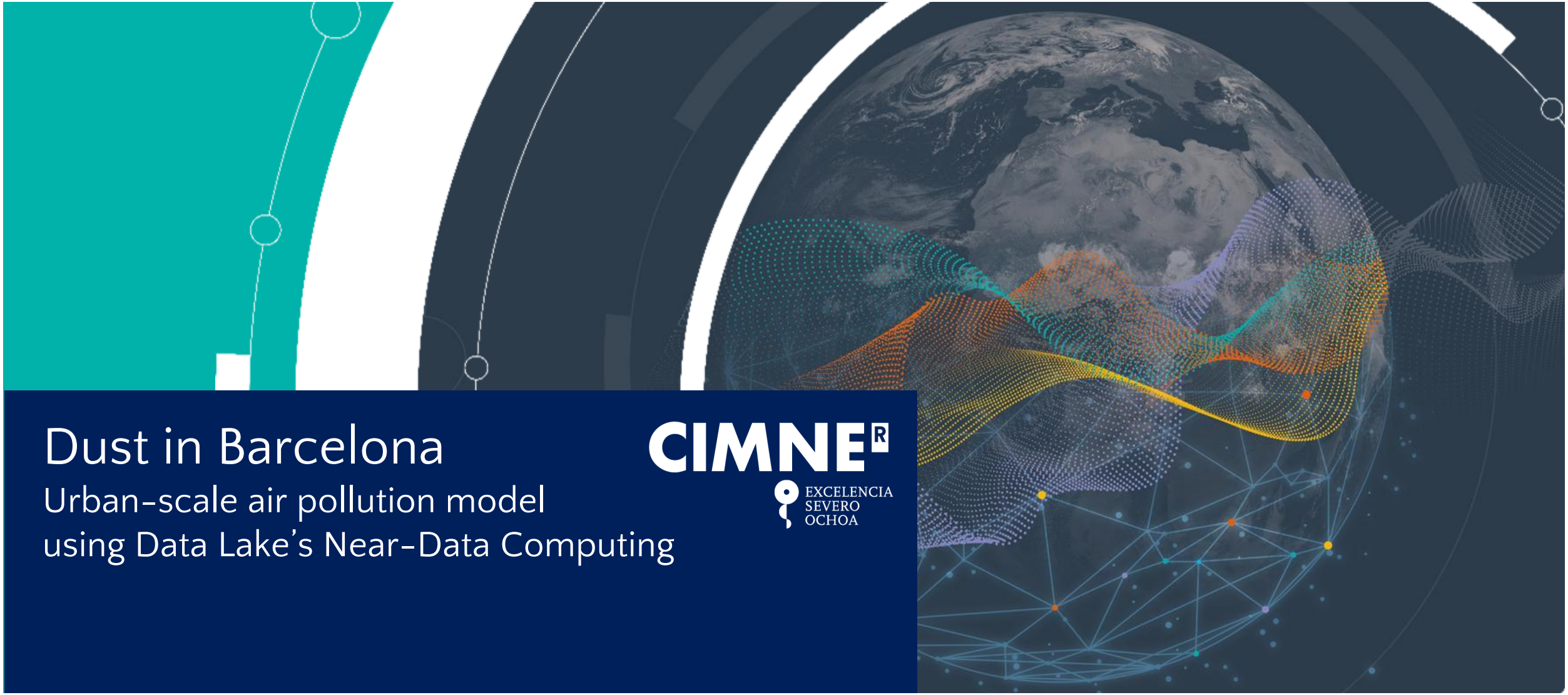




A small increase can be observed at the *BCN-Poblenou* node.

Highlights

- A practical demonstration of use of the DEDL and possibilities for reuse of resources on the DestinE platform.
- A numerical tool prototype able to provide a fast, urban-scale and short-term prediction of the particulate matter immissions in any street of an urban area, including local pollution events.
- A robust computational framework that can be easily adapted to other transport problems such as nitrogen dioxide, odors, allergens, etc.
- Easy to export/extrapolate to other geographies and datasets



Dust in Barcelona

Urban-scale air pollution model using Data Lake's Near-Data Computing

CIMNE
EXCELENCIA SEVERO OCHOA