The AirHeritage Hierarchical Network: *Sensing, Calibration, Deployment strategies for fixed, mobile air quality monitoring and modeling in urban scapes.*

Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

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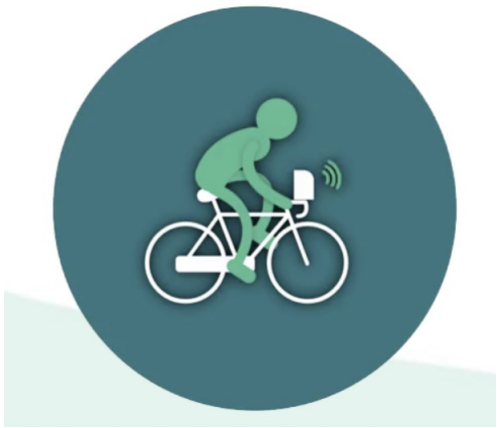
Outline:

-Project AirHeritage: Motivation and Methodology

-Calibration, Deployment, Modeling challenges and solutions

-Full scale model data pipeline

-Conclusions



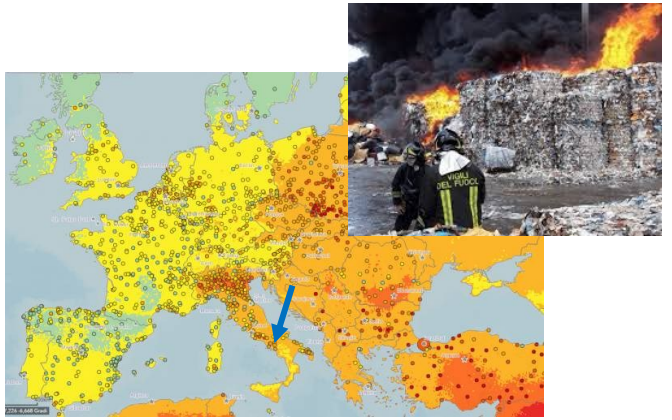
The starting point: Naples Metropolitan area AQ network

- Regulatory AQM network in Naples metropolitan area.
- 8 Stations are currently used for AQ monitoring in the Naples urban area (117Km2, 955k inhabitants).
- **Roughly, that accounts for one station for each 15Km2 and/or one station each 120k inhabitants!**
- It is worth to note that this is one of the most dense network in Europe and it is perfectly in line with the regulating EC directive.
- **As a results small towns have limited knowledge of what happens at their urban scale.**

A relatively dense regulatory grade monitoring network which leaves many densely inhabitated area with limited knowledge on local scale AQ

Social Perception and Health

- Italy has a concerning situation, with **some of the most polluted areas** in Eu.
- South of Italy experiments a **lack of authoritativeness** of main environmental and health protection agencies (citizen does not believe to official statements), prejudices on possibility to impact, fatalism.
- Lack of **scientific approach** to the problem, **lack of trust** in mitigation and regolation actions with consequent lack of participation.



- A quantitative example: Portici is a small city with high population density (**55k people on 4 Km^2 with 33k cars**) in which:
  - •Car traffic and House Heating are the main emission sources
  - •Extremely high propension to use personal car – 60% of students use family car to go to school when maximum distance from school is less than 500m
  - •No targeted information on air quality

EUROPEAN UNION
European Regional Development Fund

UIA URBAN INNOVATIVE ACTIONS

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LEGAMBIENTE

Successful Citizen Science for AQ, AirHeritage project goals

What ? Come up with a reasonable but motivating goal with sustainable impact.
How? Clarify and merge your scientific and impact goals, keep the involvement of citizens at a reasonable load.

Reconciliate the primary actors and proceed towards a shared solution …

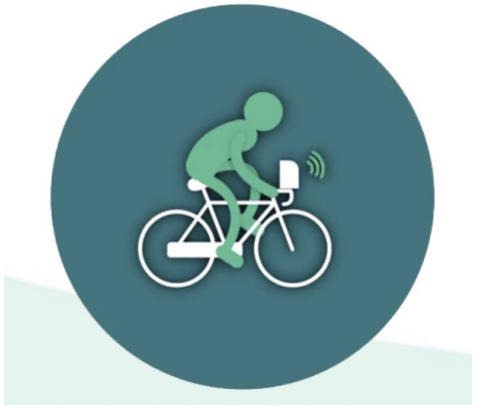
…with a community based, participative approach to…

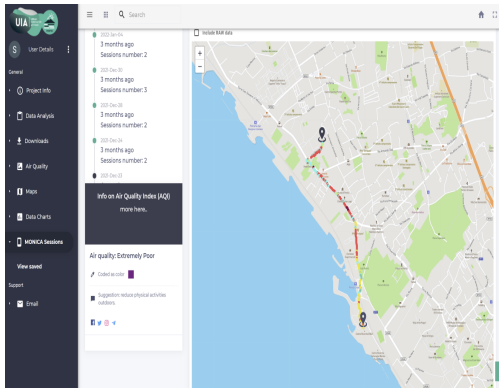
monitoring and….

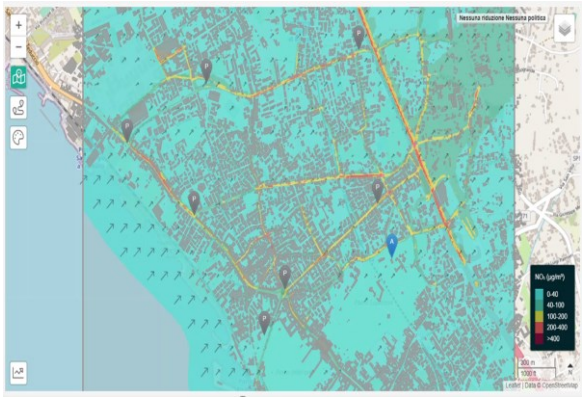
…..car traffic regulation

using technological enablers.

Successful Citizen Science for AQ: AirHeritage project Pillars







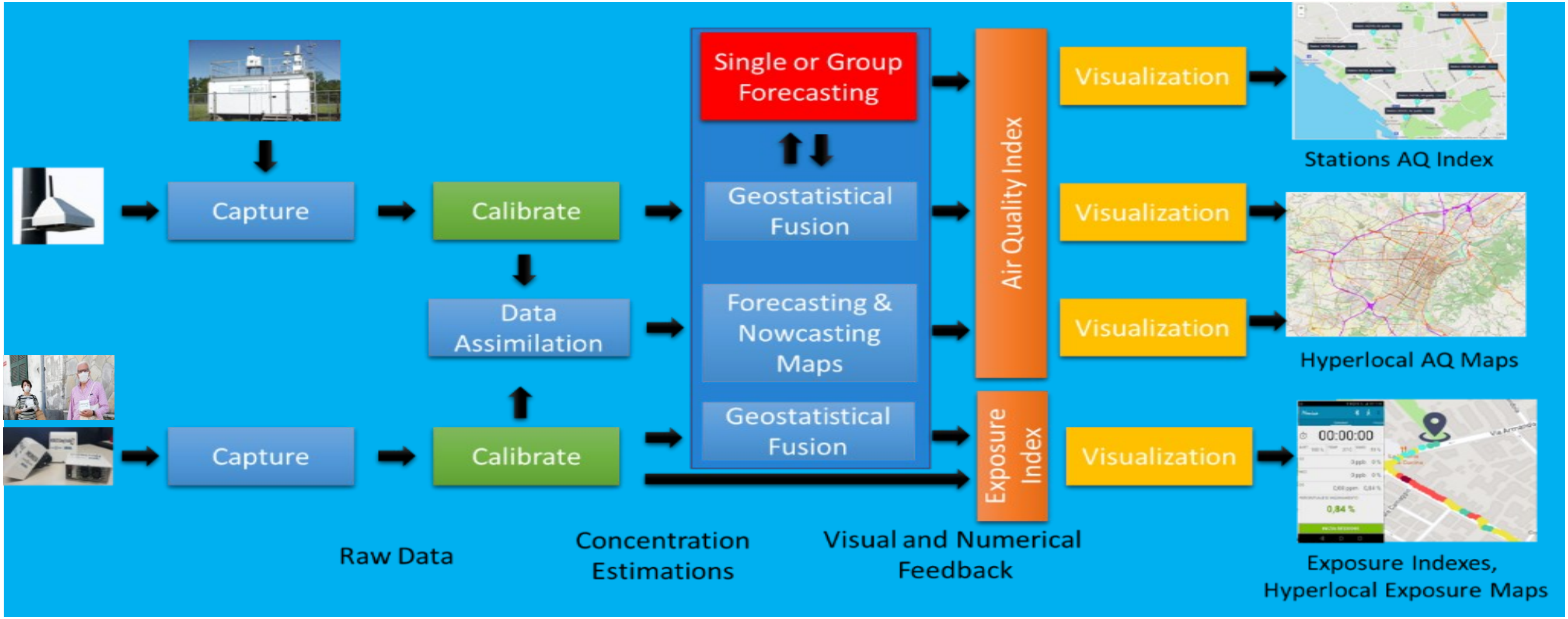
Community based approach:

Monitoring & Sustainable hyperlocal mobility experience:
Volunteers from associations will implement “pedibus” mobility for schools students. Moving back and forth from schools, pedibus users will monitor air quality and produce high spatial and temporal density opportunistic AQ data.

Enhanced Awareness:
Opportunistic Data, Regulatory and fixed monitoring stations Data have been communicated along with data assimilation based air quality mapping model predictions . Hi-res nowcasting and forecasting maps have been returned to citizens.

Traffic Car regulation:
Maps and traffic simulations are at the basis of a DSS that will help MUA to develop participated traffic regulation strategies to improve AQ.

Project Air Heritage: Data pipeline



Project Air Heritage: a Hierarchical Network as a technological basis

Pervasivity

- 1 Regulatory grade ARPAC Station
- 1 Mobile Regulatory grade Multigas Analyzer
- 7 Fixed LCAQM Stations
- 30 Mobile & Personal Gas & PM Multisensors devices

Accuracy

MultiSensors Architectures and Limits

2 Different platforms (Fixed, Mobile) monitoring

Both share sensing technologies:

- EC Sensors based CO, NO2, O3 Estimation
- OPC based PM1, PM2.5, PM10 Estimation

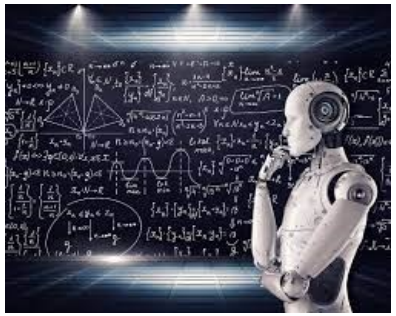
Affected by well known issues:

Environmental interferents (T -> EC Sensors, RH-> PM Sensors)

Non Target gas interferents (O3->NO2 sensors and viceversa)

Significant EC sensors fabrication variance (Sensitivity, ZeroResponse)

Calibration Strategy (1)



FIELD CALIBRATION (I.E. BY COLOCATION: MIN 3 WEEKS EACH NODE)

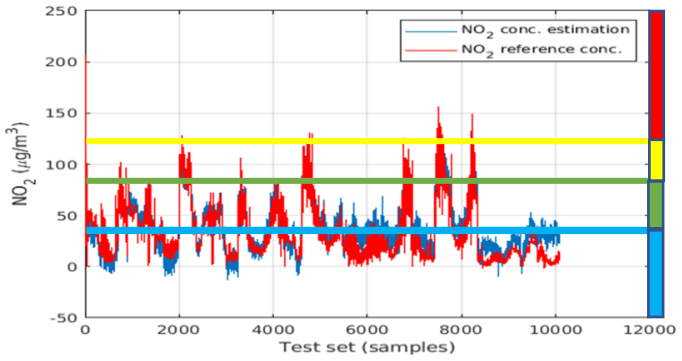
ADDRESSING ROBUSTNESS WITH PERIODICAL (6MONTHS) RE-CALIBRATION

DATA DRIVEN ALGORITHMS (MLR, NN)

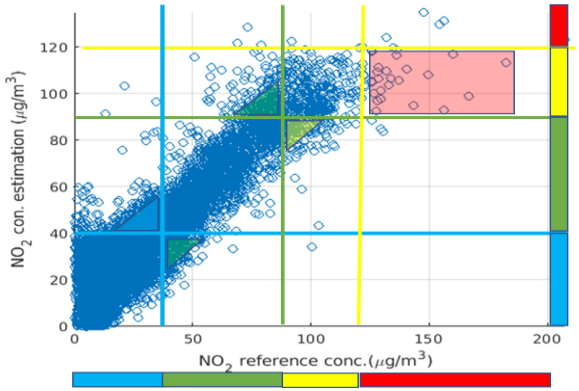
CALIBRATION COEFFICIENTS DOWNLOADED BY MONICA COMPANION APP FOR MOBILE AND OPPORTUNISTIC CITIZEN SCIENCE MONITORING

CALIBRATION COEFFICIENTS IMPLEMENTED IN-CLOUD FOR FIXED STATIONS

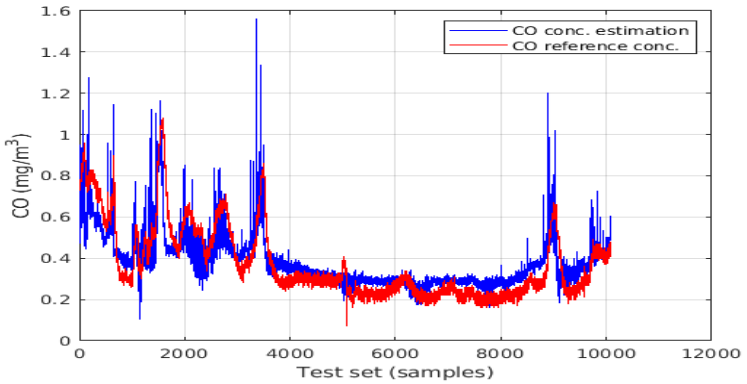
Comparing LCAQMS with Regulatory grade stations



NO2, O3 SENSORS REACT TO THE PROCESS BY FOLLOWING TRUE CONCENTRATIONS NICELY (ON SEPARATE TEST DATA SETS)



USING SENSORS CONCENTRATION ESTIMATIONS TO EVALUATE EAQI FOR FEEDBACK COMMUNICATION LEADS TO VERY LIMITED ERRORS. THE VAST MAJORITY OF CASE, THE FUNCTION MISCLASSIFY IN THE ADJACENT EAQI CLASS.



CO SENSOR IS FORCED TO WORK CLOSE TO ITS LOD SO SIGNIFICANT RELATIVE ERROR IS EXPECTED AT VERY LOW CONCENTRATIONS

Yearly results by using complete calibration set

Results are in line with consolidated literature in the mid term (3 months) or when using both summer and winter time recorded training data

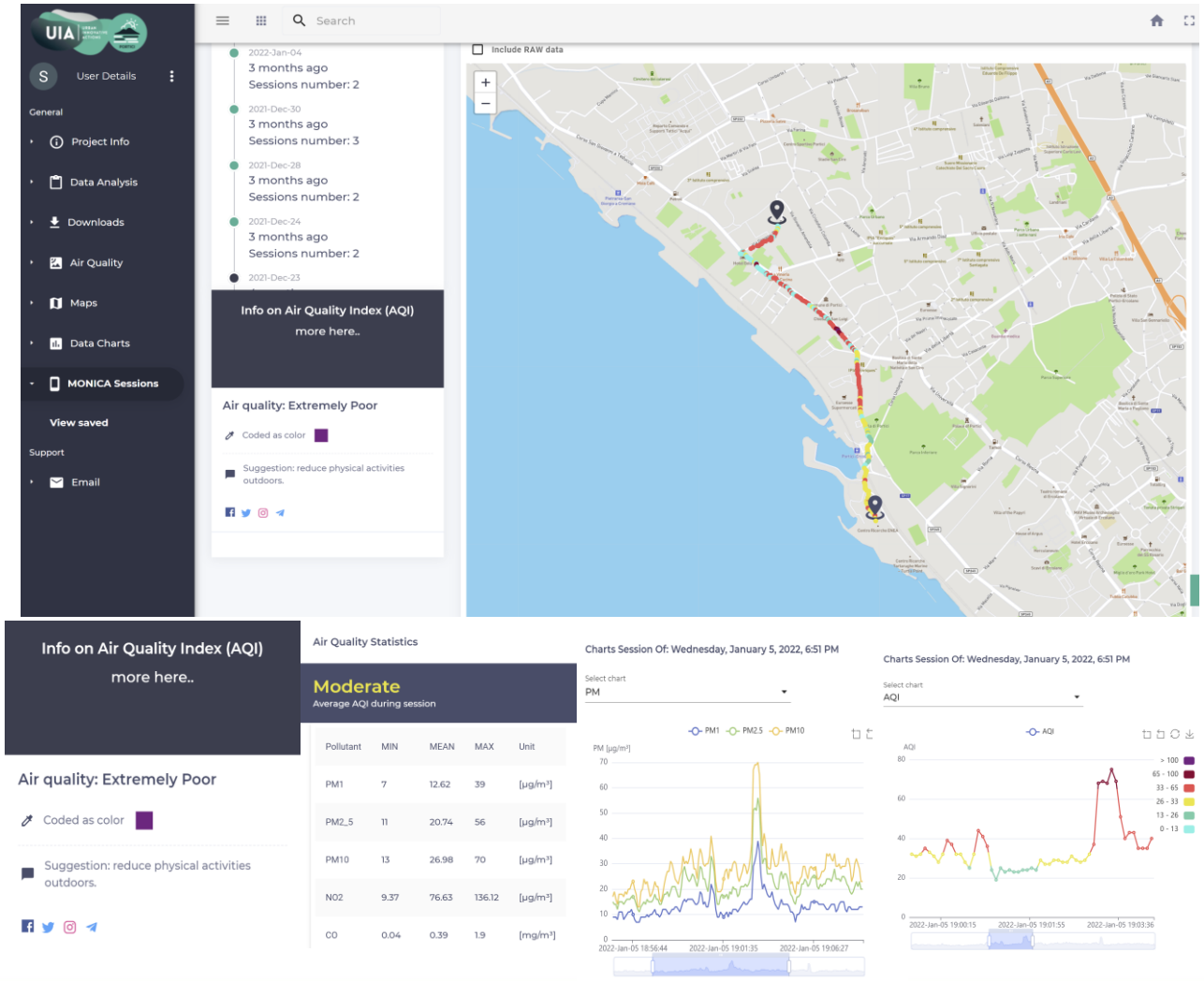
	R^2 (median)	R^2 (mean)	R (mean)	MAE	Err (%)
PM2.5_AVG	**0.40**	**0.39**	**0.67**	**5.88**	**0.13**
PM2.5_STD	0.12	0.10	0.05	1.04	0.05
PM10_AVG	**0.21**	**0.20**	**0.60**	**9.78**	**0.18**
PM10_STD	0.10	0.10	0.05	2.10	0.07

Yearly results by using complete calibration set

Results are in line with consolidated literature in the mid term (3 months) or when using both summer and winter time recorded training data

	R^2 (median)	R^2 (mean)	R (mean)	MAE	Err (%)
NO2_AVG	0.60	0.40	0.81	10.73	0.13
NO2_STD	0.12	0.37	0.04	2.89	0.05
O3_AVG	0.85	0.74	0.94	9.93	0.18
O3_STD	0.05	0.22	0.02	2.86	0.07
CO_AVG	0.16	-0.19	0.44	0.18	0.03
CO_STD	0.21	0.52	0.50	0.07	0.03

Personal Results @ Airheritage.portici.enea.it

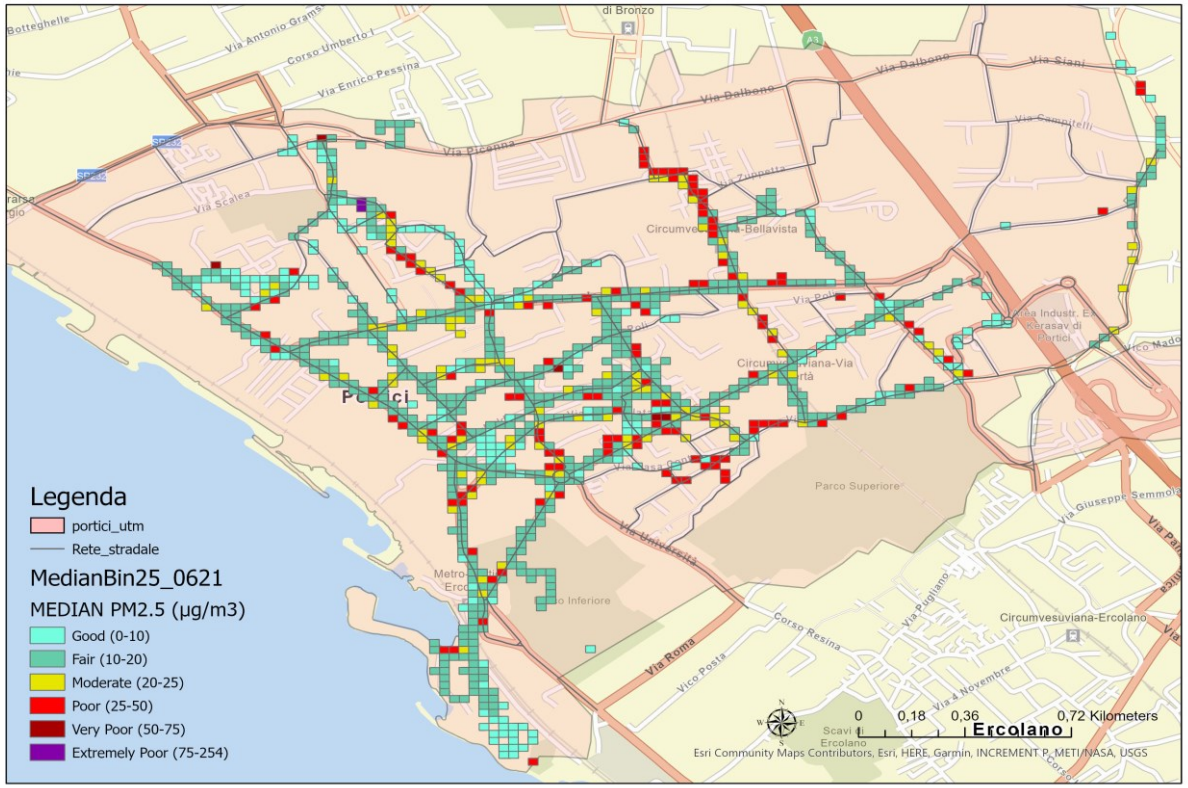


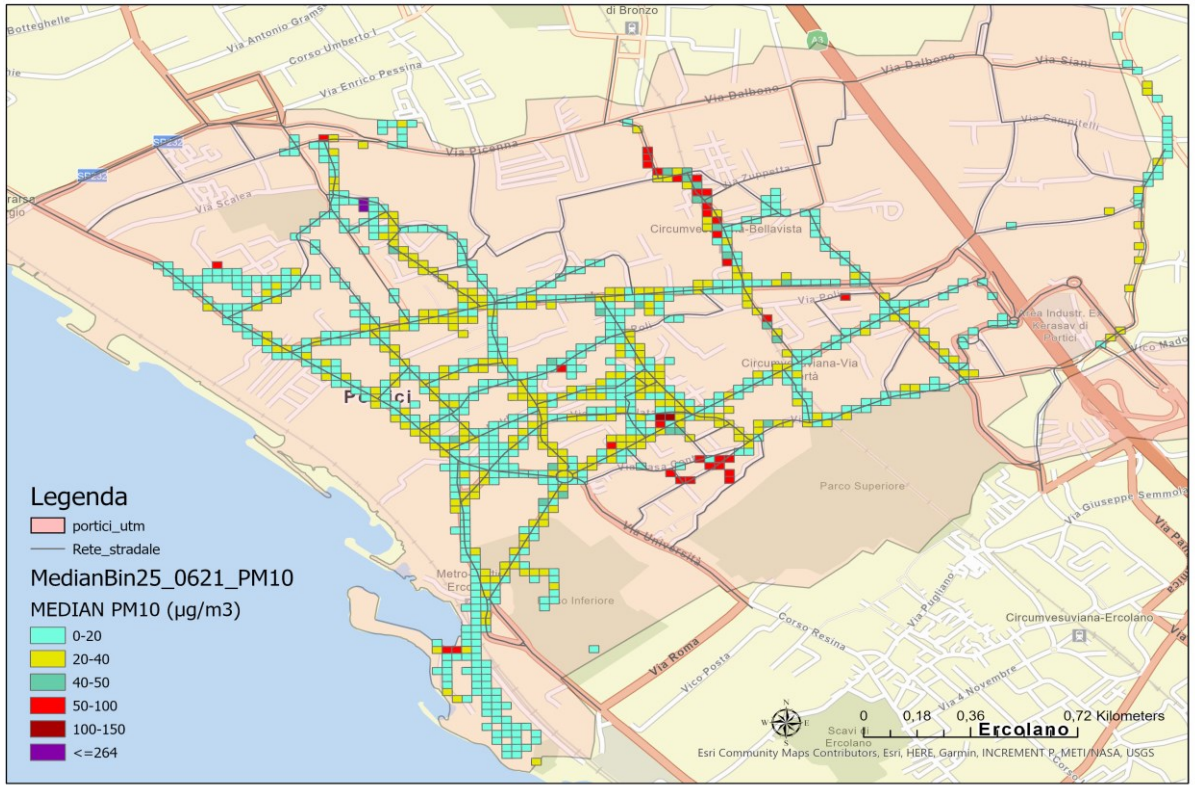
- Personal in city mobility session
- Active Life Feedback (Personal Exposure) based on EAQI estimations
- Simplified Statistics
- Graphical Trends
- Freely downloadable raw and calibrated data

Findable Accessible Interoperable Reusable

{JSON}

Mobile Stations Results





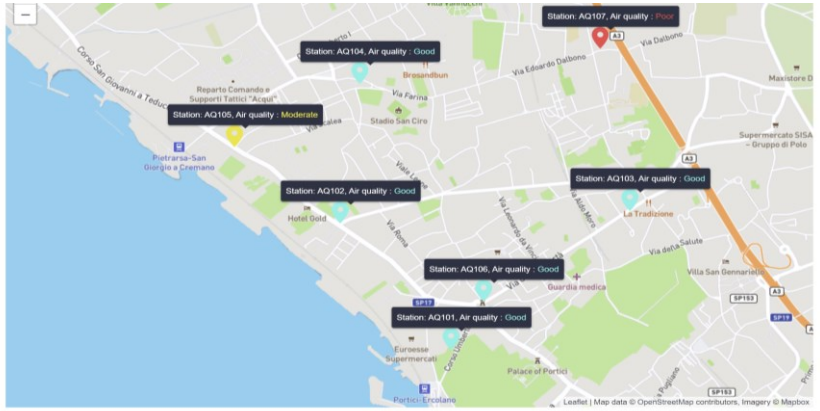
25X25MT SPATIAL BINNING MAPS USING SINGLE SEASON OPPORTUNISTIC DATA RECORDED BY CITIZENS WITH MOBILE DEVICES.

MIN 20 DATA POINTS PER BIN, AVERAGED TO COMPUTE EAQI CORRESPONDING TO SINGLE POLLUTANT

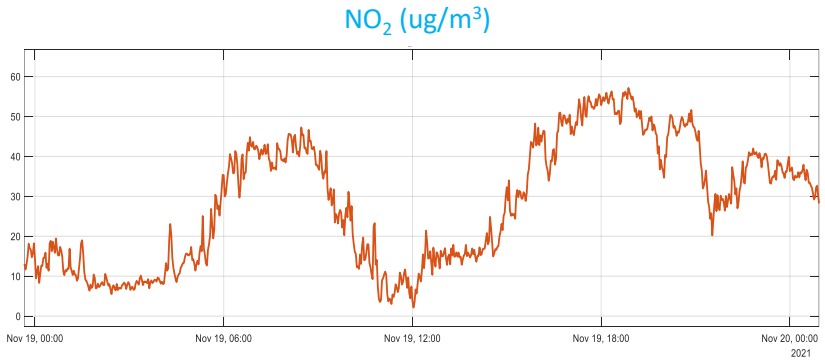
HOTSPOTS CONSISTENTLY DETECTED IN HEAVY TRAFFIC AND CITY CANYONS

De Vito S. et al., Sensors **2021**, *21*, 5219.

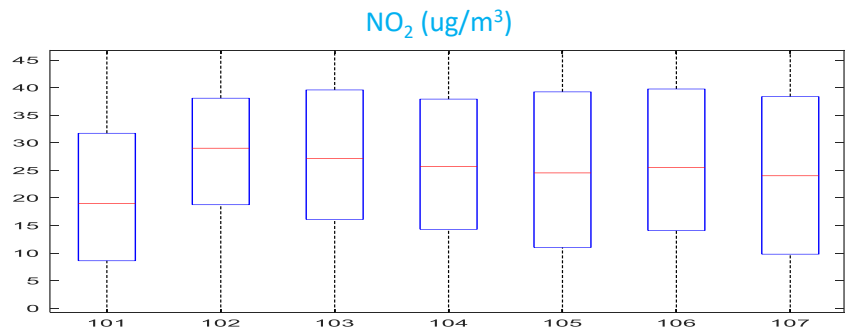
Fixed stations results



7 STATIONS CONTINUOUS MONITORING SERVICE COVERING HOT AND COLD SPOTS



MULTI TIME-SCALE VARIANCE PATTERNS IN SINGLE STATIONS DISCOVERY



ANNUAL AVERAGE SPATIAL PATTERNS HIGHLIGHTING EXPOSURE ENVIRONMENTAL DISPARITIES