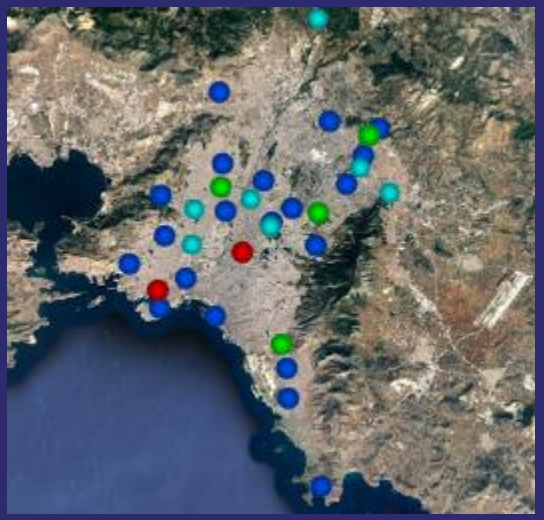
e-shape

EuroGEO Showcases: Applications Powered by Europe



# Air quality monitoring through sensor-based networks in large metropolitan areas: The case of Athens, Greece


Dr. Georgios Grivas

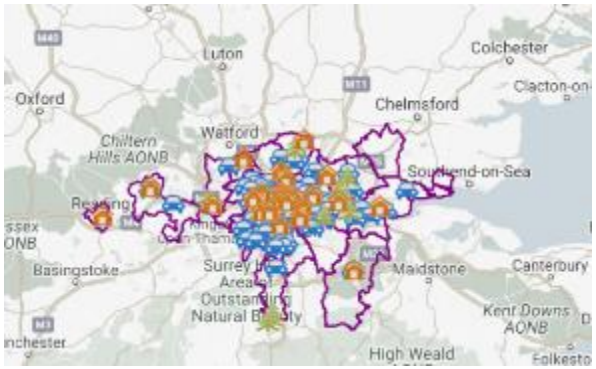
Research Fellow, National Observatory of Athens (IERSD/NOA)



The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

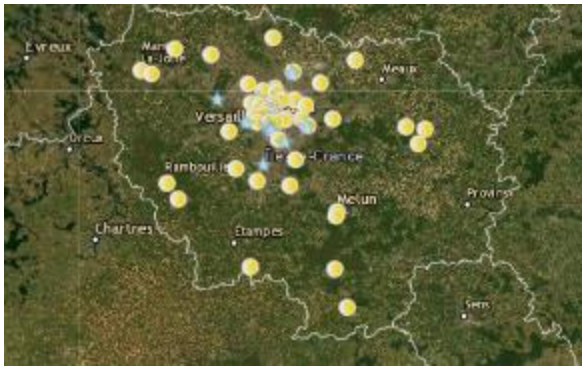
# Dense Air Quality Monitoring Networks in major European cities

London Air




No. of stations: ≈ 120

AIRPARIF




No. of stations: ≈ 70

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

No. of stations: ≈ 50

Calidad del aire
Comunidad de Madrid

No. of stations: ≈ 50

# A less dense Air Quality Monitoring Network in a major European City

## GREATER AREA OF ATHENS (GAA)

**Population:** 3.6 mil. (2019 – Eurostat)

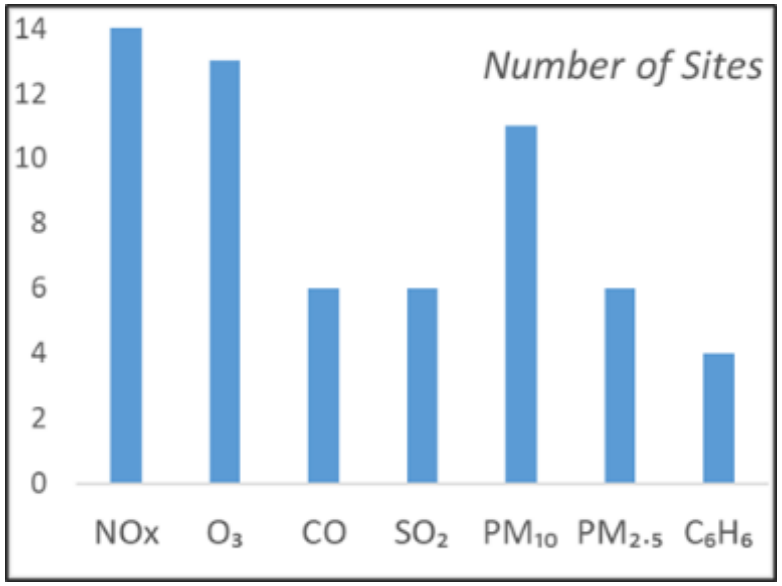
**Area:** 412 km$^2$ (Athens Basin)

**Regional Units:** 8

**Municipalities:** 56

**Population Range:** 18-664k *(by municipality)*

**Density Range:** 0.1-21.2 k/km2 *(by municipality)*




| Population of agglomeration or zone (thousands) | If maximum concentrations exceed the upper assessment threshold (1) | |
|---|---|---|
| | Pollutants except PM | PM (2) (sum of $PM_{10}$ and $PM_{2,5}$) |
| 0-249 | 1 | 2 |
| 250-499 | 2 | 3 |
| 500-749 | 2 | 3 |
| 750-999 | 3 | 4 |
| 1 000-1 499 | 4 | 6 |
| 1 500-1 999 | 5 | 7 |
| 2 000-2 749 | 6 | 8 |
| 2 750-3 749 | 7 | 10 |
| 3 750-4 749 | 8 | 11 |
| 4 750-5 999 | 9 | 13 |
| ≥ 6 000 | 10 | 15 |

# Local factors exacerbating common European AQ issues

## Wintertime "smog" due to residential wood-burning

- *Research studies feature Athens as the biomass-burning capital of the EU*
- *Extreme short-term levels for $PM_{2.5}$ (>200 $\mu gm^{-3}$, hourly), with high contributions of organic compounds and black carbon*

## Summertime photochemical smog

- *High ozone levels with frequent exceedances of alert and information thresholds*
- *The majority of urban background sites in the GAA each year breach the annual EU target-value*

## Aging vehicle fleet – Surge of diesel-powered cars

- *A ban on private diesel cars ended in 2011, and they have since dominated new and used-car sales*
- *Greece has one of the most aged vehicle fleets in the EU ($4^{th}$ most aged for private cars, $1^{st}$ most aged for trucks)*
- *Persistent AQ-standard violations for $NO_2$, $PM_{10}$ at traffic sites*

## Shipping emissions

- *Piraeus in the GAA is the busiest European passenger port and the $2^{nd}$ most busy port in the Mediterranean*

# Episodic air quality events aggravate short-term exposure

## Wildfire smoke impacting the urban area

- *The GAA has been affected by emissions from a wildfire event almost every summer since 2017*
- *The impact of the August 2021 wildfire lasted for over a week and led to extreme short-term $PM_{2.5}$ levels (>300 $\mu gm^{-3}$)*

## Industrial accidents emitting hazardous pollutants

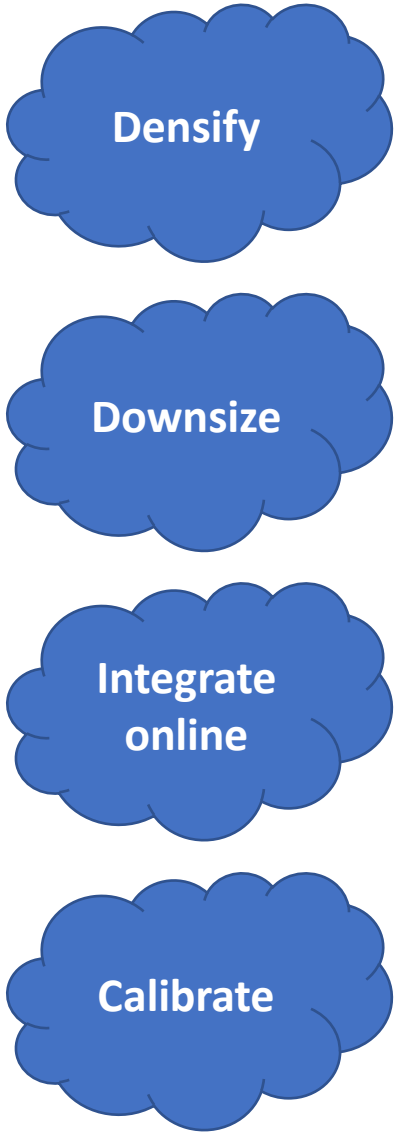
- *In the recent years (2016-2020), there have been two large scale industrial accidents in plastic-recycling plants of the GAA*
- *Atmospheric dispersion carried the plumes over the Athens basin, leading to excessive PM levels, characterized by high BC contribution*

## African dust intrusions

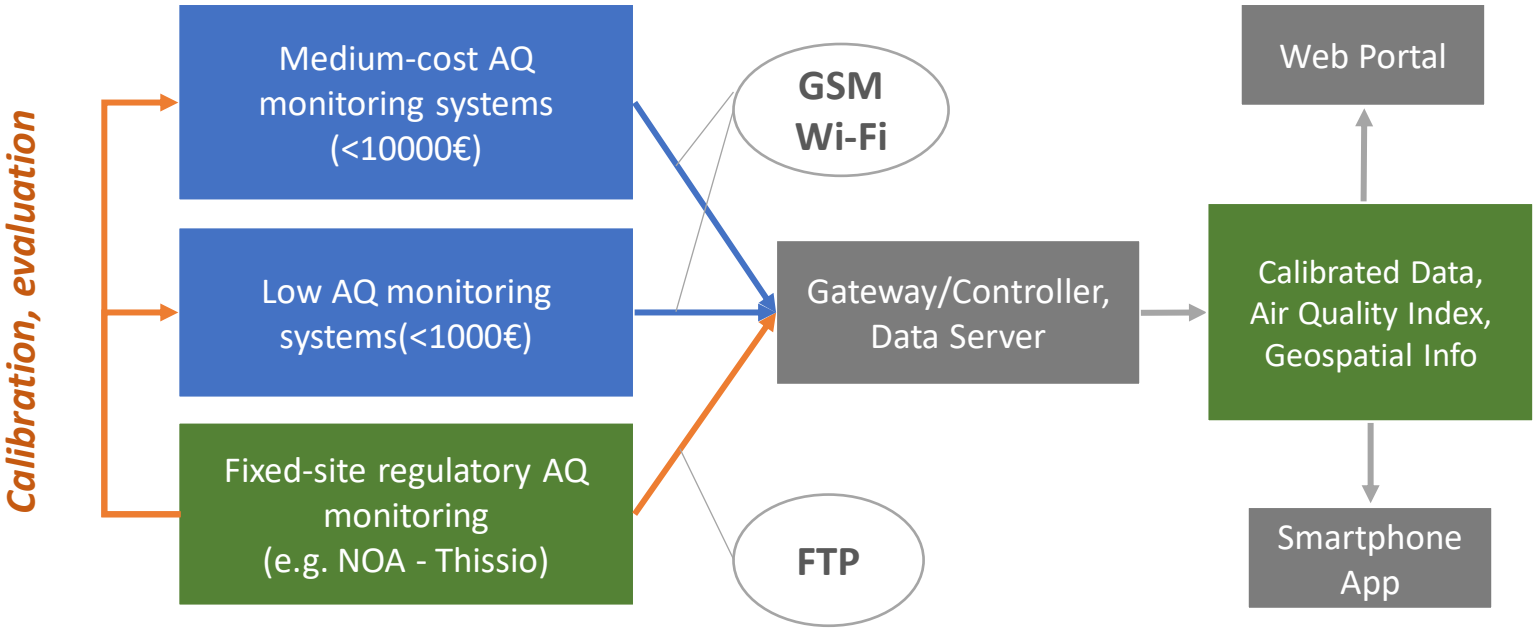
- *Dust events due to Saharan dust transport are very common in Southern Greece, especially during spring, leading to extreme $PM_{10}$ levels and also aggravating short-term $PM_{2.5}$ exposure*

# Identifying the special needs for AQ monitoring in metro areas

- Large exposed populations necessitate spatially representative measurements, to capture within-area variability and reduce exposure misclassification error
- Large areas mean that atmospheric dynamics can induce substantial intra-urban variability
- The heterogeneous urban landscape and source mixture dictate measurement at different site types
- Multiple stakeholders at different levels (governmental, regional, municipal, private sector) have different AQ management priorities and require solutions for local issues
- Large investments required to expand regulatory network
- Episodic events but also increased urban mobility call for near-real time information
- Need for IoT integration and personalized exposure information (online platforms, smartphone apps, etc.)
- ***While sensor-based solution will not substitute regulatory AQ monitoring stations for compliance assessment, it is imperative to calibrate their outputs for reliable results***



# Designing an integrated AQ monitoring network in Athens



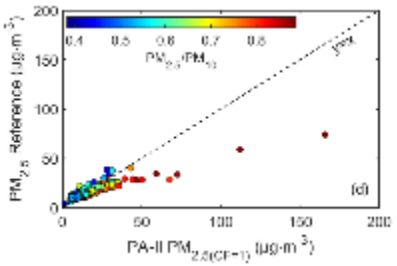

- Design and implementation of an integrated IoT network and data-visualization platform
- Products and services to inform and protect the public from excessive exposure
- Incorporation of other available monitoring networks providing calibrated data

# Sensor-based monitoring instruments used by NOA in Athens

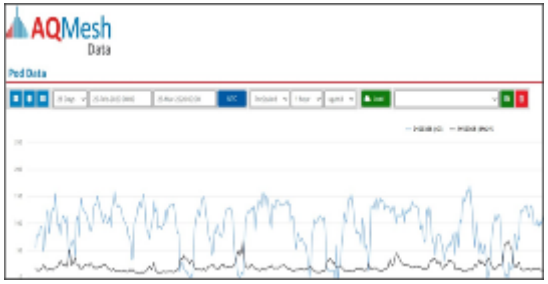
## Low-cost system for $PM_{2.5}$ monitoring

### PurpleAir PA-II (PMS5003)

- Low cost device, can be deployed in dense networks
- Easy to install and operate, transmits data via wi-fi to an online platform
- Real time monitoring (resolution ≈ 2 min)
- Strong correlations with $PM_{2.5}$ reference monitors (except in cases of dust)

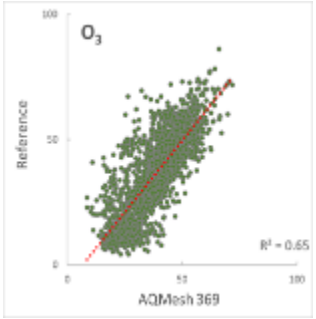


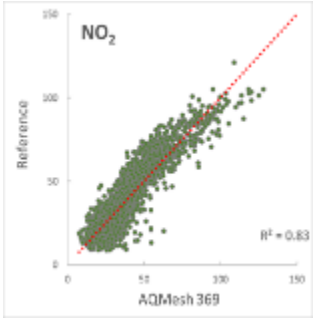

## Multi-pollutant systems for $O_3$, $NO_2$, CO and PM

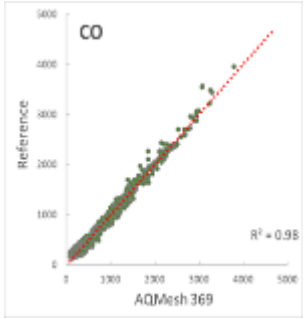



### AQMesh Multi-pollutant monitor

- Alphasense electrochemical sensors for gas measurements, correcting for T interferences
- Integrated in a user platform for data access and parametrization (3G transmission, API)
- Real time monitoring (min. resolution = 5 min)
- Strong correlations with CO, $NO_2$ and $O_3$ reference monitors



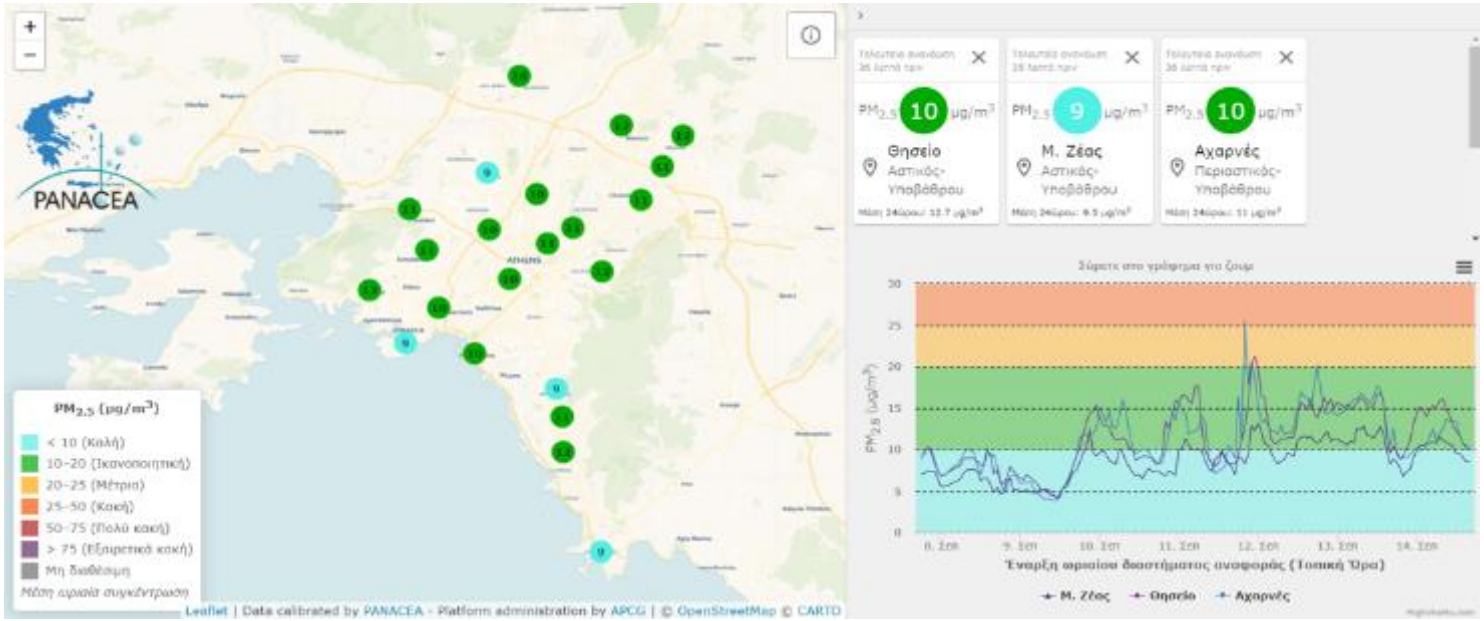
# Calibration of sensor-based systems at the NOA supersite

- NOA urban background supersite in Thissio, central Athens
- Concurrent operation with reference instruments using standard methods
- Statistical evaluation of sensor performance
- Linear models for correction of sensor outputs
- Examination of T, RH effects and cross-pollutant interferences
- Periodic calibration of sensors on-site (using golden-pods or the NOA mobile AQ monitoring station)

# The NOA/PANACEA $PM_{2.5}$ monitoring network in Athens

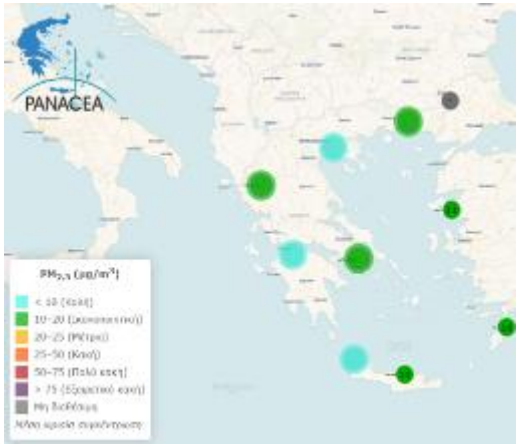
[https://air-quality.gr](https://air-quality.gr)

**$PM_{2.5}$ monitoring in the GAA using low-cost sensors**



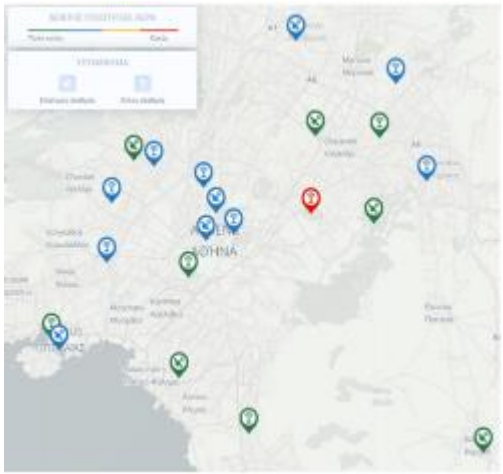

**24 measurement sites in the GAA**

**≈ 80 measurement sites in Greek cities (in the framework of RI-PANACEA, with the cooperation of Greek Universities, such as UPatras)**



# The NOA/EMISSION multi-pollutant monitoring network in Athens

## *https://emission-web.meteo.noa.gr*



$O_3$, $NO_x$, CO, $PM_x$ measurements in the GAA, using AQMesh and custom made low-cost systems

**15 measurement sites in the GAA**

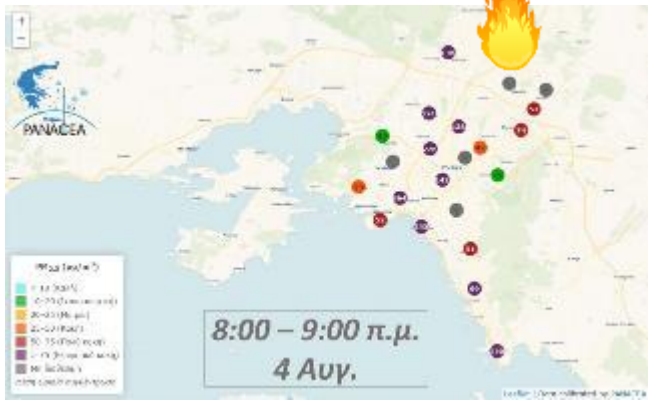
*Envi4Athens (DRAXIS)*

- Smartphone app for the EMISSION network
- Personalized AQI and info
- Citizen engagement

# An example: The August 2021 wildfire events

Start of event

Nearing the city




Covering the basin

# The utility of a sensor-based network in the context of e-shape

## Pilot: S2-P3: EO-based pollution-health risks profiling in the urban environment

*Target:* *Blend EO platforms for AQ with socio-economic and health data, into an integrated risk assessment system to support decision making*

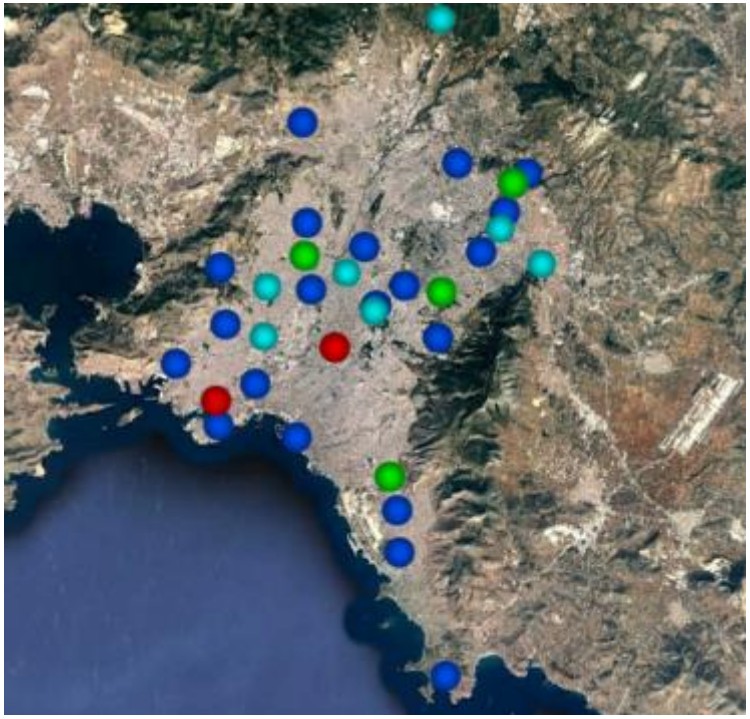
*Key tools:*

- *High-resolution, city-scale AQ modeling system (see upcoming presentation)*
- *Dynamic population exposure methodology*
- *Health impact assessment tools*

*Possibilities opened up with AQ monitoring in high resolution*

- *Improved validation and assimilation of the AQ modelling system*
- *Characterization of AQ at the municipality level*
- *Utilization of measurements in land-use regression models for spatial prediction of long-term exposure*
- *Provision of data for improved health impact assessment*

# The path to an integrated network of calibrated data



- Reference sites
- Mid-cost multi-pollutant systems
- Low-cost multi-pollutant systems
- Low-cost $PM_{2.5}$ systems

| | |
|---|---|
| **Urban Traffic:** | **3** |
| **Urban Background:** | **15** |
| **Suburban Background:** | **13** |
| **Near-city Rural Background** | **2** |

***$PM_{2.5}$ network densification***

***Aim → Coverage at the municipality level***

e-shape

***Thank you !!***

ggrivas@noa.gr