High resolution mapping of population exposure to PM2.5 for use in public health assessments

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About this study

e-shape (https://e-shape.eu) is a unique initiative that brings together decades of public investment in Earth Observation and in cloud capabilities into services for the decision-makers, the citizens, the industry and the researchers. The work presented here is done in the frame of HSAQ, one out of the 37 pilots of e-shape.

The 'Health Surveillance Air Quality' Pilot, fuses Earth observations for AQ (in situ monitoring stations, satellite retrievals, atmospheric numerical models, citizen observatories) with population and health data towards tailored, added value products that support public air quality and health assessments, informed decision making
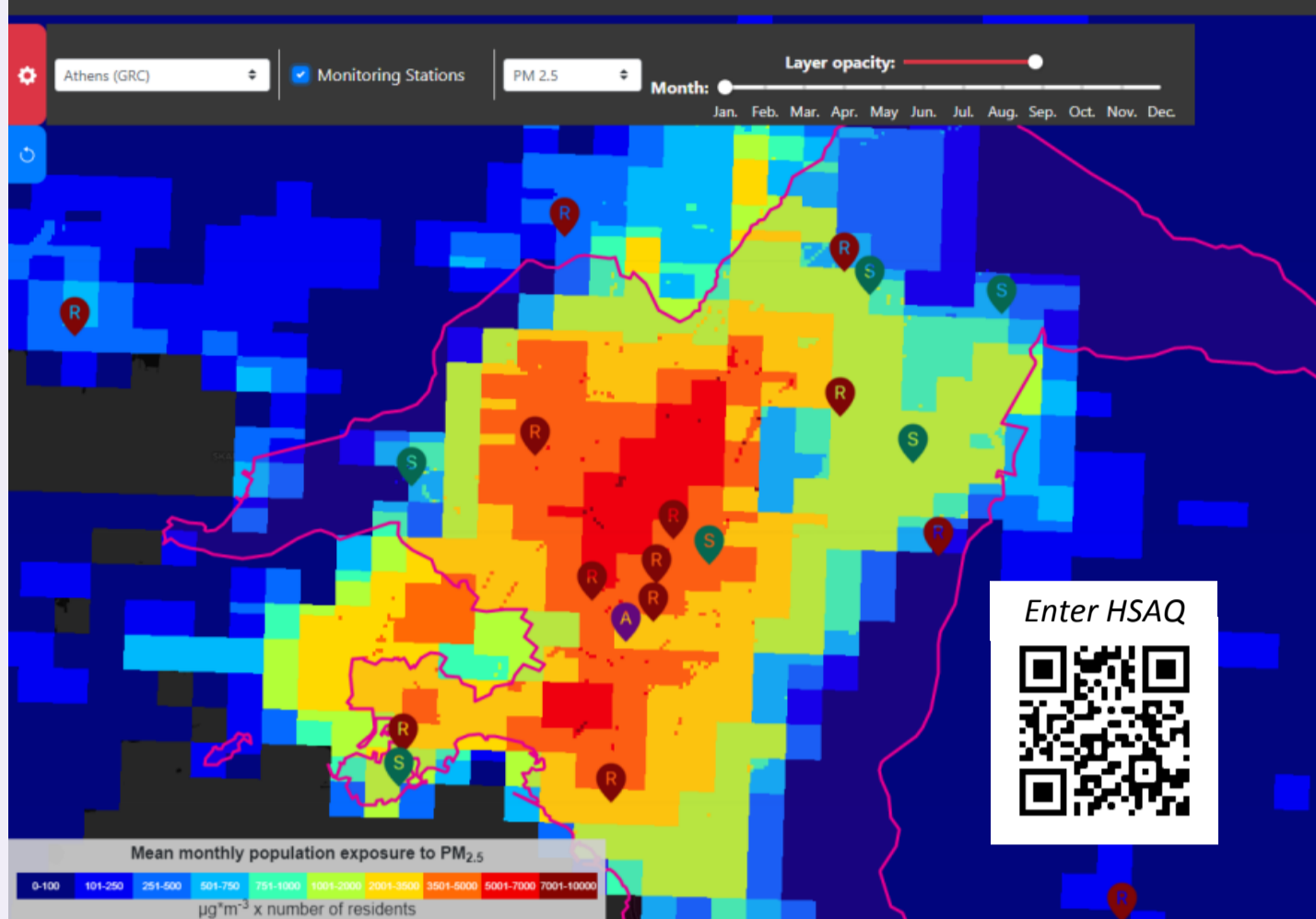

as well as urban planning. More than 50 cities of the globe participate in HSAQ. For Athens (Greece), the mapping of population exposure to air pollution is estimated for a reference year (2019), with emphasis on the exposure above the newly published (late 2021) WHO air quality guidelines for NO2 and PM2.5.

Where does the data come from?

* EPISODE-CityChem (v1.5): A Chemistry Transport Model to enable chemistry/transport simulations of reactive pollutants on the city scale [Karl et al., 2019; Hamer et al., 2019]. The model is designed for treating complex atmospheric chemistry in urban areas (1 by 1 km) and improved representation of the near-field dispersion (100 by 100 m).

** Anthropogenic CAMS emissions are improved over the domain of interest with the spatial disaggregation approach and tool UrbEm, documented in [Ramacher et al., 2021].
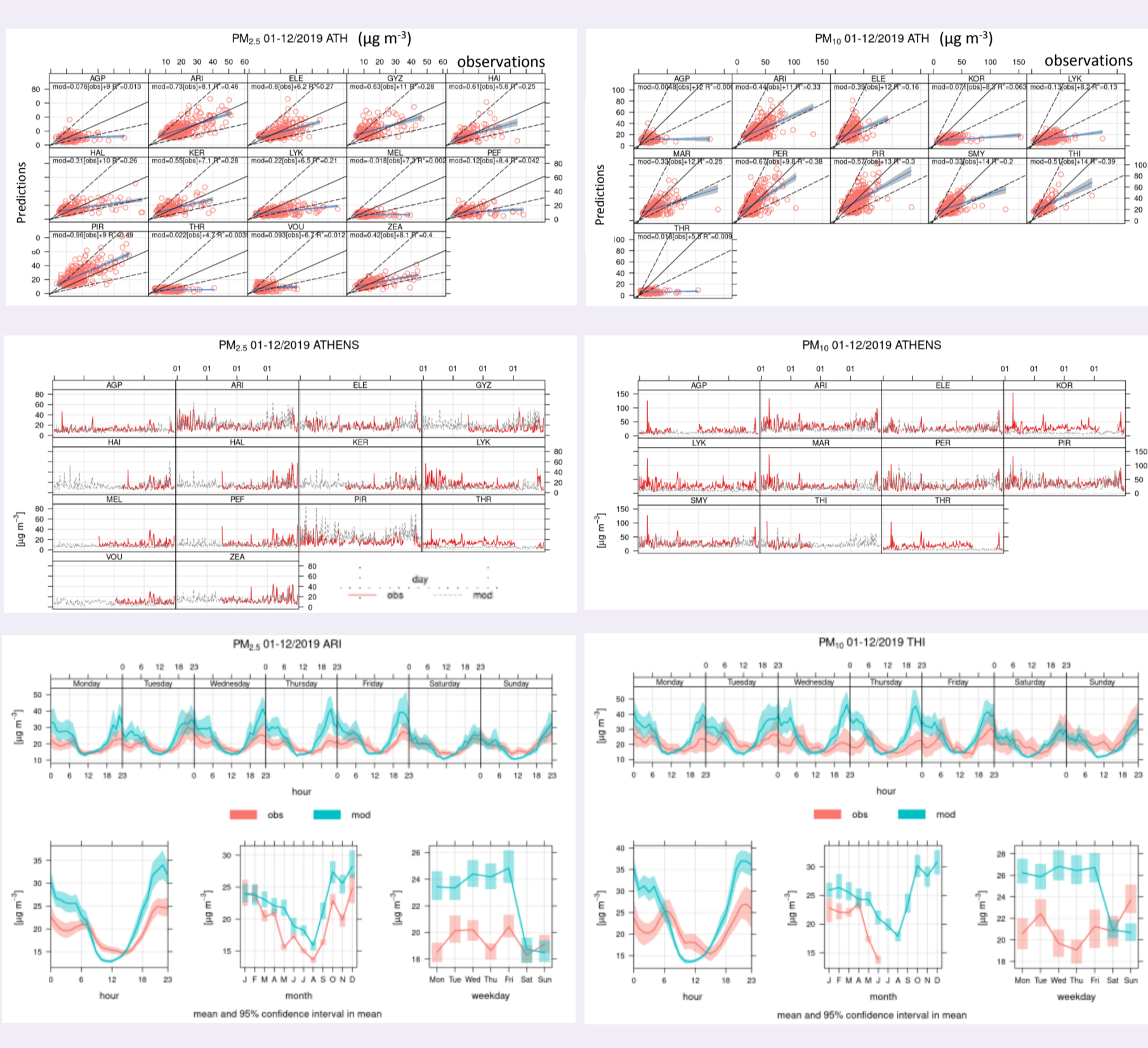
*** WRF-4.3: The Weather Research and Forecasting (WRF) Model is a mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications [Skamarock et al., 2020]. The current application is fed with synoptic-scale meteorological reanalysis ensemble means
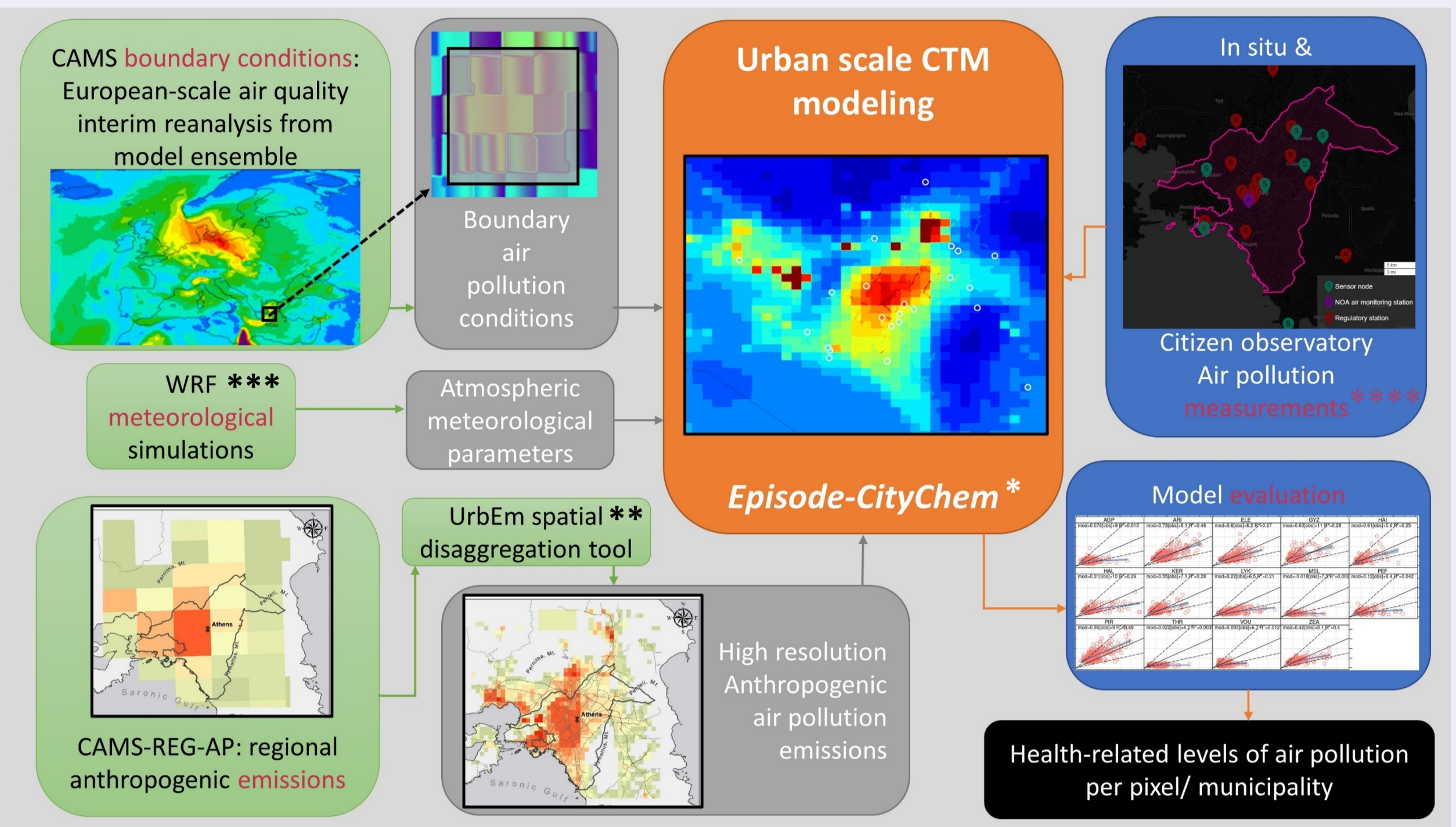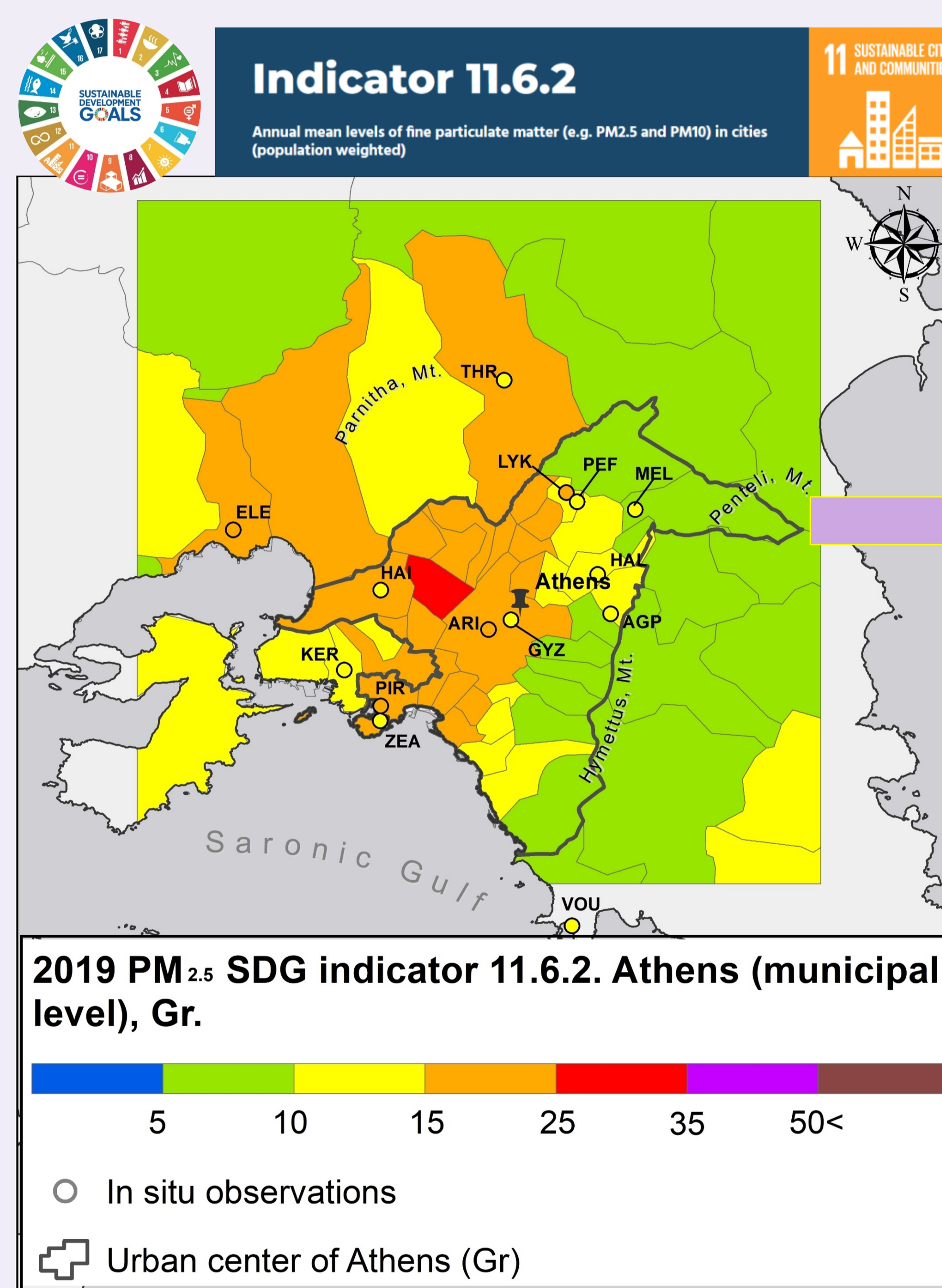

*** (continue) (ECMWF ERA 5). A telescoping (3 domains) and 2-way nesting is applied.

**** In situ data for air pollutants are derived from the National Regulatory Network, the super-site of Thissio (NOA) and PM2.5 sensors (https://air-quality.gr/en, RI-PANACEA).

Model evaluation

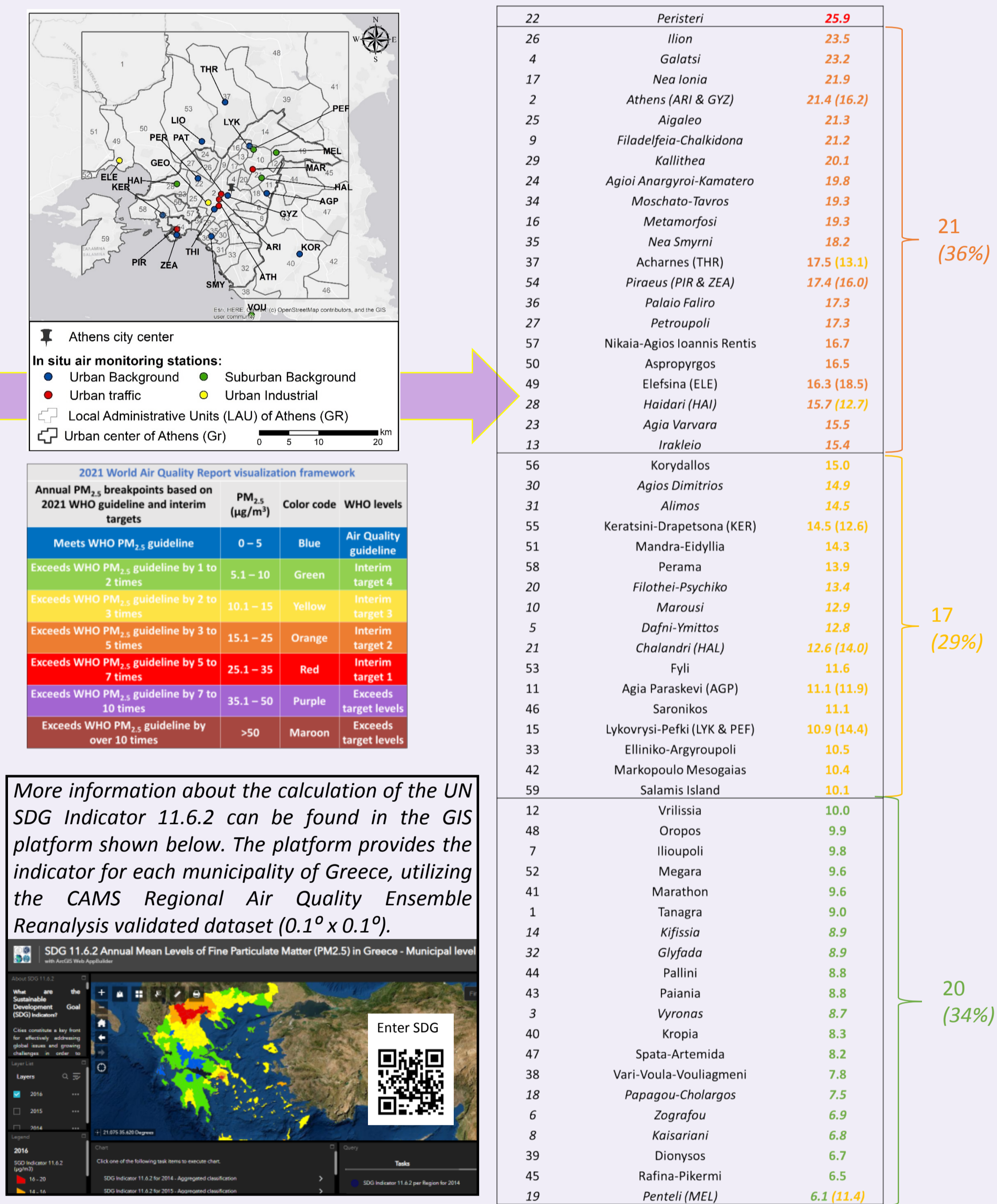## Athens map of 2019 PM2.5 concentrations by municipality

Indicator 11.6.2
Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)

11 SUSTAINABLE CITIES AND COMMUNITIES

2019 PM2.5 SDG indicator 11.6.2. Athens (municipal level), Gr.

5   10   15   25   35   50<

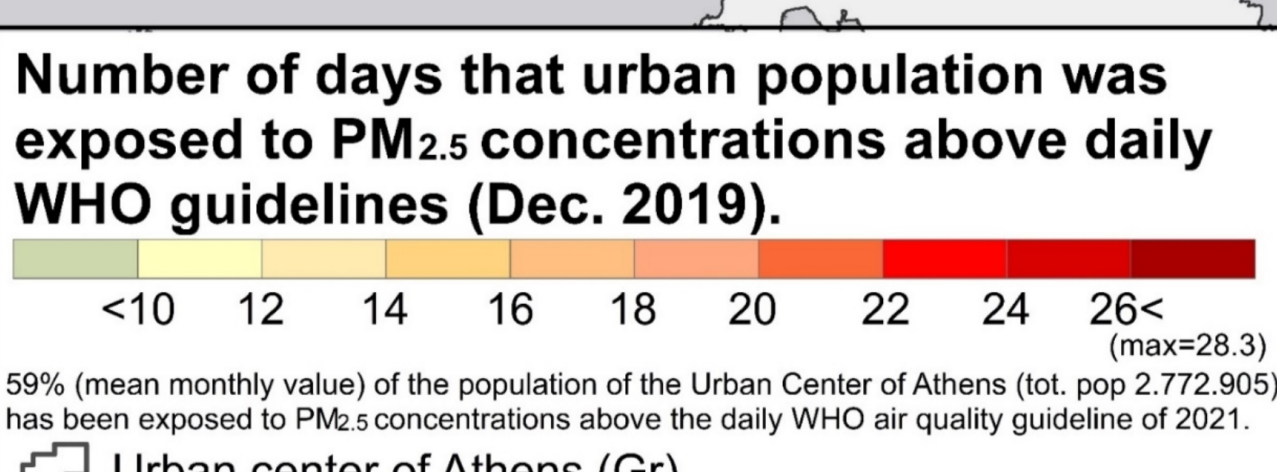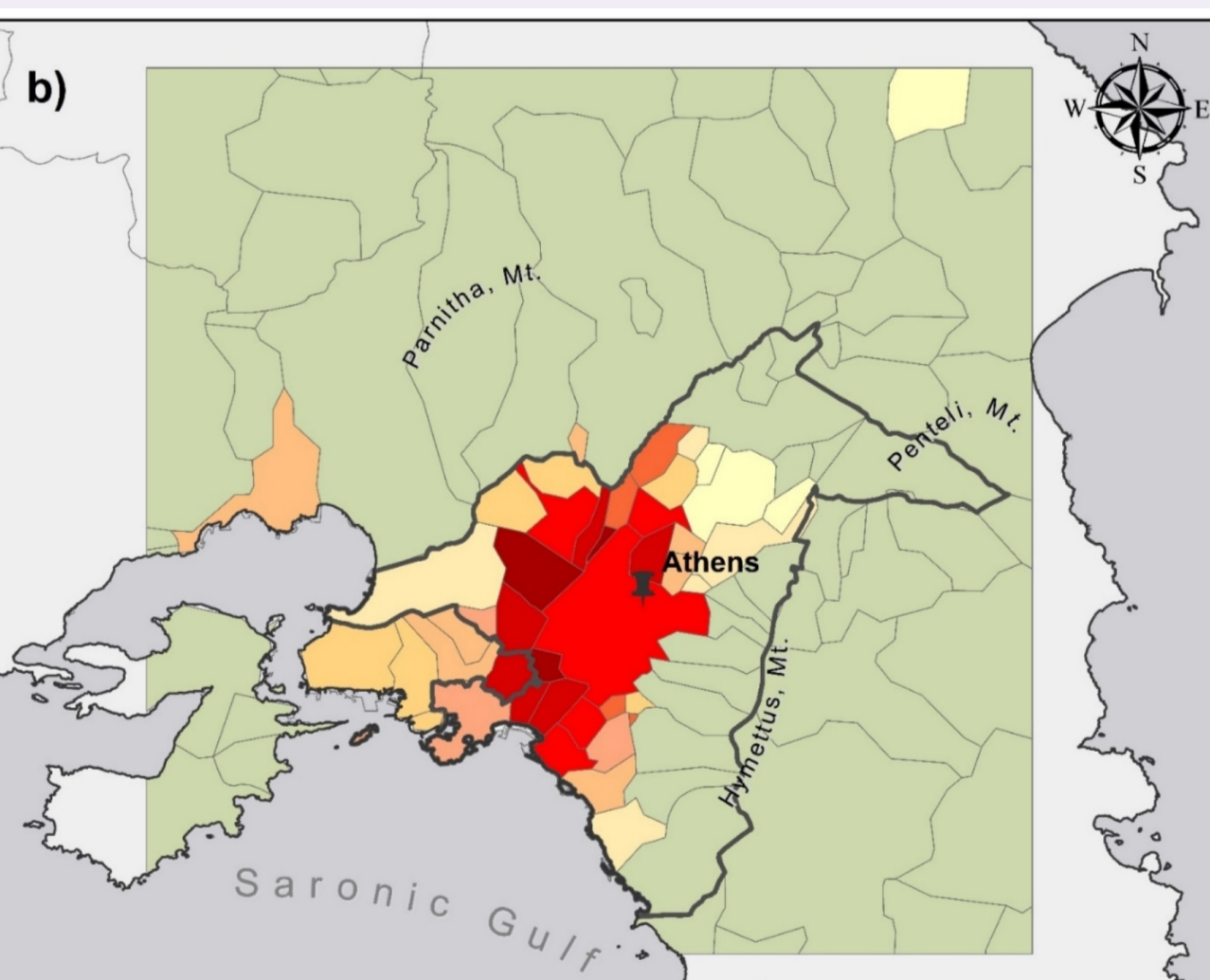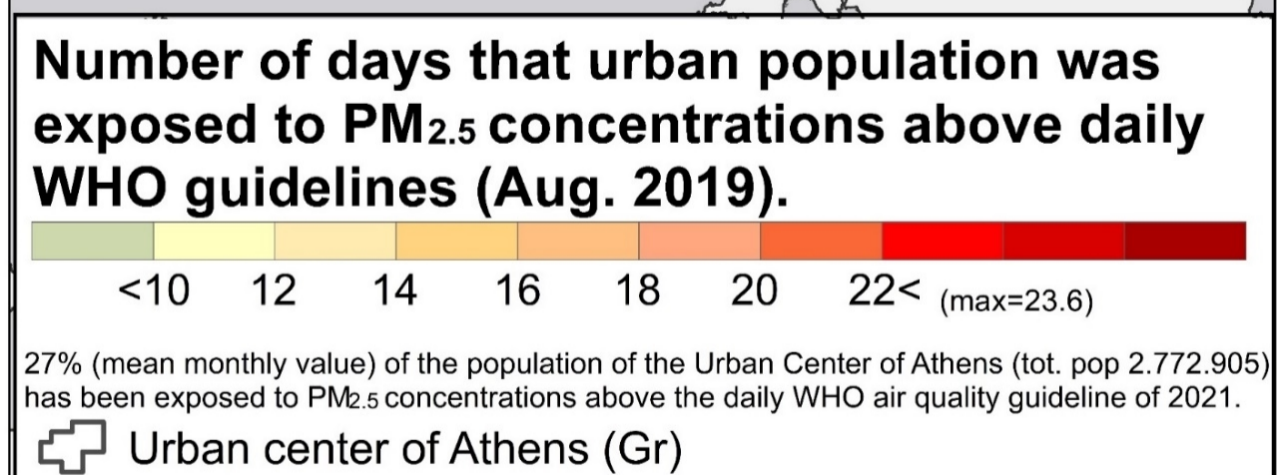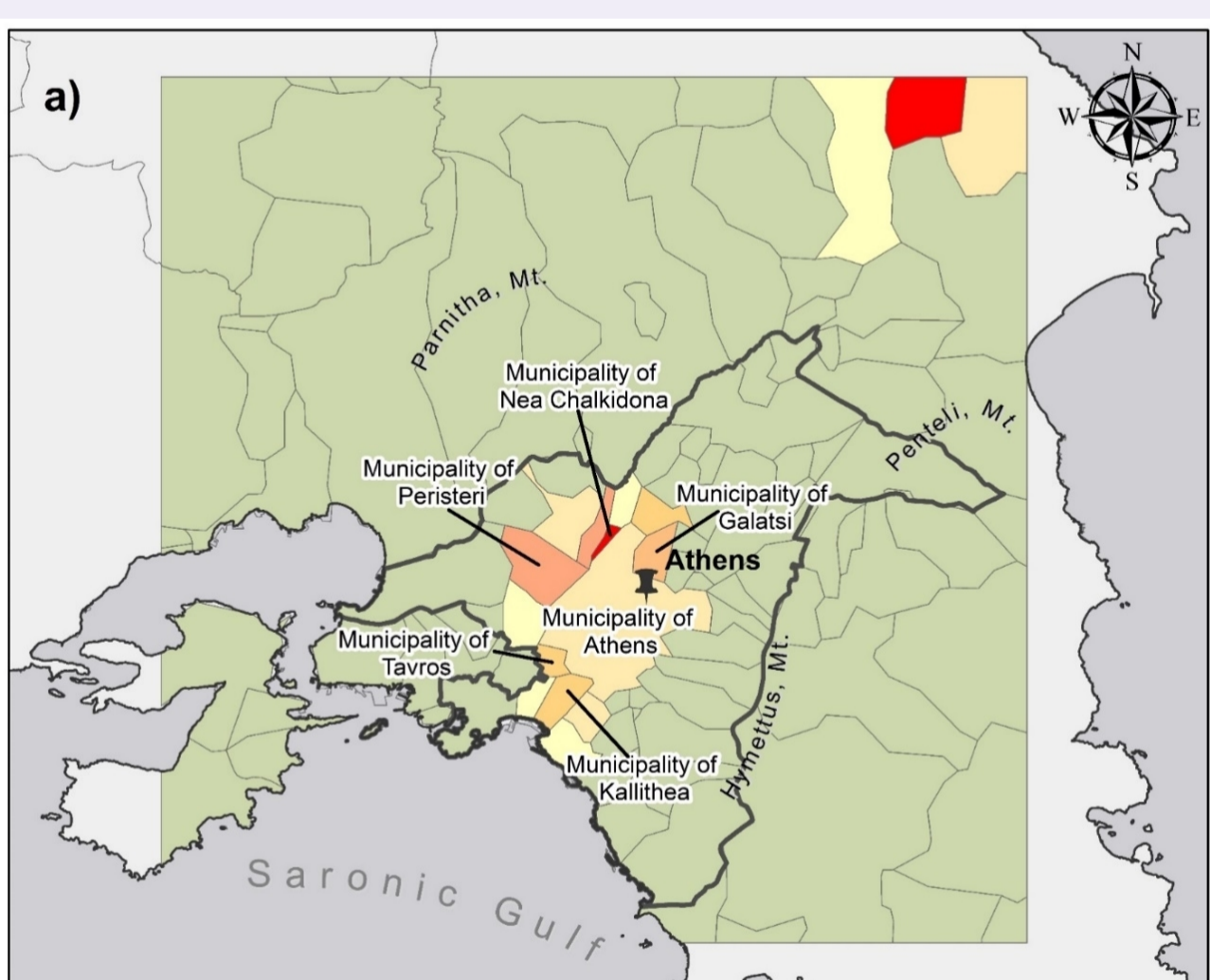○ In situ observations

Urban center of Athens (Gr)

2019 municipality ranking Athens, Greece
Average annual PM2.5 concentration (μg m⁻³) for municipalities in descending order

Rank	Municipality	PM2.5
22	Peristeri	25.9
26	Ilion	23.5
4	Galatsi	23.2
17	Nea Ionia	21.9
2	Athens (ARI & GYZ)	21.4 (16.2)
25	Aigaleo	21.3
9	Filadelfeia-Chalkidona	21.2
29	Kallithea	20.1
34	Agioi Anargyroi-Kamatero	19.8
34	Moschato-Tavros	19.3
16	Metamorfosi	19.3
35	Nea Smyrni	18.2
37	Acharnes (THR)	17.5 (13.1)
54	Piraeus (PIR & ZEA)	17.4 (16.0)
36	Palaio Faliro	17.3
27	Petroupoli	17.3
57	Nikaia-Agios Ioannis Rentis	16.7
50	Aspropyrgos	16.5
49	Elefsina (ELE)	16.3 (18.5)
33	Haidari (HAI)	15.7 (12.7)
23	Agia Varvara	15.5
3	Irakleio	15.4
56	Korydallos	15.9
8	Agios Dimitrios	14.9
31	Alimos	14.5
55	Keratsini-Drapetsona (KER)	14.5 (12.6)
51	Mandra-Eidyllia	14.3
58	Perama	13.9
20	Filothei-Psychiko	13.4
10	Marousi	12.9
5	Dafni-Ymittos	12.8
21	Chalandri (HAL)	12.6 (14.0)
3	Fyli	11.6
11	Agia Paraskevi (AGP)	11.1 (11.9)
46	Saronikos	11.0
15	Lykovrysi-Pefki (LYK & PEF)	10.9 (14.4)
53	Elliniko-Argyroupoli	10.5
42	Markopoulo Mesogaias	10.4
59	Salamis Island	10.1
12	Vrilissia	10.0
48	Oropos	9.9
5	Ilioupoli	9.9
52	Megara	9.6
41	Marathon	9.6
1	Tanagra	9.0
14	Kifisia	8.9
32	Glyfada	8.9
43	Pallini	8.8
43	Paiania	8.8
3	Vyronas	8.7
40	Kropia	8.3
47	Spata-Artemida	8.2
13	Vari-Voula-Vouliagmeni	7.8
18	Papagou-Cholargos	7.3
6	Zografou	6.9
7	Kaisariani	6.8
39	Dionysos	6.7
35	Rafina-Pikermi	6.5
19	Penteli (MEL)	6.1 (11.4)

21 (36%)

17 (29%)

20 (34%)

Athens city center

In situ air monitoring stations:
- Urban Background ● Suburban Background
- Urban traffic ● Urban Industrial
- Local Administrative Units (LAU) of Athens (GR)
- Urban center of Athens (Gr)

2021 World Air Quality Report visualization framework

Annual PM2.5 breakpoints based on 2021 WHO guideline and interim targets	PM2.5 (μg/m³)	Color code	WHO levels
Meets WHO PM2.5 guideline	0 – 5	Blue	Air Quality guideline
Exceeds WHO PM2.5 guideline by 1 times	5.1 – 10	Green	Interim target 4
Exceeds WHO PM2.5 guideline by 2 times	10.1 – 15	Yellow	Interim target 3
Exceeds WHO PM2.5 guideline by 3 to 5 times	15.1 – 25	Orange	Interim target 2
Exceeds WHO PM2.5 guideline by 5 to 7 times	25.1 – 35	Red	Interim target 1
Exceeds WHO PM2.5 guideline by 7 to 10 times	35.1 – 50	Purple	Exceeds target levels
Exceeds WHO PM2.5 guideline by over 10 times	>50	Maroon	Exceeds target levels

More information about the calculation of the UN SDG Indicator 11.6.2 can be found in the GIS platform shown below. The platform provides the indicator for each municipality of Greece, utilizing the CAMS Regional Air Quality Ensemble Reanalysis validated dataset (0.1° x 0.1°)

SDG 11.6.2 Annual Mean Levels of Fine Particulate Matter (PM2.5) in Greece - Municipal level

Enter SDG

Urban population exposure to PM2.5

Number of days that urban population was exposed to PM2.5 concentrations above daily WHO guidelines (Aug. 2019).

<10 12 14 22< (max=23.6)

27% (mean monthly value) of the population of the Urban Center of Athens (tot. pop 2.772.905) has been exposed to PM2.5 concentrations above the daily WHO air quality guideline of 2021.

Urban center of Athens (Gr)

Number of days that urban population was exposed to PM2.5 concentrations above daily WHO guidelines (Dec. 2019).

<10 12 14 26< (max=28.3)

59% (mean monthly value) of the population of the Urban Center of Athens (tot. pop 2.772.905) has been exposed to PM2.5 concentrations above the daily WHO air quality guideline of 2021.

Urban center of Athens (Gr)

Summary

This is a report of an overview of PM2.5 air quality data for Athens (Gr), 2019, based on high-resolution atmospheric numerical predictions. A thorough comparison with observations shows a slight underestimation by the simulations (MB: -3 μg m⁻³, r= 0.3). The PM2.5 data presented here is reported in units of micrograms per cubic meter (μg m⁻³), are spatially aggregated at the municipal level and utilizes the latest World Health Organization (WHO) annual PM2.5 air quality guideline and interim targets as a framework for data visualization.

The Attica region is represented by 66 municipalities, 58 of which are included in the selected domain. The annual mean PM2.5 value averaged for the urban center of Athens is 15 μg m⁻³, which falls by 25% over the rest of the domain. The municipality of Athens is the most populated (697,480 residents), but is predicted to have better air quality (SDG indicator 11.6.2), than the adjacent municipalities on the West (Peristeri and Ilon) and Northeast (Galatsi and Nea Ionia).

The spatial aggregation of the high-resolution predictions at the municipal level reveals an SDG Indicator 11.6.2 (2019) ranging from 6.1 μg m⁻³ in Penteli (ranked at 59) to 25.9 μg m⁻³ in Peristeri (ranked at 1). In 2019 -the most recent year free of anthropogenic activity restrictions- the newly recommended 5 μg/m³ WHO PM2.5 annual air quality guideline is exceeded in all observational sites and estimations at the municipal level. In particular, most of the municipalities (37, 63%) included in the Attica region, exceeds this guideline by 1 to 3 times, the rest (22) and around 37% of the total municipalities exceeds the WHO guideline by over 3 times. Almost half of the municipalities in the urban center of Athens currently reaches the Interim target 2 (Athens basin and Piraeus), the rest half equally divided in municipalities reaching interim targets 3 and 4.

For the calculation of the population exposed to air quality above the latest daily WHO limit for PM2.5 (15 μg m⁻³), the months of August and December were chosen as least and the most polluted months of 2019, respectively. The combined calculations of population (GHSL, 2015, to be replaced with the newly published GHSL, 2022) and exposure to PM2.5 (current predictions) As calculated for the urban center during the reference year of 2019, the amount of population that is subjected to harmful levels of PM2.5 on a daily basis is 750.000 in August (~ 25% of 2.800.000), but raises up to 1.700.000 (~ 60% of 2.800.000). The residents of the central municipality of Athens, although highly impacted (up to 23 days per month, while WHO regards safe the exposure by up to 4 days yearly), are less affected than those living in several adjacent municipalities in the west.