Friday 18th

Topic 6: Use of modelling in health and exposure assessments

Madrid's Plan A Health Impact Assessment

H20-025

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OUTLINE

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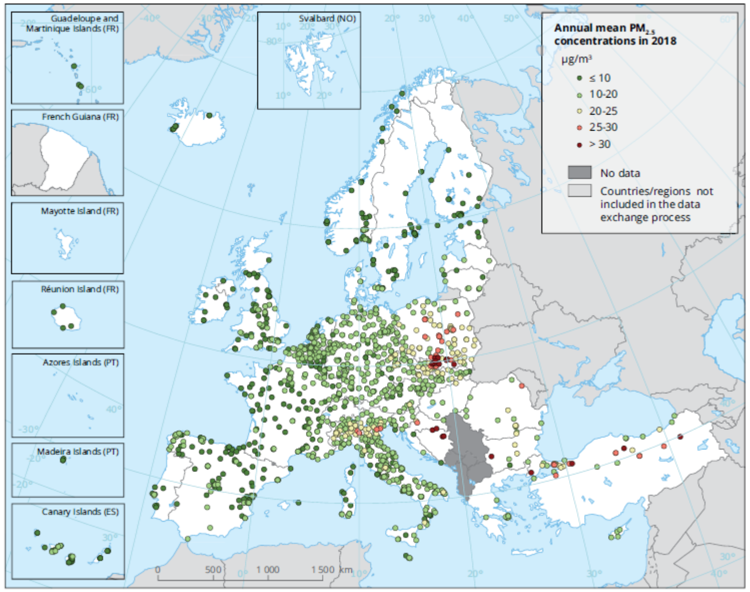
   - Madrid's Plan A
2. Methodology
   - General approach
   - Air quality modelling system and scenarios
   - Concentration-Response Functions (CRF), population and mortality
3. Results
   - Health impact assessment
4. Conclusions and further work

1. INTRODUCTION

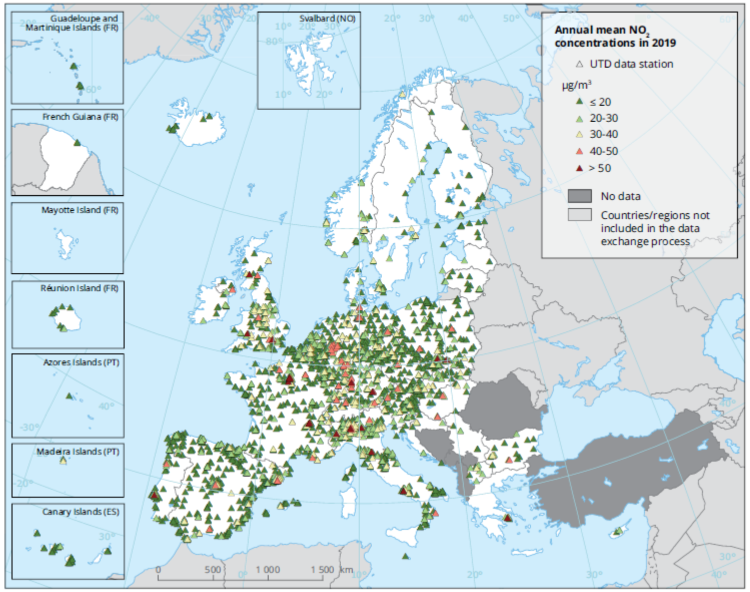
Air pollution: a long-standing health concern

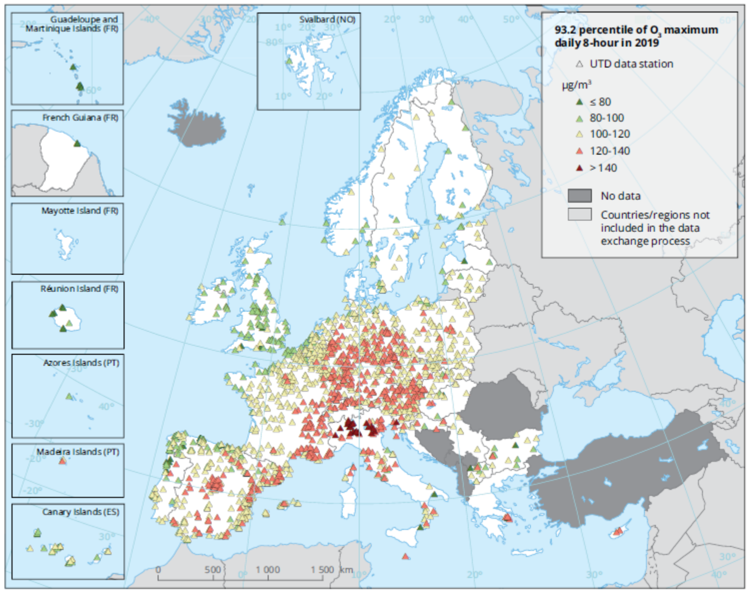
- Significant abatement efforts and positive air quality trends (for most pollutants) in Europe
- Still over 500,000 premature deaths attributable to $PM_{2.5}$, NO_2 and O_3 exposure



$PM_{2.5}$

NO_2





O_3

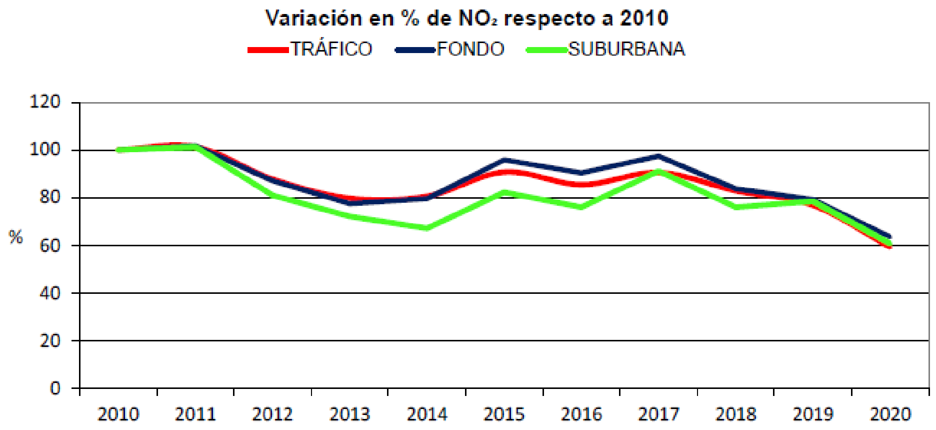
EEA, 2020

- Further need to design and implement urban air quality plans such as the Air Quality and Climate Change Plan for the city of Madrid (Plan A)

- Approved in 2017, horizon 2020 (AQ) and 2030 (GHG)

- Objectives:

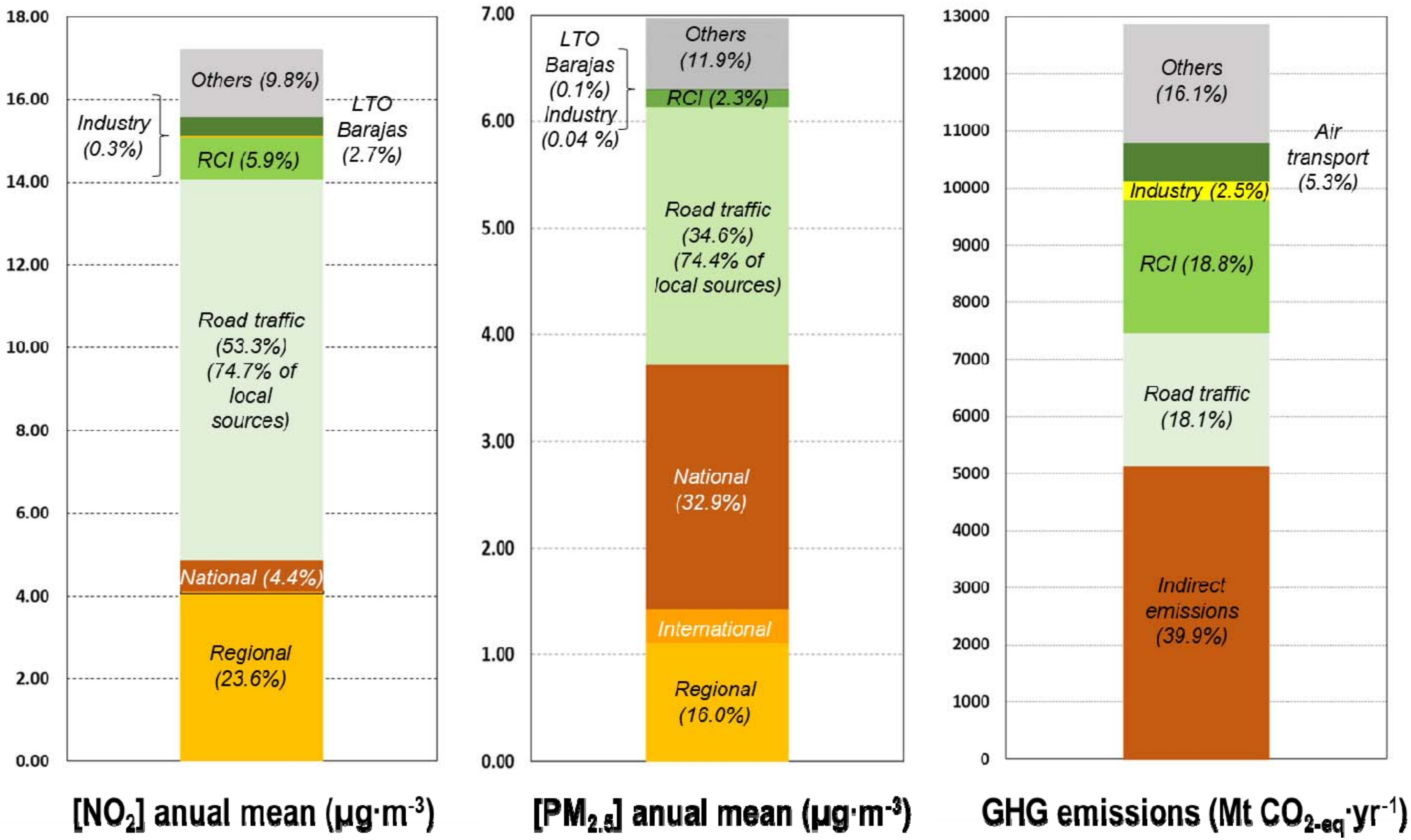
- Meet AQD air quality standards (including NO_2)



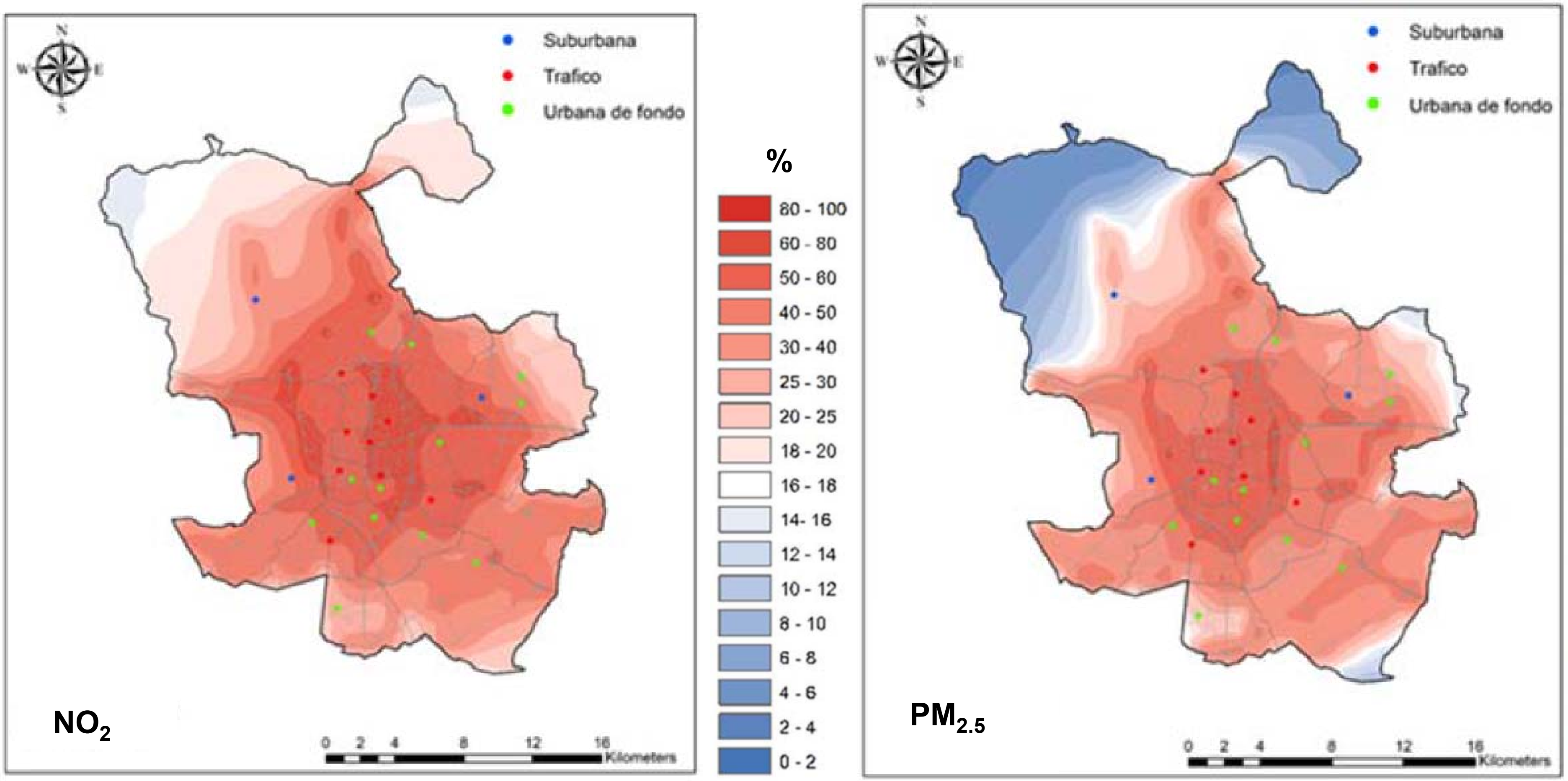
Madrid City Council (MCC), 2021

- Meet WHO guidelines for PM
- 40% reduction in total GHG emissions relative to 1990
- 50% reduction in GHG emissions caused by urban mobility relative to 2012
- reduce climatic vulnerability and risks

- Most of the 30 measures are related to sustainable mobility, since road traffic is the main contributor to PM, but mostly NO_2 ambient concentration levels:



- Contribution of local road traffic (SNAP 07) to annual average concentration in the Madrid municipality



- Measures in the sustainable mobility area expected to reduce NO_X emissions from road traffic by 40% (consistently with the local inventory methodology)

Variation of emissions of the main substances relevant to air quality due to Plan A (absolute)

Variation of emissions in 2020 with respect to base year (t/year); negative values mean a reduction						
CO	NMVOC	NH3	NOX	PM10	**PM2.5**	**SO_2**
-3972.8	-1688.2	-26.3	-3011.3	-223.0	**-221.6**	**-426.0**

Variation of emissions of the main substances relevant to air quality due to Plan A (relative)

Variation of emissions in 2020 from the base year (%); negative values mean a reduction						
CO	**NMVOC**	**NH_3**	**NO_X**	**PM10**	**PM2.5**	**SO_2**
-31.5	**-7.4**	**-2.6**	**-19.5**	**-22.7**	**-27.1**	**-42.8**

2. METHODOLOGY

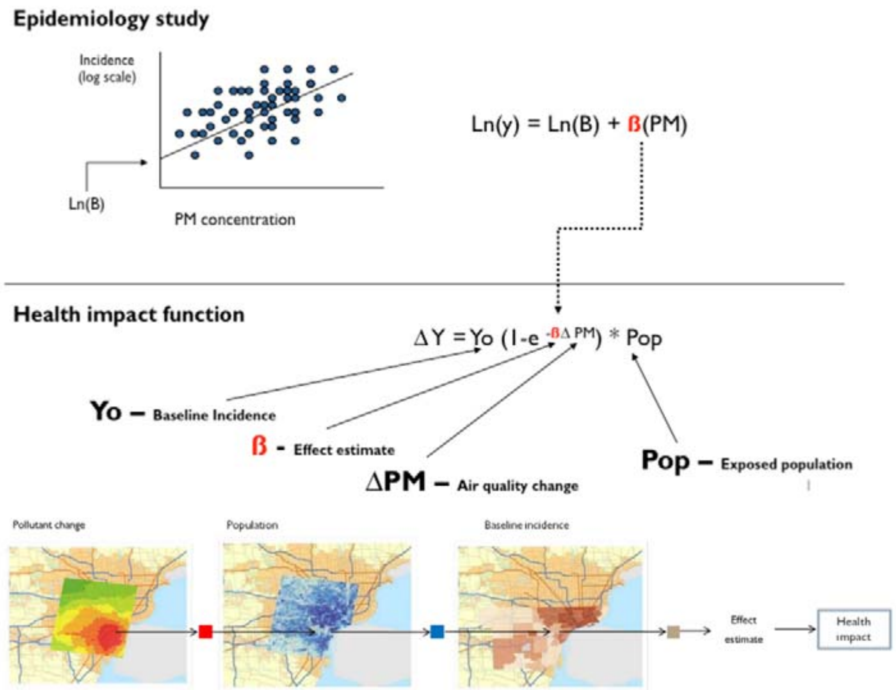
General approach

- Standardized HIA methods based on mortality relative risks and concentration changes from 2012 (reference scenario) and 2020 (Plan A temporal horizon)

$$\Delta Y = Y_0 \left(1 - e^{-\beta \Delta x}\right) P$$

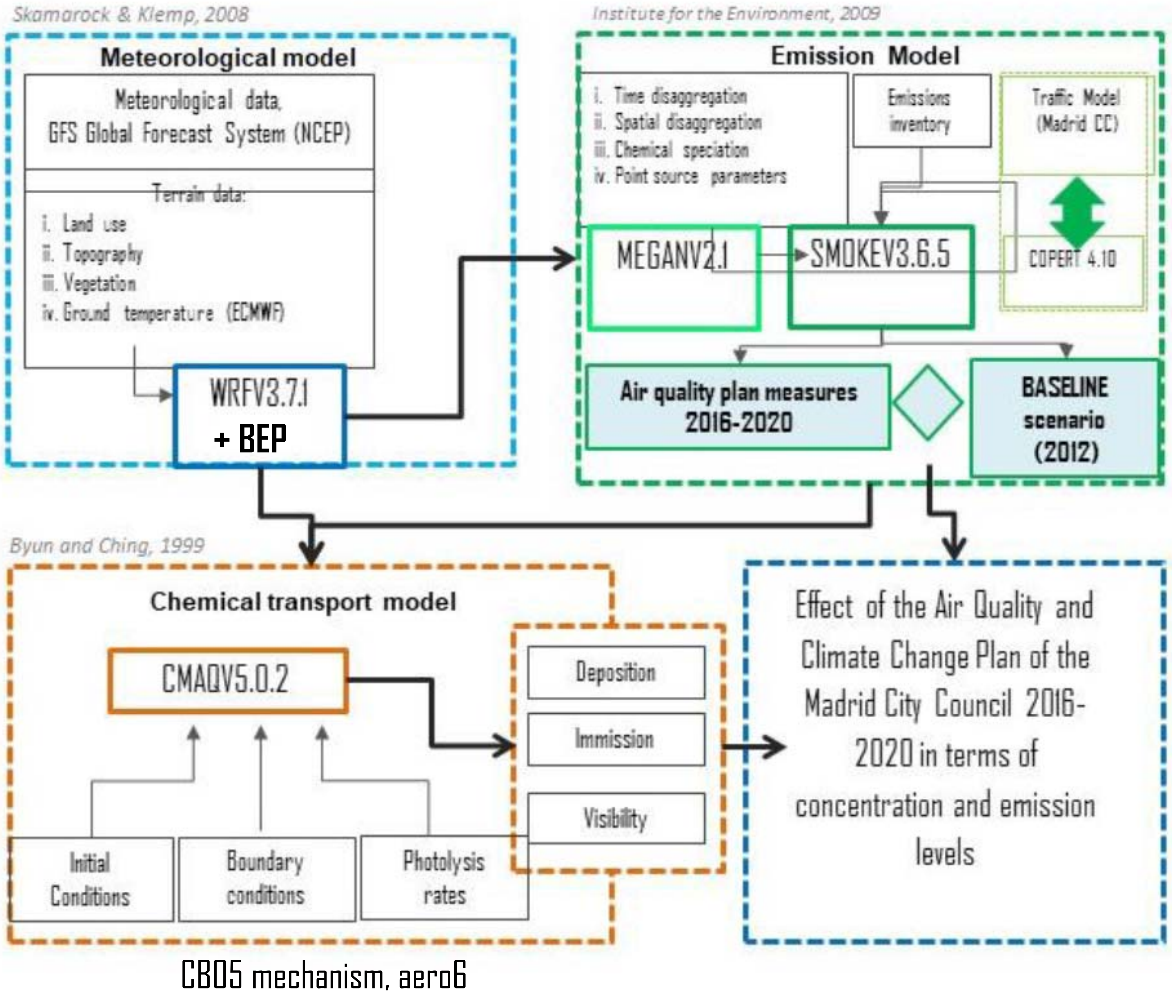
Where:

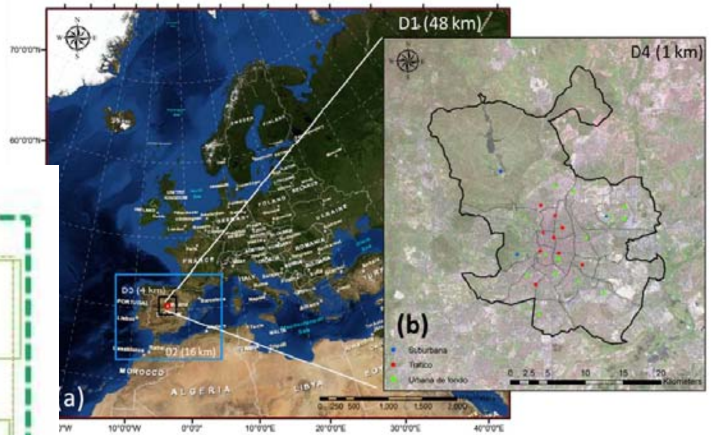
- ΔY is the change in the mortality between a future scenario and the current situation (refernce scenario), 2020 and 2012, respectively
- Y_0 is the mortality rate at the reference scenario (for each specific health endpoint and age group according to applied concentration-response functions, CRF)
- β is the coefficient of the CRF for an increase in air pollution concentrations of 1 μg m^{-3}
- Δx is the change in the pollutant concentration between the baseline (2012) and projected scenario (2020) (μg m^{-3})
- P is the projected population for year 2020.



USEPA, 2015

Air quality modelling system and scenarios



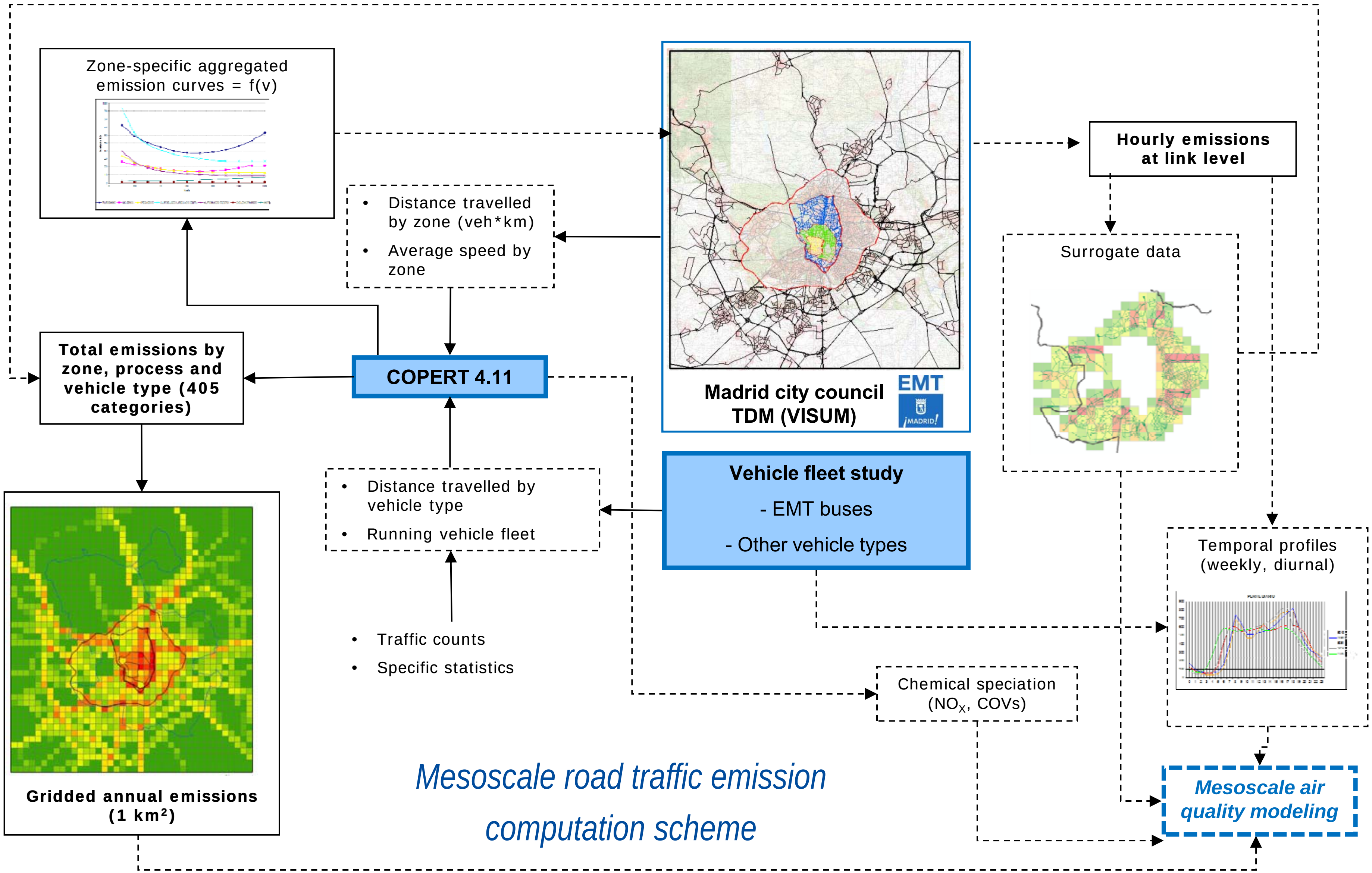


- Four nested domains up to 1 km^2 resolution, 38 vertical levels
- Two annual model runs (baseline and future): identical except for local emissions

Plan A effect by comparison (future-baseline)

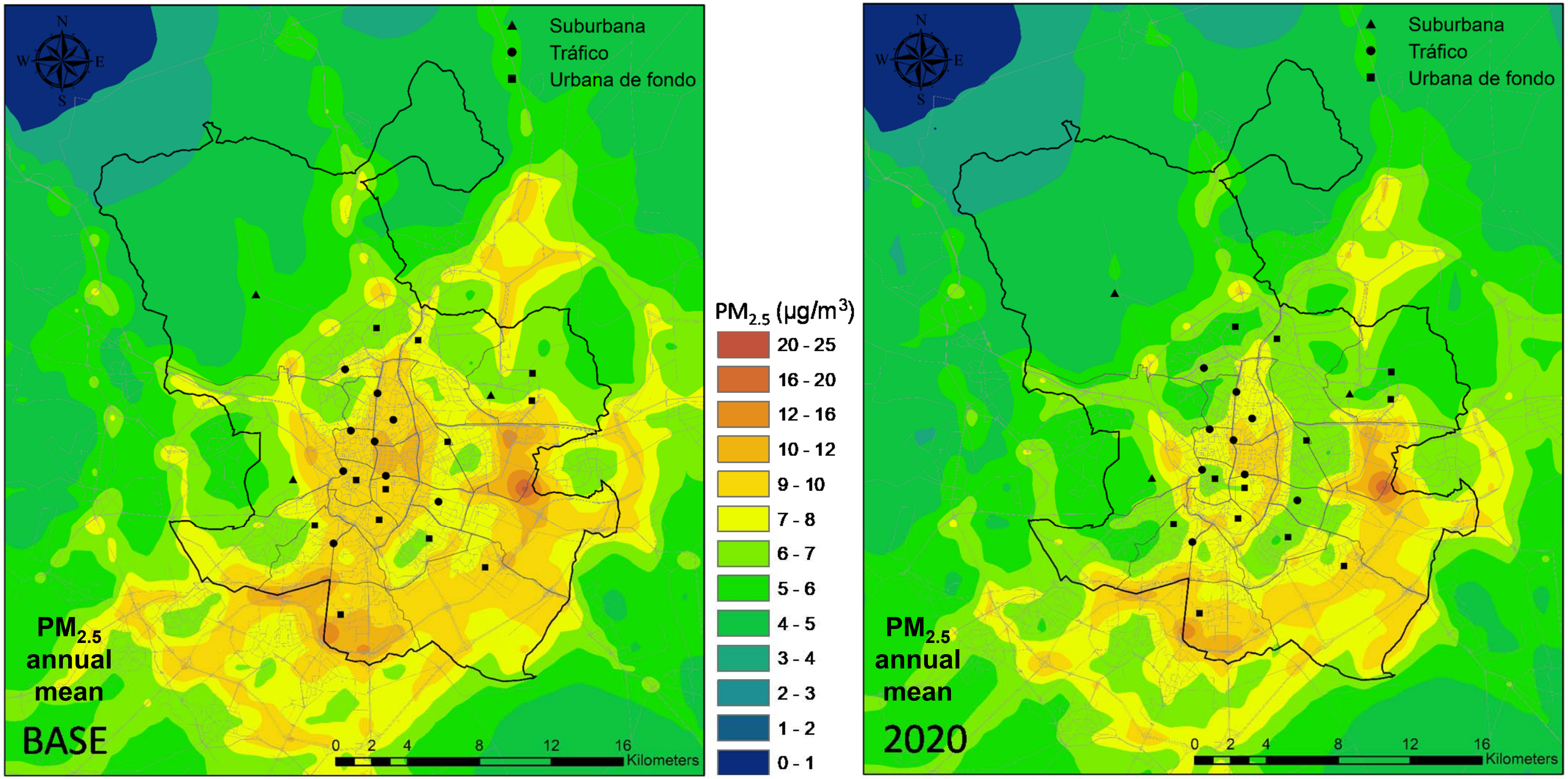
- Very detailed traffic modelling system and emission computation

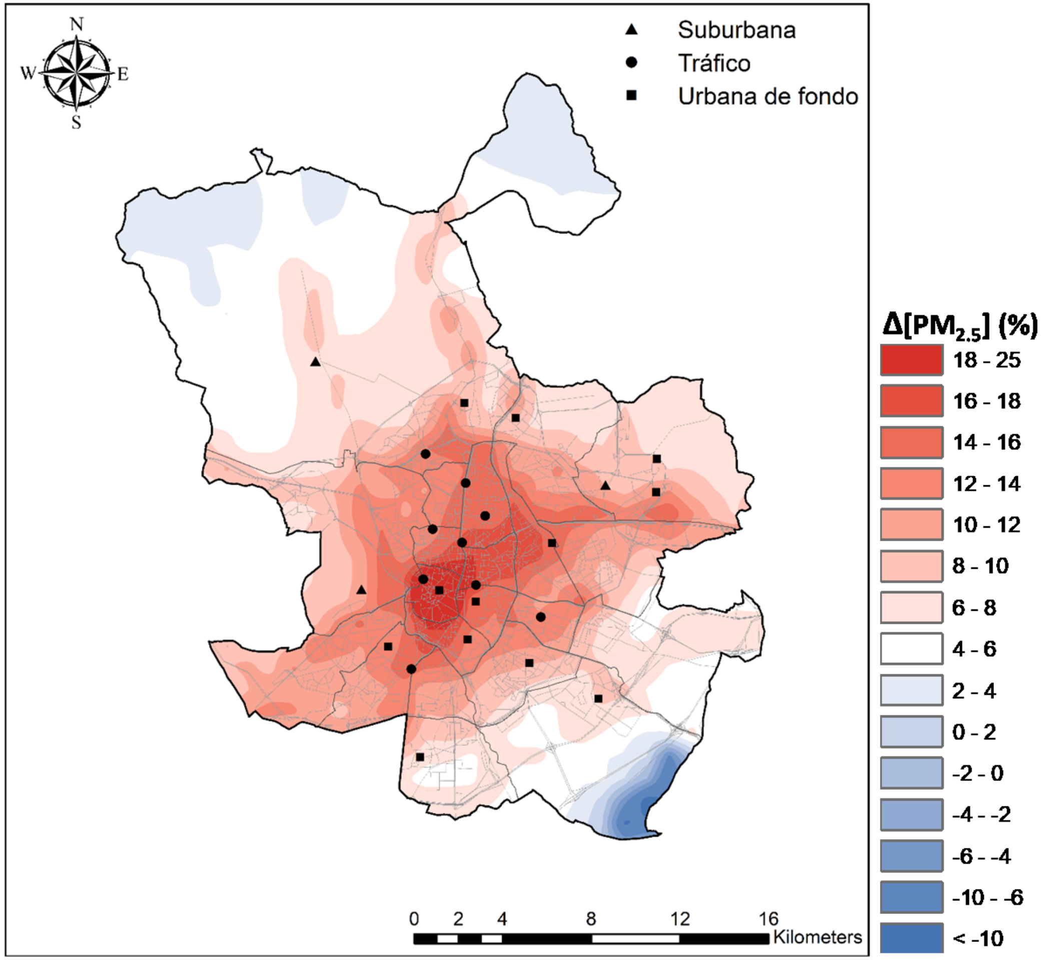
Borge et al., 2018



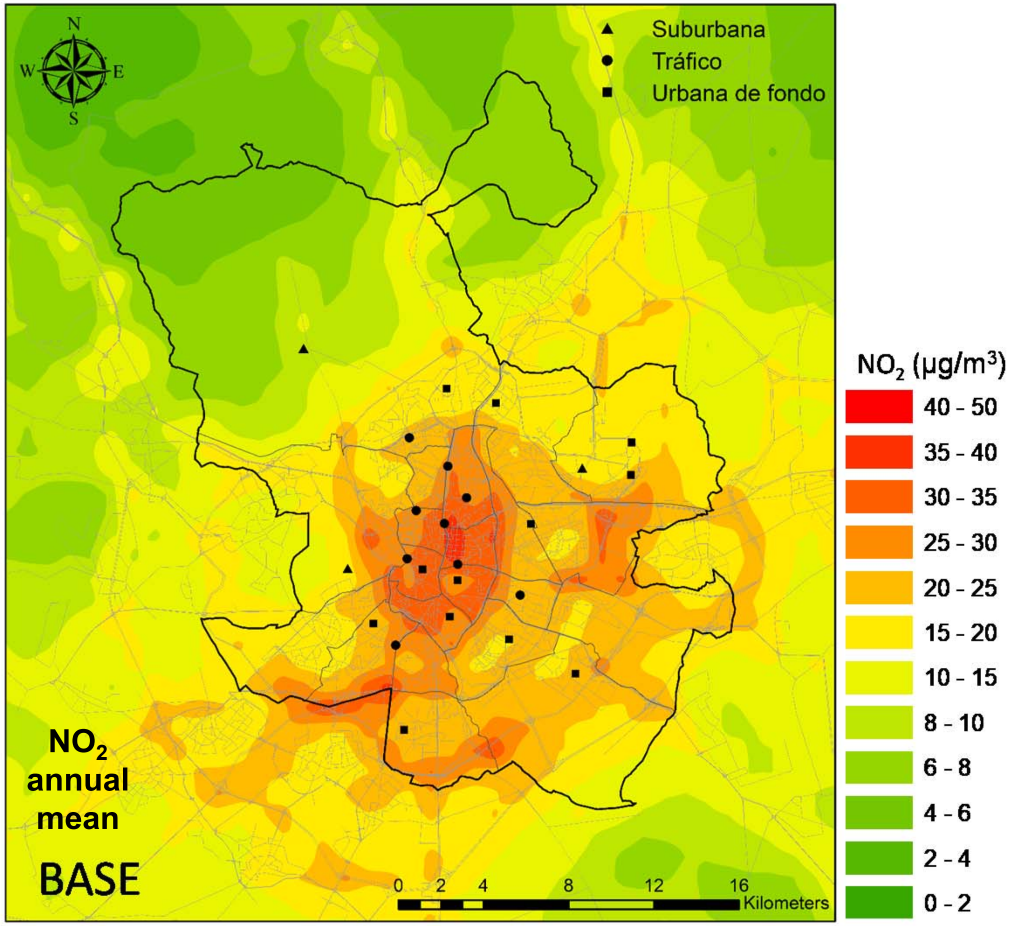
Mesoscale road traffic emission computation scheme

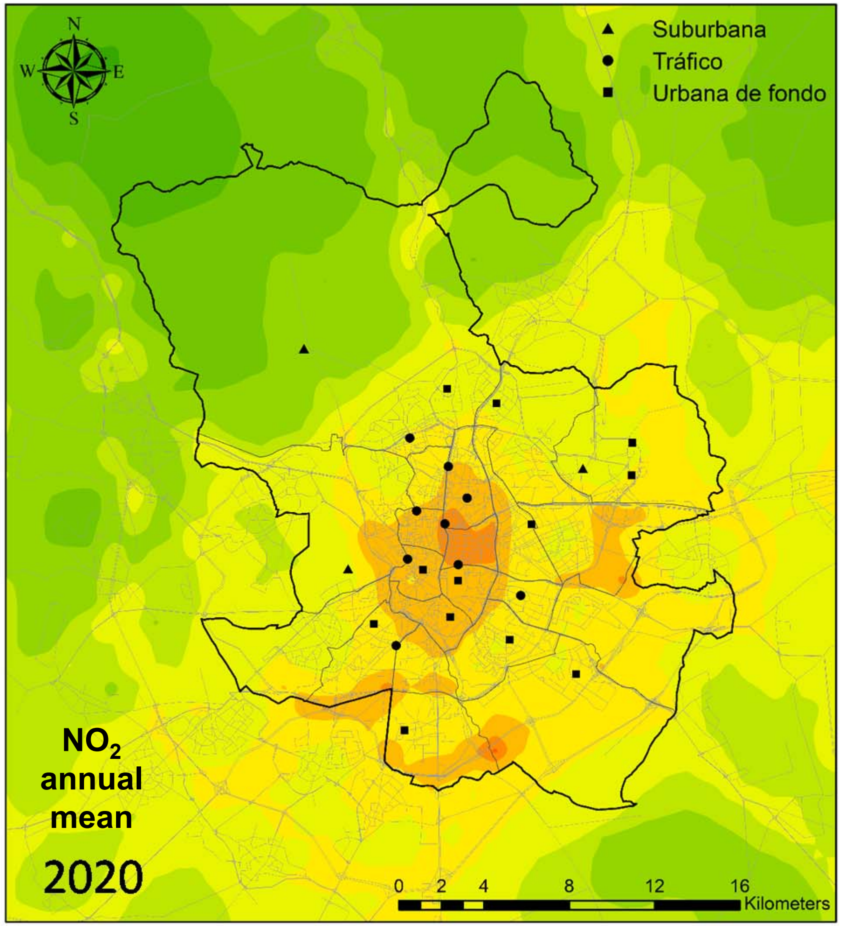
Δx: pollutant concentration change between the baseline (2012) and projected scenario (2020)





- $PM_{2.5}$ annual mean expected to improve more than 2 μg·m^{-3} in Madrid downtown
- Urban background levels reduced by 13%; higher in heavily trafficked areas


Suburbana
Tráfico
Urbana de fondo
N
S
W
E
NO_2
annual
mean
BASE
0 2 4 8 12 16
Kilometers
NO_2 (µg/m^3)
40 - 50
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2


Suburbana
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N
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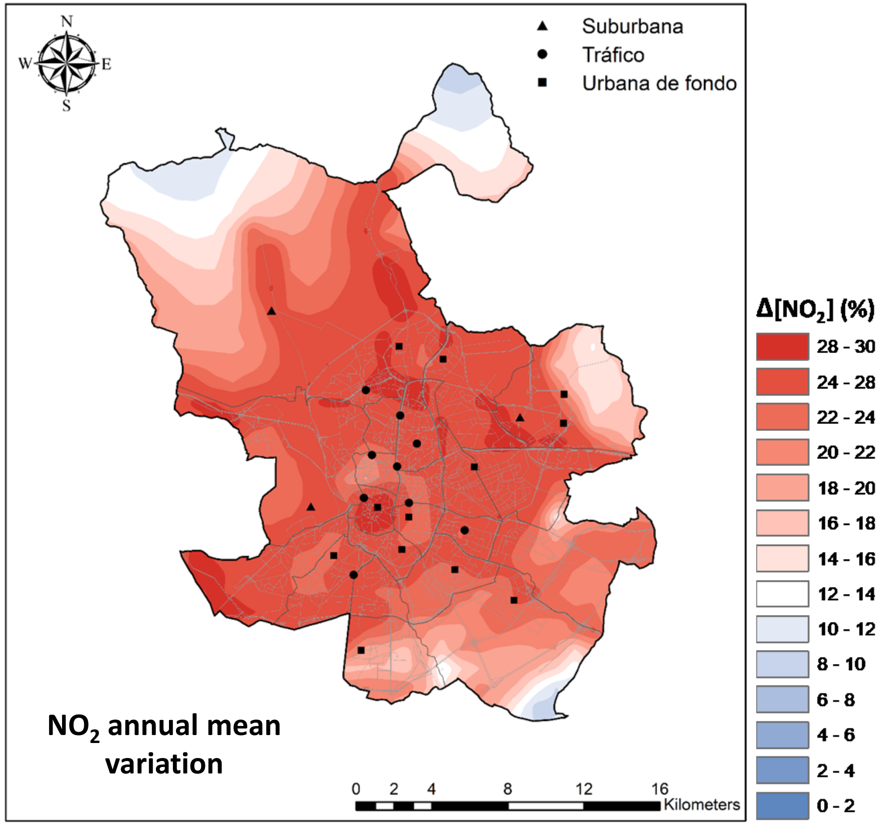
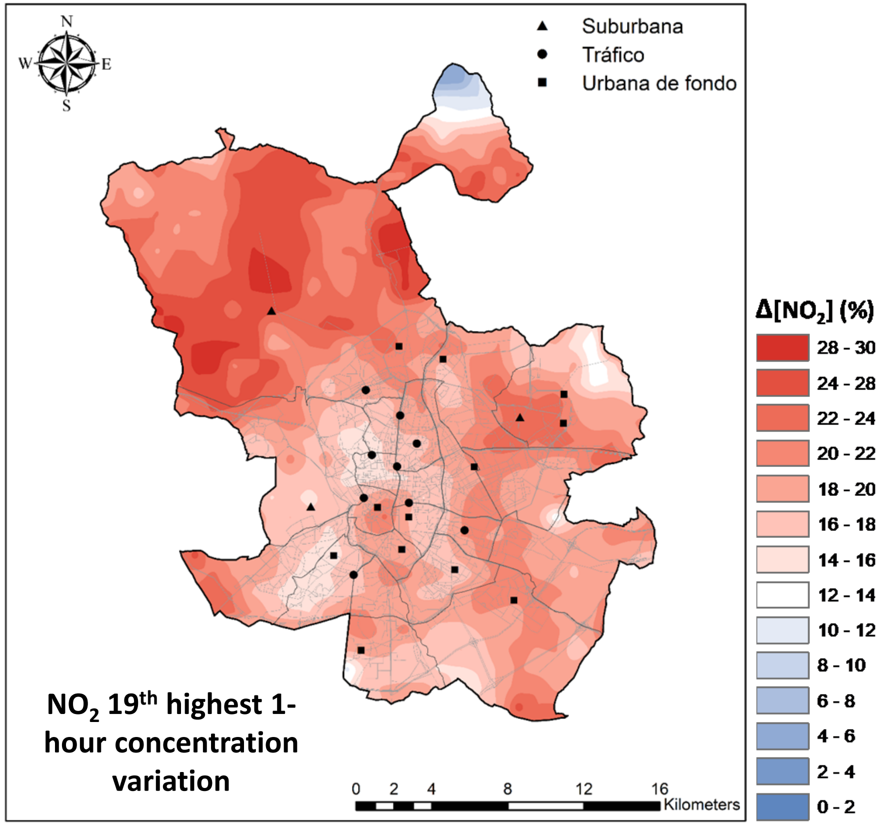
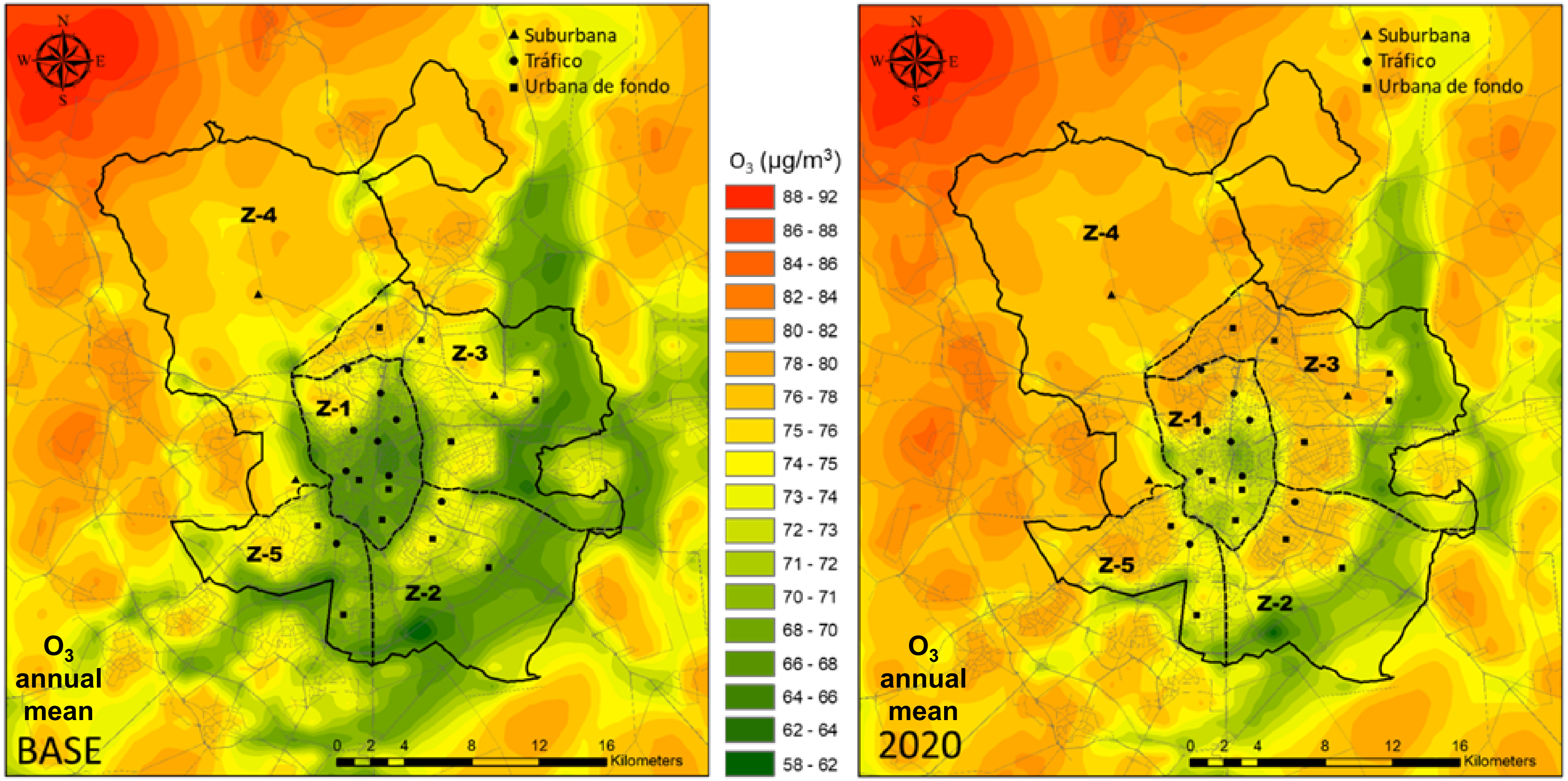
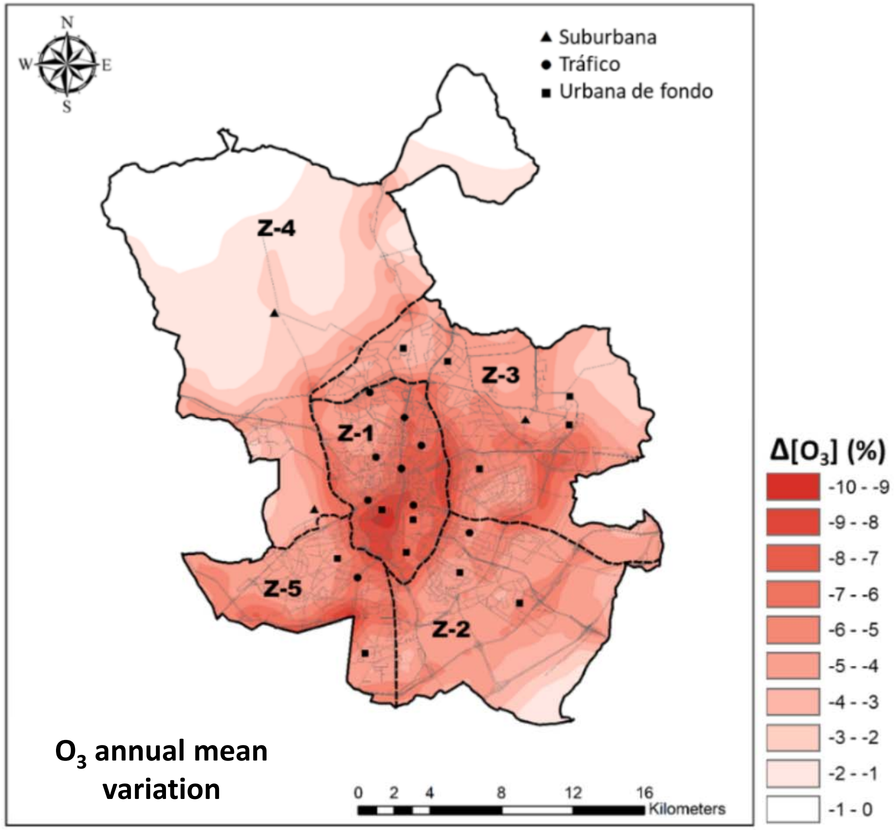
NO_2
annual
mean
2020
0 2 4 8 12 16
Kilometers

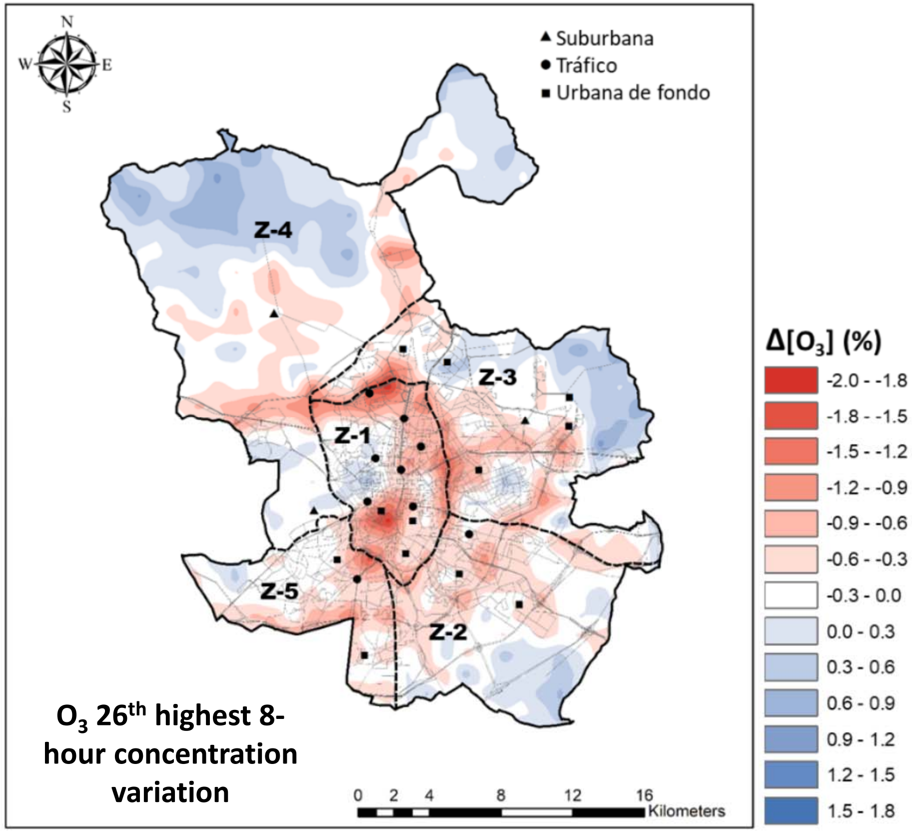




- NO_2 annual mean expected to improve more than 10 $\mu g \cdot m^{-3}$ in Madrid downtown
- Urban background levels reduced by 25%; higher in heavily trafficked areas
- NO_2 peaks reduced up to 30 $\mu g \cdot m^{-3}$

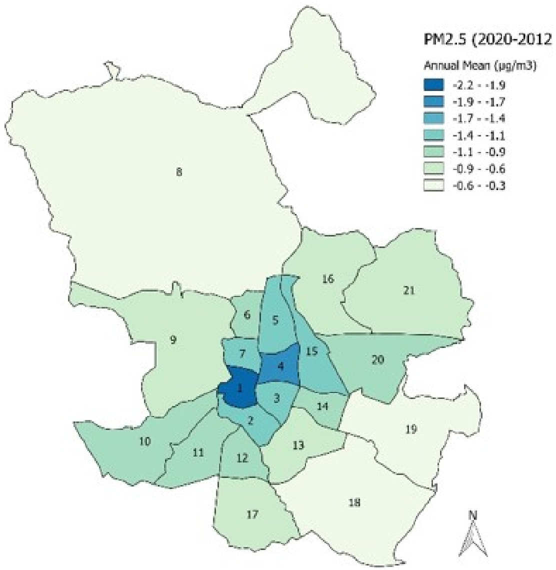

Suburbana
Tráfico
Urbana de fondo
Z-1
Z-2
Z-3
Z-4
Z-5
O3 annual mean
BASE
2020
0 2 4 8 12 16 Kilometers
O3 (µg/m3)
88 - 92
86 - 88
84 - 86
82 - 84
80 - 82
78 - 80
76 - 78
75 - 76
74 - 75
73 - 74
72 - 73
71 - 72
70 - 71
68 - 70
66 - 68
64 - 66
62 - 64
58 - 62

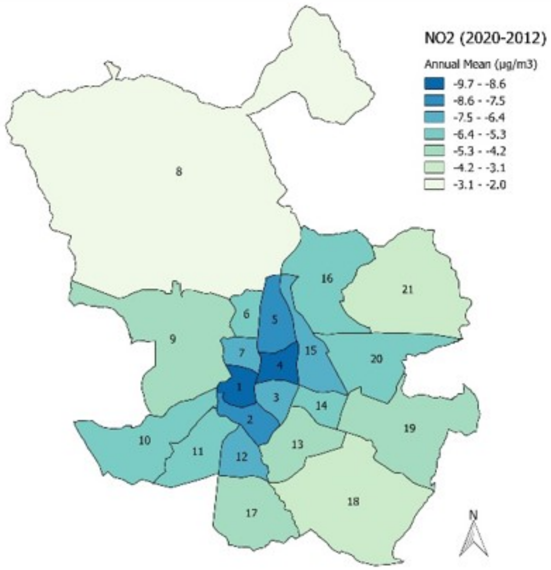


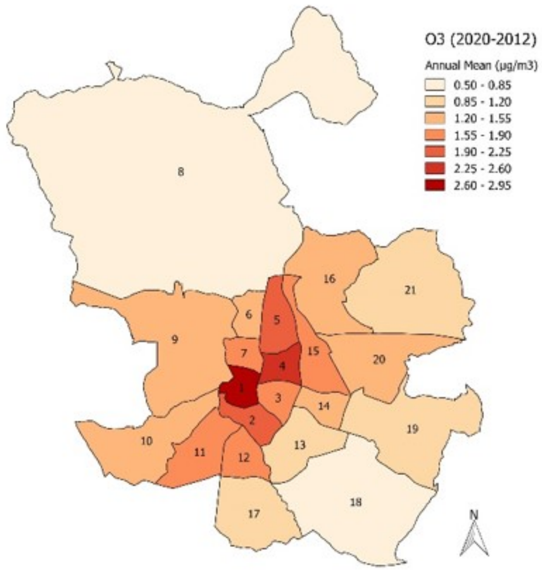


- O_3 annual mean expected to increase around 3 µg·m^{-3} in Madrid downtown
- Urban background levels increased by 5%; up to 10% in the city centre
- Negligible effect on 8-hour daily maxima (increments around 0.4%)

- Variations of relevant metrics (those of C-R functions) averaged at district level (using grid centroids)







- Concentration changes averaged over the whole Madrid municipality:

$PM_{2.5}$ ~ - 0.6 µg m^{-3} NO_2 ~ - 4.0 µg m^{-3} O_3 ~ + 1.0 µg m^{-3}

Concentration-Response Functions (CRF), population and mortality

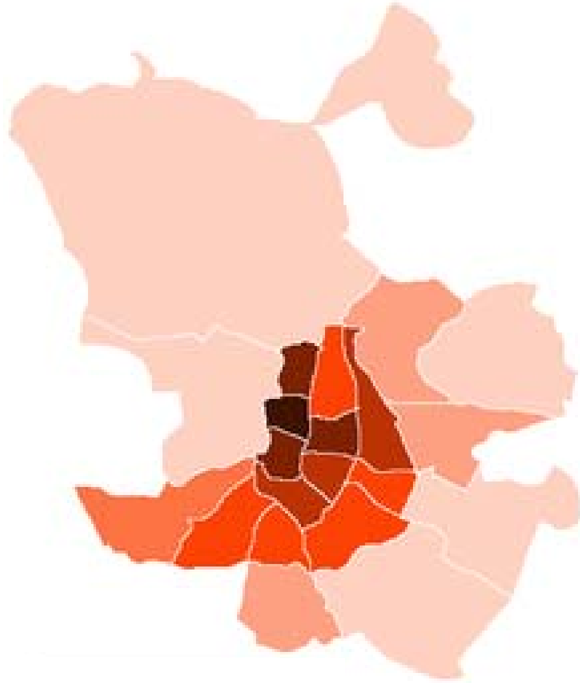
World Health Organization REGIONAL OFFICE FOR Europe

- Health risks of air pollution in Europe (HRAPIE)
- Review of evidence on health aspects of air pollution (REVIHAAP" (WHO)

Pollutant metric	Health endpoint (ICD-10 code)	Relative Risk (95% CI) per 10 µg m^{-3} increment	Reference
• $PM_{2.5}$ annual mean concentrations	All-cause (natural) mortality in adult populations (age > 30) (A00-R99)	**1.062** (1.040–1.083)	Hoek et al., 2013
• NO_2 annual mean concentrations		**1.055*** (1.031–1.080)	Atkinson et al., 2018; Hoek et al., 2013
• O_3 summer months' (April–September) average of daily maximum running 8-h means above a 70 µg m^{-3}	Respiratory mortality in adult populations (age >30) (J00-J99)	**1.014** (1.005–1.024)	Jerrett et al., 2009

* long-term NO_2 effects might overlap with effects of long-term $PM_{2.5}$ (up to 33%)

- Population data and projections for 2020 provided by the Department for Statistics of Madrid City Council according to the official census
- Baseline number of deaths (corresponding ICD-10 codes) diseases for 2012 were provided by the Madrid Regional Statistical Office
- Both at disctrict level (21)



Population for year 2012 and projected 2020-population at 1st January of year, and 2012-baseline mortality corresponding to all non-accidental causes (ICD-codes A00-R99), cardiovascular (ICD-10, codes I00–I99) and respiratory (ICD-10, codes I00–I99) diseases in city of Madrid. Mortality is showed in terms of number of absolute deaths and crude rates per 100000 population.

Age group	Sex	Population		2012-Mortality (deaths in absolute numbers)			2012-Mortality rate (deaths per 100000 population)		
		2012	2020	All-causes	Cardiovascular disease	Respiratory disease	All-causes	Cardiovascular disease	Respiratory disease
All-ages	Total	3247998	3226378	25463	6609	4096	784	203	126
	Man	1518016	1511750	12028	2600	1963	792	171	129
	Woman	1729982	1714628	13435	4009	2133	777	232	123
> 30 years	Total	2436499	2302112	25127	6600	4086	1031	271	168
	Man	1109549	1045399	11849	2596	1959	1068	234	177
	Woman	1326950	1256713	13278	4004	2127	1001	302	160

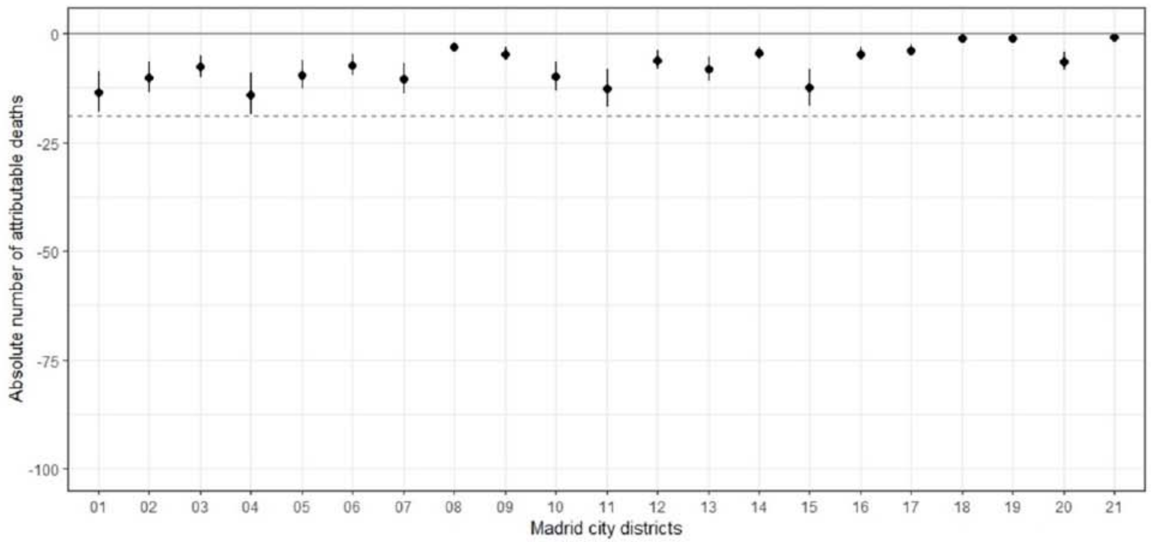
Izquierdo et al., 2020

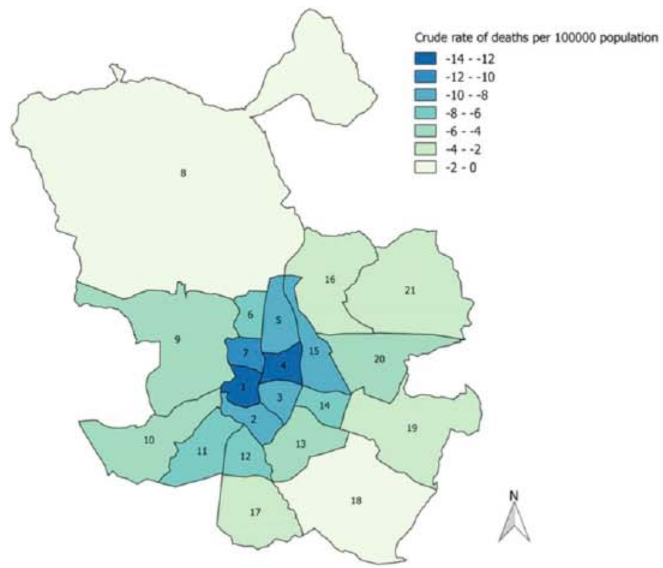
3. RESULTS

Health impact assessment

Sex	Deaths in absolute numbers (95% CI in brackets)
Total	**−88 (−57, −117)**
Men	−41 (−27, −55)
Women	−47 (−30, −62)

$PM_{2.5}$



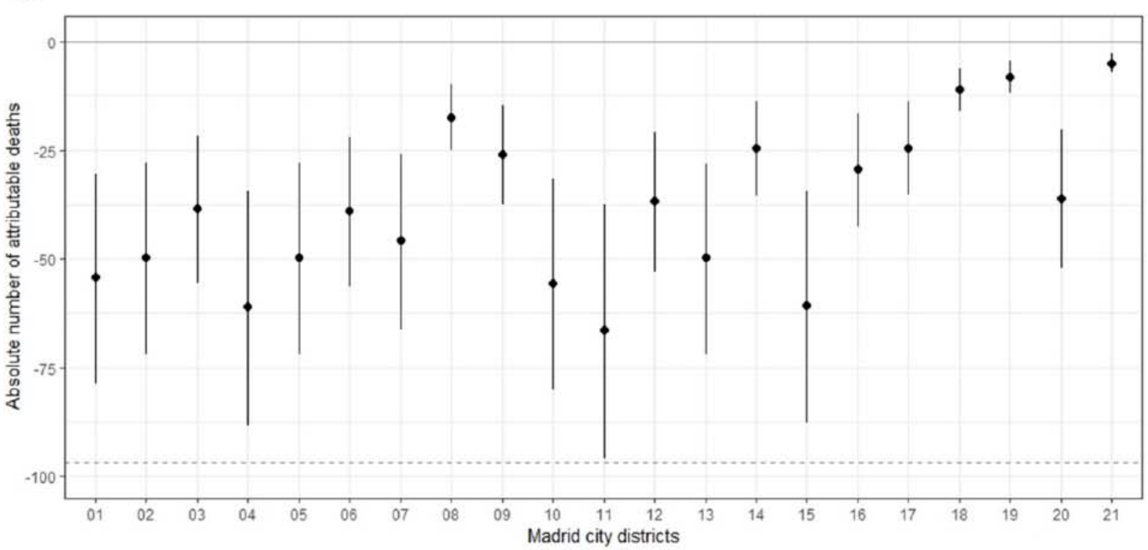


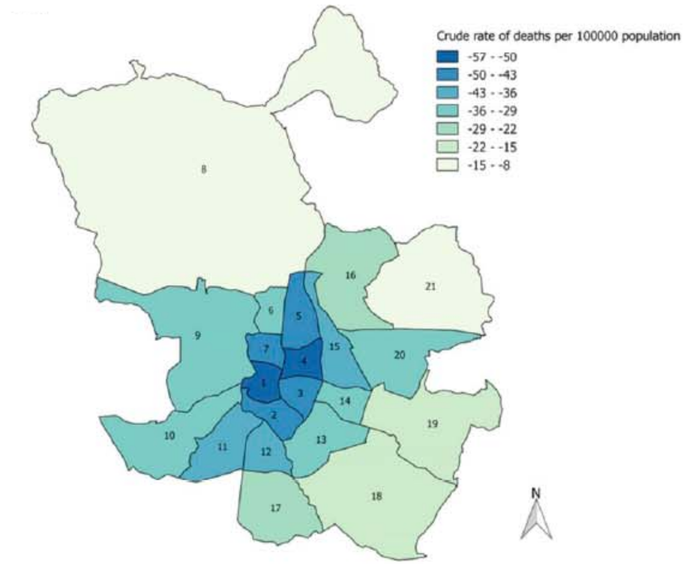
- 88 (57, 117) attributable deaths avoided
- Crude mortality rates reduced up to 14 (by 100,000 populations) in the city centre

Health impact assessment

Sex	Deaths in absolute numbers (95% CI in brackets)
Total	**−519 (−295, −750)**
Men	−244 (−139, −353)
Women	−275 (−156, −397)

NO_2



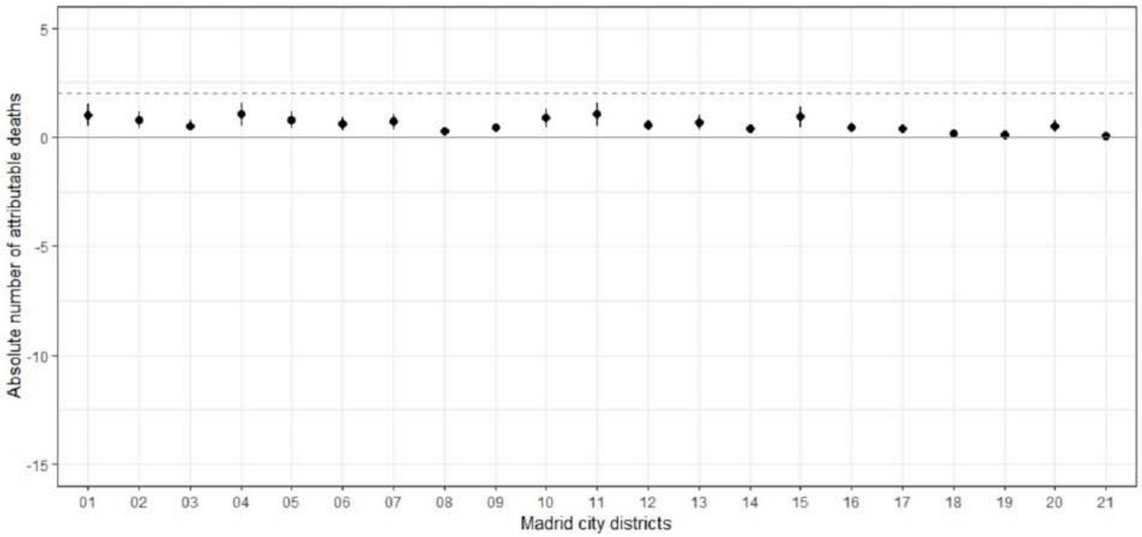


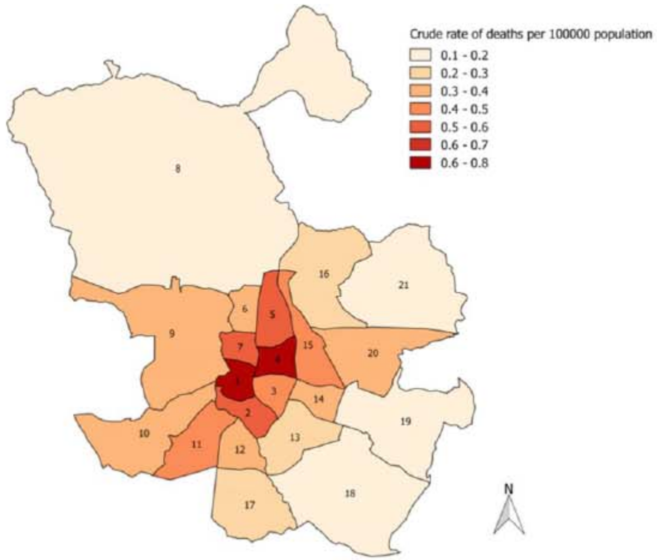
- 519 (295, 750) attributable deaths avoided
- Crude mortality rates reduced up to 57 (by 100,000 populations) in the city centre

Health impact assessment

Sex	Deaths in absolute numbers (95% CI in brackets)
Total	**0 (0, 0)**
Men	0 (0, 0)
Women	0 (0, 0)

O_3





- 0 (0, 0) attributable deaths avoided
- Crude mortality rates increases lower than 1 (by 100,000 populations)

4. CONCLUSIONS AND FURTHER WORK

- The effective implementation of Plan A in Madrid city would lead to better air quality and more than 500 all-cause premature deaths could be postponed annually
- Mostly related to the reduction of NO_2 levels due to emission abatements in the road traffic sector
- Positive effects concentrate in the city centre, targeted by many measures (e.g. LEZ)
- No significant effects due to O_3 increase

⬇

- Need to address health inequity in the review of Plan A to yield larger benefits all over the city
- Additional research into O_3 dynamics in Madrid is needed in order to design improved and more comprehensive air-quality control strategies
- Consider climate-related benefits

Friday 18th

Topic 6: Use of modelling in health and exposure assessments

HIA study funded by the European Project ICARUS (Integrated Climate forcing and Air pollution Reduction in Urban Systems; Horizon 2020, GA N° 690105) and SaludAire-España (Contaminación atmosférica y salud en España: morbilidad en atención primaria y mortalidad; Carlos III Health Institute, AESI grant PI18CIII/00022)

Air-quality modelling was funded by the Madrid City Council within the framework for the development and assessment of Plan A.

Thank you for your attention!

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