# Assessing the Impact of the COVID-19 Lockdowns

## Results and Implications from a Modelling Application in two Mediterranean Cities

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# Lockdowns and air quality: Exploiting the toolboxes of observation- and modelling-based analysis

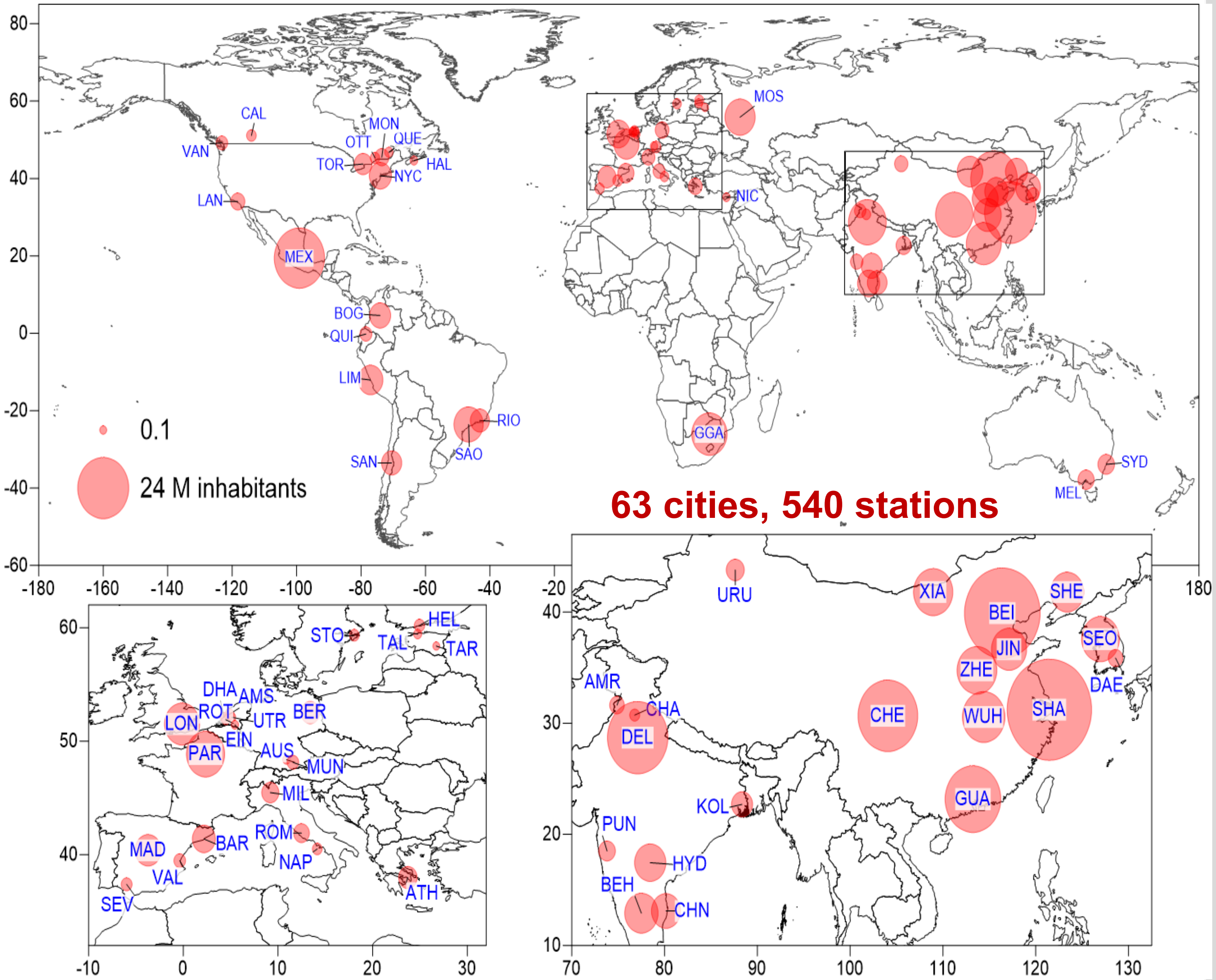
- Activity restrictions related to lockdowns across the world have been causing an unprecedented effect, particularly in urban areas. A unique opportunity for boosting data/model synergies:

- ***Observation-based*** assessment efforts allow
  - quantifying *changes in ambient pollutant levels* using statistics from monitoring station data before, during and after the lockdown period, and
  - disambiguating the role played by *meteorology, local emission effects, long-range transport and activity sectors.*

- ***Modelling-based*** assessment can help testing and validating emissions and dispersion models in activity levels and regimes hard to observe under normal conditions. Dispersion models provide the basis for
  - ascertaining the *magnitude of the effects*, particularly where no observations are present,
  - quantifying the contribution of *individual activity sectors* and
  - investigating the role of *meteorology* and *secondary pollutant formation.*

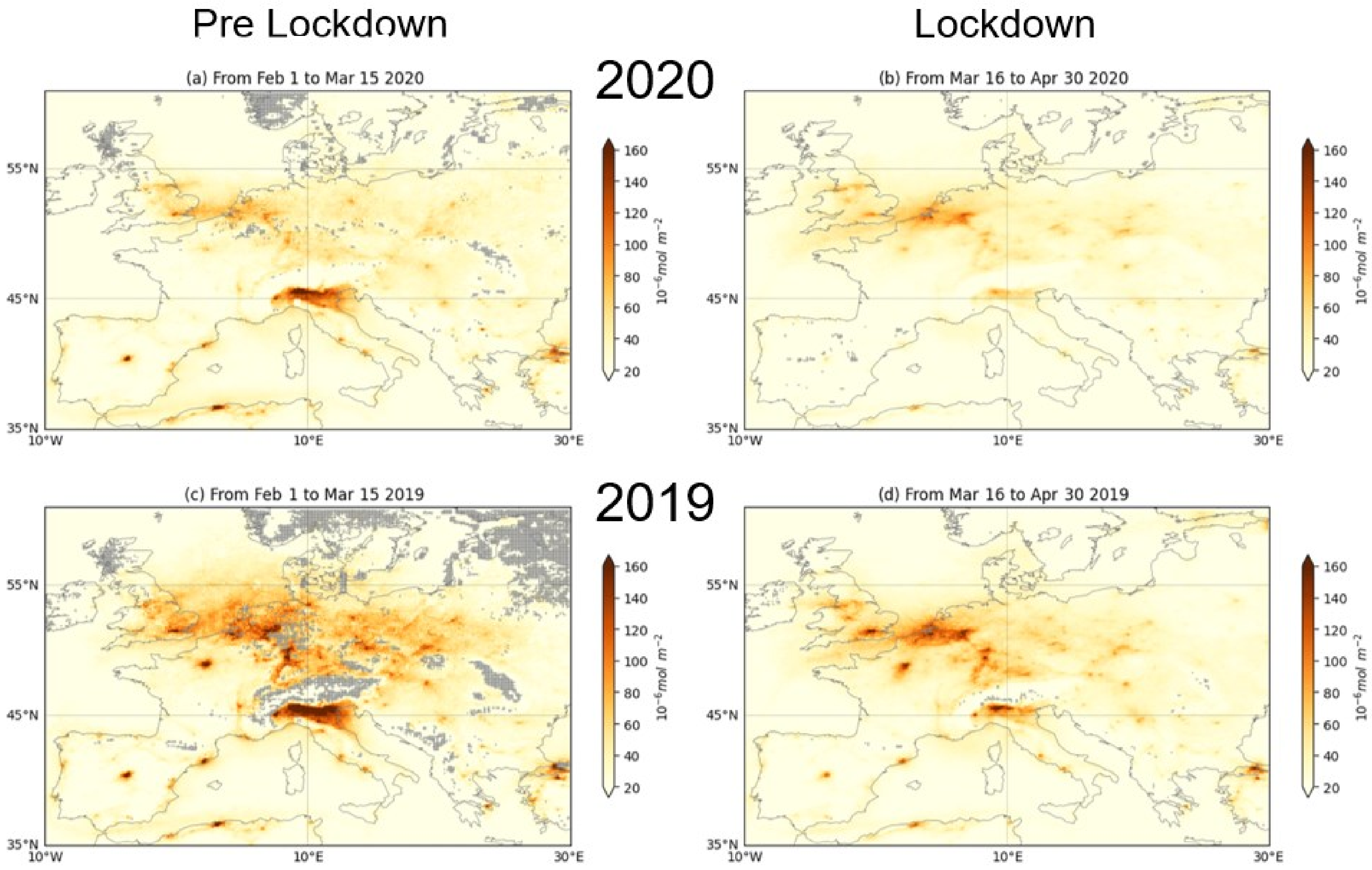
# WMO/GAW* observation-based study COVID-19 and air quality

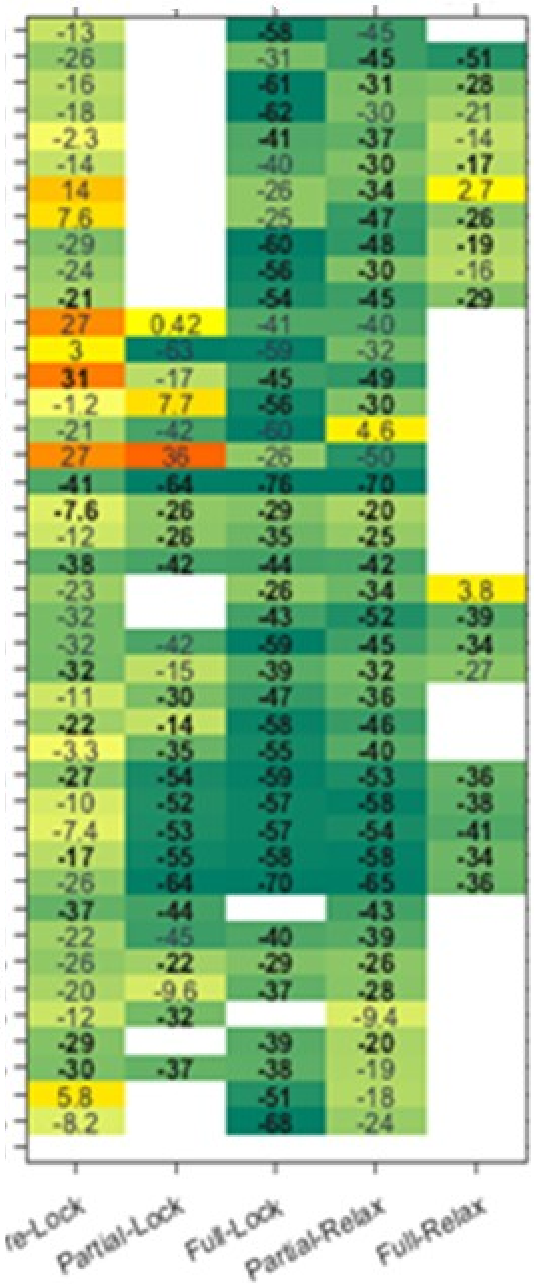
- Participation of research groups and national, regional and local authorities
- Encompasses ongoing independent work, coordinated studies
- $PM_{2.5}$, $PM_{10}$, PMC (coarse fraction of PM), $NO_2$, $SO_2$, $NO_x$, CO, $O_3$, $O_X$ (= $NO_2$ + $O_3$)
- Pre-lockdown, partial lockdown, full lockdown and two relaxation periods (January to September 2020)
- In situ ground-based air quality observations.




* GAW: Global Atmosphere Watch programme

# TROPOMI Satellite-derived $NO_2$ time averages




Barré et al., Atmos. Chem. Phys., 21, 7373–7394 (2021) https://doi.org/10.5194/acp-21-7373-2021

# First conclusions from air quality observations

- Decreases of up to about 70% in mean $NO_2$ and between 30% and 40% in mean $PM_{2.5}$ concentrations over 2020 full lockdown compared to the same period in 2015–2019.
- PMC and mobility changes was also seen for some Asian and South American cities
- Long-range transport of African dust and/or biomass burning (corroborated with the analysis of $NO_2$/CO ratio).
- Changes in $O_3$ concentrations were highly heterogeneous, with no overall change or small increases (Europe)
- $NO_2$/CO ratio indicated that specific sites (such as those in Spanish cities) were affected by biomass burning plumes, which outweighed the $NO_2$ decrease due to the general reduction in mobility (ratio of ~60%).

ELSEVIER

Environment International
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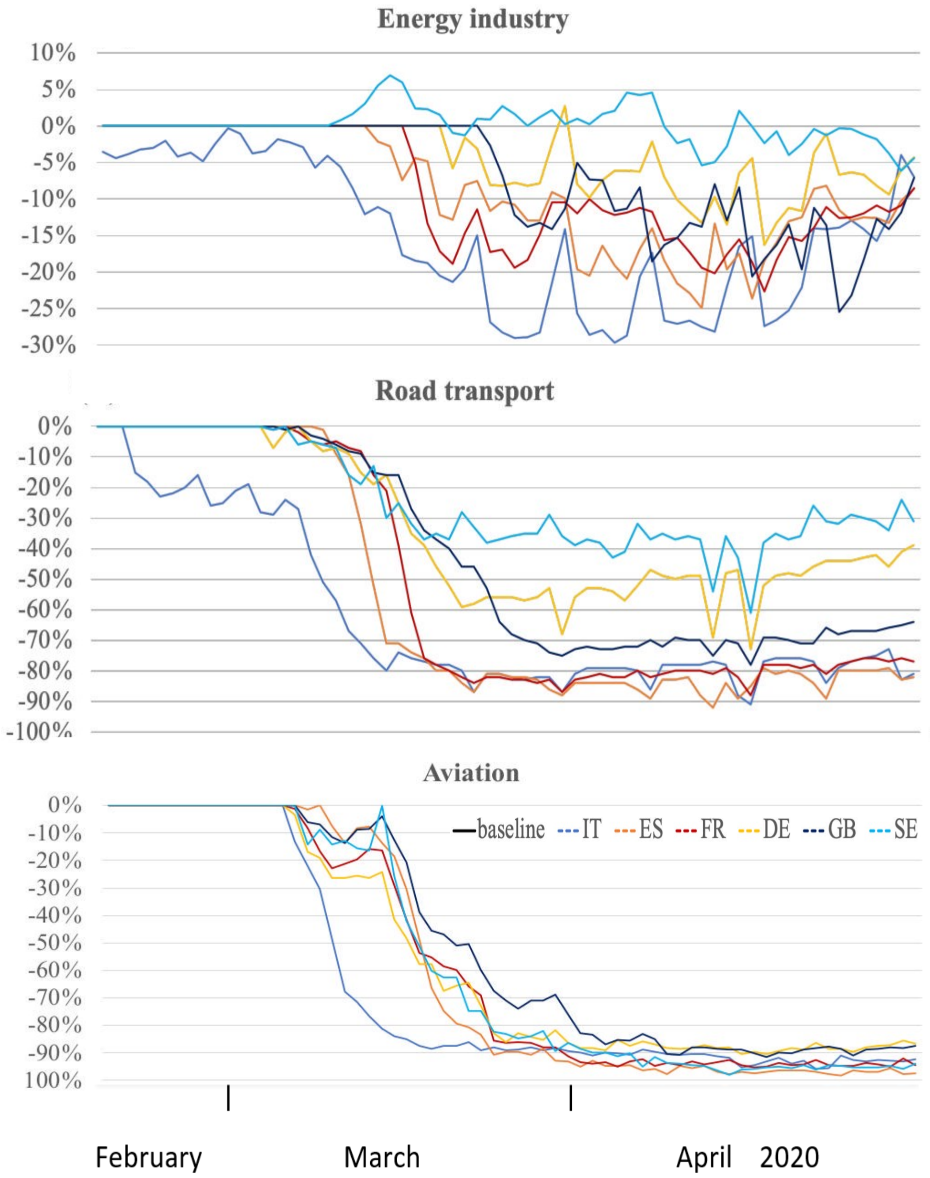
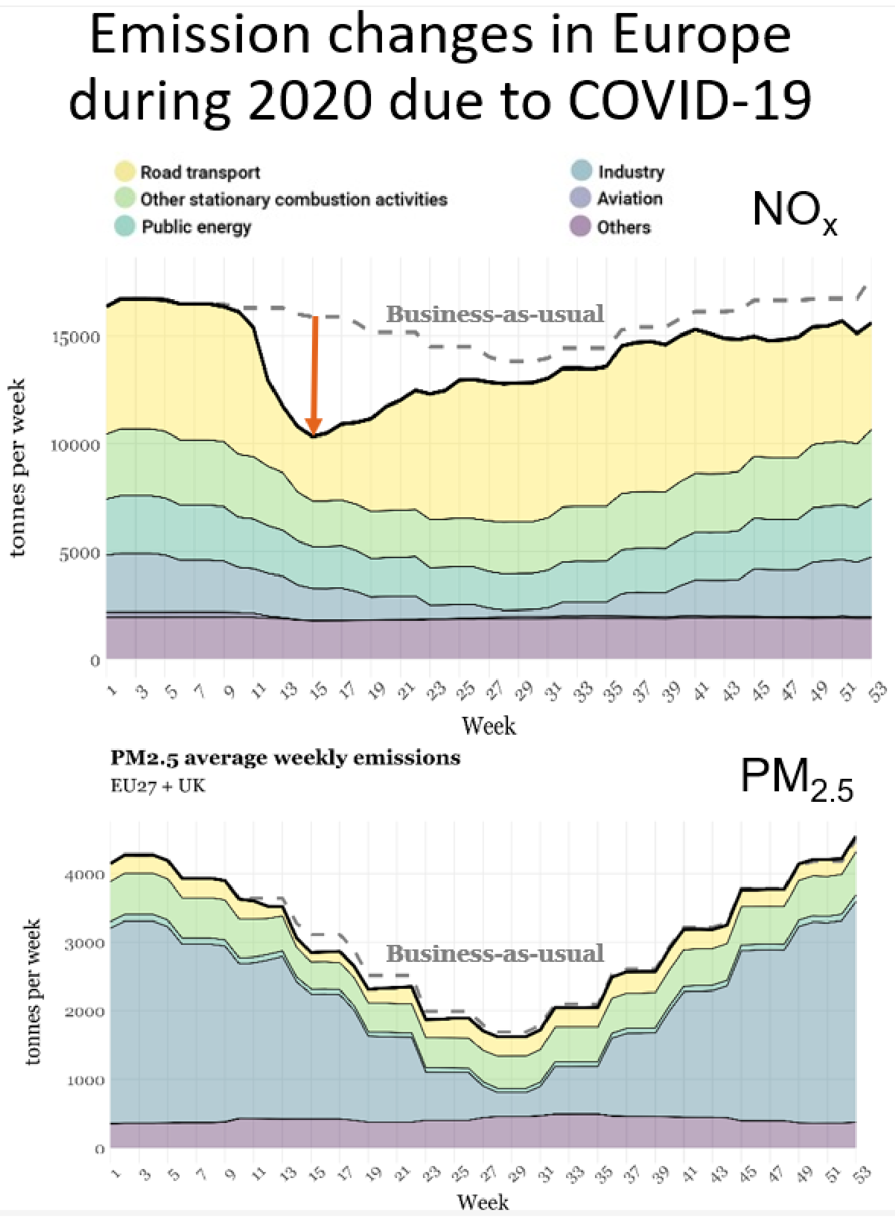
A global observational analysis to understand changes in air quality during exceptionally low anthropogenic emission conditions (Sokhi *et al.*)

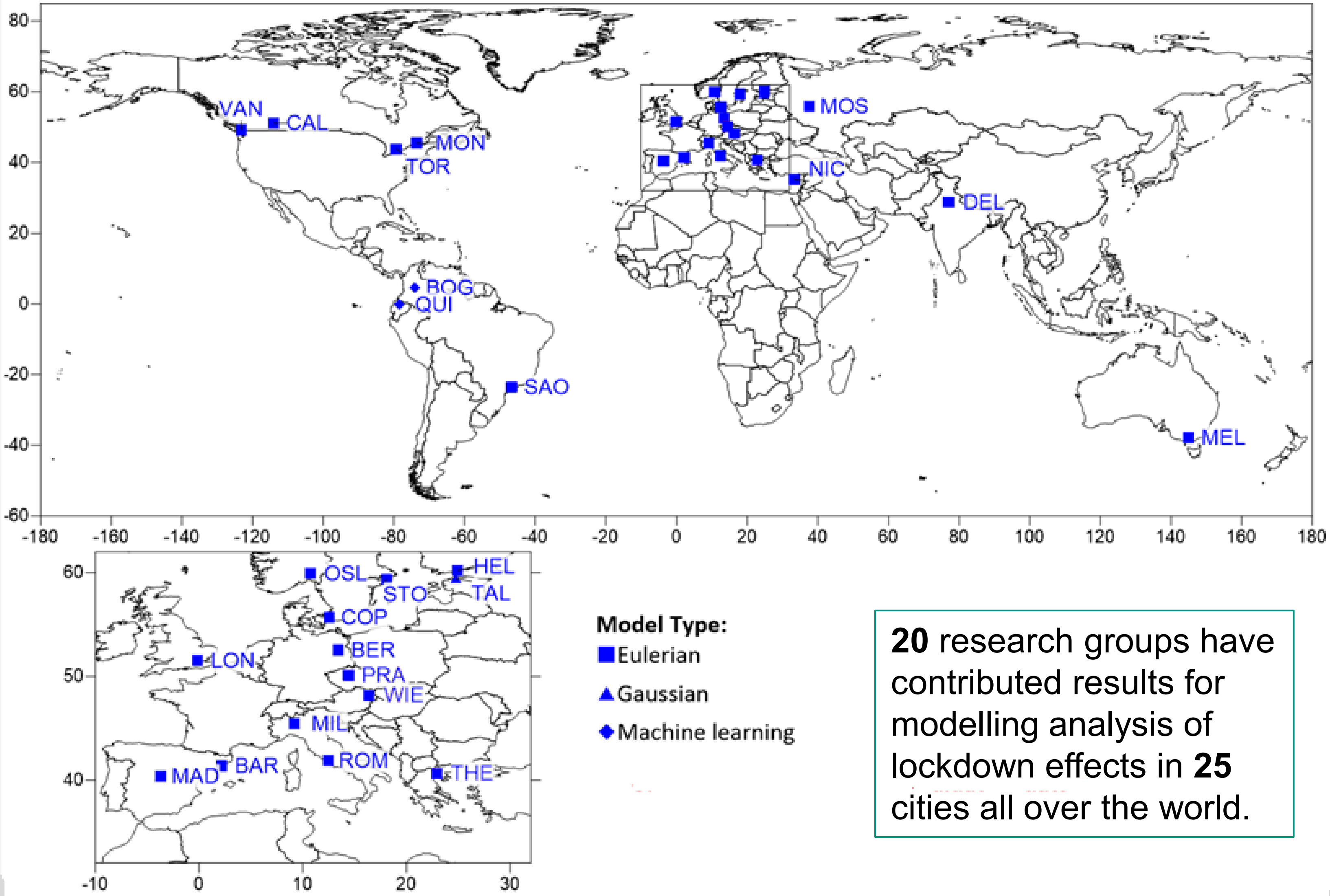
# EU- Emission reductions (Copernicus – CAMS estimates)




Guevara M. et al., Atmos. Chem. Phys. 21, 773–797, 2021 https://doi.org/10.5194/acp-21-773-2021



# WMO/GAW study, coordinating a modelling-based analysis




- Setup modelling methodological framework, coordinate various contributions
- Refine model validation practices

**20** research groups have contributed results for modelling analysis of lockdown effects in **25** cities all over the world.

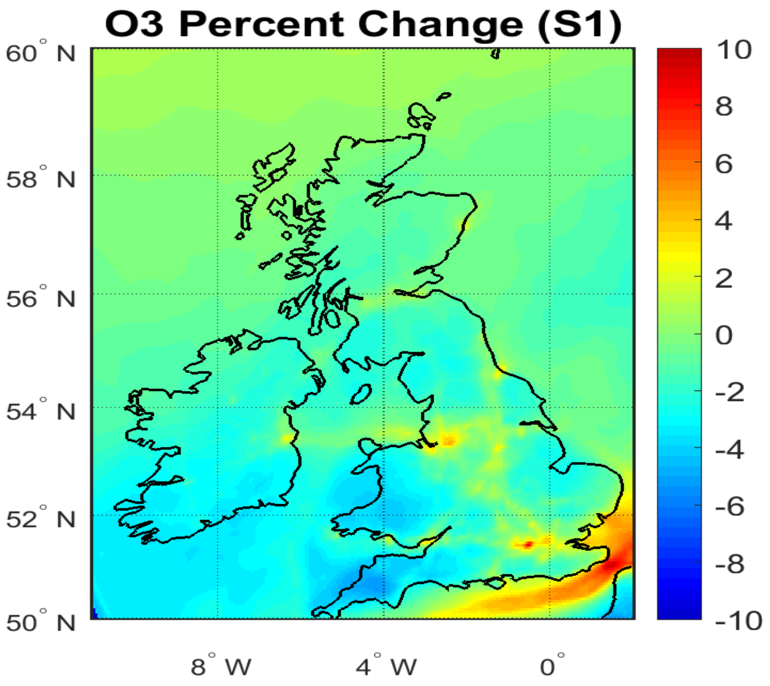
→ *tasks led by AUTh/SEL:*

- Coordinate the analysis
- Summarize the findings in two scientific reviews

# Science questions for the modelling analysis

- How does model performance vary according to different phases of the lockdown measures? Can models quantify the degree/extent of variations/rate of change?
- How accurately do models capture the changes in particulate matter (including component species), oxides of nitrogen and ozone during lockdown measures across the globe?
- What role was played by:
  - emission changes per sector
  - meteorological variations across different cities
- How well did the models capture the general atmospheric regimes:
  - for ozone and oxidative capacity of the atmosphere ($O_x$)?
  - distinguish between local and regional/LRT changes in air quality for ozone and $PM_{2.5}$?
- What lessons were learnt for local and regional air quality management?
  - Implications for policy and health e.g. WHO 2021 Guidelines

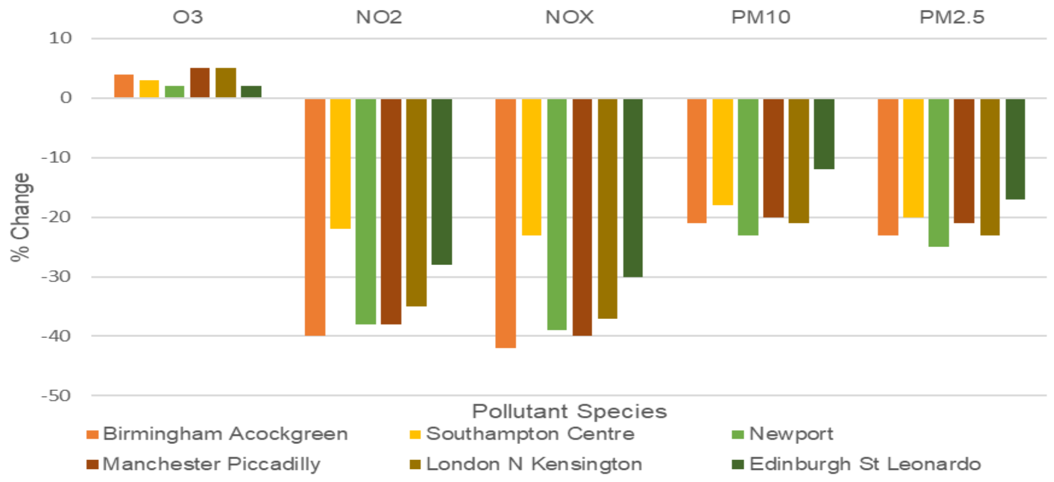
## Calculations for the 1st UK lockdown period using the WRF-CMAQ modelling system



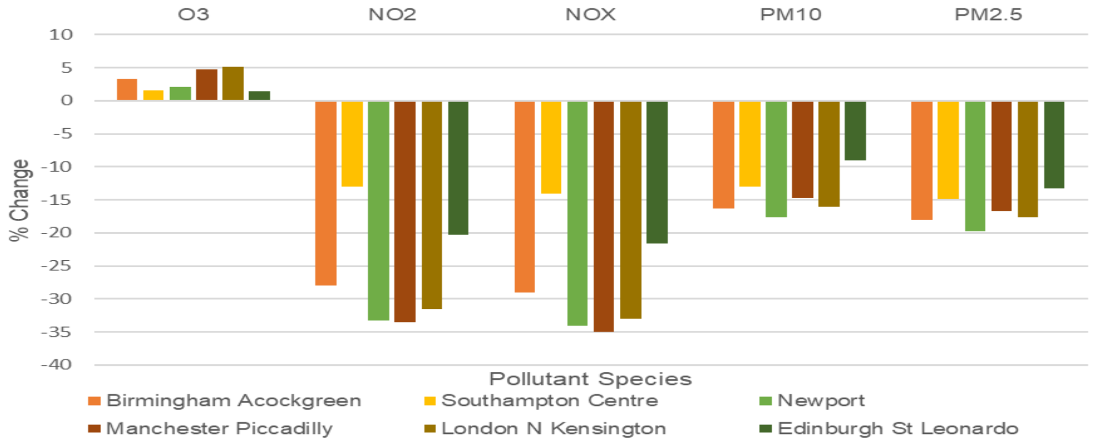

- Most of the changes can be attributed to reductions in road traffic emissions
- $O_3$ as a secondary pollutant is affected (increased) near urban centres



### Urban locations: Scenario 1 – overall emission changes




### Urban locations: Scenario 2 – reductions in road traffic only



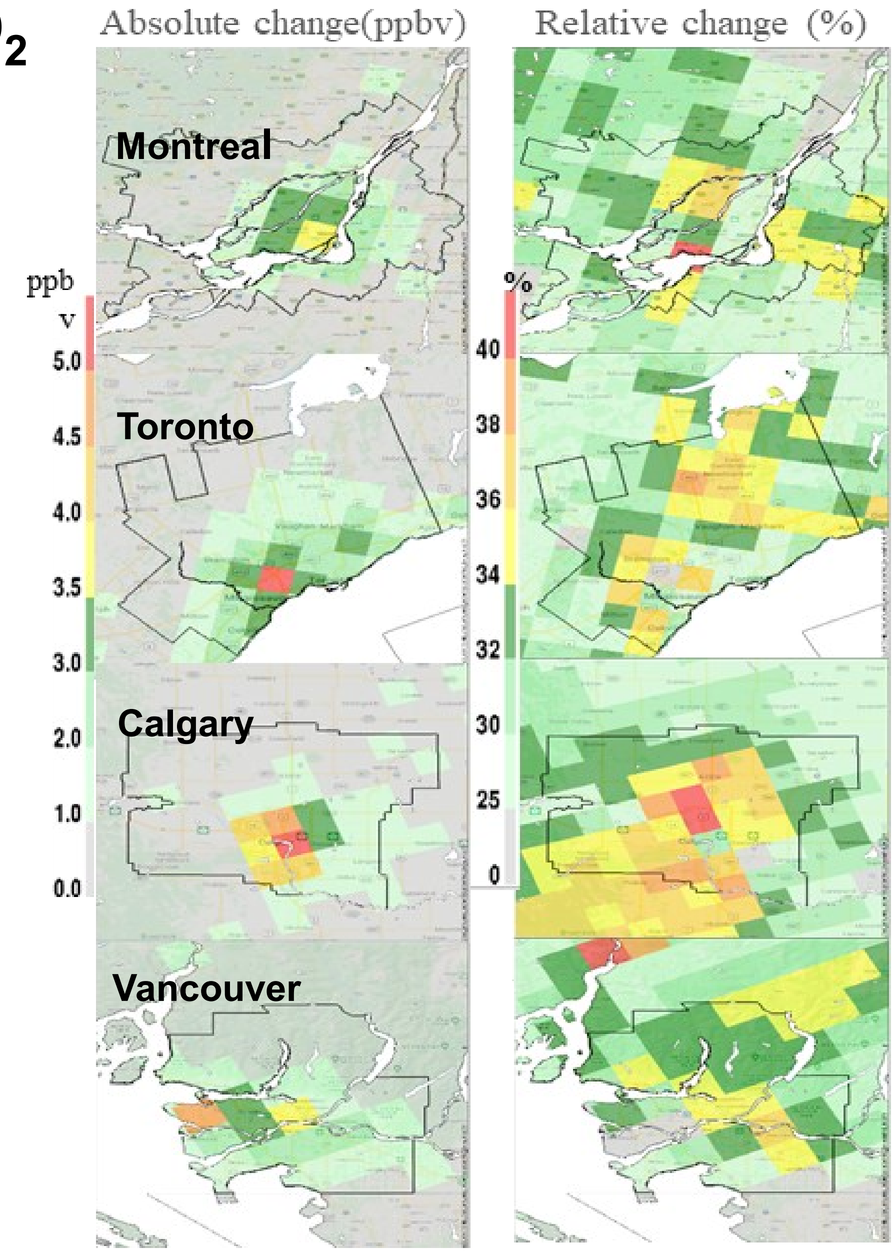

**Lockdown period 24 March to 26 April 2020**

**Environment and Climate Change Canada**
Air Quality Policy-Issue Response Section
Air Quality Research Division


- **ECCC Global Environmental Multiscale–Modelling Air-quality and Chemistry (GEM-MACH) model**
- 10-km grid resolution
- Simulation period:
  - BAU: 1 February to 11 May
  - COVID: 15 March to 11 May



# $NO_2$



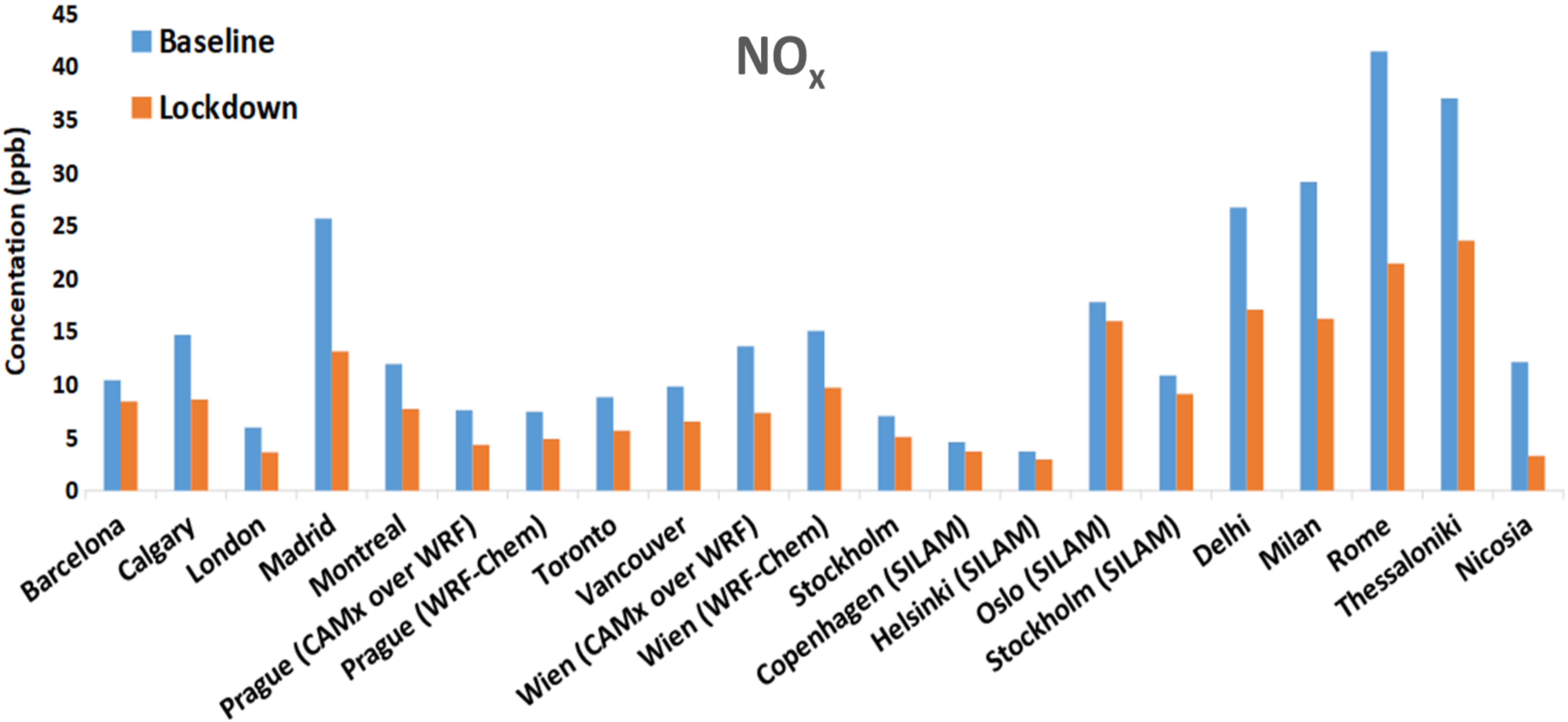

Max 41%
Min 22%
Mean **31%**

Maximum 39%
Minimum 24%
Mean **32%**

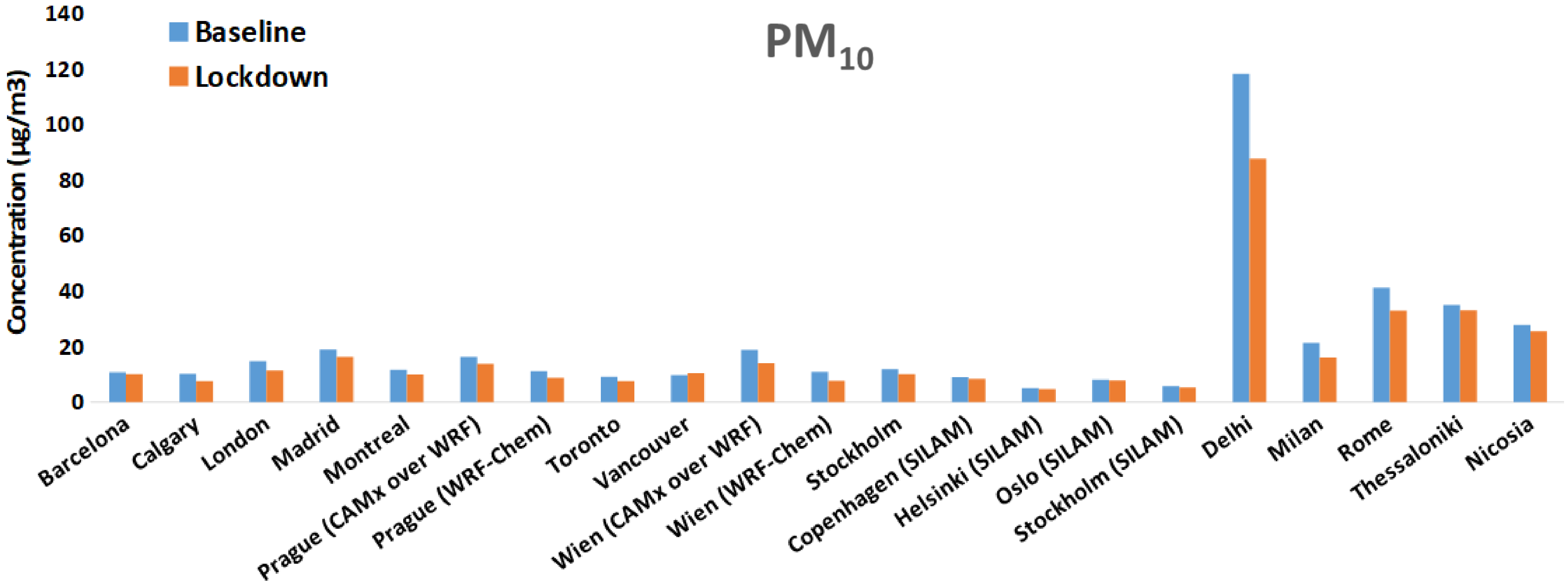
Maximum 41%
Minimum 20%
Mean **33%**

Maximum 37%
Minimum 20%
Mean **31%**

# Model results (lockdown vs. baseline scenarios) for cities of the WMO/GAW study (1/2)



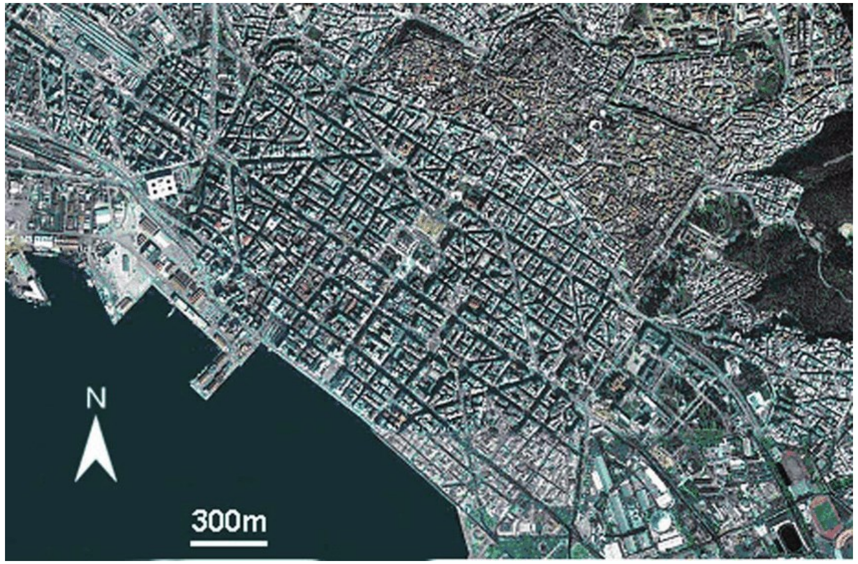
# Model results (lockdown vs. baseline scenarios) for cities of the WMO/GAW study (2/2)

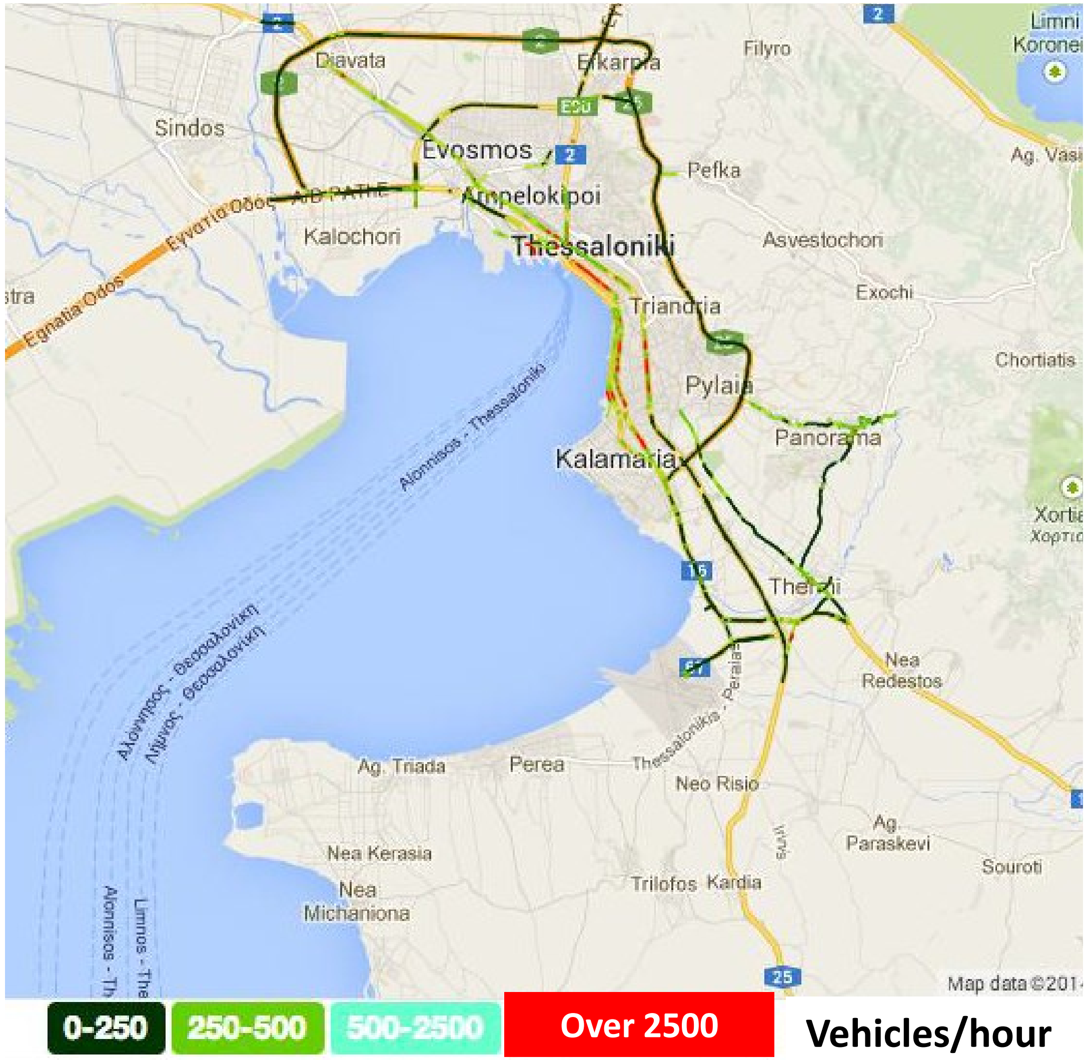


# Case study Thessaloniki, Greece

City features:

- Population: 811000 inhabitants (Metropolitan city 2019)
- Climate, Köppen Classification: Cfa, Humid Subtropical Climate
- Per capita GDP: 20.324,25 USD (2018)
- 493 cars per 1000 inhabitants (2017, Statista)
- Urban structure: Compact with corridor features



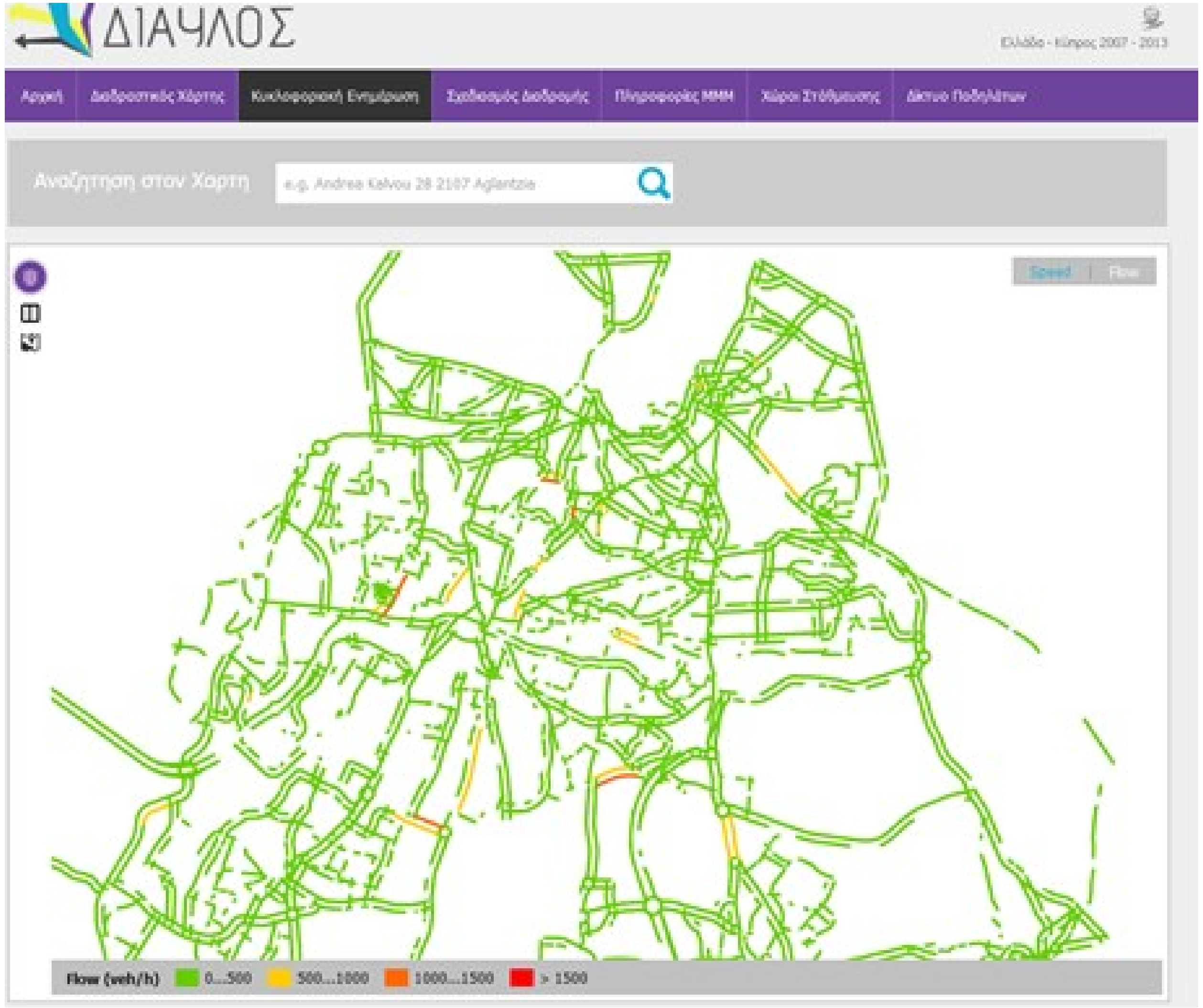




*Traffic flow in Thessaloniki (from Gavanas et al., 2014)*

# Case Study Nicosia, Cyprus

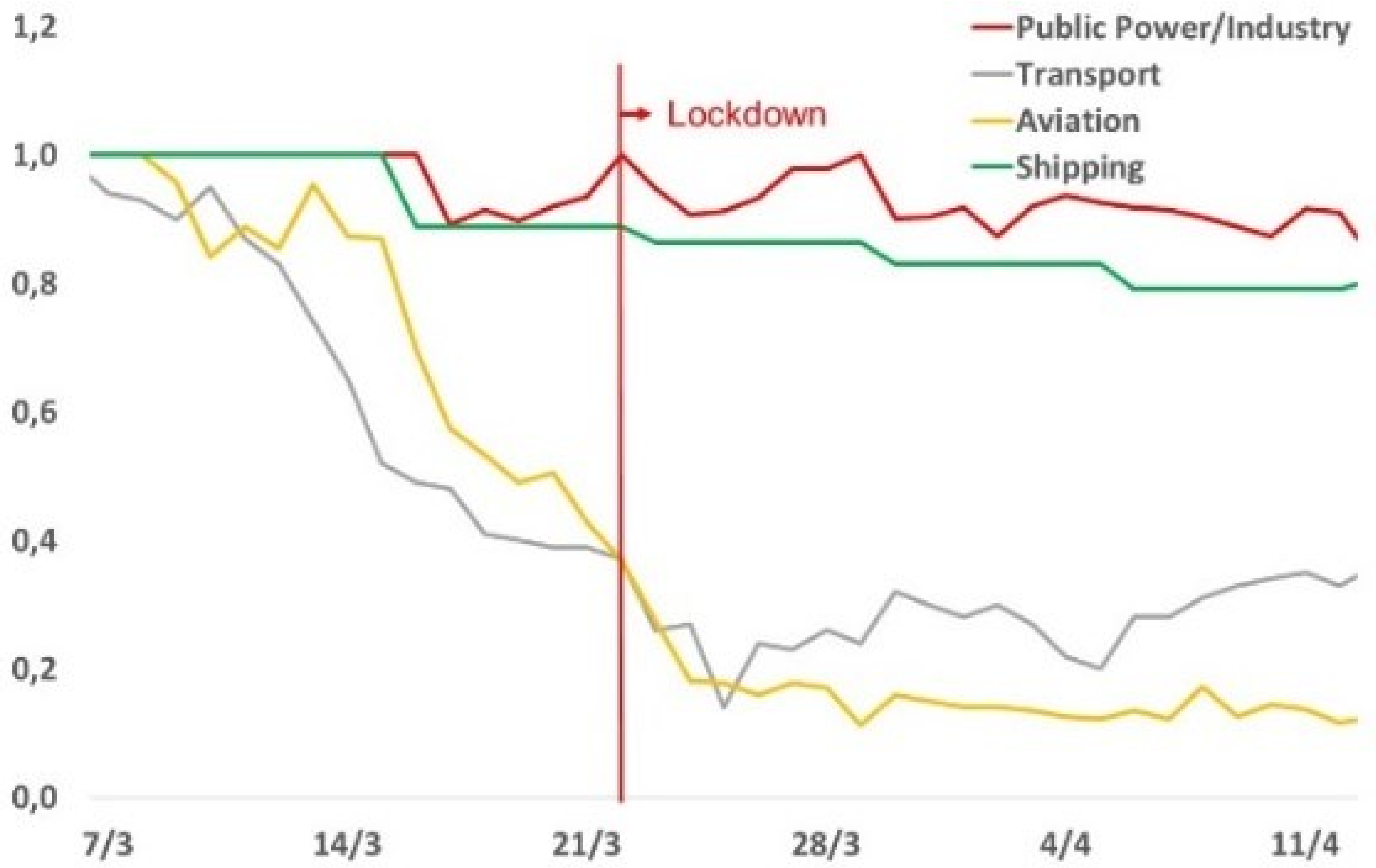
City features:

- Population: 332200 inhabitants (2020)
- Climate: Köppen Classification: Bsh, Mid-Latitude Steppe and Desert Climate
- Per capita GDP: 28.159,30 USD (2018)
- 595 cars per 1000 inhabitants (2016, Statista)
- Urban structure: radial expansion, with the existence of a widespread/extensive centre




*Traffic flow information in Nicosia from DIAVLOS system*

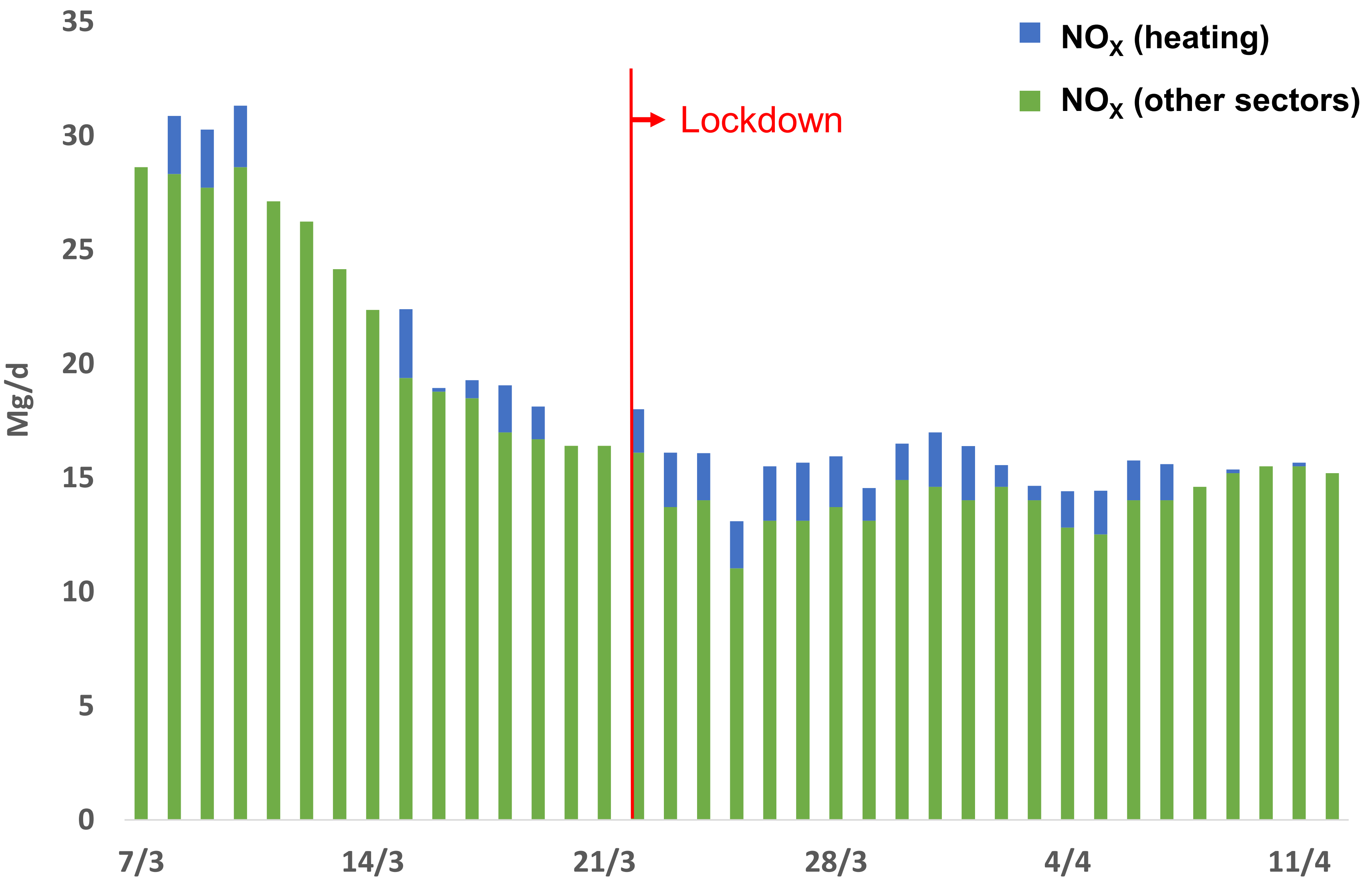
# Activity reductions for both case studies (Copernicus – CAMS estimates)



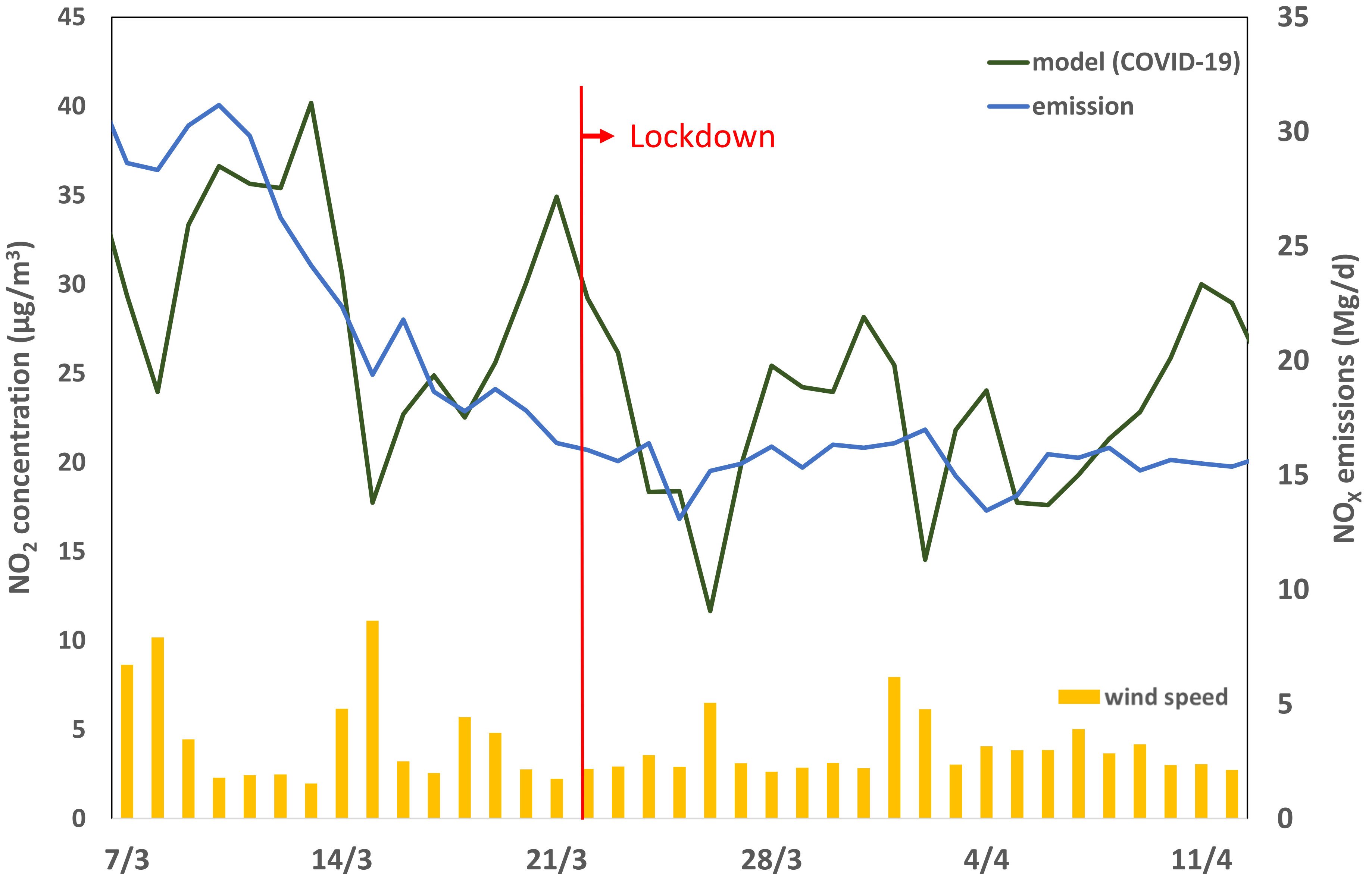
# AUTh/SEL's model system

- MEMO
  - A non-hydrostatic, prognostic, fully 3-dimensional meteorological model
  - Solves the determining equations for mass, momentum and radiation.
  - Provides hourly 3-d fields of the main meteorological fields over nested domains.
  - Can cover areas up to 10,000 km with horizontal resolutions down to 500 m.
  - Since the mid '90s it has been extensively applied and validated in areas around the world.
- MARS-aero
  - A Eulerian, fully 3-dimensional model for the dispersion and chemical transformation of atmospheric pollutants
  - Includes chemical transformation mechanisms with hundreds of predefined reactions, simulating photochemistry and secondary aerosol effects.
  - Provides hourly concentration and deposition fields for gaseous and particulate pollutants, including $NO$,$NO_2$, $O_3$, $SO_2$, $CO$, $PM_{10}$ and $PM_{2.5}$

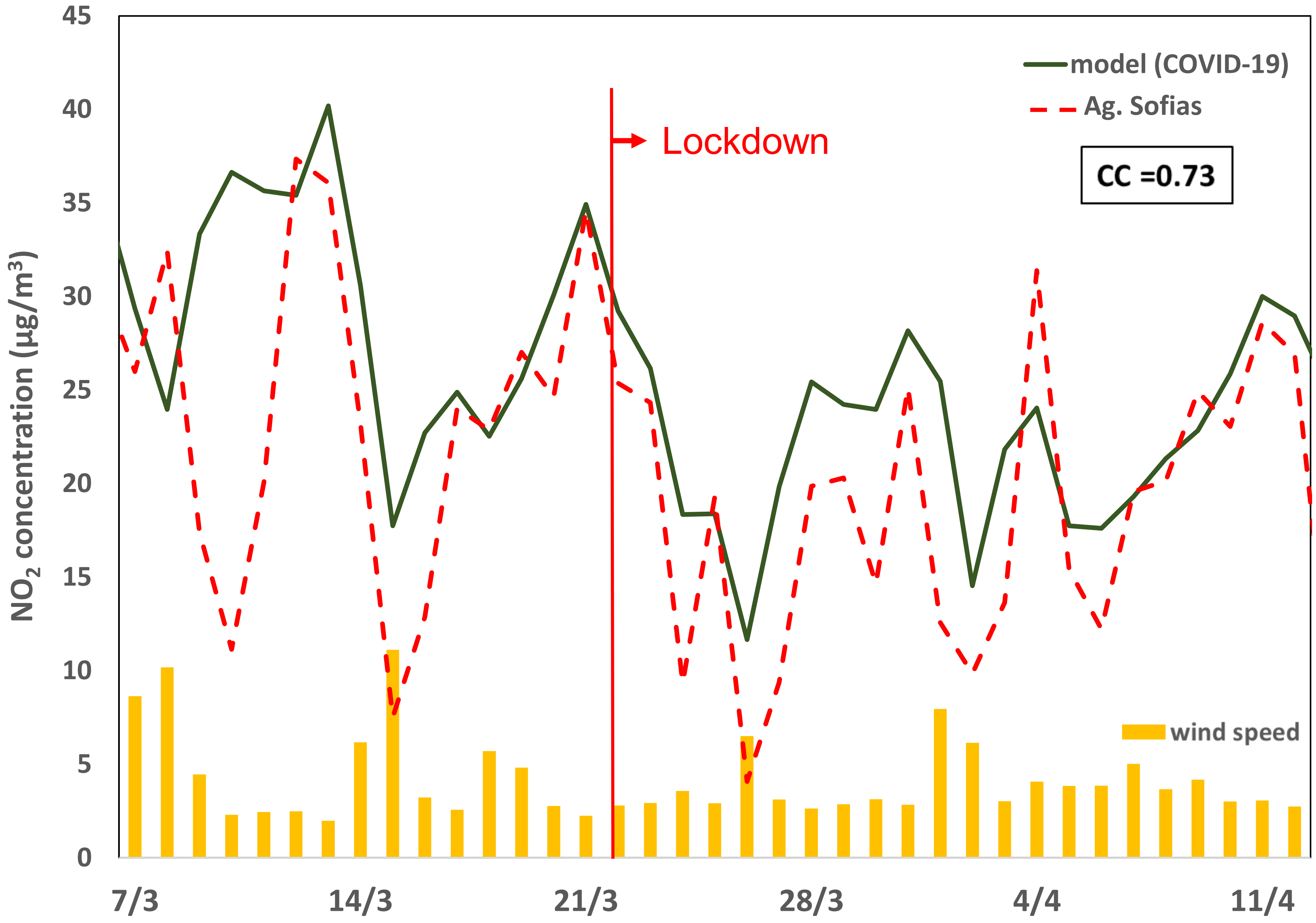
# Thessaloniki - $NO_X$ emissions



# Thessaloniki - $NO_2$ (1/3)

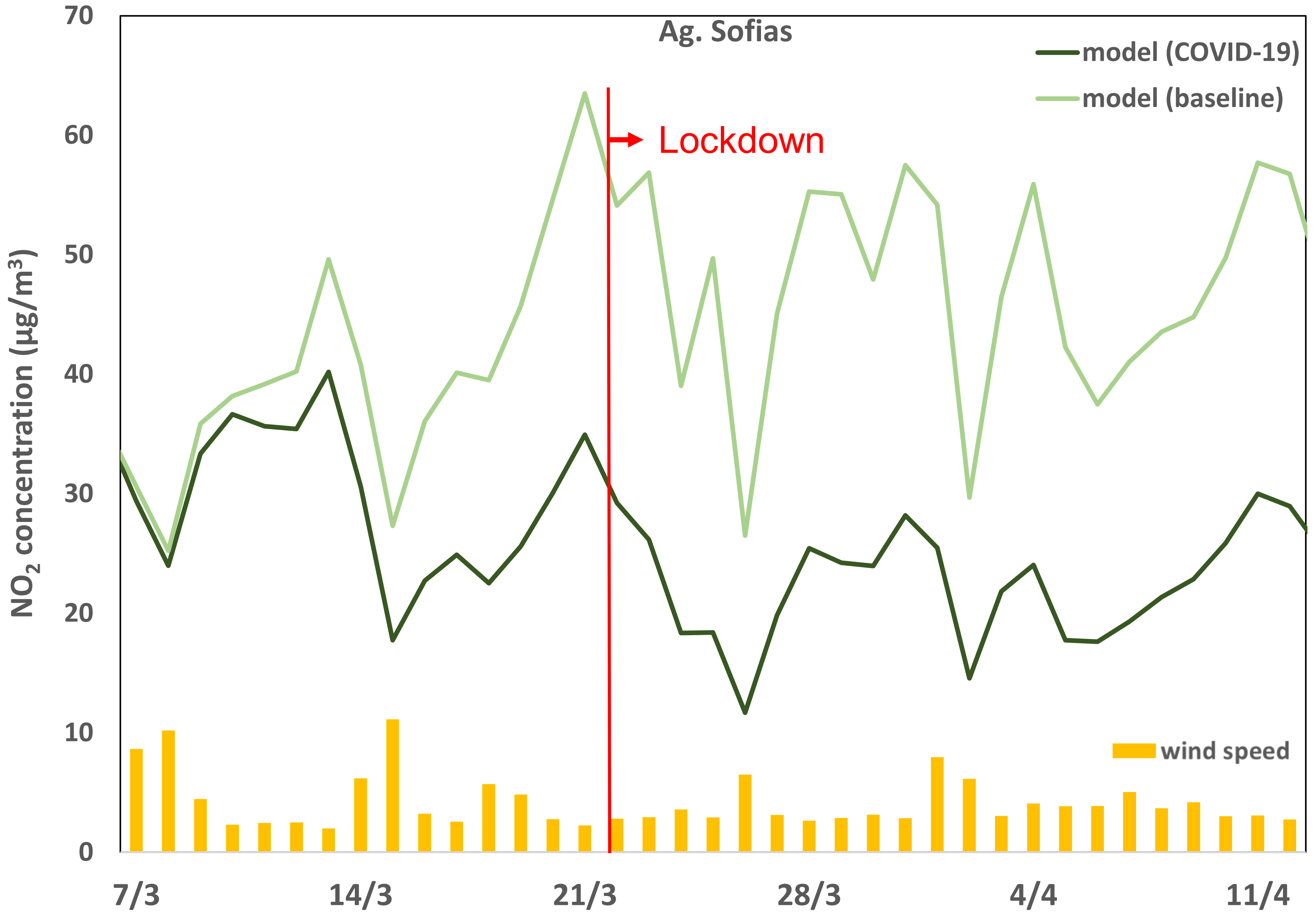


# Thessaloniki - $NO_2$ (2/3)



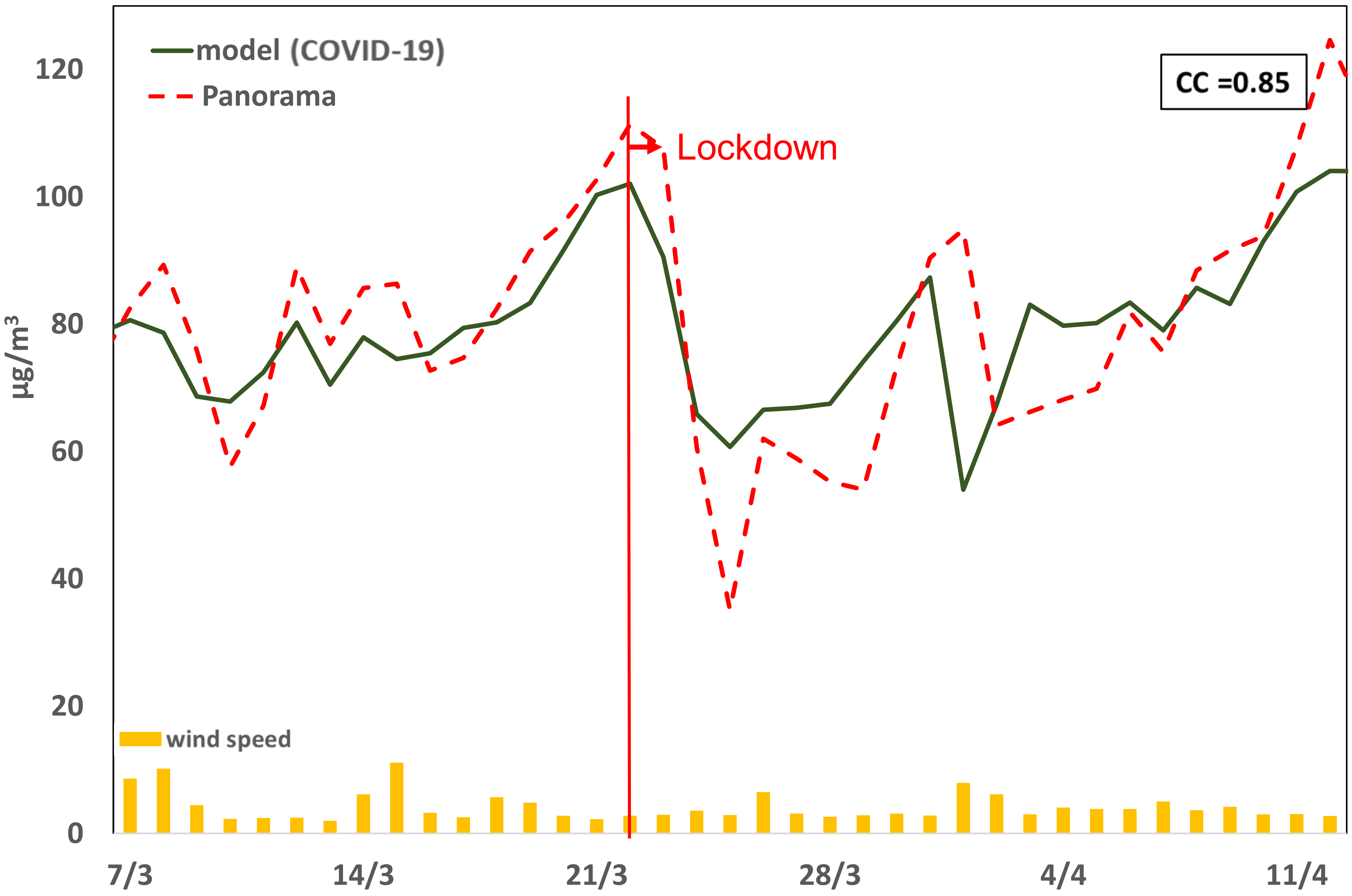

Ag. Sofias:
Urban
hot spot
location

# Thessaloniki - $NO_2$ (3/3)



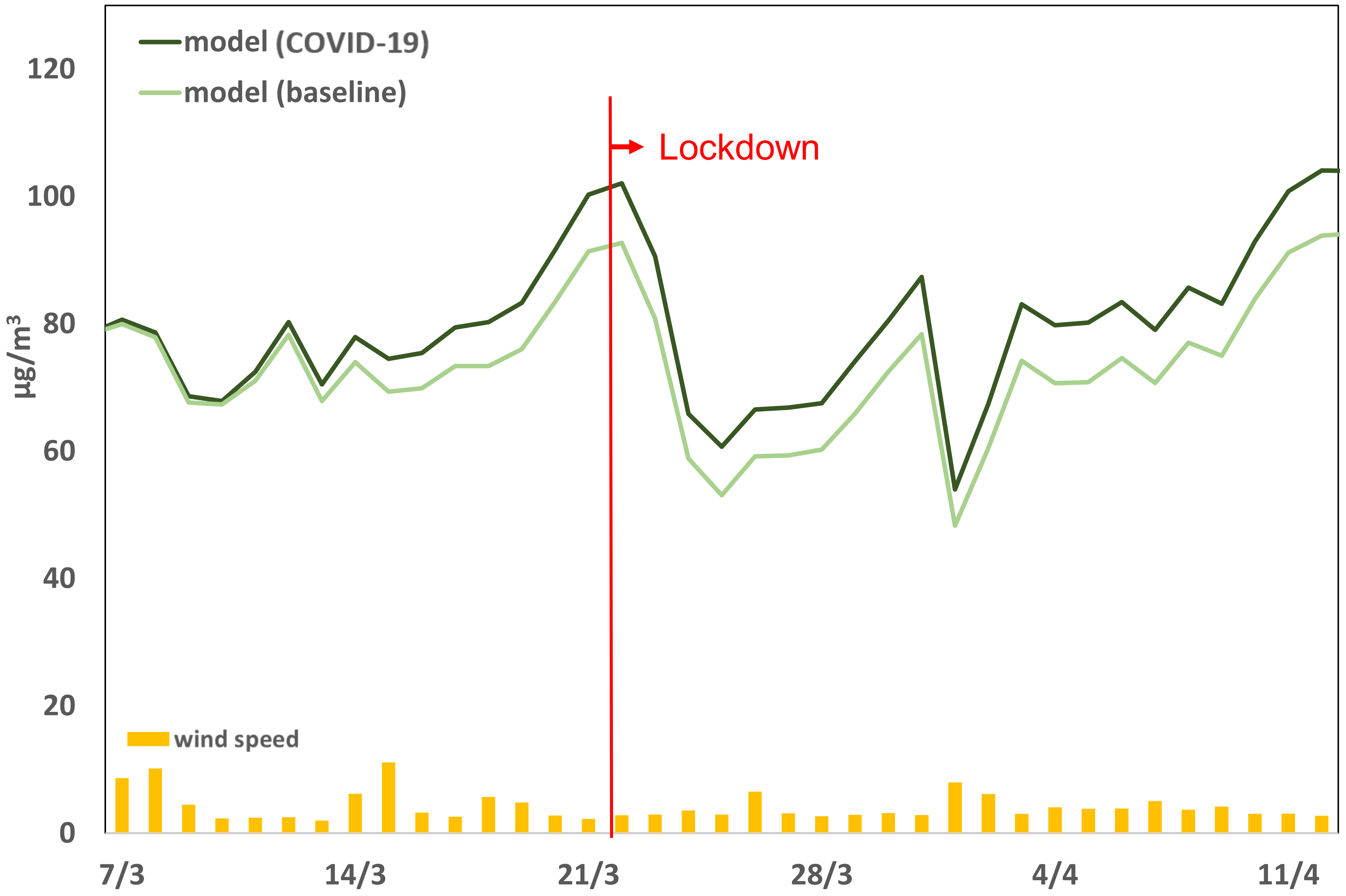

Ag. Sofias:
Urban
hot spot
location

# Thessaloniki (suburb) - $O_3$ (1/2)



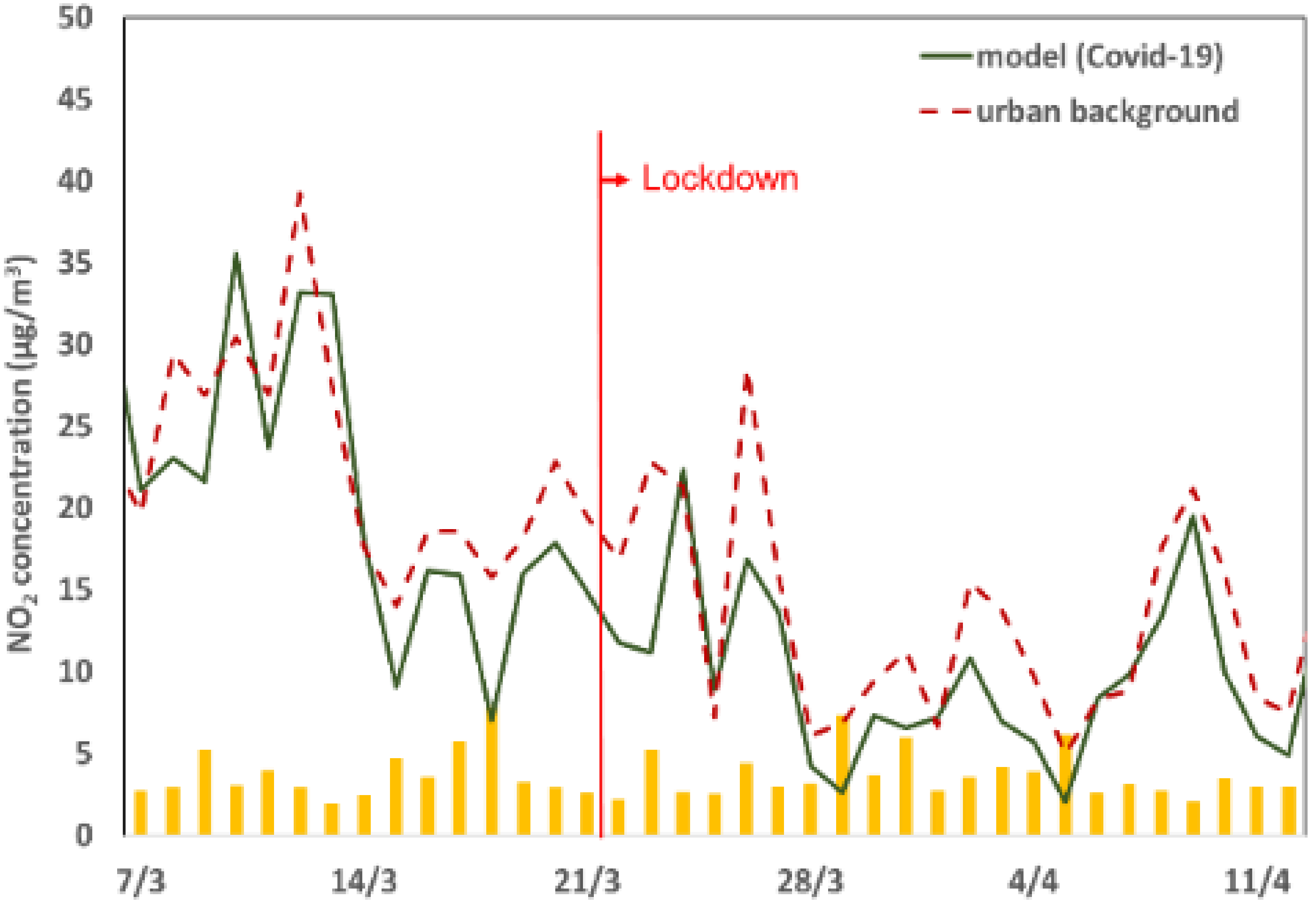

Panorama: Suburban location

# Thessaloniki (suburb) - $O_3$ (2/2)

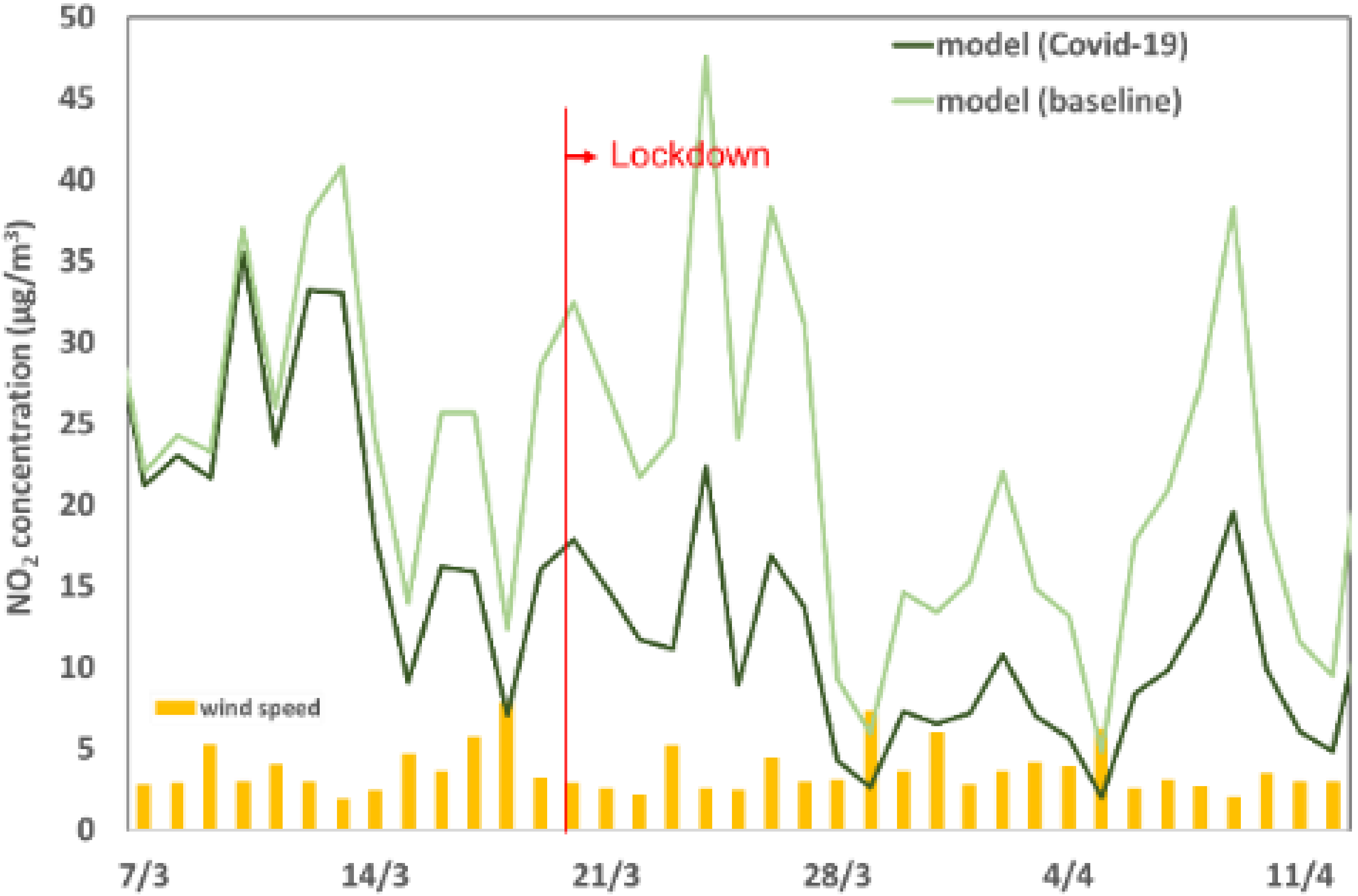



Panorama: Suburban location

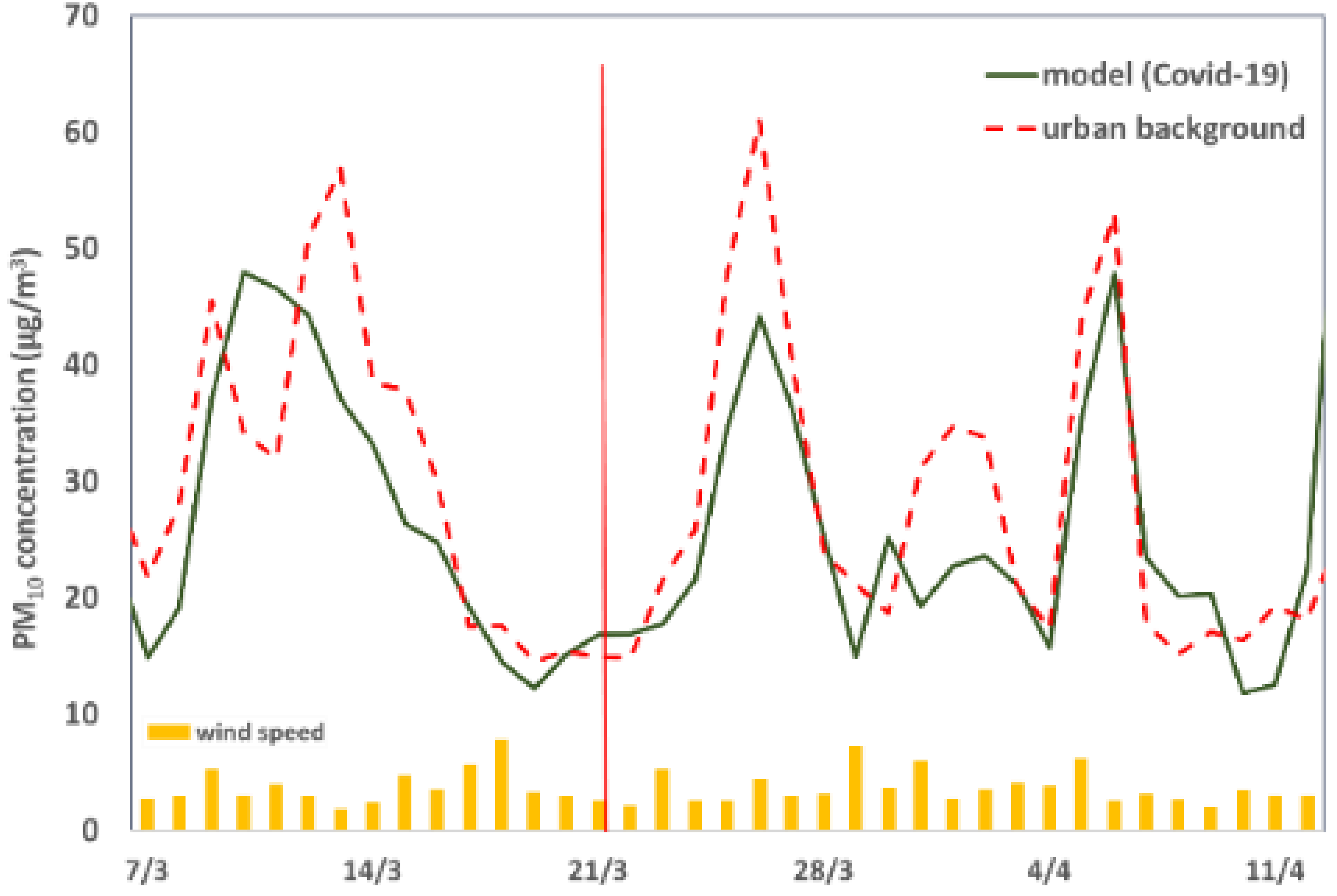
# Nicosia - $NO_2$ (1/2)



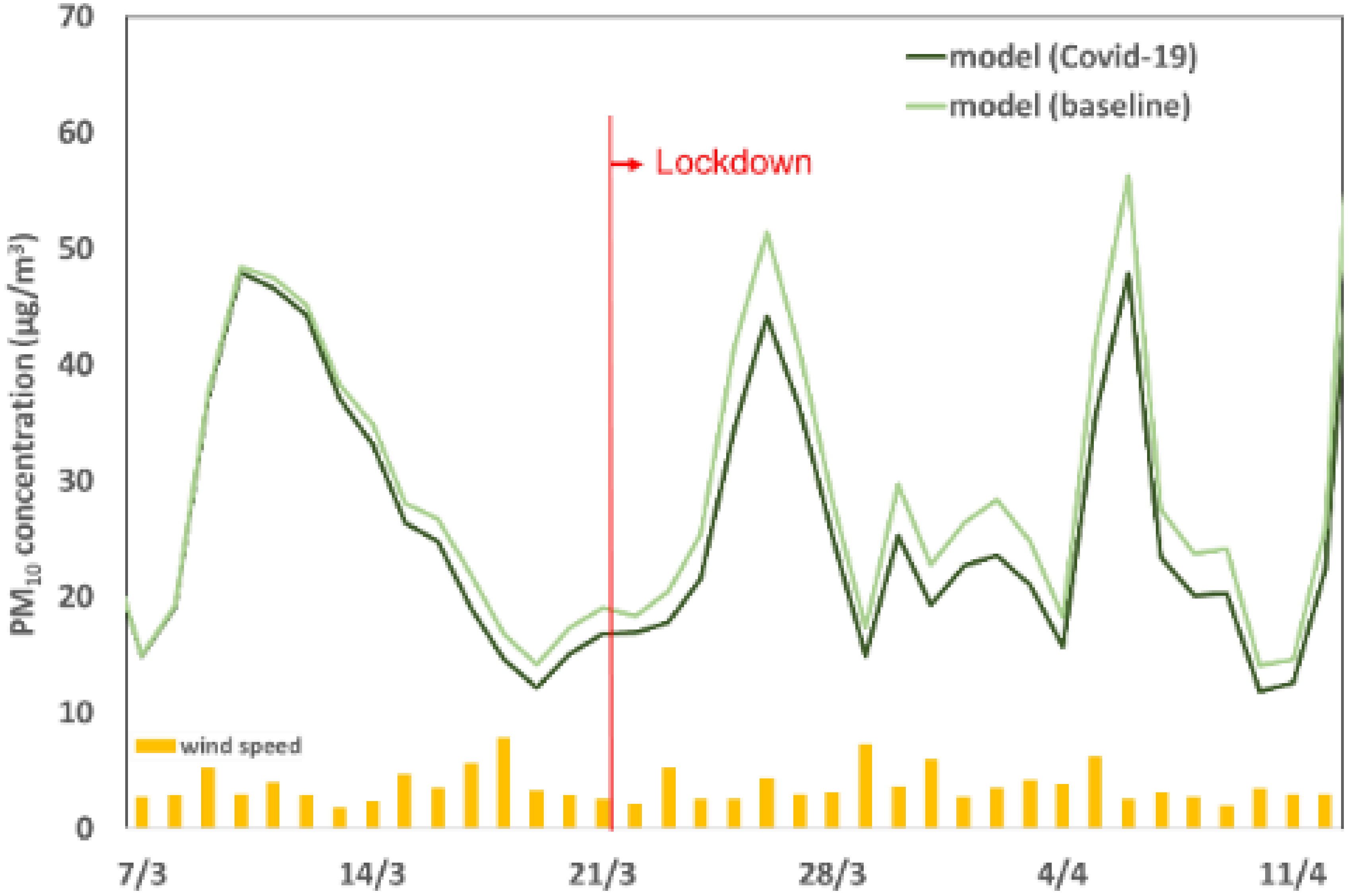
# Nicosia - $NO_2$ (2/2)



# Nicosia – $PM_{10}$ (1/2)



# Nicosia – $PM_{10}$ (2/2)



# Conclusions

- Large reductions in urban $NO_2$ concentrations during the springtime 2020 lockdown point to an *important impact of road traffic reductions* in urban centres. PM was much less affected.
- Changes in $O_3$ concentrations were ***highly heterogeneous***, with no overall change or small increases.
- *Only measurements are insufficient* for quantifying the significant influences of other emission sectors, weather variability and long-range transport.
- *Air quality models are a powerful tool* in disaggregating the effect of the aforementioned factors.
- Local sectoral contributions and regional transport have ***distinct and traceable contributions***.
- ***Statistical assessment of dispersion model results*** is ongoing, focus on urban-rural differentiation, PM speciation and the role of effects associated with secondary pollutants, including ozone formation.
- ***Per-pollutant emission reduction factors*** are now available.
- ***"Inverse" modelling methods*** and other novel approaches could be required to re-tune emission inventories under such extreme activity changes.

# Thank you for your attention!

Engineering for Sustainability - Challenges for the Future

30 years Laboratory of Heat Transfer and Environmental Engineering

1990 - 2020

Our Lab's new name: **Sustainability Engineering Laboratory**

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