Influence of COVID-19 Lockdown Measures on Air Quality

An observational and modelling analysis in the frame of the World Meteorological Organisation's Global Atmospheric Watch (WMO/GAW) programme

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Lockdowns: Unprecedented chance to validate models

- Activity restrictions related to lockdowns are causing an unprecedented effect, particularly in urban areas – the "***largest scale experiment ever***" in air pollution research. Unique opportunity for boosting data/model synergies!
- So far, efforts have focused on
  - quantifying ***changes in ambient pollutant levels*** using statistics from monitoring station data before, during and after the lockdown period, and
  - accurately ***measuring the activity reduction***, with a focus on the transport and energy sectors.
- Chance for ***testing and validating simulation models*** in activity levels and regimes hard to observe under normal conditions.
- Modelling tools are instrumental in assessing
  - the ***magnitude of the effects***, particularly where no observations are present
  - the contribution of ***individual activity sectors***.

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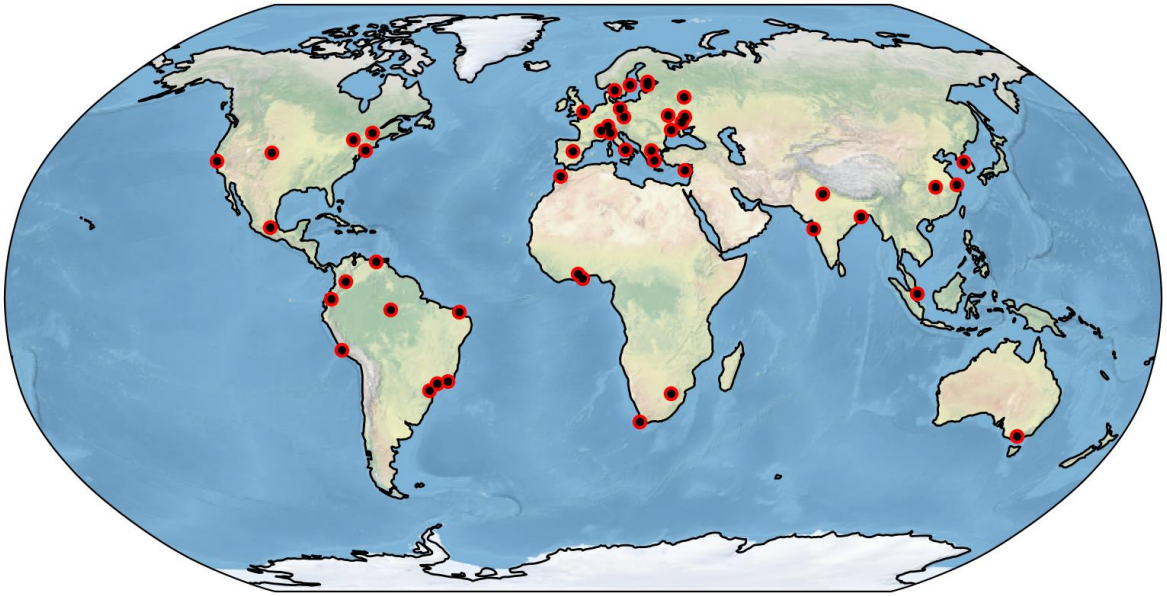
(GAW: Global Atmosphere Watch programme)

More than 45 cities in 29 countries, 5 continents



- Participating groups: research institutions, national, regional and local authorities
- Encompasses ongoing independent work, coordinated studies
- Observations → surface & satellite- based / NO_2, NO_x, $PM_{2.5}$, PM_{10}, O_3, CO, SO_2
- Numerical modelling → dispersion of pollutants, sectoral assessment
- Emissions estimation → direct calculation, “inverse” modelling

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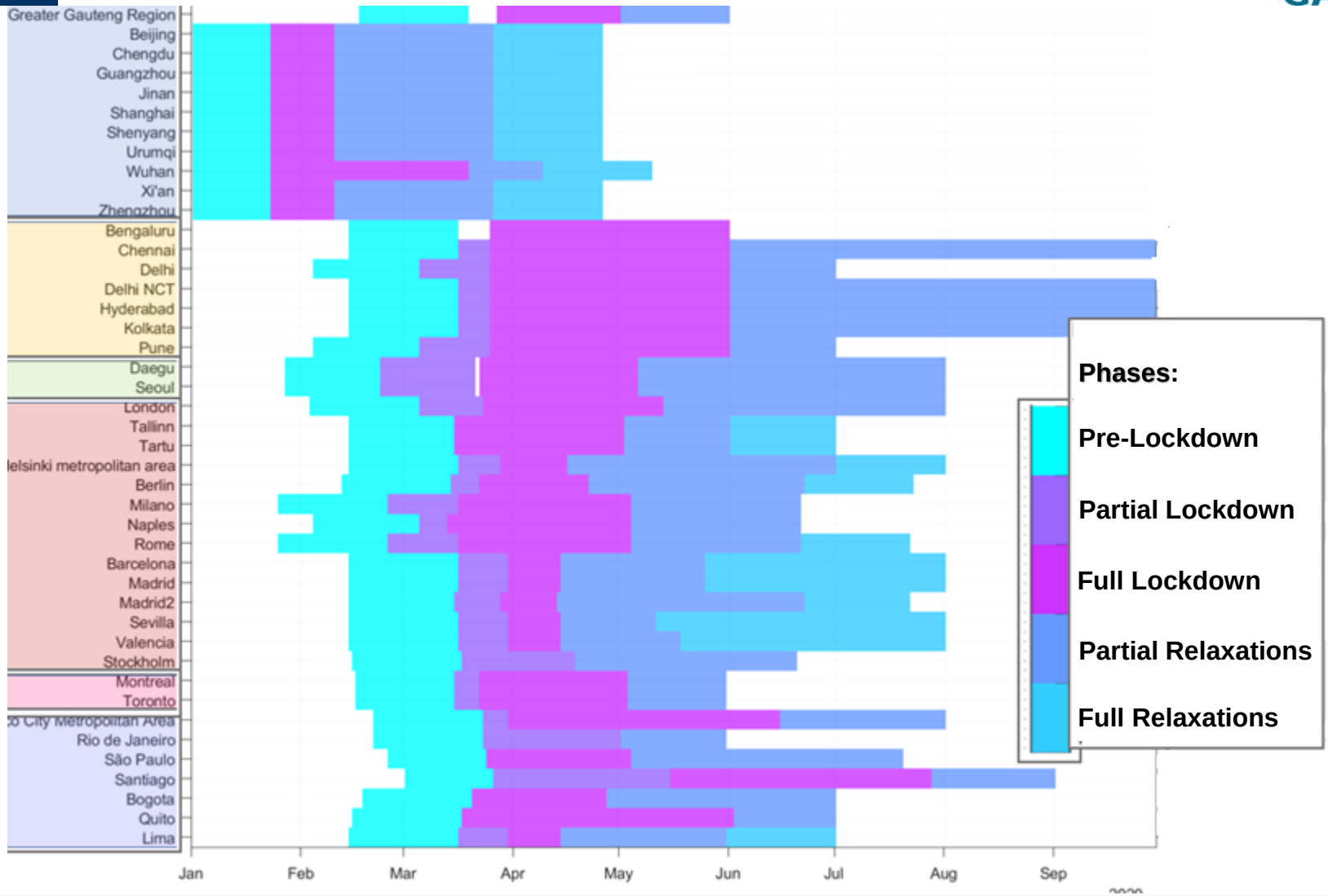
Lockdown periods across different cities



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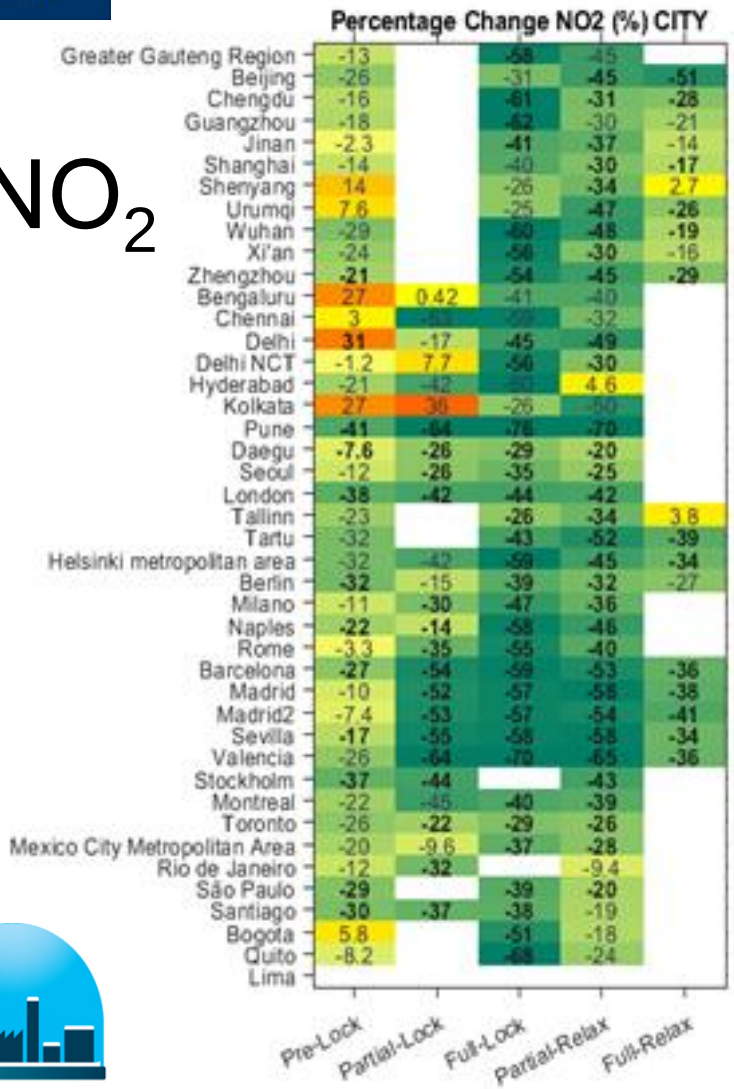
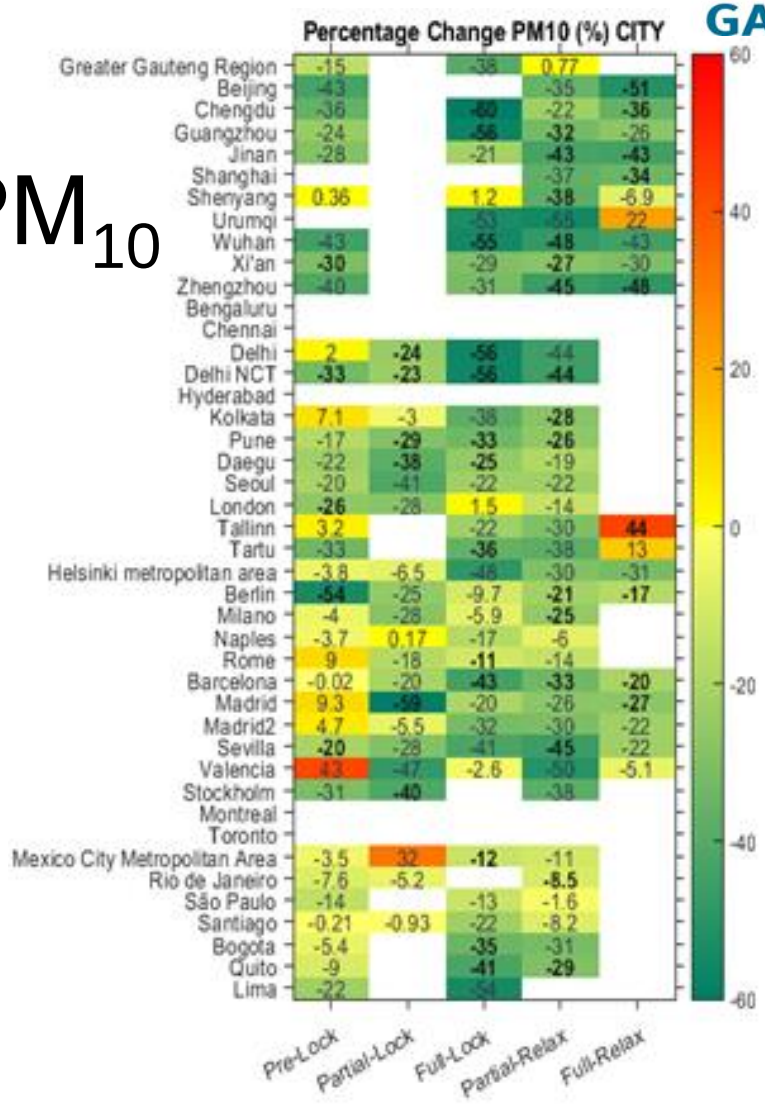
%change (2020 vs 2015-2019 averages)

NO_2



PM_{10}



First conclusions from air quality observations

- Other factors apart from emissions, such ***as weather conditions***, may also significantly affect concentrations, explaining why lower air pollution ***may not occur at all locations*****.**
- More detailed analyses of air quality measurements allow assessing ***systematic differences between monitoring stations*** with different characteristics (e.g., ***"background"*** or ***"traffic"***)**.**
- Efforts to assess and disaggregate the contribution of different emission sectors are underway by several research groups.
- Preliminary estimates from the ***Copernicus CAMS consortium*** show that reduced activity and emissions in the traffic (including aviation and shipping) and industrial sectors can largely account for the observed reduced concentrations.

Questions that can/should be answered with models

- Emission reductions from specific traffic sectors can be quantified, but solely measurements are insufficient *for accurately describing more complex issues*.
- What is the effect of reducing loads of *specific fleet segments*?
- How do *non-transport emissions* contribute to poor air quality in cities?
- Using the ability of the models to isolate non-emissions effects (e.g., meteorology), what is the true *net effect of emissions reduction* on AQ?
- What is the effect on *secondary pollutants*, like ozone or SOA?
- Would legislation-targeted emission reductions offer a *real AQ benefit*?
- To what extent is legislation targeting the major *pollution culprits* (e.g., “dieselgate”)?

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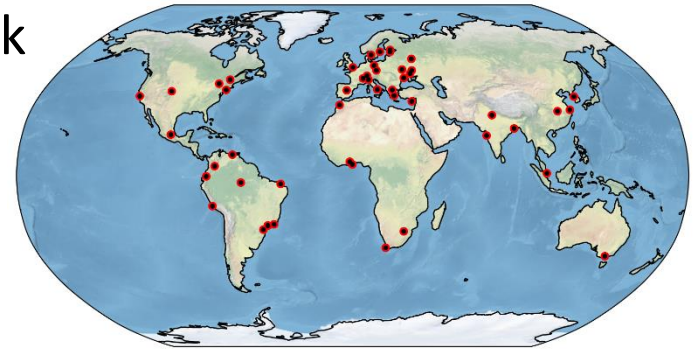
Modelling tasks

Setup modelling methodological framework

Refine model validation practices

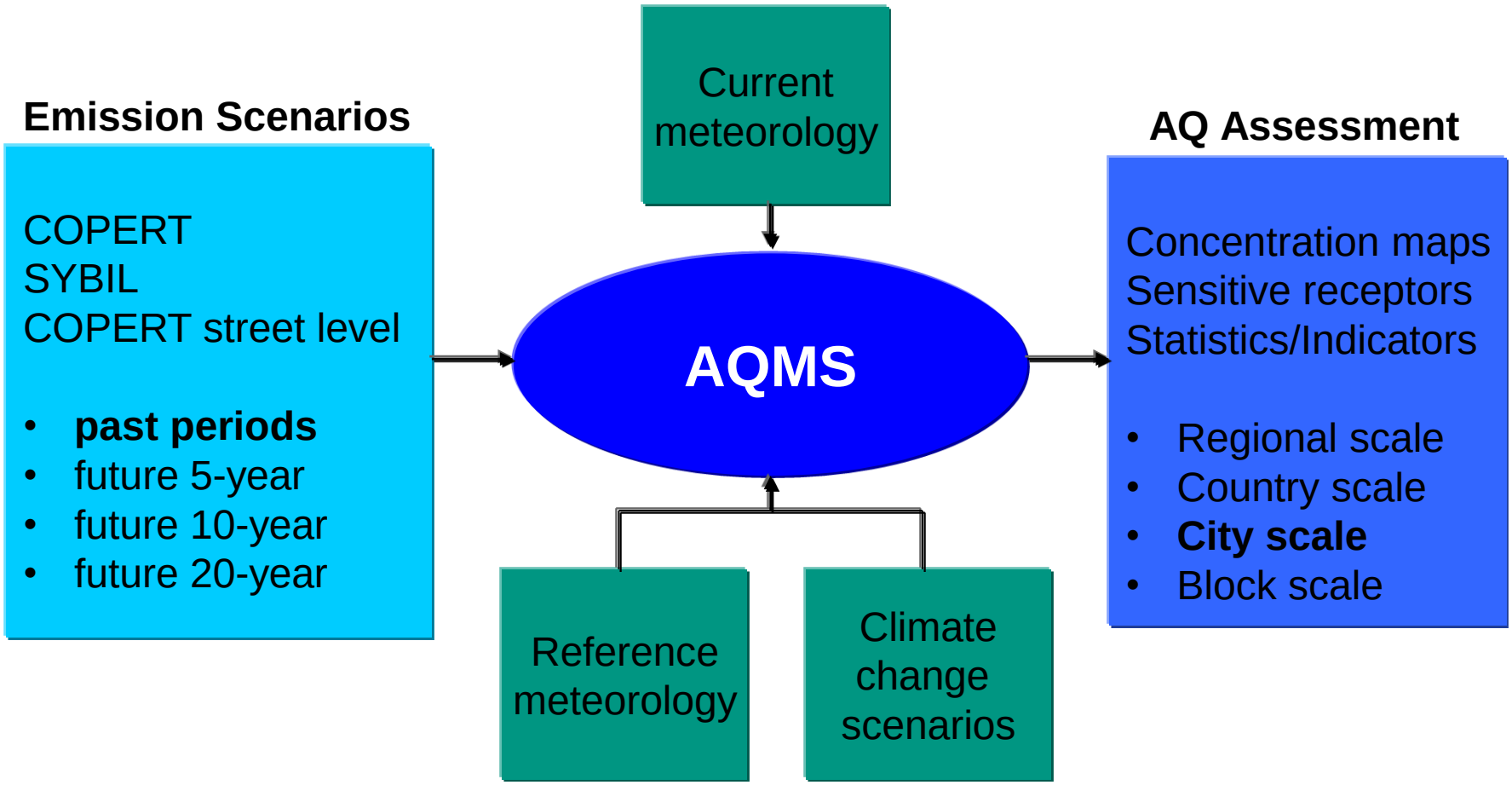
→ tasks led by AUTh/LHTEE



In detail:

- Analyse data and provide phenomenological interpretation
- Describe influence of meteorology and long-range transport
- Relate air quality impacts to emission changes
- Provide sectoral attribution using multiple approaches
- Coordinate discussion of implications to science, technology and policy

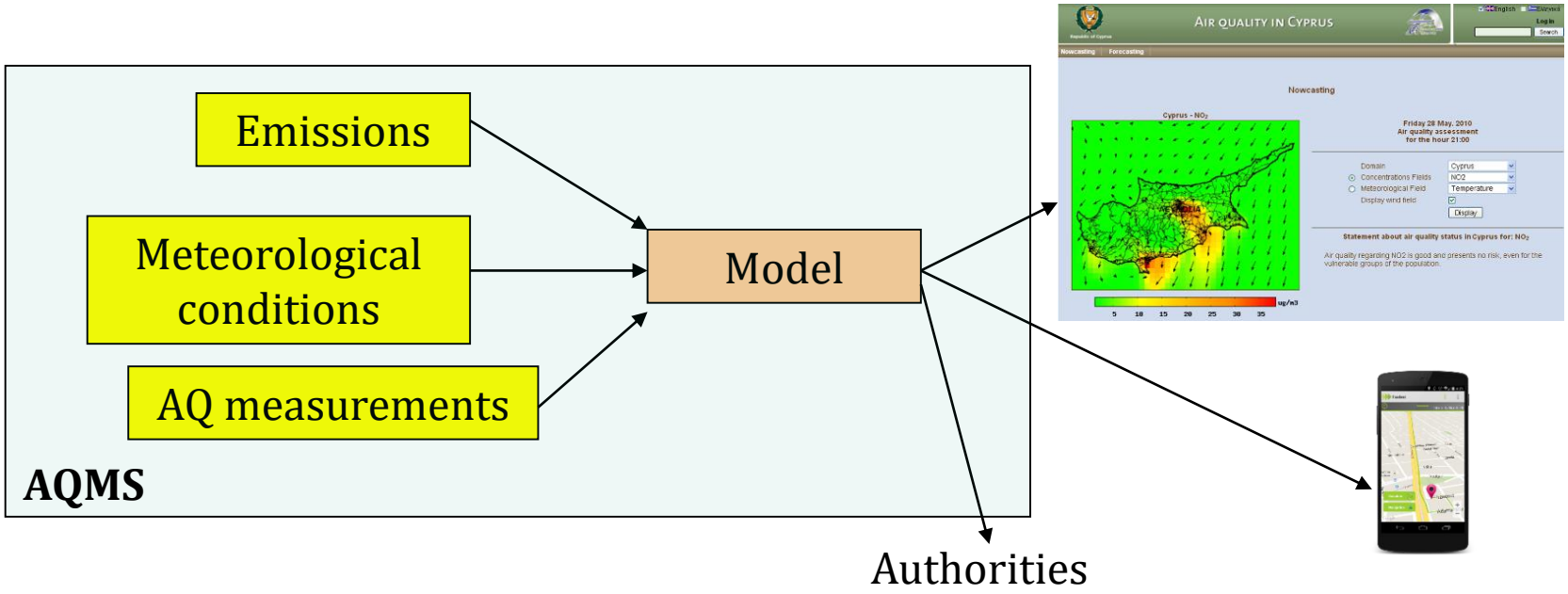
The role of Air Quality Management Systems in activity and emissions scenario assessment



AUTh/LHTEE'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 $PM_{2.5}$

AUTh/LHTEE has deployed AQMSs with operational features in Thessaloniki, Greece and Nicosia, Cyprus

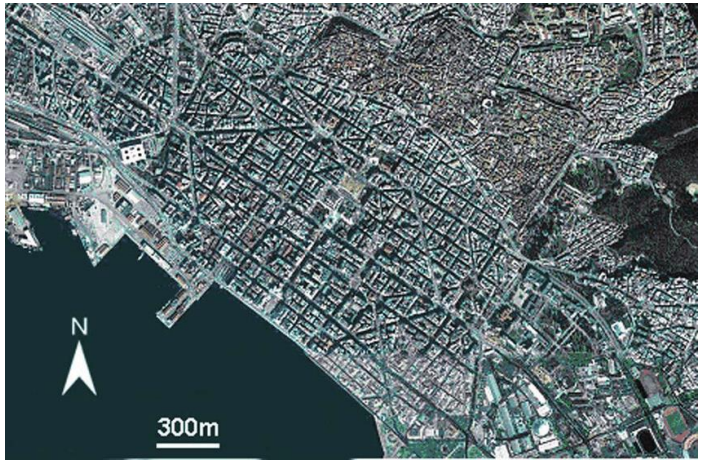


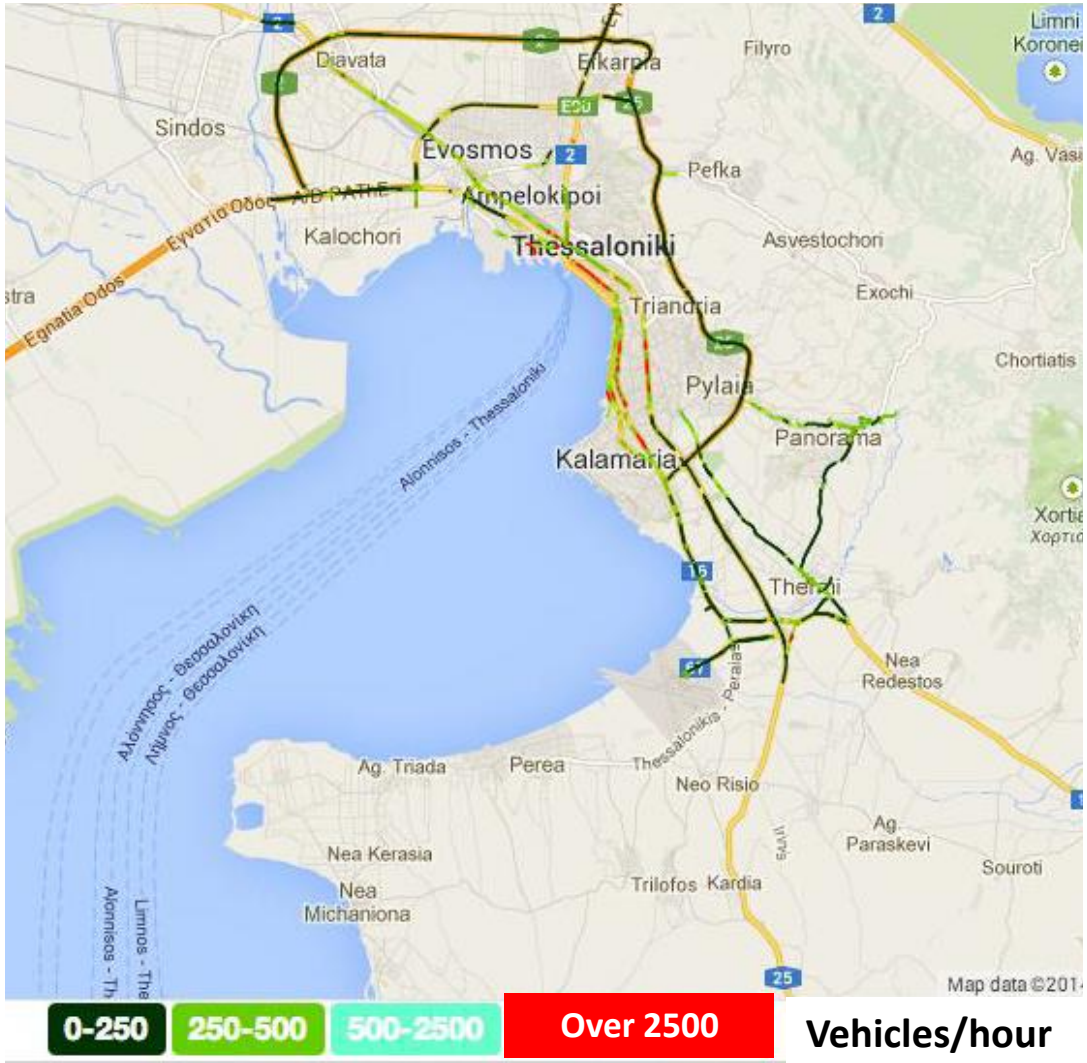
- Present-hour and next-day AQ estimates for the whole region and zoomed over urban areas
- Informational messages about the air quality situation are automatically displayed on the webpage, can also be sent to smart devices (phones).

Case study
Thessaloniki, Greece

City features:

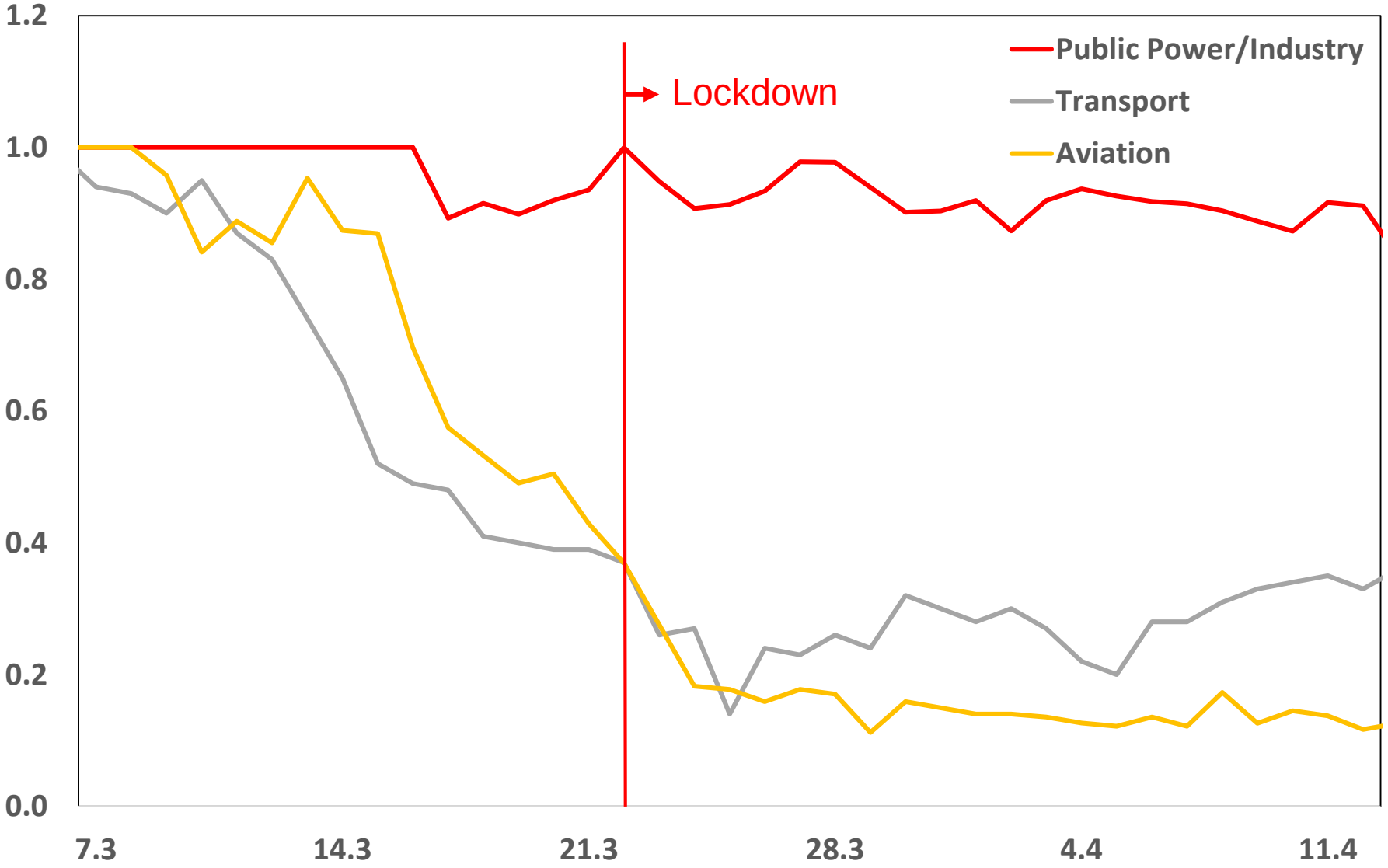
- Population: 811000 inhabitants (Metropolitan city 2019)
- Climate, Köppen Classification: Cfa, Humid Subtropical Climate
- Per capita GDP: 20.324,25 USD (2018)
- 493 cars per 1000 inhabitants (2017, Statista)
- Urban structure: Compact with corridor features



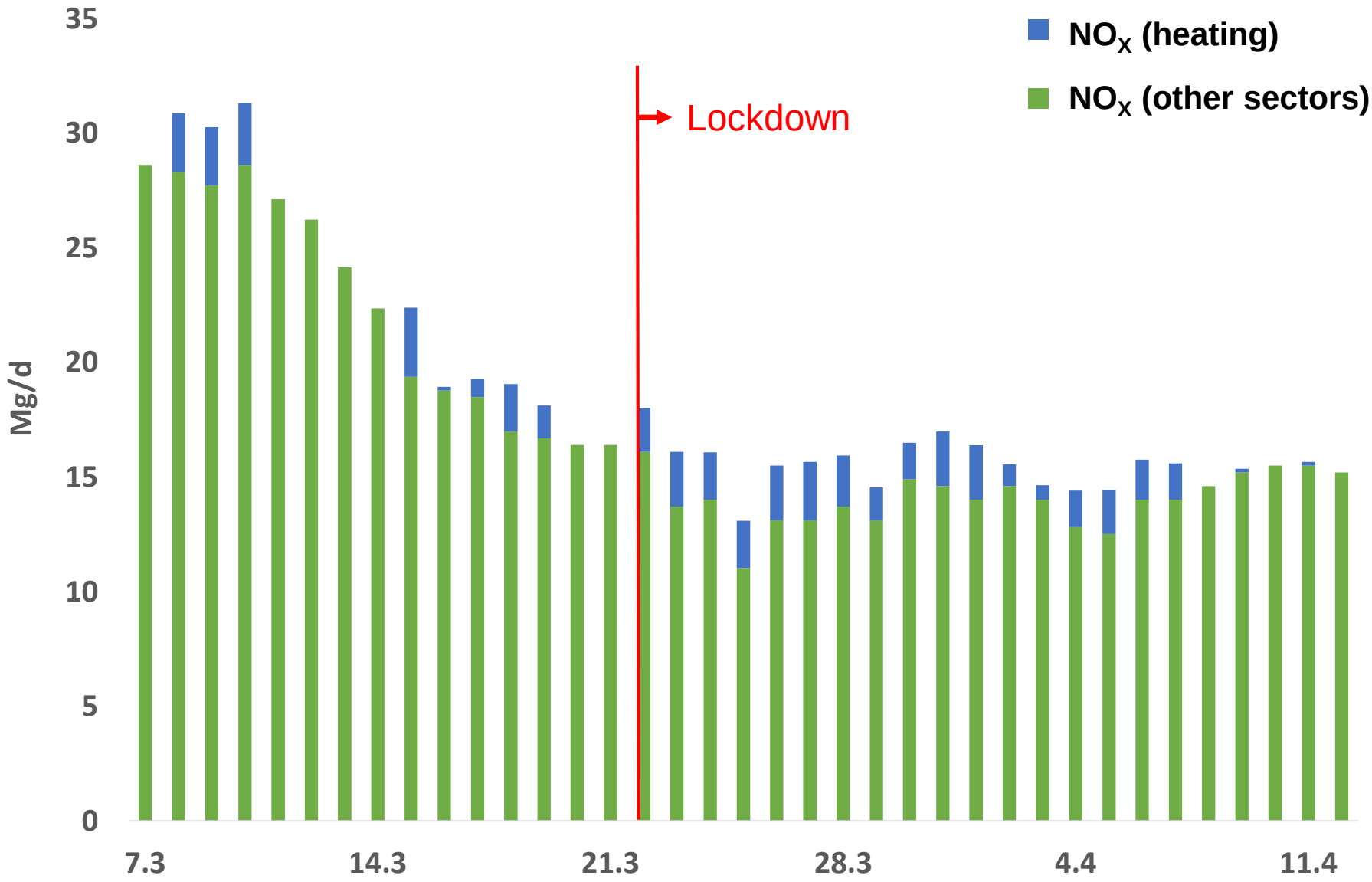


Traffic flow in Thessaloniki (from Gavanas et al., 2014)

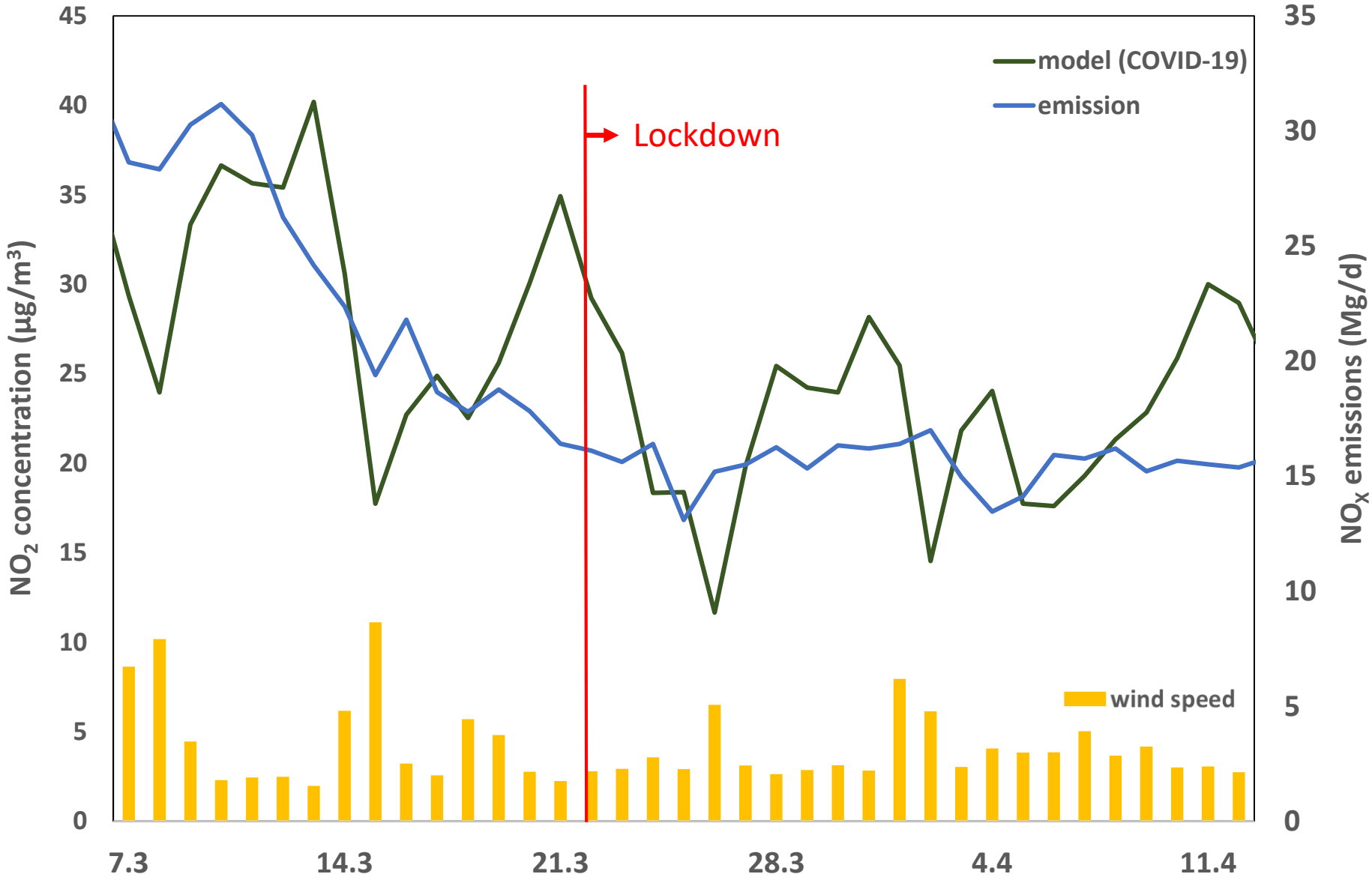
Thessaloniki - Activity reductions (Copernicus – CAMS estimates)



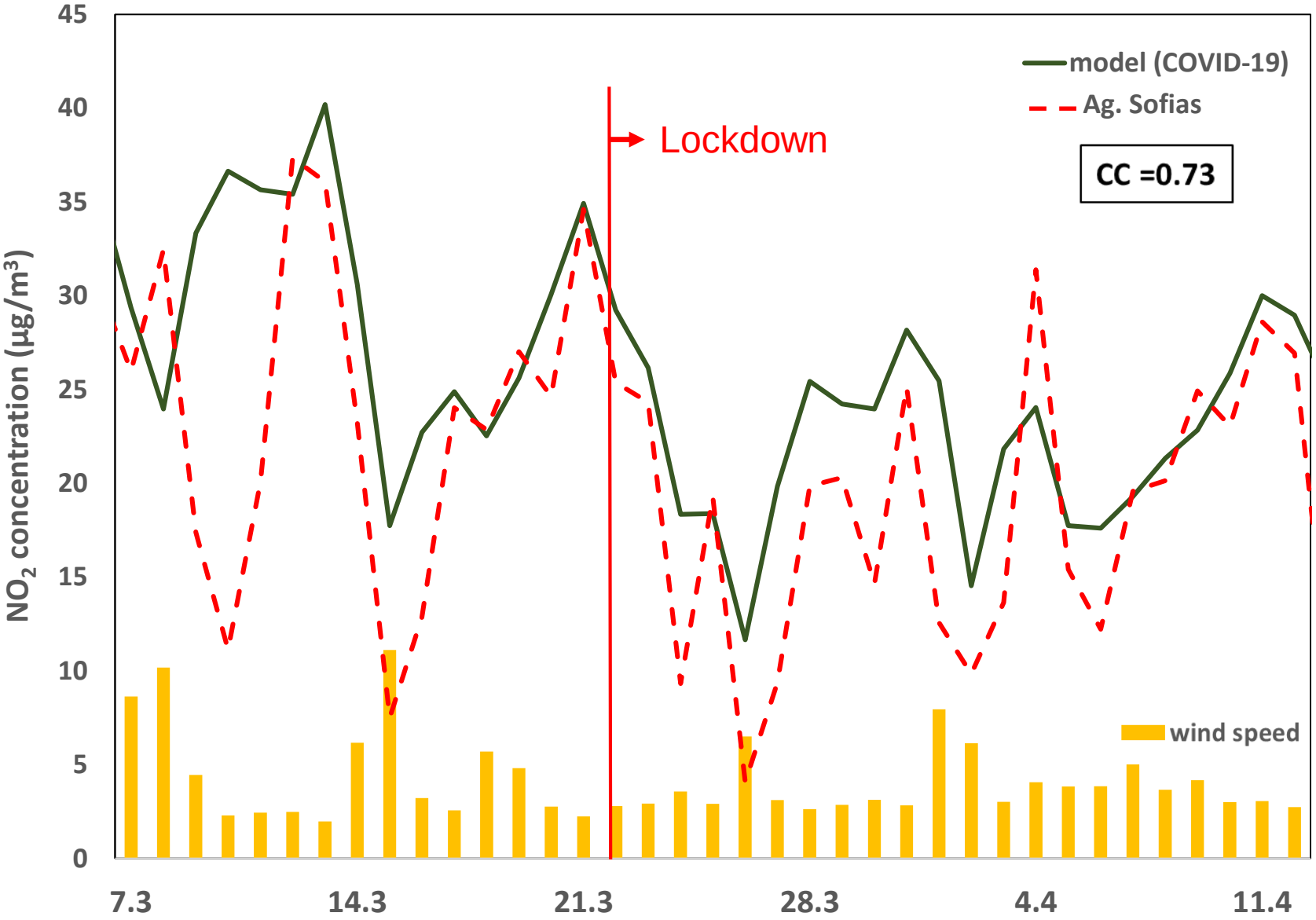
Thessaloniki - NO_x emissions



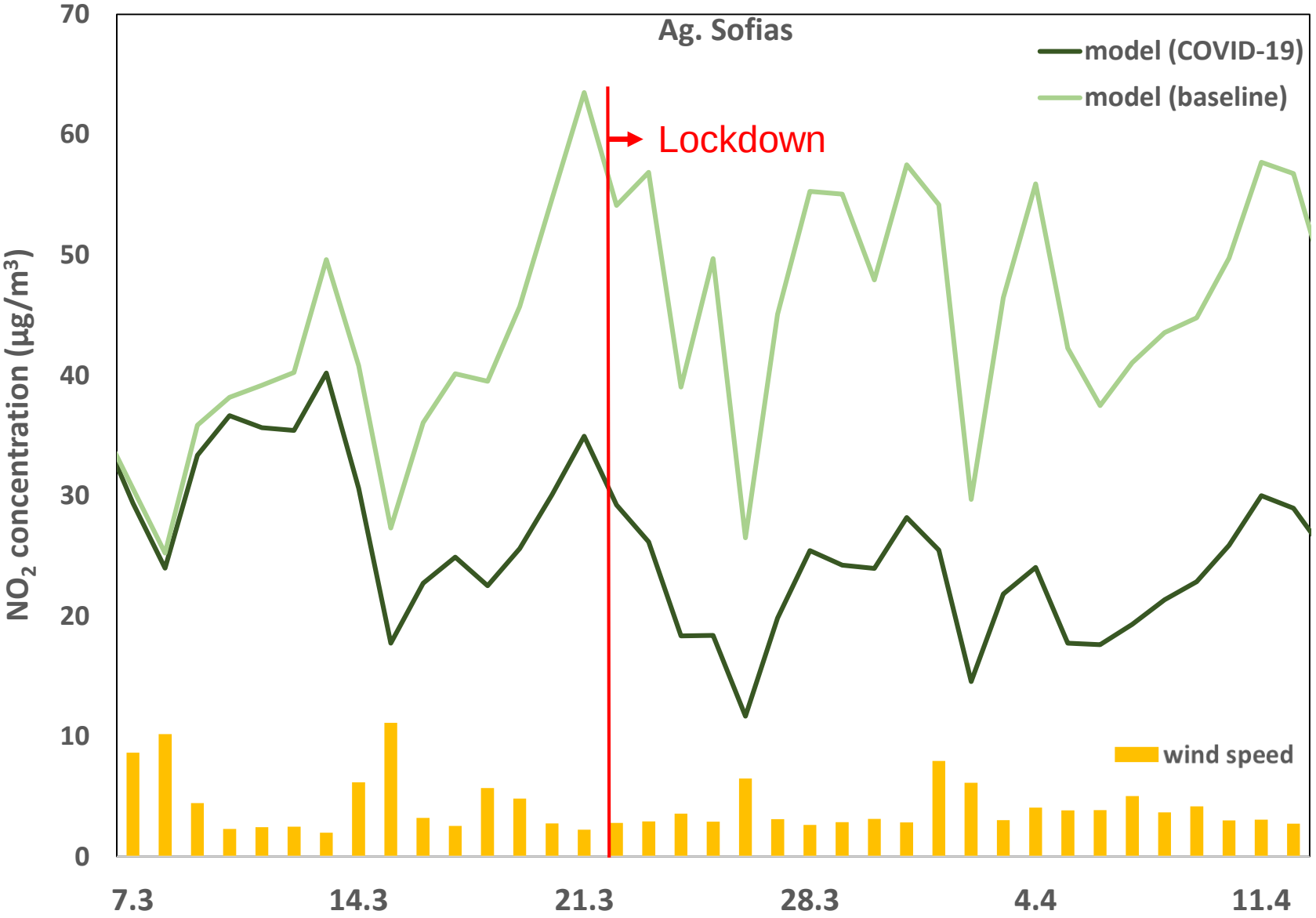
Thessaloniki - NO_2 (1/3)



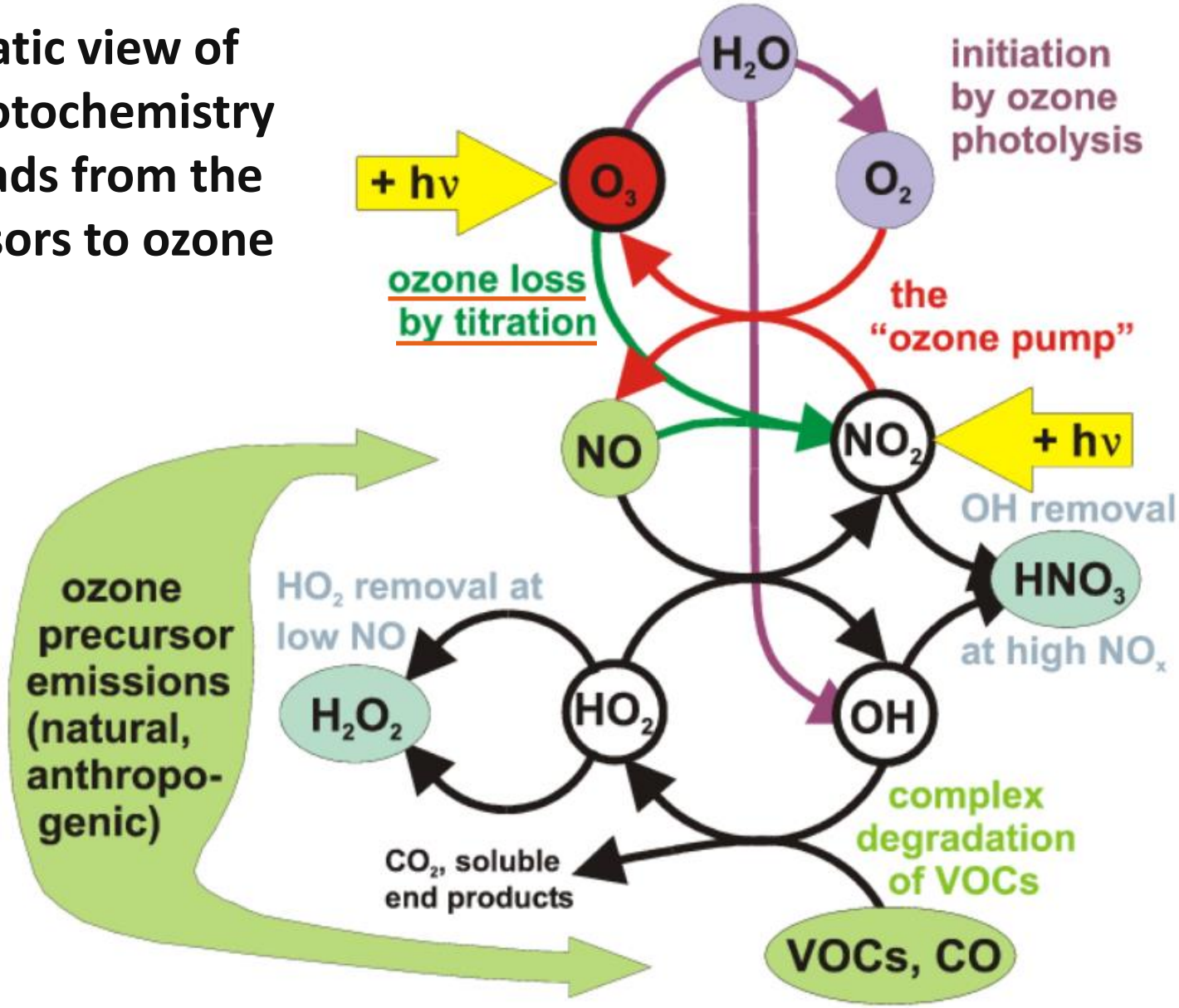
Thessaloniki - NO_2 (2/3)



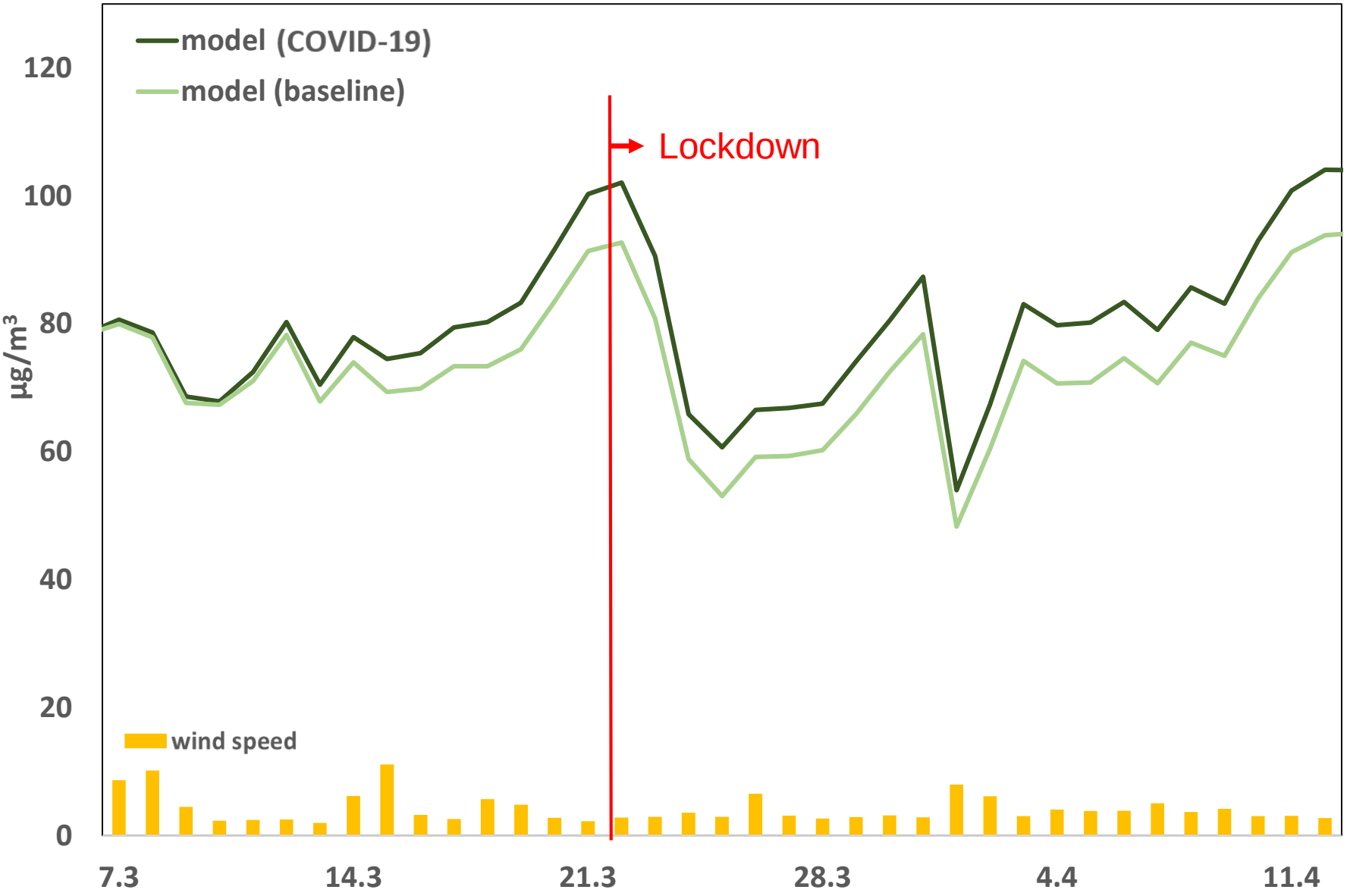
Thessaloniki - NO_2 (3/3)



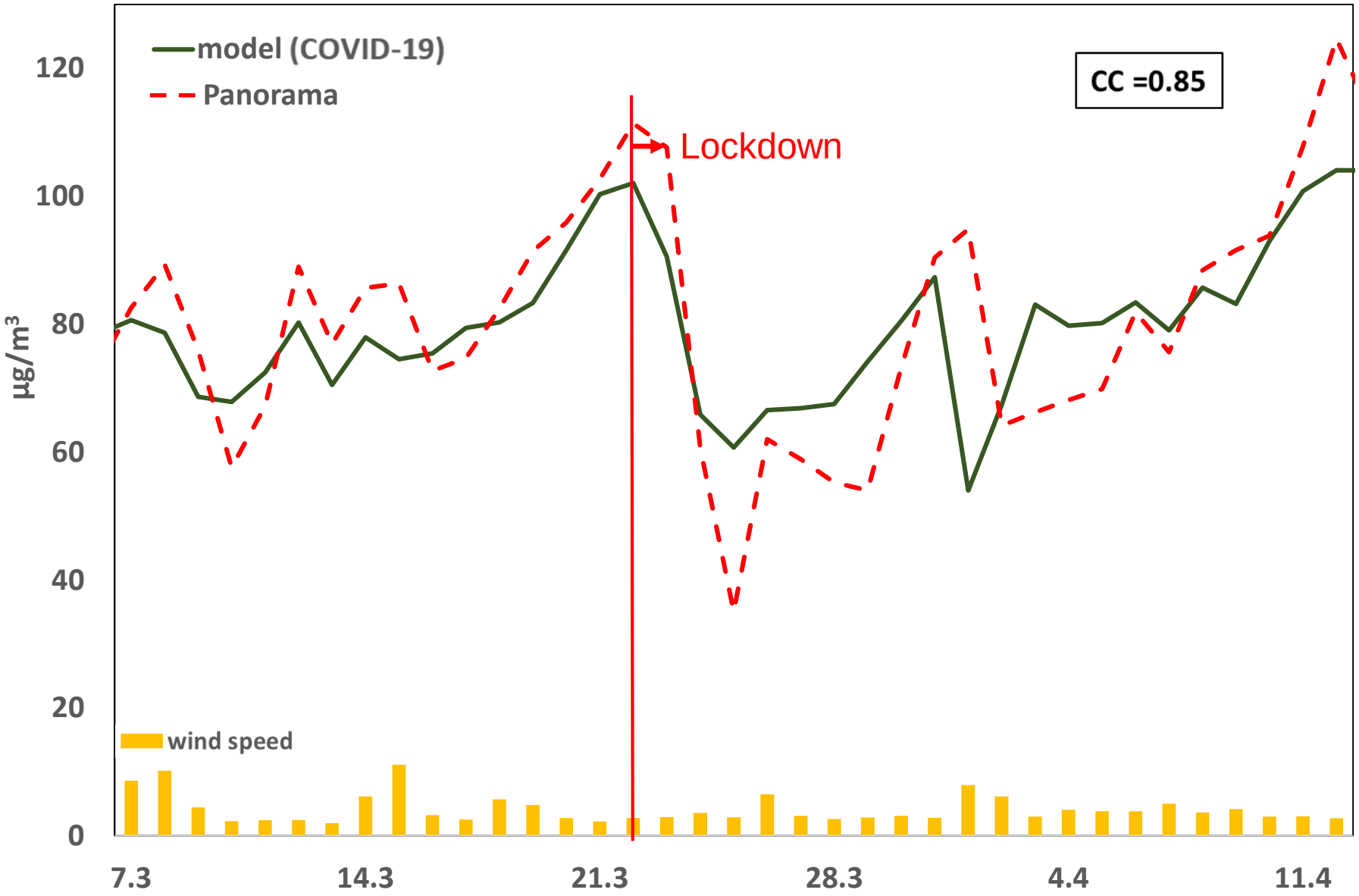
Schematic view of the photochemistry that leads from the precursors to ozone



Thessaloniki (suburb) - O_3 (1/2)



Thessaloniki (suburb) - O_3 (2/2)



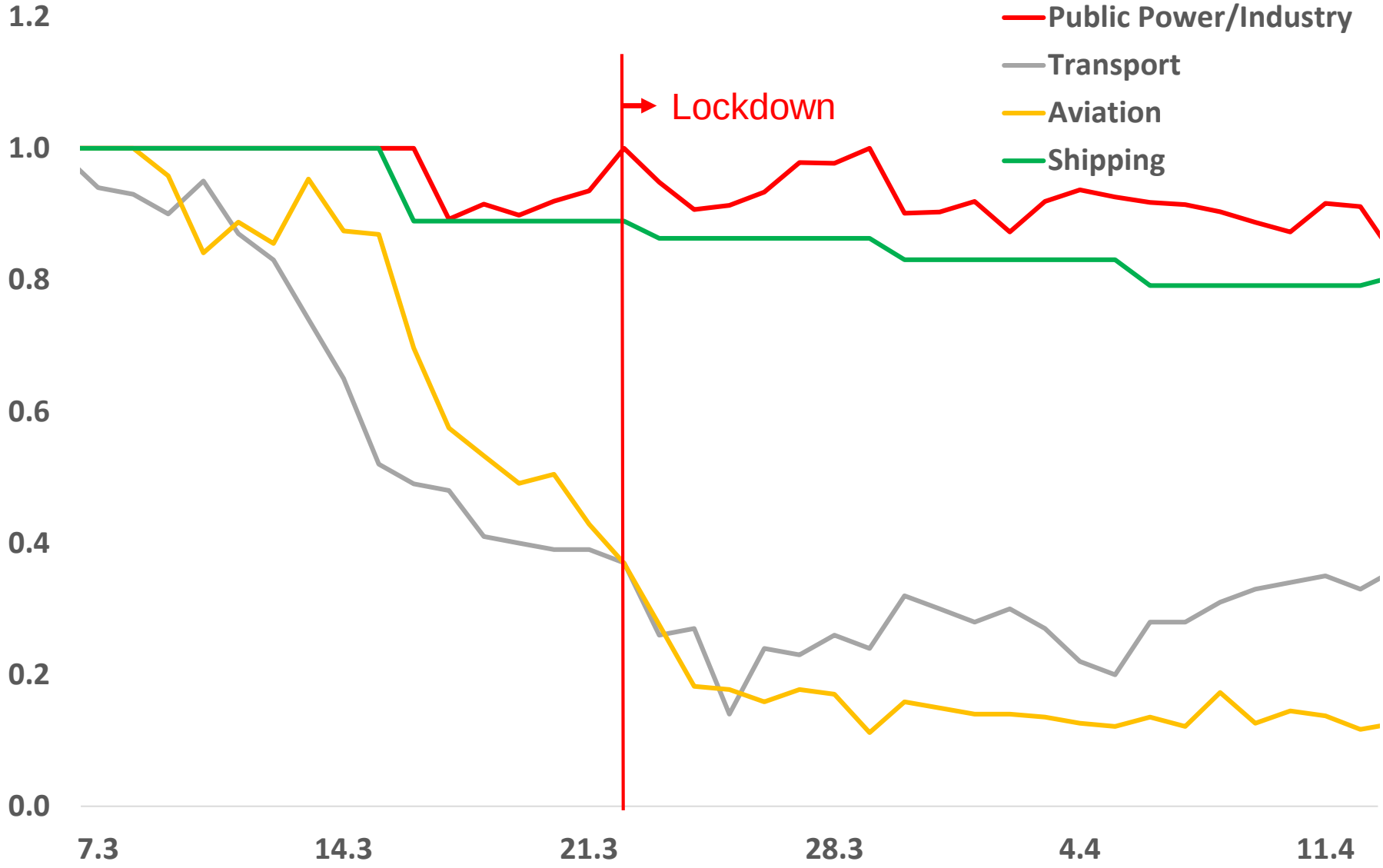
Case study
Nicosia, Cyprus

City features:

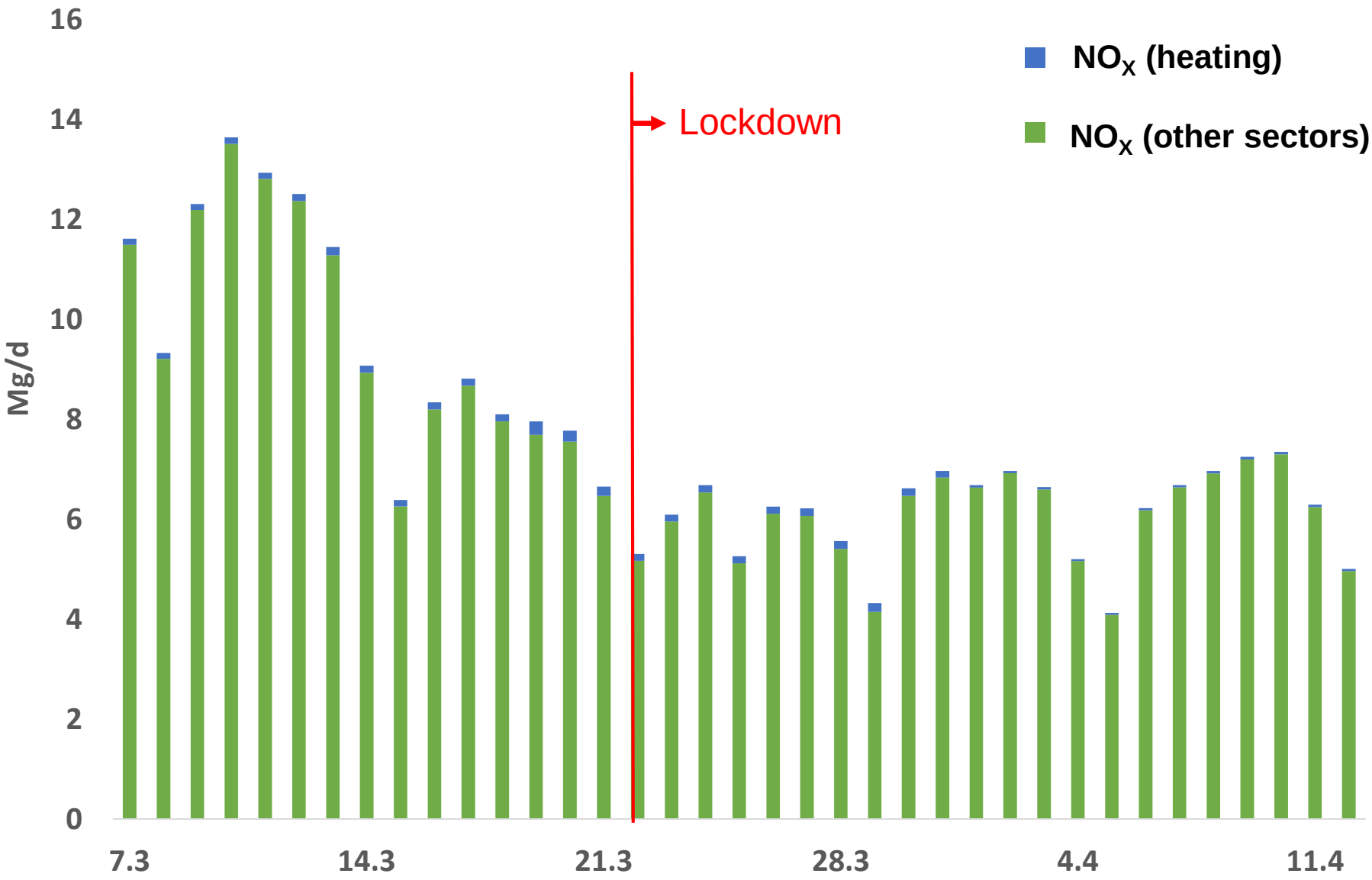
- Population: 332.200 inhabitants (2020)
- Climate, Köppen classification: Bsh, Mid-Latitude Steppe and Desert Climate
- Per capita GDP: 28.159,30 USD (2018)
- 595 cars per 1000 inhabitants (2016, Statista)
- Urban structure: radial expansion, with the existence of a widespread/extensive centre

Traffic flow information in Nicosia from DIAVLOS system

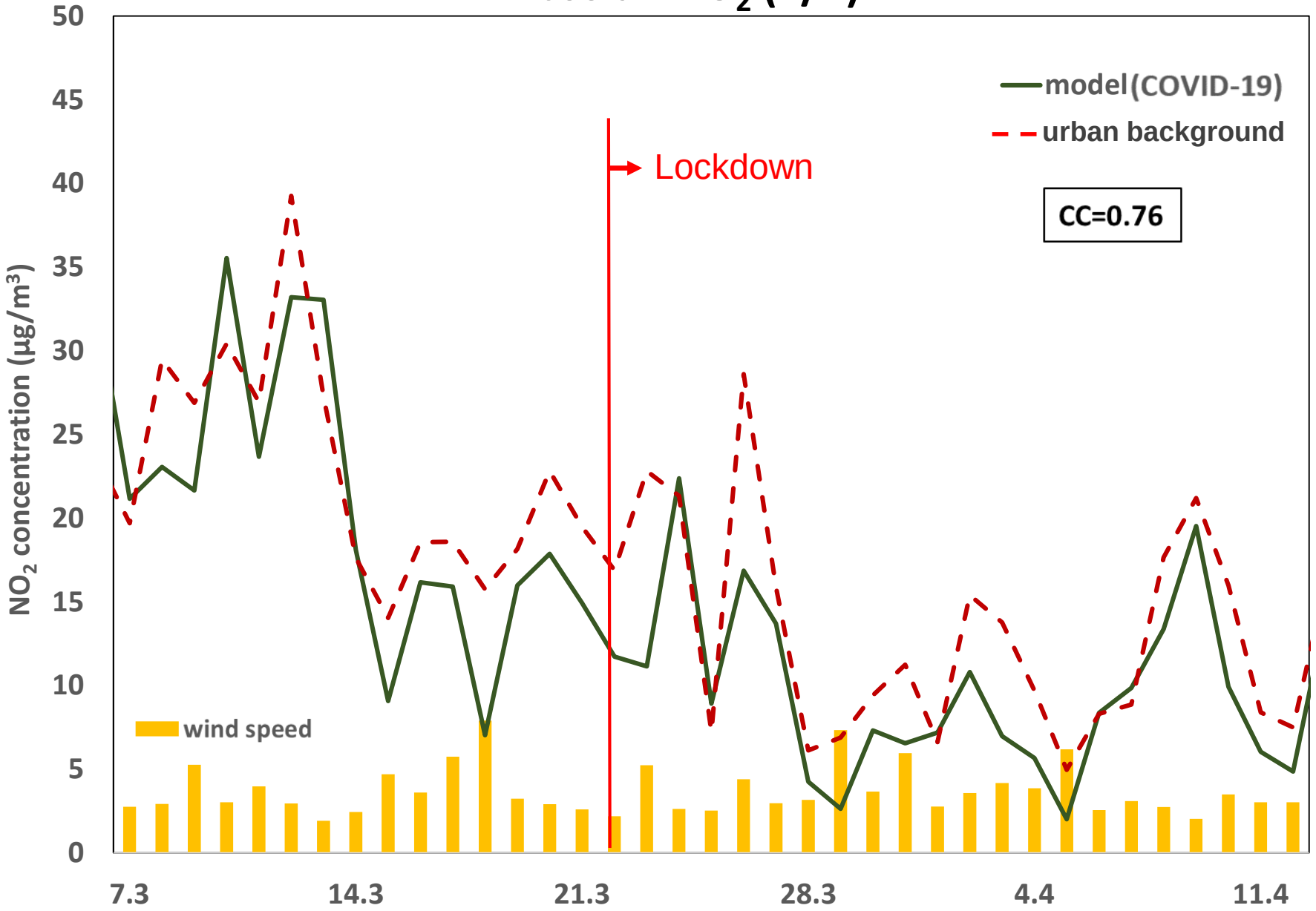
Nicosia - Activity reductions (Copernicus – CAMS estimates)



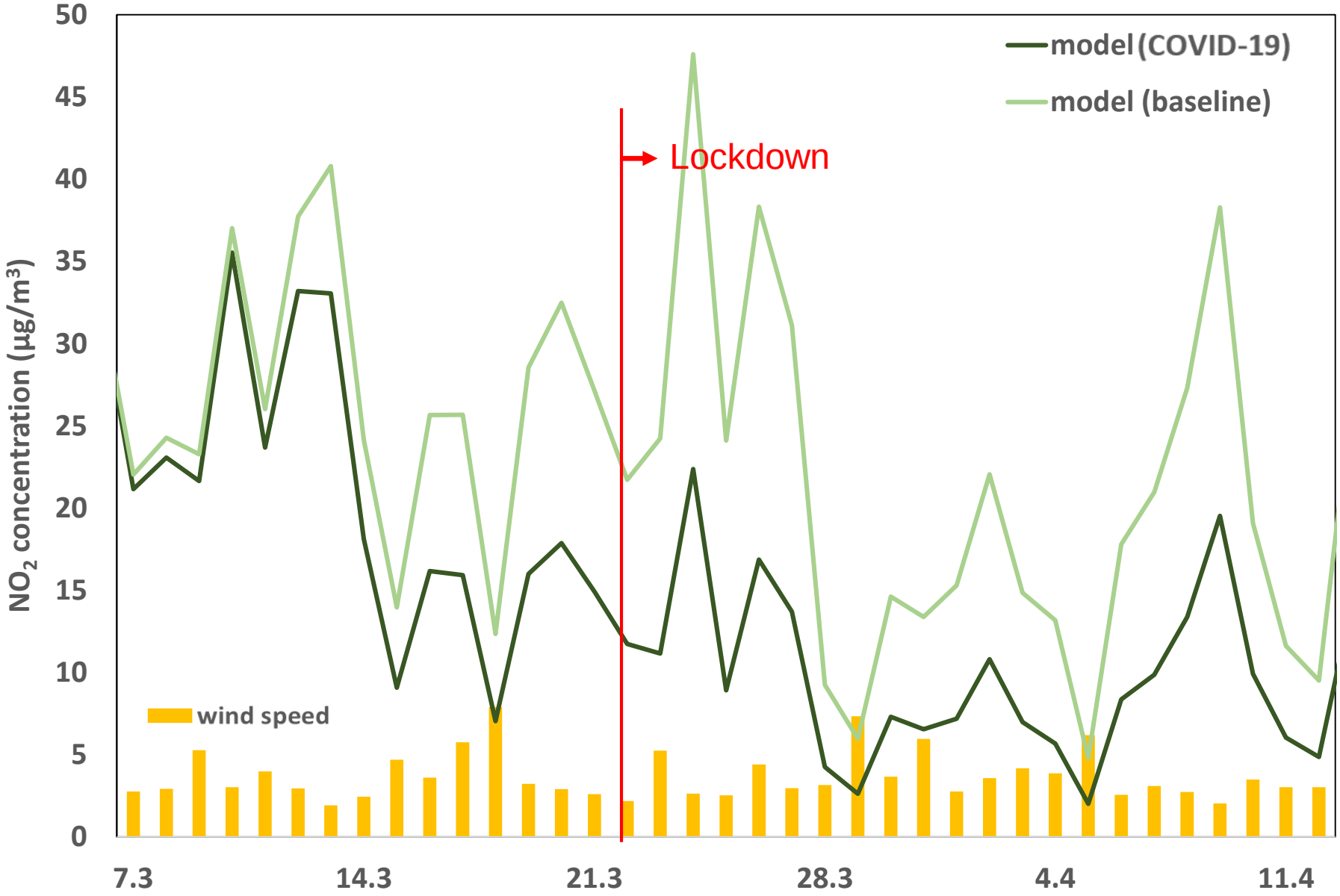
Nicosia - NO_X emissions



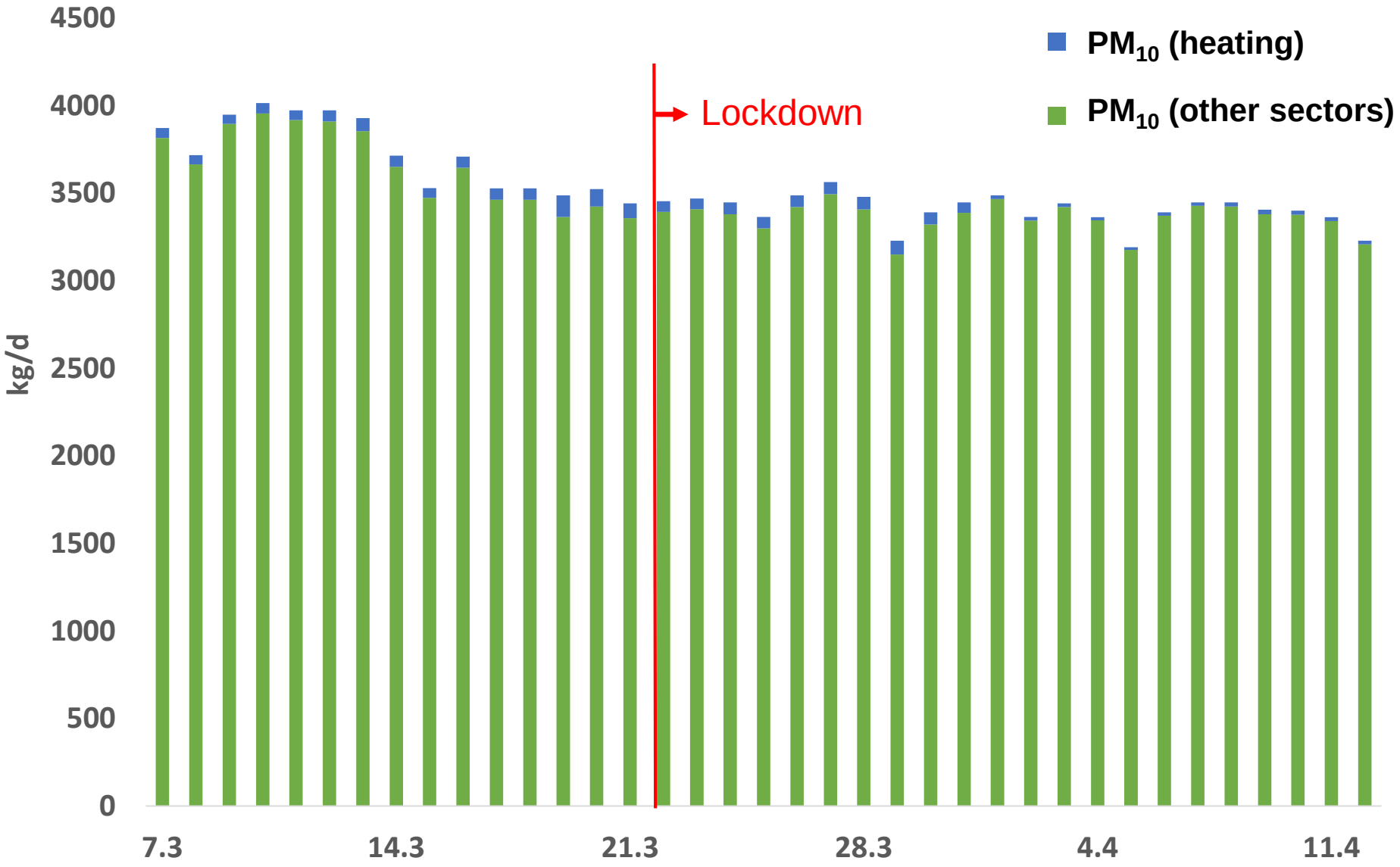
Nicosia - NO_2 (1/2)



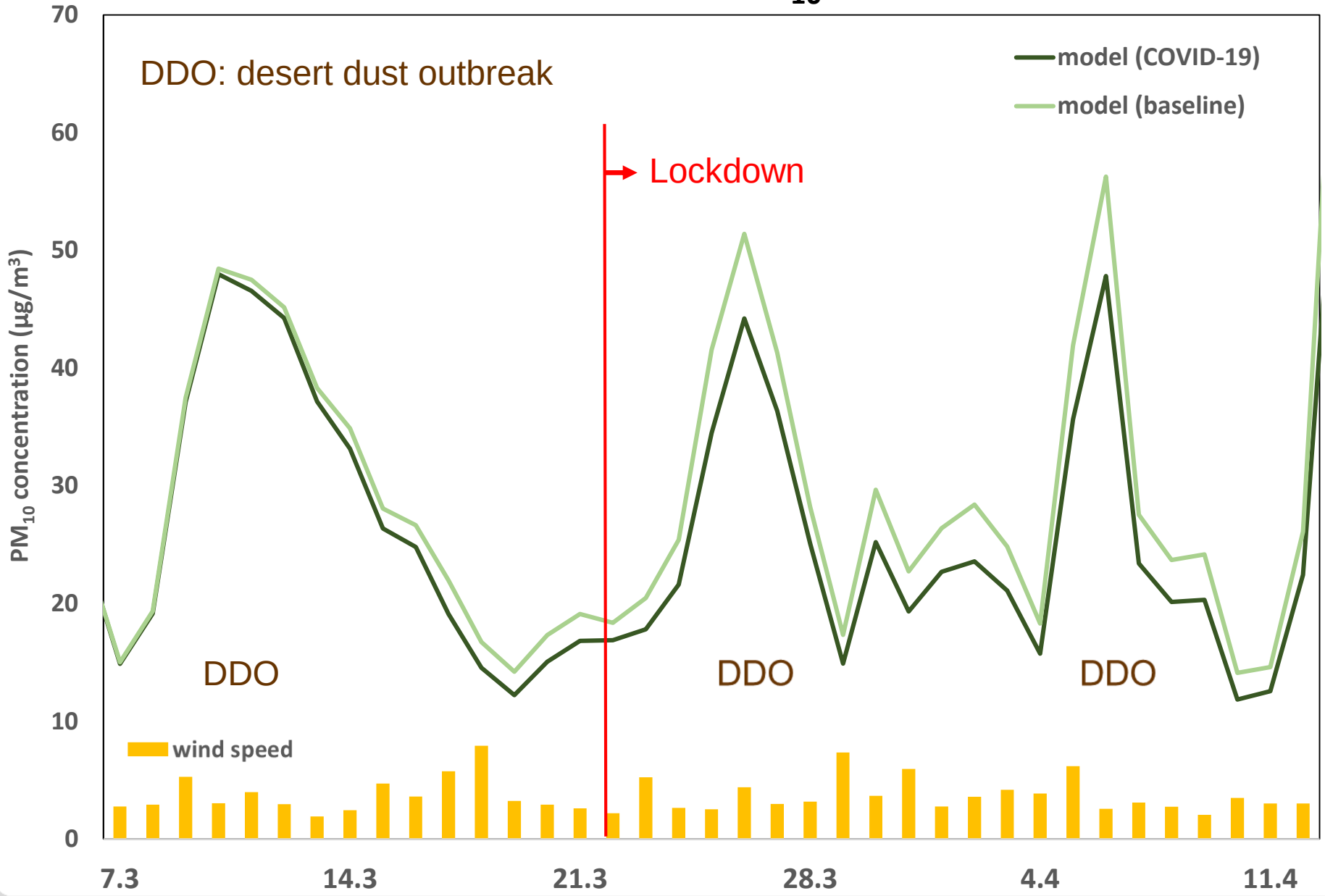
Nicosia - NO_2 (2/2)



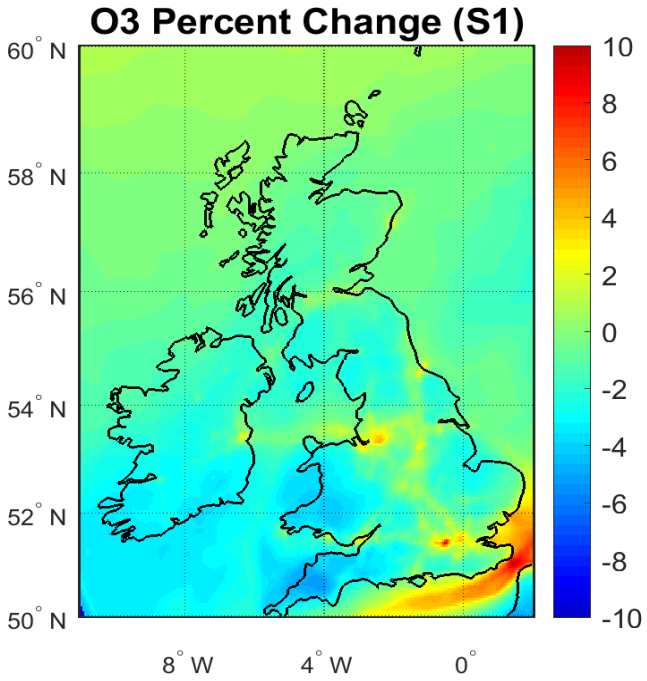
Nicosia - PM_{10} emissions



Nicosia – PM_{10}

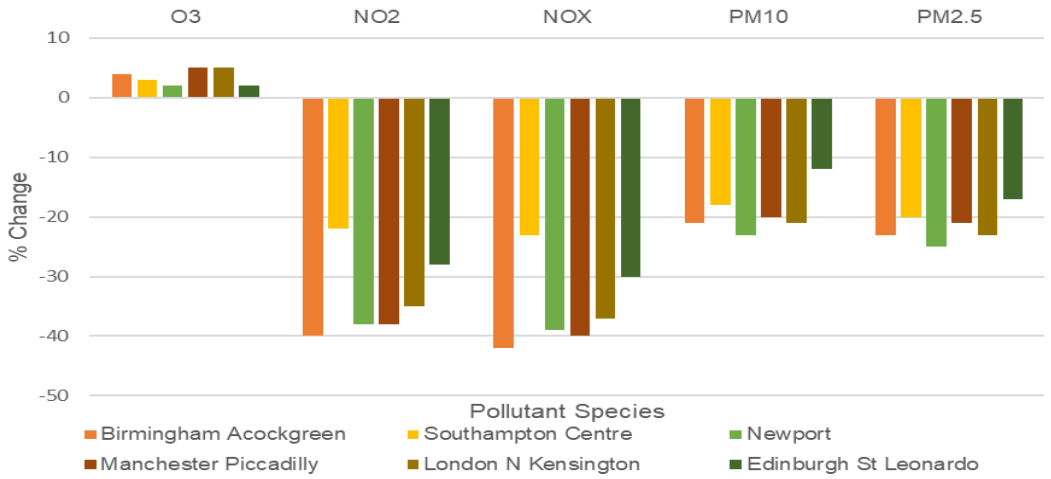


Calculations for the 1st UK lockdown period using the WRF-CMAQ modelling system

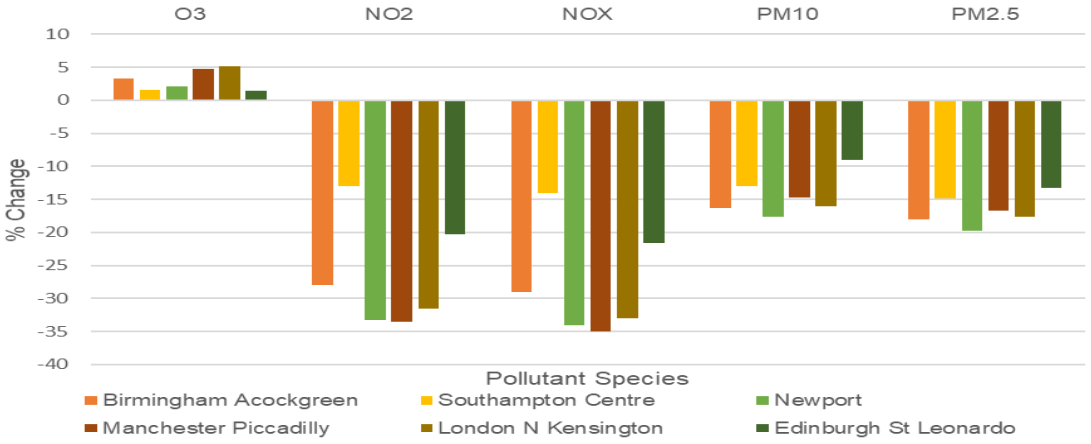


- Most of the changes can be attributed to reductions in road traffic emissions
- O_3 as a secondary pollutant is affected (increased) near urban centres

Urban locations: Scenario 1 – overall emission changes



Urban locations: Scenario 2 – reductions in road traffic only



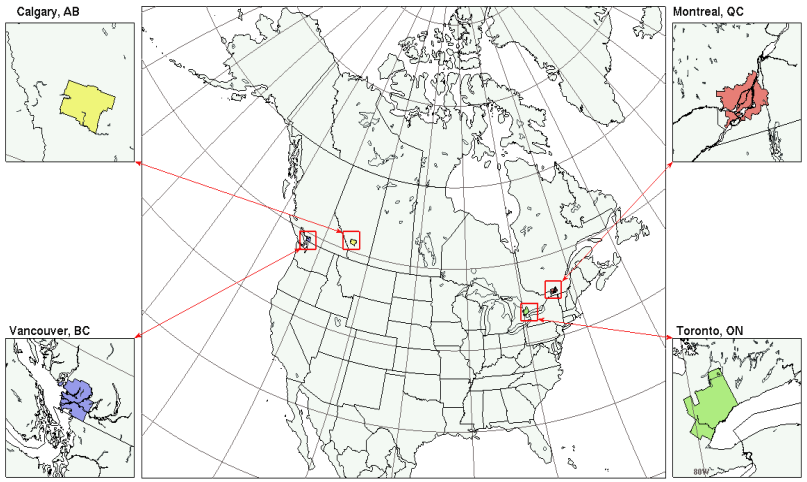
Lockdown period 24 March to 26 April 2020

Environment and Climate Change Canada

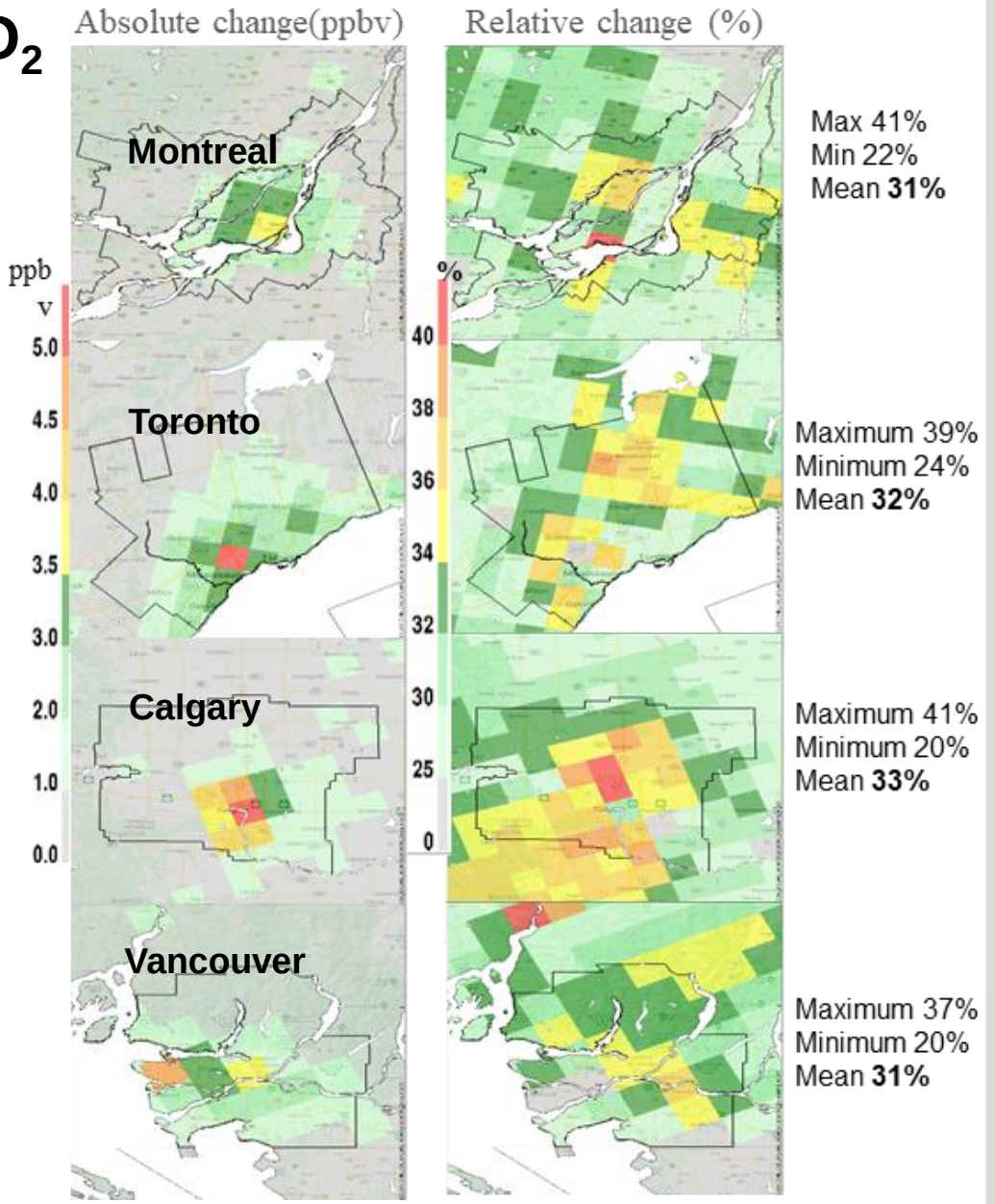
Air Quality Policy-Issue Response Section

Air Quality Research Division

Canada



- **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



Conclusions

- Large reductions in urban NO_2 concentrations and corresponding ozone increases during the springtime 2020 lockdown point to an ***important impact of road traffic reductions*** in urban centres. PM was much less affected.
- ***Only measurements are insufficient*** for quantifying the significant influences of other emission sectors, weather variability and long-range transport.
- Operational and hindcast ***air quality models are a powerful tool*** in disaggregating the effect of the aforementioned factors.
- "Inverse" modelling methods and other novel approaches are expected to further allow ***widening the modelling capabilities***.
- The "***largest scale experiment ever***" in air pollution research will result in a significant improvement of validation practices regarding pollutant dispersion models.

Thank you for your attention!

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