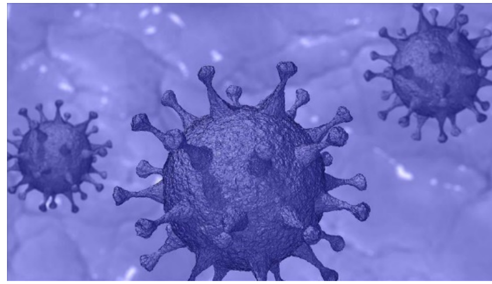
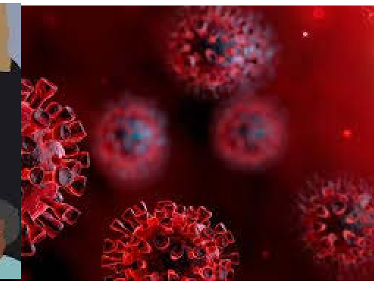




FIRST CONCLUSIONS FROM THE WMO/GAW COORDINATED STUDY ON IMPACTS OF COVID - 19 LOCKDOWN MEASURES ON AIR QUALITY:
AN OBSERVATIONAL AND MODELLING ANALYSIS

Ranjeet S Sokhi, Vikas Singh, Xavier Querol, Sandro Finardi, Maria Fatima Andrade, Rebecca Garland, Radenko Pavlovic, Admir Admir Créso Targino, Shaofei Kong, Kester Momoh, Rajasree Meethal, Sabine Fritz, Push Raj Tiwari, Marc Guevara, Hugo Denier van der Gon, Vincent-Henri Peuch, Greg Carmichael, Oksana Tarasova, Alexander Baklanov, Lu Ren
and many global contributors

Format of presentation

- Background to the WMO/GAW study
- Observational analysis ~ 45 cities
- Improvement in air quality compared to WHO guidelines
- Modelling case study for UK
- Key conclusions and where next?

WMO/GAW Coordinated study

Aim: To understand how air quality and population exposure has changed in cities as a result of measures to control the spread of the COVID-19 virus

Specific objectives:

1. To quantify the **changes in air pollutant concentrations** on local to regional scales
2. To understand how the **balance and mix of local and regional contributions** has shifted for air pollutant species
3. To understand **how changes in air quality are influenced by factors** e.g. location, characteristics of cities, demography, emissions, weather, climate
4. To gain new insight into the **performance of air quality prediction and forecasting models** for quantifying changes in different air pollution regimes
5. To extend our understanding of the **effectiveness and implementation of strategies and measures** to improve urban air quality

Issues when designing the study

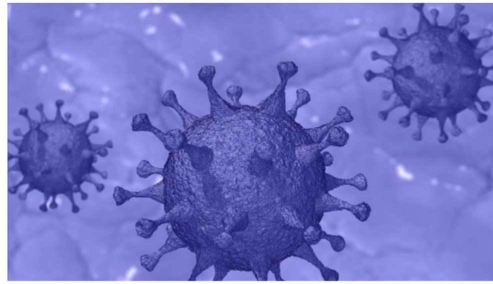
WHO declared COVID-19 as a pandemic on 11 March 2020

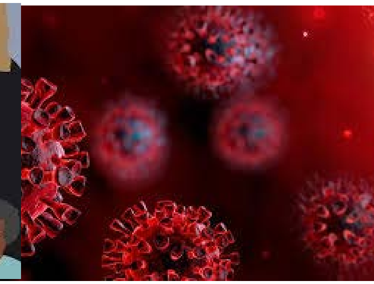
Varied timelines for strictness and relaxation of lockdown periods – how to define comparison periods e.g. China, SE Asia, Italy, France and Spain, UK etc…

Observational analysis - five periods defined

> **Meteorology -** Complexity of how to account for meteorological differences year to year
>
> **Community input** currently ~ 45 cities in the analysis

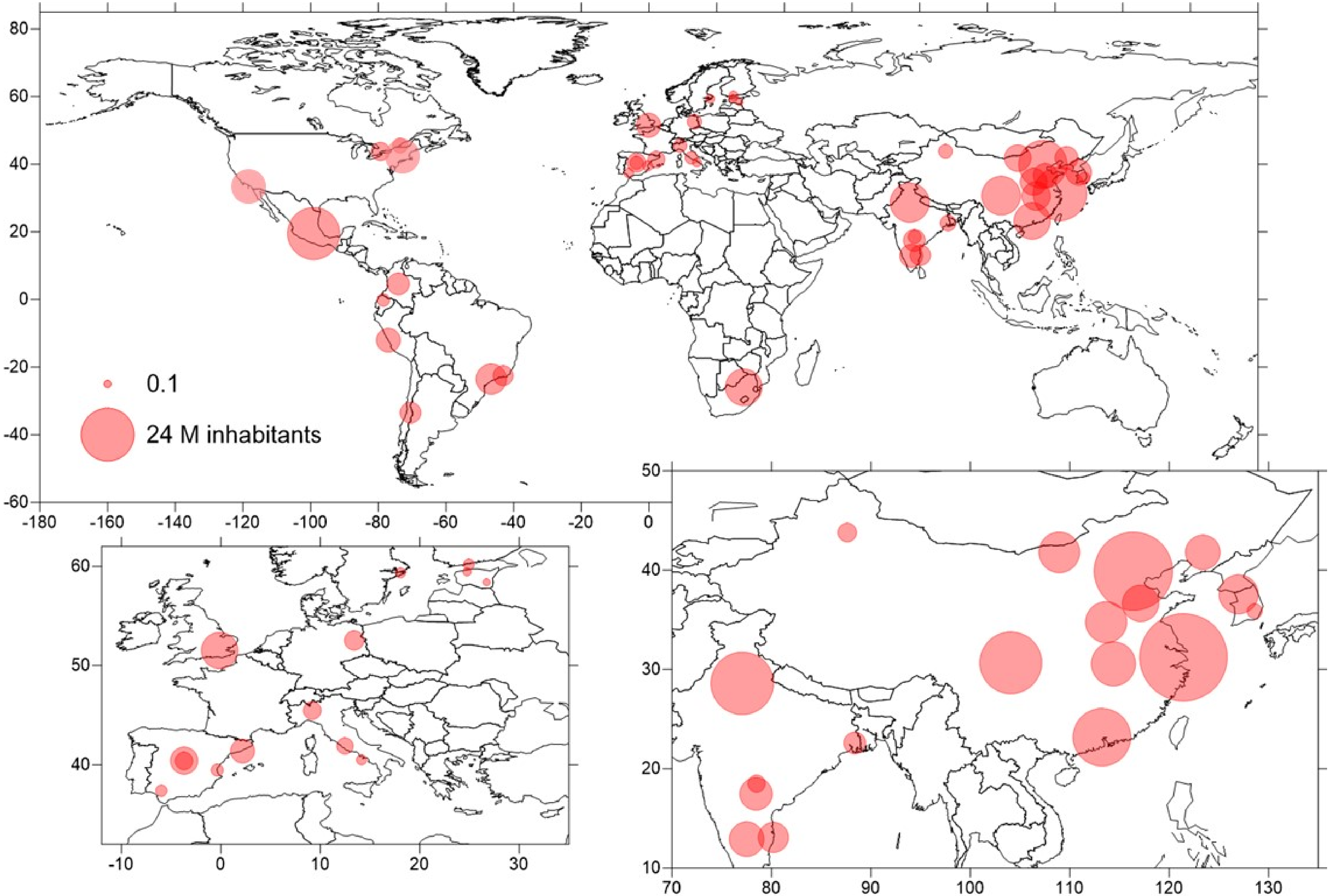
For modelling analysis two period defined - Pre-lockdown and lockdown periods





Observational study

First phase of analysis
~ 45 Global cities



Observational analysis

Five period defined from Feb 2020:

Pre-lockdown
Partial lockdown
Full lockdown
Partial relaxation
Full relaxation

Meteorological influences:

Average of five years of historic data used for comparison: 2019 - 2015

Station types:

Type - Traffic or Background
Subtypes – urban, industrial, regional rural, suburban, rural

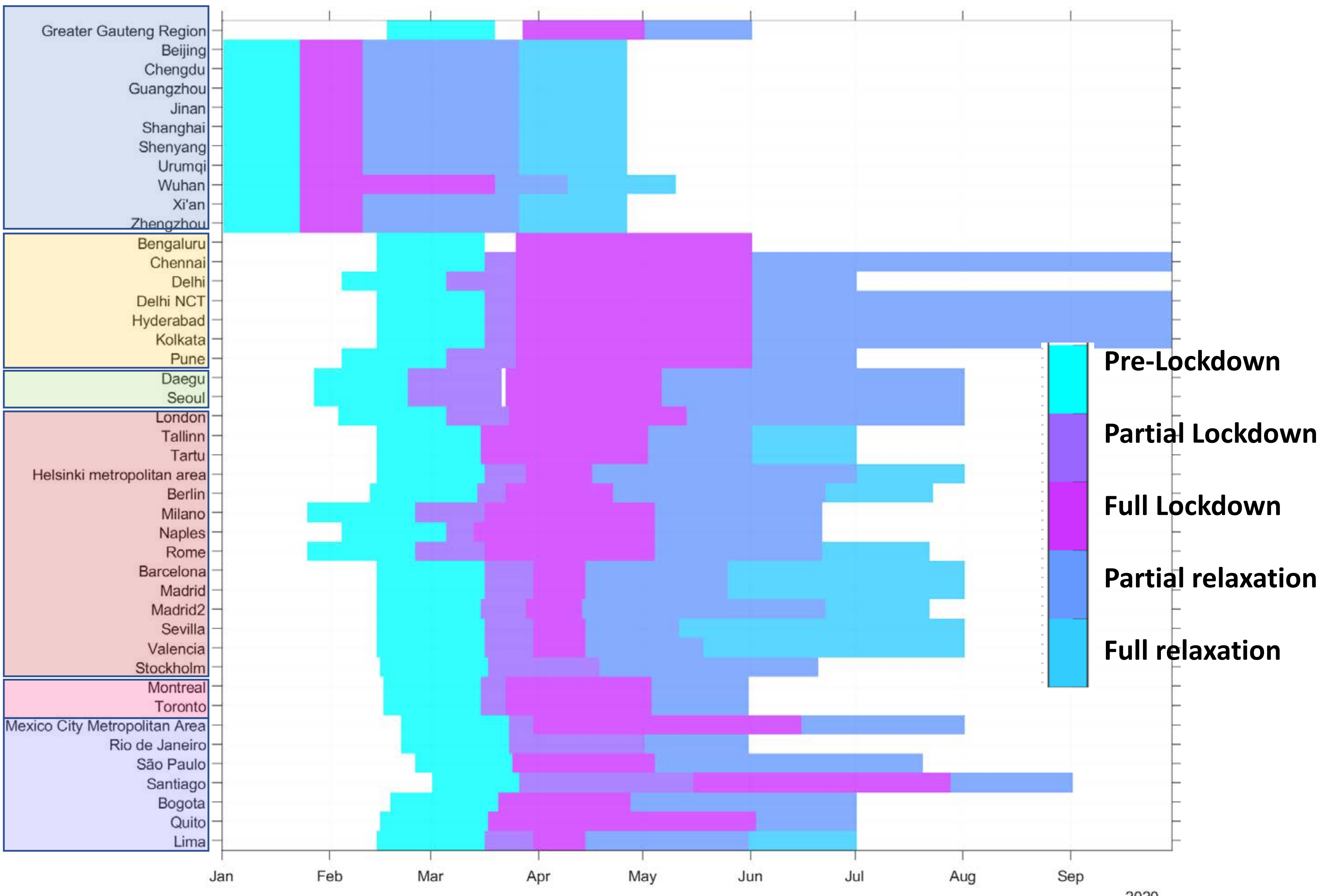
- 70% of ratified data

Analysis

Air pollutants: **PM10, PM2.5,** NO, **NO2, O3, CO**, SO2, CH4
Meteorological variables: u (10m), T(2m), RH (2m), radiation, precip.
Changes in air pollutant and met parameters:

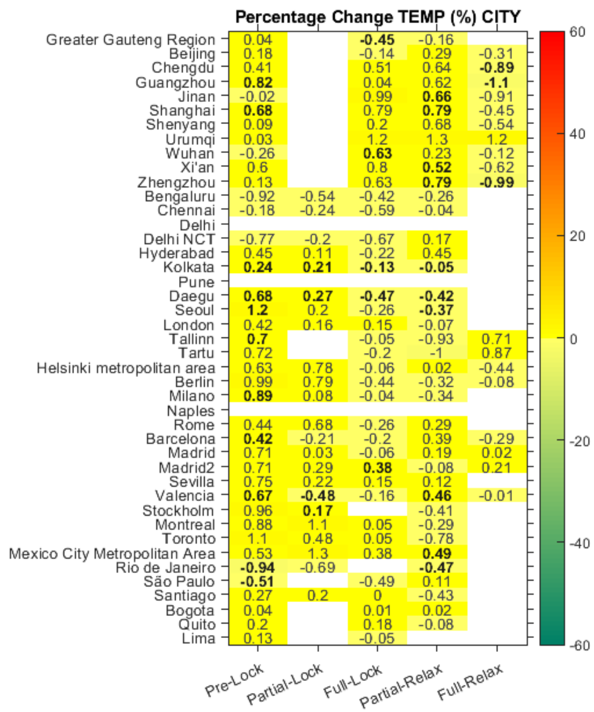
2020 compared to mean of 2015-2019
According to lockdown periods and station types

Lockdown periods across different cities

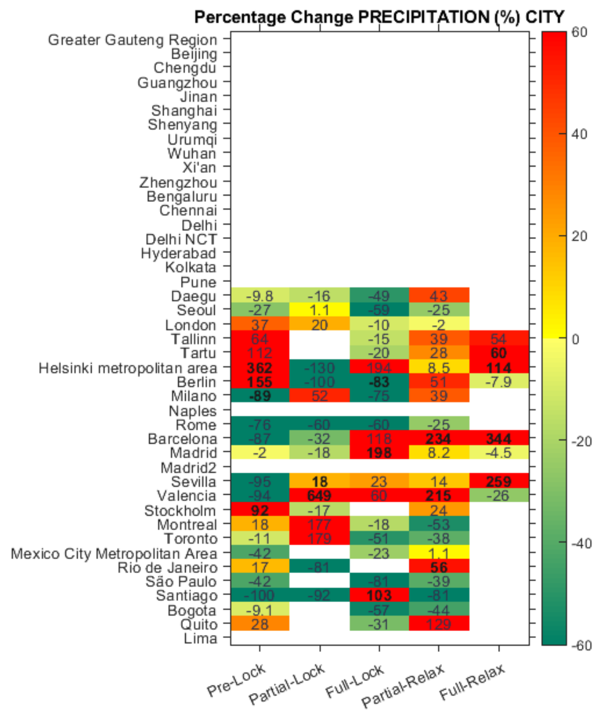


% Changes in meteorology paraemeters over different lockdown periods: comparison of 2020 to 2015-2019 mean

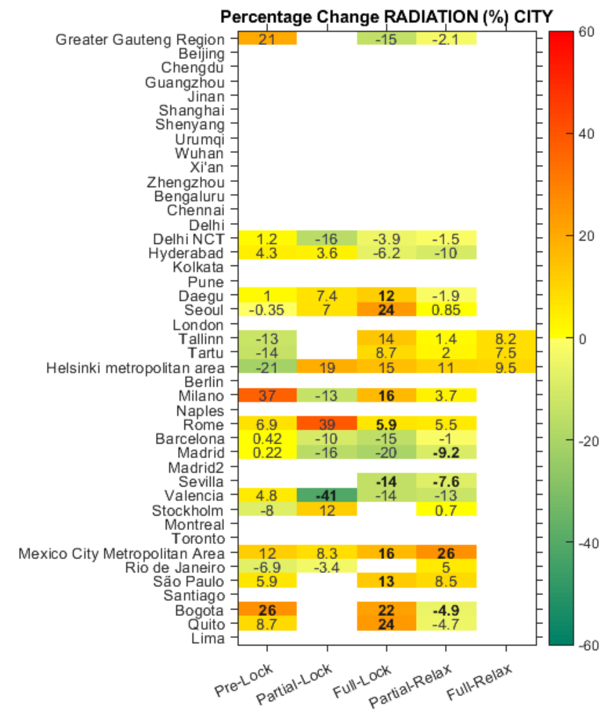
Temperature



Precipitation



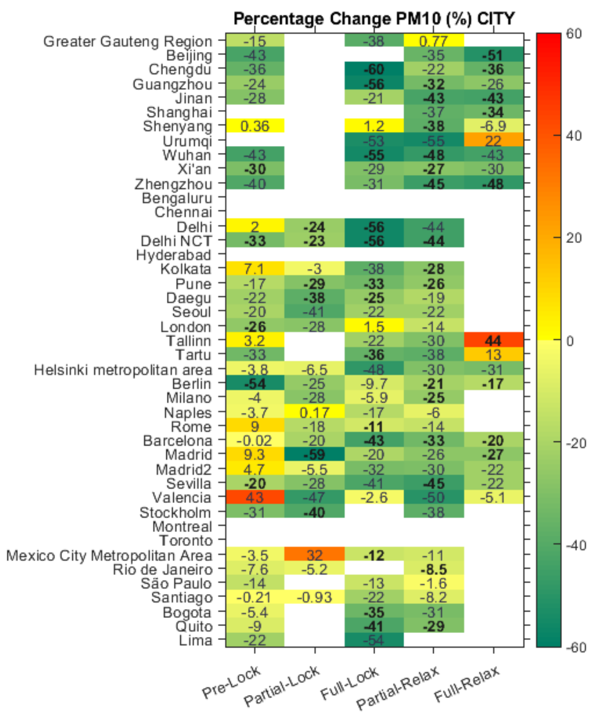
Solar Radiation



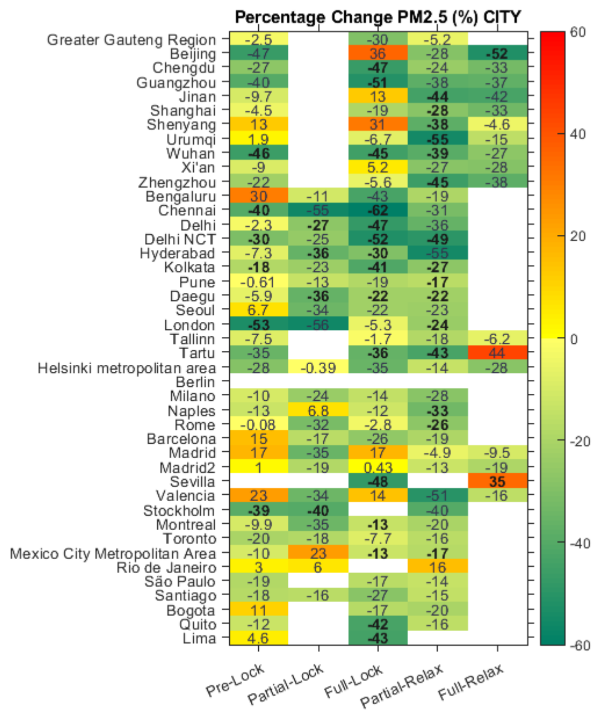
Other meteorological parameters: wind speed, RH

% Change in PM during different lockdown periods - comparison of 2020 to 2015-2019 mean

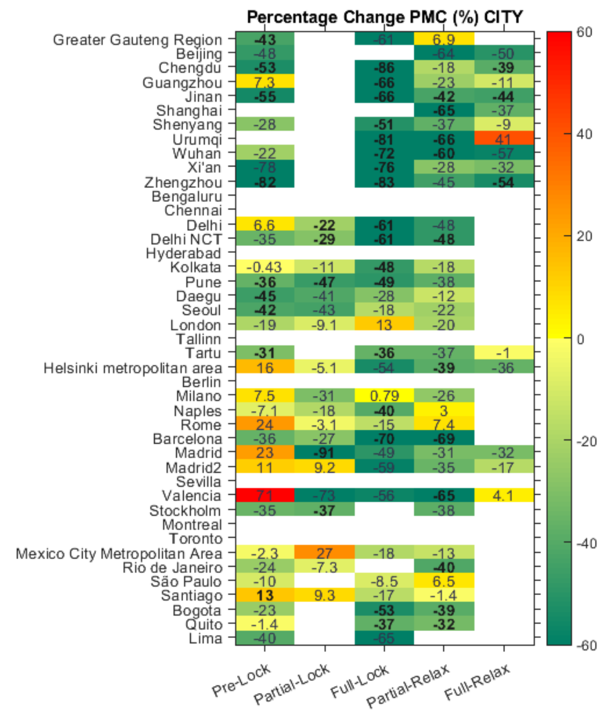
PM10



PM2.5

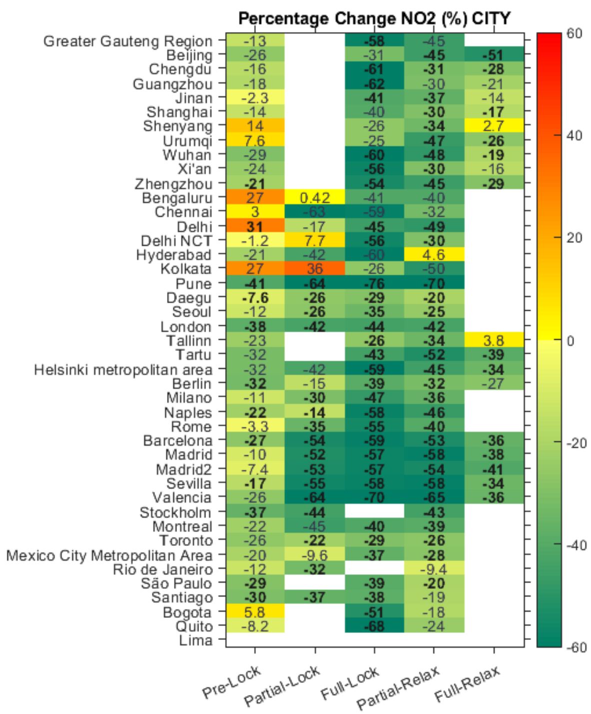


PMC

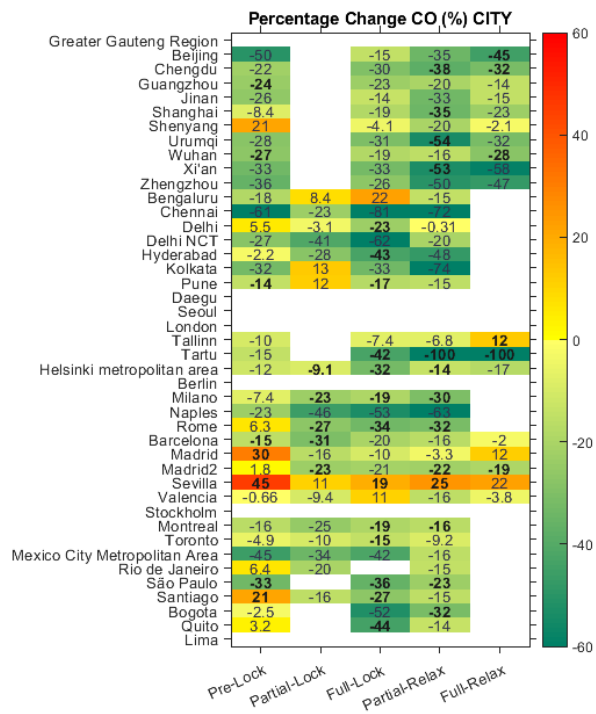


% Change in NO2, CO and CO/NOx ratio during lockdown periods - comparison of 2020 to 2015-2019 mean

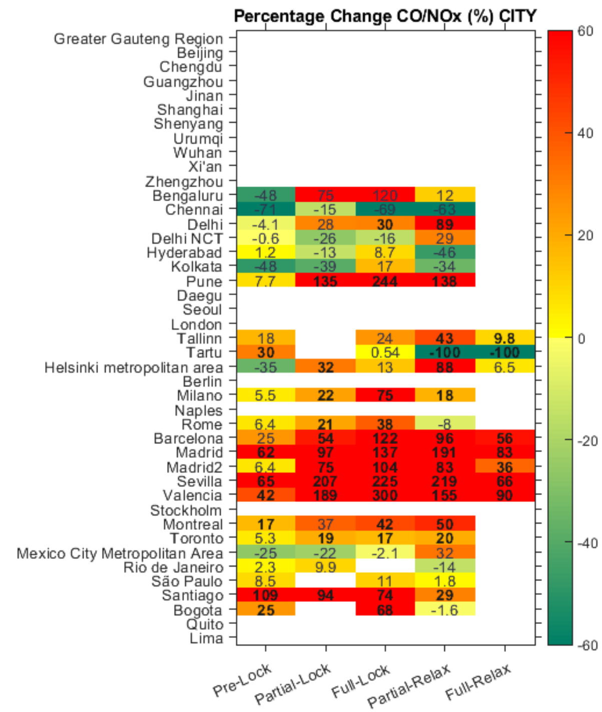
NO2



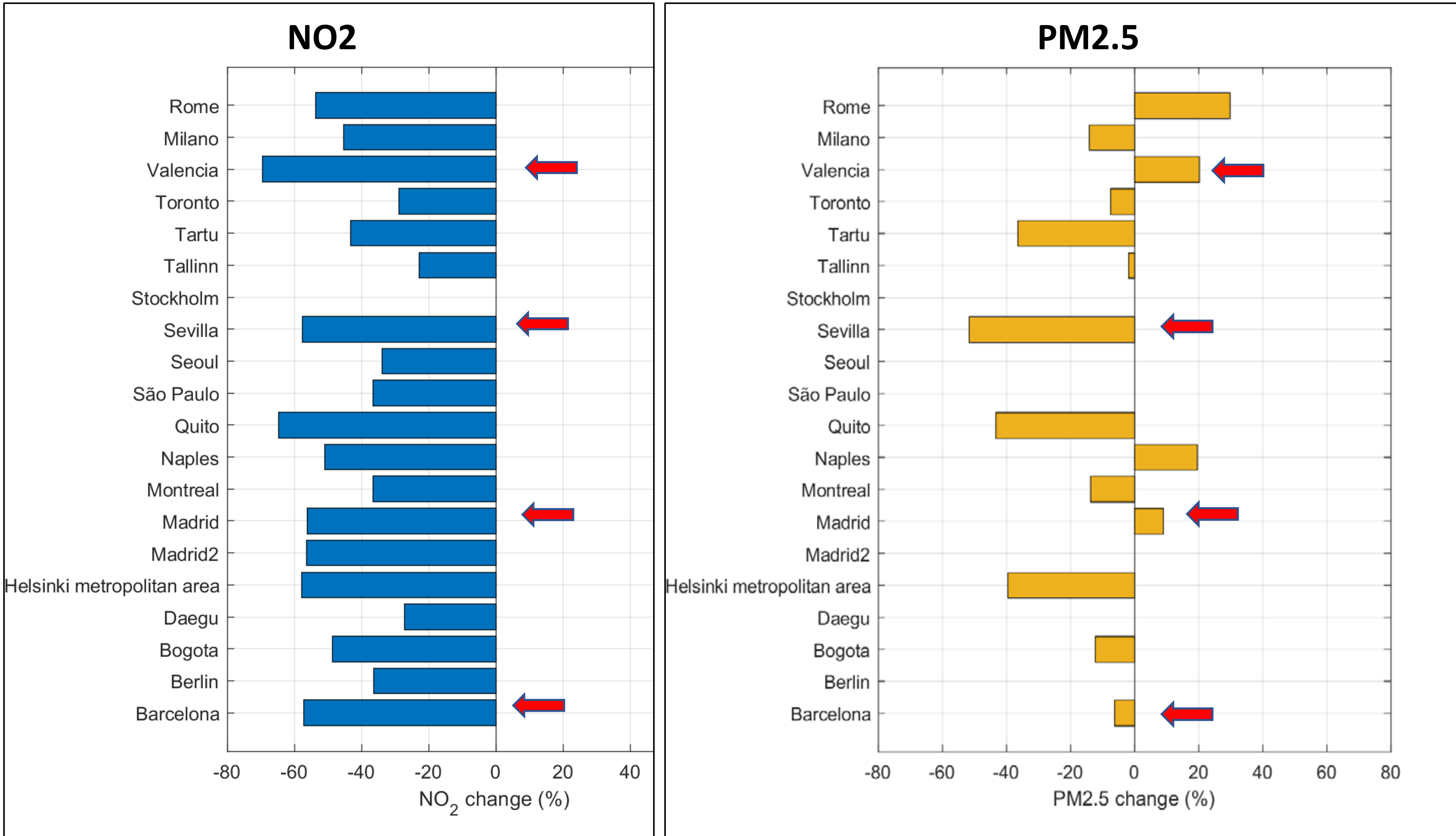
CO



CO/NOx



% Change in NO2 and PM2.5 from pre-lockdown to full lockdown for selected cities

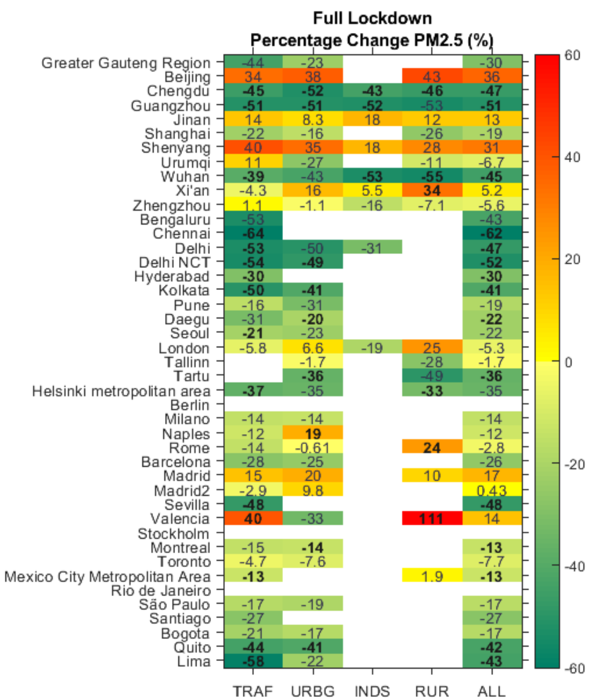


Consistent reduction in NO2

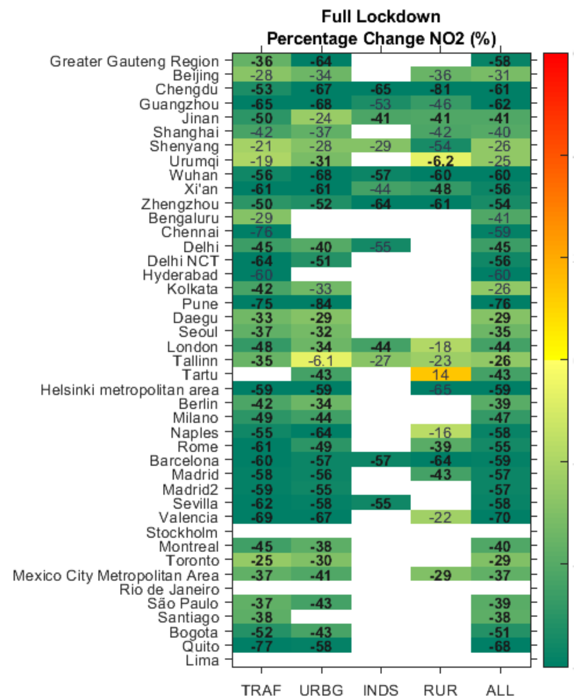
Greater variability in PM changes

% Change in PM2.5, NO2 and O3 during full lockdown period at different station types

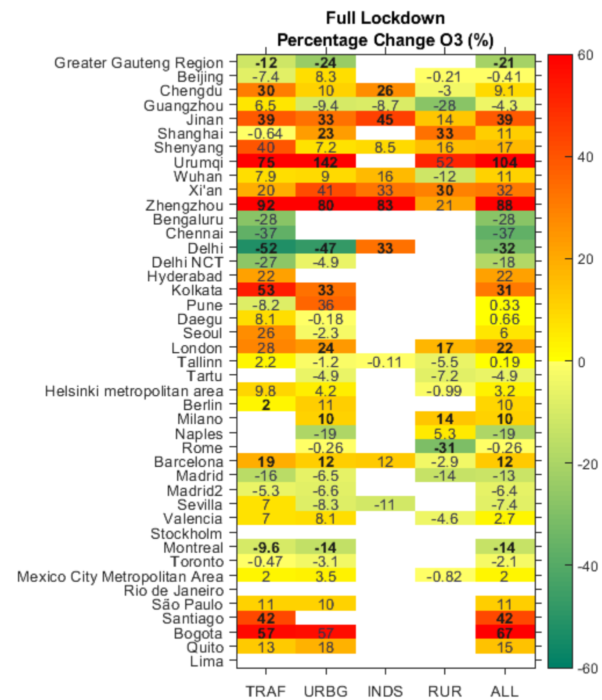
PM2.5



NO2

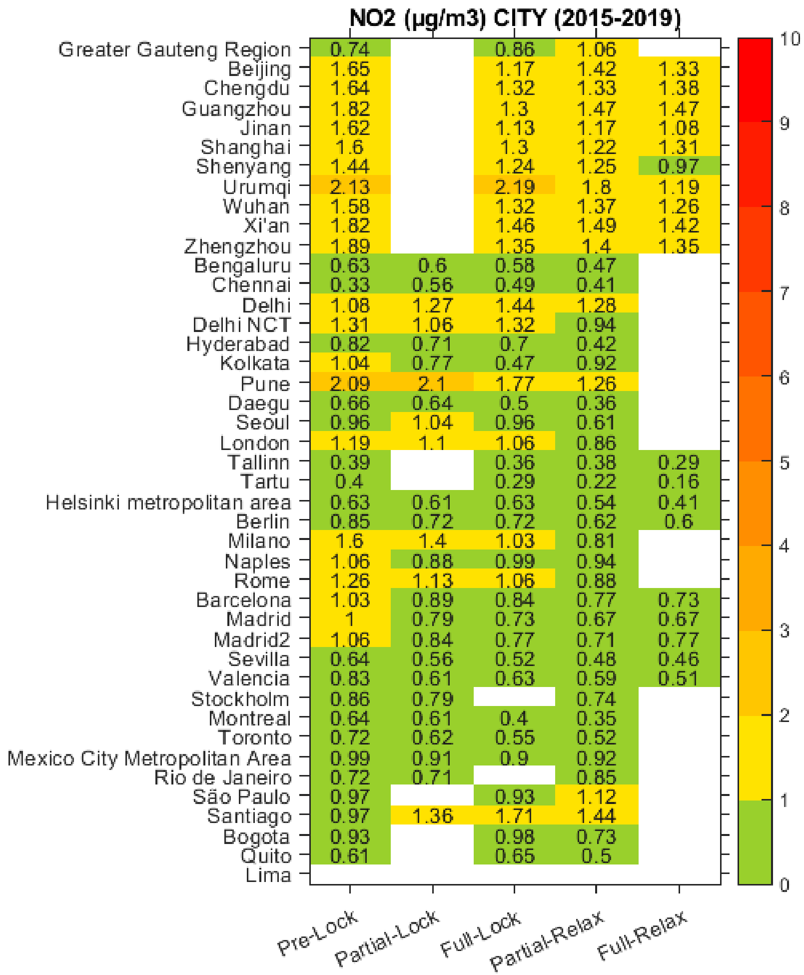


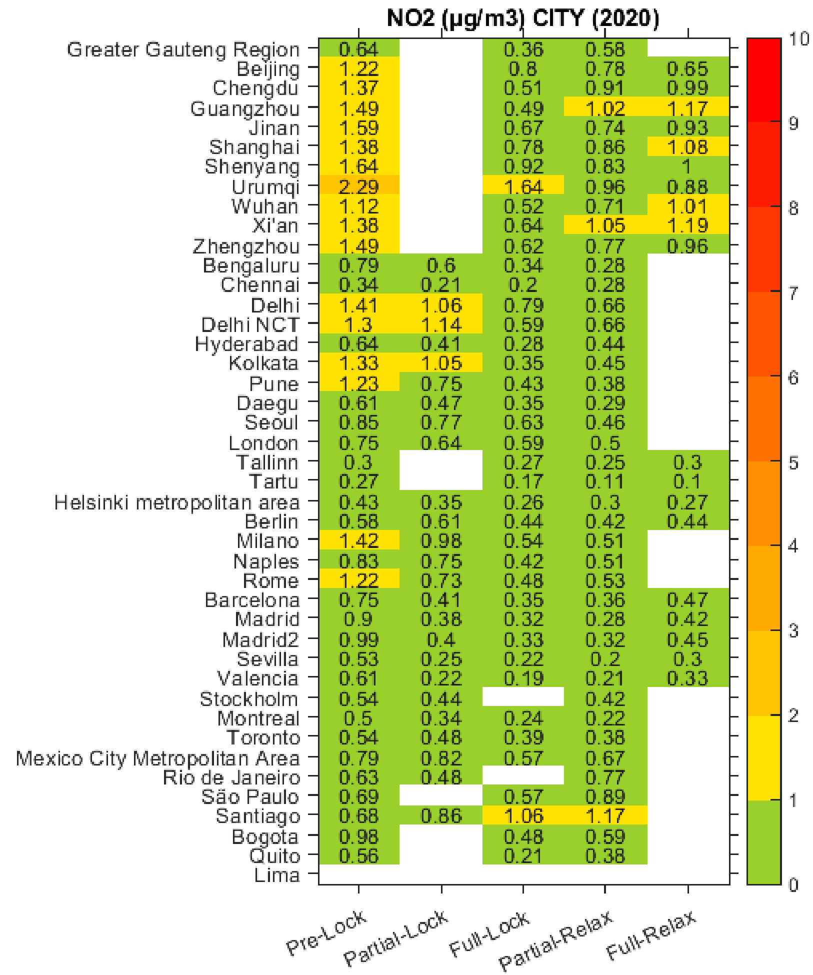
O3



Improvement in air quality compared to WHO Guidelines

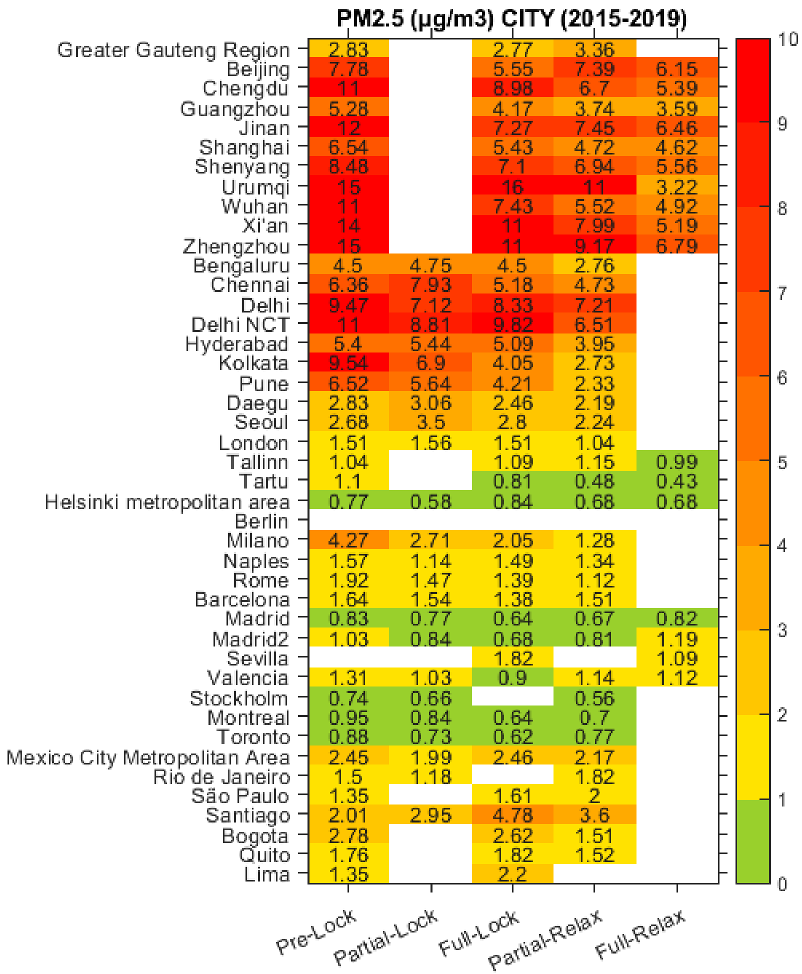
NO2 Exceedance > 40 ug/m3

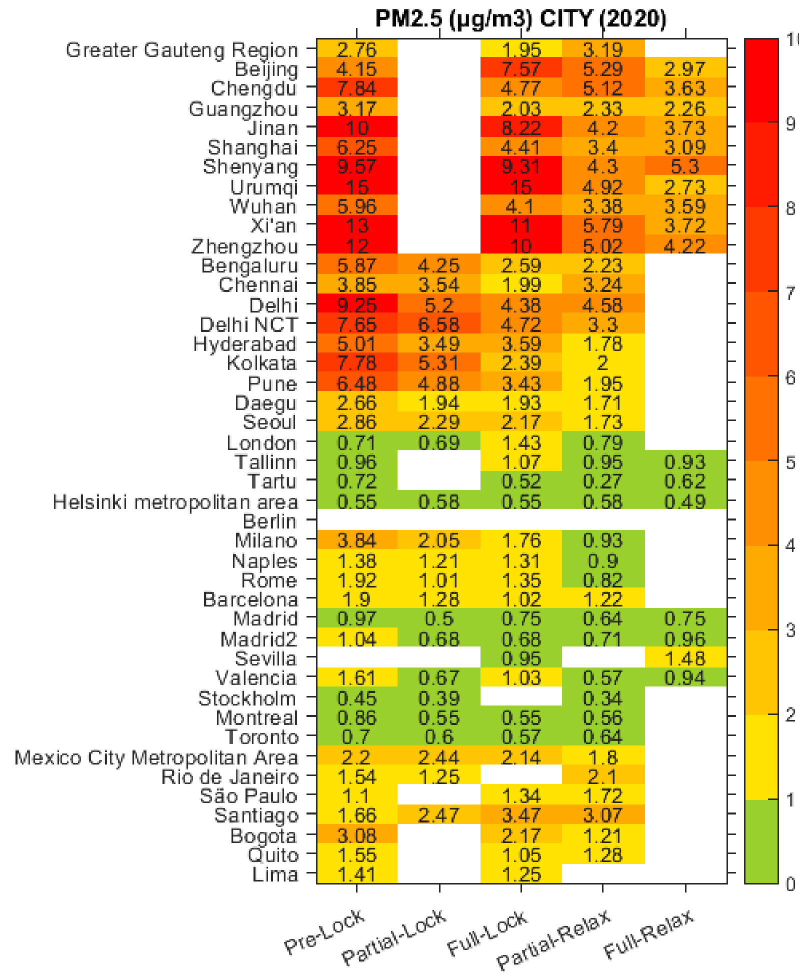


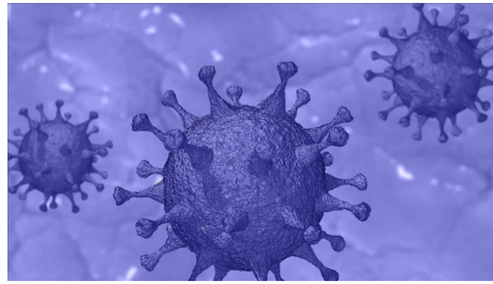


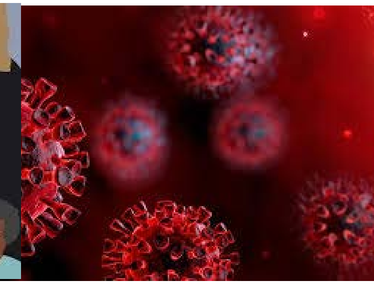
Was there any improvement in air quality compared to WHO Guidelines? Analysis of Exceedances

PM2.5 Exceedance > 10 ug/m3









Modelling study
UK case study

CAMS/BSC Scaling emissions reduction factors

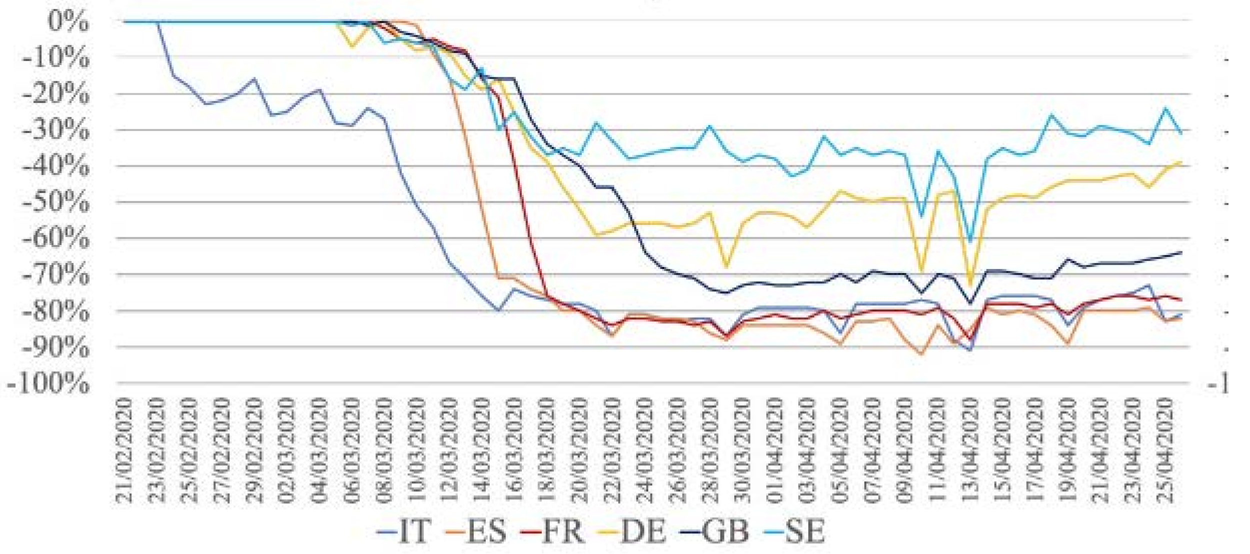
Time-resolved emission reductions for atmospheric chemistry modelling in Europe during the COVID-19 lockdowns

Marc Guevara et al., ACPD 2020

Countrywide and daily-resolved reduction factors for sectors:

- Energy industry (power plants),
- Manufacturing industry,
- Road traffic and
- Aviation (landing and 15 take-off cycle)

Computed changed in road traffic



Average emission reductions across Europe:

-33% for NOx, -8% for NMVOC, -7% for SOx, -7% for PM2.5

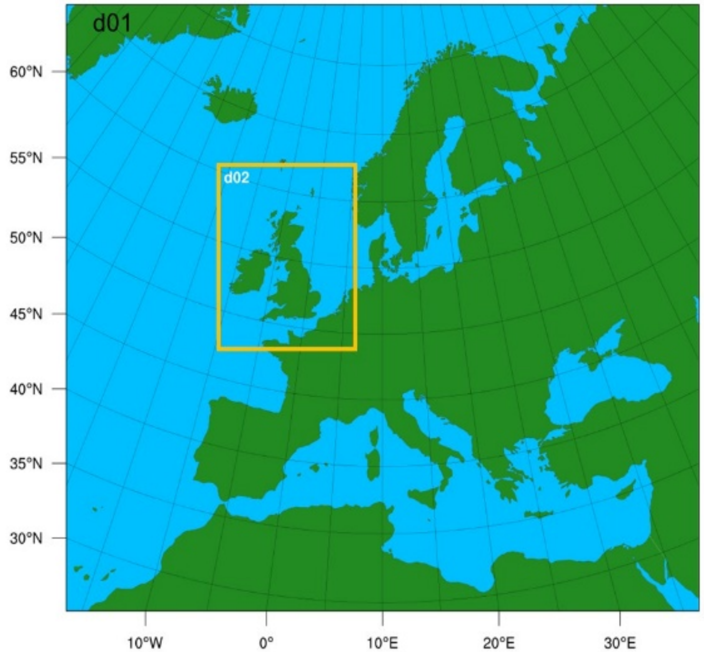
Analysis scenarios for the UK study

Baseline (BL) represents the UK and Europe emissions assuming no lockdown measures between **1 March to 26 April 2020**

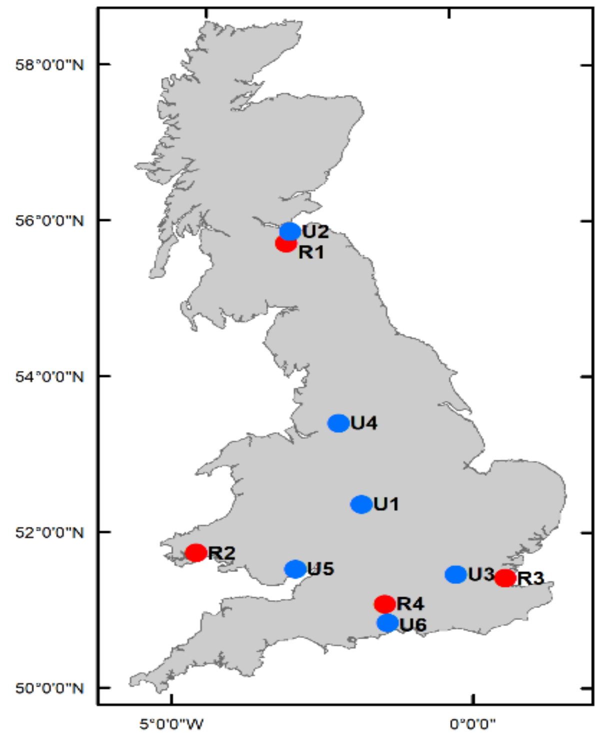
Scenario 1 is a plausible scenario to represents the overall comprehensive changes in emissions in the key sectors over the lockdown period of **24 March to 26 April**

Scenario 2 (S2) - sensitivity scenario to estimate the changes in air quality species attributable to **reductions only in road traffic emissions** over the lockdown period of **24 March to 26 April**

Approach – WRF-CMAQ modelling system



WRF/CMAQ model domain based on the NCAS air quality forecasting system



Location of AURN measurement stations used for model evaluation

Station name	Type	Label
Auchencorth Moss	Rural	R1
Narberth	Rural	R2
Rochester Stoke	Rural	R3
Chilbolton Observatory	Rural	R4
Birmingham Acocks Green	Urban	U1
Edinburgh St Leonards	Urban	U2
London N. Kensington	Urban	U3
Manchester Piccadilly	Urban	U4
Newport	Urban	U5
Southampton Centre	Urban	U6

Baseline pre-lockdown model evaluation 01/03/2020 – 23/03/2020

London North Kensington - Urban BG station – Hourly data

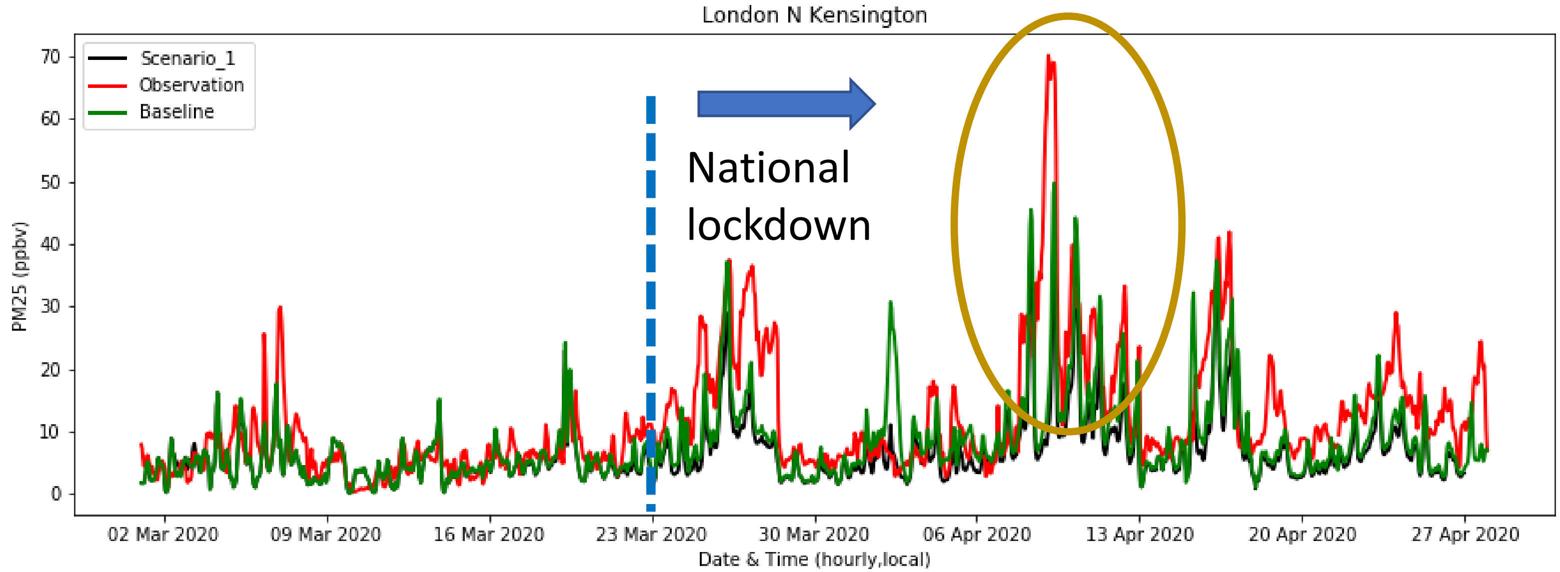
	n	FAC2	MB	MGE	NMB	NMGE	RMSE	R
O3	550	0.882	-11.374	12.284	-0.403	0.435	14.461	0.421
NO2	550	0.464	5.906	6.488	0.522	0.573	9.717	0.378
NOx	550	0.431	8.168	8.698	0.581	0.618	16.08	0.304
PM10	550	0.601	4.291	5.237	0.387	0.472	7.122	0.356
PM2.5	550	0.7	1.449	2.945	0.221	0.45	4.295	0.403

All Urban BG stations – Daily data

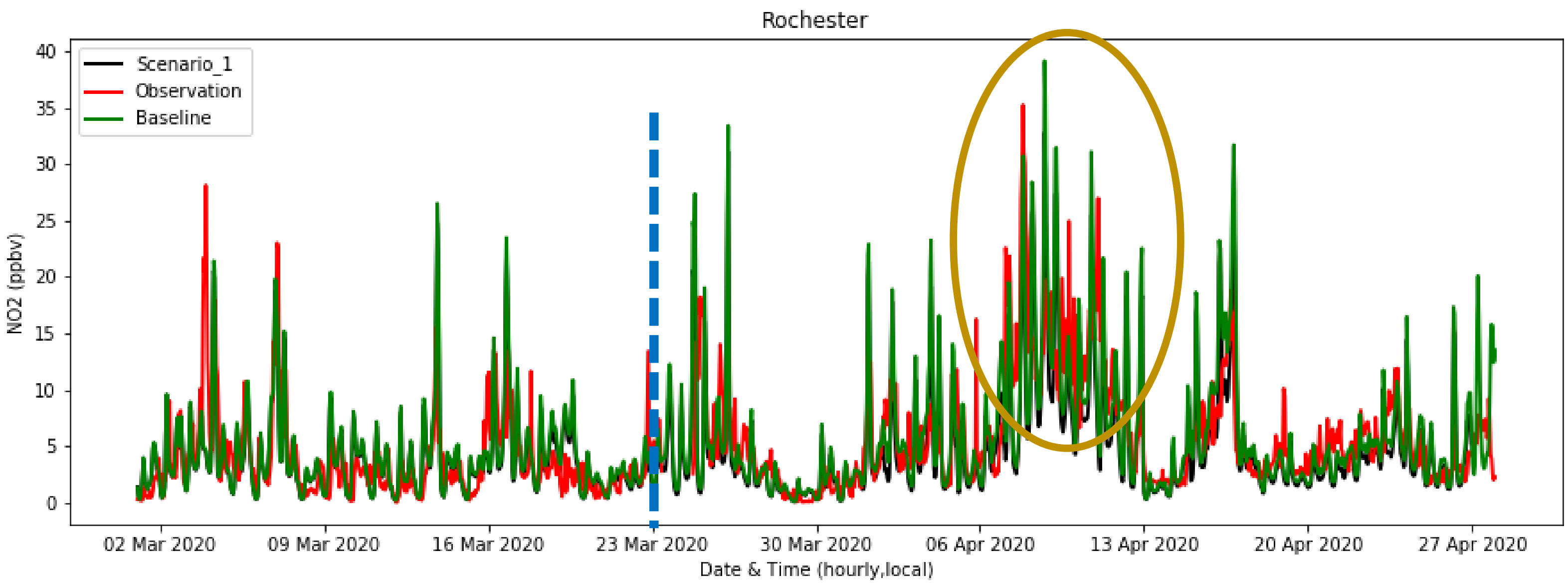
Metric	NO2	NOx	O3	PM2.5	PM10
Baseline, pre-lockdown period of 1 - 23 March 2020					
FAC2	0.906	0.877	0.983	0.906	0.899
MB	0.655	1.061	0.317	0.646	1.237
NMB	0.068	0.088	0.012	0.097	0.105
RMSE	4.868	7.218	5.514	2.893	5.117
Scenario 1, overall emission changes due to lockdown, 24 March to 21 April 2020					
FAC2	0.914	0.914	1	0.831	0.802
MB	-0.335	0.529	-2.742	-2.684	-3.925
NMB	-0.038	0.051	-0.085	-0.241	-0.212
RMSE	3.540	4.607	6.468	5.410	8.828

Baseline and Scenario 1 model predictions 01/03/2020 – 26/04/2020

PM2.5 London Urban BG station



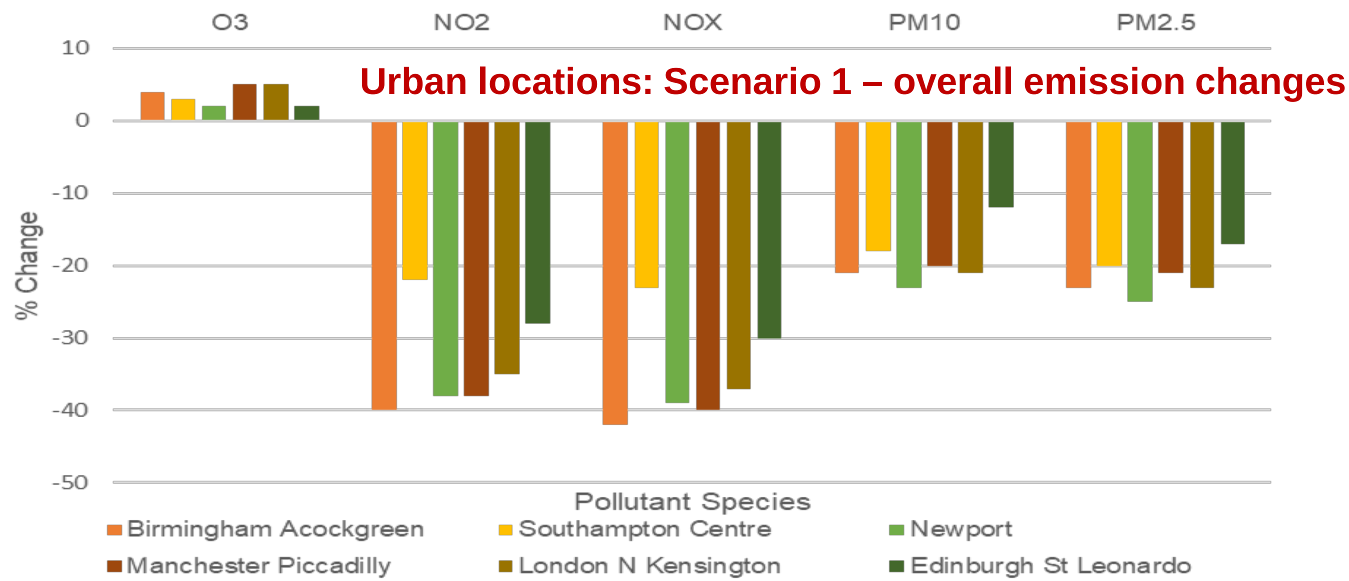
NO2 Rural BG station



Predicted changes during the lockdown period at URBAN locations over the UK

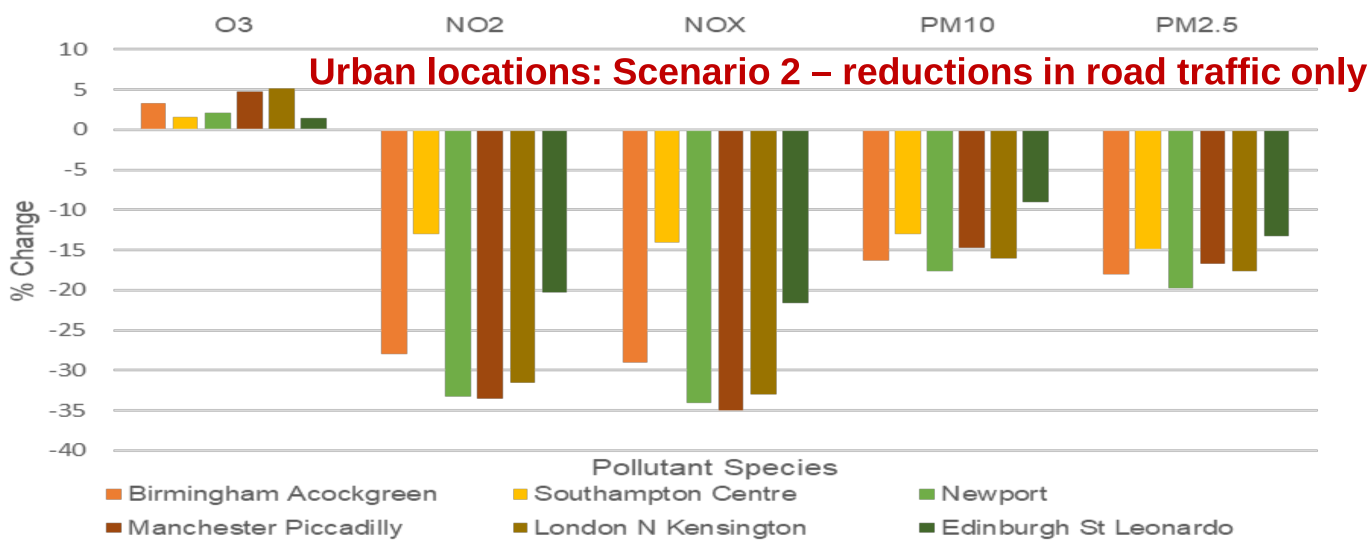
Lockdown period 24 March to 26 April 2020

Scenario 1



Most of the changes can be attributed to reductions in road traffic emissions

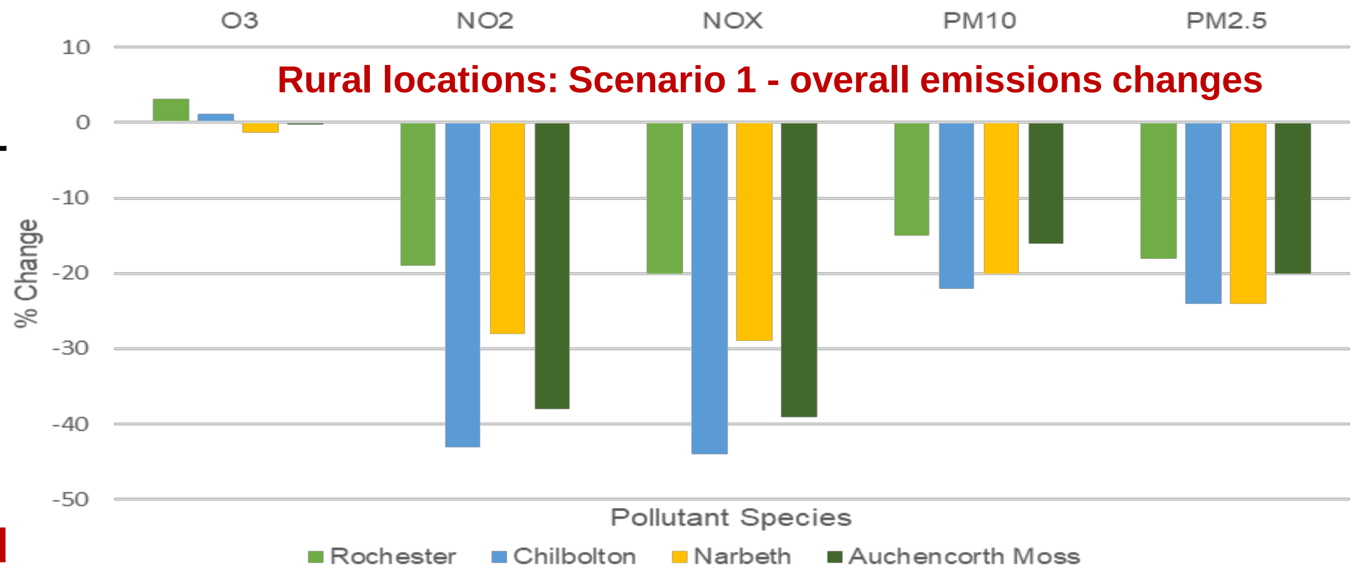
Scenario 2



Predicted changes during the lockdown period at RURAL locations over the UK

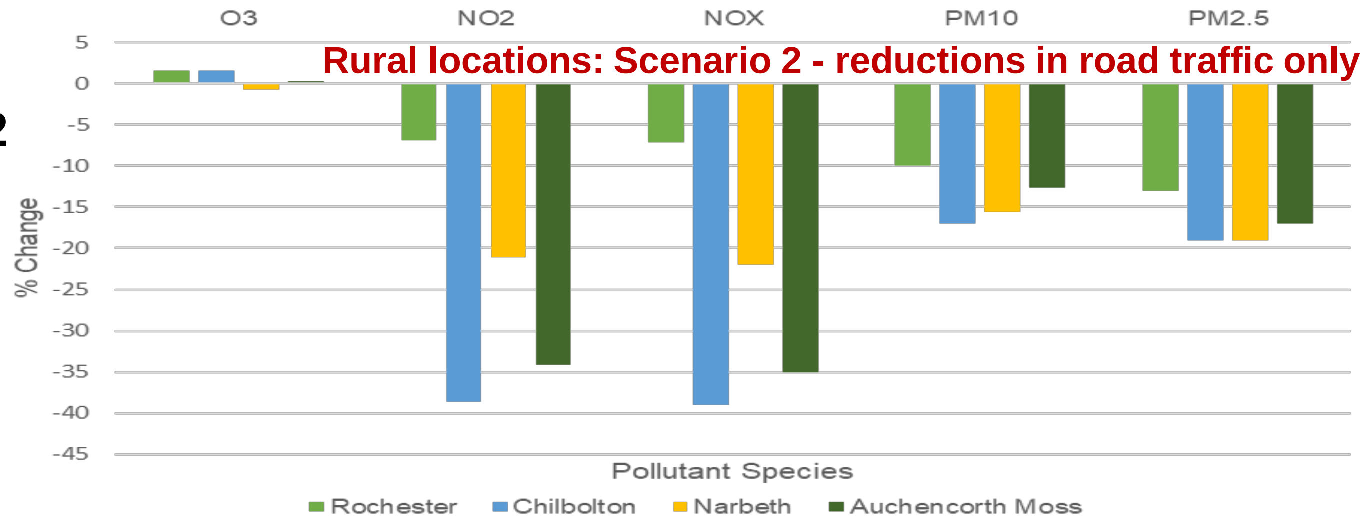
Lockdown period 24 March to 26 April 2020

Scenario 1

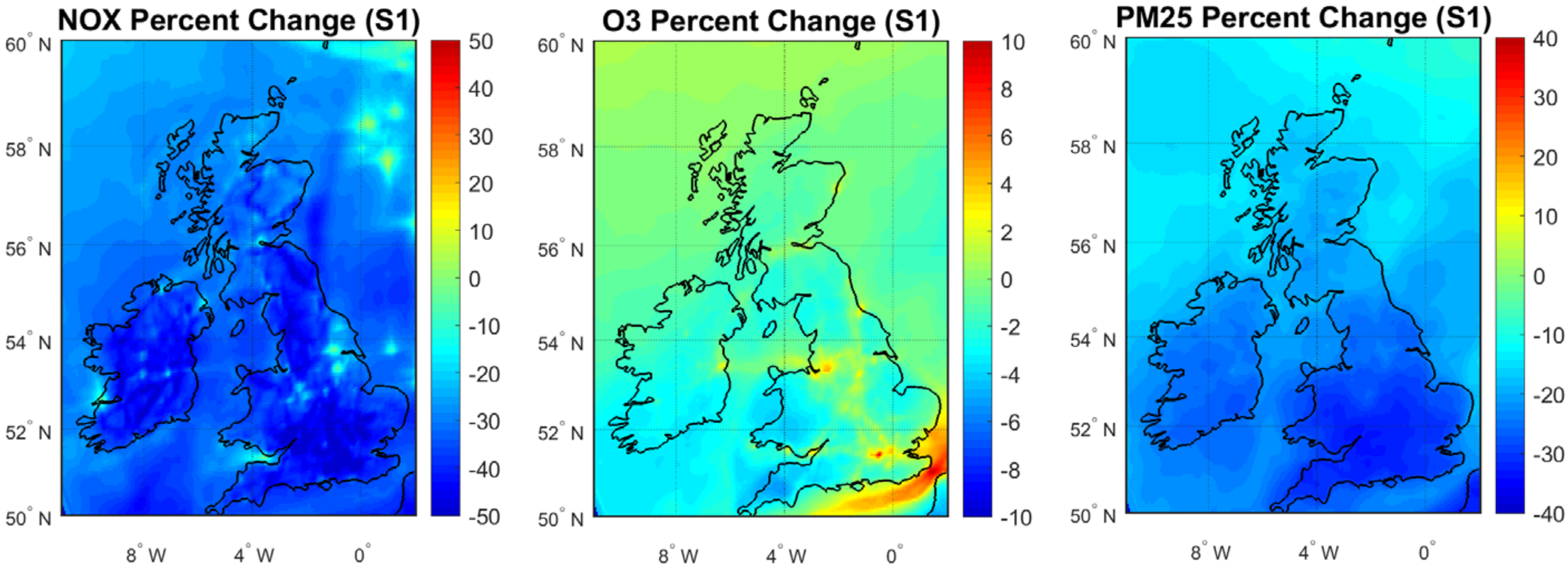


Most of the changes can be attributed to reductions in road traffic emissions

Scenario 2



Predicted spatial changes in urban and rural locations – Scenario 1



Mean modelled percentage changes in NOx, O_3 and $PM_{2.5}$ over the UK during the lockdown period (24 March – 26 April 2020) based on Scenario 1 – overall emissions changes

Predicted percentage changes in air pollutant species averaged over UK regions during the lockdown

Previous analysis

	Scenario 1 – Overall emissions changes						Scenario 2 – All transport emisions changes					
Regions	NO2	NOx	O3	PM10	PM2.5	PMC	NO2	NOx	O3	PM10	PM2.5	PMC
NE England	-39	-40	-1.4	-16	-21	-4.9	-32	-32	-1.4	-15	-20	-3.2
NW England	-41	-41	-0.8	-20	-25	-7.3	-35	-36	-0.8	-18	-23	-4.6
Yorkshire/ Humberside	-32	-32	-1	-20	-25	-7.3	-26	-26	-1.1	-18	-24	-4.9
E Midlands	-36	-37	-1.2	-24	-29	-10.3	-32	-32	-1.2	-22	-27	-7.7
W Midlands	-39	-39	-1.5	-25	-30	-10	-34	-35	-1.5	-22	-28	-7
E England	-39	-40	-1	-24	-28	-10.9	-36	-37	-0.9	-22	-27	-8.7
London	-40	-41	2.1	-26	-30	-13.7	-37	-38	1.8	-24	-28	-9.2
SE England	-43	-44	-0.3	-26	-31	-12.2	-41	-41	-0.3	-24	-29	-9.5
SW England	-40	-41	-3.3	-26	-32	-10.8	-38	-38	-3	-24	-30	-8.9
Wales	-37	-37	-3.1	-24	-29	-7.3	-32	-32	-2.8	-22	-27	-5.2
Scotland	-31	-31	-0.9	-12	-18	-1.2	-26	-27	-0.7	-12	-18	-0.4
N Ireland	-36	-36	-1.9	-16	-22	-3.3	-31	-31	-1.5	-15	-21	-2.3

Indication of spatial variations

Concluding remarks

- Changes in NO_2, NOx, $PM_{2.5}$. PM_{10}, PMC and O_3 for ~40 global cities
- Observational analysis shows a reduction up to 60% in NO2 and up to 40% in PM2.5 but with regional differences e.g. in some cities there is an increase in PM2.5
- Comparison with WHO Guidelines:
  - NO2 decreased and improved
  - PM2.5 improvement is smaller and still above guidelines for many regions, especially China, India, S Korea, Latin America
- Modelling analysis for UK predicts reductions in:
  - NO_2 of about 30-40% in urban and 20-40% in rural areas
  - PM ~ 20% in urban locations and ~15% in rural areas
  - PMC up to 14% reduction, mostly in urbanised areas
  - An increases in O_3 near airports and urban areas.
- Most of the changes during lockdown can be attributed to reduction in road traffic emissions

Where next?

- Analysis being extended to more global cities
- Analysis of PM species and changes in O3
- Process and modelling analysis is underway
- Linking changes in air pollutant species to emissions changes
- Identifying regional differences across the globe
- Lessons learnt for transitioning to lower air pollution emissions and improved air quality in global cities

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