



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

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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

Solar Radiation

Precipitation

Percentage Change TEMP (%) CITY Percentage Change RADIATION (%) CITY Percentage Change PRECIPITATION (%) CITY Greater Gauteng Region 60 60 60 Greater Gauteng Region --0.45 Greater Gauteng Region 0.29 0.64 0.62 **0.66** -0.14 Beijing Beijing Chengdu Chengdu 0.41 0.51 -0.89 Guangzhou -Chengdu 0.82 0.04 -1.1 Guangzhou Guangzhou -0.02 Jinan 0 99 -0.91 Jinar Shanghai -Jinan 0.79 0.68 -0.45 Shanghai 0.68 0.79 Shanghai 0.09 -0.54 Shenyang 0.2 Shenvano Shenyang 1.3 0.23 **0.52 0.79** -0.26 -0.04 40 40 Urúmai 1.2 -0.12 -0.62 40 Urumqi Urumqi Wuhan -0.26 0.63 Wuhar Wuhan 0.8 0.63 -0.42 -0.59 Xi'an -0.6 Xi'an Xi'an Zhengzhou -0.99 Zhengzhou Zhengzhou -0.54 -0.92Benğaluru · Bengaluru Benďaluru Chennai -0.18Chennai Chennai Delhi Delh Delhi 20 20 Delhi NCT Delhi NC1 -0.77 -0.67 -0.22 -0.13 0.17 20 -16 Delhi NCT Hvderabad 0.45Hyderabad Hvderabad -0.05 Kolkata Kolkata Kolkata Pune Pune Pune Daegu 0.68 -0.47 -0.42 Daequ 12 24 Daegu 0.2 -0.37 Seoul 1.2 -0.26 Seoul 0.35 Seoul 0.15 -0.07 London 0.42 London London Tallinn 0.7 -0.05 -0.93 0.71 - 0 Tallinn - 0 Tallinn 0.72 -0.2 -1 Tartu Tartu 0.02 Tartu Helsinki metropolitan area -0.06 -0.44 Helsinki metropolitan area Helsinki metropolitan area 0.79 -0.08 Berlin 0 99 Berlin Berlin -0.34 Milano 0.89 -0.04 Milano Milano Naples Naples Naples Rome --0.26 Rome Rome -0.2 -0.29 0.02 0.21 -0.21 0.39 Barcelona 0.42 -20 Barcelona -20 Barcelona -20 Madrid -0.03 Madrid Madrid 0.29 0.38 -0.08 Madrid2 Madrid2 Madrid2 Sevilla Sevilla -7.6 Sevilla Valencia -0.01 Valencia 0.67 -0.48 -0.16 0.46 -41 -13 Valencia Stockholm 0.96 0.17 -0.41 Stockholm Stockholm 0.29 Montreal Montreal Montreal Toronto -0.48 0.05 -0.78 Toronto -40 -40 Toronto -40 Mexico City Metropolitan Area 1.3 0.38 0.49 Mexico City Metropolitan Area Mexico City Metropolitan Area Rio de Janeiro -0.94 -0.69 -0.47 Rio de Janeiro -6.9 Rio de Janeiro -0.49 0.11 São Paulo -0.51 São Paulo 5.9 São Paulo Santiago 0.27 0.2 0 -0.43 Santiago antiago -Bogota -Santiago 0.04 0.01 0.02 Bogota Bogota Quito 0.18 Quito Quito Lima Lima -60 Lima -60 -60 Partial-Relax Partial-Lock Partial-Relax Full-Lock Full-Relax Partial-Lock Full-LOCK Full-Relax pre-Lock Pre-Lock Partial-Lock Partial-Relax FUIL-Relax Pre-Lock Full-LOCK

Other meteorological parameters: wind speed, RH

Temperature

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

PM10



PM2.5







% 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 prelockdown 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 <u>different station types</u>

NO2





PM2.5



Improvement in air quality compared to WHO Guidelines

NO2 Exceedance > 40 ug/m3

Mexico

NO2 (µg/m3) CITY (2015-2019)						NO2 (μg/m3) CITY (2020)							
Greater Gauteng Region -	0.74		0.86	1.06	1	Դ 💻 10	Greater Gauteng Region	0.64		0.36	0.58		. 🗾 10
Beliing -	1.65		1.17	1.42	1.33		Beijing	1.22		0.8	0.78	0.65	· 📕 🛛
Chengdu –	1.64		1.32	1.33	1.38		Chengdu	1.37		0.51	0.91	0.99	
Guangzhou -	1.82		1.3	1.47	1.47		Guangzhou	1.49		0.49	1.02	1.17	· .
Jinan -	1.62		1,13	1.17	1.08	- 9	Jinan	1.59		0.67	0.74	0.93	9
Shanghai -	1.6		1.3	1.22	1.31		Shanghai	1.38		0.78	0.86	1.08	
Snenyang -	1.44		1.24	1.25	0.97		Shenyang	1.64		0.92	0.83	1	
Urumqi -	2.13		2.19	1.8	1.19	E	Urumqi	2.29		1.64	0.96	0.88	
Vilan -	1.00		1.02	1.37	1.20	8	Viunan	1.12		0.52	1.05	1.01	8
Zhongzhou -	1.02		1.40	1.45	1.42		Zhongzhou	1.00		0.62	0.77	0.96	
Bengaluru -	0.63	0.6	0.58	0.47	1.00	L	Bengaluru	0.79	0.6	0.34	0.28	0.30	
Chennai -	0.33	0.56	0.49	0.41		-	Chennai	0.34	0.21	0.2	0.28		· 📃 🚽
Delhi -	1.08	1.27	1.44	1.28			Delhi	1.41	1.06	0.79	0.66		· 🗖 🔴
Delhi NCT -	1.31	1.06	1.32	0.94			DelhiNCT	1.3	1.14	0.59	0.66	-	· 📃 👘
Hyderabad -	0.82	0.71	0.7	0.42			Hyderabad	0.64	0.41	0.28	0.44		
Kolkata -	1.04	0.77	0.47	0.92			Kolkata	1.33	1.05	0.35	0.45		·
Pune -	2.09	2.1	1.77	1.26		- 6	Pune	1.23	0.75	0.43	0.38		6
Daegu -	0.66	0.64	0.5	0.36			Daegu	0.61	0.47	0.35	0.29		·
Seoul -	0.96	1.04	0.96	0.61			Seoul	0.85	0.77	0.63	0.46		
London -	1.19	1.1	1.06	0.86	0.00		London	0.75	0.64	0.59	0.5	0.0	·
	0.39		0.36	0.38	0.29	C 5	I allinn Tortu	0.3		0.27	0.25	0.3	5
Holsinki motropolitan aroa -	0.4	0.61	0.29	0.22	0.10		Helsinki metropolitan aroa	0.27	0.35	0.17	0.11	0.1	
Red in -	0.03	0.72	0.03	0.54	0.41		Reisinki metropolitari area	0.43	0.55	0.20	0.3	0.27	
Milano -	1.6	14	1.03	0.81	0.0		Milano	1 42	0.04	0.54	0.51	0.44	
Naples -	1.06	0.88	0.99	0.94		- 4	Naples	0.83	0.75	0.42	0.51		. 4
Rome -	1.26	1.13	1.06	0.88		-	Rome	1.22	0.73	0.48	0.53	-	· 📃 👘
Barcelona -	1.03	0.89	0.84	0.77	0.73		Barcelona	0.75	0.41	0.35	0.36	0.47	· 📃 👘
Madrid -	1	0.79	0.73	0.67	0.67	- 2	Madrid	0.9	0.38	0.32	0.28	0.42	2
Madrid2 -	1.06	0.84	0.77	0.71	0.77	- °	Madrid2	0.99	0.4	0.33	0.32	0.45	
Sevilla -	0.64	0.56	0.52	0.48	0.46		Sevilla	0.53	0.25	0.22	0.2	0.3	
Valencia -	0.83	0.61	0.63	0.59	0.51		Valencia	0.61	0.22	0.19	0.21	0.33	
Stockholm -	0.86	0.79	0.4	0.74			Stockholm	0.54	0.44	0.04	0.42		
Iviontreal -	0.64	0.61	0.4	0.35			Montreal	0.5	0.34	0.24	0.22		2
vice City Metropolitan Area -	0.72	0.02	0.00	0.02			Mexice City Metropolitan Area	0.04	0.40	0.59	0.30		
Rio de Janeiro -	0.99	0.71	0.9	0.92			Rio de Janeiro	0.63	0.02	0.57	0.07		
São Paulo -	0.97	0.71	0.93	1.12		- 1	São Paulo	0.69	0.40	0.57	0.89		1
Santiago -	0.97	1.36	1.71	1.44		FL 1.	Santiago	0.68	0.86	1.06	1.17	-	· · · ·
Bogota -	0.93		0.98	0.73		-	Bogota	0.98		0.48	0.59	-	
Quito -	0.61		0.65	0.5			Quito	0.56		0.21	0.38	-	
Lima –						ל	Lima	┨					· 📃 👝
						0				'			0
	LOCK .	LOCK	, ock .	2 elax	Delax			1 OCK	LOCK .	1 OCK	zelax .	2018×	
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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 dailyresolved reduction factors for sectors:

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

0% -10% -20% -30% -40% -50% -60% -70% -80% -90% -100% 21/02/2020 25/04/2020 23/02/2020 23/04/2020 25/02/2020 26/03/2020 30/03/2020 07/04/2020 09/04/2020 1/04/2020 3/04/2020 5/04/2020 7/04/2020 21/04/2020 27/02/202 29/02/202 8/03/2021 2/03/202(6/03/2020 8/03/2020 20/03/2020 22/03/2020 24/03/2020 28/03/2020 01/04/2020 33/04/2020 9/04/2020 12/03/202 04/03/202 0/03/202 4/03/202 05/04/202 -ES -FR -DE -GB -SE

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



ric & Clim

CACP

d01

60°N

55°N

50°N

45°N

40°N

35°N

30°N

the

system

10°W

NCAS

Location of AURN measurement stations used for model evaluation

52°0'0"N	J5 U3 R4 U6 0°00"	R3.
Station name	Туре	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

R1

U4

U1



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
03	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	03	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					











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



Predicted <u>spatial</u> 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 NO₂, NOx, PM_{2.5}. PM₁₀, PMC and O₃ 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:
 - NO₂ 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 O₃ near airports and urban areas.
- Most of the changes during lockdown can be attributed to reduction in road traffic emissions











- 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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