## A global observational analysis to understand changes in air quality during exceptionally low anthropogenic emission conditions

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## **Supplementary Material**

The supplementary material is subdivided into Sections having the same name and numbers of the manuscript Sections. This choice allows the reader to easily access Figures and Tables referred in the manuscript. Tables and Figures are identified by tree numbers indicating: section, subsection, and figure number as, e.g., Figure S3.2.12.

## S2.1 Description of cities and regions

| Acr        | City                             | Country Continent      |                                | City/Metro |              | Population  | Climate    | Winter house heating                |  |  |  |  |
|------------|----------------------------------|------------------------|--------------------------------|------------|--------------|-------------|------------|-------------------------------------|--|--|--|--|
|            | <u></u>                          |                        | • •                            |            | (m)          | (millions)  | (Koppen)   | season                              |  |  |  |  |
| URU<br>SHE | Urumqi                           | China<br>China         | Asia<br>Asia                   | M          | 800<br>51    | 3.6<br>8.3  | Dwb        | October-April<br>November-March     |  |  |  |  |
| XIA        | Shenyang<br>Xi'an                | China                  | Asia                           | M          | 400          | 10.2        | Dwa<br>Cwa | November-March                      |  |  |  |  |
| BEI        | Beijing                          | China                  | Asia                           | M          | 44           | 21.5        | Dwa        | November-March                      |  |  |  |  |
| SHA        | Shanghai                         | China                  | Asia                           | M          | 4            | 24.3        | Cfa        | none <sup>1</sup>                   |  |  |  |  |
| JIN        | Jinan                            | China                  | Asia                           | M          | 148          | 8.9         | Cwa        | November-March                      |  |  |  |  |
| ZHE        | Zhengzhou                        | China                  | Asia                           | M          | 148          | 10.4        | Cwa        | November-March                      |  |  |  |  |
| CHE        | Chengdu                          | China                  | Asia                           | M          | 500          | 16.6        | Cwa        | none <sup>1</sup>                   |  |  |  |  |
| WUH        | Wuhan                            | China                  | Asia                           | M          | 20           | 11.2        | Cwa        | none <sup>1</sup>                   |  |  |  |  |
| GUA        | Guangzhou                        | China                  | Asia                           | M          | 7            | 15.3        | Cfa        | none <sup>1</sup>                   |  |  |  |  |
| SEO        | Seoul                            | South Korea            | Asia                           | C          | 38           | 9.7         | Dwa        | October-March                       |  |  |  |  |
| DAE        | Daegu                            | South Korea            | Asia                           | M          | 49           | 2.4         | Cfa        | October-March                       |  |  |  |  |
| AMR        | Amritsar                         | India                  | Asia                           | М          | 234          | 1.2         | BSh        | November-February <sup>2</sup>      |  |  |  |  |
| СНА        | Chandigarh                       | India                  | Asia                           | M          | 320          | 1.1         | Cwa/BSh    | November-February <sup>2</sup>      |  |  |  |  |
| DEL        | Delhi                            | India                  | Asia                           | M          | 220          | 16.8        | Cwa/BSh    | November-February <sup>2</sup>      |  |  |  |  |
| KOL        | Kolkata                          | India                  | Asia                           | M          | 10           | 14.1        | Aw         | December-January <sup>2</sup>       |  |  |  |  |
| PUN        | Pune                             | India                  | Asia                           | M          | 560          | 5.1         | Aw/BSh     | November-February <sup>2</sup>      |  |  |  |  |
| HYD        |                                  | India                  | Asia                           | M          | 540          | 7.7         | BSh        | ,                                   |  |  |  |  |
|            | Hyderabad                        |                        |                                |            |              |             |            | December-January <sup>2</sup>       |  |  |  |  |
| CHN        | Chennai                          | India<br>India         | Asia                           | M          | 6            | 8.7         | Aw         | December-January <sup>2</sup>       |  |  |  |  |
| BEH        | Bengaluru                        | India                  | Asia                           | M          | 920<br>26    | 8.5         | Aw<br>Dfb  | December-January <sup>2</sup>       |  |  |  |  |
| HEL<br>STO | Helsinki<br>Stockholm            | Finland<br>Sweden      | Europe<br>Europe               | C          | 26<br>15     | 1.2         | Dfb        | October-April                       |  |  |  |  |
| TAL        | Tallinn                          | Estonia                | Europe                         | c          | 30           | 0.4         | Dfb        | October-April<br>September-May      |  |  |  |  |
| TAR        | Tartu                            | Estonia                | Europe                         | C          | 50           | 0.1         | Dfb        | September-May                       |  |  |  |  |
| MOS        | Moscow                           | Russia                 | Europe                         | M          | 150          | 12.7        | Dfb        | October-April                       |  |  |  |  |
| LON        | London                           | UK                     | Europe                         | М          | 14           | 8.9         | Cfb        | October-April                       |  |  |  |  |
| AMS        | Amsterdam                        | Netherlands            | Europe                         | С          | 3            | 0.9         | Cfb        | October-April                       |  |  |  |  |
| UTR        | Utrecht                          | Netherlands            | Europe                         | С          | 3            | 0.4         | Cfb        | October-April                       |  |  |  |  |
| DHA        | Den Haag                         | Netherlands            | Europe                         | С          | 3            | 0.5         | Cfb        | October-April                       |  |  |  |  |
| ROT        | Rotterdam                        | Netherlands            | Europe                         | С          | 3            | 0.6         | Cfb        | October-April                       |  |  |  |  |
| EIN        | Eindhoven                        | Netherlands            |                                | C          | 3            | 0.2         | Cfb        | October-April                       |  |  |  |  |
| PAR<br>BER | Paris<br>Berlin                  | France                 | Europe                         | C<br>C     | 5<br>34      | 9.8<br>3.8  | Cfb<br>Cfb | October-March                       |  |  |  |  |
| AUS        | Augsburg                         | Germany<br>Germany     | Europe<br>Europe               | C          | 494          | 0.3         | Cfb        | October-April<br>October-March      |  |  |  |  |
| MUN        | Munich                           | Germany                | Europe                         | c          | 519          | 1.6         | Cfb        | October-March                       |  |  |  |  |
| MIL        | Milano                           | Italy                  | Europe                         | M          | 122          | 3.3         | Cfa        | 15 October – 15 April               |  |  |  |  |
| ROM        | Rome                             | Italy                  | Europe                         | С          | 21           | 2.8         | Csa        | November – 15 April                 |  |  |  |  |
| NAP        | Naples                           | Italy                  | Europe                         | С          | 100          | 1.0         | Csa        | 15 November - March                 |  |  |  |  |
| BAR        | Barcelona                        | Spain                  | Europe                         | М          | 13           | 5.1         | Csa        | November-March                      |  |  |  |  |
| MAD        | Madrid                           | Spain                  | Europe                         | М          | 667          | 6.1         | Csa/BSk    | October-March                       |  |  |  |  |
| VAL        | Valencia                         | Spain                  | Europe                         | M          | 16           | 1.6         | Csa        | November-March                      |  |  |  |  |
| SEV        | Sevilla                          | Spain                  | Europe                         | M          | 11           | 1.3         | Csa        | November-March                      |  |  |  |  |
| ATH        | Athens                           | Greece                 | Europe                         | M          | 70           | 3.7         | Csa        | November-April                      |  |  |  |  |
| NIC<br>GGA | Nicosia<br>Gr. Gauteng Reg.      | Cyprus<br>South Africa | Europe<br>Africa               | M          | 220<br>1500  | 0.3<br>15.5 | BSh<br>Cwb | November-March<br>June-August       |  |  |  |  |
| CAL        | Calgary                          | Canada                 | North America                  | M          | 1084         | 1.6         | Dfc        | October-May                         |  |  |  |  |
| VAN        | Vancouver                        | Canada                 | North America                  | M          | 4            | 2.6         | Cfb        | October-April                       |  |  |  |  |
| QUE        | Quebec City                      | Canada                 | North America                  | М          | 74           | 0.8         | Dfb        | October-April                       |  |  |  |  |
| MON        | Montreal                         | Canada                 | North America                  | М          | 77           | 4.1         | Dfa/Dfb    | October-April                       |  |  |  |  |
| OTT        | Ottawa                           | Canada                 | North America                  | М          | 114          | 1.4         | Dfb        | October-April                       |  |  |  |  |
| HAL        | Halifax                          | Canada                 | North America                  | М          | 242          | 0.4         | Dfb        | November - May                      |  |  |  |  |
| TOR        | Toronto                          | Canada                 | North America                  | M          | 77           | 5.9         | Dfa/Dfb    | October-April                       |  |  |  |  |
| NYC        | New York City                    | USA                    | North America                  | C          | 10           | 8.3         | Dfa        | October-May                         |  |  |  |  |
| LAN<br>MEX | Los Angeles<br>Mexico City M. A. | USA                    | North America<br>North America | C<br>M     | 93<br>2250   | 4.0         | Csa        | November-March<br>December-February |  |  |  |  |
| BOG        | Bogota                           | Colombia               | South America                  | M          | 2250<br>2625 | 23.6<br>7.7 | Cwb<br>Cfb | no heating                          |  |  |  |  |
| QUI        | Quito                            | Ecuador                | South America                  | M          | 2835         | 2.8         | Cfb/Cwb    | no heating                          |  |  |  |  |
| LIM        | Lima                             | Peru                   | South America                  | C          | 124          | 9.7         | Bwh        | June-September                      |  |  |  |  |
| RIO        | Rio de Janeiro                   | Brazil                 | South America                  | C          | 20           | 6.7         | Am         | no heating                          |  |  |  |  |
| SAO        | São Paulo                        | Brazil                 | South America                  | С          | 745          | 12.2        | Cfa        | no heating                          |  |  |  |  |
| SAN        | Santiago                         | Chile                  | South America                  | М          | 500          | 7.2         | Csb        | May-August                          |  |  |  |  |
| SYD        | Sydney                           | Australia              | Australia                      | М          | 70           | 5.3         | Cfa        | May-September                       |  |  |  |  |
| MEL        | Melbourne                        | Australia              | Australia                      | М          | 31           | 5.1         | Cfb        | June-October                        |  |  |  |  |

Table S2.1.1. Geographic, climatic and demographic features of the analysed cities.

<sup>1</sup>Buildings are not provided with central heating in southern China and no heating season is prescribed and regulated. <sup>2</sup>Heating period is not regulated. Hence, the definition is based on the coolest months of a year.

### S2.3 Data sources and analysis protocols

#### S2.3.1 Air quality data sources

Table S2.3.1. The number of cities and sites (in brackets) analysed for each lockdown period and for each air pollutant species. Although data were analysed for a total of 63 cities and 540 sites, there was no city for which a complete dataset for all pollutants, lockdown phases and site types was available. The most comprehensive datasets were for NO<sub>2</sub>, O<sub>3</sub> and PM, while NO had the lowest coverage.

| Pollutant         | Pre-<br>lockdown | Partial<br>lockdown | Full<br>lockdown | Partial relaxation | Full relaxation |
|-------------------|------------------|---------------------|------------------|--------------------|-----------------|
| PM <sub>10</sub>  | 52 (339)         | 28 (245)            | 50 (341)         | 49 (317)           | 30 (141)        |
| PM <sub>2.5</sub> | 59 (343)         | 36 (236)            | 59 (349)         | 56 (298)           | 29 (118)        |
| NO                | 46 (390)         | 34 (304)            | 44 (386)         | 43 (378)           | 20 (175)        |
| NO <sub>2</sub>   | 62 (529)         | 38 (391)            | 60 (529)         | 59 (495)           | 31 (236)        |
| СО                | 49 (231)         | 31 (146)            | 48 (227)         | 46 (196)           | 24 (98)         |
| SO <sub>2</sub>   | 48 (244)         | 29 (188)            | 48 (246)         | 45 (223)           | 23 (84)         |
| 03                | 59 (394)         | 35 (268)            | 57 (393)         | 54 (308)           | 31 (176)        |

#### S2.3.3 Mobility data

Cities associated to each of the considered mobility data sources:

- a) Apple driving: Greater Gauteng, Bengaluru, Chennai, Delhi, Hyderabad, Pune, London, Helsinki, Paris, Augsburg, Berlin, Munich, Athens, Naples Milano, Rome, Amsterdam, Eindhoven, Rotterdam, Den Haag, Utrecht, Barcelona, Madrid, Sevilla, Valencia, Stockholm, Calgary, Halifax, Montreal, Ottawa, Quebec, Toronto, Vancouver, Mexico City, Los Angeles, New York, City, Moscow, Melbourne and Sidney.
- b) Google Retail: Chandigarh, Amritsar, Kolkata, Seoul, Tallinn, Tartu.
- c) Waze: Rio de Janeiro, São Paulo, Santiago, Bogotá, Quito, Lima.
- d) Baidu: Beijing, Chengdu, Guangzhou, Jinan, Shangai, Shenyang, Wuhan, Xian, Zhengshou.

Figure S2.3.1 presents the mobility variation index for each period of mobility (pre-, partial-, full-lockdown, partial relaxation and full relaxation) for all the cities from different mobility databases: Apple, Baidu, Google, and Waze. It is possible to observe that during the full-lockdown period they show coherence in the abatement of mobility.

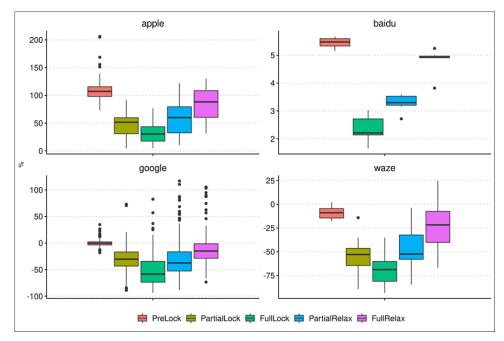


Figure S2.3.1. Average index for all the cities for mobility databases from Apple, Baidu, Google and Waze, for each period of analysis, pre-lockdown, partial lockdown, full lockdown, partial relaxation and full relaxation.

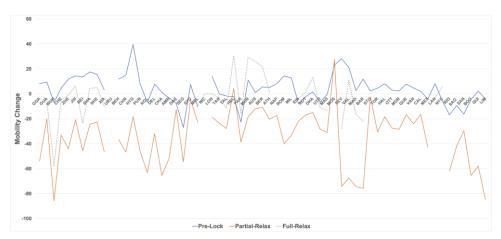


Figure S2.3.2. Mobility change during the periods classified as pre-lockdown, partial relaxation and full relaxation.

## S3 Results analysis and discussion S3.1 Changes in mobility and emissions

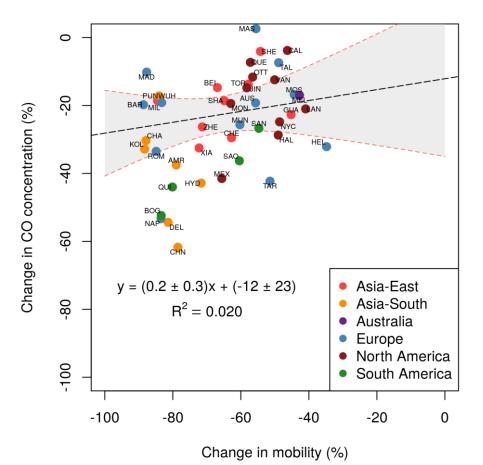
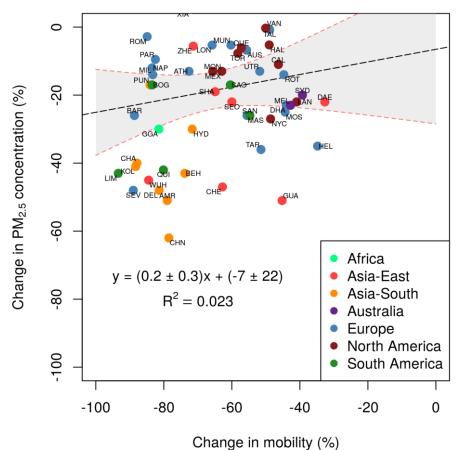


Figure S3.1.1. Linear regression fit (dashed line) and equation between CO and mobility percentage changes during full lockdown. The shaded area represents the 95% Confidence

Interval.



Change in mobility (78)

Figure S3.1.2. Linear regression fit (dashed line) and equation between PM2.5 and mobility percentage changes during full lockdown. The shaded area represents the 95% Confidence Interval.

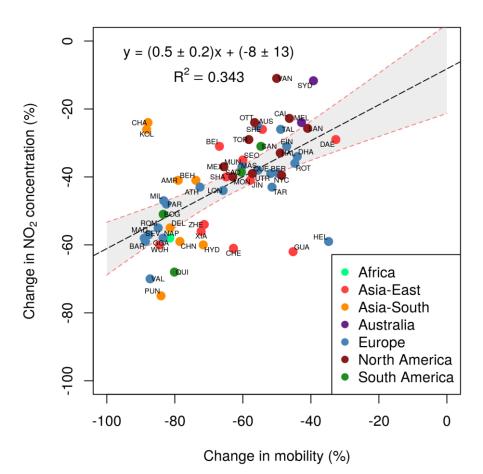
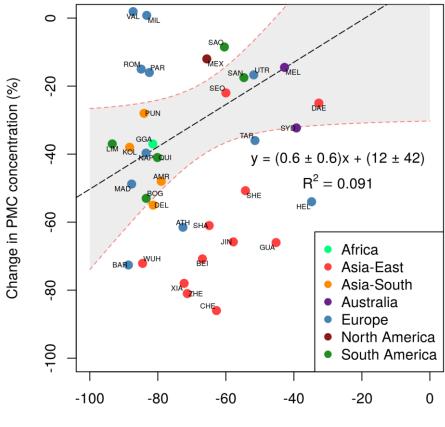


Figure S3.1.3. Linear regression fit (dashed line) and equation between NO2 and mobility percentage changes during full lockdown. The shaded area represents the 95% Confidence Interval.



Change in mobility (%)

Figure S3.1.4. Linear regression fit (dashed line) and equation between PMC and mobility percentage changes during full lockdown. The shaded area represents the 95% Confidence Interval.

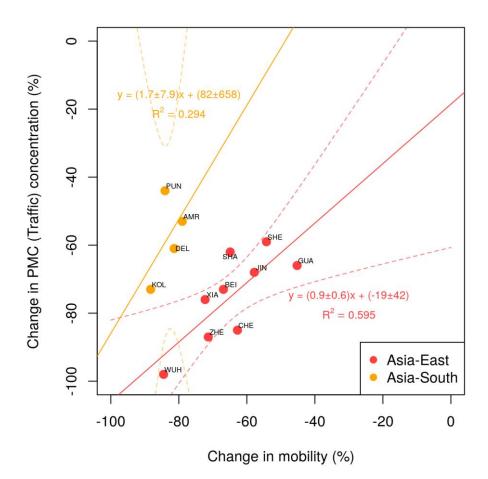


Figure S3.1.5. Linear regression fit (dashed line) and equation between PMC and mobility percentage changes during full lockdown for Indian and Chinese traffic sites. The dashed lines delimit the 95% Confidence Interval (Indian and Chinese cities only).

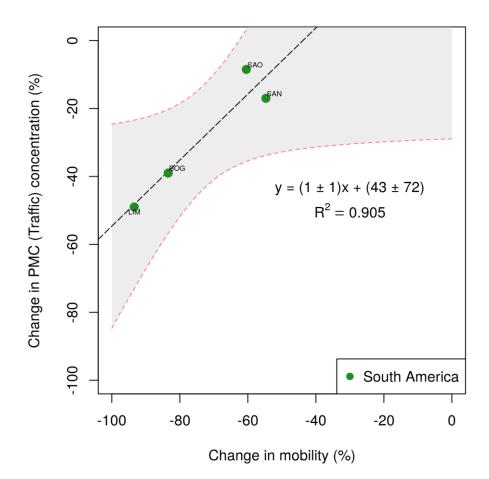
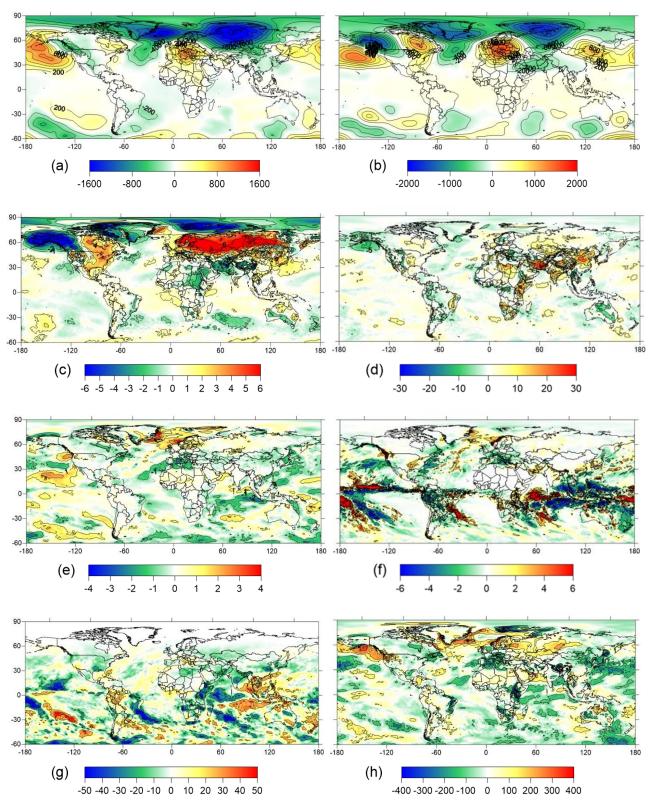


Figure S3.1.6. Linear regression fit (dashed line) and equation between PMC and mobility percentage changes during full lockdown for traffic sites in South America. The shaded area represents the 95% Confidence Interval.



**S3.2** Implications of prevailing meteorology to changes in air quality

Figure S3.2.1. January 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10-m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

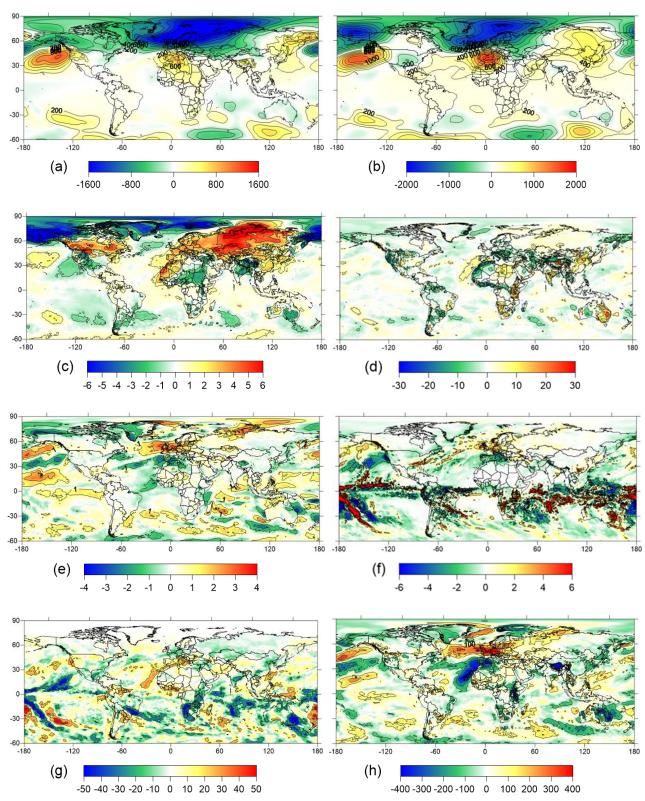


Figure S3.2.2. February 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10-m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

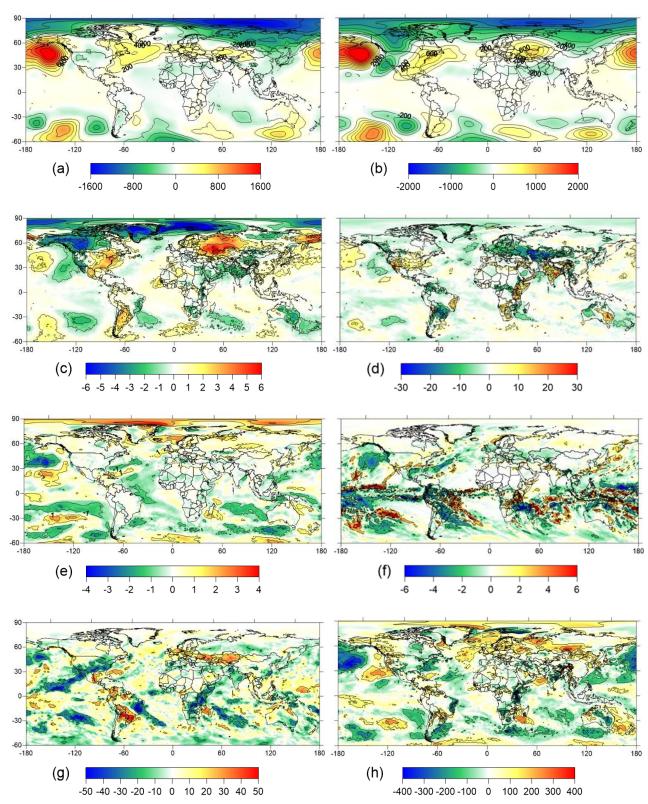


Figure S3.2.3. March 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

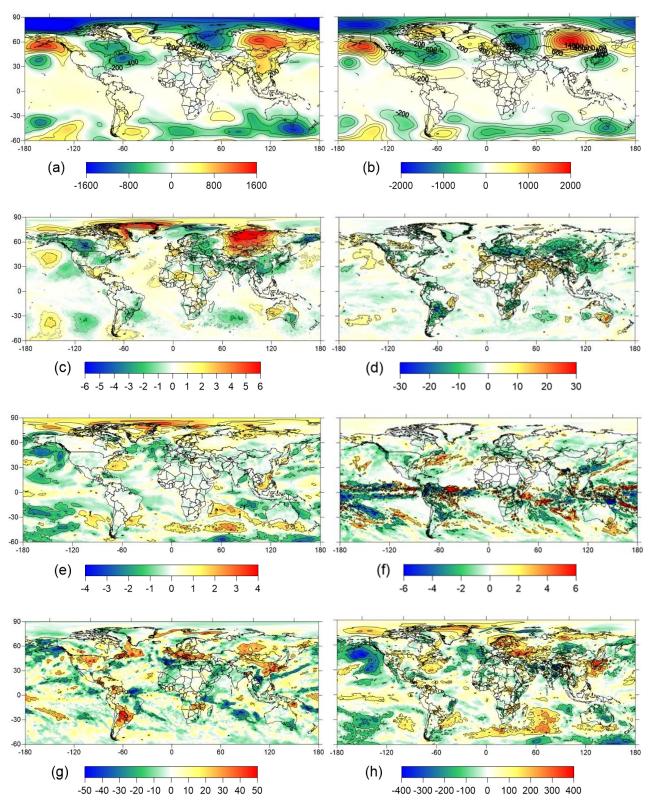


Figure S3.2.4. April 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2m temperature (K), (d) 2m relative humidity (%), (e) 10m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

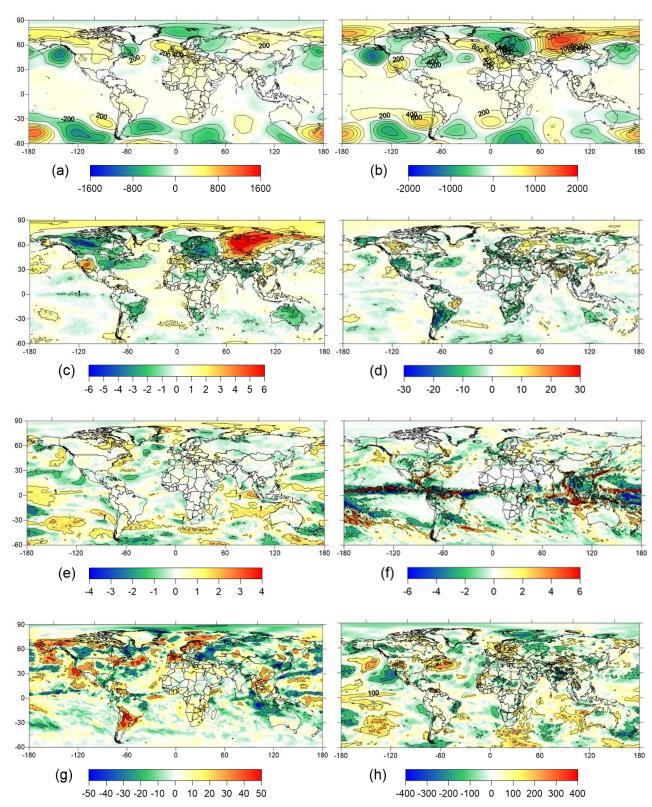


Figure S3.2.5. May 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

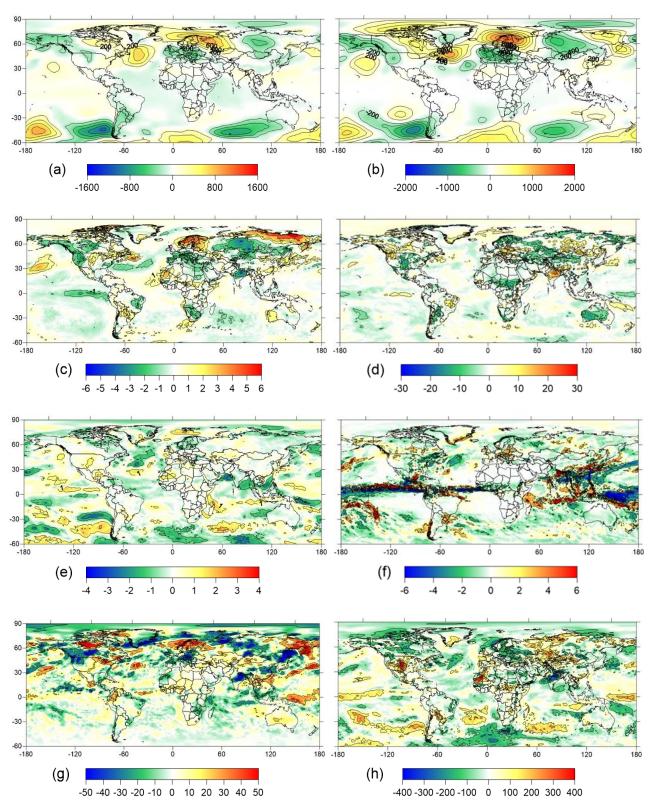


Figure S3.2.6. June 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation (W/m<sup>2</sup>), (h) boundary layer depth (m).

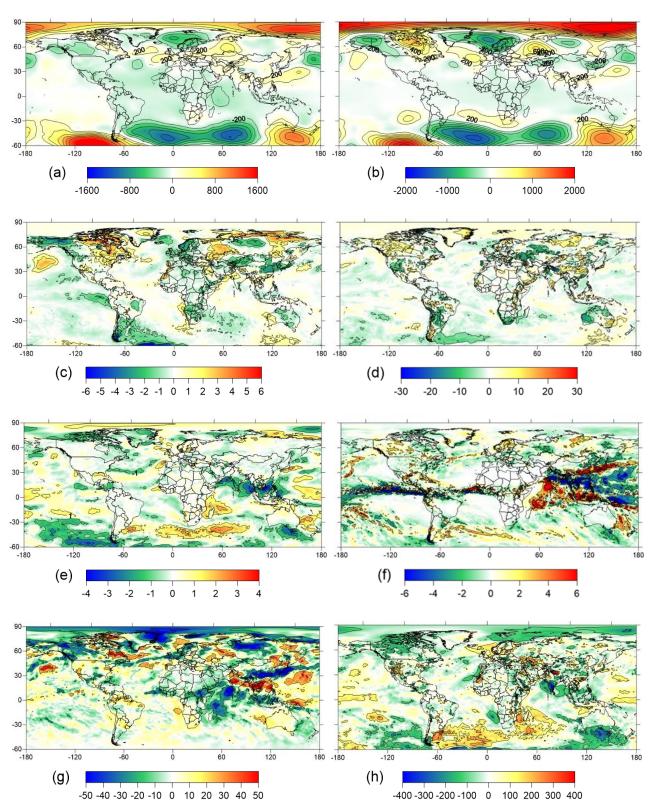


Figure S3.2.7. July 2020 anomalies with respect to 2015-2019 mean ERA5 reanalysis of (a) sea level pressure (Pa), (b) geopotential at 500 hPa ( $m^2/s^2$ ), (c) 2-m temperature (K), (d) 2-m relative humidity (%), (e) 10m wind speed (m/s), (f) precipitation rate (mm/day), (g) solar radiation ( $W/m^2$ ), (h) boundary layer depth (m).

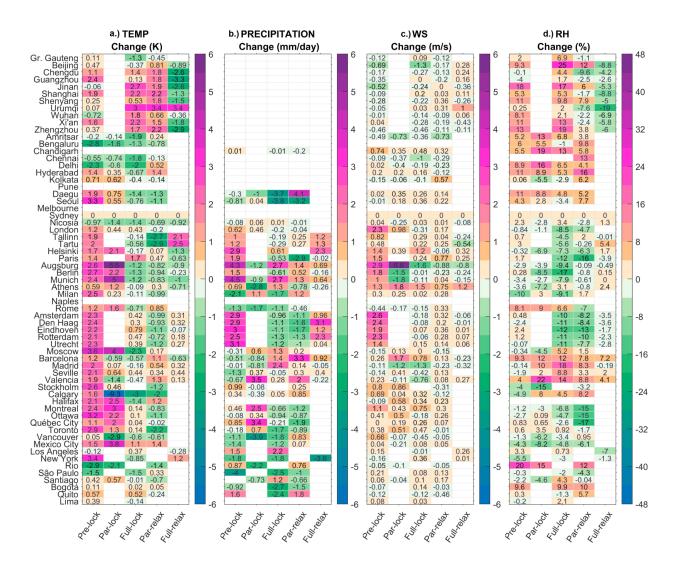


Figure S3.2.8. Mean observed in situ anomalies during the different COVID-19 lockdown phases compared with their corresponding periods in 2015-2019, (a) 2-m temperature (K), (b) precipitation rate (mm/day), (c) 10-m wind speed (m/s), (d) 2-m relative humidity (%).

## S3.3 Air quality and long-range transport of pollutants

Table S3.3.1. Air pollution episodes and atypical anticyclonic conditions affecting cities of interest during the lockdown periods during 2020.

| City  | Event                               | Period  |
|---|-------------------------------------|---|
| Seville, Madrid, Valencia,<br>Barcelona                                 | LRT Dust                            | 15-20 March                                   |
| Naples, Rome  | LRT Dust                            | 18-20 April                                   |
| Milan   | LRT Dust                            | 27-29 March                                   |
| Athens  | LRT Dust                            | 7-9 and 23 March; 3-5 April                   |
| Nicosia   | LRT Dust                            | 5-7, 13-15 and 24 March;-5 and 21-23<br>April |
| Zhengzhou   | LRT Dust                            | 24 January, 4 February, 18 March              |
| Xi'an, Beijing and Jinan  | LRT Dust                            | 18 March                                      |
| Several European regions (e.g.<br>Amsterdam, Ausburg, Munich,<br>Paris) | LRT Dust                            | 16-30 March                                   |
| Moscow  | LRT biomass burning                 | 29-31 March, 14-15 April                      |
| Mexico city   | LRT biomass burning                 | 26 April – 19 May                             |
| Bogotá  | LRT biomass burning                 | 2 February – 1 May                            |
| All Asian cities except Urumqi,<br>Xi'an and Hyderabad                  | LRT biomass burning                 | During different lockdown periods             |
| Vancouver   | Atypical anticyclonic conditions    | February to April                             |
| Halifax   | Atypical anticyclonic<br>conditions | March   |
| Seville, Madrid, Valencia,<br>Barcelona                                 | Atypical anticyclonic<br>conditions | February                                      |
| Shenyang, Beijing, Seoul, Daegu   | Atypical anticyclonic<br>conditions | January, February                             |

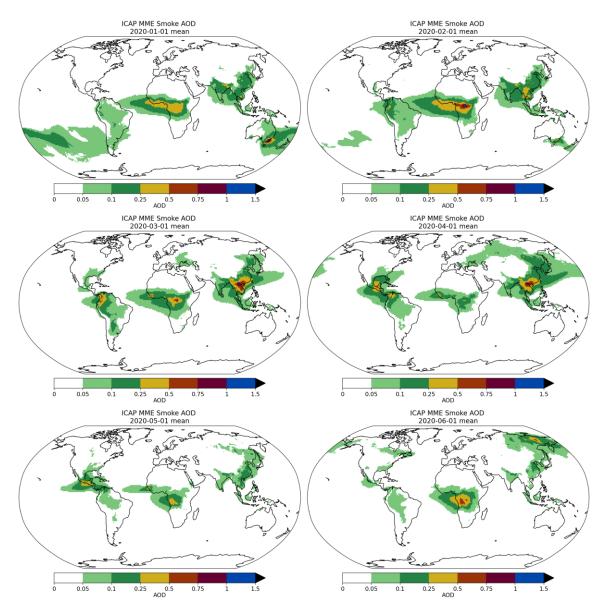


Figure S3.3.1. Monthly means (January to June 2020) of the ICAP/MME smoke AOD

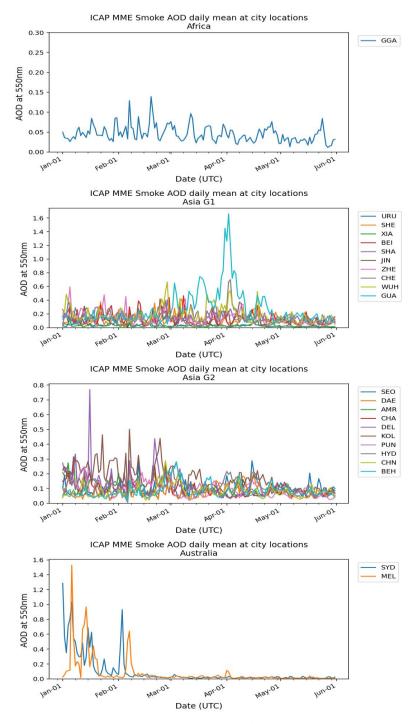


Figure S3.3.2. Time series (January to June 2020) of ICAP/MME daily means of the **smoke** AOD over considered cities in Africa, Asia and Australia. The three-letter city acronyms are defined in Table S2.1.1.

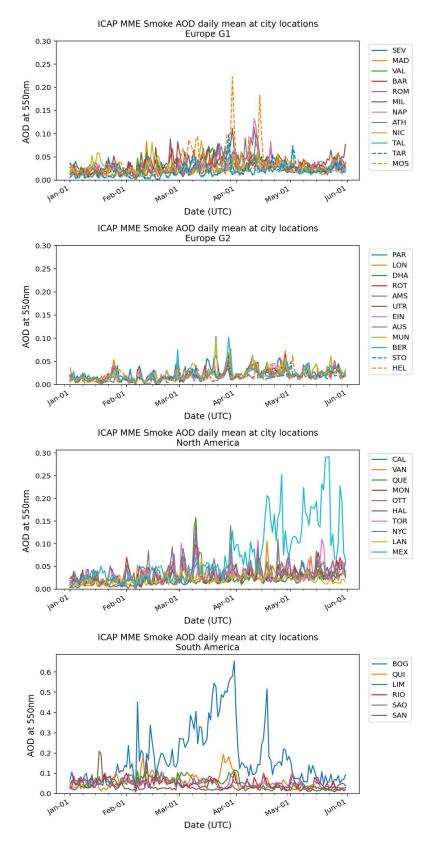


Figure S3.3.3. Time series (January to June 2020) of ICAP/MME daily means of the **smoke** AOD over considered cities in Europe, North and South America. The three-letter city acronyms are defined in Table S2.1.1.

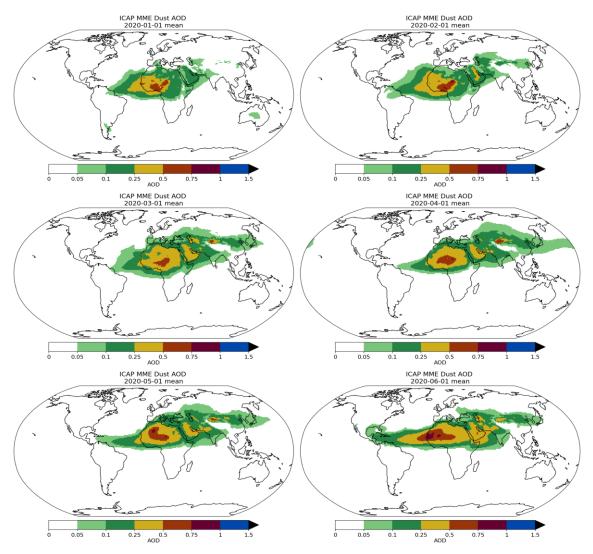


Figure S3.3.4. Monthly means (January to June 2020) of the ICAP/MME **Dust** AOD.

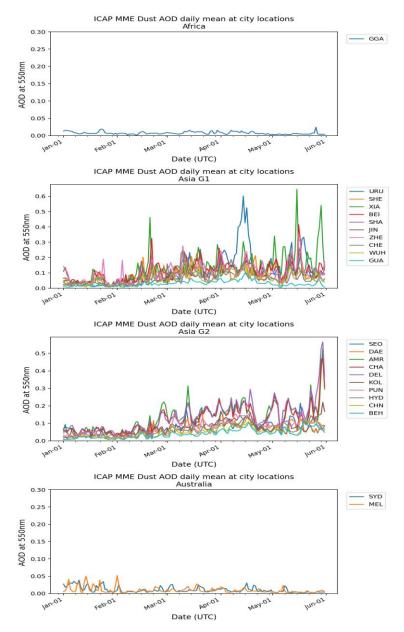


Figure S3.3.5. Time series (January to June 2020) of ICAP/MME daily means of the **Dust** AOD over considered cities in Africa, Asia and Australia. The three-letter city acronyms are defined in Table S2.1.1.

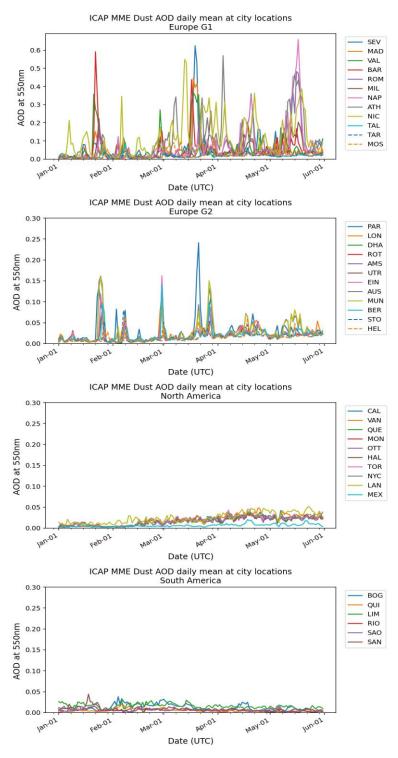


Figure S3.3.6. Time series (January to June 2020) of ICAP/MME daily means of the **Dust** AOD over considered cities in Europe, North and South America. The three-letter city acronyms are defined in Table S2.1.1.

# S3.4 Changes in air pollutant concentrations during the lockdown periods

#### S3.4.1 Carbon monoxide concentrations for 2015–2019

On a global scale, CO concentrations were the highest in Asia in 2015–2019 (see Figure S3.4.17a). The Indian and Chinese cities recorded the highest concentrations (750–4000  $\mu$ g/m<sup>3</sup>), followed by the South American and some Italian cities (600–1200  $\mu$ g/m<sup>3</sup>). The Canadian, US, Australian and rest of the European cities recorded the lowest concentrations (200–400  $\mu$ g/m<sup>3</sup>).

Strong inter-annual CO variations were observed in many countries, due to a combination of changes in emissions, meteorology and chemistry seasonal cycles (e.g., Sheel et al., 2014; Rozente et al., 2017). Cities in India and China recorded marked decreasing trends (up to -38%) for 2015–2019, probably following the trends described by Zheng et al. (2018) derived from continuous emission control policies. Decreasing trends were also observed in Mexico, Australia, some south-eastern Canadian cities (Montreal, Quebec and Ottawa), and Europe (Estonia, Finland, Italy, coastal cities of Spain and France). For a few cities, such as Madrid and Amsterdam, a 30% increase was observed over the period.

A pronounced seasonal pattern was evident in most NH cities, where CO concentrations decreased from the pre-lockdown to the relaxation periods (Figure S3.4.17b), which we believe to have been driven by both meteorological changes from winter to summer and by energy use (e.g., mobility and indoor heating). An opposite pattern was observed in the SH, especially in the Andean cities (Santiago, Quito and Bogotá) with maximum CO concentrations in the full lockdown period, coinciding with the winter season, with Santiago showing a nearly three-fold increase. Mendez-Espinosa et al. (2019), using a 10-year climatology of trace pollutants, have shown that CO peaks occur in February and March in Bogotá, associated with biomass burning and stagnant atmospheric conditions.

#### S3.4.2 Relative CO changes by type of environment

The available CO data were predominantly from traffic and urban background sites, except for China (see Figure S3.4.17e). In most American, Indian and European cities, the decreases during the lockdown were most likely dominated by the reduction in traffic emissions, since negative CO anomalies were higher at traffic sites. Conversely, CO variations in several Chinese cities showed a more homogeneous spatial pattern across rural, industrial and urban background sites, suggesting that all different anthropogenic activities affected the CO concentrations. Seville and Madrid showed the largest increases at traffic and rural sites, respectively, but the signal may have been affected by domestic biomass burning because the sites are located within residential areas.

#### S3.4.3 Sulphur dioxide concentrations for 2015–2019

 $SO_2$  showed variability on a worldwide scale (Figure S3.4.23), with higher concentrations in Asia than in other regions. The Chinese and Indian cities registered the highest mean  $SO_2$  concentrations during the corresponding lockdown periods in BAU periods of 2015-2019 (from 10.7 to 78.5 µg/m<sup>3</sup> and from 7.3 to 15.9 µg/m<sup>3</sup>, respectively). Other cities exhibited lower  $SO_2$  concentrations, with all but Mexico City and Madrid having mean concentrations in BAU lower than 6 µg/m<sup>3</sup>, with the lowest values (0.38-1.6 µg/m<sup>3</sup>) in Estonian cities. Strong inter-annual  $SO_2$  variations were evident in most countries in 2015–2019. A decreasing trend from 2015 to 2019 was seen in China, South Korea, Europe (France, Estonia, Italy and the Netherlands), Mexico, US, Brazil, and Ecuador. Some countries, however, showed either no changes or increasing trends, including India, Australia and Europe (Cyprus, Finland, Spain except Barcelona), and the cities of Halifax and Bogotá.

Temporal variabilities in  $SO_2$  concentrations were observed for most cities from 2015 to 2019 (Figure S3.4.23). In Asian cities (except Chennai, Delhi and Hyderabad), the decreases were prominent from the pre-lockdown to the relaxation periods. As the temperature increased from pre-lockdown to

full lockdown, a reduction in residential heating emissions may have partly contributed to the temporal decrease in SO<sub>2</sub> (Liu et al., 2016; Zhai et al., 2019). In other NH cities, such as those in Europe and North America (except for Naples, Toronto, and Vancouver), decreases were also large (up to 64%). Conversely, in the SH, the SO<sub>2</sub> concentrations increased which may be attributed to the winter heating emission and the influence of the Amazonian fires (Buchholz et al., 2018). Besides, enhanced oxidizing capacity can promote the formation of sulfate by oxidizing SO<sub>2</sub>, and increases in OX can be understood as enhancements in the abundance of oxidants (e.g., OH) (Lee et al., 2020; Shen et al., 2021). Hence, increased seasonal OX in most NH cities while decreases in SH cities (not shown) can be another cause for the opposite temporal variabilities in worldwide SO<sub>2</sub> levels.

#### S3.4.4 Relative changes during full lockdown period by type of environment

Because most SO<sub>2</sub> monitoring stations were either traffic or urban types (Figure S3.4.23e), the SO<sub>2</sub> decreases during the lockdown compared to the 2015–2019 means at traffic sites were prominent in China, some southern European and American cities (most saw decreases larger than -40%) and two of the three Indian cities (Delhi and Hyderabad). In the case of Chennai, there was an increase of 20% at the traffic site but a significant decrease of 66% at the industrial station which requires further investigation. Chinese, some northern European and southern American urban background sites also showed large decreases, while Naples, Calgary, and Ottawa had increases at urban background sites (6.2 to 29%). All of the industrial stations showed reductions during 2020 compared to BAU. For rural stations only Valencia showed an increase (+9.9%) for 2020. As mentioned above, interpreting isolated instances is difficult for SO<sub>2</sub> but overall, there were decreasing trends globally over the 2020 lockdown periods compared to BAU at most station types.

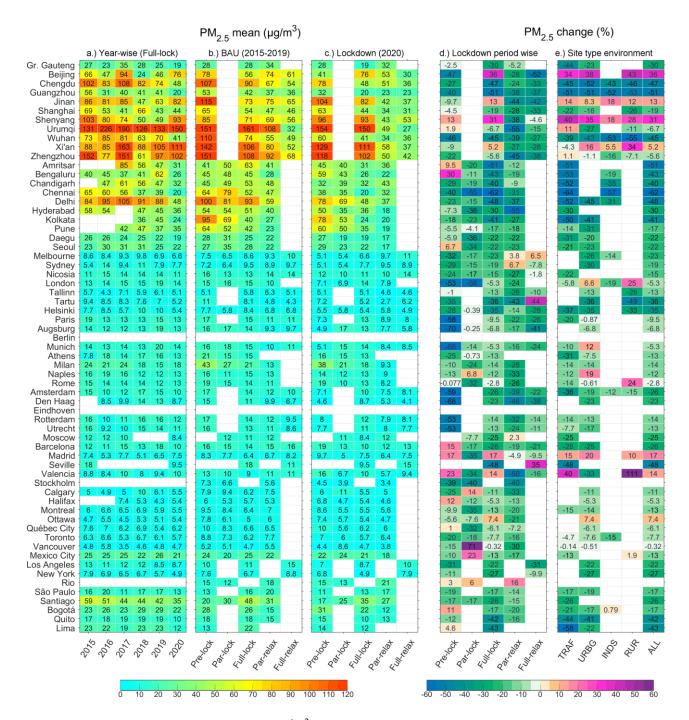


Figure S3.4.1. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in PM<sub>2.5</sub> (a) Mean concentrations for the full lockdown period for years 2015 to 2020, (b) Mean concentrations for different matching lockdown periods during BAU, (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

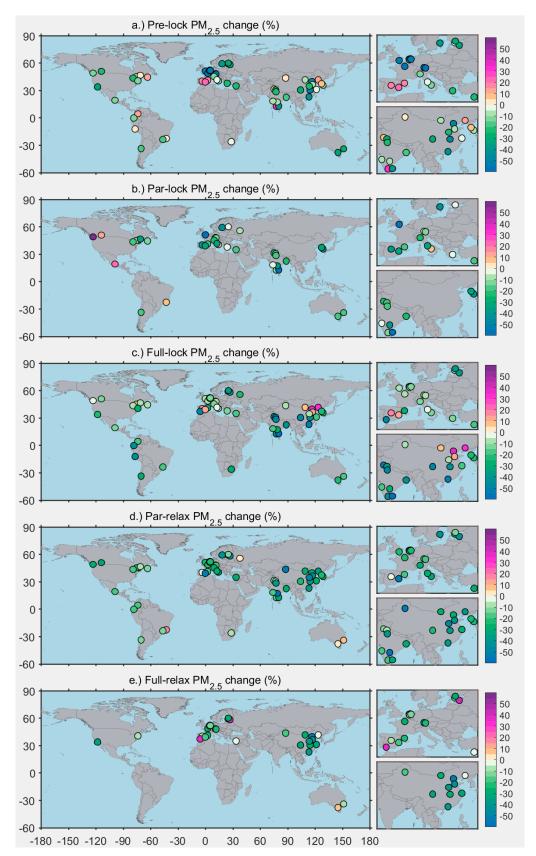


Figure S3.4.2. Observed percentage change in  $PM_{2.5}$  on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zooms of European and Asian countries.

#### $PM_{2.5}/PM_{10}$ mean (Ratio)

 $\mathrm{PM}_{2.5}^{}/\mathrm{PM}_{10}^{}$  change (%)

|             |      |      |       |       |         |      | 2              | 5        | 1    | 0         |                   | `     | ,               |       |  |             |      |        |                  |        |           |        | 2.5   | 10      |        | · · · | '     |         |
|-------------|------|------|-------|-------|---------|------|----------------|----------|------|-----------|-------------------|-------|-----------------|-------|--|-------------|------|--------|------------------|--------|-----------|--------|-------|---------|--------|-------|-------|---------|
|             | a.)  | Yea  | r-wis | e (Fu | ull-loc | ck)  |                | b.) E    | BAU  | (201      | 5-20 <sup>-</sup> | 19)   | C               | ) Loc | kdow   | n (202      | 20)  | d      | ) Lo             | ckdov  | vn pe     | riod w | vise  | e.) Sit | e type | envir | ronme | ent     |
| Gr. Gauteng |      |      |       |       |         | · ·  | 0.6            |          |      | •         | 0.65              | ,     | 0.74            | ,     | 0.79   | •           | ,    | _      | 7.2              |        | 6         | 12     |       | -3.6    | 11     |       |       | 6       |
|             |      |      |       |       |         |      |                |          | _    |           |                   | 0.40  |                 | -     |  |             | 0.47 |        | 4                |        | 39        |        | 2.0   | -3.6    |        |       | 75    | 39      |
| Beijing     |      |      |       | 0.46  |         |      | 0.1            |          |      |           | 0.81              |       | 0.73            | _     |  | 0.88        |      | 1      |                  |        |           | 8.1    | -2.9  |         | 40     | -     | 75    |         |
| Chengdu     |      |      |       |       |         |      | 0.6            |          |      |           | 0.62              |       | 0.75            |       |  | 0.6         |      |        | 13               |        |           | -3.2   | 4.6   | 30      | 29     | 34    | 35    | 31      |
| Guangzhou   |      |      |       |       |         |      | 0.6            |          |      |           | 0.62              |       | 0.51            | _     |  | 0.58        | 0.51 |        | -22              |        |           | -7.6   | -14   | 12      | 10     | 8.5   | 2.4   | 11      |
| Jinan       |      |      |       |       |         |      | 0.5            |          |      |           | 0.53              |       | 0.74            | -     |  | 0.52        |      |        | 27               |        |           | -1.5   | 2.5   | 48      | 37     | 48    | 42    | 44      |
| Shanghai    |      |      |       | 0.91  |         |      | 0.8            |          |      |           | 0.73              |       | 0.91            | _     |  | 0.85        |      |        | 8.5              |        |           | 17     | 3.9   | 8.7     | 28     |       | 16    | 9.7     |
| Shenyang    |      |      |       | 0.62  |         |      | 0.6            |          |      |           | 0.63              | 0.48  | 0.78            |       |  | 0.62        |      |        | 13               |        |           | -1.4   | 3.1   | - 38    | 27     | 29    | 23    | 31      |
| Urumqi      | 0.41 |      |       | 0.41  |         | 0.86 | 0.6            |          |      | 0.48      |                   | 0.35  | 0.91            |       | 0.86   |             |      |        | 35               |        | 81        | 27     | -32   | 124     | 59     |       | 45    | 81      |
| Wuhan       | -    |      | 0.68  |       | 0.68    |      | 0.7            |          |      |           | 0.53              | 0.46  | 0.66            |       |  | 0.64        |      | · ·    | -13              |        | 20        | 19     | 27    | 59      | -7.8   | 16    |       | 20      |
| Xi'an       | 0.54 | 0.55 | 0.75  | 0.67  | 0.71    | 0.9  | 0.6            | 67       |      | 0.64      | 0.54              | 0.39  | 0.9             |       | 0.9  | 0.54        | 0.4  | · ·    | 35               |        | 40        | -0.79  | 3.2   | 36      | 46     | 37    | 58    | 40      |
| Zhengzhou   | 0.66 | 0.57 | 0.74  | 0.59  | 0.66    | 0.91 | 0.7            | 7        |      | 0.64      | 0.58              | 0.41  | 0.91            |       | 0.91   | 0.57        | 0.48 | · ·    | 30               |        | 42        | -2.2   | 18    | 49      | 35     | 42    | 46    | 42      |
| Amritsar    | -    |      |       | 0.48  | 0.39    | 0.49 | 0.5            | 51 0     | ).51 | 0.44      | 0.43              |       | 0.48            | 0.47  | 0.49   | 0.5         | -    |        | -6               | -8.3   | 12        | 15     |       | 12      |        |       |       | 12      |
| Bengaluru   | -    |      |       |       |         | -    | -              |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        | -     | -       |        |       |       | -       |
| Chandigarh  |      |      | 0.39  | 0.47  | 0.35    | 0.43 | 0.4            | 7 0      | .45  | 0.4       | 0.5               |       | 0.35            | 0.46  | 0.43   | 0.58        | -    |        | -27              | 1.9    | 7.1       | 17     | -     | -       |        | 7.1   |       | 7.1     |
| Chennai     |      |      |       |       |         |      | -              |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        | -     | -       |        |       |       |         |
| Delhi       | 0.38 | 0.34 | 0.43  | 0.35  | 0.35    | 0 44 | 0.4            | 7 0      | ) 42 | 0.37      | 0.39              |       | 0.48            | 0.46  | 0.44   | 0.42        |      |        | 1.1              | 9.3    | 20        | 7.2    |       | 16      | 12     | 69    |       | 20      |
| Hyderabad   | 0.00 | 0.04 | 0.40  | 0.00  | 0.00    | 0.11 | 0.4            |          |      | 0.07      | 0.00              |       | 0.40            | 0.40  | 0.44   | 0.42        |      |        |                  | 0.0    | 20        | 1.44   |       | -       | 14     | 00    |       | 20      |
| Kolkata     |      |      |       | 0.5   | 0.54    | 0.54 | 0.5            | 6 0      | .58  | 0.52      | 0.51              |       | 0.52            | 0.53  | 0.54   | 0.48        |      |        | -7.5             | -8.4   | 3         | -6.6   |       | 37      | -6.1   |       |       | 3       |
|             |      |      | 0.52  | 0.59  |         |      | 0.5            |          |      | 0.52      | 0.51              |       | 0.52            | 0.64  |  |             |      |        | 20               | -0.4   | 19        | 5.3    |       | 21      | 10     |       |       | 19      |
| Pune        | 0.50 | 0.45 |       |       |         |      |                |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        |       | - 7     |        |       |       |         |
| Daegu       |      |      |       | 0.46  |         |      | 0.5            |          |      | 0.48      | 0.59              |       | 0.69            |       | 0.5  | 0.55        | -    |        | 22               | 1.4    | 4.2       | -5.6   | -     |         | 3.8    |       |       | 4.2     |
| Seoul       |      |      |       |       |         |      | 0.5            |          |      | 0.49      | 0.58              |       | 0.67            | 0.58  |  |             |      | 1      | 27               | 3.8    | -3.4      | -1.2   |       | -5.4    |        |       |       | -3.4    |
| Melbourne   | 0.62 | 0.45 | 0.57  | 0.44  | 0.35    | 0.44 | 0.3            |          |      | 0.49      | 0.64              | 0.73  | 0.3             | 0.29  |  |             | 0.65 |        | -20              | -22    | -9.8      | -4     | -11   | 1       | -9.8   |       |       | -9.8    |
| Sydney      |      |      |       |       |         |      | 0.3            |          |      | 0.49      | 0.64              | 0.63  | 0.29            |       |  |             | 0.65 | -      | -13              | -9.8   | 12        | 7      | 3.6   | 1       | -1.1   |       |       | 12      |
| Nicosia     |      |      |       |       |         |      | 0.4            | 9 0      | ).47 | 0.42      | 0.47              | 0.5   | 0.55            | 0.37  | 0.49   | 0.45        | 0.54 |        | 12               | -20    | 18        | -5.2   | 8.7   | 17      |        |       |       | 18      |
| London      |      |      |       |       |         |      | 0.6            |          |      | 0.64      | 0.56              |       | 0.52            |       |  | 0.56        |      | -      | -17              | -27    | -7.2      | -1.1   | ŀ     | -8.2    | -1.9   | -22   | -3    | -7.2    |
| Tallinn     |      |      |       |       |         |      | 0.             |          |      | 0.53      | 0.53              | 0.52  | 0.53            |       | 0.47   |             | 0.5  |        | 5.9              |        | -11       |        | -4.2  | -       | -11    |       |       | -11     |
| Tartu       |      |      |       |       | 0.28    |      | 0.5            |          |      | 0.33      | 0.28              | 0.31  | 0.54            |       | 0.33   |             | 0.4  |        | 1.7              |        | 0.27      | -10    | 27    | -       | 0.27   |       |       | 0.27    |
| Helsinki    |      |      |       | 0.39  |         |      |                |          | 133  | 0.36      | 0.39              | 0.56  | 0.35            | 0.43  | 0.45   |             | 0.6  |        | -24              | 31     | 26        | 27     | 5.9   | 8.3     | 14     |       |       | 26      |
|             |      |      |       | 0.56  |         |      | 0.4            |          |      |           |                   |       |                 |       | 0.43   |             |      |        | 24               | 51     |           |        |       |         |        |       |       |         |
| Paris       |      | 0.62 | 0.55  | 0.56  | 0.50    | 0.59 |                |          |      | 0.58      | 0.55              | 0.51  | 0.47            |       |  |             | 0.44 |        | -25              | 0.00   | 0.83      | -20    | -14   | 2.2     | -1.2   |       |       | 0.83    |
| Augsburg    | 0.69 | 0.7  | 0.72  | 0.8   | 0.74    | 0.59 | 0.7            | 8 0      | ).75 | 0.73      | 0.71              | 0.64  | 0.71            | 0.74  | 0.59   | 0.67        | 0.49 |        | -9.1             | -0.62  | -19       | -5.4   | -24   | 1       | -19    |       |       | -19     |
| Berlin      | 1    |      |       |       |         |      | 1              | _        |      |           |                   |       |                 |       |  |             |      |        | _                |        |           |        |       |         |        |       |       | -       |
| Munich      |      |      |       | 0.64  |         |      | 0.6            |          | 0.64 | 0.65      | 0.62              | 0.59  | 0.52            | 0.62  |  | 0.6         | 0.59 | · ·    | -19              | -4.3   | -8.6      | -2     | -0.33 | -9.5    | -7.7   |       |       | -8.6    |
| Athens      | 0.44 | 0.43 | 0.6   | 0.45  | 0.58    | 0.7  | 0.6            | 63 0     | 0.59 | 0.5       |                   |       | 0.64            | 0.77  | 0.7  |             |      | · ·    | 1.2              | 31     | 40        |        | -     | 12      | 51     |       |       | 40      |
| Milan       | 0.75 | 0.71 | 0.72  | 0.64  | 0.62    | 0.66 | 0.7            | 7 0      | ).74 | 0.69      | 0.62              |       | 0.73            | 0.76  | 0.66   | 0.62        | -    | · · ·  | -4.9             | 1.4    | -4.2      | -0.33  | -     | -5.4    | -3     |       |       | -4.2    |
| Naples      | 0.5  | 0.48 | 0.55  | 0.38  | 0.45    | 0.58 | 0.5            | 51 0     | ).46 | 0.47      | 0.5               |       | 0.48            | 0.51  | 0.58   | 0.4         | -    | · · ·  | -4.8             | 9.8    | 22        | -21    | -     | 28      | 26     |       |       | 22      |
| Rome        |      |      |       | 0.52  |         |      | 0.6            |          |      | 0.56      | 0.54              |       | 0.61            | 0.5   | 0.59   |             |      |        | -8               | -14    | 6         | -17    | -     | 7.9     | 5.7    |       | 15    | 6       |
| Amsterdam   |      |      |       | 0.68  |         |      | 0.0            |          |      | 0.64      | 0.63              | 0.57  | 0.46            | 0.0   | 0.5  | 0.47        | 0.55 |        | -35              | -14    | -22       | -25    | -4    | -20     | -19    | -6.8  |       | -22     |
|             | 0.75 |      |       | 0.6   |         |      | 0.0            |          | _    | 0.54      | 0.00              | 0.4   |                 |       | 0.4  | 0.3         | 0.25 |        | 57               |        | -22       | -40    | -4    | -20     | -13    | -0.0  | -17   | -22     |
| Den Haag    | 1    | 0.5  | 0.5   | 0.0   | 0.57    | 0.4  | 0.0            | 0        |      | 0.54      | 0.5               | 0.4   | 0.26            | _     | 0.4  | 0.5         | 0.25 |        | -57              |        | -20       | -40    | -30   | 1       | -20    |       |       | -20     |
| Eindhoven   | 1    |      |       |       |         | -    | 1              | _        |      |           |                   |       |                 |       | _  |             |      | · ·    | _                |        |           |        | -     | 1       |        | _     |       |         |
| Rotterdam   |      |      |       |       |         |      | 0.6            |          |      | 0.62      | 0.58              | 0.5   | 0.5             |       |  | 0.44        |      |        | -25              |        | -9.5      |        | -3.6  | -12     | -7.4   |       |       | -9.5    |
| Utrecht     | 0.6  | 0.57 | 0.57  | 0.69  | 0.7     | 0.65 | 0.6            | 62       |      | 0.62      | 0.6               | 0.49  | 0.55            |       | 0.65   |             | 0.59 |        | -11              |        | 4.5       | -3     | 20    | 4.5     |        |       |       | 4.5     |
| Moscow      |      |      |       |       |         | 0.48 | -              | 0        | ).34 | 0.38      | 0.48              |       |                 | 0.35  | 0.48   | 0.5         |      |        |                  | 2.6    | 26        | 4.1    | -     | 26      |        |       |       | 26      |
| Barcelona   | 0.59 | 0.53 | 0.68  | 0.63  | 0.74    | 0.83 | 0.6            | 63 0     | 0.65 | 0.63      | 0.64              | 0.65  | 0.75            | 0.69  | 0.83   | 0.84        | 0.66 |        | 20               | 6.4    | 31        | 32     | 1.5   | 32      | 32     |       |       | 31      |
| Madrid      |      |      |       |       |         |      | 0.6            | 6 0      | 0.63 | 0.61      | 0.61              | 0.55  | 0.58            |       | 0.76   | 0.66        | 0.6  |        | -3               | 45     | 25        | 7.8    | 10    | 24      | 27     |       | -2.2  | 25      |
| Seville     | -    |      |       |       |         | -    | -              |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        | -     | -       |        |       |       | -       |
| Valencia    | 0.84 | 0.63 | 0.72  | 0.75  | 0.59    | 0.84 | - 0.7          | 2 0      | 66   | 0.71      | 0.71              | 0.73  | 0.66            | 0.81  | 0.84   | 0.74        | 0.67 |        | -7.5             | 23     | 18        | 4.5    | -7.5  | 25      |        |       | 21    | 18      |
| Stockholm   |      | 0.00 | 0.12  | 0.10  | 0.00    | 0.01 |                | 31 0     |      | 0.11      | 0.29              | 0.10  |                 | 0.22  |  | 0.28        |      |        | 2.7              | 2.7    | 10        | -4     | 1.0   |         |        |       |       |         |
|             |      |      |       |       |         |      | 0.5            |          | 1.21 |           | 0.29              |       | 0.51            | 0.22  | _  | 0.20        |      |        | 2.1              | 2.1    |           | 4      |       |         |        |       |       |         |
| Calgary     | 1    |      |       |       |         |      | 1              |          |      |           |                   |       | 1               |       |  |             |      | i 1-   |                  |        |           |        | -     | 1       |        |       |       |         |
| Halifax     | 1    |      |       |       |         |      | 1              |          |      |           |                   |       | 1               |       |  |             |      | i 1-   |                  |        |           |        | -     | - 1     |        |       |       | · · · · |
| Montreal    | 1    |      |       |       |         |      | 1              |          |      |           |                   |       | · ·             |       |  |             |      | 1      |                  |        |           |        |       | 1       |        |       |       |         |
| Ottawa      | 1    |      |       |       |         |      | 1              |          |      |           |                   |       | 1               |       |  |             |      |        |                  |        |           |        |       | 1       |        |       |       |         |
| Québec City | 1    |      |       |       |         | ŀ    | 1              |          |      |           |                   |       | -               |       |  |             |      |        |                  |        |           |        | ŀ     | -       |        |       |       | ŀ       |
| Toronto     | -    |      |       |       |         | ŀ    | -              |          |      |           |                   |       | -               |       |  |             |      |        |                  |        |           |        | ŀ     | -       |        |       |       | ŀ       |
| Vancouver   | -    |      |       |       |         | -    | -              |          |      |           |                   |       |                 |       |  |             |      | -      |                  |        |           |        | -     | -       |        |       |       | ŀ       |
| Mexico City | 0.61 | 0.55 | 0.56  | 0.57  | 0.57    | 0.58 | 0.5            | 5 0      | ).49 | 0.57      | 0.54              |       | 0.46            | 0.46  | 0.58   | 0.54        |      | -      | -6.8             | -5.9   | 0.27      | -1.4   | -     | 0.27    |        |       | -9.9  | 0.27    |
| Los Angeles |      |      |       |       |         |      | 0.             |          |      | 0.45      |                   | 0.46  | 0.32            |       | 0.34   |             | 0.29 |        | -36              |        | -24       |        | -37   | -       | -24    |       |       | -24     |
|             | 0.02 | 0.00 | 0.00  | 0.43  | 0.20    | 5.04 | 0.0            | -        | _    | 0.40      |                   | 0.40  | 0.02            |       | 0.04   |             | 0.20 |        | 00               |        | 24        |        |       | -       | 27     | -     |       | - 1     |
| New York    |      |      |       |       |         |      | 0              |          | 40   |           | 0.40              |       | 0.57            | 0.45  |  | 0.00        |      |        | 14               | 7 5    |           | 25     |       |         |        |       |       | [       |
| Rio         | 0.0  | 0.50 | 0.00  | 0.0   | 0.55    | 0.54 | 0.             |          | ).42 | 0.55      | 0.46              |       | 0.57            |       |  | 0.62        |      |        | 14               | 7.5    |           | 35     |       | 1       |        |       |       |         |
| São Paulo   |      |      |       | 0.6   |         |      | 0.5            |          |      |           | 0.59              |       | 0.55            |       | 0.54   |             |      |        | -4.8             |        | -5.3      | -9     |       | -5.3    |        |       |       | -5.3    |
| Santiago    |      |      |       |       |         |      |                |          | 0.41 |           | 0.49              |       |                 | 0.34  | 0.51   |             |      |        | -23              | -17    | -6.3      | -10    |       | -6.3    |        |       |       | -6.3    |
| Bogotá      |      |      |       |       |         |      | 0.5            |          |      |           | 0.45              |       | 0.62            |       |  | 0.52        |      |        | 20               |        | 27        | 17     |       | 12      | 30     |       |       | 27      |
| Quito       |      |      |       |       |         |      | 0.4            |          |      |           | 0.32              |       | 0.39            |       |  | 0.35        |      |        | -13              |        | -9.1      | 7.7    |       | -       | -9.1   |       |       | -9.1    |
| Lima        |      |      |       |       |         |      | 0.4            | 15       |      | 0.41      |                   |       | 0.58            |       | 0.5  |             |      |        | 27               |        | 23        |        |       | -8.4    | 20     |       |       | 23      |
|             |      |      |       |       |         |      |                |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        |       |         |        | -     | -     |         |
|             | 3    | 20   | ~     | <078  | 20      | N    | que los        | 2 0 10 N | ds.  | Willock . | to and the second | to at | Q <sup>Le</sup> | 20110 | the state of the s | to to to to | (at  |        | , 40 g           | 100% W | A Million | to     | ्रके  | X       | ŝ      | Sal   | Š     | ×1      |
|             | 2    | 2    | 2     | 2     | 3       | S.   | ×              | 2        | 8.   | 20        | Ser.              | Se .  | 20              | 20    | 20   | Ser.        | Se . |        | ~                | 20     | 20        | Ser.   | Ser.  | R       | £      | Ż     | Ŷ     | 4       |
|             |      |      |       |       |         |      | Q <sup>r</sup> | 20       | 4    | 5 0       | 8 1               | 3     | 2 V             | 20 1  | S.   | à i         | 3    | Q      | í q <sup>6</sup> | o y    | 5 0       |        | 5     |         | $\sim$ |       |       |         |
|             |      |      |       |       |         |      |                | •        |      | ~         | ~                 |       |                 | -     | - 4  | . ~         |      |        | •                |        | ×         | ×      |       |         |        |       |       |         |
|             |      |      |       |       |         |      |                |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        |       |         |        |       |       |         |
|             |      |      |       |       | 0.16    |      | 0.32           |          | 0.48 | 2         | 0.64              |       | 0.8             | 0.9   | 6  |             |      | -60 -5 | 0                | 10     | 30 -2     | 1      | ) 0   | 10 2    | 20 30  | 0 40  | 50    | 60      |
|             |      |      | U     |       | 0.10    | (    | J.32           |          | 0.48 | 0         | 0.04              |       | 0.0             | 0.9   | 0  |             |      | -00 -5 | -4               | +0 -3  | -20       | J -10  | 0     | 10 2    | 0 30   | J 40  | 50    | 00      |
|             |      |      |       |       |         |      |                |          |      |           |                   |       |                 |       |  |             |      |        |                  |        |           |        |       |         |        |       |       |         |

Figure S3.4.3. Observed concentration ratios and percentage changes in PM<sub>2.5</sub>/PM<sub>10</sub> concentration ratios (a) Mean concentration ratios for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentration ratios for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentration ratios during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

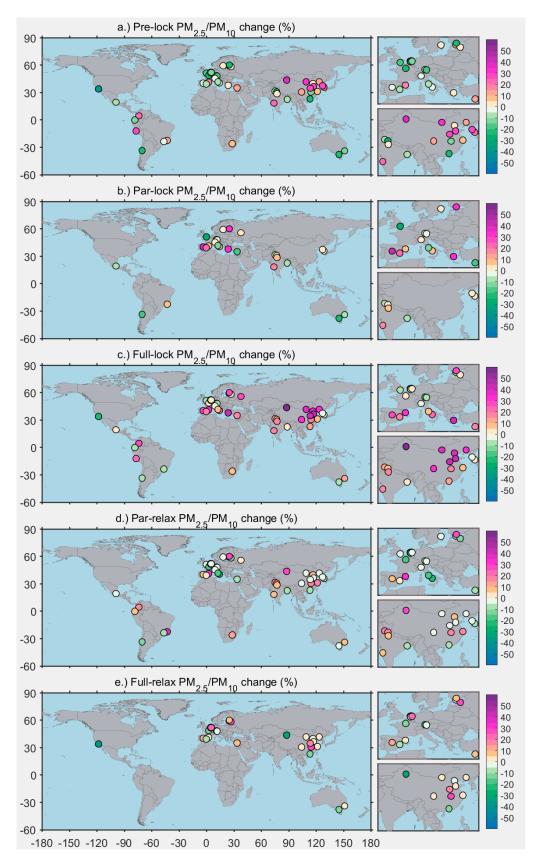


Figure S3.4.4. Observed percentage changes in  $PM_{2.5}/PM_{10}$  on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.



Figure S3.4.5. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in PM<sub>10</sub> (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

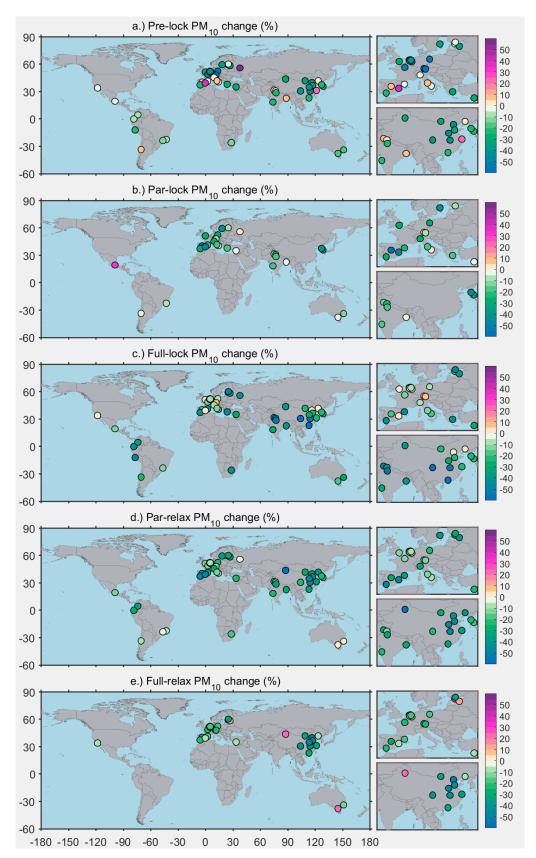


Figure S3.4.6. Observed percentage changes in  $PM_{10}$  on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

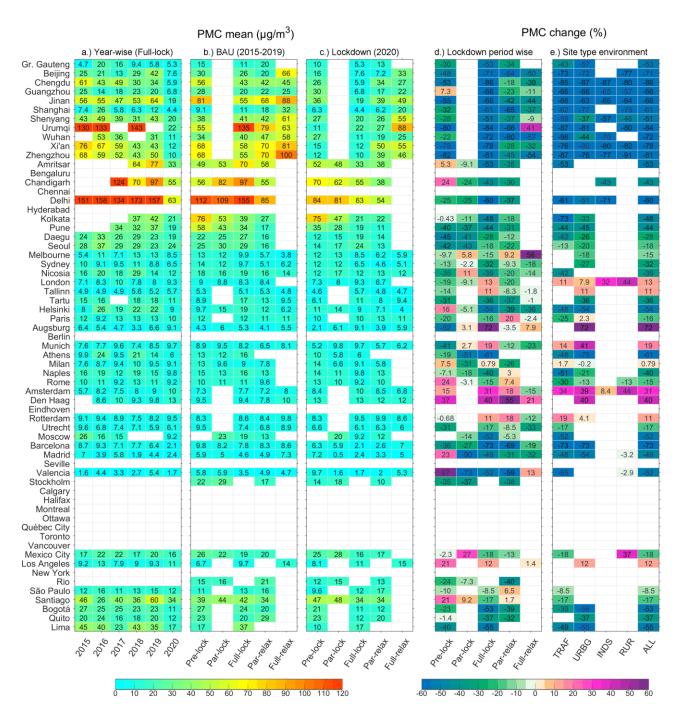


Figure S3.4.7. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in PMC (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

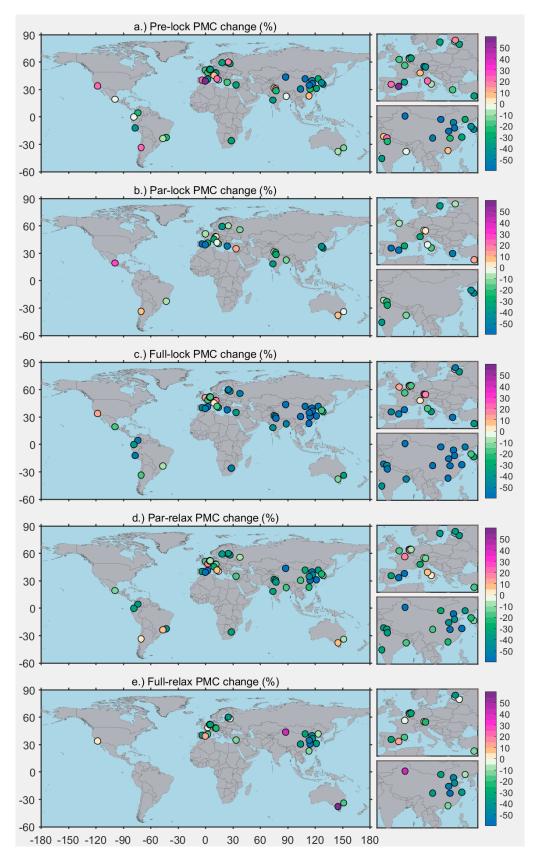


Figure S3.4.8. Observed percentage changes in PMC on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

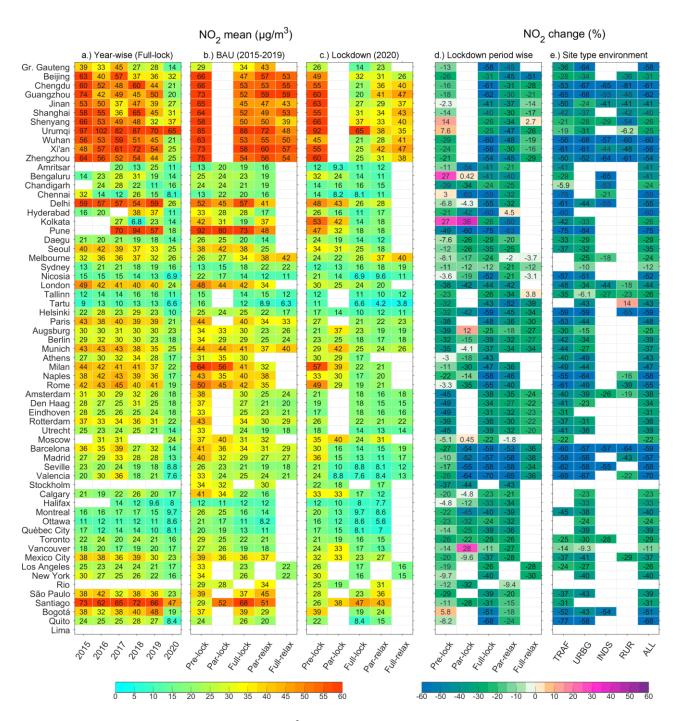


Figure S3.4.9. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in NO<sub>2</sub> (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

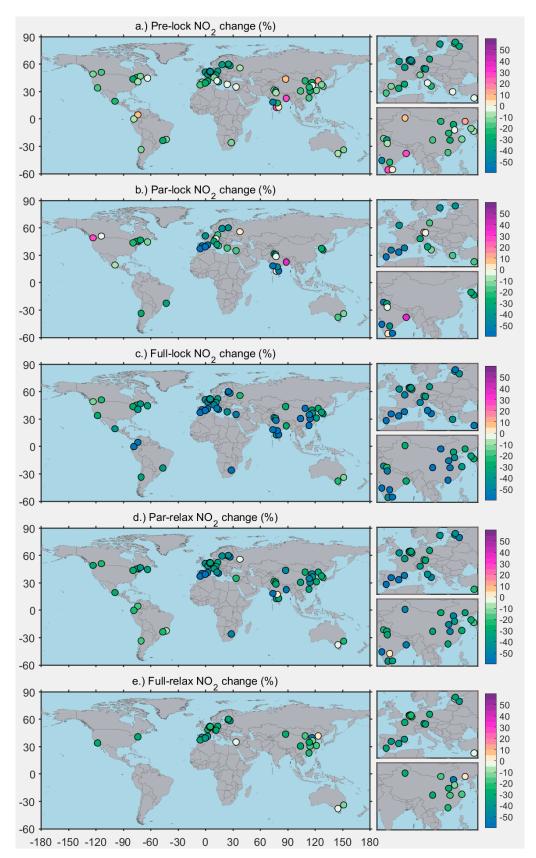


Figure S3.4.10. Observed percentage changes in  $NO_2$  on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

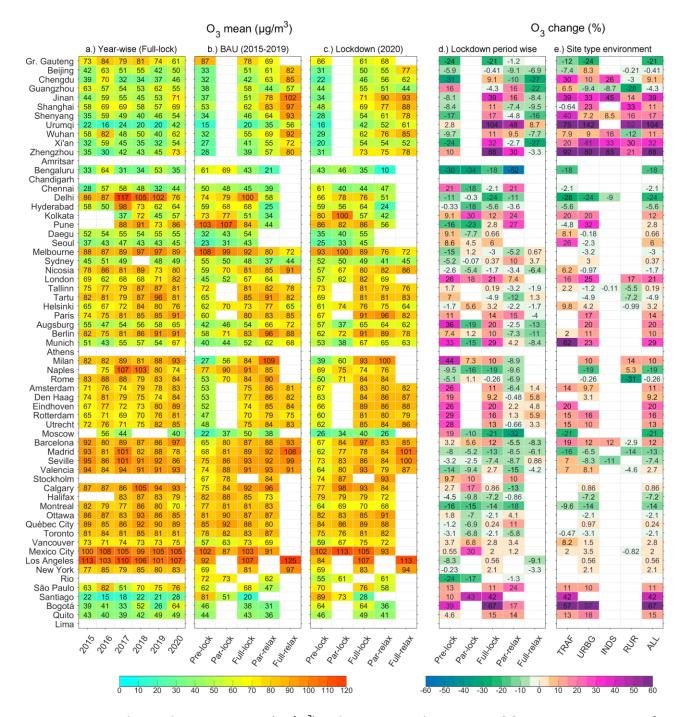


Figure S3.4.11. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in O<sub>3</sub> (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

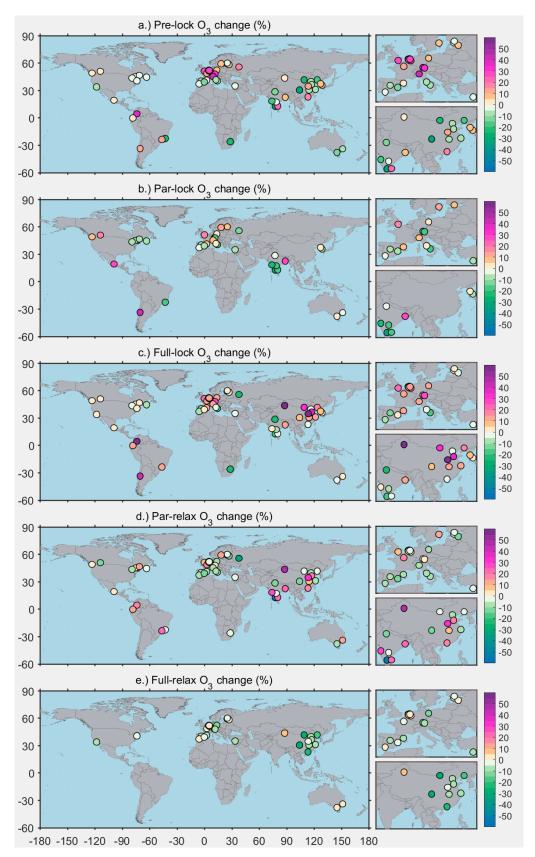


Figure S3.4.12. Observed percentage change in  $O_3$  on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of Europe and Asian countries.

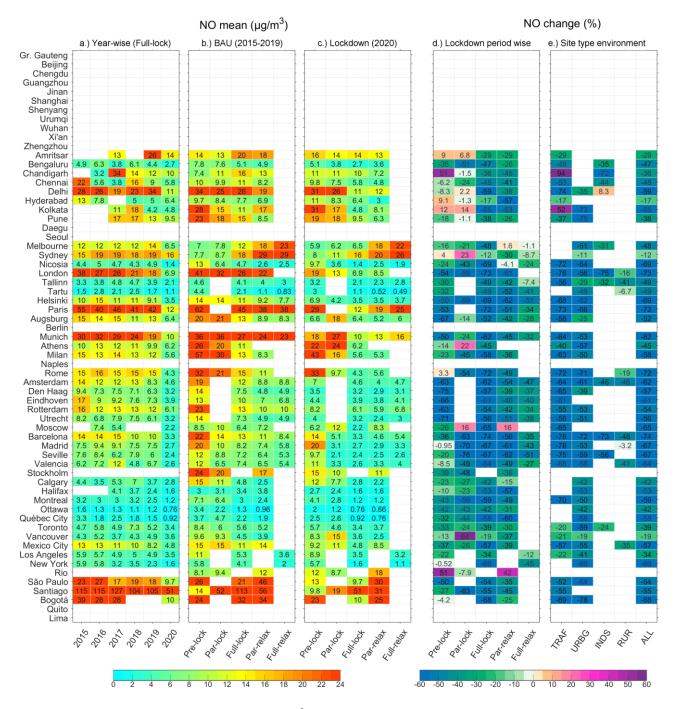


Figure S3.4.13. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in NO (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

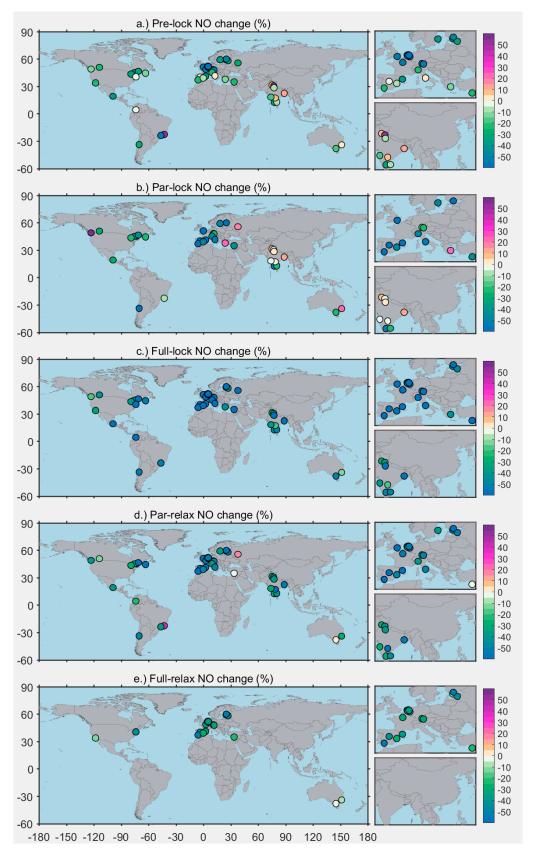


Figure S3.4.14. Observed percentage changes in NO on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

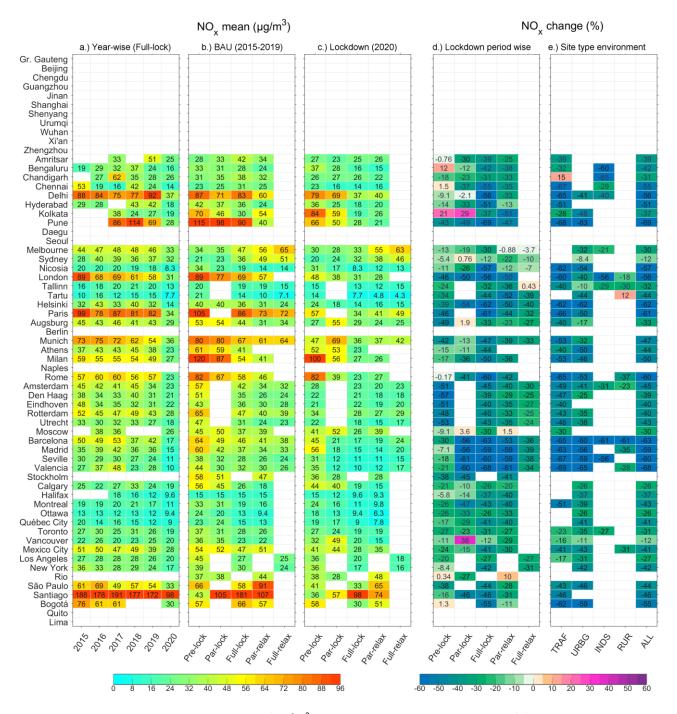


Figure S3.4.15. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in NO<sub>x</sub> (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

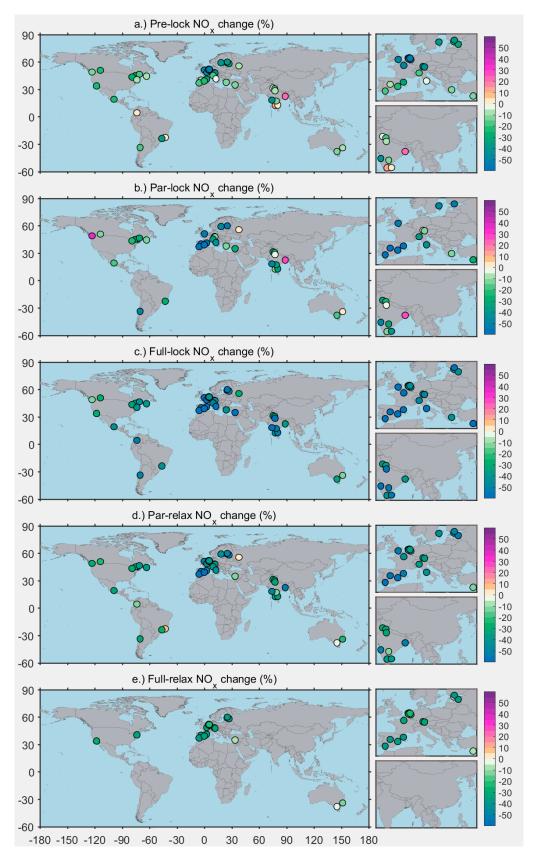


Figure S3.4.16. Observed percentage changes in  $NO_x$  on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

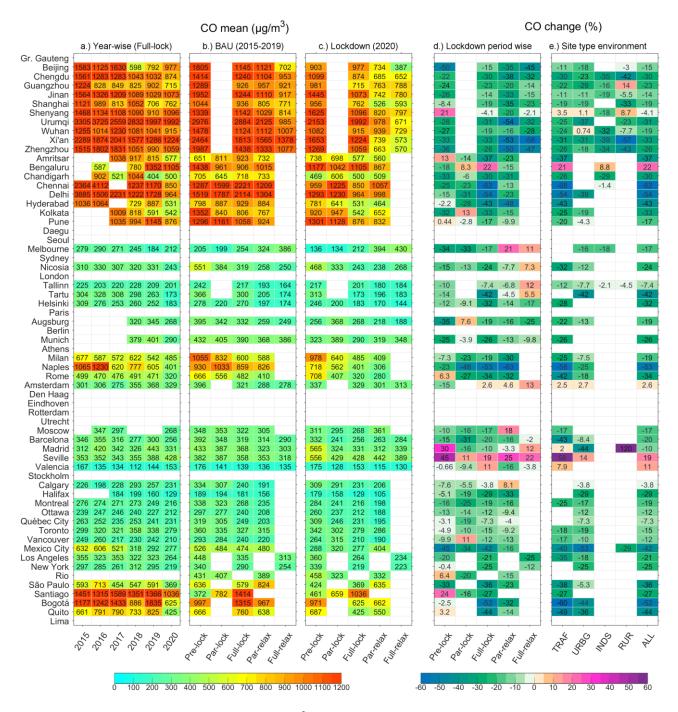


Figure S3.4.17. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in CO (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

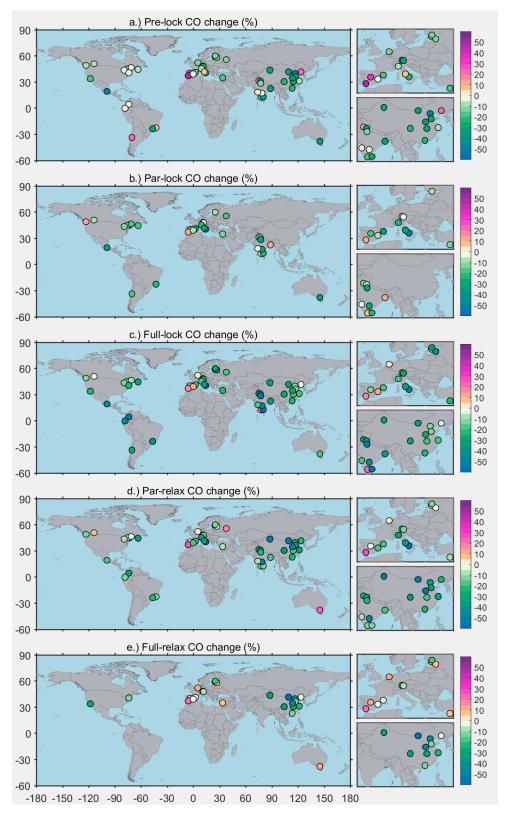


Figure S3.4.18. Observed percentage changes in CO on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

## NO<sub>2</sub>/CO mean (Ratio)

### NO<sub>2</sub>/CO change (%)

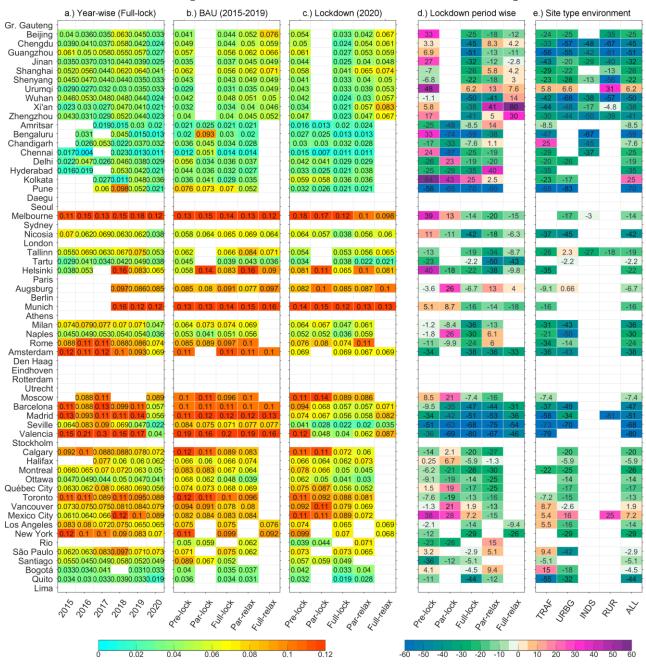


Figure S3.4.19. Observed concentration ratios and percentage changes in NO<sub>2</sub>/CO concentration ratio (a) Mean concentration ratios for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentration ratios for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentration ratios during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

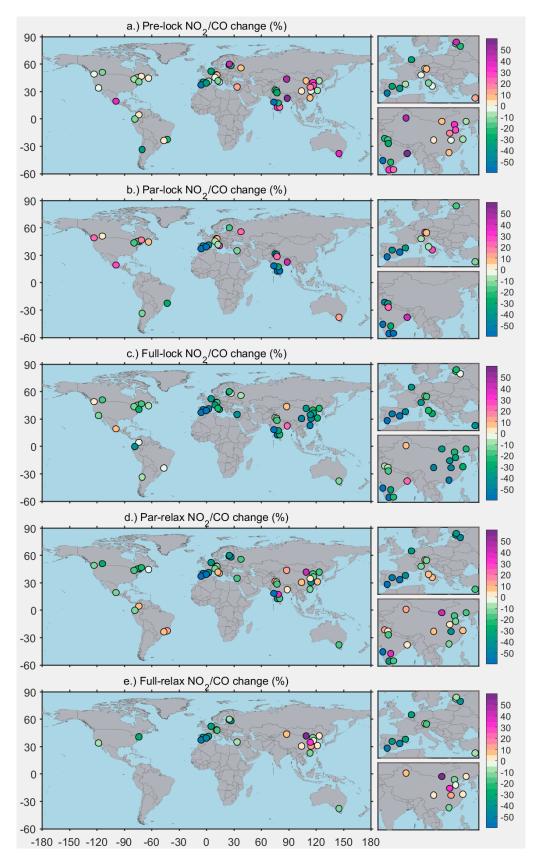


Figure S3.4.20. Observed percentage changes in  $NO_2/CO$  ratios on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

# NO<sub>x</sub>/CO mean (Ratio)

NO<sub>2</sub>/CO change (%)

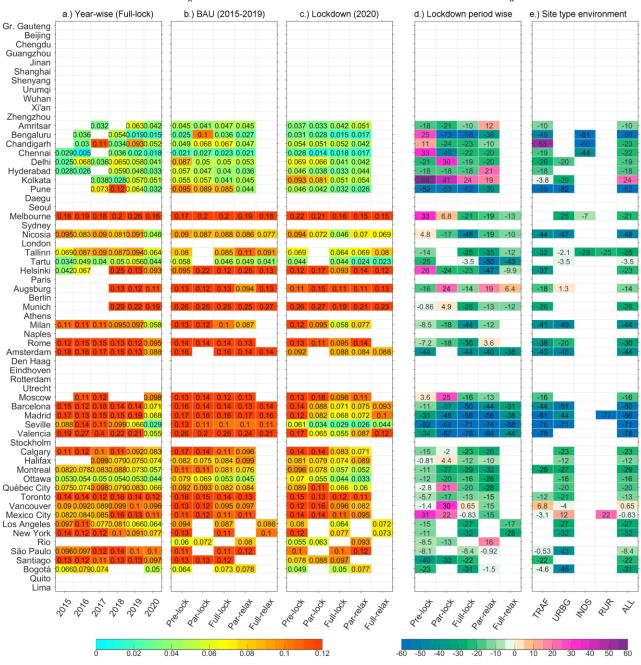


Figure S3.4.21. Observed concentration ratios and percentage changes in NO<sub>x</sub>/CO concentration ratio (a) Mean concentration ratios for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentration ratios for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentration ratios during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

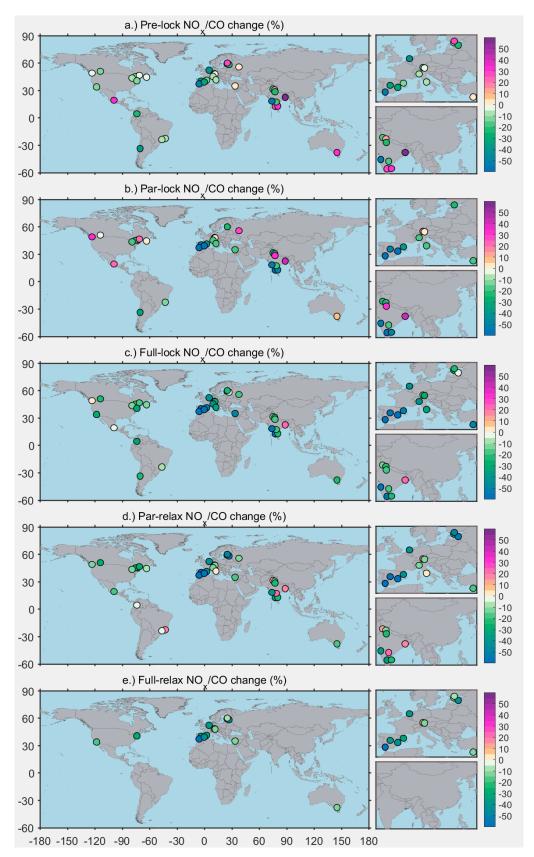


Figure S3.4.22. Observed percentage changes in  $NO_x/CO$  ratios on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

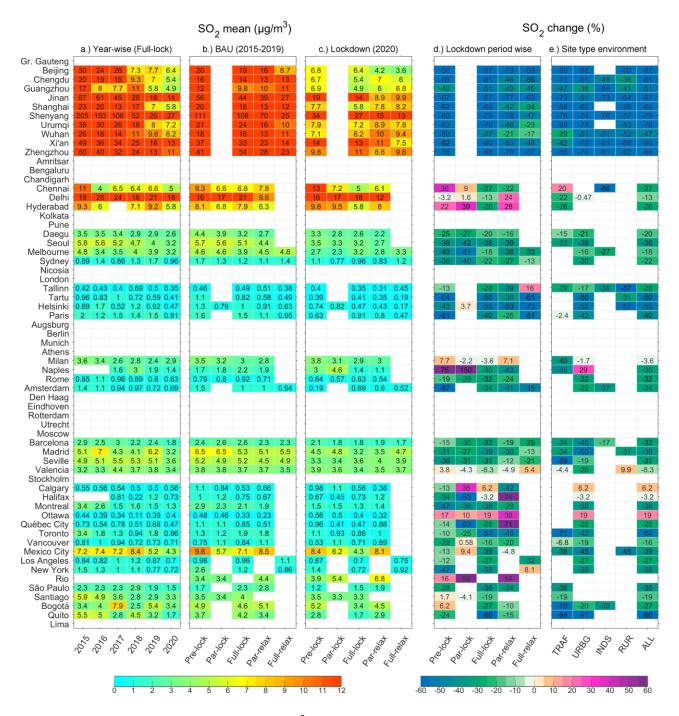


Figure S3.4.23. Observed concentrations ( $\mu$ g/m<sup>3</sup>) and percentage changes in SO<sub>2</sub> (a) Mean concentrations for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentrations for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentrations during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

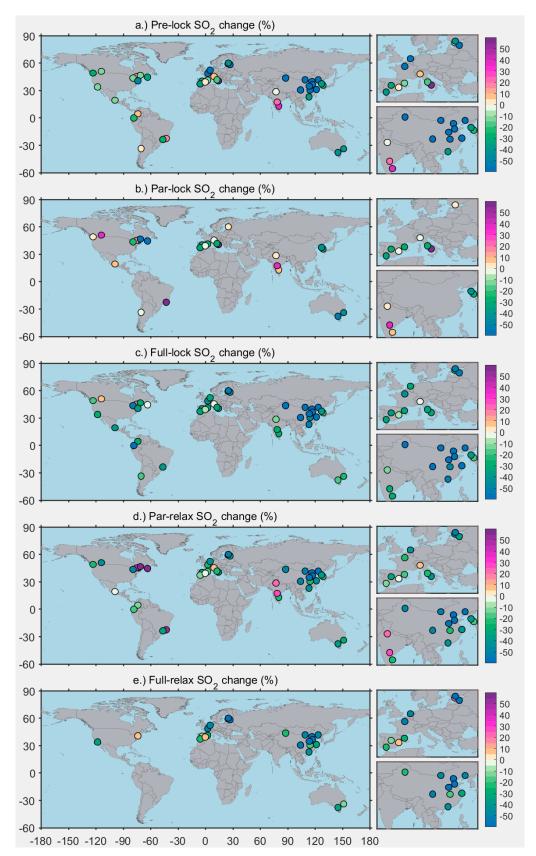


Figure S3.4.24. Observed percentage changes in  $SO_2$  on global map for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

### NO<sub>2</sub>/NO<sub>2</sub> mean (Ratio) NO<sub>2</sub>/NO<sub>v</sub> change (%) b.) BAU (2015-2019) e.) Site type environment a.) Year-wise (Full-lock) c.) Lockdown (2020) d.) Lockdown period wise Gr. Gauteng Beijing Chengdu Guangzhou Jinan Shanghai Shenyang Uruma Wuhan Xi'an Zhengzhou 0.48 0.47 0.41 0.47 0.53 -13 -13 -13 Amritsar 0.480.46 0.43 Bengaluru Chandigarh 0.83 0.83 0.81 -5 ).75 0.73 0.81 0.88 0.84 0.88 0.82 0.88 0.57 0.63 0.4 0.59 0.6 0.71 0.76 0.62 0.65 0.53 0.67 0.69 0.74 0.71 0.65 0.76 0.56 0.72 0.74 0.78 0.88 0.64 0.73 -18 0.62 0.59 0.59 2.6 0.77 0.65 0.55 0.67 Chennai Delhi 0.59 0.62 0.5 0.67 0.53 0.66 0.67 0.67 0.56 -5.2 -0.18 9.6 -16 0.7 0.63 0.76 -0.68 10 Hyderabad 0.76 0.76 0.69 0.66 0.71 0.64 0.85 -7.4 -13 24 0.71 0.46 0.85 0.76 Kolkata 0.69 0.67 0.71 0.76 -1.4 0.7 2.9 .81 0.68 -9.9 -8.5 Pune .83 0.83 Daegu Seoul .73 0.75 0.75 0.76 0.69 0.8 .67 0.6 0.59 0.6 0.58 0.59 .83 0.81 0.83 0.84 0.82 0.86 Melbourne 8.5 10 8.5 0.74 0.69 0.6 0.8 0.67 0.64 1.5 -2 -2.2 0.61 0.51 0.51 0.83 0.85 0.86 Sydney Nicosia 0.7 0.8 0.59 0.59 0.51 -15 5.7 -3.4 -0.91 0.29 -3.4 0.49 -2.4 12 0.75 0.83 3.5 4.1 -0.24 0.77 0.85 0.86 -2.9 4.8 4.1 .63 0.67 0.67 0.71 0.71 0.7 0.8 0.82 0.76 0.79 0.83 0.8 0.64 24 9.1 -0.26 17 5.2 London 0.58 0.68 0.69 11 7.6 17 7.9 6.2 0.69 3.8 1.1 1.5 1.9 Tallinn 0.8 2.3 5.2 3.8 0.82 0.84 0.82 1.1 Tartu Helsinki 86 0.83 0.83 0.84 0.88 0.86 74 0.7 0.72 0.76 0.75 0.79 59 0.66 0.62 0.64 0.61 0.74 0.85 22 1.5 0.79 0.37 1.5 1.5 7.3 18 0.86 0.72 0.73 0.75 0.62 0.66 0.81 0.79 0.79 0.74 0.72 7.3 5.9 4.2 6.9 0.7 0.74 12 Paris 0.54 0.66 0.67 0.69 24 18 10 5.5 11 Augsburg 0.66 0.75 19 5 13 1.6 6.6 2 0.74 0.73 0.78 0.75 0.7 0.67 6.6 0.45 -1.1 Berlin Munich 0.68 0.71 0.7 0.69 0.73 17 8.1 12 4 0.42 8 12 21 0.79 0.72 0.7 1.5 5.5 Athens 0.74 0.79 0.8 0.79 0.7 0.66 -3.4 7.9 1.5 1.8 5.5 -1.5 0.76 0.81 0.79 Milan 76 0.75 0.77 0.76 0.54 0.57 0.71 0.8 6.4 8.9 2.4 Naples 8.3 0 78 9.1 9.8 9.1 Rome 0.71 0.76 0.83 -3 9.7 2.5 4.2 9.1 8.5 7.6 12 7.5 Amsterdam 0.77 0.77 0.77 0.8 0.8 0.8 0.79 0.79 0.81 0.8 13 17 8.5 4.4 2 5.3 16 4.8 6.9 4.6 0.8 0.84 7.6 12 7.5 0.79 0.83 13 3.3 Den Haag 2.6 0.740.740.770.770.750.740.760.74 12 9.6 Eindhoven 0.77 0.7 0.81 11 16 4.3 4.8 5.1 Rotterdam 0.74 3 3 6.1 10 Utrecht 0.83 183 16 5 6.1 3.5 4.4 86 3.5 079077 0.86 10 -3.5 10 Moscow -3.5 0.74 0.75 0.75 0.77 0.82 0.77 0.79 0.8 0.81 0.85 0.73 0.82 0.74 0.78 0.81 0.75 0.75 0.77 0.79 0.78 0.03 -0.77 7.2 Barcelona 0.67 0.77 0.7 0.82 0.77 4.4 4.7 8.8 15 8.8 Madrid 0.84 0.85 0.8 -3.5 9.3 6.9 1.7 1.2 4.5 13 3.1 -12 6.9 -0.31 -0.21 Seville 0.76 0.77 0.77 0.84 0.76 1.5 11 3.7 -1.5 16 3.7 Valencia Stockholm 0.75 -4.7 -6.3 -4.8 -9.3 -3.1 -0.45 -6.4 9 -4.8 0.8 0.77 0.67 0.68 0.71 0.67 -2.9 0.66 0.83 0.87 0.78 0.75 4.8 6.7 Calgary Halifax 0.82 0.86 3.3 1.2 4.8 -0.99 4.8 0.74 0.77 0.76 0.86 6.7 0.81 0.83 6.7 9.5 6.7 12 3.6 2.7 4.3 Montreal 0.87 0.87 0.88 .81 0.82 0.87 0.8 0.86 6.1 4.3 3.6 2.3 1.8 1.6 2.2 2.7 4.3 Ottawa 3 3 -0.15 2.7 Québec City 0.87 0.85 0.87 0.87 4.8 0.87 0.89 4.3 0.82 0.84 0.82 0.84 0.8 0.81 0.86 0.85 0.83 0.8 0.85 0.83 0.83 0.79 0.84 0.84 0.84 0.87 0.74 0.85 4.6 1.4 2.5 2.6 4.6 1.4 Toronto 51 -1.2 0.81 6.2 0.8 Vancouver 0.2 -6.7 1.4 1.3 Mexico City 0.77 0.78 0.8 0.8 0.84 0.74 0.72 0.78 0.74 0.84 6.1 6 7.7 5.5 3.3 1.6 2.5 7.7 0 79 Los Angeles 0.93 0.85 1.1 -2.4 1.1 New York ).85 0.87 -1.6 4.4 1.8 4.4 4.4 0.67 0.77 0.62 Rio 0.78 0.74 0.69 -13 -8.5 -8.8 0.68 São Paulo 12 7.1 12 0.65 0.55 12 0.74 14 14 0.67 Santiago Bogotá 0.4 0.36 0.34 0.43 0.41 0.5 0 69 0.5 0.39 0 49 0.5 0.6 6 30 23 30 30 31 53 0.54 0.54 Quito Lima Store Store <0202 <0102 2020 ore hos Full oct a to lot Full rolat and the second Full dot Full release 200, 100 to 00, 100 Full dot A to to Full release AN AN Sal and and a 202 502 200,00 01e 100 t \$02 23<sup>3100</sup>t AL. 10 20 0.32 0.48 0.64 0.8 0 96 -50 -40 -30 -20 -10 0 30 40

Figure S3.4.25. Observed concentration ratios and percentage changes in  $NO_2/NO_x$  concentration ratio (a) Mean concentration ratios for the equivalent full lockdown period for each year from 2015 to 2020, (b) Mean concentration ratios for different equivalent lockdown periods during BAU (2015-2019), (c) Observed mean concentration ratios during 2020 for different lockdown periods, (d) Percentage changes observed for different lockdown periods, and (e) Percentage changes observed for full lockdown in different environments.

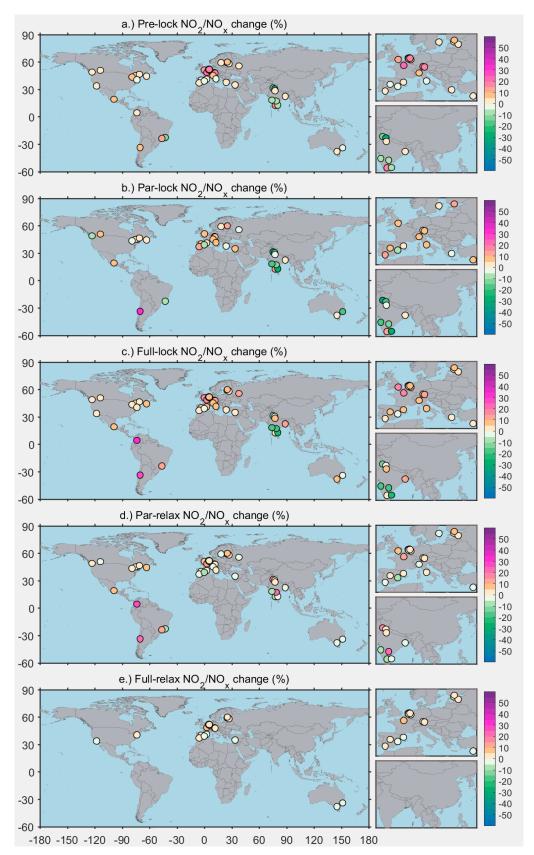


Figure S3.4.26. Observed percentage changes in  $NO_2/NO_x$  ratios on global maps for (a) pre-lockdown, (b) partial lockdown, (c) full lockdown, (d) partial relaxation, and (e) full relaxation. The small sub-panel maps show zoom of European and Asian countries.

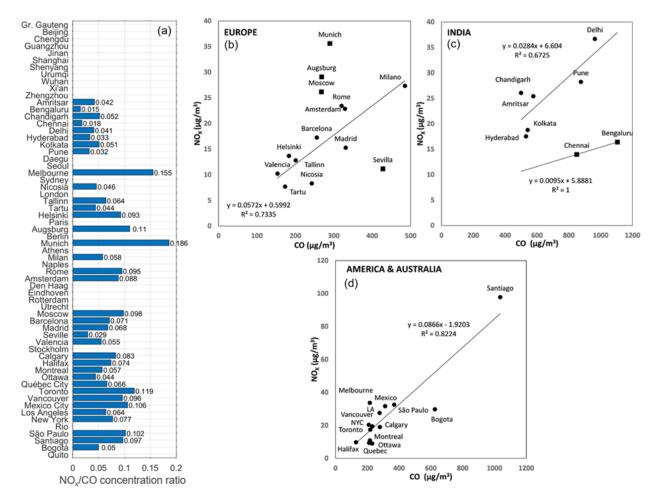


Figure S3.4.27. Ratio of NO<sub>X</sub>/CO as a mean over the 2020 full lockdown period shown as (a) bar plot for each city, and (b-d) cross correlation plots for the cities grouped by regions.

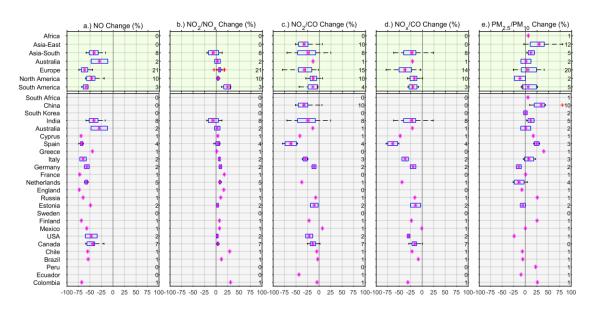
| Country and                | City (site) | Site type | Mear     | <u>n</u> daytime | (8:00 - 1 | 7:00) cha | inges    |            | 2015-2019  |                     | 2020       |            |                     |
|----------------------------|-------------|-----------|----------|------------------|-----------|-----------|----------|------------|------------|---------------------|------------|------------|---------------------|
| period of<br>data analysis |             |           | δ8hO₃    | δO₃              | δΝΟχ      | δNO2      | δΟΧ      | Slope      | Intercept  |                     | Slope      | Intercept  |                     |
|                            |             |           |          | р                | pb and [% | 6]        |          | [95% C.I.] | [95% C.I.] | NO <sub>2</sub> /OX | [95% C.I.] | [95% C.I.] | NO <sub>2</sub> /OX |
|                            |             |           |          |                  |           |           |          |            | ppb        |                     |            | ppb        |                     |
|                            | Barcelona   | Urban     | 3.3      | 2.3              | -36.2     | -15.9     | -13.6    | 0.19       | 46         | 0.53                | 0.23       | 38         | 0.33                |
|                            | (Eixample)  |           | [9.9%]   | [8.4%]           | [-58.3%]  | [-51.7%]  | [-23.5%] | [0.17;     | [44; 47]   |                     | [0.16;     | [36; 40]   |                     |
| Spain                      |             |           |          |                  |           |           |          | 0.21]      |            |                     | 0.30]      |            |                     |
|                            | Barcelona   | Rural     | -8.3     | -7.2             | -3.9      | -3.2      | -10.3    | 0.10       | 51         | 0.11                | 1.0        | 38         | 0.06                |
| March 16 –                 | (Tona)      |           | [-15.2%] | [-15.8%]         | [-50.4%]  | [-54.6%]  | [-19.9%] | [-0.1;     | [49; 53]   |                     | [0.14;     | [34; 41]   |                     |
| July 31                    |             |           |          |                  |           |           |          | 0.3]       |            |                     | 1.9]       |            |                     |
|                            | Madrid      | Urban     | 2.2      | 2.4              | -24.0     | -13.1     | -10.7    | 0.14       | 54         | 0.43                | 0.54       | 40         | 0.26                |
|                            | (Aguirre)   |           | [5.3%]   | [7.1%]           | [-59.9%]  | [-50.6%]  | [-18.0%] | [0.10;     | [52;56]    |                     | [0.37;0.7  | [37; 43]   |                     |
|                            |             |           |          |                  |           |           |          | 0.17]      |            |                     | 1]         |            |                     |
|                            | Madrid      | Rural     | -7.5     | -5.9             | -0.6      | -0.5      | -6.4     | 0.44       | 49         | 0.04                | 11         | 21         | 0.03                |
|                            | (El Atazar) |           | [-13.5%] | [-12.3%]         | [-21.0%]  | [-28.2%]  | [-12.8%] | [-0.16;    | [47;51]    |                     | [8.3; 13]  | [15;26]    |                     |
|                            |             |           |          |                  |           |           |          | 1.0]       |            |                     |            |            |                     |
|                            | Milan       | Urban     | -0.9     | -1.0             | -10.7     | -6.2      | -7.0     | -0.12      | 56         | 0.30                | -0.14      | 48         | 0.20                |
|                            | (Pascal)    | backgrou  | [-1.8%]  | [-2.7%]          | [-44.3%]  | [-41.9%]  | [-13.1%] | [-0.17;    | [55;58]    |                     | [-0.28;    | [46;51]    |                     |
| Italy                      |             | nd        |          |                  |           |           |          | -0.07]     |            |                     | 0.01]      |            |                     |
|                            | Milan       | Urban     | -0.1     | 0.7              | -6.6      | -5.0      | -4.3     | -0.33      | 60         | 0.23                | -0.41      | 55         | 0.14                |
|                            | (Saronno)   |           | [-0.3%]  | [1.7%]           | [-41.9%]  | [-44.6%]  | [-7.8%]  | [-0.41;    | [59;62]    |                     | [-0.62;    | [52;57]    |                     |

Table S3.4.1. Mean concentration deltas and percentage changes inf NO<sub>2</sub>, O<sub>3</sub>, NOx and Ox in 2020 compared to the same period in 2015-2019. Also shown are the slopes and intercepts, their 95% confidence intervals (C.I.) and the fraction of NO<sub>2</sub> within OX.

| February 25 |                            |                |          |          |          |          |          | -0.25]           |         |      | -0.19]           |         |      |
|-------------|----------------------------|----------------|----------|----------|----------|----------|----------|------------------|---------|------|------------------|---------|------|
| – July 31   | Rome                       | Urban          | 1.6      | 1.7      | -13      | -7.7     | -6.0     | 0.09             | 48      | 0.36 | 0.19             | 41      | 0.23 |
|             | (Cipro)                    | backgrou<br>nd | [4.3%]   | [5.2%]   | [-47.4%] | [-42.7%] | [-11.9%] | [0.05;<br>0.13]  | [47;49] |      | [0.04;<br>0.35]  | [39;44] |      |
|             | Rome                       | Rural          | -12.3    | -10.7    | -1.3     | -0.9     | -11.2    | -0.02            | 47      | 0.07 | 0.46             | 34      | 0.07 |
|             | (Guido)                    |                | [-25.3%] | [-24.4%] | [-29.9%] | [-26.4%] | [-23.9%] | [-0.22;<br>0.18] | [46;48] |      | [-0.02;<br>0.94] | [32;36] |      |
|             | London                     | Urban          | 11.4     | 11.1     | -87.7    | -31.9    | -20.8    | 0.19             | 41      | 0.78 | 0.16             | 38      | 0.45 |
| England     | (Marylebone)               |                | [63.6%]  | [88.1%]  | [-71.4%] | [-61.5%] | [-32.2%] | [0.18;           | [39;42] |      | [0.10;           | [35;41] |      |
|             |                            |                |          |          |          |          |          | 0.20]            |         |      | 0.23]            |         |      |
| March 5 –   | Chilbolton                 | Rural          | 1.6      | 1.6      | -2.0     | -1.8     | -0.2     | 0.59             | 38      | 0.12 | 2.8              | 38      | 0.07 |
| July 31     |                            |                | [3.8%]   | [4.5%]   | [-37.0%] | [-38.8%] | [-0.5%]  | [0.36;<br>0.82]  | [36;39] |      | [2.0; 3.5]       | [28;39] |      |
|             | São Paulo                  | Urban          | 4.6      | 4.2      | -19.1    | -8.0     | -3.9     | 0.12             | 32      | 0.57 | 0.08             | 32      | 0.38 |
| Brazil      | (Pinheiros)                |                | [21.9%]  | [24.6%]  | [-42.8%] | [-38.9%] | [-10.4%] | [0.08;           | [30;35] |      | [0.01;           | [29;34] |      |
|             |                            |                |          |          |          |          |          | 0.16]            |         |      | 0.16]            |         |      |
| March 23 –  | São Paulo                  | Mountai        | -0.5     | -1.5     | -4.1     | -2.4     | -4.0     | 0.02             | 36      | 0.23 | 0.12             | 32      | 0.17 |
| July 19     | (Pico                      | n site         | [-1.5%]  | [-5.0%]  | [-36.4%] | [-29.2%] | [-10.6%] | [0.01;           | [33;37] |      | [-0.32;          | [29;36] |      |
|             | Jaraguá)                   |                |          |          |          |          |          | 0.4]             |         |      | 0.54]            |         |      |
|             | (No data for<br>2015-2016) |                |          |          |          |          |          |                  |         |      |                  |         |      |
|             | Delhi                      | Urban          | -11.8    | -11.2    | -12.2    | -10.6    | -22.4    | 0.98             | 30      | 0.41 | -0.39            | 35      | 0.39 |

| India                  | (Puram)                                |       | [-35.7%] | [-34.7%] | [-52.2%] | [-52.5%] | [-41.8%] | [0.76;           | [28;36] |      | [-0.88;                    | [30; 41]       |      |
|------------------------|--|-------|----------|----------|----------|----------|----------|------------------|---------|------|----------------------------|----------------|------|
| March 16-<br>September | (data                                  |       |          |          |          |          |          | 1.1]             |         |      | 0.1]                       |                |      |
| 30                     | available<br>until August<br>31, 2020) |       |          |          |          |          |          |                  |         |      |                            |                |      |
|                        | Delhi                                  | Urban | -1.9     | -1.9     | -6.3     | -5.9     | -8.2     | 0.76             | 25      | 0.39 | -1.1                       | 47             | 0.42 |
|                        | (Shadipur)                             |       | [-7.0%]  | [-7.9%]  | [-31.6%] | [-37.4%] | [-20.0%] | [0.63;<br>0.89]  | [22;28] |      | [-1.6;<br>-0.5]            | [39; 55]       |      |
| Canada                 | Toronto                                | Urban | -1.2     | 1.6      | -6.7     | -4.4     | -2.8     | 0.08             | 42      | 0.26 | -0.38                      | 45             | 0.17 |
| March 15 –<br>May 31   | (Toronto<br>West)                      | Orban | [-3.1%]  | [4.9%]   | [-40.3%] | [-39.5%] | [-6.3%]  | [-0.01;<br>0.18] | [41;44] | 0.20 | -0.38<br>[-0.69;<br>-0.07] | 43<br>[41; 48] | 0.17 |
| Chile                  | Santiago                               | Urban | 4.8      | 3.5      | -31.0    | -10.1    | -6.2     | 0.16             | 33      | 0.58 | 0.06                       | 36             | 0.43 |
| March 26 –<br>July 31  | (Puente Alto)                          |       | [22.5%]  | [18.6%]  | [-40.3%] | [-39.7%] | [-14.3%] | [0.13;<br>0.18]  | [32;36] |      | [-0.04;<br>0.15]           | [32; 39]       |      |
| Colombia               | Bogotá                                 | Urban | 5.2      | 5.0      | -18.2    | -6.7     | -2.1     | -0.01            | 36      | 0.69 | -0.02                      | 34             | 0.54 |
|                        | (Carvajal)                             |       | [39.4%]  | [39.4%]  | [-26.0%] | [-27.2%] | [-5.9%]  | [-0.05;          | [32;40] |      | [-0.11;                    | [32;40]        |      |
| March 20 –<br>June 30  |  |       |          |          |          |          |          | 0.05]            |         |      | 0.03]                      |                |      |
| China                  | Wuhan                                  | Urban | 6.0      | 6.3      | -15.3    | -9.0     | -2.7     | 0.09             | 50      | 0.46 | 0.03                       | 49             | 0.31 |
| January 1 –<br>May 9   | (Qingshan<br>Ganghua)                  |       | [41.9%]  | [21.3%]  | [-47.8%] | [-39.4%] | [-5.2%]  | [0.03;<br>0.15]  | [47;52] |      | [-0.26;<br>0.32]           | [43; 54]       |      |

| South Africa         | Greater      | Urban    | 0.8     | -0.65   | -13.5    | -2.6     | -2.5    | 0.12    | 37      | 0.35 | 0.29    | 32       | 0.29 |
|----------------------|--------------|----------|---------|---------|----------|----------|---------|---------|---------|------|---------|----------|------|
|                      | Gauteng      |          | [2.4%]  | [-2.3%] | [-33.6%] | [-17.5%] | [-5.6%] | [0.07;  | [36;40] |      | [0.23;  | [30; 34] |      |
| March 27 –<br>May 31 | (Kliprivier) |          |         |         |          |          |         | 0.14]   |         |      | 0.37]   |          |      |
| Australia            | Sydney       | Urban    | 4.6     | 2.8     | -4.7     | -2.2     | 0.6     | -0.01   | 26      | 0.43 | -0.04   | 26       | 0.30 |
|                      | (Rozelle)    |          | [26.3%] | [18.3%] | [-22.0%] | [-19.7%] | [2.4%]  | [-0.03; | [25;27] |      | [-0.06; | [24;28]  |      |
| March 16 –           |              |          |         |         |          |          |         | 0.04]   |         |      | 0.18]   |          |      |
| June 30              | Sydney       | Urban    | -2.2    | -1.3    | -0.5     | -0.5     | -1.8    | -0.02   | 26      | 0.11 | -0.12   | 25       | 0.10 |
|                      | (Bargo)      | backgrou | [-8.1%] | [-5.6%] | [-10.3%] | [-16.5%] | [-6.7%] | [-0.08; | [25;27] |      | [-0.27; | [24;26]  |      |
|                      |              | nd       |         |         |          |          |         | 0.05]   |         |      | -0.01]  |          |      |



# S4.1 Regional changes in air quality during full lockdown

Figure S4.1.1. Continental/country-wide changes in air pollution shown as boxplots for the full lockdown period for (a) NO, (b)  $NO_2/NO_x$ , (c)  $NO_2/CO$ , (d)  $NO_x/CO$ , (e)  $PM_{2.5}/PM_{10}$ . Numbers on the right-hand side of the panels indicate number of cities. The red + symbol is the outlier (values more than 1.5 times the interquartile range)