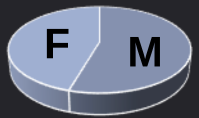
The Global Impacts of COVID-19 Lockdowns on Urban Air Quality: A Critical Review and Recommendations



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NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

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The New York Times

Pandemic's Cleaner Air Could Reshape What We Know About the Atmosphere

Coronavirus shutdowns have cut pollution, and that's opened the door to a "giant, global environmental experiment" with potentially far-reaching consequences.

New Delhi *India Gate, New Delhi*

THE WALL STREET JOURNAL.

ECONOMY

Coronavirus Lockdowns Clear the Air, but the Green Effect Could Be Fleeting

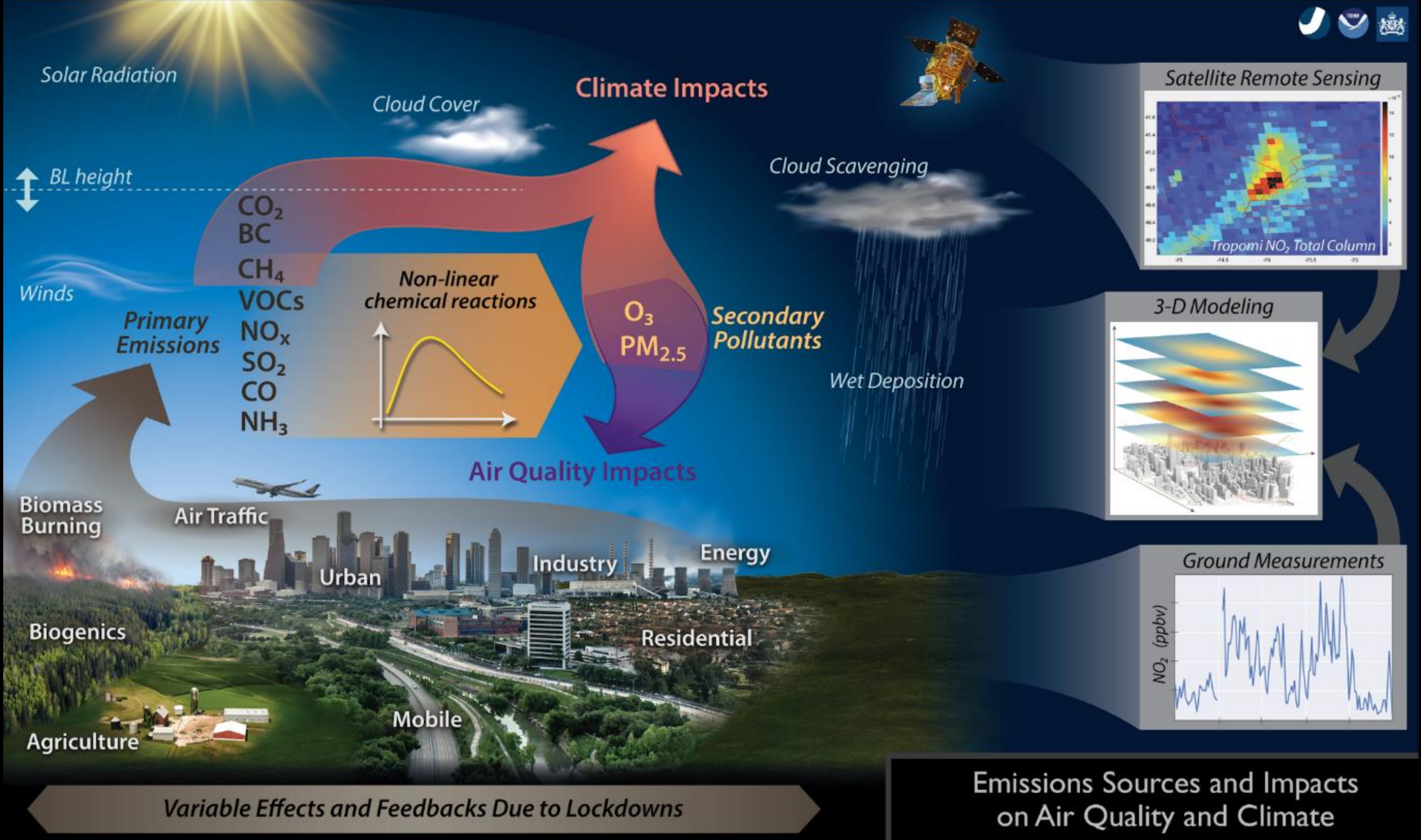
Some worry long-term environmental efforts will suffer as governments look to stimulate growth

The Guardian

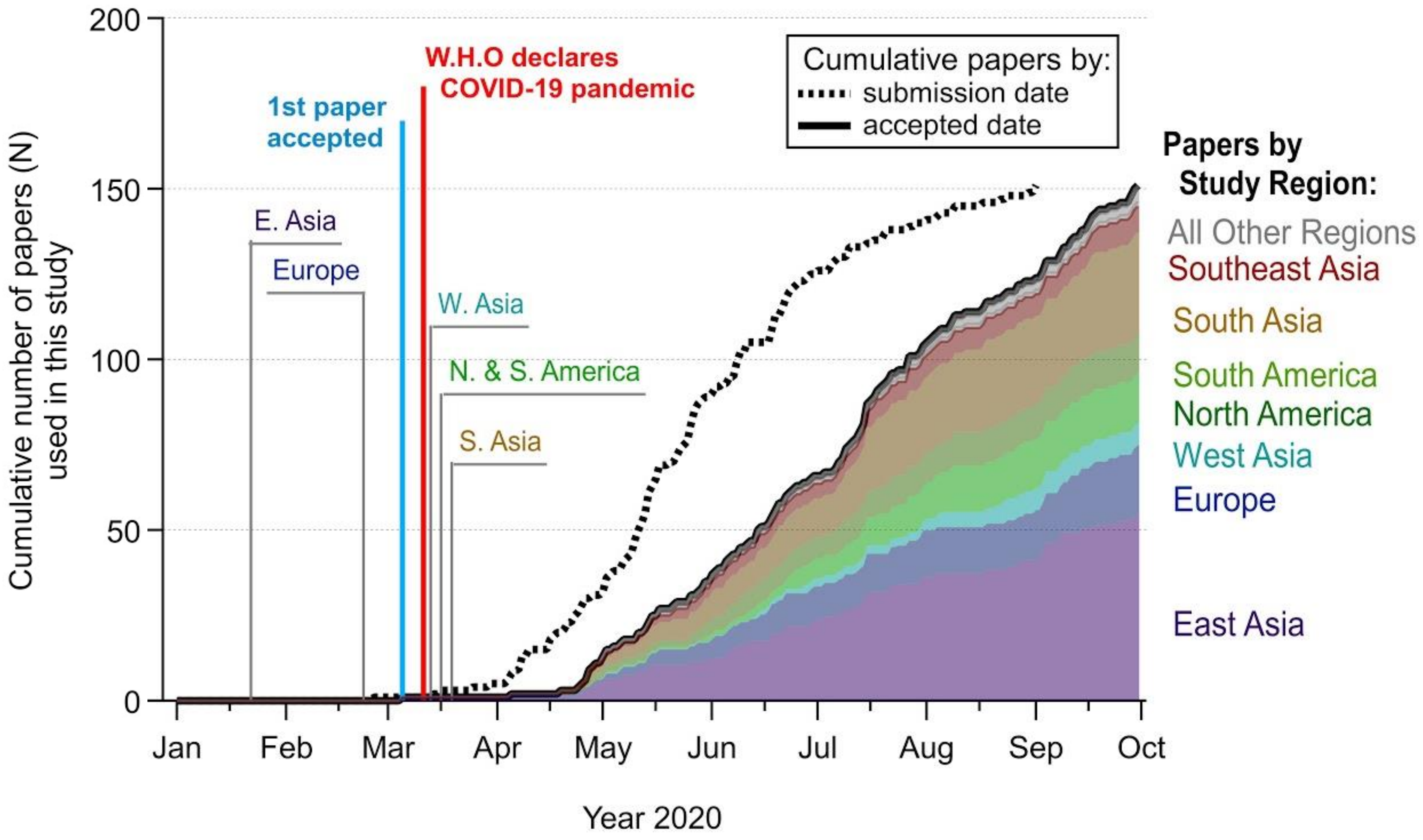
Covid-19 lockdowns have improved global air quality, data shows

The Washington Post

Washington has its cleanest spring air in 25 years: How air quality has improved during the coronavirus crisis


Solar Radiation
Cloud Cover
Climate Impacts
BL height
CO_2
BC
CH_4
VOCs
NO_x
SO_2
CO
NH_3
Winds
Primary Emissions
Non-linear chemical reactions
O_3
$PM_{2.5}$
Secondary Pollutants
Air Quality Impacts
Cloud Scavenging
Wet Deposition
Satellite Remote Sensing
Tropomi NO_2 Total Column
3-D Modeling
Ground Measurements
NO_2 (ppbv)
Biomass Burning
Air Traffic
Urban
Industry
Energy
Biogenics
Residential
Mobile
Agriculture
Variable Effects and Feedbacks Due to Lockdowns
Emissions Sources and Impacts on Air Quality and Climate

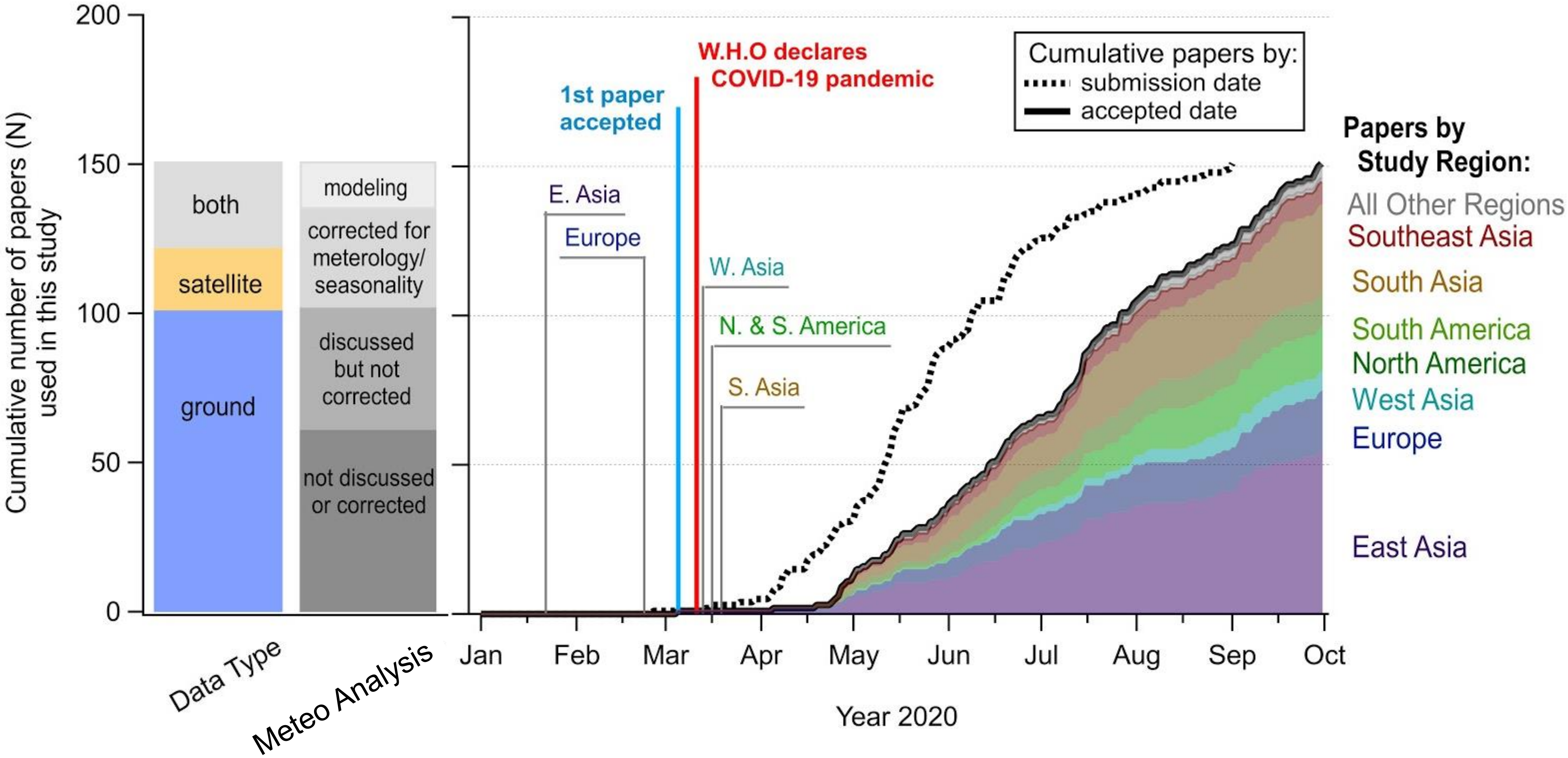
Literature review process: Response to the pandemic



Information per publication manually catalogued

- Percent change of pollutant concentrations
- Absolute pollutant concentrations
- the region and periods studied,
- Methods to measure
  - Ground-based
  - Satellites
- First author
- Journal name
- Dates of submission, acceptance,
- How authors may or may not have accounted for the effects of seasonality/meteorology.
- … and more

Literature review process: Response to the pandemic



How drastic changes do we expect?

BEFORE

Before Lockdown

Reference period

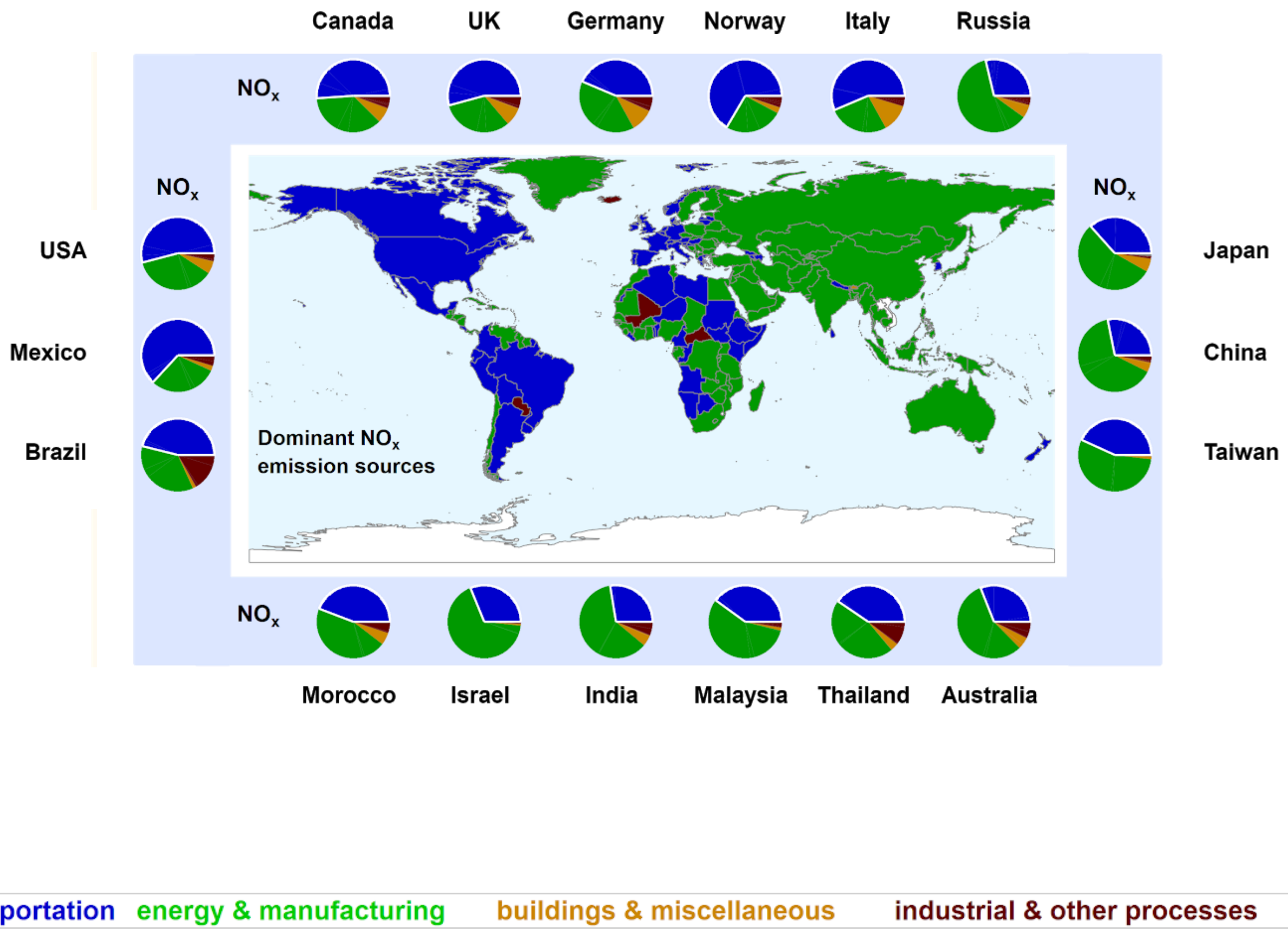
How much are we expecting transportation to contribute to the overall emissions?

LOCKDOWN

During Lockdown

Lockdown period

Inventory-based business as usual emission scenario

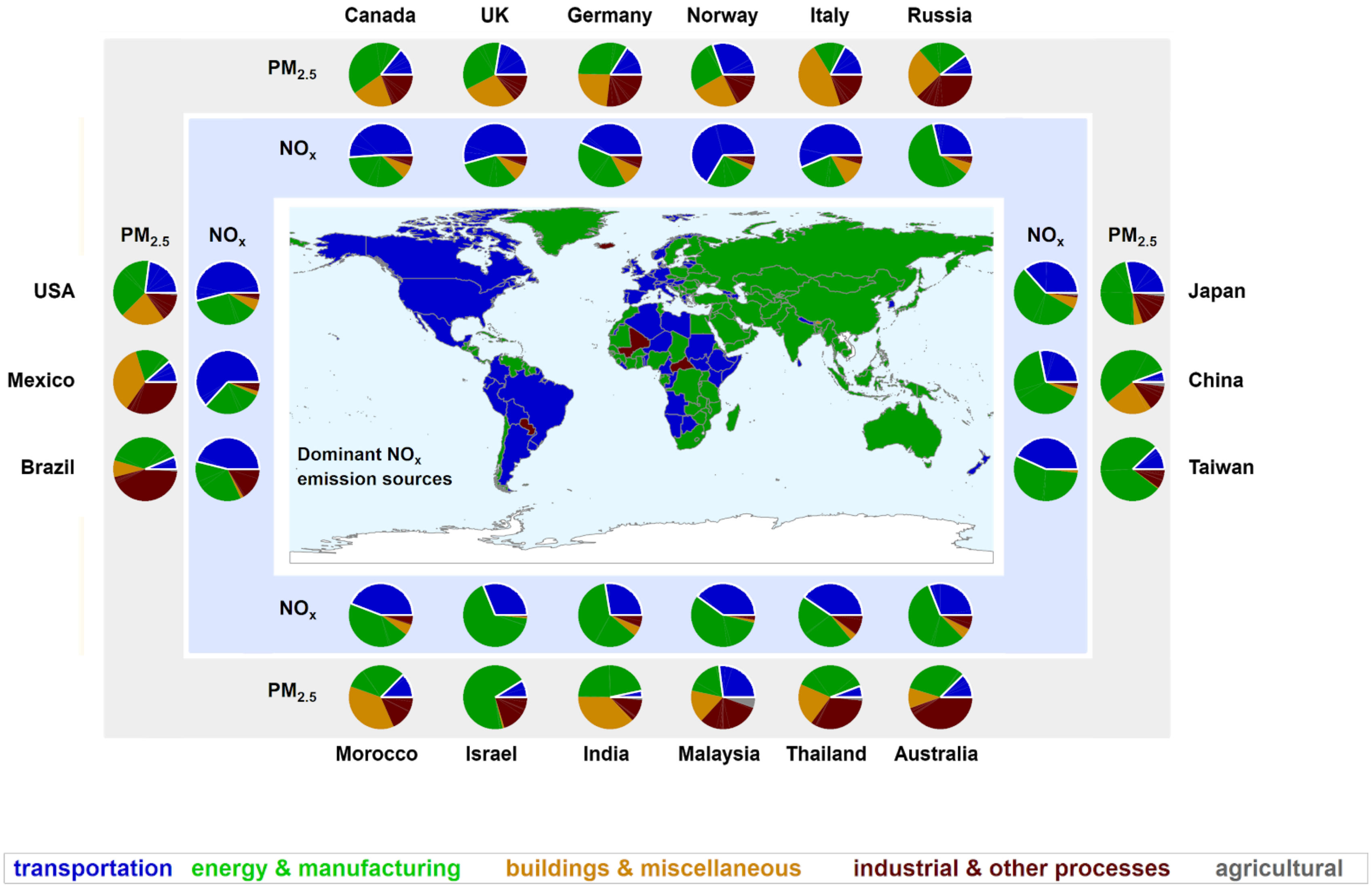


The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

NO_x: 36% (15–51%)

Inventory-based business as usual emission scenario



The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

NO_x: 36% (15–51%),

$PM_{2.5}$: 8% (3–19%),

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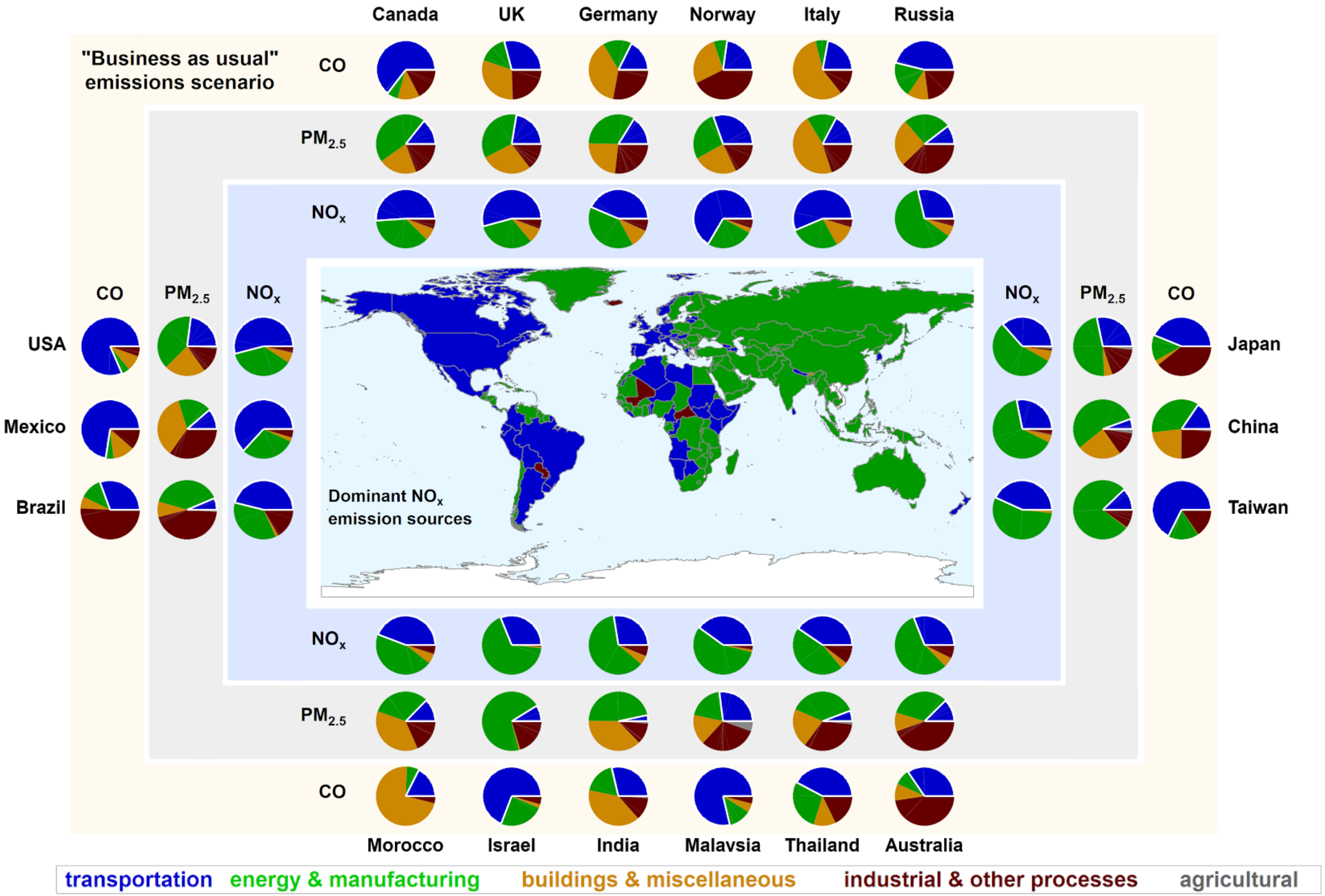

The global EDGAR inventory provides context for expected changes in air pollutant species in the atmosphere due to the COVID-19 pandemic.

Transportation contributed

NO_x: 36% (15–51%),

$PM_{2.5}$: 8% (3–19%),

CO: 30% (5–70%)

NO_2 > CO > $PM_{2.5}$

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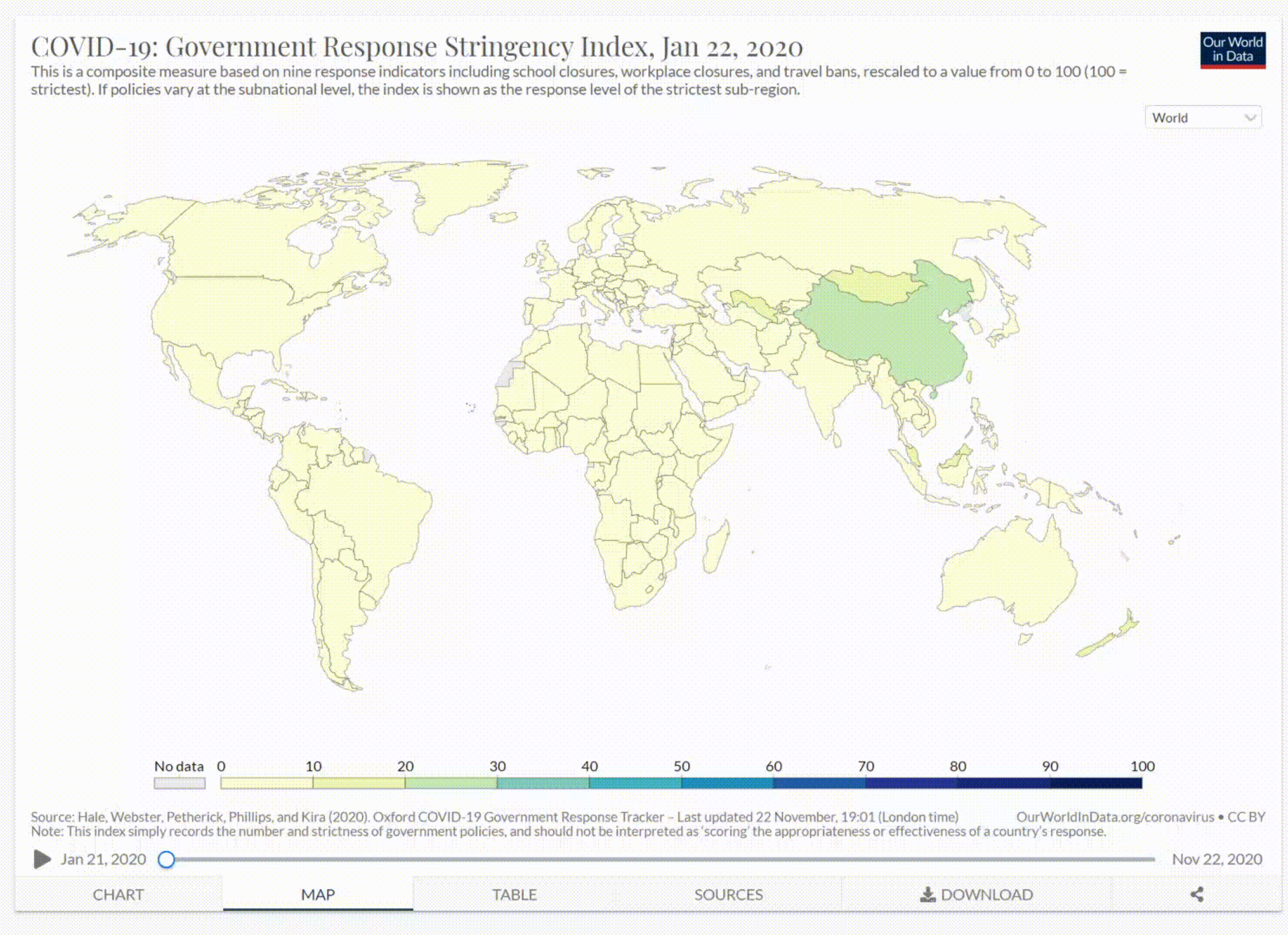
Stringency index as a metric for lockdown measures

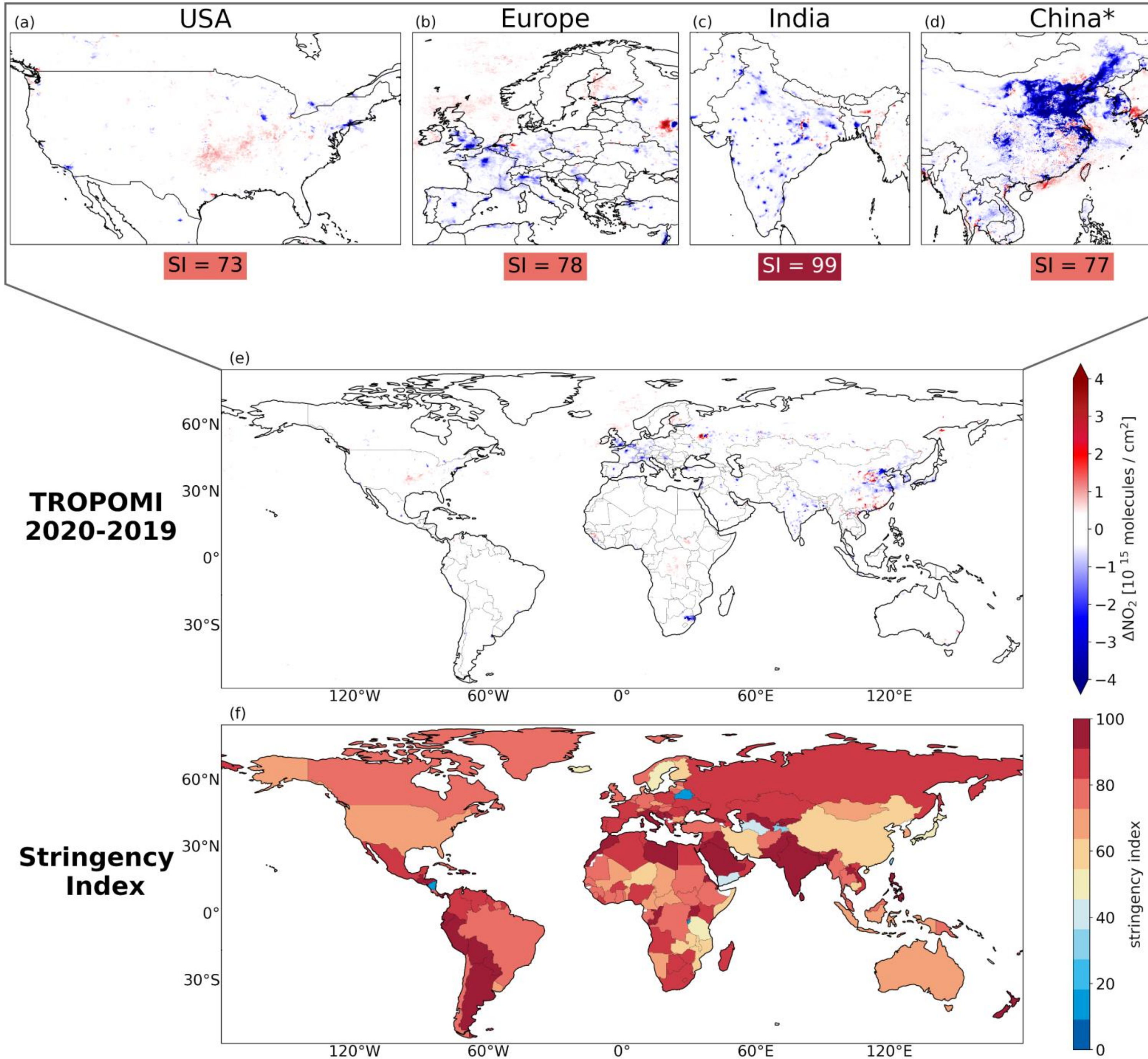


Categories included are:

- the implementation and extent of school closures
- implementation and extent of workplace closures
- restrictions on public events
- Gatherings
- closure of public transport
- degree of public information campaigns
- extent of measures to enforce stay-at-home
- restrictions on internal movement,
- international travel
- testing policy, and
- contact tracing.

As such the index ***includes both measures that impact emissions and measures with no obvious consequence for emissions***.

https://ourworldindata.org/grapher/covid-stringency-index



Anne Lange

Henk Eskes

We did our own bit of analysis first

Difference in NO_2 column concentrations based on the TROPOMI measurements for 2020 compared to 2019.

Stringency index is used for April as a representative month for the most stringent conditions globally. China is an exception where lockdown measures were implemented in February-March and relaxed in April.

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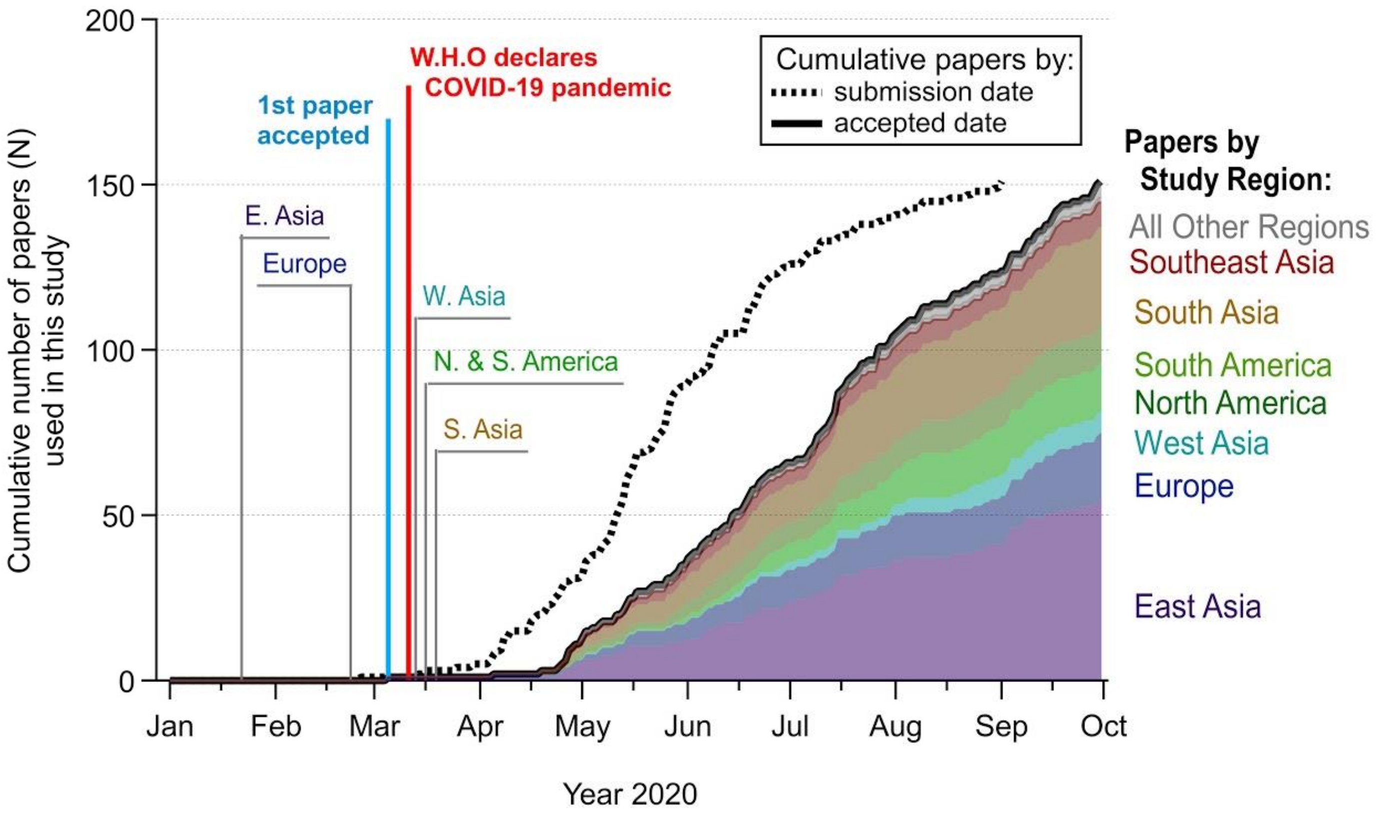
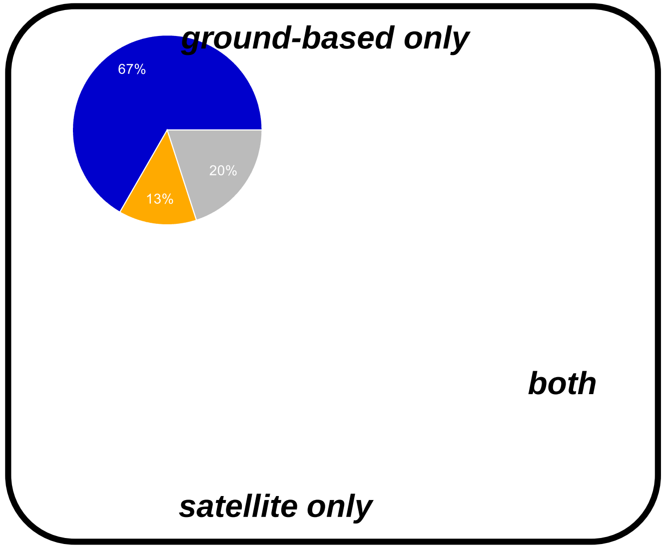
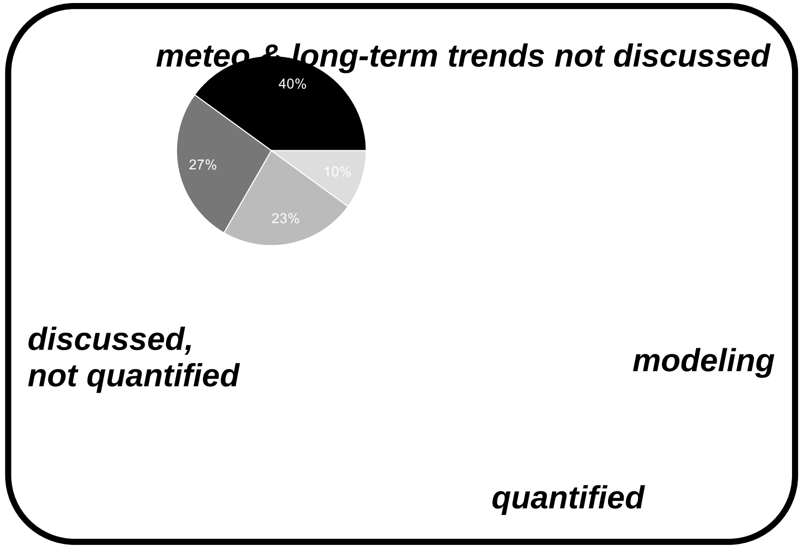
Data included in the upcoming analysis





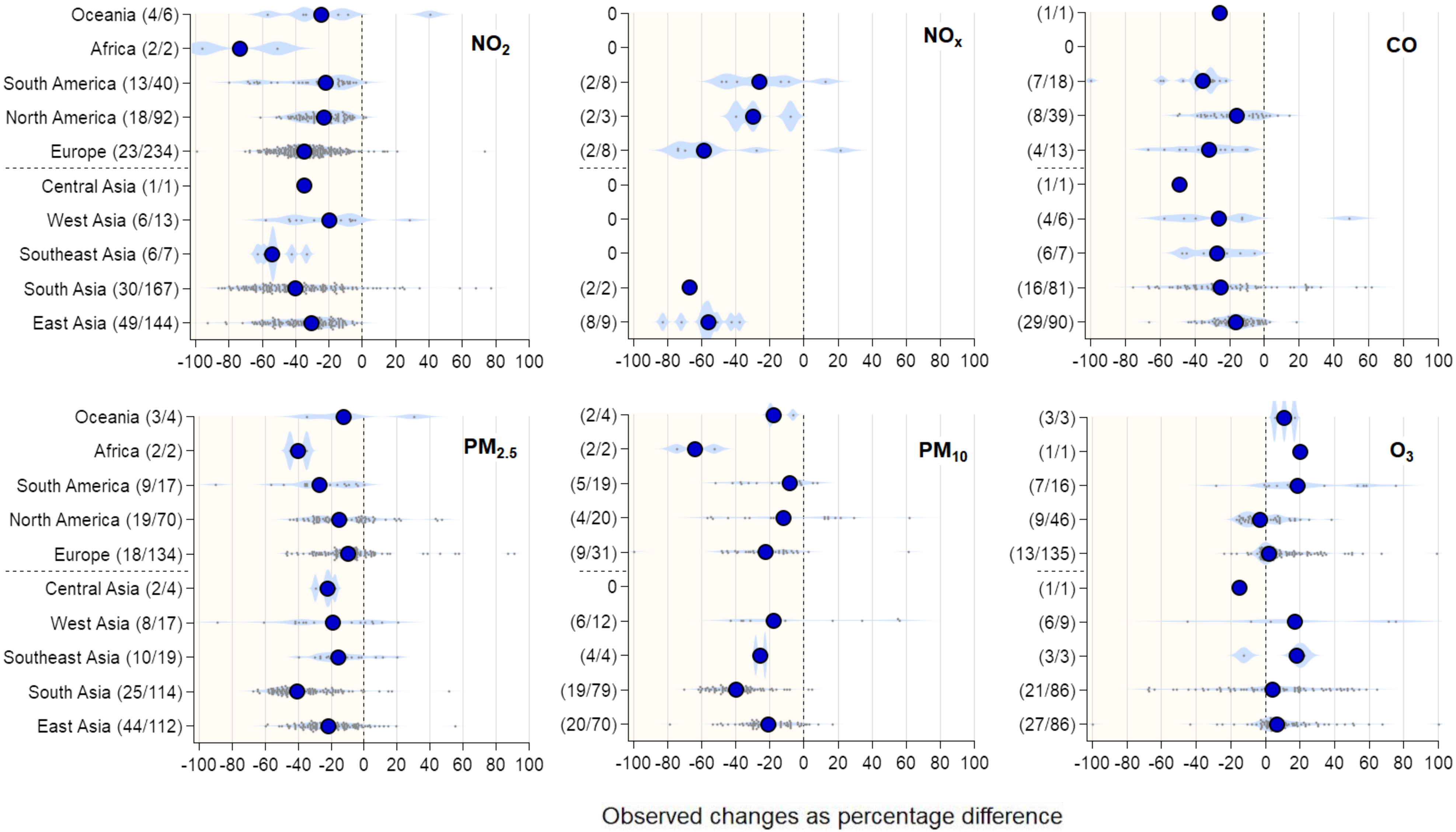
PLATFORM USED



METHOD USED

Observed changes as percentage difference

(N/N) = (number of publications / number of datasets)



NO_2, NO_x, and CO have the largest expected contribution from transportation

$PM_{2.5}$, and O_3 as the most relevant pollutants for health impacts that are also secondary;

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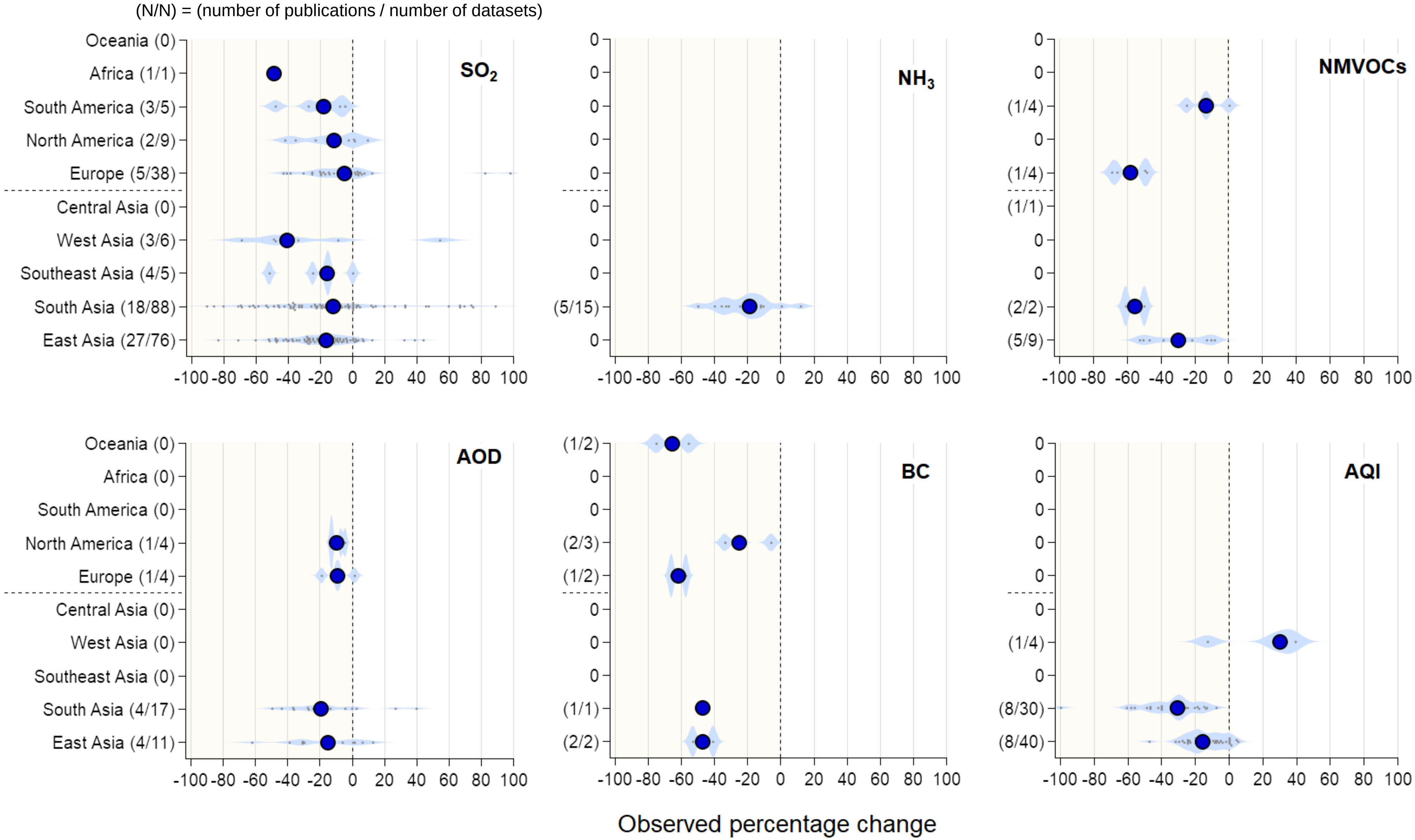
Observed changes as percentage difference



SO_2, NH_3, and non-methane volatile organic compounds (NMVOCs) mostly related to primary gas-phase emissions,

PM_{10}, aerosol optical depth (AOD), black carbon (BC), and air quality index (AQI).

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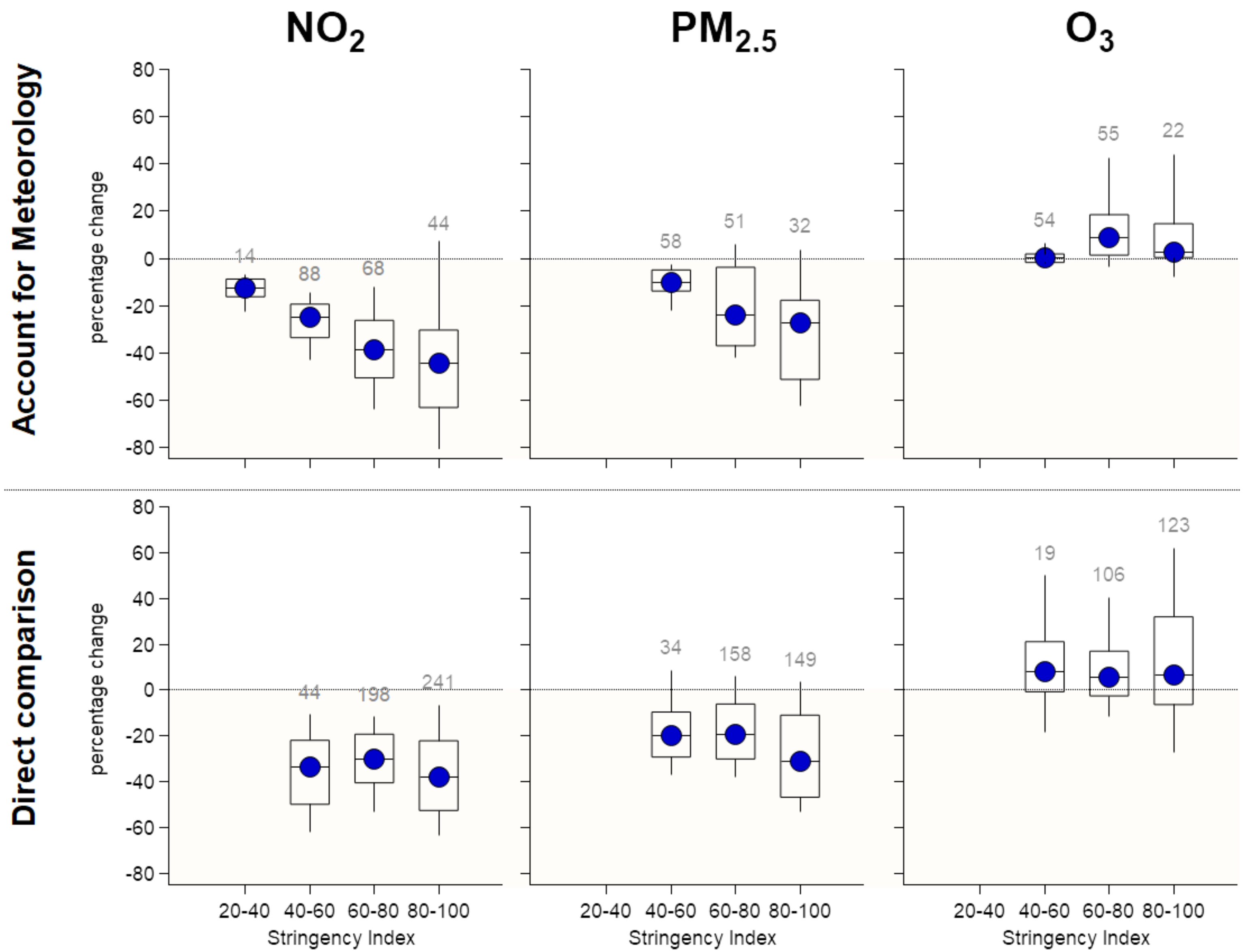
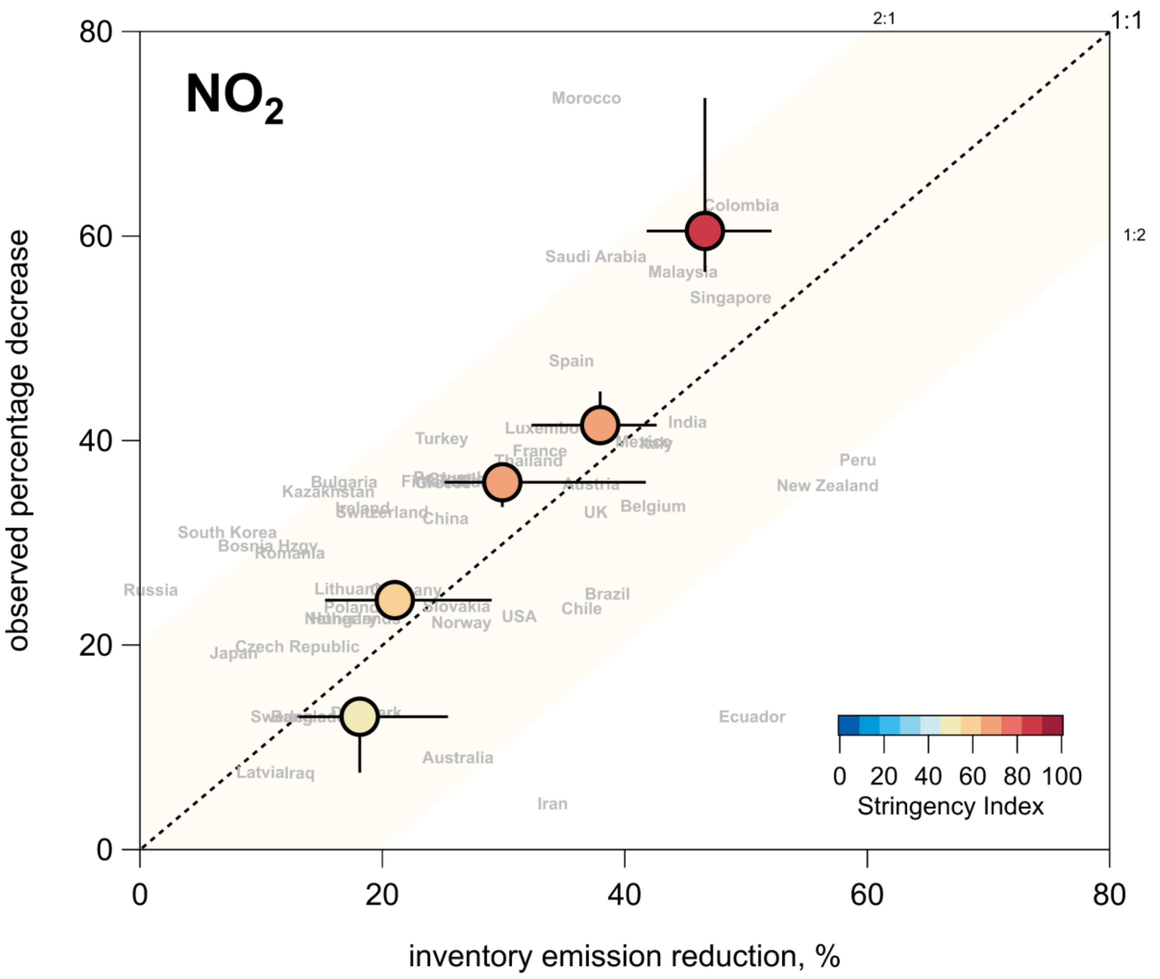
Percent changes vs. stringency index



- Emission of primary pollutants are expected to decrease as the lockdown measures become stricter
- It is essential to account and quantify the effects of meteorology to quantitatively link changes in atmospheric abundance with changes in emissions

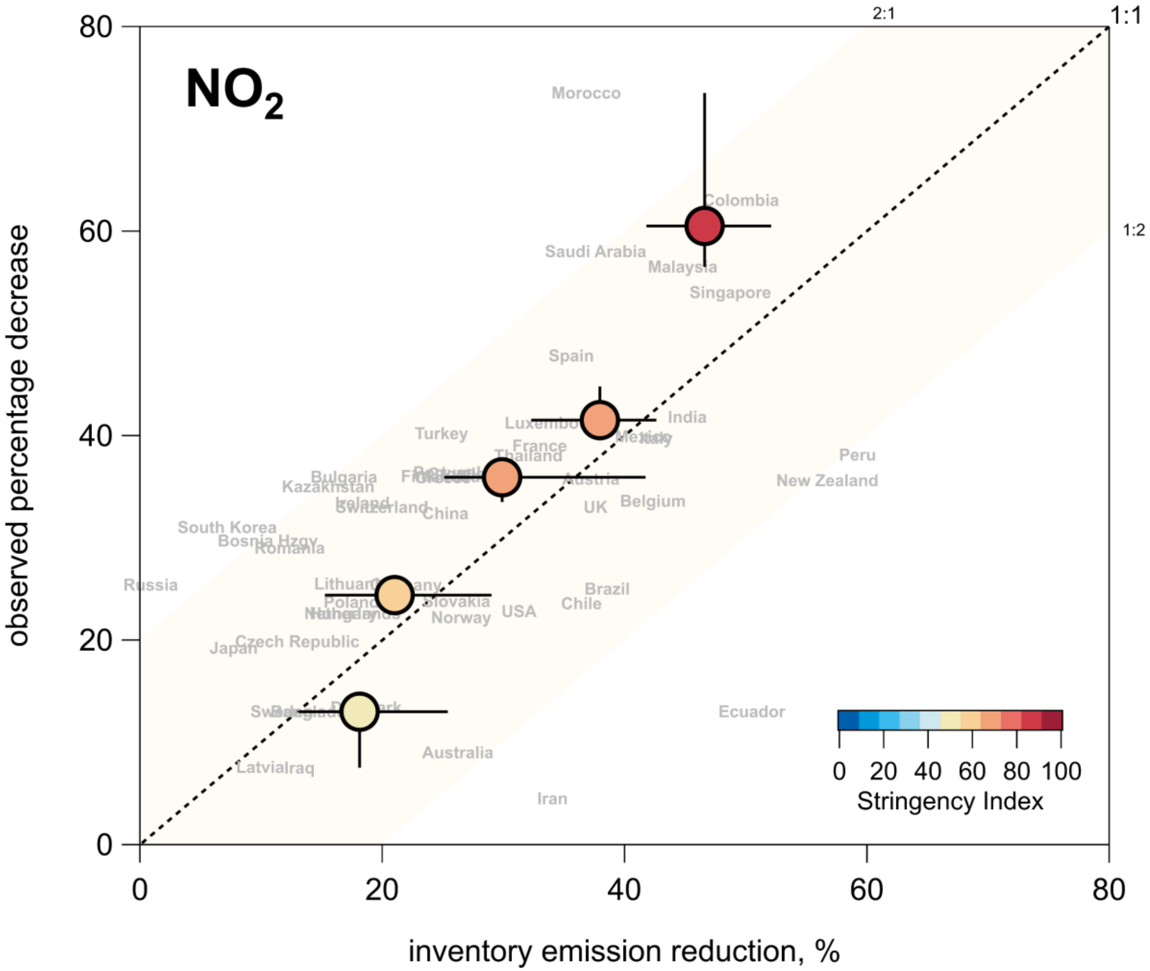
Comparison of observations to the Forster inventory



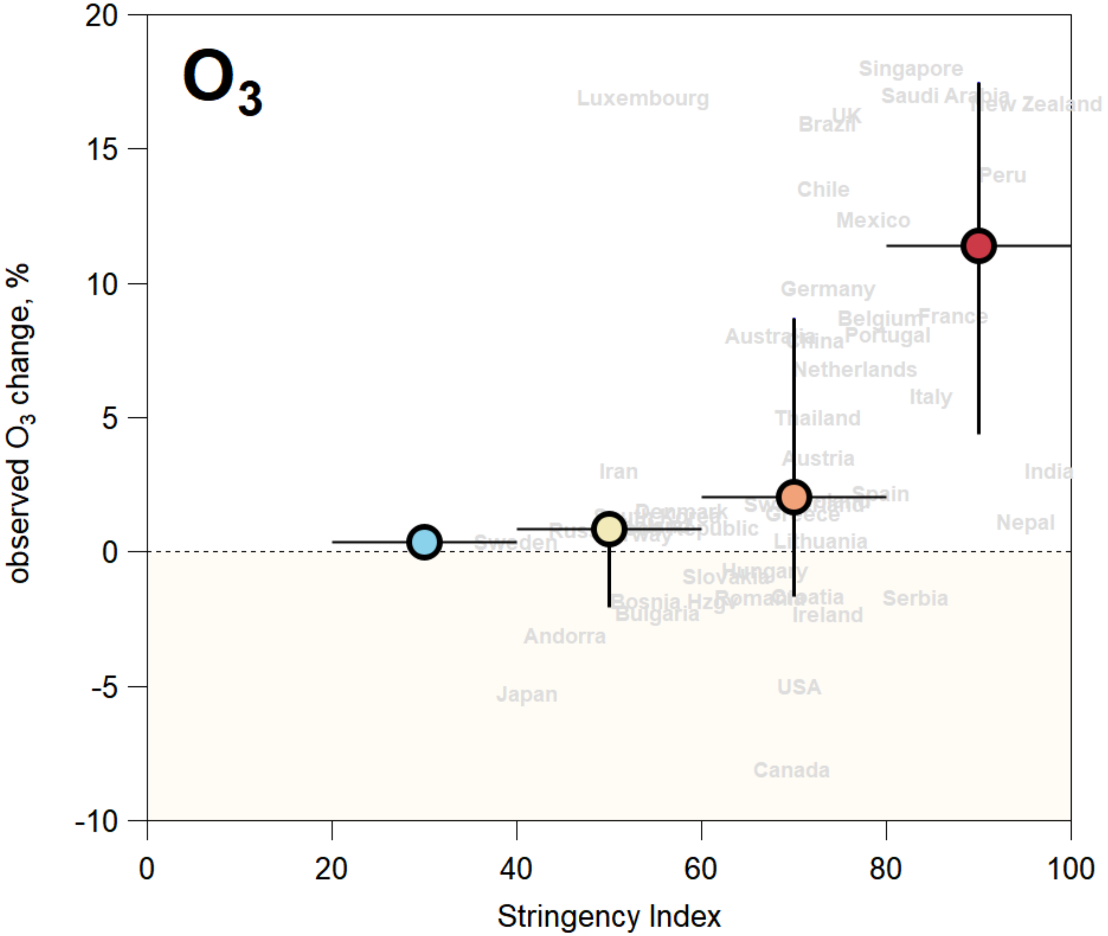
Forster et al. (2020), Nature

- Agreement within a factor of 2, within the associated uncertainties.
- The stringency of lockdown measures has a strong relationship with levels of traffic
- The similarity between changes in the emissions inventory and atmospheric observations due to COVID-19 lockdown measures suggests the importance of traffic as a source of NOx in cities around the world.

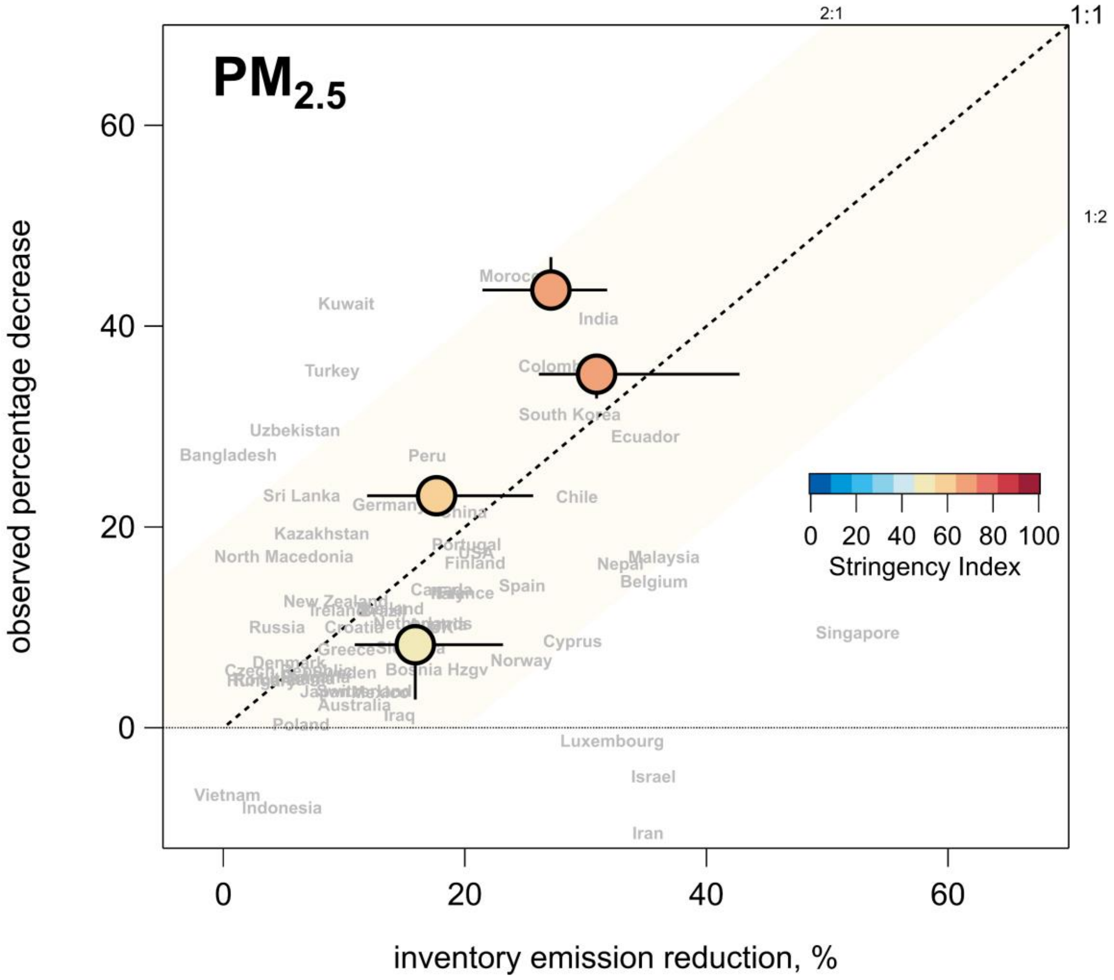
O_3 percent changes and correlation to stringency index



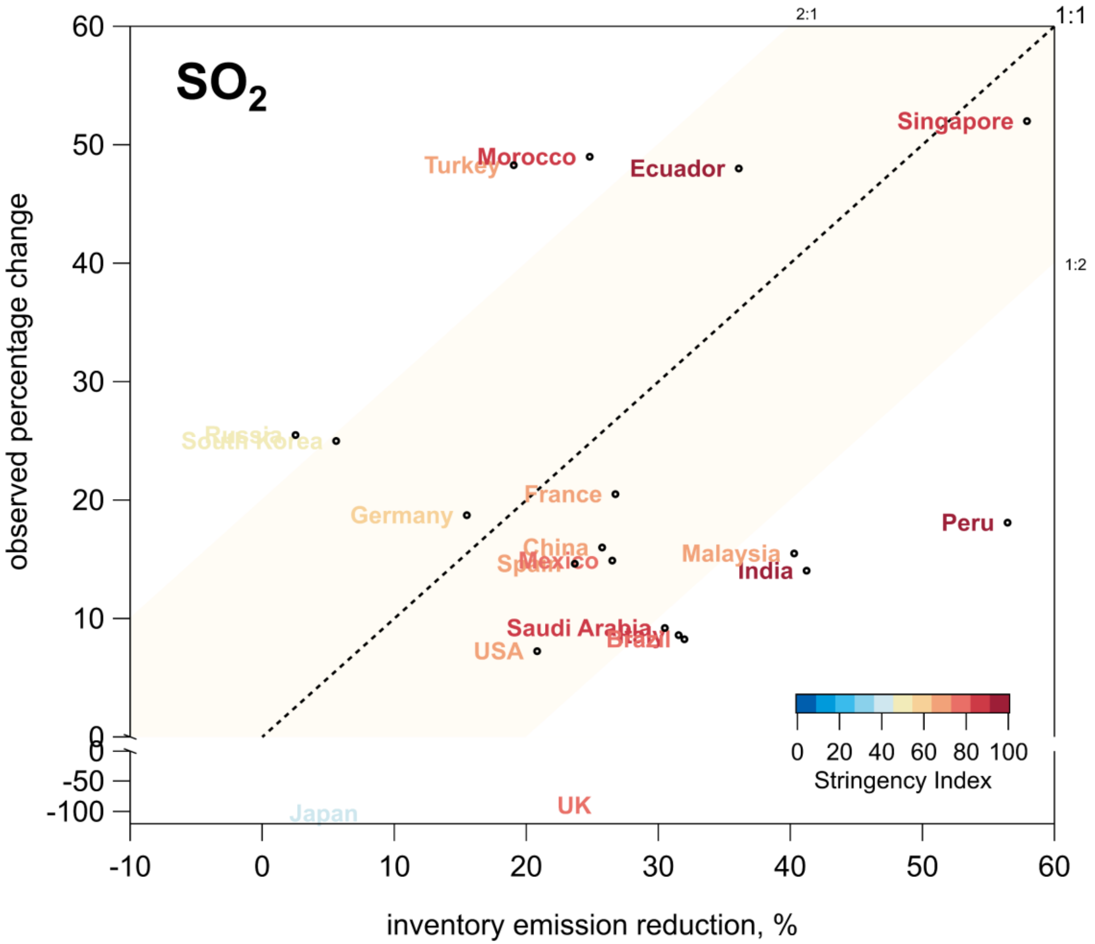
Forster et al. (2020), Nature



$PM_{2.5}$ and SO_2 observations compared to the Forster inventory



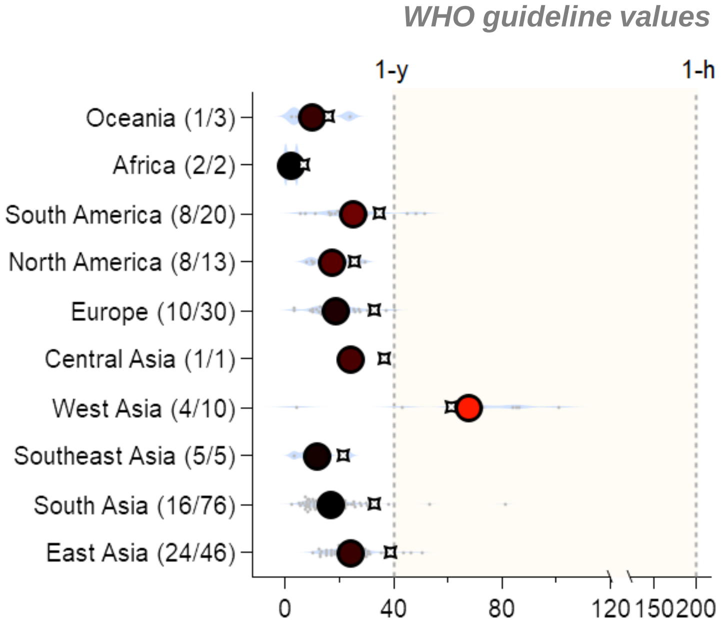
Forster et al. (2020), Nature



Forster et al. (2020), Nature

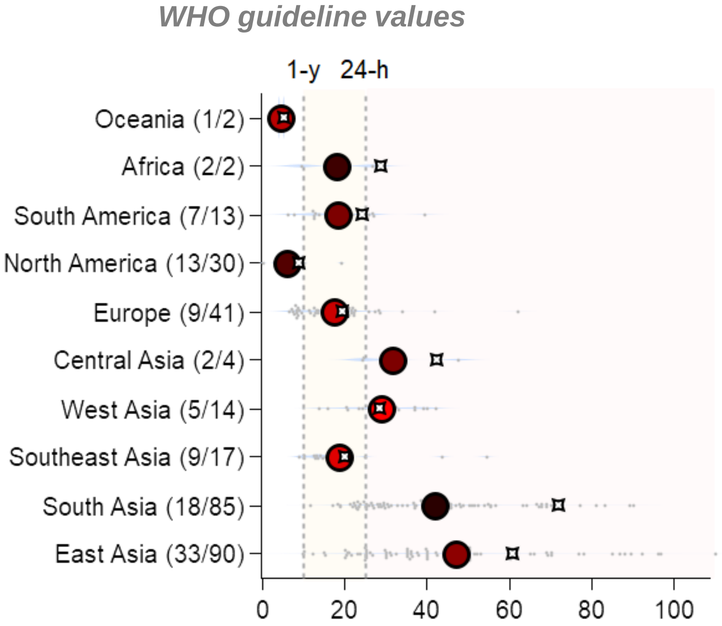
Absolute concentrations: Lockdown vs. Reference periods

(N/N) = (number of publications / number of datasets)



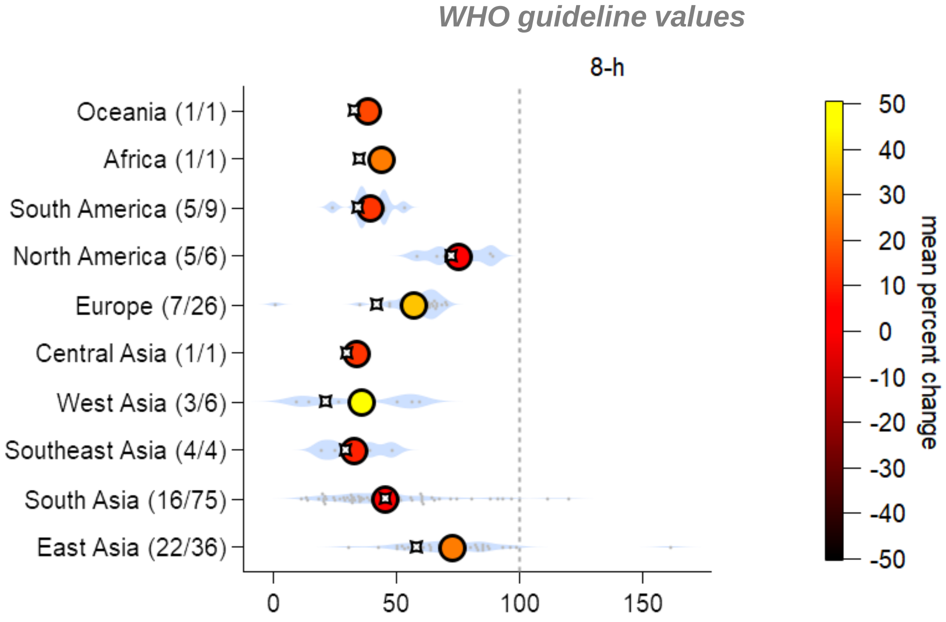
NO_2 concentration ($\mu g\ m^{-3}$)

-40 ± 26%



$PM_{2.5}$ concentration ($\mu g\ m^{-3}$)

- 21 ± 13%

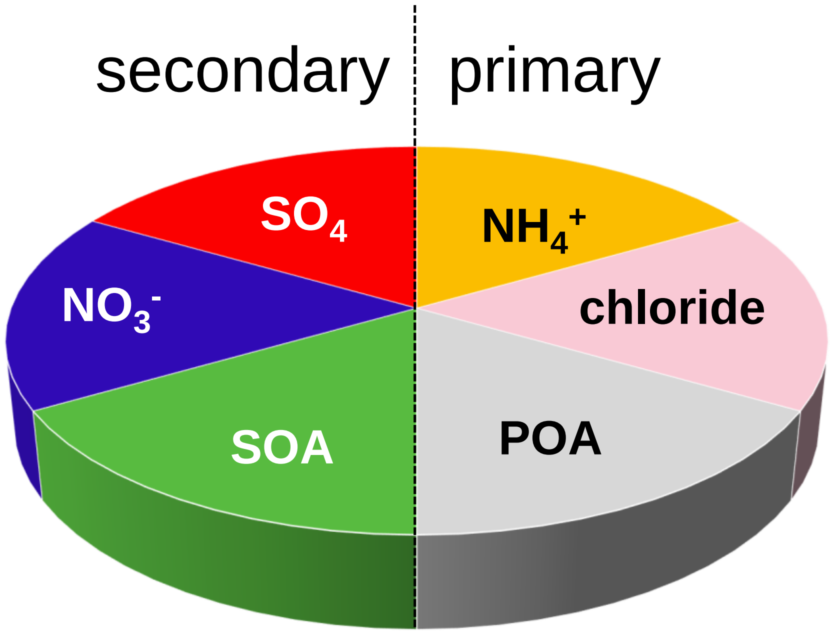


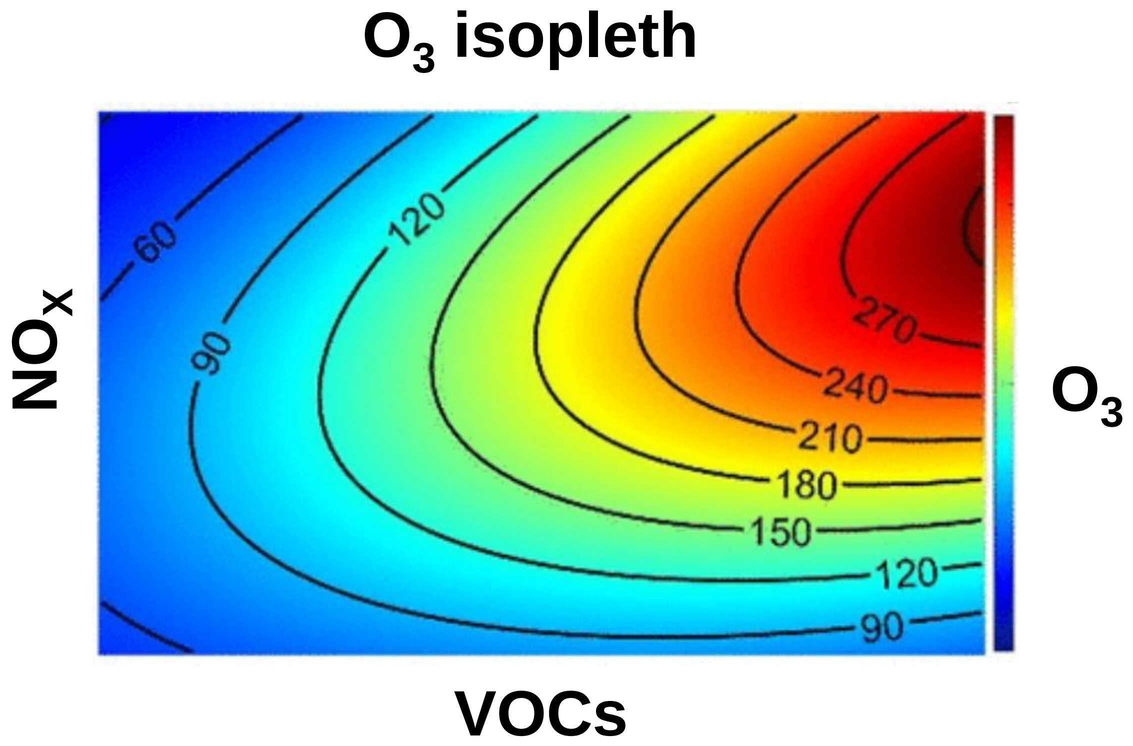
O_3 concentration ($\mu g\ m^{-3}$)

+ 21 ± 19%

- - - - WHO guideline means
lockdown violin plot
lockdown measurements
lockdown mean
reference period mean

How well do we understand $PM_{2.5}$ and O_3?



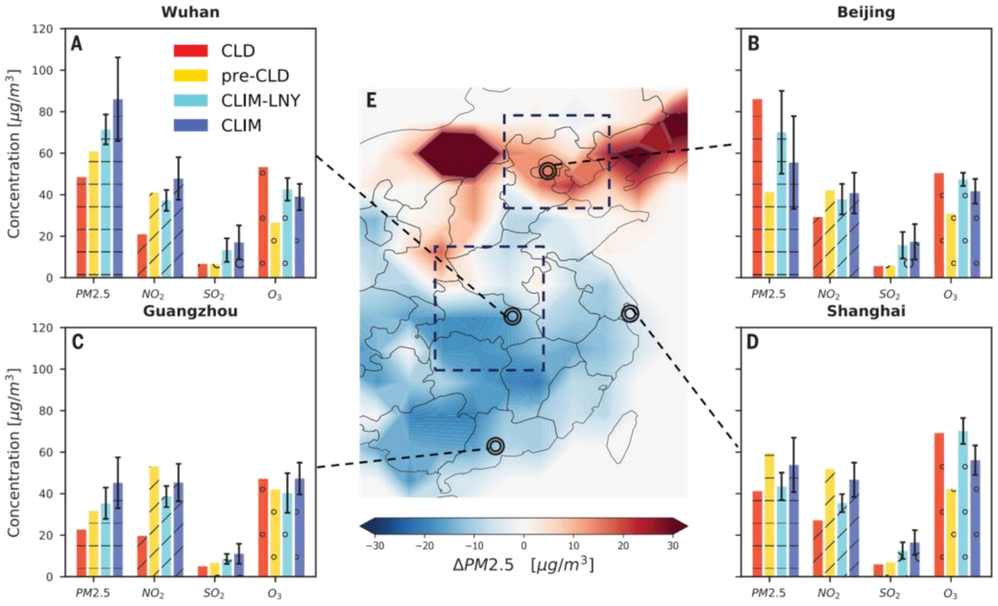


What is the chemical composition of $PM_{2.5}$?

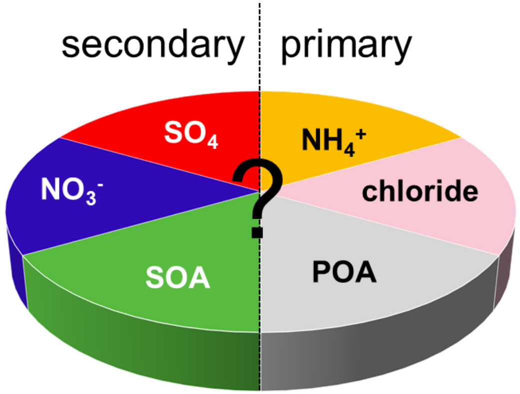
What happens in chemically active seasons?

What is the role of secondary $PM_{2.5}$ on air quality?

In China during lockdowns $PM_{2.5}$ % even increased



Le et al., Science, (2020)



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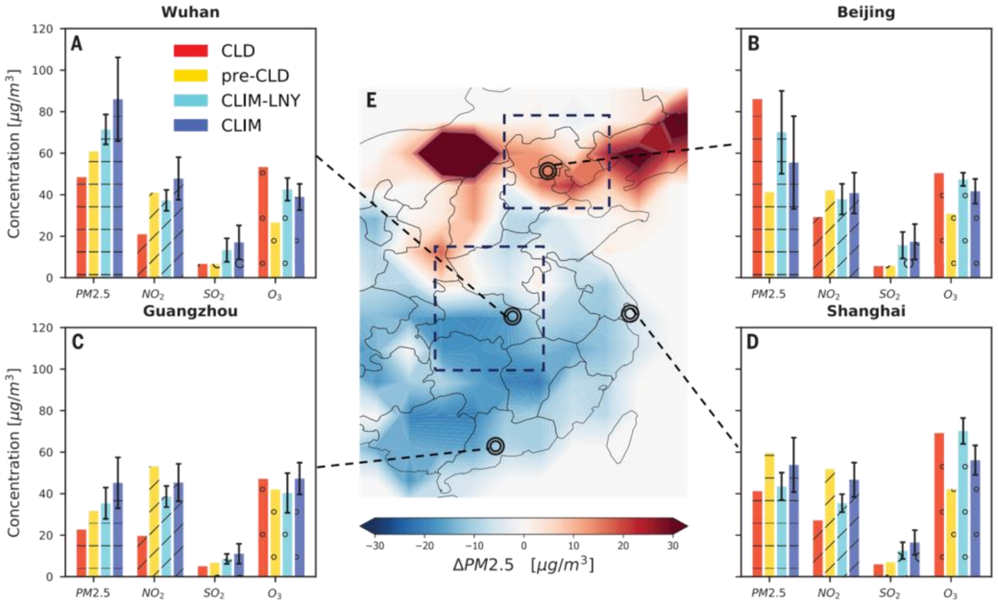
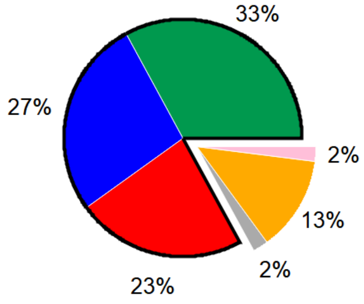
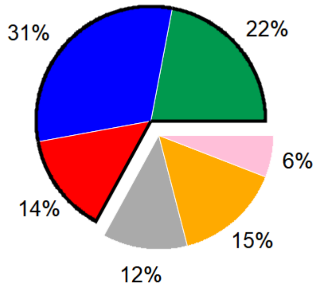


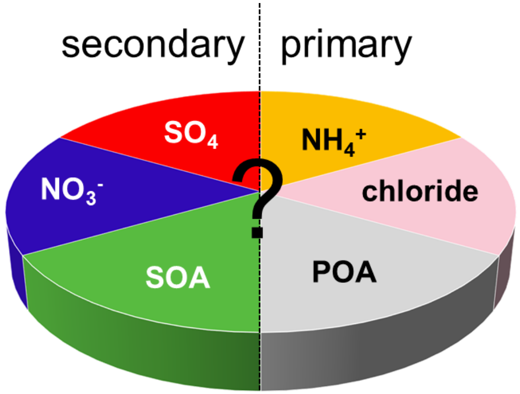
Guo et al., PNAS, 2014



Gkatzelis et al., GRL, 2021



POA SOA nitrate sulphate ammonium chloride



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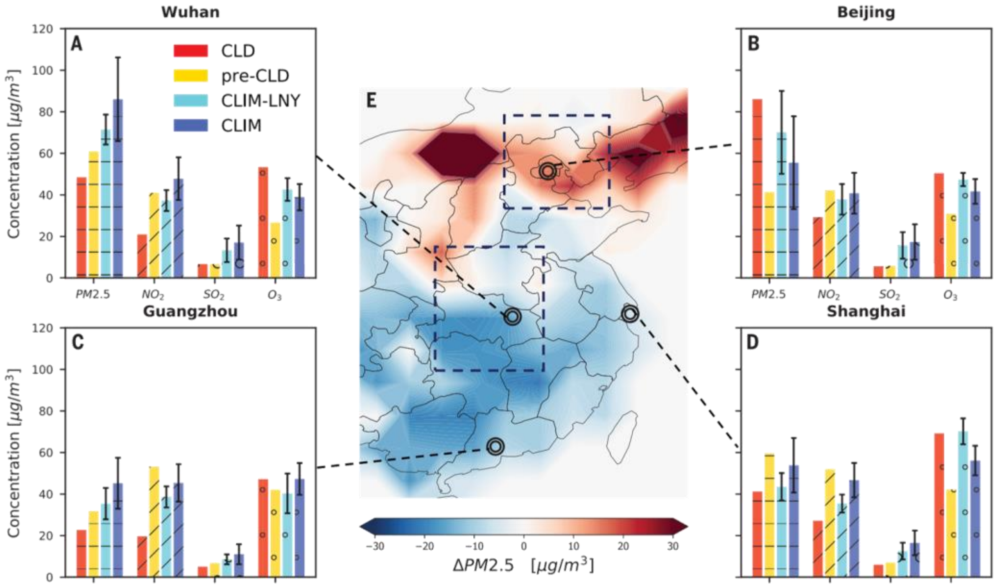
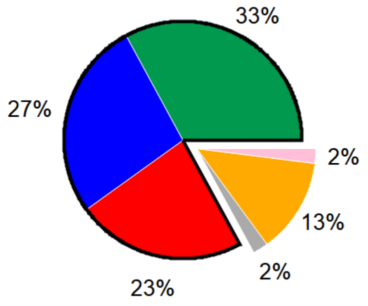
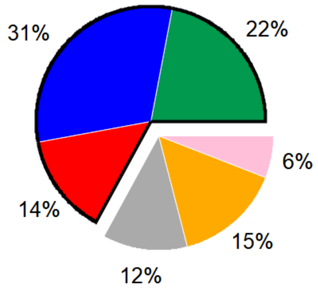


Le et al., Science, (2020)

Guo et al., PNAS, 2014



Gkatzelis et al., GRL, 2021



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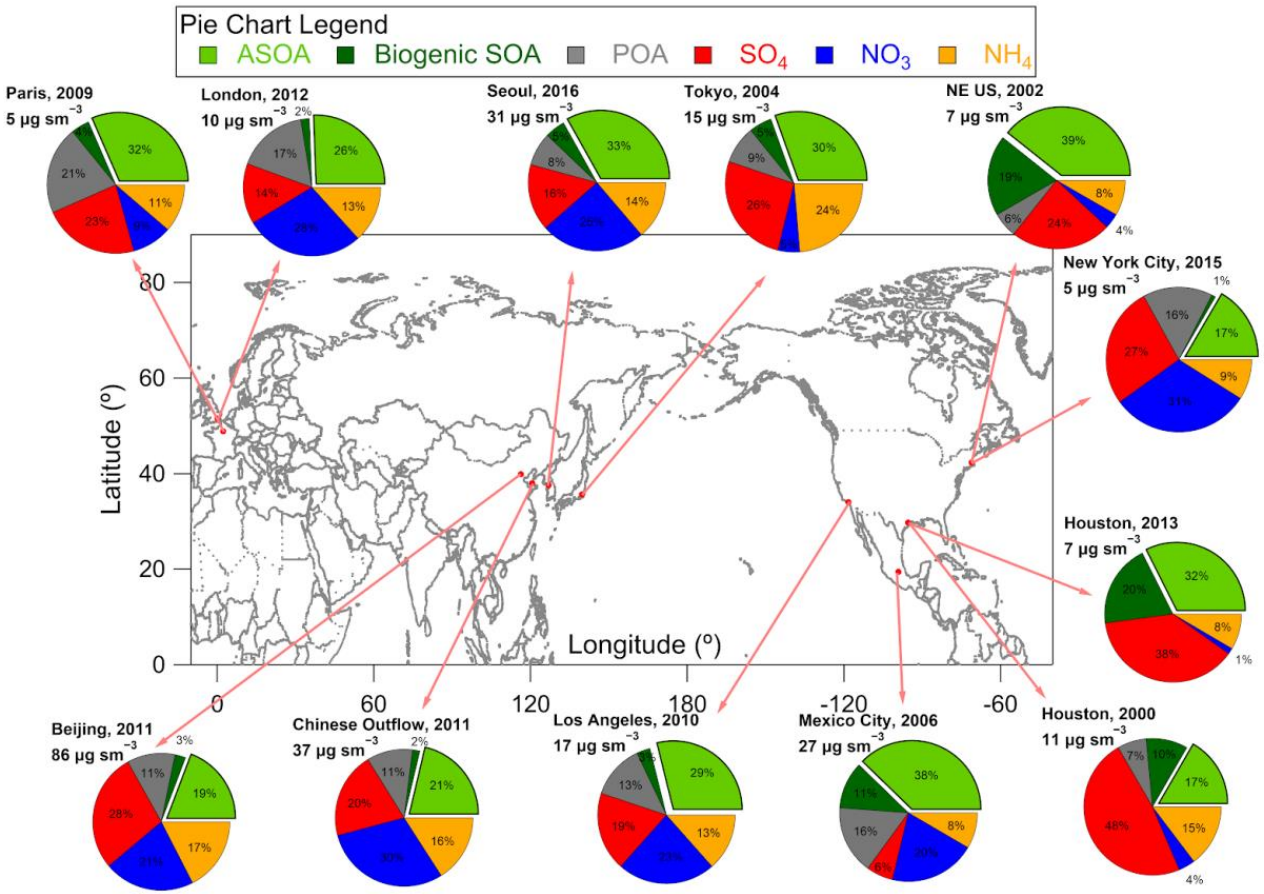
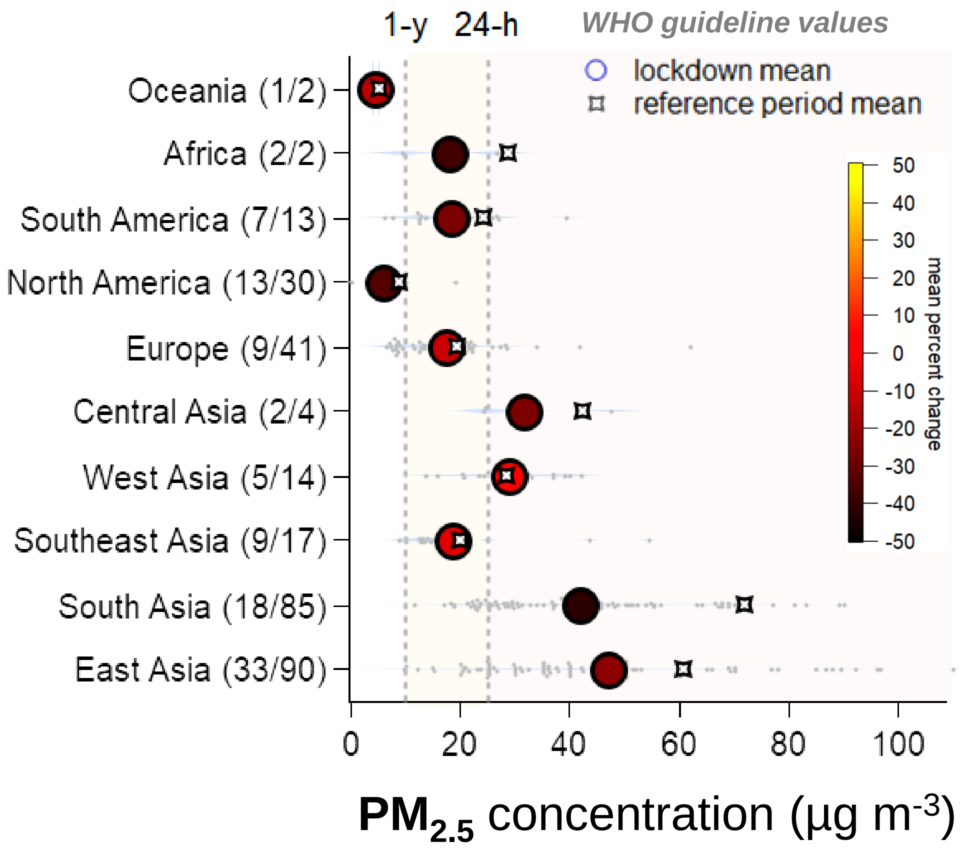


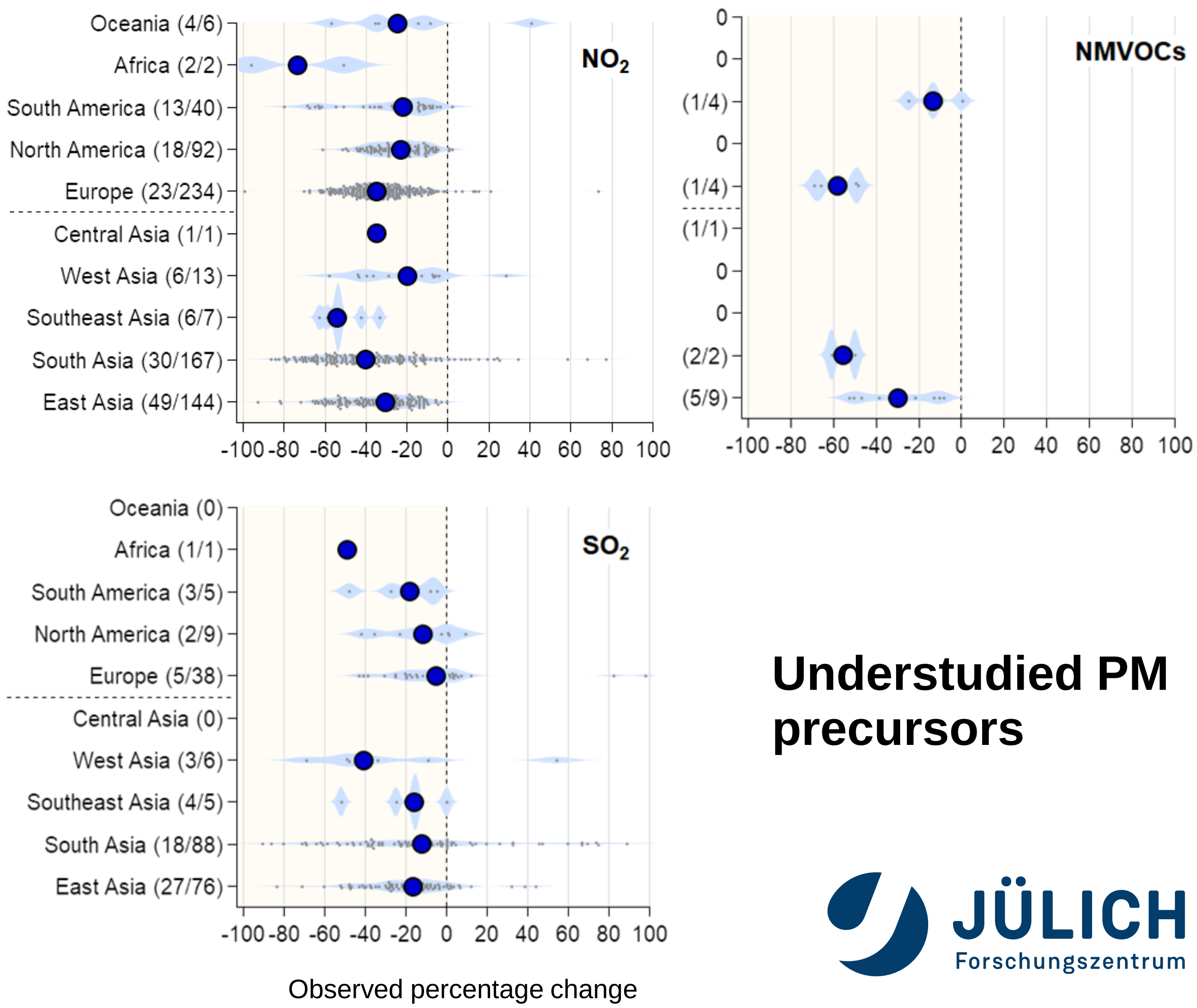
Nault et al., ACP, (2021)

- ***Secondary PM represent the dominant fraction of the mass***

$PM_{2.5}$ concentrations and precursor compound reductions

PM guideline values are still exceeded





Understudied PM precursors

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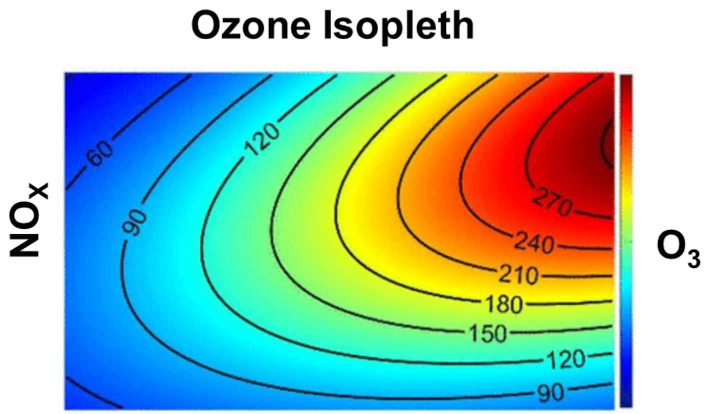
How do VOC emissions change during lockdowns?



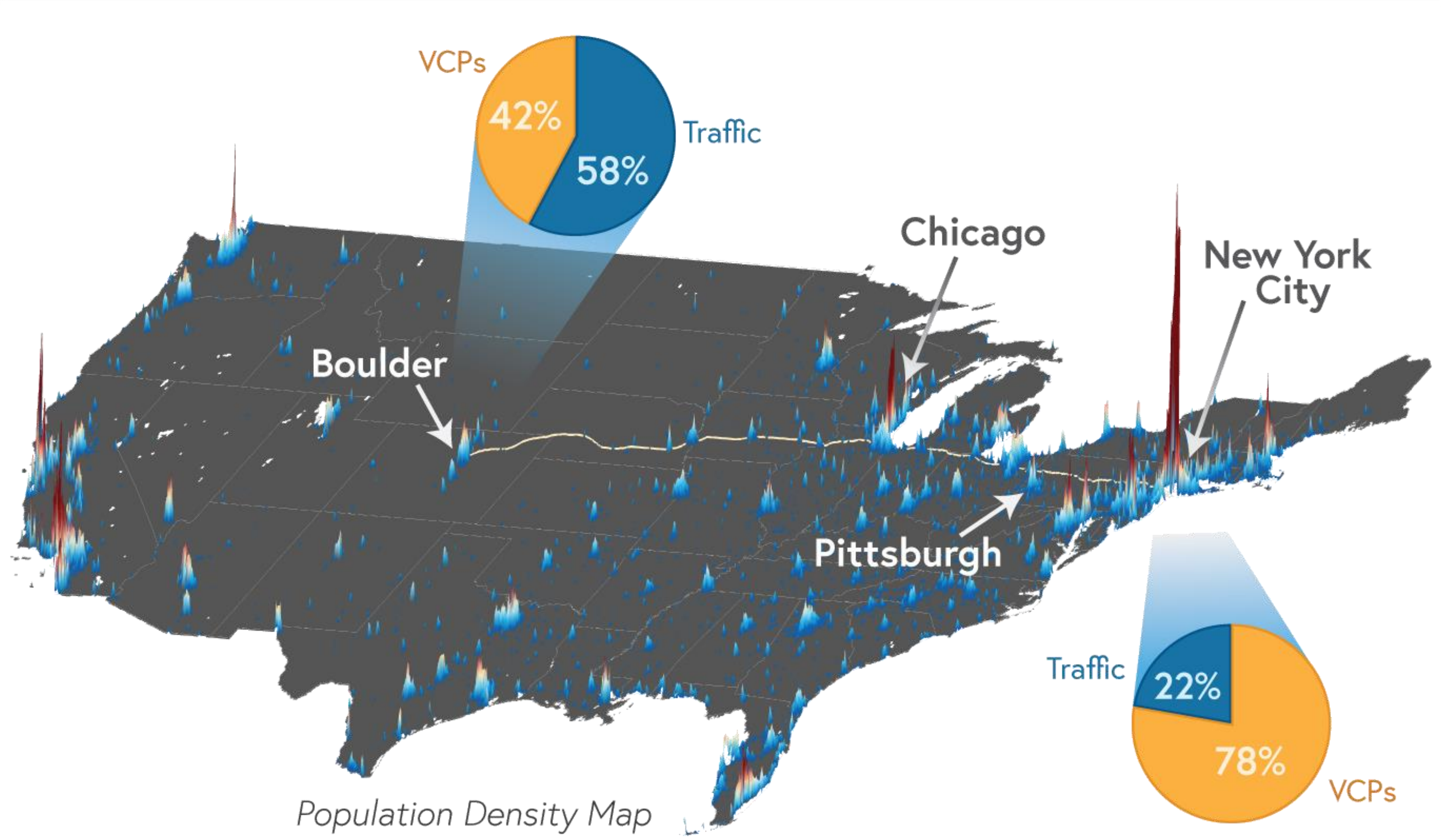
- To get O_3 right you need both NO_X and VOC emission reductions
- NOx emission reductions can be quantified relatively well
- But which VOC emission sectors are expected to change though?

Expectation

reductions

unknown

Importance of residential emissions in urban environments

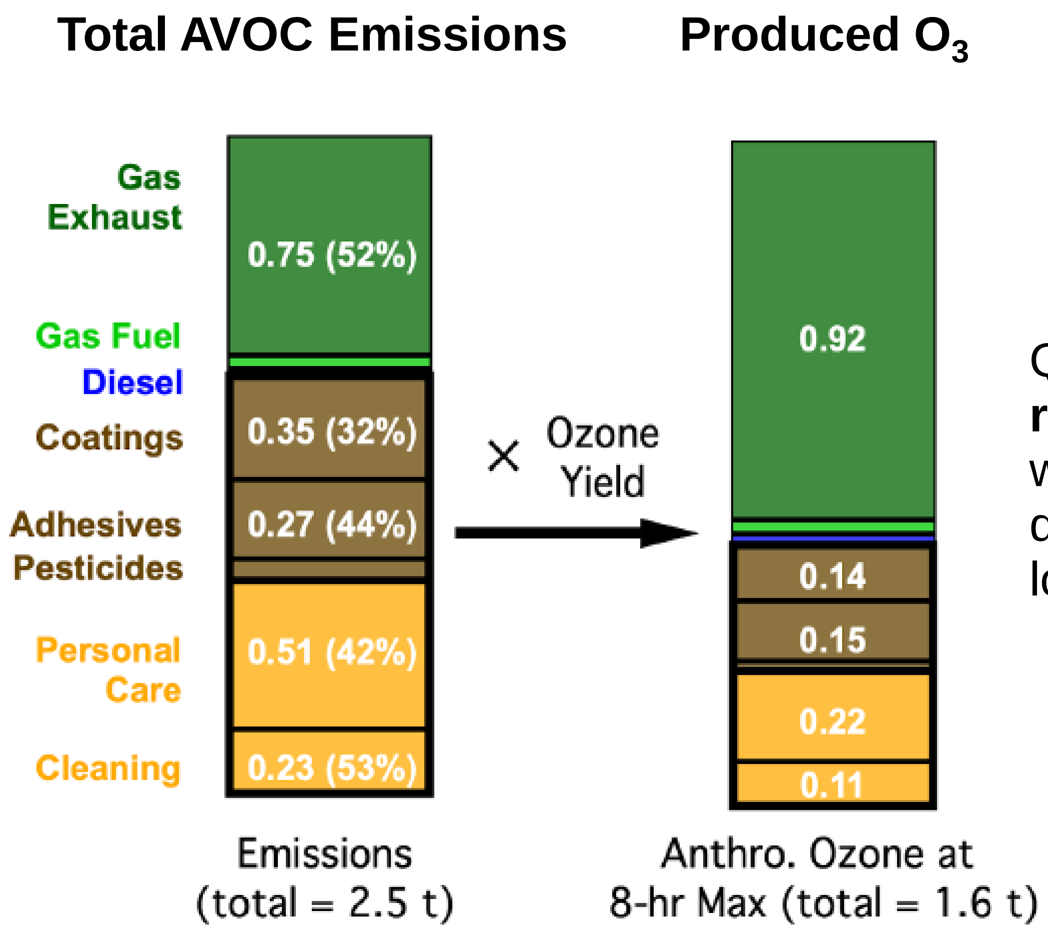


- Volatile chemical products (VCPs) contribute significantly to urban VOC emissions in the US
- Places with drastically different population densities show high fraction of VCPs
- Do these emissions contibute to O_3 production?

Gkatzelis et al., ES&T, 2021

O_3 formation in New York City during a heatwave

NOAA Instrumented Mobile Laboratory in NYC

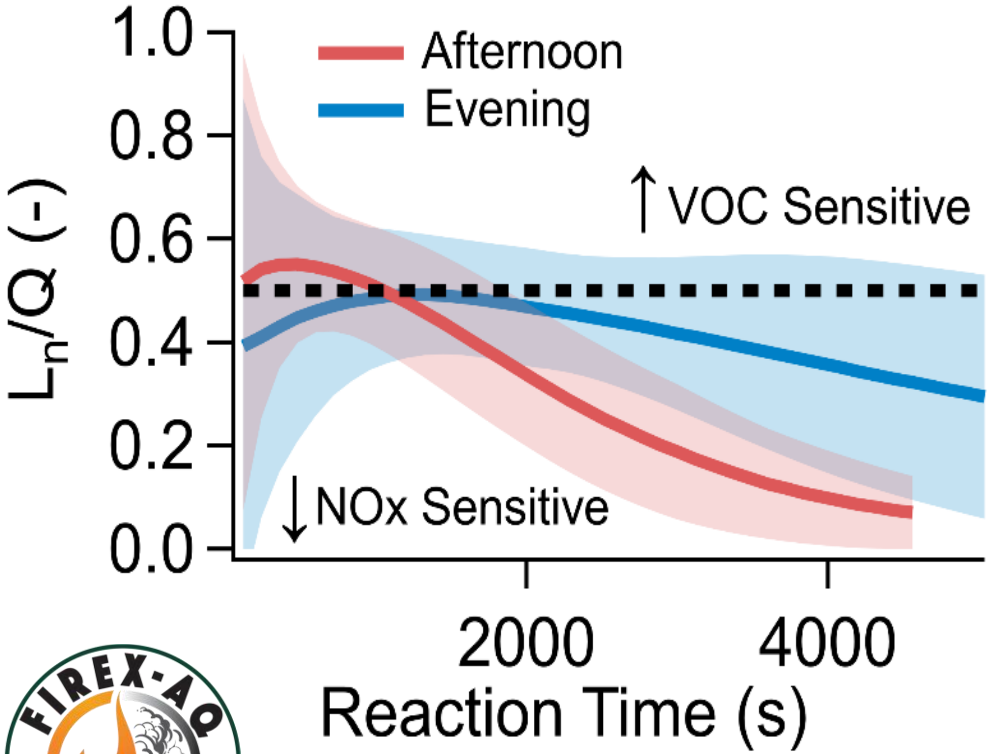


Quantifying changes in **residential VOC emissions** will be essential in accurately determining O_3 during the lockdown periods

Coggon et al., (2021), in press

How could wildfire season affect O_3 formation in lockdowns

Radical production & termination balance

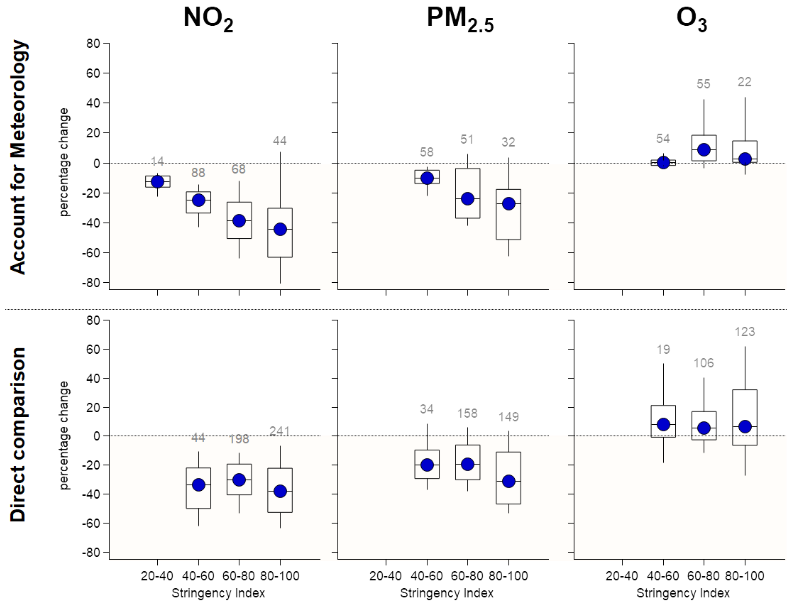


- Fast transition to a NO_X sensitive regime
- O_3 production expected to increase moving over an urban environment
- Periods influenced by biomass burning will be challenging to compared to previous years

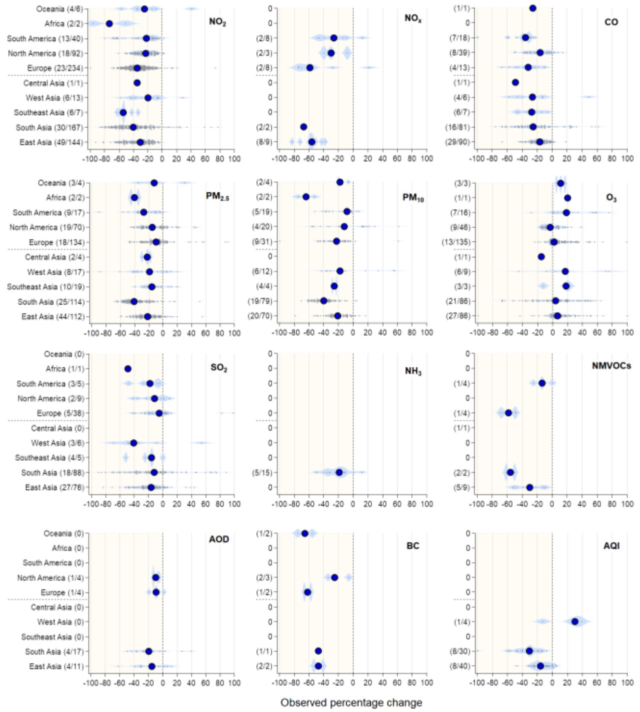
Robinson et al., (2021), in review

Concluding Remarks

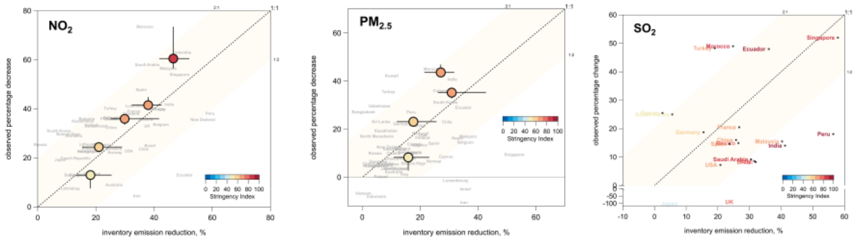
1. Importance of Accounting for the Effects of Meteorology and Long-term Trends



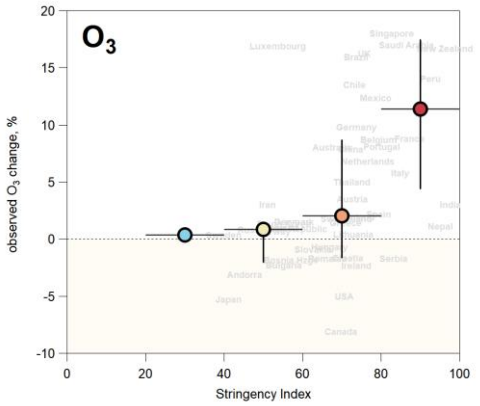
2. Statistics for certain pollutants is good but for other not.

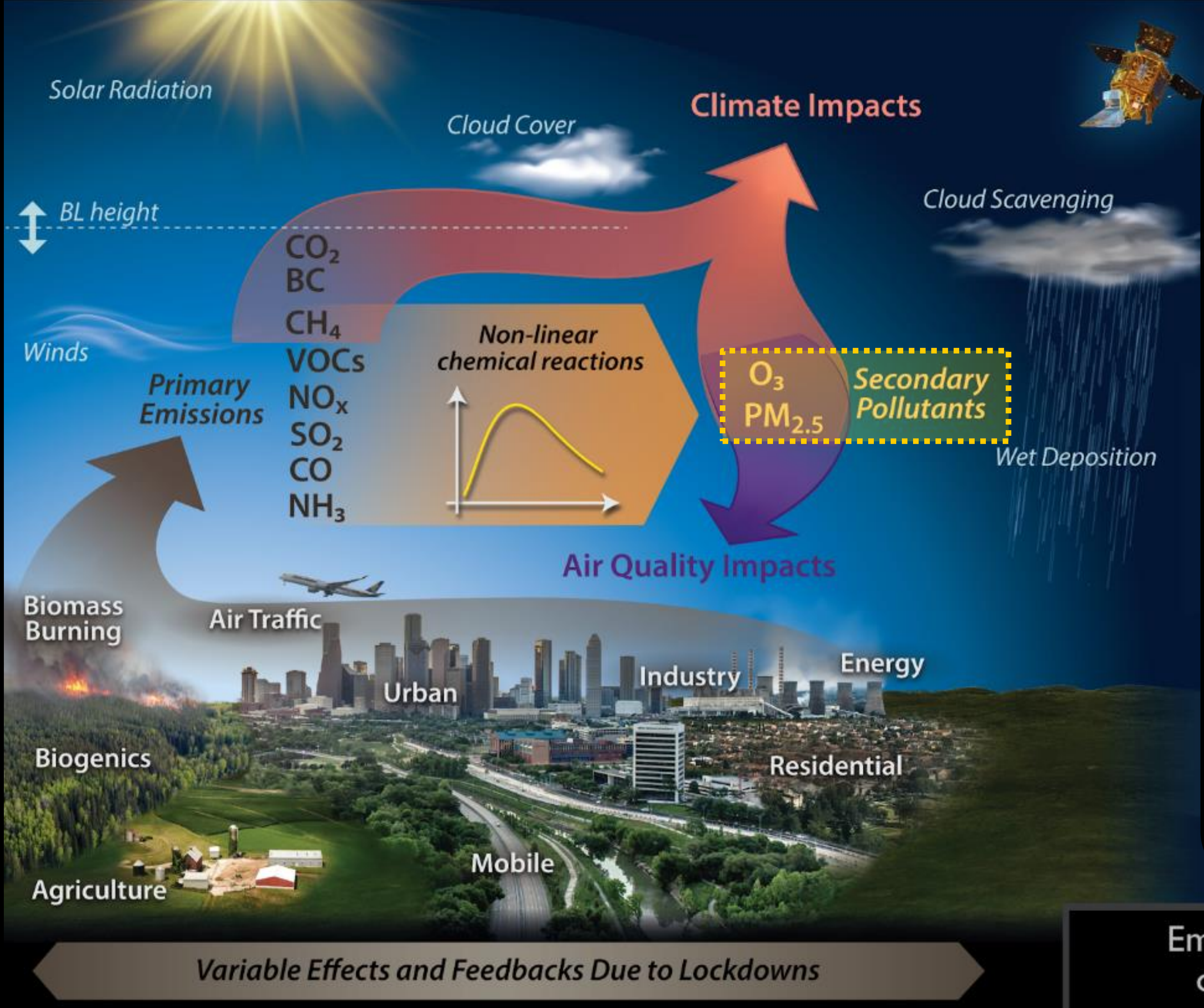


3. Comparisons to emission inventories is good for NO_2 but for other pollutants more work is required



4. A logarithmic O_3 increase with increasing stringency index is evident





Future Recommendations

1. Changes in O_3 associated with COVID-19 emissions reductions, particularly **O_3 during photochemically active seasons**.

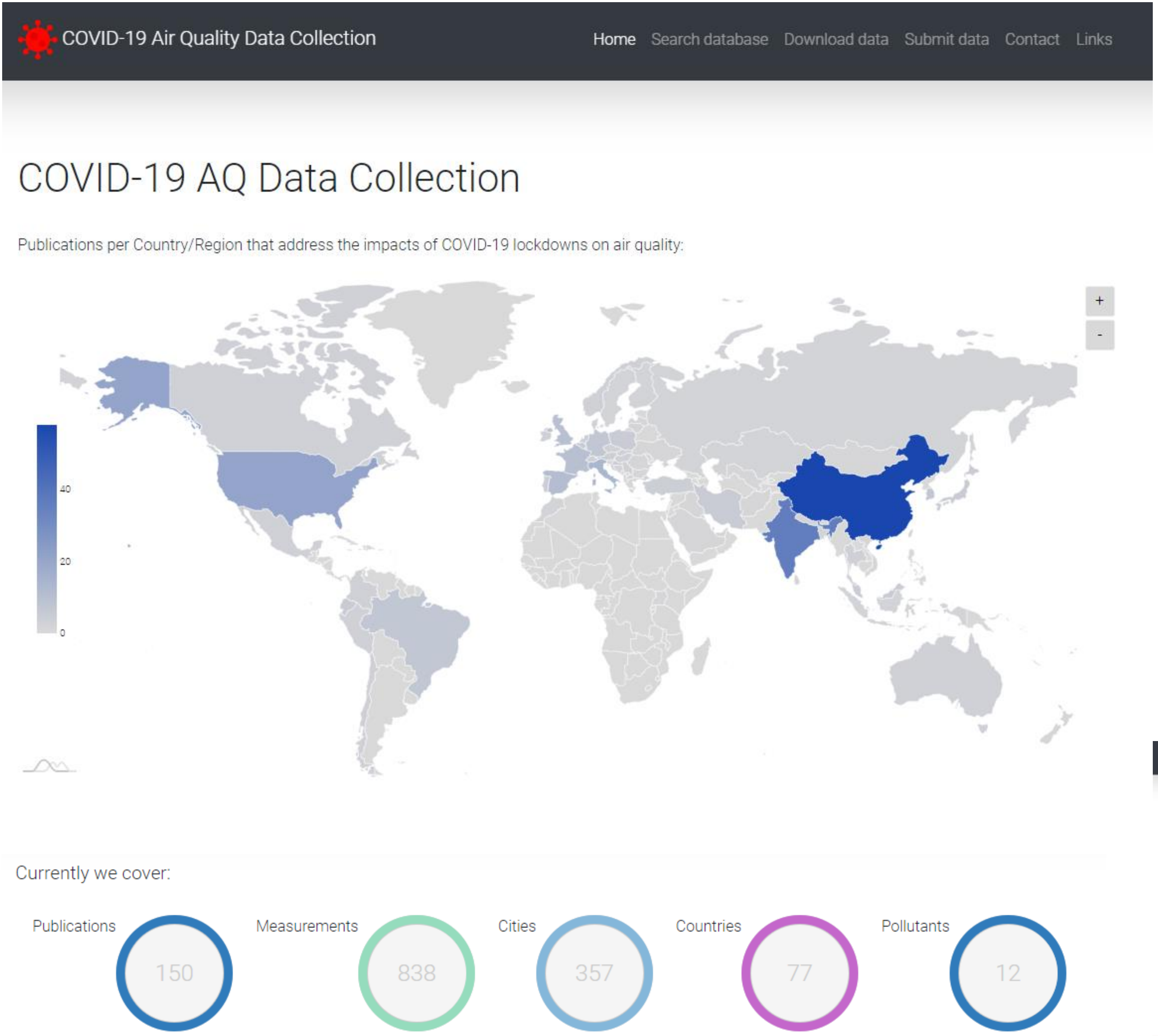
2. Changes in $PM_{2.5}$ may enable similar sensitivity analyses to primary emissions. A larger analysis of **chemically speciated $PM_{2.5}$ data**, where available, will be especially informative.

3. Expansion of the available analyses to **include a larger number of short-lived species** would help to constrain and inform emissions inventories

4. Analysis of the **radiative forcing associated with short-lived climate forcers** is a priority.

5. This review has been limited in scope to short-lived air pollutants that are relevant to air quality and climate, but **not to longer lived species such as CH_4, CO_2, N_2O and halogenated short lived climate forcers.**

Emissions Sources and Impacts on Air Quality and Climate



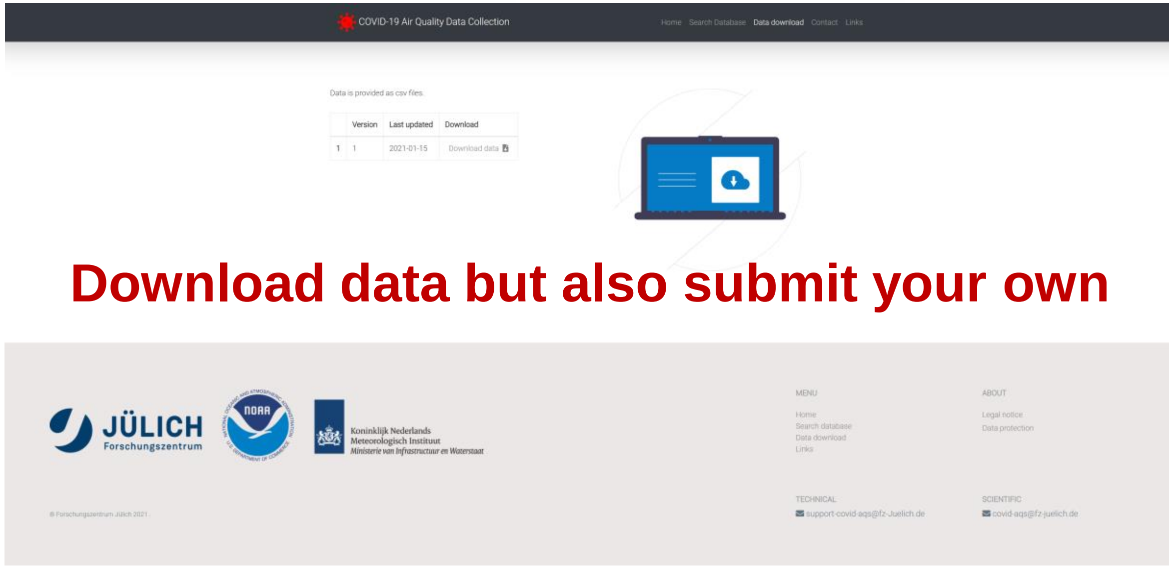
https://covid-aqs.fz-juelich.de/

Georgios Gkatzelis, g.gkatzelis@fz-juelich.de

Online Database Available Now!

Rita Gomes

Michael Decker



Download data but also submit your own