STATS 604

Project II: What can we learn from COVID?

COVID as a natural experiment

- COVID upended almost every aspect of our lives.
- Delivered a huge shock to the global economy, government policy, environment, travel, education, social norms, etc. etc.
- Since (almost) nobody saw it coming, COVID can be used as an instrument to study causal relationships that affect these and other phenomena.
- It is also interesting to study questions related to the pandemic: impact of lockdown policies, mask mandates, vaccine skepticism, ...

Seismology

- Global reduction in seismographic noise:
  - Commencing in China in late January 2020
  - Followed by Italy,
  - the whole of Europe,
  - and the rest of the world in March to April 2020.
- Lasted longer and was often quieter than the Christmas–to–New Year period.

REPORT

SEISMOLOGY

Global quieting of high-frequency seismic noise due to COVID-19 pandemic lockdown measures

Thomas Lecocq[1]*, Stephen P. Hicks[2], Koen Van Noten[1], Kasper van Wijk[3], Paula Koelemeijer[4], Raphael S. M. De Plaen[5], Frédérick Massin[6], Gregor Hillers[7], Robert E. Anthony[8], Maria-Theresia Apoloner[9], Mario Arroyo-Solórzano[10], Jelle D. Assink[11], Pinar Büyükakpınar[12,13], Andrea Cannata[14,15], Flavio Cannavo[15], Sebastian Carrasco[16], Corentin Caudron[17], Esteban J. Chaves[18], David G. Cornwell[19], David Craig[20], Olivier F. C. den Ouden[11,21], Jordi Diaz[22], Stefanie Donner[23], Christos P. Evangelidis[24], Läslo Evers[11,21], Benoit Fauville[25], Gonzalo A. Fernandez[26], Dimitrios Giannopoulos[27,28], Steven J. Gibbons[29], Társilo Girona[30], Bogdan Grecu[31], Marc Grunberg[32], György Hetényi[33], Anna Horleston[34], Adolfo Inza[35], Jessica C. E. Irving[34,36], Mohammadreza Jamalreyhani[37,13], Alan Kafka[38], Mathijs R. Koymans[11,21], Celeste R. Labedz[39], Eric Larose[17], Nathaniel J. Lindsey[40], Mika McKinnon[41,42], Tobias Megies[43], Meghan S. Miller[44], William Minarik[45,46], Louis Moresi[44], Víctor H. Márquez-Ramírez[5], Martin Möllhoff[20], Ian M. Nesbitt[47,48], Shankho Niyogi[49], Javier Ojeda[50], Adrien Oth[51], Simon Proud[52], Jay Pulli[53,38], Lise Retailleau[54,55], Annukka E. Rintamäki[7], Claudio Satriano[54], Martha K. Savage[56], Shahar Shani-Kadmiel[21], Reinoud Sleeman[11], Efthimios Sokos[57], Klaus Stammler[23], Alexander E. Stott[58], Shiba Subedi[33], Mathilde B. Sørensen[59], Taka'aki Taira[60], Mar Tapia[61], Fatih Turhan[12], Ben van der Pluijm[62], Mark Vanstone[63], Jerome Vergne[64], Tommi A. T. Vuorinen[7], Tristram Warren[65], Joachim Wassermann[43], Han Xiao[66]

Human activity causes vibrations that propagate into the ground as high-frequency seismic waves. Measures to mitigate the coronavirus disease 2019 (COVID-19) pandemic caused widespread changes in human activity, leading to a months-long reduction in seismic noise of up to 50%. The 2020 seismic noise quiet period is the longest and most prominent global anthropogenic seismic noise reduction on record. Although the reduction is strongest at surface seismometers in populated areas, this seismic quiescence extends for many kilometers radially and hundreds of meters in depth. This quiet period provides an opportunity to detect subtle signals from subsurface seismic sources that would have been concealed in noisier times and to benchmark sources of anthropogenic noise. A strong correlation between seismic noise and independent measurements of human mobility suggests that seismology provides an absolute, real-time estimate of human activities.

Seismometers record signals from more than just earthquakes: Interactions between the solid Earth and fluid bodies, such as ocean swell and atmospheric pressure (*1*, *2*), are now commonly used to image and monitor the subsurface (*3*). Human activity is a third source of seismic signal. Nuclear explosions and fluid injection or extraction result in impulsive signals, but everyday human activity is recorded as a near-continuous signal, especially on seismometers in urban environments. These complicated signals are the superposition of a wide variety of activities happening at different times and places at or near Earth's surface but are typically stronger during the day than at night, weaker on weekends than weekdays, and stronger near population centers than sparsely inhabited areas (*4*–*7*). Seismometers in urban environments are important to maximize the spatial coverage of seismic networks and to warn of local geologic hazards (*8*), even though anthropogenic seismic noise degrades their capability to detect transient signals associated with earthquakes and volcanic eruptions. Therefore, it is vital to understand urban seismic sources, but studies have been limited to confined areas or distinct events, such as road traffic (*9*, *10*), public transport (*7*, *11*), and "football quakes" (*11*, *12*). Broad analysis of the long-term global anthropogenic seismic wavefield has been lacking. The impact of large, coherent changes in human behavior on seismic noise is unknown, as is how far it propagates and whether seismic recordings offer a coarse proxy for monitoring human activity patterns. Answering these questions has proven challenging because datasets are large, monitoring networks are heterogeneous, and the many possible noise sources likely vary spatially and overlap in time (*13*).

The coronavirus disease 2019 (COVID-19) outbreak was declared a global health emergency in January 2020 (*14*) and a pandemic in March 2020 by the World Health Organization. The outbreak resulted in emergency measures to reduce the basic reproduction rate of the virus (*15*), beginning in China and Italy and then followed by most countries. These measures disrupted social and economic behavior (*16*), industrial production (*17*), and tourism (*18*). In this paper, we use the term "lockdown" to

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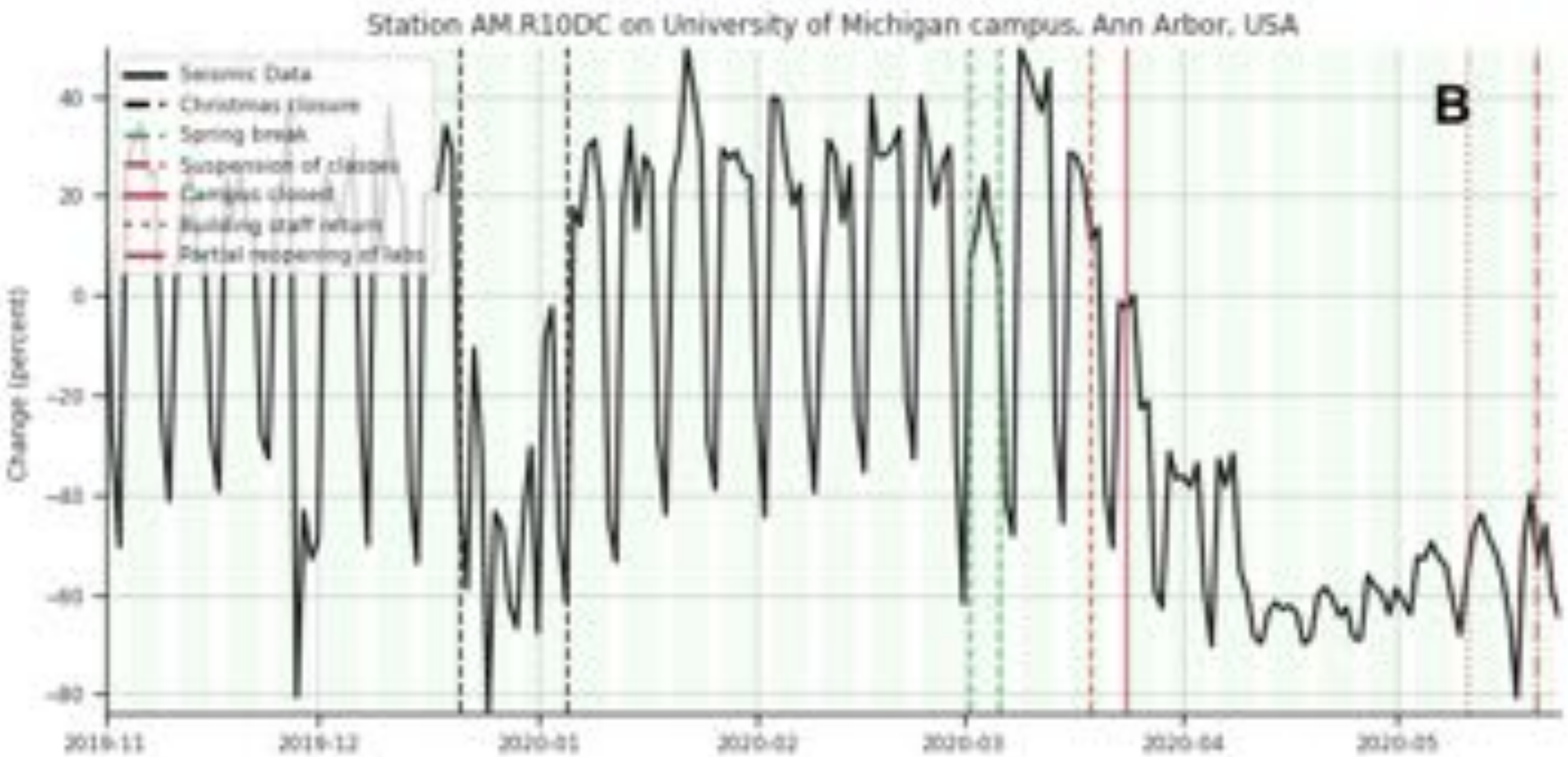
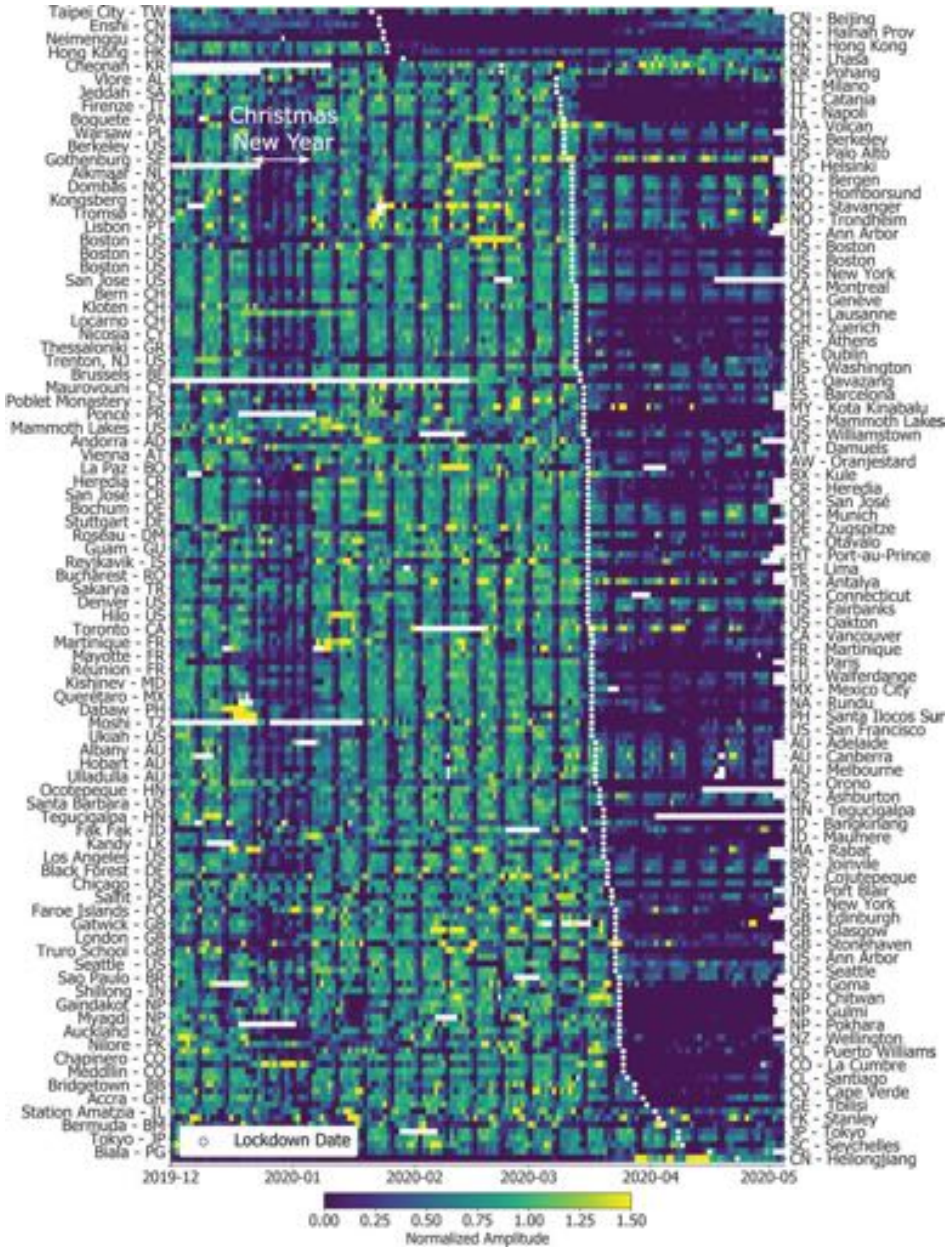
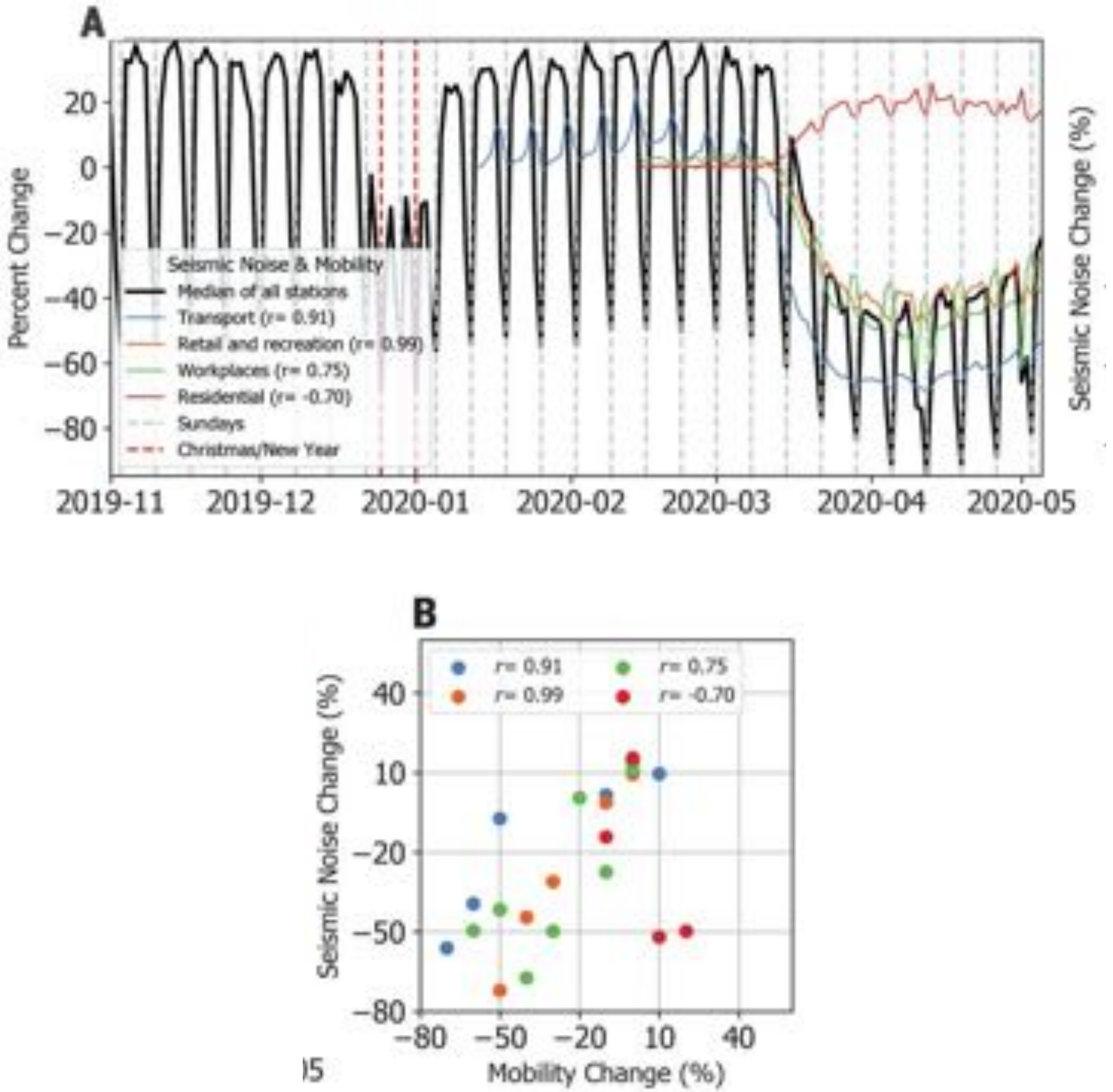

Station AM.R10DC on University of Michigan campus, Ann Arbor, USA
Seismic Data
Christmas closure
Spring break
Suspension of classes
Campus closed
Building staff return
Partial reopening of labs
B
Change (percent)
2019-11
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05


Christmas
New Year
Lockdown Date
2019-12
2020-01
2020-02
2020-03
2020-04
2020-05
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Normalized Amplitude

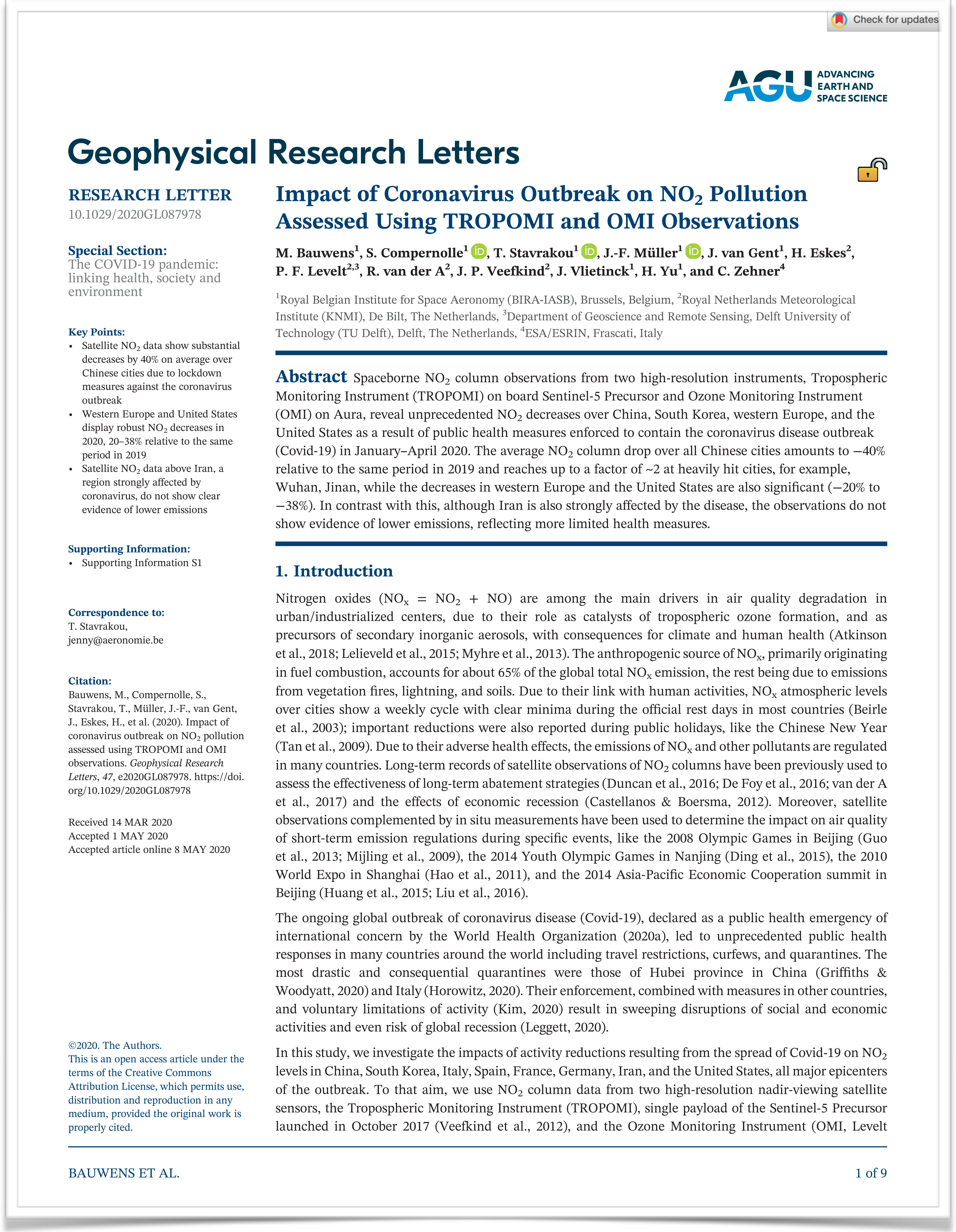
Research questions

- Seismic data is cheap and readily available, can it predict other things that are harder to measure?
- Assess impact of mitigation policies?
- Measure economic activity in general?



Air Quality

"Spaceborne NO2 column observations ... reveal unprecedented NO2 decreases over China, South Korea, western Europe, and the United States as a result of public health measures enforced to contain the coronavirus disease outbreak (Covid-19) in January–April 2020."



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Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL087978

Special Section:
The COVID-19 pandemic: linking health, society and environment

Impact of Coronavirus Outbreak on NO_2 Pollution Assessed Using TROPOMI and OMI Observations

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Key Points:
- Satellite NO_2 data show substantial decreases by 40% on average over Chinese cities due to lockdown measures against the coronavirus outbreak
- Western Europe and United States display robust NO_2 decreases in 2020, 20–38% relative to the same period in 2019
- Satellite NO_2 data above Iran, a region strongly affected by coronavirus, do not show clear evidence of lower emissions

Supporting Information:
- Supporting Information S1

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Abstract Spaceborne NO_2 column observations from two high-resolution instruments, Tropospheric Monitoring Instrument (TROPOMI) on board Sentinel-5 Precursor and Ozone Monitoring Instrument (OMI) on Aura, reveal unprecedented NO_2 decreases over China, South Korea, western Europe, and the United States as a result of public health measures enforced to contain the coronavirus disease outbreak (Covid-19) in January–April 2020. The average NO_2 column drop over all Chinese cities amounts to −40% relative to the same period in 2019 and reaches up to a factor of ~2 at heavily hit cities, for example, Wuhan, Jinan, while the decreases in western Europe and the United States are also significant (−20% to −38%). In contrast with this, although Iran is also strongly affected by the disease, the observations do not show evidence of lower emissions, reflecting more limited health measures.

1. Introduction

Nitrogen oxides (NO_x = NO_2 + NO) are among the main drivers in air quality degradation in urban/industrialized centers, due to their role as catalysts of tropospheric ozone formation, and as precursors of secondary inorganic aerosols, with consequences for climate and human health (Atkinson et al., 2018; Lelieveld et al., 2015; Myhre et al., 2013). The anthropogenic source of NO_x, primarily originating in fuel combustion, accounts for about 65% of the global total NO_x emission, the rest being due to emissions from vegetation fires, lightning, and soils. Due to their link with human activities, NO_x atmospheric levels over cities show a weekly cycle with clear minima during the official rest days in most countries (Beirle et al., 2003); important reductions were also reported during public holidays, like the Chinese New Year (Tan et al., 2009). Due to their adverse health effects, the emissions of NO_x and other pollutants are regulated in many countries. Long-term records of satellite observations of NO_2 columns have been previously used to assess the effectiveness of long-term abatement strategies (Duncan et al., 2016; De Foy et al., 2016; van der A et al., 2017) and the effects of economic recession (Castellanos & Boersma, 2012). Moreover, satellite observations complemented by in situ measurements have been used to determine the impact on air quality of short-term emission regulations during specific events, like the 2008 Olympic Games in Beijing (Guo et al., 2013; Mijling et al., 2009), the 2014 Youth Olympic Games in Nanjing (Ding et al., 2015), the 2010 World Expo in Shanghai (Hao et al., 2011), and the 2014 Asia-Pacific Economic Cooperation summit in Beijing (Huang et al., 2015; Liu et al., 2016).

The ongoing global outbreak of coronavirus disease (Covid-19), declared as a public health emergency of international concern by the World Health Organization (2020a), led to unprecedented public health responses in many countries around the world including travel restrictions, curfews, and quarantines. The most drastic and consequential quarantines were those of Hubei province in China (Griffiths & Woodyatt, 2020) and Italy (Horowitz, 2020). Their enforcement, combined with measures in other countries, and voluntary limitations of activity (Kim, 2020) result in sweeping disruptions of social and economic activities and even risk of global recession (Leggett, 2020).

In this study, we investigate the impacts of activity reductions resulting from the spread of Covid-19 on NO_2 levels in China, South Korea, Italy, Spain, France, Germany, Iran, and the United States, all major epicenters of the outbreak. To that aim, we use NO_2 column data from two high-resolution nadir-viewing satellite sensors, the Tropospheric Monitoring Instrument (TROPOMI), single payload of the Sentinel-5 Precursor launched in October 2017 (Veefkind et al., 2012), and the Ozone Monitoring Instrument (OMI, Levelt

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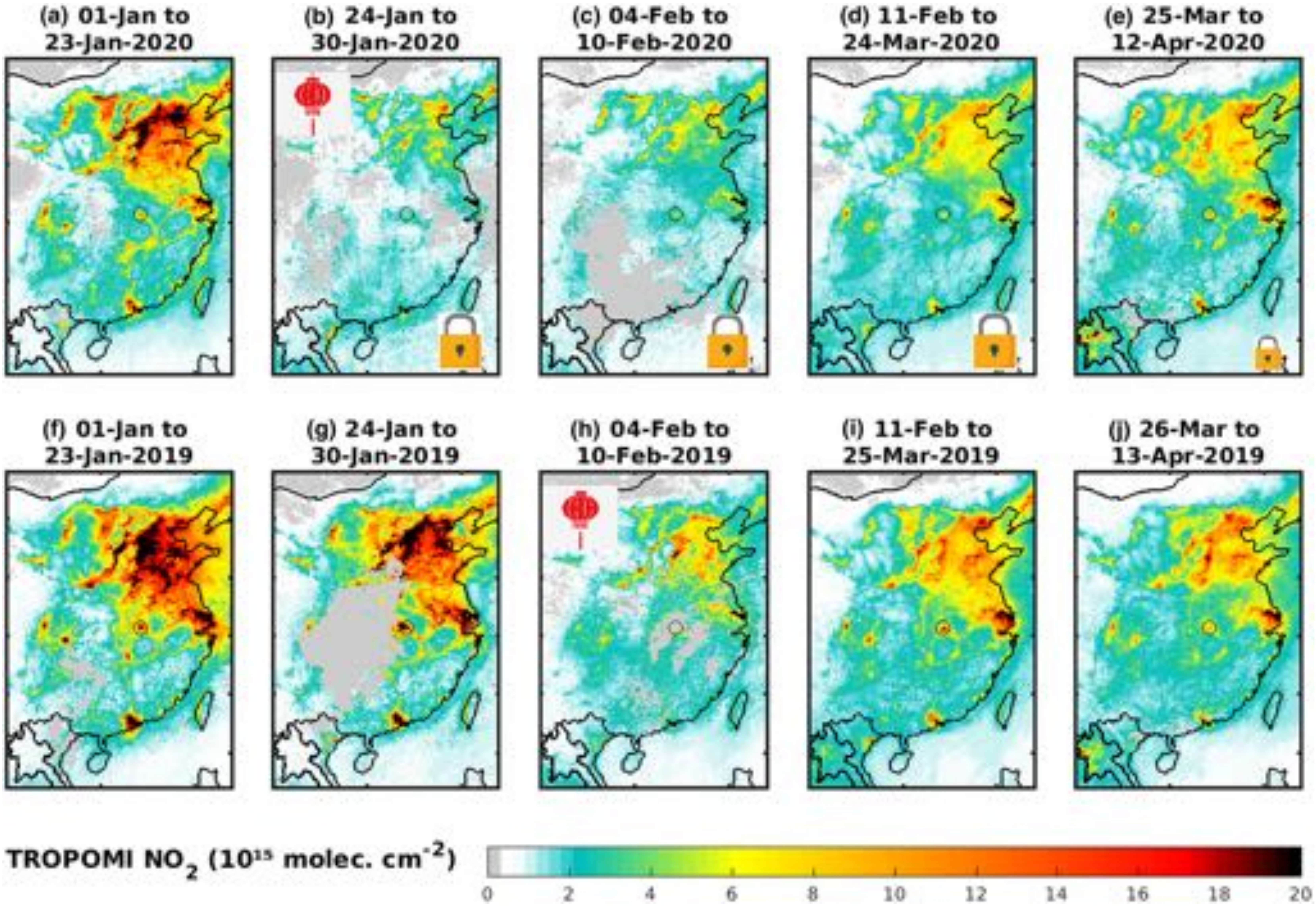
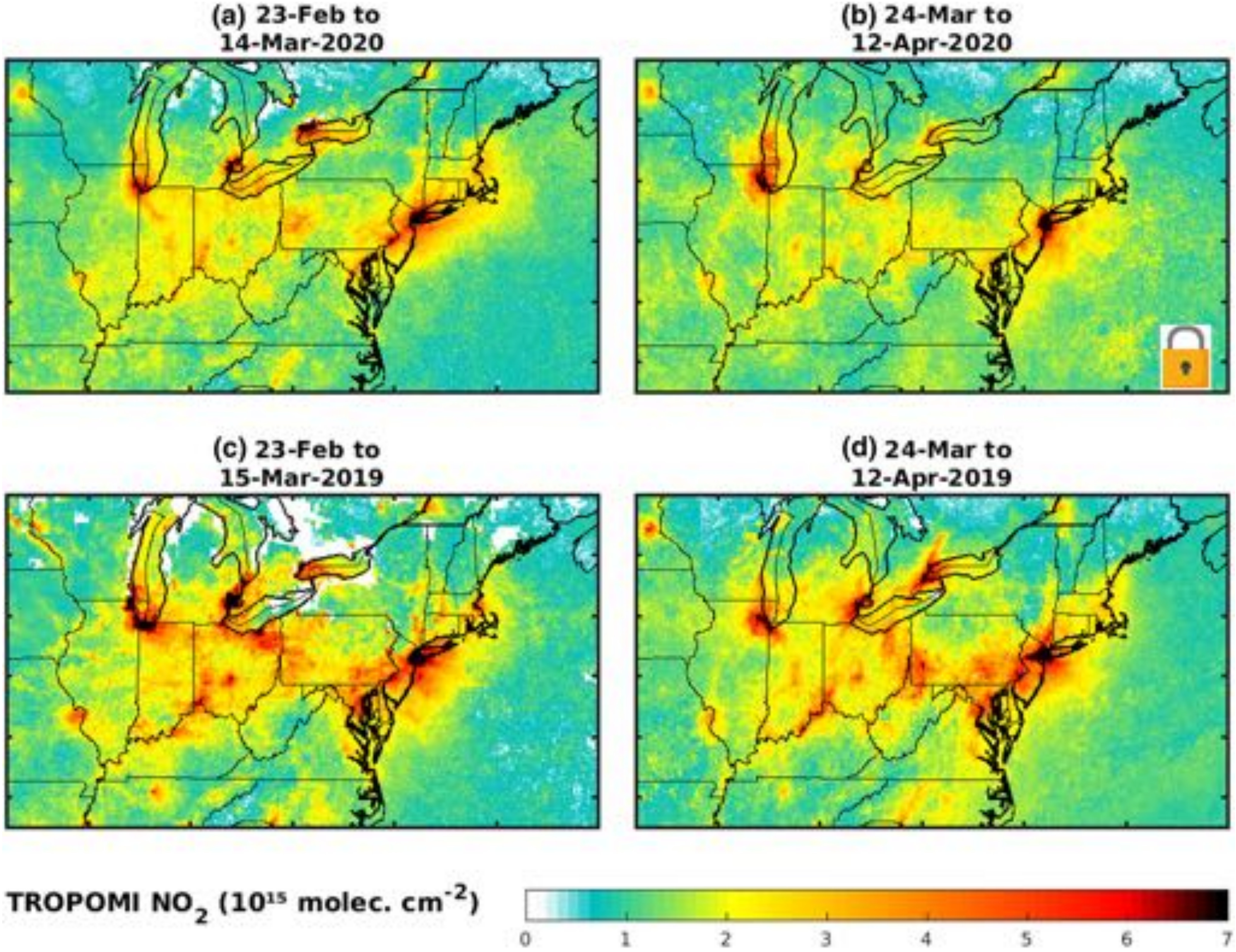


(a) 01-Jan to 23-Jan-2020
(b) 24-Jan to 30-Jan-2020
(c) 04-Feb to 10-Feb-2020
(d) 11-Feb to 24-Mar-2020
(e) 25-Mar to 12-Apr-2020
(f) 01-Jan to 23-Jan-2019
(g) 24-Jan to 30-Jan-2019
(h) 04-Feb to 10-Feb-2019
(i) 11-Feb to 25-Mar-2019
(j) 26-Mar to 13-Apr-2019
TROPOMI NO_2 (10^{15} molec. cm^{-2})
0 2 4 6 8 10 12 14 16 18 20


(a) 23-Feb to 14-Mar-2020
(b) 24-Mar to 12-Apr-2020
(c) 23-Feb to 15-Mar-2019
(d) 24-Mar to 12-Apr-2019
TROPOMI NO2 (10^15 molec. cm^-2)
0
1
2
3
4
5
6
7

Research questions

- Mortality:
  - Air pollution kills 5+ million people globally every year.
  - Did COVID decrease premature deaths due to air pollution?
  - How to model/measure?
- Attribution:
  - Determinants of air quality: human vs. natural, personal vs. industrial, etc.
  - How to model/measure?

Disparities

- NO2 exposure is higher in minority and low-income communities.
- How should we address these disparities?

Check for updates

COVID-19 pandemic reveals persistent disparities in nitrogen dioxide pollution

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The unequal spatial distribution of ambient nitrogen dioxide (NO_2), an air pollutant related to traffic, leads to higher exposure for minority and low socioeconomic status communities. We exploit the unprecedented drop in urban activity during the COVID-19 pandemic and use high-resolution, remotely sensed NO_2 observations to investigate disparities in NO_2 levels across different demographic subgroups in the United States. We show that, prior to the pandemic, satellite-observed NO_2 levels in the least White census tracts of the United States were nearly triple the NO_2 levels in the most White tracts. During the pandemic, the largest lockdown-related NO_2 reductions occurred in urban neighborhoods that have 2.0 times more non-White residents and 2.1 times more Hispanic residents than neighborhoods with the smallest reductions. NO_2 reductions were likely driven by the greater density of highways and interstates in these racially and ethnically diverse areas. Although the largest reductions occurred in marginalized areas, the effect of lockdowns on racial, ethnic, and socioeconomic NO_2 disparities was mixed and, for many cities, nonsignificant. For example, the least White tracts still experienced $\sim$1.5 times higher NO_2 levels during the lockdowns than the most White tracts experienced prior to the pandemic. Future policies aimed at eliminating pollution disparities will need to look beyond reducing emissions from only passenger traffic and also consider other collocated sources of emissions such as heavy-duty vehicles.

nitrogen dioxide | air pollution | environmental justice | COVID-19 | TROPOMI

Adverse air quality is an environmental justice issue, as it disproportionately affects marginalized and disenfranchised populations around the world (1–4). Growing evidence suggests that these populations experience more air pollution than is caused by their consumption (5–7). Within the United States, disparities in exposure are persistent, despite successful regulatory measures that have reduced pollution (8, 9). Nitrogen dioxide (NO_2) is a short-lived trace gas formed shortly after fossil fuel combustion and regulated by the National Ambient Air Quality Standards under the Clean Air Act. Exposure to NO_2 is associated with a range of respiratory diseases and premature mortality (10–12). NO_2 is also a precursor to other pollutants such as ozone and particulate matter (13). Major sources of anthropogenic NO_2, such as roadways and industrial facilities, are often located within or nearby marginalized and disenfranchised communities (14, 15), and disparities in NO_2 exposure across demographic subgroups have been the focus of several recent studies (4, 8, 16–18).

In early 2020, governments around the world imposed lockdowns and shelter-in-place orders in response to the spread of COVID-19. The earliest government-mandated lockdowns in the United States began in California on 19 March 2020, and many states followed suit in the following days. Changes in mobility patterns indicate that self-imposed social distancing practices were underway days to weeks before the formal announcement of lockdowns (19). Lockdowns led to sharp reductions in surface-level NO_2 (20–23) and tropospheric column NO_2 measured from satellite instruments (21, 24–27) over the United States, China, and Europe. According to government-reported inventories, roughly 60% of anthropogenic emissions of nitrogen oxides ($NO_x \equiv NO + NO_2$) in the United States in 2010 were emitted by on-road vehicles (28), and up to 80% of ambient NO_2 in urban areas can be linked to traffic emissions (29, 30). As such, NO_2 is often used as a marker for road traffic in urban areas. Multiple lines of evidence such as seismic quieting and reduced mobility via location-based services point to changes in traffic-related emissions as the main driver of reductions in NO_2 pollution during lockdowns, due to the large proportion of the population working from home (21, 23, 31, 32).

Here we exploit the unprecedented changes in human activity unique to the COVID-19 lockdowns and remotely sensed NO_2 columns with extraordinary spatial resolution and coverage to understand inequalities in the distribution of NO_2 pollution for different racial, ethnic, and socioeconomic subgroups in the United States. Specifically, we address the following: Which demographic subgroups received the largest NO_2 reductions? Did the lockdowns grow or shrink the perennial disparities in NO_2 pollution across different demographic subgroups? Although the lockdowns are economically unsustainable, how can they advance environmental justice and equity by informing long-term policies to reduce NO_2 disparities and the associated public health damages?

Significance

We leverage the unparalleled changes in human activity during COVID-19 and the unmatched capabilities of the TROPOspheric Monitoring Instrument to understand how lockdowns impact ambient nitrogen dioxide (NO_2) pollution disparities in the United States. The least White communities experienced the largest NO_2 reductions during lockdowns; however, disparities between the least and most White communities are so large that the least White communities still faced higher NO_2 levels during lockdowns than the most White communities experienced prior to lockdowns, despite a $\sim$50% reduction in passenger vehicle traffic. Similar findings hold for ethnic, income, and educational attainment population subgroups. Future strategies to reduce NO_2 disparities will need to target emissions from heavy-duty vehicles.

Author contributions: G.H.K., D.L.G., and S.C.A. designed research; G.H.K. and D.L.G. performed research; G.H.K. and D.L.G. analyzed data; and G.H.K., D.L.G., and S.C.A. wrote the paper.

The authors declare no competing interest.

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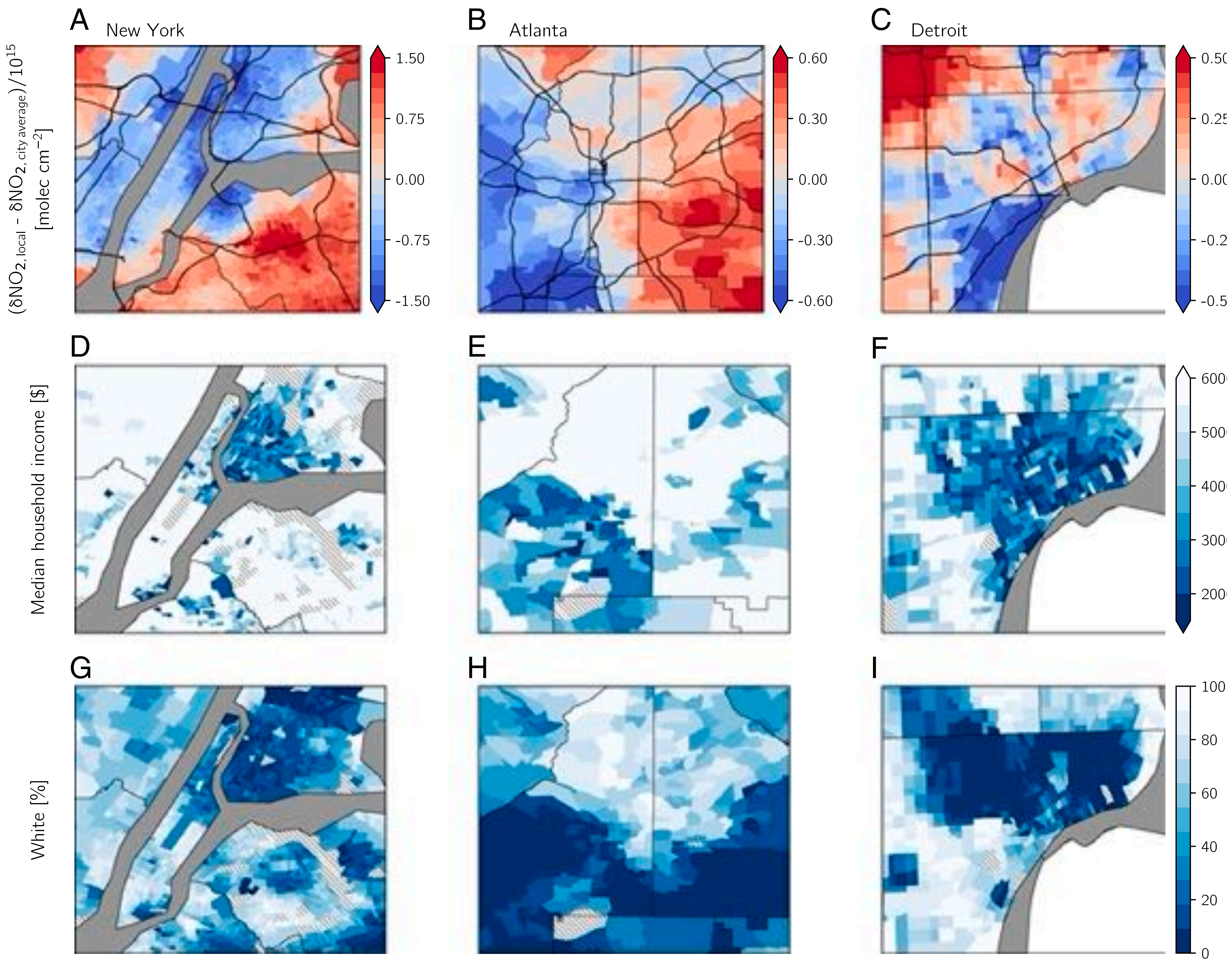
EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES
SUSTAINABILITY SCIENCE

Conclusions

- A dramatic drop in NOx emissions mainly from the passenger vehicle sector narrowed NO2 disparities only modestly and not consistently across major US cities.
- Heavy-duty diesel vehicles maintained same activity levels during lockdowns, and use highways and interstates disproportionately located in marginalized communities.
- "Targeting NOx emissions from heavy-duty diesel vehicles is likely the most effective strategy for reducing disparities across cities nationwide."



Effect of mitigation policies

- Did masking/lockdowns/etc. save lives?
- What role did individual behavior play?
- How many more people would have died if the government did not intervene?

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Causal impact of masks, policies, behavior on early covid-19 pandemic in the U.S.

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Behavior

ABSTRACT

The paper evaluates the dynamic impact of various policies adopted by US states on the growth rates of confirmed Covid-19 cases and deaths as well as social distancing behavior measured by Google Mobility Reports, where we take into consideration people's voluntarily behavioral response to new information of transmission risks in a causal structural model framework. Our analysis finds that both policies and information on transmission risks are important determinants of Covid-19 cases and deaths and shows that a change in policies explains a large fraction of observed changes in social distancing behavior. Our main counterfactual experiments suggest that nationally mandating face masks for employees early in the pandemic could have reduced the weekly growth rate of cases and deaths by more than 10 percentage points in late April and could have led to as much as 19 to 47 percent less deaths nationally by the end of May, which roughly translates into 19 to 47 thousand saved lives. We also find that, without stay-at-home orders, cases would have been larger by 6 to 63 percent and without business closures, cases would have been larger by 17 to 78 percent. We find considerable uncertainty over the effects of school closures due to lack of cross-sectional variation; we could not robustly rule out either large or small effects. Overall, substantial declines in growth rates are attributable to private behavioral response, but policies played an important role as well. We also carry out sensitivity analyses to find neighborhoods of the models under which the results hold robustly: the results on mask policies appear to be much more robust than the results on business closures and stay-at-home orders. Finally, we stress that our study is observational and therefore should be interpreted with great caution. From a completely agnostic point of view, our findings uncover predictive effects (association) of observed policies and behavioral changes on future health outcomes, controlling for informational and other confounding variables.

1. Introduction

Accumulating evidence suggests that various policies in the US have reduced social interactions and slowed down the growth of Covid-19 infections.[1] An important outstanding issue, however, is how much of the observed slow down in the spread is attributable to the effect of policies as opposed to a voluntarily change in people's behavior out of fear of being infected. This question is critical for evaluating the effectiveness of restrictive policies in the US relative to an

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1 See Courtemanche et al. (2020), Hsiang et al. (2020), Pei et al. (2020), Abouk and Heydari (2020), and Wright et al. (2020).

https://doi.org/10.1016/j.jeconom.2020.09.003

Causal model

- $Y_{i,t+\ell}$ is the outcome (COVID cases/deaths) for unit i time of infection t, lag to confirmation/death ℓ.
- P_{it} adopted policies (mask mandates, lockdowns, school closures, ...)
- B_{it}: human behavior (time spent in transit/shopping/working)
- I_{it}: information available to each person
- W_{it}: confounders

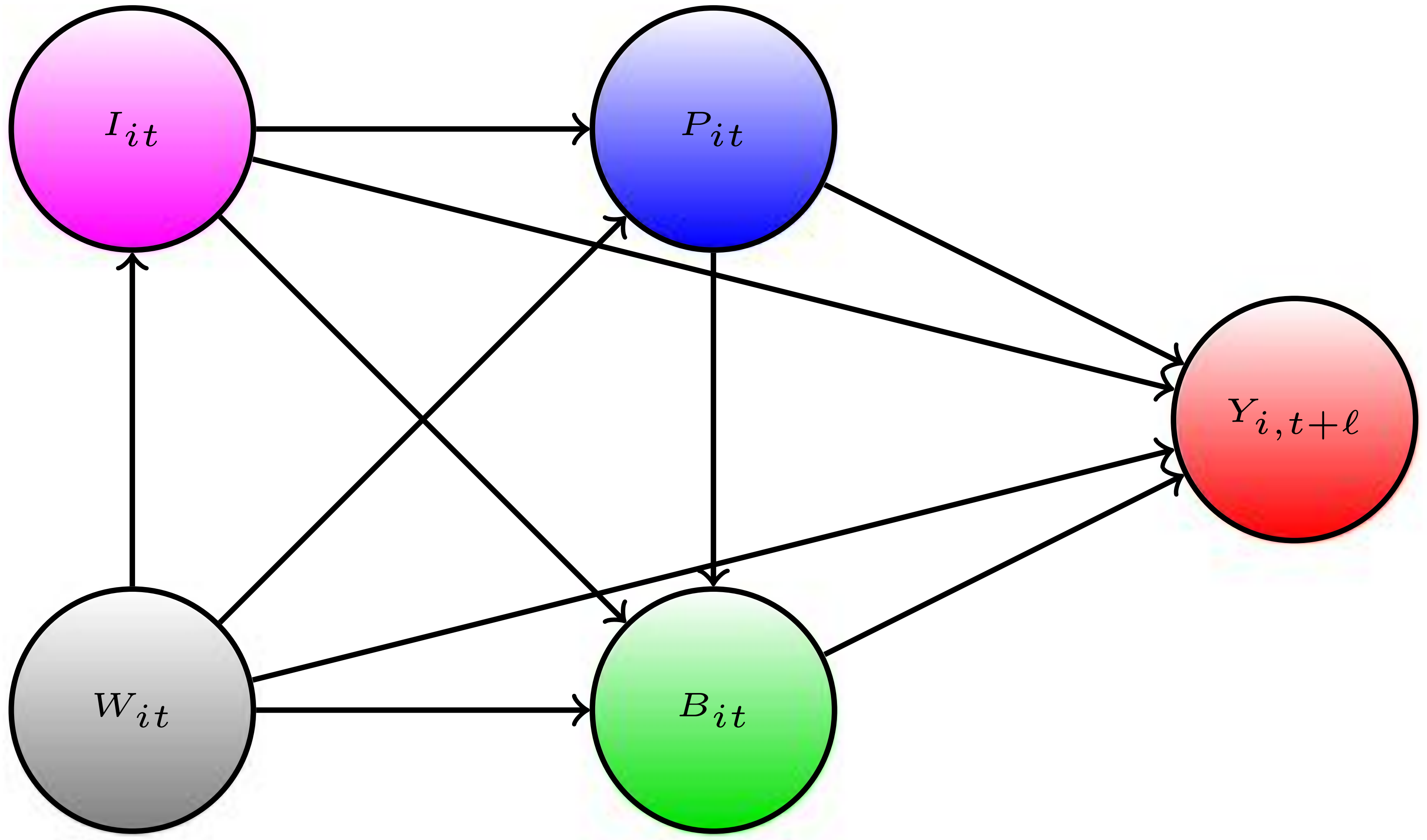

Fig. 4. S. & P. Wright type causal path diagram for our model.

Potential outcomes

$$
\begin{aligned}
Y_{i,t+\ell}(b, p, \iota) \quad &:= \alpha' b + \pi' p + \mu' \iota + \delta_Y' W_{it} + \varepsilon_{it}^{y}, \\
B_{it}(p, \iota) \quad &:= \beta' p + \gamma' \iota + \delta_B' W_{it} + \varepsilon_{it}^{b},
\end{aligned}
$$

- b is behavior
- p are policies
- ι (iota) is information

Effect of mitigation policies II

- Mitigation policies went into effect in different places at different times.
- Can we use as an instrument?
- Simple model:

$$y_{it} = \alpha_i + \gamma_t + \beta \cdot \text{lockdown}_{it} + \epsilon_{it}$$

  - y_{it} is outcome (COVID deaths say) for country i at time t.
  - α_i is a country-specific effect.
  - γ_t is a shared trend.

Potential confounders

- $\hat{\beta} = (\bar{Y}_{\text{madrid,post}} - \bar{Y}_{\text{madrid,pre}}) - (\bar{Y}_{\text{liverpool,post}} - \bar{Y}_{\text{liverpool,pre}})$
- What do we need to assume?
    - Are all lockdown measures comparable?
    - Reverse causality?
    - Individual behavior?
    - Differences in measurement?

Using Difference-in-Differences to Identify Causal Effects of COVID-19 Policies

Andrew Goodman-Bacon, Jan Marcus

May 12, 2020

Abstract

Policymakers have implemented a wide range of non-pharmaceutical interventions to fight the spread of COVID-19. Variation in policies across jurisdictions and over time strongly suggests a difference-in-differences (DD) research design to estimate causal effects of counter-COVID measures. We discuss threats to the validity of these DD designs and make recommendations about how researchers can avoid bias, interpret results accurately, and provide sound guidance to policymakers seeking to protect public health and facilitate an eventual economic recovery.

Keywords: difference-in-differences, non-pharmaceutical interventions, COVID-19, causal inference
JEL: C1, I18

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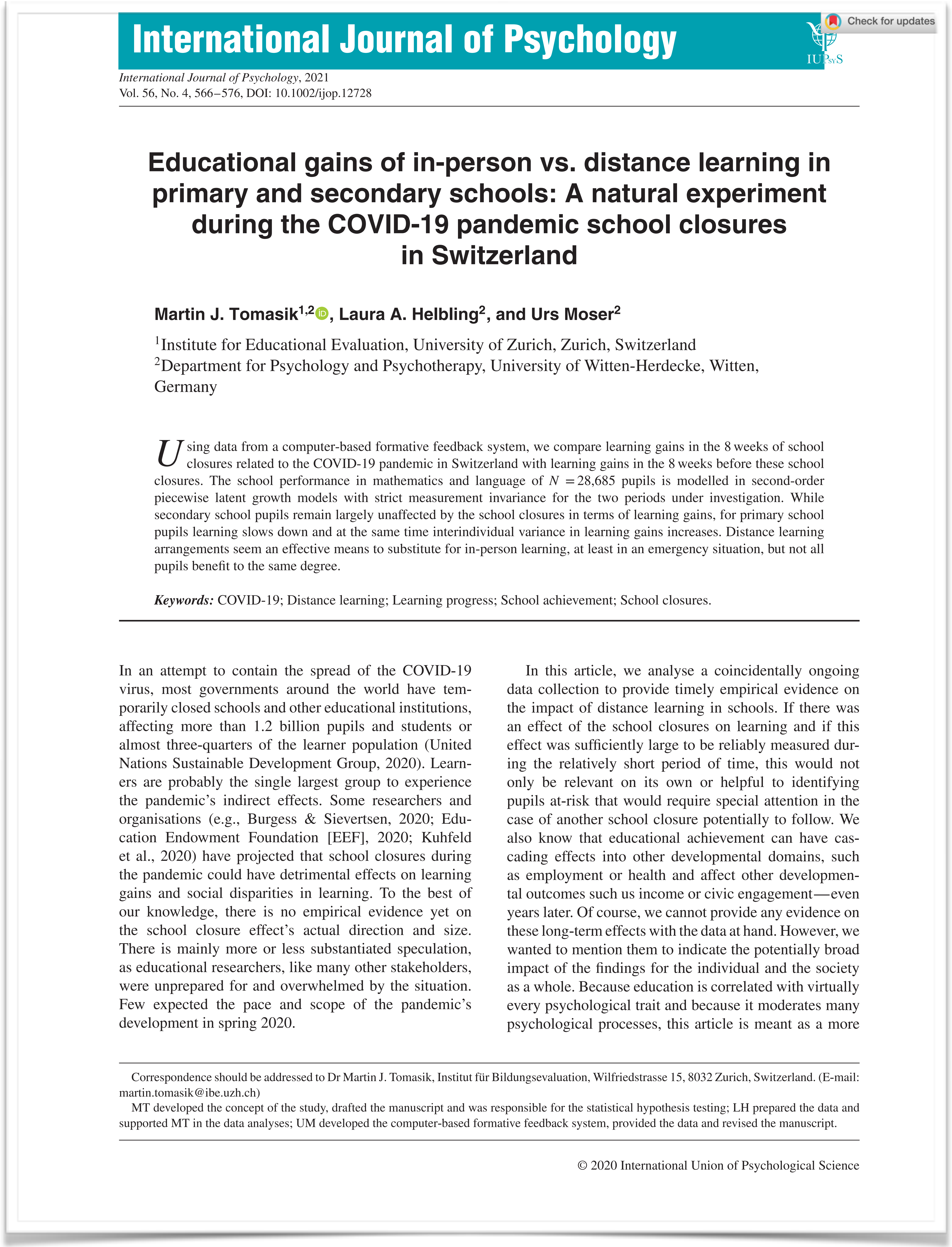
Remote learning

- Key findings:
  - The learning progress of primary school pupils during in-person learning was more than twice as high as during school closures, and this difference was highly significant.
  - For secondary school pupils, slopes did not differ significantly from each other.


International Journal of Psychology

International Journal of Psychology, 2021
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Educational gains of in-person vs. distance learning in primary and secondary schools: A natural experiment during the COVID-19 pandemic school closures in Switzerland

Martin J. Tomasik[1,2], Laura A. Helbling[2], and Urs Moser[2]

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Using data from a computer-based formative feedback system, we compare learning gains in the 8 weeks of school closures related to the COVID-19 pandemic in Switzerland with learning gains in the 8 weeks before these school closures. The school performance in mathematics and language of $N = 28{,}685$ pupils is modelled in second-order piecewise latent growth models with strict measurement invariance for the two periods under investigation. While secondary school pupils remain largely unaffected by the school closures in terms of learning gains, for primary school pupils learning slows down and at the same time interindividual variance in learning gains increases. Distance learning arrangements seem an effective means to substitute for in-person learning, at least in an emergency situation, but not all pupils benefit to the same degree.

Keywords: COVID-19; Distance learning; Learning progress; School achievement; School closures.

In an attempt to contain the spread of the COVID-19 virus, most governments around the world have temporarily closed schools and other educational institutions, affecting more than 1.2 billion pupils and students or almost three-quarters of the learner population (United Nations Sustainable Development Group, 2020). Learners are probably the single largest group to experience the pandemic's indirect effects. Some researchers and organisations (e.g., Burgess & Sievertsen, 2020; Education Endowment Foundation [EEF], 2020; Kuhfeld et al., 2020) have projected that school closures during the pandemic could have detrimental effects on learning gains and social disparities in learning. To the best of our knowledge, there is no empirical evidence yet on the school closure effect's actual direction and size. There is mainly more or less substantiated speculation, as educational researchers, like many other stakeholders, were unprepared for and overwhelmed by the situation. Few expected the pace and scope of the pandemic's development in spring 2020.

In this article, we analyse a coincidentally ongoing data collection to provide timely empirical evidence on the impact of distance learning in schools. If there was an effect of the school closures on learning and if this effect was sufficiently large to be reliably measured during the relatively short period of time, this would not only be relevant on its own or helpful to identifying pupils at-risk that would require special attention in the case of another school closure potentially to follow. We also know that educational achievement can have cascading effects into other developmental domains, such as employment or health and affect other developmental outcomes such us income or civic engagement—even years later. Of course, we cannot provide any evidence on these long-term effects with the data at hand. However, we wanted to mention them to indicate the potentially broad impact of the findings for the individual and the society as a whole. Because education is correlated with virtually every psychological trait and because it moderates many psychological processes, this article is meant as a more

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MT developed the concept of the study, drafted the manuscript and was responsible for the statistical hypothesis testing; LH prepared the data and supported MT in the data analyses; UM developed the computer-based formative feedback system, provided the data and revised the manuscript.

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Project II

- Design a study that uses COVID data to research a social or scientific question that interests you.
- Document the process of discovery: question refinement, data acquisition and cleaning, analysis, results, and conclusions.
- 15m presentation two weeks from today.
- Grade: 80% peer review/20% presentation.

Formulating a research question

- Is it interesting?
- Is it answerable?
  - Do the data exist?
  - Is there enough time?
- Iterate until you arrive at a concrete question.
  - Is it still interesting?

Image courtesy of Bin Yu

Example question formulation

- “Will I contract COVID today?”
  - Definitely interesting (at least to me).
  - Not answerable as stated.
- Refinements:
  - “What are my odds of getting COVID today?”
    - Not answerable.
    - Still interesting.
  - “What is the positivity rate on campus today?”
    - Not answerable.
    - Still interesting.
  - “What was the positivity rate on campus last week?”
    - Answerable.
    - Interesting?

Deciding on a topic

- Work with your groupmates to think of potential topics for Project II.
- Iterate the question formulation process, and write down your progress.
  - Think about potential data sources (use Google).
  - Think about whether it can be done in two weeks!
- We will circle back in a few minutes to discuss everyone's process and outcome.